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PALEOGENE SNAKES OF MISSISSIPPI

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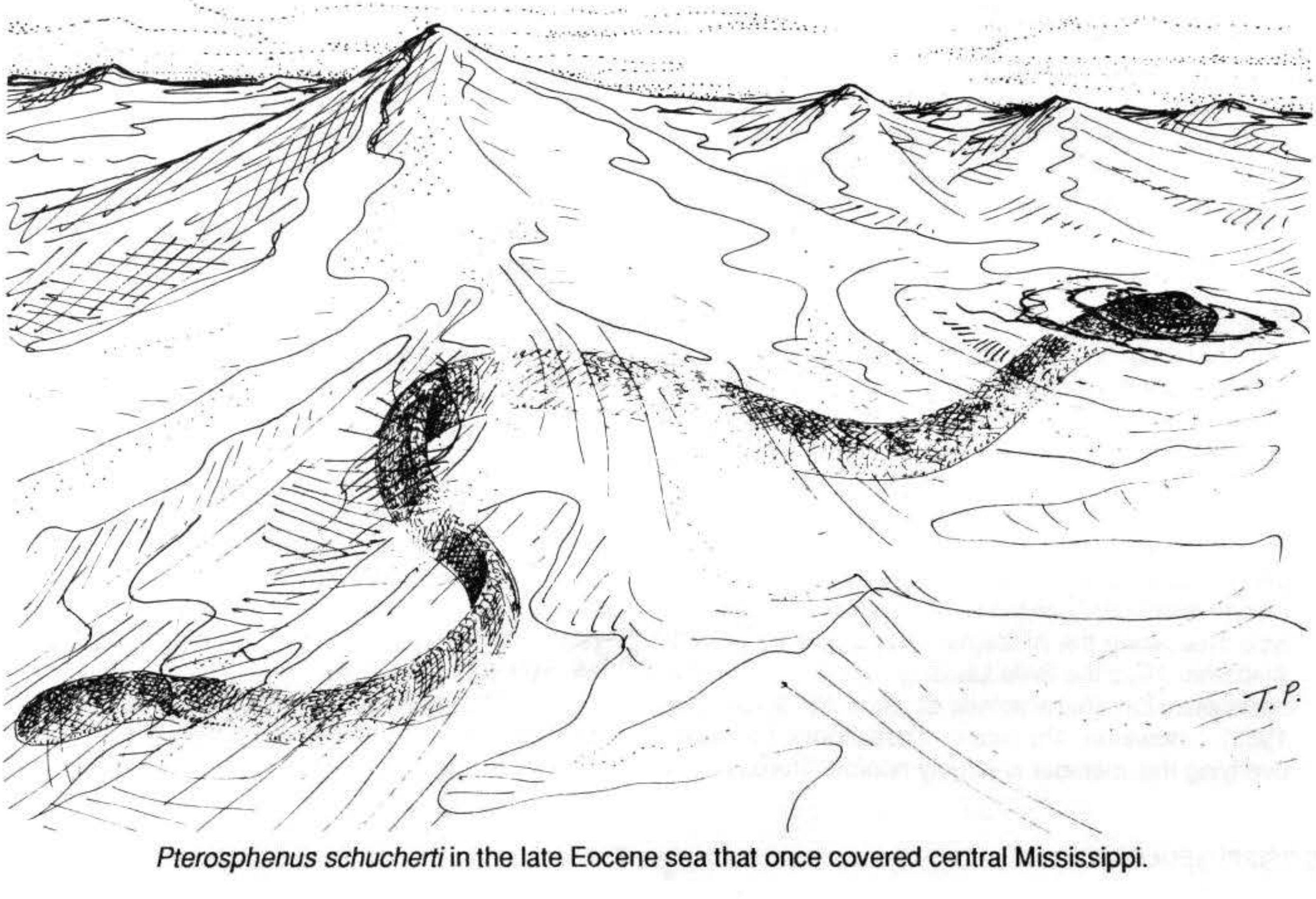

Pterosphenus schucherti in the late Eocene sea that once covered central Mississippi.

ABSTRACT

Mississippi has twice as many palaeopheid snakes as any other state and all four species that occur in North America: *Palaeophis casei, P. littoralis, P. virginianus,* and *Pterosphenus schucherti. P. casei* is diminutive, *P. littoralis* is medium-sized, and the latter two species are giant snakes. From an evolutionary standpoint *Pterosphenus* is more derived than *Palaeophis* and *Palaeophis casei* and *P. littoralis* are more derived than *P. virginianus.* The vertebrae of all of these snakes are very highly modified for an aquatic existence and the main habitat for all of them seems to have been an estuarine one. Ecological differences between these snakes involve differences in prey size as well as the fact that *Pterosphenus schucherti* probably could exist far out at sea as well as in estuaries.

INTRODUCTION

The Paleogene snakes of Mississippi form a unique part of the Tertiary paleofauna of the state. These snakes all belong to a single family, the Palaeopheidae, whose species range in size from a very small form about 472 mm (18 inches) long to giant forms about 5.5 meters (18 feet) long. Thus far, knowledge of Mississippi Paleogene snakes has been confined to brief accounts scattered in the literature (Dessem, 1976; Westgate and Ward, 1981; Holman, 1982; Rage, 1984; Holman and Case, 1988; and Parmley and Case, 1988).

This situation is rectified in the present report, which presents new and previous records of occurrences of Paleogene snakes in Mississippi; a discussion of the stratigraphy of the sites where these snakes have been found; and a general discussion of the taxonomy and distribution, morphology and paleoecology of these snakes.

Stratigraphy

The occurrence of fossil palaeopheid snakes in Mississippi is restricted to two intervals within the state's Paleogene sequence. The earliest of these possibly straddles the Paleocene-Eocene boundary and includes occurrences in the upper Tuscahoma Formation (Late Paleocene ?) and the Bashi Formation (Early Eocene). In western Alabama and eastern Mississippi the age of the Tuscahoma Formation is based largely on the marine microfossils of the Bells Landing Member in its type area along the Alabama River in Clarke County, Alabama. Here the Bells Landing contains calcareous nannoplankton characteristic of Zone NP 9 (Siesser, 1983). However, the upper Tuscahoma Formation overlying this member is largely nonfossiliferous. The next datable unit above the Bells Landing Member is the Bashi Formation, a very fossiliferous marine sand containing calcareous nannoplankton of Zone NP 10 (Bybell, 1980) and planktonic foraminifera of Zone P 6 (Mancini, 1981). The Bashi Formation overlies the Tuscahoma Formation and the Tuscahoma-Bashi contact is generally considered to be the Paleocene-Eocene boundary.

The discovery of a diverse vertebrate fauna in the upper Tuscahoma Formation at Meridian, Mississippi, by Case has renewed interest in the age of the uppermost section of this formation. This fauna occurs above a diastem at the base of a thin bed of glauconitic sand just ten feet below the Tuscahoma-Bashi contact and includes the teeth and vertebrae of marine/estuarine sharks and fish (Case, 1986), snake vertebrae, and teeth of terrestrial mammals. A very similar vertebrate fauna occurs within the Bashi Formation at this same locality. Therefore, the upper Tuscahoma estuarine site of Case may be either Late Paleocene or Early Eocene in age. The land mammal fauna of this site indicates a Clarkforkian-Wasatchian land mammal age (Chris Beard, personal communication). This age spans the Paleocene-Eocene boundary and provides no additional information to the problem. A recent examination of dinoflagellates by Lucy Edwards (personal communication) from the clay unit underlying the vertebrate bed indicated a Late Paleocene age.

While the Tuscahoma and Bashi fossil snake finds occur within a 15-foot section (including the upper ten feet of the Tuscahoma Formation and the five-foot thickness of the Bashi Formation), the next fossil snake records occur within a 400-foot plus section of Late Eocene sediments of the Moodys Branch (15 feet thick) and Yazoo (400 feet thick) formations. The Moodys Branch Formation is a nearshore transgressive shelf unit and the Yazoo Formation is an offshore clay sequence. The occurrence of fossil snakes in this sequence suggests that they had an open marine habitat.

SYSTEMATIC PALEONTOLOGY

Class Reptilia Laurenti, 1768
Order Squamata Oppel, 1811
Suborder Serpentes Linnaeus, 1758
Superfamily Booidea Gray, 1825
Family Palaeopheidae Lydekker, 1888
Subfamily Palaeopheinae Lydekker, 1888

All Mississippi records of Paleogene snakes represent members of the Subfamily Palaeopheinae of the Family Palaeopheidae and are based entirely on vertebral remains.

