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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

GEOLOGY OF THE OSWEGO QUADRANGLE

ROOSEVELT COUNTY, MONTANA

by

Roger B. Colton

U. S. GEOLOGICAL SURVEY

OPEN FILE REPORT
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This report is preliminary and has not been edited or reviewed for conformity with Geological Survey standards or nomenclature

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1951

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ILLUSTRATIONS

INTRODUCTION

The Oswego quadrangle has been mapped as a part of the U. S. Geological Survey's program for geologic mapping of areas where land development is proposed under the Missouri River Basin Construction and Rehabilitation Plan. Water from the Missouri River will be used for new and supplemental irrigation in the southern half of the quadrangle.

Cattle raising and wheat farming are the principal industries of the area but farming will probably become more diversified with increased irrigation.

Two maps accompany this report. One shows bedrock and surficial deposits; the other shows bedrock geology.

LOCATION

The Oswego quadrangle is in northeastern Montana (fig. 1) and extends from 48° to 48° 15' north latitude and from 105° 45' to 106° west longitude. Most of the quadrangle, except that part south of the Missouri River, lies within the Fort Peck Indian Reservation.

DRAINAGE

The Missouri River flows from west to east through the southern portion of the quadrangle. Of several intermittent tributary creeks, Oswego Creek, Elk Prairie Creek, Flynn Creek, and Wolf Creek are the most important.

Over a period of time, the course of the Missouri River has shifted. Comparison between a map made in 1910 and aerial photographs taken in 1949 shows the amount of change (fig. 2).

