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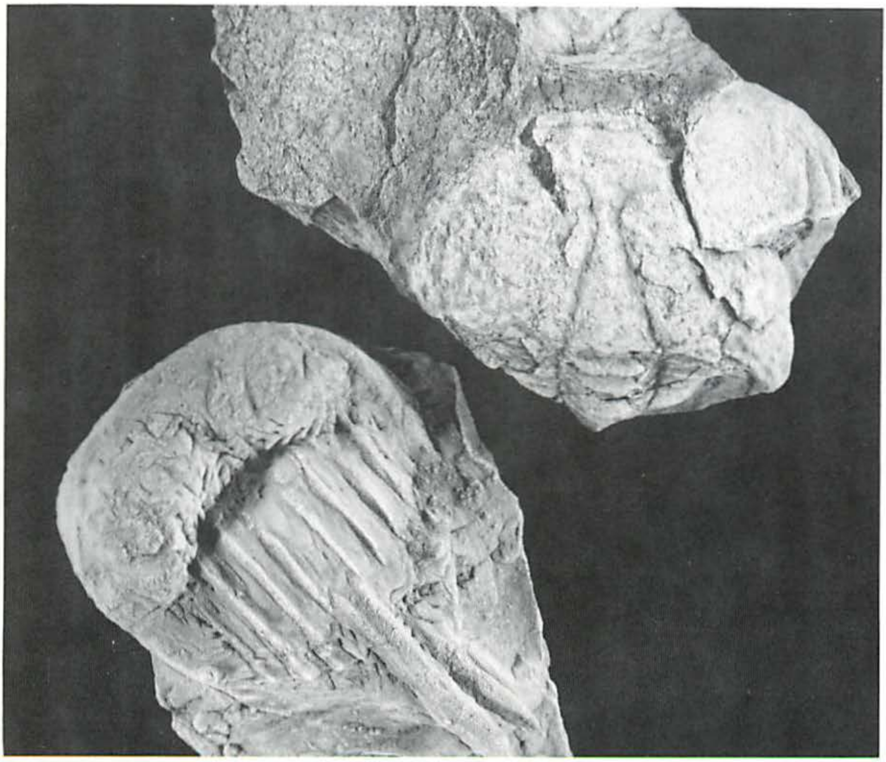

COMMONWEALTH OF PENNSYLVANIA
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CONTENTS

ON THE COVER

Horseshoe crabs and a trace fossil produced by a horseshoe crab from the Upper Devonian Chadakoin Formation in Erie County, Pa. Body fossils of *Kasibelinurus randalli* (upper left) are part of a mass accumulation of variously disarticulated remains. The trace fossil *Protolimulus eriensis* (lower right) is a resting or burrowing trace probably produced by *K. randalli* on a tidal flat. Specimens collected by Scott C. McKenzie and deposited in the U.S. National Museum of Natural History (USNM 484524, left; USNM 484525, right); x1. Photograph by Loren E. Babcock.

PENNSYLVANIA GEOLOGY

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VOL. 26, NO. 2 **SUMMER 1995**

STATE GEOLOGIST'S EDITORIAL

GEOLOGICAL PRODUCTS ("the times they") ARE "A-CHANGIN'"

Geologic and topographic information traditionally has been provided in the form of physical products, such as printed reports illustrated with figures and tables, as well as maps that have multicolored lines and patterns to summarize complex geological data and relationships in a printed graphic format.

Printed products are very time consuming to produce. And, except for popular, educational, or selected other products, only a relatively few tens of copies of scientific reports and maps are usually required to meet user needs. Printing, however, by its very nature, is designed to produce many copies that require bulk storage.

Traditional methods of information distribution are changing. Most Survey reports reproduced for dissemination now involve some digital technology. For example, all Pennsylvania Survey reports now are prepared using word-processing computer software. Most texts of geologic and hydrogeologic reports now easily fit on one or two small computer disks. Geographic and geologic databases created from groundwater and oil and gas well records are increasingly distributed via digital methods. Compilation of base topographic maps now is almost exclusively done using digital technology.

The newly revised physiographic map of Pennsylvania (see announcement on page 16) was prepared for distribution using digital technology and can be provided to you in digital format. Graphic copies of this map can also be individually "printed" by commercial outlets, as well as by users who have access to digital printers and software that can read Arc/Info export files, rather than by standard printing, to avoid needless bulk storage. As necessary changes are made to this map, no manual drafting is required to provide an improved version.

The future of timely and economical information distribution of geological and topographic information is thus largely digital. At the Pennsylvania Geological Survey, we plan to increase digital distribution of geologic and topographic information.

In order to best serve you, the users of Survey distributed information, we seek your comments on planned information distribution

(continued on page 14)

Horseshoe Crabs and Their Trace Fossils From the Devonian of Pennsylvania

New Data Suggest Reinterpretation of Their Sedimentary Environments as Marginal Marine

by Loren E. Babcock and Marilyn D. Wegweiser, The Ohio State University; Arthur E. Wegweiser, Edinboro University of Pennsylvania; Thomas M. Stanley, Kansas Geological Survey; and Scott C. McKenzie, Erie, PA

Horseshoe crabs that thrive today along the Atlantic coast of the United States belong to an ancient group of pincer-bearing arthropods (jointed-leg animals). These fascinating creatures left numerous fossils in the Upper Devonian rocks of northern Pennsylvania and adjacent areas of New York and Ohio. Based on trace fossils and new sedimentologic evidence, the depositional environments where many of these creatures lived are reinterpreted here as marginal marine.

