April 1995

Geology of the Ogallala/High Plains Regional Aquifer System in Nebraska

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Published in

Geologic Field Trips in Nebraska and Adjacent Parts of Kansas and South Dakota: Parts of the 29th Annual Meetings of the North-Central and South-Central Sections, Geological Society of America

Lincoln, Nebraska

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Guidebook No. 10

Published by the Conservation and Survey Division, Institute of Agriculture and Natural Resources, University of Nebraska-Lincoln, in conjunction with the GSA regional sections meeting, April 27–28,1995.

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Field Trip No. 6

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This guide is mostly figures with a reference section containing some of the pertinent literature on the Cenozoic geology we will see over the next four days. Copies of some of the cited works will be assembled in a packet and handed out on the morning of April 29th. We will make all 17 stops (fig. 1) if the weather is reasonably good and the roads are passable. On the first day, April 29, we will try to get to stops 1-5, the more distal parts of the Ogallala and younger deposits in Nebraska. On April 30, we will try to visit stops 6-9. Stops 10-15, in areas closer to the sediment sources of the Ogallala and some of the younger units, will be examined on May 1. Stops 16-17 will be made on our return trip to Lincoln.

April 29, 1995

Stop 1. **Todd Valley.** Our first stop will be north of North Bend, Nebraska, on the surface of the Todd Valley fill to see some of the Quaternary geomorphology of eastern Nebraska and to review some aspects of Quaternary stratigraphy in the eastern part of the state. From Lincoln to the Platte River valley, we have traveled across land underlain by glacial tills, loesses, and fluvial deposits of Quaternary age. A great deal about the early views on Pleistocene geology in eastern Nebraska is in Lugn (1935). More recently, Reed and Dreeszen (1965) attempted to classify and show the relationships between Pleistocene units in Nebraska (fig. 2). This classification was widely accepted until the work of Boellstorff (1978) began to show that the stratigraphy was even more complex in places than previously depicted. At present, I believe that this classification is still in a state of flux; several workers are trying to clarify the relationships between units and to better define the ages of those units. Between the work of Lugn and that of Reed and Dreeszen, Lueninghoener (1947) tried to work out the post-Kansas geologic history of the lower Platte River valley (fig. 3). We are standing on the Todd Valley terrace, noted in figure 2 as medial Pleistocene, and are looking south at the Platte Valley. The valley fill beneath the terrace surface and the Holocene alluvium beneath the Platte Valley are good aquifers and

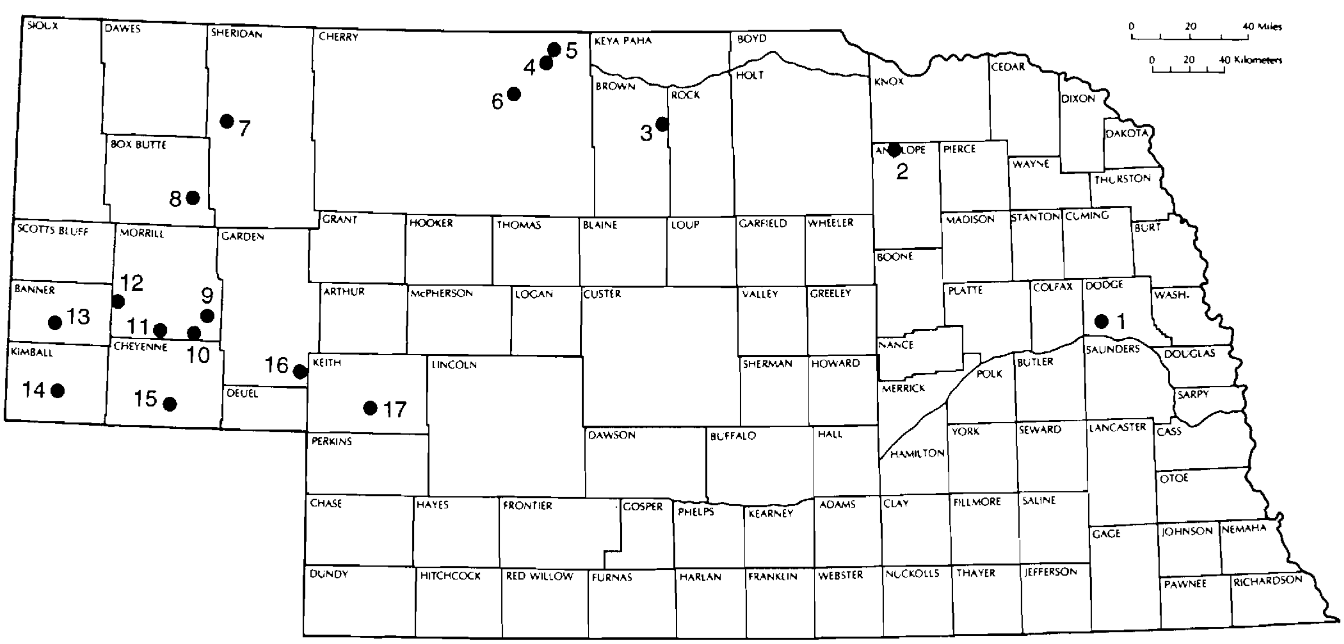

Fig. 1. Map of Nebraska showing locations of stops on field trip no. 6.

CLASSIFICATION							TERRACE SURFACES	
TIME STRATIGRAPHIC		ROCK STRATIGRAPHIC						
		EOLIAN	FLUVIATILE		GLACIAL	SOILS		
WISCONSINAN	Late	Bignell Loess and Dunesand	Bignell Formation	silt / sand-gravel	Absent		2a, 2b	2
	Medial	Peoria Loess and Dunesand	Peoria Formation	silt / Todd Valley sand	Harrington Till	Brady	3	3
	Early	Gilman Canyon Loess	Gilman Canyon Formation		Absent	Unnamed	?—?	
SANGAMONIAN						Sangamon		
ILLINOIAN	Late	Loveland Loess	Loveland Formation	silt / Crete sand-gravel	Absent			
	Medial	Beaver Creek Loess	Beaver Creek Formation	silt / sand-gravel	Santee Till	Unnamed	4	4
	Early	Grafton Loess	Grafton Formation	silt / sand-gravel	Clarkson Till	Unnamed		
YARMOUTHIAN						Yarmouth		
KANSAN	Late	Sappa Loess	Sappa Formation	silt / Grand Island sand-gravel	Probably Absent			
	Medial	Walnut Creek Loess*	Walnut Creek Formation	silt / sand-gravel	Cedar Bluffs Till	Unnamed		5
	Early	Red Cloud Loess*	Red Cloud Formation	silt / sand-gravel	Nickerson Till / Atchison Sand	Fontanelle		
AFTONIAN						Afton		
NEBRASKAN	Late	Fullerton Loess*	Fullerton Formation	silt / Holdrege sand-gravel	Iowa Point Till		5	
	Early	Seward Loess*	Seward Formation	silt / basal sand-gravel	Elk Creek Till / David City Sd-Gr	Unnamed		6

KEY: Pearlette Volcanic Ash; Minor Erosion; Major Erosion; Interstadial Soil; Interglacial Soil; *Not Currently Identified

Fig. 2. Classification of the Pleistocene deposits of Nebraska (modified after Reed and Dreeszen, 1965, fig. 3).

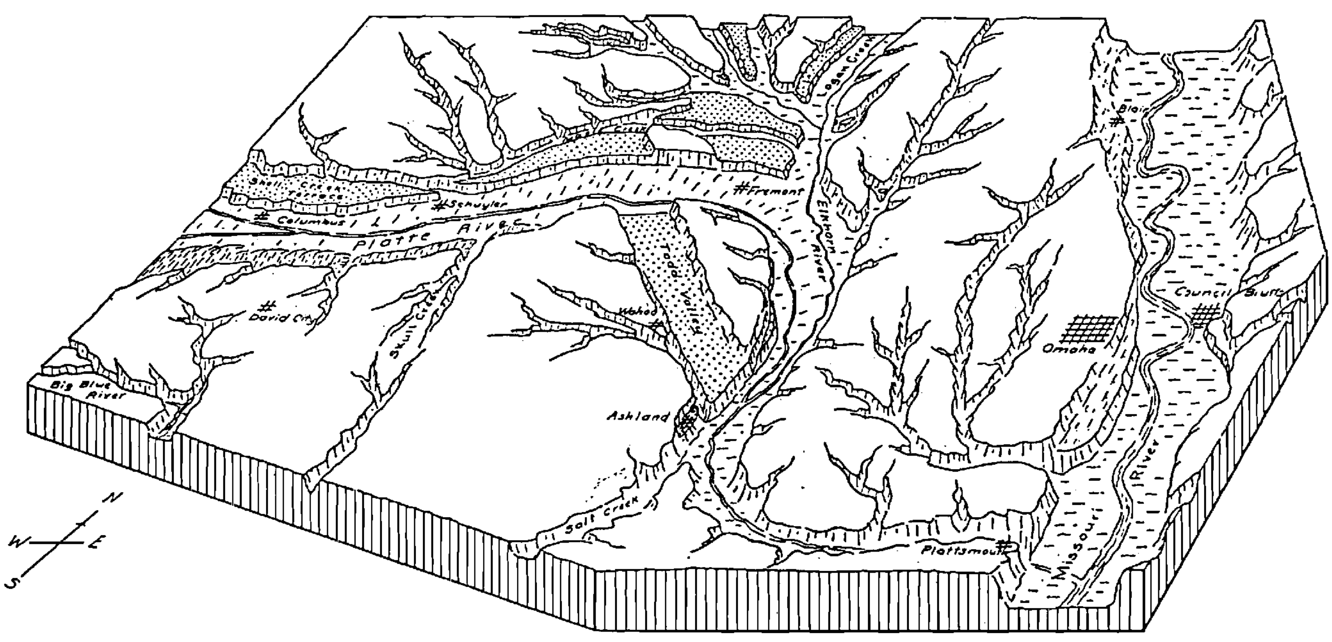

Fig. 3. Map of lower Platte Valley area. Approximate dimensions of block are 50 x 80 miles (after Lueninghoener, 1947, fig. 1).