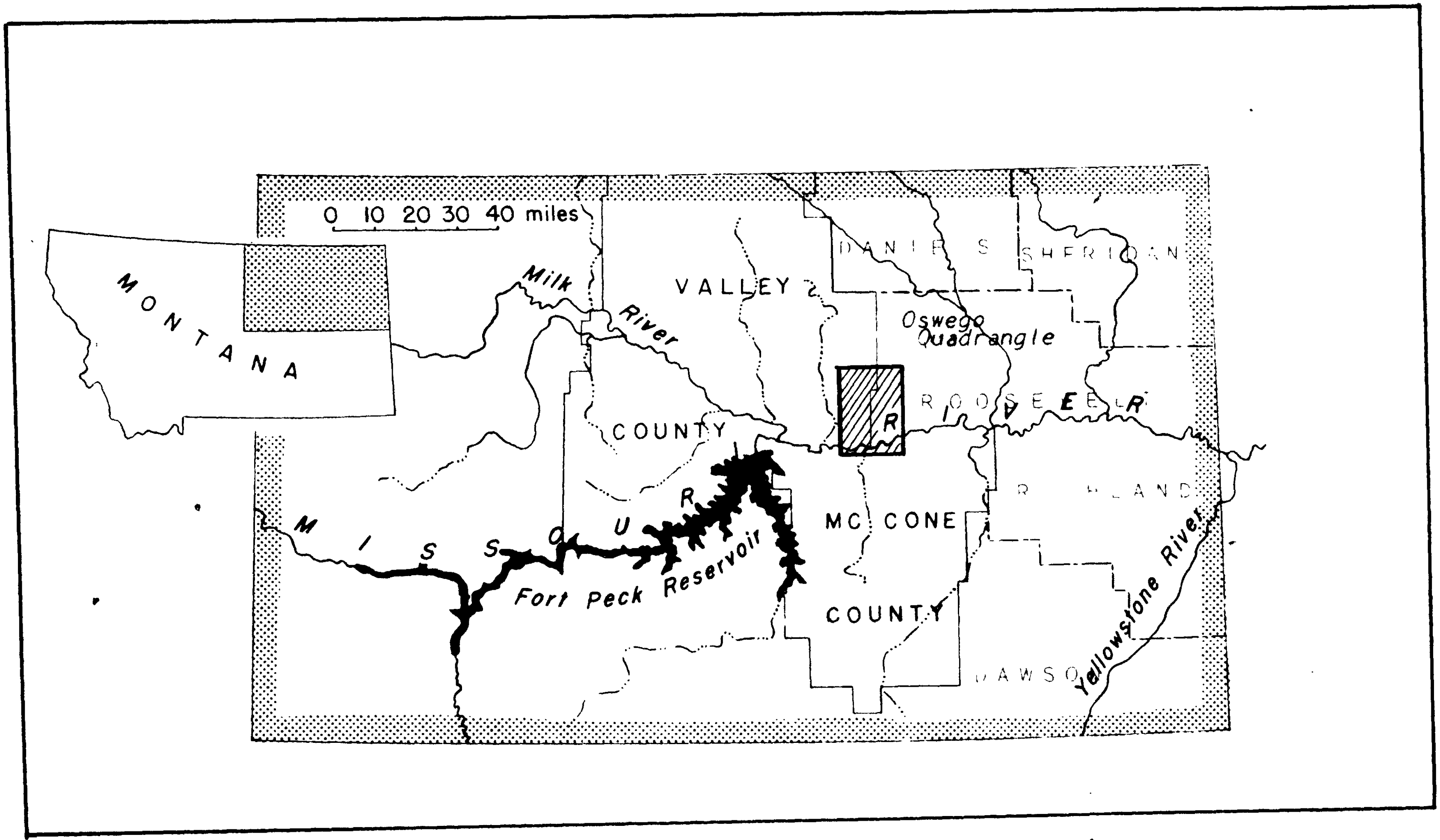


Figure 1. Index map showing location of Oswego quadrangle

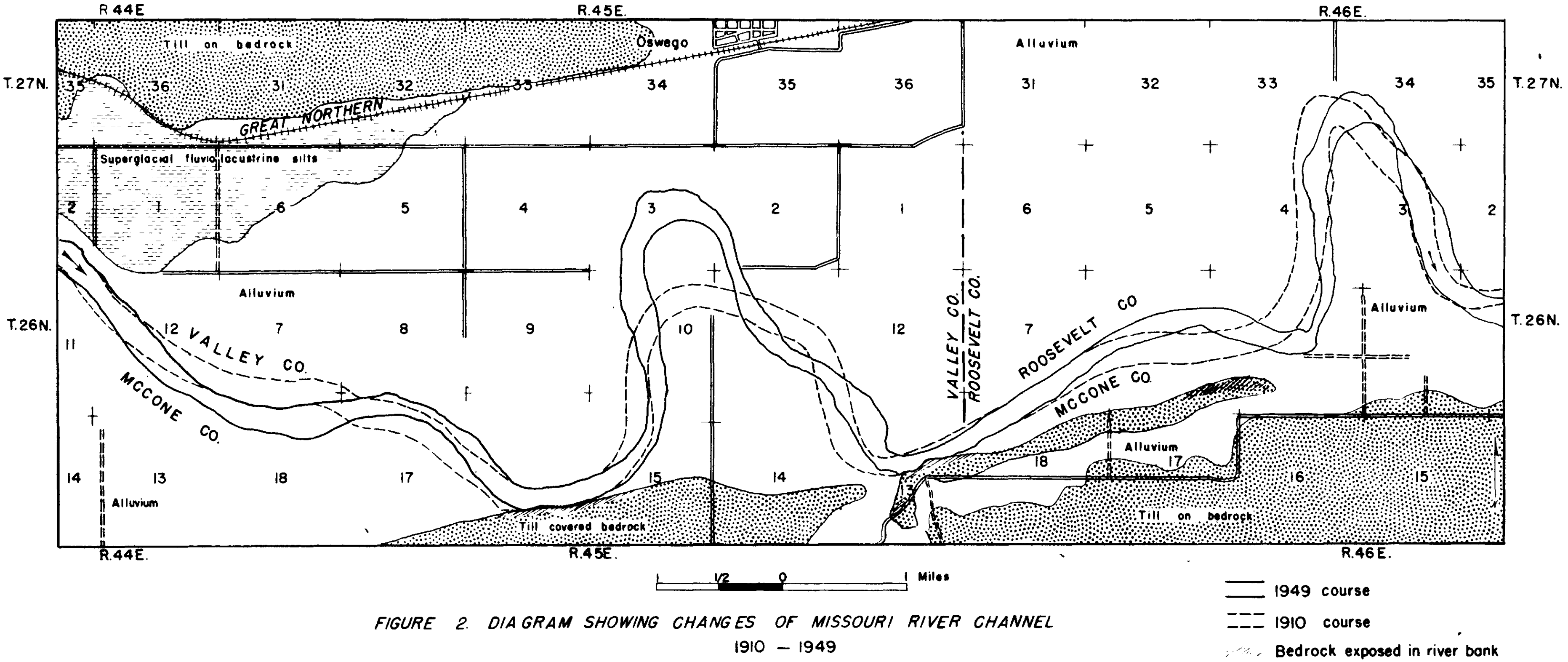


FIGURE 2. DIAGRAM SHOWING CHANGES OF MISSOURI RIVER CHANNEL
1910 — 1949
OSWEGO QUADRANGLE, MONTANA

FIELD METHODS

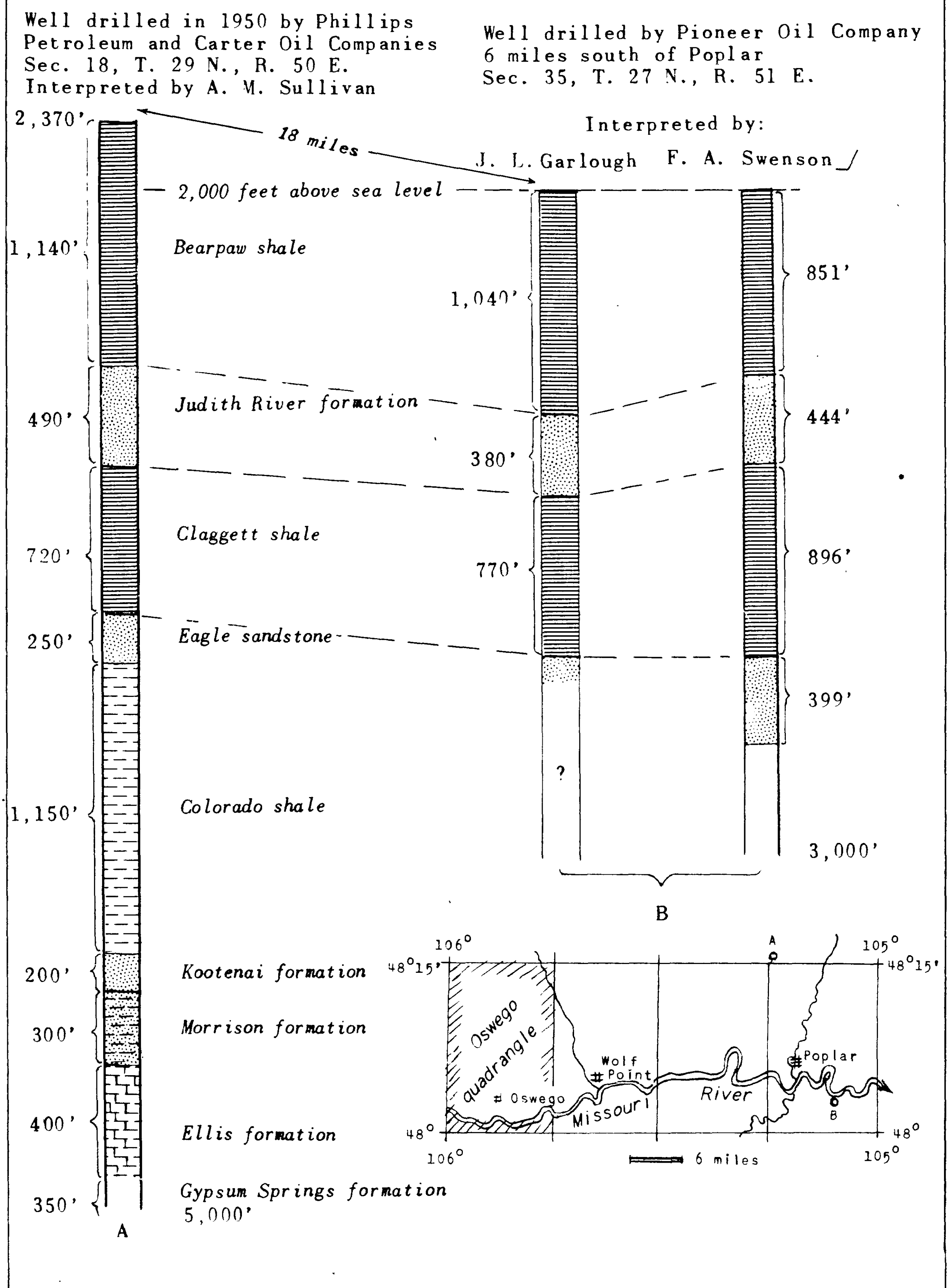
Mapping in the quadrangle was done during the summer of 1950. The geology was plotted on aerial photographs at a scale of 1:20,000 and transferred to a base map by vertical sketchmaster and Saltzman projector.

GENERAL GEOLOGY

Four bedrock units crop out in the quadrangle. The oldest is the Bearpaw shale, deposited during Upper Cretaceous time. Overlying the Bearpaw shale are about 50 feet of transitional silts that comprise the lower part of the Fox Hills sandstone (Upper Cretaceous) in this area; the upper part of the formation consists of 30 to 70 feet of sandstone. Unconformably overlying the Fox Hills sandstone is the Hell Creek formation (Upper Cretaceous). An erosional unconformity separates this formation from the overlying Flaxville gravels (Tertiary) of Miocene or Pliocene age.

No deep wells have been drilled in the quadrangle but 35 miles northeast of Oswego a test well was drilled during the summer of 1950 by the Carter Oil Company and the Phillips Petroleum Company (fig. 3). Another well was drilled by the Pioneer Oil and Gas Company 6 miles south of Poplar. Two different interpretations of the log of this well are shown in figure 3.

A number of gravel deposits younger than Flaxville gravels are covered by till of the Wisconsin stage of glaciation. They contain teeth of a mammoth identified as early Wisconsin. This till sheet covers most of the quadrangle except for the alluvial flat of the



Swenson, F. A., *Geology and Ground-water Resources of the Missouri River, 1950 (unpublished manuscript).*

Figure 3. Sketch showing well log interpretations and location of deep wells A and B drilled on the Poplar anticline.

Missouri River and the Flaxville plain.

Superglacial fluvio-lacustrine deposits consisting of silts and sands overlie the ground moraine in several areas bordering the alluvium of the floodplain. The melting of the ice on which these deposits were originally formed allowed them to collapse onto the underlying till. Only one kame was mapped. Scattered outwash deposits are found in glacial meltwater channels.

A large swale south of the Missouri River in the quadrangle is interpreted to be a former course of the Missouri River. Alluvial deposits in this older channel have been separated from the modern alluvial deposits on the basis of age and elevation. Modern alluvium fills a gorge about 140 feet deep which was probably excavated and filled a number of times and through which the present day Missouri River flows.

Colluvium is accumulating through the action of slopewash and creep adjacent to outcrops of bedrock and surficial deposits. Lacustrine materials are accumulating in closed depressions.

PHYSIOGRAPHY

The quadrangle may be divided into several physiographic areas (fig. 4). The highest and oldest area consists of remnants of the Flaxville plain in the northern part of the quadrangle at an elevation of about 2,700 feet. Several meltwater channels are incised into these remnants. One small driftless area is at the north edge of the area.

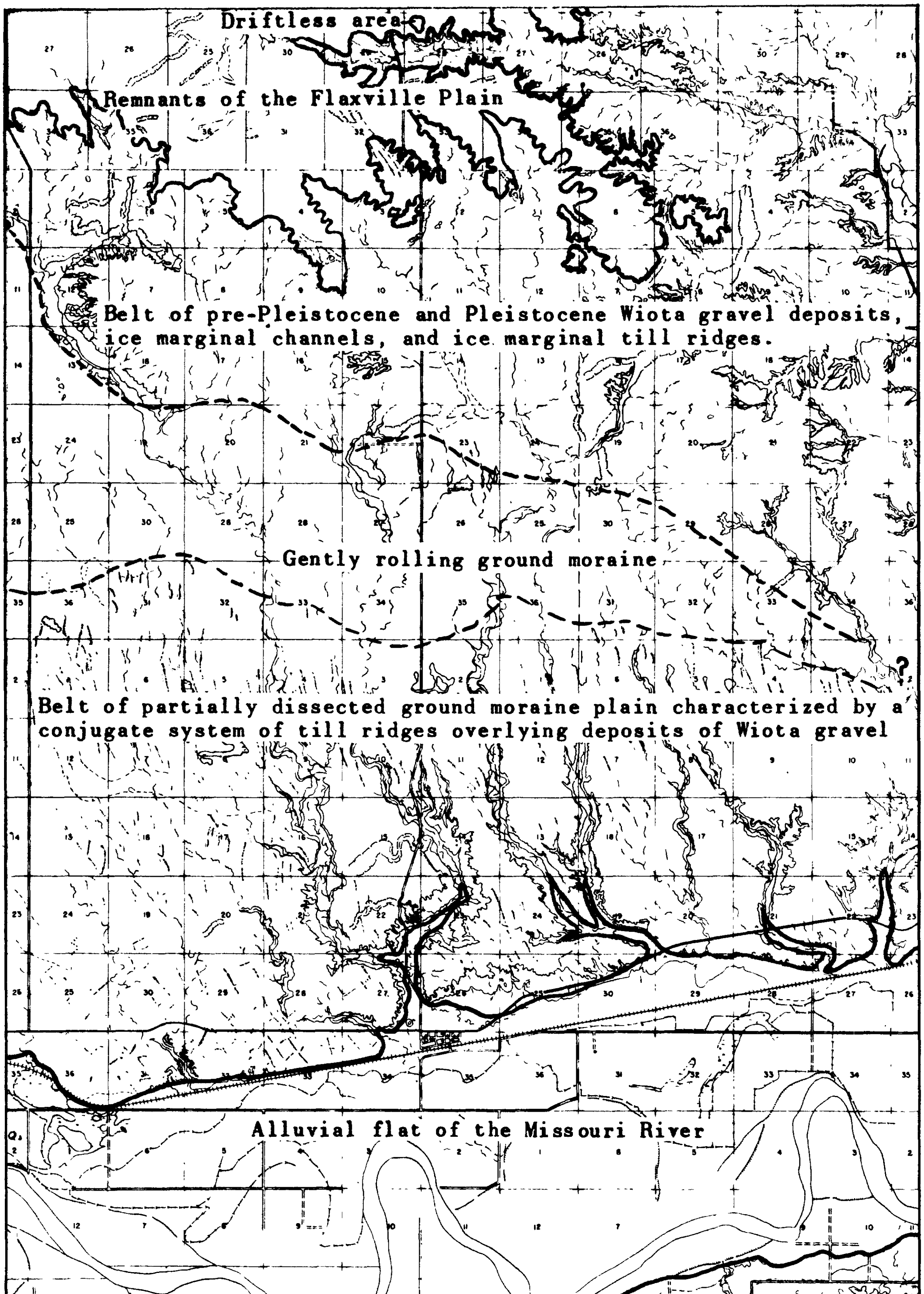


Figure 4. Sketch map showing physiographic areas in the quadrangle.

A 3-mile-wide belt of pre-Pleistocene and Pleistocene Wiota gravel deposits, ice marginal channels, and ice marginal till ridges border the Flaxville gravel remnants on the south and east.

To the south and at a lower altitude of 2,300 to 2,400 feet, there is a belt of gently rolling ground moraine. South of this, and extending to the edge of the alluvial flat, is a 4 to 7 mile wide belt of partially dissected ground moraine plain characterized by a conjugate system of till ridges oriented northwest-southeast and northeast-southwest.

The Missouri River floodplain is a three-mile-wide belt just north of the steep cliffs comprising the south valley wall of the Missouri River.

BEDROCK

Bearpaw shale (Kb)

Name and definition.--The Bearpaw shale of Upper Cretaceous age was first described by J. B. Hatcher and T. W. Stanton (1903) from exposures in the area east of the Bearpaw Mountains in Montana. It is the lowest unit of the Cretaceous that crops out in the quadrangle.

