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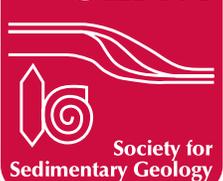
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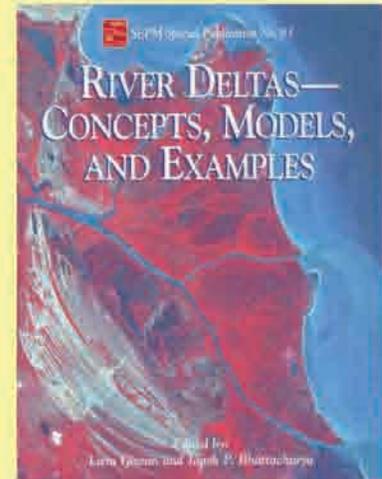
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*On the Cover: Convergence in tooth morphology and overall jaw structure of the Late Cretaceous mosasaur *Tylosaurus* (lower) and the Cenozoic cetacean *Tursiops* (upper). See article by Ciampaglio et al.*

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Editors

Loren E. Babcock, Department of Geological Sciences, The Ohio State University, Columbus, Ohio 43210
<babcock.5@osu.edu>

Stephen A. Leslie, Department of Earth Science, University of Arkansas at Little Rock, Little Rock, Arkansas 72204
<saleslie@ualr.edu>

Marilyn D. Wegweiser, Bucking Dinosaur Consulting; P.O. Box 243; Powell, WY, 82435;
<thedoc@180com.net> <wegwmari@isu.edu>

SEPM Staff

6128 East 38th Street, Suite #308, Tulsa, OK 74135-5814

Phone (North America): 800-865-9765

Phone (International): 918-610-3361

Dr. Howard Harper, Executive Director
<hharper@sepm.org>

Theresa Scott, Associate Director & Business Manager
<tscott@sepm.org>

Bob Clarke, Publications Coordinator
<rclarke@sepm.org>

Michele Woods, Membership Associate Coordinator
<mwoods@sepm.org>

Edythe Ellis, Administrative Assistant
<eellis@sepm.org>

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<w.a.morgan@conocophillips.com>

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<dalrymple@geol.queensu.ca>

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<stratum@gly.uga.edu>

Ron Steel, Councilor for Sedimentology
<rsteel@mail.utexas.edu>

Vitor Abreu, Councilor for Research Activities
<vitor.abreu@exxonmobil.com>

Kitty Lou Milliken, Co-editor, JSR
<kittym@mail.utexas.edu>

Colin P. North, Co-editor, JSR
<c.p.north@abdn.ac.uk>

Christopher G. Maples, Editor, PALAIOS
<chris.maples@dri.edu>

Laura J. Crossey, Co-editor, Special Publications
<lcrossey@unm.edu>

Donald McNeill, Co-editor, Special Publications
<dmcneill@rsmas.miami.edu>

Tim Carr, President, SEPM Foundation
<tcarr@kgs.ku.edu>

A Toothy Tale of Evolution:

Convergence in Tooth Morphology among Marine Mesozoic – Cenozoic Sharks, Reptiles, and Mammals

Charles N. Ciampaglio*, Gregory A. Wray†, and Bruce H. Corliss‡

*Wright State University, Lake Campus, 7600 State Route 703, Celina, OH 45822 chuck.ciampaglio@wright.edu

†Duke University, Department of Biology, Box 90338, Durham, North Carolina 27708

‡Duke University, Earth and Ocean Sciences, Box 90338, Durham, North Carolina 27708

ABSTRACT

Although mechanisms of niche replacement are discussed thoroughly in the evolutionary paleontological literature (i.e., extinctions, competition, evolution of new adaptive morphologies), actual studies involving quantitative analyses are not common. In this study, morphological features of dentition in Late Cretaceous and Cenozoic marine vertebrate predators were analyzed. The analysis included species of Late Cretaceous and Cenozoic sharks, Late Cretaceous marine reptiles, and Cenozoic marine mammals. Dental characters used in the study were both discrete and continuous. Species included in the analysis were originally collected from Late Cretaceous and Cenozoic rocks from the south-central, southeastern, and the mid-Atlantic regions of the United States, as well as Europe and the Pacific Rim.

A morphometric “tooth space” was constructed using the eigenvectors generated from Principal Component Analysis of the dental character data. The results of the analysis show that Mesozoic marine reptiles occupied a small, discrete region of the tooth morphospace, whereas Cretaceous sharks occupied a much larger, diffuse region of the morphospace. During the Paleogene a profusion of shark tooth morphologies occurred and then expanded into new areas of tooth morphospace. Yet, no overlap with the morphospace previously occupied by Mesozoic marine reptiles occurred. A large number of novel tooth morphologies evolved with the evolution of marine mammals during the Cenozoic. Remarkably, many of the tooth forms converged on the Mesozoic marine reptile designs, and hence a major overlap of marine mammal tooth morphospace with the previously occupied Mesozoic marine reptile morphospace occurred. Additionally, the shift from heterodonty (teeth of different types) to homodonty (teeth of similar types) occurred in several members of both the Mesozoic marine reptiles and the Cenozoic marine mammals.

Based on dental morphology, this study indicates that following the extinction of the Mesozoic marine reptiles during the Late Cretaceous, Cenozoic sharks failed to occupy the vacated niches, yet Cenozoic marine mammal dentition converged on the previous Mesozoic marine reptile tooth designs. Apparently, Cenozoic marine mammals occupied the vacated Mesozoic marine reptile dietary niches.

