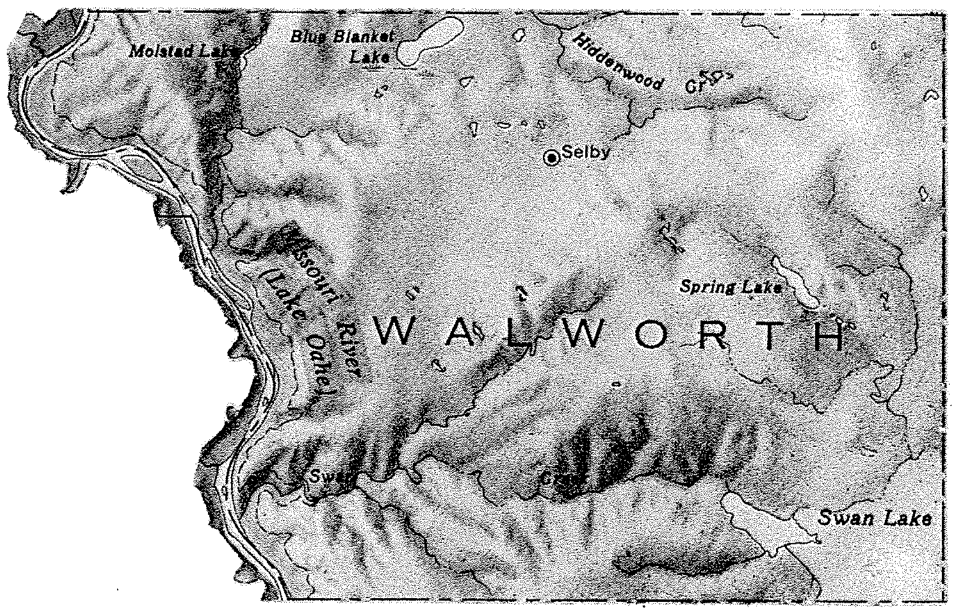
BULLETIN 30

GEOLOGY OF WALWORTH COUNTY, SOUTH DAKOTA



by Lynn S. Hedges

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

DEPARTMENT OF WATER AND NATURAL RESOURCES
SOUTH DAKOTA GEOLOGICAL SURVEY-1987

STATE OF SOUTH DAKOTA
George S. Mickelson, Governor

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

GEOLOGICAL SURVEY
Merlin J. Tipton, State Geologist

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Science Center
University of South Dakota
Vermillion, South Dakota

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ABSTRACT

Walworth County is located in north-central South Dakota and contains an area of 733 square miles. Dominant topographic features of the County are the Missouri River trench and undulating uplands of the Coteau du Missouri.

Pre-Pleistocene rocks underlie the entire County and range in age from Precambrian to Cretaceous. The upper Cretaceous Pierre Shale directly underlies the glacial deposits and crops out extensively along the Missouri River.

Pleistocene age deposits mantle the Pierre Shale bedrock and attain a thickness of 350 feet. These deposits consist mostly of till, outwash-alluvium, and lake clays of the Pollock Formation.

A new non-glacial Pleistocene unit of Kansan Age, the Java Formation, consists of a basal sand and gravel as much as 60 feet thick overlain by windblown silt containing ash shards. Total thickness of the unit is 185 feet. No glacial deposits older than late Wisconsin were identified in Walworth County.

The main resources of economic value are ground water and sand and gravel aggregate.

INTRODUCTION

This report contains the results of a cooperative study of the hydrology and geology of Walworth County conducted by the South Dakota Geological Survey and the United States Geological Survey. It is one of a series of county studies (fig. 1) which are being undertaken 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 study was initiated at the request of the Walworth Commissioners and funds were made available through the South Dakota Geological Survey, the United States Geological Survey, Walworth County, and the Oahe Conservancy Sub-District.

The results of this investigation will be published as a Bulletin of the South Dakota Geological Survey. Part I, this report, discusses the geology. Part II will report on the hydrology. Copies of the written reports and the basic data will be provided to the County. Additional reports will be made available at cost on demand to other interested parties.

Walworth County includes approximately 733 square miles in north-central South Dakota and is part of the Coteau du Missouri Division of the Great Plains Physiographic Province (fig. 1). Good descriptions of the physiography of South Dakota are found in Rothrock (1943) and Flint (1955).

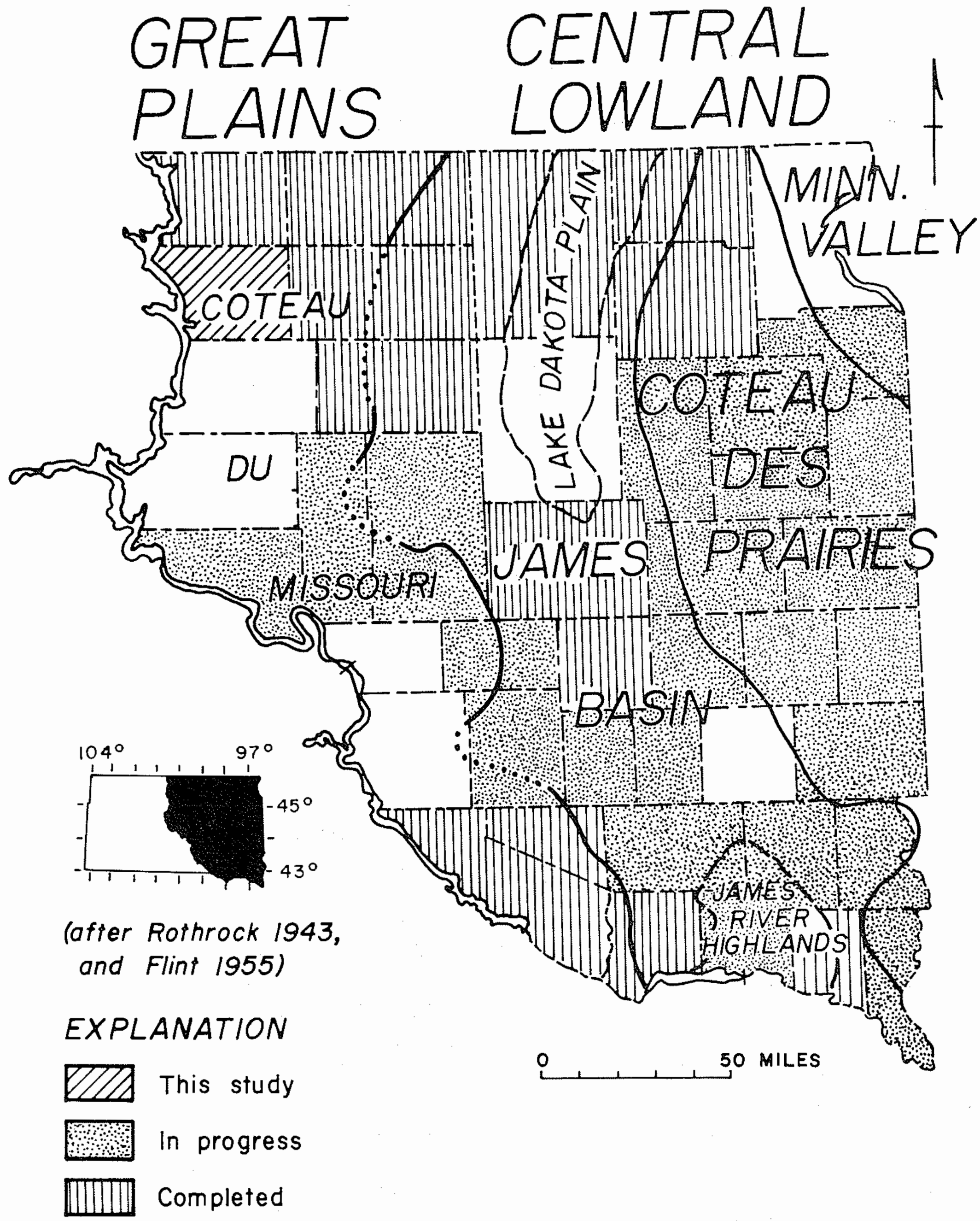

Figure 1. Map of eastern South Dakota showing location of physiographic divisions and location of county water resource studies.

The residents of Walworth County, the Oahe Conservancy Sub-District, and the Board of County Commissioners are acknowledged for their participation and cooperation throughout this project.

STRATIGRAPHY

Precambrian

Two oil tests have completely penetrated the sedimentary sequence in Walworth County and both tests reported Precambrian granite as the basement rock (table 1). Granite from the Pray No. 1 Kranzler has a Rb-Sr date of 1.69 billion years (Goldich and others, 1961).

A map of the Precambrian surface of South Dakota shows a surface sloping toward the northwest into the Williston Basin (Steece, 1961). In the southeast corner of the County the Precambrian surface is about 1,300 feet below sea level while in the northwest corner of the County it is about 2,700 feet below sea level. The Percambrian surface thus has an average slope of about 33 feet per mile across Walworth County.

Paleozoic

Nomenclature for paleozoic rocks in Walworth County conform to Schoon (1967). These rocks consist of over 1,500 feet of limestone, dolomitic limestone, and dolomite; however, thin sandstone and shale units may also be present throughout much of the section. Thickness, age and general lithologic description of the individual formations are shown graphically on figure 2. The Permian to Cretaceous rock sequence, lying between the Hayden Formation and the Inyan Kara Group (fig. 2) is a red clay that may be highly weathered Paleozoic sediments or a deposit post-dating the Paleozoic rocks.

Mesozoic

The only known Mesozoic sediments in Walworth County are Cretaceous in age. They are, from oldest to youngest, the Inyan Kara Group, Skull Creek Shale, Dakota Formation, Graneros Shale, Greenhorn Limestone, Carlile Shale, Niobrara Marl, and the Pierre Shale. Their thickness and general lithologic description along with a typical electric log are shown in figure 2.

The only Cretaceous age rocks exposed in Walworth County are the upper members of the Pierre Shale (fig. 3). For the purposes of this report the members of the Pierre Shale have not been differentiated either in outcrop or in the subsurface. For a detailed discussion on the nomenclature and lithologies of these members around Pierre, South Dakota, see Crandall (1958). Hedges (1972) offers some additional discussion of those members

Table 1

Sequence of sedimentary rocks in Walworth County

WELL NAME	Peppers No. 1 State	Pray No. 1 Kranzler
DATE DRILLED	1952	1952
LOCATION	NE SE sec. 36, T. 123 N., R. 76 W.	NW NW sec. 14, T. 121 N., R. 77 W.
ELEVATION *	2064 (Kelly Bushing)	1881 (Kelly Bushing)
TOTAL DEPTH **	3,914	3,808

DEPTH TO FORMATION TOP **

Greenhorn	1,497	1,320
Dakota	1,884	1,710
Fall River	2,240	2,085
Minnekahta	0	2,260
Minnelusa	2,420	2,280
Madison	2,620	2,515
Devonian	3,140	3,056
Red River	3,320	3,200
Precambrian	3,895	3,805

* Elevation in feet above mean sea level.

