SUBSURFACE GEOLOGY AND FOUNDATION CONDITIONS

IN

GRAND FORKS, NORTH DAKOTA

BY

STEPHEN R. MORAN

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E. A. NOBLE, State Geologist

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PREFACE

This report is written for the non-geologist who is concerned with construction on or below the ground surface in Grand Forks. Its purpose is to describe the position, composition, origin, and engineering properties of the various layers of sediment which underlie the city.

This report is a compilation of all the data currently available in the files of the North Dakota Geological Survey. It is not intended to be the final word on the geology and engineering properties of soil materials in Grand Forks. The report is not intended to be a replacement for site exploration studies on future construction projects. Indeed, no report of this type can be used in this manner. This report should be used in planning site exploration studies and may be useful in interpreting the results of such studies. The summaries of engineering test data are just that, summaries of existing data. They are not intended to be predictions of the characteristics of the various units, except in a very general way, beyond the sites where the borings are made.

Much of the basic data which is necessary to compile a report such as this must come from organizations other than the Geological Survey. One of the most valuable sources of such information is private engineering firms and contractors who make their data available to geologists of the Geological Survey, give us access to excavations, and provide information on buried wood and fossil animal remains that are found during construction. The information contained in this report was obtained from studies of samples, descriptive logs and electric logs of testholes that were drilled by the North Dakota State Water Commission, from soil borings that were made by the Soil Exploration Company of St. Paul, Minnesota, and from published information contained in a paper by Rominger and Rutledge (1952).

Lee Clayton (Department of Geology, University of North Dakota), Mike Arndt (North Dakota Geological Survey), P. B. DuMontelle (Illinois State Geological Survey), T. H. Thornburn (Department of Civil Engineering, University of Illinois), and R. L. Whartman (U.S. Army Corps of Engineers, St. Paul, Minnesota) critically read this report and offered many helpful suggestions. While acknowledging with thanks their assistance, I wish to make clear that the information and interpretations contained in this report are my own and they are in no way responsible for the conclusions.

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GEOLOGIC SETTING

The Grand Forks area (Plate 1) is in the center of a plain which once was the floor of glacial Lake Agassiz. The clay which immediately underlies the city to a depth of 75 feet was deposited in Lake Agassiz (units 2 and 3, Plate 1). This clay, which extends the entire length of the Red River Valley from near the South Dakota boundary to well north of the international boundary, is thickest in the center of the valley along the Red River. The clay thins westward and eastward from the center of the valley. Westward from the Grand Forks Air Force Base and eastward from near Crookston, Minnesota, the clay is absent and the lake plain is composed of eroded glacial sediment (till). At the time of the maximum extent of Lake Agassiz, its shorelines were located just east of Niagara and just east of Red Lake Falls, Minnesota; and the water at Grand Forks was about 400 feet deep.

PREVIOUS STUDIES

The history of Lake Agassiz has been studied for many years, but very little work has been done on the deposits of the lake. The best summary of present knowledge on the history of the lake is given by Elson (1967). Rominger and Rutledge (1952) discussed the stratigraphy and engineering characteristics of borings in Grand Forks and Fargo, North Dakota, and Crookston, Minnesota. Hill and Rutledge (undated) discussed the engineering properties of the lake clay and its effect on landslides. Nordlund and Deere (1970) discussed the engineering characteristics of clays in Fargo at the site of a large grain elevator which collapsed in 1955. Brophy (1967) described the geology of the deposits of Lake Agassiz in the Fargo area. Data from test holes drilled in Lake Agassiz clays in Richland, Cass, Traill, and Grand Forks Counties, North Dakota, have been published (Baker, 1966; Kelly, 1968; Klausing, 1966; Jensen, 1967). The geology of Grand Forks County was mapped by Hansen and Kume (1970).

From these studies it has become apparent that the clayey deposits in the Red River Valley can be separated into different units on the basis of differences in their physical characteristics. Only the upper two widespread units have been traced throughout this part of the Red River Valley. Other units have been described below these two upper units, but none of these older materials has been traced far from the area where it was described.

THIS REPORT

In this report, the deposits underlying Grand Forks are separated into the 8 units shown on the cross sections of Plate 1 on the basis of geologic characteristics. Unit 1 contains clay, silt, and small amounts of sand, all of which commonly contain organic material. Unit 2 consists of thin layers of silty clay alternating with silt or very fine sand. Unit 3, which underlies unit 2, is a thick, unlayered or very slightly layered clay. Unit 4 is silty clay loam glacial sediment (till) which overlies unit 5, a clay similar to unit 3. Unit 6 is a thin unit consisting of pebbly loam glacial sediment (till). Unit 7 is clay similar to units 2, 3, and 5. Unit 8 is a thick unit containing pebbly loam glacial sediment (till), lake clay, and some sand and gravel. Its top is everywhere marked by a layer of pebbly loam glacial sediment (till). Unit 8 overlies shale or limestone.

The amount of sand, silt, and clay present was determined for 53 samples from the Grand Forks area. The grain size data for the various units are summarized in Figure 1 and Table 1. The clay mineral composition of the smaller than 0.0039 mm fraction of 57 samples was determined by X-ray diffraction techniques. The clay mineral data is summarized in Figure 2 and Table 1.

Table 1

Summary of Texture and Clay Mineralogy of Geologic Units in the Grand Forks Area

	Texture				Clay Mineralogy (percent of total clay)			
	N	Percent Sand	Percent Silt	Percent Clay	N	Kaolinite and Chlorite	Illite	Expandable Minerals
Unit 2	12	0.5	36	63.5	10	9	12	78
Unit 3	9	Tr	22	78.0	8	10	14	76
Unit 4	22	18.0	48	34.0	25	15	19	66
Unit 5	5	2.0	28	70.0	5	9	13	78

N .... Number of Analyses
Sand.......... 2.0 to 0.0625 mm
Silt .... 0.0625 to 0.0039 mm
Clay .... Less than 0.0039 mm
Tr .... Trace

The clay-size fraction of a sediment is made up of many mineral components. Among them are quartz, feldspar, calcite, and the clay minerals kaolinite, chlorite, illite, montmorillonite, and other mixed-layer clays. Because of their sheet-like structure and their properties when wet, the clay minerals play a very important role in determining the characteristics and behavior of the sediments containing them. Montmorillonite and some mixed-layer clays are particularly significant because they can absorb large quantities of water into their crystal structures and cause significant changes in volume of the soil mass on wetting or drying. These clays are referred to in the remainder of this report as expandable clay minerals.

The available data on natural water content, dry density, liquid limit, plasticity index, and unconfined compressive strength are summarized in Plate 2 and Table 2. This data was obtained from Rominger and Rutledge (1952) and from the Soil Exploration Company of St. Paul.

The natural moisture content displays considerable variation among the five units but fairly small variation within any one unit. The dry density also shows very minor variation within each unit and considerable variation among units. The three units of lake sediment, units 2, 3, and 5 possess fairly high water contents and low dry densities, whereas the two units of glacial sediment (till), units 4 and 6, have lower water contents and higher densities (Plate 2, Table 2).