have been developed for irrigation and municipal water supplies. As we go north, we will drive off of the fairly flat lands of the Todd Valley fill and up onto the better dissected lands underlain by eolian deposits and glacial tills that generally have more limited water resources. We will be traveling over these deposits for the most part until we reach the valley of the Elkhorn River near Norfolk, Nebraska, where we will once again be driving over Holocene alluvium.

From near Norfolk we will drive west across the glacial till border and begin to cross lands underlain by eolian sands, loesses and alluvium. The alluvium we will see from this point on ranges in age from late Pliocene to Holocene. For the most part, these deposits were laid down by the developing Platte River and its tributaries from late Pliocene to late Wisconsinan time (fig. 4). Most of the Ogallala/High Plains Aquifer System in Nebraska and most of the sites of greatest abundance of groundwater in Nebraska (fig. 5) occur in the areas where the Platte system or its ancestral drainages developed.

As we travel from U.S. Highway 20 north to Ashfall Fossil Beds State Historical Park (stop 2), we will encounter some of the stratigraphic units noted by Diffendal and Voorhies (1994) and shown in figure 6. Of the four Pliocene stratigraphic units recognized in parts of north-central Nebraska, only the Long Pine Formation is present in this area. The relationships of Pliocene and older Cenozoic units in north-central Nebraska and south-central South Dakota and those in western Nebraska are illustrated in figure 6. Swinehart and Diffendal (1990) have shown the general Pliocene and older stratigraphic units beneath the Nebraska Sand Hills area between north-central and western Nebraska.

***Stop* 2. Ashfall Fossil Beds State Historical Park.** This is one of the truly extraordinary mammalian vertebrate fossil localities in North America. Mammal fossils have been known from this area at least as far back as the 1920s, but the site was first studied in 1971 by M. R. Voorhies, who found the first skull and later the rest of the skeleton of a baby rhino here. A test excavation, opened in 1977, revealed the intact skeletons of rhinos and three-toed horses. Much more faunal and some floral remains have been found here subsequently and described by Voorhies in a number of papers, particularly Voorhies (1985, 1990a). The fossils occur in a volcanic ash in the Caprock Member of the Ash Hollow Formation (fig. 7).

Land for the park was acquired in 1986, and the park was dedicated in 1991. Since then tens of thousands of visitors have come to see the fossils and the continuing excavation and study of these fossils by Voorhies and other paleontologists.

The formations exposed in the area (fig. 7) are part of the Ogallala/High Plains Aquifer System, which the U.S. Geological Survey has defined in a

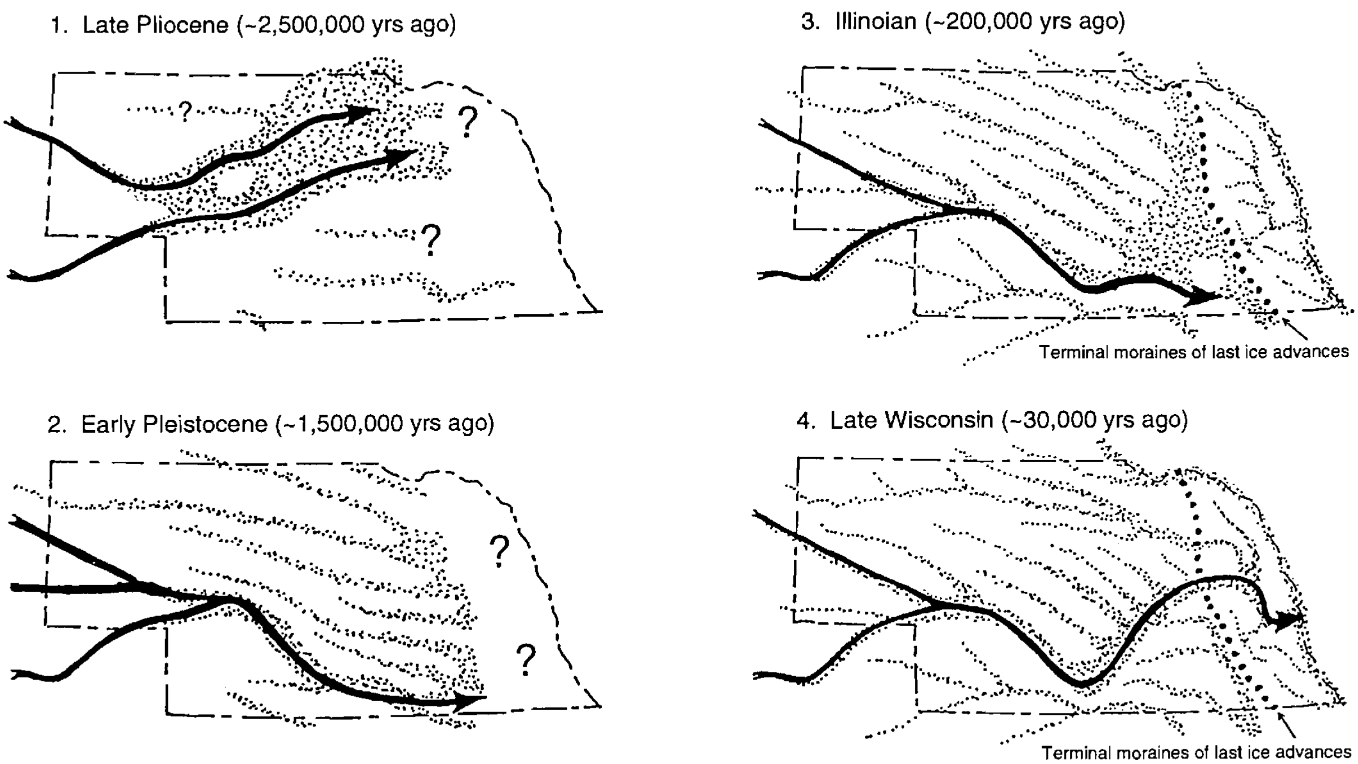

Fig. 4. Postulated evolution of Platte River and related drainages (modified after Souders, Swinehart, and Dreeszen, 1990).

