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ORIGIN OF CLASTIC DIKES IN THE PORTERS CREEK CLAY AT PINSON, TENNESSEE

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ABSTRACT

Clastic dikes are tabular bodies, generally of sandy material, that transect the bedding planes of the country rock. The formation of clastic dikes is dependent upon the existence of a clastic material in a potentially mobile state, commonly a water-saturated sand, adjacent to the country rock; an opening in the country rock into which the material can move; and a force of sufficient intensity to move the clastic material into the country rock. Clastic dikes have been found in many exposures of the Porters Creek Clay in western Tennessee. One of the best exposures is located about 1 mile northeast of Pinson, Madison County, Tennessee.

The Pinson dikes are composed mostly of fine, micaceous, brownish sands that are lithologically similar to the Clayton (Paleocene) and Ripley (Cretaceous) Formations, and some sandy zones in the Porters Creek Clay (Paleocene). The sands were injected into fault zones and later, in some places, into cavities in the Porters Creek Clay. The dikes commonly are associated with minor faults caused, for example, by differential settling after the sediments were deposited. The faults observed associated with the dikes in the Pinson area generally have a vertical displacement of a fraction of an inch to a foot. Large dikes such as the principal dike, which is 15 feet in width, may have required other geologic processes, such as the formation of cavities, to account for this large size. The principal dike at Pinson probably was originally much smaller and may have been the result of an injection of sand during movement along a fault plane. Later the fault blocks were separated by tension resulting from downwarping of the Mississippi embayment syncline; subsequent stretching of the unconsolidated sediments allowed additional injections of clastic material, and the dike eventually reached its present size. The existence of cavities (usually water-filled openings in the country rock) has been observed during the drilling of water wells in West Tennessee at depths ranging from 60 to 550 feet below land surface. Ground water under hydrostatic pressure is believed to have been the lubricant that facilitated the movement of the sand into the country rock and provided part of the external forces that initiated and sustained the injection. The dikes and cavities are post-Porters Creek in age.

INTRODUCTION

Several clastic dikes are exposed about 1 mile northeast of Pinson, Madison County, Tennessee (Figs. 1 and 3). They are tabular bodies of mostly fine, micaceous, tan to brown sand, that transect the bedding planes of the Porters Creek Clay. The largest dike is exposed on the hillside overlooking the South Fork of the Forked Deer River and is visible from Ozier Road (Figs. 2 and 3). The dikes near Pinson were first described by Roberts and Collins (1928, p. 48). Glenn (1906) describes other clastic dikes in western Tennessee but does not specifically mention those at Pinson.

The purpose of this paper is to suggest a possible mode of origin for the dikes by: (1) describing the dike material and indicating its similarity to sediments lower (older) in stratigraphic position, thereby showing that older material has been injected upward into younger sediments; (2) summarizing what has been written about the dikes of western Tennessee; (3) indicating the mobility of the sand and the occurrence of cavities as described by water-well drillers, and (4) summarizing these factors as they relate particularly to the possible origin of the principal Pinson dike.

Fig. 1. Map of West Tennessee showing Madison County and the town of Pinson.

A general knowledge of the stratigraphy of the area will aid in understanding the geologic setting of the dikes. The geologic units are described briefly in Table 1.

DESCRIPTION OF THE PINSON DIKES

The principal clastic dike (Fig. 2) has a maximum width of about 15 feet and a vertical exposure of 15 feet. It is composed primarily of unconsolidated very fine sand with some medium sand. The grains are well sorted and consist mostly of clear or gray subangular quartz. The dike is also very micaceous; some flakes of muscovite are as large as coarse sand. Lignite is common and is generally the size of very fine to fine sand. Concentrations of rutile and other heavy minerals are similar to the heavy mineral zones in the Ripley Formation (Table 1). Roberts and Collins (1928, p. 48) report that the clastic dike material contains very minor amounts of weathered glauconite. The dike material generally is yellow, tan, or brown because of ferruginous cement and weathering. The minor dikes have essentially the same composition as the principal dike but

Table 1
Stratigraphic units underlying Pinson.

