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U.S. DEPARTMENT OF THE INTERIOR
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Chicxulub impact event

Computer animations and paper models

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Open-file Report 97-442-A

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Description of Report

This report illustrates, by means of computer animations and two paper models, how dinosaurs may have become extinct as a result of an asteroid impact . By studying the animations and the paper models, students will better understand the mass extinctions that have been part of the Earth's history.

Included in the paper and diskette versions of this report are templates for making the two paper models, instructions for their assembly, and a discussion of a possible asteroid impact at Chicxulub, Mexico. In addition, the diskette version includes two animations of an asteroid impact, one view from space and the other from the Earth.

Many people provided help and encouragement in the development of this HyperCard stack, particularly Page Mosier, Sue Priest and Henry Moore. This report was enhanced by reviews from Jim Pinkerton and Richard Pike.

Table of Contents for paper version of this report.

Description of Report

Requirements for using the diskette version are: Apple Computer, Inc., HyperCard 2.2™ software and an Apple Macintosh™ computer with an internal disk drive. If you are using System 7, we recommend having at least 8 MB of physical RAM with 4.5MB of memory available for HyperCard.

The animation is accompanied by sound. If no sound is heard, change the memory of HyperCard to 4500K and ensure that the control panel "Sound," which is in the "Control Panels" folder under the "Apple" menu, has the volume set to at least 2. To change the memory available to HyperCard, quit this stack. Highlight the HyperCard program icon and choose "Get Info" from the File Menu. Change the "memory requirements" to 4500K and start this stack again.

Purchasers of the diskette version of this report, which includes all of the text and graphics, can use HyperCard 2.2™ software (not supplied) to change the model (by adding patterns, symbols, colors, etc.) or to transfer the model to other graphics software packages.

To see the entire page (card size: MacPaint), select "Scroll" from the "Go" menu and move the hand pointer in the scroll window. If you are experiencing trouble with user-level buttons, select "message" from the "Go" menu. Type "magic" in the message box and press return. Three more user-level buttons should appear.

The date of this Open File Report is 7/7/1997. OF 97-442-A, paper copy, 36p.; OF 97-442-B, 3.5-in. Macintosh 1.4-MB high-density diskette.

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Asteroid impact on Earth

Throughout Earth's history several episodes of mass extinctions have resulted in the disappearance of more than 50% of all known species of life in a relatively geological instant, (usually less than 2 million years). Many theories have been proposed to explain this sudden loss of biodiversity. This HyperCard animation illustrates just one of these theories, the theory that seeks to explain why the dinosaurs suddenly went extinct about 65 million years ago. Though the connection between the extinction of the dinosaurs and an extraterrestrial impact event has been proposed several times, a piece of the puzzle was always missing. All that changed with a hypothesis that brought together the fields of biology, geochemistry, and astronomy.

The current asteroid hypothesis dates back to 1980 when a team of scientists at University of California at Berkeley suggested that such an impact might have caused the world-wide demise of many organisms at the end of the Cretaceous Period. What the scientists at Berkeley described was a thin layer of clay, found in ancient marine sediments in Italy, which contained an unusually high concentration of iridium and osmium. These two elements are common in meteorites and probably exist in the Earth's core, but are absent from continental and oceanic rocks in the crust. The scientists also noted that certain kinds of microscopic organisms, called foraminifers, are not found in the younger deposits above this clay layer. The layer marks the Cretaceous-Tertiary (K-T) boundary which is also the boundary between the "Age of Reptles" and the "Age of Mammals." The Alvarez hypothesis named for Walter Alverez, the leader of the Berkeley group suggested that the large concentration of the rare elements iridium and osmium in this clay layer was due to the accumulation of dust generated by the impact of a large asteroid hitting the surface of the Earth.

At the time, scientists had knowledge of many small impact craters on the Earth's surface but had little evidence of very large impact craters.

More recent research located the most likely site of the asteroid impact. A large buried crater located on the northern coast of Mexico's Yucatan Peninsula, Fig. 1, was described by Alan Hildebrand, at the University of Arizona, in 1992. This very large feature, now known as the Chicxulub Crater (pronounced CHICK-shoe-loob), is 180 kilometers in diameter and has characteristics similar to those of impact craters on the moon and other planets. The rocks within the Chicxulub Crater contain shocked granite. The presence of shocked quartz provides additional evidence in support of the impact theory. Special features such as in these rocks indicate that a violent force shocked the quartz grains.

An asteroid impact also would have thrown a large amount of dust into the atmosphere, preventing sunlight from reaching the surface and disrupting the Earth's heat balance for tens of years, if not centuries. Terrestrial and oceanic animals and plants, both large and small, would be affected by the impact. Because the asteroid vaporized limestone, a huge pulse of carbon dioxide was ejected into the air, creating a greenhouse effect. When mixed with rain the sulfur rich dust would produce an "acid rain" (diluted sulfuric acid) which along with the decrease in light, necessary for photosynthesis, stressed or destroyed the land plants. Many of the microscopic marine plants perished approximately 65 million years ago. With the disappearance of these organisms, the food chain was disrupted and marine animals which consumed these plants started to die off. A similar pattern is seen on land, where land plants also started to die off.

With the base of the food chain destroyed both on land and in the ocean, and global temperatures dropping, the dinosaurs, which belong to a class of animals called reptiles, also disappeared. Paleontologists have estimated that more than half of all the species of plants and animals perished approximately 65 million years ago. The smaller animals, including ancestral mammals, had a better chance to survive by feeding on insects and decaying vegetation. Because the fossil record is not perfect and the reasons why animals and plants become extinct is not known exactly, the asteroid impact hypothesis is just one of several hypotheses for the great die-off at the end of the Mesozoic Era. There are many unresolved questions regarding the concept and nature of mass extinctions. By gaining a better understanding of the extinction that occurred at the K-T boundary we may gain a better view of what "could" happen to human life in the future.

