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THE PROBLEM OF THE ORIGIN OF THE MAX MORAINE OF NORTH DAKOTA AND CANADA*

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ABSTRACT. The name Max moraine is proposed for the range of morainic hills trending northwest for some 800 miles from the vicinity of Bismarck, North Dakota. The terms Altamont and terminal have previously been applied to the moraine. These terms are shown to be misused and misleading, respectively. The name Max is taken from the town of Max, North Dakota, because the terrain in its vicinity is typical. The bedrock, which is the Fort Union formation, is shown to be higher in altitude under at least part of the moraine than it is under adjacent areas, giving the moraine the deceptive appearance of having great thickness. The high area of bedrock may be due to structural elevation. Four steps in the history of the moraine are proposed as a working hypothesis:

(1) Advance of the glacier beyond the Max moraine.
(2) Retreat of margin of glacier to area where bedrock is high in altitude.
(3) Deposition of Max moraine largely by ablation.
(4) Retreat of ice margin and deglaciation.

INTRODUCTION AND PURPOSE

THE Max moraine, formerly known as the Altamont terminal moraine, is a unique range of morainic hills 10 to 25 miles wide and trending northwest from the vicinity of Bismarck, North Dakota, for more than 800 miles (fig. 1). The crest of the range, 200 to 500 feet above the relatively flat plains on either side, is a continental divide between drainage to Hudson Bay and drainage to the Missouri River. Although the great size alone makes the moraine unusual, scattered evidence found by early workers and detailed evidence presented here indicate that, at least in places if not everywhere, the bedrock is higher in altitude under the moraine than under adjacent deposits. The moraine is, in effect, perched on a topographic high of the erosion surface on the underlying bedrock.

If the thickness of the moraine is judged only by ground surface elevations without regard to the bedrock, one might conclude that the drift is generally 200 to 500 feet thick. Such a thickness is not extraordinary for the end moraines

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of valley glaciers in mountain regions, but it would be regarded as an exception in continental glaciation. Flint (1947, p. 127) states, "the end moraines of ice sheets, common in central North America and in central Europe, rarely exceed 100 to 150 feet in height. . . ." Even without any direct evidence, an explanation of the great height of the moraine would be required. The moraine's uncommonly great length and width and position on a bedrock high are not characteristic of typical moraines and, therefore, they prompt caution in classification of the deposit and speculation on its origin.

The problem of origin of the Max moraine has been confused by loose application of the words "Altamont" and "terminal." Altamont, South Dakota, is the type locality for a typical, narrow, arcuate end moraine. The implication that the huge moraine trending through northwestern North Dakota is simply a continuation of the Altamont moraine in South Dakota may dissuade some workers from giving ample consideration to the anomalies of the larger deposit. The word terminal is also misleading. Where, in a 25-mile-wide terminal moraine, was the terminus of the glacier? What

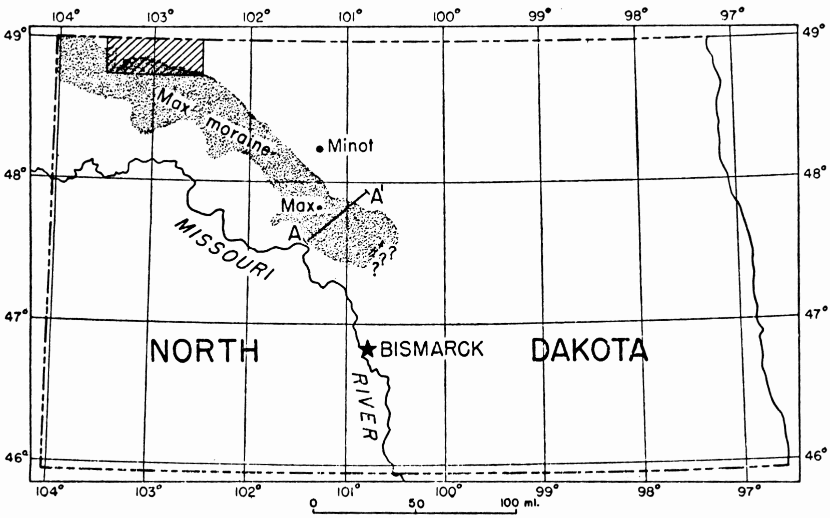

Fig. 1. Index map of North Dakota showing approximate location of Max moraine and area mapped in detail (diagonal lines) by authors. Boundaries of Max moraine modified in part from Andrews (1939, p. 61). Line A-A′ is the location of the diagrammatic cross section shown in figure 5.

are the mechanics of deposition of such a wide moraine, and what was the nature of the ice front? Owing to the bedrock high under the moraine, the drift is thinner than might be suspected if the thickness is judged only by height of the deposit above the surrounding plains. The bedrock high was doubtless a barrier to southward advance of the glacier, and what might otherwise be considered a thick terminal moraine may actually be a type of ground moraine deposited largely by ablation.

