River Warren flood deposits near St. Peter, Minnesota

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ABSTRACT

The alluvial terraces of the Minnesota River valley near the city of St. Peter, Minnesota are composed of sediments deposited by River Warren, an outlet stream of Glacial Lake Agassiz. Outcrops of terrace sediment in the oldest, preserved terraces near St. Peter contain 10 to 15 m of sand and gravel that varies considerably both laterally and vertically, ranging in gravel content from 0 to 30%. The sediment occurs in large-scale foreset-like beds that are up to 15 m high and that dip generally to the north, which is the general paleocurrent direction. Internally, the foresets are composed of smaller-scale bedded and cross-bedded units that exhibit complex paleocurrent directions. Locally, foresets are cut by channel-shaped erosional surfaces that are filled with thick grain-flow deposits. The foreset beds are truncated at the top by crudely bedded gravel deposited in a braided stream environment.

These features indicate a period of rapid filling by downstream, prograding sand bodies. The overlying gravels indicate winnowing and downcutting of the flood deposits by a gravel-bed braided stream during a time of relatively more stable flow conditions. Incision of these deposits by later outburst floods from Glacial Lake Agassiz left them behind as terraces.

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INTRODUCTION

The purpose of this project was to undertake a detailed study of Minnesota River Valley terrace sediments and to examine the sedimentary structures found in the sediments. These sediments were deposited by River Warren, an outlet for Glacial Lake Agassiz, a lake which covered an 350,000 km^2 in what is now Minnesota, North Dakota, and Manitoba (see figure 1). Glacial Lake Agassiz began forming approximately 12,000 years ago (Matsch, 1972) as the Des Moines lobe of the Laurentide ice sheet retreated into the Red River Lowland. Water pooled at the margin as the ice prevented drainage to the north into Hudson Bay. The River Warren cut a large valley through which the Minnesota River, a classic example of an underfit stream, now flows. The River Warren channel was cut through glacial drift and the flat-lying Paleozoic sedimentary rocks and underlying Precambrian rocks. River Warren was an outlet for Glacial Lake Agassiz until 9200 years B.P. (Matsch, 1972) Through interpretation of sedimentary structures found in the terrace sediments, conclusions are made about the nature of the flow of River Warren.

The study focused on a freshly exposed outcrop located in an active gravel pit three miles south of St. Peter, Minnesota in the SE 1/4, SE 1/4, section 5, T. 109 N. R 26 W. The surface of the terrace studied is relatively flat and lies at roughly 890 feet in elevation. A higher terrace lies just to the east of the study area at approximately 910 feet (see figure 2). At the study location the terrace sediments are approximately 15 m thick. The general paleocurrent direction in River Warren in the Saint Peter area was to the north.

Prominent features found in the terrace sediments include large- scale foreset beds 10 to 15 m in height which seem to indicate some type of prograding, large-scale bar at the bed of a relatively deep and swiftly moving stream. Locally, cross-bedded sand and gravel, plane-bedded sand and gravel, grain flow deposits, and ripple-bedded sand are common features. The terrace sediments consist largely of sand and gravel units containing less than 50% gravel. The terrace sequence is capped by a coarse gravel layer of distinctly larger grain size than the other units and which shows little or no evidence of bedding.

METHODOLOGY

Field work consisted of sketching the outcrop noting the contacts between sedimentary units and the sedimentology of the units. Strike and dip measurements were recorded for both bedding and foresets. Samples of the different sedimentary units were ~~taken to be submitted for~~ dry sieved.

In the lab, photographs were used in combination with outcrop sketches to create more detailed and accurate drawings of the outcrops. Contacts between sedimentary units were traced directly from the photographs while information about the nature of the units was taken from the field sketches.

DISCUSSION

Units

Figures 3, 4, and 5 are outcrop sketches in the study area, a map of which is shown in figure 6. The outcrop sketches show the locations of the units described above. The sketches depict the sediments as viewed parallel to flow (figure 3) and perpendicular to flow (figures 4 and 5).

Seven units were defined in the terrace sequence studied. Unit F consists of silts and fine sands grading upward into the modern soil profile. An example of unit F is shown in figure 7. The sediments of unit F are interpreted to be overbank deposits of a braided stream. Alternatively, they may be loess deposits.

Unit S consists of stratified sand containing less than 10% gravel and in many cases less than 1% gravel. Much of the sand is plane bedded, however ripple bedding and cross bedding are quite common. In some cases, large scale foresets and/or climbing ripples are present. Figure 8 displays some of the sedimentary structures present in unit S.

Unit Sm consists of massive sand deposits. These commonly contain little or no gravel. These are interpreted as being deposited by grain flow or grain fall, which may have resulted from plumes of sand being swept over the crest of the dune and being deposited near the base of the dune. The lack of bedding in these deposits seems to indicate a raining out of sand sized particles. Alternatively, these may represent deposits of grain flows down the slip face of the bar. Sand typical of unit Sm is shown in figure 9.

Units Sg and Gs consist of stratified and cross bedded sand and gravel with Sg containing less than 30% gravel and Gs containing more than 30% gravel. The grain size distribution of the two units is shown in figure 10. Units Gs and Sg exhibit large scale foresets reaching a height of 15 m. An example of these features is shown in figure 11. These large scale foresets are interpreted to be the result of a large scale migrating bar in a high discharge stream with units Gs and Sg being predominantly bedload deposited in dunes superimposed on the downstream face of the bar. Climbing ripples are also present (see figure 4).

Unit Gsm consists of fining upward channel fills with lateral overbank-like extensions. These commonly grade from 20 to 30% gravel at the base to 0 to 5% gravel at the top. These are interpreted as being deposited by grain flow resulting from failure of dune faces. Commonly, multiple fining upward sequences are present in a channel fill and are interpreted as multiple pulses of sediment flow. An example of unit Gsm grading upward into unit Sm sand is shown in figure 12.

Unit Gm consists of unsorted, clast-supported, massive sand and gravel interpreted to have been deposited as channel bars in a braided stream. Unit Gm is much coarser than any of the other units found in the study area. This is attributed to the winnowing action of the braided stream that removed much of the sand but was not able to move the coarser gravel. An example of unit Gm is shown in figure 7.

The presence of units Gm and F at the top of the sequence indicates a drastically shallower stream than that which was responsible for the deposition of units Gsm, Gs, Sg, Sm, and S which appear to have been deposited in a deep, swiftly moving stream.

