AMERICAN MUSEUM OF NATURAL HISTORY

SEASONAL RECORDS OF GEOLOGIC TIME

By CHESTER A. REEDS

REPRINTED FROM *NATURAL HISTORY*, JULY-AUGUST 1923

AMERICAN·MUSEUM·PRESS

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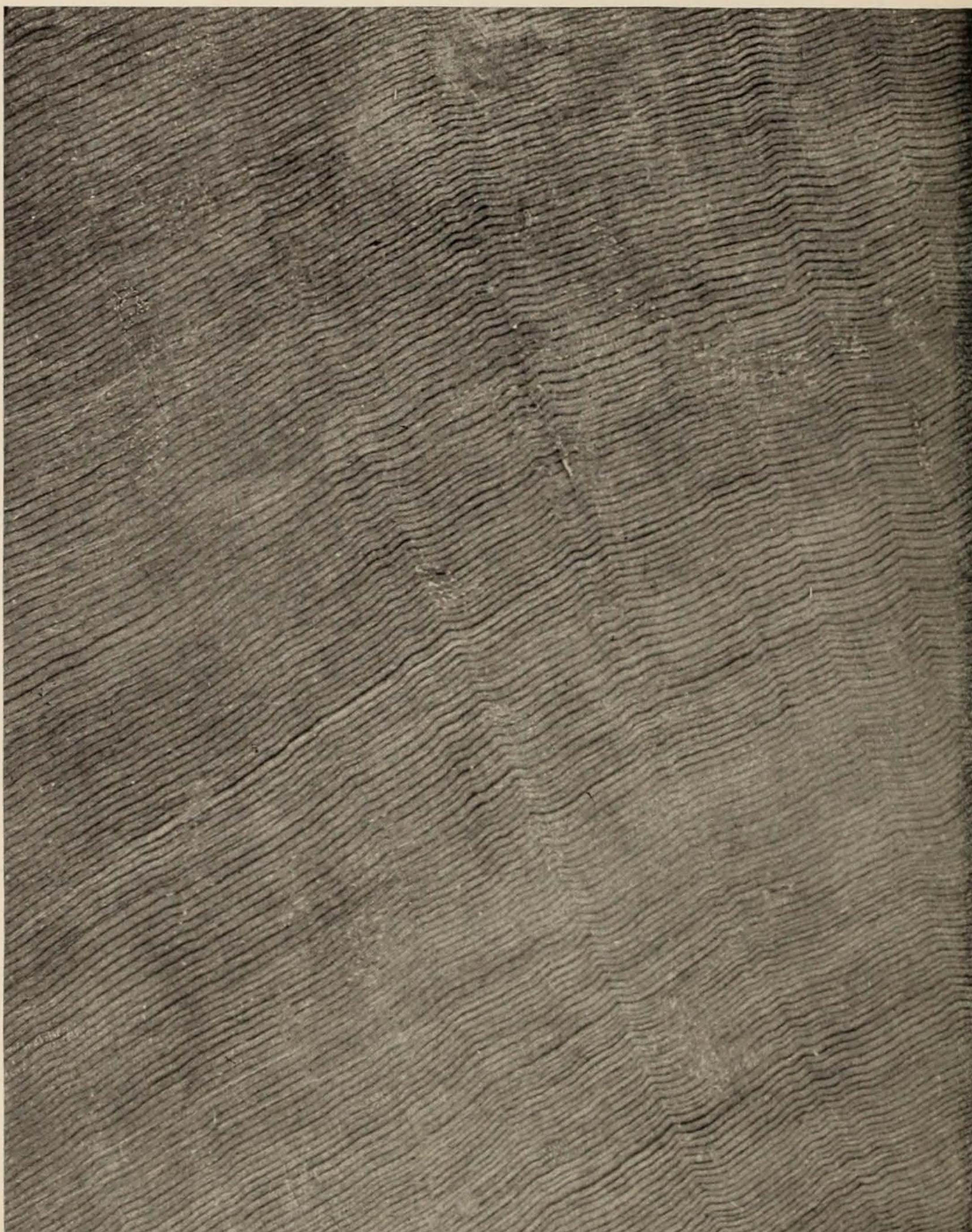
[*Reprinted from* NATURAL HISTORY, VOL. XXIII, NO. 4, 1923, pp. 370-380]



TREE RINGS USED IN MEASURING TIME

Two hundred three years of seasonal records, as shown by the annual rings (natural size) on the section of the big *Sequoia* tree in the American Museum of Natural History. Time represented 1150 A.D. to 1353 A.D.

