A Preliminary Report on

THE GEOLOGY OF THE BISMARCK-MANDAN, NORTH DAKOTA AREA

Bismarck, Schmidt, and Sugarloaf Butte Quadrangles

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by
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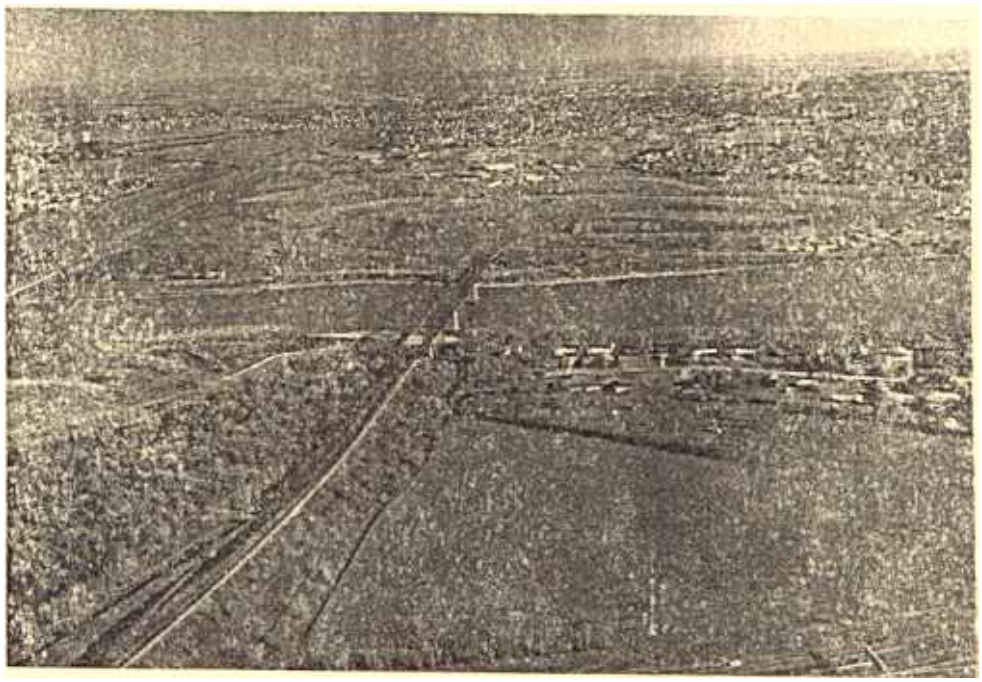

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John P. Bluemle, State Geologist
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On the Cover: Oblique aerial photograph taken looking east towards Bismarck, North Dakota. The cities of Bismarck and Mandan are situated on rolling topography adjacent to the Missouri River, seen in the center of the photo.

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INTRODUCTION

The Bismarck-Mandan urban corridor is one of the fastest growing metropolitan areas in North Dakota. With a combined population of approximately 65,000 people, this region is the second largest urban area in the state. Construction of both single-and multiple-family dwellings, as well as industrial buildings, has boomed in recent years. Expansion of the urban corridor has resulted in construction in many avoidance areas including: location of buildings over valuable sand and gravel deposits in south Bismarck, single-and multiple-family dwellings constructed adjacent to abandoned landfills in north Bismarck and south Mandan, and single-family dwellings constructed on or adjacent to steep slopes in both Bismarck and Mandan. There are several points of geological and environmental concern in this area, including at least three abandoned garbage dumps and three operating sanitary landfills, an oil refinery, a coal-fired electric generating plant, numerous sand and gravel pits, several large landslides, flood prone areas, and a state park. The Missouri River Valley also has exceptional recreational value. In addition to a state park, there are historical sites, game management areas, hiking trails, and boating opportunities within the area mapped.

Map Area

The area contained within the Bismarck-Mandan mapping project is a block of nine adjoining 7.5 minute quadrangle maps in south-central North Dakota. The quadrangle maps are centered around the Bismarck 7.5 minute topo sheet and represent an area of approximately 460 square miles. Three of the quadrangle maps (Bismarck, Sugarloaf Butte, and Schmidt) were completed in 1997. Two additional maps are being completed under the Edmap program, and the four remaining quads will be finished in 1998 *(Figure 1)*.

The entire nine-quadrangle mapping area lies on the edge of the Great Plains physiographic province, in a region designated as the Glaciated Missouri Plateau. The region is dominated by rolling, grass-covered prairies surrounding the Missouri River Valley, its flood plain, and its tributaries. Outside of the Bismarck-Mandan metropolitan area, most of the land is used for rangeland and grazing. Some row crops are grown on the lower elevations on the flood plains and terraces of the Missouri, Heart, and Little Heart rivers and their tributaries.

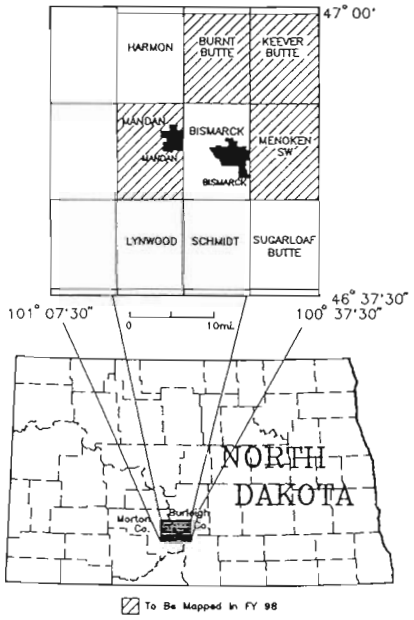

Figure 1. The nine quadrangle maps included in the Bismarck-Mandan mapping project.

Objective

The objective of this project is to create nine 1:24,000-scale multipurpose geologic maps and technical reports of the Bismarck-Mandan area. The maps and accompanying reports will assist contractors, developers, city planners and engineers, geotechnical consultants, homeowners, and sand and gravel companies in identifying areas of unstable ground, poor load-bearing sediments, buried waste, and gravel deposits. As they are completed, colored geologic maps of the individual quadrangles will be made available to the public from the North Dakota Geological Survey (NDGS). Upon completion of the nine quadrangle maps, a general interest report, fieldtrip guide, and geologic map of the greater Bismarck-Mandan area (1:62,500) will be published by the NDGS.

Previous Investigations

A.G. Leonard (1912) completed a geologic portfolio of the Bismarck quadrangle. Leonard mapped an 816-square-mile area which included the Bismarck, Sugarloaf Butte, and Schmidt quadrangles. Leonard also mapped portions of Morton and Burleigh counties as part of *"The Geology of South-Central North Dakota"* (1912). Leonard's report focused on the lignite, clay and cement potential of the south-central part of the state. Over fifty years later, Kume and Hansen (1965) reported on the geology of Burleigh County. In 1983, Carlson reported on the geology of Morton County. Both of these investigations were part of the statewide County Groundwater Studies program completed by the NDGS and the State Water Commission. The investigations included the completion of 1:125,000-scale geologic maps on a planimetric base, and documented the geology and groundwater resources of all counties in the state.

The most recent geologic map of the region was completed in 1980 by Groenewold. Groenewold (1980) produced seven 1:24,000-scale geologic maps of the Bismarck-Mandan area, including portions of the Bismarck, Sugarloaf Butte, and Schmidt quadrangles. The maps were distributed in black and white without standard lithologic symbols for the map units. Lithologic contacts are indicated by a thick line, which often obscures topographic features. City officials complained that the format makes them difficult to understand and consequently, they are not widely used.

Various other investigations have taken place within the nine-quadrangle map area. Several boreholes were completed by Pusc (1984) during his hydrogeologic investigation of the south Bismarck region. In addition, Pusc (1984), constructed several detailed cross-sections through the alluvium in south Bismarck. Murphy (1995a) and Murphy et. al. (1995) measured several geologic sections in the area.

Geology

Bismarck and Mandan are located on the east and west banks, respectively, of the Missouri River. Prior to the completion of the Garrison Dam in 1954, the southern portion of Bismarck, located on the Missouri River flood plain, was routinely inundated in the spring. In the area south of Bismarck the Missouri River trench is filled with over 100 feet of alluvial sediments.

Outside the flood plain, most of the twin-city area is underlain by sandstones and mudstones of the marine Cannonball Formation (Paleocene) or a veneer of glacial drift (Kume and Hansen, 1965; Randich and Hatchett, 1966; Groenewold, 1980; Pusc, 1984; Murphy, 1995a). The till or Cannonball strata is commonly overlain by windblown silt up to 10 feet thick *(Figure 2)*. Additional strata exposed in the area includes nonmarine sandstone, siltstone, mudstone, and claystone of the Hell Creek (Cretaceous), Ludlow and Bullion Creek (Paleocene) formations.

Organization of This Report

This report is organized into three sections: Bismarck Quadrangle, Sugarloaf Butte Quadrangle, and Schmidt Quadrangle. Each section describes the methods and geologic map units for each quadrangle. Because different workers prepared different quadrangles, there is a slight difference between the geologic map units from one quadrangle map to the next. These differences will be resolved in the final map compilations, scheduled to be completed by the end of 1998.

BISMARCK QUADRANGLE

Methods

Aerial photographs for the years 1938 (1:10,000), 1950, 1957, and 1959 (photos from the 1950's at 1:20,000) were used in the surficial mapping of the Bismarck quad. In addition, photos of various scales from 1948, 1952, 1961, 1964, and 1972 are available for the Bismarck area. Features such as stabilized eolian dunes, fluvial terraces, erratics, slopewash, and landslides were easily identifiable in stereo pair photos. However, the lithologies of the bedrock units are so similar that their contacts are often not discernable on aerial photographs. Preliminary geologic maps were generated during the spring of 1997 based on aerial photographic interpretation. Potential outcrops and unique geologic features were marked on the quadrangle maps and field checked in the summer. Subsurface information for the study area was obtained from files in our agency, the files of the Bismarck City Engineer, geotechnical consultants, North Dakota State Water Commission well file, files of the North Dakota State Health Department, and county soil surveys.

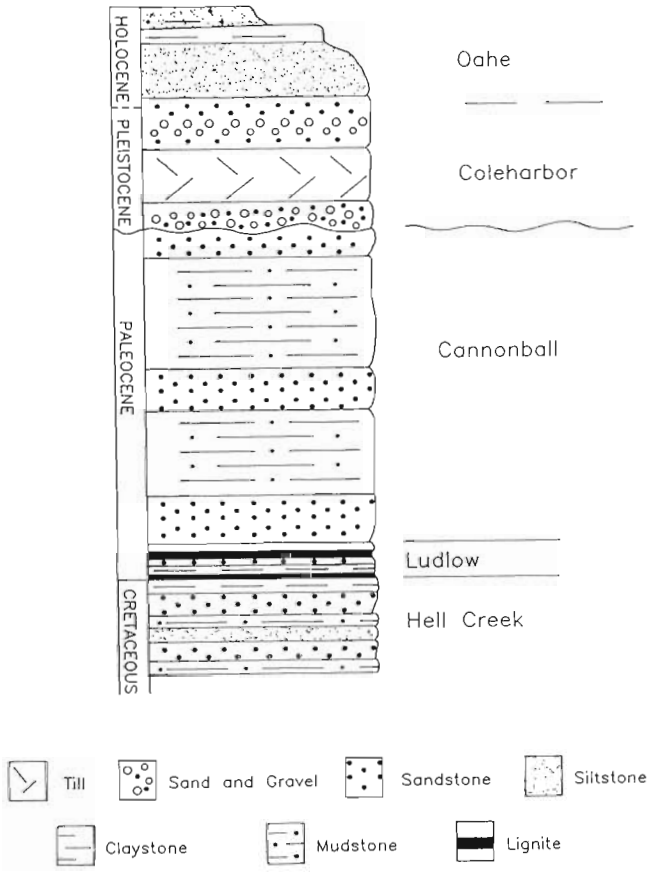

Figure 2. Generalized stratigraphic column for sediments and sedimentary rock exposed at the surface in the Bismarck-Mandan area.

All passable roads and trails were traversed during the summer and pertinent outcrops were visited and geologic observations recorded. A truck-mounted Giddings probe was used to obtain subsurface information in areas where there was insufficient outcrop control *(Figure 3)*. A number of holes were drilled in sections 17 and 18 (T139N, R80W) to match outcrop patterns on aerial photographs with drill-hole data. The drilling results for this area were used to map the geology of much of the surrounding area. A total of 242.5 feet was drilled in 31 holes in this quad, an average of approximately eight feet per hole.

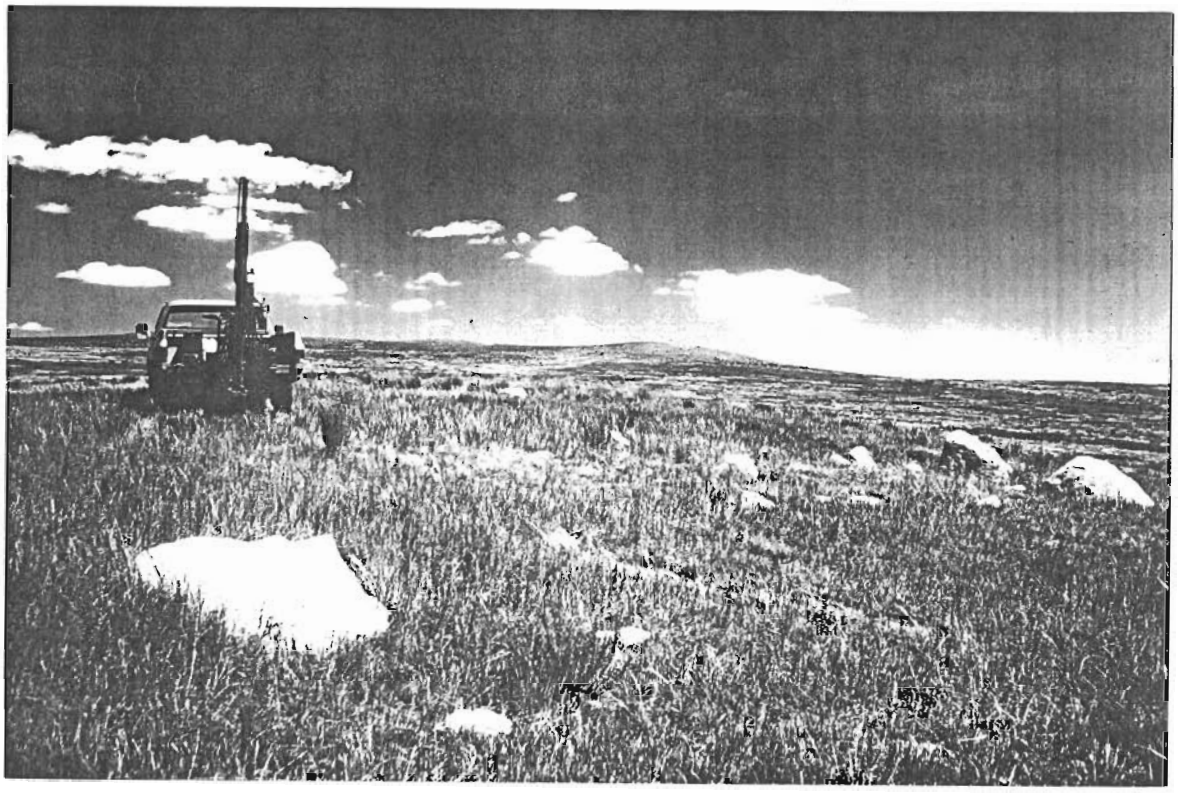

Figure 3. Truck-mounted Giddings soil probe used during this project. The truck is pictured north of Bismarck (T139N, R80W, section 18 nwswse).

Geologic Map Units

Oahe Formation (Qo)

The Oahe Formation consists of unconsolidated sediments deposited since the end of glaciation, approximately 10,000 years ago. Sediments range in grain size from clay to cobble and were deposited by various methods including slope failure, slope wash, river, pond, and wind. The Oahe Formation ranges in thickness from less than a foot to over 25 feet in the map area.