Series	Group	Formation	Thickness (in feet)	Description
Post-Paleocene	post-Midway undifferentiated		0-50	Fine to coarse sands, colored gray to reddish depending upon the degree of weathering. The alluvium and terrace contain gravels. Units are locally lignitic and micaceous; may contain thin layers of sandy gray clay.
Paleocene	Midway	Porters Creek Clay	<100	Dark-gray to black plastic to shaly clay containing a few lenses of fine micaceous sand. Considered to be nonlignitic.
		Clayton	Av. 40	Fine to medium micaceous, clayey, glauconitic sand.
Upper Cretaceous		Owl Creek	Av. 40	Gray to black, micaceous, fossiliferous clay.
		Ripley	Av. 390	Mostly fine to coarse sand, color usually white to gray, sometimes buff or varicolored. Unit is partly lignitic, often very micaceous, and contains lenses of gray to black, silty to sandy, carbonaceous clays.

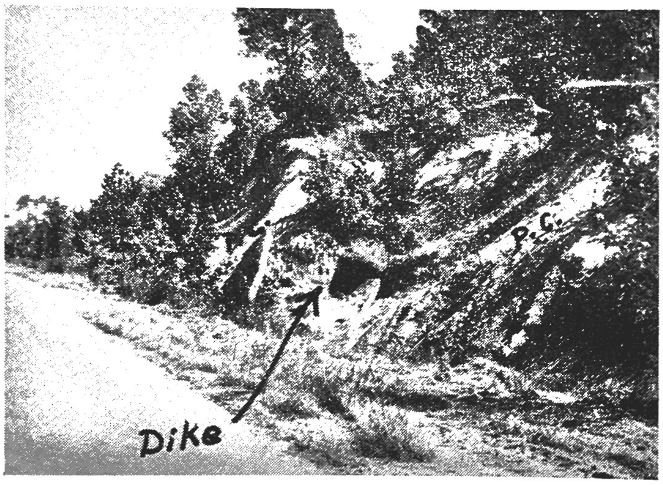

Fig. 2. Photograph of the principal dike from Ozier Road. P. C. is Porters Creek Clay.

generally are more consolidated and have weathered to a tan or dark-brown sandstone.

The texture and mineralogy of the dike material are very similar to the texture and mineralogy of the Clayton and Ripley formations (Table 1) in exposures in the area. Whether or not the dike material was derived from these units is not definite, but the material probably is a composite of the material in the stratigraphic section from the Ripley upward through the Porters Creek. Most of the dike material, however, is representative of the Clayton and Ripley formations.

Geologic Structure of the Pinson Dikes

The Pinson dikes vary considerably in general trend, as shown in Fig. 3. The principal dike is not sufficiently exposed to indicate a definite attitude. One of the minor dikes has an essentially east-west strike and an average dip of 75° to 80° N, but this attitude may not be representative of the majority of the dikes.

Other small clastic dikes in the Porters Creek Clay are exposed in southeastern Madison County, but geologic mapping is not sufficiently detailed to indicate the regional trends of possible faults, joints, or other zones of weakness that may have provided structural control for the emplacement of the dikes.

A dike in the center of a fault zone, or zone of shear, is shown in Fig. 4. The vertical displacement along the fault probably ranges from a fraction of an inch to 1 foot. Most of the exposures of dikes do not show shear zones as well defined as those in Fig. 4. Although faulting probably was a part of the origin of many clastic dikes, it does not seem to have contributed to the formation of all the dikes.

Origin of the Dikes

Historical

Numerous authors have described clastic dikes in the Porters Creek Clay, but opinions differ concerning the direction of emplacement of these dikes—whether the material was injected from above or below. Glenn (1906, pp. 30-31) concludes from his work in West Tennessee and Kentucky that saturated sands inter-