Seasonal Records of Geologic Time

AS NOTED IN ANNUAL RINGS OF TREES, BANDED GLACIAL CLAYS, AND CERTAIN DEPOSITS MADE DURING PERIODS OF ARID CLIMATE

By CHESTER A. REEDS
Associate Curator of Invertebrate Palæontology, American Museum

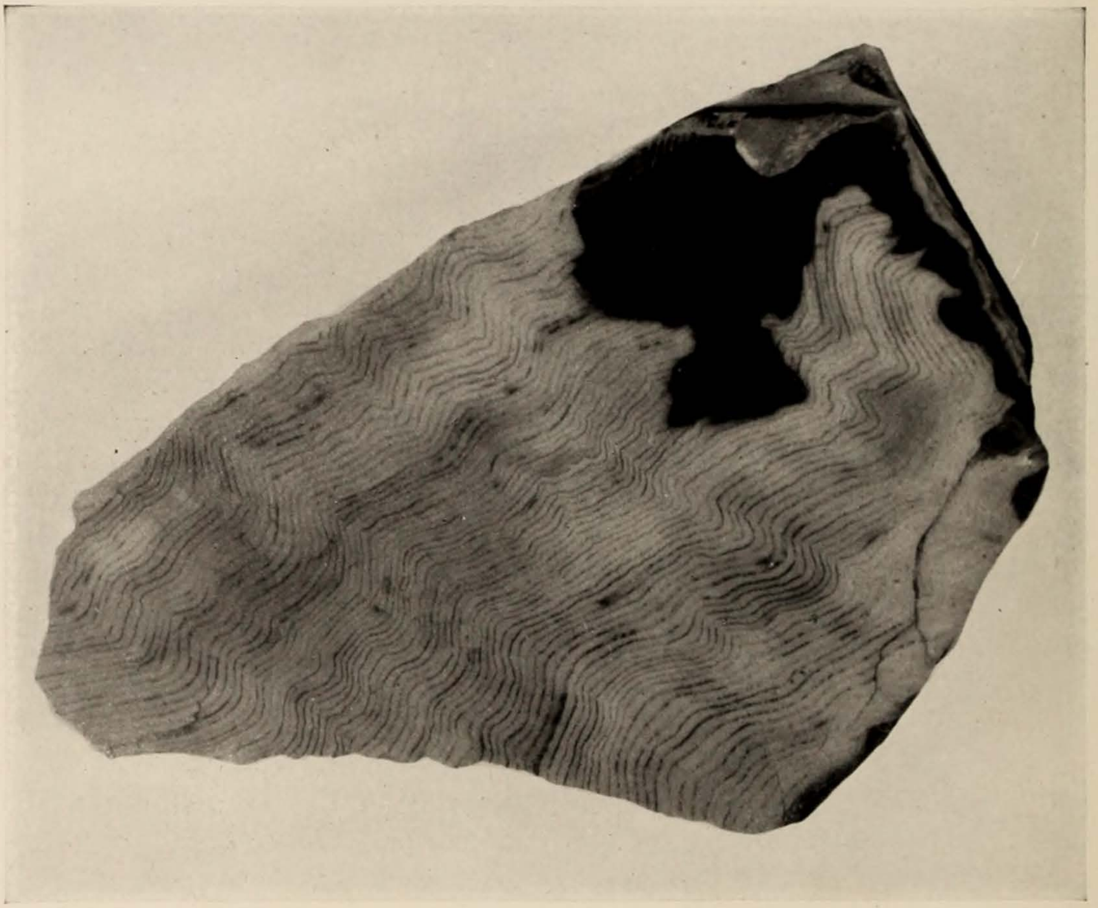
WE are all impressed with the variable daily amount of light and heat received from the sun and with the recurrence of day and night caused by the revolution of the earth on its axis every twenty-four hours. We are not unmindful, too, of the gradual passing of the seasons, spring, summer, autumn, and winter, and the accompanying variations in temperature and moisture, as the earth completes its annual circuit about the sun. The questions naturally arise: what is the net result of these seasonal fluctuations, for how many years have they been going on, and what will be their tendency tomorrow? We turn to the past records for an indication as to the future. We know that there have been seasonal variations for the thousands of years that man has been keeping his calendars and writing history. We also have good reason to assume that they were true for prehistoric man, who kept no tangible records, as well as for the great eons of time that preceded the advent of man upon the earth.

Those of us who have observed nature in one or more of her varied phases are greatly impressed with the effect of the seasonal changes upon the plants, which have adapted their growing periods to spring and summer, and their resting or maturing stages to autumn and winter. The researches of Dr. Ellsworth Huntington and Prof. A. E. Douglass on trees and climate are especially interesting in this connection.

In the trees the seasonal changes are recorded in the annual rings. Soft white cells grow at a rapid rate in the spring. This growth is dependent upon the relative amounts of snowfall and rainfall of the preceding winter as well as upon the porous or compact nature and depth of the soil. In the autumn, due to lowered temperature or diminished water supply, there is a gradual cessation of the activity of the tree. This change is recorded by the deposition of denser and darker material in the cell walls. During the winter, growth practically stops.

Occasionally, due to two stages of growth in one year, superfluous rings may arise, or, due to the lack of a spring development, two or more autumn rings may merge together and an apparent omission of rings will occur. To detect a possible error in counting these abnormal rings, groups of rings in different trees are compared and "cross-identifications" are thus established. Years deficient in rainfall or lowered temperature are more noticeable and more widespread than favorable years, for a deficient year is characterized by an individual ring that is small compared to those beside it. Large rings are more apt to come in groups and are not so extensive geographically as small rings.

