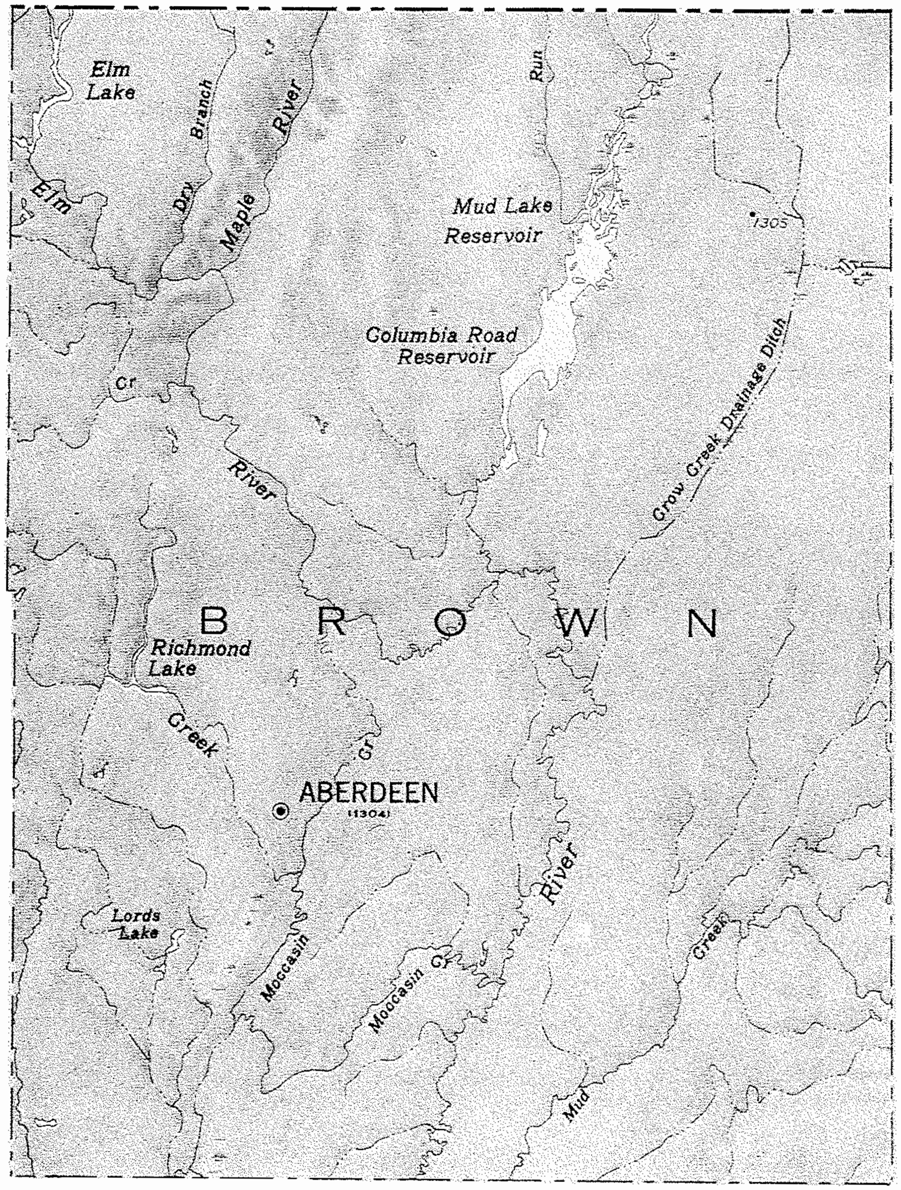
BULLETIN 25

GEOLOGY AND WATER RESOURCES OF BROWN COUNTY, SOUTH DAKOTA



PART I: GEOLOGY

by Darrell I. Leap

Prepared in cooperation with the United States Geological Survey, Oahe Conservancy Sub-District and Brown County

DEPARTMENT OF WATER AND NATURAL RESOURCES
SOUTH DAKOTA GEOLOGICAL SURVEY-1986

STATE OF SOUTH DAKOTA
William J. Janklow, Governor

DEPARTMENT OF WATER AND NATURAL RESOURCES
John J. Smith, Secretary

GEOLOGICAL SURVEY
Merlin J. Tipton, State Geologist

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Science Center
University of South Dakota
Vermillion, South Dakota
1986

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ABSTRACT

Brown County, in the northeastern part of South Dakota, comprises an area of about 1,728 square miles. Major topographic features include the James River, Lake Dakota plain, and till highlands east and west of the Lake Dakota plain.

Pre-Pleistocene rocks range in age from the Precambrian basement rocks to the Cretaceous Pierre Shale. Only the latter crops out at the surface. The Niobrara Marl subcrops beneath glacial drift in isolated areas.

Between the Precambrian rocks and the Pierre Shale are formations representing the Cambrian, Ordovician, Devonian, Mississippian, Pennsylvanian, Jurassic, and Cretaceous periods.

With the exception of a few scattered outcrops of Pierre Shale, and small areas of Recent stream alluvium and lake silt, the entire County is covered by Pleistocene glacial drift. This drift includes till, outwash, lake silt, and sand. Lacustrine deposits and sand are found in greatest quantity in the bed of Ancient Lake Dakota.

Major geomorphic features include large areas of recessional moraine, the Lake Dakota plain, and small areas of stagnation drift and sand dunes.

Evidence indicates Brown County has been glaciated only once; the James Lobe of late Wisconsin age advanced southward through the James Basin and spread out onto the highlands east and west of the basin. There may have been at least two rapid advances and withdrawals of the ice. During the final retreat, Ancient Lake Dakota formed between the retreating ice front and a morainal dam at the Beadle-Spink County boundary.

Mineral resources of value include large amounts of ground and surface water and sand and gravel. No significant metallic or fossil fuel reserves have been located.

INTRODUCTION

Location and Size of Area

Brown County is located in the northeastern part of South Dakota (fig. 1) and comprises an area of approximately 1,728 square miles. The County is bordered on the north by Dickey and Sargent Counties, North Dakota. It borders Day and Marshall Counties to the east, Spink and Faulk Counties to the south, and Edmunds and McPherson Counties to the west.

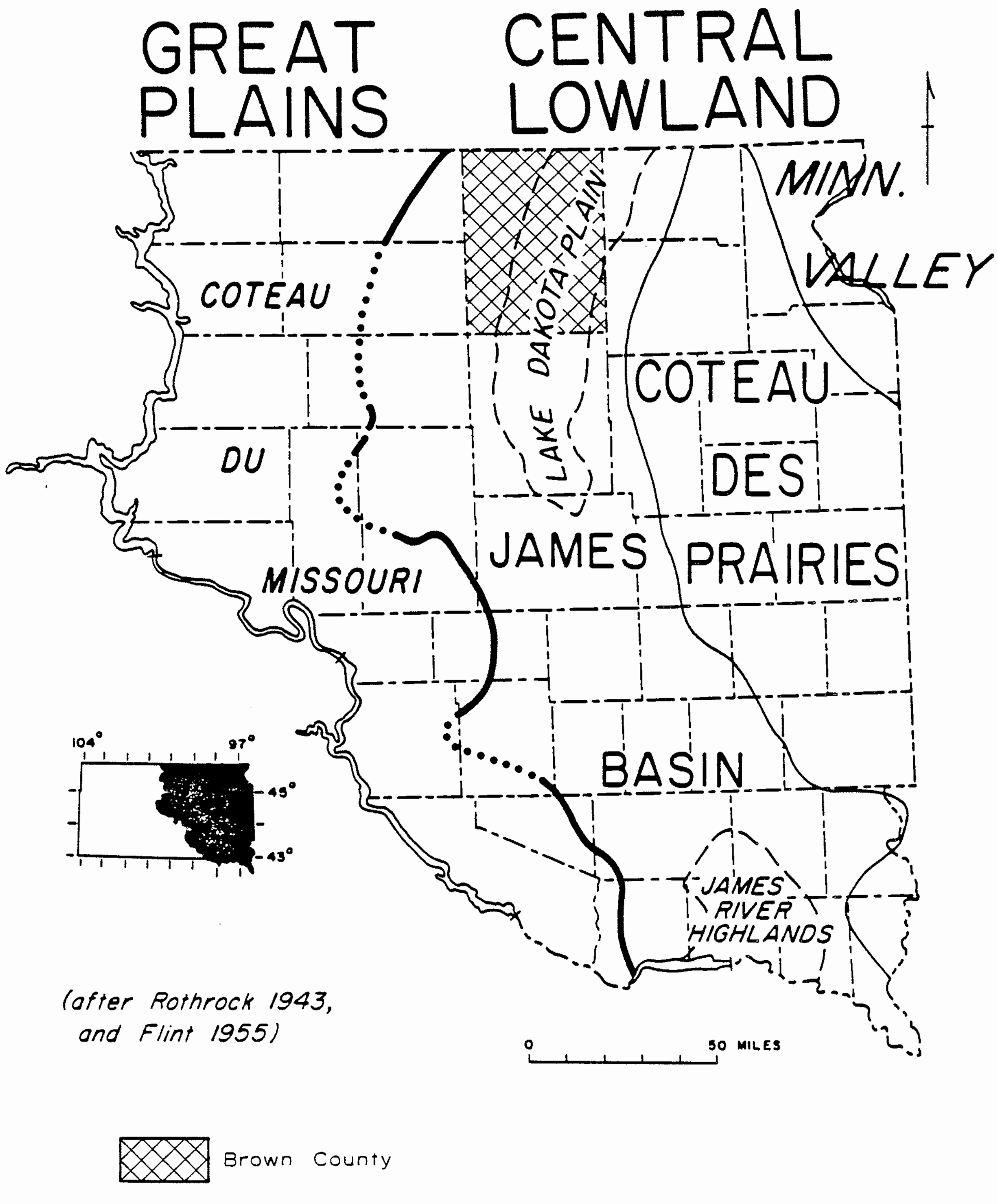


Figure 1. Index map of eastern South Dakota showing the physiographic divisions and location of Brown County.

Purpose of the Investigation

This investigation is one of a continuing series of investigations conducted as cooperative studies with the U.S. Geological Survey. Major goals are the location and evaluation of water and mineral resources in the County, and the interpretation of the geology. This phase of the study has concentrated mostly on Pleistocene geology. Results of this study will be published in two parts. Part I (this report) is a result of the geologic investigation; whereas, Part II (Koch and Bradford, 1976) is a report of the hydrologic investigation. The basic data collected and used in the preparation of the two reports will be published as open file reports available in the offices of the South Dakota Geological Survey in Vermillion and the United States Geological Survey in Huron.

Methods of Investigation

Field work for the project was conducted during the summers of 1967-1971. Field mapping of surficial deposits and outcrops was displayed on aerial photographs having a scale of about 1 inch equals 1 mile and the data were later transferred to base maps of the same scale.

Subsurface data were gathered from numerous test holes drilled by rotary and power auger equipment. In addition, many hand-auger holes were dug into shallow deposits.

Previous Investigations

The first known geological investigation of Brown County was conducted by Chamberlin (1883); Todd (1909) mapped nearly all of Brown County. Further studies were conducted by Leverett (1932), Johnson (1942), and Rothrock (1943, 1946). Curtiss (1949) and Hubbard (1952) investigated the geology of Brown County but never published their findings. Flint (1955) mapped the Pleistocene geology of all of eastern South Dakota including Brown County.

Studies predominantly of a hydrologic nature but also contributing to the geological knowledge of the County include McClure (1887), Darton (1909), Sayre (1936), Rothrock (1955), Black and Veatch (1956), Koopman (1957), Baker (1963), Hopkins and Petri (1962 and 1963), Barari and Brinkley (1970), and Koch and Bradford (1976).

Acknowledgments

The investigation and preparation of this report were performed under the direction and supervision of Merlin J. Tipton, State Geologist, who, along with many additional persons listed in the following paragraphs, contributed greatly to the success of the project; their help and advice are greatly appreciated.

Cleo M. Christensen of the South Dakota Geological Survey contributed advice in field conferences as did N. C. Koch of the United States Geological Survey and Dr. Richard R. Parizek of the Pennsylvania State University.

Messrs. Terry Blankenship, Richard Bretz, David Carver, Steven Constable, David Gaylord, Ron Helgerson, Michael Johnson, George Lee, Scott McGregor, Gary Ochsenbein, and Lon Thompson aided greatly in their positions as summer field assistants.

Drillers and technicians who helped in making the investigation successful were Lloyd Helseth, Millard Thompson, and Wendell Bradford.

The United States Soil Conservation Service in Aberdeen gave generously of the information in their files as did Mr. Don Crampton of the South Dakota Department of Highways.

Financial support for the project was granted by the South Dakota Geological Survey, the United States Geological Survey, the Oahe Conservancy Sub-District, and Brown County.

The investigation was initiated at the request of the Brown County Commissioners. The author wishes to acknowledge the cooperation of the Commissioners and the many residents of Brown County.

PHYSIOGRAPHY

Brown County is situated entirely within the James Basin Physiographic Division of the Central Lowlands Physiographic province (fig. 1). Its northwest corner is about 5 miles from the western boundary of the Great Plains Physiographic province. Approximately 750 square miles of the surface (43 percent of the total area of the County) are comprised of lacustrine silts of Ancient Lake Dakota. The remainder of the County on both sides of the Lake Dakota plain portrays higher topography and is covered by recessional moraines of the late Wisconsin glaciation.

The bed of Ancient Lake Dakota is nearly flat with relief seldom exceeding 10 feet except where stream valleys have been incised into it or where, as in the northern half of the County, blow-outs and sand dunes have created a rather rough topography.

The gross topography of Brown County can be characterized by a long north-south trending depression with highlands rising on both sides. The bottom of the depression is occupied by the bed of the James River and the land surrounding the river bed is covered with lake silt and aeolian sand and silt. On figure 2 this

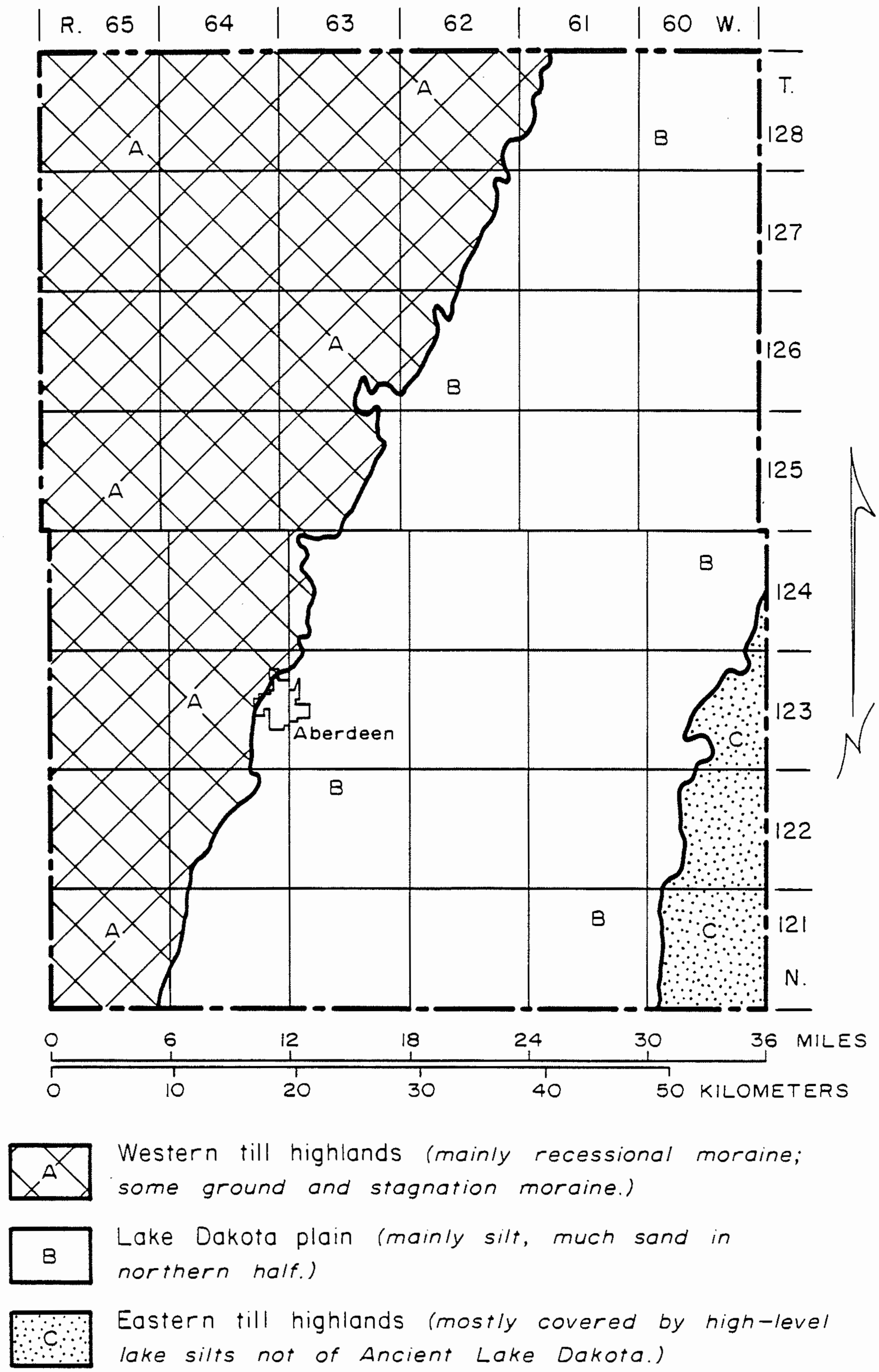


Figure 2. Map showing major physiographic features of Brown County.

area is the Lake Dakota plain. Highlands are composed predominantly of late Wisconsin till with scattered areas of outwash and lake silts. These areas comprise the western till highlands and the eastern till highlands (fig. 2).