Relation to adjacent formation.--The Bearpaw shale overlies the Judith River sandstone and underlies the transition beds of the Fox Hills sandstone. It is equivalent to the upper part of the Pierre shale (Cockerell, T. D. A. preface by Stanton, T. W.).

Occurrence.--The shale is well exposed along Oswego Creek and in the bluffs south of the Missouri River. In the remaining till-covered southern two-thirds of the quadrangle are numerous small exposures.

Lithology and physical characteristics.--The formation consists of fissile, well-jointed, olive-gray marine shale containing numerous thin bentonite beds and concretionary zones. Most of the concretions are calcareous although some are limonitic.

Three concretionary zones are exposed within the quadrangle. The uppermost is calcareous and is about 40 feet below the Bearpaw shale-Fox Hills sandstone contact. Another calcareous zone, 50 feet thick, is approximately 200 feet below the first one; about 100 feet lower than the second zone is a third horizon of limonitic concretions.

The shale is nearly impervious and free water occurs only along main fracture planes; this water is highly mineralized.

Fresh shale has an approximate moisture content of 15 percent (Jensen 1951).

Excavations are easily made with power tools unless large calcareous concretions are abundant. Where fractured, the shale may be easily excavated, but cribbing, timbering, and other support may be necessary. Slumping on a large scale may occur. Slope stability is about 15 degrees (Jensen, F. S., 1951). Bentonite beds swell and flow when wet and may cause foundations to slip.

Wet Bearpaw shale is a very sticky slippery clay. All-weather roads cannot be constructed unless gravel surfaced.

Thickness.--The formation is approximately 1,000 feet thick in this part of Montana according to Collier and Knechtel (1939), but Jensen (1951) reports that it is about 1,100 feet thick.

Fossils.--Numerous marine fossils are present in the calcareous concretions. Numerous baculites and ammonites as well as crayfish were found.

Fox Hills sandstone (Kfh)

Name and definition.--Meek and Hayden (1861) named the Fox Hills sandstone of Upper Cretaceous age from Fox Ridge in northwestern Armstrong and southwestern Dewey Counties, South Dakota. The strata of Fox Hills age described in my report appear to be equivalent to the Colgate member of the Montana group.

Fossils--Only a few fossil pelecypods were found.

Relation to adjacent formation.--The Fox Hills sandstone-Bearpaw shale contact is transitional from shale to silts of the lower portion of the sandstone but there is a very sharp deeply channeled erosional contact with the overlying Hell Creek formation.

Occurrence.--Fox Hills strata are well exposed in the badlands and bluffs along the southern margin of the quadrangle south of the Missouri River; and a few small exposures are in the northern part of the quadrangle.

Lithology.--The formation in this area is composed of two units. The lower unit is a marine sequence which is transitional between the underlying Bearpaw shale and the upper Fox Hills sandstone member. It consists of thin-bedded well-laminated shale which, in the lower portion, differs only slightly from the Bearpaw shale although there is some difference in color which is more evident on the weathered surface.

The shale becomes increasingly silty and sandy upward. A concretionary sandstone which is probably the equivalent of the Colgate sandstone overlies this shale. The color is not white as is that of the Colgate sandstone but ranges from dark yellowish-brown or orange to light olive-gray.

The lower unit of the formation has low permeability whereas the upper unit is more porous. Wells drilled in this upper unit will probably strike water. Cementation is variable and there may be perched water tables.

Excavations by power tools can be made with ease in the soft uncemented sandstone but concretions may require blasting. The unconsolidated silts of the lower part of the formation erode easily and have low slope stability whereas the sandstone of the upper portion of the formation stands out locally in steep cliffs, especially where protected by sandstone concretionary layers. Inasmuch as the sandstone is fairly porous, surface and subsurface drainage is good. Permeability decreases sharply toward the base of the lower unit.

The following columnar sections indicate the character of the unit in this area:

COLUMNAR SECTIONS

Composite section near the intersection of sections 13, 18, 19, and 24, T. 26 N., R. 45 and 46 E.

Top of section	Feet
Hell Creek formation	
1. Sandstone, yellowish gray (5Y 7/2) Goddard, E.N., (1948) salt and pepper appearing sand, discontinuous lenses of gravel in lower few feet, pebbles are almost entirely concretion fragments 2 or 3 inches in diameter	15

Fox Hills sandstone

2.	Sand, thin bedded, few thin rusty-brown clay partings; at top is a half foot of thin-bedded hard dark yellowish orange siltstone.	9.0
3.	Clay, yellowish-gray (5Y 7/2) alternating gray to olive, intercalated tan to brown sandy lenses.	4.0
4.	Clay, fissile, brown to gray.	0.5
5.	Sand, light brown (5Y 6/2), very fine	1.5
6.	Clay, light olive-gray (5Y 5/2), fissile intercalated with very fine sand; beds 1 to 2 inches thick	3.0
7.	Sand, very fine	5.5
8.	Shale, thins laterally.	1.3
9.	Sand, yellowish gray (5Y 7/2), very fine clay partings in the middle of the bed	4.0
10.	Shale, dark yellowish brown (10 YR 3/2), fissile carbonaceous, contains plant fragments.	0.5
11.	Sand, massive, fine	4.0
12.	Sandstone, concretionary, calcareous.	2.5
13.	Sand, yellowish-gray (5Y 6/2), massive.	11.0
14.	Sand, light olive-gray (5Y 5/2), beds 2 feet thick, numerous silty clay beds or partings.	7.0
15.	Clay, light yellowish brown (10 YR 6/4), sandy, carbonaceous, shaly	0.9
16.	Sand, light dusky yellow (5Y 7/4), fine, massive.	5.5
17.	Sandstone, yellowish gray (5Y 8/1), concretionary	6.5
18.	Sand, dark yellowish gray (5Y 6/2), very fine	7.5

19. Claystone or sandy silt, olive gray (5Y 4/1) to light yellowish-brown (10YR 6/4). 16.5

Total 105.7

Composite section in section 20, T. 28 N., R. 47 E. (2.5 miles east of the Oswego quadrangle).

Top of section	Feet
Hell Creek formation	
1. Sandstone, buff, sugar and spice appearance, bone fragments, quartzite pebbles.	50 plus
Fox Hills sandstone	
1. Sandstone, yellowish, massive, comprises upper part of Fox Hills sandstone and probably equivalent to the Colgate sandstone member	35.6
2. Shale, very light gray, fissile, comprising the transition beds of the Fox Hills sandstone. About 33 feet above the base of this unit, the strata are very silty and little clay is present. About 38.5 feet above the base the unit is sandy. Forty-two feet above the base is a concretionary ledge of laminated sandstone about 1.5 feet thick which is yellowish-gray (5Y 8/1).	59.5
Bearpaw shale	
1. Shale, light olive-gray (5Y 5/1)	100.0
Total	245.0

Thickness.--Considerable erosion of Fox Hills strata occurred before deposition of the Hell Creek formation. The strata remaining range in thickness from 40 to 120 feet in this area.

Hell Creek formation (Khc)

Name and definition.--The name "Hell Creek formation" was given by Barnum Brown (1907) to a sequence of Upper Cretaceous strata typically exposed on Hell Creek in Garfield County, Montana. Thom and Dobbin (1924) modified Brown's limits of the formation to include the top 100 feet of strata that Brown had termed "lignitic beds" and had correctly classified as Fort Union in age.

Relation to adjacent formations.--In many places the Hell Creek formation is deeply channeled into the Fox Hills sandstone. Individual channels are usually 10 to 15 feet deep but channels over 50 feet deep have been observed.

The basal portion of the Hell Creek formation is conglomeratic, containing mud balls one foot in diameter, fragments of sandstone and limonite concretions, and sparse quartzite pebbles several inches in diameter (fig. 5). Bone fragments are found in the conglomerate.

Marked lithologic differences outline the contact between the Hell Creek formation and the underlying Fox Hills formation. The sandstone above the contact appears decidedly grayer than the strata immediately below the contact. The grain size of the basal sandstone of the Hell Creek formation is much larger than that of the Fox Hills sandstone.

Quartzite cobbles in basal conglomerate of Hell Creek formation overlying Fox Hills sandstone in NE$\frac{1}{4}$SW$\frac{1}{4}$, sec. 9, T. 26 N., R. 47 E., McCone County, Montana.

The sandstone above the contact appears to have a "salt and pepper" appearance. No quartzite pebbles are present below the base of the Hell Creek strata nor are dark minerals visually evident.

The formation in unconformably overlain by the Flaxville gravel.

Occurrence.--The most extensive exposures of the Hell Creek formation are in the bluffs south of the Missouri River and in the northern part of the quadrangle. Several small exposures occur along the upper reaches of the tributaries which flow into Wolf Creek in the eastern part of the quadrangle, especially where the Flaxville gravel forms a protecting cap rock.

Lithology.--The Hell Creek formation is a sequence of shales, siltstones, sandstones, and carbonaceous shales. The overall color is greenish-gray but shades of tan, dark brown, and gray are present. Because of its dull coloration, the formation has been referred to as the "somber beds".

Approximately 50 percent of the total thickness of the formation is sand or sandstone, with grain size ranging from medium to fine. There are abundant dark minerals and the sands markedly contrast with the underlying Fox Hills sandstone. About 30 to 40 percent of the total sequence of beds is shale.

There are two types of shale, bentonitic and carbonaceous. Bentonitic shales exhibit a characteristic spongy appearance caused by the swelling of the bentonite. The carbonaceous shales are brown, thin-bedded and fissile, consisting largely of macerated plant fragments.

The sandstone zones, especially those in the lower one-third of the formation, are generally water-bearing. They are a possible source of fine aggregate for concrete.

The following columnar section indicates the character of the Hell Creek strata:

COLUMNAR SECTIONS

Composite section of strata exposed along the east side of Wolf Creek in the northwest part of the Wolf Point quadrangle in the NE$\frac{1}{4}$SW$\frac{1}{4}$, sec. 35, T. 29 N., R. 46 E. and in sec. 20, T. 28 N., R. 46 E.

