

SVERIGES GEOLOGISKA UNDERSÖKNING.

SER. C.

Afhandlingar och uppsatser.

N:o 26.

ON THE CAUSES  
OF  
THE GLACIAL PHENOMENA

IN THE NORTH EASTERN PORTION OF NORTH AMERICA.

BY

OTTO TORELL.

WITH A MAP.

EXTRACTED FROM BIHANG TILL K. SVENSKA VET. AKAD. HANDLINGAR.  
BD. 5. N:o 1. (APRIL 1877.)

Pris 50 öre.

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STOCKHOLM, 1878.  
P. A. NORSTEDT & SÖNER.  
KONGL. BOKTRYCKARE.

It may be assumed that the circumstances essential to the formation and movement of glaciers are these:

1. Abundance of moisture in the atmosphere.
2. A low temperature, due either to great elevations in low latitudes or to high latitudes with or without such elevations of land.

These conditions insure such accumulations of snow above the line of perpetual frost as will sooner or later descend below the line of perpetual snow and be changed to ice and water.

The water forms glacial rivers, and the ice will move as a plastic mass to a line determined by the amount of snow on the one hand and the climate on the other.

The advancing movement of the glacier is accompanied by erosion and scratching of the rocks below and by the formation of different kinds of moraines, as *till* or blue boulder-clay, and yellow unstratified masses, — terminal, lateral and superficial moraines. Simultaneous with these phenomena, we have the action of the glacial rivers, consisting in a partial denudation of the moraines, and the formation of stratified gravel, sand and clay.

The glacial phenomena of the glacial period were as follows:

1. The sinking of the temperature, accompanied by the formation and increase of glaciers.
2. The motion of the ice to its extreme limit.
3. The formation of moraines, of which a part were moved forward and constituted terminal moraines, while

another portion was passed over by the ice and then became bottom- or ground-moraines.

4. The removal by this advancing glacier of the glacial river-deposits, or their being covered by the glacier itself and its ground-moraine.

A geological section at the edge of the ice would then present either:

- a. Preglacial beds.
  - b. Stratified glacial deposits.
  - c. A ground-moraine.
  - d. The ice with its terminal moraines.
- or
- a. Scratched rocks.
  - b. A ground-moraine.
  - c. Ice and terminal moraines.

The first named section is the most common one in the parts of Europe covered by Scandinavian erratics. The second is found generally in Scandinavia and in the United States.

The retrograde movement of a glacier during the period of melting is characterized:

1. By the formation of upper or terminal moraines, which are more or less levelled by the local backward and forward movement during successive intervals of time.

2. By stratified river-deposits lying upon the unstratified yellow moraines, so that a section above the sections just described will present:

- a. Preglacial beds.
- b. Stratified deposits
- c. *Till* or ground-moraine.
- d. Terminal moraines levelled down to great fields containing unstratified material.
- e. Stratified beds formed by glacial rivers with gradually ascending sources.

The characteristics of the deposits *b* are: that only in the vicinity of high mountains they contain rounded stones, while farther away they consist of deposits of sand and clay.

The characteristics of the deposits *c* are: a blue colour, due to seclusion from the oxydizing action of the air; compactness and hardness; rounded form of the boulders, which are polished and scratched, and also generally brought from remote places.

The characteristics of the deposits *d* are: a yellow and reddish colour, occasioned by peroxidation of the iron; comparative looseness of the mass; and greater angularity of the boulders, which are rarely scratched and usually belong to neighbouring localities.

The characteristics of the deposits *e* are: stratification; abundance of rounded and unscratched boulders; they generally consist of beds of gravel and sand without clay.

These phenomena are found not only in Europe wherever there are traces of the ice-age, but are also observable in the United States and in the region to the north of them. Each glacier has had its own limited area, and the same appears to have been the case with all the great drift-deposits in North America.

The greatest ice-field of Europe was that which originated in the highlands of Scandinavia and thence extended over those portions of northern Europe which are known to be covered by Scandinavian erratics. By investigations extending through a long period of years, I have found that the above-mentioned glacial beds or deposits exist in all the countries above indicated.