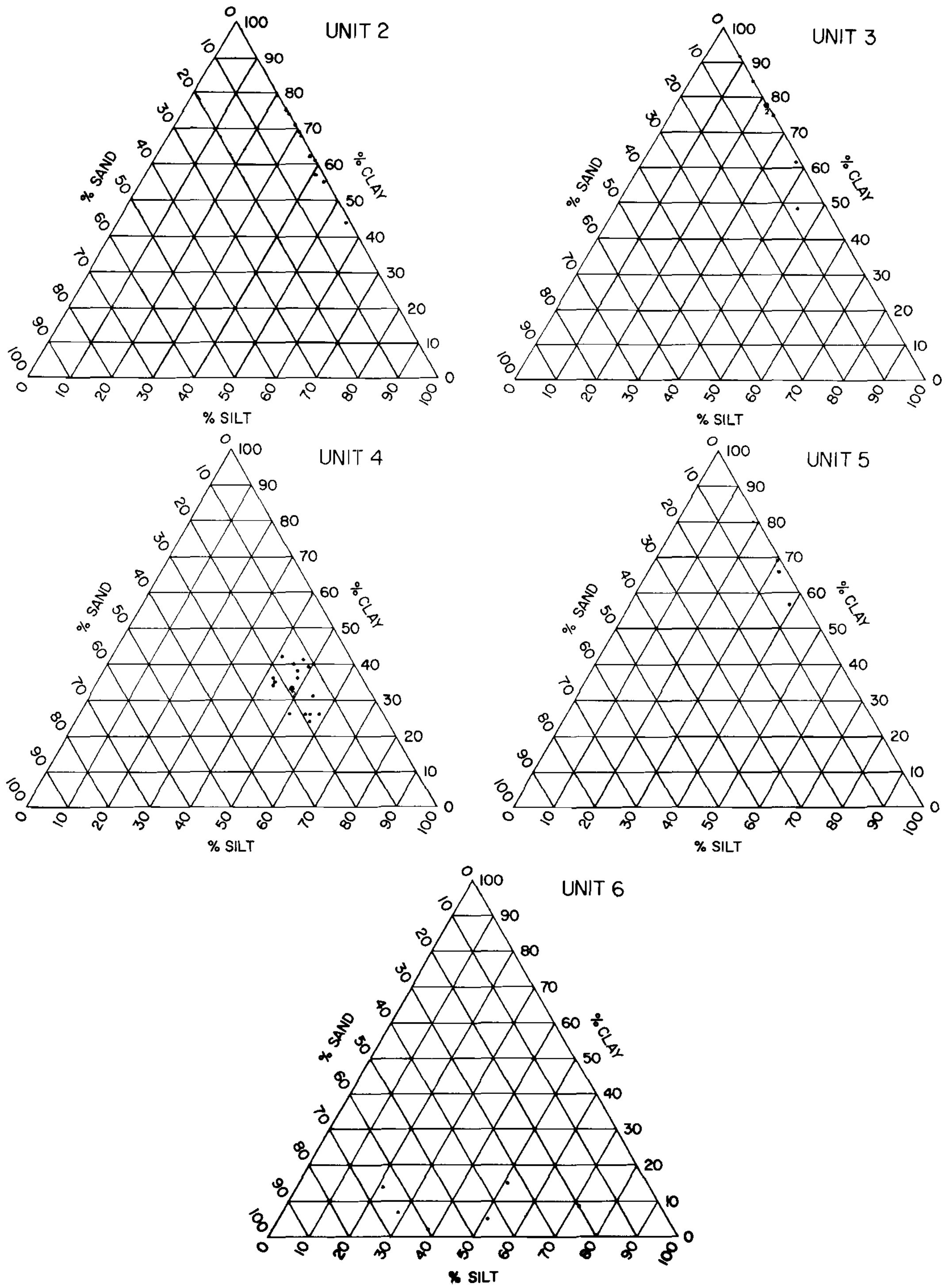

FIGURE 1. **Texture of Units 2 through 6, Grand Forks Area. (Sand - 2.0 mm to 0.0625mm; Silt - 0.0625 mm to 0.004 mm; Clay - less than 0.0039 mm.)**

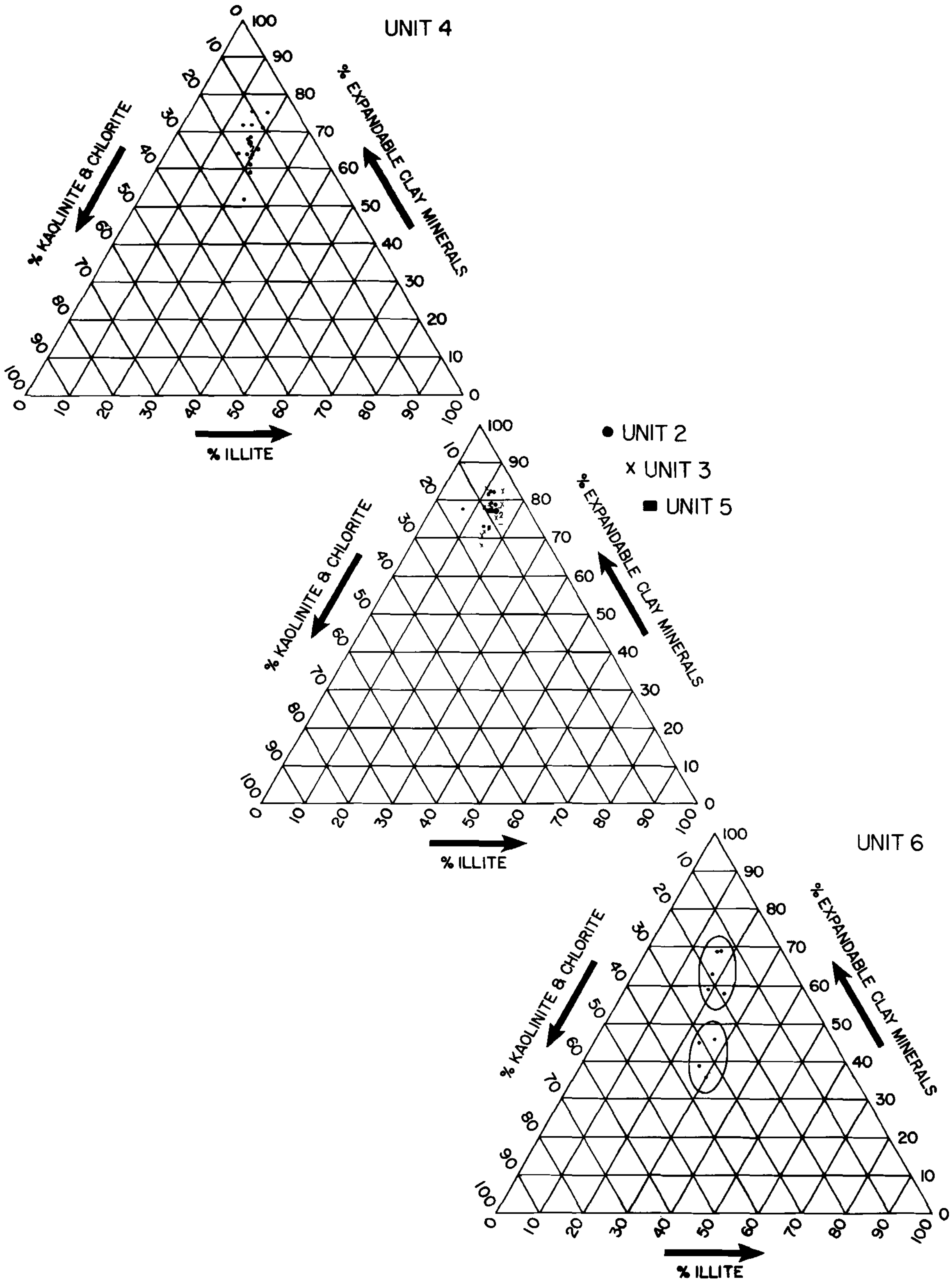

FIGURE 2. Clay mineralogy of Units 2 through 6, Grand Forks Area.

Table 2

Summary of Engineering Test Data for Geologic
Units in the Grand Forks Area

		Natural Water Content (%)	Dry Density (pcf)	Liquid Limit (%)	Plasticity Index (%)	Unconfined Compressive Strength (psf)	Standard Penetration Test
Unit 1	N	(9)	(4)	(8)	(8)	(5)	–
	$\bar{X}$	34	93	64	38	3520	–
	60% Range	28-43	–	59-69	31-43	–	–
	Range	25-48	90-98	53-74	29-47	1600-5300	–
Unit 2	N	(18)	(15)	(16)	(5)	(18)	(246)
	$\bar{X}$	39	85	61	32	2328	9
	60% Range	34-44	76-87	49-73	–	1500-2900	6-11
	Range	27-47	74-96	38-84	28-49	1000-3700	2-23
Unit 3a	N	(9)	(6)	(7)	(6)	(6)	(9)
	$\bar{X}$	40	82	58	39	2300	16
	60% Range	34-45	75-89	55-67	33-42	1700-3000	10-24
	Range	30-58	66-94	24-85	26-56	1200-3400	10-26
Unit 3b	N	(18)	(7)	(16)	(13)	(9)	(119)
	$\bar{X}$	63	63	101	62	1680*	5
	60% Range	56-74	58-67	75-117	41-75	1200-2000	4-7
	Range	52-75	57-69	67-123	41-86	980-3300	1-10
Unit 4	N	(14)	(9)	(10)	(6)	(9)	(23)
	$\bar{X}$	25	103	40	17	2030	12
	60% Range	21-25	100-106	32-45	14-20	1500-2600	9-15
	Range	21-39	96-107	28-62	12-23	1400-3400	6-21
Unit 5	N	(3)	(3)	(3)	(1)	(3)	(12)
	$\bar{X}$	42	79	72	42	2270	10
	60% Range	–	–	–	–	–	8-11
	Range	35-52	70-87	58-85	–	1700-3400	5-12
Unit 6	N	(4)	(4)	(1)	(1)	(2)	(40)
	$\bar{X}$	8	136	18	7	–	100+
	60% Range	–	–	–	–	–	–
	Range	6-12	127-140	–	–	38,500-45,000+	21-100+

N: Number of Analyses
$\bar{X}$: Mean Value
60% Range: 60% Of The Test Values Lie Within These Limits
Range: All Test Values Lie Within These Limits

* As is discussed in the text, this value is much higher than the actual field strength of the unit, which is probably about 450 psf.

Large differences exist among the mean values of liquid limit and plasticity index of each of the units (Plate 2, Table 2). However, these properties display considerably greater variation within each unit than do the moisture-density properties. The glacial sediment (till), units 4 and 6, possess much lower liquid limits and plasticity indexes than does the lake sediment of units 2, 3, and 5. Unit 3 in particular is characterized by very high values of both liquid limit and plasticity index. The reasons for this are discussed at some length by Rominger and Rutledge (1952).

The mean unconfined compressive strength of the various units ranges from 450 psf in unit 3b to more than 35,000 psf in unit 6 (Table 2). The compressive strength of the remainder of the units is nearly the same, about 2200 psf, except for unit 1, which has a mean compressive strength of 3520 psf. The variation in compressive strength within each of the units is large (Table 2).

GEOLOGIC HISTORY

The geologic history of each of the units described in this report in the Grand Forks area is different, and this difference is in part responsible for differences in the physical properties of the units. A knowledge of the geologic history of the area can give an understanding of the origin of each of the units, the origin of their characteristics, and a general appreciation for the history of the area.

Unit 8 consists of a complexly alternating sequence of glacial sediment (till), lake clay and silt, and river sand and gravel. It, along with the clay of unit 7 and the glacial sediment (till) of unit 6, consists of the deposits of numerous glacial advances which occurred in the Red River Valley prior to the last advance, which began sometime after 28,000 years ago. Each glacial advance dammed the northward draining valley, forming a lake. As yet we do not know how many glaciations are represented by these units nor when they occurred. Most of the glacier that deposited the glacial sediment (till) of unit 6 is believed to have melted from North Dakota by 13,000 years ago. The weight of this glacier consolidated the glacial sediment (till), producing materials which have high strengths.