EVOLUTIONARY HISTORY OF HORSESHOE CRABS. The horseshoe crabs (order Xiphosurida) are a small group of arthropods whose origins date back at least 500 million years. This group commonly has been cited for its conservatism in shape and behavior. This interpretation, although not entirely correct (Fisher, 1984), may have been an inevitable consequence of the rather primitive, trilobite-like appearance of living horseshoe crabs. Also, as demonstrated by fossil examples (Figure 1), some of these creatures looked basically the same 365 million years ago as their relatives do today.

Horseshoe crabs from Pennsylvania and adjacent states belong to two extinct lineages of the order Xiphosurida (Fisher, 1984). *Kasibelinurus randalli* (Figure 1A–C and cover photograph) belongs to the ancestral group that gave rise to "*Euproops*" *morani* (Figure 1D) and the modern horseshoe crabs (Fisher, 1984). The familiar modern species *Limulus polyphemus* (Figure 1E) is the one that occurs in abundance along the Atlantic coast, and often it can be observed swimming in shallow nearshore waters or in estuaries, or crawling along beaches or tidal flats. The best time to see living horseshoe crabs is during the late spring and early summer, when *L. polyphemus* comes ashore in great numbers to lay eggs on tidal flats and beaches.

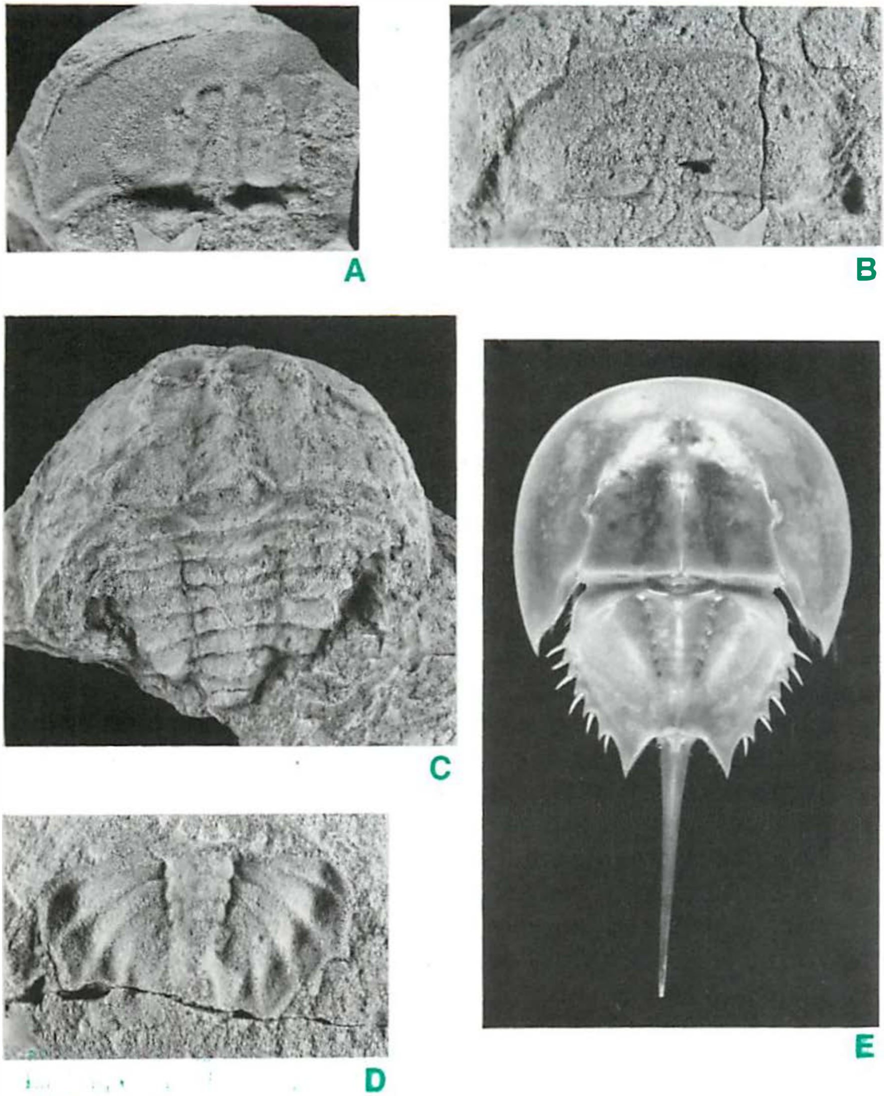

Figure 1. A. *Kasibelinurus randalli*, holotype prosoma (head shield) probably from the Venango Formation (Upper Devonian) of Warren County, Pa. (YPM 9010; x1.25). B. *Kasibelinurus randalli*, paratype prosoma from the same location as the holotype (YPM 30656; x1). C. *Kasibelinurus randalli*, a more complete specimen from the Chadakoin Formation of Allegany County, N. Y. (CM 11065; x1.25). D. "*Euproops*" *morani*, holotype abdomen from the Venango Formation of Warren County, Pa. (CM 11574; x1.25). E. *Limulus polyphemus*, Holocene (recent) from the Atlantic coast of the United States, shown for comparison (x1). Fossil specimens are in the Peabody Museum of Natural History, Yale University (YPM), and the Carnegie Museum of Natural History (CM).

