REPRINT OF SOUTH DAKOTA PART OF INQUA GUIDEBOOK AND SUPPLEMENTAL DATA FOR

Field Conference C

UPPER MISSISSIPPI VALLEY

South Dakota Geological Survey Guidebook
Series One

INQUA

INTERNATIONAL
ASSOCIATION FOR QUATERNARY RESEARCH

VIIth CONGRESS

August-September 1965

UNITED STATES OF AMERICA

CONTENTS

ILLUSTRATIONS

Guidebook for Field Conference C

UPPER MISSISSIPPI VALLEY

DAY 4—AUGUST 17

Start: Yankton, South Dakota, 8:00 a.m.
End: Watertown, South Dakota
Mileage: 200 miles (320 km)
Leaders: Merlin J. Tipton[1] and Fred V. Steece[1]
Contributors to guidebook: Merlin J. Tipton and Fred V. Steece
Itinerary: Yankton, Sioux Falls, Watertown

INTRODUCTION TO PLEISTOCENE OF BIG SIOUX RIVER BASIN IN SOUTH DAKOTA

Glacial and interglacial deposits up to a known maximum thickness of 710 feet, representing most of Pleistocene time, make up the Coteau des Prairies and are exposed in the valley of the Big Sioux River and its major tributaries (fig. 4-1). Glacial tills of Nebraskan, Kansan, Illinoian, and Wisconsin Glaciations are interbedded with Aftonian, Yarmouth, and Sangamon interglacial deposits and soil horizons in numerous localities, particularly in southeastern South Dakota and extreme northwestern Iowa. The Quaternary geology of South Dakota is described by Lemke, and others (1965).

The Pleistocene deposits of northwestern Iowa and adjacent parts of South Dakota and Minnesota have for many years been an engrossing subject of study by numerous workers. Among the most important contributors to the Pleistocene stratigraphy in these areas are: Chamberlin (1883), Wilder (1899), Bain (1898), Carman (1917, 1931), Kay and Apfel (1929), Kay and Graham (1943), Leverett (1932), Smith and Riecken (1947), Ruhe (1950), and Flint (1955).

Deposits of late Wisconsin age were delineated by Chamberlin (1883). Leverett (1932), Todd (1896, 1899), Rothrock and Newcomb (1932), Rothrock (1934, 1935, 1946), Searight and Moxon (1945), Flint (1955), and Steece and others (1960) all refined Chamberlin's monumental work.

Deposits of early Wisconsin and pre-Wisconsin age in the area received no such agreement of views. The early Wisconsin drift in the interlobate area between the James and Des Moines lobes was identified by

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[1]South Dakota Geological Survey, Vermillion.

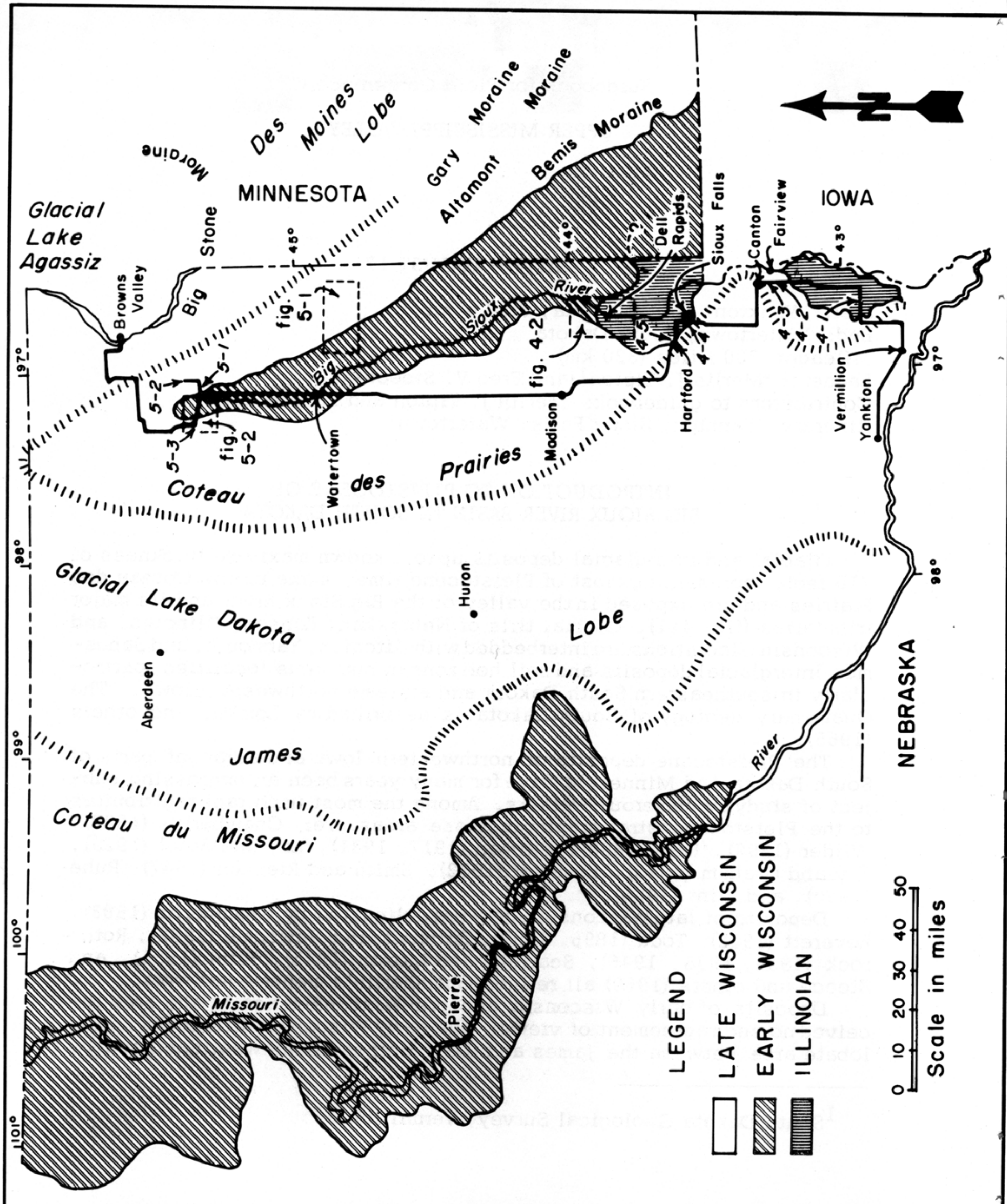

Fig. 4-1. Map of eastern South Dakota showing generalized Pleistocene geology and route of field trip.

ERRATA: Reprint of South Dakota Part of INQUA Guidebook and Supplemental Data for Field Conference C, Upper Mississippi Valley, South Dakota Geological Survey Guidebook Series One, INQUA, International Association for Quaternary Research, VIIth Congress, August-September 1965, United States of America.

Please insert the enclosed sheet in place of Fig. 4-1, Map of eastern South Dakota showing generalized Pleistocene geology and route of field trip. This figure is on page two of the INQUA Guidebook.