Genus *Palaeophis* Owen, 1841

Two genera, *Palaeophis* with three species and *Pterosphenus* with only one, occur in the Paleogene of Mississippi. The three species of *Palaeophis* consist of a very small form, a moderately small form and a giant form. The single *Pterosphenus* species is a giant form.

Methods of distinguishing the vertebrae of *Palaeophis* and *Pterosphenus* have been discussed by Gilmore (1938), Holman (1977, 1982), Rage (1984) and more recently by Parmley and Case (1988). Holman (1977) expressed some doubt about the validity of the two genera, stating "I am here recognizing the two genera *Palaeophis* and *Pterosphenus*, but until fully articulated, complete vertebral columns of these forms are found, I am not convinced that *Palaeophis* and *Pterosphenus* do not represent variations along the vertebral column of a single form."

We are not aware of any complete palaeopheid vertebral columns to date, but the paleoherpetological community has continued to accept both genera as valid (Westgate and Ward, 1981; Holman, 1982; Rage, 1984; Hutchison, 1985; and Parmley and Case, 1988). As of

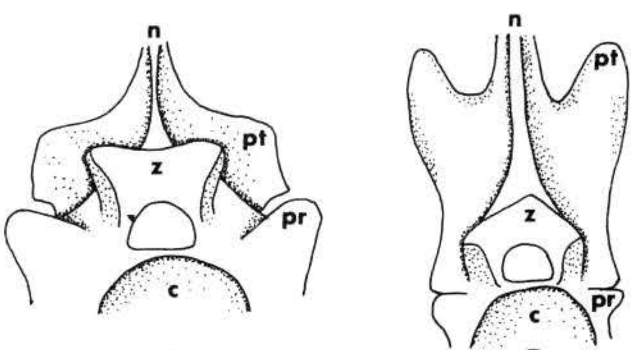

Figure 1. Major differences between vertebrae of A, *Palaeophis*, and B, *Pterosphenus* redrawn from Parmley and Case (1988). c, condyle; pr, prezygapophyses; z, zygosphene; pt, pteropophyses; n, neural spine.

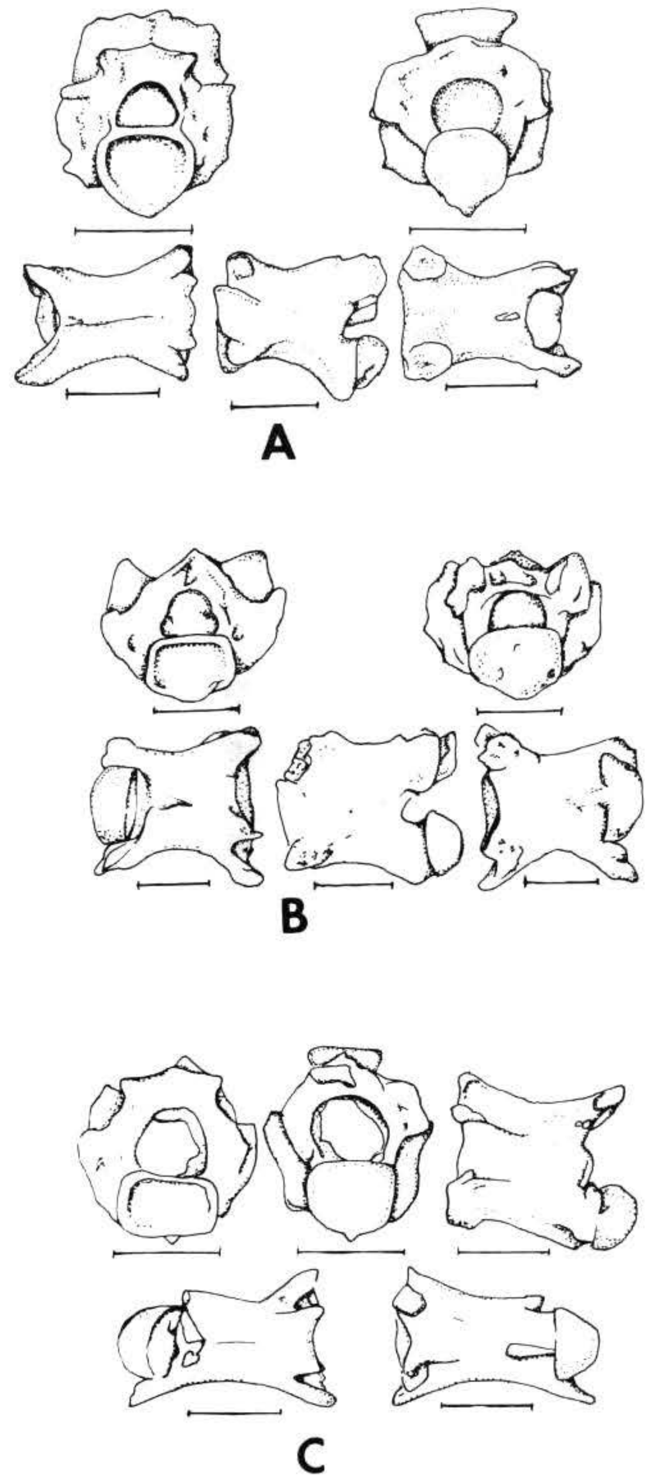

Figure 2. (right) Vertebrae of *Palaeophis casei* redrawn from Holman (1982). A, Holotype vertebra of *P. casei:* upper left, anterior; upper right, posterior; lower left, dorsal; lower middle, lateral; lower right, ventral. B, Paratype vertebra of *P. casei:* upper left, anterior; upper right, posterior; lower left, dorsal; lower middle, lateral; lower right, ventral. C, Paratype vertebra of *P. casei* from a more posterior part of the vertebral column: upper left, anterior; upper middle, posterior; upper right, lateral; lower left, dorsal; lower right, ventral. Each line equals 2 mm.

this writing, the senior author believes that the two genera are valid because normally such variations as occur between *Palaeophis* and *Pterosphenus* do not occur within single vertebral columns of modern genera of snakes, especially in the dorsal vertebral parts.

Parmley and Case (1988) have given a thorough set of vertebral differences between *Palaeophis* and *Pterosphenus*. It is difficult to accurately paraphrase other writers' descriptions of snake vertebral shapes, so we include the entire quotation from Parmley and Case (1988). "The vertebrae of *Pterosphenus* are high and laterally compressed, whereas in *Palaeophis* they are lower and relatively wider in shape. *Pterosphenus* has well-developed, elongated pteropophyses, but in *Palaeophis* these processes are considerably shorter. In *Pterosphenus* the planes of the prezygapophyseal articular facets are level, or nearly so, with the floor of the neural canal, whereas in *Palaeophis* they are above the neural canal floor. The zygosphene of *Pterosphenus* is thick and triangular-shaped viewed anteriorly, whereas in *Palaeophis* it is often thinner and flat to slightly convex. *Pterosphenus* has a strong ridge extending from the prezygapophyseal buttress to the base of the pteropophysis. This ridge appears to be absent or weakly developed in North American *Palaeophis*, but according to Rage (pers. comm.) it is well developed in *Palaeophis africanus* Andrews from the middle Eocene of Nigeria. In *Pterosphenus* the prezygapophyseal buttresses are not greatly dorsolaterally expanded, but somewhat compressed against the centrum. In *Palaeophis* the buttresses are wider, extending farther dorsolaterally. *Pterosphenus* usually has a large posterior hypapophysis connected to a shorter anterior hypapophysis by a sharp keel (double hypapophyses). Double hypapophyses may be absent in at least some species of *Palaeophis*, but are known to occur in others (*P. littoralis*). Moreover, *Pterosphenus* probably has only a single posterior hypapophysis on at least some of its vertebrae (Gilmore, 1938). Thus, considering the present lack of knowledge of intracolumnar variation in the palaeopheids, this character may be of little diagnostic value."

Figure 1, redrawn from Parmley and Case (1988), indicates the major differences between the vertebrae of *Palaeophis and Pterosphenus*. Clearly, *Pterosphenus* is the more highly derived of the two palaeopheid genera. Therefore, in this paper, *Palaeophis* will be discussed first, and its species will be listed in alphabetical order.

