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The biogeography and geomorphology of the Niobrara River Valley near Valentine, Nebraska.

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THE BIOGEOGRAPHY AND GEOMORPHOLOGY OF THE NIOBRARA RIVER VALLEY NEAR VALENTINE, NEBRASKA

A thesis
Presented to the
Department of Geography-Geology
and the
Faculty of the Graduate College
University of Nebraska

In Partial Fulfillment
of the Requirements for the Degree
Master of Science
University of Nebraska at Omaha

by
Paul J. Hearty
May 1978

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Accepted for the faculty of the Graduate College of the University of Nebraska at Omaha, in partial fulfillment of the requirements for the degree of Master of Science.

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THE BIOGEOGRAPHY AND GEOMORPHOLOGY OF THE NIOBRARA RIVER VALLEY NEAR VALENTINE, NEBRASIA

ABSTRACT

By

Paul J. Hearty

Within the study area located near Valentine, Nebraska, the Niobrara River is deeply entrenched in Tertiary siltstones and sandstones, and covered with Pleistocene and Holocene eolian deposits of sand and loess. The 100 m depth of the valley reflects this entrenchment. Periods of equilibrium of the river are indicated by the numerous benchlands that lie within and adjacent to the valley. Mass wasting in the form of landslides and creep significantly alter the form of these terracelands when it is combined with the shifting of the river and saturation by groundwater. Many of the terraces have been correlated with climatic events of the Pleistocene and Holocene epochs. There is some evidence of uplift in the area. The stratigraphy of the low terraces reflects the overall downcutting interspersed with periods of aggradation.

Some elements of the vegetative community are unique to the grasslands, to Nebraska, and to the Great Plains. Representatives of the Rocky Mountain, eastern deciduous, and northern forests interact with variables of topography, stratigraphy, and microclimate. Active landslides and newly exposed terraces are revegetated in a definite

sequence from annuals to hardwood forests or to grasslands in some cases. The parallel zones of woody vegetation on the right bank is disrupted by mass wasting events. The paper birch is a Pleistocene relic and thrives in the valley under stringent habitat requirements such as north facing slopes, springs, and shade of other trees.

The results of this study are numerous and diverse. However, in synthesis, they present a concept of the dynamic interaction of the physical and biological factors in the area. From these individual factors, a grander hypothesis was formulated that describes the Niobrara River as the principal contributor of sand in the formation of the Nebraska Sandhills.

ACKNOWLEDGEMENTS

The completion of this project would have been impossible were it not for the help of many people. My sincere gratitude is extended to all who helped, mentioned here or not. Special thanks go to the Wayne Sharp family who provided a campground on their land but most of all for their friendship and hospitality. Dr. John Shroder and the Geography Department at the University of Nebraska at Omaha provided a camper in which I was able to work and sleep in comfort. Dr. Shroder aided greatly in the conception and completion of this paper. To him, and to my other advisors, Drs. Bariss and Sharpe, I extend my gratitude. Dan Miller gave his time and energy to assist in the field and stimulated thought throughout. Many thanks go to Mark Laustrup and Dr. Rundquist who provided maps and other help. Finally and most of all, I thank my parents Fred and Josephine Hearty, my sisters, Chris and Eileen, my friends Nancy, Ted, dear Sarah Newman, and Butch Matthews who provided money and help (both physical and mental) throughout this oversized undertaking.

INTRODUCTION

The Niobrara River, like most rivers of the Plains, reflects the Cenozoic history of the area in its geology, geomorphology, and paleontology. The vegetation, for the most part, has developed into its present distribution since the end of the Quaternary. This study will deal primarily with the geomorphology and vegetation of the area. Hypotheses have also been generated from this research on the relationship of the Niobrara River to the neighboring Sandhills which are a constant source of interest to many Quaternary scientists.

The geology of the study area is typical of a large part of the High Plains, being composed of the White River and Ogallala Groups of the Tertiary period. The terraces of the study area resemble terrace sequences of many other river valleys of the Plains. The vegetation, on the other hand, is representative of only a small area of north-central Nebraska. It contains some species at the periphery of their range, and others which are extralimital. It is because of a presumed unusual interplay between landforms and vegetation that the vegetation ecology was included in this study.

Hence, the purpose of this study is twofold: first, to highlight many of the natural elements in the area including their interrelationships; and second, to relate features of the study area to the region and its Cenozoic history. In order to develop this synthesis of environmental dynamics in a historical perspective, it has been necessary to combine what is known about the geology and biology in the study site with some of my observations in order to give the reader a clear picture of existing conditions. These conditions have a direct bearing on the central thesis: that is, that the dynamics of the geomorphology in the area have a dramatic and continuing impact on the vegetation, and that the vegetative distribution is an excellent indication of recent and past geomorphic events.

Study Area

The study area, the eastern edge of which lies 22 km east of Valentine, Nebraska, involves an area of approximately 80 km^2. Only a portion of that was subject to actual field observation and study. The investigation concentrated on the river valley, but pursuit of details relative to that led far beyond the valley and study area (fig. 1).

This area includes a variety of geomorphic features in a relatively homogeneous geologic setting. Among the general landforms are dunes, rock benches, alluvial terraces, a floodplain, and a river in its progressive entrenchment. Deeply incised and parallel tributary canyons enter the river from approximately north 35° west.

The Niobrara River is narrow and swift, often rushing through confined straights and rapids in the study area. Further downstream, near Johnstown Bridge, it becomes a braided stream (see fig. 5) and continues in this manner eastward. The reasons for this change are yet unknown.

Aerial black and white and infra-red photos highlight a number of ancient meander re-entrants and cusps. These exist today as numerous

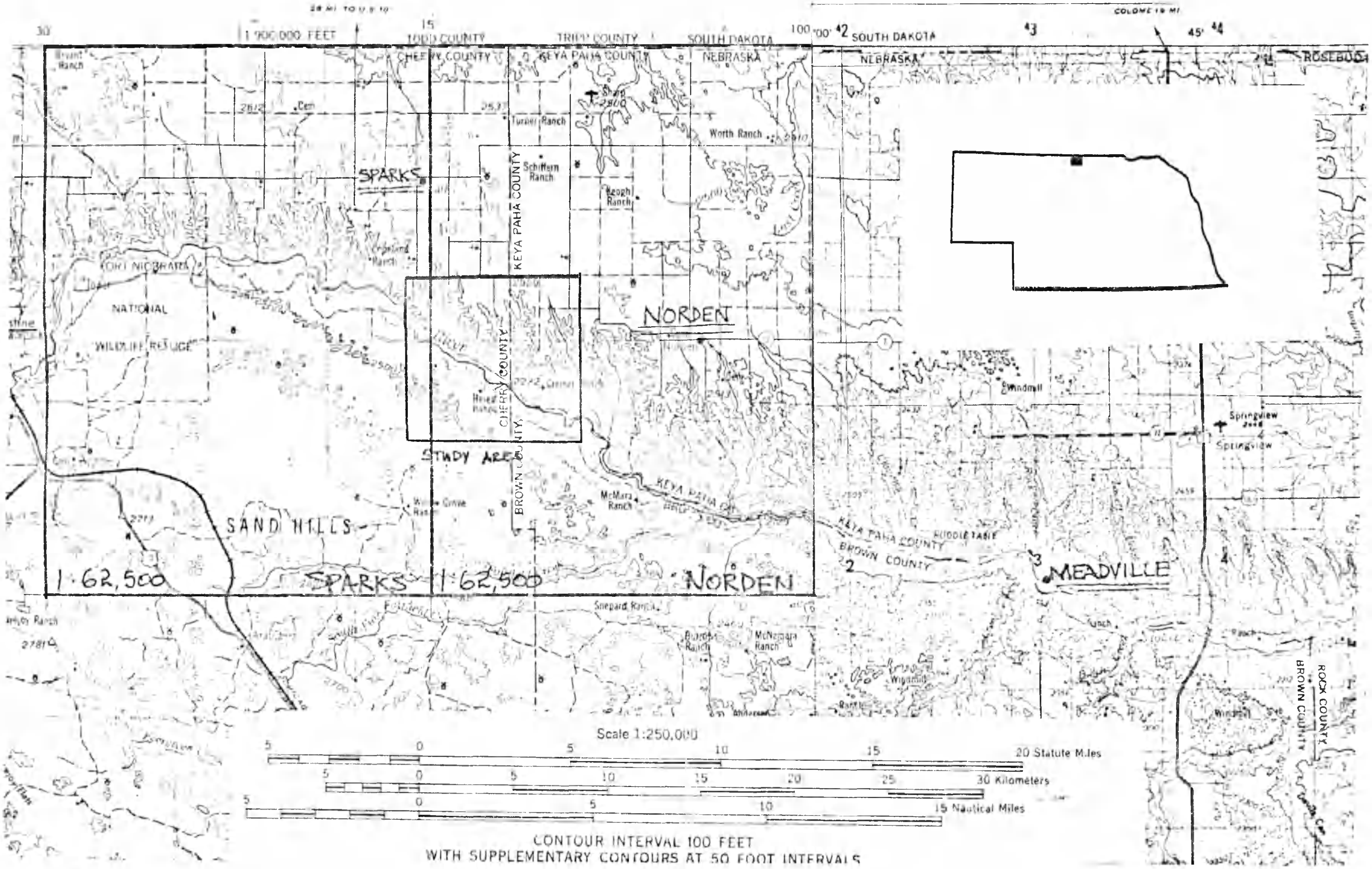


Figure 1- Location map of study area and principle geographic features in north-central Nebraska. Note outlines of 1:62,500, Norden and Sparks 15' Quadrangles. (Map reproduced from U.S.G.S., 1:250,000, Valentine and O'Neill maps).

terraces that lie at various elevations above the river. With progressive entrenchment the river presumably encounters a greater number of rock obstacles which alter its meandering form. The thalweg, being almost entirely cut in rock of a resistant nature, exerts control on the lateral and vertical movements of the river. These shifts occur during high water following heavy rains in the spring and summer, and during ice jams in the winter months (W. Sharp, per. comm.). The flow of the river is supported by numerous springs flowing from above the impermeable Rosebud Formation. Many enter the river along the steep right (or south) bank as waterfalls, while others flow and maintain circulation through marshes and abandoned channels.

The majority of the sediments that compose the valley walls are Tertiary sands and gravels that overlie Cretaceous marine shales and limestones. These clastics were laid down over the High Plains in response to the Laramide Orogeny. Atop these Tertiary sediments are additional fluvial and aeolian sediments deposited in times roughly corresponding to Pleistocene glacial advances further east.

As a result of rapid entrenchment and continuous undercutting of the banks by lateral movements of the river, unstable conditions exist in the area. Mass wasting occurs frequently and in a variety of forms. The most obvious examples are the large debris slides on the right bank.

The Niobrara River has cut its valley into the Springview Table that slopes northeastward to the north of the river. On the south, high and broad dune-mantled terraces form the southern rim of the valley. The dunes become progressively larger on higher terraces until merging with the Sandhills (fig. 2). The modern valley, its terraces, floodplain, and tributaries average about 3 km in width. The higher terraces that merge with the Sandhills may be greater than 20 km wide.

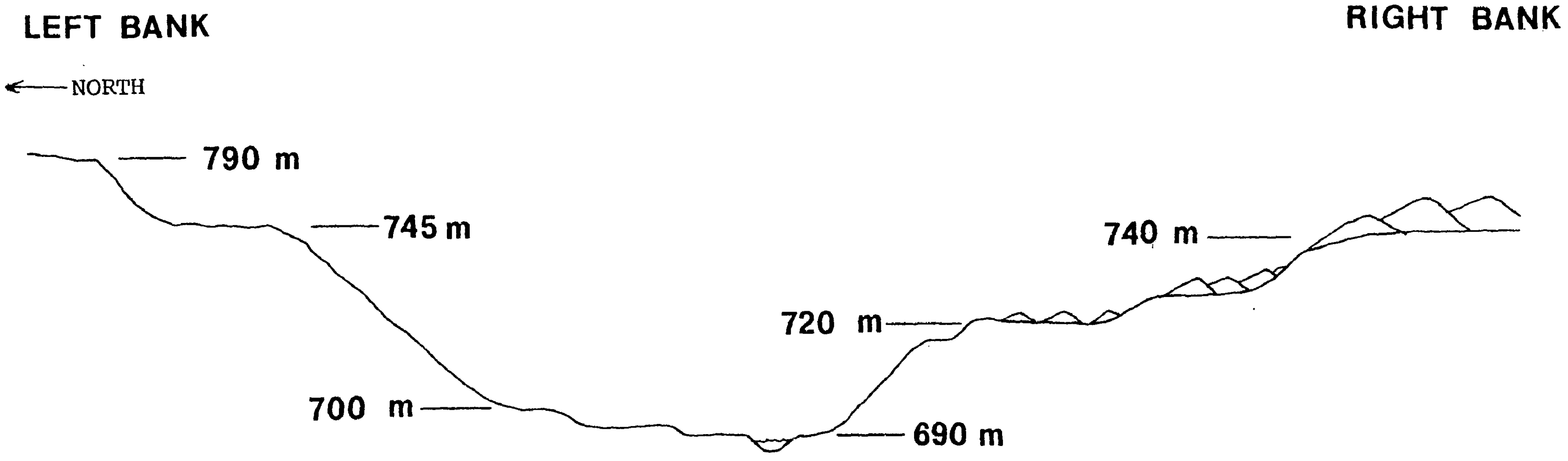
The Niobrara River, in flowing across the Great Plains, has created a deep and sheltered valley that provides a habitat for more mesic species than the surrounding grasslands permit. Indeed, it provides a riparian connection between the gymnosperms of the Rockies and the deciduous trees of the central and eastern United States. In addition, relic species of the boreal forest, present during the Wisconsinan glacial age, are able to thrive under the microclimatic conditions afforded by the valley. These include a combination of slope, slope exposure, shade, and moisture that is provided by springs. These types occupy zones parallel to the river. Beneath these forest communities exists an understory of grasses and other herbaceous plants. Large open areas of grasses are common.

The following chapters will provide in greater detail facts and observations essential to the general understanding of the physical and biological interactions in the Niobrara River valley. Unfortunately, important factors such as wildlife and the influence of man cannot be considered in detail in this study despite their obvious role in this river ecosystem.

Geology

The following chapter is provided for a general understanding of the geology of the area. It also provides unique information about the area which is essential to the development of the central thesis of this work.

Figure 2- A generalized north-south profile of the Niobrara River Valley near the Cherry Co. line. The Springview Table lies to the north of the rim of the left bank.



The geological setting of the Niobrara valley is similar to that of many valleys in the High Plains. It is cut in the Ogallala Group, which is composed of silts, sands, and gravels of the Tertiary period. The Miocene White River Group (Rosebud Formation) is also represented and forms the basal rocks in the valley from near Valentine to near the eastern border of the study area. Further downstream, the valley bottom is filled with sands and gravels to near Meadville (fig. 1) where the Pierre Shale is exposed (Skinner and others, 1972).

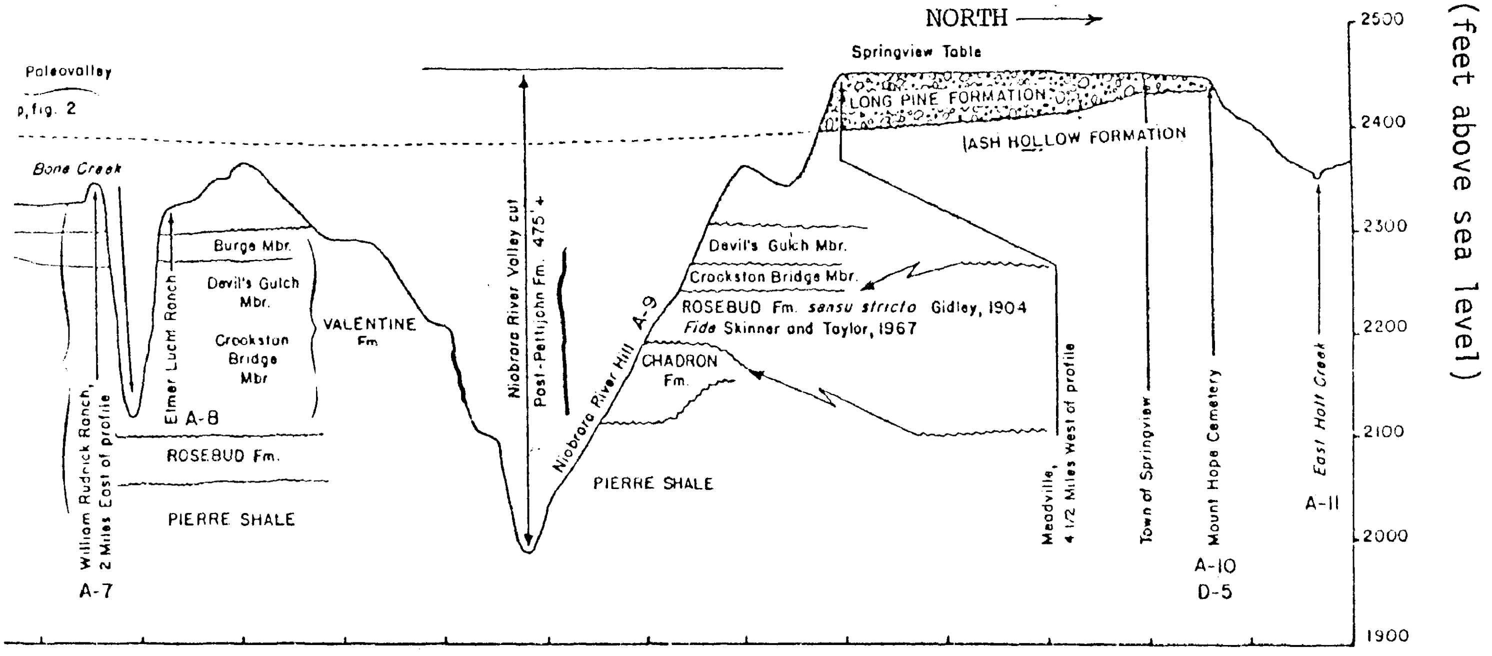
Although Nebraska, with few exceptions, is tectonically stable, activity has been noted on the Chadron Arch to the west of the study area (Stanley, 1971). Evidence that some uplift may occur near the study area is presented in this paper.

A combination of the Tertiary stratigraphic setting and periods of incision results in the interesting geomorphology of the deep valley. The geomorphology is inherently tied to the geology as both are a product of the Cenozoic history of the Plains and reflect its changing climates.

Stratigraphy

Throughout the study area the Rosebud formation (Brule) of the early Miocene forms the base on which the Niobrara River flows (fig. 3). This and other Tertiary formations have been described by Skinner and others (1972) and Lugn and Lugn (1956). The Rosebud Formation is a fine-grained, horizontally bedded, pinkish to gray siltstone. The sandstone grades to a browner color, and has more crumbly weathering and a slightly coarser texture toward the top of the formation

Figure 3- A north-south geologic cross-section at Meadville, Nebraska (fig. 1). (After Skinner and others, 1972)



NOTE: See Map, fig. 1, for locations of profiles and sections

(Skinner and others, 1972). In most of the region the formation is observed to be in direct superposition on the Pierre Shale of the Cretaceous, although it does not outcrop in the study area. Further to the east, near Meadville, Nebraska (fig. 3) the Chadron Formation lies between the Pierre Shale and the Rosebud Formation. The Chadron Formation does not outcrop in the study area. An erosional unconformity between the Rosebud and the overlying Valentine Formation, creates an irregular contact and causes the Rosebud to vary from 25 m to 45 m in thickness. The Rosebud is impermeable while the Valentine "sands" are quite permeable. Consequently, springs are plentiful and related to many features in the area (fig. 4).

The Valentine Formation is Pliocene in age and lies unconformably on the Rosebud. This contact is easily observed along this course of the Niobrara due to the great differences in character of the two formations. The Rosebud is a consolidated sequence and forms steep cliffs, whereas the Valentine is light in color and forms gentler slopes. The Rosebud is often stained with oxides precipitated by springs flowing over it.

There are three members of the Valentine Formation that are difficult to distinguish due to similar lithologic character and color. The Crookston Bridge, Devil's Gulch, and Burge Members are generally medium sands and yellowish in color.

The distribution of the Valentine Formation of the Ogallala Group and other Tertiary formations are thought to have been largely controlled by tectonic events of that period (Stanley, 1971; Stanley and Wayne, 1972). It was earlier thought and more recently refuted that

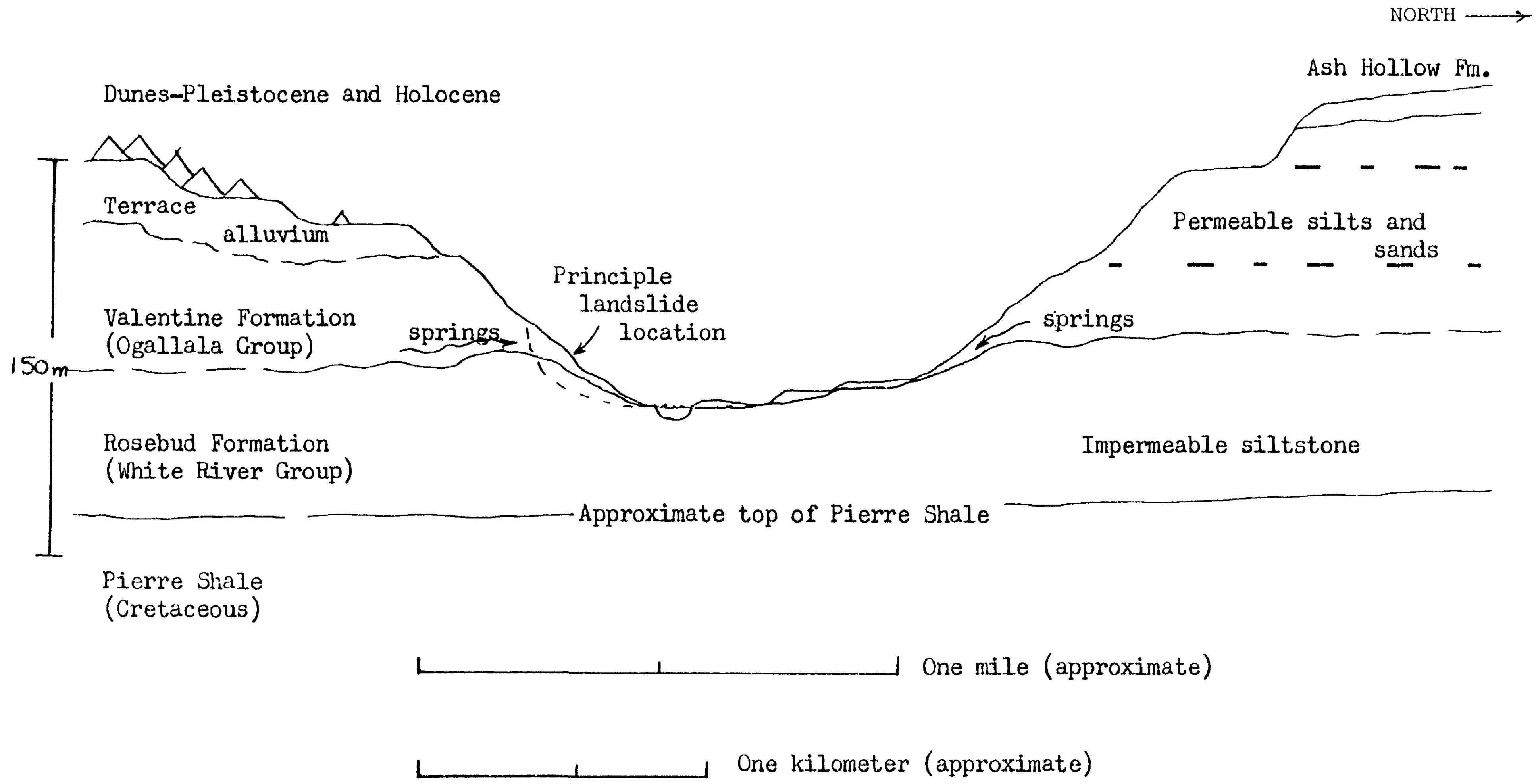


Figure 4 - Geologic cross-section within the study area (as interpreted by the author from known formations).

these sediments were of a lacustrine origin (Lugn and Lugn, 1956).

The only observed representative of the later Pliocene Ash Hollow Formation, is the Caprock Member. This formation can be seen throughout the region as it forms the north rim of the Niobrara valley and is composed of a well-cemented, grey, weathered siliceous rock. The Ash Hollow is not represented on the lower south side as the surface has been eroded below that elevation. A thin mantle of dune sand lies atop the broad terraces of the south side. Those on the lower high benches probably represent minor Holocene shiftings and are not contemporaneous with the major dune formation as described by Smith (1965) and A. Warren (1976).

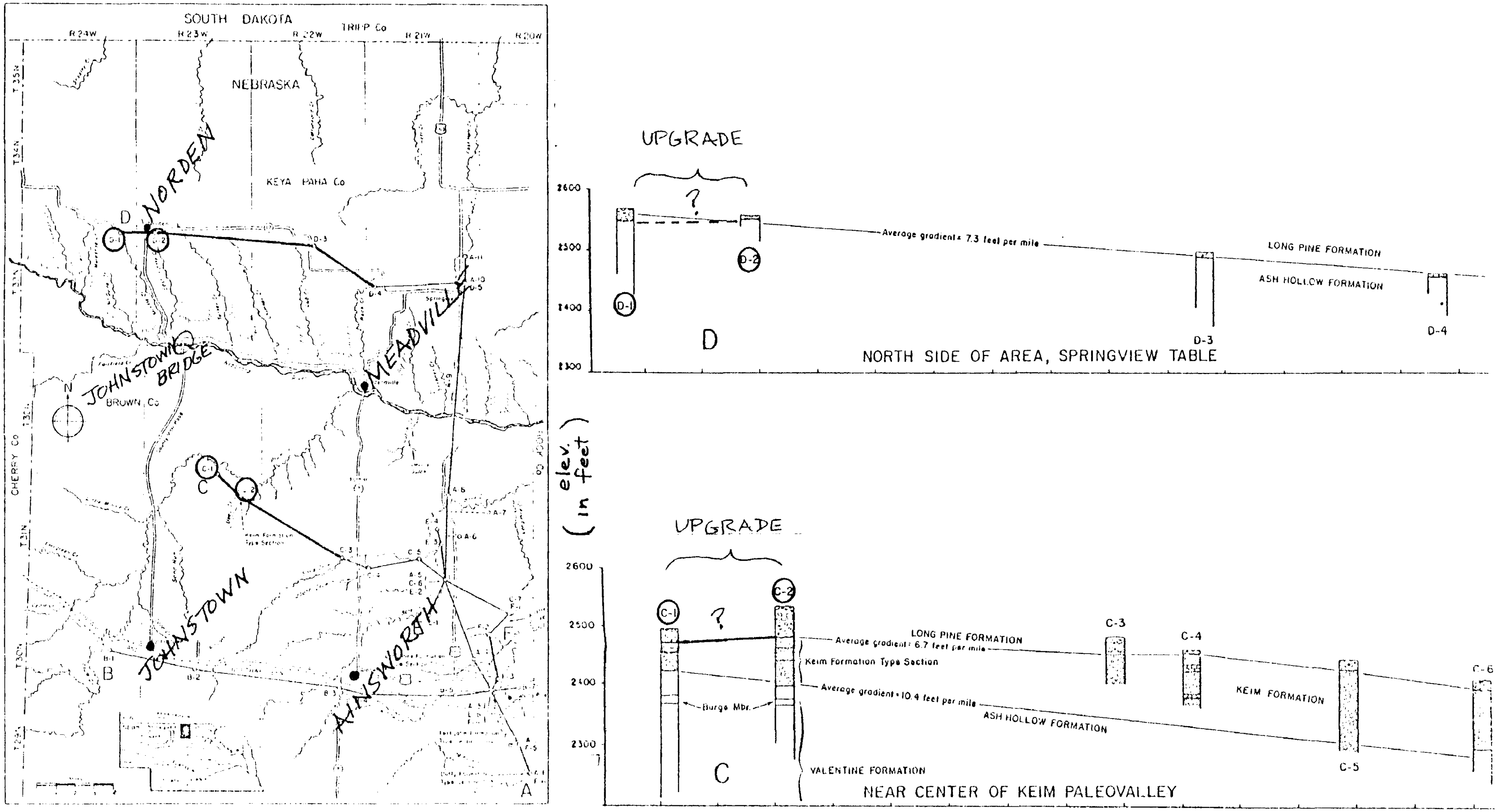
The dune sands of the Sandhills and fluvial sands and gravels deposited in the Pleistocene are thought to be periglacial manifestations of the glacial events of eastern Nebraska and the Upper Middle West (Reed and Dreezen, 1965). The Long Pine Formation (Skinner and others, 1972) is Pleistocene gravel present on the Springview Table to the north of the Niobrara. This and other formations not present or observed in the study area are cited in fig. 3 and fig. 5.

Tectonics

Skinner and others (1972) suggested the possibility of tectonic activity as a cause of the entrenchment of the Niobrara River. There has been no actual substantiation of faulting or warping in the area, yet, there is increasing evidence that some form of crustal movement is occurring.

