

The Science Hill Sandstone Member of the Warsaw Formation and its Relation to Other Clastic Units in South-Central Kentucky

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*Prepared in cooperation with the
Kentucky Geological Survey*



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By RICHARD Q. LEWIS, SR., and ALFRED R. TAYLOR

CONTRIBUTIONS TO STRATIGRAPHY

G E O L O G I C A L S U R V E Y B U L L E T I N 1 4 3 5 - D

*Prepared in cooperation with the
Kentucky Geological Survey*

*A general description of the
unit, local stratigraphy, and
geologic setting*



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CONTENTS

Abstract -----	Page D1
Previous and current work -----	1
Science Hill Sandstone Member -----	4
Lower sandstone unit -----	9
Upper sandstone unit -----	10
Depositional relations and paleogeography -----	12
Depositional history -----	13
References cited -----	15

ILLUSTRATIONS

PLATE 1. Measured sections and location map of the Science Hill Sandstone Member and adjacent lithofacies -----	Page In pocket
FIGURE 1. Index map of Kentucky showing area of this report (shaded) and coverage by 7½-minute quadrangles-----	D3
2. Generalized composite sections constructed from measured sections showing configuration of the Science Hill Sandstone Member and its relation to other units-----	7
3. Isopach map of the Science Hill Sandstone Member -----	8
4. Photograph of outcrop of Science Hill Sandstone Member at Latham Branch northwestern part of Shopville quadrangle at measured section 84 (pl. 1)-----	9
5. Photograph of contact of Science Hill Sandstone Member with overlying St. Louis Limestone (hammer at contact) showing basal part of St. Louis chert breccia on crossbedded, calcite cemented sandstone of the upper subunit of the Science Hill, Latham Branch (see section 84, pl. 1) -----	10
6. Diagrammatic cross section showing relationship of the Science Hill Sandstone Member to the Garrett Mill Sandstone Member-----	14

CONTRIBUTIONS TO STRATIGRAPHY

THE SCIENCE HILL SANDSTONE MEMBER OF THE WARSAW FORMATION AND ITS RELATION TO OTHER CLASTIC UNITS IN SOUTH-CENTRAL KENTUCKY

By RICHARD Q. LEWIS, SR., and ALFRED R. TAYLOR

ABSTRACT

The Science Hill Sandstone Member (Mississippian) is a deltaic sandstone body derived from a source area to the east and deposited in the eastern part of the basin of Warsaw age in south-central Kentucky. It covers an area of more than 2,600 km² and attains a thickness of more than 13 m. It commonly makes up the lower part of the Warsaw Formation, but where thickest, it constitutes most of the formation. It is stratigraphically lower than the Garrett Mill Sandstone Member of Butts, and intertongues or is gradational into clastic carbonate rocks, siltstone, and shale to the west and south.

The Science Hill formed a partial barrier influencing the deposition of adjacent lithofacies to the northeast. Recognition of the nature of the sandstone body is essential to an understanding of the depositional history and Mississippian stratigraphy in the region.

PREVIOUS AND CURRENT WORK

In the Mississippian of south-central Kentucky, the Salem and Warsaw Formations, which overlie the Borden Formation and underlie the St. Louis Limestone, commonly range in thickness from about 12 to 37 m, are mostly carbonate rocks, and lesser amounts of sandstone, siltstone, and shale. The lithologies and accompanying sedimentary structures indicate deposition in the broad shallow basin that deepened westward. Ripple marks, cross-bedding, and other shallow-water features, increased amounts of clastic noncarbonate material in the eastern part of the basin, and thinning of the rock units eastward suggest shallow water and a near-shore environment of deposition.

Butts (1922) and Stockdale (1939) described several noncarbonate units in the area and assigned them member status within the Warsaw or Salem Formations and Harrodsburg Limestone. Be-

cause of the regional nature of their studies, they only briefly described the units and drew no conclusions about their origin or genetic significance.