TRACE FOSSILS OF HORSESHOE CRABS. Fossils of the body parts of horseshoe crabs are generally rare in Upper Devonian rocks of Pennsylvania. Evidence of their existence in the form of trace fossils produced by their movement (Figures 2, 3, and cover photograph), however, tends to be quite common in those same rocks, particularly at exposures in Erie, Warren, McKean, and Susquehanna Counties.

Trace fossils produced by horseshoe crabs include both elongate trails or trackways and resting or burrowing pits. Trails or trackways (Figure 2) are similar in shape to the better-known trace called *Cruziana*. *Cruziana* is thought to have been formed by trilobites ploughing through sediment. Other trace fossils are resting or burrowing traces named *Protolimulus eriensis* (Figure 3 and cover photograph). Previously, *Protolimulus* was regarded as being a body fossil of a horseshoe crab (Packard, 1886; Lesley, 1889). It is clear from its preservation, however, that it is actually a trace fossil. All known specimens of *Protolimulus* are impressions produced by the bottom, or ventral, side of the animal, and many specimens show distinct scratches or depressions made in sediment by the appendages or telson (tail spine).

Traces made by horseshoe crabs are commonly preserved in relief and found protruding from the undersides of siltstone or sandstone beds as natural casts. The traces were originally left in soft, unconsolidated sediment (such as silt or clay) and then filled by the rapid deposition of a silt or sand layer. After turning to rock, the less resistant shaly layers were removed by weathering and erosion, revealing detailed casts in siltstone or sandstone.

The traces are important not just because they reveal information about how early horseshoe crabs lived, but also where they lived. Because the traces were formed in unconsolidated sediments, they would have been easily destroyed by current action, and therefore

Figure 2. A trace fossil (ploughing trail) probably produced by *Kasibelinurus randalli*, from the Chadakoin Formation (Upper Devonian) of Erie County, Pa. (x0.75). The animal was moving from right to left. The specimen is in the U.S. National Museum of Natural History (USNM 484523).

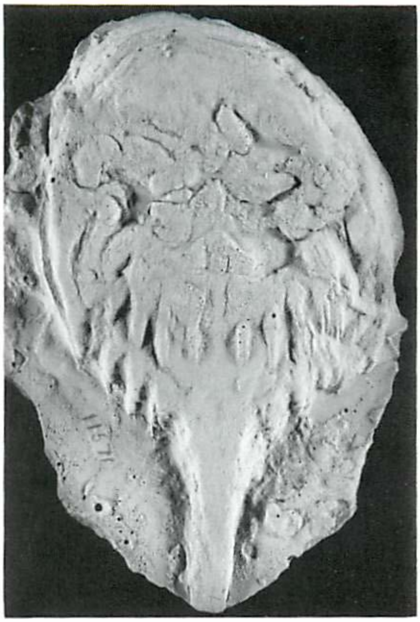

Figure 3. ***Protolimulus eriensis*, plaster cast of the holotype, a resting or burrowing trace probably produced by *Kasibelinurus randalli*, from either the upper Chadakoin Formation or the lower Venango Formation (Upper Devonian) of Erie County, Pa. (x0.75). The cast is in the Carnegie Museum of Natural History (CM 11571).**

could not have been transported any distance. Body fossils, on the other hand, could have been transported, although most in the rock record are probably of relatively local origin. Horseshoe crab exoskeletons are remarkably resistant to disarticulation and breakdown, and can be transported tens of kilometers without showing any obvious effects of transport (Babcock, 1994). For this reason, the presence of horseshoe crab body fossils alone is insufficient evidence that horseshoe crabs were living in any one particular area. Traces of their activities that were made in unconsolidated sediment, though, show that horseshoe crabs lived in the places where the traces have been preserved.

STRATIGRAPHIC SETTING AND DEPOSITIONAL ENVIRONMENTS. Horseshoe crab body or trace fossils are present in the Chadakoin, Venango, and Catskill Formations of Pennsylvania. In adjacent states, they are found in equivalent strata representing marginal marine to nonmarine depositional environments. The type specimens of *Kasibelinurus randalli* (Figure 1A and 1B) are apparently from the oil sands of the Venango Formation in Warren County, Pa. Since the time that Beecher (1902) named *K. randalli,* additional horseshoe crabs have been found in the Chadakoin and Venango Formations. Among them is a single specimen of "*Euproops" morani* (an incomplete abdomen, Figure 1D) from the Venango Formation of Warren County. The Chadakoin and Venango Formations are currently regarded (Berg and others, 1986) as being of late Famennian (late Devonian) age.

