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A Landslide Near Oslo, Minnesota

Roger C. Zejdlik

A LANDSLIDE NEAR
OSLO, MINNESOTA

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by

Roger C. Zejdlik

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ABSTRACT

A landslide occurred on the bank of the Red River two and a half miles north of Oslo, Minnesota on the Minnesota side. The area involved in the slide comprises about 45,000 square feet. A mass-movement occurred which was vertical but largely horizontal. A block roughly 45 by 100 feet dropped on a skid plane between two related blocks which gave the effect of "graben" structure. At the same instant, however, a large mud bar roughly 150 feet long was pushed up in the river reducing the channel to about half its normal size. The cause of the slide was probably due to the undermining action of the river plus the saturation of clays due to subterranean waters.

The geologic formations underlying the area are the glacial drift of Pleistocene age, stream and lake deposits of Recent age, and Cretaceous sediments which extend beneath the glacial drift and the lake sediments.

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INTRODUCTION

According to Sharpe (1938, p. 3),* "Recognition of the importance of mass-movements in the shaping of the lands has lagged far behind our knowledge of the action of running water, glaciers, winds, and waves." Since there has been much geologic phenomena related to landslides already established by the excellent work of Sharpe and others, and since there is a need for more specific observations, this report may serve as an example of some of these phenomena.

The site of the landslide is located on the bank of the Red River two and a half miles north of Oslo, Marshall County, Minnesota. A mass-movement occurred which was vertical, but largely horizontal, producing a "graben" at the head of the slip. At the same time a large mud bar was pushed up in the river reducing the channel to about half its normal size.

Previous Investigations. To the author's knowledge, there have been no previous studies made specifically of the geology of this particular landslide, however, much work has been done by the Minnesota Geological Survey on the geologic

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* Numbers in parentheses refer to literature cited in the Bibliography.

formations of the area. Bulletins of the Minnesota Geological Survey have been of great value as background material, especially bulletins 11 and 22, which list many data on subsurface formations and clays of the area. Grout and Soper (Bull. 11, 1914, p. 128, 46-48, 54-56), discussed the geologic formations and associated clays of the area and also listed typical wells of the area. Allison (Bull. 22, 1932, p. 117-127), discussed the water resources of northwestern Minnesota in general terms and he also made wells and maps of the area being reported upon. There has also been much work on landslides done by Sharpe (1938), who has contributed immensely to this subject.

Acknowledgments. This investigation was made under the general supervision of Dr. Gordon Bell, Assistant Professor of Geology, University of North Dakota. The present study was further facilitated by the ready cooperation of the farmers in the immediate area. Also thanks to Richard Zejdlik, an architect, for producing the drawings used in this report.

Location and Occupation of the Area. The area covered by this report is about 45,000 square feet along the river bank in the $SW\frac{1}{4}/SW\frac{1}{4}$, Sec.19, T.155N., R.50W., Marshall County, Minnesota. Farming is the principal occupation on the upland, while the bank of the river is being used for cattle grazing. The landslide area was being farmed at the time and the grain had just been removed before the slump took place. The land is relatively very flat before the river.

DESCRIPTION OF THE SLIDE

Time, Size, and Shape of the Slide. During the night of the 19th of September 1954, a landslide or more appropriately slump took place on the Minnesota side of the Red River. The distance from one end of the break to the other is about 400 feet. The sunken area is full of deep cracks, many of them large enough to hold the average man. The sunken area dropped as much as 8 feet in places. The crescent-shaped crack runs north and south along the river with the concave portion of the crescent toward the river. (See fig. 1). Throughout most of the length of the slip the whole slope was very much unaffected by the slide, and the north and south ends of the upper edge of the slipped area tapered downward until finally the break in the slope died out. Also during the same night and apparently resulting from the slumping action of the bank, a crescent-shaped island was formed in the river. (See fig. 2). This island is about 35 feet longer than the 400 foot fracture on the bank which is more to an advantage than a disadvantage, however, this will be discussed subsequently. The water