Grain size plots and rose diagrams

Cumulative frequency plots on the probability scale for the eleven samples taken are shown in figure 10. For units Gm, Gs, and Sg, the slopes of the curve indicate that grains were relatively evenly distributed from -4 to 2 phi. Units Sm, S, and F seem to be better sorted with a high content of grains in the 0 to 2 phi range.

Figure 13a depicts dip directions for bounding surfaces between cross-bedded units. The diagram shows that the predominant dip direction is north which corresponds with the assumed paleocurrent direction for the River Warren. Figure 13b depicts dip directions of cross-bedding. The dip direction of the cross-beds is to the east as well as to the north indicating that these smaller scale features were controlled by smaller scale currents as well as the predominant northward flow.

INTERPRETATION

The large scale terrace sediments in the study area clearly indicate a period of incision to the pit floor. The period of incision was followed by a period of rapid deposition of sand and gravel in a bar containing the large foresets. Because they are seen in outcrop at heights up to 15 m, deposition of these structures took place in a stream that was at least 15 m deep.

Further evidence suggests that the stream responsible for these sediments was deeper than 15 m. Figure 14 depicts a possible sequence of events leading to the formation of the terrace studied. It shows a period of channel incision followed by rapid channel filling. As the flow of River Warren waned considerably a smaller scale braided stream flowed over what is now the terrace surface depositing the massive gravel of unit Gm. A period of incision by this stream resulted in two sand and gravel surfaces, one at 890 feet and another at 910 feet. Today these are two distinct levels of sand and gravel terrace. The outcrop studied is located on the lower terrace but at the base of the slope of the higher terrace. The relationship between the two terraces is shown in figure 2. Investigation of outcrops in the higher terrace indicate that it is capped with massive gravel as well. The conspicuous absence of a massive gravel cap from the section of outcrop depicted in figure 3 (B to B') is due to the fact that it is on the slope between the two terraces and therefore did not experience deposition as the stream was flowing over the lower surface.

Evidence for only one period of channel filling is seen in the outcrop B to B' (figure 3). Therefore, the channel must have filled to the level of the upper terrace which is 6 to 7 meter higher than the top of the 15 meter foresets. From this it can be suggested that River Warren reached a depth of 22 meters or more during an extreme flood event. Whether or not there was more than one such event cannot be determined from the outcrops studied.

Weile and Mooers (1989) concluded that the River Warren flood events were caused by surging of the ice margin into Glacial Lake Agassiz. In a related study they concluded that the peak flow of River Warren was $3x10^5$ meters/second. The ice margin surge theory suggests that more than one such flood occurred.

Fraser (1988) described a similar terrace sequence in the Wabash River Valley of northern Indiana. He used the term megasets to describe cobble gravels in cross sets as much as 5 meters thick. Fraser concluded that these were deposited by "floods of extreme magnitude." These were the result of rapid drainage of glacial Lake Maumee which was in the Lake Erie basin to the northeast. These floods were possibly similar to those which occurred in the River Warren.

CONCLUSIONS

From this study, it can be concluded that an incision event by the River Warren was followed by channel filling which resulted in units Gsm, Gs, Sg, Sm, and S studied in the terrace outcrops. Although more than one episode of incising and filling may have occurred, evidence for only one episode is seen in the particular outcrop studied. The sediments exhibit large scale foreset-like structures which indicate that the channel filling was a relatively rapid event and that the stream responsible for their deposition was at least 22m deep. The large scale foreset-like structures may indicate that the sediments were deposited in some type of prograding channel bar.

Following the channel filling, a smaller scale braided stream flowed over the terrace surface. The sediment supply to this stream was high while the discharge was greatly reduced relative to the large outflow event(s) which preceded it. Unit Gm is interpreted to have been deposited by this stream as it winnowed away many of the finer sediments resulting in the massive sand and gravel cap present on the terrace surface. The silts and fine sands of unit F are interpreted to be overbank deposits or loess from this stream.

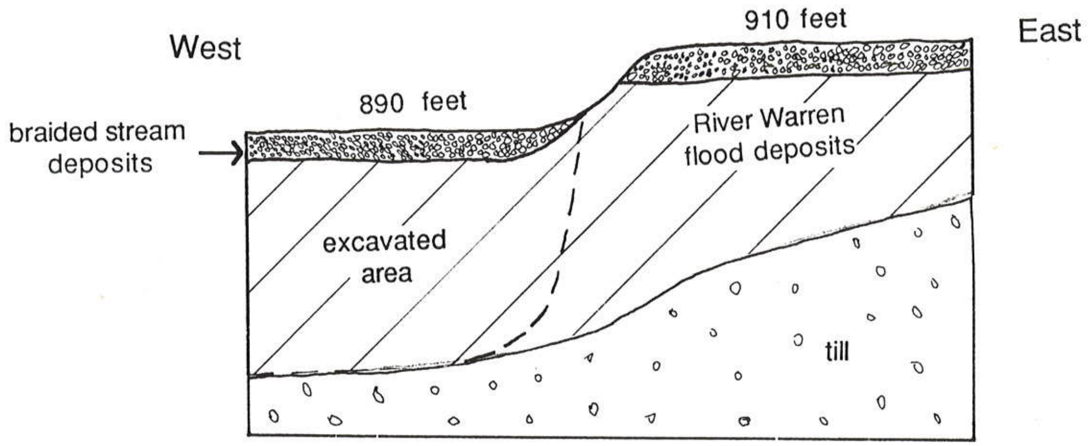


Figure 2 - -Generalized east-west cross section through study area showing area of excavation.

WHAT IS THE DASHED LINE?

Legend for figures 3, 4, and 5

Braided Stream Deposits

F - silts and fine sands; overbank deposits.

Gm - unsorted, clast supported massive sand and gravel; channel bars.

Extreme Flood Deposits

Gsm - fining upward channel fills with lateral "overbank" extensions; mass-flow deposits with erosive bases generated by large-scale failure of fore-sets.

Gs - stratified and cross-bedded sand and gravel containing greater than 30% gravel; dominantly bedload deposits in migrating dunes.

Sg - stratified sand and gravel containing 10 to 30% gravel; dominantly bedload deposits.

Sm - massive sand; grain fall or grain flow.

S - stratified sand; horizontally bedded, cross-bedded, or ripple bedded; deposited by bedload, grain flow, or grain fall.