Brown County is located between two major Coteaus. Immediately west of the western border of the County lies the Coteau du Missouri and immediately east of its eastern border the elevation rapidly rises to form the western boundary of the Coteau des Prairies.

Several streams flow down the slopes crossing the till highlands and the two Coteaus to join the James River in the lower part of the depression. On the west side of the County the major streams include Elm and Maple Rivers and Dry Branch, Dry Run, Willow Creek, Foot Creek, Snake Creek, and Moccasin Creek. The eastern slope of the County is drained by Mud Creek and its numerous tributaries. Drainage is well integrated in all but the northeastern quarter of the County where blowing and drifting silt and sand obliterate newly formed channels. This is an area of swampy ground and drainage must be established artificially by means of ditches. All streams with the exception of the James River and Elm River are intermittent, flowing only after heavy rain or snowmelt.

Most of the County is dotted with numerous depressions in the glacial drift with a few large enough to hold significant amounts of water. The major natural lakes are Salt, Alkali, Pond, and Lords' Lake in the western part of the County. Salt Lake and Alkali Lake, as their names imply, are saline. They are closed depressions and inflowing ground and surface water evaporates, constantly increasing the salt content of the lake water. Numerous artificial lakes include Richmond, Willow Creek, Elm, Engle, Sand and Mud Lakes which were created by damming of streams.

STRATIGRAPHY

The following description of the rock sequence conforms to nomenclature accepted by the South Dakota Geological Survey (Agnew and Tychsen, 1965) and the American Commission on Stratigraphic Nomenclature. The rocks are described in order from the lowermost (oldest) to the uppermost (youngest). Table 1 is a generalized stratigraphic section of formations and deposits in Brown County.

Precambrian Rocks

The Precambrian basement underlying Brown County is part of the Canadian Shield which slopes northwesterly into the neighboring Williston Basin (Agnew and Tychsen, 1965). Steece (1961) shows that the Precambrian surface slopes from an elevation of 200 feet above sea level at the southeastern corner of the County

Table 1. Generalized stratigraphic section for Brown County.

ERA	PERIOD	EPOCH	GLACIAL AGE	DEPOSIT	THICKNESS (in feet)	DESCRIPTION
CENOZOIC	QUATERNARY	RECENT		Loess	unkn./few in.	Loess not mapped as separate areas. Probably occurs over all of Brown County east of western boundary of Ancient Lake Dakota.
				Alluvium	0–30	Medium- to dark-brown, heterogeneous mixtures of sand, gravel, silt and clay in channels in till highlands. On Lake Dakota Plain, material composed of tan- to light-brown sand, silt and clay,
				Lacustrine silts	unknown	Dark-brown to black, organic-rich silts. Occurs as upper sediments of ponds and lakes.
		PLEISTOCENE	LATE WISCONSIN	Aeolian sand	0–45	Fine-grained sand with some silt; derived from underlying water-laid sand; covers most of northeastern Brown County.
				Waterlaid sand	0–45	Fine- to medium-grained sand. Covers most of northeast quarter of Brown County. Upper part has been reworked by wind.
				Deltaic sediments	0–60	Mixture of sand, silt, and clay. Some gravel in upstream parts. Found in deltas of Elm River, Foot Creek, and Mud Creek. More blocky in texture than lake sediments.
				Lacustrine silts	0–95	Light-yellow to light-tan silt with minor amount of clay. Thickest deposit in bed of Ancient Lake Dakota. Minor deposits in lower parts of ponds.
				Outwash	80 max.	Sand and gravel composed of reworked Cretaceous sediments and fragments of igneous and metamorphic rocks.
				Till	0–230	Light- to dark-gray clay. Contains sand, silt, and intercalated gravel. Occasionally contains large boulders. Occurs in large buried bodies and as surface deposits.
				Deep channel sediments	0–160	Gravel, sand, silt, and clay confined to the deepest parts of the Ancient Grand-Moreau-Cheyenne Channel.

Era	Period			Formation	Thickness (ft)	Description
MESOZOIC	CRETACEOUS			Pierre Shale	320 max.	Medium- to dark-gray shale; very plastic; contains numerous seams of bentonite; often contains ferruginous concretions. Underlies all of Brown County and is probably conformable with Niobrara below.
				Niobrara Formation	50-175	Generally a white- to light- or dark-gray marl with microfossils. Underlies all of Brown County and subcrops in several deep bedrock channels beneath glacial drift. Probably conformable with Codell beneath.
				Codell Sandstone	25-50	Upper member of Carlile Shale. Generally a fine-grained sandstone associated with some dark-gray shale. Probably conformable with underlying shale of the Carlile. Absent in a few places in northeastern Brown County.
				Carlile Shale	275 max.	Medium-gray shale, very plastic, ironstone concretions and stringers of fine-grained sandstone. Present throughout all of Brown County and conformably overlies the Greenhorn Limestone.
				Greenhorn Limestone	50-70	White- to light-gray limestone. Composed in part of beds of the fossil pelycepod, <u>Inoceramus Labiatus</u>. Occasional interbedded seams of gray shale. Underlies all of Brown County and rests conformably upon the Graneros Shale.
				Graneros Shale	200-300	Dark-gray shale, fissile to blocky. Occasionally contains ironstone concretions. Present in all parts of Brown County and is in transitional contact with Dakota Formation beneath it.
				Dakota Group	200-300	White, gray, yellow, and red sandstone, fine- to medium-grained, interbedded with numerous layers of gray shale. In the extreme eastern part of the County it unconformably overlies the Precambrian. In most places it rests on the Skull Creek Shale.

MESOZOIC	CRETACEOUS	Skull Creek Shale	0-65	Dark-gray shale with beds of glauconitic siltstone. Covers most of western and central Brown County. Probably absent in extreme eastern part of County. It is thickest in the northwestern part of the County. Probably conformable with Fall River Formation.
MESOZOIC	CRETACEOUS	Fall River Formation	0-150	White, fine- to medium-grained sandstone, interbedded with gray, green and brown shale. Rests unconformably on lower formations. Occurs in western part of Brown County but is thickest in northwestern part. In most places it overlies the Precambrian basement.
MESOZOIC	JURASSIC	Sundance Formation	0-80	White- to light-gray sandstone with shale lenses. Occurs under all but extreme eastern part of Brown County. It is thickest in the central part of the County where it overlies the Sundance unconformably. In the eastern area of distribution it overlies the Precambrian unconformably.
MESOZOIC	TRIASSIC	None	none	None reported.
PALEOZOIC	PERMIAN	None	none	None reported.
PALEOZOIC	PENNSYLVANIAN	Minnelusa Formation members undiff.	unknown	Mostly brown- to gray limestone. Some white- to red sandstone, green- to red shale and brown dolomite. Occurs in western part of Brown County in scattered locations. Probably rests unconformably on Madison Group.

PALEOZOIC	MISSISSIPPIAN	Madison Group undiff.	0-45	White- to gray sandstone and white- to brown limestone. Upper parts contain some anhydrite. It is found only in the north-western part of Brown County and is known to rest unconformably upon the Precambrian. It may rest on some older Paleozoic formations in scattered places.
PALEOZOIC	DEVONIAN	Undif. Duperow and Souris River	unknown	Varicolored shale and red siltstone, light-brown limestone and dolomite, thin gray shale. Sporadic occurrence in north-western Brown County. Rests unconformably on older Paleozoic formations or on Pre-cambrian.
PALEOZOIC	SILURIAN	None	none	None reported.
PALEOZOIC	ORDOVICIAN	Red River Formation	unknown	Light-brown to pale-red limestone, partly dolomitized, and light-colored chalk. Probably only sporadic occurrences in northwestern Brown County. It may rest conformably on the Winnipeg where the latter is present.
PALEOZOIC	ORDOVICIAN	Winnipeg Formation	unknown	Fine-grained quartzite, sandstone, and shale. Sporadic occurrence in northwest-ern Brown County. Where the Deadwood is present it may rest conformably upon the latter. Otherwise it sits unconformably upon the Precambrian.
PALEOZOIC	CAMBRIAN	Deadwood Formation	unknown	Red-brown sandstone, gray shale, dolomites and buff limestones. Where present it rests unconformably upon the Precambrian basement. Occurs sporadically only in the northwest part of Brown County.
PREC.		Granite	unkn.	Red, hornblend granite in Brown County.

to 600 feet below sea level at the northwestern corner. A hole drilled in Aberdeen penetrated red hornblende granite at a depth of 1221 feet, 23 feet above sea level. The exact lithology of the Precambrian in other parts of the County is unknown although it is suspected to be composed of igneous and/or metamorphic rock as evidenced from drill holes in surrounding counties.

Age of the Precambrian in Brown County has not been determined, although the Milbank Granite, also Precambrian, which crops out approximately 100 miles east of Aberdeen in the Minnesota Valley, has been reported by Goldich et al. (1961) to have an average age of 2.0 billion years. It is very probable that the Precambrian granite underlying Brown County is of a similar age.

Paleozoic Rocks

Information concerning the distribution and thickness of Paleozoic rocks in Brown County is very scarce. The Paleozoic rocks are sporadic in occurrence and no known wells in Brown County obtain water from them. All ground water is obtained from rocks of Mesozoic Age or younger above the Paleozoics; consequently, there has been little drilling into the Paleozoic section.

From consideration of stratigraphic information west of Brown County in the deeper parts of the Williston Basin, and data collected by Koch and Bradford for Part II of this report, it is known that a few Paleozoic formations are represented, mostly in the northwestern part of the County.

The lowermost formation is the Deadwood (Cambrian in age) composed of sandstone, limestone, dolomite, and shale; this formation, where present, rests on the Precambrian basement. The Deadwood was named by Darton (1901) from an exposure near Deadwood, South Dakota. It underlies only the northwestern part of Brown County where the Precambrian Basement is deepest, and thickness of these rocks in the County is not known.

Above the Deadwood is the Ordovician Winnipeg Formation composed of shale and sandstone and the next highest Ordovician strata, the limestones of the Red River Formation. Thickness of these formations in Brown County is not known at the present time. The Winnipeg was named by Dowling in 1895 from exposures at Lake Winnipeg, Manitoba; whereas, the Red River Formation was named by Foerste (1929) and probably derives its name from Red River, Manitoba (Agnew and Tychsen, 1965). These formations also occur only in the northwestern part of Brown County.

Resting upon the Ordovician and restricted to the northwest part of the County are undifferentiated Devonian rocks of unknown thickness composed of sandstone, limestone, dolomite, and shale.

The Mississippian Period is represented by the Madison Group. A hole drilled in NE 1/4 NE 1/4 sec. 33, T. 128 N., R. 64 W., revealed the top of the Madison at a depth of 1412 feet. In this hole the Madison is 43 feet thick and rests directly upon the Precambrian granite and is capped by the Dakota Formation of Cretaceous age. Named by Peale (1893) from the Madison Range in Montana, the Madison also is represented only in the deeper part of the basin in the northwestern part of the County. Typically, the Madison is characterized by limestone and dolomite with some shale, especially in the lower part, and sandstone in the upper part.

The Minnelusa Formation of Pennsylvanian age is composed of shale and limestone and, because Permian beds have not been reported, represents the youngest Paleozoic rocks in Brown County. These rocks occur only in the western part of the County and their thickness is not known. Winchell (1875) obtained the name Minnelusa from the Indian name for Rapid Creek in Pennington County, South Dakota, where the type exposure is found.

The location of the previously mentioned hole which penetrates the Madison Group is just east of the eastern edge of the Williston Basin and it is unlikely that the Paleozoic rocks extend east of this point. Holes to the Precambrian in Marshall and Day Counties and eastern Brown County have not revealed Paleozoic rocks, but rather, Cretaceous Formations resting upon the Precambrian.

Scarcity and sporadic occurrences of Paleozoic strata in western Brown County can be attributed to deposition of thin beds followed by subsequent uplift and erosion. In the eastern half of the County, deposition of these beds probably did not occur because the area is east of the basin of deposition.

Mesozoic Rocks

Absence of Triassic Rocks

Rocks of the Triassic period have not been found in Brown County. During early Mesozoic time the area of Brown County was near the east edge of the depositional basin and either the Triassic sediments were never deposited, or they were deposited and later eroded away.

Jurassic Rocks

Jurassic rocks are represented in Brown County by the sandstone, siltstones, and shales of the Sundance Formation which attains a maximum thickness of 80 feet in the northwest part of the County. Its boundaries are not known in Brown County but it does occur in the western part. The Sundance was named by Darton (1899) from an exposure near Sundance, Wyoming. According to nomenclature accepted by the South Dakota Geological Survey, these sediments would belong to the Lower Cretaceous Inyan Kara Group (personal communication, Schoon, R. A., 1971).

Cretaceous Rocks

FALL RIVER FORMATION

The oldest and lowermost Cretaceous rocks in Brown County consist of the Fall River Formation which is typically a sandstone containing shale lenses. Within the County the formation attains a maximum thickness of 150 feet. This formation which was first described by Russell (1927) from the type locality in Fall River County, South Dakota, underlies all but the extreme eastern part of Brown County.

SKULL CREEK SHALE

Above the Fall River Formation the Skull Creek Shale attains a maximum thickness of 65 feet. The Skull Creek, named from exposures along Skull Creek, Wyoming, by Collier (1922), is thickest in the northwestern part of Brown County and is probably absent in the extreme eastern part of the County.

DAKOTA FORMATION

The Dakota Formation underlies all of Brown County and is characteristically a fine-grained sandstone containing numerous shale lenses varying in color from white to gray, yellow, and red.

The Dakota was first described by Meek and Hayden (1861) from an exposure in Dakota County, Nebraska. Thickness of the Dakota in Brown County generally ranges between 200 and 300 feet and attains a maximum of 330 feet.

In the extreme eastern part of the County, the Dakota probably sits on the Precambrian basement and in the central and western parts of the County, it rests on the Skull Creek. Where the Skull Creek is missing, the Dakota overlies the Fall River, and in one known location, it overlies the Madison Formation. The Dakota slopes northwesterly into the Williston Basin and also thickens in that same direction.

