NORTH DAKOTA GEOLOGICAL SURVEY
E.A. Noble, State Geologist

MISCELLANEOUS MAP 11

GEOLOGIC MAP of DUNN COUNTY by LEE CLAYTON

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EXPLANATION

- A — **Fluvial sediment** of modern streams: clayey silt and gravelly sand; flat bottomlands.
- B — **Fluvial sediment** of early Wisconsinan (?) periglacial and glacial streams: sandy gravel; flat terraces.
- C — **Till** of the Coleharbor Formation: (early Wisconsinan ?); pebbly sandy silty clay; undulating topography subdued by creep and slopewash activity.
- D — **Arikaree Formation** (Miocene) and some White River Group (Oligocene): dense lacustrine limestone and tuffaceous sandstone capping Killdeer Mountains.
- E — **Golden Valley Formation** (Eocene): fluvial and lacustrine sand, silt, and clay; rolling topography with some badland topography.
- F — Undulating and rolling
- G — Hilly
- H — Badlands

Sentinel Butte Formation (Paleocene): fluvial and lacustrine clay, silt, sand, and lignite.

- Western limit of early Wisconsinan (?) glaciation; the western edge of abundant glacial boulders.
- Western limit of scattered glacial boulders (pre-Wisconsinan).
- Present drainage divides in the bottoms of early Wisconsinan (?) glacier-margin river channels.
- Direction of flow in early Wisconsinan (?) glacial river channels.
- Escarpment of north edge of the Green River uplands.

NORTH DAKOTA GEOLOGICAL SURVEY
MISCELLANEOUS MAP 11

PRELIMINARY GEOLOGIC MAP OF DUNN COUNTY, NORTH DAKOTA

by

Lee Clayton

Map reliability.–The geologic map on the reverse side of this sheet is a result of a field reconnaissance during three weeks of August, 1968. The geologic contacts are based largely on an interpretation of airphoto stereopairs with a minimum of field checking. Several entire townships were never visited. As a result, the contacts may be imprecise in many places.

MAP-UNIT DESCRIPTIONS

Map units F, G, and H: Sentinel Butte Formation.–The Sentinel Butte Formation, of Paleocene age, is at least 650 feet thick in the northwestern part of the county. It is continuously exposed in the Badlands along the Little Missouri River but is poorly exposed throughout most of the rest of the county.

The formation consists of alternating layers and lenses of gray silt, clay, sand, lignite, sandstone, "scoria," and limestone. The silt and clay make up about 60 percent of the formation, the sand about 35 percent, the lignite about 2 percent, and the sandstone, "scoria," and limestone each less than 1 percent.

Most of the sediment is of fluvial origin. The silt and clay is largely overbank sediment. The sand is largely point-bar sediment with large-scale, high-angle, trough-shaped cross bedding. Most of the point-bar sediment is an immature silty sand, but the uppermost member consists of a much more mature, clean sand. Lesser amounts of the silt and clay consist of lacustrine offshore sediment. Some beds of clean sand and sandstone are shoreline sediment with small-scale ripple cross bedding.

Map unit E: Golden Valley Formation.–The Golden Valley Formation, of Eocene age, is about 200 feet thick. It consists of two members. The lower member is about 30 feet thick and consists of (i) a lower gray silt and clay layer, (ii) a middle white or orange kaolinitic clay layer, and (iii) an upper lavender-gray silt and clay layer. The white or orange layer is the most conspicuous and best exposed part of the formation. The lower member is at least partly of lacustrine origin.

The upper member consists largely of point-bar sediment. It is a conspicuously cross-bedded micaceous sand, sandstone, or silty fine grained sand. Silt and bentonitic clay are abundant in the upper part of the member.

Map unit D: Arikaree (?) Formation.–The Killdeer Mountains are capped by about 400 feet of the Arikaree Formation (Miocene) and perhaps the White River Group (Oligocene) (Denson and Gill, 1965). The unit consists largely of lacustrine limestone at the north end of the mountains interfingering southward with increasingly larger amounts of ripple-cross-bedded shoreline sandstone (Quirke, 1918).

Map unit C: Coleharbor Formation.–The Coleharbor Formation (Pleistocene) is defined in a North Dakota Geological Survey Bulletin (McLean County) in preparation by John Bluemle. In Dunn County, it consists largely of glacial till that is an unsorted, relatively homogenous mixture of about equal amounts of sand, silt, and clay, a few percent of pebbles, and less than a percent of cobbles and boulders. The formation also contains some sandy gravel (largely outwash), part of which is included in map unit B. The Coleharbor Formation is, at most, a few tens of feet thick in Dunn County.

