23. THE POSTPLUVIAL OR NEOTHERMAL

By Ernst Antevs

DIVISION OF AGE

To obtain a basis for long-distance correlation the present writer suggested in 1931 that the Postglacial be reckoned from the time when the temperature in the southern parts of the previously glaciated areas had risen to equal that at present, which occurred some 9000 years ago, and that the age be subdivided on the basis of summer temperature in the Early, Middle, and Late Postglacial (Antevs, 1931, pp. 1, 2, 6). The Middle Postglacial was to comprise the age of distinctly higher summer temperature than at present.

At the same time, von Post proposed that the Postglacial of northern Europe be divided into a period of increasing warmth, period of maximum temperature, and period of decreasing warmth (1931, also 1944).[1] According to von Post the temperature in Sweden rose very slowly during and after the release from the last ice sheet (1933, p. 57). It seems to have reached a culmination roughly 4500 B.C. and to have maintained this for some 2000 years. About 2500 B.C. the temperature began a decline which has been distinct for the last 4000 years. A similar view had previously been presented by Granlund (1932, p. 169): The temperature was distinctly higher than at present from 6000 to 2000 B.C. and had its maximum during the age 4500-2500 B.C. The last age was coolest during the centuries before and after Christ, an opinion shared by Fröman (1944, pp. 670, 675). Thus the expression "decreasing warmth" does not fit the last 1500 years. Other datings of the warmest age: In northern Sweden (63° N.) and in Finland, 5000-3500 B.C. (Fromm, 1938, pp. 379, 380; Sauramo, 1942, pp. 234, 263); in Denmark, 5600-4000 (Movius, 1942, pp. 20, 23), or 6000-2500 B.C. (Iversen, 1944, p. 480). According to the present knowledge the warmest age thus prevailed from about 5000 to 2500 B.C., that is during the marine Littorina stage (5500 or 5000-2000 B.C.) of the Baltic Basin.

The warmest postglacial age of northern Europe was characterized by a relatively insular climate with warmer summers and milder winters than now prevail (Magnusson and Granlund, 1936, p. 242). The mean annual temperature was probably about 2° C. (3.6° F.) higher than today, corresponding to a shift of five degrees of latitude (van Post, 1933, pp. 60, 15); but according to one estimate the temperature of the warmest month was 2° C., that of the coldest month 0.5° C. (about 1° F.), higher than at present (Iversen, 1944, p. 479).

Studies also show that the summer temperature remained at its high level for quite some time longer, perhaps till about 1200 B.C., while the winter temperature dropped (Magnusson and Granlund, 1936, pp. 238, 243; Fröman, 1944, pp. 670, 674; Sandegren, 1944, p. 530). The temperature

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of the warmest month during this late stage has been estimated at 2° C. above, that of the coldest month at 1° C. below, the modern (Iversen, 1944, p. 479). Consequently, the summer temperature in northern Europe was distinctly higher than at present from about 6000 to 1200 B.C. However, according to Fröman (1944, pp. 673-76), this long age was not one of unbroken warmth but was composed of a number of brief relatively warm periods, alternating with cooler periods during which heat-loving plants ceased to spread or perhaps were killed. The conditions can perhaps be interpreted by a wavy temperature curve whose mean formed a long flat wave crest recording a higher general temperature than now prevails. The crests of the temperature curve were rather high and spaced a few to several hundred years. Some of the wave troughs possibly touched the modern temperature level.

A warm postglacial age is known in the entire northern and central Europe, in North America, New Zealand (Cranwell, 1936), Tierra del Fuego (Aver, 1933, p. 285), and the Antarctic (Ahlmann, 1944, p. 651). It was perhaps universal, while there surely were contributing regional factors. Therefore, neither the age of maximum temperature, nor that of higher summer temperature, need to have been fully contemporaneous in remote parts of the globe. In northern Europe, as stated, the warmest age prevailed 5000-2500 B.C. (7000-4500 Before Present), the age of higher summer temperature, 6000-1200 B.C. (8000-3200 B.P.). In the American West some basins began again to contain permanent bodies of water roughly 2000 B.C. (see below), showing that the driest and warmest age was well past by that time. A climatic age boundary may therefore be set tentatively at 2500 B.C. In the West there is no real basis for dating the beginning of the distinctly warmer age, but 5000 B.C. or somewhat earlier seems a reasonable provisional date.

