Joints in Clay and Their Relation to the Slope Failure at Greenbelt, Maryland, December 28, 1962.

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Abstract

Joints in the clay of the Patapsco Formation of Late Cretaceous age contributed directly to a slope failure that occurred in a cellar excavation at Greenbelt, Maryland, in December 1962. The cut face that failed was part of a cellar for a new department store that was dug 40 to 50 feet below the surface in the Patapsco clay. Elastic rebound on relief of pressure of the excavated material and desiccation contributed to the opening of incipient fractures in the clay. The largest and most persistent of these fractures are east-trending joints, which are nearly vertical and intersect only the west and east faces. The cellar was dug in early December 1962. On the 28th, a section of the north cut face about 40 feet long, 15 feet high, and about a foot thick, toppled (instead of slumping or sliding) against a concrete form, killing 5 men and injuring 11. The following sequence of events is postulated to account for the failure: The ground was frozen to a depth of about 3 feet and was covered by about 2 inches of snow. During a thaw, melt water flowed toward the point of failure into a joint that was parallel to and about a foot from the north face. The water penetrated down the joint until it was stopped by the frozen ground. The pressure of the water forced open the joint, until the section along the wall became overbalanced, and the frozen outer block toppled as a unit.

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A joint set in the stiff clays of the Patapsco Formation of Cretaceous age has been found to have had a direct bearing on a slope failure of major consequence. Although joints in clay have previously been reported to have contributed to slope failures (Terzaghi and Peck, 1948, p. 363), in the failure that occurred at Greenbelt, Maryland, on December 28, 1962, a joint surface can be identified as the locus of failure.

In 1961, the U. S. Geological Survey began a detailed geologic study of the Washington Metropolitan area. This project is one of several being carried out in cities throughout the United States, designed to yield geologic maps of urban areas, scale of 1:24,000 that depict not only the major lithologic units but also the general engineering properties of these units and the available mineral resources. In the course of these studies excavations are examined in order to study the lithology and engineering characteristics of the rocks exposed. It was during the course of the geologic investigations of the Washington area that the excavation at Greenbelt was examined.

Greenbelt, which lies northeast of Washington, D. C. (fig. 1), is underlain by thin Pleistocene gravel and about 200 feet of clay, silty clay and sandy clay of the Patapsco Formation. The Greenbelt area is undergoing a building boom in dwellings and large stores. One project, started in 1962, was the excavation for a department