Map unit B.–Map unit B contains a variety of different sediments of late Pleistocene age; all consist of fluvial sandy gravel or gravelly sand. Most of unit B east of the western limit of early Wisconsinan (?) glaciation consists of the gravelly phase of the Coleharbor Formation. Most of unit B west of the limit consists of sediment of local or western, rather than northeastern, origin. The gravel on the pediments flanking the Killdeer Mountains consists entirely of fragments (largely limestone and sandstone) derived from the Killdeer Mountains. The gravel in the terraces along the Green River consists in large part of quartzite, argillite, and porphyry pebbles that were ultimately derived from the Rocky Mountains, plus locally derived agate, silicified wood, and concretions. The gravel in the terraces along the Knife River and its tributaries consists almost entirely of chert (including "pseudoquartzite"), silicified wood, and fragments of concretions eroded locally from the Sentinel Butte Formation. Similar gravel, but with some pebbles derived from the northeast, occurs beneath the modern alluvium in the glacier-margin channels.

Map unit A.–Map unit A consists largely of Holocene fluvial sediment that differs from the sediment of map unit B in being much finer grained. It consists mainly of overbank sediments (organic silt and clay) plus smaller amounts of point-bar sediment (cross-bedded gravelly sand).

Topography.–The general topographic regions in Dunn County are indicated in Figure 1. The Killdeer Mountains consist of two large, flat-topped buttes that are irregular in outline and rise 800 feet above the adjacent uplands. The uplands are undulating to rolling and contain a few small areas of badlands topography. The Green River uplands are separated from the Knife River uplands by a north-facing escarpment about 100 feet high. This escarpment marks the encroachment of the rejuvenated erosion in the Knife River basin into the Green River upland. The Green River uplands are flatter, have older, deeper soils, and have large blowout depressions, which are lacking north of the escarpment. The topography of the part of the Knife River uplands that was covered by early Wisconsinan (?) ice is more subdued than the part that was not. The Little Missouri Badlands, resulting from a later erosional rejuvenation, have been cut 650 feet below the Knife River uplands.

PLEISTOCENE HISTORY

Napoleon (?) drift.–The surface till of map unit C is guessed to be of early Wisconsinan age for several reasons. The till is not markedly more weathered than the late Wisconsinan drift north and east of the Missouri River; the Williams soil series is developed on both. The drift of map unit C is much less weathered than the Dead Man drift in McLean County (Bluemle, in preparation), which is considered to be pre-Wisconsinan. The till has undergone considerable erosion but is preserved mainly along local drainage-divide areas (map unit C). Where it is preserved, it still retains its morainic topography, with nonintegrated drainage and numerous undrained sloughs, but this morainic topography has become subdued by slope-wash activity. In all of these respects the surface drift in Dunn County resembles the Napoleon drift of south-central North Dakota, which has been considered to be early Wisconsinan in age. For these reasons, the surface drift in Dunn County is designated the Napoleon (?) drift.

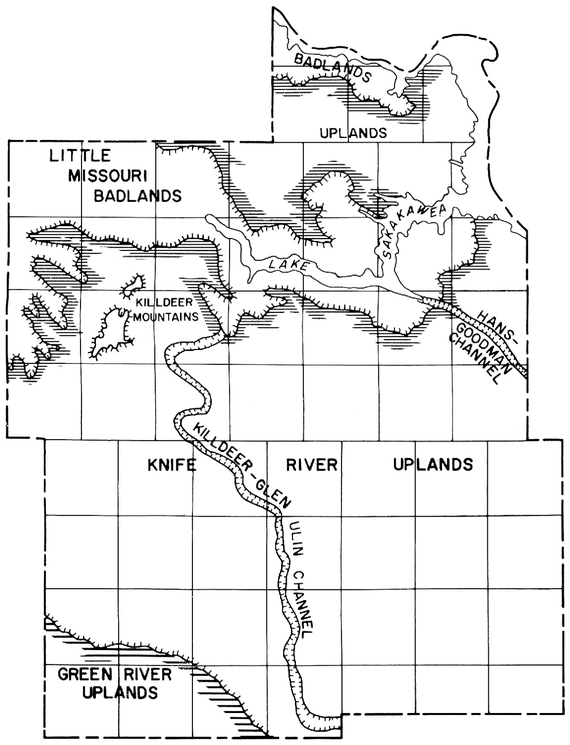

FIGURE 1. –Topographic regions in Dunn County.

