ARTICLE 13

# Late-Glacial Deposits Near Lockerbie, Dumfriesshire

By W. W. BISHOP, Ph.D.

## INTRODUCTION

Early in 1960, two interesting late Pleistocene deposits near Lockerbie, Dumfriesshire, were brought to my notice by Mr Robert Little of East Hayrigg, Lockerbie. I am grateful to Mr Little for his assistance in surveying the sites and for the wealth of local knowledge which he placed at my disposal. Also, I acknowledge my debt to the members of the Lockerbie Extra-Mural Class of Glasgow University, whose enthusiasm for investigations in their local area led them to help in many different ways.

The valleys of the River Annan, Water of Ae, the Kinnel and Dryfe Waters, and the Water-of-Milk, within a radius of 5 miles of the centre of Lockerbie (figure 1), exhibit a surface morphology dominated by depositional features characteristic of dwindling valley glaciers. The extent to which these landforms have been modified or eliminated by post-glacial river and stream action depends upon their situation relative to the rivers mentioned above.

Excellent artificial sections have been opened recently in both glacial, outwash and later fluviatile deposits in cuttings and gravel pits associated with the re-alignment of the A.74 between Beattock and Ecclefechan. A number of natural exposures also occur and serve to supplement the morphological evidence.

## CLEUCHSIDE BURN

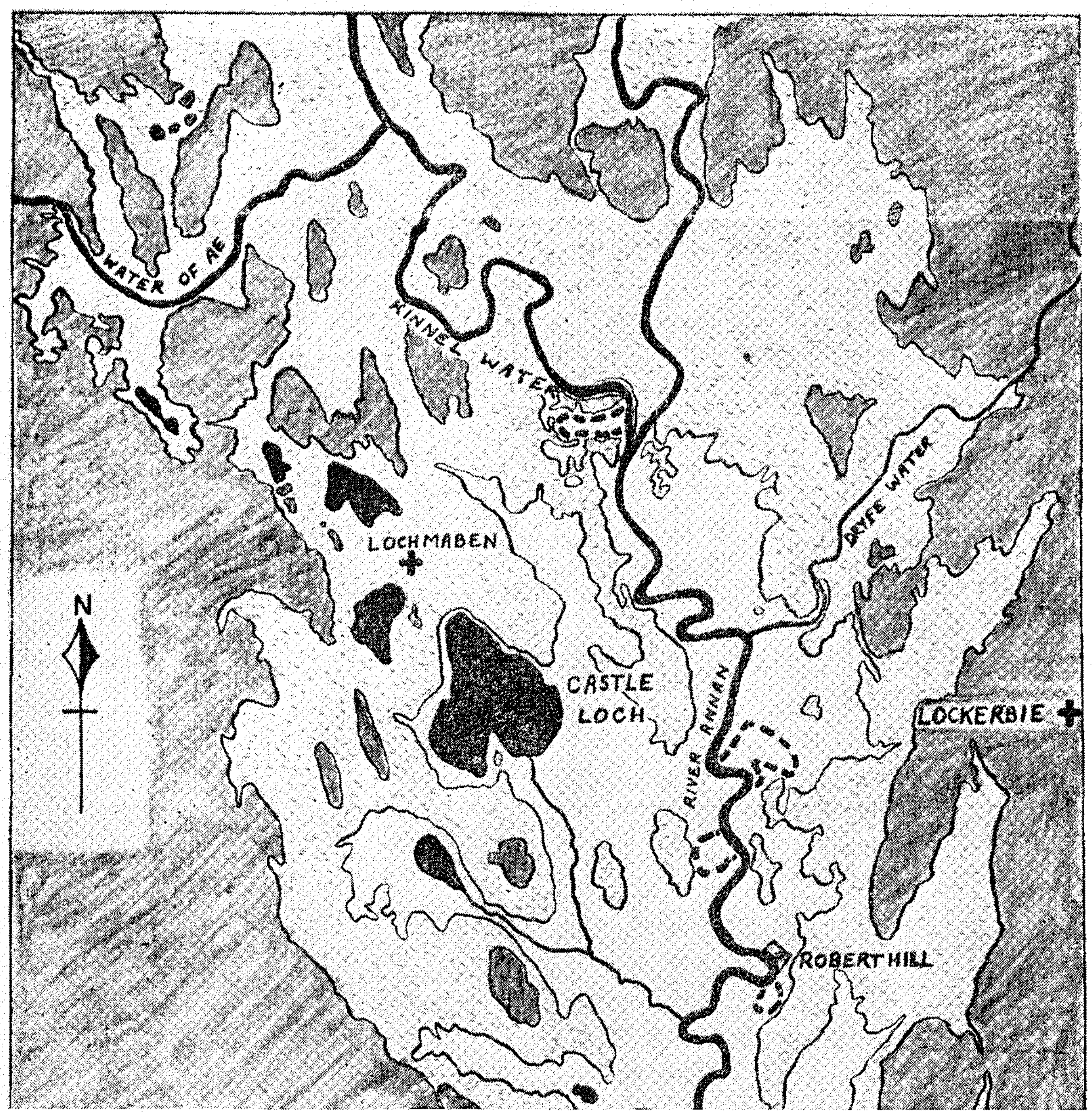
One interesting temporary section was exposed on 1st June, 1960, on the line of the A.74, near Cleuchside (5.35.159787), 3 miles south-south-east of Lockerbie.

A variable thickness of silts, peaty silts and peat, to a maximum depth of 10 feet, had to be removed to provide a firm foundation on stiff sandy glacial till. A north-south cut was made along the line of the road across a former swampy hollow. The surface morphology suggests that this hollow was elongate in a north-south direction, being rather less than 1000 feet long and some 300 to 400 feet in width with its surface lying at about 300 feet above O.D. The feature is encircled by undulating country underlain by the red-brown sandy till which rises on the east and south to rounded summits approximately 100 feet above the hollow.

Northwards the rim of this shallow basin has been breached by the present Cleuchside Burn. This flows to the north across a low ridge of sandy boulder clay and gravel to join the Water-of-Milk upstream from Gimmenbie-cleuch bridge.

