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A MIDDLE EOCENE *ZYGORHIZA* SPECIMEN FROM MISSISSIPPI (CETACEA, ARCHAEOCETI)

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INTRODUCTION

One of the premier exhibits of the Mississippi Museum of Natural Science is the mounted skeleton of an archaeocete whale. This excellent specimen, MMNS VP 130, is considered to be a *Zygorhiza kochii* (Reichenbach), as have most of the smaller basilosaurid remains taken from the Eocene of the eastern and southern coasts of North America.

MMNS VP 130 was discovered in 1971 in the bed of Thompson Creek near Tinsley, Yazoo County, Mississippi. The finders were members of the Mississippi Gem & Mineral Society, and excavation of the skeleton became a club project. Much of the preparation work was done by members also (Pitts, 1971a and 1971b; Neilson, 1974). In the fall of 1982, the Mississippi Museum of Natural Science Foundation was able to bring a suitable technician to Jackson to finish preparation and mount the skeleton for exhibit (Carpenter and Dockery, 1985). The skull and mandible were mounted in fiberglass and resin replicas because of their weight. The original parts are on display in a Lucite case underneath the skeleton.

Restoration was necessary at the zygomatic arches, the dorsolateral parts of the lambdoidal crest, the tip of the muzzle, the coronoid rami, and a number of lesser breaks. The bullae were found lying loose but intact, and were reattached. An extra vertebra was added from the cabinets, and six more were constructed, to make up Kellogg's (1936) count for the anterior regions of *Zygorhiza*'s column (seven cervicals, fifteen thoracics, fifteen lumbosacrals). The forelimbs, hyoid apparatus, and pelvis (if any) were not found in the creek bed. Replicas of the forelimbs and hyoid bones were created for the mount from borrowed specimens.

The mounted skeleton is 464 cm long (15'2½"). Its skull, at 81.8 cm (32.2"), makes up 17.6% of the total length. Kellogg (1936) reconstructed *Zygorhiza kochii* at 493 cm long (16'2"), with the skull constituting 16.8% of the total length. Another mounted skeleton of *Zygorhiza* exists in the Museum of Arts and Sciences in Macon, Georgia. This specimen is about 546 cm (18') long. Its skull is a cast from a slightly smaller individual because it is not quite as long as the mandible.

STRATIGRAPHY AND PROVENANCE

The stratigraphy of Thompson Creek in the area where MMNS VP 130 was found was reported by Dockery (1974). It lay in the indurated upper part of the Moodys Branch Formation. Most of the bedrock of Yazoo County is Yazoo Formation, overlain by Pleistocene loess. The underlying Moodys Branch Formation is exposed in the creek bed because of a structural high known as the Tinsley Dome.

The Yazoo and the Moodys Branch formations together make up the Jackson Group, Upper Eocene. The uppermost Yazoo Formation belongs to planktonic foraminiferal zone P17, and so must be at or somewhat below the Eocene-Oligocene boundary. The lower part of the Yazoo Formation and the Moodys Branch Formation belong to P14 (Obradovich, Dockery and Swisher, 1993). Zones P15, P16, and P17 comprise the Priabonian marine stage of Europe, while the lower Yazoo and the Moodys Branch represent the upper part of the upper Middle Eocene Bartonian stage. Upper Middle Eocene is therefore the age of MMNS VP 130. Basilosaurid parts are regarded as common fossils in the Gulf Coast states, but the vast majority of these are from the Upper Eocene. MMNS VP 130 is the oldest good specimen known from the area.

The very oldest *Zygorhiza* specimens may have been found in New Zealand (Köhler and Fordyce, 1997). The source formation is believed to be late Lutetian to middle Bartonian in age, and the fossils from it would be about three million years older than the Moodys Branch skeleton. Details of two upper premolars led to the tentative identification of the New Zealand animal as a *Zygorhiza*, based on the description of an Alabama skull by Kellogg (1936).

A partial skeleton of *Basilosaurus cetoides* has been described from the lower Yazoo Formation of Louisiana (Lancaster, 1982), which is thus slightly younger than MMNS VP 130. A few fragmentary archaeocete remains have been found in recent collections from Moodys Branch localities (Breard, 1978, 1991; Lancaster, 1982).

Two similar basilosaurids contemporary with MMNS VP 130 are in the literature. *Dorudon serratus* Gibbs is based on fragmentary remains from the Carolinas on the east coast of North America (Kellogg, 1936). *Zygorhiza wanklyni* (Seeley) was described from a skull from the Barton Clay of England (Seeley, 1876). *D. serratus* was distinguished from *Z. kochii* by its thicker snout, in addition to some features of its dentition. The skull of *Z. wanklyni* has been lost, and its possible identity with *Z. kochii* must remain uncertain.

Five genera of basilosaurids are now recognized from North Africa (Gingerich, 1992; Uhen, 1996; Gingerich and Uhen, 1996). *Basilosaurus isis* (Beadnell *in* Andrews) and *Dorudon atrox* (Andrews) are found in the Gehannam and Birket Qarun formations of late Bartonian to early Priabonian age, and are therefore near contemporaries of MMNS VP 130. *Ancalecetus simonsi* Gingerich and Uhen is from the Birket Qarun, and is a little younger. The other two African basilosaurids are *Saghacetus osiris* (Dames) and *Dorudon stromeri* Kellogg. They are found in the upper Qasr-el-Sagha Formation and are of late Priabonian age.

The general picture from Egypt is that archaeocete species changed between the Bartonian-Priabonian boundary and the late Priabonian, from *B. isis* and *D. atrox* to *S. osiris* and *D. stromeri*. In North America, *B. cetoides* and *Z. kochii* are believed to persist through the entire span. Now that a good specimen of *Z. kochii* seems to be available from the North American Bartonian, we may be able to confirm its longevity.

FEATURES OF THE SKULL

The skull of MMNS VP 130 is undistorted except for an upward bend of the muzzle at the narial fossa. In general, its skull conforms to the description of *Zygorhiza kochii* by Kellogg (1936), and with the four other skulls assigned to that species preserved in museums. These others include USNM 11962, of the United States National Museum, Kellogg's exemplar and the best preserved, from Melvin, Choctaw County, Alabama; RMM 2739, a nearly complete skull in the Red Mountain Museum of Birmingham, from Clarke County, Alabama; and partial skulls USNM 16638 from Hinds County, Mississippi, and 16639 from Choctaw County, Alabama.

On viewing Kellogg's plates, one has the impression that *Zygorhiza* has a slimmer skull than other basilosaurids. Measurements were made for width/length ratios, to bear out the impression if possible. The *Zygorhiza* skulls could be measured from the actual objects, at least to an estimate. Measurements of other basilosaurids were taken from Kellogg's table of skull measurements on his page 246. Results indicate that *Zygorhiza* may differ from most other basilosaurids with respect to skull width (see table 1). The only overlap is due to three specimens of *S. osiris*.

Table 1. Width/length ratios for archaeocete skulls. Width is the greatest zygomatic width (Kellogg's fifth measurement) and length is from the end of the rostrum to the posterior surface of the occipital condyle (Kellogg's second measurement).