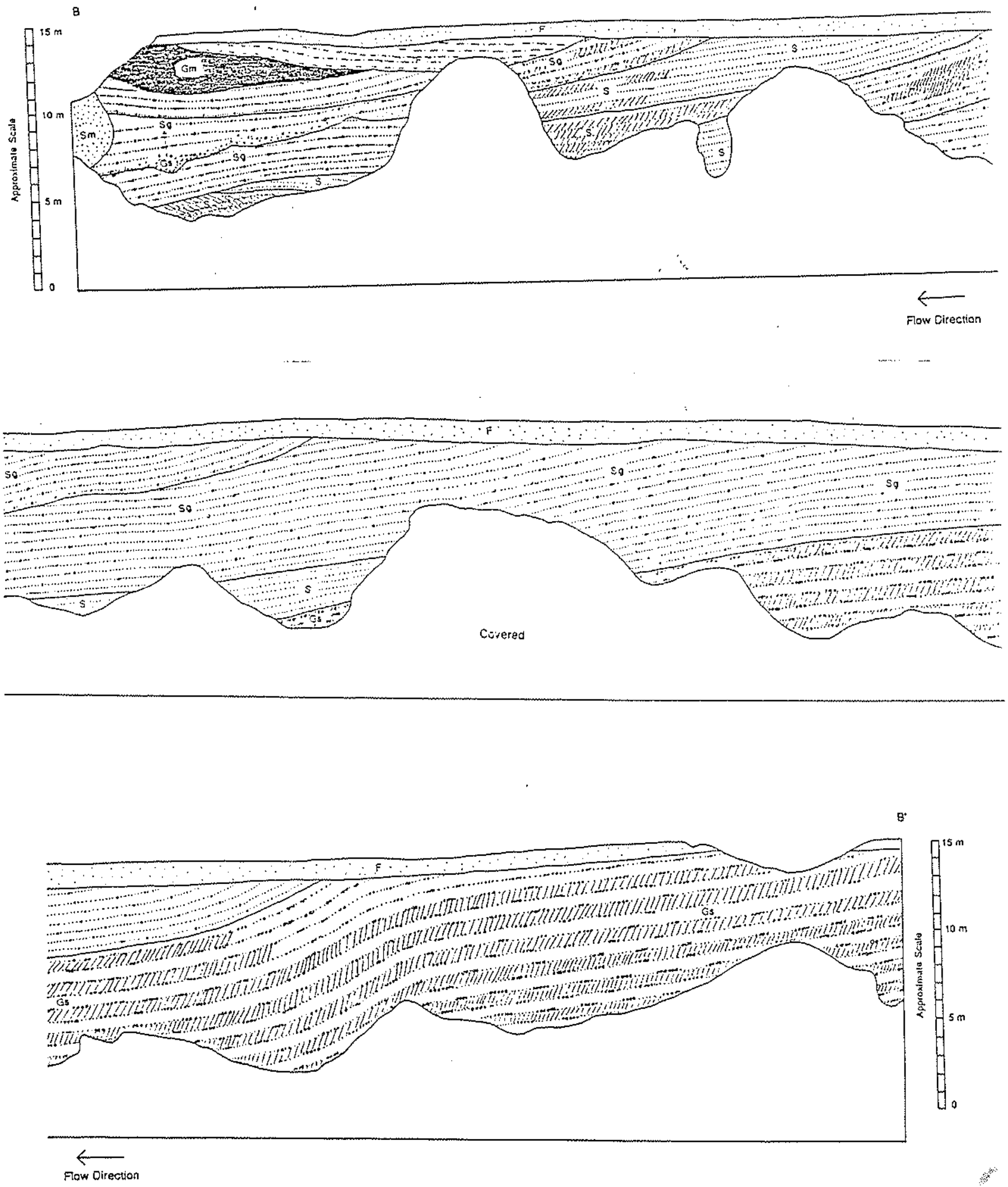


Figure 3 - Outcrop diagram B to B'

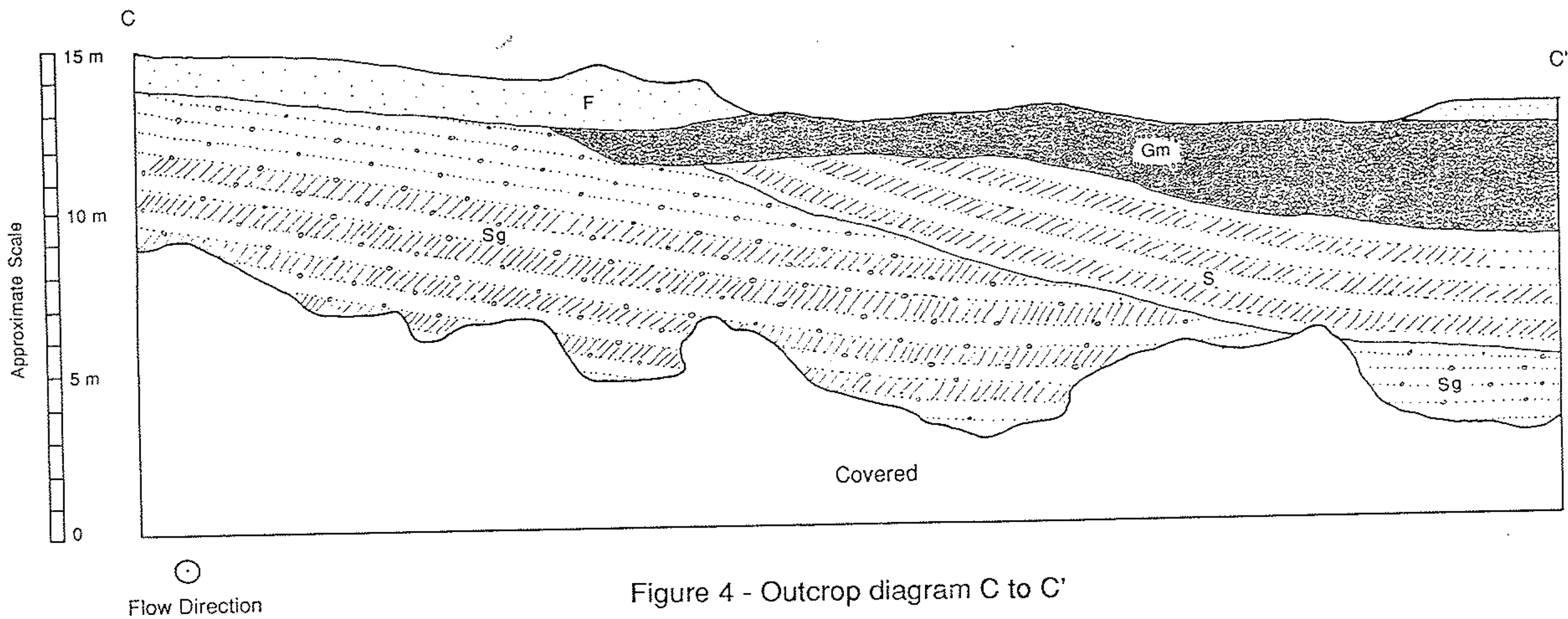


Figure 4 - Outcrop diagram C to C'

