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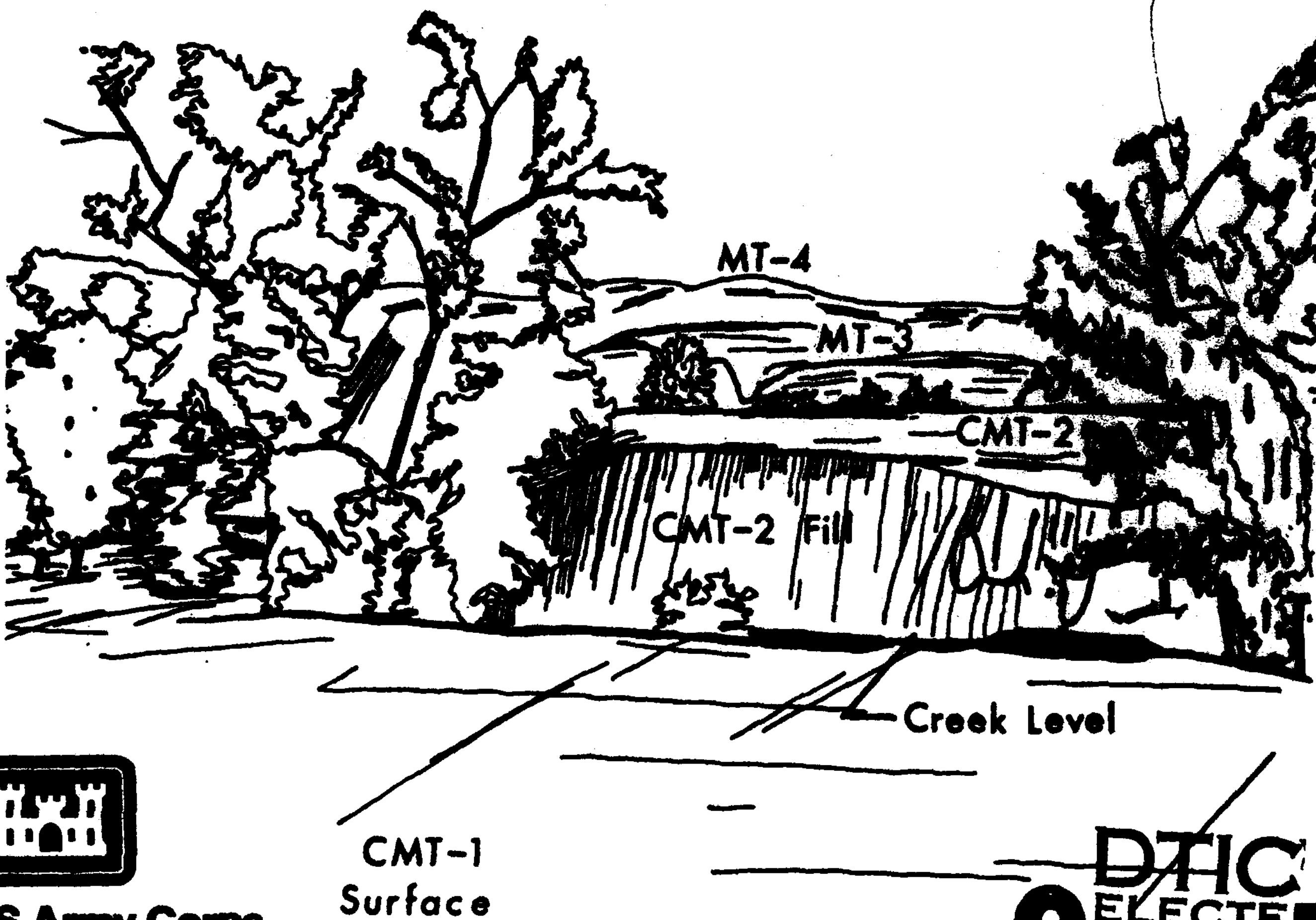
HOLOCENE GEOMORPHIC AND STRATIGRAPHIC FRAMEWORK OF ARCHEOLOGICAL SITES ALONG THE MISSOURI RIVER, CENTRAL SOUTH DAKOTA



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Sedimentation model	Archaic	Paleosols

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report summarizes the depositional and erosional history of the late Wisconsin and Holocene strata of the Missouri River Trench in South Dakota. It also proposes a model of sedimentation and erosion based on a modification of the work of Clayton et al. (1976). Finally, it relates the new model to the interpretation of archeological sites in the Big Bend Reservoir, South Dakota.

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The concepts adopted here are based on the work of Clayton et al. (1970) in North Dakota as applied, tested and modified in the Lake Sharpe, South Dakota area using detailed analysis of various geologic and archeological sites.

In the revised model emphasis is put on the erosional surfaces which separate depositional units of the Holocene strata rather than on the sedimentary units themselves. These erosional surfaces and their related paleosols provide a practical means of separating and identifying time-stratigraphic depositional intervals in the Holocene section which in archeological terms contain cultural levels which range from Paleoindian to Plains Village.

HOLOCENE GEOMORPHIC AND STRATIGRAPHIC FRAMEWORK OF ARCHEOLOGICAL SITES ALONG THE MISSOURI RIVER, CENTRAL SOUTH DAKOTA

by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

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This report summarizes the depositional and erosional history of the late Wisconsin and Holocene strata of the Missouri River Trench in South Dakota. It also proposes a model of sedimentation and erosion based on a modification of the work of Clayton et al. (1976). Finally, it relates the new model to the interpretation of archeological sites in the Big Bend Reservoir, South Dakota.

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INTRODUCTION

Background

The general geologic framework of the Late Pleistocene and Holocene summarized in this report is based on approximately three months field work in central South Dakota in support of two contracts to the Division of Archeological Research, Department of Anthropology, University of Nebraska, Lincoln carried out under the direction of Mr. Carl Falk, the Director. In addition, use was made of previously published work on the late glacial and Holocene history of central and eastern South Dakota and south-central North Dakota. Subsequent work in North Dakota in cooperation with the Department of Anthrolopology, University of North Dakota, in particular with Dr. Stanley Ahler and Mr. Dennis Toom aided in the interpretation. The approach was tested on the Mondrian Tree Site (32MZ58) in North Dakota (Coogan, 1983).

This report summarizes the geologic setting of the Holocene strata in the Lake Sharpe area, South Dakota. Lake Sharpe extends along the Missouri River approximately from Fort Thompson to Pierre, South Dakota. Reference is also made to areas of critical importance for interpretation both north and south of the area of focus including areas in the Oahe Reservoir near Mobridge and Pollock, South Dakota and near Yankton, South Dakota (Figures 1, 2).

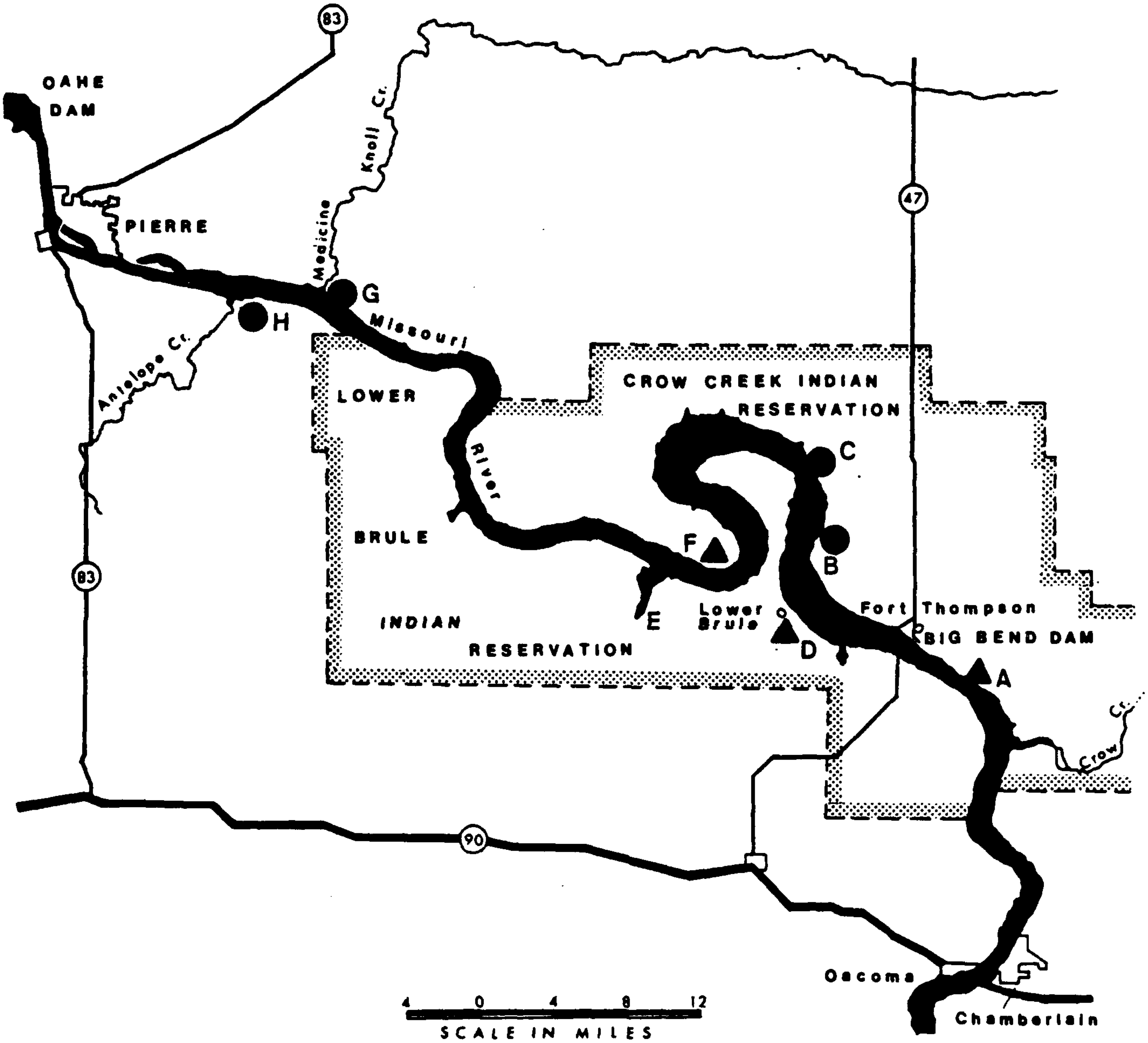
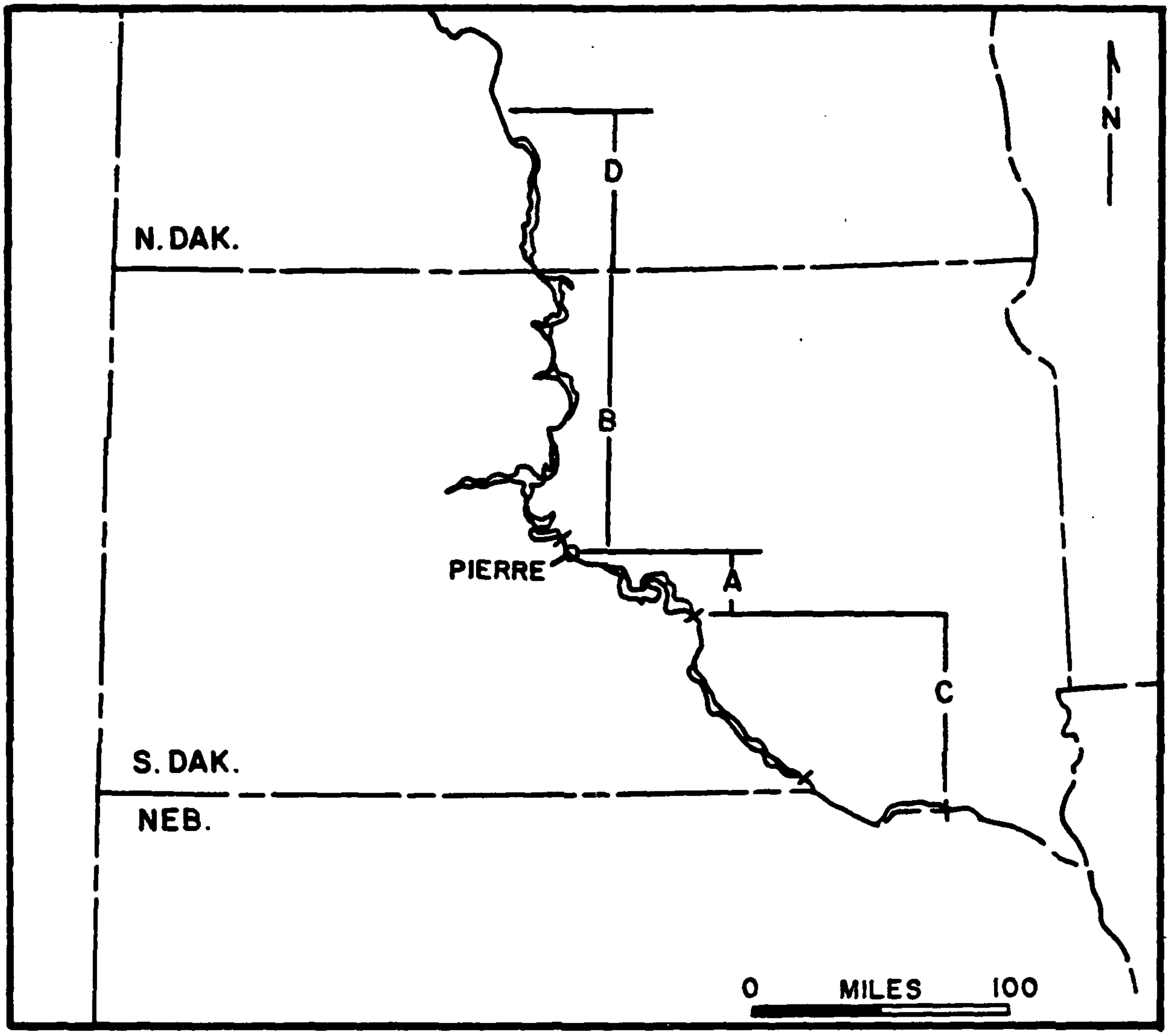


Figure 1. Map of central South Dakota, Big Bend Reservoir Area, showing the location of key sections and localities discussed in this report. Circles indicate a described site or section. Triangles indicate location of the type section of a designated terrace: A=Crow/Wolf Creek; B=Rattlesnake; C="Erosional"; D=Lower Brule; E=Joe Creek; F=West Bend; G=Rousseau and Medicine Knoll Creek; H=Antelope Creek.



LOCATION MAP

Figure 2. Map of South Dakota showing the broad area of geological investigation on which this report is based. A=Big Bend Reservoir area of extensive field work, mapping and site investigation. B=Oahe Reservoir area of extensive field work, some basic mapping and site investigations. C=area of geological reconnaisance in support of Big Bend field work and interpretation. D= area of geological reconnaisance in support of Oahe Reservoir work.

Terrace Sequence in the Missouri River Trench

The Missouri River Trench is a major physiographic feature of central South Dakota. It is incised into the uplands which are called the Coteau du Missouri and Coteau du Prairie. Within the trench, one sees a series of steps or levels, not everywhere present, which have been recognized by early travelers and all geologists who have described the area in recent times (Crandell, 1953; Flint, 1955; Rockroth, 1944; Warren and Crandell, 1952; Coogan and Irving, 1959, Clayton et al., 1976 and Coogan, 1983). At the present time, five recognizeable surfaces are mapped in the stretch between Fort Thompson and Pierre, South Dakota (Figure 3). Following the convention introduced by Coogan and Irving (1959), the terraces are sequentially numbered from zero upward and lettered "M" (=Missouri) and "T" (=Terrace).

MT-0 is the flood plain terrace of the modern river. It can be seen just south of the Oahe Dam near Pierre and just south of the Fort Thompson Dam (Figures 4-6). MT-1 lies at about 35 feet (11 m) above the river at Crow Creek, south of Fort Thompson and was exposed at Lower Brule in the 1950's before the dam at Fort Thompson was completed. MT-2 is about 100 feet (33 m) above the river. It is broadly developed at the present site of Fort Thompson (Figures 4-6) at an elevation of about 1,420-1,460 feet. MT-3 occurs at about 200 feet (65 m) above the river. It is easily seen on the north side of the Big Bend Reservoir of the Missouri River in southern Hughes County at an elevation of about 1,510-1,540 feet (Figure 7). MT-4, or the lower slopes of the Coteau du Missouri, is seen east of Joe Creek in Hughes County, South Dakota (Figure 7).

Each of the terraces, except MT-0, has a stratigraphy which in general consists of four major units. The base (1) is the bedrock Cretaceous Pierre Shale into which the Missouri River cut its trench. Overlying the Pierre Shale one commonly sees (2) gravel and then (3) sand deposits which are capped by (4) eolian silt. The silt, if present, may contain dark humic bands (reminants of paleosols). Occasionally, one may see similar features in sand. The stratigraphy of the terraces is extremely complex; nevertheless, progress has been made in recent years (Clayton et al., 1976 and this report) in understanding the processes which locally caused the development of the terraces and of the silt and sand which covers the terrace surfaces and which contain Holocene cultural materials.

Archeological remains have been found in the silt cap, on gravel or sand surfaces and on the present ground surface. The geologic task in support of archeological research is to unravel the Late Pleistocene and Holocene history of the terrace cuts, fills and surfaces, to determine the relationship between the terrace fills to Pleistocene and Holocene events and to provide a framework for time-stratigraphic dating of the archeological sites.

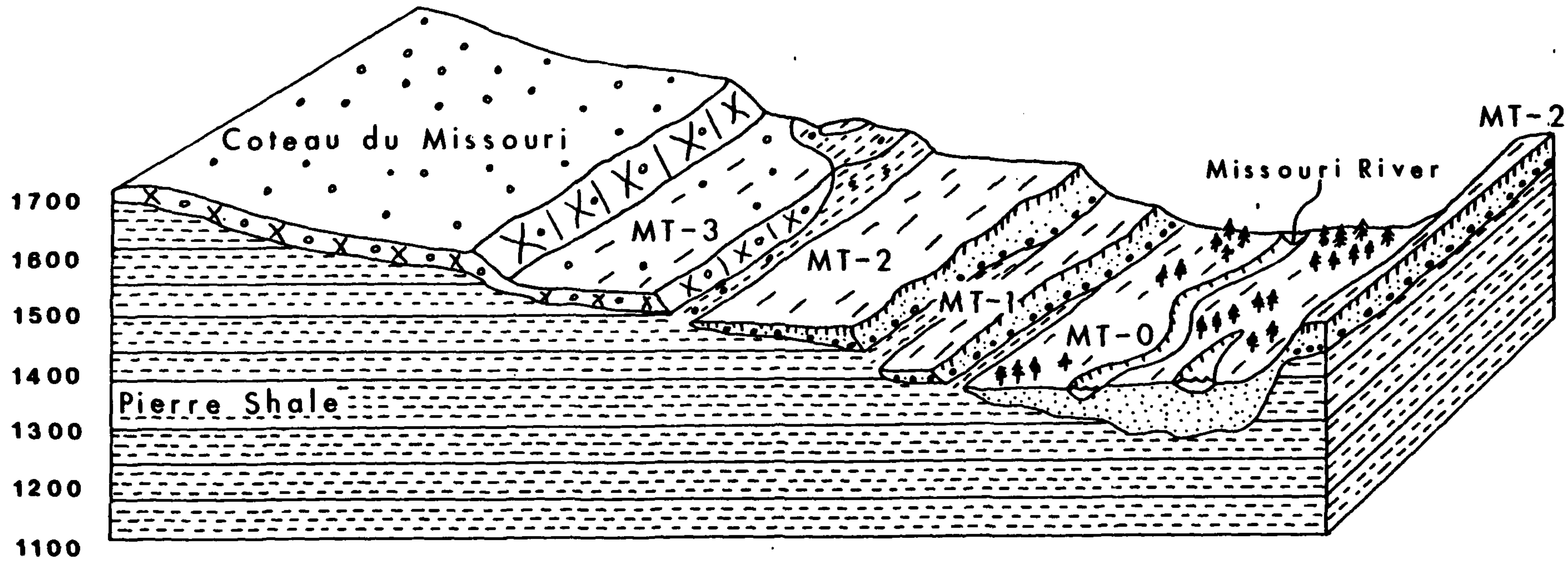


Figure 3. Terraces of the Missouri River Trench mapped between Fort Thompson and Pierre, South Dakota. Approximate elevations of the terraces are shown from the scale on the left. The Coteau du Missouri and MT-4 (not labelled) grade one into another. The terrace fills are generalized as sand and gravel (dots and circles) and silt cap (short vertical lines). The bedrock Cretaceous Pierre Shale underlies the terrace fills everywhere and may crop out at any level.

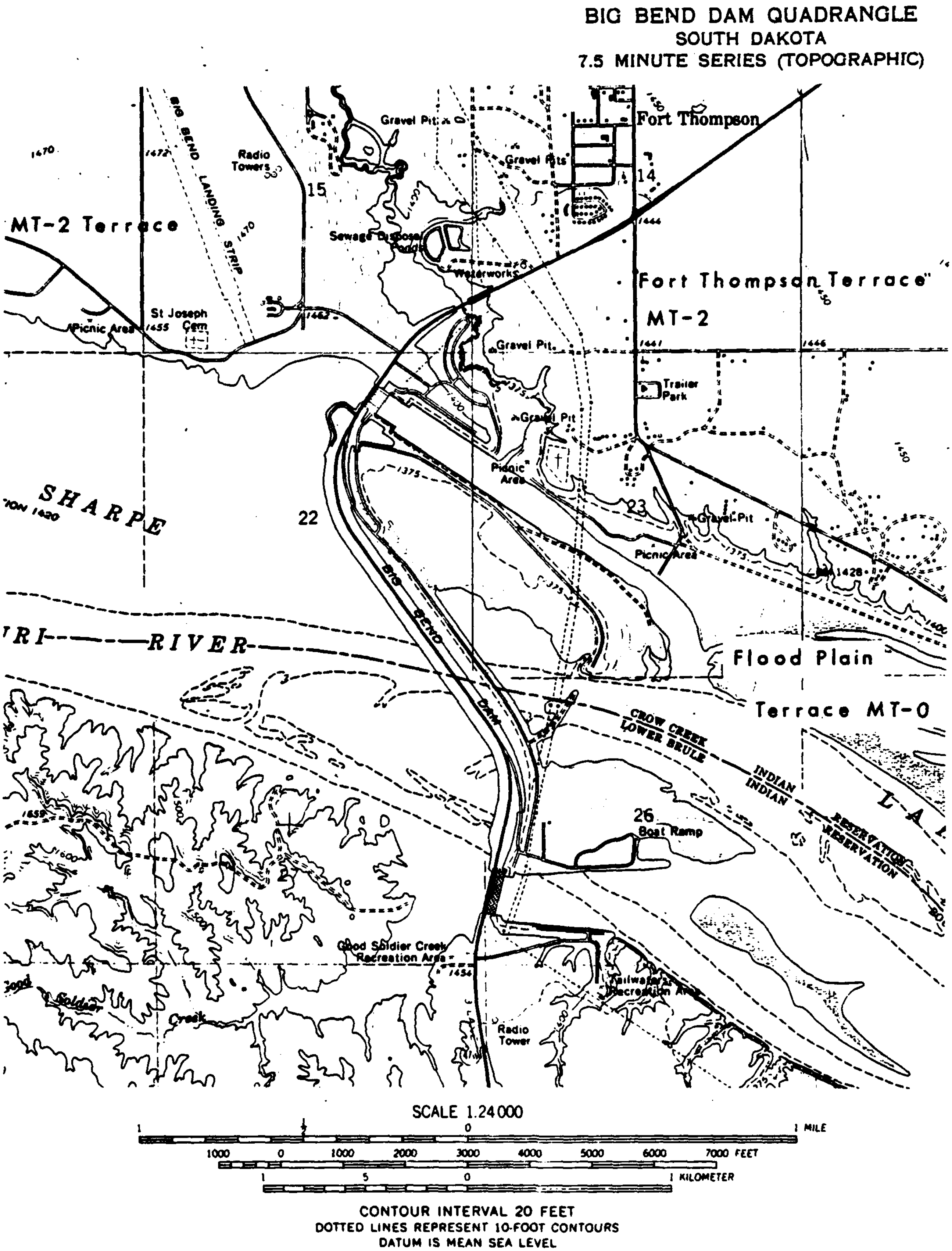


Figure 4. Portion of the Big Bend Dam Quadrangle (U.S.G.S., 7.5 min. topographic) showing the designation of the flood plain terrace (MT-0) and the Fort Thompson Terrace of Rockroth (1944) (MT-2), near the site of the Big Bend Dam.

