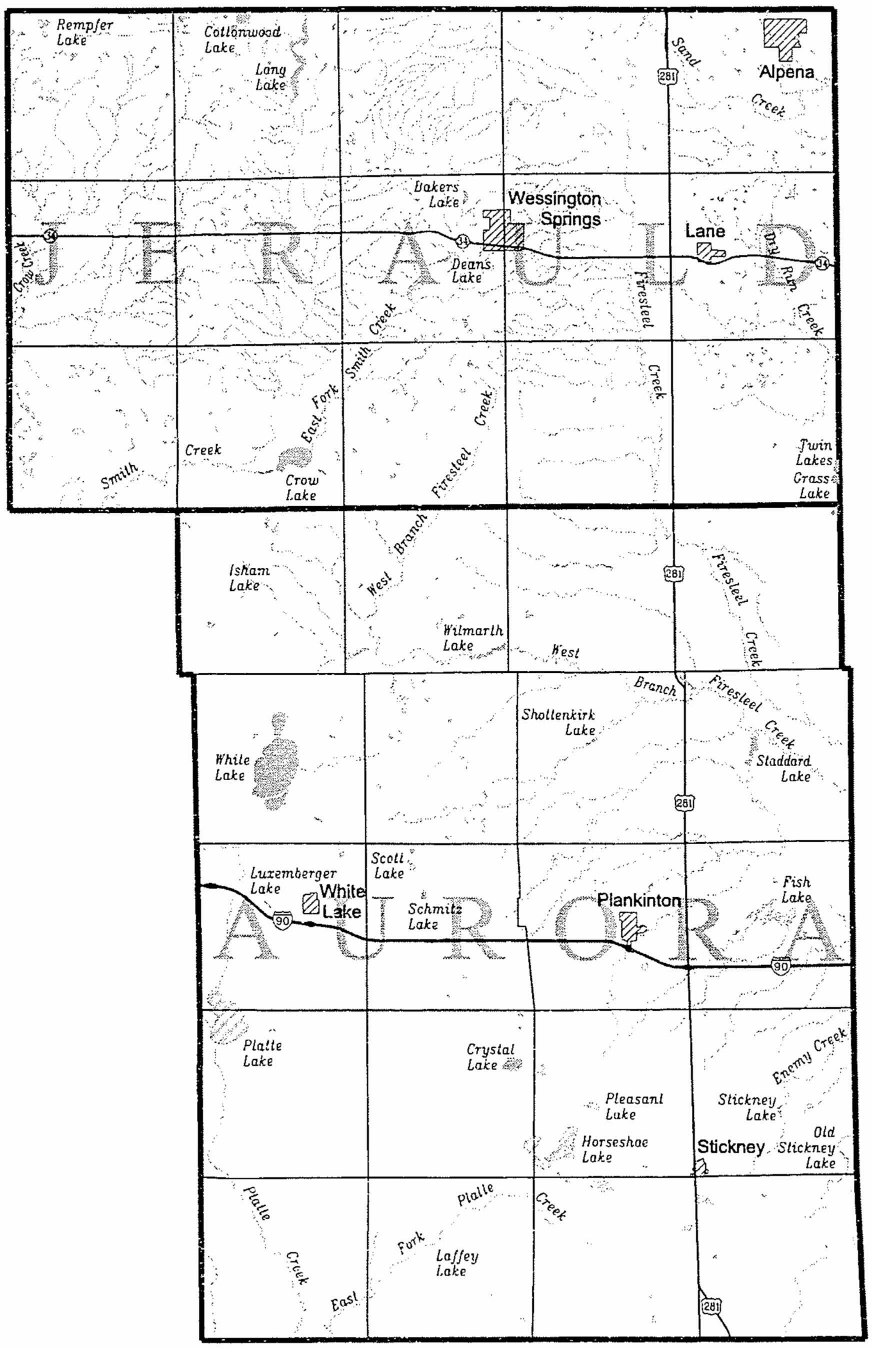
BULLETIN 32

GEOLOGY OF AURORA AND JERAULD COUNTIES, SOUTH DAKOTA

Lynn S. Hedges



Department of Environment and Natural Resources
Geological Survey

2001

SOUTH DAKOTA GEOLOGICAL SURVEY

SCIENCE CENTER
414 EAST CLARK STREET
VERMILLION, SOUTH DAKOTA 57069-2390
605-677-5227

Derric L. Iles, M.S.	State Geologist
Sarah A. Chadima, M.S.	Senior Geologist
Tim C. Cowman, M.N.S.	Natural Resources Administrator
Dragan Filipovic, M.S.	Senior Hydrologist
Ann R. Jensen, B.S.	Senior Geologist
Kelli A. McCormick, Ph.D.	Senior Geologist
Stan F. Pence, M.S.	Hydrology Specialist
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Dennis D. Iverson	Civil Engineering Technician
Gary Jensen	Civil Engineering Technician
Scott Jensen	Civil Engineering Technician
E. Thomas McCue	Natural Resources Technician
Colleen K. Odenbrett	Word Processing Supervisor
Lori L. Roinstad	Graphic Designer
Priscilla Young	Senior Secretary

RAPID CITY REGIONAL OFFICE

2050 WEST MAIN, SUITE 1
RAPID CITY, SOUTH DAKOTA 57702
605-394-2229

J. Foster Sawyer, M.S.	Hydrology Specialist
Mark D. Fahrenbach, Ph.D.	Senior Geologist

STATE OF SOUTH DAKOTA
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Derric L. Iles, State Geologist

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GEOLOGY OF AURORA AND JERAULD COUNTIES, SOUTH DAKOTA

by

LYNN S. HEDGES

Prepared in cooperation with the
James River Water Development District,
Aurora and Jerauld Counties, and
the U.S. Geological Survey

Science Center
University of South Dakota
Vermillion, South Dakota

2001

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ABSTRACT

Aurora and Jerauld Counties include an area of approximately 1,250 square miles in south-central South Dakota. Western portions of both counties lie in the Coteau du Missouri division of the Great Plains physiographic province. The eastern portions of both counties lie in the James Basin division of the Central Lowland physiographic province.

Precambrian granitic-type rocks underlie both counties. Precambrian Sioux Quartzite overlies the granitic-type rocks throughout most of Aurora County. Cretaceous sandstones, shales, and marls as much as 1,800 feet thick overlie the Precambrian rocks. Several isolated occurrences of greenish clay or sandstone of Tertiary age are present on the highest bedrock elevations.

Quaternary deposits consisting of glacial and nonglacial sediments as much as 500 feet thick are present in the Ancient White River Valley in southern Aurora County. Western-derived nonglacial sands and gravels are present along the course of the Ancient White River Valley and on the higher bedrock elevations in both counties. Glacial drift from one pre-Wisconsin and two late Wisconsin advances has been identified. The sediments of the two late Wisconsin advances are separated by lake deposits containing abundant woody material that has been radiocarbon dated at 12,180±360 years before present (B.P.), and remnants of a weakly-developed weathered horizon.

Although large reserves of water and sand and gravel are present, quality and distribution often hinder practical development of these resources. Current data support little likelihood for development of commercial deposits of metals or fossil fuel resources.

INTRODUCTION

This report contains the results of a study of the geology of Aurora and Jerauld Counties. It is part of a joint study conducted by the South Dakota Geological Survey and the U.S. Geological Survey to investigate the geology and water resources of the two counties. The purpose of the study is to determine the mineral and water resources available for future development, and to establish the basic geologic and hydrologic framework upon which future development and management decisions can be based. The location of Aurora and Jerauld Counties and the status of other county studies are shown on figure 1. This study was initiated at the request of the Aurora and Jerauld County Commissioners and funds were made available through the South Dakota Geological Survey, the U.S. Geological Survey, Aurora and Jerauld Counties, and the James River Water Development District.

The geology is reported in this publication. The hydrology has been published by the U.S. Geological Survey (Hamilton, 1985). All basic data compiled for this report are stored on computer at the U.S. Geological Survey District Office in Huron, South Dakota, or at the South Dakota Geological Survey office in Vermillion, South Dakota. Computer printouts of the basic data are available upon request.

Residents of Aurora and Jerauld Counties, the James River Water Development District, and the Boards of County Commissioners are acknowledged for their participation and cooperation throughout this project.

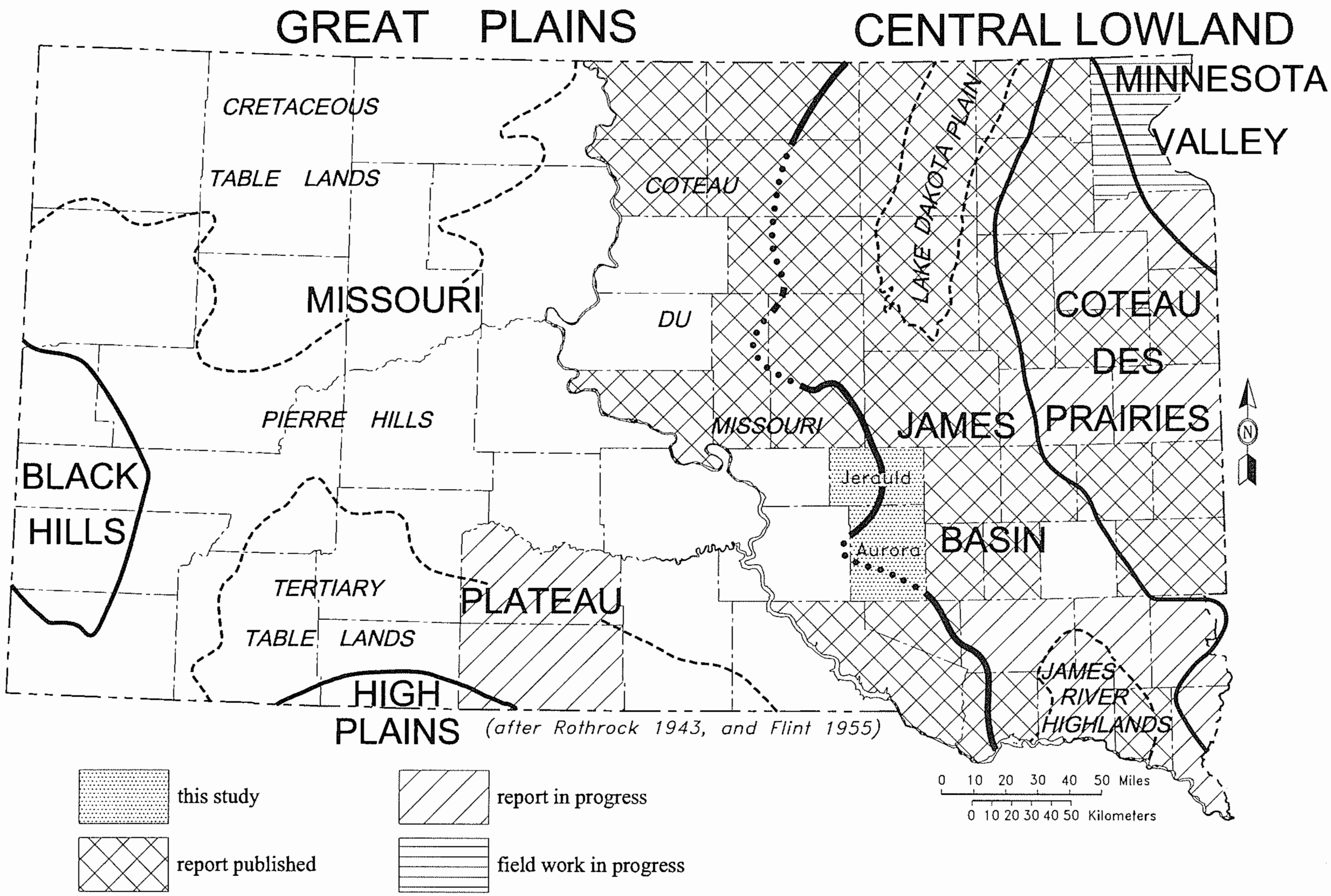

Figure 1. Map of South Dakota showing physiographic divisions and locations of county water resource studies.

PHYSIOGRAPHY

Aurora and Jerauld Counties include approximately 716 and 533 square miles, respectively, in south-central South Dakota. Western portions of both counties lie in the Coteau du Missouri division of the Great Plains physiographic province. Eastern portions of the counties lie in the James Basin division of the Central Lowland physiographic province (fig. 1).

The Coteau du Missouri is a highland with elevations ranging from about 1,600 feet in elevation in southeastern Aurora County to over 2,000 feet in elevation in western Jerauld County and northwestern Aurora County. Its eastern border through Jerauld County and northwestern Aurora County is marked by a bedrock-cored steep escarpment rising 300 to 400 feet above the James Basin. The steep escarpment is absent to the southeast through Aurora County.

Local relief on the Coteau du Missouri generally is between 50 and 100 feet, although it may exceed 150 feet. Local relief in the James Basin is generally less than 50 feet, although it may approach 100 feet. Local relief is controlled primarily by constructional features of the late Wisconsin glaciation and exhibits large undrained areas containing potholes, lakes, and sloughs dissected by meltwater channels.

Smith Creek and Crow Creek drain the Coteau du Missouri westward, joining the Missouri River a few miles south of Fort Thompson. Platte Creek drains a small portion of south-central Jerauld County and western Aurora County south-southwest to join the Missouri River in northwest Charles Mix County. In the James Basin, Sand Creek in northeastern Jerauld County and Firesteel Creek in Aurora and Jerauld Counties drain southeast and join the James River.

STRATIGRAPHY

Rocks in Aurora and Jerauld Counties range from Precambrian, dated at 2.5 billion years, to Holocene. They include Precambrian granite and quartzite rocks; Mesozoic shales and sandstones of late Cretaceous age; and Cenozoic nonmarine silts and sandstones of Tertiary age. The Quaternary includes Pleistocene nonglacial and glacial sediments, and Holocene sediments.

Precambrian

The Sioux Quartzite and older granitic rocks of Precambrian age underlie Aurora and Jerauld Counties. Where the Sioux Quartzite is present, it overlies the granitic rocks (fig. 2). Structure contours on the Precambrian surface show more than 600 feet of relief on its eroded surface (fig. 2). This relief is dominated by a Sioux Quartzite high in north-central Aurora County on the western extension of the Sioux Ridge (Darton, 1909).

Various types of granitic rocks have been reported in and around Aurora and Jerauld Counties. Regional studies indicate that these rocks represent several geologic provinces in the two-county area (fig. 2). Throughout South Dakota, basement-rock ages range from about 1.2 to 2.7 billion years, so the two dates shown on figure 2 fall within that time span. Some of the data used in the construction of figure 2 are taken from unpublished information provided by Dr. W.R. Van Schmus, Kansas University Center for

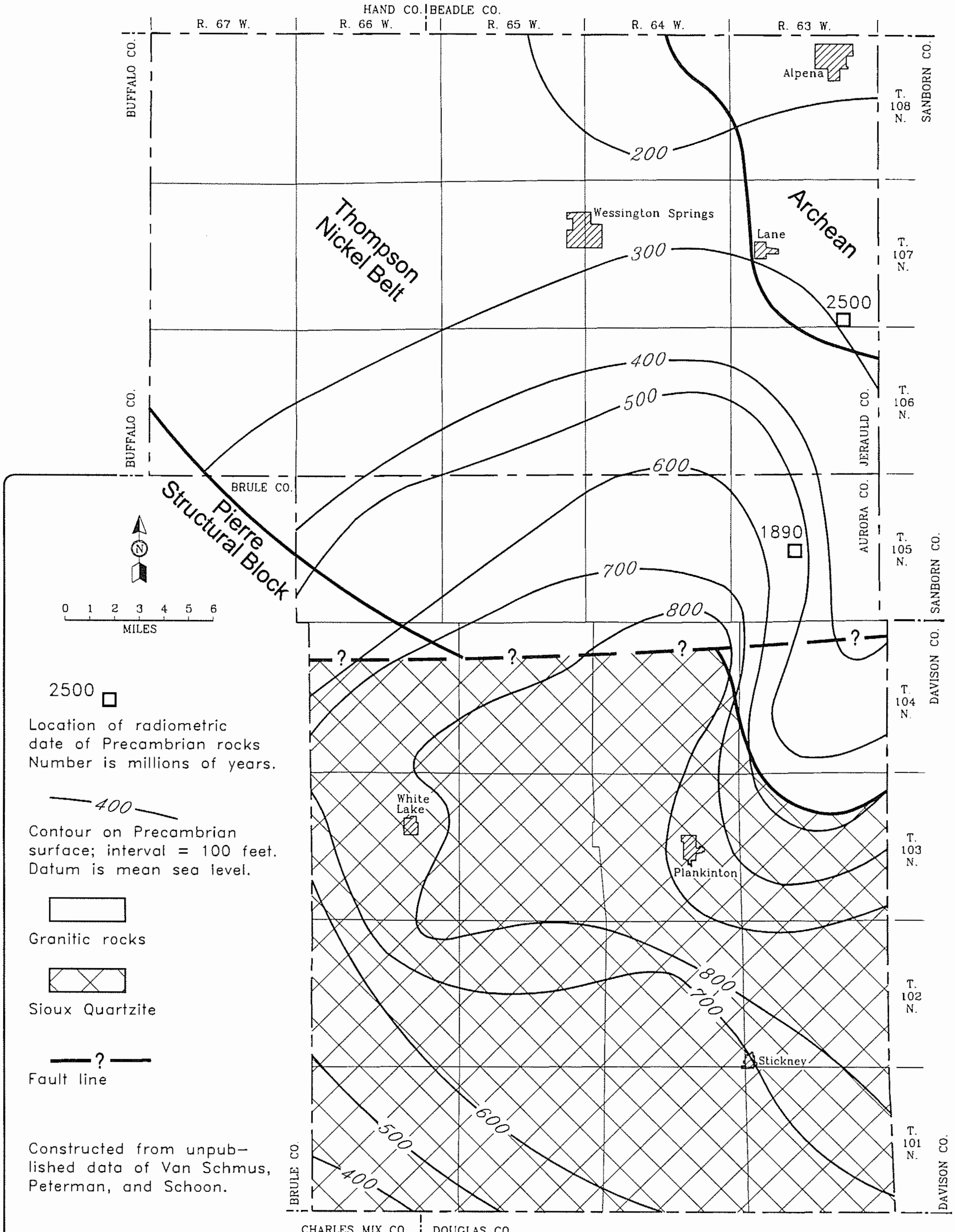

Figure 2. Structure contours on the upper contact of the Precambrian rocks.