Variations in climate can thus be detected in the growth rings of trees. Successive years are not all alike, for a factor like rainfall may be variable; besides, more than one factor may



A portion of a fossil Sequoia tree of Middle Tertiary (Miocene) age from the Yellowstone National Park, showing annual rings

affect the tree rings, such as rainfall, temperature, and length of growing season. In regions where trees have an abundance of moisture there is often noticed a beautiful rhythm of annual rings which matches with the sun-spot cycle of 11.4 years. Other cycles of 6 years, 22 years, 35 years, and 100 years have been noted. In fact, different centuries may have different combinations of climatic cycles. When they are better known, they may give us a basis for long-range weather forecasting. Some of them have been used by Professor Douglass in determining the relative dates of prehistoric ruins in northern New Mexico.[1]

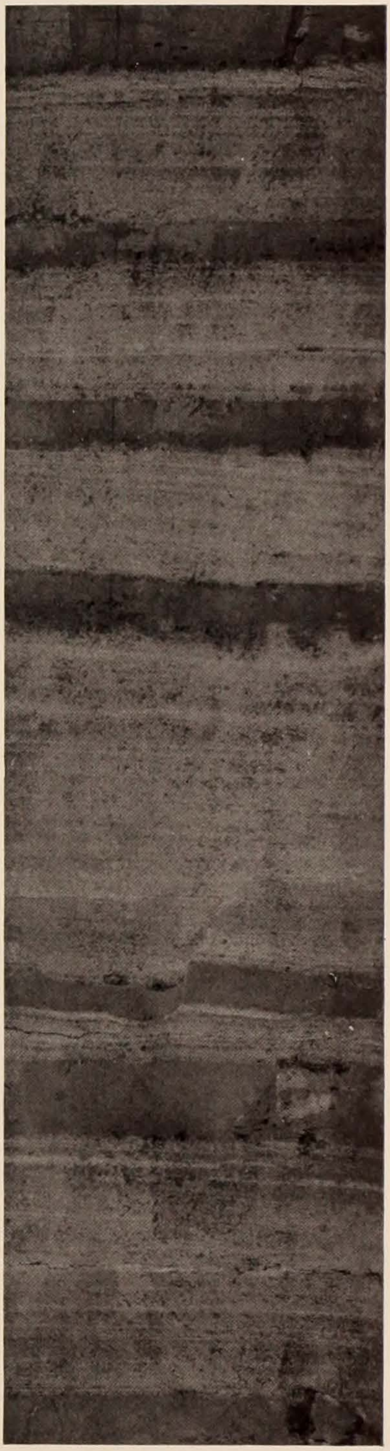
[1]See the article entitled "Dating Our Prehistoric Ruins," by A. E. Douglass, NATURAL HISTORY, January-February, 1921, pp. 27-30.

The longest record of tree growth is that found in the "big trees" of California, the *Sequoia washingtoniana*. Some of these trees have lived for more than 3000 years. In the Jesup collection of North American woods in the American Museum, there is a cross section of a large *Sequoia* tree which was cut in 1894. According to the count of the annual rings this tree started to grow in A.D. 550. Recently Doctor Huntington has added to this exhibit a climatic curve based on the variable growth in the *Sequoia* and has indicated the rise and decline in response to climatic variations of the great governments of the countries bordering the Mediterranean from 1300 B.C. to the present. This comparison is possible since a study of the countries bordering the Mediterranean shows that the climatic pulsations felt there were similar to those indicated by the "big trees" of California, and indeed the climate of the two regions is still of the same type.

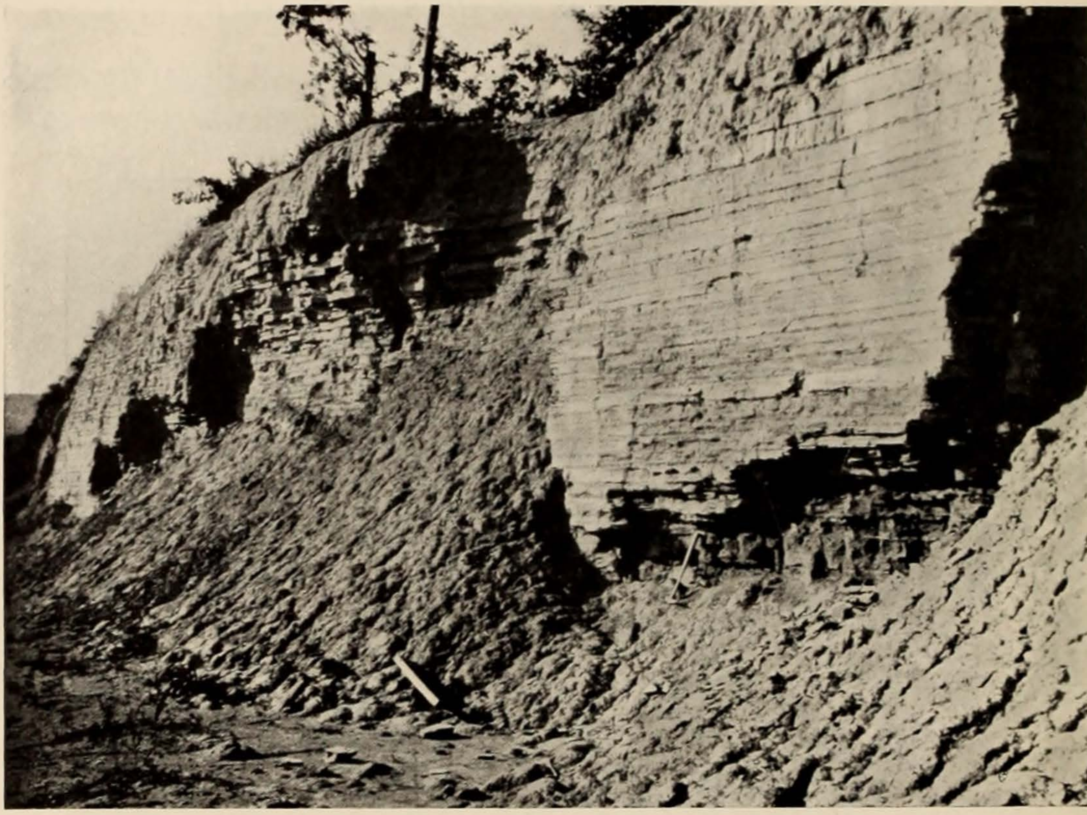
From the trunks of fossil trees it is probable that a very much longer record will be obtained. Trunks of fossil *Sequoia* trees occur in the Yellowstone National Park, in the eastern foothills of the Rocky Mountains, and elsewhere, in places where the trees do not now grow. The cross section of the silicified wood sample, p. 372, shows ninety-two well marked rings with a thickness of about one millimeter each. Fossil woods exhibiting annual rings have been found in rocks of various ages from the Upper Devonian Period to the present, that is, as far back as 18,000,000 years ago, but only comparatively few have been collected and are accessible.