Figure 5. Oblique aerial photograph, view to the north, of the tail race of the Big Bend Dam, lying on MT-0 below the MT-2 terrace. Soldier Creek is outlined by a dark string of trees. The community of Fort Thompson, S. D. is upper left.

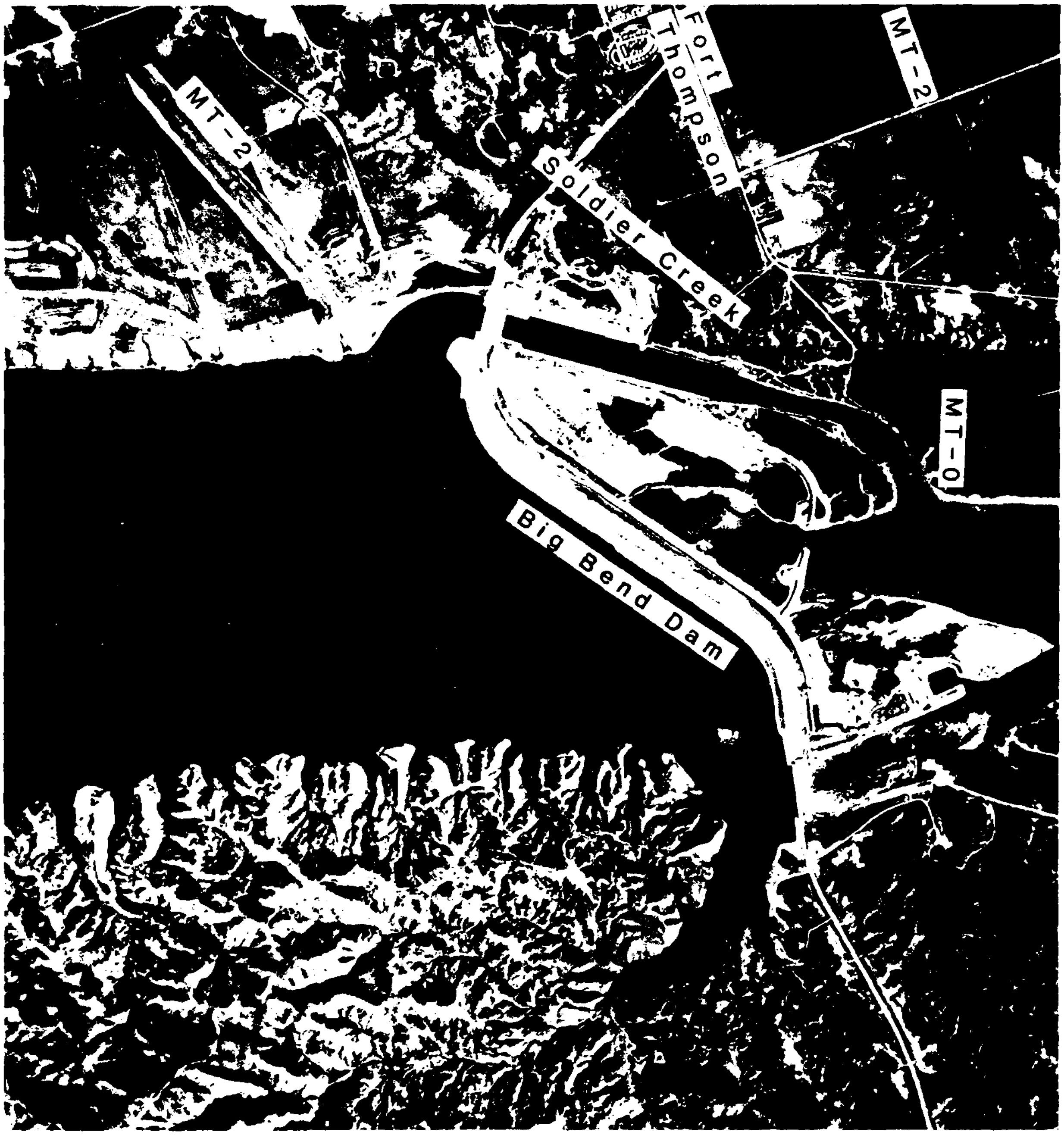
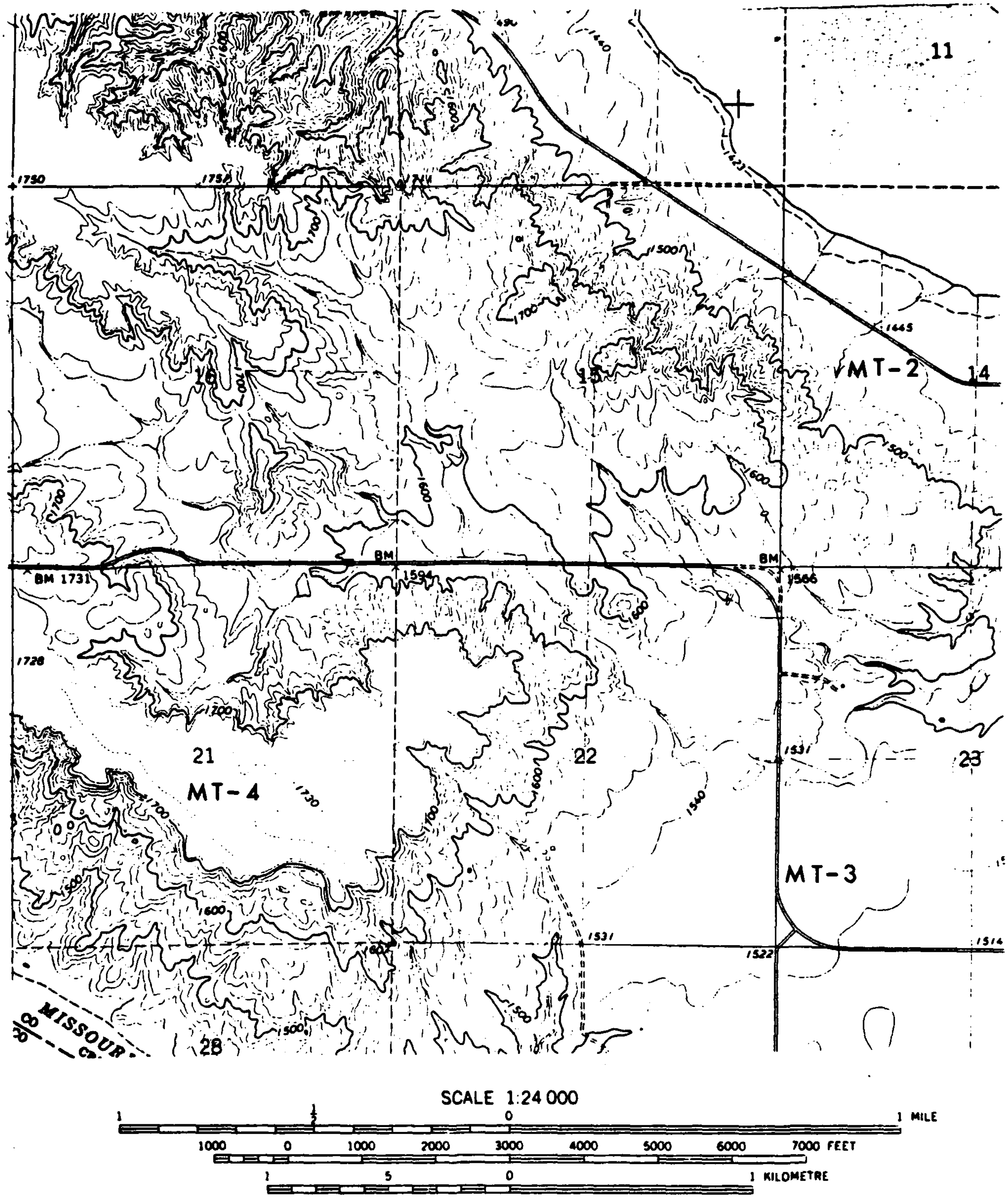


Figure 6. Vertical aerial photograph of the area surrounding the Big Bend Dam, on the Missouri River, Fort Thompson, South Dakota showing Mt-2, Mt-0, the dam, Fort Thompson, Soldier Creek and the west bank. Photoscale approximately 1:24,000.

LOWER BRULE NE QUADRANGLE
SOUTH DAKOTA
7.5 MINUTE SERIES (TOPOGRAPHIC)



CONTOUR INTERVAL 20 FEET
DOTTED LINES REPRESENT 10-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Figure 7. Portion of the Lower Brule, N.W. Quadrangle (U.S.G.S. 7.5 min. topographic) showing the terrace levels MT-2, MT-3 and MT-4. The latter two terraces are defined by the surfaces shown on this map.

History of Geological Ideas Regarding Terrace Formation

Flint's Work.-

Although Rothrock (1944) described the location and gross lithology of many of the terraces along the Missouri River, it was Flint (1955) and his students (Crandell, 1953; Warren and Crandell, 1952) who attempted to explain the geologic history of the Missouri River terrace sequence. Basically, Flint (1955) recognized various terraces and correlated them to various Wisconsin glacial stages by tying terrace gravel trains eastward from the Missouri River trench to the end moraines on the Coteau in eastern South Dakota. The correlations did not include terraces along the whole course of the trench in the Big Bend Reservoir. Instead, reconnaissance of the trench was supplemented by detailed mapping in and around Chamberlain and Pierre, South Dakota. Flint (1955), and his students in unpublished studies, essentially correlated MT-1 with the Mankato glacial event. MT-2 was called Cary and MT-3 was called Tazewell. The cutting and filling of each terrace was attributed to an episode of glacial activity and deposition of outwash which generally consisted of glacially transported sands and gravels. Each terrace, at progressively lower levels in the trench, presumably represented a downcutting of the river during an interglacial or interstadial period.

The soil stabilization horizons in the silt cap on the terraces (the paleosols) were in turn correlated with the Wisconsin interglacial or interstadial episodes. The result of this interpretation, quite simply, was that each terrace was seen to be the result of outwash from a particular ice sheet which stood near the Missouri River Trench during the Wisconsin glacials. The soil stabilization horizons were seen to represent soil formation related to each terrace. Consequently, all but the highest or uppermost of these soil horizons or dark humic bands were thought to be Pleistocene. Accordingly, the higher (and older) terraces should have more soil horizons (humic bands) than the lower (and younger) ones. This approach is evident from the descriptons of profiles recorded by Flint (1955). Flint stated that it was not possible to map the terraces along the river. This was probably true at the time because the contour interval of maps available to him was simply too great to permit one to distinguish the levels now recognizable on 7.5 minute quadrangle sheets. Because the terraces were not mapped, Flint did not realize that the terrace levels distinguished and named at Chamberlain were not correctly correlated to those named at Pierre.

Coogan & Irving's Work.-

In the late 1950's, as part of an archeological survey conducted by the Smithsonian Institution, Coogan and Irving (1959) restudied the terrace sequence described by Flint between Chamberlain and Lower Brule. They partly accepted Flint's designations and correlations of the terraces to glacial events.

They also designated reference sections for MT-2 at Crow/Wolf Creeks in Buffalo County (Figure 8, Table 1) and for MT-1 near Lower Brule in Lyman County (Figure 9, Table 2). The "M" and "T" terminology was introduced to avoid a forced mental correlation of terrace levels with glacial/interglacial events. In addition, they recognized that the soil stabilization horizons (humic bands) in the silt cap could not be as old as previously thought because artifacts found associated with the upper horizons were no older than 1,000 years.

In the late 1950's, it was thought that the soil stabilization periods were attributable to wet intervals which were coincident with the downcutting of the Missouri River in its trench. The occurrence of the silt cap without soil horizons (humic bands) was thought to represent intervening, dry "sterile" periods during which substantial silt was deposited by winds blowing off the flood plain of the Missouri River, as Clayton et al. also subsequently asserted.

Consequently, as in Flint's scheme, Coogan and Irving thought that older terraces should have more soil stabilization horizons than younger terraces and that some of these, the older ones must be as old as Pleistocene. The total lack of soil horizons at a given locality was seen as the result of varying rates of deposition and erosion, for example, as seen in many profiles including those of the Medicine Crow Site (39BF2).

In addition, Coogan (1960) recognized that the river terraces had correlative creek terraces which were graded to the main river terraces. The creek terraces extended up the creeks to higher and higher elevations. This observation was especially true for the creek terraces associated with MT-2. The observation provided a means of recognizing the MT-2 level along the river trench where there were several intervening miles between terrace reminants. This approach is still important in terrace identification.

<u>Clayton et al.'s Work</u>.-

Nearly twenty years later, Clayton et al. (1976), working in North Dakota, recognized the widespread occurrence of the silt cap on both sides of the Missouri River Trench. They mapped it over all of the terraces and onto the upland of the Coteau du Missouri, except in those local areas where silt had not been deposited on steep slopes or had been removed by erosion. The silt sedimentologic unit was given a formal stratigraphic name, the Oahe Formation (Figure 10), consisting of four members. Based on the correlation with climatic events, the Oahe Formation was dated as Late Pleistocene (Wisconsin) and Holocene. Again, an attempt was made to relate the subdivisions of the silt cap (now the members of the Oahe Formation) to certain physiographic settings, including the height of the terrace and to climatic events. No attempt was made to correlate the terraces in central North Dakota with those previously described in central South Dakota (Flint, 1955; Coogan and Irving, 1959).

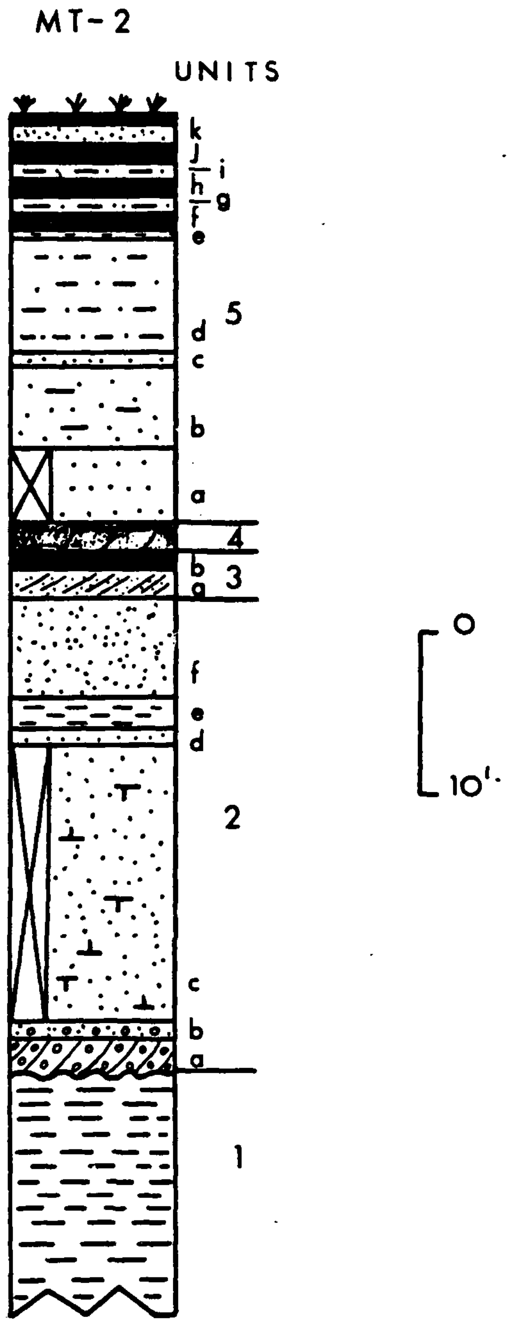


Figure 8. The Wolf Creek (also known as Little Elm Creek) section of MT-2 from Coogan and Irving (1959), near the site of 39BF4. Unit 1 is the Cretaceous Pierre Shale. Unit 2 is a combinaton of the lower, orange-stained Pleistocene glaciofluvial sands and gravels and the upper calcareous sands and silts which are probably equivalent to the Mallard Island Member of the Oahe Formation. Unit 3 and 4 are the dark brown paleosol, dated by Carbon 14 at 9,345 yBP and probably equivalent to the Aggie Brown Member of the Oahe Formation. Unit 5 (a-c) is the fine, eolian sand and silt equilvalent to the Pick City Member. Unit 5 (d-k) is the equivalent of the Riverdale Member and contains soil stabilization horizons. The section is 58 feet thick. See Table 1 for detailed lithologic descriptions of major and lettered subunits.

Table 1

Description of the Wolf (Little Elm) Creek Section
MT-2 Terrace, Banks of Lake Francis Case
Buffalo County, South Dakota

Unit #	Description	Thickness
1	Gray, bedded shale, Cretaceous Pierre Shale	Not measured
2a	Orange, limonite stained gravel and sand.	2 feet
b	Buff, coarse sand and gravel	1
c	Partly covered, calcareous sand	17
d	Buff, slightly silty, very fine sand	1
e	Tan, laminated, sandy silty clay	2
f	Buff, clacareous very fine sand	6
	Thickness of Unit 2 = 29 feet.	
3a	Yellow, calcareous, clayyey very fine sand; "B" horizon of soil	1.5
b	Dark brown to black, noncalcareous very fined sand; "A" horizon	1
	Thickness of Unit 3 = 2.5 feet.	
4a	Dark brown to black humic clayey sand	1.5
5a	Partly covered, very fine sand	4.5
b	Buff, very fine clayey sand	5
c	Buff, very fine sand 80%, silt 20%	1
d	Buff very fine sand 60%, silt 40% calcareous, non laminated.	7.3
e	Buff very fine sandy, clayey silt	0.3
f	Tan to brown, humic, calcareous very fine silt; paleosol.	
g	Buff calcareous very fine sandy, clayey silt	0.5
h	Tan to brown, calcareous, very fine sandy silt; obscure paleosol	1
i	Buff, calcareous, clayey sandy silt	1.2
j	Dark, calcareeous, sand silty with traces of bone; paleosol	0.8
k	Tan or buff very fine sand, 50%, silt, 50% with "A" soil horizon 0.3 feet thick.	2
	Thickness of Unit 5 = 24.6 feet	

Thickness of Total Measured Section above top of Cretaceous Pierre Shale: 57.6 feet

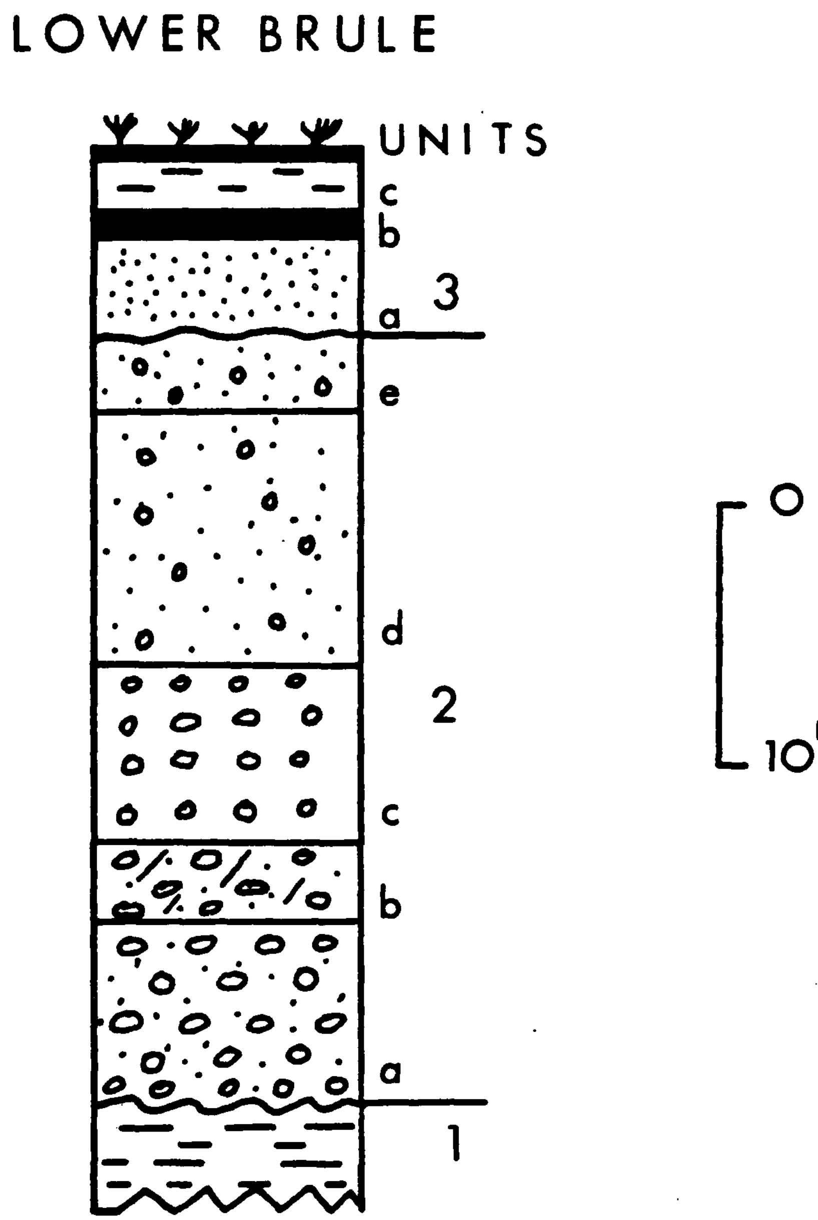


Figure 9. The Lower Brule section of MT-1 from Coogan and Irving (1959). Unit 1 is the Pierre Shale. Unit 2, the main terrace fill, is glaciofluvial outwash of Pleistocene age. Unit 3, subunit 3a, contains some fine sand which may be the equivalent of the Pick City Member. The terrace is now under the waters of Lake Sharpe and the critical observations on erosional surfaces were not made in the 1950's which would clarify this correlation. Unit 3, subunits b-c, consists of eolian silt with one prominent paleosol and possibly a higher, very weak paleosol in sediment equivalent to the Riverdale Member of the Oahe Formation. The section from the top of Unit 1 to the surface is 37 feet. See Table 2 for detailed lithologic description.