The purpose of this paper is not to give a final solution to the problems of origin of the Max moraine or of end moraines in general, but to present evidence that the problems exist. The relations of the moraine to other glacial features and to bedrock are too complex to carry interpretations far from areas mapped in detail. Moreover, the largest part of the deposit, including most of its boundary, is still unmapped. It is hoped that the paper will be only the first step toward more regional study, and also that future workers in the area will re-evaluate some of the principles of glacial geology in the light of evidence obtained in this area.

The purpose of this paper is to:

(1) Propose that the term "Altamont" not be applied to the moraine trending northwest from near Bismarck, North Dakota, through northwestern North Dakota, and far into Canada.

(2) Propose that the word "terminal" not be used to refer to the moraine northwest of Bismarck.

(3) Propose that the moraine northwest of Bismarck be known as the "Max moraine."

(4) Present evidence that the bedrock under at least part of the Max moraine is higher in altitude than under adjacent areas, thereby confirming the suspicion of early workers.

(5) Propose a working hypothesis for the origin of the Max moraine and its underlying high area of bedrock.

FIELD WORK AND ACKNOWLEDGMENTS

Since World War II, members of the U. S. Geological Survey have done the geologic mapping of many thousands of square miles in the vicinity of the Max moraine in northwest North Dakota. This work is part of the Geological Survey's program to provide background information for reclamation and development in the Missouri River Basin, and was done in cooperation with the U. S. Bureau of Reclamation. The area near Crosby, North Dakota, shown in figure 2, was mapped in the summer of 1947 by the writers, assisted by R. W. Fary, Jr., and Leonard S. Rolnick. The work of Messrs. Fary and Rolnick is gratefully acknowledged. Townsend returned to the area for three weeks in May 1948 to collect additional data. Confidence in most of the conclusions expressed here has been greatly increased by data, ideas, and criticism given freely by several other members of the U. S. Geological Survey who have mapped much larger areas in adjacent parts of North Dakota and Montana. They are R. W. Lemke, Clifford A. Kaye, Garland Gott, William E. B. Benson, I. J. Witkind, and J. Hiram Smith. Some of these workers came independently to the same conclusions but have refrained from publishing because the area near Crosby contains better supporting evidence. The writers are further indebted to Mr. Benson for his critical review of the manuscript.

Drill hole and well data were supplied by Wilson M. Laird, North Dakota State Geologist, the U. S. Bureau of Reclamation, the U. S. Army Engineer Corps, and the Ground Water Division of the U. S. Geological Survey. Elevations of critical locations were supplied by members of the Topographic Division, U. S. Geological Survey, who were working in the area in 1947. Drilling and water well data were freely given by the many residents in the area.

PREVIOUS WORK

Prior to 1946, published work related to the Altamont terminal moraine in North Dakota (the Max moraine of the present report) consisted of reports on reconnaissance work or on specialized subjects in which the moraine was only incidental. Nevertheless, even the earliest workers noted the abnormal size of the deposit and recognized that its position on a bedrock high gives the deceptive appearance of great thickness.

In 1875 Dawson (p. 614) described the Missouri Coteau along the international boundary but did not call it an end