INTRODUCTION

The idea of faunal niche replacement has been discussed for well over a century. Darwin (1859) first proposed the idea by using the analogy of “wedges hammered into a log.” Classic paleontological examples include the replacement of non-avian dinosaurs by mammals (Benton, 1990, 1996a,b), the replacement of brachiopods by pelecypods as the dominant post-Paleozoic benthic bivalved fauna (Gould and Calloway, 1980), and even the replacement of whole monophyletic groups of articulated brachiopods by other monophyletic articulated brachiopod groups (Ciampaglio, 2004). Less attention has been paid to morphological convergence as a direct consequence of faunal niche replacement. Although the phenomenon has been addressed, particularly within reef complexes throughout the Phanerozoic (McKerrow, 1978; Wood, 1999), studies involving quantitative analyses are rare in the paleontological literature.

Morphological convergence among Mesozoic marine reptiles and Cenozoic marine mammals is well known (Figure 1). When the fossilized remains of Eocene whales were first uncovered in Louisiana and Alabama they were originally identified as belonging to a “plesiosaur-like” reptile and named *Basilosaurus* by Harlan (1834, 1835). It was nearly five years later that Owen (1839) corrected Harlan’s taxonomic mistake and properly identified the fossilized animals as marine mammals. Recently, many studies analyzing the biomechanics of swimming and feeding have used the modern cetaceans as suitable proxies for Mesozoic marine reptiles (Taylor, 1987; Massare, 1987, 1997; Budney, 2002). In addition to converging upon similar body plan, marine mammals have also converged upon the small number of tooth morphologies exhibited by Mesozoic marine reptiles (Massare, 1997).

In this study, morphological features of dentition of Late Cretaceous and Cenozoic marine vertebrate predators were analyzed using multivariate statistics. While Mesozoic marine reptiles and Cenozoic marine mammals show a surprising amount of morphological convergence, elasmobranchs (sharks and rays) display a wide, divergent array of morphological tooth types (Kent, 1994; Capetta, 1987). Although morphological tooth diversity among elasmobranchs is high during the Late Cretaceous, the greatest number of tooth designs are present throughout the Eocene.

Since tooth morphologies reflect dietary preferences, convergence among functionally homologous tooth types most likely indicates dietary convergences as well. Thus, by analyzing the species content of the occupied regions of the tooth morphospace we propose that it is possible to unravel guild structures, investigate cases of tooth convergence, and determine the overall expansion or contraction of feeding strategies among the marine vertebrate predators from the Late Cretaceous Period through the Cenozoic Era.

DENTITION IN MARINE VERTEBRATES

Late Cretaceous marine reptiles – Marine reptiles were the dominant predators of the Jurassic and Cretaceous seas. Large, mobile, fully pelagic, predatory groups include the orders Ichthyosauria, Sauropterygia (plesiosaurids and pliosaurids), and the family Mosasauridae. Although the basic dental crown design is a simple cone, many complex morphologies have arisen, including modified designs for piercing, crushing, cutting, and tearing (Peyer, 1968; Pollard, 1968; Massare, 1987). Most Mesozoic

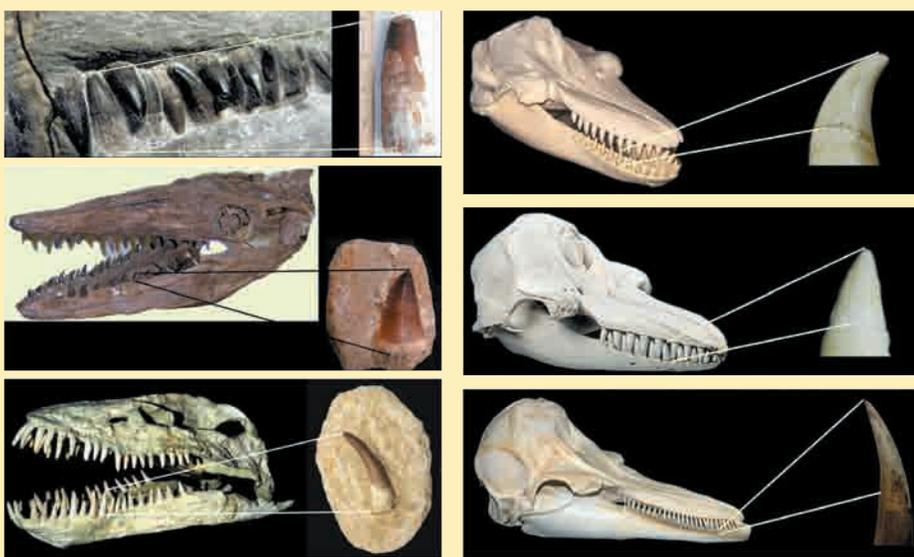


Figure 1: Selected skulls and dentitions of Late Cretaceous marine reptiles and Cenozoic marine mammals. Clockwise from upper-left: Ichthyosaurus; Killer Whale; False Killer Whale; Pacific White Sided Dolphin; the plesiosaur *Thalassomedon*; the mosasaur *Tylosaurus*.

marine reptiles have a homodont dentition (teeth of similar types), but in many cases, e.g., ichthyosaurs, homodonty is a derived character (Massare and Calloway, 1990).

Cetaceans and pinnipeds (Cenozoic marine mammals) – The predominant Cenozoic vertebrate predators belong to the mammalian orders Cetacea (whales, dolphins, and porpoises) and Pinnipedia (seals, sea-lions, and walruses). The first known cetaceans date to the early Eocene (Gingerich et al., 1983). Early whales, the protocetids and basilosaurids, had a heterodont dentition (teeth of different types). Molars are generally multi-cusped and have a more complicated form than premolars. The early cetaceans could use their dentition to shear and grind, as well as pierce and secure their prey (Fordyce, 1982). Later cetaceans, including the modern odontocetes (toothed whales, dolphins, and porpoises) have a homodont dentition. Some delphinids (oceanic whales and dolphins) have sharp, pointed, slender teeth that are used to pierce and secure their prey, while killer whales have sharp, robust teeth used not only for cutting flesh, but also for chopping and breaking bones (Massare, 1987).

