University of Texas Bulletin

No. 2327: July 15, 1923

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BY

E. H. SELLARDS, B. C. THARP AND R. T. HILL

Bureau of Economic Geology and Technology
Division of Economic Geology

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The benefits of education and of useful knowledge, generally diffused through a community, are essential to the preservation of a free government.

Sam Houston.

Cultivated mind is the guardian genius of democracy. . . It is the only dictator that freemen acknowledge and the only security that freemen desire.

Mirabeau B. Lamar.

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Land classification map of Gilbert Creek Valley.

INVESTIGATIONS ON THE RED RIVER MADE IN CONNECTION WITH THE OKLAHOMA-TEXAS BOUNDARY SUIT[1]

By

E. H. SELLARDS, B. C. THARP, and R. T. HILL

INTRODUCTION

BY E. H. SELLARDS

The investigations which form the basis of the following papers were occasioned by the necessity of obtaining scientific evidence in connection with the Oklahoma-Texas Boundary Suit, and were made during the summer and fall of 1921. They were undertaken at the request of the Attorney General of Texas and were carried on jointly under the direction of that department and the State Reclamation Department of Texas. These investigations were made in an effort to solve some of the problems that were at issue in the boundary suit particularly as to the age of the alluvial lands of the river valley, and the habits of the river in building the valley lands.

The Boundary Suit

The boundary suit brought to establish the line between the states of Texas and Oklahoma was of more than ordinary interest by reason of the large property values involved, the considerable cost of the litigation, and the extent to which scientific investigations were utilized. The value of the property, particularly the small part of it known to be oil bearing, can be estimated only in millions of dollars. The testimony in this case as submitted to the Supreme Court, exclusive of the attorneys' briefs, and arguments, amounted to more than five thousand printed pages. This testimony was accompanied by about five

* Manuscript submitted June 20, 1923; published August, 1923.

hundred photographs and more than one hundred original maps and charts, prepared especially for this case. The cost of printing the testimony exclusive of maps and engravings was in excess of twenty-five thousand dollars. The total cost to the litigants probably exceeded one-half million dollars.

In its historic setting this case dates back to a treaty between this country and Spain made by John Quincy Adams in 1819, confirmed in 1821, which was intended to define the boundary line between the territory of the United States and Spain. A part of this boundary line is defined as following the course of the Red River (Rio Roxo of Natchitoches) from a point due north of the place where the 32nd degree of latitude intersects the west bank of the Sabine River to the 100 meridian of longitude. By subsequent treaties between the United States and Mexico, the United States and the Republic of Texas, and by enactments of the United States Congress this line became the boundary line between the States of Oklahoma and Texas from the southeast corner of Oklahoma to the 100 meridian of longitude. As thus established the Red River forms the boundary line between the States of Texas and Oklahoma for fully 300 miles as measured in a direct line, and for a much greater distance (about 539 miles) if measured by the meanders of the stream. In the case of the Sabine River, it was specified that the boundary line should be on the west bank; and of the Arkansas, on the south bank. But with the Red River the boundary was merely described as following the course of the river.

As early as 1890, the meaning of this treaty, in so far as the Red River was concerned, was called into question and in 1896 the Supreme Court of the United States in what is known as the Greer County Case interpreted the treaty as making the south bank of the river the boundary line. Following the discovery of oil at Burkburnett in 1918, and in the river valley in 1919, the exact place of this boundary was called into question and suit was brought by Oklahoma against Texas to which the United States became intervener, the object of this suit being to ascertain and mark upon the ground the exact boundary line. In the fall of 1919 investigations were made in the

Red River valley by scientific experts employed by the United States Department of Justice. Following these investigations the United States entered as an intervener in the suit, and the Supreme Court of the United States appointed a receiver for the properties pending a settlement of the case.

SCIENTISTS ENGAGED IN THE INVESTIGATIONS.

The evidence presented consisted of scientific and lay testimony. The maps, incident and necessary to Texas in this suit were made under direction of Arthur Alvord Stiles, State Reclamation Engineer. The topographers engaged in this work were: S. P. Floore, D. B. Penick, and S. T. Penick. Geologic investigations were made for Texas by E. H. Sellards, and R. T. Hill; and ecologic investigations by B. C. Tharp. Chemical analyses were made under direction of E. P. Schoch. P. T. Seashore assisted in the soil and other investigations. Certain of the land surveys were made by W. D. Blackburn. The panoramic views and some other photographs were made for Texas by A. M. Nash and L. P. Kramer.

Scientists engaged by the United States and Oklahoma included L. C. Glenn, Isaiah Bowman, H. C. Cowles, L. L. Janes, and C. H. Miller. The map making for the United States and Oklahoma was under direction of R. W. Livingston, of the United States Land Department, assisted by A. L. Banks, H. D. Craig, A. N. Kimmell and E. H. Kimmell. Late in the fall of 1921 and following testimony as to soil conditions given by the State of Texas, certain members of the United States Bureau of Soils were called into the investigation by the United States. The results of these soil investigations were presented by H. H Bennett, B. H. Hendrickson, and L. B. Olmstead. Testimony relating to stream measurements was given by F. F. Wilson, and relating to early surveys by A. D. Kidder and N. B. Smeitzer. The evidence in full in this case appears in the records of the Supreme Court of the United States.[1]

[1]The State of Oklahoma, Plaintiff, vs. The State of Texas, Defendant. The United States of America, Intervener. No. 23, Original, October, 1920, and No. 20, Original, October, 1921, Vols. I to IX, 5,513 pages.

While the testimony in the case has been printed in full in the Supreme Court records, the maps, charts, and diagrams are there reproduced only in part. Other exhibits, including photographs, soil and tree samples, and fossils are briefly described in the published record. An abstract of the evidence both lay and scientific is given in Part II of the Brief for the Defendant, 766 pages, published by the State of Texas, office of Attorney General. An abstract of the scientific testimony of the United States and Oklahoma is contained in an Appendix to Brief for the United States and Oklahoma, 523 pages, Government Printing Office.

As indicating the scope of the investigations there is here included a list of the principal original maps made by Texas and by the United States and Oklahoma. The maps of this list preceded by an asterisk are included in this report. The other maps not republished may doubtless be consulted in Washington. Those made by Texas may also be consulted at the office of the State Reclamation Engineer of Texas, or at the Bureau of Economic Geology of the University of Texas.

List of Original Maps Prepared by the State of Texas and by the United States and Oklahoma in Connection with the Oklahoma-Texas Boundary Suit. Those Preceded by an Asterisk Republished in This Report.

MAPS MADE BY TEXAS

Outline map of the Red River valley from the ninety-eighth to the one hundredth meridian, five sheets, numbered 1, 2, 3, 4 and 5, prepared under direction of Arthur Alvord Stiles, State Reclamation Engineer. Scale two inches equals one mile. Engraved in colors.

Topographic maps: Grandfield Bridge, Big Bend, Devol Bridge, Brushy Creek and Gilbert Creek topographic sheets. Scale of maps one to six thousand (one inch equals five hundred feet). Contour interval two feet, prepared under direction of Arthur Alvord Stiles, State Reclamation Engineer. Engraved in colors. These topographic maps serve as the base for the geologic, physiographic, soil and timber maps.

*Geologic map of the Grandfield Bridge topographic sheet, by E. H. Sellards and R. T. Hill. Scale one to six thousand. Engraved in colors.

Geologic map of the Big Bend topographic sheet, by R. T. Hill and E. H. Sellards. Scale one to six thousand. Engraved in colors.

*Physiographic map of the Big Bend topographic sheet, by E. H. Sellards and R. T. Hill. Scale one to six thousand. Engraved in colors.

*Soil map of the Big Bend topographic sheet, by E. H. Sellards and P. T. Seashore. Scale one to six thousand. Engraved in colors

Soil maps of the Grandfield Bridge, Devol and Brushy Creeks topographic sheets, by E. H. Sellards and P. T. Seashore. Scale one to six thousand. Engraved in colors.

*Map of the timber growth, showing approximate distribution of trees in the Big Bend topographic sheet, by B. C. Tharp and E. H. Sellards. Scale one to six thousand. Engraved in colors.

Map of the timber growth, showing approximate distribution of trees in the Devol and Brushy Creeks topographic sheet by B. C. Tharp and E. H. Sellards. Scale one to six thousand. Engraved in colors.

*Age classification of land in the Gilbert Creek valley, by E. H. Sellards. Scale one to six thousand. Engraved in colors.

*Reduced topographic map of the Big Bend area. Scale one to twelve hundred (one inch equals one thousand feet). This map includes the Grandfield Bridge, Big Bend, Devol and Brushy Creek topographic sheets, and is made from the large scale topographic maps. Contour interval two feet.

Structural map of the northwest extension of the Burkburnett Oil Field. The structural features in this oil field are taken with permission from a map prepared by the Petroleum Division of the United States Bureau of Mines. On the original structural map has been indicated the position of the river valley and Texas bluff. Made under direction of Arthur Alvord Stiles. Scale one inch equals one thousand feet. Engraved in colors.

Sketches and diagrams by R. T. Hill, as follows: (1) Natural provinces of Texas; (2) stream patterns of the greater Texas region; (3) evolution of Texas topography; (4) rivers of the greater Texas region; (5) rivers of the high plains and central provinces; (6) rivers of the great prairie belt; (7) rivers of the Nacogdoches and Corsicana belt; (8) rivers of the coast prairie; (9) suggestions of old coast belts shown by patterns of stream junctions; (10) showing how one group of rivers apparently heads or encircles another; (11) map and profile showing the typical physiography of the central section of the Red River; (12) cross-sections of the south bank of the Red River, snowing terraces and benches; (13) section across valleys, benches and terraces, south side of the Red River, Big Bend area; (14) diagrams illustrating work of the winds and building of dunes; (15) encircled rivers of the Texas region; (16) the entrenched sections of some of the Texas rivers; (17) the great bends in the rivers of the plains; (18) straightening meanders of the Big Bend of the Red River; (19) as the stream patterns of the sand plains of the Big Bend valley would look if it were an encircled stream; (20) cross-section of Mulberry Canyon, a tributary of the Red River, showing the Miocene formations of the Staked Plains.

Maps showing photograph stations in the Grandfield Bridge, Big Bend, Devol Bridge and Brushy Creek sheets. Station locations super-imposed upon topographic maps.

*Profile of moving sand dune in the Big Bend, by E. H. Sellards.

Map showing location of soil holes, localities for fossils, soil tubes and cut trees on the Big Bend and Grandfield Bridge, by E. H. Sellards. The data contained on this map were subsequently transferred as follows: Soil holes and soil tube localities to the soil maps; fossil localities to the geologic maps; and cut trees to the timber maps.

Graph showing relative fineness of top soils of dunes, by E. H. Sellards.

Reconnaissance Survey of bends in the Sabine River, from Orange to Hemphill, by S. B. Floore. Engraved in colors. Scale one inch equals 250 feet.

Restoration map of a part of the Big Bend area, by R. T. Hill. Scale one to twelve thousand.

Aside from maps and charts there were introduced by Texas: twenty-five soil tubes, illustrating actual thickness of soils with explanation of each; fossils from eleven localities including a skull of buffalo; sixteen tree sections showing the age of the timber growth; and two hundred and thirty photographs with suitable explanations. Of the photographs forty-five were panoramic views.

MAPS MADE BY THE UNITED STATES AND OKLAHOMA

Outline map of the Red River. Twelve sheets covering the river from near Denison, Texas, to the west boundary of Oklahoma, at the one hundredth meridian. Scale, two inches equals one mile. Made under direction of Robert W. Livingston. Blue print.

Relief map of the Red River Oil Field, by Robert W. Livingston. Scale, one inch equals thirty chains (1980 feet). Engraved in colors.

Cross-section of the Red River bottoms, by Robert W. Livingston. Blue print.

Map of double cut off in the river, by A. N. Kimmell. Scale four inches equals one mile. Blue print.

Cross-sections of the Red River valley, by H. D. Craig and Robert W. Livingston. Blue print.

Profile of the Red River, through ranges 13, 14 and 15, west of the Indian meridian, Oklahoma, by Robert W. Livingston. Blue print.

Sketched vertical profiles of the terraces and flood plains of the Red River by L. C. Glenn, three sheets. Blue prints.

Map of old alluvial area on the Red River, near Doan (Doan valley), by L. C. Glenn. Blue print. Scale, four inches equals one mile.

Map of Electra Bridge alluvial area (Electra Bridge valley), by L. C. Glenn. Blue print. Scale, four inches equals one mile.

Map of the flood plain of the Red River, opposite township 5 S., ranges 15 and 16 W. (China Creek valley). Blue print. Scale, one inch equals ten chains (660 feet). By L. C. Glenn, R. W. Livingston and A. N. Kimmell.

Map showing composite origin of the alluvial area in the Big Bend area, by L. C. Glenn. Blue print. Scale, four inches equals one mile.

Sketch map of the alluvial area (in Texas opposite) township 5 S., 12 and 13 W. By L. C. Glenn (Gilbert Creek valley). Scale, approximately six inches equals one mile. Blue print.

Profile of the Red River from the east to the west boundary of Oklahoma. Compiled from data taken from railroad bridges and from war department maps. By Charles H. Miller. Scale, horizontal one inch equals twenty miles, vertical one inch equals two hundred feet.

Red River flood plain in Stanfield region, Clay County, Texas, by L. C. Glenn. Scale, four inches equals one mile. Blue print.

Sketches illustrating life history of islands by L. C. Glenn. Blue print.

Sketches showing relation of bluffs, flood plains and terraces, to river cutting, by L. C. Glenn. Blue print.

Cross-section of south channel of the Red River during April high water, 1921. Blue print.

Rainfall and drainage of the Red River region, by Isaiah Bowman. Blue print. Hand colored.

Dune roses by Isaiah Bowman. Blue print. Hand colored.

Ecologic map (of a part of the Big Bend area), by L. L. Janes. Scale, one inch equals five chains. Blue print.

Ecologic map (of the greater part of the Big Bend area), by L. L. Janes and H. C. Cowles. Blue print.

Ecologic map showing elevations in the vicinity of (tree) sample No. 6, by L. L. Janes. Blue print.

Map showing location of certain trees. Blue print.

Map showing location of soil holes. Super-imposed upon the Big Bend topographic sheet made by Texas. Blue print. Scale, one to six thousand (1 inch equals 500 feet).

Soil profiles of the deep holes in the Big Bend area and Burkburnett Bridge area. Hand colored. Eight sheets. On profile cloth. Scale, one to six thousand (1 inch equals 500 feet).

Soil maps of the Big Bend topographic sheet, a part of the Grandfield Bridge topographic sheet, the Burkburnett Bridge sheet and Hamill Island, by H. H. Bennett and others. Hand colored maps. Scale, one to six thousand (1 inch equals 500 feet).

Sketch map of a choked off channel in Hamill Island.

Section through dune in the Big Bend area. Hand colored.

Development map of the Red River Oil Field. Scale, one inch equals ten chains, by R. W. Livingston. Printed map.

Contour map of the Red River Oil Fields. Scale, one inch equals ten chains (660 feet). Contour interval five feet. Printed map.

Contour map of a part of the Big Bend area, by E. H. Kimmell. Scale, one inch equals three hundred and thirty feet. Blue print. Contour interval two feet.

In addition to the maps and diagrams, the United States and Oklahoma submitted sixteen samples illustrating the age of trees and about two hundred photographs illustrating conditions in the Red River valley.

As a matter of convenience to the Court numerous published maps and records not included in this list were submitted by both parties to the suit.

The Problem Stated

Throughout its course from the 100 meridian to the southeast corner of Oklahoma the Red River flows in a valley entrenched between more or less well defined bluffs. The width of the valley between the bordering bluffs varies from between one and two miles at and near the 100 meridian to several miles in places in the lower reaches of the river. The height of the bordering bluffs varies from as much as 100 feet or more to a very moderate height of a few feet followed by a gentle slope back to the higher land. The River Valley, as the term is here used, includes the land between the bordering bluffs consisting of the channel or channels to which the river is confined at low water stages; a sand stretch or sand flat varying from one mile or more in width in places in the upper part of the river to a narrow belt of sand or sand bars in the lower river; and valley lands varying in heighth above the average water level and normally covered by vegetation. The sand flat in the upper river and the sand bars in the lower river are overflowed at a moderate flood stage and are free of vegetation or nearly so.

Although by the decision of 1896, reaffirmed in 1921, the south bank of the river had been made under the treaty the boundary line between the two states, it remained to be determined what constituted the south bank of the river; where on that bank the boundary line should be drawn; and whether or not the boundary line had been affected by changes in the course of the river during the one hundred years since the treaty was made.

Much of the scientific testimony was concerned with the habits of the river, particularly in building its valley lands. With rivers in general the valley lands of course are built chiefly as the result of sediments deposited on or against the existing lands. Thus an existing valley if it is being added to at all is added to and enlarged gradually by the deposition of sediments. In legal terminology the gradual addition of new land to old by the deposition of sediment carried by the water of the river is known as accretion, and it is a long established rule in equity that when a river which forms a boundary, changes its course as a result of land added by accretion, the boundary line changes with the change in the river. Just where the channel of the Red River was located in the valley throughout the whole course of the river one hundred years ago, when the treaty was made with Spain, it is obviously impossible to determine. However, such changes as have been made by accretion are immaterial, since in any case the boundary would follow the river.

On the other hand it is an equally well established principle of law that where a river changes its course abruptly as in the case of an ox-bow cut off, the land between the new and the old channels remaining undisturbed, under these conditions the boundary does not follow the river in its new channel but is construed as following the channel abandoned by the river. If therefore the Red River in making whatever changes it may have made throughout its course in the past one hundred years since the treaty was made has changed by avulsion, then under these conditions the boundary line according to established legal precedent must follow the old channel of the river of the time when the treaty was made. For these reasons it became important to determine by what process the river has built additions to its valley land and in what way it has changed its channel.

CONTENTIONS OF THE UNITED STATES AND OKLAHOMA.

In testimony submitted in connection with the boundary suit some of the scientists representing the United States and Oklahoma submitted the thesis that in the upper part of the Red River west of the west line of Clay County the valleys of the river are built up and added to by a process described as "island building," the new land being first formed in the bed of the river as an island and subsequently attached to the mainland. Under the terms of the treaty all the islands in the river were to be the property of the United States. Hence newly formed islands in the river would obviously be the property of the United States and presumably would continue to be the property of the United States after their union with the mainland.

If the "island theory" should be accepted there would still remain the difficult problem of determining how much land had been added in this way within the past one hundred years. However some of the scientists representing the United States and Oklahoma estimated that the destruction of the banks and building of new lands progressed at such a rate that all of the valleys in the upper course of the river with minor exceptions had been destroyed and remade within the past century.

The theories advanced, if sustained, would have resulted in placing the state boundary line at or near the foot of the Texas bluff, thus throwing practically all of the river valley land of the upper part of the river into the State of Oklahoma. That is, under this interpretation Texas constantly loses by erosion of the banks, but never gains by deposition of the eroded sediments, the rate of loss progressing with such rapidity that practically the whole of the valley land in the upper stretches of this river has been lost to Texas within an interval of one century.

The investigations centered on one particular part of the river, known as the "Big Bend" near Burkburnett in Wichita County, the land in this bend having become very valuable by reason of the discovery of oil underlying the river valley. The investigations, however, were by no means confined to this bend and it is in any case recognized by all parties that the principles, which apply to river action at this locality apply likewise to the upper stretches of the river. With respect to the "Big Bend" it was held by at least one scientist representing the United States and Oklahoma, Dr. H. C. Cowles, that at the time of the treaty with Spain one hundred years ago, the channel of the river in this bend flowed at the foot of the Texas bluff. Other scientists representing the United States and Oklahoma, including L. C. Glenn, Isaiah Bowman, and C. H. Miller, placed the river of one hundred years ago near, but not actually at the bluff. These claims with respect to the "Big Bend" were made notwithstanding the fact that at the present time the river valley at this locality is in excess of one mile in width at its widest part, the river now flowing at the foot of the Oklahoma bluff opposite the bend. Trees in this valley in excess of one hundred years of age were said by the ecologists representing the United States to have had their inception on islands. These contentions, if sustained, would have placed this, as well as other Texas valleys, in the State of Oklahoma.

CONTENTIONS OF THE STATE OF TEXAS.

The State of Texas, on the other hand, maintained that neither the Red River channel, nor the sand stretch which borders the channel, nor any part of the channel or sand stretch lay adjacent to the Texas bluff in the Big Bend area so recently as within the past one hundred years. With regard to changes in the course of the river, it was contended that in this river, as in other rivers, the change throughout the entire course of the river occurs in some instances by erosion and accretion and in some instances by avulsion, and that normally in this river where the land is being built up, as has been done in the past ages in the Big Bend area, the change of the course of the river is by erosion and accretion. The larger valleys are regarded as in general exceeding one hundred years in age, at least in their older lands. Around the original nucleus of the valleys, in most instances, newer lands have been added from time to time, the controlling building process being by accretion. Ecologic studies indicate that the older portions of the Big Bend and other larger valleys have reached the climax stage of plant development, in this respect agreeing with the adjacent terraces and uplands. Under this interpretation the valley lands on the south side of the river belong wholly to the State of Texas throughout the entire course of the river where it forms the boundary.

The evidence presented in this suit may be classed as: (1) Physiographic, including discussion of the physical features of the valleys, such as sand dunes, their age and habits of building and shifting, sand bars, back valley streams, marginal fans, old stream channels and interdune depressions: (2) geologic, including discussion of sedimentation of river valleys in general, and such evidence as was available from fossils, particularly the more or less well mineralized bones of the buffalo and other animals formerly living in the valleys; (3) agrogeologic, including thickness, method of accumulation, age indications, alteration and succession of soils; and (4) ecologic, including relation of the vegetation of the valleys to that of the upland, as well as the age indication of the timber, shrubs and herbaceous vegetation of the valleys.

The Decision of the Supreme Court

Under the decision rendered by the Supreme Court the river valley land up to the margin of the sand bed of the river remains in the State of Texas, while the sand bed of the river to the middle of the channel is adjudged to be the property of the United States. The "cut bank" along the southerly side of the sand bed constitutes the south bank of the river, and the boundary is on and along that bank[1]. The "Big Bend" is

[1]The term "cut bank" which appears in this decision is a term introduced and used in the testimony as a convenient term applied to the more or less pronounced bank or declivity which borders the sand flat of the river and as a rule limits growth of vegetation towards the river. In some places this bank or declivity is scarcely perceptible, elsewhere it rises abruptly to an elevation of from one or two to fifteen or twenty or twenty-five feet above the sand flat, the maximum elevation being usually occasioned in part or entirely by sand dunes. The "cut bank" of the testimony and of the decision is therefore the place at which the vegetation covered land of the valley gives place to the sand flat of the river.

recognized as being larger now than sixty years ago, the enlargement being by accretion. On the outer part are physical evidence of the formation being comparatively young, and on the inner of being old. The boundary in the Big Bend as elsewhere on the river is placed at the cut bank, around the northerly limits of the valley.

Relation of the Decision to the Scientific Ttestimony.

The relation of the decision to the scientific testimony is summarized in the paragraphs which follow.

The principal questions at issue in this suit, in so far as the scientists were concerned, were the habits of the river in building its valley lands and the age and permancy of the river valleys.

The Supreme Court's decision, in so far as it relates to the method of building, is that the river valley land is built by accretion and that the law as applied to rivers in general applies likewise to this river. This decision is in accordance with the scientific testimony given by the State of Texas, accompanied by descriptive statements and a photographic record of the river. It is in direct opposition to the main contention of the scientists representing the United States and Oklahoma who maintained that the river valley land was first built in the form of islands and afterwards added to the mainland, this being the "Island Building Theory" as developed by them.

The second important contention of scientists representing the State of Texas was that the Big Bend valley in Wichita County in its present form, aside from additions by accretion, is more than one hundred years old. Some of the scientists representing the United States and Oklahoma on the other hand maintained, first, that there are no appreciable additions to this or other valleys in the upper part of the river by accretion, and that one hundred years ago a channel of the river flowing near the Texas bluff separated the land of the Big Bend valley from the mainland. The decision of the Supreme Court is that there is no adequate proof that a channel flowed near the Texas bluff one hundred years ago.

The further contention advanced by some of the scientists representing the United States and Oklahoma to the effect that the destructive work of the river proceeds with such rapidity as to destroy and remake all valleys on the upper river within the one hundred years that have intervened since the treaty was made is disposed of so far as this suit is concerned by that part of the decision of the Supreme Court which holds that the building processes of the river are by accretion. Under the law the *method* of adding land and not the *rate* at which it is added is the determining factor.

Ecologists representing the United States and Oklahoma, Dr. H. C. Cowles and L. L. James, maintained that the numerous and well scattered trees in the valley found to be more than one hundred years old all began their growth on islands and that these islands were subsequently united to the mainland. This testimony in regard to trees on islands, the Supreme Court concluded was "speculative and not a proper basis for judgment."

Some of the scientists representing the United States, particularly Dr. Bowman, went extensively into the discussion of the actual and relative stability of the river valley land, which was intended to apply on the question of where along the bank the boundary should be drawn, it being the contention of the Attorneys representing the United States and Oklahoma that lack of stability in the valley lands would necessitate placing the boundary line for this reason, if for no other, at or near the foot of the Texas bluff. In placing the boundary on and along the cut bank the Supreme Court disposed of any contentions as to the instability of the river valley land in so far as the placing of the boundary is concerned.

Attorneys representing the State of Texas maintained that rights inherent in the treaty guaranteeing access to the river water placed the boundary line at low water mark in the river. In the scientific testimony, Dr. R. T. Hill expressed the view that the sand plain or sand flat which lies adjacent to the channel is to be regarded as a part of the flood plain of the river, and that the bank of the river is at the line of contact of the water and the land. One of the judges of the Supreme Court, Mr. Justice McReynolds, in his dissenting opinion supports the contention of the Texas Attorneys. This contention, however, was not sustained in the majority opinion of the Court.

It is thus seen that with the one exception noted the contentions advanced by the State of Texas are sustained in the decision of the Supreme Court.

Extract from the Decision of the Supreme Court of the United States in the Case of Oklahoma vs. Texas, United States Intervener, Rendered January 15, 1923, pp. 10-14.

The following extract includes that part of the opinion of the Supreme Court relating to questions involving scientific testimony.

"The valley land always has been dealt with as upland. The United States surveyed and disposed of that on the north side under its public land and Indian laws, and Texas surveyed and disposed of that on the south side under her land laws. Both treated the cut banks as the river banks and carried their surveys to those banks, but not beyond. Patents were issued for practically all the land. Individuals freely sought and dealt with it as upland. Much of that on the south side was disposed of by Texas fifty years ago, some of it seventy. Thousands of acres on that side were improved, occupied and cultivated under these disposals, and larger acreage was occupied and used under them for pastures. Through the long period covered by this course of action there never was any suggestion that this valley land was part of the river bed, nor that the shifting elevations of sand within the sand bed were the river's banks, nor that the land on the south side belonged to the United States. Not until some land on the south side and part of the river bed were discovered to be valuable for oil was this unbroken course of action and opinion drawn in question. However much the oil discovery may affect values, it has no bearing on the questions of boundary and title.

"Our conclusion is that the cut bank along the southerly side of the sand bed constitutes the south bank of the river and that the boundary is on and along that bank at the mean level of the water when it washes the bank without overflowing it.

"The boundary as it was in 1821, when the treaty became effective, is the boundary of today, subject to the right application of the doctrines of erosion and accretion and of avulsion to any intervening changes. Of those doctrines this Court recently said:

"It is settled beyond the possibility of dispute that where running streams are the boundaries between States, the same rule applies as between private proprietors, namely, that when the bed and channel are changed by the natural and gradual processes known as erosion and accretion, the boundary follows the varying course of the stream; while if the stream from any cause, natural or artificial, suddenly leaves its old bed and forms a new one, by the process known as an avulsion, the resulting change of channel works no change of boundary, which remains in the middle of the old channel." Arkansas v. Tennessee, 246 U. S. 158, 173.

"Oklahoma and the United States question the applicability of the doctrine of erosion and accretion to this river, particularly the part in western Oklahoma,—and this because of the rapid and material changes effected during rises in the river. But we think the habit of this river is so like that of the Missouri in this regard that the ruling relating to the latter in Nebraska vs. Iowa, 143 U. S., 359, 368, is controlling. * * *.

"Common experience suggests that there probably have been changes in this stretch of the Red River since 1821, but they cannot be merely conjectured. The party asserting material changes should carry the burden of proving them, whether they be recent or old. Some changes are shown here and conceded. Others are asserted on one side and denied on the other.

"A controverted one is ascribed to the so-called Big Bend area, which is within the oil field. That area is now on the south side of the river and connected with the bluffs on that side. Oklahoma and the United States assert that in 1821 a channel of the river ran between it and the bluffs and that the river has since abandoned that channel. Texas denies this and insists that the situation in 1821 was practically as now. Stimulated by the large values involved, the parties have exhausted the avenues of research and speculation in presenting testimony thought to bear on this question. The testimony, particularly of the experts, is conflicting. It is so voluminous that it does not admit of extended statement or discussion here. We can only refer to important features and give our conclusions.

"There are no surveys or records depicting the situation in 1821; nor are there any human witnesses who knew this part of the river then. But there are inanimate witnesses, such as old trees, which tell a good deal. At that place the river makes a pronounced but gradual bend to the north and back to the south. The area in question is on the inner side of the bend. It is larger now than sixty years ago, but how much is uncertain. The enlargement is the result of intervening accretions. The habit of the river is to erode the outer bank of a bend and to accrete to the opposite bank. Three surveys executed by Texas in 1856 and covering less than the whole area disclose the presence at that time of over 1700 acres. On the outer part are physical evidences of the formation being comparatively recent. On the inner part are like evidences of the formation being old, among them being the presence of living trees more than a century old. One of the trees, a pecan, attained an age of 170 years. A part of the area was cultivated and the remainder used for pasturage as early as 1877. At that time there were more trees than now. Many were taken by early settlers for firewood, fencing posts and building logs, some logs being over three feet through. To overcome the inference arising from the presence of the old trees, which were well scattered, testimony was presented to show that in 1821 these trees were all on islands, which aterwards were consolidated amongst themselves and with the land on the south side. We think this testimony is essentially speculative and not a proper basis for judgment. In this area, as elsewhere in the valley, a succession of depressions is found at the foot of the bluffs and some testimony was produced to show that in 1821 the river, or a part of it, flowed there. It may be that the river was there long ago, but the testimony that it was there in 1821 is far from convincing. Texas has been exercising jurisdiction over the area and asserting proprietorship of the soil for more than half a century and has surveyed and disposed of it all, the earliest disposals being in 1856. Some of the later surveys seem to conflict with those first made, but all name the river bank as a boundary. In those of 1856, and possibly others, it was the controlling call. See Schnackenberg vs. State, 229 S. W., 934; Cordell Petroleum Co. vs. Michna, 276 Fed., 483. The jurisdiction and title of Texas stood unchallenged until shortly before the suit. Our conclusion is that the claim that the river, or any part of it, ran south of this area in 1821 is not sustained. So the boundary follows the cut bank around the northerly limit of the area."

Under this decision all of the river valleys on the Texas side including grazing and farming lands and homes remain in the State of Texas throughout the entire course of the river where it forms the boundary. Of the oil wells involved in the controversy the greater number including all of those located in the river valley are restored to Texas ownership, while a smaller number located in the bed of the river become the property of the United States.

GEOLOGIC AND SOIL STUDIES ON THE ALLUVIAL LANDS OF THE RED RIVER VALLEY.

BY E. H. SELLARDS.

The writer's observations on the alluvial lands of the Red River valley were made in detail in a limited area known as the "Big Bend," located in Wichita County, near Burkburnett and occupied in part by the northwest extension of the Burkburnett oil field. The observations made in this valley, however, were subsequently checked by observations on the valley lands on the river, both above and below this locality. At the time these investigations were made the boundary line on this river between Texas and Oklahoma was in dispute, the object of the investigation being to contribute information of service in determining this boundary.[1]

GENERAL CONSIDERATION.

The Red River takes its origin in the high plains of West Texas, some of its tributaries originating in northeastern New Mexico. From its head-waters to the northeast corner of Texas the direction of flow is in the main slightly south of east, although locally and for a distance of some miles it may depart from this course. After passing the northeast corner of Texas the river turns south to Shreveport and thence makes its way in a southeasterly direction to the Mississippi River.

In its long course, this river and its tributaries encounter wide diversity of climatic conditions as well as varying formations through which it has cut its channel. The series of formations cut through by the river include the Tertiary formations of the high plains of Texas, the outcropping edges of the Triassic sandstone, the red beds of the Permian System, some of the upper Pennsylvanian formations, the Cretaceous series of northeastern Texas, and the Tertiary and alluvial deposits of Louisiana. The character of the sediments and the lay of

[1]The writer's testimony will be found in full in the Supreme Court records in this case, Vol. VII, pp. 3800-4054; 4057-4197; 4199-4219; Vol. VIII, pp. 4221-4238; 4634-4660; and 4834-4856.

the formations as well as the climatic conditions have without doubt influenced the course and directions of the stream and the character of the river valley and stream bed. To some of these features it will be necessary to refer subsequently.

TERRACES ON THE RED RIVER.

The age of the Red River as a drainage system is indicated by the depth and width of the channel or valley that it has cut into the formations over which it flows. The valley of the river lies one hundred feet or more below the adjacent uplands. In width the valley varies from one or two to several miles. The history of development of the river valley is recorded in the alluvial deposits, remaining as terraces, that it has built up in and at the sides of its valley. Remnants of these alluvial deposits, back to an early date are at places left at the sides of the river channel. The oldest of these terraces are those which now lie at or near the top of the present river bluff, and record a time when the river was working at a level of between seventy and one hundred feet above its present level. At successively lower levels are other terraces recording later stages in the down cutting of the river channel and the development of the river valley. In the cut made by the public road leading down the bluff from Bridgetown in Wichita County may be seen an excellent exposure of the materials of this high terrace consisting of loess with gravel layers at the base. Somewhat below the middle of the bluff there is seen on this road remnants of another group of terraces. These remnants are seen capping small hills of red Permian sediments at either side of the road. Upon reaching the valley the road passes onto lower terraces, the lowest alluvial deposits being the present flood plain of the river. At some other localities terraces of the river are more completely preserved than at Bridgetown. In the geologic map the terraces of the river have been indicated. (Geologic map of the Grandfield Bridge sheet.)

The terraces found and mapped in the vicinity of the Big Bend may be regarded as representative of the terrace formations of this part of the river system. The age of the oldest of these terraces representing the first records we have of the history of this river system is very probably early Pleistocene. It is therefore apparent that the Red River drainage system is of great antiquity as compared to the particular problems involved in this investigation.

PHYSICAL FEATURES OF THE RIVER VALLEYS

The term river valley, as used in this paper, is restricted to the stretch of land between the bordering bluffs, including the channel of the river, the sand flat and sand bars adjacent to the channel, and the river valley land. The parts of the valley between meanders of the stream are likewise referred to individually as valleys, as for example the "Big Bend valley."

The Channel of the River

The channel of the river is that depression to which the water is more or less confined at low water stages. In the lower Red River there is for the most part only one channel. In the upper river, however, there are in places two or more channels even in relatively low water stages of the river. The channel, as is usual in rivers, increases in depth and width and in the quantity and permanency of water from the headwaters to the mouth of the river.

The Sand Flat of the River

Bordering the channel, in places on both sides and elsewhere wholly on one side, is a strip of land, bare or nearly so of vegetation, consisting chiefly of sand, commonly known as the sand flat or sand bed of the river. In the testimony given by the writer in the Oklahoma Texas boundary suit this stretch of sandy land adjacent to the stream channel was refered to by the descriptive terms "sand plain," "sand stretch" and "sand flat." (R. 7-3839.) Owing to the force of the currents, the absence of vegetation, and the character of the sand, considerable irregularities in elevation exist in this area, the sand in places being thrown into low elevations and elsewhere dug into, forming depressions. The actual elevation of the sand flat above water level in the river channel at average low stage of the river is as a rule from one to two or three feet. The sand flat being elevated but little above the water level of the river channel is overflowed with each successive rise in the river. During intervals between floods parts of this sand flat may become more or less covered with vegetation particularly weeds and some grasses, and in places young willows and cottonwoods. At flood stage such growth may be in part or entirely swept away leaving the sand again bare.

The river valley increases in width progressively from its headwaters towards its mouth. The sand flat which accompanies the channel on the other hand is progressively reduced in width from the upper stretches of the river towards the gulf, finding its maximum width opposite Hardeman, Wilbarger and Wichita Counties. The sand flat of the upper river by reduction in width becomes sand bars in the lower river.

The River Valley Land

Bordering the sand flat and rising above it from one or two to twenty or twenty-five feet is the land of the River Valley normally covered by vegetation. Within this area of land covered by vegetation the principal land forms to be noted are first the low valley lands rising not more than a few feet above the level of the sand flat; the sand dunes which rise from a few feet to twenty or twenty-five feet above the level of the sand flat; and fans formed by the wash of lateral streams entering from the adjacent bluffs. It will be shown in a subsequent section of this report that the valley land is gradually added to at the outer margin by land formed by processes of accretion.