Palaeophis casei Holman, 1982
(Figure 2)

Material.--Holotype: Princeton University Vertebrate Paleontology Number (hereafter abbreviated PU) 23488, a trunk vertebra from the Tuscahoma Formation (previously thought to be Bashi Formation, Holman, 1982), Meridian, Lauderdale County, Mississippi, collected by Gerard R. Case and Paul Borodin, fall 1980. Paratypes: PU 23489, thirteen trunk vertebrae (some fragmentary) collected from the same locality by the same collectors, fall 1980. Tuscahoma Formation, Meridian, Lauderdale County, Mississippi: Michigan State University Museum Vertebrate Paleontology Number (hereafter abbreviated MSUVP) 1198, five vertebrae collected by G. R. Case, spring 1982, and reported by Parmley and Case (1988).

Remarks.--Holman (1982) diagnosed this very small species of *Palaeophis* as follows: "Differs from other species of *Palaeophis* by the following combination of characters: (1) very much smaller size, (2) only one short posterior hypapophysis, (3) a very small neural spine restricted to the posterior one-third of the vertebra, and (4) posterior edge of neural arch deeply grooved."

Among American species of *Palaeophis, P. casei* was said by Holman (1982) to be most similar to *P. virginianus* from which it differed by (1) being very much smaller, (2) having a longer vertebral form, (3) having narrower and smaller postzygapophyseal faces, and (4) by having deeper grooving of the posterior edge of the neural arch. Holman went so far as to suggest that *P. casei* might eventually be separated generically from *Palaeophis* and *Pterosphenus*.

Holman, however, did not mention how *P. casei* differed from *P. littoralis*, a form that occurs in the same Tuscahoma Formation site. These differences are as follows.

Both *P. casei* and *P. littoralis* are much smaller than the other Mississippi palaeopheid snakes, but *P. casei* appears to have been significantly smaller than *P. littoralis*. Measurements of vertebral length of the seven measurable specimens of *P. casei* (Holman, 1982, and Parmley and Case, 1988) compared to the vertebral length of the 20 known measurable specimens of *P. littoralis* (this paper and Parmley and Case, 1988) are summarized as follows.

Palaeophis casei

Range 3.2-4.5 mm; Mean 3.64 mm; Number 7; Standard Deviation .5704

Palaeophis littoralis

Range 6.7-9.8 mm; Mean 8.16 mm; Number 20; Standard Deviation .8139

It may then be said that in the narrow context of the

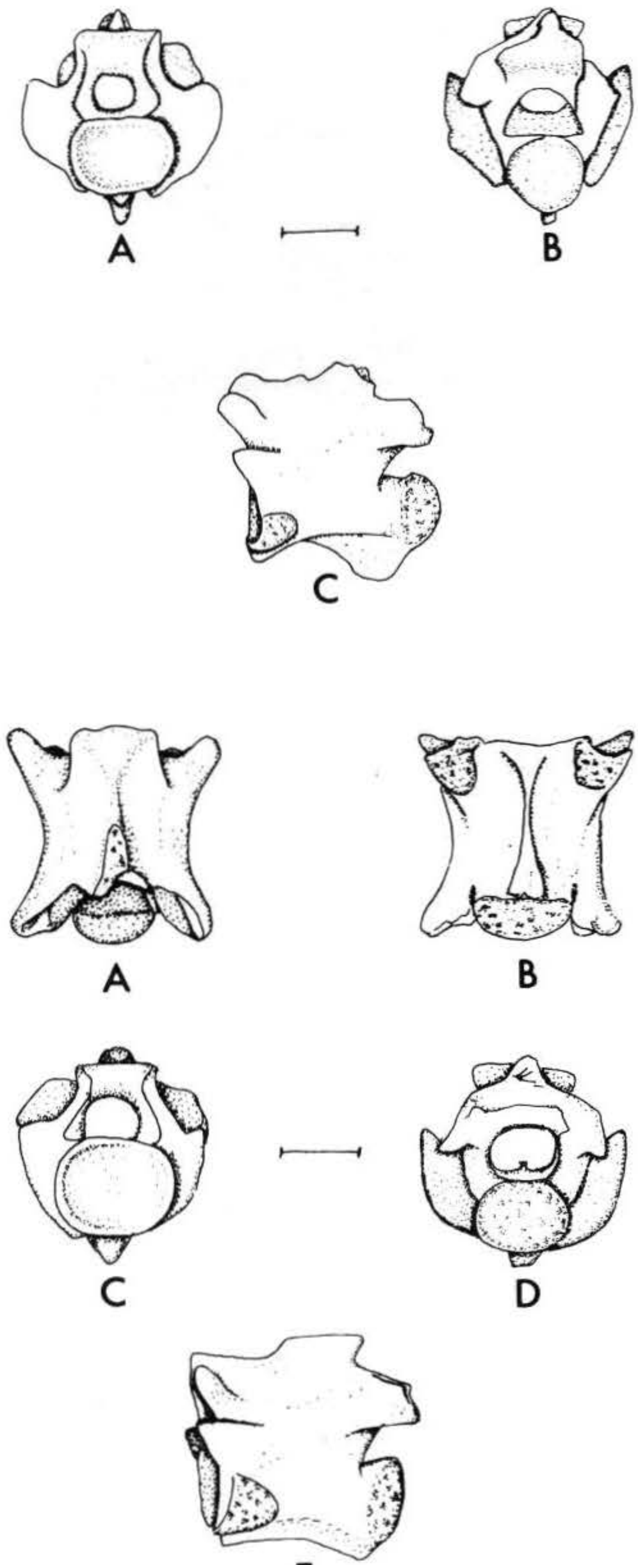

Figure 3. (left) Vertebrae of *Palaeophis littoralis* redrawn from Parmley and Case (1988). Upper three vertebrae: anterior vertebra of *P. littoralis*; A, anterior, B, posterior, C, lateral. Lower five vertebrae: posterior vertebra of *P. littoralis*; A, dorsal, B, ventral, C, anterior, D, posterior, E, lateral. Each line equals 3 mm.

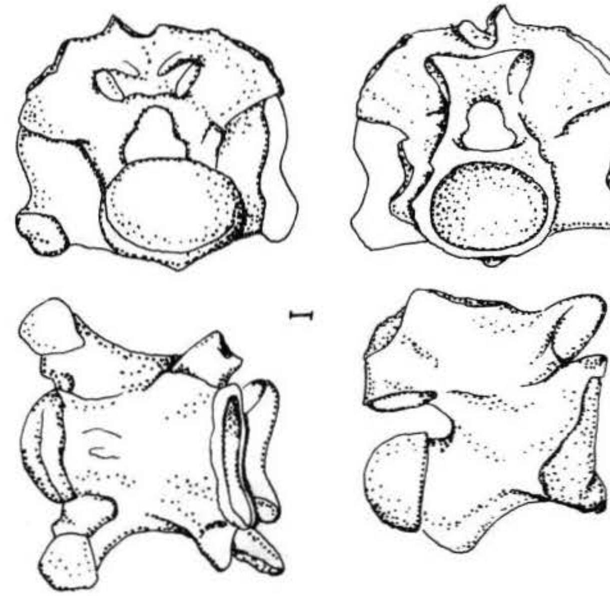

Figure 4. Vertebra of *Palaeophis virginianus* redrawn from Holman and Case (1988) after Gilmore (1938). Upper left, posterior; upper right, anterior; lower left, ventral; lower right, lateral. The line equals 2 mm.

Mississippi specimens that the vertebrae of *P. casei* average about 45% shorter than those of *P. littoralis*. Compared with skeletons of modern snakes, *P. casei* would represent a snake about 508 mm (20 inches) in length (vertebral comparisons based on an adult specimen of a small species of gartersnake, *Thamnophis butleri*). *Palaeophis littoralis* would represent a snake about 1000 mm (39.4 inches) in length (vertebral comparisons based on an adult green watersnake, *Nerodia cyclopion*). In simple terms, one might describe *P. casei* as being the size of a small gartersnake and *P. littoralis* as being the size of a moderately large watersnake.

A character that appears to separate *P. casei* from *P. littoralis* occurs in the posterior part of the neural arch. In *P. casei* the posterior border of the neural arch slopes gently into the postzygapophysis (Figure 2), whereas in *P. littoralis* this border slopes quite abruptly into the postzygapophysis (Figure 3). This character results from the much more upswept posterior neural arch of *P. littoralis* compared with *P. casei*. A caudal vertebra (MSUVP 1213) designated as *P. casei* by Parmley and Case (1988) was suspiciously large, having a total centrum length of 8.8 mm. This vertebra appears to have the upswept posterior neural arch of *P. littoralis,* and is herein assigned to that species.

