The Paleontograph

A newsletter for those interested in all aspects of Paleontology
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From Your Editor

Welcome to our first issue for 2014. I hope you had a good holiday season. I was trying to get this issue out last month but time just got away from me. I just back from the Tucson show. I had a great time seeing many cool fossils and many cool friends. I don't think I saw anything new and fabulous. There were many of the standards. I did see one very cool Cretaceous fish, a rare species and probably the most complete one ever found. I hope it ends up in a museum. There is a line that amateurs and commercial dealers have to walk, where we can find a scientifically valuable fossil and you have to decide whether to keep it, sell it or donate it. I've donated many fossils to many museums around the country but sometimes the expense and effort preclude a donation. We all need to work together but personalities often get in the way. There are many professional paleontologists that work together with amateurs and commercial dealers and many that absolutely refuse to even consider the concept. Too bad.

I have some good stuff for you this month.

The Paleontograph was created in 2012 to continue what was originally the newsletter of The New Jersey Paleontological Society. The Paleontograph publishes articles, book reviews, personal accounts, and anything else that relates to Paleontology and fossils. Feel free to submit both technical and non-technical work. We try to appeal to a wide range of people interested in fossils. Articles about localities, specific types of fossils, fossil preparation, shows or events, museum displays, field trips, websites are all welcome.

This newsletter is meant to be one by and for the readers. Issues will come out when there is enough content to fill an issue. I encourage all to submit contributions. It will be interesting, informative and fun to read. It can become whatever the readers and contributors want it to be, so it will be a work in progress. TC, January 2012

Edited by Tom Caggiano and distributed at no charge

Tomcagg@aol.com

Fossil Sites of Michigan

Jack Stack

These are some of the best public fossil sites in the state of Michigan. These sites are easily found and collected at and are a great way for any fossil collector to expand his/her collection. Most of these sites contain Middle Devonian age marine invertebrate fossils, with a few exceptions. Although one of these sites is not in Michigan, it contains fossils that are similar to those found in Michigan and is very close to Michigan. It is important to remember that these sites are a natural gift, and must be treated with utmost care and respect to preserve them for future generations. With that being said it is also important to have fun and enjoy the beauty of the natural world. Fossil hunting tours of several of the below sites are available. For more info go to http://www.paleojoe.com/default.asp?iId=JDMGM.

Besser Museum Fossil Park
The Besser Museum Fossil Park is a pile of limestone in the center of a square formed by large limestone blocks, with a large and well done mural depicting what the area was like during the Devonian. On this mural one can see reconstructions of fossils found in the park. The fossil park is located next to the Besser Museum near downtown Alpena, which has a large sculpture of an eagles head out front. This is the best fossil park in the state for fossil hunting for several reasons. It is filled with rocks taken directly from the Lafarge Quarry, a limestone quarry in Alpena, which allows the average fossil hunter easy access to normally hard to obtain fossils.

You can take as much as you want, and the fossils are abundant and well preserved. Here you can find stromatolites, corals, bryozoans, trilobites, gastropods, and crinoids. You will need a hammer, chisel, bucket/ container, packing material, knee pads, glue mixture, a dental pick, a tool box for holding it all, and a coat if the weather is bad. If you are willing to pay for access to a second similar arrangement behind the museum, the material is less picked over. Also, the museum is very well done and has several interesting exhibits on the history of the Alpena area.

The mural at the Besser Museum Fossil Park by Judith Dawley

Rockport Quarry
Rockport Quarry is an abandoned strip mine about 15 minutes north from Alpena. This site is more suited for dedicated fossil hunters, as it is harder to get to and requires some hard work. To get there, drive north along U.S. 23. You will drive along Long Lake until you reach Rockport Road. Follow Rockport road for three miles until you reach a parking area on the shore of Lake Huron. From here walk down a footpath heading north through the woods for about a quarter mile. Halfway along you will cross a large hill. When you reach a huge clearing full of long, parallel piles of shale laid out diagonally to the trail, you have arrived. In the crisscrossing piles of shale you can find many large horn and colony corals, branching bryzoans, and stromatolites, along with the occasional trilobite, brachiopod, crinoid, or fish. Fish are usually large plates that are often mistaken for stromatalites, to tell, look at the side of the specimen and check to see if it continues into the rock. If it doesn't, it is a fish. These fossils come from a once thriving reef, from a very different time in Michigan's history. Also, one can find railroad spikes or tools from when the mine was in operation. These tools include railroad spikes and ties, nails, telegraph poles, springs, slag, screws, washers, and hinges. Be careful, there is modern trash mixed in with the good stuff.