Figure 2 shows a general view, looking north, of an east-west face exposed by the excavations. A slight dip of the deposits to the east, towards the line of the burn, can be seen in the photograph. A detailed section measured on the face illustrated in figure 2, near the deepest part of the excavation, and situated 9 feet north of the Castle Milk water supply pipe, and 27 feet west of the western boundary fence of the new road, was as follows:

| | Thickness Feet | Depth Feet |
|---|---|---|
| 11. Loamy soil | 0.5 | 0.5 |
| 10. Reddish sandy gravel | 1.2 | 1.7 |
| 9. Dark, humified, matted peat with wood and roots | 1.3 | 3.0 |
| 8. Structureless, light brown peat. Some rootlets but essentially a detrital deposit | 2.5 | 5.5 |
| 7. Russet to red-brown peaty silts with horizontal bedding visible and root channels. Grades up into 8 | 0.6 | 6.1 |
| 6. Green to grey-brown peaty silt. Horizontally bedded with some root channels which fade out at depth | 0.8 | 6.9 |
| 5. Blue to light grey soft clay with stringers of plant material | 1.2 | 8.1 |
| 4. Dark, carbonaceous band at base overlain by banded pink and grey silty clays | 0.5 | 8.6 |
| 3. Light grey silts with some pebbles | 0.7 | 9.3 |
| 2. Grey varved silts (sandy) and clays | 0.7 | 10.0 |
| 1. Thin loose gravel with New Red and Silurian pebbles. Passes down into stiff, sandy red-brown till. Seen to | 1.0 | 11.0 |


WATER OF AE
KINNEL WATER
DRYFE WATER
LOCHMABEN
CASTLE LOCH
RIVER ANNAN
LOCKERBIE
ROBERT HILL
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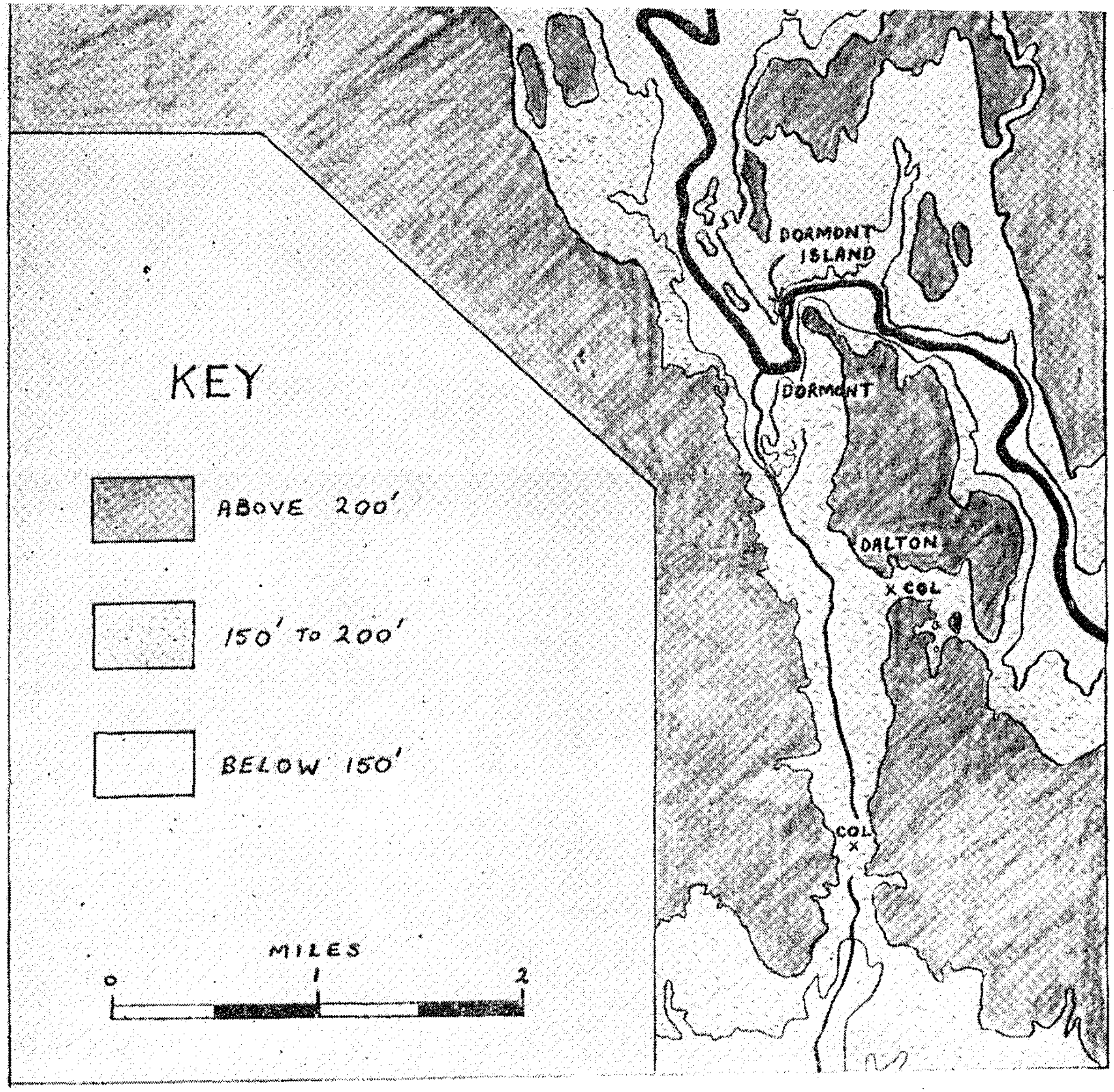



Fig. 1.—Map showing the principal relief features of the Annan Valley in the Lockerbie-Lochmaben area and the probable extent of Late-glacial Loch Maben as defined approximately by the present 150 foot contour.

The hollow almost certainly dates from the final melting of a tongue of valley ice in this area and may possibly represent a large kettle hole. The varved sediments in the lowest part of the hollow resting on the gravelly surface of the sandy boulder clay are the first of a series of Late-glacial deposits to be laid in the hollow under standing water when the area was still under a largely glacial climatic regime. The infilling of the small lake by successively more peaty, horizontally bedded sediments seems likely to span at least the whole Late-glacial period, although this requires to be substantiated by analysis of the pollen content. The natural depositional and vegetation sequence ended with the virtual elimination of the hollow and the formation of the matted, humified peat containing birch wood.

However, the occurrence of from 1.2 to 2.0 feet of reddish sandy gravel which has a clayey matrix, above the dark matted peat in all the localities investigated, including the full length of the road cut and the burn section, provides a sharp contrast to the peaty sequence and suggests a marked change in conditions. The lithology and general appearance of the deposit would seem to argue derivation under the action of solifluction from the surrounding sandy boulder clay slopes. For such a deposit to move over the almost flat surface of the hollow to seal in the peaty deposits would require permafrost conditions. These might have occurred during the post-Allerod cold period. This would require the whole 10 feet of deposit in the hollow to have accumulated during the Late-glacial period. The nature of the pollen spectra from the peat sequence should establish whether this was the case.