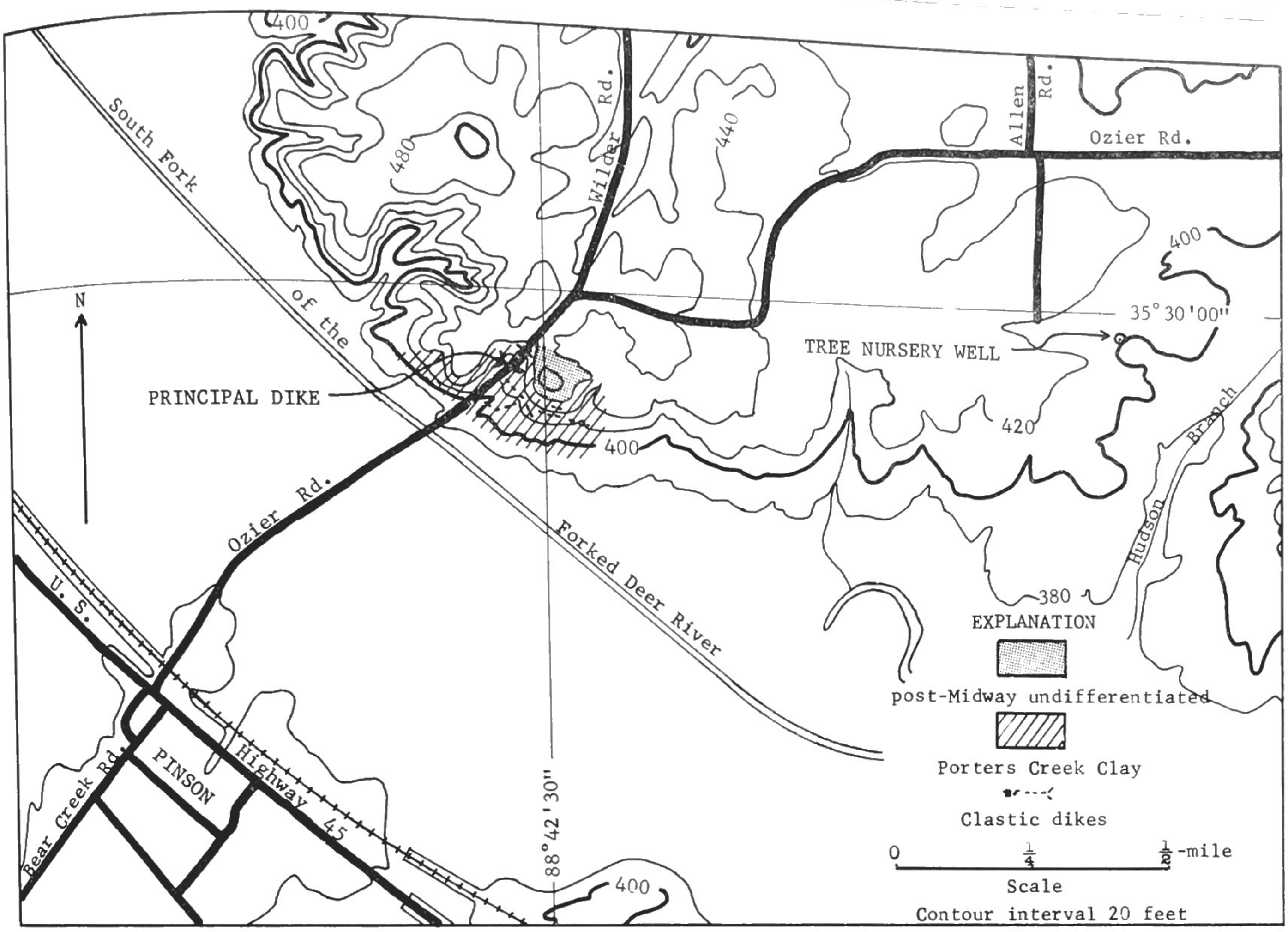

Fig. 3. Topographic map showing the location of the Pinson dikes and a partial geologic map of the adjacent area.

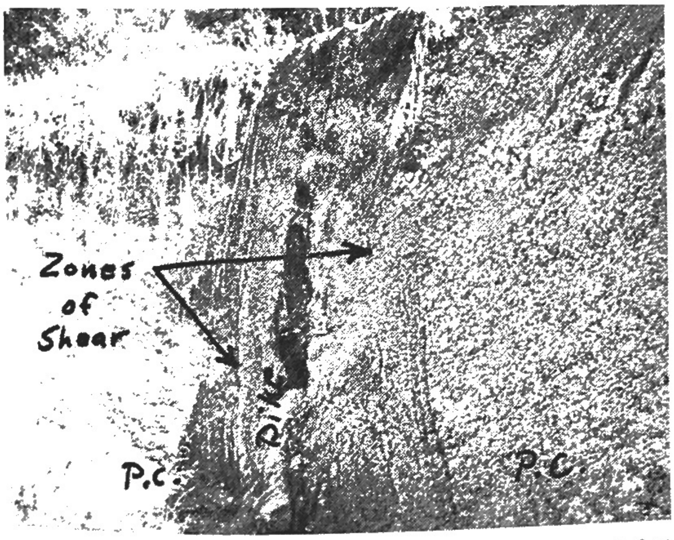

Fig. 4. Photograph of a dike in a fault zone having less than 1 foot of vertical displacement.

bedded in the Porters Creek Clay were injected upward into fissures shortly after the formation was deposited. According to Glenn the fissures were produced during earthquakes in the same manner that sand-filled fissures were formed during the New Madrid earthquakes of 1811 and 1812. Glenn also noted slickensides at the contact between some of the indurated dikes and the country rock, suggesting additional faulting after the dikes had hardened.