The Scandinavian glacier crossed the Baltic and the German ocean and extended its moraines into the suburbs of London on the west, to the slopes of the Riesengebirge in the southeast and to the Tscheskaia bay of the Icy sea on the northeast.

The presence of precisely similar phenomena in North America has established in the minds of a majority of geologists the conviction that a vast area, over which such phenomena are found, has also been covered with ice. But if we carefully examine this region, it will readily appear that the glacial area is not continuous from ocean to ocean, but is divisible into the northeastern area and the Rocky mountain area and others to the west, separated by a broad driftless belt extending from the base of the Rocky mountains to the close vicinity of the Mississippi, thus forcing the conclusion that the great eastern and western ice fields have had totally different sources.

It has been the opinion of many distinguished American geologists that the source of the eastern ice-field is to be searched for in the Canadian highland. Against this opinion several important reasons may be urged. First, in those parts of Canada in which the glaciers in question are supposed to have originated we have reason to believe that the rocks are *rounded* and *scratched*, phenomena everywhere recognized as glacial, but, I think, in no case characterizing rocks known to have been covered with perpetual snow.

Again, the elevation and extent of the highest portions of Canada are hardly sufficient to account for the requisite accumulation of snow and ice. And, finally, so far as I have learned, there is not formed upon the rocks of the northern slope of Canada, nor in boulders moved by glacial force, any satisfactory evidence that there has been a northward as well as southward movement of glaciers from the highlands of Canada.

If, therefore, the phenomena of the northern and eastern United States usually supposed to be glacial are indeed such, and if there is not sufficient reason for assuming the Canadian highlands to have been the source of the glaciers which produced these phenomena, then their source must be found elsewhere. I think it will be conceded by all

geologists who have studied the glacial phenomena of these regions that both the character of the erratics and the direction of the scratches upon the rocks show that this source must lie to the northeast. Following the line of glacial movement across Baffins bay and Davis' strait to Greenland, we find the largest body of land in the northern hemisphere covered by ice and snow to a depth not less than 2000 feet and at this moment sending down its icebergs as far as the middle Atlantic.

From the 60<sup>th</sup> degree of latitude to above the 80<sup>th</sup>, this vast area of land is known to be ice-covered, and from the scarcity of the icebergs on the eastern compared with the western coast of that land, it may be concluded that the general slope of the surface is to the southwest, and in the exact direction of the glacial markings and of what is known to have been the course of transported boulders in north-eastern America.

Moreover, if we bear in mind the ascertained fact that during the glacial period the glaciers moving from the heights of Greenland toward the sea could not have formed detached icebergs, as now, but must have for the time blocked up all avenues except the one of easiest escape for the immense accumulations of ice, we may reasonably assume that this avenue was southwestward directly across the British America and the northeastern parts of the United States.

Finally, it may be remarked that this view is strongly confirmed by a comparison of the Scandinavian with the American glacial areas, for, in addition to the identity of the general phenomena, there is observable a marked resemblance in the proportion between the extent and other circumstances of the two areas, and that by allowing due weight to all the evidences adduced in support of the view that Greenland was the source of the glacial phenomena of the area in question, we find a probable and rational solution of a hitherto enigmatical problem.

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**Addendum.**

What strengthens and cogently proves the truth of my previous statements is the circumstance that Professor NORDENSKIÖLD during his expeditions to the Yenisei, from the mouth of that river to Yeniseisk, found no evidence showing that any grand covering of ice existed in the Arctic lowlands of Siberia during the Glacial period. The fact that the glaciers of the Altai did not reach as far as to Yeniseisk may be explained by the dry climate of the highlands of Asia. —

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MAP  
showing the extent of the Northern Drift  
and  
the direction of the Glacial Furrows  
in  
EUROPE AND NORTH AMERICA

Explanations:

— Limit of Drift Area (where the line is dotted  
the limit is only conjectural)  
The arrows mark the direction of the glacial furrows



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