BULLETIN OF THE UNIVERSITY OF UTAH

Vol. 38 June 30, 1948 No. 20

THE GREAT BASIN

With Emphasis on Glacial and Postglacial Times

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BIOLOGICAL SERIES, Vol. X, No. 7

PUBLISHED BY
THE UNIVERSITY OF UTAH
SALT LAKE CITY

III.

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III.

Climatic Changes and Pre-White Man

ERNST ANTEVS

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Introduction

The climatic conditions in the Great Basin during the Quaternary were greatly influenced by the state of glaciation in western Canada and contiguous parts of the United States. During extensive glaciation the storm tracks were pushed south of their modern courses, and the Great Basin received precipitation also during the warm seasons. Thus glacials and interglacials in the North were corresponded by pluvials (rainy, wet ages) and interpluvials in the Great Basin. Since there was no very great difference in the area of the successive glaciations, and the interglacials were comparable to the Postglacial, a review of the climatic conditions and changes in the Great Basin during the ages corresponding to the last main glacial, the Wisconsin, and the Postglacial covers in a general way the Quaternary since the beginning of glaciation.

Data bearing on the climatic conditions are furnished by positions and fluctuations of lakes, glaciers, and snow lines; deposition and erosion by water and wind; plants and animals; rate of tree growth; and, in historic time, by measured precipitation, runoff, and lake levels. The rate of tree growth is a disputed indicator of rainfall and moisture. Assumptions that trees growing in dry situations are virtually natural rain guages have inevitably provoked the counter view that they are too unreliable and the conditions too complicated for any conclusions of past or future rainfall (*45*).[1] To be sure, the climatological significance of the growth rate of the giant sequoia is not known, or its ring records (*39b*) "at best represent only first approximations to rainfall indices" (*86f*, p. 5), but on the whole, the truth may lie somewhere between the extreme views. By using great effort to select trees whose growth variations are determind by precipitation as the sole climatic factor, by only sampling trees growing on steep slopes underlain by pervious rocks and near the lower or dry border of the forest (*86a*, pp. 60–63; *86c*, pp. 9–18, 29-32), Schulman has constructed admirable indices of past winter rainfall and runoff (*86–86g*). The importance of tree ring records is, of course, greatly enhanced by their continuity and by the absolute dates. However, the fact

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[1] Italic numbers in parentheses refer to References at end of paper.

that the radial growth of the trees used is determined by the winter and spring (October-June) precipitation, little if at all by the summer rainfall (*86a*, p. 63; *86c*, p. 30), somewhat limits the usefulness of the records. Thus Gladwin (*44a*, pp. 9, 22, 32) holds that past crop conditions, as dependent to a considerable degree on the summer (July-September) rains, cannot be judged from tree rings, that past crop failures and consequent migrations cannot be concluded from narrow rings, as those of A. D. 1276–99. Furthermore, since grasses, which are the foremost protectors of the soil from erosion, are mainly or entirely dependent on summer rainfall, series of subnormal rings do not necessarily mean ages of soil erosion; and there might have been erosions that are not recorded by narrow rings. Comments on man's antiquity in the Great Basin have been appended.

West–Canadian ice sheets and pluvials in the Great Basin

The Wisconsin Glacial included western (Cordilleran and Keewatin) and eastern (Labrador and Patricia) ice, the line of demarcation extending along western Hudson Bay and the Mississippi River. The western ice is believed to have had one early maximum, the Iowan, some 65,000 years ago, and one late one, the Mankato, some 25,000 years ago. The eastern ice had one intervening culmination with successive regional maxima called the Tazewell and the Cary. The Tazewell is marked by the Shelbyville morainic system in Illinois, Indiana, and Ohio and probably by the Ronkonkoma moraine on Long Island. It was attained probably some 40,000 years ago. The Cary maximum is recorded by the St. Croix–Johnstown–Mississinawa morainic system in Wisconsin, Illinois, Indiana, and Ohio, by the peripheral Wisconsin moraine in northwestern Pennsylvania, the Binghamton drift border in western New York (*68*), and probably by the ice advance at Northampton, Massachusetts. It occurred probably some 27,500 years ago. The Valders (*94*, p. 84, fig. 66) is an important recessional stage of the eastern ice, roughly contemporaneous with the Mankato maximum of the western ice. The Valders ice border was located south of Lake Superior, at Milwaukee, the Port Huron morainic system, Buffalo, southern Adirondacks, and St. Johnsbury in Vermont, which dates it at about 25,000 years.[2]