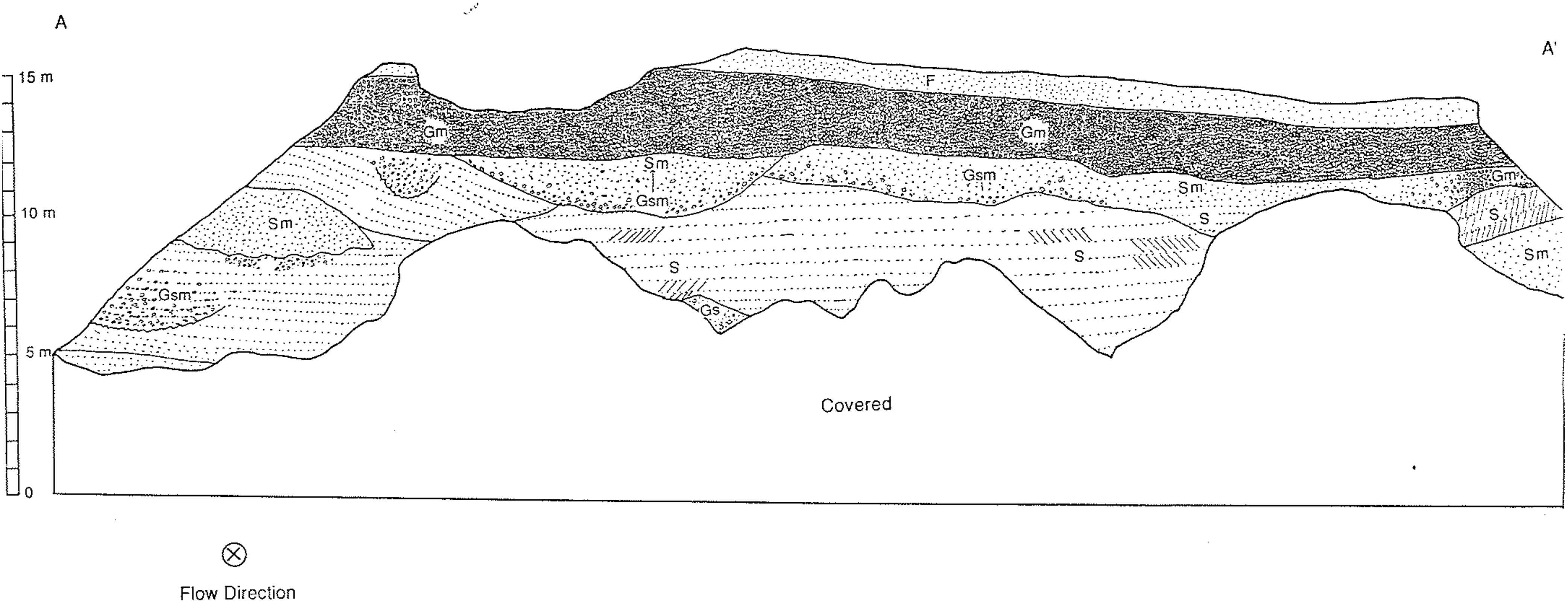


Figure 5 - Outcrop diagram A to A'

Figure 6 - Map view of study area.

