son's "Bright-line" (3) curve[5] and has the equation

$$y = 53.359\left(1 + \frac{x}{11.0856}\right)^{3.96821}\left(1 - \frac{x}{14.4504}\right)^{5.17262}.$$

Curve II. is Pearson's "Bisection" (3) curve[6] and has the equation

$$y = 71.56246\left(1 + \frac{x}{11.349400}\right)^{5.41665}\left(1 - \frac{x}{6.998136}\right)^{3.33995}.$$

Curve III. is Pearson's "Bisection" (2–3) curve[7] and has the equation

$$y = 59.43126\left(1 + \frac{x}{16.16672}\right)^{9.763885}\left(1 - \frac{x}{13.55284}\right)^{8.185180}.$$

Curve IV. is Pearson's "Bisection" (1–2) curve[8] and has the equation

$$y = 56.2136\left(1 + \frac{x}{28.15012}\right)^{35.390655}\left(1 - \frac{x}{37.69023}\right)^{47.384605}.$$

It will be noted that these are all Type I curves and represent a rather wide range of values of the a's and m's. The expression for y_0 in a Type I curve is

$$y_0 = \frac{N}{b} \cdot \frac{m_1^{m_1} m_2^{m_2}}{(m_1 + m_2)^{m_1 + m_2}} \cdot K,$$

where

$$K = \frac{\Gamma(m_1 + m_2 + 2)}{\Gamma(m_1 + 1)\,\Gamma(m_2 + 1)}.$$

The table shows the change in the maximum ordinate, y_0, produced by altering $\log K$ to the amount indicated.

TABLE I

Showing the Maximum Effect on an Ordinate of the Curve Produced by a Change in the Value of the Log Gamma Term of the Indicated Amount

Curve	Amount of Change in Log K				
	.0000001	.000001	.00001	.0001	.001
I......	.00002	.00013	.00123	.01229	:12303
II.....	.00002	.00016	.00164	.01647	.16496
III...	.00001	.00014	.00137	.01369	.13700
IV....	.00001	.00013	.00130	.01295	.12958

From this table it is evident that:

1. An alteration of as much as one in the third decimal place in $\log K$ makes a change in the maximum ordinate of between 1 and 2 in the first decimal place, an amount practically negligible in many curve-fitting studies.

2. A degree of approximation to $\log \Gamma(n)$ such as is obtained by interpolation from a table of $\log \lfloor n$, when *only second differences* are used in the interpolation,[9] involves errors in the fourth decimal place in $\log \Gamma(n)$, or the fifth for values of $n > 25$ *circa*. These mean errors of the order of .02 *ca.* in the maximum ordinate (and, of course, smaller absolute errors in all other ordinates).

3. Interpolation from a table of $\log \lfloor n$ using second differences is, as we concluded in the earlier paper, quite sufficiently exact for all practical curve-fitting purposes. If any one desires to use ten-place logarithms or some other method, and make all his computations precisely exact to seven (or for the matter of that to 15, 20 or 50) places of figures he may, of course, do so. It is reasonably open to question, however, whether the *additional* contributions to knowledge which may fairly be expected to accrue from such procedure are likely to be of such magnitude or originality as to justify the labor.

RAYMOND PEARL

THE ORIGIN OF LOST RIVER AND ITS GIANT POTHOLES

IN a short article in SCIENCE in 1913,[1] Mr. Robert W. Sayles, of Harvard University, described and sought to explain the block-filled gorge and giant potholes of Lost River, in the Kinsman Notch, New Hampshire. During a first visit to the place, last summer, I saw certain features which seem worthy of attention, in formulating any working hypothesis of the origin of the phenomena.

As Mr. Sayles stated, Lost River is a small stream which flows eastward from the notch between Mt. Moosilauke and Mt. Kinsman, eddying and cascading beneath a deep pile of huge angular blocks and rifted ledges for a

[5] *Loc. cit.*, p. 287.

[6] *Loc. cit.*, p. 288.

[7] *Loc. cit.*, p. 288.

[8] *Loc. cit.*, p. 289.

[9] *Cf.* Table I. of the writer's earlier paper.

[1] Vol. XXXVII., pp. 611–613.

distance of over a quarter of a mile. The ledges and fragments are all of one type of rock—a coarse granite gneiss—which also outcrops in cliffs on the spur of Mt. Kinsman immediately above the gorge of Lost River, and appears in a talus-like mass of blocks on the steep slope between these cliffs and the gorge. In many cases the blocks appear to have been shifted very little from the ledges against which they lie in tipped or overturned positions; in other cases they are poised in such a way as to make it seem likely that they have been moved a considerable distance. The potholes in question include several semi-cylindrical pits or alcoves of from 15 to 25 feet diameter, and numerous holes and curved channels of much smaller size, similar to the potholes at Agassiz Basin, four miles down the stream. The giant potholes are in no case complete or even approximately so, but appear to have been cracked up and dislocated by the same agency which jostled the blocks generally, along the line of the brook.