The Big Bend of the Red River in Wichita County

The "Big Bend" of the Red River to which these studies particularly relate is a valley on the Texas side of the River in Wichita County. It extends from somewhat below the town of Burkburnett upstream to Bridgetown, the whole length of the valley being between nine and ten miles. The valley narrows at either end, but widens in the central part the maximum width being about one and one-third miles.

The selection of this area for detailed study is desirable since the particular lands giving rise to the boundary suit between the States of Oklahoma and Texas to which the United States became intervener are located in and near the upstream end of this valley where the land has become especially valuable by reason of the discovery of oil in the valley. It is believed however that the principles of land development derived from the study of this particular valley are equally applicable to the other valleys of the river, above and below this locality.

PHYSICAL FEATURES OF THE BIG BEND VALLEY

The River Channel in the Big Bend

The river channel opposite this valley is near the Oklahoma side of the river and when passing around the valley flows at the foot of the Oklahoma bluff. At the upstream end of the valley the river channel flows close to or against the Texas bluff. At the downstream end of the valley the river again strikes the Texas bluff. This valley is therefore similar to other valleys of the river in that a "crossover" of the river occurs above and below the valley.

The Sand Flat in the Big Bend

Above and below the Big Bend valley the sand flat "crosses over" with the channel from one side of the river valley to the other. Above or upstream from the valley the sand flat is found extending to the foot of the Texas bluff, or separated from the Texas bluff merely by the river channel. From this place the sand flat crosses over with the river channel and opposite the "Bend" is found extending to the Oklahoma side or separated from the Oklahoma bluff only by the river channel. Towards the lower end of the "Bend" the sand flat with the river channel again comes to the Texas bluff. The sand flat or sand plain in the Big Bend varies in width from three thousand to six thousand feet, while the channel of the river in the sand plain at low water stage has a width of from three hundred to about six hundred feet. A rise of a few feet causes the water to spread across the entire stretch of sand.

These features of the river valley are accurately depicted on the topographic maps and may be seen also in the photograph, Plate 1.

The River Valley Land Covered by Vegetation in the Big Bend

By reference to the map it will be seen that the valley land in the Big Bend projects from the Texas bluff towards the Oklahoma bluff having a maximum width of about one and one-third miles. Upstream the valley is rapidly reduced in width while downstream it narrows much less rapidly. It is concluded in these studies that this land has been built outwards gradually from the Texas bluff to which it is now attached. The alternate contention on the part of scientists representing the United States and Oklahoma is that the land was built first in the form of islands, which were subsequently joined to the mainland, with the further contention that attachment to the mainland has occurred within the past one hundred years.

Agencies Operating in Building the Land Above the Sand Bed of the River

The river valley land covered by vegetation is built upon pre-existing sand flat or sand bed of the river. The agencies most effective in building the valley land are the following: 1. The growth of vegetation; 2. Sedimentation by the river when in flood stages; 3. Sedimentation brought in by the tributary streams; 4. Sedimentation by the wind.

VEGETATION AS A RECLAIMING AGENCY

An important agency in reclaiming the sand flat and transferring it into more permanent land is the growth of vegetation, particularly grass, weeds, young willow and young cottonwood. This vegetation spreading from the main land on to the adjacent sand flat helps it to withstand subsequent floods and ultimately little by little to extend the area of the higher land covered by vegetation. It is true that vegetation frequently springs up at places on the sand flat at localities other than those immediately adjoining the land masses. In such isolated patches however, the new vegetation being surrounded on all sides by sand has but little chance of withstanding flood waters. Much greater possibility for permanency exists for vegetation which makes a start adjacent to pre-existing vegetation, and particularly at the downstream side of the existing vegetation-covered land. Most of the land reclaimed from the sand flat is reclaimed in this way.

The influence of vegetation in building up the land area begins with reclaiming the land from the sand flat in the manner already described. Not only do the roots of the plants assist in preventing the destruction of the reclaimed land by floods but the growth of vegetation itself assists in lodging and retaining wind blown sediments. Likewise during flood stages of the river vegetation retards the flow of the water currents reducing its eroding power and promoting deposition of sediment from its waters. Moreover the decay of successive vegetation growth on the land promotes the formation of soils and this in turn favors increased vegetable growth all of which further assists in building up the land.

SEDIMENTATION FROM FLOOD WATERS AS A LAND BUILDING AGENCY

In the time of flood the river water more or less completely overflows the valley lands. In the overflowed lands bearing vegetation the force of the current is retarded by grass, weeds and young tree growth and with reduced velocity the sediments in suspension in the river water tends to drop out. In this way a top covering is formed consisting of very fine sediment which has settled out of the river waters. The soil formed from such sediment is a mellow and very fine loam which forms soil conducive to the growth of grasses and other vegetation. The depressions which exist in the land surface are filled at flood stage by river water from which all sediment in suspension in the water settles to the bottom. In this way there is a tendency to fill up natural depressions and to produce a relatively level stretch of vegetation covered land. The development of an overflow silt soil from the flood waters of the river is a slow process. Nevertheless such soils, in many instances now buried beneath soil subsequently formed are found underlying the whole of the river valley land covered by vegetation. In some places as much as a foot or more of a loam built up by these processes has accumulated over the land.

WIND SEDIMENTATION AS A LAND BUILDING AGENCY

In persistency of operation and quantity of material transported, wind sedimentation is a factor of paramount importance in building the land of the river valley above the flood plain level particularly in the upper part of the river. Dune building in particular is a conspicuous result of wind activity. In addition, however, the wind sediments are scattered very generally over the land surface, thus assisting in building slowly the land above the sand plain level. Tests made in the course of these investigations have shown that it is entirely practicable to identify by mechanical analysis the several types of sedimentation in this valley. The wind blown sands of the dunes for example maintain a reasonable uniformity as to the size of the sand grain which is on the average smaller or less coarse than is the sand of the sand plain of the river. The loam of the overflow silt of the river on the other hand is extremely fine. Practically all particles of this silt pass through a two hundred mesh screen, that is a screen with two hundred openings to the lineal inch of surface or forty thousand openings per square inch. The sand of the sand dune on the other hand is very largely lodged on the one hundred mesh screens.

BUILDING OF VALLEY LANDS BY WASH FROM THE BLUFFS

Wash from the surrounding bluffs and sediment brought in from the high lands by the streams aid in building up the valley lands. In front of each small stream there is built a delta like deposit commonly called an alluvial fan. In addition to the fan-like accumulations of the smaller streams, there is spread out over a much larger area of the valley an accumulation of fine sediment brought into the valley by the larger streams. Wild Horse Creek is an illustration of this type of deposition in the Big Bend valley. Such lateral streams as flow directly into the river channel of course accumulate no such deposits since the force of the current removes the sediments as rapidly as the lateral streams bring them in. On the other hand the lateral streams debouching onto the river valley plain build an alluvial fan which increases in size and extent as time goes on and affords to some extent a means of measurement by which to determine the age of the bench on which it is accumulating. The possible use of these outwash plains in determining the age of the flood plain and terrace of the river valley will be discussed later.

The materials brought into the valley by wash from the bluffs are very heterogeneous depending upon the character of the formations through which the stream flows. Streams entering across the Permian clays, limestones and sandstones, bring in chiefly clay sediments intermixed with rock fragments. Those lateral streams on the other hand, which in flowing into the valley cut across the fine sediments of the higher terrace deposits bring in chiefly fine silts which form loam soils.

The height to which the land of the valley is built by the combined effect of these several agencies varies from a few feet to twenty-five or thirty feet. In the Big Bend, the maximum height of the valley above the water bed is about twenty-two feet, this elevation being found on sand dunes.

THE FLATS OF THE BIG BEND VALLEY

Between the dunes occupying the inter dune area are belts of flat lands which have a superficial resemblance to former river channels. An examination of these flats will show that they represent a part of an originally extensive belt of flat lands upon which the sand dunes have been built. The soil on these flats consists largely of river silt deposited at times of flood waters. It is however only in the newest of the land area that no more than a single loam layer exists. In the somewhat older lands there is found in these valleys a layer of river overflow loam followed by sand and other soil accumulation amounting in some instances to several feet of sediments variously derived overlying the original river overflow loams of thes flats.

The physical features of the Big Bend valley as thus briefly presented are essentially those of the river valley in general and present no exceptional features as compared to other valleys of the river in this part of its course.

THE AGE OF THE RIVER VALLEY LAND IN THE BIG BEND

At the time the investigations were made the principal problems under consideration were the habits of the river in building its valley lands and the age of the alluvial lands in the valley, particularly as to whether or not the valley, or a part of it had been in existence in its present form for a period of one century or more. Before these investigations were undertaken scientists representing the United States and the State of Oklahoma had expressed the opinion that approximately one hundred years ago a channel of the river was flowing at or near the Texas bluff in this valley; and that the method of enlarging the valleys in this river was by a process described as "island building."[1]

To secure information as to the age or approximate age of the river valley land was therefore one of the important results sought in this investigation. This problem differs in many ways from that which is ordinarily presented in geologic investigations. Usually the geologist is dealing with geologic formations, in which if time as calculated in years enters at all it is only in intervals of centuries or of milleniums. In this case on the contrary actual age in years is sought or at least the actual minimum age, the question being whether the land is one hundred years old or less or whether any part of it, as a channel near the bluff is less than one hundred years in age. While this problem of age of the land is difficult it is not necessarily incapable of approximate solution. It is agreed by all observers that underlying all of this river valley land is found river accumulated sediments including sand and gravel, and that upon this foundation has been built by the combined operation of several agencies the land mass now found to exist there. The problems under consideration are probable length of time that has been required to build this land mass to its present

[1]In the Supreme Court of the United States, October term, 1919. No. 27, original, pp. 82-89 and pp. 103-105.

height and extent, and the length of time that the valleys in their older parts have existed essentially in their present form.

The evidence bearing on the age of the land of the river may conveniently be presented under the following headings:

(1) Age of the valley as indicated by physiographic features.

(2) Age of the valley as indicated by geologic features;

(3) Age of the valley land as indicated by soils; and

(4) Age of the river valley lands as indicated by the timber growth.

The Age of the River Valley Land as Indicated by Physiographic Features.

Physiography is primarily the science of the interpretation of land forms. In the earlier pages of this report a brief statement was given as to the land forms of the Red River drainage system, including the river channel, sand flat, flood plain and the several terraces of the bluffs. It will be the object of this particular section of the paper to apply the interpretation of these land forms, in so far as possible, to the question of the age of the river valley lands.

In this connection it is well to bear in mind that it is not the age of the trough or depression in which the river flows, nor of the several high terraces of the river that is called into question. The river is recognized as an ancient feature of the landscape The several terraces record the successive stages in the development of this valley and afford within themselves evidence of their age, even the relatively low terraces being of the Pleistocene period. It is therefore only the low river valley land including the present flood plain of the river that is under question as to age.

THE SAND DUNES

Among the land forms of the Big Bend valley none are more conspicuous or striking than are the sand dunes or sand drifts.[1]

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[1]For convenience of reference the sand accumulations will be referred to as dunes. In some instances perhaps they are scarcely more than sand drifts.

To fully appreciate the time interval involved in building theses dunes it becomes necessary to inquire fully into the method or manner in which dunes are formed as well as their subsequent history up to the present time.

Source of Sand Supply Controls the Place of Formation of Sand Dunes

In the course of these inestigations it has been observed that in the Red River valley the source of supply of sand and not the directions of the prevailing winds controls the place of formation of sand dunes, and that the dunes form parallel to the sand bed from which the sand is derived. (R.-7-3845.)[1] It is observed that adjacent to a broad sand flat, dunes form extensively provided there is no impediment to the movement of sand such as the presence of a river channel between the land and the sand flat. An illustration of this is seen in the Big Bend where the sand flat lies north of the valley land and the river channel is at or near the Oklahoma bluff. In this bend of the river sand dunes are extensively developed having been built up by winds blowing from a northerly direction. On the other hand in the bend of the river lying next down stream from the Burkburnett Bridge the conditions are reversed, that is the valley land lies on the Oklahoma side. Next south of this land is the sand bed of the river, and the river channel is at the Texas bluff. Under these conditions sand dunes are built on the Oklahoma side, the sand being carried by winds blowing from a southerly direction across the sand plain. If other illustrations are required to establish this principle they are not lacking. It may be seen for instance that at the northwest corner of "Goat Island" a sand dune is building at the margin of the land, having been built up by winds blowing from a westerly or southwesterly direction, while on the opposite side of this land mass dunes are building by winds blowing from northeasterly direction. If dune formation were con-

[1]Throughout this paper the references given are to the original printed testimony. In these references R. is used as an abbreviation for "Record," the second entry is the volume and the third the page or pages.

trolled by the direction of the prevailing winds the dune series built up in this valley should all be parallel, the one to the other. If on the other hand dune building is not controlled by the direction of the prevailing winds, but is controlled as maintained in the preceding paragraph by the location of the principal source of supply, it follows that the successive dunes series built in the valley will not necessarily parallel each other, but each series will parallel the source of supply as it existed at the time the dune was formed. Illustrations of the fact that the dunes do actually build parallel to their source of supply or essentially so are numerous. An inspection of the new dunes of the Big Bend area as shown on the soil map which accompanies this report will show how in each instance the new dune faces the sand flat from which it has accumulated. (Soil map in pocket.) The application of this principle of dune formation in the Big Bend area is of great importance in the present investigation, and will be referred to again. It is obvious that winds when crossing the sand flat will gather a full load and hence will tend to build dunes on the higher land bordering the sand bed. The observations on the ground are entirely in accord with this expectation.

Dune building was discussed by Drs. Glenn and Bowman. Dr. Glenn refers to the dunes as distributed along the bank, only by such winds as blow towards the bank from the river carrying sand. (R.-5-2200.) With this statement the writer agrees fully. Dr. Bowman discussed dune formation at length using dune roses to illustrate his meaning. He stated that "there is a close correspondence, in fact an extremely close correspondence between the orientation of dunes and the orientation of the river channels." (R.-5-2405.) Upon reading Bowman's testimony it will be seen that the word channel is used by him to apply to the depressions in the sand flat of the river to which the water is more or less confined. Accordingly if correctly understood his conclusions in regard to the dunes is not in agreement with that of the writer. Instead of forming at the margin of channels, as Bowman contends, sand dune formation is inhabited by a channel to the extent that it carries water. Moreover the channels through the sand flat rarely have banks of sufficient height to induce dune formation, so that dune formation cannot in any sense be said to trend with the river channels. The sand dunes in fact trend with the sand plain or sand flat of the river as it existed at the time of the formation of the dunes and have no relation to channels of the river except that on the average they are remote from such channels as persistently carry water.[1]

Dunes Form on Pre-existing Land.

The writer's observations led to the conclusion that not only do sand dunes build ordinarily near and parallel to the sand plain of the river but that they build on the land as a rule rather than on the sand bed of the river. On this point testimony was given as follows (R.-7-3857.)[2]

"I have already stated that when vegetation takes possession of the land it assists in blocking the force of the river at the overflow stage and brings down the silt in the river waters; and, therefore, for that reason, and because the water stands on the land in over-flow stages, there is built in time a stratum of silt which is recognizable as silt settling out of the river water, recognizable regardless of how old it may be, or how long ago it may have been made, or what may have covered it subsequently. And I have examined this land in this particular area to find to what extent such a silt layer underlies the land as a whole. I wished to do that because I believed it would give me some information on the question of whether or not a sand dune builds directly on the sand plain as such or builds upon land that has been land for some

[1]In summarizing testimony attorneys representing the United States (Appendix to Brief for the United States and Oklahoma, p. 233) state that "Doctor Bowman illustrated the fact that the lines of sand dunes are in general parallel with the sand bed of the river." If Doctor Bowman's conclusion is that the dunes trend with the sand flat of the river, which they do in fact, it is difficult to understand his repeated statements that they trend with the channels of the river, which they do not.

[2]In quoting from the record here and elsewhere in this paper the writer has taken the liberty of making minor alterations in the spoken testimony where such changes improve the sentence form without altering the meaning.

time and has accumulated this layer of silt from the river waters. It is true that on the sand plain from place to place there are little layers of this particular kind of silt I am talking of, but generally speaking on the sand plain I have not been able to find that there is anything like the definite and thick and characteristic and uniform and continuous layer of fine silt that develops on land that is over-flowed by the river, and all the land at one time was low land. Therefore, I put down excavations in the land, generally, whether on the low land or in the dune, to find to what extent this particular silt layer is to be found under the dunes, or to find what else, whatever is to be found under the dunes that would bear on the question of whether or not the dune had been built out on the sand flat or had been built on land as such.

"My observations are that the silt layer passes under the dunes * * *. I have dug trenches back in what we would ordinarily call the low land where the silt is plainly to be found and have dug trenches from that point into the dune so that if the particular soil layer that I am observing passes under the dune it may be so seen in the excavation, and I have found it to be the case that regularly such silt layers pass under the dunes in the Big Bend."

The relation of the sand dunes to the land in which they were formed may be seen in such dunes as have been cut across by the river affording a section, and numerous photographs were submitted indicating this relation. Inasmuch as the same relation may be seen in dunes now accumulating in the same valley it will perhaps be sufficient to refer to a single photograph in this connection. The photograph referred to is No. 30 of Texas Exhibit No. 51, the legend of which is as follows:

"View illustrating the relation of sand dune to the land on which it was formed. The bluff seen in this view represents a natural exposure made by the river cutting through a dune and through a trough or depression between dunes. The car stands in the trough at the base of the dune. The lower part of the bluff, consisting chiefly of sand, is to some extent obscured by loose sand and debris. Above this sand is seen layers of a dark colored material, which, upon examination, is found to be fine silty loam such as accumulated from the river water at overflow stages. Above this loam in the trough is found a few feet consisting chiefly of sand. When followed to the left in the picture, the loam layers may be seen to pass underneath the dune, indicating that the dune was formed subsequent to the accumulation of the loam. Above the loam layers may be seen a thin dark line, which upon examination, is found to represent a flood layer, indicating a flood which occurred at a time when the valley land in this trough or depression had not yet built to its present level. Following this flood layer to the left in the picture, it may be seen that it rises diagonally through the present dune, thus indicating that a considerable part of this dune has been formed subsequent to the date of the particular flood recorded by the loam layer. This view was taken in the Big Bend of Wichita County on the Texas side near longitude 98-38-49, latitude 34-8-42. The bluff faces in a westerly direction. The dune therefore, has migrated southward since the time of the flood referred to. The cottonwood trees seen growing on the dune, have reached their present stage of maturity since the dune came to rest at the locality in which it is now found."

At the present time one finds dunes building as a rule on and near the margin of the existing land and these observations indicate that in the past, as at present, such has been, as a rule, the location of building dunes.

Absence of Dunes from Land Areas Separated from the Sand Plain by a Water Channel.

An observation believed to hold in the main is that sand dunes do not form extensively on a land area separated by a water channel from the sand flat. (R.-7-3847–3852.) This observation is likewise very pertinent to the present investigations. It is a matter of observation that where a water channel borders a land area and separates it from the sand flat on such land mass no extensive dune formation is found. An illustration of this fact is to be seen at the Grandfield Bridge crossing of the Red River. It is known from the Dubois Survey that a part of the valley land covered with vegetation on the Oklahoma side at this crossing is more than forty-six years old. The principal channel of the river is now, and probably has been for a long time in the past, adjacent to this land. On this land are no dunes of appreciable size. If however, this belt of land on the Oklahoma side be followed upstream a mile or so where the channel normally lies against the Texas bluff and where a broad sand flat intervenes between the river channel and the valley lands it will be observed that at this locality dunes have built in the usual way on the river valley lands.

This condition is explained, of course, by the well known fact that sand, at least the heavier particles, is carried by the wind not continuously but through a succession of short journeys, the sand being frequently dropped to the earth and picked up again. All of the sand grains that are dropped, either in the stream or on the moist land adjacent to the stream, are lost to wind action. Only those sand grains that completely clear the stream and the moist land at either side can continue the journey. That a water channel does interfere with sand transportation will be apparent to any one who will observe conditions during a sand storm. It will be seen that much of the sand is carried within a few feet of the ground, and that while on the windward side of the stream the wind is carrying a heavy load of sand, when crossing the stream the load is lost, except for the lighter particles which float high in the air.

Migratory Dunes.

After their accumulation the dunes are in some instances and and to some extent migratory. This fact is illustrated in the accompanying profile of a moving dune in the Big Bend. The characteristics of the dune are a gentle or gradual slope on the windward side up which the sand is carried and a steep slope on the lee side. The degree of steepness on the lee side varies with the amount of vegetation or other impediments to the movement of sand. In the absence of vegetation the lee side of the dune may approach or assume the angle of repose of sand. The windward side is further characterized by an accumulation at the surface of such heavy objects as were imbedded in the sand, such as sticks, roots or gravel. The growth of grasses on the windward side is usually in bunches, each clump of grass occupying more or less of an elevation; the trees have roots more or less exposed, and the surface in general is as a rule pitted by the irregular removal of sand. In these respects the windward side is in contrast with the lee side where the dune surface is smooth and the sand is accumulating around such tree, grass and other vegetation as may be growing on that part of the dune. (Fig. 2, Page 44).

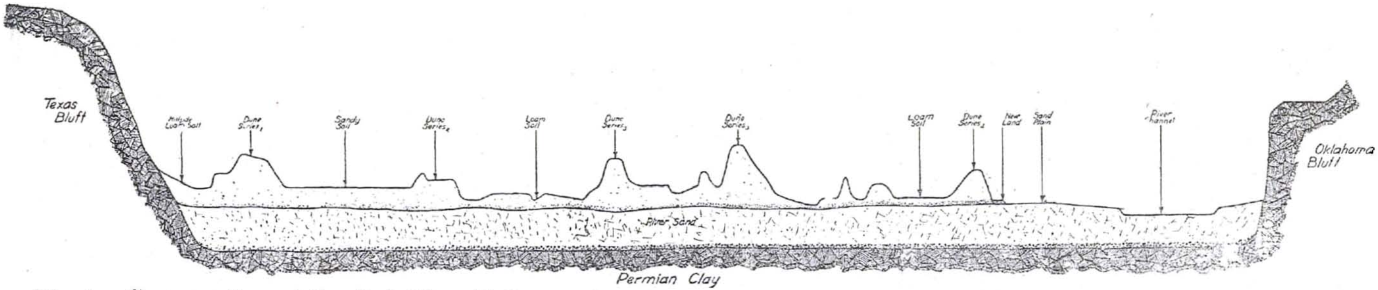

Fig. 1. Cross section of the Red River Valley in the Big Bend of Wichita County. Vertical scale, one inch equals 60 feet; horizontal scale, one inch equals 1500 feet. The elevations used in making the sketch are taken from the topographic map of the Big Bend, the height of the bluffs, sand dunes and other features being plotted true to scale.

Fig. 2. Profile across a moving sand dune in the Big Bend. Vertical and horizontal scale as indicated. Circles indicate location of stations at which the elevations were taken to be used in plotting the profile. Sloping windward side at the right; steep lee side at the left. A part of the same dune may be seen in the photograph of Plate 2, Figure 1.

The Sand Dunes in the Big Bend Valley.

The dunes extensively developed in the Big Bend valley are not scattered in a haphazard manner over the land. On the contrary the dunes there developed fall into definite series, there being at least four series of dunes representing four periods of dune building in this valley. Important principles as to the growth and formation of the valley lands may be clearly deduced from a study of the position and development of the dune series of this valley.

Dune Series One.

An inspection of the map of the Big Bend valley reveals the location of the dune series to which reference has been made. There is first of all a distinct dune series, marked on the soil map as ''DS1'' originating at the Texas bluff approximately one mile below the Grandfield Bridge, near longitude 98 degrees 39 minutes, and extending slightly north of east to and beyond the eastern limits of the Big Bend topographic sheet. At the place where the dune series ties onto the Texas bluff the dunes are narrow in width forming one continuous ridge of dunes except where cut across by streams and where partially interrupted by possibly wind blown gaps. Farther to the east it will be seen that the dune system instead of being confined to a single dune ridge scatters through a belt of country between fifteen hundred and two thousand feet in width. It will be noted that the north margin of the dunes remain essentially intact and in alignment while at the south side the dunes ''string out'' in an indefinite manner. By referring to the reduced topographic map of this valley it may be seen that this dune series again approaches the Texas bluff and ties on to the bluff near or below the Devol Bridge.

Dune Series Two.

From the physiographic and soil maps it will be seen that a second dune series comes onto the map approximately two thousand feet north of the Texas bluff and about one mile downstream from the Grandfield Bridge, marked "DS2." This second dune series evidently formerly extended farther to the west, but the westernmost part has in late years been destroyed by the river. This second dune series extends about due east and does not therefore quite parellel the first series. To the east on the Big Bend topographic sheet this dune series pinches out between dune series one and three, but comes in again as indicated on the Devol topographic sheet, and ultimately ties to the Texas bluff east of Burkburnett.

Dune Series Three and Four.

The third dune series observed in the Big Bend trends in a direction south of east. This dune series, or at least that part of it now preserved, is complex in character and is possibly capable of being resolved into more than a single series. It is apparent that this dune series likewise formerly extended farther to the northwest. To the east this particular dune series seems to extend from the mainlind onto "Goat Island." On the physiographic map the dunes of this series are designated by the symbol "DS3." Although cut out by the action of the river between the Devol public road and the Wichita Falls and Northwestern railway bridges the downstream end of dune series three is preserved, and the dunes are seen approaching the Texas bluff in the lower part of the Big Bend valley. Partly surrounding these older dune series and forming parallel to the present sand plain is to be seen the fourth series of dunes including those dunes that are not yet so far stabilized but that they are even now shifting in character. These dunes are marked as "DS4" on the physiographic and soil maps. These new dunes are forming adjacent to the present sand flat of the river.

They represent the latest dune forming activity and include dunes that are accumulating at the present time adjacent to the sand flat as dunes of the other series have accumulated in past ages adjacent to the sand flats of former time.

RELATIVE AGE OF DUNES.

Dune series one, marked DSI, on the map is interpreted as including the oldest dunes of this valley, the other series following in the order named. In support of this interpretation is first of all the position of dune series one which is the nearest of the several series to the Texas bluff. The observed place of formation of dunes in the Red River valleys is on the valley land adjacent to the sand flat of the river, and the dunes of dune series one according to these observations must therefore have accumulated before the valley reached its present size and form.

Dune series two is interpreted as being next younger than dune series one, this interpretation being based, among other things, upon the position of the dunes. By reference to the maps it will be seen that these dunes not only lie nearer the river than those of dune series one, but surround and for the most part enclose the older dunes. Dune series three in turn lies farther out in the valley than dune series two and shows the same tendency to surround and enclose the older dunes. At the present time both dune series two and three are being cut into and destroyed at places by the river. This is particularly true in the upper part of the valley where both dune series have been in part destroyed.

Dune series four which obviously contains the newest dunes, including those now forming, lies adjacent to the present sand flat of the river.

In grouping the dunes into series the writer is seeking to place in each series those dunes that are substantially of the same age. In other words the time interval between each series is believed to be appreciably greater than the difference of age between the oldest and youngest dunes of any particular series. That such is the case is more fully indicated in the detailed observations on the age of the dunes which follow.

Age Indications of Dunes.

New dunes in the valley are unmistakably characterized. They are either imperfectly covered with vegetation or if thickly covered are clothed with a type of vegetation differing from that found on old dunes. The soil conditions, or perhaps more properly absence of soils, are distinctive. Old dunes are equally distinctive in that they have a soil. With this soil and in part at least as a result of its presence is a characteristic vegetation, varying with the varying conditions of moisture and other growth conditions but invariably distinct from the vegetation of new dunes. The form or shape of the dune likewise becomes to some extent modified with age. In the ageing of a dune are found more or less definitely recognizable stages and in the paragraphs which follow certain of these stages recognized in the dunes of the Big Bend valley will be discussed. These successive stages are recognized in the soil conditions and in the plant growth, the soil conditions and plant growth being very closely related.

The Soil Characteristics of a New Dune.

As already stated a new dune can scarcely be said to have a soil. It is still in the shifting stage. The top sands which should form soil are loose, light colored, lack organic matter, are relatively coarse in texture and undifferentiated from the sand of the dune as a whole. However, when vegetation gains a foothold, more or less fine wind blown material lodges among the plants affording with organic matter from the plant remains a beginning in the mixture of materials which forms soil..

With regard to timber growth as a rule a shrub willow takes possession of the dune. Cottonwood not infrequently is intermixed with willow and in some instances young cottonwood are observed to come ahead of willow. How long the dune continues, in what may be called the willow growth stage, is undetermined in years. However, in time the willows disappear and a later stage, although still a new dune, includes cottonwood as the dominant timber growth.

This condition of a new soil or absence of soil accompanied by willow and small cottonwood growth is illustrated in the dunes of dune series four, the newest dunes of the valley. (See Plate 1).

An appreciably later stage in the ageing of dunes is that in which a soil has developed to some extent. At this time the top soil of the dunes differs in some respect from that underneath, at least to the extent of the inclusion of more or less organic matter. The timber growth at this stage is chiefly cottonwood. This cottonwood timber growth as seen in the Big Bend presents the characteristics common to timbered lands, in that some of the trees have reached the age to which they are able to attain under the existing conditions and are dead or dying. Replacing the dead trees are other smaller trees of the same kind coming on. The undergrowth at this stage includes prickly ash and other shrubs. How long the dunes continue in this phase of soil and plant development is undetermined. Cowles, as I understand him, maintains that but one generation of cottonwood grows on a dune. However, in view of the varying age of the existing timber growth the idea that generation may follow generation of cottonwood on this land, suggests itself, and this I understand is the conclusion reached by Tharp.

This phase of plant and soil development is illustrated in the Big Bend by the dunes of dune series three. Maturity of soil conditions over that of dune series four is indicated not only by the prickly ash undergrowth but also by the presence of scattered pecan, hackberry and chittam, none of which have been observed on the new dunes. (See Pl. 6, Figs 1-2).

The soil conditions of dune series one and two differ in the increased firmness of the top soils and in the increased diversity of soil particles. In fact the increased diversity of soil particles is doubtless in part the cause of increased firmness. The difference in this respect between the soils of dune series one and two on the one hand and that of dune series three on the other is more pronounced and obvious than any other stage in soil development in these dunes.

The differences in vegetation are likewise equally well marked. Cottonwood which is the chief timber growth on the earlier stage is here wanting, or practically so, only an occasional cottonwood persisting. On the other hand at localities favorable to timber growth is found a hardwood growth including elm, pecan, chittam, hackberry and other trees. Much the greater part of the dunes of this phase of maturity, however, are destitute of timber growth. While these dunes thus present a contrast to dune series three, the differences between series one and two are much less marked and scarcely to be recognized except on more detailed observations on either soil constituents or plant growth.

That the several stages described represent actual stages in the development of dunes as physiographic features becomes the more evident when the observations made in this valley are checked against those made in other valleys up and down the river. The equivalent stages of dune series four and of dune series three are readily recognized throughout the valleys in general. The same is true of the next older series, dune series two as compared to the two younger series. The age differences between dune series one and two as already stated are much less pronounced than between three and four.

The same grouping of dunes into series determined by age characteristics is observed in all of the valleys where dunes have formed.

Relative Age of Dunes Indicated by the Top Soils.

In connection with the Red River investigations it occurred to the writer that the progressive changes with age in the top soils of dune which are obvious to the eye could possibly be farther demonstrated by mechanical analysis of the soils. For this purpose representative samples were taken from the several dunes series. These samples after being dried were passed through screens in order to mechanically separate the soil constituents. The screens used were the Tyler screens, made by the Tyler Company of Cleveland, Ohio The screen meshes used were 8, 14, 20, 48, 100 and 200. That is screens varying from 8 to 200 openings per lineal inch or from 64 to 40,000 openings per square inch. Mechanical analyses had previously been made of various soils in the river valley. The object of this examination of the top soils was to find the relative amount of fine material in the top soils. In taking the samples a cylinder was used having a diameter of about one and three-fourth inches. This cylinder was inserted into the soil to a depth of three inches. In this way a perfect core of soil was obtained for each sample. For this examination samples were taken as follows: From dune series number one, eleven samples; from dune series two, nine samples from series three, fourteen samples; and from series four, nine samples.

The results obtained from these mechanical analyses are shown in the following tabulated statement. (R.-7-3921-3925.)

TABULATED DATA ON THE TOP SOILS OF THE SUCCESSIVE DUNE SERIES IN THE BIG BEND. DEPTH, 0-3 INCHES.

Dune Series No. 1.

Soil hole number.	Near Longitude.	Near Latitude.	Percentage lodged on screens arranged according to size of mesh of screen.						Pass 200.
			8.	14.	28.	48.	100.	200.	
66	98-38-47	34-8-41	0	0	Tr.	8.7	67.5	13.2	10.6
67	98-38-46	34-8-41	0	0	.1	17.5	61 3	10.5	10.5
68	98-38-45	34-8-41	0	0	Tr.	6.5	46 7	18 7	28.0
69	98-38-44	34-8-41	0	0	Tr.	7.8	44.6	25.1	22.5
70	98-37-25	34-8-50	0	0	Tr.	10 3	61.0	16.4	12.2
71	98-37-24	34-8-50	0	0	Tr.	7.9	44.0	26.1	21.8
72	98-37-13	34-8-45	0	0	0	4.2	45.4	30.2	20.1
37	99-38-48	34-8-41	0	0	Tr.	7.0	55.2	17.8	20.0
73	98-36-45	34-8-55	0	0	0	2.3	38.7	34 5	34.5
59	98-37-29	34-8-54	0	0	.3	14.0	44.4	15.9	25.4
100	98-36-35	34-8-5	0	0	Tr.	3.6	56 2	24.2	16.0

Average amount of fine material passing a 200-mesh screen in top soil of Dune Series No. 1 in the Big Bend, as determined by analysis of eleven samples.....20 1%

Dune Series No. 2.

Soil hole number.	Near Longitude.	Near Latitude.	Percentage lodged on screens arranged according to size of mesh of screen.						Pass 200.
			8.	14.	28.	48.	100.	200.	
75	98-38-47	34-8-58	0	0	.4	5.2	31.4	31.4	31 4
76	98-38-48	34-8-58	0	0	Tr.	6.3	51.2	34.2	8.3
77	98-38-49	34-8-58	0	0	.5	9 0	50.0	30.0	10.5
78	98-38-50	34-8-58	0	0	Tr.	5.8	52 2	29.2	12 8
79	98-38-51	34-8-58	0	0	Tr.	4.7	46.9	36.4	12.0
80	98-38-16	34-8-57	0	0	Tr.	6.6	44.5	31.1	17.9
24	98-38-17	34-8-57	0	0	Tr.	8.2	45.7	27.5	18.4
99	98-38-43	34-8-28	0	0	Tr.	9.6	47.9	21.2	21.2
104	Near No 24	----------	0	0	.2	7.2	49.3	28.5	14.8

Average amount of fine material passing a 20-mesh screen in top soil of Dune Series No. 2 in the Big Bend as determined by analysis of nine samples...... 16.3%

Dune Series No. 3.

Central Part of Big Bend.

Soil hole number.	Near Longitude.	Near Latitude.	Percentage lodged on screens arranged according to size of mesh of screen.						Pass 200.
			8.	14.	28.	48.	100.	200.	
82	98-38-34	34-9-19	0	0	Tr.	8.2	69.0	19.4	4.3
83	98-38-35	34-9-19	0	0	Tr.	5.2	72.1	19.2	3.3
84	98-38-36	34-9-19	0	0	Tr.	5.2	71.3	19.2	4.2
85	98-38-26	34-9-21	0	0	0	5.9	69.7	20.9	3.4
86	98-38-25	34-9-21	0	0	Tr.	5.7	73.5	18.4	2.4
42	98-38-45	34-9-1	0	0	1.2	20.4	61.3	11.7	5.1
44	98-38-43	34-9-5	0	0	.3	13.8	64.5	13.8	7.4
105	98-38-31	34-9-20	0	0	0	3.2	68.3	24.2	4.2
28	98-38-17	34-9-15	0	0	0	3.5	53.3	35.6	7.5

Dune Series No. 3.

Goat Island.

Soil hole number.	Near Longitude.	Near Latitude.	Percentage lodged on screens arranged according to size of mesh of screen.						Pass 200.
			8.	14.	28.	48.	100.	200.	
88	98-36-50	34-9-13	0	0	Tr.	3.2	48.3	32.2	16.2
89	98-36-47	34-9-14	0	0	Tr.	2.0	55.5	34.6	7.8

Dune Series No. 3.

Northern Part of Big Bend.

Soil hole number.	Near Longitude.	Near Latitude.	Percentage lodged on screens arranged according to size of mesh of screen.						Pass 200.
			8.	14.	28.	48.	100.	200.	
90	98-38-11	34-9-33	0	0	Tr.	6.9	79.8	10.9	2.2
91	98-38-7	34-9-32	0	0	Tr.	3.2	73.5	20.2	2.9

Dune Series No. 3.

Oklahoma.

Soil hole number.	Near Longitude.	Near Latitude.	Percentage lodged on screens arranged according to size of mesh of screen.						Pass 200.
			8.	14.	28.	48.	100.	200.	
101	Sec. 23-5	S.-13 W.	0	0	0	1.3	53.0	42.2	3.5

Average amount of fine material passing a 200-mesh screen in top soil of Dune Series No. 3 in the Big Bend, including one in Oklahoma, as determined by analysis of fourteen samples	5.3%

Dune Series No. 4.