GRANEROS SHALE

Graneros Shale immediately overlies the Dakota Sandstone throughout Brown County and has a reported thickness ranging from 200 to 300 feet. Normally, the Graneros, which was first described by Gilbert in 1896, is medium- to dark-gray in color, quite silty, and contains interbedded sand and silt lenses.

GREENHORN LIMESTONE

The Greenhorn Limestone is known locally by drillers as "Cap Rock" and is very distinguishable on electric logs by its characteristic "kick." It is a white to light medium gray, impure limestone, that may be composed in part of beds of the fossil Inoceramus Labiatus. In Brown County the Greenhorn dips gently toward the northwest and may vary in thickness from 50 to 75 feet. This formation was first described by Gilbert (1896).

CARLILE SHALE

Carlile Shale, first described by Gilbert in 1896, is more plastic than the Graneros Shale but is similar in color and appearance. It conformably overlies the Greenhorn Limestone and in Brown County attains a maximum thickness of 275 feet.

CODELL SANDSTONE

The Codell Sandstone, a member of the Carlile Shale, normally occurs at the top of the Carlile but occasionally is found beneath a few feet of shale. This member is characterized by fine-grained sandstone associated with varying amounts of dark-gray shale. The Codell is found sporadically in Brown County with thicknesses between 25 and 50 feet.

NIOBRARA MARL

The Niobrara Marl (or Niobrara Chalk) was originally described by F. B. Meek, and F. V. Hayden (1862) from exposures of "lead-gray calcareous marl" occurring in southeastern South Dakota. Niobrara Marl can be found in drill holes throughout Brown County. It does not crop out on the surface but is found in subcrops beneath the glacial drift where the overlying Pierre Shale is absent (pl. 1). In Brown County the Niobrara ranges from 50 to 175 feet in thickness.

PIERRE SHALE

The Pierre Shale is the uppermost bedrock formation in Brown County (pl. 1). It is a dark-gray shale containing lenses of bentonite and was first named the Fort Pierre Group (Meek, F. B., and Hayden, F. V., 1862). The name was shortened to Pierre by Darton (1896).

Sufficient data does not exist within the study area to subdivide the Pierre into members, but since it is believed to be conformable with the underlying Niobrara Marl, and in Brown County attains a maximum thickness of 320 feet, it is reasonable to assume that the rock represented in Brown County is the lower part of the Pierre. The Pierre underlies the glacial drift in Brown County and crops out extensively (pl. 2), notably along stream channels in the western part of the County.

Cenozoic Rocks

Absence of Tertiary Rocks

No tertiary deposits have been found in Brown County. The area that is now Brown County was located near the eastern edge of the depositional basin in early Tertiary time--the Cannonball Seaway (Stokes, 1966, chap. 14).

Tertiary deposits have been found along the Missouri River, 150 to 200 miles south of Brown County (South Dakota Geological Survey, personal communication). Hedges (1972, p. 7) found possible Tertiary rocks just west of Campbell County about 100 miles west of Brown County.

The paleogeographical location of Brown County near the edge of the Cannonball Seaway and the great distance from the County to the nearest Tertiary outcrops suggest that the area was undergoing erosion rather than deposition during Tertiary time.

Pleistocene Deposits

CLASSIFICATION OF PLEISTOCENE DEPOSITS

Pleistocene geologists have recognized and classified four major advances of Pleistocene glaciers in the midwestern United States. They are listed (from youngest to oldest) with the interglacial warm periods which separate them as follows:

Glacier Advance	Interglacial Warm Period
	Post glacial
Wisconsin	
	Sangamon
Illinoian	
	Yarmouth
Kansan	
	Aftonian
Nebraskan	

(after Flint, 1971, p. 543).

This classification is quite broad and now is generally accepted for the midcontinent region. Since no glacial drift older than Wisconsin has been recognized in Brown County, the present discussion will be limited to that subdivision of the Pleistocene. The probable absence of glacial deposits in Brown

County older than late Wisconsin is explained in Christensen and Harksen (1975).

The classification accepted by the South Dakota Geological Survey is that of Lemke and others (1965) and is the one used in this report. In the report of Lemke and others (1965) the Wisconsin deposits are numbered in sequence from oldest to youngest with four major ice margins recognized in South Dakota. In Brown County the majority of the glacial deposits belong to advance 3 with a small portion in the northeastern part of the County correlative with advance 4. Under this classification the glacial deposits would all be late Wisconsin in age.

METHODS OF CORRELATION

Data from drill holes and outcrops were correlated to determine the stratigraphy of Pleistocene deposits. Stratigraphy and surface features such as lithology and geomorphology were then compared to formulate a theory regarding the actual depositional and erosional dynamics as well as a relative time frame for these processes. This composite, conceptual model was then extrapolated outside Brown County and placed into a larger time-rock framework and tested for its "fit" into the overall picture of Pleistocene history in northeastern South Dakota.

Fortunately during this investigation, geologic and hydrologic studies were being conducted in Edmunds, McPherson, and Faulk Counties to the west by C. M. Christensen (1977) of the South Dakota Geological Survey. N. C. Koch (1975) of the United States Geological Survey was conducting similar studies in Marshall County as was the writer in Day County (Leap, 1974). Brown County is in the middle of this area geographically, and correlation of stratigraphic and geomorphic features from Brown County to the east and west was greatly facilitated.

LATE WISCONSIN DEPOSITS

Glacial Till

Glacial till of late Wisconsin age is present throughout the County except for a few small areas where the Pierre Shale crops out. In large areas it is covered by lake silt, alluvium, outwash, and aeolian deposits (pl. 2).

The till was deposited entirely by the late Wisconsin James Lobe ice (Lemke and others, 1965) and generally is composed of a mixture of clay, silt, sand and gravel which is of a dark- to medium-gray color when unweathered. In a few test holes the till and its intercalated outwash lenses contain lignite indicating that the glacier probably passed over lignite deposits in North Dakota on its way to Brown County. In Brown County, the till is as much as 230 feet thick.

Outwash

Glacial outwash composed primarily of sand and gravel may be found in three major types of deposits.

Surface deposits include scattered areas (pl. 2) containing outwash deposited mainly by streams carrying meltwater and sediment from melting glaciers. Most major stream valleys in the till highlands to the east and west of the Lake Dakota plain contain such deposits varying in thickness from 5 to 50 feet. Such deposits are ready sources of sand and gravel for road work and construction use but are often of limited use because of their high shale content. Most of these deposits are found in or around stream channels but a few in T. 128 N., R. 65 W., are in the form of disintegration ridges indicating that they were formed in tunnels or crevasses in the ice (pl. 2). Such deposits are also found in sec. 36, T. 128 N., R. 62 W., and in sec. 7, T. 128 N., R. 61 W.

A second type of outwash occurs as intratill deposits throughout the till. These deposits were formed in small depressions in the ice when summer melting produced the necessary meltwater. These outwash bodies vary in thickness from a few inches to 10 feet and probably do not exceed a few hundred square feet in area.

The third type of outwash deposit is primarily of pro-glacial origin and consists of buried meltwater channel deposits. These deposits form a complicated network of cut and fill sequences which extend vertically throughout the section and may or may not be connected to each other locally. The stratigraphic occurrence of these outwash deposits is illustrated in figures 3 through 10 by the symbol Qwlo.

In general there are three different levels of these buried pro-glacial outwash deposits. The lowermost or basal outwash is found in the deepest part of the Ancient Grand-Moreau-Cheyenne River Channel. This deposit covers an area of about 250 square miles and ranges in thickness up to a maximum of 160 feet. This outwash, the Deep James Aquifer, is 1 to 5 miles wide and trends north-south through central Brown County (Koch, Bradford, and Leap, 1973, fig. 2).

Overlying the basal outwash but still confined to or along the edges of the Ancient Grand-Moreau-Cheyenne River Channel is another outwash body comprising an area of about 530 square miles and ranging in thickness to 70 feet. This outwash may be in direct contact with the basal outwash or separated from it by till or buried lacustrine deposits (figs. 3 through 10). This body of outwash comprises the Middle James Aquifer whose distribution is shown in Koch, Bradford, and Leap (1973, fig. 3).

The uppermost buried outwash is as much as 80 feet thick and covers approximately 390 square miles. Locally, it may be in

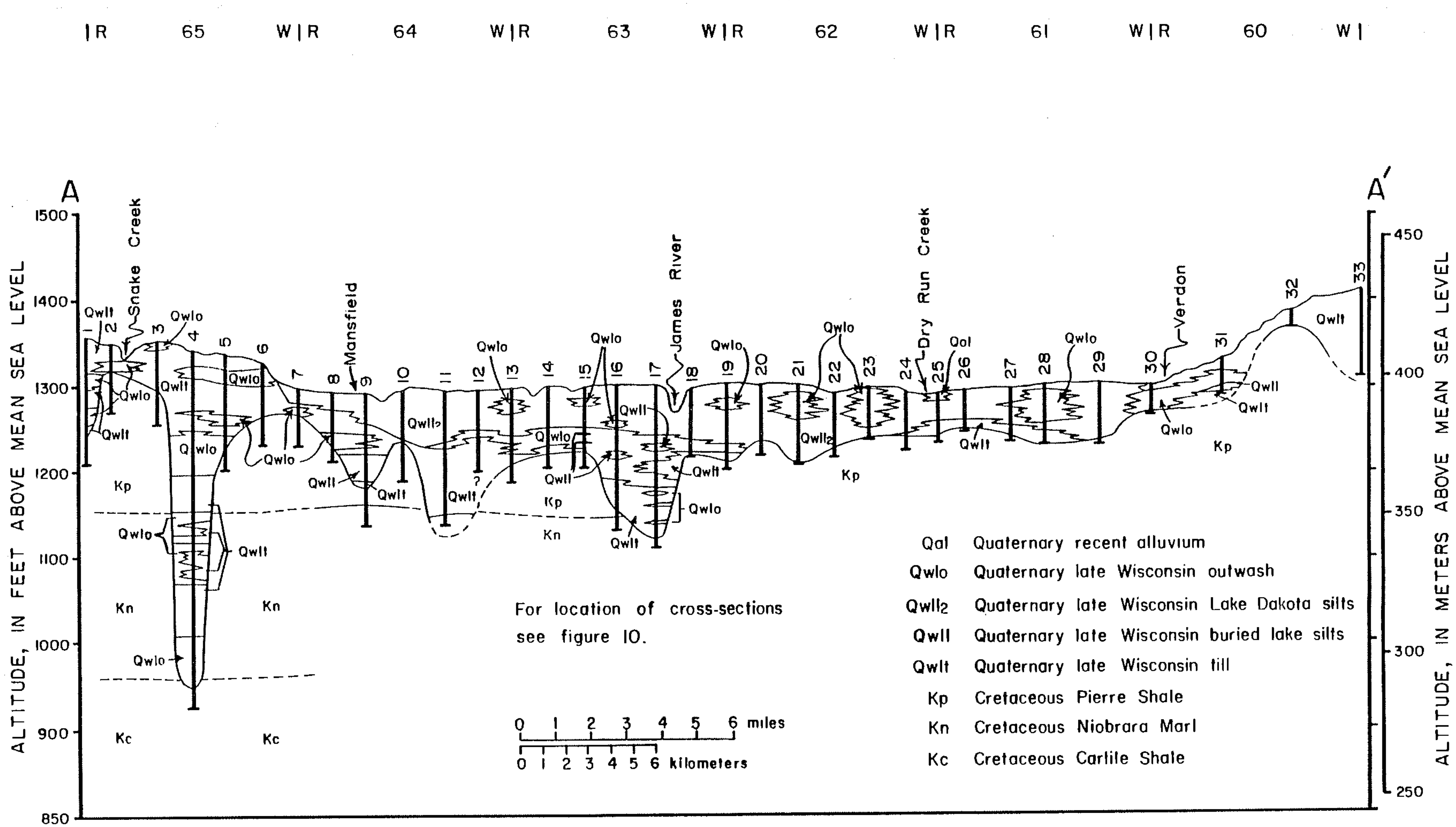


Figure 3. Geologic cross-section A-A′.

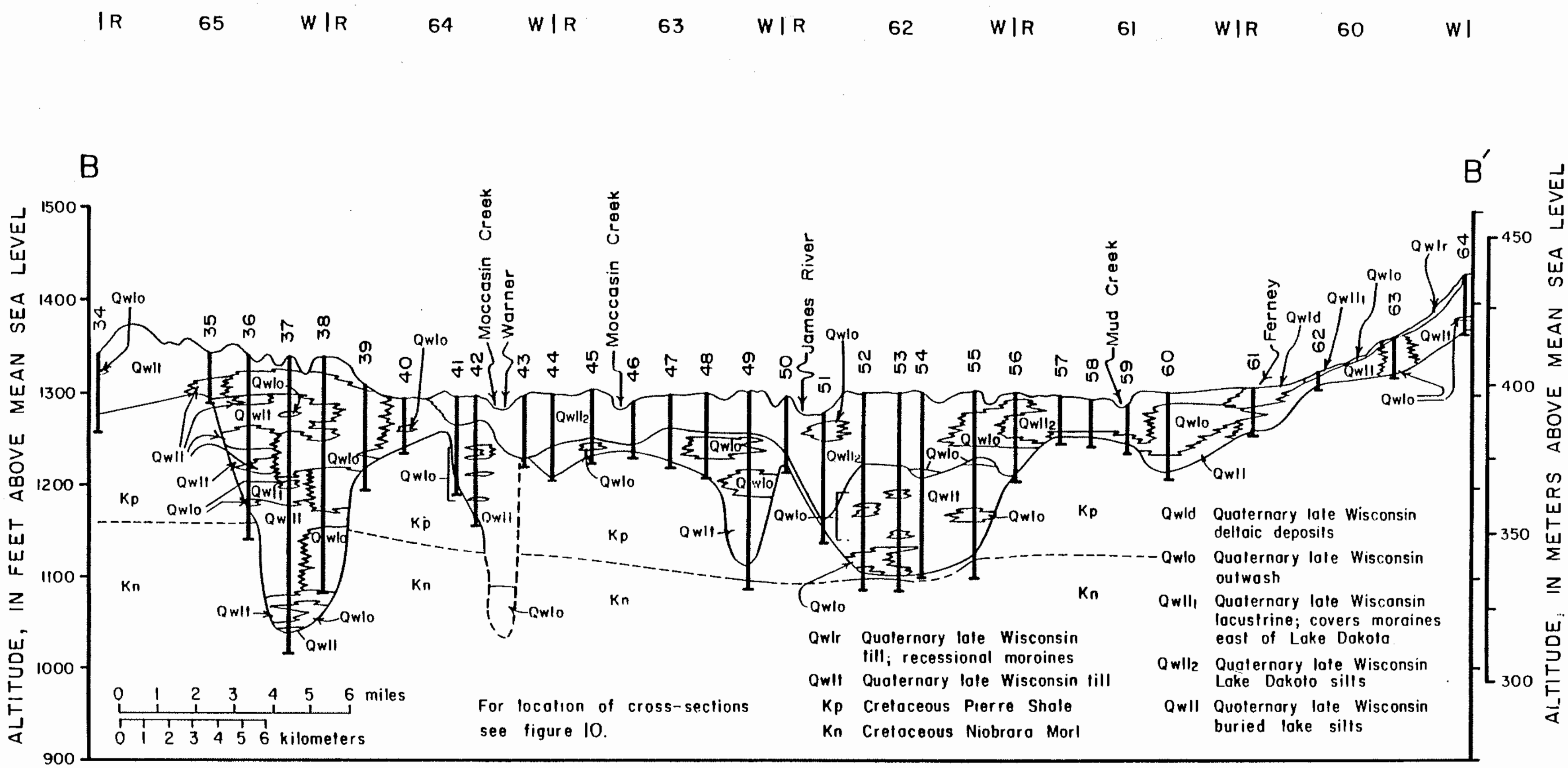


Figure 4. Geologic cross-section B-B′.

