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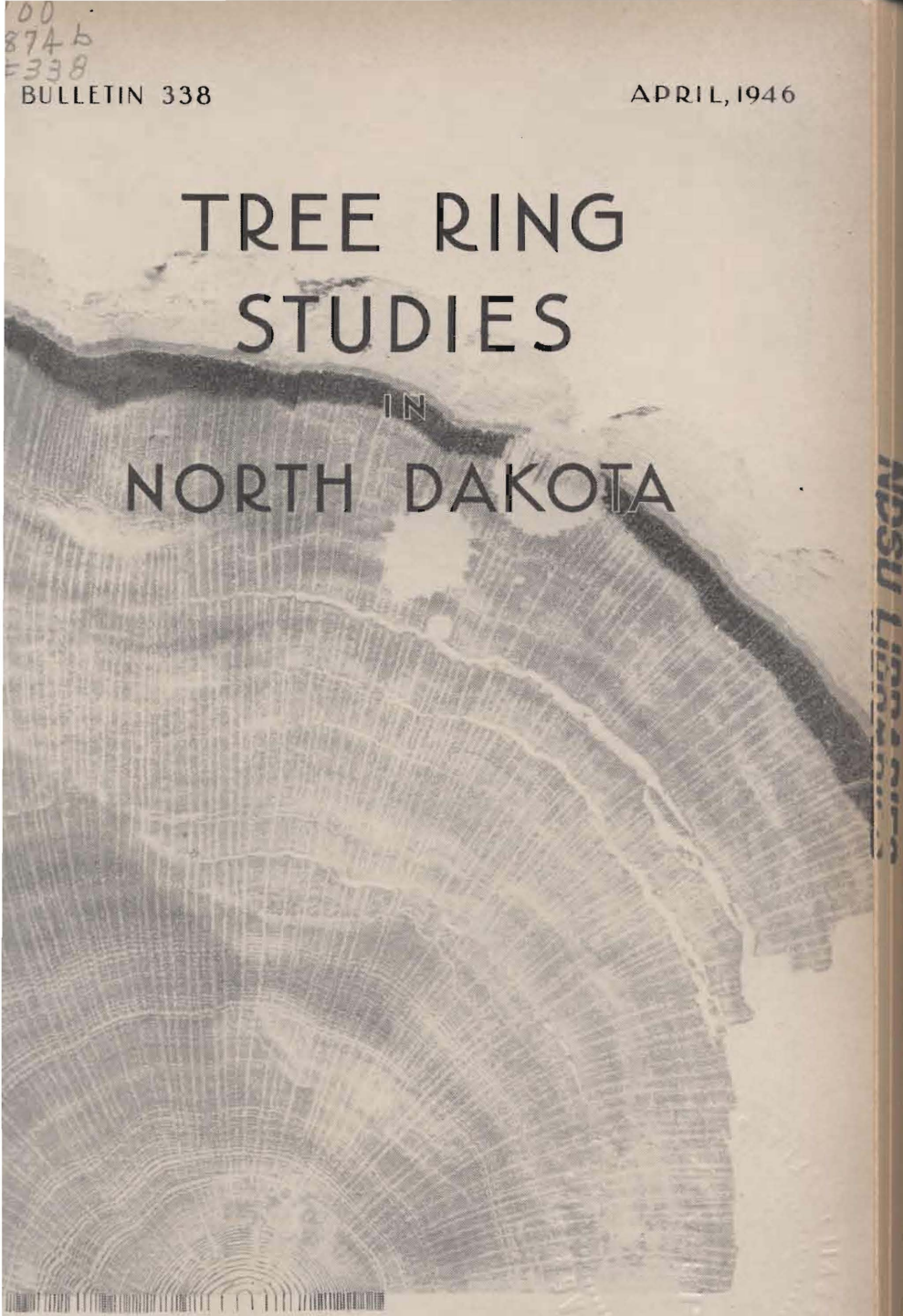
TREE RING STUDIES IN NORTH DAKOTA



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FOREWORD

The material presented in this paper is the result of long hours of study and much discouraging repetition and comparison in order to arrive at a rather small volume of definite information. It is hoped, however, that this information is sufficiently valuable to justify its publication and that such publication may lead to further and more valuable studies along the same line. While extreme care has been taken in working out and preparing data there are always possibilities of error, and such undoubtedly occur. However, even with some errors and mistakes the work should prove to be valid so far as it goes and serve to stimulate interest in the subject.

Without the kindest interest in the work and close co-operation from the staff of the State Historical Society the study could not possibly have been made. Particularly to Russell Reid, Superintendent of the Historical Society and of the fine Historical Museum at Bismarck, for advice and encouragement, and to Mr. Thad Hecker of the Society staff for collecting many of the specimens and preparing them for study, thanks are outstandingly due. Thanks are also due to H. L. Walster, Director of the North Dakota Agricultural Experiment Station for interest in the study and encouragement in carrying it out.

GEO. F. WILL

Tree Ring Studies in North Dakota

By Geo. F. Will [1]

PART I: TREE RING RECORDS IN DATING AND WEATHER IN THE NORTHERN PLAINS

A number of years ago, Dr. A. E. Douglass, a professor of Astronomy and Research Fellow of the Carnegie Institution first made public a method of reading weather data from tree rings in sequoias. This was followed by his work with ponderosa pine, principally on the Colorado plateau. This latter phase of his work led to the dating of old Pueblos and Cliff dwellings by comparison of the rings in old house timbers with those of already known dates in the series worked out in meteorological studies. In the continuation of that work a definite calendar of building dates for many of the old ruins has been worked out for a period of nearly two thousand years.

The work in the Southwest has drawn general attention, particularly of archaeologists, to the possibilities of similar work in other fields. At the University of Chicago a study by Florence Hawley of tree ring data from the central states was published a year or so ago. In 1943, Dr. Harry Weakly, Junior Agronomist, Division of Dry Land Agriculture, U.S. Dept. of Agriculture, at the University of Nebraska published in the Journal of Forestry, Vol. 4, No. 11, a paper on precipitation records from tree rings in western Nebraska. Ponderosa Pine and Red Cedar were the principal trees used in that area. Undoubtedly studies from other regions will be forthcoming.

The method of obtaining precipitation records from tree rings is based on the fact that annual rings in all trees vary in width depending on the amount of moisture available to the roots in the year in which each ring is formed. This fact was definitely established many years ago and definitely proven by Dr. Douglass. It is hardly necessary to present further proof. However, since this study deals with a new area and somewhat different species it was found possible to find and advisable to present some factual evidence derived from U.S. Dept. of Agriculture records. This material is taken from Miscellaneous Publication No. 471, "Crop Yields and Weather", U.S.D.A. Bureau of Agr. Economics, Agr. Marketing Service and U.S. Dept. of Commerce, Weather Bureau, 1942. This publication gives a detailed record of precipitation by states for a period from 1886 to 1941, accompanied by crop production for the same period.

[1]Mr. Geo. F. Will is a businessman of Bismarck, North Dakota. He is the senior author of "Corn Among the Indians of the Upper Missouri" by Geo. F. Will and Geo. E. Hyde, published by the William Harvey Miner Company, Inc., St. Louis, Missouri, 1917. He is also the senior author of the monograph, "The Mandans: A study of their culture, archaeology and language" by G. F. Will and H. J. Spinden, published by the Peabody Museum of American Archaeology and Ethnology, Harvard University, August 1906. Mr. Will is President of the North Dakota Historical Society. In recognition of his contributions to agricultural production and to the history of agriculture, the North Dakota Agricultural College conferred upon him the honorary degree of Doctor of Agriculture in June 1940. (H. L. Walster, Director)

In the process of studying tree rings the first step is to obtain a cross section of the tree to be studied which will show on a plane surface the annual rings from the center to the bark. A full circular section is preferable for study as there are often variations in the width of rings at different points in their circumferences. However, fairly good readings can be obtained from much smaller sections, even from borings of around two inches in diameter. In regions with longer growing seasons a study of this type is often complicated by double rings. In this northern region that difficulty seems to be very slight as the season is generally too short to allow the double ring formation.