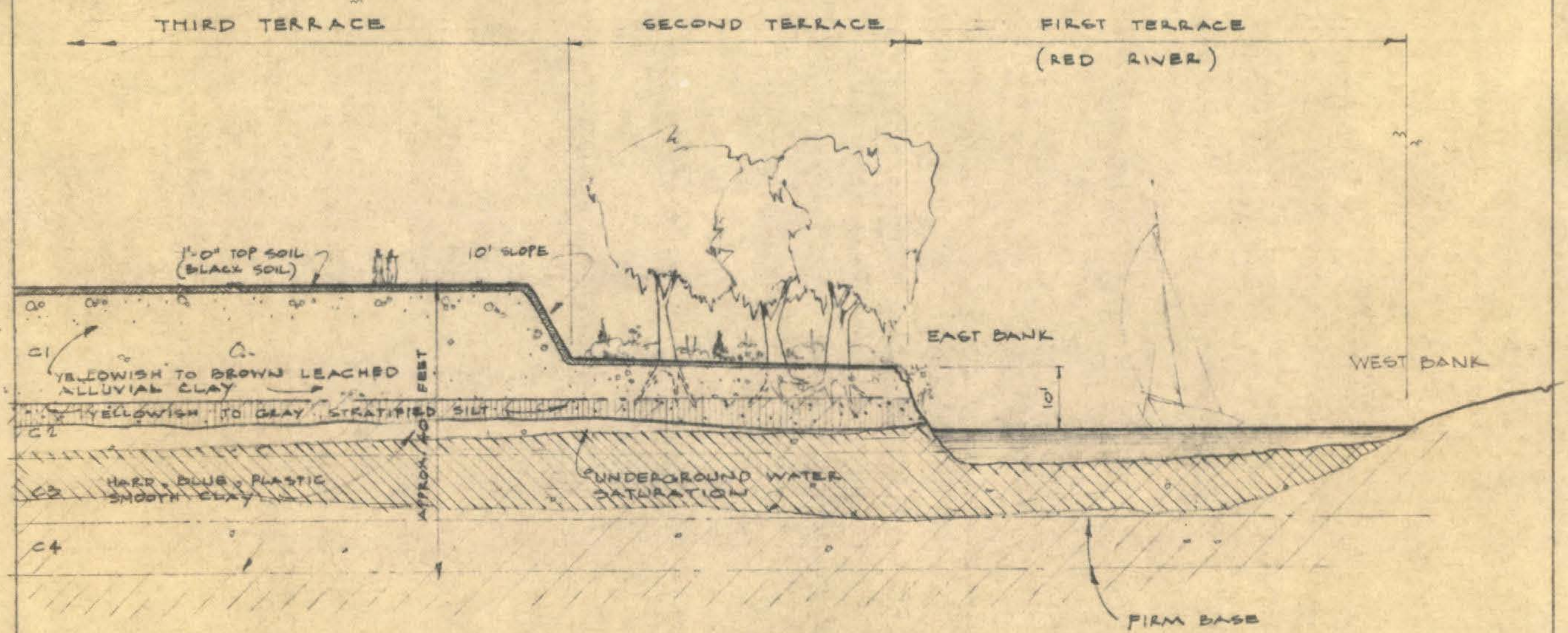
Figure 1. View looking southward along the break on the third terrace at the head of the slip. Note the very scabrous crescent-shaped fracture.

Figure 2. View looking southwest of the island running diagonally across the river. Note the rapids in the water, and also the main portion of the island on the slip-off slope of the river. Photo was taken standing at the north end of the island. Note the sharp bend in the river (upper left). It is not more than six feet deep across this portion of the river.

rushes through the narrow channel creating rapids which is a strange sight on the usually quiet Red River. The distance from the center of the fracture to the river is about 150 feet. This distance is the area covered by the higher flood of the Red River, however, for purposes of explanation, it will be divided into three step-like terraces. (see fig. 3). The first terrace consisting of the bottom of the river, the second terrace being a flat, brush, and tree-covered area running inland about 100 feet before rising sharply a distance of 15 feet to the third step-terrace. The fracture of the slide is 50 feet from the edge of the third terrace. Although only 50 feet of the surface actually dropped, the other 100 feet making up the second terrace remained in place. The only sign of sliding of the second terrace was the tilting of the trees away from the river and a slight back-drop. (see fig. 4).

Characteristic Features. This slide possesses some characteristics of earthflow and associated slumping, but it also characterizes some "graben" structure on both sides of the crescent-shaped block. Actually the block, 400 feet long and 50 feet wide at its center, moved almost vertically on a slight skid plane, forming fractures, 8 feet in depth, on both sides of the block.

