AN ABSTRACT OF THE THESIS OF

Bradley L. Hedstrom for the Master of Science Degree in Physical Science presented on April 25, 1986.

Title: Early Pleistocene Vegetation of Eastern Kansas and Nebraska

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The vegetational environment of the Early Pleistocene is poorly understood. The main reason for this is a lack of physical evidence. During the summer and fall of 1985, several pieces of wood were discovered buried in the lower gray till at two separate locations in northeastern Kansas, and in the lower gray till along the south bank of the Platte River near Fremont, Nebraska.

Observation of the macerated wood with an optical microscope and photographing the wood samples under a scanning electron microscope are the two processes used to identify the wood. Characteristics of the features observed in the wood, such as tracheids, resin canals, wood rays and bordered pits all demonstrate that the wood is spruce.

I propose that the first Kansan glacial advance overrode a forest which was dominated by spruce.

The vegetational history of the Late Pleistocene should serve as a model for the vegetational makeup of the Early Pleistocene. Evidence from pollen sequences show that during the maximum extent of the Wisconsin glaciation spruce forest covered most of the eastern and central United States. In southern Minnesota there is evidence that tundra vegetation existed adjacent to the ice sheet. As the ice lobes retreated the spruce forest was succeeded by deciduous forest and this in turn was succeeded by grasslands.

The gray till in northeastern Kansas has long been recognized as being deposited by the Kansan glaciers, and the gray till in Nebraska as being deposited by the Nebraskan glaciers. There has been debate over whether these tills have two separate origins, or if they were both deposited during the Kansan glaciation. The fact that wood was found both in Kansas and Nebraska argues in favor of the proposal that they are the same tills.

EARLY PLEISTOCENE VEGETATION OF EASTERN KANSAS AND NEBRASKA

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CHAPTER I

INTRODUCTION

In June, 1985, buried wood was discovered in the lower gray till near Wathena in northeastern Kansas. These are the first large branches of wood to be found buried in the Kansan glacial till. In October, 1985, several more pieces of wood were retrieved from the Wathena site and additional pieces were found buried in the lower gray till at an exposure west of Atchison, Kansas. This area is the type region used to define and recognize the Kansan glaciation, an early glacial stage during the Pleistocene Epoch (Ice Ages). Buried wood was also discovered in July, 1985, in the lower gray till along the south bank of the Platte River south of Fremont, Nebraska.

The Kansan glaciation is one of four traditional glacial stages of the Pleistocene Series. The names of the stages from youngest to oldest are as follows: Wisconsin, Illinoian, Kansan, and Nebraskan (Chamberlin, 1896; Shimek, 1909). Chamberlin (1895) stated the following about the Kansan glacial stage:

> The earliest (glacial) formation which has been worked out into sufficient definiteness to merit specific recognition in the United States is an expansive sheet which reaches southward nearly to the junction of the Ohio and the Mississippi and southwesterly beyond the Missouri. The term Kansan has been applied to it because of its great extent in the direction of the arid plains and because it appears in the state of Kansas free from complications with other formations.

To date not much is known of the vegetational history of the Kansan glacial stage. However the vegetational history of the Wisconsin stage has been depicted by palynologists. Because the glacial stages of the Pleistocene Epoch share similar environments, these studies of the Wisconsin vegetational history provide insight into the possible vegetational history of the Kansan stage. With the discovery of these Kansan specimens, a potential new source of information has been found concerning the Kansan glaciation.

STATEMENT OF GOALS

A description of the vegetational environment for the Kansan glacial stage has in the past eluded geologists because of a lack of evidence. It is hoped that the recently discovered wood samples found in the lower gray till at the Wathena and Atchison sites and along the Platte River south of Fremont, Nebraska, will provide more insight into this problem. The goal of this research is to correctly identify the wood samples that have been collected and to interpret the Kansan vegetational environment.

This research is significant because there has never been an interpretation of the vegetational environment of the Kansan glaciation. The proper identification of the wood samples from northeastern Kansas and Nebraska could lead to the determination of the Kansan stage vegetational environment.

The identification of the wood will help to determine if the till in northeastern Kansas and that in Nebraska are the same or are two separate tills as has long been believed. The end result of this research would be an improved perception of the Early Pleistocene.

CHAPTER II

LITERATURE REVIEW

The vegetational history of the Kansan glaciation is poorly understood whereas the vegetational history of the latest glacial stage, the Late Wisconsin, is well documented. There are several reasons this situation exists: older organic materials are beyond the range of radiocarbon dating, later glaciations have reworked older pollen sequences, and less evidence has been found to put together a Kansan vegetational history. Because the glacial stages of the Pleistocene Epoch share similar environments, a description of the Wisconsin glacial history might provide an insight into the vegetational history of the Kansan stage.

Late Wisconsin Vegetation

The modern vegetational environment of the central Great Plains is a vast grassland. Studies by palynologists have shown that this was not always the case and that the grasslands are in fact a recent development. The grasslands began to spread over the great Plains approximately 12,600 years ago in northern Nebraska to approximately 8,000 years ago in southern Minnesota (Watts and Wright, 1966). Pollen studies show that the Great Plains were covered during the maximum Late Wisconsin glaciation by a vast boreal forest dominated by spruce. The modern boreal forest of North America is located between 50° and 70° north latitude in Canada.

Evidence also shows that in certain areas of central North America there was once a tundra environment adjacent to the Late Wisconsin ice sheet. One location where this is well documented is in south-central Minnesota near Norwood. The vegetation in this area consisted of herbs, dwarf shrubs and aquatic plants that established themselves after the ice melted but before the spruce forest moved in and dominated the area. This belt of tundra is dated at 11,500 to 10,500 years old (Watts, 1967).

Studies from other areas show that tundra did not exist adjacent to the ice sheet as in south-central Minnesota. A site near Iowa City was dominated by a treeline assemblage which indicates a parkland environment. This site is dated at 17,000 years B.P. The southern edge of the Des Moines Lobe was bordered by this cold parkland environment rather than by open tundra (Schwert and Ashworth, 1981).