The ice that deposited the glacial sediment (till) of unit 6 melted down until a lake, which was dammed to the north by ice, formed in the Red River Valley. Unit 5 was deposited in the deep, quiet waters of this lake, which stretched from well north of Grand Forks south into eastern South Dakota, where it drained into the Minnesota River valley.

The ice was reactivated and advanced southward past Grand Forks into central Traill County. Unit 4 was deposited by this glacier as it moved southward. Because much of the material making up unit 4 was derived by erosion of the underlying lake sediments of unit 5, the characteristics of unit 4 are very similar to those of the lake sediment.

About 12,500 years ago the glacier once again began to melt down and retreated northward out of the Red River Valley. The soft black clay of unit 3 was deposited in the cold, deep waters of this lake (Lake Agassiz). About 11,000 years ago the glacier had melted far enough northward that low-level outlets into Lake Superior were opened in the area of Lake Nipigon in Ontario. Lake Agassiz then drained into Lake Superior and the level of the lake dropped below Grand Forks. A river flowed northward down the center of the exposed lake floor in roughly the same location as the present Red River. Other streams flowed across the exposed lake plain from the higher land on the east and west just as the modern Red Lake, Sheyenne, Maple, Turtle, and Pembina Rivers do today. These streams carried sand and gravel which today is the cause of major groundwater problems in excavations which intersect them. During this period, groundwater levels were lowered below the surface in some places and considerable consolidation of the clay occurred, altering the upper part of unit 3 to form unit 3a. The soft, wet, plastic clay of unit 3b was not affected by this episode of drying.

Approximately 10,000 years ago a glacier advanced again into the region north of Lake Superior and blocked the eastern outlet of Lake Agassiz. Lake Agassiz rose until it drained, once again, into the Minnesota River valley. Unit 2 was deposited in the Grand Forks area during this period.

Approximately 9,000 years ago the eastern outlets of the lake were opened for the final time and Lake Agassiz drained from the Grand Forks area. Floods of the Red River spilling over the exposed lake floor during the next 9,000 years deposited the layer of overbank sediment of unit 1 in the area roughly one-half mile on either side of the present river.

DESCRIPTION OF THE UNITS

Unit 1

Unit 1, a layer of clayey silty river sediment, occurs in low areas along the Red River and on the flat areas of the lake plain, possibly as much as a mile from the river (Plate 1). On the low terraces along the river, unit 1 may be 15 to 20 feet thick, but on the flat areas back from the river it is probably nowhere more than a few feet thick. This sediment, which is deposited when the Red River overflows its banks, is layered, although not nearly so clearly as the clay of the underlying unit, unit 2. Unit 1 commonly contains roots and stems, as well as disseminated organic matter which gives it a dark gray or black color. Numerous bison bones have been found in this unit.

Unit 2

Unit 2 is composed of thinly layered clay and silty clay. Layers of silt and locally very fine sand alternate with the clay. The layers are generally from 0.1 to 0.5 inch thick, but in some places layers as much as several inches thick have been observed. Unit 4 of Rominger and Rutledge (1952) is equivalent to unit 2. In the Grand Forks area unit 2, which ranges in thickness from 11 to 40 feet, has a mean thickness of 30 feet. The upper 25 to 30 feet of the unit is brown but the base is gray. The boundary between the brown and gray is usually gradational. Reddish iron oxide concretions and whitish calcareous concretions commonly occur in the upper 15 feet of unit 2. The uppermost 5 feet of the unit commonly appears massive without any evidence of layering. This results from disturbance of the clay by frost and by churning by man and burrowing animals. Soil-filled burrows of ground squirrels and gophers are commonly observed in this zone.

In many areas, particularly in downtown Grand Forks, several feet of man-made artificial fill overlies unit 2. This material has a varied composition, including clay, gravel, and broken bricks and concrete, but is generally sandier than the clay of unit 2.

The variable nature of unit 2 is reflected in the grain size data for the unit (Fig. 1). The unit contains layers which range from clayey silt to nearly pure clay. The sand content of the unit is very low, ranging from a trace to 2 percent. Pebbles are totally absent. The clay content of the twelve samples tested ranged from 30 to 90 percent. Only 58 percent of the samples tested had a clay content within 10 percent of the mean of 63.5 percent.

The clay mineral composition of unit 2, which is shown on Table 1 and in Figure 2, is characterized by a large amount of montmorillonite. This high content of montmorillonite is reflected in the relatively high natural water content and liquid limit of the unit. The variability of the unit is reflected in the large variability in dry density, liquid limit, and unconfined compressive strength (Table 2 and Plate 2).

Unit 3

Unit 3 is a uniform dark gray to black clay which everywhere underlies unit 2 (Plate 1). The elevation of the upper surface of unit 3 is shown on Figure 3. This unit includes units 1, 2, and 3 of Rominger and Rutledge (1952). It is unlayered or has very obscure layering. The clay making up this unit is very weak, and when not confined it deforms readily under very low stress. It commonly exhibits slikensides on broken surfaces resulting in the name "the slikensided clay" by which it is called by some. Unit 3, which ranges from 7 to 48 feet in thickness, has a mean thickness of 32 feet.

Unit 3a, the upper 5 to 10 feet of unit 3, is much harder and more consolidated than the remainder of the unit, 3b. It is readily recognized by the increased number of blows needed to penetrate it; otherwise, it appears the same as unit 3b.

Small chalky white or tan pebbles (generally less than 0.25 inch in diameter) are scattered throughout unit 3b. These pebbles, which can be readily crushed between the fingers, are composed of clay and soft limestone. These pebbles were considered by Rominger and Rutledge (1952) to be calcareous concretions; but their angular corners and random distribution, as well as their similarity to some of the rocks exposed farther north in Manitoba, indicates that they are pebbles. The upper part of unit 3b contains only a few of these chalky pebbles, but near its base they become abundant. Harder pebbles also occur scattered throughout the lower part of unit 3b.

The grain size composition of unit 3 is much more constant than that of unit 2 (Fig. 1). Only a trace of sand and pebbles was found in this unit. Unit 3 varies from silty clay to clay with clay-sized particles composing from 62 to 92 percent of the material. The lowermost part of unit 3b becomes sandier and less clayey as it grades into unit 4.

The clay mineral composition of unit 3 is very similar to that of unit 2 (Figure 2, Table 1). The high montmorillonite content of unit 3 (78 percent) is in part responsible for the fact that unit 3b has the highest natural water content, liquid limit, and plasticity index, and the lowest dry density and unconfined compressive strength of all the units (Table 2, Plate 2).

Significant discrepancies occurred between the values of the strength obtained from test specimens of unit 3b and those obtained in the analyses of actual failures involving the unit. For this reason thorough studies of the strength of unit 3b have been made by Hill and Rutledge (undated) and by Nordlund and Deere (1970). Hill and Rutledge found that as larger and larger specimens were tested, the compressive strength became less and less. Compressive strength values as low as 420 psf were obtained with 5-inch diameter specimens (Hill and Rutledge, undated, p. 9). They concluded that a value of approximately 450 psf was more representative of the field compressive strength of unit 3b than were the higher values obtained by testing small diameter samples (Table 2).

Unit 4

Unit 4 is a bed of slightly pebbly, silty clay loam or clay loam (till). The elevation of the top of this unit is shown in Figure 4. Unit 4, which is massive glacial sediment (till), ranges in thickness from 33 to 72 feet and has a mean thickness of 46 feet.