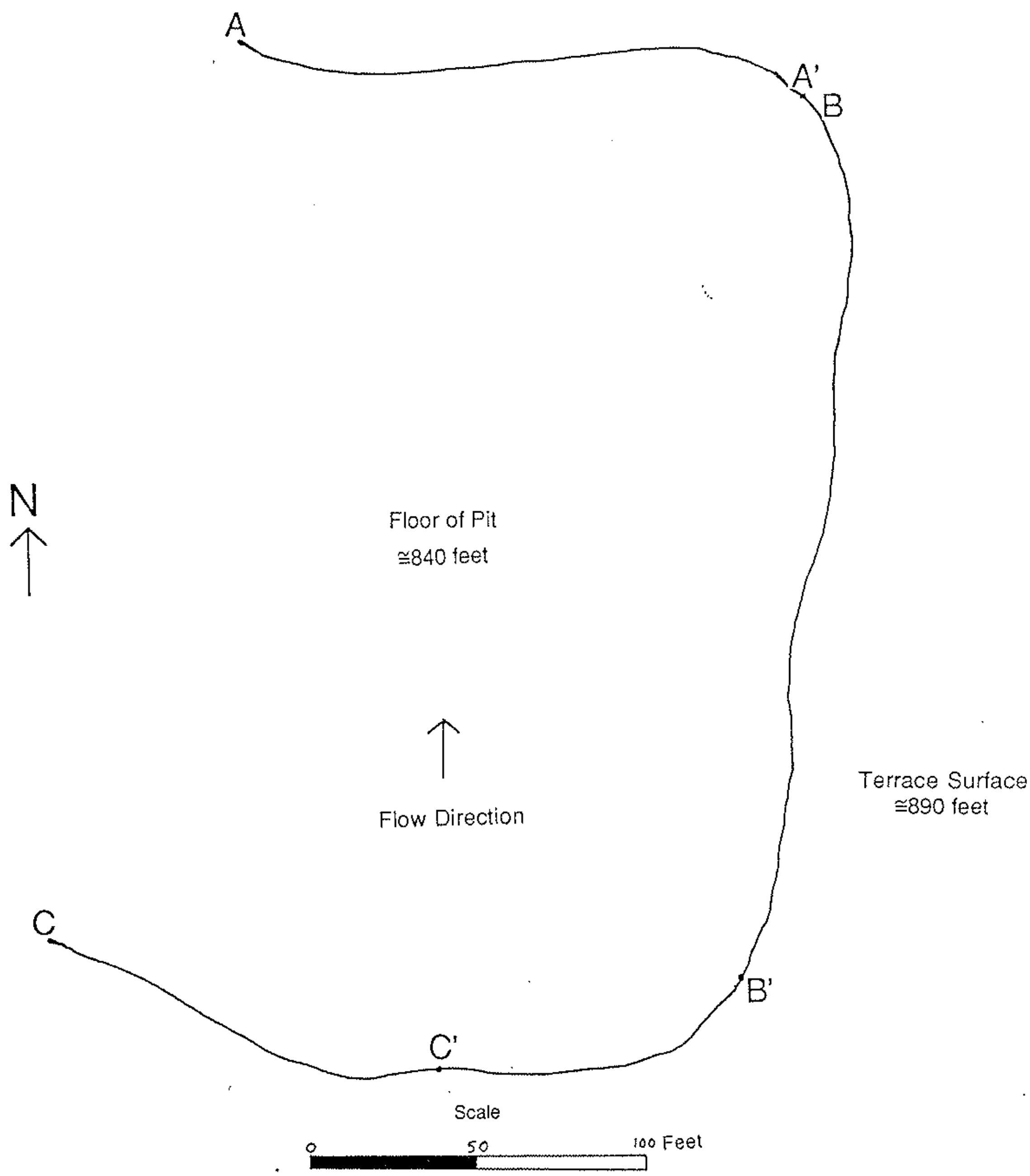


Figure 7 - Unit Gm overlain by unit F.