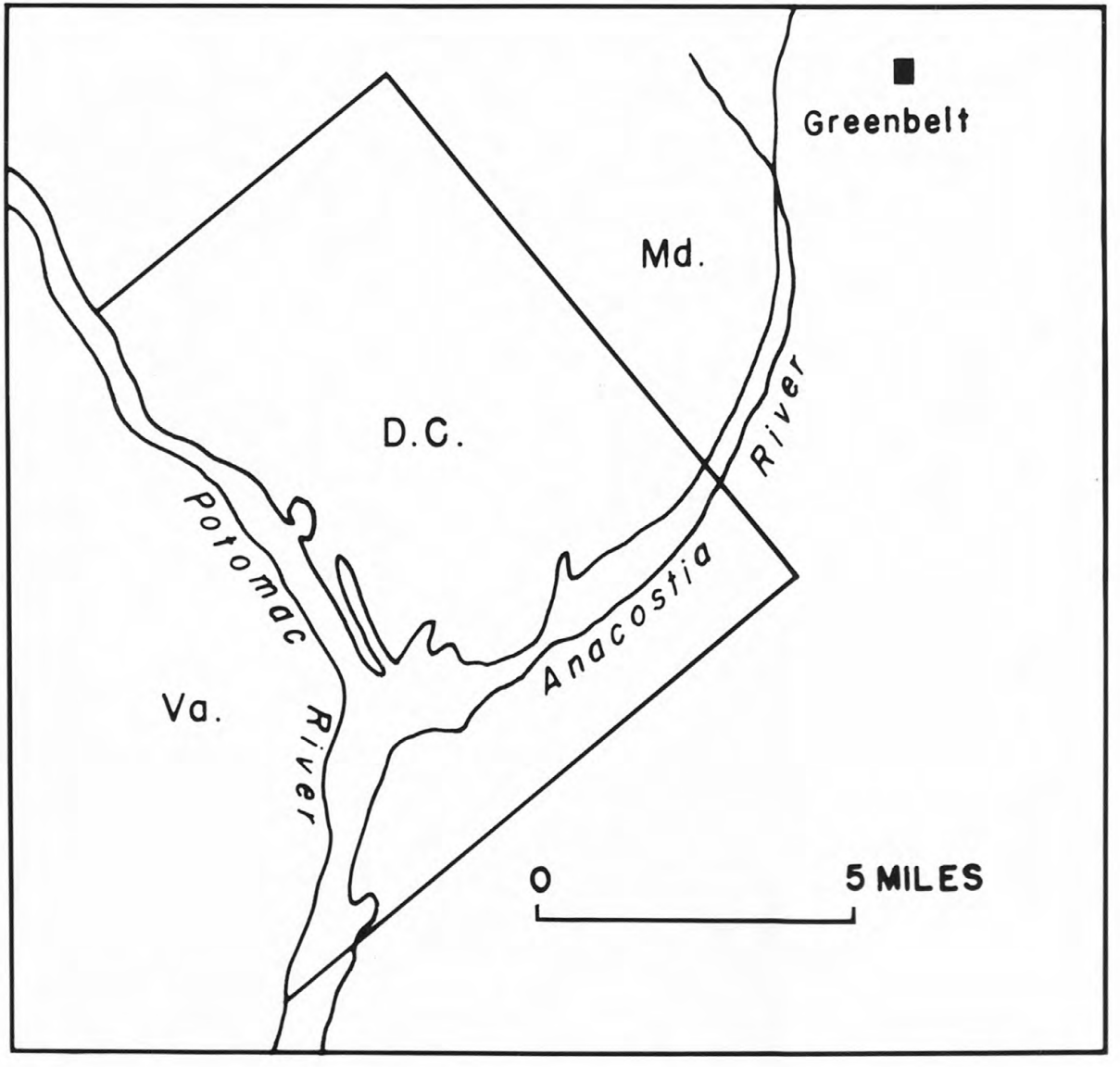

Figure 1: Index map of Washington, D.C. and vicinity

store, which consisted of leveling the side of a hill as much as 80 feet and digging an 18-foot-deep cellar approximately 400-feet square. With the exception of the gravel in the upper 10 feet, all the excavation is in the Patapsco Formation (fig. 2).

About 100 feet of the lower part of Patapsco Formation is exposed in the excavation. A section from the base upward shows about 20 feet of red clay overlain by about 80 feet of red sandy clay. Thin green sand layers occur scattered throughout in the clay and a persistent bed of yellow sand 5 feet thick occurs about 65 feet from the base of the cut. The clay minerals in the formation at the site of the excavation consist of between 75 and 90 percent kaolinite, with illite making up the remainder (J. W. Hosterman, oral communication, 1963). The undisturbed clay contains as much as 30 percent pore water by weight which is lost when the clay is exposed to the air. Samples taken from near the base of the cut for the cellar and tested for potential volume change (Lambe, 1960), range from "very critical" for the clay and silty clay to "marginal" for the sandy clay.