In his paper Mr. Sayles considered three agents as possible factors in the breaking up of the ledges and scattering of the blocks: (*a*) frost action, (*b*) disruption by a moving glacier, and (*c*) earthquake movements along the line of the gorge, attended by rock falls from the cliff above it. He considered frost action inadequate because of the depth to which the ledges have been ruptured and displaced, and because in the lowest caverns there are "cases where blocks which have slipped from between other huge blocks in place have left the upper and lower blocks entirely unmoved in the solid ledge"; he rejects disruption by the moving ice sheet for the same reason, adding to it the circumstance that no erratic material occurs among the blocks, and that in one case a block has been shifted four inches against the direction of advance of the ice sheet. He adopts the theory of earthquake movement and rock fall because of the close association of the blocks of the gorge with the inclined heap of blocks on the overhanging slope, on the one hand, and with the cracked and torn ledges beside the stream on the other; because of lateral movements among the blocks, of the pell-mell manner in which they are heaped, and because of "smooth slickenside-like patches." It is conceived that after the potholes had been excavated, by a large glacier-fed torrent heading in the Kinsman Notch, an earthquake, originating along the line of the gorge, cracked the river-worn ledges and jostled the fragments, shaking down masses, at the same time, from the cliffs on the hill near by.

After looking over the phenomena at Lost River, it does not seem to me that the facts warrant a preference for the earthquake theory over that of glacial sapping and frost action; nor do I feel convinced that the "giant potholes" are products of torrent action. My reasons are these: (*a*) Positive evidence of earthquake movement seems to be meager if not wholly absent. I did not see the "slickenside-like patches" mentioned by Mr. Sayles, nor any other marks of faulting, although I looked for them. The presence of one or two such surfaces, however, even if *bona fide* slickensides, would not necessarily prove post-glacial faulting; for small faults, probably of earlier date, are common throughout the White Mountain region. If, as Mr. Sayles supposes, the earthquake rift follows the gorge, it would be natural to expect slickensides to be extensively and distinctly developed. (*b*) The presence of the inclined heap of blocks at the foot of the cliffs, near the head of Lost River, does not seem to me to demand an earthquake. It is well known that rock falls may result from other causes. One may suppose, for instance, that during the evacuation of the notch by the ice sheet, insecure masses of rock on the crags above Lost River, and angular fragments of the same, occupying an englacial position in the ice near by, would slide or fall to the ground as soon as their support vanished, and would produce a heap of blocks such as we see here. In the transportation of these rock falls to points beyond the foot of the cliffs, an inclined floor of stagnant, melting ice might play an important part. It is also conceivable that the production and accumulation of talus, by ordinary processes, might proceed at an abnormally rapid rate during the seasons immediately following the retreat of the ice sheet, and that a mass of angular blocks might be left which, because of its uniformly weathered aspect, would appear to have gained little or nothing from annual frost action within more recent time. In either case, an earthquake would be unnecessary to the theory. (*c*) I agree with Mr. Sayles that the extent of fracturing and dislocation in the gorge itself is too great to be attributed to frost action under ordinary circumstances, both as to the depth reached and the amount of movement registered by the blocks; yet I can not see why plucking or quarrying of blocks by the ice sheet, supplemented by abnormally severe freezing and thawing, as the last vestiges of the ice sheet melted away from the pass, is not a perfectly valid alternative hypothesis. In plucking a large joint block from its place in the ledge, the ice sheet might rotate it so that one end of the block would be moved a few inches in a direction opposite to glacial movement, while the other end was moved forward. Even a case where a block had been moved bodily in a direction opposite to glacial movement, but through a space of only a few inches, as reported by Mr. Sayles, could be accounted for by the action of ice in crevices and angular "cavities" between the blocks at the close of the period of actual glaciation, when the ice surrounding the blocks had lost its ability to move *en masse,* but expanded and contracted in response to temperature changes, somewhat as capillary water and frost behave, in crystalline rocks, but on a much large scale. "Lateral movement" among the blocks, and "pell-mell arrangement" would be natural results of this type of ice action.[2] For these reasons it seems to me that the facts thus far reported do not demand the occurrence of an earthquake at Lost River, but are adequately met by the hypothesis of glacial plucking, followed by rock falls and frost work on a scale larger than has been possible since the last remnants of glacial ice vanished from the Kinsman Notch.

[2] See paper by J. B. Tyrrell, on "Rock Glaciers or Chrystocrenes," *Journal of Geology,* Vol. XVIII., 1910, pp. 549–553.

The size of some of the "giant potholes" is extraordinary. Although they may have been produced by a glacial torrent passing through the notch and on through Agassiz basin, where tortuous channels and large torrent-worn cauldrons are well developed, there are two features which lead me to question the reality of such an origin. (*a*) In more than one place, where a concave niche or alcove in the wall of the gorge suggests the side of a pothole, from which the other sides have been removed, I saw a curved joint crack in the ledge, one or two feet back of the concavity, and approximately concentric with it. The detachment of the intervening concavo-convex slab, by frost or glaciation, would have left an alcove equally cylindrical in form to, but of larger radius than the "pothole." (*b*) I was shown by Mr. E. R. Grinnell, superintendent of the reservation, examples of blocks with convex sides, which seem to match the concave niches or incomplete "potholes." One of these abuts against one of the giant potholes, near "the guillotine," and from its shape and form a pegmatite vein which traverses it appears to have dropped from the side of the ledge so as to produce what at first sight would be accepted as part of a huge pothole. Nowhere else have I seen examples of joint cracks with such sharp curvature, yielding partial cylinders of 15 to 25 feet diameter; but their existence here is certain. The question whether the giant potholes are surviving portions of real, torrent-carved potholes, or are imitative forms left by the extraction of joint blocks with curved sides can only be settled by careful measurements of the concave and convex surfaces and a geometrical study of the relations between the ledges and the blocks which still rest against them. As yet no large water-worn boulders seem to have been found in the largest "potholes."

As regards both the true character of the giant potholes, and the earthquake theory, it appears, therefore, that the geological history of Lost River deserves further study.

J. W. GOLDTHWAIT

DARTMOUTH COLLEGE,
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