During the time of the maximum extent of the Late Wisconsin glaciation spruce forest covered most of the eastern and central United States. In many areas throughout the central Great Plains, pollen sediment records show up to 80% of the pollen consisted of spruce. Most authorities agree that only small amounts of spruce pollen are subject to transport over long distances. A closed spruce forest is indicated in the areas where these high spruce pollen percentages have been found (Bradbury, 1980). Values of 10 - 15% spruce pollen have been found as far south as the Texas panhandle. This would indicate a fairly strong colonization of spruce in this area (Oldfield and Schoenwetter, 1975).

A recently discovered peat layer found in a terrace deposit along the Arkansas River near Wichita indicates an open boreal forest once existed there. Included in this peat layer were pieces of pine and spruce wood along with spruce needles. Pollen grains of deciduous trees and nonarboreal species were also found. Spruce pollen makes up 40% of the total pollen sum of this assemblage. This collection of samples indicates that this area may have been the southern extent of the boreal spruce forest during the Late Wisconsin glaciation. The samples are radiocarbon dated at 19,340 $\pm$ 200/210 years B.P. (Jaumann et al., 1985).

In 1972, Caspall reported finding spruce wood in northeastern Kansas buried in the base of the Peoria loess. The wood was dated at 18,200 years B.P. From his studies of loess deposition in the area, he suggested that a boreal forest existed from 18,000 to 13,000 years ago in northeastern Kansas.

Radiocarbon dates from samples throughout the Great Plains give geologists an idea of how quickly the Wisconsin ice lobes retreated and approximately where the ice fronts were located at a specific time. Radiocarbon dates of pollen samples from the time of spruce dominance range from 24,500 to 23,040 near Muscotah, Kansas; 12,580 near Rosebud, South Dakota; 11,740 near Qually, Minnesota to 9,500 years B.P. near Riding Mountain, Manitoba (Wright, 1970). The trend of vegetational change in this area was a migration to the north-northeast. As the spruce forests retreated, deciduous forests briefly dominated the area. These deciduous forests were in turn replaced by grasslands.

A pollen sequence at Trolinger Spring, Missouri is dated at 32,200 to 25,650 years B.P. (Mehringer et al., 1970). This pollen sequence suggests a pine dominant environment which gave way to spruce dominance during the mid-Wisconsin interstade, prior to the Late Wisconsin ice advance.

Kansan Vegetation

In 1892, L. C. Wooster reported finding buried wood in northeastern Kansas. He suggested the existence of a forest bed at a depth of 80 feet in southern Nemaha county. He observed sticks and carbonaceous earth being brought up in wells from that depth in several localities.

In a description of the lower till layer of the McCredie Formation in northern Missouri, M. Guccione (1983) reported pieces of wood embedded in the till. She described this till as being dark gray with contorted sand bodies, with inclusions of stratified gravel, and silt lenses. This till has been assigned to an unspecific pre-Illinoian stage and was traditionally called Nebraskan (Heim, 1961). This description is identical to the lower Kansan till of northeastern Kansas.

In June, 1985, during a phone conversation, Dr. W. Dort, of the University of Kansas, informed Dr. Jim Aber that small fragments of wood had been found at the West Atchison site and near Doniphan. He stated that these specimens had been identified as spruce in thin sections, but that this information had never been reported in written form. He also stated that large branches had never been found (or reported) from northeastern Kansas before.

Kansas Drift Stratotype

The till exposure west of Atchison, Kansas, where White Clay Creek cuts into the south bank, has been designated as the stratotype for the Kansas Drift. In an abstract published for the Kansas Academy of Science in 1938, Schoewe gave the following description of the till exposure:

> . . . west of Atchison, is a series of excellent exposures of glacial deposits. The outcrops occur in the steep south valley walls of Clay Creek. . .two distinct tills are present. The lower till is a typical unaltered or fresh, dark gray to blue compact boulder clay, as much as 20 feet thick. Its upper surface is irregular. the upper till, from 10 to 15 feet thick, is seperated from the lower one by 50 feet or more of stratified sand. This till in contrast to the lower one is brown in color, and is very stony. . .

Originally the Kansan Stage was believed to be one single ice advance into Kansas. Studies by Bayne (1968) reported that the tills in northeastern Kansas were deposited by two ice advances. The Kansan Stage was divided into an early Kansan Stade and a medial Kansan Stade.

Continued stream erosion of the West Atchison site has revealed more information about the ice advances into Kansas. This erosion has exposed ice pushed features in the lower gray till. Two large diapirs have been pushed up into the overlying sand. The orientation of the folds and the diapirs in the till show the initial ice advance into Kansas was from the northeast. The upper Kansan till was deposited on top of the sand layer. The orientation of the recumbent folds and till fabric point to a second ice advance from the northwest (Aber, 1985).

The designated Kansas Drift Stratotype located west of Atchison shows two ice advances into northeastern Kansas. The initial ice advance deposited a dark gray till. Small pieces of wood have been found buried in this till. There was then a period of deglaciation in which the Atchison sand formation was deposited. Lastly there was a second ice advance, this time from the northwest, which deposited the upper brown till.

CHAPTER III

METHODS AND PROCEDURES

Field Work

The wood samples were collected in the summer and fall of 1985 from three separate locations: (Fig. 1) a gravel pit south of Wathena, Kansas, in Sec. 33, T.3 S., R.22 E.; along the south bank of the Platte River south of Fremont, Nebraska, in Sec. 34, T.17 N., R.8 E.; and along the bank of White Clay Creek west of Atchison, Kansas, in Sec. 10, T.6 S., R.20 E. The first sample (W1) was found buried in the lower gray till at the Wathena site (Plate 1 & Fig. 2). The sample was approximately 30 cm long and was surrounded by an oxidation zone about one cm thick. This zone could have developed as a result of pyrite in the till oxidizing around the organic matter. The piece of wood was carefully excavated with a shovel and trowel and was photographed in place (Plate 2).

The till in which the wood was buried is dark gray, clayey, highly deformed by ice pushing and contains boulders which are dispersed throughout (Plate 3). Another sample (W3) which was approximately 20 cm long was found at this till exposure during the summer (Plate 4). Small wood fragments (W2) were also recovered. Binoculars were used to scan the till exposure at Wathena. Due to the steepness of the till exposure, access to the bluff wall was gained by tieing a rope to a tree above the exposure and scaling the bluff wall. Additional samples were found in October in a slump block at the Wathena site.