** Depth in feet.

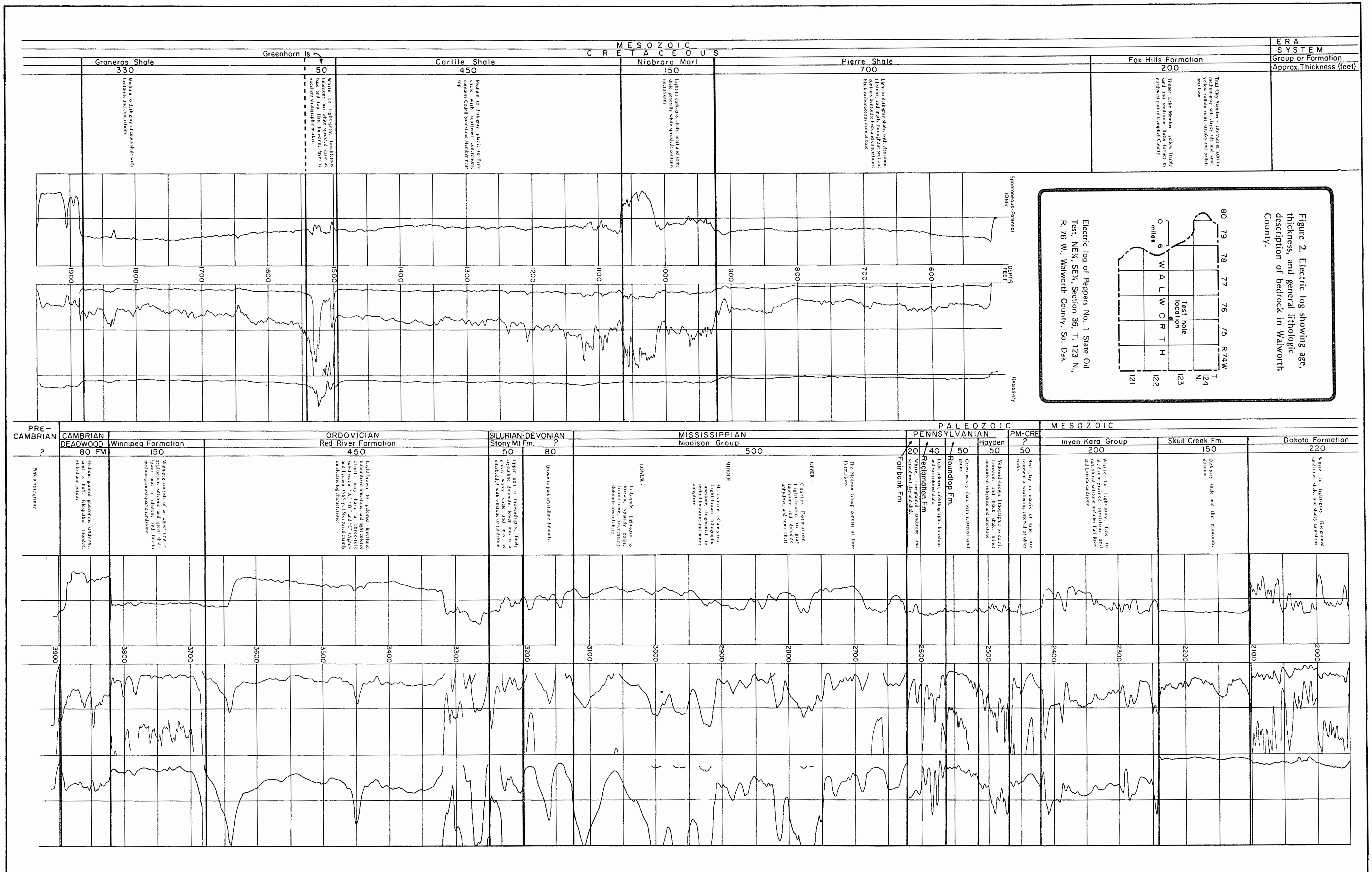

Figure 2. Electric log showing age, thickness, and general lithologic description of bedrock in Walworth County.

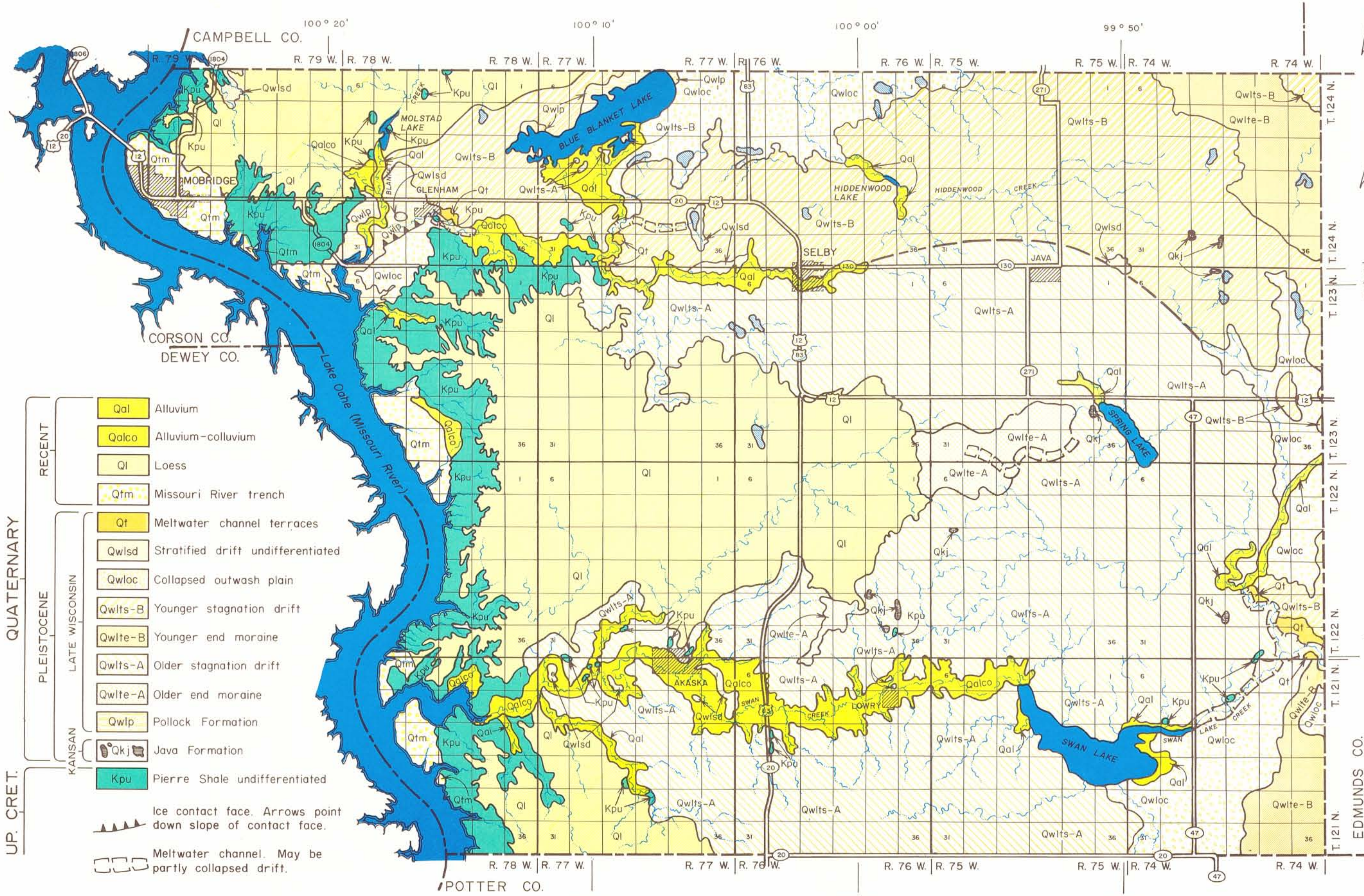

Figure 3. Geologic map of Walworth County.

cropping out in Campbell County. All of the Pierre Shale outcrops with the exception of a few thin isolated outcrops are mapped on published South Dakota Geological Survey geologic quadrangles. Those covering parts of Walworth County are listed below:

Mouth of the Moreau	(Mickelson and Baker, 1950)
Akaska	(Baker, 1952)
Mobridge	(Baker, 1952)
Cheyenne Agency	(Mickelson, 1952)
Little Cheyenne	(Mickelson, 1952)

The Greenhorn Limestone is widespread and quite uniform in character, and it is easily identifiable in the subsurface from sample cuttings and electric logs. This characteristic makes it a good subsurface marker bed. A structure map drawn on top of the Greenhorn (Petsch, 1953) shows the Greenhorn dipping to the northwest into the Williston Basin at an average of about 12 feet per mile from a starting elevation of about 650 feet above sea level at the southeastern corner of the County.

The history of nomenclature and problems of correlation of the stratigraphic interval containing the Dakota Formation, Skull Creek Shale and the Inyan Kara Group are complex in South Dakota. This problem is discussed in some detail by Schoon (1965). A comparison of older nomenclature (presently used by most well drillers in the area) and that of Schoon are shown below:

Old Nomenclature	Schoon (1965)
Dakota	Dakota Formation
Morrison	Skull Creek Shale
Sundance	Inyan Kara Group

Cenozoic

Tertiary deposits are now known to exist east of the Missouri River in north-central South Dakota. No deposits belonging to the Tertiary were found during the mapping of Walworth County. This conclusion was also determined to be true in Campbell County, just north of the present study (Hedges, 1972).

Pleistocene Non-Glacial

Pleistocene non-glacial deposits in Walworth County are the Java Formation (new name) and a non-glacial gravel in the buried Moreau River channel.

The Java Formation is present in a large portion of eastern Walworth County (fig. 4). In most places it is covered by as much as 100 feet of glacial drift but several isolated outcrops do occur (fig. 3). The thickness varies from a feather-edge near the margins to as much as 185 feet thick at the type section in

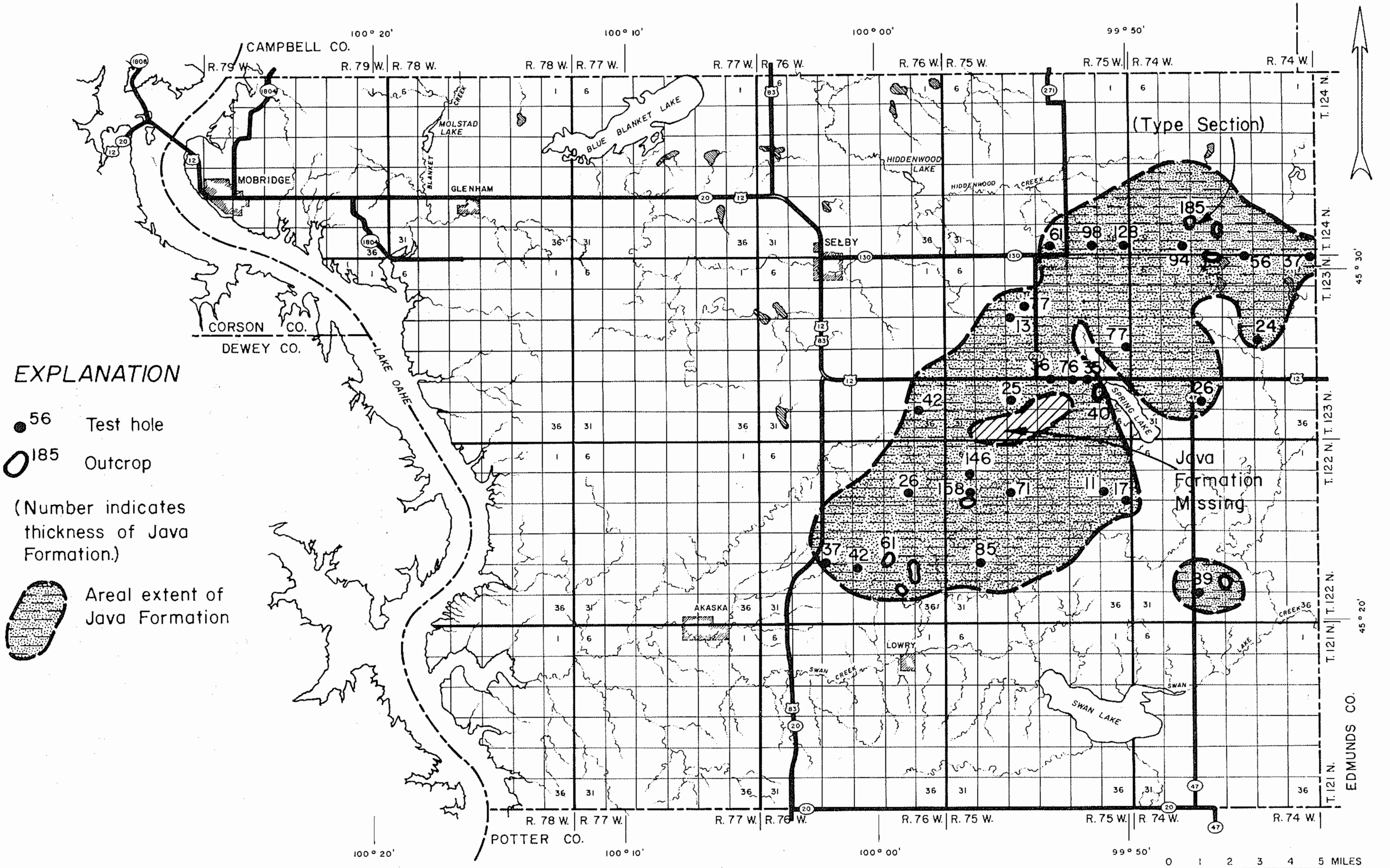

Figure 4. Map showing distribution and thickness of the Java Formation.

NW NW NW NW sec. 33, T. 124 N., R. 74 W. The geologic cross sections (figs. 5-10) show the stratigraphic relationship of the Java Formation to the bedrock surface and the glacial drift. Figure 11 shows locations of the cross sections and table 2 is a list of test holes in the cross sections.

The basal portion of the Java Formation is a river channel deposit that varies from a clean, well-sorted fine to medium quartzose sand near its southern extent, to a fine gravel over the northern three-fourths of the extent. The sand is as much as 60 feet thick while the gravel facies has a maximum known thickness of 30 feet.