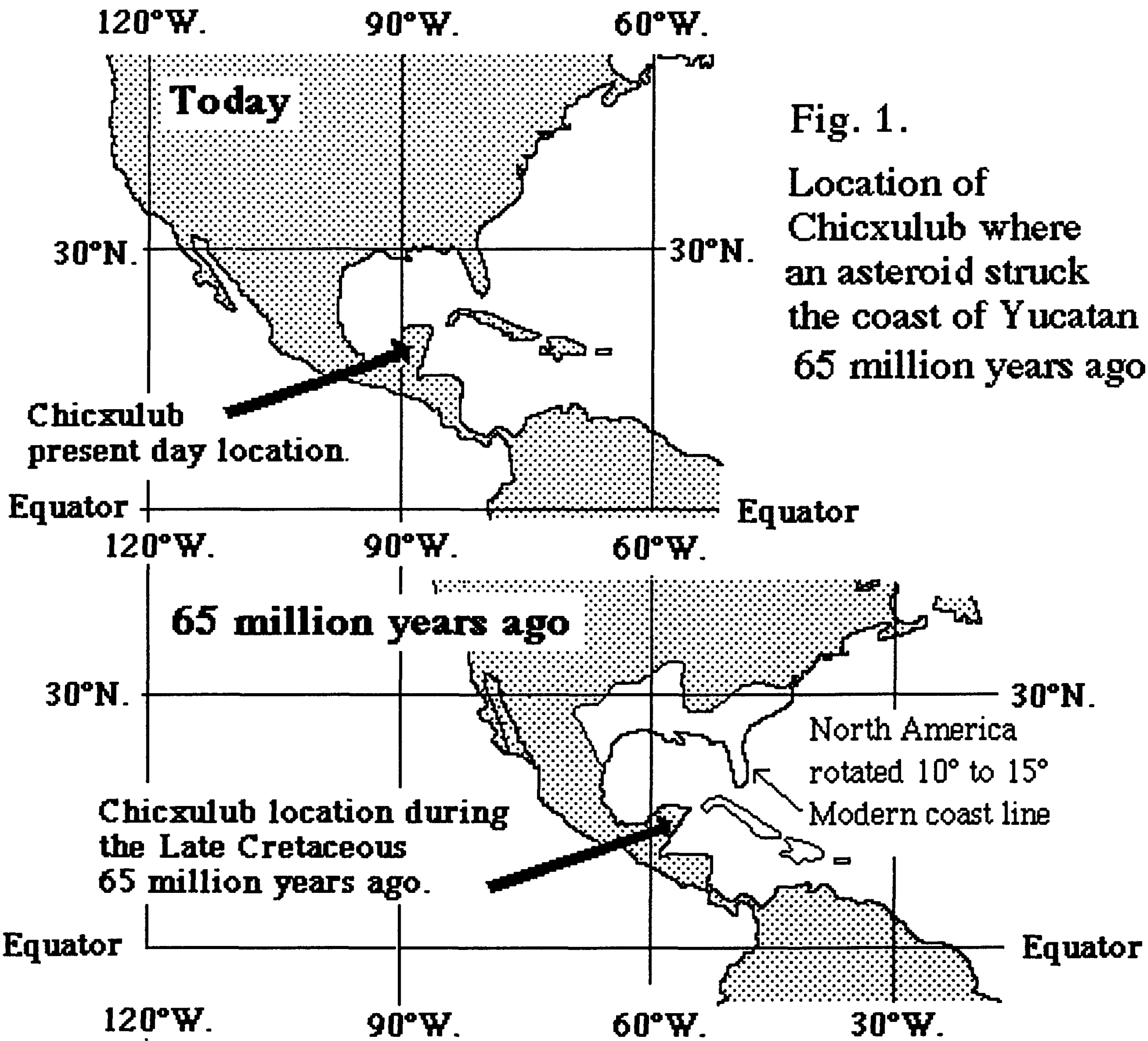
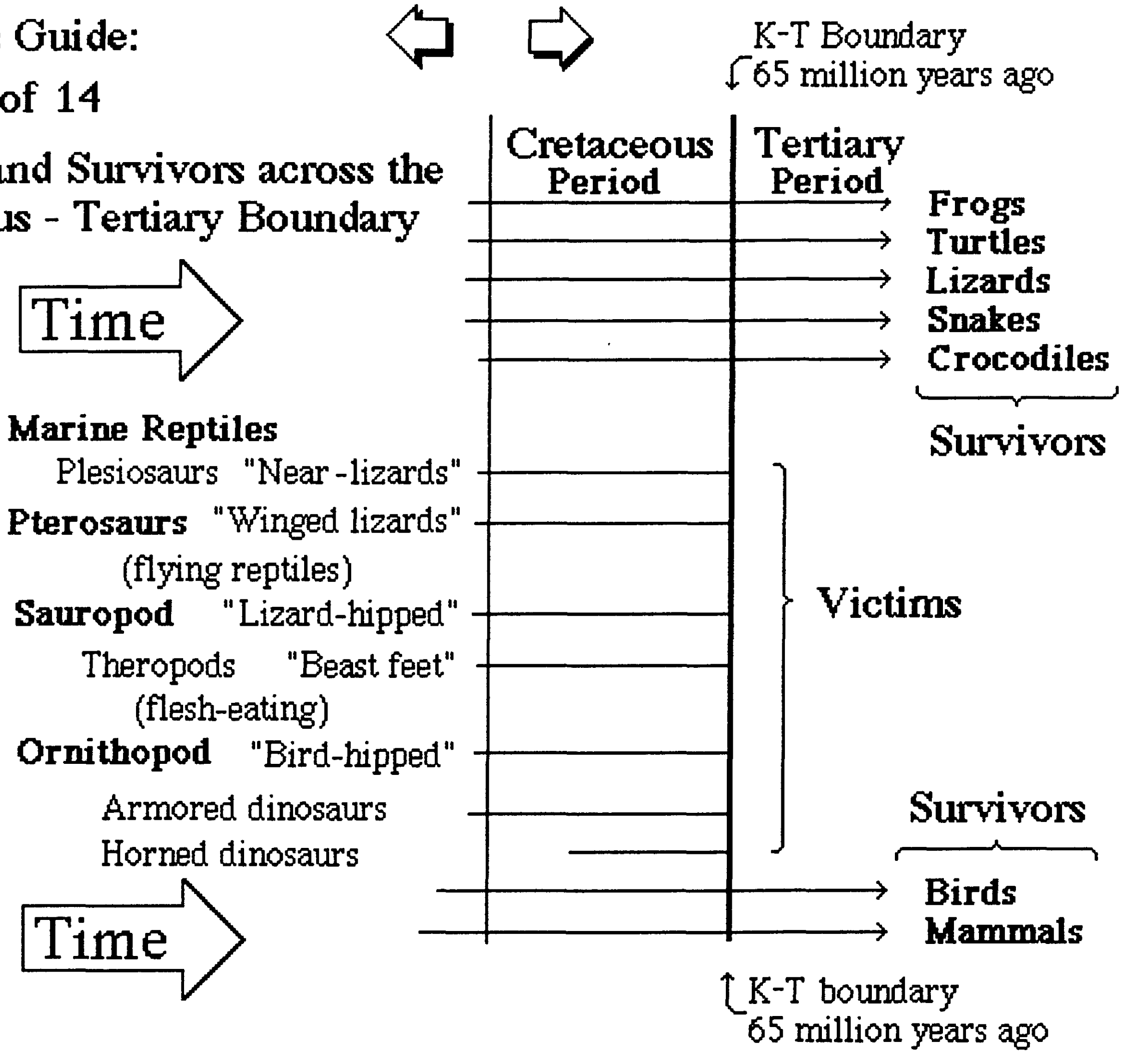


Fig. 1.

Location of Chicxulub where an asteroid struck the coast of Yucatan 65 million years ago.

Victims and Survivors across the Cretaceous - Tertiary Boundary



K-T

Abbreviated geologic time scale

Cenozoic Era	Quaternary	0 (now)
	Tertiary	
		65 Ma
Mesozoic Era	Cretaceous	
	Jurassic	
	Triassic	
		240 Ma
Paleozoic Era		etc.

Time ↑

Ma = mega annum or million years

Although the asteroid impact appears to have affected marine life as much as terrestrial life we have limited our HyperCard animation to just two groups of land animals. We will use the ceratopsians ("horned" dinosaurs) and the Pterosauria (flying reptiles) as examples of land animals which disappeared 65 millon years ago at the end of the Cretaceous.

Introduction to the Ceratopsians - The Horned Faced Dinosaurs

The ceratopsians belonged to the group of dinosaurs known as ornithischians, or "bird-hipped" dinosaurs. About 100 million years ago, during the Late Cretaceous, ceratopsians began to diversify in North America and Asia. As ceratopsans evolved, a wide variety of frill sizes and shapes, as well as, variations in the number, location, and size of horns developed. This diversity in horns is matched by the diversity of horns found on African antelopes today. These large horned or frilled dinosaurs can be divided into groups based on the length of their frill. The *Torosaurus* (bull lizard) is an example of a long-frilled ceratopsian. The animals could attain a length of 25 feet and weigh 8 to 9 tons. The *Triceratops* (three horned face) is a good example of a short-frilled ceratopsian. A *Triceratops* might be up to 30 feet long and weigh as much as 6 tons.

Although no ceratopsians are living today, a modern ecological analog would be the elephant or rhinoceros, large herbivores which travel in herds. Both these animals use their horns/tusks to protect themselves. The rows of grinding cheek teeth and their "beak"-like snout suggest that these animals fed on tough vegetation. Like elephants, ceratopsians probably traveled in herds for protection against attacks from predators like *Tyrannosaurs*. Evidence that the animals traveled in herds comes from fossil "bone beds" in the western United States that contain bones of hundreds of individuals of the same species. Most of the *Triceratops* fossils are found only in rocks of Late Cretaceous age in North America.

Introduction to the Pterosauria - The Flying Reptiles

These flying reptiles ruled the skies in the Late Triassic, Jurassic and Cretaceous Periods of the Mesozoic Era. The pterosaurs (Greek for "winged lizard") included the largest vertebrates ever known to fly. The pterosaurs can be divided into two groups based on the length of their tail. A long-tailed variety, the Rhamphorhynchoidea, was the dominant form in the Jurassic, with the short-tailed variety, the Pterodactyloidea, being dominant in the Cretaceous. Fossils of the Cretaceous pterosaurs are found on all contintnents except Antarctica.

The major feature of the Cretaceous pterosaurs was their size, with some forms having wing spans of nearly 15 meters or 50 feet. Most pterosaurs lived near water, on the coast or islands. They fed on aquatic life and were specialized feeders. Some forms had long slender teeth which were used to gather and filter small organisms. Other forms had sharp pointed beaks with strong crushing teeth which could spear fish or crush the shells of crabs, clams, and snails. Pterosaurs were gliders and had a flying lifestyle with very specialized feeding adaptations. However a disruption in the environment (for example, an asteroid impact) may have changed the air and ocean temperatures on a global scale. Global cooling may have changed the seasonal wind patterns. The pterosaurs which lived at the end of the Cretaceous were adapted to flying in a light wind. A slight change in wind speed may have made flight difficult for these reptiles. Although the reason for the extinction of the pterosaurs remains unclear we do know that the flying reptiles did not cross (survive) the K-T boundary.

Questions

How long ago did the dinosaurs die off?

What evidence do we have for asteroid impact on Earth?

Are there other impact craters on Earth besides Chicxulub Crater?

How would a large asteroid impact on the Earth's surface change the climate? Could the climate become warmer?

When water and sulfur are combined, an acid is formed; what is the name of this acid?

After an asteroid impact why would a small mammal have a better chance of survival than a large dinosaur?

What modern animals are similar in size to a triceratops?

The paper model of a pterosaur has a short tail; what is this variety of pterosaur called?

Could a mass extinction caused by an asteroid impact happen again?

Glossary

Asteroid: A small planet, smaller than any of our solar system's major planets (and their satellites) in orbit around the sun. Most asteroids have orbits between Mars and Jupiter and do not come from outside of our solar system. Some asteroids pass quite close to Earth.

Cenozoic Era: The geologic time interval (Era) after the Mesozoic (Era). Also known as the period of "Recent Life", and "Age of Mammals". The Cenozoic includes the last 65 million years of Earth's history.

Ceratopsian: A general name for the horned-faced dinosaurs. Ceratopsian were large herbivores (plant eaters).

Chicxulub crater: This area is the most likely place for the impact crater that formed when an asteroid hit the Earth 65 million years ago. It is located beneath the surface of the northern coast of the Yucatan Peninsula, in Mexico.

Cretaceous Period: The last period in the Mesozoic Era. The Cretaceous lasted from 144 to 65 million years ago.

Extraterrestrial object: An object, not from the Earth, floating in space.

Frill: A bony plate (shield) around the neck of an animal that protects the head and provides support for the powerful muscles that work the jaw.

Iridium: Rare on Earth, a silvery-white, hard, brittle, very heavy metallic element. Its chemical symbol is Ir

Jurassic Period: The middle period of the Mesozoic Era. The Jurassic lasted from 214 to144 million years ago.

