1995

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Recommended Citation
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PHYSICAL DESCRIPTION AND SIGNIFICANCE OF TILLS AT THE DOBMEIER PIT NEAR PARK RIVER, NORTH DAKOTA

A Senior Thesis

By

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Grand Forks, ND

December 20, 1995

ABSTRACT

This study was conducted to describe an exposure of tills and correlate them with the known sequence of tills elsewhere. The Dobmeier pit is a large spring discharge site approximately 3 miles west of Park River, North Dakota (Edinburg Quadrangle, T157N, R56W, Sec. 23, 1/4SE, 1/4NW, 1/4SE). It is between 50 and 75 meters across and 15 to 20 meters deep. It is located on the east edge of the Edinburg Moraine and the south side of the Park River valley. Exposed at the base is a cross-bedded sand and gravel unit. Above is a compact gray till, which is separated by a relatively thin, discontinuous sand lens. Overlying the gray till is a much less compact, yellow brown till. Above the upper till are lenses of cross-bedded sand then a tan, jointed, silty unit; above this the A and B soil horizons are developed in shaley sand and gravel. The pit walls were photographed, sketched and samples collected at 1 meter intervals in the tills and at either side of the contact of the gray and yellow-brown till. Colors of the samples were described using the Munsell Soil Color Chart. Texture was determined by the NDGS hydrometer and sieve method. The coarse sand fraction was then divided into four lithologic groups; shale, carbonate, crystalline, and other. The lower till is very dark grayish-brown to dark olive gray in color. The normalized texture is 34+5 % sand, 45+5 % silt, and 21+3 % clay. The normalized coarse sand lithology is 51+7 % shale, 24+6 % carbonate, and 26+5 % crystalline grains. The upper till is yellowish-brown to brownish-yellow and olive brown in color. The normalized texture is 40+20 % sand, 45+21 % silt, and 15+1 % clay. The normalized coarse sand lithology is 47+7 % shale, 26+6 % carbonate, and 27+1% crystalline grains. The results of this analysis were compared to previous descriptions of tills of the region. The lower unit compares well with the Dahlen Formation. The till of the Dahlen Formation was deposited by a glacier that moved in from the northwest in Late Wisconsinan time, about 12,000 years BP. Stratigraphically, the upper till is most likely the Falconer Formation of which the Edinburg Moraine marks the western extent. The Falconer Formation was deposited in latest Wisconsinan time by a readvance of the same glacier that deposited the Dahlen Formation before 11,000 years BP.

PURPOSE

The first major goal of this project was to contribute knowledge and ideas to the regional stratigraphy and glacial history of northeastern North Dakota. Standard methods were used to describe glacial tills. The results reported here were applied to the known glacial stratigraphy and history of northeastern North Dakota.

The second major goal was to provide a learning experience through a project that encompasses fieldwork through the steps of lab analysis, tabulation and interpretation of results, and finally yielding a document that summarizes the study.

BACKGROUND

Physiographic Setting

Samples were taken from one study site, located in central Walsh County, North Dakota (Figure 1), approximately 5 kilometers west of the town of Park River along Walsh County Highway 17. The site is a few hundred meters north of the highway on the southern edge of the Park River valley and the eastern edge of the Edinburg Moraine (Edinburg Quadrangle, T157N, R56W, Sec. 23, 1/4SE, 1/4NW, 1/4SE). In the vicinity of the site the topography is gently rolling to flat with the crest of the moraine 1-2 kilometers to the east. The Park River has cut a valley 30 to 60 meters below the crest of the moraine (Figure 2).

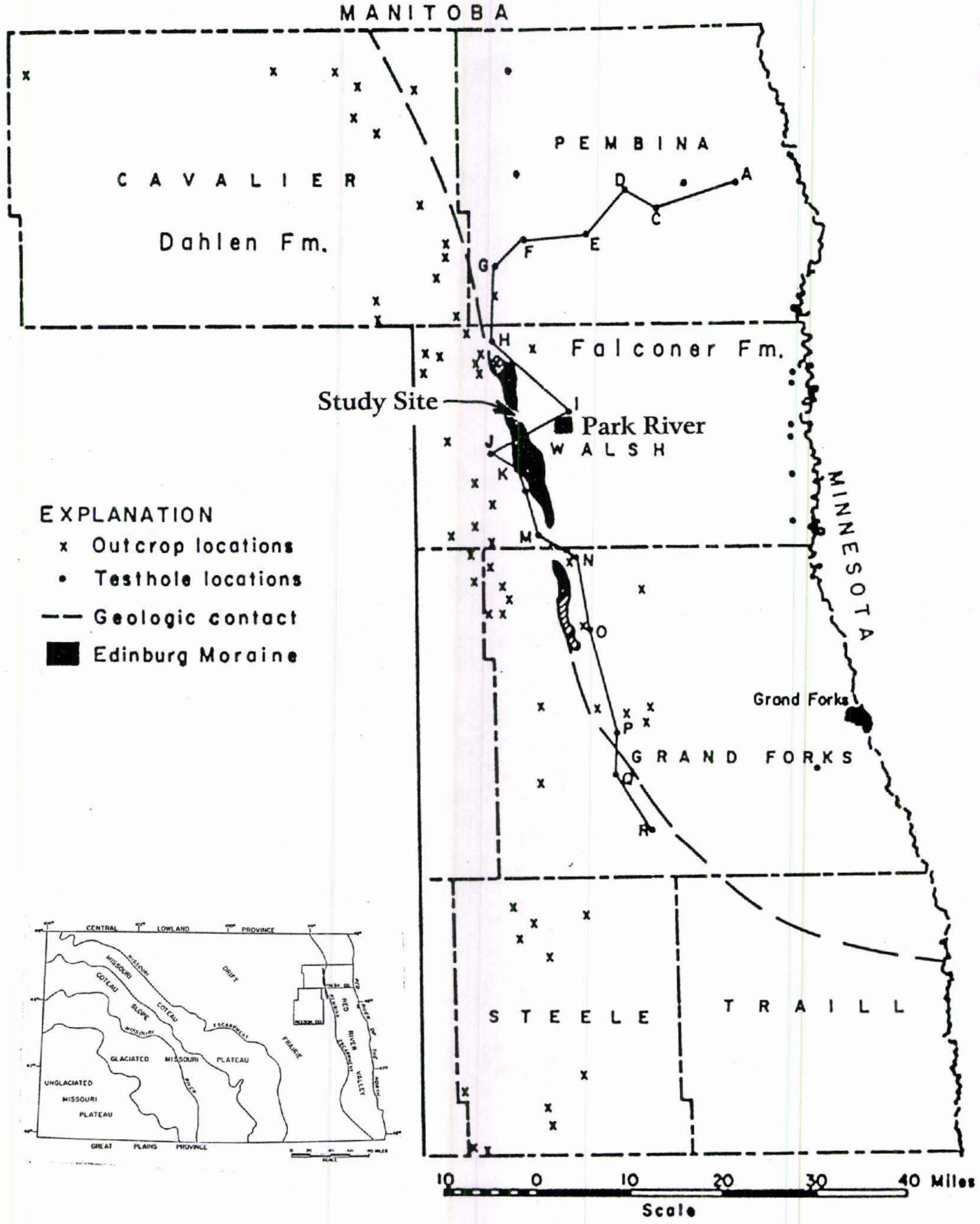

Figure 1. Map showing location of study site and line of stratigraphic cross-section (Figure 4) (adapted from Salomon, 1975).