SPECIES	SPECIMEN	RATIO
Zygorhiza kochii	MMNS VP 130	41%
(from skulls)	USNM 11962	39
	USNM 16638 (est.)	37
	USNM 16639 (est.)	35
	RMM 2739	42
average		38.2
Saghacetus osiris	AMNH 14382	43
(Kellogg's table)	M. 10228 (BM[NH])	45
	11235, Stuttgart	40
	11626, Stuttgart	46
	11786, Stuttgart	42
	1902. XI. 59, Munich	39
average		42.5
Dorudon stromeri (Kellogg's table)	1904. XII. 134e, Munich	47
Dorudon atrox (Kellogg's table)	1904. XII. 134a, Munich	48
Basilosaurus cetoides	USNM 4674	46
(Kellogg and Lancaster)	LSUMG V1	46
Basilosaurus isis	11787, Stuttgart	51
(Kellogg's table)	AMNH 14381	49

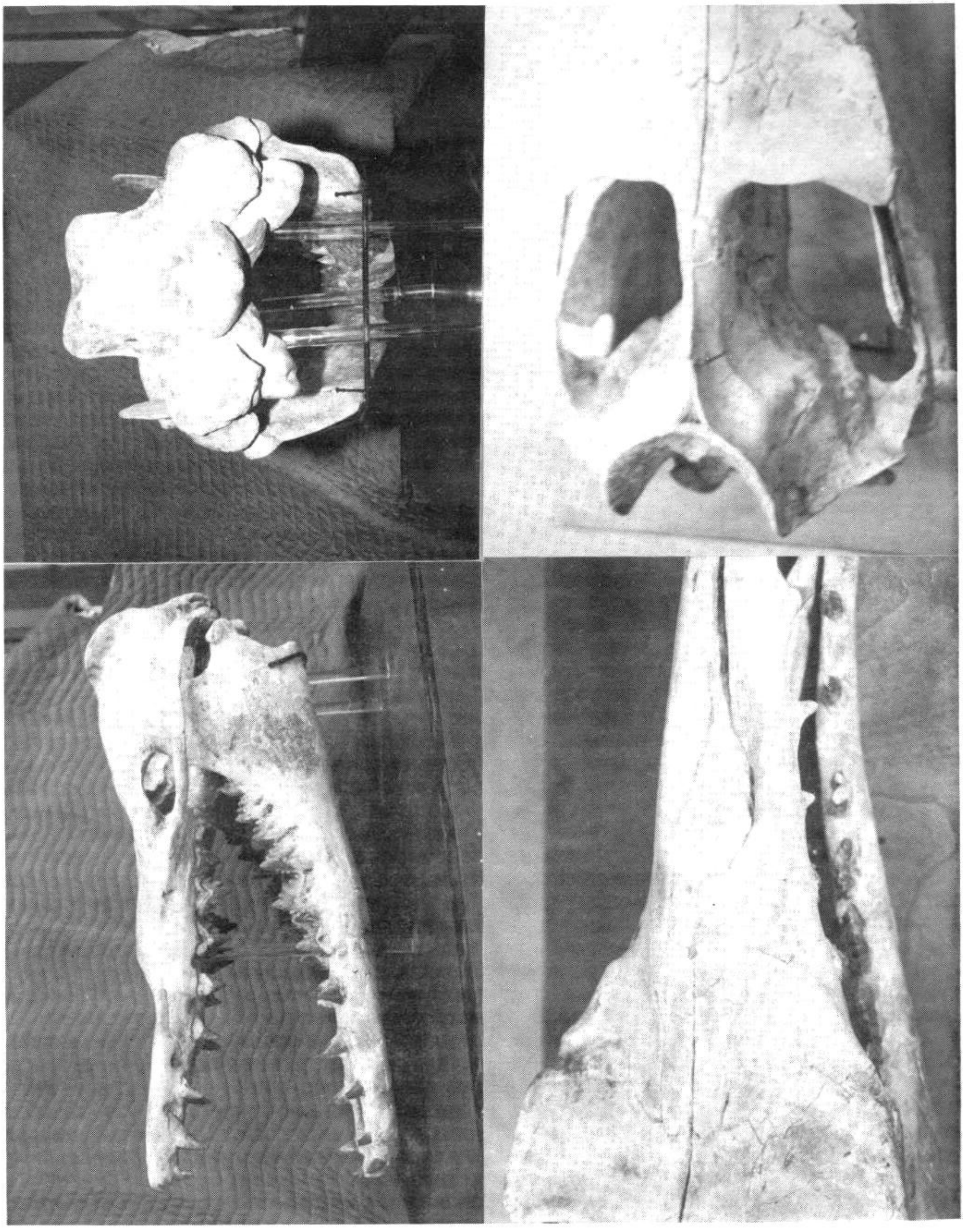


Figure 1. Four views of the skull of MMNS VP 130, *Zygorhiza kochii*.

A few other proportions were considered for comparison, but no differentiating results were obtained from preliminary efforts. Breakage and distortion work against this approach. Qualitative features little affected by such factors are most desirable for comparisons.

One such character is the triangular pit seen at the junction of the sagittal and lambdoidal crests, present on MMNS VP 130's skull and most other known *Zygorhiza* specimens. USNM 13773, a partial juvenile skull specimen, appears to be an exception, because the pit is not present on Kellogg's figure of it (the specimen is not in the National Museum at present). The partial skull from the Bartonian of New Zealand lacks the pit also, unless the small parietal foramen on the posterodorsal left side corresponds to it (Köhler and Fordyce, 1997). Other basilosaurids lack the pit, so far as known.

The narial fossa of MMNS VP 130 has a rounded or bluntly pointed anterior border. The bone of the lower, anteriormost edge is delicate and damaged, but the curve of the remaining lateral border seems to indicate this shape. The anterior end is above the space between the upper canines and the upper first premolars. Anteriorly the fossa opens into a rounded depression on the premaxillae. The depressed area shallows toward the front, and terminates without a definite anterior rim, midway above the space between the last upper incisors and the upper canines.

Zygorhiza skulls were inspected with the muzzle of MMNS VP 130 in mind. USNM 11962, the best preserved example, closely resembles MMNS VP 130 in the narial area. The anterior edge of the fossa is missing, but the curvature of its lateral walls suggests a rounded shape. The depression is present, matching that of MMNS VP 130 in size, shape, and position. The other two National Museum skulls are not revealing in the area. RMM 2739, although less well preserved than USNM 11962, seems to have a narial region like that of MMNS VP 130.

Kellogg's plates and figures show the basilosaurid narial fossa to be sharply pointed anteriorly within a narrow valley formed on the premaxillae. *Zygorhiza* is an exception, but apparently not uniquely. *D. atrox* has been described as having the rounded premaxillary depression (Andrews, 1906; Uhen, 1996). Kellogg's Plate 28 of the skull of *D. intermedius* (*D. atrox*, Gingerich, 1992; Uhen, 1996), specimen No. 1904 (Alte Akademie) shows that it has a short rounded narial fossa. However, the skull specimen of Plate 30, No. M.10173 (British Museum [Natural History]) shows an elongate, pointed narial fossa that matches the basilosaurid form shown in most of the other plates.

The shape of the exposed part of the nasal bones is easy to observe, even on plates, and can vary markedly from one skull to the next. The nasals of MMNS VP 130 are close to rectangular in shape, with a slight widening posterior of middle. Each shows a small concavity on its side, just posterior to the narial fossa. The closest match to the nasal form of MMNS VP 130 is on the muzzles of USNM 16638 and 16639. These sets of nasals are likewise basically rectangular, although departing from that shape somewhat more than MMNS VP 130. USNM 16638 has nasals damaged anteriorly. The nasals of USNM 16639 and 11962 narrow a little anteriorly and form a V-notch between them so that the narial fossa is pointed posteriorly rather than rounded.

The nasals of USNM 11962 and RMM 2739 diverge posteriorly, as with other known basilosaurids. If their posterior divergence were straightened, their nasals would be rectangular. RMM 2739 possesses the most aberrant of nasals, so deeply divergent that they meet only for a short distance immediately behind the narial fossa. They diverge again anteriorly, sending unequal legs along either side of the fossa.

