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THE TRACE FOSSIL ZOOPHYCOS AS AN INDICATOR OF WATER DEPTH

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THE TRACE FOSSIL ZOOPHYCOS AS AN INDICATOR OF WATER DEPTH

RICHARD G. OSGOOD, JR.[1] AND EUGENE J. SZMUC[2]

ABSTRACT

A geographically widespread occurrence of the trace fossil *Zoophycos* is described from the Lower Mississippian Cuyahoga Formation of northeastern Ohio. Although Seilacher (1955, 1964, 1967a, 1967b) stated that *Zoophycos* is most common in "intermediate water depths," numerous environmental indicators (oscillation ripple marks, large scale cross lamination, and *Lingula)* demonstrate that in northeastern Ohio *Zoophycos* flourished in shallow water which was above wave base. At present the genus encompasses too wide a range of morphologic variables. Detailed studies are needed in order to determine the limiting factor of the environment. Water depth does not appear to provide the answer.

INTRODUCTION

As Seilacher demonstrated, one of the major values of trace fossils is that they can be used to indicate water depth in cases where other evidence is absent. In a series of papers, Seilacher (1955, 1963, 1964, 1967b) established several "ichnofacies" each with its suite of trace fossils and each indicative of a certain environment. The *Zoophycos Facies,* characterized by the roostertail-like trace fossil of the same name was proposed for an environment which was "sublittoral to bathyl, below wave base, and without turbidite sedimentation" (Seilacher 1964, p. 311). It should be noted that Seilacher (1964, fig. 7) listed four deep-water deposits containing *Zoophycos,* and that in 1967 he reported the first occurrence of *Zoophycos* in "deep-sea" cores of Recent sediments take by Lamont-Dougherty Geological Observatory. At the same time he conceded that *Zoophycos* may occasionally occur in shallower water ". . . due to local channeling or restriction" (Seilacher, 1967b, p. 418). In spite of these exceptions the authors conclude, upon analysis of Seilacher's works, that Seilacher believed that the majority of occurrences of *Zoophycos* represent intermediate water depth. Further justification for this belief will be given below.

The purpose of this paper is to discuss a *major widespread* occurrence of *Zoophycos* from the Lower Mississippian rocks of northeastern Ohio. As will be demonstrated, the body fossils, primary sedimentary structures, and the regional geologic setting, all indicate that large numbers of *Zoophycos* occur here in rocks that were deposited in shallow water that was above wave base. The validity of *Zoophycos* as a reliable depth indicator is thereby somewhat in doubt.

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MORPHOLOGY OF ZOOPHYCOS

Diagnosis — slightly helicoid trace fossils possessing a marginal tube; the *Spreite* radiating from the center frequently give the genus a "rooster-tail" like appearance.

Discussion — *Zoophycos* Massalongo, 1855 is a common form which has been reported from nearly every continent in rocks ranging from Ordovician through Tertiary in age. As Häntzschel (1962, 1965) and Simpson (1970) pointed out the genus is extremely variable in form. It is badly in need of a monographic study, and no attempt will be made here to discuss the genus in depth. For a more detailed analysis of *Zoophycos* and its taxonomic problems the reader is referred to Plička (1968, 1970), Lessertisseur (1955), Häntzschel (1965), and Simpson (1970).

Perhaps the wide range of morphology exhibited by *Zoophycos* can best be demonstrated by considering three forms figured in the literature. Sarle (1906, fig. 1) illustrated a specimen from the Silurian of New York State which resembles a "rooster-tail." The marginal tube is clearly visible as are the arcuate *Spreite*. A more typical occurrence of *Zoophycos* is shown by Häntzschel (1962, figs. 137-1a, 2a). It is a flat helix with the *Spreite* radiating from the apex of the cone. No marginal tube is present but this may be due to imperfect preservation. According to Seilacher (1967a) this form, which he had found in the Alpine Tertiary section, is a variant of a more complex Cretaceous form, which takes on a flat antler-like appearance (Seilacher, 1967a, p. 79 top). Compounding the problem is the fact that many times *Zoophycos* has a distinct three dimensional aspect. Moreover, as Sarle (1906, fig. 2) pointed out several helices can be interlaced, making study even more difficult. In its most extreme three dimensional form the *Zoophycos* structure can resemble a corkscrew with *Spreite*, where the vertical dimensions exceed the diameter of the helix. These forms are assigned by most authors to *Daedalus* Rouault, 1850.[3]

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[3]Simpson (1970) was well aware of the morphological variation included in *Zoophycos* and made some attempt to limit it by restricting the circular forms to *Spirophyton* Hall, 1963. However, as one can see, and as Simpson himself admitted, the *Zoophycos* still contains a wide variety of morphologic expressions (see Simpson, 1970, fig. 1).

