included in the figure. No spines, however, appear upon the columns, and, in so far as these are absent, Mr Salter's drawing conveys a somewhat inadequate idea of this beautiful encrinite.

Subsequent to Professor Sedgwick's discovery of this species in the Wenlock, fragments of its remarkable column, with the spine-like auxiliary processes unbroken, were found in the Upper Ludlow Quartzite of Shepherd's Quarry, Kendal, Westmoreland, but I do not know by whom.

I have been able to add a third locality to the two just mentioned, by discovering this rare species near Galt-y-celyn, Derwen, Denbighshire. I have since discovered another and fourth locality for this Encrinite at Pen-y-Forrest, Llanellidan, Denbighshire.

Having regard to its extreme rarity, it has been thought that the accompanying lithographed Plate will prove a useful reference to palæontologists, as it embodies all the known characters of the species. It is rare to discover any specimen of this species with the attachment of cup to column entire; and this circumstance increases the value and interest of the specimen now figured, as the specific characters of its cups, columns, and spines, are combined and exhibited in a single specimen.

II. *On two River Channels Buried under Drift, belonging to a period when the land stood several hundred feet higher than at present.* By JAMES CROLL, of the Geological Survey of Scotland. (Illustrated with map of Midland Valley of Scotland, fig. 1., and relative section, fig. 2, Plate XVI.)

Remarks on the Drift Deposits.—The drift and other surface deposits of the country have chiefly been studied from sections observed on the banks of streams, railway cuttings, ditches, foundations of buildings, and other excavations. The great defect of such sections is that they do not lay open a sufficient depth of surface. They may no doubt represent pretty accurately the character and order of the more recent deposits which overlie the boulder-clay, but we are hardly warranted in concluding that the succession of deposits belonging to the earlier part of the glacial epoch, the period of the true till, is fully exhibited in such limited sections.

Suppose, for example, the glacial epoch proper—the time of the lower boulder-clay—to have consisted of a succession of alternate cold and warm periods; there would, in such a case, be a series of separate formations of boulder-clay; but we could hardly expect to find on the flat and open face of the country, where the surface deposits are generally not of great depth, those various formations of Till, lying the one superimposed upon the other.

C. R. Bone, of Jermyn St., London, Del't

Scott & Ferguson Lithog. Edin'

ACTINOCRINUS PULCHER.—(SALT. MSS.)

(NATURAL SIZE.)

From a Specimen found by DR. ROBERTS in an old and abandoned quarry near Galt-y-celyn, Derwen, Denbighshire, North Wales.

MAP OF PART OF MIDLAND VALLEY OF SCOTLAND TO ILLUSTRATE THE PAPERS OF MR JAMES CROLL & MR ROBERT DICK.

FIG. I.

NOTE.—Stippled parts represent the area which would be covered by sea were the land submerged to the extent of 200 Feet.

The heavy black lines A, B and C, represent buried River Channels;—A and B show the direction of those described by Mr Croll, and C that by Mr Dick.

SECTION OF BURIED RIVER-BED NEAR TOWNCROFT FARM, GRANGEMOUTH TO ILLUSTRATE MR CROLL'S PAPER.

FIG. II

James Croll, Delt.

SECTION AT C OF RAVINE BURIED UNDER DRIFT NEAR WISHAW, TO ILLUSTRATE MR DICK'S PAPER.

FIG. III.

Robert Dick, Delt.

For it is obvious that the till formed during one ice period would, as a general rule, be either swept away, or re-ground and laid down by the ice of the succeeding period. If the very hardest rocks could not withstand the abrading power of the enormous masses of ice which passed over the surface of the country during the glacial epoch, it is hardly to be expected that the comparatively soft boulder-clay would be able to do so. It is probable that the boulder-clay of one period would be used as grinding materials by the ice of the succeeding periods. The boulder-clay which we find in one continuous mass may, therefore, in many cases, have been ground off the rocks underneath at widely different periods.

If we wish to find the boulder-clays belonging to each of the successive cold periods lying, the one superimposed on the other in the order of time in which they were formed, we must go and search in some deep gorge or valley, where the clay has not only accumulated in enormous masses, but has been partially protected from the destructive power of the ice. But it is seldom that the geologist has an opportunity of seeing a complete section down to the rock head in such a place. In fact, excepting by bores for minerals, or by shafts of pits, the surface, to a depth of one or two hundred feet, is never passed through or laid open.

Examination of Surface by "bores."—With the view of ascertaining if additional light would be cast on the sequence of events, during the formation of the boulder-clay, by an examination of the journals of bores made through a great depth of surface deposits, a collection of about 250 bores, put down in all parts of the mining districts of Scotland, was made. An examination of these bores shows most conclusively that the opinion that the boulder-clay, or lower till, is one great undivided formation, is wholly erroneous.