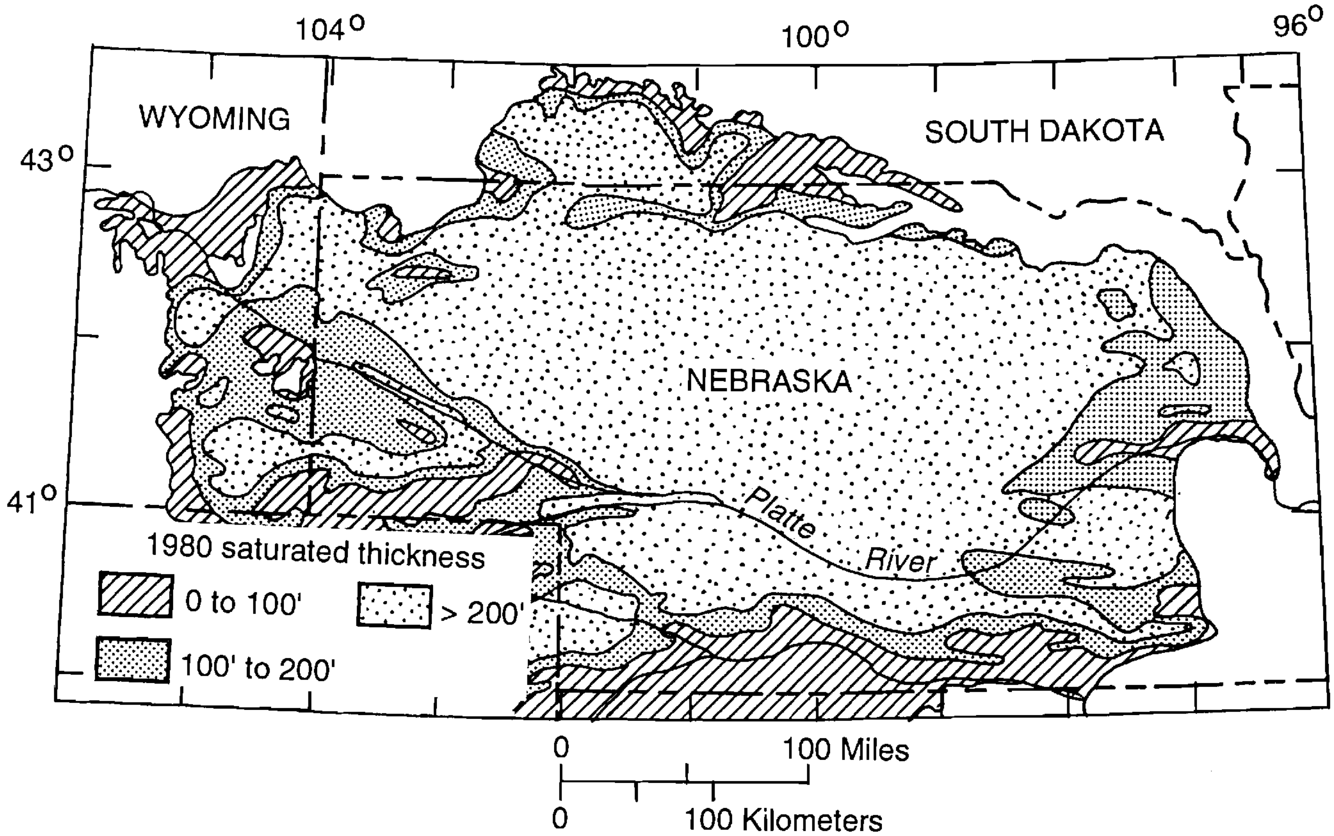

Fig. 5. Saturated thickness of the High Plains Regional Aquifer in Nebraska (modified after Weeks and others, 1988).

number of publications as including almost all of the Cenozoic units named in figure 6. For an overview, see Gutentag and Weeks (1980), Weeks and Gutentag (1981), and Weeks and others (1988). The various tributaries of Verdigre Creek in the area are perennial streams fed by springs coming from the Long Pine Formation and the Ogallala Group.

Stop 3. **Long Pine Formation.** Skinner and Hibbard (1972) described the units in this area and originally placed them in the early Pleistocene. The Keim, Long Pine, Duffy, and Pettijohn formations have subsequently been placed in the Pliocene and are equivalent in age to the Broadwater Formation of western Nebraska (fig. 6). The physical connection of these two named units was implied by Stanley in Stout and others (1971). The Keim, Duffy, and Pettijohn are local units, while the Long Pine is widespread (fig. 8). At this stop we will view the Long Pine Formation and part of the Keim Formation. From this point west, we will be passing through large areas covered by the Nebraska Sand Hills. This dune region has been studied extensively by J. B. Swinehart and colleagues. Results of those studies have been published in several papers, particularly Swinehart (1990).

Stop 4. **Valentine Formation.** This is a short stop to see some of the sands of the Valentine Formation and the Niobrara River valley. The geology of the area along and adjacent to the river has been described in detail most recently by Skinner and Johnson (1984) and by Voorhies (1990b).

Stop 5. **Valentine and Ash Hollow formations.** Skinner and Johnson (1984) subdivided these formations into a number of members, some of which can be seen exposed in roadcuts and natural exposures northeast of the city of Valentine, Nebraska (fig. 9). We will get a good view of these at this stop and also see the late-Pleistocene fluvial high terrace along the Niobrara River.

April 30, 1995

Stop 6. **Snake River Falls.** The geologic section exposed here (fig. 10) was illustrated and described by Skinner and Johnson. Part of the Caprock Formation of the Ash Hollow forms the resistant ledge over which the Snake River falls. From here to stop 7, we will be going mostly through the Sand Hills. We will see older units exposed only where bedrock highs come to the surface, where they have been cut through in a few roadcuts, or along river valleys.

Stop 7. **Box Butte Tablelands, Niobrara Valley, and Pine Ridge.** Swinehart and others (1985) have described the stratigraphy of this area in general and have placed in the Ogallala Group several units previously included by some workers in the Hemingford Group. We will stop at some of these older

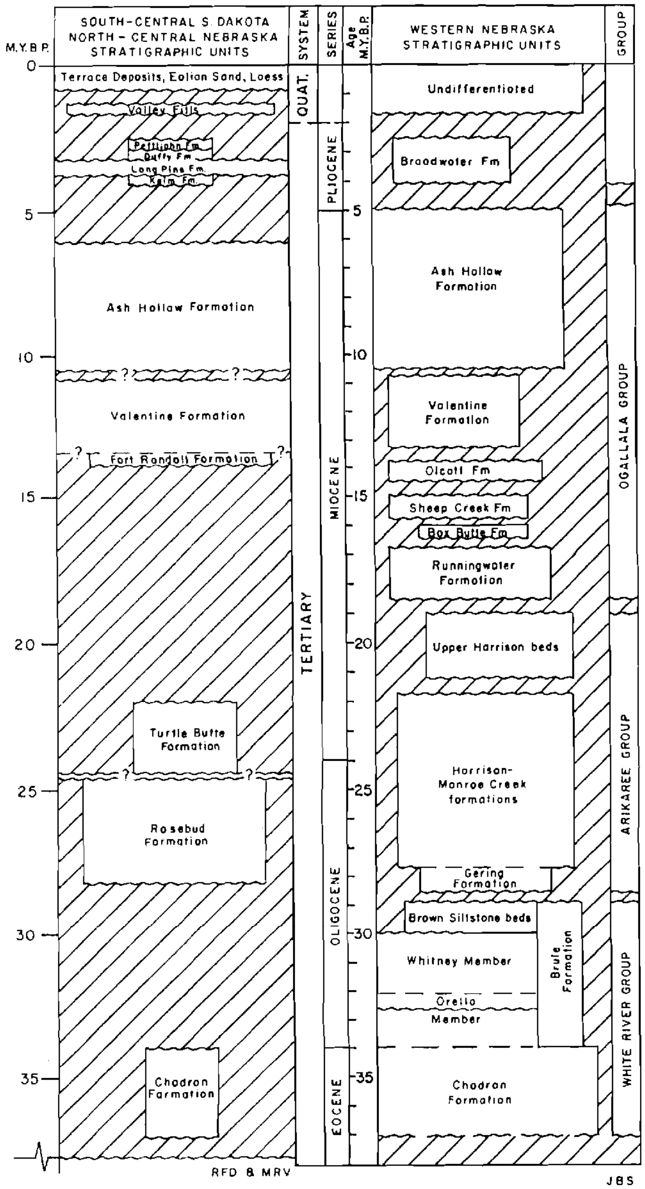

Fig. 6. Correlation of stratigraphic units between north-central Nebraska/south-central South Dakota and western Nebraska (modified after Diffendal and Voorhies, 1994, and Swinehart and others, 1985).

Ogallala units exposed in roadcuts between Hay Springs and Alliance, Nebraska. The geology of this area has been discussed in a number of publications. For a more detailed overview than that given in Swinehart and others (1985), see Souders (1981) and Souders, Smith, and Swinehart (1980).

Stop 8. **Carhenge.** Considered folly by some, this piece of folk art by a local resident is intended to resemble the British stone circle, Stonehenge.

Noteworthy but not a stop. **Entering the North Platte Valley.** Swinehart and Diffendal have two geologic maps in press with the U.S. Geological Survey covering Morrill County (1:63,360) and the southern half of the Nebraska Panhandle (Scottsbluff; 1:250,000). In addition, Diffendal (1991) published the North Platte 1:250,000 map. Groundwater reports, including those by Smith and Souders (1975) and Souders (1981), have been prepared for most of the counties in the southern Panhandle.

Stop 9. **Duer Ranch.** Swinehart and Diffendal (1987) described this area (fig. 11) in detail. We will walk over parts of the area and see spectacular examples of Ogallala Group gully fills, Ash Hollow Formation sands and gravels filling channels and basal inner channels of the Broadwater Formation (=Long Pine).

May 1, 1995

Stop 10. **Multiple volcanic ash deposits in the Ash Hollow Formation south of Broadwater, Nebraska** (fig. 12). Diffendal (1984b) and Swinehart and others (1985) published maps showing the distribution of volcanic ash beds in the area. These ash beds and others found by Diffendal, Voorhies and others in the Ogallala across Nebraska and northwestern Kansas are currently the focus of studies by M. Perkins of the University of Utah, aided by Diffendal and Voorhies. Preliminary results indicate that ash chemistry may allow discrimination and correlation of ash deposits across the Great Plains and also of Ogallala ashes on the Great Plains with volcanic sources in Idaho and Nevada. The Ash Hollow Formation fills a paleovalley, the base of which is more than 150 feet below the lowest exposures here. Perennial springs issue from the lowest exposed Ash Hollow sands and gravels at several spots just east of this stop.