Unusual findings during the field work in the study area indicate a possibility of recent local movement in the form of uplift. The most

Figure 5- Rock columns containing Pleistocene fluvial formations near the study area. These sections show anomalous characteristics in that their grades in C-1, C-2 and D-1, D-2, slope uphill toward the east. There is no record of westward flowing streams in the Plains during the Pleistocene suggesting possible tectonic activity in the area. (After Skinner and others, 1972)



obvious is the asymmetry of the valley in the study area. Other indications such as a change in the channel type from meandering to braided to the east of the study area and inconsistent grades on terraces support this hypothesis. A number of other supportive details were accumulated by the author in investigating this possibility.

In tracing the grades of three high terraces adjacent to the valley, an inconsistency was encountered in the area of Muleshoe Creek (fig. 6). There an eastward grade of approximately 1.7 m/km to 1.9 m/km, over a 40 km distance, neared a grade of zero in each case. On the Springview Table near Norden, Nebraska (fig. 5), the grade actually rises uphill to the east. This is anomalous since the Plains are (and have been) drained to the east. Additional evidence for this irregular grade is illustrated on figure 5 taken from Skinner and others (1972, fig. 3, pp. 18-19). There is an upgrade eastward at the base of the Long Pine Formation in sections C-1 and C-2, and D-1 and D-2 (fig. 5). This is difficult to explain in terms other than tectonics. In addition, the following other changes occur in the same area: (1) An increase in the number of elevated terraces occurs at the confluence of Fairfield Creek and the Niobrara River. (2) There is a change in the nature of the channel of the Niobrara at this location from meandering to braided suggesting either an increase in grade or discharge. Detailed analyses of the grade have not been made as there are no 1:24,000 scale maps available throughout the area. There is no substantial addition of water either by tributaries or springflow, thereby making the increased discharge supposition doubtful. (3) The geomorphic nature of the area changes noticeably east of Muleshoe Creek. There it becomes more rough and broken in the vicinity of Middle and East Middle Creek, east of which slopes then become more gentle (fig. 6).

The number of topographic anomalies in this area thus indicates an unusual erosional history that is possibly tied to relatively recent tectonism. Further research of this problem is indicated.

Cenozoic History

Although Cretaceous rocks underlie the Tertiary sediments of the Ogallala Group, no known significant event, either lithologic or tectonic, has occurred previous to the Laramide Orogeny that would have directly affected the Niobrara valley. As a result, no consideration of events previous to the Cretaceous-Tertiary boundary will be given. Special emphasis is placed on the Miocene and Pliocene time periods during which the rocks forming the valley walls were deposited, and on the Pleistocene during which the principal geomorphic features were created. The events of the late Pleistocene are largely responsible for the greatest number of landforms now present in the area.

The withdrawal of the Cretaceous sea and the onset of the diastrophic movements of the Laramide Orogeny occurred near the Mesozoic-Cenozoic boundary. The area of north-central Nebraska was probably still inundated when the first folds began to appear further west. Sedimentation was confined to the west within intermountain basins throughout the Paleocene and Eocene. The greater elevation of the Rockies and the tilt of the plains to the east gave streams the competency to carry sediments further to the east (Lugn and Lugn, 1956).

Deposition of the sediments into which the Niobrara is cut began during the Oligocene (White River Group, Rosebud Formation) and continued

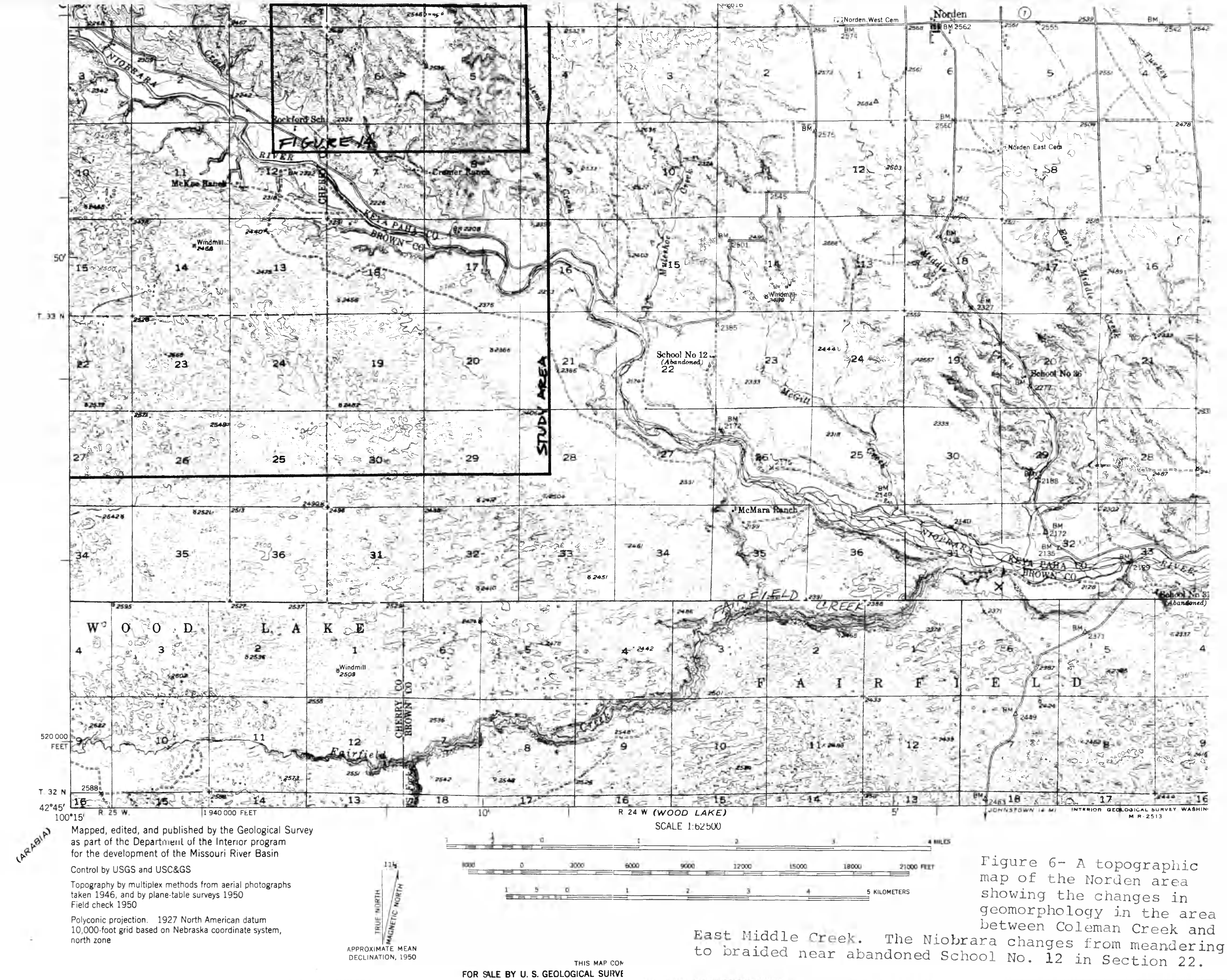


Figure 6- A topographic map of the Norden area showing the changes in geomorphology in the area between Coleman Creek and East Middle Creek. The Niobrara changes from meandering to braided near abandoned School No. 12 in Section 22.

through the Pliocene (Ogallala Group Valentine and Ash Hollow Formations). Upon these were deposited Pleistocene fluvial and eolian sediments. The climate varied from steppe (Elias, 1942) in the Eocene to a subtropical Oligocene environment in which magnolia, fig, and breadfruit were common (Dorf, 1959). Lugn (1935) suggested that the Miocene was characterized by subtropical climate in the High Plains. There was a slow return to temperate conditions as indicated by fossil evidence of oak and beech (Dorf, 1959). This gave way to the warmer, drier conditions of the Pliocene. Late in the Pliocene the climate must have become cooler and more humid to allow the growth of the algal beds of the Kimball Formation (Lugn and Lugn, 1956).

Pulses of the Laramide Orogeny, along with climatic fluctuations, controlled the sedimentation patterns throughout the Tertiary (Love, 1960; Stanley, 1971; and Stanley and Wayne, 1972). The drainage was southeastward in the Mid-Tertiary and is thought to have been largely controlled by a spasmodically rising Chadron Arch. In late-Tertiary, the Laramide Uplift shifted this flow more toward the east (Stanley, 1971). It is possible that a proto-Niobrara drainage may have become established during this time. Broad, wide valleys with grades of 0.2 to 0.6 meters/kilometer (1 to 3 ft./mi.) spread mid-Tertiary sediments over the Plains (Lugn, 1935). There was no permanent establishment of valleys during this time as the shallow channels would fill and overflow into others as they aggraded the plain. Stanley and Wayne (1972) suspected the Platte River Basin was in existence in the Miocene.

The initial incision of the valleys in the High Plains began in the late Pliocene and continued into the Pleistocene with cooler and wetter climates (Brice, 1964). Broad terrace formation has been studied by Reed and Dreezen (1965), Lugn (1935), and Alden (1924). These authors determined that major terrace formation occurred on the principle river systems in the Plains during early to mid-Pleistocene (fig. 7). The highest terrace plains adjacent to the Niobrara may have been formed during this period and could correlate with glacial events to the east. Figure 7 indicates some correlation between these terraces and those determined by this study. Although altitude comparisons are not reliable, the sequences are similar in this correlation. The presence of the Niobrara during the mid-Pleistocene is substantiated by the work of Simpson (1960), where a buried reach of the Niobrara in southeastern South Dakota was determined to be 6 km wide and nearly 70 m deep. The "smooth and gently sloping" valley was buried with sediments as old as Illinoian (Simpson, 1960). Almost directly to the north of the study area, in central South Dakota, Flint (1955) found the Missouri to be Illinoian in age. The Niobrara, not having been directly altered by glaciers as the Missouri was (in central South Dakota), therefore probably predates it.

Renewed valley-deepening preceded Wisconsin deposition of extensive dune tracts and loess in Nebraska (Frey and Leonard, 1957). It appears that a progressive valley deepening of the Niobrara was contemporaneous with major dune formation. There is a diminution of dune size and extent on terraces of decreasing height in the Niobrara indicating a termination of the Wisconsinan glacial event (fig. 8).

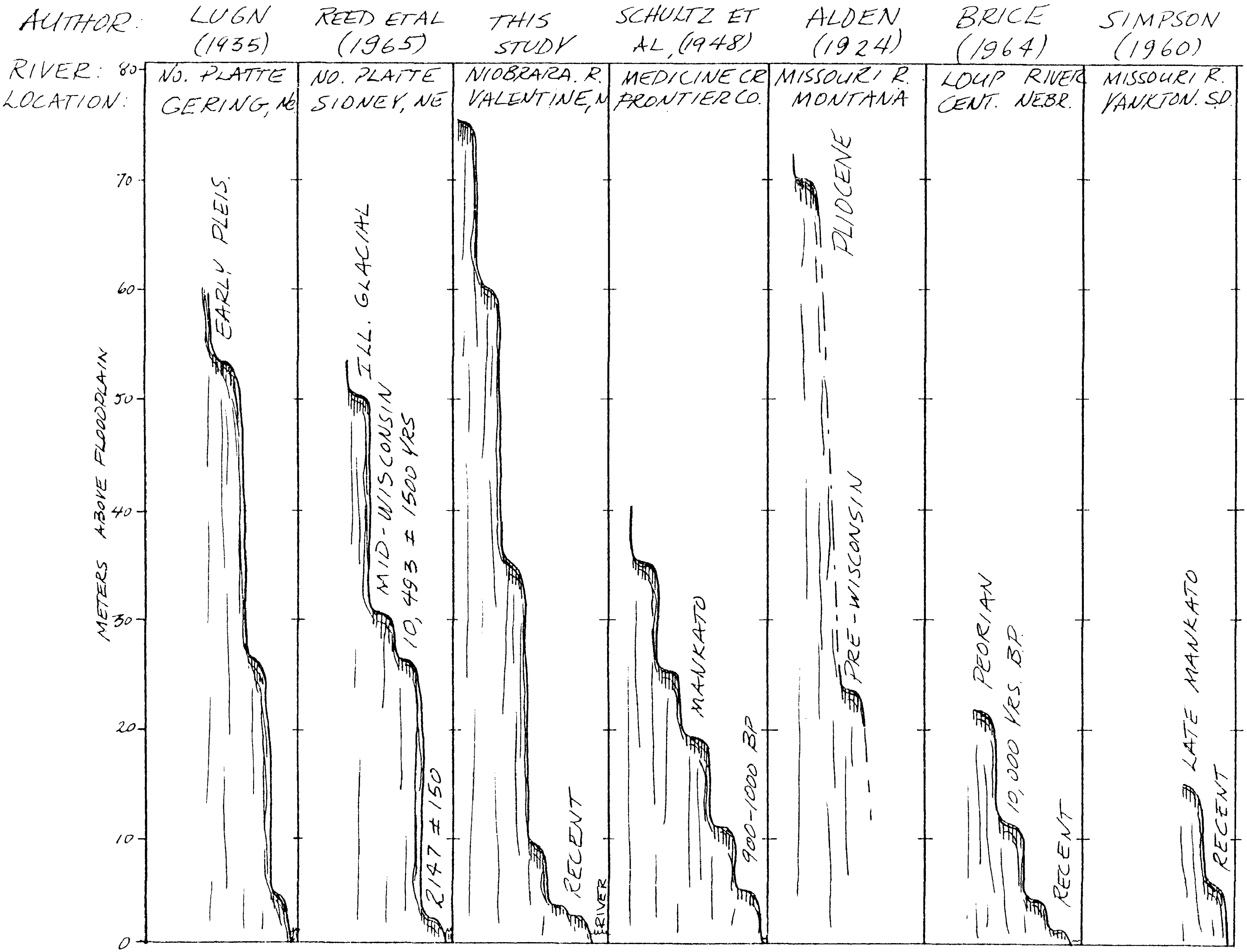
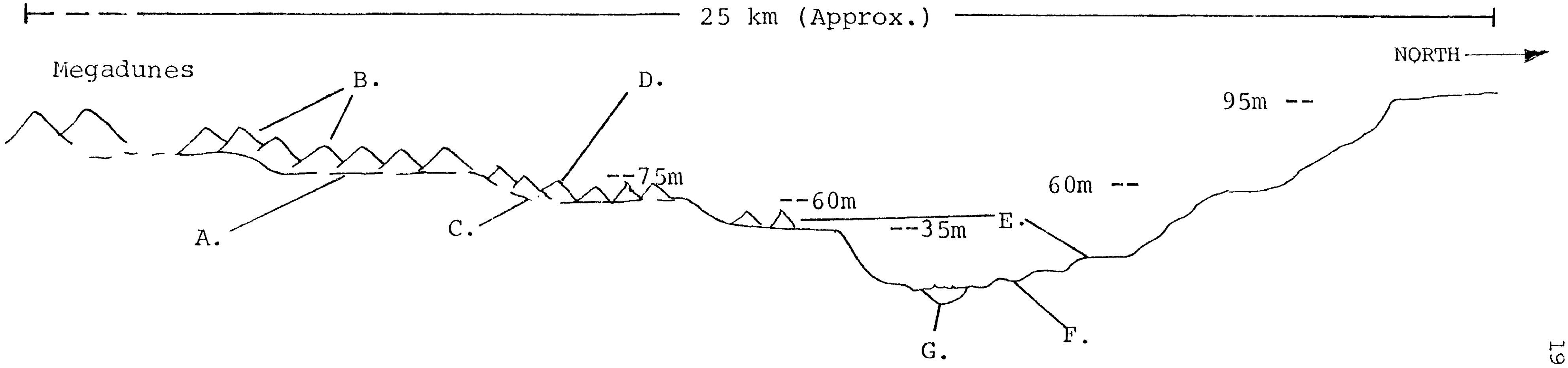


Figure 7 - Correlation of terrace sequences determined by various authors. Terrace height above the floodplain is not a reliable method of correlation but sequences and ages may provide a method of comparison between studies.

Figure 8 - Diagram of a hypothetical sequence in the development of the Niobrara River Valley morphology.

A. Possible establishment of the Niobrara as an outwash stream in early to mid Pleistocene.
B. Late Pleistocene dune formation providing a constant sand supply to the enlarging Sandhills.
C. Wisconsin cut and fill.
D. Late Wisconsin or Altithermal dune formation.
E. Holocene cut to the 9 meter level and local dune shifting on the 35 meter level.
F. Holocene cuts into bedrock on the 2.5 meter and 3.5 meter terraces; Local cut and fill by minor shiftings of the Niobrara.
G. Present floodplain formation.



GEOMORPHOLOGY

The following chapter deals with the geomorphological regions within the study area, which include landforms created by fluvial erosion and mass wasting. Special sections are dedicated to landsliding, terrace stratigraphy, and terrace morphology because they constitute the principal active geologic processes in the area. Other important geomorphic factors exist, such as eolian and other processes which are less obvious or presumably less important to the overall biogeography and geomorphology of the area.

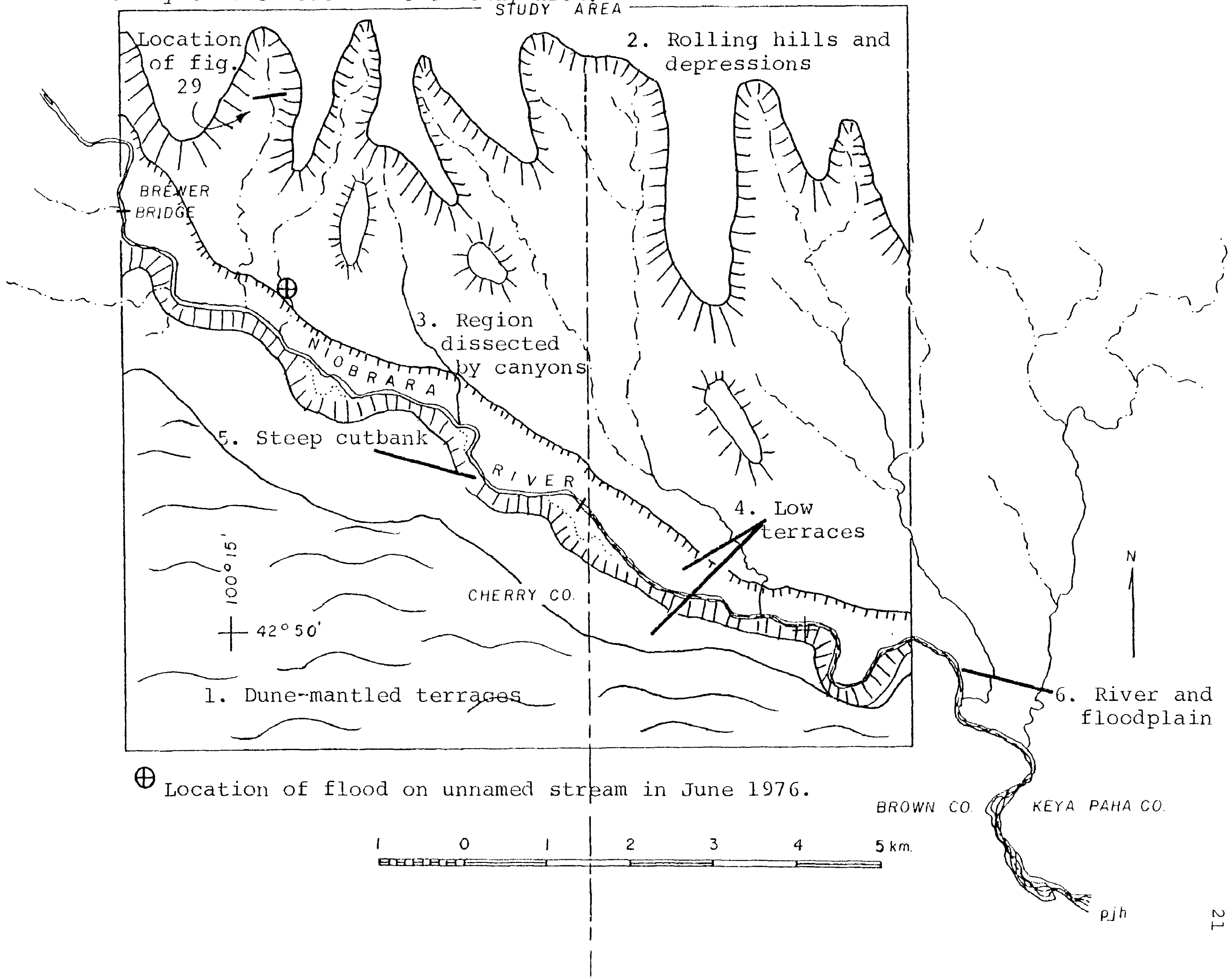
Geomorphological Regions

The first of the six geomorphic regions is one of broad, dune-mantled terraces that lie to the south of the river (region 1). The remaining areas are the rolling hills and depressions of low relief of the Springview Table (region 2), the region deeply dissected by canyons to the north of the river (region 3), the low terraces adjacent to the river (region 4), a steep cutbank on the right bank (region 5), and the river channel and floodplain (region 6) (fig. 9).

Region 1.

The dune-mantled terraces south of the river range from 5 km to 20 km in width and are present throughout the region. There are two terraces positively identified and possibly a third one entirely covered with dunes. The dunes on the lower one of these probably represent small, Holocene shiftings of larger dunes established during the Pleistocene.

Figure 9- Map showing geomorphic areas within the study area. The Nebraska Sandhills lie directly to the south of the study area.



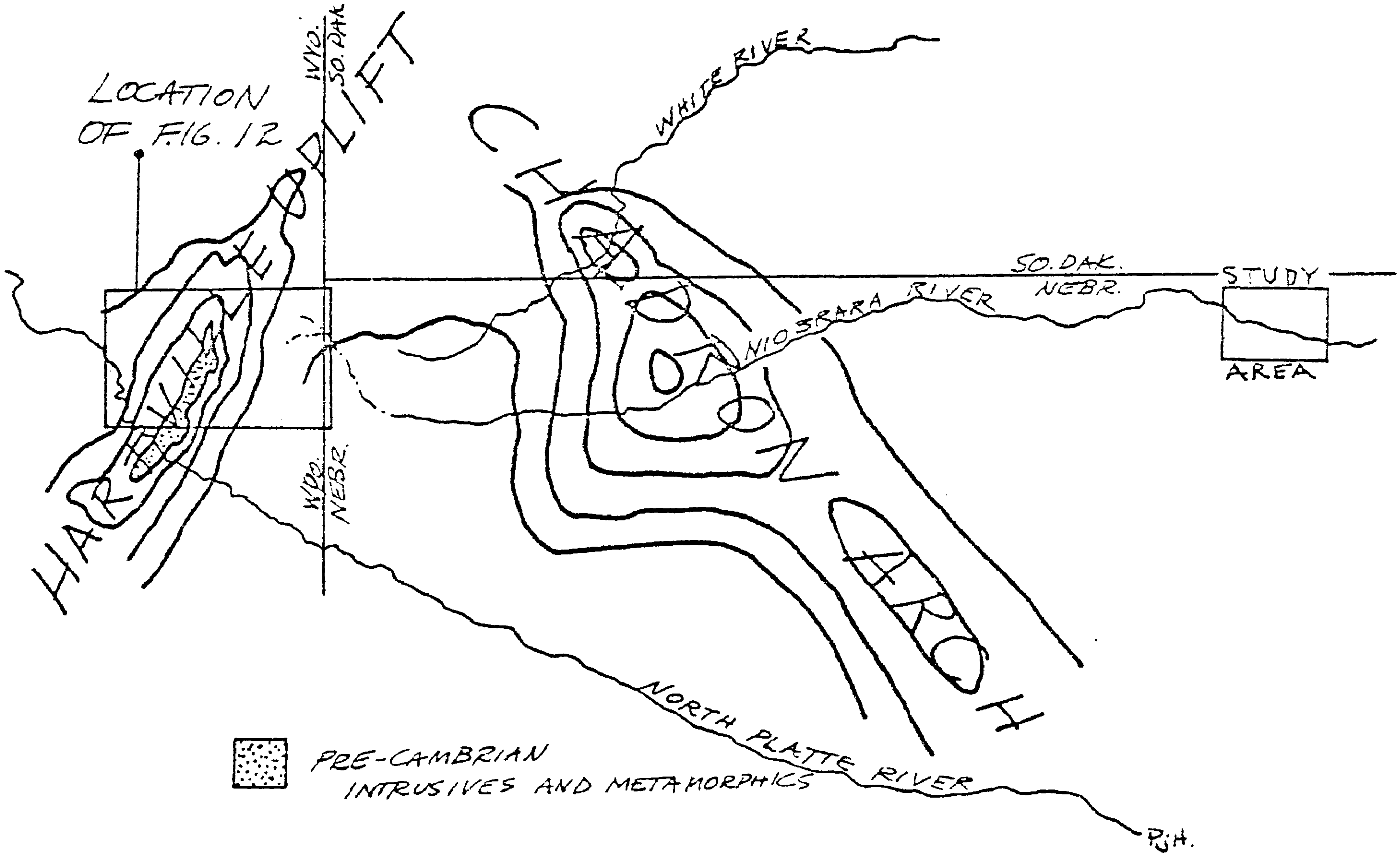
The highest of the terraces lies at about 75 m above the river and is suspected to be Sangamon in age as indicated by fossil evidence (Voorhies, per. comm.). The terraces obviously predate the dunes, but precise periods of the events have not been assigned to the sequence.

The dunes have been largely stabilized presumably by a general climate change and a rising water table. The most operable process on them now, however, is common deflation (blowouts) initiated by disturbed or absent grass cover. Because much of the area is heavily grazed by cattle, blowouts are always present in varying degrees of stabilization through revegetation.

On a larger scale, synthesis of information gathered from working on the high terraces indicates a possible role of the Niobrara River in the evolution of the High Plains, particularly the Nebraska Sandhills. A critical factor is the possible capture of the headwaters of the Niobrara by the North Platte River. Capture of the headwaters appears to have taken place as a result of: (1) activity on the Hartville Uplift in eastern Wyoming in the late Pleistocene or Holocene (fig. 10), (2) obstruction of the flow of the Niobrara waters by durable Pre-Cambrian granite and metamorphics (fig. 10), and (3) decreased downcutting ability of the Niobrara upstream from the uplift of the Chadron arch (Stanley, 1971; Stanley and Wayne, 1972).

Evidence for the Niobrara having drained the Colorado and Wyoming Rockies, now drained by the North Platte, is: (1) Granites (including anorthosite) are present in the Niobrara's fill terraces (Stanley, 1971). There is no outcropping of granite in the present drainage basin. (2) The width of the terraces near Valentine are of a much

Figure 10 - A location map of areas of uplift and rivers in central and western Nebraska and eastern Wyoming. The location of figure 12 is noted where the drainage areas of the Niobrara and the North Platte Rivers are nearest. It is in this area that stream capture is suspected.



(Taken from the Tectonic Map of North America, 1969, Denoyer-Geppert) greater size (20 km) than appropriate for the short, upriver length. (3) A 7 km width and a 70 m depth of a buried reach of the Niobrara near Yankton, South Dakota (Simpson, 1960), filled with Illinoian sediments, attests to the greater size of the Niobrara in the past. (4) ERTS photographs and topographic maps of the area show a broad, upland surface typical of late Pleistocene outwash streams (fig. 11). Such terraces could not have formed with the Niobrara heading in the plains as it does now. (5) A low divide (fig. 12A) separates the two systems between Lusk and Douglas, Wyoming--the location of the Hartville Uplift. In addition, north-south profiles (fig. 12B) reveal what may be interpreted as a broad valley of the ancestral Niobrara River.

The following hypothesis is, in part, contingent upon the validity of the previous evidence: the Niobrara, as an outwash stream heading in the Rockies during the Wisconsinan, could provide part of a continuous sediment source, instrumental in the formation of the Sandhills of Nebraska.

Evidence supporting this theory is as follows: (1) The Niobrara and its major tributaries form the complete northern boundary of the Sandhills (fig. 13). (2) The high terraces of the Niobrara near Valentine show an 'intertonguing' effect with the Sandhills by having larger, successively better developed dunefields on progressively higher terraces (fig. 11). This illustrates the decreasing discharge of the Wisconsinan rivers concurrently with the termination of major dune formation. Lower terraces with smaller, more disorganized dunes may represent local Holocene shiftings.