Butts (1922) briefly described and named the Garrett Mill Sandstone Member of the Warsaw along the Kentucky-Tennessee State line. The type locality is at Garrett Mill, north of the town of Livingston, Overton County, Tenn. He described the sandstone as a thin blanketlike deposit in the uppermost part of the Warsaw Formation. Later, he noted sandstone in Pulaski and Rockcastle Counties, Ky., and assumed that sandstone to be an extension of the Garrett Mill Sandstone Member (Butts, 1922, p. 107). Butts (1922, p. 104) found a thin sandstone at Kings Mountain in Lincoln County, Ky., and considered it to be the "Wildie Sandstone." Butts (1922) originally described and named the Wildie Sandstone Member in Rockcastle County, Ky., and assumed it to be a part of the Warsaw Formation. Later work by Stockdale (1939) and Weir, Gualtieri, and Schlanger (1966) showed that the Wildie is part of the Borden Formation probably correlative with the Floyds Knob Formation. Stockdale (1939, p. 211) assigned the same outcrop at Kings Mountain to the Muldraugh "Formation" of the Borden Group. Stockdale (1939, pp. 226-227) noted sandy and pebbly limestone in measured sections at and near Somerset, Pulaski County, Ky., and concluded it to be the Garrett Mill of Butts, though he included these strata within the Salem Limestone. Later workers mapping the area of Pulaski and Rockcastle Counties, Ky., have not mapped the sandstone but have included it within the Borden Formation or Salem and Warsaw Formations.

The authors determined the areal extent and thickness of the sandstone reported by Butts in Pulaski and Rockcastle Counties, Ky., and found it to be separate from the Garrett Mill, somewhat different in nature, and at a different stratigraphic position (fig. 1). As a result, they recently designated the unit as the Science Hill Sandstone Member of the Warsaw Formation (Lewis and Taylor, 1975).

In south-central Kentucky, the rocks between the base of the St. Louis Limestone and the top of the Borden and Fort Payne Formations have been treated as a single unit, the Salem and Warsaw Formations. A reasonable assumption is that the upper part of the unit be assigned to the Salem and the lower part of the Warsaw; however, correlation is tenuous, and neither name may be appropriate. Inasmuch as this paper is not the place to revise regional stratigraphic nomenclature, the entire interval is for convenience herein termed Warsaw, although the rocks are not the lithic and possibly not the temporal correlatives of the type Warsaw.