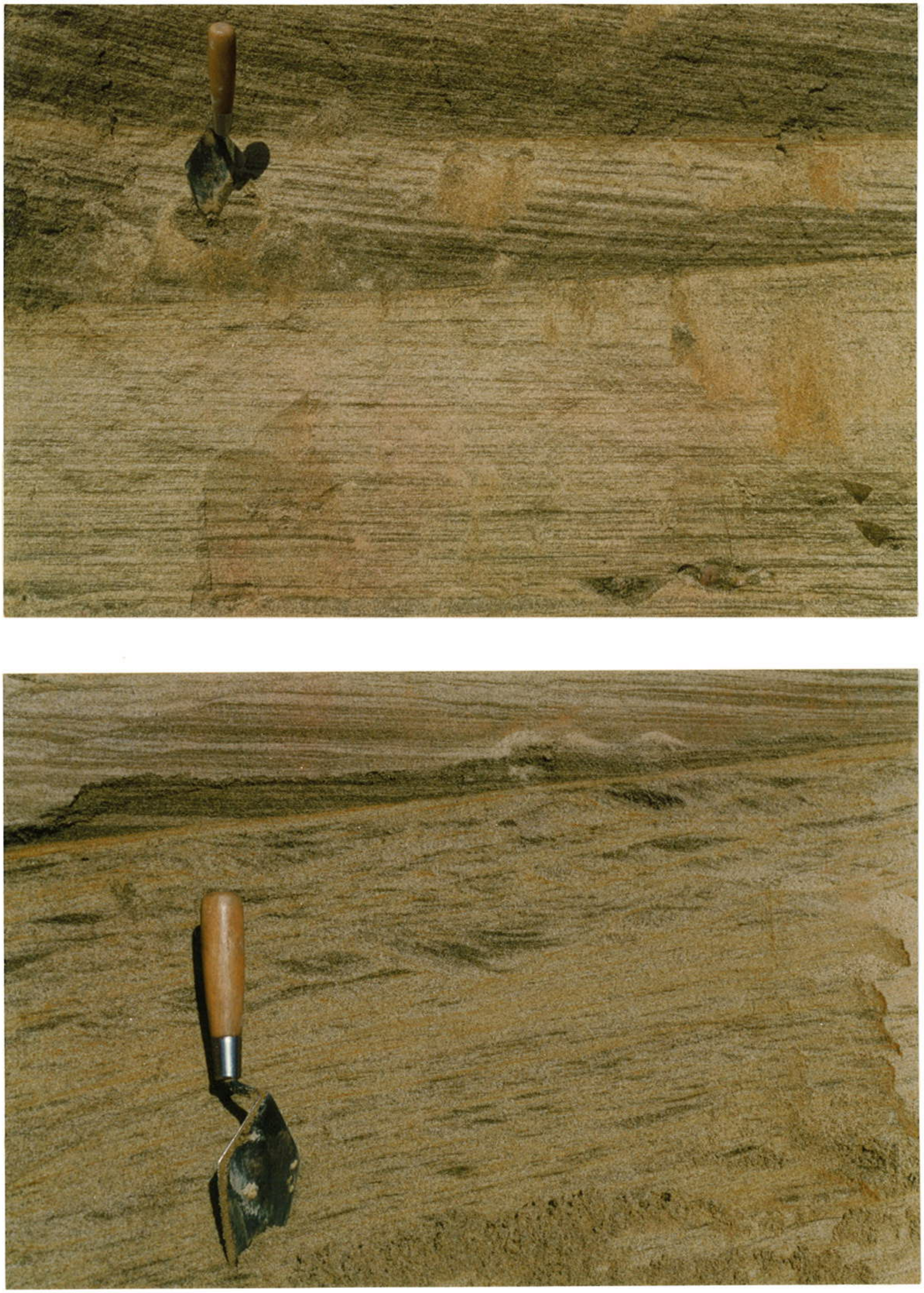
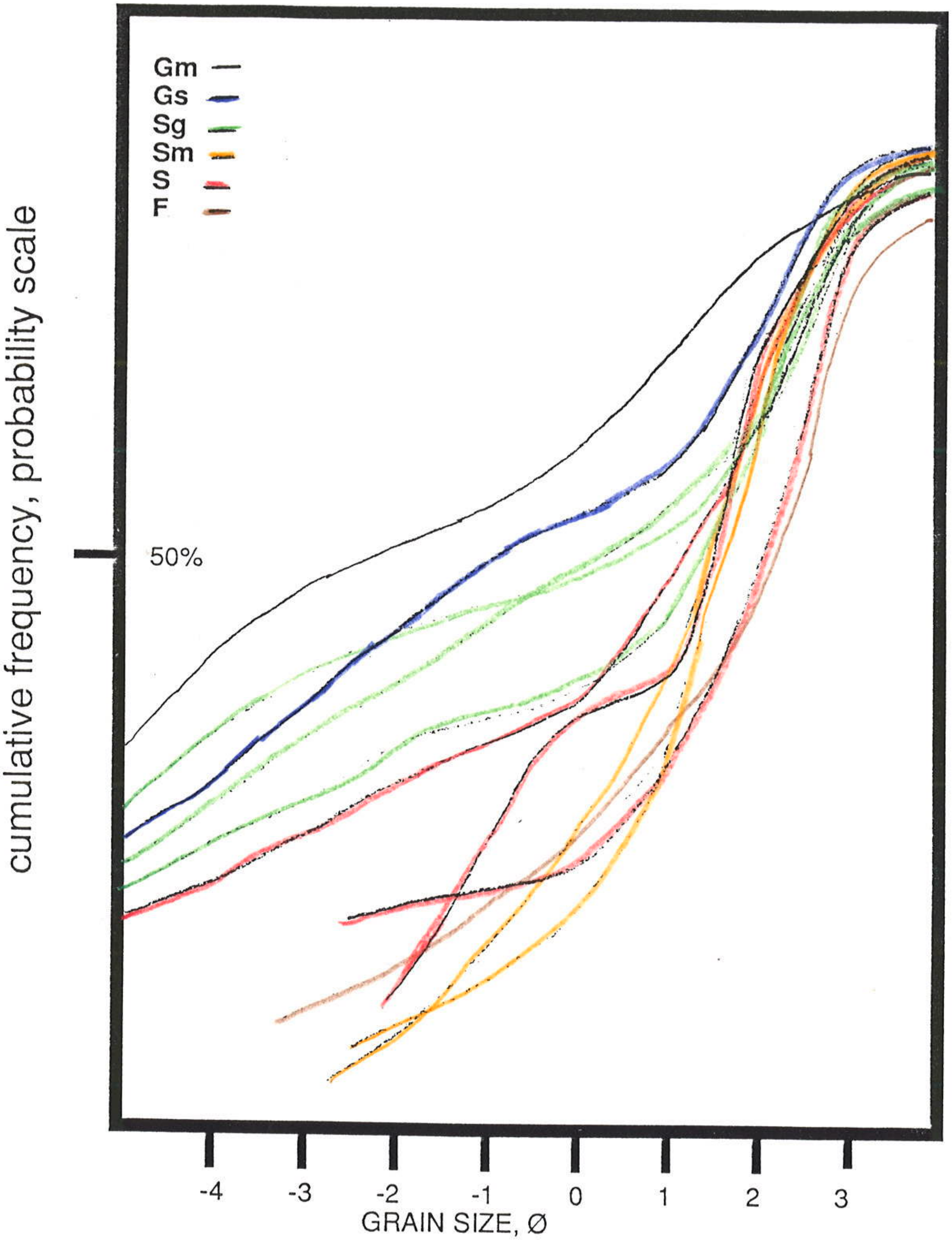
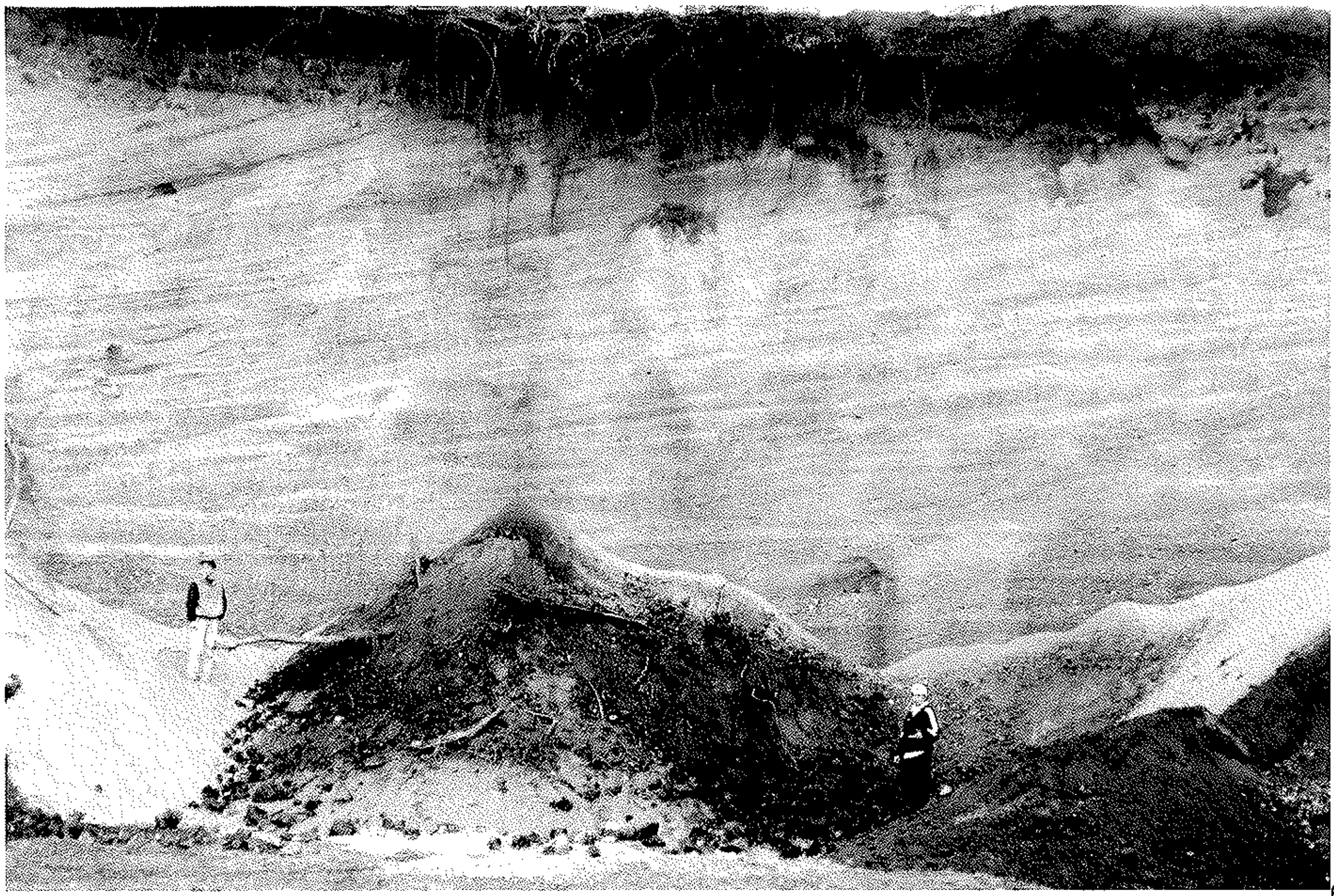


Figure 8 - Ripple lamination, cross lamination, and plane bedding within unit S.