These 250 bores represent a total thickness of 21,348 feet, giving 86 feet as the mean thickness of the deposits passed through. Twenty of these bores have one boulder-clay, with beds of stratified sand or gravel beneath the clay; 25 have two boulder-clays, with stratified beds of sand and gravel between; 10 have three boulder-clays; 1 has four boulder-clays; 2 have five boulder-clays; and 1 has no fewer than six separate masses of boulder-clay, with stratified beds of sand and gravel between; 16 have two or three separate boulder-clays, differing altogether in colour and hardness, without any stratified beds between. We have, therefore, out of 250 bores, 75 of them representing a condition of things wholly different from that exhibited to the geologist in ordinary sections.

These bores bear testimony to the conclusion that the glacial

epoch consisted of a succession of cold and warm periods, and not of one continuous and unbroken period of ice, as was at one time generally supposed.

The full details of the character of the deposits passed through by these bores, and their bearing on the history of the glacial epoch, have been given by Mr James Bennie, in an interesting paper read before the Glasgow Geological Society,* to which I would refer all those interested in the subject of surface geology. But it is not to the mere contents of the bores that I wish at present to direct attention, but to a new and important result to which they have unexpectedly led.

River Channel, Kilsyth to Grangemouth, Firth of Forth.—These borings reveal the existence of a deep pre-glacial, or perhaps inter-glacial, trough or hollow, extending from the Clyde above Bowling across the country by Kilsyth, along the valley of the Forth and Clyde Canal, to the Firth of Forth at Grangemouth. This trough is filled up with immense deposits of mud, sand, gravel, and boulder-clay. These deposits not only fill it up, but they cover it over to such an extent, that it is absolutely impossible to find on the surface a single trace of it; and had it not been for borings, and other mining operations, its existence would probably never have been known. In places where the bottom of the trough is perhaps 200 feet below the sea-level, we find on the surface not a hollow, but often an immense ridge or elliptical knoll of sand, gravel, or boulder-clay, rising sometimes to 150 or 200 feet above the present sea-level.

I need not here enter into any minute details regarding the form, depth, and general outline of this trough, or of the character of the deposits covering it, these having already been described by Mr Bennie, but shall proceed to the consideration of circumstances which seem to throw light on the physical origin of this curious hollow, and to the proof which it unexpectedly affords that Scotland, during probably an early part of the glacial epoch, stood higher in relation to the sea-level than it does at present; or rather, as I would be disposed to express it—the sea stood much lower than at present.

From the fact that all along the line of this trough the surface of the country is covered with enormous beds of stratified sands and gravels of unquestionably marine origin, which proves that the sea must have at a recent period occupied the valley, my first impression was that this hollow had been scooped out by the sea. This conclusion appeared at first sight quite natural, for at the time that the sea filled the valley, owing to the Gulf-stream impinging on our western shores, a strong current would probably then pass through from the Atlantic on the west to the German

* Trans. of the Geol. Soc. of Glasgow, vol. iii. part i. page 123.

Ocean on the east. However, considerations soon began to suggest themselves wholly irreconcilable with this hypothesis.

The question immediately arose, If the tendency of the sea occupying the valley is to deepen it, by wearing down its rocky bottom, and removing the abraded materials, then why is the valley filled up to such a prodigious extent with marine deposits? Does not the fact of the whole valley being filled up from sea to sea with marine deposits to a depth of from 100 to 200 feet, and, in some places, to even 400 feet, show that the tendency of the sea filling this valley is to silt it up rather than to deepen it? What conceivable change of conditions could account for operations so diverse?

That the sea could not have cut out this trough, is, however, susceptible of direct proof. The height of the surface of the valley at the watershed or highest part, about a mile to the east of Kilsyth, where the Kelvin and the Bonny Water, running in opposite directions,—the one west into the Clyde, and the other east into the Carron,—take their rise, is 160 feet above the sea-level. Consequently, before the sea could pass through the valley at present, the sea-level would require to be raised 160 feet.

But in discussing the question as to the origin of this pre-glacial hollow, we must suppose the surface deposits of the valley all removed, for this hollow was formed before these deposits were laid down. Let us take the average depth of these deposits at the watershed to be 50 feet. It follows that, assuming the hollow in question to have been formed by the sea, the sea-level at the time must have been at least 110 feet higher than at present.

