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JOINTING IN THE FORT PAYNE AND CHATTANOOGA FORMATIONS ALONG THE NORTHWESTERN HIGHLAND RIM ESCARPMENT, TENNESSEE

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ABSTRACT

Joints in the Fort Payne and Chattanooga Formations were measured along a section of the northwestern Highland Rim escarpment in Middle Tennessee. The area studied extends approximately from Gallatin (Sumner County) in the north to Franklin (Williamson County) in the south. A total of 1,068 measurements were made at 103 locations. Two prominent trends are indictated for both formations. The most prominent trend is N 55°-70° W, and these appear to be shear joints. The secondary trend is N 30°-45° E, and these exhibit characteristics of tension joints. There is a less prominent trend in the Chattanooga Shale of N 80°-85° W. A search of geological literature relating to joint studies was also conducted. Others report joint patterns similar to those of the present study area, and these trends appear to be common to all rocks in Middle Tennessee.

INTRODUCTION

Jointing in rock units directly and indirectly affects excavation and other construction activities. An understanding of jointing is also critical in the prevention of certain types of landslides. Joints also control the rate and volume of ground water movement in many areas. Since the northwestern Highland Rim escarpment is an area that is highly jointed and has slope stability problems, and is adjacent to an expanding urban environment, it was selected for this study. The report area extends from Gallatin (Sumner County) in the north to Franklin (Williamson County) in the south (Fig. 1). This study is part of a comprehensive analysis of the geology and geomorphology of this segment of the Highland Rim escarpment.

PHYSIOGRAPHIC SETTING

The Highland Rim escarpment is the boundary between the Central Basin and the Highland Rim Plateau. In most places the escarpment is very irregular with numerous valleys extending into the Highland Rim and with remnant hills of the Highland Rim along the periphery of the Central Basin (Fig. 1). Along this outer zone of the Central Basin, the general elevation ranges from 450 to 600 feet. Numerous high hills capped by the Fort Payne Formation (lower Mississippian) and Chattanooga Shale (upper Devonian) exceed 1000 feet in elevation. The Highland Rim Plateau is capped by Fort Payne and younger cherty Mississippian rocks with the outlying hills representing the remnants of a once-continuous cover of the Central Basin by these rocks.

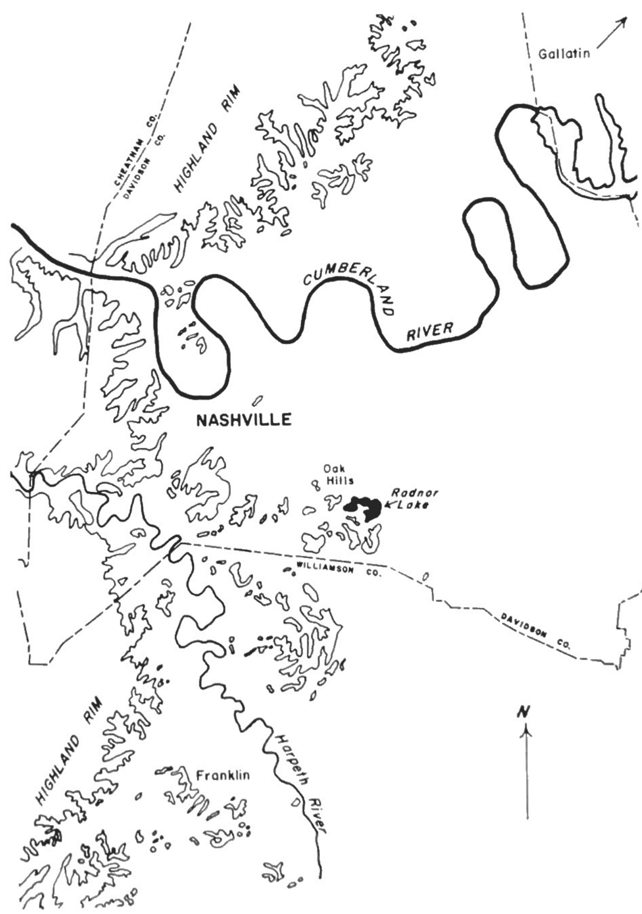

FIG. 1: *Location of study area.*

There are two prominent areas of these Fort Payne capped hills in Williamson and Davidson counties, in the west central part of the Central Basin. These "strings" of hills have an essentially northwest-southeast orientation. One is in the Oak Hills-Radnor Lake area and the other is to the north of the Harpeth River

(Fig. 1). There is a third line of hills just north of and parallel to the West Harpeth River. Many other scattered outliers are present around the periphery of the Basin, but do not have a well-defined orientation.