Point Betsie
Point Betsie is a beach next to the lighthouse named Point Betsie a few minutes north of the town of Frankfort. It is located on Lake Michigan, and is an absolutely beautiful area. This is not only an excellent place for fossil hunting, but a good place for swimming and general rock collecting.

Cont'd

Michigan Sites Cont'd

Here you can find corals, bryozoans, and brachiopods, and even the elusive Petoskey Stone. Although these fossils are usually distorted by erosion caused by the motion of the waves, many are quite beautiful. They can make beautiful display specimens, especially the Petoskey Stone.
The best place to find fossils is at the waterline, where the wetness of the rocks shows the fossil more clearly for the untrained eye. There are also some of the best skipping stones in the state.

Burkholder Road Site
The Burkholder Road Site is a ditch right next to Sytek Park near Bagley Road in Alpena, Michigan. It is hard to see but it is one of the best fossil sites in Michigan for beginners. Traveling west on route M32, turn right (north) on Bagley Road. The first intersection is Burkholder Road, which only goes to the left (west). You can park next to the ditch, but the park is best if you have more than one person. If you've passed the river you've gone too far, in fact the ditch drains into the river. No tools but a dental pick, a hand lens, and a container are necessary!

You can pick the fossils up with ease, but you will need to clean them. You can find crinoids, corals, bryzoans, gastropods, brachiopods, the occasional trilobite and rare blastoids. The fossils literally carpet the side of the ditch farthest from the road. This site has the best gastropods anywhere outside of a quarry. You can take as much as you want from the ditch, but most of the land above the ditch is private property. The right side of the ditch is far more productive, but the center also has some fossil material.

A view of the Burkholder Road Site from Bagley road.

The Walgreens Site
This site is a large backfill pile next to the Alpena Walgreen's store, just south of the M32-Bagley Road intersection. At this site you can find many bryozoans and stromatolites, along with some brachiopods. The origin of the rocks in the pile is unknown. The pile itself is covered with nettles, but many fossils can be found below the pile in a lower area.

Platte River
The Platte River is located in Northwest Michigan, north of Frankfort, with a campground and a park located on Lake Michigan. To get there turn from North Scenic Highway 22 onto Co Highway 708 which becomes Lake Michigan Road. Near where the river empties into Lake Michigan, one will find black rocks which contain brachiopods, bryozoans, corals, and the occasional trilobite. These rocks are found near where the river merges with Lake Michigan, and are well mixed up with the other rocks. Farther up the beach one can find some Silurian corals,mostly Halysites.

Marquette
Marquette is a city in the Upper Peninsula of Michigan and has the oldest rocks in all of Michigan, from the Archean age. These rocks, while containing few fossils, are fascinating. The fossils found in these rocks are stromatolites, ancient cyanobacteria that are some of the earliest forms of life. Several outcroppings can be searched for specimens, but the stromatolites are hard to move without destruction. Several public exposures are found on the shores of Lake Superior, just south of Marquette. Do not attempt to climb the cliffs or hammer rocks out of them. These are beautiful natural gifts that should be preserved for future generations.

Bibliography
A Complete Guide to Michigan Fossil Hunting: Joseph Kchodl

Ed. Note:
I would love to have more articles like this. Why not write one about your area?

LAGs Do Not Imply Ectothermy

Bob Sheridan July 28, 2012

Cut a cross-section through the long bone of most modern reptiles and one can see concentric "lines of arrested growth" (LAGs). These presumably represent times where the growth of the bone has slowed, presumably once per year. Therefore, one can use the LAGs to estimate the age of the animal, much as one could with tree rings. Most dinosaurs have LAGs in their bones as well, and there is a whole field that uses the LAG-estimated age of dinosaurs to estimate their growth rate.