Mesozoic Era: The middle time interval (Era) between the Paleozoic and Cenozoic Eras. The Mesozoic lasted from 240 to 65 million years ago and is commonly referred to as the "Age of Reptiles."

K-T boundary: The time boundary between the Cretaceous ("K") Period and the Tertiary ("T") Period. In many sequences of sedimentary rocks, it is marked by an unusual thin layer of clay.

Glossary (continued)

Ornithischians: This "bird-hipped" group of dinosaurs includes all of the dinosaurs which had hips like birds. The group includes most of the large two-legged plant-eating dinosaurs.

Osmium: An uncommon and extremely hard bluish-white or grayish metallic element, usually associated with iridium. Its chemical symbol is Os.

Paleontologist: A scientist who documents the history of life on Earth through the study of fossils and ancient forms of life.

Photosynthesis: A process by which plants use the energy from the sun to make sugars and starches from carbon dioxide and water.

Pterodactyloidea: Pterosaurs with short tails.

Pterosauria: From the Greek words - pteron and sauros - "wing lizard". This is the group of flying reptiles that lived during the Mesozoic.

Rhamphorhynchoidea: Pterosaurs with long tails.

Shocked quartz: Microscopic linear fractures in quartz grains formed by the brief but high-pressure action of shock waves from a meteorite or asteroid impact.

Tertiary Period: The first period in the Cenozoic Era. The Tertiary lasted from 65 to 1.6 million years ago.

Triassic Period: The first period in the Mesozoic Era. The Triassic lasted from 240 to 214 million years ago.

Torosaurus: An example of a long-frilled ceratops.

Triceratops: An example of a short-frilled ceratops. There may have been fifteen different varieties in this group of animals.

Tyrannosaur: A group of large carnivorous dinosaurs that lived at the end of the Cretaceous.

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Fundamental Concepts

"SCIENTIFIC LITERACY FOR ALL STUDENTS is a National goal. The National Science Education Standards are a contribution toward achieving that goal." (Draft, November 1994, National Science Education Standards, prepared by the National Research Council, National Academy of Science)

After building these models and reading the text all students should have developed a basic understanding of the following fundamental concepts of Earth and Space Science as recommended in the National Science Education Standards. Some of these concepts for grades 5-8 and 9-12 are:

Grades 5 - 8

+ Fossils provide important evidence of how life and environmental conditions have changed through time.

+ The Earth processes we see at work today are similar to those that operated in the past.

Grades 9 - 12

+ Populations of organisms evolve over time.

+ Geologic time can be estimated by observing rock sequences and using fossils to correlate similar sequences at various locations.

+ Creativity, imagination, and a good knowledge base are all required in the work of science and engineering.

+ Changes in natural systems can exceed the limits of organisms to adapt naturally or humans to adapt technologically.

Additional Models and Animations

Alpha, Tau Rho, 1989, How to construct two paper models showing the effects of glacial ice on a mountain valley: U. S. Geological Survey Open-File Report 89-190 A&B (Available as a 3.5-in. MACINTOSH disk or a 30-p. report)

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Pterosaur Pattern

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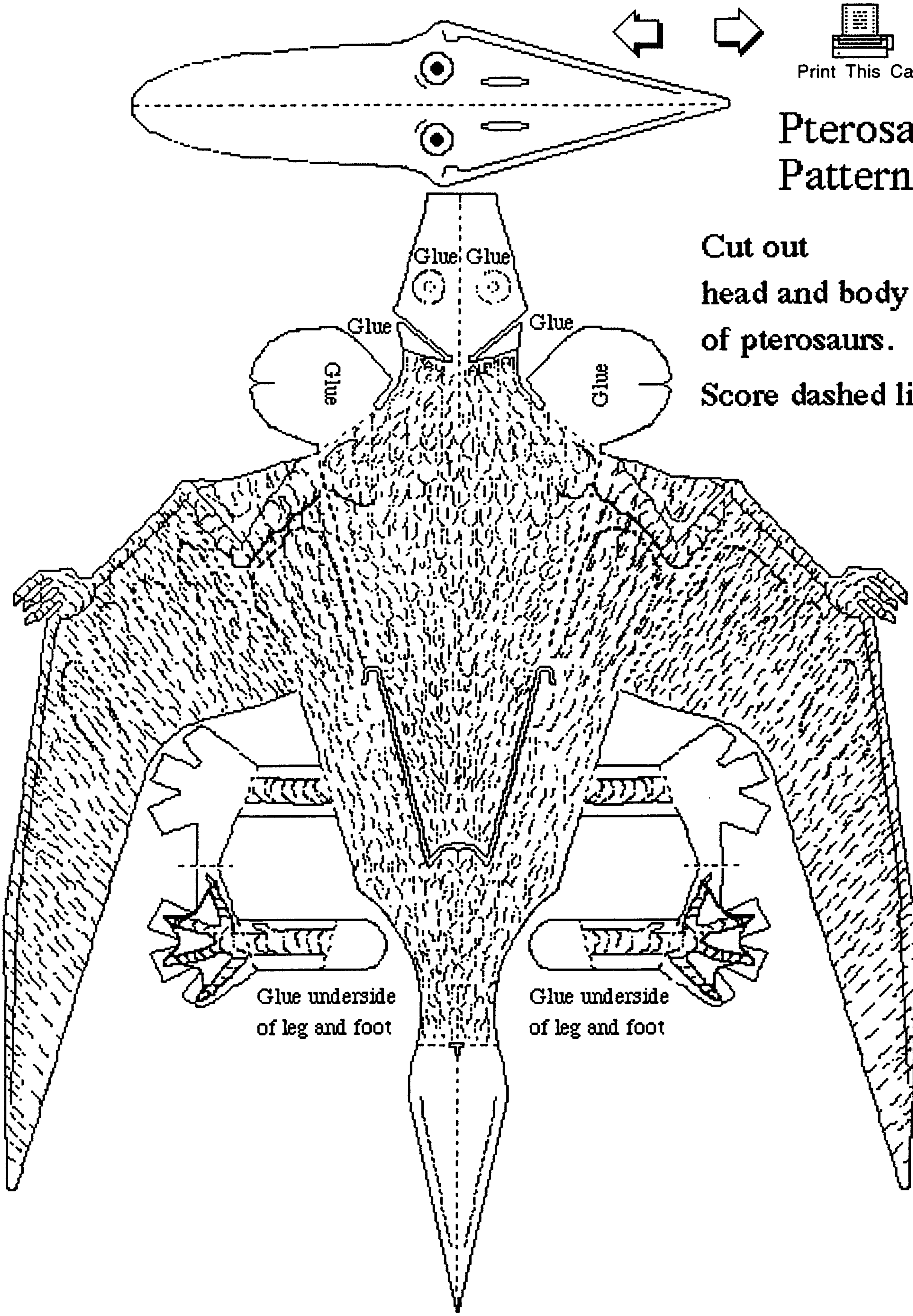
Score dashed lines.



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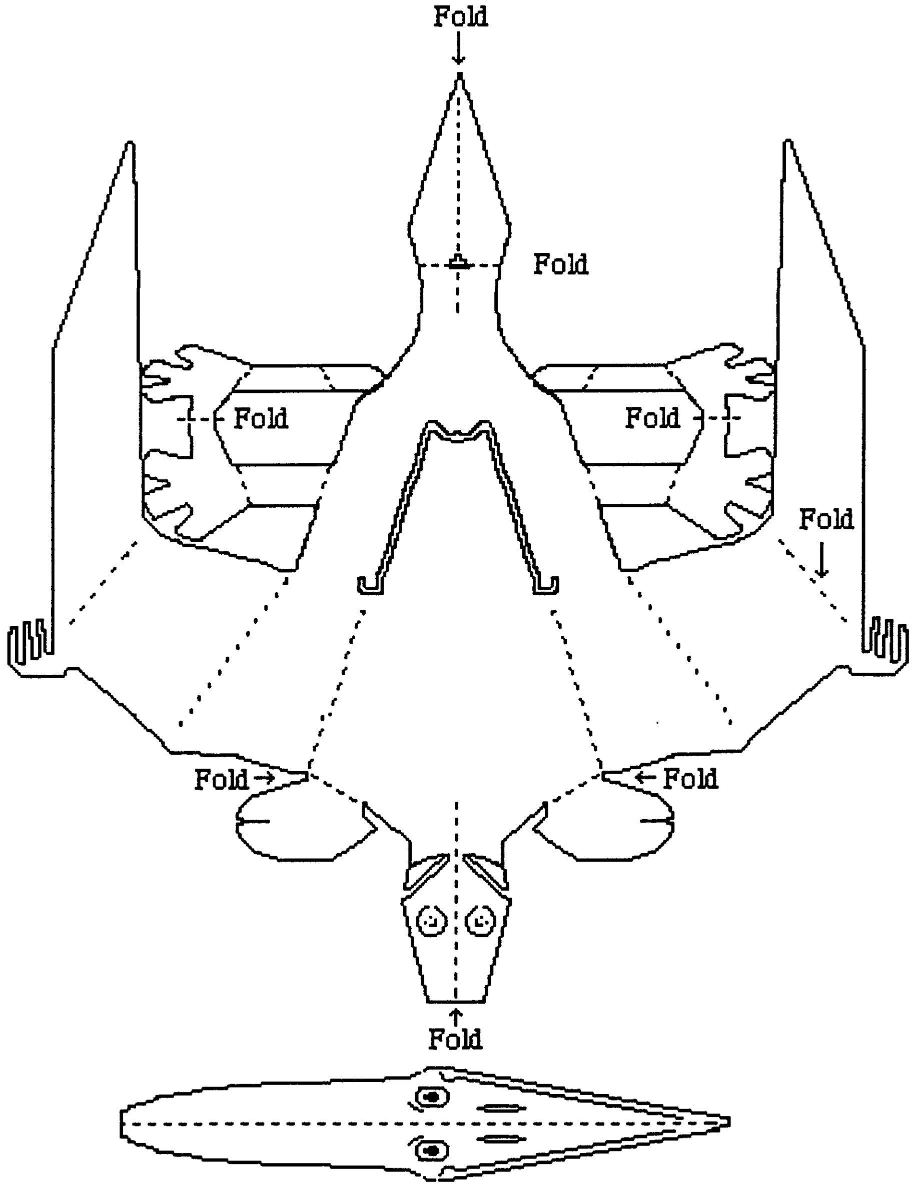