The first known pinnipeds date to the latest Oligocene (Mitchell and Tedford, 1973; Barnes, 1979). Early members retain the dental features of their terrestrial carnivorous ancestors, namely well-defined carnassial teeth used to shear meat. Many later families have a modified dentition similar to that of the cetaceans; distal curving cusps, widely spaced cheek teeth, and similar molar and pre-molars. In some cases homodonty is present (Peyer, 1968; Hillson, 1986; Carroll, 1988).

Elasmobranchs (sharks and rays) – While the fossil record of sharks extends back into the Late Silurian, it was during the Late Devonian that a burst of evolutionary diversification occurred (Zangerl, 1981; Carroll, 1988). Paleozoic tooth forms are generally sharply pointed, with one or more cusps. This form of dentition provides an effective means for grasping and holding prey. During the later part of the Mesozoic and early Cenozoic, neoselachian (modern sharks, rays, and skates) squaliform, lamniform, and carchariform shark groups developed a highly effective jaw mechanism that allowed these sharks to gouge and wrench large pieces from prey. Additionally, many neoselachians evolved sharp, blade-like teeth, often with serrated edges, which served to slice deep into the flesh of large fish and marine mammals. This allowed for predation on prey larger than the sharks themselves and opened up new feeding niches (Moss, 1977; Capetta, 1987; Vermeij, 1987).

While some groups of neoselachians developed formidable serrated blade-like teeth, other tooth morphologies also evolved, including teeth designed for tearing, clutching, and crushing. In general, neoselachian anterior teeth are sharper and narrower than the lateral teeth, upper teeth are relatively wide and slanted posteriorly, lower teeth are relatively narrow and straight (Moss, 1977; Capetta, 1987; Kent, 1994).

General vertebrate tooth types – Several schemes have been used to classify basic tooth designs in sharks (Peyer, 1968; Moss, 1977; Capetta, 1987; Kent, 1994), Mesozoic marine reptiles (Peyer, 1968; Massare, 1987, 1997),

and marine mammals (Peyer, 1968; Hillson, 1986; Massare, 1987). Since this study involves all three vertebrate groups, a comprehensive classification scheme that accommodates each major tooth type was required. What follows is a hybrid tooth scheme based on the previous classifications referenced above (Figure 2).

Clutching – Teeth are generally small, with a low profile crown, typically surrounded by small cusplets. The enameloid is frequently folded or ridged longitudinally, increasing the strength of the crown. Clutching dentition is used to restrain prey, as well as crush weakly armored prey.

Crushing/Grinding – Teeth generally have a high crown with a polygonal outline, or are robust with a bulging crown that is transversely streamlined. Typically individual teeth form a dental plate with a nearly planar surface, or functional rows. This form of dentition is used to fragment or smash open hard-shelled prey that typically inhabit benthic or near bottom settings.

Grasp/Crush/Chop – Teeth are usually conical and robust. Sometimes teeth bear fine longitudinal ridges. This type of dentition is used to puncture and restrain prey, as well as to smash and chop bones.

Pierce/Gouge – Teeth are smooth and pointed. Sometimes teeth are recurved. Teeth may be delicate and slender, or relatively robust. This dentition is used to pierce and grasp prey, or used to wrench out pieces of flesh.

Slicing/Gouge – Teeth are generally flattened labio-lingually or ellipsoid in cross-section. The crown may be serrated, or have cutting edges. Teeth function to slice and/or gouge the flesh of relatively large prey.

MATERIALS AND METHODS

Dental character data collected from Late

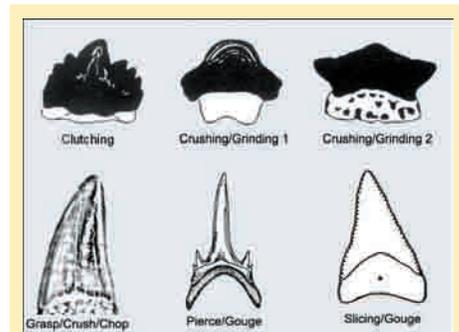


Figure 2: Representative tooth types found among predatory marine vertebrates. Note that there are two types of Crushing/Grinding teeth. Type 1 teeth have a robust, semi-rounded dental crown, while type 2 teeth have a polygonal outline and a relatively high dental crown.

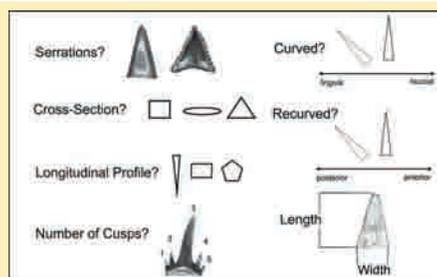


Figure 3: Examples of the characters used in the morphological analysis. In the figure all characters are discrete except length and width.

Cretaceous marine reptiles, Cenozoic marine mammals, and Late Cretaceous - Cenozoic elasmobranchs were analyzed using PCA (Principal Component Analysis) because of the wide variety of tooth morphologies among marine vertebrate predators, morphological convergence and divergence. The eigenvectors generated from the analysis were used to construct a morphometric “tooth space.” Analysis revealed that semi-discrete regions of the tooth morphospace are occupied predominantly by single tooth types. Since tooth morphology can be reasonably correlated to diet, the semi-discrete regions of occupied tooth morphospace can be used as proxies for feeding guilds (Moss, 1977; Capetta, 1987; Massare, 1987, 1997; Taylor, 1987).

Data Collection – The analysis included 39 species of Late Cretaceous sharks, 20 species of Paleocene sharks, 40 species of Eocene and Oligocene sharks, 20 species of Late Cretaceous marine reptiles, and 29 species of Cenozoic marine mammals (which represents all major Cenozoic tooth types). While the number of species used in the analysis is large, it is not comprehensive. However, all major tooth types for each major group were included.