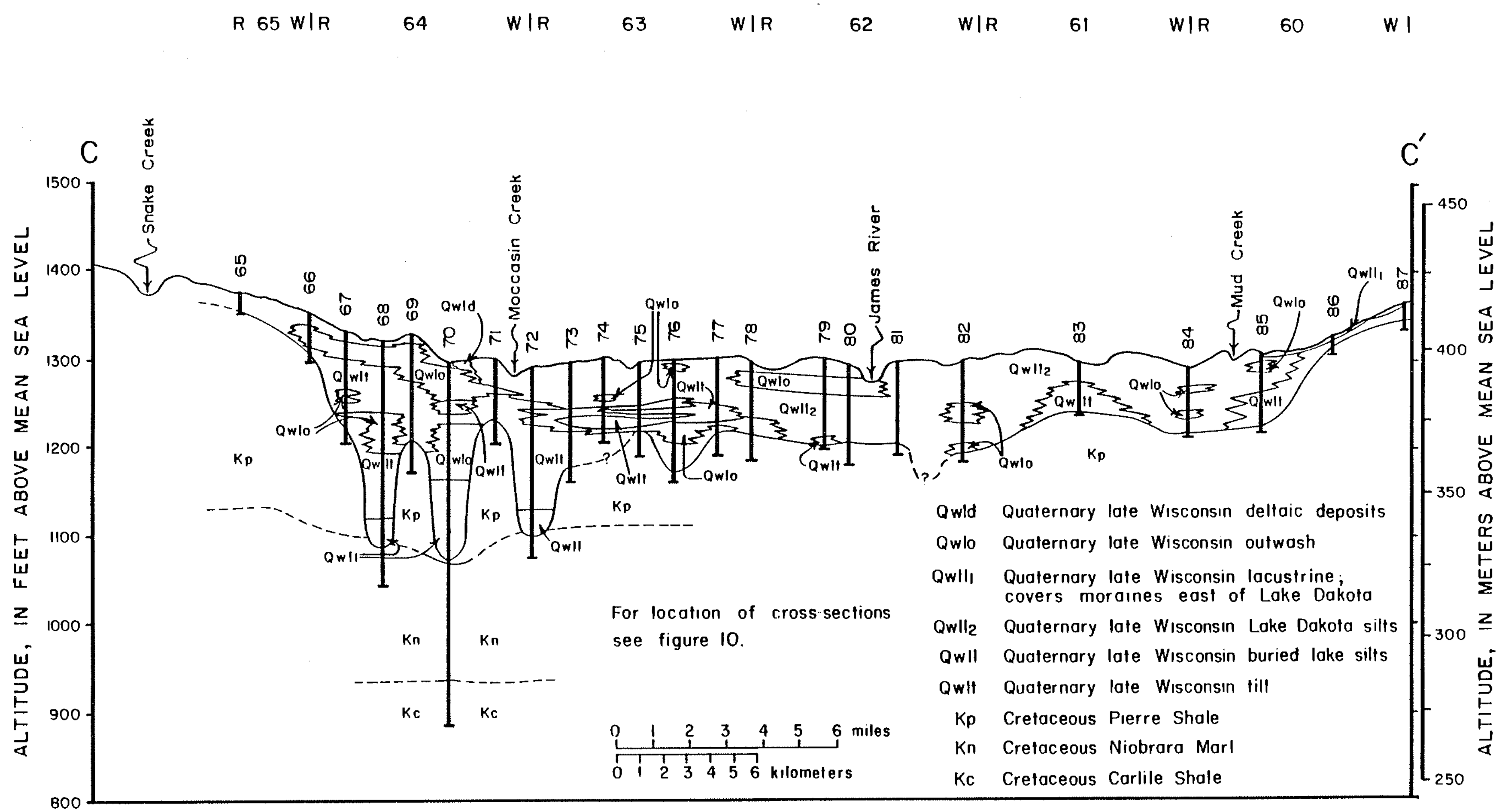


Figure 5. Geologic cross-section C–C′.

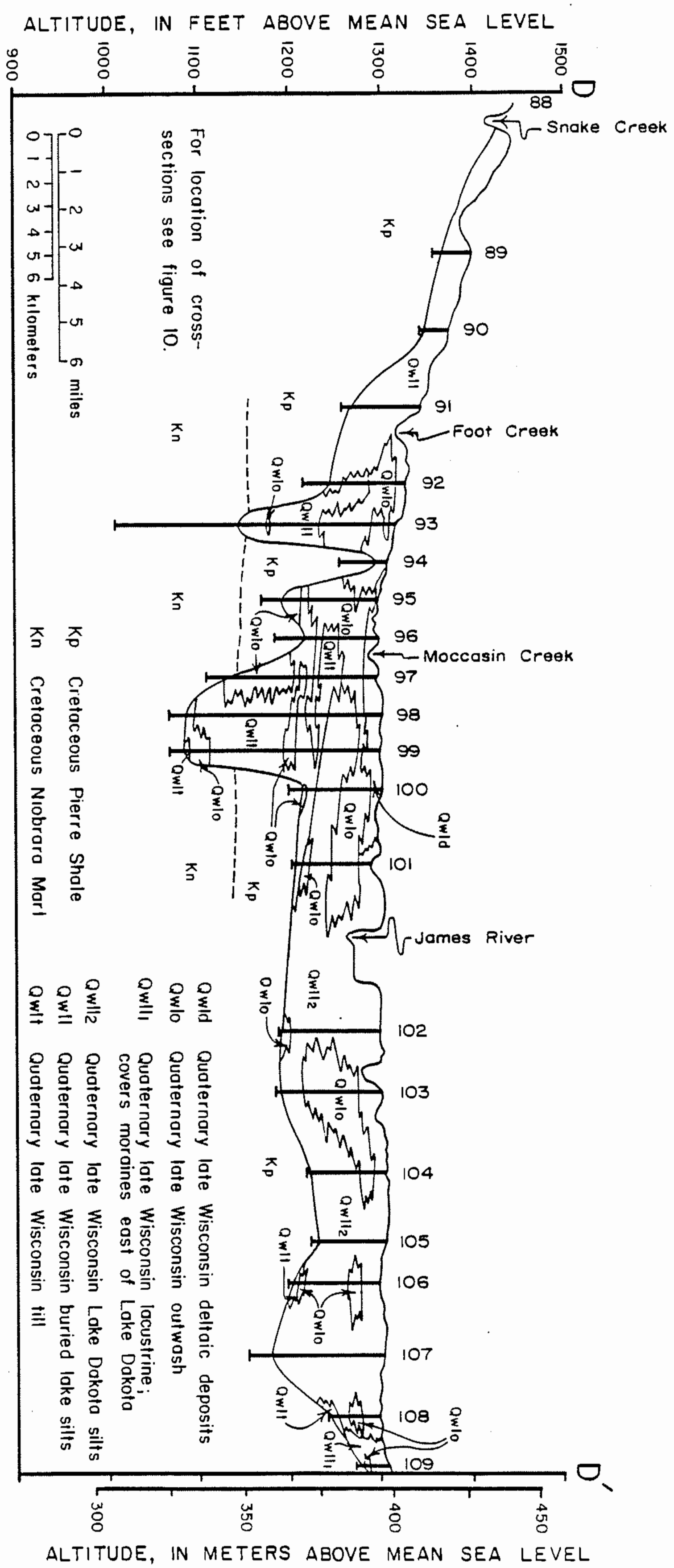


Figure 6. Geologic cross-section D-D′.

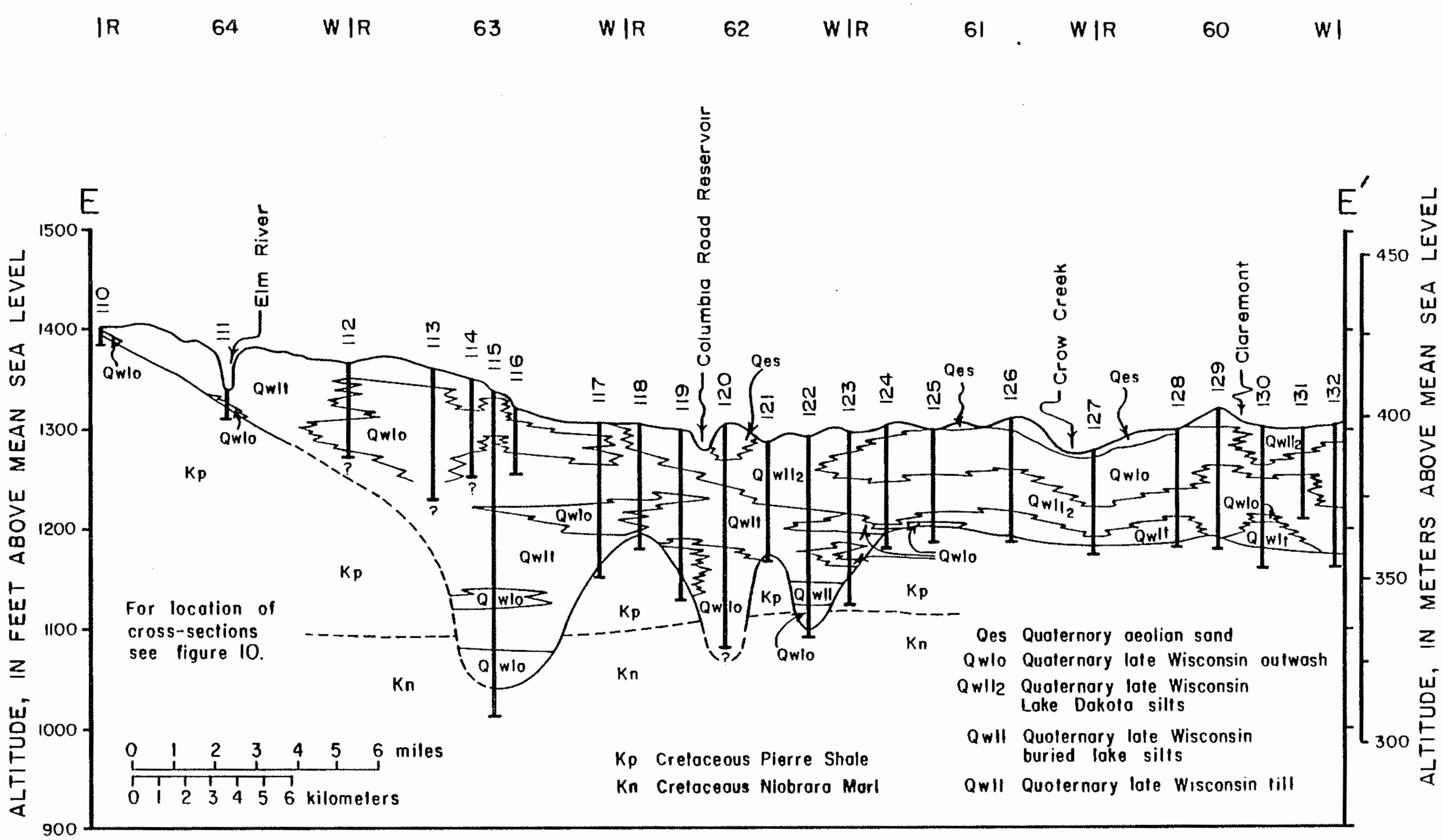


Figure 7. Geologic cross-section E-E′.

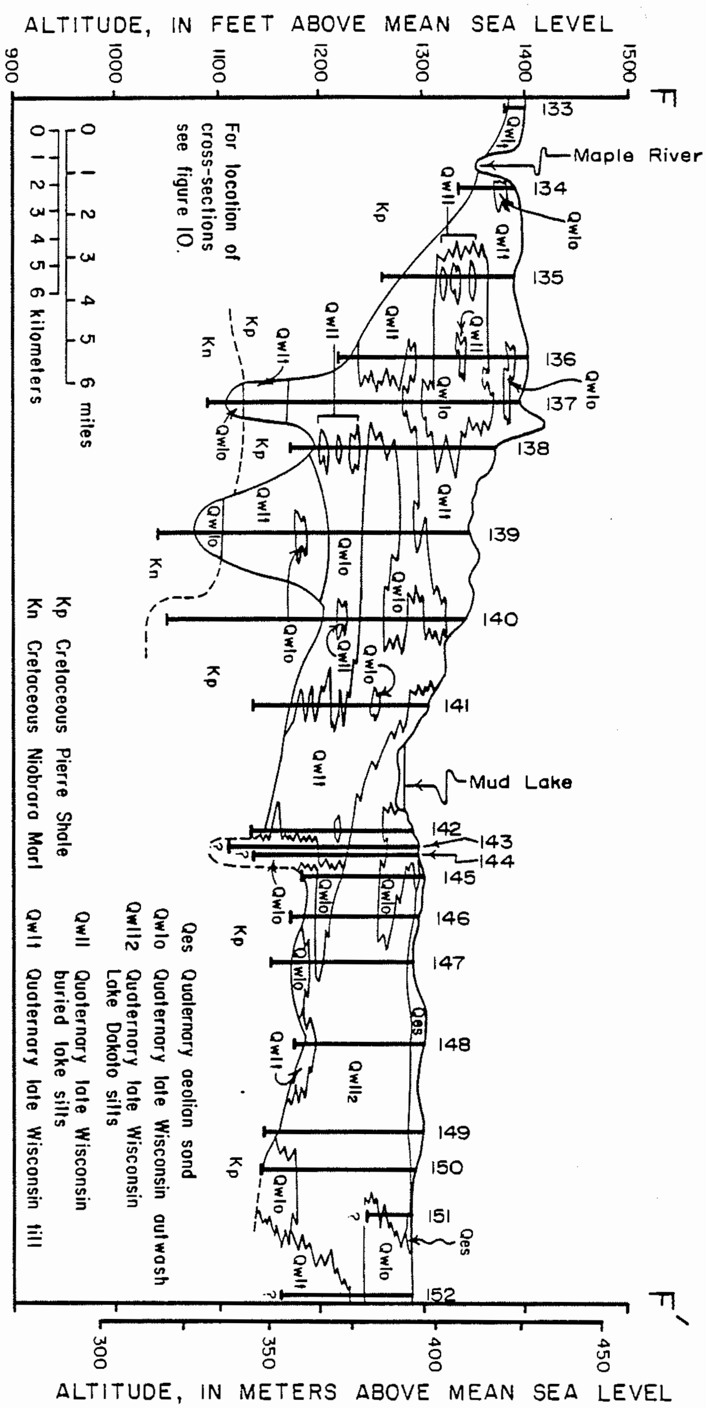


Figure 8. Geologic cross-section F-F′.