Research, Lawrence, Kansas; Z.E. Peterman, U.S. Geological Survey, Denver, Colorado; and Robert Schoon, South Dakota Geological Survey, Vermillion, South Dakota.

Granitic rocks underlie Cretaceous sediments in Jerauld County and the northeastern portion of Aurora County (fig. 2). A test hole drilled to the Precambrian near Wessington Springs penetrated pink biotite granite at a depth of 1,665 feet. Depth to the Precambrian may be greater than 1,665 feet in western Jerauld County at higher land surface elevations.

The Sioux Quartzite in Aurora County is part of the Sioux Ridge which extends westward from southwestern Minnesota and northwestern Iowa to east-central South Dakota. It is part of the more extensive "Baraboo interval quartzite" (Dott, 1983) which is interpreted as braided fluvial deposits. The Sioux Quartzite is a hard, massive, light pink to red siliceous orthoquartzite. It may contain beds of red sericitic claystone commonly referred to as catlinite or pipestone. Thickness of the Sioux Quartzite is unknown, however, 3,800 feet were reported in an oil test in Charles Mix County (Bolin and Petsch, 1954). A map showing the approximate distribution of the Sioux Quartzite (fig. 2) indicates that it is not present in Jerauld County. In Aurora County the Sioux Quartzite is found at depths ranging from about 600 to 1,200 feet. However, 5 miles southeast of Mitchell in Davison County (Christensen, 1989), the Sioux Quartzite crops out along the James River. The age of the Sioux Quartzite has been estimated to range from about 1.2 to 1.7 billion years (Goldich and others, 1959).

Paleozoic

There are no known rocks of Paleozoic age in Aurora and Jerauld Counties (Hedges and others, 1982). This may be due to nondeposition on the Sioux Ridge, which has been a positive structural area since Precambrian time. Alternatively, if any Paleozoic sediments were deposited, they may have been eroded before Mesozoic deposition began.

Mesozoic

Mesozoic sediments in Aurora and Jerauld Counties are all of late Cretaceous age. They are, oldest to youngest, the Dakota Formation, Graneros Shale, Greenhorn Limestone, Carlile Shale (including the Codell Sandstone Member), Niobrara Formation, and the Pierre Shale. The stratigraphic nomenclature used in this discussion conforms to names applied to rock units in South Dakota as proposed by Agnew and Tychsen (1965).

Dakota Formation

The Dakota Formation consists of alternating beds of varicolored siltstone, friable to cemented sandstone, and shale. The Dakota Formation ranges in thickness from less than 100 feet, where it overlies the crest of the Sioux Quartzite ridge in central Aurora County, to over 500 feet in the northeastern corner of Jerauld County (fig. 3). In that part of Jerauld County and adjacent Beadle County where the Dakota Formation is 500 feet or more in thickness, some Cretaceous Inyan Kara Group sediments may be included with the Dakota Formation. Structure contours on top of the Dakota Formation show it gently dipping to the northwest at about 8 feet per mile (fig. 4) as compared to a northwesterly dip of about 31 feet per mile for the underlying Precambrian surface.

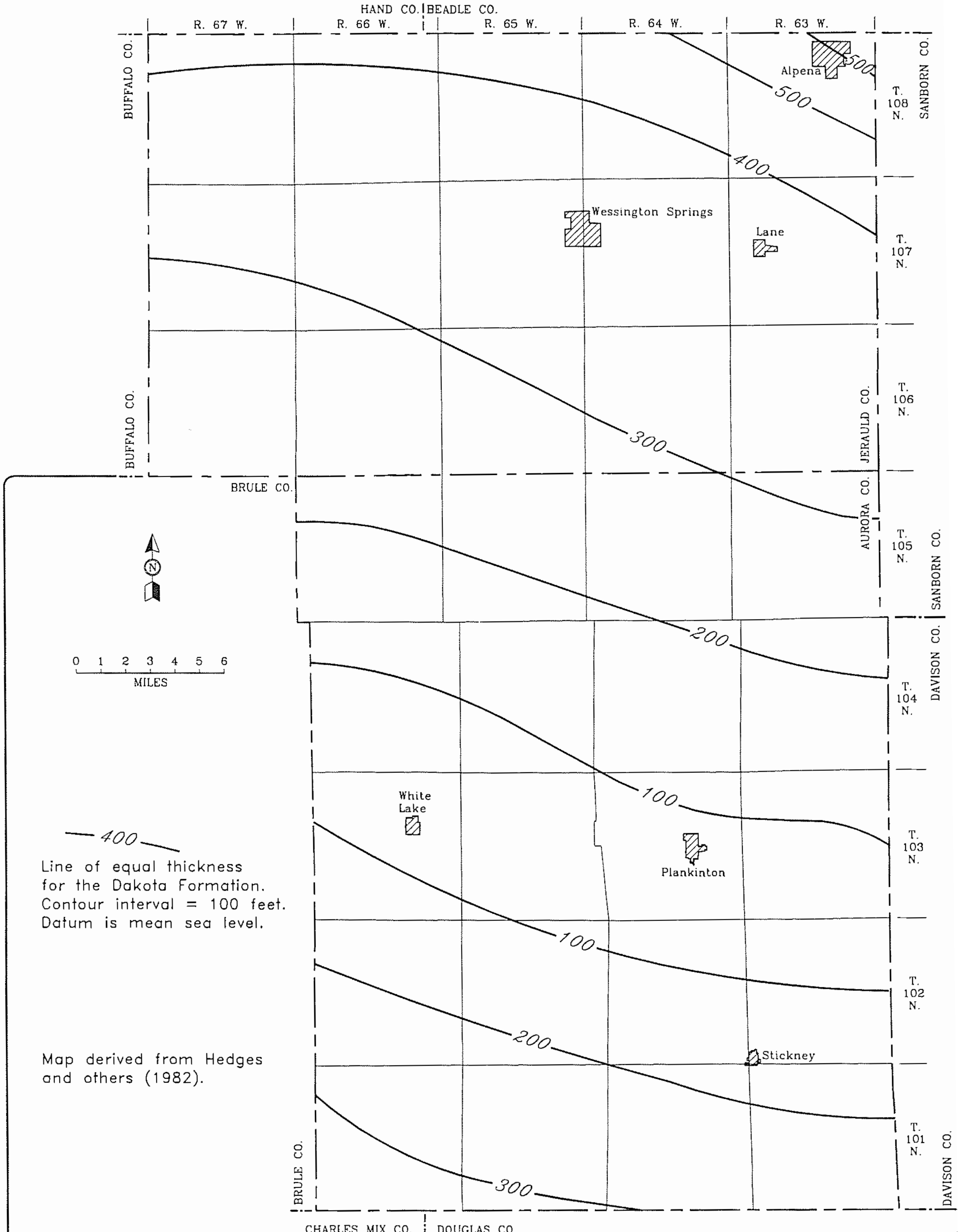

Figure 3. Thickness of the Dakota Formation.

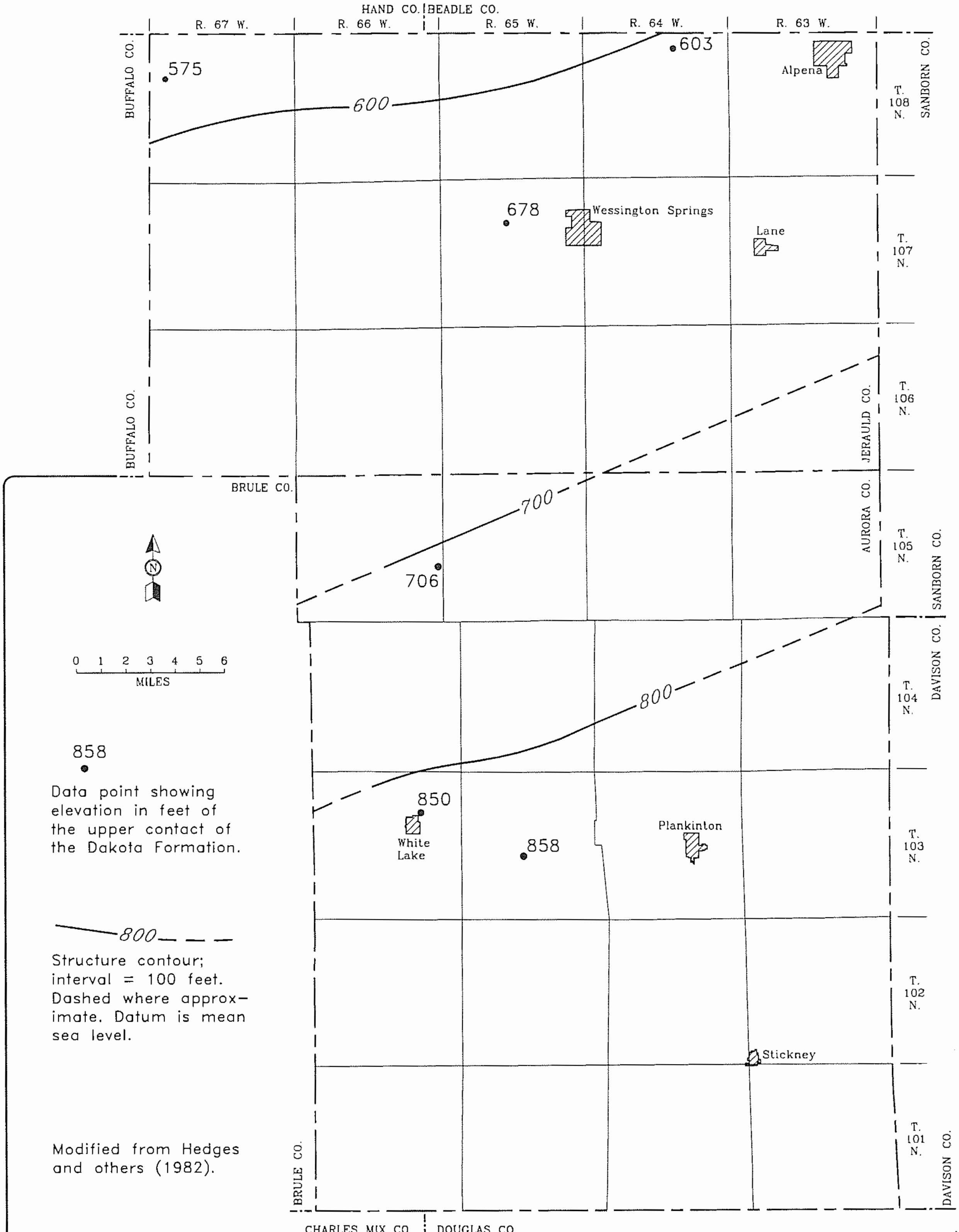

Figure 4. Structure contours on the upper contact of the Dakota Formation.

Graneros Shale

The Graneros Shale is a medium to dark gray, noncalcareous, silty shale. Thin sand stringers may be present throughout the section but are more common near the base. Thickness of the Graneros Shale is variable, ranging from about 130 feet to a maximum of about 335 feet. The thicker portions within the study area are in northwestern Jerauld County and southwestern Aurora County.

Greenhorn Limestone

The Greenhorn Limestone is composed of gray marine marl and white speckled fragmental limestone dominated by the fossil *Inoceramus*. The hard fragmental limestone serves as a good marker bed in the Cretaceous sequence throughout most of South Dakota. It is generally quite distinctive in drill cuttings and has a characteristic "kick" on geophysical logs. Thickness of the Greenhorn Limestone in Aurora and Jerauld Counties is quite uniform, averaging about 60 feet.

A structure contour map depicting the upper surface of the Greenhorn Limestone is shown on figure 5. It shows a northerly dip of about 6 feet per mile or a total of 300 feet from White Lake, in west-central Aurora County, to the northeastern part of Jerauld County.

Carlile Shale

The Carlile Shale is a gray to black, noncalcareous, silty, marine shale found throughout the two-county area. It is variable in thickness, ranging from about 100 to 225 feet, including the Codell Sandstone Member.

The Codell Sandstone Member is a fine- to medium-grained friable sand or sandstone. It is varicolored including shades of green, brown, gray, and yellow. The Codell Sandstone Member is generally located stratigraphically in the upper portion of the Carlile Shale, either in contact with the overlying Niobrara Formation, or several feet below the Niobrara Formation-Carlile Shale contact. The Codell Sandstone Member is present in about the eastern two-thirds of the two-county area (fig. 6) and has a general range in thickness of 30 to 70 feet, although as much as 120 feet have been reported in the southeastern corner of Aurora County. In general, the Codell Sandstone Member thins to the west.

The Codell Sandstone Member is not exposed in Aurora or Jerauld Counties, however, excellent outcrops of Codell Sandstone Member are present a few miles east of the Aurora-Davison County line along Firesteel Creek (Christensen, 1989). The Carlile Shale is present directly underlying the glacial drift in northeastern Aurora County and in the Ancient White River Valley (pl. 1). A test hole located in SE SE SE SE sec. 16, T. 102 N., R. 65 W. penetrated the Codell Sandstone Member of the Carlile Shale. This occurrence suggests that the Codell Sandstone Member may subcrop more extensively below the Quaternary deposits in the Ancient White River Valley. Other test holes penetrating the Carlile Shale in the subcrop area encountered black shale.

Niobrara Formation

The Niobrara Formation underlies the entire two-county area except for a small portion of east-central Aurora County and in the Ancient White River Valley (fig. 7) where it has been completely eroded to

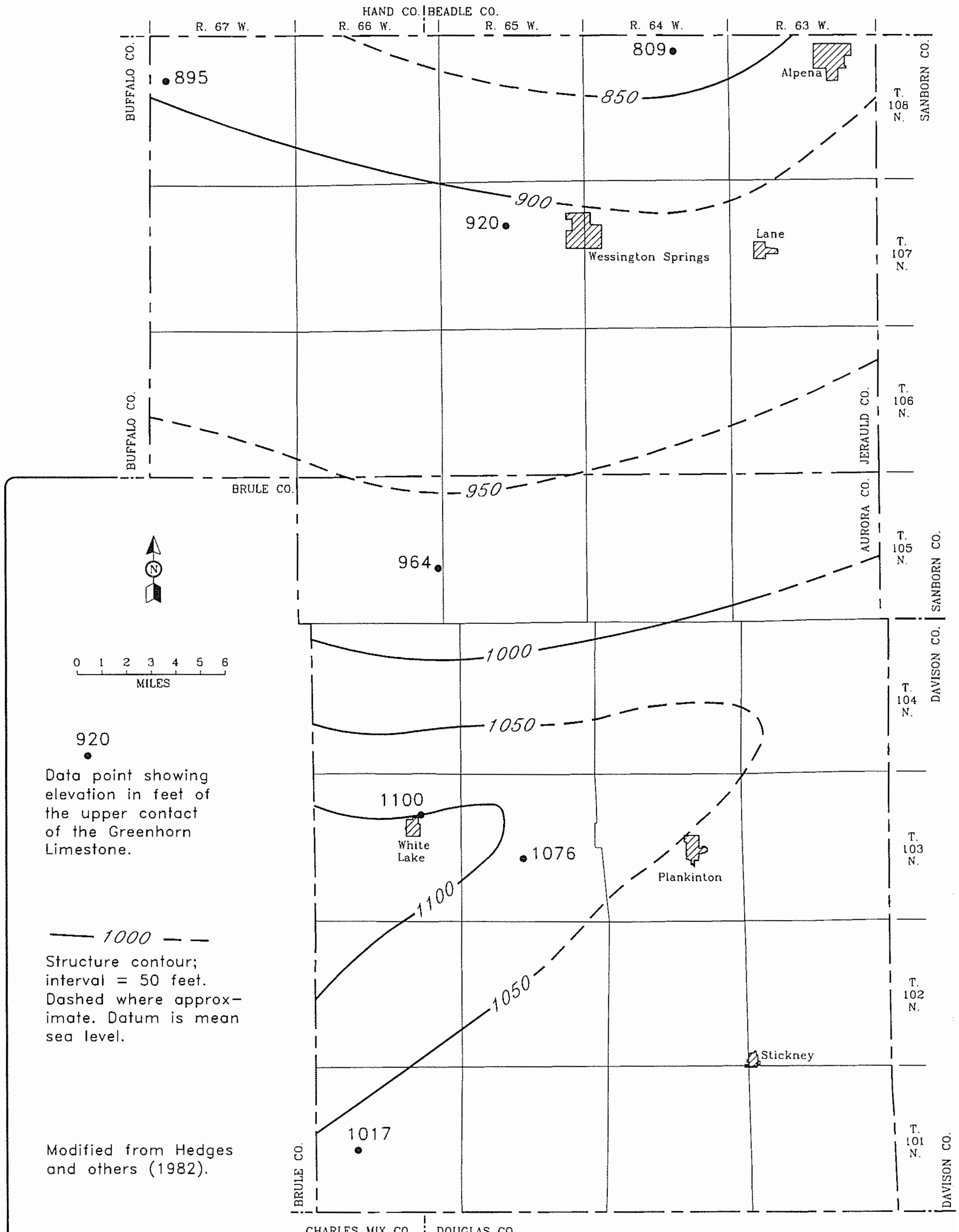

Figure 5. Structure contours on the upper contact of the Greenhorn Limestone.

