AN ARTICULATED PHYTOSAUR SKELETON: PREPARATION TECHNIQUES FROM FIELD TO EXHIBIT

by

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CHAPTER I

INTRODUCTION

On September 17, 1996, Dr. Sankar Chatterjee, Curator of Paleontology at the Museum of Texas Tech University, received a telephone call from Mr. Robert Macy inquiring about a skeleton that had been unearthed by bulldozer on the Macy Ranch near Post, Texas. Chatterjee, accompanied by a crew of Geology and Museum Science students, and funded by a grant from the National Geographic Society, visited the Macy Ranch on September 20 to find that Mr. Macy's discovery was that of a Pleistocene elephant, and not the remains of a Triassic dinosaur. Due to a lack of time, resources, and space at the Museum, it was decided to leave the elephant skeleton in situ.

Undaunted, Mr. Macy led the crew to a "dinosaur footprint" that his wife, Debbie Macy, had discovered. Photographs showed the impression to be a huge print, approximately two feet long, and resembling that of a three-toed theropod dinosaur. After careful examination, the impression proved to be a phenomenon of weathering; a natural sculpture created by a water vortex and pebbles. Although disappointed, Mr. Macy gave permission for the crew to prospect for Triassic fossils on his 16,000 acre ranch.

Near the site of the "footprint," Carter Keairns discovered the partially exposed skeleton of a Triassic animal, later identified as a phytosaur. Students and faculty from the Geology and Museum Science departments assisted in the excavation, and the Macys made regular visits by helicopter. Over the ensuing weeks, the fossil was fully exposed, revealing a nearly complete, articulated skeleton (Figure 1.1). The specimen was then removed to the Museum of Texas Tech University.

The Museum of Texas Tech University houses one of the finest collections of Triassic fossils in the United States. This collection includes many holotype specimens including *Postosuchus*, *Shuvosaurus*, *Technosaurus*, and *Protoavis*. The Museum collection houses excellent specimens of other Triassic vertebrates, including metoposaurid amphibians and dicynodonts. Additionally, the vertebrate paleontology collection contains many fine phytosaur skulls, encompassing all four genera found in West Texas. The addition of an articulated phytosaur skeleton is a valuable accession; it is extremely rare; the only such known in the United States, and one of only three world wide.

The discovery of a complete phytosaur skeleton is, in itself, an exciting event. Further examination reveals that the skeleton exhibits several cranial and postcranial characteristics that are unique to this specimen. Phytosaurs are typically long-snouted, archosaurian reptiles resembling the modern gharial of India. The Macy Ranch animal possesses an abbreviated snout and several other diagnostic morphological differences that indicate that it represents a new genus and species.

All previous collections made by the Museum were completely freed from the matrix for in-depth study of three-dimensional anatomical information. It was decided to leave the Macy Ranch phytosaur in its articulated death pose, creating a dramatic exhibit specimen, and preserving the in-situ aesthetics of this rare fossil. This provides exciting opportunities for the description of a new taxon, and for the preparation of a unique specimen.

The rarity and importance of the Macy Ranch phytosaur mandate its careful treatment. Preparation and presentation of a holotype specimen require thoughtful consideration as to the least invasive techniques for excavating, preserving, casting, and exhibiting the fossil. Therefore, the purpose of this thesis is to present the Macy Ranch phytosaur as a new taxon, to define proper paleontological preparation techniques, to explore the use of alternative materials for the excavation, laboratory preparation, and museum exhibition of the specimen, and to investigate the use of Paper Pulp Epoxy--a new gap-filling compound.

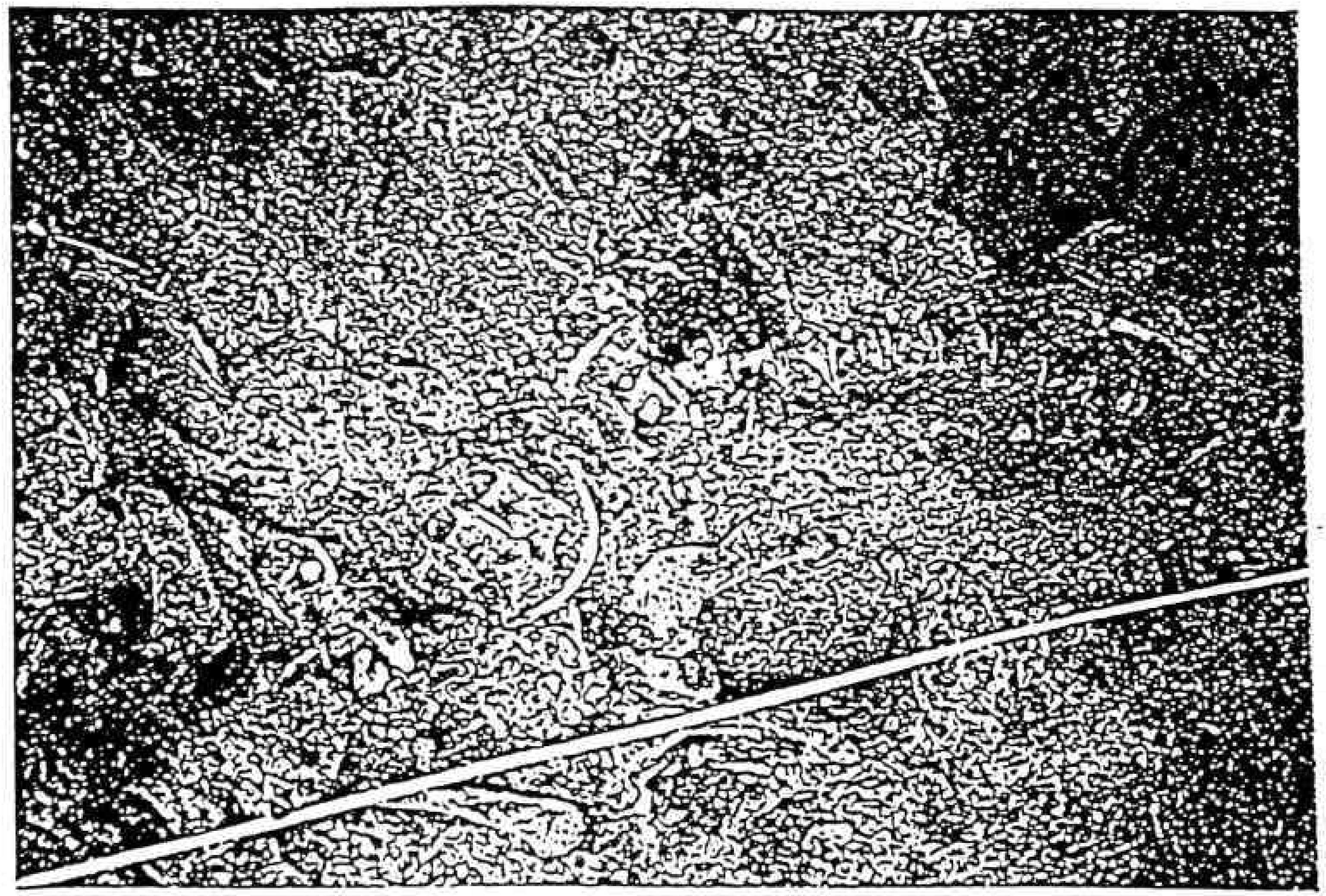


Figure 1.1. Photograph of Macy Ranch phytosaur, in situ.

CHAPTER II

DESCRIPTION OF PHYTOSAURS

2.1 Introduction

Phytosaurs (= parasuchids) are long-snouted, archosaurian reptiles resembling, in size and inferred lifestyle, modern gharials (*Gavialis gangeticus)* of India (Figure 2.1). Phytosaur remains have been found exclusively in the Upper Triassic continental sediments of North America, Europe, North Africa, India, Madagascar, and Thailand. During the Upper Triassic (230-206 million years ago), the Earth's land masses were joined together into a supercontinent called Pangea, allowing for the global distribution of phytosaurs. Phytosaurs became extinct at the end of the Triassic, along with a number of other archosaur fauna, although the cause of this Triassic mass extinction is still unknown (Chatterjee, 1978).