The idea of conducting tree ring work in the Missouri Valley of North Dakota was conceived sometime ago. There are innumerable old sites of village Indians in the area, the greater part of them abandoned so long ago that no definite historical dates exist. It was, therefore, necessary to find some other reliable method of dating if the archaeological story of the region was to be satisfactorily worked out.

As has been said, most of the early tree ring work was based on several coniferous species and experiments with deciduous trees in the southwest had been definitely unsatisfactory. Satisfactory specimens in Dakota which might tie in with timbers from the old villages seemed to be non-existent. At present there are no coniferous trees in the region. The nearest specimens are in the Badlands of western North Dakota and consist of Pinus scopulorum and Juniperus scopulorum. At the present time there are no pines of any great age left but some junipers have been found with ages around four hundred years. However, there is a considerable difference in precipitation between the area where those trees are found and the Missouri Valley region and such sections could only be used after comparison with material from the primary area to be studied.

With this problem in mind attention began to be given in frequent long hikes over the Missouri bluffs to the location of trees which might be valuable in tree ring work. It seemed self evident that trees growing on the lowlands of the Missouri would be valueless because those areas are subject to recurrent floodings which are often due to ice gorges in the stream and which very frequently do not occur in years of high precipitation. The search was, therefore, confined to the sides of the many coulees leading down from the bluffs to the lowlands which often carry considerable timber. This timber consists of green ash, boxelder, shrubby trees, such as Buffaloberry, Chokecherry, Juneberry and Sheepberry, Elm and Oak. Much of this timber was cut for wood, logs and fence posts by settlers in the 70's and 80's. Furthermore it soon became evident that the ash, elm and boxelder, even the largest specimens, did not attain an age great enough to carry back even to the years when the Mandan Indians are known to have inhabited their last villages in the region.

Thus the only hope of finding trees of sufficient age seemed to rest with the oak, of the burr oak species. For many years the N.D. State Historical Society had been saving fragments of logs and posts from many of the old Indian

villages. As interest in the study increased these were unearthed from storage. Some sixty cross sections were cut and trimmed from this miscellaneous collection. Fortunately care had been taken to mark the site from which each fragment had come. As the pieces were examined it became evident that they were derived nearly altogether from burr oak and juniperus scopulorum trees. In connection with that fact it is interesting to recall what the Mandan matron, Scattered Corn, who possessed the knowledge and right to build earth lodges and who laid out the first reconstructed lodge built by the Historical Society on the State Capitol grounds, had related. She said that when the Great Chief Above was instructing her ancestors how to build earth lodges, he had specified that the timbers should be of Oak. According to her story that practice was followed so long as oak timber was available but that as the villages grew in numbers and in population the oak became exhausted and it was necessary to turn to the less enduring cottonwood. Moreover it is doubtful whether even if some cottonwood were present in the older sites, there would be anything left of it except masses of decayed wood.

The discovery that oak had been the chief timber used in the building of the old lodges led to a more careful search for very large old living oaks. At length two very large old trees, badly broken and damaged by wind, fire and weather but still alive, were discovered in a beautiful hidden and little frequented coulee some six miles northwest of Bismarck and within a few miles of several old village sites. The land belonged to Mr. Frank Wilcox of Bismarck who very graciously gave the Historical Society permission to cut the trees and remove suitable cross sections from them for study.

One of these great oaks, both of which had diameters of three to four feet, had been long ago badly damaged by fire, which had caused serious distortion in the ring growth over a considerable period. However, the other one though the smaller of the two, presented a perfect picture of regular growth and gave the foundation for a definite tree ring chart. **(See cover page for cross section of the key specimen or master oak).**

Since the acquisition of this key specimen a number of other satisfactory cross sections of cedars and oaks from different parts of the state have been acquired and it is hoped that additional specimens will continue to come in. Though not of particular value archaeologically they are of definite value in meteorological studies.

After the key cross section was taken to the laboratory it was carefully smoothed and dressed in such a way that the rings showed to best advantage. It was then found that the rings, some three hundred and seventy-three in all, were in many cases so small as to be almost indistinguishable. Recourse was had to a good reading glass which was supplemented by a jeweler's glass which left both hands free in marking and counting rings. As the study continued it became evident that no actual definite measurements of the rings could give an undistorted picture of the comparative rainfall at different periods in the tree's growth. This was due to the fact that as the trees grew older the rings grew narrower

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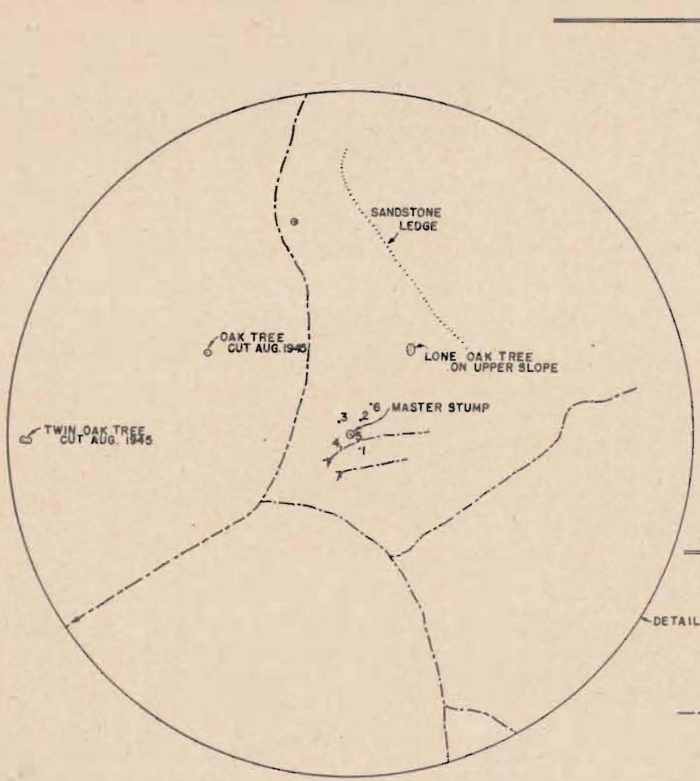
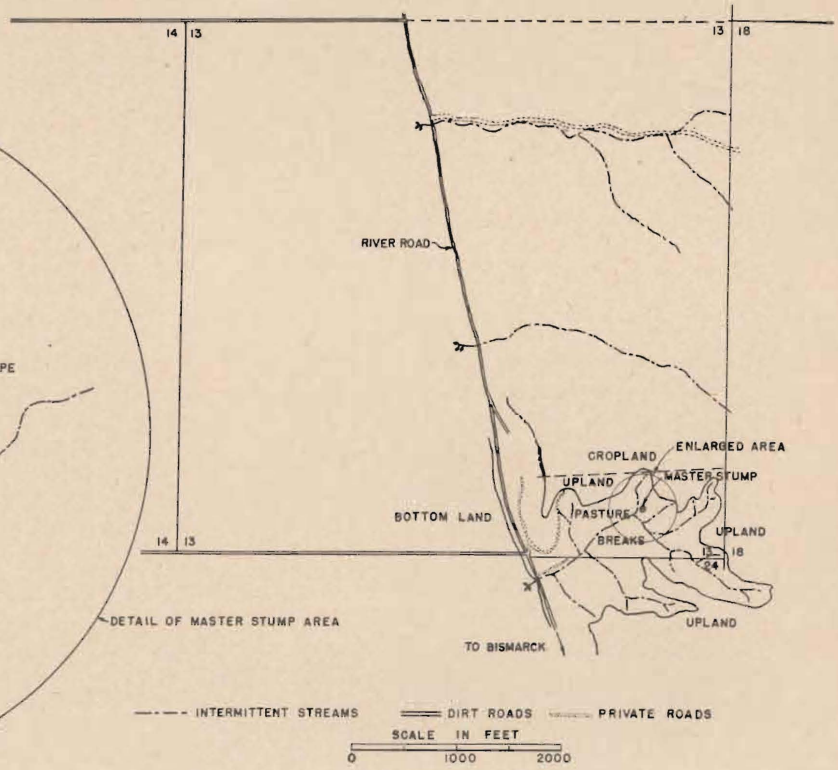