Stop 11. **Greenwood Canyon south of Bridgeport, Nebraska.** A general stratigraphic section of the rocks exposed in this area was published in Stout and others (1971). Subsequently, Diffendal (1984b) studied the area and, among other things, found multiple volcanic ash beds in the Ash Hollow Formation of the Ogallala Group (fig. 13). This stop is about 10 miles west of stop 10. We will look at some of these ash beds.

Stop 12. **Early Quaternary fluvial deposits of Pumpkin Creek valley.** If you look once again at figure 4, you will see that I have depicted a tributary to the North Platte River in the general position of Pumpkin Creek valley on the early Pleistocene maps, but have not shown it on the map of Pliocene drainages. This stop is at a gravel pit that yielded fossils of early Pleistocene mammals. It is one of several remnants of the topographically highest fluvial terrace in the valley. No older terraces are known from this valley. Today, Pumpkin Creek is an underfit stream, small even when rains are heavy. It is underfit, in part, because it has been pirated by other tributaries of the North Platte both eastward in Morrill County and in eastern Wyoming (fig. 14).

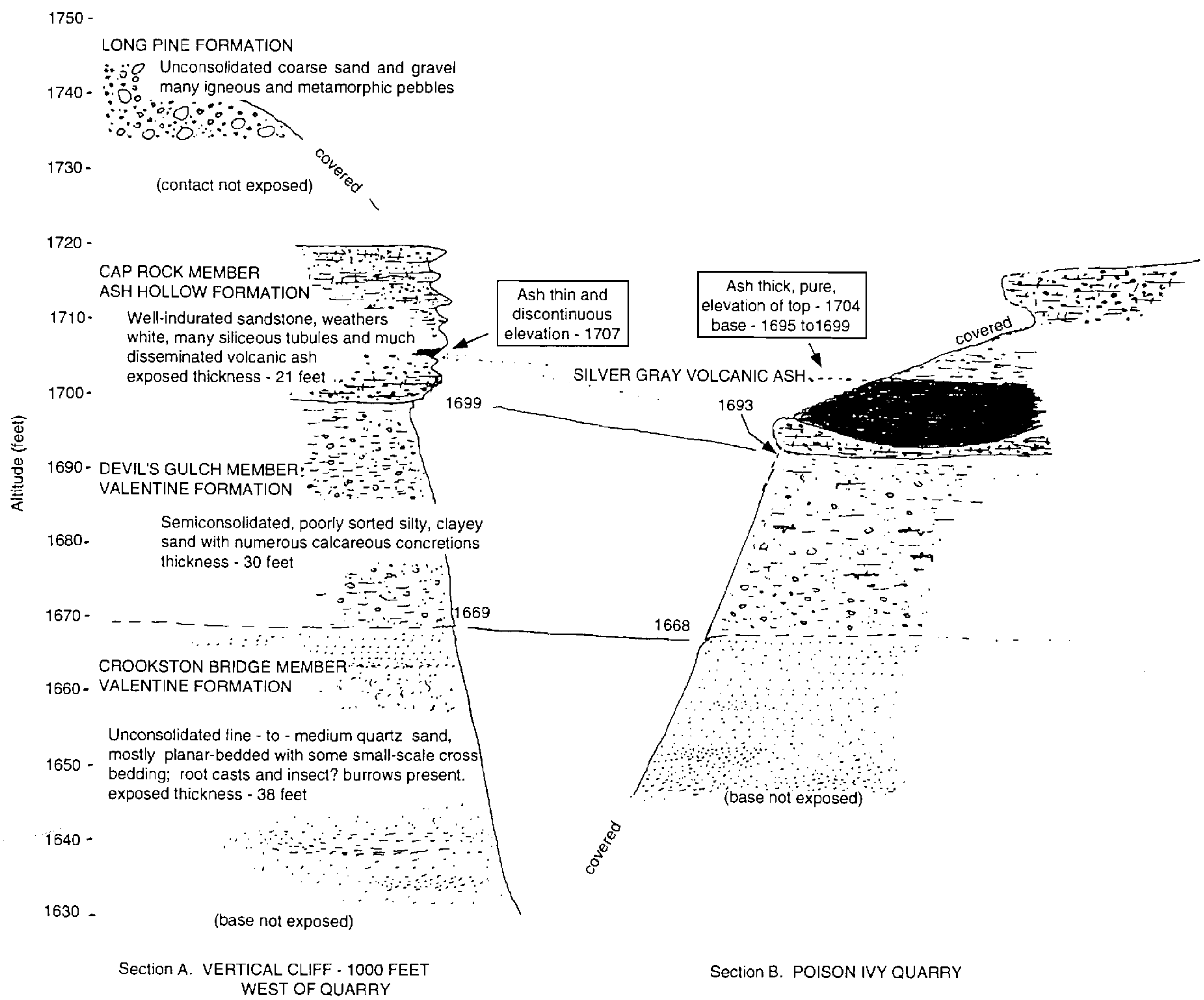

Fig. 7. Geologic sections in the vicinity of Ashfall Fossil Beds State Historical Park (after Voorhies, 1985, fig. 2).

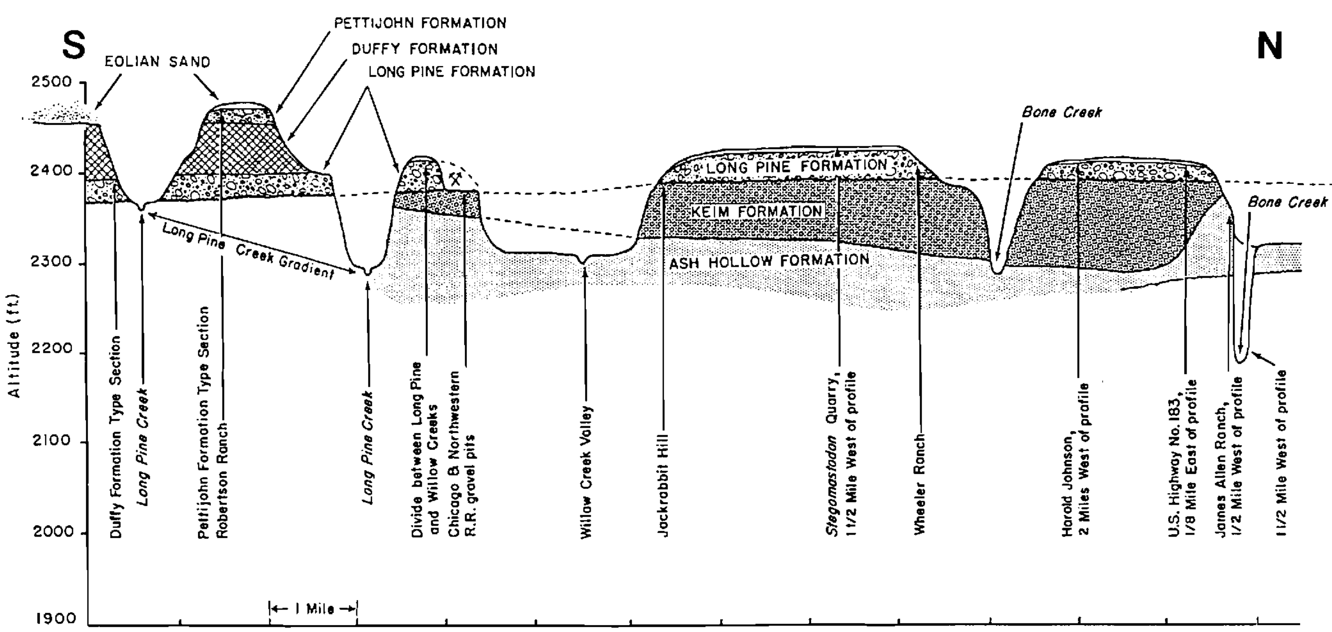

Fig. 8. S-N profile from Long Pine, Nebraska, northward (after Skinner and Hibbard, 1972, fig. 3; courtesy of the American Museum of Natural History).