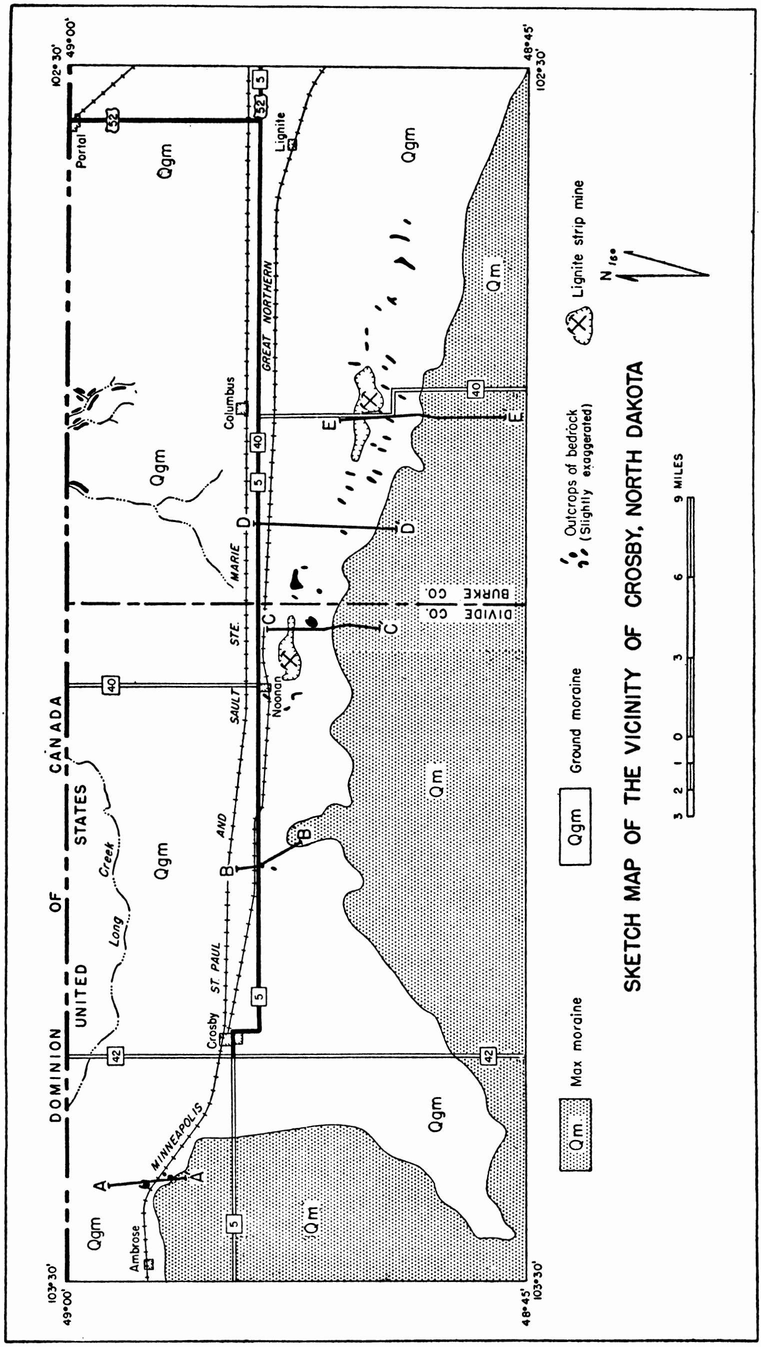

Fig. 2. Map of vicinity of Crosby, North Dakota, showing location of cross sections given in figures 3 and 4.

moraine. Without benefit of detailed field evidence, he made the following canny analysis concerning the Coteau:

> "Taking the difference of level between the last Tertiary rocks seen near the eastern base of the Coteau, and those first found on its western side, a distance of about 70 miles, we find a rise of 600 feet. The slope of the surface of the underlying rocks is, therefore, assuming it to be uniform, a little less than 10 feet per mile. On and against this gently inclined plane the immense drift deposits of the Coteau hills are piled."

In 1883 Chamberlin (p. 396) prefaced a description of "Moraines of the Missouri Coteau" with:

> "To prevent possible misunderstanding, it may be distinctly and quite positively asserted that this great Coteau is not mainly a drift accumulation, but a pre-existent plateau of chiefly Cretaceous rock, which was carved into all its grander features in preglacial times by drainage erosion. The effect of glaciation has been to grind off something of the roughness of its exposed faces, to fill up its creases, and to heap upon it, in an irregular, bunchy manner, the glacial debris, in the form of morainic hills. These hills, while very notable objects in themselves, owe their general elevation and much of their individual prominence to the concealed Cretaceous terrain beneath. The prominence which the old underlying plateau, with its preglacial inequalities, gives to certain portions of the drift, and the influence exerted by it in effecting exceptional local accumulation, resulted in special moraine-like aggregations that are to be discriminated from those which mark the extreme edge of the ice and constitute the true terminal moraine."

It is not clear that the above unqualified statement was meant to apply to the whole of the Missouri Coteau because Chamberlin described in detail only the moraines south of the 47th parallel and east of the 100th meridian and quoted Dawson's (1875) description for more than 200 miles of moraine trending northwest into Canada. Northwestern North Dakota was not of easy access before the turn of the century.

In 1885 Todd (p. 382) also described the Coteau in what is now southern North Dakota as being "built mostly of Cretaceous clays of the St. Pierre group and capped with thin even layers of the Fox Hill northward. . . ." Wood (1902, pp. 844-897) classified the moraine as terminal and speculated on the nature of the erosion surface of the bedrock underlying the glacial deposits with the statement:

> "It does not seem unlikely that the surface of the county was more or less broken in a manner approaching that of the bad lands. The banks of the streams were generally steep; sharp slopes prevailed everywhere, and the butte was the common type of hill."

The county mentioned was the old Ward County, which was larger than at present and included that portion of Burke County shown in figure 2. In 1904 Willard and Erickson (pp. 17-18) made the first specific statement regarding the influence of the bedrock high (plateau) on the location of the moraine.

> "The continental moraine in North Dakota lies in such relation to the plateau that it suggests that something more than accident caused the moraine to lie just upon the edge of the plateau through a distance of 300 miles in North Dakota. The front or edge of the plateau, it has been stated before, extends across the state in a northwest-southeast direction. The moraine also extends across the state lying almost parallel to the edge of the plateau, and nowhere more than a few miles back from the slope which marks the edge of the plateau. Often in fact the coteaus or hills of the moraine are encountered immediately upon entering upon the higher lands of the plateau top. The accompanying diagram (plate IV) will assist in making clear the relations.
> "The direction of movement of the ice of the great ice sheet in this part of North America was probably very nearly at right angles to the front of the great plateau, so that the escarpment of the plateau served as a dam to hold back the ice in its onward movement, and so the moraine occurs along the edge of the plateau because the ice could not advance beyond this position, a moraine always being formed at the edge of the ice sheet."

In 1925 Leonard and Eaton measured dips of 23° and 33° and reported a dip of 45° in a coal seam in the Fort Union formation 7 miles south of Alkabo, North Dakota. This point is approximately 24 miles southwest of Ambrose, North Dakota, and high in the Max moraine.