Another factor to be considered, however, is that the meltwater drainage (and that of the hollow) was initially to the south through the col at 310-320 feet O.D., between Cowdens and Breckonhill, which is followed by the Glasgow-Carlisle railway. Active downcutting by a tributary of the Water-of-Milk to the north later allowed the Cleuchside

Burn to capture and drain the hollow. Thus peat accumulation may have been brought to an end at the close of the Late-glacial or during the Post-glacial period as a result of the establishment of the lower local base level. In this case the movement of sandy gravel over the surface of the hollow may be the result of agricultural activity on the surrounding slopes initiating mass movement of weathered and eluviated till. This sealing-in could also have been assisted by human activities in reclaiming the "moss" area for cultivation.

## ROBERTHILL—RIVER ANNAN

The investigation of this site near Roberthill Farm (5.35.110797, figure 1) was initially carried out in May, 1960, as a rescue operation. A series of sections was measured of natural exposures occurring along the east bank of the River Annan. During mid-summer of 1960, the exposures in question were covered with large New Red Sandstone blocks to try to prevent the rapid undermining of the bank which was taking place.

The natural exposures were obscured for some 18 months during which time eight auger holes were bored to supplement the evidence already obtained. Floods early in 1962 resulted in the removal of some of the protective blocks and a little natural exposure was visible again during the summer of 1962.

*The deposits:* The feature which attracted the attention of Mr Little was an arched structure or antiform in parallel bedded grey clays and silts (figure 3). These deposits include one major peaty horizon approximately one foot in thickness while several of the bedding planes contain thin lamellæ of detrital vegetable material. The grey clays and peaty horizons prove extremely resistant to river erosion when they are below water level and form resistant clay banks or shoals stretching well into the river. However, the same deposits are extremely susceptible to erosion in large slumped blocks when undercutting of exposed banks occurs.

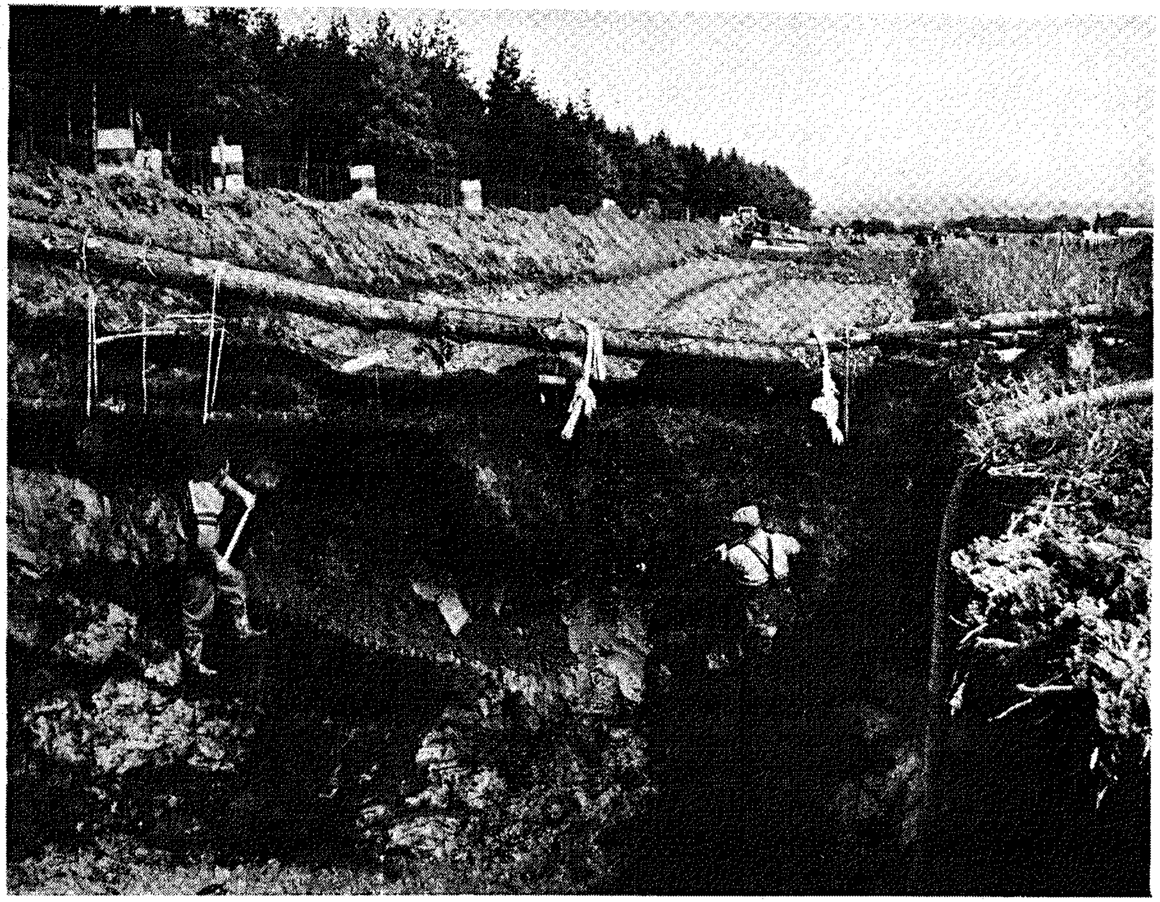


Fig. 2—View looking north of the face exposed in the Cleuchside Excavations. The bottom of the hole is in Boulder clay and the junction between lighter grey silts and overlying darker peaty silts grading up into peat can be seen dipping towards the right.

A measured section through the crest of the antiform (figure 4, Locality 4) gave the following sequence:

| | Thickness Feet | Depth Feet | O.D. Height |
|---|---|---|---|
| | | 0 | 139.0 |
| 10. Alluvium | 2.1 | | |
| | | 2.1 | 136.9 |
| 9. Clean, false bedded sands with limonitic concretions at base | 1.3 | | |
| | | 3.4 | 135.6 |
| 8. Light grey, gritty clay. Resistant to erosion (SPECIMEN G.10) | 0.5 | | |
| | | 3.9 | 135.1 |
| 7. Alternating fine sands and silts with plant material | 1.1 | | |
| | | 5.0 | 134.0 |
| 6. Dark detrital peat horizon divided into Upper (SPECIMEN G.8) and Lower horizons (SPECIMEN G.7) by a 0.1 foot band of more sandy peat. Wood for C.14 dating | 0.7 | | |
| | | 5.7 | 133.3 |
| 5. Grey silty fine sand which grades up into 6 | 0.2 | | |
| | | 5.9 | 133.1 |
| 4. Dark brown sand with stringers of vegetable matter and a thin plant horizon 0.2 ft. from top of bed (SPECIMEN G.5) | 1.0 | | |
| | | 6.9 | 132.1 |
| 3. Grey-brown fine sand with vegetable matter | 0.8 | | |
| | | 7.7 | 131.3 |
| 2. Grey silty sand with pebbles. Irregular base. | 0.7 (+ –) | | |
| | | 8.4 | 130.6 |
| 1. Clean medium sandy gravel containing much New Red Sandstone and Silurian material. Unconsolidated and buff in colour owing to limonite. Seen to | 1.2 | 9.6 | 129.4 |

SPECIMENS G5, G7, G8 and G10 refer to samples submitted to Mr N. Moar of the Botany School, Cambridge

University. The results of Mr Moar's pollen analyses are described on p. 133 of this Journal.