The lack of homologous tooth morphology among the major groups analyzed required a combination of discrete as well as simple dimensional measurements. Dental characters utilized in the study included tooth length, width, cross-sectional outline, and longitudinal outline, the presence of serrations, number of lateral cusps, the presence of curvature and/or the presence of recurvature (Figure 3). Species included in the analysis were originally collected from Late Cretaceous and Cenozoic rocks located in the south-central, southeastern, and the mid-Atlantic United States, as well as Europe and the Pacific Rim. Specimens used in the study were obtained from the National Museum of Natural History and the North Carolina Museum of Natural Sciences.

Analysis of measurement data – A correlational PCA was performed using the program PC-ORD (McCune and Mefford, 1999). All

characters were included in the PCA analyses, as were all species included in the study. A morphometric tooth space was constructed using the eigenvectors generated from the PCA of the dental data.

RESULTS

The first two eigenvectors of the analysis capture over 50% of the variance. The resulting morphometric tooth space is divided into semi-discrete regions defined by the resulting clusters of the following tooth types; clutching, piercing/gouge, crushing/grinding, slicing/gouge, and grasp/crush/chop (Figure 4). Figure 4 shows a sub-sample of the total number of species that occupy each semi-discrete region. In the figure, and the entire analysis, each tooth represents a single species, except in the case of the early whales. Here, due to heterodonty, both the canines and molars are used in the analysis.

Figure 5 shows occupation of the dental morphospace during the Late Cretaceous, Paleocene, Eocene, and Oligocene – Neogene. Color-shaded polygons represent the occupied region of the tooth morphospace by each group under analysis. In each case, the shaded polygons represent more-or-less evenly filled regions (i.e., the data points are not patchily distributed within the polygon). In each panel the region of morphospace occupied by Late Cretaceous marine reptiles is shown for comparison.

During the Late Cretaceous marine reptiles occupy a small, discrete region of morphospace. With the exception of a small region of the crushing/grinding morphospace, the Late

Cretaceous marine reptiles solely occupy the grasp/crush/chop portion of morphospace. Conversely, Late Cretaceous sharks occupy a much greater portion of the tooth morphospace, nearly filling the crushing/grinding and piercing/gouging regions and substantially filling the clutching region. Only a few species occupy the slicing/gouge region, while none occupy the grasp/crush/chop region of morphospace.

During the Paleocene, sharks partly occupy the piercing/gouging, crushing/grinding, and slicing/gouge regions of the tooth morphospace. Throughout the remainder of the Paleogene and during the Neogene a profusion of shark tooth morphologies evolved. Partial occupation of the clutching, pierce/gouge, and crushing/grinding regions occurred, while the slicing/gouge region of morphospace was nearly totally occupied. As in the Late Cretaceous, Paleogene and Neogene sharks failed to occupy the grasp/crush/chop region of morphospace.

Eocene marine mammals consist solely of two groups of cetaceans, basilosaurids and protocetids. Together the two groups occupy the grasp/crush/chop and slicing/gouge region of morphospace. These early cetaceans essentially had a dual dentition, posterior teeth designed to slice and shear, anterior teeth capable of grasping and restraining prey. From the Oligocene onward through the Neogene a burst of marine mammal evolution occurred. In addition to the first odontocetes, pinnipeds also appeared. A significant shift occurred in the occupied regions of the tooth morpho-

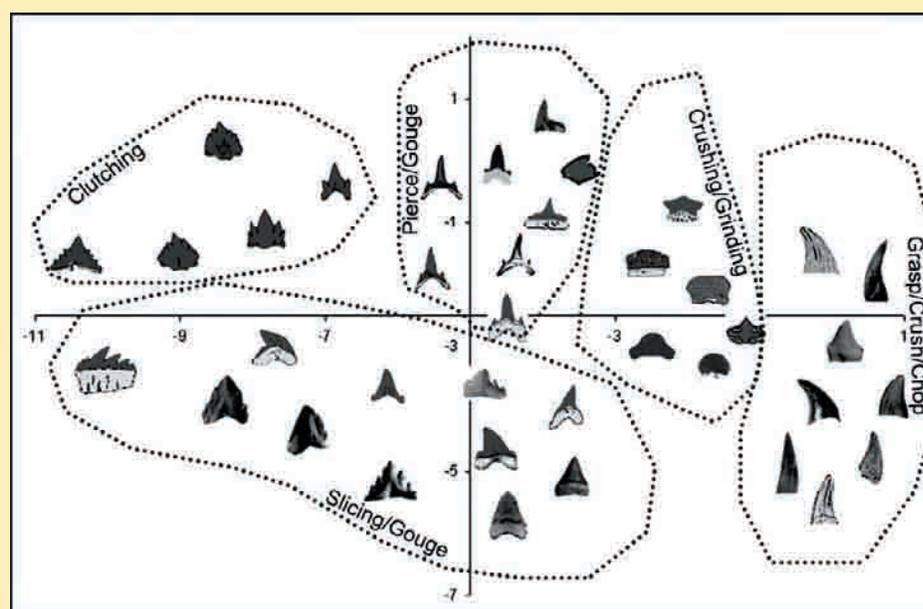


Figure 4: The “tooth” morphospace based on the first two principal eigenvectors generated from the PCA analysis. Semi-discrete regions occupied by specific tooth types are labeled. A sub-sample of the total number of species that occupy each semi-discrete region is shown (each tooth shown represents a single species).