FEATURES OF THE MANDIBLES

As with the skull, the lower jaw has been largely covered in Kellogg's (1936) description. The coronoid rami of MMNS VP 130 are not preserved, so their conformity cannot be verified.

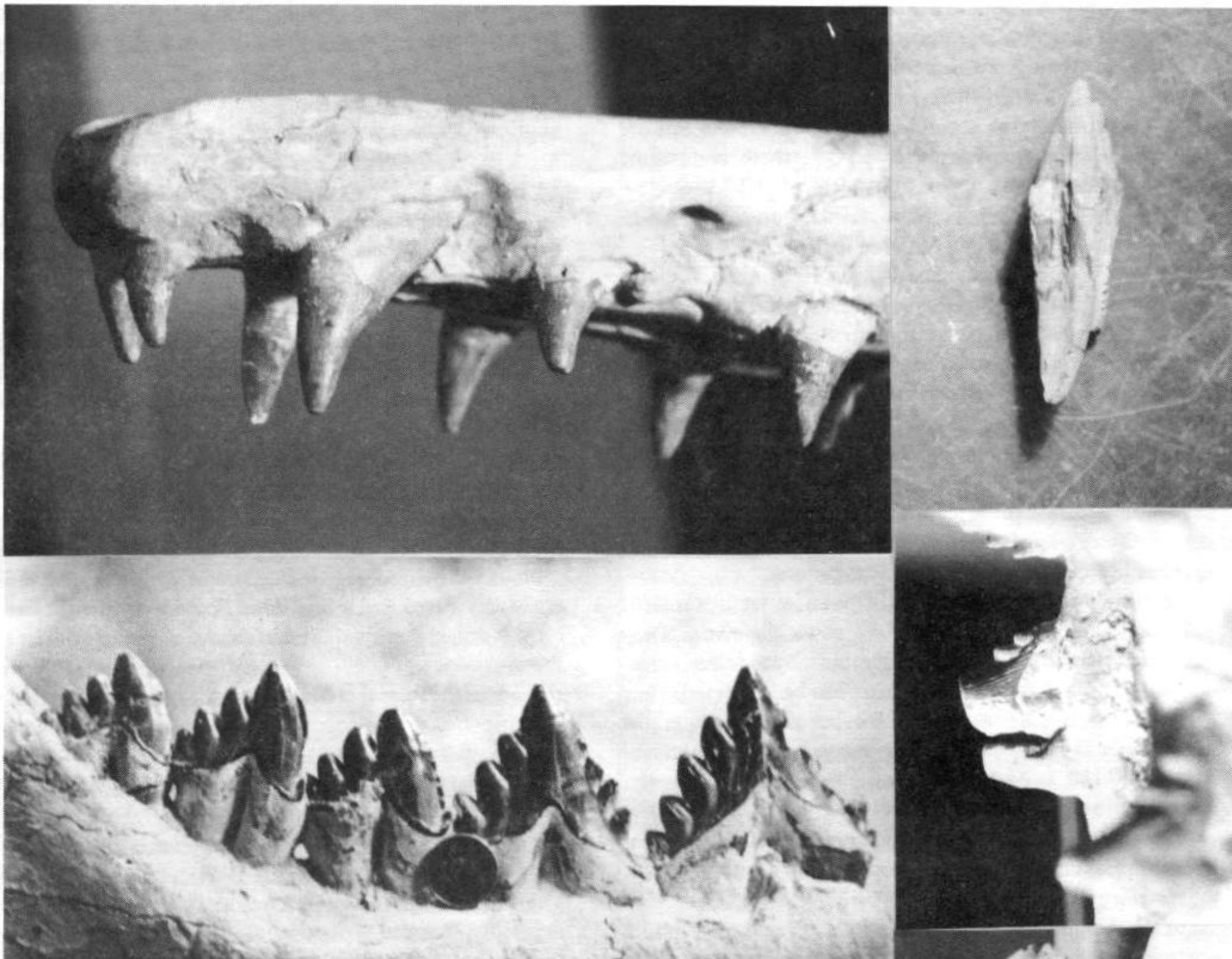
Kellogg (1936) observed that the angles of the mandibles of USNM 11962 were reduced relative to those of other archaeocetes. The condyles are set low relative to the tooth row. If a string were laid on a figure of USNM 11962, extending from the posterior midpoint of a condyle, and thence parallel to the horizontal ramus, it would cross the tooth row anterior to the alveolus of the first lower molar. By contrast, if the same thing were done with Kellogg's (1936) figure of *B. cetoides*, the string would cross the tooth row posterior to the alveolus of the second lower molar, which is higher on the coronoid process than the first.

MMNS VP 130's condyles are high in position, like those of USNM 4674 (*B. cetoides*) rather than those of USNM 11962. The condyles of the mounted *Zygorhiza* in Macon, Georgia, are also high. LSUMG V1, the Montgomery Landing *B. cetoides*, has low-set condyles rather than high ones like USNM 4674 (plate, Lancaster, 1982). There is no discernible significance to these differences at present.

FEATURES OF THE DENTITION

The delicate teeth suffered much attrition between the time MMNS VP 130 was collected from the creek bed and its exhibition, and they have been extensively restored. Original

Figure 2.(Right) Dentition in *Zygorhiza kochii*. Counterclockwise from top left: anterior teeth of MMNS VP 130; posterior cheek teeth of left dentary in MMNS VP 130, lingual view; posterior cheek teeth of left maxilla in MMNS VP 130, ventral view to show buttresses; the same view in NMNH 11962; the defective lower first premolar of MMNS VP 130, lingual view; a lower second molar of NMNH 11962 in anterior view.



tooth material was distinguished from the reconstructed by the presence of fine vertical ridging. MMNS VP 130 preserves examples of all the teeth except I_1.

I^2 is the largest of the caniniform teeth, and the lower canine is probably the second largest (both canine tips are restored). I_2 is the smallest preserved front tooth, and I^1 is the second smallest. The upper front teeth of VP 130 incline slightly outward as well as downward and forward. Its lower front teeth have little if any outward inclination.

Other *Zygorhiza* specimens with front teeth were inspected for their size relations. On USNM 11962, I^2 is much the longest caniniform tooth, though the upper canine is thicker at the base. I^1 and I_2 are not preserved. This individual's upper front teeth are larger than the lowers, and they incline outward a little. On RMM 2739, I^1 is the longest upper front tooth, though the I^2 is thickest at the base. Its lower front teeth are not preserved. This may be evidence of a general tendency in *Zygorhiza* to have the longest grasping teeth at the anterior end of the upper jaw. With basilosaurids in general, the largest caniniform tooth in either jaw is the third incisor or the canine.

Kellogg (1936) used features of the cheek teeth of USNM 11962 as diagnostic characters of the genus *Zygorhiza*. They must have seemed unusual at the time, but they are clearly non-diagnostic now that other specimens can be inspected. One of these characters is P^2 as the largest upper cheek tooth. RMM 2739 shares this, but P^3 is the largest in USNM 11638 and MMNS VP 130, as it is in most known basilosaurids. Usually, P^2 and P^3 are close in size.

Another stated diagnostic character is that *Zygorhiza*'s largest upper cheek tooth has four accessory cusps on both the anterior and posterior edges. RMM 2739 has four accessory cusps on the anterior edge of its upper P^2, and three on its posterior edge. A fragmentary Moodys Branch specimen, LSUMG V3 (of the Louisiana State University Museum of Geoscience), includes two large upper cheek teeth that resemble *Zygorhiza* premolars (Lancaster, 1982). The larger of these has five accessory cusps and a cingular cusp on its anterior edge, and three cusps behind.