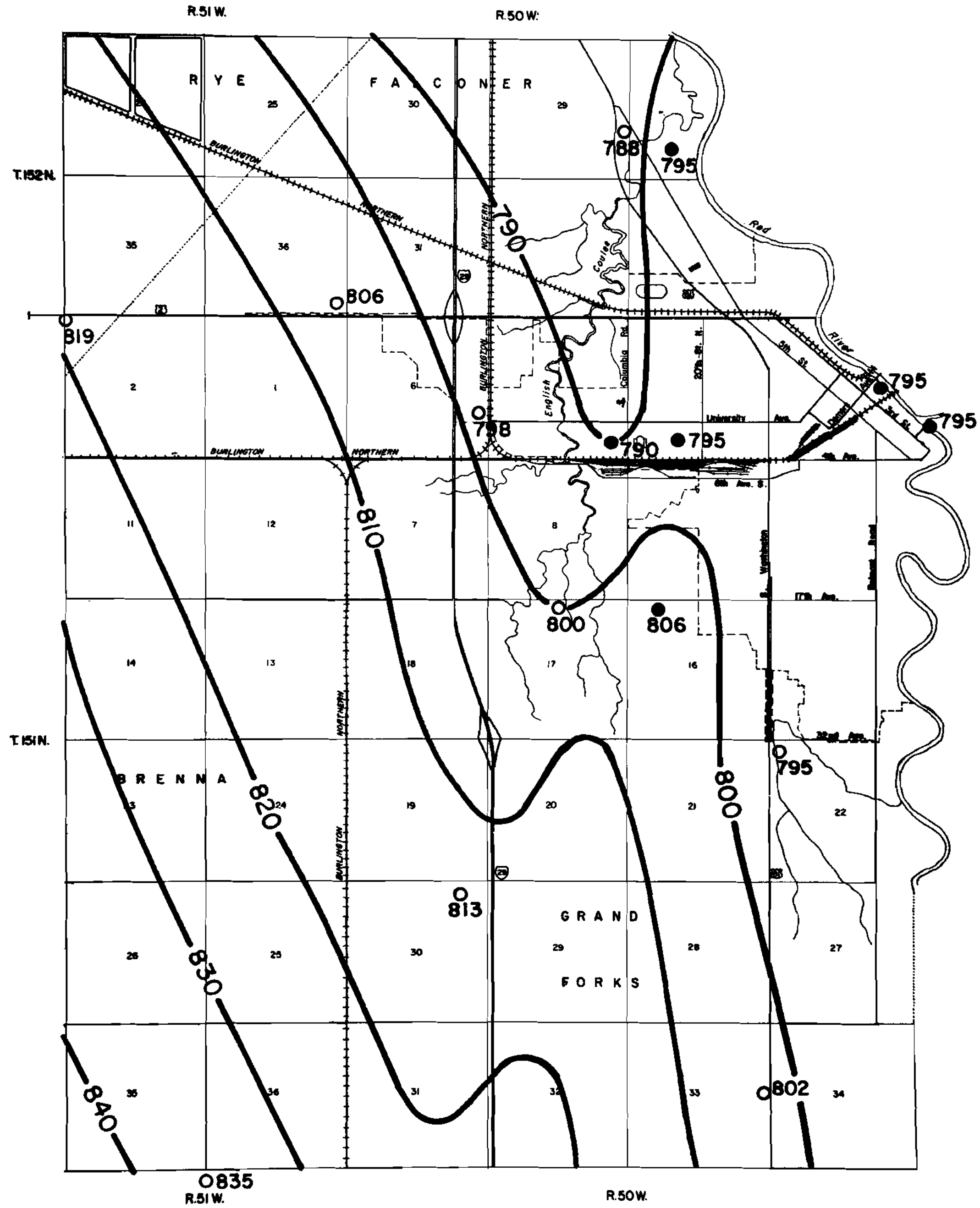

FIGURE 3. **Elevation of the top of Unit 3, Grand Forks Area. See Plate 1 for explanation of symbols used.**

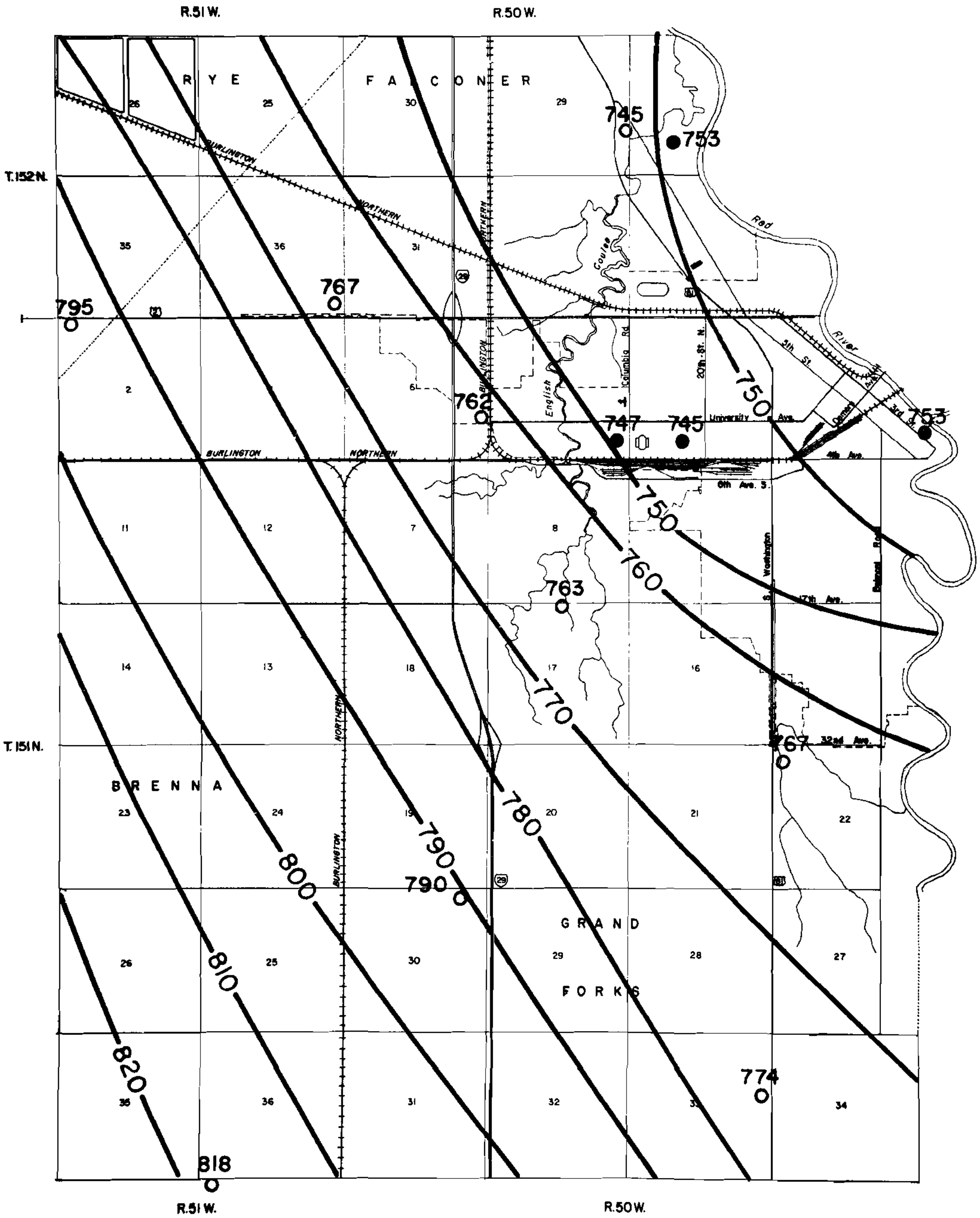

FIGURE 4. Elevation of the top of Unit 4, Grand Forks Area. See Plate 1 for explanation of symbols used.

Unit 4 is the least variable of all the units. As can be seen in Figure 1, the clay content ranges from 24 to 42 percent, and except for two samples the sand content ranges from 15 to 24 percent. The pebble content ranges from 1 to 10 percent. This very small variation in grain-size composition is a characteristic commonly observed in sediments deposited by glaciers.

Unit 4 contains more kaolinite, chlorite, and illite, and less expandable clay minerals, than do units 2, 3, and 5 (Figure 2, Table 1). These differences are reflected in lower water contents, liquid limits, and plasticity indexes of unit 4. The difference in clay mineralogy is not solely responsible for these differences in properties, but undoubtedly contributes to them.

Unit 5

Unit 5 is a bed of unlayered to weakly layered clay containing scattered pebbles of chalky limestone. It is very similar to unit 3b and is distinguished from it only by the presence of unit 4 lying between them (Plate 1). Unit 5 ranges in thickness from 7 to 34 feet and has a mean thickness of 17 feet. The elevation of the top of unit 5 is shown in Figure 5.

In some places in the southern part of the Grand Forks area, unit 5 contains sand and gravel below the clay. In the western part of the Grand Forks area the clay of unit 5 is replaced entirely by sand and gravel (Plate 1).

Based on five samples, the grain size of unit 5 is similar to unit 3 (Figure 1); the sand content of unit 5 is somewhat higher (averaging 2 percent, ranging from a trace to 4 percent), and the clay content is somewhat lower (averaging 70 percent, ranging from 57 to 80 percent).

The clay mineralogy of unit 5 is very similar to that of units 2 and 3 (Figure 2, and Table 1). Like units 2 and 3, unit 5 has a high natural water content, liquid limit, and plasticity index, and a low dry density and compressive strength (Plate 2, and Table 2).

Unit 6

Unit 6 is a layer of massive pebbly loam to pebbly sandy loam glacial sediment (till) which everywhere underlies unit 5 (Plate 1). The elevation of the top of unit 6 is shown on Figure 6. Unit 6 ranges in thickness from 5 to 49 feet, with a mean of 21 feet. As is shown in the cross sections on Plate 1, unit 6 is the thinnest in the northern part of the city of Grand Forks. Where unit 6 is locally absent, unit 5 lies directly on unit 7.

In the area of the University, beds of sand and gravel occur in unit 6. At least locally, in that area, the upper 10 feet of the unit consists of sand, and it is possible that in some places it consists entirely of sand.

Unit 6 consists of at least two different layers of glacial sediment (till) as is shown by the two distinct groupings of textural composition and clay mineral composition within the unit (Figures 1 and 2). It is believed that these different layers are the deposits of two different glacial advances.

Unit 6 has the lowest natural water content, liquid limit, and plasticity index, and the highest dry density and unconfined compressive strength of all the units studied in the Grand Forks area (Table 2 and Plate 2). Caissons for high rise buildings in Fargo are set in a unit that is equivalent to unit 6.