Construction Fill (Qoc)

Construction fill was mapped where it was evident that a site had been backfilled. There are always a number of fill areas in an urban setting, however, these areas are generally too small to map at 1:24,000 scale. Roads, buildings, and parking lots often make it difficult to identify areas of fill. A number of pits,

likely abandoned gravel pits, are present in south Bismarck on the 1938 and 1950's aerial photographs. Most of these pits were backfilled in the 1950's and 1960's and homes and businesses have since been constructed in those areas. These sites were identified on the map because they may offer an explanation for foundation problems that exist in the areas and also identify areas where caution should be used before constructing new buildings. Sometimes by chance, aerial photographs record construction activities in progress. The 1952 aerial photographs show backfilling of a ravine along a two-block stretch of 3rd Street in the area now occupied by the St. Mary's High School parking lot and practice fields.

Slope Failure (Qof)

Sediments interpreted as "slope failure" include a combination of soil, unconsolidated sediments, and sedimentary rocks that have slid down the local slope under their own weight. Slope failure is readily identifiable on aerial photographs by a vertical or near-vertical, often semi-circular, nonvegetated cliff face (scarp) and a series of ridges which often terminate in a semi-circular pattern (toe) downslope of the scarp. In the map area, slope failures occur primarily along the valley of the Missouri River. Failures generally occur within one of three common stratigraphic positions: at Hell Creek bentonites, at the contact between Hell Creek and Ludlow strata, and at the contacts between Cannonball mudstones and sandstones.

Two small slides were mapped northwest of Bismarck along a major ravine leading into the Missouri River in the Bismarck quad (T139N, R80W, sections 19 and 30). Both slides are old and have been inactive for quite some time, as evidenced by the presence of vegetation and windblown silt covering the area. One of the slides (T139N, R80W, section 30) has become detached from a ridge which now is occupied by houses. In recent years, housing developments have built right to the edge of this ravine in sections 19 and 30 and continued expansion will likely occur. While it appears that these slopes have been relatively stable in the past, increased water infiltration due to lawn irrigation may cause these slopes to become unstable in the future. A study of Cannonball strata west of Mandan indicates that the Cannonball mudstones are particularly prone to slope failure when periods of high precipitation are preceded by extended periods of low precipitation (Murphy, 1979).

A large area of slope failure is also present along the east approach to the Bismarck railroad bridge. Shortly after the bridge was completed in 1882, the east pier began sliding towards the river. For the next seventy years, the Northern Pacific Railway tried numerous unsuccessful methods to stabilize the slope. It was not until a significant portion of the cliff above the east approach was removed in 1951 that the area was finally stabilized (Murphy, 1995b). It appears likely that the east approach was built on an ancient landslide and that activities in the area reactivated the slide. Unfortunately, no 1880 photographs have been found that would address this issue. A series of landslides also occurred in the area now occupied by Highway 1806 and an old Northern Pacific spur line (T138N, R81W, sections 12 and 13). The thick subbase of the road in this area, visible on 1938 aerial photographs, suggests that the depressions caused by the ancient slide were present when the road was first built. These photos also suggest that the railroad may have cut the toe of the slide in this area. During the spring of 1997, a large slide occurred in one of these ancient landslides. A four-foot scarp that developed in the roadway may result in the permanent abandonment of this stretch of road.

Alluvium (Qoa)

Holocene alluvium in this area is typically moderately sorted sand, silt, clay, and gravel. The alluvium is typically grayish brown to dark brown, moderately to obscurely bedded, and often contains aquatic shells and plant fragments. These sediments were deposited over the last 10,000 years on the flood plains of the Missouri River, Apple Creek, and associated tributaries. Holocene alluvium in this area is up to several tens of feet thick.

Alluvium covers over one third of the area of the Bismarck quadrangle. Most alluvium can be found along the Missouri River but alluvium is also present along Hay Creek, Beaver Creek, and several unnamed tributaries. The Missouri River is underlain in places by over 120 feet of sand, silt, clay, and gravel. The majority of these sediments, and certainly all of the coarser grained fraction, were likely deposited shortly after the ancestral Missouri River was diverted into this area during Pleistocene time. During the Holocene, the Missouri River flooded frequently, inundating areas up to an elevation of 1,640 to 1,650 feet. Less frequently, primarily during the wetter portions of the Holocene or during significant ice jams, the floods may have reached elevations significantly closer to 1,700 feet.

Pond Sediment (Qop)

Pond or lacustrine sediments are typically laminated, dark brown to black, silt and clay. These lacustrine sediments are found in topographically low areas that may now periodically hold water, but likely held water for extended periods in the Holocene when the climate was wetter. These deposits are generally less than 10 feet thick in this area. Only one area of lacustrine sediments was mapped in the Bismarck quadrangle(T139N, R80W, section 21). This 20-acre area is dissected by the old Bismarck landfill and held water periodically during the 1930's-1950's as evidenced by aerial photographs. Garbage washed into this ponded area during the 1940's and 1950's and is likely to be found incorporated into the top of this unit.

Windblown Sediment (Qow)

Windblown sediments are typically moderately to well sorted, grayish brown to tan, sand and silt. These sediments commonly contain one or two ancient soil horizons, or paleosols, consisting of one- or two-foot thick layers of dark brown silty clay. The eolian sediments are typically only moderately to poorly vegetated. The windblown sediments generally form two distinct types of topography: 1) gently rounded topography which slightly drapes the underlying sediments or sedimentary rock, and 2) high relief (20- to 30-foot high) stabilized eolian dunes that can completely mask the underlying strata. The silt was deposited primarily by winds eroding and transporting flood deposits from the Missouri River Valley.

The surface sediments in the north half of the Bismarck quad (north of Rosser Avenue) are predominantly windblown silt *(Figure 4)* that slightly obscures the pre-existing topography. The silt deposits are typically three feet thick or less, but may be up to 10 feet thick in some places. Depending on the thickness of the deposit and the type of construction, special engineering methods should be taken to transfer the bearing load to underlying materials.

Alluvial Terrace Deposits (Qoct)

Alluvial terrace deposits typically consist of gravel and medium- to coarse-grained sand. The gravel consists primarily of pebble- to cobble-sized igneous rock and locally derived rock fragments and is commonly iron stained and occasionally iron cemented. Overall, the unit is poorly sorted but it generally contains well-sorted sand lenses. These quartz sand lenses typically contain thin layers of lignite and clinker fragments. The sand and gravel lenses commonly range in thickness from 10 to 20 feet and are typically overlain by three to 10 feet of windblown silt. Alluvial deposits are generally found on terraces 20 to 50 feet above the Missouri River, between elevations of 1,640 to 1,700 feet. Terrace deposits are easily identified in aerial photographs and on the ground by flat surface topography and the presence of steep cliffs or hillslopes on the Missouri River side of the deposit.

The narrow terrace deposits along both sides of the Missouri River in the Bismarck quadrangle are typically relatively thin (less than 15 feet) and generally contain less than five feet of gravel. In this area, terrace deposits are underlain by Cannonball strata. In contrast, the terrace deposits of south Bismarck contain up to 20 feet of sand and gravel at the surface and are underlain by up to 150 feet of fine- to coarse-

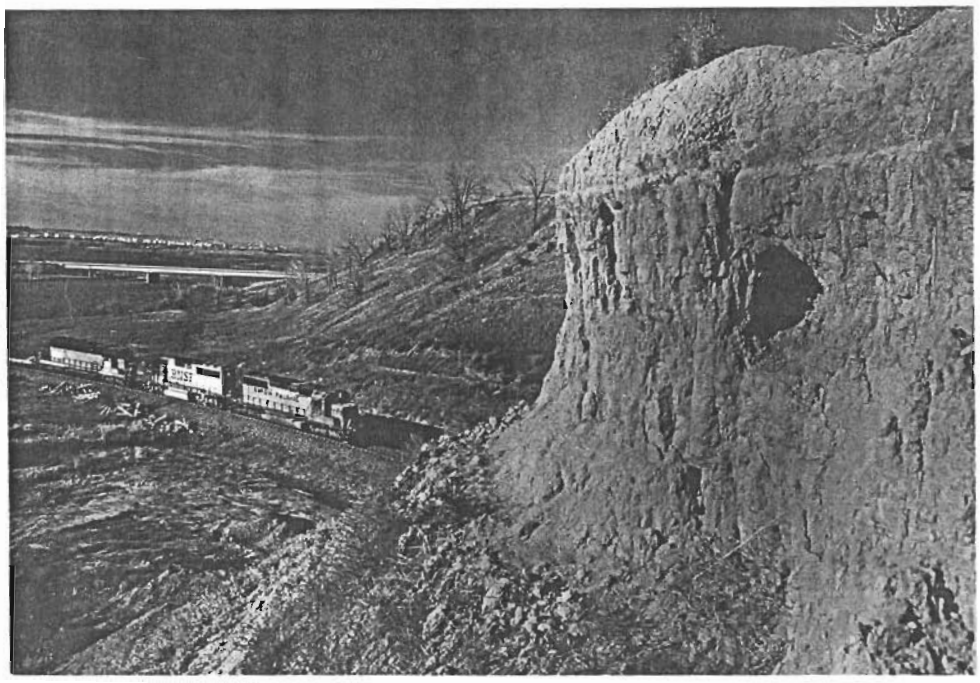

Figure 4. Up to 10 feet of silt (right foreground) caps Cannonball strata (covered) just east of the railroad bridge at Bismarck (T139N, R80W, section 31, 1,500 from east line [fel], 2,000 from north line [fnl]). Photo taken looking north. The outcrop of Cannonball mudstone, just to the right and above the lead locomotive, is shown in Figure 8.

grained alluvium. The majority of sand and gravel pits that have operated south of Bismarck have obtained gravel from these terrace deposits. These terraces have been informally named Penitentiary and Fort Lincoln (Pusc, 1984).

Coleharbor Formation (Qc)

Till (Qct)

Till is a poorly sorted mixture of pebbly, gray to brown sand, silt, and clay. Till once mantled the entire area as evidenced by the presence of erratics scattered throughout the map area. Till has been eroded from much of the area around Bismarck and is generally confined to the hilltops north of town. These areas are well vegetated and till exposures are extremely limited. The only exposures found in this area were temporary excavations made by building contractors *(Figure 5)*. Till is discernible on aerial photographs due to its relatively flat featureless surface, in contrast to the highly dissected bedrock units which typically exhibit a discernible outcrop pattern on air photos due to cemented or well indurated layers.

Till is one of the dominant lithologies in the north half of the Bismarck quadrangle. It is typically restricted to topographically high areas and has been removed by erosion at lower elevations along the drainages that lead to the Missouri River. Lack of time and the limitations of the Giddings probe prevented a determination of till thickness and reconstruction of pre-glacial topography in this area. In several areas in the Bismarck quadrangles (e.g., T139N, R80W, sections 17 and 18) an abundance of erratics at the surface identified areas where till was completely eroded away *(Figure 6)*.

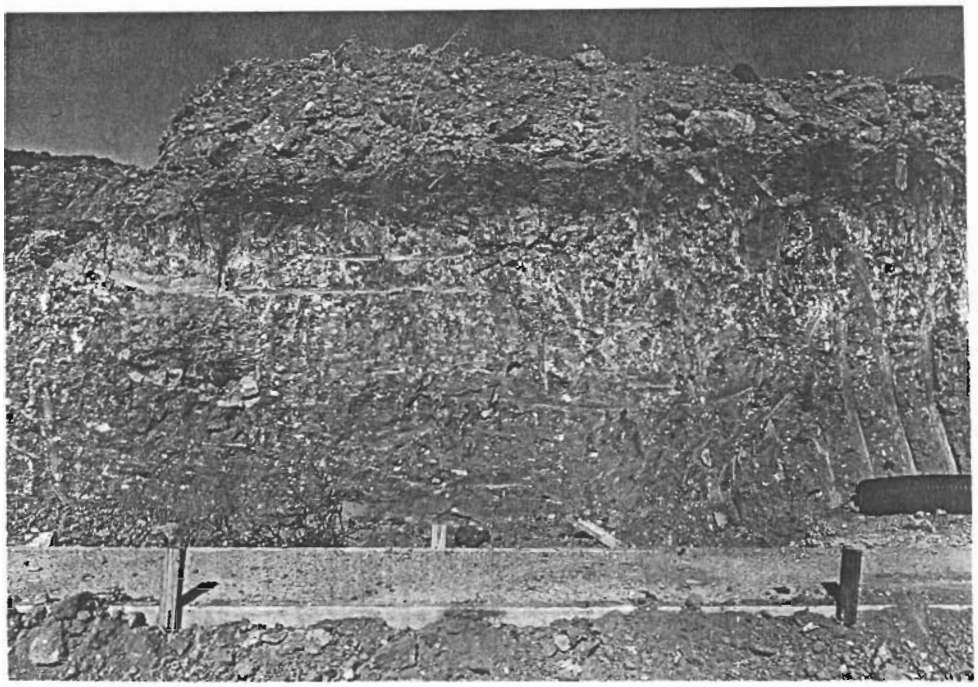

Figure 5. Till exposed in basement cut in northwest Bismarck (T139N, R80W, section 20 swnene). A one-foot block of Cannonball strata is incorporated into the till on the left side of the photo.

Figure 6. Erratics at the surface north of Bismarck (T139N, R80W, section 18). Till has been completely eroded from this site and the erratic is underlain by six feet of silt which overlies the Cannonball Formation. Photo taken looking southeast to High Meadows Subdivision in northwest Bismarck.

Outwash (Qco)

Outwash consists of moderately to poorly sorted sand and gravel deposited by melting glacial ice. A non-sinuous, northeast-trending ravine in north Bismarck (T139N, R80W, sections 15, 21, and 22) is believed to have been formed by glacial meltwater at the end of active glaciation in this area. A drainage divide occurs in this ravine just north of Centennial High School. The under fit nature of the small intermittent stream that now occupies this ravine, the absence of a large drainage area, and the straight nature of the ravine in these relatively soft sediments, suggest that this is a small meltwater channel. In addition, there are three exposures of sand and gravel in the walls of this channel: 20 feet of sand and gravel and incorporated blocks of till are exposed above a retaining wall (T139N, R80W, section 21, 2,200 fel, 2,000 fsl), a large abandoned gravel pit in that same township (section 14, 300 fwl, 2,000 fnl), and a small gravel pit (section 14, 200 fwl, 1,200 fnl). In addition to these three outcrops, aerial photographs indicate that outwash is present along the sides of this channel. A large gravel pit operated along the southern edge of this channel (section 21, 2,000 fel, 700 fnl) from the 1930's to the 1950's. Drilling by Groenewold (1980) in the middle of this channel found only three feet of sand and gravel and four feet of underlying till.

Cannonball Formation (Tc)

The Cannonball Formation consists of alternating beds of marine sandstone and mudstone. The sandstone is grayish green to yellowish brown, medium to fine grained, generally poorly cemented and burrowed, containing the trace fossil ophiomorpha. The poorly cemented sandstones commonly contain two- to three-foot-thick, well cemented, lenticular sandstones *(Figure 7)*. These well-cemented sandstones often create flat topography that is easily discernable on aerial photographs. The mudstone is light to dark gray to black, blocky claystone and commonly is banded with lenses of white to yellowish brown silt and very fine sand. The mudstone forms smooth, rounded slopes not unlike some of the strata of the underlying Ludlow and Hell Creek formations. The maximum thickness of the Cannonball Formation in this area is approximately 400 feet.