Top of section	Feet
Flaxville gravel	
1. Gravel, brown, quartzose.	17.5
Fort Union formation	
2. Clay, dark yellowish orange (10YR 6/6) Goddard, E. N., (1948) to pale yellowish gray (10YR 6/2), very silty, contains concretions, becomes increasingly darker upwards. Weathers to light dusky yellow (5Y 7/4)	19.0
3. Lignite and carbonaceous shale zone	5.5
4. Shale dark yellowish-brown (10YR 4/2) fissile, carbonaceous, very silty. Weathers to dark yellowish gray (5Y 6/2). Becomes sandy and concretionary both laterally and upwards	11.0
5. Lignite and carbonaceous shale zone. Fault has shifted this bed downward about 20 feet	10.0

Hell Creek formation

6. Claystone, light moderate yellowish-brown (10YR 6/4), becomes darker upward, sandy. Weathers to yellowish gray (5Y 7/2). Lenses of silty material are present. . . 22.0

7. Sandstone, dark grayish orange (10YR 6/4) which weathers dark yellowish gray (5Y 6/2). Contains numerous limonitic and sandstone concretions and scattered carbonaceous zones. 24.5

8. Claystone, light olive gray (5Y 5/2), very silty and bentonitic with numerous scattered sandstone concretions throughout (probably indicating former channels). Weathers yellowish gray (5Y 8/1). 16.5

9. Claystone, light olive gray (5Y 5/2), bentonitic, weathering to spongy dark yellowish gray (5Y 6/2) 12.4

10. Carbonaceous zone color 0.2

11. Clay, light olive-gray (5Y 5/2), bentonitic, silty. Weathered surface is spongy and dark yellowish gray (5Y 6/2). 10.0

12. Shale, grayish-brown (5YR 3/2), very carbonaceous, fossiliferous, weathers to medium brownish gray (5YR 5/1) 1.0

13. Sandstone, medium olive-gray (5Y 6/2) which weathers yellowish gray (5Y 7/2); characterized by fairly extensive horizon of highly crossbedded sandstone concretions toward the top. Top 2 feet clayey and somewhat bentonitic 13.9

14. Clay, pale yellowish brown (10YR 6/2), silty, fissile becomes increasingly carbonaceous toward top. Weathers to pale yellowish brown (10YR 6/2). . . . 1.5

15. Sandstone, moderate yellowish brown (10YR 5/4) which is limonitic and weathers medium dark yellowish gray (5Y 6/2) 6.0

16. Shale dark yellowish-brown (10YR 4/2), carbonaceous; numerous plant fossils. Weathers pale yellowish-brown (10YR 6/2) 1.8

17. Shale, medium yellowish-brown (10YR 5/2), silty to sandy 2.8

18. Shale, medium yellowish-brown (10YR 5/2), carbonaceous; numerous plant fossils; becomes lignitic locally. Weathers pale yellowish-brown (10YR 6/2) . . . 1.4

19. Shale, light olive-gray (5Y 5/2), fissile, non-silty. Weathers yellowish-gray (5Y 7/2). Grades laterally into medium yellowish-orange (10YR 7/6) sandstone. 2.0

20. Clay, light olive-gray (5Y 6/1), silty, somewhat bentonitic, in part carbonaceous, contains some plant fossils, slickensided; weathers yellowish-gray (5Y 5/1). 12.3

21. Sandstone, dusky yellow (5Y 6/4), silty, contains plant fossils, weathers yellowish gray (5Y 7/2). 5.5

22. Covered interval . . . . approximately 80.0

23. Sandstone, grayish orange (10YR 7/4), much crossbedded, has brownish "salt and pepper" appearance, contains lenses of conglomerate and sparse quartzite pebbles. (Exposed in sec. 20, T. 28 N., R. 46 E. 40.0

Total 316.8

Thickness.--The Hell Creek formation is approximately 300 feet thick in the adjacent Wolf Point quadrangle to the east. The full sequence of strata is not exposed anywhere in the Oswego quadrangle but is estimated to be about 200 feet thick.

Fossils.--Numerous dinosaur bone fragments, are scattered throughout the Hell Creek formation. These are common enough in some areas to be used as a criterion for differentiating the strata in which they are found from the Fox Hills sandstone below and the Fort Union formation above. There are also some zones where plant fragments are fairly common.

Flaxville gravel (Tfg)

Name and definition.--The Flaxville gravel was spread across northeastern Montana in Miocene and Pliocene time on a planation surface of slight relief. It was first described from exposures near the town of Flaxville, Montana, about 60 miles northeast of Oswego by Thom and Collier, (1918).

Age.--The age is thought to be Pliocene or Miocene by Gidley, Collier and Thom, (1918). Recent collections of fossils made by R. W. Brown and the author were identified by Louis Gazin of the U. S. Museum as probably early Pliocene but possibly very late Miocene. These fossils show signs of having been reworked.

Occurence.--The Flaxville gravel covers about 12 square miles in the northern part of the quadrangle. The average thickness of the strata is about 40 feet and the approximate volume of these deposits is 50 million cubic yards.

Lithology.--Fifty percent of the gravel consists of pebbles and fifty percent is sand. Collier and Thom, (1918) describe it as follows:

"The Flaxville gravel is composed of yellowish to ash-gray gravel, clay and sand, but in some places it contains beds of white marl and volcanic ash. The gravel consists of well rounded pebbles from less than one inch to a foot or more in diameter, of quartzite and argillite derived from the Rocky Mountains...The materials composing the Flaxville gravels are mostly noncoherent and are excavated easily by well diggers, though beds of hard sandstone and conglomerate cemented with calcite from one foot to several feet thick are encountered in most of the wells".

No clay was found in Flaxville gravel deposits in the quadrangle but otherwise the description matches. Green tinguaite porphyry pebbles are a distinctive component of the gravels. The Sweetgrass Hills in northwestern Montana have been tentatively identified as their place of origin. They definitely differ from the tinguaites in the Bearpaw Mountains in north central Montana.

The uncemented gravel is easily worked with hand and power tools and is a source of construction material. If it is crushed to provide numerous sharp angles, it will make good concrete aggregate. For foundations, the finer material may require control to give adequate compaction and drainage.

Thickness.--The gravel is estimated to be 150 feet thick in some areas but the maximum is 50 feet in the Oswego quadrangle and the average about 40 feet.

Relation to adjacent formations.--The Flaxville gravel lies on a relatively flat erosion surface with a regional southeastward dip of 6 to 10 feet per mile. Locally there are channels where the relief may be as high as 80 feet.

At one time the gravel was thinly covered by till but erosion has removed everything except a few erratics and small patches of till.

STRUCTURE

The structure of the bedrock is a south-eastward dipping homocline. The dip does not exceed 25 feet per mile and averages 20 feet per mile.

Faulting is indicated but cannot be demonstrated. A small outcrop of Fox Hills strata on the east side of Oswego Creek, half a mile north of Oswego, is apparently surrounded by Bearpaw shale. The surrounding Bearpaw shale is stratigraphically about 200 feet below the Fox Hills-Bearpaw shale contact. This wedge or block of Fox Hills strata may have been downfaulted at least 100 feet. Possibly, however, the strata were slumped downward on the Bearpaw shale at a time when the Missouri River was flowing 140 feet below its present floodplain.

In the southeastern part of T. 28 N., R. 46 E., the altitude of the Bearpaw shale-Fox Hills sandstone contact decreases sharply from west to east suggesting that a northeast-southwest trending fault may be present. No actual displacement was observed as the area is nearly completely covered with ground moraine and a minor flexure would adequately explain the decrease in altitude.

Wiota gravels (Qw)

Name and definition.--Gravels deposited later than the Flaxville gravel and earlier than the latest till have been designated by Jensen (1951) working in areas to the west, as Wiota gravels. There are two subdivisions of these gravels in the Oswego quadrangle. One appears to be preglacial and other interglacial. The preglacial gravels constitute three or four gently sloping till covered gravel benches, each about a square mile in area in the northern part of the quadrangle, (fig. 6).

The absence of erratics in these deposits is evidence for this age assumption. The possibility exists that all soluble erratics such as limestones and dolomites have been leached out but granitic or other igneous erratics should still be present. Also their topographic position suggests that they are preglacial. The highest gravel benches are at an altitude of 2,500 feet, about 100 feet lower than the lowest outcrop of the Flaxville gravel. From this bench, the gravel slopes toward the Missouri River (fig. 7) on a preglacial erosion surface formed at a time when the river was flowing at an altitude of about 2,300 feet. Most of this surface was covered by a sheet of gravel mostly removed by Pleistocene erosion.

