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ARTICLE IV.

GEOLOGIC AND ARCHÆOLOGIC TIME.

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RECENT researches and publications by two eminent glacialists of Sweden, Dr. Nils Olof Holst and Baron Gerard De Geer, present estimates and measurements of the Postglacial period in northern Europe quite nearly like the estimates earlier published by Professors N. H. Winchell, G. F. Wright, and the present writer, for this latest period of geology in America. Because many other geologists, however, hold widely different views of the duration of time since the Ice Age, magnifying it several times beyond the 5,000 to 10,000 years ascribed to it by these glacialists, we may profitably review for general readers the evidences on this question for both the European and the North American ice-sheets.

In a memoir by Holst, published in 1909 by the Geological Survey of Sweden (Series C, No. 216, pages 74), on the length of the Postglacial period, he argues, from his lifelong work on the glacial geology and archæology of Sweden, and from the work of his associates in that country, that the time since the ice-sheet was melted away in Scania, the southmost district of Sweden, has been 6,900 years; and that the earliest trace of primitive man in Scandinavia, belonging to a Neolithic culture stage, was 6,150 years ago. This first advent of

man in the south end of the peninsula was during the middle part of the existence of the Ancylus lake, as the Baltic sea (with the gulfs of Bothnia and Finland) is called for the time while the earth movements attending the departure of the ice-sheet raised the present mouth of that sea, between Sweden and Denmark, above the sea level. The Baltic basin then held for some time, estimated by Holst as 1,675 years, a vast fresh-water lake, known by its shells of *Ancylus fluviatilis*, with an outlet in southern Sweden on the latitude of the present lakes Vetter and Vener, where the Göta canal crosses the peninsula watershed, 300 feet above the present Baltic sea and the ocean.

Previous to this Ancylus lake, the Baltic basin and all this peninsula had stood lower than now, during the early part of the final melting of the ice-sheet, so that the earliest Post-glacial (or more correctly Late Glacial) sea beaches and other marine deposits of that time have been since uplifted (with all the land area and sea bed) to altitudes that increase from near the sea level in eastern and northern Denmark and in Scania to several hundred feet about Stockholm and northward. Arctic marine shells, species of Yoldia and other genera, in these deposits, give the name Yoldia Sea to the waters then laving Sweden and Norway.

The depression of this large tract of the earth crust, recorded by the Yoldia clays, seems probably to have been caused by the great weight of the long enduring ice-sheet: and in the central part of the glaciated area, between the latitudes of 60 and 65 degrees, the land had sunk to a maximum depression about 900 feet below its present height in relation to the ocean. The subsequent uplift, taking place for its larger part (or at least generally for about half of its entire amount) during the Yoldia and Ancylus stages, but

continuing at a diminished rate through the longer ensuing Littorina stage, until the present time, has been differential, in that its aggregate vertical extent gradually increases from the border of the uplift to the center. For the Scandinavian peninsula, this Late Glacial and Postglacial uplift averages some 500 feet or more; for the bed and shores of the Gulf of Bothnia, it averages about 700 feet; and for the more southern and eastern tracts of the Baltic sea bed and the Gulf of Finland, some 250 feet.

The Littorina stage was ushered in by the progressive rising of the land northward and submergence of The Sound, adjoining Copenhagen, whereby the Ancylus lake was changed into the Baltic sea, with access of the ocean tides at its mouth, yet not receiving so large inflow as to give it the full salinity of the ocean. Holst estimates the date of the change as 4,775 years ago. The Ancylus species could not endure the saltness, but was succeeded by the Littorina and other salt-loving marine shells.

Definite measurements, instead of estimates, of Late Glacial and Postglacial time in Sweden are supplied by De Geer, as published in a report of the Eleventh International Geological Congress, held at Stockholm in 1910. This report (lviii and 459 pages), dealing with changes of climate throughout the world since the maximum of the last Ice Age, comprises about fifty papers contributed by specialists in glacial geology and meteorology. The paper by De Geer, in pages 303–310, is entitled "A Thermographical Record of the Late-Quaternary Climate." From his writing there and his earlier publications, giving results of observations and studies during the last twenty-five years, W. B. Wright, of the Geological Survey of Ireland, in Chapter XV. of "The Quaternary Ice Age" (1914, 464 pages), sums up the work

of De Geer on time measurements, with maps and other illustrations.