Cannonball strata are best exposed in the following areas: the western one third of Bismarck, northwest of Bismarck within a two-mile corridor east of the Missouri River, and along a one mile corridor west of the Missouri River and south of Mandan. Cannonball strata are generally poorly exposed due to vegetative cover and slopewash. Outcrops are generally limited to a few tens of feet in height. The best exposures of mudstone and sandstone were found at the Bismarck Water Plant, a common stop for geology fieldtrips. Unfortunately, the cliff face was sloped back and grassed over during expansion of the plant in 1994. Good exposures can still occasionally be found along both River Road and U.S. Highway 1806. At present, the best exposures of mudstone can be found just east of the Bismarck railroad bridge where the constant repair of unstable slopes create clean exposures *(Figure 8)*.

Ludlow and Hell Creek strata are not exposed within the Bismarck Quadrangle. Information was obtained on both formations from a hole drilled at the Bismarck Water Plant. The Ludlow Formation was determined to be only 17 feet thick and the contact between the Ludlow and Cannonball Formations occurred at an elevation of 1,630 feet. The contact between the Hell Creek and Ludlow formations was penetrated at an elevation of 1,613 feet.

Mineral Resources

Sand and Gravel

Sand and gravel companies have operated in various areas of south Bismarck since the late 1800's. The primary sources of sand and gravel have been the Penitentiary and Fort Lincoln terraces. At present, the thickest near-surface gravel deposit that has yet to be mined is in the Fort Lincoln Terrace (west half of

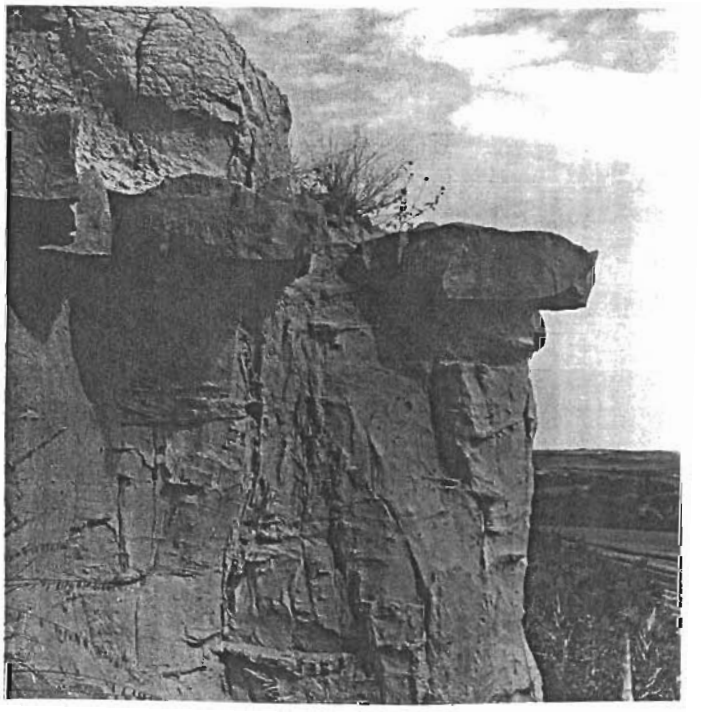

Figure 7. Outcrop of Cannonball Formation sandstone above the Heart River Valley west of Mandan. The lenticular, ledge-forming sandstone near the top of the outcrop typically forms flat-lying topography that is easily discernable from the rounded hills of the underlying and overlying nonmarine stratigraphy.

Figure 8. Cannonball Formation mudstone exposed in a recent cut in an area of unstable slopes northeast of the railroad bridge at Bismarck (T139N, R80W, section 31 1,900 fel, 1,800 fnl). The mudstone consists of alternating beds of burrowed sandstone and claystone. Penny for scale.

section 15, T138N, R80W). The growth of housing developments in this general area may preclude development of some important sand and gravel deposits.

Hazards

Abandoned Pits

Several abandoned gravel pits can be seen in southeast Bismarck on the 1938 photos. The abandoned gravel pits were located on the southeast corner of the intersection of Front Avenue and 12th Street, on the south side of Sweet Avenue between 11th and 12th streets, on the southwest corner of the intersection of 12th Street and Indiana Avenue, the north half of the block bounded by 14th and 15th Streets and Ingals and Michigan Avenues, and most of the block bounded by Front and Sweet Avenues and 15th and 16th Streets. By the fall of 1950, most of the abandoned pits had been filled in. Subsequently, streets and homes have been built over many of these areas. An inspection of one of the identified areas found parallel cracks in a sidewalk, retaining wall, and house foundation. These cracks may have come from differential settling due to poor compaction of the fill placed in the abandoned gravel pits. Development over these abandoned pits should be avoided or should proceed only after thorough investigation and extension of foundation down to undisturbed sediments.

Slope Stability

The majority of unstable slopes occur along the edges of the Missouri River Valley which is not surprising given the steepest slopes are generally found in this area. In the Bismarck area, slope failure generally occurs at the contact between Cannonball mudstone and sandstone *(Figure 9)*. A few small areas of slope failure have also been noted along some of the drainages and hillsides north of Bismarck.

Figure 9. The scarp of a slump developed in Highway 1806 north of Fort Lincoln State Park in the spring of 1997 (T138N, R81W, section 12). Three to four feet of displacement is present in the scarp. This stretch of Highway 1806 (and another stretch just to the south) was built on an ancient landslide. Patching tar had been used in recent years at this site to seal cracks which had developed, precursors to the large failure. This stretch of the highway has been abandoned and may not be repaired. Photo taken looking north.

Abandoned Garbage Dumps

There are at least two abandoned garbage dumps located within the Bismarck city limits. An active dump, located between 8th and 10th Streets and Bowen and Arbor Avenues (near the present sites of the Law Enforcement Center and the Public Works Department) is visible on a 1938 aerial photograph. By the spring of 1948, the approximately 375 foot by 700 foot dump was no longer active. The 20-foot high mound of garbage ash, metal, and sediment was removed during excavation of the Public Works Department in 1965.

Several additional areas of disturbed earth where garbage may have been buried are visible on either the 1938 or 1950 aerial photographs. These areas are the southeast corner of the intersection of 7th Street and Bowen Avenue, the southwest corner of 5th Street and Bowen Avenue, two areas that are presently located in the north end of the Kirkwood Plaza parking lot, and both the north and south sides of Sweet Avenue between 3rd and 5th Street. A large site at Bowen Avenue and 3rd Street was the temporary holding pond for the city's storm sewer runoff.

In 1938, a gravel pit was operating north of Century Avenue, northwest of the present site of Century High School. By 1948, garbage was being dumped into the old gravel pit at this site and spilling over into the adjacent water-filled ravine. Smoke from burning garbage is visible on the May 11, 1948 aerial photographs. The site grew to encompass an area of 40 acres before it was abandoned in 1964.

Pre-Development Surface Drainage Patterns in the Bismarck Area

Development within the city of Bismarck has, in some places, obscured the original surface drainage systems. However, surface runoff or shallow groundwater continues to flow along some of these drainage paths occasionally creating problems for homeowners. There are several large surface drainage systems in the Bismarck area. One of these extends southwest from near Mapleton Avenue and U.S. Highway 83 through Tom O'Leary golf course to Zonta Park. Although development has obscured this drainage throughout much of its course, the ravine is still present just north of Mapleton Avenue, between Ryan and Marian Drives, the northwest portion of the Tom O'Leary Golf Course, North Parkview Drive, West Avenue B, and Zonta Park. This drainage contained several dams and in May, 1948, it held a series of at least nine bodies of standing water. The largest body of water was near the intersection of Century Avenue and 4th Street and covered approximately 20 acres.

Another surface drainage system extended from the northeast quarter of section 28 (T139N, R80W) near the intersection of 9th Street and Interstate Avenue southwestward to Catherine and Meredith Drives, through the coulee behind Arrowhead Plaza (which often contained surface water), along the west edge of 3rd Street to the intersection with Avenue A, and then southwestward to the old underpass at South Washington Street and Front Avenue.

SUGARLOAF BUTTE QUADRANGLE

Methods

Aerial photographs for the years 1938 (1:10,000), 1950, 1957, and 1959 (photos from the 1950's at 1:20,000) were used in the surficial mapping of the Sugarloaf Butte quad. Features such as stabilized eolian dunes, fluvial terraces, erratics, slopewash, and landslides were easily identifiable in stereo pair photos. However, the lithologies of the bedrock units are so similar that their contacts are often not discernable on aerial photographs. Preliminary geologic maps were generated during the spring of 1997 based on aerial photographic interpretation. Potential outcrops and unique geologic features were marked on the quadrangle maps and field checked in the summer. Subsurface information for the study area was obtained from files

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All passable roads and trails were traversed during the summer and pertinent outcrops were visited and geologic observations recorded. A truck-mounted Giddings probe was used to obtain subsurface information in areas where there was insufficient outcrop control *(Figure 3)*. A total of 103 feet was drilled in 13 holes, an average of approximately eight feet per hole.

Geologic Map Units

Oahe Formation (Qo)

The Oahe Formation consists of unconsolidated sediments deposited since the end of glaciation, approximately 10,000 years ago. Sediments range in grain size from clay to cobble and were deposited by various methods including slope failure, slope wash, river, pond, and wind. Sediments of the Oahe Formation range from less than a foot thick to over 25 feet thick in the map area.

Slope Failure (Qof)

Sediments interpreted as slope failure include a combination of soil, unconsolidated sediments, and sedimentary rocks that have slid down the local slope under their own weight. Slope failure is readily identifiable on aerial photographs by a vertical or near-vertical, often semi-circular, nonvegetated cliff face (scarp) and a series of ridges which often terminate in a semi-circular pattern (toe) downslope of the scarp. In the map area, slope failures occur primarily along the valley of the Missouri River. Failures generally occur within one of three common stratigraphic positions: 1) at Hell Creek bentonites, 2) at the contact between Hell Creek and Ludlow strata, and 3) at the contacts between Cannonball mudstones and sandstones.

Several large areas of slope failure, ranging from 10 to 40 acres, are present along the southern edge of the Missouri River Valley in the Sugarloaf Butte Quadrangle. Two of these slides involve Hell Creek strata (T136N, R80W, section 1, T137N, R80W, section 26) and a third involves both Hell Creek and Ludlow strata (T136N, R80W, section 3). Landslides are common in a four-mile stretch along the northern edge of the Missouri River V alley. Most of these slides occur primarily within Hell Creek strata but slides in sections 8, 17, and 18 (T137N, R79W) occur within sands and gravel in the Soo Channel, a diversion channel of the ancestral Missouri River that was active during the Pleistocene.

Slopewash (Qos)

Slopewash includes poorly sorted sand, silt, clay and cobbles that have been transported downslope relatively short distances by runoff. These sediments are typically grayish brown to tan and obscurely bedded. In this area, slopewash is generally found at the base of hillsides, especially along Hell Creek strata. Slopewash is readily discernable on aerial photographs as smooth aprons of sediment that slope away from topographically high areas. Sediments are commonly less than 10 feet thick in the map area.

Several large areas of slopewash (10 to 160 acres) were mapped in the southern portion of the Sugarloaf Butte Quadrangle. All of the slopewash in this area originated from Hell Creek strata. No outcrops were found of this map unit.

Alluvium (Qoa)

Holocene alluvium in this area is typically moderately sorted sand, silt, clay, and gravel. The alluvium is typically grayish brown to dark brown, moderately to obscurely bedded, and often contains aquatic shells

and plant fragments. These sediments were deposited over the last 10,000 years, on the flood plains of the Missouri River, Apple Creek, and associated tributaries. Holocene alluvium in this area is up to several tens of feet thick.

Alluvium covers over one third of the area of the Sugarloaf Butte quadrangle. Most alluvium can be found along the Missouri River but alluvium is also present along Hay Creek, Beaver Creek, and several unnamed tributaries. The Missouri River is underlain in places by over 120 feet of sand, silt, clay, and gravel. The majority of these sediments, and certainly all of the coarser grained fraction, were likely deposited shortly after the ancestral Missouri River was diverted into this area during Pleistocene time. During the Holocene, the Missouri River flooded frequently routinely inundating areas up to an elevation of 1,640 to 1,650 feet. Less frequently, primarily during the wetter portions of the Holocene or after significant ice jams, the floods may have reached elevations significantly closer to 1,700 feet.

Pond Sediment (Qop)

Pond or lacustrine sediments are typically laminated, dark brown to black silt and clay. These lacustrine sediments are found in topographically low areas that may now only periodically hold water, but likely held water for extended periods in the Holocene when the climate was wetter. These deposits are generally less than 10 feet thick in this area. Pond sediments occupy a 40-acre area (T137N, R80W, section 1) in an old tributary of the Soo Channel in the Sugarloaf Butte quadrangle.

Windblown Sediment (Qow)

Windblown sediments are typically moderately to well sorted, grayish brown to tan, sand and silt. These sediments commonly contain one or two ancient soil horizons, or paleosols, consisting of one- or two-foot thick layers of dark brown silty clay. The eolian sediments are typically only moderately to poorly vegetated. The windblown sediments generally form two distinct types of topography: 1) gently rounded topography which slightly drapes the underlying sediments or sedimentary rock, and 2) high relief (20- to 30-foot high) stabilized eolian dunes that can completely mask the underlying strata. This silt was deposited primarily by winds eroding and transporting flood deposits from the Missouri River Valley.

Stabilized (or vegetated) eolian dunes are common throughout the north half of the Sugarloaf Butte quadrangle. These dunes are especially prevalent on the east side of the Soo Channel Aquifer (T138N, R79W, sections 28, 29, 32, and 33; T137N, R79W, sections 4 and 5). These dunes are typically about 10 feet high but may be as high as 30 feet *(Figure 10)*. Unfortunately, there are very few drillholes in this area. A considerable amount of drilling would be needed in this area to accurately determine the underlying bedrock topography and the true thickness of the windblown deposits. Because silt is present at the surface throughout all of the north half of this quadrangle, silt (Qow) was generally not mapped unless it was more than three feet thick.

Windblown Sediment over the Soo Channel (Qows)

As stated earlier, the Soo Channel is a one to 1.5 mile wide diversion channel of the ancestral Missouri River that was active during the Pleistocene. The five-mile-long channel is filled with up to 180 feet of fluvial sediments. During the Holocene, three to 10 feet of windblown silt was deposited in this flat valley. This moderately to well sorted, grayish brown to tan sand and silt forms flat to gently undulating topography (low relief, stabilized eolian dunes) in this valley. The flat topography is the only real defining difference between this map unit (Qows) and the surrounding eolian sediments (Qow). The Soo Aquifer is an important source of irrigation water in the area. The Qows map unit was created to clearly identify the boundaries of the unconfined Soo Aquifer to help protect it from improper development that might adversely impact water quality *(Figure 11)*.

Figure 10. A blowout in stabilized eolian dunes southeast of Bismarck (T138N, R79W, section 29 neswse).

Figure 11 Three to 10 feet of windblown silt covers the surface throughout the area shown on this photograph. The level area in the middle of the photograph is the Soo Channel, the steep topography marks the edge of the Soo Aquifer Photo taken looking east from the northeast quarter of section 36 (T138N, R80W).

Windblown Sediment over Soo Channel Tributary (Qowt)

This map unit consists of windblown materials that overlie tributaries of the Soo Channel in the west-central portion of the Sugarloaf Butte quadrangle. The windblown sediment contains well-sorted, grayish brown to tan colored silt (approximately three to 10 feet thick) that forms relatively flat lying topography. The silt is underlain by an undetermined thickness of fine- to coarse-grained alluvium which in turn is underlain by Hell Creek strata. No significant exposures of this unit were found in the map area and no holes were drilled through it. Locally this unit may be much thicker or thinner than suggested. This unit was separated from the surrounding windblown material (Qow) in order to emphasize the position of the tributary channel which may locally be an important aquifer and may contain valuable sand and gravel deposits.