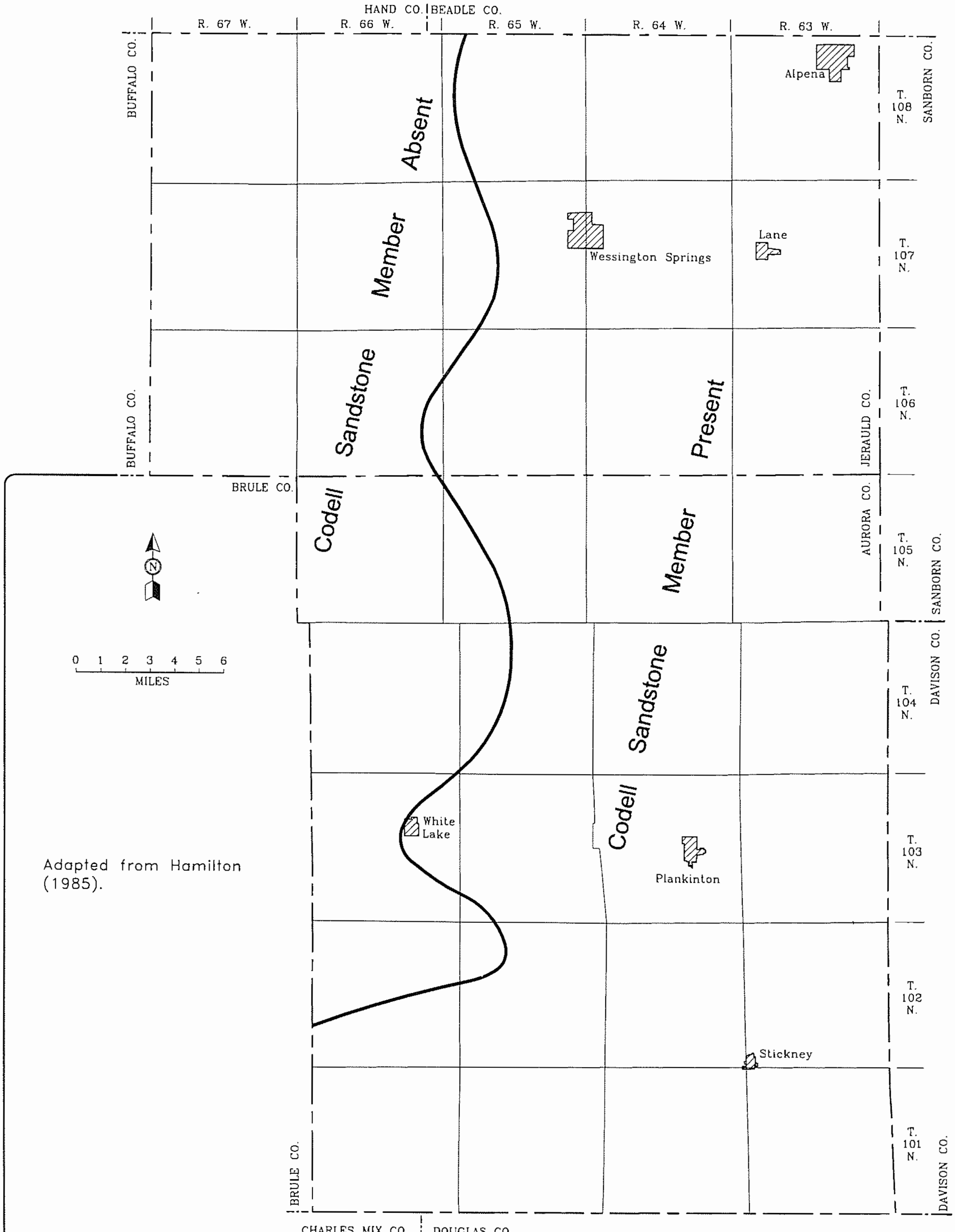

Figure 6. Distribution of the Codell Sandstone Member of the Carlile Shale.

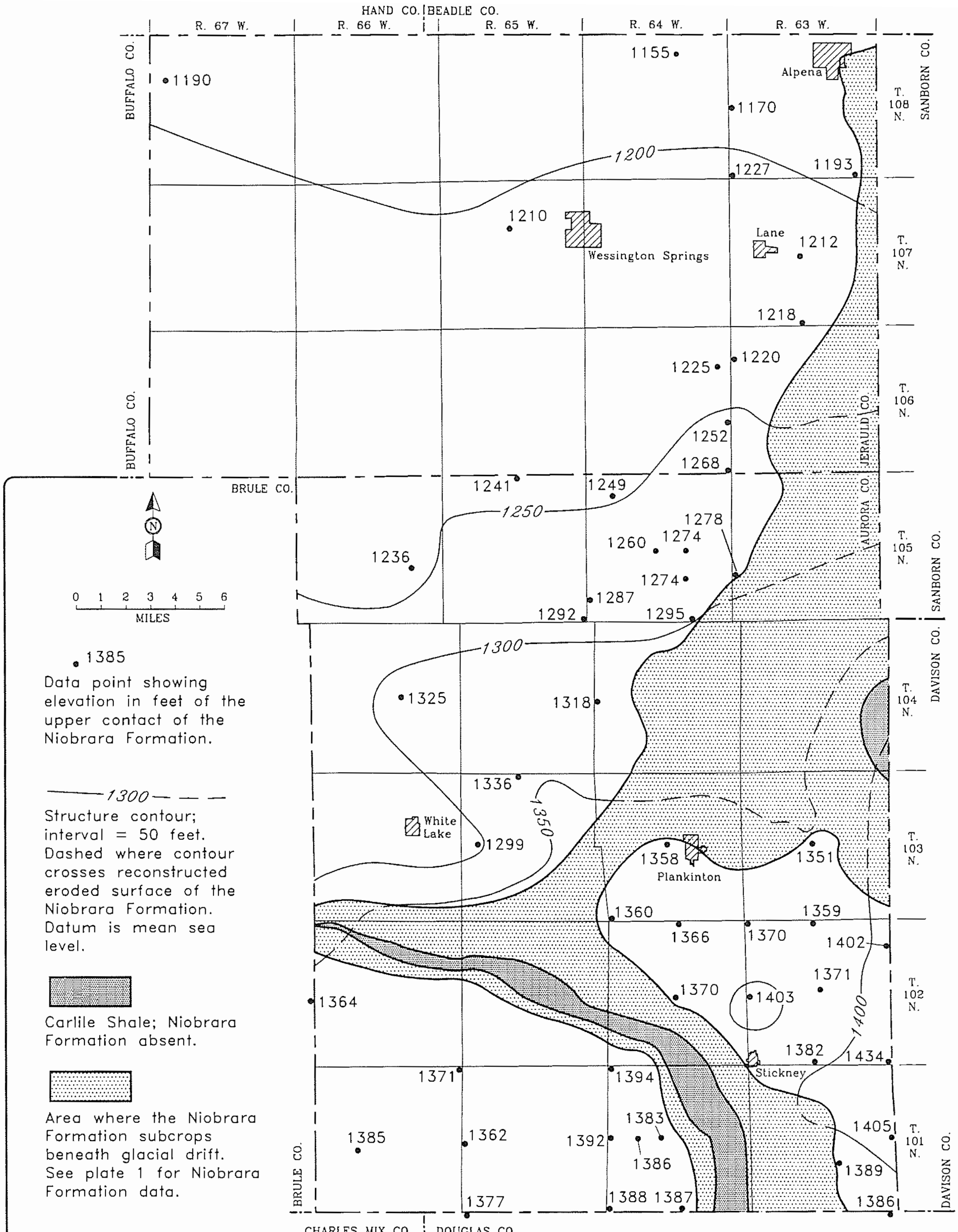

Figure 7. Structure contours on the upper contact and subcrop distribution of the Niobrara Formation.

expose the underlying Carlile Shale. Thickness of the Niobrara Formation is quite uniform at about 110 feet. The upper Niobrara Formation, which comprises about two-thirds of the sediments, is a medium- to dark-gray, speckled, brittle, calcareous, chalk-like material. The lower one-third of the Niobrara Formation is a white to light gray, soft, gritty, marl.

A test hole in northwestern Aurora County located in NW NW NW NW sec. 3, T. 105 N., R. 65 W. reported 144 feet of Niobrara Formation which is about 40 feet more than is generally encountered throughout the remainder of study area. This increased thickness is represented by a 40-foot thick basal unit consisting of interbedded gray marls and noncalcareous shales. Due to lack of subsurface information in northwestern Aurora County and the western half of Jerauld County, the extent and significance of this basal zone are unknown. A structural map with contours representing the top of the Niobrara Formation (fig. 7) shows a nearly uniform northerly dip of about 7 feet per mile across the study area.

Pierre Shale

The Pierre Shale underlies most of Jerauld County and about 60 percent of Aurora County (pl. 1). Where it is absent, it has been stripped by a combination of subareal and glacial erosion. The Pierre Shale has been divided into eight members (Crandell, 1958) around Pierre, South Dakota, where it crops out extensively along and west of the Missouri River. The Pierre Shale does not crop out in Aurora County and only sparingly in Jerauld County along the escarpment of the Coteau du Missouri, and in the west-central portion of the county (pl. 2). Due to lack of outcrops, detailed mapping of the Pierre Shale was not attempted for this study. In general, the Pierre Shale consists of light-gray to black shale. Some members may contain iron and manganese concretions, limestone, bentonite, marl, or black organic shale. Maximum thickness of Pierre Shale in Aurora and Jerauld Counties is about 700 feet and probably includes all members. Maximum thicknesses are present in northwestern Aurora County, near Wessington Springs, and the northwestern part of Jerauld County where the bedrock surface elevations are about 1,900 feet (pl. 1).

Numerous test holes penetrating the basal portion of the Pierre Shale and upper Niobrara Formation throughout eastern Jerauld and most of Aurora Counties showed two consistent lithologic units at the base of the Pierre Shale. The lowermost of these units at the Niobrara Formation-Pierre Shale contact is a black, blocky, organic shale with numerous bentonite beds and is 10 to 20 feet thick. Overlying this unit is a white to gray, gritty, soft marl 20 to 40 feet thick. These units may correlate with the Sharon Springs and Gregory Members of the Pierre Shale, respectively. The marl unit is very similar to the basal portion of the Niobrara Formation and can be easily confused with that unit where good stratigraphic control is unavailable.

Cenozoic

Cenozoic sediments in the Aurora-Jerauld County area consist of Tertiary age continental deposits containing vertebrate fauna of probable Pliocene age; Quaternary age deposits of western-derived sand and gravel alluvial deposits of Plio-Pleistocene age; pre-Wisconsin and late Wisconsin glacial deposits; and Holocene alluvium and colluvium associated with slopes and drainages.

Tertiary

Several isolated outcrops of Tertiary age sediments in Jerauld County are described by Steece (1967a). These outcrops are located along the Coteau du Missouri escarpment just west of the town of Wessington Springs (pl. 2). The exposed sediments consist of buff to tan massive-bedded silt and green conglomeratic sandstone. The massive-bedded silt contains vertebrate fossils which suggest that these sediments are correlative with the Pliocene Valentine Formation of south-central South Dakota (Green, 1965). The maximum observed thickness of these sediments is 15 feet (Steece, 1967a). Because the lower contact of the sediments could not be determined, the total thickness of Tertiary sediments in this general area is unknown.

Another location in Jerauld County where Tertiary sediments were tentatively identified is from a test hole at NW NE NW NW sec. 12, T. 108 N., R. 67 W. in which 29 feet of tan to green very fine sand was penetrated. The top of the sand was encountered at a depth of 134 feet and an elevation of about 1,906 feet.

A test hole in NE NW NW NW sec. 20, T. 105 N., R. 66 W. in northwestern Aurora County contains a light-green sandy clay at a depth of 62 to 74 feet. The clay is underlain by weathered shale and overlain by a nonglacial gravel of probable western origin. Because of its lithology, stratigraphic position, and elevation (1,878 feet), it is likely that this clay is Tertiary in age and may be correlative to the Tertiary sediments previously described in Jerauld County. The highland area in northwestern Aurora County in T. 105 N., R. 66 W. is the only bedrock area that is topographically high enough to expect remnants of Tertiary sediments in Aurora County.

Quaternary

Quaternary sediments in Aurora and Jerauld Counties consist of Pleistocene western-derived nonglacial alluvium, glacial deposits, loess, and Holocene alluvium and colluvium. Collectively, these sediments exceed 500 feet in thickness and comprise all the surficial sediments in Aurora and Jerauld Counties with the exception of several isolated outcrops of Mesozoic Pierre Shale and the Valentine Formation of Tertiary age.

At the beginning of the Quaternary, the landscape of the two-county area was much different from that of today. At that time Pierre Shale was the predominant sediment at the land surface with less extensive areas of the Valentine Formation capping the higher elevations. An unknown, but generally eastward-flowing drainage system was present several hundred feet higher than today's land surface. Eventually, the downcutting streams established a drainage system in southern Aurora County now recognized as the eastward extension of the present White River west of the Missouri River (Flint, 1955). This ancient valley and its western-derived sediments, subsequently buried by late Wisconsin glacial sediments, are referred to as the Ancient White River Valley on plate 1.

NONGLACIAL ALLUVIUM

The nonglacial alluvial sediments in Aurora and Jerauld Counties consist of Plio-Pleistocene age, western-derived, fluvial sand and gravel deposits. These sediments are identified as western-derived by: a high content of quartz and/or feldspar; the absence of shale, concretionary fragments, and other rock types normally associated with glacial outwash; and by the presence of occasional fossil mammal bone fragments. For this report, the nonglacial alluvium has been categorized into three occurrence types based on elevation: high-level alluvium, low-level alluvium, and the Wagner Formation.

High-Level Alluvium

Three occurrences of high-level western-derived sand and gravel deposits are present in northwestern Aurora and Jerauld Counties. The base of these sediments occurs at elevations of 1,848, 1,862, and 1,916 feet (fig. 8) and are remnants of an undefined western drainage system that predates the down-cutting that created the Ancient White River Valley as shown on plate 1. All known occurrences are identified from test hole cuttings. A search of the adjacent highlands and slopes failed to locate any outcrops containing lithologically similar sediments.

No dateable material has been found associated with the high-level deposits in Aurora and Jerauld Counties, however, there is no reason to believe that they differ in general age range from lithologically similar deposits in other areas of eastern South Dakota (Christensen and Stephens, 1967; Christensen 1974; and Hedges, 1975, 1987). Based on mammal fossil remains, these deposits have been variously dated as late Pliocene to late Kansan. Positive age determinations are unavailable because of lack of diagnostic fossil material for dating, and lack of other dateable stratigraphic units bracketing these deposits.

Low-Level Alluvium

Low-level western-derived sand and gravel deposits are located mostly in southeastern Aurora County. Elevations at the base of these sediments range from 1,272 to 1,557 feet (fig. 8). These deposits are located along or near the course of the Ancient White River Valley (pl. 1) and may represent earlier downcutting episodes of the Ancient White River (cross sections F and G, pl. 3). No glacial deposits have been found underlying either the high- or low-level nonglacial alluvium.

Wagner Formation

Western-derived, nonglacial, alluvial sand and gravel deposits are the basal deposits in the floor of the Ancient White River Valley (pl. 1). They occur in the deeper portions of the bedrock valley at elevations as low as 1,113 feet (fig. 8). These deposits are lithologically similar to the low- and high-level deposits previously described, thus providing evidence of their western origin. No dateable material has been recovered from these sediments.

