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GLACIAL LAKE EVIDENCE IN WESTERN MINNESOTA AS INTERPRETED FROM THE SOIL SURVEY

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ABSTRACT – Soil surveys in several counties in western Minnesota have revealed a soils pattern which provides geomorphic evidence for a previously unrecognized glacial lake. This glacial lake, here called Glacial Lake Benson, is about 60 miles long, 40 miles wide and of almost one million acres in area. Soils along its northern boundary are generally developed in coarse outwash. The central and southern portions of the lake basin have well-sorted silty soils, similar to those in Glacial Lake Agassiz. The elevation of the outer edge of the Benson basin is about 1,050 feet. Topographic maps were used to prepare transects which helped determine the size and shape of the lake basin. The soil parent materials are water-sorted. The source of water for Glacial Lake Benson came from the north and drained to the southeast.

Materials transported and deposited by water are characterized by size sorting of particles. Mineral material deposited under quiet or slowly moving water is mainly fine size silt and clay, and is termed lacustrine sediment. They often are laminated, depicting periodic deposition. Glacial till, on the other hand, is unsorted material deposited from the glacial ice. It is a heterogenous mixture of clay, silt, sand and stones intermingled.

Soil surveys in Swift and Chippewa counties in western Minnesota indicate large areas of lacustrine and outwash sediments. According to geologic information, this area was covered with calcareous glacial drift of late Wisconsin age. Upham (1888), Leverett and Sardeson (1932), and Wright (1965) recognized outwash areas associated with the Pomme de Terre and Chippewa Rivers but did not record any associated lacustrine area. These sediments record the existence of a pro-glacial lake which is here named Glacial Lake Benson (Fig. 1).

The soil survey identified many soils formed from differing parent materials. Table 1 shows the particle size distribution of some representative soils in and adjacent to Glacial Lake Benson. The Barnes and Buse soil series are representative of glacial till soils, Hecla and Renshaw series represent the coarse textured outwash soils, and Colvin, Bearden and Hegne are representative of the lacustrine soils (Fig. 2).

Glacial Lake Benson covers a somewhat heart-shaped area of about 1,500 square miles. It has a maximum length of 60 miles and maximum breadth of 40 miles, and is oriented in a southeasterly direction. The Minnesota River transects the lower portion of the lake basin, flowing in the valley formed by the Glacial River Warren, which was the outlet for Glacial Lake Agassiz. Glacial Lake Benson covers parts of seven counties and includes the present city areas of Appleton, Benson and Montevideo.

The lake boundaries

The eastern and northern boundaries of the lake are most easily determined, since soil surveys have been completed in those areas. These boundaries are near 1,050 ft., in elevation. Comparisons between soil survey maps and topographic maps show that soils derived from glacial till are dominant above 1,050 ft., whereas soils formed in lacustrine sediment are dominant at elevations below 1,050 ft. The eastern boundary is not clearly distinguished in the field, since definite beaches have not formed on this nearly level topography, but small areas of sandy and gravelly soils are common near the 1,050-foot contour.

The northern boundary is marked by outwash fans of the many streams which enter the lake basin (Fig. 3). Nearly all of the parent material of the soils along the northern boundary of the lake basin is coarse textured. The different textures of materials are associated with present stream valleys and are evidence for the sources of water that flowed into the lake basin during the post glacial period.

The southwestern boundary of the glacial lake was determined from soil surveys completed in Lac Qui Parle and Yellow Medicine counties. On this boundary glacial till soils are above the 1,050 elevation, and at lower elevations lacustrine soils. This is similar to the pattern of soil parent materials along the eastern and northern boundary.

The lake basin

Elevations in the lake basin range from near 1,050 ft at the outer edge to less than 930 ft. in the channel of the Glacial River Warren. Although the lake basin slopes continuously from the outer edge to the present Minnesota River valley, there is considerable variation in the soil materials of the basin (Fig. 2). Land features such as stream channels, outwash deposits, lacustrine deposits, and re-worked sediment, are noticeable throughout the basin.

The main channel of the Glacial River Warren cut through the entire lower part of the lake basin, and alternate channels of the Glacial River Warren are common in an area between Appleton and Montevideo.

Delta-like outwash fans are along all the principal streams below the point where they entered the lake basin (Fig. 3). The two most prominent outwash areas are associated with the Pomme de Terre and the Chippewa Rivers.

Pomme de Terre outwash

The Pomme de Terre River, north of the lake basin, has eroded a uniform sized valley for many miles northward.

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This has been described by Wright (1965) as a tunnel valley. When the waters from the glacial Pomme de Terre River entered the basin, they spread from less than a mile in the tunnel valley to several miles in the lake. Sediment then was deposited quickly when the carrying capacity of the stream was reduced.