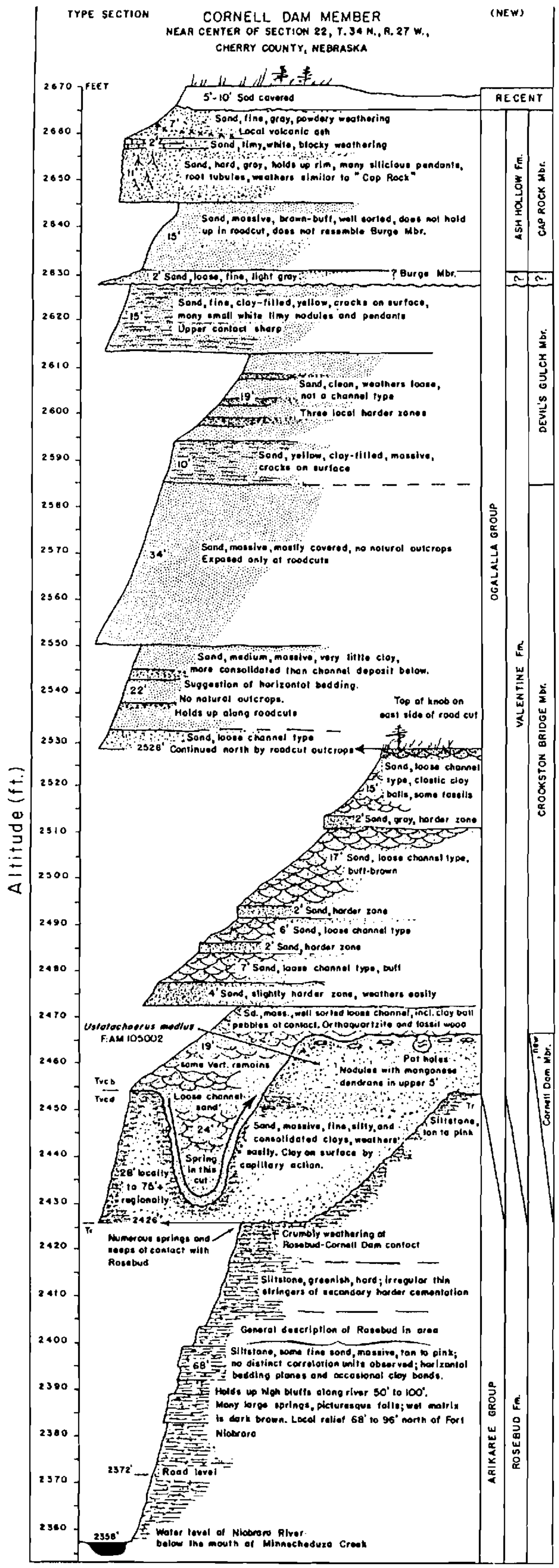

Fig. 9. Stratigraphic section north of Niobrara River northeast of Valentine, Nebraska (after Skinner and Johnson, 1984, fig. 5; courtesy of the American Museum of Natural History).

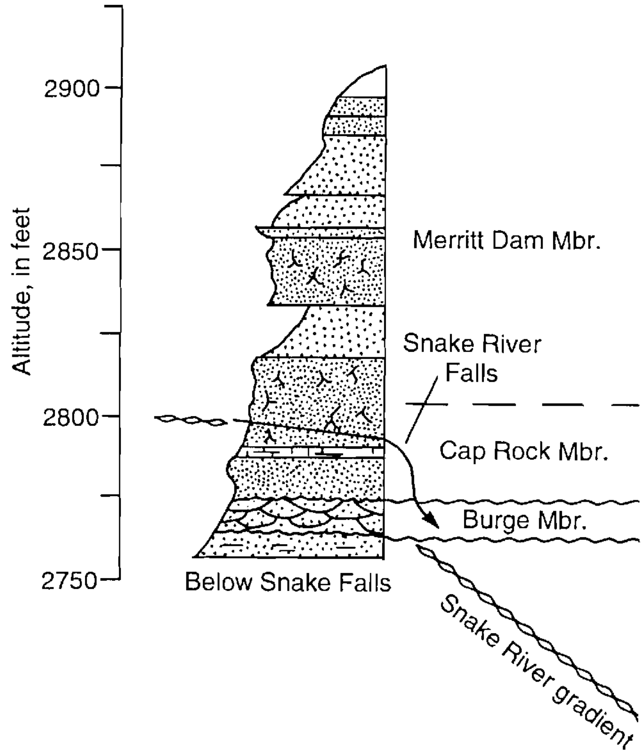

Fig. 10. Stratigraphic section at Snake River Falls (after Skinner and Johnson, 1984, fig. 38 in part; courtesy of the American Museum of Natural History).

Stop 13. **Faden and Van Pelt ranches--Ash Hollow Formation valley fills.** At Faden Ranch, the basal Ash Hollow Formation fills inner channels like those of the basal Broadwater Formation on Duer Ranch (stop 9). On the Van Pelt Ranch, we will look at part of one valley fill, tributary gully fills, opal beds, caliches and other interesting features. We will also see evidence of two Ash Hollow valley fills of different ages in this area (fig. 15). The Ogallala exposures on the Van Pelt and adjoining pastures were in part designated as separate formations younger than the Ash Hollow, called the Sidney Gravel and the Kimball Formation by Lueninghoener and Lugn (Diffendal, 1985). This terminology has been abandoned, and all of the Ogallala rocks here have been placed in the Ash Hollow Formation by Diffendal (1985, 1990). Caliches and groundwater cements at this stop and stop 14 (fig. 16) have been studied and reported on by Gardener, Diffendal, and Williams (1992).

Stop 14. **Exposures of the "typical Kimball" south of Kimball, Nebraska.** This stop includes the supposed stratigraphically highest parts of the so-called Kimball Formation of the Ogallala.

Stop 15. **Exposures of the "typical Sidney Gravel" near Sidney, Nebraska.** We will look at compositional differences of this supposed unit, now included in an expanded Ash Hollow Formation (fig. 17).

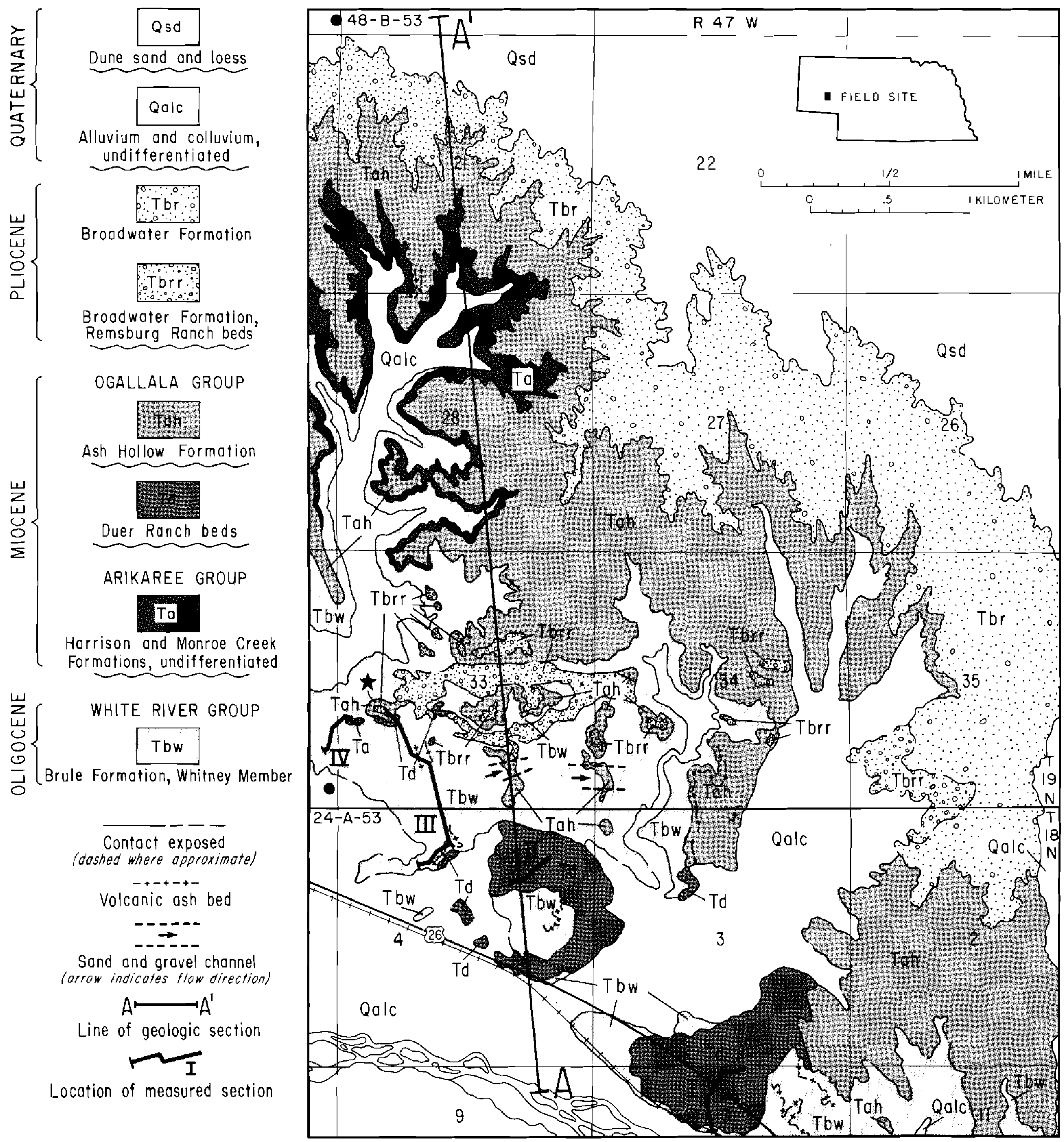

Fig. 11. Geologic map of the Duer Ranch locality (after Swinehart and Diffendal, 1987, fig. 2).