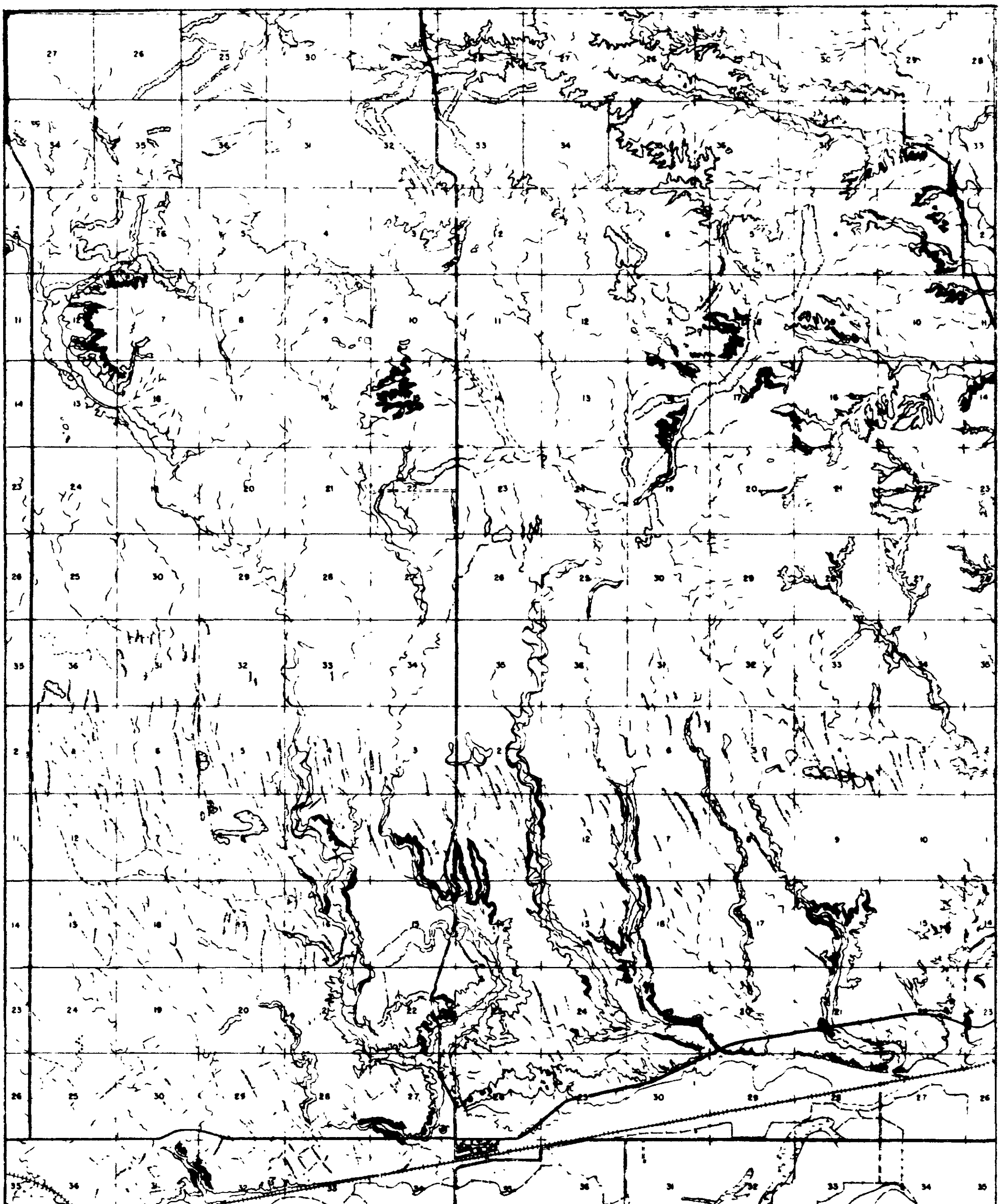


Figure 6. Sketch map showing location of outcrops of Wiota gravels in the Oswego quadrangle. Wiota gravels shown by solid pattern.

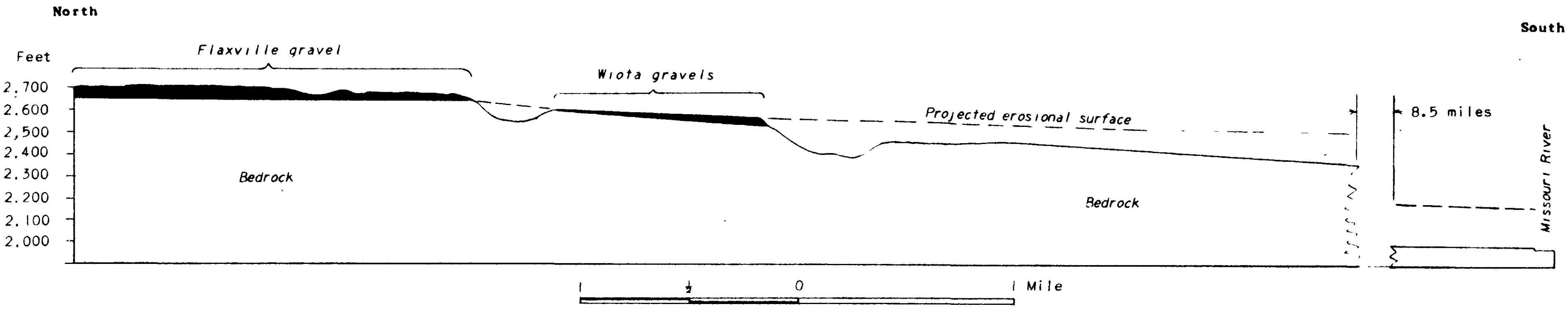


Figure 7. **Diagram showing relation to high-level Wiota gravels to Flaxville gravel and present slope of Missouri River valley wall.**

All the interglacial gravels are distinguished by the presence of glacial erratics. They are in drainage channels subsequently filled with till and re-excavated by Recent erosion to again expose the gravels. The presence of glacial erratics in these gravels which are overlain by till proves that there were at least two ice advances in the area.

Relation to adjacent formations.--Wiota gravels overlie rocks ranging in age from upper Cretaceous to Miocene or Pliocene. In the vicinity of Oswego they overlie Bearpaw shale and at higher altitudes to the north they overlie Fox Hills and Hell Creek strata.

Lithology.--The Wiota gravels, generally reddish-brown in color, vary laterally from deposits consisting entirely of sand to those containing coarse gravel with all gradations between. However, a few feet of silt and fine-to medium- grained sand usually forms the top of the deposit.

The preglacial gravels consist entirely of reworked Flaxville gravels. They are composed of gray, pink, green, and brown smooth, well-rounded, percussion-marked argillite and quartzite pebbles as much as 7 inches in length. A small percentage of pitted brown chert pebbles as much as three inches in diameter as well as sparse greenish tinguate porphyry pebbles from the Sweetgrass Hills may have been reworked from the Flaxville gravels. The tinguaite porphyry pebbles are more abundant in the glacial Wiota gravels than they are in the Flaxville gravels. This is especially true in the vicinity of Tiger Butte west of the quadrangle (fig. 8).

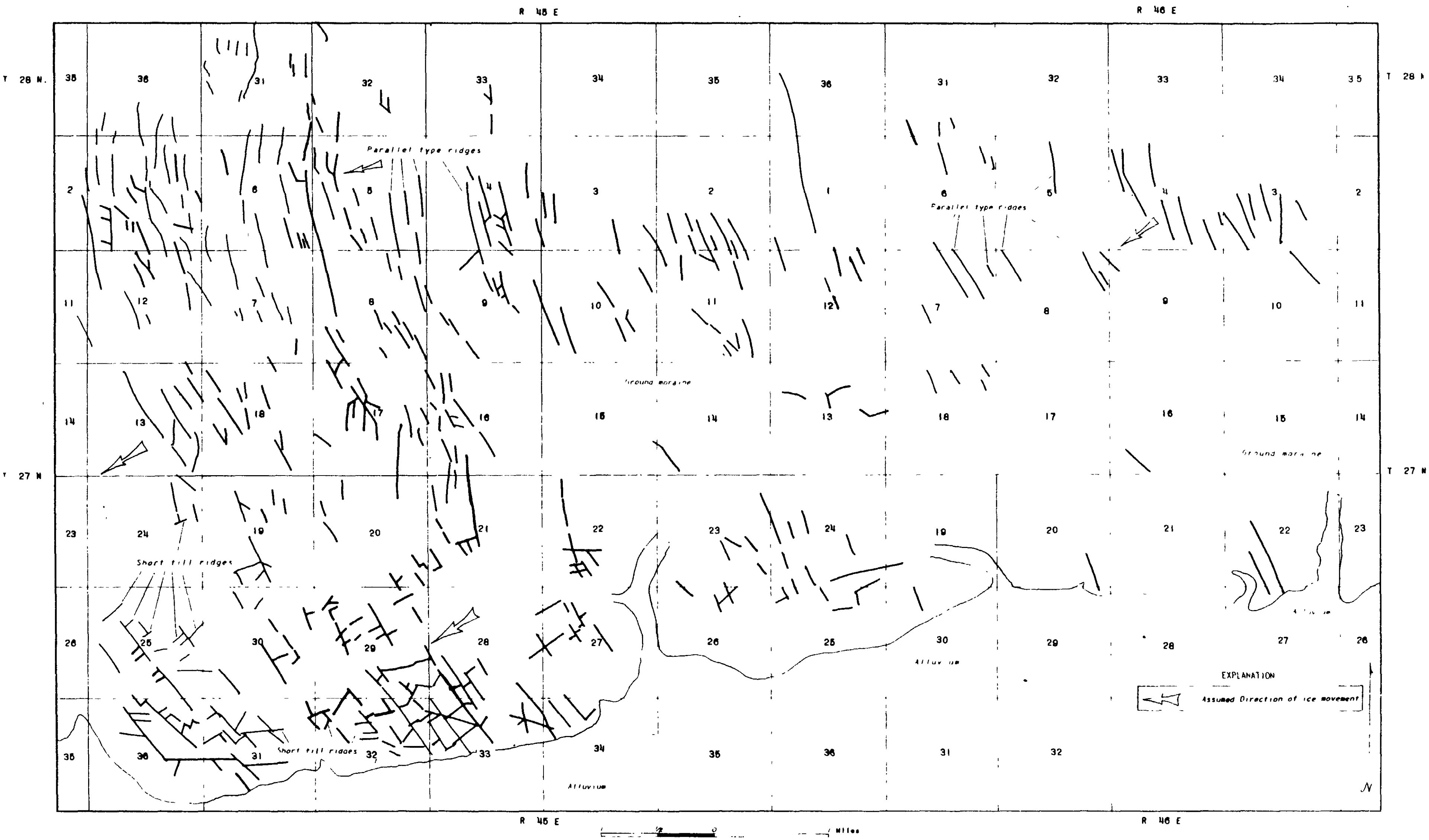


FIGURE 2 DIAGRAM SHOWING PATTERN OF TILL RIDGES IN OSWEGO QUADRANGLE

The interglacial gravels are similar to the preglacial gravels except that they include a small percentage of granitic, limestone, and dolomite erratic pebbles derived from Canada.

The Wiota gravels can be easily excavated by power tools and the overburden of till can usually be removed with little difficulty by a bulldozer.

Reservoirs lose their water if they are in Wiota gravels.

Thickness.--The gravels range in thickness from 1 to 25 feet but commonly are 10 to 15 feet thick.

Fossils.--Many bone fragments and a few mammoth teeth have been found in Wiota gravel pits. The mammoth teeth have been examined and are thought to be early Wisconsin in age.