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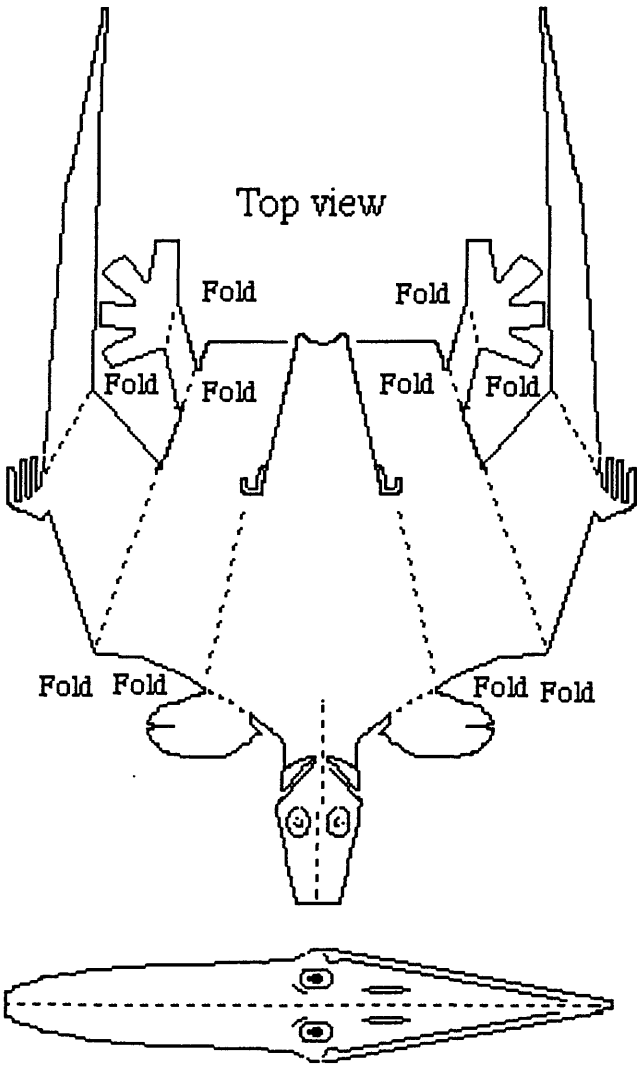

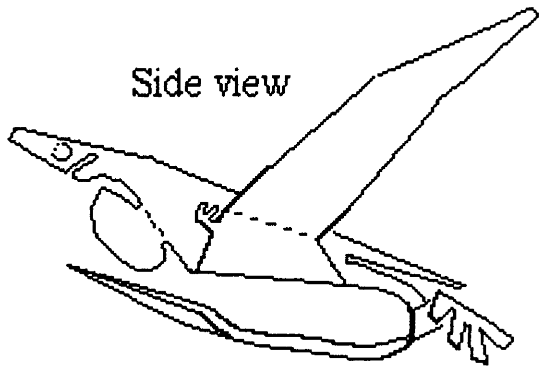

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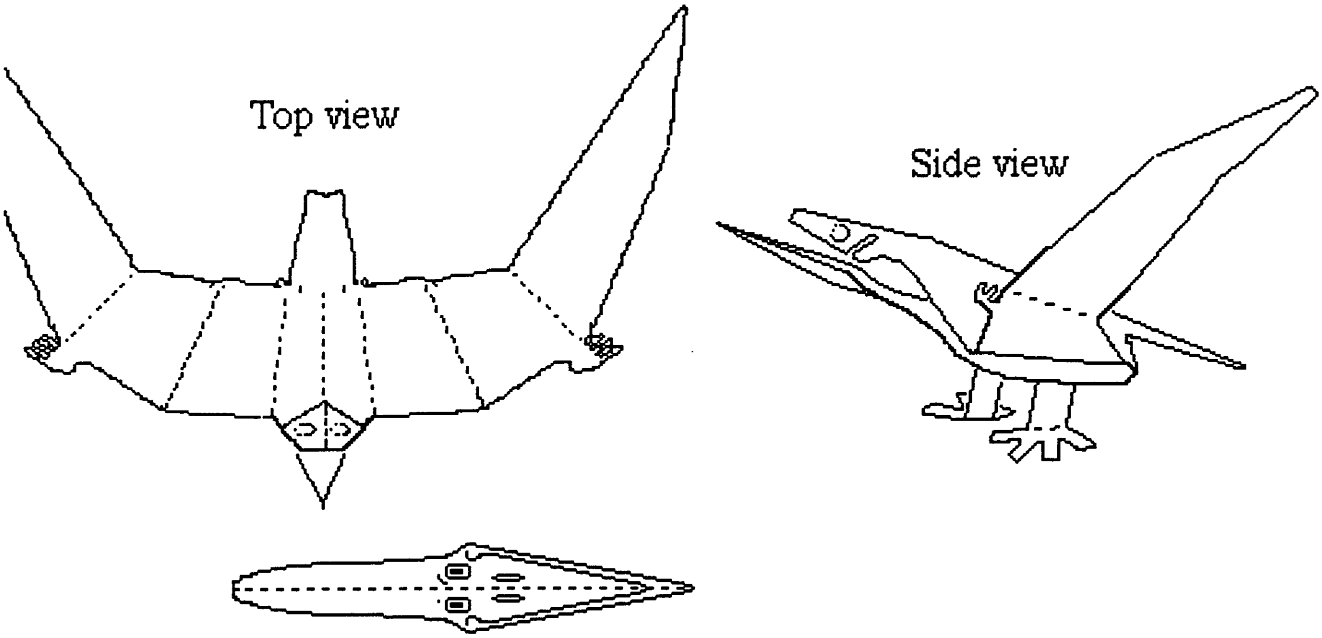

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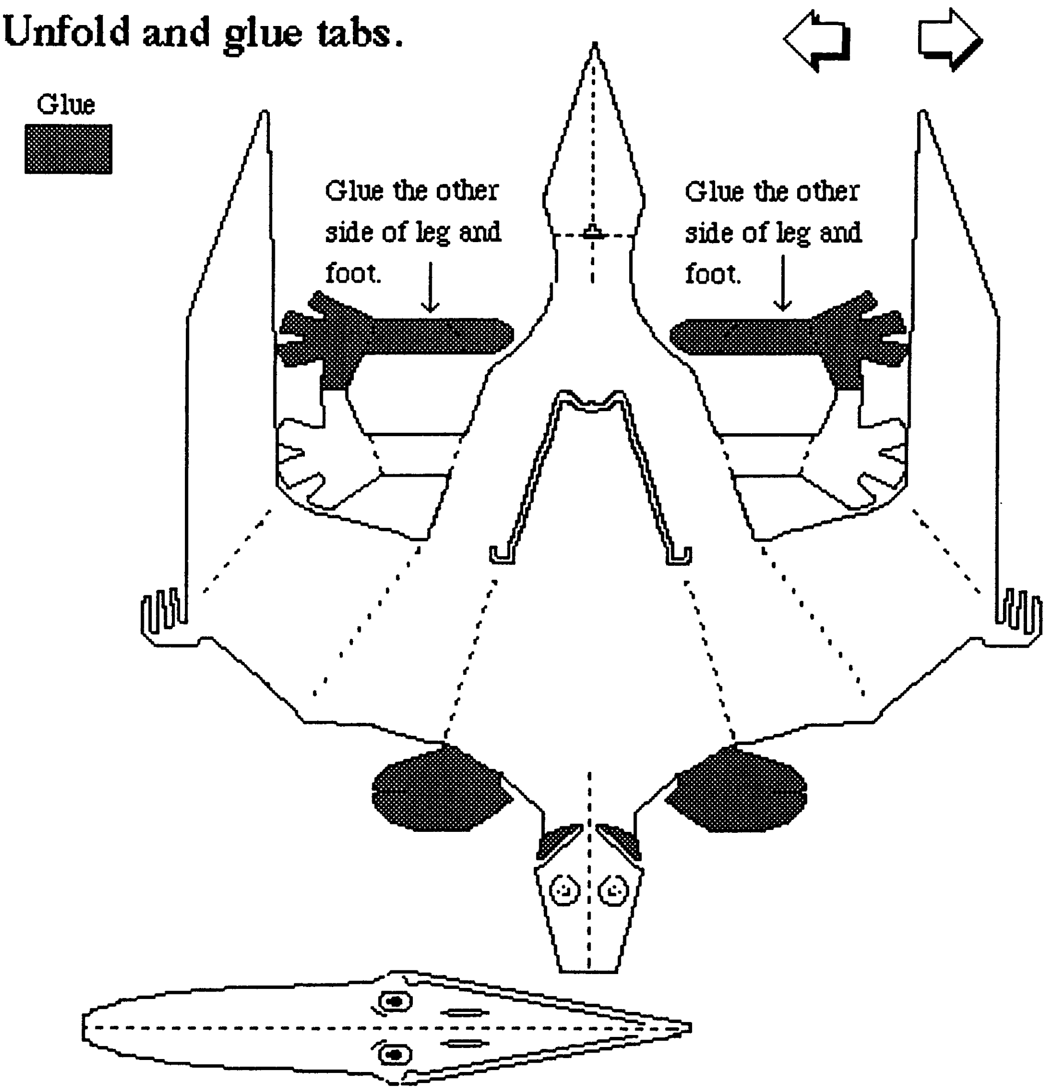
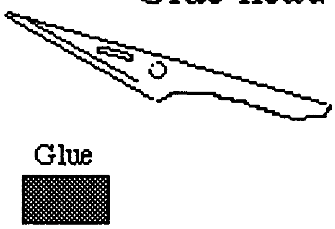
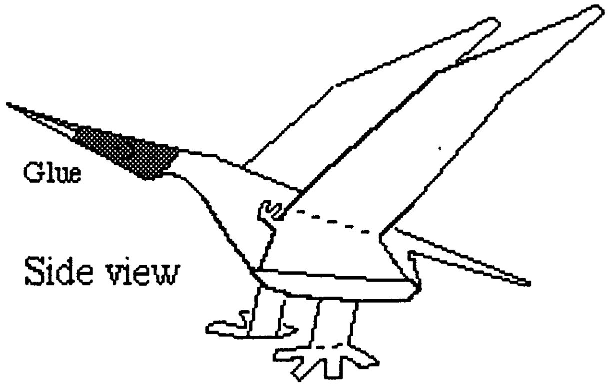