Table 2

Description of the Lower Brule Section MT-1, now submerged by the waters of Lake Sharpe, Lyman County, South Dakota

Unit #	Description	Thickness
1	Gray, thinbedded Cretaceous Pierre Shale	Not measured
2a	Coarse sandy cobble, pebble gravel	7 feet
b	Orange, limonite-stained, sandy gravel	3
c	Coarse sandy, cobble, pebble gravel	7
d	Coarse to medium sand and gravelly, pebbly sand	10
e	Tan, medium to coarse sand 90%, pebble 10%	3
	Thickness of Unit 2 = 30 feet.	
3a	Buff, very fine sand and silt with scattered pebbles and coarse sand, Bone at depth of 4 feet	4
b	Brown, calcareous silty fine sand; Paleosol	1
c	Buff, very fine sand ans silt. "A" soil horizon to depth of 0.5 feet.	
	Thickness of Unit 3 = 7 feet	
Thickness of Total Measured Section above Cretaceous Pierre Shale:		37 feet

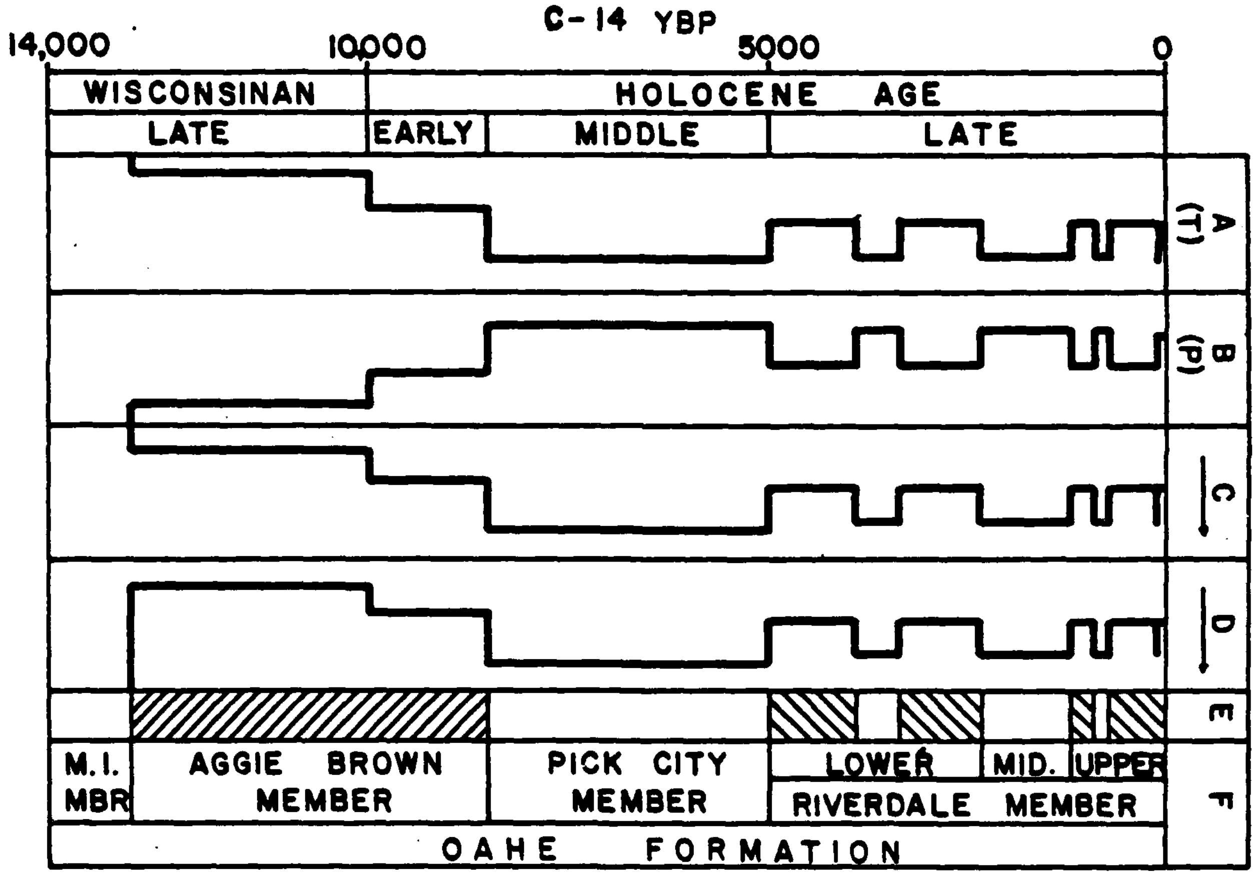


Figure 10. Diagrammatic representation of the relationships between changes in annual temperature, percipitation, slopewash on steep slopes and eolian deposition during the late Wisconsin and Holocene (from Clayton et al., 1976, Figure 7).

The Oahe Formation was proposed to consist of distinctive, mappable lithologic units. These lithologic units were deposited in response to Late Pleistocene and Holocene alternating periods of wet and cool climate and of dry and warm climate during the last 10,000 years (Figure 10). As such, the members of the Oahe Formation are used as time-stratigraphic, rather than lithostratigraphic units, as defined and applied by North American stratigraphers (Anon, 1983 Code of Stratigraphic Nomenclature). It is a distinction which makes a difference .

Consequently, a correlary of Clayton et al.'s work is that the various members of the Oahe Formation have a distinctive lithology by which one can identify the member correctly and from which one can then estimate the age of the deposit and its contained archeological materials. The estimate is grounded in the correlation of climatic events in the Holocene with the deposition of certain types of deposits in the Missouri River Trench. Based on the work presented here, this assumption in its simple form is generally unfounded.

The invaluable contribution of Clayton et al. (1976), one which completely revised the outlook of previous workers regarding the origin and age of the widespread silt cap along the Missouri River Trench, is significant for archeologists. It means that archeological materials may be found throughout the the thickness of this silt cap, regardless of the terrace level on which the silt lies, regardless of its thickness and regardless of the number of soil stabilization horizons in the silt. This is because almost all of the Oahe Formation is younger than 14,000 years. Remember, Flint correlated some of these silts to several interstadials in the Pleistocene.

Finally, the key hypothesis of their work, the one which relates silt deposition and soil stabilization to climatic changes is based on a number of studies and observations. Basically, the two opposite controlling conditions, coupled with slope stability, are shown in Figure 11. Cool, moist periods during the Holocene are seen to result in downcutting rivers, stable hill slopes covered with thick vegetation and formation of soils. Warm, dry periods result in alluviation of stream valleys, deposition of dry, loose materials on stream bars, easily eroded hillslopes (e.g. the "breaks" of the Missouri), thin vegetation, minimal soil formation and deposition of substantial silt during dust storms. This general mechanism of Clayton et al. is accepted in this report. It is the erosional events that interrupt the sequence (Figure 12) which greatly complicate the Holocene stratigraphy of the Missouri River Trench and make further analysis of specific archeological sites necessary if geologic information is to be useful in exploration for sites, for their interpretation or as guides for excavation.

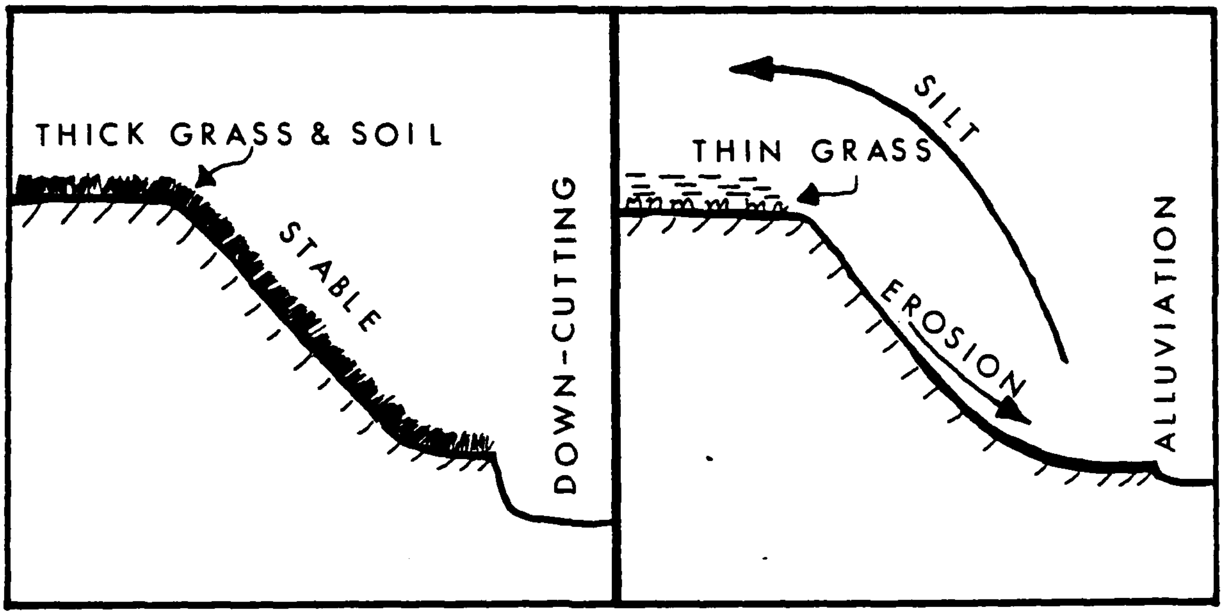


Figure 11. Contrasting depositional conditions controlled by hillslope stability and climate (from Clayton et al., 1976, Figure 5).

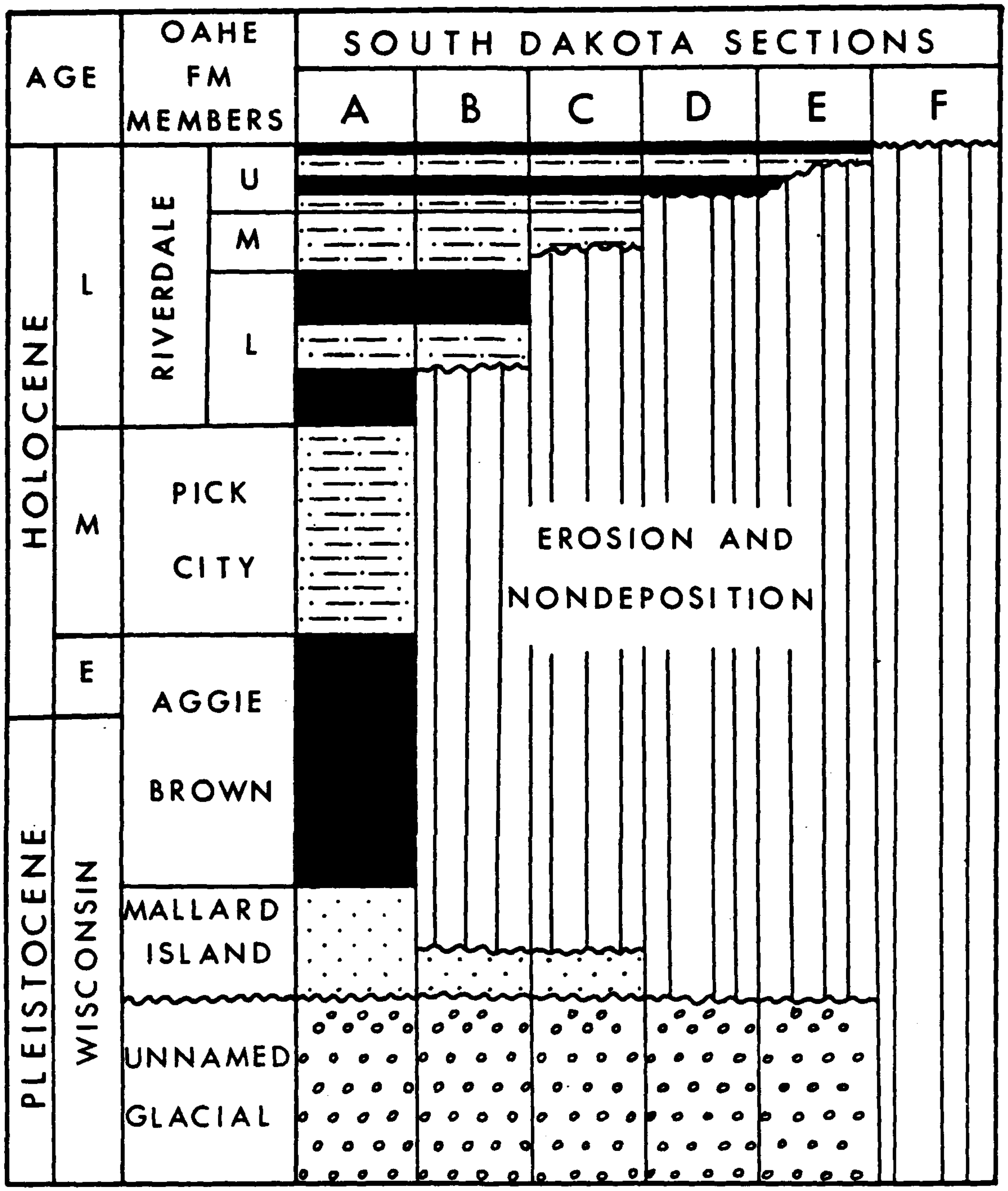


Figure 12. Correlation diagram showing the sequence of deposits from late Pleistocene through Holocene at various sites in South Dakota, mainly in the Big Bend Reservoir on the MT-1, MT-2 and MT-3 terraces compared to the Oahe Formation members (Clayton et al. 1976).

The South Dakota Sections are as follows: A= Crow/Wolf Creek (39BF11) B=Medicine Crow (39BF2), C=Joe Creek, D=Near 39BF42, E=Near 39BF42, F=Erosional Site. Only at section A is a full depositional-preservational sequence observed. At F, for example the "Erosional Site", no Quarternary deposits are preserved. Sections B-E are intermediate in the depositional-preservational history of Pleistocene and Holocene sediments.

Current Revisions.-

As a result of the field work done in support of the archeological survey of the Lake Sharpe Shore, Big Bend Reservoir, a modification of both Clayton et al.'s ideas on the development of the Holocene sequence of deposits and Coogan and Irving's ideas on terrace formation was necessary. The principal advantage in working on Holocene stratigraphy along the Missouri River in the late 1970's and early 1980's is that bank erosion from wave attack and slumping on on the shores of Lake Sharpe provide miles of exposed stratigraphic section which could not be seen in the 1950's. The principal disadvantage is that the lower terraces are under lake waters, except in the tail race areas of the Oahe and Big Bend dams. Nevertheless, geological observations in the summer of 1978 and later showed that the physical continuity of Clayton et al.'s members of the Oahe Formation, i.e. their mapability, was so poor that regardless of their validity as climatic-stratigraphic units, they could not be used directly as a tool for archeological dating in South Dakota. The general framework of Holocene deposition (from Clayton et al., 1976) is shown in Figure 12, together with sequences of late Pleistocene and Holocene deposits at various archeological sites and localities in the study area for deposits on MT-1 and MT-2. Pleistocene and Holocene erosion severely cuts out various portions of the Oahe Formation. At Wolf and Crow Creeks (39BF11) it appears that a full sequence of sediment equivalent to the Oahe Formation is present and recognizeable in central South Dakota. At the Rattlesnake Site (39BF41), it was also thought that a full sequence was present. However, at Medicine Crow (39BF2) and other sites shown on the right of the diagram (Figure 12), the full development of the Oahe Formation was lacking because of erosion and non-deposition. Finally, at the "Erosional" Site near 39BF42, the MT-2 terrace was cut into Cretaceous Pierre Shale and there were no younger deposits overlying the cut surface.

Summary

By the middle of the project period detailed investigation of stratigraphic profiles and mapping of terraces from the vicinity of Chamberlain to Pierre, South Dakota on 7.5 minute, topographic quadrangle maps, supplemented by aerial photographs and 1947 U.S. Corps of Engineers maps of the Missouri River established the following facts and observations applicable to the deposits of the Missouri River Trench in the area of the Big Bend Reservoir.

1. Flint's (1955) correlation of the terraces of the Missouri river with specific glacial events could not be substantiated.

2. Flint's (1955) correlation of paleosols (soil stabilization horizons) in the silt cap with various glacial events was clearly wrong.

3. The number of terraces recognized by Coogan and Irving (1959) had to be expanded from three to four.

4. The number of soil stabilization horizons (humic horizons) in the silt cap was unrelated to either the elevation of the terrace or the "MT" number of the terrace.

5. There were substantial erosional events during the Holocene which affected the sequence of deposits in the silt cap.

6. Clayton et al.'s (1976) Oahe Formation could be recognized in South Dakota as the principal Holocene depositional unit, but its lithologic members could not be used directly for time-stratigraphic dating because of the Holocene erosional events and because of local sedimentologic facies changes.

7. Climatic events during the Holocene which affected the silt cap and formation of gullies did seem to be related to Clayton's model of warm/dry and cool/wet periods.

8. The composition of terrace fills, especially of MT-2 was varied and not easily explained by a simple depositional model.

9. The terraces were mapped through the Lake Sharpe area of the Missouri River Trench and could be extended up the creek valleys. MT-2 was a terrace event of major importance. The terrace is widespread, easily recognizeable and was formed in response to some major event which raised the level of the Missouri River.

10. The mechanism for terrace cutting and filling did not logically extend back in time because if extended some terrace fills would have to have been deposited during wet/cool periods, others during dry/warm periods. In other words, Clayton's model and mechanisms for it did not logically reach back into and explain the Late Pleistocene events.

11. Archeological materials could be expected in the silt deposits on the terraces anywhere along the river trench because the silt cap is mainly Holocene. They are not expected in or below the gravel terrace fill for preservational reasons and because much, but not all, of the gravel is older. Deeply buried archeological sites and early Holocene occupations are probably numerous in the silt cap.

12. Although not described so far, the stratigraphy of individual sites can be examined on the basis of an "event sequence" stratigraphy. The approach allows for an estimation of the age of cultural remains which are deeply buried in the silt cap.

13. Combined archeological/geological/radiocarbon-dated sequences were needed in several places to build a useful framework of Holocene events.

This summary of the status of knowledge on the stratigraphy of the terrace fills applied before the final field season in the Oahe Reservoir and subsequent work in North Dakota. The investigation of the site areas along the banks of Lake Sharpe did provide clues for going forward, but the locality which provided the key to unraveling much of the confusion evident in the 13 points listed above was the Walth Bay Site, described by Ahler, Falk, Davies and Madsen (1974). There, a compressed geologic section, a good exposure, a sequence of cultural stratigraphy, radiocarbon dates and accessability assisted in developing other concepts regarding the erosional depositional history of the Late Pleistocene and Holocene of the Missouri River Trench.

The observations made at Walth Bay, combined with those made elsewhere in the Oahe and Big Bend reservoir areas and near Yankton, South Dakota, provide the stratigraphic and geomorphological framework for the discussion of individual sites. The general scheme of Holocene depositional history developed by Clayton and his colleagues at the University of North Dakota (1976, and pers. commun.) is accepted as the main touch point here (Figure 13). New excavations and new radiocarbon dates may modify the details.

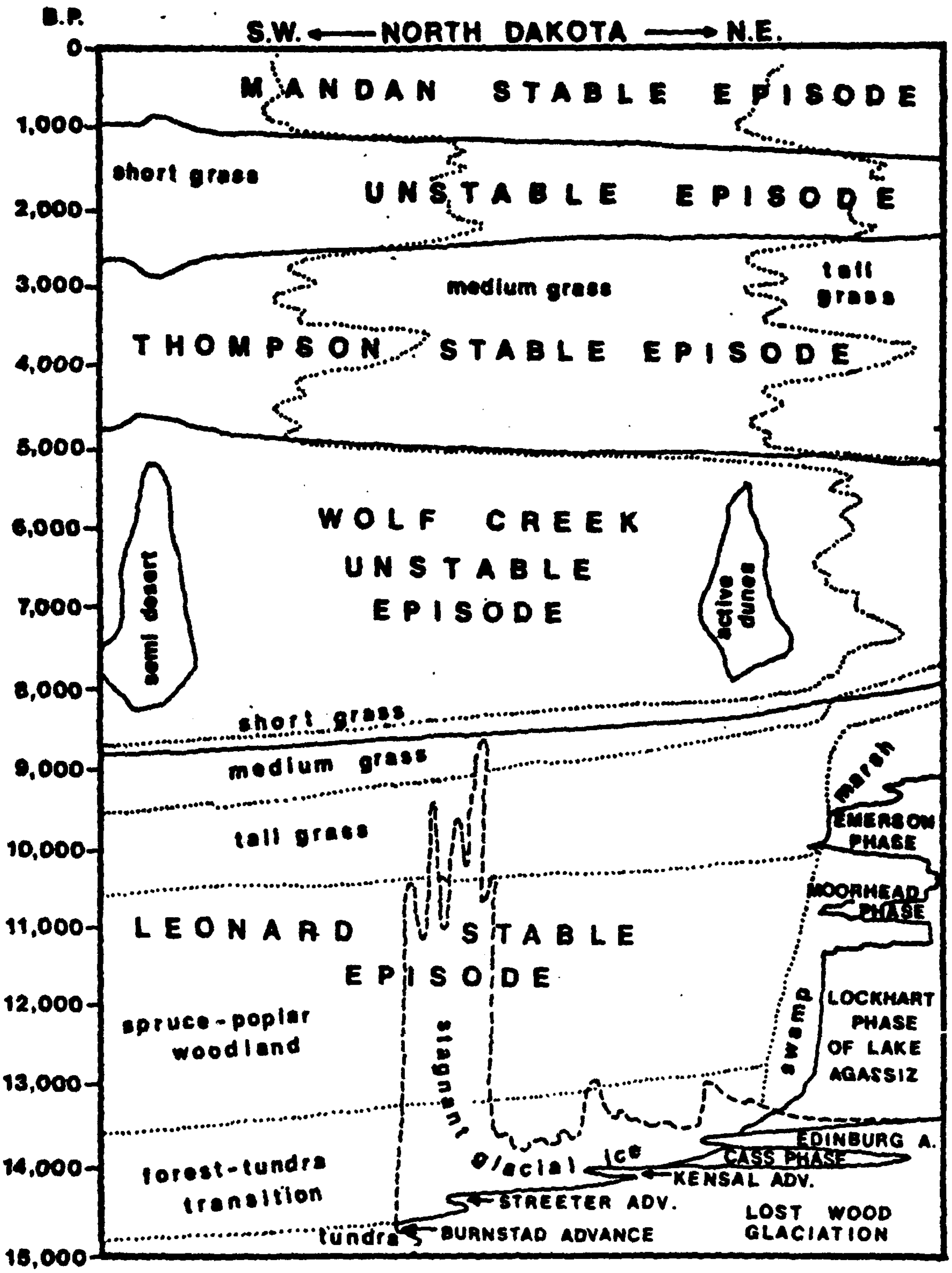


Figure 13. Time-length diagram of late Pleistocene and Holocene strata of North Dakota, provided by Clayton and based on faculty and student research at University of North Dakota.