Alluvial Terrace Deposits (Qoct)

Alluvial terrace deposits typically consist of gravel and medium- to coarse-grained sand. The gravel consists primarily of pebble- to cobble-sized igneous rock and locally derived rock fragments and is commonly iron stained and occasionally iron cemented *(Figure 12)*. Overall, the unit is poorly sorted, but it generally contains well-sorted sand lenses. These quartz sand lenses typically contain thin layers of lignite and clinker fragments. The sand and gravel lenses commonly range in thickness from 10 to 20 feet and are typically overlain by three to 10 feet of windblown silt. These alluvial deposits are generally found on terraces 20 to 50 feet above the Missouri River, between elevations of 1,640 to 1,700 feet. The terrace deposits are easily identified on aerial photographs and on the ground by flat surface topography and the presence of steep cliffs or hillslopes on the Missouri River side of the deposit.

The narrow terrace deposits along both sides of the Missouri River in the Sugarloaf Butte quadrangle range from a few feet to 15 feet of sand and gravel. The coarse gravel fraction of this deposit is generally less than 10 feet thick. These deposits are underlain by Hell Creek and Cannonball strata in this quadrangle *(Figure 13)*. A large terrace deposit in portions of sections 2, 11, and 14 (T137N, R80W) consists of 15 feet of sand and gravel, which is overlain by 10 feet of windblown silt. The sand and gravel layer contains thin (less than two feet) well-sorted sand lenses, but is generally poorly sorted *(Figure 14)*.

Cannonball Formation (Tc)

The Cannonball Formation consists of alternating beds of marine sandstone and mudstone. The sandstone is grayish green to yellowish brown in color, medium to fine grained, generally poorly cemented and burrowed, containing the trace fossil ophiomorpha. The poorly cemented sandstones commonly contain two- to three-foot-thick, well cemented, lenticular sandstones. These well cemented sandstones often create flat topography that is easily discernable on aerial photographs. The mudstone is light to dark gray to black, blocky claystone that's commonly banded with lenses of white to yellowish brown silt and very fine sand. The mudstone forms smooth, rounded slopes not unlike some of the strata of the underlying Ludlow and Hell Creek formations. The maximum thickness of the Cannonball Formation in this area is approximately 400 feet.

The Cannonball Formation is not well exposed anywhere in the Sugarloaf Butte quadrangle. Exposures of Cannonball mudstone can be uncovered by digging through slopewash along the hillsides above the valley of Apple Creek (T138N, R80W, section 26 southeast quarter and section 35 northwest quarter). A few feet of burrowed mudstone is present in the base of a ravine on the east side of the Soo Channel (T138N, R79W, section 29 1,200 fwl, 900 fsl). Blocks of Cannonball sandstone are scattered across the top of a hill (T137N, R79W, section 36 southwest quarter) where excavation for a rural water line has exposed them.

Figure 12. Iron-cemented sand and gravel (Qoct) from an abandoned gravel pit in a terrace of the Missouri River (T137N, R80W, section 26 nenwnw). The gravel consists of both locally derived rock fragments and igneous rocks. Penny for scale.

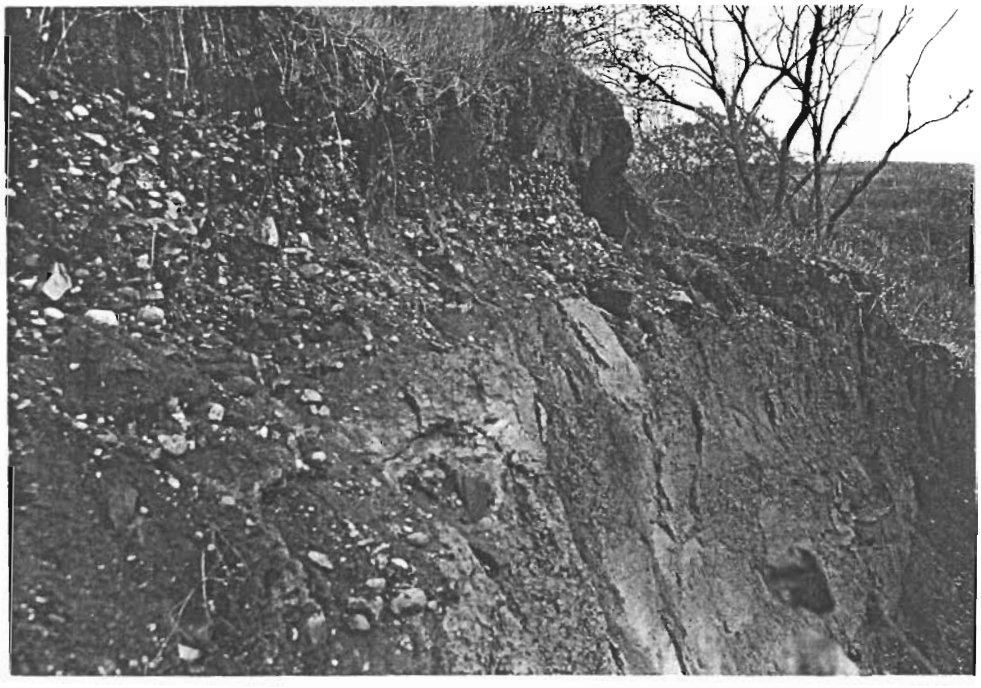

Figure 13. A few feet of sand and gravel (Qoct) overlying Hell Creek strata in a terrace along the Missouri River (T137N, R80W, section 26 nenwnw).

Figure 14. Ten feet of windblown silt is well exposed at the edge of the Missouri River Valley south of the University of Mary (T137N, R80W, section 11 neswsw). The silt is underlain by 15 feet of poorly exposed sand and gravel which in turn overlies Hell Creek strata. The silt was included in the Qoct map unit to enable these potential gravel sources to be emphasized on the map.

Ludlow Formation (Tl)

The Ludlow Formation consists of alternating beds of nonmarine sandstone, siltstone, claystone, mudstone, and lignite. The Ludlow strata are commonly shades of brown, are unique from the underlying and overlying strata because of the presence of lignite, and only rarely include well-developed popcorn (swelling) claystones. The base of the Ludlow often occurs at the base of a carbonaceous mudstone or coal which generally coincides with a break in slope *(Figure 15)*. The Ludlow strata are typically poorly exposed due to vegetative cover.

Outcrops of the Ludlow Formation in the Sugarloaf Butte quadrangle occur primarily along the southern edge of the Missouri River trench and along Apple Creek. There is an additional outcrop along the southwestern edge of a butte in T137N, R80W, section 16. With the exception of a few isolated outcrops in sections 1 and 3 (T136N, R80W) and sections 25 and 26 (T137N, R80W) the Ludlow is generally very poorly exposed due to slope wash and vegetative cover. The better exposures occur along Apple Creek or in scarps that have resulted from landslides or rotational slumps. The slumps generally expose only a few feet of strata. A complete section of Ludlow strata was not found exposed anywhere within the quadrangle. The Ludlow Formation was estimated to be 30 to 40 feet thick in this area.

Hell Creek Formation (Khc)

The Hell Creek Formation consists of alternating beds of nonmarine (except for a thin marine sandstone tongue) sandstone, siltstone, claystone, and mudstone *(Figure 16)*. The Hell Creek strata are commonly very drab colored shades of gray and purple and contain numerous swelling claystones and mudstones. The moderate to poorly cemented, moderately sorted sandstones generally contain large, sweeping foresets

Figure 15. A change in slope and an increase in vegetation often occurs at the Hell Creek and Ludlow stratigraphic contact. A cattle trail has developed on this change in slope further accentuating the lithostratigraphic contact between these units northeast of the University of Mary (T138N, R80W, section 26 nwnese). Photo taken looking northeast.

Figure 16. Hell Creek sandstone and mudstone exposed along the east banks of the Missouri River south of the University of Mary (T137N, R80W, section 11 neswsw). Photo taken looking south.

that are discernible due to organic-rich lenses or beds, and are highly rilled due to surface weathering. Hell Creek strata can be identified on aerial photographs based on the general absence of vegetative cover, marked change in slope at the Hell Creek-Ludlow contact, and high susceptibility to slope failure due to the presence of swelling claystone beds *(Figure 17)*. The Hell Creek Formation is approximately 250 feet thick in the Bismarck-Mandan area.

Hell Creek strata are exposed along both sides of the Missouri River Valley in the southern portion of the Sugarloaf Butte quadrangle and along Apple Creek in the northwest corner of the map. The contact between the Hell Creek and Ludlow formations in the Sugarloaf Butte quadrangle ranges from an elevation of 1,865 feet along the southern edge of the quadrangle to 1,680 feet in the northwest corner, dipping to the north at a rate of approximately 30 feet per mile. The thickest Hell Creek exposures (150 to 200 feet of strata) occur along the southern edge of the Sugarloaf Butte quadrangle.

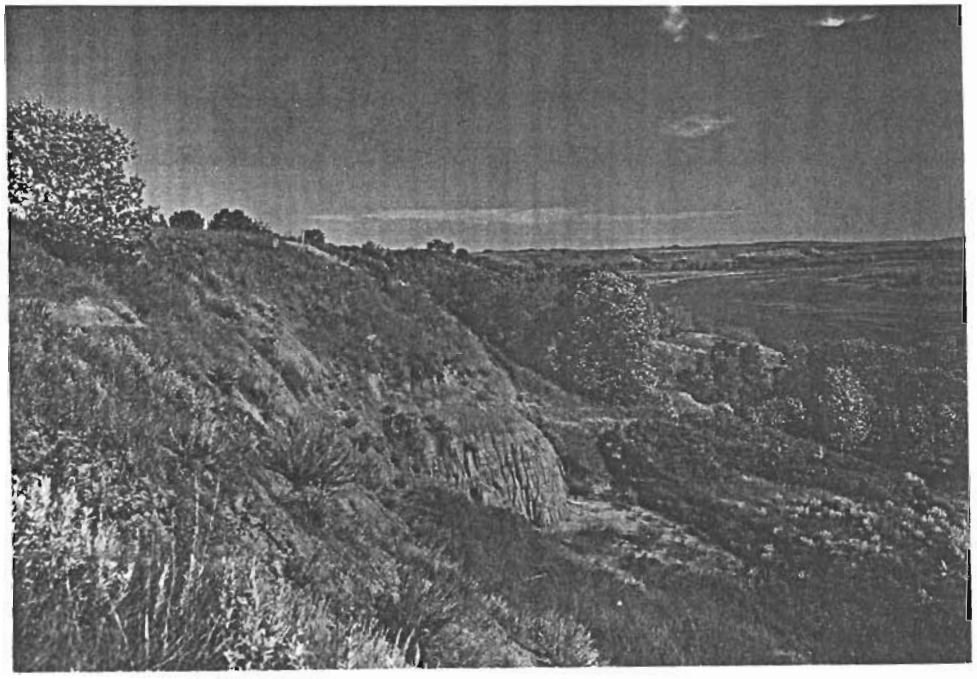

Figure 17. Hell Creek sandstone and mudstone exposed along the north edge of the Missouri River Valley (T137N, R79W, section 15 swswsw). Note the steep slope and rilled weathering pattern that has developed on this sandstone (typical of Hell Creek strata). Photo taken looking east-southeast.

Mineral Resources

Sand and Gravel

A small inactive gravel pit is present in terrace gravels northwest of Huff (T137N, R80W, section 26 nenwnw). The best potential sources of gravel in the Sugarloaf Butte quadrangle are the terrace gravels (Qoct) in sections 2, 11, and 14 (T137N, R80W).

Hazards

Slope Stability

The majority of unstable slopes occur along the edges of the Missouri River Valley which is not surprising given that the steepest slopes are generally found in this area. In the Sugarloaf Butte quadrangle, slope failure generally occurs on swelling claystones within the Hell Creek Formation or at the Hell Creek-Ludlow contact. Several large areas of slope failure, ranging from 10 to 40 acres, are present along the southern edge of the Missouri River Valley in this quadrangle *(Figure 18)*. Two of these slides involve Hell Creek strata (T136N, R80W, section 1; T137N, R80W, section 26) and a third involves both Hell Creek and Ludlow strata (T136N, R80W, section 3). Landslides are common for a four-mile stretch along the northern edge of the Missouri River Valley. Most of these slides occur primarily within Hell Creek strata but slides in sections 8, 17, and 18 (T137N, R79W) occur within sands and gravel in the Soo Channel. Care must be exercised when locating houses in the area to avoid steep slopes, bentonites, and the contacts between Cannonball mudstones and sandstones.

Windblown sediments are often poor building materials because they are not very cohesive and tend to compact (settle) or fail under relatively low stress conditions. It may be prudent to transfer the bearing load through the eolian sediments and into the underlying strata.

Figure 18. A slump at or very near the contact between the Hell Creek and Ludlow formations just north of Huff Hills Ski area (T136N, R80W, section 3). The main scarp is obscured by shadows and the toe of the slide is touching the east edge of the road. The additional moisture from the manmade snow at the ski area has the potential to create slope stability problems in the area. Photo taken looking northeast.

Abandoned Garbage Dumps

No large garbage dumps were detected in the Sugarloaf Butte quadrangle. However, there are most certainly numerous small farm dumps spread throughout the area. These dumps typically may contain household refuse, ash, white goods, tires, as well as farm chemicals. Housing developments in the area must be carefully evaluated to ensure that they do not contain any of these small dumps.

SCHMIDT QUADRANGLE

Methods

A variety of geologic mapping techniques were used to map the geology of the Schmidt quadrangle. Inspection of aerial photographs, field mapping and a review of previous geologic mapping in the area was completed. Aerial photographs from July 1938, October 1950, August 1957, May 1959 and May 1964, were used as a preliminary tool to evaluate landforms, geologic contacts, and possible cultural features. The series of photographs from 1959 and 1964 provided the most complete coverage of the mapping area. Fluvial terraces, erratics, slopewash and landslide areas are features that can be easily distinguished on the photographs. However, the lithologies of the bedrock units are so similar that they are difficult to distinguish on the aerial photographs.

Field methods consisted of traversing roads and accessible trails by vehicle throughout the quadrangle. Inaccessible areas were reached by foot, if possible. Roads and trails are not prevalent in the Schmidt quadrangle, so access to outcrops was limited. Outcrop locations are indicated on the geologic map.

Subsurface information was obtained by using a Giddings truck-mounted soil probe *(Figure 3)* to drill 25 drill holes throughout the study area. Location of drill holes was based on two criteria: 1)boreholes were located in areas where there was insufficient outcrops to maintain stratigraphic control; and 2)the drilling site must be accessible with the drill truck. Additional subsurface information was obtained from the geologic logs of test holes and boreholes previously completed by the North Dakota Geological Survey, the U.S. Geological Survey and the State Water Commission (Ackerman, 1977; Randich, 1965; and Laird and Mitchell, 1942). Due to the scarcity of subsurface information for the quadrangle, geologic logs of domestic water wells, stock wells, and private test holes were also used. Locations of geologic boreholes completed as part of this investigation, as well as locations of all other subsurface information used in the completion of this study, are indicated on the geologic map.

Description of Map Units

Holocene

Qos Silt and clay deposited on the flood plains of the Little Heart and Missouri Rivers (alluvium). Also deposited within flood plains of tributaries and intermittent streams of the Little Heart River. Sediment is typically laminated and may contain organic detritus. Alluvium may be <10 feet thick to over 100 feet thick.

Qof Silt and clay of modern river valleys (alluvium); backwater areas prone to flooding and high water table in the Missouri River bottom lands. Backwater areas are suitable as nesting or breeding habitats for many species of water fowl and other birds.

Qow Silt and sand (windblown sediment). Moderately to well-sorted gray/brown to tan colored sand and silt. Commonly contains one or two paleosols. The paleosols are typically 1-2 foot thick layers of dark brown silty clay. Forms both gently rounded dunes, which slightly obscure the underlying

bedrock, and high-relief (20- to 40-foot high) dunes. The high-relief dunes are stabilized by vegetation, although blowouts can occur in places.