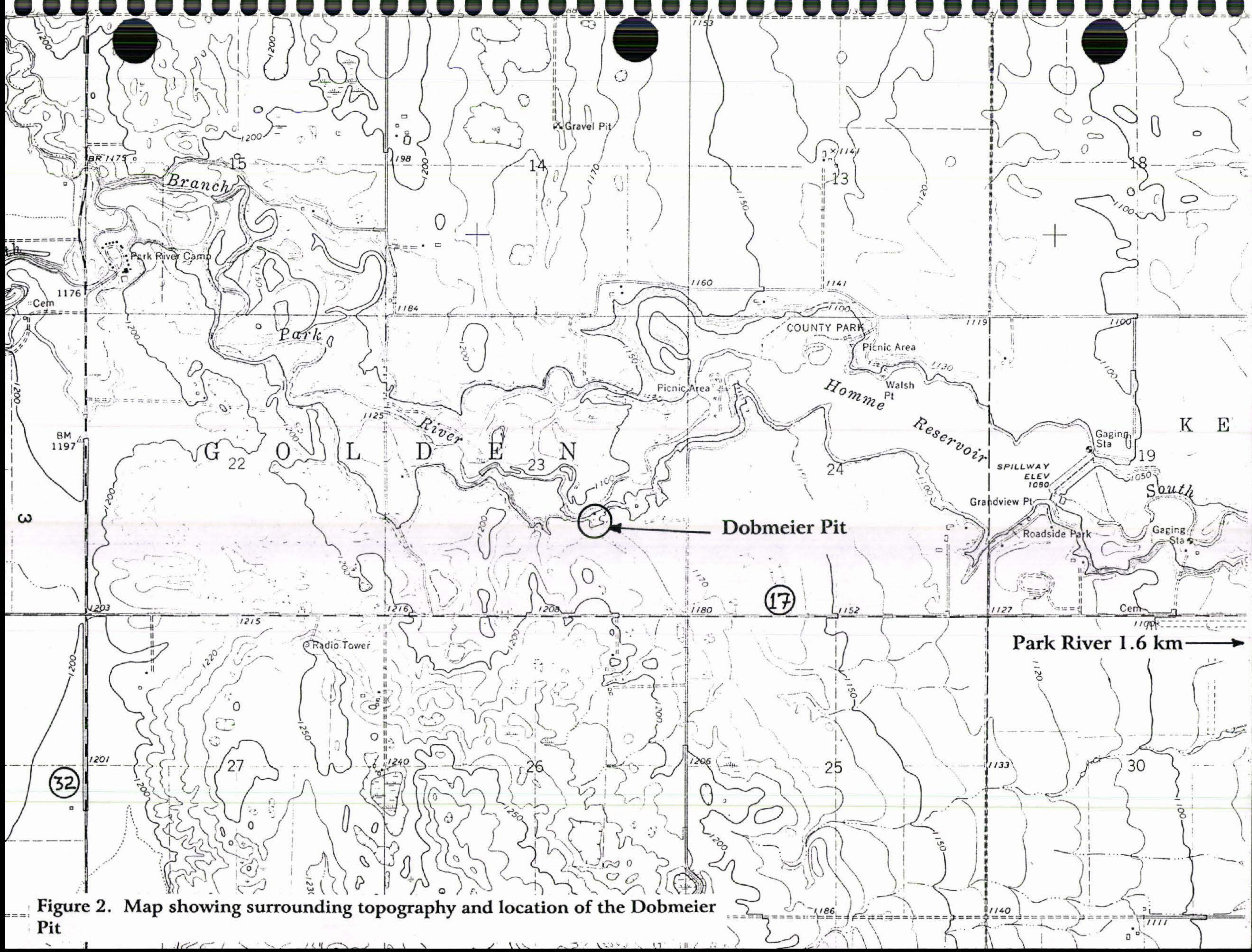

Figure 2. Map showing surrounding topography and location of the Dobmeier Pit

Previous Work

Quaternary sediment in northeastern North Dakota is comprised predominantly of glacial drift of the Coleharbor Formation. In Nelson and Walsh Counties the Coleharbor Formation is 0 to 190 meters thick (Bluemle, 1971). It overlies Mesozoic and Precambrian rocks (Bluemle, 1971). Salomon (1975) provided a more detailed division of the stratigraphy of the Coleharbor Formation as shown in the stratigraphic cross-section of northeastern North Dakota (Figure 3 and Table 1). Late Wisconsinan units most relevant to this study are the Dahlen Formation and the overlying Falconer Formation. Both formations are mostly glacial tills, separated in some areas by the Wylie Formation, which is composed of lake bottom sediments (Salomon, 1975). The western extent of the Falconer Formation is the Edinburg Moraine (Clayton and Moran, 1982). The Dahlen Formation extends farther south and west (Clayton and Moran, 1982). Table 1 shows characteristics of the Dahlen and Falconer Formations and others in the Coleharbor Formation in northeastern North Dakota.

The Study Site

The study site is a spring discharge pit, located on Gerald Dobmeier's land. The pit is a horseshoe-shape feature with the open end to the north at the Park River valley. It is between 50 and 75 meters across and 15 to 20 meters deep. Much of the bottom is very soft to quick where water is actively discharging; the remainder of the bottom is hidden by trees and other riparian vegetation. The water discharges from the head of the pit, forms a few small pools near the open end, and flows as a small stream approximately 0.5 kilometer north into the Park River. Three exposures in the walls of the pit yield an excellent view of the geology. These occur at the east, west, and south walls. Between the exposures, the walls of the pit are less steep, vegetated, and actively sliding and slumping. The remainder of the walls are actively slumping. Stratigraphic relationships at the Dobmeier Pit are shown on the stratigraphic cross-section (Figure 3).

The south exposure was studied in the most detail (Figure 4). Exposed at the bottom is a unit of cross-bedded sand and gravel (6-7 meters thick), from the base of which the spring discharges. Above this is a very dark grayish-brown to dark-olive gray till (7 meters thick), separated approximately halfway by a sand lens. The sand lens is not traceable beyond the south exposure. Overlying the lower till is a much less compact, yellowish-brown to brownish-yellow till (2-3 meters thick). The contact is gradational and irregular. Above the upper till are lenses of cross-bedded sand, then a tan, jointed, silty unit (1-1.5 meters thick). Topmost, the A and B soil horizons are developed in shaley sand and gravel (0.5-1 meter thick).

FIELD METHODS

Fieldwork was done in late August and early September 1995. The first trip was for reconnaissance. During the second trip sketches were made of the pit and all the exposures of the walls; characteristics of the exposures were noted and measurements taken of the units. Further detailed study was concentrated only on the tills. During the third trip samples were collected from the south exposure tills

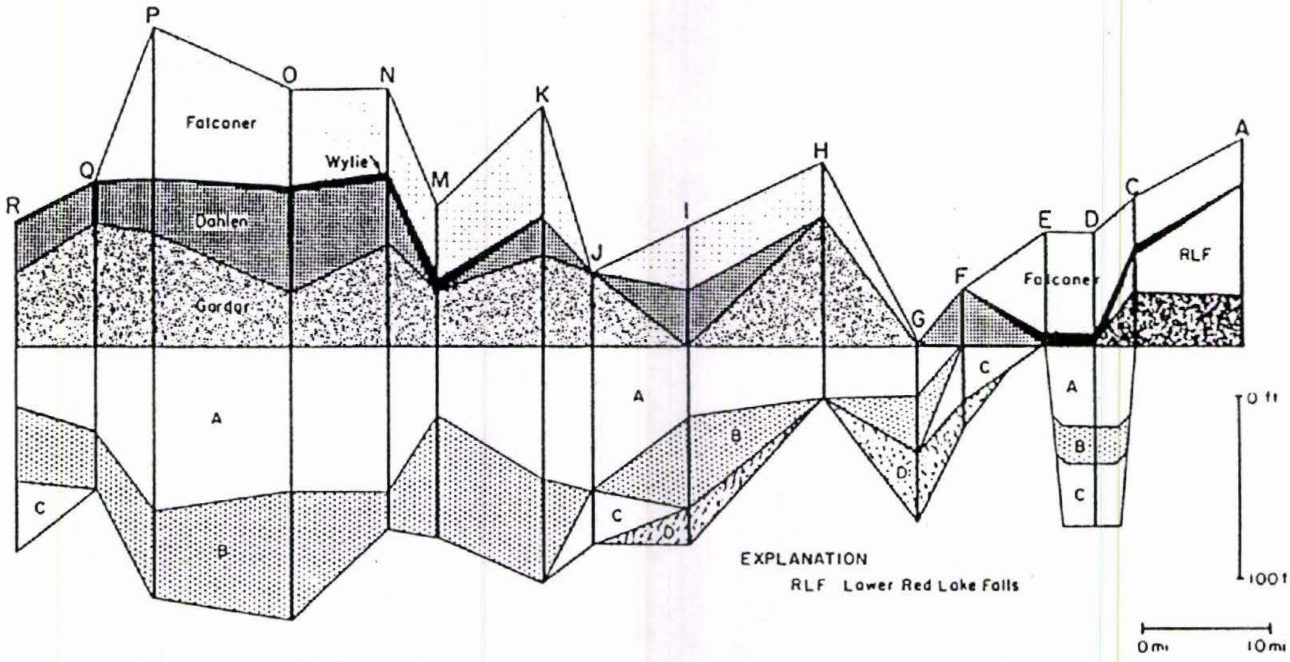

Figure 3. Stratigraphic cross-section of Pleistocene formations in northeastern North Dakota. Datum is the top of unit A - base of Gardar Fm. Location shown on Figure 1 (from Salomon, 1975).

Formation	Color	Structure	Pebble[B] lithology	Number of samples	Mean[C] grain size (%) (Sd-St-C1)	Mean[B] coarse-sand lithology (%) (Cy-Cb-Sh)	Average thickness (feet)	Extent
Falconer[A]	Olive gray	Unbedded, friable	Cb>Cy>Sh	73	31-49-20	40-36-24	20-40	N.E. N.Dak.
Wylie[A]	Olive gray	laminated	No pebbles	0	Silty clay		5-10	N.E. N. Dak. N.W. Minn.
Dahlen[A]	Olive gray	Unbedded, friable	Sh>Cy>Cb	111	35-45-20	31-21-48	10-30	E.N. Dak.
Gardar[A]	Olive gray	Unbedded, blocky	Sh⩾Cy≅Cb	98	35-43-22	13 -9-78	40-70	E. N. Dak.
Lower Red Lake Falls	Olive gray	Unbedded, blocky	Cb>Cy⩾Sh	15	42-39-19	43-54- 3	30-60	N.E. N.Dak. N.W. and W. central Minn.
Unit 1	Olive gray	Unbedded, hard	Cb⩾Cy>Sh	6	32-48-20	32-67- 1	10-30	N.E. N. Dak.
[A]Unit A	Olive gray	Unbedded, blocky	Sh>Cy≅Cb	39	34-37-29	21-17-62	40-80	N.E. N. Dak.
Unit B	Olive gray	Unbedded, friable	Cb>Sh>Cy	24	35-37-28	25-21-54	30-60	N.E. N. Dak.
Unit C	Olive gray	unbedded, hard	Cb>Sh>Cy	11	30-32-38	29-30-41	30-40	N.E. N. Dak.
Unit D	Olive gray	Unbedded, hard	Cb>Cy>Sh	7	28-34-38	35-44-21	10-40	N.E. N. Dak.

[A] Formation cropping out in northeastern North Dakota.
[B] Cy=Crystalline, Cb=Carbonate, Sh=Shale.
[C] Sd=Sand, St=Silt, Cl=Clay.

Table 1 Descriptions of Pleistocene formations in northeastern North Dakota (from Salomon 1975)

Figure 4. Photograph showing units of the south wall.

approximately every 1 meter and at either side of the contact of the upper and lower tills. Samples were not collected from the sand lens, but above and below. Seven samples were collected in the lower till and three in the upper. Each sample's position was measured from the base of the lower till. Approximately 1-2 kilograms of sediment were collected at each location with the surficial wall material removed to expose fresh material. The main features and geology of the pit were thoroughly photographed, as well as the till at the sample locations.

LABORATORY METHODS

Color of moist samples was described using the Munsell Soil Color Chart under fluorescent lighting. Textural analysis was carried out using the North Dakota Geological Survey hydrometer and sieve method (Perkins, 1977). The coarse sand fraction (1-2 mm mean diameter) was sorted into four lithologic groups using a binocular microscope. The groups were shale, carbonate, crystalline, and other. The "other" category covers miscellaneous clasts, such as dark microcrystalline fragments of non-carbonate rock, a few shells, and common aggregates. The aggregates are cemented clay to sand particles. One coarse sand lithology analysis was done for each sample, while two textural analyses were done for each sample except for sample numbers 1, 8, 9, and 10. Due to mistakes in the first analysis these samples weren't completed. The results of the two analyses for the other samples were comparable. Sample number 4 was a random sampling of pebbles from the lower 2 meters of the lower till. No analysis was done on this. The percentages were calculated, charted, and averages and standard deviations determined from average values of each sample location.