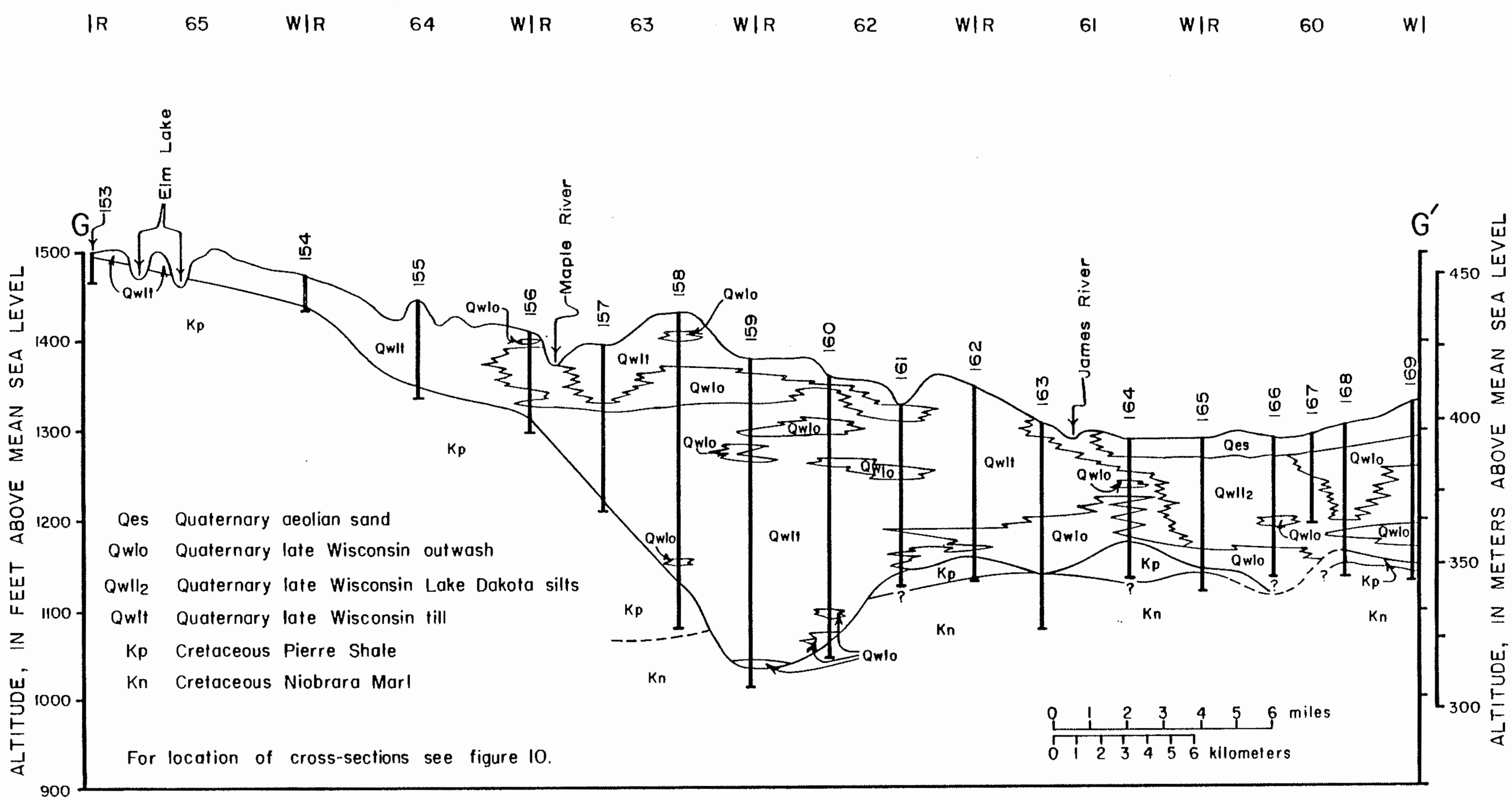


Figure 9. Geologic cross-section G-G′.

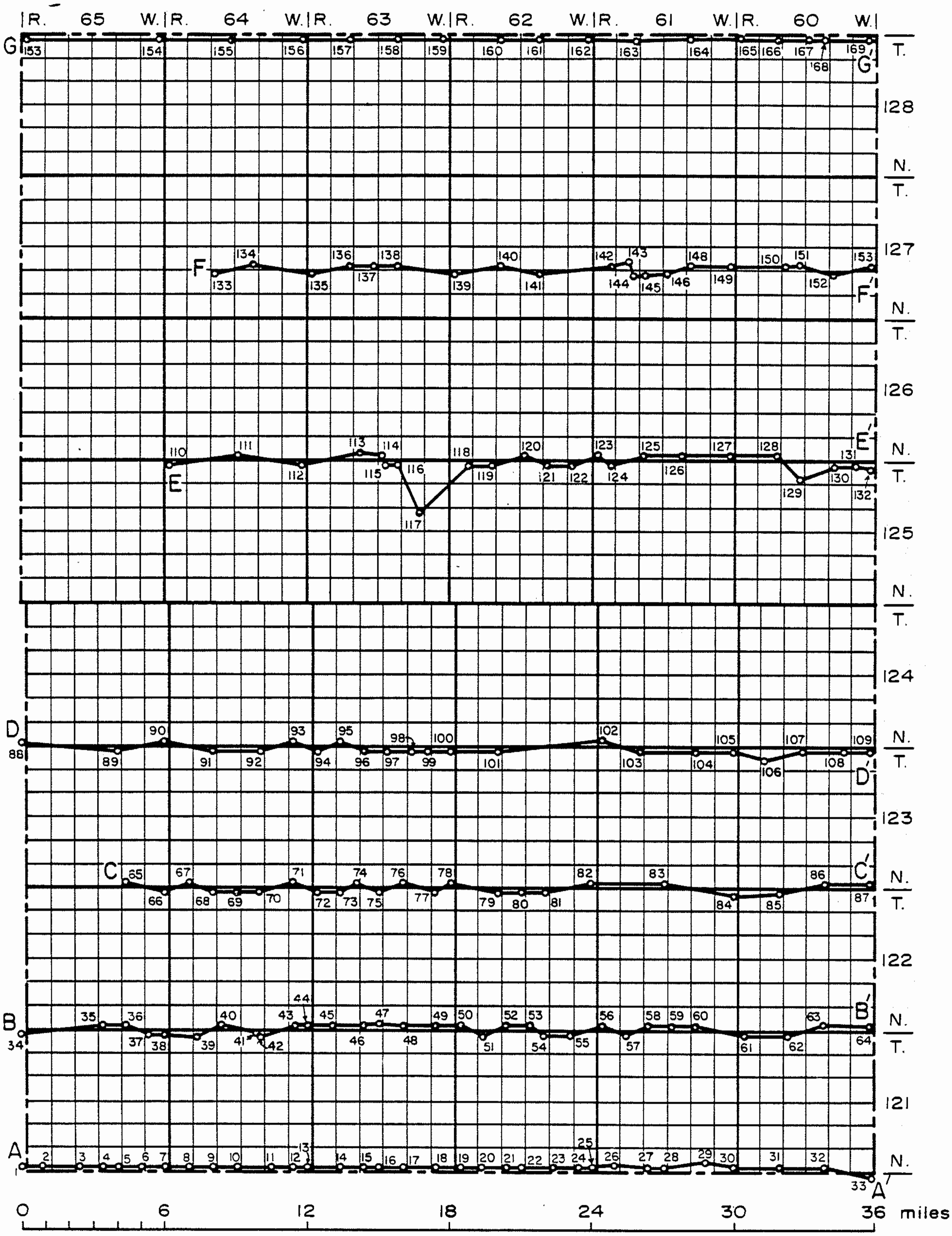


Figure 10. Index map of Brown County showing location of geologic sections A-A′ to G-G′.

contact with the middle outwash below it or the surface outwash mentioned earlier. The Elm Aquifer, as the upper buried outwash is called, in part overlies the middle outwash or is to the west of it (Koch, Bradford, and Leap, 1973, fig. 3).

In the deeper portions of the bedrock valleys the buried outwash is intercalated with till. Indirect evidence already mentioned suggest that only late Wisconsin till is present in Brown County. Furthermore, the present study found no evidence of glacial deposits older than late Wisconsin so by inference, all the buried outwash is of late Wisconsin age. That portion of the channel fill directly overlying bedrock could conceivably be pre-late Wisconsin although the present study found no evidence supporting this possibility.

Lacustrine Deposits

Lacustrine deposits in Brown County can be categorized under three major types and are all shown on plate 2. The first type comprises numerous lacustrine areas represented as potholes and depressions in the glacial till. These deposits normally cover areas of a few hundred to a few thousand square feet and probably do not exceed 10 feet in thickness.

The second type of lake deposit is made up of silts deposited in Ancient Lake Dakota and covers an area of about 750 square miles. The lake bed itself varies from 10 miles in width at the North Dakota line to about 25 miles in width at the Spink County line. The average thickness of the deposit is about 50 feet but ranges from 1 foot or more around its edges to about 95 feet in the central part between Hecla and Stratford. These silts (pl. 2) are generally a cream to tan colored, very fine textured material.

The third major type of lacustrine deposit is found in the southeastern part of the County at higher elevations than the silt of Ancient Lake Dakota. The type three silts were deposited in water that was ponded between the ice of the receding James Lobe and the till highlands in the southeastern part of the County (pl. 2). These silts occur as a thin veneer overlying buried recessional moraines and show distinct lineations on aerial photographs.

Deltaic Deposits

Three major deltas occur in Brown County (pl. 2). On the west edge of the Lake Dakota bed in the vicinity of Ordway is a large delta extending south and east from the town. The Ordway Delta was produced when sediment-rich meltwaters from late Wisconsin ice were debouched into the Lake Dakota bed from the Elm River releasing the load of silt, sand, and gravel. Material in the Ordway Delta is characteristically sandy silt near its lake-ward edge and becomes more rich in gravel toward the west. Thickness of this deposit approaches 60 feet.

South of the Ordway Delta, in the vicinity of Aberdeen, the Foot Creek Delta was deposited in the Lake Dakota bed by waters of Foot Creek. Lithology of this delta is similar to that of the Ordway Delta. Foot Creek Delta averages about 35 feet in thickness in its interior and covers an area of about 14 square miles.

On the east side of Lake Dakota in the vicinity of Ferney is the Mud Creek Delta which covers an area of about 15 square miles. The lithology is predominantly sandy silt and, through drilling, the sediments were found to range in thickness from 40 to 50 feet in the interior of the Delta. This Delta was deposited by Mud Creek carrying meltwater from ice in the highlands to the east.

Aeolian Deposits

Approximately 130 square miles of the northeastern quarter of the County is covered by aeolian sand (pl. 2). The source of this sand is a deposit of water-laid sand on which the aeolian sand rests. After Ancient Lake Dakota had accumulated a thick layer of silt, streams flowing off the Coteau des Prairies carried sand-laden meltwater which was subsequently deposited on top of the lake silts. The continuous action of prevailing westerly winds sorted out the finer-grained sand and transported it eastward. Evidence of such wind action is found today in numerous blowouts in various parts of the sand area and many dunes on the Marshall-Brown County line just east of Hecla which were formed from the aeolian material.

Total thickness of sand, both water-laid and aeolian, averages about 45 feet in the deeper parts. In many places the sand has been blown away completely, revealing underlying lake sediments.

Loess

Most of the eastern part of Brown County is covered by a few inches of loess. Cultivation as well as wind action have made it difficult to determine loess from lake silts in all parts of the County.

Recent Deposits

ALLUVIUM

Alluvium of recent origin can be found in nearly all stream valleys. In most streams in the till highlands the alluvium may range from a few inches to 6 feet in thickness. Alluvium in streams cutting through the silts of Ancient Lake Dakota is as much as 30 feet thick. Normally, the alluvium reflects the composition of its source sediments--clay and sand with some gravel in the highlands and almost pure silt in the Lake Dakota bed.

LACUSTRINE DEPOSITS

Recent lacustrine deposits are found in the many potholes and sloughs throughout the till highlands. These materials grade almost imperceptibly into Pleistocene lake silts beneath and are usually very rich in organic materials.

GEOMORPHOLOGY

Pre-Pleistocene Geomorphology

General Bedrock Geomorphology

Bedrock topography of Brown County is shown on plate 1 which in general portrays a wide valley containing the channel system of the Ancient Grand-Moreau-Cheyenne River. The channel system is oriented generally northeast to southwest with highlands on either side of the valley rising to over 1400 feet in the southeast and western parts of the County and slightly over 1100 feet in the northeastern part. The channel bottom itself varies in elevation from about 1030 feet near the southern boundary of the County to about 1000 feet at the northern boundary.

Tributary to the main channel are several deep, smaller channels. Several more large channels exist in the area east of the main channel which itself anastamoses considerably. It is difficult to say with certainty if all the ancient stream channels shown on plate 1 were formed before the Pleistocene glaciation of the James Basin or if their present form is due to modification by glaciation and/or meltwater action. It is likely that the larger channels were carved before the glacier entered the James Basin and that they have been modified slightly by the action of ice and meltwater.

Ancient Grand-Moreau-Cheyenne Channel

The channel shown on plate 1 surely served as the major drainage in this area before the late Wisconsin glaciation. This channel continues into North Dakota and was the major drainage to the north into the Arctic Ocean. This conclusion is supported by the work in counties to the south and west in Sanborn County (Steece and Howells, 1965), Beadle County (Hedges, 1968), Campbell County (Hedges, 1972), McPherson, Edmunds, and Faulk Counties (Christensen, 1977), Hyde and Hand Counties (Helgerson, in preparation), and Walworth County (Hedges, in preparation). It would thus now appear that this Ancient Grand-Moreau-Cheyenne Channel in Brown County served as the sluiceway for all the major pre-diversion streams north of the Sioux Ridge.

Pleistocene Geomorphology

Absence of End Moraine

No end moraines are present in Brown County. The late Wisconsin James Lobe advanced southward through the James Basin and terminated near the Missouri River in the vicinity of Yankton, building an end moraine complex in that area. At the same time it spread out from the James Basin eastward to form lateral end moraines on the Coteau des Prairies (Koch, 1975), (Leap, 1974), and to the west forming end moraines on the Coteau du Missouri (Hedges, 1972; Christensen, 1977). Therefore the end moraines of the late Wisconsin glacier are to the south, east, and west of Brown County in South Dakota.

Recessional Moraine

Several recessional moraines exist in Brown County. All of these moraines were formed when the James Lobe ice melted northward up the James Basin. The general form and character of the recessional moraines is of quasi-parallel bands of rough and hummocky material generally running northeast-southwest on both sides of the Lake Dakota plain. Plate 2 shows recessional moraines as Qwlr.

Long spillways for meltwater run northeast to southwest, parallel to the large recessional moraines in the western part of the County. These channels probably formed as ice-marginal streams during periods of time when the ice margin persisted at one location.

On the east side of the County recessional moraines contain lacustrine silts between them and often as a thin covering over their crests. As the ice of the James Lobe retreated away from the Coteau des Prairies, water was ponded between the ice front and the edge of the Coteau and a thin layer of silt was deposited in the ponded water.

Ground Moraine

Ground moraine is shown on plate 2 as Qwlg and covers large strips of the County on the west side of Lake Dakota (fig. 11). The ground moraine here differs in appearance from recessional moraine in that it is much less hummocky and rugged than recessional moraine. This relative smoothness reflects the process of origin of the ground moraine which was deposited when the ice retreated at a rather rapid and steady rate. In contrast the recessional moraines were formed when the ice margin was in equilibrium for short periods of time.