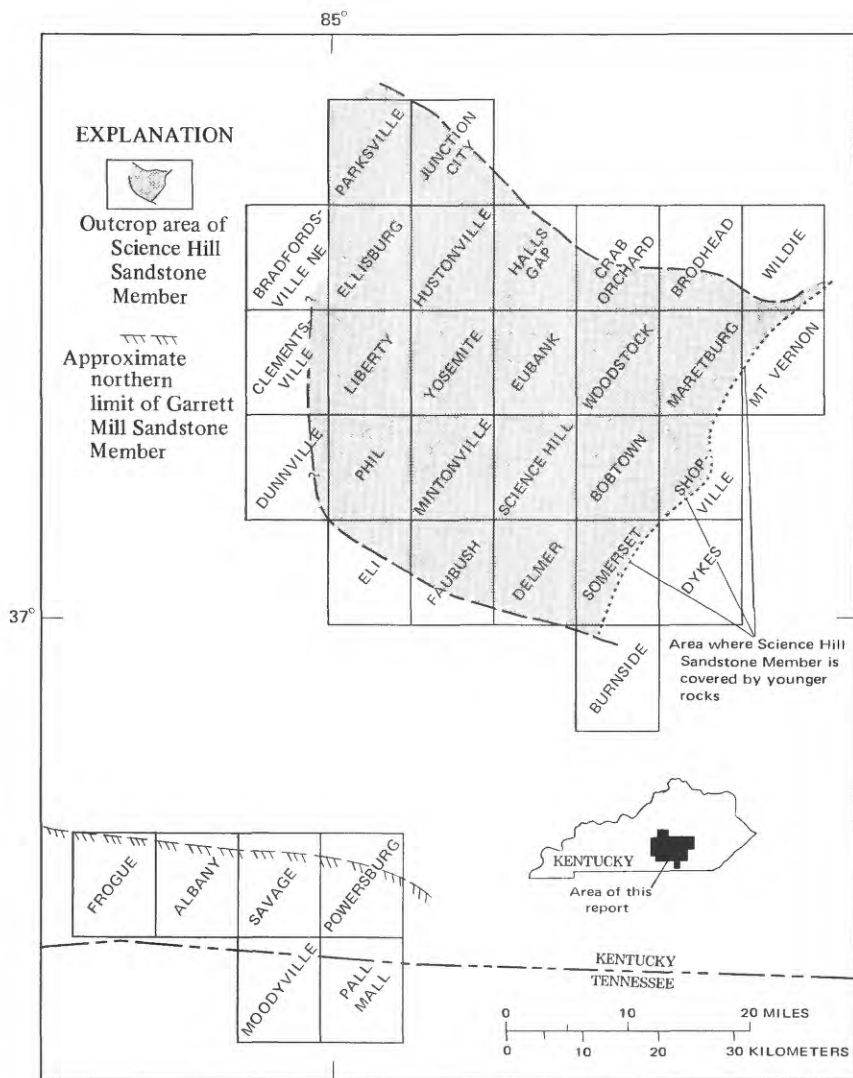


FIGURE 1.—Index map of Kentucky showing area of this report (shaded), 7½-minute quadrangles, approximate outcrop area of the Science Hill Sandstone Member, and approximate northern limit of the Garrett Mill Sandstone Member.

The authors believe that the Garrett Mill and Science Hill Sandstone Members represent the distal parts of a high constructive lobate delta system (Blatt and others 1972, p. 107, and Fisher and others, 1969) deposited in shallow water near the eastern edge of the Warsaw basin. The units are covered by younger rocks of Mississippian and Pennsylvanian age to the east where there is very little reliable subsurface data. Therefore, whether the Garrett

Mill and Science Hill Sandstone Members were deposited by the same stream system at different times or deposited by separate stream systems cannot be determined.

The purpose of this report is to describe the physical nature of the Science Hill Sandstone Member and to present some conclusions regarding the paleogeography at the time of its deposition and the relationship to adjacent units.

Weir, Gualtieri, and Schlanger (1966) determined that strata of Mississippian age beneath the St. Louis Limestone in the vicinity of Renfro Valley, Rockcastle County, differ in lithology from time equivalent units elsewhere in south-central Kentucky. They proposed a new member, the Renfro Member of the Borden Formation, recognizing that the Renfro includes equivalents of the Salem and Warsaw Formations, Muldraugh Member of the Borden, and possibly part of the St. Louis Limestone as determined by Butts (1922) and Stockdale (1939).

No attempt was made by Weir, Gualtieri, and Schlanger (1966) to determine why strata in the Renfro area are so distinctly different from time equivalent units exposed nearby; the main concern at the time was to furnish a usable map unit for field men in the area. The name Renfro was not used in the Halls Gap quadrangle (Weir, 1972) where the Salem and Warsaw and Muldraugh Member of the Borden were recognizable. In that quadrangle, Weir assigned the strata to the Salem. To the south and west of the Renfro type locality, the Science Hill is within the Renfro as mapped in the Woodstock quadrangle (Weir and Schlanger, 1969), Brodhead quadrangle (Gualtieri, 1967a), Crab Orchard quadrangle (Gualtieri, 1967b), and the Mareburg quadrangle (Schlanger, 1965).

In the Mount Vernon quadrangle (Schlanger and Weir, 1971), the thin north edge of the Science Hill is in rocks mapped as the Renfro Member and locally Halls Gap Member of the Borden Formation.

SCIENCE HILL SANDSTONE MEMBER

The Science Hill Sandstone Member of the Warsaw Formation (Upper Mississippian), a sandstone consisting mostly of quartz, makes up a considerable part of the Warsaw in part of south-central Kentucky. The sandstone was named for the town of Science Hill, Pulaski County, Ky. (Lewis and Taylor, 1975). The type section is about 10 km northwest of the town of Science Hill in the northwestern part of the Science Hill 7½ minute quadrangle.

The Science Hill crops out over an area of more than 2,600 km², and its areal extent and thickness were determined by field investigations in the Eubank (Lewis and others, 1973a), Bobtown (Lewis