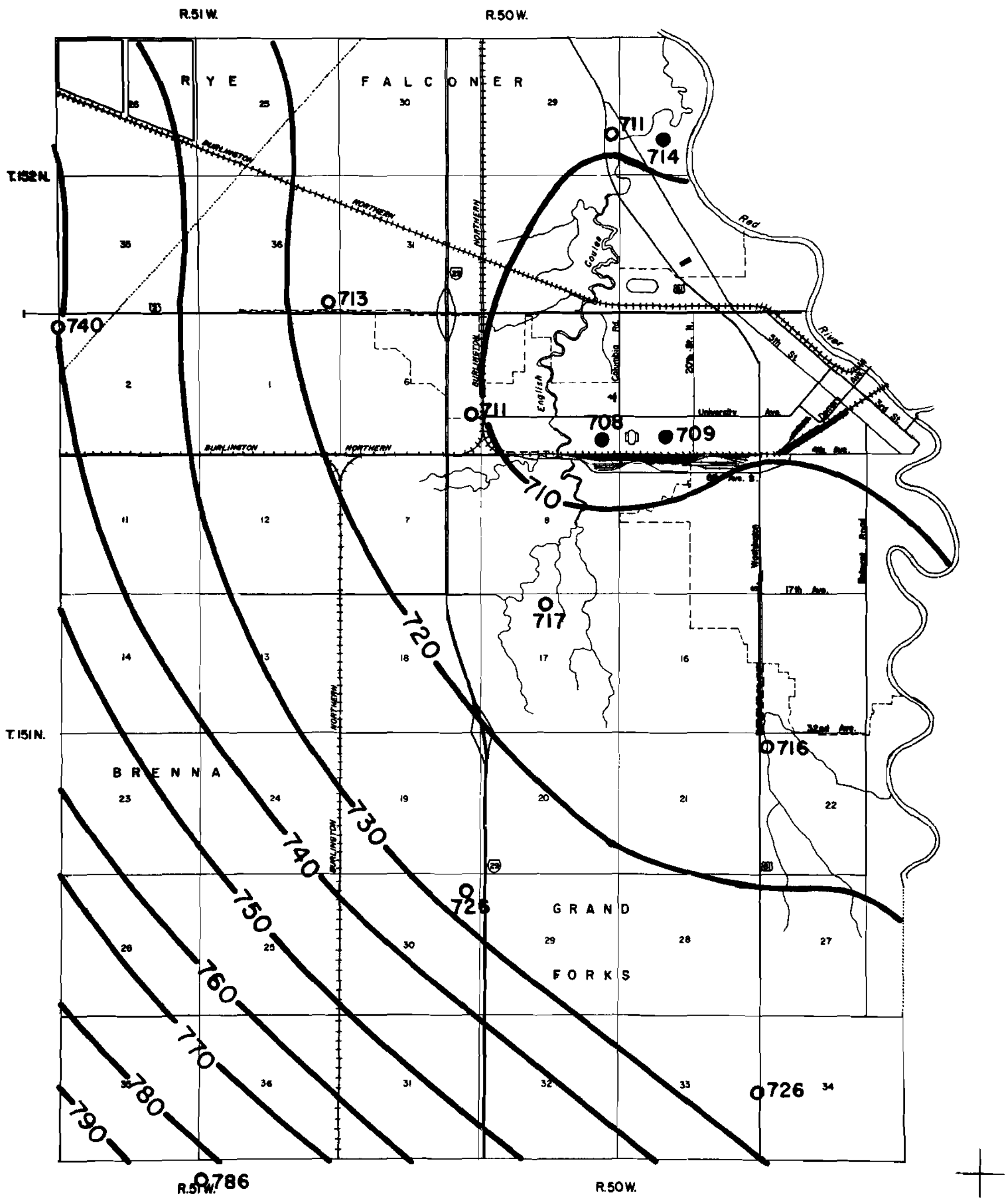

FIGURE 5. Elevation of the top of Unit 5, Grand Forks Area. See Plate 1 for explanation of symbols used.

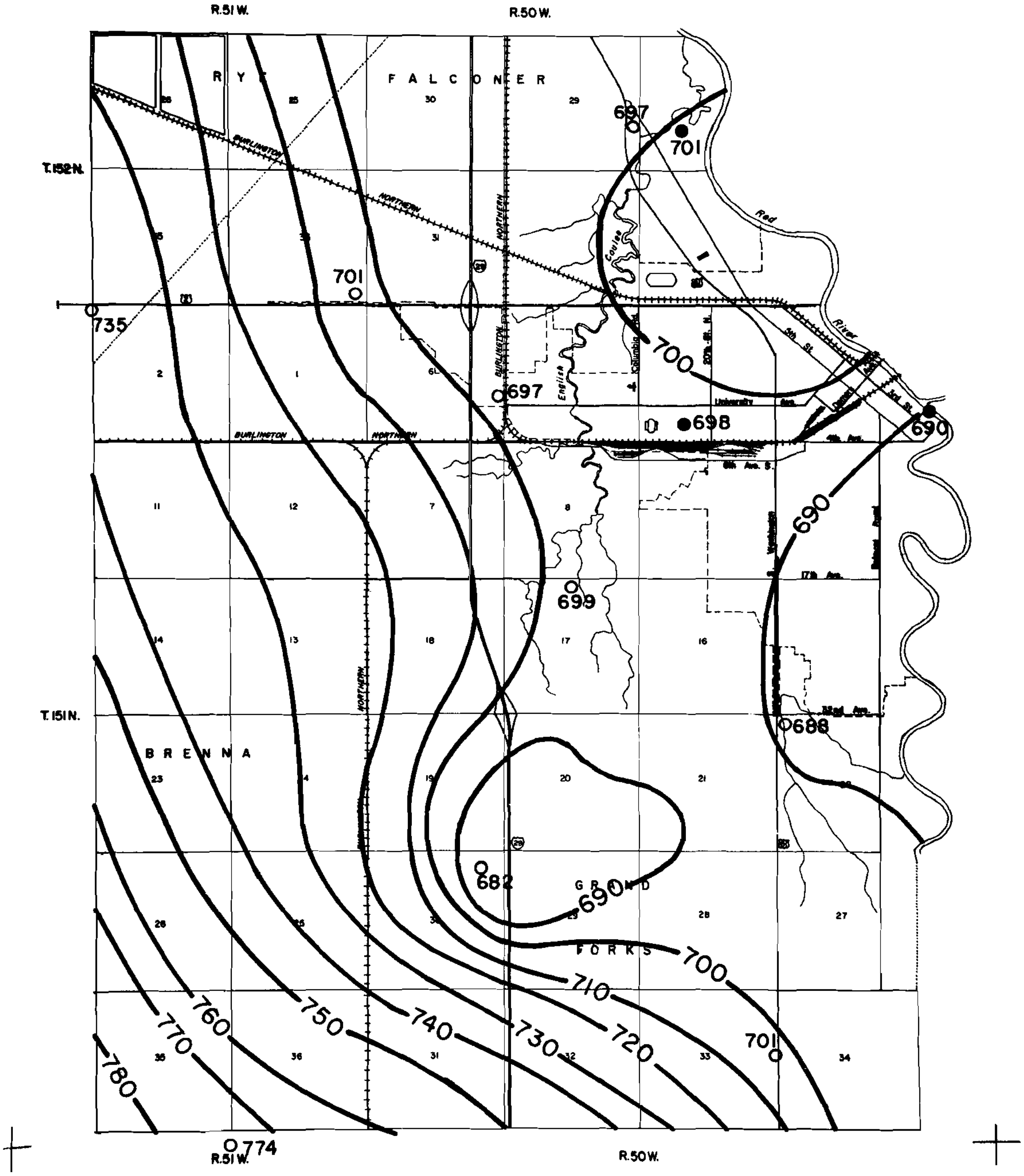

FIGURE 6. Elevation of the top of Unit 6, Grand Forks Area.
See Plate 1 for explanation of symbols used.

Unit 7

Unit 7 consists of clay similar to that of units 2, 3, and 5. This unit varies in thickness from 4 to 74 feet, with a mean thickness of 22 feet (Plate 1). The thickest part of the unit occurs in the northern part of the Grand Forks area. Toward the southern and southwestern part of the Grand Forks area, where unit 7 is thinnest, it is locally represented by sand and gravel.

Although no data are available regarding the characteristics of unit 7, the texture, mineralogy, and engineering characteristics are believed to be similar to units 2, 3, and 5.

Unit 8

Unit 8 is a complex sequence of layers of sand and gravel, silt and clay, and pebbly loam (till), which everywhere underlies unit 7 (Figure 7). It has a mean thickness of 100 feet, but the thickness ranges from 32 feet to 241 feet. Unit 8 rests on hard limestone, shale or sandstone. The top of unit 8 is everywhere marked by a layer of hard pebbly loam (till) very similar to unit 6 (Plate 1). No information on the characteristics of this pebbly loam, which makes up the bulk of the unit, is available, but they are believed to be very similar to those of unit 6. Units 7 and 8 are treated separately from unit 6 in this report, because in some areas unit 6 may be absent or so thin that unit 8 affords the only firm foundation available.

FOUNDATION CONDITIONS

Groundwater Conditions

Groundwater levels in the Grand Forks area are high. In the borings included in this study, the depth to water ranged from approximately 5 feet to 15 feet. In most places the permeability of units 1 and 2 is sufficiently low that excavations well below this depth will not encounter significant water problems. However, layers of coarse silt and fine sand occur locally throughout unit 2, and excavations encountering such a layer below the surface of the groundwater may be expected to have considerable water problems. A thorough program of test-boring prior to construction should alert the contractor to the potential problem.

Fairly extensive bodies of sand and gravel may occur at the surface of unit 3 (although no such aquifers were encountered in the borings used in this study). If an excavation intersects such a sand body, major groundwater problems can be anticipated. Construction of Interstate 94 just west of Fargo was held up for nearly a year when a railroad underpass intersected such a sand deposit (Bell, 1968). A thorough pre-construction program of test boring should reveal whether this type of water problem is to be encountered on a given site.

