LAKE PASSAIC: AN EXTINCT GLACIAL LAKE

Published @ 2017 Trieste Publishing Pty Ltd

ISBN 9780649022038

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Edited by Trieste Publishing Pty Ltd.
Cover @ 2017

www.triestepublishing.com

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Trieste

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An Extinct Glacial Lake.

BY

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Presented as a Thesis for the Doctor's Degree,

The University of Chicago.

July, 1895.

Compliments of

Henry B. Kümmel, Ph.D.,

Geological Survey,

Trenton, N. J.

TRENTON, N. J.:
THE JOHN L. MURPHY PUBLISHING COMPANY, PRINTERS.
1895.

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INTRODUCTORY STATEMENT.

In the Annual Report of the State Geologist of New Jersey for 1880, Professor Cook made mention of a glacial lake which existed in the upper part of the Passaic drainage basin during the latter part of the Glacial epoch. The lake was stated to have covered the area of the Great swamp, the Black meadows, the Troy meadows, the Lee meadows, the Hatfield swamp, the Great Piece swamp and the contiguous low land. A number of localities, where evidence of the lake's existence were thought to occur, were cited. Because of its hydrographic position, the lake was called Passaic.* Although the boundaries of the lake were not traced out, its supposed level was determined at a few points. On the strength of these determinations, the area of the lake was represented on a map accompanying the report referred to. The average altitude of the border of the lake was stated to be 385 feet.

Later, Professor W. M. Davis visited the region, and observed what he interpreted as shore features at a number of points, but he never published his observations. In his further studies, he encountered what seemed to him grave difficulties in the way of the hypothesis which Professor Cook had put forth.

C. C. Vermeule,† in his description of the topography of New Jersey, made mention of a number of gravel terraces at elevations of about 400 feet, which showed that a lake existed in the basin between the Highlands and the Watchung mountains. He did not, however, discuss the data further than to call attention to the terraces.

During the field season of 1891, Professor Rollin D. Salisbury, in

*Annual Report of the State Geologist of New Jersey, 1880, pages 61–64.

†Geological Survey of New Jersey, Vol. I., Topography, pages 156–160.

connection with his detailed work in mapping the surface formations, brought to light many new facts, readily explicable upon the hypothesis of a glacial lake. These facts were presented and discussed by Professor Salisbury in the Annual Report of the State Geologist for 1892.* The data then at hand were sufficient to demonstrate, beyond reasonable doubt, the existence of Lake Passaic, but they were hardly sufficient to afford a clear insight into its history.

Further study of the lake was undertaken during 1893, more especially by the author of this paper for the purpose—1°, of gathering new data; 2°, of correlating more perfectly data already known; 3°, of explaining certain apparent contradictions and deficiencies; 4°, of working out the different stages in the lake's history, and 5°, of determining the possible changes, especially deformations, which the lake basin had undergone since the water disappeared from it. Two months of field work during the autumn of 1893 were given to this work. During a part of this time assistance was received from Mr. C. F. Sproul, an experienced surveyor and topographer, by whom were drawn the topographical sketches of shore features accompanying this paper, and with whose aid the heights of the various shore features were determined.

All the known facts concerning the lake have already been presented and discussed in a joint paper by Professor Salisbury and the author, published in the Annual Report of the State Geologist of New Jersey for 1893.† In that paper (page 225) Professor Salisbury has indicated the share which he and the writer had in the preparation of that report. The present paper gives in somewhat briefer form the facts concerning the lake and the conclusions derived from them, and is published with the permission of Professor Salisbury. For a more complete statement of all the details, the reader is referred to the joint paper mentioned above.

PRELIMINARY CONSIDERATIONS.