With temperatures as at present or higher, the last 9000 years as a whole have been warm in comparison to the glacial ages. In climatic respects these millenia are comparable to the interglacials. Whether they are the early part of an interglacial or of a complete deglaciation, they form an age which is so intimately associated with the Ice Age or Pleistocene that they should be included into it (Kay and Leighton, 1933, p. 672; Flint, 1947, p. 208). Their incorporation would make the term "Ice Age" and "Pleistocene" synonymous with "Quaternary."

The distinctive age of the last 9000 years has no universally accepted name. The term "Postglacial" (or "Postpluvial" in regions), which is rather generally used in Europe, does not appeal to American geologists who prefer to employ "postglacial," not as a term, but as an elastic word to designate the age, deposits, events, and conditions since the local or regional departure of the last ice sheet, whether this occurred 40,000 or 10,000 years ago. The terms "Recent" and "Post-Pleistocene," used with little enthusiasm in America, are inappropriate. The word "recent" means "modern" in Scandanavian languages; and the age in consideration is properly a part of the Pleistocene, not a successor. "Holocene" has been tried both in Europe and America (Williams, 1942, Pl. 1). Here is therefore suggested the term "Neothermal," adj. and n., from "neo-" meaning "new;" "recent," and from "thermal," meaning "of or pertaining to heat." "Neo-" is included to distinguish this late warm age from the interglacials which would be more appropriately named warm or thermal ages. In a classification scheme the Neothermal age should have the same rank as the Wisconsin Glacial and the Sangamon Interglacial

(Sangamon Thermal).

Table - The Neothermal (Postglacial or Postpluvial)

	General temperature	Moisture conditions in Great Basin and contiguous areas
Present		
	Medithermal Moderately warm	Arid and semiarid:[2] Rebirth of lakes and glaciers; Summer Lake maximum 45 feet above average modern stand
2000 B.C.		
	Altithermal Distinctly warmer than at present	Arid: Disappearance of lakes and glaciers; Summer basin dry
5000 B.C.		
	Anathermal At first as today, but growing warmer	Probably subhumid and semiarid: Lake in Summer basin at least 90 feet higher than modern lake
7000 B.C.		

In the accompanying table related terms are suggested for the general postglacial temperature ages, discussed above, to supersede the terms Early, Middle, and Late Postglacial and Postpluvial. The prefix "ana-" means "upward;" "alti-," "high;" and "medi-" means "of intermediate degree." Moisture conditions are too regional to be used as a basis for a general time division. Those given in the table apply only to the Great Basin and some contiguous areas.

THE ANATHERMAL AGE

The moisture conditions in the Great Basin during the Anathermal age seem to be indicated by a relatively high lake in the Summer basin, south-central Oregon. As shown by a pumice bed in its deposits this lake existed during the climatic eruptions of Mt. Mazama, the ancient volcano whose collapse formed the caldera holding Crater Lake (Allison, 1945). To date the pumice bed, which also occurs below and in peat deposits, therefore means to date the lake. The final eruptions of Mt. Mazama are held by Williams to have been short-lived; and nowhere has there been found more than one bed of Mt. Mazama pumice. The age of the pumice and of Crater Lake has been estimated by Williams at 4000 to 7000 years (1942, pp. 112-14); by Hansen at not more than 10,000 years and perhaps less (1947, p. 118); and by Allison at 10,000 to 14,000 years (1945, pp. 800-804). Here another estimate will be attempted on the basis of Hansen's and Allison's seemingly best data.

From Lairds Bay, 25 miles south of Klamath Falls, Oregon, Hansen has described a significant peat profile, which is briefly (1942c, pp. 104, 111-13, Fig. 57; 1947, pp. 102-104):

At top, 0.9 meter of fibrous peat with a minimum of yellow pine pollen and a maximum of western white pine pollen. Gap in deposition.