The succession of deposits at locality 4 was repeated with remarkable constancy of thickness and lithology in sections exposed for some 100 feet in the downstream direction (figure 4, Localities 5, 6 and 7) and a similar distance upstream (localities 1, 2 and 3). In moving away from the crest of the arch towards either the north-west or south-east, the sequence of grey clays and silts with peat (beds 2 to 8, Locality 4) was found to be overlain by a progressively thicker series of clean pinkish unconsolidated sands, of which bed 9 of Locality 4 seemed to represent the basal member.

The sands, which had a minimum observed thickness of 8 feet (locality 1) contrasted in lithology with the grey clays and sands but appeared to overlie them with only slight local disconformity. The bulk of the sand sequence had been eroded off the crest of the arch during the development of the present flood plain of the River Annan. Thus the 1.3 feet of sand recorded at Locality 4 is succeeded by "recent" alluvium.

The section across the arch as originally exposed in the 12 feet high banks of the River Annan is illustrated in figure 5. The section has been extended upstream towards the north-west by evidence from holes bored with a 4 in. bucket auger.

At points 12 and 13 the holes had to be abandoned without reaching the characteristic grey clays and silts, owing to the amount of water and sand inflow from the pink clean sands as river level was approached. A similar situation was encountered in a hole at Locality 8 (figure 4) situated to the south-east of the crest of the antiform and 100 feet from the river bank and also at hole No. 11. At No. 9, the grey clays and silts and the main peat horizon were located at depths equivalent to those suggested by the exposures in the adjacent river bank. Hole No. 10 was sunk on the presumed line of the axis of the arch structure. At a depth of 11 feet below the flood plain the hole had to be abandoned in grey slightly clayey sands owing to the constant inflow of water and sediment. Other holes in this vicinity failed to reach any greater depth because of mass movement along the surface of the water table, at a height of 2-3 feet above river level.

As only clayey sands were reached at this depth it must be assumed that the peat horizon may have been removed by erosion. However, it seems more likely that the arch seen in section in the bank and which strikes into the river in a south-westerly direction is dome-like in plan, at least at the north-eastern end of its axis. Thus the structure fades out or pitches to the north-east so that the peat band is at or below river level near locality 10. On this interpretation, the borehole would have ended just at the top of the grey clay and silt sequence, near its junction with the overlying sands, and water flow would be likely to be at a maximum.

Upstream of localities 12-13, the grey sediments are again encountered, emerging from below river level at locality 14 where they are identical in thickness and lithology to those seen in the main arch. At 14 the dip of sediments was downstream and again a clay bank feature strikes south-west into the river.

It thus appears that the sediments re-appear to the north-west of a basin or synform with its axis possibly in the vicinity of the small tributary ditch (figure 4). The presence of a second arch, although in this case more completely breached by the river and much obscured by slumping of the river bank, is supported by the fact that at locality 15, a further 100 feet to the north-west, the grey sediments and peat were again located dipping upstream. A bore-hole confirmed the similarity of the sequence and a resistant " clay bank " again strikes into the river.

The steep step of the clay bank in this case faces downstream by contrast with that at locality 14 and thus as in the case of the main arch the whole core of the antiform has been removed by undermining of the clays following removal of the unconsolidated basal gravel. The circulation of the river in these deep clay rimmed "pot holes" is shown in figure 4.

The general relationships of the beds are shown in figure 5 and the various outcrops are tentatively joined into a continuous structure. Unfortunately, in the intervening areas the outcrop is lost because of river erosion or recent bank slumping. Proving the structure further at depth was impossible because of the water problems encountered in augering. Further information might possibly be obtained during very dry periods when the River Annan and its adjacent water table are at an absolute minimum.

The area was searched for further occurrences of these easily recognisable deposits and a small isolated outcrop of clay which contains fossil wood was located at river level (figure 4) some 220 feet upstream from locality 15, which appears to be the last appearance of the beds towards the north-west. In addition, some half-a-mile downstream from Roberthill, identical grey clays occur just below river level and suggest a more widespread distribution of the deposits beneath the spread of recent river gravel and alluvium. The problem is complicated by the meandering course of the River Annan which has left many cut-off loops and by the fact that extensive flooding still occurs annually up to heights of approximately 142 feet O.D.

The deposits seem best explained in terms of a glacial meltwater gravel (Bed 1 of main section) directly overlain by still-water deposits of lacustrine origin which vary from fine sand to silt in grade, are predominantly grey in colour and contain variable amounts of vegetable matter (Beds 2 to 8).

Mr Moar's pollen spectra of samples G6, G7, G8 and G10 which span the main sequence of the lacustrine deposits are discussed by him on p. 133. The pollens indicate a typical Late-glacial flora and suggest a peri-glacial climate. A piece of wood from the lower part of the main dark detrital peat horizon (Bed 6) was kindly dated by Dr Eric Willis at the Cambridge University Radiocarbon

Fig. 3—General view of the east bank of the River Annan at Roberthill, showing members of the Lockerbie Extra-Mural class going to examine the arch structure. The flood plain alluvium truncating the crest of the structure can be seen, together with the flood dykes in the background. The dark band within the flexured sediments is the main peaty horizon.

Dating Laboratory. The sample (Q-643) yielded an age of 12.940+ years.[1] Unless the wood is derived this would suggest that the deposits fall largely within Pollen Zone 1 of the British Late-glacial sequence. This is in keeping with the interpretation that the lowest still-water deposits rest directly upon glacial gravel.

It remains only to discuss the origin of the arch structure but this is best understood after the general morphological setting of Roberthill has been described.

*Morphological Evidence:* The river Annan flows southwards from near Moffat broadly following a narrow outcrop of New-Red Sandstone. The New-Red outcrop widens in the vicinity of Lockerbie to become a broad basin bordered by subdued remnants of the mountains composed of Silurian strata, which originally dominated the intermontane desert basins of Permian times. The soft Permian sandstones have suffered considerable differential erosion by valley glaciers compared with other strata and this has resulted in a subdued " Permian basin " being re-established at the present time. This glacial scouring of the Permian rocks has resulted in the River Annan having only a very gentle gradient for some 6 miles from north-east of Lochmaben to Dormont (figure 1).