The upper portion of the Java Formation is predominantly a light-tan to cream-colored to light reddish-brown wind-blown silt with some clay and very fine sand. Fist-sized nodules of calcium carbonate cemented matrix, carbon flecks, and ash shards are scattered throughout. The basal 14 feet at the type section is weakly calcareous to noncalcareous, clayey, contains numerous sand grains and is a darker brown to reddish-brown, suggesting that this is a soil development zone.

At an outcrop site near Spring Lake the Java Formation is a tan, fine to medium sand with much clay, silt, and pebble-sized material. It overlies the basal well-sorted fine gravel and is overlain by late Wisconsin till. On the basis of an extensive vertebrate fauna (Java local fauna) contained in the sand at this location, Martin (1973) concluded that the basal Java Formation was a paleostream sediment, presumably part of the ancient Cheyenne River drainage system. Martin stated that the representative fauna indicated that it belonged to an early phase of the Kansan glaciation, postdating the Aftonian Borchers fauna and predating the Kansanian Cudahy fauna, both of Kansas. Mollusk shells collected at the Spring Lake outcrop site were submitted to the U.S. Geological Survey for radiocarbon dating and yielded a date of >28,000 years B.P. (W-2044). A personal note on the radiocarbon analysis sheet (Rubin Meyer) stated that these mollusks may be about 28,500 years old but he was reluctant to give a finite age on these shells. Thus, if a finite date is accepted then it must be assumed that the shells were contaminated with younger carbon from percolating ground water.

Another Pleistocene non-glacial sediment was found occupying a portion of the Ancient Moreau River Channel in western Walworth County (fig. 12). A test hole in NW NW NW NE sec. 31, T. 122 N., R. 77 W. penetrated fine sand to fine, sandy gravel from 53 to 172 feet. The total thickness is unknown since drilling operations ceased at 172 feet due to extreme caving and water loss. This material contained much coal and lacked shale pebbles and glacially derived rock fragments characteristic of the outwash in this area. The lower gravelly portion apppears to be similar to other western derived stream sediments in eastern South Dakota. The overlying finer material may or may not be related to the gravel. Unfortunately drilling conditions prevented good

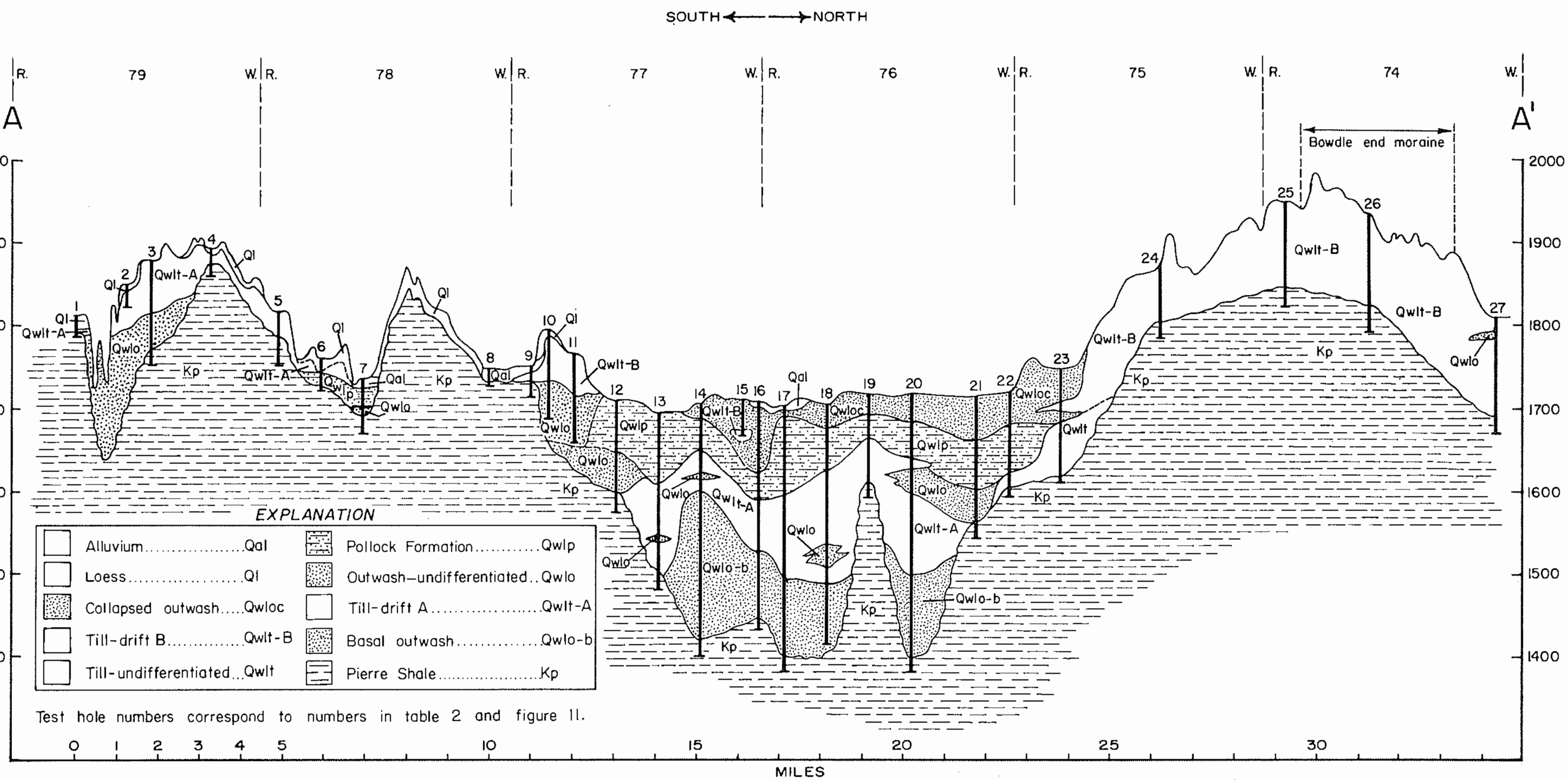

Figure 5. Cross section showing stratigraphic relationship of the Pleistocene deposits.

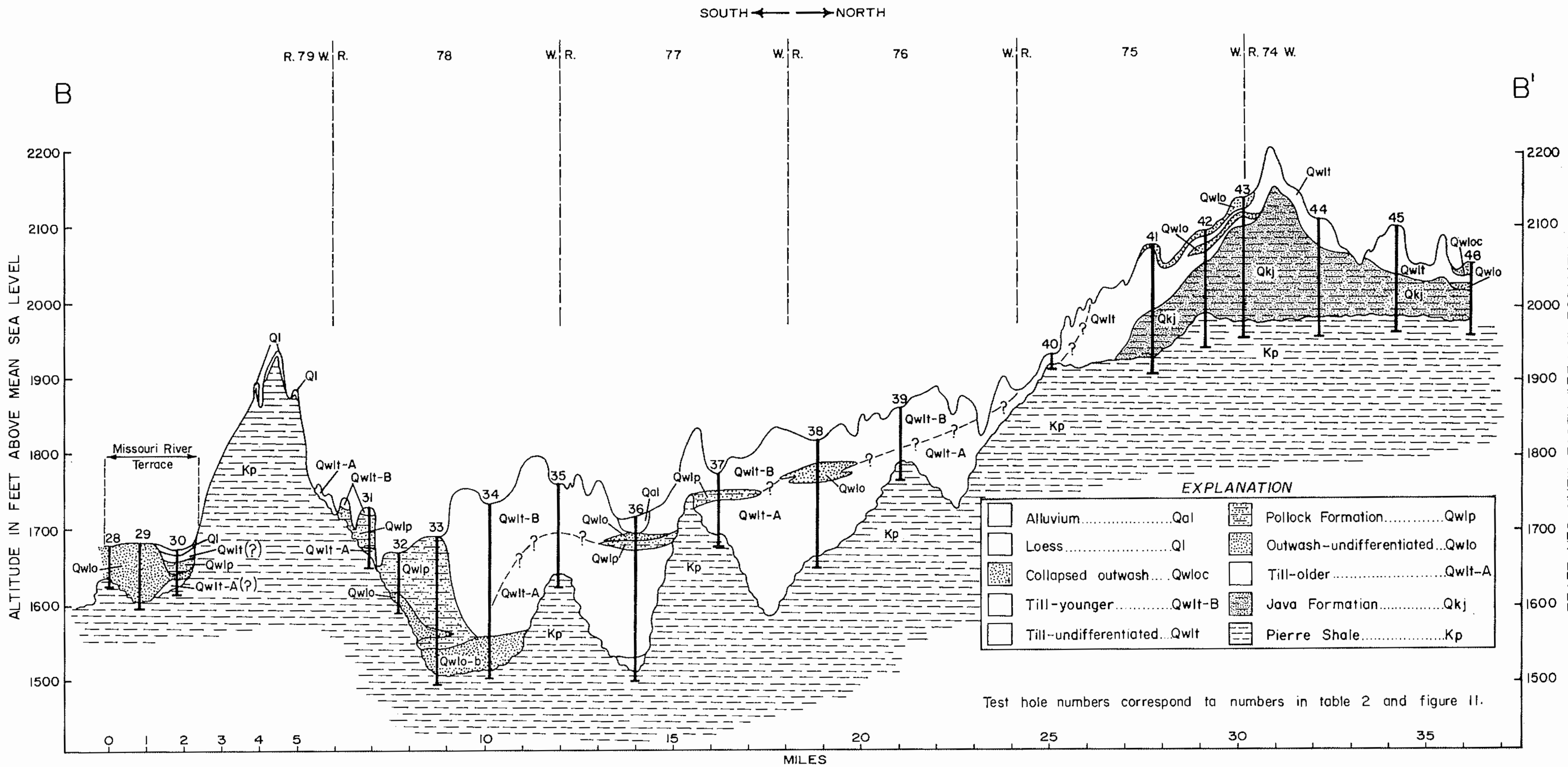

Figure 6. Cross section showing stratigraphic relationship of the Pleistocene deposits.

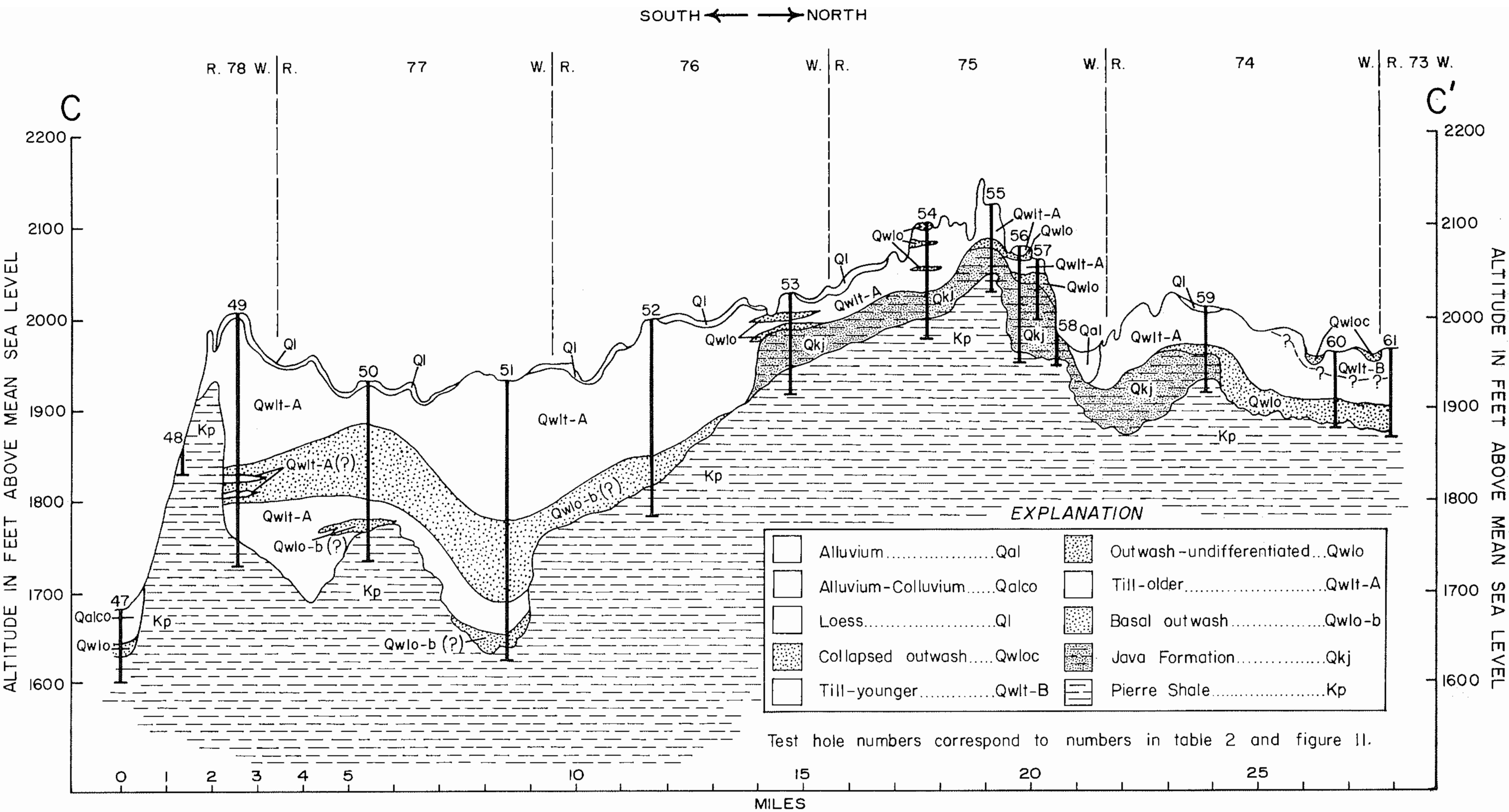

Figure 7. Cross section showing stratigraphic relationship of the Pleistocene deposits.