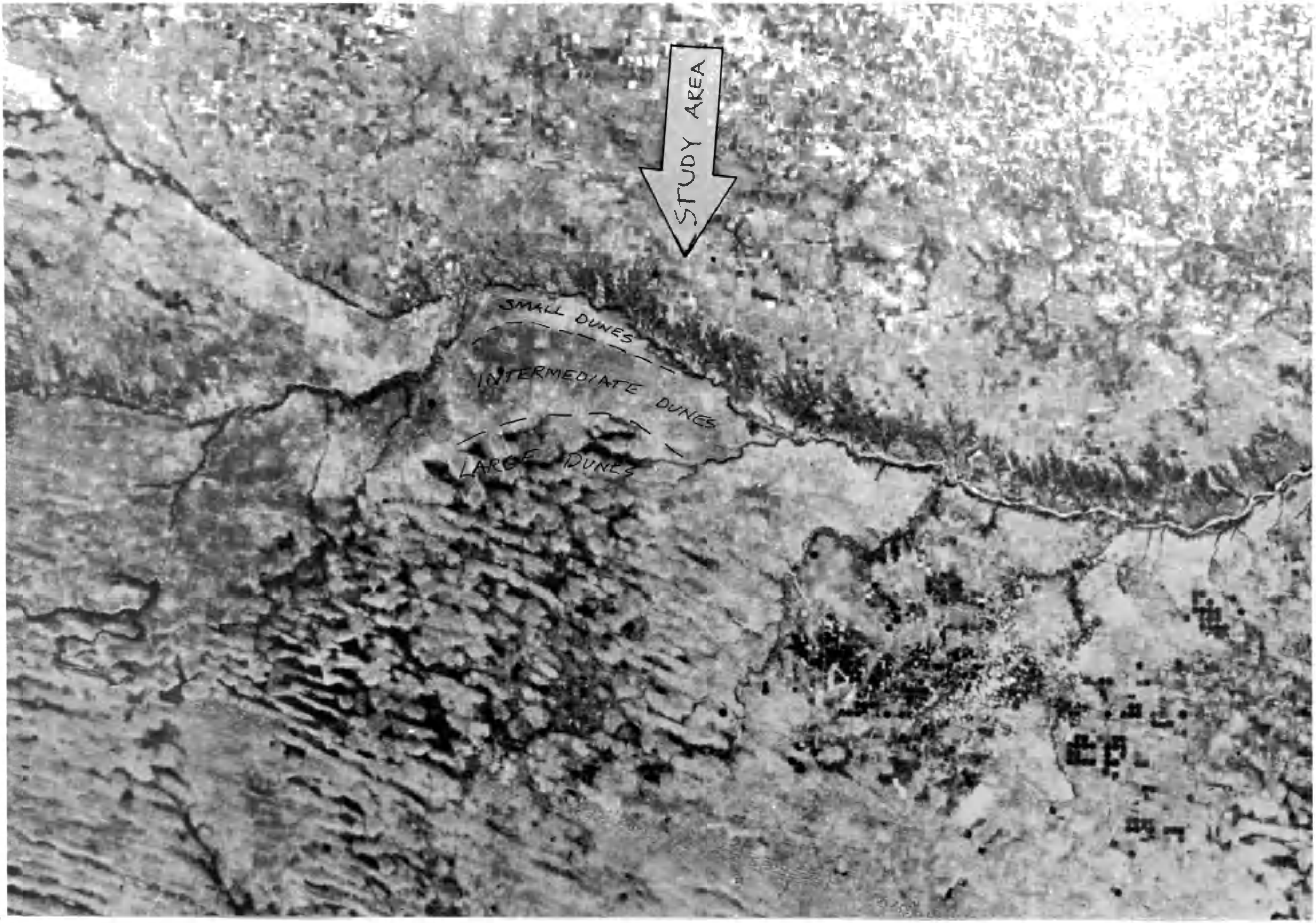


Figure 11 - ERTS image showing broad, upland, dune-mantled terraces south of the Niobrara River. The scale is approximately 1 cm = 5.6 km.

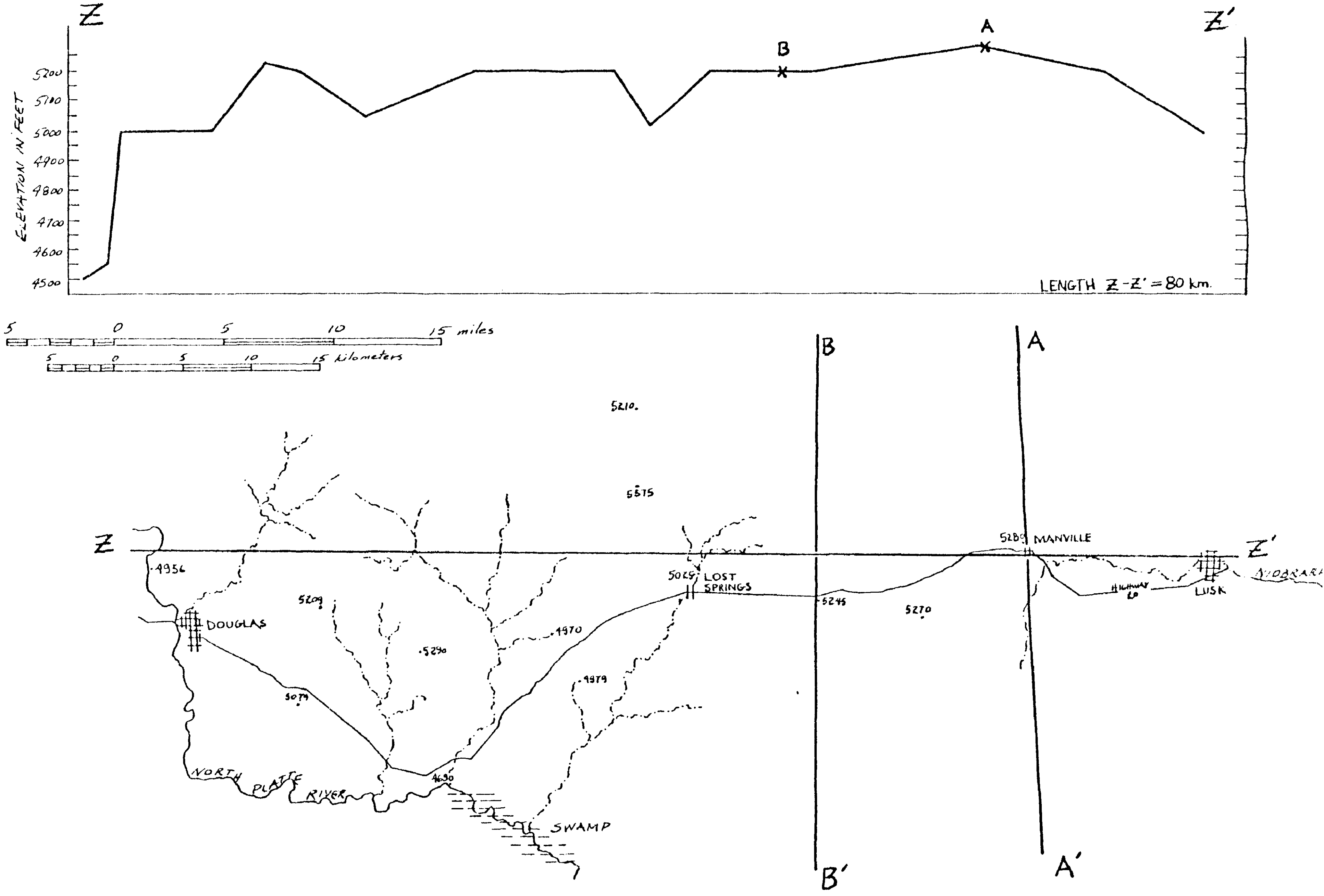


Figure 12A - Map and profile Z-Z' in the area between the Niobrara and North Platte drainage areas in eastern Wyoming. Profile Z-Z' follows the suspected route of the ancestral Niobrara. Profiles B-B' and A-A' cross the suspected valley. (Taken from U.S.G.S., 1:250,000 topographic map)

Figure 12B - Profiles across suspected Pleistocene Niobrara Valley between Lusk and Douglas, Wyoming. (See figure 12A for location map)

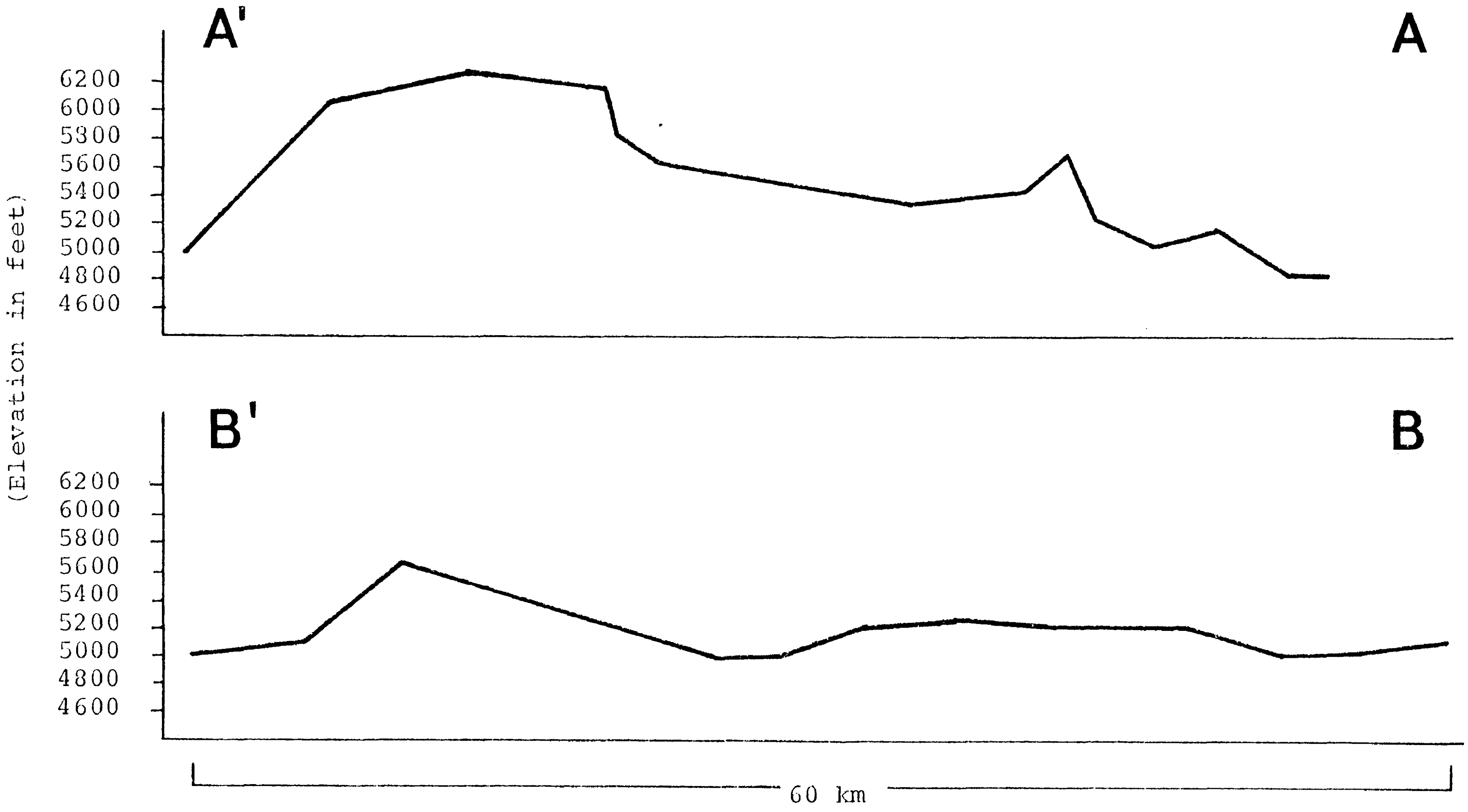


Figure 13 - ERTS image showing the Niobrara River and its tributaries at the northern edge of the Nebraska Sandhills. The scale is approximately 1 cm = 12 km.

Many attempts have been made to explain the great volume of sand of the Sandhills. Lugn (1935) first thought the Ogallala Formation (Group) to be the source of the sand. Later, Lugn (1951), Reed and others (1965), Stanley and Wayne (1972) and Wayne and Stanley (1972) implied that the early Pleistocene alluvium, which becomes finer to the east, was the probable main source of both the dune sand and the loess. A. Warren (1976) stated that the megadunes were derived from winnowing of underlying fluvial sands. These theories of a static sand source (degradation of Pliocene and Pleistocene beds) could be amended or superseded with the addition of a continuous recharge of sand by the ancestral Niobrara. The present theories seem to be insufficient to explain the volume and extent of the Sandhills.

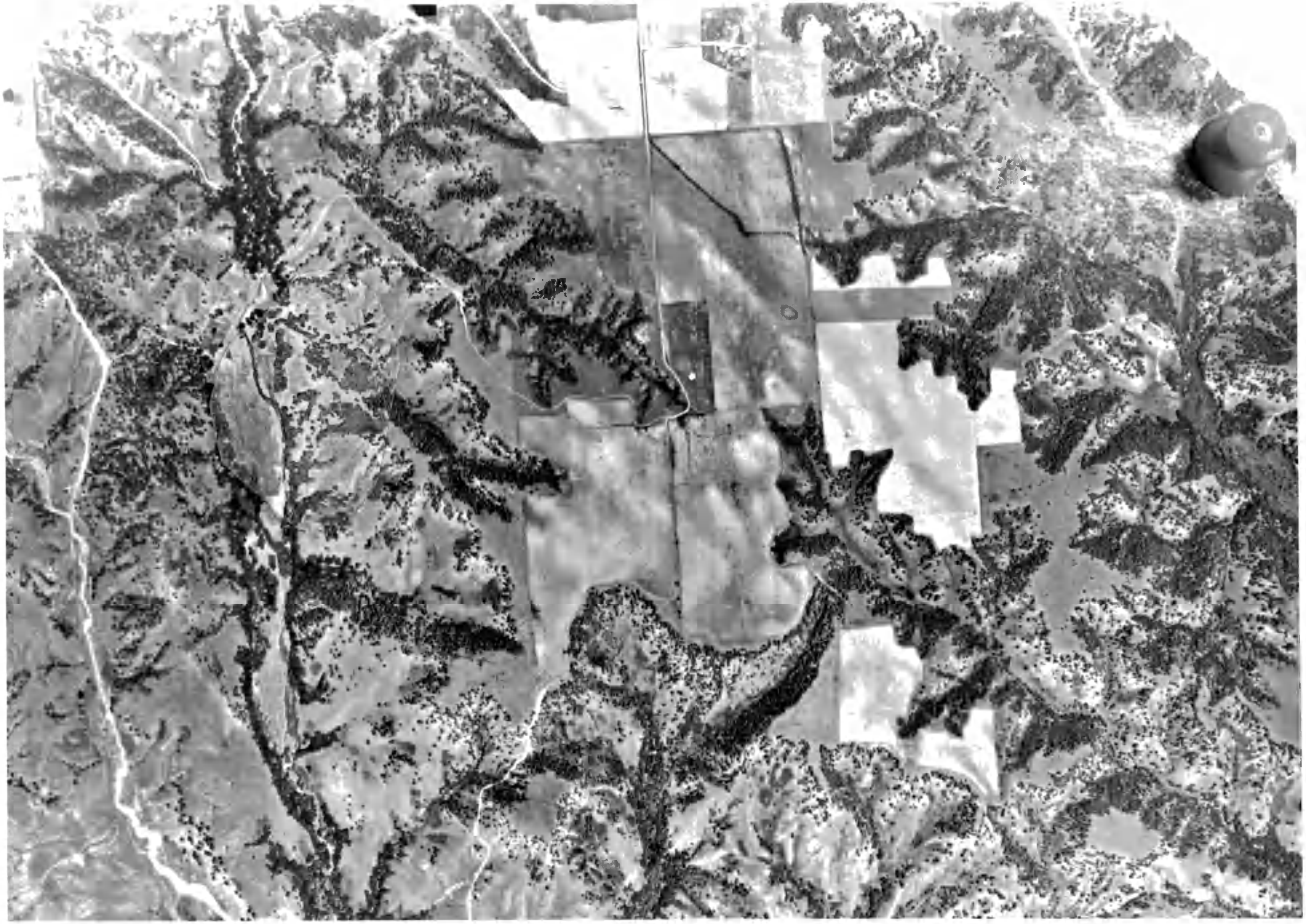
Region 2. The most suitable description of the second region is one of rolling hills and depressions, with 5 m to 10 m relief on the Springview Table. This area lies entirely to the north of the river. It slopes gently eastward and northward and is substantially higher by 20 m to 30 m than the south rim. Steep cliffs are present at the north rim which are due to the resistant Caprock Member of the Ash Hollow Formation of the late Pliocene.

Several buttes of the Ash Hollow Formation lie atop the Springview Table and, upon examination, disclosed interesting periglacial features. Flaty rock fragments were heaved, presumably by frost, into vertically oriented positions most likely during Wisconsinan glacial events when this region was subject to a periglacial environment. Flat-top Mountain, which is located about 5 km west north west of Sparks, Nebraska (fig. 1), is approximately 30 m higher than the surrounding plain and contains these features. The rock fragments resemble caliche and commonly stand 50 cm to 80 cm higher than the ground surface.

Region 3. This region is related to the rolling hills of the second region as they are both oriented at approximately north 35° west. Region 3 has been greatly dissected by streams that are rapidly cutting into Tertiary White River and Ogallala Formations. This suggests not only the same genesis, but a relationship where the morphological features of the plain provide 'leaders' for the headward eroding canyons (fig. 14). The streams originate in the depressions.

The oriented canyons are cut up to 80 m into the Valentine and Rosebud Formations. They resemble the oriented topography described by Russell (1929), White (1961), and Beaty (1975). It appears that wind-oriented dunes and possible valley training by the wind may also play a role.

The streams that drain these canyons are intermittent for the most part, although springflow above the Rosebud may cause them to be otherwise during better years. The streams may be up to 5 km in length and drain areas from 5 km^2 to 9 km^2. Summer thunderstorms and resultant high water alters the character of the canyons significantly. During such a storm in June of 1976, the author recorded a change in depth of an unnamed intermittent creek (located in figure 9) from 15 cm to 110 cm in less than one hour. The bed of the stream (Rosebud



Scale:1 cm = .133 km

Figure 14 - Aerial photograph of oriented valleys with 'leaders' at the heads of the tributaries north of the Niobrara River in the study area (fig. 6). Note how the orientation of the undulating topography on the plateau surface conforms to that of the canyons.

Formation) was deepened by 10 cm, while 30 cm of sand was deposited on the flats near the river.

Headward erosion by these tributaries may also be very rapid because the scarps in the headlands are usually devoid of vegetation and inclined at angles up to 60°. Mass wasting in the form of rock falls and slides aid in the process of erosion. Because of the southerly exposed headwalls, presumable thermal expansion and freeze-thaw accelerate the mass movement processes as well as increase the effect of gullying by the production of loose material.

All of the previously described canyons lie to the north of the river. There are small V-shaped tributaries on the south side of the river but none exceed 1 km in length. This apparently is the result of the preferential undercutting of the right bank and the inability of those tributaries to keep pace with the downcutting of the master stream. The numerous waterfalls on the right bank serve as an indication of this inability. The preferential undercutting of the right bank will be explored further in this paper.

Region 4. This region is immediately adjacent to the canyons of region three, and is persistent throughout the lower portions of the valley. It is composed of nearly flat-lying terraces on the left bank at 2.5 m, 3.5 m, and 9.0 m above the river. They have no obvious pairing with terraces on the right bank except possibly that at 2.5 m. Together the low terraces are approximately 0.5 km wide although they may vary in width from 25 m to 1.5 km.

It is the broad, flat-lying nature of this area which allows the most intensive agriculture in the river valley. Some alteration of the surface morphology has occurred because of human activity. Large deposits of fine-grained alluvium are deposited as fans on the terrace flats and at the mouths of canyons. Sheetwash and gullying rapidly remove soil from bare or newly tilled fields. Buried soils are frequent at depths of tens of centimeters below fine, light sands and silts (see section on terrace stratigraphy). The low terraces and steep cutbank on the right side of the river will be more thoroughly discussed later in this chapter.

Region 5. This area is contemporaneous in formation with the fourth, yet it differs greatly in morphology. The right bank is considerably steeper than the left, with fewer terraces. Most of these are isolated benches at no persistent level. The right bank is actually a terrace riser that has been greatly modified (by mass wasting) located at the base of the 35 m terrace. The surface of this terrace slopes upward at approximately 1.0° toward the higher terraces and the Sandhills which lie 1.0 km and 15 km distant, respectively. The terrace is generally flat except for a few small dunes that have migrated across it. The scarp at the base of the terrace is inclined from 20° to 50° as a result of undercutting by the river and calving by landslips.

Because of the steep slope and previously described stratigraphy, there is constant and widespread springflow midway up the cutbank. This is an important factor in many cases in this study.

Region 6. This geomorphic area is the river and its floodplain which follow a meandering course throughout the study area. The single-channeled river is an average of 25 m in width although there are several gaps through which the river accelerates as rapids. Occasionally, ephemeral islands appear in the river and may migrate downstream.

The thalweg, which is generally 1.0 m to 2.0 m deep, is cut in rock through most of the study area and has a peculiar relationship to the entire river bed. The usual location of the thalweg at the outside of a bend, does not hold true in many reaches in the Niobrara valley. It may appear at the inside of a bend as shown in figure 15.

Mass Wasting

Introduction

Landsliding is the most obvious process altering the form of the river valley. It operates in conjunction with the lateral and vertical cutting of the river by broadening the distance between the valley walls and depositing the material in the river to be carried away.

Methodology

Data were collected at five slide sites of varying ages and degrees of activity. Tape and level measurements were made and tree core samples were taken; the slide material was sampled and identified. Diagrams were made and photos were taken of the areas as the processes were investigated. Other sites were observed and compared to the five study sites. Tree coring was done not only to determine the ages of slides but also to aid in the development of a revegetation scheme later in this work.

Figure 15 - An aerial photograph of a length of the Niobrara River where the thalweg is located in anomalous places within the river. The dashed line is the thalweg while the solid line is the entire width of the river. North is toward the top of the photo.

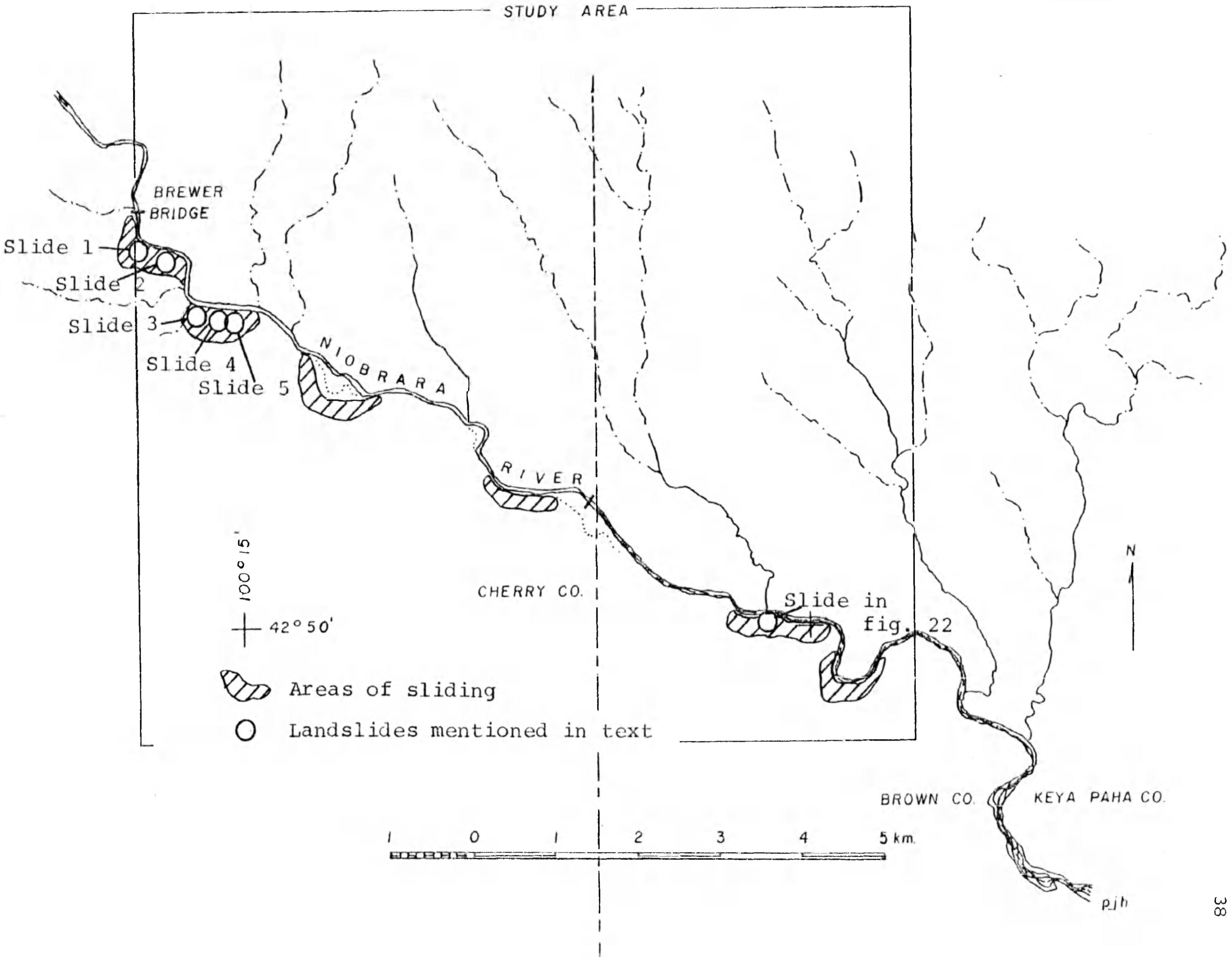
Findings

On a regional basis, sliding occurs from near Valentine, throughout the study area, to the mouth of the Niobrara. The Pierre Shale outcrops near Meadville, Nebraska, and is largely responsible for larger-scale sliding downstream from that point. Within the study area, the sliding is confined to those reaches where the river aids the process by the formation of steep slopes up to 55°. The process of river undercutting is concomitant with processes of mass wasting, that may, at times, operate semi-independently as a result of maturation of the soil and accumulation of debris on the slope. This accumulation is a function of creep, sheetwash, sandruns, and sliding at higher levels on the slope. Saturation takes place because groundwater flows easily through the Valentine Formation that lies above the nearly impermeable Rosebud. This stratigraphic situation can be found from near Valentine, Nebraska, to near Meadville where the Pierre Shale forms the basal rocks.

The occurrence of debris sliding is, for the most part, restricted to the south bank. There are fewer comparable situations on the north due to the gently sloping nature of that side of the river. On the south, the banks are generally greater than 40° and have north to east exposures. Of the 12 km of river valley within the study area, approximately 5 km are susceptible to landsliding due to steep slopes alone (fig. 16). Landsliding occurs most commonly at bends in the river; however, it is also frequent elsewhere.

Two types of slides were identified: the first is a greatly deformed debris slide (II-B, Varnes, 1958) of which slides 1 through 4

Figure 16 - Map of areas highly susceptible to landsliding within the study area.



are characteristic (figs. 17-20); the second type, slide 5 (fig. 21), originates similarly to the first one but differs as it enlarges itself by additional sliding, gullying, and creep. The latter slide usually appears as a large, white, and unvegetated scar as large as 50 m in height.

The movement in slides 1 through 4 appears to have taken place at a fairly rapid rate on the order of seconds to hours. The enlargement of the bare slope as represented in slide 5 may take tens of years. Slide 1 may be at the initial stages similar to slide 5 type since additional sliding has taken place there within the study period (fig. 17). There were no cases where intermediate stages of sliding were observed (e.g. large cracks, toppled trees, etc.).

The slides are typically composed of colluvium and bedrock with a buried or surface soil of variable thickness. Sometimes they include dense stands of woody vegetation whose roots often bind the mass together during the slide. Trees may be severely tilted or dislodged from the soil material, but many remain upright indicating that the sliding took place in one coherent movement.

In a new slide that occurred in the spring of 1977, a large, already dead, ponderosa pine (Pinus ponderosa), was broken in half during the slide but remained upright at the base of the scar (fig. 22). This slide is located 2.5 km southeast of the Cherry County line on the river. The tree slid from high on the bank to the river and remained upright which suggests that sliding, as opposed to flowing, was the mechanism involved. The fact that the tree was freshly broken suggests rapidity of motion. Because a large amount of material is bound by the roots, a very low center of gravity also must aid in

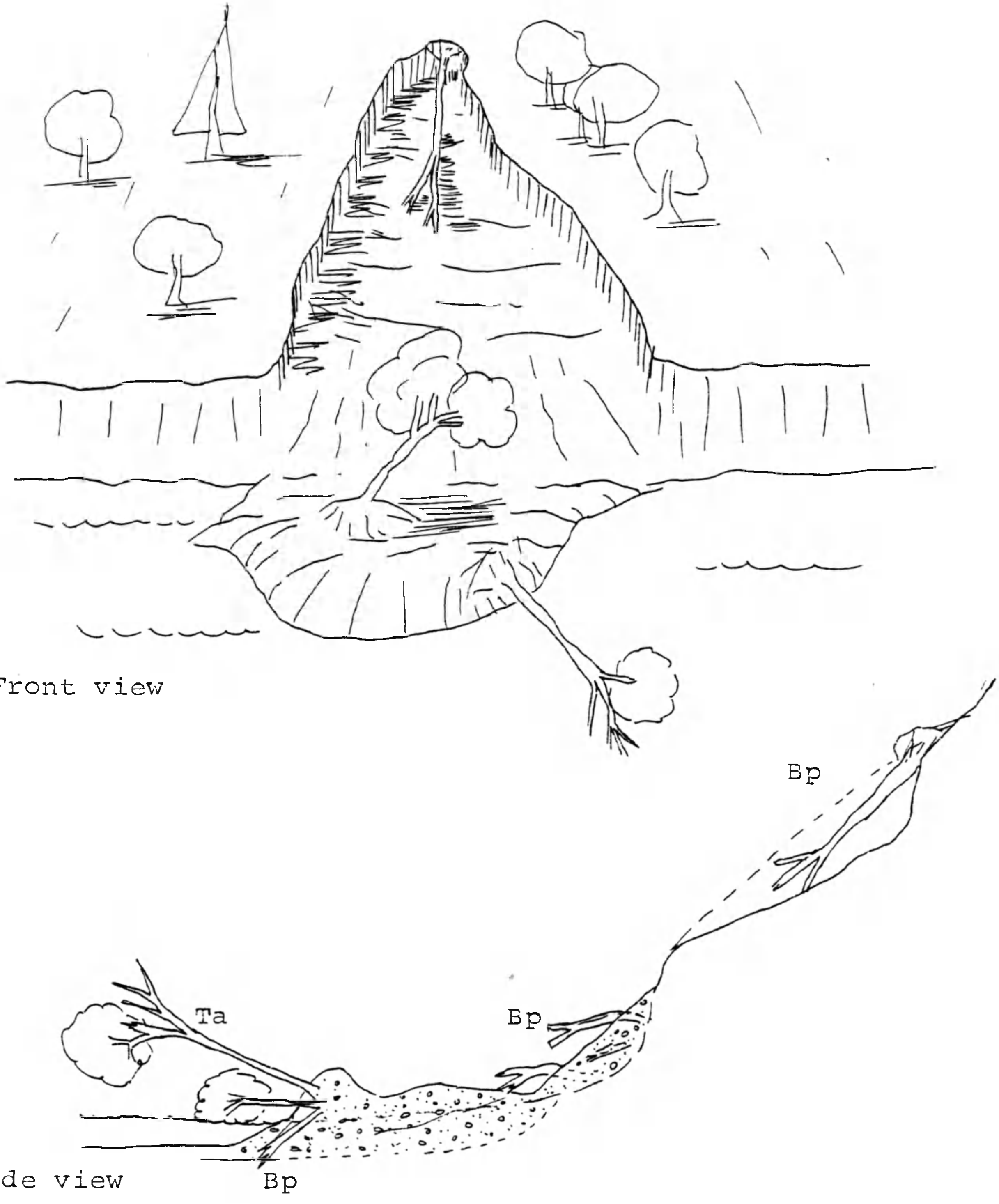


Figure 17A -Front and side views of Slide 1 in 1976, shortly after sliding. Species symbols (Ta, Bp) are explained in figure 34.