There has been an implicit assumption that the time of "arrested growth" appears seasonally because, during the winter, the temperature of ectothermic (i.e. "cold-blooded") animals falls, and their metabolism and grow rate falls as well. This idea is consistent with the fact that birds and mammals, which are endothermic, appear to not have LAGs. However, since birds grow very rapidly and most of the mammals examined so far have been small, one can not really distinguish between "LAGs means the animal is ectothermic" and "LAGs mean the animal reaches full growth in one year."

The approach to tease these apart is to examine endothermic animals that do not attain full growth in a year. Kohler et al. (2012) examine the bone histology of 100 wild ruminants (deer, giraffe, bovines, etc.) from a variety of latitudes. Ruminants are ideal for this study because they exist throughout the world, represent advanced mammals, and can take several years to grow. The results are unambiguous. LAGs occur in all the ruminants, from the smallest to largest, and from all climates.

Clearly the LAGs in ruminants do not have to do directly with the temperature of the growing bone, which in mammals should be more or less constant. The authors suggest that LAGs have more to do with annual changes in food availability (plants, in the case of ruminants). In the tropics this would be controlled by with drought vs. the rainy season. At the poles, this would be the amount of sunlight. We know some modern mammals seasonally adjust their metabolism to the season, and this would support that idea.

Not mentioned in this paper are carnivorous animals, who are not directly dependent on plants. We know carnivorous theropod dinosaurs have LAGs. It would be good to next look for LAGs in carnivores like the big cats.

Sources:

Kohler, M.; Marin-Moratella, N.; Jordana, X.; Aanes, R.
"Seasonal bone growth and physiology in endotherms shed light on dinosaur physiology." **Nature** 2012, 487, 358-361.

Padia, K.
"A bone for all seasons."
Nature 2012, 487, 310-311.

Abominable Science!--A Review

Bob Sheridan, December 10, 2013

Normally I wouldn't review a book for the Paleontograph that didn't have a strict paleontological theme. However, I am making an exception for "Abominable Science!," a book debunking cryptozoology. Cryptozoology is the study of animals that are unknown to science, but that many believe exist. "Cryptids" is the general name given to these animals. The first author of "Abominable Science" Daniel Loxton is a writer for Skeptic magazine, published by the Skeptics Society. The second author Donald Prothero is a paleontologist at the Department of Vertebrate Paleontology at the Los Angelos County Natural History Museum.

There are three reasons for my review:

1. For every cryptid there are those who think it is from a group thought to be extinct, e.g. the Loch Ness Monster is proposed to be a plesiosaur, the yeti is proposed to be Gigantopithecus (a large Miocene ape related to orangutans), Mokele Mbembe is proposed to be a sauropod, etc.
2. Belief in cryptozoology has a lot in common with disbelief in evolution.
3. Donald Prothero wrote a book "Evolution. What the Fossils Say and Why It Matters" (2007) which I greatly admire.

Cont'd

Abominable Cont'd

This book covers five specific cryptids and the evidence (or more pointedly the lack of evidence) for them as separate chapters:

1. Bigfoot (the sasquatch).
2. The yeti (the abominable snowman).
3. Nessi (the Loch Ness Monster)
4. Sea serpents

5. Mokele Mbembe (the Congo dinosaur)
The opening chapter is "Cryptozoology: science or pseudoscience", and the final chapter is "Why do people believe in monsters?"

Belief in cryptids has a broad popular appeal. For example, it seems every other show on Animal Planet or the History Channel concerns finding Bigfoot or Nessi. Off the top of my head, I can name at least one feature film about each. With the possible exception of Bigfoot, which is thought to be found in many different places in North America, the presumed locations of these animals are popular tourist spots.