The mud island runs diagonally across the river, how-

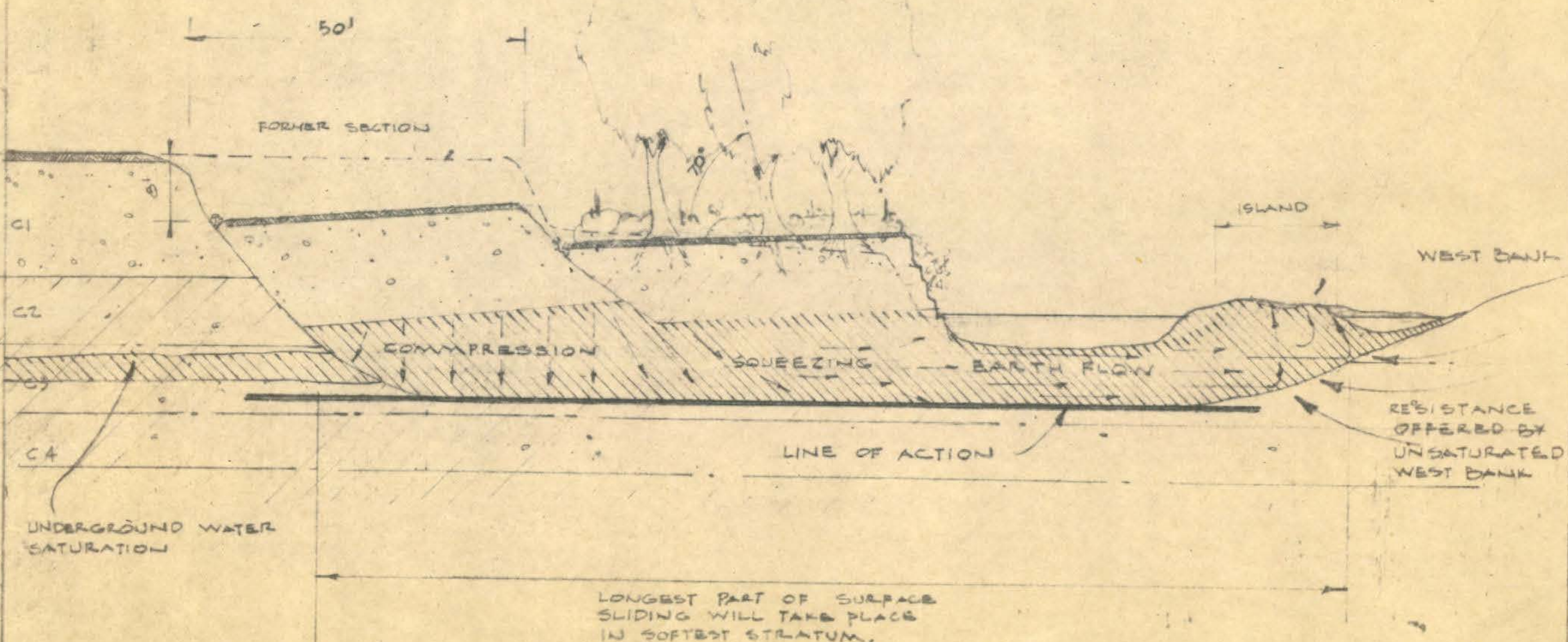


SOIL CONDITION PREVIOUS TO ACTION

CROSS-SECTION PRIOR TO THE LANDSLIDE FIG. 3.

SC: 1" = 20'-0"

AS THE EARTHFLOW MATERIAL WAS BEING COMPRESSED LATERALLY, IT WAS PROBABLY CHECKED BY THE RESISTANCE OF THE WEST BANK. DUE TO THE COMPACTION OF MATERIAL, THERE WAS BULGING THROUGH THE SOFTER RIVER MUDS.



EARTH MOVEMENT BY LATERAL SPREADING

CROSS-SECTION AFTER THE SLIDE TOOK PLACE

SC: 1" = 20'-0"

FIG. 4

ever, it is parallel to the sides of the cut. For the most part, this island is composed of muds from the river bottom plus the clay that upheaved the island which is the same clay found beneath the unaffected slope.

This slide is interesting in that the second terrace is heavily laden with trees and undergrowth while the third terrace is a grain field. It is noted that the second terrace only showed signs of back-drop and rotation and a tilting of the trees. There were also signs of soil-fall on the bank where the river's bend was the sharpest. (See fig. 5). Also, on the third terrace, there was an indication of tensile stress where the crack was formed because the crack strikes directly across a slight bowl-shaped depression about 200 feet in diameter.

A Mrs. Quern, whose home is on the upland just north of the slip about 115 feet from the river, explained when questioned, that, when she looked out in the morning, there was the sound of rushing waters which was very unusual. Not long after, she went to the slope and noticed the mud bar in the river which caused rapids in the water, and she also noticed the large crack along the top of the third terrace and then she made a quick look to see if there was any fracturing near her home. She also stated that she did not hear any rumbling or noise accompaning the movement and that the slip was still moving slowly.