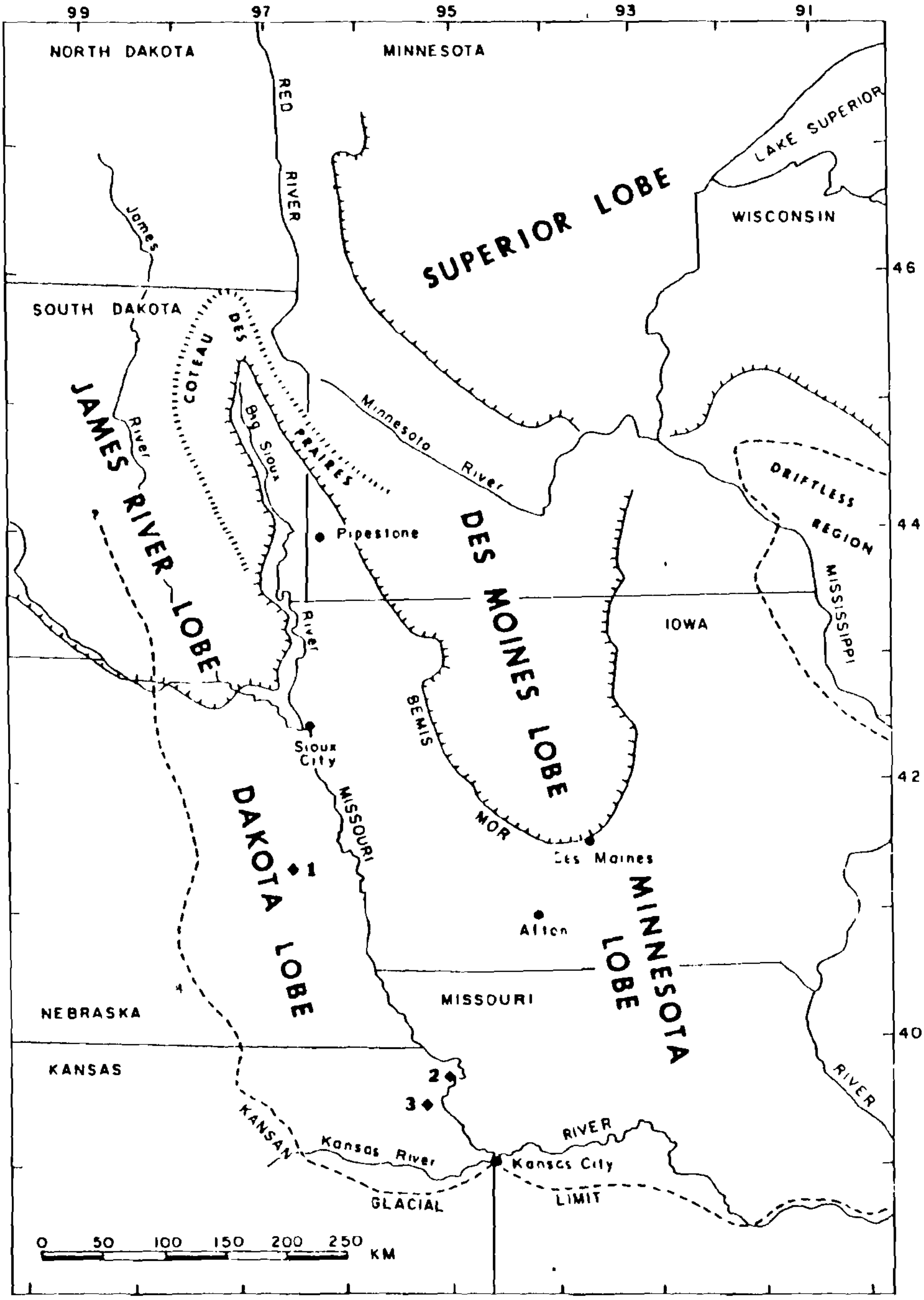

FIGURE 1. Map showing maximum extent of Wisconsin and Kansan glacial ice lobes. Map shows three sites where wood was found; 1. Platte River site, 2. Wathena site, 3. Atchison site. Adapted from Aber (1985 fig. 8)

