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Geology of the Pre-dune Strata

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Geology

Introduction

The geology of the Sand Hills can, in a simplified way, be divided into two sections. The first section will discuss most geologic aspects of the Sand Hills area except for the geology of the sand dunes themselves, which will be covered in the second section. The first part could extend back several billion years to the origin of the earth, but for the purposes of this atlas, the story will start almost 100 million years ago and continue to the present. The section on the geology of the Sand Hills wind-blown deposits, hypothesized to be no older than 8,000 years, will include a discussion of pertinent aspects of eolian deposition, dune classification and formation, dune-sand stratification (bedding), and source and age of the dunes.

The geology of the sediments beneath the Sand Hills is probably less well understood than that beneath any other area of Nebraska because of the mantle of dune sand covering older deposits and because of the small amount of subsurface information available. Over the last two decades, staff members of the Conservation and Survey Division of the University of Nebraska-Lincoln, often in cooperation with people from other state and federal agencies, have drilled test holes in the Sand Hills to increase our knowledge of the subsurface geology of the area. What is known about this facet of Nebraska's geology comes largely from the results of this drilling. This test drilling represents pioneering efforts at establishing the framework of the subsurface of the Sand Hills. Because more complete information about the subsurface provides a better foundation for understanding the region's water-related and other natural resources, further subsurface investigations are needed to provide a more detailed picture of the geology of the Sand Hills.

Geology of the Pre-dune Strata

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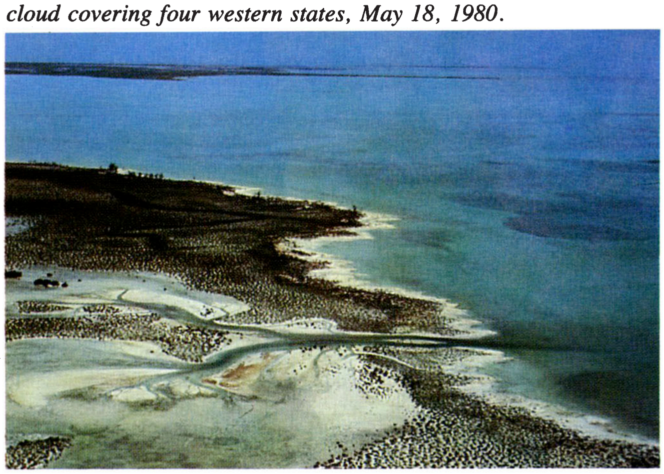
Over the last 98 million years, four general geological processes have acted to shape the ancient landscapes buried beneath the Sand Hills (fig. 3-1). Three of these affected the area directly, either depositing sediments on the land surface or eroding it, while a fourth took place west of Nebraska, but affected the region nonetheless.

Fig. 3-1. a) Marine processes; b) Alluvial processes; c) Eolian processes; d) Volcanic activity—satellite view of Mount St. Helens ash cloud covering four western states, May 18, 1980.

a



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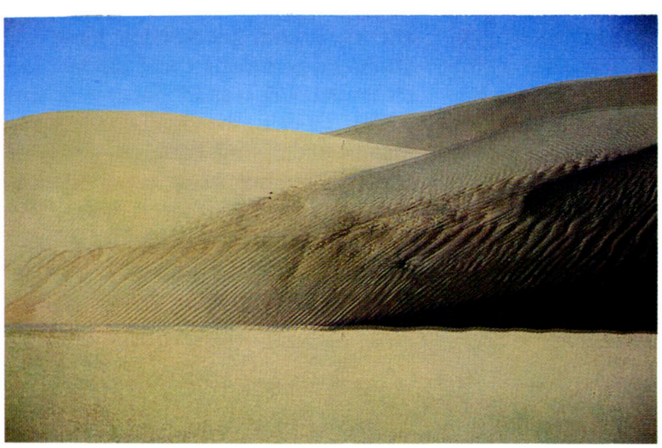

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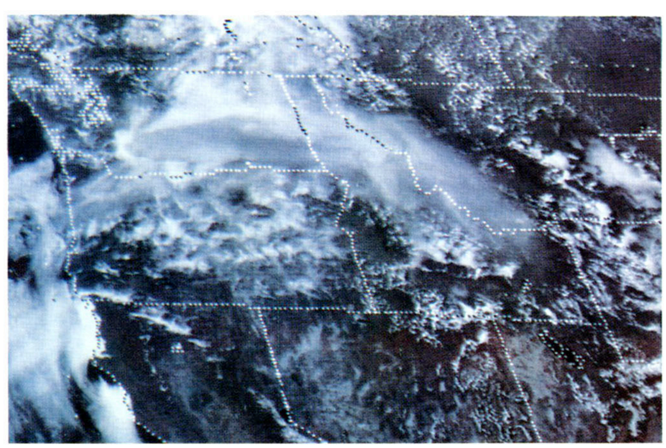

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Shells of clams, oysters, and numerous other kinds of creatures similar to forms that live today in the seas are preserved as fossils in the chalks, limestones, and shales that form the oldest rocks beneath the Sand Hills that will be described. These deposits indicate to geologists that seas once covered the area and that marine (oceanic) processes of sediment transport and deposition were active during this time.

After the seas retreated, streams played a major role in depositing the strata overlying the marine sediments. Nonmarine fossils of plants and animals occur in alluvial (stream-deposited) sands, gravels, and silts laid down within the last 37 million years.

The third process that actively shaped the area was eolian (wind-blown) deposition. Winds have played a major role in the geologic evolution of the entire Great Plains. They have formed the Sand Hills and considerable volumes of older, nonmarine strata. In addition, erosion by both wind- and water-related processes has helped carve the ancient landscapes buried beneath the Sand Hills.

Volcanic activity far to the west and southwest of Nebraska is the fourth process that affected the Sand Hills. Fine-grained debris from volcanic eruptions was carried by high-altitude winds and deposited on the plains. The work of rivers, winds, and, to a lesser extent, volcanoes continues today. Ash from the recent eruption of Mount St. Helens in Washington was carried eastward, and fallout from the eruption cloud was deposited far downwind, including a light dusting of the Sand Hills.

Stratigraphic Summary

The story will begin about 98 million years ago, when shallow Cretaceous seas covered the area and sediments of the Graneros Formation through the Pierre Shale were deposited (table 3-1). These strata accumulated for about 33 million years until sea level fell worldwide and they were exposed to weathering and erosion by streams and wind. Except for soils developed by weathering of the exposed Cretaceous rocks, no sediments are known to have been deposited in the region during the interval from 65 to 37 million years ago.

If a bedrock geologic map were made of the Sand Hills and surrounding region about 38 million years ago, just prior to deposition of the Chadron Formation, it probably would have appeared as shown in figure 3-2. Uplift along the Chadron and Cambridge arches during Late Cretaceous and early Cenozoic time, combined with stream erosion, resulted in the removal of up to 1,800 feet of Cretaceous sediments (Swinehart and others, 1985). This erosion appears to have produced a significant low area over the Chadron Arch in northern Grant and southwestern Cherry counties (figs. 3-2, 3-3, 3-4, and 3-5).

The Cenozoic strata underlying the eolian sand of the Sand Hills and overlying the eroded Jurassic and Cretaceous strata fall into two major packages based on grain size, composition, and environment of deposition. The first is a relatively homogeneous set of fine-grained sediments containing abundant volcanically derived grains and is primarily of eolian origin (White River and Arikaree groups, table 3-1). The second is a heterogeneous set of primarily alluvial sediments, typically coarser grained than those found in the White River and Arikaree groups and derived mostly from Rocky Mountain and more local sources (Ogallala Group and younger deposits). These sediments contain much lower percentages of volcanic debris than do the White River and Arikaree groups. For hydrologic purposes, the Arikaree Group is included with the Ogallala Group and younger deposits to form the High Plains Aquifer (see groundwater chapter). Cross sections A-A' and B-B' (figs. 3-4 and 3-5) present an estimation of the distribution of these Cenozoic strata.

White River Group

The Chadron and Brule formations of the White River Group are present under all but the easternmost part of the Sand Hills and reach a maximum thickness of around 1,250 feet in southwest Cherry County. A significant amount of this material probably came from the present-day Colorado area (Swinehart and others, 1985). The top of the White River Group generally corresponds to the base of the principal groundwater reservoir in the Sand Hills (see groundwater chapter). A paleovalley (ancient river valley) filled with up to 50 feet of Chadron Formation sand occurs beneath most of Garden County (Swinehart and others, 1985). Only fragmentary evidence of other Chadron paleovalleys has been found under the Sand Hills. The Brule Formation, while interpreted to be mostly composed of eolian silt, does contain some alluvial sediment. The landscape during deposition of the Brule Formation was probably an eastward-sloping plain of low relief. Grains of volcanic ash, erupted from huge volcanic complexes in the western United States, make up more than two-thirds of the volume of White River Group sediments.