DESCRIPTION AND INTERPRETATION OF FIVE KEY STRATIGRAPHIC REFERENCE SECTIONS

Five key sections are described and discussed in this part of the report. They are the Walth Bay site (39WW203) on Lake Oahe in Walworth County, the Crow Creek site (39BF11) at Crow and Wolf Creeks on Lake St. Francis Case, the section south of 39BF42, the Rousseau site (39HU102) and the Rattlesnake site (39 BF41) on Lake Sharpe.

Walth Bay

General.-

At Walth Bay, cultural horizons were discovered in a compressed section of the Oahe Formation. The site lies at the juncture of the lower slopes of MT-3 and the upper proximal slopes of Mt-2 (Figure 14). In general, the setting at the time of occupation of the lower two levels (Ahler et al., 1974) would be similar to the upper portions of MT-2 at Fort Thompson where the Pierre Shale is close to the surface and where the terrace fill is being covered by slope wash. The site was directly on the shore of Oahe Reservoir in 1979 and undergoing destruction by shoreline erosion.

Stratigraphic sections were drawn from numerous profiles along the shore of Lake Oahe over a distance of 300 yards and adjacent areas were inspected. The sequence of deposits is shown in Figures 15 and 16 as laterally composite cross sections, the history of which is described below. Figure 15 shows the bank profile as described. Figure 16 is the same bank profile with units above the sand (D) removed and the lateral continuity of subsequently removed strata reconstructed.

Sequence of Events.-

Unit A is the Cretaceous Pierre Shale (Figures 15, 16). A valley was excavated into the Pierre Shale at the site. The base of the valley is under Lake Oahe at the site proper but the valley walls can be seen in either direction laterally along the shore. as the bedrock sides of the small knolls. This excavation represents the cutting of the Missouri River Trench sometime during the Pleistocene. Flint has suggested a pre-Wisconisin development of the first part of the trench.

Overlying the eroded Pierre Shale surface is a deposit of orange-stained (B1), partly cemented, sandy gravel (B2) of Pleistocene glaciofluvial origin (Figure 17). This deposit partly fills the locally eroded valley in the Pierre Shale. The sandy, crossbedded deposit (Figure 16) labelled B1 is a lateral variation of the orange gravel as is the cemented gravel labelled B2. The till (B3) may be later or one developed from a pocket of melting ice in the glaciofluvial outwash. It is not clear from the sections whether the surface of this Pleistocene gravel and

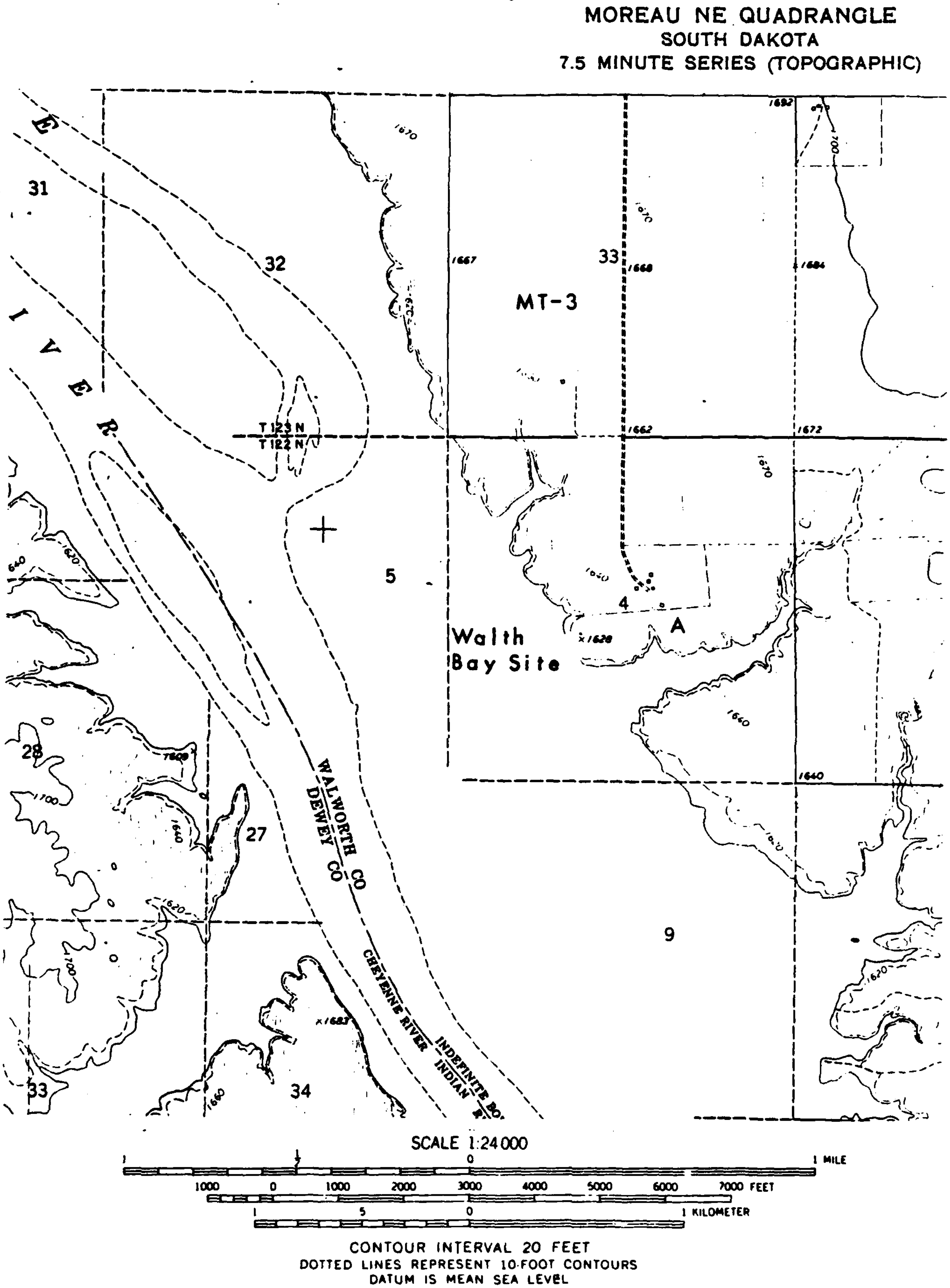


Figure 14. Part of the Moreau, S.E. Quadrangle (U.S.G.S. 7.5 min., topographic), Walworth County, South Dakota, showing the location of the Walth Bay site (39WW203) on the lower slopes of the MT-3 terrace (A).

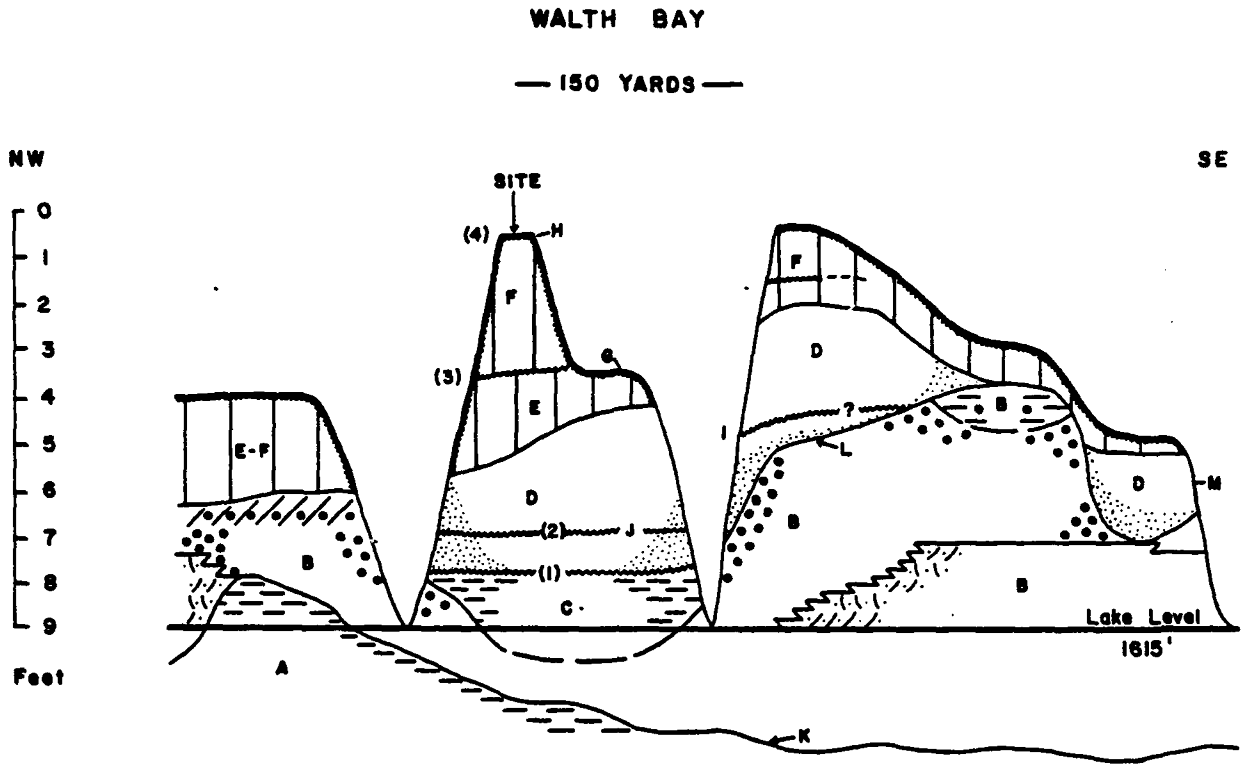


Figure 15. Cross section of the Walth Bay site, constructed from a series of profiles taken along the bank edge at and adjacent to the Walth Bay Site, proper.

The letters designate the following components: A= Cretaceous Pierre Shale. B (also B1, B2 and B3)= glaciofluvial, sandy gravels of Pleistocene age. C= black mud, the surface of which (1) was an occupation site at about 8-10,000 yBP. D= eolian sands, interpreted as middle Holocene. E= late Holocene silt cap, separated from an even younger late Holocene siltcap (F) by a soil stabilization horizon (G) which laterally merges with the modern soil. H= modern soil and surface. I= soil stabilization horizon in Unit D. J= faint soil stabilization horizon in unit D. K= erosional surface on Cretaceous Pierre Shale. L=erosional surface on glaciofluvial gravels. M= erosional surface of gully which is older than the modern surface and younger than soil stabilization horizons in the silt cap which it cuts out. Numbers 1, 2, 3 and 4 indicate cultural levels at the Walth Bay Site described by Ahler et al. (1974). All lines below the lake surface level are reconstructed.

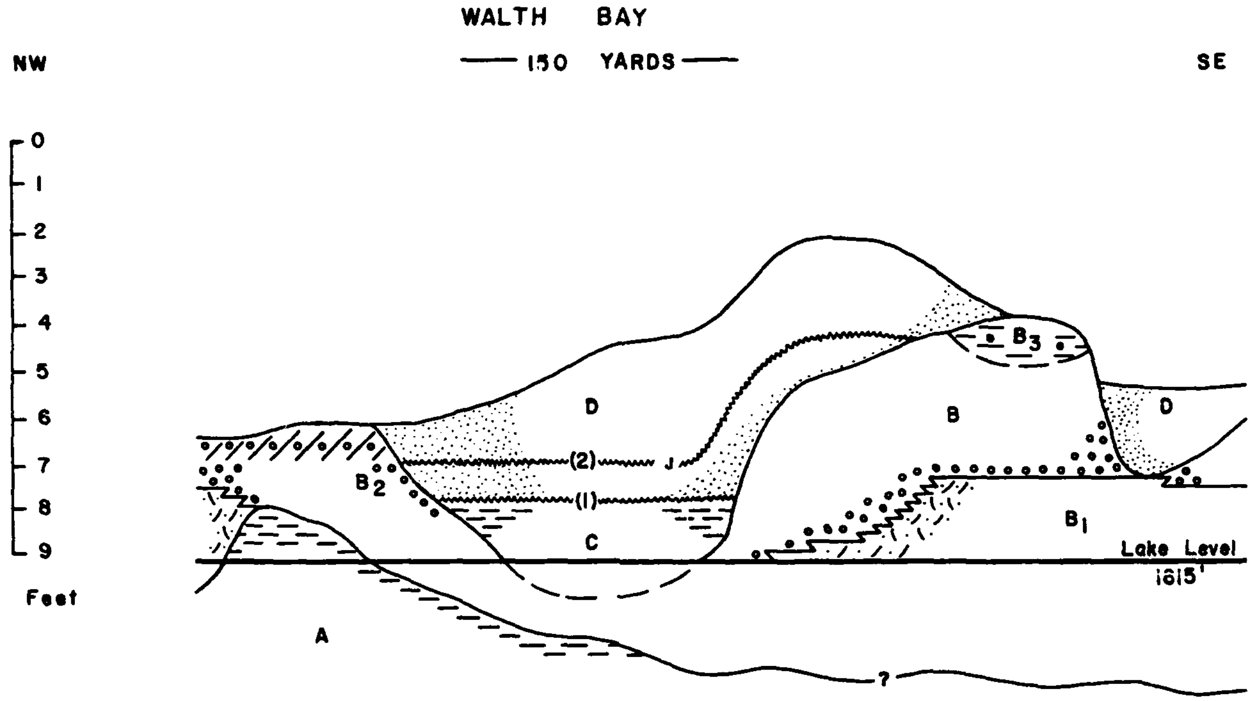


Figure 16. Reconstruction of the depositional units at Walth Bay from the erosion of the underlying bedrock Pierre Shale through the middle Holocene eolian sands of Unit D.

The sequence is as follows: Erosional cut into Pierre Shale (Unit A). This cut or valley was filled in with glaciofluvial gravels and sands and possibly till (Unit B). B1 designates the main body of the cross bedded, orange stained gravel and sand. B2 shows an outcrop of the cemented gravels. B3 is the deposit interpeted as till.

Erosion of the surface of this deposit in the late Pleistocene created new gullies. The first Holocene deposit is lettered C, a black clay with rootlets on its surface, which is also the location of Paleoindian materials (1). The deposit may have been a swamp or small lake. Unit D, windblown sands, then filled in and covered over the irregular surface on the glaciofluvial gravels. Some of the Unit D sand may have come from these very gravels. A faint soil stabilization horizon (J) above (1) follows an ancient topography. It is the site of Archaic tradition materials dated at 8-10,000 yBP.

Figure 17. Photograph near the Walth Bay site proper, showing the exposure of Unit B gravels, overlain by the late Holocene silt cap (F).

sand deposit had a very irregular configuration with knobs and swales (Figure 16, center) which lapped upon the sides of the Pierre Shale valley to the southeast part of the section or whether the surface was more uniform and higher. If the latter, then erosion of the gravel deposit caused the development of gullies, for example, where unit C fills a depression in the gravel (Figure 16).

Unit C is a dark gray to black clay with apparent rootlets at its upper surface. It formed in a swale in the gravel and is probably a pond deposit. It is found only at this one place on the section. The upper surface of C has a faint soil stabilization horizon and is the site of a Paleoindian occupation level (1) dated at 7,000 yBP based on bone. It is probably older, that is between 8-10,000 yBP because overlying, better dated material is that old.

Above the black clay is a deposit of tan sand (unit D), interpreted here as windblown, which filled the depressions on the gravel surface (B) (Figures 15-17). The sand deposit contains faint soil stabilization horizons and occupation levels (2) of the Archaic tradition which have been radiocarbon dated at 6-7,000 yBP. Note that this is coincident with the Wolf Creek unstable period detailed by Clayton et al. (Figure 13).

Subsequent to the deposition of unit D, an eolian silt was deposited which is preserved at the site as units E and F (Figure 15) which also contains a soil stabilization horizon (G) estimated to be about 3,000 yBP, based on comparison with the Rousseau site stratigraphy and the unstable period beginning at the end of the Thompson Stable Period (Figure 13). It could be older, but cultural materials suggest an age of 1-2,000 B.C. Note that horizon G is terminated laterally by gullies on the one hand and that it combines with the modern soil (H) horizon on the other.

Deposition of unit F silt postdates unit G (Figures 15-17). The silt unit has a weak soil stabilization horizon. The modern soil is developed on unit F and on other older surfaces as they are exposed on the slopes of gullies. The scale of the diagram is greatly exaggerated vertically. Gully formation took place after the formation of unit G, probably during the unstable phase about 2,000 yBP. The thin silt cap also probably contains some erosional breaks because one does not see all the expected paleosols.

Note that the entire section at Walth Bay is less than ten feet thick and contains a record of depositional and erosional events which span a period of at least 15,000 years, probably longer. The sequence of events at the Walth Bay site is summarized in Table 3.

TABLE 3

SEQUENCE OF DEPOSITIONAL AND EROSIONAL EVENTS AT WALTH BAY SITE

EVENT	APPROXIMATE AGE
1. Erosion of valley into the Pierre Shale.	Pleistocene
2. Deposition of gravels and crossbedded sands as glaciofluvial deposits (B-1, B-2)	Pleistocene
3. Deposition of till (B-3). May be part of same depositional events as 2.	Pleistocene
4. Erosion of gullies and swales into gravels. Surface L.	Pleistocene
5. Cementation of gravels and sands (B-2).	?
6. Deposition of black clay, pond deposit. Unit C.	?
7. Development of thin soil on the clay. Occupyation of site (1) by Paleoindians, about 7,000 yBP.	Early Holocene
8. Deposition of brown sand, possibly with a soil equivalent othe soils in the Aggie Brown Member. Unit D.	Early Holocene
9. Deposition of lower sand and silt. Occupation of site (2) between 8-10,000 yBP.	Middle Holocene
10. Some erosion of silt and development of a soil stabilization horizon (suggested age about 3,000 yBP). Units E and G.	Late Holocene
11. Erosion of gullies.	Late Holocene
12. Deposition of uppermost silt and modern soil. Occupation by Plains Village cultures. Unit F.	Late Holocene
13. Erosion by modern gullies (M).	Late Holocene

Summary.-

The sequence of geologic events evident from the profiles at Walth Bay, if applicable to broader areas in the Missouri River Trench, provide the basis for the following generalizations.

1. The trench was cut to at least the level of the lower part of MT-3 by late Wisconsin time and ice was present in the trench. Flint notes ice-contact deposits even lower in the trench elsewhere.

2. The orange-stained gravels (also cemented at Walth Bay) are Wisconsin glaciofluvial outwash deposits. The mainly buried surface on top of these gravels is erosional.

3. The overlying units, correlative with the Mallard Island and Aggie Brown Members, like other members of the Oahe Formation, may be absent owing to nondeposition or erosion.

4. The eolian deposits of the Middle Holocene (correlative with Clayton et al.'s Pick City Member of the Oahe Formation) may be absent owing to nondeposition or erosion.

5. The number of soil stabilization horizons in the middle to late Holocene silt is a function of slope, climate, and local conditions, including erosion.

6. Many of the gullies seen along the banks of the present lakes are rather young. Older gullies are also present, but some have been buried by sand or silt.

7. Soil stabilization horizons may be cut out laterally or join with younger or older ones.

Rousseau Site

General.-

The Rousseau Site (39HU102) is located on the left bank of the Missouri River (Lake Sharpe), just down stream from Medicine Knoll Creek (Figure 18). The site is exposed in the cut bank of the lake on a slope between MT-2 and MT-3, i.e. on the upper slopes of MT-2. The importance of the site for the establishment of a general geologic framework is that the cut exposes a complicated but substantial section of middle Holocene eolian deposits and displays erosional and depositional features in the late Holocene part of the section. Radiocarbon dates from hearths provide age control. Additional information on the site is available in the site report (Coogan, 1986).

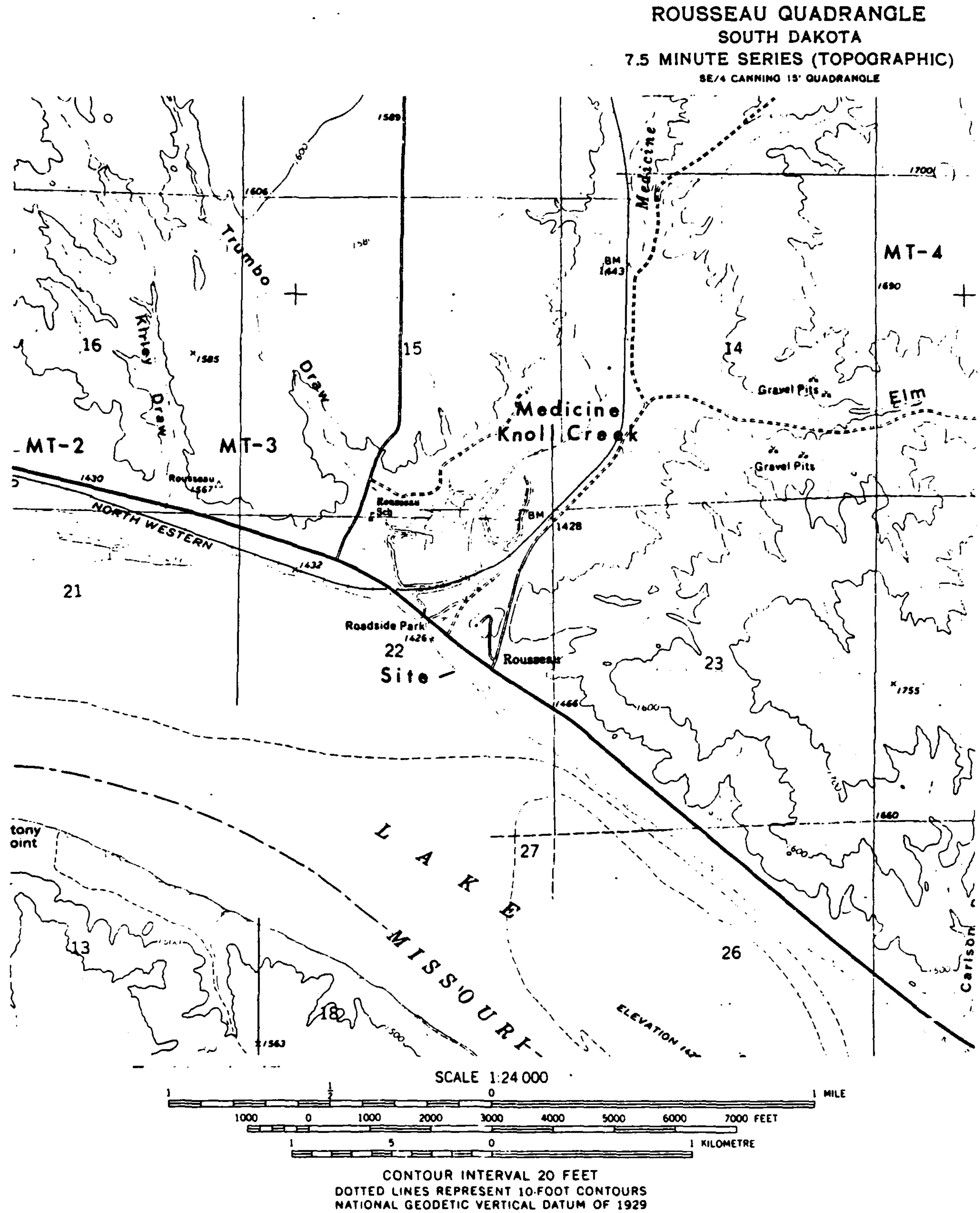


Figure 18. Portion of the Rousseau Quadrangle (U.S.G.S., 7.5 min. topographic) showing the location of the site and the terrace levels, MT-3 and MT-4 along Medicine Knoll Creek.