The Mississippian forms from Ohio contribute little to the general knowledge of the morphology or ethology exhibited by *Zoophycos*. They closely resemble those specimens illustrated by Häntzschel (1962, fig. 137-1a) and Simpson (1970, fig. 1b). They occur in gray, micaceous siltstones and their overall pattern is somewhat masked by their three-dimensional aspect. One specimen (Pl. 1, fig. 2) retains a small fragment of the marginal tube. The tube is ovoid in cross-section and measures 5 mm by 3 mm. Because the species of *Zoophycos* are so poorly defined, no attempt at specific identification will be made here.

Interpretation — The interpretations given to *Zoophycos* are as varied as the morphology of the genus itself. Several earlier authors (*e.g.* Rouault, *in* Lebesconte, 1884) believed that it was the impression of marine algae. It has also been assigned to the Porifera by Lebesconte (1887) and to the Alcyonaria by Lucas (1938). Other workers regarded it as inorganic, caused by either current activity (Nathorst, 1886), or gas bubbles (Korn, 1929).

Today it is generally agreed that *Zoophycos* represents the feeding structure of an unknown soft-bodied wormlike organism (Häntzschel 1962, 1965; Seilacher 1967a). A notable excepton is Plička (1968, 1970) who, working with Tertiary material from the Carpathians, described the arcuate *Spreite* as the impression of the prostomia of sabellid annelids.

The present authors accept the trace fossil assignment although they are unable to comment on Plička's material. The three dimensional preservation of *Zoophycos*, as well as the lack of any microstructure, rules out a vegetable origin. Moreover, the arcuate *Spreite* are a variant of a feeding method frequently observed in trace fossils. *Phycodes* and *Rhizocorallium* could be cited as examples. Basically each arc represents the course of the organism as it moved along, ingesting the sediment. When the elastic limits of the body were reached the animal contracted and proceeded to excavate a new burrow directly adjacent to the old one. Seilacher (1967a) postulated that the antler-shaped *Zoophycos* from the Cretaceous are actually a less efficient variant of the more compact Tertiary forms. In the former the area between the horns is left unexploited whereas this does not occur in the compact forms. Because the burrows of *Zoophycos* are normally three dimensional it is probable that they were excavated below the depositional interface.

The above description of the origin of the burrow is greatly simplified. The only detailed attempts to describe the habits of the organism are those of Bischoff (1968) and Simpson (1970).

In summary, *Zoophycos* is variable in overall appearance but all forms assigned to the genus possess the arcuate *Spreite*. Because of its variability it must be regarded as a form genus. It represents a feeding burrow although the actual mechanics of formations of the burrow are still not clear for all members of the genus.

TRACE FOSSILS AS INDICES OF WATER DEPTH

Seilacher (1955) compared the trace fossils from five sections of diverse geologic ages.[4] He found some sections (*e.g.* Lower Cambrian of the Salt Range of Pakistan) were characterized by shallow resting traces (Cubichnia of Seilacher, 1953a) which probably served as places of temporary concealment. He interpreted these as indicative of a shallow-water environment well within the euphotic zone, an area where predators would be most active. Conversely other sections such as the Tertiary Alpine Flysch contained no Cubichnia but numerous grazing traces (Pascichnia of Seilacher 1953a). Seilacher interpreted Pascichnia as two-dimensional feeding trace analogous to strip mining, where the organism attempts to cover a large area with a minimum amount of effort. This can lead to unusual geometric patterns such as the tight spiral of *Helminthoida.*

Observations of Recent sediments have served largely to confirm Seilacher's hypotheses. It is difficult to observe Cubichnia in the process of formation since the organism quickly covers itself with sediment. However, Recent stelleroids and ophiuroids are known to burrow for protection (Seilacher, 1953b), and it is not unreasonable to assume that *Rusophycus,* which is abundant in lower Paleozoic sediments represents a burrow of trilobites. While Pascichnia remain unreported in photographs taken within the

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[4]For a more detailed discussion of Seilacher's ichnofacies see Osgood (1970, pp. 399-404).

euphotic zone their presence has been confirmed by photographs taken at great depth (see Seilacher 1967b, pl. II).