Arikaree Group

The Arikaree Group, between 28 and 19 million years old, is more restricted in occurrence than the White River Group (figs. 3-4 and 3-5). The Arikaree covers most of the western third of the area but elsewhere under the Sand Hills appears confined to paleovalleys. One such paleovalley, up to 25 miles wide and filled with more than 200 feet of fine to medium sand, has been identified by test drilling. It trends easterly under northern Grant and central Hooker counties (figs. 3-4 and 3-5) and then turns southeasterly into Custer County. No attempt has been made to subdivide the Arikaree into separate formations, as was done in western Nebraska (table 3-1); however, much of the paleovalley fill described above probably correlates with the Gering Formation.

Ogallala Group

A significant episode of stream erosion began about 19 million years ago, after deposition of the Arikaree Group. When deposition resumed, Ogallala Group sediments began accumulating in what was to become a major sedimentary basin in this region. Here the Ogallala consists primarily of sand-sized grains and contains only small amounts of fine-grained volcanic debris, but discontinuous volcanic ash beds do occur. Ogallala sediments were deposited in a variety of paleovalleys and alluvial environments. The larger paleovalleys had source areas in the mountains of Wyoming, Colorado, and possibly South Dakota. In western Nebraska, where outcrops and subsurface data are more abundant, a variety of Ogallala paleovalleys of different ages and geometries have been described (Swinehart and others, 1985; Diffendal, 1982; and Skinner and others, 1977). To date, the Ogallala Group sediments underlying the Sand Hills generally have not been subdivided into formations recognized elsewhere (table 3-1) because of the difficulty of recognizing these in the subsurface. In addition, the complexity of the erosional and

Table 3-1. Generalized lithostratigraphic classification of geologic units referred to in atlas.

ERA	PERIOD	EPOCH	GROUP	FORMATION	ENVIRONMENTS OF DEPOSITION
Cenozoic	Quaternary	Holocene — 0.01 — Pleistocene		Unnamed	Eolian, alluvial
				Unnamed	Alluvial, eolian
	Tertiary	— 1.6 — Pliocene — 5 —		Broadwater/ Long Pine	Alluvial, lacustrine
		Miocene	Ogallala	Ash Hollow	Alluvial
				Valentine	
			— 19 —	Runningwater	
			Arikaree	Upper Harrison beds	Eolian, alluvial
		— 24 —		Monroe Creek-Harrison	
		Oligocene	— 28 —	Gering	
			White River	Brule	Eolian, alluvial
		— 38 —	— 37 —	Chadron	Alluvial, eolian
		Eocene-Paleocene	Rocks of this age not known to occur under the Sand Hills.		Soil developed on older rocks
Mesozoic	Cretaceous	— 65 — Late	Montana	Pierre Shale	Marine
			Colorado	Niobrara	
			Colorado — Benton	Carlile	
			Colorado — Benton	Greenhorn	
		— 98 —	Colorado — Benton	Graneros	
		Early	Dakota		
	Jurassic	— 144 —		Morrison	

Note: Approximate age of boundaries given in millions of years

Sand Hills boundary is bold black line.

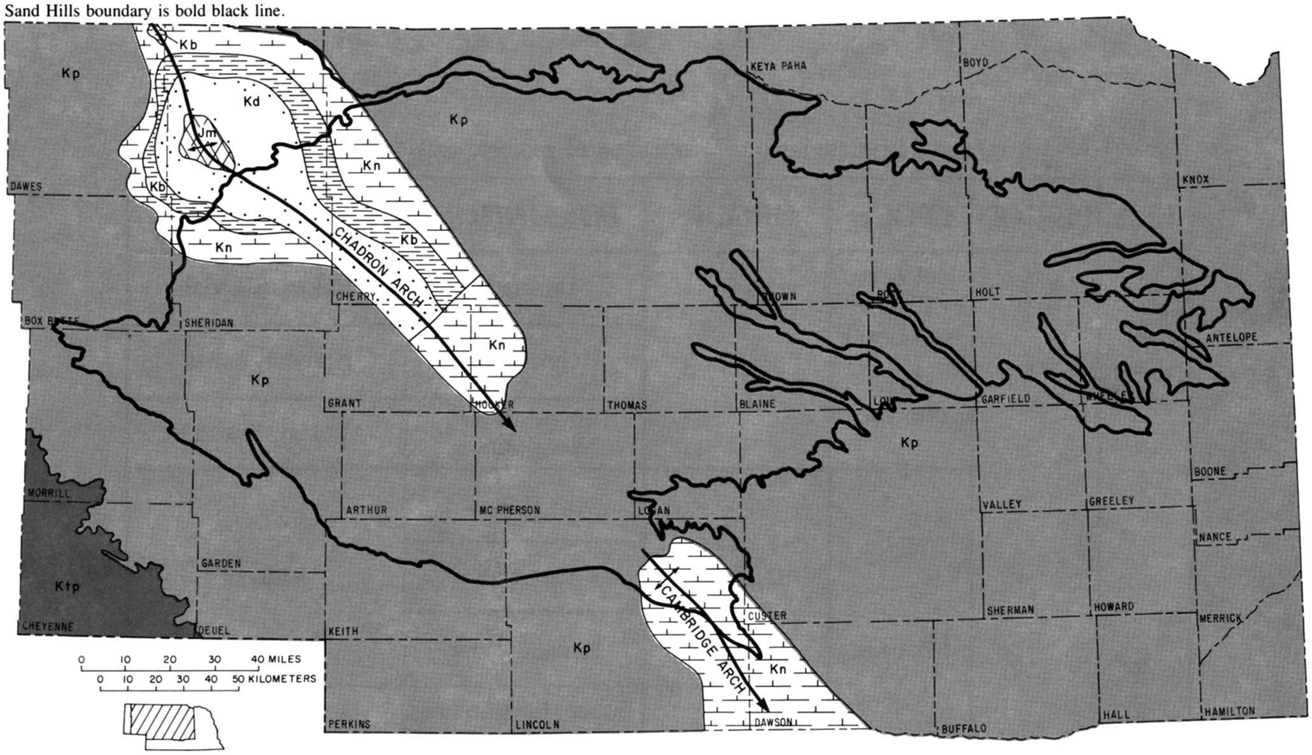
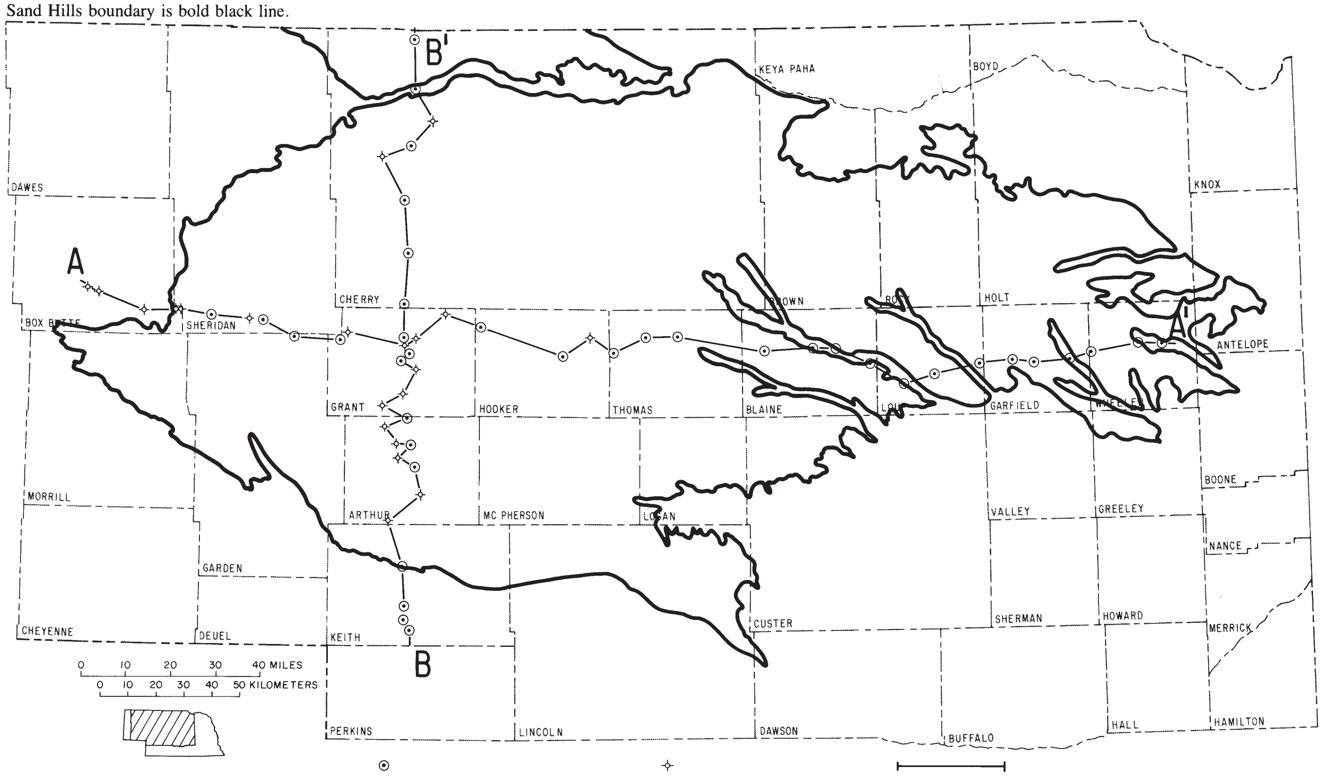