SANDSTONE LEDGE
OAK TREE CUT AUG. 1940
LONE OAK TREE ON UPPER SLOPE
TWIN OAK TREE CUT AUG. 1945
MASTER STUMP
DETAIL OF MASTER STUMP AREA


14 13
13 18
RIVER ROAD
CROPLAND
ENLARGED AREA
UPLAND
MASTER STUMP
BOTTOM LAND
PASTURE
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14 13
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UPLAND
TO BISMARCK
INTERMITTENT STREAMS
DIRT ROADS
PRIVATE ROADS
SCALE IN FEET
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Figure 1 shows the location of the "master stump" or master oak, position 5, in a coulee above the river road some six miles northwest of Bismarck, North Dakota. Mr. Lloyd Shoesmith, Soil Surveyor for the Soil Conservation Service made a thorough examination of the soils in the area describing them as follows:

Location 1. "Very fine sandy loam to a depth of 7 feet."

Location 2. "Very fine sandy loam to a depth of six feet, numerous sandstone fragments between 5 and 6 feet. Dark colored silt loam 6 to 7 feet. This dark layer is probably a dark colored layer of the Fort Union Formation. Small holes indicate that roots have grown in this layer."

Location 3. "Profile same as for location 1."

Location 4. "Profile same as for location 1."

Location 5. (One foot south of the master oak stump) "Very fine sandy loam to 40 inches, dark colored silt loam from 40 to 84 inches. This appears to be a buried soil, however it may be the same layer the Fort Union Formation noted in Location 2."

Location 6. "Very fine sandy loam to 7 feet, very stony 5 to 7 feet, dark colored silt loam 7 to 9 feet. This appears to be a layer in the Fort Union Formation. All of the material above this dark layer has been transported to this site since the deposition of the Fort Union Formation."

The slope between the "lone oak tree on upper slope" and the master oak stump is about 35%. The soils on this slope have developed in colluvium from the slope above the lone oak. This colluvium consists of sandstone fragments with a small amount of glacial debris. The soils in the vicinity of the master oak stump indicate that loessial material blown from the Missouri River flood plain has contributed to the soil material as the colluvium was deposited."

Exact Location of Master Burr Oak Stump

The stump is located 500 feet north and 800 feet west of the southeast corner of section 13 T 138 N, R 81 W. The map shows section 13—the circle at the left is an enlarged view of the circle around the master oak stump. The master oak was sixteen and three-fourths inches in cross section. The tree was cut in 1940 and has 373 growth rings. During the month of August two living smaller oak trees, both about 6 inches in diameter, were cut on the slope to the north of the main coulee—their locations are indicated in the large circle in Figure 1. Peculiarly one of them was only about 50 years old whereas the other was approximately 120 years old. There seemed to be little difference in their respective locations except that the younger one was in a slight pocket while the older was not. The latter had the most microscopic ring of any tree upon which the author has tried counting rings. The two agree fairly well except that there were more dry years in the older of the two. It was impossible to determine much about the possibility of the outside rings being wider since, of course, the last six or eight years have been naturally producing wider rings. On the older of the two the last five were wider and in the younger, the last six.

For the sake of comparison the occurrence of dry, wet and average years was plotted on cross-section paper for these two small trees alongside of similar plotting of the weather bureau record mentioned in this bulletin, the author's master chart or plotting of the master oak and cross-sections from earlier trees from "digs", the larger of the two larger oaks, and a plotting of the master oak by Gladwin of **Gila Pueblo Tree Ring Laboratory, Santa Barbara, Calif.** All six were found to be in agreement in about 40 years out of 110 years compared and all six were in complete agreement in all but one case in 42 other years. This makes a total of slightly more than 80 years of reasonable agreement among the six charts used.

The Gladwin chart (not reproduced in this bulletin) was made from a cross-section of the master-oak. It is in general agreement except for the last ten years, nor do any of the other five charts mentioned in the foregoing agree in the last ten or twelve years. It should be pointed out that the master oak was cut in 1940. Further study of the interpretation of the Gladwin chart is needed in order to obtain closer correlation with the techniques used by the author.

(Continued from Page 5)

though preserving still the very definite variation from year to year. Hence the best solution seemed to be to consider each ring in comparison with its neighbors. Thus the reading of the rings is largely a matter of judgment rather than actual measurements. For that reason a large number of different readings and transcriptions were made, along with various co-ordinations between several of the transcriptions. Still there seemed to be too much variation. The handling of the blocks of wood was cumbersome, marking was difficult and the number of rings present never seemed to exactly agree in the different transcriptions. This led to the search for some better method of handling the problem. It occurred to some of the Historical Society staff members that a somewhat enlarged photostat could be made with the fine machine belonging to the State Highway Department. The experiment was made and turned out unexpectedly satisfactory. The rings stood out much more clearly and it was found that transcriptions repeatedly made were practically in agreement, even though a considerable number were made. There were still variations to a slight degree due to differences in judgment at different times but these were eaily straightened out by co-ordinating a number of the transcriptions.

Figure 2.—View of a portion of the center of the master oak, or stump whose location is shown in Figure 1.

So at last there evolved a reasonably accurate tree ring chart for a period of three hundred and seventy-three years. The ring to ring transcriptions were still too closely spaced to read accurately without considerable difficulty and recourse was now had to the Douglass system with some variations. By this method the rings are transferred to a long, narrow slip of coordinate paper. From a mid line in the center of the strip, lines are drawn, one to each square of the paper, perpendicular to the mid line, above the line for dry years, below for wet years, with a dot to represent an average year and a square given to each year. This method produced an easily read chart and laid the foundation for further progress.

The next step was the study of the many post remnants and cross sections that had been gathered. These were carefully and repeatedly transcribed also. Owing to their age some of the fragments yielded rather imperfect charts, but all of them proved complete enough to establish co-ordination with the main chart. Furthermore as has been mentioned the material came from rather a wide area and there was some variation due to local precipitation variations. These proved, however, not to show serious diversion from the definite periods of wet and dry years into which the whole period seemed to divide.

Sections from cedar trees from the Badlands, an oak from western North Dakota and a huge oak from Stump Lake in Nelson County were also studied and charted. There were definite variations showing a greater number of wet years in the Stump Lake oak and a considerably smaller number in the cedars. Nevertheless co-ordination proved to be still not too difficult. Many of the average years in the master chart appeared in the Stump Lake oak as wet years and in the cedars as dry years but the general period patterns persisted to an identifiable extent with all of them.

Mention has already been made of the publication "Crop Yields and Weather". In order to test the validity of the master chart a chart was worked out from the rainfall data given year by year in that publication, on co-ordinate paper in exactly the same way that the ring charts had been made. Fortunately the master chart ended in 1940 and the published data extended from 1886 to 1941. Thus the two gave us two parallel charts for some fifty-four years. The published data, however, covered the averages for the state as a whole. Nevertheless the two charts corresponded in nearly seventy-five per cent of the years and the alternating periods of moisture and drought agreed almost perfectly. This comparison seems to be very definite proof of the validity of rainfall history as shown by our tree ring record. If the correspondence is so fully in agreement for a period of fifty-four years, in spite of the difference in the area covered, it would seem perfectly safe to assume that the rest of the master chart is equally valid.

