and Peratherium innominatum, are well represented in the screen washed concentrate. An upper incisor of an apatamyid has also been recovered. Three lithopithecian species include 1) a new species of Macrocanon (the most abundant species at the locality), 2) a new very small nyctitherium, and 3) a relatively larger species known only from a multiblast 12. An upper molar of a very diminutive microsyopidae has also been recovered and it is smaller than any described species known from the upper dentition. The Castle Gardens fauna also includes three rodent species. A new species of Acrioteparamys is known from more jaws than any other Castle Gardens taxon, while Paramys copei and P. saurus are only known from a single specimen each. Additional larger mammals found in the screen washed concentrate include Hyaenotherium grangeri, Ectocion parvus, Phenacodus vortmani, Copecon davisi, and Acacitris ranii.

Castle Gardens is a very successful screen wash locality. The combination of surface collecting and screen washing has resulted in the collection of over 200 specimens, representing twenty-eight mammalian species, vastly increasing our knowledge of mammal evolution during the earliest Wasatchian.

EVALUATION OF TWO METHODS FOR ESTIMATING MISSING DATA IN MORPHOMETRIC STUDIES OF VERTEBRATE SKELETONS

STRAUSS, Richard, Biological Sciences, Texas Tech University, P.O. Box 3131, Lubbock, TX, 79409-3131; ATANASSOV, Monkchil, Geosciences, Texas Tech University, Lubbock, TX 79409-1053.

Vertebrate skeletons, particularly fossils, commonly have structures that are damaged, distorted, or missing. Because multivariate morphometric methods require complete data matrices, there are two possible solutions: (1) to omit the specimens or characters having missing values, or (2) to estimate missing values from the remainder of the data. Omission of specimens or characters has the disadvantage of reducing the power to detect patterns or differences. Estimation of missing values is useful when the positions of the missing data are a representative sample of the entire data set, but is thought to reduce variation.

Two common multivariate methods for estimating missing data are based on character covariances: (1) the expectation-maximization (EM) method, which uses the covariance matrix, and (2) the principal-component (PC) method, based on regression of character states on components. We evaluated their performance by simulation of random missing data in complete data (Pterosuchus) and recent (Alligator, Canis) data sets, and by introducing missing data into generated structured matrices. The latter involved homologous matrices of varying size but representing differing numbers of specimen groups and character suites; matrix structure was assessed by three heterogeneity measures. We tested the reliability of predicted values, the largest proportions that can be estimated, and the dependence of predictions on matrix size. For homogeneous data matrices, the EM method was found to perform much better than the PC method, giving reliable estimates for up to 50% missing data. Performance of the EM method degraded little with increasing heterogeneity, indicating that the algorithm is robust.

STEGOCERAS VISITED

SULLIVAN, R. M., Section of Paleontology and Geology, The State Museum of Pennsylvania, Third and North Streets, Harrisburg, PA 17108-1026

The dinosaur genus Stegoceras (Ornithischian: Pachycephalosauridae) has held the dubious distinction of being one of the most studied, yet poorly understood, dinosaurs ever since its recognition. Confused originally with Iguanodon (Theropoda), Stegoceras (sensu lato) has been the recipient of a number of species, most of which have been placed in synonymy with S. validum, or have been transferred to new genera (i.e. Gravitholos, Ornatotholos) while others have been interpreted as being sexually dimorphic. Morphometric studies have done little to clarify the taxonomic identity of various morphotypes within Stegoceras (sensu lato). Moreover, the interpretation that gender recognition is possible among Stegoceras (sensu lato) is rejected in the absence of a taxonomic revision of the genus.

A preliminary assessment suggest that Stegoceras validum (sensu stricto) is a primitive pachycephalosaur characterized by a well-developed squamosal shelf and open supratemporal fenestra; Ornatotholos browni has a partial identical to S. validum and is therefore a subjective junior synonym. Those specimens represented by flat frontal are considered a sexual dimorph (possibly female) of that species. "Siegoceras" lambi is the oldest Northern American species. It is distinct from S. validum and represents a new taxon. "S." sternbergi and Gravitholos albertae are the same species; thus Gravitholos sternbergi is a new combination. I have demonstrated elsewhere that "S. breve" and "S. edmontonensis" are in fact referable to the genus Prenocephale, P. brevis and P. edmontensis respectively. Consequently, this taxonomic revision demonstrates that small to medium sized pachycephalosaurs were rather diverse during the late Campanian (Judithian).

REFINING THE CONCEPT OF THE LATE PALEOZOIC CHRONOFAUNA: EARLY PERMIAN VERTEBRATES OF THE EarLIEST EXCLUSIVELY TERRESTRIAL ECOSYSTEM

SUMIDA, Stuart S., Biology, California State University San Bernardino, 5500 University Parkway, San Bernardino, California, 92407; EBERTH, David A., Royal Tyrell Museum, Drumheller, Alberta T0J 0Y0, Canada; BERNAN, David S., Section of Vertebrate Paleontology, Carnegie Museum of Natural History, 4400 Forbes Avenue, Pittsburgh, Pennsylvania 15213.