In 1932 Alden (pp. 126-129) described the moraine and quoted from a description by Dawson; on the map attached to the report, the moraine is classified as terminal. In a diagrammatic cross section through the Minot region, Andrews (1939, p. 61) postulates a bedrock high of the Fort Union formation under the so-called Altamont moraine. The maximum thickness of the moraine as shown on the same diagram is about 140 feet. Five hundred miles of the moraine extending northwest from the boundary of Canada is called Altamont by Bretz (1943). Howard, Gott and Lindvall (1946, pp. 1204-1205) report, "Fort Union beds, including coal, are exposed at and near the crest of the so-called Altamont terminal moraine in northwestern North Dakota" and suggest, "the topographic prominence of the moraine in this area may, therefore, be due to a high in the bedrock surface rather than to an unusually thick accumulation of drift." In an unpub-

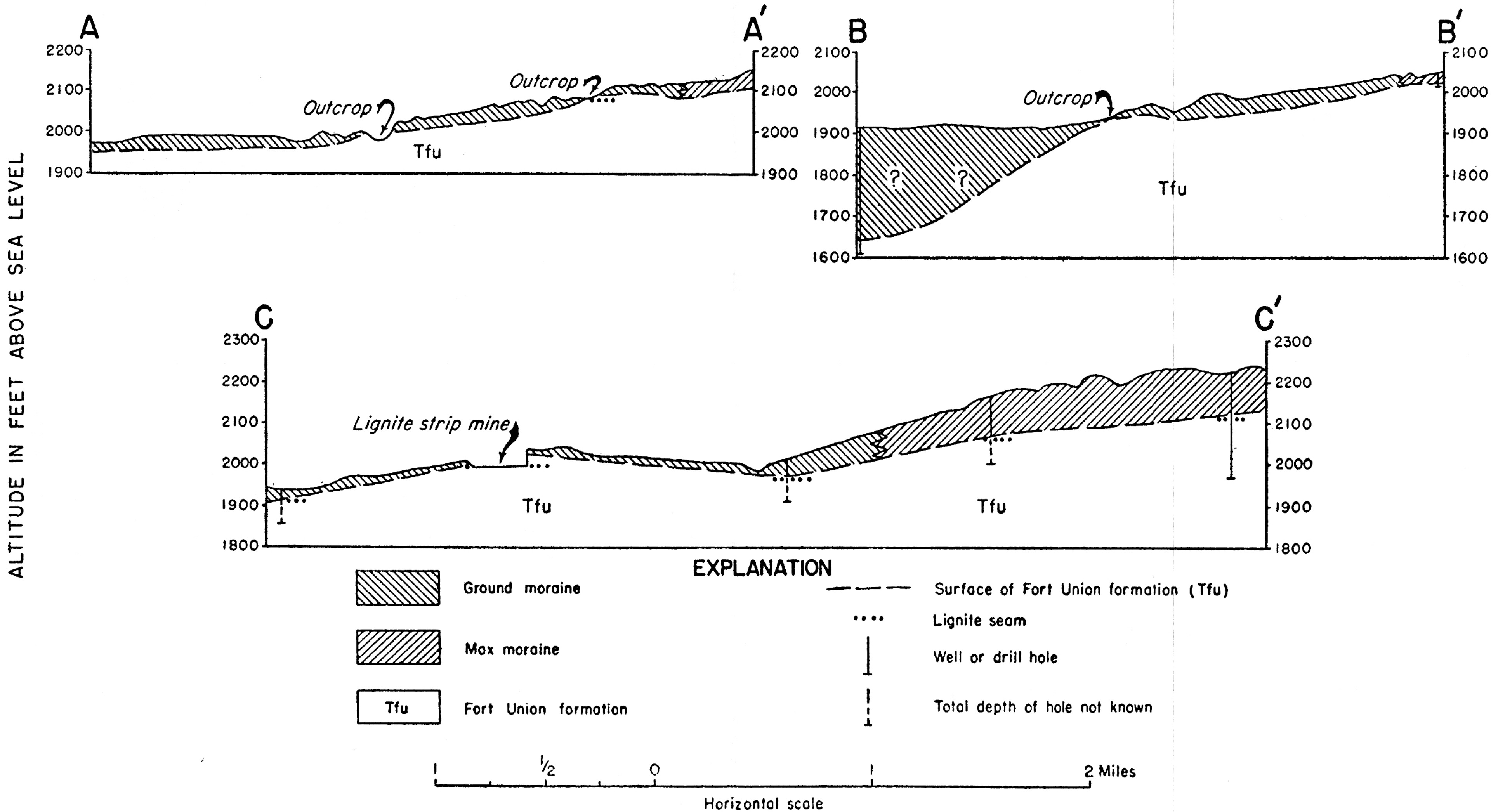

Fig. 3. Diagrammatic cross sections (vertical scale exaggerated) along lines A-A′, B-B′, and C-C′ on map in figure 2.