Phytosaurs are quadrupedal archosaurs that exhibit modifications specific to a semi-aquatic and piscivorous lifestyle (Long and Murray, 1995). Several characters of phytosaur cranial anatomy indicate a piscivorous lifestyle, including the elongated snout; the shape of the mandible; the arrangement of the teeth; a low, wide skull; laterally compressed tail; and dorsally oriented external nares and orbits (Hunt, 1994; Long and Murry, 1995). These characters are present in several recent and extinct piscivorous, semi-aquatic animals, including modern crocodiles and alligators, proterochampsids, champsosaurs, and many crocodyliforms (Hunt, 1994). Phytosaurs have a relatively primitive appendicular skeleton, exhibiting a sprawling or semi-sprawling posture. These animals were heavily armored, with dermal armor possibly restricted to the neck, body, and limbs. There is a robust development of ventral gastralia (Hunt, 1994).

In the United States, phytosaur fossils are abundant in the Late Triassic Chinle and Dockum sediments of the Southwest (Texas, New Mexico, Arizona, Oklahoma, Wyoming, Utah, and Colorado), and in the Newark Supergroup of the Atlantic Coast (New Jersey, North Carolina, Pennsylvania, Connecticut, Virginia, and Maryland) (Hunt, 1994). Figure 2.2 illustrates the global distribution of phytosaurs.

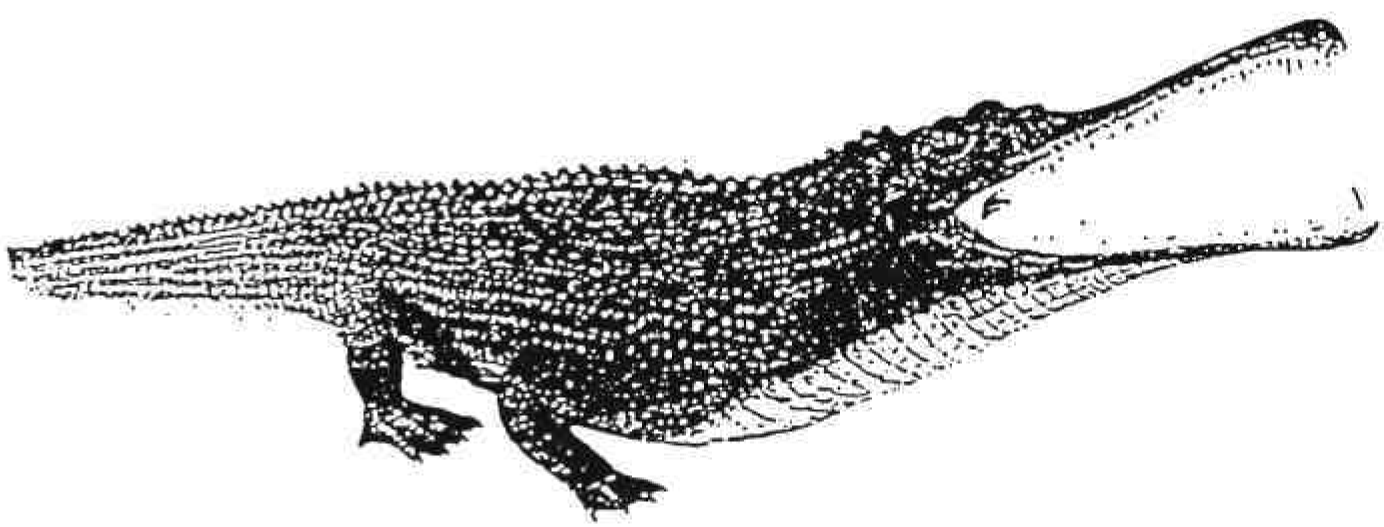


Figure 2.1. Life reconstruction of a phytosaur (From McGinnis, 1982).

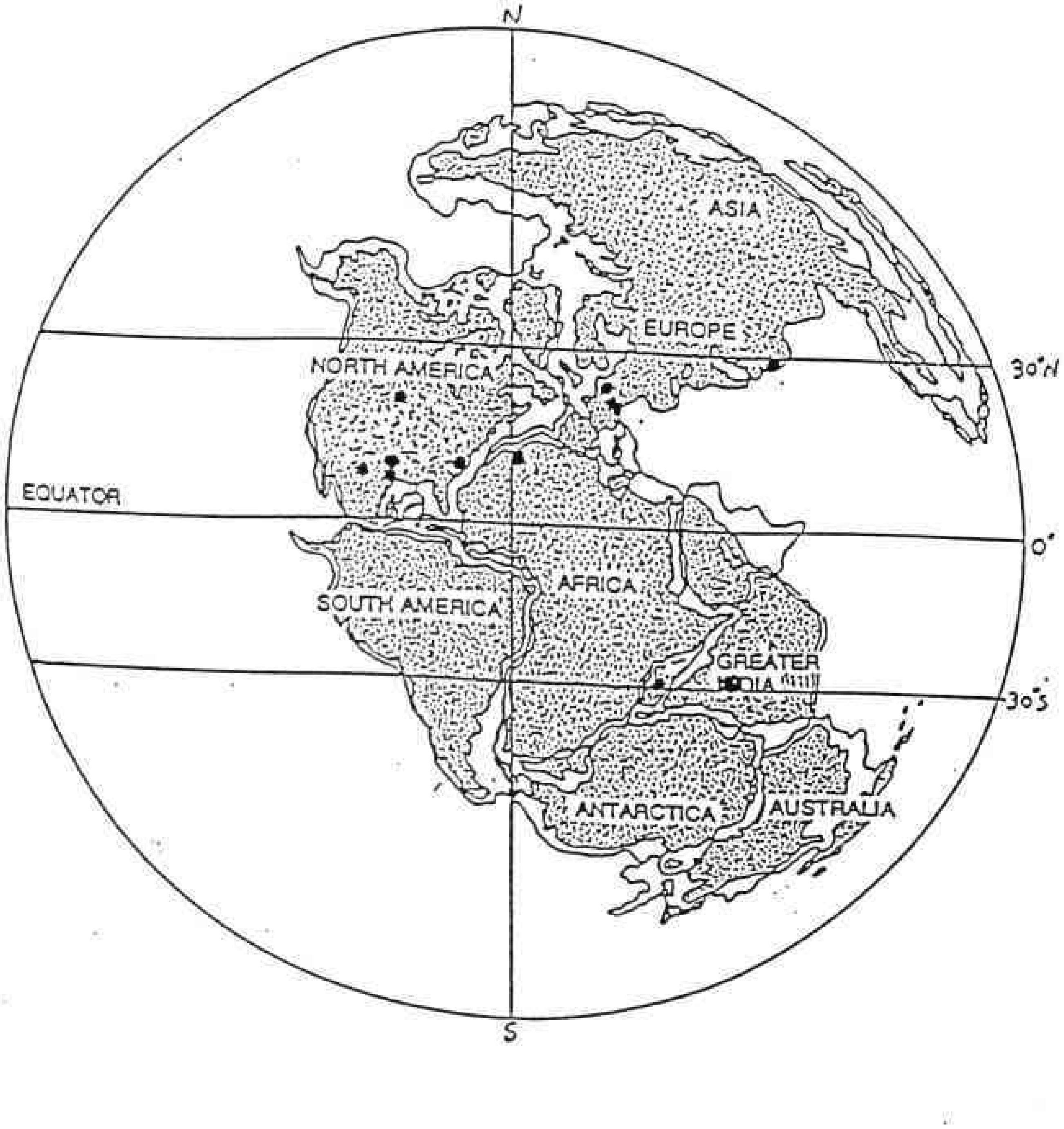


Figure 2.2. Distribution of phytosaur fossils in the Triassic Pangean world (From Simpson, 1998).