Front view

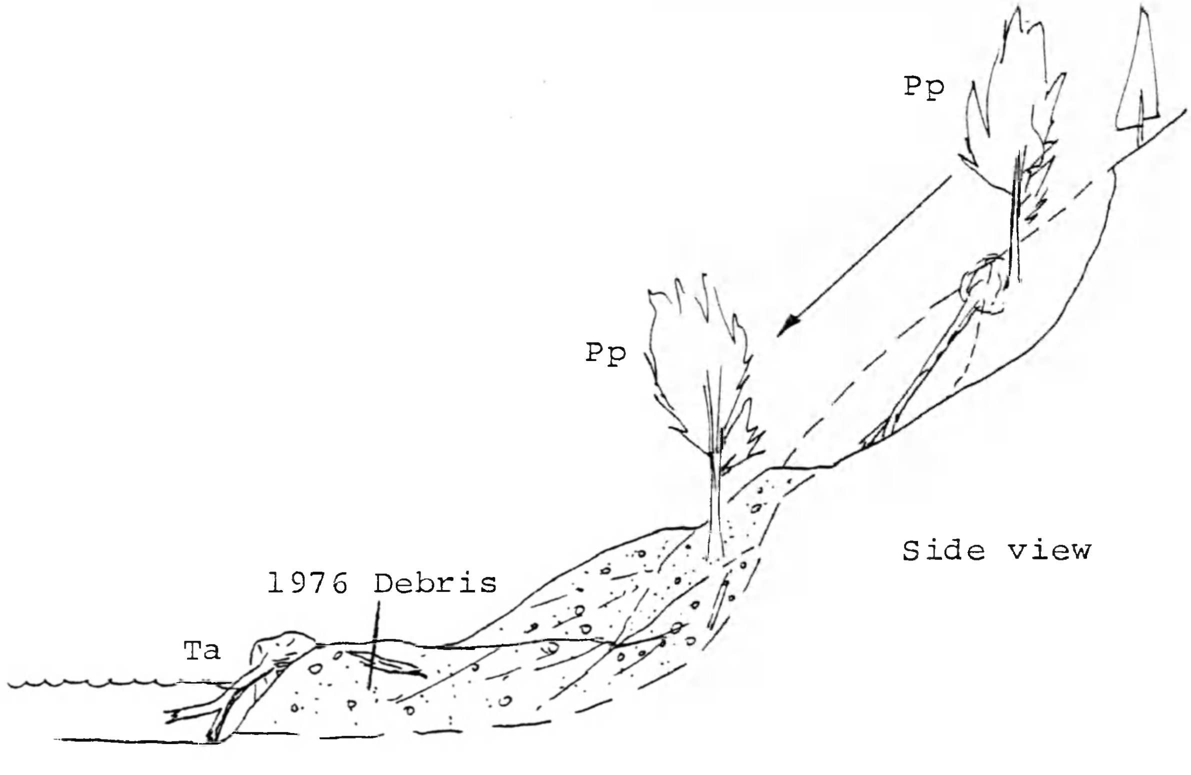


Figure 17B - Front and side views of Slide 1 in 1977, after additional sliding took place. The outline of the 1976 slide area is marked in the upper figure. (See figure 34 for symbol explanation).

Figure 17C - Photos of Slide 1 in 1976 and in 1977, after additional sliding took place. Note that the fallen paper birch at the top of the slide in the top photo is also present in the lower photo.

1976

1977

Table I - Data on Slide 1 in 1976 and 1977. See figure 16 for location and figure 17 for diagrams and photos.

Slide 1 - Fall 1976

Slope: Average cutbank slope, 40°; slide scar 41.5°.

Approximate volume: 300 m^3.

Length: 20 m.

Width: Maximum, 12 m.

Shape: Parabolic scar; base slightly concave.

Approximate age: Less than 3 years.

Vegetation cover: Bare to covered with sparse annuals.

Slide 1 - Summer 1977

Slope: Average cutbank slope, 40°; scar, 41.5° to 50°.

Approximate volume: 700 m^3.

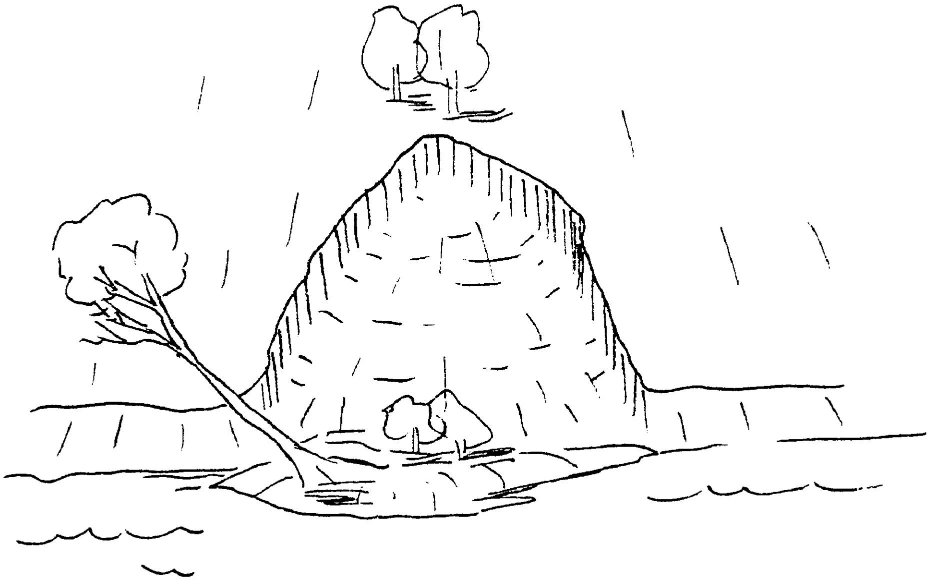
Length: 35 m.

Width: 30 m.

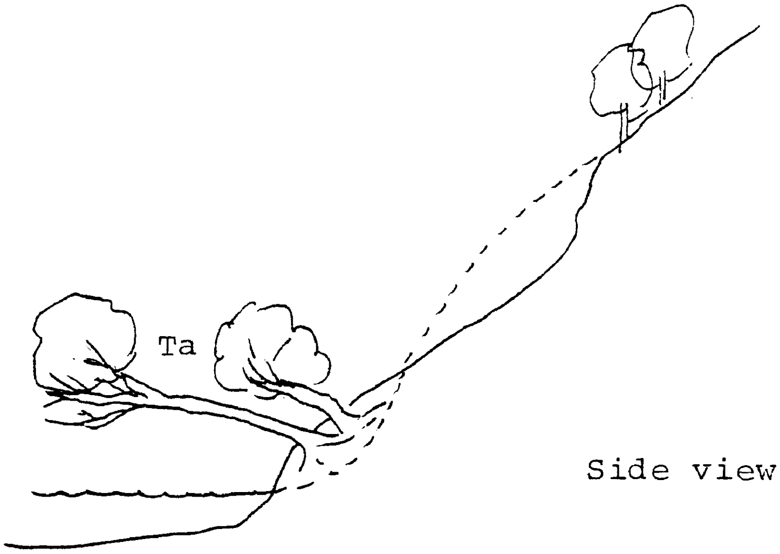
Shape: Three interlocking parabolas.

Approximate age: Less than 9 months.

Vegetation cover: Bare; isolated annuals.



Front view



Side view

Figure 18 -Front and side views of Slide 2. Asymmetric rings in the tilted trees at the base of the scar indicate the slide occurred less than 5 years previous to 1977. (See figure 34 for species code)

Table II - Photograph and data on Slide 2.

Slide 2

Slope: 41.5°.

Volume: 100 m^3.

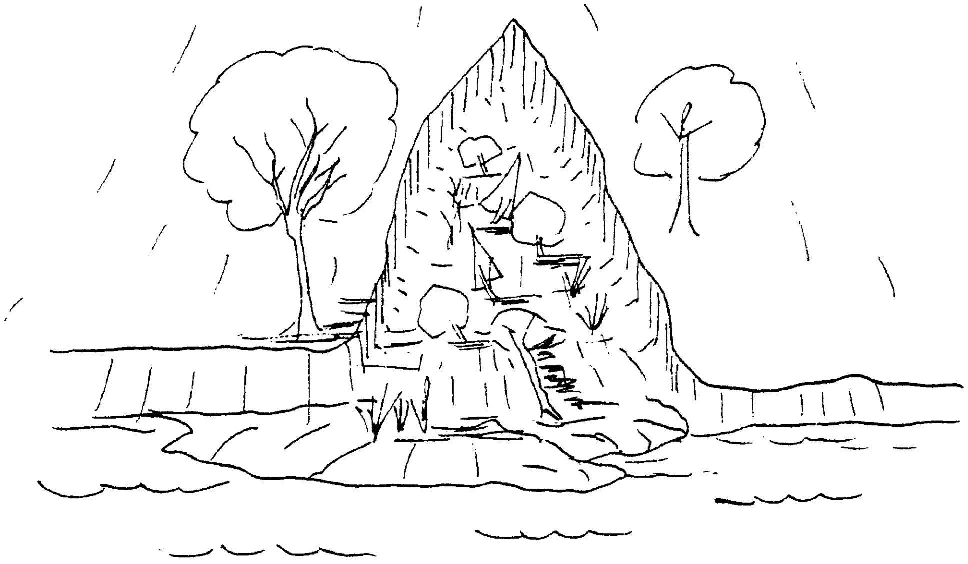
Length: 10 m.

Maximum width: 7 m.

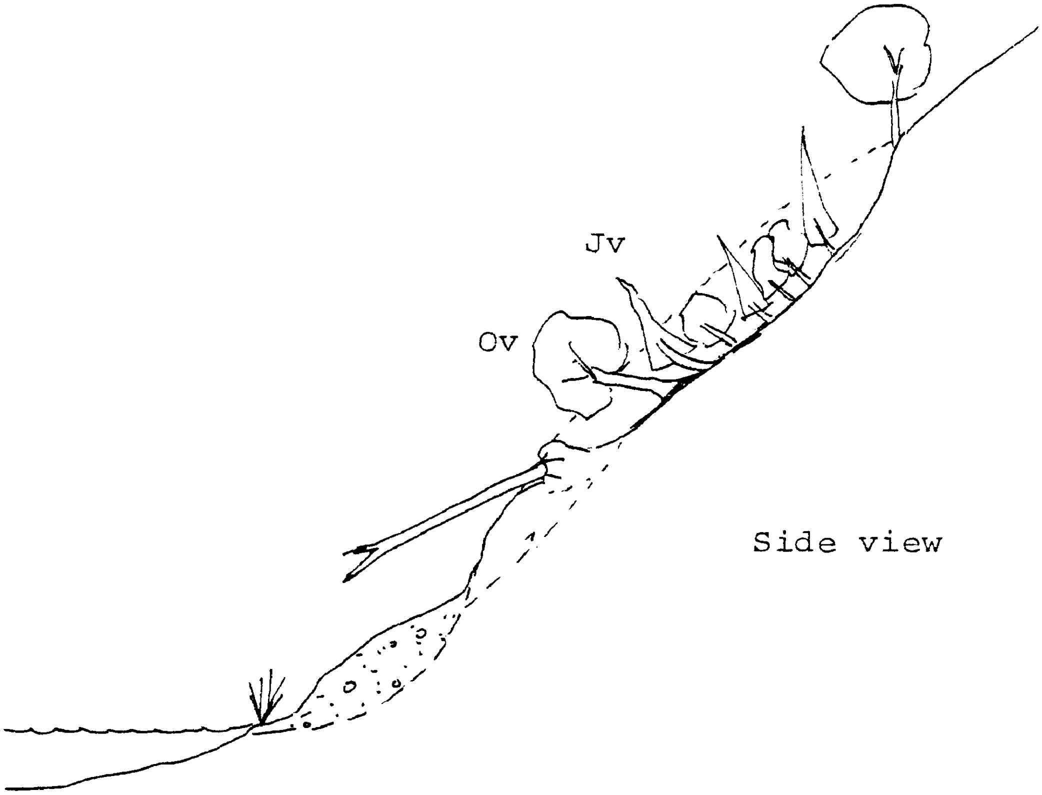
Shape: Semi-circular to slightly parabolic.

Approximate age: Less than 5 years.

Vegetation cover: Thin, with many small annuals.



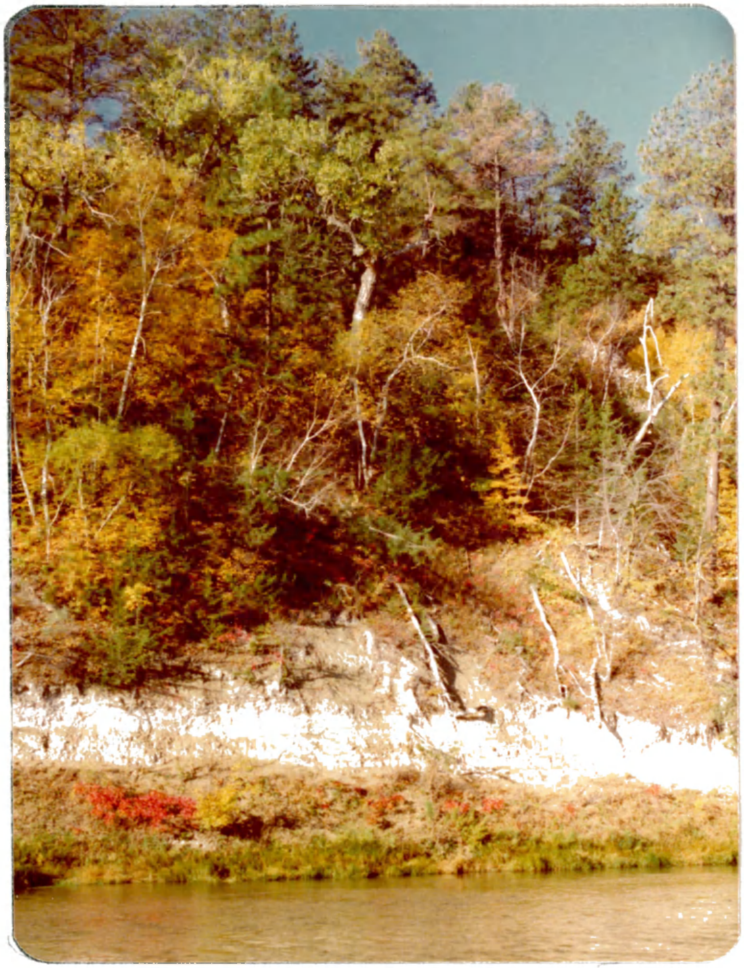
Front view



Side view

Figure 19 - Front and side views of Slide 3. Note young trees growing on the slide scar. Their average age (by coring and sectioning) was determined to be approximately 25 years. The approximate age of the slide is thus, 30 years, allowing for the first sere of annuals. (See fig. 34 for species code).

Table III - Photograph and data on Slide 3.



Slide 3

Slope: 35°.

Volume: 400 m^3.

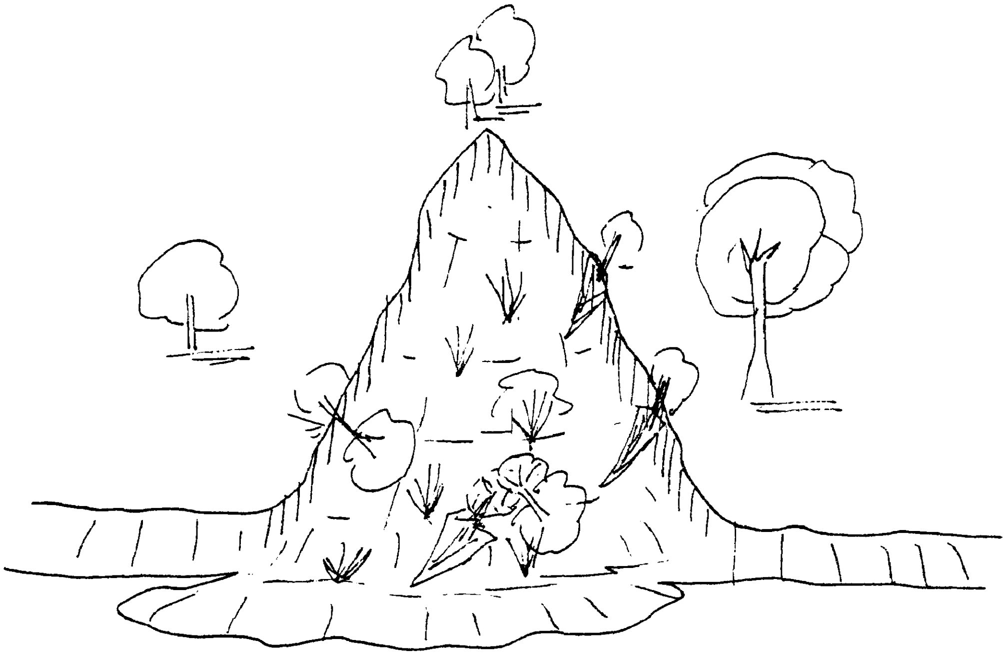
Length: 30 m.

Maximum width: 15 m.

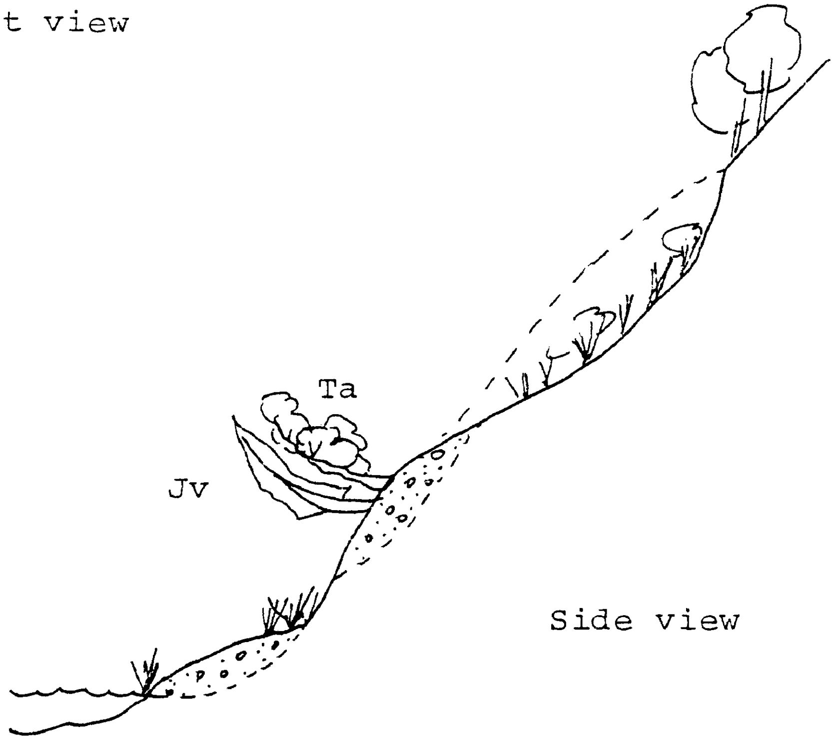
Shape: Nearly triangular.

Approximate age: 30 years or less(± 5).

Vegetation cover: Ironwood and juniper saplings; herbaceous ground cover.



Front view



Side view

Figure 20 - Front and side views of Slide 4. Cores taken from the juniper (Jv) and basswood (Ta) indicate the slide took place from 5 to 15 years previous to 1976. (See figure 16 for location).

Table IV - Photograph and data on Slide 4.

Slide 4

Slope: 40°.

Volume: 350 m^3.

Length: 35 m.

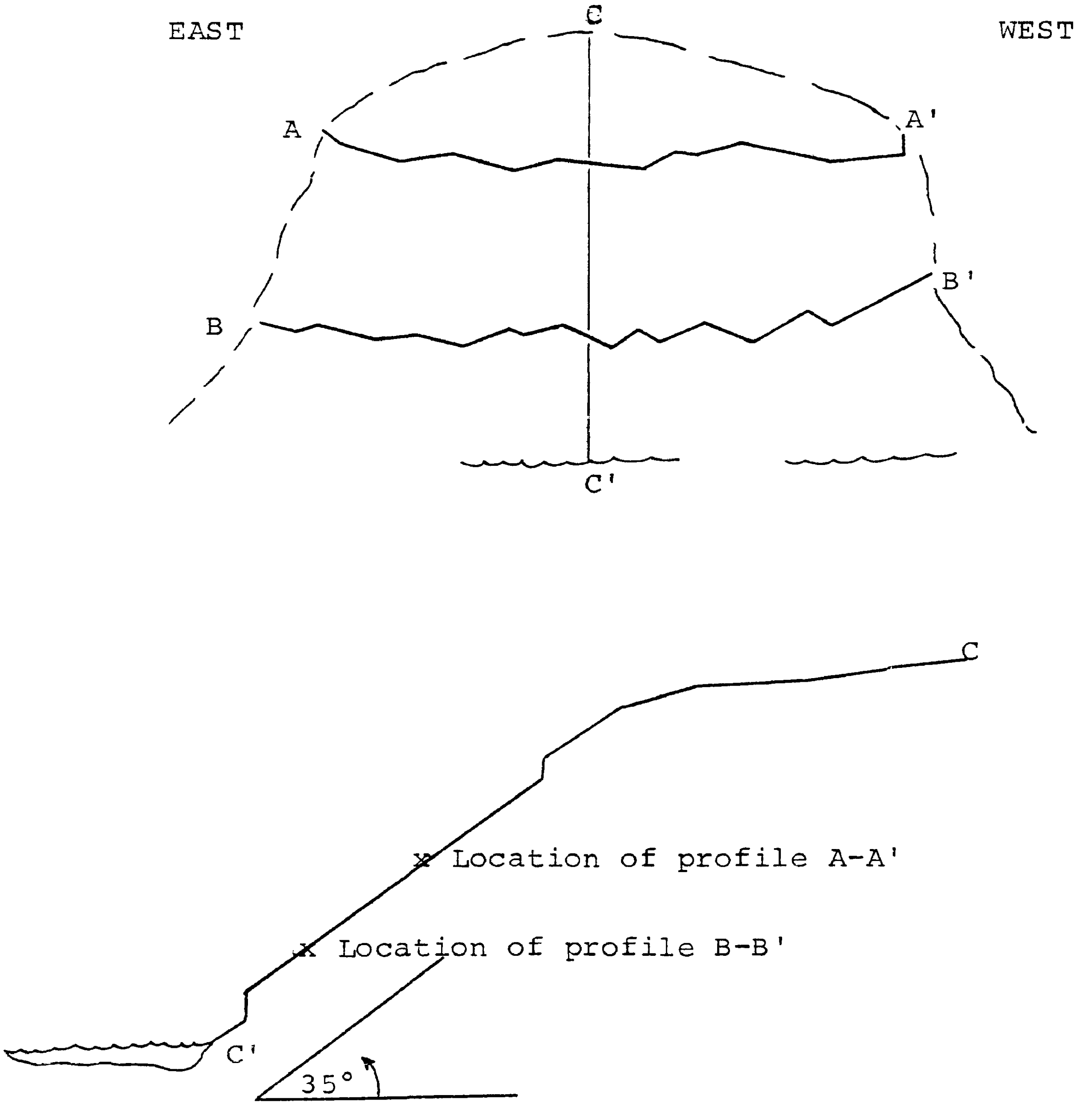
Width: 10 m.

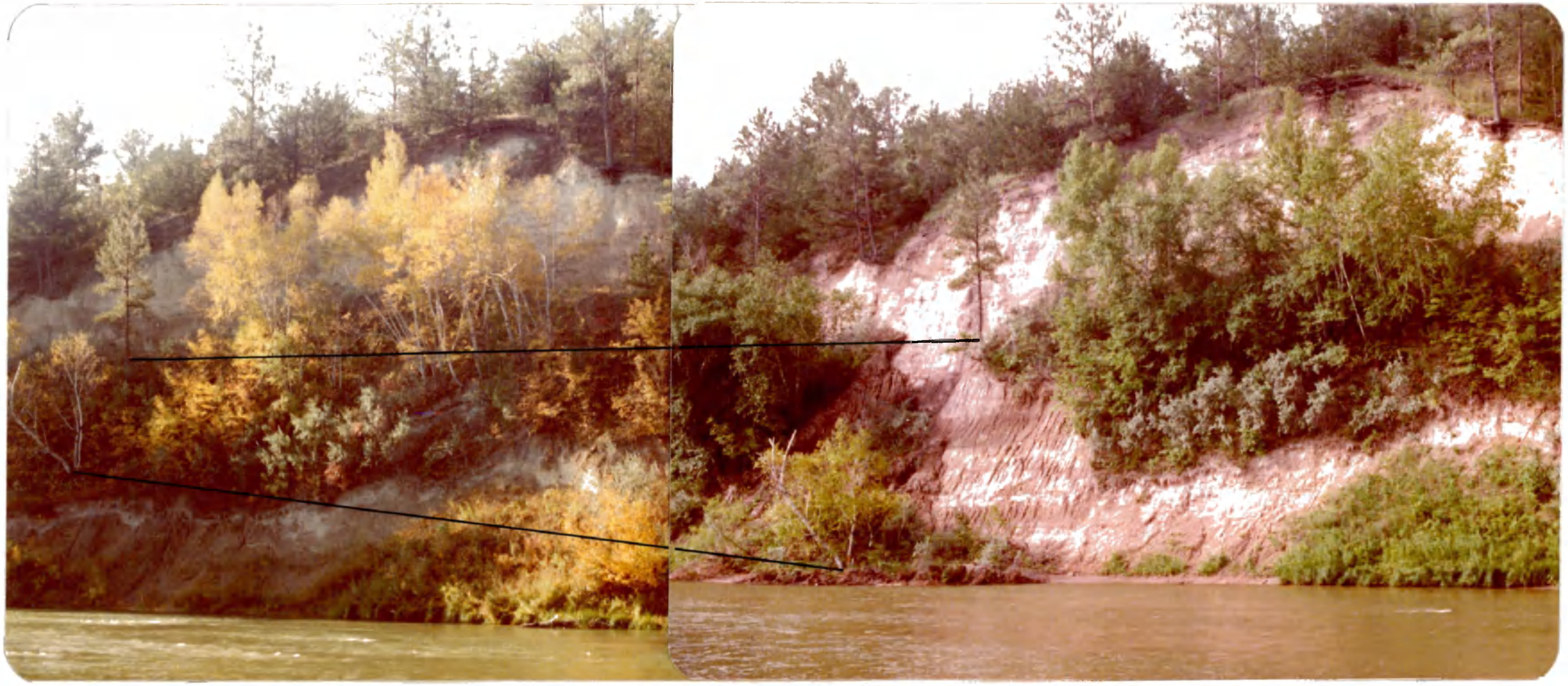
Shape: Nearly triangular.

Approximate age: 5 to 15 years.

Vegetation cover: Annuals, Equisetum, and sapling pine, juniper, and ironwood.

Figure 21A - Horizontal, A-A' and B-B' (contour), and vertical, C-C', profiles on a slide bank similar to Slide 5. Note the saw-edged effect from gullying on the horizontal profiles and the vertical cliffs on the C to C' profile. The scale is approximately 1 mm = 1 meter.





Fall 1976

Spring 1977

Figure 21B - Photographs taken in the fall of 1976 and the spring of 1977 showing additional sliding on Slide 5. The ponderosa pine (top line) is a reference point from which the displacement of the slide debris can be determined. The paper birch (bottom line) is contained within that debris.