Sections of the laminated clays, showing the yearly deposition, have been carefully examined by De Geer from Scania north to the latitude of Stockholm, and from that city north to the ancient Lake Ragunda, near the latitude of Östersund and Trondhjem, where the waning ice-sheet became divided into northern and southern remnants, this division of the melting icefields being taken as the time of separation between the Glacial and Postglacial periods. The number of years occupied in the glacial recession to the vicinity of Stockholm is measured as about 3,000 by counting the series of very thin laminæ annually deposited by the waters that flowed away from the wasting ice margin. Similarly it is found that the next 2,000 years swept back the glacial boundary to Lake Ragunda and to the bipartition of the far diminished ice-sheet, which De Geer considers to mark properly the termination of the Ice Age, its late stages in Sweden having thus comprised about 5,000 years.

Further, in sections of the clay and fine silt beds of Lake Ragunda, which was completely drained in 1796, De Geer has counted about 7,000 annual laminæ, showing that the ice-sheet was melted from that district and was divided into the two parts about 7,000 years ago. It is thus known that its recession on the Scandinavian peninsula began some 12,000 years ago, but no measure has been obtained for the considerable preceding time of the glacial retreat from the great marginal moraines in Germany, south of the Baltic sea, which are named collectively as the Baltic Ridge.

Comparing the recognized stages in the departure of the ice-sheet and in the progressing uplift of the earth crust with the archæologic record given by the stone, bronze, and

iron implements, kitchen middens, and other traces of early man in Scandinavia, we have first to note that already the long Palæolithic stages of very ancient handiwork had passed, being followed by the greater skill of Neolithic times, before men came into Denmark, Sweden, and Norway. Near the middle of the duration of the Ancylus lake, men began to immigrate northward along its borders; but their oldest considerable settlements, with large kitchen middens or rubbish heaps, containing shells, bone fragments, and occasional implements, occur on or near the highest and oldest strand lines of Littorina time. In the vicinity of Stockholm, as also of Christiania, the land uplift since those beaches were formed has amounted to about 225 feet, or approximately half of the whole uplift there from the maximum submergence in the Yoldia sea.

The length of Postglacial time, and the amount and the rate of progress of uplift of the earth crust from its depression under the ice weights, are closely analogous in Europe and North America. We may add also that both of their great glaciated areas have similar sequence in the stages of ice accumulation, its maximum extension, the boundary fluctuations, and the modes of deposition of drift during the final melting of their ice-sheets. In each area the duration of the wavering glaciation was evidently very long, in comparison with the geologically sudden and rapid wane and disappearance of the icefields. But in Sweden and Norway the retreat and decrease of the glacial boundaries have been more prolonged than in the northern United States and Canada; for we may even regard the small icefields yet lingering on the mountain plateaus of Norway to be remnants in an unbroken lineage from the general ice-sheet that once covered about 2,000,000 square miles of northern and northwestern Europe.

With the 7,000 years more or less closely estimated by Holst and even counted by De Geer for the time since the ice-sheet melted away respectively from Scania and from the Lake Ragunda district, compare the well-known estimate of Professor N. H. Winchell, made nearly forty years ago, that about 7,800 years have passed since the border of the North American ice-sheet was melted from southern Minnesota and the site of the Falls of St. Anthony. Professor G. F. Wright and myself also conclude that approximately the same measure of Postglacial time is indicated by the length of the Niagara gorge, with its rate of extension in the recession of the falls, and by the steepness and general verticality of the rock walls inclosing the gorge, having suffered scarcely more through processes of weathering at its lower end than immediately adjoining the present falls.

It may therefore be confidently affirmed that only about 10,000 to 5,000 years ago the great continental ice-sheets on opposite sides of the North Atlantic ocean were finally, and in a geologic sense rapidly, melted back, with the formation of drumlins, eskers, and marginal moraines, the latter being amassed wherever the ice border paused in its gradual recession or even at times of any series of exceptionally favorable years made some readvance.