J. K. Rogers, in describing movements of this type from the edge of clay terraces, states that:

> Certain features seem to characterize this type of slide, which is developed in terraces of horizontal laminated clays, undercut by the lateral shifting of stream courses. The first manifestation of instability is bowing up at the toe of the slope. From a study of the profiles of the slides, it seems probable that this upward bulging is due to plastic or viscous flow of no great depth, rather than to the rotational movement of the mass which is apparent in the next stage. The sliding is usually rapid, taking place along a curved surface or zone. There appear to be three main divisions of the landslide mass: (1) at the head, a down-slipped block or series of blocks, with surfaces tilted into the slope; (2) in the central part, a buckled and disrupted area, with wide fissures transverse to the direction of movement; (3) in the lower part of the slide, an anticlinal ridge or series of ridges, the foremost of which may be over-thrust and often occupies a part of the former stream channel (abstract, 1929, p. 167).

These phenomena characterize this slide in that: (1) there is a down-slipped block with the surface slightly tilted into the slope; (2) Rogers states that the central part should be widely fissured and buckled, but because of different circumstances, this may have taken place beneath the second terrace, however, this will be discussed subsequently; (3) in the lower part of the slide, however, the anticlinal ridge may be the mud island itself.

CONDITIONS AFFECTING THE SLIDE

Stratigraphic. In order to obtain stratigraphic data, sections were taken from the fracture itself, and also from data previously recorded by Grout and Soper (1914, p. 128) which included an area of 100 acres. (Table 1).

TABLE 1

SECTION OF THE AREA

1. Black soil..................................	1 foot
2. Yellowish to gray alluvial clay...........	10 feet
3. Yellowish to gray stratified silty sand...	15 feet
4. Hard, blue, plastic, smooth clay..........	Depth unknown

Just within the blue-plastic clay (Table 1, No. 4) and just below the stratified silt (Table 1, No. 3) is the horizon in which the slide probably took place.

Climatic. According to the farmers in the area, the weather at the time of the slip was dry, windy, and cool. In the vicinity of Grand Forks, however, 22 miles south, a total of 1.49 inches of rain fell from Sept. 10 to Sept. 19. Table 2 shows the distribution of rainfall during the 10-day period previous to the slide obtained from the "Grand Forks Herald." The exact amount of rain in the area of the slide is not known, however, with regard to the cause of the land-slip, it is somewhat remarkable that the fall should have occurred during a spell of rather moderate weather, and not after a heavy rain. The data so far, seems to point to some

TABLE 2

CHART OF RAINFALL

Date	Inches of Rain
September 10	0.06
September 11	0.99
September 12	0.00
September 13	0.01
September 14	0.13
September 15	0.00
September 16	0.12
September 17	0.03
September 18	Trace
September 19	0.15

other cause than rain, and such exists in the undercutting of the bank and springs. There is also a possibility in that the clay is known to be scattered throughout with limestone pebbles, a concentration of which, would greatly aid in the mobility of the clayey mass.

Ground-Water. It is known that the ground-water in this county increases toward the west, and that there are especially heavy flows along the Red River. (Allison, 1932, p. 126). This indicates possible saturation of the clays in the landslide area, probably enough to be one of the main causes of the slip. Subterranean waters sometimes produce disastrous results by adding their weight to loose or porous deposits and so giving occasion to landslides. Water lubricates, and lessens friction. It forces itself through impermeable material, thus extending the lubrication; but the greatest effect of water is from the pressure. According to Ries and Watson (1936, p. 380), ground water in rocks exerts a weakening influence, increasing their tendency to deformation because: (1) it adds to the weight of the mass; (2) it weakens the substance by solution and softening; and (3) it increases the mobility of a mass.

DESCRIPTION OF SEDIMENTS IN THE AREA

> According to Grout and Soper (1914, p. 54), "Very thick beds of stratified clay, however, occur in the central portion of the Red River Valley, and their position shows that they were not deposited by the waters of the lake, . . . At the present time much of the area of the stratified clay is covered by the higher flood of the Red River, and probably no portion of these stratified clays is more than 10 feet above the high water line of the Red River or its tributaries. Since the river may have been much larger about the close of the glacial epoch, it seems clear that the clays were deposited as alluvium, in part of glacial time, and in part recent. . . . Their depth and the width they cover increase northward. . . . The clay is rather silty and contains considerable carbonaceous material. Near the surface the clay is colored yellow and is nicely laminated between gray and yellow. The yellow is caused by oxidation near the surface, and is highly calcareous, . . . The clays here have been leached to depths of from 1 to 10 feet. Overlying the clay is a thin layer of black loam. The leached portion of the clay usually is quite free from the limestone pebbles and is less plastic and dries more safely than the lower clays. The lower clay is spoken of as joint clay because of the tendency to crack when drying, . . . This clay extends to depths of almost 100 feet."

