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PLASTICITY STUDIES OF TILL INTRUDED INTO JOINTED LIMESTONE IN FAIRMOUNT QUARRY, ILLINOIS

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For a number of years limestone for road metal and agricultural use has been quarried about three miles southwest of the village of Fairmount in east-central Illinois (Fig. 1). The quarry is in the Livingston limestone in the upper part of the McLeansboro group of the Pennsylvanian System.

The limestone occurs as a small outlier north of the main area of Livingston on a small anticline on the east flank of the major structural feature, the LaSalle Anticline. The overburden of 15 to 20 feet of glacial till with a thin mantle of loess is removed by stripping.

The upper surface of the bedrock is nearly flat and contains two conspicuous and a third minor set of striations; one set trends about S 10° W, one about S 45° W, and the minor set trends southeast.

Essentially vertical openings a few inches to several feet wide and up to about 10 feet deep were formed by solution along joints in the thin-bedded limestone. The joint system is composed of two sets, one set trending N 63° E and the other about N 25° W. The enlarged joints are filled with several different kinds of material which aid in the interpretation of the post-Paleozoic geological history of the region. The filled joints and the glacial striations on the stripped surface of the limestone are visible in Figure 2.

The Pleistocene deposits in the Fairmount area belong, except for joint fillings, to the Tazewell substage of the Wisconsin stage of glaciation. Eveland (1952) described the following section in the south wall of the Fairmount Quarry:

Wisconsin (Tazewell)		
Loess	(leached)	1′ 8″
Champaign Till		
Buff, oxidized, leached		1′ 0″
Buff, oxidized, calcareous		8′ 6″
Blue-gray, calcareous		4′ 6″
Pennsylvanian System		
Limestone		

The inner Champaign moraine crosses the northern two-thirds of the quarry, and the south part of the quarry lies within the Champaign drift plain between the middle and inner moraine.

Although the Shelbyville moraine lies some 30 miles farther south, no Shelbyville till is recorded by Eveland; this indicates that he regarded it as lacking because of nondeposition or because of removal prior to deposition of the Champaign till.

SAMPLING SITES

In April, 1955, blasting operations exposed a new section of the quarry showing several vertical enlarged joints nearly 2 to 3 feet in width and up to about 10 feet deep. The joints were filled with what appeared to

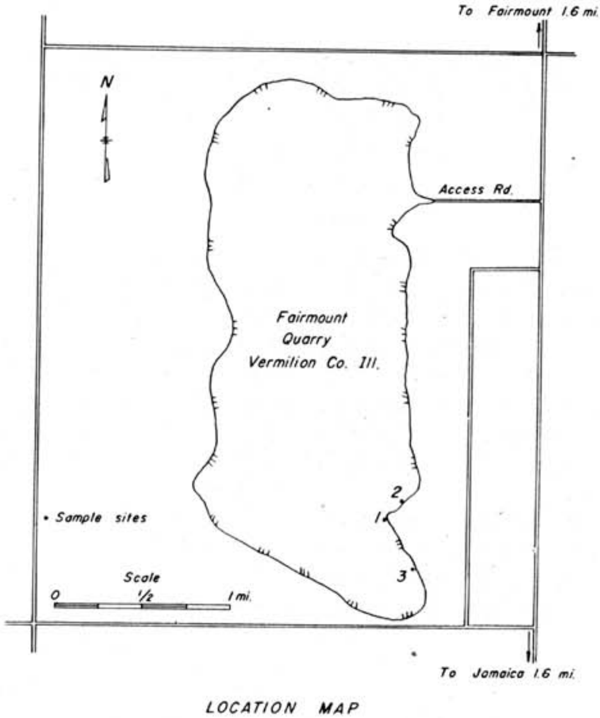

FIG. 1.—Map showing sites from which samples were taken.

FIG. 2.—Filled joints and striations on stripped surface at Site 3.