On both continents the ice accumulation far earlier had reached its maximum extent, but had generally left there no morainic drift hills or ridges, its outermost drift having instead a gradually attenuated border. From the many detailed studies of the drift formations of northern Europe, of the Alps and their contiguous lowlands, and of the northern half of North America, we receive many diverse estimates of the proportional lengths of the several recognized stages of the Ice Age. As an aggregate estimate, I believe the en-

tire complex period of fluctuating glaciation was probably twenty times as long as the meager 10,000 years, more or less, of its wane from the latest time of great ice accumulation and advance. The whole duration of the Quaternary era, including the Ice Age, is thus estimated to be about 200,000 years.

Archæologic or Anthropologic time has approximately the same limit, for the earliest evidences of man's existence are found in the closing part of the Tertiary era or in the early part of the Quaternary. The Chellean and Acheulian stages at the beginning of Palæolithic time are represented by the rudely flaked stone implements in the lowest and oldest gravel beds of the Somme valley in northern France, associated with numerous marine species of shells. From my examination of the very remarkable implement-bearing gravels of that valley in and near Amiens and Abbeville, eighteen years ago, following the classic discoveries there half a century before by Boucher de Perthes and the critical studies of many other archæologists, I deem these observations as demonstrative that mankind had attained to well-defined Palæolithic art or skill previous to the very great preglacial uplift of that part of the European coast line. This uplift amounted generally for the coastal region to thousands of feet, and for large areas it raised the land and the sea bed about a mile or more above their present elevation, as shown by the submerged valley of the Adour river, by the depths of the Norwegian fjords, and by littoral shell beds encountered in soundings at great depths in the ocean west of Norway.

Among the conditions and causes that brought the very exceptional accumulation of snow and ice during the Glacial period, I think the very high land elevation to have been the most important. Beginning, and probably attaining its max-

imum height and area, before the time of greatest thickness and extent of the ice-sheets, the high uplift doubtless persisted a very long time, through the greater part of the Ice Age. When the earth crust finally sank under its load nearly or quite to its present level, or for very large central parts of the glaciated areas a few or even many hundred feet beneath this level, the more temperate climate which was then restored along the boundaries of the ice-sheets caused them to be melted rapidly back, thus gradually uncovering these areas, with deposition of the drift that was being borne forward in the basal part of the ice.

We may suppose that a shrinking of the earth's mass by slow loss of heat and by compression, in progress through long geologic periods and culminating in early Quaternary time, produced the widely extended uplift which preceded and in chief degree caused the Ice Age; but a part of the great depression beneath the ice load, and all of the comparatively moderate re-elevation since it was removed, are attributable to the tendency of the earth crust to maintain an equilibrium of weight upon all large segments of the surface, which Major C. E. Dutton about twenty-five years ago named isostasy.

The magnitude of the Late Glacial and Postglacial uplift of northwestern Europe, with adjoining and inclosed areas of the sea bed, may be partially understood in stating that it affected an area about 1,200 miles long with an average width of about 700 miles, and with an average uplift of about 125 meters or a little more than 400 feet. Translated into terms of the dimensions of a mountain belt of equal mass, the volume of subcrustal inflow of rock at a great depth equaled a mountain system 1,000 miles long, 50 miles wide, and having a mean altitude of 6,700 feet. In other words, such

a belt of mountains might have ranges and peaks 10,000 to 15,000 feet high, with intervening valleys 2,000 feet or more above the surrounding country.

In North America the uplift of this time probably extended nearly to the boundaries of the ice-sheet on all sides, covering about 4,000,000 square miles and elevating this vast area on an average fully 300 feet. It was equal in mass to a mountain belt 3,000 miles long, stretching from Labrador to the Pacific ocean, 50 miles wide, and raised 7,800 feet, or to altitudes of 15,000 feet or more in the highest ranges, and of a half mile to one mile in the valleys.