P^3 usually has three accessory cusps on each edge whether it is the largest upper cheek tooth or not. Exceptions are the Moodys Branch *Zygorhiza*s and the *B. cetoides* specimens. MMNS VP 130 has four accessory cusps anteriorly on one of its P^3s, as also with the second largest premolar with LSUMG V3. *Basilosaurus* specimen USNM 4674 has four accessory cusps on both edges of its surviving left P^3, while LSUMG V1 has four on the anterior edges of its P^3s.

Another of Kellogg's (1936) diagnostic characters for *Zygorhiza* is the presence of conspicuous crenulated cingula on P^2, P^3, and P^4. Kellogg's exemplar USNM 11962 has crenulated cingula on P^2 through M^2, and also cingula on P_2 through M_3, with crenulation on P_3s and P_4s, and M_2s and M_3. The distribution of cingula on the cheek teeth of MMNS VP 130 is almost the same: P^2 through M^2, and P_3 through M_3. However, none are crenulated. RMM 2739 conforms somewhat in its upper dentition, with cingula on the lingual sides of P^2 through M^1 (M^2 is not preserved). In its lower jaw, RMM 2739 shows only a slight cingulum on the visible side of P_3. The general picture is that *Zygorhiza* specimens always have cingula on at least some of their cheek teeth, and sometimes the cingula are crenulated. The cheek teeth of other basilosaurids sometimes have cingula and they are seldom crenulated.

In basilosaurids, the posterior roots of the upper posterior premolars are expanded lingually into a buttress that is considered a remnant of the protocone that is still present in protocetids. Usually, P^3 and P^4 are involved in basilosaurids, including *Zygorhiza* specimens USNM 11962, USNM 16638, and RMM 2739. MMNS VP 130 has lingual buttresses on its P^2s and P^3s, and probably its P^4s also (P^4 is restored on both sides in the area). *B. cetoides* is the only other basilosaurid to have three upper premolars with buttresses.

In the right P_1 position on MMNS VP 130, two teeth are pressed together, one behind the other. The larger, posterior tooth must be the permanent premolar, which replaces the milk molar from behind. Its visible posterior edge bears two small accessory cusps and a tiny basal denticle, while the anterior edge is crushed against the unshed molar remnant. The intact anterior edge of the dP_1 has no cusps or serrations. The left P^1 resembles the P_1, in that it bears two accessory cusps and a basal denticle on its posterior edge, and has no features on its anterior edge. Left P_1 and right P^1 are restored teeth.

For the most part, the lower cheek teeth of MMNS VP 130 are like those of other basilosaurids. The right P_2 is unusual in having three definite cusps on its anterior edge, where others have denticles or serrations (left P_2 is restored with serration). The lower molars likewise conform in having three or four accessory cusps on their posterior edges. M_1 has three, M_2 has three and a basal denticle, and the last has three showing clear of the jaw ramus. USNM 11962, reported to have five posterior cusps on its M_3 (Kellogg, 1936), actually has four and a basal denticle.

A feature of *Zygorhiza*'s lower molars not previously noted is that their cingula loop up over their anterior grooves, rather than being interrupted. The lingual legs of the cingular loops are continuous with the anterior carinae of the molars, while the buccal legs curve over the top of the grooves.

FEATURES OF THE VERTEBRAE

MMNS VP 130 has a total of 60 vertebrae, including the seven added vertebrae and 23 recovered caudals. Kellogg's (1936) estimate included 21 caudals, which was based on the number found with a *Basilosaurus* specimen. The 23 caudals of MMNS VP 130 include a tailpiece of three fused vertebrae that terminates the column.

An important observation not previously published is that the neural arches do not articulate posterior to the dorsals. Vertebrae 22 and 23 are the last with articulated arches. This became evident when the restored vertebrae were assembled on the mount. The specimen in Macon, mounted by another preparator, shows the same feature.

With the aid of a portable elevator, the centra of MMNS VP 130 were measured in length, width, and height. The latter two measurements were taken anteriorly, as Kellogg measured his specimens. The added vertebrae were not identified during the process, and so their dimensions are included at unknown positions in Table 2.

Width is nearly always the largest dimension on *Zygorhiza* centra. On MMNS VP 130 the widths of the anteriormost thoracic centra were not measured because of the presence of ribs and sternum. The vertebral series 14 (seventh thoracic) through 26 (fourth lumbosacral) is not progressive with regard to width; the measurements cluster near eight cm. At vertebrae 26 through 29, width increases by a centimeter, and thence remains static at about nine cm through vertebra 51, which was the last measured. This pattern seems to be present on USNM 4679, another specimen that preserves an extensive series of vertebrae. An anterior non-progressive sequence exists, from vertebra 13 through 22, in which centra are about eight cm wide, and a posterior sequence, including 33, 34, 42, 47, and 51 to 53, in which centra are about nine cm wide. Other specimens do not include long series, and the existence of static segments cannot be verified.

Centrum height is usually the second-largest dimension on MMNS VP 130. It increases gradually until vertebra 28 (sixth lumbosacral) where it enters upon a non-progressive sequence that lasts until 53, after which height diminishes. Length of centrum catches up with height, and from 33 to 41, length exceeds height except towards the end of the tail. No static sequences in centrum height have been detected on any specimen other than MMNS VP 130. In the preserved lumbar region of USNM 4678, centrum height is less than or about equal to length, while in the lumbars of USNM 12063, height is greater than length. *Zygorhiza* specimens thus vary somewhat in centrum shape.

Table 2. Centrum measurements in mm of MMNS VP 130.

	LENGTH	WIDTH	HEIGHT
cervicals			
2nd		55.8	39.5
3rd	27.3	60.3	55.0
4th	27.5	63.2	45.7
5th	31.0	63.4	49.5
6th	28.7	59.5	44.0
7th	31.8	50.5	45.5
thoracics			
8th	38.7		46.5
9th	38.3	67.7	63.0
10th			
11th	48.2		51.2
12th	47.1		51.6
13th	50.1		56.5

Table 2. (continued)
Centrum measurements in mm of MMNS VP 130.

	LENGTH	WIDTH	HEIGHT
14th	52.0	85.0	58.3
15th	52.5	78.2	58.4
16th	60.0	79.1	58.1
17th	61.8	79.1	65.7
18th	63.2	87.2	60.9
19th	65.6	80.6	65.6
20th	69.0	80.4	70.5
21st	65.8	80.0	73.9
22nd	67.8	78.5	71.7
lumbosacrals			
23rd	67.7	76.1	77.0
24th	69.9	78.7	73.5
25th	67.6	77.5	78.0
26th	68.5	74.9	68.3
27th	72.5	83.0	72.5
28th	70.2	85.6	81.6
29th	74.0	89.1	78.6
30th	73.0	90.5	81.0
31st	85.7	87.2	75.5
32nd	78.5	90.6	81.3
33rd	83.2	89.0	79.4
34th	85.0	86.6	77.5
35th	89.3	86.2	78.1
36th	82.9	93.5	80.6
37th	84.4	92.5	74.4
caudals			
38th	80.9	87.7	82.8
39th	85.7	90.9	85.0
40th	84.5	85.7	81.2
41st	83.9	90.0	73.8
42nd	81.4	84.7	85.0
43rd	81.8	89.0	82.1
44th	75.2	89.4	84.9
45th	78.7	92.9	82.0
46th	72.5	89.7	82.4
47th	82.0	108.0	74.0
48th	81.0	88.4	78.1
49th	81.0	90.5	87.2
50th	77.7	81.0	81.0
51st	77.6	90.2	85.6
52nd	70.5		81.6
53rd	58.6		82.0
54th	45.0		73.6
55th	40.1		66.0
56th	35.7		56.4
57th	39.0		47.5
58th	35.3		41.9
59th	22.5		35.5
60th	38.4		31.6