Trace fossils produced by horseshoe crabs are among the more common fossils in the upper Chadakoin and lower Venango Formations of Erie, Warren, and McKean Counties, Pa. Two places where they may be collected have been described by Hoskins and others

(1983) as localities 19 (Erie County) and 53 (Warren County). Additional specimens have been reported from the Catskill Formation of Susquehanna County (Caster, 1938).

Kasibelinurus randalli and "*Euproops*" *morani* probably lived in a marginal marine to nonmarine environment. For parts of the Chadakoin and Venango Formations at least, this interpretation differs markedly from previous views concerning the depositional environments of these units. Previous interpretations (for example, White, 1881; Caster, 1938) were principally based on the types of body fossils present in the units. The body fossils include brachiopods, molluscs, sponges, fish parts, crinoid pieces, horseshoe crabs, and abundant terrestrial plant remains. Most of the animal fossils seem to be of shallow-marine origin. It is possible that some of the animals could tolerate nearshore brackish water, although sedimentologic evidence suggests that most of the fossils were washed into marginal-marine to nonmarine environments by waves.

Sedimentologic characteristics of the rocks provide the strongest evidence of the depositional environments of the upper Chadakoin and lower Venango Formations in northwestern Pennsylvania. This succession mostly consists of siltstones, sandstones, and conglomeratic sandstones. Red beds, which are generally indicative of nonmarine sedimentation, are common. Siderite (iron carbonate), which often forms in marginal-marine areas that are influenced by freshwater influx from streams, is a common mineral in these units. Sedimentary structures include symmetrical to slightly asymmetrical ripple marks, flaser bedding, reactivation surfaces, intraclastic conglomerates, and mud cracks. Symmetrical ripple marks normally form in shallow, relatively quiet water by the oscillation of currents, whereas asymmetrical ones form where a unidirectional current is present. Flaser bedding develops mostly in tidal and stream environments where thin streaks of mud have accumulated in troughs of sand ripples. Reactivation surfaces are places where sedimentation of a single, migrating bed of unconsolidated sediment has stopped and another migrating bed has been deposited on top. They are formed where changes in flow rates, tidal stage, or tidal current direction occur. Intraclastic conglomerates are formed by the rip up and nearby redeposition of mud chips. Commonly, the mud chips are pieces of semihardened sediment that have broken from mud cracks on sun-dried mudflats. Mud cracks, which result from the wetting and drying of sediment, show unequivocally that some of the upper Chadakoin and Venango strata were subaerially exposed at times.

Finally, the abundance of horseshoe crab trace fossils offers evidence that the upper Chadakoin and lower Venango Formations were deposited in marginal-marine to nonmarine environments. Many similar trackways in the rock record are from estuarine (brackish water) and tidal-flat settings (Miller, 1982; Pickett, 1984), including those from the Catskill Formation of Pennsylvania (Caster, 1938). These are the environments where many potentially preservable horseshoe crab tracks are being formed during modern times. The sediment must be cohesive (wet) enough at the time the animal passes through it for a trace to be preserved, and the environment must inhibit the existence of other creatures that subsequently could burrow through the sediment and destroy the trace. Such conditions occur commonly in marginal-marine, brackish-water, and freshwater settings.

The authors thank R. D. White, Peabody Museum of Natural History, Yale University, and J. L. Carter and A. Kollar, Carnegie Museum of Natural History, for arranging loans of specimens described in this article. L. I. Anderson, University of Manchester, provided taxonomic advice. G. J. Wasserman, The Ohio State University, printed the photographs. This work was supported in part by a grant from the National Science Foundation to L. E. Babcock and a grant from the Pennsylvania Bureau of Topographic and Geologic Survey to M. D. Wegweiser.

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Biomarkers (Chemical Fossils) in Pennsylvania Rocks

by Christopher D. Laughrey
Pennsylvania Geological Survey

Many readers of *Pennsylvania Geology* are familiar with articles that contain descriptions of the abundant and diverse fossils found in Pennsylvania's rocks. Fossils provide a natural record of ancient plant or animal life. Rarely, the original material of an ancient organism is preserved unaltered, such as the frozen remains of woolly mammoths found in Siberia. A good local example of preservation of unaltered material is the recent discovery of the carbonate mineral aragonite in the shells of numerous molluscs in the Pennsylvanian-age Brush Creek marine zone of the Conemaugh Group in western Pennsylvania (Cercone and others, 1989). A newly recognized example of preservation of unaltered to slightly altered biologic material is described in this article.

INTRODUCTION TO CHEMICAL FOSSILS. Certain organic chemical compounds qualify as fossils. The presence of organic chemical compounds in rocks has long been known, but scientists previously thought that these materials had no paleontological or biological value because of extensive degradation during deposition. We now know that this presumption is quite wrong and that many organic molecules can persist virtually intact, or at least in recognizable form, for many millions of years. Mackenzie (1984, p. 115) defined these chemical compounds, called *biomarkers,* as "any organic compound detected in the geosphere whose basic skeleton suggests an unambiguous link with a known, contemporary natural product." The term "skeleton" in this definition refers to the chemical structure of the molecule.