Relief on the Highland Rim escarpment ranges from 400 to 500 feet. The Highland Rim is characterized by a gently rolling topography with the escarpment dissected by many stream valleys. These deeper valleys are cut into pre-Chattanooga rocks, and the streams flow into the Central Basin.

JOINT CHARACTERISTICS

Joints are fractures or cracks in sedimentary rocks that are vertical or nearly vertical and along which there has been no visible displacement. They are of special interest to geologists because they are a manifestation of the stress field(s) to which the rocks have been subjected, and thus offer some insight to the structural history of the area. They are also zones along which weathering proceeds more rapidly, and they serve as avenues for the downward movement of ground water.

Joints may be classified into two major subgroups, shear joints and tension joints. Each of these types has distinctive features that allow for identification in the field. Shear joints are more common, and are remarkably planar. They extend cleanly through different lithologies, even through concretions embedded in shales. Most of

FIG. 2 *Shear joints in Chattanooga Shale—Gassaway member.*

them are nearly vertical, but they may be inclined as much as 15°. The traces of these joints extend over distances ranging from a few feet to several hundred feet or more, and commonly disappear under stream banks or beneath residuum. Shear joints are also "tighter" when unweathered.

Featherlike or flamelike markings are present on some of the shear joint surfaces. These are a series of minute, irregular ridges 1/4" or less wide, with a relief of about 1/16" (Roberts, 1941). They are discontinuous and usually curved, arranged in parallel and in echelon. Generally a separate "plume" is present on each layer through which a joint passes, especially in the Fort Payne Formation where joints project through the dolosiltites and carbonates into one of the chert layers. These features have also been observed in the Chattanooga Shale. They are not generally visible on joints in Middle Tennessee because they disappear quickly upon weathering.

In contrast to shear joints, the surfaces of tension joints are typically curved and irregular with a rough, torn appearance, especially where they cut different rock types. They approach a planar habit in thick shales such as the Chattanooga. They curve both along strike and vertically, and variations of 5° to 10° in strike in short distances are common. Because of the irregular surfaces of tension joints, they rarely exhibit plumose markings, even when unweathered. Tension joints are uncommon in thickly bedded rocks, such as the Fort Payne Formation.

In general, the thicker the rock layer, the less numerous and more widely spaced are the joints, either shear or tension joints. This principle is illustrated by a comparison of jointing in the Gassaway member of the Chattanooga Shale and the overlying lower part of the Fort Payne Formation. Almost everywhere the Gassaway is encountered it displays numerous, closely spaced joints. Far fewer joints are observed in the Fort Payne, even where there are fresh exposures showing well developed jointing.

JOINT MEASUREMENTS

Several problems are encountered in measuring joints. For example, Hoblitzell (1970) found that measurements may vary as much as 8° when the same joint is measured by different individuals. Joints perpendicular to a roadcut are especially difficult to measure. Repeated measurements by the same person may vary by as much as 8°. This is especially true of joints in the Gassaway member of the Chattanooga Shale. Therefore, the measurements given herein may be assumed to have a possible error range of up to 8° in strike. None of the measurements noted in this report were corrected for magnetic declination (1°E., 1975), since such accuracy is not attainable.

Joint measurements in the study area indicate two prominent trends, one to the northwest, another to the northeast. The most prominent of these is N 60°-70° W in the Chattanooga and N 55°-65° W in the Fort Payne. The second prominent trend is N 30°-45° E in both of these formations. There is a third, less significant trend of N 80°-85°W in the Chattanooga. The northeast trending joints appear to be tension joints, whereas the others are shear joints. Significant variations on these trends were not apparent along strike in the study area.

Hoover (1954) measured joints in the Chattanooga Shale and Fort Payne Formation in DeKalb County on the Eastern Highland Rim and found two major trends. The most prominent is N 55°-75° W, and his description and photographs indicate they are mostly shear joints. Hoover's data are in close agreement with those of this report.