Figure 9 - Close-up of unit Sm. In this photograph massive sand appears to grade upward into stratified sand without any clear break.

Figure 10 - Grain size distribution of facies





12.

Figure 11 - Large Scale foresets composed of Gs. Smaller scale cross laminated units are visible upon close inspection.

Figure 12 - Sharp contact of unit Gsm over unit S sand. Several gravel beds within unit Gsm in this photograph represent pulses of sediment in the grain flow.

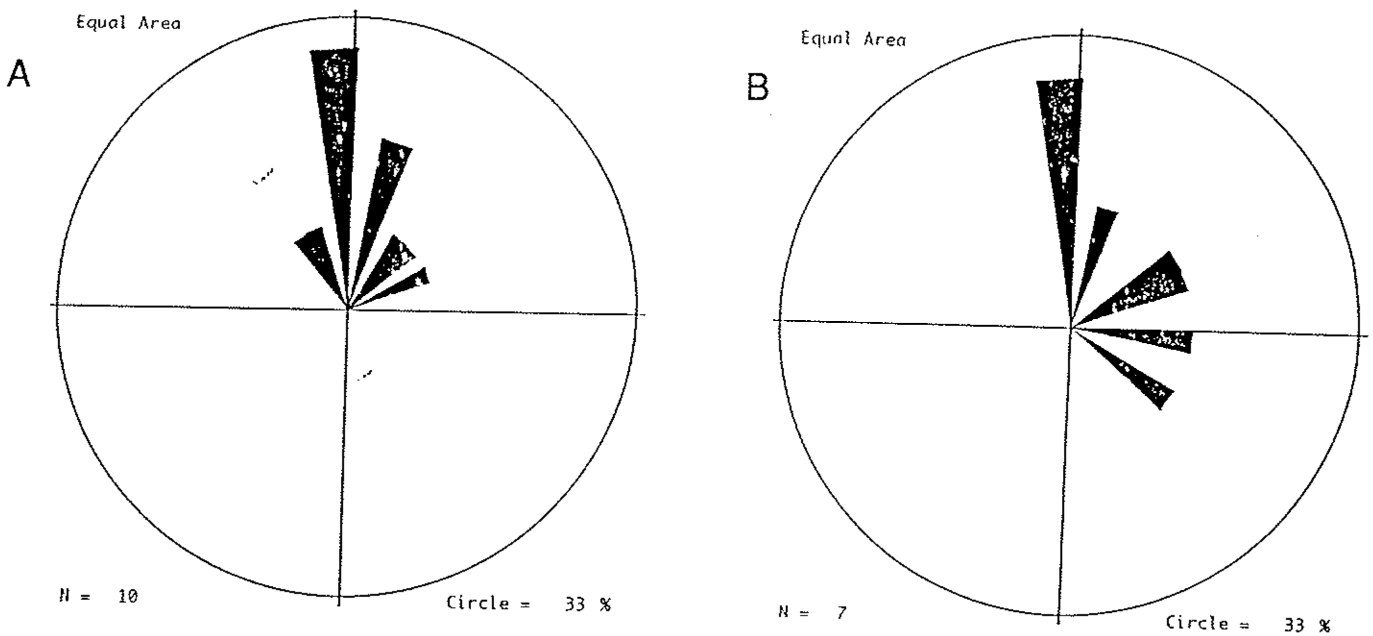
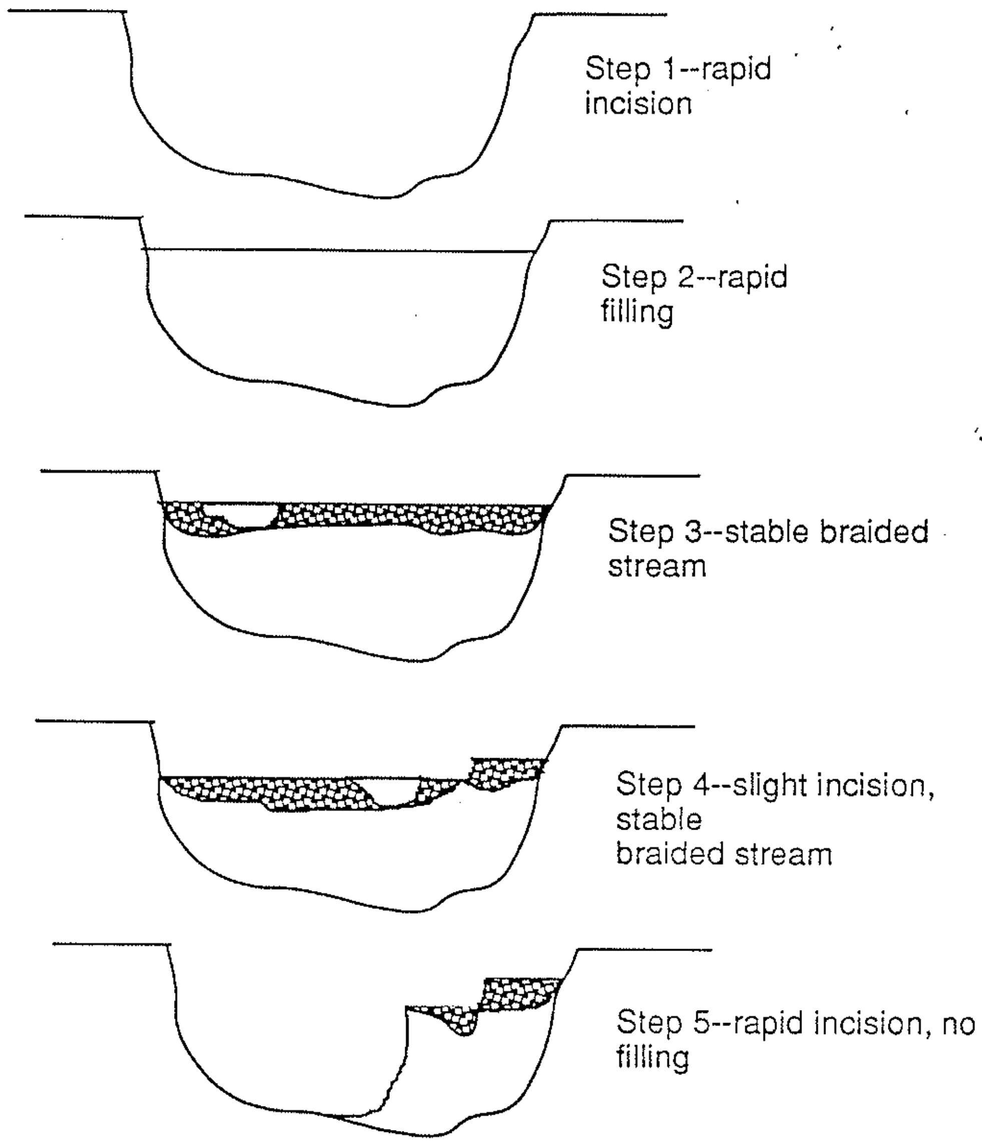