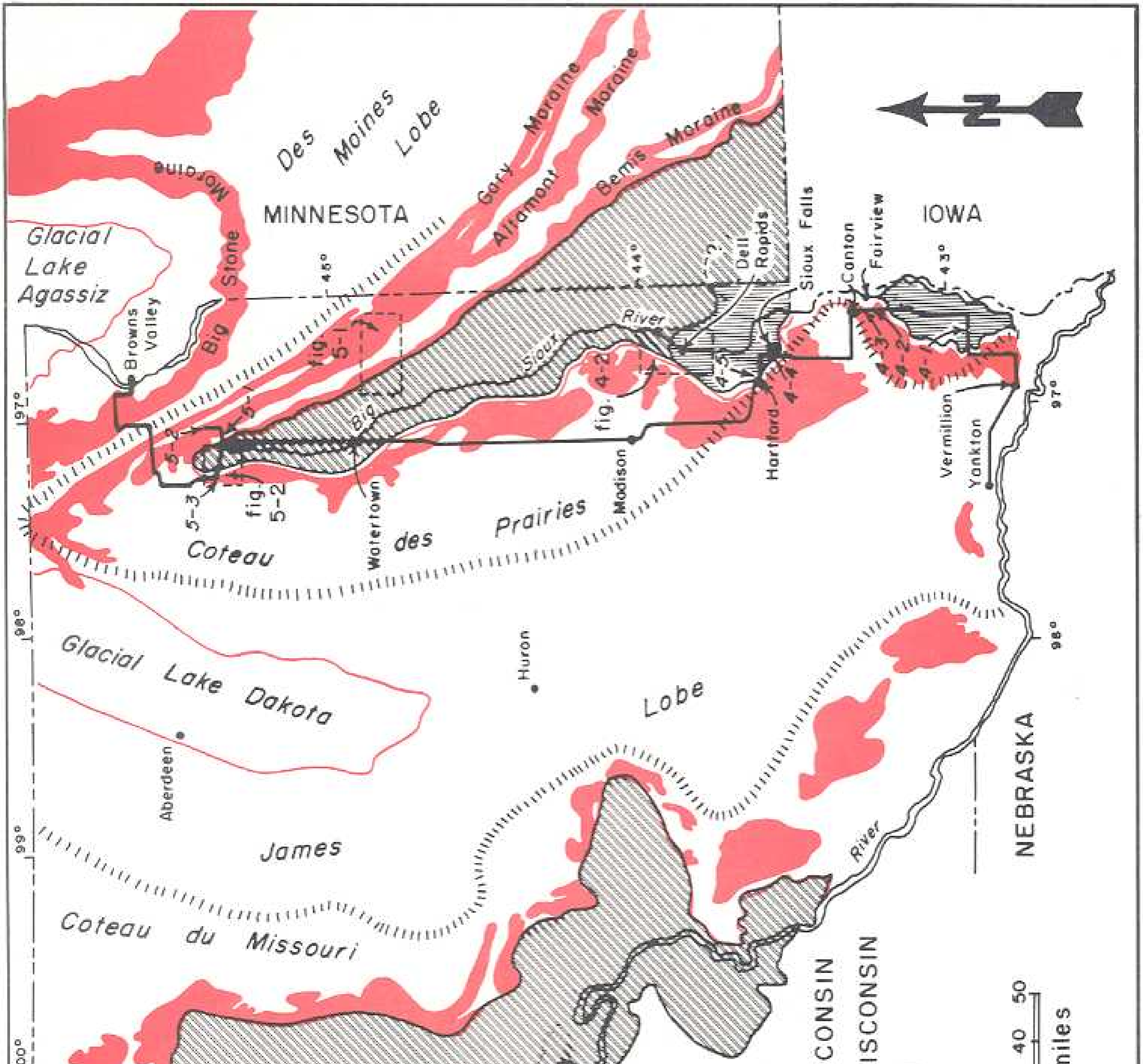

Fig. 4-1. Map of eastern South Dakota showing generalized Pleistocene geology and route of field trip.

Rothrock (1926) as Kansan. This correlation was based on work of Leverett and Sardeson (1919) and Carman (1917) in Minnesota and Iowa respectively. This drift and the corresponding drift in northwestern Iowa was believed to be post-Kansan, pre-Peorian loess (but not Iowan either as stage or substage) by Kay, Leverett, and Carman (Kay and Apfel, 1929, p. 118). This same view was held much earlier by Wilder (1899, p. 123-132) and by Bain (1898, p. 343-4).

In the late 1940's, R. F. Flint, G. D. Smith, F. F. Riecken, and Iowa Geological Survey personnel held field conferences in northwestern Iowa and adjacent areas (Flint, 1955, p. 83) which culminated in: "all of the drift in South Dakota classified by Leverett as Kansan is classified here as Iowan." Smith and Riecken (1947) had classified this same drift in northwestern Iowa as Iowan; the drift to the southof their border they mapped as Kansan. Ruhe (1950) corroborated their work and made further reclassifications of the Wisconsin drifts in northwestern Iowa and southwestern Minnesota.

The problem of the age of this interlobate drift was studied further by Steece and others (1960), Tipton (1958, 1959, 1960) and Steece (1959a, b). They found possible Iowan end moraine remnants in the Dell Rapids-Trent area, north of Sioux Falls. South of these Iowan end moraine remnants are deposits of an earlier drift sheet believed to be Illinoian. (Detailed evidence is given in a later part of this guidebook.)

Beneath the Illinoian drift are deposits of Yarmouth, Kansan, Aftonian, and Nebraskan age.

Cretaceous marine sedimentary rocks and Precambrian quartzites and granites make up the bedrock of eastern South Dakota and crop out locally in the area.

En route from Yankton to Stop 4-1

Proceed eastward from Yankton (fig. 4-1) along South Dakota Highway 50. The route is on the Missouri River floodplain which is from 2 to 10 miles wide. The valley fill is as much as 150+ feet thick and is of Pleistocene and Recent ages. At Vermillion, the route climbs the north bluff of the Missouri trench onto the late Wisconsin till plain. Locally in this area low smooth end moraine remnants attest to the former presence of a late Wisconsin ice margin. The drift topography is smoothed and mantled by an average of 5 feet of loess. Enter Vermillion and continue eastward on State Highway 50 to Interstate Highway 29. About 5 to 6 miles east of Vermillion the route crosses end moraine remnants and other remnants can be seen to the south. Proceed northward on late Wisconsin till plain for about $7\frac{1}{2}$ miles and rise abruptly onto Illinoian till plain. Late Wisconsin ice locally overrode the Illinoian highland here for a distance of about 1 mile to the east. A test hole located 6 miles east and $7\frac{1}{2}$ miles north of Vermillion on the nose of the Illinoian highland, $NE\frac{1}{4}NE\frac{1}{4}SE\frac{1}{4}SE\frac{1}{4}$ sec. 1, T. 93 N., R. 51 W., Clay County, drilled in 1964, revealed the following sequence:

Late Wisconsin till; light yellowish-brown, clay-rich, pebbly, very silty, contains much loess...........44 feet
Early Wisconsin loess; light yellowish-brown to brown..................29 feet
Illinoian till; light yellowish-brown, clay-rich, silty, pebbly, compact...... 8 feet

The loess thins from an average thickness of 20-30 feet in this area to an average of 10-15 feet within 5 miles eastward.

Notice reentrant in the Illinoian margin occupied by late Wisconsin drift. About a mile to the east is a kame (?) terrace built against the Illinoian highland, formed when the late Wisconsin ice invaded this reentrant. Rise on Illinoian highland for short distance and again descend onto late Wisconsin till plain. From this area northward for the next 8 miles the late Wisconsin till plain rises gradually from about 1,300 feet to over 1,500 feet. This increase of over 200 feet in elevation is due to the late Wisconsin ice overriding the Illinoian highland which formed a buttress to the advance of the ice.

Leave Interstate 29 at Volin exit and proceed east to Union County Road 1-C. Proceed south 1 mile and turn east on Union County Road 15 for $3\frac{1}{2}$ miles to Stop 4-1. When crossing Brule Creek, notice the width of the valley. To the north of this sector the floodplain broadens and locally contains outwash valley train deposits. The valley from this crossing southward was constricted by the late Wisconsin ice margin abutting against the Illinoian highland. Notice also the fresh late Wisconsin till in road cuts just west of the valley, and thick loess in cuts on road ascending east bank of this valley.

Stop 4-1: Nora Section, road cut on north side of Union County Road 15, $\frac{1}{2}$ mile west of abandoned Nora townsite. Center South line sec. 23, T. 94 N., R. 50 W., Union County.

Unit	Thickness (feet)	(meters)
3. Wisconsin loess, light brownish-yellow, massive, calcareous; calcium carbonate concretions; carbonaceous flecks throughout; modern soil in top $1\frac{1}{2}$ feet............	5.8	1.8
2. Sangamon soil horizon, clay, silty, dark reddish-brown, becomes slightly lighter in color with depth; compact, very slightly calcareous in spots; a few scattered carbonaceous flecks; several weak sub-vertical joints filled with buff calcareous silt and occasional calcium carbonate nodules; upper 3 to 4 inches of this unit show crude laminae of brown clay and buff silt..................	4.3	1.3
1. Illinoian till, clay, reddish-brown, slightly calcareous, compact, scattered pebbles of basalt, quartzite (green),		

Unit	Thickness (feet)	(meters)
sandstone, granite, and quartz (base of cut)............	2.5	.8
Hand auger hole at base of cut: Illinoian till, medium yellowish-brown to medium olive-brown (some olive-gray mottling below), slightly sandy; slightly calcareous in upper 1 foot, strongly calcareous below; tough; abundant pebbles; abundant white carbonates near base...	4.0	1.2
TOTALS	16.6	5.1

A similar soil horizon 6 miles southeast of Stop 4-1 was described by Tipton (1958), and Steece and others (1960). Several outcrops within 15 miles of this stop, although not exposing soils as such, exhibit deposits believed to represent Sangamon weathering. These have been studied by Steece, but the information is not yet published.

These occurrences of Sangamon-age deposits coupled with evidence presented later in this guidebook constitute evidence of pre-Wisconsin, post-Yarmouth till in southeastern South Dakota and adjacent Iowa.

Proceed eastward 4½ miles to Union County Road 2 and turn north. The route traverses typical deeply dissected loess-mantled, Illinoian till topography. Enter Alcester and continue north on County Road 2. About 2 miles north of Alcester descend onto Brule Creek floodplain; on and off floodplain for about 2 miles. Compare this feature here with the steep narrow valley mentioned west of Stop 4-1. Cross State Highway 46 and enter Lincoln County. Continue north on Lincoln County Road 131 to Norway Center. Norway Center is about 2 miles southeast of the late Wisconsin drift border. Turn east on Lincoln County Road 152 for 3 miles. Turn north on Lincoln County Road 135 for 5½ miles to Stop 4-2.

Stop 4-2: Fairview West Section, road cut on east side of County Road 135, 4 miles (6 km) west of the town of Fairview and about ½ mile south of Newton Hills State Park. NW¼SW¼NW¼ sec. 19, T. 97 N., R. 48 W., Lincoln County.