Ground Moraine (Qgm)

Name and definition.--The ground moraine is a sheet of till 15 feet or more thick forming an undulating plain of gently sloping swells, sags, and closed depressions.

Occurrence and areal extent.--Most of the quadrangle is covered by ground moraine. South of the Missouri River only a very thin veneer covers some of the highlands. A blanket of ground moraine 15 feet thick covers the gently sloping surface which rises northward from the alluvial flat to the break in slope a mile south of the outcrop of the Flaxville gravel. Three or four long east-west till ridges mark the northern limit of the general sheet of ground moraine. Farther north there are small thin patches of till and only a few erratics.

Lithology.--There are two types of till: lodgement till which is very clayey, tough, and dense, and loose pebbly ablation till which was deposited in crevasses and also collapsed onto the lodgement till as the ice melted.

Till comprising the ground moraine is a tough, compact, plastic, highly impermeable, calcareous mixture that is predominantly clay but also contains sand, pebbles, cobbles, and boulders. The oxidized till present in most exposures is generally yellowish gray; unoxidized till is considerably darker. Thin lenses of sand and sandy gravel are locally intercalated within the till. Also locally, the ground moraine shows a vague-to-distinct horizontal layering indicating deposition by a plastering-on action of the ice. Vertical prismatic jointing is distinct in many of the larger exposures.

The till consists of approximately 65 percent clay, probably derived in great part from the Bearpaw shale; 25 percent sand, probably derived from the Hell Creek formation and Fort Union formation; 5 percent pebbles and cobbles which are 80 percent Flaxville and 20 percent glacial erratics; 3 percent boulders which are all glacial erratics, chiefly granites and gneisses; and 2 percent miscellaneous fragments.

Ground moraine is unconsolidated in fresh, damp exposures and can be easily worked with power tools, but as it dries it becomes a hard, tough, rock-like material. It has high slope stability when dry and stands in steep cliffs over 35 feet high. When wet, it tends to slump, and becomes very slippery. Roads constructed of till become impassable when wet.

Lenses of sand and gravel in the ground moraine yield some water.

Well compacted till has been used as a lining for irrigation and other types of canals.

There are many narrow ridges of till in the ground moraine in the area. They are 50 to 100 feet wide, 5 to 15 feet high, and vary in length from one-eighth of a mile to more than a mile in length. The longer ridges are parallel, 1,100 to 1,200 feet apart, and trend north-south but form an arcuate areal pattern which is convex westward (fig. 9). The ridges are of two types: a long parallel type and short intersecting cross ridges usually at a 45° angle to the longer ridges (fig. 9).

In the southern part of the quadrangle just north of the Missouri River floodplain, the till ridges have a geometric plan. This is probably the result of the development of a conjugate set of fractures in stagnant ice. Debris from the ice fell into the fractures and when the supporting ice melted, the material was left as till ridges.

This fracture pattern roughly indicates the direction of ice movement, the long parallel ridges being parallel to the ice front or normal to the direction of movement. This means that a lobe of ice moved across the quadrangle from east to west. This conclusion is supported by the presence of long discontinuous east-west ridges near the southern edge of the Flaxville plain in the northern part of the quadrangle. They mark the approximate northern edge of the lobe of ice. The numerous east-west ice marginal channel systems, the few erratics on the Flaxville plain, the small eroded patches of till on the Flaxville plain, the driftless area in the Todd Lakes and other quadrangles, the large ice-marginal channel on the south side of the river, and the general

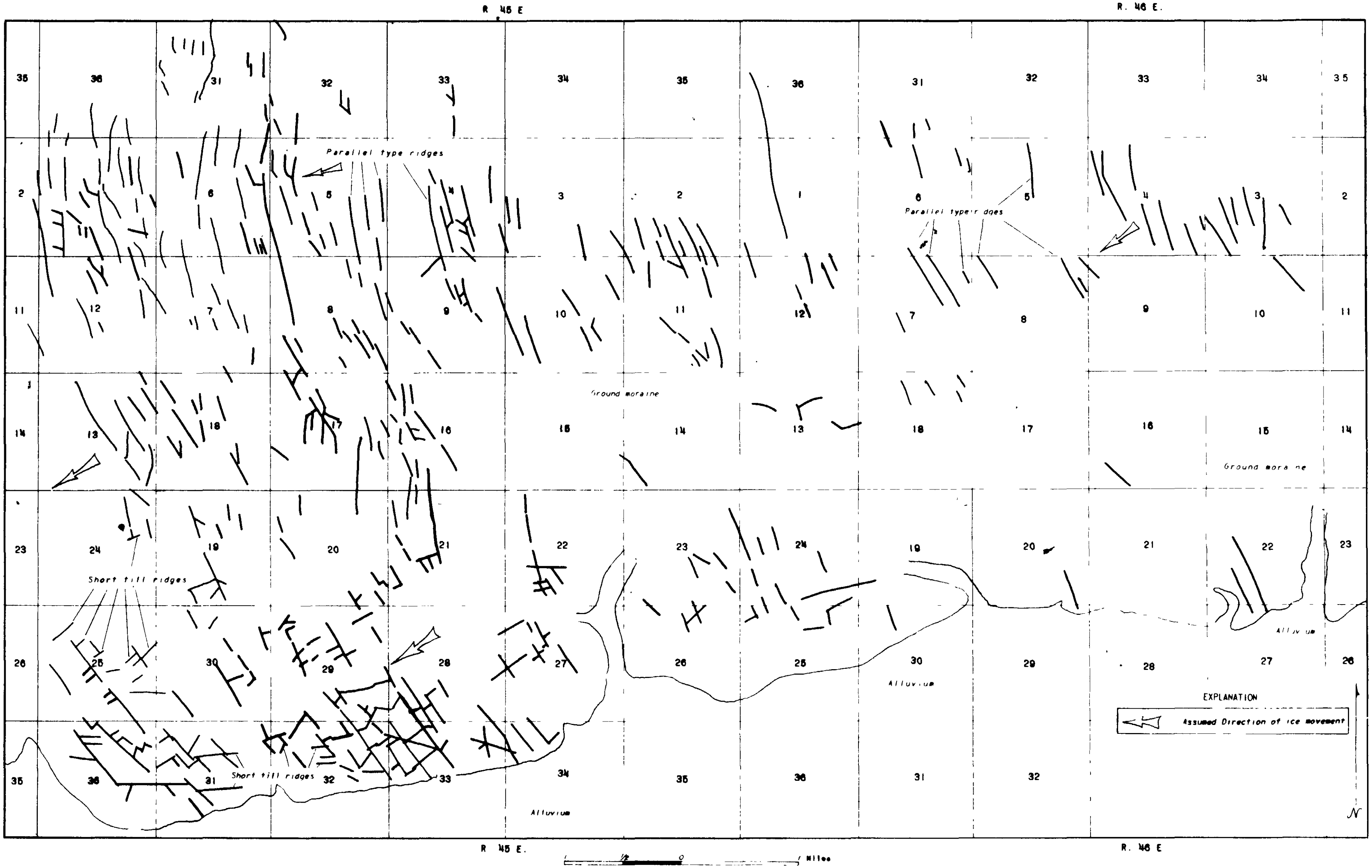


FIGURE 9 - DIAGRAM SHOWING PATTERN OF TILL RIDGES IN OSWEGO QUADRANGLE

distribution of the till sheet indicate the former existence of such a lobe of ice.

Thickness.--The average thickness of the till in the quadrangle is about 15 feet. Thicknesses, however, of slightly over 30 feet have been observed in several places and maximum estimated thicknesses are slightly in excess of 80 feet.

Age.--Early Wisconsin teeth of mammoths have been found in the Wiota gravel. Thus the overlying till was probably deposited during an advance of Carey(?) ice into the area.

Glacial Outwash Gravel Deposits (Qo)

A number of thin gravel deposits floor glacial meltwater channels and contain numerous erratics. Some of these channels coincide with modern drainage but the majority do not. Deposits are only a few feet thick and generally are not more than a hundred feet wide; some are as much as two miles long.

Outwash deposits that lie on the Flaxville gravel cannot be distinguished lithologically from the underlying gravel. Only the presence of an occassional erratic indicates that the deposit is gravel outwash. Outwash deposits on the Flaxville gravels have been included in calculations of the volume of the Flaxville gravels.

Super glacial Fluvio-lacustrine deposits (Qs)

Silts and sandy silts underlie about 2 square miles of area north of the Missouri River and adjacent to its floodplain in secs. 1 and 2, T. 26 N., R. 44 E. There are other smaller areas in the quadrangle underlain by these silts. The sediments, from which these deposits are believed to have been derived, were originally deposited on glacial ice that covered this area but upon the melting of the ice, the material collapsed into its present position. Part of the original sediments were deposited on the ice by slow flowing glacial meltwater. Locally, however, the meltwaters were ponded and lacustrine deposits were laid down. Thus the silts deposited in this manner are finely laminated whereas the deposits laid down by flowing water are somewhat coarser and less finely bedded. The collapsing of these beds has produced considerable folding and fracturing.

The topographic expression is one of low well-rounded mounds characterized by poorly- or nonintegrated drainage. There are numerous closed irregular-shaped depressions which locally, by their shape and rude lineation, may reflect the fracture patterns of the ice.

The age of the superglacial fluvio-lacustrine deposits is post-till and pre-alluvium as indicated by the fact that there are localities in the adjoining Frazer quadrangle to the west where the topography reflects the pattern of till ridges through the overlying silts that collapsed on the till (fig. 10).