The Iowan glaciation is believed to have started by accumulation of snow and ice in the mountains and on the plateaus of northwestern North America (*40*, pp. 63–73; *10*, *14*). In the relatively low saddle of the Rockies between the 54th parallel and Mt. Logan the glaciers flowed down the eastern slopes and spread onto the plains. This mountain saddle must be assumed to have been depressed, or to have stood, 2000 to 3000 feet below its present level to permit relatively free entry for cyclonic storms. After long ages, when the ice on the plains about Great Slave and Athabasca lakes had reached the same level as the ice in the mountains, it developed an independent center of outflow, the Keewatin center, which changed position with the uneven growth and wastage of the ice sheet. When the ice sheets had attained large size in western Canada, the permanent snow and ice made the air pressure and precipitation (but not the temperature) conditions of the summer resemble those

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[2] In 1948 these figures appear to be too high. The figure 25,000 years for the Valders and the Mankato glacial maxima, which forms the main basis for the other figures, was agreed upon by Frank Leverett, G. F. Kay, and me in 1930 (Kay in Bull. Geol. Soc. Amer., vol. 42, 1931, p. 460). Leverett (Science, vol. 72, 1930, p. 193) employed the estimates of the recession of the Niagara Falls, which are now known not to be valid (9, p. 20). I used varve counts in Sweden and North America, which I correlated, and estimates for gaps in the American varve series. It still seems reasonable that the border of the ice sheet left Mattawa, 185 miles north of Toronto, 14,000 to 15,000 years ago (9, pp. 2, 6, 33; Journ. of Geol., vol. 55, 1947, p. 528); but 5000 to 6000 (instead of 10,000) years now appear sufficient for the ice retreat from the Port Huron morainic system-Buffalo to Mattawa. This would date the Valders and the Mankato culminations at about 20,000 before the present.

of the modern winter; that is the pressure and precipitation conditions prevailing during the modern winter persisted through the year.

During the modern winter all Canada and the waters to the north are covered by snow and ice which by reflecting the solar heat give rise to intensely chilled air. A great contrast is developed between the temperature and pressure of the air over the snow and ice on one hand, and over the bordering open oceans and snow-free land on the other. The steep gradient of the anticyclonic pressure and the general circulation frequently send waves of cold polar air sweeping southward. This cold air is met by the westerlies, which are warm air masses coming from the subtropical high pressure belt about Lat. 30°. The interaction of the contrasting air masses give rise to the travelling lows and highs; and where the air masses clash on a large scale there are developed semi-permanent lows, the Aleutian Low and the Iceland Low. In the cyclones precipitation is produced by condensation of moisture contained in the warm air masses by their being raised and thus suddenly cooled. Most North Pacific cyclones travel northeastward into the Gulf of Alaska. Several reach the continent in southern British Columbia or in Washington, and some of these cross the Rockies and move eastward along the International Boundary. Still others take a more southerly route and give California most of its precipitation.

During the modern summer, with snow and ice gone, low pressure conditions are established over the continent. The Aleutian Low is reduced to a trace. Instead there is formed over the Pacific on Lat. 40° a strong anticyclone which controls the North American west coast. This high causes a practically rainless summer in California, but permits occasional cyclones to bring some rain to the coast from Oregon to Bering Sea.

When the west–Canadian ice sheets were large these modern summer conditions could not establish themselves, though, of course, the temperature rose especially outside the ice sheets causing seasons, but the described winter conditions of pressure and precipitation were fairly permanent. The Aleutian Low persisted through the summer, and the subtropical high pressure may have remained on or below Lat. 30°. As a consequence moving cyclones, bringing precipitation, crossed the western United States in spring, summer, and autumn as well as in winter. Hence the West had a pluvial period.

Ultimately the western ice sheets became so large, and the glacial anticyclone so strong that the storm tracks were pushed off their normal courses, and the heaviest precipitation occurred well to the south of the ice border, or in northern Nevada and Utah. Resulting undernourishment together with a probable temperature rise made the ice sheets retreat; and the additional feeding caused the lakes and the mountain glaciers to attain their maxima. The pluvial culmination was thus contemporaneous with the early stages of retreat of the western ice sheets. When these latter had shrunk so that their anticyclone was weakened, the storm tracks moved northward and the precipitation diminished in the Great Basin. After long ages these ice sheets again received sufficient nourishment and were rejuvenated.