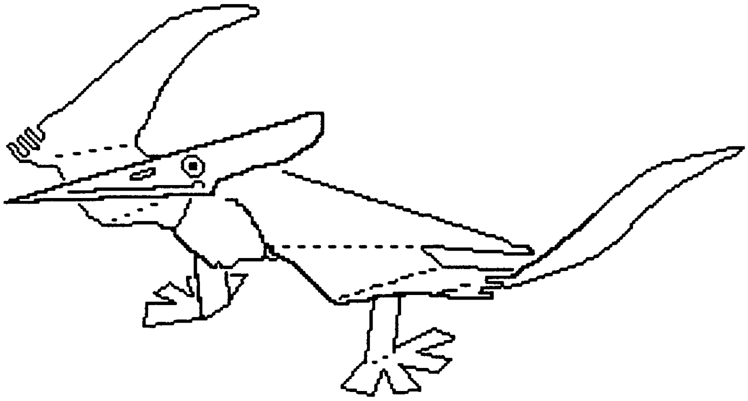
Refold the glued body.

Glue head to body.

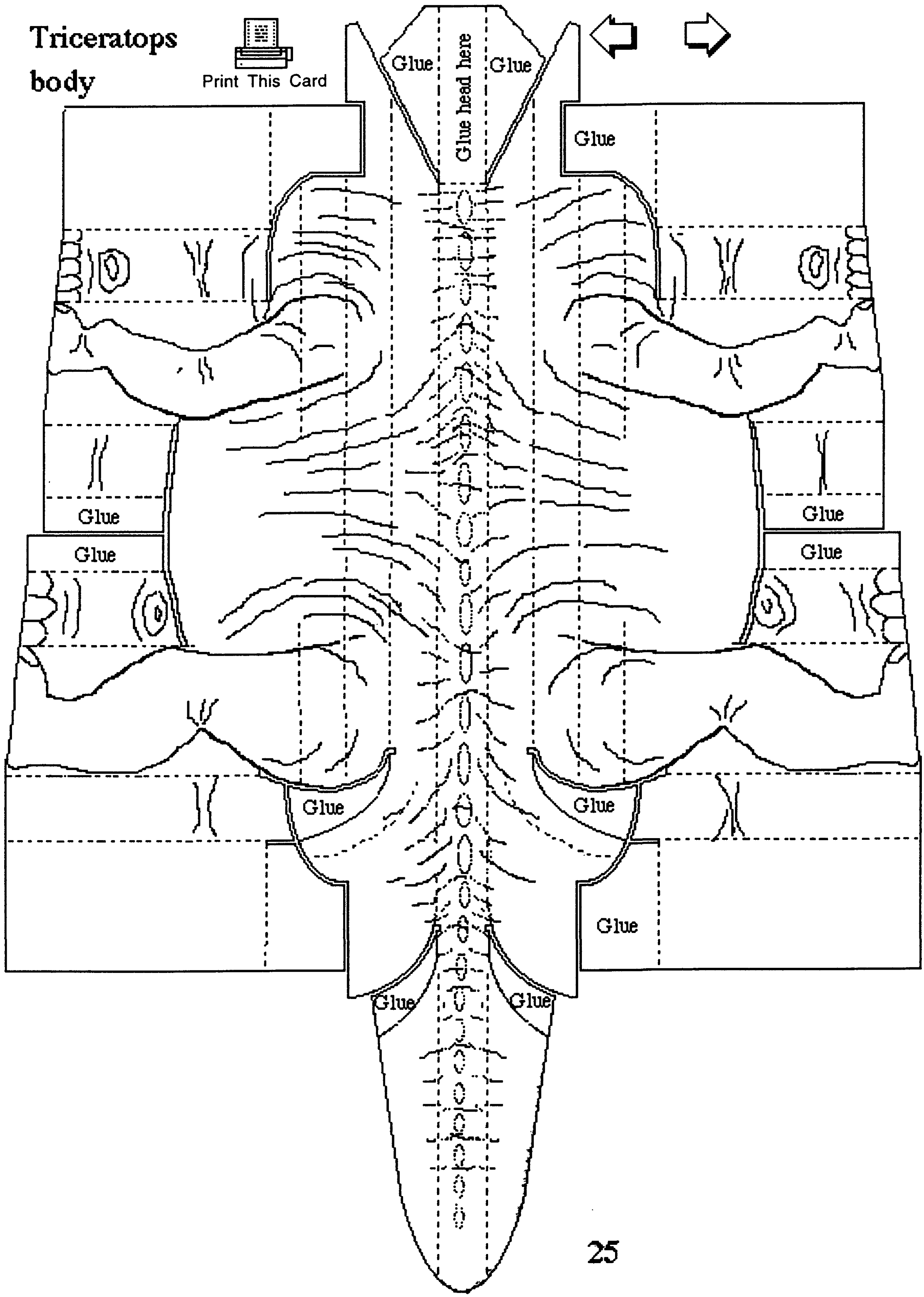




Finished pterosaurs should look like this. Paper models

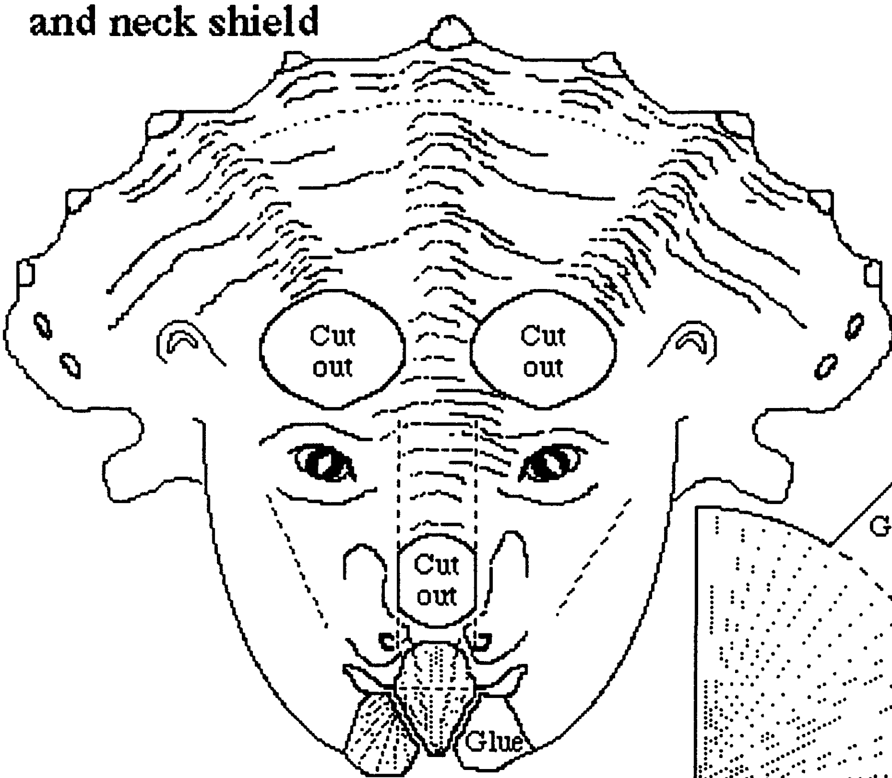


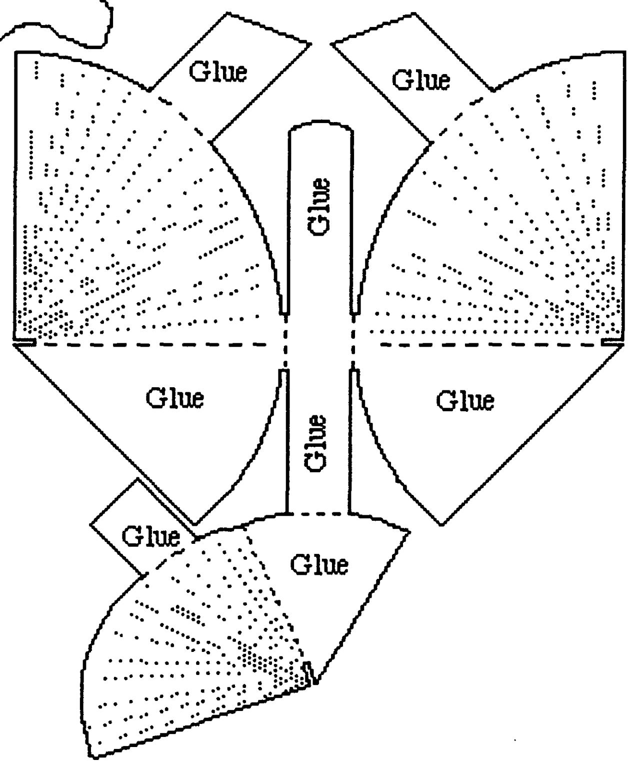
Triceratops body



Triceratops
head, horns
and neck shield

Print This Card