Soil hole number.	Near Longitude.	Near Latitude	Percentage lodged on screens arranged according to size of mesh of screen.						Pass 200.
			8.	14.	28.	48.	100.	200.	
92	98-38-13	34-9-39	0	0	19.5	29.3	63.2	6.5	.7
93	98-38-7	34-9-40	0	0	.4	3.0	64.9	18.4	3.2
94	98-38-12	34-9-39	0	0	1.2	30.4	63.3	4.5	.4
97	98-38-22	34-9-40	0	0	Tr.	6.7	86.0	6.7	.6
98	98-37-21	34-9-25	0	0	0	4.1	74.0	21.1	.7
102	Average 5 samples in dune cross section		0	0	2.3	41.4	50.7	5.5	.6
103	North point "Goat Island"		0	0	Tr.	4.1	72.2	21.9	.8
95	Sec. 23-5 S.-13 W. Oklahoma		0	0	0	5.5	82.0	12.1	.2
96	Sec. 23-5 S.-13 W. Oklahoma		0	0	0	2.8	67.5	29 0	.8

Average amount of fine material passing a 200-mesh screen in top soil of Dune Series No. 4 in the Big Bend, as determined by analysis of nine samples...... .88%

It will be seen that these analyses indicate a progressive increase with age in the amount of fine material in the top soils. The amount of material passing the finest screen, the 200-mesh or 40,000 openings to the square inch, is the most striking, varying according to these results from an average of less than one per cent. in samples from the new dunes, dune series four, to slightly more than twenty per cent. in the oldest dunes, dune series one.

It has been previously noted that in general appearance the soils of dune series one and two are similar. Accordingly it is not unxpected that the top soils of dune series two are found to contain almost as much fine material as those of dune series one, the average as obtained from nine samples being sixteen and three-fourths per cent. as against twenty and one-tenth per cent. in dune series one. In contrast to this are the much younger soils of dune series three, where the average fine material in the top soil appeared as five and three-tenths per cent.

The conclusion drawn from these analyses is that the fine material in the top soils of dunes undergoes a progressive increase with the age of the dunes. This increase in fine material is evidently one of the factors in the alteration of soils followed as it is by the alteration in plant growth, including successive plant associations until the climax stage of plant development is attained.

In a study of the alteration in top soils dunes present special advantages. Most soils include as formed a mixture of coarse and fine material. This, however, is not true of dunes. In the work of the wind the coarse material of the sand bed is left behind while the very fine material is lifted high into the air and entirely removed. The dune includes sand grains of selected sizes such as the wind is able to lift and transport short distances, without dropping and finally to push up the sides to the crest of the accumulation dune. The result is the accumulation of sand having the grains of uniform size within narrow limits. The dune begins its life history, therefore, with a soil of uniform sized grains. The pronounced increase, in the relative amount of fine material in the top soils of the dunes is therefore accepted as an age characteristic.

The Actual Age of the Dunes.

Although the relative age of dunes in the river valley is indicated by the character of the top soils, their actual age remains unknown. If, however, it be assumed that age of any one of the dune series, as for instance the youngest, can be approximately determined by its timber growth, and if uniformity in the rate of accumulation of fine material in the top soils be assumed, an actual minimum age can then be computed for all of the dunes. Calculations of this kind were given in the testimony. (R.-7-3931.)

CAUSES OF INCREASED FINENESS IN TOP SOILS OF DUNES.

The agencies which operate in soil formation in the dunes are doubtless essentially the agencies that bring about soil formation elsewhere. When first accumulated, as already noted, dunes consist of sand grains approximating uniformity in size. They include at this time such material as the wind is able to transport no more than a short distance beyond the margin of the sand plain of the river, which is the source of supply, the very coarse material being left behind and the very fine entirely removed. However, once cut off from the source of supply as by an intervening strip of vegetation covered land the dunes no longer receive additions of sand of this degree of coarseness, and after coming to rest or approximately to rest, soil formation begins. Thereafter alteration in the soil materials so far as concerns mechanical constituents is necessarily in the direction of increased fineness, as coarse wind blown material can no longer reach the dunes.

Disintegration of Soil Particles.

Agencies bringing about disintegration of rock particles operate universally over the earth's surface. In the processes of decay, rocks fall into smaller particles. Heat and cold, acting alternately bring about expansion and contraction resulting in fracturing the rocks. By reason of the expansive force of ice freezing promotes fracture of rocks and materials. Solution, in so far as it operates, reduces the size of the mineral particles affected. In estimating the effect of these agencies on sand dunes and the time required to bring about changes, it is necessary to take into consideration the character of the sand of dunes, which is chiefly silica, a mineral very resistant to these disinetgrating agencies. Increased fineness in the top soil of sand dunes if brought about entirely by the ordinary agencies of decay would necessarily be a very slow process. An appreciable change in the texture of the top soils of dunes attributed to these agencies, therefore, would indicate long intervals of time.

Addition of Fine Material to the Soil by the Decay of Plants.

The decay and disintegration of plants adds fine materials to the top soils. Since these dunes became stable successive generations of grasses, weeds, shrubs, and trees have grown to maturity and decayed. In the woody structure of plants are included, more or less inorganic material such as remains as ash when the plants are burned. Upon decay this plant ash or a part of it becomes an ingredient of the soil and adds to the relative fineness of soil particles.

Wind Blown Material in the Soil

In connection with the work of the wind it was stated that the very fine material taken by the winds are lifted into the air and entirely removed. The distance these lighter materials are carried is unknown and the place where the fine dust ultimately falls has not been determined. That it becomes widely scattered is certain, and that some of it settles on the dunes as on other lands is a reasonable assumption.. If this is true, the dunes in the valley are constantly receiving some fine material from this source, bringing about increased fineness in the top soils roughly proportionate to the age of the dunes.

Dust Settling from the Atmosphere.

That dust in small quantities is very generally present in the atmosphere is a fact made known by a number of scientists. The slow accumulation of dust from this source affects all land more or less. On the high early Pleistocene terraces of the Red River are loess deposits which in the vicinity of Bridgetown reach a thickness of about thirty feet. (R.-7-3837.) The loess deposits are by some regarded as including chiefly dust deposited from the atmosphere. If loess deposits have accumulated to a thickness of thirty feet, since early Pleistocene time, it is not unreasonable to assume that similar materials deposited from the atmosphere have materially affected the top soils of the older dunes in this valley.

It is thus shown that among agencies operating to bring about increased fineness in the top soils of dunes are: (1) Decay, disintegration and partial solution of the soil particles, a process operating slowly in the case of a dune composed of siliceous sand; (2) decay in plants, thus adding the inorganic constituents of ash of the plant stem to the soil, a process by which the fine materials of the ash are added to the soils; (3) plant roots traversing the soils, promoting partial solution and hence reduction in size of soil particles; (4) fine wind blow material gathered from the sand plain of the river; and (5) atmospheric dust which settles generally over the land and is derived from unknown and probably various sources.

There are doubtless other agencies affecting the top soil However, while it may be difficult to recognize all the agencies operating and the relative importance of each, it is possible to recognize the result which is a gradual development of a soil with diversity of soil particles in contradistinction to the loose sand of approximate uniformity of size of particles of the original sands of the dunes.

WORK OF THE UNITED STATES BUREAU OF SOILS ON DUNES.

After the discussion on the top soils of dunes and on soils in general in this valley had been presented, the United States called into the case certain men of the United States Bureau of Soils, including H. H. Bennett, L. B. Ohlmstead, B. H. Hendrickson and others. The purpose of calling in these men was to check the observations made by the State of Texas on dune soils and on soils in general. With regard to the top soil of dunes their results may be briefly stated as follows in terms of materials of sufficient fineness to pass a 200-mesh screen: For Dune Series 1, 18.5%; for Dune Series 2, 15.7%; for Dune Series 3, 12.5%; and for Dune Series 4, 8.2%. (R. 9-5092-5098).

Upon comparing these results with those previously obtained by the writer it will be observed that with regard to the question of relative age of dunes the results are in agreement to the extent at least of indicating that the older the dune the higher the percentage of fine materials in the top soils. As regards Dune Series 1 and 2 it will be seen that there are no material differences in results. For Dune Series 1, the writer's average of material passing a 200-mesh screen is 20.1%, as against 18.1% in this check test; and for Dune Series 2, 16.% as against 15.7% in the check test. In Dune Series 3 and 4, however, the differences in this respect are material. The writer's test on Dune Series 3, indicated an average of 5.%, passing the 200-mesh screen, while Bennett and Ohlmstead obtain an average of 12.5%. In Dune Series 4, the differences in results are much greater, the writer's average being less than one per cent, while theirs is in excess of 8%.

The method of treatment of these samples of top soils were intended to be the same and probably were essentially so. In the methods of taking the samples, however, there were differences, which may have materially affected the results. As already explained all samples taken by the writer were essentially cores of soil. That is a hollow cylinder was pushed into the ground to a depth of three inches and upon removal brought with it a core of soil to that depth with no possibility of including an undue amount of soil from any particular level in the three inch sections. The method of taking samples followed by Messers. Bennett and Ohlmstead as described by them was to first excavate into the soil and to take a sample to the depth of three inches from the side of the excavation by means of a shovel.

A sample for this purpose should contain a true and proper amount of soil from each inch or fractional part of an inch of the whole three-inch section. When a shovel is used there is necessarily a breaking down and caving of the soil at the sides and particularly at the tip of the shovel, the result being possibly an imperfectly proportioned sample.

Whatever may be the explanation of the considerable difference in result with respect to Dune Series 3 and 4, the differences are not such as to affect the conclusion of this observation, namely that increased age of dunes is accompanied by a relative increase in the fine materials of the top soils.

Mr. H. H. Bennett of the United States Bureau of Soils states (R.-9–5129.) that he had read the testimony in the case and that he understood the writer's conclusions to be that the fine material of the top soils of dunes came from the atmosphere, and based his discussion on that understanding. How imperfect was his understanding of the testimony will become apparent by referring to the writer's testimony on this point where the following statement was made and was available to him at the time his testimony was given:

"* * * I will say in that connection that settlings from the atmosphere would not be the only factor operating in making fineness in the soils of the dunes, that is to say, sand piled up will of itself gradually disintegrate, particularly when it has a lot of vegetation overlying it with the roots running through the sands and the juices or acids of the roots operating on the sand, also the organic matter of plants growing and falling into the sands all will influence the fineness of the top soil. So that the factor of settling from the atmosphere is not the only one concerned in increased fineness of top soils in such an accumulation of sand. However, the principle involved does not materially differ. The point that is sought is to find first if there is an increase in the amount of fine material which might be epxressed as an increased loaminess of the top soil, increased amount of loam in the top soil; hence the idea that I had in mind apparently could be followed regardless of what particular factor may have been influential in increasing the fineness of the top soil. * * *." (R.-7-3928.)

AGE AS INDICATED BY BORDERING BLUFFS.

The bordering bluffs in many cases may be used in determining relative ages of the valleys or parts of a valley. A bluff recently abandoned by the river is in general steep and abrupt, but after being abandoned gradually decreases in steepness, the slope becoming progressively gentle with age. Given uniformity of materials and conditions therefore the slope of the bluff will indicate the relative age of the valleys or parts of a valley. There are however, many conditions which modify the operation of this process. First among these conditions is the character of the material of which the bluffs are composed. In some localities the bluff may consist chiefly of rock, which of course is resistant to decay. At other localities the bluff may consist of layers of rock, alternating with softer materials. Under either of these conditions the bluff retains its steepness for relatively long periods of time. On the other hand the bluff may consist of soft materials, either loess, clays or shales. These materials although but little indurated may nevertheless behave differently under processes of decay. The loess in particular frequently maintains in erosion and disintegration a vertical front, practically regardless of age.[1]

[1]Dr. J. A. Udden in a personal communication has suggested the following explanation to account for loess bluffs weathering vertical. Assuming that the loess is wind deposited it certainly accumulated very slowly, and in the course of its accumulation there grew up successive generations of plants of various kinds, including grasses, weeds, shrubs and in many cases timber growth. The roots of these plants, particularly the larger plants such as shrubs and trees, must

In addition to materials of which the bluffs are composed there are other factors affecting the development of the slopes. Thus springs emerging at the foot of a bluff may assist in maintaining the steepness of the bluff. This effect is brought about doubtless by the fact that the water-soaked material at the foot will under these conditions disintegrate more rapidly than the less water-soaked material higher in the bluff, thus maintaining the steepness of the bluff. Timber growth on and at the foot of the bluffs presumably assist in maintaining the steepness. The presence or absence of a backwater stream flowing adjacent to the bluff likewise affects the rate at which the bluff loses its steepness. There are doubtless other factors and conditions that should be enumerated in this connection. However, notwithstanding all such factors the general observation holds that the relative age of the valleys may in general be determined by the characteristics of the bluff. In general parts of the valley, which upon other characteristics are classed as the oldest land of the valley, have the most gentle or gently sloping bluffs, while the newest valleys or newest parts of each valley, have in general relatively steep bluffs. Where exceptions are found to this rule, the explanation is usually apparent either from the character of the materials of the bluff or from some one of the other conditions mentioned.

While the bluffs are thus of aid in determining the relative age of valleys, no opportunity has been found to utilize the bluffs in determining actual age in years.

Among other physical features of the river valley should be mentioned, perhaps the flats between the dunes. In most cases these flats as elsewhere stated merely represent so much of the original river valley land not covered by the accumulation of dunes. In some cases of course the river at overflow stages has passed across such lands and has left an accumulation of sedi-

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certainly exert in the course of their growth lateral pressure on the accumulating deposits. In the main the roots penetrate downwards so that the compacting of the deposits tends along vertical lines. The stems and roots of plants upon decaying likewise create lines of weakness. It is this lateral compacting by plant growth according to Dr. Udden's suggestion that accounts for the loess weathering to vertical bluffs.

ments or in some instances has produced scour channels. There are also local gouges caused by the river at overflow stage Such gouges, forming in some instances small ponds of water, are particularly likely to occur at the place where the river water in overflow stage passes from higher onto lower land, the gouge being due to the increased velocity of the water in passing down the slope. These last named features however, have not been found to be of service in determining the relative or actual age of the river valley land.

The discussion of the alluvial fans of the river valley with regard to the age of the land will follow the discussion of the timber growth.

AGE AS DETERMINED BY GEOLOGIC FEATURES.

It is probably true that the flood plain of this river is of so late date that extinct animals cannot be expected to be found included as primary fossils in the sediments. At least no such fossils were obtained in connection with this investigation. However, remains of the existing bison, and some assocated animals were taken from various places in the valley.[1]

The bison is known to have become extinct in this valley so recently as some forty or fifty years ago. The recovery of the bison remains therefore has no particular significance as to the age of the valley, the range of this species being from probably late Pleistocene to the present. It was thought possible however, that chemical analyses of the bison and other bones might contribute information of some value in this connection. Accordingly chemical analyses were made under direction of Dr. E. P. Schoch of a number of bones from the valley land, checked by the analyses of two bones from the known Pleistocene terrace, and a recent bone. The result of these analyses are indicated in the accompanying table. (R.-7-3967).

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[1]The writer is indebted to Dr. O. P. Hay for having reviewed the identification of all bison remains obtained from this valley.

TABULATED STATEMENT OF CHEMICAL ANALYSES OF FOSSIL BONES.

Sample No.	Moisture at 110°C.	Volatile matter.	Phosphoric acid, P_2O_5.	Calcium oxide, CaO.	Silica and other matter insoluble conc. HCL.	Iron oxide, Fe_2O_3.	Aluminum oxide Al_2O_3.
Recent bone							
No. 24	4.20%	37.59%	22.73%	31.80%	0.60%	1.05%	1.50%
Bones from the river valley							
No. 4	10 40%	22.68%	17.78%	32.88%	1.86%	1.24%	1.18%
No. 5	8.90	24.41	23.89	35.45	0 68	0 29	0.33
No. 15	7.52	17 81	19.80	39.60	2 96	0.82	0.60
No. 20	8.39	27.58	25.68	29.74	0.26	1.91	3.08
No. 23	7 14	20 37	25.60	30.10	0 15	11.21	2.87
No. 26	5.72	20.05	27.74	37.40	11.37	0.95	1.21
No. 27	7.48	23 98	22.75	36.45	0.18	0.85	0.85
No. 28	7 18	16.86	25.73	33.80	12.58	1.07	Trace
No. 31	8.40	20.45	25.74	31.32	1.48	3.06	1.35
No. 32	6.15	13.95	23.09	29.58	17.70	3.83	4.73
Pleistocene bones							
No. 25	8 22%	25 60%	19.27%	31.70%	6.48%	0.71%	2.66%
No. 30	7 02	16.87	24.10	34.00	7 06	1.17	Trace

The localities from which these bones were obtained are as follows:

No. 4. Scapula of bison, found about one-third mile above Grandfield Bridge, at a depth of three and one-half feet from the surface. Locality 4 on geologic map.

No. 5. Astragalus of bison, same locality and depth as No. 4.

No. 15. Pelvic bone of bison, found approximately one mile above the Grandfield Bridge.

No. 20. Bison bones, found at the entrance of Wild Horse Creek into the valley. Locality 20 on geologic map of the Big Bend topographic sheet (not republished).

No. 23. Part of rib from locality in the Big Bend, 4,000 feet from the Texas bluff, found in sand dune at a depth of seven feet. Longitude 98-38-18.

No. 26. Buffalo spine from about one-third mile west of Bridgetown and near locality 4 on geologic map of the Grandfield topographic sheet.

No. 27. Part of vertebra of bison from same locality as No. 26.

No. 28. Bison bone, from same individual as skull shown in Plate 4, found 2,000 feet west of Bridgetown at a depth of six feet from the surface. Locality No. 2 on the geologic map of the Grandfield Bridge sheet.

No. 31. Bone, unidentified, from sand dune at depth of three feet. Locality No. 31 on the Big Bend geologic map (not republished). Longitude 98-38-45, latitude 34-08-50.

No. 32. Bone, probably bison, found imbedded in clay at a depth of two feet and four inches. Found in the valley about 3,000 feet north of Wichita Falls and Northwestern railroad and 1,000 feet from the Texas bluff.

Nos. 25 and 30. From the Pleistocene terraces on the Texas bluff, near Bridgetown.

In the case of all bones used in making chemical analyses the condition of ocurrence is such as to indicate primary fossils Nos. 4 and 5 are probably of the same individual and show no erosion, the thin margins of the scapula being well preserved. Nos. 26 and 27 occur under similar conditions. No. 15 includes pelvic bones. At the locality from which No. 20 came are found numerous bison bones including teeth and parts of the skull.

The skull, Fig. 1, Pl. 4, and associated bones, No. 28, are found in the re-entrant valley of a small stream imbedded at a depth of six feet.

The localities at which the fossils were found are indicated on the geological maps of the Grandfield, and Big Bend topographic sheets. Of these the Grandfield Bridge sheet is reproduced in this report.

In November, 1921, and while testimony in this case was being given in Washington, Mr. P. T. Seashore, working under the writer's direction, discovered parts of a bison skeleton in the river valley near the northern margin of the Devol Bridge topographic sheet, at a distance of about 3200 feet from the Texas bluff. (Longitude 98-36-30, latitude 34-08-55.) This skeleton was found in a slight depression. The parts preserved included the greater part of the four legs and parts of the scapulae. The animal had evidently become mired in the pond, only that part of the skeleton remaining, which was in the mud. The bones are well mineralized and have the characteristics of fossil as distinguished from recent bones. (Plate IV, Fig. 2.).

The skeleton obtained at this locality was shipped to Washington. However, owing to delay in transportation it was not received until taking of testimony had been completed and it was not possible, therefore, to submit evidence relating to this fossil.

With regard to these analyses it will be seen that the bones obtained from the river valley are mineralized and in some instances are as much mineralized as are the bones from the known Pleistocene terrace. On the other hand it is observed that the bones are not uniformly and consistantly mineralized to an equivalent degree among themselves nor by the same chemical agencies. The votalile matter is considerably lower in the fossils than in the recent bone. The fossil bones have on the average acquired an increased amount of silica although in some bones the amount of silica is not at all increased. One bone obtined from a sand dune was notably high in iron.

The mineralized condition of the bones of the bison and other smaller animals found imbedded in the river valley lands suggests with other features a considerable although undetermined age of the valleys.

AGE OF THE RIVER VALLEY AS INDICATED BY THE SOILS.

The soils in the Big Bend valley were studied and mapped by the writer, assisted by Mr. P. T. Seashore. Soil maps were made for the four topographic sheets covering this valley, the Grandfield Bridge, Big Bend, Devol and Brushy Creek sheets. Of these maps the Big Bend sheet is reproduce in this bulletin. The soils were treated from the standpoint of diversity, succession and thickness.

Diversity of Soil.

The diversity of soil is expressed by the soil map. With regard to age characteristics the writer expressed the opinion that diversity of soil in this valley was an indication of considerable age. The particular agencies mentioned as bringing about diversity of soils progressive with age were the following: The river valley land when first built in by the river is level or flat, sandy and presents in a broad sense but little diversity. However, when subjected to overflow by the river the soil is modified by the accumulation of very fine sediments, which settles out of the river water. The soil at this time is therefore characterized by a relatively thin covering of fine loam or silt. Underneath this silt forming the sub-soil is found the river-accumulated sand. Soil of this kind was placed by the writer under the generalized classification of river-loam soil. In the areas which have scarcely received any part of this overflow silt and which are limited in extent, the soil is sandy and was designated merely as new soil. A further step in the differentiation in the soils is the accumulation of sand dunes which are piled by the action of the wind onto the river valley land. The presence of the wind blown sand introduces an entirely different type of soil. The dunes themselves, as has already been explained, undergo modification progressively with age presenting variation in soils. In addition to the wind blown sands sediments are washed in directly from the bluffs or carried in by the numerous streams which enter from the high lands, forming fans. The material of the alluvial fans differs in character from that carried by the river. Since therefore the land in the course of time receives accumulation in the form of silt in the overflow of the river, sand dunes resulting from wind activity, and alluvial fans resulting from wash from the adjacent bluffs, there is developed increased diversity in soil progressive with time. Aside from stating that such increased diversity of soils indicates considerable age the writer did not attempt to determine actual age from these observations.

With regard to diversities of soils scientists representing the United States Bureau of Soils in their report made subsequently on this valley contended that great diversity in soils indicates youth. In their classification the soil mentioned by the writer as river loam is broken up according to its minor modifications into numerous soils. No objection is made to the breaking up of one general type of soil, mapped by the writer as the river-loam, into various soil types, provided of course that such subdivisions can actually be recognized. The principles on which the writer's arguments on age of this valley are based are not affected by the more detailed subdivisions of the soils in the newer parts of the valleys.

Age of the River Valley Lands as Indicated by Succession of Soils.

The soil in this river valley land does not consist of a single soil, but as a rule consists of a succession of soils, one overlying the other. Almost without exception in excavating in this valley there can be recognized the first or original valley land soil, that is the soil that first accumulated and on which vegetation undoubtedly had its first undisturbed growth. This soil corresponds in a general way to that which the writer has mapped in the newer parts of the Big Bend as river-loam soil. Overlying the river-loam soil in all the older parts of the valley are soil materials subsequently accumulated to varying depths.

As in the case of diversity of soils no attempt is made from succession of soils to determine actual age. The fact, however, of the existence of successive soils in these valleys, together with the reasonable assurance that each soil stratum represents changing conditions, and required time for its accumulation, and undoubtedly supported its own characteristic timber or plant growth, is in accordance with the general view that the land of the valley is of considerable age as measured in years.

Age of the River Valley Land as Indicated by the Thickness of Soils.

Soil materials have accumulated above the original river-loam level in this valley from one to eight feet in thickness. In the sand dunes of course there is a much greater accumulation of wind blown materials, amounting in some instances to as much as twenty or twenty-five feet.

The thickness of the soils together with the timber growth was used as a basis in making some estimates as to approximate age of the valley lands. In this conection the soil section at certain localities was described in detail and illustrated by soil tubes showing the actual thickness and character of the entire soil section.[1]

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[1]The soil tubes of which a total of twenty-five tubes representing twenty-three soil sections were submitted were put up in the following form: An excavation was first made through the soil to the underlying river deposited sand. From the sides of this excavation there was then taken from each recognizable stratum, enough soil to fill the tube an amount equal to the thickness of the soil stratum. Thus a five foot soil would require a five foot tube, and the tube when filled would show each soil layer according to its true thickness and character. The excavations were made by pick and shovel, except in the high dunes where a soil auger was used.

The increased thickness of soils obviously would be on the average an indication of increased age. Particularly is that true in valley land that is being built by the settling of silt from the river water and by the accumulation of wind blown sediments and by materials washed from the bluffs.

One of the localities on which detailed observations were made is located back of the Dune Series No. 1, at or near longitude 98-38-41, and within about one hundred and twenty-five feet of the Texas bluff (locality 35 on the soil map). The soil at this locality down to the original river sand has a depth of eight feet. An elm tree growing in this soil upon being cut was found to have an age of one hundred and eleven or one hundred and thirteen years, as indicated by the growth rings. Examination was made of the tap or brace roots of this tree, which were found to be imbedded in the soil to a depth of from three to six inches. Measuring, however, to the center of the tap root there would possibly be indicated a fill of about nine inches above the center of the tap root. Assuming that the soil has accumulated at an approximately uniform rate and that as much as one foot has accumulated within the life of this tree, we should have indicated here soil accumulation at this locality at a rate approximating one foot per century. Upon this basis a rough estimate of the time necessary to accumulate the eight foot section would be in round numbers eight hundred years. The locality as will be seen from the soil map is back of Dune Series No. 1 and near the Texas bluff.

With regard to the estimate of age as indicated by this soil section the original testimony (Record page 3941) is in part as follows:

"With regard to the soil sample at this particular locality I wish to repeat in a general way the statements about time being required for the accumulation of each successive soil stratum from the point that is above the material identified as river sand to the surface. I will not attempt to further describe each particular stratum except to say that there seem to have been materials forming top soil from time to time and on which, from their organic content and their appearance, I would naturally infer that vegetation was growing. Now, I have stated with regard to the soil tube previously introduced that I had no basis by which to calculate into years the length of time required to build the soil. With regard to the locality immediately in question at this time, there is a tree growing quite near where the soil sample is taken and I have observed the roots and root system of the tree to see if it showed any indication of beginning its growth when the land level was much lower than now. I found that the lateral roots or brace roots were quite near the top of the present soil, between three and six inches under the present soil. I therefore interpreted the fill at that place to be from three to six inches. However, those tap roots are of considerable size and if they were put out a little under the original soil and also grew and expanded, the center of the root remaining about where it started, but all sides growing, the top might have been at the top of the soil if the soil had remained stationary. So that I should say the fill there must be estimated at something like nine inches since that tree put out its brace roots. The amount of fill may be a little more or it may be a little less than that exact amount stated; I obtained my results by digging with a shovel down to the roots and making a measurment, and that is a close statement of the amount of fill. * * *

"I wished to use this tree to try and get an idea of the age of this soil. I met with the difficulty that there are numerous strata of soil—several strata of soil in the section. I cannot tell that each stratum accumulates at the same rate as each other stratum, in other words, there is no assurance of a uniformity in the rate of the accumulation. Therefore, I could make no progress in estimating the age of the land unless I make, for convenience of getting a concrete idea, some kind of an assumption as to the rate of progress. And not knowing whether the rate of progress on the average was faster than in recent years and not knowing whether the rate of progress of accumulation of soil was not so fast in former as in recent years, I merely assumed that probably the rate of accumulation taken stratum by stratum was something like an average uniformity. By that I do not mean that each stratum was necessarily the same length of time in accumulating the same number of inches, but taking stratum by stratum and strike an average, that you can then apply the supposition that something like uniformity prevailed. The tree, as stated, is certainly above a hundred years, but I would rather consider it simply as a tree one century old in this estimate, all of which is an approximation. Then I would also feel that to be safe we should think of those brace roots as coming out down as much, we will say, as a foot below the present surface, if we wish to be safe, and then with that estimate we shall get the result at something like 800 years as a minimum age for the accumulation of that soil, and since the whole estimate is a very rough approximation I would not wish to go beyond that statement."

AGE AS INDICATED BY TIMBER GROWTH ON ALLUVIAL FANS.

The timber growth of the river valley will be discussed by Professor Tharp, and reference will be made here to only a few trees. As a means of making an approximate estimate of the time interval involved in accumulating fans in front of the streams entering from the high land, the writer cut and made observations on two trees. One of these trees found growing on an alluvial fan entering the valley near longitude 98-39-9, latitude 34-08-39 (tree No. 26 of the tree map of the Big Bend topographic sheet), when cut was found from the growth of the rings to have an age of about one hundred and fifty years. Excavations made around this tree uncovering the tap roots indicated that the main tap roots were covered by fill or wash from the bluff to a depth of no more than a few inches. An excavation made at the side of this tree indicated the total fill at this place above the river deposited sand amounted to about four feet, varying from three and one-half to four and one-half feet. If the fill around the tap roots of the tree represents an interval of time coincident with the life of the tree amounting to one hundred and fifty years, and if it be assumed that the rate of fill in front of this small stream has progressed at a uniform rate, the length of time necessary to accumulate this amount of fill as will be seen is six hundred years. That this represents the actual interval of time during which fill has been accumulating at this locality is not to be assumed. It does appear, however, that this method assists in giving a concrete idea of the fact that some centuries have elapsed since this stream began to accumulate a fan on the river valley land.[1]

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[1]Mr. Janes expressed the opinion in his testimony that this particular tree grew not in the river valley proper, but on the bluff at the side of the valley. While the trees stood near the bluff, a soil boring made by the writer between the tree and the bluff established the fact that the river deposited sand extends under the tree and that the tree, although near the bluff, is in fact in the river valley. The relation of this tree to the bluff may be seen from the photograph, Figure 2, Plate 3.

The second tree cut for the purpose of making an estimate on the age of the river valley land is located in the river valley in front of the entrance of Wild Horse Creek (tree No. 25, as shown on the timber map). This tree, an elm, was found from the growth rings to have an age of about one hundred years. Its tap roots were covered to a depth not in excess of six inches. The whole soil section at this locality to the river deposited sand was found to be four and seven-tenths feet. According to these measurements and allowing one foot as the amount of fill in one century, and assuming uniform rate of the accumulation of sediments it would appear that the sediments washed in by the river and the tributary had been accumulating here during an interval of between four hundred and five hundred years.

In conection with this locality in front of Wild Horse Creek, however, it is to be observed that this creek heads several miles inland and becomes therefore in times of flood a considerable stream. Within the valley it has in places excavated a trench or channel for itself. It cannot be assumed therefore that deposition at this place within the valley of this stream has been continuous throughout the whole history of the valley. The soil on the particular spot where the tree is growing may have been reworked more than once by the stream itself. The only conclusion which this particular tree affords therefore is that the soil immediately at this spot has not been reworked within an interval estimated under these observations at four hundred or five hundred years. The actual age of the valley during which the stream has been operating may be several times as long.

The contention advanced by ecologists representing the United States and Oklahoma that all of the trees in the valley of an age in excess of one hundred years began their growth on islands is very properly characterized in the opinion of the Supreme Court as "speculative and not a proper basis for judgment." The absurdity of this contention in regard to the trees is very well shown in the case of an elm known as "Tree No.

12" located in the depression occupied by Wild Horse Creek.* Upon being cut this tree was found to have attained an age of one hundred and forty-one years. (R-8-4344). The soil in which the tree grew is unlike the soil formed from river sediments. On the contrary it is soil derived from the red Permian clays of the adjacent uplands carried in and deposited by Wild Horse Creek. The processes incident to river transportation result in the complete pulverization of the earth and the separation by flotation of the fine clay-like materials from the sand. Transportation by the lateral streams is intermittent, the material is carried relatively short distances, is moved quickly, and the separation of materials is imperfect, resulting in soils differing from those formed from river-borne sediments. The tree referred to very evidently began its growth on land attached to the mainland and in soil carried into the valley from the mainland by the small stream now known as Wild Horse Creek.

How long the land was attached to the mainland before the small stream established itself and deposited the soil in its valley is undetermined. Whether the particular elm in question belongs to the first generation of elms that grew in this soil or to some succeeding generation is unknown. The first timber growth on new land in this valley is invariably willow and cottonwood and the length of time that these trees hold possession of the land before giving place to the hardwood timber growth is likewise to be taken into consideration. That conditions in this part of the valley one hundred and forty-one years ago were as at present is witnessed by this elm. For how long previous to that time the conditions have been as now must be determined on other evidence.

In closing the discussion as to the age of the river valley land, it may be said that the attempt here has been to find methods which may be available in determining the approximate age of river valley land. It is not asserted that ac-

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*The location of this tree is shown on the Tree map of the Devol Bridge topographic sheet which is not reproduced in this publication. The approximate location which is near longitude 98-35-53 and latitude 34-08-34 may be determined from the reduced topographic map, in pocket. The distance from the Texas bluff is about one-half mile.

tual ages have been established in any case. It is believed, however, that an age far beyond that of one century is established for all of the older part of the Big Bend valley and for similar valleys on the river.

THE DESTRUCTIVE WORK OF THE RIVER.

Along with land building there is of course the destructive work of the river including erosion of the banks and the scour channels formed by the river when at flood stage. With regard to the erosion of the banks there is nothing in particular to be said, as this phenomenon is a familiar and recognized feature of the work of rivers in general. In the Red River erosion of the banks is often rapid, but does not differ otherwise from erosion on other rivers. The scouring activity of the river is of course likewise common to rivers in general. Owing to the relatively low lands of the river, together with the violence of some of the floods, the scouring activities in the valley land in the upper river is often very pronounced.

The larger scour channels at times cut off areas of relatively old land. Such a channel in 1920 cut off a part of the Curtis Creek valley. Less pronounced scour channels develop in many localities when the river overflows newly formed low lying and relatively incoherent land.

Emphasizing the considerable gradient of the stream, the rapid rise of floods, the heavy load of sediment carried, and the great width of flow in flood stage, the scientists who represented the United States and Oklahoma have elaborated the island building theory. To be sure many land areas are found to lie detached from the mainland. The detachment of one such area in Curtis valley was observed to take place while this suit was in progress. The detachment of another such area in Ayers valley was proven by lay witnesses to have taken place in the same way about 1902. Similar detachment of land areas are indicated in the Big Bend, Gilbert Creek and other valleys. That these isolated land areas were formed as a part of the mainland and have subsequently been detached by scour channels is a conclusion much more in accord with the observed habits of the river than the assumption that they represent land areas originating in the sand flat and now in process of being united with the mainland.

THE HABITS OF THE RIVER IN BUILDING ITS VALLEY LAND.

Rivers in general build their valley lands for the most part by depositing sediments on or against the existing land, and such in the writer's opinion is the controlling method of building by the Red River. However, as already stated, scientists representing the United States and Oklahoma contended that a different and unusual method of building the river valley prevails in the upper part of the Red River, the addition of new land being through the formation of islands, which subsequently became attached to the mainland. As previously explained if new land is added in the valley in the way usual to most rivers, that is by gradual deposition of sediments, or by accretion to existing banks, changes arising in this way would not be material to the suit since the boundary would in any case follow with the river. On the other hand if the new land formed is first an island and if this island subsequently becomes attached to the mainland this unusual feature of land building would perhaps not be covered by precedent in legal procedure. For this reason the habits of the river in building its valley lands became a problem of great importance in connection with the boundary suit.

It has already been shown that the scientists representing the United States presented two main contentions under this heading. The first is the island building theory; the second presented by Dr. L. C. Glenn is that the destructive work of the river proceeds at such rate as to entirely destroy and remake the river valley land within a period of one century. With neither of these propositions is the writer able to agree On the contrary it seems certain that the controlling method in the addition of new land to old in the river valleys both in the upper and lower river is by the process known as accretion, and that the making and destruction of the river valleys does not proceed at such a rate as to renew the valleys of the river within so short a period as one hundred years. In fact, the larger valleys are proven to be of an age much in excess of one hundred years.

With regard to the habits of the river in building the valley lands one cannot do better than to observe what is taking place at numerous localities where the valley land at the present time is being added to. In this connection we are concerned of course not with exceptional features but are seeking that which is the controlling process of adding to the river valley land. Likewise we are not in this connection concerned with the processes that build the valley lands to a high level, but are concerned only with those which extend or enlarge the valley. In the earlier pages of this paper the writer has described in some detail the processes which build the land when formed to an increased elevation above the river. The processes now to be described are those that extend and enlarge the river valley land.

THE PHOTOGRAPHIC RECORD.

To one who cannot visit the river, the building processes are perhaps best described through the use of photographs. For this purpose twenty-nine photographs were presented in this case. Of course the number could have been indefinitely extended since the river is in fact building at innumerable localities. Of these photographs six with their legends are included in this report. Reproduction of a large number of these photographs, although desirable, is not practicable. However, those included are illustrative of conditions common to all parts of the river. (See Pls. 7, 8 and 9; also Pl. 1).

In these photographs of the river two features of river building are repeatedly illustrated. It is observed first that when the river or a channel of the river after cutting or eroding the Texas bank turns away from the bank across the sand plain or sand flat there is thrown up invariably a sand bar-like accumulation of sand against the cut bank just below or downstream from the turn of the channel. Not infrequently the accumulation of sand under these conditions brings the sand plain to a level with the adjacent low valley lands. Under these conditions all that part of the sand plain or sand bed of the river which lies on the right side of the channel is thereby united to the Texas bank, and is united without having first been formed as an island.