Were the surface deposits of the country entirely removed, the district to the west and north-west of Glasgow would be occupied by a sea which would stretch from the Kilpatrick Hills, north of Duntocher, to Paisley, a distance of about five miles, and from near Houston to within a short way of Kirkintilloch, a distance of more than twelve miles. This basin would contain a few small islands and sunken rocks, but its mean depth, as determined from a great number of surface bores obtained over its whole area, would be not much under 70 or 80 feet. But we shall, however, take the depth at only 50 feet. Now, if we raise the sea-level so as to allow the water just barely to flow over the watershed of the valley, the sea in this basin would therefore be 160 feet deep. Let us now see what would be the condition of things on the east end of the valley. The valley for several miles to the east of Kilsyth continues very narrow, but on reaching Larbert it suddenly opens into the broad and flat carse lands through which the Forth and Carron wind. The average depth at which the sea would stand at present in this tract of country,

were the surface removed, as ascertained from bores, would be at least 100 feet, or about double that in the western basin. Consequently, when the sea was sufficiently high to pass over the watershed, the water would be here 210 feet in depth, and several miles in breadth.

But in order to have a current of some strength passing through the valley, let us suppose the sea at the time to have stood 150 feet higher in relation to the land than at present. This would give 40 feet as the depth of the sea on the watershed, and 200 feet as the depth in the western basin, and 250 feet as the depth in the eastern.

An examination of the Ordnance Survey map of the district will show that the 200 feet contour lines which run along each side of the valley from Kilsyth to Castlecary come, in several places, to within one-third of a mile of each other. From an inspection of the ground, I found that, even though the surface deposits were removed off the valley, it would not sensibly affect the contours at those places. It is therefore evident that though the sea may have stood even 200 feet higher than at present, the breadth of the strait at the watershed and several other points could not have exceeded one-third of a mile. It is also evident that at those places the current would be flowing with the greatest velocity, for here it was not only narrowest but also shallowest. A reference to Plate XVI. fig. 1 will show the form of the basins. The stippled portion represents the area which would be covered by the sea were the land submerged to the extent of 200 feet.

Let us take the breadth of the current in the western basin at, say, three miles. This is two miles less than the breadth of the basin itself. Suppose the current at the narrow parts between Kilsyth and Castlecary to have had a velocity of, say, five miles an hour. Now, as the mean velocity of the current at the various parts of its course would be inversely proportionate to the sectional areas of those parts, it therefore follows that the mean velocity of the current in the western basin would be only $\frac{1}{3}$ of what it was in the narrow pass between Kilsyth and Castlecary. This would give a mile in nine hours as the velocity of the water in the western basin. In the eastern basin the mean velocity of the current, assuming its breadth to be the same as in the western, would be only a mile in eleven hours. In the central part of the current the velocity at the surface would probably be considerably above the mean, but at the sides and bottom it would no doubt be under the mean. In fact, in these two basins the current would be almost insensible.

The effect of such a current would simply be to widen and deepen the valley all along that part between Kilsyth and Castlecary where the current would be flowing with considerable

rapidity. But it would have little or no effect in deepening the basins at each end, but the reverse. It would tend rather to silt them up. If the current flowed from west to east, the materials removed from the narrow part between Kilsyth and Castlecary, where the velocity of the water was great, would be deposited when the current almost disappeared in the eastern part of the valley. Sediment carried by a current flowing at the rate of five miles an hour would not remain in suspension when the velocity became reduced to less than five miles a day.

But even supposing it were shown that the sea under such conditions could have deepened the valley along the whole distance from the Clyde to the Forth, still this would not explain the origin of the trough in question. What we are in search of is not the origin of the valley itself, but the origin of a deep and narrow hollow running along the bottom of it. A sea filling the whole valley, and flowing with considerable velocity, would, under certain conditions, no doubt deepen and widen it, but it would not cut out along its bottom a deep, narrow trough, with sides often steep, and in some places perpendicular and even overhanging.

This hollow is evidently an old river bed scooped out of the rocky valley by a stream, flowing probably during an early part of the glacial period.

During the latter part of the summer of 1868 I spent two or three weeks of my holidays in tracing the course of this buried trough from Kilsyth to the river Forth at Grangemouth, and I found unmistakable evidence that the eastern portion of it, stretching from the watershed to the Forth, had been cut out, not by the sea, but by a stream which must have followed almost the present course of the Bonny Water.

I found that this deep hollow enters the Forth a few hundred yards to the north of Grangemouth Harbour, at the extraordinary depth of 260 feet below the present sea-level. At the period when the sea occupied the valley of the Forth and Clyde Canal, the bottom of the trough at this spot would therefore be upwards of 400 feet below the level of the sea.

A short distance to the west of Grangemouth, and also at Carron, several bores were put down in lines almost at right angles across the trough, and by this means we have been enabled to form a pretty accurate estimate of its depth, breadth, and shape at those places. I shall give the details of one of those sections.