1.8 meters (depths of 0.91-2.7 meters) of sedimentary peat. Between the depths of 1.7 and 0.91 meter the yellow pine attains its maximum in the profile, and the white pine its minimum. In the top-most part of the bed, between the levels of 1.04 and 0.91 meter, there are artifacts.

The presence of artifacts shows that the lake at one time subsided sufficiently to permit man to camp on the exposed lake bed; and the overlying peat indicates a renewed inundation. The great subsidence of the lake can only have taken place during the last part of the Altithermal (see below); and the conditions as a whole make it clear that the peat between the depths of 1.7 and 0.91 meter together with the gap represent the Altithermal age, the fibrous top bed the Medithermal age. Of particular interest in this connection is the dating of the pollen maxima and minima of yellow and white pines in the regions. Much the same frequency variations of the yellow and white pines occur in a continuous peat profile, named Klamath Falls, from a point 10 miles southwest of that city (Hansen, 1942c, p. 105, Fig. 60; 1947, p. 103).

From Klamath Marsh, 50 miles north of Klamath Falls, Hansen has analyzed another peat profile which is of importance for the present discussion because it shows similar frequency variations of yellow and white pines as do the two profiles mentioned, except that lodgepole pine begins to increase at the expense of both 0.5 meter below the (Hansen, 1947, pp. 31, 32, 103, 104). Thus yellow pine has its maximum and white pine a minimum between the depths of 2.15 and 1.35 meters, while white pine has a maximum and yellow pine has a lower representation above the 1.35-meter level. The 2.15 to 1.35-meter zone may be a correlative of the bed at Lairds Bay and Klamath Falls with similar representation of yellow and white pines, that is it may derive from the Altithermal age. Below the 2.15-meter level there are 35 centimeters more limnic peat, and below the peat there is a thick bed of Mt. Mazama pumice. Evidently the pumice eruptions antedated the Altithermal age.

Since the rate of deposition of limnic peat in the Pacific Northwest seems to have averaged about a meter in 3500 years (Hansen, 1947, p. 37), the lowest one-third meter of peat in Klamath Marsh may represent at least 1000 years. Since furthermore some time may have elapsed between the pumice fall and the beginning of peat deposition, the Mt. Mazama pumice eruption may have preceded the Altithermal age by at least 1500 years. The age of the Mt. Mazama pumice and of Crater Lake is perhaps 8500 to 9000 years. This estimate agrees with the intermediate values quoted above.

Pumice from Mt. Mazama has, as mentioned, been recognized by Allison in the sediments of pluvial Winter Lake, the predecessor of Summer Lake (1945, pp. 789, 796, 800, 801). On Ana River just north of the lake, the pumice occurs at the elevation of about 4225 feet and is underlain by clayey silt and overlain by 6 feet of stratified sand, silt, clay, pumice, and volcanic ash. Lamination and even thickness of the beds show that all of them were laid down without a break in water (Allison, 1945, pp. 795-98). Therefore, during the entire time of deposition of these beds, the water surface cannot have fallen below the 4235-foot level, cannot have stood less than 90 feet above modern Summer Lake at about 4145 feet altitude (4146 feet on September 1, 1944).

Since the drainage basin of Summer Lake is entirely separated from the Cascades, and since the regional mountains attain only some 7300 feet in altitude and were not glaciated (Waring, 1908), the high lake cannot be attributed to glacial melt water. On the contrary, because of its isolation the water body in the Summer basin was and is an excellent and prompt recorder of the climatic conditions (Antevs, 1938a, pp. 7, 14-19). It follows that during and for a long time after the Mt. Mazama eruption the climate was distinctly moister than it is at present.

The relative moisture at various ages is somewhat revealed by the lake levels in the basin, which are (Allison, 1945, pp. 791-94, 801):

	Feet
Lake Chewaucan of Bonneville Pluvial..............................	4500
Interpluvial Ana Lake...................................... about.	4210?
Winter Lake at Provo Pluvial maximum..............................	4360
Winter Lake at Mt. Mazama eruption.....................at least..	4235
Altithermal age... basin	dry
Highest level during Medithermal age..............................	4190
Modern Summer Lake, highest stand.................................	4178
Summer Lake at present..	4145

Thus at the time of the Mt. Mazama eruption the water level stood possibly as much as 125 feet below the Winter Lake maximum, at least 45 feet above the highest stand attained during the Medithermal age, and at least 90 feet above the present lake level. If, as concluded above, the eruption occurred 8500 to 9000 B.P. all of the Anathermal age, except perhaps the very last part, was moister than at present, and most of the age was probably subhumid and semiarid in the Great Basin.