In 1964 Seilacher expanded his analysis to include 42 sections of varying geologic age and locality. He formally named the suite of trace fossils dominated by Pascichnia as the *"Nereites Facies"* while the Cubichnia suite was entitled the *"Cruziana Facies."* In addition he proposed the *"Zoophycos Facies"* at this time. Unlike the *Nereites* Facies and *Cruziana* Facies which normally contained several different trace fossils, *Zoophycos* was commonly the sole trace fossil. Seilacher (1964, 1967b) cited several examples from the geologic record to support his views. Moreover, in the Ordovician of Iraq there is a vertical gradation through the *Nereites-Zoophycos-Cruziana* Facies.

In subsequent papers Seilacher (1963, 1967b) enlarged the number of facies to six. These additional facies, which need not concern us here, are indicative of shallow water or special environmental conditions.

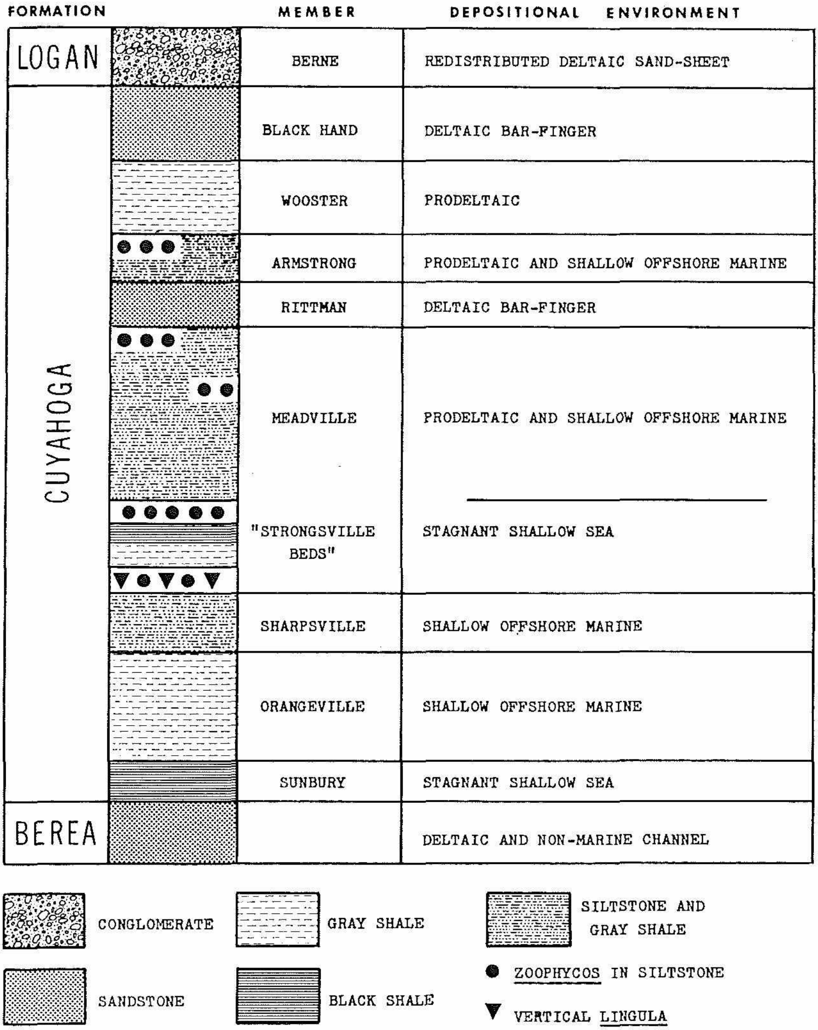
The authors of this paper take no issue with Seilacher's interpretation of the environmental significance of the *Cruziana* and *Nereites* Facies. They are supported by both well-reasoned arguments and Recent observations. The *Zoophycos* Facies rests on weaker evidence. Why should this particular three-dimensional feeding burrow be confined to "intermediate" depth water and why are there virtually no other trace fossils occurring with it?