Sequence of Events.

A series of six short profiles provides the control for the composite cross section along the bank at the Rousseau Site (Figure 19). Note that to the left (northwest), the Pierre Shale (A) crops out and is overlain by crossbedded glaciofluvial gravels (B). Both of these units are terminated laterally by erosion of a valley (surface D′) into which sands and thin gravel layers, probably slope wash, were deposited. These sands (C, E) are mainly eolian.

Near the top of the exposure, on the left (northwest) side, a soil stabilization horizon (D) is present at the top of the sandy unit (C) and the base of the eolian silt (E). This paleosol is approximately dated from cultural materials as Plains Woodland (AD 900-1,000) and radiocarbon dated in a test-pit back from the bank at 1,660 yBP (AD 370-390). The surface changes laterally to the right (southeast) to a barely discernable one (D′). Originally, field work indicated that there might be a cloe age connection between the paleosol (D) and surface D′. A hearth (L) lies on surface D′ which laterally rises to the southeast. Along it a paleosol (D") appears. The hearth is dated twice--once at 3,380 yBP and again at 3,800 yBP. Between units (D) and (L-D") is an erosional surface (D′) and a post-erosional fill (E). In other words, D′-D" is a gully surface which cuts into (C) and which is subsequently filled by a sand unit (E), most of which is apparently older than the paleosol unit (D), i.e. older than about 3,500 yBP. Units (F-H), the eolian silt cap, overlie all of these and have a modern soil developed on it (M). In test pits, back from the bank, another shallow paleosol may be present which is dated on cultural remains at about 300-600 yBP (unit G).

Farther to the southeast (right), along a portion of the bank profile which is not shown here, a large granitic erratic is present at present lake level; it is covered by sand of units (C) or (E). The boulder may be an erratic from upslope or part of the deposition of unit (B). Gullies cut through the sequence, as in the case at Walth Bay, removing all of the units except part of unit (F-H) and the modern soil.

Summary.-

Based on the data from the Rousseau Site, one can make the following generalizations:

1. The cutting of the Missouri River Trench into the Pierre Shale and the deposition of glaciofluvial gravels (and perhaps till with boulders) is like the lower sequence at Walth Bay.

2. There is an erosional, gully-forming period from about 4,000 to 3,000 yBP documented at Rousseau. The erosional surface grades laterally into a paleosol (D) which must be approximately the same age. This paleosol appears to coincide with the upper

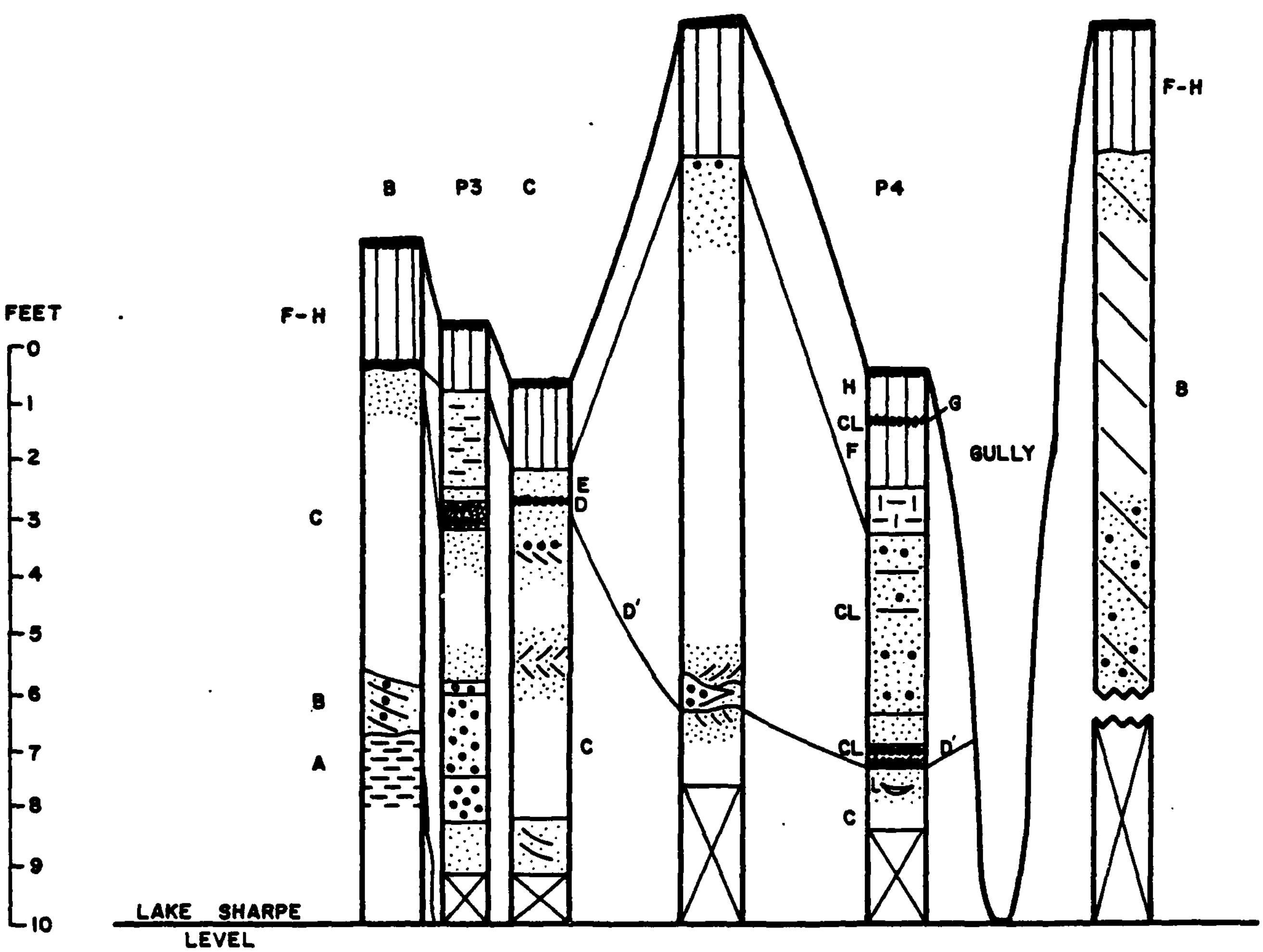


Figure 19. Composite cross section of the Rousseau site constructed from numerous profiles along the bank edge. A= Cretaceous Pierre Shale. B= glaciofluvial gravels and sands. C= Eolian sand (part equivalent to Pick City?). D= Paleosol dated at 400-1,000 yBP by correlation. D′= Correlation line phyically traced between the paleosol and dated cultural levels (CL). E= Sand fill of gully excavated down six feet to level of hearths (L) and surface D′. F= Eolian silt (=Riverdale). G= Paleosol in eolian silt. H= Eolian silt. F-H= Combined silt unit without palesol G. M= Modern surface and soil on MT-2. CL= cultural level.

Thompson paleosol (Lower Riverdale) as defined by Clayton et al. (1976) and shown in Figure 11.

3. Subsequent eolian activity and slope wash healed the gully during the Late Holocene, probably in the period between 2,500 to 1,000 yBP.

4. The silt cap (F-H) is late Holocene and lacks one or more of the paleosols one might expect to see at this site if the Oahe Formation were fully developed.

The profiles at the Rousseau Site are consistent with the general picture developed at Walth Bay for the Late Wisconsin and middle Holocene. They also provide the dating of a late Holocene period of gully formation and confirm the information from Walth Bay that the late Holocene to recent gullies cut out units as young as (G), i.e. 300-600 years.

Rattlesnake Site

<u>General Sequence of Events.-</u>

The Rattlesnake Site (39BF41) is located at the edge of MT-2 on an embayment of Lake Sharpe (Figure 20). Geological investigation of profiles along the shore of the embayment show the following sequence of events (Figure 21).

A terrace was cut into the Pierre Shale at elevations in this area of less than 1,400 feet. This is not shown on Figure 21, but is evident along the shore of Lake Sharpe north and south of 39BF41 where the Pierre Shale bedrock rises to elevations of about 1,400 feet.

Glaciofluvial, orange-stained, bedded sands and gravels were deposited (Unit G), often with a steep dip eastward. The sediment pile reached almost as high as the top of MT-2 at this site. This deposit was eroded by gullies (Surface I). No soil horizons were seen on this buried erosion surface, but limonite staining of gravel is more intense there.

The gullies were filled with colluvial (slope wash) sand and gravel from the gully sides and by windblown sand. Filling was nearly to the top of the ridges between the gullies. This fill is designated with the letters C, D, E and F.

A soil stabilization horizon (P) is developed on part of the upper surface of unit (C). This surface follows over the underlying topography (Figure 21), overlapping the ridges between the gullies. Deposition of windblown silt continued (Unit B, Figure 21). The modern soil is developed in it. Laterally the depositional units (G-C) are cut out by gullies formed in the late Holocene. Only unit (B) and the modern soil appear to be traceable into the modern gully. The cultural materials at the site (39BF41) are associated with unit (C), Figure 21.

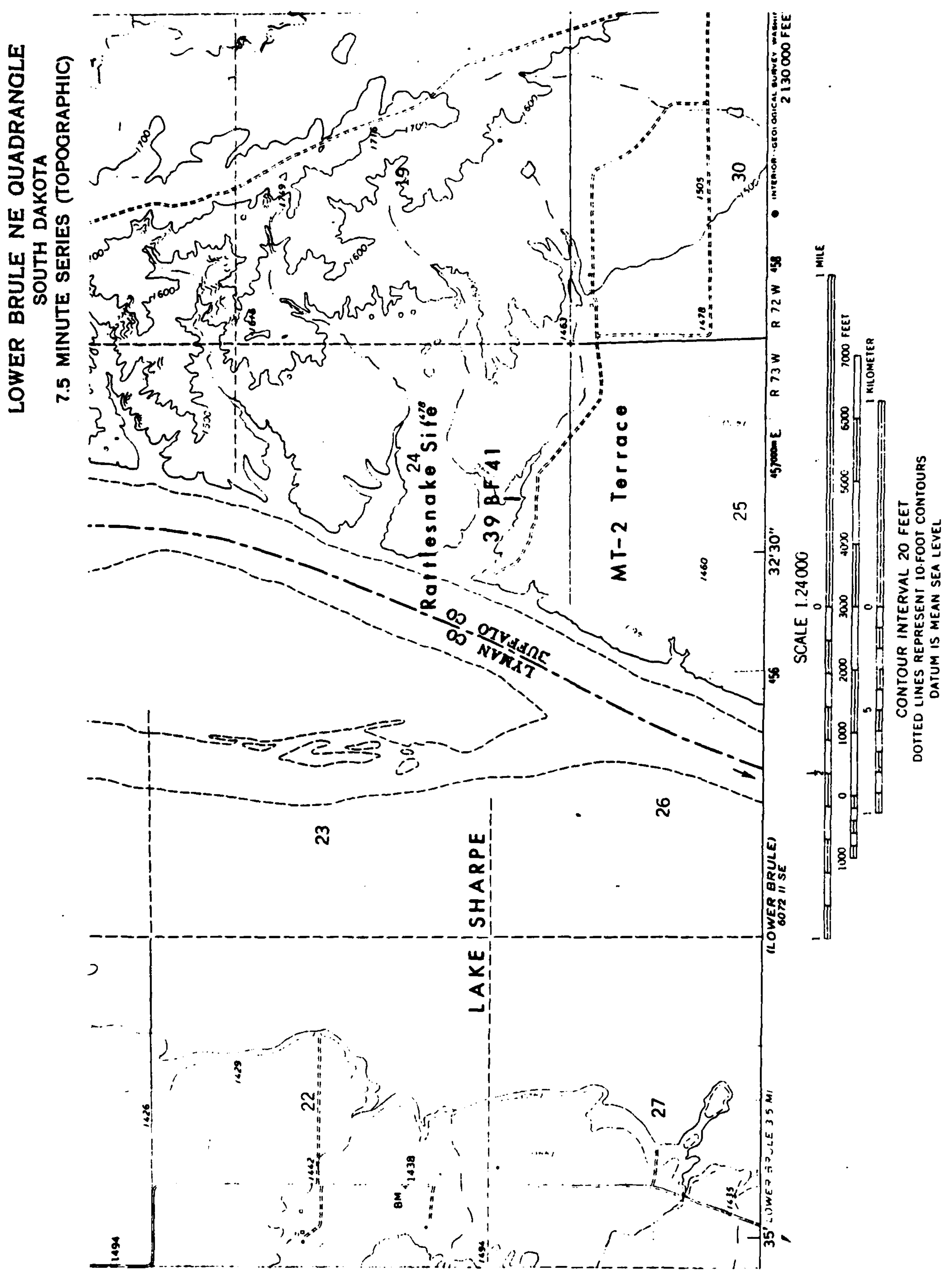


Figure 20. Part of the Lower Brule, N.E. Quadrangle (U.S.G.S., 7.5 min., topographic) showing location of the Rattlesnake site (39 BF41), edge of MT-2, Lake Sharpe.

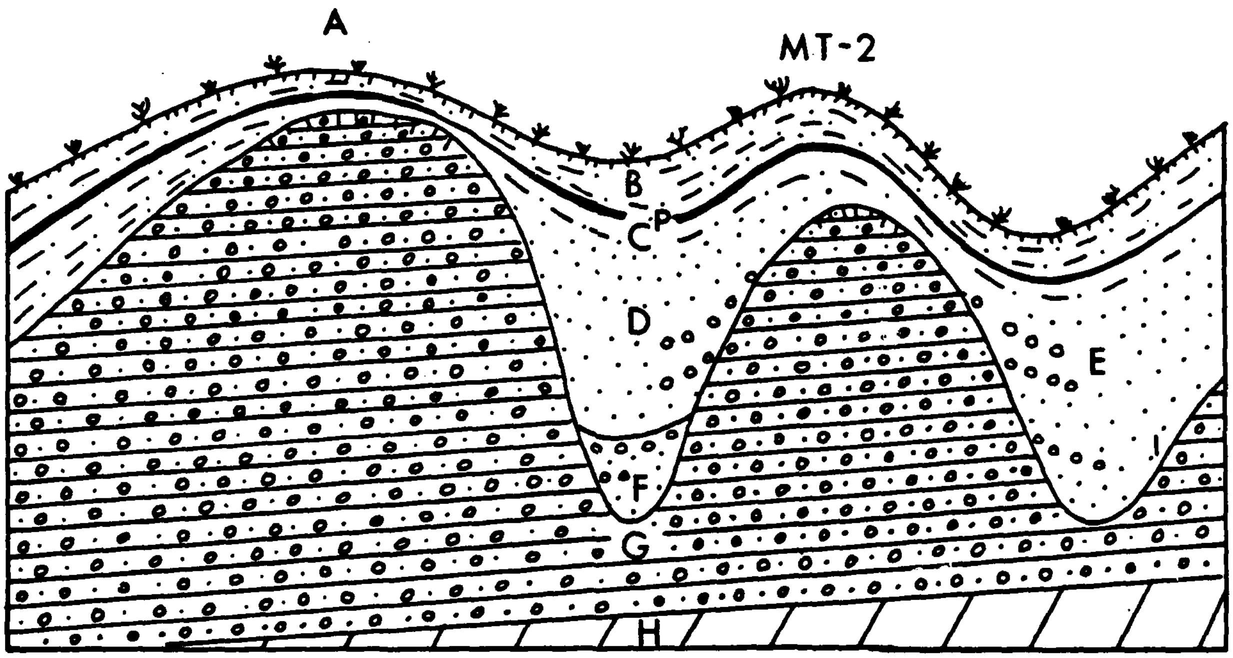


Figure 21. Diagrammatic cross section of the bank cut of MT-2, northwest of Rattlesnake site proper. A= modern surface of MT-2. B=silt cap. C= silty top of Unit D, filling gully. Between C and B is a paleosol (P). D to E is the silt and sandy fill of the gully with slope wash from the gully sides at E. F= gravelly slope wash at the base of the gully. G= Pleistocene glaciofluvial, dipping bedded gravels. H= covered slope, just above level of Lake Sharpe. I= gullied surface of Unit G.

Summary.-

The sequence of geologic events at the Rattlesnake Site can be added to what is known from Walth Bay and Rousseau. As at Walth Bay, the downcutting of the Missouri River Trench excavated a valley into the Pierre Shale. In this valley, glaciofluvial bedded sands and gravels were deposited, probably during the late Wisconsin. The surface of these deposits was eroded. Here the evidence of that erosion is uncontrovertable, because the erosional surface truncates dipping beds. The erosion was not as clear at Walth Bay. The gullies are filled with slope wash from their sides and with windblown sand and silt which generally is finer upward. The texture of the deposit is greatly influenced by its proximity to higher lying gravel and sand units. A soil stabilization surface caps the windblown sand and is at the base of a finer eolian silt. At Rousseau, a similar paleosol surface was dated at 3,000-4,000 yBP. Here cultural remains of the Archaic tradition are consistant with that date. The gully filling on the gravel unit appears to be middle Holocene, that is, correlatable with the Pick City member. The eolian silt is thin to absent, overlaps all older units, as at Rousseau, and is not truncated by modern gully erosion in a substantial way.

The Rattlesnake Site analysis appears to confim what was described at other sites. Additional radiocarbon dates would be helpful, but lacking them, there appear to be no major inconsistencies in the general sequence of events.

Crow and Wolf Creek Site

General.-

The section is exposed in the steep banks of Wolf Creek and along the edge of Lake Francis Case about midway between Fort Thompson and Chamberlain, South Dakota. It is discussed here because it is the type area of the MT-2 terrace (Coogan and Irving, 1959) and because it contains one of the thickest sections of the Oahe Formation. The Oahe Formation here has several soil stabilization horizons and a very thick sequence of sediment. As such, it represents essentially the extreme development of the depositional phase of the Holocene in this area (Figure 12). The section can be observed on the Wolf Creek bank side or on the Lake Francis Case side of the bluffs (Figures 22-23). The section is described in Coogan and Irving (1959) and illustrated in Figure 8 and Table 1 of this report.

Sequence of Deposits and Events.

As with other sections, the Missouri River eroded into the bedrock Pierre Shale (Unit 1), here into the chalky members. Overlying the Pierre Shale is 29 feet of orange stained gravel and 3 feet of orange stained sand (Unit 2). Over this is 26 feet

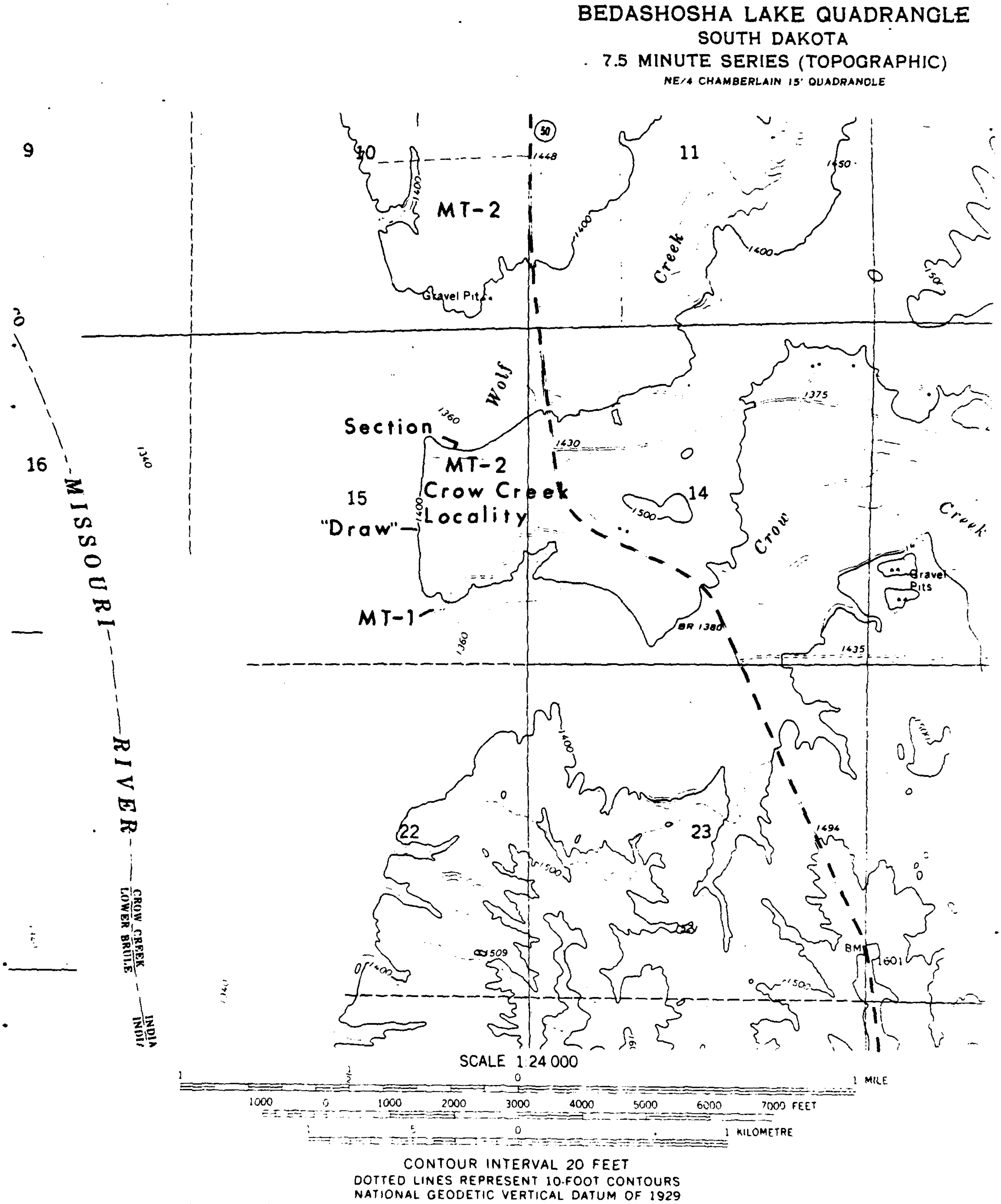


Figure 22. Part of the Bedashosaha Lake Quadrangle (U.S.G.S., 7.5 min., topographic) showing the location of the Crow Creek site between Wolf and Crow Creeks (39BF11) A=site of detailed section (Figure 9). B= location of Figure 33. C= Exposure of MT-1.