The trap ridges, known as the Watchung or Orange mountains, rise in long crescentic curves three and four hundred feet above the general level of the Triassic sandstone lowland on either side of them. The crescents are convex towards the southeast. The horns curve towards

* Pages 126-144.
† Pages 225-328.

the northwest and connect with the crystalline schist or gneiss highlands. The basin which is thus formed between the highlands on the northwest and the trap ridges on the south, southeast, east and northeast, is now drained in a very roundabout way by the Passaic river, which finally escapes across the trap ridges at Little Falls and Paterson. The height of the river where it crosses Second mountain at Little Falls is 158 feet.

Leaving out of account the low line of drainage along the Pompton river at the north, which, when the lake existed, was closed by the ice sheet, there is no other break in the rim of the basin lower than 331 feet. At this height there is an outlet across the trap mountains at Moggy Hollow, about two miles west of Liberty Corner, in the southwestern part of the basin. The altitude of the Great swamp is about 230 feet, and therefore about 100 feet below the Moggy Hollow outlet. Within the basin thus inclosed, rise several smaller trap ridges, of which Long Hill, extending from Chatham to Basking Ridge, is the most important. The trap hills near New Vernon (south of Morristown), Livingston, and Whitehall and one or two hills of Triassic conglomerate or hard shale near New Vernon rise about two hundred feet above the surrounding lowlands. Between Chatham and Morristown the terminal moraine forms a ridge 100 to 250 feet above its surroundings. This ridge divides the topographic basin into two parts.

Such being the drainage and topography of this region, there is *a priori* reason for believing that when the ice sheet blocked the outlet of the Passaic at Little Falls or Paterson and filled the Pompton valley to the north, a lake was formed in front of the ice, in the basin between the gneiss highlands on the northwest and the crescentic trap ridges on the southeast, unless at that time there was a gap across the trap ridges south of Little Falls. As will be shown later, well borings prove that there is a deep drift-filled gap across the trap ridges near Short Hills and Millburn. The depth of the rock bottom of this gap renders it certain that a large part of the pre-glacial drainage of the present Passaic basin was across the trap ridges at this point. The pre-glacial drainage of the northern part of this basin probably escaped by the gaps at Little Falls and Paterson. The two drainage systems could have been separated by no more than a low divide.

A part of the drift in the Short Hills-Millburn gap may be first glacial. If any considerable proportion of it is of this age, all the

inter-glacial drainage may have escaped via Little Falls and Paterson. If this was the case, it is possible that the drainage held its course beneath the ice for a shorter or longer time after the edge of the same had reached the Little Falls outlet across the trap ridge; but it is difficult to believe that such could have been the case, after the ice had advanced any considerable distance beyond Little Falls. It is well-nigh incredible that such a sub-glacial drainage outlet could have persisted until the ice occupied the position marked by the terminal moraine at Morristown and Madison. If the sub-glacial outlet did not persist, and if the drift in the Short Hills gap is largely early glacial, Lake Passaic must have existed long before the ice reached the line of the moraine.

If, on the other hand, all or by far the greater part of the drift in the Short Hills gap is last glacial, as is quite probable, the lake would not have been formed until the ice had closed this outlet. A small lake, however, might have existed in the basin of such stream as flowed through the Little Falls gap, after the ice had closed that outlet. Such a lake, if it existed, must have been shallow, as it would have overflowed the low divide into the basin of the river, which flowed through the Short Hills-Millburn gap. When the ice had advanced to the line of the terminal moraine it must have filled the Short Hills gap. It would seem, therefore, that Lake Passaic must have existed during and after the time when the ice held this position.

Barring the outlets at Little Falls and Paterson, the lowest point on the rim of the basin which enclosed the lake is the notch near Liberty Corner, at an elevation of 331 feet. Through this notch the lake, if it existed, must have drained.

As the glacier retreated from the position of the terminal moraine the lake must have increased its area by occupying those parts of the basin from which the ice successively withdrew, until at length its waters were able to escape either under the ice or through the gap at Little Falls. When the recession of the ice opened the Little Falls outlet again, the water of the lake must have fallen promptly to the level of the outlet. If this outlet was much higher than now, the lake must have continued a diminished existence until the outlet had been cut down nearly to its present level.