In the meantime the Labrador ice sheet is believed to have formed, nourished at first mainly by snow from moist east and northeast winds induced essentially by the Iceland Low, then situated to the south of its modern site. When this ice extended to New York City the growing strength of its glacial anticyclone had reduced the cyclonic snowfall in its marginal area so that the ice supply became balanced by the enormous wastage in this low latitude. Ice advance ceased, and retreat interrupted by oscillations soon set in. After the ice border had withdrawn to the general region of the Vermont–Quebec boundary and beyond the straits connecting lakes Michigan and Huron there was a halt. This was followed by a readvance to a curving line running

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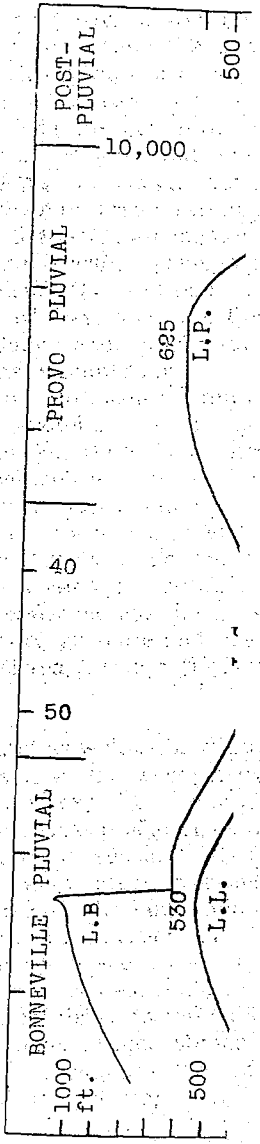

Wisconsin continent
United States.
Area of ice roughly
The curves to the l
hontan in broad sense.
L. S: = Lake Stansbury.
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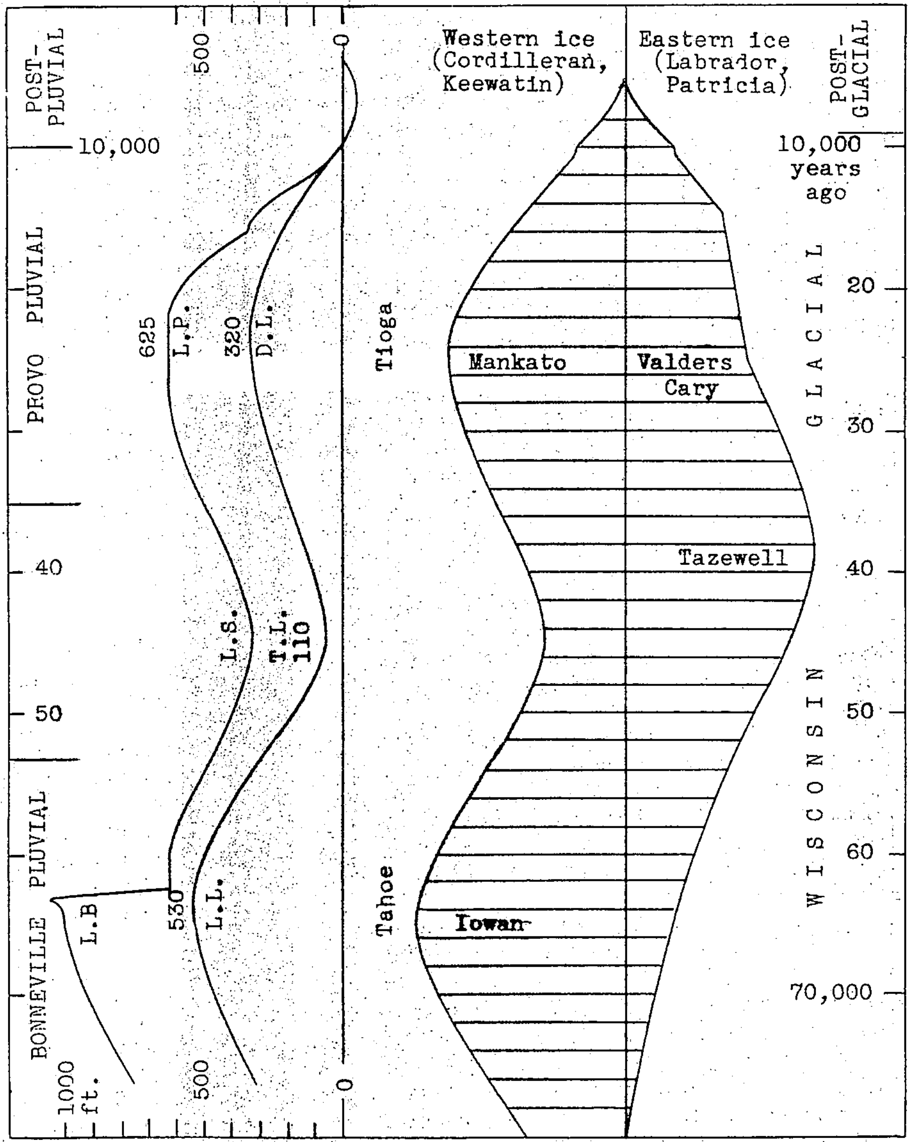
somewhat south of Lake Superior and through Milwaukee, Saginaw, etc. to to St. Johnsbury, that is to the line which marks the ice border of the Valders substage. The Valders readvance was greatest in the Lake Michigan basin. The increase in the snowfall on the ice in the region of the Upper Great Lakes was probably caused by east-moving cyclones which now successfully fought