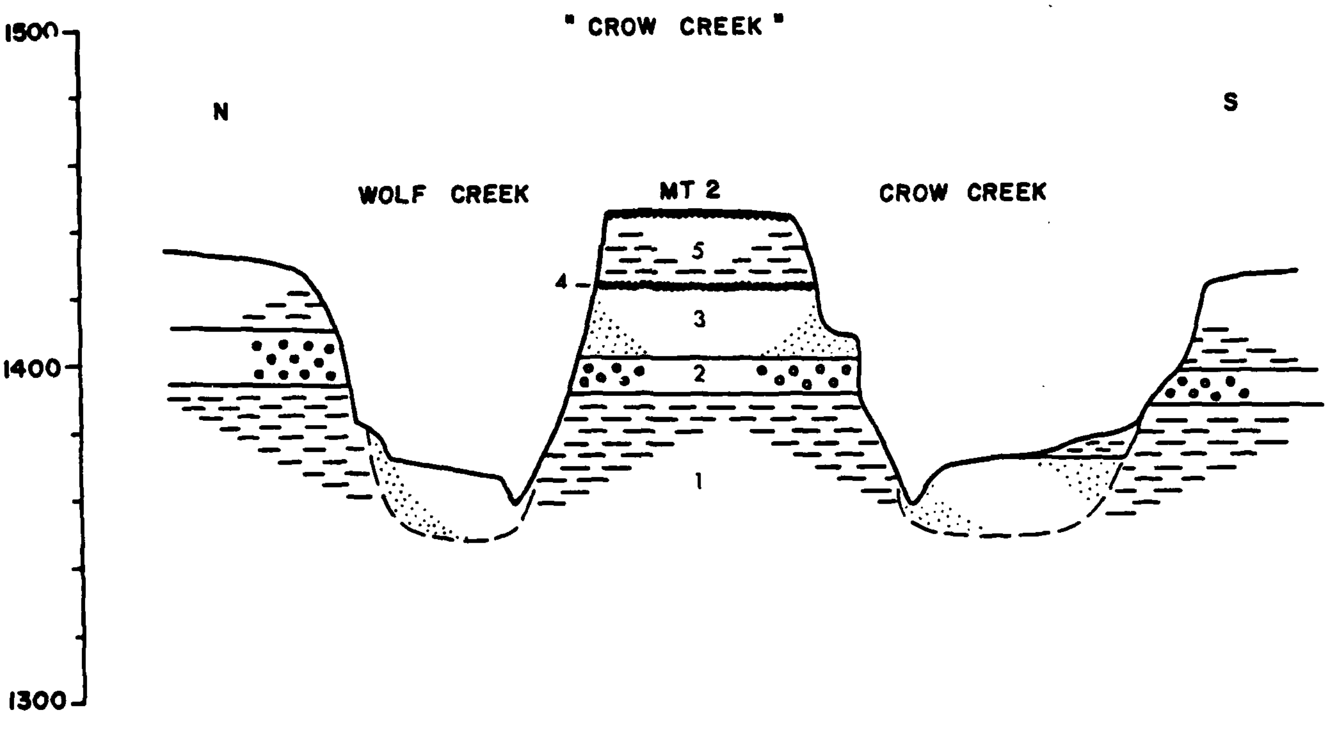


Figure 23. Diagrammatic cross section of Crow Creek site and MT-2 terrace. Pierre Shale (1) underlies all units. Glaciofluvial gravels (2) and sands (3). Unit 4= prominent dark paleosol (9,345 yBP) underlies middle Holocene and late Holocene sediment (5). Compare to Figures 8 and 32.

of finer calcareous sand with some silt and clay (Unit 2). These deposits are now interpreted as the glaciofluvial deposits of the late Wisconsin overlain by sediments of uncertain age. They have the stratigraphic position and composition consistent with a designation as Mallard Island Member of the Oahe Formation (Figure 10).

Overlying these sands is a two part paleosol (Units 3-4) (Figures 23-24). The upper part is dark brown to black. Bone from here has a radiocarbon date of 9,345 yBP. The paleosol is correlated with the Aggie Brown Member of the Oahe Formation and is early Holocene in age. It has not been definitely located elsewhere in the Big Bend Reservoir.

Above the paleosol is about 18 feet of very fine sand and silt (Unit 5) without soil stabilization horizons. This is now interpreted as equivalent to the Pick City Member of the Oahe Formation, of middle Holocene age. The top 6-7 feet of Unit 5 contain at least three soil stabilization horizons in the eolian silt. These appear to correspond to the upper units of the Oahe Formation (Figure 12), designated as the Riverdale Member.

Thus, the full sequence equivalent to the Oahe Formation, as described in North Dakota, appears to be present at Wolf Creek. Sadly, it is not well dated in the barren Pick City equivalent. Archeological correlations provide a rough date for the upper soil stabilization horizon at 1,000 to 1,500 yBP (Coogan and Irving 1959) which is consistent with the scheme in Figures 12 and 10.

Note that the total section above the Pierre Shale is nearly 60 feet thick and that the section above the glaciofluvial gravel is about 56 feet thick. This is five to ten times more deposit of Holocene strata than preserved at Walth Bay, Rousseau or the Rattlesnake sites. Not surprisingly, the multiple erosional events so evident at Walth Bay, Rousseau and Rattlesnake in the post-glaciofluvial sediments are not at all evident here. The Wolf Creek site seems to have been one where deposition predominated during the Holocene. It does have a few soil stabilization horizons. Note that the site lies in a bend of the Missouri River downwind from formerly exposed sand bars, a setting which was probably a contributing factor to its depositional/preservational aspects.

<u>Summary.-</u>

The Crow Creek/Wolf Creek section (39BF11)is the most complete found in the Big Bend Reservoir area, in fact, the most complete found along the Missouri between Yankton, South Dakota and Bismarck, North Dakota. The history of the lower part of the section is consistent with events described at other sites, including the deposition of the glaciofluvial gravels and sands. It's completeness above those deposits points up the incompleteness of the Holocene sections at Walth Bay, Rousseau,

Figure 24. Photograph of a natural gully draining the steep bank at Crow Creek site from the level of the MT-2 surface. A= eolian sand and silt. B= paleosol dated at 9,345 yBP.

Rattlesnake and other sites, in fact, most sites or profiles along the river trench. A comparison of the four localities described also shows that the interpretation of incomplete sections must be responsive to any key stratigraphic surfaces which mark the erosional and depositional events in the Holocene.

"Erosional" Site

General and Sequence.-

Along the left bank of Lake Sharpe, in the Big Bend of the Missouri River in Buffalo County, there is one area worth including as a control section because it contrasts so greatly with the others. It is informally called the "Erosional" Site here because there are no cultural sites nearby, no named creeks or other geographic names and essential no Holocene deposits. It is up river from 39BF42 (Figure 25).

No late Pleistocene or Holocene deposits are found at the Erosional Site. Instead, the hills are formed of outcropping Pierre Shale (Figure 26). This is one of the Pierre Shale "hills" between the Holocene sediment-filled valleys which were preferentially cut during the excavation of the Missouri River Trench by now unseen streams. Put another way, bedrock which is everywhere present under the glacial and post-glacial deposits (Figure 3) outcrops here, either because no glacial deposits were ever emplaced or they have been eroded away. The nondepositional idea is preferred because one can observe that the terrace levels (Figure 26) are cut into the Pierre Shale as socalled "strath" terraces. These have no substantial windblown silt or any sand or gravel on them. Gullies which cut the bedrock appear to be relatively recent.

The area around the "Erosional" Site (Figure 12) illustrates the opposite extreme from the Crow Creek-Wolf Creek site area. All the other named sites and stratigraphic sections observed or measured in the Big Bend Reservoir are intermediate between the situation illustrated by the "Erosional" Site and Crow-Wolf Creeks in terms of thicknesses and completeness of Holocene strata. Other similar examples exist, however. On the right bank of Lake Sharpe, southeast of Joe Creek, the Pierre Shale bedrock is high in the cut bank and covered with a thin veneer of eolian silt on what was the slope of MT-3 before the Lake was developed. The silt in such a situation usually has only the modern soil layer and perhaps one other soil stabilization horizon (Figure 27).

The information summarized from these key sections is grouped into a model of late Pleistocene and Holocene deposition.

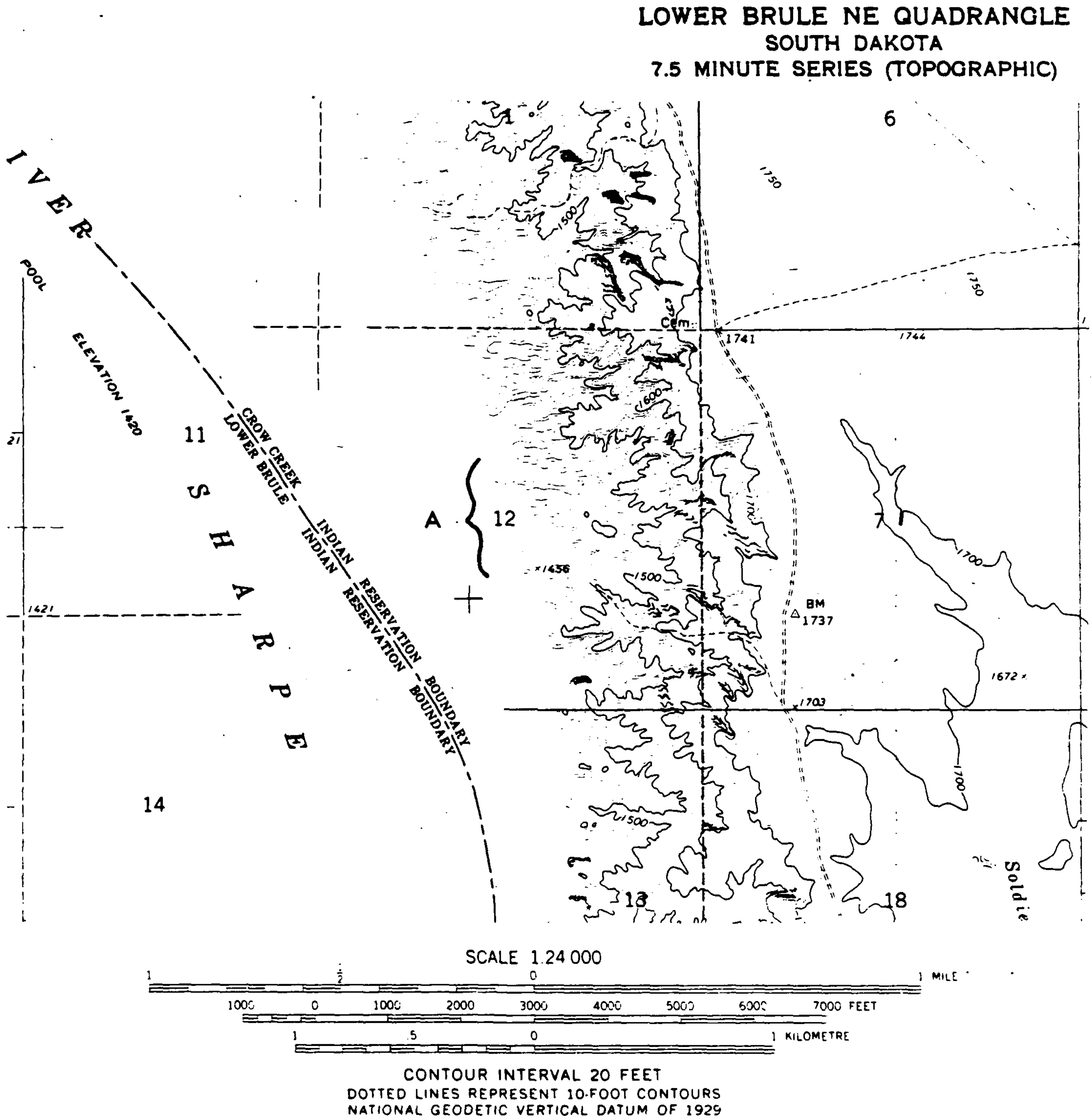


Figure 25. Portion of the Lower Brule, N.E. Quadrangle (U.S.G.S., 7.5 min. topographic) showing (A) the approximate area of the "Erosional" site developed on eroded slopes of Pierre Shale.

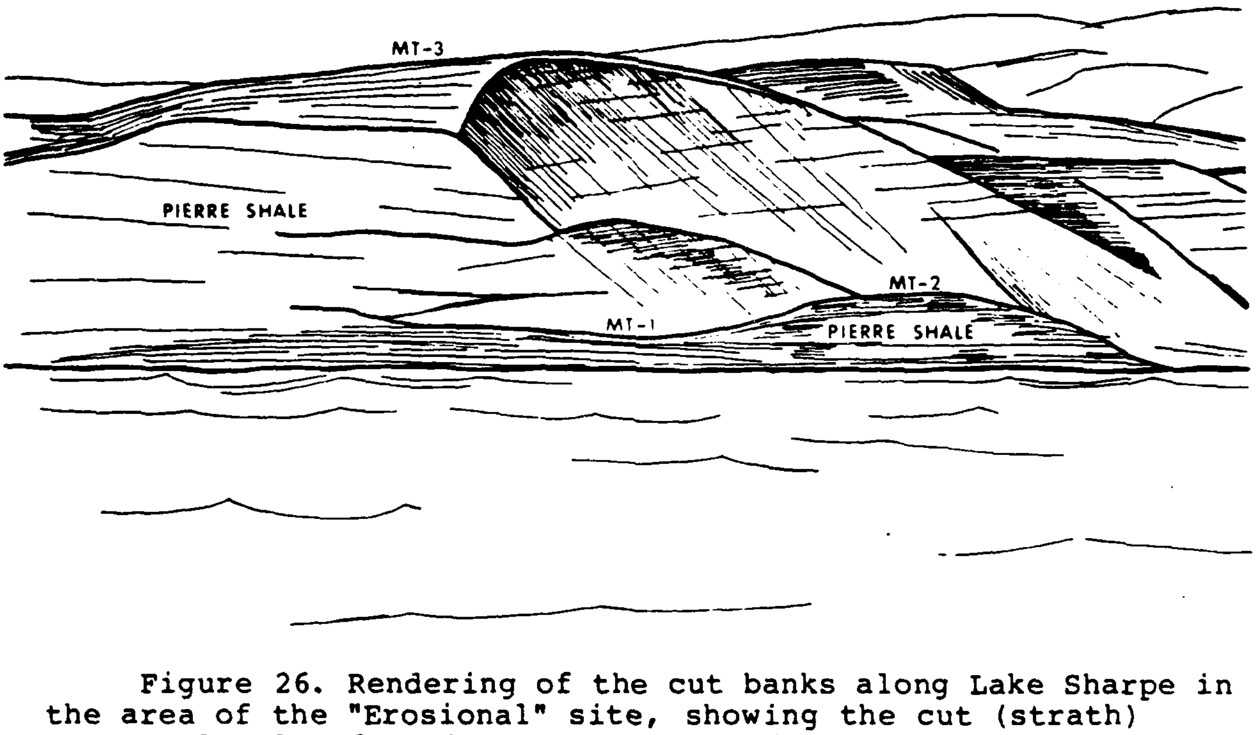


Figure 26. Rendering of the cut banks along Lake Sharpe in the area of the "Erosional" site, showing the cut (strath) terrace levels of MT-1, MT-2 and MT-3 in the Pierre Shale. Note lack of Pleistocene and Holocene sediment on the Pierre Shale.

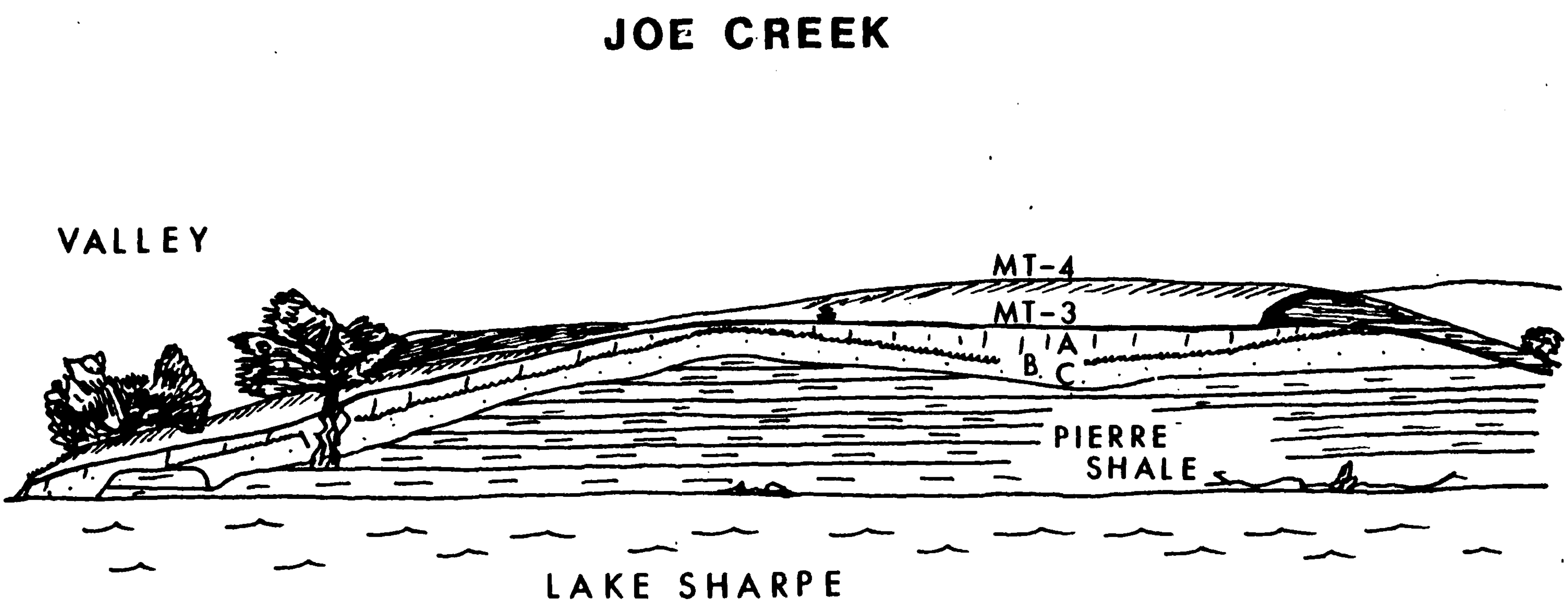


Figure 27. Rendering of the right bank of Lake Sharpe across from Joe Creek, showing the cliff of Pierre Shale overlain by the vertical standing cliffs of Riverdale Silt (A,C) with one prominent paleosol (B). The surface is MT-3 and in the background one can see the MT-4 terrace surface.

LATE PLEISTOCENE AND HOLOCENE DEPOSITIONAL AND EROSIONAL EVENTS IN THE MISSOURI RIVER TRENCH

General

The work by Clayton et al. (1976) together with that reported here provide the basis for a new summary of geologic events which occurred in the Missouri River Trench. The particular focus is on the Late Pleistocene and Holocene strata which contain cultural remains. The dating of the events is less precise than desired, the usual situation in stratigraphy. Revisions may be needed as radiocarbon dates from other controlled sequences become available.

The emphasis here is primarily on the Holocene sequence of events because of the archeological materials found in the Holocene strata. Older units are discussed because they too are observed in outcrop. Before discussing the principal events, several reservations must be kept in mind:

1. There are insufficient radiocarbon dates for control of the age of the members of the Oahe Formation as defined in North Dakota. The same applies to the comparable strata at Crow Creek, in South Dakota which appear to have nearly a complete record of Holocene sedimentation.

2. The lithologic descriptions of some members of the Oahe Formation provided by Clayton et al. are not unique. Variations occur in these units depending on the source of the sediment and the slope on which the deposit was formed. Restated, one may say that there are facies of the formations not present at the type sections.

3. Many of the paleosols (humic horizons) are ill-defined and difficult to recognize in the field.

4. Single stratigraphic profiles and excavations are difficult to interpret without investigation of lateral outcrops.

5. The erosional surfaces within formations are also difficult to trace laterally in some outcrops.

Nevertheless, the general sequence of erosional and depositional events can be pieced together from the previously described sections and other data from the terraces of the Missouri River. The data for the generalizations on sequence are shown in the form of a correlation chart which ranges from the section at Crow Creek to that at the "Erosional" Site (Figure 12). The new depositional model is shown in Figure 28.