THE LOWER MISSISSIPPIAN SECTION IN NORTHEASTERN OHIO

The Mississippian stratigraphic units in northern Ohio comprise a composite thickness of more than 300 meters of fine-to-coarse-grained clastics that were deposited in the northwestern part of the Appalachian marginal basin. They include shallow-water marine, transitional, and to a lesser degree nonmarine sediments.

The stratigraphic sequence shown in Text-figure 1 is conformable except for an erosional break of considerable relief at the base of the Berea Formation and a minor unconformity or reworked surface at the Cuyahoga-Logan contact.

Four major types of lithologic groups are shown in Text-figure 1: 1. Conglomerate, 2. Sandstone and pebbly sandstone, 3. Gray shale and siltstone, 4. Black and gray shale and siltstone.



Text-figure 1. Composite section of Lower Mississippian stratigraphic units in northern Ohio and their deduced depositional environments. Vertical dimensions of the units are not drawn to scale.

The Berne Member of the Logan Formation is a thin, widespread fine-pebble conglomerate which contains a moderately abundant marine invertebrate fauna. Hyde (1915) interpreted the conglomerate as a wave-reworked "lag concentrate" of pebbles derived from the underlying pebbily sandstones of the Black Hand Member.

The sandstones are predominately deltaic in origin. The Berea Sandstone is a channel-deltaic unit composed of nonmarine, transitional, and marine strata (Pepper, *et al.*, 1954). The Rittman Member and Black Hand Member are regarded as delta-complex deposits composed primarily of bar-finger sands which grade laterally into finer clastics of the Wooster Member and Meadville Member (Barclay, 1968; Szmuc, 1970).

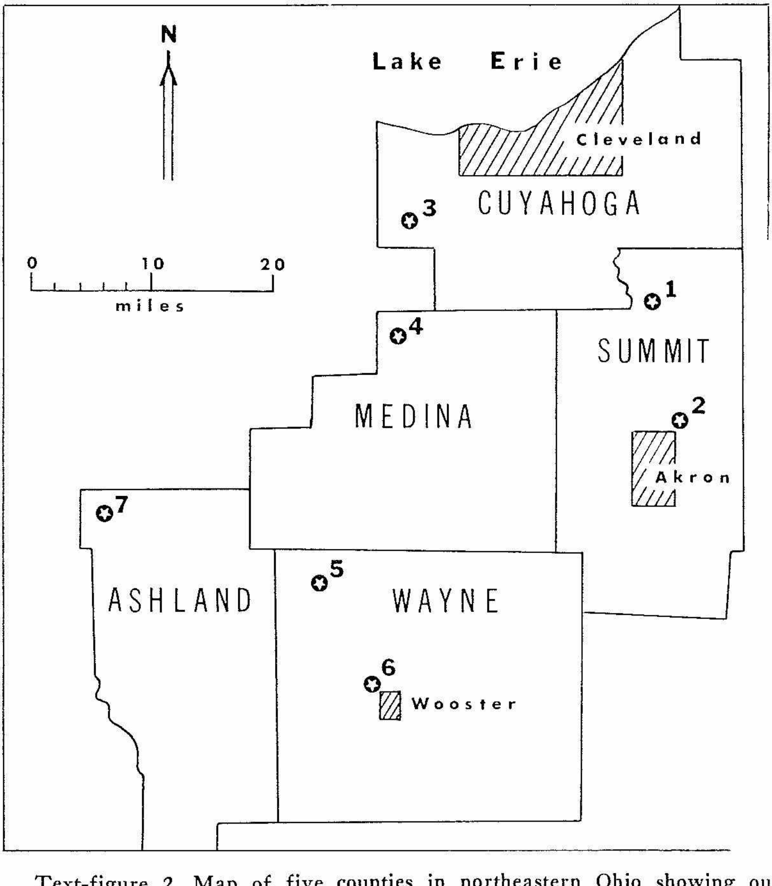
The gray shale beds and the flaggy siltstone-shale beds of the Orangeville Member, Sharpsville Member, and Wooster Member, and the upper portion of the Meadville Member are composed of prodeltaic and shallow-water offshore marine sediments (Barclay, 1968; Szmuc, 1970). A sparse to abundant marine fauna composed of brachiopods, bryozoans, corals, and many other invertebrates is dispersed irregularly throughout these units.