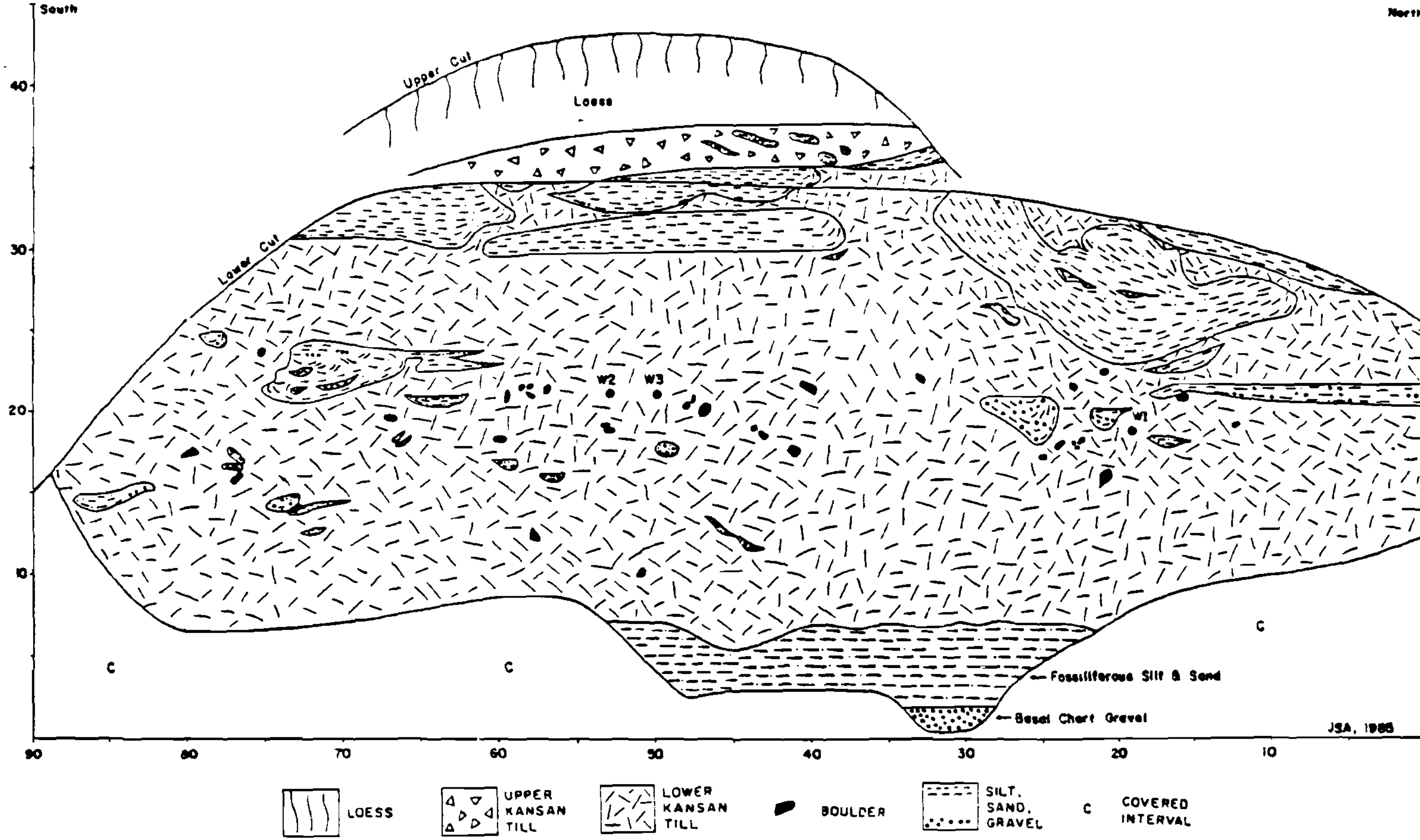

FIGURE 2. Measured section of Wathena gravel pit in Sec. 33, T.3 S., R.22 E. as it appeared in June, 1985. Scale is in meters. W1, W2, and W3 are locations where wood was found in Lower Kansan Till.

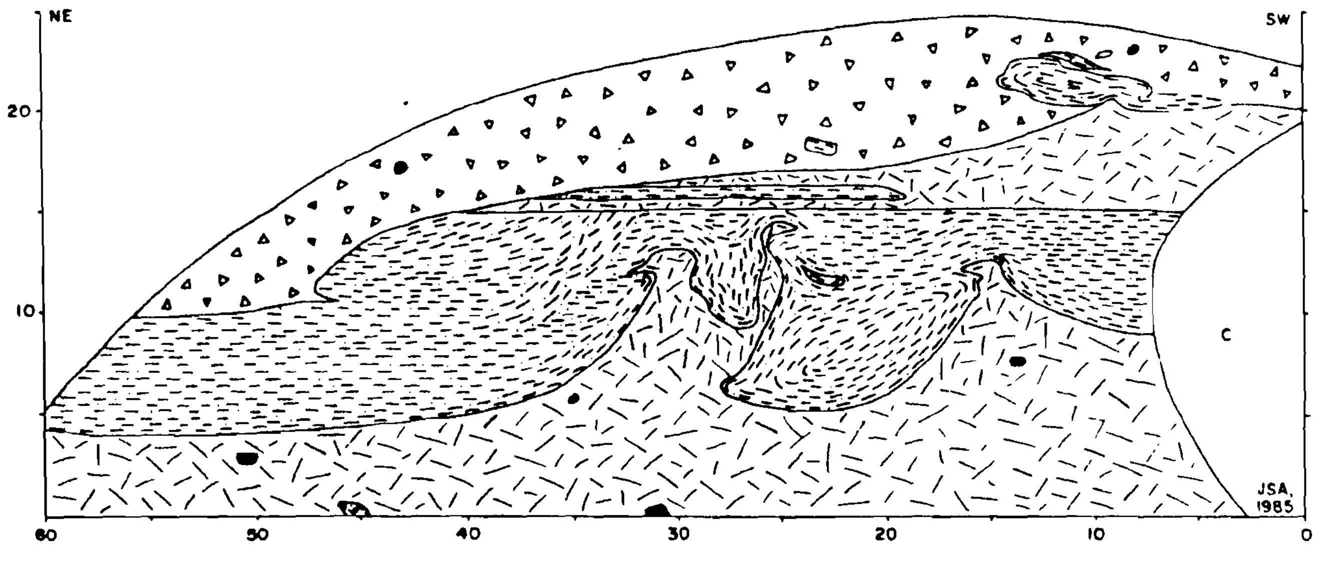

FIGURE 3. Measured section of Kansas Drift in Sec. 10, T.6 S., R.20 E. as it appeared in June, 1985. Lower Kansan Till is separated from Upper Kansan Till by Atchison sand formation. All strata display ice pushed features. Two pieces of wood were found in Lower Kansan Till between 50 and 60 meter marks.