After the many posts and fragments had been properly charted the task of comparison with the master chart came next. Material from the most recent of the old sites was first compared with the master chart. This material came from the Ft. Lincoln Mandan site which according to the information

given to Lewis & Clark was abandoned and immediately burned by the Sioux about 1760. The various pieces from each of the different sites were first compared with each other. This required careful study. Most prominent groups of rings, either wet or dry were located in each chart, they were then placed side by side and the less clear agreements were traced until the charts could be arranged side by side in the correct order of cutting. The cutting date was considered to be the date of the last ring when growth had ceased. It must be borne in mind that this study does not deal with a desert region but with one in which, although there are years of extreme drought interspersed with wet years, yet no year is so completely deficient as to stop growth and kill the trees. In the above mentioned publication it is noteworthy that even in the driest years no absolutely complete crop failure is recorded. As a matter of fact it is pretty well proven by the debris from even the oldest village sites that throughout their life in the region the Mandans raised crops of corn, beans, squashes, etc., and derived a very large part of their subsistence from them. They gradually adapted the crops that they grew to the somewhat severe conditions of the region and on the arrival of the white men turned over to them a number of acclimated varieties of all their crops. This heritage has been of inestimable value in the white settlement of the region and continues to be so today.

After the youngest site had been definitely linked up with the master chart and pretty well dated, came the problem of the still older sites. It was soon found that the fragments from some of them coordinated with rings found in the earlier periods of growth in some of the larger fragments from the Ft. Lincoln site. In turn it was found that pieces from still older sites matched up with the early portions of fragments from the site which showed earlier dates than Ft. Lincoln. By this method it was possible to carry the ring calendar considerably farther back than the earliest date of the master chart. In this way, from the oldest fragments that were on hand the ring calendar was completed back to the year 1406, that being the sprouting date of the oldest tree cut in the building of the oldest site from which material was available. Thus there is available a continuous record of precipitation over a period of five hundred and thirty six years. There is reasonable hope that usable material from sites of apparently still greater age than those studied, sites which from fairly good evidence are considerably older than any from which material is at present available, may be excavated as opportunity offers.

It should be emphasized that dates are not always exact although there seems little chance for variations in reading of more than four or five years. As has been pointed out, decay may have cut off a few rings on the outside of some fragments and poor condition of the wood in the interiors may occasionally obscure the readings. This latter possibility is, however, minimized since there are a number of fragments from each site which obviously must fall within a restricted period. In the case of unusual variation in the cutting dates of wood from the same site another fact should be taken into

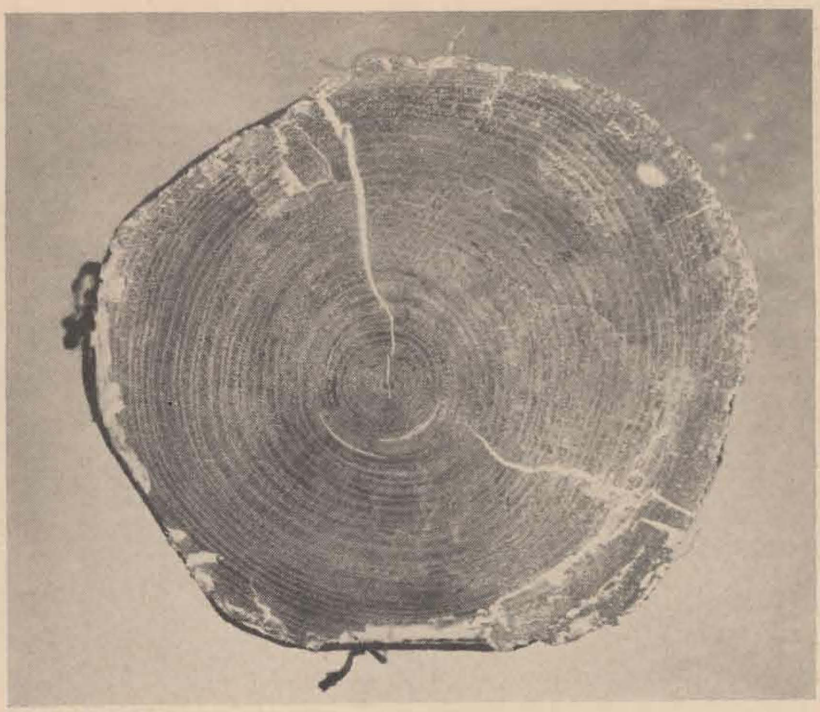

Figure 3.—Cross section of cedar log 7½ inches in diameter—Slant Village, Ft. Lincoln park, Columbia University dig. This tree was probably cut in 1666. The earliest date of cutting of some 12 timbers from this site is 1652 and the latest date 1738.

account. We have historical evidence that when a village was moved some of the better timbers in the old village were taken along and re-used when the new one was built. It is very probable that this habit prevailed at least occasionally in the older villages as it did in some of the later ones.

And now let us turn to a brief account of the villages from which timbers have been dated. Youngest, as has been mentioned, is the Ft. Lincoln or Slant Village Site. This Site forms a part of the Ft. Lincoln State Park which comprises besides the village site, the site of two U.S. Army Military Posts. It is located some five miles south of Mandan, N. D. Considerable excavating has been done at this site which shows evidence of long occupation. Debris of lodges, sometimes several built consecutively the one over the other, is found to a depth of twelve to fifteen feet. This site was, as stated above, abandoned about the year 1760. The Mandans suffered at that time from the first great smallpox scourge, in the midst of which the Sioux are said to have attacked the village, driven out the survivors and burned all the lodges. A layer of burned material just below the surface over nearly all of the old site seems to corroborate the story.

From this site were available some twelve remains of posts and

timbers consisting of four of oak and eight of cedar. It was found in studying the material that the oak and cedar co-ordinated satisfactorily and the cedar was better preserved and more easily read. It is an interesting fact that cedar occurs with considerable frequency in all these old sites. Today no cedar at all is found within a hundred miles of the region. Apparently it was so esteemed by the early inhabitants of the region that it has been entirely exterminated. In that connection it is to be noted that, while there was considerable cedar along the bluffs of the Cannon Ball river thirty years ago, today there is not a trace of that species.

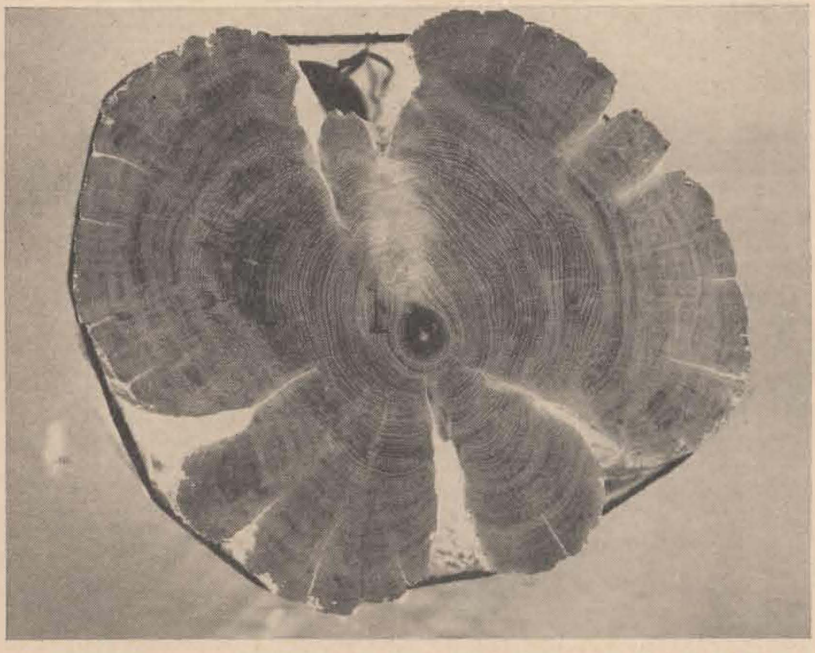

Figure 4.—Cross section of buried cedar log, 8 inches in diameter, from Slant Village, Ft. Lincoln park, Columbia University dig. This tree was probably cut in 1735, the latest date of any of the timber from the Slant Village site.