The outwash delta of the Pomme de Terre (Fig. 3) extends from the edge of the basin south to the Minnesota River valley, and southeast to the Chippewa River. The coarsest sediments are near the edge of the lake basin where the elevation is about 1,020 ft., which is 5 to 10 ft. higher than the areas to the west, or east, indicating that as the coarse material settled out, a large delta fan accumulated.

As the waters from the Pomme de Terre flowed further south, sand was deposited in the form of large sand bars which are oriented to the southeast. The well-drained soils are on the sloping upland and the poorly drained soils are in the deeply carved low lying swales. Deep borings in this sandy area indicates the presence of calcareous glacial till at depths ranging from 1 to more than 15 ft. Still farther south, in northwestern Chippewa county, sandy to fine silty material is common.

An interesting feature occurs along the eastern edge of the Pomme de Terre delta fan. Here the channel of the present Chippewa River flows into a deeply set valley which is about 1 mile wide and 50 ft. deep. This valley is too well formed to have been shaped by the Chippewa River. Since it has dimensions similar to the Pomme de Terre Valley north of the lake basin, it is probable that this valley was carved by the Pomme de Terre River when the glacier covered the area, and the tunnel valley of the Pomme de Terre extended through it. As the lake basin filled, the Pomme de Terre River channel filled with coarse sediments. In seeking to outlet its water, the Pomme de Terre carved three succeeding channels through the delta fan.

Buried soils are common throughout a large portion of the Pomme de Terre delta, most common on the gravelly outwash but less easily observed in the sandy outwash. Depth to the buried soil varies from one to six ft. In the sandy outwash the buried soil commonly has both an A and B horizon. On convex slopes, however, only the buried B horizon often exists.

Chippewa River outwash

The Chippewa River delta fan (Fig. 3) begins in Pope county where the dominant material is gravelly. It is a 35-square-mile area extending to within a mile of the southern border of both Pope and Stevens counties. Farther south as the water from the Chippewa spread out and the carrying capacity was reduced, sandy sediments were deposited.

The present course of the Chippewa River is approximately on the eastern edge of the sandy part of the delta.

River Warren sandbar

An area of outwash sand and gravel extends along the northeastern edge of the Minnesota River valley (Fig. 3). It is about 60 miles long and varies in width from less than one-half mile to several miles. Its direction is almost straight, being oriented E.S.E. However, along the northern one-half of the sandbar the materials are mixed, with textures varying from sand to silt. In this area the sandbar is difficult to distinguish because it is intermixed with the outwash of the Pomme de Terre River.

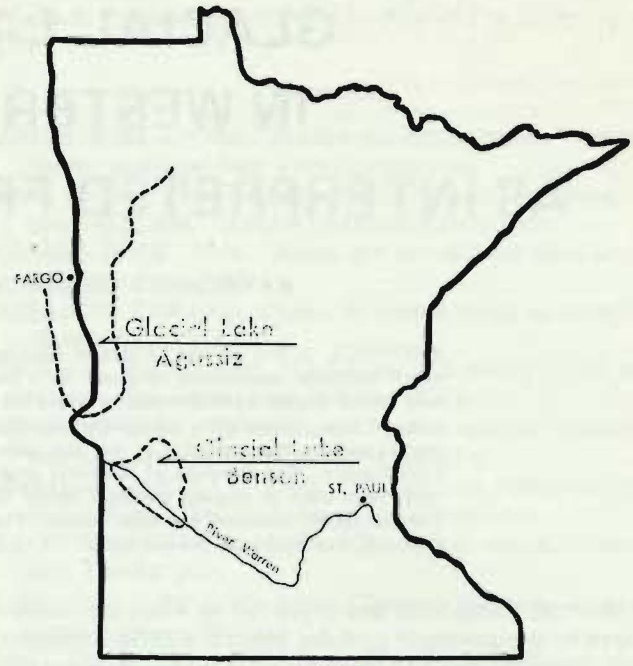

FIGURE 1. Location of Glacial Lake Benson in relation to certain glacial features in Minnesota.

The southern half of the sandbar is easily distinguished. It is relatively narrow, one-fourth to one mile in width with elevations of between 1,030 and 1,050 ft., which is higher than the lacustrine silts to the northeast or the glacial till to the southwest.