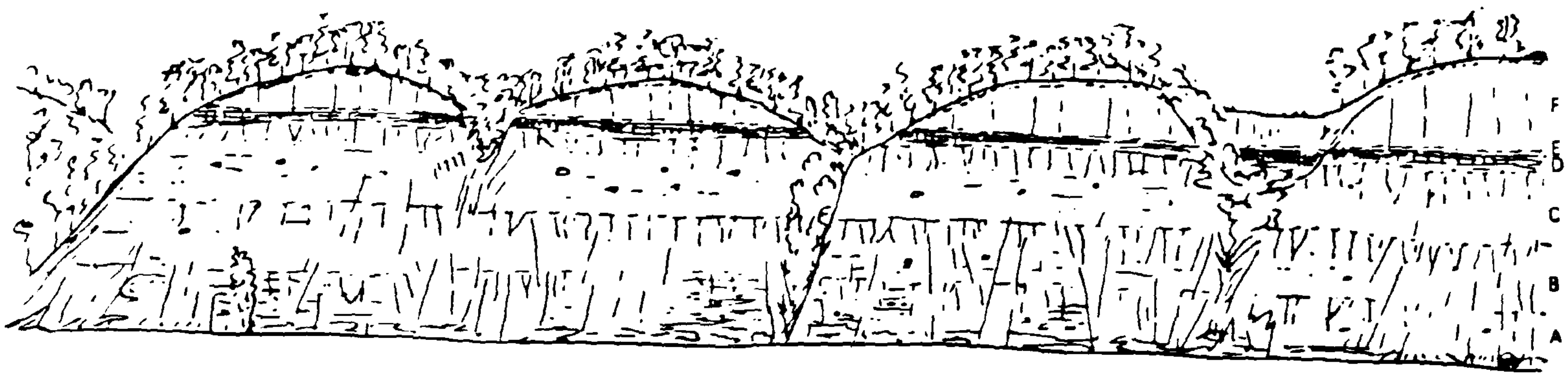

FIGURE 4. Sketch of Platte River bluff section in Sec. 22, T.17 N., R.27 E. Letters correspond to different strata at the site; A. Nebraskan or Fremont Till, B. Nickerson Till, C. Cedar Bluffs Till, D. Yarmounth-Sangamon Paleosol, E. Gilman Canyon Loess Bed, F. Peoria Loess (Wayne, 1984). Wood was found along the foot of the bluff wall in Lower Gray Fremont Till. Some samples were found higher up in the Fremont Till. Approximate scale is 30 meters high and 1 kilometer long.

Two small specimens of wood were found buried in the lower gray till west of Atchison, just above the water level at White Clay Creek in October, 1985 (Fig. 3). These samples were also excavated with a shovel and trowel, and were photographed in place (Plate 5). Thin oxidation zones also surrounded these specimens. The gray till at this site is identical to the till at the Wathena site and has the same characteristics.

Several wood specimens were found buried in the gray till along the south bank of the Platte River south of Fremont, Nebraska (Fig. 4, Plate 6). Access to the south bank was gained with the aid of a canoe. The largest of all specimens was found approximately seven meters above the water level. This sample was approximately 50 cm long. This sample was also surrounded by an oxidation zone about 1 cm thick. It was excavated and photographed in place (Plate 7). All of the other specimens at this site were found at or just above the water level, along the foot of the bluff. All of the specimens that were collected from the three different sites were relatively unaltered. No petrification of the wood cells had taken place. The first sample collected from Wathena (W1, Plate 4b) appeared to have been twisted. The large sample from the Platte River (Plate 7) showed signs of being cut or gnawed off at the exposed end. As this sample dried, it split into several long pieces.

One small sample from the Platte River was partially covered with charcoal. The surface of the wood appeared to be cracked and possibly could have been burned before becoming incorporated into the till.

Laboratory Technique

Wood maceration and photographing the wood under a scanning electron microscope are the two procedures that have been used to identify the wood samples. Wood maceration involves placing slivers of the wood into very strong acid. The wood breaks down so that individual cells can be observed under an optical microscope. Upon the initial observation of the wood under the microscope, it was discovered that the samples were covered with silica. The wood was soaked in hydrofluoric acid for 24 hours and then was washed with tap water to remove the silica.

A mixture consisting of equal amounts of 10% chromic and 10% nitric acid was recommended to macerate the wood (Beryln and Miksche, 1976). However, an acid mixture of this concentration did not break down the wood. Maceration of the wood was then attempted using increasingly potent concetrations of the acid. A mixture of equal amounts of 30% chromic acid and 30% nitric acid succeeded in macerating the wood.

The acid mixture and the wood were put into vials to soak for 24 hours. After soaking, the contents of the vials were poured onto filter paper to separate the wood from the acid. The wood was washed from the filter paper into a beaker with tap water. The macerated wood and water was then poured into vials.

Samples of the macerated wood were obtained from the vials with a pipette, and the macerated samples were placed on a slide for observation under an optical microscope. Characteristics of individual cells could then be observed. Figure 5 shows some of the features used to distinguish between different woods. Some samples were stained with safranin oil to enhance the details of the cells. Some of the observed features were elliptical bordered pits on the tracheids and circular bordered pits on the wood rays. Upon observation of the macerated samples under the microscope it was discovered that the features of the wood were poorly preserved.

Observing and photographing the wood under a scanning electron microscope was the second procedure used to help in identifying the wood. This allowed for observing the features under very high magnifications. The scanning electron microscope in the Entomology Department at Kansas State Univeristy was used. The K-State technicican operated the microscope and prepared the samples.

Two samples from the Wathena site, one from the Atchison site, and two from the Platte River site were observed. The samples were broken off of the wood specimens, and had not been treated with acid. The first step was to glue a piece of the wood sample onto a small pedestal which was one-half inch in diameter. Two pieces from each sample were glued to the pedestals. Each piece was oriented so that it was possible to get a cross-sectional view and a radial view of each sample. One sample from Wathena was viewed in cross-sectional and tangential orientations.

After the samples had been glued to the pedestals, the pedestals were placed into an air tight chamber. A vacuum was applied to this chamber to draw all of the moisture out of the wood. After the wood was thoroughly desiccated, the samples were coated with a thin layer of carbon.

The samples were ready to be viewed under the scanning electon microscope. One sample at a time was placed into the chamber where it was bombarded by electrons. As the electrons bombarded the wood, an image of the wood was projected onto a small television screen. The samples were observed at magnifications ranging from 120 to 2000x. The wood samples were scanned looking for distinguishing features that would help to identify the wood. Such features as the arrangement of the tracheids and position of the resin canal with regard to the annual ring could be seen(Plate 8). The shape of the bordered pits on the tracheids could be seen. An internal view of a tracheid (Plate 10) also shows the shape of the bordered pits. Characteristic of the bordered pits on the wood rays could be seen (Plate 11).

As the samples were scanned and a feature was observed that would help to identify the wood, the image was brought up to a desired magnification. A photomicrograph was taken of the feature and was developed within a minute after it was taken. This procedure provided the necessary information to make a positive identification of the wood.