The pieces of wood have for convenience been numbered from one to twelve. The first piece seems to have been cut in 1738; the second piece, of Cedar, some 7½ inches in diameter seems to have been cut in 1666; the third piece of oak, 8 inches in diameter was cut in 1664; No. 4 was of cedar, 8 inches in diameter and was cut in 1670; No. 5, also cedar, and of about the same size, was cut in 1657; No. 6, of oak, was cut in 1652; No. 7, also oak, was cut in 1695; No. 8, well preserved cedar about 8½ inches in diameter, was cut in 1705; No. 9, cedar, 7½ inches in diameter, was cut in 1686; No. 10, an 8 inch in diameter cedar post, was cut in 1735, the latest date obtained from any of the timbers; No. 11, also of cedar, was cut in 1701; No. 12, cedar and 8 inch in diameter, was

cut in 1691. As bearing on the disappearance of the cedar in the vicinity, it is to be noted that all of the cedar posts were cut more than fifty years before the destruction of the village. There are in the site remains of many badly decayed cottonwood posts of much larger size than those of oak and cedar. The tougher and harder cedars and oaks, in smaller sizes, were equal in strength to considerably larger cottonwoods. It might be, from the facts stated above, that in the later years the cottonwood was the only remaining available material.

In the North Dakota Historical Quarterly, January-April number, Vol. XI, Nos. 1 and 2, there appears a classification of village sites along the Missouri in North Dakota and rough approximation of their relative age. In this attempt at relative dating the Sperry site is listed as of the same culture period but somewhat older than the Ft. Lincoln site. From the Sperry site there are available fairly well preserved remains of six timbers. They were dated by comparison first with the ring charts from the Ft. Lincoln timbers, and then with the master chart. Determination of cutting dates shows a slightly older average for the material from the Sperry site. The first timber from this site, the timbers being numbered Sperry one to six inclusive, was cut in 1655; No. 2 was cut in 1644; No. 3 in 1627; No. 4 was cut in 1639; No. 5 shows the oldest cutting date, 1626; No. 6 was cut in 1675, being the youngest in the list. Comparing these dates with those from the Ft. Lincoln site the average is seen to show a considerably older date. For Ft. Lincoln, the average of the dates is 1684. For the Sperry site, the average is 1644.

Next to be considered is the Larson site, also belonging to the latest or Heart River culture period, but giving evidence of having been abandoned somewhat earlier than either the Ft. Lincoln or the Sperry site. From this site the available material consists of pieces of six timbers. These are numbered Larson 1 to 6 inclusive. No. 1 was cut in 1641 and was of oak; No. 2, of oak, 4½ inches in diameter was cut in 1615; No. 3, 7½ inches in diameter was cut in 1618; No. 4, also of oak and about 7 inches in diameter was cut in 1635; No. 5 was cut in 1613, being the earliest cutting date; No. 6 was cut in 1637. The average date for the Larson site ring charts is 1626. The Sperry and Larson sites, both on the east side of the Missouri while the Ft. Lincoln site is on the west side, show a rather higher percentage of oak to cedar than does the Ft. Lincoln site.

Here it is well to pause and consider facts which have already been determined about the sites dealt with. All of the sites from which dates have been determined from a number of timbers are almost certainly Mandan. Mandan occupation has already been culturally divided into three periods. Sites of the earliest period, distinguished by lack of fortification and widely spaced, rectangular houses, have been classified as belonging to an archaic period. Following them come a large number of sites placed in a middle Mandan period. These sites average considerably larger and pottery artifacts show a definite advance in design and manufacture. The houses are still widely spaced, but

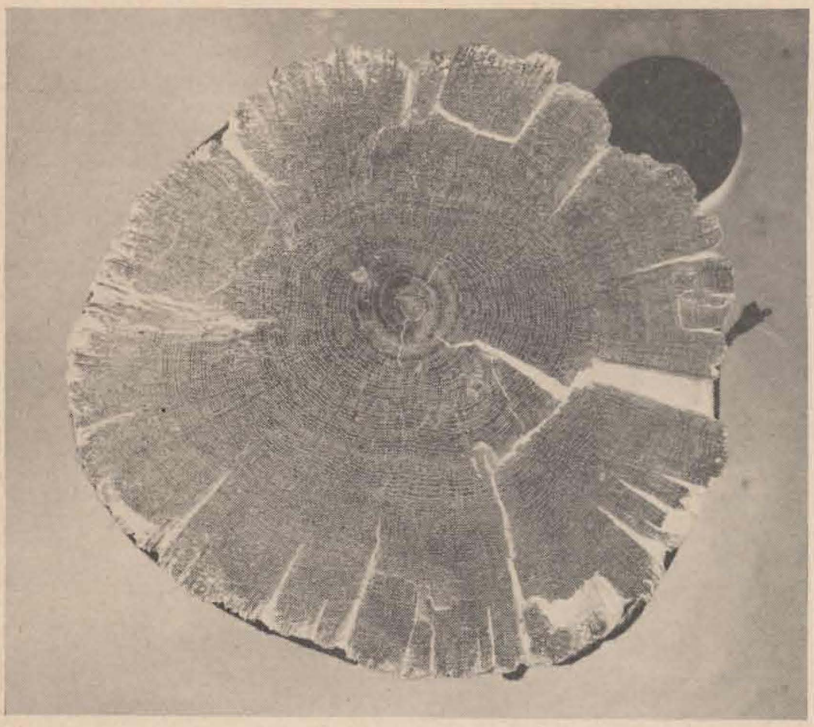

Figure 5.—Cross section of buried oak log, 7½ inches in diameter, Larson site—log was part of Lodge post. This tree was probably cut in 1618. The average date of cutting of 6 timbers from the Larson site is 1626.

a new feature is introduced, the fortifying by means of a wall, ditch and bastions of the village area. These fortifications vary from very crude in the earliest middle period site to a highly elaborate and perfected system such as is found at the Huff site. This fact leads to the placing of that site as towards the end of the middle period.

Between the two periods there is evidence of several transitional sites, material from one of which, is considered in this paper.

The last period which ended in the practical dissolution of Mandan culture is termed the Late Heart River Period. To this period belong the three sites already mentioned above. The distinguishing marks for the sites of this period are a much closer crowding of houses in relatively smaller areas, the use of a round earth lodge instead of a rectangular one, and a very noteworthy advance and unification of type and method in pottery manufacture. As has been said, this period ended about 1760. Later sites further north show a very definite cultural decay.

The next site from which material is available apparently belongs to the transitional period between the middle and Heart River. This site, known as the Ward site is also on the east side of the Missouri some six miles below the Sperry site and five miles above

the west side Ft. Lincoln site. It has been assigned to the transitional period since the lodges seem to have been modified rectangular, shading in some cases into round.

Six timbers are included in the collection from the Ward site. These are numbered Ward 1 to 6. No. 1 was cut in 1551 and is of oak, 6 inches in diameter; No. 2 was cut in 1563; No. 3 was cut in 1527; No. 4 of oak, 6 inches in diameter was cut in 1536; No. 5, of cedar with a double center, was apparently cut in 1558; No. 6 was cut in 1551. The average cutting date for the timbers at the Ward site is 1547. There is a notable time gap between the cutting dates of the Ward site timbers and all those from the late Heart River sites. There are, however, other sites which from all available evidence fit in between, and from which material will doubtless be obtained in due time.