Geochemists use stick figures, such as those shown in Figure 1, to illustrate the skeleton of an organic compound. For example, the stick figure in Figure 1A is of a chlorophyll molecule, which consists of two principal parts, porphyrin and phytol. The porphyrin part is a complex organic compound made up of several interconnected ring structures, each of which contains four carbon atoms and one nitrogen atom. The phytol part is an alcohol whose role is to aid the porphyrin in chemically associating with specific proteins within the cell membranes of organisms.

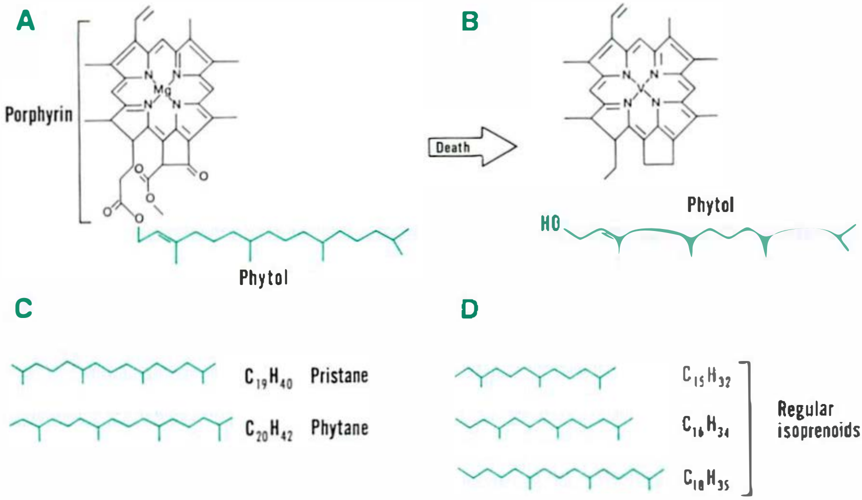

Figure 1. Biomarkers from the chlorophyll molecule. A. Chlorophyll consists of two principal parts, a porphyrin structure and a phytol structure. B. When the chlorophyll-bearing organism dies, these two parts separate. The magnesium (Mg) in the porphyrin is replaced by a vanadyl ion (V) and this new structure becomes a common biomarker found in many crude oils. C. In the presence of oxygen (high Eh), the phytol is converted to pristane. In the absence of oxygen (low Eh), the phytol is converted to phytane. D. These molecules can then be degraded further to form other molecules, called regular isoprenoids.

Let us follow the fate of the phytol skeleton in a molecule of the plant pigment chlorophyll as it decomposes in a sedimentary environment. As chlorophyll decays in sediment on a sea or lake floor, it breaks down into parts of the original molecule (Figure 1B). The now separate porphyrin and phytol parts are further modified in the depositional environment. The fate of the phytol molecule depends to a large extent on the chemistry of the water. If the water column and bottom sediment contain adequate dissolved oxygen, the phytol molecule is oxidized to an organic acid which eventually degrades to a hydrocarbon called pristane (Figure 1C). If reducing conditions prevail, the phytol is readily hydrogenated and reduced to a hydrocarbon called phytane (Figure 1C). In both cases, fragmentation of these diagenetic products may yield other biomarker compounds (Figure 1D). All of these biomarker molecules bear the vestige of their parent phytol derived from the chlorophyll material.

Biological markers have a great variety of chemical structures, all distinctly indicative of a biological origin. Hydrocarbons that form straight-chain molecular structures called *n-alkanes* (the *n* means normal) are common constituents in the leaf waxes of higher plants and in the membrane lipids of algae and bacteria. The skeletal chain lengths of these compounds provide information as to the origin of organic matter in a sediment or rock. Short-chain compounds having 15 to 19 carbon atoms and medium-chain compounds having 20 to 24 carbon atoms generally are the product of algal and/or bacterial sources (Figure 2). Longer chain compounds, with 27 to 33 carbon atoms, characterize a higher type of plant.

Many different biomarkers can provide information concerning the general environmental setting of a rock at the time of deposition. For example, a group of compounds of bacterial origin called hopanoids, which are ubiquitous constituents of many sedimentary rocks, often reflect reducing to anoxic conditions in the sedimentary environment (Peters and Moldowan, 1993). Hopanoids belong to a diverse assemblage of biomarkers known as *terpanes*. Terpanes are cyclic hydrocarbon compounds largely derived from bacterial membrane lipids (Peters and Moldowan, 1993). *Steranes* comprise another assemblage of biomarkers which are derived from compounds called sterols (which include, for example, the infamous cholesterol) that are formed by living organisms (Hunt, 1979). The relative concentrations of certain steranes and terpanes provide information on the depositional input of algae and higher plants versus bacteria in the original depositional environment (Peters and Moldowan, 1993).

A BIOMARKER EXAMPLE FROM NORTHWESTERN PENNSYLVANIA. Several biomarkers have been recovered from rock core of the Upper Devonian Huron Shale obtained during the drilling of a gas well on Presque Isle in Erie County. Using the biomarkers, we can determine the environmental conditions in an epeiric sea about 360 million years ago.