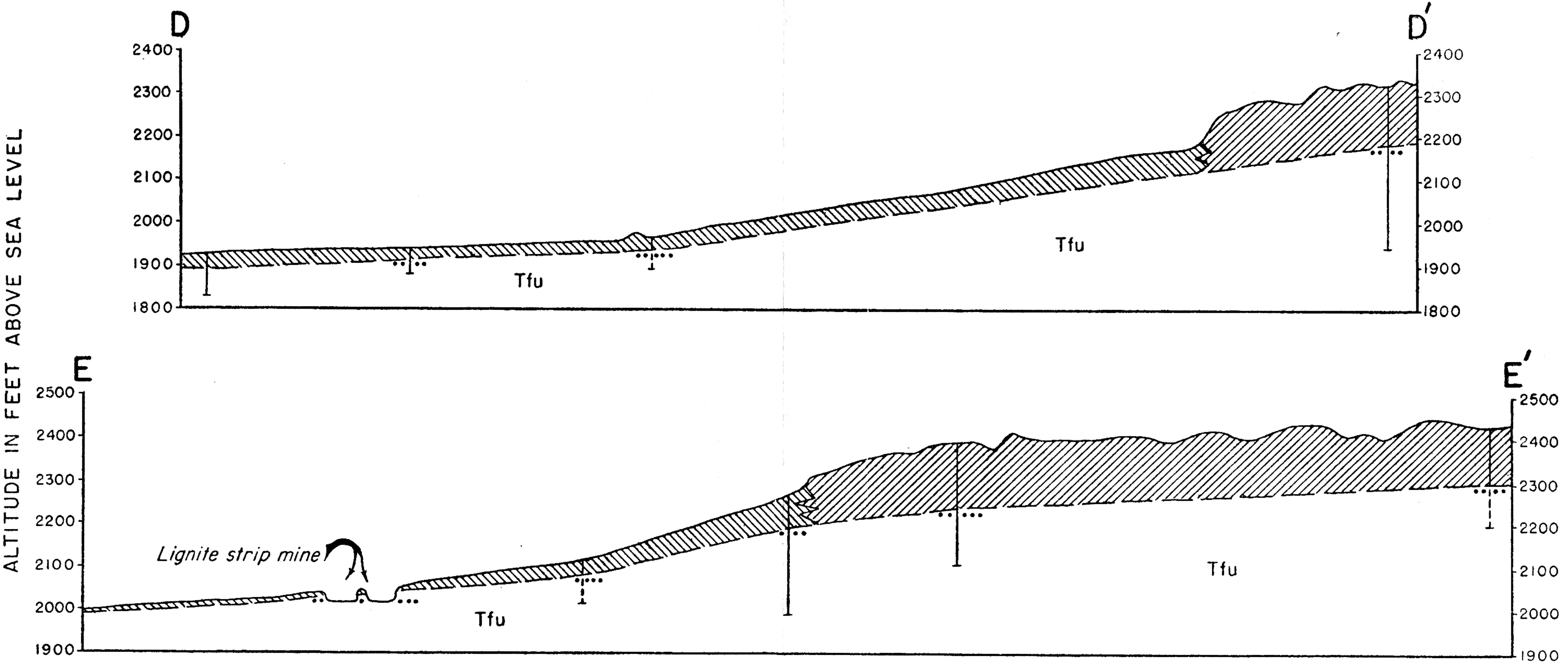

Fig. 4. Diagrammatic cross sections (vertical scale exaggerated) along lines D-D′ and E-E′ on map in figure 2. Explanation and horizontal scale are the same as for the cross sections in figure 3.

lished report, Lemke cites an outcrop of coal high in the moraine a few miles southeast of the area shown in figure 2. Since that report was prepared, he further states[1] that the Fort Union formation crops out high in the Max moraine about 40 miles southeast of Minot, and indirect evidence indicates that it is present at shallow depth along much of the length of the northeast-facing escarpment in this area. He suggests that the prominence of the moraine is due to its position on a bedrock plateau.

The publication of the abstract by Howard, Gott, and Lindvall (1946) marks the beginning of reports on detailed work in and around the so-called Altamont terminal moraine (Max moraine). They called the moraine terminal, prefaced the word Altamont with the term "so-called," and implied that even though earlier workers believed bedrock to be high under the moraine, the theory needs the support of detailed study.

TERMINOLOGY

Misuse of the term Altamont.—The Altamont moraine was named for the town of Altamont, South Dakota. In the vicinity of its type locality it is a relatively small, typical terminal moraine, arcuate in shape and more or less well defined (Leverett, 1922; 1932). The northwest end of this moraine is approximately 200 miles southeast of the nearest part of the huge range of morainic hills trending northwest from near Bismarck, North Dakota. Although Chamberlin's map (1883, plate XXXV) showed the two deposits to be distinctly separate and dissimilar in outline, early workers, concerned with reconnaissance of wide areas, carried the term Altamont northwest. Apparently they thought that the moraine in North Dakota and the Altamont moraine were part of the same drift border and were the same age. Wood (1902, pp. 89-90), Leonard (1904, p. 175) and Alden (1932, pp. 126-127) state that the Altamont moraine has been traced through northwestern North Dakota, but they do not indicate by whom the work was done. Andrews (1939, p. 63) also calls the huge range Altamont, and Bretz (1943) shows the Altamont moraine trending northwest for more than 500 miles in Canada.