Belief in the cryptids listed above is an amalgam of eyewitness testimony, reinterpretation of local legends, overly hopeful interpretation of trace evidence like footprints, and uncritical acceptance of obvious hoaxes or deliberate distortions. The presumed appearance of the animal changes with time and is highly influence by popular culture. Many searches are done, but they come up empty. Belief continues no matter how much the "evidence" is shown to be faulty (a photographer confesses to faking photos of Nessi, the "yeti scalp" is shown to be made from the pelt of an Asian ungulate by DNA testing, etc.). Science believes in the lowland gorilla, the okapi, and the coelacanth, animals that were unknown a relatively short time ago, because we have a body, live or otherwise. There is no physical body for any of the cryptids above, and hardly any other evidence that can withstand scrutiny.

This book makes several important non-obvious points, that can apply to any of the cryptids, but that I will illustrate with the "sea serpent" a presumed enormous snake-shaped creature that lives in the ocean. It is usually drawn with several coils or humps protruding above the surface.

1. The eye is easily fooled, especially in the ocean where it is hard to estimate distance. Many things that are not serpents can take on a serpent-like appearance. A school of dolphins following each other can easily mimic the protruding coils of a serpent. Waves or large clumps of seaweed on an undulating surface can take on a serpent-like appearance. As a matter of fact, any randomly placed collection of rounded objects seen from the side can look serpent-like.

2. Legends are of much more recent origin than we would expect. Since humans have been sailing the ocean for a long time, one would expect descriptions of sea serpents to go back a long way. However, while sailors have described various monsters in the ocean, and there are many legends about giant land serpents, there are no reports of the sea serpent until the early1800s.

3. We see the monsters we are familiar with from popular culture, and this changes with time. Many of the ancient descriptions of sea monsters resemble the hippocamp, a chimera with the head and forequarters of a horse (sometimes with front fins instead of hoofs), and the hindquarters of a fish. The hippocamp is an artistic convention of the Greeks borrowed by the Romans. Serpents in the sea were not described until fossil sea creatures like the ichthyosaur and plesiosaur were discovered.

4. Many cultures do not clearly distinguish between facts, stories, and beliefs, so it is hard to rely on stories from locals. This is sometimes true even in our own culture. If a stranger from a foreign culture came to your house and asked about Santa Claus, you might describe the sleight, eight reindeer, etc. without thinking to point out that Santa is fiction. Also cultures in remote areas are not as out of touch as we think; they almost always have access to Western popular culture, which can influence their descriptions.

5. There is something contradictory about the sightings of cryptids. The animals are common enough that many people see them, but no one comes across a corpse, and there is no fossil record of similar animals.

This book does not discuss the chupacabra ("goat sucker"), but it does fit point 3 perfectly. This is a monster that supposedly attacks livestock and drains them of their blood. It was described by witnesses in Central American and the Caribbean as large and rodent-like, or reptilian. In the past few years people have posted on the internet pictures and videos of what appears to be a hairless coyote (probably from mange), claiming this was the chupacabra. Clearly these are hoaxes or practical jokes, but soon after, sightings of the chupacabra described a smaller, more dog-like animal, and there was at least one scifi movie on television with a wolf-like chupacabra.

Cont'd yet again

Abominable Cont'd

So why do people persist in believing in animals for which there is no evidence? There are many possible reasons discussed in this book, some of them pretty complex, some of them pretty simple. The most simple is monetary: you can attract tourists by pretending there is a monster in your town. The more complex ones have to do with human nature: people want to find something new and exciting, and people also like to thumb their nose at authority (Science in this case). The most depressing explanation is that people have many irrational beliefs and don't appreciate basic concepts of critical thinking like "burden of proof" or "Occam's razor". Finally, there is a discussion about whether cryptozoology can be turned into a real science, and whether cryptozoology does any harm. No resolution there, but interesting.

The writing of "Abominable Science!" is good, if a little dense in places. The illustrations are apt, although not plentiful. I was not aware of most of the information therein. This book is worth a read.

Sources:
Loxton, D.; Prothero, D.R.
"Abominable Science! Origins of the yetti, Nessi, and other famous cryptids."
Columbia University Press, NY, 2012, 411 pages.
$30 (hardcover).