A comparison of the bedrock topography from the present study (pl. 1) with the bedrock topography from Charles Mix and Douglas Counties (Hedges, 1975) shows that the Ancient White River Valley in Aurora County is a northwestern extension of the Corsica Channel in Douglas County. The Corsica Channel and related deep bedrock valleys in Charles Mix and Douglas Counties also contain a western-derived alluvial deposit lithologically similar to the one in Aurora County. Thus, it seems likely that the western-derived alluvium occupying the valley in Aurora County is an extension of the Charles Mix County sediments. In Charles Mix and Douglas Counties, this deposit was described and named the Wagner Formation by Hedges (1975). The age of the Wagner Formation is uncertain. In Charles Mix and Douglas Counties, the formation stratigraphically overlies till that was indirectly dated as no older than late Kansan, and underlies one pre-late Wisconsin till (Hedges, 1975). However, neither of these till ages has been confirmed. The current study has not produced any evidence to help clarify this age determination. Based

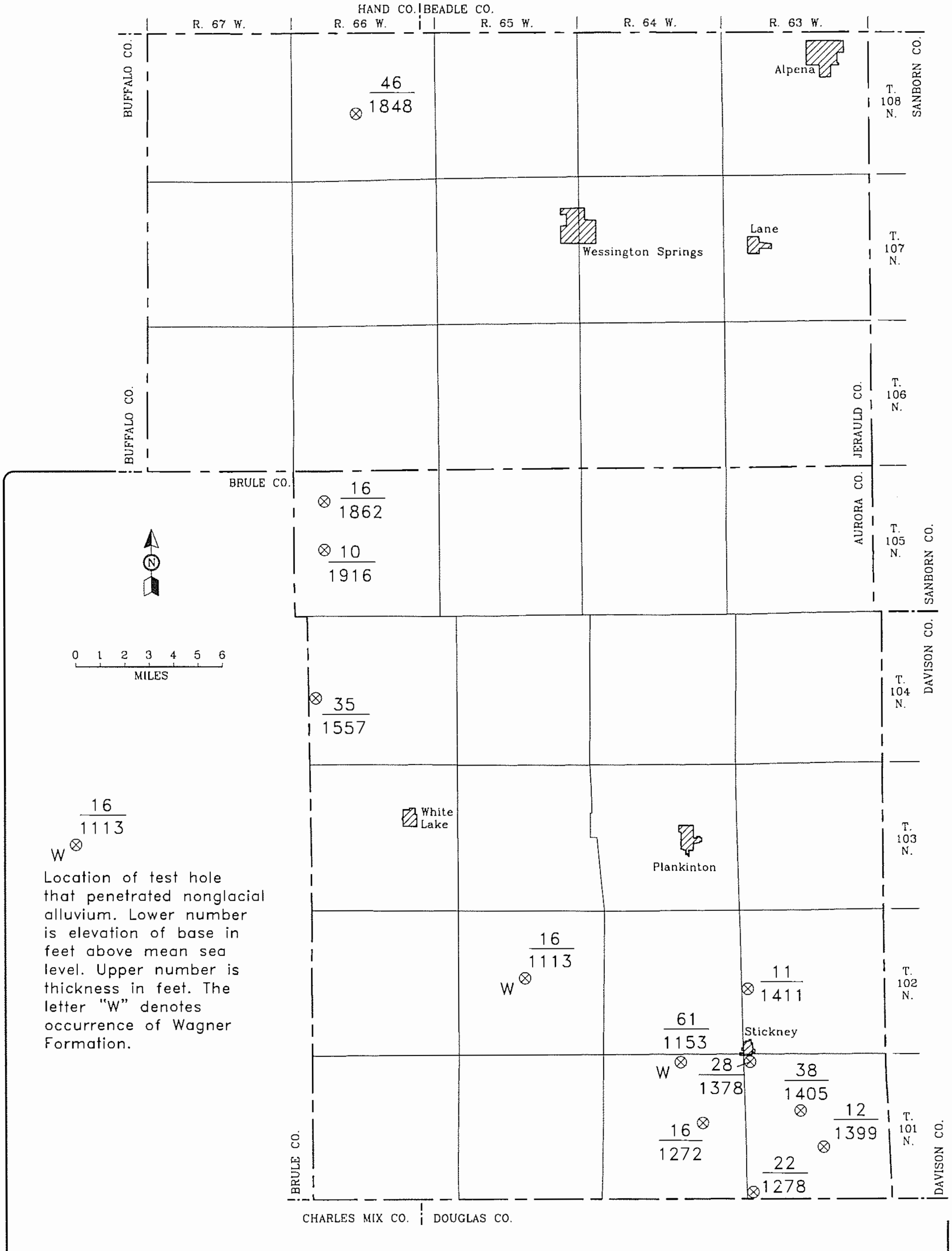

Figure 8. Location, elevation, and thickness of nonglacial alluvium.

on geomorphic development and the presence of till underlying the Wagner Formation in Charles Mix and Douglas Counties, there is little doubt that the Wagner Formation is substantially younger than both the high- and low-level western-derived alluvium.

On figure 8 the highest elevation at the base of the high-level deposit is 1,916 feet while the lowest elevation at the base of the Wagner Formation is 1,113 feet. Thus, there has been mass stripping of the landscape by erosion and an inversion of topography amounting to at least 800 feet between deposition of the two sediments.

PLEISTOCENE GLACIAL DEPOSITS

Three glacial advances have been identified in the Aurora-Jerauld County area including a pre-Wisconsin advance and two late Wisconsin advances. For this report glacial drift deposited from the late Wisconsin advances will be referred to as, from oldest to youngest, drift B and drift A.

Figure 9 shows the thickness of the Quaternary deposits. Pleistocene tills comprise the bulk of the Quaternary deposits although locally Pleistocene outwash or lake deposits may be significant. The Quaternary deposits may also include Plio-Pleistocene western-derived fluvial sand and gravel deposits and Holocene alluvium and colluvium.

Plate 1 is a contour map of the bedrock surface. Comparison of figure 9 and plate 1 shows that, in general, the glacial deposits are as much as 500 feet thick along the course of the Ancient White River Valley in southern Aurora County, and as much as 310 feet thick in the bedrock channel in southwestern Jerauld County. On the upland divides glacial deposits generally range from 50 to 100 feet in thickness.

Pre-Wisconsin Deposits

Pre-Wisconsin glacial deposits consisting of till, outwash, and loess of unknown age are located on the Coteau du Missouri portions of Aurora and Jerauld Counties.

Till

Till of probable pre-Wisconsin age has been identified in drill holes in Aurora and Jerauld Counties. The locations in Jerauld County are SE SE SE SE sec. 29, T. 108 N., R. 66 W. and NW NW NW NW sec. 28, T. 106 N., R. 67 W.; and in Aurora County NW NW NW NW sec. 30, T. 104 N., R. 66 W. These occurrences are located on or near the bedrock highlands located in the northwestern part of each county (pl. 1). These high topographic settings would be likely areas for preservation because subsequent modification by glacial activity has been less here than in the lower topographic areas. In these areas some pre-Wisconsin till may be included with late Wisconsin till B on the stratigraphic cross sections (pl. 3).

The pre-Wisconsin till ranges from 11 to 65 feet in thickness. The oxidized till is tan to yellow-brown pebbly clay and the unoxidized portions are a pebbly gray clay. The limited samples from the three test holes did not exhibit any lithologic characteristics that would distinguish it from the younger overlying till of drift B.

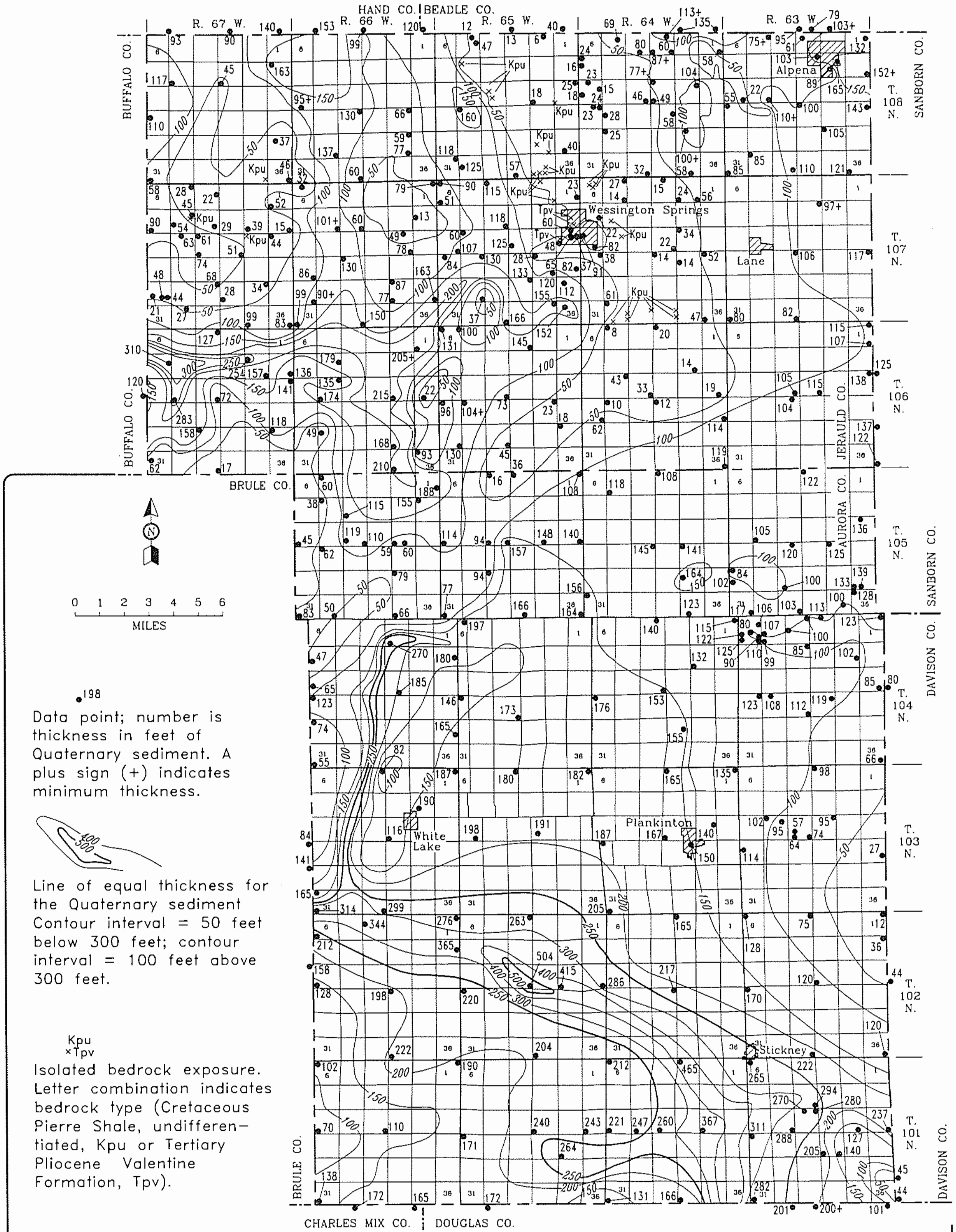

Figure 9. Thickness of Quaternary sediments.

Stratigraphically, the pre-Wisconsin till underlies the older of two late Wisconsin tills. It is identified in drill holes by the presence of an upper oxidized zone underlying unweathered till. Areally, the location of the pre-Wisconsin till lies outside the maximum extent of the youngest late Wisconsin glacial advance that deposited drift A (fig. 10), but is buried by the older late Wisconsin till of drift B. Thus, it must represent a third till in the two-county area. Steece (1967a) also recognized at least three tills in Jerauld County. The oldest till identified by Steece was thought to be pre-Wisconsin and probably Illinoian in age. This is likely the same till identified as pre-Wisconsin in this report. Since there are no documented occurrences of an early Wisconsin till, that is, older than about 25,000 B.P., in the Coteau du Missouri area of South Dakota, it is likely that the older till is pre-Wisconsin in age. Unfortunately, there are no radiocarbon dates or other evidence available that would be helpful in documenting the age of the pre-Wisconsin till.

Hedges (1975) and Christensen (1974) have tentatively identified pre-Wisconsin tills in Charles Mix and Bon Homme Counties, south of the study area. However, several counties in the James Basin and Coteau du Missouri north of Aurora and Jerauld Counties have been mapped and drilled in detail and there were no pre-Wisconsin glacial deposits reported in any of these studies (Brown County, Leap, 1986; Campbell County, Hedges, 1972; Walworth County, Hedges, 1987; McPherson, Edmunds, and Faulk Counties, Christensen, 1977; and Hyde and Hand Counties, Helgerson and Duchossois, 1987). Thus, if in the future this till in Jerauld County is determined to be pre-Wisconsin in age, it would be the northernmost known occurrence of this age till in South Dakota west of the Coteau des Prairies.

Outwash

Pre-Wisconsin outwash has been identified in three locations in T. 106 N. where outwash was penetrated stratigraphically lower than the buried weathered horizon underlying drift B. At many other locations outwash has been penetrated underlying drift B; however, without the weathered horizon serving as a stratigraphic marker and because there are no easily identifiable lithologic differences between the late Wisconsin and pre-Wisconsin outwash, it is uncertain whether these outwash deposits are late Wisconsin or pre-Wisconsin in age. Pre-Wisconsin outwash could also be present in the deep bedrock valleys, however, none has been identified.

Loess

Pre-Wisconsin loess has been tentatively identified in test holes at the same three locations in T. 106 N. (fig. 11) where pre-Wisconsin outwash was identified in the preceding section of this report. The loess is composed of silt or clayey silt and ranges from 9 to 18 feet in thickness. The entire thickness is weathered buff to reddish brown except in the SW corner sec. 26, T. 106 N., R. 66 W., where the loess is 18 feet thick and only the upper 13 feet appear to be weathered. Stratigraphically, the loess underlies unweathered till of drift B which is the oldest late Wisconsin drift identified during this study, and it overlies the older pre-Wisconsin till or outwash. The presence of the weathered loess serves as a stratigraphic marker and is a further indication of the existence of a pre-Wisconsin till in the area.

Late Wisconsin Deposits

Late Wisconsin deposits include till, outwash, and lake deposits as much as 500 feet thick and cover all of Aurora and Jerauld Counties except for isolated outcrops of Cretaceous shales and Tertiary fluvial

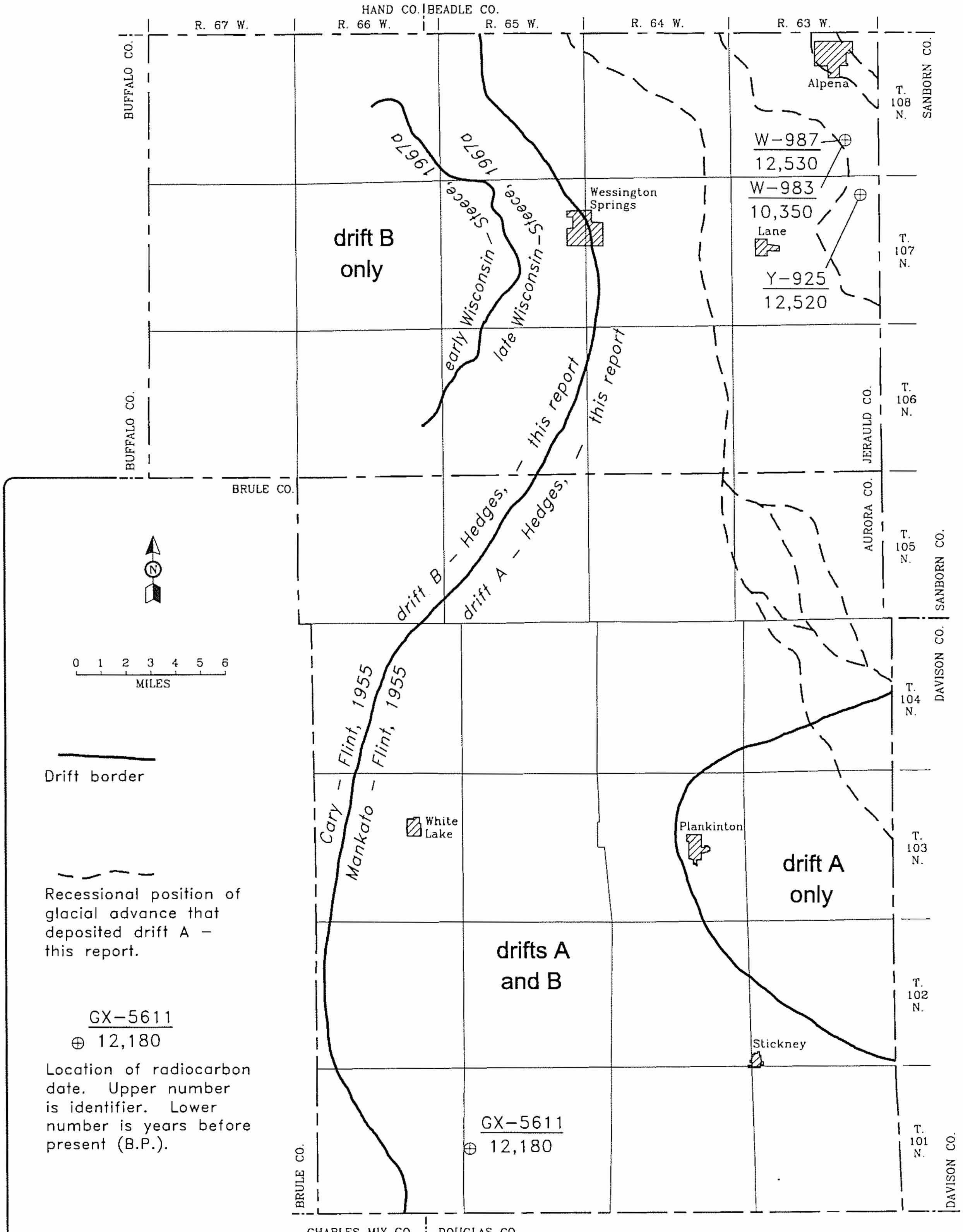

Figure 10. Occurrence of drifts A and B, radiocarbon dates, and recessional positions of drift A.