Wells (1933, p. 88) notes the existence of sandstone dikes in the Porters Creek but does not elaborate on them. Whitlatch (1936, pp. 138-139) describes the presence of horizontal beds of discontinuous sand that show a considerable range in stratigraphic position within the Porters Creek Clay in Hardeman County but does not associate them with clastic dikes. Blade (1963) and Olive (1963) have plotted the location of clastic dikes in the Porters Creek Clay on geologic quadrangle maps showing the Porters Creek outcrop in Kentucky.

Authors who discuss the origin of dikes agree on two basic points: (1) a clastic material in a potentially mobile state must have been available (for example, a sand saturated with water and under the pressure of hydrostatic head and the static load of overburden); and (2) an opening, or fissure, must have been exposed to the potentially mobile clastic material. The author believes that most of the dikes near Pinson were formed as sand under pressure worked into fissures, or along minor faults during movement. The faults may have been caused, for example, by differential settlement after deposition. This origin probably accounts for the small dikes that are commonly a foot or less in thickness. Very large dikes, however, such as the principal dike at Pinson, may have required an additional geologic process, such as cavity development, to account for their large size because it is less plausible that a fault with a foot or less of displacement, even with repeated movements, could result in the intrusion of clastic material 15 feet in thickness. The following discussion concerns the mobility of clastic material and the occurrence of cavities, and later these factors will be related in a final theory of origin.

The Movement of Clastic Material

Water generally is recognized as the lubricant that facilitates the movement of clastic material. The frequency of sand heaves (where water-saturated sand flows into bore holes during drilling) below the water table at depths of 100 feet or more is well known to drillers of water wells. For example, during the drilling of an oil test in 1953 at Neely Station (location on Fig. 5) by cable-tool methods, unconsolidated sands of Eocene age heaved from depths of 145-150, 158-180, and 210-215 feet. The sand from the depth of 210-215 feet heaved to within 160 feet of the surface. Eventually, after several months of effort, drilling was abandoned at a depth of 300 feet.

It is well known that in the Pinson area the Ripley and Clayton formations are saturated with water under hydrostatic head. Moreover, the hydrostatic head is great enough to cause some wells in the Pinson area to flow. A good example is the irrigation well at the State Tree Nursery (Fig. 3), which has a flow of about 100 gallons per minute. The hydrostatic pressure, together with the static load of the overburden overlying the Ripley and Clayton formations, probably would be sufficient to cause the water-saturated sands to flow into any adjoining openings and cavities.

The Occurrence of Cavities

Cavities (commonly water-filled openings in the country rock) have been found in clays or sandy clays during the drilling of water wells in Madison County and in other areas of West Tennessee and adjacent states. A cavity is indicated during drilling by a sudden drop of the drilling pipe, usually a fall of 3 or 4 feet, and by a loss of circulation of the drilling mud. Usually the driller attempts to fill the cavity and restore circulation to insure that the drill cuttings are being removed from the hole, but the filling of a cavity cannot always be accomplished.

A summary of well and cavity information is given in Table 2; locations of the wells are shown in Fig. 5. Not all known cavities are listed in the table, but those given indicate the variety of occurrence. The cavities recorded occur in post-Paleocene sediments; the author knows of none specifically in the Porters Creek Clay. However, the cavities listed here are examples of a geologic process that probably has been active throughout the development of the Mississippi embayment syncline.

Drillers in the area state that cavities are more common in some areas than in others, although in general they are quite rare. The fact that no cavities have been found in the Porters Creek Clay therefore may be fortuitous rather than a true indication of their absence.

Theory of Origin

This author proposes that the material composing the clastic dikes near Pinson was injected from below because the dike material most resembles material that is older than, and hence is underneath, the Porters Creek Clay. The injection of the dikes from below is considered to have been contemporaneous with fracturing and minor faulting and later, in some cases, by the formation of cavities in fault zones or other zones of weakness.

Cavities possibly may have been formed in the Porters Creek Clay as a result of the clay being ruptured by tensile forces that accompanied the gradual downwarp of the Mississippi embayment syncline and subsequent adjustments along faults near the embayment axis. The occurrence of such stresses is indicated by the repeated shocks in the New Madrid seismic area (Moneymaker, 1960, p. 2022). The stress caused by the downwarp of the embayment probably is transmitted efficiently throughout the embayment because artesian aquifers, such as the Ripley, act as lubricated, mobile units which facilitate the gradual

Table 2
Tabulation of data concerning wells in which cavities were found.