A longer annual record than that afforded by the living *Sequoia* trees has been obtained in Sweden from the glacial clays deposited in fresh-water lakes which laved the retreating ice front of the last continental glacier. The stratified clays of the Hudson, Hackensack, and Connecticut river valleys and of many other points in America were likewise deposited in fresh-water lakes which followed the retreating ice border of the last great North American ice field.

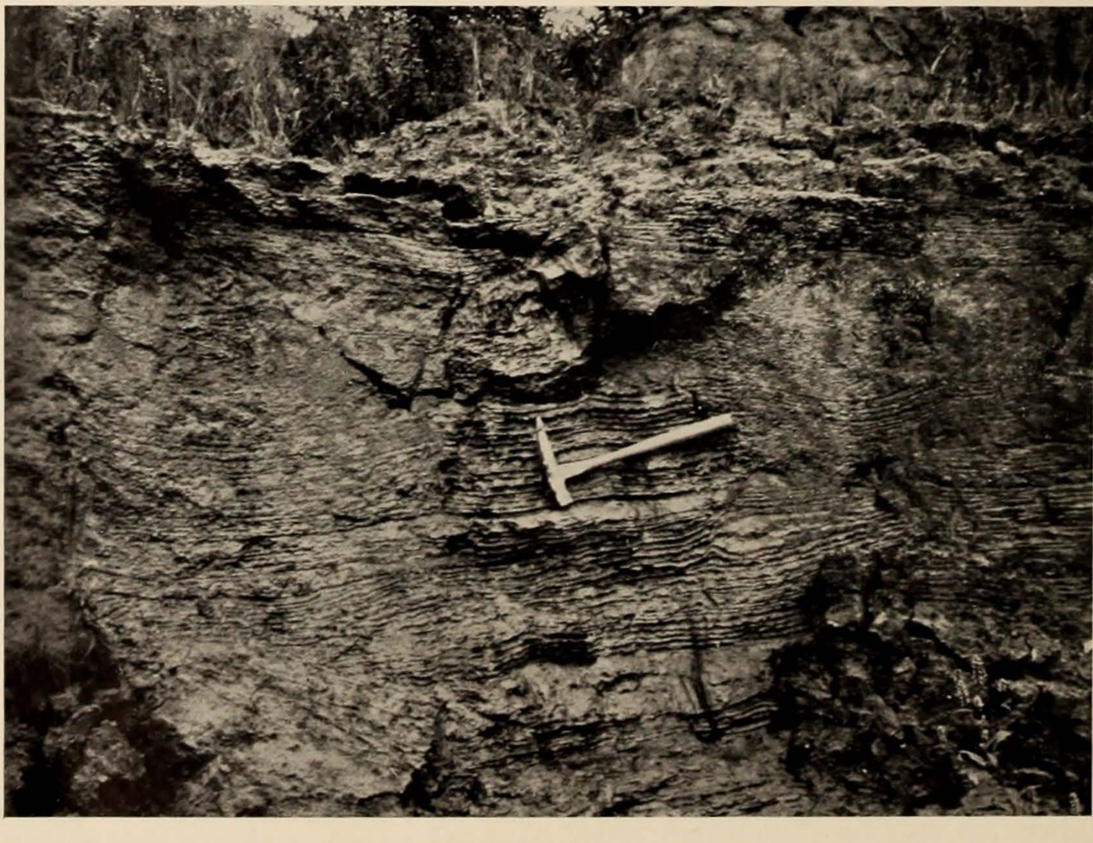
On close inspection these glacial clay deposits show distinct seasonal layers or bands: a summer layer, which is the thicker, of more sandy material, and of lighter color, usually gray; a winter layer, which is the thinner, of very fine clay, and of darker or reddish color, depending upon the color of the rock from which the fine clay particles were derived. In passing upward from a dark winter layer to the