Thus, the term Altamont appears to have been used er-

[1] Lemke, R. W., oral communication.

roneously for the moraine in North Dakota. Although the true Altamont moraine might eventually be proved to be the time equivalent of the moraine in northwestern North Dakota, the two are topographically separate and dissimilar.

Plans for reclamation and development of the region have stimulated new interest in the area northwest of Bismarck, resulting in a vast amount of both detailed and reconnaissance mapping. Continued use of the term Altamont causes confusion and prevents objective analysis of the larger and more complex moraine. It is suggested that the term Altamont not be applied to the moraine shown on figure 1 as the Max moraine.

Terminal moraine.—The results of extensive mapping may prove in the future that the moraine on the Coteau du Missouri is a terminal moraine, but at the present time the anomalism of the moraine is demonstrated by three features. First, although a terminal moraine of great length is quite conceivable, one would reasonably doubt that the deposition of morainic material over a width of 10 to 25 miles is typical of terminal moraines. Second, present evidence shows that bedrock is higher in altitude under at least 300 miles of the moraine than under areas adjacent to the moraine: evidence of the bedrock high is discussed in detail further in this paper. Third, an esker is deposited on top of the moraine southeast of Noonan, adding further doubt to the terminal character of at least this portion of the moraine. In the quotation from Chamberlin under "Previous Work" above, it may be seen that in 1883 he took particular pains to point out that the morainic deposits differ from the true terminal moraine. Until a satisfactory explanation is accepted for the combination of great width and position on a bedrock high, the moraine should be given a name without genetic connotations.

Max moraine.—In view of the probable misuse of the term Altamont, the doubts about the terminal character of the moraine, and the large amount of new work being done in the area, the writers believe the moraine should be given a new name. The name should refer only to general location, leaving room for later correlation, genetic definition, possible differentiation within the deposit, and possible extension of the boundaries of the deposit.

It is suggested that the name Max moraine be applied to the range of morainic hills trending northwest from near Bismarck, North Dakota, into Canada for a total length of approximately 800 miles. The portion of the moraine that is in the United States is approximately 300 miles long and is typified by the terrain in the vicinity of Max, North Dakota (fig. 1). The town of Max is 15 to 16 miles due south of the escarpment of the moraine on U. S. Highway 83, and 12 miles southwest of the nearest point of the escarpment.

DESCRIPTIVE GEOLOGY

Fort Union formation.—The only bedrock exposed in the area shown in figure 2 is the Paleocene Fort Union formation, a series of discontinuous beds of sandstone, shale, clay, silt, and lignite, which underlies all the glacial deposits in this region. Further southeast, in the central part of North Dakota, the bedrock under the Max moraine consists of Cretaceous rocks. The exposed beds are essentially horizontal in the area mapped, except for those in a long, narrow zone approximately 6 miles southwest of Lignite. In this zone the beds are closely folded and faulted, in general striking N. 74° W. or parallel to the adjacent escarpment of the Max moraine.

The slightly generalized cross sections in figures 3 and 4 show the relations between the glacial deposits and bedrock. The location of drill holes and wells for which reliable data are available is shown. Lignite beds are the best criterion in this area for identifying the Fort Union formation in drill holes and wells. The bedrock surface is shown at the top of the lignite where present, although it may be assumed that there are clay and silt layers of the Fort Union formation above the lignite in most of the drill holes. The cross-section lines are approximately normal to the edge of the Max moraine, and the sections are drawn in the zone along the Max moraine-ground moraine contact. This is a critical zone because the difference in elevation between ground moraine and Max moraine is marked, and it is here that one might expect to detect the inclined surface of the bedrock.

It is evident from figures 3 and 4 that the Fort Union formation in the vicinity of Crosby is at a higher altitude under the Max moraine than under the adjacent ground moraine. Figure 5 shows the same relationship southeast along the Max moraine. This diagrammatic cross section through the whole moraine is drawn along line A-A′ in figure 1, or nearly perpendicular to the northwest-trending axis of the moraine. The cross section is modified from an unpublished detailed profile provided by the U. S. Army Engineer Corps. The basis of the profile is a series of core borings.

The upper surface of the Fort Union formation is erosional. Pre-Pleistocene valleys filled with till and outwash have been exposed in the strip mines near Noonan and Columbus. Wood (1902, p. 97) has said that the pre-Pleistocene surface in this region resembles badlands topography. The hypothetical badlands topography is not shown in the cross sections, although drill hole and well data throughout the area mapped strongly suggest a pre-Pleistocene topography of buttes and mesas.

Bedrock relations in the deep re-entrant in the outline of the Max moraine southwest of Crosby (fig. 2) are not typical. Here drill holes in the ground moraine plain penetrate several hundred feet of glacial material before reaching bedrock. The thick deposits of drift probably fill a major valley in the erosion surface of the Fort Union formation. Judging from the shape of the re-entrant, the buried valley may extend south into or even through the area of the Max moraine. Alden (1932) postulated that the old channel of the Yellowstone River crossed the area here. The test hole at the 19-mile point on figure 5 indicates that the upper surface of the Fort Union formation is relatively low. Three additional test holes nearby show the existence of a pre-Pleistocene valley in this area.