2.2 Phytosaur Genera

The Museum of Texas Tech University (TTUM) houses an excellent collection of phytosaur cranial material which was collected over a period of twenty years from the Dockum redbeds. Recently, Simpson (1997) reevaluated the skull material, questioned its biostratigraphic utility, and recognized four valid genera: *Paleorhinus*, *Angistorhinus*, *Rutiodon*, and *Nicrosaurus* (Figure 2.3). Traditionally, the position of the external naris in relation to the antorbital fenestra, the position of the upper temporal fenestra, and the size and depth of the squamosal hook are considered as key characters for the diagnosis of phytosaur genera. The unique characters (autapomorphies) of each genus are shown below.

Paleorhinus Williston, 1904

1. A prenarial to postnarial length ratio of less than 1.15.
2. Anterior placement of the external naris of at least 50 percent relative to the antorbital fenestra.
3. Posterior placement of the internal nares relative to the external nares.
4. Relatively short squamosal process.
5. Robust paraoccipital process.
6. Homodont to weakly heterodont dentition.
7. Non-overlapping scutes (Simpson, 1998; Chatterjee, 1978).

(See Figure 2.4.)

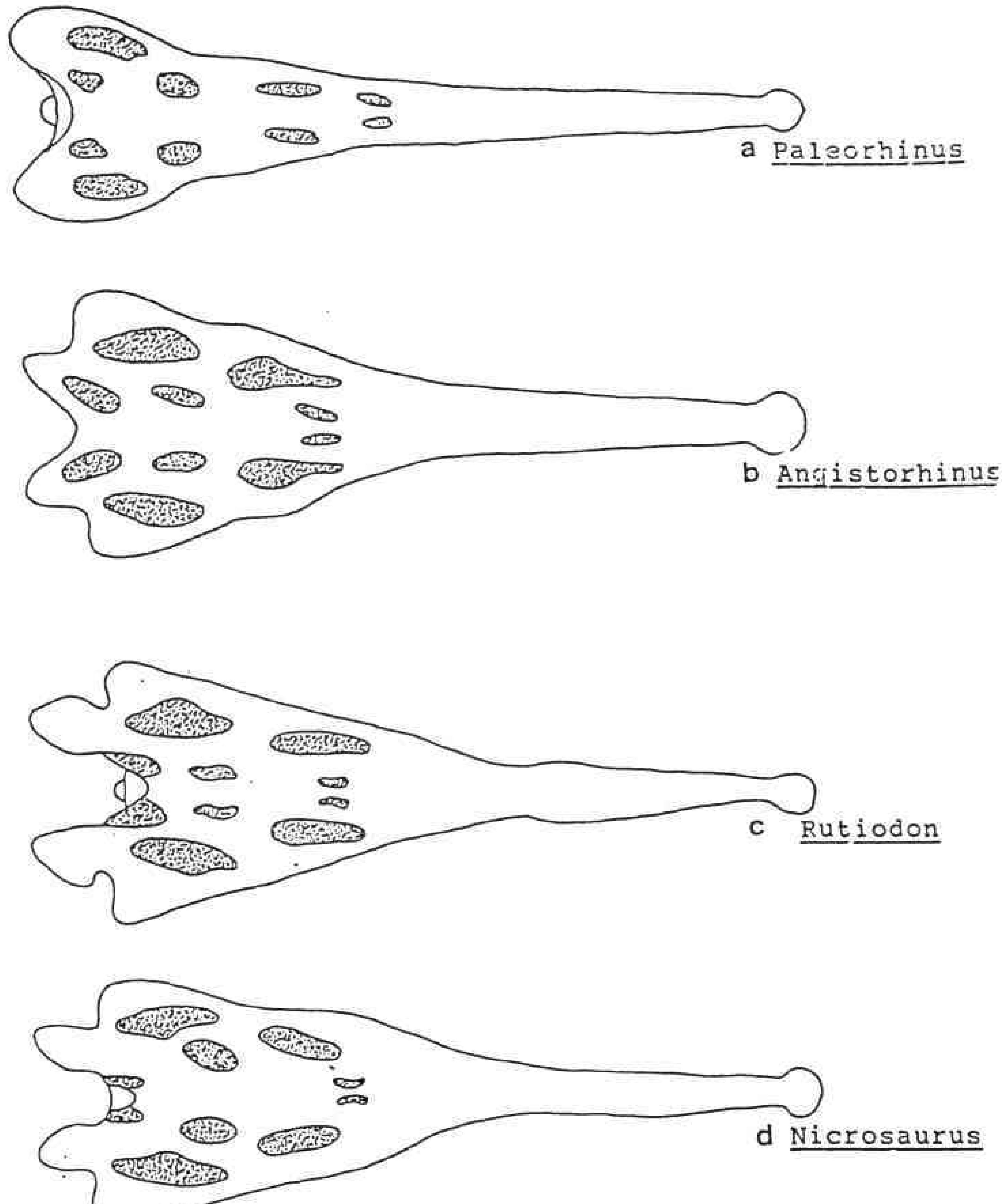


Figure 2.3. Phytosaur skulls (Shelton, 1984).

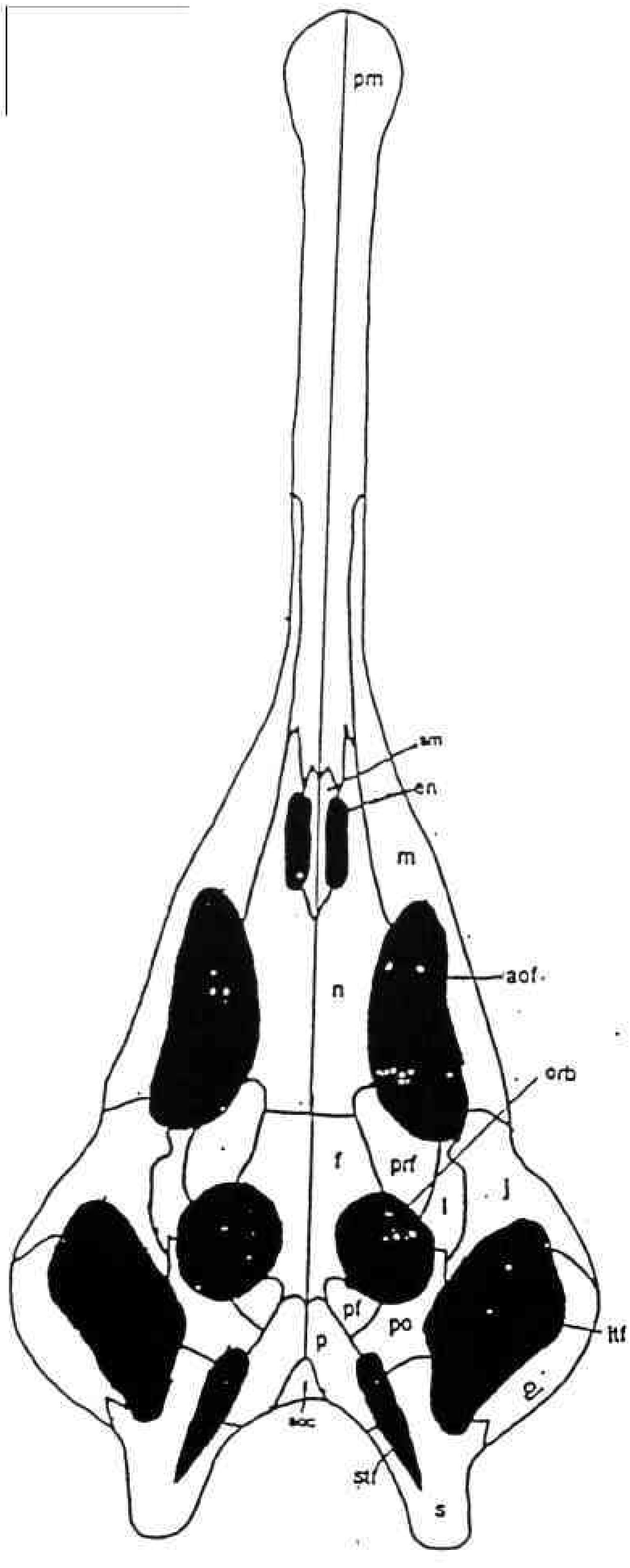


Figure 2.4 Reconstruction of *Paleorhinus* (Simpson, 1998). See Appendix for abbreviations.