THE ALTITHERMAL AGE

The Altithermal age was clearly dry besides warm in the Great Basin (Antevs, 1938b; 1941, pp. 36-39). One line of evidence is supplied by Abert and Summer lakes in Oregon and Owens Lake in California. These lakes lacked outlets in postpluvial times, but nevertheless have only a low salinity, a salinity so low in fact that they cannot be remains of the pluvial lakes in the same basins. The pluvial lakes must have dried, and the accumulated salts must have been removed by the wind or have become buried, before the modern lakes came into existence. The amount of salts in the waters of these lakes in 1887 to 1912, the salt contents of their main feeder streams, and the rate of evaporation suggest that the accumulation of the salts may have required some 4000 years (Van Winkle, 1914, pp. 117-123; Gale, 1915, pp. 259, 263, 264). This means that the modern lakes were reborn 4000 years ago and that their basins were dry for long ages before 2000 B.C.

The modern glaciers in the western mountains had a history similar to that of the lakes, according to Matthes (1939; 1940; 1941; 1942, pp. 211-21; 1945). All the fifty-odd modern cirque glaciers in the Sierra Nevada, almost all the glaciers in the Rocky Mountains within the United States, and all the lesser glaciers of the Cascade Range and the Olympic Mountains may represent a new generation of ice bodies that came into being only a few thousand years ago. Prior to this there was complete or essential disappearance of permanent ice in the mountains, which means a long warm age.

Arid conditions during the Altithermal age are also recorded by channel erosion (arroyo cutting) and wind erosion in Arizona, New Mexico, and western Texas; by an exceptionally low level of Utah Lake (Hansen, 1933); by wind excavation in Fort Rock basin, Oregon (Allison, 1946, p. 64); and by pollen profiles in peat deposits in Oregon and Washington (Hansen 1942a, p. 218; 1942b, pp. 57, 59-62).[3]

THE MEDITHERMAL AGE

From the above statements it follows that a relatively cool and moist age began about 2000 B.C. The principle evidences are: accumulation of water in desert basins to form lakes; development and growth of glaciers in high mountains; deposition of clays and silts in arroyos and valleys eroded during the Altithermal age; anchoring of dunes by vegetation; and a vegetation requiring more moisture.

On the Whitewater Creek near Douglas in southeastern Arizona the standard deposits above post pluvial erosion surfaces are two to three feet of unlaminated brown cienega (wet meadow) clay and about a foot of yellow laminated silt forming the ground surface (Antevs, 1941, pp. 35, 43, 44, 56). The top silt, which frequently overlies an erosion surface, may have been deposited from 1300 to 1875 A.D. The cienega clay may indicate moister conditions than does the yellow silt, which in turn suggests slightly moister climate than now prevails. At two places erosion interrupted the formation of the cienega clay, and the upper cienega clay is sandy (Antevs, 1941, pp. 43, 53, 54, 56). An undecorated potsherd suggests that this erosion occurred about the time of Christ or later. These conditions seem to show that in southeastern Arizona the two millenia before Christ were moistest and the past millenium was driest.

From stream deposits and erosion in northeastern Arizona Hack (1942, pp. 56, 63, 68, 69) concludes that the moistest age probably prevailed between 3000 B.C. and 1200 A.D.; and from Pueblo dwellings built on stabilized dunes he infers that the climate was moister and cooler than today in the first millenium A.D. (1942, pp. 42-44).

It is not known which of the last millenia was moistest in the Pacific Northwest (Hansen, 1946, p. 121), but sometime during the Medithermal age Summer Lake reached the level of 4190 feet, which is 12 feet above the highest modern stand or 45 feet above the present average level (Allison, 1945, pp. 791, 794, 801).