Max moraine.—The exact limits of the Max moraine of Late Wisconsin age will not be known until many more miles of the boundary are mapped in detail. At present the moraine is believed to be a topographic unit nearly continuous for 800 miles, 300 miles of which are in the United States. The general trend of the deposit is northwest from near Bismarck, North Dakota, and the work of Bretz (1943) is cited as evidence that the deposit is present over a distance of approximately 500 miles in Canada. When considered in their entirety, the boundaries on the proximal (northeast) and distal (southwest) sides are probably roughly parallel, but owing to crenulations in these boundaries, the width of the deposit is in places less than 10 miles, and at its widest, more than 25 miles. The average

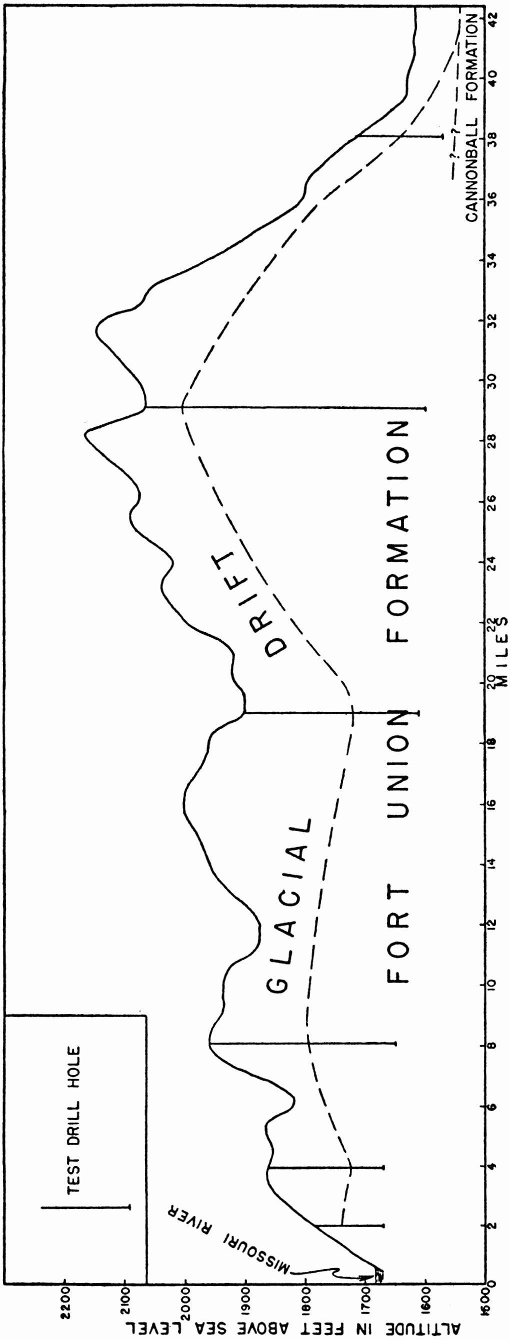

Fig. 5. Diagrammatic cross section of the Max moraine along line A-A′ in figure 1, modified from an unpublished profile supplied by the U. S. Army Engineer Corps, and from data supplied by Richard W. Lemke.

width is approximately 18 miles; south of Ambrose the moraine is at least 24 miles wide.

The moraine consists of a mass of irregularly arranged knobs, hills, and ridges between which are kettles, enclosed depressions, sloughs, and lakes. The topography completely lacks integrated drainage. The smallest of these features is barely perceptible; the largest is more than a mile in length. Except for a slightly concentric arrangement of some of the arcuate ridges, no uniformity or pattern can be discerned in the topography. Most of the hills are rounded and show no evidence of being eroded. From a distance the moraine appears as an escarpment or range with a fairly even horizon, but in detail the hills have no common level. The local relief is generally 50 to 150 feet, and the average overall relief probably exceeds 300 feet. In places the edge of the rough moraine is abrupt and marked by an escarpment as shown on the cross sections of figure 4. In other places flat plains grade gently into the confusion of hills and depressions.

I. J. Witkind[2] reports difficulty in mapping the boundary on the distal side because the topography of the moraine grades almost imperceptibly into the topography of other drift deposits. In contrast the proximal side is an escarpment clearly discernible in most places.

The lithology of the Max moraine is typical of morainic material in the region. The moraine consists predominantly of unstratified, pebbly, clay till, but it also contains knobs and irregularly included masses of stratified drift with all degrees of sorting and stratification. Except for some eskers deposited atop the moraine, there is apparently little pattern to the location of the water-laid deposits. Boulders are abundant both at the surface and within the till.

The cross sections in figures 3, 4, and 5 show that the morainic material is generally approximately 100 feet thick in the area mapped; where the moraine is known to be thicker than 150 to 200 feet, it is suggested that much of the glacial material may be filling a pre-Pleistocene valley in the bedrock.