RESULTS

Raw data are reported in Appendix I. Color, normalized texture (percentages by weight excluding gravel, for sand, silt, and clay), and normalized coarse sand lithology (percentages not including the "other" category), for each sample are reported in Table 2.

INTERPRETATION

Samples 1, 2, 3, 5, 6, 7, and 8 were defined as belonging to the lower till, based on stratigraphy, color, texture, and coarse sand lithology. Samples 9, 10, and 11 were defined as belonging to the upper till, based on stratigraphy and color.

The standard deviations of the lower till are small compared to that of the upper till, especially for sand and silt, which are plus or minus 20 and 21 percent, respectively. From the data (Table 2) it can be seen that moving vertically upward from sample number 9 to number 11 the sand content decreases from 67 percent to 35 percent to 19 percent. The silt percentages increase from 17 percent to 50 percent to 67 percent for sample numbers 9, 10, and 11, respectively. The clay percentages stay within 1 percent of each other.

			Color		Texture (Percent by Weight) Normalized			Coarse Sand Lithology (Percent by Count) Normalized		
	Sample Number	Height Above Till Base (m)	Munsell	Description	Sand	Silt	Clay	Shale	Carbonate	Crystalline
Upper Till	11	9.8	10YR 5/8 10YR 5/4	Yellowish-Brown Yellowish-Brown	19	67	14	37	35	29
	10	8.9	10YR 5/6	Yellowish-Brown	35	50	16	51	23	26
	9	7.9	10YR 6/8 2.5Y 4/4	Brownish-Yellow Olive-Brown	67	17	15	52	21	27
	Averages				40	45	15	47	26	27
	Standard Deviation				20	21	1	7	6	1
Lower Till	8	6.9	2.5Y 3/2	V. Dk. Grayish-Brown	37	49	15	45	33	22
	7	5.9	2.5Y 3/2	V. Dk. Grayish-Brown	40	40	20	45	28	27
	6	4.9	2.5Y 3/2	V. Dk. Grayish-Brown	28	47	25	54	25	21
	5	4.3	5Y 3/2	Dk. Olive-Gray	42	38	20	42	23	35
	3	2.6	5Y 3/2	Dk. Olive-Gray	31	47	22	52	24	24
	2	1.6	2.5Y 3/2	V. Dk. Grayish-Brown	31	48	21	61	15	25
	1	0.3	5Y 3/2	Dk. Olive-Gray	30	49	21	55	20	25
	Averages				34	45	21	51	24	26
	Standard Deviation				5	5	3	7	6	5

Table 2. Summary of characteristics of the samples and tills at the Dobmeier Pit.

In Figures 5 and 6 the textures of samples from the lower and upper tills are plotted and compared to tills described by Salomon (1975) using ternary diagrams. In Figure 6 the sample numbers refer to the table in Appendix I. Salomon's Gardar, Dahlen, and Falconer Formations all have approximately the same texture as the lower till and the average of the upper till. Figures 7 and 8 show the coarse sand lithology plotted from Salomon's data and the lower and upper tills. Both of the tills from this study fall in the same general area on this diagram and they coincide most closely with the Dahlen Formation (Salomon, 1975).

Salomon's Dahlen Formation is olive-gray in color (Table 1), similar to the lower till which is very dark grayish-brown to dark olive-gray (Table 2). Salomon's Falconer Formation is also olive-gray (Table 1). In contrast, the upper till is yellowish-brown to brownish-yellow with a little olive-brown (Table 2).

Although the upper till from this study is different in physical characteristics from reported units, it fits stratigraphically as the Falconer Formation with the lower till as the Dahlen Formation. This stratigraphy also fits spatially. The Falconer Formation should be the uppermost till on the east edge of the Edinburg Moraine (Salomon, 1975)(Figure 1).

Margin J (Clayton and Moran,1982) marks the southwestern-most extent of the Dahlen Formation in North Dakota and shows correlated ice margins in the upper midwest (Figure 9). Margins K and L are the margins of intermediate minor readvances of the ice sheet which occurred before a major retreat into southern Manitoba. During this retreat, sediments of the Wylie Formation were deposited. Margins J, K, and L are younger than 12,025 + 205 BP (Clayton and Moran, 1982). Margin M marks the western-most extent of the Falconer Formation at the Edinburg Moraine, evidence of another readvance (Figure 10). Margin N marks extent of the last known advance into North Dakota. Margins M and N are dated between 9570 + 130 BP and 10,960 + 300 BP (Clayton and Moran, 1982). All dates are based on radiocarbon dated wood. Figure 11 shows the ice sheet and marginal features in Nelson and Walsh Counties during the deposition of the Dahlen Formation (after margins J, K, and L). Figure 12 shows the position of the ice during deposition of the Edinburg Moraine in Walsh County (margin M).

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK

The lower till described in this study is most likely the Dahlen Formation deposited around 12,000 BP. The upper till is likely the Falconer Formation of which the Edinburg End Moraine marks the western extent. Deposition of the Falconer Formation occurred around 11,000 BP.

The results of this study are tentative because conclusions were drawn from one study site. A more extensive description of all the units should be done of the south exposure and the other exposures in the Dobmeier Pit should be done and the lateral extent of the units should be found. This will give clearer stratigraphic model of northeastern North Dakota and allow correlation with a current model of the southern Red River Valley (Harris, in preparation). An excellent computer program developed by Harris of the Minnesota Geological Survey is being used to define tills and correlate them with units described by other workers. This program will further aid in developing

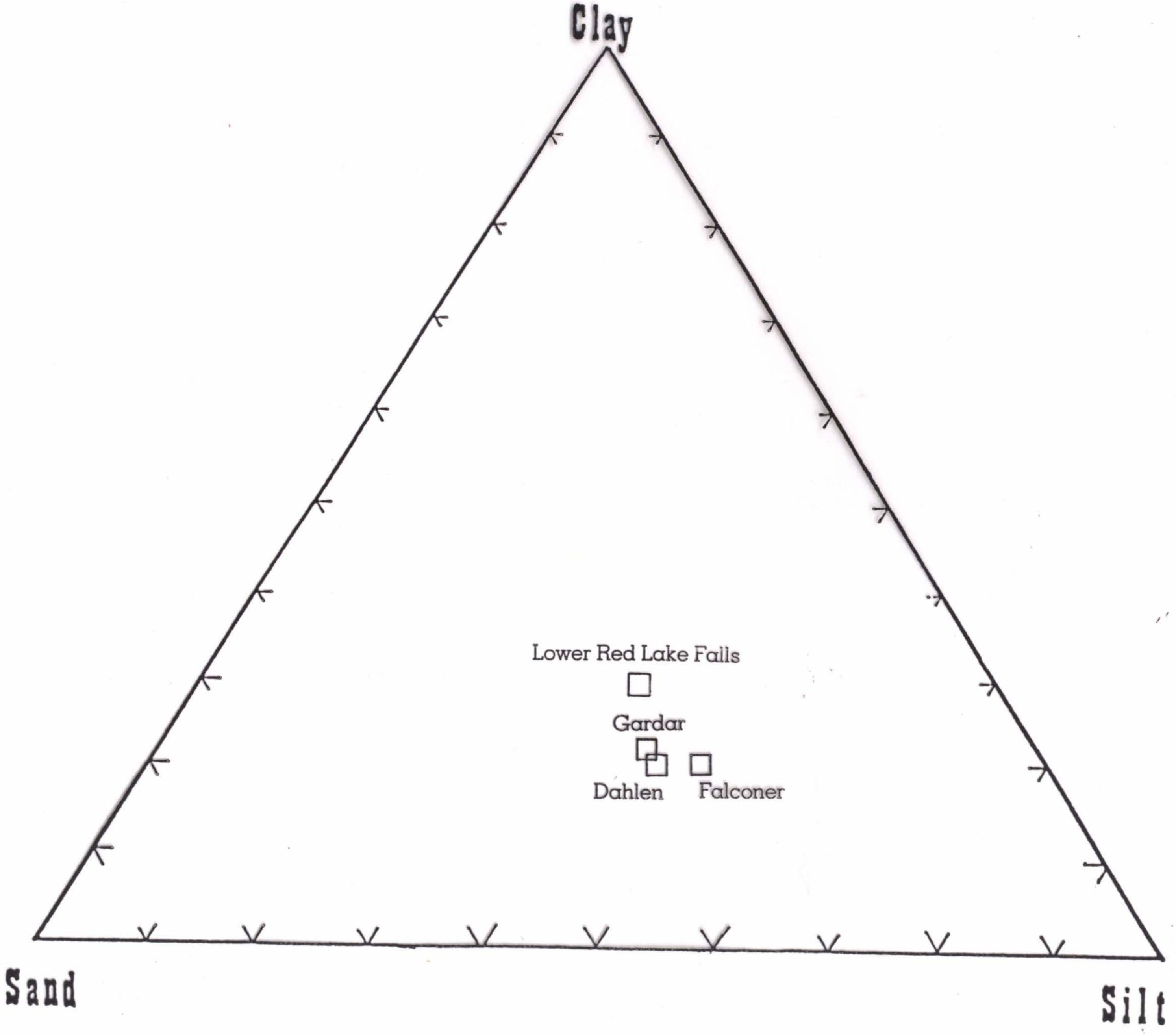

Figure 5. Texture of tills in northeastern North Dakota (plotted from data of Salomon, 1975).