Finally, as pointed out by Parmley and Case (1988), the neural arch of *P. littoralis* is more vaulted and the zygosphene is more massive than in *P. casei.*

Palaeophis littoralis Cope, 1868
(Figure 3)

Material.--Tuscahoma Formation, Meridian, Lauderdale County, Mississippi: MSUVP 1212, four vertebrae collected by G. R. Case and reported by Parmley and Case (1988); MSUVP 1305, seventeen vertebrae collected by K. C. Beard, G. R. Case, J. J. Leggett and A. R. Tabrum, April 23-27, 1990, and reported for the first time in the present report.

Remarks.--Parmley and Case (1988) first reported *Palaeophis littoralis* from Mississippi. In their report they presented a welcome revised diagnosis of *P. littoralis* as follows: "Differs from all other North American species of the genus in the following characters: (1) moderate size, (2) vaulted neural arch, (3) short pterapophyses, and (4) thick zygosphene." This diagnosis is based on a combination of these four characters, not four unique characters.

Parmley and Case also discussed how to distinguish anterior from posterior vertebrae of *P. littoralis,* and stated that Cope's original description must have been based on an anterior vertebra. The anterior vertebra has two hypapophyses, an anterior very small one and a larger posterior one. The three posterior vertebrae discussed by Parmley and Case (1988) have only a single posterior hypapophysis.

In the April 23-27, 1990, collecting trip to the Tuscahoma Formation, Meridian, Lauderdale County, Mississippi, K. C. Beard, G. R. Case, J. J. Leggett, and A. R. Tabrum collected 17 additional vertebrae of *P. littoralis* as part of a "Tuscahoma Formation Expedition" sponsored by the National Geographic Society. As far as can be determined, most of the vertebrae appear to represent elements from the posterior part of the column, as all of the vertebrae that are complete enough to display the character have only a posterior hypapophysis (Figure 3C upper).

Measurements of all *P. littoralis* vertebrae from Mississippi are summarized in the previous section on *P. casei.*

Palaeophis virginianus Lynn, 1934
(Figure 4)

Material.--Bashi Formation, Locality 4, Meridian, Lauderdale County, Mississippi: un-numbered vertebra reported by Dessem (1976). Bashi Formation, Locality 5, Wayne County, Mississippi: 12 un-numbered vertebrae reported by Dessem (1976). Bashi Formation, Whynot Locality, Lauderdale County, Mississippi: MSUVP 1202, one vertebra collected by G. R. Case and reported by Parmley and Case (1988). Tuscahoma Formation, Meridian, Lauderdale County, Mississippi: MSUVP 1200 and 1201, four vertebrae collected by G. R. Case and reported by Parmley and Case (1988); MSUVP 1306, 19 vertebrae collected by K. C. Beard, G. R. Case, J. J. Leggett and A. R. Tabrum April 23-27, 1990, and first reported in the present report.

Remarks.--Parmley and Case (1988) reported that the vertebrae of *Palaeophis virginianus* differ from those of all other North American *Palaeophis* species on the basis of their large size, squarish shape, single posterior hypapophyseal tubercles, depressed neural arches, and flat zygosphene as viewed anteriorly. This is a giant snake reaching the size of some of the largest living boas and pythons of today. A *Palaeophis virginianus* vertebra from Virginia was similar in size to a trunk vertebra of a python (*Python reticulatus*) with a total length of 5.486 meters (18 feet) and that weighed 31.7 kilograms or about 70 pounds (Holman, 1982).

Pterosphenus schucherti Lucas, 1899
(Figures 5 and 7)

Material.--Moodys Branch Formation, Locality 3, Jackson, Hinds County, Mississippi: Mississippi Bureau of Geology un-numbered large vertebra (Figure 5) previously reported by Dessem (1976). Yazoo Formation, Locality 2, Cynthia, Hinds County, Mississippi: Mississippi Bureau of Geology three un-numbered vertebrae previously reported by Dessem (1976).

Remarks.--This "giant snake" has the most strikingly derived vertebral form of any palaeopheid snake and one of the most strikingly derived vertebrae of any snakes Recent or fossil. The many differences between the vertebrae of *Pterosphenus* and *Palaeophis* have been detailed under the section on *Palaeophis* above. Only one species of *Pterosphenus* has been recognized from North American deposits, *P. schucherti.*

The Moodys Branch Formation specimen measured 26.3 mm in length through the zygapophyses. A trunk vertebra of a python (*Python reticulatus*) measured 27.3 mm in length through the zygapophyses. This python had a total length of 5.486 meters (18 feet) in life

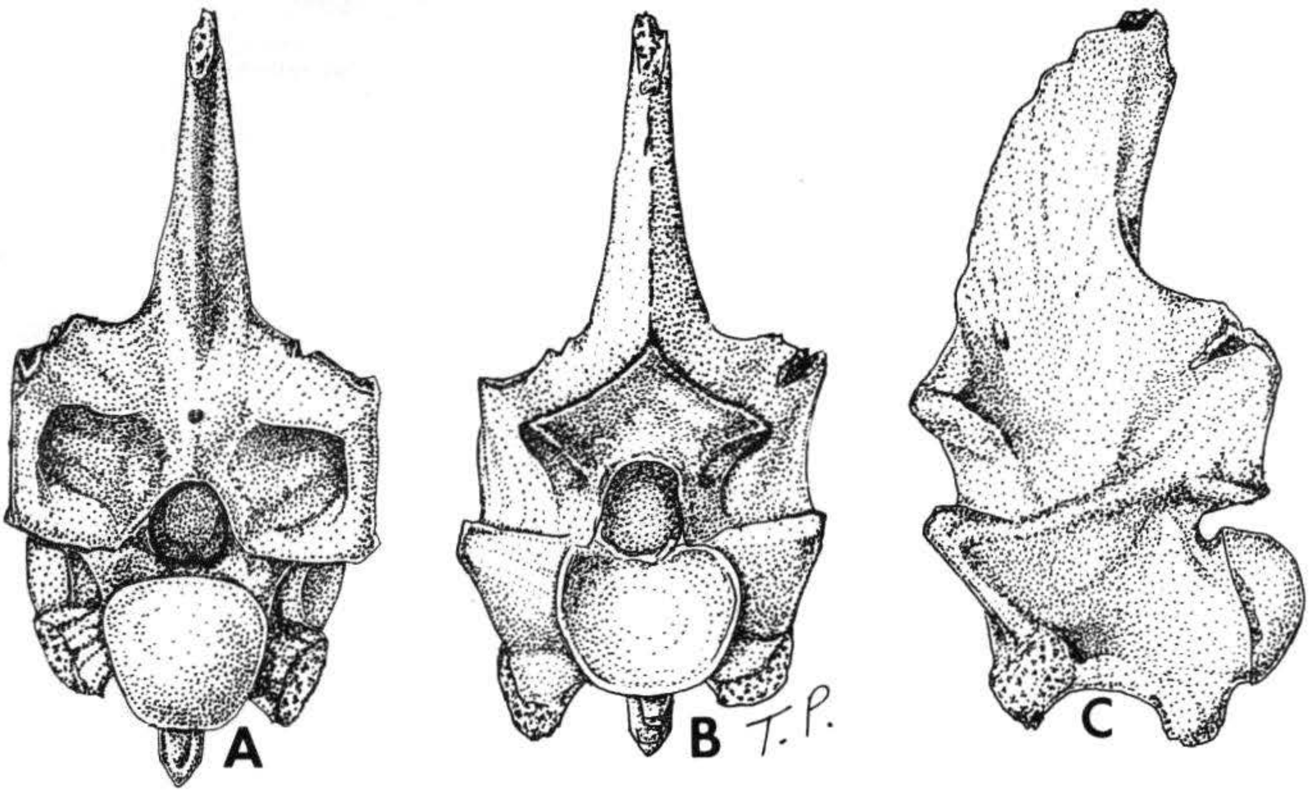

Figure 5. Vertebra of *Pterosphenus schucherti* from the Eocene Moodys Branch Formation of Mississippi. A, posterior; B, anterior; C, lateral. Shown twice actual size.

and weighed 31.7 kilograms (70 pounds). The largest of the Yazoo Formation snakes was about the same size as the Moodys Branch specimen but was much more fragmentary and could not be measured for intrazygapophyseal length. The two other Yazoo Formation specimens were smaller.