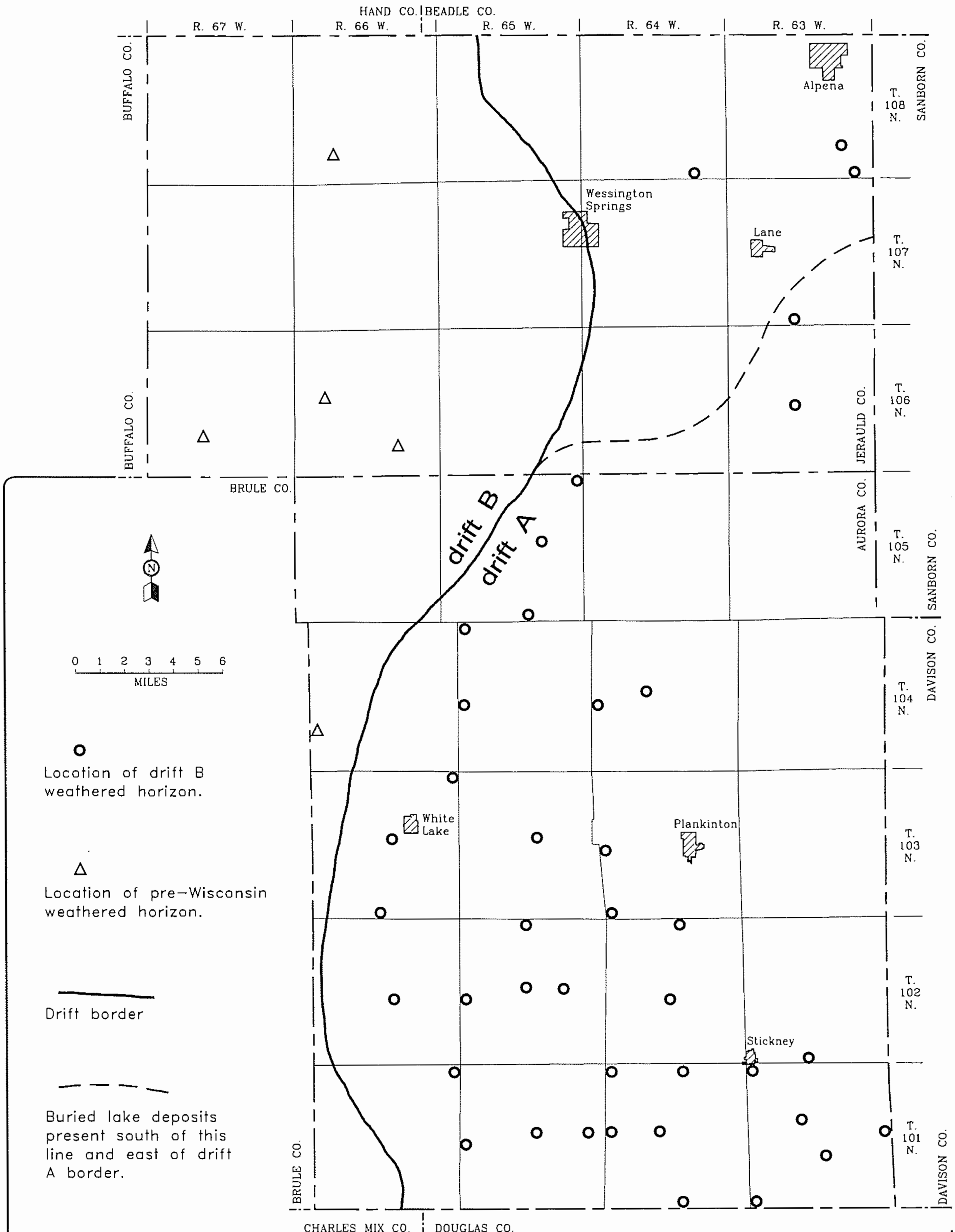

Figure 11. Occurrence of buried weathered horizons and extent of buried lake deposits.

sediments. Two late Wisconsin glacial advances have been identified in Aurora and Jerauld Counties. For this report the resulting glacial deposits are referred to as drifts A and B. During the interstadial period between the two late Wisconsin advances, a weakly weathered horizon developed on the older drift B surface and extensive lake sediments were deposited. The extent of various late Wisconsin ice advances is shown on figure 10. The tills associated with drifts A and B are referred to as till A and till B, respectively. The stratigraphic relationship of the tills and associated deposits is shown on the stratigraphic cross sections (pl. 3).

Till

Unweathered portions of tills A and B are dark gray to olive gray, clay rich, and calcareous. The upper weathered portions are buff-colored to various shades of yellow-brown to olive-brown and are generally 20 to 30 feet thick. Although no lithologic analyses are available from these two tills, field examination of many drill hole cuttings and outcrops revealed no obvious lithologic differences that could be used to differentiate the two tills. Geomorphic expression and inter-till features are used to differentiate tills A and B.

Till B, the older of the two tills, covers all of Aurora and Jerauld Counties with the possible exception of a small area in east-central Aurora County (fig. 10). The apparent lack of drift B in this area is likely the result of both subareal and glacial erosion rather than nondeposition. This is consistent with findings in adjacent Davison County where only one late Wisconsin drift has been identified (Christensen, 1989).

Till A is the surface material over most of Aurora County and the eastern one-half of Jerauld County (fig. 10). The lithologic similarity of till A and till B makes them difficult to differentiate in drill-hole cuttings. The occurrence of glacial lake sediments (described later) between the two tills, a weakly weathered zone on till B, and other sediments underlying till A often provide a good marker zone for distinguishing the two tills in the subsurface.

During test drilling, wood fragments were commonly found near or at the base of drift A, or enclosed within the lake sediments separating drift A and B. Samples of this wood were collected from a test hole in southwestern Aurora County (fig. 10, sample GX5611, and test hole 87 in stratigraphic cross section G-G'; pl. 3) and yielded a radiocarbon age of 12,180 years B.P. This date corresponds closely with two additional dates in northeastern Jerauld County (fig. 10) of 12,530±350 years B.P. (W-987) and 12,520±100 years B.P. (Y-925) from within or at the base of drift A. Date W-983, 10,350±300 years B.P., is from wood collected from the same location and depth as W-987. There is no apparent reason for the different reported dates. Three other nearby radiocarbon dates on wood from drift that is correlated with drift A (W-1372 in Beadle County, W-1757 in Sanborn County, and W-1756 in Davison County) yielded dates between 12,200 years B.P. and 12,680 B.P. Thus, the age of drift A in this part of South Dakota appears to be 12,000 to 13,000 years B.P.

A short interstadial period between the ice advances that deposited drifts A and B is documented by a thin weathered zone recognized at the surface of drift B and other deposits in the subsurface. The weathered zone is marked by the occurrence of light olive-gray to yellowish-brown sediments recovered from drill cuttings. As shown on stratigraphic cross sections D-D' through F-F' (pl. 3), and distribution of weathered horizons (fig. 11), numerous test holes penetrated this weathered horizon. Thickness of the weathered zone could not be precisely determined but it is thought to be generally less than 10 feet thick.

Drift B underlies drift A and thus is older than about 13,000 radiocarbon years. While there are no radiocarbon dates available to document a maximum age, the youthful topography of the drift where it occurs at the surface and the thin weakly-weathered horizon where it is buried suggests that it is also a relatively young deposit. Drift B may correspond in age to the Toronto till on the Coteau des Prairies which has numerous radiocarbon dates ranging from about 20,000 to 30,000 years B.P. (Gilbertson and Lehr, 1989).

The drift A boundary in Aurora and Jerauld Counties (fig. 10) likely extends south through Charles Mix (Hedges, 1975) and Bon Homme Counties (Christensen, 1974) to the Missouri River and essentially matches the western boundary of the Mankato drift of Flint (1955). Thus, that part of the James lobe drift from southern Beadle County southward to the Missouri River is younger than 13,000 years B.P.

Extensive drilling and mapping in Beadle County (Hedges, 1968) and those counties to the northwest in the James Basin and on the Coteau du Missouri have failed to yield any evidence of a short period of deglaciation during the late Wisconsin (Christensen, 1977; Leap, 1986; Hedges, 1972 and 1987; and Helgerson and Duchossois, 1987). In Davison County, located more centrally in the James lobe, wood found at the contact of the surface till and Cretaceous bedrock had a radiocarbon age of 12,340 years B.P. (Christensen, 1989) and thus is equivalent to till A of this report. At this location the combination of meltwater and glacial erosion likely removed all previously existing Pleistocene deposits. These same conditions may account for the absence of interstadial evidence throughout much of the central James lobe where effects of erosion by meltwater and the subsequent glacial advance likely were greatest. Alternatively, areas to the north may not have been completely deglaciated during this time, although this explanation is less likely.

Steece (1967a) identifies one early and one late Wisconsin till, and one pre-Wisconsin till in Jerauld County. Flint (1955) identified the early Wisconsin till as a probable equivalent of the Tazewell. Drift B of this report and the early Wisconsin of Steece (1967a) are probably equivalent.

Steece's (1967a) boundary between early and late Wisconsin drift in Jerauld County is shown on figure 10. The evidence cited for this interpretation is based on geomorphic features, loess distribution, and stratigraphic evidence. Similar geomorphic evidence and loess distribution relationships between two drifts have been found in other areas on the Coteau du Missouri (Hedges, 1972, 1975, and 1987; and Christensen, 1974), and in these instances both drifts were interpreted as late Wisconsin in age. Unfortunately, there are no radiocarbon dates available on the Coteau du Missouri in South Dakota to corroborate either interpretation.

Outwash

Outwash in Aurora and Jerauld Counties occurs at the surface (pls. 2 and 4) and in the subsurface (pl. 3). Casual examination provides no noticeable lithologic differences between drift A outwash and drift B outwash. Thus, differentiation can only be made using areal distribution and stratigraphic and geomorphic relationships. Except where noted in the discussion on pre-Wisconsin outwash, all the outwash below till B is identified as late Wisconsin.

Glacial Lake Deposits

Buried lake deposits are present over a large portion of Aurora County and a small portion of southeast Jerauld County. The lake deposits are gray to olive-gray clay and silty clay and contain abundant wood fragments and logs. The lake deposits are as much as 96 feet thick at SW SW SW SW sec. 17, T. 101 N., R. 64 W., but average about 25 feet thick. Where they are present, these lake deposits are a good stratigraphic marker unit separating the younger drift A deposits from older drift B deposits (pl. 3).

The buried lake deposits terminate to the south in extreme northern Charles Mix and Douglas Counties in the drainages and collapsed outwash associated with Platte and Choteau Creeks. Detailed test drilling and surface geologic mapping of those counties have failed to identify lake deposits south of Aurora County (Hedges, 1975). These buried lake deposits apparently terminate to the east at about the Aurora and Jerauld County line because no evidence of any extensive buried lake deposits has been recorded in either Sanborn County (Steece and Howells, 1965) or Davison County (Christensen, 1989). This fact is not necessarily surprising because Christensen (1989) reports the presence of only one drift (drift A of Aurora and Jerauld Counties) in Davison County. As mentioned earlier, this suggests that most or all of any older Pleistocene deposits were stripped from that county by the combination of meltwater erosion and basal erosion by the encroaching ice. A similar explanation could also be possible for the absence of buried lake deposits in Sanborn County.

Flint (1955) postulates the possible existence of an earlier Lake Dakota in the James Basin. The buried lake deposits in Aurora and Jerauld Counties and buried lake deposits in northern Beadle County (Hedges, 1968), as well as extensive buried lake deposits in southwestern Spink County (CENDAK Drainage Steering Committee, 1987) all occur at the same stratigraphic position and may represent part of an earlier "Lake Dakota" as envisioned by Flint (1955).

According to the scenario described above, there likely were widespread glacial lake deposits in the central portion of the James Basin prior to the last glacial advance. The documented absence of these deposits throughout much of the James Basin indicates they were removed prior to, or during the last ice advance that deposited till A in Aurora and Jerauld Counties. It seems likely that much of this material would be incorporated in till A covering Aurora and Jerauld Counties. In fact, many test holes core-drilled by the U.S. Bureau of Reclamation throughout northeastern Aurora County, northwestern Beadle County, southwestern Spink County, and east-central Hand County report glacial lake sediments and till intermixed. Rotary drilling conducted as part of this investigation also indicated that till and glacial lake sediments were intermixed at several locations. Because it is difficult to distinguish between reworked and in situ glacial lake sediments from rotary drill cuttings, caution must be exercised in interpretation of specific test hole logs where glacial lake sediments are reported.

Buried Weathered Horizon

The remnants of a buried weathered horizon is present throughout eastern Jerauld County and much of Aurora County (stratigraphic cross sections D-D' through G-G', pl. 3; and fig. 11). This weathered horizon is present on both the upper surface of till B and lake deposits. The weathered horizon varies in color from yellowish-brown to olive-brown to light olive-gray and is generally 10 feet thick or less. The color, thickness, and apparent absence of a well-developed soil profile indicate a weakly oxidized weathering horizon. Some of the weathered lake deposits contain finely disseminated organic particles and may in fact be loess. Distinguishing a thin, silty, weathered lake deposit from loess based on rotary drill cuttings is difficult. If some of the lake deposits are in fact loess, the loess would likely be equivalent to the discontinuous layer of loess covering early Wisconsin drift (drift B of this report) in the southwestern portion of the Wessington Springs quadrangle (Steece, 1967a).

Because of the limitations previously mentioned for interpretation of rotary drill samples as "loess" or "lake deposits," and the uncertainty whether a specific deposit is in situ or reworked, the writer is hesitant to draw conclusions regarding the stratigraphic relationship of the two units. However, in spite of the uncertainties mentioned above, three conclusions seem warranted. One, there was an interstadial event between till A and till B during which a weakly weathered horizon developed on the upper surface of till B and loess or lake deposits, and the area was reforested. Two, extensive lake sediments were deposited between till A and till B. Three, the ice advance that deposited till A incorporated reworked lake sediments and tree fragments into the till.

HOLOCENE

Holocene deposits consist of colluvium on steeper slopes along the eastern slope of the Coteau du Missouri and alluvium in stream valleys in Aurora and Jerauld Counties.

Colluvium is material that has been moved downslope by a combination of gravity and running water. It consists primarily of reworked till and soil, generally less than 5 feet thick, that probably started accumulating during late Pleistocene and has continued to the present time. Where identified in road cuts or other exposures, it may show rudimentary bedding. A dark upper layer more than 2 feet thick represents an accumulation and intermixing of topsoil and till. Colluvium was not mapped for this study.

Alluvium is primarily stream-overbank deposits and depression fillings consisting of gray to black clay containing varying amounts of silt and sand. Throughout Aurora and Jerauld Counties alluvium is generally less than 10 feet thick, except in the valley of Crow Creek in western Jerauld County where alluvium as much as 38 feet thick was penetrated in test holes. The alluvium along streams may overlay outwash or it may lay directly on till. Alluvium is present along the course of most streams and gullies and in most depressions in the two-county area. Only those more extensive deposits along stream courses have been mapped for this study (pls. 2 and 4). Steece (1967a and b) shows a large alluvial flat 2 to 4 miles east of Wessington Springs. The likely origin of this alluvium is from coalescing overbank deposits from minor eastward flowing streams draining the Coteau du Missouri escarpment. Because they are thin (less than 5 feet thick) and discontinuous, they are not shown on plate 2.

GLACIAL LANDFORMS

The predominant glacial landforms in Aurora and Jerauld Counties result from widespread stagnation of the late Wisconsin James lobe ice sheet along its western terminus on and near the Coteau du Missouri. In general, stagnant ice features are best developed, more varied and more numerous in the northern counties of the state than those counties to the south. Aurora and Jerauld Counties, being located towards the southern portion of the state, exhibit less well-developed stagnant ice features. However, the relationship of stagnation moraine and collapsed outwash to other glacial landforms, reveal a widespread pattern of glacial stagnation consistent with other areas of the state.

Stagnation Moraine

Stagnation moraine is composed primarily of till that has been "let down" from an englacial or superglacial position within areas of stagnant ice. It is devoid of linear features except where conditions allowed formation of various types of disintegration ridges such as eskers or other linear ice-contact features. The primary distinguishing features of stagnation moraine are its nonlinear hummocky surface expression, containing many small and irregular sloughs, and its association with other ice-contact features such as ice-walled outwash plains, ice-walled lake plains, and collapsed outwash and lake sediments.

Stagnation moraine has been mapped throughout the extent of the Coteau du Missouri in South Dakota (Christensen, 1974 and 1977; Hedges, 1972, 1975, and 1987; Helgerson and Duchossois, 1987; and Duchossois, 1993). The model of glacial landform development exhibited by these studies is that of a regional shrinking (active ice sheet) once it reached its maximum extent approximately along the course of the present Missouri River. Various sections of the ice, containing englacial and superglacial drift, stagnated along its outer margin creating a restriction to the active ice that would cause an accumulation of drift in the form of end moraine. As ice flow diminished, this process was repeated eastward across the Coteau du Missouri and into the James Basin leaving masses of stagnation moraine separating end moraine.