The second feature illustrated in these photographs is that of the gradual spread of vegetation from valley land onto the sand plain of the river. If conditions remain undisturbed for a brief space of time, some weeks or some months, vegetation makes no inconsiderable growth riverwards. In addition to the spread from the older land, vegetation of course to some extent springs up over the sand plain, converting it into valley land.

In this connection the writer made the following statement:

> "The method of building which leads to the enlargement of the valley land is typically and usually the accumulation of new material adjacent to the old land when and at such times as the direction of the currents are such as to permit such accumulation. Then after such accumulation there is a spread of vegetation onto the new land converting what was sand plain into land in the ordinary sense.
>
> "Subsequent rises may destroy such new made land or they may cut into it or wash it, depending upon the course of the currents while crossing it. On the other hand such new made land may persist intact and build higher and be termed a part of the river valley." (R.-7-4071.)

The building processes as a whole are perhaps best illustrated in the photograph of plate one. The well derrick in this picture stands at the margin of the newly accreted level vegetation-covered land, younger in age than the sand dunes seen at the left. At the right in the picture is what may be described as accreting land. This land altho a part of the sand plain of the river stands at a relatively high level and is being reclaimed by the extension of vegetation from the mainland. Farther out is the sand flat with the Oklahoma bluff in the distance. Similar building of new lands are seen in the photographs of plates seven, eight and nine.

BUILDING PROCESSES AS ILLUSTRATED IN THE VALLEYS OF THE RED RIVER.

The photographs referred to as having been submitted in connection with the testimony, illustrate the building processes of the river valleys. To describe the observations in each valley in detail would unduly extend this paper and in order to economize space further reference will be made only to those photographs here reproduced. A more complete account of each valley will be found in the Record.

The first valley to be considered is a valley on the Texas side of the river at or just below the one hundredth meridian. As illustrating building in this valley two photographs were submitted of which one is here reproduced. This photograph (Pl. 7, Fig. 1) is taken at a locality where the sand plain is built up approximately if not fully to the level of the valley land. The vegetation is seen creeping out onto the sand plain and thus reclaiming it, making of it valley land in the ordinary sense.

Another valley in which the processes are recorded in the photographs is located near the Hardeman-Wilbarger County line on the Texas side of the river. Two views were submitted from this valley of which one is here reproduced. In this photograph as in the one taken at the one hundredth meridian, it may be seen that the sand plain, a part of which shows in the foreground has been built by the river fully to the level of the valley land at this locality and that the grasses are spreading and coming up through the sand. (Pl. 7, Fig. 2).

Another valley in which the building processes are here illustrated by photograph is Electra valley, somewhat above the Big Bend. Of the two photographs presented from this valley one is here reproduced. (Pl. 8, Fig. 1). This view taken a short distance downstream from the Electra Bridge, shows the sand plain of the river built almost to the level of the vegetation covered land, and the vegetation gradually spreading out onto and reclaiming the sand plain.

Another valley from which the building processes were illustrated is what is known as the Stein valley in Clay County. This valley is also on the Texas side of the river. The photograph taken looking upstream shows sand formed against the older land and being reclaimed by the growth of the vegetation. (Pl. 8, Fig. 2).

Similar conditions in the building of new land are seen in the photographs reproduced in plate nine, showing land building in Stanfield valley in Clay County; and in the Spanish Fort valley in Montague County.

Other photographs illustrating land building in the Big Bend valley and in Gilbert Creek valley were submitted. However, for these valleys detailed topographic maps are available which have the advantage over a photograph of depicting the valleys as a whole. By reference to the soil map of the Big Bend topographic sheet, it may be seen that while the river has been cutting recently at the northern part of the valley, beyond the turn or point of land downstream the river is building a considerable strip of river land (marked NS on the map, seen also in photograph Pl. 1) having been added within recent years, extending the land beyond the newest of the sand dunes. This extension of the new land beyond existing dunes, on which subsequently new lines of dunes will accumulate typifies the controlling building processes which prevail on this part of the river.

The building processes, as illustrated by these photographs, are in no sense exceptional. On the contrary the photographs illustrate the processes common to the river and seen in operation in all of the valleys.

INTERPRETATION OF THE HISTORY OF THE RIVER VALLEYS.

The habits of the river in building its valley lands, as well as the age characteristics of the valleys, if correctly understood, afford the basis for interpreting the history of the individual valleys. The oldest part of each valley as determined by its physiographic, geologic, soil and ecologic characteristics is found to lie adjacent to the bluffs. Around this older land is found successive additions of newer land.

The history of the formation of the Big Bend valley interpreted in accordance with these principles is as follows: (R.-7-4082). The oldest land of this valley is that which lies adjacent to the Texas bluff and medial with respect to the length of the valley. On the outer margin of this older land are found the dunes designated as dune series one. In accordance with observations elsewhere on the river we may be sure that this strip of land was built up first as low lying level river valley land and that in its early stages it was entirely or practically destitute of dunes. At this early stage without doubt the land was covered with grass as such new lands on the river usually are. It may have had shrubs and trees; the newly built level river lands in some instances have shrubs or trees or in some places only grasses. As an illustration of land in this early stage of development note the land on the Oklahoma side, at the Grandfield Bridge.

The next stage in the development of this valley was the formation of dune series one. This dune series, which as previously stated, ties onto the Texas bluff near longitude 98-39, at first diverges from the bluff as shown by its course on the Big Bend topographic sheet. Followed downstream, however, as seen on the Devol Bridge topographic sheet the dunes again converge and tie onto the Texas bluff downstream. At the time of the formation of this land and the accompanying dune series the sand plain of the river according to the observed habits of dune building extended outward or northward from the north margin of the dunes. This is believed to be true since large dune series in this valley build in no place other than on the margin of the valley land adjacent to the sand flat. The sand flat was necessarily north of the dunes since at both ends the dunes tie to the Texas bluff. Moreover, that the sand flat was north of the dunes is clearly indicated by the even north or riverward margin of the dune series. On the south side there is lack of a uniform or even margin, the dunes stringing out in an irregular and more or less detached manner. These features uniformity of the riverwards margin and lack of uniformity of the inland limits of the dunes are illustrated at various places along the river where dunes are now accumulating, as, for instance, at the outer margin of the present Big Bend valley. (See maps.)

The next unit or part of the Big Bend valley to be reclaimed from the sand plain is that which lies immediately riverward from dune series one. A considerable part of this next belt of land is seen on the maps of the Big Bend topographic sheet. It extends from the north margin of dune series one to the north margin of dune series two. This part of the valley is regarded as having been built at a time when the sand plain of the river lay immediately north of the present north margin of dune series two. It is not necessary to assume that this whole strip of valley land was built simultaneously. It is rather a unit of river building activity. That there were advances with perhaps parts of the new built land being cut away is possibly indicated by a few scattered dunes resting on the land. A period, however, when the sand plain remained for a time stationary is indicated by dune series two, which is interpreted as having formed at the north margin of this new built land. At the time of the formation of dune series two we must believe in accordance with known principals of dune building that the sand flat of the river was spread out immediately to the north. At this time the trend of the sand plain in this part of the valley was approximately east-west, as shown by the trend of the sand dunes. The trend of the sand plain at that time therefore differed somewhat from the trend of the sand plain at the time dune series one was formed. In the case of dune series two as in dune series one it is seen that the dunes have a sensibly even north margin, that is on the margin towards the sand plain. On the opposite side away from the sand plain the dunes string out more or less.

The strip of land now under discussion pinches out as seen on the Big Bend topographic sheet by the approach downstream of dune series one and two. However, on the Devol sheet next downstream it is seen that land and dunes of this type come into the valley again thus completing the encircling belt of land and dunes of this age. The cutting out of this land near the south margin of the Big Bend sheet is of course incident to the trend of the sand plain at that time, not paralleling its trend of an earlier date when the older land and dunes of dune series one were formed. Dune series two is shown by excavations to have been formed on the pre-existing valley land of that time in the way the dunes are commonly formed at the margin of existing land at the present time.

All the land north of dune series two is found to be appreciably younger than the land south of that line. The land south of this line forms a bench which stands on an average at a higher level than the land farther to the north. In fact the largest pysiographic break found within this valley occurs at the north margin of dune series two.

North of dune series two the valley land aside from the dunes consists of a comparatively thin covering of river-deposited loam overlying the river sand. It is of the type of land that in its soil characteristics must be classed as newer land having received relatively little material other than that which has been added to it in the overflow stages of the river. On this land dunes have accumulated which are younger in age than are the dunes of either dune series one or two. In the part of the valley now preserved these dunes are somewhat irregularly scattered. The trend of the dunes is such as to indicate that the trend of the sand plain at this time differed from the trend at the time either dune series one or dune series two were formed. From the trend and the age characteristics of these dunes it seems probable that dune series three originally extended through what is now Goat Island and came back towards the Texas bluff, at a point farther downstream, as shown on the Devol Bridge and Brushy Creek topographic sheets.

An extension of the valley was made in the usual manner beyond dune series three on which is built dune series four. Beyond dune series four at the outer margin of the valley is seen another and newer extension of the valley land, marked "NS" on the soil map on which in time doubtless another line of dunes will accumulate. It is the writer's interpretation based on the soil and dune characteristics that Goat Island at one time was a part of the Big Bend valley and subsequently became detached.

The interpretation of the history of the development of this valley as will be seen is wholly in opposition to the "island building" theory and is inconsistent with that theory. The fact that the north or riverwards margin of the dune series is a uniform unindented line, means that the sand plain was north and not south of the dunes at the time they were formed. Likewise the fact that the dunes tie onto the Texas bluff means that the land on which they were built was likewise united to the Texas mainland.

CONCENTRIC BUILDING OF THE RIVER VALLEYS.

In the interpretation of the history of the Big Bend valley it was indicated how successive belts of new land had been added which more or less completely encircled and surrounded the older lands. To this habit of building, which is common to the valleys in general, the writer applied the term concentric building. (R.-8-4645.) In illustrating the fact that this method of building is common to the valleys of this river the writer described six valleys in some detail: The valleys described in this connection in addition to the Big Bend were: Doan valley, Electra valley, Burkburnett valley, Curtis valley and Gilbert Creek valley.

Doan Valley.

Doan valley is located on the Texas side of the river in Wilbarger County. It is a large valley three or four miles wide and about nine miles long. The available maps of Doan valley include the outline maps of the river made by the United States and Oklahoma, and by the State of Texas; a special map of this valley made by Dr. L. C. Glenn and a map made some years ago by the United States Bureau of Soils, known as the Vernon area. Of these maps the last mentioned is the only one published, the others having been submitted as exhibits in this suit and not republished.

It is a noticeable feature of the Doan valley that it consists chiefly of land mature in its soil and physiographic features. Dunes comparable in age to those of dune series one and two of the Big Bend or possibly older are found to extend in places to the present bank of the river. This is true of the dunes opposite to the Doan settlement near the north end of the valley and again two miles south of Fargo. In places the upper ends of these older dunes are cut by the river indicating a former larger extension of this valley now lost by erosion. However, around these older lands newer lands have formed at several places. The formation of newer land is not confined to the downstream end of the valley. At a point slightly northeast of Doan Settlement it will be found that there can be recognized no less than three or four ages of land. The newest land is that which has been very recently reclaimed from the sand plain. It is low level land lacking sand dunes and on which there is a sparse growth of vegetation. The next older land is slightly higher in elevation on which practically no dune material has accumulated. The third bench is higher and appreciably older. Of this bench there remains at the present time only the downstream end, the upper part having been cut away. At the margin of this bench there is a sand dune which at its downstream end ties onto the next higher bench. The fourth bench is the much older land of this part of the river valley. Two miles farther downstream where the current passes around a projecting point of land there is again building of valley land, a strip of land approximately a half mile in width having been added to the valley. The new land is in part detached from the valley owing as the writer believes to the formation of scour channels. At another locality examined within about three miles of the lower end of the valley at a point where the channel turns away from the Texas side, there is found extensive building of new land.

With regard to this valley as a whole it is found that the oldest land lies not exclusively at the downstream end but in the central part of the valley adjacent to the Texas bluffs. Around this older land newer land has formed or is forming at various places.

Electra Valley.

The second valley described in this connection is that known as the Electra Bridge valley, on the Texas side of the river at the Wichita-Wilbarger County line. Of this valley no published maps are available. The valley is, however, shown on the outline maps of the river, made by Texas and by the United States and Oklahoma and in a special map made by Dr. Glenn. In this valley the land which has characteristics of being the oldest land of the valley is located adjacent to the Texas bluff and extends from near the upstream end of the valley to a point somewhat below the crossing of the Electra Bridge public road. This land is in the main level although there are some dunes at its outer margin, which tie to the Texas bluff at the upstream end of the valley and after diverging from the bluff again approach the Texas bluff downstream. Outward or riverward is found a belt of land that appears younger in its age characteristics. The dunes on this younger land are believed to correspond in age in a general way to the dunes of dune series three of the Big Bend. These dunes tie to the Texas bluff at the extreme upstream end of the valley and although in part cut out by the action of the river in the central part of the valley, farther downstream they again approach the Texas bluff, this newer belt of land with its accompanying dunes entirely surrounding the older land. At the present time new land is found building near the northern end of the valley, and at various other points downstream. The maximum amount of building of new land in this valley, however, is at or near the lower end of the valley. The new land is low and has been cut through by numerous scour channels of the river. Building in this valley includes the addition of newer land surrounding the older land with maximum amount of recent building at the downstream end of the valley.

Burkburnett-Bridge Valley.

A third valley considered was the Burkburnett-Bridge valley, which is located on the Oklahoma side of the river. This valley lies within the Burkburnett topographic sheet of the United States Geological Survey, which, however, is a small scale map and of little service in detailed study. Maps submitted in the suit, not republished, including this valley were the outline maps of the river and a special soil map made by the United States Bureau of Soils.

In the Burkburnett-Bridge valley it will be found that there is a pronounced line of dunes having the characteristics of old dunes, which at their downstream end tie to the Oklahoma bluff. At the upstream end this series of dunes approaches the Oklahoma bluff, but does not tie to the bluff, the extreme upper end having been removed by the cutting action of the river. Around this older land and dunes are found other flat lands followed by a second series of dunes which in general correspond to dune series two of the Big Bend. Near the present river is found land and dunes corresponding to dune series three and dune series four in order. Land building at the present time in this valley includes a limited amount of building in the upper part of the valley and somewhat extensive building in the central part of the valley. At the extreme lower end of the valley as at the extreme upper end of the valley the river is cutting the bank, no new land being in evidence at the present time. The building of this valley is distinctly concentric in the sense that newer land as a rule surrounds the older land. The maximum amount of recent building has been opposite the central part of the valley or slightly downstream from the central part.

Curtis Creek Valley.

Curtis Creek Valley on the Oklahoma side, the valley next upstream from the Big Bend valley, was also referred to in this connection. The lower part of this valley is shown on the Grandfield Bridge topographic sheet. The valley is shown also on the outline maps of the river. (See geologic map in pocket.)

With regard to this valley the following statement was made: (R.-8-4652.)

"If this valley be examined with respect to the relative age of land within it, it will be found, I believe, that near the central part of the valley there is a broad belt of land now to a considerable extent in cultivation, extending from the Oklahoma bluff outwards a distance which is more than a quarter of a mile, and that at the outer margin of this belt of land there are found dunes, a line of dunes. Those dunes followed downstream will be found to reach their maximum distance from the Oklahoma bluff, afterwards to turn in and unite with the Oklahoma bluff before reaching Curtis Creek. If followed upstream the same line of dunes will be found to tie themselves onto the Oklahoma bluff before reaching the extreme upper end of the valley. We have then a belt of old land next to the Oklahoma bluff nearly encircled and enclosed by this line of old dunes, a condition identical with that seen in the Big

Bend, where dune series one serves to enclose such a belt of land. Outward from this old dune series will be found newer land, and such newer land extends entirely around the older land coming to or near to the Oklahoma bluff upstream and coming to the Oklahoma bluff downstream. It one continues out into the valley, one comes finally at the present time to a channel of the river, carrying the greater part, in low water stages, of the water of the river, and beyond that channel a considerable area of detached land. * * * In examining the present day building along this particular valley I observed first the new channel to which I have referred, and I have taken a photograph to illustrate how that channel is cutting one bank and building another, in the way in which this river usually cuts and fills. The photograph which illustrates that feature is Photograph No. 115 of Texas Exhibit No. 51, showing the behavior of the channel, not yet a year old. Following upstream I took at a point not more than half a mile above that particular area of detached land Photograph No. 116. This photograph is taken at a place where a channel of the river is turning away from the Oklahoma side into the sand plain, and gives the characteristic land building seen at such places. A little further upstream, not more perhaps than one-fourth of a mile I took Photograph No. 117 to illustrate in the same way the features of new land building."

Land building in this valley is thus seen to consist of the addition of newer land surrounding the older land.

Gilbert Creek Valley

The sixth valley used in illustrating building is that known as Gilbert Creek valley, which is located on the Texas side of the river in Wichita County, downstream from the Big Bend valley. Of this valley a special map designated as a Land Age Classification map was made and is reproduced in this bulletin. (In pocket). An examination of this map will assist in understanding the characteristics of this valley. Upon examining this valley it will be found that the oldest land of the valley marked "High Bench" on the map is located next to the Texas bluff and stands at an elevation somewhat higher than other parts of the valley. Next towards the river from this high bench is a belt of land which stands at a lower elevation and on the map is marked "Intermediate Bench." This intermediate bench, as will be seen, completely surrounds the high bench on the river side, extending from the Texas bluff upstream and again touches the Texas bluff downstream. At the margin of the intermediate bench there is an appreciable terrace and a limited development of sand dunes. Towards the river from the margin of the intermediate bench is a considerable belt of land of appreciable younger age. The dunes developed on this land for the most part are of the character of the dune marked as dune series three on the Big Bend, and on this map they are marked as "DS3." At the upstream end of the valley this belt of land touches the Texas bluff above the upstream termination of the intermediate bench. Downstream below the mouth of Gilbert Creek it is cut into by a channel of the river. It seems probable, however, that in former times this belt of land was continuous with the detached land area seen somewhat below the mouth of Gilbert Creek.

Land building is seen at the margins of this valley at several localities. At the upstream end of the valley is a very narrow strip of new land not indicated on the map. At and near the mouth of Gilbert Creek a belt of new land several hundred feet wide has recently been addd in this valley. On the map this new land is marked "Level Land, Salt Willow." On this newest land a few small dunes of the character of dune series four have accumulated. As previously mentioned the channel which separates the mainland from the area of detached land south of the mouth of Gilbert Creek is interpreted as a scour channel. Since this land became detached land building has gone on more or less at either side, the newly built land being designated as new land on the map.

The entire evidence relating to these valleys indicates that they originate at some place along the bluff favorable as a locality for the deposition of sediments. Around the land thus built a newer belt of land is added, more or less completely enclosing the older land. To this in turn other land is added. The process, however, is by no means continuous. The river may build at one place and by shifting of the currents destroy building at this place and build anew at another locality, only to destroy and shift again its place of building. On the whole, however, there can be recognized in these valleys cycles or periods of building followed by periods of relative inactivity in building in so far as this particular valley is concerned, the whole resulting in the concentrically built valley.

CONCLUDING STATEMENT.

The controlling principle in the enlargement of the valleys on this river as described in this paper is the gradual addition of new land to old by deposition of sediment in accordance with the processes known as accretion; the habit of building is by the successive addition of new land more or less completely enclosing the older land; the life cycle of each individual valley is not such as is completed within so short a time as one century, but is on the average measured by an undetermined number of centuries.

ECOLOGIC INVESTIGATIONS IN THE RED RIVER VALLEY

BY B. C. THARP[1]

Introduction

The ecologic investigations upon which this paper is based, made in connection with the Oklahoma-Texas boundary suit, were begun on July 16, 1921, and extended intermittently through October 14, 1921. Data were gathered for the most part during the interval of July 16-22, inclusive. These data were compiled into the tables and lists embodied in the present paper during the month of August, 1921, under pressure arising from two sources: (1) Instructions to have the material ready for presentation by September 1, 1921; and (2) responsibility to a fulltime teaching position from July 26 to August 31. The investigations were made chiefly in and near a valley of the Red River in Wichita County, Texas, known locally as the "Big Bend."

Summary of Results

The results of the investigation may be briefly summarized as follows:

The climax stage of plant development for the region in which the Big Bend area is located is that designated by Clements[1] as the short-grass plains modification of mixed prairie association.

The treeless portions of the Big Bend valley have virtually attained the climax association, as is indicated by comparing an analysis of the vegetation of such portions with that of the bluffs on both sides of the river.

While the length of time required for the vegetation of a given area to pass from initiation to climax cannot be definitely

[1]The writer's testimony will be found in full in the Supreme Court Records in this case, Vol. VIII, pp. 4238-4394.

[1]F. E. Clements: *Plant Indicators*, Carnegie Institution of Washington, Publication No. 290, p. 139, 1920.

stated in years, there is much evidence to support the view that it must take at least several hundreds of years: e.g.

1. Upon a tract on the Oklahoma side above Grandfield Bridge, which in its oldest portion must have exceeded 100 years, only ten climax dominants had become established.

2. At the southernmost limit of the cottonwood savannah, along the transect which yielded List XII, estimated to be upward of 150 years of age, only five of a total of eighteen climax dominants noted for the valley in this area had appeared.

3. Using the conditions as they exist in the cottonwood savannah as a basis for judgment, it seems entirely conservative to estimate 150 years as the minimum time required for the cottonwood stage to pass from initiation to extinction.

4. There is no evidence of greater correlation between the age of the oldest trees in the valley and the maximum age of the soils which support them than there is between the same comparative ages of the trees and of the soil along the upland stream courses.

5. The contentions of the United States and Oklahoma as expressed in the opinions stated by Dr. Cowles and in part quoted in this paper are, in so far as ecology is concerned, based upon inadequate investigation and upon misinterpretation of the development and structure of the vegetation in the area studied.

Occasion for the Investigation

The discovery of oil in the Big Bend, which enhanced values stupendously, precipitating the controversy between Oklahoma and Texas on the question of the location of the boundary between the two states; subsequent investigations on the part of scientific experts in the employ of the U. S. Department of Justice; the reports of these experts, which caused the entrance of the United States as an intervener in the suit; and the appointment of a receiver to represent the United States Supreme Court pending the settlement of the controversy; all have been briefly outlined in the general introduction and need not be repeated here.

The ecologic problem involved in the boundary suit, in view of the contentions of the United States, was to ascertain whether there was any evidence to be found in the vegetation of the river valley that would give a decisive answer to the question: Is the valley land in the Big Bend of the Red River less than 100 years old? If there was such evidence, to consider it carefully, test its soundness and place it at the disposal of the court. If there was evidence to show that any parts of the valley land were more than 100 years old, to consider its soundness also, together with the extent of such parts and then to place this evidence at the disposal of the court. It was to answer these questions that the ecologic investigations on the part of the State of Texas were undertaken.

Contentions of the United States and Oklahoma

The contentions of the United States and Oklahoma in so far as they involve ecology were largely the result of preliminary investigations on the part of Dr. Henry C. Cowles of the University of Chicago. They may be stated in Dr. Cowles' own words as follows:[1]

"Since the climate of the region is arid or semi-arid, the general country level, apart from the valley of the Red River, is unsuited to tree growth. Instead of trees, the characteristic vegetation of the region as a whole is prairie or grass land. On account of the greater supply of available water, trees are found in the valley of the river, both on the islands and at the foot of the bluffs and also along the tributary draws. It was found that as an island grows in area and height, it shows characteristic vegetation stages or successions. Indeed, the very growth of the island is largely made possible by such vegetation. At the outset, when the island consists merely of a bar or sand-flat and consequently is subject to more or less frequent overflow, the only vegetation that can exist at this stage of an island, is a vegetation made up of short lived annual weeds or shrubs or trees that tolerate a greater or less amount of overflow. Preeminent among such water-tolerant forms are willows and cottonwoods. Both of these species are abundantly found as pioneers on newly formed bars or sand-flats. These willows and cottonwoods, on account of the abundant water supply, often grow several feet in height the first year, thus starting out almost as vigorously as would be the case in more humid climates; consequently when winds blow along the valley floor carrying a

[1]In the Supreme Court of the United States, October term, 1919, No. 27, original, pp. 106-111.

load of sand, these willow and cottonwood saplings furnish an obstacle to the sand-laden winds. In this way therefore dunes are formed about growing plants.

"Cottonwoods and willows are admirably suited to life among dunes, since they grow rapidly in height as the dune grows. The higher the dune grows the higher the trees grow, seemingly as if to keep above the sand. This makes it possible for the dune to grow higher and so things may continue for many years, both the plants and the dunes stimulating the growth of the other. This stage of dune formation with willows and cottonwoods may be termed the second stage in the successional history of the flood plain vegetation. As the dunes increase in height and thus get farther away from rich supplies of ground water, various grasses and shrubs of arid regions begin to get a foot-hold. Shortly after the third stage is well under way, it was noted that many species of grasses and weeds come in abundantly forming a relatively dense mat of vegetation over the dune surface. Henceforth, the sand dunes cease to blow—the dunes being fixed or stabilized by the mat of vegetation. It was found from the second day's study that this fourth stage is reached in the strikingly short time of 20 or 25 years.

"In this day's study, as noted above, we had the perfectly definite date of 1875, the time of the United States Public Land Survey, to compute from. It may be noted also that the age studies of the trees served as a check on the line as reported by the surveyors, in other words it would have been possible from ecological evidence to determine the position of the 1875 line from the living trees alone. In this case the trees agree exactly with the records of the surveyors. * * *

"*Age Studies of Trees*:—There are no more faithful witnesses to past ecological conditions than trees; in fact one may be absolutely certain as to what the conditions of an area have been from the time of germination to the present. No trees growing in the region are able to germinate in water; consequently areas now occupied by trees must have been land throughout their life; also areas suitable for the growth of trees will have trees growing on them so that absence of trees from a given area commonly indicates conditions unsuitable to the growth of trees. In the area under investigation, however, the conditions for tree growth are not so good as in the more humid regions farther east. There is ample water on the flood plain of the river but the numerous rapid changes that the river regularly undergoes make the establishment and growth of trees somewhat difficult. Again because of the relative absence of trees in the region, as a whole, there are often difficulties in the way of sufficient seed formation to seed new grounds. For these reasons there seems to be more abundant tree life in draws or near the mouths of draws than elsewhere. * * *

"On account of the careful study of tree ages made by Mr. Janes, I paid comparatively small attention to ring counts. However, I made a number of such counts in representative areas and I made careful estimates of age based on tree and growth conditions. As a result of this, I am satisfied that the entire area of the 'Big Bend' is less than 100 years of age. No tree with an age greater than 100 years was seen on the flood plain, whereas several trees of an age of 100 years or over were seen on the adjacent bluffs.

While trees are not abundant on the flood plain as a whole, they are abundant enough to form the basis of an accurate ecological estimate of the age of the flood plain. From this aspect of the study, I conclude that in 1819 a channel of the Red River was running along the foot of the Texas bluff, that it had been there for some years previous to 1819 and that it was there some years subsequent to 1819 and that at some time between 1819 and the present, the river abandoned this channel. It is likely that the avulsion occurred more than fifty years ago, since a considerable amount of side wash material has come down over the channel floor and because the old channel now contains, here and there, a considerable number of young trees.

"*Summary:*—It is concluded from the evidence herein submitted, that in 1819 and for some years prior and subsequent thereto, the main channel of the Red River in the 'Big Bend' area was at the foot of the Texas bluff. This conclusion is based upon the following facts:

"*1. Physiographic evidence:*—In the Red River flood plain new land appears in the form of islands rather than by accretion from the bluffs; later these islands may become joined with the bluffs by avulsion or less commonly by accretion from the island side. Specifically in the Big Bend area, several islands originated mostly, if not wholly, since 1819 and since have become merged by the abandonment of channels by the river. They have also become merged with the mainland, this process having taken place by avulsion.

"2. *Ecological evidence:*—Apart from trees, the vegetation of the mainland bears signs of considerable ecological antiquity far antedating 18 9; on the other hand, the vegetation of the flood plain bears signs of ecological youth. From a perfectly definite study of the length of time necessary to secure dune fixation, it was decided that any area of the flood plain not bearing trees, could have reached this present state of stabilization within fifty years. At no place in the flood plain of the Big Bend area was there seen a place where the evidence indicated an age of more than 100 years. Since the age of the bluff is more than 100 years and the age of the flood plain less than 100 years, it follows that the Red River must have run along the foot of the Texas bluffs 100 years ago.

"3. *Evidence from age of trees:*—This evidence follows closely that submitted under 2. That is, trees were found on the bluff over 100 years of age. None of 100 years of age were found on the flood plain, although some of this age were found in the mouths of draws at the edge of the flood plain. Thus the tree evidence, which is the most exact and precise of all lines of evidence bearing on the problem shows that beyond question, the channel of the Red River in 1819 in the 'Big Bend' area was at the foot of the Texas bluff.

"*Supplemental Report:*——As supplemental to my report, further investigations were made in the 'Big Bend' area on May 9 and 10, 1920. In these investigations, my attention was directed to a line of red posts which were said to have been placed for the purpose of indicating the thread of the channel of Red River as it existed in 1819. All of the trees which I observed to the north of this line, either at this time or during previous investigations, are less than 100 years old, so that the establishment of this line is in harmony with my investigations."

The testimony in chief of Dr. Cowles, testifying in Oklahoma City, September, 1921 (R. pp. 2679-2777), was in essential harmony with the opinions above set forth, except that he testified as to having seen trees on the valley floor more than 100 years old, one (Sample No. 6) being as much as 170-180 years of age. But all these he disposed of by stating the belief that they were on islands in and for some years subsequent to 1819.

However, on rebuttal, in the city of Washington, D. C., November 28, 1921, after having read the ecologic testimony on behalf of Texas, Dr. Cowles (R. pp. 5365-5386) admitted:

1. That a large part of the valley of the Red River in the Big Bend had attained the ecologic climax characteristic of the uplands on both sides of the river, citing the river valley south of Goat Island, and at the longitude of the Boner Refinery as typical climax areas. (See table II.)
2. That he made no particular study of the Big Bend area with a view of analyzing the climax vegetation.
3. That there is no means of judging in years the exact or approximate age of a plant formation.
4. That practically all of the plants characteristic of the climax are unable to make much headway in moving sand; and
5. That he never liked to make an affidavit without having gone more carefully over a thing than he had up to the time when the above report and its supplement were made.

Dr. Cowles at this time, November 28, 1921, still contended that the ecologic climax characteristic of the vicinity might be essentially attained in 45 years, but with cottonwood still present as a "leftover." The body of the present paper will seek to present the data which caused the writer to disagree, in general, with the original contentions of Dr. Cowles and with the specific contention to which he still held in his rebuttal testimony.

Explanation of Terms.

Before outlining the ecologic investigations dealt with in this paper and the results which they yielded, it may not be out of place to make a few general statements which will aid the average layman in better understanding the discussion.

Ecology is that phase of botany which deals with plants in relation to their environment, and with the inter-reactions between the two. By *Growth-form* is meant the response in form which a plant makes to the influence of its environment. To illustrate: there is a common oak (*Quercus breviloba*) which on the limestone hills of Central Texas has the tree form. This same species of oak growing upon the semi-arid sandy soil of upper Red River is a scrubby shrub often not more than knee high. This difference in form which it assumes in response to its environment is known as growth-form. This responsive change in growth-form on the part of plants is a common occurrence and quite significant in ecologic investigations.

Plant Groupings:—Large areas clothed with a somewhat uniform type of vegetation are called *plant formations*, e. g. grassland formation, desert scrub formation, coniferous forest formation, etc. Subdivisions of the formation are *associations*, e. g., the post-oak-black-jack association of the deciduous forest formation; the *Bouteloua-Bulbilis* association of the grassland formation. All the above are *climax formations* and associations. Beginning with the arrival of the first pioneer plants upon a bare area, whether new as in the case of a sandbar, or merely denuded, as by fire, cultivation, etc., there will, in the absence of further interference, ensue from year to year a continuous change both in the number of individuals and in the number of species to be found upon such an area, terminating ultimately in a stable balanced vegetation incapable of further change under existing conditions. A *climax formation* or association is therefore that formation or association which will finally result and be permanent in a given area so long as certain climatic factors for such an area are relatively stable and unchanged. Any association between the first (or initial) and the last (or climax) is called a seral or successional association, the term *formation* being properly applicable only to climax vegetation of vast territorial extent.

Climatic Factors:—The climatic factors influencing the character and richness of vegetation, in the order of their importance are:

1. Water.
    a. Atmospheric.
    b. Soil.
2. Light.
3. Temperature.
4. Soil.
    a. Texture.
    b Richness or fertility.
        (1) Mineral content.
        (2) Organic content, including soil organisms.
        (3) Air content.
        (4) Depth.
5. Wind.

Light being the source of energy for all green plants, is of the first magnitude in importance. Dominant prairie and plains forms of vegetation make the strongest demand of all plants for light; therefore such plants are not to be found growing in the shade of forest trees. On the other hand, there are plants, especially the lower forms such as mosses and ferns, but also some seed-plants, which not only tolerate but demand shaded places.

Moisture is as important as light. Without an adequate supply any plant will suffer, and, beyond a certain minimum, will die.

Temperature plays an important part in determining the form of vegetation, but it is subordinate to light and usually more or less dependent upon it.

Soil is a very complex factor, containing water, subject to temperature change, having some light in the uppermost layer, and in addition made up of particles which give it texture. The texture is coarse or fine according to whether the particles are large or small. Soil of fine texture holds a higher percentage of water and holds it with greater tenacity than coarse soil does. The richness or fertility of soil depends upon:

Its texture and capacity to hold water;

Its mineral content, or those substances in solution which are essential to the life of plants;

Its organic content, or humus, including soil organisms, which not only furnishes elementary materials used by plants, but also materially increases the water-holding capacity;

Its air-content, soil air being essential to the roots of all plants except those adapted to marsh, swamp, or bog conditions;

Its depth, that is, the depth of the layer containing the materials above mentioned.

Wind:—The stronger the wind the greater the consequent rate of evaporation, humidity being constant.

Taken in their entirety the factors suggested above constitute a complex the potency of any one of which it is frequently difficult to estimate in a specific case. Water and light, however, are always in the greatest demand, and when the former is used to include atmospheric as well as soil water the importance of that factor increases still more. In the area under consideration water is by far the most important factor, since light is practically always at a maximum and evenly distributed.

Method of Study.

The usual equipment necessary for botanical study and analysis of vegetation composed the field apparatus for the work. Thus equipped, field studies were made as follows: Transects were run along the representative lines indicated below; that is, these lines were traversed slowly and carefully and the name of every known plant encountered, together with a statement of its relative abundance and importance was noted. Unknown or doubtful plants were collected, numbered and provided with the necessary data to make them valuable as soon as their identity should be determined. These unknown and doubtful plants were then pressed and brought to the laboratory, the grasses later being sent to the U. S. National Herbarium, all other plants to the New York Botanical Garden for verification or identification, as the case might be.

Acknowledgment.

The writer wishes here to express his gratitude to Mrs. Agnes Chase of the U. S. National Herbarium and to Dr. J. K. Small of the New York Botanical Garden for valuable assistance given him in identifying unfamiliar plants. The writer wishes also to thank Dr. Frederic E. Clements of the Desert Laboratory of the Carnegie Institution of Washington, Tucson, Arizona, for the opportunity afforded by his invitation of again visiting (September 22, 1922), in his company, the principal area covered by the investigations; for the generous counsel which he gave at that time; and for reading and criticising the manuscript of the present paper. Dr. Clements was invited by the State of Texas, in the fall of 1921, to make a survey of the Big Bend area and report his findings in order that he might testify in the case. Previous engagements of a pressing nature prevented his accepting the invitation; but he kindly offered if possible to do so during the fall of 1922. Hence the occasion for the visit mentioned, with the writer as his guest. Colleagues who have also been kind enough to read and criticise the paper are: Dr. Frederick McAllister, Dr. E. H. Sellards, and Mr. George Finlay Simmons.

The Big Bend Vicinity.

The geographic location of the Big Bend of Red River has already been given as the northern part of Wichita County, Texas. It remains briefly to describe the physiography and fertility of the lands constituting the upland back of the river on both sides, and to state the ecologic location of the general area investigated, together with its economic history.

PHYSIOGRAPHIC FEATURES.

The Texas Side:—Lying back of the bluff on the Texas side there is an almost level stretch of country whose sandy soil is very fine in texture, rich in fertility, and of the reddish color characteristic of the region. Through this level country small streams have cut their way, their courses being marked by a scant growth of elm, hackberry, pecan, and cottonwood trees.

The Oklahoma Side:—Back of the bluffs on the Oklahoma side, which are decidedly lower in this vicinity than are those on the Texas side, there stretches for three-fourths mile or so a series of old sterile sand dunes. The rough topography of these dunes stands out in contrast to the level area lying back of the Texas bluff, as does also their great sterility compared with the fertility of the land on the Texas side. Beyond the dunes, the soil on the Oklahoma side also is fertile, and given over to the cultivation of the same kinds of crops as grow on the Texas side.

Ecologic Location:—The Big Bend of Red River lies toward the eastern limit of that part of the grassland formation known as the mixed prairie association. Intensive grazing frequently so suppresses the tall beard-grasses of this association that a sub-climax condition known as short-grass plains appears. This, however, is a purely artificial condition, though continuous over-grazing may cause it to be in effect permanent.