Between Towncroft Farm and the river Carron a bore was put down to the depth of 273 feet before the rock was reached. About 150 yards to the north of this there is another bore giving 234 feet as the depth to the rock; 150 yards still further north the depth of the surface deposits, as determined by a third bore, is 155 feet. This last bore is evidently outside of the hollow,

for one about 150 yards north of it gives the same depth of surface which seems to be about its average depth for a mile or two around. About half a mile to the south of the hollow at this place the surface deposits are 150 feet deep. From a number of bores obtained at various points within a circuit of $1\frac{1}{2}$ miles the surface appears to have a pretty uniform depth of 150 feet or thereby. For the particulars of these "bores" I am indebted to the kindness of Mr Mackay, of Grangemouth.

To the south of the trough (see Plate XVI. fig. 2) there is a fault running nearly parallel to it, having a down-throw to the north, and cutting off the coal and accompanying strata to the south. But an inspection of the section will show that the hollow in question is in no way due to the fault, but has been scooped out of the solid strata.

The main coal wrought extensively here is cut off by the trough, as will be seen from the section, at a depth of 40 fathoms from the surface. Mr Dawson, of Carron Iron Works, informs me that at Carronshore pit, about a mile and a quarter above where this section is taken, the coal was found to be completely cut off by this trough. In one of the workings of this pit, about forty years ago, the miners cut into the trough at 40 fathoms below the surface, when the sand rushed in with irresistible pressure, and filled the working. Again, about a mile below where the section is taken, or about two miles below Carronshore, and just at the spot where the trough enters the Firth, it was also cut into in one of the workings of the Heuck pit at a depth of 40 fathoms from the surface. Fortunately, however, at this point the trough is filled with boulder-clay instead of sand, and no damage was sustained. Here, for a distance of two miles, the main coal is cut off by this hollow; or rather, I should say, this hollow has been cut through the coal-seam, for all the other accompanying strata pass on intact till the great fault to the south of the trough is reached, where all the beds are finally cut off. Two seams of coal, called respectively the "Coxroad" and the "Under Coxroad," lying the former about 12 fathoms, and the latter about 14 fathoms, below the position of the "Main" coal, as will be seen in the descriptive section (Plate XVI. fig. 2), are not reached by the trough, and pass undisturbed under it.

This hollow would seem to narrow considerably as it recedes westwards, for at Carronshore pit-shaft the surface is 138 feet deep; but not much over 150 yards to the south of this is the spot where the coal was cut off by the trough at a depth of 40 fathoms or 240 feet. Here it deepens upwards of 100 feet in little more than 150 yards. That it is narrow at this place is proved by the fact, that a bore put down near Carronbank, a little to the south, shows the surface to be only 156 feet deep.

In the section (Plate XVI. fig. 2) the line described as "*150 feet above sea-level*" registers the height of the sea-level at the time when the central valley was occupied by sea 40 feet deep at the water-shed. Now, if this hollow, which extends right along the whole length of the valley, had been cut out by the sea, the surface of the rock 150 feet below the present surface of the ground would be the sea-bottom at the time, and the line marked "*150 feet above sea-level*" would be the surface of the sea. The sea would therefore be here 300 feet deep for several miles around. It cannot be supposed that the sea acting on a broad flat plain of several miles in extent should cut out a deep, narrow hollow like the one exhibited in the section, and leave the rest of the plain a flat sea-bottom.

And it must be observed, that this is not a hollow cut merely in a sea-beach, but one extending westward to Kilsyth. Now, if this hollow was cut out by the sea, it must have been done not by the waves beating on the beach, but by a current flowing through the valley. The strongest current that could possibly pass through the narrow part between Kilsyth and Castlecary would be wholly insensible when it reached Grangemouth, where the water was 300 feet deep, and several miles broad. Consequently, it is impossible that the current could have scooped out the hollow represented in the section.

Again, if this hollow had been scooped out by the sea, it ought to be deepest between Kilsyth and Castlecary, where the current was narrowest; but the reverse is actually the case. It is shallowest at the place where the current was narrowest, and deepest at the two ends where the current was broadest. In the case of a trough cut by a sea current, we must estimate its depth from the level of the sea. Its depth is the depth of the water in it while it was being scooped out. The bottom of the trough in the highest and narrowest part of the valley east of Kilsyth is 40 feet above the present sea-level. Consequently, its depth at this point at the period in question, when the sea-level was 150 feet higher than at present, would be 110 feet. The bottom of the trough at Grangemouth is 260 feet below the present sea-level; add to this 150 feet, and we have 410 feet as its depth here at the time in question. If this hollow was scooped out by the sea, how then does it thus happen that at the place where the current was strongest and confined to a narrow channel by hills on each side, it cut its channel to a depth of only 110 feet, whereas at the place where it had scarcely any motion it has cut, on a flat and open plain several miles broad, a channel to a depth of 410 feet?

