5. From the author

Lake Basins
Cumberland

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THE ORIGIN OF SOME OF THE LAKE-BASINS OF CUMBERLAND.

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The ORIGIN *of some of the* LAKE-BASINS *of* CUMBERLAND. By J. CLIFTON WARD, Esq., Assoc. R.S.M., F.G.S., of the Geological Survey of England and Wales.

[PLATES IX. & X.]

FIRST PAPER.

THE subject of the origin of lake-basins is one which has received considerable attention at the hands of several eminent observers, and notably of Professor Ramsay. At the present time I propose to discuss the origin of those depressions in which some of our Cumberland lakes lie, taking as examples Derwentwater and Bassenthwaite, and Buttermere, Crummock, and Loweswater. The two former lakes I have myself carefully sounded; the latter were sounded many years since by Mr. P. C. Crosthwaite; and the depths obtained by him will here be made use of, with some observations of my own.

The first point is to obtain a true idea of the proportions and depths of the lakes as compared with the surrounding mountains. For this purpose I have drawn a number of sections on a true scale (the same vertical and horizontal), both in the direction of the length of the lakes and transverse to that direction. In the case of the longitudinal sections (figs. 1–3), outlines of the mountains on the left sides of the respective valleys are inserted, with their true height, and the lakes are indicated by deep-black lines of a thickness corresponding to the various depths. To form a strictly accurate idea of the original size of the lakes, the following points must also be taken into account. Both Derwentwater and Buttermere must formerly have extended nearly a mile higher up their respective valleys (see Map, Pl. IX.). Derwentwater and Bassenthwaite were once continuous, though now parted by some three miles of alluvial land. Buttermere and Crummock were likewise originally one, though three quarters of a mile of alluvium now separates them. The filling up of the head of Derwentwater is due to the matter brought down by the river Derwent and the Watendlath beck; and the soundings for a mile and a quarter north of the mouth of the Derwent show how this process is still going on, the depths for that distance only increasing from 5 to 18 feet, there being much deeper channels on either side the northern part of this shallow tongue (fig. 17). The Barrow beck has also done its share of work in forming an alluvial fan projecting into the lake, and in shallowing the parts immediately beyond. The tract of alluvium between Derwentwater and Bassenthwaite has been formed by the river Greta flowing from the east, and the Newlands beck and its tributaries flowing from the south and west. The head of Buttermere has been filled up by the detritus borne down by the Gatesgarthdale and Warnscale becks, flowing westwards on either side of

Honister Crag; and the alluvium separating Buttermere from Crummock is mainly the product of Mill beck flowing down from the north, and Sourmilk Gill from the south, upon the opposite side.

In the absence of borings the thickness of these alluvial deposits cannot be estimated; but it might be that, formerly, the greatest depths of the original long lakes were at points somewhere between Derwentwater and Bassenthwaite in the one case, and Buttermere and Crummock in the other.

The figures 5–10 and 13–16 inclusive, give the forms of the lakes in transverse section, while figs. 1, 2, & 3 represent their longitudinal sections along the lines of greatest depth.

When the true dimensions are thus laid down to scale, the point that first strikes one is the insignificance of the hollows in which the lakes lie as compared with the elevations of the surrounding ground. But since these lakes are not sheets of water merely dammed back by moraine mounds, but lie in hollows scooped out of the solid rock, it becomes an interesting and legitimate question to inquire what was the agent which produced the hollows.