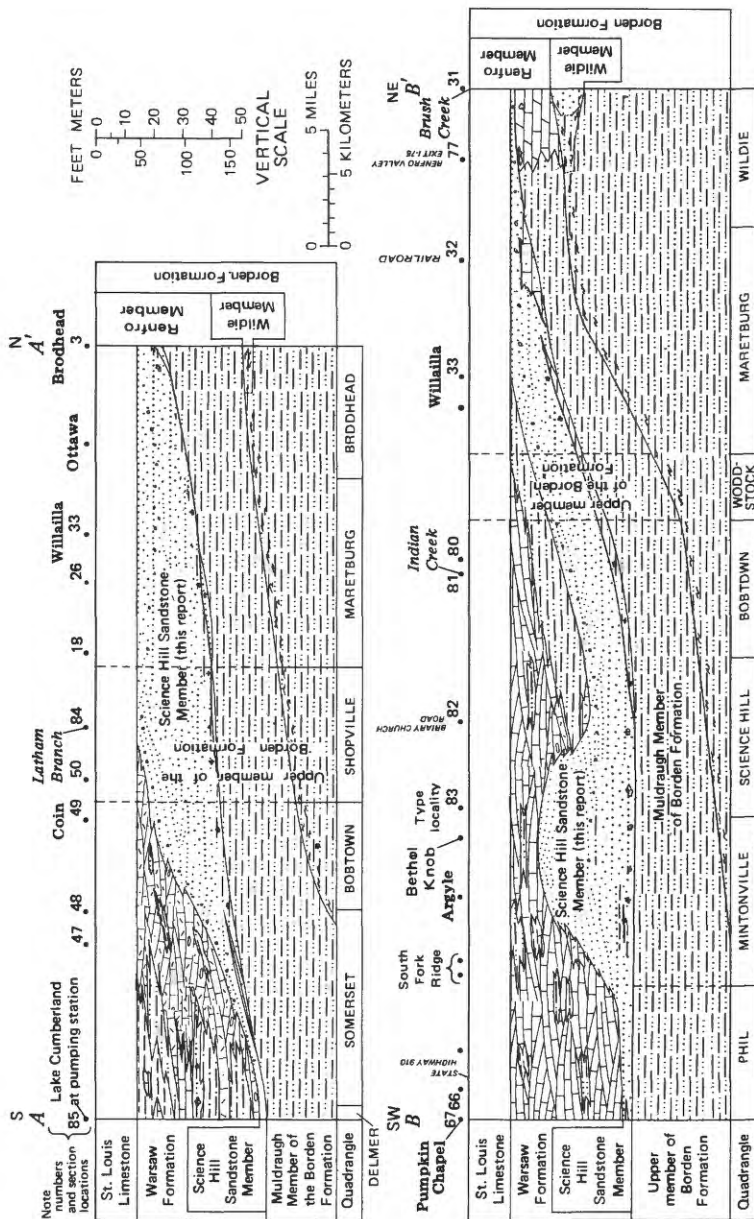
and others, 1973b), and Science Hill (Taylor and Lewis, 1973) quadrangles, and in adjacent areas (fig. 1). It extends from the vicinity of Shopville, Ky., and Mount Vernon, Ky., westward, and pinches out in the vicinity of the Liberty and Phil quadrangles about 70–80 km west of the easternmost exposures. It extends from Lake Cumberland south of the city of Somerset, Ky. (Somerset Quadrangle), north to the vicinity of Halls Gap, Ky. (Halls Gap quadrangle), a distance of about 50 km.

In the southern part of the Yosemite quadrangle (fig. 1) the Science Hill is present wherever the lower part of the Warsaw Formation is exposed, and in some areas most of the formation is composed of sandstone. Sandstone is also present but is much thinner, north of Yosemite in the southeastern part of the Hustonville quadrangle, and it may be continuous with a sandstone reported by Harris (1972) farther north in the Junction City quadrangle.

The sandstone ranges in thickness from almost zero near its western and southern margins to as much as 13.1 m in the southern parts of the Woodstock and Maretburg quadrangles and the northern parts of the Shopville and Science Hill quadrangles (pl. 1, secs. 33, 57, 83 and 84). Generally, it is thickest in the east-central outcrop areas and thins progressively westward and toward the northern and southern flanks of the deposit (pl. 1; figs. 2 and 3).

To the east of the outcrop area, the sandstone is covered by younger Mississippian and Pennsylvanian sedimentary rocks. To the north it grades into medium- to fine-grained fossil fragmental calcarenite and dolomitic siltstone. The transition of sandstone to the calcarenite and siltstone is gradational within a few meters to tens of meters and has little apparent interfingering. To the west and south, the sandstone grades into and interfingers with fossil fragmental calcarenite, shale, and siltstone and is commonly overlain by shale or crossbedded light-gray, medium-gray, or dark-gray fossiliferous calcarenite (pl. 1, secs. 85 and 57). These facies or units are all part of the mapped Salem and Warsaw Formations (Limestones) and equivalent to the Warsaw Formation of this paper.