The black shales of the Sunbury Member and the siltstones and black and gray shales of the basal portion of the Meadville Member (here designated informally as the "Strongsville Beds") contain a depauperate biota composed of conodonts, plant debris, and inarticulate brachiopods. These strata were deposited in restricted, stagnant, and deoxygenated shallow seas.

The Strongsville Beds are noteworthy because they typically display one to six meters of gray and black shales intercalated between two areally extensive siltstone beds which at many exposures contain profuse numbers of *Zoophycos* on their upper bedding surfaces. One or both of the *Zoophycos*-bearing siltstones are prominently displayed at Brandywine Creek, Cuyahoga Falls, Strongsville, and Valley City (Sections 1, 2, 3, and 4 of this report).

OCCURRENCE OF ZOOPHYCOS IN THE MISSISSIPPIAN OF NORTHEASTERN OHIO

The main objective of this study was to locate *Zoophycos* in the field and to search for sedimentary structures, body fossils and trace fossils which would provide some evidence of water depth. Numerous exposures were sampled and described in detail in a five-county area, including the seven representative localities shown in Text-figure 2. The results of the study are presented below.



Text-figure 2. Map of five counties in northeastern Ohio showing outcrops of Lower Mississippian strata at selected localites. 1. Brandywine Creek. 2. Gorge Park, Cuyahoga Falls. 3. Strongsville. 4. Valley City. 5. Killbuck Creek. 6. Wooster Quarry. 7. Buck Creek. See Appendix at end of report for detailed locality data.

A) *Stratigraphic distribution of Zoophycos*

Zoophycos is confined to certain siltstones of the Meadville Member and Armstrong Member. The sandstones, conglomerates, and the gray and black shales are devoid apparently of *Zoophycos.*

B) *Abundance of Zoophycos*

The density of distribution of *Zoophycos* in the Strongsville Beds is comparable to certain beds in the Mississippian Borden Group of Kentucky, where their intertwined patterns locally cover entire bedding planes. Although *Zoophycos* is more sparsely represented on bedding planes in the Armstrong and upper part of the Meadville, its common presence clearly demonstrates that it is not a chance occurrence. It was usually possible to locate three to four specimens on a surface of four square meters.

The authors were able to confirm Seilacher's (1964) observation that only rarely does *Zoophycos* occur with other trace fossils. The only associated form is *Palaeophycus* sp. (as defined by Osgood, 1970). This is a common trace fossil and not diagnostic of any particular environment.

C) *Associated invertebrate and plant fossils*

Few body fossils were found in association with *Zoophycos.* This is not too surprising because the section is predominantly clastic, and fossil occurrences within this part of the Mississippian tend to be localized. Fragmented pelecypod, sponge, crinoid, and articulate brachiopod remains were found from a few centimeters to 20 meters (vertical distance) of *Zoophycos,* but not within the same or adjacent beds. There are, however, two significant exceptions: 1) At the Strongsville locality (Section 3) specimens of *Lingula* cf. *melie* Hall were found *in situ* within the *Zoophycos* beds (Pl. 2, fig. 1). As most of them assume the life position it is unlikely that they were washed into the area. It is well known that Recent *Lingula* prefers a shallow-water environment and is the only living brachiopod which can sustain itself for short periods of time in brackish waters (Rudwick, 1965). According to Hatai (1940) Recent *Lingula* extends from the low-water line to about 20 or 23 fathoms, although one specimen of *Lingula unguis* was recorded from a depth of about 50 fathoms near Seto, Japan.

2) At the Valley City locality (Section 4) a black shale two to three meters thick is in contact with the upper *Zoophycos* siltstone of the Strongsville beds. Within the shale are a few thin (2 to 3 mm thick) beds of cross-laminated siltstone. This shale is also present at the Strongsville locality and apparently represents a local basin. Its significance for this study is that it contains abundant carbonized cordaite fragments, some several centimeters long. While this is not indicative of any particular water depth, the abundance of the plant fragments would seem to demonstrate a near-shore occurrence.

D) *Sedimentary features associated with Zoophycos*

Several lines of evidence point to abundant current or wave activity.

1) Many of the siltstone beds in the Meadville Member and Armstrong Member pinch and swell and some are abruptly lenticular. Cross-laminations are common and many are large-scale sets which range from 3 to 5 meters in lateral extent and display dips of 5 to 15 degrees. While we are unable to assign the large-scale structures to a particular depositional environment *(e.g.* point bar) it seems unlikely that they originated below wave-base.