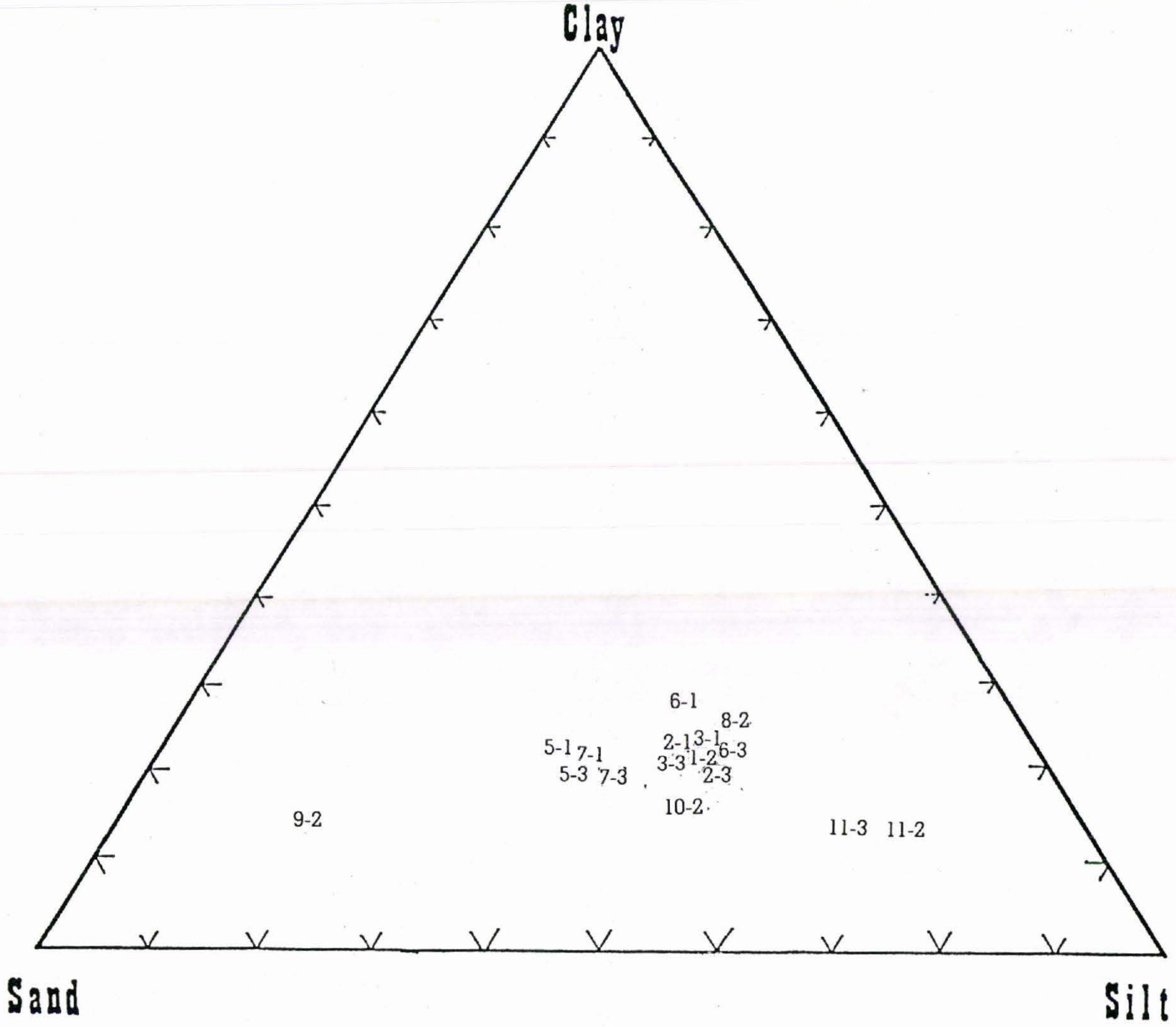

Figure 6. Texture of samples from the Dobmeier Pit, south wall.

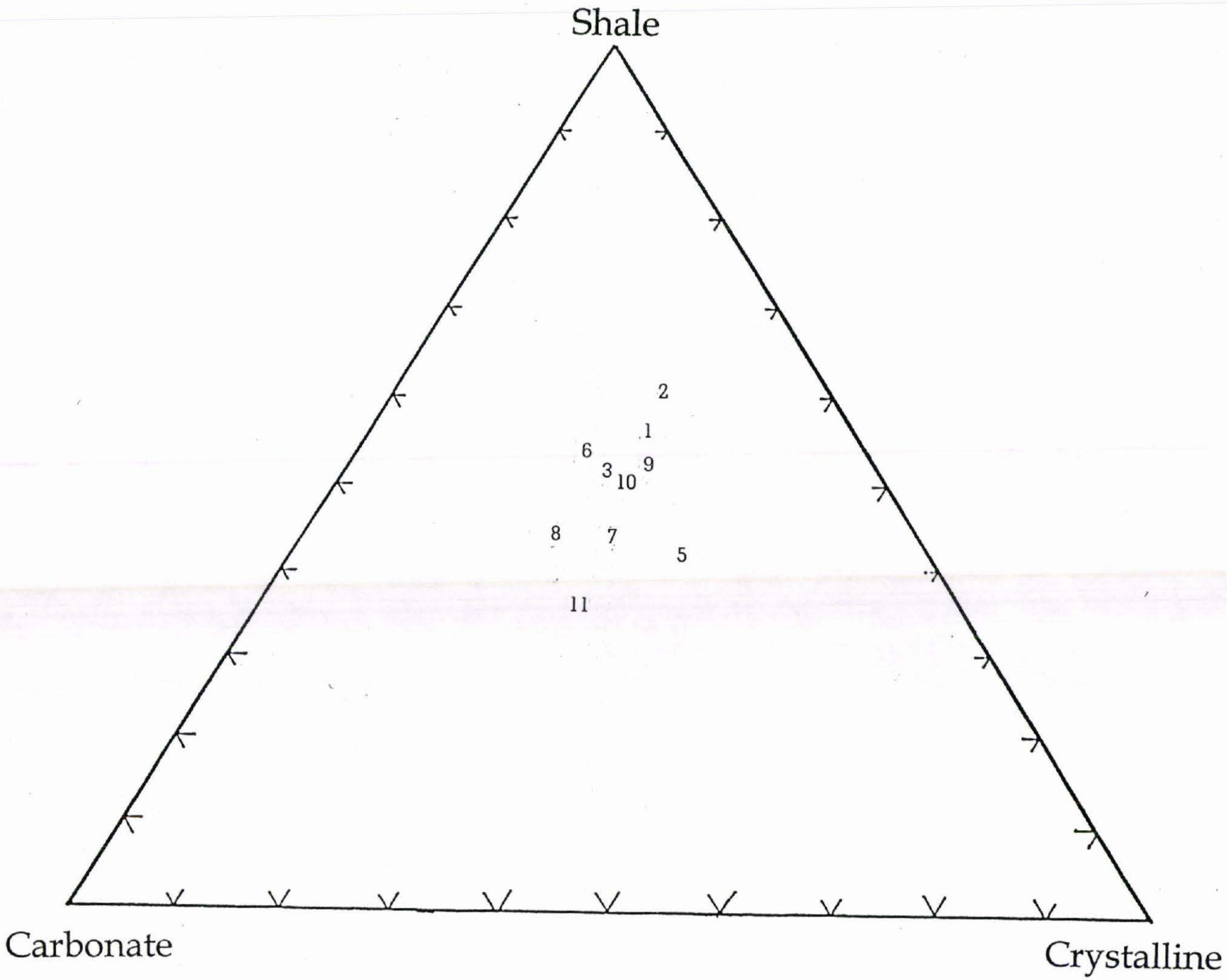

Figure 8. Coarse sand lithology of samples from the Dobmeier Pit, south wall.

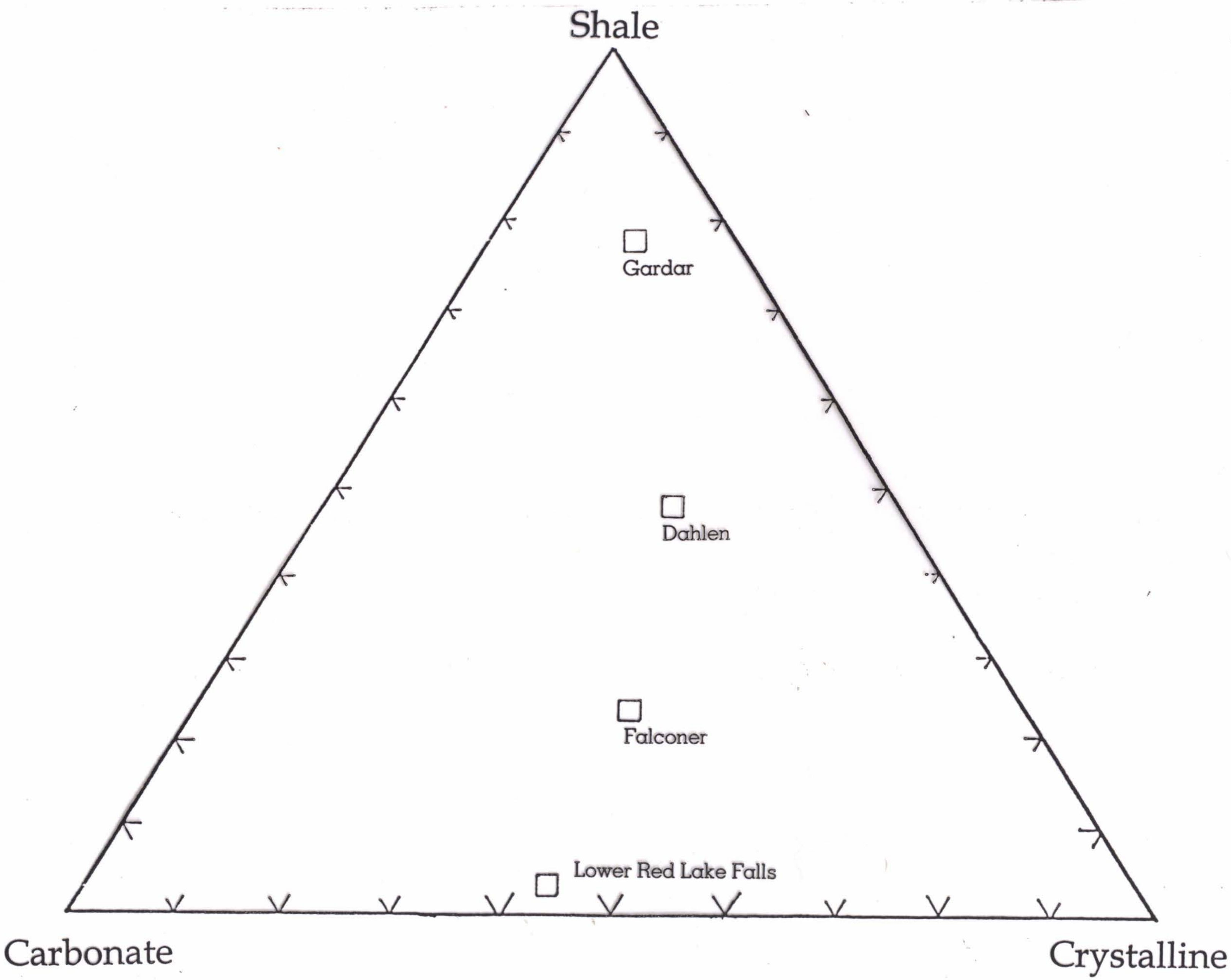

Figure 7. Coarse sand lithology of tills in northeastern North Dakota (plotted from data of Salomon, 1975).