Angistorhinus Mehl, 1913

1. A 1:1 ratio of skull height to width.
2. A prenarial to postnarial length ratio of between 1.15 and 1.30.
3. Anterior margin of the external naris slightly rostral to the antorbital fenestra.
4. Slight overlapping of external and internal nares.
5. Robust paraoccipital process.
6. Weakly heterodont teeth with posterior teeth laterally compressed and enlarged.
7. Non-overlapping scutes (Simpson, 1998; Chatterjee, 1978).

(See Figure 2.5)

Rutiodon Emmons, 1856

1. A prenarial to postnarial length ratio of more than 1.40.
2. Anterior and posterior margins of the external naris completely within the margins of the antorbital fenestra.
3. External nares above the internal nares.
4. Gracile paraoccipital process.
5. Squamosal process at least half as tall as the skull.
6. Strongly heterodont teeth.
7. Non-overlapping scutes.
8. Depressed supratemporal fenestra (Simpson, 1998; Chatterjee, 1978).

(See Figure 2.6.)

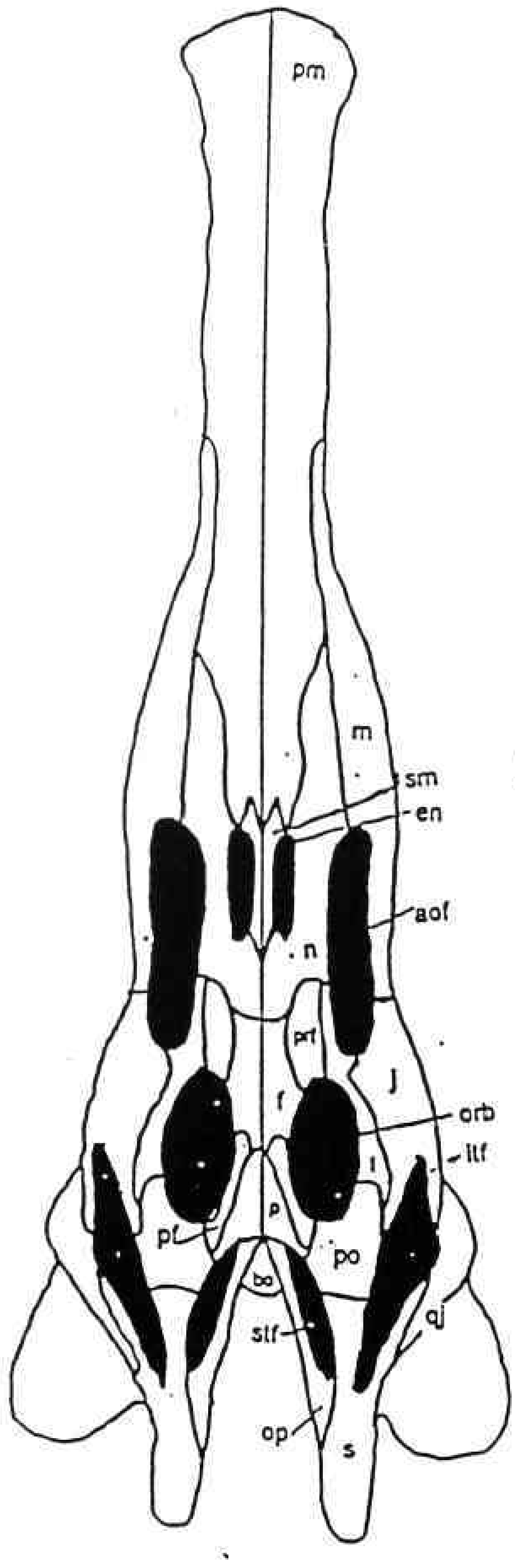


Figure 2.5. Reconstruction of *Angistorhinus* (Simpson, 1998). See Appendix for abbreviations.

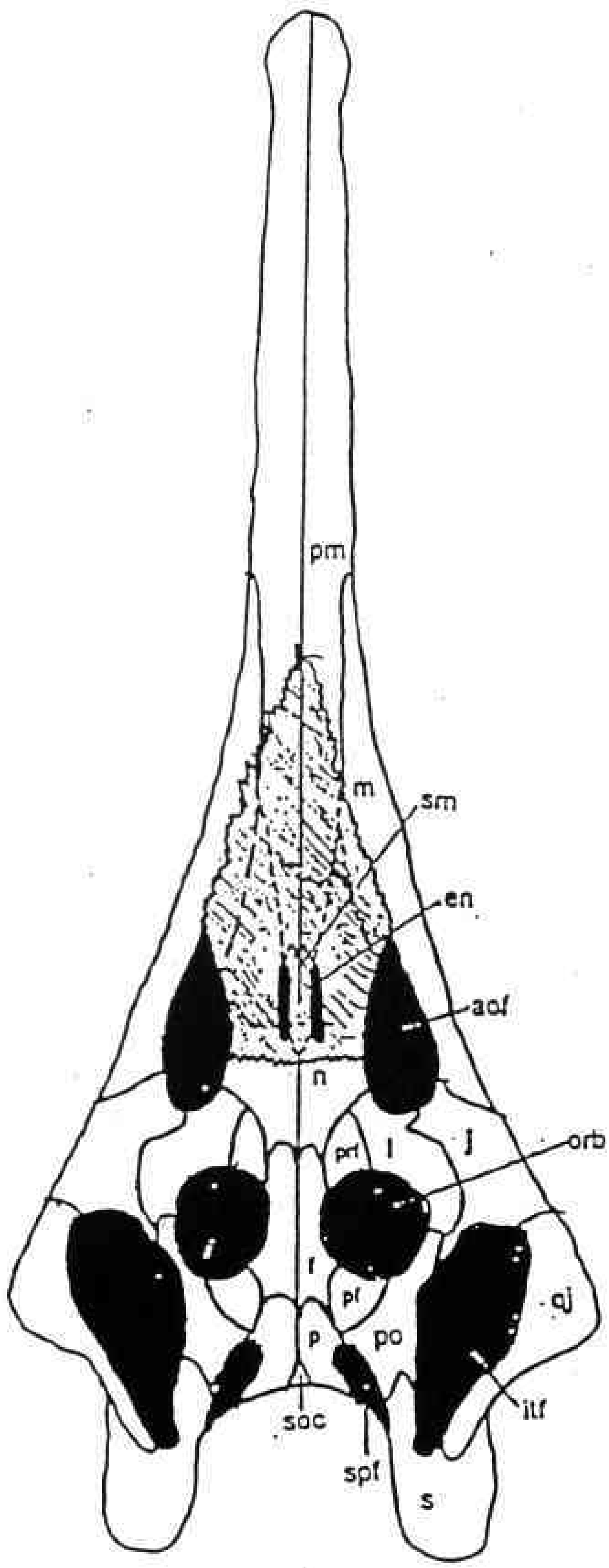


Figure 2.6. Reconstruction of *Rutiodon* (Simpson, 1998). See Appendix for abbreviations.

Nicrosaurus Fraas, 1866

1. A prenarial to postnarial length ratio of between 1.30 and 1.40.
2. Anterior and posterior margins of the external naris completely within the margins of the antorbital fenestra.
3. External nares above the internal nares.
4. Gracile paraoccipital process.
5. Relatively large posttemporal fenestra.
6. Strongly heterodont teeth.
7. Overlapping scutes.
8. Depressed supratemporal fenestra (Simpson, 1998; Chatterjee, 1978).

(See Figure 2.7.)

2.3 A New Phytosaur from the Macy Ranch

Although phytosaur fossils have been known for more than a century, the long-snouted form is ubiquitous in all taxa. The new phytosaur specimen, from the Macy Ranch, is unique because it has a short snout. However, the Macy Ranch specimen has external nares near the top of the head, as in all phytosaurs. Among living crocodilians, both long-snouted (*Gavialis gangeticus)* and short-snouted (*Crocodylus sp.)* variants are common. Therefore, it is not unlikely to see both variants among phytosaurs. Because of this remarkable discovery, the new material warrants a new taxonomic name.