Stagnation moraine is found associated with both drifts A and B in Aurora and Jerauld Counties (pls. 2 and 4). Local relief on stagnation moraine ranges from 25 to 75 feet on the Coteau du Missouri, and 10 to 50 feet in the James Basin. Ice-contact features such as ice-walled outwash plains, ice-walled lake plains, and eskers are absent, which suggests that the ice was thin and did not contain large amounts of englacial or superglacial drift, and that a long-lived source of meltwater and sediments was absent. However, large areas of collapsed outwash in western Aurora and Jerauld Counties, southern Aurora County, and smaller areas throughout both counties indicate widespread stagnant ice conditions. Also, a 12-square-mile area 3 miles northeast of Aurora Center in Aurora County contains landforms similar to the "doughnuts" described by Gravenor and Kupsch (1959). They attributed formation of this landform in association with stagnant ice.

End Moraine

End moraine is an accumulation of drift along the margin of active ice. The form is usually constructional and in Aurora and Jerauld Counties may vary from a distinct narrow linear ridge one-half mile wide and rising up to 100 feet above the surrounding topography, to a broad end moraine complex as much as 7 miles wide with varying topographic relief and surface expression. Factors controlling the topographic form of an end moraine are rate and duration of ice flow, the preexisting topography, the amount of drift contained in the advancing ice, and the rate of ablation. In general, where ice flow is restricted by preexisting topography or stagnant ice, the resulting landforms will be narrower and of higher relief than where no such restriction exists. The end moraine may change from one form to another along its course, depending on the controlling factors. Till is the dominant sediment type in end moraines. However, if there has been a great amount of meltwater involved, substantial outwash may be present.

In east-central Jerauld County, the end moraines are typically narrow, linear, well defined, and mostly continuous ridges ½ to 3 miles wide and 35 to 100 feet high. The ridges trend north-south or are slightly arcuate following the profile of the Coteau du Missouri and generally lack hummocky topography associated with stagnant ice. The dominant controlling factor in formation of these ridges is the steep, east-facing escarpment of the Coteau du Missouri which caused a restriction in ice flow. To the south and north, where the ridges approach Aurora and Beadle Counties, the influence of the Coteau du Missouri is less dominant and the end moraines gradually change to the broad end moraine complex.

The change in end moraine form is illustrated by the end moraine ridge that starts 3 miles south of Wessington Springs and is positioned along the east edge of the West Branch of Firesteel Creek (pl. 2). At this location the ridge is one-half mile wide, nearly 100 feet high, and devoid of hummocky topography. This portion of the end moraine may be partly bedrock controlled. From here it trends south to southwest into Aurora County where it crosses the east-flowing West Branch of Firesteel Creek (pl. 4). At this point the end moraine is about 3 miles wide, has a maximum height of about 50 feet, and exhibits a hummocky topography. Continuing south and east, the end moraine bifurcates and eventually becomes discontinuous. Portions of the moraine are as much as 7 miles wide with up to 50 feet of relief. Locally, potholes and ridges with 10 to 20 feet of relief are aligned parallel to the trend of the end moraine complex.

A striking example of the narrow, linear, ridge-type of end moraine is the ridge crossing State Highway 34, 3½ miles east of Lane, in eastern Jerauld County (pl. 2). Locally known as part of the Pony Hills, this ridge trends northwest-southwest, is ½ mile wide by 4 miles long, and nearly 100 feet high. Stagnant ice in this area may have been influential in blocking the active ice that built the impressive Pony Hills and other nearby associated ridges.

On the Coteau du Missouri in western Jerauld County, south to southwesterly trending end moraines separate the major drainages as well as separating the East Fork Smith Creek from the east edge of the Coteau du Missouri (pl. 2). From the valley floors to ridge crests the moraines rise up to 150 feet. Between the Coteau du Missouri and the East Fork Smith Creek, local relief is as much as 75 feet and potholes, lakes, and sloughs are more numerous. In general, local relief is more subdued and numbers of depressions decrease westward from one ridge to the next.

East of the Coteau du Missouri end moraines that formed between the major drainages delineate the west to east progression of the active ice front. In northeast Aurora County in R. 63 W., numerous ice-marginal meltwater channels (pl. 4) delineate short-lived active ice margins during deglaciation.

Ground Moraine

Ground moraine is composed primarily of till with low relief and is devoid of linear elements. Ground moraine covers about 18 square miles in northeastern Jerauld County and about 36 square miles in southeastern Aurora County (pls. 2 and 4). With the exception of incised drainages, local relief in these areas generally does not exceed 10 feet, and linear constructional features are absent. The general topographic relationship of ground moraine to other morphologic units nearby can be seen on the stratigraphic cross sections. The town of Lane (pl. 3, cross section B-B') is located near the southern extent of the ground moraine in northeast Jerauld County (pl. 2), while the eastern (R. 63 W.) portion of stratigraphic cross section F-F' (pl. 3) is representative of the ground moraine in southeast Aurora County (pl. 4).

Collapsed Outwash

Collapsed outwash is defined as outwash that was deposited on, or against, stagnant ice and subsequently let down as the ice melted. Its surface expression results from a combination of factors such as ice thickness, thickness of the outwash sediments, and the relief of the preexisting topography. The texture may vary greatly depending on source material, water velocity, duration of flow, and distance from source. Collapsed outwash often has a hummocky surface with low relief (10–20 feet) caused by ice melting from below or within. Larger, well-defined depressions may occur as ice blocks melt, leaving a pitted appearance.

Large areas of collapsed outwash are present across southern Aurora County (pl. 4) and northern Charles Mix and Douglas Counties (Hedges, 1975, pl. 1). These areas of collapsed outwash have a typical hummocky topography with local relief of 10 to 20 feet, and are devoid of well-defined, large ice-block depressions. The collapsed outwash marks the terminus of the ice that deposited till A in this area. A general absence of meltwater channels leading to the collapsed outwash areas indicates the presence of stagnant ice in the source area. Other small areas of collapsed outwash are located in eastern Jerauld County (pl. 2) and are associated with the distal margin of the end moraine forming the Pony Hills. These areas of collapsed outwash also have typical hummocky topography with local relief of 10 to 20 feet. Areas of outwash too small to exhibit typical collapse features, but which are clearly associated with nearby larger areas of collapsed outwash are also shown as collapsed outwash on plates 2 and 4.

An extensive area of collapsed outwash is also present in western Jerauld County (pl. 2). Topographic relief across this collapsed outwash exceeds 100 feet, and most of it lacks the hummocky or pitted topography normally associated with collapsed outwash areas. The absence of hummocky topography is probably related to the relatively high relief of the preexisting topography and thicker ice. However, a portion of the outwash located along State Highway 34 and the Jerauld-Buffalo County line does exhibit hummocky topography characteristic of collapsed outwash. Numerous incised drainages through this area reflect a continued abundant supply of meltwater after the outwash was deposited and the buried ice melted.

Meltwater Channels

Meltwater channels are valleys or trenches incised along former ice margins or outwards from them. The upstream end may terminate abruptly in drift. Meltwater channels also may not be part of the present drainage system or, they may contain underfit streams if they are part of the present system. Where streams are underfit or absent, lakes or sloughs may be present.

The numerous meltwater channels mapped across western Jerauld County and in northeastern Aurora County (pls. 2 and 4) are all located along the distal margin of end moraines. The meltwater was trapped between the advancing ice and the forming end moraine, and stagnant ice or end moraine of the preceding end moraine building event. The numerous short and narrow meltwater channels associated with Firesteel Creek in northeastern Aurora County (pl. 4) probably developed as short-lived ice-marginal drainages between the rapidly retreating active ice front and stagnant ice. In contrast, the larger, better developed meltwater channels on the Coteau du Missouri in Jerauld County were occupied for a longer time. The source of meltwater was from the relatively larger mass of stagnant ice on the Coteau du Missouri which probably was supplemented by meltwater from active ice that continued to override the Coteau du Missouri from the northeast. Long Lake, located in north-central Jerauld County (pl. 2), extends for 3 miles in the upper reach of Smith Creek. This is a good example of a lake occupying a meltwater channel with underfit present drainage.

ECONOMIC GEOLOGY

Ground water and sand and gravel are both abundant in Aurora and Jerauld Counties. However, their uneven spatial distribution and often poor quality for desired purposes do not always make development practical. The sand and gravel resources of the two counties are described in Blaze (1980) and Blaze and Hammond (1980). The occurrence, distribution, and quality of the water resources are described by Hamilton (1980, 1985).

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APPENDIX

Legal descriptions for test holes shown on plate 3

1. SE SE SW SE sec. 32, T. 109 N., R. 67 W.
2. SW SW SW SW sec. 35, T. 109 N., R. 67 W.
3. SW SW SW SW sec. 31, T. 109 N., R. 66 W.
4. SE SE SE SE sec. 32, T. 109 N., R. 66 W.
5. SE SE SE SE sec. 34, T. 109 N., R. 66 W.

6. SW SW SW SW sec. 31, T. 109 N., R. 65 W.
7. SE NE NW NE sec. 05, T. 108 N., R. 65 W.
8. SE SE SE SE sec. 34, T. 109 N., R. 65 W.
9. SE NE NW NE sec. 05, T. 108 N., R. 64 W.
10. SE SE SW SW sec. 35, T. 109 N., R. 64 W.

11. SW SW SW SW sec. 31, T. 109 N., R. 63 W.
12. SE SE SE SE sec. 32, T. 109 N., R. 63 W.
13. SE SE SE SW sec. 34, T. 109 N., R. 63 W.
14. SE SE SE SE sec. 34, T. 109 N., R. 63 W.
15. SE SE SE SE sec. 35, T. 109 N., R. 63 W.

16. SE SE NE NE sec. 01, T. 108 N., R. 63 W.
17. SW SW SW SW sec. 07, T. 107 N., R. 67 W.
18. NW NW NW NW sec. 16, T. 107 N., R. 67 W.
19. SE SE NE SE sec. 09, T. 107 N., R. 67 W.
20. NW NW SW SW sec. 11, T. 107 N., R. 67 W.

21. NE NW NW NW sec. 13, T. 107 N., R. 67 W.
22. SE SE SE SE sec. 12, T. 107 N., R. 67 W.
23. SE SE SE SE sec. 08, T. 107 N., R. 66 W.
24. SE SE SE SE sec. 09, T. 107 N., R. 66 W.
25. NW NW NE sec. 14, T. 107 N., R. 66 W.

26. NW NW NW NW sec. 17, T. 107 N., R. 65 W.
27. SE SE SE SE sec. 09, T. 107 N., R. 65 W.
28. NE NW NW NW sec. 14, T. 107 N., R. 65 W.
29. NE SE SW NW sec. 13, T. 107 N., R. 65 W.
30. SW SW SW NE sec. 13, T. 107 N., R. 65 W.

31. NE NE NE SE sec. 13, T. 107 N., R. 65 W.
32. SW SW NW SE sec. 18, T. 107 N., R. 64 W.
33. NE NE NE NE sec. 19, T. 107 N., R. 64 W.
34. NW NW NW NW sec. 22, T. 107 N., R. 64 W.
35. SW SE SE SE sec. 15, T. 107 N., R. 64 W.

36. NE NE NE NW sec. 23, T. 107 N., R. 64 W.
37. NW NW NW NW sec. 24, T. 107 N., R. 64 W. 1*
38. NE NE NE NE sec. 21, T. 107 N., R. 63 W.
39. NE NE NE NE sec. 24, T. 107 N., R. 63 W.
40. SW SW SW NW sec. 31, T. 106 N., R. 67 W.

41. SW SW SW SW sec. 33, T. 106 N., R. 67 W.
42. NW NW NW NW sec. 05, T. 105 N., R. 66 W.
43. SW NW SW SW sec. 04, T. 105 N., R. 66 W.
44. SW SW SW SW sec. 35, T. 106 N., R. 66 W.
45. NE NE NE SE sec. 01, T. 105 N., R. 66 W.

46. NW NW NW NW sec. 03, T. 105 N., R. 65 W.
47. NE NE NE NE sec. 01, T. 105 N., R. 65 W.
48. SW SW SW SW sec. 05, T. 105 N., R. 64 W.
49. NW NW NW NW sec. 03, T. 105 N., R. 64 W.
50. SE SE SE SE sec. 36, T. 106 N., R. 64 W.

51. NW NW NW NW sec. 03, T. 105 N., R. 63 W.
52. SW SW SW SW sec. 31, T. 106 N., R. 62 W.
53. SW SW SW SW sec. 31, T. 105 N., R. 66 W.
54. SW SW SW SW sec. 35, T. 105 N., R. 66 W.
55. SW SW SW SW sec. 31, T. 105 N., R. 65 W.

56. SW SW SW SE sec. 34, T. 105 N., R. 65 W.
57. SE SE SE SE sec. 36, T. 105 N., R. 65 W.
58. NE NW NE NE sec. 04, T. 104 N., R. 64 W.
59. SW SE SW SW sec. 35, T. 105 N., R. 64 W.
60. NW NW NW SW sec. 06, T. 104 N., R. 63 W. 1*

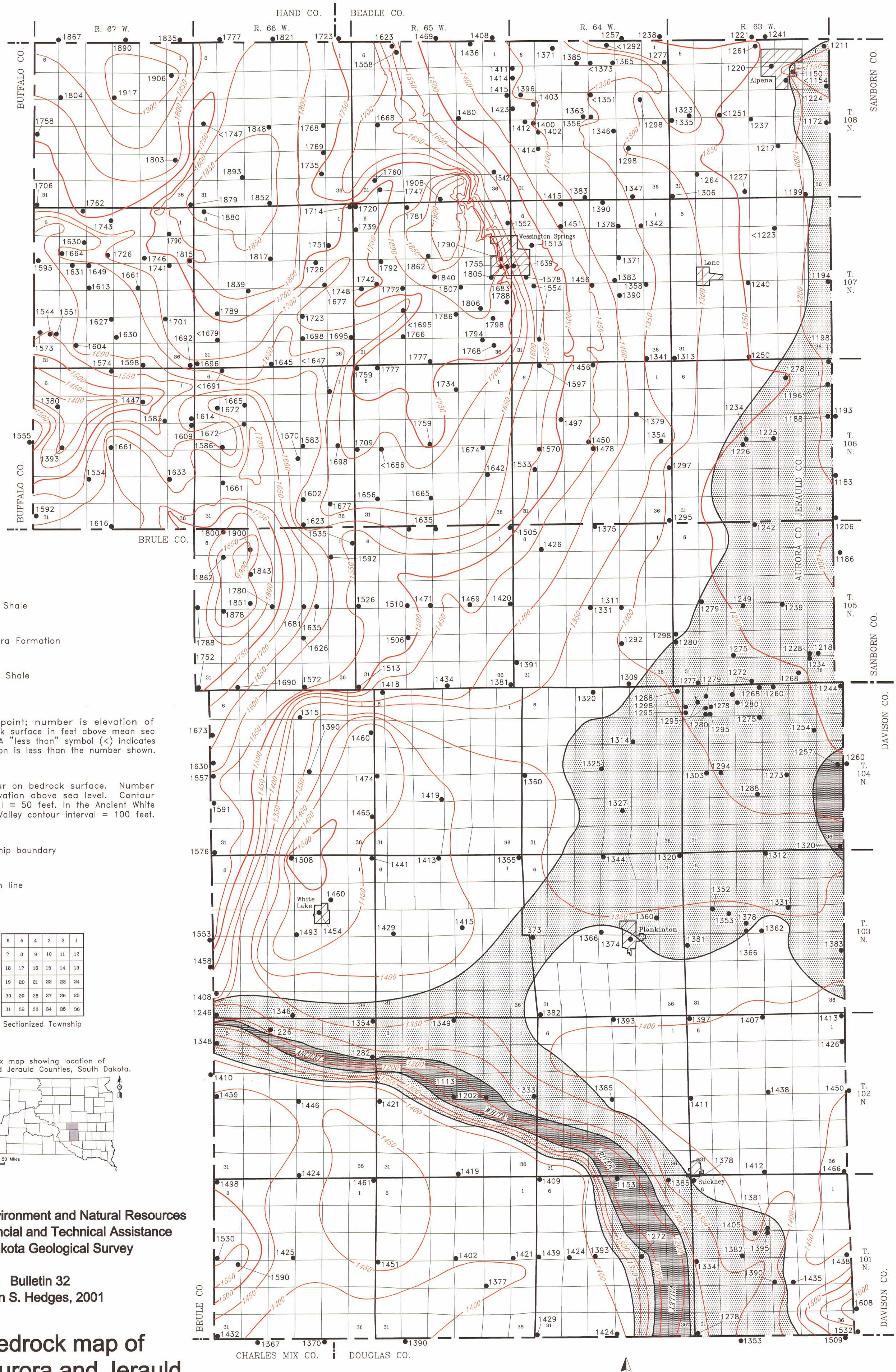
61. SE SE NW NE sec. 06, T. 104 N., R. 63 W. 1*
62. SE NE NW NE sec. 04, T. 104 N., R. 63 W.
63. NE NE NE NW sec. 03, T. 104 N., R. 63 W.
64. NE SE NW SE sec. 35, T. 105 N., R. 63 W.
65. SE SW SW SW sec. 31, T. 105 N., R. 62 W.

66. SW SW SW SW sec. 31, T. 104 N., R. 66 W.
67. NE NE NE NE sec. 04, T. 103 N., R. 66 W.
68. NE NE NE NE sec. 01, T. 103 N., R. 66 W.
69. NE NE NE NE sec. 04, T. 103 N., R. 65 W.
70. NE NE NE NE sec. 01, T. 103 N., R. 65 W.