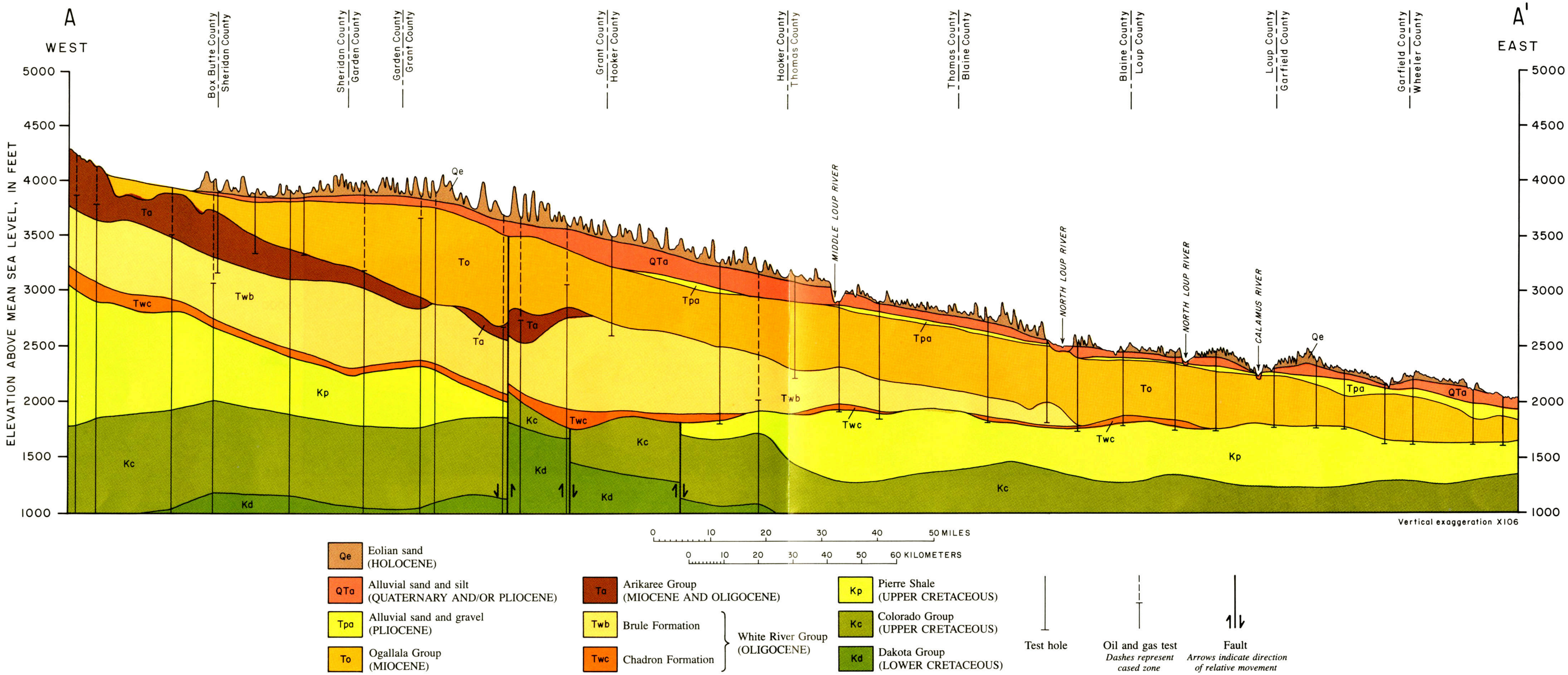
Fig. 3-2. Pre-Cenozoic geologic map of the Sand Hills and surrounding areas. Map symbols are: Jurassic System: Jm-Morrison Formation; Cretaceous System: Kd-Dakota Group; Kb-Benton Group; Kn-Niobrara Formation; Kp-Pierre Shale; Ktp-Transition zone-Pierre Shale. The Chadron and Cambridge arches are large complex anticlines. Faults are not shown. The map was made using data from oil and gas tests evaluated by H. M. DeGraw of the Conservation and Survey Division.

Sand Hills boundary is bold black line.



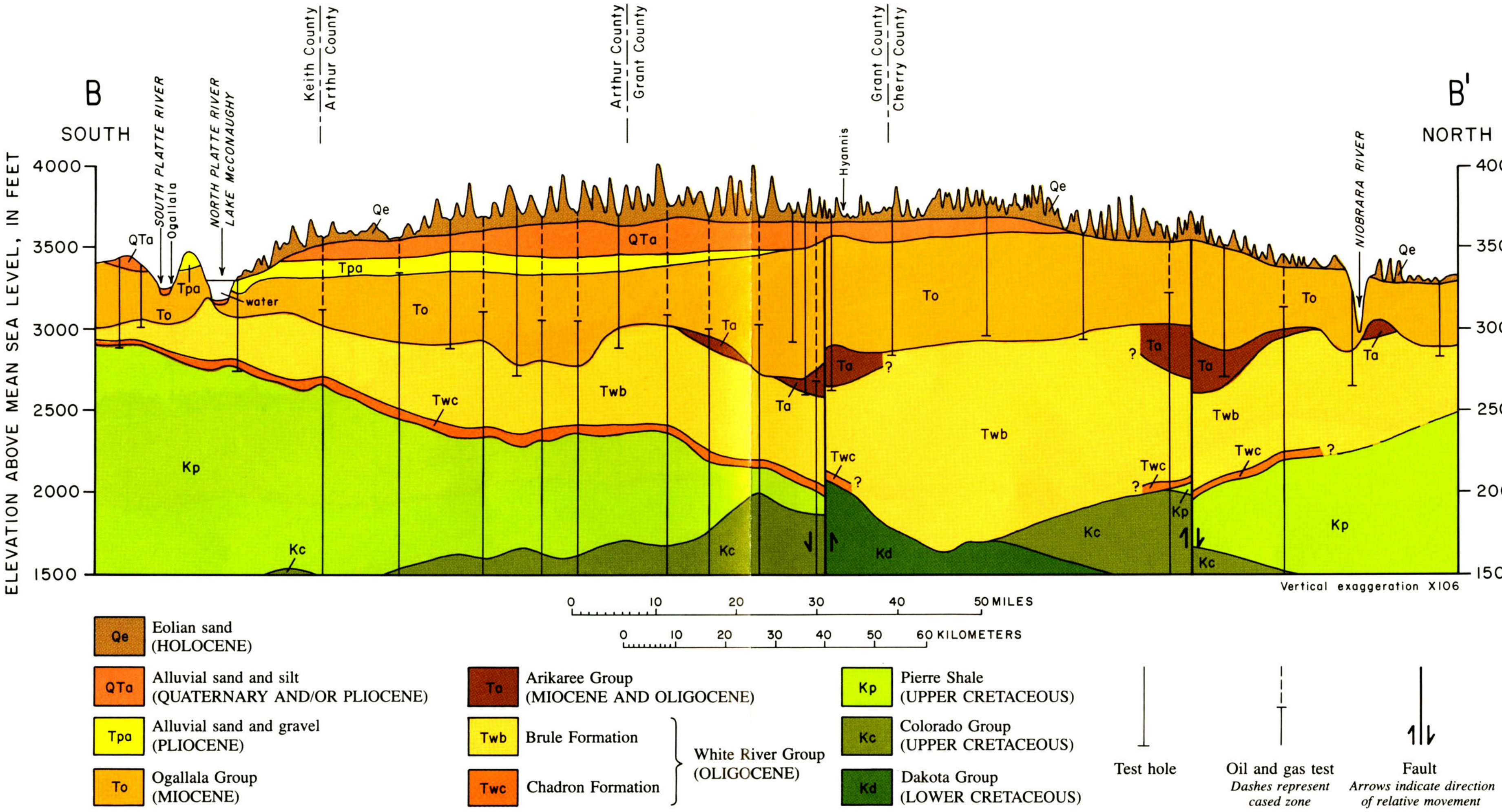
Test hole Oil and gas test Line of geologic section

Fig. 3-3. Location of geologic sections shown in figures 3-4 and 3-5.



Geologic Section, West to East

Fig. 3-4. Geologic section A-A' running west to east across the Sand Hills. This and section B-B' (fig. 3-5) were constructed after evaluating samples and electric logs from test holes and electric logs from oil and gas tests. Configuration maps of the top of the Colorado Group, base of the White River Group, and base and top of the Ogallala Group (figs. 3-7 and 3-11) were used to draw correlation lines between drill holes. In most regions of the Sand Hills, the base of the principal aquifer (see groundwater chapter) is defined as the top of the relatively impermeable White River Group (Twb and Twc). In the eastern Sand Hills, the White River Group is not present, and the Ogallala Group lies directly on the impermeable Pierre Shale (Kp). The Pliocene alluvium (Tpa) consists primarily of sand and gravel but locally contains fine-grained beds as thick as 15 feet. Note that slopes appear much steeper than they actually are because the vertical scale is exaggerated by 106 times.