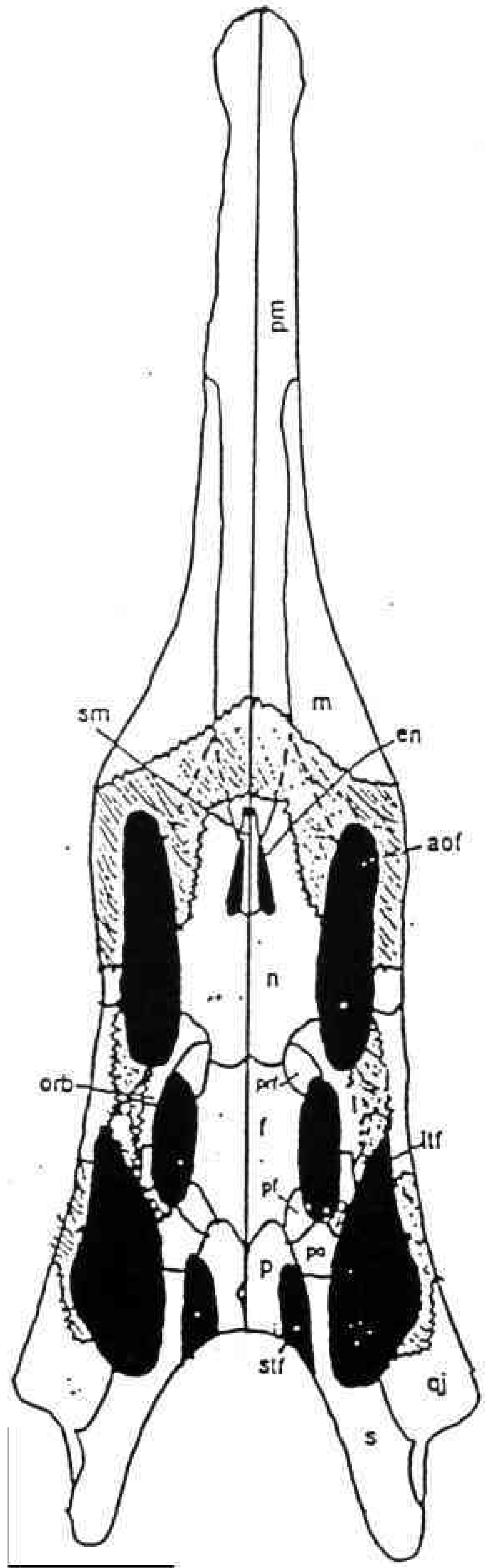


Figure 2.7. Reconstruction of *Nicrosaurus* (Simpson, 1998). See Appendix for abbreviations.

2.3.1 Systematic Paleontology

The new phytosaur specimen can be placed into the following systematic hierarchy:

Archosauria	Cope, 1869
Suchia	Krebs, 1974
Pseudosuchia	Zittel, 1890
Phytosauridae	Lydekker, 1888.

Diagnosis of the family. Phytosaurs are defined by the following cranial synapomorphies: skull elongate and dorso-ventrally compressed; elongated premaxillaries; a rostrum composed almost entirely from the premaxillaries; external nares positioned dorsally near the top of the head rather than the tip of the rostrum; nasals extended anteriorly, completely encompassing the external narial openings; ossified septomaxillae sutured medially in the dermal skull roof and lateral displacement of the nasals; a bicephalic quadrate; a fused pterygoid and basisphenoid; contact between the premaxilla and palate; a braincase fused to the skull; subtriangular quadratojugal; symphysis formed in part by the splenial and at least half the length of the mandible; a screw-shaped mandibular articulation; secondary palatal shelves; a crescentic coracoid; enlarged interclavicle; calcaneal tuber directed postero-laterally; linguiform osteoderms with compressed central ridges and eminent radial ridges and grooves (Simpson, 1998; Long and Murry, 1995; Hunt, 1994; Ballew, 1989).

Genus *Macysuchus*, n. gen.

Etymology. The generic name is given in honor of Mr. and Mrs. Robert Macy.

Species *Macysuchus brevirostris*, n. gen., n. sp.

Etymology. The specific name alludes to its short rostrum; in Latin brevis "short" + Latin rostrum "snout" + -is (feminine ending).

Holotype. Articulated skeleton and skull, TTUP 9425, housed in the Museum of Texas Tech University.

Type locality. Macy Ranch, Garza County, Texas.

Horizon. Cooper Canyon Formation of the Dockum Group, Late Triassic.

Diagnosis. The new species is distinguished from all other phytosaur taxa by the following autapomorphies: short premaxillae with a prenarial to postnarial ratio of 0.6; sacrum composed of three vertebrae.

2.3.2 Description of *Macysuchus brevirostris*

Skull. The dorsal and right-lateral sides of the skull are visible (Figures 2.8, 2.9). The right side of the skull is nearly complete, missing the tip of the snout and mandible. The skull is somewhat crushed sideways so that the ventral margin of the right side projects downward relative to that of the left side. The bones are beautifully preserved, showing individual sutures and interrelationships. The surface texture is somewhat rugose and pitted. There are at least four tooth marks on the skull which show signs of healing. Like other phytosaurs, the skull roof is fenestrated by upper and lower temporal openings, orbits, antorbital fenestrae, and external nares. The abbreviated snout is not an artifact, because the aveolar margin, although crushed, appears to be complete.

The main measurements in millimeters of *Macysuchus brevirostris* are given as Table 2.1.

Table 2.1. Main body measurements of *Macysuchus brevirostris.*

Bone	measurement	Bone	measurement
Skull length	590	Skull width	215
Skull height	180	Prenarial length	205
Postnarial length	328	Distance from rear of naris to front of orbit	81
Interorbital width	68		
Preorbital length	337	Postorbital length	185
Total length of the mandible	314	Presacral column length	1416
Scapulocoracoid height	249	Breadth apex of scapula	60
Coracoid breadth	182	Gastralia	163
Humerus length	314	(measured ½ of the median element)	
Humerus, least diameter of the shaft	103	Ulna length	252
		Ilium, crest length	217
Ilium height	183	Ishium height	194
Pubis height	170	Femur length	359
Femur, least diameter of the shaft	124	Tibia length	210
		Fibula length	204
Sacral column	187		

Dermal bones of the skull roof.

Premaxilla . This is a slender bone that tapers forward to form the alveolar margin. Posteriorly, a narrow dorsal process extends backward to meet the septomaxilla. Below the septomaxillary contact, the premaxilla articulates with the nasal. Ventrally, the premaxilla meets with the maxilla.