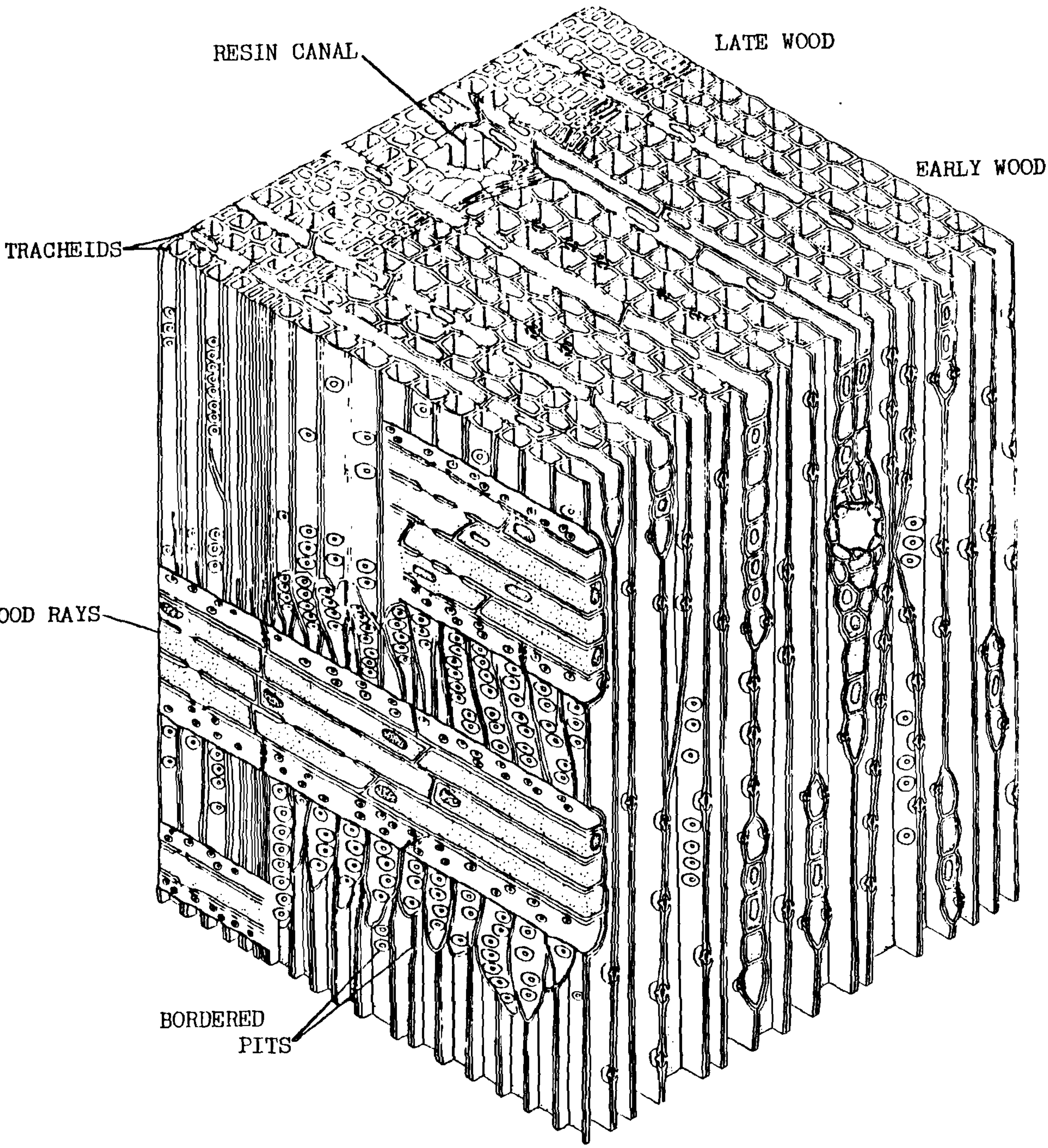

Figure 5. Block diagram of pine showing wood features. (Evert and Eichorn, 1981)

CHAPTER IV

WOOD IDENTIFICATION

The first distinction to be made about the wood samples was whether they were deciduous of coniferous. In cross-sectional view deciduous wood contains large vessels that are dispersed among the tracheids. In coniferous wood the tracheids are all fairly uniform in size and they are arranged into straight rows (Raven & Evert, 1981). The photomicrograph of the cross-section (Plate 8) shows that the wood is definitely coniferous.

An abrupt versus a gradual transition in the size of the tracheids from earlywood to latewood is another feature used to distinguish between different woods. The hard pines and larch have an abrupt transition, and the soft pines and spruce have a gradual transition (Core et al., 1979). Plate 8 shows the gradual transition in the size of the tracheids.

The position of the resin canals with respect to the annual ring and the number and size of the canals is another distinguishing feature. Resin canals are present in pine, larch , spruce and fir. Resin canals are more abundant and larger in pine than in other woods. In spruce the resin canals are located near the annual ring. This is the main feature used to distinguish between spruce and fir (Core et al., 1979). The resin canals in the samples collected from Nebraska and Kansas are sporadic and are positioned near the annual ring (Plate 8).

The shape and arrangement of the bordered pits on the wood rays is another important feature. The bordered pits are circular in shape and are arranged into groups of four (Plate 10). This is a characteristic of spruce (Core et al., 1979).

Bordered pits are also present on the tracheids. The shape of most of the bordered pits had decayed, or had been destroyed to the point where the original shape could not be determined (Plate 9). The bordered pits on the pine tracheids are fenestriform and pinoid in shape. The pits in spruce are piceoid, shaped like narrow slits, (Core et al., 1979). A photomicrograph of the interior of a tracheid shows the bordered pits are piceoid shaped (Plate 10).

One key feature that distinguished this wood as spruce rather than pine, fir or larch is the gradual transition in the size of the tracheids from earlywood to latewood, which is characteristic of the soft pines and spruce. A feature which distinguished between the soft pines and spruce is the size and placement of the resin canals. The resin canals are more abundant and larger in pine and are sporadic and located close to the annual ring in spruce. The arrangement of circular bordered pits into groups of four on the wood rays, and the piceoid shape of the bordered pits on the tracheids are also characteristics of spruce.

According to Core (1979) an identification of the wood as red, white, or black spruce cannot be ascertained by gross characteristics or minute features of the wood. Therefore, unless the pollen or other macrofossils, such as spruce needles, can be located with the wood specimens, a species identification is not possible.

However, the study of the peat bed near the Arkansas River by Jaumann et al. (1985) turned up needles and cone scales that belong to white spruce (Schwert et al., 1981). The study of the insect assemblages at Johns Lake, North Dakota found there were nine species of insects that only inhabit white spruce. These studies indicate the dominant species of spruce during the Late Wisconsin is Picea glauca, white spruce.

The modern boreal forest is also dominated by white spruce. Based on this evidence it can be speculated that the wood collected is also white spruce.