71. NW NW NW NW sec. 03, T. 103 N., R. 64 W.
72. NE NE NE NE sec. 01, T. 103 N., R. 64 W.
73. NW NW NW NW sec. 03, T. 103 N., R. 63 W.
74. SE SE SE SE sec. 36, T. 104 N., R. 63 W. 2*
75. SW SW SW SW sec. 18, T. 102 N., R. 66 W.

76. NW NW NW NW sec. 22, T. 102 N., R. 66 W.
77. NW NW NW NW sec. 19, T. 102 N., R. 65 W.
78. SE SE SE SE sec. 16, T. 102 N., R. 65 W.
79. SW SW SW SW sec. 14, T. 102 N., R. 65 W.
80. SE SE SE SE sec. 13, T. 102 N., R. 65 W.

81. NE NE NE NE sec. 21, T. 102 N., R. 64 W.
82. NE NW NW NW sec. 19, T. 102 N., R. 63 W.
83. SW SW SW SW sec. 15, T. 102 N., R. 63 W.
84. NE NE NE NE sec. 12, T. 102 N., R. 63 W.
85. SW SW SW SW sec. 18, T. 101 N., R. 66 W.



CRETACEOUS

Pierre Shale

Niobrara Formation

Carlile Shale

1426 Data point; number is elevation of bedrock surface in feet above mean sea level. A "less than" symbol (<) indicates elevation is less than the number shown.

1500 Contour on bedrock surface. Number is elevation above sea level. Contour interval = 50 feet. In the Ancient White River Valley contour interval = 100 feet.

Township boundary

Section line

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

Sectionized Township

Index map showing location of Aurora and Jerauld Counties, South Dakota.

0 50 Miles

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Division of Financial and Technical Assistance
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Plate 1. Bedrock map of Aurora and Jerauld Counties, South Dakota.

Plate 2. Geologic map of Jerauld County, South Dakota.

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6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

Sectionized Township

Index map showing location of Jerauld County, South Dakota.

0 1 2 3 4 5 6 Miles

SCALE 1:100,000

QUATERNARY — HOLOCENE

- **Qal** ALLUVIUM *Silt and clay deposited along floodplains; may be sandy and gravelly.*

QUATERNARY — PLEISTOCENE — LATE WISCONSIN

- **Qwlo** OUTWASH, UNDIFFERENTIATED *Predominantly sand and gravel with minor amounts of silt and clay; geomorphic distinction undifferentiated.*
- **Qwloc** OUTWASH, COLLAPSED *Predominantly sand and gravel; irregular topography characterized by numerous closed depressions in larger areas.*
- **Qwlts** TILL, STAGNATION MORAINE *Heterogeneous mixture of boulders, gravel, sand, silt, and clay; hummocky topography of varying relief.*
- **Qwlte** TILL, END MORAINE *Heterogeneous mixture of boulders, gravel, sand, silt, and clay; linear features of small distinct ridges or broad hummocky ridges.*
- **Qwltg** TILL, GROUND MORAINE *Heterogeneous mixture of boulders, gravel, sand, silt, and clay; characterized by low relief, shallow depressions, and nonlinear features.*
- **Qwltc** TILL, COTEAU SLOPE MORAINE *Heterogeneous mixture of boulders, gravel, sand, silt, and clay; characterized by moderate to high relief and abundant stream dissection and slumping.*

TERTIARY — PLIOCENE

- **Tpv** × VALENTINE FORMATION *Silty, sandy clay and green siliceous sandstone.*

CRETACEOUS — UPPER CRETACEOUS

- **Kpu** PIERRE SHALE, UNDIFFERENTIATED *Shale, gray to black, fissile to blocky.*

Meltwater channel

Geologic contact, dashed where approximate

Lake

Intermittent lake

Intermittent stream

Major highway

Township boundary

Section line

Geology of Jerauld County adapted from Hoff (1960), Steece (1967a), and an unpublished geologic map of Jerauld County by Fred V. Steece.

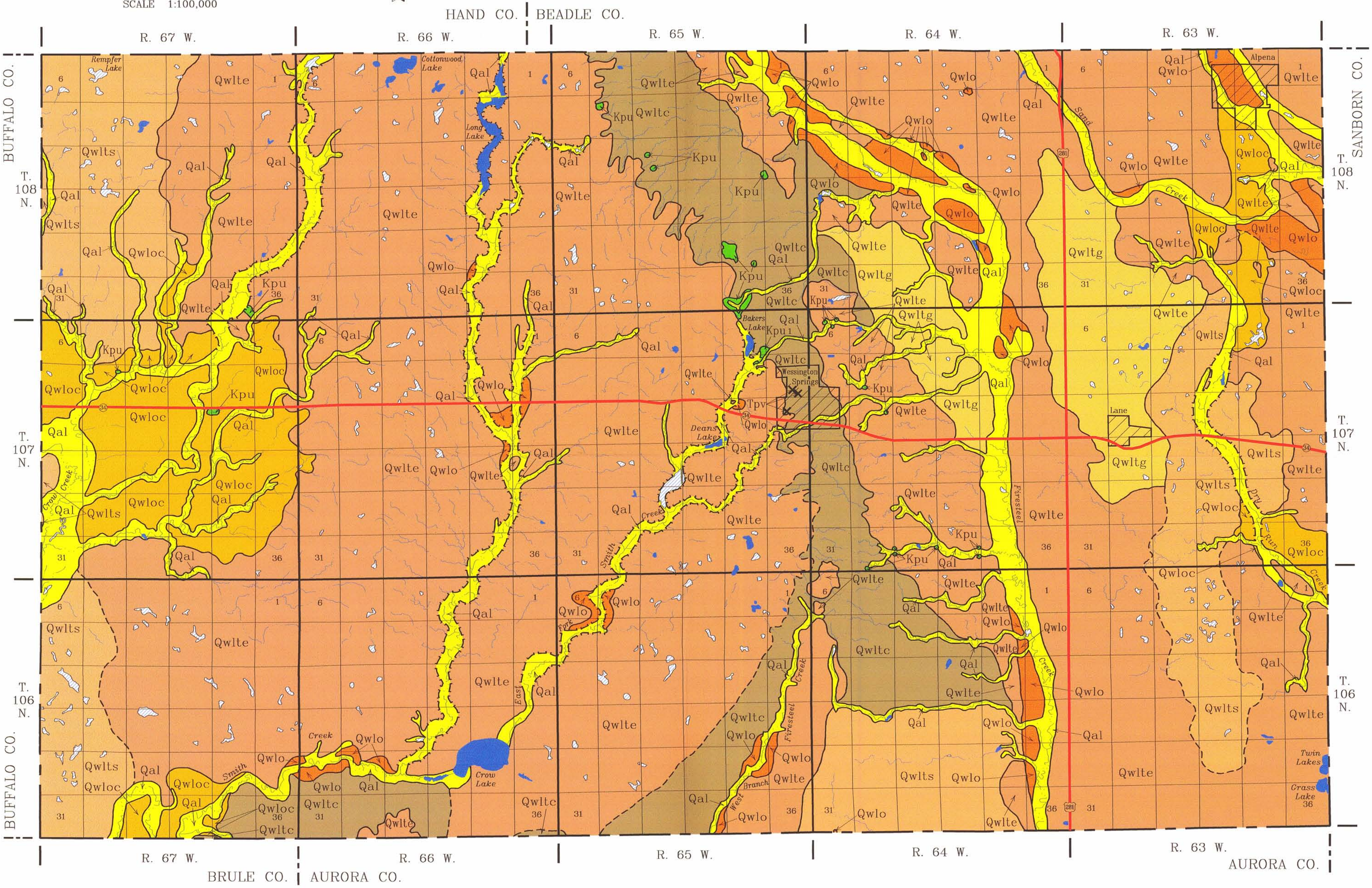

Plate 3. Stratigraphic cross sections of Aurora and Jerauld Counties, South Dakota.

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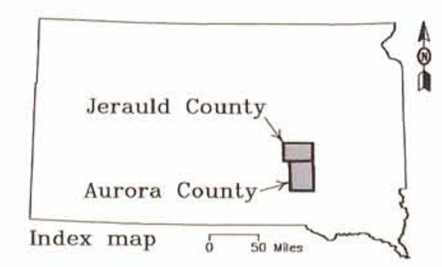
Quaternary — Holocene		Qal	alluvium
		Qco	colluvium
Quaternary — Pleistocene	late Wisconsin	Qwloc	outwash, collapsed
		Qwlo	outwash, undifferentiated
		Qwlt-A	till A
		Qwll	lacustrine
		Qwlt-B	till B
		Qwlt	till, undifferentiated
	Kansan	Qkw	Wagner Formation
Tertiary? Plio-Pleistocene		Qwa	nonglacial alluvium
Cretaceous		Kpu	Pierre Shale, undifferentiated
		Kn	Niobrara Formation
		Kc	Carlile Shale
		Kcc	Codell Sandstone Member, Carlile Shale
		Kgh	Greenhorn Limestone

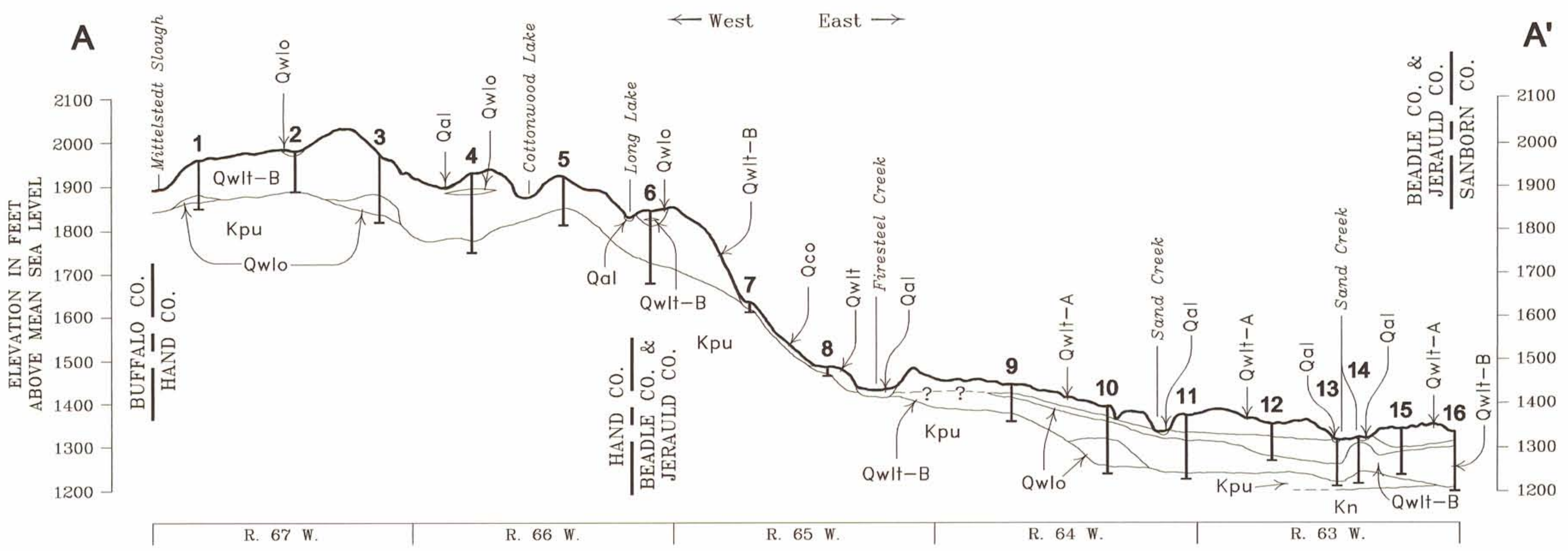
buried weathered zone

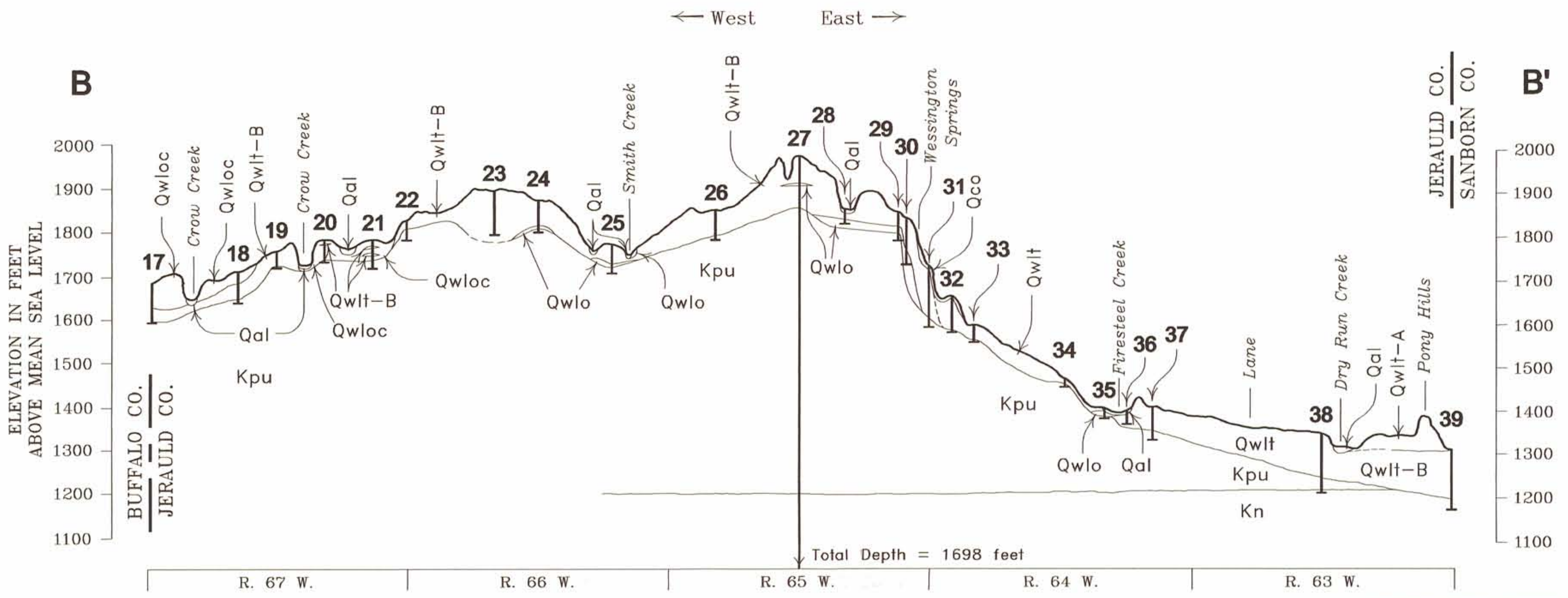
approximate geologic contact

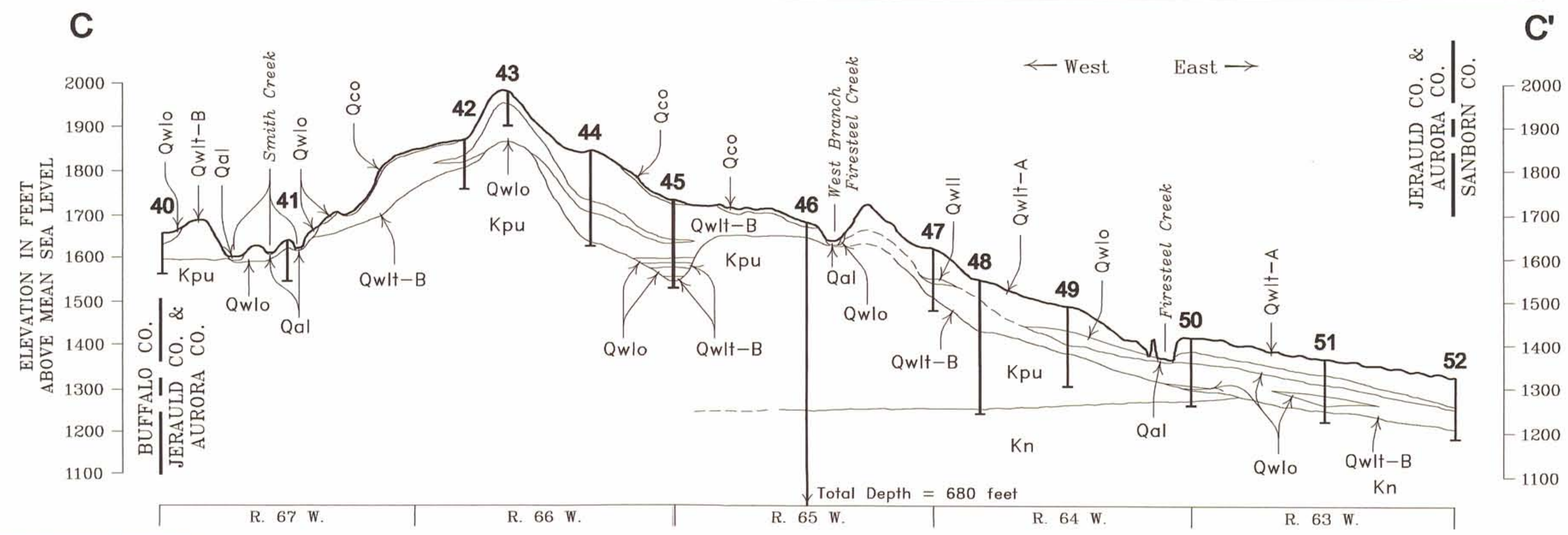
40 Test hole. Number corresponds to index map showing locations of stratigraphic cross sections and list of legal descriptions in appendix. Logs of test holes are available from the South Dakota Geological Survey.