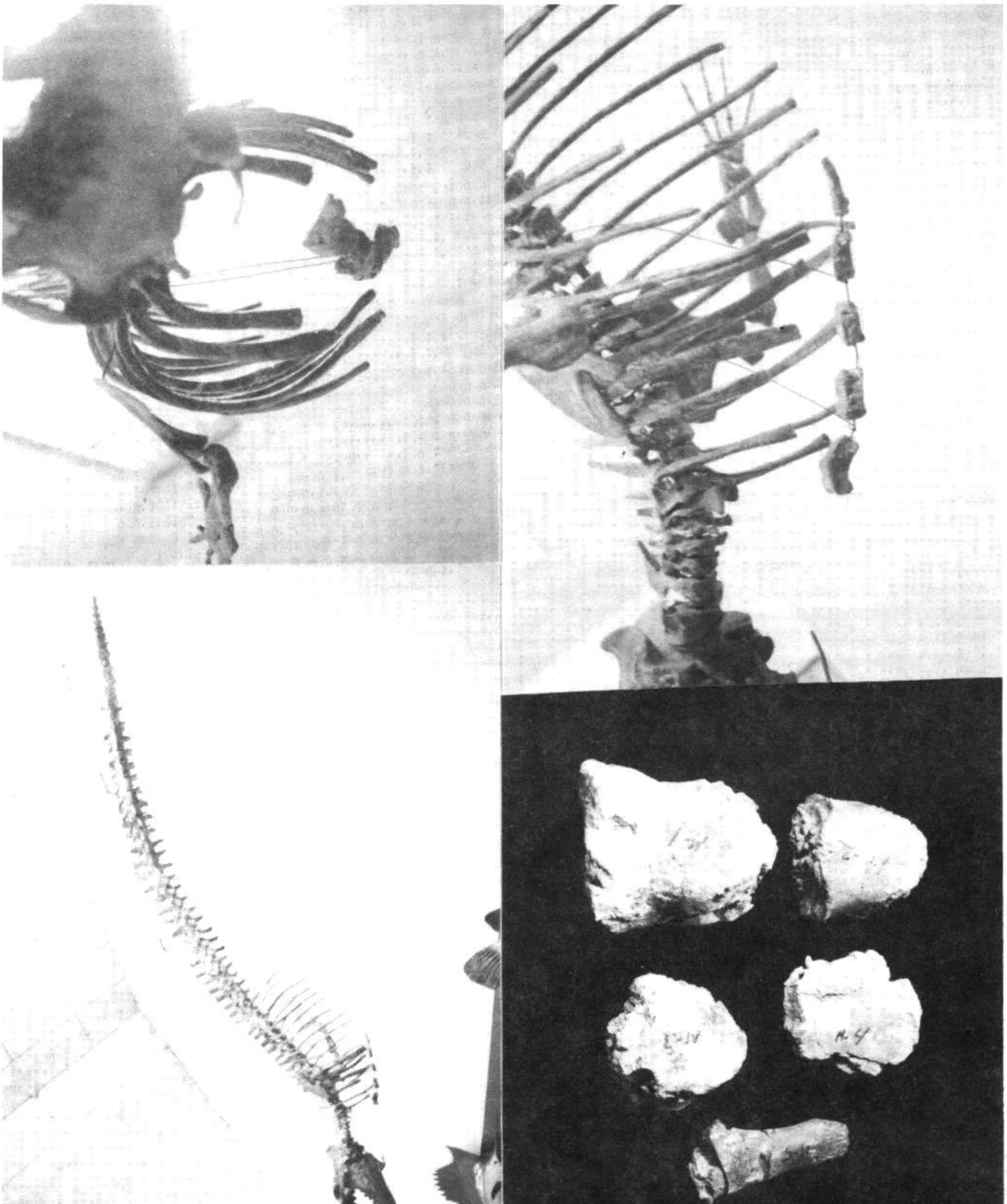


Figure 3.

FEATURES OF THE RIBS

Kellogg (1936) based his description of *Zygorhiza* ribs on USNM 4678 and USNM 4679, which include unrestored partial rib series. The rib series of MMNS VP 130 is well preserved anteriorly, but pairs eight through fifteen are extensively restored. Measurements were made on the left side, because the right side of the mount was toward the wall and could not be reached from the elevator.

The first pair of ribs is distinct from those of USNM 4678 and USNM 4679. They are not enlarged to any degree, as are other adult basilosaurid anterior ribs, which are pachyostotic and have what Kellogg called a pestle-like enlargement towards their distal ends. The free ends of MMNS VP 130's first ribs flare a little all around. On the left, the rib end is oval (3.9 x 2.6 cm), and on the right it is more nearly round.

The first pair of ribs differs also in that the ribs are not twisted. Usually a rib undergoes a half-turn so that its largest diameter changes from the plane of the rib heads to one conforming to the curve of the body wall. Instead, the first ribs of MMNS VP 130 are anteroposteriorly flattened and present an edge outward. In anterior view they closely resemble the left front rib of USNM 4678, as shown on Pl. 16 of Kellogg (1936). They curve in their proximal third, changing direction from nearly horizontal to vertical. They differ from Kellogg's plate only in lacking a visible corner on the outer side of the curve. Distally, MMNS VP 130's first ribs curve slightly inward.

The second pair of ribs shows the half-turn and the club-like enlargement found on the anterior ribs of the other two *Zygorhiza* rib specimens. In anterior view, the second ribs are longer versions of the first ones, with a downward bend just distal to the tuberculum and a nearly vertical descent from there.

The third and subsequent pairs of ribs have a more uniform curvature. The distal pachyostosis is most prominent on the third ribs, as it is on USNM 4678. It is less developed on the fourth pair, and slight on the fifth and sixth. Distal enlargement of the ribs of USNM 4679 is most developed on the second pair and persists through the seventh.

The mounted *Zygorhiza* skeleton in Macon, Georgia, has a noticeably more capacious thorax than does MMNS VP 130. Because of the extensive restoration of the ribs of this specimen, its present appearance has no certain significance.

Figure 3.(Left) Some postcranial features of MMNS VP 130.
Upper left, a lateral view of the whole mount.
Upper right, an anterior view of the thorax.
Lower left, the five sternebrae in ventral view.
Lower right, a lateral of the mounted sternebrae. They are somewhat anterior of their natural position here.

Table 3. Measurements of first seven pairs of *Zygorhiza* ribs. Lengths in cm, measured around the outer side. L, left; R, right.

	MMNS VP 130 L	USNM 4678 R	USNM 4678 L	USNM 4679 L
1st	25.2			26.4
2nd	34.8	30.5		38.4
3rd	45.6			51.6
4th	50.4			
5th	54.0		48.0	42.0
6th	56.4	58.8		60.0
7th	57.6		50.4	

Greatest diameters in cm

	130 L	4678 R	4678 L	4679 R	4679 L
1st	2.62	2.86			2.65
2nd	2.92	3.23	3.29		4.55
3rd	3.41	3.43		4.41	4.34
4th	3.00	3.40		3.73	3.69
5th	2.50				3.19
6th	2.45	2.48	2.43	2.50	2.69
7th	2.00				

THE STERNUM

A complete set of sternal elements was preserved with MMNS VP 130, lying in their original relations. The sternum consists of a manubrium, three mesosternal elements, and a slim, non-bifurcate xiphisternum. In a general way the four anterior segments resemble the sternum described for *Basilosaurus* by Kellogg (1936). Their flattest side was understood to be dorsal.