Wisconsin continental glaciations and corresponding mountain glaciations in the western United States.

Area of ice roughly estimated.

The curves to the left show the probable fluctuations of Lake Bonneville and Lake Lahontan in broad sense. L. B. = Lake Bonneville proper, L. L. = Lake Lahontan proper. L. S. = Lake Stansbury, T. L. = Thinolite Lake. L. P. = Lake Provo, D. L. = Dendritic Lake. The zero level is the lake shore gauge zero of Great Salt Lake, which stands 4203 feet above sea level, and the level of Pyramid Lak in 1882, which stood at 3867 feet elevation.

Confer foot note 2 on page 167.

the weakened glacial anticyclone. The western ice sheets may have received snow from the same storms, and they attained their second maximum, the Mankato, approximately at the same time as the Valders readvance reached its limit. The Mankato glacial maximum in turn caused a second culmination of the pluvial lakes and of the mountain glaciers in the West. Finally also the western ice sheets withdrew; and a marked temperature rise led to the disappearance of all the ice shets.

The Bonneville and Provo Pluvials

The history of the Great Basin, of Lake Bonneville in Utah (*44, 76, 61*) and Lake Lahontan in Nevada (*81, 62, 7*), may now be fitted into the above general picture of the climatic changes during the Wisconsin Glacial. Of the three main Bonneville stages distinguished by Gilbert (*44*, pp. 260, 262, 316) the "second Bonneville epoch of high water" alone may represent the Wisconsin Glacial. This "second epoch of high water" includes two fine-grained sedimentary beds, viz. the white marl and the underlying yellow clay (*44*, pp. 190, 198). These two clay beds in conjunction with the upper section in the Old River Bed (*44*, pp. 194, 198), 45 miles southwest of Utah Lake, suggest that the epoch really included two separate high-water stages, though this fact is discounted by Gilbert (*44*, p. 199) and ignored in his final discussions of the geological events (*44*, pp. 260, 262, 316). The two high-water stages are recorded by the Bonneville and the Provo shore lines, whose formation, however, probably was separated by a long interval during which the water level withdrew below the upper section in the Old River Bed but not to the lower section (*44*, p. 198, fig. 30). The high-water stages consequently were distinctly separate lakes and may be called Lake Bonneville in restricted and proper sense and Lake Provo. Lake Bonneville proper was upon its maximum partially drained to the Snake River and the Pacific through the Red Rock Pass, whose lime stone floor held the level of Lake Provo. (See figure.)

The history of Lake Lahontan was naturally parallel to that of Lake Bonneville in wide sense. A corresponding interpretation, which is a modification of that given by Russell (*81*, pp. 102, 204, 236, 237, 263), is shown in the figure. The arguments, too complicated to be briefly stated, are set forth in another paper (*19*, p. 30). Lake Lahontan in restricted and proper sense was contemporaneous with Lake Bonneville proper, and Dendritic Lake (from dendritic tufa, "Dendritic terrace") probably with Lake Provo.