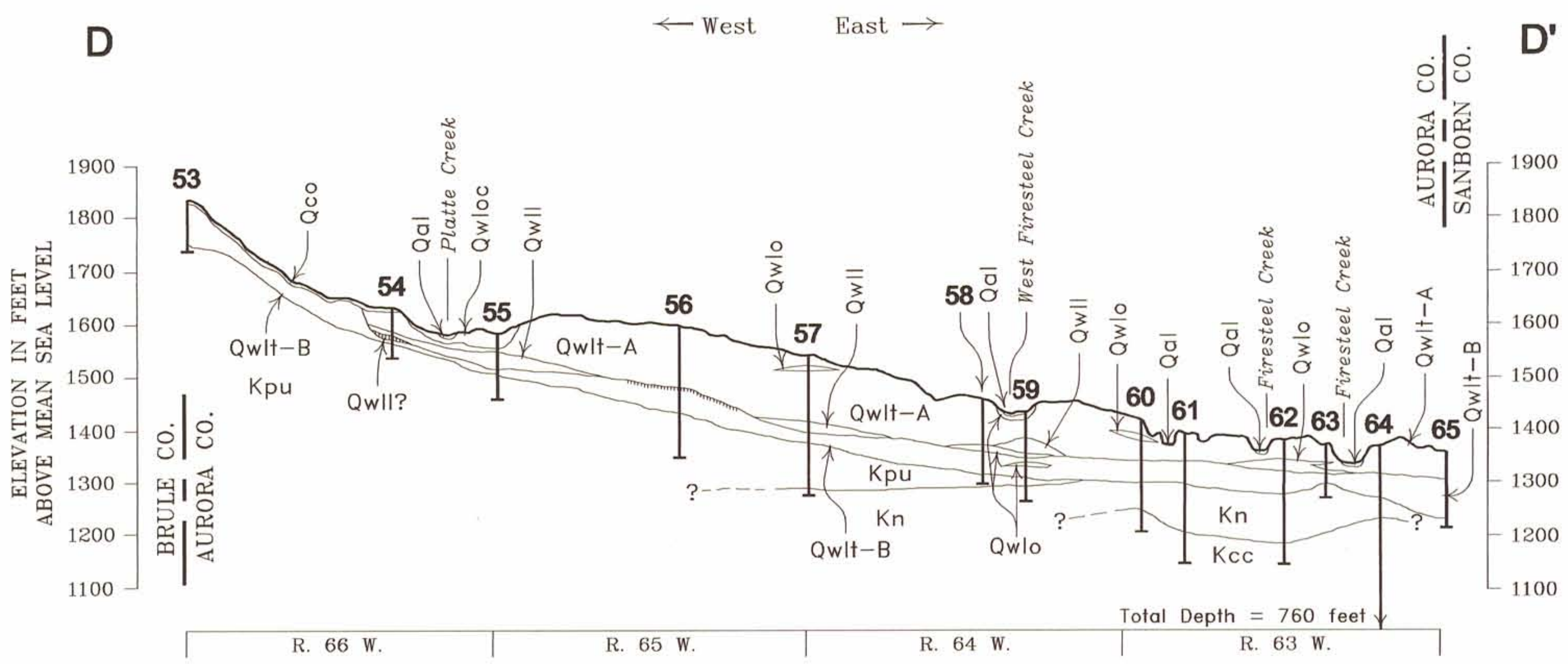
Vertical exaggeration = 52.8x

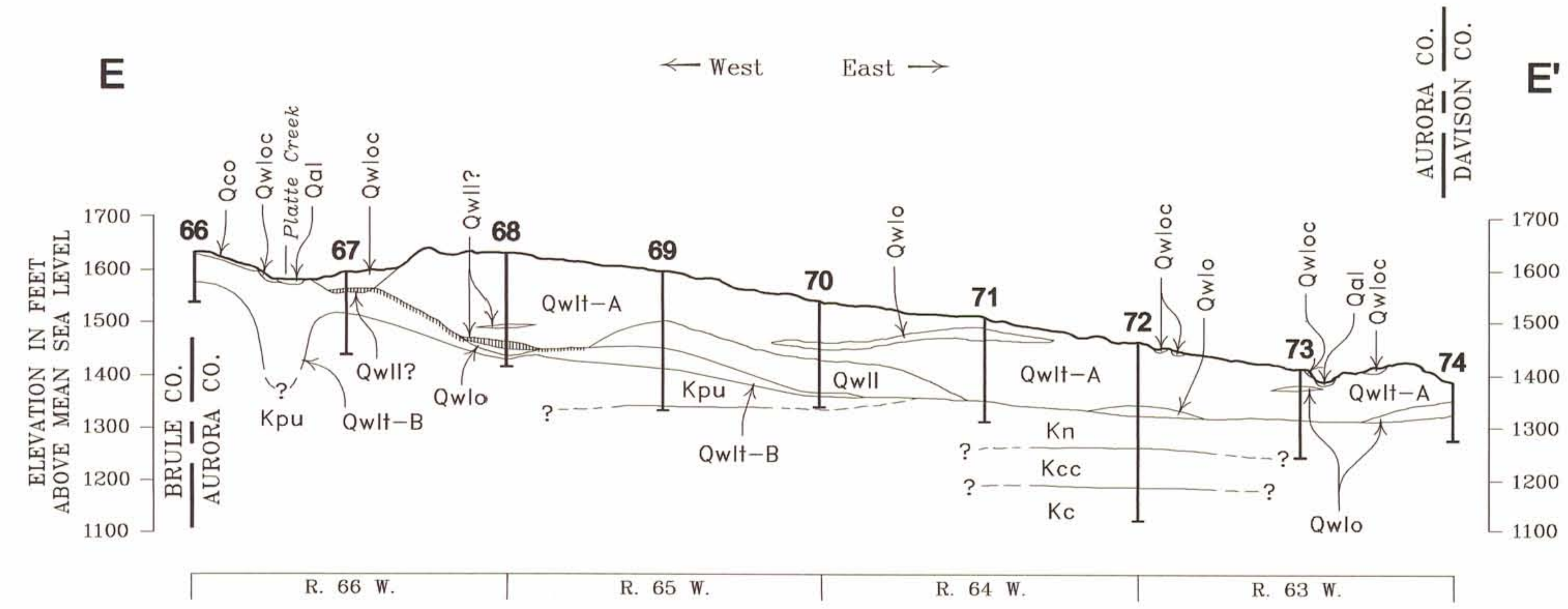


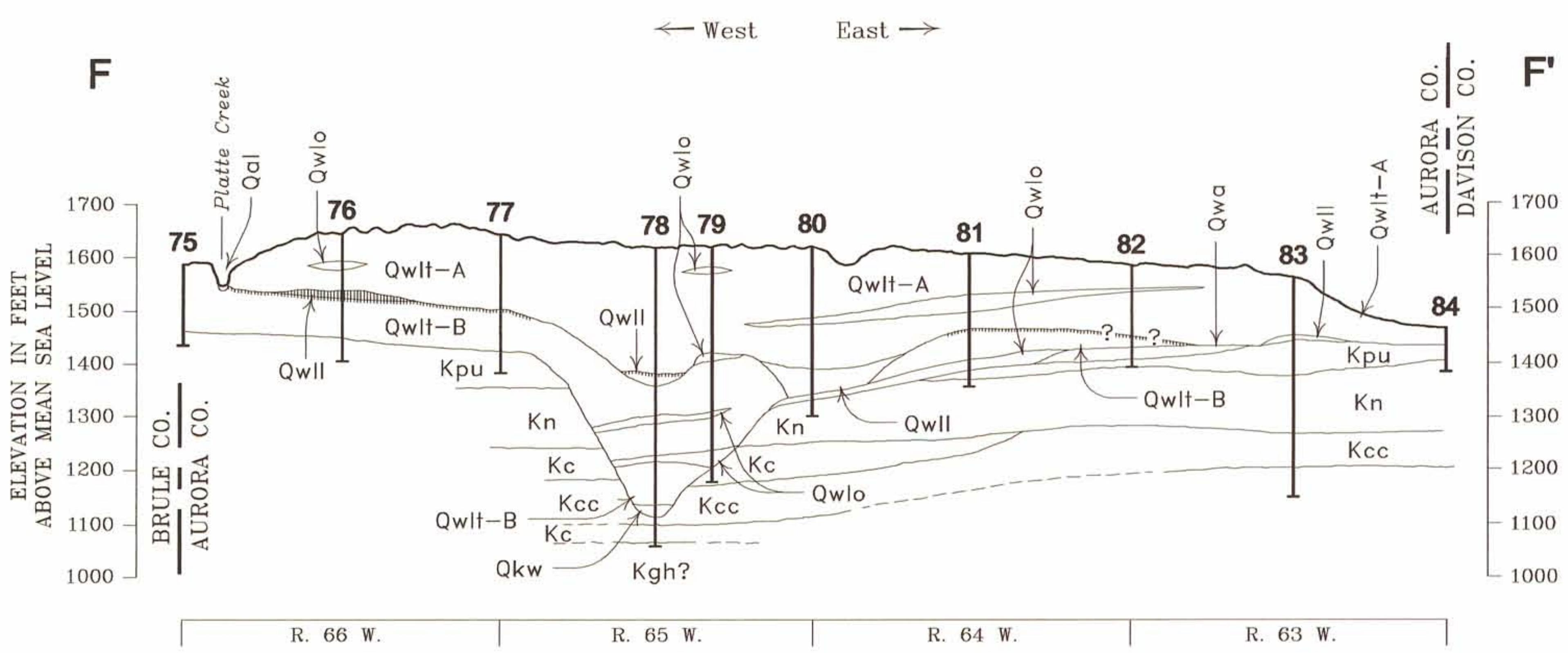


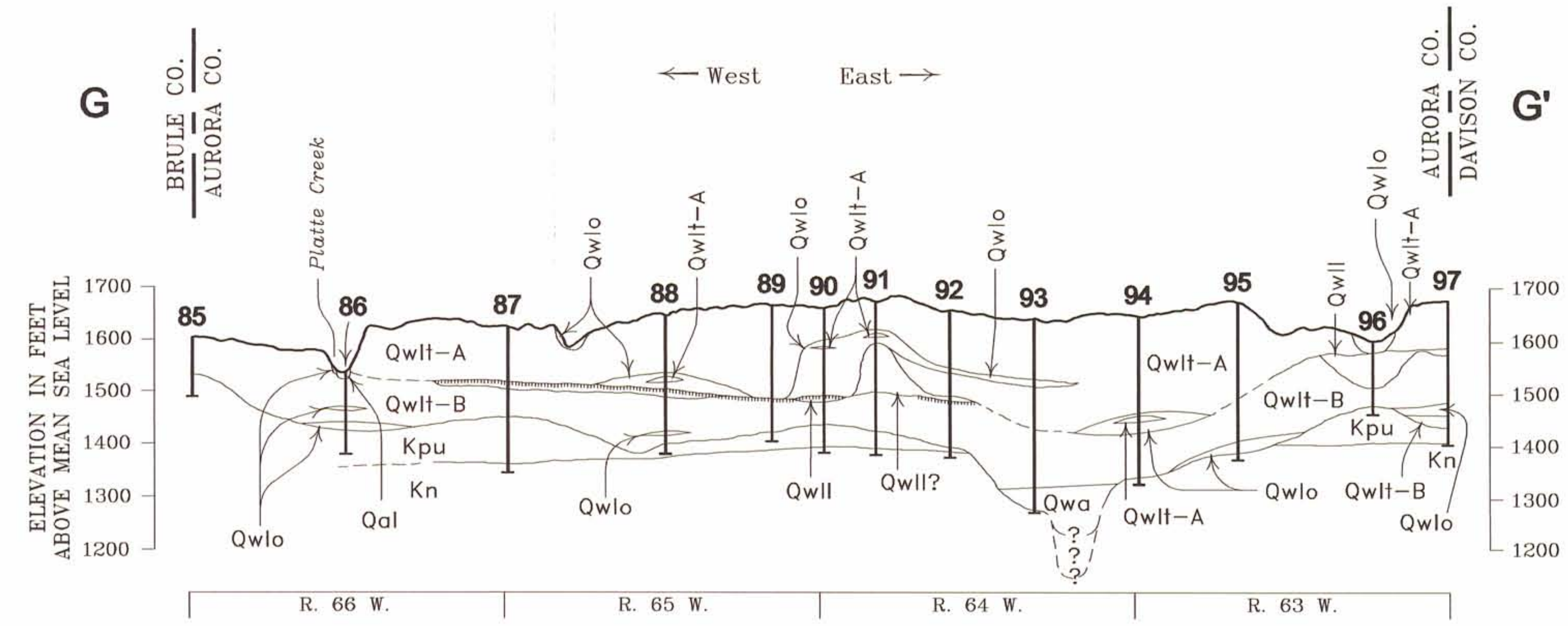


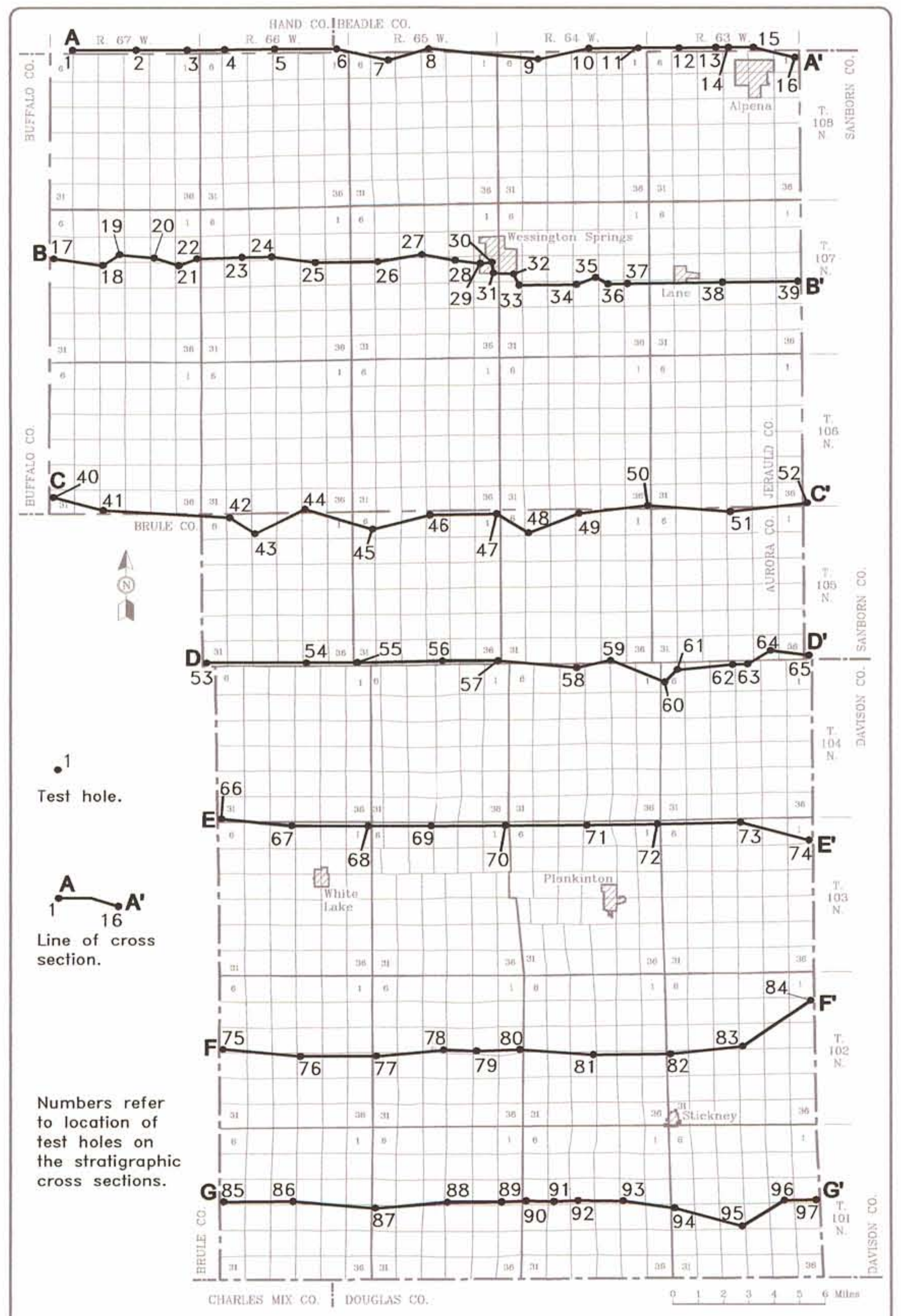












Index map of Aurora and Jerauld Counties showing locations of stratigraphic cross sections and test holes.

Plate 4. Geologic map of Aurora County, South Dakota.

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6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

Sectionized Township

Index map showing location of Aurora County, South Dakota.

0 1 2 3 4 5 6 Miles
SCALE 1:100,000

QUATERNARY — HOLOCENE

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QUATERNARY — PLEISTOCENE — LATE WISCONSIN

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- Meltwater channel
- Geologic contact, dashed where approximate
- Lake
- Intermittent lake
- Intermittent stream
- Major highway
- Township boundary
- Section line