Owner	Location	Year drilled	Depth to cavity (feet)	Quantity of material pumped into well to plug cavity
G. W. McMasters	4 miles northeast of Jackson	1960	80	3 tons of clay and 500 lbs. of corn cobs*
Frank Herron	Johnsons Grove	1953	60	2 tons of clay*
Pet Milk Co.	Martin	1948	548	90 tons of clay
Whitehaven Utility Dist.	Southwest corner of field	1961	280	18 tons of drilling clay, 30 tons of cement

* Cavity not filled.

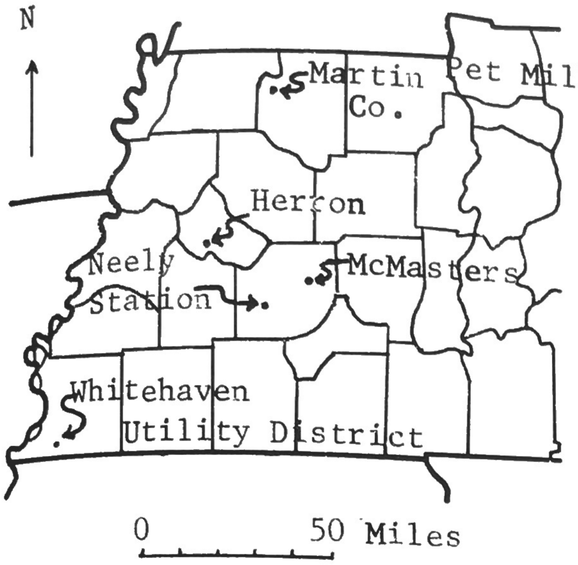

Fig. 5. Location of Neely Station and wells in which cavities were found.

westward sliding movement of the entire mass of unconsolidated sediments. The location and horizontal extent of cavities in local areas may correspond to major irregularities in the basement floor which would cause increased and localized stresses. Where the cavities extend to water-saturated sands a clastic dike is formed, and with each expansion of the cavity there is an additional injection of sand.

The Porters Creek Clay north of Pinson is less than 100 feet thick, especially beneath the flood plain of the South Fork of the Forked Deer River (Fig. 3). The relative thinness of the Porters Creek in the outcrop area very possibly could allow the formation of a cavity connecting the Clayton and possibly penetrating to the Ripley. Thus, the potentially mobile, saturated sands of these formations would be exposed to the voids formed during repeated earth movements. Subaerial erosion has uncovered and modified the dikes to their present state of exposure.

Because the dikes cut the Porters Creek Clay, they must be considered younger than this formation.

In summary, clastic dikes generally are discordant beds of sand found in fractures or fault zones in the country rock. The faulting in the Pinson area has a minor amount of displacement; therefore, it would seem unlikely that the principal dike, which is 15 feet wide, was developed entirely because of faulting. Therefore, an additional geologic process may be necessary to account for the large size of this dike. Cavities have been found from near the earth's surface to several hundred feet below, and the development of a cavity adjacent to, or along the original fault plane or fracture, may have provided access for the additional injections of clastic material. The cavity possibly developed as the unconsolidated sediments of the Mississippi embayment were stretched and redistributed as the embayment deepened and enlarged.

Acknowledgement

The author wishes to thank the driller, Harold Stephenson, Jackson, Tennessee, for his assistance and for information concerning the McMasters and Herron wells; and the Layne-Central Co., Memphis, Tennessee, for information concerning the Pet Milk and Whitehaven Utility District wells.

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NEWS OF TENNESSEE SCIENCE

(Continued from page 142)

is being explored as a possible weapon in the fight against cancer. The study will be a continuation of basic investigations Dr. Wood already has started at the Medical Units. One of the group he will be working with in Italy is Dr. Doriano Cavallini, professor of biochemistry at the University of Rome, who is considered an authority in the field of sulphur biochemistry. Dr. Wood and Dr. Cavallini have done similar work in past years and will collaborate in their studies during the next 12 months.

The University of Tennessee has been awarded a $28,000 grant from the National Science Foundation for support of a special research project in the department of botany. Under the direction of Dr. Ronald H. Peterson, assistant professor of botany, the grant covers a three-year period concerning "A Taxonomic Study of the North American Genera Clavulinopsis, Lentaria and Clavulina."

Dr. George K. Schweitzer, professor of chemistry at University of Tennessee was invited to lecture at Oxford University this summer. He and several other scientist theologians conducted a symposium on the interrelationships of natural science and the world religions.