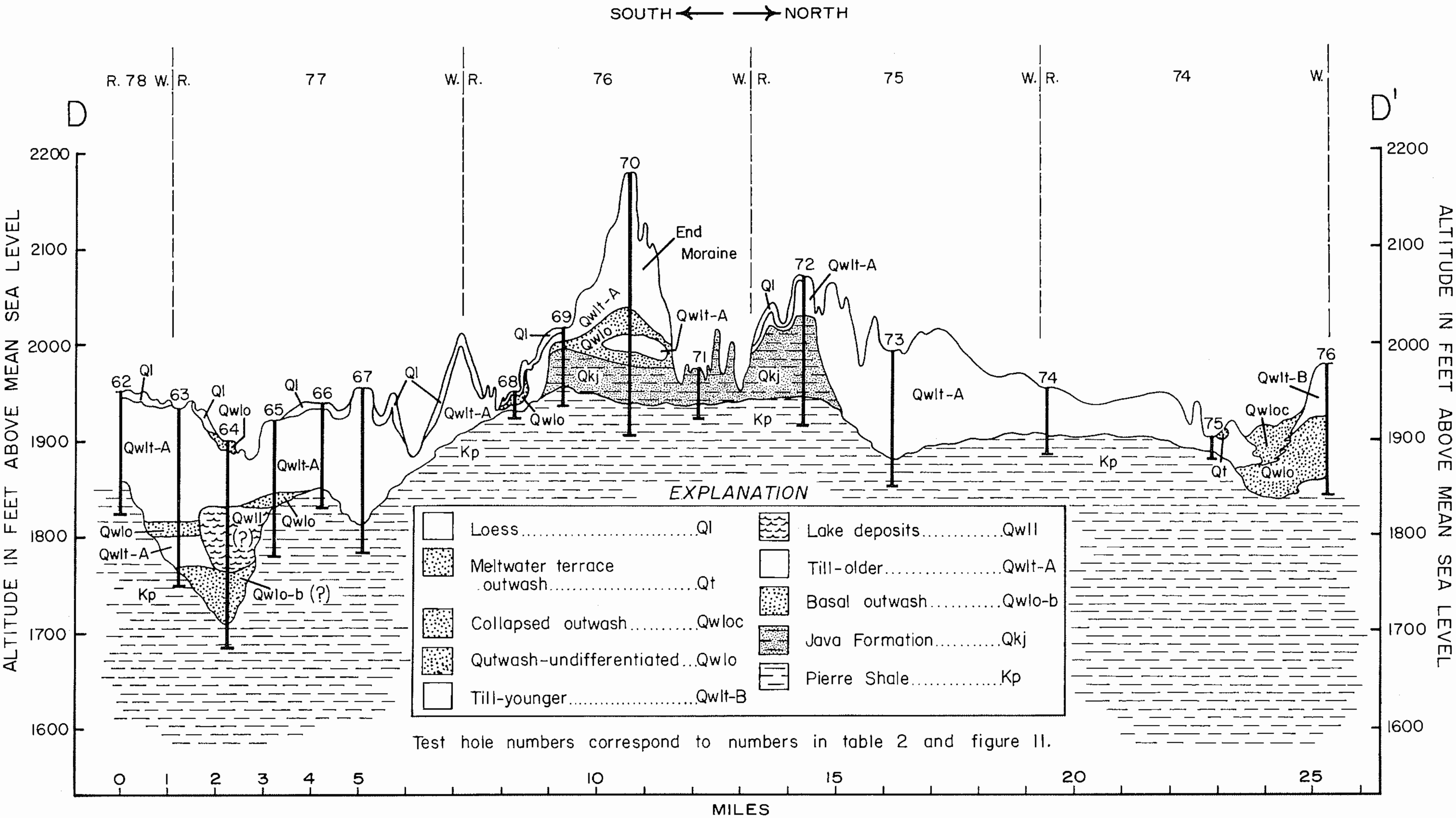

Figure 8. Cross section showing stratigraphic relationship of the Pleistocene deposits.

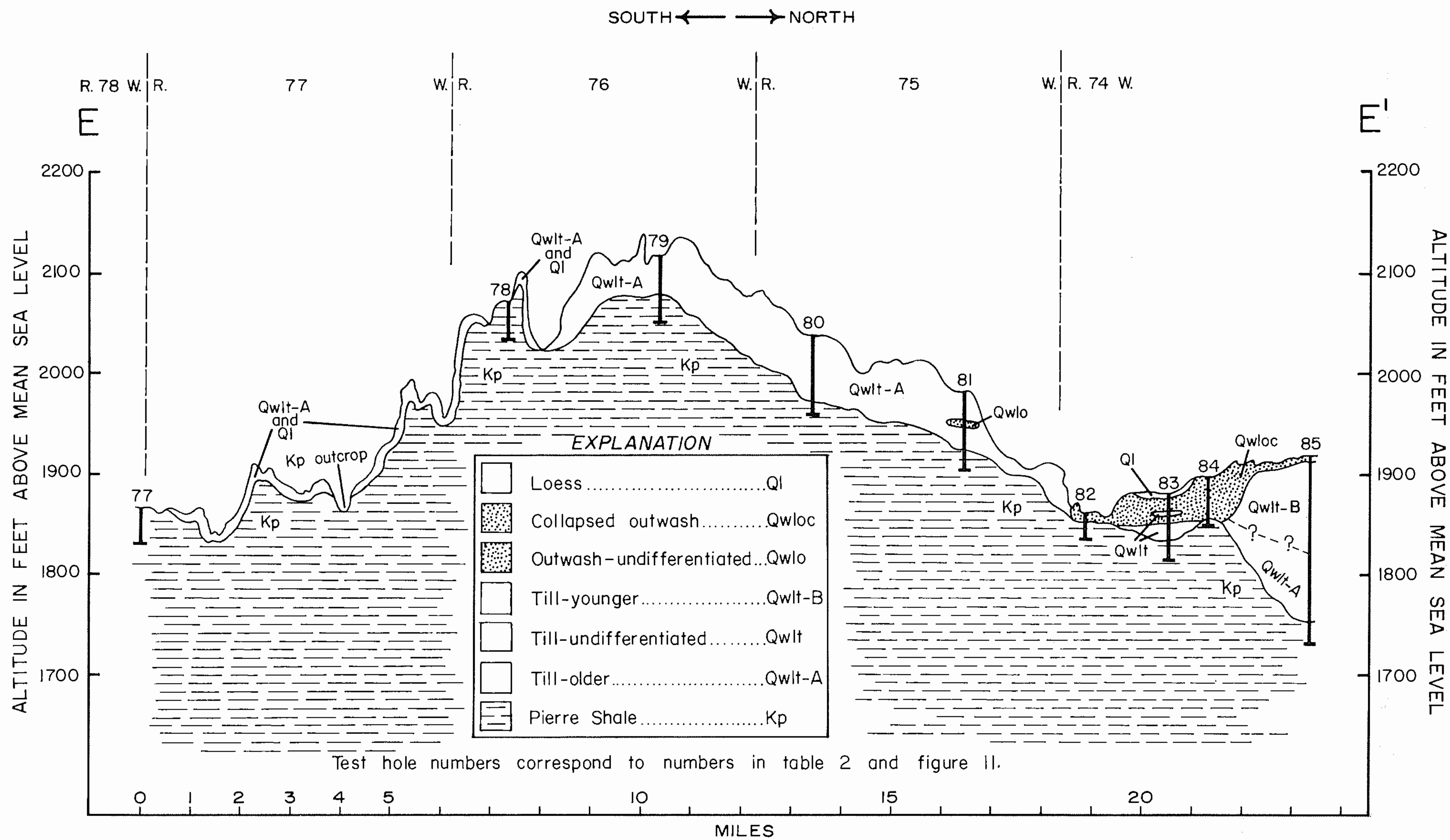

Figure 9. Cross section showing stratigraphic relationship of the Pleistocene deposits.

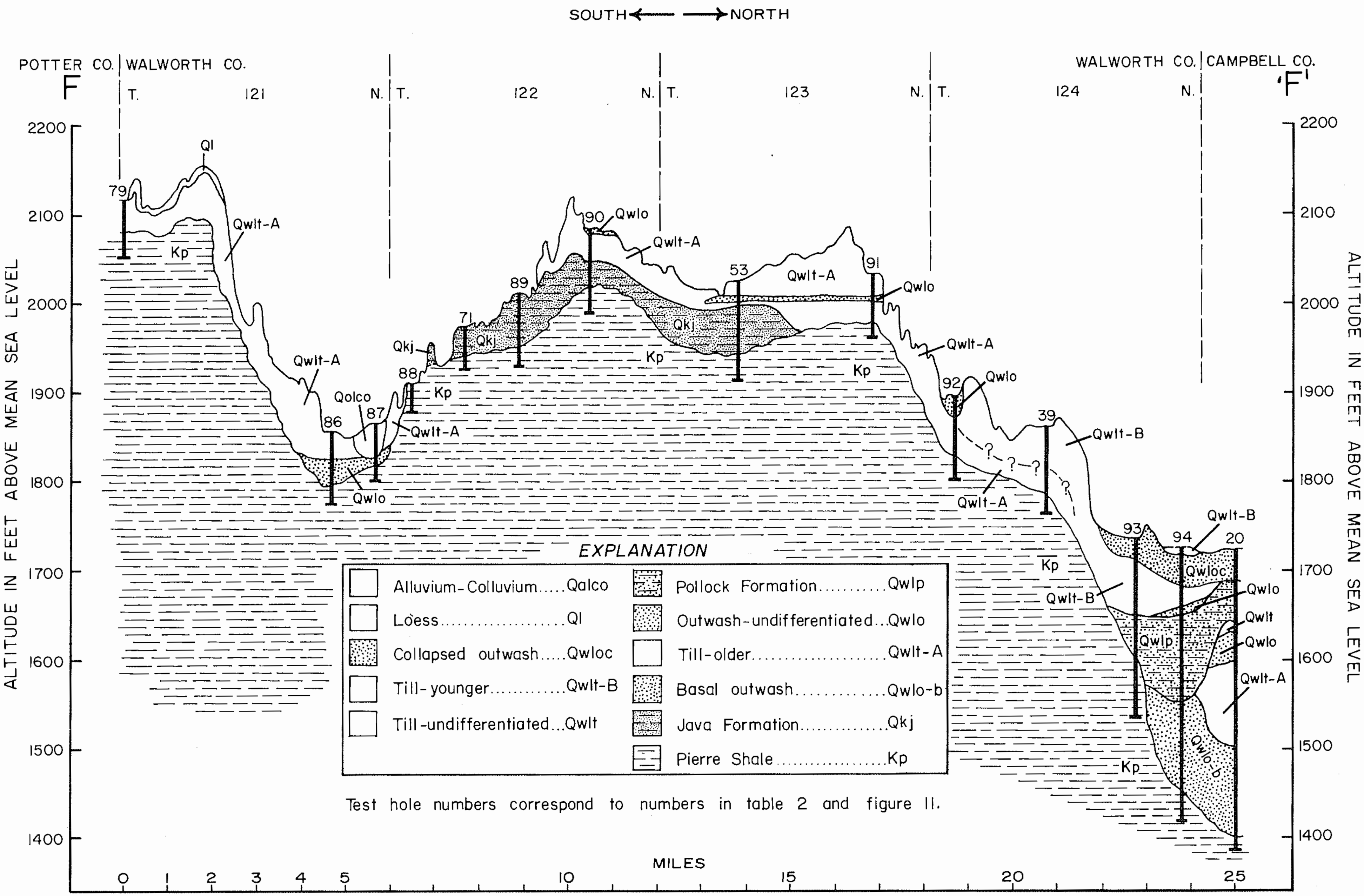

Figure 10. Cross section showing stratigraphic relationship of the Pleistocene deposits.