Banded glacial clay (varve clay) from New Haven, Connecticut, showing seven dark winter layers and six lighter summer layers (natural size). An annual deposit consisting of a summer layer and the succeeding winter layer is called a varve. Collected by Dr. E. Antevs, 1922



Postglacial banded clay exposure at Dunnings Point on the Hudson River near Beacon, New York. Photograph by the author, September, 1922



Varve clay from clay pit one-quarter mile north of Mountain View, New Jersey. The deposit was made on the bottom of the former glacial lake, Passaic. Photograph by the author, September, 1922 coarse gray summer layer, the change is abrupt; from the summer layer to the winter layer, however, the change is gradual in all cases. The coarse summer layers have very fine wavy lines of bedding while the fine winter layers are homogenous and uniform in appearance. These seasonal layers alternate in position without exception throughout the deposits. A pair of such layers is called a varve, or annual deposit.

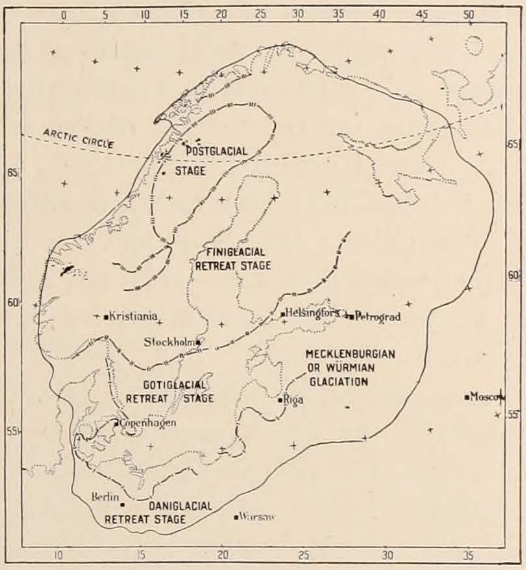
In different years different quantities of sediments were carried to the glacial lakes and consequently there arose variations in the thickness of the varves. Over the several areas of sedimentation, however, the varve for a particular year is approximately of the same relative thickness. Another circumstance of considerable note is that the varves overlap each other very much like the shingles on a roof. This was brought about by the amount of summer melting and the annual retreat of the ice northward. The location of the northern limit of each varve, that is where it touches the bed rock, thus enables one to determine the position of the ice for a particular year as well as the rate of retreat.

In Sweden the rate of glacial retreat was irregular; in Scania and Belecking about 75 meters a year. Before reaching the two great Fennoscandian moraines near Stockholm, which represent distinctly adverse climatic conditions, it increased to 100 meters or a little more. North of the great moraines the retreat fluctuated from 100 to 300 meters or more a year and only occasionally was it interrupted by a stoppage or small advance.

This retreat of the last glaciation in Sweden, (see map) may be subdivided and summarized as follows:

(1) Daniglacial—Part of Denmark, part of Scania, and north central Germany south of the Baltic Moraine. Time undetermined.

(2) Gotiglacial—Retreat from the terminal moraines in middle Scania to the southern border of the great Fennoscandian moraines south of Stockholm, 11,600 B.C. to 8600 B.C., or 3000 years.



Retreat stages of the last glaciation in northwestern Europe. After Osborn and Reeds, 1922

(3) Finiglacial—The retreat from the southernmost of the Fennoscandian moraines to the parting of the land ice into two parts in the Ragunda district, 8600 B.C. to 6600 B.C., or 2000 years.

(4) Postglacial of Swedish geologists, based on the work of Lidén in the valley of the river Angermanälven, 6600 B.C. to 1900 A.D., or 8500 years. The above figures give a total of 13,500 years for the retreat of the last ice sheet from central Scania to the present small ice caps in north central Sweden.

The glacial clay studies in Sweden have been made chiefly by Baron Gerard de Geer[1] and a number of younger men trained by him, particularly Dr. R. Lidén and Dr. E. Antevs. It was in 1878 that De Geer arrived at the conclusion that a pair of these seasonal layers constituted an annual deposit, or varve. De Geer also developed a method of correlating these

[1]See the article entitled "Baron Gerard de Geer and His Work" by James F. Kemp. Natural History, Vol. XXI, pp. 31-3.

deposits not only in the same region but also in different regions.

Studies of glacial clay, deposited during the retreat of the last ice sheet in North America, have been made by a few investigators, particularly Antevs, 1921–22, who has determined a sequence of varve clays representing 4100 years for the retreat of the ice front from Hartford, Connecticut, to Saint Johnsbury, Vermont, a distance of 185 miles. The average rate of retreat was a little more than one mile in 22 years, but it was not regular. Between Springfield and Amherst, Massachusetts, a distance of twenty miles, it was much slower, about a mile in 47.5 years. Then for 350 years the ice front remained in the vicinity of Amherst, but at the termination of that span of years retreated more rapidly, about a mile in 15 to 16 years. The results of Doctor Antevs' investigations have been published in book form, under the title of *The Recession of the Last Ice Sheet in New England*, by the American Geographical Society, New York, 1922.