Lake Bonneville and Lake Lahontan proper may represent the pluvial age which corresponded to the Iowan continental glaciation; Lake Provo and Dendritic Lake the pluvial which was the correlative of the Mankato glacial maximum. The two pluvials may be called the Bonneville Pluvial and the Provo Pluvial. These have just been recognized also in the Summer and Fort Rock Basins of south-central Oregon (*5*, p. 801; *6*). The corresponding mountain glaciations are in the Sierra Nevada called the Tahoe and the Tioga (*23*, pp. 870, 884), and in northeastern Nevada the Lamoille and the Angel Lake (*87*, pp. 306–309). In the Wasatch and Uinta mountains the two Wisconsin glaciations seem to have been combined by Atwood (*20*) as the "later epoch of glaciation," in the Uintas called the "Smith Fork glaciation" by Bradley (*26*, pp. 194–196). The large and bulky outer moraines of the "later epoch"—the deposits of the "earlier epoch of glaciation" are in the Wasatch Mountains few and relatively insignificant—may be correlatives of the Tahoe moraines in the Sierra Nevada; and small inner moraines, the equivalents of the Tioga moraines.

During the Iowan–Bonneville Glacio–Pluvial Lake Bonneville rose 1000 feet above the zero level of Great Salt Lake and overflowed. It covered 19,750 square miles, while Lake Michigan has an area of 22,400 square miles. Lake Lahontan rose 530 feet above the 1882 level of Pyramid Lake and attained an area of about 8,500 square miles, but probably did not overflow. The Great Basin, especially the northern area, was crowded with large and deep lakes (*74*). In comparison to this vast expansion of lakes the local glaciation was *small, especially in the mountains to the east* (*20*, Pls. IV, X, "later epoch;" *8*, p. 648). Only three glaciers extended below the Bonneville shore line at about 5200 feet, moraines of the "later epoch" (the Tahoe) being covered by Bonneville deltas on the Alpine, South Dry, and Little Cottonwood creeks, situated some 14 to 20 miles south of Salt Lake City (*20*, pp. 79, 80, 83, 92; also *44*, pp. 308–311, Pl. 42; *23*, p. 915). On the east flank of the Sierra Nevada the glaciers extended to an average altitude of 7000 feet (*23*, p. 891), or to some 4300 feet below the modern glaciers. The relative magnitude of the lakes and the glaciers demonstrates that the *wet precipitation was very much greater than the solid*. It was the cyclonic rains during the warm seasons which made the chief difference from the conditions at present. This glaciopluvial was the wettest and coldest age of the Wisconsin judging from the mountain glaciers and Lake Lahontan. Lakes Bonneville and Provo do not *seem to supply any evidence on this point*. The few and small Bonneville deltas and the numerous and huge Provo deltas and other features which made Gilbert (*44*, pp. 129, 130, 153–166, 308–311) infer that the Provo stage was the wettest and coldest, do not necessitate that conclusion, for the formation of deltas was far more favorable at the Provo level (*76*, pp. 41, 52, 54, 55), and that level was held for much longer ages.

Lake Bonneville reached its overflow level, which must have been somewhat above the Bonneville shore line, after the Wasatch glaciers, upon their culminations, had withdrawn above the Bonneville shore; *or, more precisely*, the Wasatch glaciers culminated and withdrew above the Bonneville shore line before or during the formation of this shore and before the lake attained the overflow level. This is shown by the mentioned occurrence of moraines beneath deltas close to the Bonneville shore and by the presence of deltas material up to the Bonneville level in the gap between the lateral moraines of Little Cottonwood glacier, as observed by Blackwelder (*23*, p. 915). The absence of the Bonneville shore line (which is visible close by) from the moraines of the Little Cottonwood glacier (*44*, pp. 308–310), can be due to checking of the waves by stream currents and by upbuilding of the delta (*23*, p. 916).

During the Bonneville–Provo Interpluvial the lake in western Utah may have withdrawn roughly to the 350-foot level above Great Salt Lake, judging from Gilbert's (*44*, p. 198) sections in the Old River Bed. This level coincides approximately with the Stansbury shore line at about 325 feet above Great Salt Lake (*44*, pp. 134, 167, 186; *76*, p. 42). The Stansbury shore line is locally cut in rock and has large terraces and great accumulations of tufa, and consequently represents such a protracted lingering of the water level that Gilbert (*44*, p. 186) believed it was determined by an outflow or its equivalent, yet, it does not seem to have any deltas worth mention. It seems possible that this shore line was formed largely during the Interpluvial, only in part during the final fall of Lake Provo, and thus records the lowest interpluvial lake level. The post-Lahontan lake in Nevada probably subsided to the 110-foot level, forming the Thinolite terrace. The Interpluvial may have been distinctly moister and cooler than the present.