The clays which have a glacial origin are known as the gray drift clays. This drift covers more than half the state of Minnesota, and it may be the product of more than one invasion. The clay is characterized throughout by the occurrence of limestone pebbles. The drift usually has an overburden of only a few inches of soil, however, in the area of the slide, the gray drift is covered to depths of 100 feet with alluvial clays.

POSTULATED MODE OF ORIGIN

The foregoing facts are significant of this slide. "This landslide is suggestive of beginning with original soil-fall, that gave way to slump and earthflow."[1]

Because of the sharp bend in the river which is profound here, the undermining action of the river under the valley walls, tended to and most likely came in contact with clays solely softened by subterranean waters. Subsequently, the porous, silty sand and lower clays became water-soaked and were then rendered mobile. These layers overlain by other horizontal strata became so softened by the water from the river and the underground seepage, that they gave way under the pressure of the overlying mass causing the latter to slide and to be pressed out laterally toward the river, and also causing the superincumbent mass above to sink. Possibly, as the clayey mass was being subjected to these pressures, folding and crumpling, on a small scale, took place beneath the second terrace and the river. It is not known whether or not the area under the second terrace, the

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[1]Dr. Gordon Bell, Assistant Professor of Geology, Univ. of North Dakota, November 26, 1955. Personal communication.

central portion of the slide, was buckled or fissured, although if there was a tendency to fissure, the pressures of the upland laterally and the second terrace from above, would probably more or less have compacted the clay together and pushed it out.

The island in the river may be explained as happening subsequently to the dropping of the block which caused pressures to be exerted laterally toward the river; and, with these pressures affecting the viscous and plastic clays, there would be occasion for possible crumpling of the mass. Because the clays being softened and more water-soaked beneath the river, in all probability, caused a point of weakness which was taken advantage of by the pressures of the slide. The mud bar, however, situated on the opposite side of the river gave the impression that the pressures were exerted on the slip-off side of the river, which not being as saturated, formed a point of resistance and subsequently there resulted a zone of compacted clays, (See fig. 4) also, the pressure being exerted on the mass may have been decreased and because of the decrease in pressure, the mass could only penetrate points which offered the least resistance, such as the soft, saturated river bottom. The results in both cases are: compaction, overthrusting of layers, and a tendency to move in a direction of least resistance which in this case was the river bottom. This island is nearly 35 feet longer than the block that had actually dropped. This, according to Sharpe (1938, p. 54), is due to the subsequent widening and bulging which accompanies earthflows of this type.

The area of land that actually sank or slumped was part of the third terrace which by far had more weight than the second terrace. As it sank, the crescent-shaped mass moved outward slightly along the clay layer. A tension crack developed as the block pulled away laterally and sank. A crack about 2 feet in width was formed, and outlined the block which constitutes the "graben" structure. The weight of the upland exerts a greater pressure on the clay beneath it than is exerted on the clay by the second terrace. If the clay is wet enough and plastic enough, this pressure might squeeze some clay from under the third terrace laterally beneath the second terrace also causing rotation of the second terrace. This would permit the block of the upland to sink, and because of rotation, widen the tension cracks. Thus the block would sink as it makes way for itself by forcing out the clay.

As was observed, the second terrace showed only slight signs of movement. This was observed in the fact that the trees were all tilted and the river bank was raised and squared-off, as if the mass moved laterally and up into the river, giving evidence of rotation. Also, previous soil-fall is indicated by the squaring effect. This terrace compared to the upland has a heavy growth of trees and undergrowth while the block that dropped was part of a grain field. Whether or not the effect of trees and other growth had anything to do with this specific slide is not known, but the significance of it will be furthered upon. The significant difference in conditions under which the slumping took place and the area of ground beneath which most of the action took place, may lie in the fact that the slope in the first case had only the cover of grass, while in the latter case it was well covered with vegetation. However, it is already known that on areas underlain by clay when a condition of sufficient saturation is reached, whether the slope is covered or not, slumping may still take place. Never-the-less, the back-drop of the second terrace shows signs of slight bowing and small wrinkles running parallel to the break. This condition plus the fact that the action may have taken place rather shallow, may indicate that the trees had a tendency to hold the second terrace in place. None of the trees showed any great signs of struggle, however, they were all slightly tilted. It is doubtful that they would have entirely prevented the slipping. It is possible, however, that the trees might have modified the slip somewhat and permitted less movement of the second terrace.