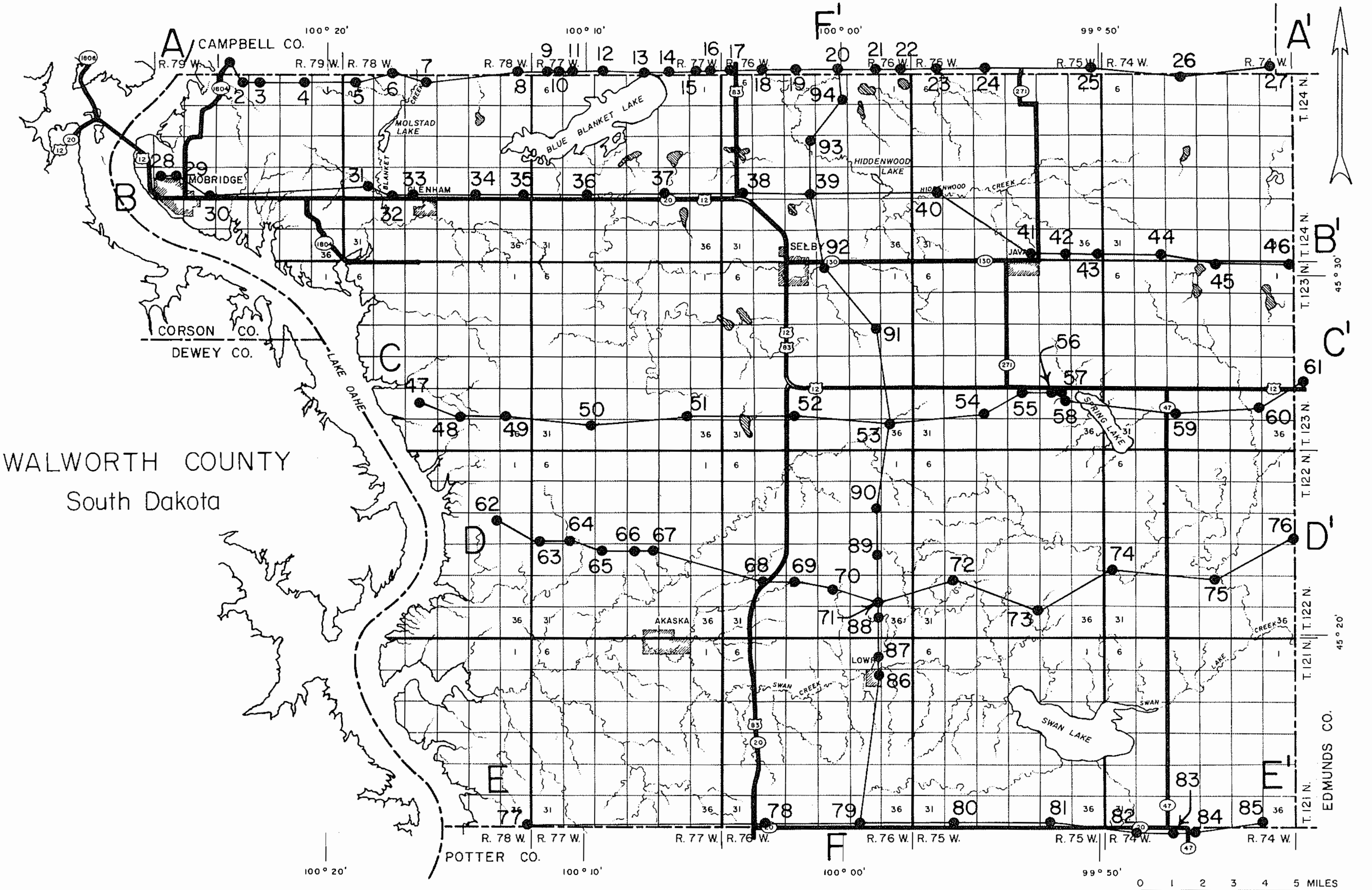

Figure II. Location map of geologic cross sections (See table 2 for legal locations).

Table 2

Locations of test holes used to construct figures 5 through 10

Test-Hole No.		Location
1	....	NE NW SW SW sec. 34, T. 125 N., R. 79 W.
2	....	NE NE NE NE sec. 4, T. 124 N., R. 79 W.
3	....	NW NE NE NW sec. 3, T. 124 N., R. 79 W.
4	....	NE NE NE NE sec. 2, T. 124 N., R. 79 W.
5	....	NW NE NE NW sec. 6, T. 124 N., R. 78 W.
6	....	SW SW SW SW sec. 33, T. 125 N., R. 78 W.
7	....	NW NW NW NE sec. 4, T. 124 N., R. 78 W.
8	....	SW SW SW SW sec. 31, T. 125 N., R. 77 W.
9	....	SW SW SW SW sec. 32, T. 125 N., R. 77 W.
10	....	SE SE SE SW sec. 32, T. 125 N., R. 77 W.
11	....	SE SE SE SE sec. 32, T. 125 N., R. 77 W.
12	....	SE SE SE SE sec. 33, T. 125 N., R. 77 W.
13	....	SW SW SW SW sec. 35, T. 125 N., R. 77 W.
14	....	SE SE SE SE sec. 36, T. 125 N., R. 77 W.
15	....	SE SE SW SE sec. 36, T. 125 N., R. 77 W.
16	....	SW SW SW SW sec. 31, T. 125 N., R. 76 W.
17	....	SE SE SE SE sec. 31, T. 125 N., R. 76 W.
18	....	SW SW SW SW sec. 33, T. 125 N., R. 76 W.
19	....	SE SE SE SE sec. 33, T. 125 N., R. 76 W.
20	....	SW SW SW SW sec. 35, T. 125 N., R. 76 W.
21	....	SE SE SE SW sec. 36, T. 125 N., R. 76 W.
22	....	SW SW SW SW sec. 31, T. 125 N., R. 75 W.
23	....	SE SE SE SW sec. 32, T. 125 N., R. 75 W.

Test-Hole No.	Location
24	SE SE SE SE sec. 33, T. 125 N., R. 75 W.
25	SW SW SW SW sec. 31, T. 125 N., R. 74 W.
26	NW NW NW NE sec. 4, T. 124 N., R. 74 W.
27	SE SW SE SE sec. 36, T. 125 N., R. 74 W.
28	SE SW SW NW sec. 19, T. 124 N., R. 79 W.
29	SE SW SE NE sec. 19, T. 124 N., R. 79 W.
30	NE SE SE SE sec. 20, T. 124 N., R. 79 W.
31	NE NE NE SE sec. 19, T. 124 N., R. 78 W.
32	SW SW SW SE sec. 20, T. 124 N., R. 78 W.
33	SE SE SE SW sec. 21, T. 124 N., R. 78 W.
34	SW SW SW SW sec. 23, T. 124 N., R. 78 W.
35	SE SE SE SE sec. 24, T. 124 N., R. 78 W.
36	SE SE SE SE sec. 20, T. 124 N., R. 77 W.
37	SW SW SW SW sec. 23, T. 124 N., R. 77 W.
38	SW SW SW SE sec. 19, T. 124 N., R. 76 W.
39	SE SE SE SE sec. 21, T. 124 N., R. 76 W.
40	SE SE SE SE sec. 19, T. 124 N., R. 75 W.
41	SE SE SE SW sec. 34, T. 124 N., R. 75 W.
42	SE SE SE SE sec. 35, T. 124 N., R. 75 W.
43	SE SE SE SE sec. 36, T. 124 N., R. 75 W.
44	SE SE SE SE sec. 32, T. 124 N., R. 74 W.
45	NE NE NE NE sec. 3, T. 123 N., R. 74 W.
46	NE NE NE NE sec. 1, T. 123 N., R. 74 W.
47	SE SE SE NW sec. 28, T. 123 N., R. 78 W.
48	SW SE SE SE sec. 27, T. 123 N., R. 78 W.

Test-Hole No.		Location
49	....	SW SW NW NW sec. 25, T. 123 N., R. 78 W.
50	....	NE NE NE NE sec. 32, T. 123 N., R. 77 W.
51	....	SE SE SE SE sec. 26, T. 123 N., R. 77 W.
52	....	SW SW SW SW sec. 28, T. 123 N., R. 76 W.
53	....	NW NW NW NW sec. 36, T. 123 N., R. 76 W.
54	....	SW SW SW SW sec. 28, T. 123 N., R. 75 W.
55	....	NE NE NE NW sec. 27, T. 123 N., R. 75 W.
56	....	NW NW NE NW sec. 26, T. 123 N., R. 75 W.
57	....	NE NE NE NW sec. 26, T. 123 N., R. 75 W.
58	....	SE SE NE NE sec. 26, T. 123 N., R. 75 W.
59	....	SE SW SW SW sec. 28, T. 123 N., R. 74 W.
60	....	NE NE NE SE sec. 26, T. 123 N., R. 74 W.
61	....	SW SW SW SW sec. 19, T. 123 N., R. 73 W.
62	....	NE NE NE NE sec. 14, T. 122 N., R. 78 W.
63	....	SW SW SW SW sec. 18, T. 122 N., R. 77 W.
64	....	SW SW SW SW sec. 17, T. 122 N., R. 77 W.
65	....	NW NW NW NW sec. 21, T. 122 N., R. 77 W.
66	....	NW NW NW NW sec. 22, T. 122 N., R. 77 W.
67	....	NE NE NE NE sec. 22, T. 122 N., R. 77 W.
68	....	NE NW NW NW sec. 29, T. 122 N., R. 76 W.
69	....	NW NW NW NW sec. 28, T. 122 N., R. 76 W.
70	....	NW SE SW NW sec. 27, T. 122 N., R. 76 W.
71	....	SE SE SE SE sec. 26, T. 122 N., R. 76 W.
72	....	NW NW NW NW sec. 29, T. 122 N., R. 75 W.
73	....	NE NE NE NE sec. 34, T. 122 N., R. 75 W.

Test-Hole No.		Location
74	....	SW SW SW SW sec. 19, T. 122 N., R. 74 W.
75	....	NE NE NW NE sec. 27, T. 122 N., R. 74 W.
76	....	SE SE SE SE sec. 13, T. 122 N., R. 74 W.
77	....	SE SE SE SE sec. 36, T. 121 N., R. 78 W.
78	....	NE NE NW NW sec. 6, T. 120 N., R. 76 W.
79	....	SW SW SW SW sec. 35, T. 121 N., R. 76 W.
80	....	SW SW SW SW sec. 32, T. 121 N., R. 75 W.
81	....	SW SW SW SW sec. 35, T. 121 N., R. 75 W.
82	....	SW SW SE SE sec. 31, T. 121 N., R. 74 W.
83	....	NE NW NE NW sec. 5, T. 120 N., R. 74 W.
84	....	NW NW NW NW sec. 4, T. 120 N., R. 74 W.
85	....	SE SE SE SE sec. 35, T. 121 N., R. 74 W.
86	....	SE NE NE NE sec. 11, T. 121 N., R. 76 W.
87	....	NE NE NE SE sec. 2, T. 121 N., R. 76 W.
88	....	SE SE NE NE sec. 35, T. 122 N., R. 76 W.
89	....	SE SE SE NE sec. 23, T. 122 N., R. 76 W.
90	....	SE SE SE SE sec. 11, T. 122 N., R. 76 W.
91	....	NE NE NE NE sec. 14, T. 123 N., R. 76 W.
92	....	NW NW NW NW sec. 3, T. 123 N., R. 76 W.
93	....	NE NE NE NE sec. 16, T. 124 N., R. 76 W.
94	....	SE SE SE SE sec. 3, T. 124 N., R. 76 W.