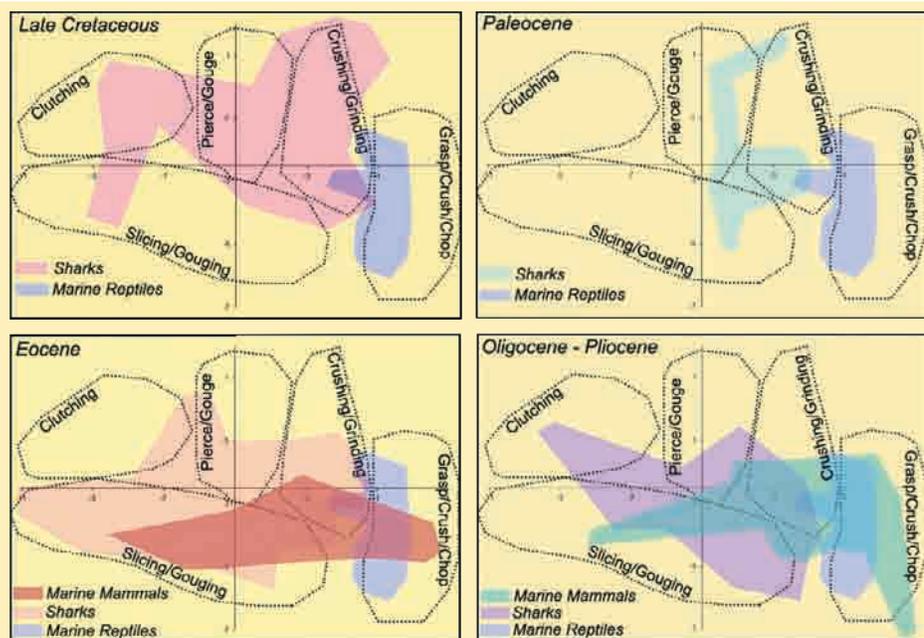


Figure 5: Occupation of the tooth morphospace during the Late Cretaceous, Paleocene, Eocene, Oligocene – Pliocene. Color shaded polygons represent the amount of morphospace occupied by each indicated group. In each panel the shaded portion of tooth morphospace occupied by the Late Cretaceous marine reptiles is shown for comparison.

space. During the Neogene marine mammals nearly fill the grasp/crush/chop region of morphospace, and almost completely overlap the region of space previously occupied by the Late Cretaceous marine reptiles.

DISCUSSION

Analysis of the tooth morphospace points to two phenomena. First, during the Cenozoic a profusion of shark tooth morphologies evolved, yet there is little overlap with the vacated Late Cretaceous marine reptile tooth morphospace. Second, with the evolution of marine mammals in the Cenozoic many tooth forms converged on the previously occupied Late Cretaceous marine reptile tooth morphospace. If dental morphologies are an indicator of dietary niches, then Cenozoic sharks failed to occupy the niches vacated by the marine reptiles, while Cenozoic marine mammals nearly completely occupied the vacated niches. This is clearly not a case of competitive exclusion. There is nearly a 10 million year gap between the extinction of the Late Cretaceous and the evolution of the Cenozoic marine mammals.

Jaw morphology and anatomy may partially explain the failure of sharks to occupy the grasp/crush/chop dietary niche. Paleozoic shark feeding mechanisms featured terminal mouths coupled with a grasping cladodont dentition characterized by a wide tooth base, a large central cusp and a variable number of lateral cusps. Subsequent modification of the jaw and dentition throughout the late Paleozoic and Mesozoic included a relative

shortening of the jaws, a modification of the braincase and jaw structure allowing the upper jaw to move freely, and a modified hyomandibular bone which allowed the upper and lower jaws to be raised and lowered relative to the braincase resulting in movement fore and aft (Moss, 1977; Carroll, 1988). Sharks were able to feed on large prey by forcing their jaws into the body and gouging out pieces. Accompanying this new jaw design were blade-like teeth modified to slice. Many of the large sharks also developed serrated dentition, which became much more common during the Cenozoic, perhaps in response to the evolution of marine mammals. Flexible jaws, serrated blade-like, or sharply pointed teeth, allowed sharks to feed by wrenching and gouging the flesh of their “fleshy” marine mammalian prey. Thus, the dentition of many Cenozoic sharks, particularly the squaliform, lamniform, and carchariniform groups, may have been shaped more by anatomy than by ecology.

Morphological innovation among Cenozoic marine mammals was undoubtedly constrained by fluid mechanics, as were their distant reptilian “cousins.” The shape of the head determines the drag exerted by surrounding water during sideways sweep. In order to minimize resistance, the cross-sectional area of the head must be kept to a minimum, especially near the anterior end. This yields a slender profile that is dorso-ventrally compressed. Yet, the jaws must be robust enough to capture and restrain prey. Together this trade-off leads to

the familiar shape of both the Cenozoic marine mammal and Late Cretaceous marine reptile head profile (Figure 1) (Moss, 1977; Massare, 1987; Taylor, 1987).

Prey acquisition is another important aspect of living in a fully marine environment. Plesiosaurs, ichthyosaurs, mosasaurs, cetaceans, and most pinnipeds fed on pelagic prey. In order to capture, restrain, and reduce prey to edible pieces, caniniform (conical, and usually recurved) dentition is optimal (Taylor, 1987). Size and girth of the caniniform tooth depends on the prey preference of the predator. Many dolphins and plesiosaurs have slender, pointed teeth suitable for piercing fish, while killer whales, some ichthyosaurs, and mosasaurs have robust, sharp teeth for seizing and chopping the bones of their marine tetrapod prey (Massare, 1987).

Perhaps the most remarkable aspect of tooth convergence among marine reptiles and marine mammals is the “switch” from heterodonty to homodonty. Many Early Triassic ichthyosaurs, such as *Mixosaurus*, *Grippia*, and *Phalarodon* had heterodont dentitions. By the Middle Triassic many ichthyosaurs had homodont dentitions, a trend that continued throughout the Jurassic and Cretaceous. Likewise, protocetid and basilosaurid whales during the Paleogene had heterodont dentitions. By the Miocene most toothed cetaceans had homodont dentitions (Massare, 1987, 1997).