Five Skulls from Dmanisi

Bob Sheridan, October 24, 2013

Human remains from the Pleistocene are very fragmentary. Cranial material tends to be crushed and incomplete, making the reconstruction of hominin skulls a matter of educated guesswork. A recent paper by Lordkipanidze et al. (2013) describes the first complete, undistorted adult skull from the early Pleistocene. This specimen ("skull 5") consists of a cranium (D4500) and a mandible (D2600) that were excavated at different times (2005 and 2000, respectively) from Dmanisi, a town in Georgia (formerly known as Soviet Georgia). Skull 5 joins four other, less complete, skulls from Dmanisi. The skulls are from an elderly toothless male, two mature males, a young female, and an adolescent of indeterminate sex. The sizes of the skulls vary considerably. All the specimens come from what was an underground carnivore den, and the owners of these skulls were probably dragged into the den by a cheetah or other large cat. Dating of the den material places it between 1.85 to 1.77 Myr. old.

One of the most striking things about these skulls is how primitive they are. They have very small brains (~550 cubic centimeters--not much larger than Australopithecus), and very large jaws. Given that skull 5 is intact and undeformed we can be pretty sure this is what early Pleistocene really were like. Analysis of the shapes of the five Dmanisi skulls, plus those from chimps, modern humans, and other hominin specimens is done by means of a principal components plot. The variation of shape among the Dmanisi skulls is about the same as the variation between modern chimps and among modern humans. Interestingly, on this plot the Dmanisi skulls are not really distinct from known members of *Homo erectus, Homo ergaster,* and *Homo habilis*. Thus, while the Dmanisi skulls are obviously early Homo, it is not clear what species name to assign them. The authors feel they are closest to Homo erectus but the name they have assigned reflects the ambiguity: *Homo erectus ergaster georgicus*.

Two new ideas are generated from the Dmanisi skulls:

1. *Homo erectus* is the first hominin to leave Africa. *Homo erectus* was assumed to have a fairly large brain. Now it appears the brain of early Homo like erectus may not have been so large, so perhaps a large brain was not required to leave Africa.
2. If we assume the Dmanisi skulls represent one species, and the variation among them is so large, it is possible that all the species names workers have assigned to early *Homo species (habilis, erectus, ergaster, rudolphensis*) were really a single species.

Sources:

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"Stunning skull gives a fresh portrait of early humans."
Science 2013, 342, 297-298.

Estimating the Mass of Fossil Birds as Accurately as Possible

Bob Sheridan, December 6, 2013

An estimate of the body mass of fossil animals is critical for saying anything about their physiology, evolution, etc. There are basically two ways of estimating the mass. The first is to build a scale model (real or virtual) of the living animal, measure the volume of the model, scale up to the volume of the model to that of the living animal, then use an estimate of the density of living animals to get the mass. Of course, the limit of this is that most fossil animals are not known completely enough to build an accurate model. Even if the animal is known completely, one can build a skinny or fat model, so there is a large error in the mass estimation.

The second way is to find a measurement X from the skeleton that correlates highly with mass (M) in living animals, and then use the equation that links M to X to estimate the mass of fossil animals. Of course, M will almost always have some detectable correlation with the cube of X, where X is some linear measurement. Typically, to generate an equation, one graphs the log of M against the log of X for a number of different animals. (One can use the "natural log"--base 2-- or the "common log"--base 10. It doesn't matter as long as you are consistent.) Hopefully all the values will fall on a straight line from which one find a slope and intercept. Just a few technical details more. The correlation between log(M) and log(X), i.e. the scatter around the straight line is measured by R-squared. R-squared can go from 0 (no correlation) to 1 (perfect positive or negative correlation). One issue with mass estimates in the literature is that workers do not provide error bars on their estimates. The root-mean-square deviation (RMSE) of points from the line in the plot is one type of "error-bar" on the estimate of M, the smaller RMSE, the more reliable. For instance an estimate of the mass could be 50 +/- 10 grams. Another might be 50 +/ 40 grams. Obviously the first estimate is more meaningful. Typically higher R-square means a smaller error-bar.