The manubrium of MMNS VP 130 has an almost horizontal anterior border, without a notch or anterolateral projections. It is still widest in front, spreading laterally in the anterior third of its length. In profile view, the manubrium angles downward, although this form is counterintuitive. Its dorsal surface is concave from side to side, and its upper profile is provided by the near lateral edge, which runs straight forward to a median peak at the point of inflection. Two knobs are positioned at the ventral anterior corners of the bone, as with the abnormal manubrium (USNM 12063) described by Kellogg. Ventrally, the manubrium of MMNS VP 130 is rounded from side to side and gently concave from end to end, except in front where the knobs increase the curvature. The thick posterior end bears two diverging rugose surfaces that meet at a median vertical keel.

A partial sternum of another *Zygorhiza*, part of MMNS VP 398, is in the museum's collections. MMNS VP 398 was recovered from an excavation in the city of Jackson and is probably from the Yazoo Formation. This manubrium departs from the expected form in that its dorsal side is not concave, but slopes away from a prominent median peak, giving the bone an almost pyramidal lateral view. Its ventral surface is gently convex and does not have any sign of inflection, except for its slight concavity from end to end. The two ventrolateral knobs, seen on MMNS VP 130 and USNM 12063, are present in the same position. The right knob is much less prominent than the left one, due to the abnormality of the anterior end. A coarsely pitted rugosity covers the surface between the ventrolateral corners and the ventral knobs. Whatever caused this rotten-looking area encroached upon the right knob, eroding it or preventing its normal development. The posterior end of the manubrium is likewise coarsely pitted, and excavated back within the upper and lower surface layers of bone.

The mesosternal elements of MMNS VP 130, like those described by Kellogg for *Basilosaurus*, are thick slabs of bone with rugose sides around their circumferences. The middle element is the smallest, while the first and third are approximately equal in size.

Table 4. Measurements in cm of the sternebrae of VP 130.

manubrium	9.34 L	x 8.27 W	(anterior meas.)
second	8.13	6.98	(anterior meas.)
third	7.05	6.9	(midlength meas.)
fourth	7.65	7.3	(anterior meas.)
xiphisternum	9.25	3.43	(anterior meas.)

The anterior end of the first mesosternal element resembles the posterior end of the manubrium, with two diverging rugose surfaces, except that the divergence is more acute and the keel more marked. The posterior end, and the anterior end of the second element, have the same general form. The posterior end of the second element, and the anterior end of the third, are more rounded. The third element is square-ended posteriorly.

MMNS VP 398 includes two mesosternal elements. These are smaller relative to their manubrium than those of MMNS VP 130. Their sides are as rugged as the ends of the manubrium, and their upper and lower surfaces are undercut so that the bones appear waisted. They are roughly shield-shaped, pointed in front. The larger of the two is very slightly concave from side to side on the (presumed) dorsal side. The smaller bone is flat on one surface and complexly curved on the other, with an arch on the (presumed) front, and convexity from front to back.

Their irregular sides indicate that the sternal elements were continued in cartilage. Indeed the sternum of *Zygorhiza* could have been a unitary structure in life.

DISCUSSION

Despite its geological age, there are not yet compelling grounds to assign MMNS VP 130 to a separate species from the younger *Zygorhiza* specimens. Its only discernible difference has to do with the shape of the ribs. The untwisted first rib pair indicates that MMNS VP 130 had a narrower anterior chest than other known specimens, because ribs usually present their flat side to the body wall. As the latter curved inward toward the neck, it would have faced more forward than laterally. Differences like this could be due simply to dimorphism or individual variation.

A separate question is whether *Zygorhiza* True 1908 is a valid genus, or whether it is a synonym of *Dorudon* Gibbs 1845. We have seen that the dental features that Kellogg (1936) used to diagnose *Zygorhiza* are questionable or invalid when specimens other than USNM 11962 are inspected. If new ones cannot be recognized, the genus will disappear in synonymy, despite Kellogg's judgment that it is distinct. Kellogg notes that the type specimen of *D. serratus* has a lesser interalveolar distance between P^1 and P^2 than does USNM 11962, and that it has a deeper snout. With regard to the former, USNM 11962 measures 32 mm and USNM 166392 8.1 mm, where the type of *D. serratus* is 15 mm, MMNS VP 130 is 15 and 20 mm, and RMM 2739 10.7 mm. Depth of snout may similarly turn out to be within the range of variation of both species. Neither character seems sufficient to distinguish the two at the generic level.

Some possible diagnostic characters for the genus *Zygorhiza* were noted in the descriptive section. These include the presence of a pit where the sagittal and lambdoidal crests meet, and I^2 as the largest caniniform tooth. Another candidate is the rounded narial fossa, which appears to distinguish *Zygorhiza* from other basilosaurids, with the possible exception of *D. atrox*. However, these characters could reasonably be considered diagnostic at the specific rather than at the generic level. The other differences, narrowness of skull and prevalence of cingula, are not exclusive enough to be defining but may be suitable as aids in identification.

The distinction between *Zygorhiza* and *Dorudon* is not robust at present. However, taxonomic revision can be delayed pending more information on the anatomy of *Dorudon*.

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TOPOGRAPHIC MAP REVISIONS IN MISSISSIPPI: A COOPERATIVE PROJECT

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In 1998 the Mississippi Office of Geology and the U.S. Geological Survey (USGS) developed a cooperative pilot project to improve topographic map revision. Prior to that time, the USGS produced maps using digital line graph (DLG) data, and information added to the map was not verified in the field. This process produced revised graphic maps and DLG data at the same time, which maximized the production process. However, the revised maps did not contain all the information traditionally shown. These early computer-generated maps left off those map symbols that required placement through a time-consuming manual process. For instance, a church cross or school flag must be properly oriented on the building, which is easy for a human to do but difficult to write computer code for. Note: this production process has been replaced by a new digital mapping process that does not depend upon the DLG's. Using this new process allows existing landmark buildings to retain their names and proper symbols if they still exist.

After reviewing several of these early maps, Mike Bograd of the Mississippi Office of Geology contacted Ray Fox of the USGS to complain about this loss of valuable information. This