Figure 22 - A photograph of a new landslide that occurred in May of 1977, 2.5 km southeast of the Cherry County line (fig. 16). Note the broken tree projecting from the landslide debris. This and the living basswood to the right suggest that sliding, as opposed to flowing was the mechanism involved.

keeping the tree upright. Other upright living trees that typically bound large chunks of material were also present in the slide debris. An interweaving of roots aids a coherent slide although there is some breaking apart of these individual root masses during sliding.

Water seeping over the Rosebud at the base of the Valentine saturates parts of these formations as well as the surface mantle of colluvium. In doing so the pore pressure is increased, decreasing the shear strength of the material, resulting in failure on the slope. The coherence of the Valentine (loosely to unconsolidated sands) is readily lost upon saturation. The Rosebud, on the other hand, increases in stability with constant saturation. This property is noted at sites where springs and larger falls enter on the right bank. The small streams, instead of creating an incision in the bank where they enter, actually create a protrusion in the rock over which the spring flows. In those areas where the Rosebud is alternately wet and dry, the material crumbles readily. The latter property may owe its existence to the expansion and contraction of clays in the formation.

Immediately after sliding, before material accumulates on the scar, the bank often remains wet and in some cases may have springs flowing over it. Because the paper birch is inherently linked to steep, north-facing slopes and moist conditions, presence is a good indicator of potential slide areas. Paper birch are commonly found in slide debris.

In addition to landsliding, other forms of mass wasting are present in the area. A more subtle form of mass movement is the imperceptible but ever-operating soil creep. This process continually interacts with the debris slides by overloading already steep banks with additional colluvium. Arched and toppled trees commonly occur and serve as an indication of this and other types of movement.

Earthflows are thought to occur but none have been positively identified. Deposits resembling those of an earthflow have been located on the right bank but are much overgrown by vegetation. Another form of mass wasting is derived from the sands of the Valentine Formation. 'Sandruns' may flow in a wet or dry state and are a source of colluvium overloading slopes.

Terrace Morphology

Introduction

The terraces along the Niobrara reflect the downcutting and the resulting entrenchment of the river. Treads are evident along its course at levels from the modern floodplain to those disappearing below the Sandhills. The terraces are ancient floodplains resulting from periods of stability of climate or tectonism in the downcutting process of the river.

Methodology

The approach used to describe the terrace morphology is twofold and suited to the scale of the terrace groups. The first is the construction of topographic profiles by the tape and Abney hand level method. Thirty-one profiles were made from the rim of the south bank to the tread of the 9 m terrace on the north. The profiles were spaced every 200 m in the western 3 km of the study area, and every 400 m in the remainder. The topographic profiles were drafted both individually and in two five-profile composites to illustrate terrace persistence (see appendix I). The second method was the use of U.S.G.S. 1:62,500 maps to locate the largest of the terraces (appendix II). ERTS photographs also facilitated description of higher terraces. Thorough descriptions were then made of many details of the terraces.

Findings

The terraces were ranked in three distinct groups: the lowest group having terraces at 2.5 m, 3.5 m, and 9.0 m; the intermediate group having occasional broken segments between 15 m and 50 m, with a persistent level at approximately 35 m; and the high group having levels at roughly 60 m, 75 m, and 95 m above the modern floodplain.

These terraces have been formed as a result of alternating periods of stability and downcutting. Possible reasons for the downcutting are: (1) regional uplift, (2) changes in discharge, and (3) a decrease in load. The river, as indicated by numerous low terraces on the left bank and the steep cutbank and lack of low terraces on the right bank, has cut in an asymmetric fashion. Reasons for this asymmetry may include: (1) uplift from the north, (2) bedrock topography inclined to the south, (3) "pushing" of the river to the south by tributaries entering the river from the north, (4) Coriolis effect, and (5) any combination of these.

The persistent terraces of the low group are often nearly level and sometimes sloping away from the river. These were referred to as glacis terraces (Hitchcock, 1857). In spite of this common occurrence, the mean slope for the 2.5 m terrace is 0.6° toward the river. The

3.5 m terrace also has these characteristics with a mean slope of 1.4° toward the river. Abandoned channels, overflow channels, marshes and swamps are common on these two lowest terraces as a result of both high ground water and the glacis terrace feature. The riser slopes of these vary greatly from 3° to 85°. The mean slope of the risers decreases with terrace age which corresponds to the height above the river. The riser slope decreases rapidly up to the level of the 3.5 m terrace and gradually from then with increasing terrace tread height (fig. 23). Slope equilibrium is apparently reached near the 3.5 meter level and corresponding age, or at about 10° slope. The present riser slope is dependent on its original configuration and subsequent degradation through time. The low terraces on the north bank are generally wider than their equivalents (if they exist) on the south. An unusual feature on the south bank is the presence of many swamps and marshy areas--which are not present in a similar location on the north bank.

The 9 m terrace is the highest persistent terrace of the low group. The tread rises at an average of 2.9° and varies from sloping 1.0° away to 7.0° toward the river.

Many landforms alter the normally flat nature of the low terraces. Included are: small gullies and streams, steplike meander scars, natural levees, alluvial fans, and abandoned channels. The gullies develop as water flows over terraces during heavy rains. Some gullies in poorly maintained areas enlarge rapidly unless preventive measures, such as diversion ridges, are taken. In rainy years, standing water may be present on the glacis terraces, encouraging the growth of marsh and sedge plants. There are six major tributary streams that cross the low

Figure 23 - A comparison of terrace tread height with riser slope showing the rapid degradation of slope in the early period after formation, and the slower degradation of slopes above the 3.5 meter level.

TREAD HEIGHT	RISER SLOPE (DEGREES)														
2.5 meters	85.0	10.5	14.0	7.5	—	10.0	21.0	33.0	29.5	40.0	—	14.5	13.0	31.0	—
3.5 meters	16.0	6.5	—	8.0	4.0	—	2.0	1.5	—	8.5	24.0	4.0	9.0	9.0	12.5
9.0 meters	12.0	—	—	—	10.5	—	6.0	5.5	3.0	—	6.5	15.0	6.0	8.5	3.0

	MEAN SLOPE = $\bar{M}$	
2.5 meters	25.75°	(12 SAMPLES)
3.5 meters	8.75°	(12 SAMPLES)
9.0 meters	7.60°	(10 SAMPLES)

TREAD HEIGHT vs. RISER SLOPE

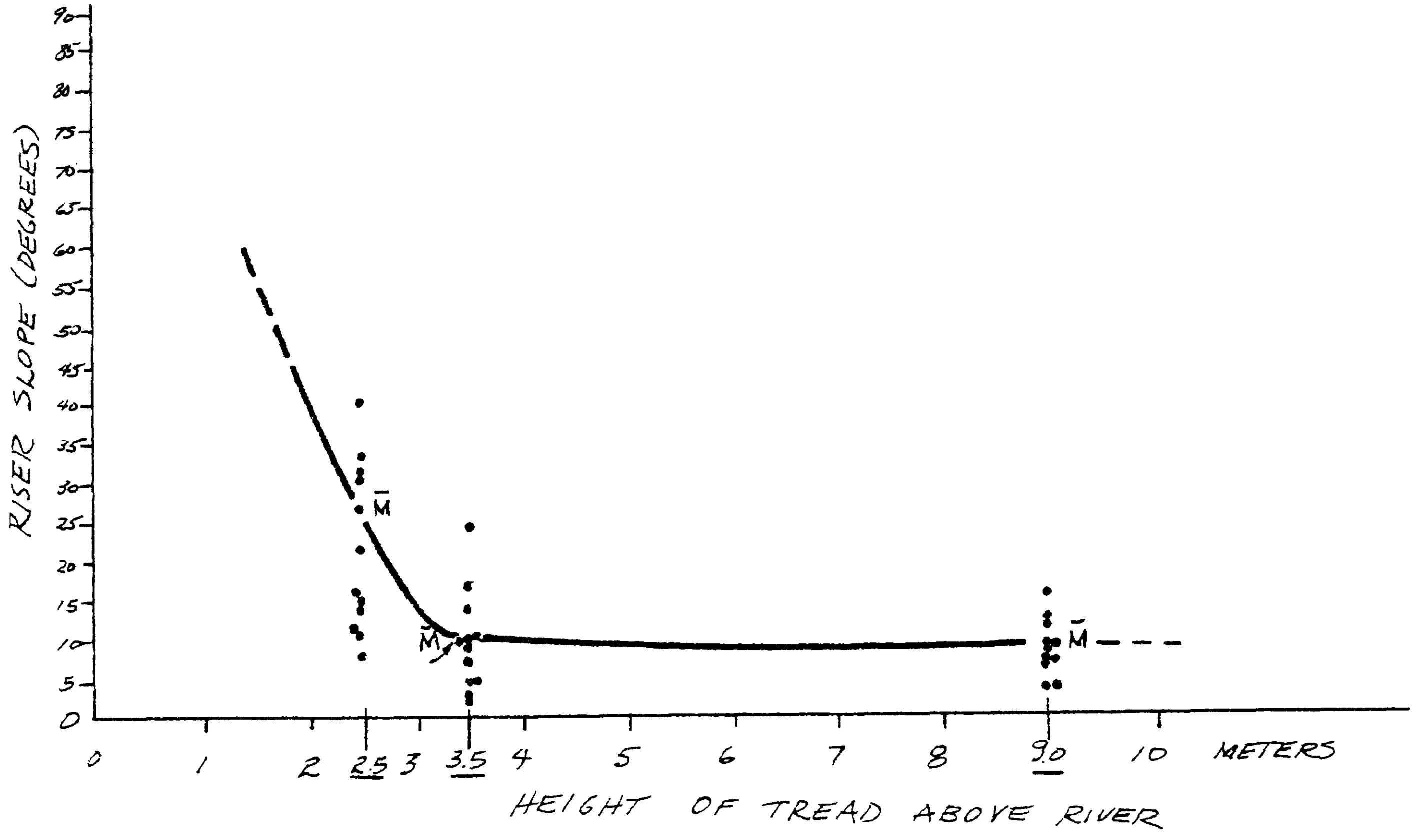


Figure 24, a & b - Ground (a) and aerial (b) photographs of step-like morphology that occurs on many meander reentrants abandoned in the process of downcutting. The upper photo is directed toward the northeast; north is to the top of the aerial photo.

a.

b.

terraces within the study area.

Small, steplike terraces, no more than 0.5 m high, illustrate the simultaneous vertical and lateral cutting of a meander. Erosion occurs from the outside of the meander and progresses inward and downward (fig. 24). These landforms result from the impediment of the downstream migration of meanders by rock-defended cusps, causing the meander to move out of the re-entrant.

Another interesting landform that occurs on some low terraces is a rise on the lip of the terrace adjacent to the lower terrace riser. The rise is usually 0.5 m higher than the tread on which it is located. It probably owes its existence to natural levee formation that occurred during the original floodplain formation and its subsequent preservation.

Several abandoned channels in various stages of invasion by plants are present throughout the valley. The older channels are generally open, grassy areas, while the newer are filled with water provided at times by springflow.

The mechanisms that alter the form of the terraces to the greatest degree are gullying and the formation of alluvial fans. With time, the processes of erosion and deposition erase the angular form of the terraces and replace it with rounded and gently sloping hills. The gullies attack the risers and fans are deposited on gently sloping treads. Erosion occurs where the relief is the greatest, and deposition increases on more gentle declivities. The result of these processes is a decrease in the rectilinear form of the slope and a slow progression toward a smoother form through time. Rapid gullying and deposition of fans has been documented in several cases following heavy rains (fig. 25). These are primary mechanisms for altering the landscape. This decrease in the rectilinear form of the benchlands is evidenced by the increase in tread slopes as the height of the tread above the river increases (or as the age increases). An averaging effect seems to operate throughout the valley where the steeper slopes become gentler, and the flatter areas increase in slope with time. The tread slopes on the 2.5 m, 3.5 m, and the 9.0 m terraces average 0.6°, 1.4°, and 2.9°, respectively. Figure 26 illustrates how a terraced valley wall would evolve through time by the processes of gullying on the risers and deposition on the treads. Additional degradation of the slope occurs through mass wasting, which may by calving and slumping periodically increase the slope of the riser.

There are no persistent terraces above the 9 m level and below the 35 m level. The terraces that are present are small, isolated benches, located mainly on the right bank. Features similar to these lie at 14 m and 18 m. The lack of terraces at this intermediate level may represent an interval of progressive downcutting, during which most surfaces were destroyed by a duration of lateral and vertical movement. The 9 m tread, being broad and persistent, may indicate a period of stability at one level. A period during which the river did not downcut would allow for greater lateral movements (fig. 27) and for the valley configuration as it is today.

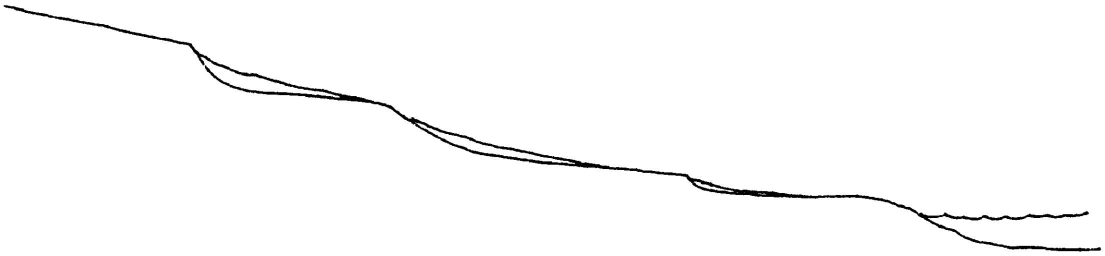
Those terraces that lie in the high terrace group occur regularly at elevations of 60 m, 75 m, and 95 m above the river. They are broad, flat benches as much as 15 km wide. They are often cut by deep tributary valleys, creating large plateau-like areas. They grade gently a.

b.

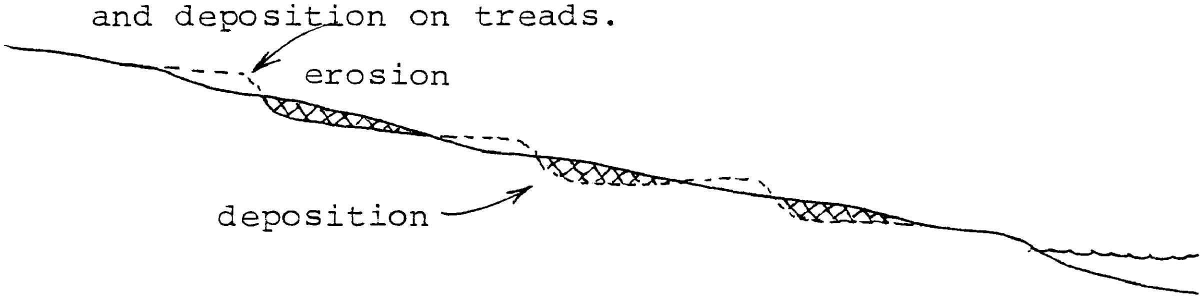
Figure 25 a & b - (a) A gully eroding the edge of the 3.5 m terrace (note the river beyond the gully). (b) Erosion of a terrace riser (foreground) and deposition of a fan on the tread of a 3.5 m terrace. The river lies within the trees at the top of the photo.

Figure 26 - Diagrammatic sequence of the evolution of terrace-land morphology.

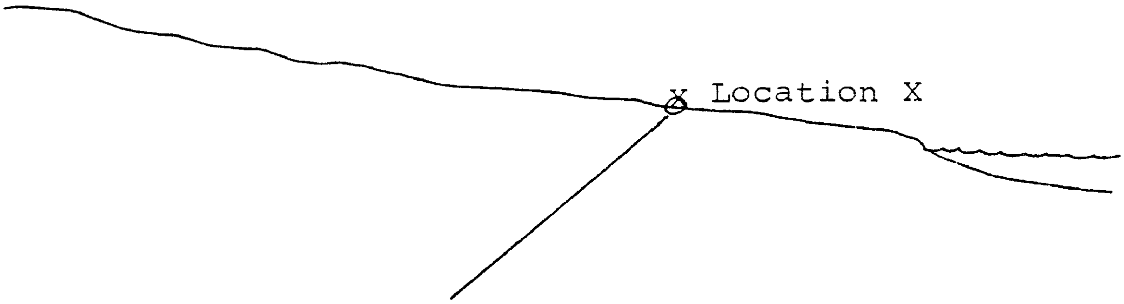
A. Terrace formation by downcutting. Note angular form.



B. Obliteration of angular form by erosion of risers and deposition on treads.



C. Slope modified to gently sloping.



D. New terrace formation by downcutting and initiation of the cycle.

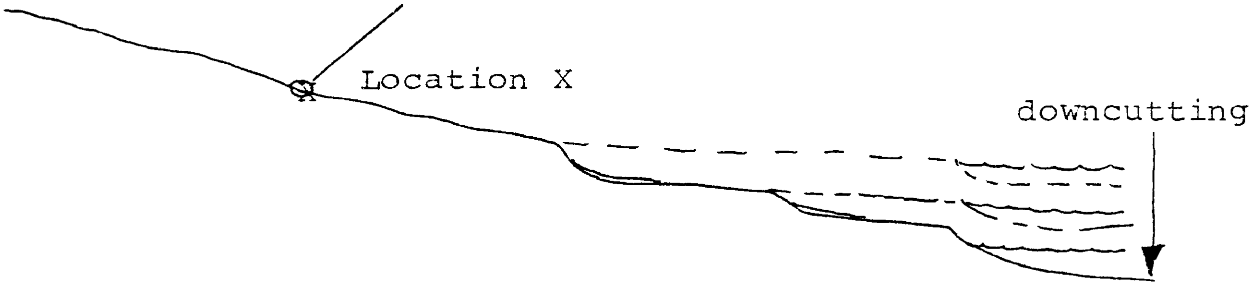
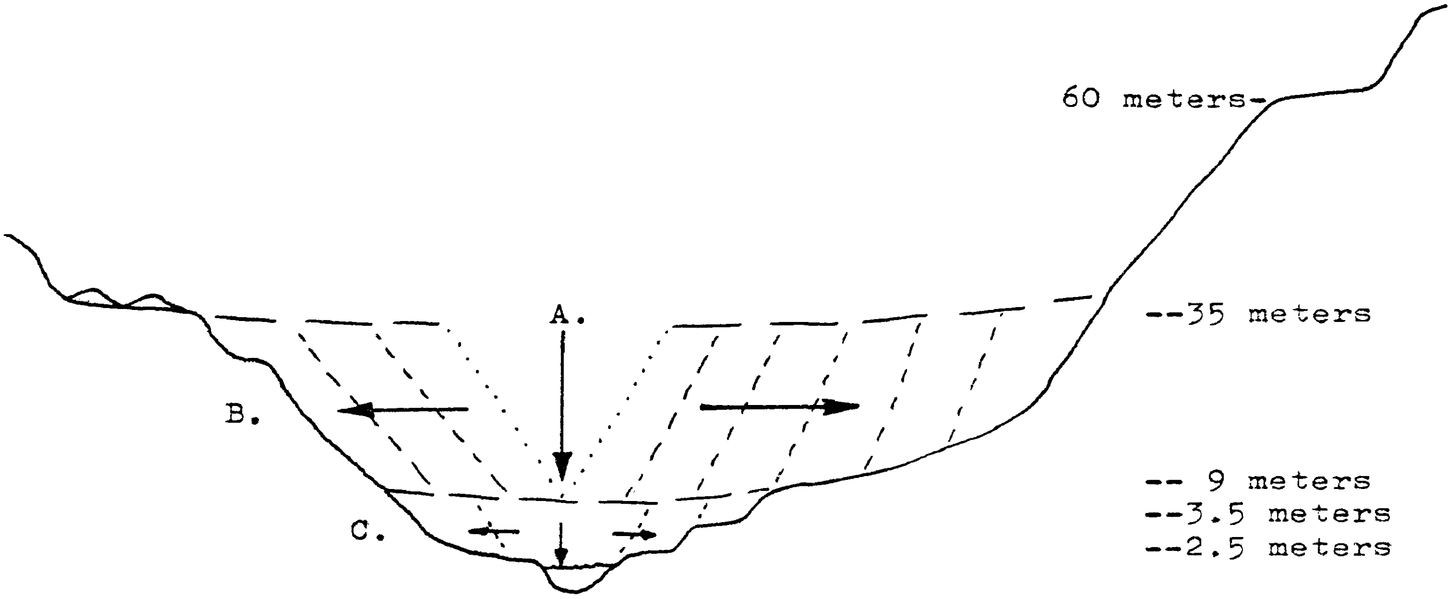


Figure 27 - Probable evolution of the lower valley morphology as dictated by periods of stability and downcutting. These periods were dictated by both climate and tectonic activity. (Elevations at the right of the diagram are meters height above the river)



A. Rapid vertical cut from the 35 meter level.

B. Prolonged stability at the 9 meter level during which parallel retreat widens valley floor.

C. Degradation proceeds to present level of the river.

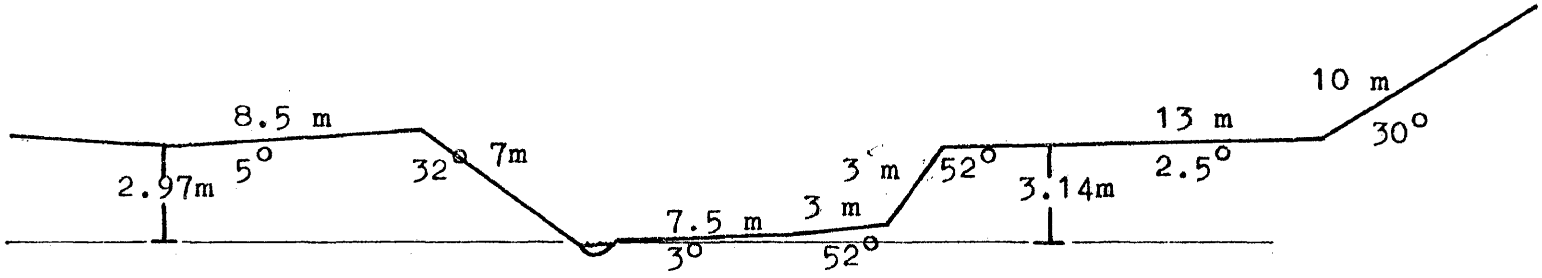
eastward at slopes of 1.5 m/km to 1.9 m/km. The high terraces within the Niobrara Valley appear as rolling hills with accordant summits (fig. 28). The 60 m terrace on the north of the river clearly depicts this morphology.

Most of the tributaries flowing into the Niobrara River from the north have paired terraces in the middle parts of their lengths (fig. 29). They have been destroyed lower in the valley by downcutting of the tributary streams. The tributary terraces appear, however, to be accordant with those of the master stream. No terrace formation has occurred along the right bank tributaries. This could be a result of the rapid undercutting of that bank and the consequent rapid cutting of the tributaries. Accordance, however, does not occur as evidenced by the numerous waterfalls.

It is the nature of a stream of diminishing load to degrade its bed to form terraces simply by the sweep of the river as it degrades (Davis, 1906). This factor combined with possible uplift in the area has created a spectrum of terraces through time along the Niobrara River. The incision of the Niobrara into Tertiary beds has probably taken place since mid-Pleistocene (Skinner and others, 1972). It occurred in pulses in response to both climatic fluctuations and possible tectonic activity. The periodicity of the downcutting is represented by the numerous gaps where no persistent terraces are present. No reversal of this trend has been indicated.

Figure 28 - A panoramic photograph of the north rim of the Niobrara River Valley taken from the 35 meter terrace (right bank) at the west edge of the study area. In this photo looking northwest, the 60 meter terrace surface lies just below the horizon and is composed of a number of rolling hills with accordant summits. The river is approximately 80 meters downslope from the trees in the foreground.

Figure 29 - A topographic profile of a northern tributary of the Niobrara River. The line runs east-west, 2.4 km upstream from the Niobrara (fig. 9), Section 27, R 25 W, T 33 N.



Terrace Stratigraphy

Introduction

This section is essentially a supplement to the previous section on terrace morphology. The stratigraphy of the low terraces gives an impression of the recent history on the order of several hundred years. There are details of this stratigraphic record that appear to correspond to the arrival of Europeans circa 1870.

Methodology

Seven stratigraphic sections were measured; two with a hand soil auger and the remainder by trenching or from exposed outbanks. Diagrams and photos were taken of each of the five trenches. All of the sections were made on the north side from 2.5 m and 3.5 m terraces except for trench 5 taken from the 9 m terrace (fig. 30).

Findings

In all cases there were unconsolidated sediments lying on the Rosebud Formation which formed rock benches (fig. 31). The particle size of the sediments ranged from fine clays to 25 cm cobbles. The strata were generally horizontally and cross bedded silts to medium sands, with lenses of clays. Cobbles typically formed the bases of the sections. Most of the materials were light colored; the sands were about 95 percent quartz with the remainder feldspar. The cobbles were apparently locally derived caliche. The clays were light brown in color in the thick lenses of 5 cm to 10 cm. At the base of trench 2, a rich, black silty clay about 30 cm thick was exposed. Occasionally strings of limonite pebbles were present in horizontally bedded sands and silts.

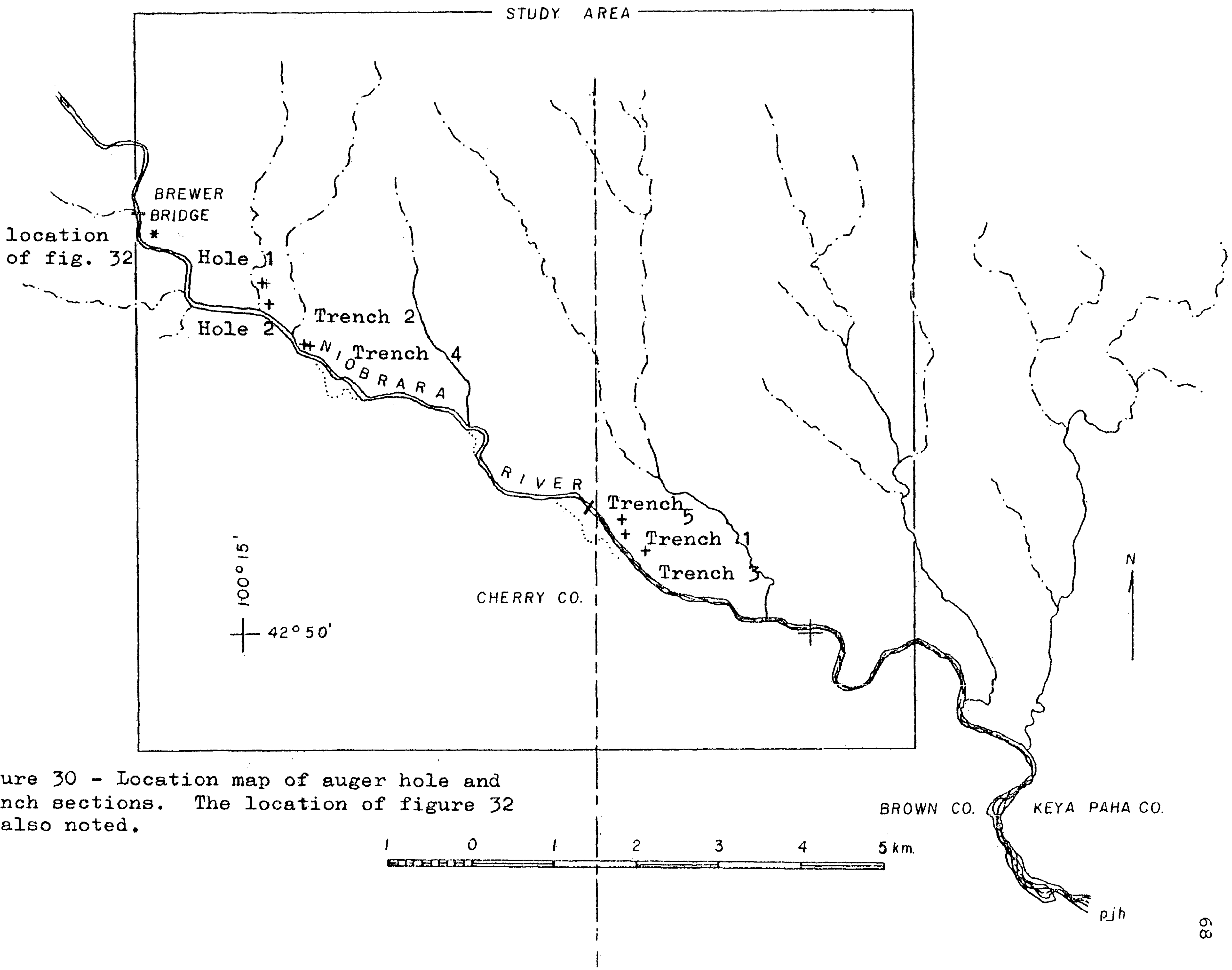


Figure 30 - Location map of auger hole and trench sections. The location of figure 32 is also noted.