If the lake existed, as above outlined, it was naturally divisible into two parts—the extra-morainic and the intra-morainic. The former occupied that part of the basin lying southwest of Morris-

town, Madison and Chatham, extending to Basking Ridge and Union Village. It included the Great swamp and the surrounding areas below the level of the outlet at Moggy Hollow. This part of the lake had a longer, or at any rate, a more interrupted history than the other, and so far forth the record of its existence should be more distinct. The intra-morainic portion of the lake extended from the moraine on the southwest to Boonton, Montville and Pompton Plains on the north, to Caldwell on the east, and to Summit on the south, including Black meadows, Troy meadows, Great Piece meadows and Hatfield swamp, besides considerable areas of higher ground.

If Lake Passaic existed, that fact ought to be capable of more or less complete proof. Even if its life were short, the lake must have left sufficient record of itself to place the fact of its existence beyond question.

This record would be expected to consist of (*a*) shore features, (*b*) berg deposits, (*c*) lacustrine deposits, (*d*) something of a difference between the pre-lacustrine surface formations within and without the lake area, and (*e*) a difference in the nature of the till within the lake basin and that without. These differences last mentioned may be very slight; they may not be recognizable at all points, and may be difficult of detection at most; yet they might reasonably be expected to exist. The presence of unmistakable shore features, even in the absence of the other lines of evidence, would prove the existence of the lake. If shore features were altogether absent, all the other lines of evidence might be inconclusive, since berg deposits, lacustrine deposits, lacustrine-like modifications of till and of other surface formations may be simulated more or less closely by other agencies. While no one of these other lines of evidence might be conclusive, their combined testimony might have great weight. Yet if the lake had so protracted an existence as to develop these various phenomena in such strength as to make them available in evidence, it could hardly have failed to develop recognizable shore features. The chief reliance must be placed on shore features. The other lines of evidence may have much corroborative interest and weight.

One of the principal conditions which control the development of shore features and lacustrine deposits is the time element. Other things being equal, a lake with a long life would bring about a better development of shore features and lacrustrine deposits than one of briefer history. Relying on this principle, it is possible to make

some inference concerning the length of life of an extinct lake from the degree of development of its shore features.

Another factor determining the distinctness of the shore features of lakes is their size. The larger the lake, the greater the sweep of its waves, and, other things being equal, the better the development of its shore features.

After a lake is drained and its shore features are exposed to the ordinary agents of sub-aërial erosion, they may soon lose their distinctness. If, therefore, we find wave-cut cliffs and terraces sharp and distinct; spits, bars, beaches, and deltas with normal profiles, and but slightly gullied by post-lacustrine erosion, we may safely infer that post-lacustrine time has been short and that the lake was drained but recently. If, on the contrary, the shore features are indistinct, and if this indistinctness can be shown to be due not to lack of original development but to subsequent destruction, we must conclude that post-lacustrine time has been long.

If the history of an extinct lake was a complicated one, involving various stages during which the water stood at different levels, shore features may be preserved at various altitudes. From the nature and relations of these various sets of shore features, something of the history of the lake may be read. Under favorable conditions, the record of the events of a lake's life may be very complete. If shore features were distinctly developed at the successive levels of a lake, if they are well preserved, and if their relationship to each other is clearly and unequivocally shown, the history of the lake may be made out with great clearness and detail. In so far as the record is fragmentary, or in so far as these conditions are not all fulfilled, the history of the lake remains obscure in some or all its parts. It may be here added, in anticipation of that which is to follow, that the shore features of Lake Passaic are not, at most points, conspicuously developed, and that their obscurity is plainly not the result of subsequent erosion. It must be inferred that they were never well developed. Since the size of the lake was sufficient to have allowed of waves of several miles fetch, the meager development cannot be ascribed to the smallness of the lake. It is, therefore, concluded that the life of the lake was short. The evidence is sufficient to show that the history of Lake Passaic was not a simple one, but the record is not sufficiently complete or definite to make it possible to decipher with certainty all its stages.