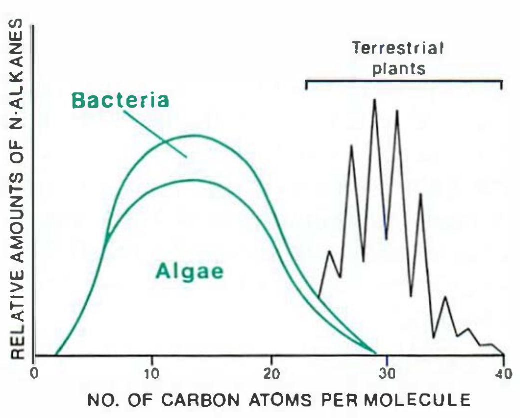

Figure 2. Selected chain-length distributions (number of carbon atoms) for n-alkanes from different kinds of organic matter in sedimentary rocks.

Table 1 is a list of the principal biomarkers identified from the Huron Shale core, their presumed biological origin, and the interpreted depositional environment in which they originated. The n-alkanes in the Huron Shale are of medium molecular weight having 10 to 36 carbon atoms (nC_{10} to nC_{36}). The nC_{11} (short for the hydrocarbon $C_{11}H_{24}$) molecule dominates the n-alkanes in the rock, whereas compounds above nC_{20} are negligible (Figure 3). This n-alkane distribution is typical of hydrocarbons generated during the degradation of marine algae (Martin and others, 1963; Tissot and Welte, 1984).

All five of the regular *isoprenoids* (Figure 1C and 1D) occur in the Huron Shale (Figure 3). Pristane and i-C_{16} (an isoprenoid molecule with the tongue-tying name 2,6,10-trimethyltridecane) are the most abundant of this class of biomarkers. All of these compounds probably originated in the phytol side chain of chlorophyll associated with marine algae in the Late Devonian Catskill sea. The predominance of pristane over phytane suggests that the seawater contained free oxygen and that the topmost layers of sediment were at least moderately aerated during part of the deposition of the shale. Lesser amounts of phytane in the samples indicate that the depositional environment of the shale was at least partially suboxic or dysoxic at times; that is, periodic oxygen depletion occurred in the Huron Shale depositional regime.

The distribution of hopanoids, derived from bacterial membranes, supports the above interpretation. Geochemists use the relative distri-

Table 1. ***Biological Origin and Depositional Environments of Biomarkers from the Huron Shale***

BIOMARKER	BIOLOGICAL ORIGIN	DEPOSITIONAL ENVIRONMENT
n-alkane	Phytoplankton; benthic algae	Shallow marine
Regular isoprenoids	Phytol side chain in phototrophic organisms; archaebacteria	Oxic to suboxic shallow marine
Other terpanes		
Tricyclic	*Tasmanities*[1]	Shallow marine
Tetracyclic	?	High salinity
Norneohopane	Bacteria	Clay-rich sediment, oxic to suboxic conditions
Steranes		
C_{27} to C_{29}	Algae and higher plants	Shallow marine
Norcholestane	Bacterial oxidation of larger steroids	Nonspecific
Diasterane	Sterols	Oxic, clay-rich sediments

[1]Algal microfossil.

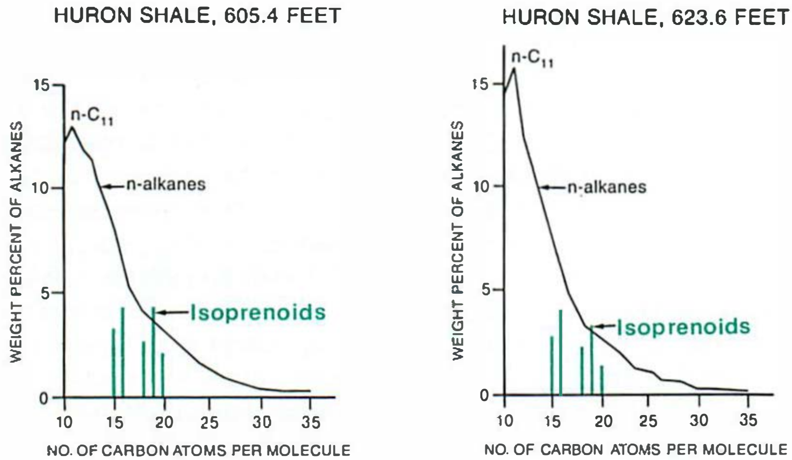

Figure 3. Distributions of n-alkanes and regular isoprenoids in two core samples of the Huron Shale. The vertical axes of the graphs represent the weight percent of alkane hydrocarbons in the samples. The normal alkanes (n-alkanes) have straight-chain structures. Isoprenoids have branched-chain structures, as shown in Figure 1D. The horizontal axes show the number of carbon molecules in the alkanes. Alkanes from $C_{10}H_{22}$ to $C_{36}H_{74}$ occur in the shale, but those from nC_{10} to nC_{20} predominate. All five regular isoprenoids (Figure 1C and 1D) occur in the samples.

bution of certain hopanoids as an indicator of the reducing-oxidizing (redox) potential (Eh) during and immediately after deposition of an organic-rich sediment. For example, large concentrations of C_{33}, C_{34}, and C_{35} hopanoids compared to C_{31} and C_{32} hopanoids indicate highly reducing (low Eh) marine conditions with no available free oxygen during deposition (Peters and Moldowan, 1993). When free oxygen is available in the depositional environment, however, the precursor materials are converted to C_{31} and/or C_{32} hopanoid biomarkers, which reflect the oxic to suboxic depositional conditions (Peters and Moldowan, 1993). Figure 4 shows the relative distribution of these hopanoid biomarkers in the Huron Shale. C_{31} and C_{32} clearly dominate the distribution of these compounds in the shale, indicating oxic to suboxic sedimentary conditions. The presence and relative amounts of other biomarkers such as norneohopane and diasterane (Table 1) also indicate oxic to suboxic conditions in the Huron Shale.