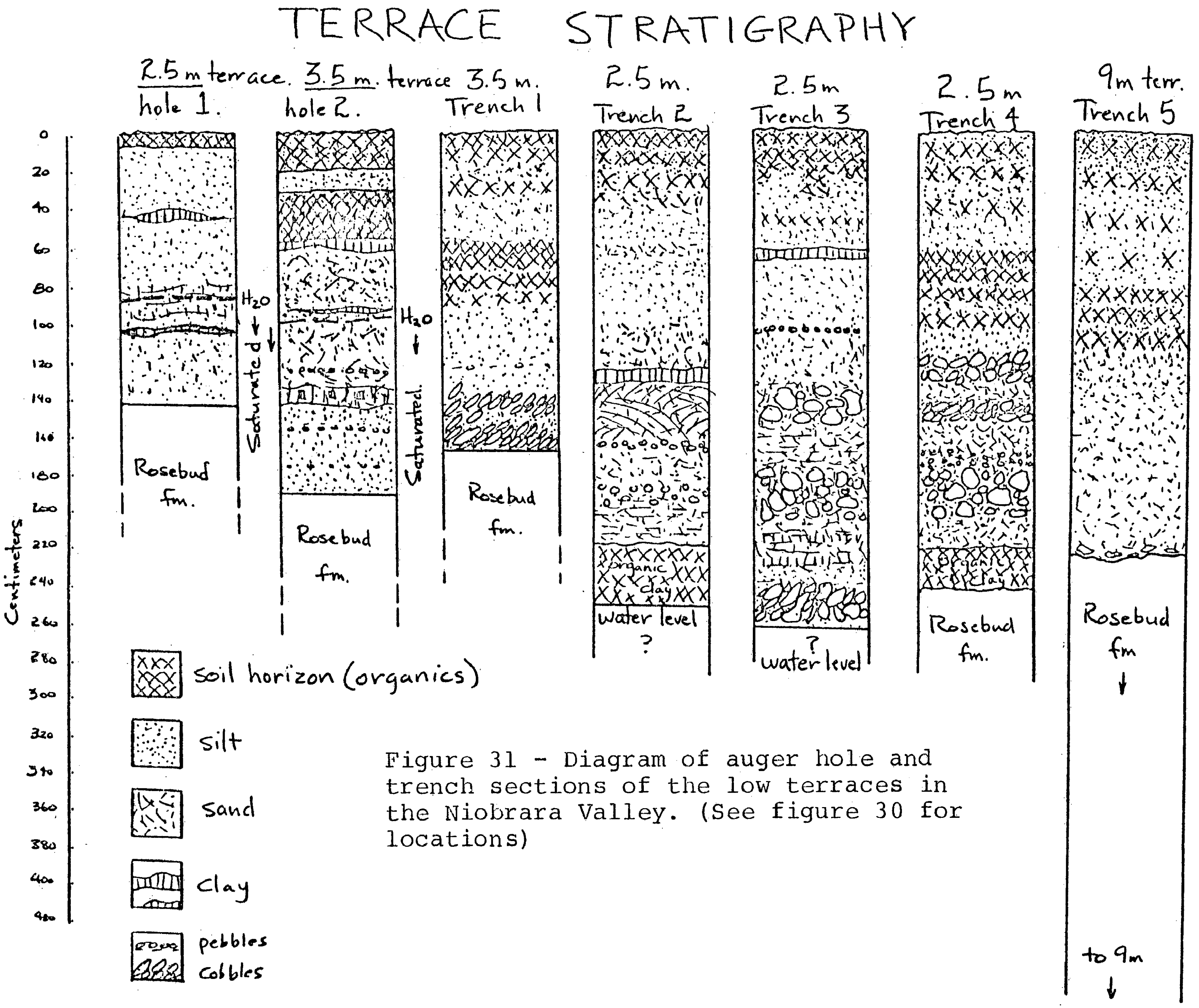


Figure 31 - Diagram of auger hole and trench sections of the low terraces in the Niobrara Valley. (See figure 30 for locations)

Imbricated cobbles found in trenches 1 and 3 indicated, by their orientation, a direction of flow similar to the present. A centimeter square piece of charcoal was found at 130 cm depth in hole 2. The specimen was collected for possible radio carbon dating.

Possibly due to provenance, past history, and leaching, the sands that compose the terrace alluvium were free of calcareous material when tested under a 40x microscope with hydrochloric acid. The sands and clays were generally very clean with no apparent oxidized material other than a few limonite pebbles. These may have been transported into the area.

The azonal soils of the terraces increase in thickness from a 5 cm-thick weak "A" horizon on the 2.5 m terrace to an average of 15 cm-thick horizon on the 3.5 m level and to a 70 cm profile on the 9 m terrace. This is a reflection of the increasing age with height of the terrace above the river.

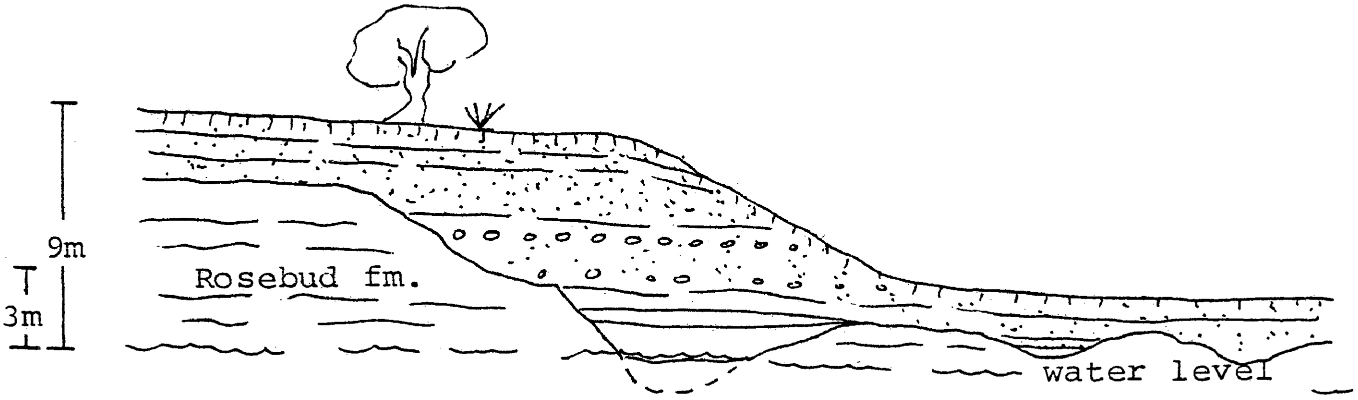
In some locations, soil horizons were observed buried at some depth below the surface. These cases appear to have resulted from alluvium recently deposited by sheetwash and flooding. The breaking of the sod by plowing and overgrazing has accelerated erosion rates from the valley sides, and also deposition on the treads on the valley bottom. On several occasions, the author has witnessed recent erosion and deposition on terraces. On the low terraces, large gullies were cut in risers, while large fans, hundreds of meters across, were created in a single storm in May 1977 (fig. 25). During this thunderstorm nearly 70 cm of silty sand was deposited on the 3.5 m terrace. The size of the deposit was not only increased by three preceding drought years which destroyed much of the vegetation cover, but also by newly tilled fields for spring planting. After many years of such deposition, alluvial fans two and three meters thick are not uncommon. An iron bean pot, presumably of the late 19th century, was found in an enlarging gully under approximately 2 m of sediments (A. Connor, per. comm.). Another rich, buried soil occurs at the headwall of slide 3, midway up the large cutbank of the right bank. It lies below 90 cm of colluvium in which well-established, woody vegetation grows.

Locally, there have been episodes of cut and fill as the river shifted across the floodplain. In a cutbank located 0.5 km southeast of a bridge near the Cherry County line, evidence of cut and fill is present. In the 9 m terrace in which this section is located, about 7 m of that is Rosebud, while the remainder consists of unconsolidated sediments (fig. 32A). A short distance downstream, the Rosebud slopes at about 45° to near the river level while the level of the sediments continued at the 9 m level. On higher terraces near the Sharp farm, 0.7 km east of Brewer Bridge (fig. 30), another cut and fill sequence was observed and described (fig. 32B).

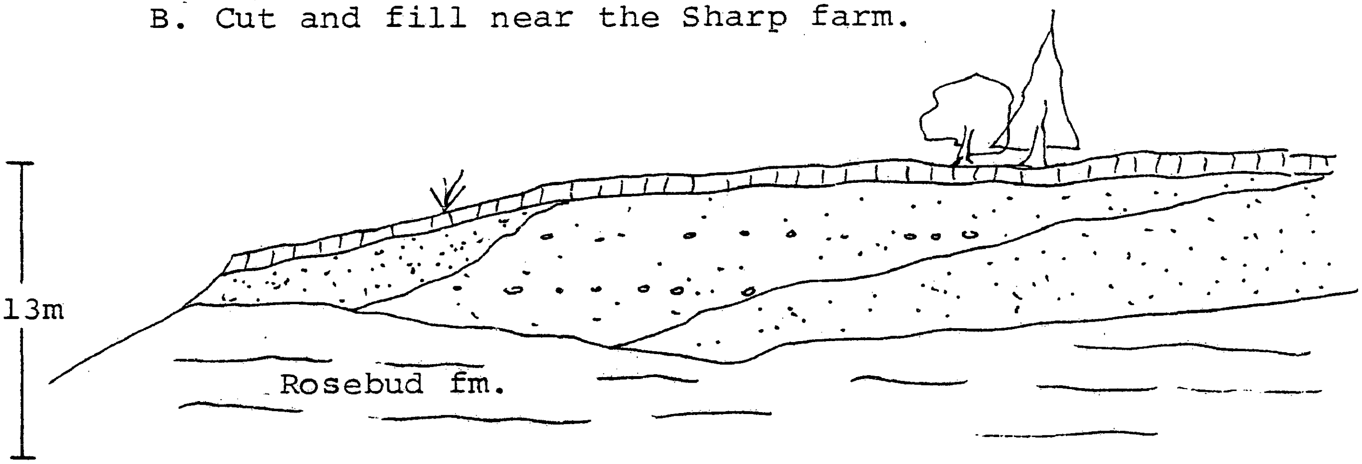
A great deal of information cannot be derived from this cursory study of terrace stratigraphy. This is due in part to the reconnaissance nature of this study and in part to the inconsistency of the data collected. However, several conclusions can be made. First, the low terraces are first cut in bedrock and then mantled with alluvium. The proportion of rock thickness to alluvium is often 1:3, respectively. Secondly, the trench sections indicate that one, or possibly two, sweeps of the river were made in the trench area. The gradational

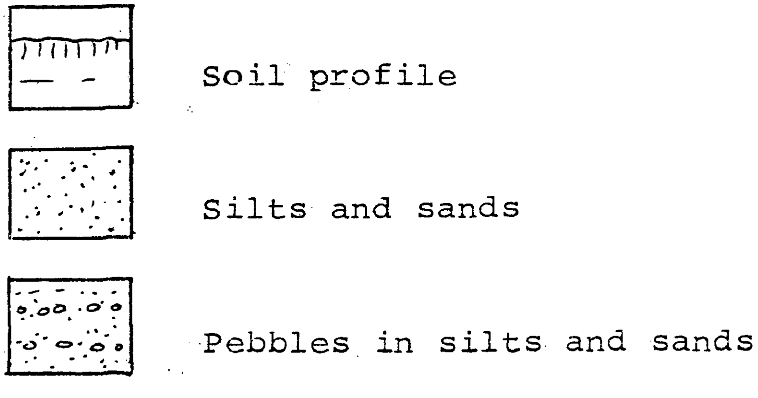
Figure 32; A and B - Local cut and fill sequences within the study area. Locations are shown in figure 30.

A. Local cut and fill near the Cherry County line.



B. Cut and fill near the Sharp farm.





sequences of rock cobbles diminishing in size upward to silty material in one or two sets are evidence to this. Thirdly, there were braided streams or migrating sandbars in the area that now contains a meandering stream. The cross bedding in the trench sections seems to indicate this possibility. Fourthly, backwater swamps or bogs were present in the area now containing the channel. Fifthly, numerous buried soils indicate rapid deposition which has recently been taking place and may be at a more rapid rate with the arrival of Europeans. Finally, terrace sections contain rock material not unlike that in the present thalweg, indicating little change in the carrying capacity of the river in the recent past.

VEGETATION ECOLOGY

Introduction

The Niobrara River and the study area lie deep within the North American prairie biome. South of the river is the Sandhills prairie dominated by little bluestem (Andropogon scoparius), reed grass (Calamovilfa longifolia), needle grass (Stipa comata), and yucca plant (Yucca glauca) (Kaul, 1975). Directly to the north of the study area, midgrass prairie dominates, while further to the west, the Sandhills prairie extends as far north as the Minnechaduza Creek (Kaul, 1975). Representatives of both of these types of prairie are present within the study area.

The asymmetric river valley in the study area presents an interesting aspect of phytogeography, as it contains a mixture of Rocky Mountain, Eastern Deciduous, and boreal species interspersed with grasslands. The river flows east to southeast through a deep valley. Dense stands of deciduous forest dominate the valley bottom on the right bank; this thins vertically and becomes a mixed bur oak (Quercus macrocarpa), red cedar (Juniperus sp.), and ponderosa pine (Pinus ponderosa) woodland. The valley rims are typically dominated by nearly pure stands of ponderosa pine. The vegetation of the left bank is characterized by a floodplain-type woodland which lines the river on the low, flat terraces, and gradually gives way to grasslands on the higher benches. The deep, tributary valleys are usually wooded. The distribution and the habitat of the vegetation in the river valley are among the principal investigations of this chapter. One must consider from the onset of this discussion that man and his agriculture have probably affected the natural vegetation a great deal and that some of the results may not be indicative of natural distribution.

The regional climate is characterized by low rainfall (500 mm per year) distributed in the form of thunderstorms in the spring and summer with smaller amounts in the form of snow in winter months. Summer temperatures may frequently exceed 38°C while those of the winter may fall below -29°C. There is an approximate 180-day growing season. Much of the precipitation results from the meeting of polar fronts with warm, moist Gulf air (U.S. Weather Service). The low precipitation and high evaporation rate places the regional climate in the class of semi-arid. This type of climate is typical of grasslands (steppe), yet, microclimatic influences (exposure, groundwater, and topography) within the study area most likely are more important in maintaining many non-grassland species at or beyond the periphery of their normal ranges.

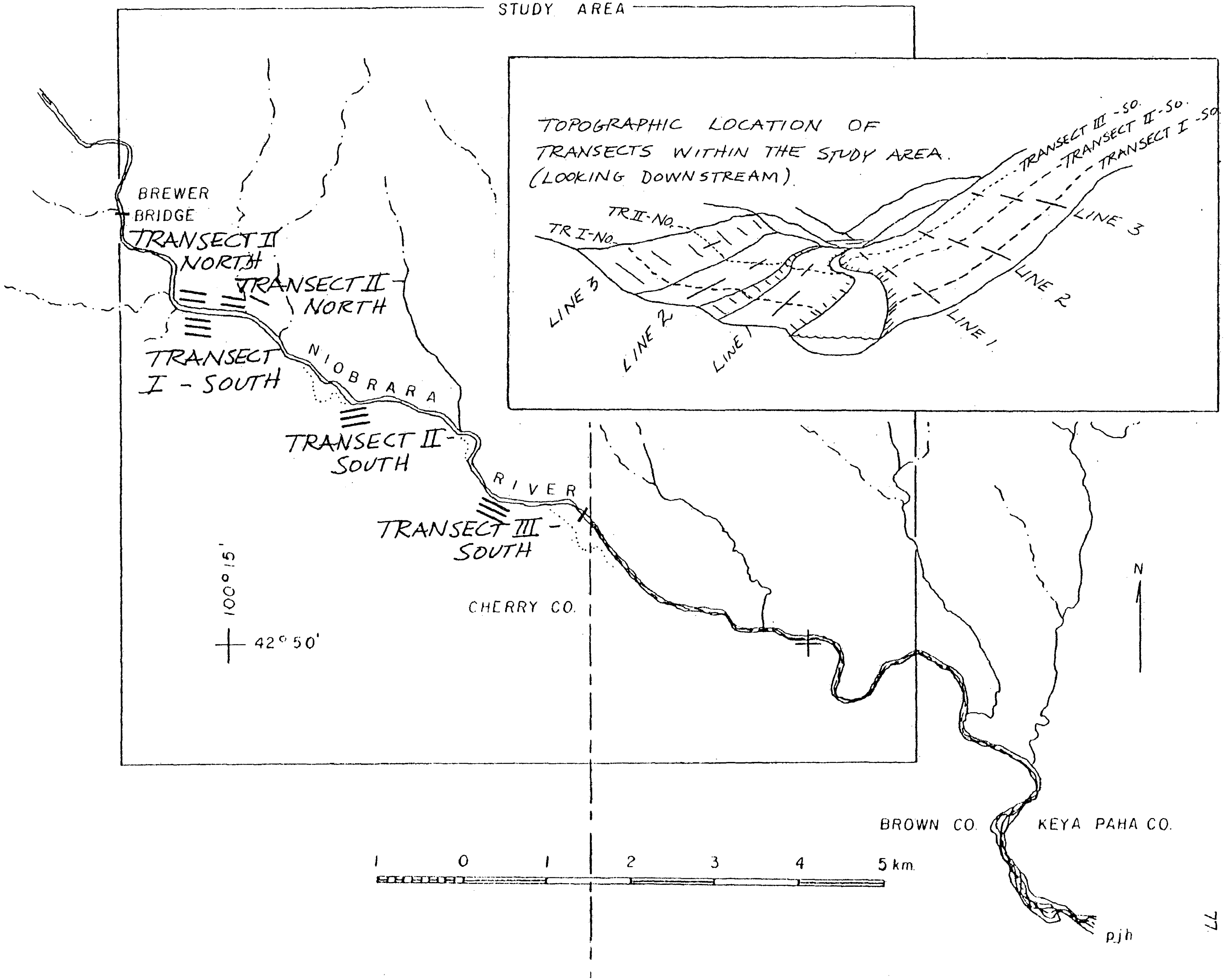
The mixed forest mapped by Pool (1914) and Küchler (1964) contains representatives of the Rocky Mountain and Eastern Deciduous forests, and relic species of northern forests in a grassland setting. Pollen profiles by Sears (1961), Watts and Wright (1966) and Moran (1973) trace the northward withdrawal of a boreal forest from 13,000 to approximately 5,000 years ago. The paper birch (Betula papyrifera) remains as evidence of this forest (and periglacial climate). Wells (1965), on the other hand, views the presence of the scarp woodlands of the Great Plains as sanctuaries from prairie fires that swept the Plains, set both naturally and by man. The scarps acted as a firebreak because of the rapid change in topography and wetter conditions that prevailed there. Recent reduction in the occurrence of prairie fires in the Plains may result in the reversal of this trend.

Methodology

The point-centered quarter method (hence referred to as PCQ) (Cottam and Curtis, 1956) was used to sample the woody vegetation. Three transects were drawn across the valley. On the right bank (south), the transects each have three lines, while on the left bank (north), they have two and three lines (fig. 33). A line is a 100 m length divided into ten points. At each point a perpendicular was drawn dividing the line into quadrants. The nearest tree was sampled in each quadrant for species, basal area and distance from the center point. A transect is the sum of lines on both the north and south sides of the river. The transects are indicated by Roman numerals I, II, and III, while the lines are indicated by Arabic numerals 1, 2, and 3, north and south. On the left bank, two locations were sampled of two and three lines each. Figure 33 shows the map and topographic location of all of the transects and lines.

Observation of plant distribution in tributary valleys and topographic profiles were used to create generalized maps of the makeup of a 'typical' tributary flora in its upper and lower reaches. Description of the vegetation present on landslips yielded a sequence of revegetation of landslips. Age of the landslips was determined by

Figure 33- Map and topographic (inset) location of point-centered quarter samples. Each of the 14 lines are 100 meters in length and follow the contour of the slope.



coring, using an increment borer on fallen or disturbed trees. Thick, dark, asymmetric rings were present in these tilted trees. Westing (1965) described this phenomenon, detectable by wood cores, as reaction wood. It occurs after a tree is displaced from its vertical orientation, when its normal pattern of secondary growth is altered, and the disorientation is counteracted. The response can be categorized as geotropic and ceases when the trunk is again vertically oriented. All ages of landslips and seres in the text are determined by this method which must be considered approximate at best.

As symbolically indicated in figures 35 and 36, some results of lines compared more favorably with adjacent lines higher or lower on the transect. This deserves only a casual mention since it is an indication of the variability of vegetation zones parallel to the river.

A separate section of this chapter deals with a general habitat of the paper birch. PCQ data as well as field observations were used in developing this description.

Results

The complete results of the PCQ sampling and the species encountered in the Niobrara Valley are included in figure 34. The dominant species were plotted on a composite profile of the vegetation and diagrammed according to similarities in dominance results (figs. 35 and 36). Habitat characteristics of each line and the dominant species therein are listed in table V.

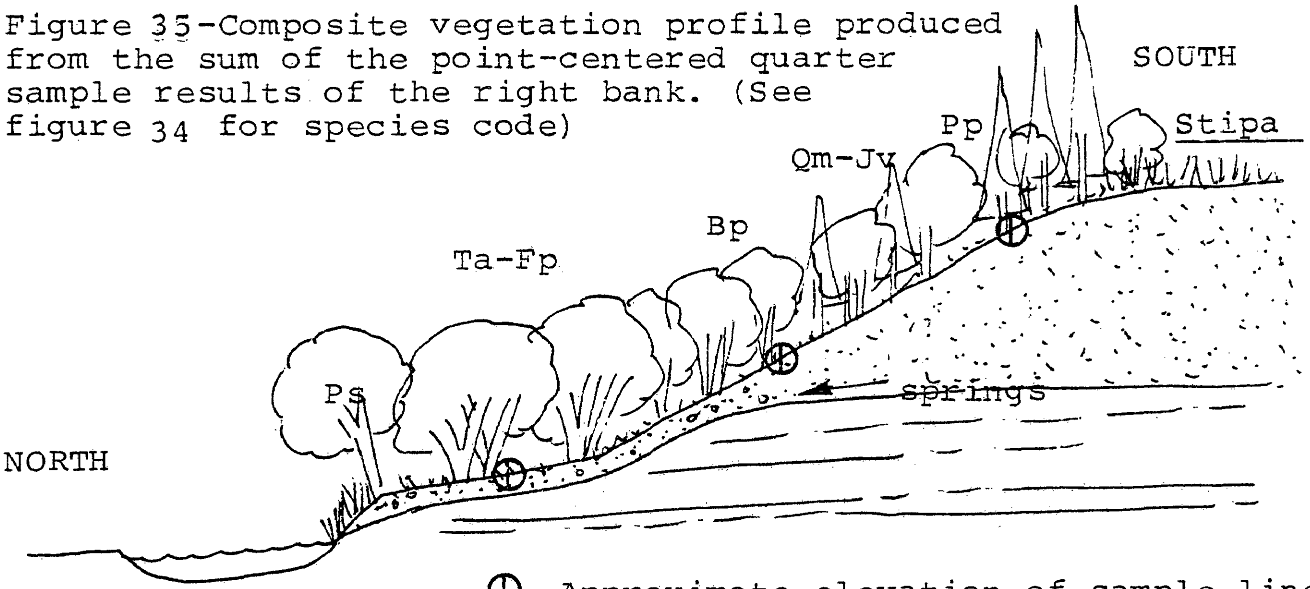
Line 1 (of transects I, II, and III--south) is frequently dominated by basswood and green ash. From the data available, it appears

Figure 34- Results of 14 lines of point-centered quarter samples. Each line is 100 meters long and contains 40 species.

TRANSECT	I	II	III	I	II	III	I	II	III	I	II	I	II	II
SIDE	So.	So.	So.	So.	So.	So.	So.	So.	So.	No.	No.	No.	No.	No.
LINE	1	1	1	2	2	2	3	3	3	1	1	2	2	3
MEAN DISTANCE (meters)	4.63	3.58	4.52	2.99	2.52	2.92	2.99	2.30	3.85	8.87	5.39	5.41	5.98	2.64
ABSL. DENSITY (No./100m²)	4.66	7.81	4.90	11.17	15.78	11.71	11.15	18.84	6.75	1.27	3.44	3.41	2.80	14.33
ABSL. DOMINANCE (%)	Ta / 45	Ov / 42.5	Ov / 25	Jv / 40	Qm/Jv / 30	Qm / 57.5	Jv / 45	Jv / 50	Pp / 58.3	An / 76.9	An / 42	Jv / 35	Jv / 37.5	Qm / 60
No. /100 m²	2.10	3.32	1.23	4.47	4.74	6.73	5.02	9.42	3.94	.98	1.45	1.19	1.05	8.60
TOTAL BASAL AREA (cm²) RANK 1	Ta 16448	Ps 3739	Fp 4630	Ta 5347	Qm 3139	Qm 9898	Qm 5316	Pp 4793	Pp 5123	An 15968	An 6388	An 7265	An 36900	Qm 9464
RANK 2	Fp 2819	Ta 3575	Qm 4070	Bp 3306	Jv 1826	Jv 1728	Pp 3767	Jv 2517	Jv 2916	Sa 3801	Sa 3161	Qm 3183	Qm 11553	Fp 1716
DOMINANCE RANK 1	Ta 1916	Ps 730	Fp 567	Ta 1492	Qm 1239	Qm 2897	Qm 1482	Pp 2258	Pp 961	An 520	An 579	An 619	An 2583	Qm 3391
RANK 2	Fp 328	Ta 698	Qm 499	Bp 923	Jv 721	Jv 506	Pp 1050	Jv 1186	Jv 547	Sa 124	Sa 287	Qm 271	Qm 809	Fp 615
RANK 3	Va 213	Fp 622	Bp 249	Pp 461	Pp 674	Ov 83	Jv 663	Qm 225	Qm 53	Va 90	Fp 108	Va 235	Jv 145	Jv 453
ABSOLUTE FREQUENCY (%) RANK 1	Ta 70	Ov 90	Ov 60	Jv 90	Jv 70	Qm 100	Jv 90	Jv 100	Pp 80	An 100	An 100	An 90	Jv 100	Qm 90
RANK 2	Ov 40	Fp 50	Jv 50	Ta 60	Qm 70	Jv 60	Qm 80	Pp 90	Jv 70	Va 40	Jv 60	Jv 70	An 80	Jv 60
RANK 3	Jv 40	Jv 50	Fp 40	Bp 60	Ov 40	Ov 30	Fp 30	Qm/Ov 30	Qm 20	Sa 30	Fp 40	Va 50	Qm 60	Fp 30

Ov = OSTRYA VIRGINIANA
Ta = TILIA AMERICANA
Fp = FRAXINUS PENN.
Co = CELTIS OCCIDENTALIS
Jv = JUNIPERUS VIRGINIANA
Va = ULMUS AMERICANA
Bp = BETULA PAPYRIFERA
Pp = PINUS PONDEROSA
Qm = QUERCUS MACROCARPA
An = ACER NEGUNDO
Sa = SALIX AMYGDALOIDES
Jn = JUGLANS NIGRA
Pd = POPULUS DELTOIDES
Ps = POPULUS SARGENTII

Figure 35-Composite vegetation profile produced from the sum of the point-centered quarter sample results of the right bank. (See figure 34 for species code)

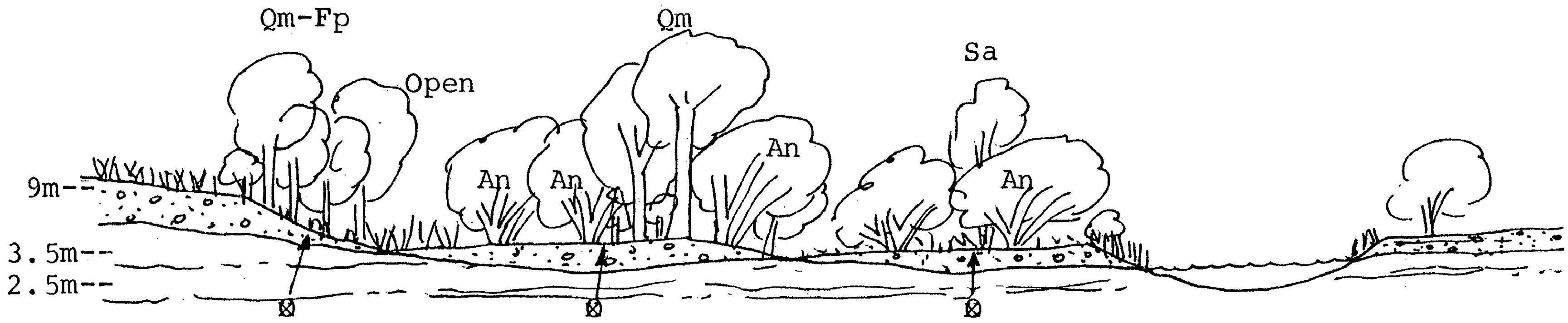


⦶ Approximate elevation of sample line.

Point-centered quarter dominance results for the south bank with graphic grouping of similar PCQ lines.

		Line 1	Line 2	Line 3	
	1	Ta	Ta	Qm	
Rank	2	Fp	Bp	Pp	TRANSECT I
	3	Ua	Pp	Jv	
	1	Ps	Qm	Pp	
	2	Ta	Jv	Jv	TRANSECT II
	3	Fp	Pp	Qm	
	1	Fp	Qm	Pp	
	2	Qm	Jv	Jv	TRANSECT III
	3	Bp	Ov	Qm	

Figure 36- Composite vegetation profile produced from the sum of the point-centered quarter sample results of the left bank. (See figure 34 for species code)



⊠ Approximate location of sample line.

Point-centered quarter dominance results for the north bank.

	Line 1	Line 2	Line 3	
1	An	An		
2	Sa	Qm		TRANSECT I
3	Ua	Ua		
1	An	An	Qm	
2	Sa	Qm	Fp	TRANSECT II
3	Fp	Jv	Jv	

Table V - Habitat characteristics for the dominant species of each line (of 14) in the Niobrara River Valley.