BIOLOGY OF MISSISSIPPI PALAEOPHEIDAE

Mississippi has four species of palaeopheid snakes, twice as many as any other state (Table 1). It also has all of the palaeopheid snake species that occur in North America. Therefore, this report appears to be a proper place to provide a short discussion and review of this interesting and poorly understood group of animals. The present section is divided into three subtopics: taxonomy and distribution, morphology, and paleoecology.

Taxonomy and Distribution

The Family Palaeopheidae Lydekker, 1888 is a member of the Superfamily Booidea Gray, 1825. Thus, palaeopheids are relatives of the pythons, true boas, sand boas, xenopeltid boids and the unique Upper Cretaceous snake genus *Dinilysia*.

The Family Palaeopheidae is in turn divided into two subfamilies, the Palaeopheinae Lydekker, 1888 and the Archaeopheinae Janensch, 1906. Only the Palaeopheinae occur in North America. The Subfamily Palaeopheinae consists of just two genera, *Palaeophis* Owen, 1841 and *Pterosphenus* Lucas, 1899.

Palaeophis is known only from the Eocene (with the exception of the Tuscahoma specimens of possible late Paleocene age) and consists of nine recognized species plus two doubtful ones (*nomina dubia*) according to Rage (1984). Species of *Palaeophis* are found in Mali, Morocco, Nigeria, Italy, France, England, Belgium, Denmark and the United States. Four of the species are considered to be generalized (Rage, 1984); one of these is *Palaeophis virginianus*, which occurs in Mississippi and other states in the U.S. (Table 1). Five species are considered to be advanced (Rage, 1984); two of these (*P. casei* and *P. littoralis*) occur in Mississippi and other states in the U.S. (Table 1).

Pterosphenus is known only from the Eocene, and consists of three species. Species of *Pterosphenus* occur in Egypt, Ecuador and the United States. Only the species *Pterosphenus schucherti* occurs in Mississippi

Table 1. Distribution of North American Palaeopheidae.

	Palaeophis casei	*Palaeophis littoralis*	*Palaeophis virginianus*	*Pterosphenus schucherti*
Mississippi	x	x	x	x
Alabama			x	x
Georgia			x	x
New Jersey			x	x
Arkansas				x
Florida				x
Louisiana				x
Virginia			x	

and the U.S. (Table 1). Table 2 depicts the concept of the primitive or derived states of the Mississippi and U.S. Palaeopheidae.

The Subfamily Archaeopheinae is known only from the Eocene of Italy and the U.S.S.R. It consists of two monotypic genera (Rage, 1984).

Morphology

The most important skeletal elements in the Palaeopheidae as well as all other fossil snakes are the vertebrae. Because of their extremely elongate bodies, snakes have a large number of vertebrae and adjoining ribs. Vertebrae are the most commonly found fossils of snakes, and fortunately for the person that studies them, they are very structurally complex and reflect differences between taxonomic groups (Holman, 1979, 1981). It must be pointed out that the unique combination of a string of very complex vertebrae joined to each other and to ribs by complex muscles, ligaments and tendons allows for the myriad of contortions and movements possible in the snake's body, as well as for the variety of ecological situations that snakes have exploited. Snakes can crawl in several different ways (and sometimes very rapidly), burrow, climb, swim, constrict prey, and literally tie their bodies in knots. Other vertebrate animals have a much more limited set of motions possible even though they have ribs, vertebrae, muscles, ligaments, tendons, anterior and posterior limbs, anterior and posterior limb girdles, and a sternum.

The basic parts of the snake vertebra include (Figures 6 and 7) the neural spine, the neural arch, the centrum, and the ventral extensions of the centrum which may take the form of an elongate hypapophysis or merely a keel. There are numerous processes for muscle attachments on the neural arches and centra (Figure 6), as well as articular surfaces for the ribs and for the adjoining vertebrae. Snakes have more structures that join vertebrae to each other than any other

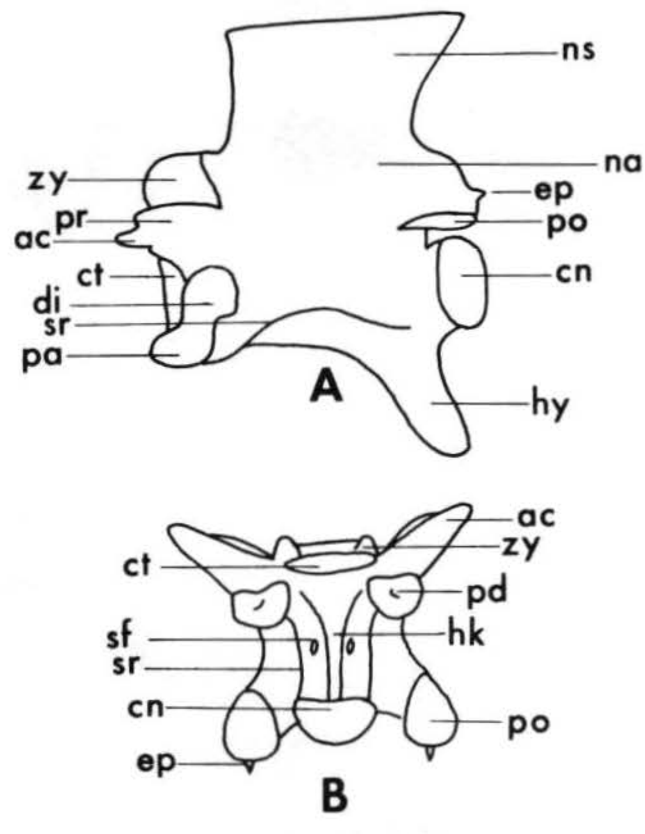

Figure 6. Generalized snake vertebra illustrating terminology of vertebral parts, redrawn from Holman (1979). A (lateral view): zy, zygosphene; pr, prezygapophysis; ac, accessory process; ct, cotyle; di, diapophysis; sr, subcentral ridge; pa, parapophysis; ns, neural spine; na, neural arch; ep, epizygapophyseal spine; po, postzygapophysis; cn, condyle; hy, hypapophysis. B (ventral view): ct, cotyle; sf, subcentral foramen; sr, subcentral ridge; cn, condyle; ep, epizygapophyseal spine; ac, accessory process; zy, zygosphene; pd, paradiapophysis; hk, hemal keel; po, postzygapophysis.

Table 2. Primitive, derived and most derived Palaeopheidae.

Palaeophis virginianus	PRIMITIVE
Palaeophis casei	DERIVED
Palaeophis littoralis	DERIVED
Pterosphenus schucherti	MOST DERIVED

vertebrates. These include the cotyle (anterior) and condyle (posterior) on the centrum; the prezygapophyses (anterior) and the postzygapophyses (posterior) on the neural arch; the zygosphene (anterior) and zygantrum (posterior) on the neural arch; and in some tree and vine snakes, interlocking processes on the neural spines (Holman, 1967).

The Subfamily Palaeopheinae is known only on the basis of vertebrae, whereas the Subfamily Archaeopheinae is known on the basis of a partial skull in one genus (*Archaeophis*) and on vertebrae and ribs. Osteological characters that separate the two palaeopheid subfamilies are therefore based on vertebrae. First, it appears that the Archaeopheinae have many more vertebrae in the vertebral column (over 400) than do the Palaeopheinae (Rage, 1984). Moreover, the Archaeopheinae have the vertebral articular processes very reduced in comparison with the Palaeopheinae (Figure 7B,C). Finally, the Archaeopheinae merely have keels on the bottom of the posterior centra (Figure 7B), whereas the Palaeopheinae have hypapophyses on the posterior centra (Figure 7D,E,F).

Rage (1984) has provided an osteological summary of the Family Palaeopheidae which we have slightly expanded upon here. The palaeopheid vertebra might best be described as being of the basic boid type, but highly modified for aquatic life. Holman (1977) provided a summary of vertebral characters that indicate relationships of *Palaeophis* and *Pterosphenus* to the Booidea. These are: (1) anterior border of zygosphene narrow and thick, (2) vertebra higher than long, (3) postzygapophyseal part of neural arch upswept, (4) foramina lacking on either side of cotyle, and (5) neural spine thick, at least at its base. Characters that indicate differences between the Palaeopheidae and other Booidea (most of these reflecting aquatic adaptations) are as follows. The vertebrae are laterally compressed, which in turn indicates a laterally compressed body needed in a swimming snake. Moreover, the neural spines are very high, and in the Subfamily Palaeopheinae the hypapophyses occur along the entire length of the vertebral column, thus adding to the overall lateral compression of the body.