Qog Sand and gravel of Holocene age. Coarse-grained sediment deposited on terraces or as river bar sediment. Sediment is of variable thickness, but is generally the best source of sand and gravel.

Qosg Silt, clay, sand and gravel of Holocene age. Sediment deposited on terraces of the Missouri River. Sediment is of variable thickness.

Pleistocene/Holocene

Qoc Colluvium (slopewash). Mixture of soil, sediments and sedimentary rock that has slid down a hillside under its own weight. In the Schmidt quadrangle, slope failure resulting in colluvial deposits, typically occurs at or near the contact of the Hell Creek and Ludlow formations. Slope failure also occurs within the Hell Creek Formation at groundwater discharge points.

Qost Silt and clay deposited on upper terraces of the Missouri River.

Pleistocene

Qct Coleharbor Formation. Glacial till. Unsorted, unstratified sediment composed of sand, silt, clay and gravel that was deposited directly by glacial ice. Scattered glacial erratics occur throughout the map area and small zones of sediment containing igneous and metamorphic clasts indicate that glacial ice once covered the area. A thin layer (less than five feet) of glacial sediment may once have existed over most of the map area, especially areas mapped as Cannonball Formation. Most of the glacial sediment has since been eroded, leaving only erratics on a veneer of till.

Paleocene

Tb Bullion Creek Formation. Yellow silt, sand, clay, and sandstone and lignite. The unit is typically brighter in color than the underlying Slope Formation. The Bullion Creek Formation reaches a maximum thickness of approximately 50 feet in the map area. The contacts between the Bullion Creek, Slope, and Cannonball formations were inferred from elevations of contacts in adjacent quadrangles, especially the Lynwood Quadrangle, immediately to the west. The geology of the Lynwood quadrangle was mapped by Ellingson (1997). According to Jacob (1976), the sediments of the Bullion Creek Formation were deposited in a fluvial, lacustrine and paludal environments.

Ts Slope Formation. Dark colored clay, silt, sand and lignite, occurring in alternating beds. A white marker bed typically marks the top of the Slope Formation. In outcrop, appearance of the Slope Formation is similar to that of the underlying Ludlow Formation. The Slope Formation was mapped only in the south central and southwest portions of the map area.

Tc Cannonball Formation. Interbedded sand and shale. The sand is a reddish olive color in outcrop, and the shale is dark brown. A distinctive feature of the Cannonball Formation is the laterally persistent sandstone benches that are readily apparent on aerial photographs and in the field. The sandstone benches are evident along the valley walls, such as occur in T137N, R81W, section 26. The lower Paleocene and Upper Cretaceous strata are visible along the banks on the east shore of the Missouri River *(Figure 19)*. Many areas mapped as Cannonball Formation may be covered by a thin (less than five feet) layer of glacial till.

Tl Ludlow Formation. Grayish brown or yellowish brown silt, sand, clay and sandstone with some lignite. According to Clayton and others (1980), the Ludlow is considered to be stratigraphically below the Cannonball Formation (where present). The Ludlow Formation in the Schmidt quadrangle is very thin (<30 feet). The best exposures of the Ludlow Formation in the Schmidt quadrangle are on the east bank of the Missouri River, near the University of Mary (T137N, R80W, section 3) *(Figure 20)*. Slumping and vegetation obscure most outcrops in the Schmidt quadrangle. For example, the Ludlow-Hell Creek Contact is marked by a slumped clinker bed along the north side of the Little Heart River in T137N, R81W, section 14. A complete exposure of the Ludlow Formation is in the Lynwood quadrangle, directly to the west, in section 13.

Upper Cretaceous

Kh Hell Creek Formation. Clay, silt, fine- and medium-grained sandstone (Frye, 1969). Typically the Hell Creek Formation is rather "drab" in color compared to the more brightly colored Ludlow Formation. The Hell Creek Formation has been divided into eight members by Frye (1969), none of which are distinguished in the Schmidt quadrangle. The Hell Creek occurs along the bluffs of the Missouri River trench, and in the Little Heart River Valley. Most of the exposures in the map area are covered by vegetation, with the exception of occurrences in T137N, R80W, sections 7 and 8 and in T137N, R81W, sections 13 and 14.

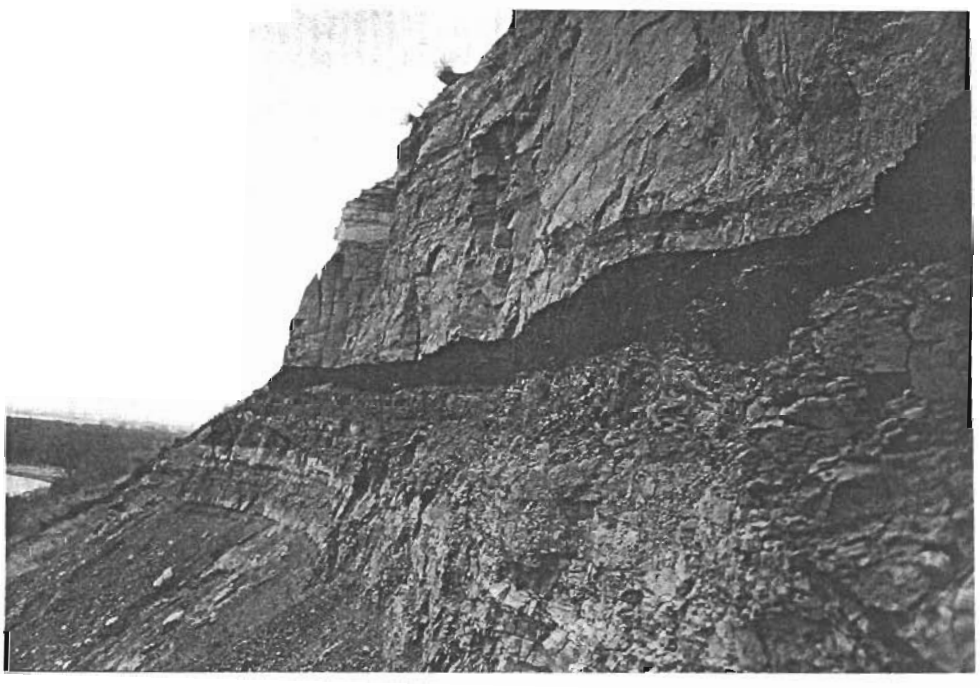

Figure 19. The top of the coal marks the upper contact of the Ludlow Formation, and lower contact of the Cannonball Formation at this site below the University of Mary. The coal is underlain by mudstones of the Ludlow Formation and sandstones of the Cannonball formation.

Figure 20. The Hell Creek, Ludlow, and Cannonball formations are exposed on the east edge of the Missouri River Valley trench beneath the University of Mary (T137N, R80W, section swnene). Arrow points to the top of the Ludlow strata, base of the Cannonball.

Special Features

+ Possible Cultural Sites. Circular-shaped depressions arranged in a manner similar to those of Mandan Indian village sites known to have existed in the area. The depressions were recognized on air photos, but were not readily apparent in the field. It is possible that some of the depressions are caused by small areas of well-drained soil, or test pits dug near gravel pit operations. Some of the depressions, like those in T137N, R80W, section 22, are more likely to be cultural sites than other depressions because of the circular arrangement and even spacing of the features.

s Saline soil. Areas of saline soil as indicated by white, salty ($NaSO_4$) precipitate present on the surface of the ground. Saline discharge can occur within the units of the Hell Creek Formation, causing slumping and slope failure. Areas of saline soil are based on field observations and reference to the Morton County Soil Survey (Edwards and Ableiter, 1951).

o Outcrop. Outcrop locations, used in preparation of the map and this report, are indicated on the geologic map.

Mineral Resources

Sand and gravel mining operations have been conducted on the terraces of the Missouri River since at least 1938 (the earliest available aerial photograph), and presumably since much earlier in the region's history. There is still the potential for sand and gravel mining operations to occur, but water removal systems may have to be installed in some of the now-flooded pits.

Thin lignite beds are visible at some outcrop localities north of the Little Heart River and on the banks of the Missouri. The lignite beds are too thin and discontinuous for economic mining in the Schmidt quadrangle.

There is an account of a cement tile factory at Schmidt (Edwards and Ableiter, 1951, p. 7). The factory was no longer operating by the late 1960's, as evidenced by examination of aerial photographs of that time period.

Geologic Hazards

Slope Stability

Most unstable slopes in the map area are located along the bluffs of the Missouri River *(Figure 21)*, although slumping does occur along intermittent streams and tributaries of the Little Heart and Missouri Rivers. Groundwater seeps combined with bentonite (swelling clays) in the Hell Creek Formation contribute to slope failure and slumping. Slope failure also occurs at the contact between the Ludlow and the Hell Creek formations. A series of ancient landslides is located in sections 27, 28, 33, and 34 (T137N, R80W). The landslides are presumably very old due to the vegetative growth and soil cover. The largest slide, located in the northeast corner of section 33, occurred at the contact between Cannonball Formation mudstones and sandstones. Small slumps in the area occurred at the Hell Creek-Ludlow formation contact.

Abandoned Refuse Sites

No large scale, abandoned refuse sites were noted on the aerial photographs. Based on inspection of aerial photographs, it appears that the gravel pits that were in operation in the 1930's were in operation in the 1960's. It is unlikely that large scale garbage dumping occurred in an active gravel pit operation. Field inspections show that dump sites, if any, are located on private land and contain old household appliances or farming equipment.

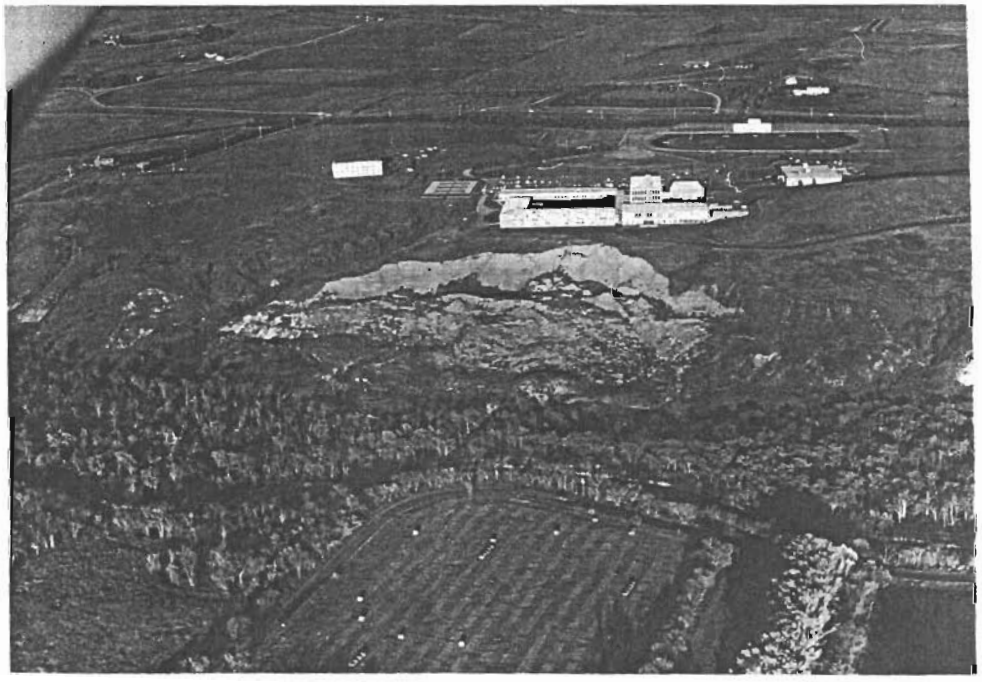

Figure 21. A large slump occurred near the bluffs below the University of Mary in the mid-1980's. The steep cliffs along the Missouri River Valley are prone to slope failure, especially when Hell Creek sediments are present at or near the base of the slope. Photograph taken in the fall of 1987.

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APPENDICES

Appendix A – Drillhole Logs for the Bismarck Quadrangle

NDGS-1 T139N, R81W, section 12 (450 fel, 2000 fsl) Elevation 1750 feet

0-3 ft	Silt, grayish brown, some very fine grained sand.
3-4 ft	Silt, yellowish brown, clayey.
4-9 ft	Sand, grayish brown, very fine grained, silty, (Tc).

NDGS-2 T139N, R80W, section 7 (800 fwl, 200 fsl) Elevation 1800 feet

0-1 ft	Soil.
1-3 ft	Silt, whitish gray, clayey.
3-9 ft	Mudstone, dark brown, silt and clay lenses, (Tc).

NDGS-3 T139N, R80W, section 7 (300 fwl, 1250 fsl) Elevation 1760 feet

0-1 ft	Soil.
1-4 ft	Silt, brown to dark brown, clayey.
4-9 ft	Mudstone, medium brown, silt and clay lenses, white ppt, FeO horizons, highly weathered Tc.

NDGS-4 T139N, R80W, section 18 (2300 fel, 1700 fsl) Elevation 1920 feet

0-1 ft	Soil.
1-11 ft	Till, grayish brown, dark brown from 6 feet on, pebbly, FeO staining, top couple of feet highly weathered.

NDGS-5 T139N, R80W, section 18 (2640 fel, 1200 fsl) Elevation 1915 feet

0-1 ft	Soil.
1-3 ft	Silt, grayish brown, some sand grains.
3-11 ft	Till, gray, sandy, pebbly, lignite fragments, FeO.

NDGS-6 T139N, R80W, section 17 (200 fwl, 2100 fsl) Elevation 1920 feet

0-0.5 ft	Soil.
0.5-9 ft	Mudstone (Tc), medium to dark brown, silt and clay lenses, highly weathered top couple of feet, FeO stained and white mineral ppt top 2 feet.

NDGS-7 T139N, R80W, section 18 (400 fel, 1850 fsl) Elevation 1885 feet

0-0.5 ft	Soil.
0.5-1.3 ft	Slopewash, brown, silt and clay, obscurely bedded.
1.3-7 ft	Mudstone (Tc), medium to dark brown, silt and clay lenses, highly weathered top couple of feet.

NDGS-8 T139N, R80W, section 18 (700 fel, 2000 fsl) Elevation 1885 feet

0-1 ft	Soil.
1-1.5 ft	Slopewash, medium brown, silt and clay, obscurely bedded.

1.5-8 ft	Mudstone (Tc), medium to dark brown, silt and clay lenses, highly weathered top couple of feet.

NDGS-9 T139N, R80W, section 18 (1000 fel, 2200 fsl) Elevation 1885 feet

0-3 ft	Silt, brown, clayey.
3-8 ft	Mudstone (Tc), medium brown, highly weathered (FeO stained, fractured) top couple of feet.

NDGS-10 T139N, R80W, section 18 (1850 fel,1250 fsl) Elevation 1875 feet

0-1 ft	Soil.
1-4 ft	Mudstone (Tc), tan, silt and clay, highly weathered--FeO stained, fractured, gypsum crystals.
4-10 ft	Mudstone (Tc), medium to dark brown, silt and clay lenses.

NDGS-11 T139N, R80W, section 18 (1700 fel, 700 fsl) Elevation 1850 feet

0-1 ft	Soil.
1-4 ft	Silt, gray, clayey, occasional pebbles, some gypsum lenses.
4-10 ft	Mudstone (Tc), medium to dark brown, weathered top 2 feet.

NDGS-12 T139N, R80W, section 8 (300 fwl, 1000 fsl) Elevation 1930 feet

0-1 ft	Soil.
1-12 ft	Till, yellowish gray, pebbles, boulder at 5 feet, top couple of feet highly weathered, high concentration of lignite fragments from 7 feet on.

NDGS-23 T139N, R80W, section 29 (200 fwl, 800 fsl) Elevation 1805 feet

0-1 ft	Soil.
1-1.5 ft	Silt, brown, clayey, some sand grains, poorly sorted.
1.5-4 ft	Silt, brown to dark brown, clayey, organic rich.
4-9 ft	Silt, light brown, to grayish brown, clayey.
9-11 ft	Sand, dark grayish brown, medium to very fine grained, clayey, dirty, FeO stains and small concretionary layers, Tc.