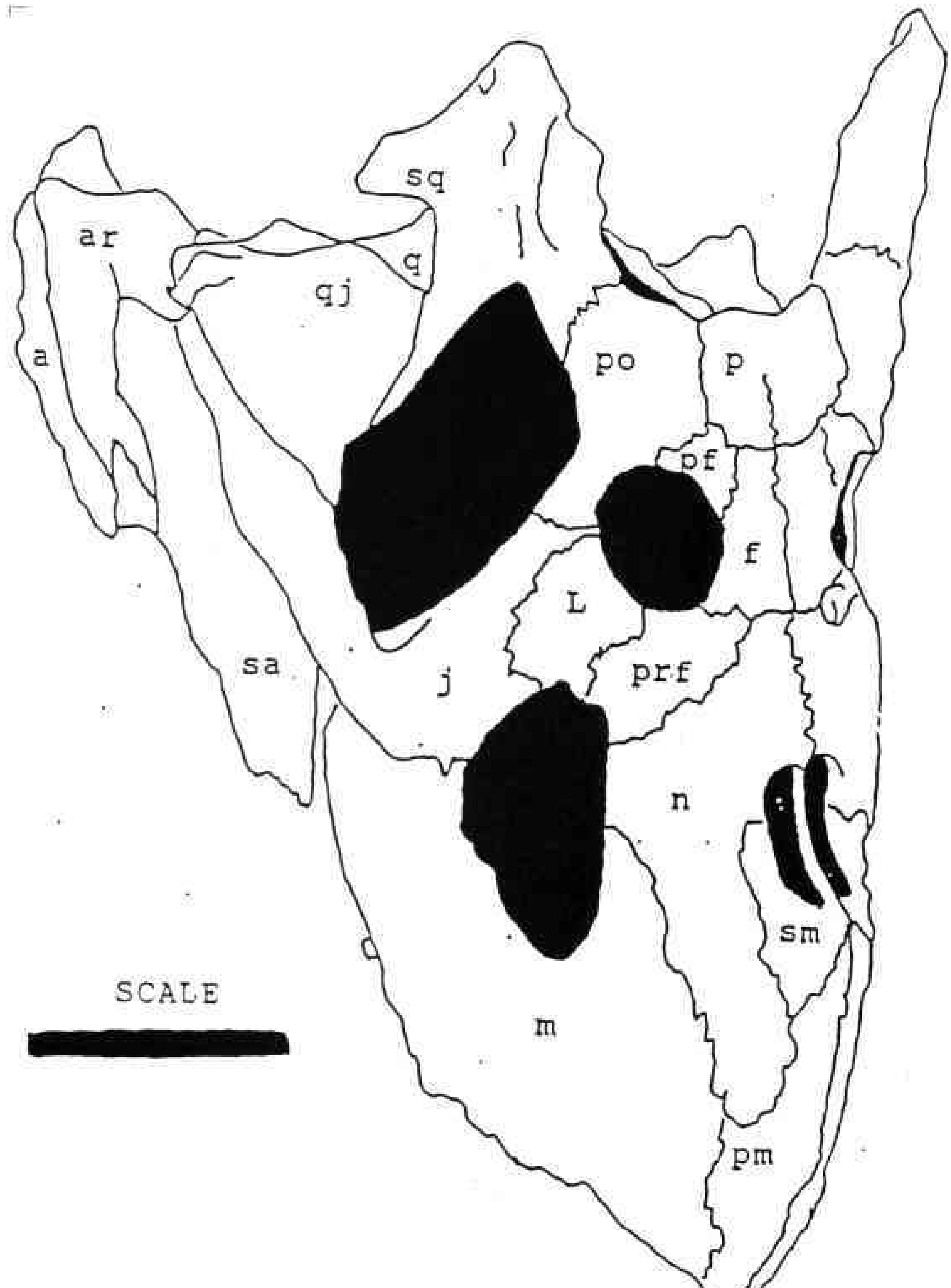


Figure 2.8. Skull of *Macysuchus brevirostris.* See Appendix for abbreviations. Scale equals 12 cm.

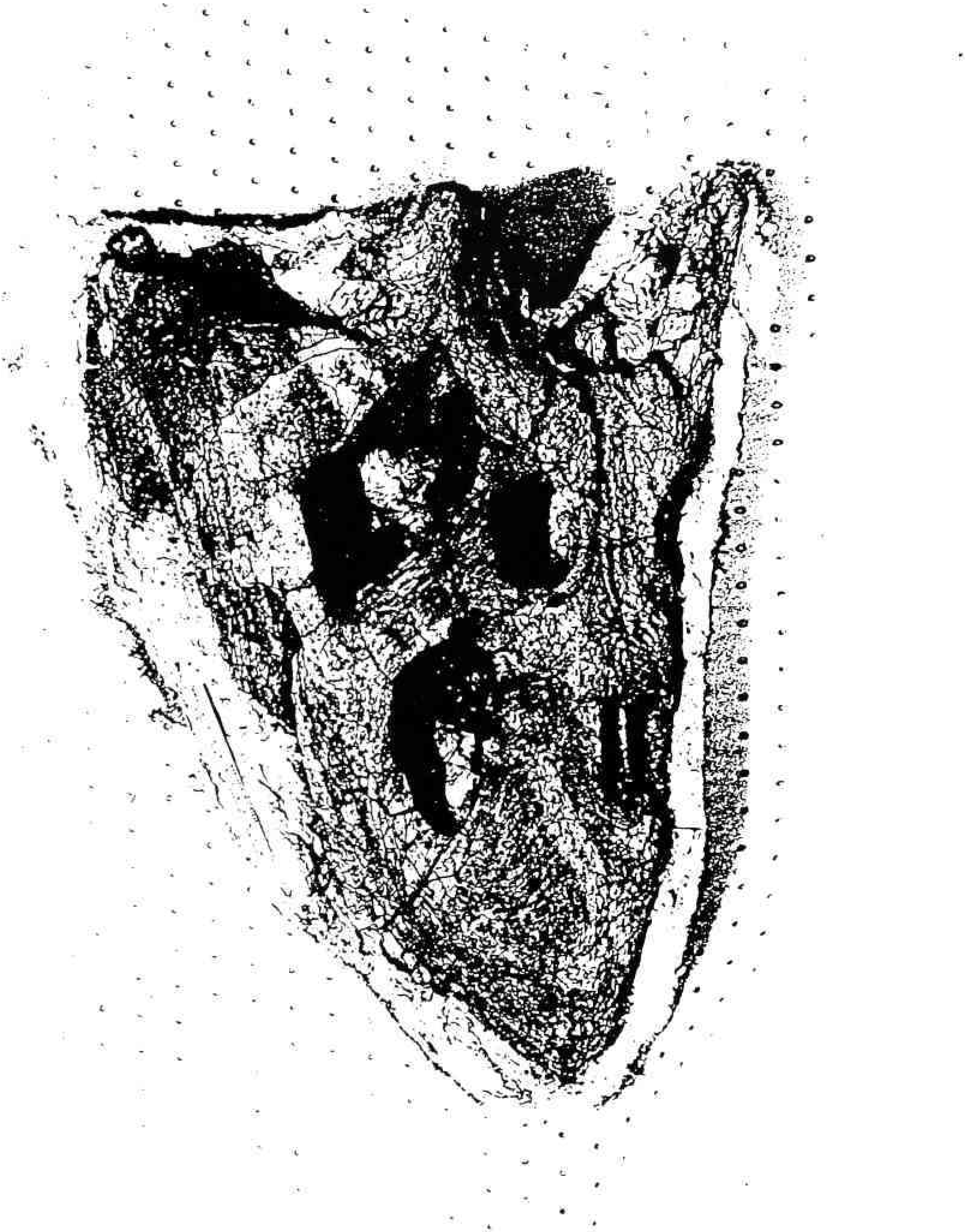


Figure 2.9. Photograph of *Macysuchus brevirostris* skull.

Maxilla. This is a large, crescentic bone forming the postero-ventral margin of the premaxilla and nasal; the anterior margin of the jugal; and the ventral, rostral, and one half of the dorsal margin of the antorbital fenestra. Most of the dentition is contained within the margins of the maxilla. The maxilla is the largest bone of the skull roof. Septomaxilla. The septomaxilla is small, separating the nasal rostral to the nares, and comprising more than half of the latero-ventral margin of the nares.

Nasal. The nasal is a large, "L"-shaped bone that articulates into the dorsal margin of the maxilla and the anterior margin of the frontal and prefontal. It contributes to part of the dorsal edge of the antorbital fenestra.

Prefrontal. This is a rectangular bone with its anterior margin articulating the nasal. It attenuates as it moves dorsally and posteriorly towards its postero-dorsal margins with the orbit and the frontal bone. The postero-ventral margin is against the lacrimal. The ventral edge is slightly cupped and formed by the antorbital fenestra.

Lacrimal. This is a rectangular bone with its anterior margin against the prefrontal and its dorsal edge against the orbit. Posteriorly, the lacrimal meets the jugal, curving anteriorly on the dorsal margin to the antorbital fenestra.

Frontal. Rostrally, the frontal bone articulates with the nasal and prefrontal; caudally it meets the parietal; ventrally it meets the postfrontal.

Parietal. The parietal is partially fused anteriorly. It forms the posterior margin of the skull table.

Squamosal. The squamosal is a large, tetraradiate bone with sharp projections pointing ventrally on the postero-ventral margin. Ventrally, the squamosal wraps around the quadrate head and extends forward over the quadratojugal. Medially, it meets with the postorbital.

