Nesting Structures of *Archeleon*: The Giant Sea Turtle of Late Cretaceous North America

© 2004 Gale A. Bishop

The Late Cretaceous seas contained many swimming marine reptiles that reached gigantic proportions, including 30 foot-long mosasaurs, 60 foot-long plesiosaurs, and 15 foot-long sea turtles. These marine reptiles joined toothed diving birds (*Hesperorinus* and *Ichthyornis*) and flying reptiles (pterosaurs) to comprise a suite of large animals that fed on the abundant food resources of the Late Cretaceous seas; the bivalves, ammonites, squids, and other invertebrates. The mosasaurs, plesiosaurs, pterosaurs, and diving toothed birds joined the dinosaurs and in the mass extinction at the end of the Cretaceous, an event that killed off 75% of the plants and animals alive during the Cretaceous and set the stage for the evolution of modern life forms. Of all these gigantic reptilian life forms, one that survived was the sea turtles!

Nesting of Loggerhead Sea Turtles at St. Catherines Island, Georgia

Modern sea turtles inhabit all the world oceans and all are now either endangered or threatened with extinction. Their numbers have rapidly declined dramatically over the last 50 years in response to man’s increasing abuse of their habitat and over exploitation of the seas. Modern representatives of these charismatic giants from the ancient past annually crawl onto sandy temperate and tropical beaches to lay eggs to propagate their kind into the future. Their nesting activities can leave a signature that is preservable in the fossil record and attest to their nesting activities in the deep past.
The possible traces left by sea turtles are limited to nesting structures made by females nesting on sandy beaches in tropical or subtropical regions. Nesting behaviors are strongly imprinted on modern sea turtles and described as a nesting ethogram (Hailman and Elowson, 1992). The ethogram for loggerhead sea turtles (Caretta caretta) includes nine distinct segments each component of which results in characteristic traces of the behaviors that form potential trace fossils. The traces also provide a clue to the evolutionary sequencing of the behavioral segments; the presence of a covering activity (resulting in production of a covering pit) would imply predation pressures existed in the past that led to the development of a hiding strategy. Although the beaches have a low preservation potential, the abundance of nests deposited year after year increases their potential for preservation. The recognition of these structures in the fossil record is difficult due to their small size, cryptic appearance, and lack of experience of geologists with structures of this sort.

Crawlways are produced by the female sea turtle ascending and descending the beach and by hatchlings scampering to the ocean. The crawlway morphology (symmetry and nest morphology) allows the sea turtle conservationist to identify the species, which produced the crawlway (Witherington, personal communication; Ga. DNR, personal communication). Individual turtles produce identifiable crawlways due to attached epizoans, flipper pathology, and individual crawling characteristics. The direction the turtle was crawling may often be determined by asymmetrical push marks from rear flippers and by v-shaped drags made by claws on the front flippers that open in the direction of...
crawling. Because of this, entrance and exit crawlways can be readily identified and used in reading the nest. Once on the beach, the turtle may have to wander to find a suitable nesting site or might become disoriented and wander about after nesting trying to find her way back to the ocean; giving rise to a wandering pattern. Upon emergence, hatchlings produce radiating arcs of overlapping crawlways leading from their emergence crater to the ocean. Occasional misorientation, disorientation, or catastrophe can be read in their crawlway patterns.

### Loggerhead Crawlway

A. Alternating comma-shaped flipper marks
B. Wavy and smoothed track center with no thin, straight, and well-defined tail-drag mark
C. No regular marking from front flippers at the margins of the track

### Leatherback Crawlway

A. Parallel flipper marks as from a "Butterfly-stroke" crawling pattern
B. Ridged track center with a thin, straight, and well-defined tail-drag mark that is punctuated by tail-point marks
C. Extensive marking from front flippers at the margins of the track and extending the total track width to 5 – 6 feet or greater.
Once the nesting sea turtle senses a change in temperature from cool to warm as she passes from tidally-cooled to solar-heated sand at the high tide line, she will often attempt to nest. This is initiated by digging a body pit by wallowing and scraping dry surface sand away from and under her body ("wallowing down" to damp sand) so she can excavate an egg chamber in damp sand that will hold vertical wall due to its cohesion. Occasionally the turtle will encounter damp sand from at surface and produce a body pit in it right at the surface forming a distinctive nest morphology (a "sand angel" analogous to "snow angels" produced by children in fresh snow). Sand angels may also be produced by hatchlings if they hang up in vegetation or are flipped on their backs during their rush to the sea.