The Science Hill Sandstone Member is at or near the base of the Warsaw, in the western and southern parts of the outcrop area, either in contact with the underlying Muldraugh Member of the Borden Formation or separated from it by a few meters of calcarenite, geodiferous siltstone, or shale. In that area it makes up only a small part of the Warsaw. In the eastern part of the outcrop area, most of the interval between the St. Louis Limestone and Muldraugh or equivalent rocks (mapped as part of the upper member of



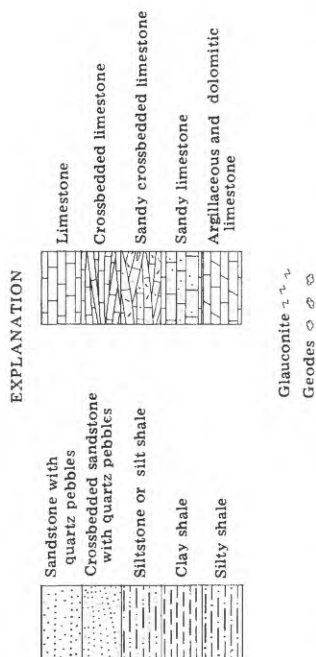


FIGURE 2.—Generalized composite sections constructed from measured sections showing configuration of the Science Hill Sandstone Member and its relation to other units. Location of sections is on plate 1.

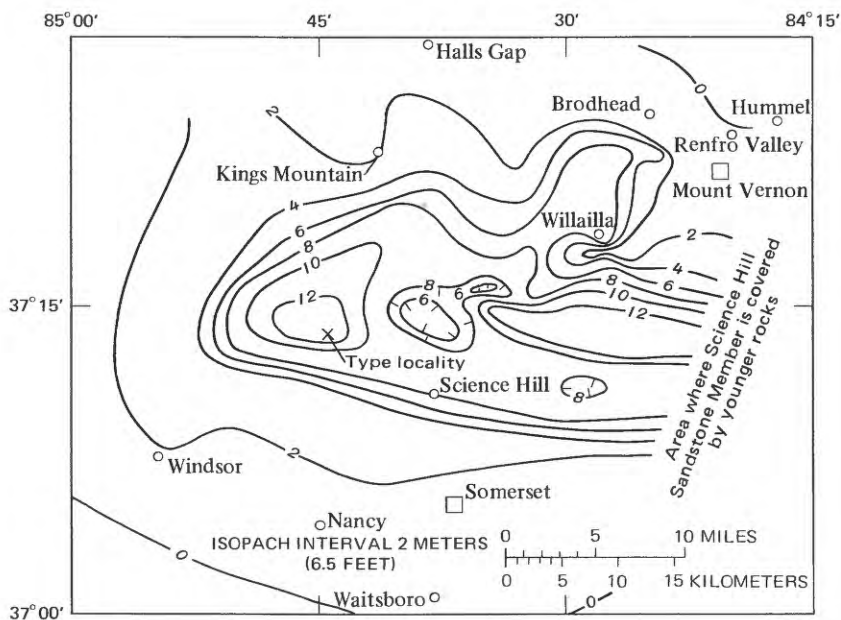


FIGURE 3.—Isopach map of the Science Hill Sandstone Member.

the Borden by Hatch (1964)) is composed of sandstone (figs. 4 and 5; pl. 1, sec. 84).

The sandstone forms a lobate lenticular body, somewhat plano-convex in cross section (fig. 2, section A-A'). The bottom is conformable with the underlying units of the Borden Formation. The body is asymmetrical, and the northern part grades abruptly into limestone (calcarenite) containing quartz sand grains or into calcareous siltstone. A large part of the northern and northwestern marginal outcrop areas has been removed by erosion; however, the transition from sandstone to limestone and siltstone is well exposed along the railroad between Maretburg and Brodhead in the vicinity of section 32 (pl. 1).