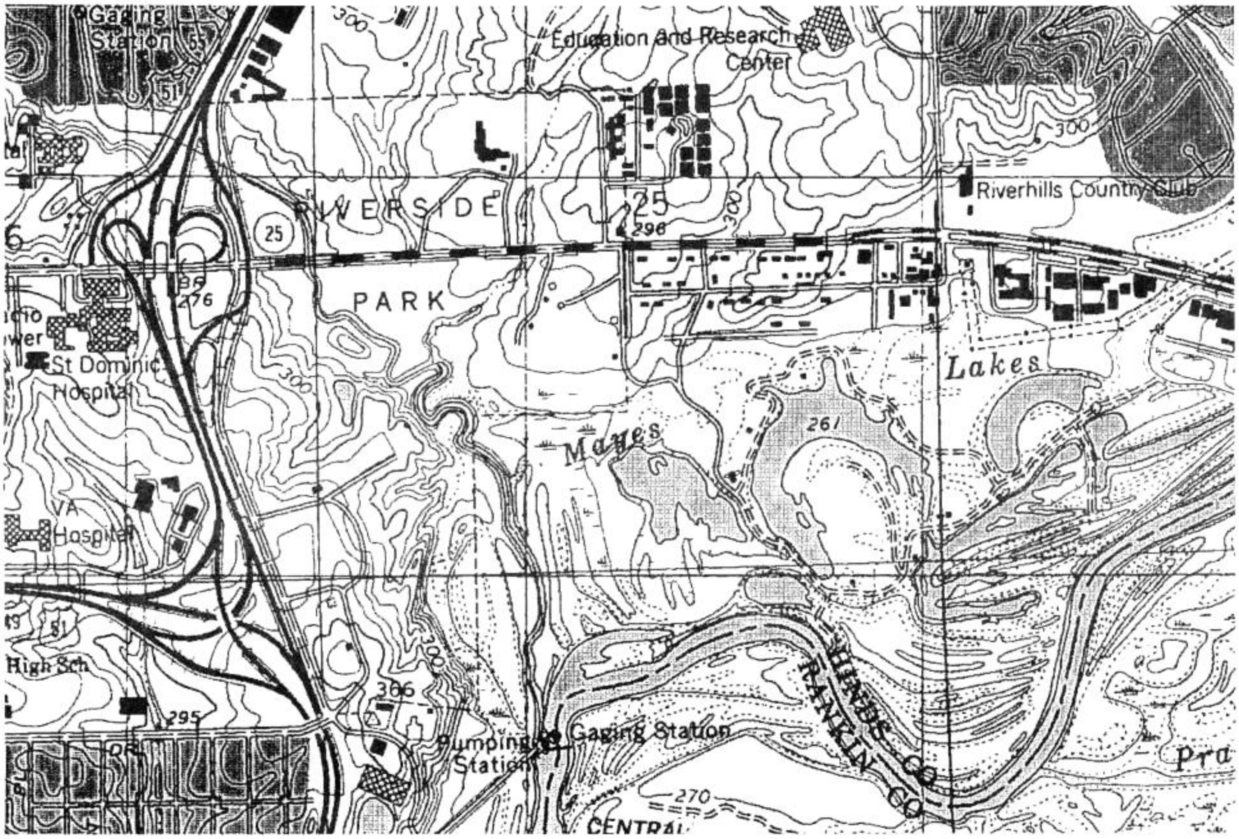

Figure 1. A portion of the Jackson quadrangle published in1980.

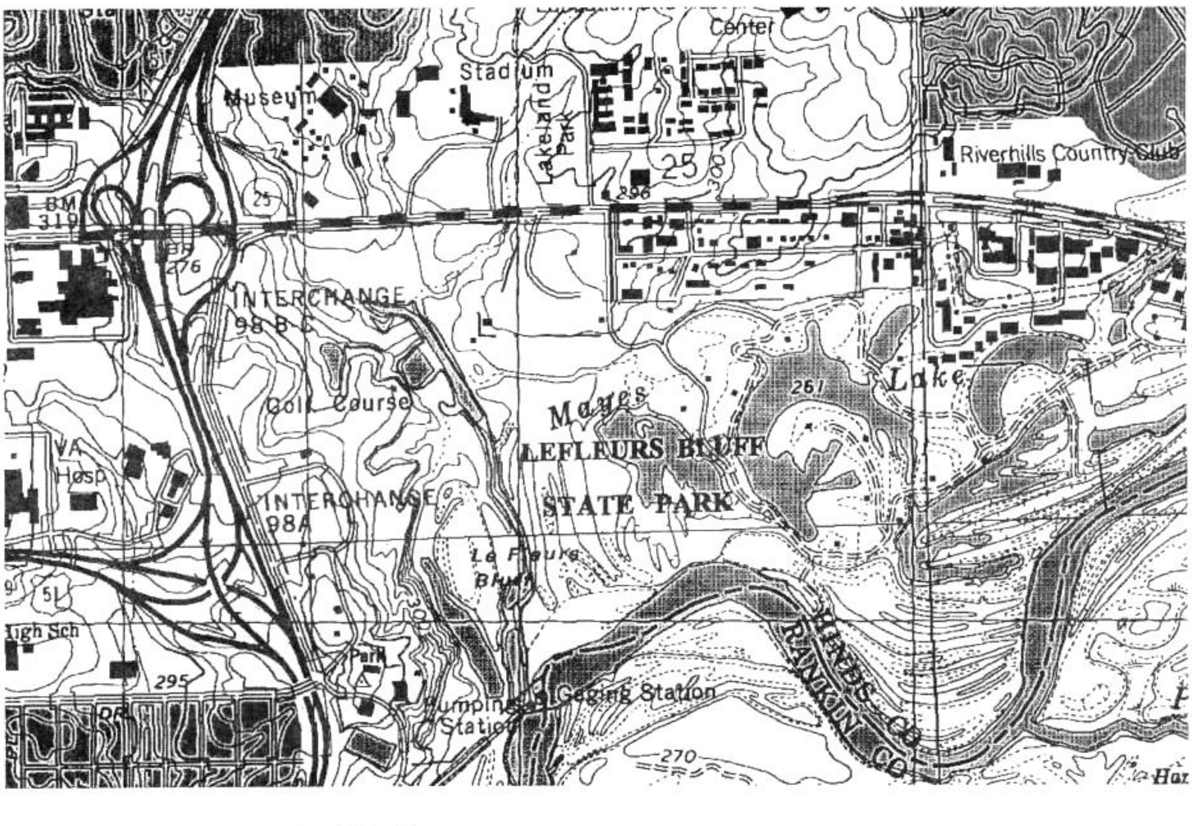

Figure 2. The same area on the 1998 published map.

call led to a discussion on how to improve the process and resulted in a four-quadrangle pilot project in the Jackson area. State Geologist Cragin Knox and others in the Office of Geology wanted the maps in the Jackson area revised and were willing to help produce a more complete map than was currently being offered. The existing maps of this urban area were 17 years old. Aerial photographs taken in 1996 were available to use in making the revisions. The question was whether to do a standard revision, which would imply that all information was updated (including changes in contours), or a digital limited update in which the landmark building names and symbols that the USGS could not verify in the field would be removed. The USGS could not field verify that information. (Contours are also not updated during a limited update.)

Because of funding cutbacks, the USGS is no longer able to perform field verification of features. Certainly, all buildings in rural areas and landmark buildings in urban areas that can be identified on the aerial photographs are plotted at the usual high mapping accuracy typical in USGS maps. Without field verification, however, these buildings cannot be labeled or symbolized. These symbols and labels are extremely useful for locating important buildings in urban areas and for orienting yourself on maps in rural areas.

Cragin Knox, many of his staff members, and many map users we talked with as they purchased topographic maps at the Office of Geology's Map and Publications Sales office were concerned that valuable information would be eliminated from the topographic maps during the revision process. The Office of Geology was so concerned about this potential loss of important information that we entered into a cooperative project with the USGS Mid-Continent Mapping Center to provide field verification for the four 7.5-minute topographic quadrangles of the Jackson metropolitan area.

Owing to the experimental nature of the project, no funds were transferred. The cooperative agreement was an in-kind services arrangement whereby the USGS staff provided instructions and specifications to Office of Geology personnel, who then performed field verifications. Field verification work began the first week of March 1998. A USGS trainer instructed four Office of Geology employees for one week on the methods used to field verify map information. The field verification work generally entailed two people in a vehicle (driver and navigator) marking annotations on aerial photographs one or two days a week. The small amount of office work primarily consisted of contacting various government officials about the locations of political boundaries. Office of Geology employees who worked on the project were Jim McMullin, Tom Ray, Steve Champlin, Ken McCarley, Seth Berman, and Jennifer Lana, representing three of the four divisions of the Office of Geology. The field information was sent to the USGS on May 18, 1998.