Once the sea turtle has wallowed down to damp sand, she will excavate an egg chamber using her rear flippers (try this yourself next time you visit the beach!) in an alternating scooping motion. The egg chamber is excavated to the depth to which the turtle can reach with her rear flippers and may show a bilateral symmetry in an urn-shaped excavation about 20-25 cm in diameter. Occasionally turtles will attempt
nesting multiple times as they encounter subsurface obstructions (logs, wrack, or roots) and may leave several open body pits and egg chambers behind as they scoot forward to try again. Once a suitable egg chamber is constructed the eggs will be extruded nearly to the top of the egg chamber and the egg chamber back-filled, and possibly even tamped, with sand by the turtle's rear flippers. This back-filling is brecciated and in beaches with heavy minerals, will be obvious as a homogeneous, bioturbated sand cutting vertically through the horizontally laminated back beach facies. In horizontal view, if the loose sand of the covering pit is removed, this biogenic sedimentary structure will stand in stark contrast to the contour-like patterns of the back beach facies. The horizontal cross-sectional area of the egg chamber is usually less than 1% of the nest area; clearly an adaptation to protect eggs against predation.

Once the egg chamber is backfilled, the turtle enters a covering behavior characterized by front flipper sweeps (Hailman and Elowson, 1992) pushing and throwing sand backwards and propelling the turtle forward. As the turtle moves forward with successive flipper sweeps, she almost always rotates 180 degrees either clockwise or counterclockwise and then exits the covering pit to crawl back to the ocean. The resultant sedimentary structure is a thin bioturbated layer (20-30 cm thick) covering the egg chamber and body pit. The structure exhibits an elliptical shape approximately 3.0 m long and 1.5 m wide bounded by flipper scarps, with an uneven surface, trails of loose, thrown sand, connected to entrance and exit crawlways. The covering pit and crawlways are exceedingly ephemeral structures on the surface, rapidly erased by wind, rain, and tides.
After approximately sixty days of incubation in the solar-heated sand, the eggs will hatch and the hatchling turtles will emerge from their eggshell. The hatchlings begin to dig themselves out by a crawling motion of flippers, loosening the sand around and above them that falls through the mass of hatchlings under the influence of gravity, often forming a "stope" or air chamber above the mass of wiggling little turtles. This mining activity continues as long as the hatchlings are in cool sand beneath the surface. When they near the surface with its solar-heated hot sand, the hatchlings stop their activity and become lethargic, until the sand cools during the night when activity is renewed and the hatchlings emerge from their nest and scamper toward the sea, forming hatchling crawlways. Near the surface the sand is dry and not cohesive, so the surface layer may fall into the stope forming a surface "dimple" announcing an imminent emergence. The final emergence often is en masse, although multiple emerges on successive nights is the norm. Synchronous emergence of large numbers of hatchlings often forms an emergence crater as the surface sand collapses into the void left by the hatchlings. Upon emergence at night the hatchlings head to the sea (downhill, away from the island silhouette, and toward the light and noise of the sea) forming a pie-shaped arc of anatomizing crawlways broadening the sea. Reading these crawlways often allows the documentation of interactions with predators on the beach and an estimate of the number of emergent hatchlings. These are exceedingly ephemeral traces easily destroyed by wind, rain, and tide.

Ancient Sea Turtles of the Western Interior Seaway

During the Cretaceous Period the seas were inhabited by many types of Cretaceous sea turtles included; including
small toxichelids, about the size of many modern sea turtles such as loggerheads and giant forms the protostegids, including the genus *Archselon*. G. R. Wieland described *Archselon ischyros* in 1895 from a specimen collected in South Dakota and now exhibited in the Yale Peabody Museum (YPM 3000). A more complete *Archselon*, discovered in 1976, was collected by Frank Watson from southwestern South Dakota, near the Cheyenne River at Buffalo Gap during the mid-1970s, in Shannon County, S.D. Initial preparation and stabilization of the fossil was done by Peter Larson of the Black Hills Institute of Geological Research for Siber & Siber of Zurich, Switzerland. Siber & Siber sold the partly prepared specimen to *Naturhistorisches Museum Wien*, Austria. Preparation and mounting were completed by Naturhistorisches Museum Wien staff for display as the centerpiece exhibit of the Vienna Museum, where it resides to this day. Dr. Kraig Derstler of the University of New Orleans, who studied this specimen (Derstler, personal communication [1992]), said: "Without exaggeration, the Vienna museum specimen of *Archselon ischyros* is one of the world's great fossils." Because modern sea turtles are all endangered or threatened and fighting for their survival, *Archselon* is an especially poignant fossil and serves as a reminder of Earth's many endangered species. This charismatic position is substantiated by the U-Haul SuperGraphics campaign featuring *Archselon* as the icon for South Dakota.
The National Geographic Society included a scaled diagram of *Archelon ischros* in its "Monsters of the Past" web site. From the diagram above, you can closely estimate the reach of the rear paddles when excavating an egg chamber.