Other more technical observations are that the synapophyses are almost always situated in a low position, quite distant from the centrum compared to other snakes. Moreover, the axis of the condyle tends to be horizontal, unlike most other snakes which have the condyle directed slightly upward.

The known ribs of the Family Palaeopheidae are only slightly curved (Figure 8). We interpret this as yet another adaptation to increase the lateral compression of the body. Another important feature that distinguishes the ribs of the Palaeopheidae from other snakes is that tuberculiform processes are lacking. We feel that this in itself is a very important character.

Hutchison (1985) provided some valuable insights on the functional morphology of the vertebrae of *Pterosphenus schucherti*. He stated that the relatively light (pneumocoel-like) construction of the vertebral marrow cavities of *P. schucherti* is concordant with its aquatic habits. He pointed out that this also indicates that the supportive function of the vertebrae against gravitational loading had apparently diminished in favor of a supportive network for the action of the locomotor muscles, analogous to those in the skeletons of fish. He mentions that the relatively narrow centrum and the long neural spines would have limited the motion in the vertical plane while the flaring and hypertrophy of the pteropophyses would have increased the leverage. He believed that taken together this would indicate *Pterosphenus schucherti* was incapable of terrestrial locomotion and that it must have given birth to living young at sea.

Paleoecology

It seems unquestionable that palaeopheid snakes were aquatic animals, but there has been some recent discussion about exactly what kinds of aquatic habitats were utilized. Most early reports indicated estuarine habitats for these snakes, but modern reports indicate that species of both genera may have lived in open sea, estuarine, or even riverine low salinity habitats. Habitats of each species are discussed next.

Holman (1982) believed that the sedimentary environment in which it was fossilized indicated that the diminutive *Palaeophis casei* was an estuarine snake. Based on its small size, he concluded that *P. casei* fed upon very small fish, or perhaps the fry of larger fish that may have utilized the estuarine situation as a breeding ground.

Oddly enough, little has been said of the habits of *Palaeophis littoralis*. Based on sediments and associated fauna we would envision an estuarine situation for

P. littoralis similar to *P. casei* with which it co-occurs in the Tuscahoma Formation of Mississippi. But *P. littoralis* was a moderately large snake that could have taken much larger fish than *P. casei;* that might have been the separation of feeding niches that allowed the two species to co-exist.

Holman (1977) reported the co-occurrence of *Palaeophis virginianus* with a terrestrial pelobatid frog and a terrestrial boid snake in the Eocene Twiggs Clay of Georgia. He came to the conclusion that the stratigraphy and associated vertebrate fauna indicated a tropical or subtropical coastline, and that the admixture of marine and terrestrial fauna indicated an estuarine situation or a river mouth.

Holman and Case (1988) found *Palaeophis virginianus* in association with a terrestrial boid snake and softshelled and river turtles in the Eocene Tallahatta Formation of Alabama and concluded that the most logical habitat would have been a tidal, riverine system along a tropical coastline. The softshelled and river turtles are normally considered to be "freshwater" species, but these commonly occur in tidal riverine situations in Gulf coastal rivers in Florida such as the Suwannee, Waccasassa, and Withlacoochee today; here sharks, rays, weakfishes, sheepshead, croakers, and drum are often found in abundance, especially at high tides. This would explain the presence of softshelled and river turtles associated with marine littoral fishes as well as with *Palaeophis virginianus*. Crocodilians at this site probably also had broad salinity tolerances as do several crocodilian species today; it is believed that the terrestrial boid snake may indicate some adjacent tropical or subtropical woodland.

Pterosphenus schucherti occurs in the Eocene Twiggs Clay of Georgia along with a terrestrial pelobatid frog and a terrestrial boid; thus it probably occurred in at least a near-shore estuarine system (Holman, 1977).

Westgate and Ward (1981) reported that all of the known specimens of *Pterosphenus schucherti* seem to have been buried under estuarine or low salinity conditions and they were intrigued by the fact that all reported specimens appear to have been buried in a disarticulated state. They reason that it was possible that *P. schucherti* suffered disarticulation during transport from fluvial environments to estuaries. They also pointed out that tidal currents, winds, and waves could have transported the decaying carcasses from the open marine environment into the shelter of the estuary, with subsequent disarticulation and burial. We might point out that this disarticulation also could have occurred because the snakes might have been deposited as undigested stomach contents of large predators, such as sharks.

Hutchison (1985) believed that the great enlargement of the marrow cavities and the thinning of the vertebral walls of *Pterosphenus schucherti* indicate specializations to a completely aquatic life and fully marine habitat. Moreover, the Florida Eocene sediments in which he recovered his *P. schucherti* fossil are indicative of a fully marine habitat; he does not believe that *P. schucherti* was limited to estuarine or other low-salinity environments. As has been discussed in the Morphology Section of the present report, Hutchison (1985) also believed that *P. schucherti* might have been incapable of movement on land and probably gave birth to its young at sea.

DISCUSSION AND SUMMARY

All of Mississippi's known Paleogene snakes are from the Eocene (with the exception of the Tuscahoma specimens of possible late Paleocene age) and represent the Family Palaeopheidae. The Palaeopheidae is subdivided into two subfamilies, the Palaeopheinae and the Archaeopheinae. Only snakes of the Subfamily Palaeopheinae occur in Mississippi.

Mississippi has twice as many palaeopheid snakes as any other state in the union, having all four of the recognized North American species (*Palaeophis casei, Palaeophis littoralis, Palaeophis virginianus* and *Pterosphenus schucherti). Palaeophis casei* is a diminutive species, *Palaeophis littoralis* is a medium-sized species, and *Palaeophis virginianus* and *Pterosphenus schucherti* are giant species.

Many vertebral characters separate the genera *Palaeophis* and *Pterosphenus* even though some past workers have suggested they might be congeneric forms. *Pterosphenus* is a more derived form than *Palaeophis* and *Palaeophis casei* and *Palaeophis littoralis* are more derived forms than *Palaeophis virginianus*.

Palaeophis is much more widespread in the world than *Pterosphenus*, with some of its species occurring in northern Europe and northeastern North America. The concentration of palaeopheid species in North America, however, is in the southeastern states.

The vertebrae of palaeopheids are highly modified for an aquatic existence. Modifications include (1) a high neural spine, (2) a narrow neural arch and centrum, (3) highly developed pterapophyses, (4) hypapophyses on all of the vertebrae in Palaeopheinae, (5) very long, very weakly-curved ribs in Archaeopheinae, and (6) pneumocoelous vertebrae, at least in *Pterosphenus*. It has even been suggested by Hutchison (1985) that *Pterosphenus* could not function on land.

It is suggested that *Palaeophis casei* was an estuarine snake that fed on very small fish or fry of larger fish using the estuarine habitat as a breeding ground. It is suggested that *Palaeophis littoralis* occupied similar