Ground moraine.—Ground moraine covers wide areas northeast of the Max moraine. The surface of this ground moraine is generally flat or slightly undulating with shallow undrained depressions. Near the Max moraine the surface is gently in-

[2] Witkind, I. J., Personal communication.

clined upward toward the hills. The maximum local relief is about 100 feet; the average is less than 40 feet. Kames, eskers and deposits of dune sand are scattered over the area. These and the Pleistocene drainage valleys cut in the surface break the monotonous flatness.

The ground moraine has essentially the same lithology as the end moraine except that boulders are less abundant.

Drill hole and well data indicate that the average thickness of the ground moraine in the vicinity of Crosby is approximately 25 feet except locally where the till has filled shallow pre-Pleistocene valleys in the erosion surface of the Fort Union formation. In areas to the southeast, however, it is probably as thick or thicker than that of the Max moraine. Deep valleys in the underlying bedrock are probably filled with outwash deposits that are mantled with ground moraine. An example of this is shown at the north end of cross section B-B′ of figure 3 where the queries indicate doubt that the great depth of glacial material is ground moraine .

In addition to this relatively detailed work, Leonard and Eaton (1925), and Howard, Gott, and Lindvall (1946) report that beds of the Fort Union formation are exposed high in the Max moraine.

ORIGIN OF THE BEDROCK HIGH

The question of character and origin of the bedrock high follows evidence that it exists. Badlands topography is common in beds of the Fort Union formation exposed today, and the supposition that similar topography is concealed in the Crosby area by glacial deposits is supported by drill hole and water well data from in and around the Max moraine. Regarding origin, the bedrock high may be a plateau or similar high area of buttes and mesas that was simply eroded more slowly than surrounding areas, but the zone of folding and faulting southwest of the town of Lignite indicates a possible structural control. This area has been described (Townsend, 1950, p. 1552) in detail, and the features are only summarized here. The deformation appears to be of deep-seated origin. The general trend of the folds and faults is remarkably parallel to the trend of the escarpment of the Max moraine, which is approximately 2 miles southwest. The escarpment is steep and its northwest trend is very straight in this area. Structural deformation that occurred prior to Pleistocene time may have created the bedrock high on which the Max moraine was deposited. In addition to the deformed strata near Lignite, Leonard and Eaton (1925) note the steep dip of a coal seam that crops out high in the Max moraine 24 miles southwest of Ambrose. This suggests that structural control of the bedrock high extends to a point at least 50 miles west of the deformed beds near Lignite.

ORIGIN OF THE MAX MORAINE

The bedrock high was almost certainly a barrier to extensive advance of glaciers, and was thereby a complicating factor in the Pleistocene history of the region. The following general steps are proposed for the history of Late Wisconsin glaciation in the area of the Max moraine:

1. *Advance of the glacier beyond the Max moraine.*—Deposits of drift are present on the distal side of the Max moraine. Although it is not definitely known whether these deposits represent the same glaciation as the Max moraine or separate advances of the Wisconsin or an earlier stage, Benson[3] states that he can prove at least three advances during Wisconsin time and possibly an earlier advance in the Knife River area on the distal side of the Max moraine. The writers were unable to find evidence for two or more glacial advances in the Crosby area. In any case, ice that flowed over the bedrock high either remained such a short time or was so poorly charged with rock debris that it left no great drift deposits comparable in magnitude to the Max moraine or other deposits that are on its proximal side.

2. *Retreat of the margin of the ice to the vicinity of the bedrock high.*—After the initial advance of the glacier beyond the bedrock barrier, the margin receded to the vicinity of the Max moraine.

3. *Deposition of Max moraine.*—Evidence is lacking for the two critical factors in the classification of the moraine: (1) the length of time the margin of the ice remained in the vicinity, and (2) the mode of deposition of the material.

In the broadest sense, an end moraine is simply a thickening of drift deposits representing a pause in the movement of a glacier. It has been previously stated that ground moraine

[3] Benson, William E. B., personal communication.

on the proximal side of the Max moraine is in places as thick as or even thicker than deposits of the Max moraine. In addition, owing to the bedrock high, the Max moraine is thinner than might be suspected. Therefore, the writers suggest that the Max moraine may be a special type more nearly related in extent and mode of deposition to ground moraine than to end moraine.

Very little is known about the mechanics of deposition of unstratified drift, particularly till consisting predominantly of clay. If the margin of the ice remained in the vicinity of the Max moraine for any significant length of time, or if the ice were considered stagnant during deposition of the moraine, one might reasonably expect to find more stratified drift deposits in the area. Without evidence for a pause in the retreat of the ice, the writers suggest that the Max moraine may have been deposited largely by ablation. The extremely rough topography of the Max moraine would then presume an uneven distribution of the rock material carried in the ice. The effect of the bedrock high and its irregular surface was to disrupt the flow of ice sufficiently to cause localization of the rock material carried in the ice. The disruption would be particularly effective in the basal portion of the ice where most of the load is believed to be carried (Flint, 1947, p. 75).

4. *Retreat of the margin and deglaciation.*—Ablation prevailed, blocks of ice were stranded, and kames, eskers, and at least the top portion of the ground moraine were deposited.

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