During the Mankato–Provo Glacio–Pluvial the lake in western Utah may have risen to the Red Rock Pass outlet and overflowed. The channel was cleared of debris to the lime stone ledge, and the lake became established 625 feet above Great Salt Lake, forming the magnificent Provo shore line. Lake Provo had an area of about 13,000 square miles, or equalled Lake Erie plus one-half of Lake Ontario in size. The lake in western Nevada seems to have reached 320 feet above Pyramid Lake of 1882, forming the Dendritic terrace. The lakes were out of proportion to the mountain glaciers. On the east side of the Sierra Nevada the glaciers stopped 500 feet higher than they did during the Tahoe, that is, they extended to the level of about 7500 feet (*23*, p. 884), or some 3800 feet below the modern glaciers. The extent of the contemporaneous glaciers in the Wasatch and Uinta mountains is not known, for there the moraines of Tioga age have not been separated from recessional moraines after the Tahoe stage. The last glacio-pluvial in the Great Basin was consequently very wet and rather cold in comparison to modern time, but not as wet or cold as the Iowan–Bonneville.

The Postpluvial or Neothermal

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 (*9*, 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 (*77*; also *79*).* According to von Post the temperature in Sweden rose very slowly during and after the release from the last ice sheet (*78*, 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 during the past 4000 years. A similar view had previously been presented by Granlund (*46*, 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 (*41*, 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. (*42*, pp. 379, 380; *83*, pp. 234, 263); in Denmark, 5600–4000 (*75*, pp. 20, 23), or 6000–2500 B. C. (*60*, p. 480). According to the present knowledge the warmest age thus prevailed from about 5000 to 2500 B. C., that is during the marine Litorina stage (5500 *or* 5000–2000 B. C.) of the Baltic Basin.

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*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 (*79*). The beginning of the Warm Age is by von Post placed at the Rhabdonema Age of the Baltic (*80*, p. 41), which has been dated by Sauramo variously at 7000-6500 B.C. and the middle Fenni-glacial (*83*, p. 234; *84*, p. 74). Thus the Postglacial Warm Age embraces the time from about 7000 to 600 B.C.; and, in spite of the 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.

The warmest postglacial age of northern Europe was characterized by a relatively insular climate with warmer summers and milder winters than now prevail (*47*, 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 (*78*, 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 (*60*, 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 (*47*, pp. 238, 243; *41*, pp. 670, 674; *82*, p. 530). The temperature 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 (*60*, 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 (*41*, 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 (*32*), Tierra del Fuego (*21*, p. 285), and the Antarctic (*4*, p. 651). It was perhaps universal. Thus, the main factor of the higher temperature was perhaps also 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 known 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 millennia 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 (*62a*, p. 672; *40a*, p. 208). Their incorporation would make the terms "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 Scandinavian 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 (*98a*, 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 ages	Moisture conditions in Great Basin and contiguous areas
Present		
	Medithermal Moderately warm	Arid and semiarid:* Rebirth of lakes and glaciers; Summer Lake maximum 45 feet above average modern stand
2500 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 Thornthwaite's (*93a*, 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

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 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 climactic eruptions of Mt. Mazama, the ancient volcano whose collapse formed the caldera holding Crater Lake (*5*). 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 (*98a*, pp. 112–14); by Hansen at not more than 10,000 years and perhaps less (*53a*, p. 118); and by Allison at 10,000 to 14,000 years (*5*, 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 (*52*, pp. 104, 111–13, Fig. 57; *53a*, 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 topmost part of this 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 region. 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 (*52*, p. 105, Fig. 60; *53a*, 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 top (*53a*, 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 thre 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 (*53a*, 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 (*5*, 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 (*5*, 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 (*96a*), 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 (*13*, 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 (*5*, 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	about 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 (*15*; *18*, 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 (*95*, pp. 117–123; *43*, 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 (*69–71*; *72*, pp. 211–21; *73*). 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 (*49*); by wind excavation in Fort Rock basin, Oregon (*6*, p. 64); and by pollen profiles in peat deposits in Oregon and Washington (*50*, p. 218; *51*, pp. 57, 59–62).[1]

THE MEDITHERMAL AGE

From the above statements it follows that a relatively cool and moist age began about 2000 B. C. The principal 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 postpluvial erosion surfaces are two to three feet of unlaminated brown colored cienega (wet meadow) clay and about a foot of yellow laminated silt forming the ground surface (*18*, 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 (*18*, pp. 43, 53, 54, 56). An undecorated pot sherd suggests that this erosion occurred about the time of Christ or later. These conditions seem to show that in southeastern Arizona the two millennia before Christ were moistest and the past millennium was driest.