Trees:—While no native trees occur except along stream courses, planted trees, especially cottonwood, thrive quite well. Farm houses are often surrounded by groups of these shade trees.

Economic History:—The area has passed through periods of both the grazing and farming industry. At the present time, except in situations where the oil industry has interfered, it supports crops of wheat, oats, corn, grain-sorghums, and cotton, though the growing of the last named crop is made somewhat precarious by the semi-arid climate.

Detailed Structure of the Vegetation:—As to the details of the native vegetation, both as regards the uplands on both sides, and the valley between the bluffs, as careful a study as time would permit was made in the manner suggested above, and the results of this study were reduced to tabular form. While it is thoroughly recognized that a tabulated statement of detail is somewhat burdensome, there is no other way to get the mass of detail into an orderly intelligible form.

Areas Studied in the Big Bend Vicinity

I. TEXAS.

Detailed observations on the Texas side were made along the lines indicated below. For these locations see reduced topographic map of the Big Bend area in pocket.

1. Following approximately longtitude 98°36′40″ from the Texas bluff on the south to the river sand-flat north of Goat Island, referred to in the tables of this report separately as River Valley south of Goat Island and as Goat Island.

2. Following approximately longitude 98°38′10″ from the Texas bluff on the south to the river sand-flat on the north, hereafter referred to as longitude of Refinery.

3. An area including both sides and top of the Texas bluff for a distance of some 600 feet beginning at longitude 98°40′18″ and extending eastward, or down stream. This locality lies just west of Bridgetown.

4. Following the base of the Texas bluff from approximately longitude 98°38′30″ in a general easterly direction to longitude 98°37′15″, this being the longitude of the mouth of Wild Horse Creek, thence following the channel of this creek to what is generally known as the Lone Cottonwood (Sample No. 5), longitude 98°36′16″, thence back along this creek to its entrance to the river valley, thence in a general north-easterly direction to longitude 98°36′40″.

5. Observations and collections were also made over the whole road system of the river valley on the Texas side from Bridgetown to longitude 98°36′0″ where the Devol road crosses the river.

II. OKLAHOMA.

Detailed observations in Oklahoma were made as follows:

1. Along the top and the sides of the Oklahoma bluff, and extending 300 to 400 ft. into the dune area which lies back of this bluff, beginning at the north end of the Grandfield Bridge and covering a distance of some 600 feet westward. This area is referred to in the tables of this report as Oklahoma Bluff.

2. Along the base of the Oklahoma bluff for several hundred yards beginning at the Grandfield Bridge and working in a general westerly direction, special attention being paid to seeps, of which there is a conspicuous line in this locality. This area is included in the tables of this paper under River Valley Oklahoma.

3. Along a general southerly line approximately paralleling the Grandfield Bridge and some 600 feet to the westward, beginning at the Oklahoma bluff and working southward across the valley to the river channel. The valley in this special part of the Oklahoma side is made up of very low dunes and separated by rather broad flats. These are included in the tables under the heading "River Valley Oklahoma."

4. Along the river valley in a general westerly direction from the Grandfield bridge to the draw through which Curtis Creek enters the valley, a distance of perhaps two miles.

5. A special trip was made on July 18 to the vicinity of Augur Creek, about six miles up-stream from the Grandfield Bridge, studies being made of the trees to be found along its course from a point several hundred yards above where it enters the river valley to a point somewhat below where its channel enters into that of the river. The distance covered here approximates 2½ miles. Since the purpose of this trip was not to make a study of the general ecologic condition of all plants but only that of trees, this area is not included in the tables.

DATES OF INVESTIGATIONS.

In all, twenty days were spent in field investigations in the Big Bend and vicinity, distributed as follows: July 16 to 22 inclusive; August 10 and 11; August 23 and 24; August 30 to September 1; September 10 and 11; September 26 and 27; October 2; October 14; Oklahoma side of valley, Augur Creek, July 18; Oklahoma side of valley, Curtis Creek, July 19.

OTHER LOCALITIES VISITED.

The following additional localities, all except Burkburnett bridge area lying up the river, were visited for the purpose of comparative studies: Oklahoma side of valley below Burkburnett bridge, July 20; Tenth Cavalry Creek and China Creek, September 27; Electra Bridge area, September 28; Doan Area and Picnic Valley (3 miles above Doan's) September 29; Round Timbers Ranch, Mulkey's Ranch, Wanderers Creek and Ayers Place, September 30; 100th Meridian, Buck Creek Ford, Twin Windmill Valley, October 1.

Tables and Lists

Table 1.[1] Having made as complete a list as possible along each transect, there followed the necessity of getting the results into tabular form so as to facilitate comparison of the various localities studied. In order to do this the name of each plant on each transect list was transferred to a separate card, which contained also a statement of the locality whence it came. The cards were then alphabetized according to plant names and Table 1 was compiled. From this table one may tell at a glance the local distribution of any and all the plants it contains. For example, *Acamptoclados sessilispicus* (Buckl) Nash, was found in the river valley south of Goat Island, on the Oklahoma bluff, on the Texas bluff, and in the river valley at the Bloner refinery (longitude 98°38′10″) as indicated by the dash in each of those columns.

Table II was compiled in the same manner as Table I, except that in Table II the three areas Oklahoma seep, Oklahoma low dunes, and Oklahoma flood plain are condensed to river valley, Oklahoma; and the common name of the plant where known was given in addition to the scientific name.

[1]Table I, since it is practically duplicated by the fuller Table II is not reproduced in this paper. All references to it may be applied equally well to the latter table.

Table III was compiled in the same manner as the two preceding, but contains only the names of plants found to be conspicuous and considered dominant in the various localities. Prominence and dominance were used in the same sense in the testimony and are so to be construed in this paper. Though there is good reason to limit the term dominance much more narrowly, such limitation would not essentially change the interpretation placed upon the results of ecologic investigations as found in the testimony and in order to avoid confusion the same meaning as used in the testimony will be retained in this paper.

List I resulted from a comparison of the column headed River Valley south of Goat Island with that headed River Valley Oklahoma. The significance of this and other comparisons will be brought out later.

List II. Plants found both in the river valley south of Goat Island and on the bluffs of Oklahoma (sides and top) as shown by a comparison of those two columns in Table II. The purpose of this list is to get a definite statement in terms of plant species as to the similarity of the vegetation in these two locations.

List III has the same purpose as List II, except that it concerns itself with a comparison between the river valley area south of Goat Island and the Texas bluff.

List IV compares two areas in the river valley about 3½ miles apart, in order to permit of a definite statement as to the uniformity of the valley vegetation.

List V. comprises a few plants found along the Refinery Transect that were also found on the Texas bluff but not in the valley south of Goat Island. The fact that they were not found along the latter transect does not necessarily mean their absence in that area: they may have been there but happened not to be encountered on the transect. Following this list one plant (*Isopappus divaricatus*) is noted as having been found in the river valley at the Refinery longitude and on the Oklahoma bluff, but neither on the Texas Bluff nor in river valley south of Goat Island. This plant, also, may have occurred in either of the latter two localities, but was not encountered in the transects run thereon.

List VI is for the purpose of showing the particular plants common to the Texas side of the valley in the Big Bend area and the bluffs on both sides but not in the Oklahoma side of the valley in the areas studied.

List VII shows the plants common to the valley area studied on the two sides of the river but not on the bluffs of either side. The vegetation of the valley on the Texas side is shown, by a comparison of lists VI and VII, to be much more like the bluffs on both sides than it is like that of the valley on the Oklahoma side. The area studied on the Oklahoma side was known from maps and testimony introduced by the United States and Oklahoma to be in part more than 45 years old. It therefore, according to the opinion of Professor Henry C. Cowles, (see his quoted affidavit, pp. 91-94) should have had ample time in which to reach the climax typical of the surrounding country. It is still far from having reached such a climax as is at once apparent from a comparison of Lists VI and VII.

List VIII comprises those plants which were not found in the river valley in any of its areas studied. It will be noted that nearly all of these species are confined to the Permian red clay and gravel terraces of the Texas bluffs, as indicated by the word "Permian" following the letter T after most of the plant names.

List IX segregates those species which were found to be dominant in some one or more portions of the river valley on the Texas side and also dominant upon either the Texas bluff or the Oklahoma bluff. Such plants as were in addition found to be dominant in some part of the valley on the Oklahoma side are marked with an asterisk.

List X shows the dominant plants common to both the Texas and Oklahoma sides of the valley. Those plants dominant on both sides of the valley and on one or the other of the bluffs, or on both, are marked with an asterisk.

List XI shows the plants found to be dominant in the valley on both sides of the river and also upon either the Texas bluff or the Oklahoma bluff or upon both.[1]

[1]The number on this list as it appears in evidence is 5. Work on the manuscript for this publication revealed an error in the caption of the list, and also in the number of species listed. Both are corrected in the list as it here appears.

List XII results from a transect beginning on the sand flat of the river, and running in a generally southerly direction, approximately along Mer. 98°38′24″ until the real prairie portion of the Big Bend south of the cottonwood timber is reached—a distance of approximately 3500 feet from the point of beginning.

Discussion of List XII.

With reference to List XII it may not be out of place to go into somewhat greater detail. The transect was begun about 450 feet north of the cut-bank of the river, on what would be called in ordinary parlance the bed of the river. This bed, or sand-flat, is so nearly devoid of vegetation that anyone upon casual observation would be inclined to say that there was no vegetation at all upon it. It appears to be pure sand. But on closer investigation and by walking over the river-bed sparse vegetation is found. It is from this type of locality that the six plants under the caption "sand flat" were found.

Newly Accreted Land:—The "newly accreted land" constituting the heading of the next section consists of a vegetation covered flat extending as a narrow marginal strip 50-60 feet back from the "cut bank" to the "first dune next to newly accreted land." The vegetation on this newly accreted land is quite appreciably dense, but the number of species is not great as reference to the list will show. Four of the six species taken from the "sand flat" are again listed on the newly accreted land.

First Dune:—The "first dune next to newly accreted land" shows eight species not before listed, together with cottonwood up to 4.9 ft. in circumference. Of the eight species not before listed all except poison ivy and grape are typical dune pioneers for the vicinity. *Reverchonia*, *Chamaesyce* and *Apocynum* normally are the first to yield to the competition of later immigrants, while *Othake*, grape, cottonwood and poison ivy are successful in maintaining themselves for considerably longer and in the face of much keener competition. The two *Adropogons*, especially *A. saccharoides*, are perennial constituents of slightly grazed sandy portion of the mixed prairie climax association typical of this general locality, and are enabled to become successful invaders of bare areas by reason of the feathery nature of their seeds which admirably adapts them to wind dispersal.

Second Flat:—The "second flat south" yields twelve species not previously encountered on this transect. Practically all of these are confined, throughout this entire vicinity, to moist flats. *Eriogonum, Isopappus* and *Eragrostis* spp. constitute the exceptions. Willow (*Salix luteosericea* Rybd.) is yielding to too strong competition, as evidenced by the dying condition which it exhibits. Its ability to compete with its neighbors is appreciably lessened by the ravages of the pine-cone gall insect, *Rhabdophaga strobiloides* Walsh., whose white cone-shaped galls resemble snails clustered about the stems. Each gall represents a blasted bud. Thickets of willow often persist for years, however, even in this decrepit condition.

Second Dune:—The vegetation of the second dune is essentially like that of the first, except that the second contains willows, which the first did not, and that these willows are in the same decrepit condition as those of the second flat.

Third Flat:—The third flat adds six species, only two of which are of special ecologic significance: *Eragrostis secundiflora* and *Iva ciliata*. The former is a common member of the climax formation while the latter is a conspicuous dominant on alluvial flood plains of this portion of the southwest, frequently forming almost pure stands on the older ones. This is so conspicuously true of the flood plain traversed by Wild Horse Creek (see reduced topographic map in pocket) that civil engineers engaged in making maps of the vicinity, for the United States and Oklahoma, and acting upon the advice of L. L. Janes, government ecologist, delimited "channels" from "islands" by the lines along which *Iva ciliata* suddenly gave way to the grass climax association common on all the oldest treeless areas except the lowest alluvial grounds; at least this was the general rule as sworn to by A. N. Kimmell (R. 2533-2542). Wherever the exigencies of the occasion seemed sufficiently to demand, the rule evidently was not followed. For example United States and Oklahoma exhibit No. 80 shows tree samples Nos. 10, 11 and 12 as having come from trees located on "islands." As a matter of fact the only vegetation that surrounded any one of the three at the time it was cut was the "wild ivy" (*Iva ciliata*) described by A. N. Kimmell as signifying "old channels"; and the actual elevation of the soil at the base of sample No. 10, as compared with the very lowest adjacent portion of the slough channel was 0.58 feet, while that of sample No. 12 was, upon the same basis, 0.99 feet! (R. 4354). The elevation of sample No. 11 was, through an oversight, not taken, but its position is more than 50 feet farther out in the slough channel than is that of the stump from which sample No. 10 came. It is safe to say that the elevation is considerably less than one foot above the lowest point in the channel at that place.

Third Dune:—Returning to a discussion of List XII, the third dune adds a dozen plants that are very interesting. Every one of them not even excepting the grape, in the abundance and condition in which it here occurs, is indicative of considerably more maturity than was found in the vegetation of the second dune. The association here begins to assume some of the aspects of the mixed prairie climax, though some cottonwoods are still present. It is also interesting to note that this portion of the transect traverses the area from which tree sample No. 7, a cottonwod 75 years old, was cut. Using the age of this tree as a basis for forming a judgment the territory is more than 75 years old. Another interesting point is the presence of the prickly ash and plum shrubs. Neither of these species was observed anywhere in the investigations as occurring upon any but rather mature dunes; and both persist as scrubby shrubs scattered sparsely among the other members of the climax long after the typical climax has been reached.

Fourth Flat:—The fourth flat brings in a few other species indicative of drier and more mature conditions of vegetation in the older, higher flats. It also marks essentially the southernmost point of the cottonwood and the beginning of the climax stage, which extends from this point as a strip some 3000 ft. wide, more or less, to near the foot of the Texas bluff.

Developmental History of the Climax Association in the Big Bend

Succession in Sand Dunes:—Those portions of List XII which deal with the vegetation on successive dunes are illustrative of the usual succession of plants in dune areas. At first both the number of species and of individuals is small because of extreme conditions of moisture and because the wind constitutes a disturbing factor of more effect than is normal for it in this area, both by its shifting of the position of the growing dune and by its addition to the dune of sand from the adjacent sand plain. The pioneer plants are able gradually to increase in numbers, however, which has two important effects upon the environment:* First, the vegetative covering exerts a stabilizing influence whose effect is directly proportional to the density of the vegetation. This at length not only stops the wind from blowing the heavier particles, but also catches and holds the very fine particles that sift down from the atmosphere as it calms after a gale. Thus, as time goes on, the texture of the surface layer of soil on a stabilized dune comes to contain a larger and larger proportion of small particles, so that surface evaporation is lessened and the water supply available for plants is increased.[1] Second, every rootlet of every pioneer, and of every subsequent plant, upon death, adds its mite to the organic content of the soil. At first, the wind-blown sand contains scarcely any organic matter; but as successive generations of plants in continuously increasing numbers die and contribute their remains or are eaten and later much of them returned to the soil as waste from animals, the

*See Plates II. and VI.

[1]The percentage of fine soil thus contained in the surface layer of dunes was used by Dr. E. H. Sellards in computing the relative and the approximate ages of different dune series. See his account of it, page 50.

organic content slowly but steadily increases. This organic content, or humus, also has a decided influence in lessening the extreme conditions typical of a primary dune habitat in that it contributes, upon decay, valuable solutes necessary to the synthetic process of its living successors and also vastly increases the water-holding capacity of the soil in which appreciable quantities of it are contained. Thus, the cumulative process of alleviating extreme conditions goes on, and as conditions become less extreme, and as seeds and other disseminules of plants adapted to the more favorable conditions are brought into the area, new plants arising from them appear and become established. These new-comers succeed in crowding out those pioneers which are especially adapted to extreme pioneer conditions, but which are not well enough adapted to the generally less extreme conditions, which they themselves have been largely instrumental in creating, to compete with the ever increasing number of better adapted new-comers. As a result such plants as *Reverchonia, Chamaesyce* and *Apocynum* soon yield to competition from such plants as those listed as occurring on the Third Dune. The two *Andropogons,* on the other hand, are capable not alone of withstanding extreme pioneer conditions, but also of meeting the keenest competition on the part of any of the inhabitants of later successions, so that they constitute dominant members of the climax association for this area.

Number of Species in Seral Stages:—Another important and interesting matter concerned with the developmental history of plant associations, as illustrated in dune successions, is that of changes in the number of species represented at various stages. In the initial stages the number of species, as shown by the list of those on the First Dune, is small; frequently there may be but one or two. But as conditions become less extreme, as stated above, others come crowding into an area, so that the older a dune grows the greater the number of plant species represented upon it, up to that stage at which it begins to take on the aspect of maturity. After that there is a steady decrease in the number of species of plants as competition gradually operates in favor of those best suited to climax conditions. Thus the climax, though comprising a denser vegetative covering, comprises actually fewer species of plants than did those of former successional stages.

Succession upon Flats:—The Flats also, as illustrated in List XII, show a marked progressive change as one compares each with that which succeeds it. The first two (those designated as "newly accreted land" and as "second flat south" respectively) differ from each other mainly in the greater richness of the vegetation in the "second flat south." Both are yet unfilled to the point where they begin to show aridity during drouth, hence the plants they contain are preeminently inhabitants of moist soil. But the next two, the "third" and "fourth flats," both show developmental signs of drying out. Not a single one of the additions offered by the fourth flat, but is a typical inhabitant of dry soil; while of those offered by the third flat there are two, *Eragrostis* and *Iva* which are indicative of stages decidedly removed from initial.

Ascendency of Dominants:—To the south of the fourth flat the climax condition is reached by the increasing dominance of such grasses as *Bouteloua*, the *Andropogons*, *Acamptoclados*, *Aristida*, *Bublilis*, *Eragrostis*, *Cenchrus*, and other semi-arid perennials, associated with such annual or perennial subdominant herbs as *Ambrosia psilostachya*, *Eriogonum*, *Gaura spp.*, *Heterotheca subaxillaris*, *Hymenopappus sulphureus*, *Phyla cuneifolia*, etc. Here also, as stated before, there remain relicts of *Baccharis*, prickly ash, *Bumelia*, and plum as scrubby shrubs. The significance of cottonwood and the part it plays in the progressive changes toward the climax of vegetation in the Big Bend are reserved for discussion in connection with the subject of Timber Growth along upper Red River.

Mature Flats:—Mature flats in the short grass plains modification of the mixed prairie association are frequently occupied almost exclusively by a single dominant. For example, if the flat is normally kept fairly moist by streams entering from

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[1]*Bulbilis*, not being in fruit at the time of the investigation and being a short-grass, was overlooked. This was a very unfortunate oversight, as knowledge of its presence in quantity would have been another potent factor in the evidence. It was found in September, 1922, upon the visit to the area in company with Dr. Clements.

*See Plates II and VI.

the upland, as the flood plain Wild Horse Slough, there will be an almost pure stand or consocies of marsh elder (*Iva ciliata*). If, however, the flat has no such source of moisture, and as a consequence becomes dry, the dominant consocies will be the small perennial ragweed, (*Ambrosia psilostachya.*) This latter plant is also a normal dominant upon many alluvial fans adjacent to the Texas bluffs, and in certain very fine-textured soils at the top of the bluff. Both marsh elder and the small perennial ragweed are common dominants in locations along creeks, rivers, and flats throughout Texas, wherever alluvial soil may accumulate and moisture conditions are similar to those in which they are found along Red River.

Relative Ages of the Various Areas Studied

As to the length of time, expressed definitely in terms of years, which it takes for an area to go through the successive changes from initial stage to climax, there is nothing in the nature of the herbaceous vegetation of an area to indicate. By comparing various representative areas in the valley with each other and with climax areas on both bluffs, however, it is possible to get a very definite estimate of the relative age of any given area. Numerous such comparisons have been made in the Summary of Plant Distribution, and a brief discussion of these comparisons follows. All comparisons were made by use of Table II, except those stated in items number 21-25 inclusive. Of these, items 21-23 were obtained by use of Table III, while items 24-25 were obtained from Table IV.*

Comparison of Areas:—Of the total of 165 plants (item No. 1) found in the whole vicinity, 154 were found on the Texas side (item No. 7) as compared with 110 on the Oklahoma side (item No. 6) Of the 154 found on the Texas side 133 (item No. 5) occur in the valley as compared with 106 on the bluffs (item No. 9.) This indicates that the vegetation in the valley, considered as a whole, has not completed the task of adjustment to climax conditions, as indicated by the greater number of species in the valley, nor can it be expected ever to become wholly adjusted, so long as the stream continues to work the valley. The valley contains every degree of moisture from

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*Table IV, used in the testimony to show the distribution of each of the various plants dealt with, is omitted in this paper for lack of space water to arid soil, and every shade of soil texture from coarse sand in moving dunes to silt in every conceivable stage of purity. Both types of soil are affected by the wide range of moisture so that the valley as a whole is much more varied in the conditions which it presents than are the bluffs. In table II the whole valley is considered. If only the older dunes were considered their vegetative covering would be found to duplicate very closely that of the dunes back of the Oklahoma bluff. In the consecutive stages leading up to the climax formation there is at first, as suggested above, a more or less rapid increase in the number of species occupying a given area. As the area becomes more and more crowded, competition between the various species for water and solutes becomes keener and keener, so that those species least adapted to these conditions of competition are crowded out by those better adapted. The result is that in the later stages of a succession the total number of species will again diminish. The number of species which will ultimately occupy a given territory will depend upon the degree of extremity of the environmental conditions; the more extreme the conditions the fewer will be the number of species capable of accomodating themselves to them. The Texas valley, as stated above, exhibits all stages of succession and hence a richer flora than either of the bluffs. The fact that the total number of 55 species found on the bluffs of Oklahoma (item No. 10) as compared with 106 on the bluffs of Texas, is not to be construed, however, as an indication that the vegetation on the Oklahoma side has approached any nearer or less near to a climax than has that on the Texas bluff. Both have long since reached the climax for the area, but the much more extreme conditions obtaining on the Oklahoma side restrict its inhabitants to those relatively fewer plants capable of accomodating themselves to these conditions.

The River Valley South of Goat Island:—Of the remaining items most have to do with comparisons involving the river valley south of Goat Island as compared with the various other areas under investigation. In explanation it may be said that the reason for choosing this particular area as a common basis of comparison was because it had every appearance throughout most of its extent of having virtually reached the climax association. A glance at the Tree map will reveal the virtual absence of any trees throughout the area. A secondary high water channel of the river separates the valley mainland from Goat Island on the north, the latter being nearly or quite comparable in age to the cottonwood area of the Big Bend lying on the valley mainland to the west. As one crosses this channel from Goat Island southward, he encounters a perpendicular "caving bank" some 6 to 8 feet high, back of which stretches a series of old dunes bearing essentially the climax association of *Bouteloua, Bulbilis* and other perennial grasses. Lines of these old dunes stretch back to the alluvial flood plain and slough of Wild Horse Creek. This flood plain with the line of seeps at the foot of the bluff just beyond to the south, gives a variety of soil and moisture which breaks into the monotony of vegetation on the dunes and adds to the total number of species accredited to this area. Moreover, the dunes themselves do not appear to be so sterile as those lying back of the Oklahoma bluffs; at any rate the vegetation which they contain is somewhat richer. A comparison of the number of plant species found on them—100 on the river valley south of Goat Island and 50 on the Oklahoma bluff (items No. 2 and No. 10) will however, furnish an inadequate basis for comparison, since the 100 valley plants include those found upon the flood plain of Wild Horse Creek as well as those upon the valley dunes.

Valley South of Goat Island Compared With:

(See Plate V, Fig. 2)

1. *The Texas Valley at the Longitude of the Boner Refinery* (98°38′10″):—Items 2 and 3 show that as regards number of species present, the valley south of Goat Island and at the longitude of Boner Refinery are about the same: but item 15 shows that only 68 duplicates of a possible 93 are actually realized. This is largely because the transect at the longitude of the Boner Refinery extends entirely across the cottonwood savannah to the sand flat or river bed. In order to have the same extension the transect run on the river valley south of Goat Island would have to traverse Goat Island also. Another reason for the low number of duplicates is to be found in the

fact that the valley south of Goat Island exhibits in its oldest portion somewhat more advanced successional stages than are to be found in the oldest portions of the valley at the Boner Refinery longitude. In other words, the complete climax typical for the vicinity has been more clearly attained in the vicinity south of Goat Island than it has in that of the Boner Refinery. As a matter of fact, there appears to be abundant reason, stated presently, for believing that the valley south of Goat Island has as nearly attained the climax as it can be expected ever to attain, so long as present climatic conditions obtain. It is so nearly stable that any changes at present are imperceptible.

2. *The Valley Area Studied in Oklahoma:*—Item No. 11 shows that of a possible 81 duplicate species (see items No. 2 and No. 8) to be found in both the valley south of Goat Island and upon the area studied in the valley on the Oklahoma side, only 49 are realized. The area studied in the Oklahoma side of the valley extended across a strip of land varying in width from about 1000 feet to 1600 feet. A map introduced in evidence as United States and Oklahoma Exhibit No. 40 purported to show the meander line (north cut bank) of the river as of the date of 1875. All territory to the north of that line would therefore be more than 46 years old at the time investigations for Texas were made. The line, in the area studied, lay, at the time the studies were made, about 600 feet on an average north of the present cut bank. This left a strip about 900 to 1000 feet wide at the foot of the Oklahoma bluff which was more than 46 years old in its youngest part, and presumably progressively older as one approached the foot of the bluff. Using the increment of 600 feet in 46 years as a basis of calculation, the land at the foot of the bluff would seem to be about 120 years old. This area was studied with the same degree of care as the other areas investigated; therefore the fact that of a possible 81 duplicates only 49 are realized, is alone strongly indicative of considerably greater age on the part of the river valley south of Goat Island over that under consideration on the Oklahoma side. Furthermore, checking off the 49 duplicates against the Valley South of Goat Island column in Table II will show the remaining 51 plants in that column to be mostly climax forms, whereas the 49 duplicates are mostly representa-

tive of early seral stages.[1] Another consideration not to be overlooked in this connection is the fact that, so far as general appearance of the vegetation on the valley south of Goat Island is concerned, the youngest portion next to the caving bank of the subsidiary channel to the north has more nearly reached the climax aspect typical of the adjacent upland prairie than any other portion of that area. This is indicated by the presence here in dominant form of *Bulbilis dactyloides*, as revealed on the visit in September, 1922. We are thus faced with the proposition that that portion of this area which must actually be the youngest shows the most advanced succession, indicating that sufficient time has elapsed since this portion of the valley was formed to give the vegetation ample opportunity both to build the soil and, by successive invasion, and the resulting competition and elimination of species, virtually to reach the climax characteristic of the surrounding country. Having already attained this climax condition of equilibrium before the investigations were made, it is as impossible to tell how long since the condition was reached as to tell the length of time necessary to reach it. It would seem certain, however, that no competent, unbiased ecologist could go over the ground and come to any other conclusion than that to assume its age as less than 100 years would be the height of absurdity.

In connection with the area in the Oklahoma side of the valley it is interesting to note from List XI the number and identity of the duplicate dominants to be found in both valleys and also on one or the other of the bluffs. These plants are (1) *Ambrosia psilostachya,* (2) *Andropogon hallii,* (3) *A. saccharoides* (*var. torreyanus*), (4) *Aristida purpurea,* (5) *Eriochloa acuminata,* (6) *Eriogonum sp.,* (7) *Cenchrus pauciflorus,* (8) *Heterotheca subaxillaris,* (9) *Hymenopappus sulphureus,* and (10) *Eragrostis spp.* All of these have seeds which are especially adapted to transportation; the second, third, sixth, eighth, ninth and tenth by wind, the fourth and seventh by animals, including man, the first and fifth by water. This adaptation, coupled with the ability to become established upon new soils and by successful competition with all subse-

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[1]See also the list of Oklahoma bluff plants not duplicated in the Oklahoma Valley in the area studied.

quent new-comers to remain dominant members of the vegetation throughout successive stages and into the climax, causes all of them except Number 1 to be found widespread throughout much of the entire prairie region, from the desert plains and Edwards Plateau on the west to the pine forests on the east, and extending south to the Gulf. Number one is also widespread within the limits described above.[1]

3. *The Oklahoma Bluff*:—Item No. 12 shows that of a possible 55 duplicates (see also items No. 2 and No. 10) between the river valley south of Goat Island and the Oklahoma bluff 46 are realized. The nine species which were found on the Oklahoma bluff not in the valley south of Goat Island are: *Euploca convolulacea*, *Calamovilfa gigantea*, *Eurytaenia texana*, *Chamaesyce petaloidea*, *Chloris spp.*, *Cyclolloma atriplicifolia*, *Prosopis glandulosa*, *Monarda sp.*, and *Isopappus divaricatus*. Of these all except *Eurytaenia texana* occur in some part of the valley studied on the Texas side. Though *Prosopis*, not having been encountered in any of the valley transects does not appear on any of the lists of these transects, it occurs in the valley between the Boner Refinery and the Grandfield bridge. *Eurytaenia* is a member of the carrot family, with a herbaceous stem coming from a thick perennial root. It is significant that only this one plant found occurring on the Oklahoma bluff should not have been found also in the Texas valley. The startling significance of this fact becomes more apparent when the Oklahoma bluff is compared with the adjacent Oklahoma valley. This comparison was not included in the testimony offered in be-

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[1]Dr. Cowles in rebuttal (R. p. 5371), trusting to his memory regarding an area below the Burkburnett bridge on the Oklahoma side which was shown by the 1875 meander line (north cut bank as of that date) to be 45 years old at the time of his investigation in 1919, named Eriogonum, Yucca, and Artemisia as climax forms which he recalled as having seen dominant on that area. He argued that the presence of these three indicated the attainment of the climax within 45 years. In this connection it is interesting to note that cottonwood itself, one of the first pioneers, does not reach its prime within 45 years; and 26 of the dominants found south of Goat Island were not shown to have appeared. From personal study of the area the writer is of the opinion that the minutest search will not reveal their presence in dominant form in this area.

half of Texas in this suit; however, the following list of species found on the Oklahoma bluff but not upon the adjacent Oklahoma valley in the area studied, can easily be verified by reference to the respective columns in Table II:

Acamptoclados sessilispicus (Prairie spike-grass).
Argemone alba (White prickly poppy).
Asclepias sp.
Euploca convolvulaceae.
Bouteloua curtipendula (Mesquite grass).
Eurytaenia texana (Wild carrot).
Cebatha carolina (Moon seed; coral bead).
Chamaecrista fasciculata (Partridge pea).
Commelina sp. (Day flower).
Engelmannia pinnatifida.
Gaura villosa (Wild honeysuckle).
Vitis sp. (Grape).
Bumelia sp. (Gum elastic).
Celtis sp. (Shrub) (Hackberry).
Jatropha stimulosa (Bull nettle).
Nuttalia stricta.
Prosopis glandulosa (Mesquite).
Paronychia jamesii.
Parosela lanata.
Paspalum stramineum.
Prunus sp. (Wild plum).
Polygala alba (Milkwort).
Othake spachelatum.
Xanthoxylum sp. (Prickly ash).
Ptelea trifoliata (Hop tree; Whahoo).
Artemisia filifolia (Sage brush).
Smilax bona-nox (Stretchberry).
Styllingia salicifolia (Prince's spurge).
Syntherisma sanguinale (Crab grass).
Isopappus divaricatus.
Sideranthus sp.
Yucca tenuistyla (Bear-grass).

Since there is no evidence whatever to support a conjecture of anything but extreme age for the land lying back of the Oklahoma bluff, speaking in terms of years, all the above listed species must be members of a climax which was reached thousands of years ago. When it is considered that of the 55 species found on the Oklahoma bluff, thirty-two have not yet been found established upon the Oklahoma valley in an area the oldest portion of which may be conservatively estimated to be more than one hundred years old, and that of this same fifty-five climax forms only one has not been found established on the Texas valley in one or more of the areas studied, the only logical conclusion to be drawn is that the Texas valley in these areas is much older than the Oklahoma valley.

4. *The Texas Bluff*:—Item No. 13 shows that of a possible 100 duplications upon the valley south of Goat Island and upon the Texas bluff (cf. items 2 and 9) 73 are realized. This represents 73% of the possible total, as compared with 60% of the possible total between the valley south of Goat Island and the valley on the Oklahoma side, these percentages lying at opposite extremes of the ecologic developmental history. When the Oklahoma bluff column is considered in connection (item No. 14) the number of duplicates between the Texas valley and both bluffs rises to 81, showing in the Texas valley only 19 plants found on neither of the bluffs. This is surprisingly few, considering the general difference in moisture content in the soil, the presence of salt spots in the valley, the difference in exposure, and other purely edaphic features, regardless of the question of comparative or actual age.

As already stated, item 15 shows that of a possible 93 duplicates (see items 2 and 3) between the valley south of Goat Island and at the longitude of the refinery 68 are realized. Reducing this to a percentage basis it is found to be 73.1%—the same percentage as between the valley south of Goat Island and the Texas bluff.

Item 16 shows nine plants occurring both upon the Texas bluff and in the valley at the longitude of the refinery but not found in the valley south of Goat Island. Their significance lies in their indication of likeness between the flora of the valley at the refinery longitude and that of the Texas bluff. The fact that nine bluff plants are here found established on the valley floor but not found in the association at the longitude of the Goat Island transect indicates an almost equal age between these two localities. Upon its face it would seem to indicate greater age for the valley at the refinery; but if the duplicates between the Texas bluff and the valley south of Goat Island not found at the refinery longitude are counted they will be found to number 21, which shows that the conclusion above suggested would be erroneous.

5. *Both Bluffs Combined:*—Item 17 shows the total number of duplicates between the valley in Texas and the two bluffs (Texas and Oklahoma) to be 94. Checking the Oklahoma bluff against the Texas bluff the former is found to contain 9 plants not occurring on the latter. Add these to the total of 106 occurring on the latter (item 9) and the number of duplicates possible between the Texas valley and the two bluffs comes to 115. Dividing 94 by 115 the percentage of possible duplicates realized is 80.7. The 27 plants found in the whole study to be confined to wet or moist soil constitute 16.3% of the total of 165. In general they are not properly considered as bluff plants since if they are found there at all it will be in seepy draws; hence they constitute a majority of those plants responsible for a lack of higher percentage of duplication between the valley and the two bluffs. In this connection it is also interesting to consider the 15 plants found on one or the other of the bluffs but not in the valley in any location (item 20). These are found named in list VIII. Of these, ten were found only in Permian red clay mixed with gravel on the Texas side; three were found only in moist, shaded slopes of the Texas bluff, one (Johnson grass) yielded only one specimen in the whole study though it should presumably become widespread unless moisture conditions are too extreme, while one (wild carrot) has already been mentioned as the only Oklahoma bluff plant not duplicated somewhere in the Texas valley. The only ones of the above plants that are of importance in this study are the ten first mentioned. List VIII is appended, as it here appears, to show the accredited distribution of these ten plants. Assuming the specific determinations of Lactuca and Neptunia to be correct, all except *Phaca elatiocarpa* are more or less common plants about Austin, where they are found in dry clayey situations, with or without a mixture of gravel. The fact that

none of the ten were found upon the dunes lying back of the bluff on the Oklahoma side would seem strongly to indicate that they are unable to make their home in, or become prominent inhabitants of dune situations. Hence in all probability, all ten of them may be expected permanently to remain confined to the Permian red clay-gravel benches of the Texas bluff where they at present occur. *Cissus incisa*, *Strophostyles pauciflora*, and *Ampelopsis* may with confidence be expected to remain confined to the moist shaded north slope of the Texas bluff. Johnson grass and *Phaca elatiocarpa* thus are left the only two exclusive Texas bluff plants concerning whose spread into the valley there may be some doubt. There are thus left 13 bluff plants each of which seems to constitute a valid reason for a lack of duplication in the valley, and leads again to the conclusion that the vegetation in the valley is in its older portions stable, and has as nearly reached the typical mixed prairie climax as can reasonably be expected of it.

Item 18 shows that of the 94 duplicates found in the valley on the Texas side and either on the Texas bluff or the Oklahoma bluff 53 have not yet migrated to the valley in areas studied on the Oklahoma side, the oldest portions of which are more than 100 years old. Since, as successions proceed and after the peak of invasion has passed, the nearer the climax is approached the slower and more difficult invasion by and establishment of new species becomes, the above figures testify strongly to the much greater age of the valley land on the Texas side than that on the Oklahoma side. The 25 duplicates between the two respective valleys not on either bluff (item 19) are composed of plants of high moisture requirement; and the number approaches strikingly near to the number 27 shown in item 24 as being restricted to moist soil in distribution.

Dominance.