Superglacial fluvio-lacustrine deposits have the following engineering characteristics: They may be worked with relative ease with both hand and power tools. When wet they become plastic due to their high clay content. Because of the general impermeability of the unit, it will be necessary to insure adequate surface drainage in any area of construction. Good compaction of the silt can be expected. Walls

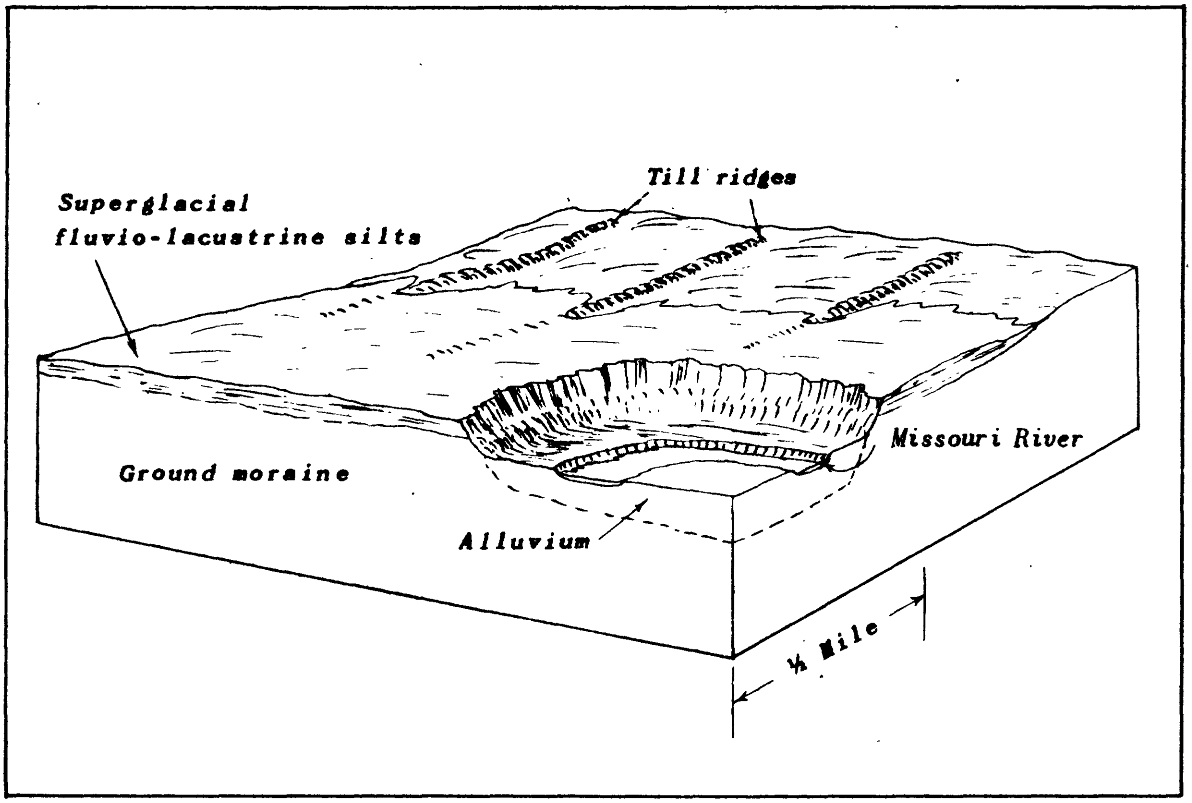


Figure 10. Idealized diagram showing relation of superglacial fluvio-lacustrine silts to ground moraine and alluvium of the Missouri River (from F. S. Jensen, Geology of the Frazer quadrangle, unpublished manuscript).

of excavations in this material will stand indefinitely during dry weather but will slump quickly during rainy weather. Slumping can be expected to occur along older fracture planes.

Maximum test figures obtained by the Montana State Highway Commission on minus 200 mesh fractions of samples were as follows: liquid limit 81.1, plastic index 54.1. Two other tests on other samples of these deposits showed liquid limits of 30 and plastic indices of 4 and 7 in the minus 200 mesh fractions. Approximately 25 percent of each sample of silt tested passed the minus 200 mesh.

Water derived from these silts is highly mineralized. Surface drainage is not well integrated and subsurface drainage is highly variable. Seepage losses are also highly variable.

Lake Clays (Ql)

Depressions in the till plain characterized by swell-and-swale topography, are partially or completely filled with a tough, plastic, relatively pure clay containing scattered pebbles. The deposits range in size from a few feet to half a mile in diameter. Thicknesses of over 6 feet are known. During wet seasons the depressions containing the clays become intermittent ponds and are impassable.

Alluvium (Qal)

Name and definition.--The Missouri River flood plain deposits cover approximately 45 square miles of the southern fourth of the quadrangle.

Lithology.--The deposits consist of fine sand, sandy silt, silty sand, and organic-rich clay. The alluvium is unconsolidated and generally permeable except where the clay content is high. Current or cross-bedding on a small scale is prevalent; little horizontal bedding is evident except where filled oxbow lakes are being eroded. Large scale channeling is evident in some river cutbanks but individual channels are not over 10 feet deep.

The following representative section was measured in the alluvium in a cutbank of the Missouri River immediately south of Oswego.

Top of section.	Feet
1. Clay, silty poorly stratified.	3.0
2. Silt	0.2
3. Clay, silty poorly stratified.	4.2
4. Sand, buff, fine grained	.05
5. Clay, dark gray, compact, poorly stratified, organic-rich	2.3
6. Sand and clay medium-grained, well stratified	0.8
7. Clay, dark blue, very silty, contains plant remains.	1.9
Bottom of section at river level Total	12.45 feet

The Bureau of Reclamation drilled a series of test holes in the Frazer and Nashua quadrangles. The alluvial fill was found to consist of (top to bottom) from 10 to 20 feet of silt, 10 to 20 feet of clayey or silty sand, 15 to 20 feet of clayey silt, and 10 to 20 feet of sand and gravel. Alluvial deposits contain many large lenticular bodies of gravel, sand, and silt. A typical drill hole is in the

Nashua quadrangle in sec. 36, T. 27 N., R. 42 E. The log shows that 7 feet of silt overlies 15 feet of loose sand which is underlain by 8 feet of clayey plastic silt. This silt overlies 14 feet of sand and gravel in which pebbles have a maximum diameter of one inch. The base of the sand and gravel rests on Bearpaw shale. A second drill hole 138 feet deep drilled to bedrock in the center of sec. 6, T. 26 N., R. 43 E. passed through 10 to 15 feet of sandy clay, 85 feet of clayey silty sand, and 40 feet of sand and gravel.

Thickness.--The thickness of the alluvial deposits in the quadrangle is nowhere exposed. The only data indicating the thickness of modern and older alluvial deposits come from well logs. Maximum depths to bedrock of 138 feet in the Nashua quadrangle and 134 feet at Blair were found in drill holes. Various wells in and around the cities of Wolf Point and Poplar have indicated over 100 feet of alluvial fill below the level of the present floodplain.

Drainage and permeability.--Abandoned meanders, former oxbow lakes, and other depressions are poorly drained or undrained. The ground water table is a few feet below the surface or at the surface in the vicinity of irrigated areas. The permeability ranges from high in sandy and gravelly portions to very low in silt and clay deposits.

Workability and compaction.--Alluvial deposits are generally saturated with water due to the high water table and therefore difficult to work. Good compaction can be achieved with good drainage.

Stability.--Saturated alluvial deposits have low stability and heavy losses of fill can be expected across swampy areas through lateral and vertical displacement of clayey alluvium. Sandy and gravelly alluvium makes relatively stable fill if well compacted and drained.

Colluvium (Qc)

The action of slopewash and creep on sloping surfaces produces gently sloping deposits of silts, silty clays, pebbly silts and clays, gravelly clays and gravels. The largest colluvial deposits have developed at the base of the steep cliffs of Fox Hills sandstone and Hell Creek formation along the south edge of the quadrangle. Here the deposits are made up almost entirely of silt and sand and have a maximum thickness of about 20 feet.

The composition of the colluvial deposits in the quadrangle varies considerably depending on the outcrop from which the material was derived. Colluvium near the town of Oswego is nearly 100 percent weathered flakes of Bearpaw shale. Where till is the parent material, the colluvium is a pebbly clay. Along the base of a Flaxville gravel outcrop, the colluvium is a poorly sorted slightly clayey sandy gravel. Where there are large outcrops of sandy strata of the Hell Creek formation, as in the northeastern corner of the quadrangle, the colluvium is nearly 100 percent sand.

Colluvium can be easily worked with power tools. Deposits derived from Fox Hills sandstone, Hell Creek formation, and Flaxville gravel are generally trafficable in wet weather; colluvium derived from till, Bearpaw shale and other clayey deposits is not.

Glaciation

The extensive till sheet which covers most of the quadrangle, numerous erratics, meltwater channels, eskers, kames, etc., indicate that the area has been glaciated at least once. No real evidence exists to prove that more than one glaciation occurred although such was probably the case. All till deposits and various other glacial features such as meltwater channels, till ridges, morainal deposits and various ice contact features could have been formed during one glaciation. The degree of weathering and dissection of the till deposits south of the river together with the thin cover of aeolian material suggest that they may be older than those north of the river.

Numerous north-south till ridges in the central portion of the quadrangle form a general arcuate pattern. These ridges were formed parallel to the retreating ice front and normal to the direction of ice movement (fig. 8). They are restricted to a belt several miles wide in the vicinity of Oswego which broadens eastward and becomes as much as 15 miles wide near Poplar. It is traceable northeastward to Medicine Lake and similar features occur as far northeast as Dagmar (fig. 11).

A lobe of ice flowed down the valley of Big Muddy Creek (fig. 8) until it was able to cover some of the higher Flaxville remnants in that area, moved into the Poplar valley, and filled it as it had Big Muddy Creek valley. The ice front then moved south into the Missouri River valley but was temporarily halted from further southward advance by the steep southern valley wall. It was thus forced to flow westward and fill the valley before it could surmount it. After doing that, the ice front moved south of the river for a distance of nearly 40 miles. The till ridges which indicate the direction of movement, were formed during the retreatal stages of ice movement. The presence of early Wisconsin mammoth teeth found in gravel deposits underlying the till and the presence of a Mankato(?) drift sheet in very northeastern Montana (fig. 8) indicate that the drift in the area is pre-Mankato and probably Carey(?).

Some lateral moraines in the northern portion of the quadrangle help confirm the above supposition. They are long east-west ridges of till about 100 to 200 feet below the edge of the Flaxville gravel generally normal to the slope.