In the high western mountains the glaciers, according to Matthes (1941; 1942, pp. 195, 197, 212, 215), attained their greatest extent of the past 10,000 years about 1850 A.D. The Great Basin lakes were low at the time (Wooley 1924, p. 16, Pl. 2; Harding, 1935, 1942; Antevs, 1938a), but they rose rapidly during the 1860's, and notably Pyramid, Winnemucca, Walker, Carson, Warner, Goose, and Great Salt lakes and Carson Sink reached unusually high levels about 1870. Pyramid and Winnemucca lakes had reached their maxima in 1868, but their volumes would have been still larger about 1911, if no water had been diverted from the Truckee River (Hardman and Venstrom, 1941, p. 83). The white coating of tufa which marks the Pyramid Lake level of 1868 at 3879 feet is still clearly visible in sheltered places and is the highest mark of its kind in the basin (Hardman and Venstrom, 1941, p. 75). In 1844 Fremont observed a white line at 3872 feet of elevation, but he does not mention any higher levels (Hardman and Venstrom 1941, p. 73). It may be concluded that the lake had not risen above the 3872-foot mark for at least 100 years before Fremont's visit. Mono Lake rose 50 feet between 1857 and 1919, and in 1914, when a few feet below its historic maximum of 1919, it drowned and killed an 150-year-old tree (Harding 1935, p. 89). The lake consequently rose higher than at any time since 1750 or earlier.[4] Great Salt Lake in 1867 submerged an old storm line at 4207 feet, which in 1850 formed the lower limit of sagebrush growth (Harding, 1935, p. 87). Assuming it would take a long time to leach the salt from the soil to permit sagebrush to grow, Gilbert concluded that the lake had not been above this storm line for perhaps several hundred years before 1850. Another storm line at 4213 feet was not quite reached during the historic maximum of the lake at 4211.5 feet in 1873. Harding computes that, if there had been no increase in the diversion of water from the tributaries, Great Salt Lake would have been as high from 1932 to 1927 as it was from 1868 to 1878.

The cause of this time relationship between the maxima of the glaciers in the high mountains and of the lakes in the adjacent basins seems to have been mainly an interaction of temperature, snow, and rain. Glaciers are predominantly controlled by temperature, the temperature sum above thaw (Ahlmann, 1940a, pp. 125-128; 1940b, p. 203). Just before 1850 the positive temperature may have reached a minimum. In the high mountains the seasons above thaw may have been cool and short, tending to produce a relatively large percentage of snow and to restrict its melting or conversion into runoff. Since about 1850 the temperature has been rising in the United States, the rate being especially marked since about 1900 (Kincer, 1940). Relatively warm and long seasons above frost may have caused a comparatively great percentage of wet precipitation at high altitudes, a considerable and rapid melting of snow and glacier ice, and a large runoff. It may have been essentially normal runoff from the high mountains which caused the exceptional rise of the lakes, for, judging from the tree growth at the lower, dry limit of the forest, the precipitation at this level 5000 to 6000 feet above the sea, was from 1850 to 1916 only in some regions above the average of the past few hundred years (Lakeview to Silver Lake, Oregon), in others of the average amount (Susanville, California, and Klamath Falls-Lapine region, Oregon) (Antevs, 1938a, pp. 60, 66, 67, Pl. I, k; Keen, 1937, pp. 185, 186).

Since the lake maxima that were actually reached, or under natural conditions would have been reached, some decades ago were the greatest in 200 or more years, and since they were causally connected with the recession or disappearance of the glaciers from their largest extent in several thousand years, at least some of these historic lake maxima might be the highest levels of the Medithermal age. However, this cannot be judged, for practically no field study has been made with the purpose of determining and dating the highest Medithermal lake levels. This latter level of Summer Lake, as stated, is found 12 feet above the highest modern stand. It is also known that these latter levels were generally not very high, for Pyramid Lake has not overflowed for several thousand years (Antevs, 1938b, p. 192). This is shown by a large intact fan barrier between the Pyramid basin and Smoke Creek Desert. This barrier at 3950 feet stands 83 feet above Pyramid Lake of 1882 and 71 feet above the high level of 1868. Evidently the moistest episode during the last several thousand years was very modest in comparison to the Provo Pluvial during which water reached 320 feet above Pyramid Lake of 1882. The Medithermal moisture fluctuations in the Great Basin may have been limited to changes in the relative extent of arid and semiarid regions.