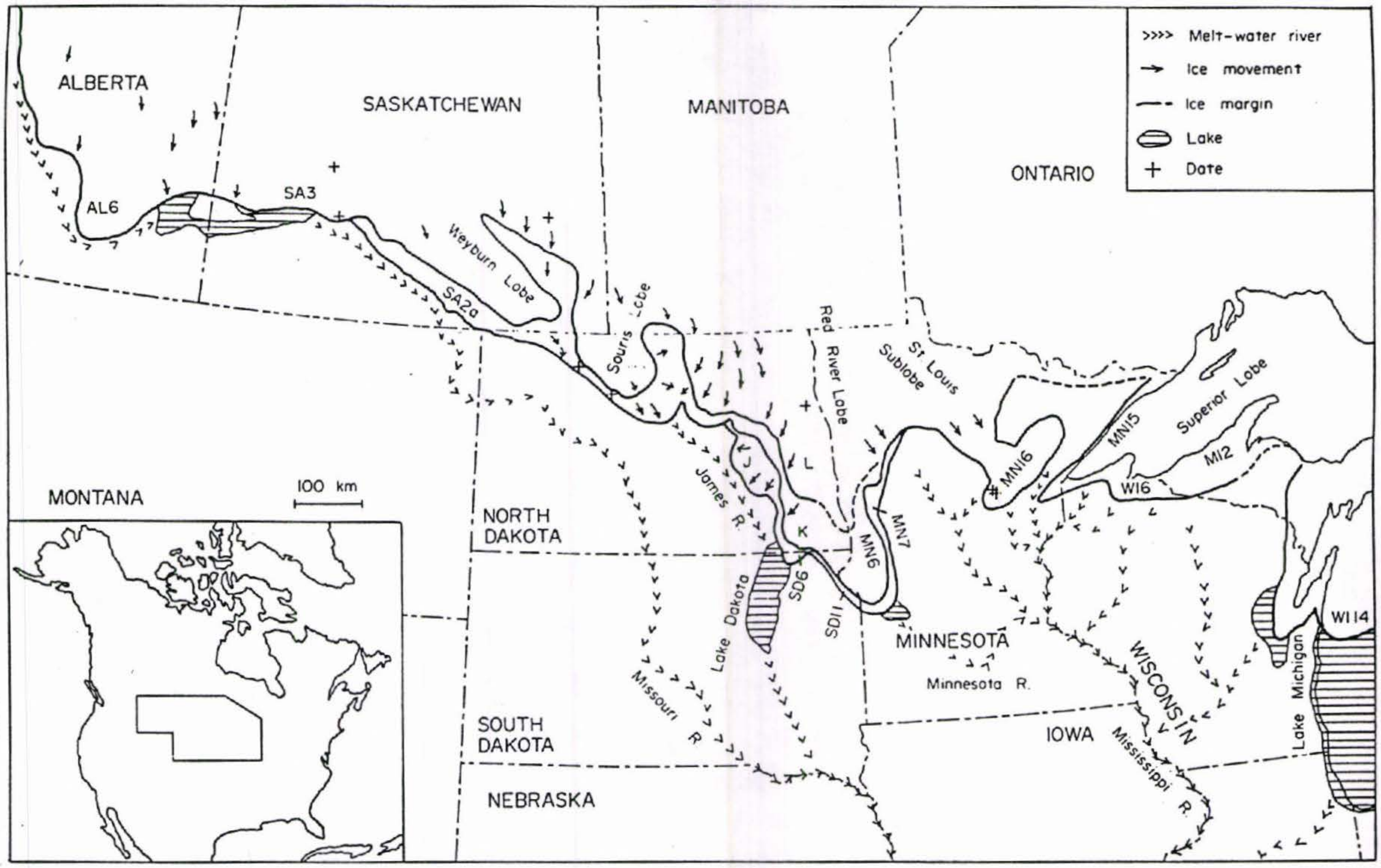

Figure 9. Ice-margins in middle North America during Late Wisconsinan time (see text for explanation) (from Clayton and Moran, 1982).

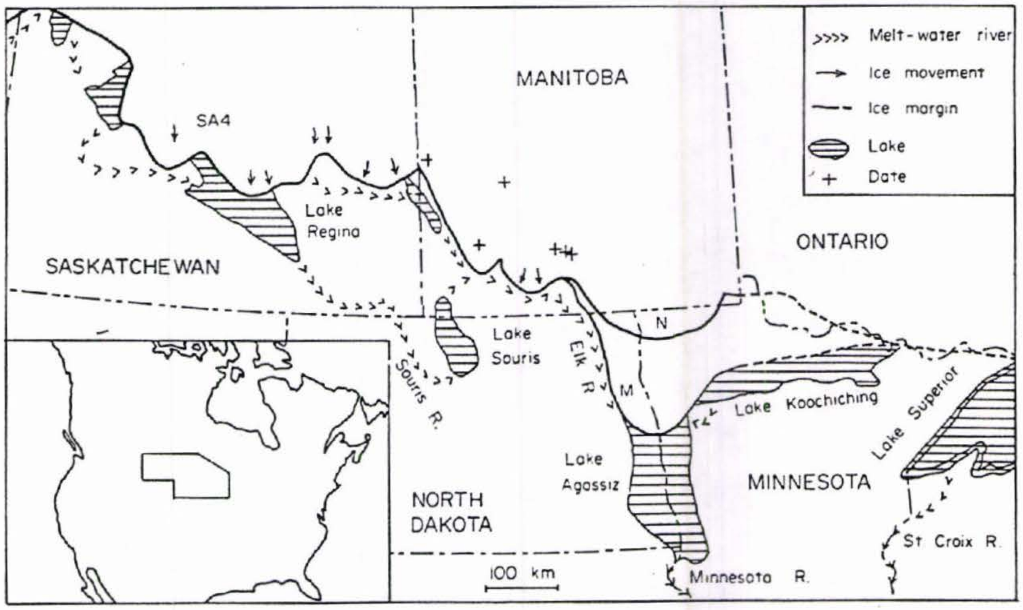

Figure 10. Ice-margins in middle North America during latest Wisconsinan time (see text for explanation) (from Clayton and Moran, 1982).

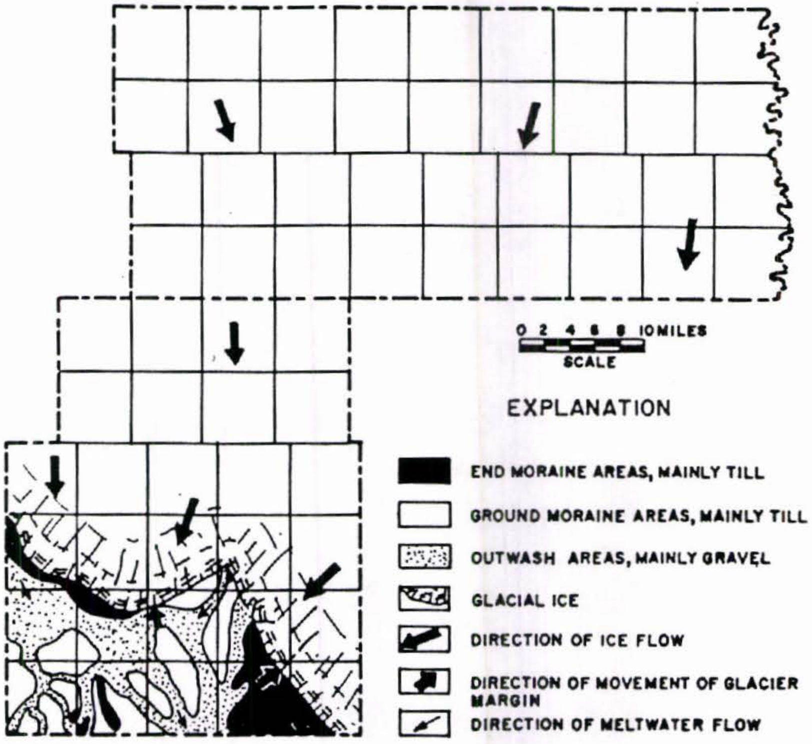

Figure 11. Glacial cover and features of Nelson and Walsh Counties during Late Wisconsinan time during the retreat that deposited the Dahlen Fm. (from Bluemle, 1973).

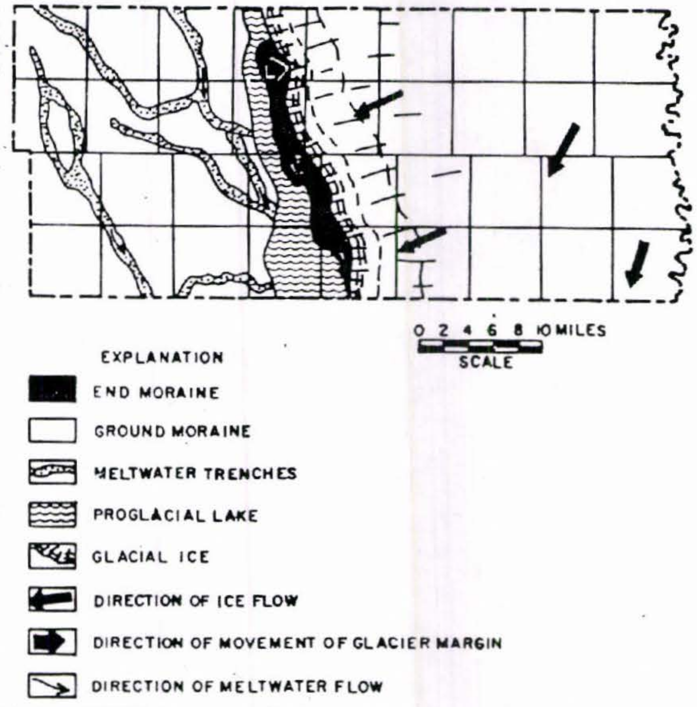

Figure 12. Glacial cover and features of Walsh County during latest Wisconsinan time, during depostion of the Edinburg Moraine.

a more refined glacial stratigraphy of the region and upper midwest. Further investigation into the specific depositional processes and environments of the units would add to knowledge and understanding of past glaciation. Such investigations might include excavating contacts, and conducting further textural as well as fabric analyses.