But, suppose we estimate the relative amount of work performed by the sea at Kilsyth and Grangemouth, not by the actual depth of the bottom of the trough at these two places below the

sea-level at the time that the work was performed, but by the present actual depth of the bottom of the trough below the rocky surface of the valley, this will still not help us out of the difficulty. Taking, as before, the height of the rocky bed of the valley at the water-shed at 110 feet above the present sea-level, and the bottom of the trough at 40 feet, this gives 70 feet as the depth scooped out of the rock at that place. The depth of the trough at Grangemouth below the rocky surface is 118 feet. Here we have only 70 feet cut out at the only place where there was any resistance to the current, as well as the place where it possessed any strength; whereas at Grangemouth, where there was no resistance, and no strength of current, 118 feet has been scooped out. Such a result as this is diametrically opposed to all that we know of the dynamics of running water.

We may therefore conclude that it is physically impossible that this hollow could have been cut out by the sea.

Owing to the present tendency among geologists to attribute effects of this kind to ocean currents, I have been induced to enter thus at much greater length than would otherwise have been necessary into the facts and arguments against the possibility of the hollow having been excavated by the sea. In the present case the discussion is specially necessary, for here we have positive evidence of the sea having occupied the valley for ages, along which this channel has been cut. Consequently, unless it is proved that the sea could not possibly have scooped out the channel, most geologists would be inclined to attribute it to the sea current which is known to have passed through the valley rather than to any other cause.

But that it is a hollow of denudation, and has been scooped out by some agent, is perfectly certain. By what agent, then, has the erosion been made? The only other cause to which it can possibly be attributed is either land ice or running water.

The supposition that this hollow was scooped out by ice is not more tenable than the supposition that the work has been done by the sea. A glacier filling up the entire valley and descending into the German Ocean would unquestionably not only deepen the valley, but would grind down the surface over which it passed all along its course. But such a glacier would not cut a deep and narrow channel along the bottom of the valley. A glacier that could do this would be a small and narrow one, just sufficiently large to fill this narrow trough; for if it were much broader than the trough, it would grind away its edges, and make a broad trough instead of a narrow one. But a glacier so small and narrow as only to fill the trough descending from the hills at Kilsyth to the sea at Grangemouth, a distance of 15 miles, along an incline of only 300 feet, is a physical impossibility. The resistance to the advance of the ice along such a

slope would cause the ice to accumulate till probably the whole valley would be filled.

There is no other way of explaining the origin of this hollow, but upon the supposition of its being an old river bed. But there is certainly nothing surprising in the fact of finding an old watercourse under the boulder-clay and other deposits. Unless the present contour of the country be very different from what it was at the earlier part of the glacial epoch, there must have then been watercourses corresponding to the Bonny Water and the river Carron of the present day; and that the remains of these should be found under the present surface deposits is not surprising, seeing that these deposits are of such enormous thickness. When water began to flow down our valleys, on the disappearance of the ice at the close of the glacial epoch, the Carron and the Bonny Water would not be able to regain their old rocky channels, but would be obliged to cut, as they have done, new courses for themselves on the surface of the deposits under which their old ones lay buried.

Although an old pre-glacial or inter-glacial river-bed is in itself an object of much interest and curiosity, still, it is not on that account that I have been induced to enter so minutely into the details of this buried hollow. There is something of far more importance attached to this hollow than the mere fact of its being an old watercourse. For the fact that it enters the Firth of Forth at a depth of 260 feet below the present sea-level, proves incontestably that at the time this hollow was occupied by a stream, the land must have stood at least between 200 and 300 feet higher in relation to the sea-level than at present.

We have seen that the old surface of the country in the neighbourhood of Grangemouth, out of which this ancient stream cut its channel, is at least 150 feet below the present sea-level. Now, unless this surface had been above the sea-level at that time, the stream would not have cut a channel in it. But it has not merely cut a channel, but cut one to a depth of 120 feet. It is impossible that this channel could have been occupied by a river of sufficient volume to fill it. It is not at all likely that the river which scooped it out could have been much larger than the Carron of the present day, for the area of drainage, from the very formation of the country, could not have been much greater above Grangemouth than at present. An elevation of the land would, no doubt, increase the area of the drainage of the stream measured from its source to where it might then enter the sea, because it would increase the length of the stream; but it would neither increase the area of drainage, nor the length of the stream above Grangemouth. Kilsyth would be the watershed then as it is now. The river Carron at present is only a few feet deep. Suppose the ancient Carron, which flowed in this old channel,