The River Annan receives at the north end of this reach the waters of several strong-flowing tributaries in the form of the Water-of-Ae and the Kinnel and Dryfe waters. The influx of the combined waters of these rivers together with the gentle gradient gives rise to extensive annual flooding. The 150′ contour line on figure 1 broadly de-limits the flood-plain in this area where the Permian and glacial deposits are largely obscured beneath an extensive spread of alluvium.

A further factor contributing to the flooding is that although a broad dry valley continues the north-south line

[1] I am indebted to Professor H. Godwin and Dr Eric Willis of Cambridge University for establishing a date for the wood and to Mr Moar for undertaking the pollen analyses. Professor Godwin also kindly discussed some of the problems involved and made helpful suggestions.

of the River Annan through Dalton (figure 1), this appears to have originated from the action of glacial meltwater. It was left as an abandoned spillway as the result of capture of the Annan drainage by a stream actively cutting back towards the north-west which now forms the lower Annan. The elbow of capture near Dormont is not particularly acute but it marks a distinct change in the direction of flow of the river while Dormont Island is the site of a major knick point. Downstream from the island the fast flowing river with rapids contrasts sharply with the meandering course bordered by frequent cut-off loops and ox-bow lakes, which is typical of the river for 6 miles north of the island.

The capture of the original north-south proto-Annan by the fast flowing and virile " lower " Annan is probably partly the result of more rapid headward erosion from the area of New-Red sediments near the town of Annan, along the outcrop of the Carboniferous strata. The rocks along this line proved less resistant than the Silurian rocks which underlie the Dalton area.

The steeply dipping Silurian flags which outcrop along the course of the Annan near Dormont Island are a further factor contributing to the flooding of the area to the north The rocks form a resistant lip or rock bar across which the Annan flows in a series of rapids. The problem of flooding was somewhat improved in 1932 when the channel at this point was made several feet deeper by blasting an artificial cut. The Annan still floods annually up to heights of 142′ - 143′ O.D. near Roberthill although it is prevented from forming an extensive lake by the presence of flood dykes.

There can be no doubt that during the Late-glacial period, immediately following the dwindling of the ice lobe which continued to occupy this part of the Annan valley after the main ice sheets waned, a considerable lake must have existed in the area under consideration. Its water level was rather less than 200′ O.D. as the col in the Dalton dry valley to the south lies a little below this height. It

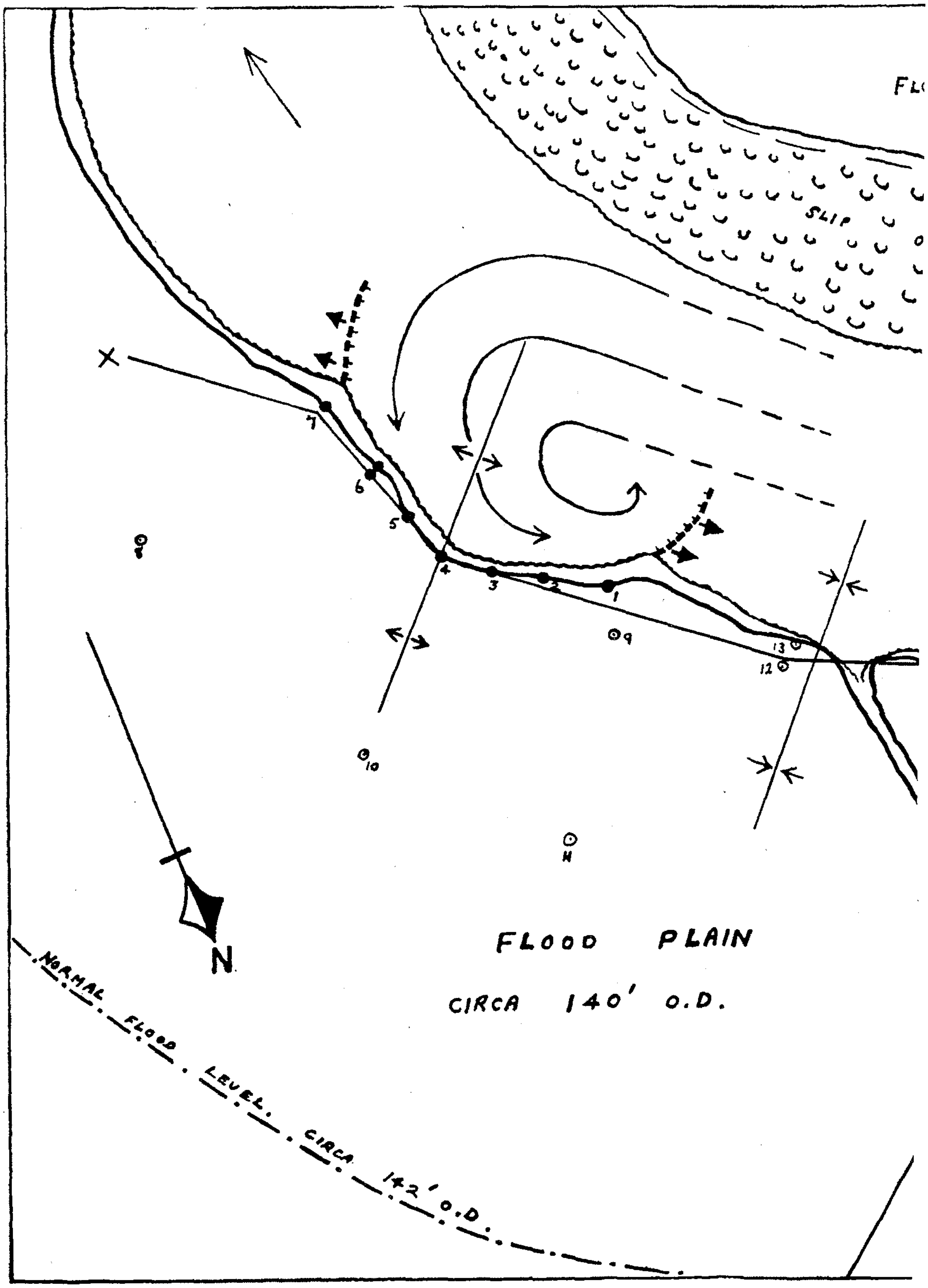
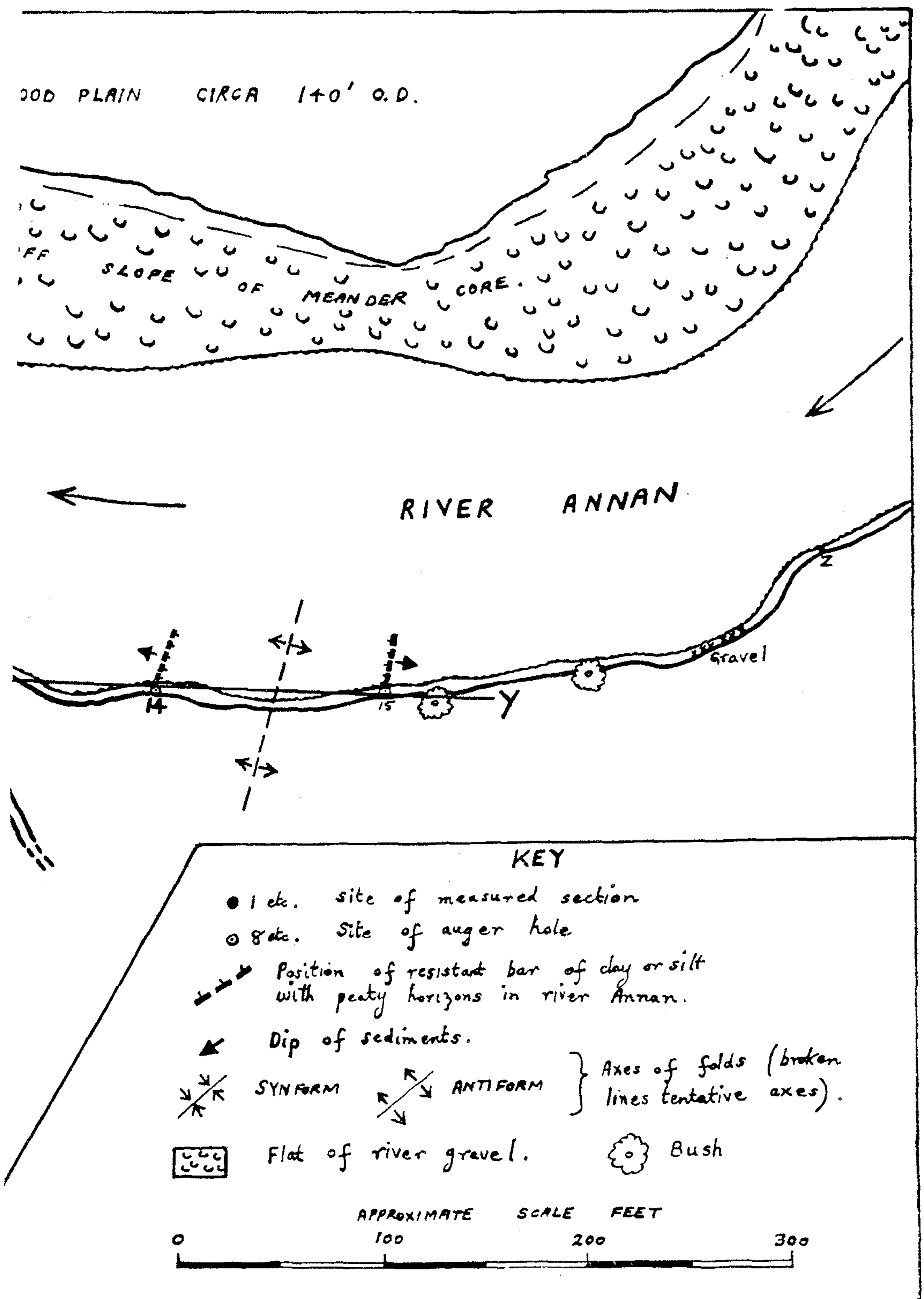