Unit	Thickness (feet)	(meters)
3. Wisconsin loess, grayish-orange (10YR 7/4), mottled with gray, becomes light olive-gray (5Y 6/1) in basal 4 feet; calcareous; carbonaceous flecks..............	15.5	4.7
2. Post-Sangamon lag concentrate of boulders and cobbles..	Band	
1. Illinoian till, dark yellowish-brown (10YR 4/2) with light olive-gray (5Y 5/2) mottling, clay-rich, abundant pebbles; compact, calcareous; oxidation joints 3 to 9 inches wide, moderate yellowish-brown (10YR 5/4) occasionally		

Unit	Thickness (feet)	(meters)
contain calcium carbonate filling in center; excellent sand-filled ice-wedge pseudomorphs................	30.0	9.2
TOTALS	45.5	13.9

This section exposes till which must be pre-Wisconsin by the following reasoning. There is a sharply defined break in the topography near Dell Rapids (about 45 miles north of this stop) (see fig. 4-2) in the drift mapped or inferred by earlier workers to be Kansan (Rothrock, 1926; Shimek, 1912; Carman, 1913; Bendrat and Spencer, 1904) and Iowan (Flint, 1955; Ruhe, 1950; Smith and Riecken, 1947). North of this border the early Wisconsin drift (Lemke and others, 1965) is smooth, well drained, moderately dissected, loess mantled, and exhibits hillocks which may represent remnant end moraines similar to the "paha" of the Iowan drift of eastern Iowa (Alden and Leighton, 1917, p. 171-181). The drift south of this border (the Illinoian) is maturely dissected, the loess mantle is thicker, the till is more deeply oxidized, occasionally jointed, contains sand-filled, ice-wedge pseudomorphs, and is commonly overlain by a lag concentrate. In addition, the surface of the Illinoian shows a northwest-southeast lineation that probably owes its origin to the prevailing wind direction during deposition of the loess that mantles the drift. This lineation possibly could be the result of constructional features on the Illinoian drift surface, although this is unlikely owing to the deep dissection present. Also, the break in topography at Dell Rapids coincides with outcrops of the Precambrian Sioux Quartzite, and could reflect structural controls by this bedrock. This also is unlikely because similar occurrences of Sioux Quartzite beneath early Wisconsin drift in southwestern Minnesota do not affect the drift topography in this manner.

The Illinoian drift at this locality and throughout this region of South Dakota and Iowa shows well-developed oxidation joints occasionally with calcium carbonate or gypsum filling in the center (in many localities better than at Stop 4-2) which alone indicate weathering of long duration; they are diagnostic of pre-Wisconsin tills in glaciated areas (Flint, 1955, p. 36). Several nearby localities show ice-wedge pseudomorphs bisecting the oxidation joints in this till. This fact proves that the joints were developed in the till before the formation of the ice wedges. The writers believe the ice wedges were formed when the Wisconsin ice invaded the region adjacent to the Illinoian highland. Also the presence of the lag concentrate at the loess-till contact suggests prolonged exposure of the till surface to subaerial erosion and weathering. The ice-wedge pseudomorphs are always terminated upward at the loess-till contact.

At nine localities within several miles of Stop 4-2, a weak inter-loessal oxidized zone associated with carbonaceous accumulation occurs from 4 to 8 feet below the land surface where the loess averages from 12-18 feet in thickness. This oxidized zone represents a time when very

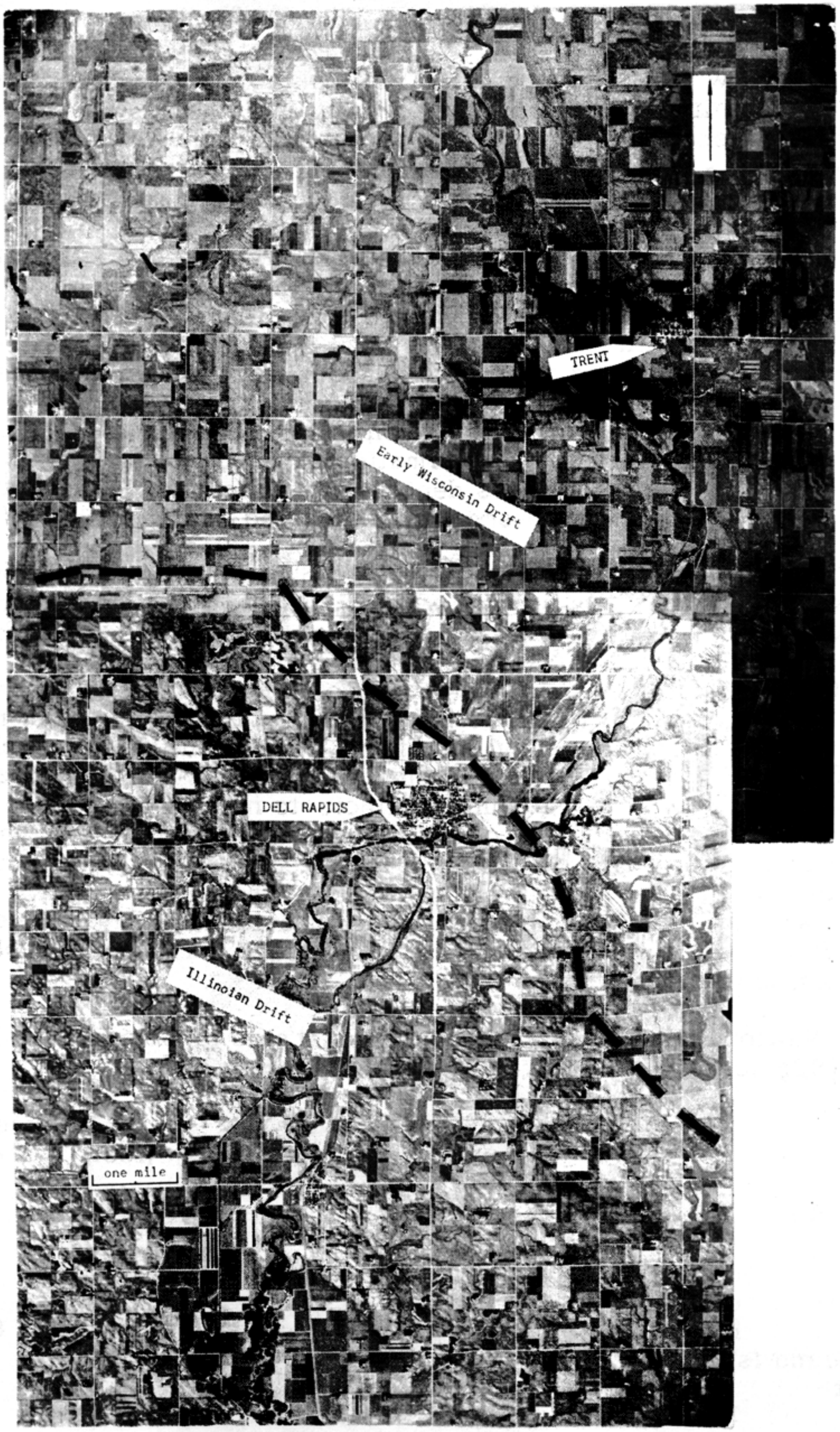

Figure 4-2. Vertical air photo of Dell Rapids, South Dakota area, showing Illinoian-early Wisconsin drift border. Location shown on figure 4-1.

little or very slow loess accumulation was taking place. The carbonaceous material, although not abundant, represents the remains of plants that grew, were short lived, and were smothered by slowly accumulating loess. Thus, in a sense these zones represent soil horizons. This time of non-deposition is believed by the writers to be during or near the time of the late Wisconsin ice advance in the region to the west. As the late Wisconsin ice sheet melted, it exposed the fresh drift plain which supplied the loess that forms the upper increment above the oxidized zone. If this oxidized zone in the loess does represent interstadial conditions just prior to the late Wisconsin advance then the frost wedges in the Illinoian till were probably formed during the early Wisconsin ice advance. The sequence of formation therefore is: 1) deposition of Illinoian till; 2) weathering of till to form well-developed oxidation joints accompanied by Sangamon soil formation; 3) erosion and formation of lag concentrate; 4) frost wedging; 5) early Wisconsin loess deposition; 6) formation of weak soil and oxidation zone on early Wisconsin loess; and 7) deposition of late Wisconsin loess (see fig. 4-3).

The absence of Illinoian gumbotil on the Illinoian drift in this region may be explained by assuming a cooler, drier climate (other factors being more or less equal) for South Dakota and adjacent parts of northwestern Iowa and southwestern Minnesota, as compared to southeastern Iowa, Illinois, and northeastern Missouri where Illinoian gumbotil is well developed. This same climatic difference prevails today and is reflected in the comparative modern soil development of the two regions (Holowaychuk, 1960, p. 6-19). The degree of development of gumbotils and ancient soils decreases northwestward from central Illinois to northwestern Iowa and southeastern South Dakota, as is obvious from a traverse between the two regions. Since the Sangamon deposits in this area were probably thin and not well developed, erosion has removed most of them.

Deposits exposed at later stops will present evidence that the till discussed at Stop 4-2 is post-Yarmouth in age. Proceed north on County Road 135 for $1\frac{1}{2}$ miles to Stop 4-3.