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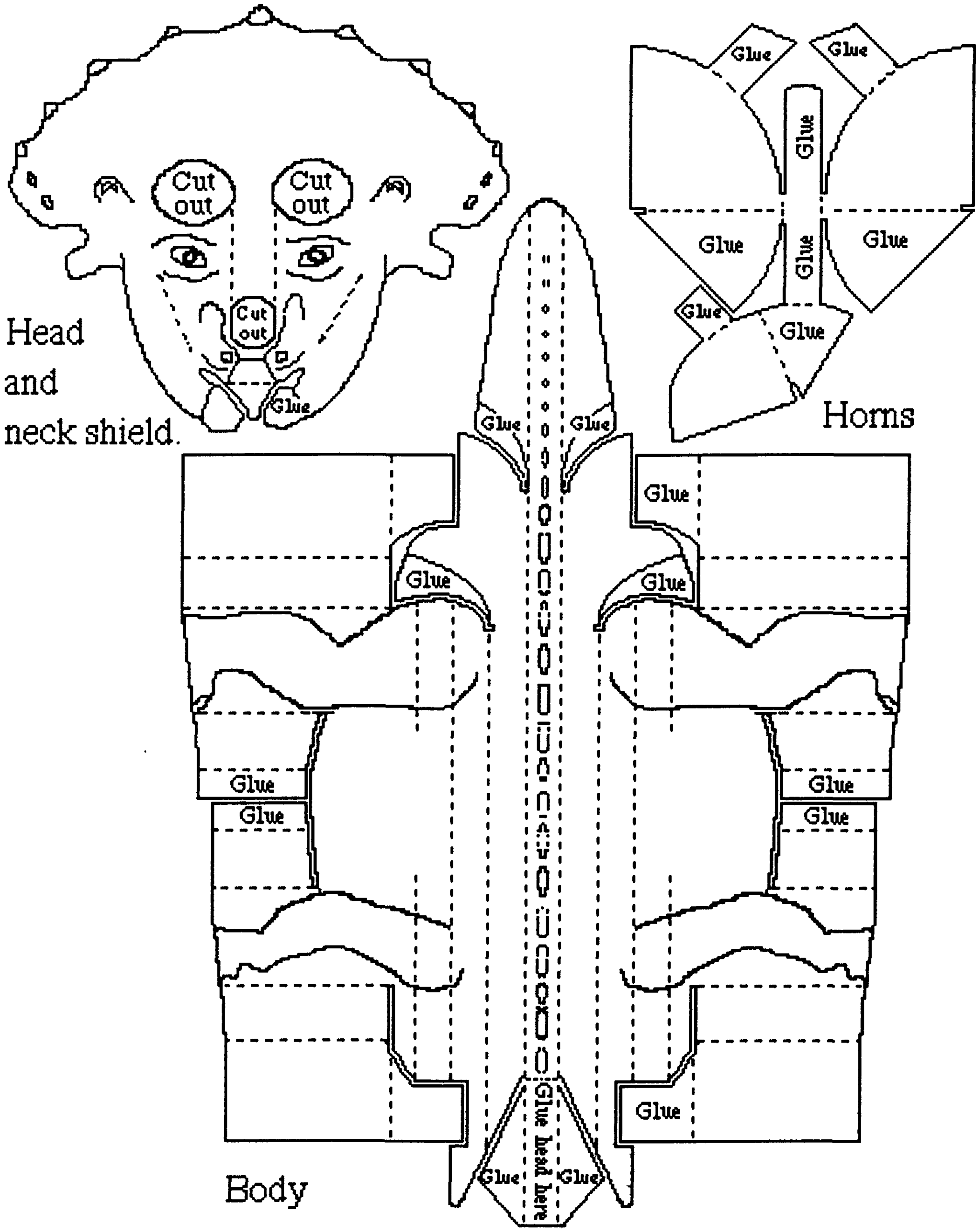
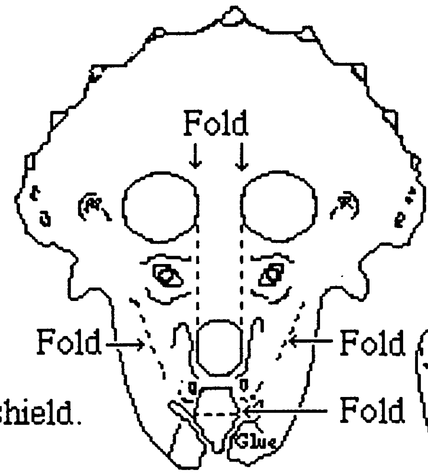
Score dashed lines.



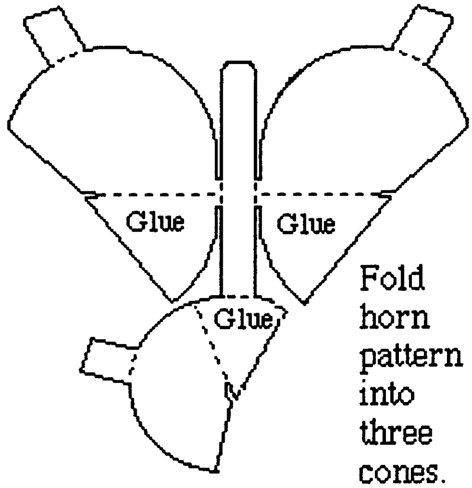
Cut out parts of Triceratops.

Score dashed lines.

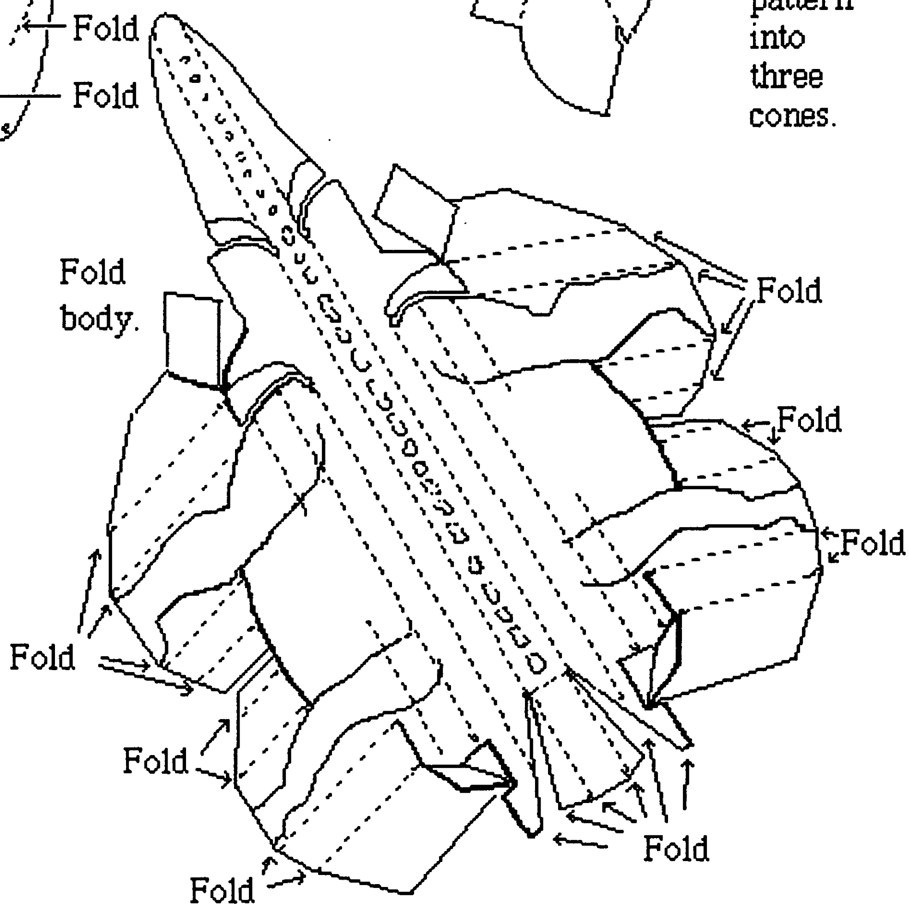
Fold the scored dashed lines.



Fold Head and neck shield.



Fold horn pattern into three cones.