ACKNOWLEDGMENTS

I would like to thank my advisor on this project, Dr. John Reid, for his help and guidance; Jon Ellingson for his help with the laboratory analyses; Jon Lever, Penny Sakry, and Karyn Alme for joining me in the field; and Luke Schmidt for the use of his car to do field work. I extend much appreciation to the UND Department of Geology and Geological Engineering for funding the costs incurred. Thanks also go to the Dobmeier family for allowing me and other University of North Dakota students access to the land on which they reside, and to the pit. Finally, thanks go to all my friends and family who provided moral support.

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APPENDIX I
Summary of Raw Data

			Texture (Percent by Weight)				Coarse Sand Lithology (Percent by Count)			
Sample	hght above till									
Number	base (m)	Color	Gravel	Sand	Silt	Clay	Shale	Carbonate	Crystalline	Other
11-2	9.8	10YR 5/8	2	17	68	13	31	29	24	16
11-3	9.8	10YR 5/4	12	19	57	12				
10-2	8.9	10YR 5/6	7	32	46	14	35	16	17	32
9-2	7.9	10YR 6/8	5	64	16	14	34	14	18	34
		2.5Y 4/4								
8-2	6.9	2.5Y 3/2	7	34	46	13	29	21	15	35
7-1	5.9	2.5Y 3/2	7	37	36	20	43	27	26	4
7-3	5.9	2.5Y 3/2	9	36	38	18				
6-1	4.9	2.5Y 3/2	8	24	36	23	52	24	20	4
6-3	4.9	2.5Y 3/2	7	26	47	21				
5-1	4.3	5Y 3/2	8	39	34	20	39	21	32	9
5-3	4.3	5Y 3/2	8	39	36	18				
3-1	2.6	5Y 3/2	6	27	44	22	50	23	23	4
3-3	2.6	5Y 3/2	6	31	44	19				
2-1	1.6	2.5Y 3/2	6	30	44	20	60	14	25	1
2-3	1.6	2.5Y 3/2	5	29	46	20				
1-2	0.3	5Y 3/2	4	29	47	20	53	19	24	4

Figure 13. Summary of raw data of samples from the Dobmeier Pit, south wall

APPENDIX II
Raw Data Sheets

TEXTURAL ANALYSIS

Batch Designation ②

Gravel 3.55% Sand 29.3% Silt 47.3% Clay 19.8%

aker Number 1

Temperature 23.5 °C

Sample Designation 1

Time Set Up 2:30:30

8:40 30

148 min

Time to Read Hydrometer 4:58:30

2 hr 28 min

45.35

A) Total Sample Weight

B) Gravel + Envelope 4.72

C) Gravel Envelope 2.61

D) Weight of Gravel 1.61 (B-C) — 3.55% % (D / A)

Corrected Sample Weight 43.74 (A-D)

	1-2mm	<1mm
F) Sand + Envelope	3.85	14.68
G) Sand Envelope	2.62	2.63
H) F-G	1.23	12.05

I) Weight of Sand 13.28 ((1-2mm H + <1mm H)) — 30.36 % (I / E)

J) Hydrometer Reading 15.5

K) Calgon Hydrometer Reading 6.5

Weight of Clay 9.0 (J-K) — 20.6 % (L / E)

M)Weight of Silt 21.46 (E - I - L) — 49.06 % (M / E)

TEXTURAL ANALYSIS

Total Sample %

Batch Designation 1

Gravel 5.70% Sand 30.0% Silt 44.3% Clay 20.0%

aker Number 2

Temperature 20°C

Sample Designation 2

Time Set Up 5:32:30
7 40 30

Time to Read Hydrometer 11:13:00

A) Total Sample Weight 45.06

B) Gravel + Envelope 5.22 g

C) Gravel Envelope 2.65 g

D) Weight of Gravel 2.57 g (B-C) 5.70 % (D / A)

Corrected Sample Weight 42.49 (A-D)

	1-2mm	<1mm
F) Sand + Envelope	4.22	14.56 ~~[illegible]~~
G) Sand Envelope	2.63 g	2.62 g
H) F-G	1.59 g	11.94 g

I) Weight of Sand 13.53 (1-2mm H + <1mm H) 31.8 % (I / E)

J) Hydrometer Reading 16.0

K) Calgon Hydrometer Reading 7.0

Weight of Clay 9.0 (J-K) 21.2 % (L / E)

M) Weight of Silt 19.96 (E - I - L) 47.0 % (M / E)

TEXTURAL ANALYSIS

Batch Designation 3

Gravel 4.81% Sand 29.2% Silt 46.1% Clay 20.0%

Beaker Number 2

Temperature 21.5°C (154.6 min)

Sample Designation 2

Time Set Up 12:02:30
2:34:30

Time to Read Hydrometer 2:37:00

A) Total Sample Weight 45.07

B) Gravel + Envelope 7.47

C) Gravel Envelope 5.30

D) Weight of Gravel 2.17 (B-C) 4.81 % (D / A)

E) Corrected Sample Weight 42.90 (A-D)

	1-2mm	<1mm
F) Sand + Envelope	6.75	17.03
G) Sand Envelope	5.30	5.34
H) F-G	1.45	11.69

I) Weight of Sand 13.14 (1-2mm H + <1mm H) 30.6 % (I / E)

J) Hydrometer Reading 15.5

K) Calgon Hydrometer Reading 6.5

L) Weight of Clay 9.0 (J-K) 21.0 % (L / E)

M) Weight of Silt 20.76 (E - I - L) 48.4 % (M / E)

TEXTURAL ANALYSIS

Batch Designation 1

Gravel 6.40% Sand 27.4% Silt 44.2% Clay 22.0%

aker Number 3

Temperature 20°C

Sample Designation 3

Time Set Up 8:36:30

1 1

2 40 30

Time to Read Hydrometer 11:17:00

A) Total Sample Weight 45.39

B) Gravel + Envelope 5.53

C) Gravel Envelope 2.63

D) Weight of Gravel 2.90 (B-C) — 6.40 % (D / A)

Corrected Sample Weight 42.49 (A-D)

	1-2mm	<1mm
F) Sand + Envelope	4.17	13.52
G) Sand Envelope	2.63	2.64
H) F-G	1.54	10.88

I) Weight of Sand 12.42 (1-2mm H + <1mm H) — 29.2 % (I / E)

J) Hydrometer Reading 17.0

K) Calgon Hydrometer Reading 7.0

Weight of Clay 10.0 (J-K) — 23.5 % (L / E)

M) Weight of Silt 20.07 (E - I - L) — 47.2 % (M / E)

TEXTURAL ANALYSIS

Batch Designation ~~#8~~ ②

Gravel 3.55% Sand 29.3% Silt 47.3% Clay 19.8%

Beaker Number ~~#~~1

Temperature ~~20°C~~ 23.5 °C

Sample Designation 1

Time Set Up ~~8:39:30~~ 2:30:30 148 min
8:40 30

Time to Read Hydrometer ~~1:10~~ 4:58:30 2 hr 28min

45.35

A) Total Sample Weight [illegible]

B) Gravel + Envelope 4.72

C) Gravel Envelope 2.61

D) Weight of Gravel 1.61 B-C 3.55% % D / A

E) Corrected Sample Weight 43.74 A-D

	1-2mm	<1mm	
F) Sand + Envelope	3.85	14.68	
G) Sand Envelope	2.62	2.63	
H) F-G	1.23	12.05	
I) Weight of Sand	13.28 (1-2mm H + <1mm H)		30.36 % I / E
J) Hydrometer Reading	[illegible] 15.5		
K) Calgon Hydrometer Reading	~~7.0~~ 6.5		
L) Weight of Clay	~~45~~ 9.0 J-K		20.6 % L / E
M) Weight of Silt	21.46 E - I - L		49.06 % M / E

-Hard, compact, well consdidated, distinctly jointed
-Breaks in massive chunks along joints parallel to face
-Color

Hue ~~10YR 3/1 very dark gray~~
5Y 3/2 Dark Olive gray
or
~~2.5Y 3/2 very dark grayish brown~~

CS Lith

Shale
[illegible] [illegible] (206)
[illegible]
53.2%

Xstalline
85+5+2
(92)
23.8%

Carbonate
11+62 (73)
18.9%

Other
13+3
(16)
4.13%

Total 387

NormTTL = 371

Shale	53.2%
Xstal	23.8%
Carb	18.9%
Other	4.13%

Norm

Shale	55%
Carb	20%
Xstal	25%

TEXTURAL ANALYSIS

Total Sample %

Gravel 5.70% Sand 30.0% Silt 44.3% Clay 20.0%

Batch Designation 1

aker Number 2

Sample Designation 2

Temperature 20°C

Time Set Up $\overset{1}{8}$:3$\overset{1}{2}$:30
7 40 30

Time to Read Hydrometer 11:13:00

A) Total Sample Weight 45.06

B) Gravel + Envelope 5.~~[illegible]~~22 g

C) Gravel Envelope 2.65 g

D) Weight of Gravel 2.57 g (B-C) 5.70 % (D / A)

Corrected Sample Weight 42.49 (A-D)

	1-2mm	<1mm
F) Sand + Envelope	4.22	~~[illegible]~~ 14.56
G) Sand Envelope	2.63 g	2.62 g
H) F-G	1.59 g	11.94 g

I) Weight of Sand 13.53 (1-2mm H + <1mm H) 31.8 % (I / E)

J) Hydrometer Reading 16.0

K) Calgon Hydrometer Reading 7.0

Weight of Clay 9.0 (J-K) 21.2 % (L / E)

M) Weight of Silt 19.96 (E - I - L) 47.0 % (M / E)