Silty lacustrine material deposited in two major areas, north and south of the Minnesota River (Fig. 3). North of the Minnesota River the lacustrine deposits are the most obvious. Here the topography is mostly level and the exposure of glacial till is uncommon. This area is bounded on the east by the 1,050-foot elevation of land and on the west and south by the Chippewa River and the sandbar of the River Warren. the waters which flowed into this area came mainly from the north and east, the Chippewa River and its tributaries. Water from the Pomme de Terre and pre-River Warren, however, also contributed sediment. In the northern part of this area the predominant soils contain very fine sandy loam textures within the profile, while farther south the entire profile (average depth of 60 inches) is silty clay loam, indicating that the source of the lacustrine sediment was from the north. The lowest elevations in this area are between 1,020 and 1,030 ft., and occur in a narrow, elongated area, generally extending through the middle of this lacustrine area from north to south. Material in this topographic low has a high content of clay, suggesting that this portion of the lake was the deepest and quietest.

The lacustrine area south of the Minnesota River valley is bounded on the south by the 1,050 ft. elevation. The topography is more sloping, and most of the lacustrine sediments are better drained than those north of the Minnesota River valley. Sediments were deposited in this area while the lake was filled to its greatest height.

Insights to sequenced events

The arrangement of the lacustrine and outwash sediments within the basin of Glacial Lake Benson provides an insight to the geologic events surrounding the formation, development and final destruction of the lake.

When the Des Moines lobe of the late Wisconsin period of glaciation was receding, it retreated to north of the Minnesota River lowland basin. Along the eastern part of Yellow Medicine county, the lowland basin became filled with glacial drift to an elevation of about 1,050 feet. Subsequently, the glacier became positioned where the Big Stone moraine now exists. The eastern edge of the glacier was in the form of a long finger-like projection corresponding to the Alexandria moraine complex (Wright, 1962). The glacier was melting rapidly, discharging a tremendous volume of water into the lowland basin. The water flowing into the lake at that time came from the glacial Rivers Warren, Pomme de Terre, Chippewa and East Branch of the Chippewa, and from many minor streams. The volume of water carried by all these streams was sufficient to fill the lake basin and deposit the silty lacustrine sediments throughout.

Eventually, the material damming the water was eroded away and most of the lake disappeared. The lacustrine area north of the Minnesota River valley and northeast of Montevideo remained as a smaller perched lake at an elevation of approximately 1,030 feet and fed mainly by the Chippewa rivers and tributaries. The waters from this sublake outletted to the southwest and south through small streams.

During this time, soil development began in the drained part of the lake basin. Dark surface horizons formed in most soils and subsoil horizons developed in the soils with good drainage. Subsequently, the glacier which had been in a stationary position began to recede northward. This additional melt water which was carrying a considerable amount of sediment entered the drained lake basin very rapidly and much of the basin was flooded for the second time. Sediment was deposited a second time in the Pomme de Terre and Chippewa outwash areas. Later, when the water of the glacial Lake Agassiz was released, the alternate channels of the River Warren were formed, which finally drained the lake basin completely.

The water in the perched sublake continued to drain to the south and southwest until the Chippewa River developed its present course through an earlier Pomme de Terre Channel. The perched sublake then lost its source of water and was reduced to several large marshes.

While the main thrust of this paper is to present evidence for a glacial lake based upon the parent material of soil, many geologic interpretations remain to be resolved. The occurrence of buried soil is of considerable significance. What was the time interval for the development of the buried soil? What is the relationship between Glacial Lake Benson and Glacial Lake Agassiz? Was the sandbar that occurs parallel to the Glacial River Warren formed by that river or is it related to the perched sublake? Further geological investigation is needed in order to understand completely the history of Glacial Lake Benson.

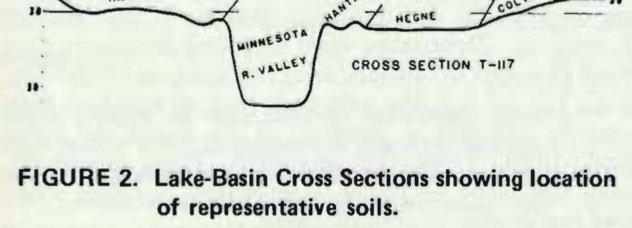

FIGURE 2. Lake-Basin Cross Sections showing location of representative soils.