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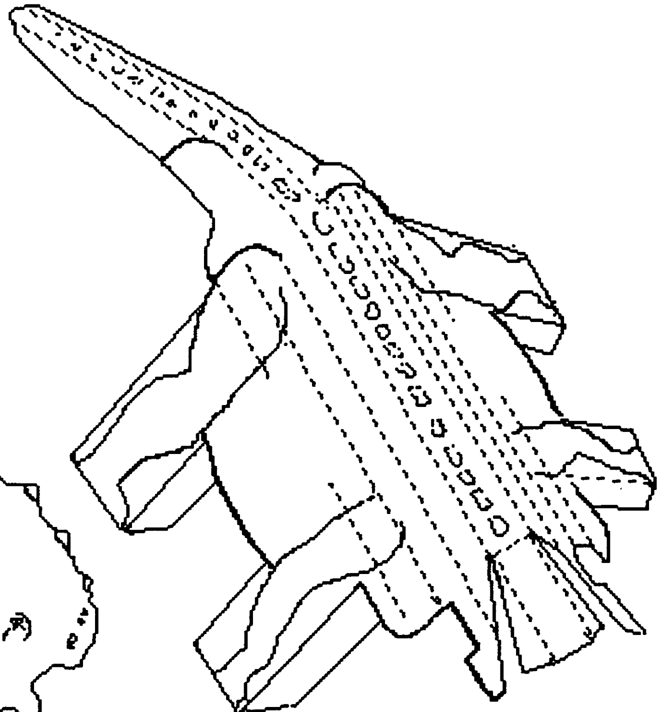
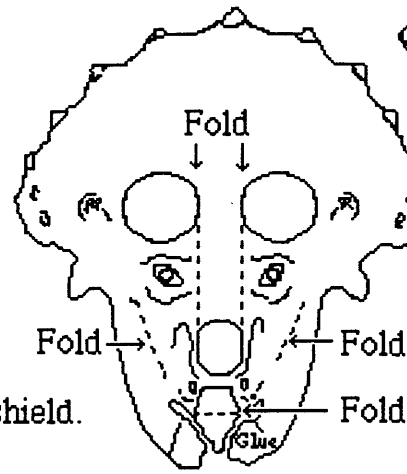
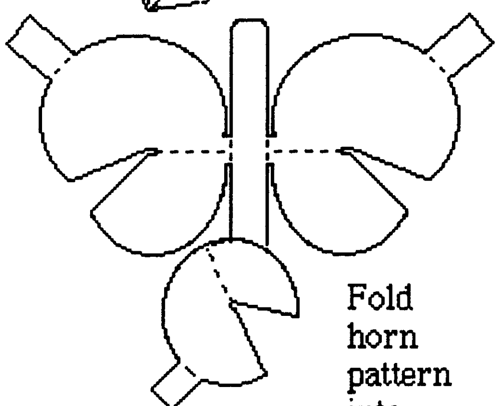


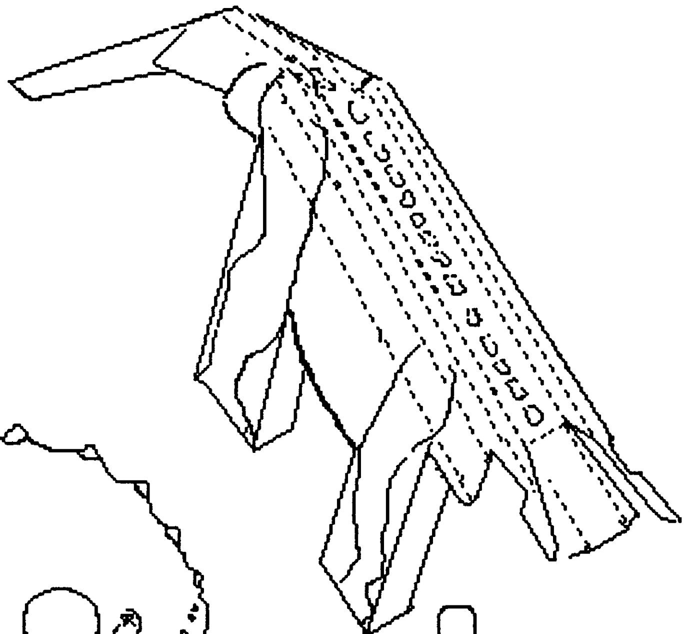


Fold Head and neck shield.

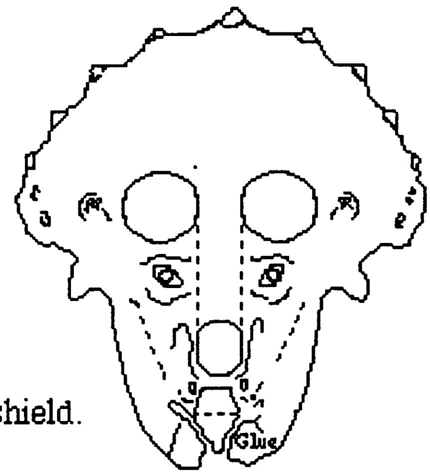


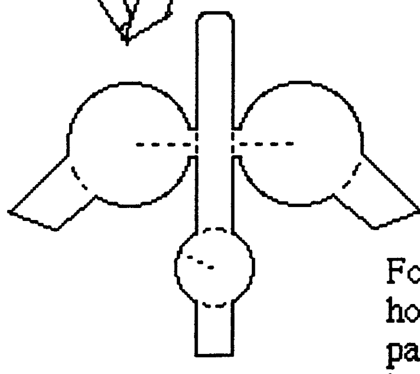
Fold horn pattern into three cones.

Fold



Fold
Head
and
neck shield.

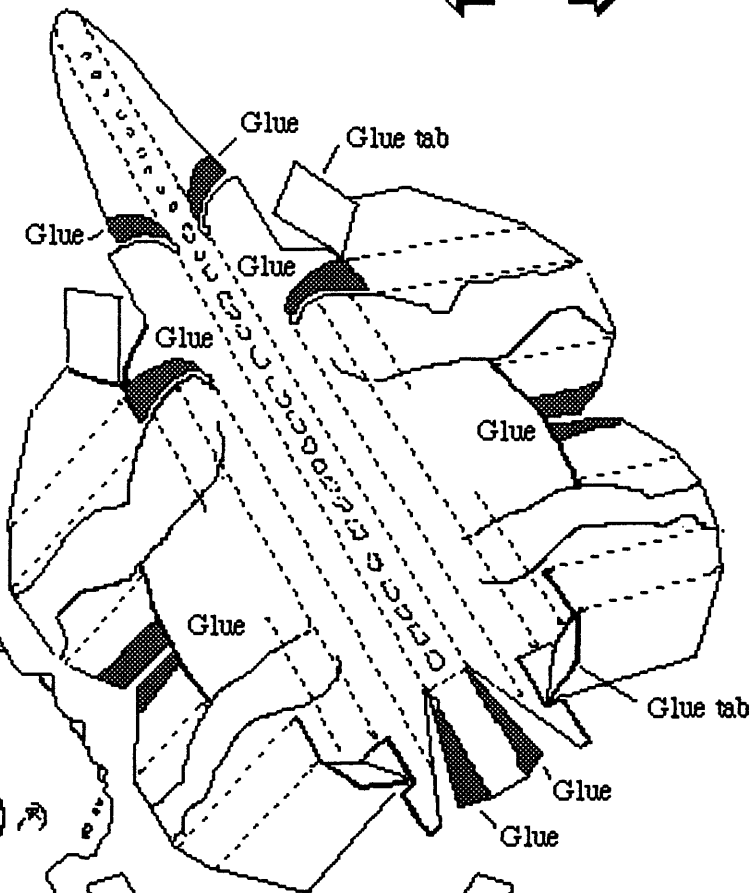




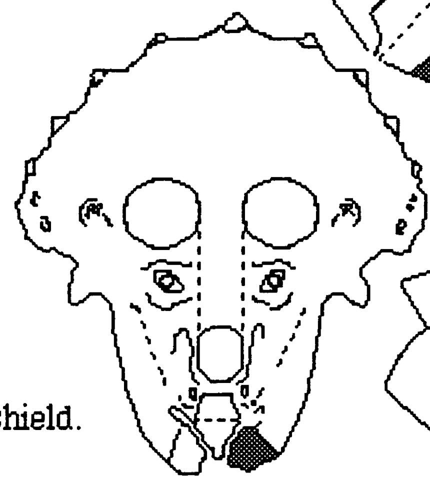
Fold
horn
pattern
into
three
cones.

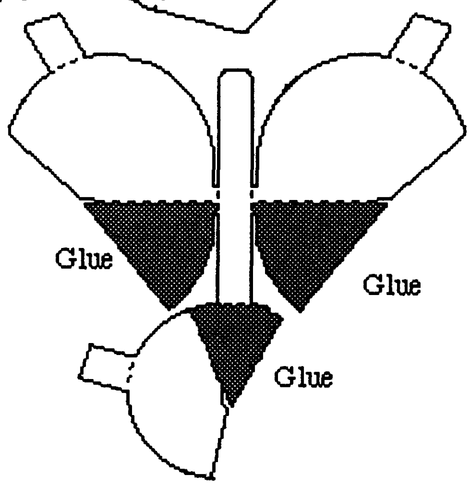
Unfold and glue tabs.