CHAPTER V

CONCLUSIONS

There are two separate tills of Kansan age in northeastern Kansas. The lower gray till in which the wood was buried is recognized as being deposited by the initial Kansan glacial advance into the area. This advance moved into Kansas from the northeast. This till layer was later deformed by a second advance from the northwest.

Analysis of all of the features of the wood indicates the wood is spruce. It would appear the initial glacial advance into Kansas overrode a boreal forest that was dominated by spruce. This spruce forest probably established itself throughout the area because of the cooler climate of the time, and was comparable to the spruce forest that developed in the same region during the Late Wisconsin glaciation. The Kansan spruce forest was then overridden by the glacial ice and the wood was incorporated into the till. The fact that there was little or no deformation of the wood indicates that it was deposited in a frozen state.

The forest could also be compared to the modern boreal forest in Canada. This forest is characterized by severe winters, with a persistent snow cover. The northern limits of this forest has rigorous arctic conditions and grades into a tundra environment. Most of the moisture falls during the summer because the cold winter air has a very low moisture content (Raven et al., 1981).

The gray till in Nebraska has long been recognized as being deposited by the Nebraskan glaciers. Because of the similarities in appearance of the gray till in Nebraska and the gray till in Kansas, there has been debate over whether these tills are the same. Both were possibly deposited by the same glacial advance. There are few deep till exposures between northeastern Kansas and Fremont, Nebraska. This makes it very difficult to correlate the till layers. This however does not mean that the gray till does not exist between the two locations. The fact that spruce wood was found buried in the till in Kansas and Nebraska argues in favor of the proposal that they are the same tills.

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APPENDIX

PHOTO PLATES

PHOTO PLATE 1. Photograph of initial wood discovery (W1) at Wathena site. Wood was exposed when bluff wall slumped down. The wood, surrounded by oxidation zone, was buried in Lower Kansan Till.

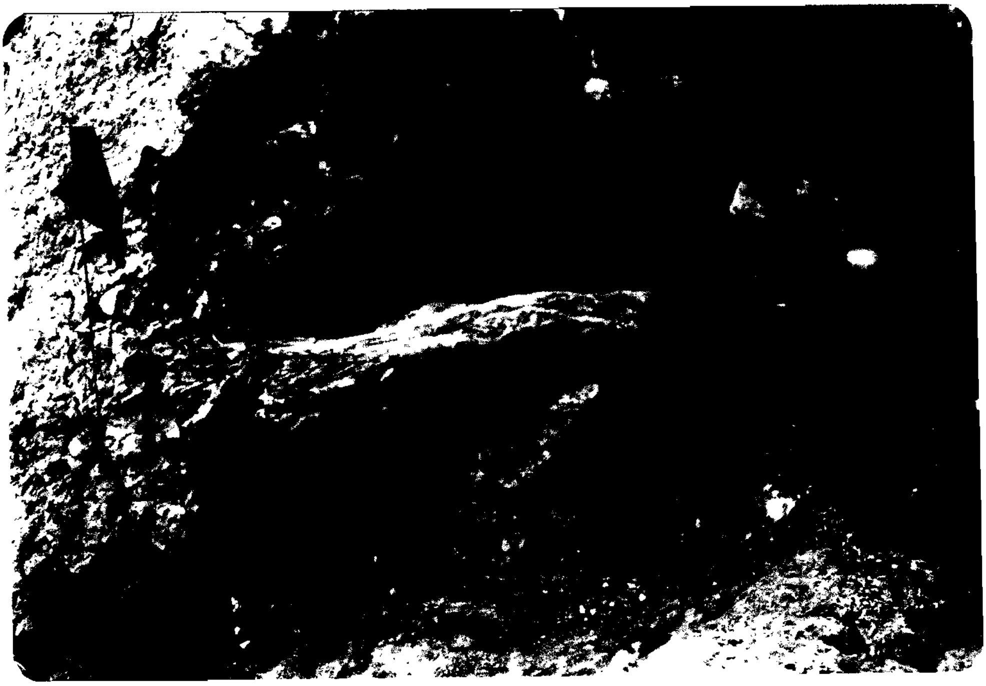

PHOTO PLATE 2. Initial wood discovery (W1) after excavation. Clay matrix of gray till helped preserve and protect the wood from decay.

PHOTO PLATE 3. Bluff wall at Wathena gravel pit where wood was found in June, 1985. Lower strata is fossiliferous silt and sand bed. Gray material above is a clayey till containing several large boulders. This till is Lower Kansan Till and is strata in which wood was buried.

PHOTO PLATE 4a. Author, Brad Hedstrom, pointing to third piece of wood (W3) found at Wathena site in June, 1985.

PHOTO PLATE 4b. Upper specimen is initial piece of wood found at Wathena site (W1); lower specimen is third piece found (W3). Ruler is 7 inches, or a little over 18cm for scale.