No serious problems were encountered during the field verification, and everything went smoothly. The field-verification work was found to be satisfactory by the USGS. All parties are pleased with the finished product—revised topographic quadrangles that maintained the labeling of landmark buildings in urban and rural areas. The cooperation of the Mississippi Department of Environmental Quality, Office of Geology, is acknowledged in the collar information. This includes the State agency logo, the first time a State agency logo has been printed on a USGS topographic map. The revised Jackson area quadrangles, Jackson, Jackson SE, Madison, and Ridgeland, have been available since January 1999. They can be purchased at the Office of Geology's Map Sales office for $5.00 apiece, or from other USGS Business Partners. For a list of Business Partners see URL http://mapping.usgs.gov/esic/map_dealers/index.html.

The successful completion of this cooperative project has led to plans to repeat the process with four 7.5-minute topographic quadrangles of the Vicksburg area. The maps date from 1962 and do not show the interstate highway and many other physical and cultural changes. This project will be a cost-share agreement with both agencies equally sharing the total cost of the revision. The USGS is estimating that the total cost for revising these four maps, Long Lake, Vicksburg West, Redwood, and Vicksburg East, including the contours, will be approximately $24,000 per map. The USGS will do a basic revision of the quadrangles, and the Office of Geology will again provide field verification of landmark buildings. This project may also include having the Office of Geology provide some elevation information in the flat river bottom areas to aid in adjusting the contours to match changes in those areas.

We look forward to further cooperative efforts between the USGS and the Mississippi Office of Geology in the vitally important topographic mapping program.

REVIEW OF *LYELL IN AMERICA*

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Lyell in America: Transatlantic Geology, 1841-1853, by Leonard G. Wilson: The Johns Hopkins University Press, 1998, 429 p., $45.00.

It is fortuitous that Charles Lyell, the author of the first modern textbook on geology (*Principles of Geology*, 1830), should visit North America, and the United States in particular, at a time when geologists were just beginning to map the country's surface geology. Geologists of the New York and Pennsylvania geological surveys had recognized rocks of Silurian, Devonian, and Carboniferous age in those states; Samuel Morton had identified Cretaceous fossils in a band of strata extending from New Jersey along the Atlantic Coastal Plain to South Carolina; and Timothy Conrad had proposed that the Tertiary fossils from various localities along the Atlantic Coastal Plain and from Claiborne, Alabama, were the same age as those from the London Clay (Eocene). Lyell wished to examine the Paleozoic rocks for himself and to see if his division of Europe's Tertiary into the Eocene, Miocene, and Pliocene epochs applied to the North American coastal plain as well.

Lyell visited America on four occasions with his wife Mary. Their first trip was prompted by was an invitation from the Lowell Institute of Boston to present a series of public lectures on geology. Funding from the Institute allowed the Lyells to travel widely from July 1841 to August 1842. These travels included a diversity of field studies, such as the Paleozoic rocks of New York (with James Hall), the Carboniferous coal mines of Pennsylvania, the Appalachian fold belt, the Tertiary of Virginia and South Carolina, the glacial erratics of Ohio, and the raised beach terraces along the Great Lakes. In Nova Scotia, Lyell studied the Bay of Fundy with its 40-foot tidal surge and the Carboniferous strata of the Cliffs of South Joggins, which contained fossil scale trees rooted in coal measures and standing in upright position. Lyell's second trip to America extended from September 1845 to June 1846 and included stops in Alabama and Mississippi.

Lyell kept extensive field notes and travel logs of these trips and published two popular accounts of his travels in North America, *Travels in North America, Canada, and Nova Scotia* (2 volumes, 1845) and *A Second Visit to the United States* (2 volumes, 1849). These volumes included a rare mix of science and local culture and were widely read by policy makers in England, including Prince Albert, whom Lyell would later advise in political and educational affairs. Along with his geological observations in the field, Lyell recorded his observations on America's public education system, infrastructure, transportation, peoples, opinions, and the situation of slaves in the South. Lyell's American experience, as recounted in these books, played a role in reforming the English university system and in bettering political relations between England and the United States (during Lyell's second visit there was much talk of war with England over the Oregon Territory).

While Lyell's *Travels in North America* and *Second Visit* included frank discussions of people, customs, and slavery (which he opposed), there was some care given not to offend those upon whose hospitality he depended should he return. What Leonard Wilson has contributed in *Lyell in America* is a summary of Lyell's travels with the added insight of the many letters he and his wife wrote home to family and friends, letters in which they were free to say exactly what they experienced and thought. Here we find Mary's critiques of her husband's lecture series at Boston, which were rather slow and methodical at first but improved with practice to the point that Mary wrote, "Even I did not suppose he could deliver them half so well & rivet the attention so completely" (p. 43). In the South, Mary complained of the spoiling of children in the frontier states of Alabama, Mississippi, and Missouri. Upon reaching New Harmony, Indiana, she was delighted to find David Dale Owen's children well mannered and likeable. Concerning the Owen's children, Mary wrote, "it is a pleasure to caress, for we have seen so many naughty children that Charles and I have become child-haters" (p. 257). While in Jackson, Mississippi, Charles talked with various men about Mississippi's repudiation of its debts in 1841, debts acquired in 1837 during a half-million-dollar building program. Lyell was puzzled that repudiation could occur when everyone he talked to opposed it. A lawyer told him that, "the only way he could explain the universal condemnation of repudiation, or reconcile it with the large majorities in favor of it, was that selfishness took advantage of the ballot box to oppose their professions" (p. 248).

Of particular interest are Lyell's contributions to the coastal plain geology of Mississippi and Alabama. The soft "nummulitic" limestones of the Vicksburg Group in Alabama had been identified as Cretaceous because of their similarity to Cretaceous chalks. Morton was thus led to identify the Vicksburg fossils of Alabama, including *Nummulites mantelli* Morton (now *Lepidocyclina mantelli*), as Cretaceous in his 1834 compendium, *Synopsis of the Organic Remains of the Cretaceous Group of the United States.* This brought the current geologic time scale into question as *Nummulites mantelli* Morton was thought to be the same *Nummulites* as that of the Eocene nummulitid limestones of Europe and northern Africa. Some proposed that the Alabama nummulitic limestones might represent an age intermediate between Cretaceous and Eocene times. Traveling down the Alabama River by steamboat, Lyell observed the nummulitic limestones of Alabama to lie above rather than below the fossiliferous Eocene strata at Claiborne Bluff and, thus, to be not only Eocene in age but very late in the Eocene Epoch (now placed as Early Oligocene). As Wilson states, "When the Nummulitic Limestone became Eocene, all its fossils became Eocene rather than Cretaceous, and by this one step almost all the fossils thought to be common to Cretaceous and Tertiary formations in the United States were eliminated" (p. 210).

In Mississippi, Lyell recognized the brown loam capping the Mississippi River bluff line from Natchez to Vicksburg to be like that of the loess in the Rhine Valley in Europe; he was one of the first to use the term loess in reference to it. Lyell also visited fossil localities at Vicksburg and Jackson and correctly recognized the Jackson fossils to be more like those at Claiborne Bluff and to be intermediate between the Vicksburg and Claiborne faunas. From these observations, he was able to construct a geologic cross section between Vicksburg and Jackson, showing the strata's true westward dip. Thus, Lyell set the Tertiary stratigraphy of the Gulf Coastal Plain in its proper order just in time for the work of Conrad, who described the fossils and named the Claiborne, Vicksburg, and Jackson groups, and in time for the work of Wailes, who wrote the first book on the geology of Mississippi in 1854.

Wilson's *Lyell in America* is like reading a who's who in the mid-Nineteenth Century scientific community of North America and England and gives insight into both the scientists and their time. It is also a good reference for understanding the contributions of various individuals working on North American geology and Gulf Coastal Plain stratigraphy in particular.

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