Geologic Section, South to North

Fig. 3-5. Geologic section B-B' running south to north across the Sand Hills. The Pliocene alluvium (Tpa) consists primarily of sand and gravel but locally contains fine-grained beds as thick as 15 feet. Note that in Arthur County, Ogallala Group (To) sediments only make up about 60 percent of the principal groundwater reservoir (more extensive than the principal aquifer; see groundwater chapter), and Pliocene and younger sediments constitute the remaining 40 percent. However, in the northern half of Cherry County, 80 percent of the principal groundwater reservoir is made of the Ogallala Group and the remaining 20 percent consists of the Arikaree Group (Ta).

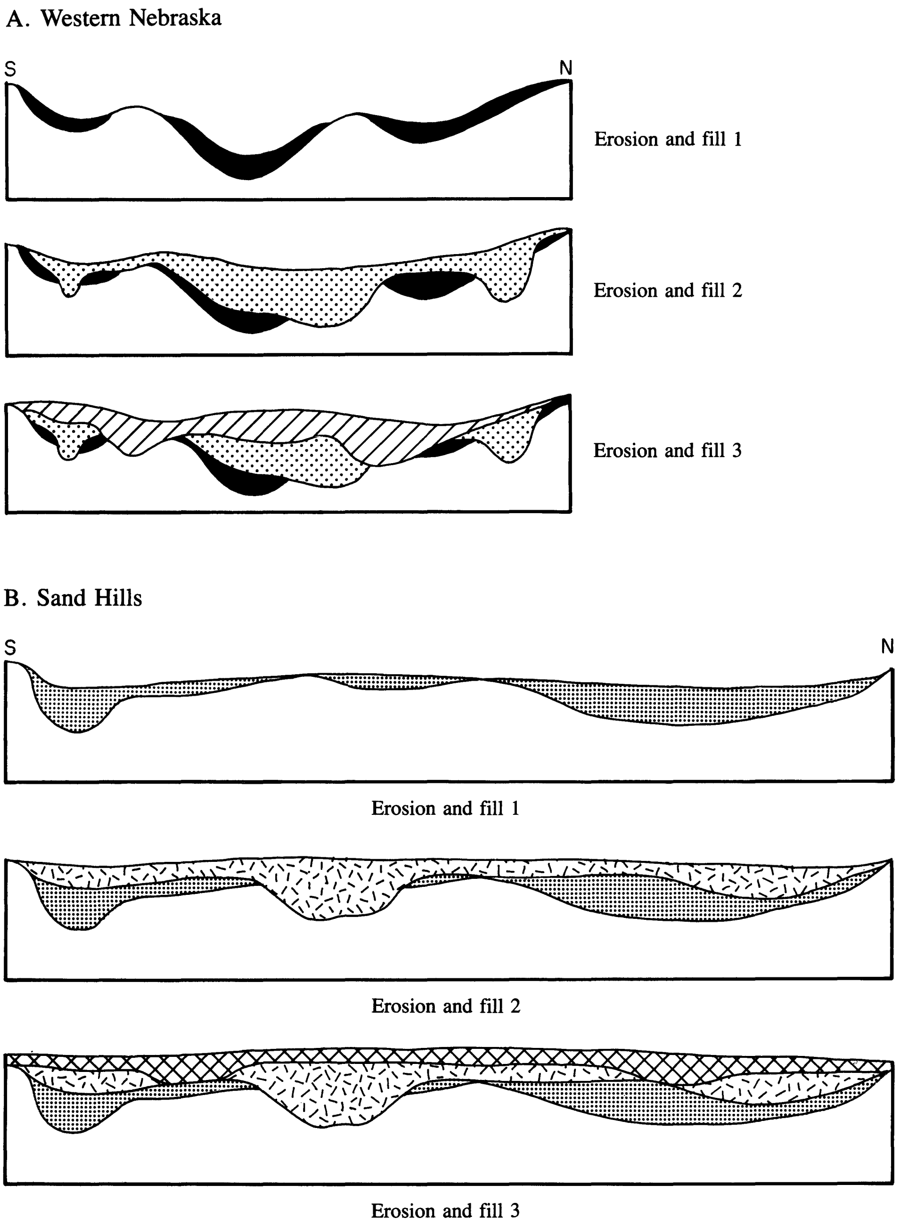


Fig. 3-6. Diagrammatic examples of multiple episodes of valley erosion and filling by streams in: a) western Nebraska; b) Sand Hills.

filling episodes known to occur in the Ogallala precludes a simple "layer cake" approach to subdivision of the Ogallala (fig. 3-6). It appears that the Ogallala of western Nebraska occupies generally deeper paleovalleys than the ones underlying the Sand Hills. Beneath the Sand Hills, the Ogallala is fairly uniform in lithology and consists mostly of fine to medium sand and lesser amounts of siltstone, volcanic ash, diatomite, and coarse sand and gravel. It contains less calcium carbonate cement than the Ogallala sediments to the west and south. The Ogallala ranges in thickness from 100 to 800 feet and is thickest beneath the west-central part of the Sand Hills, where it averages more than 600 feet.

The base of the Ogallala Group (fig. 3-7) is a complex surface representing a number of episodes of erosion. In addition, both folding and faulting have probably warped this surface. Attempts to reconstruct ancient Ogallala drainage systems from such a surface are uncertain undertakings, but a preliminary and generalized map has been made to illustrate current ideas of where these drainages were located (fig. 3-8). In most cases the sediment in these paleovalleys is somewhat coarser than that in adjacent areas. Outcrop studies along the Niobrara River valley (Skinner and Johnson, 1984) suggest that the paleovalley system depicted under the northern Sand Hills was eroded during the time represented by the Valentine Formation of the Ogallala Group (table 3-1). Some of the ancient tributaries in western Cherry County may belong to a younger episode of erosion within the Ash Hollow Formation. The same may be true of the paleovalley that occurs under Blaine, Loup, Garfield, and Holt counties. The paleovalleys shown under the western Sand Hills appear to have been filled primarily with Ash Hollow Formation sediments and contain somewhat coarser grained fills than the northern one.

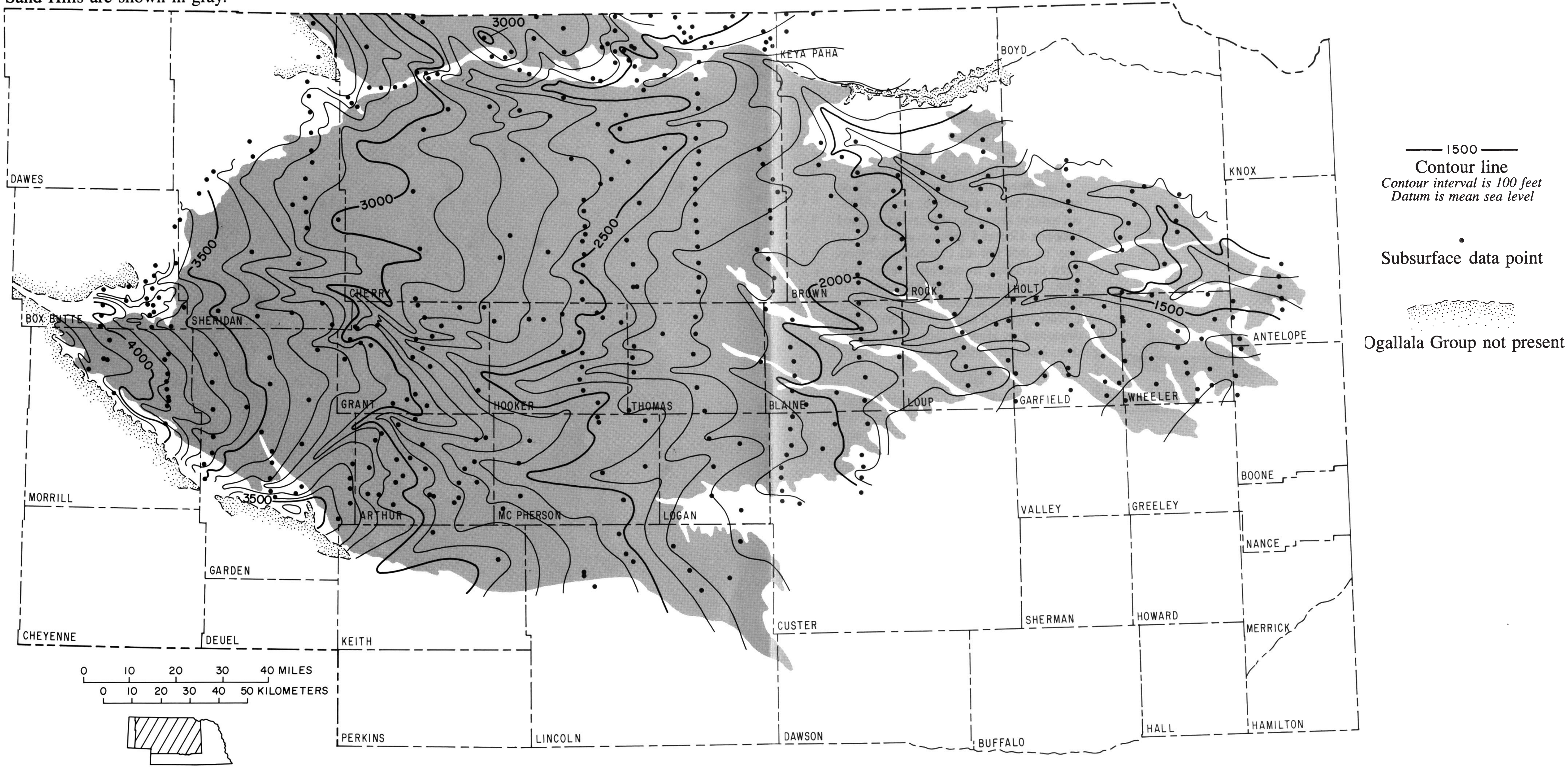
The paleovalleys depicted (fig. 3-8) represent only a portion of many different ancient drainage systems that existed between 19 and 5 million years ago. It may be that not all Ogallala sediments were deposited in confined valley systems. For instance, Ogallala sediments underlying the southern half of Cherry County (figs. 3-5 and 3-7) may have been deposited as alluvial fans or on extensive, low-relief plains.