The relationship of the sandstone to other sedimentary rocks in the Warsaw to the south and west of Somerset is intertonguing and gradational. The sandstone thins very gradually toward the south and tongues with calcarenite and the shale unit described by Butts (1922) as the "Somerset Shale Member of the Warsaw Formation." Thin stringers of sandstone, composed of quartz, in fossiliferous calcarenite, sandy calcarenite, and coarse quartz grains on bedding surfaces of the calcarenite, indicate that part of the adjoining calcarenite was deposited contemporaneously with the sandstone.

Where the Science Hill is well exposed, detailed sections show it is composed of two units; its lower part is a sandstone overlain by thin



FIGURE 4.—Photograph of outcrop of Science Hill Sandstone Member at Latham Branch northwestern part of Shopville quadrangle; measured section 84 (pl. 1).

silty shale that is, in turn, overlain by a second much thicker sandstone layer overlain by siltstone, shale, locally by calcarenite of the Warsaw, and in the eastern part of the body by micritic or micrograined limestone of the St. Louis Limestone. Thus, the sandstone body commonly consists of a somewhat restricted lower unit and a widespread upper unit separated by shale over part of the outcrop area. The division of the sandstone into two units is not as obvious in the Bobtown and Woodstock quadrangles where the Science Hill Sandstone Member is thickest and the shale is very thin or not present. However, a zone of geodes separates the units locally in that area.

LOWER SANDSTONE UNIT

The lower sandstone unit is reddish brown and various shades of brown, orange, gray, and olive and composed mostly of fine- to very fine grained angular to subrounded clear to milky quartz and minor dark minerals and rock fragments. The cementing material is mostly silica, partly as overgrowths on the grains and partly as fine crystalline interstitial authigenic quartz. The grains are very tightly packed. The unit is thin bedded to thinly laminated, and contains some low-angle crossbeds that dip westward and south-



FIGURE 5.—Photograph of contact of Science Hill Sandstone Member with overlying St. Louis Limestone (hammer at contact) showing basal part of St. Louis chert breccia on crossbedded, calcite cemented sandstone of the upper subunit of the Science Hill Latham Branch (pl. 1, sec. 84).

westward. No large-scale cut and fill, channel, or crossbed structures were noted in the lower unit. It is 0 to 2 m thick.

The contact with the underlying rocks is conformable, sharp, and is commonly marked by a thin (less than 2 mm) bluish-gray clay seam above the underlying limestone or siltstone. The lower sandstone is commonly overlain by and gradational into mudstone, shale, or dolomitic siltstone that is as much as 4.5 m thick, but commonly less than 1 m thick, and contains a zone of quartz geodes. The geodiferous zone has been very useful in the correlation of sections in different parts of the outcrop area. The absence of marine fossils and apparent lack of bioturbation features, but the presence of tabular low-angle crossbeds, indicate fluvial deposition as a thin blanket. The overlying finer clastic material and enclosed geodes appear to represent an interruption in sand deposition preceding the second incursion of coarse clastic material.

UPPER SANDSTONE UNIT

The upper sandstone unit differs markedly from the lower unit in grain size, cement, accessory minerals, and fossils. The upper unit

is the same color as the lower unit on outcrop and is composed of medium to very coarse poorly sorted angular to well-rounded light-gray quartz grains, small quartz pebbles, and sparse accessory minerals of iron oxide and mica (muscovite?) locally. Outcrops in the Wildie, Mount Vernon, Maretburg, and Brodhead quadrangles contain glauconite. Pebbles and coarse grains are well rounded, and fine grains are more angular. Grains of calcite and fossil fragments are common, particularly in the upper few feet of the unit. The principle cement is calcite; minor cement is chalcedony and iron oxide. Green clay matrix is common in the northeastern part of the area.

The grain size changes markedly within the upper sandstone, which is divisible on this basis into two subunits: a lower fine- to medium-grained sandstone and an upper medium- to very coarse grained sandstone. The upper subunit contains a layer or several layers of very coarse sand grains and small pebbles of quartz that are present throughout the outcrop area of the sandstone and are useful in correlating limited isolated outcrops.

The upper unit, as much as 13 m thick, represents a second and much greater influx of sand from a source area to the east. An isopach map of the Science Hill, in large part reflecting the thickness of the upper sandstone (fig. 3), is interpreted to indicate a deltaic deposit thickest through the area from the northern part of the Shopville quadrangle (pl. 1, sec. 84, figs. 4 and 5) to the northwestern part of the Science Hill quadrangle (pl. 1, sec. 83) where the coarse sandstone of the upper unit is 13.1 m thick. Thickness decreases abruptly to the north and south.