to have been say 10 feet deep. This would show that the land in relation to the sea at that time must have stood at least 250 feet higher than at present. If 10 feet was the depth of this old river, and Grangemouth the place where it entered the sea, then 250 feet would be the extent of the elevation. But it is probable that Grangemouth was not the mouth of the river; it would likely be merely the place where it joined the river Forth of that period. We have every reason to believe that the bed of the German Ocean was then dry land, and that the Forth, Tay, Tyne, and other British rivers flowing eastward, as Mr Godwin-Austin supposes, were tributaries to the Rhine, which at that time was a huge river passing down the bed of the German Ocean, and entering the Atlantic to the west of the Orkney Islands. That the German Ocean, as well as the sea-bed of the Western Hebrides, was dry land at a very recent geological period, is so well-known, that, on this point, I need not enter into details. We may therefore conclude that the river Forth, after passing Grangemouth, would continue to descend until it reached the Rhine. If, by means of borings, we could trace the old bed of the Forth and the Rhine up to the point where the latter entered the Atlantic, in the same way as we have done the Bonny Water and the Carron, we should no doubt obtain a pretty accurate estimate as to the height at which the land stood at that remote period. Nothing whatever, I presume, is known as to the depth of the deposits covering the bed of the German Ocean along what was then the course of the Rhine. It must, no doubt, be something enormous. We are also in ignorance as to the thickness of the deposits covering the ancient bed of the Forth. A considerable number of bores have been put down at various parts of the Firth of Forth in connection with the contemplated railway bridge across the Firth, but in none of those bores has the rock been reached. Bores to a depth of 175 feet have been made without even passing through the deposits of silt which probably overlie an enormous thickness of sand and boulder-clay. Even in places where the water is 40 fathoms deep and quite narrow, the bottom is not rock but silt.

It is, however, satisfactory to find on the land a confirmation of what has long been believed from evidence found in the seas around our island, that at a very recent period the sea-level in relation to the land must have been some hundreds of feet lower than at the present day, and that our island must have at that time formed a part of the great eastern continent.

A curious fact was related to me by Mr Stirling, the manager of the Grangemouth collieries, which seems to imply a great elevation of the land at a period long posterior to the time when this channel was scooped out.

In sinking a pit at Orchardhead, about a mile to the north of

Grangemouth, the workmen came upon the boulder-clay after passing through about 110 feet of sand, clay, and gravel. On the upper surface of the boulder-clay they found cut out what Mr Stirling believes to have been an old watercourse. It was 17 feet deep, and not much broader. The sides of the channel appear to have been smooth and waterworn, and the whole was filled with a fine sharp sand beautifully stratified. As this channel lay about 100 feet below the present sea-level, it shows that if it actually be an old watercourse, it must have been scooped out at a time when the land in relation to the sea stood at least 100 feet higher than at present.

River Channel from Kilsyth westward to the Clyde.—In all probability the western half of this great hollow, extending from the watershed at Kilsyth to the Clyde, is also an old river channel, probably the ancient bed of the Kelvin. This point cannot, however, be satisfactorily settled until a sufficient number of journals of bores are obtained along the direct line of the hollow, so as to determine with certainty its width and general form and extent. It is hoped, however, that the particulars of all the bores made in this district will shortly be obtained. That the western channel is as narrow as the eastern is very probable. It has been found that its sides at some places, as, for example, at Garscadden, are very steep. At one place the north side is actually an overhanging buried precipice, the bottom of which is about 200 feet below the sea-level. We know also that the coal and ironstone in that quarter are cut through by the trough, and the miners there have to exercise great caution in driving their workings, in case they might cut into it. The trough along this district is filled with sand, and is known to the miners of the locality as the "sand-dyke." To cut into running sand at a depth of 40 or 50 fathoms is a very dangerous proceeding, as will be seen from the details given in Mr Bennie's paper of a disaster which occurred about twenty years ago to a pit near Duntocher, where this trough was cut into at a depth of 51 fathoms from the surface.

The depth of this hollow, below the present sea-level at Drumry, as ascertained by a bore put down, is 230 feet. For several miles to the east the depth is nearly as great. Consequently, if this hollow be an old river-bed, the ancient river that flowed in it must have entered the Clyde at a depth of more than 200 feet below the present sea-level; and if so, then it follows that the rocky bed of the ancient Clyde must lie buried under more than 200 feet of surface deposits from Bowling downwards to the sea. Whether this is the case or not we have no means at present of determining. The manager to the Clyde Trustees informs me, however, that in none of the borings or excavations which have been made has the rock ever been

reached from Bowling downwards. The probability is, that this deep hollow passes downwards continuously to the sea on the western side of the island as on the eastern.