The trick to the correlation approach is to find an X where the correlation is very high (i.e. where the error bar is small) and where measurement X involves a bone that is very often preserved in fossils. For instance, one of the most used X is the circumference or length of the femur, which is probably the least fragile long bone in the vertebrate body. Another popular X is the length of the first molar. The drawback of the correlation approach is that the slope and intercept you derive from the living animals might not apply to the fossil animals you are interested in. For example, the relationship between M and X in quadrupedal mammals might not apply to bipedal dinosaurs.

The paper I am going to review today concerns the mass of flying birds generated by the correlation approach. Field et al. (2013) measured various aspects of ~830 bird skeletons (in the Yale Peabody collection) from 18 avian orders and compared those measurements to literature values of the masses for those species. This is by far the largest sample studied for this purpose. The masses vary by 3.5 orders of magnitude (hummingbird to condor). There are 13 types of measurements X involved (femur length, humerus length, coracoid width, etc.). One seldom used measurement included here is the width of humeral articulation facet in the coracoid (HAF). This requires a small explanation. In birds the coracoid bone connects to the sternum at the bottom and the scapula at the top. Near the top is a deep horizontal groove into which the humerus articulates. The HAF is the maximum width of this groove.

In this data, log(M) is highly correlated with log(X) for all 13 measurements with R2-squared varying from 0.65 to an almost perfect 0.99. As you might have expected from the previous paragraph, the almost perfect X is HAF. The next best X's are femur circumference and humerus circumference (at 0.95). That the HAF is best makes biomechanical sense in that the HAF would reflect the robustness of the joint, which is bearing the weight of the bird during flight. Also it is fortunate in that the coracoid bone is dense and often preserved in bird fossils.

The authors are also able to show that the lines for log(M) vs. log(X) for X=HAF constructed separately for 18 individual orders of birds are nearly coincident, indicating that the relationship is not much influenced by the lifestyle or other anatomical features of the bird. The most popular measurement in the past for estimating bird mass is the femur length. However the relationship of M and femur length varies much more among bird orders than does the relationship of M to HAF.

Sources:

Field, D.J.; Lynner, C.; Brown, C.; Darroch, S.A.F. "Skeletal correlates for body mass estimation in modern and fossil flying birds." PLoS ONE 8, e82000.

Triceratops to Nedoceratops to Torosaurus--Revisited

Bob Sheridan December 22, 2014

For the past few years there has been a debate between Jack Horner (Museum of the Rockies) and Andrew Farke (Raymond M. Alf Museum of Paleontology) about the status of Triceratops, Torosaurus, and Nedoceratops. These are ceratopsian (horned) dinosaurs that lived in North America at the very end of the Cretaceous. They all have two brow horns and a nose horn. Horner argues that these are not separate species, but form an ontological (growth) series: Torosaurus represents the most mature form of Triceratops and Nedoceratops is an intermediate form. Horner's argument depends on the following:

1. Triceratops, Nedoceratops, and Torosaurus lived at about the same time and in the same place.

2. All known Torosaurus specimens are old by bone histology.

3. Triceratops as a short upturned frill; Torosaurus has a long low frill. Triceratops has a thinning of the frill in the locations where Torosaurus has fenestrae. Nedoceratops is intermediate in these characteristics. In Triceratops the brow horns tend to point more forward in the larger (presumably older) animals, consistent with the forward pointing horns of Torosaurus.

If one could disprove any one of these points, it would be sufficient to disprove the presumed link between Triceratops and Torosaurus. The major difficulty is that, while there are many dozens of Triceratops specimens, there are a handful of Torosaurus specimens, and only one Nedoceratops specimen. That is, we do not have a good enough sample of Torosaurus or Nedoceratops to definitively disprove points 1 or 2.