Dominance, in the sense in which it was used in the testimony in this case, is synonymous with prominence and numeral strength. That is, those plants which were conspicuous by reason of size and number were rated as dominant. This is a much broader sense than that in which the term is currently used by leading ecologists and except that the need of simplifying the language of the testimony as much as possible is sufficient to justify a certain considerable amount of inexactness, the more exact technical terms consociation, society, clan, associes, concocies, socies, colony, family, etc., denoting degree of dominance and successional relation (whether seral or climax) should have been added. The use of these would have permitted greater exactness in definition, but since their use in number in testimony to be considered primarily by those entirely unfamiliar with ecology would tend toward confusion of mind, it was thought best to use as few technical terms as possible. Hence the list of dominant species found in Table III includes in the one group plants which in accordance with best ecologicol usage should perhaps best be separated into several climax and seral units.

Distribution of Dominants:—The criticism that distribution of dominants is also too roughly shown is quite justifiable. As List XII shows, the vegetation of each successive flat in the valley is different from that of the one either in front of or behind it, and this difference is most pronounced in the younger portions. What is true of the flats is even more pronounced in the intervening dunes, except the first and second. Even here there is a conspicuous difference due to the disappearance of species that were present on the first dune, notably *Reverchonia* and the particular species of *Chamaesyce* which was very prominent on the first dune but almost or quite gone from the second.

The Texas Valley and the Two Bluffs:—Items 21 and 22 show 50% more duplication of dominant species between the valley on the Texas side and one or both bluffs than between it and the valley on the Oklahoma side. Of the latter duplicates, 10 (cf. item 23 and list XI) are also found upon one or the other bluffs and hence are included in the 27 duplicates of item 21 and the 18 duplicates of item 22 (cf. also Lists IX and X). These ten plants, as already stated, because of their excellent adaptation to seed dispersal are among the early pioneers into new soil, while at the same time their abliity to compete successfully with all later arrivals enables them to remain throughout all the seral stages and become prominent members of the climax association in this region.[1] Deducting the ten duplicates for the three regions from 27 and 18 we have respectively 17 and 8 between the Texas valley and the bluffs and between the Texas and Oklahoma valleys; or almost 100% more of exclusive duplication of dominants between the Texas valley and one or both bluffs than between the Texas valley and the Oklahoma valley. These eight latter duplicates are all members of the early seral stages of succession only, while the seventeen former are climax forms.[2]

Significance of Dominants.

The Texas and Oklahoma Sides of the Valley:—Reference to List X will show eight exclusive duplicate dominants between the two valleys. Of these *Baccharis* and *Distichlis* are found in saline flats; *Calamovilfa* and *Populus* are dune pioneers which at length become exterminated or subordinated in the older dunes because of too keen competition on the part of subsequent arrivals; *Gaura villosa* appears later (see List XII: Third Dune) but still later also either succumbs to competition or at least loses its dominant position; *Eleocharis* and *Lythrum* are found only in very moist immature flats while *Phyla* is characteristic of flats of considerably greater maturity. All, in their dominant expression, are confined to seral stages in succession; none of them are dominant plants in the climax association.

The Texas Valley and the Texas and Oklahoma Bluffs:—Consulting the list of (unmarked) dominants duplicated upon the Texas valley and one or both bluffs but not on the Okla-

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[1]*Ambrosia psilostachya* only on old alluvial flats of other fine textured compact soil.

[2]Stating it differently, the Oklahoma valley, in the area studied, contains a total of 10 climax dominants, as against 27 contained in the areas studied in the Texas valley.

homa valley (cf. List IX) will reveal to one familiar with them that they are all climax inhabitants, able successfully to compete both with each other and with the other plants of the climax association, under the rather extreme climatic conditions imposed by their environment. Their appearance as dominants upon either bluff is prima facie evidence of their adaptation to the extreme conditions which obtain in these situations. A comparison of this list with List XII gives further enlightenment. It shows three of these dominants. *Acamptoclados*, plum, and prickly ash, first to appear upon the third dune; one *Eragrostis secundiflora*, upon the preceding (third) flat. Whether the *Parosela* found upon the newly accreted land is the same as that listed as a dominant upon the bluff is not certain from the comparison because the species name is omitted in List XI. Of the remaining 13 exclusive dominants in List IX, not one was found to have appeared up to the point where the transect which yielded List XII stopped; though this point was in territory whose age it seemed abundantly justifiable to estimate as exceeding 150 years.[1] It seems highly significant that only five out of eighteen exclusive duplicate dominants listed should have appeared upon land so old as that of the region in which this transect was discontinued. If only five had even appeared in upward of 150 years, and if the establishment of newcomers and their ascendency to dominance becomes more and more difficult, as the climax is approached, how old is land upon which the entire eighteen have become dominant and which has been shown above already to have approached as nearly to the short grass plains climax as to the local valley conditions will permit? To attempt to state such age in exact terms of years is as absurd as to conclude that it can be less than 100 years.

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[1]The evidence upon which the estimate of the age of this particular locality was based is stated in the discussion of Timber Growth along Upper Red River, p. 124.

Timber Growth Along Upper Red River.

General Statement:—In general, as already pointed out timber is very sparse all along the Upper Red River. Beginning below Denison the trees begin to decrease in size, and to be confined more and more to broken and hilly sections of the country. This decrease is more and more noticeable the farther one proceeds up the river till at and just below the 100th meridian even such an oak as *Quercus breviloba,* which is normally a fair-sized tree along dry limestone hillsides of central Texas, becomes nothing more than a knee-high shrub. Aridity, both of soil and of the atmosphere, coupled with the comparatively high and constant winds constitute the main factors in the extreme conditions which preclude the growth of timber. Exceptions to the general rule are to be found in moist draws, along creek channels, and along most of the river course in situations where soil moisture, at least, is abundant. Even in such localities, however, trees are stunted in appearance as compared with those normal to more eastern forests. Not only are the trees scrubby in size; they are also very scattered in stand. With one exception no really close or dense stands were seen anywhere along the whole upper course of the river.[1] All other stands were decidedly of the open or savannah type in which trees are scattered over grasslands. Since the climax for the region is mixed prairie, it follows that trees must be relatively transitory and unimportant members of the earlier stages of succession only, except in those favorable locations of stream

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[1]A very unusual and striking example of a typical eastern forest occurs on Round Timbers Ranch in Hardeman County, where the Kansas City, Mexico and Orient Railroad crosses Red River. Huge trees of lofty height here occur in dense stand; the long straight boles of the cottonwoods carrying their crowns so high as to overtop the giant elms with which they are mixed. This remarkable growth of timber occupies an exceptionally favorable location at the foot of a very rocky hill, almost a bluff, probably more than 150 feet high which protects it from the prevailing south and southeast winds, while at the same time the trees' roots are growing in rich alluvial soil laid by a tributary stream and watered both by the stream and by numerous seeps from the foot of the bluff.

bank and moist draw already described. There are no exceptions to this rule on the uplands: on the valley floor there is an occasional elm which has succeeded in becoming established in what must be construed as late successional stages. These will be considered following a list of both the trees and shrubs encountered in these areas of the Big Bend and vicinity covered by these investigations.

Trees and Shrubs of the Big Bend Vicinity:—A complete list of the trees and shrubs found in the area covered by the Big Bend investigations compiled from Table II follows:

Amorpha L. (False indigo; Rover locust). S.[1]
Fraxinus lanceolata Borck (Ash) T.[2]
Baccharis salicina T. & G. (Salt willow) S.
Cephalanthus occidentalis L. (Button bush; Button willow) S.
Populus deltoides Marsh (Cottonwood) T.
Ulmus, sp. crassifolica ? (Elm) T.
Celtis sp. occidentalis ? (Hackberry) TS.
Prosopis glandulosa Torr. (Mesquite) T.
Hicoria pecan (Marsh) Britton (Pecan) T.
Bumelia sp. (Gum Elastic) TS.
Prunus sp. (Plum) S.
Xanthoxylum sp. americanum? (Prickly ash) TS.
Ptelea trifoliata L. (Wafer ash; hoptree; Wahoo) S.
Schmaltzia trilobata (Nutt.) Small (Dwarf sumac) S.
Sapindus drummondii (Hook) (Wild china; Soap-berry) T.
Salix luteosericea (Sandbar willow) S.
Salix nigra Marsh (Black willow) T.
Yucca tenuistyla Trel. (Bear grass) S.

Of these, the only ones which were found in this area to form groves were elm and pecan. Frequently these were almost pure, but not infrequently there was an admixture, especially of elm and pecan with each other and also with an occasional hackberry, gum-elastic, or ash.

The Cottonwood Savannah:—Cottonwood forms by far the most extensive savannah, covering hundreds of acres of both the younger dunes and the intervening flats with stands that range from practically pure on the youngest land to very

[1]S. signifies shrub.
[2]T. signifies tree.

slightly mixed in the older portions. To be specific, one hackberry about 8 or 9 inches in diameter, and two pecans 5-6 inches in diameter were found in the whole of the cottonwood savannah in the north portion of the Big Bend valley on the Texas side. The location of these and the extent of the cottonwood savannah are indicated on the tree map in pocket. In addition to these three representatives of two species of trees, shrubs such as sand bar willow appear on the younger dunes and cling rather tenaciously to their place through the earlier stages of succession; while plum and prickly ash begin to appear later. Both normally appear about the time the last of the willows are disappearing; the prickly ash usually somewhat ahead of the plum. Neither of these shrubs was found upon the youngest dunes, the place of their first appearance along the transect which furnished data for List XII being typical of their general successional location as observed in all the developmental areas studied. Once established, both prickly ash and plum hold to their places with the greatest tenacity and are to be found extending well into the climax: the former as an occasional dwarf shrub, the latter forming rather decided thickets. This concludes the enumeration of both tree and shrub impurities as found in this particular cottonwood savannah, which is typical of all others observed throughout the extent of the investigation. It shows how remarkably near the stands of cottonwood come to absolute purity. The total absence of elm and the near absence of pecan from the cottonwood area will be taken up presently in connection with further consideration of detailed distribution of these two species.

Conditions for Growth of Cottonwood:—The generally unhealthy condition of practically all except the youngest of the cottonwood trees wherever found upon the valley floor, the representative appearance of which is shown by the reproduced photographs in Plate VI, bears testimony of the unhealthfulness of the environment for that species. Just what the causative factors in this condition are was not determined with any degree of certainty. It seems likely, however, that great fluctuation in the height of the water table, which normally varies several feet during a twelve months period, may be the chief factor: now, rising so high as to damage or kill the lower roots by drowning, now falling so low as to leave the upper layers of soil too dry to furnish sufficient water for the inadequate root system which they contain. Another probable cause is the low humidity of the air and the prevailing strong winds. If a sudden fall in the water table from a peak to near the minimum were to occur simultaneously with a strong hot north-wind of the type which in a few days will destroy the crops in this section, the result could hardly be expected to be without disastrous effect upon the cottonwoods. Alkalinity may also play a part in the situation: competition undoubtedly does. There may be other factors, unsuspected, which are more potent than any of the above. Whatever the cause there can be no question as to the result: the environment is generally unhealthful for cottonwood, so that a dense stand of seedlings is in the first few years so depleted that it becomes an open one,and thus remains till the final elimination of this species from the vegetation of an area which originally carried a dense pure stand of seedlings. As a stand becomes open, however, and other seeds are scattered over the area, new seedlings appear during favorable seasons, so that there is a variety of age represented from the oldest down to seedlings of the current year. Of course during unfavorable seasons such seedlings may not appear, so that a complete range of ages one year apart is not to be expected; but that in general there is successful effort on the part of the cottonwood during the earlier stages of succession to perpetuate its stand by the continuous production of offspring as above stated, there is an abundance of evidence to prove.

The cottonwood is able to seed its area less and less efficiently, the denser becomes the herbaceous plant covering, especially grasses, which carpets the ground beneath, catching and holding the tiny woolly cottonwood seeds so that they may not reach the soil. The most critical point connected with the establishment and maintenance of the cottonwood stage in sucession is thus the period of germination, which coincides with the period of shedding of the seed. If the seed can reach moist soil when shed, they will germinate and establish themselves as seedlings; otherwise establishment becomes impossible. The inevitable result is that so soon as the herbaceous carpet gets sufficiently dense to catch all the seeds, no more seedlings will appear. After that it is only a question of time till the last of those already present will yield to the stronger competition of other species better adapted to the environment and the cottonwood succession will, on that area, disappear. But it must be borne in mind that as new sandbars are thrown up against an existing "bank" thus opening up a new area for plant colonization, cottonwood will be one of the first pioneers to become established upon it, so that as the river builds its banks outward by accretion, the cottonwood area progresses forward. The initial stand of seedlings upon a sand bar therefore represents the advance guard, the last one to yield by death to the advancing grass land the rear guard of the cottonwood army. Upon the tree map the advance guard is at the "cut bank" of the Big Bend apex, the rear guard at the southernmost extremity of the area

The Minimum Age of the Oldest Portions of the Cottonwood Savannah:—While no attempt was made in the testimony offered as a result of these investigations to state the length of time required for the various stages of succession to pass from initial to climax, an effort was made to estimate the probable minimum time elapsing between the initiation and end of the cottonwood stage. This estimate, based upon the conditions outlined above as obtaining in the cottonwood area of the Big Bend, believed to be conservative and well founded upon adequate positive data is here repeated as follows: The location of tree sample No. 7 will be found shown upon the tree map at Lat. 34°09′20″ Long. 90°38′37″. This sample, a living tree in normal health, cut in the presence of both United States, Oklahoma and Texas representatives, was offered in evidence by the United States and Oklahoma, all witnesses concurring in the estimate of its age as being 75 years at stump height. Topographically, its stump is located at the lowest point on that meridian between two dunes which are tied together just to the west. Within a hundred feet there were three or four other trees similar in appearance, but perhaps slightly younger. In every direction, and within a radius of 300 to 400 ft. there was an abundance of younger trees, grading downward in age, some being seedlings of the previous year. There seems no reason, visible on the ground, for assuming that sample No. 7 necessarily represented the first stand of cottonwood to appear on this localized portion of the area, nor certainly to assume that the youngest seedlings represent the last stand that will appear; therefore both assumptions would seem highly conservative. It seems reasonable also to assume that of a great many seedlings at least a few, barring any wholesale destruction due to disturbances of a catastrophic nature, may be expected to reach the age and appearance of the group from among which sample No. 7 was taken. Upon these conservative assumptions the cottonwood has been an occupant of this particular locality for at least 75 years; and it may be expected, under normal progressive vegetational changes, to remain an occupant at least another 75 years or until the last of the present stand of seedlings, having lived to attain normal age of the oldest trees of the vicinity, has succumbed to superior competition of other species. Thus the 75 years which it has unquestionably already been an occupant, added to the 75 years which it seems entirely reasonable to predict that it will continue to be an occupant, will make 150 years the minimum length of time which will be required for the cottonwood stage to be initiated, run its course and disappear in the successional history of vegetation in the Big Bend under conditions as they have existed in the immediate geologic past, exist at present, and may be expected to continue to exist in the immediate geologic future.

Comparative Age of Areas not Bearing Cottonwood:—Since cottonwood is a consistent feature of all young soil throughout the whole Upper River region, it follows that the comparative age of any localized area not bearing cottonwood can as a rule be estimated from its proximity to the nearest cottonwood savannah. Its age varies directly with its distance from the rear guard of such savannah, the line where the rear guard disappears having a minimum age of at least one hundred fifty years. Two exceptions present themselves as possibilities: the first consisting of young land with no cottonwood, which if it occurs at all must be very rare; the second consisting of areas in which the prairie climax extends entirely to the cut bank (usually in such a case also a caving bank,) wholly eliminating the fringe of cottonwood which normally lines this bank wherever accretion is taking place. In the first of these exceptional cases the comparative age of the land may be estimated by carefully mapping the compositon of its herbaceous covering and matching the map with an area such as that in the longitude of the appex of the Big Bend, a transect across which will reveal all ages in unbroken series from the youngest to the climax. The locality which, along such a transect, shows a vegetable covering most nearly coincident with that upon the map, obviously will have a corresponding similarity of age. In the second exceptional case, obviously the only way confidently to determine the age of the area would be either to map the area as above suggested, or to follow it laterally up or down stream till an area of unbroken series of successional stages is reached, and then make an estimate from the nearness of the area in question to the rear guard of the cottonwood savannah.

Timber Growth Other Than Cottonwood

Timber growth, other than cottonwood certainly bears no significant relation to the age of the soil upon which it occurs. As indicated above, it never follows cottonwood in those portions of the Big Bend which are destined to become typical mixed prairie climax. Every species which in the older portions of the valley attains tree size is, in its tree growth-form, confined almost exclusively to the alluvial flood plains of tributary streams, superimposed upon the valley floor and watered from the slough-like channels of these tributary streams. Such areas seem destined for a long time to come to be covered with park-like growths of timber. Rarely a pecan, as for example sample No. 6, or elm, sample No. 24 (see reproduced topographic map in pocket for location) will be found standing well out on the prairie, constituting an exception to the rule; but these exceptions are very rare indeed. Hackberry and prickly ash occur sparsely on the old dunes in the valley, but in such locations they have the shrub growth-form. An inspection of the tree map will reveal the major distribution of timber. The line of timber along the bluff is principally elm and pecan. An occasional wild china, hackberry, cottonwood, or other tree not sufficiently numerous to give character to the group was ignored in the map legend. All of these occur sparsely in the pecan-elm mixture. An interesting group occurs just south of parallel 34°9′0″ and principally east of Mer. 98°37′30″. The stand is comparatively close, and is composed of hackberry, elm, gum elastic, pecan and, at the western extremity, a few relict cottonwoods. The copse-like appearance of the group constitutes a landscape feature which is noticeable from a considerable distance across the otherwise prairie vegetation. A glance at the topographic features reveals at once an abundance of soil water essential to the continued existence of timber in this vicinity and the rough and broken surface which facilitates the initiation and perpetuation of a stand of trees. Aside from this group and those on the flood plain of Wild Horse Creek, the whole Big Bend area south of the cottonwood savannah (or the cut bank in those situations so far advanced as entirely to have eliminated the cottonwood succession) is, as stated in previous paragraphs, to all appearance practically climax prairie in composition clear up to the foot of the line of bluffs. Such shrubs of hackberry, prickly ash, etc., as are to be found associated with the climax herbaceous plants of the valley are also commonly found exhibiting the same growth form both on the Texas bluffs and on the dunes lying back of the Oklahoma bluff.

Just as it would be manifestly absurd to attempt to use the age of the oldest tree one might find in a forested area as a dependable criterion for judging the maximum age of the land upon which it grows, so is it also absurd to do the same thing in any area which is covered with all ages of timber, and which may be expected to continue to support such timber growth indefinitely. Such are all the timbered areas along the valley of the Red River, in the Big Bend and elsewhere, both as regards cottonwood and as regards all other timber. To measure the maximum age of the soil upon which a forest grows by that of the oldest tree to be found upon it is only slightly removed in degree of absurdity from estimating the age of soil which bears prairie by that of annual plants contained in the association. That the actual age of any portion of the valley land is much less than that of the bluffs goes without saying; but it cannot be conclusively shown, nor even indicated, by an analysis and comparison of the climax covering which each supports. Much less is there a vestige of evidence to indicate that any except the youngest outer portions in certain areas like that occupied by the cottonwood savannah of the Big Bend, are less than one hundred years old.

Minimum Age of Big Bend As Shown by Tree Samples

While, as stated previously, the assumption of coincidence of maximum tree age and maximum age of soil which bears them is unsupported by evidence in the Big Bend valley, there can be no question as to the age of any of the native trees determining the *minimum* age of the soil which bears them. Therefore the list which follows constitutes the record of convincing evidence that much of the valley still bearing trees is of an age greater than 100 years. The late date of cutting these trees resulted from the difficulty experienced by attorneys for the defendant in getting the permission of the federal receiver to cut them. By agreement representatives of both sides were either present at the cutting, or were furnished duplicate samples of specimens cut. The first fifteen samples were introduced by Mr. L. L. Janes, ecologist, testifying for the United States and Oklahoma at Oklahoma City; the others except the last three, by the writer at Austin, Texas. Numbers 1, 5, 6, 10, 11, 12, 15, 17, 18, 24 and 25 each being one hundred years old or older were all well scattered over the surface of the valley, thus establishing beyond controversy the minimum age of a greater part of it as exceeding one hundred years.

LIST OF TREE SAMPLES CUT ON RED RIVER BY UNITED STATES, OKLAHOMA AND TEXAS REPRESENTATIVES IN 1921. THE NUMBER, KIND, LOCATION ON TEXAS MAP EXHIBITS, AGE OF EACH WITH DIAMETER IN INCHES, TOGETHER WITH DATE ON WHICH EACH WAS CUT ARE GIVEN.

Sample number.	Kind.	Location.		Age in years.	Diameter in inches.	Date cut.
		Latitude.	Longitude.			
1	Elm	34-08-32.5	98-36-03	118	30	Aug. 22, 1921
2	Hackberry	34-08-31.5	98-36-02	54	20-21.5	Aug. 22, 1921
3	Elm	34-08-18	98-36-00.5	65	22	Aug. 22, 1921
4	Elm (dead)	34-08-24	98-35-58	90	--------	Aug. 22, 1921
5	Cottonwood (dead)	34-08-32	98-36-40	100	53	Aug. 23, 1921
6	Pecan	34-08-55	98-38-18	175	33	Aug. 23, 1921
7	Cottonwood	34-09-20	98-38-07	75	22	Aug. 24, 1921
8	Elm	34-08-40	98-38-51	69	17	Aug. 24, 1921
9	Elm	34-08-40	98-38-49	66	22	Aug. 24, 1921
10	Elm (dead)	34-08-20	98-36-09	130	28	Aug. 24, 1921
11	Elm (dead)	34-08-21	98- 6-16	103	26.5	Aug. 25, 1921
12	Elm	34-08-34	98-35-53	141	37	Aug. 25, 1921
13	Ash	Not located	Not located	30	29.5	Aug. 25, 1921
14	Cottonwood	34-08-56	98-35-44	75	24.5	Aug. 27, 1921
15	Elm (dying)	34-08-39.5	98-37-25	102	24	Sept. 1, 1921
16	Elm	34-08-38	98-38-32	112	29	Sept. 1, 1921
17	Chittim	34-08-56	98-37-17	105	23	Sept. 1, 1921
18	Elm	34-08-56	98-37-17.5	118	25	Sept. 1, 1921
19	Prickly ash	34-08-58	98-37-17	35-40	8.5	Sept. 1, 1921
20	Cottonwood	34-09-20	98-37-26	45	30	Sept. 1, 1921
21	Cottonwood	34-09-33	98-38-18	23	13.5	Sept. 1, 1921
22	Cottonwood	34-09-34	98-38-19	22	19	Sept. 1, 1921
23	Cottonwood	34-09-39	98-38-13	24	17	Sept. 1, 1921
24	Elm	34-08-39	98-35-49	108	27	Sept. 1, 1921
25	Elm	34-08-34	98-37-09	105	23	Sept. 11, 1921
26	Elm	34-08-39	98-39-09	158	30	Sept. 11, 1921
27	Cottonwood	34-08-08	98-34-17	91	37	Sept. 27, 1921
28	Cottonwood	34-08-05	98-34-16.5	13	5.5	Sept. 27, 1921
29	Pecan	Mouth Gilbert Creek		143	32	--------------
30	Elm	Mouth Gilbert Creek		98	29	--------------
31	Elm	Round Timbers Ranch		158	27	--------------

TABLE II.

LIST OF PLANTS BY BOTH COMMON AND SCIENTIFIC NAME TO SHOW GENERAL DISTRIBUTION OF EACH PLANT

NAME OF PLANT Scientific.	Common.	Goat Island.	River Valley south of Goat Island.	River Valley Boner Refinery.	River Valley Bass Co. Lease.	River Valley Oklahoma.	Texas Bluff.	Oklahoma Bluff.
Acamptoclados sessilispicus (Buckl.) Nash	Prairie spike grass	------	—	—	------	------	—	—
Acuan illinoensis Kuntz	None	—	—	—	------	—	—	—
Allionia hirsuta Pursh	Umbrella wort	------	—	—	------	------	—	------
Amaranthus graecizans L.	Pigweed or careless weed	------	—	—	------	—	—	------
Amaranthus blitoides S. Wats.	Pigweed or careless weed	------	—	------	------	—	—	------
Amaranthus retroflexus L. (?)	Pigweed or careless weed	------	------	------	—	—	------	------
Ambrosia aptera DC.	Giant ragweed	------	—	------	—	—	------	------
Ambrosia psilostachya DC.	Small perennial ragweed	—	—	—	—	—	—	------
Amorpha fruticosa L.	None	------	------	—	—	—	------	------
Andropogon hallii Hack.	Beard grass	—	—	—	—	—	—	—
Andropogon saccharoides var. torreyanus (st) Hack.	Beard grass	—	—	—	—	—	—	—
Aphanostephus skirrobasis (DC.) Trel.	None	------	—	—	------	—	—	—
Apocynum cannabinum L.	Dog-bane. Indian hemp	------	------	------	—	—	------	------
Apocynum sibiricum Jacq.	Dog bane. Indian hemp	------	------	—	—	—	------	------
Argemone alba Lestib.	White prickly poppy	------	—	—	------	------	—	—
Aristida purpurea Nutt.	Poverty-grass	—	—	—	------	—	—	—
Asclepias lindheimeri Engelm.	Milkweed	------	—	—	------	------	—	—
Fraxinus lanceolata Borck	Ash	------	------	------	------	—	------	------
Aster spp.	Aster	------	—	—	—	------	------	------
Baccharis salicina T. & G.	Salt willow	—	—	—	—	—	------	------
Euploca convolvulaceae Nutt.	None	—	------	------	—	------	—	—
Bouteloua curtipendula (Michx.) Torr.	Mesquite grass	------	—	—	------	------	—	—
Bouteloua hirsuta Lag.	Mesquite grass	------	------	------	------	------	—	------
Glycyrrhiza lepidota Pursh	Wild liquorice	—	—	—	—	—	------	—
Cephalanthus occidentalis L.	Buttonbush. Button willow	------	------	------	------	—	------	------
Calamovilfa gigantea S. & M.	Dune Grass	—	------	—	—	—	—	—
Cardiospermum sp.	Balloon vine	------	------	------	------	—	------	------
Distichlis spicata (L.) Greene	Spike grass	—	—	—	------	—	------	------
Eurytaenia texana T. & G.	Wild carrot	------	------	------	------	------	—	—

Sessuvium sessile Pers	Sea purslane					—		
Dondia linearis (Ell.) Millsp.	None					—		
Eragrostis spp.		—	—	—		—	—	—
Cathartolinum rigidum (Pursh.) Small	Flax		—	—			—	
Cebatha carolina (L.) Brit.	Coral bead		—	—				—
Cenchrus pauciflorus Benth.	Bur grass	—	—	—	—	—	—	—
Centaurea americana Nutt.	American star thistle		—				—	
Chaetochloa spp.	Fox-tail grass	—		—		—		
Chamaecrista fasciculata Greene	Partridge pea		—	—				—
Chamaesyce prostrata (Ait) Small	Prostrate spurge		—			—	—	
Chamaesyce petaloidea (Engelm.) Small	Spurge	—		—	—	—	—	—
Chenopodium album L.	Lamb's quarters					—	—	
Chloris spp.	Crowfoot grass		—	—			—	
Cissus incisa Desmoul.	Cow-itch vine						—	
Commelina sp.	Day flower		—					—
Populus deltoides Marsh.	Cottonwood	—	—	—	—	—	—	
Croton texensis (Kl.) Muell. Arg.			—	—	—	—	—	—
Cuscuta sp	Dodder. Love vine			—				
Cucurbita foetidissima H.N.K.	Wild gourd					—	—	
Cycloloma atriplicifolia (Sp.) Coulter	None	—			—	—		—
Cleomella angustifolia Torr	Narrow leaved caper		—				—	
Cyperus spp.	Nut grass	—	—	—	—	—	—	
Dichrophyllum marginatum (Pursh.) Kl. & Garck.	White topped spurge		—			—		
Echinochloa crusgalli (L.) Beauv.	Barnyard grass					—		
Eclipta alba (L.) Hassk.	None					—		
Eleocharis spp.	Sedge	—	—	—	—	—		
Ulmus (sp. crassifolia Nutt?)	Elm		—			—	—	
Elymus canadensis L.	Rye grass					—	—	
Engelmannia pinnatifida T. & G.	None		—	—			—	—
Eriochloa acuminata (Presl.) Kunth	None	—	—	—	—	—	—	—
Eriogonum spp.	None	—	—	—		—	—	—
Erigeron sp.	None		—					
Eupatorium (sp. serotinum Michx.)	None					—		
Eustoma russellianum (L.) Griseb.	Blue-bell. Blue gentian	—	—	—	—	—		
Filago nivea Small	Rabbit tobacco						—	
Fuirena hispida Ell.			—	—		—		
Gaillardia lanceolata Michx	Loose-strife			—			—	
Gaura parviflora Dougl	Wild honeysuckle	—	—			—	—	—
Stenosiphon linifolium (Nutt.) Britt.	Wild honeysuckle		—	—		—	—	—
Gaura villosa Torr.	Wild honeysuckle	—	—	—	—		—	—
Phaca elatiocarpa (Sheld) Rydb.	False ground plum						—	
Grindelia inuloides Willd.	Gum weed		—	—	—		—	
Vitis sp.	Grape		—	—			—	—
Bumelia sp	Gum elastic		—	—				—
Gutierrezia spp.	Broomweed		—	—	—	—	—	

TABLE II—Continued.

LIST OF PLANTS BY BOTH COMMON AND SCIENTIFIC NAME TO SHOW GENERAL DISTRIBUTION OF EACH PLANT

NAME OF PLANT Scientific.	Common.	Goat Island.	River Valley south of Goat Island	River Valley Boner Refinery.	River Valley Bass Co. Lease.	River Valley Oklahoma.	Texas Bluff.	Oklahoma Bluff.
Celtis occidentalis L. (Shrub)	Hackberry		—				—	—
Celtis occidentalis L. (Tree)	Hackberry		—				—	
Hedeoma hispida Pursh				—				
Helenium microcephalum DC.	Bitterweed. Sneezeweed					—		
Helianthus petiolaris Nutt.	Sunflower		—		—	—	—	
Helianthus annuus L.	Sunflower		—	—	—		—	
Helianthus maximilianii Schrad.	Sunflower		—		—		—	
Heterotheca subaxillaris (Lam.) Br. & R.	None	—	—	—		—	—	—
Houstonia angustifolia Michx.	Bluet						—	
Hymenopappus sulphureus Rydb.	None	—	—	—		—	—	—
Indigofera leptosepala Nutt.	Indigo plant	—	—	—	—	—	—	—
Ipomoea leptophylla Torr.	Bush morning-glory		—				—	
Iva (sp. ciliata Willd.)	Marsh elder		—	—		—		
Jatropha stimulosa Michx.	Bull nettle		—	—				—
Sorghum halepense (L.) Pers.	Johnson grass						—	
Juncus torreyi Coville	Bull-rush	—		—		—		
Kallstroemia sp.	Caltrop		—	—			—	
Krameria secundiflora DC.	None						—	
Laciniaria spp.	Button root		—	—			—	
Lactuca sp.	Wild lettuce						—	
Strophostyles pauciflora (Benth.) S. Wats.	Wild bean						—	
Lepidium sp.	Pepper-grass					—	—	
Leptilon canadense (L.) Britt.	Mare's tail		—	—			—	
Lythrum lanceolatum Ell.	Loose-strife	—	—	—		—		
Nuttallia stricta (Osterh.) Greene	None		—	—	—			—
Meriolix drummondiana (Sp.) Small	Evening primrose	—	—	—	—	—	—	—
Prosopis glandulosa Torr.	Mesquite			—			—	—
Monarda sp.	Horse mint			—		—	—	—
Morongia uncinata (Willd.) Britt	Sensitive briar			—			—	

Dithyrea wislezeni Eng.	Spectacle-pod		—	—	—	—		—
Neptunia sp.	None						—	
Raimannia rhombipetala (Nutt.) Rose	Evening primrose	—	—	—	—	—	—	—
Opuntia macrorhiza Engelm.	Small prickly pear			—				
Panicum spp.	Panic grass	—	—		—	—	—	
Paronychia jamesii T. & G.	None		—	—			—	—
Parosela lanata (Spreng.) Benth.	None	—	—		—		—	—
Parthenocissus quinquifolia (L.) Planch.	Virginia creeper		—				—	
Ampelopsis cordata Michx.	None						—	
Paspalum stramineum Nash.	None		—				—	—
Hicoria pecan (Marsh) Britt.	Pecan		—	—		—	—	
Pentstemon cobaea Nutt.	Beard tongue						—	
Persicaria lapathifolia (L.) S. F. Gray	Smart weed		—			—		
Petalostemon spp.	Prairie clover	—	—	—		—	—	
Phyla cuneifolia T. & G.	None		—	—		—		
Physalis spp.	Ground cherry						—	
Phytolacca decandra	Pokeberry			—				
Plantago spp.	Plantain		—	—		—	—	—
Pluchea sp.	Marsh fleabane			—		—		
Prunus sp.	Plum	—	—	—	—		—	—
Polygala alba Nutt.	Milkwort		—				—	—
Polygonum sp.	Knot-weed	—	—	—	—		—	
Othake sphacelatum (Nutt.) Rydb.	None		—	—			—	—
Xanthoxylum sp. (Shrub)	Prickly ash		—	—			—	—
Xanthoxylum sp. (Tree)	Prickly ash		—					
Ptelea trifoliata L.	Hop tree. Whahoo		—				—	—
Ratibida columnaris (Sims) D. Don	Cone flower							
Rudbeckia hirta L.	Cone flower			—		—		
Rumex sp.	Dock					—		
Salsola pestifer A. Nels.	Russian thistle		—		—	—	—	
Artemizia filifolia Nutt.	Sage brush	—	—				—	—
Salvia azurea Lam.	Blue sage		—	—			—	
Samolus cuneatus Small	Water pimpernel	—	—	—		—		
Scutellaria resinosa Torr.	Skullcap						—	
Schmaltzia trilobata (Nutt.) Small	Dwarf sumac					—		
Sitilias multicaulis (DC.) Greene	False dandelion		—					
Smilax bona nox L.	Stretchberry		—				—	—
Solanum eleagnifolium Cav.	Trompillo		—	—		—	—	
Solanum rostratum L.	Tread softly	—		—			—	
Solanum torreyi A. Gray	Torrey's nightshade			—			—	
Solidago sp.	Goldenrod			—			—	
Stillingia salicifolia (Torr.) Small	Prince's spurge		—				—	—
Syntherisma sanguinale L.	Crab grass			—	—		—	
Thelesperma gracile (Torr.) A. Gray	None		—	—			—	—
Tribulus terrestris L.	Bur-nut		—	—			—	

TABLE II—Continued.

LIST OF PLANTS BY BOTH COMMON AND SCIENTIFIC NAME TO SHOW GENERAL DISTRIBUTION OF EACH PLANT

NAME OF PLANT Scientific.	Common.	Goat Island.	River Valley south of Goat Island.	River Valley Boner Refinery.	River Valley Bass Co. Lease.	River Valley Oklahoma.	Texas Bluff.	Oklahoma Bluff.
Vernonia interior Small	Iron-weed	------	—	—	------	—	—	------
Vincetoxycum cynanthoides (Engelm.) Vail	None	------	------	—	------	------	—	------
Cicuta maculata L.	Water hemlock	------	------	------	------	—	------	------
Tetraneuris linearifolia (Hook) Greene	None	------	------	—	------	------	—	------
Sapindus drummondii Hook	Wild china	------	—	------	------	------	—	------
Salix sp. luteosericea Rydb.	Willow (Sand bar willow)	------	—	—	------	—	------	------
Salix sp. nigra Marsh.	Willow (Black willow)	—	------	------	------	—	------	------
Xanthium sp.	Cockle-bur	—	—	—	—	—	—	------
Isopappus devaricatus (Nutt.) T. & G.	None	—	------	------	—	------	------	—
Sideranthus spinulosus (Pursh.) Sweet	None	------	—	—	------	------	—	—
Yucca tenuistyla Trel.	Bear grass	—	—	—	—	------	—	—
Heliotropium curassavicum L.	Salt heliotrope	—	------	------	------	—	------	------
Heliotropium tenellum (Nutt.) Torr.	Heliotrope	------	------	—	------	------	------	------

TABLE III.

PLANT SPECIES DOMINANT IN LOCALITIES STUDIED.

Name of Plant.	Goat Island.	River Valley Goat Island.	Oklahoma Bluff.	Oklahoma Seep.	Flood Plain Oklahoma.	Low Dune Oklahoma.	Texas Bluff.	River Valley at Refinery.	River Valley Bass Lease.
Acamptoclados sessilispicus (Buckl.) Nash		—	—				—	—	
Acuan illinoensis Kuntze					—				
Amaranthus spp.							—		
Ambrosia psilostachya DC.					—		—	—	
Andropogon Hallii Hack.		—	—			—	—	—	
Andropogon saccharoides var. torreyanus Steud.		—				—	—	—	
Aphanostephus skirrobasis (DC.) Trel.		—	—				—		
Argemone alba Lestib.							—	—	
Aristida purpurea Nutt.		—	—			—	—	—	
Baccharis salicina T. & G.				—	—			—	
Bouteloua curtipendula Torr.		—	—				—	—	
Bouteloua hirsuta Lag.							—		
Glycyrrhiza lepidota Pursh. Bur clover					—				
Cephalanthus occidentalis L. Button bush				—					
Calamovilfa gigantea S. & M.					—			—	
Distichlis spicata (L.) Greene		—			—			—	
Cathartolinum rigidum (Pursh.) Small							—	—	
Cenchrus pauciflorus Benth.		—				—	—	—	
Centaurea americana Nutt.							—		
Chamaecrista fasciculata (Michx.) Greene								—	
Populus deltoides Marsh.	—				—			—	
Eclipta alba (L.) Hassk.				—					
Eleocharis spp.		—		—					
Engelmannia pinnatifida							—		
Eriochloa acuminata (Presl.) Kunth		—	—			—	—	—	
Eriogonum spp.						—	—	—	
Gaura parviflora Dougl.						—		—	
Gaura villosa Torr.								—	
Gutierrezia spp.							—	—	
Celtis occidentalis L. Hackberry (Shrub)		—	—						

TABLE III—Continued.