Now I think there is no doubt whatever that the principal valleys of the district in which these larger lakes lie are of very great age. After more than four years' intimate acquaintance with mountain and valley, the fact is very strongly impressed upon my mind that all the grand mountain-sculpturing to be met with here is due to the apparently weak agents now in operation, the powers of the atmosphere, wind, rain, frost, and running water. Nor can I see any reason to doubt that the elaboration of our present Lake-district scenery has been going on uninterruptedly, though very likely at different rates, at least ever since the close of the Carboniferous period, and perhaps from an earlier date still. It will thus be seen that I do not consider our Cumberland valleys to be merely gigantic ice-grooves formed by a mammoth ice-cap, as was recently suggested to this Society by Mr. Campbell to suit the case of Ireland; but, rather, I look back through long past ages during which these valleys were being sketched out, formed, and deepened, under very varying circumstances and climates, now under almost tropical conditions, and now beneath an arctic mantle of snow and ice—sometimes when the district was far higher above the level of the sea than it is now, and sometimes perhaps when at a lower elevation. In all probability glaciers have moved down these old valleys at more than one period previous to the modern Glacial; and though they may have effected a large amount of denudation by attrition and transport, yet did they hinder the work of the denuding agents for long ages after, just in proportion as they left the country with a smooth and polished surface against which the atmospheric powers might beat for long in vain. Such considerations as the foregoing lead me to conclude that the lake-hollows are of very recent date, geologically speaking, and represent the removal of but some of the last rock-shavings by nature's tools. And what the special tool was which effected this we have now to consider.

Professor Ramsay has ably shown the difficulties which attend an explanation of the formation of rock-basins by such agents as the sea, running water, and mere weather-action, or by rock-disturbance, special depression, or the formation of gaping fissures. Certainly the lakes in question do not appear to have been formed by any such actions. They bear no marks of marine action, even supposing the sea capable of scooping out smooth hollows in closed fiords running far inland. Such hollows are not now being formed by running water, but rather filled up through its action. They do not lie in synclinal troughs of rock; for the general direction of the two sets of lakes is directly across and at right angles to that of the strike of the rocks. No one could suppose that the shallow basins represented in these diagrams were special areas of depression, when the contour of their bed is seen to conform so closely to that of the hills on either side, and the lie of the rocks shows no evidence of so limited a movement. Neither can they possibly be regarded as resulting from great fissures having taken place; for the rocks show no signs of such at either end of the long shallow troughs, or on either side; nor, as far as I can tell, do the lakes lie along lines of fault, with the exception of Derwentwater, which is bounded on the east side by a fault throwing together the hard Volcanic Series of Borrowdale and the soft Skiddaw Slates (fig. 13).

These lakes are, indeed, merely long shallow basins with a smoothed and well-scratched inner surface, worn out of the Skiddaw Slate, which is much crumpled, cleaved, and comparatively soft. The smoothing and the scratching of the rocks, in the direction of the length of the lakes, may be traced at many points passing under the water; so that there is no doubt that the hollows have been at one time filled with glacier-ice; and it remains to be seen how far in these cases Professor Ramsay's theory of the glacial origin of lake-basins will hold good.

In a former paper, on "The Glaciation of the Northern Part of the Lake District"*, I brought forward details to prove that at the period of greatest glaciation the large glaciers were more or less confluent, and that the greater part of the district was almost completely enveloped in ice. In the longitudinal sections (figs. 1 & 3), however, I have made the thickness of the ice no greater than the highest ice-scratches pointing down the valleys clearly warrant. In many cases ice-rounded rocks are common above the point at which the highest scratches are seen; but for our present purpose we will ignore this further evidence and take a *low estimate* of the thickness of the old glaciers. At the very outset of our examination a difficulty will present itself to some minds. If we take the case of the old Borrowdale glacier and mark its course along the valley of the Derwent, over the present sites of Derwentwater and Bassenthwaite, we are struck by the great flatness of the ground for full thirteen miles, from Seathwaite to the lower end of Bassenthwaite lake, ten miles of which is occupied along the line of section either by existing lake or alluvium representing former lake. If, then, we had to consider the old glacier a line of ice by itself, arising in the part

* Quart. Journ. Geol. Soc. vol. xxix. p. 422.