Ed Hooks reviewed The systematics of the protostegids (Hooks, 2002) and a cladistic matrix was run based upon morphologic characters. The classification of *Archelon ischyros* would be:

**Classification of Archelon ischros** Wieland, 1895

Class Reptillia
Order: Chelonia
  Suborder: Cryptodira
    Superfamily: Chelonioidea
      Family: Protostegidae
        Genus: Archelon
          Species: Archelon ischyros

NMW xxxxxx
Archelon ischyros Wieland 1895.
Late Cretaceous - 74 MYBP
Campanian - Zone of Didymoceras cheyennense?
Pierre Shale
Shannon County,
South Dakota

Facts and deductions about the Vienna specimen and other specimens of Archelon have been summarized from the BHIGR <http://www.bhigr.com/pages/info/info_arch.htm> web site, the National Geographic web site, and from the U-Haul International, Inc. web site. The original fossil skeleton of the Vienna Archelon was collected from the Pierre Shale about 45 miles south of Rapid City, South Dakota, USA in the 1970's and is owned by and displayed at the National Natural History Museum in Vienna, Austria. The Vienna specimen is the largest Archelon ischyros skeleton ever collected, is very nearly complete, the most complete of the Archelon skeletons ever collected, measures about 15'1” (4.5m) long from beak to end of tail (and said to be even longer if the neck were straightened, almost 16 feet! The skeleton measures about 16.5' (5.25m) wide across the carapace from the end of one front flipper to the end of the other outstretched front flipper. The live weight of this Archelon ischyros, is estimated to be more than 4,500 pounds (2200 kilos). Archelon has a hooked beak and, strong musculature, and probably had a very
powerful bite. This *Archelon ischyros*, having lived an estimated 100 years (determined by analogy?), probably died while brumating (hibernating) in the sea bottom and was killed and preserved partially buried in the mud of the sea floor. Cast replicas of the original fossil skeleton of *Archelon ischyros*, owned by the National Natural History Museum in Vienna, Austria, are produced by Black Hills Institute of Geological Research, Inc., under a special agreement with the Vienna Museum. Casts are displayed at Reptile Gardens in the Black Hills and another replica has been on display in Orlando, Florida at Walt Disney World's "Dinosaur Jubilee" since 1998.

Fossil sea turtle sedimentary structures were discovered in the Fox Hills Sandstone near Limon in Elbert County, Colorado in 1997…… see attached paper.

The presence of gigantic sea turtles such as *Protostega* and *Archelon* raises many questions such as what did they eat, how did they reproduce, and where did they nest. The question of nesting includes what would we expect crawlways, body pits, egg chambers, egg molds, and covering pits of *Archelon* to look like in the fossil record. To address this question, we are asking you to use your knowledge of modern loggerhead sea turtle traces, the known instances of Cretaceous traces, and extrapolate them to the size of *Archelon* and to the morphology of traces made by their close relatives, the leatherbacks.
YPM 3000 *Archelon ischyros* collected by Dr. Wieland (in photographs) in South Dakota in 1895 and exhibited in the Yale Peabody Museum. Assume Dr. Wieland is six feet tall.

Vienna, Austria specimen of *Archelon ischyros* collected in 1976 in Shannon County, South Dakota. Assume Ms. Marion Zenker is

Carnegie Museum specimen of *Archelon ischyros* … no scale.
The Return of *Archelon ischyros*

**Rationale:**

All extant sea turtles nest on sandy beaches along the oceans they inhabit. The recent discovery of sea turtle nesting structures on an ancient Cretaceous beach (in the Fox Hills Formation near Limon (Bishop et al., 1998)) in Colorado allows sea turtle nesting behavior to be extended into the Late Cretaceous. The presence of giant sea turtles (*Archelon* and *Protostega*) in Late Cretaceous seas implies that they nested and produced large-scale nesting structures. By using measurements taken from nearly complete skeletons of these giant creatures and by making analogy to recent and fossil sea turtle nests, it is possible to predict the size and morphology of their nests. This produces a “target image” for geologists and paleontologists expecting to encounter a nest of a giant sea turtle.