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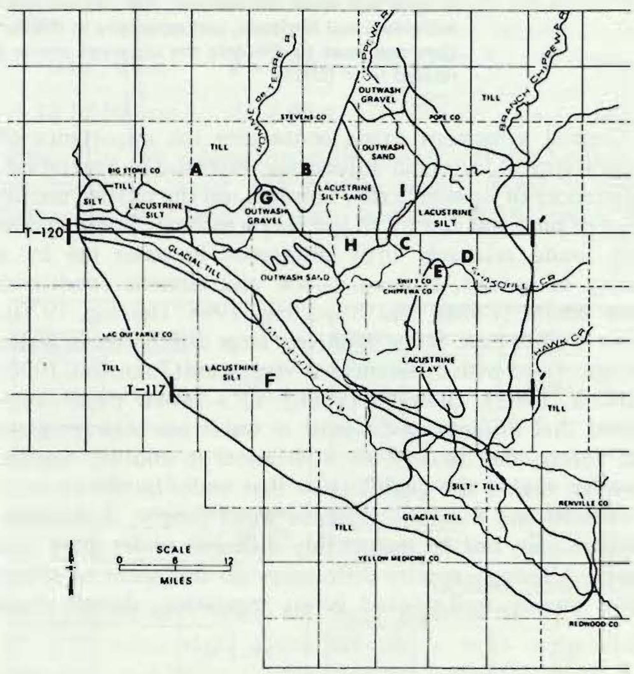

FIGURE 3. Distribution of Surficial Materials.

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TABLE 1: PARTICLE SIZE DISTRIBUTION OF PARENT MATERIAL OF NINE REPRESENTATIVE SOILS OF THE GLACIAL LAKE BENSON AREA

Site No.	Soil Series	Depth In.	Sand %	Silt %	Clay %	Texture	Nature of Glacial Mat.
A	Barnes	30-54	35.7	39.5	24.8	loam	till
B	Buse	18-60	39.0	39.3	21.7	loam	
C	Bearden	27-60	1.3	62.7	36.0	silty clay loam	lacustrine
D	Colvin	28-60	5.0	73.2	21.8	silt loam	
E	Hegne	22-60	3.3	56.2	40.5	silty clay	
F	Hantho	30-60	10.0	75.0	15.0	silt loam	
G	Renshaw[4]	22-60	54.2	10.8	5.0	sand-gravel	outwash
H	Marysland	27-60	92.3	3.5	4.2	sand	
I	Hecla	36-60	93.6	1.9	4.5	sand	

Site locations are shown on Figure 2. Depth of sampling is generally below zone of soil development. Texture is defined and characterized according to the National Cooperative Soil Survey. There is 30 percent gravel in Renshaw soil.

Observation and Prediction of Soil Water Under Different Types of Vegetation

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ABSTRACT — Soil water trends were monitored during the 1971 growing season on the Anoka Sand Plain in east-central Minnesota. Soils were sampled under four vegetation densities, ranging from old field through increasing amounts of oak overstory. There was no difference over the sampled period in total soil water content (to 100 cm) on the four sites. Differences were found in water content of individual soil horizons, and especially in the surface horizon (0 to 10 cm). A model of evapotranspiration was used to simulate the observed trends and the prediction and observations were closely correlated ($r^2 = 0.91$).

General agreement exists concerning the importance of meteorological factors in influencing water use by vegetation. Differences of opinion exist, however, on the relative importance of kind and density of species on such use. Some studies have found relatively little difference in water use by a variety of species, as long as soil and climatic conditions were similar (Cohen and Strickling, 1968; Herring, 1970). Other studies have found relatively large differences in water use associated with differences in vegetation (Johnston, 1970; Marston, 1962). Douglass (1966), in a review paper, concluded that differences do exist in water use between grass and forest, due mainly to differences in rooting depths. Douglass makes the qualification that under humid climatic conditions and a readily available water supply, evapotranspiration may not be measurably different under grass and forest. Although species differences do not seem to affect water use by well-stocked forest vegetation, density does appear to make a difference, especially following forest thinning (Barrett and Youngberg, 1965; Orr, 1968).

The objectives of this study were to determine whether measurable differences existed in soil water under different types of natural vegetation and to attempt to predict the measured soil water levels with an evapotranspiration model. Selected for study was the Anoka Sand Plain, a large glacial outwash in east-central Minnesota. The outwash material in the area is uniformly high in sand and low in silt and clay. Four sites within 0.8 km of one another were studied. These included the grass site, an old field dominated by smooth brome (approximately 60 percent cover) and lesser amounts of sand dropseed (15 percent), sandbur (10 percent), and other species. The grass cover was not continuous, and about 10 percent of the surface was bare. The other three sites had grassy understories and increasing densities of burr and red oak overstory. These latter three sites were designated grass and oak (4 m^2/ha of oak basal area), oak and grass (16 m^2/ha), and oak (22 m^2/ha). The soils underlying all sites have been tentatively classified as members of the Sartell soil series (mixed, frigid, Typic Udipsamments). These excessively-drained fine sands are found on undulating to rolling dune-shaped topography on outwash plains.

Eighteen sampling periods

Soil water was determined gravimetrically during the 1971 growing season. The three sites with oak were first sampled on 5 May, and the grass site on 19 June. Most of the statisti-

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