of the Derwent valley above Seathwaite, and having no other outward push but that due to gravitation down the two-and-a-half-mile slope from Allen Crags to Seathwaite, and to molecular gravitation throughout its length, we might be inclined to question the possibility of its moving over the thirteen miles of flat ground and scooping out lake-basins in its course. But just as the river Derwent now receives very many tributaries, some as large as itself, from the valleys and mountains on either side, and yet does not occupy a much wider channel, but acquires a faster flow and greater power of moving material onwards with it, so did the old Borrowdale glacier, the former representative of the Derwent, receive additional impulse from the numerous glacier sheets shed off the mountains on either side and down the tributary valleys. Let us see what this additional impulse really means. Above the village of Rosthwaite there met several large ice-streams. The Derwent glacier proper received reinforcement from ice coming down from Sty Head, out of Sourmilk Comb between Grey Knotts and Base Brown, and down the valley in which Comb Gill now runs due north from Glaramara. Just above Rosthwaite it was joined by the Stonethwaite glacier, made up of the Longstrath and Greenup ice-streams (see fig. 11). The union of these two glaciers (Derwent and Stonethwaite) formed the main Borrowdale glacier, which had then to be forced through the narrowest part of the valley, between Rosthwaite and Grange, a great ice-sheet moving over the fell-tops on the east side more or less coalescing with it (see Map, Pl. IX., and fig. 12).

The old Rosthwaite Lake, of an oval form, and nearly a mile in length, occurs, it should be noted, just beyond the junction of the Derwent and Stonethwaite glaciers, and where the ice, after having its rate of flow somewhat checked at the junction, would have acquired an additional impetus (see Map, Pl. IX.). About Grange the ice-sheet shed off Brund Fell and down the Watendlath valley joined the main glacier on its escaping from the so-called jaws of Borrowdale (just about Castle Crag, fig. 12). Thus increased in mass, the ice was urged through the valley, over the present site of Derwentwater, between Cat Bells* and Bleaberry Fell (fig. 13). I have little doubt that the pressure in a N.N.W. direction was here so great that the western side of the glacier partly escaped over the Cat Bell ridge—especially through the Hause Gate, between Maiden Moor and Cat Bells (fig. 3)—and became confluent with the Newlands glacier upon the other side. It is just about this part of the valley (fig. 13) that the greatest depth of Derwentwater is found—a depth, however, very slight as compared with the thickness of the ice, the former being 70 feet, and the latter something like 1100. Tracing the course of the glacier still further down the valley, it seems that about Keswick it was joined by several other large ice-sheets. There were the Newlands and Coledale glaciers wedging in about Braithwaite, and the western part, at any rate, of the great ice-sheet coming down the Thirlmere valley, pressing along the Naddle

* Skelgill Bank in fig. 13 is the northern end of the Cat Bells range.

vale, and over the low ridge towards Keswick (see Map, Pl. IX.). Besides these, sheets of ice of greater or less size probably descended the southern slopes of Skiddaw and came down the valley of the Glenderaterra. The main valley, just below Keswick, is about three miles in width, between Braithwaite and Latrigg; and it seems almost certain that the confluent glaciers occupied the whole width to the thickness at least of a thousand feet. Only two or three miles further down, however, this great volume of ice had to pass through a part of the valley not more than a mile wide at its base, between Barf and Dodd (fig. 14), beyond which it was able to escape to the west and east of the present Bassenthwaite Lake, mainly at first, I should fancy, to the west (over into Wythop vale, fig. 15), on account of the pressure from ice-sheets probably shed westward and north-westward from the lofty mountain mass of Skiddaw. It will be seen that the deepest part of Bassenthwaite is along the western side, just where resistance to the westward trending of the glacier would be most felt; and at the same time it is evident what a small proportion the depth of the long narrow trough bears to the probable thickness of the ice*.

Turning next to the examination of the case of Buttermere, Crummock, and Loweswater, we are struck at once with the difference in form of the valley-bottom, when seen in section (figs. 5–10), from that of the valley in which Derwentwater and Bassenthwaite lie (figs. 13–16). In the latter case the contour is like a more or less wide flat-bottomed pan, in the former (Buttermere, Crummock, and Loweswater) like a round-bottomed basin.

The head source of the Buttermere glacier was upon Fleetwith, below Grey Knotts, whence ice-streams flowed down on both north and south sides of Honister Crag, uniting with one another to form the main glacier just at the head of the present Buttermere Lake, where the valley is narrowest, the mountains on either side the most lofty, and where also the greatest depth of the present lake is found (see Map, Pl. IX., and figs. 5 & 19). The two ice-streams are represented in fig. 4, and the glacier after their union in fig. 5. It will also be noticed on reference to fig. 1 that the present lake commences just at the foot of the steeper part of the glacier-bed, and that beyond this point to the further end of Crummock there is scarcely any incline.