Pliocene

An unconformity (a surface representing a missing interval in the rock record) of at least 1.5 million years separates the youngest Ogallala and the next younger river-deposited sediments (table 3-1), the Broadwater and Long Pine formations (figs. 3-4, 3-5, and 3-9). These Pliocene deposits average 50 feet thick with a maximum thickness of about 300 feet. They are by far the most widespread coarse-grained sediments preserved during the last 37 million years in this part of Nebraska. These multiple sand-and-gravel bodies separated by finer grained deposits are exposed at the southwestern edge of the Sand Hills (fossil sites B and L in fig. 3-9) and contain gravel cobbles up to 12 inches in diameter. Approximately 200 miles to the northeast (sites LP and BS in fig. 3-9) somewhat younger gravels, but with a similar composition, have clasts up to 3 inches in diameter.

The principal source areas of these Pliocene deposits can be approximated better than most other Cenozoic strata. Stanley and Wayne (1972) noted the occurrence of gravel clasts composed of anorthosite at sites B, L, S, and LP (fig. 3-9). Anorthosite is an uncommon igneous rock whose only known occurrence to the west is in a small part of the Laramie Mountains in southeastern Wyoming (fig. 3-10). In addition, other unique rock types such as quartz pebble conglomerates from the Snowy Range in south-central Wyoming have been iden-

Sand Hills are shown in gray.



Base of the Ogallala Group

Fig. 3-7. Configuration of the base of the Ogallala Group beneath the Sand Hills. This surface generally coincides with the base of the principal groundwater reservoir except where the Arikaree Group is present (see groundwater chapter). Subsurface data points are a combination of oil and gas tests and test holes. Information from outcrops in the Niobrara (Skinner and Johnson, 1984) and North Platte river valleys was also used to make this map. The test hole data (samples and electric logs) were evaluated by R.F. Diffendal, Jr., V.H. Dreeszen, J.J. Gottula, D.R. Lawton, F.A. Smith, V.L. Souders, and J.B. Swinehart of the Conservation and Survey Division.

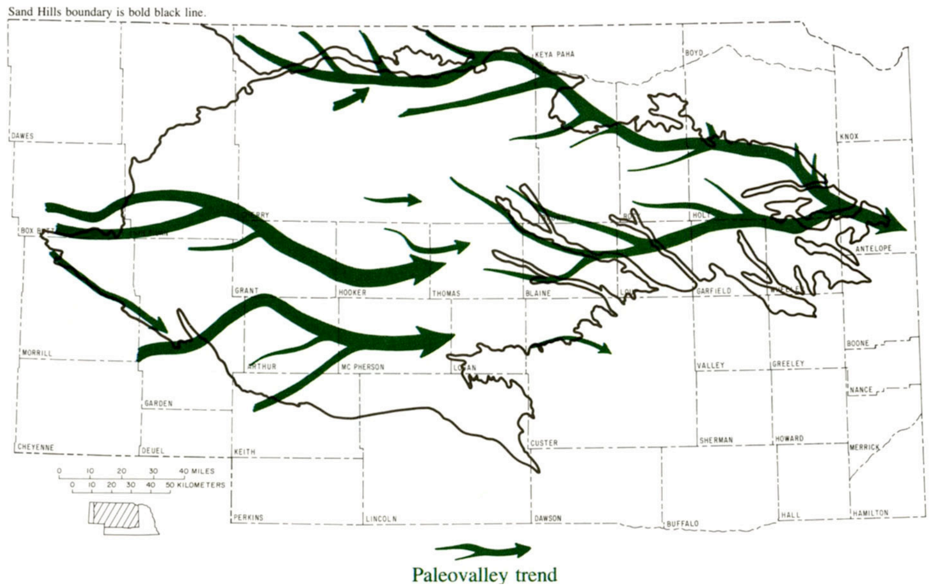


Fig. 3-8. Probable distribution of Ogallala Group paleovalleys.

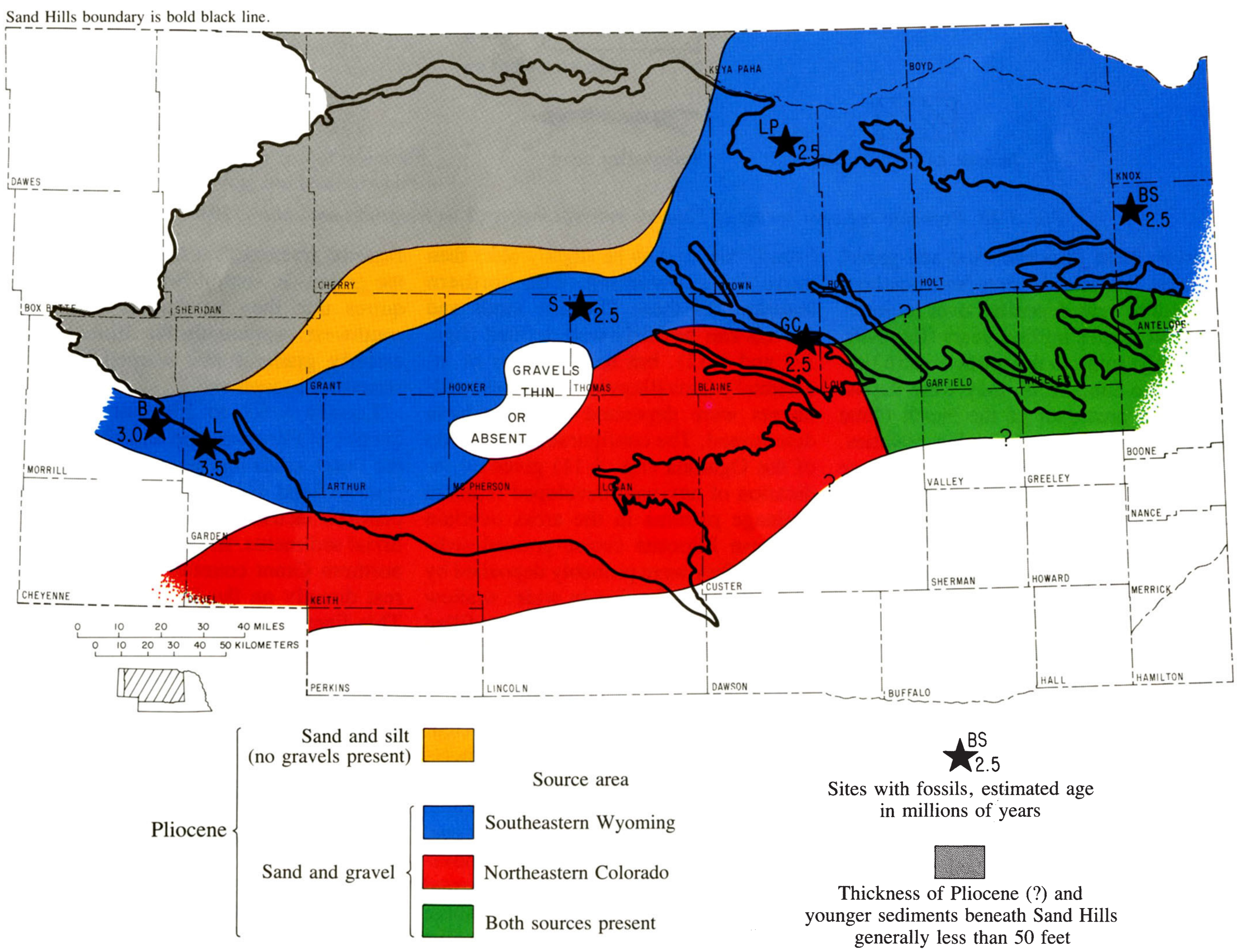


Fig. 3-9. Generalized distribution of Pliocene sediments in the Sand Hills and surrounding areas. Estimated age of fossil sites from Voorhies (personal communication). Site symbols are: B—Broadwater; BS—Big Springs; GC—Gaedke Camel; L—Lisco; LP—Long Pine; S—Seneca.