			SPECIES DOMINANCE			HABITAT CHARACTERISTICS				
			RANK 1st	2nd	3rd	EXPOSURE	SLOPE	SOIL MOISTURE	pH (?)	REMARKS
I	1	So.	Ta	Fp	Ua	N	4.5°	HIGH	5.5	MOD. LITTER - HIGH HUMUS
II	1	So.	Ps	Ta	Fp	NW	12.5°	HIGH	—	LIGHT LITTER, MOD. GRASS COV. Bp on MID. PTS.
III	1	So.	Fp	Qm	Bp	NE	10.5°	MOD	6.5	DEAD ELMS; HEAVY SHRUBS, EARLY SERE, NO Ta.
I	2	So.	Ta	Bp	Pp	N	32.5°	MOD	6.5	HUMMOCKY, LOOSE, SANDY SOIL, MOD. LITTER.
II	2	So.	Qm	Jv	Pp	NW	30.5°	MOD	—	MOD. LITTER; NO GRD. COVER. THIN VEG. ZONES
III	2	So.	Qm	Jv	Ov	NE	26.0°	MOD	6.8	THICK HUMUS; LOW GRD COVER, THIN ZONES. HIGH Pp.
I	3	So.	Qm	Pp	Jv	N	32.0°	LOW	6.5	HEAVY LITTER; MANY SAPLING Jv.
II	3	So.	Pp	Jv	Qm	NW	27.0°	MOD	—	MODERATE GRD LITTER. THIN SOIL.
III	3	So.	Pp	Jv	Qm	NE	36.0°	MOD	6.8	POSSIBLE OLD LANDSLIP
I	1	No.	An	Sa	Ua	FLAT	1.0°	LOW	6.4	FINE SANDY SOIL; PATCHES OF GRASSES.
II	1	No.	An	Sa	Fp	FLAT	1.0°	RECENT RAIN	6.0	ALL An in clusters. HEAVY Jv GROUND GROWTH.
I	2	No.	An	Qm	Ua	FLAT	1.0°	MOD	5.0	DARK, LOAMY SOIL; THICK GRASS SOD.
II	2	No.	An	Qm	Jv	FLAT	0.0°	RECENT RAIN	—	MODERATE GRAZING; HEAVY GRD. COV. (SHRUBS)
II	3	No.	Qm	Fp	Jv	SE	17.0°	RECENT RAIN	—	BARE SOIL; HEAVY GRAZING. EROSION.

Ov = OSTRYA VIRGINIANA
Ta = TILIA AMERICANA
Fp = FRAXINUS PENNSLYVANICA
Co = CELTIS OCCIDENTALIS
Jv = JUNIPERUS VIRGINIANA
Ua = ULMUS AMERICANA
Bp = BETULA PAPYRIFERA
Pp = PINUS PONDEROSA
Qm = QUERCUS MACROCARPA
An = ACER NEGUNDO
Sa = SALIX AMYGDALOIDES
Jn = JUGLANS NIGRA
Pd = POPULUS DELTOIDES
Ps = POPULUS SARGENTII

that the greatest species diversity exists in this north-facing, moist, gently to moderately sloping habitat. The zonation of the vegetation is quite well defined as indicated by the PCQ results. It appears that these belts widen and narrow in response to slope, nutrients, and landsliding.

Line 2, transect I, results resemble the findings of line 1 and could consequently be classified as such. This is also the case with line 3, transect I, which is better matched with the results of line 2. An anomaly in line 2 is the presence of ponderosa pine as the third dominant among more mesic species. This ranking occurs because of one large tree (hence, high basal area, upon which dominance is based) among the more mesic species. A possible explanation for this and other similar anomalies is that the pines and junipers are more competitive in areas of rapid soil creep and landslips, since these areas are more xeric due to thin or absent vegetation and/or soil. The parallel zonation is also disturbed directly by past landsliding as new seres occupy the scar.

Line 2 (of transects I, II, and III--wouth) is dominated by bur oak, with sub-dominants of juniper and ponderosa pine. This zone is generally steep (25° to 35°), wide, somewhat xeric, and contains morphologically low and dense vegetation. The oaks of this stratum resemble those of the riser to the 9 meter terrace on the north side (fig. 36). The low, angular form of the oaks of these two zones contrast with the tall, straight oaks of the 3.5 meter terrace. This zone will be discussed later.

Line 3 (transects I, II, and III--south) is dominated by ponderosa pine, juniper, and bur oak, in that order. The open, park-like stands, often among rocky cliffs, and xeric conditions typify this habitat. Yucca, cactus (Opuntia), and grasses are scattered around the bases of the medium-sized pines and dense clusters of juniper. Where the woodland of the south bank gives way to the grasslands of the Sandhills, there is a distinct ecotone, often less than 10 meters wide, occupied by species of Prunus and Rhus.

Disruption of the understory vegetation is occurring in the higher areas of line 2 and line 3. Both fire and overgrazing are evident. Numerous burned oak stumps are present in line 3 and large gullies are cut between root masses of larger trees in the higher areas. The long-term effect of livestock browsing on understory plants would be the disruption of the normal plant succession because of the destruction of the sapling trees. Brush fires would have much the same effect. The effect of rapid gully erosion originated by trampling of the soil-binding ground cover is much more severe.

The vegetation zones of the left bank (north) are determined mostly by the geomorphology. The zones, like the terraces, are generally sinuous, sporadic, and subparallel to the river. Areas of grasses and marsh plants which separate the woody zones are found in places that are either very dry or saturated, as in old meander scars.

Much of the virgin woodland of the low terraces has been cleared for farming (A. Connor, per. comm.), leaving only few-acre patches of this woodland. In addition, heavy grazing and rooting by cattle and hogs has taken place in the woodland which may alter the composition to some degree.

Big bluestem and sideoats gramma are commonly found in low-lying, well-managed pasture areas. These native grasses were most likely ubiquitous in the valley bottom previous to settlement. Presently, undesirable grasses and forbs (downy brome and thistle) inhabit the seriously overgrazed areas.

Line 1 (transects I and II--north) is dominated by box elder. Willows (Salix spp.) and green ash (Fraxinus pennsylvanica) are subdominants in the open riparian woodland of the 2.5 m terrace. This floodplain woodland is similar in its composition, form and habitat characteristics to many others of the Plains.

The box elder appears to be the first woody vegetation to become established on the newly-formed low terraces. It usually grows in clusters of four to six trees. The trunks at the outside of the clusters are often leaning at angles of greater than 45° from the vertical, and some are actually resting on the ground, supported by limbs. This may either be a result of flooding or saturated, weak, silty soils that are unable to support the tree. There is no evidence (Sigafoos, 1964) to indicate past flooding.

In line 2 (transects I and II--north) the dominant box elders are gradually being replaced by younger oaks and green ash. There are many sapling oaks and no sapling box elders among the understory vegetation. The box elders of this line are four times greater in basal area than on line 1. Large, straight, sixty-to-eighty-year-old oaks are present at the top of this riser to the 3.5 meter terrace. In some areas, these dominate the canopy creating shady, park-like areas. Areas toward the back of this terrace are open owing to the glacis terrace form and saturation. Figure 36 illustrates the relative distribution of these species on the low terraces.

Line 3 (transect II--north), is dominated by oaks younger than those of the adjacent lower terrace tread (fig. 36). The formation of the riser was contemporaneous with that of the tread of the 3.5 meter terrace. Considering this, one might conclude that the oaks on the riser can outcompete other species (including box elders dominant in adjacent areas) because of light, water, or other environmental factors.

Tributary Vegetation

The vegetation of the tributaries is zoned altitudinally like that of the south bank and has elements of many of the lines mentioned. In longitudinal profile, the zones wedge upstream as contour lines do in stream valleys (fig. 37A). The highest zone is dominated by pines similar to line 3, south. The middle zone (and the broadest) is an oak-juniper dominated zone as in line 2 south. The lowest, that extends onto the floodplain of the Niobrara, is most like the box elder zone (lines 1 and 2, north) of the low terraces (fig. 37B). The basswood-dominated forest of the lowest portions of the south bank does not occur in the tributary valleys of the north bank. It does, however, mix with the dense paper birch stands in the deep tributaries of the south bank. Occasional clusters of birch are found in the left bank tributary valleys where the meandering stream cuts a north-facing bank.

General Discussion

An overview of the natural factors facilitates an understanding of the patterns of the woody vegetation in the valley. The permeable sands of the Valentine Formation overlying the impermeable siltstone of the Rosebud, create springs midway up the south bank. Plants requiring plentiful moisture occupy areas from this contact downward. The area above the contact of the Valentine and the Rosebud is occupied by a lower diversity of more xeric species. Isolated terraces and the low terraces of the north bank receive more direct insolation, usually resulting in grass cover except where groundwater is near or at the surface. In such a case, a variety of hydrophytic and mesic species grow. Where increased slope allows drainage of the soil, hardwoods (oak, box elder) are typically found.

The parent material is partially responsible for the nutrients available to the plants. The sandy Valentine is easily leached of its calcium carbonate as well as the little organic matter that may accumulate. Plants requiring high levels of $CaCO_3$ (e.g. juniper) thrive in locations where the parent material is at or near the surface--near landslips and active slopes. The Rosebud, due to its finer grain composition and impermeability, allows more organic material to accumulate, hence, creating better soils to support those plants that require this (e.g. linden and birch).

In summary, the high diversity and density of woody vegetation on the lower parts of the south bank contrast with the sparser woods and grasses found elsewhere. This is due to the more favorable environmental conditions that are present in the former location. The microclimate in these more favorable areas is characterized by a constant water supply, lower winds, less insolation, more stable slopes, smaller temperature fluctuations, and better soils.

Figure 37A - A generalized map view of the tributary vegetation north of the Niobrara River. Vegetation profiles A-A' and B-B' are illustrated in figure 37B.

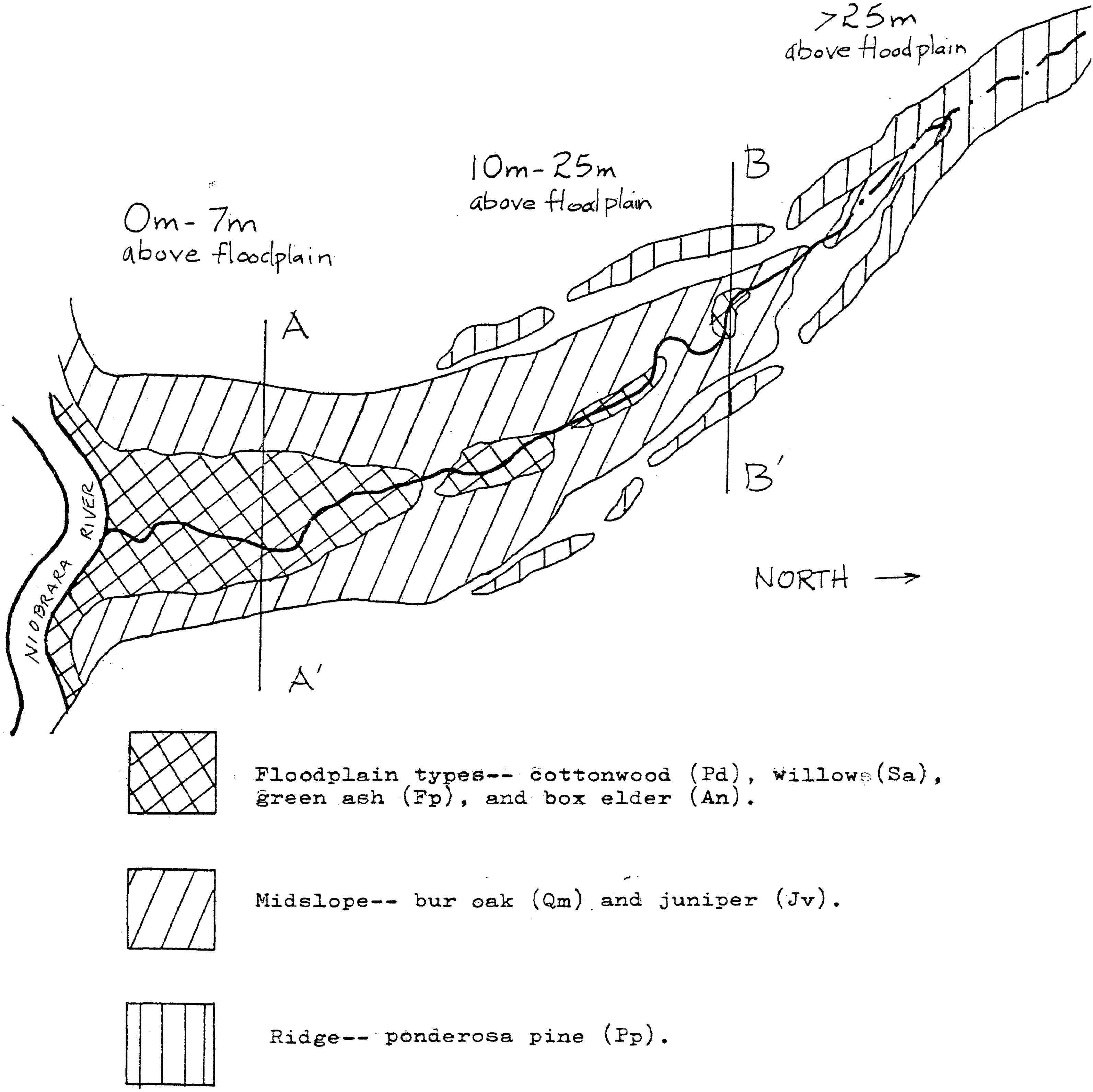
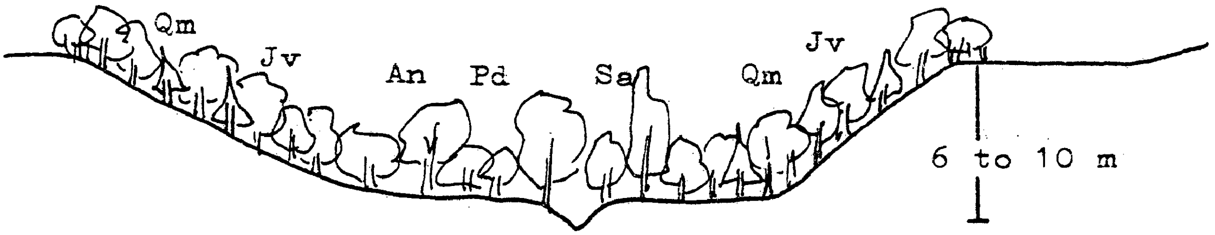


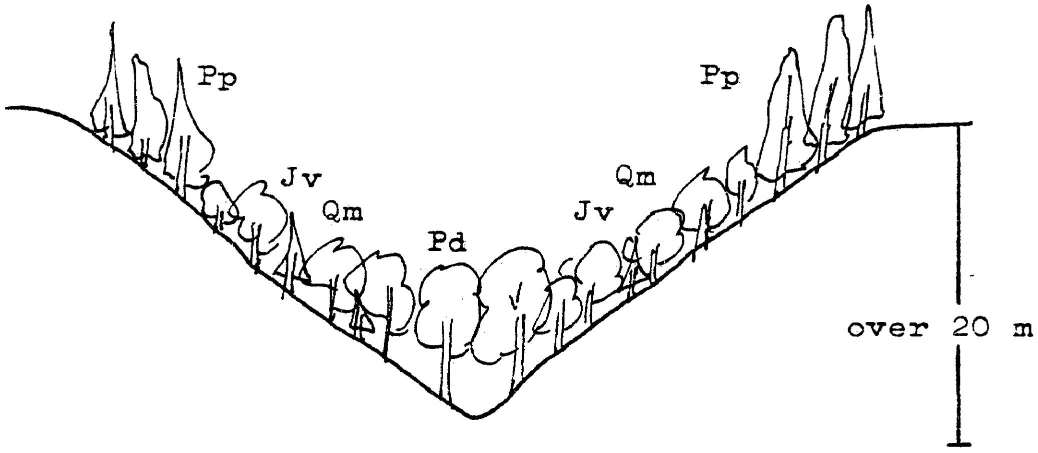
Figure 37B - Vegetation profiles across tributary valleys north of the Niobrara River. Elevations are height above floodplain. Grasses bound the woody vegetation of the valleys on both sides.

LOWER REACHES OF THE TRIBUTARY -- Profile A-A'



(See figure 37A for interpretation of species code)

UPPER REACHES OF THE TRIBUTARY -- Profile B-B'



Plant Succession on Landslips

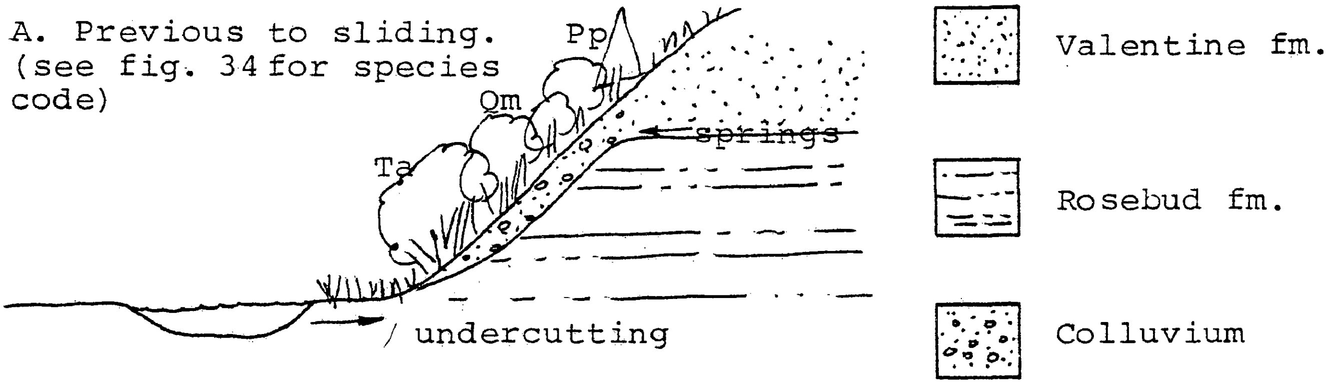
A chronology of landslide revegetation became apparent while working out frequencies of landsliding and morphological characteristics of landslides. The successional sequence in figures 38 and 39 is a rough description of the time periods and seres required to progressively reoccupy a scar laid bare by landsliding. The age references were inferred from the results of coring trees disturbed or fallen by sliding. This method is more accurate in the early stages of revegetation since these trees may still be living. The most significant research on geotropism was done by Westing (1965). Later research by Shroder (1975) used dendrochronological methods in monitoring the movement on rock glaciers in southern Utah. Approximate ages in later stages of revegetation were determined by comparison with the ages of other stands of similar composition. This was achieved by coring and sectioning of the trees of a sere and finding a mean age. Previous seres were dated by a similar method until a total approximate age of the succession could be determined.

Plant Succession on Terraces

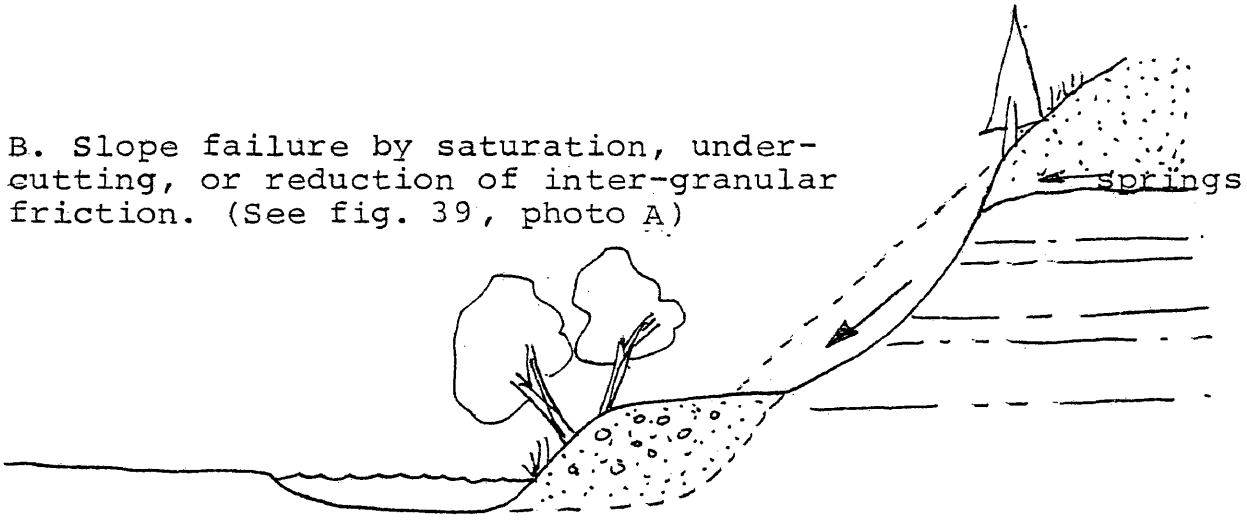
A successionary sequence, similar to that of landslide revegetation, was determined for low terraces on the left bank. As the river downcuts, it leaves its old floodplain free from seasonal flooding, and new vegetation types are able to grow (fig. 40). Each part of the succession was determined by the present location of species relative to the river level and those species dominating, or beginning to dominate the progressively higher terrace levels. The emergence of oak as a

Figure 38 - Schematic sequence of revegetation of landslip scars. The seral stages have been determined from observation of scars at various stages of revegetation. The ages are approximate and have been determined by coring of disturbed or fallen trees (see text for explanation).

A. Previous to sliding. (see fig. 34 for species code)



B. Slope failure by saturation, undercutting, or reduction of inter-granular friction. (See fig. 39, photo A)



C. Invasion of early pioneers (compositae, liliaceae, leguminosae, and graminae) from 0 to 8 years. (See fig. 39, photo B)

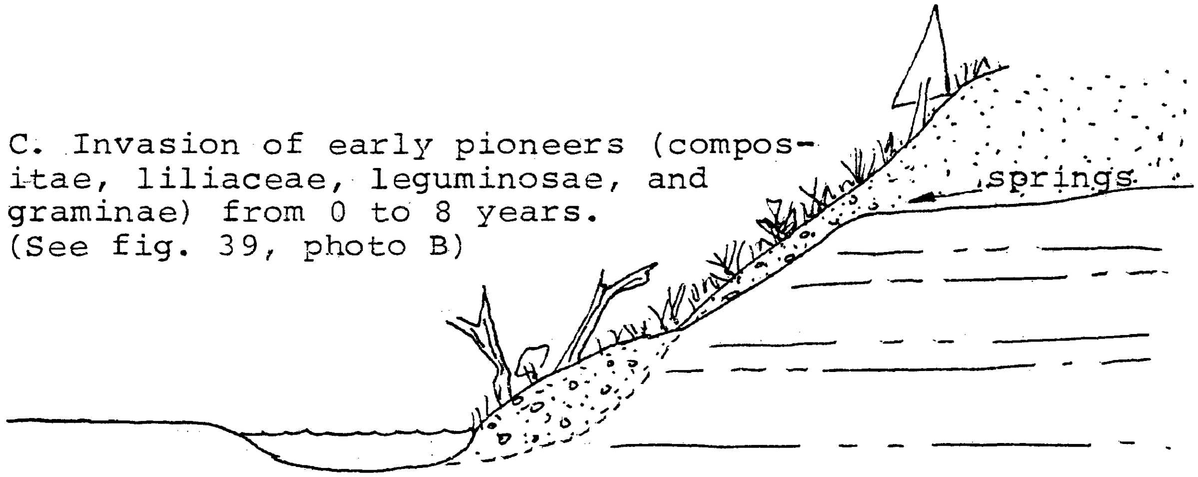
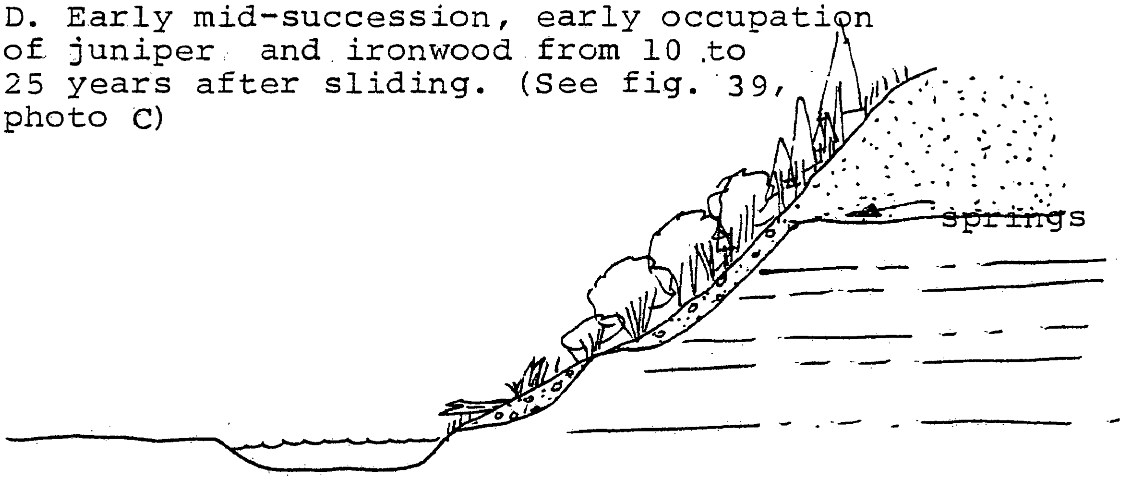
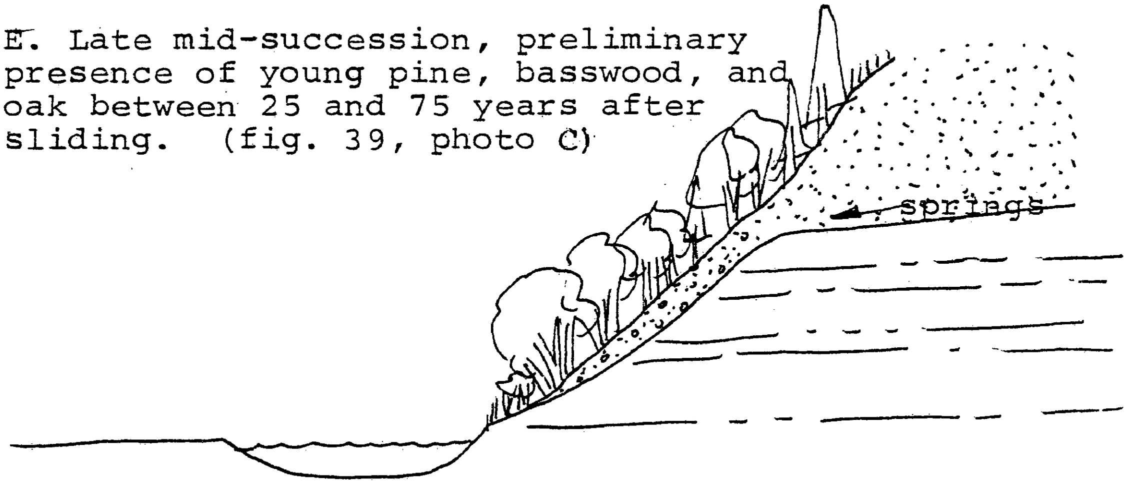


Figure 38 (cont')

D. Early mid-succession, early occupation of juniper and ironwood from 10 to 25 years after sliding. (See fig. 39, photo C)



E. Late mid-succession, preliminary presence of young pine, basswood, and oak between 25 and 75 years after sliding. (fig. 39, photo C)



F. Re-establishment of dominants (or climax) in approximately 200 years. (fig.39, photo D)

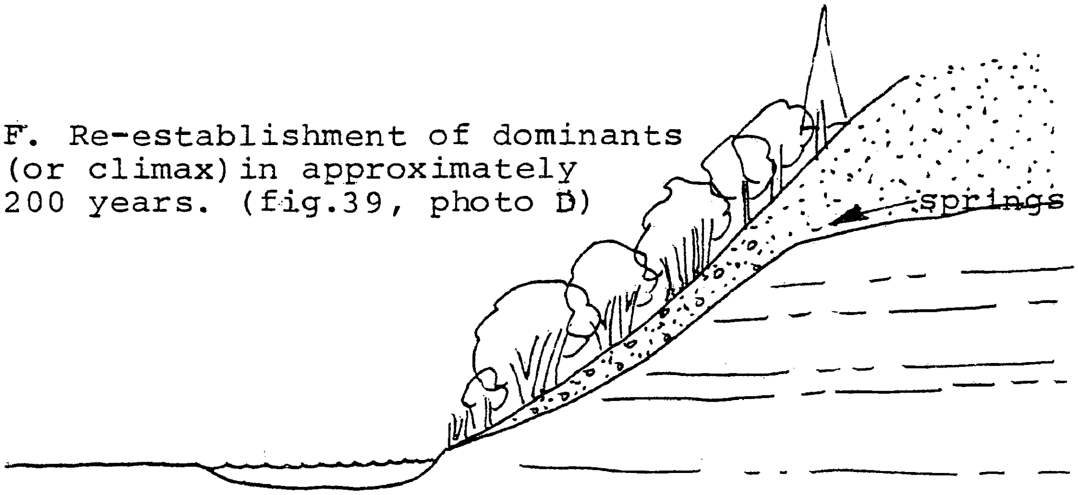


Figure 39, A thru D - Photographs illustrating plant succession on landslips. These photos were taken in the study area of landslides of varying degrees of revegetation. The sequence of letters, A,B,C, and D, correspond to the letters B,C,D-E, and F, respectively, in figure 38.