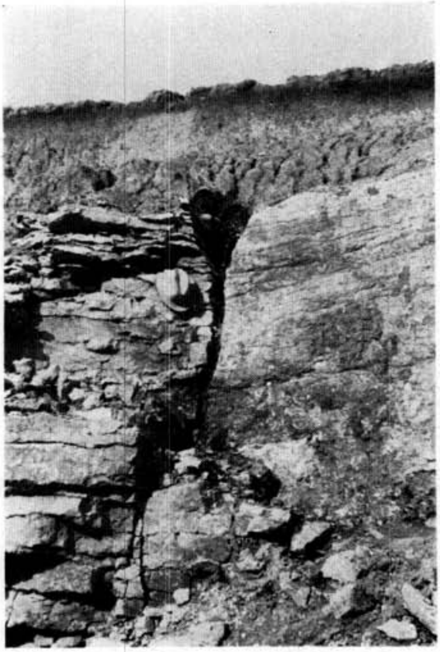

FIG. 3.—Filled joint at Site 1. Pick at contact of Champaign till above and plastic clay below.

be a heterogeneous mixture of gray, red, and purple clay, which closer inspection showed was actually several different types of material—a gray unaltered till containing many cobbles and boulders in the upper part of the joints, a much more plastic brown to purple clay containing weathered pebbles underlying the gray till, and a brown to reddish-brown clay whose relation to the other materials was not clear. The two lower clays were slickensided and squeezed laterally along bedding-planes of the limestone. The authors tentatively concluded that the two lower clays represented, respectively, weathered older till and a pre-glacial joint-filling of limestone residuum.

Unfortunately, it was found on the return to the quarry several months later for mapping and sampling that the face no longer existed and that the joint-fillings earlier exposed had been removed in the quarrying operations. Consequently, other sampling sites were selected. Those selected were two on older faces of the quarry where two rather narrow filled joints were exposed and a third site on the stripped surface at the intersection of two joints. The locations of the three sites are shown in Figure 1.

The enlarged and filled joint which constitutes Sample Site 1 (Figs. 3 and 4) is funnel-shaped, which is typical of joints enlarged by solution. The Champaign till has intruded down about ten inches into the joint.

The joint at Sample Site 2 (Figs. 5 and 6) varies from two to six inches wide. The upper part of the joint at the contact of the limestone with the Champaign till was covered by debris and was not readily available for study. The pebbly clay immediately above the geology pick (Figs. 5 and 6) is interpreted as being a slightly weathered till of pre-Champaign age. The till has been squeezed laterally several inches into the bedding plane. The underlying reddish-brown silty clay is believed to be limestone residuum.

Site 3 (Fig. 2) is located on the stripped surface. The site was investigated by means of a pit 2.5 feet deep. The intersecting joints have widths of 6 and 14 inches. The basal part of the Champaign till is intruded approximately 12 inches into the upper portion of the joint. This unaltered till contains many cobbles and boulders, some of which

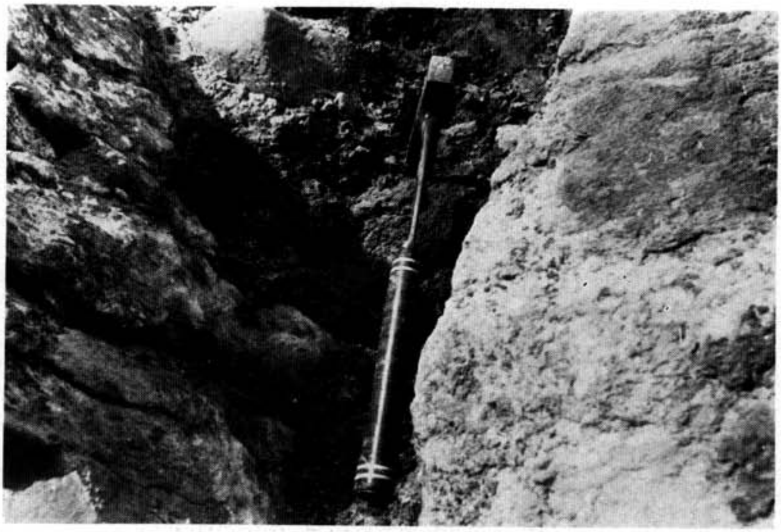

FIG. 4.—Close-up view of filled joint (Site 1). Pick at contact of Champaign till above and plastic clay below.

have been pushed in and their tops planed off and striated parallel to one set of striations on the limestone surface. Beneath the unaltered till is a brown, finely jointed, plastic clay, containing only an occasional small weathered granite or greenstone pebble. This material is tentatively identified as a weathered, older, intruded till.