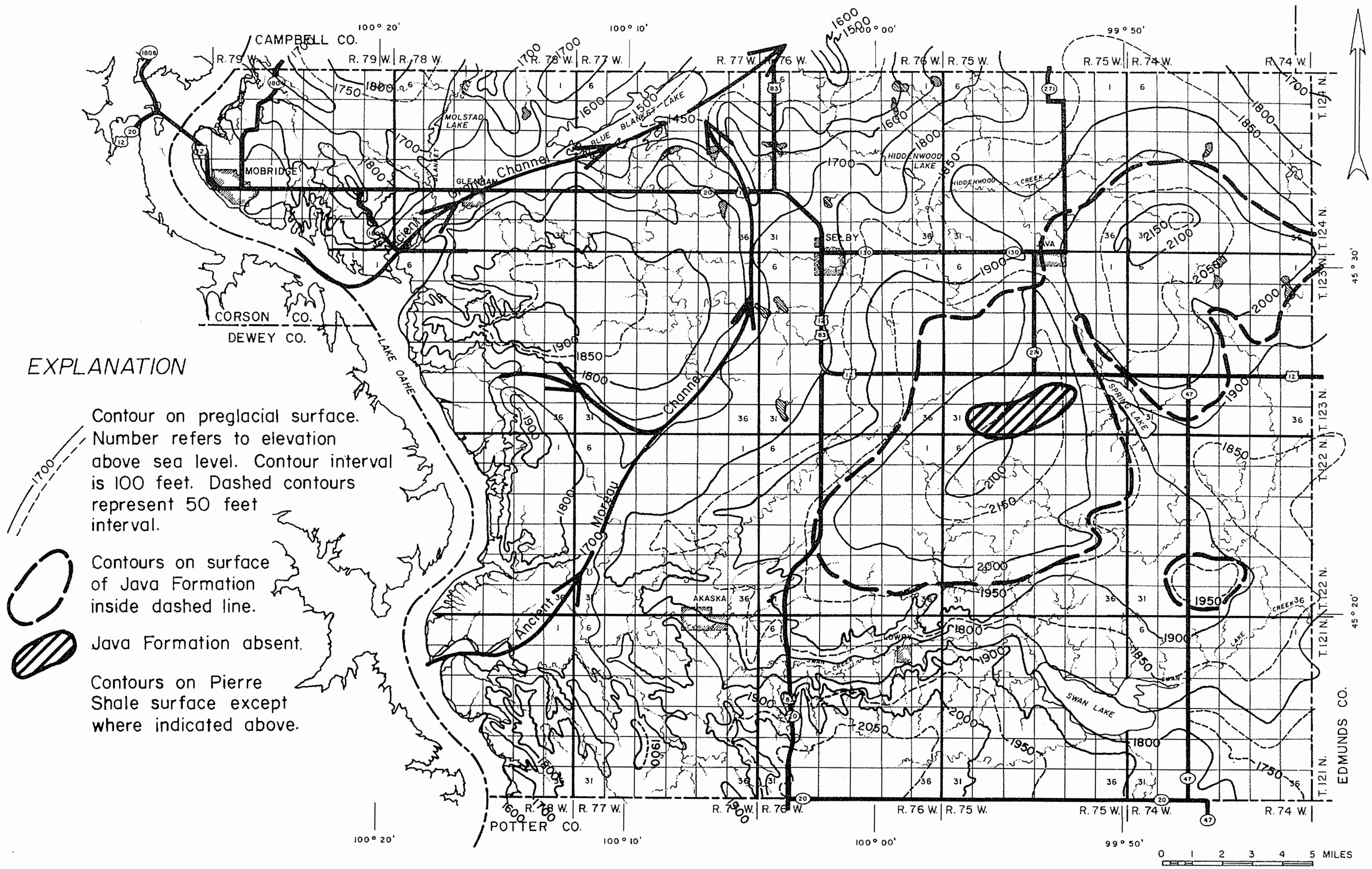

Figure 12. Preglacial contour map

sampling. Another test hole located in SW SW SW SW sec. 31, T. 124 N., R. 76 W. penetrated 26 feet (at a depth of 80 to 106 feet) of sand and gravel of western derived type lithology overlying Pierre Shale. The sand and gravel contained bone chips and shell fragments. The locations of both test holes mentioned above are shown on figure 13 and are identified by reference to western derived gravel.

The relationship, if any, of this western gravel to the Java Formation is unclear at present. Its base is 100 to 150 feet lower than the base of the Java so it could simply be reworked Java Formation material. More test drilling and sample analyses will be required before conclusive statements can be made about the origin of this deposit.

Pleistocene Glacial

A map showing the thickness of glacial deposits in Walworth County (fig. 14) may include Recent alluvium and some non-glacial western derived sand and gravel exclusive of the Java Formation. Examination of the drift thickness and comparison with the preglacial contour map (fig. 12) shows the greatest accumulation of drift in the major bedrock drainages and thinnest drift accumulation on the upland divide areas. Drift thickness on much of the upland divide area is 50 feet or less while the maximum thickness exceeds 300 feet at the northern border of the County along the course of the Ancient Grand Channel (fig. 14).

With the possible exception of the basal outwash, all of the glacial drift in Walworth County is thought to belong to the late Wisconsin substage. Within the late Wisconsin drifts two different source areas can be differentiated. This topic will be discussed in more detail under the section on till.

BASAL OUTWASH AND TILL

The basal outwash is a glacially derived sand and gravel deposit confined to the deeper part of the Ancient Grand Channel. The distribution and thickness of this deposit are shown on figure 13. It is as much as 99 feet thick along the northern border of Walworth County but averages about 40 feet thick. The entire sequence may consist of gravel, or the basal portion may be gravel grading upwards to fine, silty sand.

The basal outwash may have till interbeds and generally contains abundant coal and shale pebbles. The basal outwash portion of the Ancient Grand Channel Valley fill in Campbell County (Hedges, 1972) had a lower shale content than the equivalent basal outwash in Walworth County. It was also noted that the basal outwash in Walworth County contained fewer cobbles and boulders than did the equivalent outwash in Campbell County. This

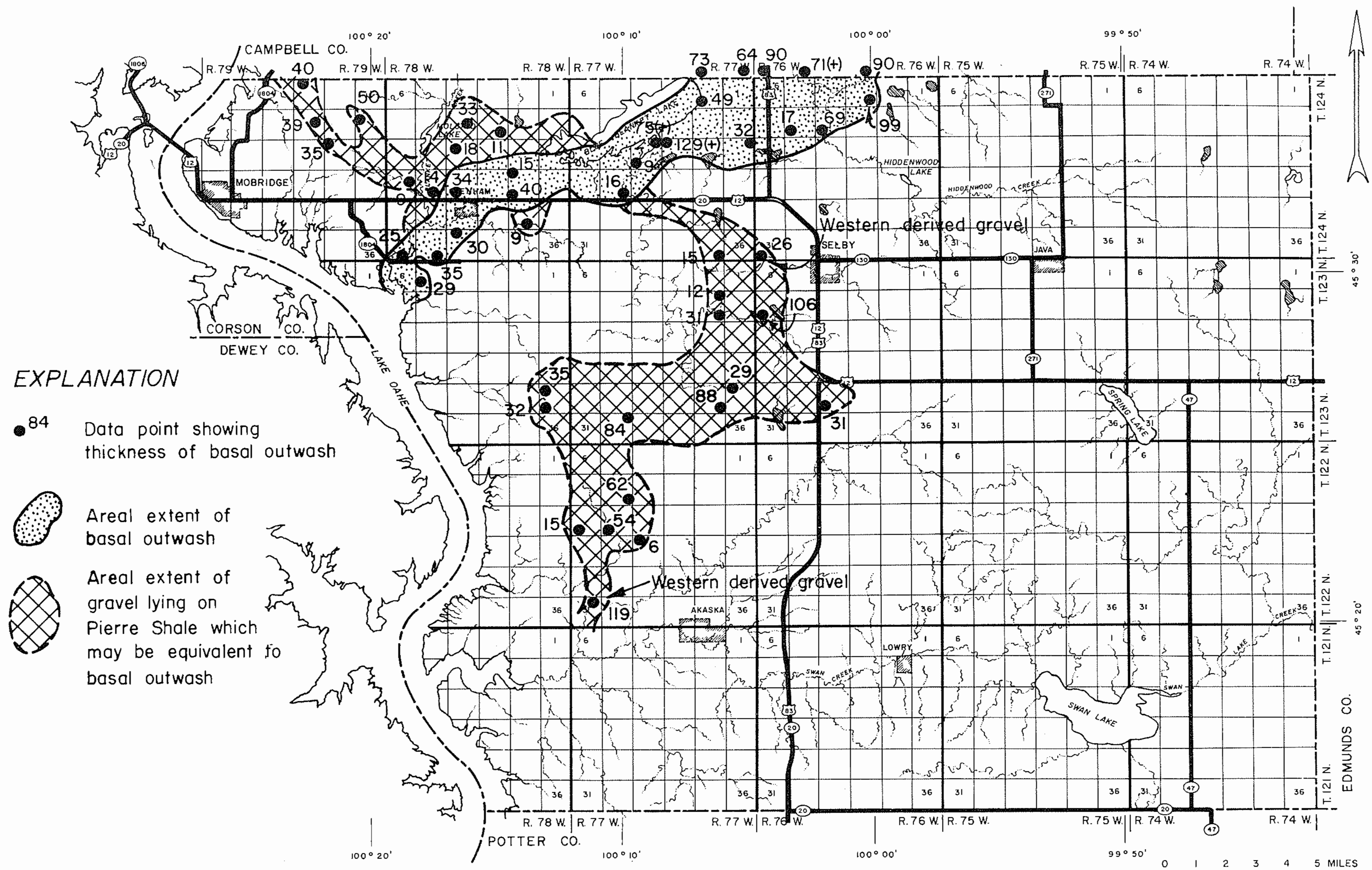

Figure 13. Distribution and thickness of basal outwash.

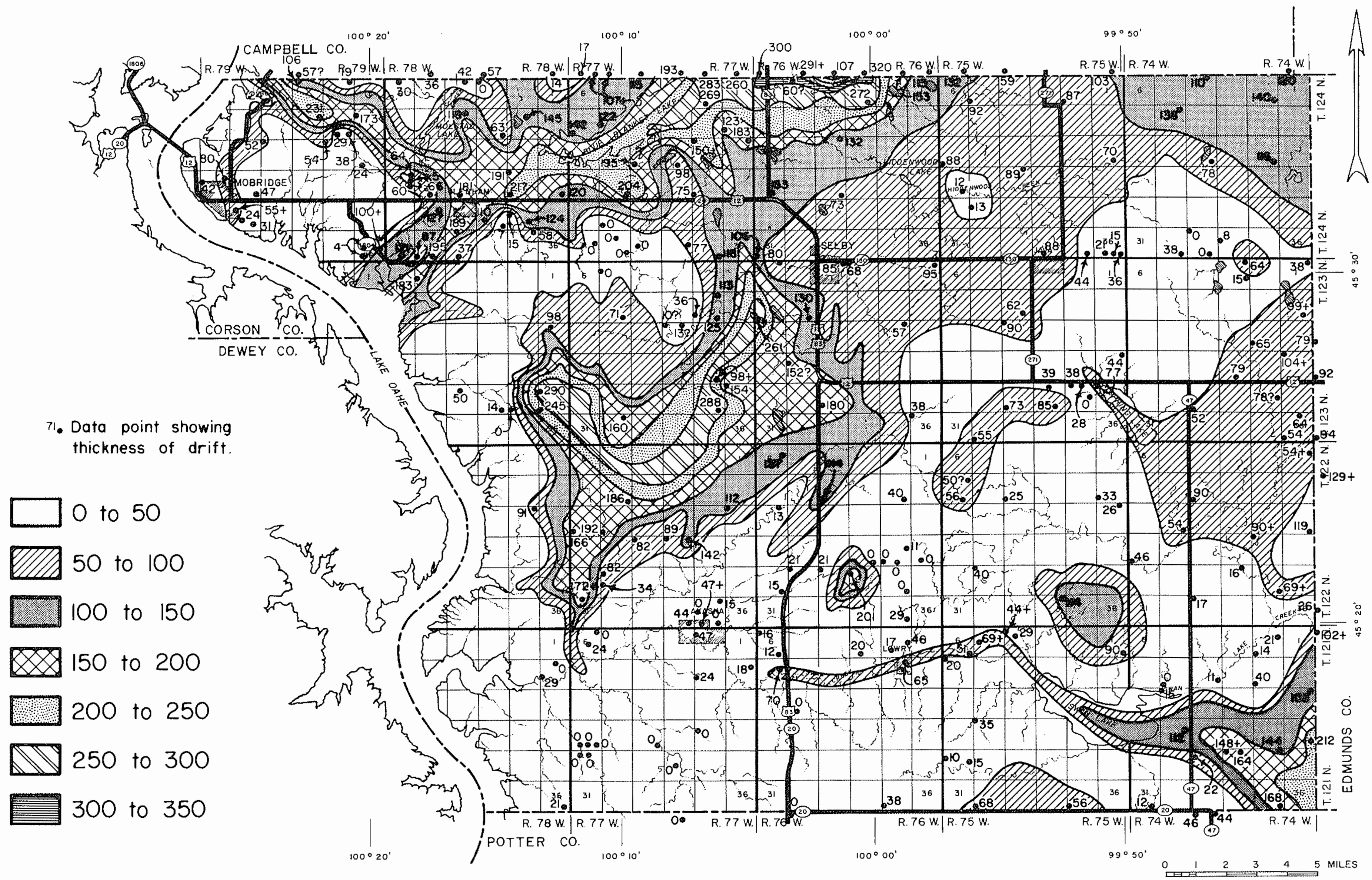

Figure 14. Thickness of glacial drift.

suggests that the ice front was farther away during the time of deposition than it was during deposition in Campbell County.