The fifth site from which a number of timber sections are available is the Huff site. This very definitely belongs to the Middle period in its latest years. It is a very large site, in its natural state and protected as a State Park by the North Dakota Historical Society. It lies along the edge of a very high terrace with a cut bank, near the village of Huff,

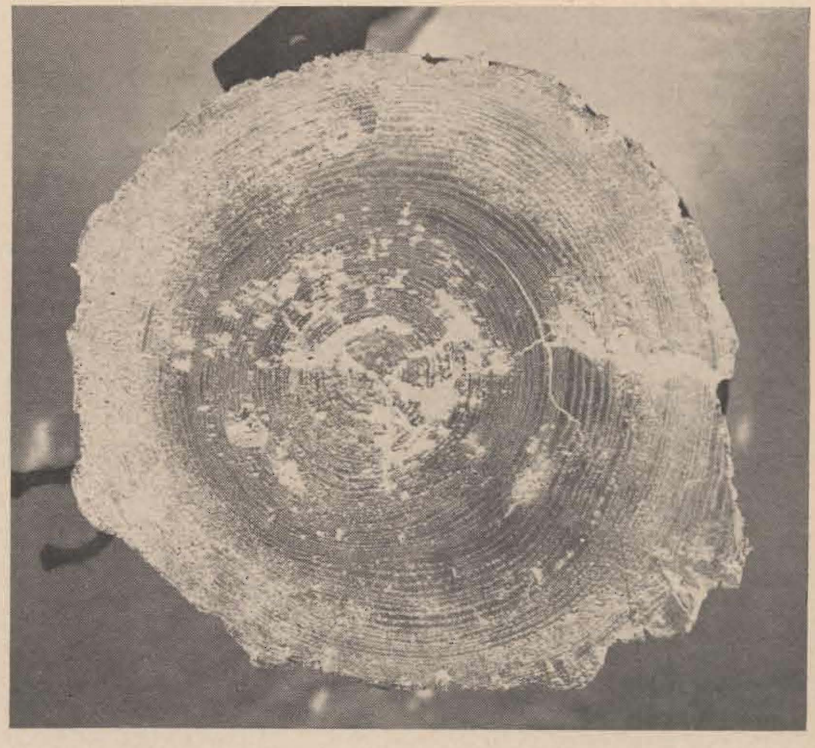

Figure 6.—Cross section of buried oak log, 6 inches in diameter. From Huff Indian village—Heeker dig. This tree was cut in 1518. The average date of cutting of 11 timbers from the Huff site is 1517.

N.D., some thirteen miles south of the Ft. Lincoln site. Here is found the most elaborate and perfected fortification among all the sites. The houses were all definitely rectangular and spaced widely apart.

From the Huff site there are sections from some eleven different timbers. These are numbered Huff 1 to 11 inclusive. Most of them are of oak, which still grows in considerable abundance in the high hills south of the site. No. 1 was cut in 1509; No. 2 was cut in 1543; No. 3 was cut in 1524; No. 4 was cut in 1515; No. 5, a 6 inch oak, was cut in 1518; No. 6, also of oak, was cut in 1526; No. 7 was cut in 1542; No. 8, another 6 inch diameter oak, was cut in 1505; No. 9, a 4½ inch oak, was cut in 1513; No. 10, another 4½ inch oak, gives the earliest cutting date from this site, 1485; No. 11, was cut in 1514. The average cutting date for the Huff site is 1517. The oldest date is 1485, the youngest 1543. Thus it would appear that building started at the Huff site some 455 years ago from timber which started to grow as early as five hundred and forty years ago.

It would appear that Mandan people occupied the area at a much earlier date than had previously been supposed. It is to be hoped that timbers from some of the earlier Middle period sites and the Archaic sites may in time be found. Meantime we have the story of a successful occupation of this area along the Missouri by an agricultural population for a period **many times longer than that of our own white race.**

Perhaps it is worth while to include here datings worked out for miscellaneous timbers which have been collected from various sources. Included in this category is a section from a large oak stump from the somewhat mysterious Stump Lake. These stumps were visible around the shores and beneath the surface of the lake ever since the first settlers visited the region and many suppositions are current as to their age and the reason for their presence. With a considerable recession of the lake during the recent series of dry years some of them emerged from the water and made possible the securing of a specimen from a submerged trunk. With only the single specimen and the normal differences in climate beween the region where the master oak grew and the east central part of the state, it is impossible to get very close agreement. However, careful comparison seems to make it very probable that the Stump Lake Oak ceased to grow for some reason in 1541.

Another single section comes from the Eagle's Nose Mandan Village on the top of a high promontory about a mile west of Huff. Artifacts from this site seem to show some decadence and would indicate that the site was briefly occupied after the general withdrawal of most of the Mandans farther north. The agreement with the master chart here is far from perfect but the long wet period from 1786 to 1802 is clearly distinguishable and the latest date on the timber is 1810 or a year or so later.

From a briefly occupied site far up the Little Missouri river near the mouth of Cherry Creek, the collection contains parts of two small cedar posts. These match with each other and agree closely

with the master chart. They show cutting dates of 1814 for the larger and 1811 for the smaller. This site is traditionally Hidatsa.

From the old village site of the Cheyenne Indians on the Sheyenne River about fifteen miles east of Lisbon, N.D., there is one small section of timber. The small size and the considerable climatic difference between the two sections renders positive dating uncertain. There is, however, sufficient agreement to give the date of cutting as very probably 1720.

From the Ft. Clark village site, occupied up to 1838 by the Mandans and later by the Arikara comes one very fine and clear section of a large post. The wood is not definitely identified but seems to resemble Hackberry. The rings from this post agree very closely with those of the master chart and show a cutting date of 1838.

From the top of a high hill a short distance below Mandan in a briefly occupied site known as the Rippel site there is a single post section which shows a date of 1814.

There is a large section from a rather recently cut cedar post sent in from the Bad Lands section of western North Dakota. Coming from the drier section of the state there is in this case, also, considerable variation from the master chart. There is, however, agreement in the longer periods of dry and wet weather which points to the year 1930 as near the cutting date. The age is one hundred and twenty six years.

A section from a large oak stump comes from near Richardton in western North Dakota with the information that it was cut many years ago but at an unknown date. Comparison with the master chart shows the usual variation due to increased dryness in the western area, but shows pretty clearly a cutting date of 1906.

Last is a section from a very large charred oak stump from a coulee some four miles north of Bismarck. The stump has stood on the banks of the coulee since before the first settlement and the wood is in remarkably fine condition. The rings are larger than those in the master oak, and very clear. The cutting date or more probably the date when the tree was girdled by fire is 1863.

This completes dating of the material at present available. It is to be hoped that many more specimens will be gradually acquired.

The dates as read give us some rather surprising information as to the long time settled occupancy of the Missouri Valley in North Dakota by members of the Indian race. It should be noted that the oldest timber from the Huff village shows that Mandan Indians were engaged in cutting timbers and building villages at least four hundred and fifty five years ago. It is, also, of interest to note that definite dates agree rather closely with estimated dates given in the Historical Society Quarterly previously mentioned. It would seem probable that material from the very large number of sites very evidently older than the one at Huff, when available, will carry the occupancy of the region by the Mandan people very nearly two hundred years farther back to a date probably between 1200 and 1300.

Material from a hundred or more other sites should be collect-

ed as soon as possible before it further deteriorates. It is obvious that only a start has been made in tree ring study. However, the basic master chart is complete for five hundred and forty years. Its working out and construction was a slow, laborious, time consuming piece of work which need not be done again. Consequently results from additional material acquired will be much quicker to compare and assign to their proper dates.