Napoleon (?) drift limit.–The western limit of the Napoleon (?) drift is indicated on the map by a line with tick marks. This drift limit apparently has never been mapped previously. Nevertheless, it is strikingly apparent in the field. East of the line, scattered patches of till are abundant; west of the line, none have been observed. East of the line, erratics are abundant (especially along a band about a mile wide immediately east of the line); west of the line, they are rare (an average of one boulder is seen along a mile of road).

Glacier-margin channels.–All of the upper Missouri River drainage west to the Rocky Mountains had to be diverted southeastward around the ice sheet, resulting in glacier-margin channels. As the Napoleon (?) ice advanced, it overrode channels that formed earlier in the advance. These overridden channels were disrupted and partly buried by till. A probable example is 1 mile southwest of Horse Nose Butte.

The westernmost glacier-margin channel is the Killdeer-Glen Ullin channel (Figure 1). It lies everywhere just west of the Napoleon (?) drift limit, indicating that it formed during the maximum expansion of the Napoleon (?) ice. The more easterly branches, such as the one at Lake Ilo, east of Killdeer, formed as the ice melted back. The Killdeer-Glen Ullin channel is at an elevation of about 2200 feet in Dunn County. Later, as the ice continued to retreat, the Hans-Goodman channel (Figure 1) formed at about 2000 feet, and later the Missouri River channel formed at a lower elevation, possibly near 1800 feet.

Proglacial lakes.–The glacier-margin channels formed when proglacial lakes spilled across divides, quickly cutting into the easily eroded Sentinel Butte Formation and causing catastrophic flooding. Proglacial lakes must have formed in every valley along the ice margin because the glacier moved up the regional slope. However, there is no known evidence for these lakes in any of the valleys west of the Napoleon (?) drift limit in Dunn County; neither shoreline sediment or landforms nor deep-water sediment was observed. Possibly all the lake sediment was eroded away or is buried under younger alluvium (such as the valley of Murphy Creek, 4 miles south of Killdeer).

Dunn drift.–The western limit of scattered erratic boulders is shown on the map. Though these boulders are of glacial origin, it is not clear whether they were ice-rafted there in proglacial lakes or carried there by a glacier. Other than the boulders, there is no known evidence that the area was glaciated. No till has been found there. The lack of a glacier-margin channel west of the boulder limit is proof that the area was never glaciated in Wisconsinan time. A glacier could not exist in that position without a proglacial channel to carry away the water from the upper Missouri drainage.

If a glacial-margin channel did exist, it existed long before the time of the Killdeer-Glen Ullin channel because all evidence of it has since been eroded away. At least 200 feet of sediment would have to have been eroded from a large part of the Knife River, Heart River, and Cannonball River basins since that time because the boulder limit crosses divides whose low points have an elevation of 2500 feet, 200 feet above the valley bottoms.

If the scattered boulders west of the Napoleon (?) limit were ice-rafted into their present position on proglacial lakes, their western limit should coincide with a contour line within individual valleys. This is not the case. Boulders occur as high as 2500 feet in section 10, T. 144 N., R. 96 W., and section 23, T. 141 N., R. 95 W., but they are lacking from large areas below 2400 feet in the upper Knife River tributary valleys. Furthermore, the Napoleon (?) ice margin nowhere rose to a high enough elevation to produce a proglacial lake at 2500 feet in the Knife River valley.

For these reasons, it is concluded that the boulders west of the Napoleon (?) drift limit are residual remnants of a pre-Wisconsinan drift, which is here named the Dunn drift. The Dunn drift must be at least several times as old as the Napoleon drift, of early Wisconsinan (?) age, because at least 200 feet of erosion has occurred throughout much of southwestern North Dakota since Dunn time, whereas only a few feet to a few tens of feet of erosion has occurred since Napoleon time throughout much of the area.

Interpreted drift ages in southwestern North Dakota are summarized in Figure 2. The early Wisconsinan (?) drift border is marked everywhere by a glacier-margin channel: the Skaar-Killdeer-Glen Ullin-Flasher-Shields-Fort Yates channel. A flat segment in the longitudinal profile of this channel west of the Killdeer Mountains indicates that a lake existed in the Little Missouri valley at a level of 2200 to 2300 feet during Napoleon (?) time.