PLASTICITY CHARACTERISTICS

Correlation of till sheets and sediments in general may be carried out by a number of techniques including grain-size analysis, pebble count, heavy-mineral determination, clay-mineral analysis, or any combination of these. The plasticity characteristics of sediments, rarely used by geologists in their correlation studies, is widely used in the field of soil mechanics. Atterberg (1913) introduced the concept of *liquid limit* and *plastic limit* for agricultural soil classification, and Terzaghi (1925) adapted the concept for use in soil mechanics. The liquid limit is the moisture content of a cohesive sediment just as it passes from the plastic state into a liquid state or slurry, at which point the sediment possesses a slight but measurable shearing strength. Addition of water to a sediment just at the liquid limit forms a slurry. Upon removal of water by drying, the sediment passes into the plastic state. Upon continued drying, the sediment passes through the plastic state to form a stiff semi-brittle material. The moisture content at this change of state is defined as the plastic limit. The liquid and plastic limits of a cohesive sediment are, therefore, the upper and lower limiting moisture contents (expressed as percentages) at which the sediment remains plastic. The numerical dif-

FIG. 5.—Filled joint at Site 2. Pick at contact of gray-brown pebbly clay above and reddish-brown silty clay below.

ference between the liquid and plastic limits is referred to as the *plasticity index* and indicates the range in moisture content over which the sediment is plastic. A large plasticity index of 50 or greater indicates a highly plastic material, while a plasticity index of 20 or less indicates a material possessing only limited plastic qualities.

The procedures for determining the liquid and plastic limits (also referred to as Atterberg limits) are arbitrary but are simple to perform and have been standardized (Casagrande, 1932). The plasticity characteristics of any given sediment are determined chiefly by the grain size of the sediment and mineralogical composition of the clay-size fraction. As both of these properties are accepted by geologists as being of correlative value, it follows that the plasticity characteristics, which are a result of the combined effects, could likewise prove a useful tool in correlation of sediments. Consequently, for the work undertaken in this investigation the plasticity characteristics of the various sediments were determined.

The plasticity characteristics of sediments can best be studied by plotting the liquid limit and plasticity index on a plasticity chart (Fig. 8). The A-line is an empirical boundary between typical clays, which plot above the line, and silts and organic sediments which plot below the line (Casagrande, 1947). The farther to the right along the A-line a particular sediment falls,

FIG. 6.—Close-up view of filled joint (Site 2). Pick at contact of gray-brown pebbly clay above and reddish-brown silty clay below.

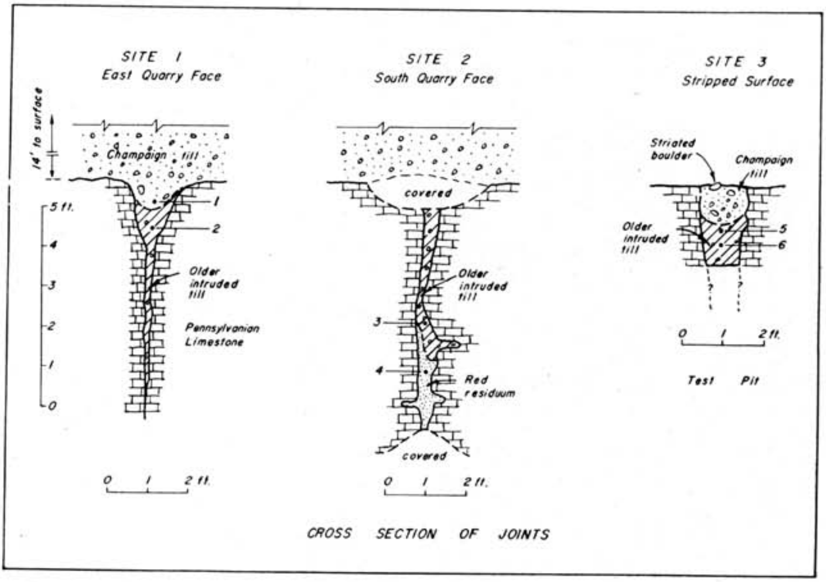

FIG. 7.—Cross-section of joints showing location of samples and type of joint filling.

the greater the plasticity of the sediment.