The history obtained from the tree rings seems to carry considerable comfort to the present inhabitants of the region. If human beings have found the area well enough suited for some seven hundred years to be a home from which there was no high incentive to move in search of better surroundings, and since there has obviously been no change in rainfall conditions for a period of some five hundred and forty years, the present dwellers in the region may well look forward to centuries of continued occupancy of the region by a reasonably prosperous population. And further as the residents become more familiar with the region and its conditions the task of so regulating their activities as to better co-ordinate with climatic conditions should serve to definitely increase their prosperity.

PART II: TREE RINGS AND PRECIPITATION RECORDS

NO SUBJECT of discussion is so common or excites more general interest than that of the weather. It is a topic of outstanding human interest which has engaged the attention of man and offered him food for speculation since primitive man found shelter from rain and snow to be one of the basic essentials of life. In this region of the Northern Plains where agriculture is the basic industry the presence or absence of moisture means success or failure for the population. As a result there are heard dozens of theories to account for the fact that some years are wet and others dry. There is much talk of cycles, sunspots and various other matters including the effect of radio, or of the firing of great quantities of explosives in war zones.

Of established data on precipitation, however, there is a great lack. The U.S. Weather Bureau supplies us with information for part of the Great Plains for only about seventy-five years. Old diaries and journals and Indian Winter counts give scraps of information here and there which are too scattered to prove of much value.

Some of the more pessimistic residents whose memory is rather fresher for drought than for wet years, have advanced the theory that the area is gradually becoming drier and drier. They have pointed to the recent dry years with their dust storms and withering vegetation as definite proof.

But with all the speculating and theorizing, there has been no definite knowledge of Northern Great Plains weather for more than the seventy-five years of record. In the Southwest it has been demonstrated that tree rings give a definite story of wet and dry years. Such information has revealed much in the history of the aboriginal inhabitants of the region that had previously been a complete mystery. Mention has already been made of the correspondence between the tree rings and the actual Weather Bureau records for a period of some fifty-four years. In spite of the fact that the official records are averaged for the whole state whereas the tree ring record is for a local area only, the correspondence is very close, forty-one of the fifty-four years being in agreement. This is in spite of the fact that local showers often occur in very small areas and that the rainfall in a given year may vary considerably between areas only a few miles apart. Consequently it seems reasonable to assume that the alternate periods of rainfall or drought as reflected in the tree rings of the master oak are reasonably valid for a very considerable area. In considering the facts to be given, therefore, it must be remembered always that the data comes from one small area and that there will be minor variations in certain years in spite of the general agreement for an area as large as the state of North Dakota. It should be remembered, also, that the records of tree ring growth will naturally be smoother, with less variation from year to year, than the actual rainfall records, since effects of a wet year may carry over to some extent into a succeeding dry year.

With the above statement noted, we come to a consideration of the precipitation record as read from

a tree ring chart of some five hundred and forty years, from the year 1406 to 1940 inclusive. In considering the tree ring records, no attempt is made to read any seasonal records, as the rings of the master oak are too minute to permit an accurate differentiation. It should nevertheless be noted that there is a differentiation between spring and summer growth. The light colored, somewhat porous appearing portion of the ring represents the spring growth which is produced by rains of the previous fall and winter precipitation. The dark portion of the ring, rather more compact in appearance marks the summer growth produced by the rains of May and June largely. The summer growth is terminated by a distinct dividing line easily seen, the lighter wood of the next Spring's growth lying immediately beside it. Thus each yearly ring is a combination of light and dark wood. The proportion of each will vary from year to year with the seasonal distribution of precipitation.

As the long chart is studied it becomes perfectly clear that years of drought and moisture seem to run in series, sometimes separated by from one to several years of average rainfall. In order to better read the record still another method of arrangement has been brought into use. This method is to make a continuous line graph following the yearly lines above and below the median and continuing along the median for average years. This method gives a much better visual picture of the precipitation variations. The successive wet and dry periods are placed in much better perspective.

As one looks over the graph it appears impossible to work out any definite pattern as to the number of years in succeeding series. That number varies greatly from one year to a maximum of thirty-nine wet years and twenty dry years. At certain points in the graph there are very short successions of one to three wet years followed by an equally small number of dry years. This is especially notable in the years from 1752 to 1784. For the most part, however, the periods are considerably longer, most of them of not less than five years.

Below is given a chronological list of the alternate periods. Further facts with regard to the data will be presented farther on.

The first period of nine years—1406 to 1415 was dry. From 1415 to 1433 there were eighteen wet years. The two years 1434 and 1435 were dry, followed by two wet years. The fourteen years from 1438 to 1452 were dry. Following came a wet period from 1452 to 1471—nineteen years. The fourteen years from 1471 to 1485 were dry. Then came three wet years. From 1488 to 1501 there were thirteen dry years. These were followed by four wet years. Then from 1505 to 1518 there were thirteen dry years. The seven years from 1518 to 1525 were wet. The six years from 1525 to 1531 were dry. Eight years from 1531 to 1539 were wet. Following were four dry years, then three wet. There were six dry years from 1547 to 1553. The nine years from 1553 to 1562 were wet. Then came a longer dry period of fourteen years from 1562 to 1576. The following wet period was one of the longest in the record—twenty years, from 1576 to 1596. This was followed, 1596 to 1611, by

fifteen dry years. Then came twelve wet years, from 1611 to 1623. Then came two dry years, followed by one wet year, and then one dry year and two average years. The next four years were wet. The sixteen years from 1633 to 1649 were dry, this being one of the longest dry periods. They were followed by five wet years from 1649 to 1654. From 1654 to 1663 there were nine dry years. Then came by far the longest wet period in the record. There were thirty-nine years of high rainfall from 1663 to 1702. One dry year followed, then again three wet years. The thirteen years, 1707 to 1720 were dry. Then came three wet years followed by four average ones. From 1728 to 1735 there were seven dry years; three wet years followed. Then there were two dry years, one of them extremely dry. From 1739 to 1744 there were five wet years. The eight years from 1744 to 1752 were dry. The years from 1752 to 1786 varied almost from year to year and totaled ten wet years and nine dry years and four average years. The sixteen years from 1786 to 1802 were extremely wet—perhaps the wettest of the whole period. Again the years from 1802 to 1831 varied from year to year with many of average rainfall. There were seven wet and seven dry years in the series. The six years from 1830 to 1836 were wet. They were followed by fifteen dry years from 1836 to 1851. The twelve years from 1851 to 1863 were wet. They were followed by three average years, then came two wet years, and again two average ones. From 1870 to 1876 there were six wet years. From 1877 to 1891 there were fourteen dry years, followed by two wet. The six years from 1894 to 1900 were dry. Then came two wet years, succeeded by three dry, the years 1906 to 1909 being average. From 1910 to 1920 there were ten wet years. This was followed by one average and fifteen very dry years from 1922 to 1937. The next three years in this immediate locality were moderately wet.

Perhaps a statistical arrangement of these wet and dry periods will give a more easily read record. An attempt to make such an arrangement is given below: (This arrangement is not in exact accord with the preceding paragraph because this tabulation omits the "average" years mentioned in that paragraph.)