The clay is cut by numerous, crooked, nearly vertical, incipient east-trending joints, which, in the undisturbed clay, are completely closed. Upon release of the pressure of overburden in the excavation, the clay rebounded, and the cracks opened up. Peterson (1958, p. 1121), in a discussion of the Bearpaw Shale of Canada, says that the rebound due to excavation takes place immediately, and that on the South Saskatchewan River the rebound amounts to as much as 0.3 of a foot. In the excavation at Greenbelt, no data are available on the extent of the rebound, but inasmuch as the Patapsco Clay has not been under as much

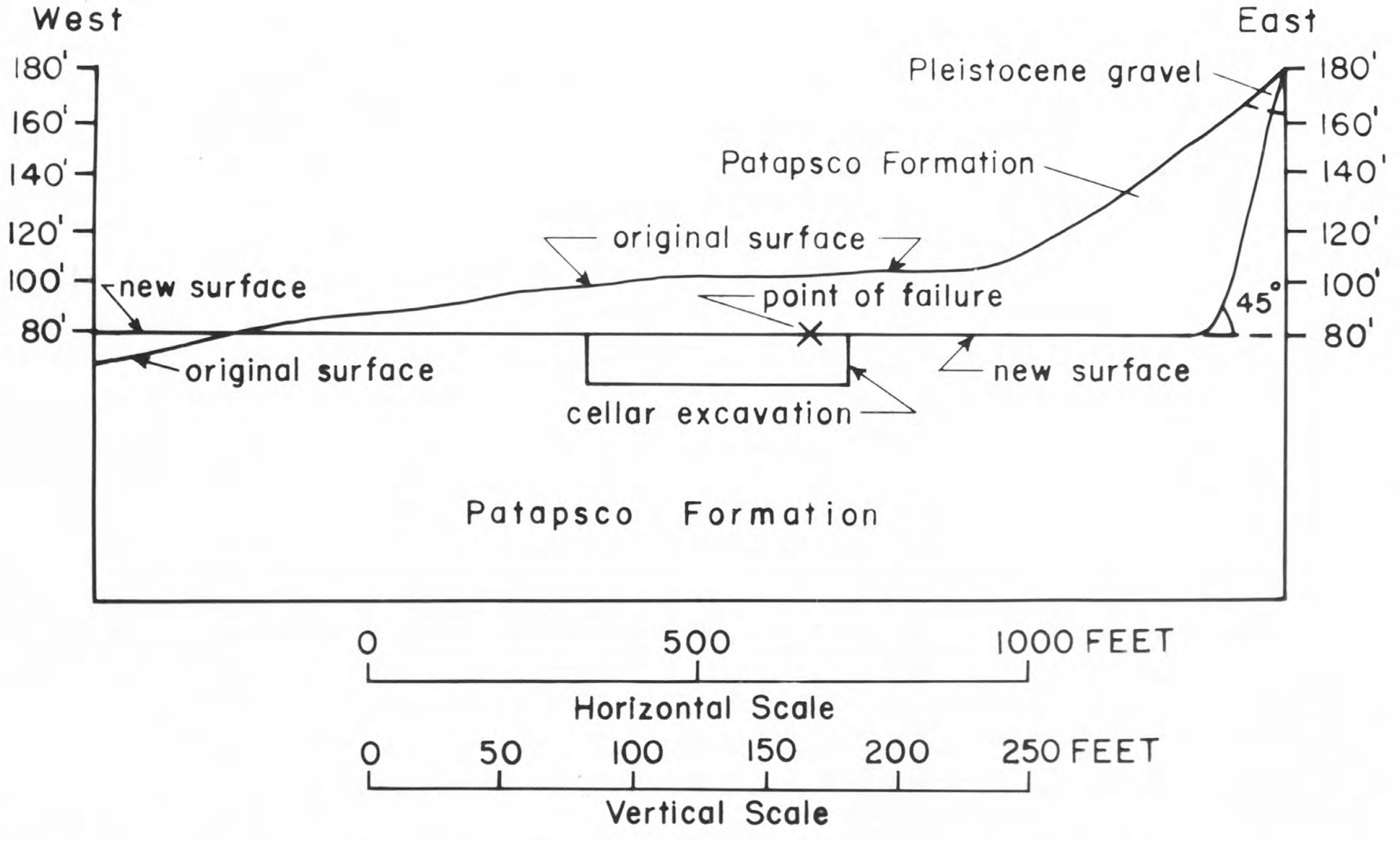

Figure 2: Sketch of East-West cross-section through the excavation at Greenbelt, Maryland, showing the original and new surfaces, and the amount of the Patapsco Formation that was moved