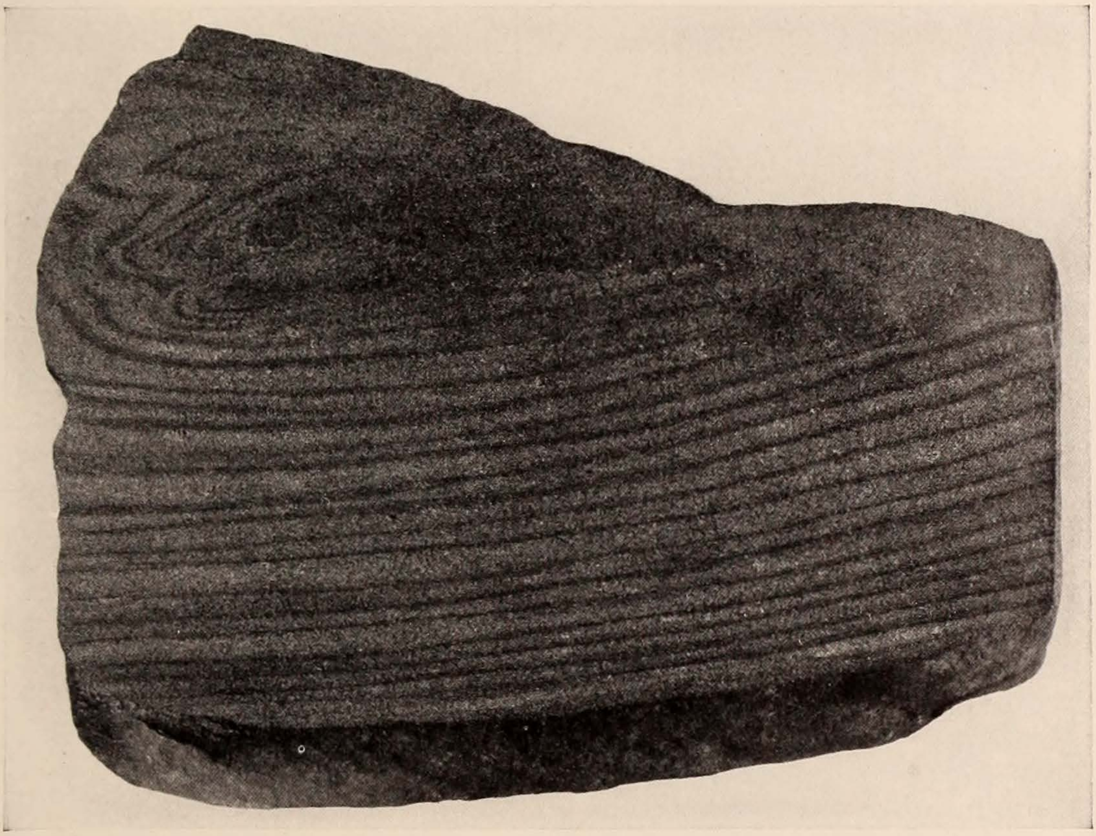
Banded clays of an earlier glaciation were described by Prof. R. W. Sayles in 1916 from the Sqantum peninsula near Boston, Massachusetts. It is estimated that they are 13,000,000 years older than the clays deposited during the retreat of the last or Quaternary (Pleistocene) glaciation of northwestern Europe and eastern North America. They are 800 feet thick and have been referred to the Permian Age, a period nearly one-fourth the way down the geological scale (see p. 378). Since deposition these ancient banded clays have been converted by diastrophic movements into slate or argillite, but they still retain their original relations and characteristics.

The most ancient glacial clays with varves so far noted appear near the base of the geological column and are estimated to be 37,000,000 years old or older. They exist as argillites associated with the Huronian glacial drift deposits at Cobalt, Ontario, Canada. According to the late Prof. Joseph Barrell, they occur at the south end of Cobalt Lake; they are delicately banded and indicate rhythmic deposition. The bands are grouped in series that show larger rhythms representing climatic fluctuations covering periods of years.

Deposits made under arid climates sometimes show seasonal developments. According to R. Görgey (1911) seasonal bands appear in certain salt deposits of northern Germany. Varves representing 5653 years have been noted in these deposits. The salt beds which exhibit this banding are associated with red formations and gypsum of Upper Permian age. Unlike the varve clays, which formed under a moist glacial climate, these salt deposits were developed from brines under a period of continued arid climate characterized by excessive evaporation during the summer.