Glue

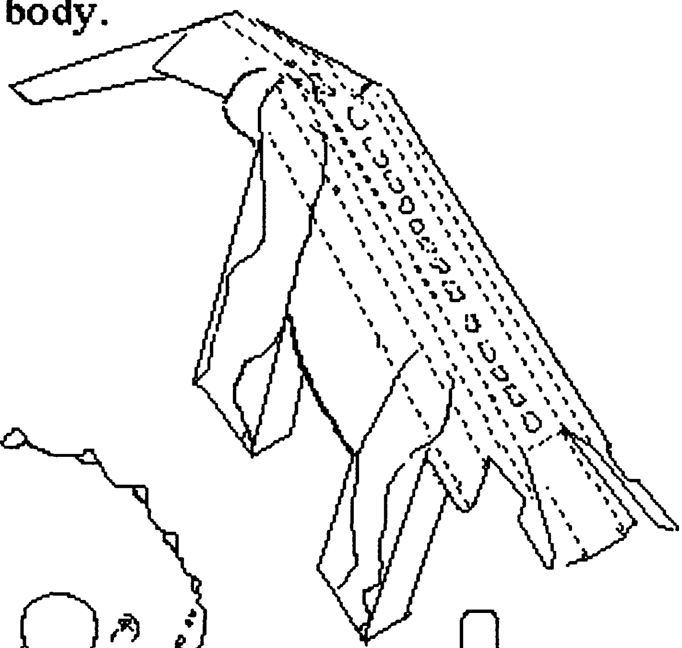


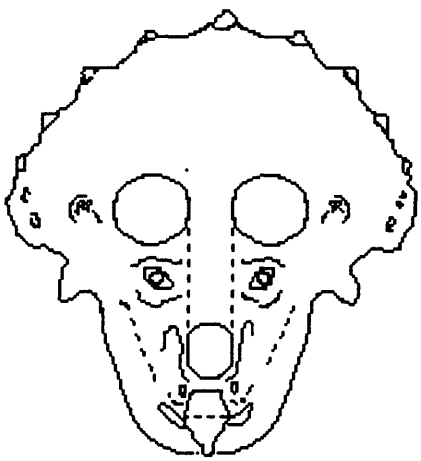
Fold Head and neck shield.

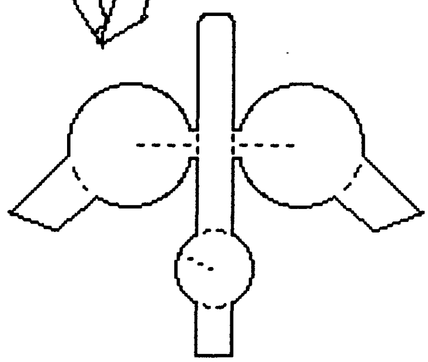




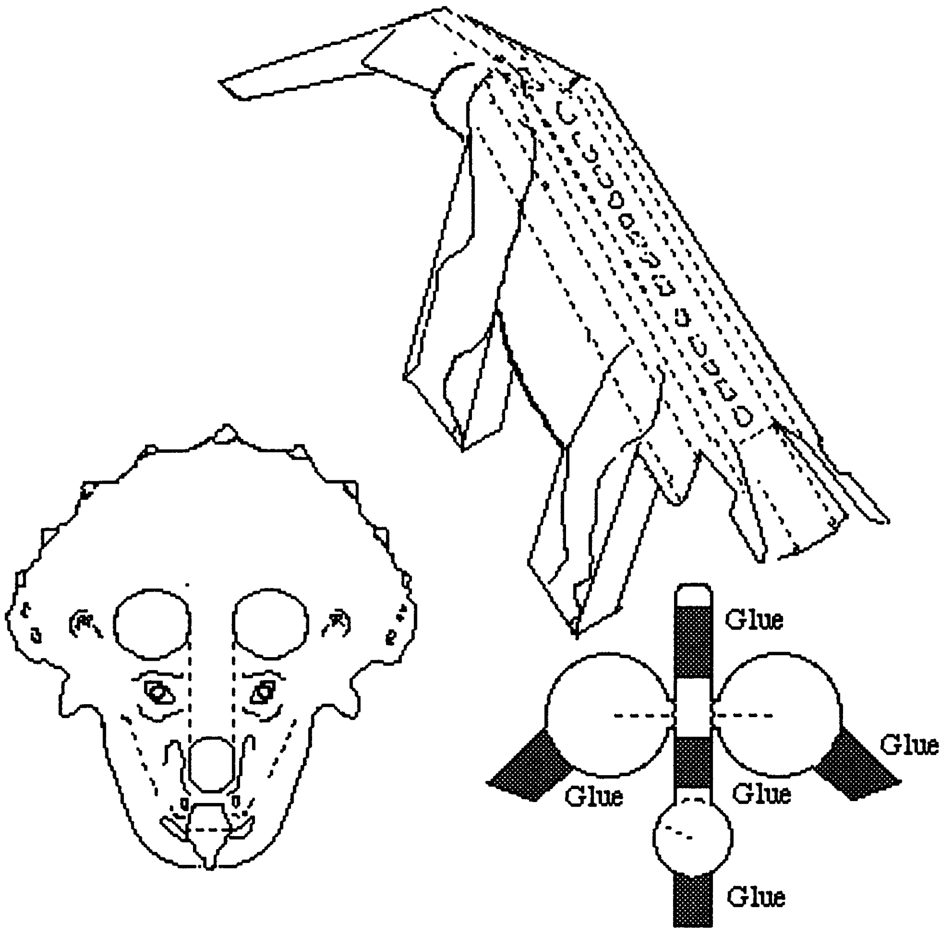
Refold the glued
head, horns, and body.



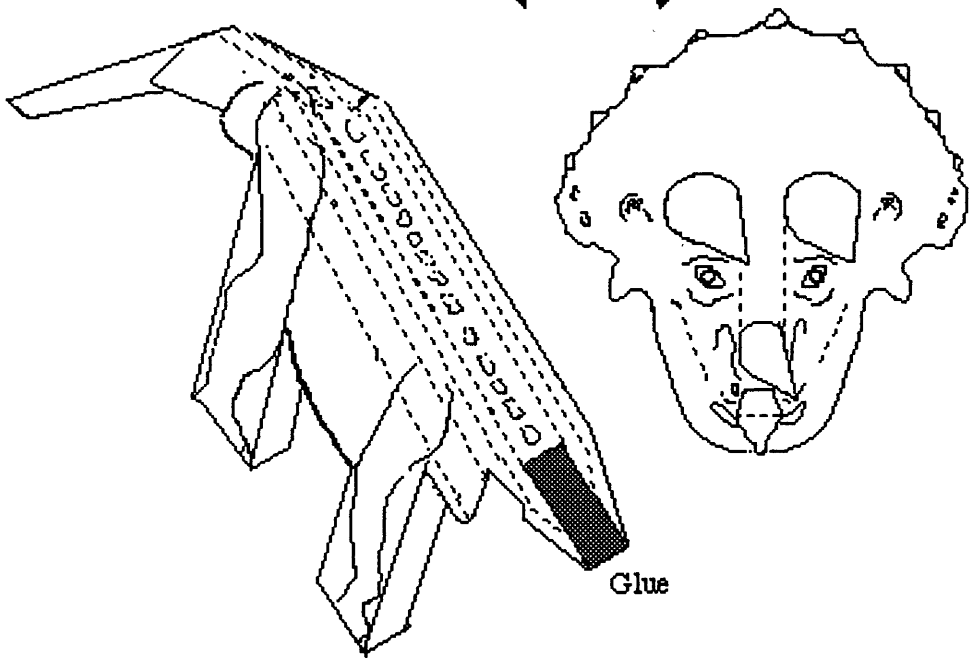




Glue horns to head and neck shield.



Glue head and neck shield to body.



Finished triceratops should look like this. ⇦ Paper models

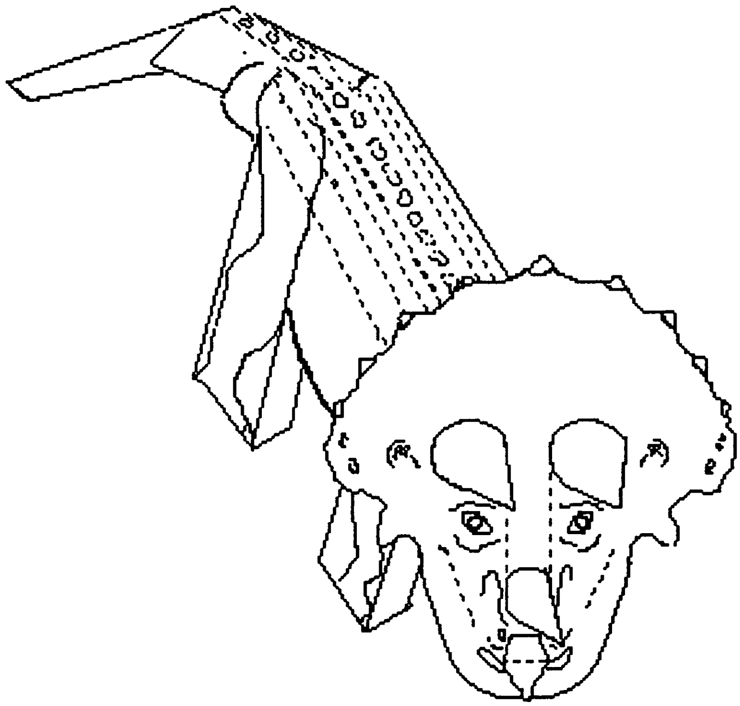


Table of Contents

The End

Alpha, Galloway & Starratt

Chicxulub impact event

Chicxulub impact event

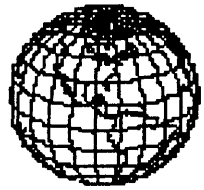
Chicxulub impact event

By

Tau Rho Alpha, John P. Galloway

and

Scott W. Starratt



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