1406-15	1415-33	1434-35	1436-37	1438-52	1452-71	1471-85	1485-88
Dry yrs.	Wet yrs.	Dry yrs.	Wet yrs.	Dry yrs.	Wet yrs.	Dry yrs.	Wet yrs.
9	18	2	2	14	19	14	3

1488-1501	1501-05	1505-18	1518-25	1525-31	1531-39	1539-43	1543-47
Dry yrs.	Wet yrs.	Dry yrs.	Wet yrs.	Dry yrs.	Wet yrs.	Dry yrs.	Wet yrs.
13	4	13	7	6	8	4	3

1547-53	1553-62	1562-76	1576-96	1596-1611	1611-23	1623-25	1626	1627
Dry yrs.	Wet yrs.	Dry yrs.	Wet yrs.	Dry yrs.	Wet yrs.	Dry yrs.	Wet yrs.	Dry yrs.
6	9	14	20	15	12	2	1	1

1627-31	1633-49	1649-54	1654-63	1663-1702	1703	1703-06	1707-20	1720-23
Wet yrs.	Dry yrs.	Wet yrs.	Dry yrs.	Wet yrs.	Dry yrs.	Wet yrs.	Dry yrs.	Wet yrs.
4	16	5	9	39	1	3	13	3

1728-35	1735-38	1738-40	1740-44	1744-52	1752-86	1786-1802	1802-30
Dry yrs.	Wet yrs.	Dry yrs.	Wet yrs.	Dry yrs.	Wet yrs.	Wet yrs.	Wet yrs.
7	3	2	4	8	10	16	7
					Dry yrs.		Dry yrs.
					9		7

1830-36	1836-51	1851-63	1865-67	1870-76	1877-91	1891-93	1894-1900
Wet yrs.	Dry yrs.	Wet yrs.	Wet yrs.	Wet yrs.	Dry yrs.	Wet yrs.	Dry yrs.
6	15	12	2	6	14	2	6

1900-02	1902-05	1910-20	1922-37	1937-40
Wet yrs.	Dry yrs.	Wet yrs.	Dry yrs.	Wet yrs.
2	3	10	15	3

Although the number of dry periods over seven years long is four greater than the number of wet, the longest periods are wet ones. There is one wet period of thirty-nine years, one of twenty years and one of eighteen and one of nineteen years. The longest dry period is of sixteen years but there are seven dry periods of thirteen to sixteen years inclusive and only one wet one. This does not give the complete picture as there are dry and wet periods both interrupted by periods of the opposite kind lasting only one to four years. For instance the period from 1471 to 1501, shows a total of twenty-seven dry years interrupted at the mid-period by only three wet years. Also the period from 1877 to 1900 contains twenty dry years and only three wet ones. On the other hand from 1786 to 1836 there are twenty-nine wet years to seven dry ones, and from 1416 to 1438 there are twenty wet to two dry years.

When we come to the shorter periods, however, the wet ones are considerably in the majority. In the periods under seven years in length there are sixteen wet periods and only ten dry with a total in years of fifty-four wet years and thirty-three dry. Altogether of long and short periods there are twenty-nine wet to twenty-seven dry. The average length of the periods is 8.8 years for the dry and 8.3 years for the wet. In evaluating these figures it is well to bear in mind that the years classed as medium or average, according to figures given in "Crop Yields and Weather" were years in which an average crop of wheat and corn was produced. This would mean that there were a total of three hundred and two years out of five hundred and thirty four which would have produced an average or better crop and only two hundred and thirty eight years that might have produced less than an average crop.

It is of interest to briefly review some of the above figures with reference to longer periods. So far as has yet been determined there are in the series no outstanding repetitions over long periods. Let us, therefore, adopt an arbitrary period of approximately one hundred years and look at the results. In the period from 1406 to 1611 there were seventeen more dry years than wet, dividing this we find fifty-one dry to forty-two wet years from 1406 to 1501 and from 1501 to 1611 fifty-eight dry to fifty-one wet. In the next two hundred years we have 1611 to 1802 with some thirty-one more

wet years than dry, divided we get from 1611 to 1707 some sixty-one wet to twenty-eight dry, and from 1707 to 1802 there are forty wet to forty-two dry. From 1802 to 1940 there are seven more wet than dry years but from 1900 to 1940 there are six more dry than wet. Carrying the estimate from 1940 to 2000 to balance with previous periods, the maximum probable dry years would be thirty-four to twenty-eight wet years.

After reviewing these figures there seems to be little in the way of general rules to be deduced. Long dry periods may be followed by long wet periods or by short ones and the reverse seems to be true. The mere fact that there has been a long series of dry years seems to have no influence on succeeding years and it may or may not be followed by long wet periods. Over the longer number of years there seems to be a slight preponderance of wet over dry years in this part of the State with a slightly larger proportion of wet years in the eastern part of the State and a larger number of dry years in the western part though the series in all areas seem to follow the same pattern.

In Dr. Weakly's paper on western Nebraska tree ring records, there appears a considerable preponderance of dry over wet years, just the opposite of findings in North Dakota. Furthermore a comparison of the time occurrence of the different periods seems to show that there has been little agreement between the two areas. Nevertheless Dr. Weakly's words in summing up are as valid for this area as for the one with which he deals. He says: "In short, there have always been frequent dry years or short periods of dry years which have been of relatively minor importance to the country, and there have been the less frequent, protracted droughts which have profoundly affected the country and its inhabitants. It is probable that during some of the protracted droughts of the past the country approached an absolute desert in character—hence the deterioration of native grass cover and the dust storms of the past few years do not indicate a permanent change in climate for this section, but more probably a recurrence of conditions that have prevailed before."

Checking into the recurrence of the periods of the same length in each category there is obtained the following table:

Length of period	Wet periods	Dry periods
39 years	1	..
20 years	1	..
19 years	1	..
18 years	1	..
16 years	1	1
15 years	..	3
14 years	..	3
13 years	..	4
12 years	2	..
10 years	2	..
9 years	1	3
8 years	1	2
7 years	2	1
6 years	2	3
5 years	2	0
4 years	2	1
3 years	5	1
2 years	4	3
1 year	1	2

There are recorded a total of two hundred and forty-one wet years and two hundred and thirty-eight dry years. There are, however, only thirteen wet periods lasting seven years or longer while there

are seventeen dry periods of seven years or more. There remains to make up the approximately 55 years classed as average. Since years shown as average in our master chart agree well with the average years as shown in the official Weather Bureau records it may be considered that they would agree generally throughout the record.

In this connection it may be noted that the drought period of 1922 to 1937 is one of the four longest in the five hundred and thirty four years of the tree ring record.

Continued study of tree rings from timbers taken in different parts of the region will serve to steadily increase our long time knowledge of conditions in the various sections. Further study of the data given above may serve in time to give determinations of relationship between wet and dry periods and to discover some rhythm in their recurrence which is not so far apparent.

The data given would seem to have some bearing on the much discussed problem of irrigation. It seems to show that more than half of the years are wet enough to discourage attempts at irrigation. In other words, the region is marginal as far as irrigation is concerned. Previous experience has shown that as a dry period fades out, interest in irrigation fades with it. Conditions are decidedly different from those in the more arid territory further west where irrigation is practically an annual necessity. Therefore, it would seem that, though irrigation would have great definite value to the area, it must be based on a system which will not carry a high overhead in favorable years, and the elements of which may be kept in a sort of dormant state, to be brought into use again as the dry periods return after the wet ones.

Some Principles for Irrigation Practice in North Dakota

A STATEMENT BY H. L. WALSTER, DIRECTOR

Mr. Will's contribution to the history of North Dakota's climate establishes the fact that its recent variability has occurred many times in the past centuries. It further establishes that relatively wet and relatively dry periods have not occurred according to any cyclic or rhythmic pattern. Whether or not irrigation systems can be so designed and operated so as to permit periods of dis-use is open to question; the alternative would appear to be the finding of ways and means for the most economic supplemental use of water so that the irrigation works could be used to advantage practically every year.

The development of a successful irrigation economy in the area will primarily depend upon the selection of land suitable for irrigation; a dependable supply of water suitable for use in irrigation, and provided at a reasonable cost; the correct use of that water when needed; the choice and development of cash crops, feed crops, and land use practices most likely to respond favorably to supplemental water; accessibility to a profitable market for the products of the soil; and protection from unfair competition in that market. When these principles are fully recognized and followed irrigation will find its proper place in both the "wet" and the "dry" years which lie ahead.