PLANT SPECIES DOMINANT IN LOCALITIES STUDIED.

Name of Plant.	Goat Island.	River Valley Goat Island.	Oklahoma Bluff.	Oklahoma Seep.	Flood Plain Oklahoma.	Low Dune Oklahoma.	Texas Bluff.	River Valley at Refinery.	River Valley Bass Lease.
Helianthus petiolaris Nutt.		—					—		—
Helianthus maximiliani Schrad							—		
Heterotheca sub-axillaris (Lam.) Br. & R.		—	—			—		—	
Hymenopappus sulphureus Rydb.			—					—	
Indigofera leptosepala Nutt.								—	
Jatropha stimulosa Michx.		—							
Laciniaria spp.							—	—	
Leptilon canadense (L.) Brit.							—		
Lythrum lanceolatum Ell.	—	—		—				—	
Meriolix drummondiana (Sp.) Small.		—	—				—	—	
Dithyrea wislezeni Engelm. Mustard.								—	
Nuttallia stricta (Osterhout) Greene.		—						—	
Paronychia jamesii T. & G.			—					—	
Parosela lanata (Spreng.) Brit		—					—		
Penstemon cobaea Nutt.							—		
Petalostemon spp.		—					—		
Phyla cuneifolia T. & G.				—				—	
Pluchea sp.				—					
Prunus sp. Plum.							—	—	
Prickly ash (Shrub).			—					—	
Artemisia filifolia Nutt. Sage brush.			—						
Scutellaria resinosa Torr.							—		
Sideranthus spinulosus (Pur.) Sweet.		—	—				—	—	
Thelesperma gracile (Torr.) A. Gray.								—	
Salix luteosericea Rydb. Willow.					—				
Yucca tenuistyla Trel.	—	—	—				—	—	
Eragrostis spp.		—	—				—	—	

LIST I.

PLANTS FOUND IN RIVER VALLEY SOUTH OF GOAT ISLAND AND ALSO IN RIVER VALLEY IN OKLAHOMA.

Acuan illinoensis (L.) Kuntze.
Amaranthus graecizans L.
Amaranthus blitoides S. Wats.
Ambrosia aptera DC.
Ambrosia psilostachya DC.
Andropogon saccharoides (Hack.).
Andropogon hallii Hack.
Aphanostephus skirrobasis (DC.) Trel.
Aristida purpurea Nutt.
Baccharis salicina T. & G.
Glycyrrhiza lepidota Pursh.
Distichlis spicata (L.) Greene.
Cenchrus pauciflorus Benth.
Chamaesyce prostrata.
Populus deltoides Marsh.
Croton texensis (KL.) Muell. Arg.
Cyperus spp.
Dichrophyllum marginatum (Pursh.) Kl. & Garcke.
Eleocharis spp.
Ulmus crassifolia Nutt.
Eragrostis spp.
Eriogonum annuum Nutt.
Eustoma russellianum (H) Griseb.
Fuirena hispida Ell.
Gaura parviflora Dougl.
Stenosiphon linifolium (Nutt) Grit.
Gutierrezia juncea Green.
Helianthus petiolaris Nutt.
Heterotheca subaxillaris (LAm.) Br. & Rus.
Hymenopappus sulphureus Rydb.
Indigofera leptosepala Nutt.
Iva ciliato Willd.
Lythrum lanceolatum Ell.
Meriolix drummondiana (Spach.) Small.
Dithyrea wislezeni Eng.
Rainmannia rhombipetala (Nutt) Ros.
Panicum spp.
Persicaria lapathafolia (L.) S. F. Gray.
Petalostemon spp.
Phyla cuneifolia T. & G.
Plantago sp.
Salsola pestifer A. Nels.

Samolus cuneatus small.
Solanum eleagnifolium Cav.
Vernonia interior Small.
Salix luteosericea Rydb.
Xanthium sp.
Eriochloa acuminata Kunth.
Engelmannia pinnatifida T. & G.
Pecan (Hicoria pecan). TOTAL 50.

LIST II.

PLANTS FOUND BOTH IN RIVER VALLEY SOUTH OF GOAT ISLAND AND ON BLUFFS OF OKLAHOMA (TOP AND SIDES).

*Acamploclados sessilispicus (Buckl.) Nash.
*Andropogon hallii Hack.
*Andropogon saccharoides Hack.
*Aphanostephus skirrobasis (DC.) Trel.
*Argemone alba Lestib.
*Aristida purpurea Nutt.
*Asclepias lindheimeri Engelm.
*Bouteloua curtipendula (Michx.) Torr.
Glycrrhiza lepidota Pursh.
Cebatha carolina — (L.) Britton.
*Cenchrus pauciflorus Benth.
Chamaecrista fasiculata (L.) Greene.
Commelina sp.
*Croton texensis (KL.) Muell. Arg.
*Engelmannia pinnatifida T. & G.
*Eragrostis spp.
*Eriogonum annuum Nutt.
*Gaura villosa Torr.
*Grape (Vitis sp.).
Gum elastic (Shrub).
*Hackberry (Shrub).
*Heterotheca subaxillaris (Lam.) Br. & R.
*Hymenopappus sulphureus Rydb.
*Indigofera leptosepala Nutt.
Jatropha stimulosa Michx.
*Meriolix drummondiana (Sp.) Small.
Nuttallia stricta Greene.
Dithyrea wislezeni Eng.
*Paronychia jamesii T. & G.

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*Indicates plants that are found on both Texas bluff and Oklahoma bluff.

*Parosela lanata (Spreng.) Britton.
*Paspalum stramineum Nash.
*Plantago spp.
*Plum (Prunus sp.).
*Polygala alba Nutt.
Othake sphacelatum (Nutt.) Rydb.
*Raimannia rhombipetala (Nutt.) Rose.
Prickly ash (Shrub) Xanthoxylum sp.
*Ptelea trifoliato L.
*Artemisia filifolia Nutt.
*Sideranthus spinulosus (Pursh.) Sweet.
Smilax Bona-nox L.
*Stenosiphon linifolium (Nutt.) Britt.
*Styllingia salicifolia (Torr.) Small.
*Thelesperma gracile (Torr.) A. Gray.
*Yucca tenuistylo Trel.
*Eriochloa acuminata. TOTAL 46.

LIST III.

PLANTS FOUND IN RIVER VALLEY SOUTH OF GOAT ISLAND AND ALSO ON TEXAS BLUFF.

*Acamptoclados sessilispicus (Buckl.) Nash.
Acuan illinoensis Kuntze.
Allionia hirsuta Pursh.
Amaranthus blitoides S. Wats.
Amaranthus graecizans L.
Amaranthus retroflexus L.
Ambrosia psilostachya DC.
*Andropogon hallii Hack.
*Aphanostephus skirrobasis (DC.) Trel.
*Andropogon saccharoides Hack.
*Argemone alba Lestib.
*Aristida purpurea Nutt.
*Asclepias spp.
*Bouteloua curtipendula Torr.
Cathartolinum rigidum Small.
*Cenchrus pauciflorus Benth.
Centaurea americana Nutt.
Cottonwood (Populus deltoides Marsh.)
*Croton texensis (KL.) Muell. Arg.
Cyperus spp.

*Indicates plants that are found on both Texas bluff and Oklahoma bluff.

Elm (Ulmus sp.).
*Engelmannia pinnatifida T. & G.
*Eragrostis spp.
*Eriogonum sp.
Gaura parviflora Dougl.
*Stenosiphon linifolium (Nutt.) Britt.
*Gaura villosa Torr.
Grindelia inuloides Willd.
*Grape (Vitis sp.).
Gutierrezia spp.
*Hackberry (Shrub).
Hackberry (Tree).
Helianthus petiolaris (Nutt).
Helianthus annuus L.
Helianthus maximiliana Shroeb.
*Heterotheca subaxillaris (Lam. Br. & R.).
*Hymenopappus sulphureus Rydb.
*Indigofera leptosepala Nutt.
Ipomoea leptophylla Torr.
Kallstroemia sp.
Laciniaria spp.
Leptilon canadense (L.) Britt.
*Meriolix drummondiana (Sp.) Small.
*Raimannia rhombipetala (Nutt.) Rose.
Panicum spp.
*Paronychia jamesii T. & G.
*Parosela lanata (Spreng) Britt.
Parthenocissus quinquefolia (L.) Planch.
Paspalum stramineum Nash.
Pecan (Hicoria pecan Marsh.).
Petalostemon spp.
Physalis spp.
*Plantago spp.
*Plum (Prunus sp.).
*Polygala alba Nutt.
*Eriochloa acuminata (Presl.) Kunth.
Polygonum sp.
*Othake sphacelatum (Nutt.) Rydb.
*Prickly ash (Xanthoxylum sp.).
*Ptelea trifoliata L.
Russian thistle (Salsola pestifer A. Nels.)
*Artemisia filifolia Nutt.
Salvia azurea Lam.
*Sideranthus spinulosus (Pursh) Sweet.

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*Indicates plants that are found on both Texas bluff and Oklahoma bluff.

*Smilax bona-nox L.
Solanum eleagnifolium Cav.
*Styllingia salicifolia (Torr.) Small.
*Thelesperma gracile (Torr.) A. Gray.
Tribulus terrestris L.
Vernonia interior Small.
Wild china (Sapindus sp.).
Xanthium sp.
*Yucca tenuistyla Trel.

LIST IV.

PLANTS FOUND IN RIVER VALLEY SOUTH OF GOAT ISLAND AND ALSO AT BONER REFINERY (LONGITUDE) BOTH ON TEXAS SIDE.

Plantago sp.
Plum.
Polygonum sp.
Othake sphacelatum (Nutt.) Rydb.
Salvia azurea Lam.
Solanum eleagnifolium Cav.
Thelesperma gracile (Torr.) A. Gray.
Tribulus terrestris L.
Vernonia interior Small.
Willow (Sand-bar).
Acamptoclados sessilispicus (Buckl.) Nash.
Acuan illinoensis Kuntze.
Allionia hirsuta Pursh.
Amaranthus blitoides S. Wats.
Amaranthus graecizans L.
Amaranthus retroflexus L.
Ambrosia psilostachya DC.
Andropogon hallii Hack.
Andropogon saccharoides Hack.
Aphanostephus skirrobasis (DC.) Trel.
Aristida purpurea Nutt.
Asclepias spp.
Aster spp.
Baccharis salicina T. & G.
Bouteloua curtipendula (Michx) Torr.
Glycyrrhiza lepidota Pursh.
Distichlis spicata (L.) Greene.
Cathartolinum rigidum (Pursh.) Small.

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*Indicates plants that are found on both Texas bluff and Oklahoma bluff.

Cenchrus pauciflorous Benth.
Cottonwood (Populus deltoides Marsh.)
Croton texensis (Kl.) Muell. Arg.
Eleocharis spp.
Engelmannia pinnatifida T. & G.
Eragrostis spp.
Eriogonum annuum Nutt.
Eustoma russellianum (H.) Griseb.
Grindelia inuloides Willd.
Gutierrezia spp.
Heterotheca subaxillaris (Lam.) Br. & R.
Hymenopappus sulphureus Rydb.
Indigofera leptosepala Nutt.
Iva ciliata Willd
Jatropha stimulosa Michx.
Kallstroemia sp.
Laciniaria spp.
Leptilon canadense (L.) Brit.
Lythrum lanceolatum Ell.
Nuttallia stricta Green.
Meriolix drummondiana Small.
Dithyrea wislezeni Engelm.
Raimannia rhombipetale (Nutt.) Bos.
Paronychia jamesii (T. & G.).
Parosela lanata (Spreng.) Brit.
Pecan (Hicoria pecan).
Petalostemon spp.
Phyla cuneifolia T. & G.
Sideranthus spinulosus (Pursh) Sweet.
Cephalanthus occidentalis L.
Chamaecrista fasciculata Greene.
Cyperus spp.
Eriochloa acuminata (Presl.) Kunth.
Fuirena hispida Ell.
Gaura villosa Torr.
Grape (Vitis sp.).
Gum elestic (Shrub).
Gum elastic (Tree).
Prickly ash (Shrub)
Xanthium sp. TOTAL 68.

LIST V.

PLANTS FOUND IN RIVER VALLEY AT BONER REFINERY (LONGITUDE) AND ON TEXAS BLUFF BUT NOT IN RIVER VALLEY SOUTH OF GOAT ISLAND.

Calamovilfa gigantea.
Chamaesyce.
Gaillardia lanceolata Nix.
Monarda sp.
Solanum rostratum.
Solanum torreyi.
Solidago sp.
Syntherisma sanguinalis.
Vincetoxycum cynanchoides (Vail) TOTAL 9.

PLANTS FOUND IN RIVER VALLEY AT REFINERY AND ON OKLAHOMA BLUFF BUT NOT IN RIVER VALLEY SOUTH OF GOAT ISLAND, NOR ON TEXAS BLUFF.

Isopappus divaricatus (Nutt) T. & G. TOTAL 1.

LIST VI.

PLANTS FOUND IN TEXAS VALLEY AND ON EITHER TEXAS BLUFF OR OKLAHOMA BLUFF BUT NOT ON RIVER VALLEY IN OKLAHOMA.

Acamptoclados sessilispicus (Buckl.) Nash.
Allionia hirsuta Pursh.
Argemone alba Lestib.
Asclepias lindheimeri Nutt.
Euploca convolvulacea Nutt.
Bouteloua curtipendula (Mx.) Torr.
Cathartolinum rigidum Small.
Centaurea americana Nutt. (?)
Cebatha carolina (L.) Britton.
Chamaecrista fasiculata Greene.
Chloris spp.
Commelina sp.
Engelmannia pinnatifida T. & G.
Gaillardia lanceolata Mx.
Gaura villosa Torr.
Grindelia inuloides Willd.
Grape
Gum elastic (Shrub) (Bumelia sp.).
Hackberry (Shrub) (Celtis occidentalis?).

Hackberry (Tree) (Celtis occidentalis?).
Helianthus maximiliana Schrod.
Helianthus annuus L.
Ipomea leptophylla Torr.
Isopappus devaricatus (Nutt.) T. & G.
Jatropha stimulosa Michx.
Kallstroemia sp.
Laciniaria squarrosa (L.) Hill.
Leptilon canadense (L.) Britt.
Nuttallia stricta Greene.
Morongia uncinata (Willd) Brit.
Paronychia jamesii T. & G.
Parosela lanata (Spreng) Britt.
Parthenocissus quinquefolia (L.) Planch.
Paspalum stramineum Nash.
Prunus sp.
Polygala alba Nutt.
Othake sphacelatum (Nutt) Rydb.
Prickly ash (Xanthoxylum sp.).
Ptelea trifoliata L.
Artemisia filifolia Nutt.
Salvia azurea Lam.
Sideranthus spinulosus (Pursh) Sweet.
Smilax bona-nox L.
Solanum rostratum L.
Solanum torreyi A. Gray.
Solidago sp.
Styllingia salicifolia (Torr.) Small.
Syntherisma sanguinale (L.) Dulac.
Thelesperma gracile (Torr.) A. Gray.
Tribulus terresthis L.
Vincetoxycum cynanchoides (Eng.) Vail.
Wild china (Sapindus drummondii Hook).
Yucca tenuistyla Trel. TOTAL 53.

LIST VII.

PLANTS FOUND ON BOTH TEXAS AND OKLAHOMA SIDES OF RIVER VALLEY BUT NEITHER ON TEXAS BLUFF NOR ON OKLAHOMA BLUFF.

Amaranthus retroflexus (L.).
Ambrosia aptera DC.
Amorpha fruticosa (L.).
Baccharis salicina T. & G.
Distichlis spicata (L.) Greene.
Chaetochloa spp.

Dichrophyllum marginatum (Pursh.) Kl. & Garcke.
Eleocharis spp.
Eustoma russellianum (H.) Griseb.
Heliotropium curassavicum L.
Iva ciliata Willd (?)
Juncus spp.
Lythrum lanceolatum Ell.
Phyla cuneifolia T. & G.
Rudbeckia hirta L.
Samolus cuneatus Small.
Willow (Salix nigra).
Willow (sand bar) (Salix luteosericia Rydb.).
Apocynum sibiricum Jacq.
Aster sp.
Cephalanthus occidentalis L.
Fuirena hispida Ell.
Bumelia sp. (Tree).
Pluchea sp.
Persicaria sp. TOTAL 25.

LIST VIII.

PLANTS FOUND EITHER ON TEXAS BLUFF OR ON OKLAHOMA BLUFF BUT NOT ON RIVER VALLEY EITHER IN OKLAHOMA OR TEXAS.

Bouteloua hirsuta Lag. T. Permian gravels, dry hills.
Carrot, wild (Eurytaemia texana T. & G.) O T prairies.
Cissus incisa Desm. T (seep soil).
Filago nivea T Permian, dry or stony soil.
Phaca elatiocarpa (Sheld) Rydb. T Permian, apparently a prairie-limestone genus.
Houstonia angustifolia T Permian, dry soil or prairies.
Johnson grass T (only one specimen found in whole area studied).
Krameria secundiflora T Permian sandy soil, Kansas to Florida, New Mexico and Mexico.
Lactuca ludovician DC.? plains and prairies.
Wild bean (Strophostyles pauciflora (seep soil, river banks).
Neptunia lindheimeri? T Permian; prairies, Texas.
Penstemon cobaea Nutt. T Permian; prairies, Kansas to Texas.
Scutellaria resinosa Torr. T Permian; prairies or hillsides.
White clover (Melilotus alba) T Permian; waste places.
Ampelopsis cordata T (seep soil). TOTAL 15.

"T" indicates Texas bluff.
"O" indicates Oklahoma bluff.

LIST IX.

PLANTS FOUND DOMINANT IN RIVER VALLEY, TEXAS SIDE (ANY LOCATION) AND ALSO DOMINANT ON EITHER THE TEXAS BLUFF OR THE OKLAHOMA BLUFF.

Acamptoclados sessilispicus (Buckl.) Nash.
*Ambrosia psilostachya DC.
*Andropogon hallii Hack.
*Andropogon saccharoides var. torreyanus (Steud) Hack.
Aphanostephus skirrobasis (DC.) Trel.
Argemone alba Listeb.
*Aristida purpurea Nutt.
Bouteloua curtipendula (Mx.) Torr.
Cathartolinum rigidum Small.
*Cenchrus pauciflorus Benth.
*Eragrostis spp.
*Eriogonum spp.
Gutierrezia spp.
Hackberry (Shrub) (Celtis ocidentalis?).
*Heterotheca subaxillaris (Lam.) Br. & R.
*Hymenopappus sulphureus Rydb.
Laciniaria spp.
Meriolix drummondiana (Sp.) Small.
Paronychia jamesii T. & G.
Parosela lanata (Spreng) Britt.
Petalostemon spp.
Plum (Prunus sp.).
Prickly ash (Shrub) (Xanthoxylum sp.).
Sideranthus spinulosus Sweet.
Yucca tenuistyla Trel. (?).
*Eriochloa acuminata Presl. Kunth.
Helianthus petiolaris Nutt. TOTAL 27.

LIST X.

PLANTS FOUND TO BE DOMINANT OR CONSPICUOUS ON SOME PART OF THE TEXAS SIDE OF THE RIVER VALLEY AND ALSO ON SOME PART OF THE OKLAHOMA SIDE OF THE VALLEY.

*Ambrosia psilostachya DC.
*Andropogon hallii Hack.
*Andropogon saccharoides var. torreyanus (Steud) Hack.

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* indicates plants that are also found dominant in the valley of Oklahoma side; the other plants were not found dominant on this Oklahoma location.

*Aristida purpurea Nutt.
Baccharis salicina T. & G.
Calamovilfa gigantea S. & M.
Distichlis spicata (L.) Greene.
*Cenchrus pauciflorous Benth.
Populus deltoides S. Wats.
Eleocharis spp.
*Eragrostis spp.
*Eriogonum annuum Nutt.
Gaura spp.
*Heteratheca subaxillaris (LAm.) Br. & R.
Lythrum lanceolatum Ell.
Phyla cuneifolia Small.
*Eriochloa acuminata.
*Hymenopappus sulphureus. TOTAL 18.

LIST XI.

PLANTS FOUND TO BE DOMINANT ON BOTH VALLEYS AND DOMINANT ALSO ON EITHER TEXAS BLUFF OR OKLAHOMA BLUFF OR BOTH.

Ambrosia psilostachya DC.
Andropogon hallii Hack.
Andropogon saccharoides var torreyanus (Steud) Hack.
Aristida purpurea Nutt.
Cenchrus pauciflorus Benth.
Eriogonum annuum Nutt.
Heterotheca subaxillaris (Bam) Br. & R.
Eriochloa acuminata (Presl.) Kunth.
Hymenopappus sulphureus.
Eragrostis spp.

LIST XII.

LIST OF PLANTS TO SHOW PROGRESSIVE CHANGES, BEGINNING WITH RIVER SAND FLAT AND WORKING IN A GENERAL SOUTHERLY DIRECTION APPROXIMATELY LONGITUDE 98°38′24″.

SAND FLAT—
Eleocharis sp.
"Carpet grass" (Distichlis spicata).
Cyperus.

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* indicates plants that were also found dominant on Oklahoma bluff or on Texas bluff or on both.

Cockle burr.
Willow.
Salsola pestifer.

NEWLY ACCRETED LAND—
Cotton wood
Willow (abundant).
Cockle burr.
"Carpet grass" (Distichlis spicata).
Nut grass (Cyperus).
Ambrosia psilostachya.
Calamovilfa gigantea.
Parosela.
Grass burr (Cenchrus pauciflorus).
Baccharis salicina.
Sporobolus sp.

FIRST DUNE NEXT TO NEWLY ACCRETED LAND—
Andropogon hallii.
Andropogon saccharoides var. torreyanus.
Reverchonia arenaria.
Chamaesyce petaloidea (Engelm.) Small.
Cottonwood (up to 4.9 feet cir. 0.
Grape (Vitis sp.).
Poison ivy (Rhus toxicodendron).
Othake.
Apocynum.

SECOND FLAT SOUTH—
Panicum virgatum.
Glycyrrhiza lepidota.
Juncus torreyi.
Samolus cuneatus.
Fuirena hispida.
Eustoma
Phyla.
Isopappus.
Willow (very scrubby; dying).
Eriogonum.
Chamaecrista.
Eragrostis sp?
Cyperus (a very small species)

SECOND DUNE—
Willows—dying.

THIRD FLAT—
Iva.
Eragrostis secundiflora

Cottonwood (up to 4 feet circumference).
Lythrum.
Pluchea.
Amorpha fruticosa.
Sessuvium.

THIRD DUNE—
Artemisia filifolia.
Aristida purpurea.
Plum (one plant).
Raimmania.
Indigofera.
Plum (40 yards farther south, thicket).
Prickly ash.
Yucca.
Gaura villosa.
Acamptoclados.
Cottonwood (4.1 feet circumference).
Prickly pear.
Grape (abundant but scrubby).
Dithyrea.

FOURTH FLAT.
Bumelia.
Pecan (small).
Cottonwood (5.3 feet circumference).
Wild flax.
Hymenopappus.
Stenosiphon.

From this point southward to the Texas bluff the flora is essentially that of a semi-arid sandy prairie.

SUMMARY OF PLANT DISTRIBUTION.

*1.	Total number of species reported in area studied, all locations	165
*2.	Total number of species in river valley south of Goat Island	100
*3.	Total number of species in river valley at longitude of refinery	93
*4.	Total number of species in river valley, Goat Island	43
*5.	Total number of species in river valley, all locations on Texas side	133
*6.	Total number of species, all locations on Oklahoma side	110
*7.	Total number of species, all locations on Texas side	154

*Compiled from Table I.

*8.	Total number of species in river valley Oklahoma (including dunes, flats and seeps)	81
*9.	Total number of species Texas bluff (sides and top)	106
*10.	Total number of species Oklahoma bluff, sides and top	55
11.	Total number of species duplicates in river valley south of Goat Island and on dunes, flats, and seeps of valley, Oklahoma side (List I)	49
12.	Total number of species duplicates in river valley south of Goat Island and on Oklahoma bluff (List II)	46
13.	Total number of species duplicates in river valley south of Goat Island and on Texas bluff (List III)	73
*14.	Total number of species duplicates in river valley south of Goat Island and either on Texas bluff or Oklahoma bluff	81
15.	Total number of species duplicates found on valley south of Goat Island and at longitude of Boner Refinery (List IV)	68
16.	Total number of species duplicates in river valley at longitude of refinery and on Texas bluff but not on river valley south of Goat Island (List V)	9
*17.	Total number of species found in river valley in Texas, all locations, and either on Texas bluff or Oklahoma bluff	94
18.	Total number of species found in river valley (Texas) all locations and on either Texas bluff or Oklahoma bluff but not on dunes, flats or seeps of river valley in Oklahoma (List VI)	53
19.	Total number of species found in river valley (Texas) anywhere and on river valley (Oklahoma) anywhere but neither on Texas bluff nor Oklahoma bluff (List VII)	25
20.	Total number of species found on either Texas bluff or Oklahoma bluff but not on river valley either in Texas or Oklahoma (List VIII)	15
21.	Total number of species found dominant on any or all localities studied on Texas side of river valley and also on either the Texas bluff or the Oklahoma bluff or on both (List IX)	27
22.	Total number of species found dominant on any or all locations studied on Texas side of river valley and also on one or more of the localities on the Oklahoma side of the siver valley (List X)	18
23.	Total number of species found dominant on both of the valleys and also on either the Texas bluff or the Oklahoma bluff (List XI)	8

*Compiled from Table I.

†24. Total number of species in whole area confined to moist soil in distribution 27

†25. Total number of species in whole area tolerant to or preferring dry or arid conditions.................... 138

†Compiled from Table IV.

SUMMARY OF PHYSIOGRAPHIC INVESTIGATIONS MADE IN CONNECTION WITH THE OKLAHOMA-TEXAS BOUNDARY SUIT.

BY R. T. HILL.[1]

It was understood I should make a brief resume of my testimony which I hope will complete the subject upon my part. First I shall give in the form of a few terse axiomatic sentences the main points I have tried to make. Lineaments of landscapes like those of human faces reflect age and experiences without the need of ecologic or other assistance. The Physiognomy of the Big Bend Valley is mature. The Physiognomy of the Valley Bench is old; the Physiognomy of the sand plain is old. The Big Bend is an old feature inherited from the ice age and beyond. Red River is an old river according to the standard of comparison of the other rivers of the Greater Texas Region. The entire valley at this point is an ancient curve probably made in Pliocene time or over 500,000 years ago. The terraces of the outer bluffs testify that the valley of Red River is an old feature. The loess is also confirmatory evidences of this antiquity. The presence of the back canyon terraces also testify to the great antiquity of the river valley. The river in the Big Bend arch has apparently been adjusting itself to its present position since Pliocene time. The groove has been there since before the ice age. Likewise the meanders of the river. Why not its benches? Old age is testified by the fact that the Big Bend of the Red River valley is permanently entrenched and the meanders of its outer valley are comparatively fixed. I have tried to show that rivers in their youth like children are

[1]At the close of his direct testimony Dr. Hill gave a summary of his investigations (Record, Vol. VIII, pp. 4622-4632) which is reproduced here in full with no alterations other than the insertion of paragraph headings, and the omission of some explanatory notes and comments incident to the Court procedings. The testimony of Dr. Hill will be found in full in the Supreme Court Records in this case, Vol. VIII, pp. 4418-4634; and 4756-4834. (Editor.)

often erratic in their course and meander wildly. Rivers like men become fixed in their habits with the approach of old age. Red River in the Big Bend area is approaching maturity and its habits are of ancient origin and permanently established. These habits are as follows: As the successor of an ancient looped meander, it has constantly followed the habit of straightening out. The meander with all of its accompanying features has followed the habit of slowly migrating downstream, although its progress has been exceptionally restrained in this instance by the obstacle of the Burkburnett structures. The tendency of the arch of the meander has also been to constantly migrate northward towards the Oklahoma side and away from the Texas side, owing to its adjustment to structural conditions.

The old age of the Big Bend in particular and of Red River in general is testified by the fact that the bend is a straightened meander, and terrace evidence shows that the straightening has been a long process. The south border of Big Bend preserves in its constructive terraces records of its ancient birth. The south border also preserves in the scars of its terraces records of their long duration in their present position. The truncation of the valley bluffs of the Oklahoma side likewise attest long erosion and continuance of the channel on that side. Another testimony to the antiquity of Red River has been given by me in the classification of the rivers, where I have tried to show that it is practically the oldest of the rivers of a series of river groups, some six or seven in number of the original coastward slope.

Long and deep erosion of the bluff signifies that a stream has long departed from its base. As a stream advances against the base of a bluff by planation it destroys the evidences of its marginal erosion. Records of the downstream contacts and migrations of the crossing heads are preserved in the topography of these margins as shown upon the Stiles map. As the channel recedes from a bluff laterals in the latter lengthen and deepen. As a channel planates a bluff the laterals are truncated and shortened. Hence a deeply scored outer bluff indicates relatively longer absence of the planation channel from its foot. The absence or shortness of lateral channels indicates long presence of the planation channel at its base. Re-entrant curves and cut banks indicate present or former points of contact of the crossing against the bluff. Significance of truncated and base leveled laterals has been explained. In regions of uncontrolled run off an intermediate valley bench or second bottom may develop between the flood plain and the valley borders, which is ordinarily called the second bottom. Big Bend bench is a flood plain formation, crowned with land made dunes. The valley bench is first in the series of terraces of the Texas Region which have been in the building since the beginnings of Quarternary time, and their occurrence in their present position is in harmony with the operations of the laws which have produced the sequence of events, consistently following one another since the beginnings of the time mentioned. It is in its present position because it belongs there according to these laws and this evolution.

The Law of Rivers.

The law of the rivers I will again state—the fundamental law of working rivers. The currents of flowing rivers in times of flood are swiftest on the convex sides of their channels. There they cut their banks and acquire sediments. The convex side of the channel is the concave side of the valley wall. The currents of rivers are slower on the concave sides of their channels. There they deposit sediments and build up benches. The concave side of the channel is the convex side of the valley. The only exception to these laws is when the currents are broken by the entrance into the channel of an interfering lateral branch. The Big Bend valley bench presents two areas of somewhat different surface aspects. Both are the surface expressions of a common foundation which constituted the original bench. The outer margin of this original bench has been stripped of vegetation during some epoch of excessively high water in comparatively recent time. The time cannot be fixed with exactitude. The west end of the Big Bend valley bench had apparently reached its maximum of growth and a cycle of decadence set in. The destructive attacks upon the west end of the Valley Bench by flood water is in harmony with the law of rivers. All the similar benches show similar destructive cuttings at the upstream end of benches and accumulations at their lower ends. Rivers cut their outer banks below crossings. If the group activities of a river travel downstream including the migration of meanders, bends and benches, then the Big Bend valley bench must fall within this law. I do not mean to say this meandering is visible or perceptible or measurable in terms of days or years. It is to be noted in geologic ages rather than in periods or epochs or the smaller divisions. I entertain the hypothesis concerning the Big Bend valley bench that the valley bench formerly had upstream extension to the northwest and west of north; that this extension reached as far as the line marked upon the map as the former outer bank of the Big Bend valley bench. I do not know whether I had the word approximate, or not or whether that is an exact quotation of the lettering on that line, but I think all understand what I mean—on the map marked defendant's exhibit 97; that this bench has receded to its present position—that the edge of this bench has receded to its present position as a result of destructive river planation instead of having grown out; that this destruction is still going on. It is also my opinion that the so-called islands, or large islands are residuals of the former extension of this bank, and that this destruction is largely the work of the tendency of the New River to cut a channel during high waters across the west end of the bench. My reasons for these deductions are as follows:

The normal advance of the working river is from this westerly direction. The work which produced the effect is still going on against the west end of the valley bench. Recent high water floods have attacked and planated the western and northwestern banks, leaving cut bluffs of considerable height and freshness. Vestiges of the former extent of the banks and benches in the westerly and northwesterly directions are reflected in the contour of the so-called islands on bars, which apparently and in my opinion, are only severed portions of the main valley benches; in the occurrence far out in the sand plain and upon some of the alleged sandbar islands of stumps and tree trunks still rooted in the ground; and in the geology and the geologic history of the bench and river in general.

The Red River a Sand River.

I also defined the Red River as a sand river and stated that sand rivers are subject to the same laws of physics as other rivers, but the application of these laws has produced some results with which the average physiographer accustomed to rivers of the older portions of the United States is unfamiliar.

The sand plain is a spreading and drying ground which is an essential accompaniment of the sand rivers and of the fringing dunes. The fringing dunes cannot be made without the presence of a drying and spreading ground, and therefore are not islands made in the river. The existence of the spreading group implies that the river must be some distance from the line of vegetation beyond which the dunes are made —beyond which or upon which dunes are made. Therefore the existence of a fringing dune implies that the river was some distance away when it was made. Flood waters spread sediments over a sand plain, and leave slight irregularities of surface. Winds re-arrange the distribution of sand over the sand plain, and reduce its irregularities to a plane surface. The topographic irregularities of the sand plain left by inundation are reduced to regularity by the winds. The topographic irregularities of the valley bench are changed to a level surface by the winds. The same winds which carry the material from the surface of the sand plain levels its irregularities and protuberances. Winds build fewer islands upon a sand plain than they destroy.

The alleged sandbars of a sand river are different from those of the Appalachian Rivers, inasmuch as they are merely inequalities in a general floor composed of sand, and as left exposed by a rapidly receding river instead of accumulations of solid material separated from the clay and gravel and other materials of a copious river, and which have been gradually built up in a continuously flowing river channel. True sandbars are not left by a receding flood upon sand plains of a sand river in this particular portion. Sandbars do not increase in size as a rule upon the sand plain of a sand river, although some smaller accumulations may be made—exceptional accumulations may be made, but on the contrary are usually reduced to the general level of the plain by the winds. There is no evidence anywhere that islands have been cut off in the Big Bend region anywhere from the Texas side and added to the Oklahoma side, or vice versa. Sand protuberances or bars are not ordinarily the beginings of islands in the big bench. In this arid, wind-swept region where wind is such a tremendous factor, the protuberances are quickly reduced towards the general level of the sand plain as fast as their surfaces become dried. Inasmuch as the after-flood surfaces of the sand plain can only be changed when it is in a condition of absolute dryness, and inasmuch as the surfaces at such times are levelled and not built up, then the alleged process of island building at such times is a fallacy. Furthermore as there are no islands the accompanying theory of island building joining falls with it.

The Fringing Dunes

The fringing dunes which have accumulated upon the land near the margins of the valley benches are features of the land and not of the water. In no manner can they be called islands. The fringing sand dunes were built upon the land and not in the water, and therefore they are not islands. They were built of dry sand derived from a dry sand plain which bordered the land bench upon which they were built. Their existence, for instance, postulates the existence of a dry sand plain between them and the waters. These dunes are not now nor have they ever been islands, unless in very brief times of exceeding high floods, of which I have no positive knowledge. The persistent position of the normal low water channel of Red River is on the north side of the Big Bend valley. Its position there has been determined by the laws of river work and actual occurrences there at all times of normal low water. The new channel of Red River sometimes—no, I should say in all or most of the time of normal low water, the new channel of Red River sometimes at the west end of the valley bench is a temporary high water one, which originates anew with each overflow and disappears in times of normal low water, returning to the main channel position.

The River Fill

If the river bottom is filled up to a depth of fifteen feet above the Permian rock floor, and this filling has taken place in recent time, which is as indicated twenty-five thousand years, then the rate of filling has been one foot in every one thousand six hundred and sixty-six years, which is a very slow process.

The width of the Big Bend valley is 6,600 feet, and if this bench has been made by accretion or island building or joining within the last one hundred years, then the rate of lateral growth or extension has been at the rate of sixty-six feet per annum, which is an absurdity.

Downstream Migration

The Big Bend bench is migrating southeast according to the law of meander migrations, and I have tried to point out that mass factors, including all the features and functions of the river geologically operate downstream. All the products of its functions migrate downstream. If this theory is true, then it would reverse the opinion that the river at some relatively recent time reached the south bank below the Grandfield Bridge.

According to the laws of rivers the Red River in its present cycle is not due to flow against the south bank opposite the apex of the bend for a good many years, I would say thousands of years, if at all, and there is neither evidence nor law of probability to show that it flowed there a hundred years ago. Only two conditions could arise whereby the river could flow against the south bank. The first of these would be a great climatic change, like one of those which took place in Glacial epochs, whereby the rainfall and run-off would be tremendously increased and the stream channel so augmented in width as to produce a larger stream and more constant stream than now. The second would be the reaching of that point by the downstream migration of the meander crossings from the present cycle which has not yet taken place.