The writer is not familiar with any other evidence on the age and degree of the greatest moisture during the Medithermal age. The giant sequoia does not supply any. Consequently the exact date of the late moisture maximum in the American West is not known. [5]

Additional climatic variations after Christ but before historic times have been distinguished in the Southwest (Antevs, 1941, pp. 43-45; Hack, 1942, pp. 67, 68). Some of these probably affected the Great Basin. The s. c. great drought of A.D. 1276-99 (1273-1300), which is indicated by narrow rings in many parts of the Colorado Plateau as far north as west-central Colorado (Douglass, 1935, pp. 49, 64; 1947; Schulman, 1946, Pl. 3; 1947a, p. 8), probably also affected at least the southern part of the Great Basin. However, among the Great Basin ring records only Keen's graph from south-central Oregon extends so far back in time (Keen 1937; Schulman, 1947b, pp. 8, 9), and thus the first part of the graph is hardly trustworthy. The period 1276-99 is normal in Douglass' best sequoia record from the west flank of the Sierra Nevada (1945, p. 28). The most severe later growth minimum on the Colorado Plateau and in southern California, that of A.D. 1573-93 (1571-97) is recorded in southernmost Nevada, and, it seems, as far north as the Lake Tahoe region (Douglass, 1940; Schulman, 1946, p. 45, Pl. 3; 1947b, pp. 8, 28, 33).

If marked growth maxima and minima of carefully selected trees really record rainy and dry periods, respectively, long tree ring records from the northwestern border region of the Great Basin indicate moist and dry periods over fairly large, but clearly restricted and fluctuating areas (Hardman and Reil, 1936; Keen, 1937; Antevs, 1938a).[6] Most of the marked maxima and minima of growth are present from Lake Tahoe to Lapine in central Oregon, while some occur in the greater part of this region and still others in more limited areas. There were here widespread growth maxima, probably rainy periods, about 1525, 1540, 1612, 1745, 1791, and 1810; and growth minima, probably droughts, about 1500, 1532, 1580, 1630, 1655, 1780, and 1848. The drought culminating in the late 1840's, which was especially acute in Oregon, was the result of a general decline in precipitation after the maximum about 1810.

Since 1850 rate of tree growth, historical data, and instrumental observations record in many parts on the Great Basin medium to large maxima of water supply culminating in 1853, 1862, 1868, 1884, 1890, 1907, and 1921; and minima culminating in 1879, 1889, 1898, 1919, 1924, 1931, and 1934 (Antevs, 1838a, pp. 59, 62, Pl. II, h, i). Brief maxima and minima are often regional, and heavy precipitation in one region is compensated by a deficiency in another. The exceptional drought in the early 1930's followed upon a general drop of the water supply since 1907. Showing considerable lag Great Salt Lake fell to its all time low of 4193.7 feet in the autumn of 1940, and Pyramid Lake to its lowest observed level of 3815.1 feet in December 1941. After 1934 the rainfall on the whole increased to reach an exceptional maximum in 1941. The Utah annual average precipitation was then 20.8 inches, the greatest in fifty years of record, and the Nevada average was 13.5 inches, the third highest ever observed.

In the great Basin, where the water supply is a determining factor in the potential development, reasonably accurate estimates of the future probable amount are important, as forcefully illustrated by many abandoned homesteads. Some idea about the future conditions may be gained from those in the past. From the time of settling by the whites about 1850 to 1923 the runoff from the high mountains was above the average, and the rainfall at the lower edge of the forest was normal to abnormal, making the total water supply excessive. During the years 1924-1934, on the other hand, both runoff and precipitation were subnormal and the temperature and the consequent evaporation were excessive, producing the severest drought in from 150 (Susanville) to over 650 (Klamath Falls-Lapine region) years (Antevs, 1938a, p. 60; Keen, 1937, p. 188). Since both dry and moist periods have been abnormal during the 100 years of settlement, we can expect in the future a more normal water supply, one which is more evenly distributed over the years and consequently better suited for long-range planning. However, the facts that most of the glaciers throughout the world attained their postglacial maxima between 1600 and 1875 A.D., especially about 1850, and thereafter have been in marked retreat (Thorarinsson, 1940, p. 147; Matthes, 1942, p. 190), might mean that the moderate Medithermal age is at an end, and that there is now a general trend to a warmer and perhaps drier climate.