Basal outwash lies on Pierre Shale in the deeply incised Ancient Grand Channel. Stratigraphically overlying the basal outwash is the Pollock Formation (Hedges, 1972), a silty-clay glacial lake deposit. The Pollock Formation serves as a marker bed, that is, any outwash underlying the Pollock is part of the basal outwash. Outside the Ancient Grand Channel there is outwash present (fig. 13) directly overlying the Pierre Shale but it is not overlain by the Pollock Formation. Thus, it cannot be positively determined that the outwash outside the Ancient Grand Channel is equivalent to the basal outwash.

The precise age of the basal outwash cannot be determined. Hedges (1972) stated that in Campbell County it is pre-late Wisconsin in age. More recent work by Christensen (1977) and Hedges (this report) indicate that this general part of South Dakota has no record of pre-late Wisconsin glaciation, thus, pre-late Wisconsin outwash is precluded, unless it was deposited from older glaciations in North Dakota. Because the Grand Channel in Walworth County belongs to a different drainage system than much of the bedrock channels in Campbell County, and because there are some lithologic differences, the age of the basal deposits in Walworth County may in fact be different than the basal outwash in Campbell County.

POLLOCK FORMATION

The Pollock Formation (Hedges, 1972) occurs in the subsurface and crops out at several locations (fig. 3) in Walworth County. The Pollock Formation is a proglacial lake sediment deposited in eastward flowing rivers which were dammed by ice. As in Campbell County its distribution is confined within the boundaries of the Ancient Grand Channel (Hedges, 1972). The known distribution and thickness of the Pollock Formation is shown on figure 15.

The Pollock Formation is composed primarily of a silty clay with some fine sandy zones and gravelly lenses. Maximum thickness encountered was 138 feet in a test hole at Glenham. To date, no fossils of any kind have been found in the Pollock Formation. It overlies Pierre Shale, or the basal outwash in the Ancient Grand Channel and is overlain by late Wisconsin till or outwash. The presence of the Pollock Formation underlying the terrace southwest of Glenham indicates that it probably was extensive in the present valley of the Missouri River, however, most of it was removed as the Missouri River deepened and widened its channel.

The age of the Pollock Formation is interpreted to be Wisconsin (Hedges, 1972); although no bracketing radiocarbon dates have been found.

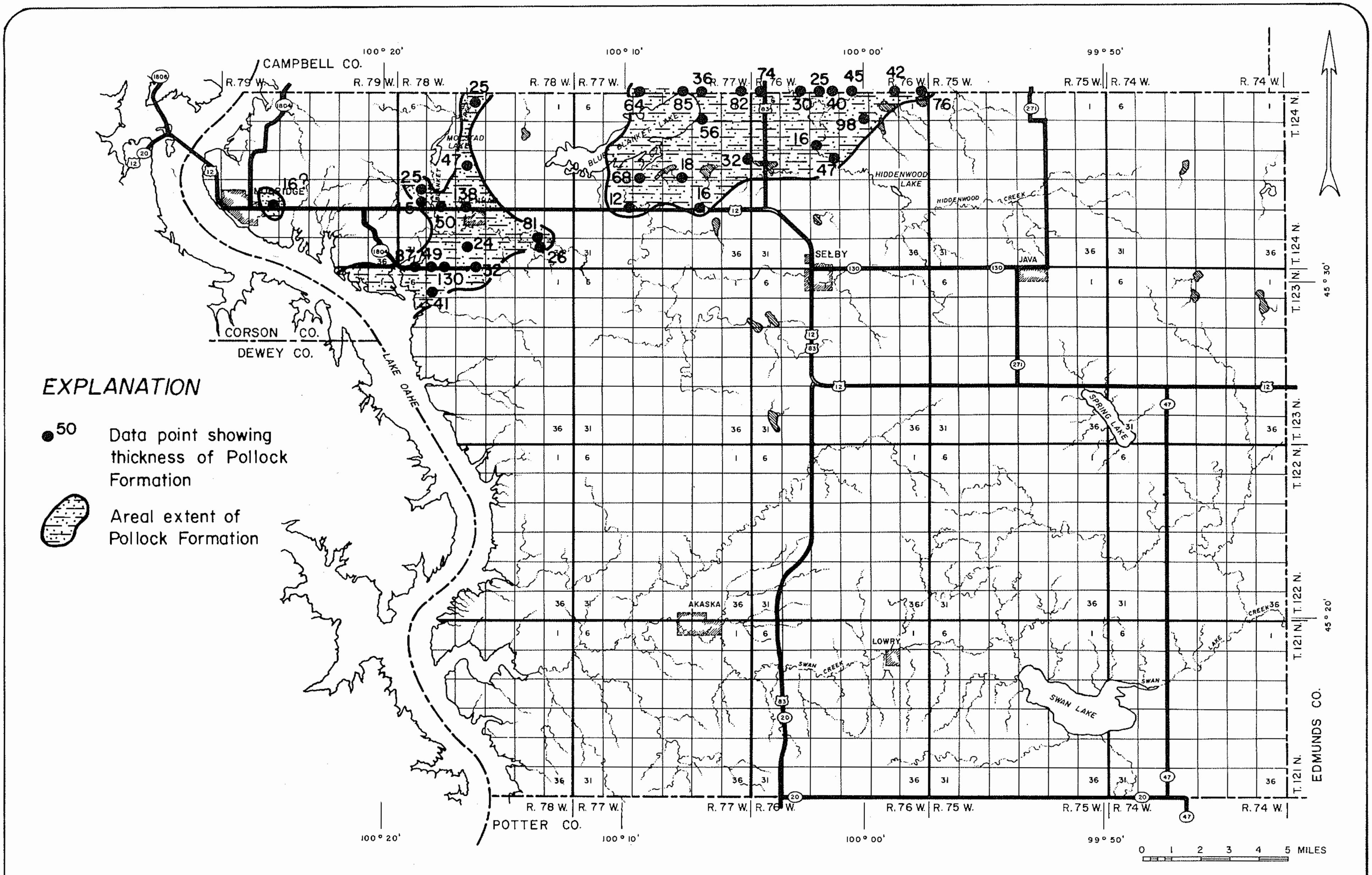

Figure 15. Thickness and distribution of the Pollock Formation.

TILL

In Walworth County, till has a maximum thickness of 255 feet in a test hole located at SW SW NW NW sec. 25, T. 123 N., R. 78 W. Several test holes may contain more than 255 feet of drift but part of that may be alluvium, outwash, lake deposits or combinations of these. The average thickness of till in the County is between 50 and 75 feet.

The age of all the till in Walworth County cannot be documented, but Hedges (1972) was of the opinion that all surface till in Campbell County was late Wisconsin in age. Recent test drilling in McPherson, Edmunds and Faulk Counties (Christensen, 1977) and this study failed to uncover any evidence of older drift in this five-county area.

Surface till and associated outwash deposits do have lithologic dissimilarities which suggest that the ice entering Walworth County came from two different directions.

The older, more extensive till A contains rock fragments of the Tongue River Formation and the Fox Hills Formation which is present in central and western North Dakota. This suggests that the ice that deposited this drift came from the north-northwest; whereas, the younger type B till rich in Pierre Shale was deposited from ice that covered the area north-northeast in North Dakota. This difference in lithology is readily apparent in the outwash fractions on the Missouri River terraces. Much of the older type A till is loess covered so access to exposures or rock piles from cultivated fields is limited for comparative purposes. The virtually non-loess covered till B provides access to many outcrops and boulder piles which show only a rare occurrence of the aforementioned rock types. These rare findings are probably the result of reworking of till A.

The concept of two different late Wisconsin phases is consistent with subsurface information, geomorphic expression of glacial landforms, and loess distribution as determined from surficial geologic mapping.

Distribution of the two tills mentioned above is shown in figure 16. The older of the two tills (till A) covers practically all of Walworth County and is the surface till throughout much of the County. The slightly younger till (till B) overlies till A in that area covered by the later phase ice. The older of the two (till A) is correlative to the Artas advance and the younger (till B) is correlative with the Herreid and Bowdle advance in Campbell County (Hedges, 1972).

OUTWASH

Outwash other than that identified as basal outwash occurs as discontinuous lenses in the till or as surface outwash. The

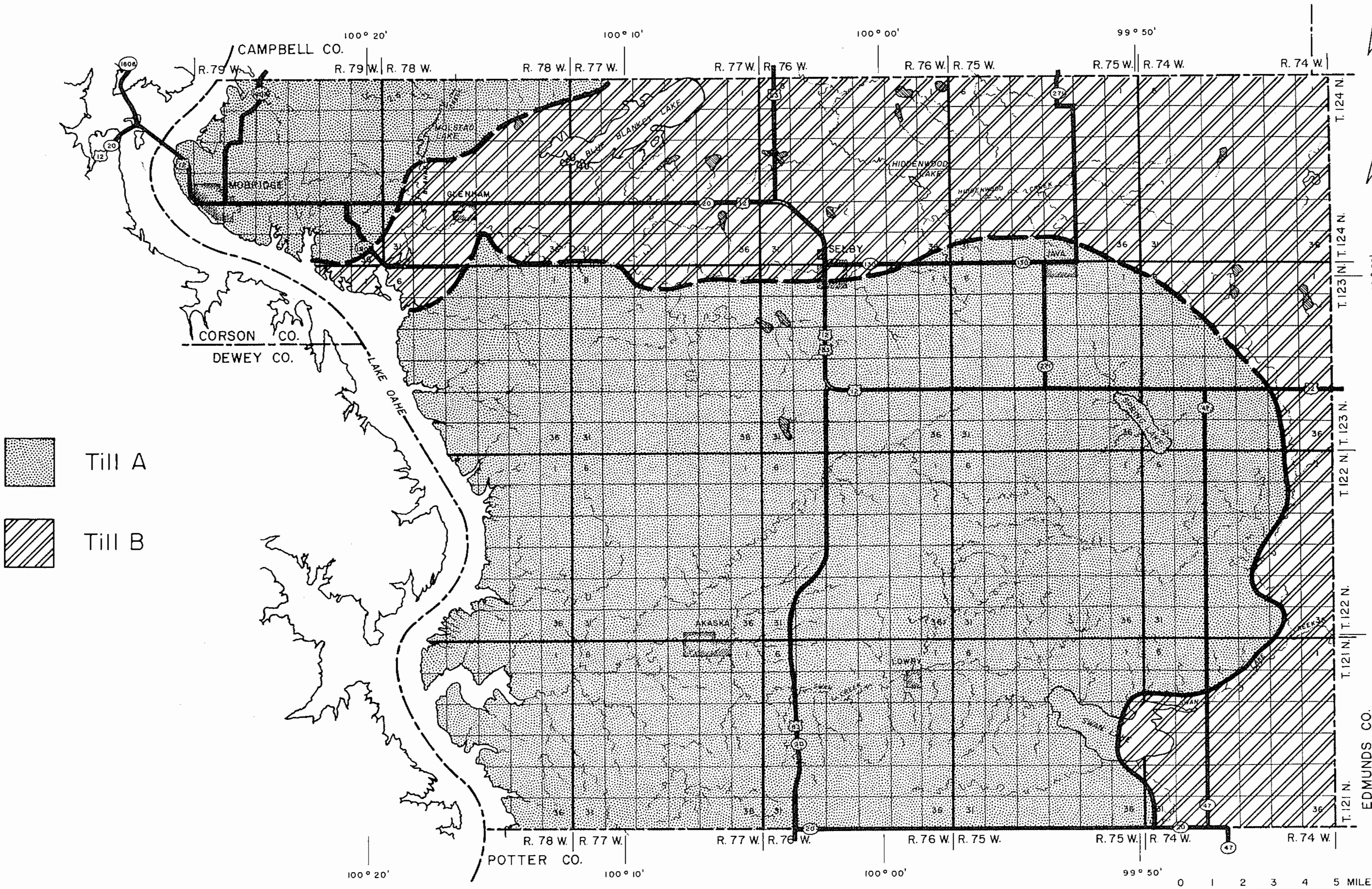

Figure 16. Distribution of Tills A and B in Walworth County.

discontinuous lenses comprise a small fraction of the total outwash material and are not delineated. Their occurrence can be determined from test hole logs and in the geologic cross sections (figs. 5-10).