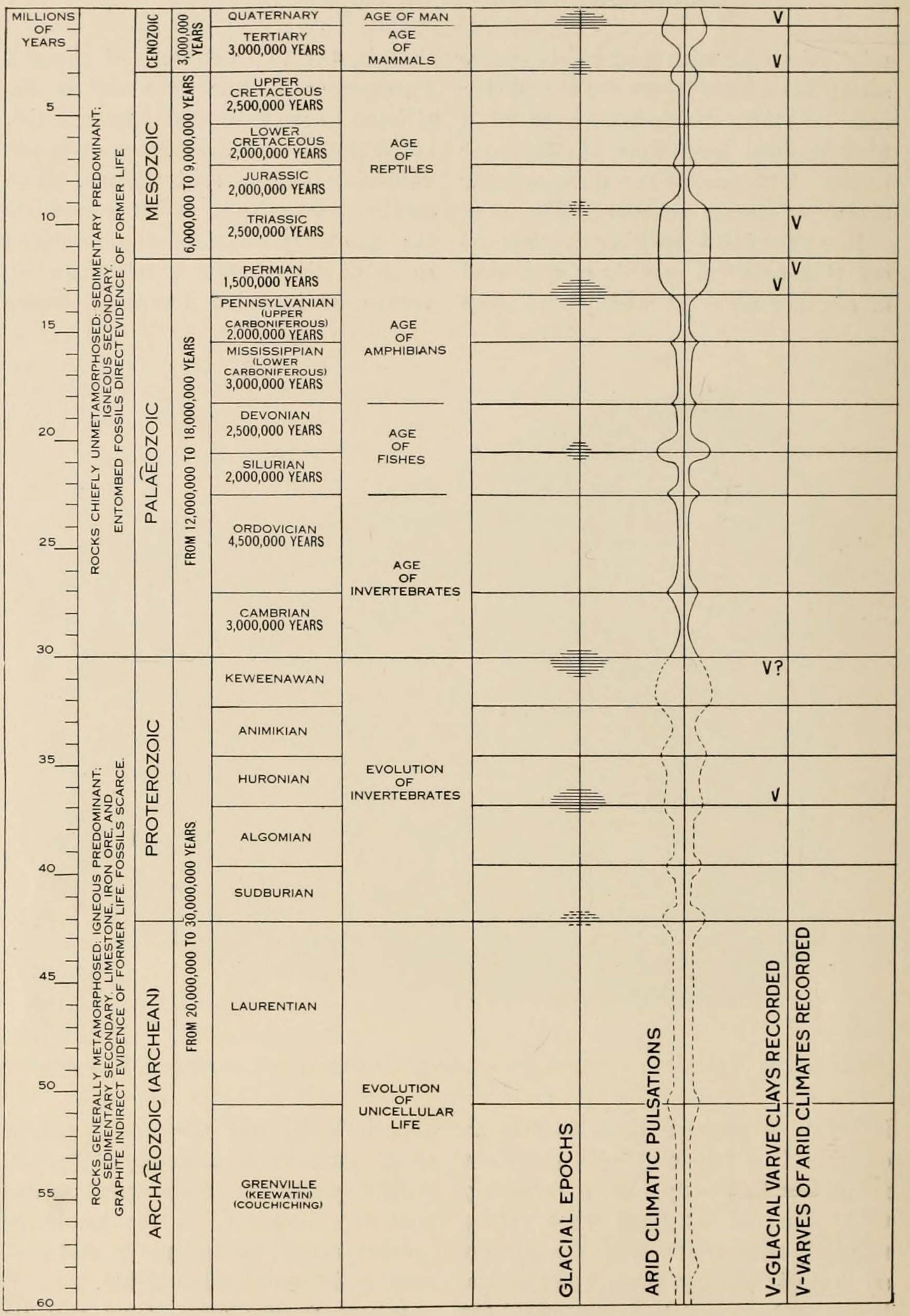
Another example of seasonal bands formed under an arid climate is furnished by the specimen of Triassic red sandstone shown on p. 377, which the author found in September, 1922, as a sporadic bowlder in the five feet of "yellow drift" overlying the late glacial clays of the Quaternary (Pleistocene) Period in the vicinity of Little Ferry, New Jersey. The normal position of the Triassic rocks in this region is beneath and on the margins of the Pleistocene clays. In cross section this specimen shows more than nineteen annual bands of red sand. The summer layers are the lighter in color and are relatively thick with moderately coarse sand; the winter layers are the darker and are thin, being composed of a finer grained sand than the summer bands. The varves are quite regular and show marked seasonal differences.

From the instances cited it is apparent that seasonal records of one kind or another occur at widely separated intervals in geologic time, in fact so early and so late and with sufficient frequency to justify one in assuming that seasonal changes took place regularly from year to year throughout all geologic history. Seasonal records, however, have not been preserved for every year, as a certain combination of circumstances must exist to bring about deposition. Sharply marked seasonal deposits were formed either under glacial or under arid conditions, that is, the two extremes of climate. Furthermore, their presence is restricted to the fresh-water lakes which laved the retreating ice front or to the vanishing lakes of arid regions. The marine formations, which constitute the greater portion of the stratified rocks of the earth's crust, show no varves or seasonal banding; hence deposits exhibiting varves form only a small part of the geologic record. Such deposits are of the greatest importance, however, in the study of geochronology, climates past and present, and the evolution of life.