NOTES

1. The Swedish terms "Warm Age," "Postglacial Warm Age," and "Postarctic Warm Age," which are synonyms, are older than and independent of von Post's division of 1931. They denote the age intervening between the subarctic climate of the Fenni-glacial (Fini-glacial) and the sudden onset of cold and raw climate on the transition between the Bronze and Iron ages. They are thus collective terms for the Boreal, Atlantic, and Subboreal ages, which are now obsolete (von Post, 1944). The beginning of the Warm Age is by von Post placed at the Rhabdonema Age of the Baltic (1945, p. 41), which has been dated by Sauramo variously at 700-6500 B.C. and the middle Fenni-glacial (1942, p. 234; 1944, p. 74). Thus the Postglacial Warm Age embraces the time from about 7000 to 600 B.C.; and, in spite of its name, its first and last parts were not warmer than the present. This term and division fills a regional need, but it does not serve our purpose, long distance correlation.

2. In Thornthwaite's (1948, p. 76 and Pl. IA) new classification the limits of the climatic types are established in terms of the relation between water need or potential evapotranspiration and precipitation. A formula $\frac{100s - 60d}{n}$ is deduced for a moisture index. In this formula s is (seasonal) water surplus, d is (seasonal) water deficiency, and n is water need. Moisture index 0 separates humid and dry climates. The types here mentioned have the following moisture index limits:

Moist subhumid	0 to +20
Dry subhumid	-20 to 0
Semiarid	-40 to -20
Arid	-60 to -40

3. In the opinion of the writer the primary cause of arroyo cutting is a drastic reduction or destruction of the plant cover, which in turn can be caused by drought or by overgrazing, trampling, and fires. The erosion takes place during heavy rains or cloudbursts if a ravaged plant cover and soil mantle are unable to absorb and retard the sudden rain water, so that this runs off too fast and concentrates in and rushes down trails, wheel ruts, valleys, and stream beds, tearing them up. When the ground has a good protective cover of vegetation and soil, sudden downpours do little or no damage, as is especially well shown in the region of Salt Lake City (Bailey, 1941, pp. 245, 248). Prehistoric channel erosion thus may represent droughts, while that since 1885 can be a result of drought, overgrazing, or a combination of both. It does not seem logical for Thornthwaite, Sharpe, and Dosch (1941, pp. 301, 302; 1942, pp. 88, 119, 127) to regard past successive channel erosions and fillings as normal processes under natural conditions broken by occasional exceptional showers and then to attribute the modern gully cutting to destruction of the vegetal ground cover by overgrazing. The modern channel erosion may naturally be ascribed to overgrazing, as long as no convincing evidence has been presented for Bryan's (1941, pp. 232, 234, 236) view that it is the result of a progressive drought, or for the greater possibility that it is caused by cooperation of drought and overgrazing. Tree growth, which correlates well

with the winter precipitation, does not indicate any distinct progressive drought during historic times in Arizona and adjoining regions to the east and north (Schulman, 1942).

4. The drownings of trees by Eagle and Tahoe lakes seems to be best explained by geological events (Antevs, 1938a, pp. 26, 37).

5. In Sweden, according to Granlund (1932, p. 169; Magnusson and Granlund, 1936, p. 236), the precipitation had its postglacial maximum in the centuries just before Christ, while the Scandanavian glaciers attained their greatest postglacial size during the age about 1740 to 1825 A.D. (Ahlmann, 1941, p. 201).

6. Before 1855 the growth rate in the region 10 to 15 miles north of Lake Tahoe seems to record the moisture, though it does not from 1885 to 1900 (Antevs, 1939, p. 91).

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