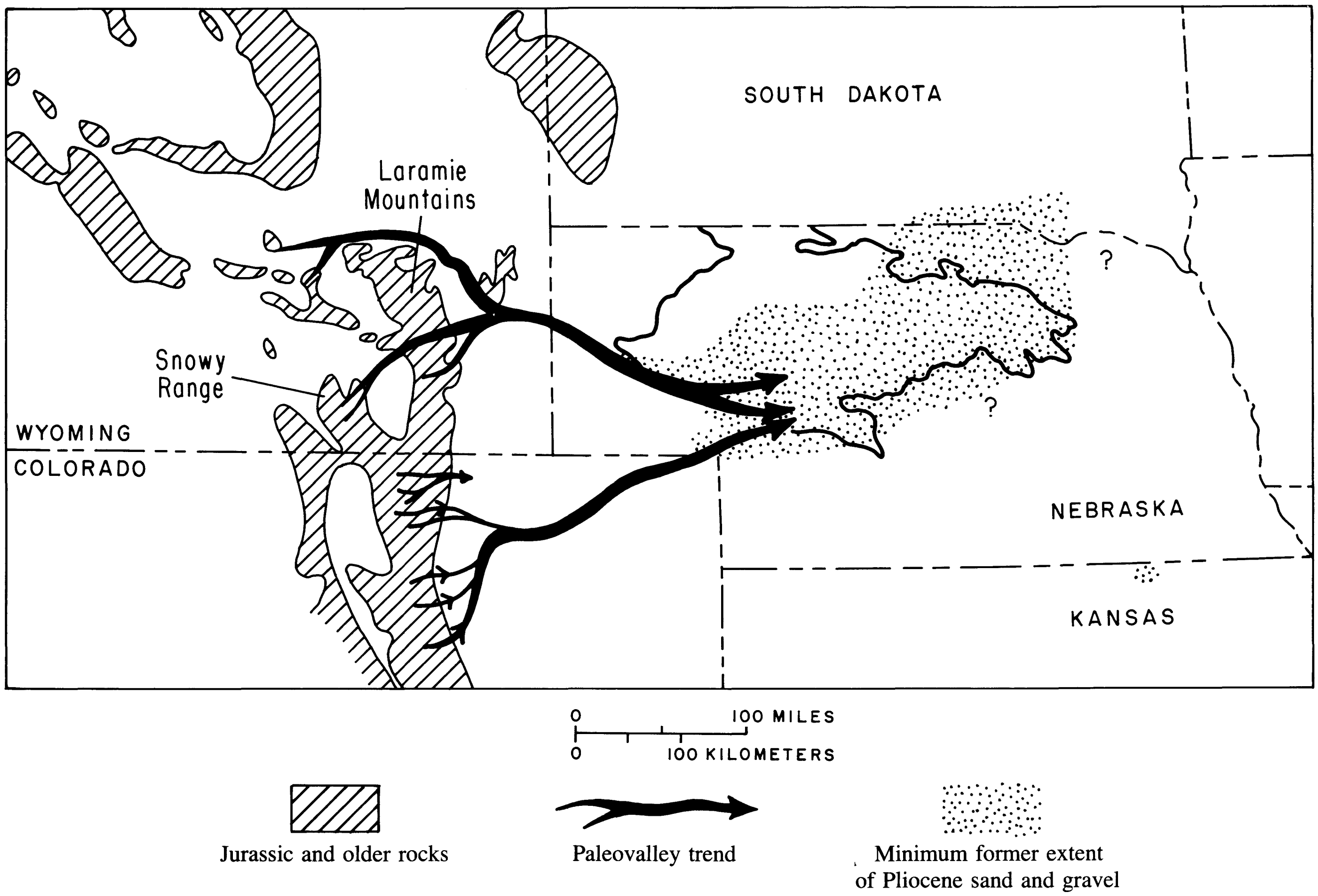


Fig. 3-10. Probable regional setting of Pliocene paleodrainages (from Swinehart and others, 1985).

tified in these Pliocene sand-and-gravel deposits. These sediments from southern Wyoming were deposited over an interval of at least 1 million years (fig. 3-9). From Wyoming to the southwestern border of the Sand Hills, they were deposited by a precursor of the North Platte River. In Morrill and Garden counties, Schultz and Stout (1948) named these sediments the Broadwater Formation. Under the Sand Hills these coarse deposits occur as multiple, widespread sheet-like bodies and trend easterly and northeasterly. In northern Brown County (fig. 3-9), Skinner and Hibbard (1972) named these deposits the Long Pine Formation.

An additional regional source area in north-central Colorado has been identified for a second set of Pliocene sands and gravels present under parts of the Sand Hills (figs. 3-9 and 3-10). The gravels contain volcanic clasts that originated from north-central Colorado. There is insufficient fossil evidence to place any definite age on these gravels, except for a few localities where sand and gravel from a source in north-central Colorado underlies sediments from southern Wyoming. Thus the sediments from Colorado may be slightly older than those from Wyoming. The northern boundary of these Pliocene sands and gravels can be fairly well defined (figs. 3-9 and 3-11), but the locations of individual paleovalleys in which these sediments were deposited have not been determined. The configuration of the top of the Ogallala (fig. 3-11) gives no indication of any well-developed regional drainage patterns in the areas overlain by these Pliocene coarse-grained sediments. They were probably deposited by braided rivers flowing in wide, shallow valleys. When the valleys became filled with sediment, the rivers would shift away from them and flow in an adjacent low area. Through time an alluvial plain with a complex history was constructed.

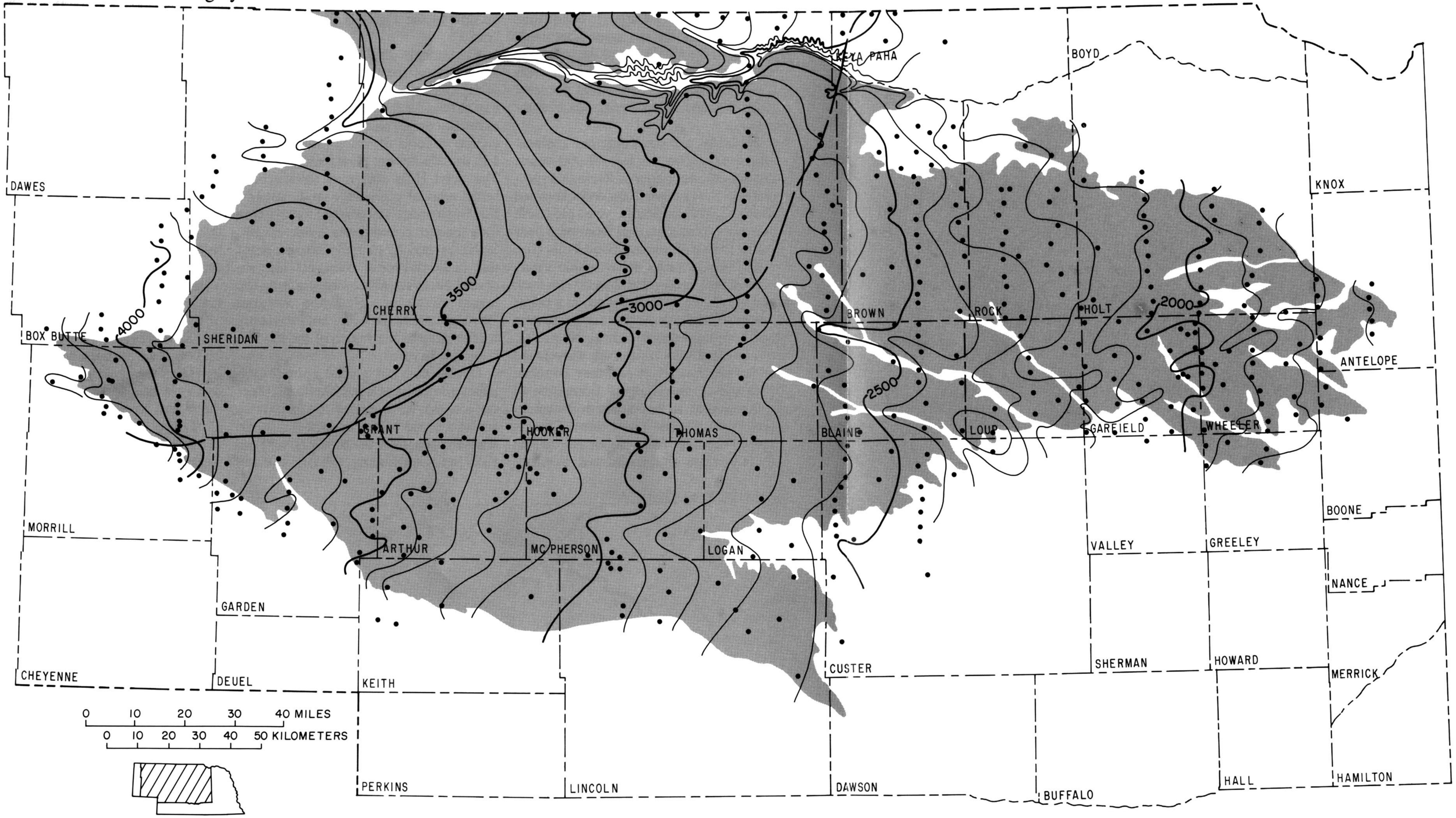
The absence of these coarse sediments under the northwestern and northern half of the Sand Hills suggests that this area was relatively high during the Pliocene. It appears that some structural movement involving these sediments occurred in the southeastern Cherry and southern Brown county areas (fig. 3-11). Here the present slope of the top of the Ogallala (and base of the Pliocene sand-and-gravel sequence) indicates an easterly or southeasterly gradient. Yet the mineralogy of the gravels in central Brown County requires that they be derived from the southwest. Apparently the initial northeasterly gradient was warped by later structural movements.