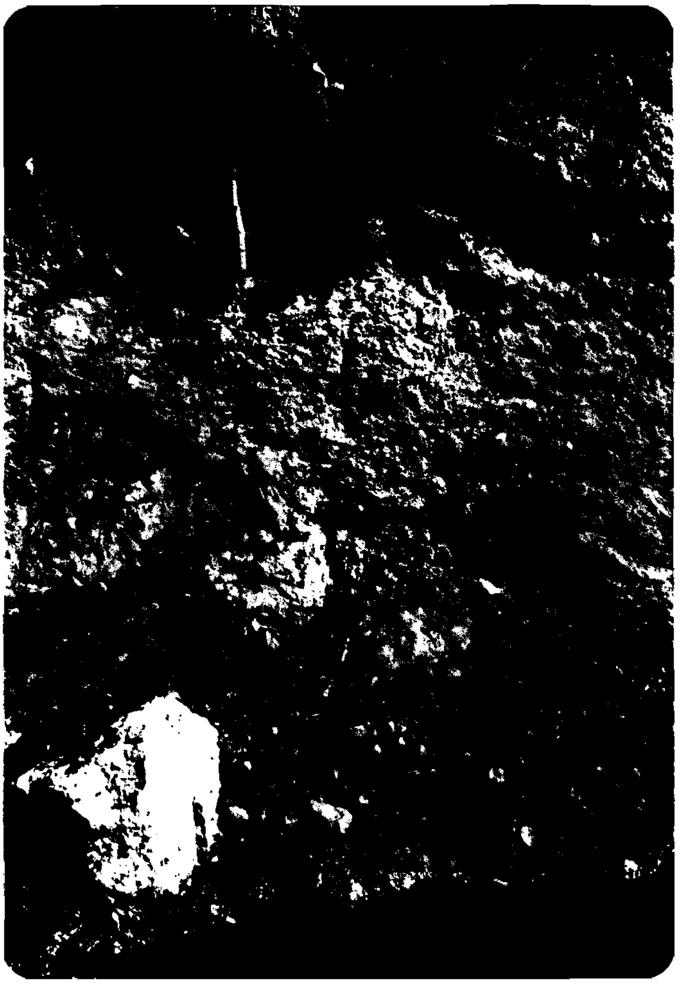

PHOTO PLATE 5. Two small specimens of wood found buried in Lower Kansan Till at Atchison site. Specimens found just above water level in October, 1985.

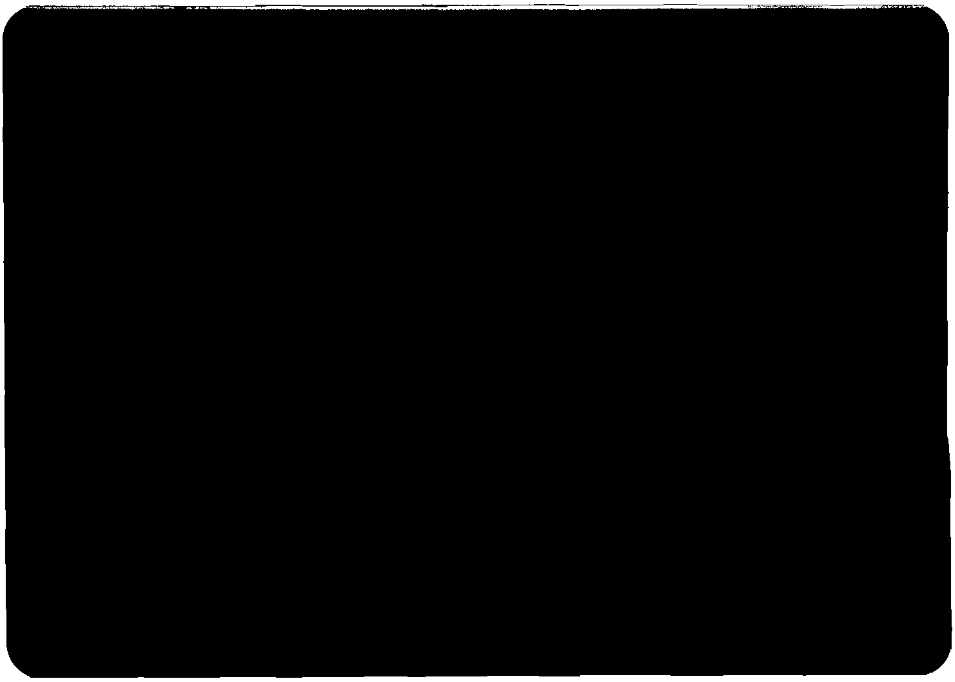

PHOTO PLATE 6. South bank of Platte River near Fremont, Nebraska. Several pieces of wood found in gray till at or just above water level at this site. A few pieces found higher up on bluff wall in gray till.

PHOTO PLATE 7. Largest wood specimen, 50 cm, found 7 meters above water level at Platte River site. Notice similarity of gray till at this site and sites in northeastern Kansas.

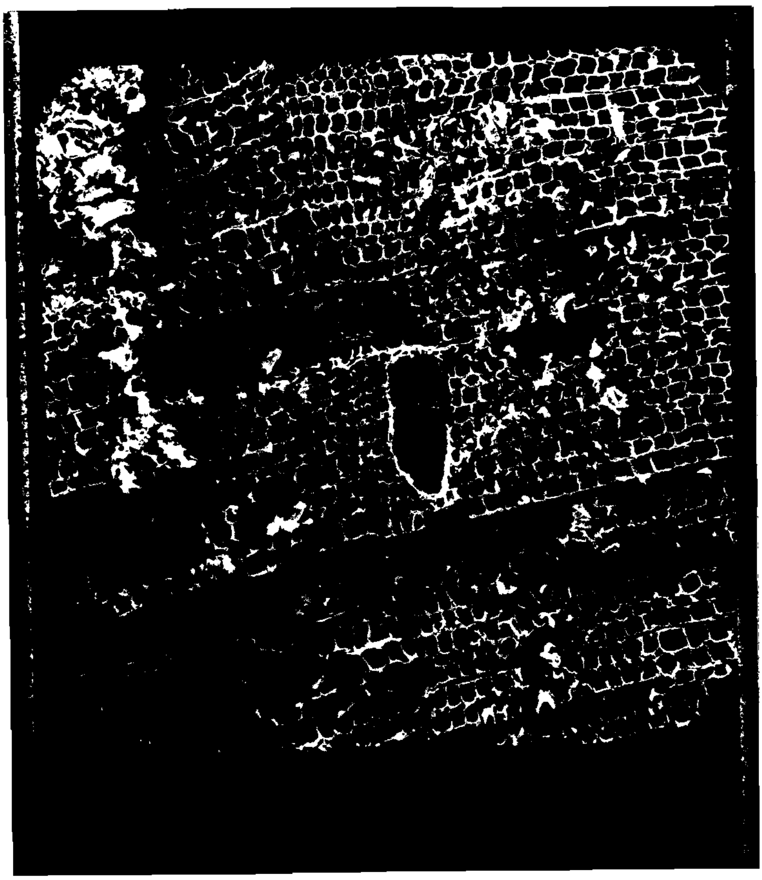

PHOTO PLATE 8. Photomicrograph of large wood specimen from Platte River. Cross-sectional view shows arrangement and gradual transition in size of tracheids from earlywood to latewood. Position of resin canal with regard to annual ring can also be seen. Magnification 120x.

PHOTO PLATE 9. Photomicrograph of radial section of wood specimen from Platte River site. Poorly preserved shape of bordered pits on tracheids can be seen. Magnification 1000x