CONCLUSIONS

While this study represents a preliminary look at the functional and dietary convergence among major marine vertebrate predators, several results stand out. For the most part, the dentition of Late Cretaceous sharks failed to converge on the tooth morphologies exhibited by Mesozoic marine reptiles. Following the extinction of the Late Cretaceous marine reptiles, Cenozoic sharks once again failed to converge on the reptilian tooth morphologies, despite a considerable evolutionary radiation. Conversely, the evolutionary radiation of marine mammals produced numerous cases of dentition that converged on the Mesozoic marine reptile tooth morphologies.

The failure of shark dentition to converge on the tooth morphologies exhibited by Late Cretaceous marine reptiles may be due more to anatomical constraints imposed by jaw structure than by ecological considerations. Alternatively, the convergence of marine mammal dentition on that of Late Cretaceous marine reptile tooth morphologies may be due to selective pressures involving ecological and biomechanical constraints.

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DIRECTOR'S CHAIR

Society Records

Along with the usual content in The Sedimentary Record this month, you will also find an Appendix. The appendix is a copy of the official Society Records and Annual Report for 2005. This information has previously been printed in the *Journal of Sedimentary Research* but will from now on be part of The Sedimentary Record, where it is a much better content fit and where we can make sure that it is received by all of our members, rather than only those that take JSR. The Society Records will also be posted online along with the digital version of The Sedimentary Record. The Society Records include a summary

report on the activities of the Society for 2005, including notes from the Annual Meeting, new publications, research conferences and miscellaneous information pertinent to 2005. We also include the full biographies and responses of the SEPM Awardees for 2005 along with their pictures. The audited financial statements are also there, although they come from the prior year due to the time it takes to complete the audit. Also included are the basic statistics on membership. As we continue to modify The Sedimentary Record to the membership needs, please do not hesitate to contact me with your thoughts about it.

Online Journal Tips

The Society has given all of its members online access to both journals for the last part of this year so that everyone can become better acquainted with the ins and outs of online searching and browsing at the GSW supplied member access sites for PALAIOS and *Journal of Sedimentary Research*. In 2006, everyone will have online access as part of the basic subscription to either of the journals or both as you have chosen. With this access now setup, I wanted to share some tips on how you can maximize it to your benefit.

The first tip is to how to setup email Alerts. These alerts will notify you at an email address of your choice when a new issue of a journal has been loaded and its Table of Contents is now available or when articles that meet your search criteria have been uploaded. First go to www.geoscience-world.org. Setting up alerts is an open access process, you do not have to login

through your SEPM member access link. Next click on the "Register" link in the upper right hand area (if you have not previously registered – not the same as your member user id and password). Here you can set up a name and password and then you are registered. GSW will assign you a registration number such as REG#### in case you need to correspond with them online. Once registered, go to "My GSW Alerts", there you can follow the directions to set up alerts for tables of contents, awareness and journal announcements. You can also set up CiteTract Alerts, which will send you email when new papers with certain search criteria (authors, key words, etc.) arrive at JSR or PALAIOS or any of the other GSW journals (if indicated).

I hope that these couple of tips will help you get more out of your online experience with JSR and PALAIOS.

Howard E. Harper, Executive Director

PRESIDENT'S COMMENTS

Why SEPM?

Several members have asked me whether SEPM, as a society, is still relevant and whether it can survive in a digital world. My response has been "Absolutely!" In fact, not only does the Society continue to be relevant, it is now more essential than ever to advancing the science of sedimentary geology.

The ability to globally communicate scientific information has advanced at such a rapid pace that online-only publications, not published by societies, have appeared. They offer rapid publication, unlimited color figures, and the ability to embed videos and other media in scientific "papers." Such publications have low production costs compared with traditional journals because they are neither printed nor shipped. They also have another significant advantage with respect to costs - they do not have the overhead associated with the operations of a society, such as SEPM. Is this the trend of the future (society-less publications distributed only online)? As a modern business model it makes sense - rapid publication and low overhead.

Is there a role for SEPM under this scenario and can it compete?

What at first glance would appear to leave SEPM outmoded and at an economic competitive disadvantage - a large, global membership requiring services and a traditional "bricks and mortars" headquarters - are, in fact, the Society's greatest strengths. They provide a competitive edge if we take advantage of them. Consider that the Society has.....

- A legacy of promoting excellence in science dating back to 1926.
- A history of publishing well-respected, often cited, peer-reviewed publications.
- A record of organizing and facilitating research conferences and meetings on topics at the forefront of the science.
- An active membership and staff that have worked together to accomplish all of the above.

Because of this rich history, SEPM has, in advertising parlance, brand marketing and wields a "seal of approval." Therefore, SEPM plays a major role in organizing and planning technical programs for meetings and conferences. SEPM has direct involvement in establishing technical sessions at our Annual Meeting with AAPG, where the Society typically sponsors 30-40% of the technical pro-

gram, and in sponsoring specific technical sessions at the GSA Annual Meeting. SEPM also advances the science by organizing several research conferences per year. The research conferences are on focused topics and deliberately designed for a small audience to foster discussion. In addition to those meetings, SEPM is often asked to endorse conferences that it does not host. Why?... Because sedimentary geologists recognize that an endorsement from SEPM lends credibility to their conference. SEPM Council carefully considers these requests and supports those that meet the mission and standards of the Society.