**Goals and Objectives:**

This set of activities is presented in three parts: 1) Computing the size of *Archelon* from published images of the skeleton, 2) Using these measurements to model an *Archelon* nest, 3) using functional morphology to determine how *Archelon* deeply *Archelon* could dig and egg chamber, and 4) using these data to predict what an *Archelon* nest in the Cretaceous will look like. The students will use a literature search, analogous Recent imagery, proportionality, critical thinking, metric to English conversions, and inventiveness to consider the life modes of these ancient giant creatures.
Location: To be done preferably on a sandy beach, an open sandy area like a school yard, or in chalk in a large parking lot or classroom.

**Time Frame:** This exercise will take approximately 1/2 to a full day (watch your tides!).

**Pre/Post-Test**

**Procedure:**

1. **How Big was BIG!**

1. 1. Read the introduction presented with this exercise, measure the following morphologic features on the diagrams presented:

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Carapace length</th>
<th>Carapace width</th>
<th>Flipper width</th>
<th>Rear Flipper Length</th>
<th>Total length</th>
<th>Estimated weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>YPM 3000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NMW xxxxxx</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carnigie</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. How deep would the body pit of this animal be?

2. Using all of the diagrams, determine the length of "reach" of the rear paddles of *Archelon ischyros*.

3. How wide would the rear flippers of Archelon ischyros have been? What is your evidence?

4. Construct a scaled map view of the body pit of this great sea turtle.

5. In the bottom of the body pit, sketch the plan view of the egg chamber neck.

6. Now construct a cross-sectional view of the body pit and egg chamber.

7. On an overlay (acetate) of your map view, sketch in the covering pit of a turtle this size, using its extant sea turtles as a model.

8. On your cross-sectional view add the cross section of the covering pit showing the base of the stirred-up (bioturbated) layer made by the covering activity.

9. Write a hypothesis to describe the egg size, morphology, and clutch size for this large sea turtle.
3. Field Exercise: Constructing an *Archelon* Nest

1. Read the introduction presented with this exercise.

2. Summarize the symmetry elements and morphology expected in a leatherback crawlway.

3. Calculate the width of the plastron dragway and flipper width (tip to tip) for your *Archelon*.

4. Lay out the edges of an *Archelon* crawlway on the beach by taping the proper flipper width and the proper plastron dragway width and mark with stake flags on the back beach and forebeach.

5. Use your ATV to drive a line between the stake flags using your outside wheel to delimitate the outer edges of the crawlway;

6. Repeat for the edges of the plastron drag.

7. Use a shovel or tool of your choice to construct flipper marks and the plastron drag.

8. Construct a body pit, egg chamber, and covering pit at the shoreward end of your crawlway (use a 3:1 ratio to scale off the covering pit).

9. Repeat to construct an exit crawlway.

10. Photograph and sketch your *Archelon* nest.
4. Synthesis: Predicting the Past

Now, considering the modeling you have done on the beach at St. Catherines Island, predict what the sedimentary structure suite will look like when an *Archelon* nest is discovered in the Late Cretaceous.
Selected References

<http://www.uhaul.com/supergraphics/turtle/archelon.html>

(from Everhart, Oceans of Kansas <http://www.oceansofkansas.com/Turtles.html>):


Derstler


Williston, S. W., 1894. A new turtle from the Benton Cretaceous. Kansas. University Quarterly 3(1):5-18, with pls. ii-.


Williston, S. W., 1902. On the hind limb of *Protostega*. American Journal of Science, Series 4, 13(76):276-278, 1 fig.

Williston, S. W., 1914. Water reptiles of the past and present. Chicago University Press. 251 pp. (Free, downloadable .pdf version here)
Zangerl, R., 1953. The vertebrate fauna of the Selma formation of Alabama, Part IV, the turtles of the family Toxochelyidae. Fieldiana (Geol. Mem.): 3(4): 137 - 277.


**Evaluation:**

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
</table>

1. Was constructing the mock *Archelon* nest fun?
   1  2  3
   Comments?

2. Was constructing a mock *Archelon* nest a good learning activity?
   1  2  3
   Comments?

3. Did you personally have to construct new thoughts in this exercise?
   1  2  3
   Comments?

4. Can you modify this activity to use in your curriculum?
   1  2  3
   Comments?

5. Would your students find this exercise (modified to grade level and discipline) fun?
   1  2  3
   Comments?

6. Can you address performance standards within the context of teaching this exercise about charismatic sea turtles?
   1  2  3
Comments?

Open Ended Question: What needs to be added, deleted, or changed to make this a functional learning experience for your curriculum? [Answer on the back of this page]

Thank you for your input!