NDGS-26 T139N, R80W, section 29 (900 fwl, 300 fsl) Elevation 1815 feet

0-2 ft	Silt, grayish brown, occasional rootlets, occ. pebbles.
2-6 ft	Mudstone (Tc), yellowish brown, silt and clay lenses, FeO staining.
6-10 ft	Sand (Tc), grayish brown, medium fine grained, slightly micaceous, moderately sorted.

NDGS-27 T139N, R80W, section 18 (1400 fwl, 100 fsl) Elevation 1850 feet

0-0.5 ft	Soil.
0.5-1.5 ft	Silt, brown, clayey.
1.5-4 ft	Mudstone (Tc), gray to light brown, highly weathered--gypsum crystals, FeO staining, fractured.
4-10 ft	Mudstone (Tc), dark brown.

NDGS-28 T139N, R80W, section 18 (600 fwl, 600 fsl) Elevation 1825 feet

0-0.5 ft	Soil.
0.5-1.5 ft	Silt, brown, clayey.
1.5-5 ft	Mudstone (Tc), yellowish brown to gray, highly weathered.

NDGS-29 T139N, R80W, section 18 (400 fwl, 1800 fsl) Elevation 1825 feet

0-0.5 ft	Soil.
0.5-2 ft	Sand (Tc), light brownish gray, very fine to fine grained, weathered.
2-6 ft	Sand (Tc), grayish green, very fine to fine grained.

NDGS-30 T139N, R80W, section 18 (300 fwl, 2300 fsl) Elevation 1805 feet

0-0.5 ft	Soil.
0.5-3.5 ft	Silt, brown, clayey, occasional pebble, some sand.
3.5-5 ft	Mudstone (Tc), grayish brown, sand and clay lenses.

NDGS-34 T139N, R80W, section 17 (600 fel, 1500 fsl) Elevation 1945 feet

0-1 ft	Soil.
1-2 ft	Silt, yellowish brown.
2-10 ft	Till, brown, very pebbly, abundant clinker and coal fragments.

NDGS-35 T139N, R80W, section 17 (1750 fel, 1500 fsl) Elevation 1945 feet

0-1 ft	Soil.
1-2.5 ft	Silt, yellowish brown, some clay, occasionally a pebble.
2.5-8 ft	Till, brown, clinker and lignite fragments.

NDGS-40 T139N, R80W, section 17 (800 fel, 2500 fnl) Elevation 1950 feet

0-1 ft	Soil.
1-3 ft	Silt, grayish brown, white ppt.
3-4 ft	Sand, brown, very fine grained.
4-6 ft	Till, grayish brown, clayey, lignite fragments.

NDGS-41 T139N, R80W, section 17 (1900 fel, 1700 fsl) Elevation 1870 feet

0-1 ft	Soil.
1-4 ft	Silt, tan, clean, well sorted.
4-8 ft	Mudstone (Tc), dark brown, silt and sand lenses.

NDGS-43 T139N, R80W, section 17 (1200 fel, 1300 fsl) Elevation 1950 feet

0-1 ft	Soil.
1-2.5 ft	Silt, gray.
2.5-3.5 ft	Pebbles, gravel ?, could not drill through.

NDGS-44 T139N, R80W, section 10 (300 fel, 1000 fsl) Elevation 1835 feet

0-1 ft	Soil.
1-2.5 ft	Silt, gray to brown, occasional pebble.
2.5-5 ft	Till, brown to medium brown, clayey, pebbles.

NDGS-45 T139N, R80W, section 15 (1000 fel, 400 fnl) Elevation 1825 feet

0-1 ft	Soil.
1-2 ft	Silt, light brown to brownish gray.
2-6 ft	Till, brown, sandy, pebbles.

NDGS-47 T139N, R80W, section 17 (2200 fwl, 2400 fsl) Elevation 1920 feet

0-1 ft	Soil.
1-4 ft	Silt, light brown to tan.
4 ft	Hit rock could not drill further.

NDGS-49 T139N, R80W, section 20 (1600 fel, 1200 fnl) Elevation 1925 feet

0-2 ft	Fill.
2-3 ft	Soil.
3-5 ft	Silt, medium to dark brown, clayey.
5-11 ft	Till, grayish green, highly weathered–FeO stained.
11-18 ft	Mudstone, medium to dark brown, silt and clay lenses.

NDGS-55 T138N, R81W, section 13 (300 fwl, 1000 fsl) Elevation 1900 feet

0-0.5 ft	Soil.
0.5-6 ft	Sandstone (Tc), grayish green, very fine grained, silty, clayey, FeO chips, highly weathered.

NDGS-56 T138N, R81W, section 13 (200 fwl, 400 fsl) Elevation 1885 feet

0-0.5 ft	Soil.
0.5-3 ft	Sandstone (Tc), gray, very fine grained, silty, highly weathered.

NDGS-57 T138N, R81W, section 13 (50 fwl, 1300 fsl) Elevation 1875 feet

0-0.5 ft	Soil.
0.5-2 ft	Slopewash, clay and silt, gray, occasional pebbles.

NDGS-58 T138N, R81W, section 13 (100 fwl, 1700 fnl) Elevation 1875 feet

0-0.5 ft	Soil.
0.5-4 ft	Mudstone (Tc), dark gray, sand and silt, weathered top couple of feet.

Appendix B – Drillhole Logs for the Sugarloaf Butte Quadrangle

NDGS-6 T137N, R79W, section 15 (400 fwl, 200 fnl) Elevation 1800 feet

0-1 ft	Soil.
1-1.5 ft	Silt, grayish brown, clayey.
1.5-6 ft	Mudstone, grayish green to brown, weakly laminated, silt lenses, top foot highly weathered.

NDGS-7 T137N, R79W, section 15 (200 fwl, 1800 fsl) Elevation 1730 feet

0-1 ft	Soil.
1-8 ft	Silt, grayish brown, to light brown, sandy to clayey, sandy at 5 feet, paleosol at 5.5 feet.
8-9 ft	Siltstone (Khc), yellowish brown, small selenite crystals.

NDGS-8 T137N, R79W, section 15 (1200 fwl, 1800 fnl) Elevation 1770 feet

0-1.5 ft	Soil.
1.5-5 ft	Mudstone (Khc), gray to brown, highly weathered top 1 foot.

NDGS-9 T137N, R79W, section 15 (900 fwl, 1800 fnl) Elevation 1770 feet

0-1.5 ft	Soil.
1.5-4 ft	Mudstone (Khc), gray to brown, top 1 foot highly weathered.

NDGS-10 T138N, R80W, section 36 (200 fwl, 200 fnl) Elevation 1825 feet

0-0.5 ft	Soil.
0.5-5 ft	Silt, light tan.
5-8 ft	Sand, yellowish brown, very fine grained, clean.

NDGS-11 T138N, R80W, section 36 (1800 fwl, 1800 fsl) Elevation 1825 feet

0-0.5 ft	Soil.
0.5-6 ft	Silt to loam, grayish brown, pebble lag at base.
6-8 ft	Mudstone (Tc), gray to medium brown, sand and clay lenses.

NDGS-12 T137N, R79W, section 6 (600 fwl, 600 fsl) Elevation 1860 feet

0-0.5 ft	Soil.
0.5-3 ft	Silt, grayish brown, clean.
3-7 ft	Sand, yellowish brown, very fine grained, clean.

NDGS-13 T138N, R79W, section 32 (1600 fel, 10 fsl) Elevation 1830 feet

0-0.5 ft	Soil.
0.5-3 ft	Silt, grayish brown.
3-8 ft	Sand, yellowish brown, very fine grained, very clean (Tc).

NDGS-14 T138N, R79W, section 32 (2200 fel, 10 fsl) Elevation 1780 feet

0-0.5 ft	Soil.
0.5-2 ft	Silt, brown, occasional pebbles.
2-3 ft	Sand, yellowish brown, occasional pebbles.
3-8 ft	Mudstone (Tc), grayish brown to black, sand and clay laminae, contains a 3" organic clay layer at 7.5 feet.

NDGS-15 T138N, R79W, section 32 (2000 fel, 500 fsl) Elevation 1775 feet

0-3 ft	Silt, grayish brown, sandy, occasional pebbles.
3-8 ft	Mudstone (Tc), brown to dark brown, silt and clay lenses.

NDGS-16 T137N, R80W, section 12 (2000 fwl, 100 fsl) Elevation 1884 feet

0-1 ft	Soil.
1-3 ft	Silt, grayish brown.
3-11 ft	Sand (Tc), grayish yellow to brown, very fine grained, clean.

NDGS-18 T138N, R79W, section 32 (2000 fwl, 1200 fnl) Elevation 1830 feet

0-0.5 ft	Soil.
0.5-3 ft	Silt, brown, sandy.
3-11 ft	Sand, yellowish brown to grayish green, very fine grained, silty.

NDGS-19 T138N, R79W, section 32 (1700 fwl, 400 fnl) Elevation 1830 feet

0-0.5 ft	Soil.
0.5-3 ft	Silt, brown to light brown, sandy.
3-10 ft	Sand, grayish green to yellowish brown, very fine grained, silty.

Appendix C – Drillhole Logs for the Schmidt Quadrangle

NDGS-1 E½ SE¼ sec. 5, T 136N, R 80W (location approximate) (Broken Heart Ranch, Hole 1)
Date: Tuesday August 5, 1997
Observer: AMF
Weather: windy, clear sky, mid 70's
Elevation: 2250 (estimated from Schmidt 7.5 minute topographic map)

0-3.5 ft	Silty clay, gray; some fine sand; dry, loose; some white CaCO3 coats on sand grains
3.5-6 ft	Sand yellow; very fine grained; some silt, loose, angular-subrounded grains; well sorted.
6-9 ft	Sand; sample collected at 9 feet
9 ft	End of boring

NDGS-2 T137N, R81W, SE¼, NW¼, NW¼ section 30 (Gregor & Erna Schmidt property, Hole 1)
Date: Tuesday August 5, 1997
Observer: AMF
Weather: clear, windy, mid 70's
Elevation: 1,860 (estimated from Schmidt 7.5 minute topographic map)

0-1 ft	Silt, tan-yellow; some very fine grained sand; carbonate layers
1-3 ft	Silty clay, yellow; <10% very fine grained sand; becomes gray with depth; becomes more clay-rich with depth; Fe stains; mottled?
3-6 ft	Clay, tan and silty clay, yellow; layered(?); both have some (<10%) sand; poor recovery
6-8.5 ft	Silty clay, yellow-brown; not layered as in 3-6 feet; poor recovery; sample from 8-8.5
8.5 ft	End of boring

NDGS-3 T137N, R81W, SW¼, SW¼, NE¼ section 36 (Schmidt Hole 2)
Date: Wednesday August 6, 1997
Observer: AMF
Weather: clear, slight wind from NW
Elevation: 1,900 (estimated from 7.5 minute topographic map)

0-3 ft	Loam, gray-tan; 30-40% sand, carbonate covers some grains, silt coats more abundant from 2-3 feet
3-5.5 ft	Clay, gray; some sand; forms 1" ribbon
5-6.5 ft	Clay, gray and yellow clay; mottled, Fe-oxide stained, white-ish grainy coats along planes, laminated?
6.5-8 ft	Silty clay, yellow; Fe-oxide stains, mottled with gray silt stringers; little sand (<5%)
8-9.5 ft	Sandy clay, gray and silty clay, yellow; carbonate mottles; gypsum crystals(?)
9.5-10.5 ft	Siltstone, tan
10.5 ft	End of boring

NDGS-4 T137N, R81W, SW¼, NW¼, NW¼ section 36 (Schmidt Hole 3)
Date: Wednesday August 6, 1997
Observer: AMF
Weather: clear, windy
Elevation: 2,020 (estimated from 7.5 minute topographic map)

0-1.5 ft	Silty clay, tan, friable
1.5-3 ft	Silty clay, gray-tan; friable; Fe-staining, smears on auger yet is powdery

3-6 ft	Silty clay, gray; as above; poor recovery
6-8.5 ft	Silty clay, gray; Fe-stained, mottled with yellow clay, white (CaCO3 ?) silt stringers
8.5-9 ft	Silty clay, gray, as above, CaCO3 crystals; sample collected.
9 ft	End of boring

NDGS-5 T137N, R81W, SE¼, NE¼, SW¼, NE¼ section 36 (Schmidt Hole 4)
Date: Wednesday August 6, 1997
Observer: AMF
Weather: sunny, hot
Elevation: 1,855 (estimated from 7.5 minute topographic map)

0-1.5 ft	Silt loam, gray/black, more silt than clay; roots, grass; 10% sand
1.5-4 ft	Silt loam, green/gray; sandier than above, 30-40% sand, CaCO3 coats; silt coats on grains
4-5 ft	Silty clay, yellow, very stiff, non-plastic; gypsum, some large (3/4") crystals
5-6 ft	Sandy silty clay, brown/green
6-7 ft	Clay, gray/green; with some yellow sand, gypsum crystals
7-9 ft	No recovery
9 ft	End of boring

NDGS-6 T137, R80, NE¼ of SE¼ Sec. 7 (Hodny Hole 1)
Date: Thursday August 7, 1997
Observer: AMF
Weather: sunny, warm
Elevation: 1,695 (estimated from 7.5 minute topographic map)

0-3 ft	Sandy loam, gray; Fe-oxide nodules, carbonate nodules, very tight drilling
3 ft	End of boring (auger refusal)

NDGS-7 T137, R80, SW¼ of NE¼ of SW¼ Sec. 7 (Hodny Hole 2)
Date: Thursday August 7, 1997
Observer: AMF
Weather: sunny, hot (lower to mid 90's)
Elevation: 1,655 (estimated from 7.5 minute topographic map)

0-0.5 ft	Silt loam, light black
0.5-3 ft	Sand, gray; very fine grained, with silt; small, white CaCO3 (?) nodules; very loose and powdery
3-6 ft	Sand, gray; very fine grained; with silt, some clay, as above.
6-9 ft	Sand, gray; as above; CaCO3 nodules become larger at 8'; tiny bits of black, soft, shiny material, coal (?)
9 ft	End of boring

NDGS-8 T137N, R80W, W½, SE¼, NE¼ section 27 (Schaedler Hole 1)
Date: Monday August 11, 1997
Observer: AMF
Weather:
Elevation: 1,702 (estimated from 7.5 minute topographic map)

0-1 ft	Silt, brown, dry and loose
1-2 ft	Silt loam, brown; roots
2-3 ft	Silt loam, tan; carbonate nodules

3-8 ft	Silt loam, tan; no CaCO3 nodules after 3' depth; poor recovery due to very dry, friable sediment
8 ft	End of boring

NDGS-9	T137N, R80W, SW¼, SE¼, SW¼ section 27 (Schaedler Hole 2)
Date:	Monday August 11, 1997
Observer:	AMF
Weather:	sunny, mid 80's
Elevation:	1,905 (estimated from 7.5 minute topographic map)

0-2 ft	Silt loam and sand, tan; very fine grained sand; CaCO3 nodules from 1- 2', roots, dry and loose
2-5 ft	Silt loam; poor recovery
5-7 ft	Loam, brown; no pebbles or observable structures; poor recovery

NDGS-10	T137N, R80W, SW¼, section 34 (location approximate) (Schaedler Hole 3)
Date:	Monday August 11, 1997
Observer:	AMF
Weather:	overcast, warm, breezy
Elevation:	2,170 (estimated from 7.5 minute topographic map)