Locally a 50- to 150-foot thick sequence of Pliocene sand and silt overlies the basal sands and gravels beneath the central Sand Hills. This sand and silt contains lacustrine (lake) as well as alluvial sediments. In southern Cherry and northern Grant counties, these deposits rest directly on the Ogallala (fig. 3-9). This finer grained sequence of strata is poorly understood and in the absence of diagnostic fossils, criteria for differentiating them from Pleistocene sand and silt deposits are not well established.

Quaternary

A scarcity of sediments between about 2 million and 40,000 years old under the Sand Hills means little can be said about the geologic history of the region during the time that several continental ice sheets moved into and retreated from easternmost Nebraska. This incomplete record results from either non-deposition or

Sand Hills are shown in gray.



—— 2000 ——
Contour line
Contour interval is 100 feet
Datum is mean sea level

•
Subsurface data point

— — — —
Northern edge of Pliocene sand and gravel

Top of the Ogallala Group

Fig. 3-11. Configuration of the top of the Ogallala Group beneath the Sand Hills. Subsurface data points are a combination of test holes and irrigation wells. Information from these was evaluated by R.F. Diffendal, Jr., V.H. Dreeszen, J.J. Gottula, D.R. Lawton, F.A. Smith, V.L. Souders, and J.B. Swinehart of the Conservation and Survey Division.

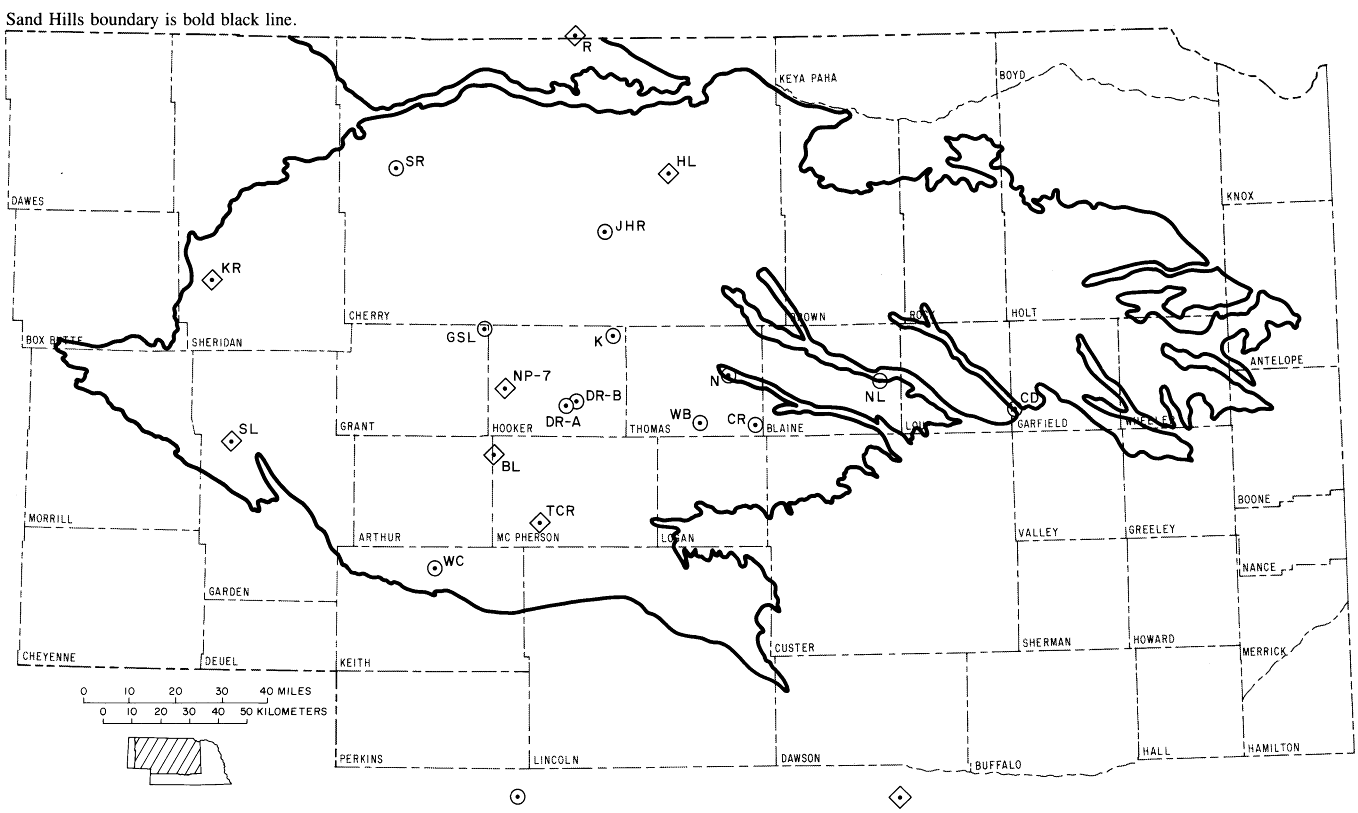
massive erosion. The landscape probably underwent significant modification as surface processes controlling such elements as rivers, winds, and soils responded to the changing conditions brought on by the ice ages. Significant erosion of the Ogallala and the overlying younger strata in the western and northwestern Sand Hills apparently occurred (figs. 3-4 and 3-11) during the Pleistocene.

Probably a more complete geologic record exists for the last 40,000 years, but our understanding of it remains speculative. Two radiocarbon dates between about 32,000 and 38,000 years old (table 3-2) have been obtained from peat beds under the south-central Sand Hills (fig. 3-12). These peats occur within sandy alluvial sediments more than 80 feet thick and may have been deposited in a major southeasterly trending drainage system heading into south-central Nebraska. Similar sandy sediments are widespread under the Sand Hills and may correlate with the Gilman Canyon Formation of south-central to northeastern Nebraska (Dreeszen, 1970). The Gilman Canyon ranges in age from about 35,000 to 20,000 years old (May and Souders, 1988). The drainage pattern in the Sand Hills during this time was probably quite different from that of today. Some of these streams derived their sand from erosion of the Ogallala in western Nebraska.

The modern drainage pattern for at least parts of the Loup system, as well as the Calamus and Niobrara rivers, began to take form some 20,000 years ago as the last major pulse of continental glaciation affected the midwest (see fig. I-5 in introduction to plants and animals). The Sand Hills area may have been a broad alluvial plain with sandy streams flowing in much lower relief valleys than their modern counterparts. For example, Voorhies and Corner (1985) estimated that in north-central Nebraska, the ancestral Niobrara River valley during the height of this last glaciation averaged "two to three times wider but [was] only half as deep as the trench of the modern Niobrara River . . ."

During this last glacial episode, extensive deposits of wind-blown silt (Peoria Loess) were deposited primarily across a broad belt of eastern and southern Nebraska. Near the border of the Sand Hills in Custer County, the Peoria Loess typically reaches a thickness of 60 feet. Lugn (1965), as well as Wright and others (1985), are among previous researchers who have hypothesized that deposition of this wind-blown silt and the large sand dunes occurred at the same time. While the Sand Hills region may have been a source area for some of the Peoria Loess, other sources of silt were the broad flood plains of the ancestral Platte, Loup, and Missouri rivers and other drainages, many of which are now buried. Obviously, some eolian sand was deposited during this interval, but the sand dunes we now know as the Nebraska Sand Hills appear to have formed during episodes of aridity and eolian activity over the last 8,000 years, long after deposition of the Peoria Loess ceased. The evidence for this hypotheses will be discussed in the following section.