May 2, 1995

Stop 16. **Ash Hollow.** Ash Hollow is the type area of the Ash Hollow Formation. Stout and others (1971) and Diffendal (1987) have described and diagrammed measured sections of the strata in this area. Diffendal's section (1987; fig. 18) shows that the formation in the subsurface thickens to the south. Multiple volcanic ash beds have been mapped in the Ash Hollow Formation in this area by Diffendal (1984b).

Noteworthy but not a stop. As we drive from here to Ogallala, observe the thick sequences of loess exposed in the canyons to the north of U.S. Highway 26. Some are up to 200-ft (66-m) thick. I will also point out sand and gravel deposits below the loess and on top of the Ash Hollow Formation that are part of the Broadwater Formation and were deposited by the ancestral South Platte River (fig. 4).

Stop 17. **Type area of the Ogallala Group.** This is the poorest type area of any we have seen. It has no exposed base and the top is erosional.

Return to Lincoln on I-80. End of trip.

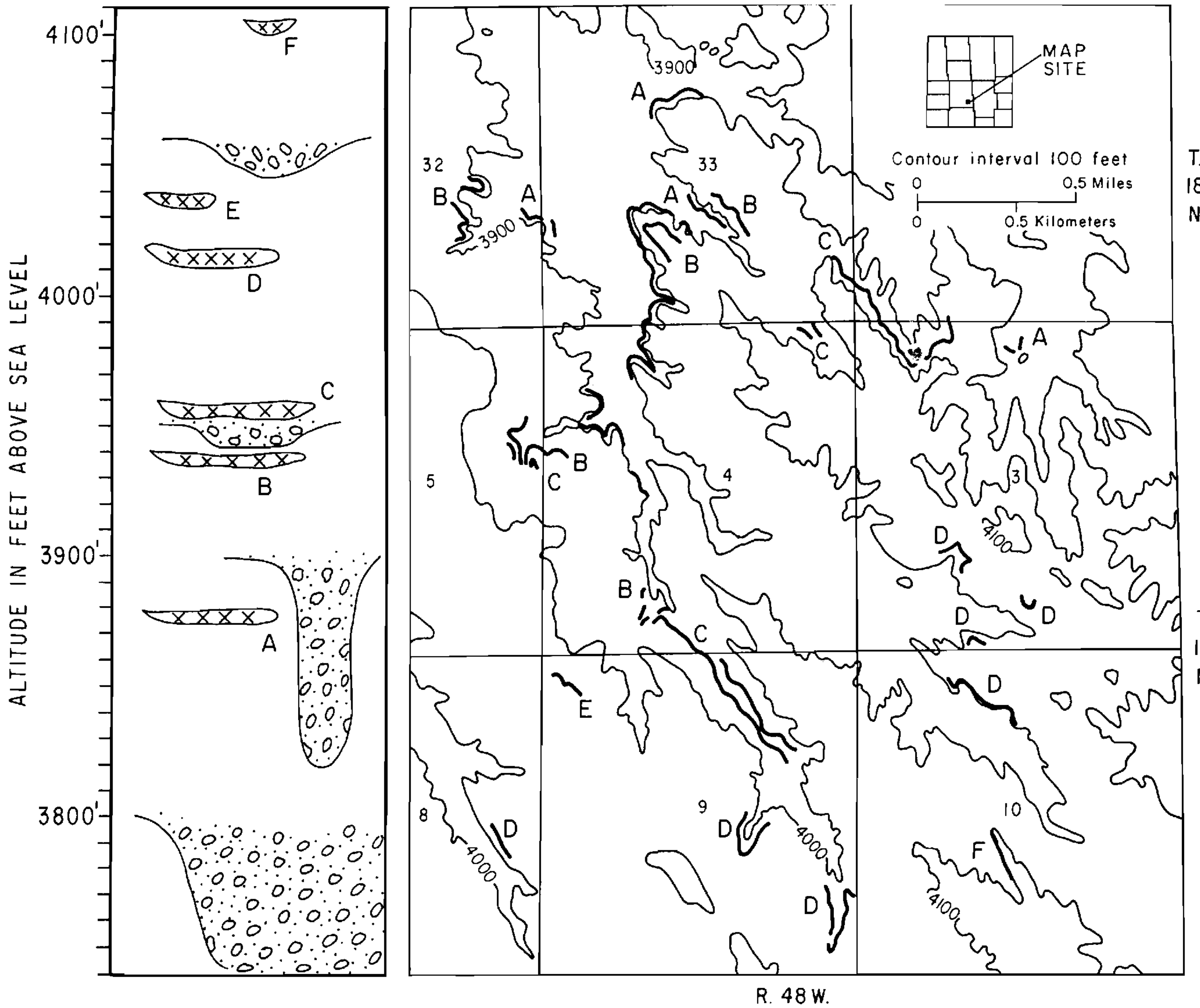

Fig. 12. Map of part of Morrill County showing superposed ash lentils in Ash Hollow Formation (after Swinehart and others, 1985, fig. 18).

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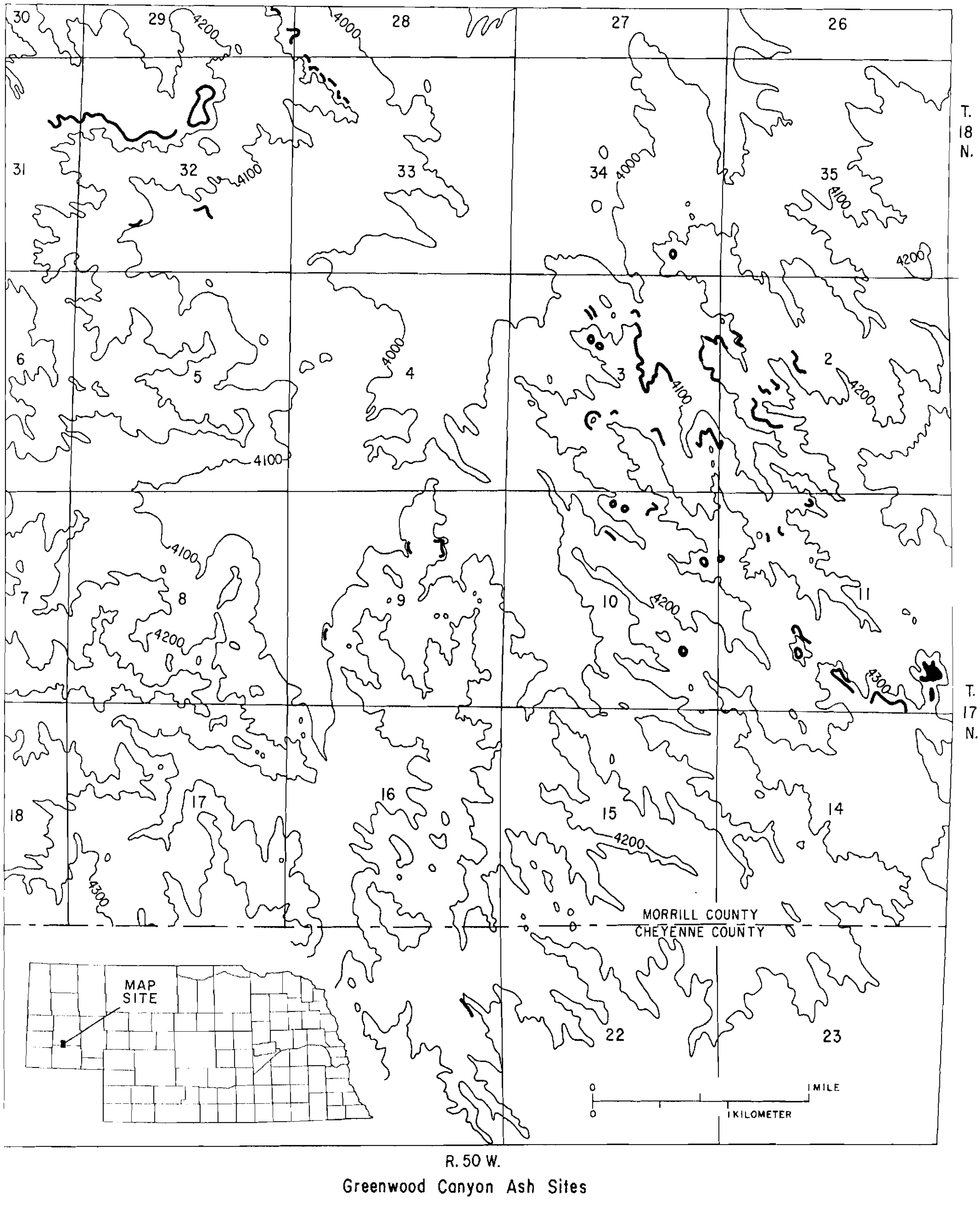

Fig. 13. Map showing locations of volcanic ash lentils in the Ash Hollow Formation in the Greenwood Canyon area (after Diffendal, 1984b, fig. 7).