Besides the small glaciers shed down the steep hill-side from Burtness† and Bleaberry Tarn‡ Combs, a considerable ice-stream, coming down the Mill-Beck valley, must have joined the main glacier and helped to swell its mass (fig. 6). In my former paper I showed that the Buttermere glacier on approaching Mellbreak was probably split into two branches, the main mass continuing down the valley, but a part of its left side being pressed across the low watershed by Black Beck, just north of Scale Force (fig. 7), to join

* It should be borne in mind that a glacier, like a river, has its motion checked on approaching a narrow part of its valley bed, and flows more swiftly on its escape. Example, the strait between Barf and Dodd.

† Between High Stile and High Crag. ‡ Between High Stile and Red Pike.

another ice-stream flowing northwards down Mosedale from Gale Fell (see Map, Pl. IX.). Any part of the ice-mass thus got rid of from the main valley at this point, however, was probably more than made up for by the ice poured down from the flanks of the Grasmoor and Whiteless Pike range. Between the northern end of Mellbreak and Grasmoor, the valley is again considerably reduced in width; and along this lower half of the lake its depth is greatest. Escaped from this narrow part, the main mass of the glacier continued down the vale of Lorton, reinforced by ice shed off from the west sides of the lofty Grasmoor and Whiteside range; and it is certain that at one time, at any rate, the left limb of the glacier passed over the present site of Loweswater, and partly enveloped Low Fell. This must have been at a time when the outward thrust of the ice was sufficiently powerful to push a portion of the glacier westward up an incline of 75 feet in a distance of a mile and a half, from Crummock to Loweswater (fig. 2). At the east end of Loweswater other ice-streams from the south met this branch of the main glacier; and the whole mass was squeezed through the narrow valley between Carling Knott and Low Fell (fig. 10), in which Loweswater now lies, its deepest part (60 feet) being midway between these highest points (fig. 21). A mile and a quarter beyond the upper end of Loweswater the ice would pass over the low watershed at Sosgill (fig. 2) into the flat country beyond.

I think that when the following points are carefully considered —the fact of the lakes under examination being but long shallow troughs, the thickness of the glaciers which moved along the valleys in which the lakes now lie, the agreement of the deepest parts of the lakes with the points at which, from the confluence of several ice-streams and the narrowing of the valley, the onward pressure of the ice must have been greatest—one can hardly resist the conclusion that the immediate cause of these lake-basins was the onward movement of the old glaciers, ploughing up their beds to this slight depth, in the way Professor Ramsay's theory suggests. At the same time it should be noticed that in the case of Buttermere and Crummock—lying in a valley with rounded bottom, as seen in cross sections—the action is merely a slight deepening of the basin, or the formation of a smaller basin of similar general form at the bottom of the larger; whereas in the case of Derwentwater and Bassenthwaite the action has been to produce a long shallow groove, of varying width, upon the flat bottom of the wide pan-like valley—this groove in the case of Bassenthwaite being situated (for probable reasons before noticed) markedly at one side of the pan, close under the rising sides.

It may be urged by some that the fact of the deeper lakes being situated in the valley bearing the glacier of least thickness is against the idea of the lake-basins being formed by the ice; but I think, in this case, the fact is rather due to the original forms of the respective valleys, the same or a less amount of rock-scooping giving rise to a deeper lake in an originally round-bottomed valley than in a flat-bottomed one.

At a future time I hope to test the results here obtained for these lakes by bringing forward like details in the case of some of the other lakes, and notably Wastwater, and also in a similar way to consider the origin of the many mountain-tarns scattered throughout the district. This latter subject leads me to make the remark that a great service would be rendered if some one could be induced, during the summer months, to visit the various tarns with a small light canoe and sound their depths. The work is one I would mostly gladly undertake myself; but as my official business will not allow me the necessary time, I must leave it, hoping some one may be found to do it out of pure love for scenery and science.