Killdeer pediments.–The Killdeer Mountains are flanked by remnants of pediments, which are capped by 5 to 10 feet of gravel (included in map unit B). The gravel is a coarse rubble of limestone and sandstone derived from the Arikaree (?) Formation on top of the Killdeer Mountains. The gravel is poorly sorted and has crude, nearly horizontal bedding; it is typical upper-flow-regime fluvial sediment, deposited by braided streams.

A continuous pediment apron once completely surrounded the Killdeer Mountains. Since then, there has locally been as much as 100 feet of erosion around the Killdeers; only about 20 percent of the original pediment surfaces are left undissected. Base level apparently lowered as the pediments formed, because pediment remnants occur at two or more different levels, separated from each other by a few feet to a few tens of feet of elevation.

The pediments seem to be graded to the level of the Killdeer-Glen Ullin channel, which is the same age as the Napoleon (?) drift. For this reason, the pediments are probably also early Wisconsinan in age.

Paleoclimatology.–In general, glaciers grow during a glacial climate but shrink during a nonglacial climate. For this reason, all the glacial features in eastern and northern North Dakota (behind the terminal late Wisconsinan moraine) were formed in a nonglacial climate, and no permafrost phenomena occur in that area. However, the early Wisconsinan (?) Napoleon drift has a much more subdued morainic topography than the late Wisconsinan drift; this may have been the result of solifluction during the early part of late Wisconsinan time, before the ice sheet reached its terminal position about 17,000 B.P.

Similarly, the Napoleon ice must have advanced to the drift limit in Dunn County in a glacial climate during an early part of early Wisconsinan time and retreated in a nonglacial climate in a later part of early Wisconsinan time. Thus, the change from glacial to nonglacial climate must have occurred about the time that the Killdeer-Glen Ullin channel was formed. This seems to be substantiated by the following evidence. The highest pediment remnants on the east side of the Killdeer Mountains are graded to a level somewhat above the bottom of the Killdeer-Glen Ullin channel; therefore, the highest remnants formed when the channel carried water, or at least no later than this. These pediment remnants have undergone permafrost activity; the fluvial gravel on these pediments is highly convoluted to depths of several feet and has probable ice-wedge fillings (well developed in the gravel pit in SE 1/4 NE 1/4, sec. 12, T. 146 N., R. 96 W.). Slightly younger (slightly lower) pediment remnants are graded to a level near the bottom of the Killdeer-Glen Ullin channel; these remnants, therefore, formed after the channel was abandoned and the terminus of the Napoleon (?) ice had retreated eastward. No evidence of permafrost activity was found in the gravel on these lower pediment remnants, suggesting that the climate had become nonglacial.

Permafrost activity is indicated by other evidence. Little or none of the coarse rubble found on the pediment is being supplied to the streams around the Killdeer Mountains today. This is undoubtedly the result of climatic differences; at the time the pediments were being formed the Arikaree (?) Formation on top of the Killdeers probably was being shattered by frost activity. Sorted polygons a few tens of feet in diameter are apparent in the cobble rubble on some parts of the top of the Killdeers. These polygons must have resulted from permafrost activity.

Paleoclimatic evidence is also given by the size of the Killdeer-Glen Ullin Channel. It is less than 2000 feet wide at its narrowest. This is only slightly larger than the present Missouri River, which drains about the same area as the former Killdeer-Glen Ullin River. In contrast, the spillways now occupied by the James and Sheyenne Rivers in eastern North Dakota are somewhat larger than the Killdeer-Glen Ullin channel and had smaller drainage areas. The James and Sheyenne spillways formed during a nonglacial climate as the late Wisconsinan glacier was rapidly melting. Therefore, the relatively narrow width of the Killdeer-Glen Ullin channel suggests that it formed in a glacial climate when the ice melted slowly.