From stream deposits and erosion in northeastern Arizona Hack (*48*, 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 millennium A. D. (*48*, pp. 42–44).

It is not known which of the last millennia was moistest in the Pacific Northwest (*53a*, 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 (*5*, pp.791, 794, 801).

In the high western mountains the glaciers, according to Matthes (*71*; *72*, 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 (*99*, p. 16, Pl. 2; *54*, *55*, *13*), but they rose rapidly during the 1860s, and notably Pyramid, Winnemucca, Walker, Carson, Warner, Goose, and Great Salt lakes and Carson Sink reached unusually high level about 1870. Pyramid and Winnemucca lakes had their maxima in 1868, but their volumes would have been

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[1] 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 (*22*, 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 (*92*, pp. 301, 302; *93*, 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 (*27*, 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 (*86*).

still larger about 1911, if no water had been diverted from the Truckee River (*57*, 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 (*57*, p. 75). In 1844 Fremont observed a white line at 3872 feet of elevation, but he does not mention any at higher levels (*57*, 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 (*54*, p. 89). The lake consequently rose higher than at any time since 1750 or earlier.[1] Great Salt Lake in 1867 submerged an old storm line at 4207 feet, which in 1850 formed the lower limit of sagebrush growth (*54*, 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 1923 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 (*1*, pp. 125–128; *2*, 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 (*65*). 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 abnormal 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) (*13*, pp. 60, 66, 67, Pl. I, k; *63*, 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 (*15*, p. 192). This is shown by a large intact fan barrier between the Pyramid basin and Smoke Creek Desert. This barrier

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[1] The drownings of trees by Eagle and Tahoe lakes seem to be best explained by geological events (*13*, pp. 26, 37).

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 the 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.[1]

Additional climatic variations after Christ but before historic times have been distinguished in the Southwest (*18*, pp. 43–45; *48*, 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 (*39*, pp. 49, 64; *39d*; *86c*, Pl. 3; *86e*, 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 (*63*; *86f*, pp. 8, 9), and this 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 (*39b*, 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 (*39a*; *86c*, p. 45, Pl. 3; *86f*, 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 (*56*, *63*, *13*).[2] 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 1840s, 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 of 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 (*13*, 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 1930s 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.

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[1] In Sweden, according to Granlund (*46*, p. 169; *47*, p. 236), the precipitation had its postglacial maximum in the centuries just before Christ, while the Scandinavian glaciers attained their greatest postglacial size during the age about 1740 to 1825 A.D. (*3*, p. 201).

[2] 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 1855 to 1900 (*16*, p. 91).

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 amount 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 white 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 1924–34, 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 (*13*, p. 60; *63*, 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 (*91*, p. 147; *72*, 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.

Man

At an early stage of the last deglaciation of western North America a corridor was opened between the shrinking Cordilleran and Keewatin ice sheets at the eastern foot of the Canadian Rockies. This opening was soon used by man spreading southward. When the migrants reached the Missouri River in western Montana, some of them were surely guided by its funnelshaped valley upstream to the mountain passes leading to the Snake River Plain. These passes, now used by railroad and highways, are less than 7000 feet high. Thus man probably arrived as early in the Great Basin as in Wyoming.

Presence of man during the Provo Pluvial and/or during theAnathermal age, is recorded by artifacts at Wikiup, in the Paisley Five Mile Point Caves Nos. 1 and 3, and perhaps in the Fort Rock Cave, all situated in south-central Oregon, and by artifacts at sites in southeastern Nevada, in Gypsum Cave, and in the region south of the Great Basin.

At Wikiup and in the Paisley caves, 60 miles north and 75 miles east of Crater Lake, respectively, the artifacts occur below a layer of pumice derived from the climactic explosions of Mt. Mazama, which have been tentatively dated above at 8500 to 9000 B. P.

The artifacts at Wikiup are stone knives (*33*, 38, pp. 45, 49). Beds below Mt. Mazama pumice in Paisley Five Mile Point Cave No. 1 contained miscellaneous stone artifacts, mat and rope of sagebrush bark, and a little basketry (*35*, pp. 53–56, 61; *37*, pp. 21, 39, 135, Figs. 5, 8). Prepumice layers in Paisley Cave No. 3 contained worked obsidian and charcoal and ashes in association with broken bones of several kinds of mammals, including horse and camel (*34*, pp. 315, 316; *35*, p. 10; *37*, pp. 93, 94, 135, Figs. 53, 95; *38*, pp. 44, 50).