Color

~~5YR 3/1~~ 2.5Y 3/2 very dark grayish brown

~~7.5YR 3/2~~

~~10YR 3/1~~

~~5Y 3/1~~

- Compact, well consolidated.
- Less compact than #1
- Breaks along mor irregular fractures than 1 & more crumbly, still along joints

V. Coarse Sand Lithology - very angular to sub rounded

Carbonate

+35+32

35

(67)

Shale very angular

100+100+80

(280)

X-stalline

25+23+32+35

48

(115)

other

(3)

Total 465

Norm TL = 462

Shale	60.2%
Xstal	24.7%
Carb	14.4%
other	.65%

Norm

Shale	61%
Carb	15%
Xsfal	25%

TEXTURAL ANALYSIS

Batch Designation 3

Gravel 4.81% Sand 29.2% Silt 46.1% Clay 20.0%

Beaker Number 2

Temperature 21.5°C (154.6 min)

Sample Designation 2

Time Set Up 12:02:30
2:34:30

Time to Read Hydrometer 2:37:00

A) Total Sample Weight 45.07

B) Gravel + Envelope 7.47

C) Gravel Envelope [illegible] 5.30

D) Weight of Gravel 2.17 (B-C) 4.81 % (D / A)

E) Corrected Sample Weight 42.90 (A-D)

	1-2mm	<1mm
F) Sand + Envelope	6.75	17.03
G) Sand Envelope	5.30	5.34
H) F-G	1.45	11.69

I) Weight of Sand 13.14 (1-2mm H + <1mm H) 30.6 % (I / E)

J) Hydrometer Reading [illegible] 15.5

K) Calgon Hydrometer Reading 6.5

L) Weight of Clay 9.0 (J-K) 21.0 % (L / E)

M) Weight of Silt 20.76 (E - I - L) 48.4 % (M / E)

TEXTURAL ANALYSIS

Batch Designation 1

Gravel 6.40% Sand 27.4% Silt 44.2% Clay 22.0%

aker Number 3

Temperature 20°C

Sample Designation 3

Time Set Up 8:36:30
2 40 30

Time to Read Hydrometer 11:17:00

A) Total Sample Weight 45.39

B) Gravel + Envelope 5.53

C) Gravel Envelope 2.63

D) Weight of Gravel 2.90 (B-C) 6.40 % (D / A)

Corrected Sample Weight 42.49 (A-D)

	1-2mm	<1mm
F) Sand + Envelope	4.17	13.52
G) Sand Envelope	2.63	2.64
H) F-G	1.54	10.88

I) Weight of Sand 12.42 (1-2mm H + <1mm H) 29.2 % (I / E)

J) Hydrometer Reading 17.0

K) Calgon Hydrometer Reading 7.0

Weight of Clay 10.0 (J-K) 23.5 % (L / E)

M) Weight of Silt 20.07 (E - I - L) 47.2 % (M / E)

- less compact + crumblier than #2 (+1)
- slightly yellow on outside of chunks (oxidation?)
- color (slightly yellower than #1)

5Y 3/2 dk olive gray

V.CS Lith

x-stalline

1+64+30+9

104

Carbonate

77 + [illegible] +2+24+1

104

Shale

100+100+29

229

Other 17

10 shell fragments
4 oxidized aggregates
2 other

Total 454

NormTTL = 437

Shale 50.4%
Carb 22.9%
Xstal 22.9%
Other 3.74%

Norm

Shale 52%
Carb 24%
Xstal 24%

TEXTURAL ANALYSIS

Batch Designation 3

Gravel 6.40% Sand 30.9% Silt 44.0% Clay 18.7%

Beaker Number 3

Temperature 21.5°C (154.6 min)

Sample Designation 3

Time Set Up 12:07:30
2:34:30

Time to Read Hydrometer 2:42:00

A) Total Sample Weight 45.47

B) Gravel + Envelope 8.19

C) Gravel Envelope 5.28

D) Weight of Gravel 2.91 (B-C) 6.40 % (D / A)

E) Corrected Sample Weight 42.56 (A-D)

	1-2mm	<1mm
F) Sand + Envelope	6.77	17.85
G) Sand Envelope	5.29	5.26
H) F-G	1.48	12.59

I) Weight of Sand 14.07 (1-2mm H + <1mm H) 33.1 % (I / E)

J) Hydrometer Reading 15.0

K) Calgon Hydrometer Reading 6.5

L) Weight of Clay 8.5 (J-K) 20.0 % (L / E)

M) Weight of Silt 19.99 (E - I - L) 47.0 % (M / E)

TEXTURAL ANALYSIS

Batch Designation 1

Gravel 7.62% Sand 38.9% Silt 33.7% Clay 19.8%

aker Number 14

Temperature 20°C

Sample Designation 5

Time Set Up 8:39:30
2 40 30

Time to Read Hydrometer 11:20:00

A) Total Sample Weight 45.40

B) Gravel + Envelope 6.16

C) Gravel Envelope 2.70

D) Weight of Gravel 3.46 g (B-C) 7.62 % (D / A)

Corrected Sample Weight 41.94 (A-D)

	1-2mm	<1mm
F) Sand + Envelope	4.90	18.08
G) Sand Envelope	2.67	2.66
H) F-G	2.23 g	15.42 g

I) Weight of Sand 17.65 (1-2mm H + <1mm H) 42.1 % (I / E)

J) Hydrometer Reading 16.0

K) Calgon Hydrometer Reading 7.0

Weight of Clay 9.0 (J-K) 21.5 % (L / E)

M) Weight of Silt 15.29 (E - I - L) 36.5 % (M / E)

- Color:
Between 5Y 3/2 Dk olive gray
2.5/2 Black

- Compact, slightly harder than #3
- Breaks along joints very slightly
- Very similar to #1 darker color

V. CS Lith

Shale [illegible] 76 142 218 233

76+142 [illegible] +2+1 +2 +1+1+1+1 +1+1+1+2+1

Carbonate

41+84 125

41

Xstalline

1+100+88+1+1

191

Other 52

1 chert?
1 twig or root hair
Lighter Carbonaceous Shale

18

Ox. Ag.

26

Dark fine grained mafic

8

Total 601
Norm TTL = 549

Shale	38.8%
Carbonate	20.8%
Xstalline	31.8%
Other	8.65%

Norm

Shale	42%
Carb	23%
Xstal	35%

TEXTURAL ANALYSIS

Batch Designation 3

Gravel 7.56% Sand 39.1% Silt 35.7% Clay 17.7%

Beaker Number 5

Temperature 21.5°C (154.6 min)

Sample Designation 5

Time Set Up 12:12:30

2:34 : 30

Time to Read Hydrometer 2:47 : 00

A) Total Sample Weight 45.23

B) Gravel + Envelope 8.69

C) Gravel Envelope 5.27

D) Weight of Gravel 3.42 (B-C) 7.56 % (D / A)

E) Corrected Sample Weight 41.81 (A-D)

	1-2mm	<1mm
F) Sand + Envelope	7.42	20.75
G) Sand Envelope	5.27	5.22
H) F-G	2.15	15.53

I) Weight of Sand 17.68 (1-2mm H + <1mm H) 42.3 % (I / E)

J) Hydrometer Reading 14.5

K) Calgon Hydrometer Reading ~~[illegible]~~ 6.5

L) Weight of Clay 8.0 (J-K) 19.1 % (L / E)

M) Weight of Silt 16.13 (E - I - L) 38.6% % (M / E)

TEXTURAL ANALYSIS

Batch Designation 1

Gravel 7.51% Sand 24.2% Silt 36.1% Clay 23.1%

Beaker Number 5

Temperature 20°C

Sample Designation 6

Time Set Up 8:42:30
2 40:30

Time to Read Hydrometer 11:23:00

A) Total Sample Weight 45.40 g

B) Gravel + Envelope 6.06

C) Gravel Envelope 2.65

D) Weight of Gravel 3.41 g B-C 7.51 % D / A

Corrected Sample Weight 37.89 A-D

	1-2mm	<1mm
F) Sand + Envelope	4.14	12.19
G) Sand Envelope	2.66	2.68
H) F-G	1.48g	9.51g

I) Weight of Sand 10.99 (1-2mm H + <1mm H) 29.0 % I / E

J) Hydrometer Reading 17.5

K) Calgon Hydrometer Reading 7.0

Weight of Clay 10.5 g J-K 27.7 % L / E

M)Weight of Silt 16.4 g E - I - L 43.3 % M / E

- Less consolidated than #5 crumbly like #3
- Same Color as #3

2.5Y 3/2 ~~dk olive gray~~
Very dark grayish brown

v.cs lith

Shale (220)
100+94+24+2

Xstaline (86)
93+2+1

Carb (102)
95+1+3+3

other (17)

Norm
Shale 54%
Carb 25%
xstal 21%

Shale 51.8%
Xstal 20.2%
Carb 24.0%
other 4.0%

Carb Shale 3
卌 |||
Ox Ag

Other (shell) ||
|
卌 卌
Dk fine grained mafic
3

Total
425

Norm TTL
408

TEXTURAL ANALYSIS

Batch Designation 3

Gravel 6.71% Sand 25.5% Silt 46.9% Clay 20.9%

Beaker Number 16

Temperature 21.5°C (154.6min)

Sample Designation 6

Time Set Up 12:17:30

2:34:30

Time to Read Hydrometer 2:52:00

A) Total Sample Weight 45.44

B) Gravel + Envelope 8.35

C) Gravel Envelope 5.30

D) Weight of Gravel 3.05 (B-C) 6.71 % (D / A)

E) Corrected Sample Weight 42.39 (A-D)

	1-2mm	<1mm
F) Sand + Envelope	6.69	15.36
G) Sand Envelope	5.26	5.22
H) F-G	1.43	10.14

I) Weight of Sand 11.57 (1-2mm H + <1mm H) 27.3 % (I / E)

J) Hydrometer Reading 16.0

K) Calgon Hydrometer Reading 6.5

L) Weight of Clay 9.5 (J-K) 22.4 % (L / E)

M) Weight of Silt 21.32 (E - I - L) 50.3 % (M / E)

TEXTURAL ANALYSIS

Batch Designation 1

Gravel 6.90% Sand 37.2% Silt 36.1% Clay 19.8%

[illegible]aker Number 6

Temperature 20 °C

Sample Designation 7

Time Set Up 6:46:30
2 40 30

Time to Read Hydrometer 11:27:00

A) Total Sample Weight 45.38

B) Gravel + Envelope 5.79

C) Gravel Envelope 2.66

D) Weight of Gravel 3.13 (B-C) 6.90 % (D / A)