Beds of water-bearing sand and gravel occur in units 4, 5, 6, 7, and 8. Although excavations will almost never be deep enough to intersect any of these units in the Grand Forks area, problems may be encountered as a result of high water pressures in these units. In the past, flowing wells have been completed in some of these units in Grand Forks. Although pumping has lowered the heads in most of these units below the ground surface

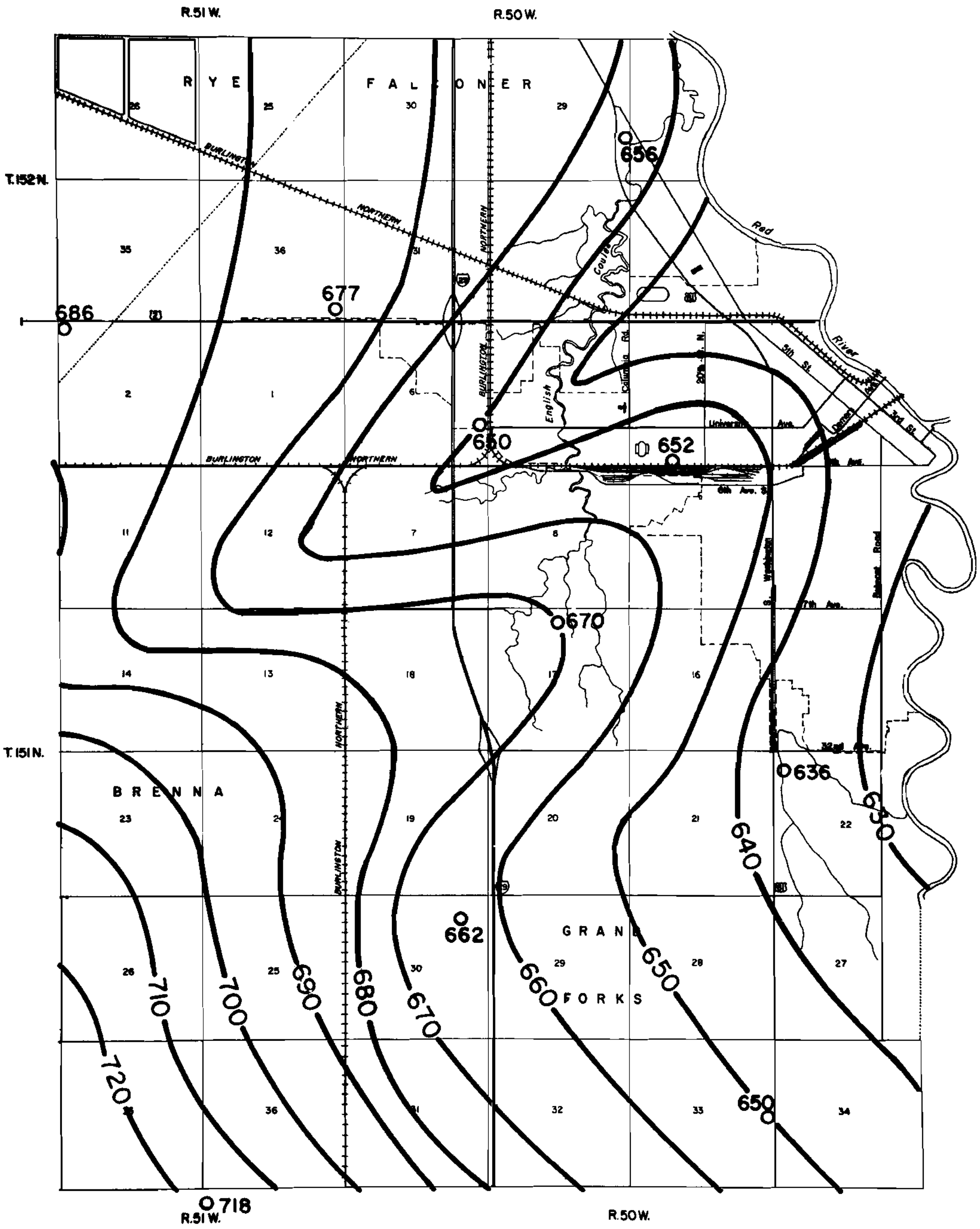

FIGURE 7. Elevation of the top of Unit 8, Grand Forks Area.
See Plate 1 for explanation of symbols used.

(Kelly and Paulson, 1970, p. 38), the possibility of flowing conditions exists where borings for caissons or other wells are made in excavations below the surface. Wherever deep holes are to be drilled in excavations, careful observation of water levels in test borings will indicate whether the head in aquifers to be encountered is above the base of the excavation. If such conditions are recognized prior to construction, plans can be made to handle the situation without problems developing.

Types of Potential Structural Failure

Four types of failure associated with clayey soils in the Red River Valley were described by Hill and Rutledge (undated, p. 3); (1) elastic deformation, (2) shrinking and swelling, (3) bearing-capacity failures, and (4) landslides.

(1) They reported that under certain conditions of uniform loading, 100-foot high grain elevators have experienced 4 to 6 inches of settlement and become 18 inches out of plumb (Hill and Rutledge, undated, p. 3). Upon unloading, the elevators returned to their original positions. Settlements of this magnitude could produce changes in the gradients of sewage lines and should therefore be considered in construction of heavy structures.

(2) Volume changes of the clayey materials caused by major changes in water content can cause significant settlement and damage to buildings which have long been stable. Such problems appear to be associated with periods of significant drought (Hill and Rutledge, undated, p. 3).

(3) Bearing-capacity failures produced by overloading or uneven loading of structures founded on slabs in the clays of unit 2 have occurred. Hill and Rutledge (undated, p. 3) briefly describe the failure of the Transcona elevator near Winnipeg, Manitoba. Nordlund and Deere (1970) discuss in considerable detail the failure of a grain elevator located west of Fargo, North Dakota, which occurred in 1955. These failures occurred by rapid uneven settlement of the slab accompanied by a rise of the ground surface adjacent to the elevator. Analyses of these bearing-capacity failures have revealed that the failure occurred in the weak clay of unit 3b (Nordlund and Deere, 1970).

(4) Wherever stream erosion or man-made excavation has thinned unit 2 enough to bring the interface between it and unit 3 near or above the ground surface, failure by landsliding may occur. Hill and Rutledge describe three such landslides along the Red River, two in Grand Forks and one in Fargo, and conclude that in each case the failure occurred in unit 3 (Hill and Rutledge, undated, p. 5-7). These slides are not catastrophic; movement is slight but continuous for several years. These slides generally extend about 400 feet back from the river.

Three small slides similar to these have recently occurred in a drainage ditch about 15 miles north and west of Grand Forks. These slides are about 200 to 400 feet across and approximately 100 feet from toe to head. The road along the ditch has dropped 3 to 5 feet at the head of the slide. The toes of the slides are marked by a mound composed of clay of unit 3 which has been pushed up in the center of the ditch.

Foundation Design

Because of the low strength, high water content, and high plasticity of the clay of unit 3b, special procedures should be followed for successful construction of major structures in the Grand Forks area as well as throughout much of the Red River Valley. The following general discussion of possible procedures is in part modified from the work of Hill and Rutledge (undated, p. 10-11).

The first step in avoiding foundation problems is site selection. Sites located within 500 feet of river, stream, and ditch banks may be susceptible to sliding failures, especially where loads in excess of 1000 psf are involved in the proposed structure (Hill and Rutledge, undated). Where thick deposits of unit 1 are present, the problems are considerably lessened, because unit 1 has considerably greater strength than units 2 or 3; but wherever unit 3 occurs near the surface, potential sliding should be considered.

A thorough site investigation, including a test-boring program, should be conducted to determine whether permeable materials, which may produce groundwater problems, are present, and to determine the depth and configuration of the upper surface of unit 3. For a heavy structure, the depth to unit 6, or to unit 8 where unit 6 is absent, should also be determined. With this information, a soils engineer can determine how to design and build the structure so that failures are less likely to occur. Unit 3 can be readily recognized in the field as the soft, black, unlayered clay which commonly contains small white calcareous pebbles; it can also be readily recognized by its high water content, liquid limit, and plasticity index, and by its low density.

Where structures must be built close to stream or ditch banks and where very heavy structures are planned, the potential problems described may be prevented by changes in foundation or structure design. For instance, an earth fill might be used safely for a highway bridge approach in western Grand Forks, but such a fill might cause landsliding if used for a bridge across the Red River. The bridge across the river might be built on piles driven to unit 6, thereby bypassing the potential sliding layer, unit 3. The effective load of a structure can be reduced by excavating an amount of material whose weight approximates the weight of the structure. In some instances, large structures, such as levees, must be built close to the river. Potential sliding problems might be avoided by loading the toe of the potential slide block with a smaller fill.

REGIONAL APPLICABILITY

The data in this report are drawn only from the Grand Forks area (Plate 1). However, the materials found under Grand Forks appear to be continuous over large areas of the Red River Valley. The geology of the units which have been discussed here is believed to be applicable to much of the central part of the Red River Valley. Although the thickness and engineering properties of the various units may vary from place to place, the general characteristics of the units should remain more or less the same from Fargo to the Canadian border.