Sample 1 of unaltered Champaign till from Site 1 is shown plotted at its test values of liquid limit 24.5% and plasticity index of 9.5%. It falls in the zone formed by the plotting of the test results of 13 samples of unweathered till from the Champaign moraine (Larsen and Thornburn, unpubl. rept.). Eighty other samples from unweathered till of the Shelbyville, Cerro Gordo, Le Roy, and West Bloomington moraine also plot in or very near this zone. These data indicate that materials of similar geological origin plot in a small zone essentially parallel to the A-line.

Sample 2 from Site 1 and Sample 3 from Site 2 (Fig. 7) occur in joints beneath the Champaign till. Sample 3 consists of slightly weathered till with scattered, nearly-fresh pebbles of granite and greenstone. It falls within a second cross-hatched zone determined by the plotting of the test results of ten samples from the B-horizon of soils developed on Shelbyville till with little or no loess cover (Thornburn, pers. comm.) in various localities in Shelby, Vermilion, and Montgomery counties. Sample 2 from Site 1 consists of weathered till with only an occasional weathered pebble and plots to the right of Sample 3 along the A-line, indicating a higher plasticity. Although it does not fall within the cross-hatched zone of the weathered Shelbyville samples it is more closely related to this zone than to the others.

Samples 5 and 6 from Site 3 consist of highly weathered, plastic, brown, clay till with an occasional highly weathered pebble. The plotted positions of these samples indi-

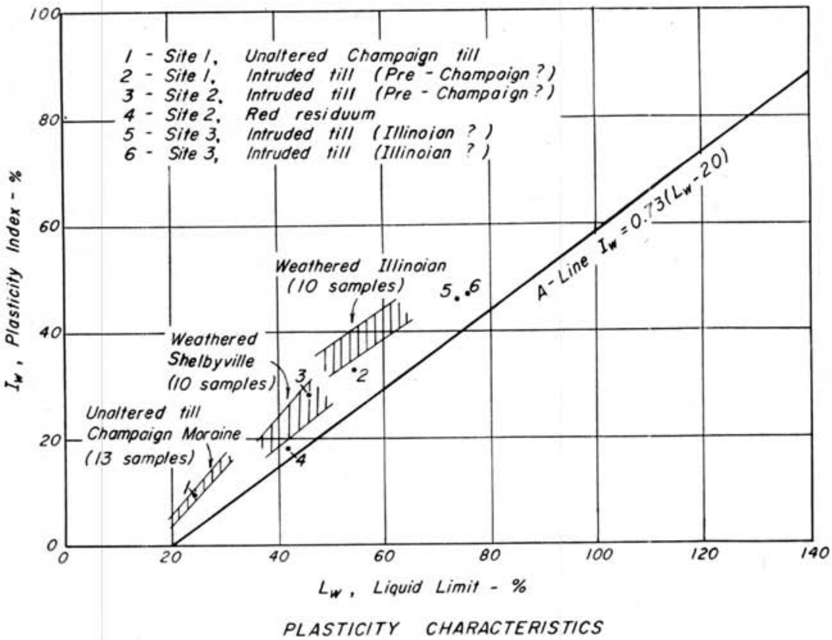

FIG. 8.—Standard plasticity-characteristics chart showing plotted positions of plasticity characteristics of samples of material intruded in joints at Fairmount Quarry and their relation to plotted positions of plasticity characteristics of other samples of till in east-central Illinois.

cate they are more plastic than any of the samples studied. They fall close to a third cross-hatched zone which includes the test results of ten samples from the B-horizon of soils developed on Illinoian till with little or no loess cover (Thornburn, pers. comm.) in Crawford, Edwards, Fayette, and Lawrence counties. Samples 5 and 6 might be included in an extended cross-hatched zone of a more thoroughly weathered and more plastic Illinoian till or they may be representatives of a till older than Illinoian.

Sample 4 from Site 2 is regarded as red residuum from the weathering of the bedrock. The point plots close to the A-line and the sample is moderately plastic. This is characteristic of limestone residual soils (Thornburn and Deere, 1955).

SUMMARY

Examination in the field of three filled-joints and laboratory study of the plasticity characteristics of the joint-filling indicate that at least four types of material are present. These are tentatively identified as unaltered Champaign till, slightly weathered pre-Champaign till—possibly Shelbyville—highly weathered till of Illinoian or pre-Illinoian age, and a pre-glacial joint-filling of limestone residuum. The problem will be further studied by observing joints as new faces are opened at the quarry and by studying the plasticity characteristics of the weathered Wisconsin and older tills in the general region.

Acknowledgments

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