The biomarker data from the Huron Shale core contradict the most popular theories concerning the processes that concentrated large amounts of organic matter in the Devonian black shales of the Appalachian basin. Many geologists believe that the Devonian shales

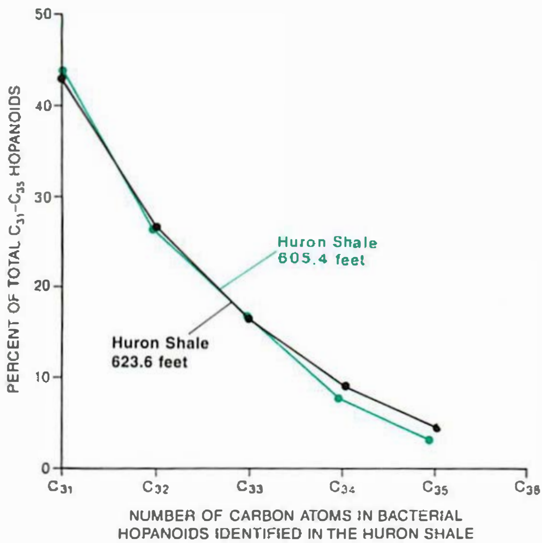

Figure 4. Relative distribution of hopanoid biomarkers in two samples of the Huron Shale. The vertical axis represents the percentage of hopanoids that have 31 to 35 carbon atoms in their structure. The horizontal axis represents specific hopanoid compounds.

were deposited in anoxic environments at great depths. A small minority of scientists, however, argue that the high organic content of the Devonian black shales is the result of high productivity of organic matter in an oxic shallow marine environment in combination with a moderate to high sedimentation rate (Tyson and Pearson, 1991; Milici, 1993). The biomarker data presented here support the latter theory and suggest that further research along these lines is warranted.

Biomarkers are fascinating fossils, and paleontology at the molecular level is as exciting as collecting sea shells from an outcrop. Biomarkers can significantly enhance a great variety of geological and biological work. The biomarkers identified in the Huron Shale testify that marine plankton and benthic microbial organisms were important life forms in the Late Devonian shallow seas of northwestern Pennsylvania. They also indicate that there is still much to learn about the sedimentary origins of some of the most studied rocks in the world.

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ANNOUNCEMENT

Free Topographic Maps

As a result of the ongoing program to revise and update 7.5-minute topographic quadrangle maps of Pennsylvania, the Survey has a stock of surplus 7.5-minute topographic maps that have been superceded by newer editions. These surplus maps are being offered at no charge, singly or in small quantities, to interested parties. Because there are too many maps to list here and because selection of individual quadrangles is not possible, we ask that those interested in obtaining the maps specify how many quadrangles, and the number of copies of each, are desired from northeast, northcentral, south-central, southeast, northwest, or southwest Pennsylvania. As long as supplies last, we will mail maps from the region(s) indicated. To obtain maps, or for more information, please contact Richard Keen, Librarian, Pennsylvania Geological Survey, P. O. Box 8453, Harrisburg PA 17105–8453, telephone 717–783–8077.

State Geologist's Editorial *(continued from page 1)*

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Donald M Hoskins

Donald M. Hoskins
State Geologist

Sandcastle Moats and Petunia Bed Holes... A New Book About Groundwater

by Dawna Yannacci
Pennsylvania Geological Survey

A colorful and interesting introduction to the basics of groundwater is now available free of charge from the Department of Environmental Protection. This 28-page booklet is entitled **Sandcastle Moats and Petunia Bed Holes...A Book About Ground Water.**

The booklet is geared toward junior high school students; however, it could also be used by teachers at all levels as a source of ideas on how to explain and demonstrate basic groundwater concepts. It is filled with colorful illustrations and helpful analogies designed to aid in the understanding of this potentially confusing subject.

Simple experiments, which demonstrate a water table, porosity, permeability, groundwater acidity, leaching, and landfills, are also described. Follow-up questions based on these experiments are provided.

Adults may find the tone of this booklet somewhat condescending, but those who keep in mind that it was written for school children will find a fun and understandable introduction to groundwater principles.

The booklet was originally written by Pat Nickinson for the Virginia Environmental Resources Center and has been adapted by James Ulanoski, Nancy Spangenberg, and Stuart Reese of the Bureau of Water Quality Management for use in Pennsylvania. This adaptation includes a special section in which the groundwater characteristics of the seven regions (physiographic provinces) of Pennsylvania are briefly discussed. In this section, the reader is given an overview of the major rock types and corresponding aquifer types, potential and known water-quality problems, and yielding capability of each region.