stress as the Bearpaw Shale, it is probably considerably less than 0.3 feet. Exposure of the clay to the air also causes drying, which in turn intensifies the cracking. In the process of rebound some movement took place along the joints and slickensides were developed on the joint surfaces. The joints became, in effect, faults, although the movement was probably no more than an inch. This method of origin of slickensides in clay was recognized by Casagrande (1949), as quoted by Peterson (1958, p. 1117-1118).

The east-trending joints, which penetrate the east and west walls of the cellar excavation at least a foot are, for the most part, less than one-half inch wide, although some measure as much as an inch in width. Figure 3 shows a portion of the clay exposed on the east wall of the cellar excavation. The nearly vertical cracks, which are as much as a foot and a half apart, are the principal joint set, and the less extensive cracks are probably the result of desiccation. The joint set was observed only on the east and west walls; none were observed on the floor of the excavation because the traffic of construction equipment obscured the details. Since the east-trending joint set is parallel with the north and south walls, they do not intersect these faces.

The cellar excavation was completed by the early part of December and concrete for the cellar walls was being poured on the north side by December 28th. A picture (fig. 4) taken about 1:00 p. m. on the 28th shows the overall view of the north wall of the excavation. At about 1:15 p. m. on the same day, a section of the north wall, 42 feet wide, 15 feet high, and about a foot thick, toppled, carrying with it a section of the forms that were being filled with concrete. Five men were

Figure 3. East wall of the excavation of Greenbelt, Maryland, showing the joint set in the clays of the Patapsco Formation of Cretaceous age. (Photo by author)

Figure 4. View of the north wall of the excavation at Greenbelt, Maryland, taken about 1:00 p.m. on December 28, 1962. (Photo by author)

killed and 11 injured. A picture (fig. 5) taken later in the afternoon of the 28th shows the same view as figure 4. Figure 6, taken 4 days later, shows a closer view of the part of the wall of the cellar excavation after the fall. Note the absence of any major cracks on this face except those connected with the failure.

December was dry and cold, and the ground was estimated to have been frozen to a depth of about 3 feet. This estimate is based on observations of other excavations in the area. On the 25th of the month about 3 inches of snow fell, and although the temperature rose briefly above freezing point on the 26th and 27th, the snow did not begin to melt until the 28th. The official maximum temperature in Washington, D. C., that day was 39°, and on the north wall of the excavation, which received full sun most of the morning, the temperature was probably above 40° for several hours. Figure 7 is a schematic cross section of the north wall, drawn from a photograph (fig. 8), and shows the part of the wall that failed. The following sequence of events could account for this failure. The snow melted and water flowed into a joint that was parallel to and about a foot from the edge of the north wall. The joint filled with melt water, and as the water could not escape because of the frozen clay, a hydrostatic pressure was built up. The pressure forced the joint surfaces apart, and in so doing, the upper part of the wall was pushed outward until it became unbalanced and fell, toppling forward instead of slumping or sliding.