0-1 ft	Silt loam, brown, roots
1- 4.5 ft	Silt loam, tan; pebbles with CaCO3 coating, pebble lithology is mostly sandstone
4.5-5.5 ft	Clay loam-clay, yellow/brown; ribbons slightly; small carbonate pebbles, also appears to have gray mottling
5.5-8 ft	Clay loam, yellow with Fe-stained streaks; 30% very fine sand; ribbons slightly; silt content greater than clay content
8-10.5 ft	Silt, yellow-brown; Fe-oxide stains on fractures/bedding planes; non-plastic, stiff; very few fine sand grains
10.5-12 ft	Clay loam, yellow brown and gray mottled; Fe-oxide stains; few fine sand grains (lithologies: dolomite, granite)
12 ft	End of boring

NDGS-11	T137, R81, NW¼ of NW¼ of SW¼ section24 (Mattson Farm, Hole 1)
Date:	Tuesday August 12, 1997
Observer:	AMF
Weather:	sunny, warm
Elevation:	1,745 (estimated from 7.5 minute topographic map)

0-2 ft	Silt loam, brown/black, roots; dry and loose
2-4 ft	Silt loam, brown, roots at 2', carbonate layer at 3'; dry, friable
4-7 ft	Clay, dark gray; with some very fine sand, some coarse sand grains; slightly plastic, dry
7-7.5 ft	Sandy clay, brown; some coarse sand grains are Fe-stained
7.5-8 ft	Clay, dark gray; stiff, mottled with white silt and some Fe-stained very coarse sand grains
8-10 ft	Clay, dark gray/tan mottled (layered?); white crystalline grains along bedding/fracture planes; few pebbles; stiff; dry.
10 ft	End of boring

NDGS-12 T 137, R81, NW¼ of SE ¼ of SE ¼ of section 23 (Mattson Hole 2)
Date: Tuesday August 12, 1997
Observer: AMF
Weather: sunny, warm
Elevation: 1,810 (estimated from 7.5 minute topographic map)

0-0.5 ft	Silt, tan
0.5-4 ft	Silt, yellow and gray mottled; dry, loose.
4-6 ft	Silt, yellow/brown; layered with gray silt; gray silt contains small (<¼") black silt nodules and Fe-stained concretions
6-10 ft	Silt, yellow/brown; layered with gray silt; as above
10 ft	End of boring

NDGS-13 T137, R 81, NE ¼ of NE¼ of SW¼ section 24 (Mattson Hole 3)
Date: Tuesday August 12, 1997
Observer: AMF
Weather: sunny, warm
Elevation: 1,765 (estimated from 7.5 minute topographic map)

0-2.5 ft	Silt, tan, friable; dry
2.5-3 ft	Silt, tan; friable, but not as bad as surface
3-5 ft	Silt, tan; as above
5 ft	Cobble, auger refusal
5 ft	End of boring

NDGS-14 T137N, R81W, SW¼ of NE¼ of NE¼ section 23 (Mattson Hole 4)
Date: Tuesday August 12, 1997
Observer: AMF
Weather: sunny, warm
Elevation: 1,705 (estimated from 7.5 minute topographic map)

0-2.5 ft	Silt loam, dark brown, roots (plowed)
2.5-3 ft	Silt, tan; friable, dry
3-5 ft	Silt, tan; as above, poor recovery
5-9 ft	Silty clay, tan; CaCO3 layer at 5.5'; friable, dry; poor recovery
9 ft	End of boring

NDGS-15 T137, R81, S½ of NW¼ of NE¼ section 13 (just west of trail)
Date: Wednesday August 13, 1997
Observer: AMF
Weather: sunny, warm
Elevation: 1,710 (estimated from 7.5 minute topographic map)

0-0.5 ft	Silt loam, dark brown, friable
0.5-2 ft	Silt loam, tan
2-4 ft	Silt loam, tan; calcareous, friable, dry
4-5 ft	Sand and gravel, light tan; poorly sorted, calcareous
5-6.5 ft	Sand; poorly sorted; and gravel, calcareous, silt coats on grains; dry, loose
6.5-7 ft	Clay, gray; stiff; difficult drilling
7-8 ft	Sandy clay, gray/tan; medium to coarse grained grains; slightly calcareous; difficult drilling
8-8.5 ft	Clay, gray/tan; slightly plastic; this unit may be thinner but its hard to tell on the auger

8.5-11 ft	Clay, gray; with some coarse sand; slightly plastic; slightly calcareous
11 ft	End of boring

NDGS-16 T137, R81, center of NW¼, section 13 (Hole 2, 8/13)
Date: Wednesday August 13, 1997
Observer: AMF
Weather: sunny, warm
Elevation: 1,672 (estimated from 7.5 minute topographic map)

0-0.5 ft	Silt loam, tan/gray
0.5-3 ft	Clay, gray and black mottled; white silt coats around some fracture/bedding planes; calcareous
3-5.5 ft	Clay, gray/black; appears banded or laminated, laminae are 1mm thick; very fine sand grains also visible; non-plastic; non-calcareous
5.5-6 ft	Silty sand, gray, very fine grained; moist
6-8 ft	Sand and silt, gray; very fine grained; moist; slightly plastic; non-calcareous; and gray clay, plastic
8-9 ft	Clay, dark gray; plastic; moist to wet; no pebbles, non-calcareous
9-11 ft	Clay, gray/tan mottled(?); plastic; no pebbles
11-12 ft	Clay, gray/tan; plastic; some silt, few pebbles visible (dolomite, sandstone); moist
12-12.5 ft	Clay, as above; with some carbonate nodules
12.5-13.5 ft	Clay, gray/tan; plastic; some silt, few pebbles visible (dolomite, sandstone); moist
13.5-14 ft	Sand, very fine grained; some coarse grains, silt in matrix; wet in pore space
14-15 ft	Clay; gray; very plastic
15 ft	End of boring

NDGS-17 T137N, R81W, SW¼ of SE¼ of NW¼ section12 (Hole 3A, 8/13)
Date: Wednesday August 13, 1997
Observer: AMF
Weather: sunny, breezy, warm
Elevation: 1,765 (estimated from 7.5 minute topographic map)

0-2 ft	Clay loam, brown; 45% sand; poorly sorted, calcareous; loose, dry
2-3 ft	Loam, tan; more sand and gravel than above
3-5 ft	No recovery
5-6 ft	Loamy sand yellow; medium to fine grained sand; moderately well sorted. Very tough drilling
6 ft	End of boring

NDGS-18 T137N, R81W, SW¼ of SE¼ of NW¼ section 12 (Hole 3B-located 1 ft south of 3A, 8/13)
Date: Wednesday August 13, 1997
Observer: AMF
Weather: sunny, breezy, warm
Elevation: 1,765 (estimated from 7.5 minute topographic map)

0-3 ft	Silt loam, calcic horizon at 2' (very strong effervescence)
3-7 ft	No recovery
7 ft	End of boring

NDGS-19 T137N, R81W, NW¼ of NE¼ of NE¼ section11 (Hole 4, 8/13)
Date: Wednesday August 13, 1997
Observer: AMF
Weather: sunny, warm, breezy
Elevation: 1,850 (estimated from 7.5 minute topographic map)

0-3 ft	Sandy loam, tan/yellow; may be road fill
3-6 ft	Sandy loam, yellow; slightly calcareous, friable
6-7.5 ft	Clay loam, yellow; some limestone pebbles; somewhat plastic
7.5-10.5 ft	Sand, yellow; medium to fine grained; with some clay
10.5 ft	End of boring

NDGS-20 T138N, R80W, SW¼ of SW¼ of SW¼ of section 30 (Darrel Suchy property, near Groenewold Hole 2909)
Date: September 15, 1997
Observer: AMF
Weather: overcast, windy, mid 70's
Elevation: 1,650 (estimated from 7.5 minute topographic map)

0-1 ft	Silt loam, black; roots, moist
1-3 ft	Silty sand, very fine sand, tan/brown
3-4.5 ft	Sand, brown; very fine grained; some pebbles; rounded
4.5-10 ft	Sand and gravel; calcareous; medium to coarse grained sand, ½" gravel (on long axis) lense at 5'; sand becomes coarser, more poorly sorted and cleaner with depth; dark layer (organic?) at 9'
10-11 ft	Sand, brown; some clay (<10%); medium grained sand; well sorted
11-11.5 ft	Sand, yellow; medium grained; moderately well sorted; relatively clean (<5% clay); mostly quartz sand.

NDGS-21 T138N, R81W SE¼ of NW¼ of NE¼ of section 26 (Don & Cherylln Schmidt, Hole 1, 9/17)
Date: Wednesday September 17, 1997
Observer: AMF
Weather: clear skies, mid 50's
Elevation: 1,720 (estimated from 7.5 minute topographic map)
Comments: Auger from 0-3', split spoon from 3-7'

0-1 ft	Silt loam, brown
1-1.5 ft	Silt loam, tan
1.5-2.5 ft	Silt loam, tan, calcareous horizon, loose
2.5-4 ft	Sandy loam, brown; medium to fine grained sand; calcareous, especially from 3'-4';
4-4.2 ft	Sandy loam, gray-green; medium to fine grained sand; calcareous coating on grains
4.2-6.5 ft	Clay, gray-green; some silt
6.5-7 ft	Sand, tan; very fine grained; some Fe staining; gravel at 6.8', CaCO3 coats on gravel
7 ft	End of boring

NDGS-22 T138N, R81W, NE¼ of NW¼ of NE¼ of section 26 (Schmidt Hole 2, 9/17)
Date: Wednesday September 17, 1997
Observer: AMF
Weather: sunny, mid 50's
Elevation: 1,740 (estimated from 7.5 minute topographic map)

0-0.5 ft	Silt loam, dark brown; roots
0.5-1 ft	Silt, brown
1-3 ft	Silt, tan; calcareous
3-5 ft	No recovery
5 ft	End of boring

NDGS-23 T138N, R81W, NW¼ of NW¼ of NE¼ of section 36 (Suchy Hole 3, 9/17)
Date: Wednesday September 17, 1997
Observer: AMF
Weather: sunny, 70's
Elevation: 1,659 (estimated from 7.5 minute topographic map)
Comments: auger 0-3, split spoon 3-7

0-1 ft	Silt loam, black; roots
1-3 ft	Clay, tan; approximately 30% very fine grained sand; non-plastic
3-6 ft	Clay, black mottled with tan sandy loam; sandy loam is calcareous, clay is not
6-7 ft	Sandy loam, tan; very fine grained sand; calcareous
7-10 ft	Clay, tan; with some sand (10-20%), very fine grained; slightly plastic; white CaCO3 'laminae' and calcareous zones throughout; poor recovery
10 ft	End of boring

NDGS-24 T138N, R81W, SW¼ of SW¼ of NE¼ of section 36 (Suchy Hole 4, 9/17)
Date: Wednesday September 17, 1997
Observer: AMF
Weather: sunny, mid 70's
Elevation: 1,665 (estimated from 7.5 minute topographic map)

0-0.5 ft	Silt, dark brown
0.5-3 ft	Silt loam, brown; dry, loose
3-5 ft	Loamy sand, light gray; very fine grained sand; clay content is greater than silt; calcareous; becomes almost golden color at 5'
5-5.5 ft	Loamy sand, as above; some sandstone gravel; higher sand content than 3-5'
5.5-6.5 ft	Sandy clay, tan/yellow mottled; very fine grained sand; Fe stained
6.5-6.6 ft	Silt, CaCO3 coatings, strong effervescence
6.6-7.2 ft	Clay, dark gray; slightly plastic; Fe stains on fracture surfaces/bedding planes; very fine grained sand lense at 7', Fe stains on top and bottom of sand
7.2-9 ft	No recovery
9-10 ft	Silty clay; with 10% very fine grained sand; light gray with faint laminations of Fe-oxide red and black (lignite?); appears that at least 1 of the laminations is lignite as small pieces are visible; laminae are thin (1-2mm); slightly plastic
10 ft	End of boring

NDGS-25 T138N, R80W, NW¼ of NW¼ of NW¼ of section 31 (Suchy Hole 5, 9/17)
Date: Wednesday September 17, 1997
Observer: AMF
Weather: sunny, mid 70's
Elevation: 1,650 (estimated from 7.5 minute topographic map)

0-3 ft	Silt, tan
3 ft	End of boring

NDGS-26 T137N, R80W, SE¼ of SE¼ of NE¼ section 21 (Anderson Broadcasting property, DH-1)
Date: Wednesday October 22, 1997
Observer: AMF
Weather: sunny, cool 50 F
Elevation: 1,665 (estimated from 7.5 minute topographic map)

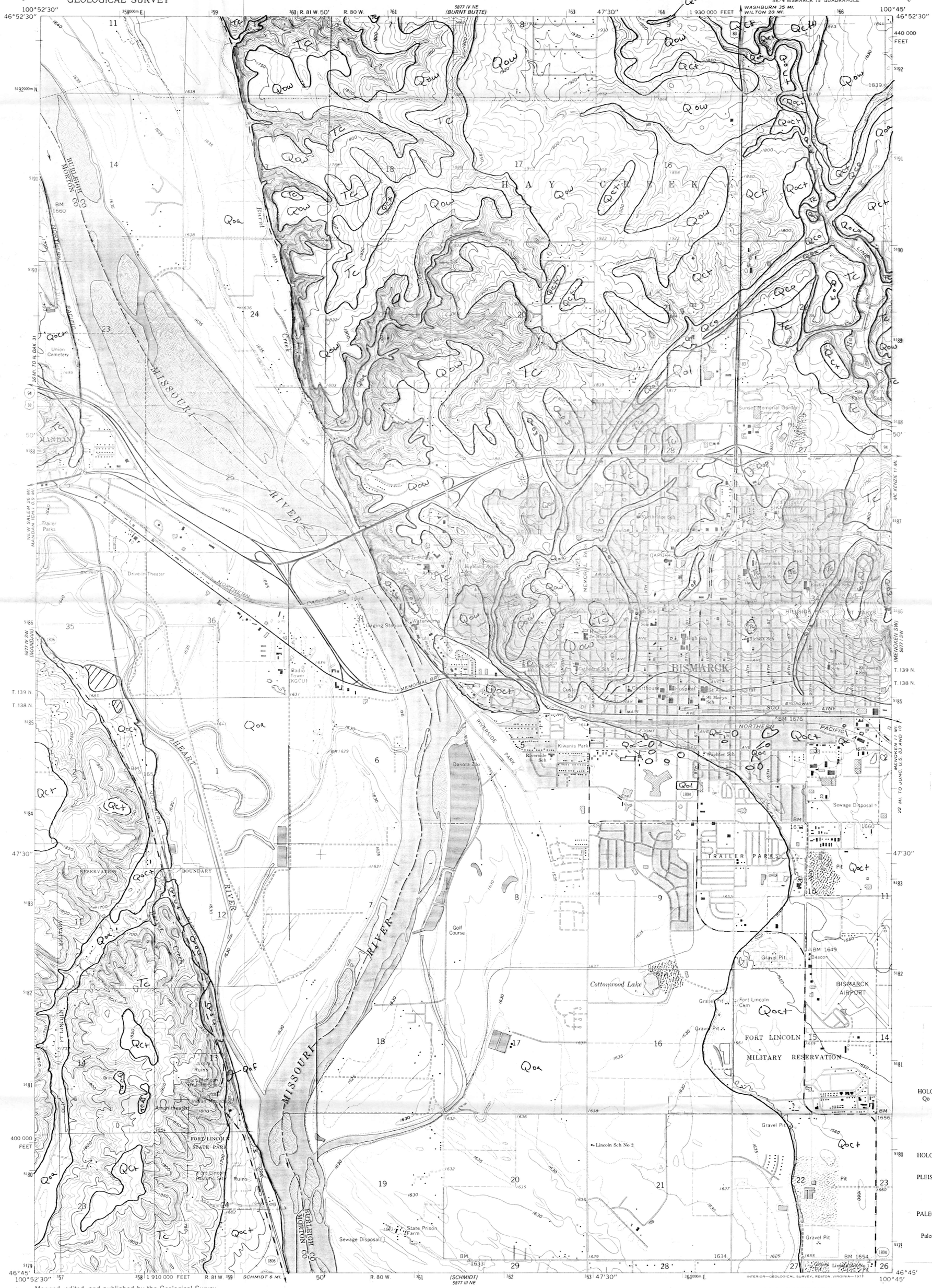
0-2 ft	Black silt loam, roots, very slightly plastic
2-3 ft	Tan silt loam, more granular than above, few roots
3-4 ft	Gray silt loam, some white silt ($CaCO_3$?) covering grains
4-5 ft	Grayish tan very fine sand and silt, calcareous coatings between grains, appears like mottling
5-6 ft	Gray silty clay, with white calcareous fillings in fractures
6 ft	Auger refusal; end of boring

NDGS-27 T137N, R80W, NE¼ of NE¼ of NE¼ of SE¼ section 21 (Anderson Broadcasting DH-2)
Date: Wednesday October 22, 1997
Observer: AMF
Weather: sunny, cool 50 F
Elevation: 1,670 (estimated from 7.5 minute topographic map)

0-1.5 ft	Black silt loam, roots, plastic
1.5-3 ft	Tan silty sand, very fine grained sand, carbonate coats on grains, rounded clasts; very fine pebbles at 3'
4-6 ft	Green sand, very fine grained, some silt, very dry and loose; carbonate layer and silt lense at approx. 5.5'
6-7 ft	Tan-green sand, very fine grained, as above
7-10 ft	Greenish-gray sand, very fine grained.
10 ft	Auger refusal; end of boring

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

BISMARCK QUADRANGLE
NORTH DAKOTA
7.5 MINUTE SERIES (TOPOGRAPHIC)
SE/4 BISMARCK 15' QUADRANGLE



BISMARCK QUADRANGLE
Mapped by Edward C. Murphy
STATEMAP No. 1434-HQ-96-AG-01509
December, 1997

LEGEND

HOLOCENE
- Qo — Oahe Formation.
  - Qoc — Construction fill.
  - Qol — Abandoned garbage dump.
  - Qof — Slope failure.
  - Qoa — Alluvium.
  - Qop — Pond Sediment.
  - Qow — Windblown sediment.