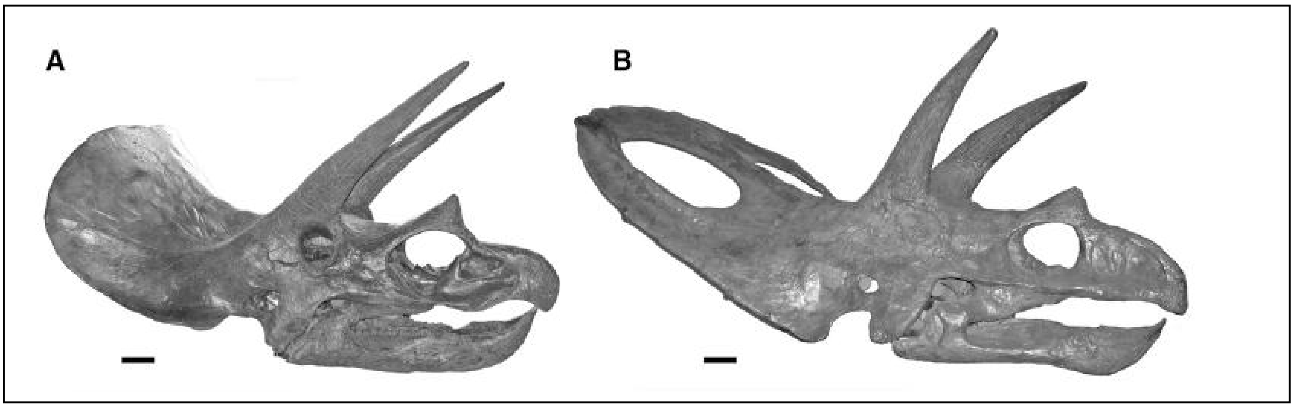
The latest paper I have come across on this topic is from Farke's lab. Maiorino et al. (2013) specifically investigate point 3, whether there is a smooth anatomical trajectory between the three species. These authors measured the distance between a few dozen bony landmarks in 28 articulated skulls and 36 squamosals (the bone that forms the frill). These skulls include two species of *Triceratops (horridus and prorsus)*, two species of *Torosaurus (latus and utahensis)*, and one species of Nedoceratops). The authors use a number of ways of comparing the skulls. For our purposes here we will talk about two ways of plotting the specimens in two-dimensional graphs. The first, the Principle Components Analysis, which is commonly used in studies of this type, is to plot the first two principal components of the distance data. These are the axes along which the specimens differ most in shape. The second type of plot plots the variation in shape on the y-axis, and the effective size on the x-axis. In this way one can follow changes in shape vs. changes in size. The authors generate these two plots for the entire skull, the skull minus the frill, the frill alone, plus the squamosal bone alone. (The squamosal forms the outer edge of the frill.) Different specimens may appear in different plots depending on how complete it is.

In the PCA plots, *Triceratops horridus* and *Triceratops prorsus* are different on the average, but the set of individual specimens overlap a great deal. This is not surprising since many workers maintain there really is only one valid species of Triceratops. Torosaurus is clearly separated from Triceratops. Nedoceratops does not fall between Triceratops and Torosaurus in the PCA plots, except for the frill or squamosal plots. That is, it is not "intermediate" except for frill characters.

The major point made by the authors is seen in the shape-vs-size plot. If there is a growth "trajectory" among Triceratops, there ought to be a correlation in Triceratops specimens between shape and size. That is, as the animals get bigger (older), they ought to also morph into a more mature-looking shape. A correlation implies that the Triceratops specimens fall roughly on a line, and they do (with a fair amount of scatter). If Torosaurus is an older Triceratops specimen, it ought to fall on the same line and be at the larger end of sizes. This is true on the frill or squamosal plots, but not in any of the others. So Torosaurus has a longish frill, as do mature Triceratops, but that is all they have in common. The authors conclude that Torosaurus and Triceratops are separate genera.

Sources:

Maiorino, L.; Farke, A.A.; Kotsakis, T.; Piras, P. "It Torosaurus Triceratops? Geometric morphometric evidence of Late Maastrichtian ceratopsid dinosaurs." PLoS ONE 2013, 8, e81608.



A Triceratops **B Torosaurus**