The upper sandstone is present beyond the outer limits of the lower sandstone unit in the northeastern part of the outcrop area. In the road cuts of Interstate Highway 75 between Renfro Valley and Mount Vernon, the sandstone body is represented by a single thin (5 to 15.2 cm thick) layer of glauconitic sandstone that is probably the thin northern edge of the upper sandstone unit. The lower unit is not present in that area.

The upper part of the upper sandstone unit is commonly cross-bedded in sets 15 to 61 cm thick in the western part of the outcrop area. Crossbeds dip from 5° to 30° to the west and southwest. Most of the crossbeds are of the wedge-shaped type (nomenclature after McKee and Weir, 1953).

Well-defined sandstone-filled channels that cut into earlier deposited sandstone appear to account for much of the sandstone in the upper unit. Although observable only in limited areas in shallow road cuts, the abundance of channel and cut and fill structures in road cuts indicate the channels may be widespread and trend mostly west to southwest.

Fossils are sparse in the upper sandstone unit, but molds and casts of brachiopods and bryozoans are present in several localities. Fossils were noted at Broughtontown, in the southeastern part of the Crab Orchard quadrangle, and at the Woodstock Baptist Church, in the southeastern part of the Woodstock quadrangle. Near Freedom School in the south-central part of the Yosemite quadrangle, the brachiopod *Spirifer lateralis* Hall (identified by the authors) is present in a thin (5 cm thick) bed of fossiliferous chert interbedded with sandstone 2.4 m above the base. Shark teeth were found in the sandstone along the northern and southern margins of the upper unit of the member, in the Yosemite quadrangle, and in the northern part of the Burnside quadrangle.

DEPOSITIONAL RELATIONS AND PALEOGEOGRAPHY

The Science Hill Sandstone Member is probably a high constructive lobate delta as classified by Blatt, Middleton, and Murray (1972). Much of the sandstone in the outcrop area apparently was deposited in a shallow submarine environment, indicated by the presence of marine fossils and some graded bedding that show reworking by waves and currents. The delta was deposited near the eastern margin of a shallow basin of Warsaw age. After deltaic sedimentation ceased, the seas transgressed eastward, and marine sediments were deposited across the top of the sandstone.

During Warsaw time, the delta was probably a barrier that partly isolated the present Renfro Valley-Mount Vernon area, Kentucky, north of the delta and east of a north-trending lobe (fig. 3). This may account for the nature of the unfossiliferous dolomitic limestone in the Renfro Member of the Borden Formation. Weir, Gualtieri, and Schlanger (1966, p. F19) described the Renfro Member at its type locality in the Renfro Valley area, Kentucky, as "dominantly of sparsely cherty unfossiliferous light-greenish-gray, yellow to orange weathering aphanitic to finely crystalline argillaceous and dolomitic limestone." These rocks may have been deposited in a lagoonal mudflat environment partly enclosed by the deltaic sands of the Science Hill. In contrast, the clastic carbonate sediments of the Warsaw were deposited in a relatively open sea environment. The strongly cross-stratified medium- to coarse-grained bioclastic limestone, typical south and west of the sand barrier that formed the Science Hill, is apparently not present in the Renfro Valley area northeast of the sandstone. Southwest from Mount Vernon, Ky., a few kilometers southwest from the type locality of the Renfro, the middle part of the Renfro grades into the Science Hill. West of the Renfro type locality, much of the Mississippian section has been removed by erosion, and the nature of the relation of the limestone

(calcarenite) to the type Renfro can only be speculated; but cross-bedded coarse-grained limestone (calcarenite) is present north of the Science Hill farther to the west in the vicinity of Brodhead, Ky.

The "Somerset Shale Member" of Butts (1922) (a shale unit that Butts named as a member of the Warsaw Formation for a type section at Somerset, Ky., that has been the subject of considerable debate about its origin and correlation) may represent prodelta sediments, largely sandy silt and clay, that were deposited in a shallow shelf area west and southwest of the delta front. The distribution of the shale to the west and southwest of the sandstone body may indicate mild north-to-south, shore currents.