Fig. 4.—Sketch Map showing sections investigated and location of auger ho




les on the north bank of the River Annan, Roberthill Farm, near Lockerbie.

seems probable that the initial surface of the lake lay at about 175′ or 180′ O.D. This level was then lowered by gradual erosion of the Dormont outlet to approximately 150′ O.D. The 150′ contour approaches very near to the level of the present river on both sides of the Annan near Dormont Island (figure 1). It appears that by the time downcutting had reached 150′ O.D. at Dormont the original lake had virtually been eliminated by the lacustrine sedimentation combined with erosion of the outlet. The river Annan at that time commenced its meandering course across the former lake bed. In places it eroded the still-water deposits and during times of flood deposited alluvium over a wide flood plain. If unmodified by human activity the extent of the flood plain would be very similar to that of the former lake.

The lochs in the vicinity of Lochmaben, namely Castle Loch, Hightae, Mill Loch and Kirk Loch, which lie a little above or below the 150 foot contour, represent the dismembered remnants of a once continuous sheet of water. Their distribution was controlled by the location of deep hollows in the original lake floor. In view of this and as much of the lake must have fallen within the present parish of Lochmaben, a suitable name for it would seem to be Late-glacial Loch Maben.

The lake deposits described above are ascribed to this lake and it seems probable that augering would reveal extensive lacustrine sediments containing Late-glacial pollen, concealed beneath much of the alluvium along this stretch of the river Annan.

Mounds of glacial gravel and till, which must have stood as islands in the Late-glacial lake, are well seen in the area between the lochs near Lochmaben. They have a characteristic north-north-west to south-south-east trend which parallels the feature delimiting the Silurian hills to the west of the Permian basin. This alignment would suggest that ice movement from the area of the Kirkmichael Fells, between the valleys of the Water-of-Ae and the Kinnel Water was more significant, at least towards the end of glaciation in this area, than was movement along the main north-south Annan valley. However, the north-south alignment of the Dalton dry valley and the similar direction of moulding of the glacial topography in this more southerly area suggest that here true " Annan ice " had a more pronounced effect.

*Origin of the Arched Structures:*

The two possibilities for the origin of the structures shown in figures 3 and 5 and described above are that they are either original depositional features reflecting undulations of the lake floor or that they result from post-depositional deformation. The first seems improbable, as the thicknesses of individual beds, including the detrital peat horizon, are remarkably consistent whether they are measured on the crests of the arches or low down on the flanks. The dips of the limbs of the arch are sufficiently steep to anticipate that if such undulations were present during the original deposition some lenses would be visible as the beds thickened into hollows and thinned across the crests of the ridges.

In addition, it has been noted that the trend of all the glacial depositional features which can be seen above the alluvial flat is between north-north-west to south-south-east, and north-south. The alignment of the Roberthill features is by contrast south west-north east which suggests that the structures do not merely mirror existing ridges and hollows on the surface of the glacial deposits. If it is accepted that the sediments were probably formed as an almost flat-lying series of beds, then some deforming mechanism has to be invoked.