2) Oscillation ripple marks are abundant at the Killbuck Creek locality (Section 5) and occur within 5 cm (vertically) of *Zoophycos.* They have an amplitude of 1 cm and a wave length of 7 to 10 cm., and many grade laterally into interference ripple marks. It is not uncommon to find three or four ripple-marked beds within a thickness of 20 cm. While the authors realize that such ripple marks may be produced by various mechanisms (see McKee, 1965) it is difficult to visualize the origin of such large numbers below wave-base. It is worthy of note that Seilacher (1967b, fig. 2) placed *Zoophycos* below the occurrence of oscillation ripple marks.

E) *Regional geological setting*

It is instructive to look at the environmental setting of the formations both underlying and overlying the Cuyahoga. In northeastern Ohio the Berea Sandstone occurs some 45 meters below the *Zoophycos* beds (Szmuc, 1970, p. 43). Pepper, *et al.* (1954) demonstrated convincingly that the Berea and the subjacent Bedford

Formation represent a deltaic, prodeltaic, and channel-fill environment. The reader is referred to their paper for a more complete discussion.

Although the Logan Formation, which lies some 35 meters above *Zoophycos,* has not been thoroughly studied by the writers, environmental indicators are abundant. The Quarry of the Wooster Medal Brick and Tile Company at Wooster (Section 6) contains one of the best exposures of the upper Cuyahoga Formation and lower Logan Formation in northeastern Ohio. In this exposure interference ripplemarks, ripple drift, and small scale channel cross-lamination are common. Rare casts of mud cracks have also been found. The Berne Conglomerate in the basal portion of the Logan consists of quartz pebbles in a sandy matrix containing chonetid brachiopods.

The stratigraphic position of the Cuyahoga beds between deltaic and delta-derived sediments is a compelling argument for a shallow-water habitat of the Ohio *Zoophycos.* The argument is strongly enhanced by the environmental setting of the Meadville, Armstrong, Rittman, and Black Hand Members. The deduced depositional histories (see Text-fig. 1) of these units are based not only on the criteria presented in this paper, but also on their body-fossil content, geometry, and stratigraphic relations with contiguous units such as the largely nonmarine Pocono Sandstone of Pennsylvania (Hyde, 1915; Barclay, 1968; Szmuc, 1970). Environmental interpretations on these bases indicate that the *Zoophycos* in the Armstrong Member is sandwiched between the Rittman and Black Hand barfinger sands, the stratigraphic separation of which is about 35 meters. Moreover, the *Zoophycos*-bearing beds in the Armstrong and in the upper part of the Meadville are intimately associated with off-shore marine and prodeltaic deposits.

There is nothing in the Ohio Mississippian section which suggests any significant deepening of the epeiric sea during Cuyahoga sedimentation. On the contrary, all available evidence indicates that *Zoophycos* lived in shallow-water, offshore environments.

CONCLUSIONS AND PROBLEMS

1) In Ohio *Zoophycos* is closely associated with shallow-water environments, as is amply attested by our interpretation of the Strongsville Beds.

2) Seilacher's *Zoophycos* Facies apparently must be broadened or expanded from an equivocal assignment of "intermediate depth" to include deposits which form well above wave base and proximate to the outer margins of bar-finger sands. This opinion is strongly indicated by our interpretation of the Armstrong beds and upper Meadville beds and related units of the Cuyahoga Formation.

3) It seems likely that water depth, which in turn reflects many physical factors (temperature, light), is not the sole factor in determining the distribution of *Zoophycos*. This conclusion is buttressed by the presence of this genus in two different shallow-water ecological niches, the Strongsville and the Armstrong-Meadville, as well as by Seilacher's accounts of *Zoophycos* in relatively deep-water deposits.

4) Trace-fossil workers are now faced with the task of conducting a closer examination of this genus. Several questions remain unanswered, *e.g.*, why is *Zoophycos* usually not associated with other trace fossils, how much morphologic variation is to be permitted to exist within the genus, and finally what are the specific physical, chemical, and biotic factors which control its distribution?