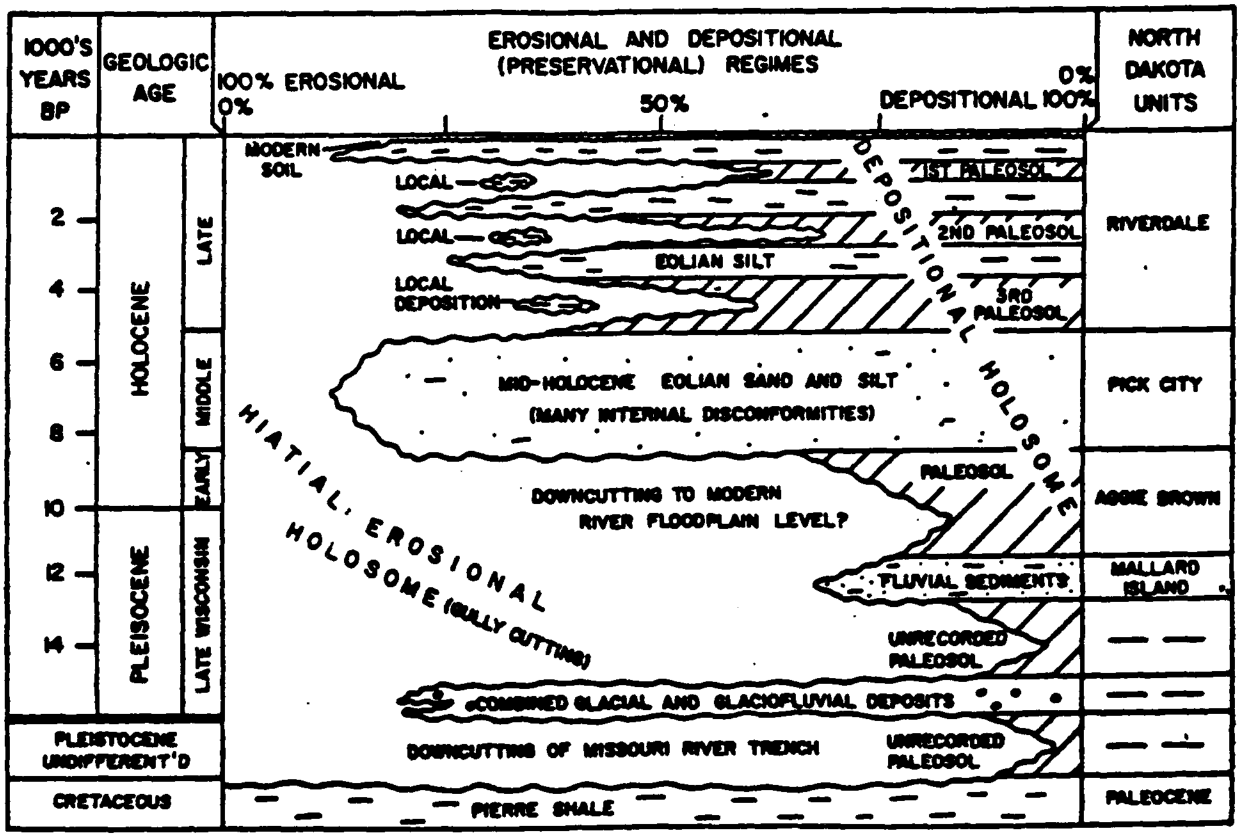


Figure 28. Diagrammatic display of the depositional and erosional-nondepositional holosomes in the Missouri River Trench. Above the Cretaceous Pierre Shale, there are at least three main depositional holosomes. At the base is the glaciofluvial holosome. Over that is the fluvial holosome of late Wisconsin age which stratigraphically is called the Mallard Island. The middle Holocene holosome is the aeolian sand and silt, stratigraphically called the Pick City. Finally there is the middle to late Holocene holosome consisting of three or more, mainly aeolian silt bodies. The depositional holosomes intertongue with the hiatial erosional and depositional holosome. The recorded and unrecorded paleosols represent the depositional equivalents of the erosional holosomes.

Depositional and Erosional Events

Sequence.-

The first major erosional event, of course, was the cutting of the Missouri River trench into the bedrock Pierre Shale. According to Flint (1955), erosion of the trench occurred subsequent to the Illinoian glaciation. In other words, the drainage from the west to east flowing major streams was diverted southward by blockage of Illinoian ice. Further, Flint cites the evidence that the early Wisconsin (Iowan in his terms) till is buried below the floor of the Missouri River flood plain. If true, the main cutting of the trench to a level below present natural stream level occured either near the end of the Illinoian glaciation as melt waters cut down to base level or during the Sangamon interglacial. The surface on the Cretaceous bedrock (or Paleocene bedrock in North Dakota) is one of erosional unconformity as is indicated by vertical lines on the correlation chart (Figure 12).

During the Wisconsin, ice advanced into the trench and deposited till and glaciofluvial outwash. Various deposits can be observed, but the relationships between them and the precise ages of the till and outwash deposits are not known. The interpretative chart shows these deposits as glaciofluvial, Pleistocene undifferentiated, lying above the Pierre Shale at many localities in the Big Bend area. At a few outcrops, deposits of simple fluvial or lacustrine origin can also be seen lying above the Pierre Shale and below clearly Holocene deposits. Finally, slope wash from higher-lying glacial deposits may also be incorporated in the deposits denominated as Pleistocene. Although difficult to differentiate, fortunately little explanation is required from an archeological standpoint because so far no artifacts or other cultural remains have been found in till or outwash.

An erosional break appears to be present between the glaciofluvial, till and fluvial deposits and the overlying late Wisconsin deposits which are themselves transitional with the Holocene strata. The fine calcareous sands present at Crow Creek and those of the Mallard Island member of the Oahe Formation in North Dakota appear to be fluvial. Their occurrence depends on the nearness of the locality to a stream, presumably the Missouri River in most cases, and preservation at a location where deposition was the principal continuing mode.

The Aggie Brown Member of the Oahe Formation, the deeply buried, 9,345 year old paleosol at Crow Creek and other similar paleosols, following Clayton et al.' scheme represent a cool and wet period at the end of the Wisconsin and the beginning of the Holocene. The soil formation should coincide with downcutting, that is, with an erosional event. Field observations indicate that the soil is found developed mainly on sandy materials. It's lateral extent at any outcrop is limited.

If coincident with an erosional event, as appears to be case of soils at other sites, then there may be an additional break in the depositional sequence between the Mallard Island Member and the Aggie Brown Member. Accordingly, the lower paleosol at Walth Bay is correlated with the Aggie Brown and the sand underneath it may be a Mallard Island equivalent. It would appear that the early Holocene and late Wisconsin were a time of mainly downcutting streams. If the Aggie Brown has an origin as a forest soil, as suggested by Clayton et al. it would not be expected to develop uniformly over the land and consequently its infrequent recognition is to be expected.

The major depositional event of the Middle Holocene is recorded as the eolian deposits of the Pick City Member of the Oahe Formation in North Dakota. Some remnant of the deposition of this windblown sand and silt is found at almost all localities where the Pierre Shale had been eroded by creeks into small valleys which entered the Missouri River. The thickness of the sand or silt, of course, depends on the amount of supply available, the amount deposited and its preservation. Deposition and preservation as a stratigraphic unit depend in part on the amount of coincident wind erosion during the several thousand years of the dry and warm middle Holocene period. Also important are the slope on which the windblown sediment was deposited and subsequent erosional events in the late Holocene. The texture of the unit varies from cross bedded fine sand to silty sand. Additional contributions of pebbles and cobbles were made from slope wash. Because overlying depositional units may also be somewhat sandy, as are the underlying ones, these Pick City equivalent deposits can not be distinguished solely on the basis of lithology. Instead, one must establish the sequence of units at a given site and the location of erosional breaks and from these work out a sequence of events for correlation. In the alternative, radiocarbon dates and cultural stratigraphy assist in identification. The eolian sands and silt are not the locus of abundant cultural materials found in place to date.

A substantial period of erosion, documented at several localities, occurred in the late Holocene. At least part of the erosion occurred at the time of formation of a paleosol or just before its formation, at about 3-4,000 yBP. This is approximately equivalent to the Lower Riverdale Member of Clayton et al. The erosion is displayed in the form of small gullies which cut into the underlying windblown sand and silt, especially on hillsides with considerable slope. Archeological sites with materials of Archaic or Woodland tradition are found associated with this surface.

The uppermost portion of the Holocene section, called middle and upper Riverdale by Clayton et al. represents the time when windblown silt was deposited as nearly vertical standing cliffs along the banks of the Missouri River and in the mouths of creeks entering the river. This upper silt cap contains one or more soil stabilization horizons or faint paleosols which may merge with the modern soil on slopes. Late Holocene gullying cuts out the lower units down to the Pleistocene glaciofluvial gravels. The top of the silt cap, however, appears in many places to follow the slope of the most recent gullies, as does the modern soil. The gullying appears to have begun in the period coincident with the deposition of the upper Riverdale sediments and continues to the present time. The paleosols are discontinuous, owing both to lack of formation of the soil and to lack of preservation or erosion. Many of these modern looking gullies predate the arrival of western farming practices into the Dakotas.

Depositional and Erosional Holosomes

Theoretical papers on time-stratigraphic correlation include a consideration of depositional and erosional units through time (Wheeler, 1958, Mitchum, et al., 1977). When lithostratigraphic units are plotted against time as the vertical axis and distance as the horizontal axis, through a sequence with adequate chronologic control, a two-dimensional display of the total space-time volume appears. Such a display (Figure 28) shows the late Pleistocene and Holocene tangible stratigraphic record, as presently understood, delineated in three-dimensional space. It incorporates not only the material, preserved record, but also those nonmaterial parts of the total space-time volume represented by nondeposition and erosion. Within the space-time continuum are sequences of material stratigraphic units bounded by unconformable surfaces. Laterally across the diagram (Figure 28) one sees intertonguing time-stratigraphic bodies called holosomes. The holosomes are of two types---depositional and hiatal (including nondepositional and erosional). The hiatuses, the erosional and nondepositional breaks, join in areas which are predominately erosional. Note that no vertical thickness is implied or stated for any of the material bodies.

During the interval from the late Pleistocene to modern times, at least three major depositional sequences are interpreted from the stratigraphic record of the terrace deposits in the Missouri River Trench. The earliest of these is a combined glaciofluvial, till and fluvial depositional system which is poorly delineated in detail. It is bounded below by the part of the hiatal holosome developed during the downcutting of the Missouri River Trench. It is doubtless a composite depositional unit, only part of which is displayed here. Above, it is bounded by the late Pleistocene erosional episode which caused the gullying of the glaciofluvial deposits. The exact time-stratigraphic extent of the erosional period is not known.

The next main depositional sequence is bounded on its lower surface by an erosional unconformity or by a paleosol. Theory suggests that the Mallard Island unit should not be part of this depositional sequence and consequently it is shown as part of a separate thin depositional holosome (Figure 28). The main body of this middle Holocene depositional sequence is the eolian sand and silt deposited during the dry and warm period.

It is terminated by an erosional unconformity or paleosol developed near the beginning of the late Holocene.

The third main depositional sequence is developed in the late Holocene. Its lower surface is an unconformity or a paleosol; its upper surface is the modern landscape. If better dating were available, it might be split into two main sequences marked by the intervening gullying period within the late Holocene.

As the illustration (Figure 28) suggests, the predominate regime during the Holocene was erosional or nondepositional. Thick deposits of Holocene strata are uncommon. Furthermore, the intervening erosional events tend to place unrelated stratigraphic units on top of one another. For example, parts of the highest depositional holosome may lie directly on the glacial gravels of the lowermost one or in fact on the Cretaceous Pierre Shale. In addition, parts of the lowermost, late Wisconsin Holosome or the Pierre Shale may be the surface unit and all of the younger depositional units B may be lacking. While almost any combination is possible, it is common that where parts of the middle, predominantely eolian depositional sequence are preserved, these are capped by parts of the uppermost sequence.

The stratigraphic task at any given locality is to recognize and separate the various depositional sequences to aid in dating cultural materials. The key to the analysis lies in recognizing the erosional surfaces and paleosols which subdivide the sequences. The results of such an analysis are suggested in the summary of the Walth Bay and Rousseau sites (Figures 15, 16 and 19). Moreover, these surfaces are important to the archeologist who is excavating deeply buried sites. The surfaces of erosion and the paleosols were once the surface of the land. As such, they are preferentially the site of archeological materials because the materials were more likely to have been left on such surfaces and because sediment accumulation, if any, was slower. Archeological materials are more likely to be concentrated on such surfaces or in the paleosols and consequently be more readily recognized and "richer".

From a stratigraphic standpoint, the depositional holosomes can be designated as allostratigraphic units, i.e. as mappable stratiform bodies of sediments defined and identified on the basis of their bounding disconformities. As such, they would be different in concept from the Oahe Formation and its members. From a practical standpoint the designation of formal allostratigraphic units would not add substantially to the recognition of sedimentary bodies or their interpretation. The principal task is still the recognition, dating and interpretation of traceable surfaces which leads to an understanding of the sedimentary unit and its contained archeological materials.

MISSOURI RIVER TERRACES AND THEIR GEOLOGIC HISTORY

General

The five easily discernable and mappable terraces of the Middle Missouri River between Fort Thompson and Pierre are described and illustrated in Figure 3. This section discusses the history of the terraces and the variations in their composition and their elevations along the river.

MT-4-Coteau du Missouri.- This terrace is a broadly sloping remnant of the landsurface before downcutting of the trench. It lies at elevations about 1,700 feet above sea level or about 300 feet above the pre-dam elevation of the Missouri River. The type area is east of Joe Creek (Figure 7) where it is mantled with glaciofluvial outwash, large granitic erratics and possibly some till. It grades gradually upslope to the broad expanse of the Coteau, the gently rolling uplands adjacent to the river. The age of the development of the cut surface on the Pierre shale can only be estimated from Flint's (1955) assertion that the diversion of the Missouri drainage took place after the Illinoian glacial advance. The terrace is mantled and modified by subsequent glacial advances into the trench. For example in the Joe Creek area, the surface which includes the MT-4 terrace is mapped by Flint as mantled by Iowan (early Wisconsin), or Tazewell (Wisconsin) drift which must be the source of the large glacial erratics which are commonly seen on it. These glacial stage names are not as widely used now as at the time of Flint's mapping, but for the purpose of this discussion, it is sufficient to note that the cut surface is covered in part by glacial materials. It is important to contrast MT-4 with the lower surfaces by emphasizing that it is a cut terrace.

MT-3.- This terrace is also a broadly sloping remnant of Pleistocene downcutting of the trench. It lies at elevations of about 1,520 to 1,560 feet above sea level or about 200 feet above the pre-dam level of the Missouri River. The type area is east of Joe Creek in the west bend of the Missouri on the left bank near Hidden Valley (Figure 7). Like MT-4, MT-3 may be mantled with glacial or glaciofluvial deposits. Its age is obviously younger than MT-4, but how much younger is not known. Glacial erratics also occur on MT-3, but not everywhere. MT-3 also is mantled with a silt cap of Holocene age, the stratigraphy of which is similar to that found on lower terraces, especially on MT-2.

The lower slope of MT-3 is commonly eroded to such an extent that the Pierre Shale crops out in a black band between the upper slope edge of MT-2 and MT-3. Solitary and groups of erratic boulders of granite and gneiss from glacial debris mantling MT-3 have rolled or been let down onto the Pierre Shale. The strath terrace cut into the Pierre Shale can also be seen as a bare, unmantled cut surface (Figure 26). Cut banks along Lake Sharpe where MT-3 intersects the lake commonly show steep, high banks of bedrock Pierre Shale mantled with a thin silt cap (Figure 27). Channels can be seen which cut into the Pierre Shale, the larger of these are the valleys described previously and which are filled with glaciofluvial sands and gravels and capped by Holocene strata. In contrast to the lower lying terraces, MT-3 is a cut terrace.

MT-2.- This terrace is the most continuous, widespread and readily recognizeable of all the terraces of the Missouri River. It may be seen throughout most of the stretch between Fort Thompson and Pierre. It is the site of numerous Plain's Village occupations. It is present at Chamberlain and down river. Above the Oahe Dam at Pierre, it is submerged by lake waters, but reappears near Mobridge, South Dakota. In the Lake Sharpe area, it lies at elevations of about 1,420-1,460 feet above sea level or about 80-100 feet above pre-dam Missouri River level. The type section is at Crow/Wolf Creeks, previously described in this report and in Coogan and Irving (1959).

All major creeks in the Big Bend Reservoir area have terraces which are graded to MT-2. Although the lower parts of these are under Lake Sharpe near Fort Thompson, the upper portions can be seen upstream in Soldier Creek, in a spectacular display in Antelope Creek (Figure 31), south of Pierre and in Medicine Knoll Creek (Figures 29-30). The grading of the creeks to the level MT-2 in the Missouri River indicates a rise in water level of the trunk stream. In other words, there are stream deposits, and perhaps lake deposits, which make up the fill of MT-2. These underlie the Holocene silts and sands. The creeks entering the Missouri River were "filled up" with the sediments of the MT-2 fill.

Consequently, the MT-2 terrace can be characterized as a cut-and-fill terrace, unlike the higher lying cut terraces. The evidence of the cutting and filling is present in the creeks to elevations as high as 1,580 feet. The cut-and-fill terrace is seen as a broad flat along the stream sides which is incised by subsequent downcutting of the Missouri River in post-glacial times.

The origin of this process of cutting and filling which caused the formation of MT-2 and then caused the subsequent cutting has been a subject of discussion for several decades. Recall that Flint (1955) correlated the terraces called MT-2 and MT-1 to the Cary and Mankato glaciations. Coogan and Irving (1959) accepted that correlation but wondered (privately) how the mechanism of cutting and filling could be fit into a scheme of climatic change such as subsequently outlined by Clayton et al. (1976). The answer now offered here is that the terrace fill, graded to a higher level of the Missouri River, is not part of a cycle of glacial-inter-glacial stages or events. Neither is it part of a climatic cycle of wet and cool versus dry and warm period. Instead, a unique solution is suggested which involves the blocking of the Missouri River by ice in the area of Yankton, South Dakota. Such a blockage was first suggested by Flint (1955)

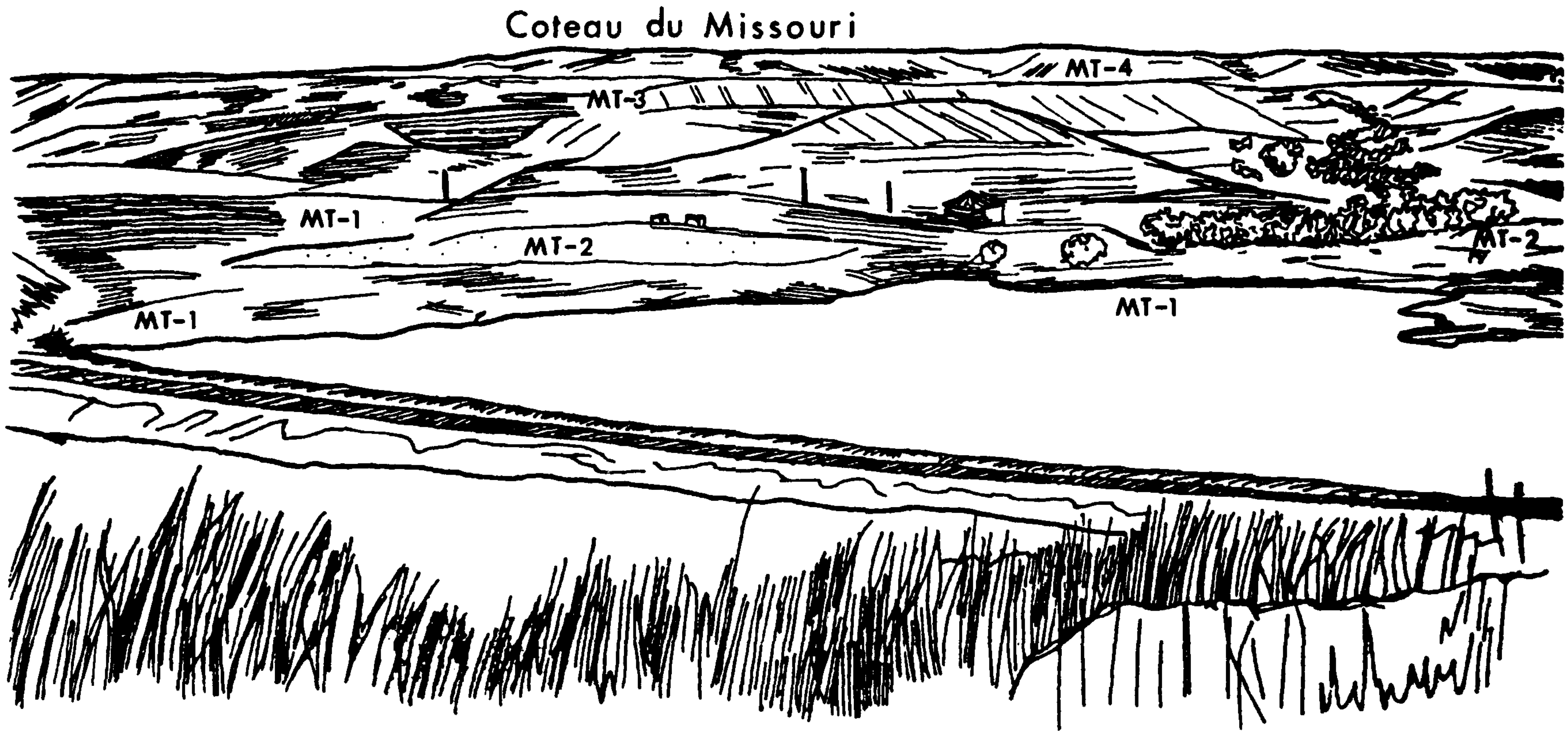


Figure 29. Rendering of the terrace sequence, looking northwest, as displayed along the valley of Medicine Knoll Creek, Hughes County. All the terrace levels can be observed from the Lewis & Clark pavilion, just off South Dakota Route 34 at the Roadside Park. See Figure 18 for location.

Figure 30. Photograph of terrace sequence similar to rendering (Figure 29) from Medicine Knoll.