Erosion history.–The Pleistocene erosion history of Dunn County can be summarized as follows:

1. During middle and early Pleistocene (?) time the Green River upland surface was formed. Extensive eolian activity produced blowouts on the surface, indicating an arid climate during part of this time.
2. During middle (?) Pleistocene time a glacier advanced into the county, depositing the Dunn drift.
3. During middle (?) and late Pleistocene times the erosion was rejuvenated, lowering the surface of much of the area about 200 feet and forming the Knife River upland.
4. During an early part of early Wisconsinan (Altonian) time the climate was glacial, permafrost was present, pediments were formed around the Killdeer Mountains, the Napoleon ice advanced southwestward into Dunn County, and a glacier-margin river flowed southeastward carrying water from all of the upper Missouri drainage.
5. Sometime during the middle (?) of early Wisconsinan time the Napoleon ice reached its maximum extent and the Killdeer-Glen Ullin glacier-margin channel formed about the time that the climate turned non-glacial.
6. The Napoleon ice then began to melt back, the Killdeer-Glen Ullin channel was abandoned, and the Hans-Goodman ice marginal channel formed.
7. The ice melted from the county and the Missouri River glacier-margin channel began to carry all the water from the west. It followed the path of the present Missouri River, except that it flowed through the Newtown sag, northeast of Dunn County. If the Little Missouri River was diverted from its route through Tobacco Garden valley to its present course at that time, the Badlands presumably then began to be dissected below the level of the Knife River upland. Since that time, roughly 40 cubic miles of sediment have been removed from the Little Missouri Badlands. That is, an average of roughly 3 cubic feet of sediment per second was discharged by the Little Missouri during approximately the past 50,000 years, and the surface of the Badlands was lowered at a rate of about 1/20 inch per year. However, as shown by Hamilton (1967), rates of erosion in the Badlands fluctuated greatly during climatic changes. Nevertheless, this seems to be near the present rate of erosion and removal of material from the Badlands.

The Killdeer pediments also began to be dissected soon after the Killdeer-Glen Ullin channel was abandoned.

8. At about the beginning of late Wisconsinan time (beginning of Woodfordian times) the climate turned glacial again and the ice sheet advanced across North Dakota until it reached the Newtown sag, where it diverted the Missouri River to its present course along the northern edge of Dunn County; the Badlands along this, the youngest segment of the Missouri River, then began to form. At about that time, perhaps, 17,000 years ago, the climate turned nonglacial and the ice sheet began to shrink. Intensive erosion in the Badlands and moderate erosion on the uplands continue to the present day.

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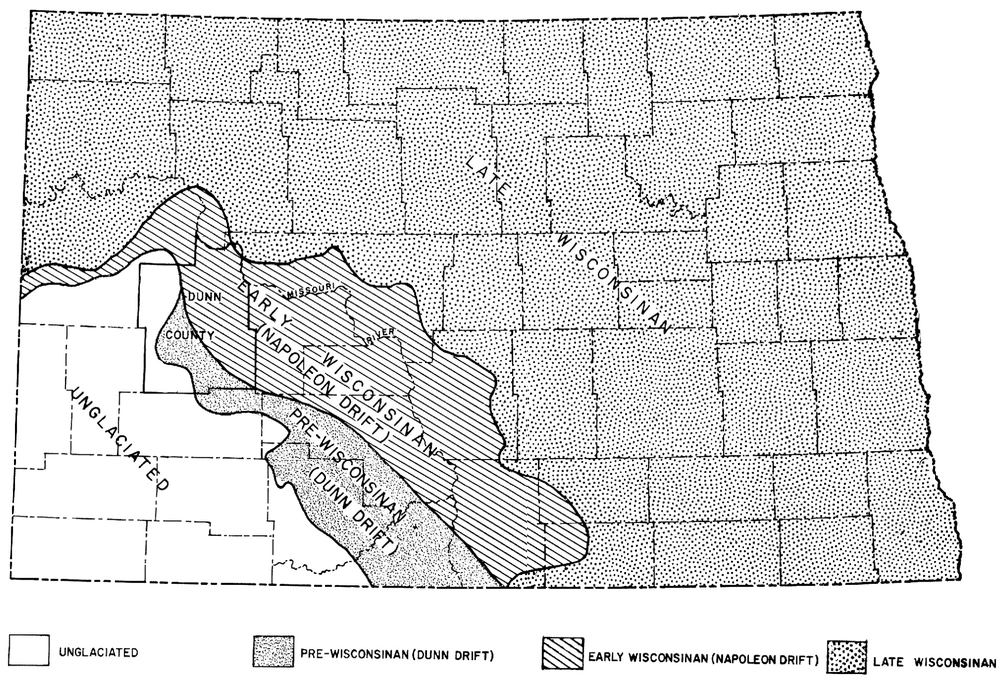

FIGURE 2. –Probable ages of glacial drifts in North Dakota.