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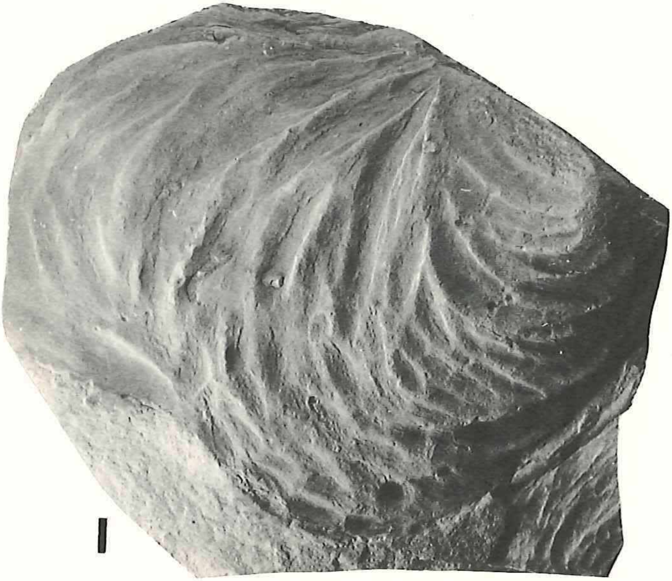
APPENDIX – DETAILED LOCALITY DATA

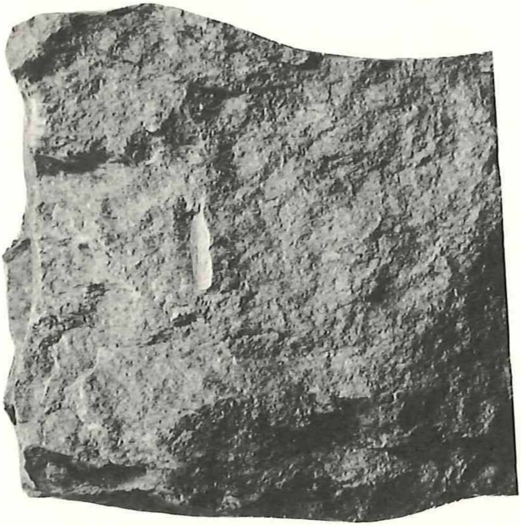
1. *Brandywine Creek locality.* Top of section is at former State Route 8 bridge at Little York, 4.2 miles south of Northfield Center; Northfield Township, Summit County, Northfield 7.5 minute Quadrangle.
2. *Gorge Park locality.* City Park in Cuyahoga Falls, outcrop is in a tributary valley on north bank of the Cuyahoga River 0.8 miles east of State Route 8 bridge; Summit County, Akron East and Akron West 7.5 minute Quadrangles.
3. *Strongsville locality.* Baker Creek, 0.1 mile west of junction of State Routes 82 and 237 and 1.25 miles west of Strongsville. Outcrop is some 300 meters south of the bridge over route 82; Strongsville Township, Cuyahoga County, Berea 7.5 minute Quadrangle.
4. *Valley City locality.* West branch of Rocky River where crossed by State Route 252 less than one mile south of intersection of State Routes 252 and 303; Medina County, West View 7.5 minute Quadrangle.
5. *Killbuck Creek locality.* Outcrop begins some 200 meters downstream from where an unnamed tributary of Killbuck Creek is crossed by Wayne County Route 36, 2.5 miles north of village of Congress; Wayne County, West Salem 7.5 minute Quadrangle.
6. *Wooster Quarry locality.* Shale pit (abandoned 1970) of Wooster Medal Brick Company on north side of Wayne County Route 22, 1.7 miles south of intersection of County Routes 22 and 106, Wooster: Wayne County, Wooster 7.5 minute Quadrangle.
7. *Buck Creek locality.* Buck Creek where crossed by State Route 60 at Hereford; Ruggles Township, Ashland County, New London 7.5 minute Quadrangle.

PLATES

EXPLANATION OF PLATE 1

Figure		Page
1.	**Zoophycos** sp.	6
	A large incomplete specimen from the Brandywine Creek locality (#1), UCGM 40644, × 0.4. Respository of figured specimens, University of Cincinnati Geology Museum, Cincinnati, Ohio, 45221.	
2.	**Zoophycos** sp.	6
	A more typical "rooster-tail" form with a small portion of the marginal tube preserved. Buck Creek locality (#7), UCGM 40645, × 0.5.	





1

2

EXPLANATION OF PLATE 2

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Note: Light face figures refer to pages. Bold face figures refer to plates.