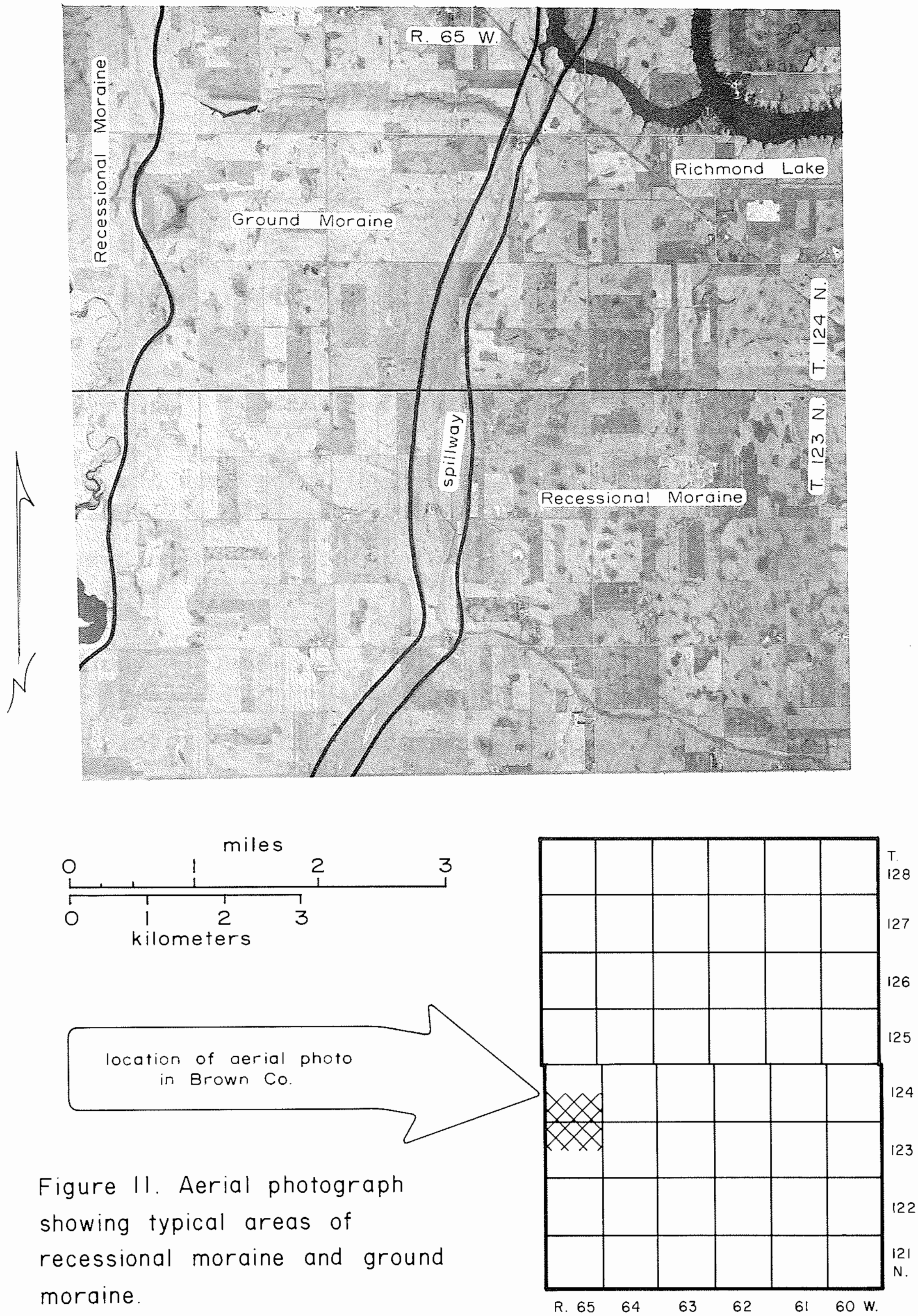


Figure 11. Aerial photograph showing typical areas of recessional moraine and ground moraine.

Lodgement till probably exists beneath the surface of the ground moraine; however, lodgement till is not known to exist at the surface and therefore, all ground moraine at the surface is assumed to be the results of ablation of rapidly receding ice.

No ground moraine is present in Brown County at the surface east of Lake Dakota plain. In this region, surface deposits consist of recessional moraines, lake silts, and aeolian sands. Some of the till encountered in drilling beneath silt and sands may be of ground moraine origin but it cannot be proven with data available.

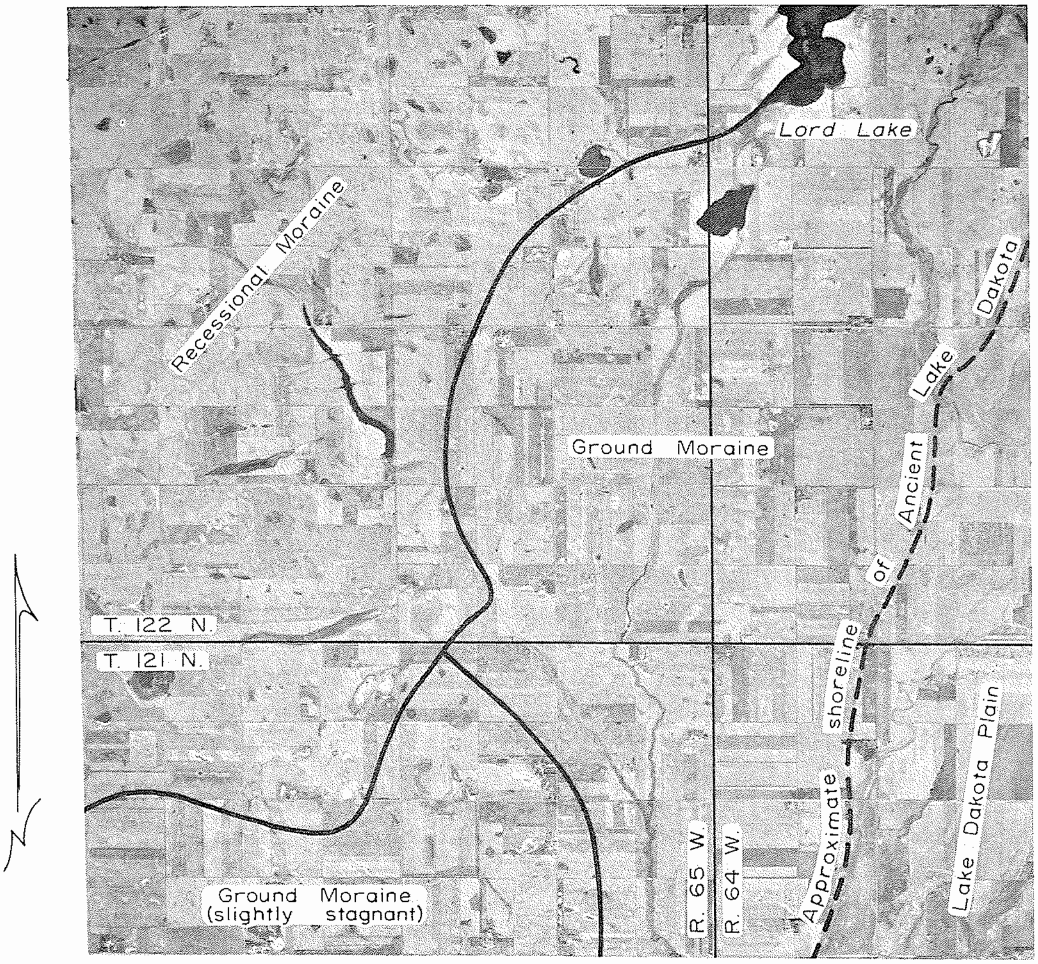
Todd (1909) described much of the ground moraine in Brown County as recessional moraine of the Antelope glaciation of unspecified age, and Flint (1955) described most of it as end moraine of the late Wisconsin, Mankato substage. The present writer has interpreted much of Todd's "recessional moraine" and Flint's "end moraine" as ground moraine.

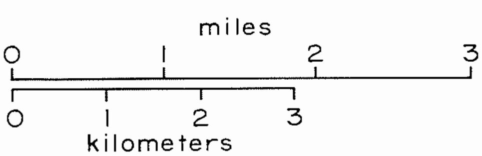
Ancient Lake Dakota Plain

The surface of the Ancient Lake Dakota plain is an essentially flat and monotonous feature except where cut by stream valleys. Distinct shorelines are rare and only in a few places can such features as wave-cut cliffs or slopes be found (pl. 2). On the west side of the lake these distinct features can be found in two places. At the Spink County line a wave-cut slope extends northward for 3 1/2 miles (fig. 12). About 5 miles north of Columbia is another wave-cut slope extending northeast for about 3 miles. On the east side of the lake plain a wave-cut slope of about 5 1/2 miles in length has been mapped just east of Ferney.

In most other places the lake shore is approximated by differences in lithology, i.e., by mapping the boundary between true lake silt and till or deltaic deposits. On the west side of the lake plain this mapping criterium works very well. However, on the east side, mapping of the shoreline is complicated by the fact that silts of Ancient Lake Dakota are in direct contact with silts laid down in water trapped between the receding ice of the James Lobe and the higher till highlands. Plate 2 shows true Lake Dakota silts as Qwlll.

The lithology of these two silts is identical and subsequent wave and wind action have obliterated any distinct shoreline that once existed. Therefore, on the east side the shoreline was placed approximately along the 1305-foot contour which is the elevation of the shoreline along known wave-cut slopes on both sides and is also the elevation of the demarcation line between silts and till on the west side of the lake in the south half of the County. At the North Dakota state line the lake boundary is approximately 1310 feet above sea level. This 5-foot difference in shoreline elevation between the north and south borders of the County is probably due to isostatic adjustment as the ice melted





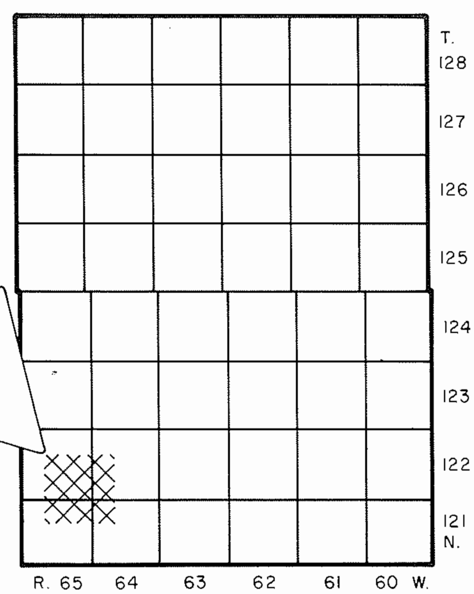


Figure 12. Aerial photograph showing contact between Ancient Lake Dakota Plain and till highland on west shore of Ancient Lake Dakota.

northward.

The northern part of the lake plain (pl. 2) contains a large area of aeolian sand previously described. The geomorpholoy of the sand area is characterized by blow-outs 5 feet or more in depth.

One particularly striking geomorphic feature of the otherwise monotonous lake plain is the near parallelism of major streams draining the plain. Plate 2 shows all the major streams and channels of abandoned streams oriented essentially northeast-southwest. This quasi-parallelism is probably due to differential compaction of silt over buried recessional moraines which are also oriented in that direction. Such differential compaction would slightly lower the elevation of the lake surface between the buried moraines below those parts of the surface directly above the moraines, thus creating a shallow trough for streams to begin. Once established in a particular direction, the stream would deepen itself and extend its length by headward erosion.

In the sandy area of the northern part of the lake plain, present-day stream drainage is nonexistent with the exception of the James River. Continually drifting sand has obliterated former drainage ways and several partially buried channels can be found in this area. In addition, the high vertical permeability of the sand precludes significant surface-water runoff.

Dunes

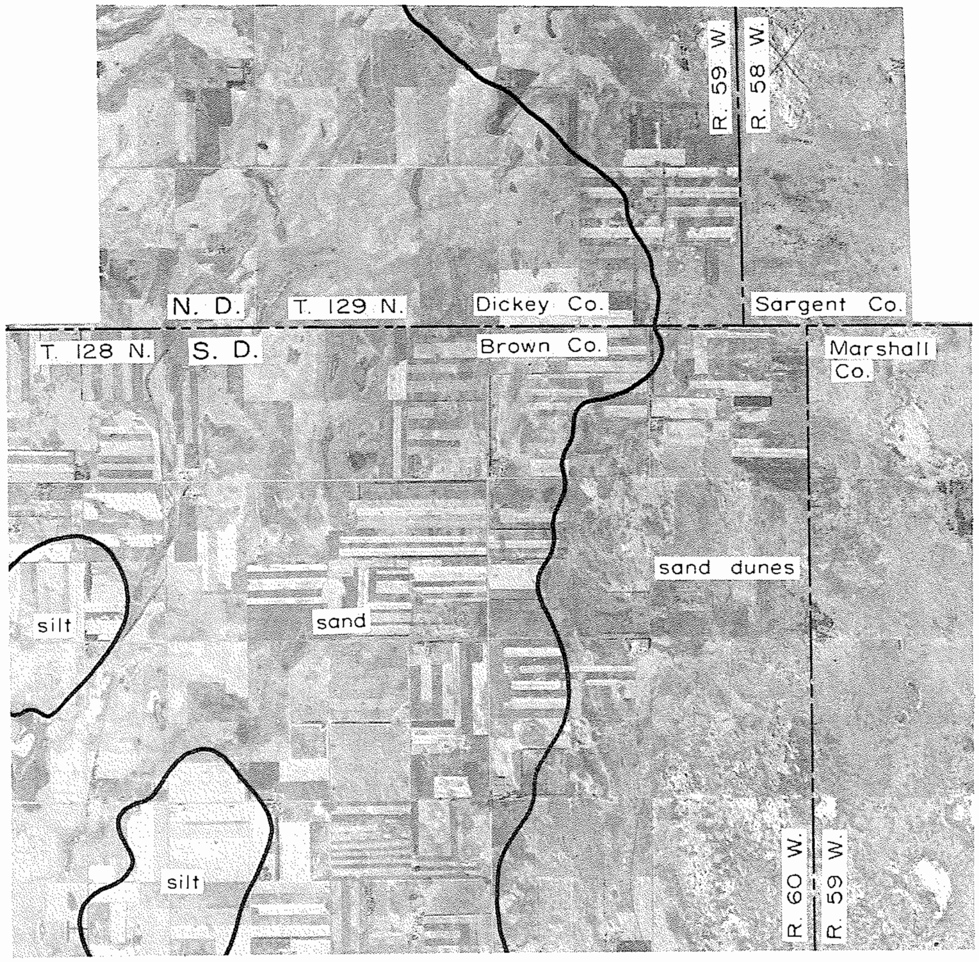
Sand dunes cover an area of about 12 square miles in the extreme northeastern corner of Brown County (pl. 2 and fig. 13). The sand is fine grained and was blown eastward from the sand plain in the Ancient Lake Dakota plain by prevailing westerly winds. Typically, the dunes are 5 to 15 feet high. There is evidence that the dunes have been shifting very recently because fences covered by 10 feet of sand have been found within the dunes.

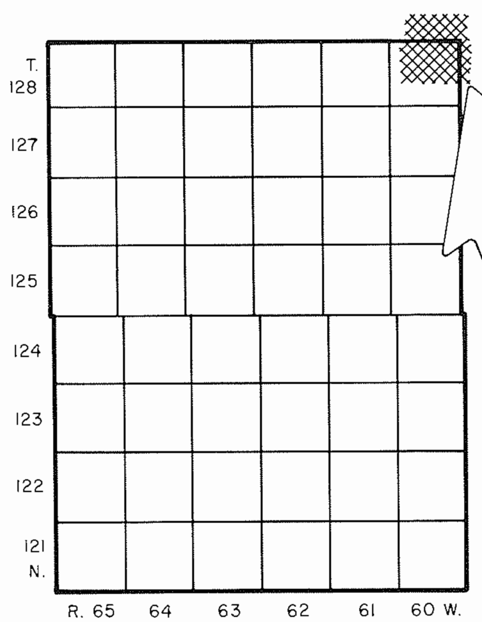
Stagnation Drift

DESCRIPTION AND ORIGIN

Stagnation or dead-ice drift is found over many parts of the western United States and Canada. It has been described by Townsend and Jenke (1951), Christiansen (1956), Colton and Lemke (1957), Bayrock (1958), Gravenor and Kupsch (1959), Clayton (1967), Winters (1963), Parizek (1961 and 1967), Hedges (1972), and Leap (1974).

Stagnation drift is typically hummocky and dotted with mounds and ridges of drift interspersed between numerous potholes and sloughs. Stagnation drift originates when a sheet of drift-laden





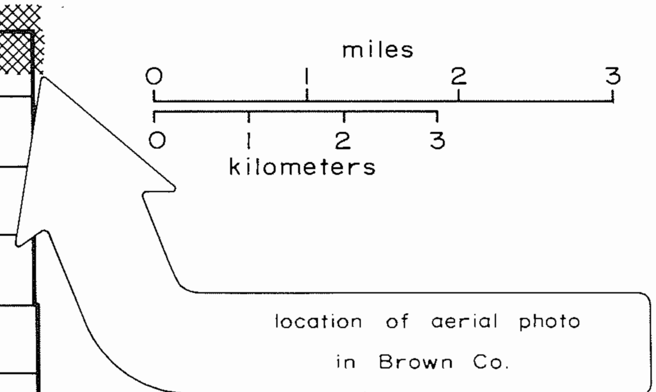


Figure 13. Aerial photograph showing sand dunes, northeastern Brown County.

ice stagnates and breaks up en masse. As a result, drift is not deposited at the edge of an evenly retreating glacier but is deposited over a wide area from any ablating pieces of ice. As a result, there is typically a great amount of slumping and sliding of saturated drift into many topographic forms.