Society-less online publications, websites, and blogs are in no position to advance the science of sedimentary geology through these types of personal interactions. It takes a well-organized society with active members to do that, and one with a strong reputation for scientific excellence among the community of sedimentary geologists. SEPM has a legacy in this regard; a legacy that has been established over an 80 year history and one that would be impossible to duplicate. Consider the hurdles, both organizational and financial, to starting an international society of sedimentary geologists today.

As a member of SEPM you receive access to two highly-regarded journals, The Journal of Sedimentary Research and Palaios, and significant discounts on excellent publications and meetings. You are also the beneficiary of being a member of a society that furthers the science of sedimentary geology by providing opportunities for personal interaction and collaboration. And, through your membership and participation in SEPM, you are in effect responsible for making those opportunities possible. It is the membership's scientific creativity, volunteerism, and financial support that underwrite SEPM and its mission to advance the field of sedimentary geology.

Is SEPM still relevant?... In a digital world, now more so than ever. SEPM plays a vital role in furthering the science of sedimentary geology, and your membership in the Society benefits the entire sedimentary geology community. This is a message that I hope you as members will communicate to your colleagues and, especially, to students.

Bill Morgan
President,
Society for Sedimentary Geology (SEPM)
w.a.morgan@conocophillips.com

NEW EDITORS

SEPM Council Announces that

Molly F. Miller, Vanderbilt University

David J. Furbish, Vanderbilt University

Steve L. Goodbred, Jr., Vanderbilt University

have agreed to become the next editors of *The Sedimentary Record*.

The Council wants to thank

Loren E. Babcock, The Ohio State University

Stephen A. Leslie, University of Arkansas at Little Rock

Marilyn D. Wegweiser, Bucking Dinosaur Consulting

for their great efforts in being the start-up editors for this publication and their dedicated spirit, even from Antarctica, in getting each issue out and filled with interesting content.

The new editors will be transitioning in during 2006.

Addressing future directions in sedimentary geology:

A word about ForSed

**John Holbrook, UT Arlington and
Chris Paola UM Minneapolis**

The Forum on the Future of Sedimentary Geology (ForSed) is for all who are interested in the future of sedimentary and stratigraphic research. We offer a venue where new research ideas can be generated, debated, and disseminated. ForSed initiated from discussions sponsored by NCED (National Center for Earth Surface Dynamics) and NSF, which detailed the critically low and diminishing sense of priority for sedimentary research among the larger academic research community. ForSed was born in recognition of the urgent need to improve our profile, particularly among funding agencies, through presentation of new, relevant, and exciting science initiatives that bear the consensus of the sedimentary community.

Sponsored by SEPM, NCED and SGD with NSF encouragement, ForSed has thus far met twice at GSA and once at AAPG for one-day sessions. Each generated lively debate. Views and consensus gained from these meetings are summarized in a white paper available at the NCED website

<http://www.nced.umn.edu>. In addition, ForSed has spawned the smaller working group Environmental Stratigraphy which recently met through the sponsorship of NCED to discuss the role of sedimentology and stratigraphy in environmental management. Notes and results of this meeting are also available at the NCED website. Several key findings have come of these efforts. Two of these are given special mention.

First, there is a broad sense that the sedimentary community is underrepresented in environmental efforts. Two areas where this can be improved are in groundwater flow modeling and sustainable environmental engi-

neering. The sophistication of groundwater flow models and the need for more detailed flow predictions are increasing rapidly. The long-anticipated, but as yet unrealized, potential for synergy between these disciplines is evolving and this drives the need for more applicable and numerically based models of flow heterogeneity in sedimentary media. Sustainable engineering involves the focusing of surficial sedimentary processes toward the natural restoration of environments and the mitigation of natural hazards. River and wetland restoration are prime examples. It is clear that knowledge of the rates, process, and extremes through which these natural systems respond to external change is pivotal to these efforts. The sedimentary record of these systems is a robust source for this information. In both cases, more demonstration projects are needed to illustrate the benefits of sedimentology to these efforts. These efforts will also depend on close cooperation with many sister disciplines.

Second, potential for a series of stratigraphic observatories/natural laboratories is emerging. The detailed reconstructions of ancient Earth-surface processes over short time periods is becoming more feasible with technologies like 3-D seismic, sophisticated geochemical proxies, and high-resolution dating. Consensus grows that it is now time to identify one or more stratigraphic volumes, and build an infrastructure that will permit us to focus these tools upon them. This would permit us to gain a better sense of how our planet surface evolves over time and through extremes. We are actively proposing the Mississippi Delta as a first such observatory to support anticipated delta restoration.

After initial successful meetings, ForSed is ready to continue in a modified form. ForSed will now meet on a regular basis the evening before the GSA Annual Meeting. The next ForSed open town hall will be the 'seds and suds' discussion Saturday evening approx 6-8 pm before GSA in Philadelphia. In addition, we anticipate a new ForSed website including an open discussion blog. We also anticipate a special meeting to further develop initiatives emphasizing cross disciplinary activities with existing outer crust dynamics and geoinformatics efforts (EarthTime, GeoSystems, CHRONOS, PaleoStrat, SedDB). Please feel free to contact either John Holbrook, holbrook@uta.edu, or Chris Paola, cpaola@umn.edu, for further information. ForSed is sponsored by SEPM (Society for Sedimentary Geology), NCED, Sedimentary Geology Division of GSA, and NSF.

SORRY

In September we listed the 2006 SEPM Medalists but we misspelled one of their names. Please excuse our error.

The winner of the 2006 Shepard Medal is Michael Sarnthein.

So where is your image?

Each month the SEPM website features another student member image with a description of its sedimentary geological significance. To date the SEPM website has shown many geological images taken by student members. Each image is chosen from all those that have been submitted and the winner each month receives their choice of SEPM publication! The awarded publication can easily be a value of over \$100.

Check the image requirements at the website and send yours to Michele Woods (mwoods@sepm.org).