Petroliferous residue has been reported (Weir and others, 1966, p. F28) in sandstone (Science Hill Sandstone Member) within the Salem and Warsaw at Halls Gap, Ky. The source areas, river system, and flood-plain areas of Science Hill time are covered by younger sediments of Mississippian and Pennsylvanian age to the east of the outcrop, and subsurface information is not available; however, the flood-plain and channel deposits might well provide suitable reservoirs for the accumulation of oil and gas. The area has not been explored.

DEPOSITIONAL HISTORY

The Science Hill Sandstone Member was formed by sand transported from an eastern source area. Transport was fluvial, and the sand of the lower unit was a thin blanket deposit. Deposition apparently started in early Warsaw time. The break between the upper and lower units, locally marked by siltstone and geodes, and the contrast in sedimentary structures in the two units probably indicates a change in the stream regimen, a hiatus in deposition, and a slight onlap of marine sediments across peripheral areas of the lower sandstone unit. Some of the sand was reworked by marine currents and deposited as scattered grains and thin lenses of sand in the adjacent clastic limestone bed.

In late Warsaw time an influx of quartz sand was deposited 32 to 48 km (20 to 30 mi) south of the Science Hill Sandstone Member. This sand formed the thin blanket-type Garrett Mill Sandstone Member of Butts (1922). Only scattered outcrops of the Garrett Mill are exposed, and where observed they appear to represent sandstone of the distal parts of a deltaic system deposited in a wave-dominated environment. The Garrett Mill may be related to the Science Hill only in that it may be a later, stratigraphically higher, lobe of the same stream system (fig. 6). However, it may be the product of a completely separate and younger system.

The authors believe that the recognition of the Science Hill as a deltaic body will help to explain the nature and relationship of the

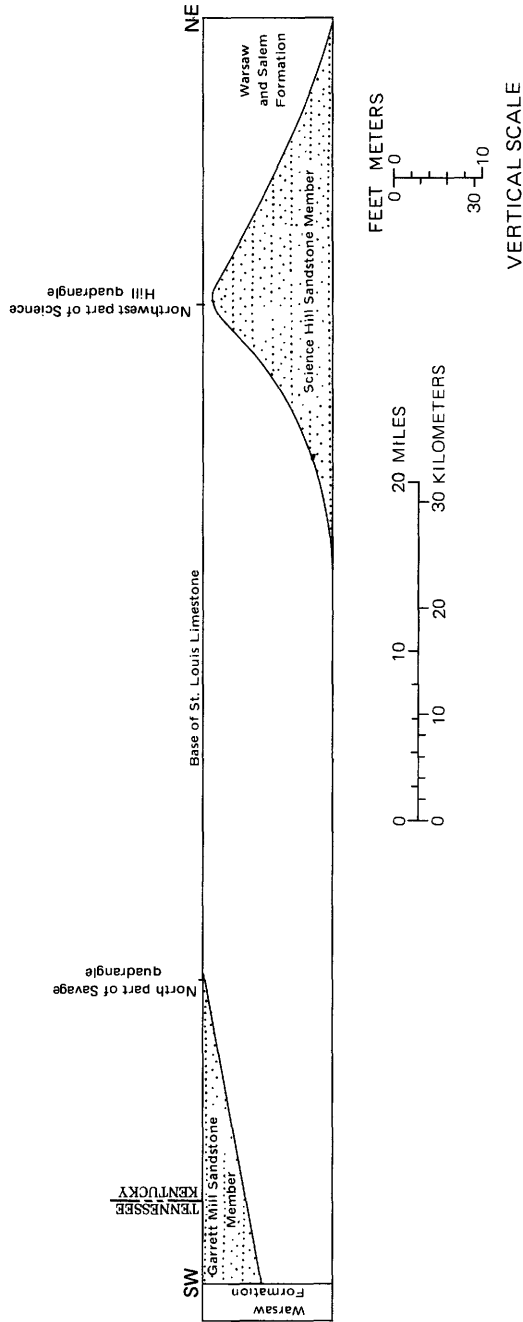


FIGURE 6.—Diagrammatic cross section showing relationship of the Science Hill Sandstone Member to the Garrett Mill Sandstone Member.

varied lithologies observable within the Warsaw Formation and Renfro Member of the Borden Formation and will offer a somewhat clearer picture of the processes dominating deposition of the rocks of Warsaw age in the eastern part of the basin.

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