So great movements of the tardily plastic and inflowing rock mass deep in the earth have taken place within the last 10,000 years, since men in Europe attained the Neolithic or Newer Stone Age, and doubtless since civilization was far advanced in China, Mesopotamia, and Egypt. That the interior of the globe is solid, not fluid, yet flowing thus in response to great isostatic stress and with remarkable lack of promptitude, is shown by the growth of the Glacial Lake Agassiz to a third of its full length previous to any uplifting of its basin, such being the northward extent of the highest Herman shore from the mouth of the lake before the earth movement there began.

To estimate the entire duration of geologic time, we must be guided by the proportional rates of changes of the flora and fauna through the successive eras, and by the amounts of their land erosion and deposition of sedimentary strata. On these grounds the comparisons made by Dana are very acceptable, that the ratios of the lengths of the Paleozoic, Mesozoic, and Cenozoic eras are approximately as 12, 3, and 1. From similar comparisons we may well estimate the duration of Cenozoic time, including the Tertiary and Quaternary

eras to the present day, to have been some twenty times as long as Quaternary time alone, giving about 4,000,000 years. The corresponding lengths of Mesozoic and Paleozoic time, in accordance with the same scale, would be respectively about twelve millions and forty-eight millions of years; so that the range of geologic records of well developed and widely differentiated forms of life would be about sixty-four million years, while the earlier Eozoic time of ill preserved life records may bring the limit of the existence of life on the earth to a hundred million years, an estimate quite harmonious with the most advanced studies of geophysics.

Dr. George F. Becker, of the United States Geological Survey, in his presidential address to the Geological Society of America at its annual meeting last winter, entitled "Isostasy and Radioactivity," writes:—

"The age of the earth, with the data now available, is only 68,000,000 years, and it does not seem possible that any corrections in the values of the constants should increase the age thus determined to more than 100,000,000 years."

How and when mankind first came to America from the areas of their origin and earliest home in the Old World, we cannot closely indicate, further than to suppose that the immigration was by land connection from Asia on the northwest, and perhaps also from Europe on the northeast. The time may have been before the Ice Age, or during its early part, for previous to the depression of the land beneath the ice weight our continental ice-sheet probably terminated both on the east and west above the sea level, leaving narrow spaces along the shores for primitive man's subsistence and spread to the great fertile regions south of the glaciation.

In Trenton, New Jersey, in a beach on the south shore of the Glacial Lake Iroquois in New York, in glacial gravels

of Ohio, at Little Falls in central Minnesota, and in a beach of Lake Agassiz in Manitoba, stone implements are found, belonging to the time of final recession of the ice-sheet. Near Lansing, Kansas, in the valley of the Missouri river, a human skeleton in the loess, found in 1902, belongs to the Iowan stage of our glaciation, probably some 20,000 years ago. More recent studies of the late Professor N. H. Winchell, on patination by the weathering of chert implements, flaked at successive and widely separated times, led him to a firm belief that men lived here so far back as the early part of the Ice Age, or even perhaps before it began.[1]

We cannot doubt that the late Major Powell argued rightly in his conclusion that the red race has attained its distinctive characters since the original immigration to this continent, and that nearly as remote antiquity is thus indicated for man in America as for the yellow, black, and white races.

But the lengths of Anthropologic and Geologic time are very different. Let a measurement of a hundred feet represent the long ages of geology, about a hundred million years; and on the same scale only two and a half inches will measure the Quaternary era, with all the progress of mankind from the dim dawn of human intelligence until to-day. Much less is the historic period of writing or inscribed monuments or any means of ascertaining a definite chronology, such a limit of about seven thousand years being on this scale merely a twelfth part of an inch.

Before the coming of the modern sciences of geology and archæology, many believed, from reading the first chapter of Genesis, that six successive days sufficed for the creation of the sun, the moon, this earth, all its living things, and

[1] But, for a more moderate estimate, see Wright's Origin and Antiquity of Man, especially chaps. x. and xv.

their consummation, man, made "in the image of God." We now know that vastly long geologic periods are represented by the six days, and that the span of the existence of mankind has been brief in comparison with all the time filled with the Creator's work. Yet to my mind the new view is a far more precious revelation of Our Father, who cares for all his children and even for a sparrow's fall.