Jugal. The jugal is an elongated, "L" shaped bone forming the ventral, and most of the anterior margins of the lower temporal fenestra. Its ascending process meets dorsally with the lacrimal and postorbital to form a bar between the orbit and the infratemporal fenestra.

Palate

The palate is missing to a large extent from the specimen. Because the skull has been crushed, the palate is sheared into two pieces. On the right side, the maxilla, palatine, and part of the ectopterygoid are preserved. On the left, two pterygoids are found fused together.

Quadrate

The quadrate is beautifully preserved on the right side of the skull. It is in articulation with the articular of the lower jaw. Medially, it has a very large flange for the reception of the pterygoid. Dorsally, the head fits firmly under the surface of the squamosal.

Braincase

The braincase is well preserved and is fused to the skull roof. It has a large, spherical occipital condyle and a pair of wing-like paroccipital processes on the dorsal surface. Ventrally, it is differentiated into a pair of basal tubera. The anterior part of the braincase is missing.

Lower Jaw

Only the posterior of the mandible is preserved, showing the articular, surangular, and angular, as well as the posterior rim of the external mandibular fenestra.

Dentition

The teeth are not well preserved. Many of the tooth sockets are empty. The few intact teeth show conical, pointed architecture without much differentiation from front to back.

Postcranial skeleton

Vertebral column. This consists of a complete cervical progression of nine vertebrae including the atlas; a complete dorsal series of 15 vertebrae; three sacral vertebrae; and an incomplete caudal series of five vertebrae (Figures 2.10, 2.11, 2.12, 2.13). From cervical to dorsal vertebrae, the rib facet on the centra (parapophysis) migrates dorsally towards the diapophysis. The neural spines are thinner for the cervical vertebrae, becoming wider as they move posteriorly with the exception of the axis which has a particularly robust neural spine. The sacrum is distinguished by its distinctive, wing-like ribs, which are fused to the centra and at the distal end of the rib. The neural spines of the five caudal vertebrae are wide and tall.

Ribs. The ribs are regionally differentiated. The cervical ribs are short, with their heads close together, but with increasing bifurcation as they move posteriorly. The anterior dorsal ribs are much longer, thicker, and recurved. The shafts are subtriangular proximally and subcircular distally. Posteriorly, the two rib heads become confluent. The sacral ribs are immovably attached to the vertebrae. Each rib is robust, with a broad head, and a distal expansion that articulates to the inner surface of the ilium. The caudal ribs are short and narrow.

Osteoderms. A beautiful series of osteoderms (scutes) is well preserved and remains largely articulated. Each vertebra receives a pair of paramedian scutes which are overlapping in the series. The first three scutes of the cervical vertebrae are smaller and triangular. Scutes become larger and more ovoid as they move posterior. Dorsally, each shows a central eminence from which ridges and grooves radiate. Ventrally, the scutes are slightly concave, allowing for the tapering anterior portion of the succeeding scute to be overlapped by its anterior predecessor. In addition to paramedian scutes, there are smaller ossicles of varying shape and size, sporadically covering the body and limb elements. These range from oval, to rectangular, to slightly recurved. None are articulated.

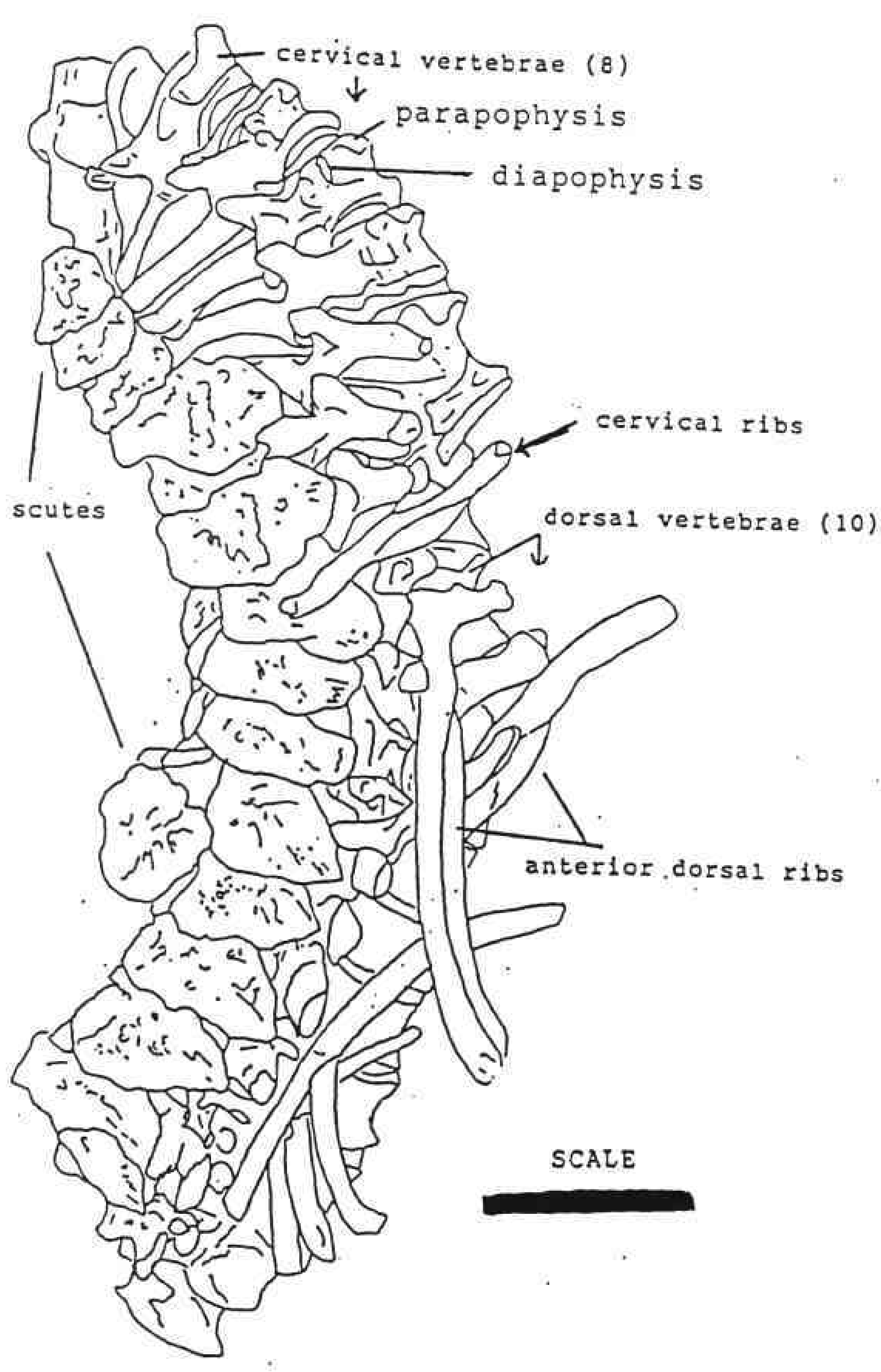


Figure 2.10. Cervical series and other postcranial elements in *Macysuchus*. Scale equals 12 cm.

Figure 2.11. Photograph of cervical series and other postcranial elements in *Macysuchus*.