The three major surficial outwash deposits are the Blue Blanket outwash, Bowdle outwash, and Hoven outwash (fig. 17). Other surficial outwash deposits occur as random ice-contact deposits, the larger of which have been identified on the map (fig. 3) as outwash, undifferentiated.

The Blue Blanket outwash covers approximately 27 square miles in Walworth County (fig. 17) and is the southern end of a much larger north-south trending outwash deposit in Campbell County (Hedges, 1972). In Walworth County, the outwash is as much as 64 feet thick and averages about 30 feet in thickness. A test hole located in NE NW NW NW sec. 14, T. 124 N., R. 77 W., penetrated more than 150 feet of sand and gravel from the ground surface. Part of this sand and gravel may be part of the basal outwash or an intermediate outwash, or both.

The Bowdle outwash covers approximately 14 square miles in Walworth County (fig. 17) and comprises about 50 percent of the western part of a surface outwash having its eastern origin at the town of Bowdle in Edmunds County (Christensen, 1977). The maximum thickness of the Bowdle outwash in Walworth County is 48 feet in a test hole located in NE NE NE SE sec. 1, T. 122 N., R. 74 W., however, the average thickness is about 20 feet. In general the outwash material becomes coarser towards the north and east, which are the source directions.

The northern half of the Hoven outwash is in Walworth County (fig. 17) and has been previously studied by Lee (1957). The southern half of the outwash in Potter County has also been studied by Lee (1956), and in more detail by Hedges (1977). That part of the outwash in Walworth County covers approximately 22 square miles, has a maximum thickness of 50 feet at NE NE NE NW sec. 27, T. 121 N., R. 74 W., and averages about 20 feet thick. Like the Bowdle outwash, the coarser material is generally to the northern and eastern margins.

Outwash within the three major surficial outwash areas was deposited from ice that deposited the younger type B till. The paucity of coal fragments and rock fragments from the Fox Hills Formation and Tongue River Formation support this conclusion. The surface outwash may be randomly covered with alluvium, loess, or ice-contact silt.

UPLAND LOESS

Upland loess (wind-blown silt) covers much of the surface of the western half of Walworth County (fig. 3). The loess is a nearly continuous blanket-like covering of silt and sandy silt as

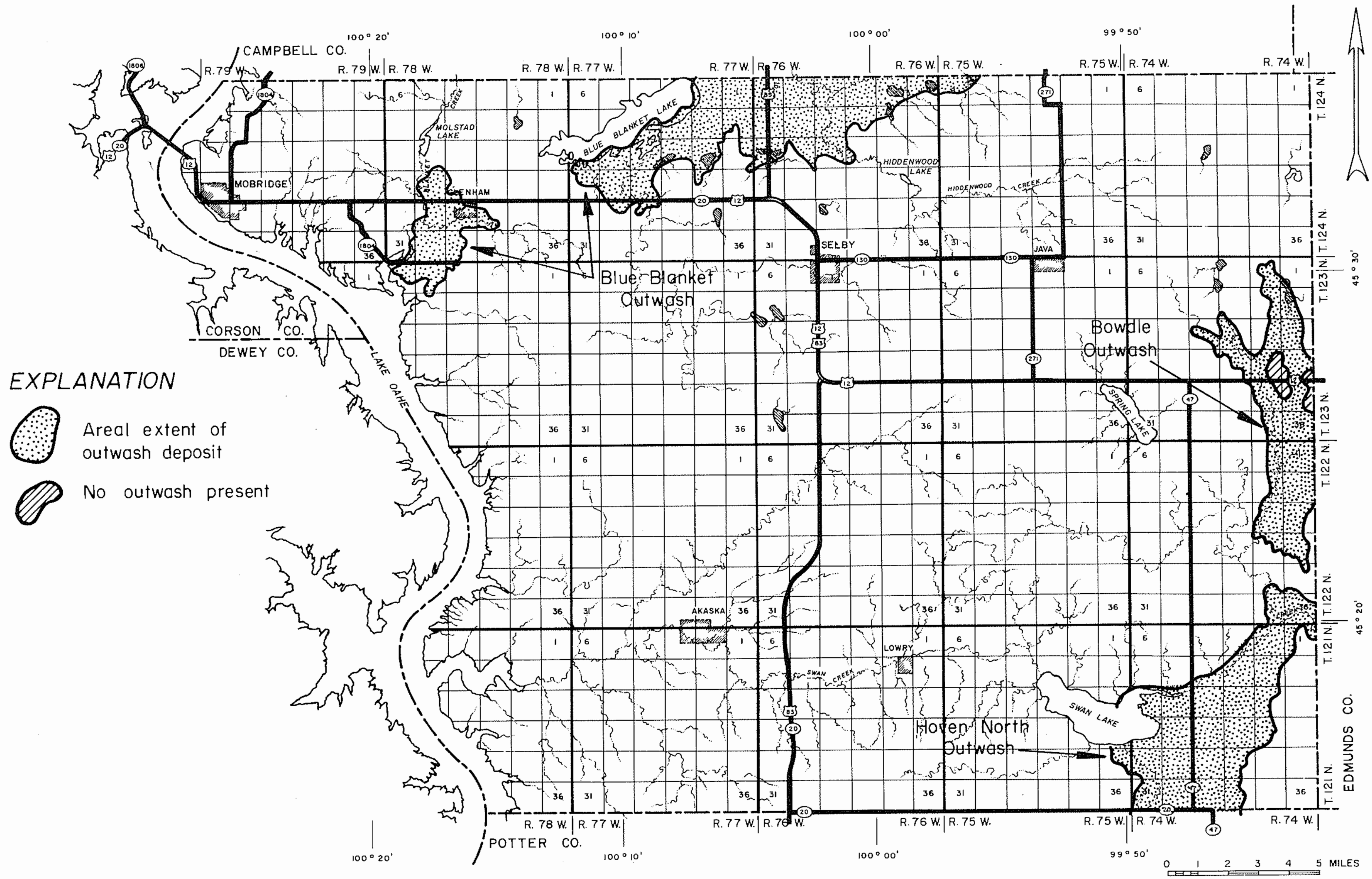

Figure 17. Location of major surface outwash deposits in Walworth County.

much as 15 feet thick but averages about 6 feet thick. There are not enough existing detailed data to determine definitely a thinning trend eastward from the Missouri River. Postdepositional erosion has modified the original thickness, thereby making local topography and drainage the most influential factor controlling thickness at any specific site.

Loess overlies the older type A till and is absent over a younger type B till. Eastward from the area of mapped loess (fig. 3) to the border of the type B till there is a discontinuous loess cover. No recognizable loess was found underlying the younger type A till in test holes. This suggests that the loess was deposited on the older type A till during and after the time that stagnation of this advance occurred. Deposition may have halted with the onset of the later advance although some loess probably continued to be deposited on top of the younger ice as it advanced and after it stagnated.

The Upland loess is significantly older than loess capping the terraces along the Missouri River (fig. 3). The reasons for this conclusion will be detailed in a later section entitled Missouri River Terrace Deposits.

TERRACE DEPOSITS

Outwash terrace deposits occur along the alluvial valley 1 mile east of Sitka, at the northeast edge of Glenham, and along Swan Lake Creek where it enters the eastern border of the County (fig. 3).

The outwash terrace deposits are medium to coarse cobbly gravel and have a maximum thickness of about 20 feet. The sand and gravel was deposited from the same ice advance that deposited the type B till and may be in part ice-contact deposits.

Recent

Recent deposits consist of material transported by running water, wind, mass-wasting processes or a combination of any of these processes since the ice melted away from the area. In Walworth County these deposits have been classified as loess (wind-blown), alluvium (stream and/or lake deposits) and alluvium-colluvium (a combination of any or all processes).

Alluvium

Alluvium occurs primarily in the major stream valleys and around mouths of streams where they empty into Swan Lake, Blue Blanket Lake and Spring Lake (fig. 3). Alluvium is mostly dark colored clay and silty clay derived from erosion of soils, although sandy zones and some gravel may occur. Thickness of alluvium is generally 10 feet or less. Tests of Gastropoda and Pelycypoda are commonly abundant.

Alluvium-Colluvium

Alluvium-colluvium occurs on the slopes adjacent to the large Missouri River terrace located between the mouths of Blue Blanket Creek and Swan Creek (fig. 3). Other locations of alluvium-colluvium are along steep slopes adjacent to drainages and in some cases include the drainage itself (fig. 3). In those areas where alluvium-colluvium is mapped in the stream valley proper, mass-wasting has moved much debris downslope and mixed it with normal stream-eroded sediments. Generally the alluvium-colluvium is a thin veneer only several feet thick, but in south-central Walworth County near Lowry the alluvium-colluvium complex reaches a thickness of 40 feet in Swan Creek. The composition of the alluvium-colluvium is dependent upon the deposits upslope, which may be shale, loess, till or even sand and gravel. Therefore the alluvium-colluvium may consist of reworked portions of any one, or combinations of all possible sources.

Missouri River Terrace Deposits

Missouri River terrace deposits are located along the Missouri River throughout its course in Walworth County (fig. 3). The terrace deposits consist primarily of wind-blown silt (loess) and lesser sporadic amounts of wind-blown sand overlying outwash sands and gravels. The wind-blown silts are as much as 10 feet thick but average consistently 5 to 6 feet in thickness. Terraces at the mouth of Swan Creek locally have some cobble gravel at the surface and are also mixed with the wind-blown deposits. The nearby shale uplands and slopes have a thin veneer of cobble gravel which suggests that mass-wasting has moved the cobbles downslope while the loess was accumulating. The other terraces have a nearly uniform blanket of loess at the surface.

The outwash sand and gravel underlying the wind-blown material is generally rich in the distinctive rock types of the older drift A. Outwash in turn overlies Pierre Shale on the Swan Creek terraces and the terrace to the north. The outwash sand and gravel on the terrace at Mobridge lies on Pierre Shale or the Pollock Formation.

In Campbell County, Hedges (1972) was of the opinion that most of the terrace loess was Recent in age, as opposed to the upland loess which is late Wisconsin in age. The reasoning leading to that conclusion is as follows:

1. The upland loess is generally thicker than the terrace loess. Assuming the Missouri River Valley was the source area, then the thicker loess should have accumulated on the terraces which were closest to

the source area rather than on the more distant uplands.
2. Soils on the terrace loess are more poorly developed than on the upland loess.
3. Plentiful Indian artifacts were found in the terrace loess at numerous locations at depths of 3 to 4 feet below the modern soil.

All of the relationships listed above are also true for Walworth County.

Paleosols are present on nearly every outcrop of terrace deposits visited in Walworth County. One particular paleosol exhibiting a dark gray to black humic horizon about 12 inches thick is persistent throughout all the terraces. This soil zone occurs near or at the base of the terrace deposits, generally directly overlying outwash. Hereafter this will be referred to as the Walth Bay Paleosol, named for its presence at Walth Bay on the large terrace about 6 miles north of the mouth of Swan Creek. At Walth Bay, where the soil derived its name, Ahler and others (1974) described an archeological excavation which is radiocarbon dated at zones equilavent to or below the Walth Bay Paleosol. Bison bone fragments were dated at 8030±1100 years B.P. (R-308) and 7010±210 years B.P. (RL-309). These dates further substantiate the relative youthfulness of the terrace loess as compared to the upland loess.

The Walth Bay Paleosol may be in part equivalent to the Aggie Brown member of the Oahe Formation of Clayton and others (1971) which is a wind-blown silt formation prevalent throughout much of North Dakota.

ECONOMIC GEOLOGY

Water and sand and gravel are both abundant in Walworth County, although their distribution in time and space do not always make it practical to use them at the present time.

The distribution of major sand and gravel outwash deposits can be determined from examination of the geologic map and text of this report. A more detailed discussion of sand and gravel resources can be obtained from Schroeder (1978).

General occurrence of the water resources can be found in Kume (1979), with a detailed examination of the water resources found in Kume (in prep.).

No commercial quantities of oil or gas have been found to date in Walworth County, although there have been several attempts. Geologic conditions do not preclude the possibility that commercial quantities of oil and/or gas do exist.

Boulders from the glacial till are used locally for riprap but are not concentrated enough to be considered for commercial use.

Three formations have potential industrial clay uses: the Pierre Shale, the Pollock Formation, and glacial till. However, special studies to determine their physical and chemical characteristics are required before any specific uses could be verified.

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