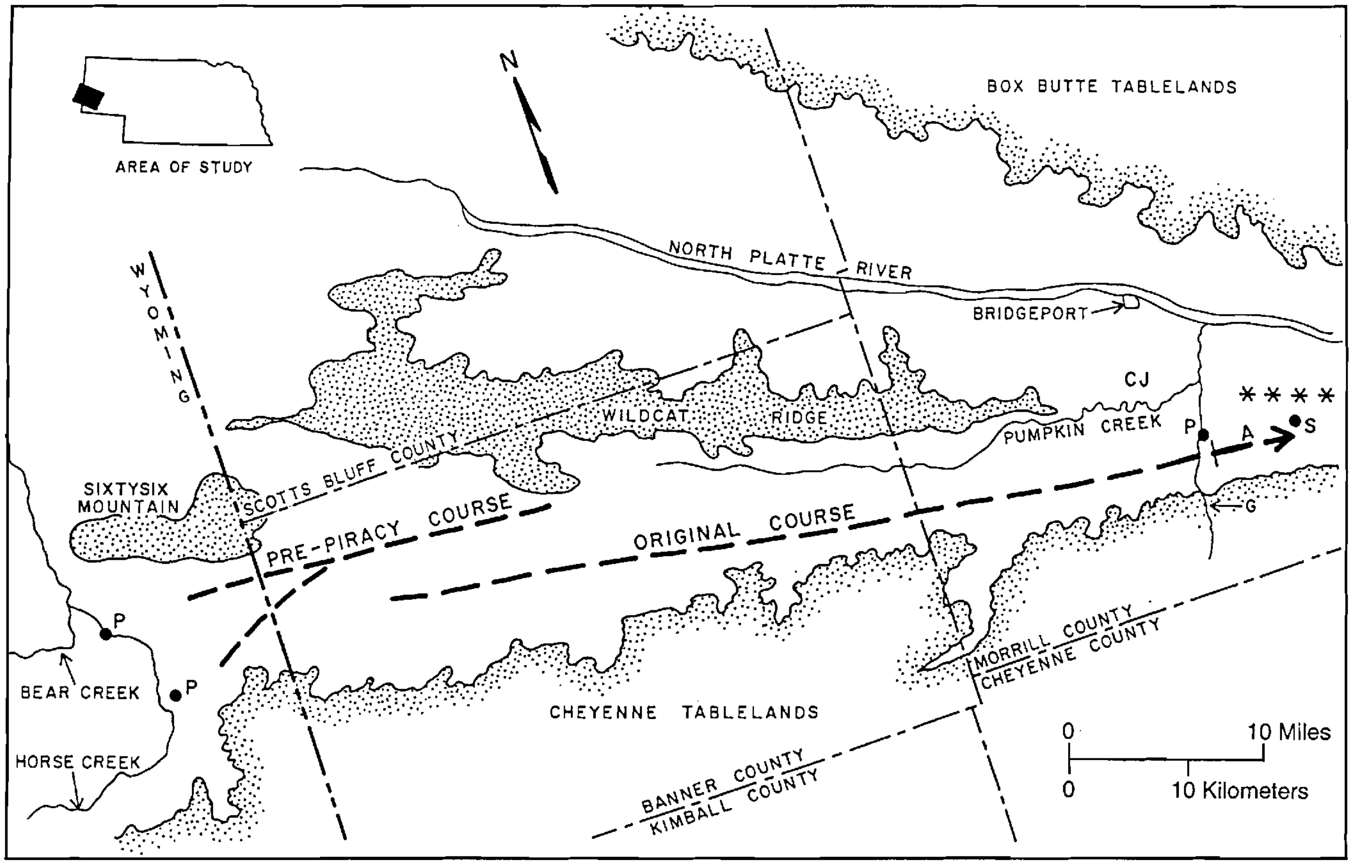

Fig. 14. Changes in course of Pumpkin Creek during the Quaternary in eastern Wyoming and western Nebraska (after Diffendal, 1984a, fig. 1).

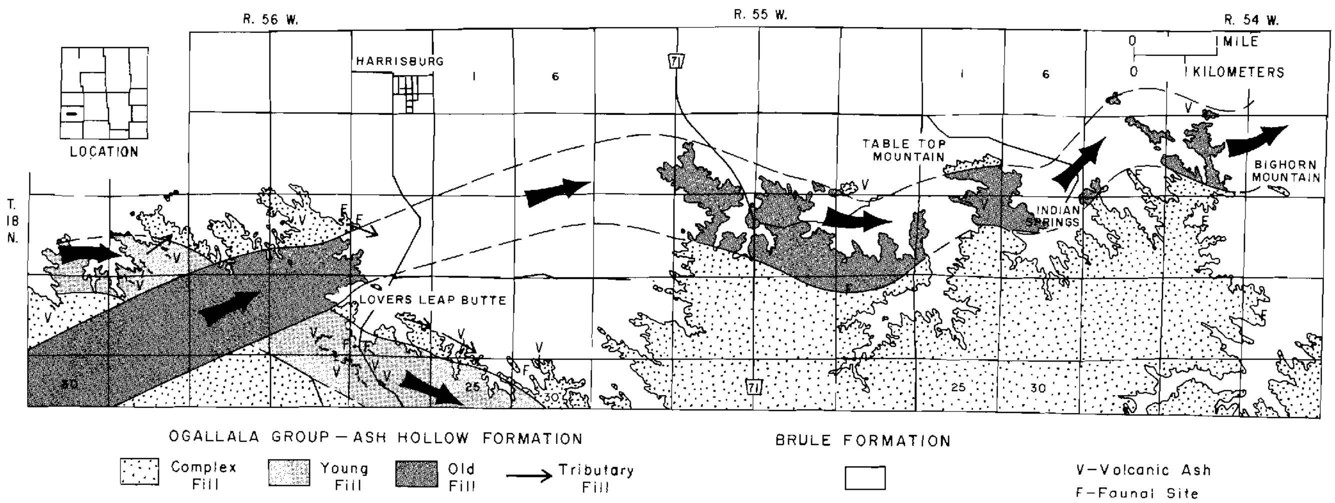

Fig. 15. Distribution and age relationships of Ash Hollow Formation paleovalleys in part of Banner County, Nebraska (after Swinehart and others, 1985, fig. 17).

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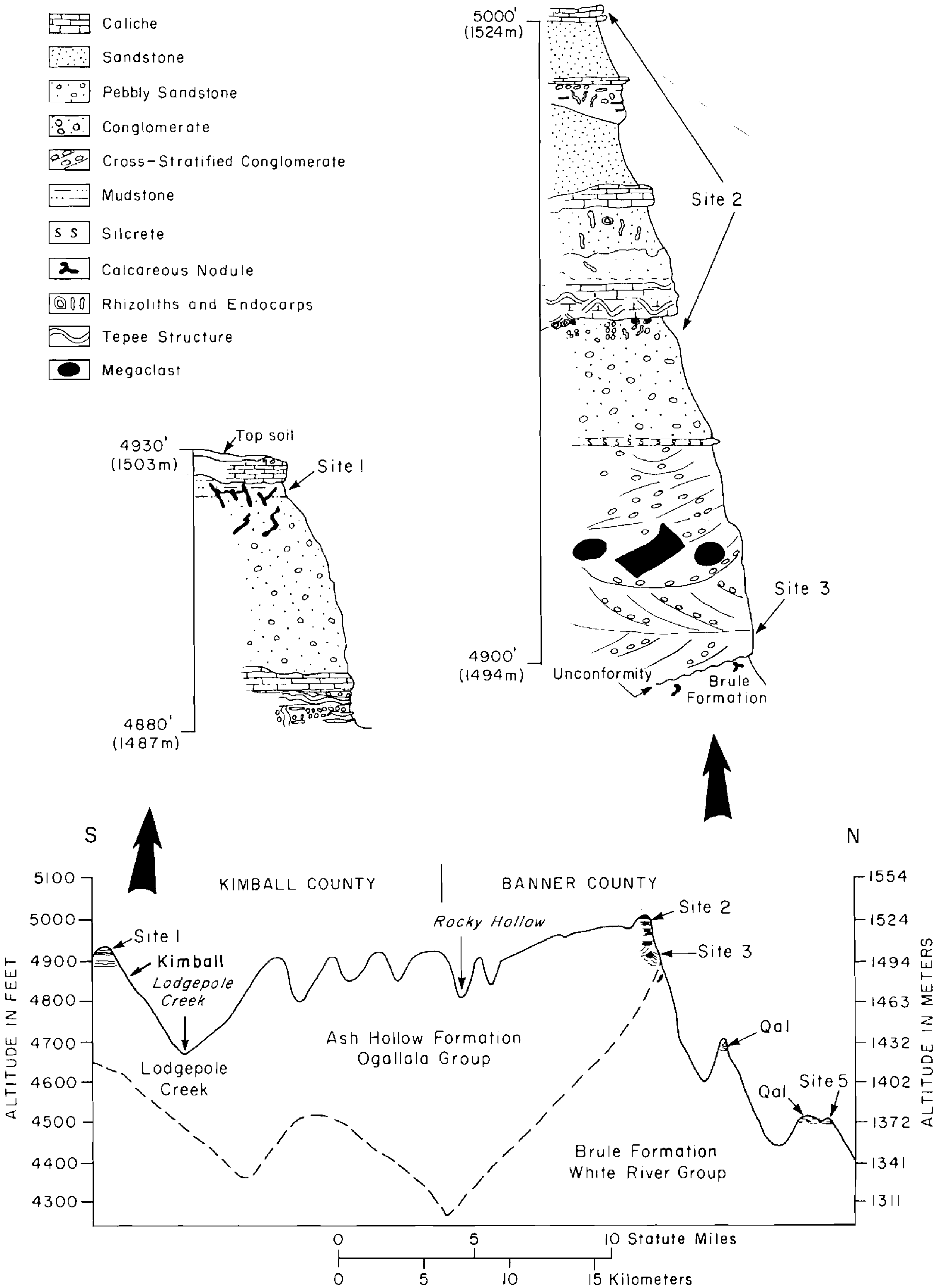

Fig. 16. Stratigraphic sections and generalized N7W cross section from Kimball, Nebraska, to southern Banner County (after Gardner, Diffendal, and Williams, 1992, fig. 3).