Stop 4-3: Newton Hills Section, road cut on east side of County Road 135, SW$\frac{1}{4}$SE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 12, T. 97 N., R. 49 W., Lincoln County.

Age	Unit	Thickness (feet)	Thickness (meters)
Illinoian			
	10. Till, moderate yellowish-brown (10YR 5/4) to dark yellowish-orange (10YR 6/6), clay rich, compact, to friable near top, blocky, calcareous, pebbly	29	8.8
Kansan, Grand Island-Sappa equivalent			

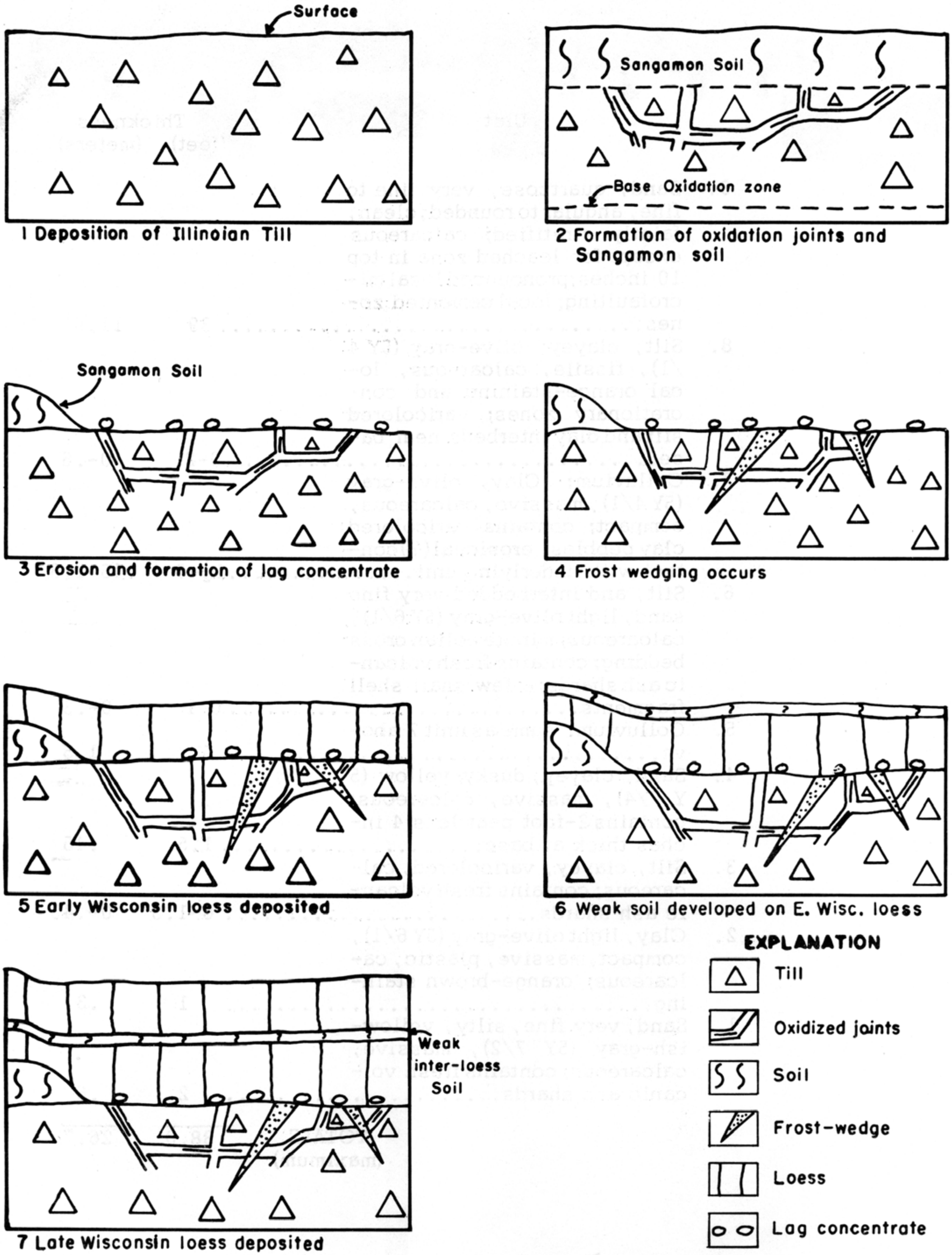

Figure 4-3. Lower Big Sioux River Area-Diagrammatic sequence of events from Illinoian to end of late Wisconsin time.

Unit	Thickness (feet)	Thickness (meters)
9. Sand, quartzose, very fine to fine, angular to rounded, clean, faintly stratified; calcareous except for leached zone in top 10 inches; pronounced local microfaulting; local cemented zones	39	11.9
8. Silt, clayey, olive-gray (5Y 4/1), fissile, calcareous, local orange-staining and concretionary zones; varicolored silt and clay interbeds near base	0-2	0-.6
7. Colluvium: Clay, olive-gray (5Y 4/1), massive, calcareous, compact; contains varicolored clay pebbles, erosional(?) contact with underlying unit	1½-6	.45-1.8
6. Silt, and interbedded very fine sand, light olive-gray (5Y 6/1), calcareous; minute eolian cross bedding; contains fresh volcanic ash shards; a few snail shell fragments	0-1	0-.3
5. Colluvium: same as unit 7 above	5	1.5
4. Sand, clayey, dusky-yellow (5 Y 7/4), massive, calcareous; contains 2-foot peat lens 4 inches thick at base	1.5	.45
3. Silt, clayey, varicolored, calcareous; contains fresh volcanic ash shards	0-1.5	0-.45
2. Clay, light olive-gray (5Y 6/1), compact, massive, plastic, calcareous; orange-brown staining	1	.3
1. Sand, very fine, silty, yellowish-gray (5Y 7/2), massive, calcareous; contains fresh volcanic ash shards	2	.6
TOTALS (maximum)	88.0	26.7

A composite section of the Newton Hills locality is as follows:

Unit	Thickness (feet)	Thickness (meters)
5. Wisconsin loess	19	5.8
4. Lag concentrate	Band	
3. Illinoian till (includes unit 10 in above section)	113	34.4
2. Kansan, Grand Island-Sappa equivalent (includes units 1-9 in above section)	140	42.7
Drill hole:		
1. Cretaceous Carlile Shale	10	3.1
TOTALS	282	86.0

The absence of oxidation joints and ice-wedge pseudomorphs in the Illinoian till at this locality is explained by the erosion which has taken place, controlled by the proximity of the Big Sioux River. The cuts along this road reveal large colluvial lenses filling former channels in the surface of the Illinoian till, indicating that considerable erosion has taken place, at least adjacent to the Big Sioux River. Several other cuts along this road south of Stop 4-3 show well-developed lag concentrate at the loess-till contact, ice-wedge pseudomorphs, and oxidation jointing in the till. Therefore, the till overlying the Sappa equivalent at this locality is probably the same till as exposed at Stop 4-2.

The silts and clays below the Illinoian till at this locality contain a very small percentage of fresh volcanic ash shards. These shards compare favorably in character with ashy deposits elsewhere in southeastern South Dakota which in turn have been identified with the Pearlette ash in Kansas (Tipton, 1958; Steece, 1960; Swineford and Frye, 1946). This fact plus the fact that the ash shards contained in the deposits at Stop 4-3 and in the adjacent region of southeastern South Dakota and northwestern Iowa, are fresh and unaltered suggests that these deposits are equivalent to the Sappa Formation of Nebraska and Kansas usage, and therefore are of late Kansan or Yarmouth age. Also, the association elsewhere of these ashy deposits with sands and gravels of nonglacial origin suggests that the sands and gravels are equivalent to the Grand Island Formation of Nebraska and Kansas usage, and are therefore of late Kansan or Yarmouth age. Several sections in northwestern Iowa east of Canton expose a sequence of Illinoian till on top of interbedded sands and gravels, and ashy silts and clays which in turn overlie an oxidized compact, blocky, clay-rich till believed to be Kansan in age.

Pearlette volcanic ash occurs in two exposures in southeastern South Dakota and lends further evidence to the solution of the problem. The first (identified as Pearlette by Swineford and Frye, 1946) exposed in the Hartford section 30 miles to the northwest (Stop 4-5, this guidebook), occurs above Kansan and Nebraskan tills and underlies Illinoian till, and is associated with Sappa equivalent silts and clays. The second Pearlette ash exposure occurs about 11 miles south of the Sangamon soil at Stop 4-1, and 6 miles south of another Sangamon soil zone developed on the Illinoian till. The ash at this second locality occurs below Wisconsin loess and above a Yarmouth (?) sand and gravel.

Further evidence of Yarmouth age for the sub-Illinoian silts and clays in this region are the associated molluscan faunas. In a cut $6\frac{1}{2}$ miles northeast of Stop 4-3, ashy silts and clays are overlain by $3\frac{1}{2}$ feet of gray clay containing an abundant molluscan fauna, which is overlain by Illinoian till. Leonard (1950) identified Gyraulus labiatus Leonard, Menetus pearlettei Leonard, and Planorbula nebraskensis Leonard, among the forms present, and concluded that the "...stratigraphic relations and the characteristics of the molluscan fauna conclusively indicate Yarmouthian age of the fossil-bearing deposit." (Leonard, 1950, p. 6). Using this faunal assemblage as a guide, Steece has favorably compared several other molluscan faunas in similar stratigraphic positions to Leonard's work.