In Fort Rock Cave, 1½ miles west of the fortress-like erosion remnant named Fort Rock, artifacts occur below pumice from the Newberry Crater, 20 miles to the north (*97*, p. 77). Newberry pumice has been identified by Allison in the topmost part of the Winter Lake sediments on Ana River, or

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at 4230 feet altitude, 5 feet above that from Mt. Mazama (*5*, p. 796). It has not been found in peat bogs (*53*, p. 58). Below the Newberry pumice in Fort Rock Cave there have been found numerous artifacts, namely scrapers, drills, propectile points, manos, bone awl, antler flaking tool, wooden tools, numerous sandals of sagebrush bark, and one piece of basketry of tule (*35*, pp. 56–59, 64–69; *37*, pp. 39, 57, 84, 85, Figs. 6, 9, 45–47, 78, 79).

The main ancient sites in southeastern Nevada are found in a basin which contained a pluvial lake (*30*). They occur well above the lowest part of the basin, dating from a time when it held more water than at present. The artifacts include fluted, Folsom-like points, and gravers, drills, knives, and scrapers, closely resembling those from typical Folsom sites. In Gypsum Cave, about 10 miles east of Las Vegas in Nevada, dart points, dart shafts, and fireplaces were found beneath and in association with remains of extinct ground sloth, camel, and horse (*58*). Sloth dung in the same beds contains fragments of plants, especially the joshua tree (*Yucca brevifolia*), which are found at present only at 3000 or more feet higher elevation (*66*). There are other human cultures of high age in the Pinto Basin north of Salton Sea (*28*) and at Baker (29) in southern California, and in Sulphur Spring Valley near Douglas (*85*) and in the Ventana Cave some 75 miles west of Tucson (*59*) in southern Arizona.

There were no artifacts above the Mt. Mazama pumice in Paisley Five Mile Point Cave No. 3 (*37*, p. 93). Artifacts did occur, however, immediately above this pumice in Paisley Cave No. 1, 25 meters to the south (*35*, pp. 54, 55, 60; *37*, pp. 21, 39, 55, 70, 135, Figs. 5, 8). They consist of pieces of obsidian, a paint mano and metate, wooden artifacts, a few sandals of tule, and some basketry and matting of tule and sagebrush bark. There is no material difference between the artifacts below and above the pumice. Artifacts were also found directly above the Newberry pumice in Fort Rock Cave (*35*, pp. 59, 62, 63; *37*, pp. 69, 83, 85, Figs. 9, 44). They include projectile points, numerous scrapers, two drills, a mano, and some wooden objects. Each cave may have been reoccupied shortly after the respective pumice fall (*35*, p. 69), *i. e.* during the early and middle Anathermal age.

The altithermal age is a blank page in the history of man in North America, there being, except in southern Arizona (*85*), an ostensible gap between the Paleo-Indian of glacial and Anathermal age and the relatively well-known man of the past few thousand years. This gap may partly be artificial, created by archeologists who have been too eager to find early man in their region, for several supposedly glacio-pluvial sites are surely younger. In part the gap is locally or regionally real. The Paleo-Indian preferred regions which (then) were subhumid to semiarid. When temperature rose and moisture decreased during the Neothermal the old regions grew less desirable or even inhospitable for game animals and man. Therefore both shifted with climatic region and vegetation to regions with more rains. Especially, steppe, bison, and Folsom hunter spread eastward from the Great Plains. In the Great Basin and the Southwest man may essentially have moved to mountain valleys and to the centers of basins with water. The cooler and moister climate of the past four thousand years induced reoccupation of abandoned regions.

There is no recognized record of man in the Great Basin from the warm and dry culmination. However, if part of the clay, silt, and fine sand in the caves on Great Salt Lake was carried in by the wind (while part may have been unintentionally brought in by man and beast), it is reasonable to assume that the one or two lowest artifact-bearing beds resting directly on Bonneville gravel in Deadman Cave (*88*) and perhaps in Black Rock Cave (*89*) derive from the Anathermal and Altithermal ages.

Lower Klamath Lake has now practically disappeared since an embankment was thrown up in 1917, preventing Klamath River water from entering the basin. At Laird's Bay there occur, several feet below the historic lake shore and under exposed peat forming the lake floor, stone and bone artifacts, showing that man once camped here (*36; 17; 37*, pp. 97–102). Peat profiles indicate that this occurred just before the end of the dry Altithermal age (*52*, p. 104, Fig. 57).

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