EXPLANATION OF PLATES.

Plate IX.

Map of the northern part of the Lake district, showing the direction of ice-scratches by arrow-marks, and the lines along which the transverse sections in Plate X. have been drawn.

Plate X.

Horizontal sections to illustrate the form of the valleys, the depth of the lakes, the height of the mountains, and the thickness of the ice; together with plans of the five lakes: all on a true scale of 1 inch to 1 mile.

Fig. 1. Longitudinal section of the Buttermere and Crummock valley, from Grey Knotts to Low Fell.
2. Longitudinal section of the Loweswater valley, from the foot of Crummock Water to Sosgill.
3. Longitudinal section of the Derwent valley, from Allen Crags to the foot of Bassenthwaite Lake.
4. Transverse section of the head of the Buttermere valley, from Scarf Gap to Dale Head.
5. Transverse section across the deepest part of Buttermere, from High Stile to Robinson.
6. Transverse section across the lower end of Buttermere, from Red Pike to High Snockrigg, and High Snockrigg to Whiteless Pike.
7. Transverse section across the head of Crummock Water, from Black Beck to Whiteless Pike.
8. Transverse section across Crummock Water, from Scale Knott to Rannerdale Knotts.
9. Transverse section across Crummock Water, from Mellbreak to Grasmoor.
10. Transverse section across the deepest part of Loweswater, from Carling Knotts to Low Fell.
11. Transverse section across the head of Borrowdale, from Great Gable to Ullscarf.
12. Transverse section across Keskadale, Newlands vale, Borrowdale, and Watendlath vale, from Knott Rigg on the west to High Tove on the east.
13. Transverse section across the deepest part of Derwentwater, from Causey Pike to Bleaberry Fell.
14. Transverse section across the head of Bassenthwaite Lake, from Lord's Seat to Skiddaw.
15. Transverse section across the deepest part of Bassenthwaite Lake, from a little south of Wythop Hall to Ullock Pike.
16. Transverse section across Bassenthwaite Lake, from Sale Fell to Little Knott.

Fig. 17.	Plan of Derwentwater,	with depths given in feet, and dotted lines along which the sections run.
18.	" Bassenthwaite Lake,	
19.	" Buttermere,	
20.	" Crummock Water,	
21.	" Loweswater,	

Discussion.

Mr. Campbell said that he had listened with great pleasure to the able paper of the author. He was not himself acquainted with the Lake-district; but he knew many similar districts in which similar phenomena existed. He agreed with the author's conclusion, that these lake-basins were the result of glacial erosion. But if ice could do so much, it might have done more. In confirmation of the author's views, Mr. Campbell said that in the Caucasus there are very few lakes. He had found no glacial phenomena in the whole range, except one small moraine near the only lake in Daghestán.

Mr. Evans inquired what effect the varying hardness of the strata, their trend and dip, might have had on the formation of the basins, and how the presence of islands was to be explained. He mentioned that at the present day the rainfall at Seathwaite was in some years nearly 200 inches, which, if there were sufficient cold, would suffice even now for an enormous supply of ice.

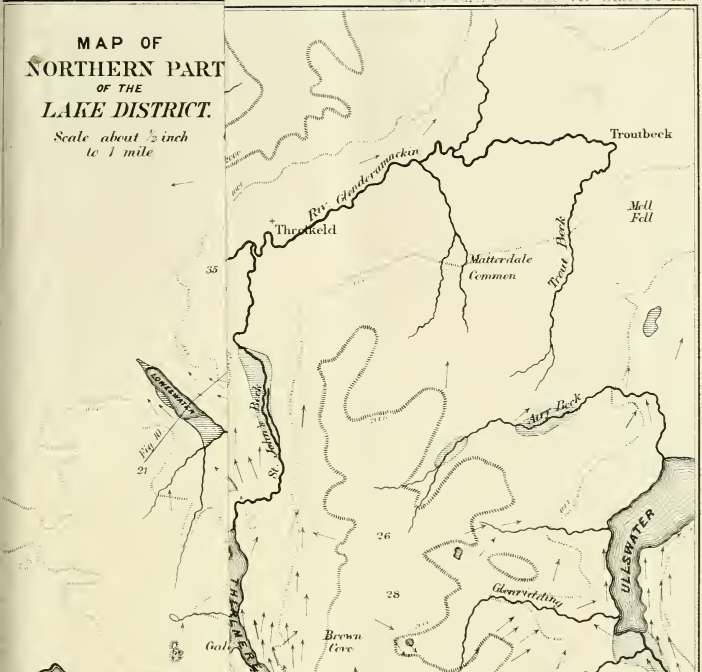
Mr. Seeley inquired whether the position of the lake-basins in the supposed glacier had any definite relation to the positions of smaller affluent glaciers, and whether the lake-basins were to be attributed to that relation.