Fossil snail shells can be found sparingly in the silts and clays at this stop, but because they are not abundant they have not yet been studied.

Continue northward on Lincoln County Road 135. Drop down to the Big Sioux River floodplain and follow the river for a short distance. A bore hole in this low area revealed about 10 feet of alluvial-colluvial material overlying Cretaceous Carlile Shale.

Notice cuts exposing mainly late Wisconsin till, on ascending from the Big Sioux Valley; some jointed unoxidized Illinoian till is below. The north end of the Newton Hills is also the north end of this segment of the Coteau des Prairies (Rothrock, 1943). The late Wisconsin ice overrode the Illinoian highland which apparently forms the core of the Coteau in this sector; the overriding ice presumably was relatively inactive because no terminal moraines were constructed at the ice margin.

Enter the city of Canton. Turn west on U. S. Highway 18 for 10 miles. The route traverses the featureless late Wisconsin till plain that rises gradually from about 1,250 feet to slightly over 1,500 feet near Sioux Falls. Turn north on Interstate 29 for 20 miles. Descend to the Big Sioux floodplain at the 41st Street interchange. This floodplain is underlain by Recent alluvium and Wisconsin valley train outwash. Cross Skunk Creek, a major tributary to the Big Sioux River. Turn east on U. S. Highway 16. Cross Big Sioux River. Enter the city of Sioux Falls. Turn south on Kiwanis Avenue for $\frac{1}{2}$ mile to Sherman Park and Stop 4-4 (also lunch stop).

Stop 4-4: Sherman Park Section, cutbank on Big Sioux River, NE$\frac{1}{4}$SW$\frac{1}{4}$ sec. 19, T. 101 N., R. 49 W., Sherman Park, southwest part of city of Sioux Falls.

Unit	Thickness (feet)	(meters)
5. Modern soil, black, sandy, calcareous.............	1-3	.3-.9
4. Wisconsin gravel, unsorted, calcareous............	3	.9

Unit	Thickness (feet)	(meters)
3. Illinoian till, brownish-yellow; weathers light buff; compact, blocky, iron-stained joints................	12	3.7
2. Kansan, Sappa equivalent:		
b. Clay, greenish-gray, plastic....................	0.1-0.5	.04-.2
a. Silt, dark reddish-brown clayey, calcareous; weathers reddish-gray; contains Yarmouth mollusks..	3.7	1.1
1. Kansan till, orange-brown, oxidized, friable, calcareous..	24.3	7.4
TOTALS (maximum)	46.5	14.2

This stop was Stop 7 of the 11th Annual Midwestern Friends of the Pleistocene field conference, 1960.

Even though the Illinoian till at this locality does not contain such features as well-developed joints and ice-wedge pseudomorphs (probably removed by erosion due to close proximity of Big Sioux River) it is judged to be Illinoian because of the topography developed on its surface in the surrounding areas, and because of its oxidized character. Also, the stratigraphic sequence here is similar to that seen in earlier stops.

The mollusks present in unit 2a were identified by Steece as Gyraulus labiatus Leonard, Succinea grosvenori Lea, Pomatiopsis cincinnatiensis (Lea), Vertigo gouldi (Binney), Retinella electrina (Gould), Helisoma anceps (Menke), Physa anatina Lea, Sphaerium cf. occidentale Prime. Only one, Gyraulus labiatus, is considered to be an index fossil. This form is restricted to Yarmouth in Kansas (Leonard, 1950). Two, Retinella electrina and Succinea grosvenori, first make their appearance in Aftonian time; Physa anatina and Helisoma anceps range from Lower Pliocene to Recent; and Vertigo gouldi and Pomatiopsis cincinnatiensis range from Yarmouth to Recent.

Retrace route to Interstate 29 and turn north for 4½ miles to Interstate 90; travel on Big Sioux floodplain for 2 miles; climb onto Illinoian till plain. Notice the similarity of the topography here as compared to that of the Illinoian farther south near Stops 4-1, 4-2, and 4-3. Turn west on Interstate 90 to State Highway 38 junction. Cross the valley of Skunk Creek just prior to leaving Interstate 90. This sector of Skunk Creek valley for a distance of 1 mile to the south and 5 miles to the northwest was constricted by late Wisconsin ice advancing locally from the west. North and south of this constricted sector the valley broadens and is occupied by valley train outwash deposits. Proceed northwestward on State 38 to county paved road and turn north for 1 3/4 miles; turn east 3/4 mile; turn north on farm lane and park in farm yard; walk about ¼ mile to Stop 4-5. (This locality was Stop 8 of the 11th Annual Midwestern Friends of the Pleistocene field conference, 1960; and Stop 2 of the 1951 Pleistocene field conference sponsored by the Iowa, Kansas, Nebraska, and South Dakota Geological Surveys.)

Stop 4-5: Hartford Section, cutbank on Skunk Creek, SW¼SW¼NE¼ sec. 11, T. 102 N., R. 51 W., Minnehaha County.

Unit	Thickness (feet)	(meters)
7. Wisconsin loess	23	7.0
6. Illinoian till	27	8.2
5. Sappa equivalent	19	5.8
4. Kansan till	17	5.2
3. Aftonian gley (?)	4	1.2
2. Nebraskan till	26	7.9
1. Precambrian Sioux Quartzite .... hit at	116	35.3
TOTALS	116	35.3

Figure 4-4 gives the stratigraphy of this section as interpreted by Flint (1955), Steece and others (1960), and as revealed by the displayed cores, from a boring at the top of the cut.

The stratigraphy is summarized as follows:

(This core description was eliminated from the INQUA Field Conference Guidebook to save space and was handed out at the Stop.)

S.D.G.S. Strat. #1 Hartford, SW¼NE¼ sec. 11, T. 102 N., R. 51 W., Minnehaha County, South Dakota
Drilled by S. Dak. Highway Commission, Drive pipe method, April 20-25, 1960
Logged by M. J. Tipton

Feet Drilled	Recovered	Interval	Lithology
0- 7	1.4	0.0-0.4	Soil, silty-clay, dark to medium brown, non-calcareous; some sand and root fragments.
		0.4-0.8	Loess, non-calcareous, lighter colored (buff) and has small black organic pellets.
		0.8-1.4	Becomes light buff and siltier; black pellets rare; last 0.1 foot slightly calcareous.
7-12	1.4	0.0-0.3	Loess, light buff, silty, with some fine sand and iron staining, calcareous.
		0.3-0.5	Becomes sandier, laminar; iron staining.