Cross section of varves in a Triassic red sandstone bowlder from Little Ferry, New Jersey

Where varves exist, they can be counted and the actual length of time involved in their deposition ascertained. In the many instances, however, where they do not exist, the duration of time is uncertain; nevertheless, the thou-



A CHART OF GEOLOGIC TIME

The glacial epochs are shown by the shaded areas (dotted where the data are indirect); the arid climatic pulsations by a curved line (dotted where the data are indefinite); and the varve deposits by a V, placed on the left of the ruled line where glacial action is responsible and on the right of the line where the varves were produced by arid climates sands of sedimentary beds represent millions of years for their deposition. Competent observers using different criteria have made various estimates as to the age of the earth. Some say that it may be 60, 100, 200, or even 750 million years old. Whatever the true estimate may be, there are actual beds of rock which represent a tremendous length of time for their deposition.

In recent years many geologists have concluded that the earth's climate has pulsated back and forth and that a stable climate has not prevailed for any great length of geologic time. There have been periods when extensive land areas, now comparatively free of ice, were covered with great ice sheets. At other times arid to semi-arid or desert conditions oftentimes prevailed in the same or even higher latitudes. To account for changes in civilization at various places in historic times, Prof. A. Penck and Dr. E. Huntington point to the shifting of climatic zones back and forth and cite examples along the northern and southern margins of the Sahara and Sonoran deserts.

Now it may be observed that due to repeated oscillations of the climate during geologic time from one extreme to the other, life has passed through successive crises and that each crisis was a step forward toward the estate of man. The various groups of life which have been successively dominant on the earth have been listed in the life column on p. 000. That these various classes of life are genetically connected is known (1) from the recapitulation, in the embryological stages of the higher animals, of the types of life that have preceded them; (2) from the finding in the geological record of large numbers of fossil specimens which bear witness of this connection and development.

Variations in climate should not be regarded as the sole cause of evolution but one of four or more contributing factors which Prof. Henry Fairfield Osborn has considered in his book, *The Origin and Evolution of Life.* It may be noted, however, that geologic and secular changes of environment have preceded many of the most profound changes in life.

In the Archæozoic Era, which embraces the oldest rocks, there is indirect evidence that unicellular forms of life were present, also that nothing higher existed.

The Lower Huronian Period, with an extensive glaciation in southern Canada and other parts of the world, was among the first of the critical life periods. The Archæocyathinæ, coral-like animals, appear in great numbers before the close of the period. They represent the oldest invertebrates known and an early step forward in the evolution of life from the unicellular forms.

Toward the close of the Proterozoic Era another pronounced glacial climate prevailed in various parts of the world, the net result of which was the sudden appearance in the Cambrian rocks of numerous examples of all classes of marine invertebrates. It is also probable that the tendency toward vertebrate life was initiated at this time, for primitive fossil fishes have been found in the Upper Ordovician rocks of Colorado and Wyoming.

The next important crisis occurred in the late Devonian when, due to the rather extensive arid conditions in many parts of the world, there was an emergence of the earliest vertebrates from the water. Huntington says it was drought which apparently drove our fishlike ancestors out of the water upon the land. He considers this a most momentous step, for only in the highly varied environment of the land does brain power develop rapidly.

Glacial conditions which were to have a far-reaching effect upon life returned in the late Pennsylvanian and again in the Permian periods. The Permian glaciation was prominent in both the southern and northern hemispheres to within 30° of the equator. It was during these trying times that the warm-blooded mammals probably arose. Their bones, however, have not been found earlier than the Upper Triassic. According to Huntington, the transition from cold-blooded to warm-blooded animals represents one of the most profound developments in the history of evolution.

Throughout the Mesozoic Era the reptiles were the grand masters of the realms of land, air, and sea. During this time they waxed strong, deployed widely, and became adjusted to their environment. Then there came a great change over the landscape in the early Tertiary: the Rocky Mountains were uplifted, seas and marshy lowlands were drained, glaciation returned, the reptile horde was diminished, and the mammals became the dominant class.

The mammals in turn took on many diverse forms and, like the reptiles, occupied all the media of land, water, and air during the millions of years of the Tertiary Period. When they had reached a condition of complete dominance and adaptation, they too were suddenly wiped out in wholesale lots. This may be attributed directly or indirectly to the severe climatic vicissitudes of the Pleistocene or early Quaternary glaciations.

The Quaternary Period is called the Age of Man. In Europe south of the fifty-third parallel evidences of Pleistocene man and even of a late Tertiary (Pliocene) man have been found. Successive types of men lived, struggled, and endured the privations of the glacial and interglacial epochs. During these times the cultural development of man centered about the perfection of stone implements of chipped flint, the palæolithic stage; then during the short Postglacial stage, with its minor climatic oscillations, he passed rapidly through the neolithic into the historic and modern culture stages. According to Huntington, it was apparently this Glacial Period which chiefly stimulated man's mental development and caused his intelligence to dominate the earth.

We pause on the threshold of the future; we dare not enter, for we have a profound respect for the past. We know that this is the Age of Man but we do not know what the next age will be. We feel assured that seasonal and climatic variations will continue in a pulsatory way as before, but as to man he will in all probability succumb in time, as did his ancestors, to the natural forces that caused him to rise and conquer.

FOR THE PEOPLE

FOR EDUCATION

FOR SCIENCE