ANTELOPE CREEK AT BRIDGE

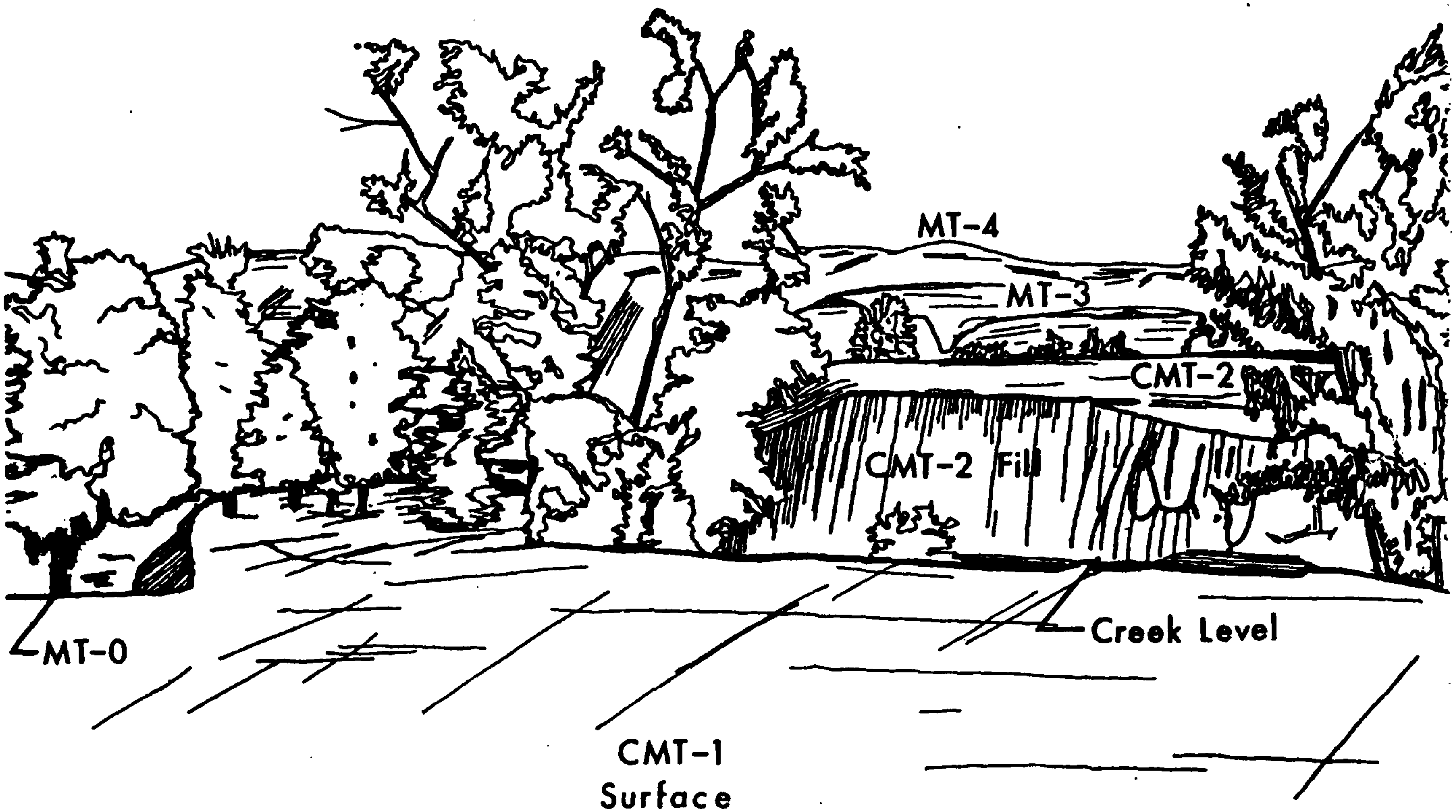


Figure 31. Rendering of terrace sequence in Antelope Creek at bridge near mouth of creek, just south of Fort Pierre, S.D. on the west bank of the Missouri River. Terraces of the creek (CMT-1 and CMT-2) are shown with the river terraces behind (MT-3 and MT-4).

who noted that the glacial deposits mapped by him as Cary crossed the Missouri River west of Yankton in Bon Homme County, South Dakota (Flint, 1955, Figure 29), as did the later Mankatô ice.

Geological reconnaissance in the Yankton area and study of relevant maps appears to confirm the presence of the glacial tills on the south side of the river, that is in Nebraska. The elevation of the topographic surface formed by this ice sheet which Flint called Cary (Figure 32) east of Bon Homme Colony in South Dakota and between Devil's Nest Recreation area and Miller Creek recreation Area in Nebraska is at or above the 1,400 foot elevation level. Bonne Homme Colony is located at a lower elevation, consistent with the ice sheets Flint called Mankato.

Regardless of the exact age or proper ice sheet identification, it does appear reasonable that the late Pleistocene ice advance into the Missouri River Trench near Yankton could have dammed the Missouri River creating a lake at or above the 1,400 foot elevation level. The filling of this lake with fluvial and lake deposits and wave action in the lake would have produced a broad flat at or near that level. Furthermore, streams entering the Missouri River would have had a base level adjusted to this higher lake level.

In the West Bend area (Big Bend Reservoir), the downcutting of the river subsequent to the formation of MT-2 can be seen to have occurred in two stages with a bluff separating the two consequent levels. The broad expanse in the West Bend and on the bend of the "neck" of the Big Bend also shows evidence of sand dunes on MT-2. The source of these sands is probably the sediments deposited on MT-2 during the high stand of the river. There is also some evidence of lake deposits in the fill of MT-2 at 39HU242 (Whistling Elk) site. The clays interpreted as lake deposits are interbedded with and overlain by fluvial sands.

MT-1.- This terrace is less prominent than MT-2. It formerly could be seen along a considerable stretch of the river between Fort Thompson and Pierre, but now is mainly covered by the waters of Lake Sharpe. The type area at Lower Brule is now under water. It was along a cut bank of the Missouri River on the right bank (Coogan and Irving, 1959). The terrace can be seen today at Crow Creek (Figures 23, 33) a small nose extending off the high bluff of MT-2. Northwest along the river, MT-1 becomes lower in elevation with regard to the elevation of the pre-dam Missouri River. The terrace is difficult to discern in the Pierre area, but is the main flat on which Fort Pierre is located. At the Fort Thompson dam, in the tail race, MT-1 occurs at an elevation of about 1,390-1,400 feet or about 35-45 feet above the pre-dam level of the river.

MT-1 is also a cut-and-fill terrace as can be clearly seen at Crow Creek on the lake edge side (Figure 33). Following the reasoning for the cut-and-fill origin of MT-2, it is suggested that MT-1 may have formed either as the result of a blockage of the river by the lower lying ice sheet called Mankato by Flint

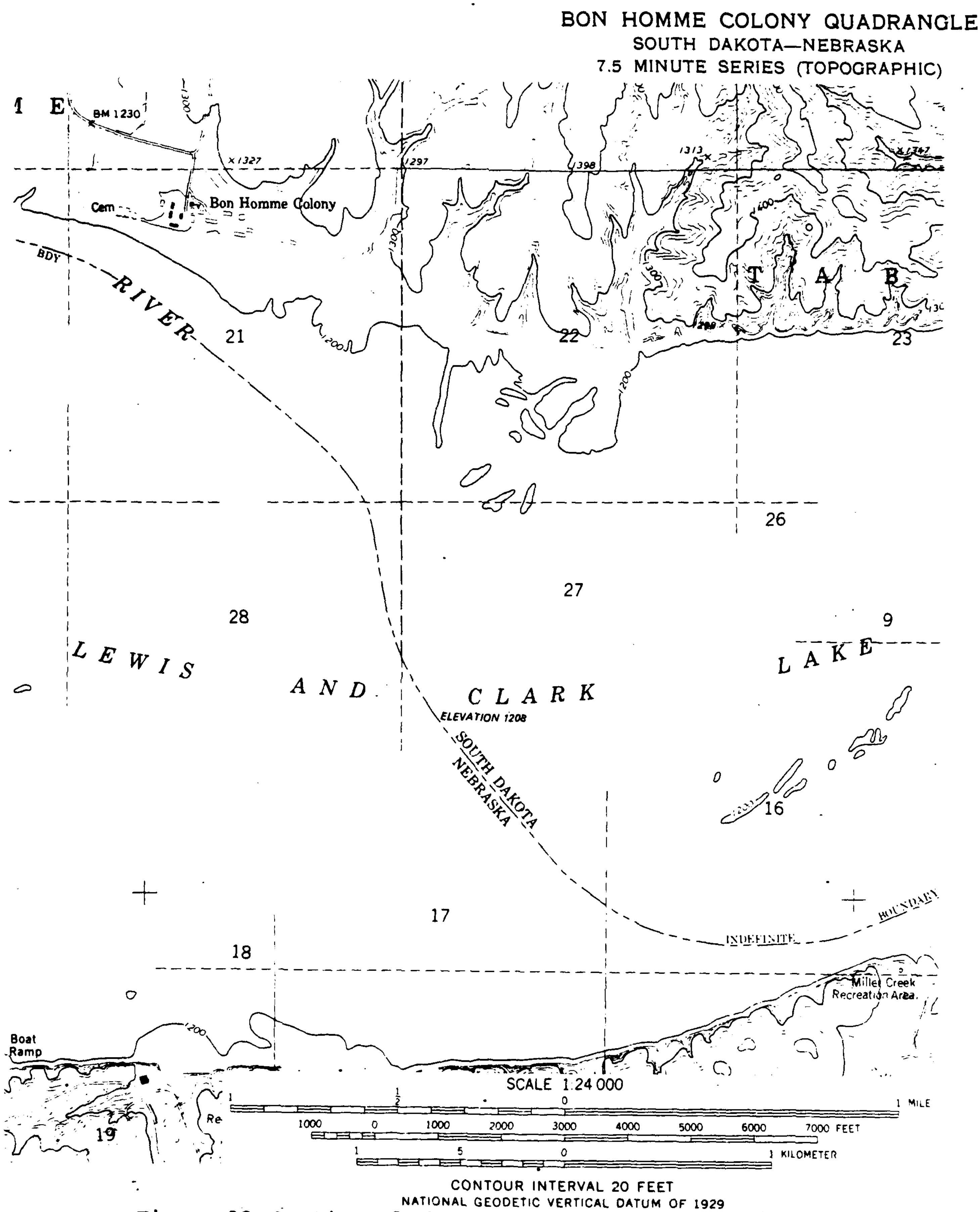


Figure 32. Portion of the Bon Homme Colony Quadrangle (U.S.G.S. 7.5 min., topographic), South Dakota and Nebraska, showing the elevation of the surface north and south of the Missouri River (now Lewis & Clark Lake) at the 1,400 foot level, which is mantled with Cary glacial deposits.

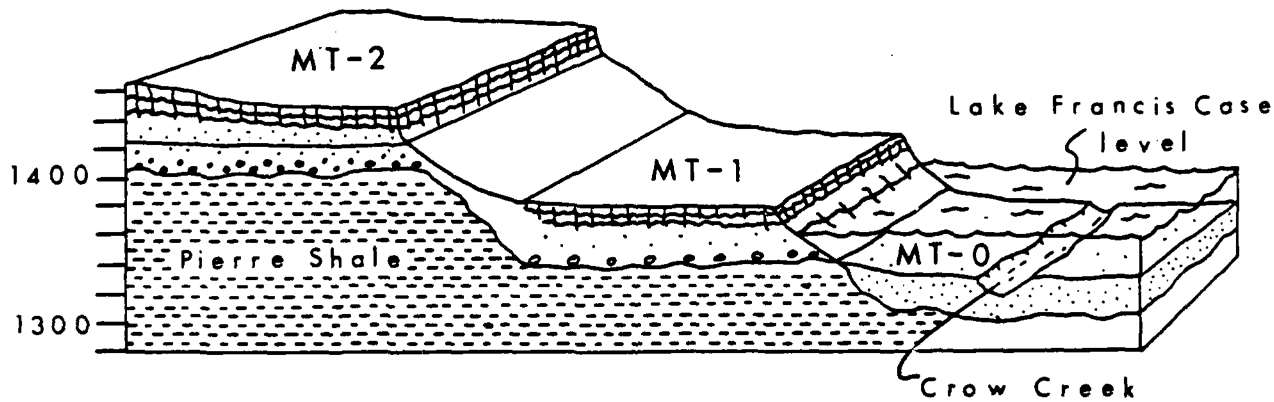


Figure 33. Diagramatic cross section of the Mt-0 to MT-2 terraces, At Crow Creek, adjacent to Lake Francis Case showing the underlying bedrock Cretaceous Pierre Shale excavated to various levels, overlying gravels and sands on MT-1 and Mt-2 and overlying silt bodies with paleosols. Terrace MT-0, the modern flood plain of the Missouri River and Crow Creek near it mouth is shown without paleosols and in its post-dam building, flooded position.

who noted that the glacial deposits mapped by him as Cary crossed the Missouri River west of Yankton in Bon Homme County, South Dakota (Flint, 19555, fig. 29), as did the later Mankato ice.

Geological reconnaissance in the Yankton area and study of relevant maps appears to confirm the presence of the glacial tills on the south side of the river, that is in Nebraska. The elevation of the topographic surface formed by this ice sheet which Flint called Cary (Figure 32) east of Bon Homme Colony in South Dakota and between Devil's Nest Recreation area and Miller Creek recreation Area in Nebraska is at or above the 1,400 foot elevation level. Bonne Homme Colony is located at a lower elevation, consistent with the ice sheets Flint called Mankato.

Regardless of the exact age or proper ice sheet identification, it does appear reasonable that the late Pleistocene ice advance into the Missouri River Trench near Yankton could have dammed the Missouri River creating a lake at or above the 1,400 foot elevation level. The filling of this lake with fluvial and lake deposits and wave action in the lake would have produced a broad flat at or near that level. Furthermore, streams entering the Missouri River would have had a base level adjusted to this higher lake level.

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MT-1 is also a cut-and-fill terrace as can be clearly seen at Crow Creek on the lake edge side (Figure 33). Following the reasoning for the cut-and-fill origin of MT-2, it is suggested that MT-1 may have formed either as the result of a blockage of the river by the lower lying ice sheet called Mankato by Flint where, near Yankton, it approached the river or it may be related to a dam formed by a lower elevation readvance of the ice sheet called Cary.

MT-1 is not recognized north of the Oahe Dam at Pierre, South Dakota now. It is calculated that if it is a level related to a Pleistocene lake, its surface would merge with the flood plain terrace surface (MT-0) between the site of the Oahe Dam at Pierre and the site of Whitlocks Crossing of the Missouri River. The reason for the merging of these two surfaces is the difference in the gradient of the river at different times.

Downcutting of the Missouri River from the level of MT-1 occurred near the end of the Pleistocene. The downcutting may coincide with the formation of the major paleosol at Crow Creek and the one called Aggie Brown in North Dakota, or both.

A panoramic view of a series of the terraces (Figures 29-30) can be seen from the Lewis & Clark shade pavilion, above the Rousseau site, on the banks of Medicine Knoll Creek in Hughes County, South Dakota. A rendering of that view, looking northwest, is shown in Figure 30. There, the creek equivalent and extension of MT-1, is just above the lake embayment level in the creek. MT-2 is higher and marked by the location of a school. MT-3 is on the far hill and forms a broad flat which is farmed. Mt-4 is seen as a riverward sloping flat lying below the high-plains level of the Coteau du Missouri. Topographic maps show that the later two grade one into another back from the "breaks" of the Missouri River.

<u>**MT-0**</u>.- This terrace is part of the flood plain of the Missouri River (Figures 3-6). Before dam construction, exceptionally high water covered all of the surface, but normally this flat bottom land stands at 10-15 feet above the river level. The islands in the river are considered part of the terrace. Since the construction of the dam at Fort Thompson, MT-0 can be seen only in the tail race areas of Fort Thompson and Oahe Dams. The extent and complexity of the flood plain terrace can be seen, however, on the U.S. Corps of Army Engineer's maps from the 1940's.

The flood plain terrace consists of typical fluvial sediments. No units older than Holocene are exposed at the surface, but drill cores made for dam excavations reveal that older Pleistocene deposits exist in the river trench (Flint, 1955, Coogan and Irving 1959, Figure 34). Physiographically different parts of the flood plain terrace can be recognized from early maps and photographs which may represent older and younger parts of the terrace. Clearly, the youngest depositional parts of MT-0, before dam construction, were as young as the last flood. The oldest parts of MT-0 exposed at the surface are not known. However, it is clear from many archeological investigations that Plains's Village and Woodland sites (Newman, 1957) are common on the flood plain as are historical sites dating from the time of Lewis and Clark.

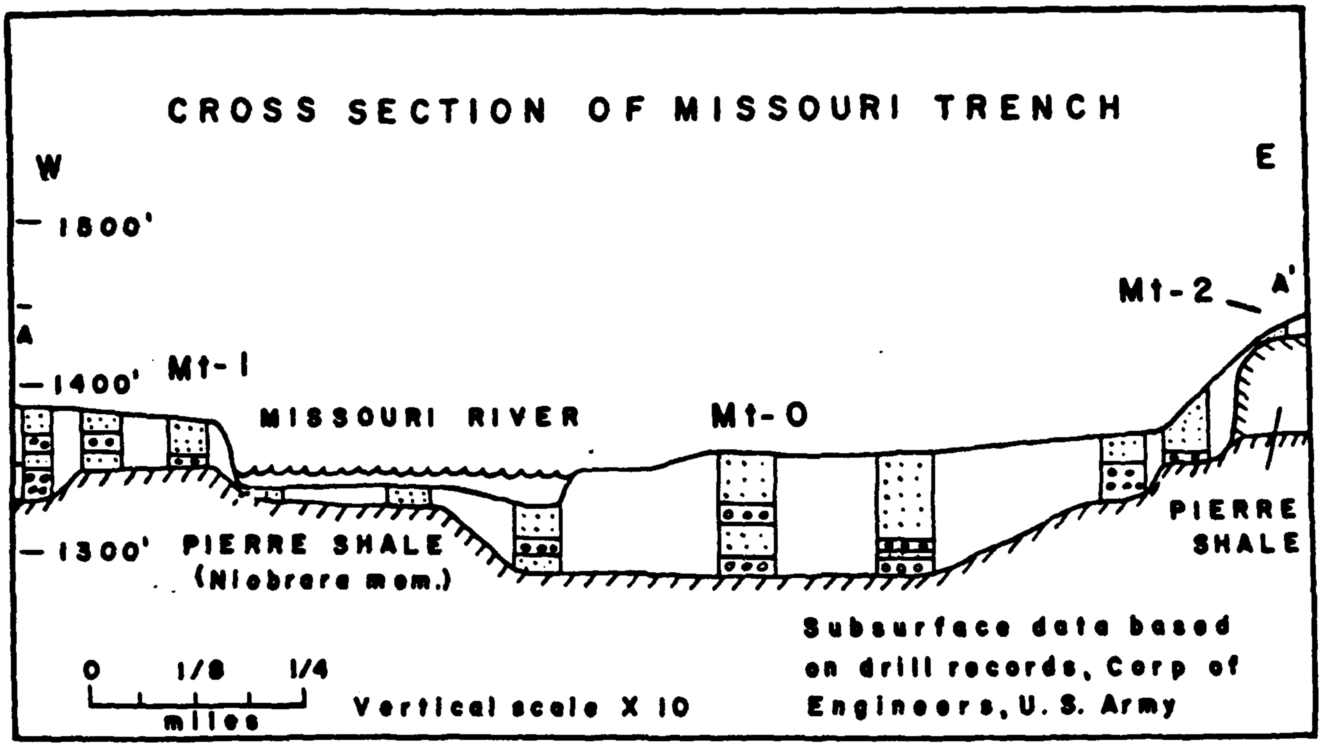

Figure 34. Cross section of the Missouri River Trench based on U.S. Corps of Army Engineer's records of drilling at the Fort Thompson Dam site.

The conclusion by Coogan and Irving (1959) that the cutting of the Missouri River Trench might be as young as middle Holocene now seems unfounded. The evidence simply points to a much older primary cutting of the trench to depths below the present level of the flood plain because ice-contact deposits are found in the trench, e.g. near Pollock, South Dakota (Flint, 1955).

From an archeological standpoint, the flood plain terrace is simply a historical fact. Little of it is exposed anywhere between Yankton and Bismarck. It does serve, however, as a constant reminder of the complexity of depositional events of more or less contemporaneous nature which one wishes to use as a model to project into the past. The timing and events which caused the deep cutting of the trench remain unknown but are geologic events worthy of explanation.

CONCLUSIONS AND TIME-STRATIGRAPHIC MODEL

General

The Holocene sediments which thinly mantle the terraces and bedrock of the Missouri River Trench contain all the presently known, deeply buried, archeological sites. The oldest surface on which Paleoindian materials have been found is the glaciofluvial outwash surface. This surface may be deeply buried or exposed at the surface.

The predominant regime during the Holocene was erosional. Deposition and preservation of the deposit in any substantial volumetric sense is the exception. This has certain implications for archeological work in these Holocene strata. It means that ancient sites may be discovered at or near the surface or may be deeply buried. It means that if a section of several meters of Holocene strata are preserved with artifacts, the depth from the surface to the occupation level is not an accurate or even rough estimate of the age of the site because the section may have been eroded at one or more times during the Holocene. It means that the key to understanding and using natural stratigraphy in support of planning and clarifying the context of sites is the recognition and tracing of surfaces, especially erosional surfaces and paleosols.

Improvements in constructing a stratigraphic framework for individual sites and for the whole of the Holocene record of the Missouri River Trench will depend on combined analysis of natural stratigraphy using surfaces of depositional units, archeological stratigraphy and radiocarbon dates. The direct, simple and easy solution to stratigraphic understanding will not work because in the Holocene sediments of the Missouri River Trench it is unfortunately true that "deep is not old, shallow is not young and depth is not time".

A Time-Stratigraphic Model

As an incentive to new observations, a theoretical model of erosional and depositional regimes in the late Pleistocene and Holocene has been constructed (Figure 28). The model shows the distribution of depositional units (gravels, sands, silts) laterally across the diagram on a scale of 0-100% depositional regime for a given area in the Missouri River Trench terrace sequences. Erosional units (blank areas of no deposits and of paleosols) are shown on the same scale. The vertical scale is time, not thickness. Several hiatal and depositional holosomes are recognized.

A few remarks are worth making. The horizontal, flat and wavy lines between depositional units are bedding planes and erosional surfaces, respectively. If bedding planes, they are for all practical purposes synchronous lines. If erosional, they are time-transgressive.

Because paleosols are seen to have been formed in wet and cool periods (Figures 10, 11, 13) at times of downcutting of streams and gullies by running water, paleosols are time equivalents of erosional periods; that is, they are compressed, botanically-induced, depositional equivalents of erosion. Paleosols should have less aerial distribution than depositional units because of botanical influence, topographic influences and because their preservation requires the preservation of a surface by a subsequent depositional event. The diagram shows soils splitting with time. The splits seen in outcrops appear to be related to small depositional events (local sedimentation of eolian deposits during the predominately wet and cool periods). These local depositional events are shown by small enclosed sediment patches within the hiatal holosome (Figure 28).

If the theory is correct, soils formed in the interval when the river cut the Missouri River Trench and in the interval when late Wisconsin erosion cut down from MT-2 to MT-1 and to the present Missouri River flood plain level. Paleosols have been drawn into the diagram for these complex, ancient and long periods of erosion, but have not been recorded in the field. The strong iron-stained upper portions of glaciofluvial gravels and their cementation seems evidence of a soil having been on that surface at one time, e.g. at Walth Bay and the Rattlesnake Site.

The diagram does not illustrate the joining of separate paleosols, one with another or with the modern soil, a phenomenon commonly seen, because it would require a more complexly drafted diagram.

The number of paleosols in the Riverdale sequence should number three according to Clayton et al. (Figures 11, 13). Four have been recorded at Jones Bay, near Pollock, South Dakota, probably because of sediment deposition during an erosional period and the formation of a "split". The minimum number of paleosols, of course, is zero.

The younger part of the late Pleistocene and Holocene sequence is better preserved, as expected, and that is shown on the model diagram by having the Riverdale units extend past the 50% erosional/depositional line. To the extent that the diagram realistically portrays Holocene events along the terraces of the Missouri River in central South Dakota, any given profile along the river can be constructed theoretically by taking a vertical sequence of erosional and depositional events and assigning a thickness to the depositional ones plus the paleosols. On the other hand, to interprete a specific profile, one must recognize and trace the paleosols and erosional surfaces equivalent to them and use these to subdivide the depositional bodies into time-stratigraphic depositional units.

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