Review of the Geography of the Greater Texas Region

In my testimony I first gave a general review of the geography of the greater Texas region, in order to bring out the relationship of the Red River, which we are discussing. I subdivided this greater Texas region into the mountainous portion of the west, concerning which we have no further consideration, and the regional slope reaching from the mountains to the sea, which I defined as the regional slope. I divided this regional slope of the greater Texas region into high plains and low plains and central region. I tried to describe the evolution of the regional slope as the sea withdrew from the west eastward, and to call attention to the belted plains which successively were brought above the sea as the sea migrated eastward, and the development of river groups upon them.

Stream Patterns of the Greater Texas Region

I also dwelt extensively upon the stream patterns of the varied groups of rivers of the greater Texas region. Those were extensively described and many peculiar and hitherto unnoted features pertaining to them were given. Illustrations of the stream patterns of the Coast Prairie, of the Neches, the Sabine, the Trinity and Edwards Plateau, the central province and the high plains groups were given, and the character of their various stream patterns were described and the peculiarities of each group pointed out. It was shown that the rivers of the Central Province and rivers of the High Plains within the Central Province were adjusted to the conditions of the stratigraphic conditions exposed in their downward erosion. The central section of Red River, crossing the Central Province of the Texas region is an antecedent adjusted type of stream. The relation of the stream patterns to structure was shown by citations of many instances. First the regional patterns or rather the persistence of certain peculiarities of patterns as the various rivers crossed certain regions, were shown, and this was exemplified by illustrating the manner in which the various rivers crossed the Central Region and were deflected northeastward from their normal southeastward directions, so as to constitute the so-called great bends, as typically exemplified in the Great Bend of the Arkansas, which defle tions were supposedly caused by the attempts of the rivers to overcome the westerly dipping strata of the Permian and Pennsylvania series as exposed by the downcutting of these rivers in their passage across a belt of such structures seen in eastern and southern Kansas, north central Oklahoma and north central Texas.

Influence of Structures Upon Stream Patterns

The influence of smaller or local structures upon the patterns of streams was also shown, especially the relations of such local structures to individual bends. Examples were given from many localities of how the adjusted streams fit their courses to the structures which they resurrect in their habits of down stripping the strata, and how sensitive the streams were to such structures which play most important parts in the occurence of oil pools. Other examples could be given but were omitted. It is also shown that many of these buried structures of arched or domed strata were discovered or determined by plotting out the subsurface geology as revealed by the well drillings.

Structures of these kinds were shown to have been developed and mapped by the recent oil boom in the Texas region, and particularly in the Big Bend district of Red River, among which were the group of structures adjacent to Burkburnett, and which had recently been mapped by the United States Bureau of Mines.

By transposing maps of these structures upon a map of the Big Bend Region, as was done, many remarkable coincidences between these structures and the patterns of the adjacent river were shown. It was shown that the apex of the south wall of the valley of the Big Bend arch practically corresponded with the apex of the structure of the northwest extension of the Burkburnett pool, and that the west crossing of the Big Bend sand plain and channel was adjusted to the north sloping arch of this structure, and that for this reason the normal low water channel of the Red River in the Big Bend was forced down the north side of the slope towards the Oklahoma side where the river now is and tends to return after each flood. Additional evidence upon the relation of the bend of the river to the northward slope of the structure was introduced in the shape of a later and more detailed map made by the receivership for the oil lands in dispute, which showed, even more clearly, the coincidence between the structure and the river habits and position. It was also shown that portions of the new and temporary channel of the Big Bend section of the Central Section of Red River and of Wild Horse Creek illustrated in a more detailed way how rivers endeavored to follow the synclinal troughs in or between these structures. Other features of the stream patterns of the Central Region which assisted in the location of the channels of the rivers of the belted plains pointed out, were the peculiar conditions described as the gathering junctions of the rivers, the encircled or nested heads of the streams, whereby the laterals of each older group encircled the heads of the next younger group of rivers, and the existence across the state of a belt of deeply entrenched meanders as seen in certain sections of the Red, the Brazos, the Colorado, the Pecos and the Rio Grande.

Subdivisions of the Red River.

Red River which rises in the eastern portion of New Mexico up on the High Plains and which flows through or adjacent to the northern part of Texas until it enters into Louisiana for a distance of six hundred and fifty miles, not counting the meanders, was next described as a typical river of the High Plains. It was shown to consist of four major sections of different habits and habitats, as follows: The High Plains, or Headwater Section, comprising that portion upon the High

Plains which flows upon or through the cap rock formations; the Central Section, or that portion which flows through the Central Province, and the Entrenched or Grand Prairie section, which flows in enlarged, entrenched lobed meanders through the Grand Prairie Country. A still lower section or sections, as the river proceeds to the east of Grayson County was mentioned but was dismissed as immaterial to the present story. The Central Section of the Red River was further subdivided into three portions, the upper, the middle and the lower respectively. The upper portion of the Central Section was briefly mentioned as that portion within and adjacent to the breaks of the Plains, where the river receives a great load of sand and silt from the Red Beds, and the middle portion includes that portion between the mouth practically of the Salt Fork and the mouth of the Big Wichita River, which most concerns this story, while the lower portion includes approximately the part below the mouth of the Red Wichita River. The middle portion of the Central Section of Red River, as exemplified by the Big Bend of Wichita County, and within which lies the phenomena which inspired this action was next described in the following sequence: The anatomy of the Valley Groove as an entirety; next, the outer walls of the valley groove; the accessory features of the valley walls, including the terraces, the lateral drainages and alluvial cones at the foot of the bluffs constituting these valley walls, the features of the valley floor including the valley bench, the subordinate features of the valley bench, including its surface and the over-deposited fringing dunes and the back stream valleys: next the sand plain, which is the flood plain of a sand river. At this point the sand rivers were described and their peculiar habits explained. It was shown that the portion of Red River under description possessed a combination of the habits of the sand rivers of the west and the near constant run-off streams of the Central Province. The channel of the river was next described and the enormous disproportion between the high and low water floods were mentioned. It was shown that both the channels and the sand plains were widest at the crossings in time of flood and narrower at the headings. A peculiar set of return water channels were shown to exist in the dry sand plain along which the flood waters were in the habit of returning to the normal or low water channel which lies adjacent to the north side of the Big Bend valley owing to the slope of the sand plain in that direction, which was shown by a comparison of the contour headings on each side of the river and as had been predetermined by the existence of the structural slope in that direction. The character of the run-off of the stream differs greatly in times of flood and low water and this is one of the peculiarities of sand rivers. Some times the high waters leave the stream temporarily in a new or high water channel from which the waters inevitably return to the north side of the valley and resumes its attack upon the foot of the valley wall in that direction. The return is made by way of the east of north extending return stream channels as previously mentioned and shown upon the maps which we have introduced. The attacks of the high floods upon the west end of the valley bench have caused a decadence of the margins of the latter feature which are shown by the cut bluffs which truncate that side of the bench and by the high water channels which temporarily in times of flood have severed certain island-like features, etc. A line marked upon the map illustrated the theoretical former extension of the valley bench adjacent to the sand or flood plain, and probably represents the maximum development of the latter. No true islands or sand bars exist within the area of the sand plain so far as could be identified, although island like vestiges stood at relatively higher positions above the dry land normally not surrounded by water. These false islands are not sandbars, but apparently relics of the former outward extension of the valley bench as proven by their outlines and lineaments which conform to those of the main bench from which they have been severed and by the fact that they are not deposits of sand segregated from the clays and gravels, as in the case of true bars in copious rivers.

Central Section of the Red River Not a Braided Stream.

The Central Section of the Red River is not a braided river as has been alleged, although in exceptional places it may slightly braid or branch. Braided rivers are aggrading streams which will not follow any one definite channel and which anastamose in most complicated patterns without the semblance to a single main channel. The runoff instead of returning to a single central or controlling channel like that on the north side of the Big Bend usually disappears by absorption in the dry sands instead of by the continuous run-off method of the waters of this section of Red River. It has been pointed out that the Big Bend Section is probably aggrading its channel, and this was testified to I think by Dr. Glenn, and if this fact is true then the Big Bend Section cannot be an aggrading braided stream. Comparisons of the stream patterns of the Big Bend of Red River with those of the Platte River of Nebraska where the typical braided streams occur show an utter dissimilarity, which was demonstrated by figures which accompanied the testimony. Inasmuch as the presupposing of the braided stream condition is a necessary factor for the establishment of the island joining theory which was introduced in this contention by the experts on the other side, the collapse of the latter theory, regardless of other evidence disproving it, seems already in sight.

The Big Bend of the Red River

The Big Bend valley bench is a crescentic accumulation of land material above the channel floor and between the outer borders of the Sand Plain and the south bluff of the valley. It is also between the convex side of the valley bluffs and the concave side of the stream channel, where according to the laws of stream deposition which have been set forth, such accretions of material constituting the beginnings of a bench or terrace always occur. This bench has been made by normal accretions of sediment along its sides and from occasional overflows above its surface. The surface has been at times crowned by elongated windrow like dunes which have accumulated upon its vegetal carpet through the deposition of traveled dry sand by the wind. This bench has occupied its present approximate position throughout a vastly long period as measured in human years, although modifications have from time to time affected its subordinate details. There is no evidence whatsoever by which one may say that the river flowed more adjacent to the southern margin of the bench a hundred years ago than now, and to determine such an occurence or the time thereof is just as futile an effort as to determine the exact age of the volcanoes of the moon. On the other hand there are ample evidences that the bench may once have had further extension to the north than now as is shown by the evidences of the still rooted trees which grew upon its former extension in that direction and now found in the denuded sand plain and the abundant evidences of stream attack and planation along the west end of the Valley Bench.

Age of the Big Bend

It has been shown that the making of the valley groove of the Big Bend section of the river took place before or during the Glacial Epochs when there were—or during the Glacial Period at least—when there were alternations of larger and smaller volumes of water in the stream of the river during the alternations of the glacial and interglacial stages, each of which epochs were thousnds of years in duration, as I have shown in a table which has been entered into the testimony. During these epochs when the running stream was immensely wider and more voluminous than today at such times of flood the axis was straighter and the margin of the currents touched the southern bluffs much lower downstream than today. In alternating cycles when the stream flow was diminished to resemblances of its present aspects the crossing contacts were farther upstream than in time of larger volume. It is presumed that the stream attained its present diminished aspects after the close of the last Glacial Epoch, some twenty-five thousand years ago, and that the valley bench and the present phenomena of the valley date from that time or at least the beginnings of them, although modifications of the bluff and growth in the northern or streamward extension of the bench have undoubtedly occurred since that time as recorded in the character of the erosion of the bluffs of the valley. The older erosion features of the south wall of the valley and the more recent and present erosion of the north wall of the valley on the Oklahoma side show that the direct contact of the stream has long been absent from the former and that it has been long continuous against the latter thereby substantiating the facts previously shown by the slope of the sand plain in the direction of the Oklahoma side, the fact that the stream is usually on that side and that there are structural conditions which determine its position should be on that side.

Relation of the Red River to Other Rivers

The work and products of Red River are the results of the same laws as those which control all rivers, although the effects of these operations are in some instances aberrant and different form those seen in the more familiar Appalachian Region. One of the rather unfamiliar effects is the work of the wind. It has been shown that the windwork is almost as equally important as the water in its operations upon the dry sand plain, by leveling its waterleft protuberances and removing material from the sand plain to the adjacent land borders. The alleged islands, as the windrow-like fringing dunes were considered, are not islands at all but are land-made features built upon the land and at times only when there was a wide strip of flood plain between the valley bench and the river channel. In fact the existence of dryness is one of the essentials to the occurrence of these dunes. Therefore they are land made and are not water made and are not islands at all. In view of these facts which I have abundantly proven, in my opinion, there is no ground whatsoever for the theory that the valley bench has been formed by the alleged process of island joining but on the other hand all the phenomena testify to the reverse of this process which is largely postulated upon the existence of the braided stream and island building conditions which do not exist in the Red River except perhaps in most exceptional instances which I have not personally seen.

Concluding Statement

In my opinion the attempt to find support in geologic or physiographic evidence for the moving of the channel of Red River nearly a mile southward in the Big Bend Valley and numerous other places from the Louisiana line to the 100th meridian so as to take in all the valley lands finds no support whatever in nature.

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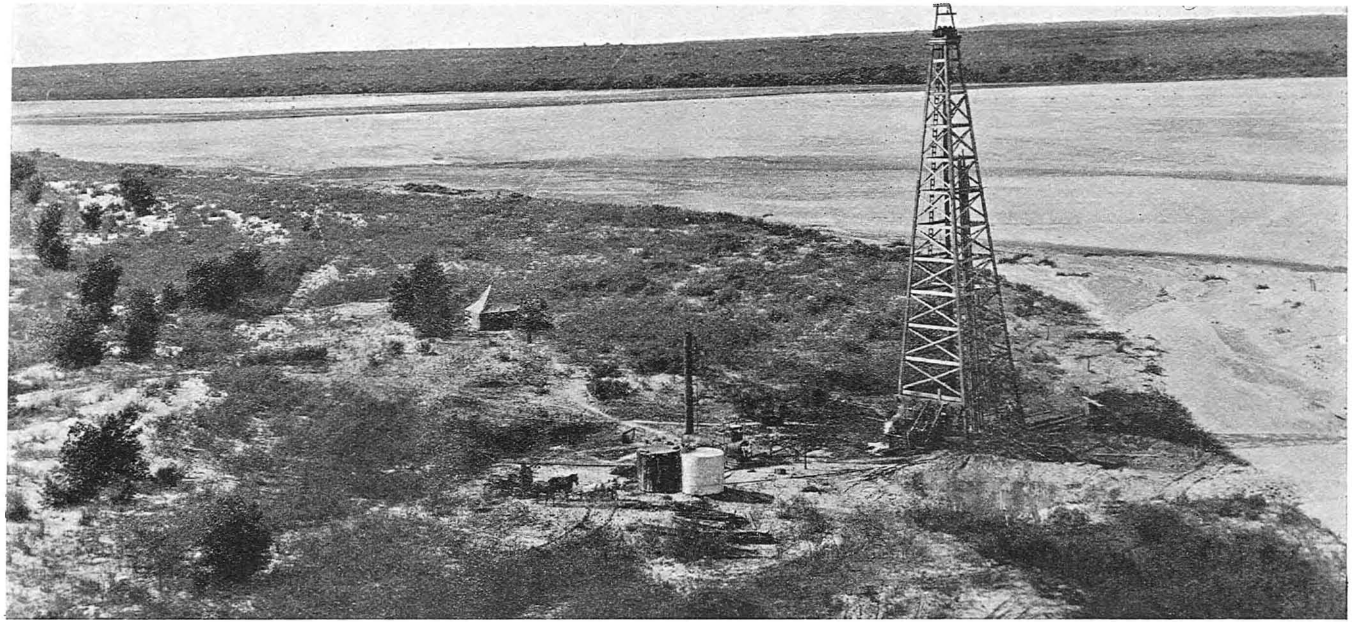

View taken at the extreme outer margin of the Big Bend in Wichita County, looking northwest, Oklahoma bluffs in the background. At the left of the photograph is seen sand dunes of Dune series four with characteristic vegetation. Riverwards from these dunes is a belt of level low lying newly accreted land of more recent origin than the dunes. At the right and within the sand flat of the river is land that is being taken possession of by the growth of vegetation and thus being added to the mainland. Beyond and between this land and the Oklahoma Bluff is the sand flat of the river. The channel of the river passes near the Oklahoma Bluff. This photograph illustrated habits of land building on the Red River.

Fig. 1. View of a moving or shifting sand dune. In this view there is seen the leeward or steep slope of the dune. The sand is observed to be accumulating around the base of the small cottonwood tree; the grasses likewise are partly buried in the sand. This dune is located in the northern part of the Big Ben of Wichita County near longitude 98° 38″ 10′. latitude 34° 9″ 38′. This view is looking north or slightly west of north.

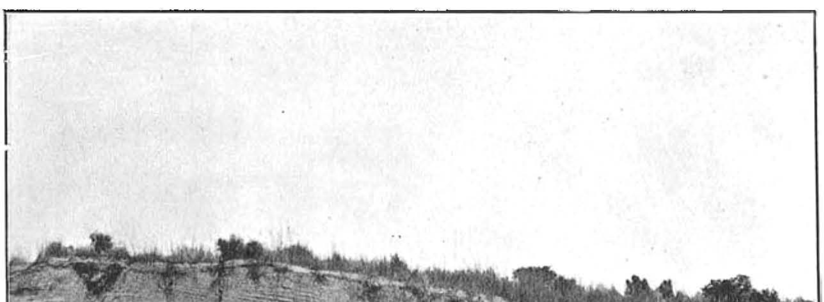

Fig. 2. View showing a cross section of the sand dune made by the river. In this view may be seen the characteristic bedding of the wind shifted sands. This dune is located in the Big Bend of Wichita County near longitude 98° 38″ 35′, latitude 34° 9″ 29′.

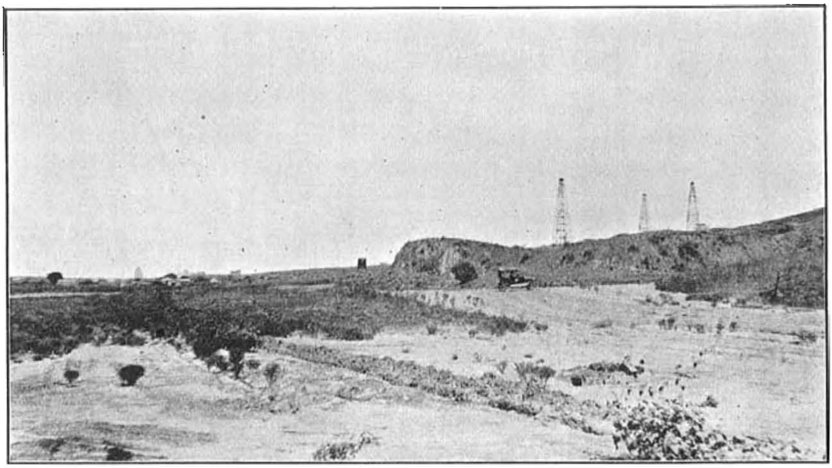

Fig. 1. View showing fan accumulation in front of the entrance of a small stream into the valley. In the center of the view there is seen a relatively steep bluff. This bluff where steep, is composed of loess, a material which although soft, stands persistently as a bluff. The more sloping bluff seen in the right of the car is composed chiefly of red clay.

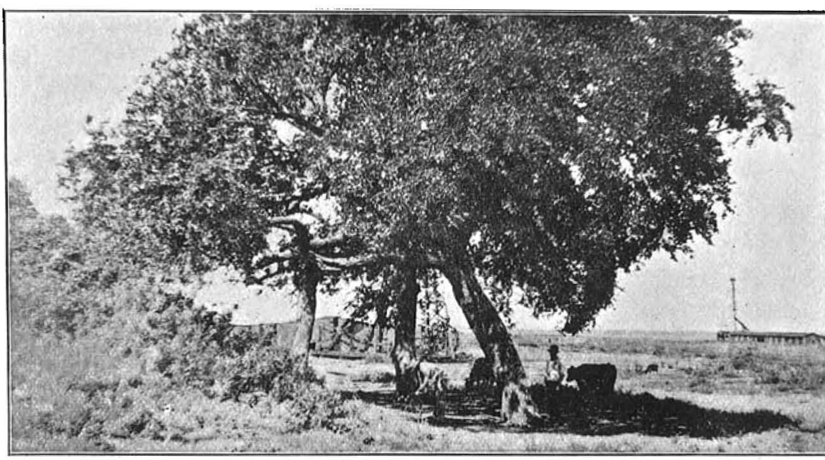

Fig. 2. View illustrating elm tree growing on fan near the Texas Bluff in the Big Bend of Wichita County. The roots of this tree are buried no more than a few inches, indicating but little fill during the lifetime of this tree. The age of the tree as indicated by ring count is about 158 years. The depth of the soil under the tree approximates four feet. No. 26 of map of timber growth. (See page 69.)

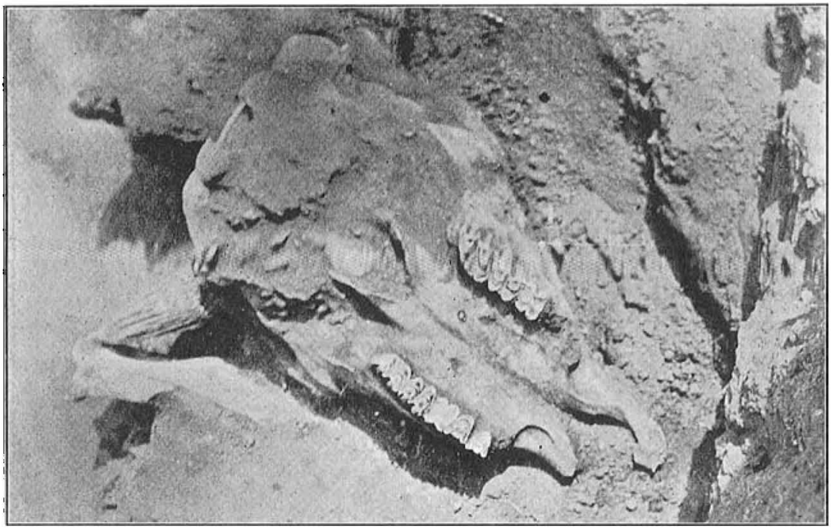

Fig. 1. View illustrating skull of a Bison. This skull was obtained at the entrance of a small stream onto the Valley plain. The locality is something less than a mile upstream from the Grandfield Bridge, near longitude 98° 40″ 35′, latitude 34° 8″ 5′. This skull was found at a depth of 6 feet from the surface. As seen in this photograph the skull is uncovered but has not yet been removed from the matrix in which it is still partly imbedded.

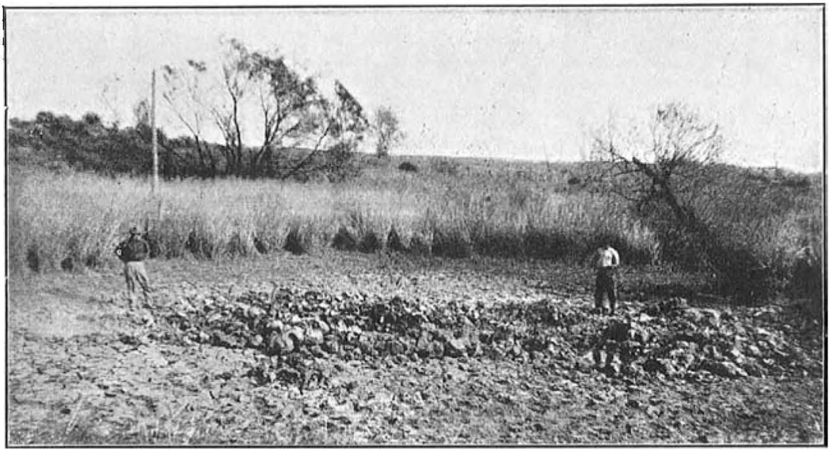

Fig. 2. Depression in the Big Bend Valley near longitude 98° 36″ 30′, latitude 34° 8″ 55′, about 3200 feet from the Texas bluff. Bison remains were found in this depression, a considerable part of the skeleton of one individual having been obtained. (See page 63.)

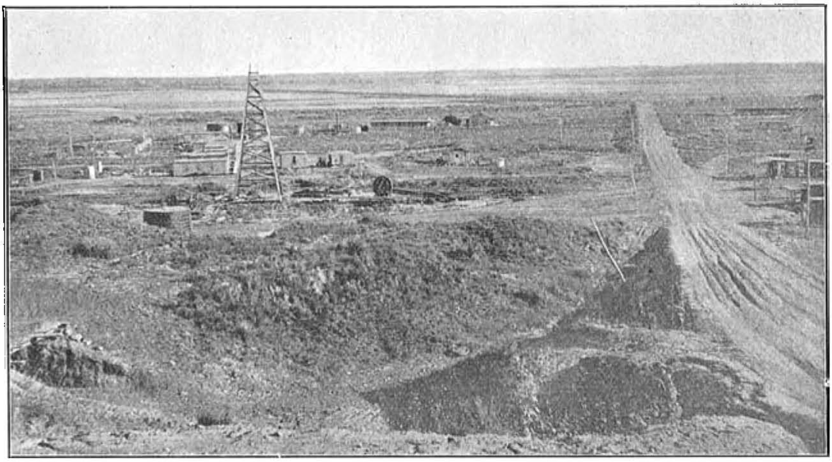

Fig. 1. View of the Red River Valley from the Texas Bluff at Bridgetown. The contested land comprised all the valley from the base of the bluff including that on which the numerous buildings are located.

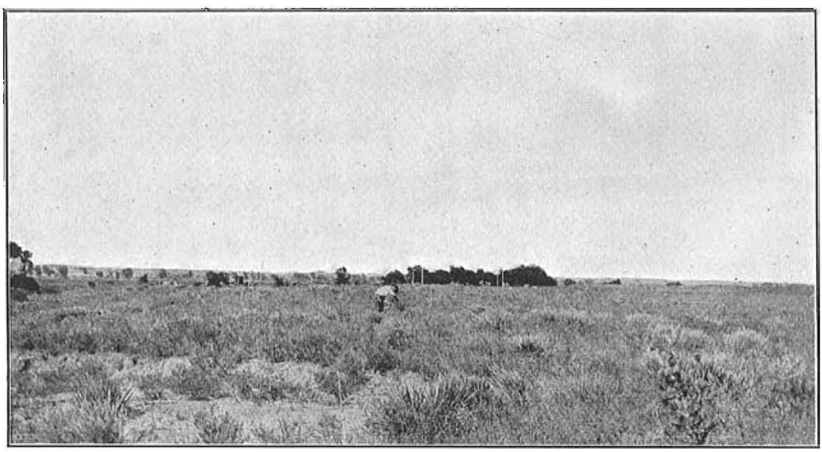

Fig. 2. View taken in the Big Bend of Wichita County approximately opposite the entrance of Wild Horse Creek onto the valley. The vegetation in the foreground composed of dominant Cenchrus, Andropogon Bulbilis and Yucca is as near the climax for this region as valley conditions would seem to permit.

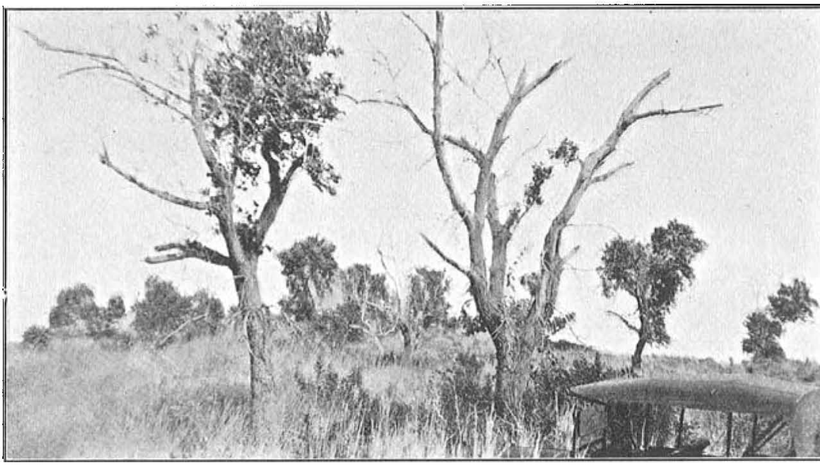

Fig. 1. View of dead and dying cottonwood, illustrative of the generally unhealthful conditions upon the valley floor of the Big Bend, even for this usually hardy tree. Upon the uplands cottonwood, when planted, will flourish without artificial watering after growth once sets in.

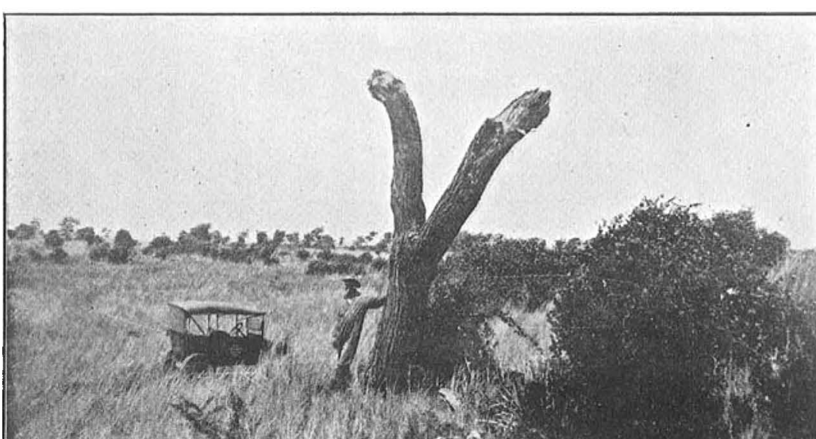

Fig. 2. Another view showing unhealthful condition of cottonwood in the valley of the Big Bend. Note the young trees of various ages which tend to perpetuate the cottonwood in open stand, even after herbaceous vegetation is comparatively thick.

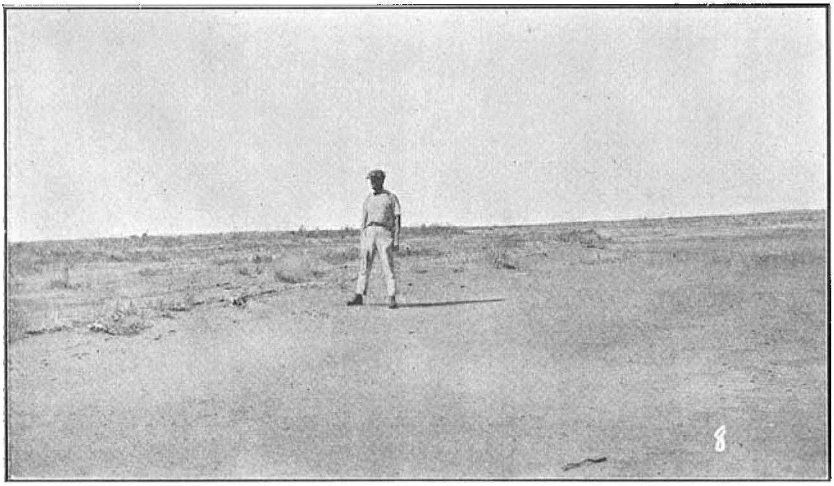

Fig. 1. View showing the addition of new land to old and the spread of vegetation from the older land onto the sand plain. In the foreground is the sand plain or sand bar formed by the river. Adjacent to this at the left is the dense vegetation, chiefly grasses, of the older land. The grasses are here spreading onto the sand plain. This view taken about one mile below the Hardeman-Wilbarger County line on the Texas side looking upstream.

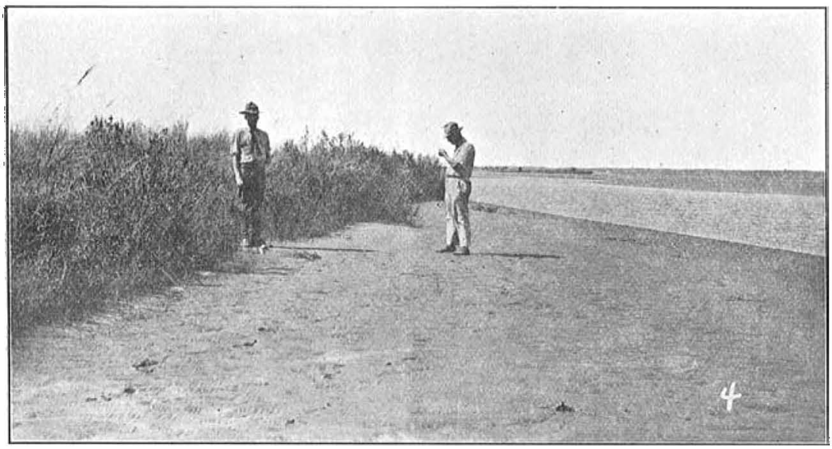

Fig. 2. View showing the addition of new land to old and the spread of vegetation onto the sand plain of the river. In the foreground of the picture is seen the sand plain of the river which is almost destitute of vegetation. In the central part of the picture is a sparse growth of vegetation obtaining a start on the sand plain. This view taken on the Texas side somewhat below the 100th meridian, and between the 100 meridian and Buck Creek Ford, on Texas side of the river looking upstream.

Fig. 1. View showing the addition of new land to old and the spread of vegetation onto the sand plain. In the right foreground is seen the sand plain or sand bar built by the river. At the left in the picture is older, vegetation covered land. The vegetation, grasses and weeds are observed to be spreading onto and thus reclaiming the sand plain. This view taken a short distance below the Electra Bridge on the Texas side of the river looking upstream, the Electra Public Road Bridge seen in the background.

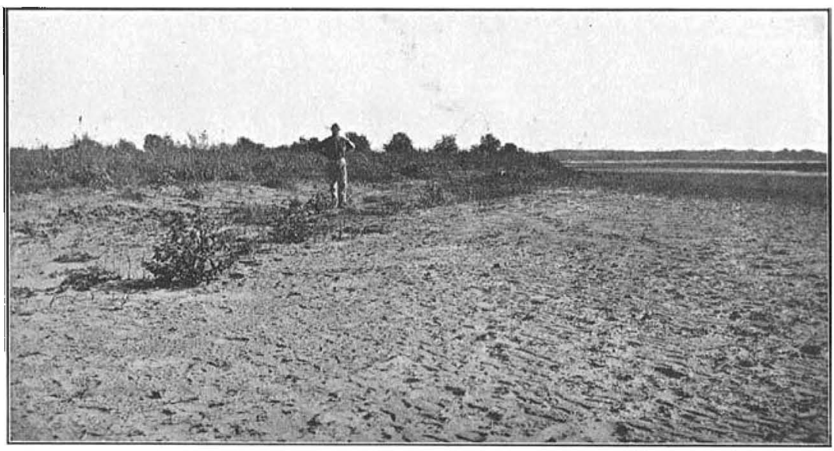

Fig. 2. View showing the addition of new land to old and the spread of vegetation from the old land onto the new. In the foreground is seen a part of the sand plain or sand bar, while in the central left part of the picture is seen vegetation covered land. The vegetation, including grasses and weeds, is spreading from the older land onto the sand plain or sand bar. This view taken on the Stein Ranch in the eastern part of Clay County on the Texas side of the river looking upstream.

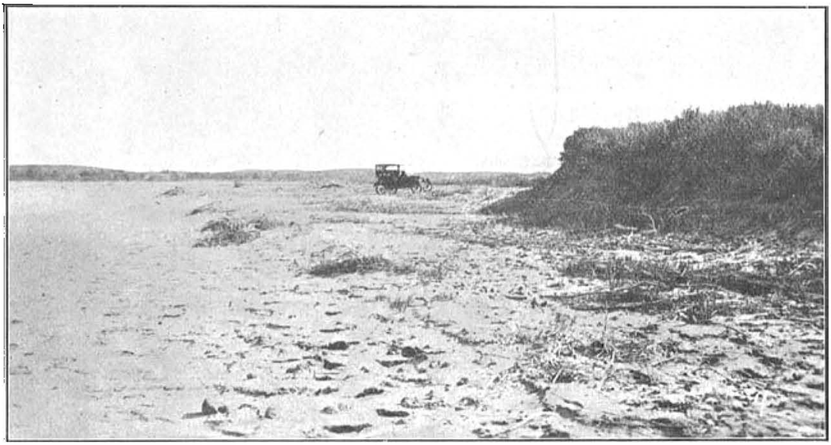

Fig. 1. View showing the addition of new land to old. At the right is seen a bank several feet in heighth. Against this bank is thrown the sand bar onto which the vegetation is gradually spreading. This view taken on the Standfield Ranch near the east line of Clay County on the Texas side of the river looking downstream.

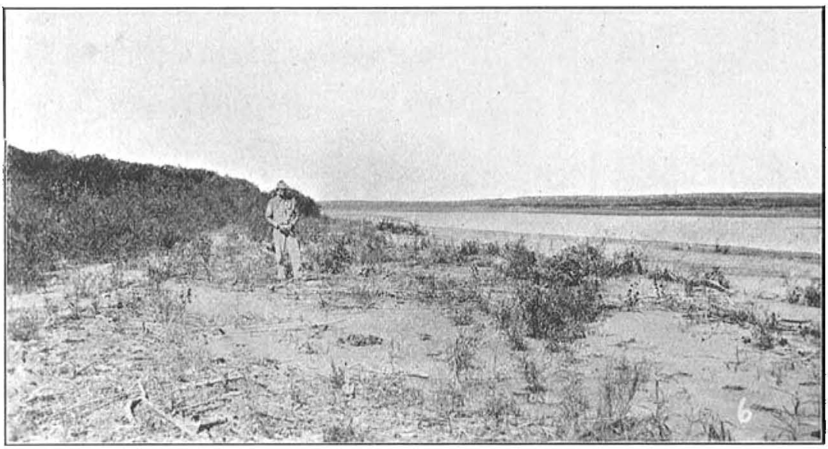

Fig. 2. View showing the addition of new land to old and the spread of vegetation onto the sand plain or sand bar. In the central part of the picture is seen the sand plain or sand bar which is being occupied by vegetation. To the left is seen the older land against which the sand bar has been formed. This view taken in Spanish Fort Bend in Montague County, on the Texas side of the river, looking upstream. Compare this view with Photograph No. 3 taken in Wilbarger County and not the essential identity in the process of sand bar building and extension of vegetation.