Corrected Sample Weight 42.25 (A-D)

	1-2mm	<1mm
F) Sand + Envelope	5.01	17.12
G) Sand Envelope	2.65	2.61
H) F-G	2.36g	14.51

I) Weight of Sand 16.87g (1-2mm H + <1mm H) 40.0 % (I / E)

J) Hydrometer Reading 16.0

K) Calgon Hydrometer Reading 7.0

Weight of Clay 9.0 (J-K) 21.3 % (L / E)

M) Weight of Silt 16.38g (E - I - L) 38.8 % (M / E)

-Same as #6

- Color:

2.5Y 3/2 very dark grayish brown

CS
Lithology

Shale (285)
100+100+79+6+ [illegible]

Xstal (173)
100+58+14+1

Carb (177)
100+64+7+6

Other (23)

Ox Ag	Carb Shale
2	4

other
2-#5

Total 658
Norm TTL=635

Shale 43.3%
Xstal 26.3%
Carb 26.9%
Other 3.50%

Norm

Shale	45%
carb	28%
Xstal	27%

TEXTURAL ANALYSIS

Batch Designation 3

Gravel 8.70% Sand 35.6% Silt 38.0% Clay 17.6%

Beaker Number 17

Temperature 21.5°C (154.6min)

Sample Designation 7

Time Set Up 12:22:00
2:34:30

Time to Read Hydrometer 2:56:30

A) Total Sample Weight 45.42

B) Gravel + Envelope 9.23

C) Gravel Envelope 5.28

D) Weight of Gravel 3.95 (B-C) 8.70 % (D / A)

E) Corrected Sample Weight 41.47 (A-D)

	1-2mm	<1mm
F) Sand + Envelope	7.08	19.59
G) Sand Envelope	5.23	5.25
H) F-G	1.85	14.34

I) Weight of Sand 16.19 ((1-2mm H + <1mm H)) 39.0 % (I / E)

J) Hydrometer Reading 14.5

K) Calgon Hydrometer Reading 6.5

L) Weight of Clay 8.0 (J-K) 19.3 % (L / E)

M) Weight of Silt 17.28 (E - I - L) 41.7 % (M / E)

TEXTURAL ANALYSIS

Batch Designation 2

Gravel 6.62% Sand 34.3% Silt 45.9% Clay 13.2%

[illegible]ker Number 8

Temperature 23.5 °C

Sample Designation 8

Time Set Up 2:33:30
2:28:00

Time to Read 5:01:30
Hydrometer

45.3

A) Total Sample Weight

B) Gravel + Envelope 8.37

C) Gravel Envelope 5.37

D) Weight of Gravel 3.00
B-C

6.62 %
D / A

[illegible] Corrected Sample Weight 42.31
A-D

	1-2mm	<1mm
F) Sand + Envelope	8.07	18.17
G) Sand Envelope	5.37	5.35
H) F-G	2.70	12.82

I) Weight of Sand 15.52
(1-2mm H + <1mm H)

36.68 %
I / E

J) Hydrometer Reading 12.5

K) Calgon Hydrometer Reading 6.5

[illegible] Weight of Clay 6.0
J-K

14.18 %
L / E

M) Weight of Silt 20.79
E - I - L

49.14 %
M / E

-Same as#7

2.5Y 3/2 very dk grayish Brown

A few oxidized aggregates
^ very few

Oxidized Aggregats are
grey, rust red brwn, + black.
composed of silt + clay ~~to~~ with med to fine sand
in matrix of silt + clay.
-Whole Agg is cemented by hematite or other FeO_x that is visible in other cases not visible.

Shale (219)
-Some rust stained
100+100+19

Xstal (108)
102+6

Carb (159)
100+41+18

other (260)

Ox Aggs
100+88+61

(249)

Other
1 shell frag
5 other
5 other

Shale	29.4%
Ox Ag	33.4%
Other (total includin Ox Ag)	(34.9%)
Carb	21.3%
Xstal	14.5%

Norm

Shale	45%
Carb	33%
Xstal	22%

Total 746

Norm TTL = 486

TEXTURAL ANALYSIS

Batch Designation ②

Gravel 5.43 Sand 63.7% Silt 16.4% Clay 14.4%

ker Number 9

Temperature 23.5 °C

Sample Designation 9

Time Set Up 2:37:15
2:38:00

Time to Read Hydrometer 5:05:15

A) Total Sample Weight [illegible] 45.09

B) Gravel + Envelope 7.75

C) Gravel Envelope 5.30

D) Weight of Gravel 2.45 B-C 5.43 % D / A

Corrected Sample Weight 42.64 A-D

	1-2mm	<1mm
F) Sand + Envelope	8.09	20.64
G) Sand Envelope	5.29	5.32
H) F-G	3.20	15.32

I) Weight of Sand 28.73 (1-2mm H + <1mm H) 67.4 % I / E

J) Hydrometer Reading 13.0

K) Calgon Hydrometer Reading 6.5

Weight of Clay 6.5 J-K 15.2 % L / E

M)Weight of Silt 7.41 E - I - L 17.4 % M / E

- crumbly,
- many oxidized lenses with brown rust color

Color varies:

10YR 6/8 Brownish yellow
to
2.5Y 4/4 Olive brown

Oxidized lens color:

≈ 10R 3/4 dusky red

Shale (312)
100+100+96+16

Carb (128)
125+3+[illegible]

Xstal (164)
140+24

Ox Ag (295)
100+100+73+22

Norm

Shale	52%
Carb	21%
Xstal	27%

Shale	34.1%
OxAg	32.2%
Xstal	17.9%
~~Other~~	
Carb	14.0%
Other	[illegible] 1.86%

Other (17)
9+8

Total 916
Norm TTL = 604

TEXTURAL ANALYSIS

Batch Designation 2

Gravel 7.26% Sand 32.1% Silt 46.3% Clay 14.4%

aker Number 10

Temperature 23.5°C

Sample Designation 10

Time Set Up 2:40:00
2:28:00

Time to Read Hydrometer 5:08:00

A) Total Sample Weight 45.20

B) Gravel + Envelope 8.58

C) Gravel Envelope 5.30

D) Weight of Gravel 3.28 (B-C) 7.26 % (D / A)

Corrected Sample Weight 41.92 (A-D)

	1-2mm	<1mm
F) Sand + Envelope	7.49	17.93
G) Sand Envelope	5.28	5.64 ~~5.27+.37~~
H) F-G	2.21	12.29

I) Weight of Sand 14.50 (1-2mm H + <1mm H) 34.6 % (I / E)

J) Hydrometer Reading 13.0

K) Calgon Hydrometer Reading 6.5

Weight of Clay 6.5 (J-K) 15.5 % (L / E)

M)Weight of Silt 20.92 (E - I - L) 49.90 % (M / E)

- Very crumbly
- oxidized lens layers also present

Color:

10YR 5/6 yellowish brown

Some shale coated w/ Ox Ag material

Coarse Sand Lith

Shale (252)
100+100+20+2+4+6+3+13+4

Carbonate (113)
106 +7

Xstal (126)
100 +26

Other (235)
3 shell frag
10 fine or dark

Ox Ags (222)
100+96+3+4+12+5+2

Normalized

Shale	51%
Carb	23%
Xstal	26%

Shale	34.7%
Carb	15.6%
Xstal	17.4%
Other (total)	32.4%
Ox Ag only	30.6%

Total = 726
Norm T+1 = 491

TEXTURAL ANALYSIS

Batch Designation 2

Gravel 1.87% Sand 16.7% Silt 68.1% Clay 13.3%

[illegible]ker Number 11

Temperature 23.5°C

Sample Designation 11

Time Set Up 2:45:00 (1)

2:28

Time to Read Hydrometer 5:13:00

[illegible]

[illegible]

A) Total Sample Weight 45.02

B) Gravel + Envelope 6.17

C) Gravel Envelope 5.33

D) Weight of Gravel .84 B-C — 1.87 % D / A

Corrected Sample Weight 44.18 A-D

	1-2mm	<1mm
F) Sand + Envelope	6.18	11.98
G) Sand Envelope	5.31	5.32
H) F-G	.87	6.66

I) Weight of Sand 7.53 (1-2mm H + <1mm H) — 17.0 % I / E

J) Hydrometer Reading 12.5

K) Calgon Hydrometer Reading 6.5

Weight of Clay 6.0 J-K — 13.6 % L / E

M) Weight of Silt 30.65 E - I - L — 69.4 % M / E

- very very crumbly, - no hardend oxidations

color extremes:

10YR 5/6 Yellowish brown

to

10YR 5/4 yellowish brown

Normalized

Shale	37%
Carb	35%
Xstal	29%

Shale	30.9%
Carb	29.4%
Xstal	24.2%
other	15.6%
Ox Ag only	13.4%

Lith

Shale (83)
53+10+18+2

Carb (79)
78+1

Xstal (65)
58+7

Other Black finegrained ㊷
6

Ox.Ag
㊱ 16+11+3+3+3

Total = 269
Nom Total = 227

TEXTURAL ANALYSIS

Batch Designation 3

Gravel 12.4% Sand 18.6% Silt 56.9% Clay 12.1%

Beaker Number 11

Temperature 21.5°C (154.6 min)

Sample Designation 11

Time Set Up 12:27:00
2:34:30

Time to Read Hydrometer 3:01:30

A) Total Sample Weight 45.30

B) Gravel + Envelope 10.86

C) Gravel Envelope 5.26

D) Weight of Gravel 5.60 (B-C) 12.4 % (D / A)

E) Corrected Sample Weight 39.70 (A-D)

	1-2mm	<1mm
F) Sand + Envelope	7.29	11.72
G) Sand Envelope	5.29	5.29
H) F-G	2.00	6.43

I) Weight of Sand 8.43 (1-2mm H + <1mm H) 21.2 % (I / E)

J) Hydrometer Reading 12.0

K) Calgon Hydrometer Reading 6.5

L) Weight of Clay 5.5 (J-K) 13.9 % (L / E)

M) Weight of Silt 25.77 (E-I-L) 64.9 % (M / E)