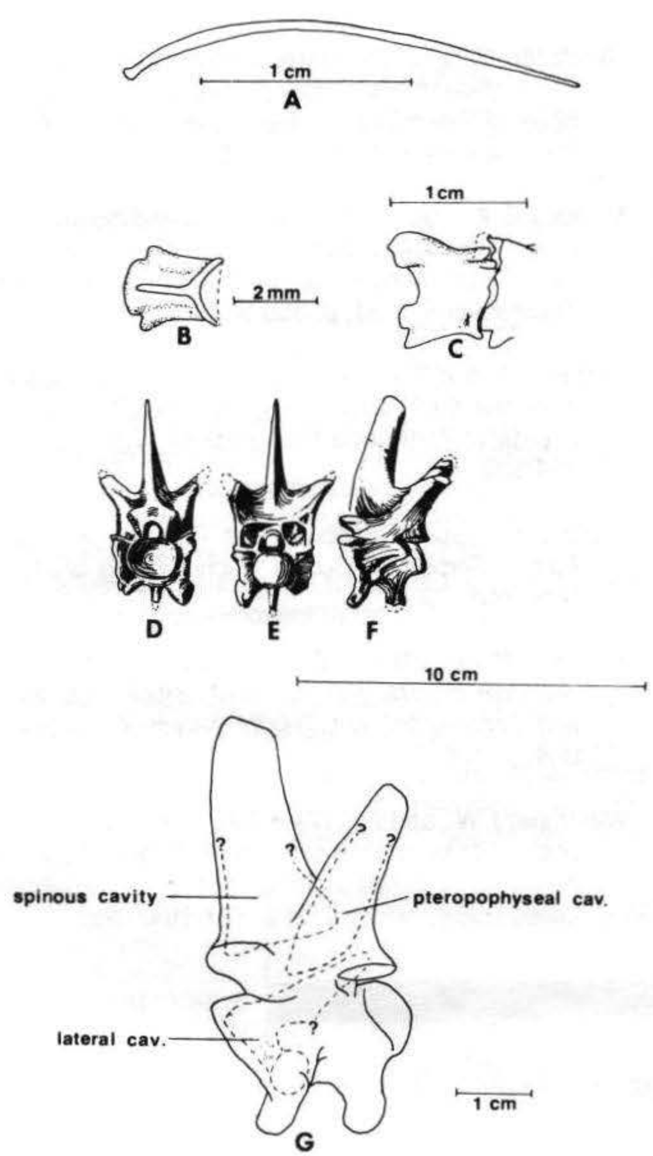

Figure 7. Fossils of various Palaeopheidae. A, rib of Archaeopheinae; B, ventral view of vertebra of Archaeopheinae; C, lateral view of articulated vertebrae of Archaeopheinae; all redrawn from Rage (1984). D, E, F: anterior, posterior and lateral view of *Pterosphenus* redrawn from Rage (1984). G, lateral view of vertebra of *Pterosphenus* showing important pneumatic cavities, redrawn from Hutchison (1985).

habitats to *P. casei*, but that it fed on larger fish. It is suggested also that the giant form *Palaeophis virginianus* lived in near-shore marine habitats.

Although the sediments and faunal associates of *Pterosphenus schucherti* indicate that it might have occurred in a low-salinity estuarine situation, a recent study (Hutchison, 1985) indicated that this form might

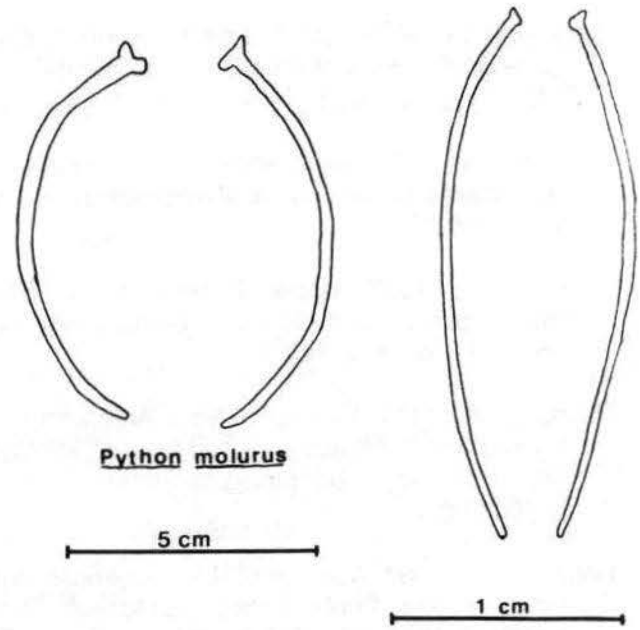

Figure 8. Comparison of ribs of (left) *Python molurus*, a terrestrial boid, and (right) ribs of Archaeopheinae, a palaeopheid, showing how curvature of ribs indicates lateral compression in the Palaeopheidae.

have been able to range far out to sea in a fully marine habitat.

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Mr. Vaughan Watkins, Jr., a prominent petroleum geologist in Jackson and frequent patron of our library, recently made a very generous donation of $250.00 to the Office of Geology Library. The contribution will enable us to purchase several new books for the library. The gift will be used to strengthen the petroleum geology collection.

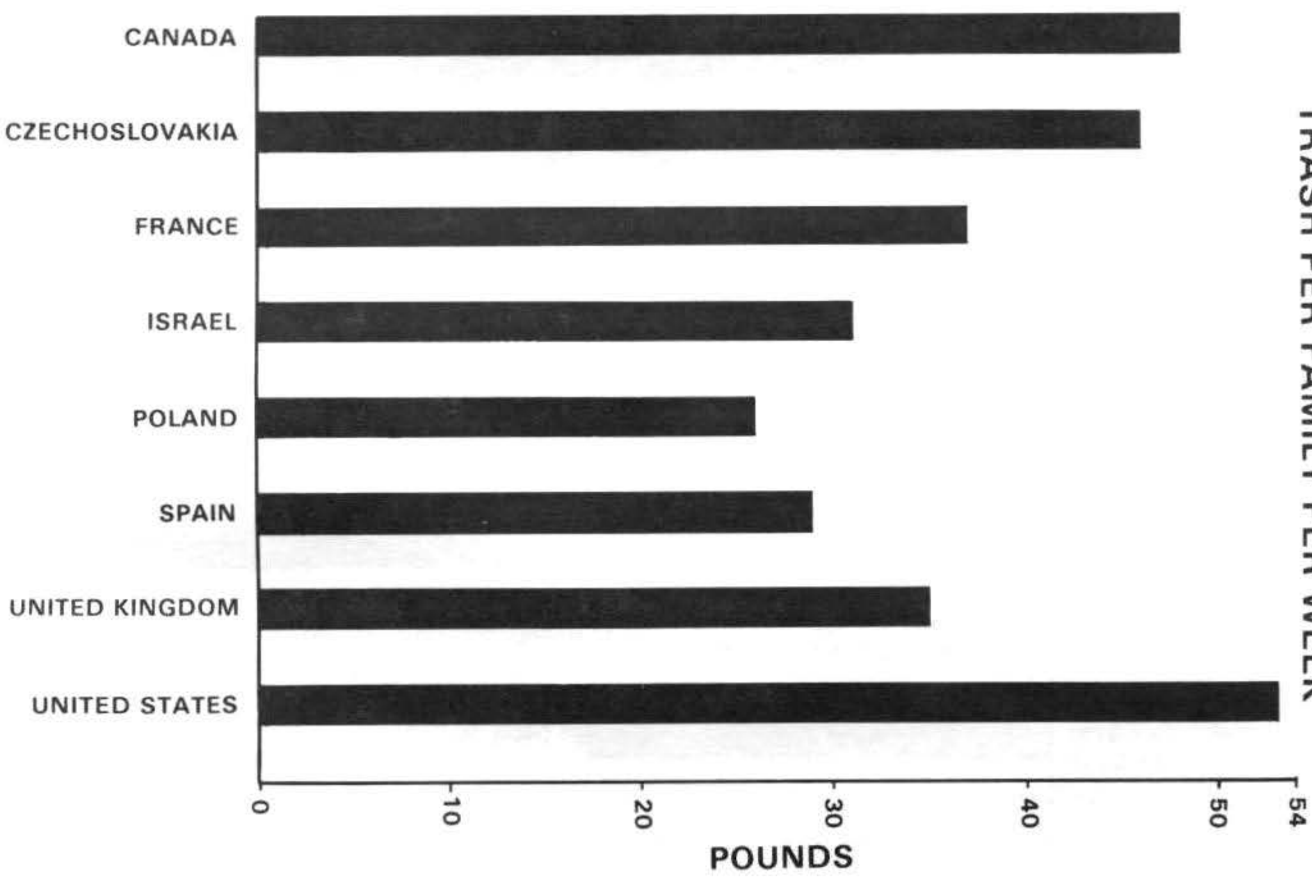
GEOLOGIC MAP INDEX OF MISSISSIPPI

The U. S. Geological Survey has published a Geologic Map Index of Mississippi, by H. Kit Fuller, Gregory B. Gunnells, and Ann France. The 1989 publication contains a geographic map of Mississippi and three indexes to geologic maps at scales 1:24,000 or larger, scales smaller than 1:24,000 through 1:63,360, and scales smaller than 1:63,360. A pamphlet contains text and a bibliography of the maps shown on the index maps. The Geologic Map Index of Mississippi is available free of charge from the U. S. Geological Survey, Books and Open-File Reports Section, Box 25425, Federal Center, Denver, CO 80225.

HOW MUCH TRASH DO WE REALLY NEED TO THROW AWAY IN OUR LANDFILLS AND HOW MUCH CAN BE RECYCLED?