Superficial valley folds have been described affecting both pre-glacial and glacial deposits. Some of the deformation in these cases was undoubtedly pre-glacial in age but folds described from near Barnsley in Yorkshire (Shotton & Wilcockson 1951) affected both coal measures and glacial deposits and the movement was referred to a time immediately following glaciation.

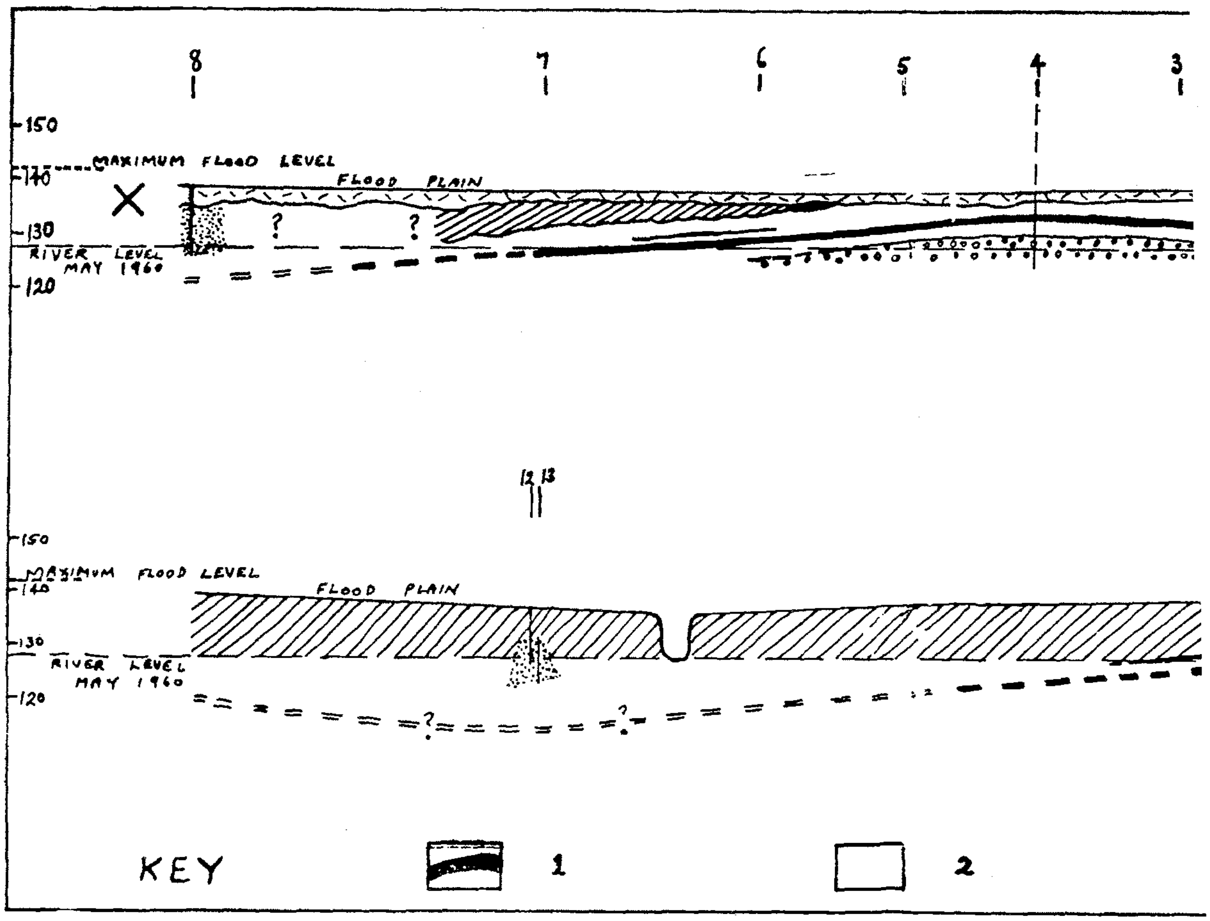
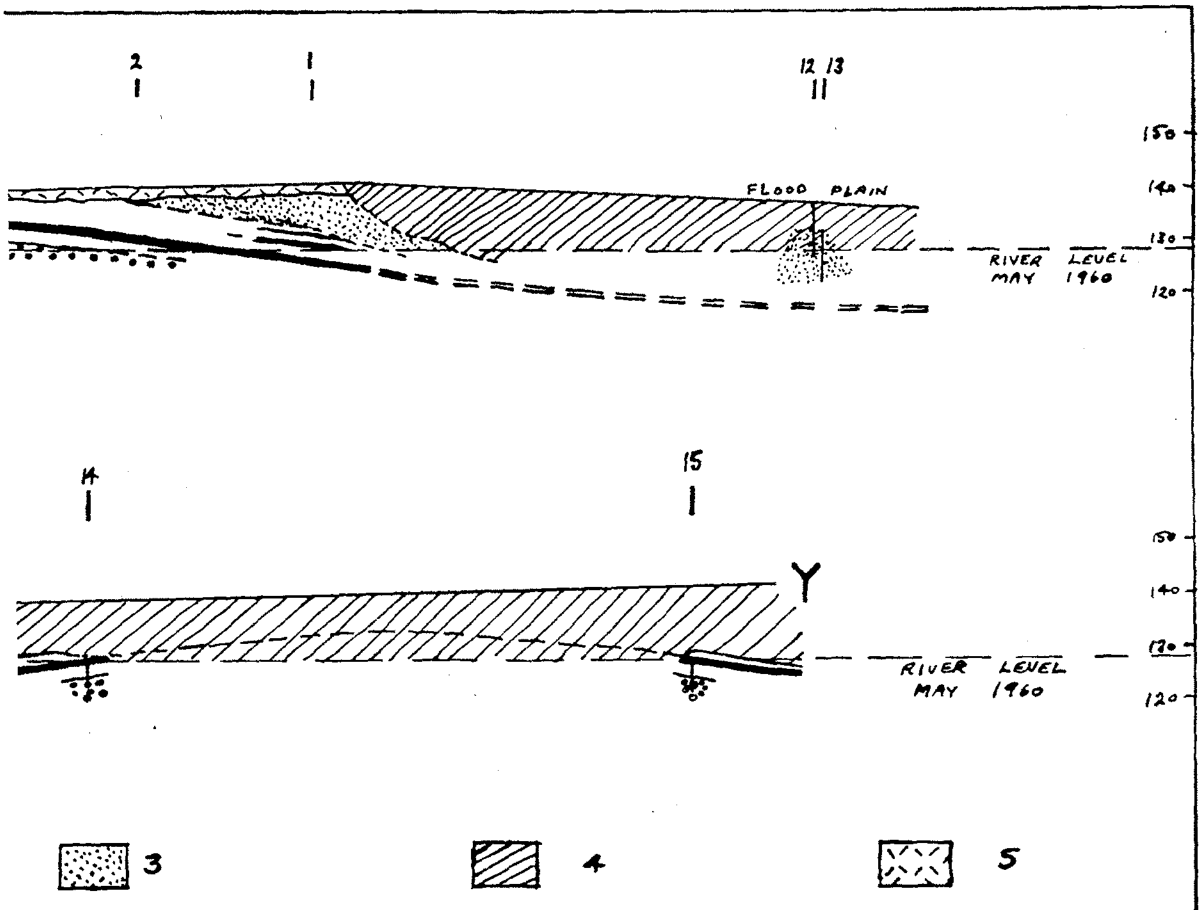