At the northern edge of the quadrangle a high hill of cemented Flaxville gravel is about 50 feet higher than the surrounding Flaxville plain. Erratics are present on the lower slopes of the hill but none were found near the crest indicating that the upper part was never glaciated. However, the lack of erratics can possibly be explained in other ways. One is that the hill was glaciated but the erratics have all been removed by erosion or man. The second is that the hill was glaciated but no deposits resulted. That the hill was not glaciated but was a nunatak is a likely explanation for they are driftless areas less than 10 miles to the north at approximately the same elevation.

There is a driftless area in the Todd Lakes, Tule Valley, Hay Creek, and Spring Creek quadrangles (fig. 11). The Cottonwood Creek escarpment of the Flaxville plain has an elevation of 2,850 feet and has a relief above the valley to the north of over 400 feet. It

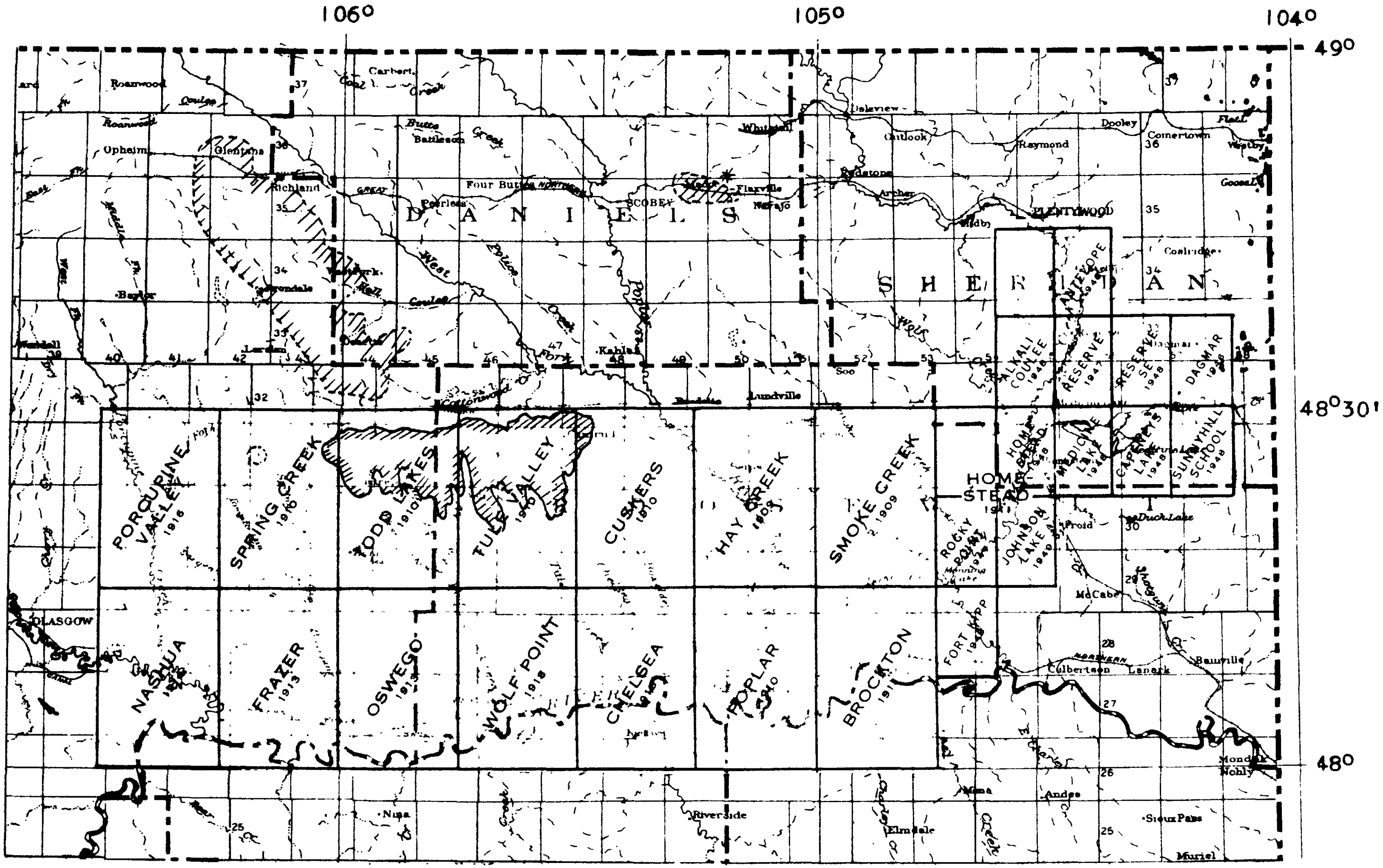


Figure 11. Sketch map showing location of Oswego and adjacent quadrangles and their relation the driftless areas. Dotted lines indicate approximate limits. *Reported by A. D. Howard.

presented a formidable obstacle to the advancing ice front and forced the ice to flow around these high areas. The highest the ice was able to advance in that area is marked by erratics and segments of ice marginal channels.

Meltwater channels.--Numerous channels and valleys open at both ends were used as meltwater channels when ice was in the immediate vicinity. Several are in the quadrangle and many more in the surrounding areas. The smaller ones are only 50 feet wide whereas the larger channels may be half a mile wide. All were essentially ice marginal channels and the majority are along what was the northern side of the ice lobe.

At least one meltwater channel in the quadrangle was buried under till. In the southern part of sec. 4, T. 27 N., R. 46 E. (fig. 12), is a depression a mile long and one quarter of a mile wide containing five small intermittent ponds reflecting this buried channel. These ponds are separated from each other by three till ridges which indicate they were formed after the buried channel.

Several changes in sea level occurred during the Pleistocene period. These changes were reflected in all major drainage systems by a lowering of baselevel in all watersheds, the Missouri River being a typical example. Drill holes in the alluvial fill indicate that it is 138 feet deep and the Missouri River once flowed that much lower than the present flood plain. Filling occurred at least once since the river flowed at the lower level.

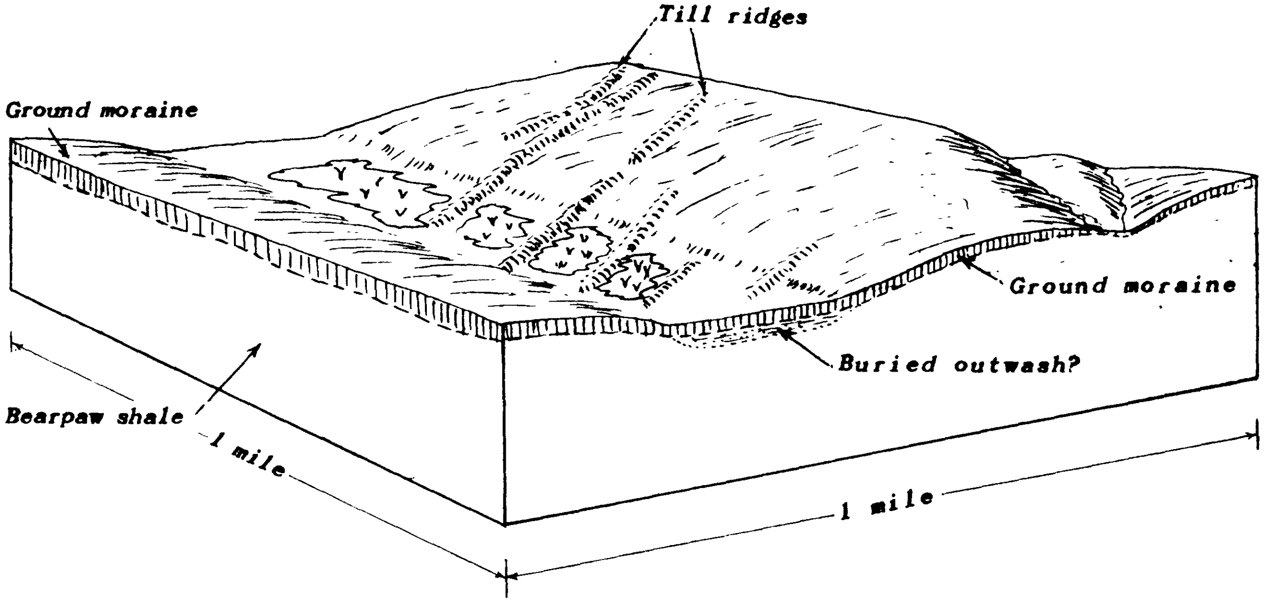


Figure 12. Diagram showing segment of buried channel in section 4, T. 27 N., R. 46 E.

ECONOMIC GEOLOGY

Sand and gravel deposits

There are extensive deposits of sand and gravel in the quadrangle. Wiota gravels have been exploited along U. S. Highway No. 2. These are overlain by dense clayey till. Where this overburden is more than 10 feet thick, it becomes a limiting factor in the amount of gravel that can be removed. There are many small deposits of Wiota gravel (fig. 7). No accurate estimate can be made of such reserves as their continuity is unpredictable. Probably the total Wiota gravel reserves total well over 1,000,000 cubic yards.

Gravel deposits are nearly nonexistent on the south side of the river. The only one of any importance is in sec. 14, T. 26 N., R. 46 E. and consists of limonite concretion fragments.

Remnants of the Flaxville plain are the largest and most important gravel deposits in the quadrangle. A sheet of quartzose sand and gravel 40 feet thick covers about 15 square miles. There are over 400,000,000 cubic yards of gravel in these deposits. Virtually no overburden is present.

Outwash deposits are a minor gravel source; the total reserves are more than 100,000 cubic yards. Extensive outwash deposits overlie Flaxville gravel but inasmuch as there is only a minor lithologic difference between the two gravels, these deposits are included with the Flaxville gravel reserves.

The basal portion of the Hell Creek formation consists of a fairly coarse sand which could be used as fine aggregate.

Some sand and gravel may be found in local lenses in alluvium.

Oil and Gas possibilities

No favorable surface structures were discovered during mapping. No drilling has been attempted but one dry hole was abandoned four miles east of the quadrangle. Other dry holes (fig. 3), have been drilled on the Poplar anticline, a low dome 30 miles east of the quadrangle.

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