Figure 5. Same view as Figure 4, 6aken later in the afternoon of December 28, 1962. Note point of failure. (Washington Post photography)

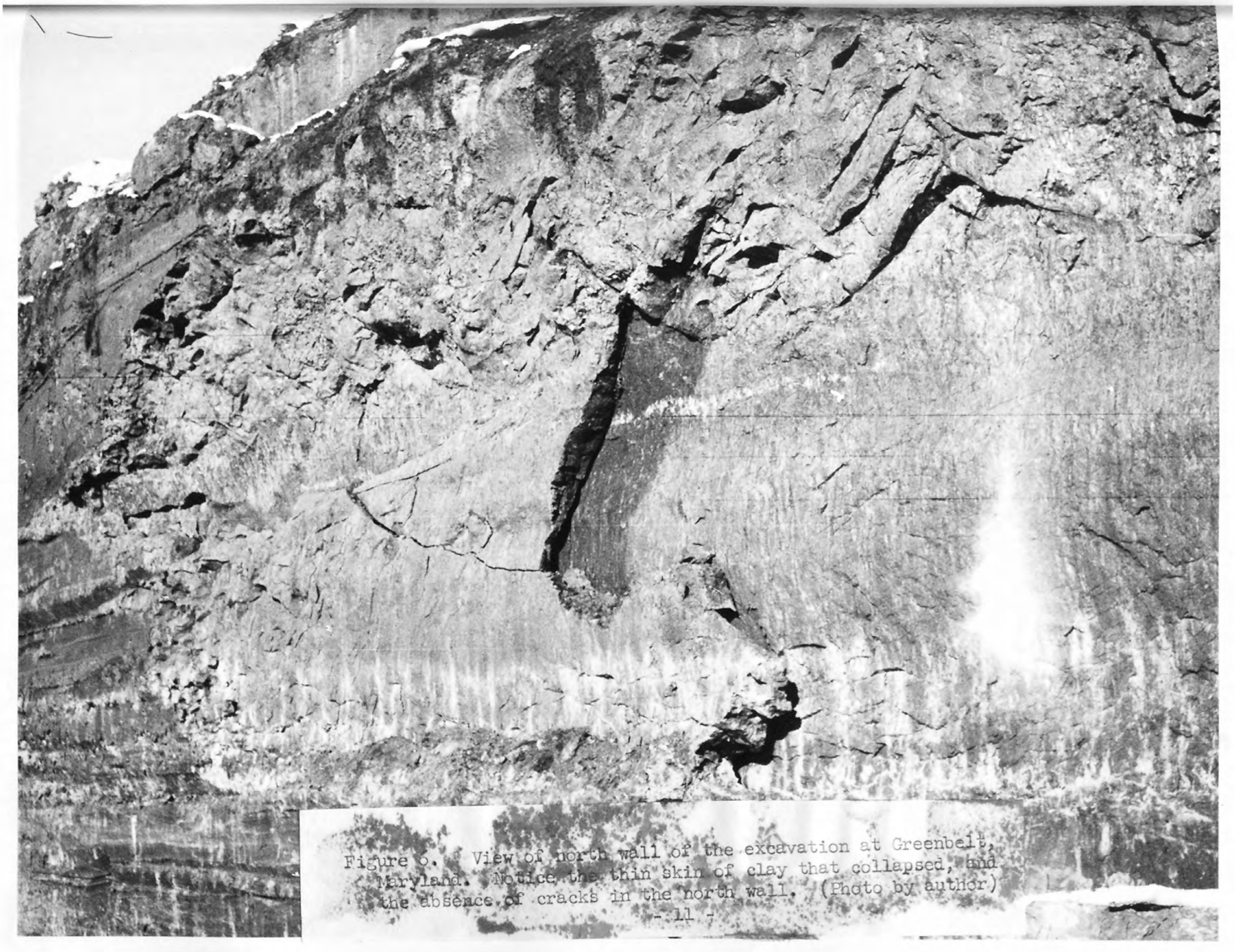

Figure 6. View of north wall of the excavation at Greenbelt, Maryland. Notice the thin skin of clay that collapsed, and the absence of cracks in the north wall. (Photo by author)