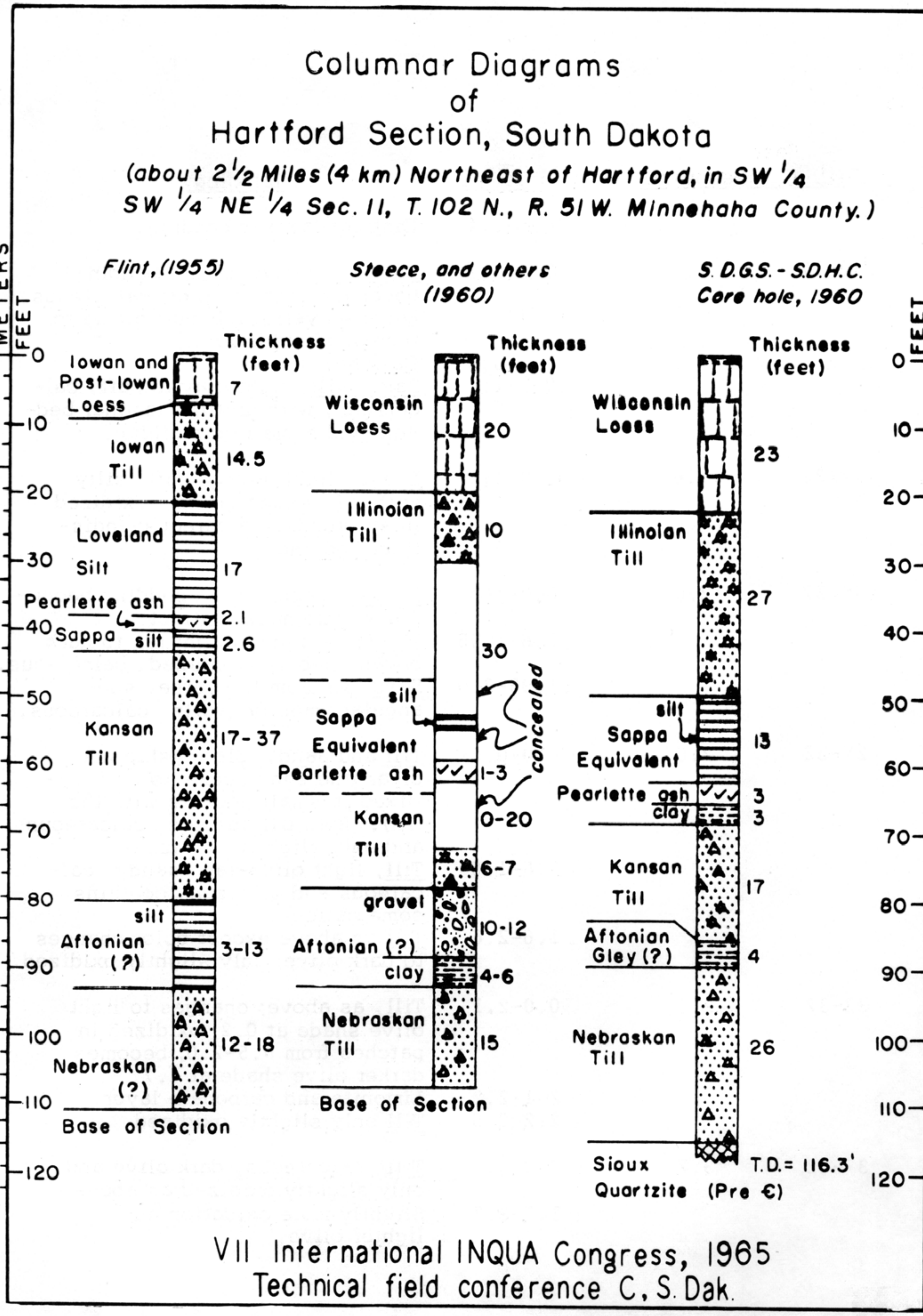

Figure 4-4. Columnar diagrams showing stratigraphy of the Hartford Section, South Dakota.

Feet Drilled	Feet Recovered	Interval	Lithology
		0.5-1.4	Distinct laminar bedding.
12-17	1.4	0.0-0.2	Loess as above except bedding becoming less distinct; calcareous.
		0.2-0.5	Becomes yellowish-buff owing to increased oxidation.
		0.5	Caliche.
		0.5-1.4	Sandy silt, light gray to buff, calcareous, with distinct laminar bedding and some iron staining.
17-22	1.6	0.0-1.6	Loess, light gray to buff, silty with a few sand grains, oxidized in splotches, calcareous; indistinct bedding.
22-27	2.0	0.0-1.8	Loess as above with bedding becoming a little more distinct.
		1.8-1.95	Till (Illinoian?), light tan to dark brown, pebbly, oxidized, calcareous.
		1.95-2.0	Sand, medium to coarse, subangular, mostly quartz, calcareous.
27-32	2.6	0.0-0.5	Till and Sand, relationship not clear (the sand seems to be intermixed in small pockets with the till). Both till and sand calcareous and only slightly oxidized.
		0.5-1.6	Till, light olive-tan, sandy, calcareous and oxidized, contains some caliche.
		1.6-2.6	Till as above except color changes to dark olive; only slightly oxidized.
32-37	2.5	0.0-2.1	Till, as above; changes to light olive shade at 0.2; oxidized in patches from 0.5-2.0; becomes darker olive shade at 1.7.
		2.1-2.2	Limonite and carbonate layer.
		2.2-2.5	Till only slightly oxidized.
37-42	3.7	0.0-1.7	Till, calcareous, dark olive and only slightly oxidized as above.
		1.7-3.7	Slightly more oxidation and a lighter olive.

Feet Drilled	Feet Recovered	Interval	Lithology
42-47	2.7	0.0-1.5	Till, as above.
		1.5-1.7	Secondary carbonate containing medium to fine sand grains; till slightly lighter colored above the carbonate for 0.5.
		1.7-2.7	Till, calcareous, medium olive-brown, containing more clay than above.
47-52	2.9	0.0-1.0	Sand and gravel, calcareous, mostly iron-stained quartz with some feldspar, quartzite, limestone, and light and dark igneous rocks.
		1.0-2.9	Till, light olive-brown, calcareous, slightly oxidized.
52-57	4.8	0.0-0.1	Till, as above.
		0.1-3.8	Interglacial deposit (loess?) silt, with some clay, light brown to tan, slightly calcareous, speckled with white secondary carbonate deposits; also small brown limonite specks; occasional quartz sand grains.
		(0.9-1.4)	Only very slightly calcareous; dark igneous pebbles at 1.2.
		(2.0-4.0)	Becomes more calcareous and darker; iron pellets at 2.4 similar to those found in the Sangamon soil and Fuson shale.
		3.8-4.0	Soil (?) only very slightly calcareous becoming slightly darker in color.
		4.0-4.8	Almost no secondary carbonate from 3.9-4.8, also an increase in clay content and decrease in silt; few black iron-manganese patches at 4.8.
57-62	4.7	0.0-0.1	Debris caved in from above.
		0.1-2.8	Soil (?), medium brown, clay with patches of iron-manganese and an occasional sand grain as above, leached; becomes siltier at 1.5-2.8.

Feet Drilled	Recovered	Interval	Lithology
		2.8-4.7	*Silt* (loess?), buff, leached, with occasional sand grain and pieces of iron-manganese; occasional volcanic ash shards at 3.3-3.6; shards rare 3.6-4.7 (Sappa?).
62-67	2.5	0.0-1.8	*Silt* (loess?), as above except contains numerous small, sand-size cavities; changes from buff to light tan at 1.2-1.3 (owing to presence of bentonite), and faint laminations are visible; becomes mottled buff to light tan at 1.3-1.5 with laminations distinct; becoming more bentonitic. Almost pure bentonite with occasional iron staining at 1.7.
		1.8-2.5	*Pearlette volcanic ash* (sharp contact); partly altered to bentonite and slightly oxidized in part; non-calcareous.
67-72	3.9	0.0-0.1	Debris probably caved in from above (including a Sioux Quartzite pebble).
		0.1-0.9	*Pearlette volcanic ash* as above; small sand-grain size cavities at 0.4.
		0.9-1.0	Sharp contact. Dark gray to black clay (soil?) mottled yellow and red, highly oxidized, leached.
		1.0-1.2	Greenish-gray, bentonitic *clay* and *silt*, mottled yellow and red by strong oxidation, occasional sand grain, leached.
		1.2-2.9	Greenish-gray *clay* and *silt*, partially oxidized, leached; occasional iron-filled rootlet casts; faint laminar bedding at 2.4; bedding becomes more distinct at 2.7; some beds composed of very fine sand.
		2.9-3.9	*Kansan clay till*, dark olive-gray, highly oxidized, leached, with black iron-manganese; some sand and a few sand layers; an occasional small pebble; some laminar bedding.
72-77	3.3	0.0-0.1	Volcanic ash (caved in from above).

Feet Drilled	Feet Recovered	Interval	Lithology
		0.1-0.7	Till, dark olive-gray, highly oxidized and leached; contains more pebbles than the above till.
		0.7-1.6	Till, yellowish-brown, calcareous and not as deeply oxidized as above till; contains a little secondary calcium carbonate.
		1.6-3.3	Till, grayish-brown, calcareous, lightly oxidized; secondary calcium carbonate increases.
77-82	2.1	0.0-0.8	Sand, glacial, calcareous (could be cavings), contains some silt, and fine, medium and coarse sand.
		0.8-1.1	Till, olive-brown, calcareous, partly oxidized; some secondary carbonate.
		1.1-1.4	Sand, fine to medium, calcareous; some silt.
		1.4-2.1	Till, yellowish-buff, calcareous, slightly oxidized, compact.
82-87	3.0	0.0-2.5	Till, yellowish-buff, calcareous, partly oxidized.
		2.5-3.0	Till, olive-brown, clayey, calcareous, partly oxidized.
87-92	3.2	0.0-0.7	Till, olive-brown as above except less oxidation. Contact smeared.
		0.7-1.1	Aftonian clay (gumbotil? or gley?), medium to dark brown, leached; occasional pebble and sand grains.
		1.1-3.2	Silty clay as above, except calcareous; contains secondary carbonate; pebbles and sand grains rare.
92-97	2.4	0.0-0.1	Silty clay, medium to dark brown as above.
		0.1-0.5	Nebraskan till, light yellowish-brown, extremely calcareous and partly oxidized; contact with silty clay above is indistinct and smeared; in places the clay appears to have been forced down through cracks into the till; faint bedding in lower part.

Feet Drilled	Feet Recovered	Interval	Lithology
		0.5-1.0	Till, as above except yellowish-brown, and rudimentary bedding more distinct; shell fragment? at 0.6.
		1.0-2.4	Till, yellowish-buff, calcareous, partly oxidized, and very compact; hard caliche nodule at 1.8-2.3.
97-102	3.1	0.0-1.3	Till, yellowish-brown, calcareous, partly oxidized and very compact.
		1.3-3.1	Till as above except lighter yellowish-brown.
102-107	3.0	0.0-1.8	Till, light yellowish-brown as above.
		1.8-3.0	Till, as above except more clayey and olive-brown; more deeply oxidized.
107-112	3.4	0.0-3.4	Till, dark olive-brown, calcareous and oxidized; more moist and less compact than above; becomes slightly lighter colored in last 0.5 feet.
112-116.3	2.8	0.0-0.9	Till, as above.
		0.0-2.5	Till, buff to light gray, calcareous, only partly oxidized, very hard and compact; shell fragment at 2.2.
		2.5-2.6	Clay band, dark gray, calcareous, containing a few sand grains.
		2.6-2.8	Till as above.
		2.8	Chips and fragments of light-pink Sioux Quartzite.