A. Failure of slope.

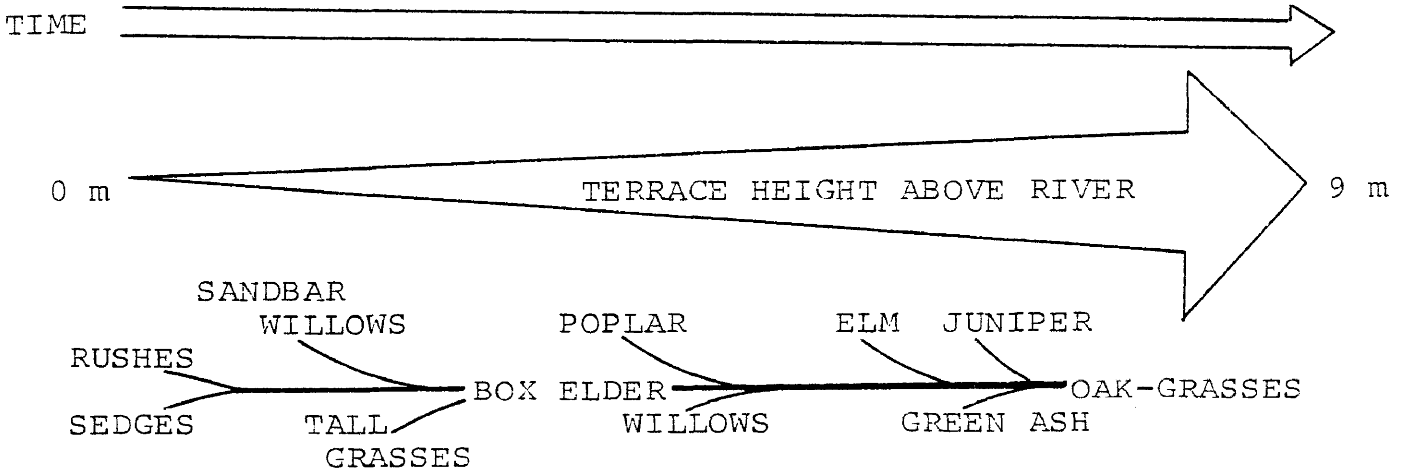
B. Invasion of early pioneers.

Figure 39 (cont')

C. Mid-succession.

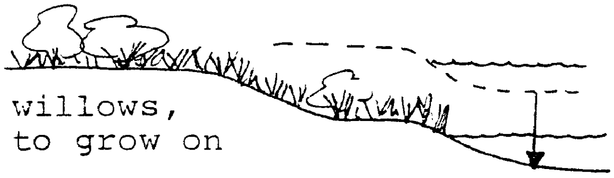
D. Re-establishment of dominants.

Figure 40 - Diagrams of plant succession on terraces. The upper diagram shows the species as they progress through the sequence. The lower diagram shows the succession relative to downcutting of the river. The terraces above the 9 m height are generally grassed. The diagrams were taken from actual situations on the Niobrara River.

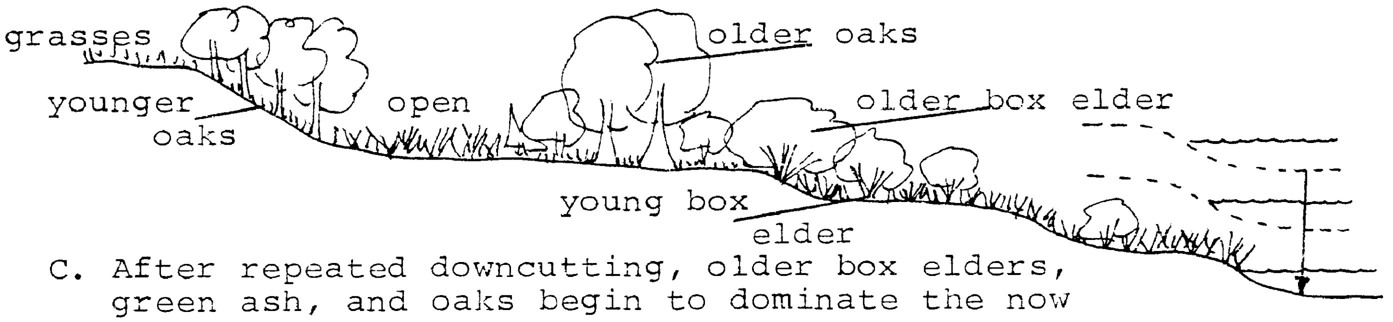


* * * * * * * * * *

A. Floodplain vegetation: grasses, sedges, willows, and rushes.



B. After downcutting of the river, willows, cottonwood, and box elder begin to grow on the higher terrace.



C. After repeated downcutting, older box elders, green ash, and oaks begin to dominate the now elevated terrace.

dominant on the 3.5 meter terrace is a good example of this concept (see lines 1, 2, and 3--north, fig. 36).

Habitat Characteristics of the Paper Birch[1]

According to Kaul (per. comm.) and Laustrup (per. comm.) the Niobrara River Valley between Valentine and Meadville is the only place in the Great Plains where western and eastern forests meet. For this reason, it is a region of great biological interest. The pines occupy the drier sites while oak and basswood are found in the more sheltered places. Paper birch is there too, the only location in the state for this tree of cooler, northern forests. The rough topography, inaccessibility of the area, and the infrequency of fire have kept the environment relatively unchanged.

Certainly, these factors are essential to maintaining a population of birch, but the microclimatic conditions are directly responsible for the survival of the population.

The location of the birch is generally in a linear zone, parallel to the river and midway up the slope on the right bank. The slope is steep, and faces north to east. The low sun angle and the surrounding, dense vegetation aid in creating a cool atmosphere in that area.

The line of birch lies at the contact of the Valentine and Rosebud Formations where numerous cool springs are present. The coolness of the water flowing down the slope modifies the local atmosphere. The air near these springs is quite pleasant even on the hottest days of summer. Accurate measurements of the microclimatic conditions are needed.

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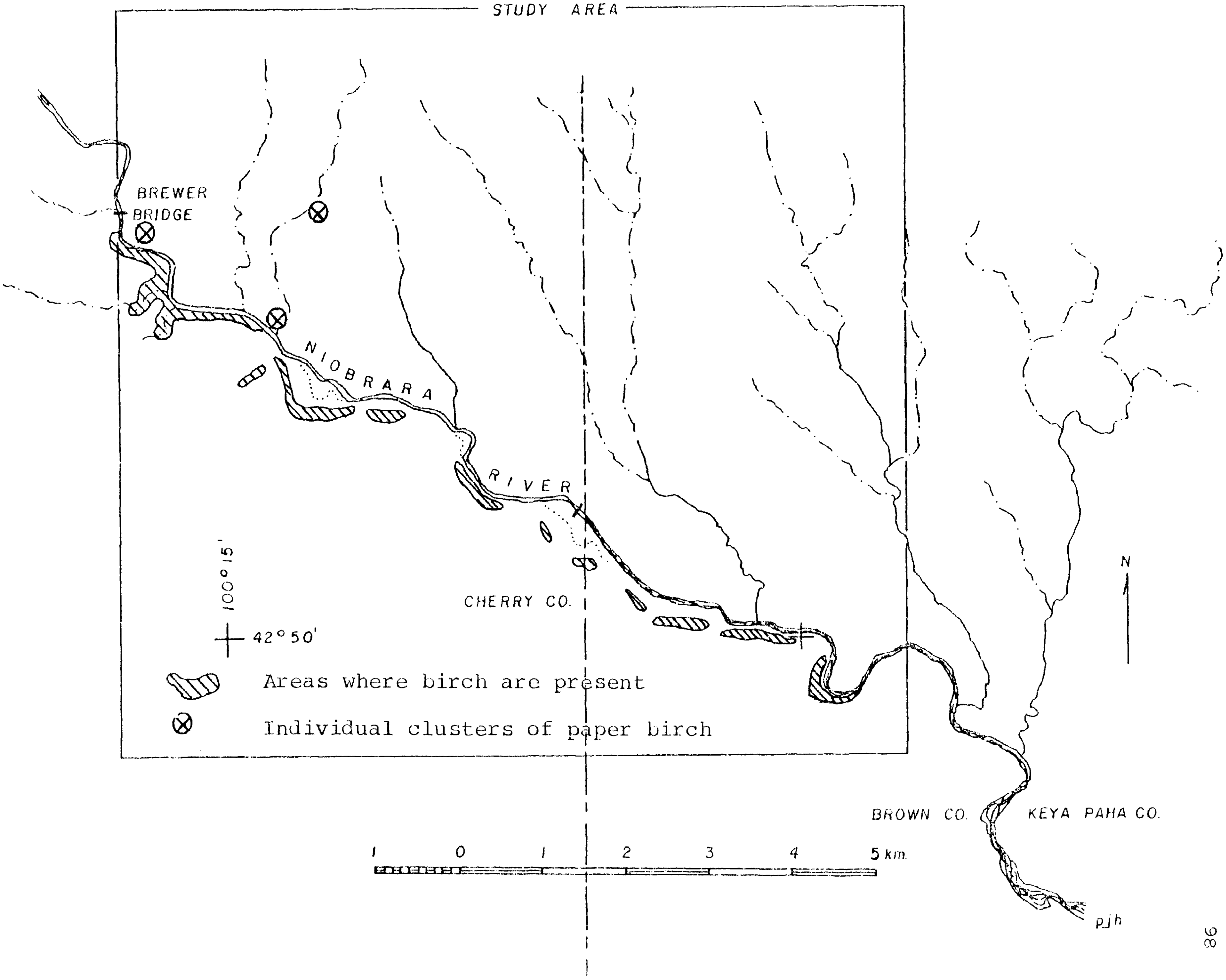
[1] Many thanks go to Mark Laustrup, a fellow graduate student, for accumulating much of the previous research on this topic.

The birch always occurred in lines 1 and 2, of the south bank transects of the PCQ samples. Absolute frequencies were as high as 60 percent (occurring in 6 of 10 points sampled), and densities were as high as 2 individuals per 100 m^2 plot. The line of birch typically lie within the boundary between the basswood-dominated and the oak-dominated woodlands. The soil usually has a thick humus layer (20 cm) and a fairly rich 'A' horizon. It is moist to saturated in most locations.

Paper birch has been found to be tolerant of an anaerobic (saturated) seed bed (Huikari, 1955). At the same time, it has been found to be tolerant of xeric conditions (Fraser, 1954). The xeric sites within its contiguous range may be moister and cooler than those described within the study area. In addition, being extralimital, the birch within the study area may have more flexible habitat requirements than those within the contiguous range. In the Niobrara Valley, there are no birch occupying xeric sties such as those described for the study area. Small clusters are, however, found on the north-facing slopes of the meandering tributary valleys of the left bank, which are significantly drier than the habitat of the right bank locations (fig. 41).

Possibly due to environmental stress, the population of birch does not appear to be reproducing sexually in the area, but does so vegetatively by cloning. Cloning is suspected because there are no sapling birch present in areas other than at the base of a cluster. In addition, there are no evenly spaced stands of individuals as they

Figure 41 - Areas supporting paper birch within the study area.



would appear if they were spreading fertile seed. Trees are found in clusters of three to ten trees of varying ages (fig. 42).

Figure 42, a & b - (a) A photograph of paper birch cloning, and, (b) in moderate to dense stands midway up the south bank.

a.

b.

CONCLUSIONS

Due to the nature of this interdisciplinary study, the conclusions are numerous and diverse. Many important findings resulted from work within the study area; other findings have gone beyond the area and made inferences on the evolution of the region based on some of the study area data. Principal findings resulting from work within the study area are:

1. The geology is representative of a large area of the Great Plains.
2. There is mounting evidence that local tectonic activity has occurred (or is occurring) in the area.
3. Broad, upland terraces resemble those described by Reed and others (1965), Lugn (1935), and Alden (1924). Also, lower terrace sequences are similar to others of the plains.
4. There are six distinct geomorphic subregions within the study area that have resulted from various processes.
5. Mass wasting processes are major influences in shaping terrace risers while fluvial processes erode the canyons and deposit alluvium on the terrace treads.
6. Of the low terrace group, treads lie at 2.5 m, 3.5 m, and 9.0 m above the Niobara River. Terraces of intermediate levels exist as small, isolated benches. The one at 35 m above the river is the only persistent terrace of this group. The high group is extensive throughout the upland areas at levels of 60 m, 75 m, and 95 m (approximate) above the river level.
7. Rates of erosion and deposition appear to have increased with the presence of agriculture in the area.
8. The river is generally downcutting but periods of aggradation have also occurred.
9. An unusual biogeographical situation exists in the area where biomes of the Rocky Mountain, Eastern Deciduous, and northern forests overlap in the deep valley within the grasslands. There are zones of deciduous, mixed, and evergreen (pine and juniper) trees parallel to the river on the terrace risers. Grasses occupy flatter areas except where the groundwater is abundant.
10. The relic paper birch occupies sites where north-facing slopes, high groundwater, and shade are present.

It is my hope that the information gathered on the Niobrara may aid other workers in the fields of geology, geomorphology, and vegetation ecology. Parts of this study are obviously cursory in nature, but the sum of the parts of this study may provide the reader a general understanding of the interaction of natural factors.

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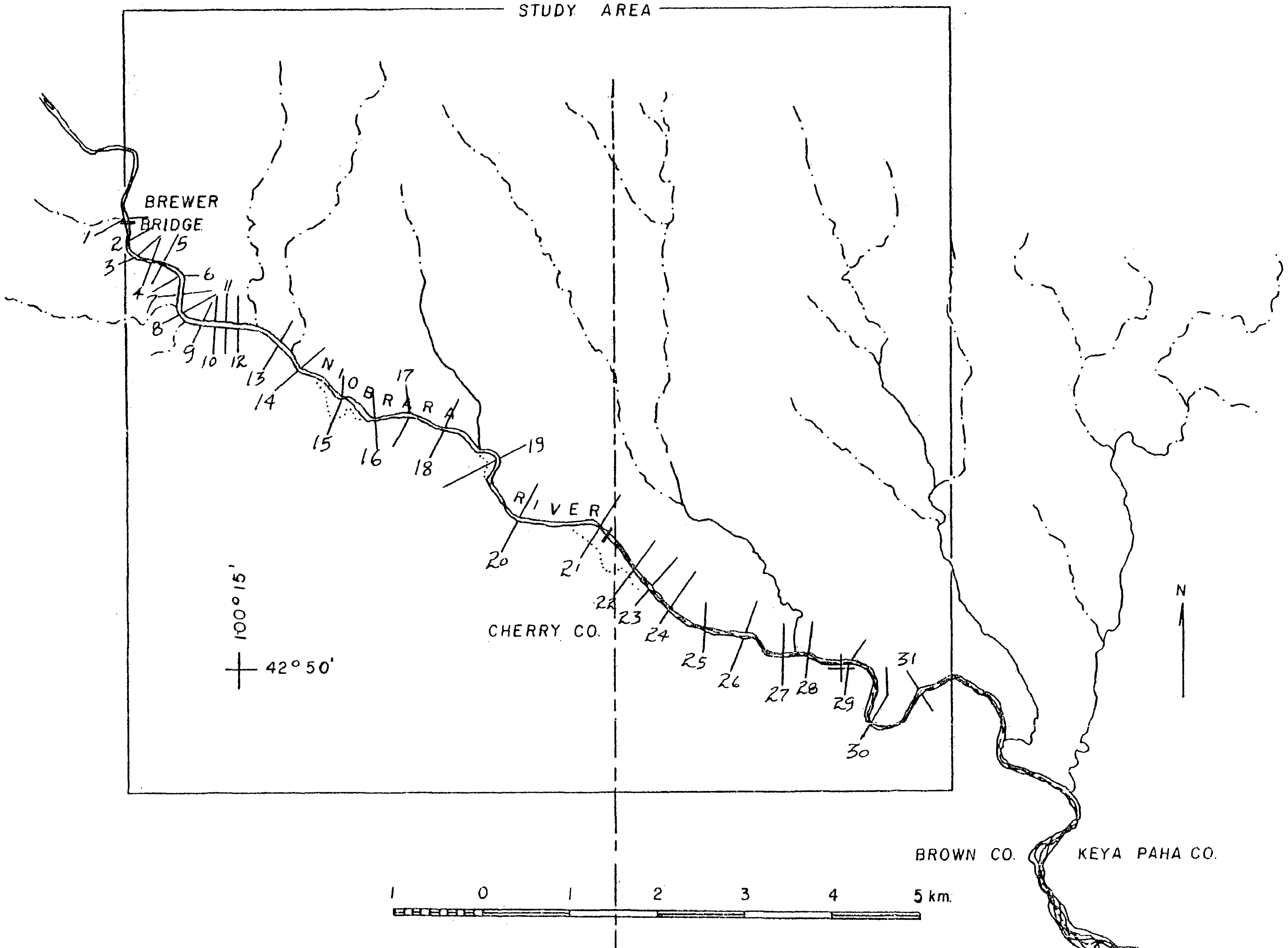
APPENDIX



Appendix I - Index to topographic profiles. (3 Sheets: Ia, Ib, and Ic)

LATITUDE

TERM PAPER
MAP

LONGITUDE

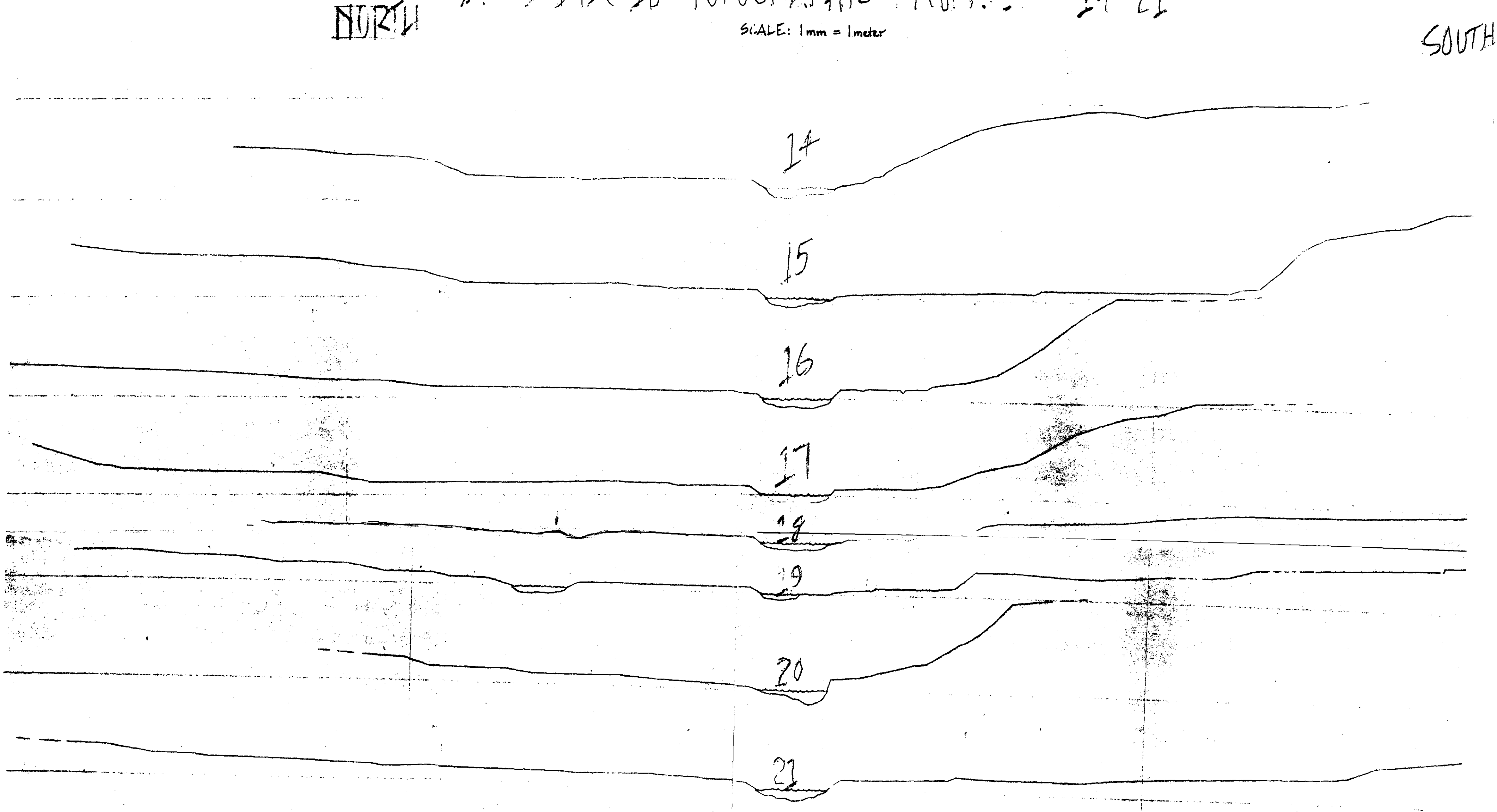
LATITUDE
1 MINUTE

1:250,000

1 MINUTE
LONGITUDE

APPENDIX I6 - TOPOGRAPHIC PROFILES 14-21

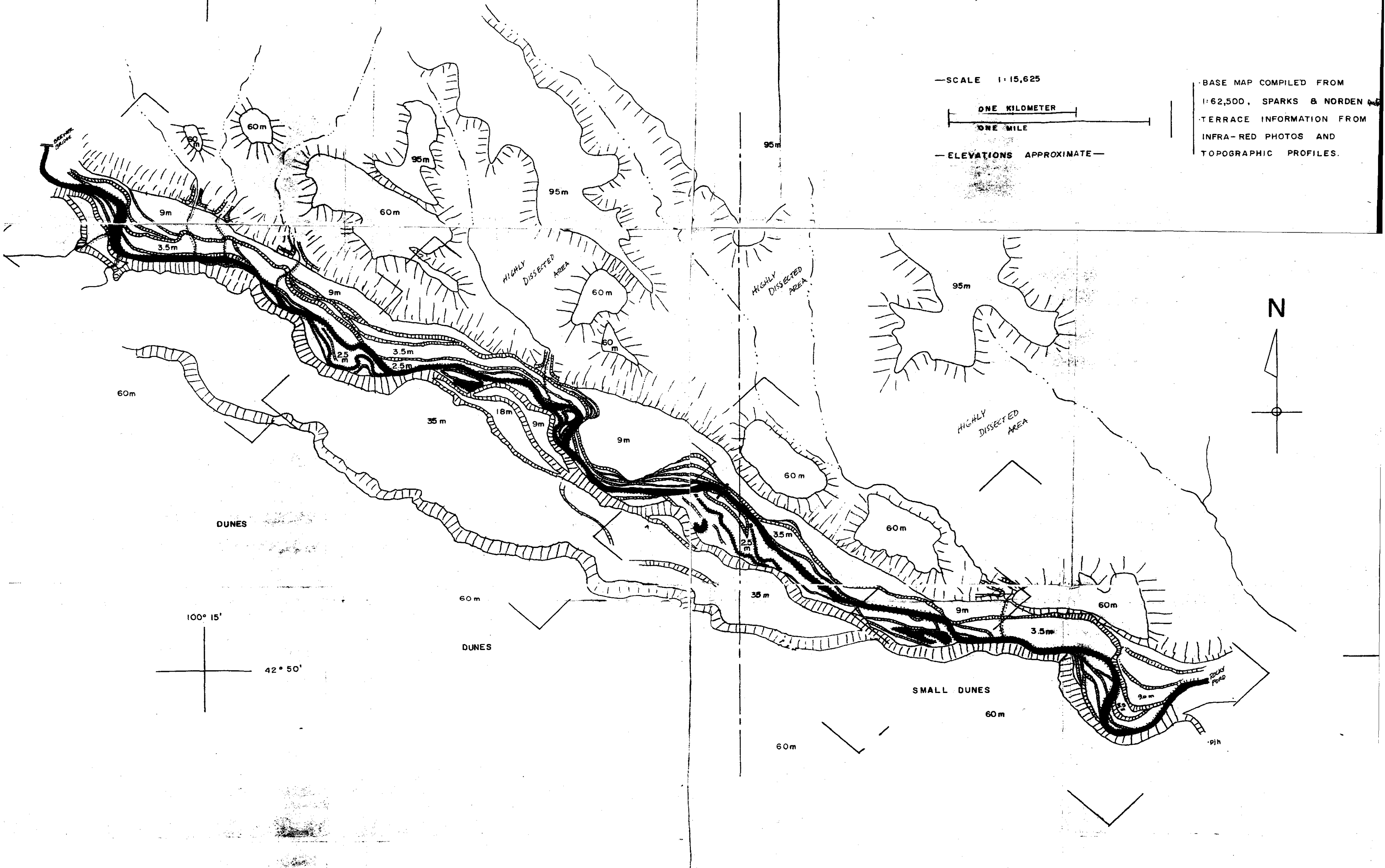
SCALE: 1mm = 1meter



APPENDIX II

TERRACES OF THE NIOBRARA RIVER

(WITHIN THE STUDY AREA)



—SCALE 1:15,625

ONE KILOMETER

ONE MILE

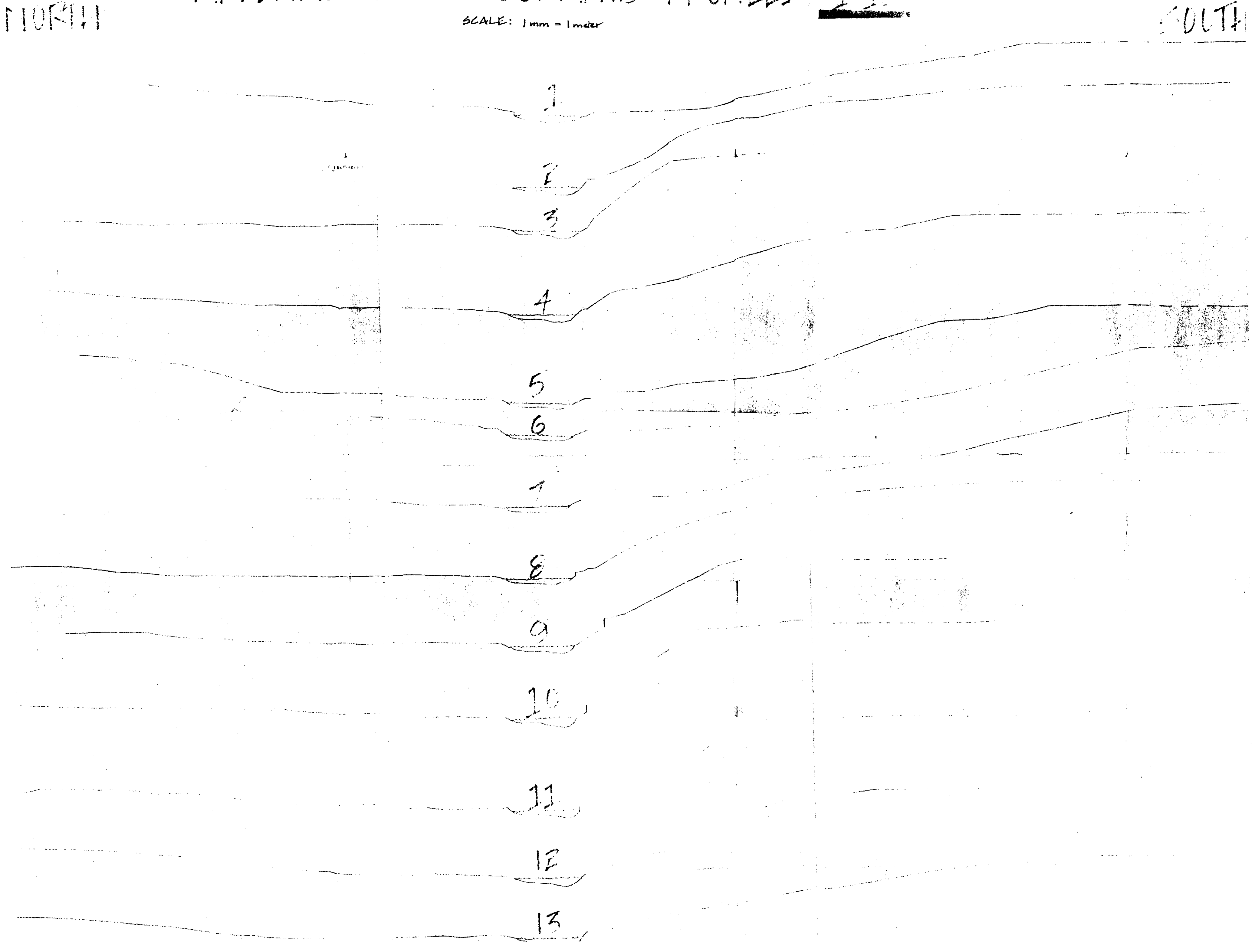
— ELEVATIONS APPROXIMATE —

·BASE MAP COMPILED FROM 1:62,500, SPARKS & NORDEN

·TERRACE INFORMATION FROM INFRA-RED PHOTOS AND TOPOGRAPHIC PROFILES.

APPENDIX Ia - TOPOGRAPHIC PROFILES 1-13

SCALE: 1mm = 1meter



Ic-COMPOSITES OF 10 VALLEY PROFILES - Looking downstream

SCALE: 1mm = 1 meter