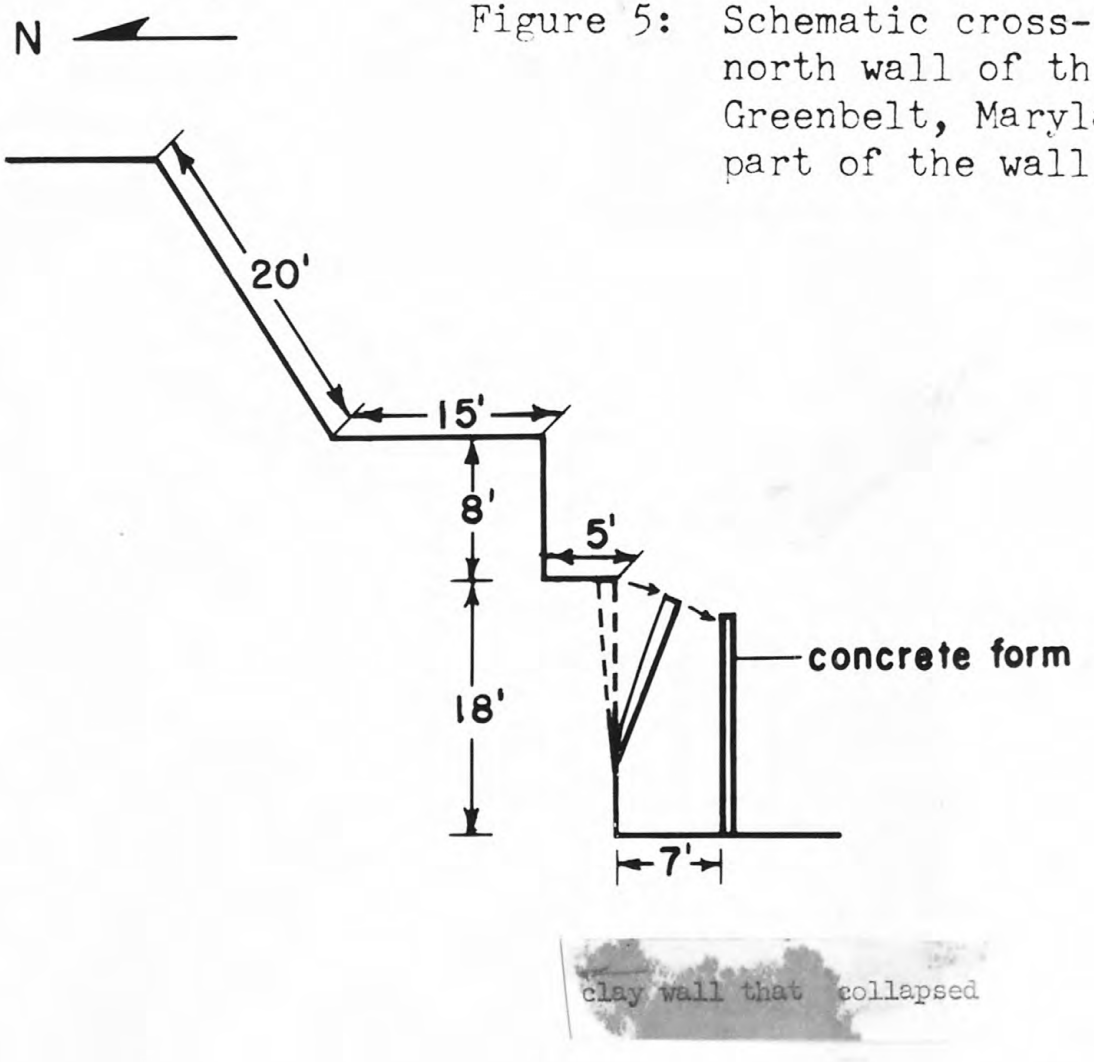

Figure 5: Schematic cross-section of the north wall of the excavation at Greenbelt, Maryland, showing the part of the wall that failed

Figure 8. Photography of the north wall of the excavation at Greenbelt, Maryland, looking east, taken December 29, 1962. This picture is the basis for Figure 7. (Photo by author)

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