It is an unofficial conviction that in the terraces built up all along the course of the Red River, landslides will be a constant danger where there are sharp bends in the river and underground streams. The valley is filled with deposits of this sort left by ice age glaciers and built up by the river in more recent times. Grass and small trees, however, will not be sufficient to prevent slipping when the conditions of saturation are reached. It therefore becomes apparent that in this and similar situations the engineer, landscape architect, and soil conservationist can not depend on cover alone for protection from slipping.

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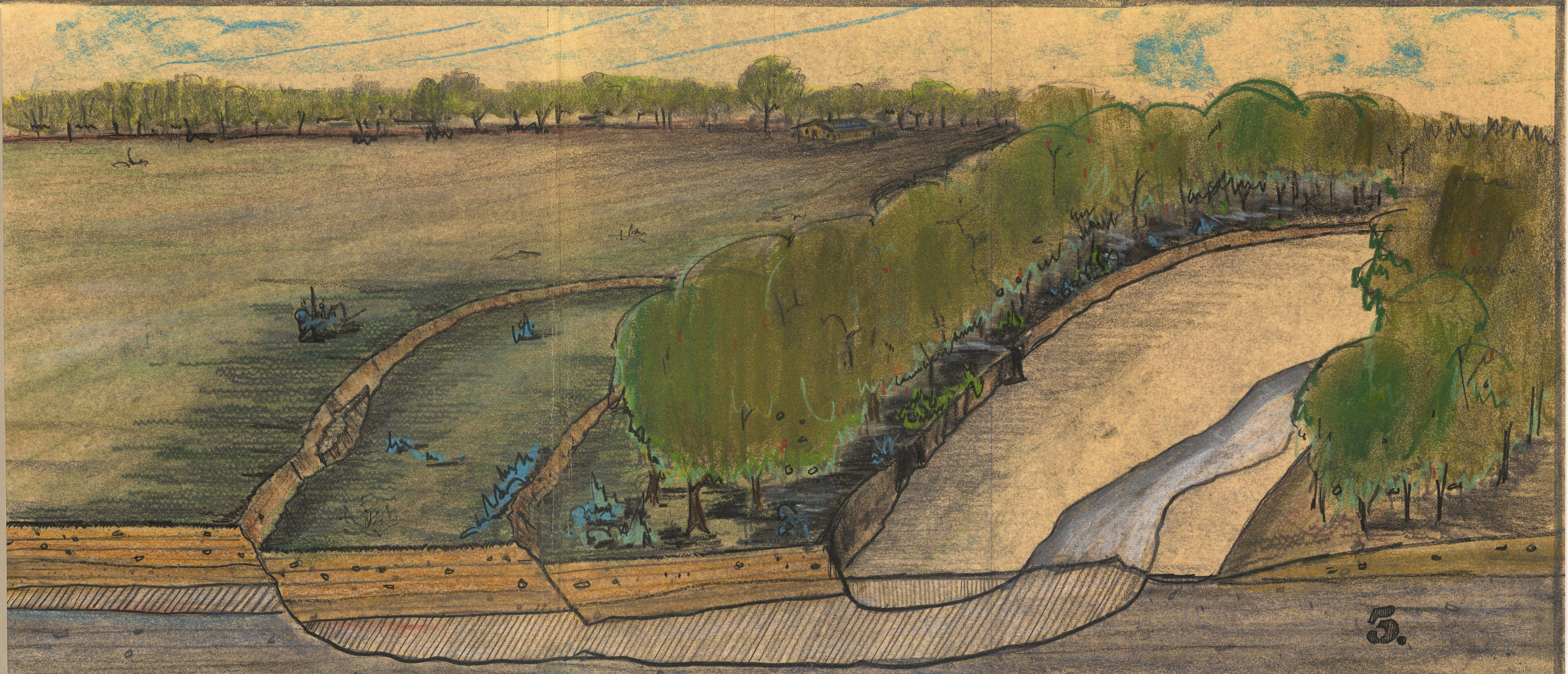

PANORAMIC VIEW OF THE LANDSLIDE AREA