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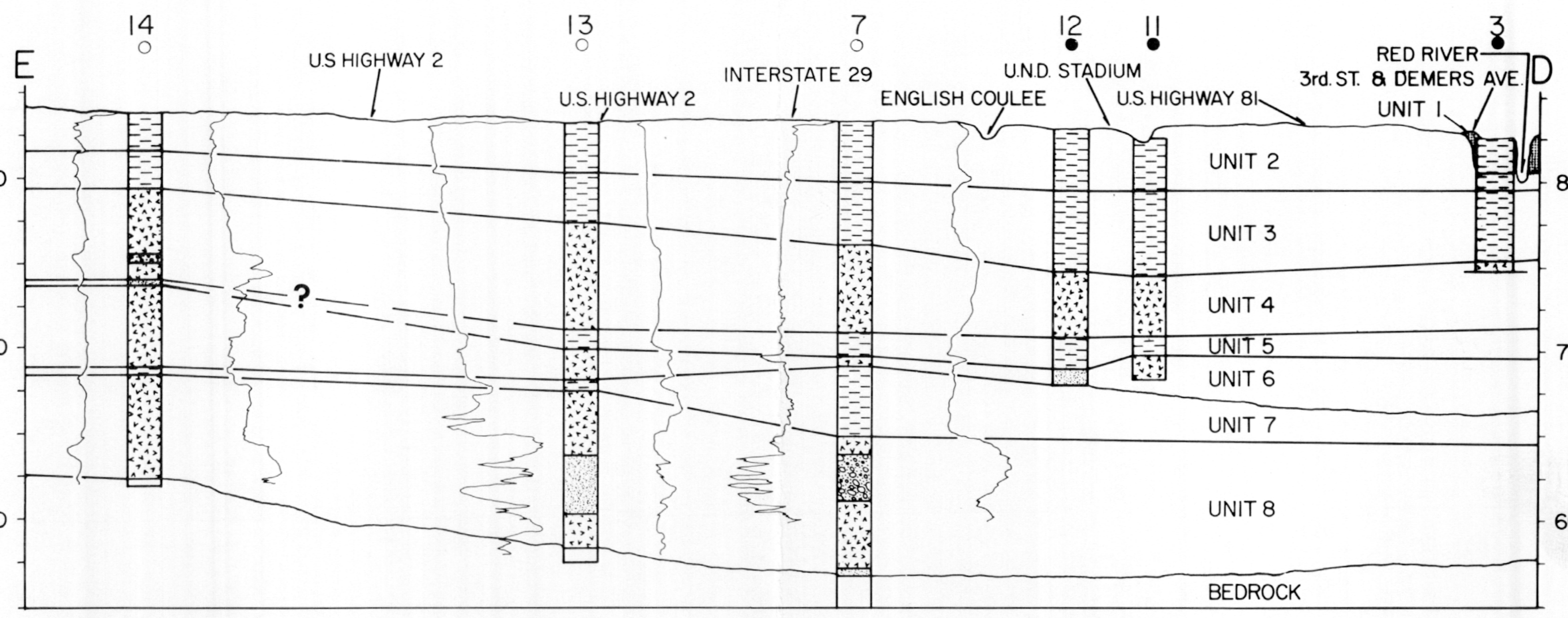
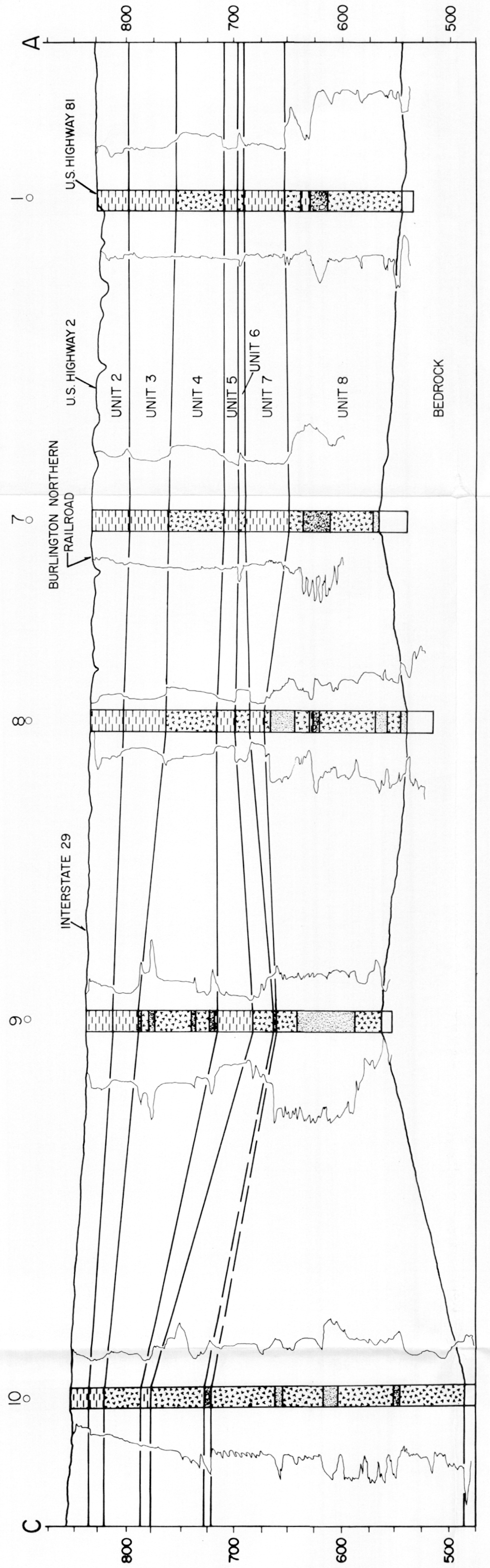
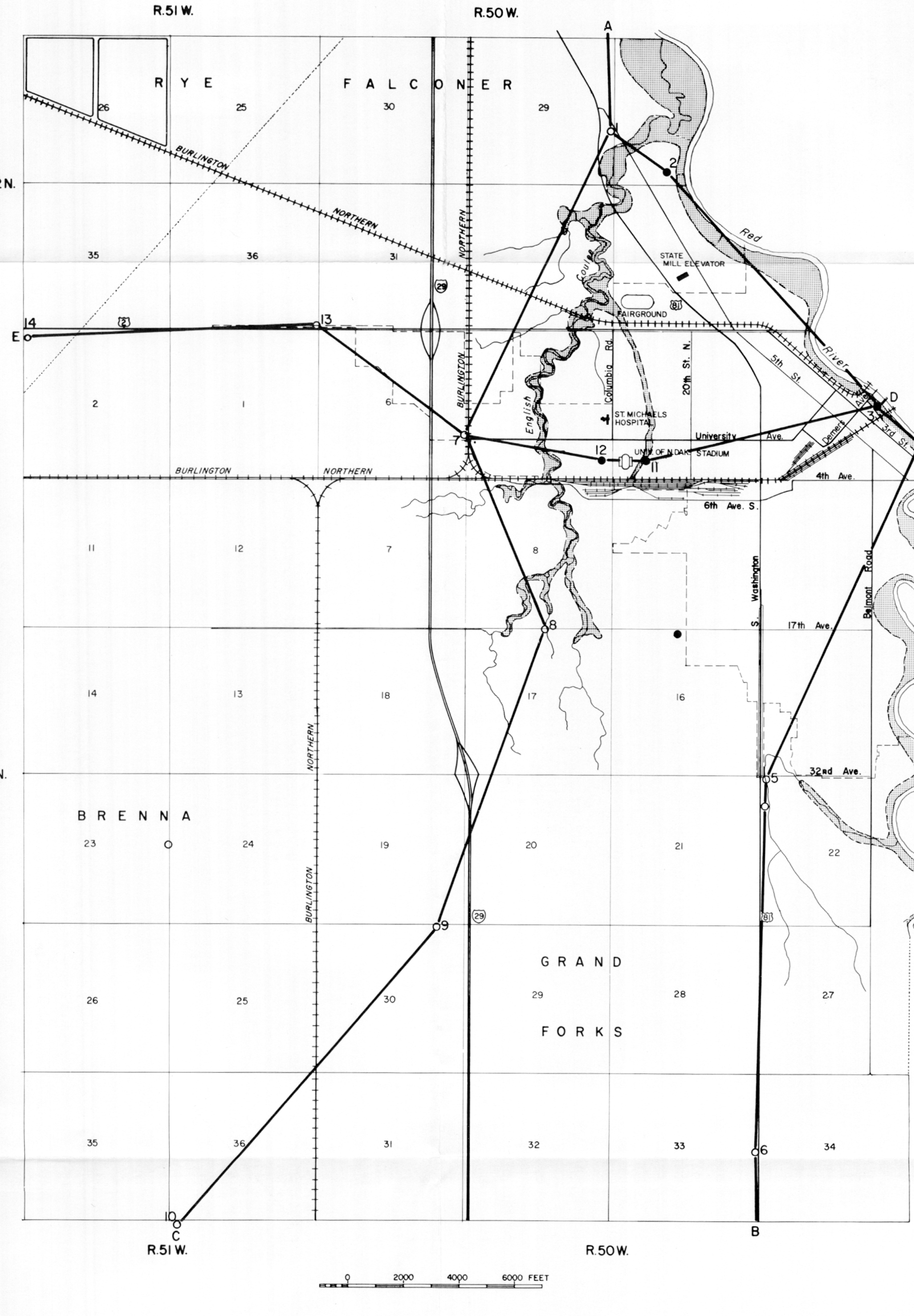
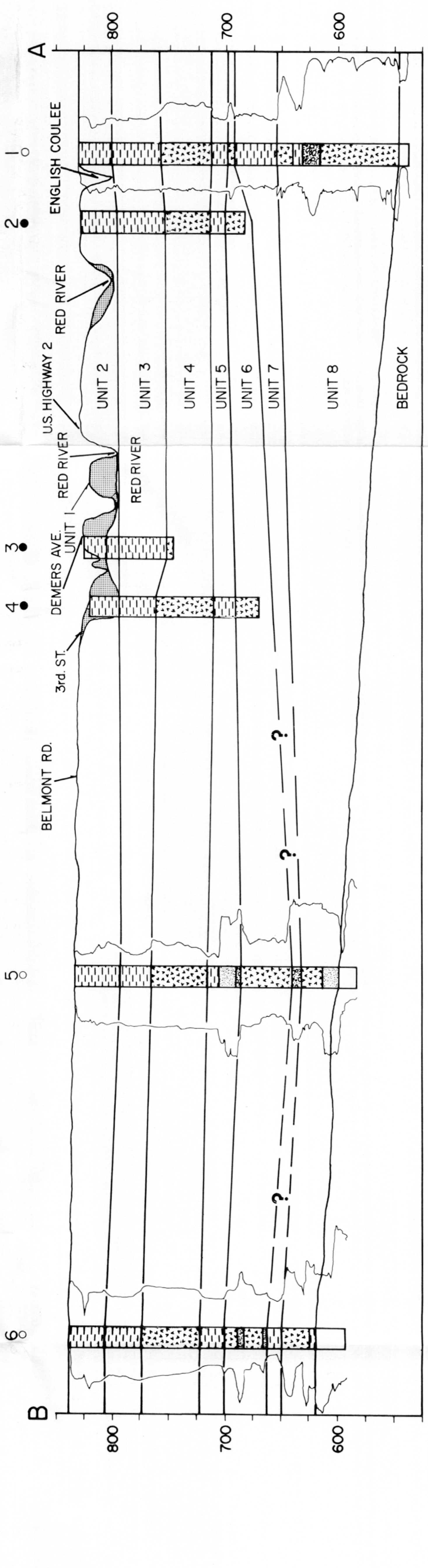
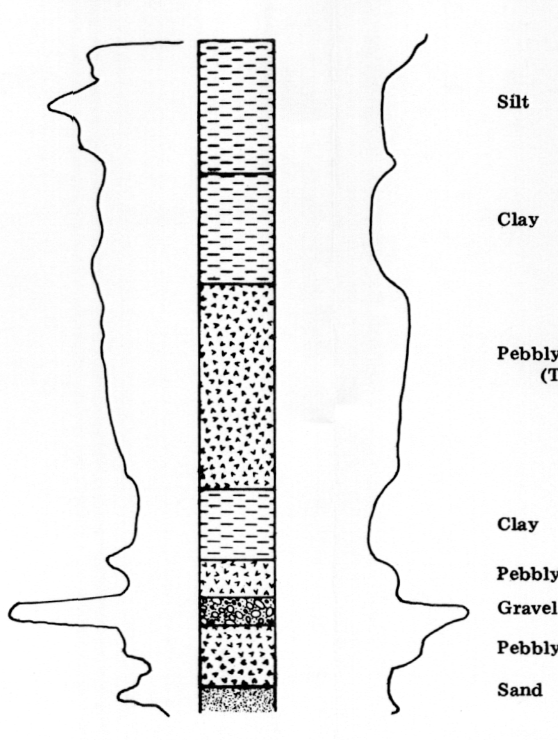