Sandcastle Moats and Petunia Bed Holes...A Book About Ground Water may be obtained by writing the Department of Environmental Protection, Bureau of Water Quality Management, P.O. Box 8465, Harrisburg, PA 17105–8465, or calling Marilyn Keifer at 717–787–9633.

NEW RELEASE

Digital Physiographic Provinces Map of Pennsylvania

The Pennsylvania Geological Survey announces the release of a digital data set entitled **Physiographic Provinces of Pennsylvania.** The data set is based on the recently completed third edition of the Survey's physiographic provinces map, by staff geologist W. D. Sevon.

The new map has several differences from the previous version, mainly in the Appalachian Plateaus province, where two sections, the Allegheny Plateau Section and the Deep Valleys Section, have been added and the boundaries of several other sections have been modified (see back cover).

The digital work was done by staff of the Survey's Geologic and Geographic Information Services Division using Arc/Info (Unix version) software. The boundaries of provinces and sections were digitized from 1:100,000-scale stable-base mylars, and each polygon was attributed with the name of the province and section. Separate coverages were prepared for the late Wisconsinan glacial border, which forms the boundary between physiographic sections in several areas, and the state and county boundaries and names, which were derived from the U.S. Geological Survey 1:100,000-scale digital-line-graph files.

The data set is available as Arc/Info export files for each coverage (physiographic boundaries and names, file size approximately 980 Kb; state and county boundaries and names, approximately 490 Kb; and late Wisconsinan glacial border, approximately 360 Kb). The data set also includes a plot file for printing a 1:500,000-scale, full-color version of the map using Arc/Info software and a raster plotter. An expanded map explanation shows the dominant topographic form, local relief, underlying rock type, geologic structure, approximate minimum and maximum elevations, drainage patterns, boundaries, and origin of each section.

Those interested in obtaining a copy of the data set will be asked to supply a Colorado 250-type blank tape for DOS-based PC's, or a blank 8-mm tape for Unix workstations. For more information or to order, please contact Christine Miles or Thomas Whitfield, Pennsylvania Geological Survey, P. O. Box 8453, Harrisburg, PA 17105–8453, telephone 717–787–8162.

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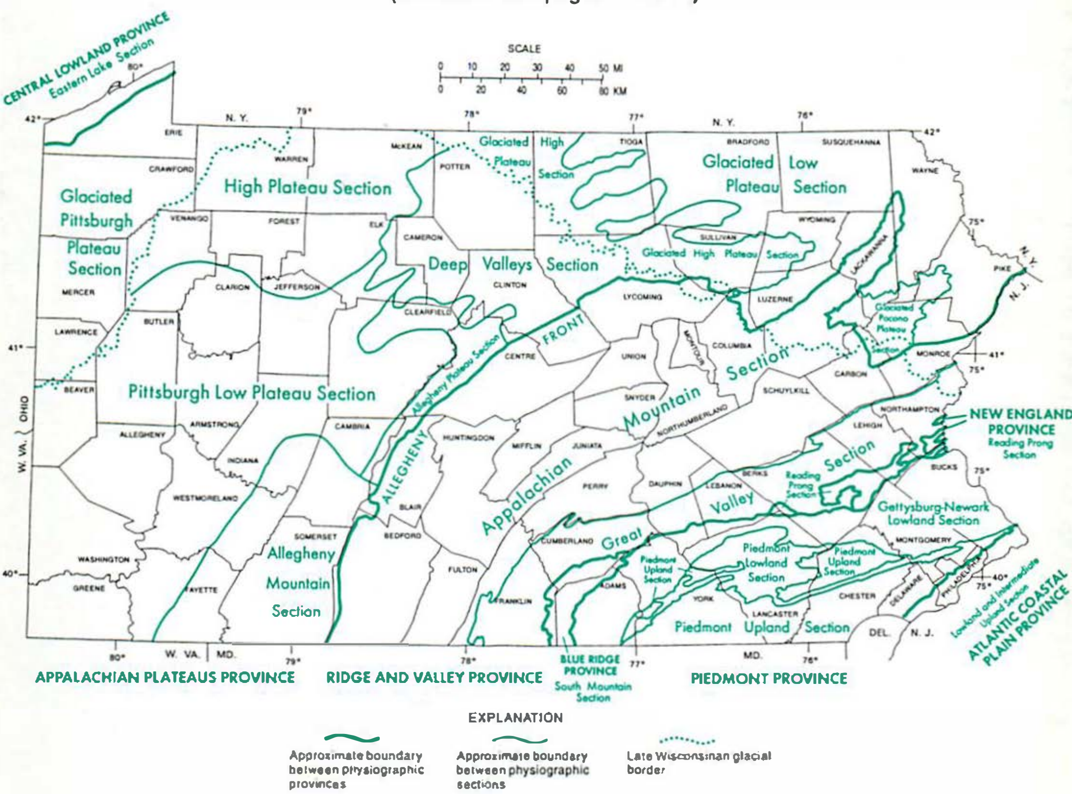
TOPOGRAPHIC MAPPING
GROUNDWATER-RESOURCE MAPPING

NEW PHYSIOGRAPHIC PROVINCES MAP OF PENNSYLVANIA

(See articles on pages 1 and 16)



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