Other Buried River Channels.—A good many examples of buried river channels have been found both in Scotland and in England, though none of so remarkable a character as the two occupying the valley of the Forth and Clyde Canal which have been just described. I may, however, briefly refer to one or two localities where some of these occur.

(1.) An ancient buried river channel, similar to the one extending from Kilsyth to Grangemouth, exists in the coalfields of Durham, and is known to miners in the district as the "Wash." Its course was traced by Mr Nicholas Wood, F.G.S., and Mr E. F. Boyd, from Durham to Newcastle, a distance of fourteen miles.* It traverses, after passing the city of Durham, a portion of the valley of the Wear, passes Chester-le-Street, and then follows the valley of the river Team, and terminates at the river Tyne. And what is remarkable, it enters the Tyne at a depth of 140 feet below the present level of the sea. This curious hollow lies buried, like the Scottish one just alluded to, under an enormous mass of drift, and it is only through means of boring and other mining operations that its character has been revealed. The bottom and sides of this channel everywhere bear evidence of long exposure to the abrading influence of water in motion; the rocky bottom being smoothed, furrowed, and waterworn. The river Wear of the present day flows to the sea over the surface of the drift at an elevation of more than 100 feet above this buried river-bed. At the time that this channel was occupied by running water the sea-level must have been at least 140 feet lower than at present. This old river evidently belongs to the same continental period as those of Scotland.

(2.) From extensive borings and excavations made at the docks of Hull and Grimsby, it is found that the ancient bed of the Humber is buried under more than 100 feet of silt, clay, and gravel. At Hull the bottom of this buried trough was found to be 110 feet below the sea-level. And what is most interesting at both these places, the remains of a submerged forest was found at a depth of from thirty to fifty feet below the sea-level. In some places two forests were found divided by a bed of leafy clay from five to fifteen feet thick.

(3.) In the valleys of Norfolk we also find the same conditions exhibited. The ancient bed of the Yare and other rivers of this district enter the sea at a depth of more than 100 feet below the present sea-level. At Yarmouth the surface was found 170 feet thick, and the deep surface extends along the Yare to be-

* British Association Report for 1863, p. 89.—*Geologist* for 1863, p. 384.

yond Norwich. Buried forests are also found here similar to those on the Humber.

It is probable that all our British rivers flow into the sea over their old buried channels, except in cases where they may have changed their courses since the beginning of the glacial epoch.

(4.) In the Sanguhar Coal Basin, at the foot of the Kello Water, an old buried river course was found by Mr B. N. Peach. It ran at right angles to the Kello, and was filled with boulder-clay which cut off the coal; but, on driving the mine through the clay, the coal was found in position on the other side.

(5.) An old river course, under the boulder-clay, is described by Mr Milne Home in his memoir on the Mid-Lothian coalfields. It has been traced out from Niddry away in a N.E. direction by New Craighall. At Niddry, the hollow is about 100 yards wide and between 60 and 70 feet deep. It seems to deepen and widen as it approaches towards the sea, for at New Craighall it is about 200 yards wide and 97 feet deep. This old channel will probably enter the sea about Musselburgh. Like the channels in the Midland Valley of Scotland already described, it is so completely filled up by drift that not a trace of it is to be seen on the surface. And like these, also, it must have belonged to a period when the sea-level stood much lower than at present.

(6.) At Hailes' Quarry, near Edinburgh, there is to be seen a portion of an ancient watercourse under the boulder drift. A short account of it was given by Dr Page in a paper read before the Edinburgh Geological Society.* The superincumbent sandstone, he says, has been cut to a depth of 60 feet. The width of the channel at the surface varies from 12 to 14 feet, but gradually narrows to 2 or 3 feet at the bottom. The sides and bottom are smoothed and polished, and the whole is now filled with till and boulders.

(7.) One of the most remarkable buried channels is that along the Valley of Strathmore, supposed to be the ancient bed of the Tay. It extends from Dunkeld by the south of Blairgowrie, Ruthven, and Forfar, and enters the German Ocean at Lunan Bay. Its length is about 34 miles.

"No great river," says Sir Charles Lyell, "follows this course, but it is marked everywhere by lakes or ponds, which afford shell-marl, swamps, and peat moss, commonly surrounded by ridges of detritus from 50 to 70 feet high, consisting in the lower part of till and boulders, and in the upper of stratified gravels, sand, loam, and clay, in some instances curved or contorted."†

* See Geological Magazine, vol. ii. p. 38.

† Proc. Geol. Soc., vol. iii. 1840, p. 342.