The climate and ecological setting of the Sand Hills region during the last 20,000 years is discussed in some detail by Holen (see anthropology chapter). A dramatic change took place in the climate and vegetation beginning about 12,000 years ago as the last continental ice sheet retreated northward from the Dakotas and Iowa. By 9,000 years ago,



Radiocarbon sample overlain by eolian sand

Radiocarbon sample not overlain by eolain sand

Fig. 3-12. Sand Hills sites with radiocarbon dates. See table 3-2 for site abbreviations.

riverine spruce forests and aspen-pine parklands containing large areas of prairie-type vegetation had given way to the expansive grasslands so typical of the Great Plains (Fredlund and Jaumann, 1987).

The Holocene (past 10,000 years) history of streams and valleys in the Sand Hills and adjacent regions is more complex than the three distinct terraces and accompanying fills envisioned by Schultz and Hillerud (1978) and Schultz and Stout (1948, 1977) for all Nebraska river valleys. For example, May and Holen (1985) documented five Holocene alluvial fills in the South Loup Valley and radiocarbon dates from the Dismal River (Ahlbrandt and others, 1983; table 3-2) suggest that the modern Dismal River valley is younger than 1,500 years old. Local and/or regional structural movements in addition to regional climatic changes may have produced different erosion and filling sequences in various river valleys in the Sand Hills. Bentall (see streams chapter) speculates on the effect of structure on streams and valleys in the region.

Table 3-2. Radiocarbon dates pertinent to determining the chronology of eolian activity in the Sand Hills

A. Sites where dated sample is overlain by eolian sand

Site name and map symbol	Legal description	Thickness of overlying eolian sand (ft)	Depth below eolian sand (ft)	Radiocarbon age in yrs BP[1]	Reference or lab number
Snake River (SR)	SE1/4,SW1/4, sec.18, T.30N.,R.38W.	26	0-0.3	860±55	Ahlbrandt and others, 1983
Kelso (K)	NE1/4,SE1/4, sec. 16, T.24N.,R.31W.	10	?	1,160±200, (charcoal)	Kivett, 1970
Calamus Dam (CD)	NW1/4,NW1/4, sec. 6, T.21N.,R.16W.	49	sample within eolian sand	3,450±110	Beta-11622
J.Hannah Ranch (JHR)	SW1/4,SE1/4, sec. 21, T.28N.,R.31W.	128	3.9-4.4 7.2-7.4	3,650±100 4,660±80 (peat)	Beta-16608 Beta-16607
Dismal River Ranch-A (DR-A)	SW1/4,SE1/4, sec. 35, T.22N.,R.33W.	144	1.3-1.5 1.3-1.5 1.5-1.8 11.3-11.8	3,000±400 3,560±70 3,810±80 4,900±500	Ahlbrandt and others, 1983
Dismal River Ranch-B (DR-B)	SE1/4,NE1/4, sec. 30, T.22N.,R.32W.	131	0.3-0.6 1.0-1.5	5,150±400 8,410±110	Ahlbrandt and others, 1983
Warner Bridge (WB)	NW1/4,NE1/4, sec. 22, T.21N.,R.28W.	3	0-1.3	3,600±400	Ahlbrandt and others, 1983
Collier Ranch (CR)	SW1/4,NW1/4, sec. 23, T.21N.,R.26W.	46	2.6-3.3	7,220±120	Ahlbrandt and others, 1983
Natick (N)	SW1/4,NE1/4, sec. 21, T.23N.,R.27W.	42	13.5-13.8 17.4-19.3	3,110±80 5,040±80 (wood)	Ahlbrandt and others, 1983
North Loup (NL)	Center sec. 5, T.22N.,R.21W.	23	5.0	8,400±250	Brice 1964
Whitetail Creek (WC)	SE1/4,SE1/4, sec. 26, T.16N.,R.38W.	20	6.5-6.6	9,930±140	Ahlbrandt and others, 1983
Gudmundsen Sandhills Lab (GSL) 12-SH-88[2]	SW1/4,SW1/4, sec. 1, T.24N.,R.36W.	152	8.0-13.0	13,160±450 (plant fragments)	Beta-27758

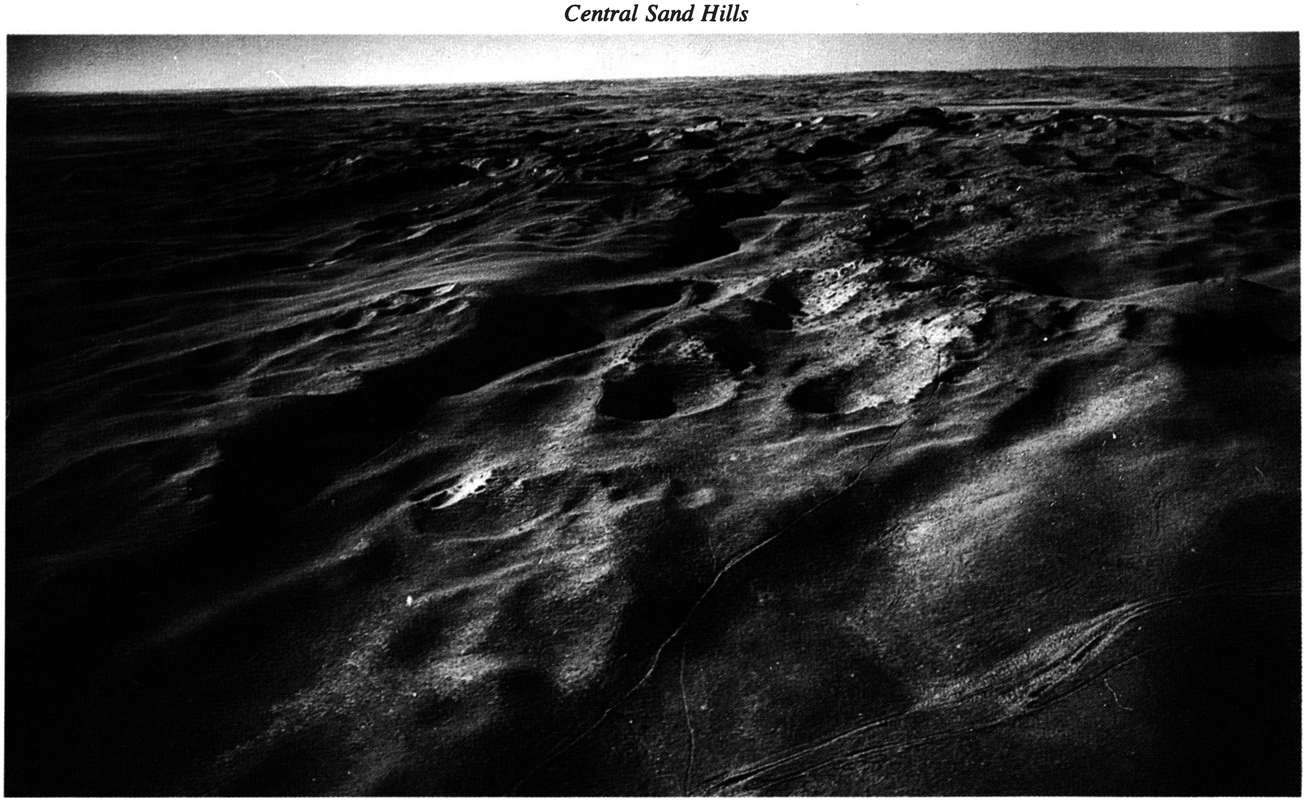
Table 3-2—Continued

B. Sites where dated sample is not overlain by eolian sand

Site name and map symbol	Legal description	Depth below land surface (ft)	Radiocarbon age in yrs. BP	Reference or lab number
NP-7	SE1/4,NW1/4, sec. 10, T.22N.,R.35W.	0-1.3	500±200	Bradbury, 1980
Hackberry Lake (HL)	sec. 23, T.30N.,R.29W.	4.9 14.8	1,100±75 5,040±160	Sears, 1961
Swan Lake (SL)	SW1/4,NW1/4, sec. 10, T.20N.,R.45W.	21.6-22.3 43.7-44.1	3,680±70 8,950±160	Wright and others, 1985
Krause Ranch (KR)[3]	NW1/4,NW1/4, sec. 23, T.26N.,R.46W.	3.9-4.3 9.0-9.2	3,140±87 12,080±380	Ogden & Hay, 1965
Rosebud (R)	NW1/4,NE1/4, sec. 21, T.35N.,R.32W.	18.0-18.4 19.7-19.8	12,580±160 12,630±160	Watts and Wright, 1966
Brown Lake (BL) 34-C-81[2]	SE1/4,SW1/4, sec. 19, T.20N.,R.35W.	201-203	32,130±1,280/1,520 (peat)	DIC-2513
Tin Camp Ranch (TCR)	SE1/4,SE1/4, sec. 2, T.17N.,R.35W.	0-0.3	38,101±1,260	Beta-16606

[1]All dates from organic sediments unless noted otherwise. BP = before present.
[2]Conservation and Survey Division test hole number
[3]Original location given as T.25 N., R.45 W.

Central Sand Hills



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