There is little doubt that the two tills below the Pearlette ash bed at this locality are Kansan and Nebraskan. Even though the Illinoian till above the ash does not reveal well-developed jointing and ice-wedge pseudomorphs as does the drift farther south, it is judged to be Illinoian because of the similarity of the topography developed on the drift in this area to that of the same drift farther south, where the above features are well developed.

Siltstone and claystone beds of the Sioux Quartzite crop out on the east bank of the creek about 200 yards upstream from this section, and the quartzite is visible in the bed of the stream below the cutbank at low water level.

Return to State Highway 38 and proceed west for 6 miles to State Highway 19. Follow State 19 to Madison about 30 miles to the north. The route from Hartford to Madison traverses late Wisconsin drift, locally exhibiting well-developed terminal moraine topography. Cross Wisconsin outwash plain just before entering Madison. Continue north from Madison on U. S. Highway 81. Travel on late Wisconsin (James Lobe Altamont) drift with local morainic topography. Pass Lake Albert, enter Hamlin County. Pass Lake Poinsett and travel on late Wisconsin (post-Altamont) outwash (in part collapsed) associated with the ice-block basin of Lake Poinsett. This outwash owes its origin to a retreatal phase of the late Wisconsin ice which was rejuvenated some 6 to 8 miles behind (west) the James Lobe Altamont moraine. In many places this outwash displays excellent pitted topography. The meltwater channel here cut through the Altamont moraine via Lake Poinsett and formed the outlet on the east side of the lake. Cross the western edge of the Altamont moraine and descend into a narrow late Wisconsin spillway formed contemporaneously with the Lake Poinsett outwash deposit. By watching carefully to the east it can be seen that the Altamont moraine is breached by this spillway channel. Climb onto the Altamont moraine and cross the crest about where the highway turns east for 1 mile. About 1 mile after the highway turns north again, leave the Altamont moraine and travel on early Wisconsin drift (fig. 4-1).

Notice the topography of the early Wisconsin surface as compared to that of the late Wisconsin. The early Wisconsin is well drained and commonly mantled by an average of 2 to 5 feet of calcareous loess while the late Wisconsin is poorly drained and essentially loess-free. Intersection with State Highway 22 to the town of Thomas. To the left (west) for the next 4 miles is a pitted outwash plain occupied by several lakes. This feature and the ice block lakes were probably formed contemporaneously with the two outwash deposits mentioned above. As the late Wisconsin ice pushed against the higher early Wisconsin terrain to the east, the meltwaters and ice blocks were captured; narrow outlets to the southeast and northeast allowed the waters to escape. These outwash bodies, particularly the pitted ones, are extremely variable in thickness, ranging from 10 to 90 feet. Terrace outwash deposits in this region suggest multiple rejuvenations of the late Wisconsin ice both in the James and Des Moines lobes. Theoretically the sequence of outwash deposition is as follows: Outwash from the Bemis advance was deposited. This was dissected by the meltwater resulting from the Altamont readvance, leaving the Bemis outwash as terraces. These relationships are seen on the east side of the interlobate region. Next, outwash deposits of the Altamont readvance were locally dissected by meltwaters from a still later readvance (Gary?) leaving the Altamont deposits as terraces. These last relationships are seen on the James lobe side of the interlobate area.

Descend the steep bluff of the Big Sioux River valley, and travel on valley train outwash to Watertown.

DAY 5—AUGUST 18

Start: Watertown, South Dakota, 8:00 a.m.
End: Minneapolis, Minnesota
Mileage: 300 miles (480 km)
Leaders in South Dakota: Merlin J. Tipton and Fred V. Steece
Leaders in Minnesota: H. E. Wright, Jr., J. E. Stone, E. J. Cushing, and C. L. Matsch
Contributors to Guidebook: Wright, Stone, Cushing, and Matsch
Itinerary: Watertown and Pickerel Lake, South Dakota; Pickerel Lake, Browns Valley, St. Cloud, Minneapolis, Minnesota
Topographic maps: Minnesota—1:250,000 scale, Milbank (Stops 5-4 to 5-6), St. Cloud (Stops 5-7, 5-8); 1:62,500 scale, Lake Agassiz outlet area (Stops 5-5, 5-6) Peever, Wheaton, Herman, (Big Stone), Beardsley, White Rock, New Effington, (Ortonville) St. Rosa area (Stop 5-8), Swanville

En route to Stop 5-1

Travel north on U. S. Highway 81 from Watertown. You are still on the Big Sioux valley train outwash. Ascend onto early Wisconsin till plain for 3 miles. Drop down to the valley train of Gravel Creek, a tributary to the Big Sioux River. Travel on this plain for 8.5 miles. Again rise onto early Wisconsin till plain for 3 miles. Cross Sioux Creek valley train, tributary to the Big Sioux, and 5 miles farther north cross another tributary outwash valley. Notice the high Des Moines lobe Bemis moraine on the horizon to the east and the James lobe Altamont moraine on horizon to west. Continue the traverse on the early Wisconsin till plain, now and then crossing outwash valleys which head in the Des Moines lobe Bemis and Altamont moraines. At junction with U. S. Highway 12 turn east and climb the Bemis moraine. Note particularly the drained surface and smooth topography. Locally, however, constructional topography is present.

Stop 5-1: Bemis Moraine, between Ortley and Summit, Roberts County, South Dakota.

This is a short "bus window" stop, to exhibit the character of the first late Wisconsin advance of the Des Moines lobe in northeastern South Dakota. Although the Bemis moraine in South Dakota has not been precisely dated, several C-14 dates from this moraine in Iowa give an age of about 14,000 years B. P. (Ruhe and Scholtes, 1959). The moraine has been traced from the type locality into Iowa by Leverett (1932) and Ruhe (1950). Outwash associated with the Algona moraine in northern Iowa which lies behind the Altamont morainal system, has been dated at about 13,000 years B. P. (Ruhe and Scholtes, 1959). Thus the Altamont moraine should date somewhere in between the two. Dates in the James lobe in southern South Dakota on drift behind the Altamont moraine range from 12,050 to 12,760 (Lemke and others, 1965) which are slightly younger than the 13,000 Algona date in Iowa. Thus, the two lobes may have advanced independently, and the James lobe may be slightly younger than the Des Moines lobe.

A date of 10,060 $\pm$ 300 (sample W-1033, Ives and others, 1964, p. 48) was determined on snail shells in a lacustrine marl overlying late Wisconsin outwash in the central part of the James lobe, and give a minimum date for the late Wisconsin ice withdrawal from central South Dakota.

Route crosses a spillway channel heading in the Altamont moraine to the east and cutting through the Bemis moraine. Rise out of spillway and ascend the hummocky Altamont moraine. The differences in the character of the two moraines is well shown by the air photo, figure 5-1. This view was chosen rather than one at Stop 5-1 because figure 5-1 shows the moraines at their type areas of Bemis and Altamont. Begin ascent of Altamont moraine. Turn north on U. S. Highway 81 for about 2 miles to Stop 5-2 at the crest of the Altamont moraine.

Stop 5-2: Altamont Moraine, north of Summit, Roberts County, South Dakota.

This also is a short "bus window" stop to show the nature of the Altamont moraine. Notice particularly that the surface is completely undrained; it is made up of hummocks and ice kettles, probably little altered since its deposition. This moraine has likewise been traced in the Des Moines lobe by earlier workers (Chamberlin, 1883; Leverett, 1932; Ruhe, 1950). The Altamont moraine continues northwestward from here for about 15 miles where it merges sharply with the outer (Altamont) moraine of the James lobe. The highest point on the Coteau of 2,110 feet is about 12 miles northeast of here on this moraine.

Retrace the route to U. S. Highway 12 and turn west. Descend Bemis moraine onto early Wisconsin till plain for a short distance and then travel on late Wisconsin outwash plain. Pass through the town of Ortley. Enter Day County. Leave outwash plain and climb the James lobe Altamont moraine. Turn north on county road at east end of Blue Dog Lake to Stop 5-3.

Stop 5-3: James Lobe Altamont Moraine, near Blue Dog Lake in eastern Day County, South Dakota. (This was Stop 5 of the 11th Annual Midwestern Friends of the Pleistocene field conference, 1960.)

Flint (1955) identified the Des Moines lobe Altamont moraine as Mankato in age, but he mapped the Bemis moraine and outer James lobe moraine as Cary in age. On the basis of topography, the writers believe the outer moraine of the James lobe correlates with the second (Altamont) moraine of the Des Moines lobe.