Mr. Godwin-Austen remarked on the acceptance which Prof. Ramsay's views had received, and the support which they were receiving. There was little doubt of the former existence of ice over a large portion of this part of Europe; but whether it could have existed in such thickness as was required by some geologists was another question. He doubted as to the power of glaciers to drive ice forward to any great extent over land either up a slope or over a horizontal space. He considered that the paper would add a great interest to the country to which it related.

Capt. Douglas Galton disputed the power of ice to act in a manner materially different from that of water. Owing to the friction of the ice at the bottom of a glacier, he thought its flow would be so much retarded that its excavating power would be almost annihilated.

Mr. Ward, in reply, stated that the basins in all the cases he had cited were excavated in the Skiddaw slate, the hardness of which was nearly uniform. The dip of the strata was very variable, but he could not point to any spot where the depth of the lake was connected with the dip. The islands in Derwentwater might be the result of an old moraine left by the glaciers in retreating up the valley. The position of the lakes was in the direct line of the principal glaciers. The thickness of the ice was proved by the existence of scratches along the sides of the valleys, such as could not have been produced in any other way. The probability was that the ice had been even thicker than shown by these marks. Though the laws of motion of ice were the same as those of water, yet the action of a hard body was of necessity different from that of a liquid.

Prof. Ramsay was so accustomed to meet with papers such as this, confirming his original views, that he was almost becoming weary of the subject. He considered, however, that the sections given by the author on a true scale were of very great value, as calculated to give a correct idea of the actual phenomena, and as showing the value of De la Beche's maxims with regard to such diagrams. He inquired whether there could be any difficulty in a body of ice, some thousands of feet in thickness, cutting out such inconsiderable hollows as those shown, just in the same manner as running water sometimes excavates its channel more deeply at one spot than another, if from local circumstances the nature of its motion is increased.



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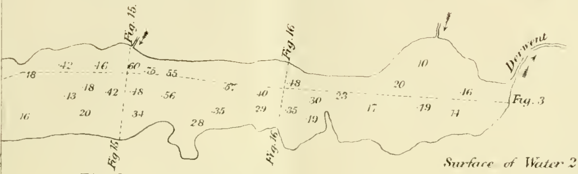
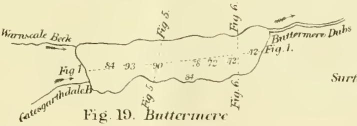


Surface of Water 226 Ft.

Fig. 18. *Bassenthwaite Lake.*

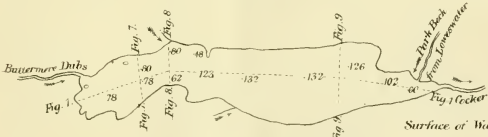
Surface of Water 238 Ft.

Fig. 17. *Derwentwater*



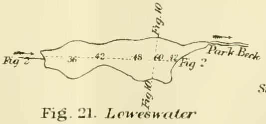
Surface of Water 331 Ft

Fig. 19. *Buttermere*



Surface of Water 321 Ft.

Fig. 20 *Crummock Water*



Surface of Water 396 Ft.

Fig. 21. *Loweswater*

Scale 1 inch to 1 mile.

Lakes with their soundings, depths in feet.

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