Symbols Used on Cross Sections



Index of Testholes on Cross Sections

	Testhole	Location
1	NDSWC Testhole 2430	T152N, R50W, Sec 29, SE, SE, NE
2	SEC Soil Borings	T152N, R50W, Sec 28, SW, SE, SW
3	NSP Soil Borings	T151N, R50W, Sec 3, SE, NW, NE
4	SEC Soil Borings	T151N, R50W, Sec 3, SE, SE, NE
5	NDSWC Testhole 2431	T151N, R50W, Sec 22, NW, NW, NW
6	NDSWC Testhole 2667	T151N, R50W, Sec 33, NE, SE, SE
7	NDSWC Testhole 2433	T151N, R50W, Sec 6, SE, NE, SE
8	NDSWC Testhole 2676	T151N, R50W, Sec 17, NE, NW, NW
9	NDSWC Testhole 2675	T151N, R50W, Sec 30, NE, NE, NW
10	NDSWC Testhole 2432	T150N, R51W, Sec 1, NW, NW, NW
11	SEC Soil Borings	T151N, R50W, Sec 4, SW, SW, SE
12	SEC Soil Borings	T151N, R50W, Sec 5, SW, SW, SW
13	NDSWC Testhole 2609	T152N, R51W, Sec 36, SE, SE, SE
14	NDSWC Testhole 2434	T151N, R51W, Sec 2, NW, NW, NW

GEOLOGY OF THE GRAND FORKS AREA

by

Stephen R. Moran

Symbols Used on Map and Cross Section

Unit 1

Unit 2 (On Map Only)

Geologic Contact

Railroads

City Limits

Electrical Transmission Line

U. S. Highway

Interstate Highway

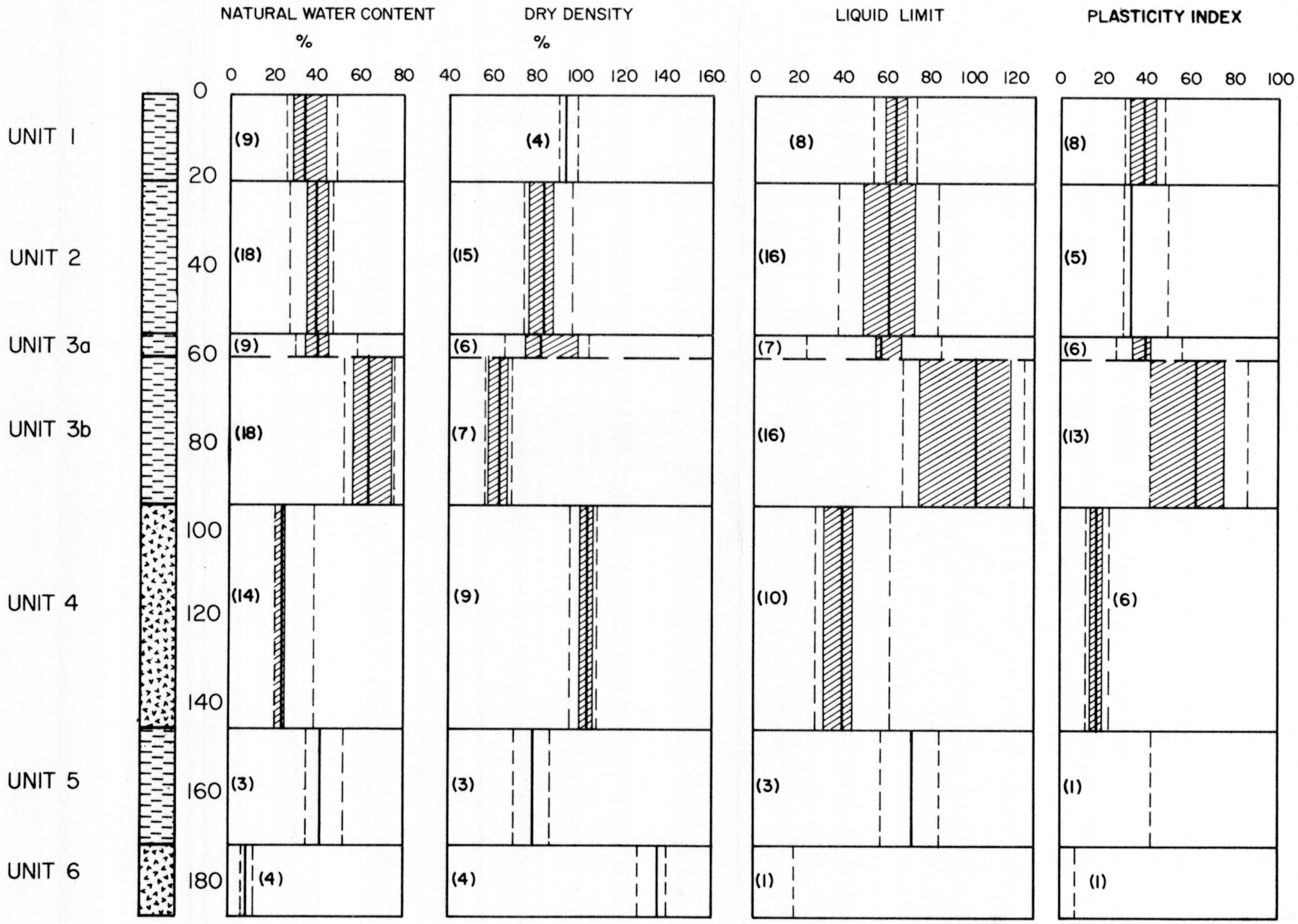
Sources of Subsurface Data

Testholes with electric logs and sample descriptions

Borings with cores

Geologic map modified from Hansen and Kume, 1970
Cartography by D. A. Doucette

SUMMARY OF ENGINEERING TEST DATA



(6) – NUMBER OF ANALYSES

| – MEAN VALUE

60 % OF THE TEST VALUES OCCUR IN THIS RANGE

ALL TEST VALUES OCCUR WITHIN THIS RANGE

UNIT THICKNESSES ARE MEAN THICKNESS IN THE GRAND FORKS AREA