Fig. 5.—Section of the deposits on the north bank of the Riv er Annan (line X - Y, Fig. 4), Ro
1, Peat; 2, Clay; 3, Sand; 4, Areas of no exp o




berthill Farm, near Lockerbie. Section drawn to natural scale with no vertical exaggeration.
sure, slipped masses, etc.; 5, River alluvium.

Domes, folds and other structures which are the result of deformation under peri-glacial, repeated freeze-thaw conditions are well known but in the majority of these cryoturbation or festooning structures are also seen. In the domes and folds produced under peri-glacial conditions, the crest of the structure is usually broken and the beds are severely disturbed.

At Roberthill, although a peri-glacial climate existed at the time of deposition of the beds from the pollen evidence, there is absolutely no evidence of cryoturbation and the bedding is undisturbed. This would seem to suggest that the beds were protected by an overlying water layer. This must have been deep enough to allow floating ice to form above some depth of water which did not reach freezing point. The deposits are thus free from deformation as a result of the growth of ground ice masses.

Other mechanisms which may cause deformation of unconsolidated sediments have been summarised as follows (McKee et al 1962):

(1) gravity slumping,
(2) drag—as from an overriding force,
(3) overloading from above or from one side,
(4) modification by boring organisms, root growth or gas bubbles.

Of these (1) and (4) can be ruled out at Roberthill but one possible solution would involve a combination of (2) and (3).

In searching for some source of drag, push or even for a load to deform these deposits it is tempting to invoke the work of glacier ice. It seems possible to the writer that in the case of the Roberthill structures a local glacial re-advance could satisfactorily account for all the pieces of evidence at present available. As far as can be ascertained all the deposits were probably laid down within Pollen Zone I. However, if the date of almost 11,000 B.C (12,940 B.P.) for wood occurring about in the middle of the main sequence is accepted as dating the deposits themselves (that is providing that the wood is not derived), then the Roberthill sequence in beds 2 to 8 (pollen samples G5, G7, G8 and G10) would be broadly equivalent to the Bolling oscillation of continental Europe. This mild interval was established on the basis of pollen evidence from Denmark and recent radiocarbon dates show that its duration was probably about 11,500 B.C. (13,500 B.P.) to 10,500 B.C. (12,500 B.P.) (Movius 1960). This warmer phase occurs towards the middle of Pollen Zone I. and serves to divide it into three subzones with a climatic sequence which runs from cold to milder to cold. The Roberthill date would seem to be broadly equivalent with the middle of this Bolling oscillation which had a duration of approximately 1000 years. Thus the radiocarbon evidence might suggest a broad equivalence of the Roberthill lacustrine deposits with the mild Bolling period. The pollen sequence established by Mr Moar does not appear in conflict with this.

In continental Europe the third (or older Dryas) division of Pollen Zone I. (Zone IC.) is dated as of approximately 500 years duration from 10,500 to 10,000 years B.C., when it was succeeded by the Allerod warm oscillation (Pollen Zone II.) (Movius 1960).

Although the link with the European botanical and inferred climatic evidence is a tenuous one it does suggest a possible explanation for the Roberthill - Lochmaben evidence. The "cold snap" following the Bolling mild conditions may have allowed a local tongue of ice to advance into the Lochmaben area from the Kirkmichael Fells. This same period on the continent saw the establishment of moraines in southern and central Sweden and near Leningrad.

Such an advance would account for the alignment of the recent looking moundy topography in the Lochmaben area. The deep hollows of Kirk Loch, Hightae Mill Loch, etc., would also be explained by such a local advance giving rise to large kettle holes as the dwindling ice masses sank while melting, into the unconsolidated still-water clays and silts over which the snout of the re-advancing glacier had moved. Finally a push as a result of advance from north-north-west or merely the effect of the weight of the ice mass as it advanced over the sediments of Late-glacial Loch Maben, could account for the small folds, striking south west-north east in the Roberthill area.

*CONCLUSION:* A series of deposits formed in Late-glacial Loch Maben contain pollen which suggests a Zone I. peri-glacial climate. The middle of the lacustrine series has yielded a radiocarbon date of almost 11,000 B.C. The deposits thus may be roughly equivalent to the Bolling oscillation of the European sequence.

It is suggested that Late-glacial Loch Maben ceased to exist following downcutting of the outlet near Dormont Island and since that time migration of the meandering course of the river Annan has resulted in the deposition of alluvium over most of the remaining lake deposits. At Roberthill excellent exposures of the lacustrine sediments are seen owing to the development of local fold structures. The fold crests have been truncated and are overlain by alluvium.

It is tentatively suggested that the folds and the lochs still existing in the Lochmaben area may be the result of a local ice re-advance towards the end of Pollen Zone I. and prior to the Allerod warm phase. The maps depicting glacial retreat stages in Scotland have been of necessity extremely generalised and much more detailed mapping in relation to accurate dating is required before a firm retreat sequence is established.

It is generally accepted that the "Highland Re-advance" is to be correlated with Pollen Zone III. and is later than the Allerod warm oscillation. At the time of this temporary halt in ice retreat there were still small cwm glaciers remaining in North Wales and the Lake District (Godwin 1960). Thus during the earlier cold phase represented by the end of Pollen Zone I. it seems highly probable that small valley glaciers would still exist in localities favourable for ice accumulation within the Southern Uplands. The Perth and Aberdeen re-advances are placed within Zone I. by Donner (1957, 1959) and both of these extended some distance into lowland areas. The distribution of remnant ice mases in the Southern Uplands during the Late-glacial period requires further investigation.

This paper is submitted in the hope that other workers will take up the cudgels, or auger rods, to prove the truth or otherwise of the above hypothesis by further investigation. But for returning to continue with East African Pleistocene studies, the writer had planned to pursue some aspects of the work himself.

## REFERENCES

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