The fossilization of most Late Paleozoic terrestrial tetrapods is frequently biased toward aquatic or semi-aquatic environments, or the intersection of such with semiterrestrial to terrestrial environments. Thus, confident determination of exclusively aquatic, intermediate, and exclusively terrestrial faunal components is difficult. In this regard, the Bromacker section of the Lower Permian, Tambach Formation, central Germany, contains important vertebrate-fossil localities that were situated near the center of a small, internally-drained paleo-graben. Sedimentological analysis of the graben setting indicates that it preserved elements from a strictly terrestrial, vertebrate-fossil assemblage which comprise a unique uplands paleoecosystem, heretofore undocumented in the Early Permian. Depositional events at both stratigraphic intervals of Bromacker were dominated by subseasonal-to-seasonal cycles of flooding in an ephemeral, alluvial-to-lacustrine setting that was hot year-round with annual precipitation similar to that of a savanna or wetter climate. Excellently preserved, articulated and disarticulated fossil vertebrates indicate virtually no transport on the floodplain prior to final burial. Significantly, Bromacker records a complete absence of aquatic fishes and amphibians, or even semi-aquatic amphibians. The faunal assemblage is dominated by the terrestrial herbivore Diadectes. Other terrestrial amphibians and reptiles are present but less common. Rarest of all are top level carnivores, represented by only a single specimen of the pelycosaur-grade synapom Dintrodex. Analysis of the faunal distributions at Bromacker allows for the first time definition of a confidently terrestrial component to Late Paleozoic paleofaunas. This in turn will allow more confident definition of exclusively aquatic and intermedieate organisms in mixed faunal assemblages already known from the North American Lower Permian.

NIPPONOSAURUS SACHALINENSIS NAGAO, 1936 (DINOSAURIA; HADROSAURI- DAE): ANATOMY AND SYSTEMATIC POSITION

SUZUKI, Daisuke, Earth and Planetary Sciences, Hokkaido University, Faculty of Science, North 10, West 8, Kitaku, Sapporo, Hokkaido, 060-0810, Japan; WEISHAMPEL, David B, Cell Biology and Anatomy, Johns Hopkins Univ., School of Medicine, Baltimore, MD 21205; MINOURA, Naoji, Hokkaido University Museum, North 10, West 8, Sapporo 060-0810, Japan.

Nippinosaurus sachalinensis Nagao, 1936, a number of Hadrosauridae, is the first-discovered dinosaur in Japan. However, it previously was regarded as a dubious taxon because the species was not based on well-defined osteological characters. In addition, since it had not been part of succeeding studies over the past 60 years, Nippinosaurus has become somewhat of an enigmatic dinosaur.

In this study, we make clear the ontogenetic stage, diagnostic characters, and systematic position of Nippinosaurus by redescribing and phylogenetically analyzing the type specimen. The type specimen of Nippinosaurus is based on a subadult individual and has several diagnostic characters. The phylogenetic analyses using 90 characters for 23 ingroup and three outgroup taxata, indicates that Nippinosaurus belongs to Lambeosaurinae and makes a small clade with Hypacrosaurus altispinus. Moreover, Hadsosauridae is collapses in our analyses and Prosaurolophus and Saurolophus are positioned as the outgroup of Lambeosaurinae. This conclusion, which differs from former studies, is due to the addition of many newly-found postcranial characters and revision of former hadrosaurine synapomorphies. This result appears to show that hadrosaurid postcranial characteristics are conservative and therefore retain a transitional state in their characters.

BUILT FOR SPEED—A BIOMECHANICAL ANALYSIS OF THE DISTAL PHALANGES OF TYRANNOSAURUS REX, A THEROPOD DINOSAUR

SWEENEY, Frank, Dinosaurs International Inc., P.O. Box 298, Shaver Lake, CA, 93664.

CAT scans and stereo x-rays used to study the structure of the distal phalanges of Tyrannosaurus rex reveal a biomechanical optimization of strength while minimizing mass of the bony elements. The broad articular surface is a spun solid composed of two half arches back to back. This creates a curved l-beam shape that wraps around the distal end of the bone. Such a structure produces a maximum surface for joint contact while minimizing mass. The epiphysis transitions to, and is supported on, a circular column of bone that transfers force evenly to the diaphysis. The distal diaphysis is domed-shaped (a spur arch). This shape causes the force to be transferred to the cortex of the phalangeal diaphysis. The result of this arrangement is that strength of the element is maximized while minimizing the mass of the distal epiphysis. This minimizing of the bony elements of the distal phalangeal results in the familiar 'dimples' in the sides of the theropod metatarsals and phalanges. Since bone is denser than other tissues this minimizes the distal mass of the limb element. Minimizing the mass of a limb element distally reduces the inertia, which reduces the energy required to accelerate that element. That in turn maximizes the acceleration for a given energy expenditure. The efficiency of this structural-functional group suggests that acceleration and speed were important forces in the evolution of the distal phalangeal elements of the Tyrannosaurus rex foot.