"It evidently marks an ancient line, by which, first, a great glacier descended from the mountains to the sea, and by which, secondly, at a later period, the principal water drainage of this country was effected."*

(8.) A number of examples of ancient river-courses, underneath the boulder-clay, are detailed by Mr Geikie in his glacial drift of Scotland. Some of the cases described by him have acquired additional interest from the fact of their bearing decided testimony to the existence of interglacial warm periods. I shall briefly refer to a few of the cases described by him.

In driving a trial mine in a pit at Chapelhall, near Airdrie, the workmen came upon what they believed to be an old river course. At the end of the trial mine the ironstone, with its accompanying coal and fire-clay, were cut off at an angle of about 20° by a stiff, dark-coloured earth, stuck full of angular pieces of white sandstone, coal, and shale, with rounded pebbles of greenstone, basalt, quartz, &c. Above this lay a fine series of sand and clay beds. Above these stratified beds lay a depth of 50 or 60 feet of true boulder-clay. The channel ran in the direction of north-east and south-west. Mr Russell, of Chapelhall, informs Mr Geikie that another of the same kind, a mile further to the north-west, had been traced in some of the pit workings.

"It is clear," says Mr Geikie, "that whatever may be the true explanation of these channels and basins, they unquestionably belong to the period of the boulder-clay. The Chapelhall basin lies, indeed, in a hollow of the carboniferous rocks, but its stratified sands and clays rest on an irregular floor of true till. The old channel near the banks of the Calder is likewise scooped out of sandstones and shales; but it has a coating of boulder-clay, on which its finely-laminated sands and clays repose, *as if the channel itself had once been filled with boulder-clay, which was re-excavated to allow of the deposition of the stratified deposits. In all cases, a thick mantle of coarse, tumultuous boulder-clay buries the whole.*"†

Mr Geikie found between the mouth of the Pease Burn and St Abb's Head, Berwickshire, several ancient buried channels. One at the Menzie Cleuch, near Redheugh Shore, was filled to the brim with boulder-clay. Another, the Lumsden Dean, half a mile to the east of Fast Castle, on the bank of the Carmichael Burn, near the parish church of Carmichael,—an old watercourse of the boulder-clay period—is to be seen. The valley of the Mouse Water he instances as a remarkable example.

* Antiquity of Man (Third Edition), p. 249.

† Glacial Drift of Scotland, p. 65.—*Trans. Geol. Soc. Glas.* vol. i. part 2. In the immediate neighbourhood of this channel, a remarkable old buried river bed, from six to seven miles in length, has lately been traced out by Mr Robert Dick, a full description of which will be found in the present part of the Society's Transactions.

One or two he found in Ayrshire, and also one on the banks of the Lyne Water, a tributary of the Tweed.

The question naturally arises, When were those channels scooped out? To what geological period must those ancient rivers be referred? It will not do to conclude that those channels must be pre-glacial simply because they contain boulder-clay. Had the glacial epoch been one unbroken period of cold, and the boulder-clay one continuous formation, then the fact of finding boulder-clay in those channels would show that they were pre-glacial. But when we find undoubted geological evidence of a warm condition of climate of long continuance, during the severest part of the glacial epoch, when the ice to a great extent must have disappeared, and water began to flow as usual down our valleys, all that can reasonably be inferred from the fact of finding till in those channels, is that they must be older than the till they contain. We cannot infer that they are older than all the till lying on the face of the country. The probability however, is, that some of them are of pre-glacial and others of inter-glacial origin. That many of these channels have been used as watercourses during the glacial epoch, or rather during warm periods of that epoch, is certain, from the fact that they have been filled with boulder-clay, then re-excavated, and finally filled up again with the clay.

III. *On the Discovery of a "Sand-dyke" or Old River Channel running north to south, from near Kirk of Shotts to Wishaw, Lanarkshire.* By ROBERT DICK. (Illustrated with map of Midland Valley of Scotland, fig. 1, and relative section, fig. 3, Plate XVI.)

Any one who has been engaged in mining matters for any lengthened period, or whose duty it has been to open up new mineral fields, must in the course of his experience have met with what are termed in *mining* phrase, "*sand-dykes*," or "*clay-dykes*." They are, I believe, not confined to any particular district, though rarely met with, and that only in those fields where the seams that are being worked do not exceed 40 or 50 fathoms in depth. It is one of these sand-dykes that I propose to make the subject of my remarks.

When I first heard of the sand-dyke as having been found in the mineral field which was under my charge, I had no distinct idea of what it was. There was a local tradition that two extinct pits, which had been worked fifty or sixty years previous, named the Spatchall and the Mutton pits, were sunk through the dyke. Whence the first of these pits derived its name, I do not know, but the second owed its title to the fact of bones having been found in it while sinking, which were supposed to be those of