Figure 13--Rose diagrams of dip directions of foresets and cross beds.
a. Dip direction of foresets and bounding surfaces of cross-bedded units. Note that dip directions are predominantly to the north.
b. Dip directions of cross beds. Note that, although many of these dip to the north, parallel to the dominant flow direction, many dip in directions quite different from flow. One example shown in figure 4.

Figure 14- Sequence of events to form terrace sequence



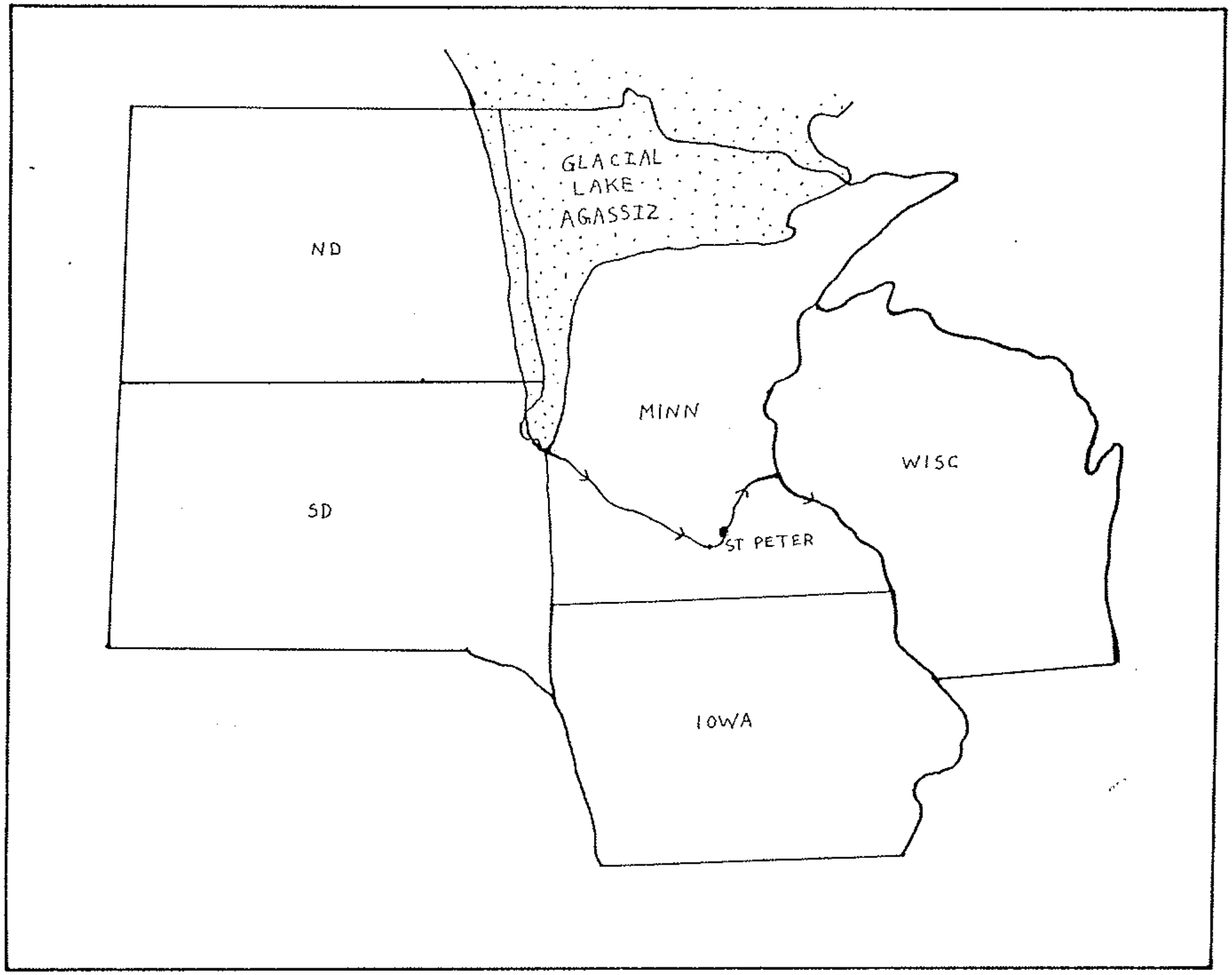


Figure 1 - Map of the Upper Midwest showing the southern portion of Glacial Lake Agassiz, the River Warren, and the location of the study area near St. Peter Minnesota. (Matsch, 1976)

REFERENCES

Fraser, Gordon S. and Bleur, Ned K., 1988, Sedimentological consequences of two floods of extreme magnitude in the late Wisconsinan Wabash Valley, Geological Society of America Special Paper 229, pp. 111-125.

Matsch, Charles L., 1972, Quaternary Geology of Southwestern Minnesota, In Geology of Minnesota: A Centennial Volume, ed. P. K. Sims and G. B. Morey, pp. 548-578.

Weile, S. and Mooers, H. D., 1989, Glacial River Warren: steady state and peak discharge, Geological Society of America, 1989 annual meeting, vol. 21, p. 60.

______, 1989, Glacial Lake Agassiz: glacial surges and large outflow events, Geological Society of America, 1989 annual meeting, p. 54.