Sarah Elizabeth Melton
Vicksburg, Mississippi

NOTE: Imagine yourself judging another science fair, perhaps the third or fourth one this year. You sincerely enjoy the interaction with these students so the event is a pleasant one. You've come to expect a certain degree of proficiency in the exhibits and the knowledge of the exhibitors; that level is not always where you wish but these are only youngsters. In the fair at hand you are assigned earth and space for the 5th and 6th grades. This is your first exposure to these really young ones. You expect that the level of exhibit and knowledge will be less than you've become accustomed to. There they are; one by one you introduce yourself and try to calm the terrified and reassure the timid. You approach a cute little 5th grader whose I.D. card says Sarah Melton from Culkin Elementary in Vicksburg. Her pleasant smile, soft voice, and eye to eye contact are an enjoyable beginning. As she makes her presentation it becomes obvious that this is something special. With a pleasant confidence that comes from knowing her subject she discusses her project on Trash, Landfills, and Recycling. Your method has been to ask questions to determine the depth of knowledge they have acquired from their project. So you ask and she answers; you ask again to sound bottom, but she gives an enjoyable straight answer. Again and again you ask questions and she responds with clarity and understanding. You finish your visit and turn to proceed up the line of competitors. As you turn there is a sense of joy at what just transpired. The smile on your face says it all. I hope the reader, through my words and Sarah's, can share a little of this joy of seeing the next generation begin to blossom. - *Jack Moody, Office of Geology.*



I got my idea from watching my grandfather separate aluminum cans from the rest of his trash. This made me wonder, if I separated my trash would I be able to tell how much trash had to be thrown in the landfills. I then made separate containers for plastic, paper, metal and glass, and trash that could not be recycled. For one week I separated the household goods into those four categories.

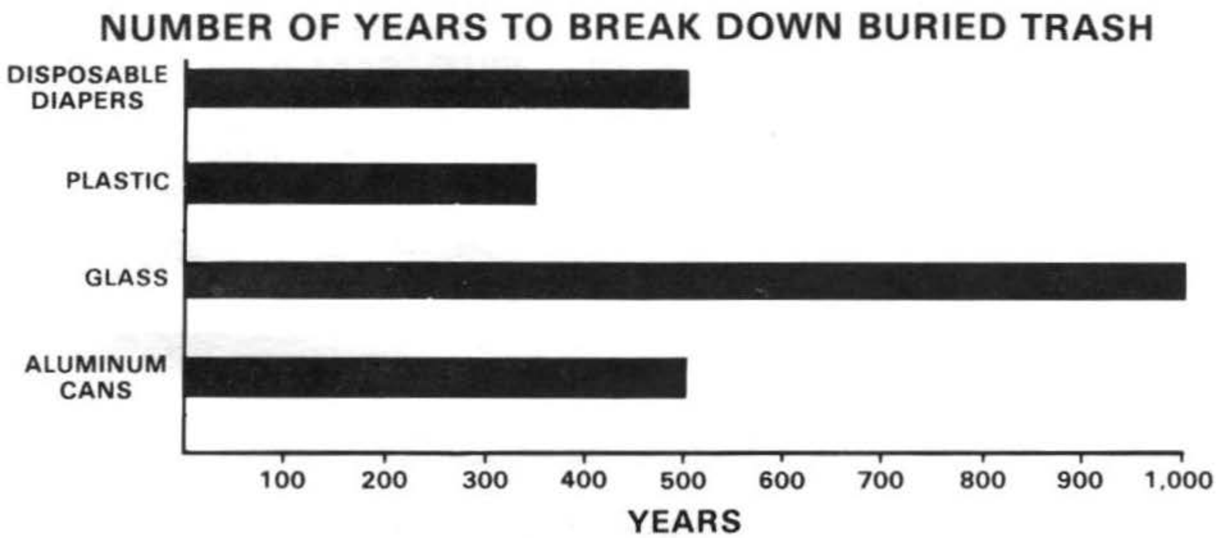
When the week was over I figured up the cubic feet by measuring length, width, and height. I then multiplied length by width by height to get my cubic feet. I got 1 cubic foot for plastic, 2 cubic feet for paper, 1/2 cubic foot for metal and glass, and 1/2 cubic foot for trash that could not be recycled.

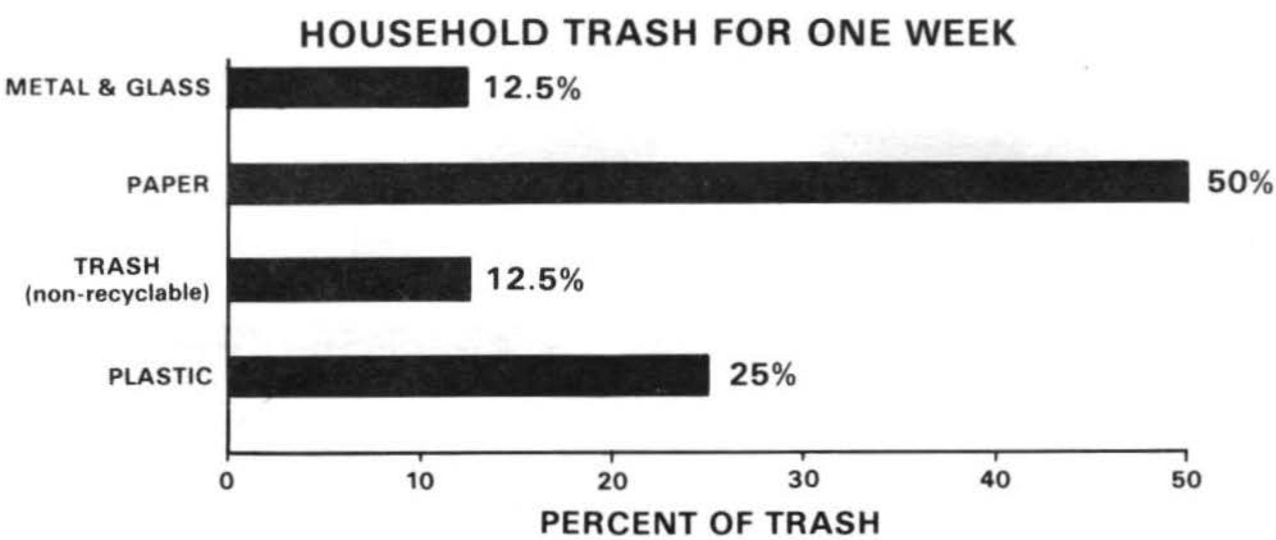
In my research I found out that there is a lack of land for landfills. People dump so much trash in the landfills that there is not much more land for landfills. In one holiday weekend the United States throws away enough trash to have a line of garbage trucks 42 miles long. The United States leads the world in trash by throwing out 53 pounds per family per week.

Landfills are painful to the eye! I've been to our landfill and saw mostly paper, plastic, some fabric, glass and cans. There are some solutions to these problems. We can bury the trash after we dump it. This method is called a sanitary landfill. It was introduced in England in 1912. Bacteria in water and in soil can break down much of the food and some of the paper very quickly.

Usually the trash is deposited in landfills and covered within 24 hours with dirt to form an effective seal. Things such as paper, plastic, metal, and glass do not break down quickly. These wastes just keep piling up. Every year people must find more places to dump such wastes.

It takes about 500 years to break down a buried aluminum can. A disposable diaper takes 500 years, a plastic bottle takes 350 years, and a glass jar can take thousands of years to break down.





Hefty has a plastic bag that is degradable, but it only breaks down after exposure to sun, wind and rain. This helps, but if the bags are covered within 24 hours and don't have a chance to break down, what good is the bag?

Another way to deal with trash is to recycle it - change it into materials that can be used again. Paper, plastic, glass, metal, clothing and rubber can be recycled. Recycling reduces the amount of trash. Making new products from recycled trash costs less and uses less energy than making products from raw materials.

The basic steps that are involved in recycling are collection, separation, and processing. After a week of separating my trash I came up with 50% paper, 25% plastic, 12-1/2% metal and glass, and 12-1/2% trash. I learned that when you separate trash it gets kind of messy. You have to have different sacks for each kind of product. Before you throw something away you have to think about what it is made of. Some of the trash was made up of different things, such as metal and plastic together.

I have learned we can limit the amount of trash we throw out. After separating our trash for a week I found in a family of four we had only 12-1/2% of our trash that could not in any way be recycled.

Companies could make packaging simpler. The government could help companies start or improve recycling plants. But most important is what we can do. We could stop buying products that have a lot of extra packaging. And, after visiting a plastic recycling plant, I realize that we can recycle. By recycling we are saving our landfills and our non-renewable natural resources.

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