In another study Johnson (1975) measured joints in

the Fort Payne Formation in the Yellow Creek area of northeastern Mississippi, and his data likewise indicated two major trends. These are N 54° W ± 5° and N 38° E ± 5°. He did not state which is the dominant trend, but his data indicated that the most prominent is the northwest trend.

In a study of the Well's Creek Basin, Wilson and Stearns (1968) reported two trends of joints in the Mississippian rocks of that area. These are approximately N 10° E and N 75° W, with the trends persisting both inside and outside the deformed area (cryotoexplosive structure).

Wilson (1935) measured 350 joint lineations in Ordovician and Silurian limestones, the Chattanooga Shale, and the Fort Payne Formation, and found two major trends, N 50° -80° W and N 10° -50° E.

Although the discussion above centers on dominant (i.e., majority) joint trends, it should be noted that joints were measured in the study area that ranged the entire 180° arc of the compass.

CONCLUSIONS

Although joints are randomly distributed in the rocks of Middle Tennessee, certain linear trends are dominant. The dominant trend of joints in the study area (N 60° -70° W) is essentially perpendicular to the axis of the Nashville dome, and the secondary trend (N 30° -45°E) is approximately parallel to this axis. Although the mechanisms by which movement along this axis could have caused these joints to form are not well understood, their empirical relationships are significant.

The measurements of joints in older rocks in Middle Tennesee have yielded results similar to those data summarized in this report. A few joints in rocks underlying the Chattanooga Shale were measured by the author in the study area, and they also are similar in strike to the dominant trends in the Chattanooga and Fort Payne Formations. All of these data indicate that these major trends are common to all rocks in the Middle Tennessee area.

Future studies of jointing and other structural features in Middle Tennessee may lend more insight to the history and development of the Nashville dome.

The following is a summary of factors for consideration in relating joints to human activities:

1. Joints, especially those that are weathered, are zones or planes of weakness in rock units.
2. In foundation or dam construction, quarrying, or other excavation, a knowledge of jointing can be advantageous and deleterious effects can be minimized.
3. Weathered joints are important recharge zones for groundwater, and understanding them can be of value in the search for groundwater supplies.
4. Jointing may be a factor in slope stability, and may increase hazards in the event of slope failure. Excavation activities and structure design should be tailored to those potential problems related to jointing.

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LITERATURE CITED

Billings, M. P. 1954. *Structural geology* (Second Edition), Englewood Cliffs, N.J., Prentice-Hall, Inc., p. 106-123.

Hoblitzell, T. A. 1970. *Joints along interstate highway I-40 Smith and Wilson Counties, Tennessee:* Vanderbilt University, unpublished Master's Thesis.

Hoover, K. V. 1954. *Joint Patterns in the Chattanooga shale of DeKalb County,* Tennessee, University of Tennessee, unpublished Master's Thesis.

Johnson, V. L., 1975, Fracture patterns of the Yellow Creek area, Mississippi, Southeastern Geology, Volume 16, p. 173-177.

Miller, R. A., 1973, Environmental geology summary of the Kingston Springs quadrangle, Tennessee, Tennessee Division of Geology, E.G.S., No. 2, p. 2.

Parker, J. M., 1942, Regional systematic jointing in slightly deformed sedimentary rocks, Geol. Soc. Amer. Bull., Vol. 53, No. 3, p. 381-408.

Stearns, R. G., and Marcher, M. V., 1962, Late Cretaceous and subsequent structural development of the Northern Mississippian embayment area. Geo. Soc. Amer. Bull., Vol. 73, p. 1387-1394.

Stearns, R. G., and Wilson, C. W., Jr., 1968, Geology of the Wells Creek structure, Tennessee, Ten. Div. of Geol. Bull., 68, p. 104-107.

Wilson, C. W., Jr., and Stearns, R. G., 1968, Geology of the Nashville dome, Jour. of Geol. Volume 73, No. 5, p. 358-463.

Wilson, J. M., and Stearns, R. G., 1971, Hydrology, geology and erosion by leaching in Skillman basin of the western Highland Rim, Lawrence County, Tennessee, Tenn. Div. of Water Resources, Research Series No. 3, p. 17.