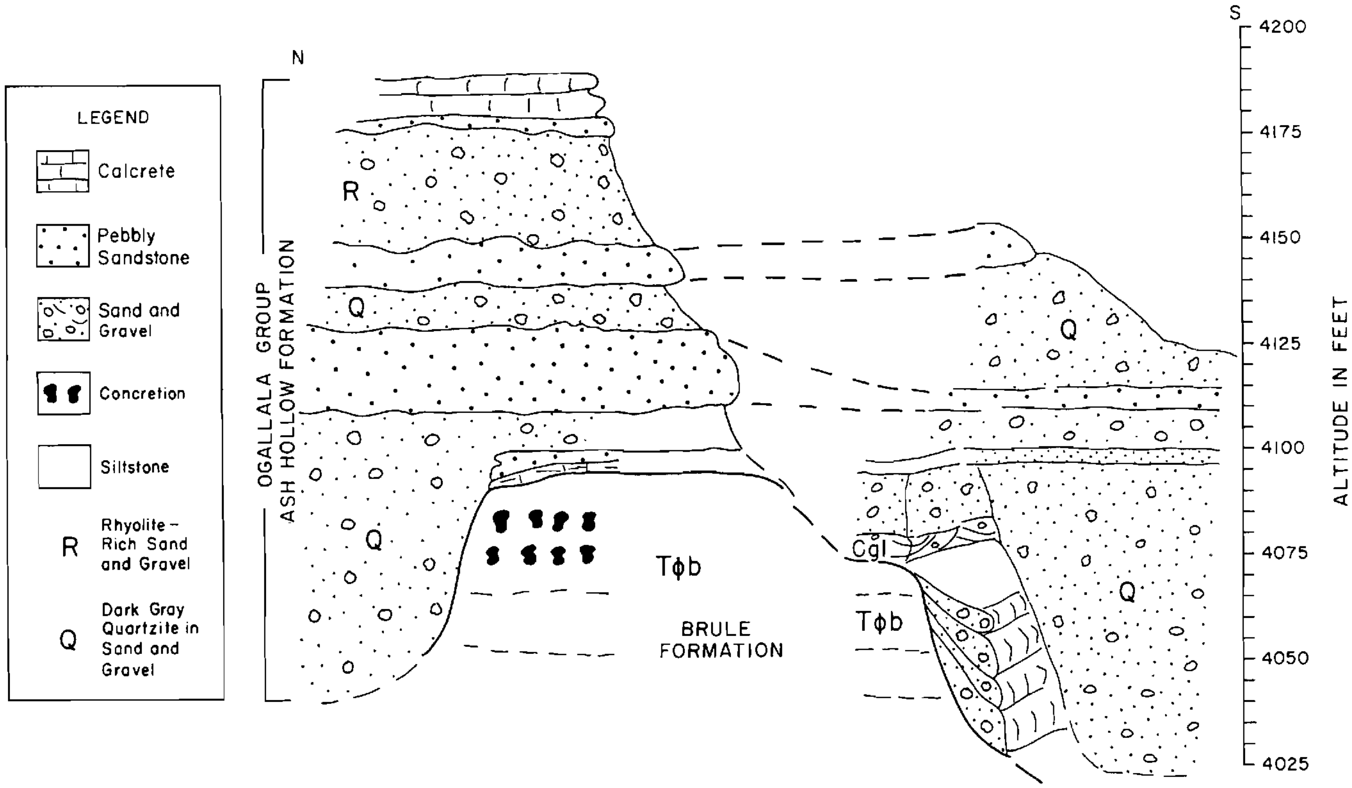

Fig. 17. Ash Hollow Formation stratigraphy section east of Sidney, Nebraska (after Diffendal, 1990, fig. 7).

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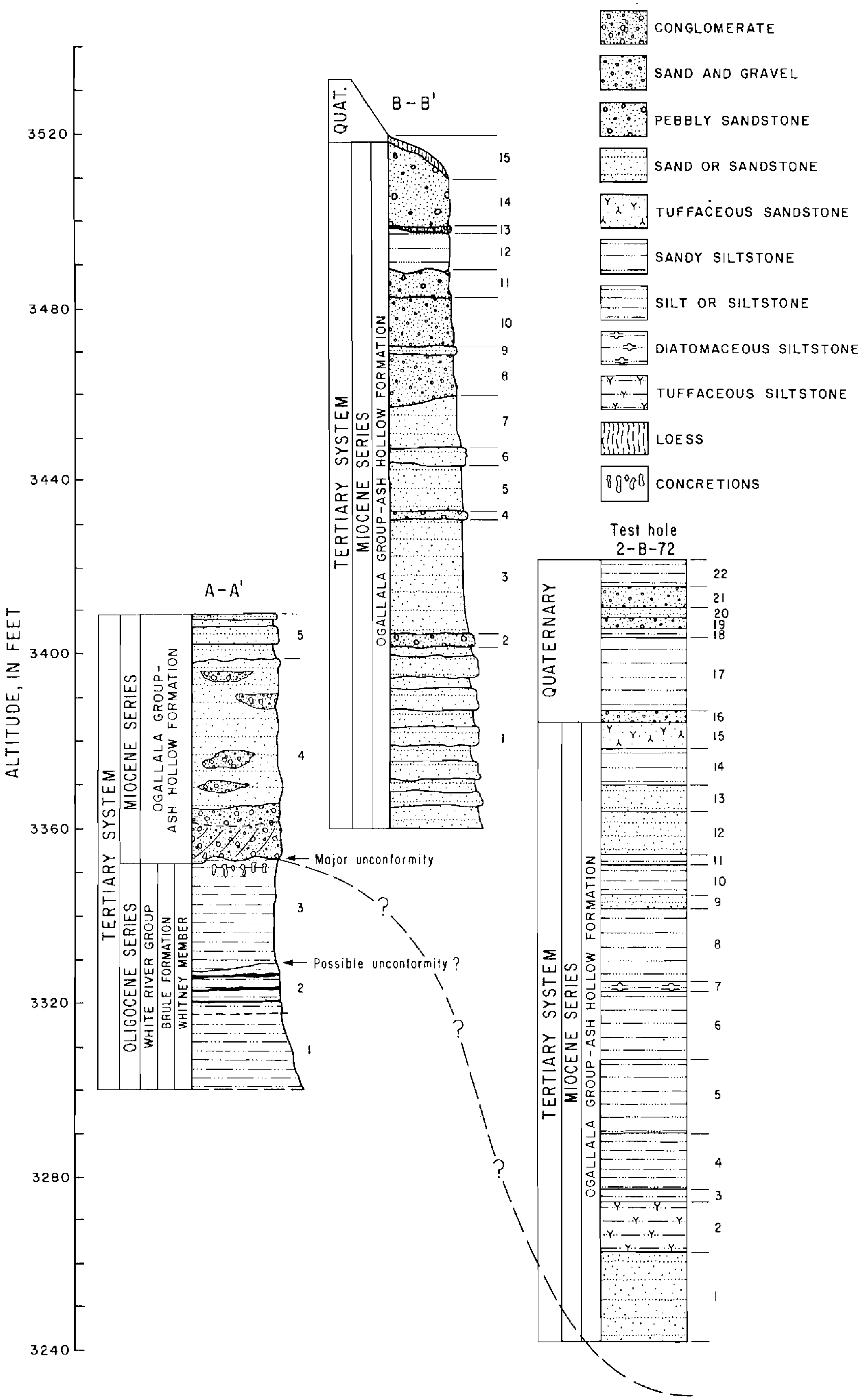

Fig. 18. Ash Hollow stratigraphy along Ash Hollow Creek, Garden County, Nebraska (after Diffendal, 1987, fig. 3).

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