CALL FOR MEDALIST NOMINATIONS

Each year SEPM honors scientists within the fields of Sedimentary Geology. These medalists are nominated by you, the members of this society. Only by having members active enough to nominate their peers can the work of the people who push our science forward be recognized and honored.

Please nominate candidates at www.sepm.org/events/awards/awardshome.htm

SEPM Student Ambassador Program

Being a student member of SEPM has always had great benefits from the Free Books to Students offers to the online access to both journals. Now we have an additional benefit, the Student Ambassador Program. This program is designed to encourage SEPM student members to participate in the geoscience community by awarding points for activities, such as, publishing papers, giving poster or oral presentations, purchasing SEPM publications and several others. The earned points can then be exchanged for discounts on SEPM items, including books, CDs and logo ware. An additional bonus is a graduation gift, awarded when a student member converts to a full membership, as they begin their professional career.



Pictured to the left is President Bill Morgan and Dr. Kimberly Johnson, who is the first Ambassador Program Graduation Gift awardee. Kimberly chose SP #81 on cyclostratigraphy as her gift, a \$154 value.

So how do you join the Ambassador Program? SEPM Council has decided that all SEPM Student Members are automatically enrolled when they join or renew their membership, so there is no extra work. However, each student must contact SEPM Headquarters (Michele Woods, mwoods@sepm.org) to report when they have participated in a point earning activity. Go to www.sepm.org/membership/students/ambassador.htm to see the details.

FIELD TRIPS

PLAN AHEAD FOR THE 2005 AAPG/SEPM ANNUAL MEETING - HOUSTON, APRIL 9-12
REGISTER EARLY TO RESERVE YOUR PLACE—www.aapg.org

Trip #7 (AAPG - SC/SEPM)

Quaternary Depositional Systems of the East Texas Coast and Shelf

Date: Friday, April 7, Leader: John B. Anderson (Rice University), Fee: Students Only \$25.

Trip #8 (SEPM)

Mass Transport Complexes and Thin-bedded Turbidites in the Paleocene Chicotepec Formation, Northeastern Mexico, Date: Tuesday, April 4– Friday, April 7, Leaders: Stephen P. J. Cossey (Cossey and Associates, Inc.), Fee: \$1,325.

Trip #11 (SEPM)

Carboniferous Mounds Architecture, Sacramento Mountains, New Mexico

Date: Thursday, April 13– Saturday, April 15, Leaders: Xavier Janson (BEG, Texas) and Steve Bachtel (ConocoPhillips), Fee: \$735.

Trip #12 (SEPM/AAPG)

Quaternary Depositional Systems of the East Texas Coast and Shelf

Date: Thursday, April 13, Leader: John B. Anderson (Rice University, Houston, TX), Fee: \$280

Trip #13 (SEPM)

Carbonate Reservoir Heterogeneity Styles: Albian (Cretaceous), Pecos River Canyon

Date: Thursday, April 13– Sunday, April 16, Leaders: Charlie Kerans and Laura Zahm (BEG, Texas), Fee: \$875



2006 SEPM-GSL Joint Research Conferences



March 27-29, Burlington House, London, UK

External Controls on Deep-Water Depositional Systems: Climate, Sea-Level, and Sediment Flux

Conveners: Ben Kneller (Aberdeen), Ole Martinsen (NorskHydro), Bill McCaffrey (Leeds) & Henry Posamentier (Anadarko)

INFORMATION: WWW.GEOLSOC.ORG.UK/DEEPWATER

July 11-13, Snowbird Resort, Utah, USA

The Application of Earth System Modeling in Exploration

Conveners: Paul Markwick (Leeds), Joe Curiale (Chevron) & John Suter (ConocoPhillips)

INFORMATION: WWW.SEPM.ORG/EVENTS/RESEARCHCONFERENCES/RCONFERENCEHOME.HTM

SHORT COURSES & CORE WORKSHOPS

PLAN AHEAD FOR THE 2006 AAPG-SEPM ANNUAL MEETING—HOUSTON, APRIL 9-12
REGISTER EARLY TO RESERVE YOUR PLACE—WWW.AAPG.ORG

Course #14 (SEPM)

Sequence Stratigraphy for Graduate Students, Date: Saturday-Sunday, April 8-9

Instructors: Vitor Abreu and Jack Neal (Exxonmobil), Fee: Grad Students-Free¹ / Professionals \$250 each.

Course #15 (SEPM)

3-D Seismic Interpretation for Geologists, Date: Saturday—Sunday, April 8-9

Instructor: Bruce Hart (McGill Univ.), Fee: First 20 Grad Students-Free² / Professionals \$300 each.

Course #16 (SEPM/AAPG)

Core Workshop: Giant Hydrocarbon Reservoirs of the World: From Rocks to Reservoir Characterization and Modeling, Date: Saturday-Sunday, April 8-9, Conveners: P.M. (Mitch) Harris (Chevron) and L.J. (Jim) Weber (Exxonmobil), Fee: Professionals \$250 / Students \$50³.

Course #17 (SEPM)

Applied Ichnology: The Use of Trace Fossils in Sequence Stratigraphy, Exploration and Production

Geology, Date: Thursday-Friday, April 13-14, Instructors: S. George Pemberton (Univ. Alberta) and James MacEachern (Simon Fraser Univ.), Fee: Professionals \$280 / Students \$140.

Course #18 (SEPM)

Quaternary Reefs and Platforms: Bridging the Gap between the Ancient and the Modern, Date: Thursday-Friday, April 13-14, Conveners: William F. Precht (PBS&J), P.M. (Mitch) Harris (Chevron) and Richard Aronson (Dauphin Island Sea Lab), Fee: Professionals \$340 / Students \$170.

Students Sponsored by ¹-Exxonmobile, ²-ConocoPhillips and ³-Chevron