HOLOCENE/PLEISTOCENE
- Qoct — Terrace deposits of sand and gravel.

PLEISTOCENE
- Coleharbor Formation.
  - Qct — Till.
  - Qco — Outwash.

PALEOCENE
- Tc — Cannonball Formation.

Paleo Indian Village Site

Mapped, edited, and published by the Geological Survey
in cooperation with State of North Dakota,
Water Conservation Commission

Control by USGS, USC&GS, and USCE

Planimetry by photogrammetric methods from aerial photographs taken 1948. Topography by planetable surveys 1949 Revised 1962

Polyconic projection. 1927 North American datum
10,000-foot grid based on North Dakota coordinate system, south zone
1000-meter Universal Transverse Mercator grid ticks,
zone 14, shown in blue

Red tint indicates areas in which only landmark buildings are shown

Fine red dashed lines indicate selected fence and field lines where generally visible on aerial photographs. This information is unchecked

SCALE 1:24 000

1 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 .5 0 1 KILOMETER

CONTOUR INTERVAL 10 FEET
DOTTED LINES REPRESENT 5-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

GN MN 1°19' 23 MILS 11° 196 MILS
UTM GRID AND 1976 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
AND STATE WATER COMMISSION, BISMARCK, NORTH DAKOTA 58501
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

NORTH DAKOTA
QUADRANGLE LOCATION

ROAD CLASSIFICATION
- Primary highway, hard surface
- Secondary highway, hard surface
- Light-duty road, hard or improved surface
- Unimproved road
- Interstate Route
- U. S. Route
- State Route

Revisions shown in purple compiled from aerial photographs taken 1976. This information not field checked

Purple tint indicates extension of urban areas

BISMARCK, N. DAK.
SE/4 BISMARCK 15' QUADRANGLE
N4645—W10045/7.5

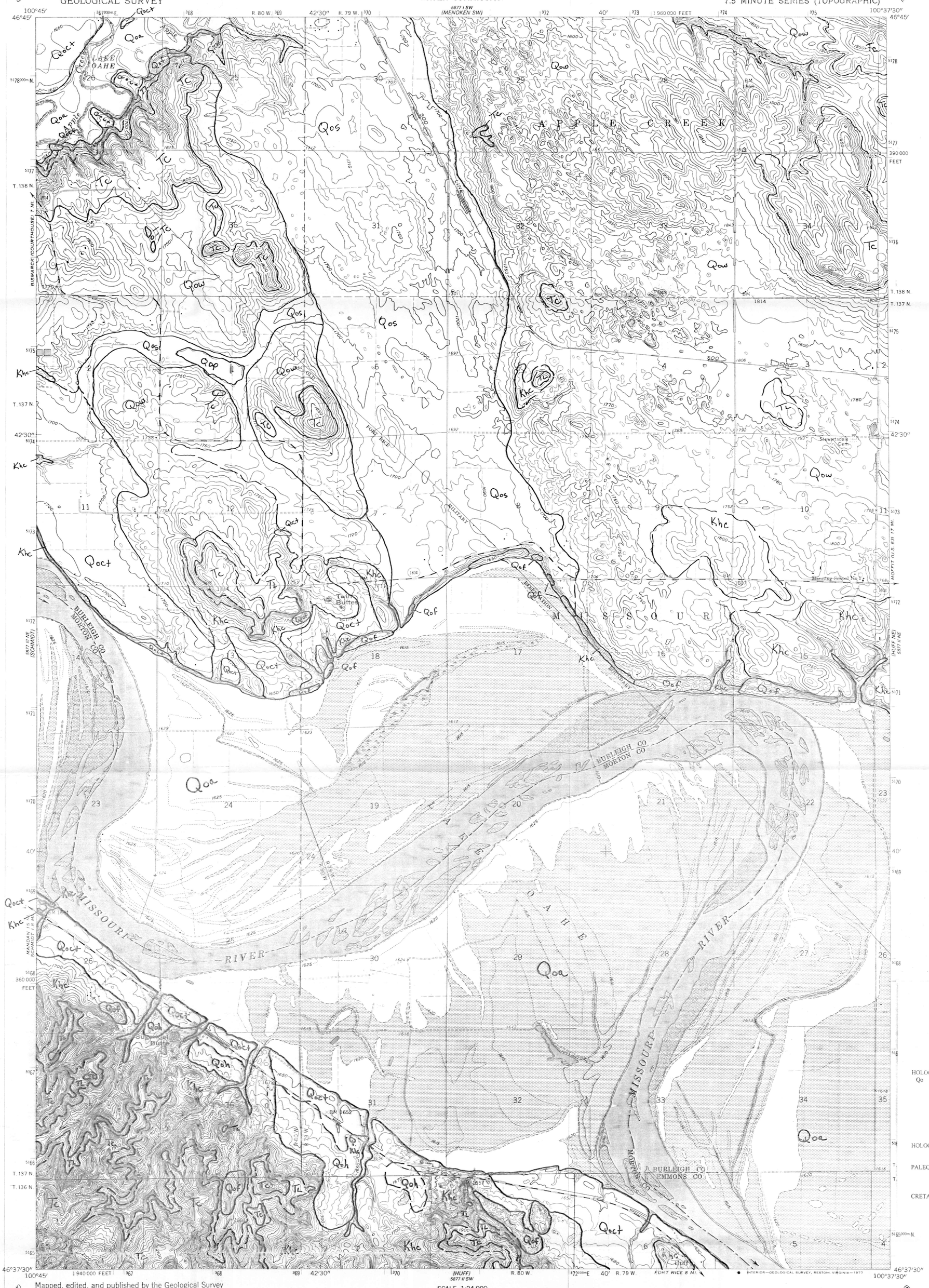
1962
PHOTOREVISED 1976
AMS 5877 IV SE—SERIES V871

INTERIOR—GEOLOGICAL SURVEY, RESTON, VIRGINIA—1979

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

STATE OF NORTH DAKOTA
WATER COMMISSION

SUGARLOAF BUTTE QUADRANGLE
NORTH DAKOTA
7.5 MINUTE SERIES (TOPOGRAPHIC)



Mapped, edited, and published by the Geological Survey

Control by USGS and USC&GS

Topography by photogrammetric methods from aerial photographs taken 1959 and planetable surveys 1962

Polyconic projection. 1927 North American datum
10,000-foot grid based on North Dakota coordinate system, south zone
1000-meter Universal Transverse Mercator grid ticks, zone 14, shown in blue

Areas covered by dashed light-blue pattern are subject to controlled inundation

Fine red dashed lines indicate selected fence and field lines where generally visible on aerial photographs. This information is unchecked

Revisions shown in purple compiled from aerial photographs taken 1976. This information not field checked

UTM GRID AND 1976 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

CONTOUR INTERVAL 10 FEET
DOTTED LINES REPRESENT 5-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

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A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

NORTH DAKOTA
QUADRANGLE LOCATION

ROAD CLASSIFICATION
Medium-duty — Light-duty
Unimproved dirt
State Route

SUGARLOAF BUTTE QUADRANGLE
Mapped by Edward C. Murphy
STATEMAP No. 1434-HQ-96-AG-01509
December, 1997

LEGEND

HOLOCENE
- Qo Oahe Formation.
  - Qos Slopewash.
  - Qof Slope failure.
  - Qoa Alluvium.
  - Qop Pond Sediment.
  - Qow Windblown sediment.
  - Qows Windblown sediment over Soo Channel.
  - Qowt Windblown sediment over Soo tributary channel.

HOLOCENE /PLEISTOCENE
- Qoct Terrace deposits of sand and gravel.

PALEOCENE
- Tc Cannonball Formation.
- Tl Ludlow Formation.

CRETACEOUS
- Khc Hell Creek Formation.

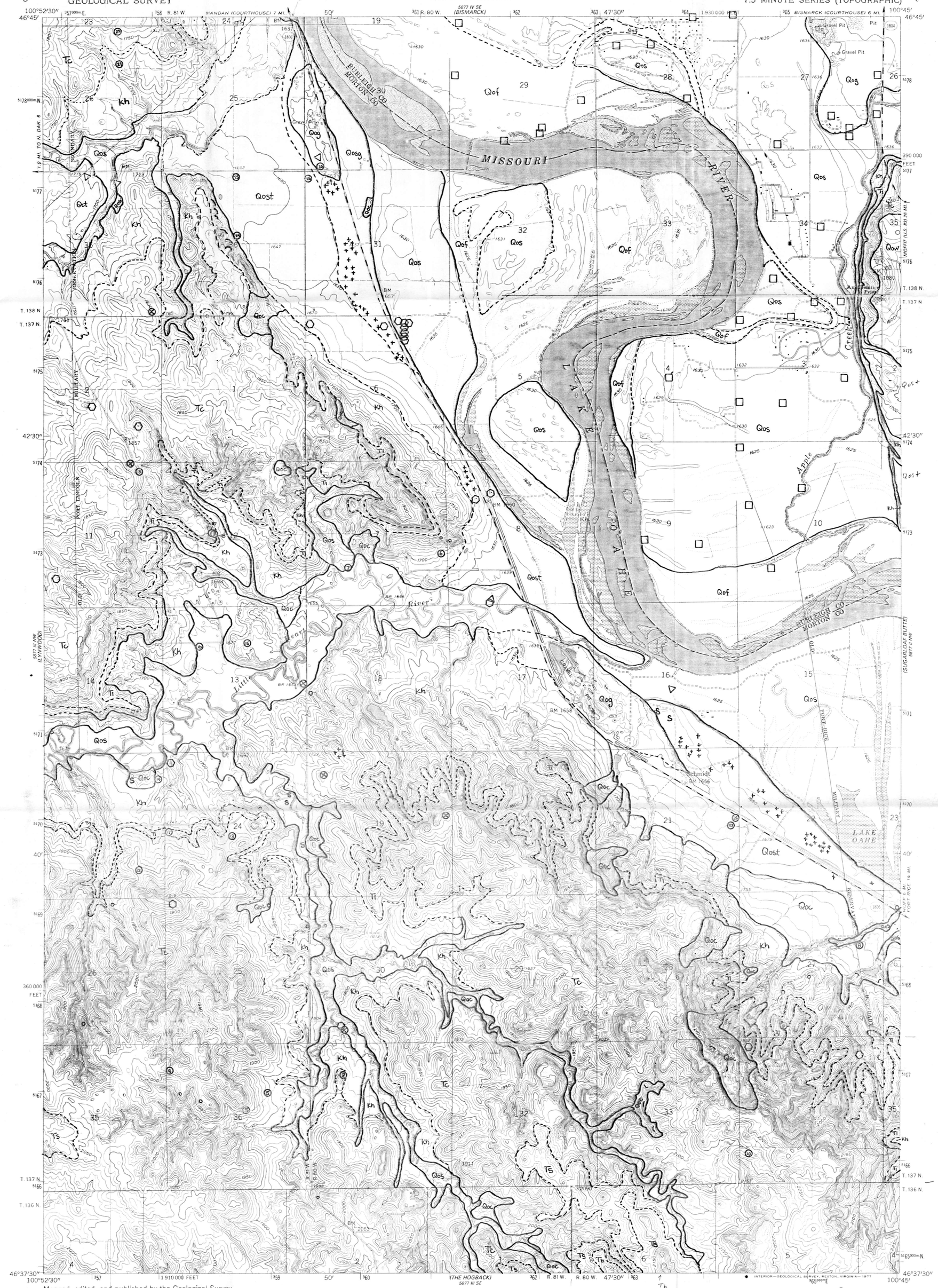
SUGARLOAF BUTTE, N. DAK.
N4637.5—W10037.5/7.5

1962
PHOTOREVISED 1976
AMS 5877 II NW—SERIES V871

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

STATE OF NORTH DAKOTA
WATER COMMISSION

SCHMIDT QUADRANGLE
NORTH DAKOTA
7.5 MINUTE SERIES (TOPOGRAPHIC)



Mapped, edited, and published by the Geological Survey

Control by USGS and USC&GS

Topography by photogrammetric methods from aerial photographs taken 1959. Field checked 1962

Polyconic projection. 1927 North American datum
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UTM GRID AND 1976 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 KILOMETER

CONTOUR INTERVAL 10 FEET
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NORTH DAKOTA
QUADRANGLE LOCATION

ROAD CLASSIFICATION
Medium-duty — Light-duty
Unimproved dirt
State Route

SCHMIDT, N. DAK.
N4637.5—W10045/7.5

1962
PHOTOREVISED 1976
AMS 5877 III NE—SERIES V871

Surficial Geology
drawn by
Ann Fritz, NDGS
1997

HOLOCENE
- Qos — silt and clay (alluvium)
- Qof — silt and clay (alluvium); backwater areas prone to flooding and high water table
- Qow — Oahe Formation — silt and clay (windblown)
- Qog — Oahe Formation — sand and gravel
- Qosg — Oahe Formation — silt, clay, sand and gravel

PLEISTOCENE / HOLOCENE
- Qoc — colluvium (slopewash)
- Qost — silt and clay deposited on terraces along Missouri River

PLEISTOCENE
- Qct — Coleharbor Formation — glacial till

PALEOCENE
- Tb — Bullion Creek Formation
- Ts — Slope Formation
- Tc — Cannonball Formation
- Ti — Ludlow Formation

UPPER CRETACEOUS
- Kh — Hell Creek Formation

area prone to landslides, slumping
geologic contact (approximate)

① NDGS drillholes (1997)(this report)
⊗ Groenwold (1980) drillholes
△ NDGS Bulletin 72 (1977) drillholes
□ Water Commission test holes/monitor wells
⬡ domestic water wells/stock wells
○ outcrop location (this report)
\+ possible cultural site
S areas of saline soils

INTERIOR—GEOLOGICAL SURVEY, RESTON, VIRGINIA—1977

SCHMIDT N DAK-(IR)
LINE DRAWING (PURPLE)
PURP