At this stop we want to emphasize the remarkable similarity in topography of the James lobe Altamont moraine (fig. 5-2) to the Des Moines lobe Altamont moraine (fig. 5-1), and point out the equally remarkable contrast to the Bemis moraine. The Altamont moraine of both lobes shows complete lack of drainage (except at the margins of the Coteau), and is characterized by a disordered arrangement of sharp hummocks and deep

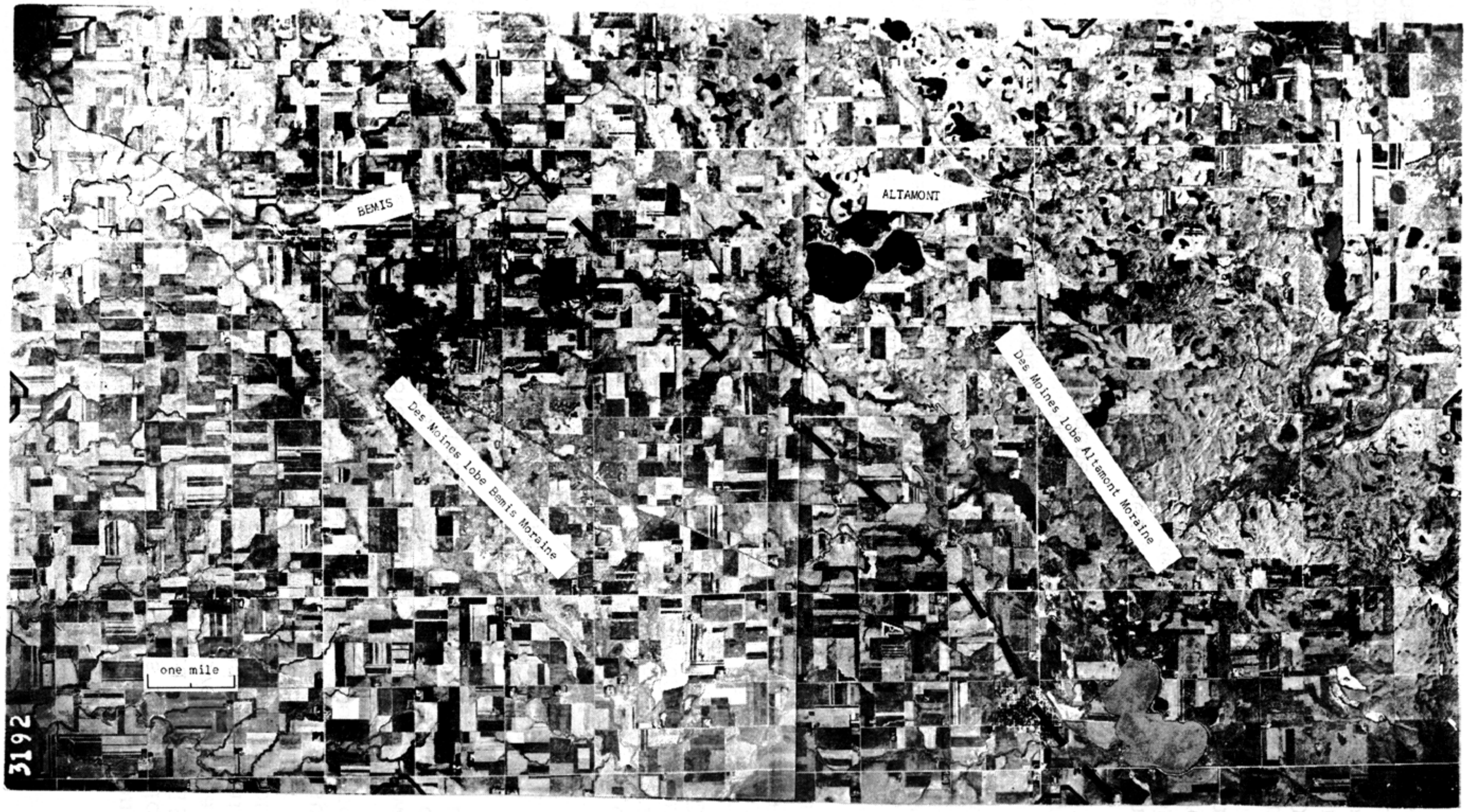

Figure 5-1. Vertical air photo of Bemis-Altamont area, South Dakota, showing the character of the Bemis and Altamont moraines at their type areas. Location shown on figure 4-1.

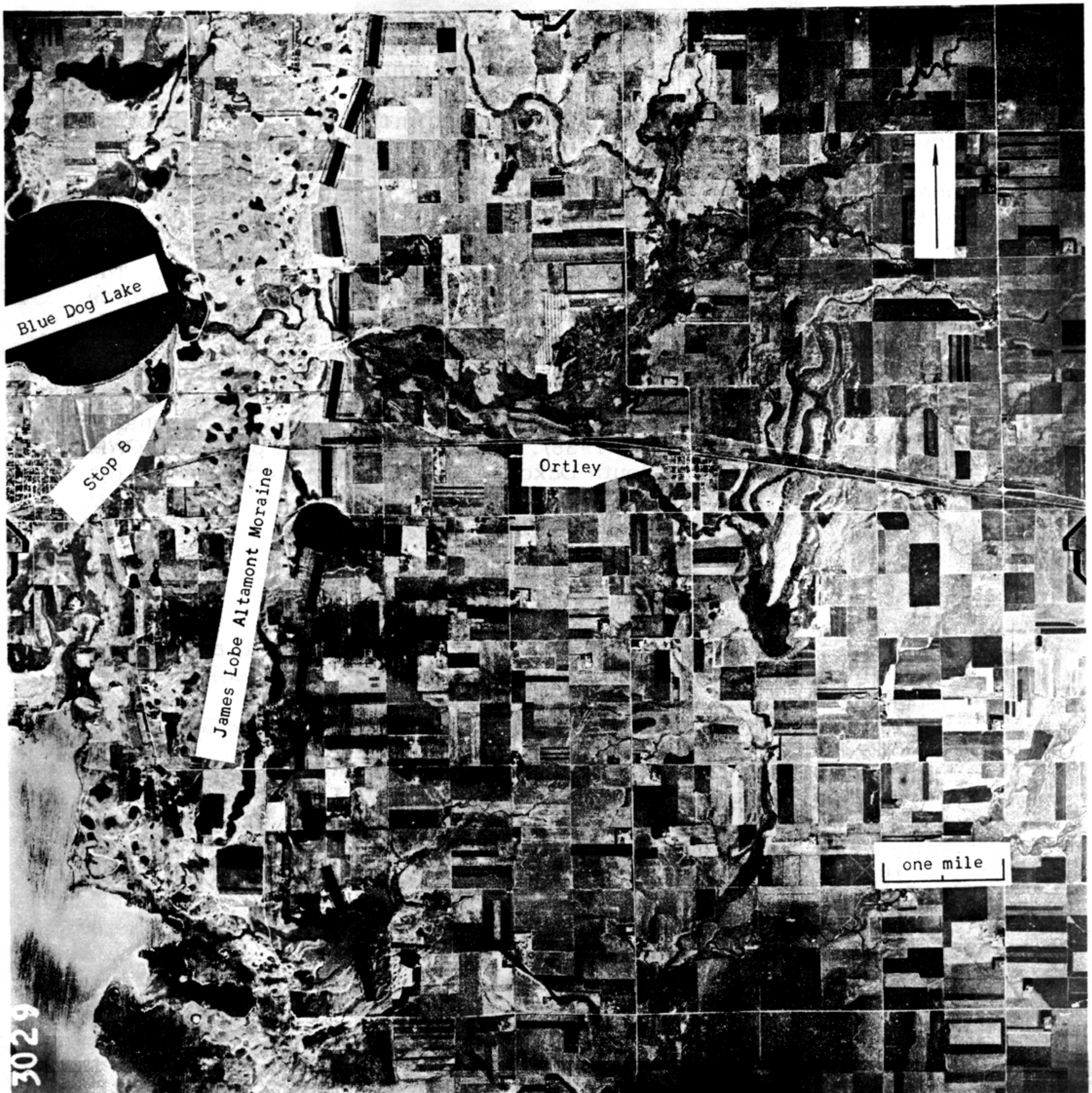

Figure 5-2. Vertical air photo of Blue Dog Lake - Ortley, South Dakota area, of Stop 5-3, showing James Lobe Altamont moraine as compared with Des Moines Lobe Altamont and Bemis shown on figure 5-1. Location shown on figure 4-1.

ice-block kettles, the latter occurring at discordant elevations. The Bemis moraine, on the other hand, is a smooth drained ridge that only locally exhibits constructional topography as described by Leverett (1932, p. 58).

Ruhe and Scholtes (1959, p. 591) have shown that the Altamont moraine in Iowa is Cary (pre-Two Creeks) in age and therefore cannot be the correlative of the Port Huron (post-Two Creeks Mankato, Wright, 1964, p. 636). Since there are no known major stratigraphic horizons equivalent to the Two Creeks interval (approximately 11,800) in South Dakota (except perhaps glacial lakes Dakota and Agassiz II), it is probable that the whole of the James lobe drift in South Dakota is pre-Two Creeks in age. The South Dakota Geological Survey, accordingly, has established the practice of referring to Wisconsin events prior to about 14,000 years B. P., as early Wisconsin and to later events between 14,000 years and 11,800 years B. P. as late Wisconsin. The terms early and late do not necessarily imply the same meaning as Leverett's "early" and "late" Wisconsin. Nor does early Wisconsin in our usage correspond to the "early Wisconsin" in Ohio (Goldthwait and Burns, 1958). Nevertheless, some post-Two Creeks events are recorded in South Dakota, but these occurred after the ice had completely withdrawn from the State.

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