DISTRIBUTION

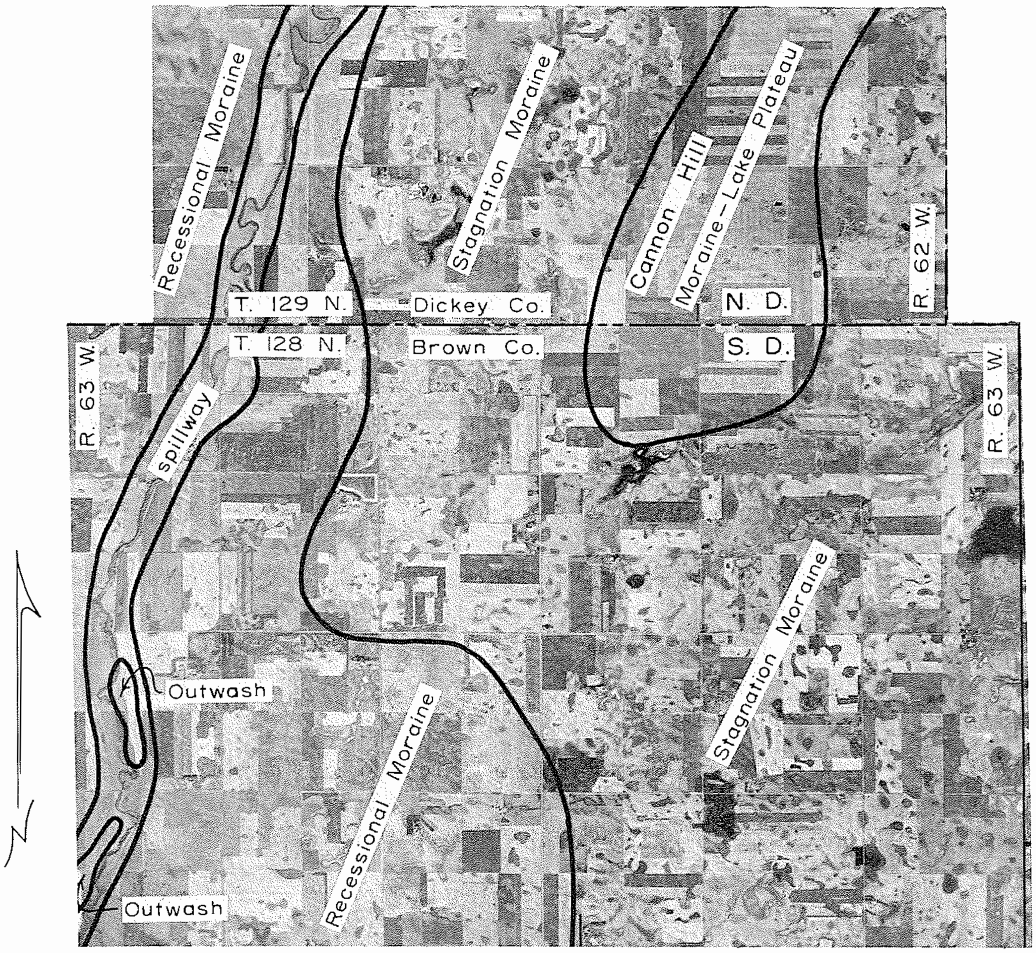
Brown County exhibits few areas of stagnation drift because its present-day surface is primarily the result of deposition by fairly rapidly retreating glaciers, and in addition, large parts of the County are blanketed by lake silts and sand. In a few areas stagnation features are apparent (pl. 2).

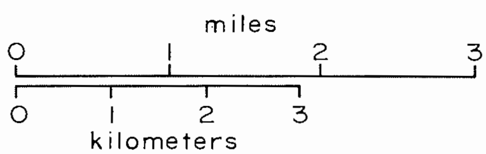
In the southwest corner of the County an area of stagnation drift covers about 27 square miles. The area is unique in that it is much more hummocky than true ground moraine next to it and much less hummocky than known stagnation drift on the Coteau des Prairies, on the Coteau du Missouri, and elsewhere in Brown County. Within this area, just east of Salt Lake is about 1 square mile of typical stagnation drift which is extremely hummocky and contains numerous sloughs. For this reason this area has been mapped as stagnation drift rather than as ground moraine.

In the northwest corner of the County is another area of stagnation drift which covers about 28 square miles (pl. 2). This area contains numerous disintegration ridges and kames composed of sand and gravel.

Another stagnation drift area exists in the northcentral part of the County (pl. 2) along the North Dakota border. This area covers about 52 square miles although the entire area exhibits typical stagnation drift features, the most outstanding geomorphic feature in the area is the large moraine-lake plateau along the northern edge denoted on plate 2 as MLP. This feature, known locally as Cannon Hill, extends northward into North Dakota for several miles (fig. 14). It is composed of silt and clay which were deposited in an ice-walled lake. After the lake filled, the ice surrounding it melted leaving the deposit as a steep-sided, mesa-like feature.

The fourth area of stagnant drift is immediately south of the area just discussed (pl. 2). This area covers about 4 square miles and is notable not only for its hummocky appearance but also for a large, nearly, circular disintegration ridge about 1 1/2 miles in diameter.





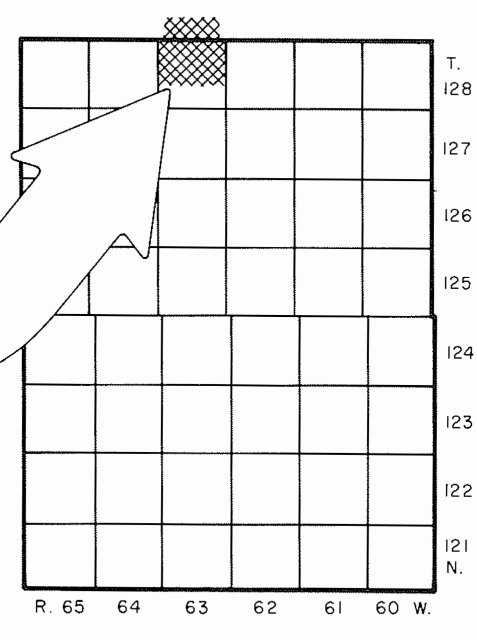


Figure 14. Aerial photograph showing Cannon Hill, a large moraine-lake plateau.

GEOLOGIC HISTORY

Pre-Pleistocene History

Precambrian History

The Precambrian basement of eastern South Dakota is part of the southern extension of the Canadian Shield which crops out in northern Minnesota and southern Canada. Before the beginning of the Paleozoic Era a large structural downwarp began to form in the tri-state area of Montana, North Dakota, and South Dakota and formed the Williston Basin which is elongate generally north to south. Brown County is on the eastern edge of this basin.

Paleozoic History

The Williston Basin was a depositional area during Paleozoic time. Rock units deposited during this time and which are known to be present in Brown County include the Deadwood Formation (Cambrian), Winnipeg and Red River Formations (Ordovician), some undifferentiated Devonian rocks, the Madison Group (Mississippian) and the Minnelusa Formation (Pennsylvanian). Data for all of these units are too scarce to allow accurate estimates of distribution and thickness. However, they probably exist only in the western part of the County because it is here that the depositional basin is deeper than in the other parts of the County. In addition, because the eastern edge of the depositional basin is located in this area it can be expected that erosion had removed much of these early sediments before Mesozoic sedimentation began.

Mesozoic History

After a period of uplift and subsequent erosion at the end of the Paleozoic Era, downwarping of the earth's crust began again over a large area of North America including the Williston Basin.

Triassic formations are not found in Brown County. Stokes (1966) indicates that the Brown County area was located on the edge of the depositional basin. It is possible that Triassic sediments were once deposited but eroded away before the Jurassic period.

The first of the Mesozoic formations to be deposited was the Jurassic Sundance Formation. After this the following Cretaceous formations were laid down: the Fall River Formation, Skull Creek Shale, Dakota Formation, Graneros Shale, Greenhorn Limestone, Carlile Shale, Niobrara Marl, and Pierre Shale.

Cenozoic History

It is unlikely that any significant Tertiary sediments were ever deposited in Brown County. Before the Pleistocene Epoch, the surface of Brown County was essentially a bedrock trough with a large channel system in the lower parts similar to that shown in figure 15.

Pleistocene History

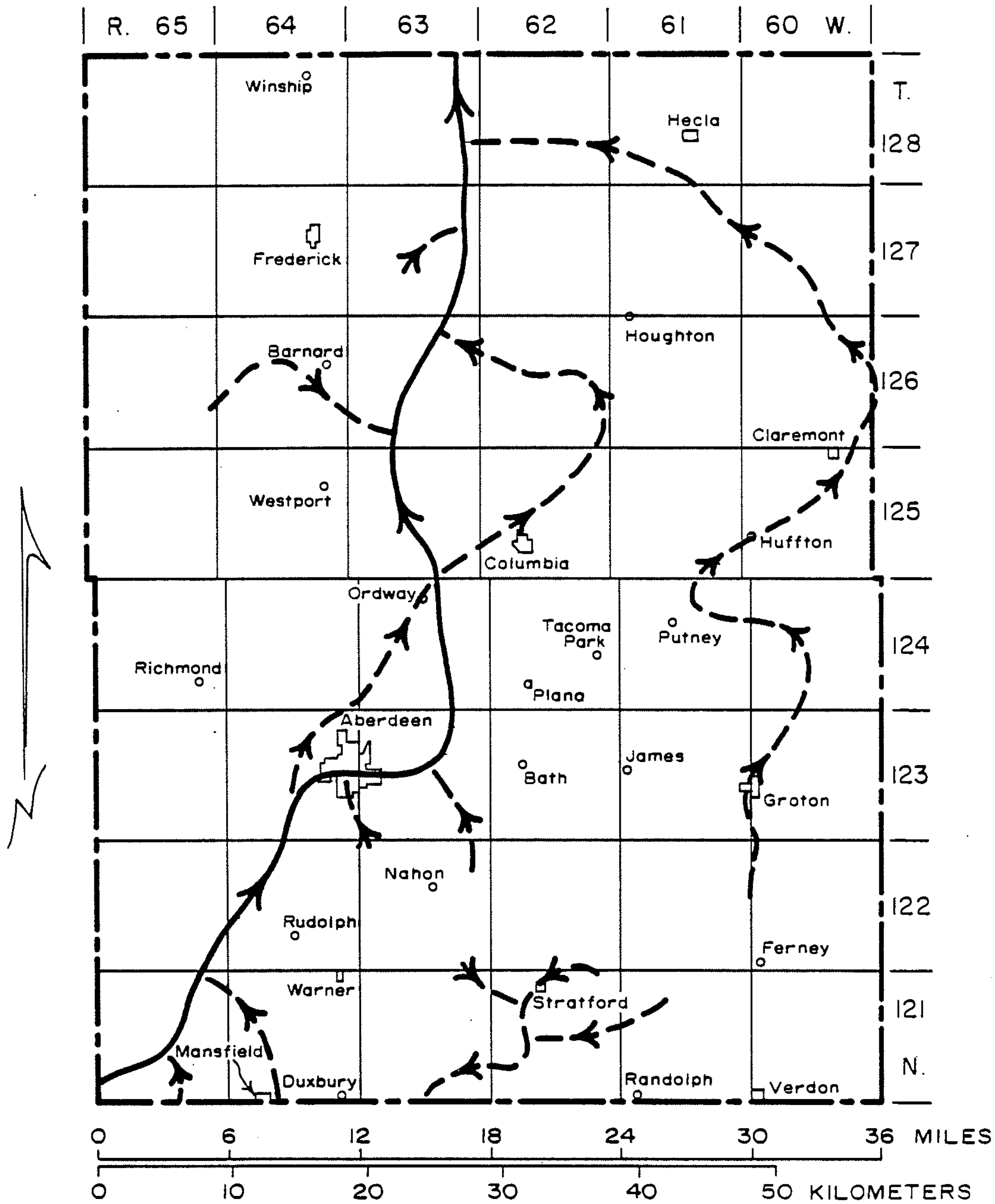
The Pleistocene history of Brown County is less complicated than that of surrounding counties. Extensive drilling in Brown County has revealed no buried oxidized horizons or paleosols. From this evidence, and from the fact that the drift is fairly thin, it is concluded that only one major glacial advance ever entered Brown County, i.e., the late Wisconsin. This conclusion is strengthened by the identification of only late Wisconsin drift in counties west of Brown County which is in lithologic and geomorphic continuity with that in Brown County (Hedges, 1968; Christensen, 1977).

All of the till in Brown County was deposited in late Wisconsin time from the James Lobe which advanced into Brown County from the north. Most of the lake silt and sand in the Lake Dakota plain were derived from the same lobe, although there is a possibility that a small amount of these materials came from the Des Moines Lobe in Marshall County via meltwater.

Outwash deposits in the deep bedrock channels were probably deposited proglacially from the advancing ice sheet whose meltwater also carved new channels. The bedrock map shows several intersections and diverging channels indicating considerable rearrangement of drainage by the advancing ice. As the ice moved south, it also spread laterally onto the Coteau du Missouri to the west and onto the Coteau des Prairies to the east. The preexisting southwest-trending lowland in the bedrock tended to channel the flow of ice and probably at maximum thickness contained at least 1,500 feet of ice.

At its maximum extent the James Lobe advanced to the Missouri River near Yankton leaving Brown County completely covered with ice. At this time flow direction of the ice was probably similar to that shown in figure 16. As the ice receded up the James Basin it left arcuate recessional moraines which are characteristically concentric with their convex parts pointing down the James Basin and their limbs quasi-parallel to the Basin.

When the ice melted back to the vicinity of the Beadle-Spink County line, it built a rather large and broad complex of recessional moraines. As the ice melted northward from this complex, meltwater became ponded between it and the ice front and thus began Ancient Lake Dakota.



Center of Ancient Grand–Moreau–Cheyenne Channel. *Arrows indicate inferred flow direction.*

Center of minor channels. *Arrows indicate inferred flow direction. (minor channels possibly were not present before Pleistocene but were cut during the Pleistocene by meltwater.)*

Figure 15. The surface of Brown County before the Pleistocene Epoch.

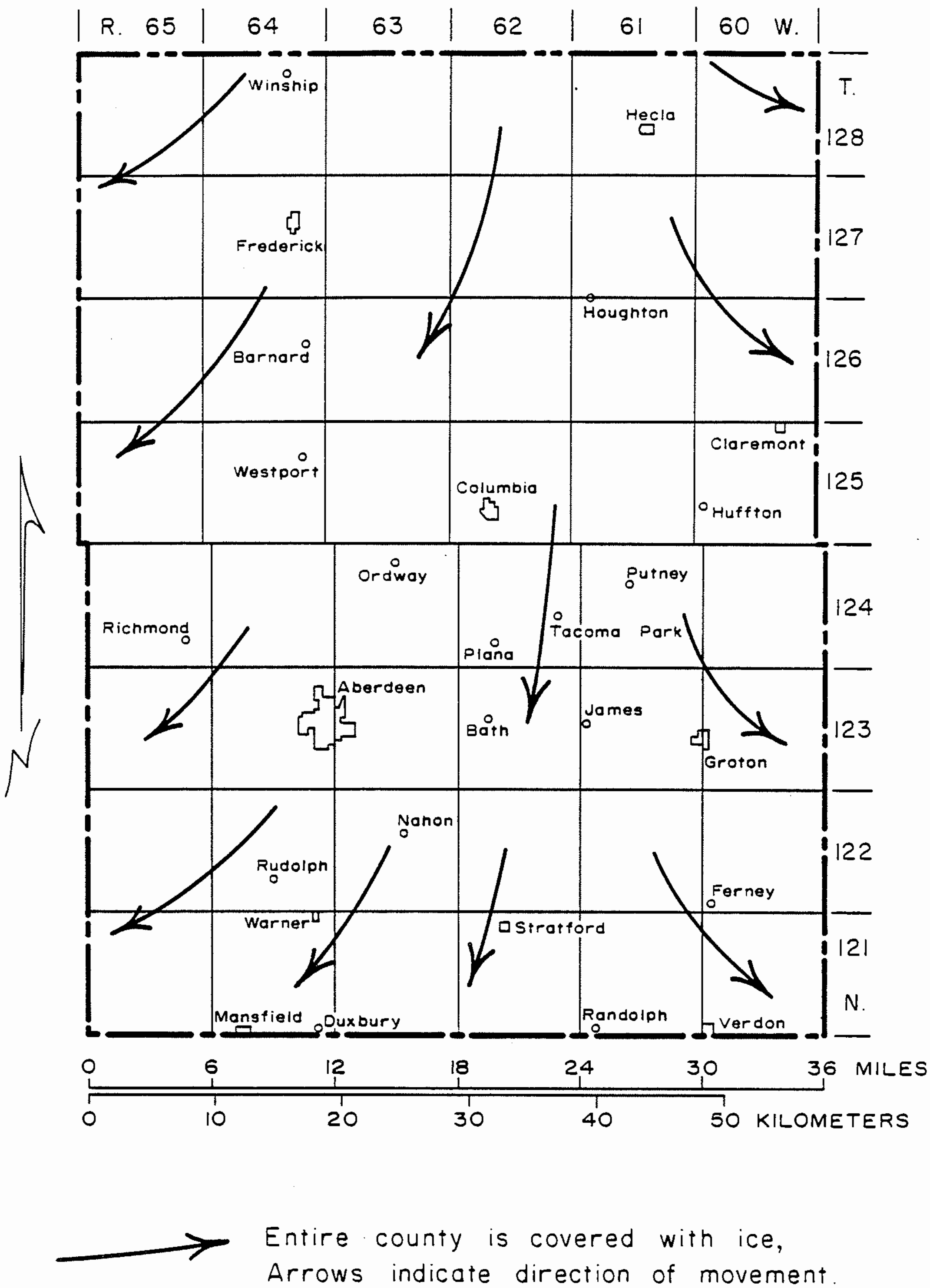


Figure 16. The surface of Brown County after the maximum advance of the James Lobe.

The ice continued to retreat northward while also retreating away from the edge of the Coteau des Prairies to the east and away from the Coteau du Missouri to the west of Brown County. As the ice receded it left the large areas of recessional moraine on both sides of Lake Dakota (pl. 2). Large spillways were formed against the edge of the receding ice (pl. 2).

Long after the ice had retreated from the James Basin, Ancient Lake Dakota was still receiving water from melting stagnant ice on the Coteau des Prairies, the Coteau du Missouri, and from North Dakota. This ice had stagnated from the main mass of the James Lobe and persisted, slowing melting, until as late as 9,000 years before present (Christensen, 1977). Silts carried by the meltwater were deposited to thicknesses as great as 95 feet.

Late in the period that Ancient Lake Dakota existed, the afore-mentioned deltas of Foot Creek and Elm River were being built out of materials carried by meltwater from stagnant melting ice on the Coteau du Missouri. At probably the same time, the delta of Mud Creek on the east side of the lake bed was also being built of outwash from the ice on the Coteau des Prairies.

At some time during the lake's history the morainal dam was breached and the lake began to drain southward through the ancestral James River.

Very late in the history of Lake Dakota while water still occupied the lake, a large area of the lake plain in northeastern Brown County was covered by sand (fig. 17). This sand is believed to have been deposited by meltwater from ice on the Coteau des Prairies in Marshall County. The writer is uncertain at the present time if this ice was stagnant ice left on the Coteau when the James Lobe began receding or if it was ice from a minor resurgence of the James Lobe which terminated in the Oakes Moraine in the northern part of Marshall County. The Oakes Moraine is buried by lake silts in western Marshall County indicating that the lake was still in existence at the time the ice receded.

The sand deposited is a mixture of fine- and medium-grained material which directly overlies or is intermixed with lake silts. This combination of fine texture and stratigraphic position indicates a late deltaic sequence or possibly even fine-grained outwash plain deposit.

The presence of a layer of sand resting on lacustrine silts has suggested to some the existence of two Lakes Dakota (Baker, 1963). Flint (1955) also hints that there might have been two such lakes but does not affirm it. Extensive drilling in Brown County has not revealed any evidence that more than one Lake Dakota ever existed.

Eventually the ice melted out of the James Basin although it still persisted on the two Coteaus. This ice too finally melted

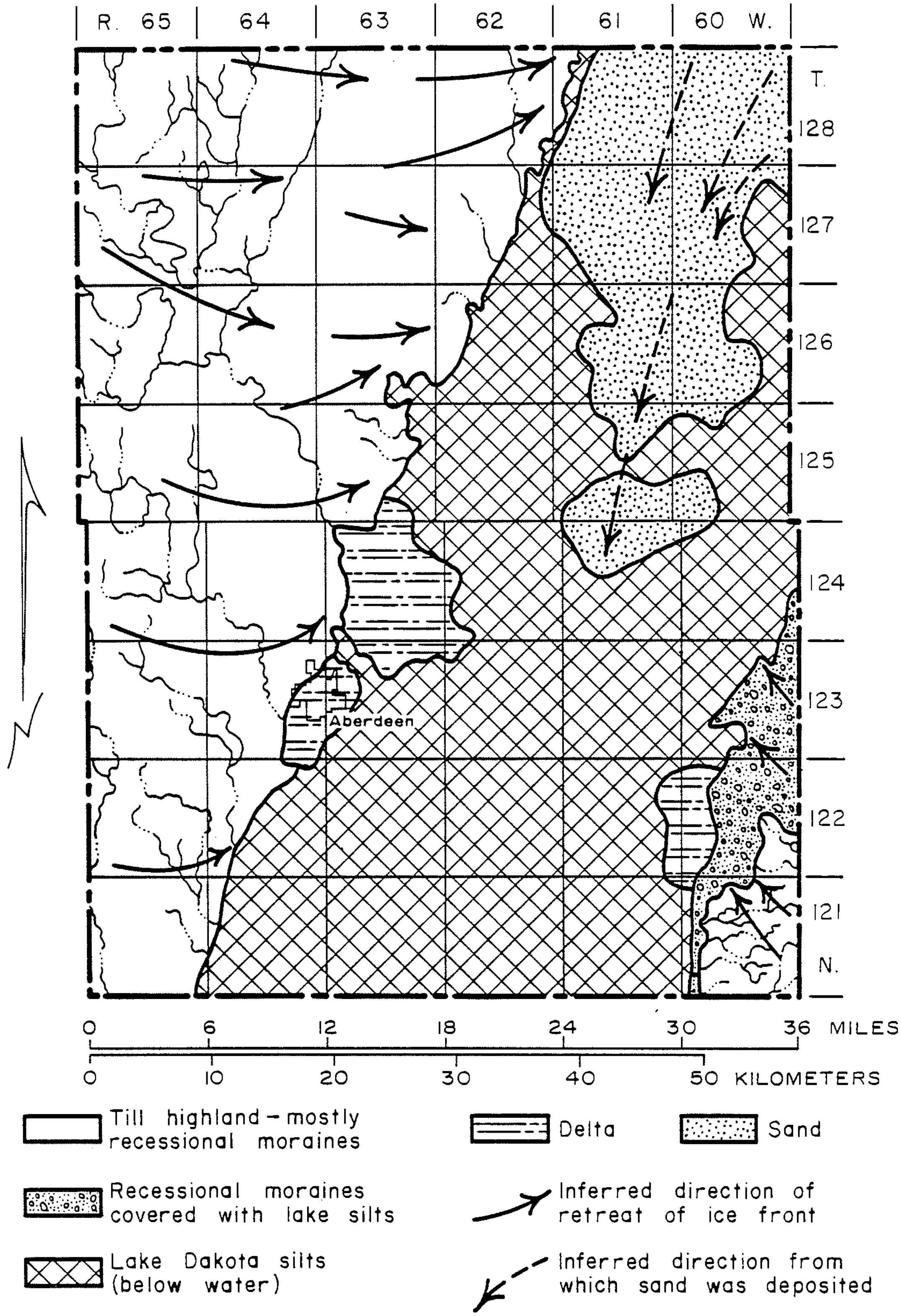


Figure 17. The surface of Brown County after retreat of James Lobe and after building of the deltas and deposition of waterlaid sand.

depriving Ancient Lake Dakota of water. By this time silts had filled the lake and eventually it dried up.

Recent History

After the demise of Ancient Lake Dakota and the final melting of ice, stream patterns began developing on the lake plain.

Streams which had once carried large volumes of meltwater and sediment into the lake were greatly diminished in volume. Thus, new paths were established across the lake silts to connect with the James River which was rapidly extending its channel northward by headward erosion.

Differential compaction of lake silts over buried recessional moraines also played an important role in establishing direction of early drainage on the lake bed.

Subsequent stream piracy has greatly changed the probable early stream pattern explained above. Many large channels (pl. 2) are now abandoned and their small, underfit, present streams join other streams in a near-rectangular drainage pattern.

Drainage on the lake plain in the northern half of the County (pl. 2) is practically nonexistent with the exception of the James River. Several abandoned and partially buried channels in this region testify to action of blowing and drifting sand. Streams that formed in this area in recent times did not last long because the drifting sand blocked their flow. The James River is protected because of its position upwind of the sand plain.

In recent times, most of the streams occupying channels cut during the Pleistocene Epoch have become small, underfit, and intermittent in character owing to the lack of water nourishing them (pl. 2). Further stream activity during recent time includes the gradual headward erosion of many small intermittent streams and deposition of alluvium in most of the stream valleys.

In the area of the sand plain, wind has been a powerful geomorphic agent in recent time producing numerous blowouts and drifting of large amounts of sand in addition to building the area of dunes in the Brown-Marshall County border area (pl. 2), (fig. 18).

ECONOMIC GEOLOGY

Water Resources

Brown County is well supplied with both ground and surface water. Ground water can be found in numerous glacial outwash

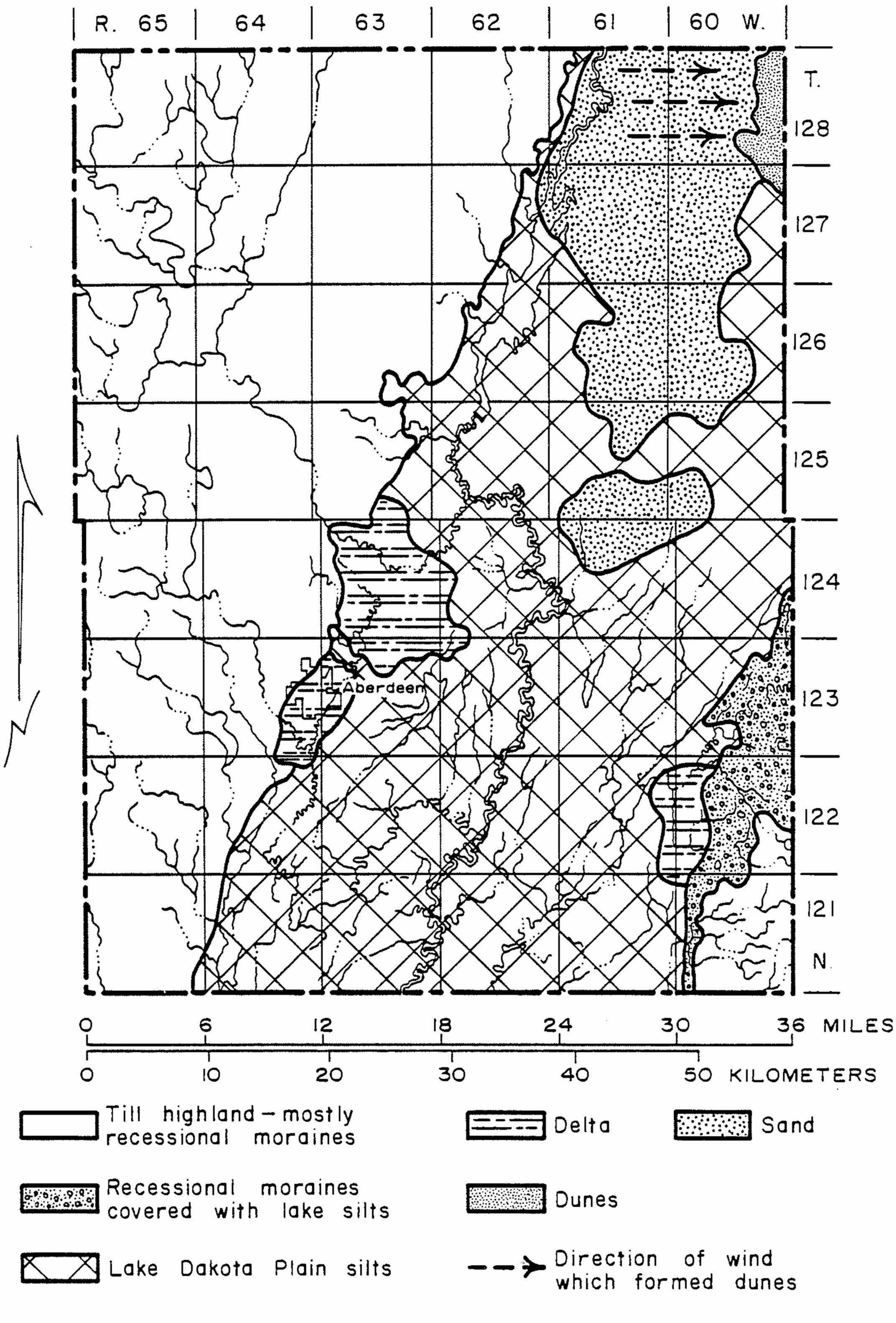


Figure 18. The surface of Brown County after Lake Dakota disappears and after dunes are formed.

aquifers throughout the County and from several deep bedrock aquifers. Surface water has been obtained for several years from a number of dammed reservoirs in the County. A complete discussion of the water resources of Brown County can be found in Part II of the report of these investigations (Koch, 1976).

Sand and Gravel

Sand and gravel constitute the most important solid resources of Brown County. The land surface is dotted by numerous deposits of glacial outwash sand and gravel on both sides of the Lake Dakota plain (pl. 2). A more detailed description of the sand and gravel potential of Brown County can be found in Koch, Bradford, and Leap (1973). Although there is a large supply of sand and gravel in the County, the shale content limits its use for concrete.

Oil and Gas

A few oil and gas tests have been made in Brown County; however, no commercial quantites have yet been found. More data are needed about the deep Cretaceous and Paleozoic strata. Records of oil and gas test wells are on file with the South Dakota Geological Survey in Vermillion.

Clay, Shale, and Boulders

The surface of Brown County is quite young geologically (8,000 to 10,000 years) and leaching of carbonates has not proceeded far enough to rid the clay of carbonates. Therefore, the carbonate content of the clay is probably too high for making high quality brick. The clay could probably be used for making rough ceramic materials such as field tile. In addition, the Pierre Shale which crops out in the deeper stream valleys might also be examined for similar uses. In any event, further laboratory tests will have to be made on both clay and shale to determine their precise potential uses and limitations.

The hilly parts of the recessional moraines and many of the large Pleistocene spillways contain scattered areas of limestone, dolomite, igneous, and metamorphic boulders. These boulders could be crushed for rip-rap and aggregate. Several farm fields in the hilly areas contain piles of boulders gleaned from fields and are also suitable for the above purposes.

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