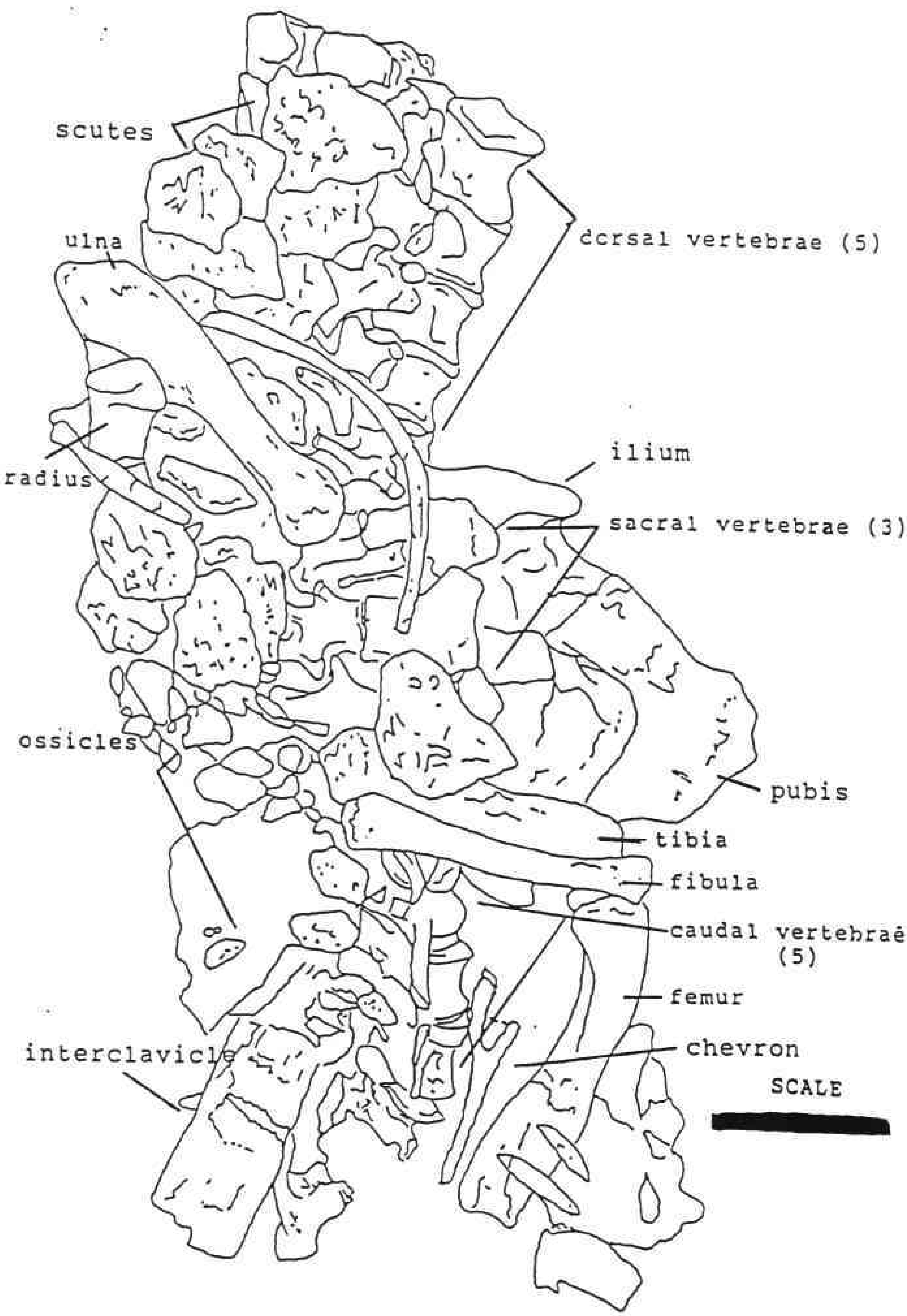


Figure 2.12 Dorsal series and other postcranial elements in *Macysuchus*. Scale equals 12 cm.

Figure 2.13 Photograph of dorsal series and other postcranial elements in *Macysuchus*.

Gastralia. The gastralia are largely intact (Figures 2.14, 2.15). There are at least 14 rows of stout rods, each consisting of a long, "V" shaped, median element, and a pair of short, lateral elements. Inside this ventral basket, the metacarpal bone of a small animal was found, possibly having been ingested.

Shoulder girdle

Scapula. The scapula and coracoid are fused together to form a large, glenoid cavity for the reception of the humerus. The scapula is curved to fit around the ribs and it broadens distally.

Coracoid. The coracoid has a notch posteriorly, and a large projection (Figures 2.16, 2.17).

Interclavicle. Part of the interclavicle is preserved. It is a plate-like bone, slightly curved, and has a pair of ridges on the ventral surface.

Forelimbs

The humerus, radius, and ulna are preserved; however, the hand bones are missing.

Humerus. The humerus is expanded at both ends with a slim shaft. Proximally, the head is well differentiated below the head, and there is a prominent deltopectoral crest. Distally, it is divided into two prominent condyles for the reception of the radius and ulna. There is a prominent supinator crest on the lateral edge.

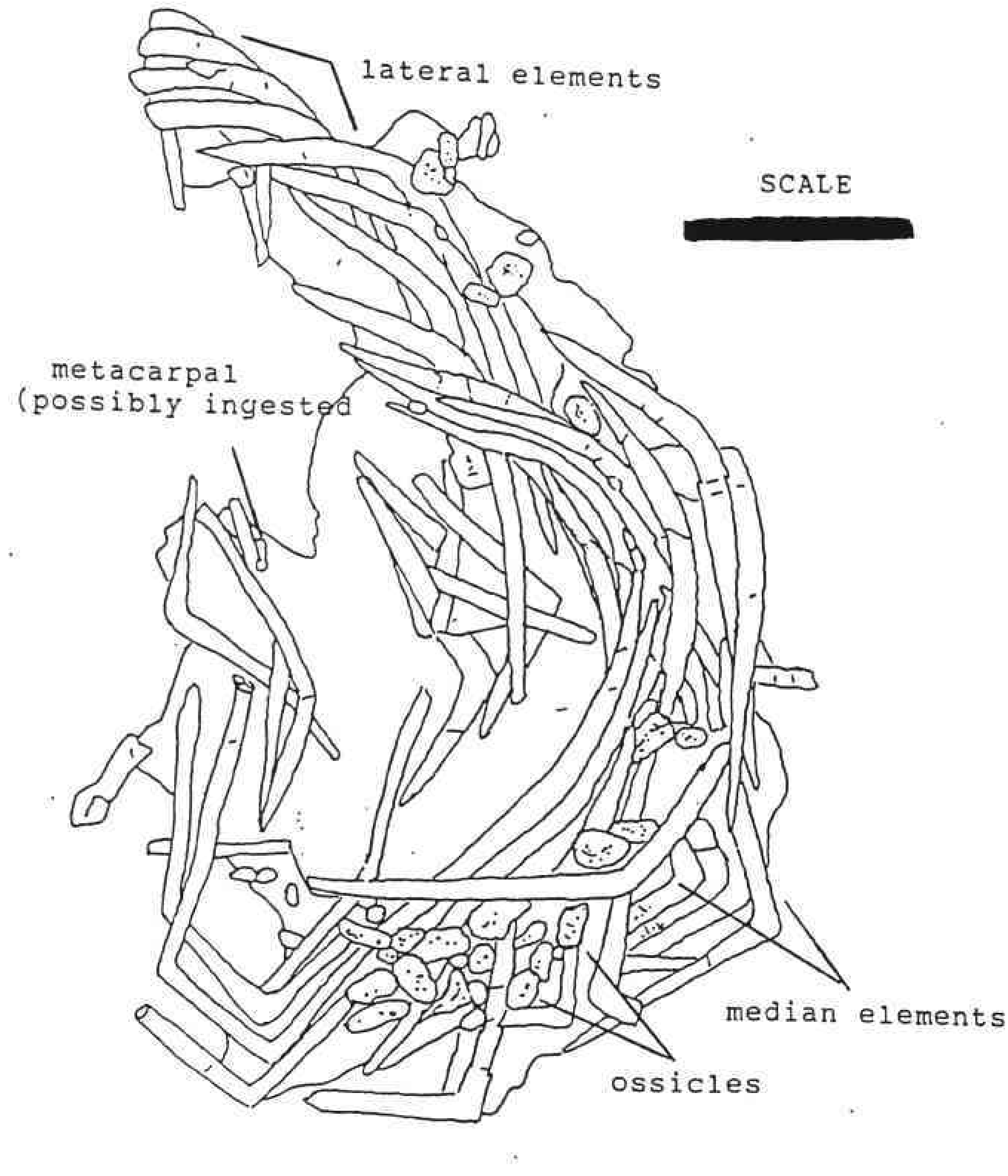


Figure 2.14. Gastralia of *Macysuchus*. Scale equals 12 cm.

Figure 2.15. Photograph of gastralia of *Macysuchus.*

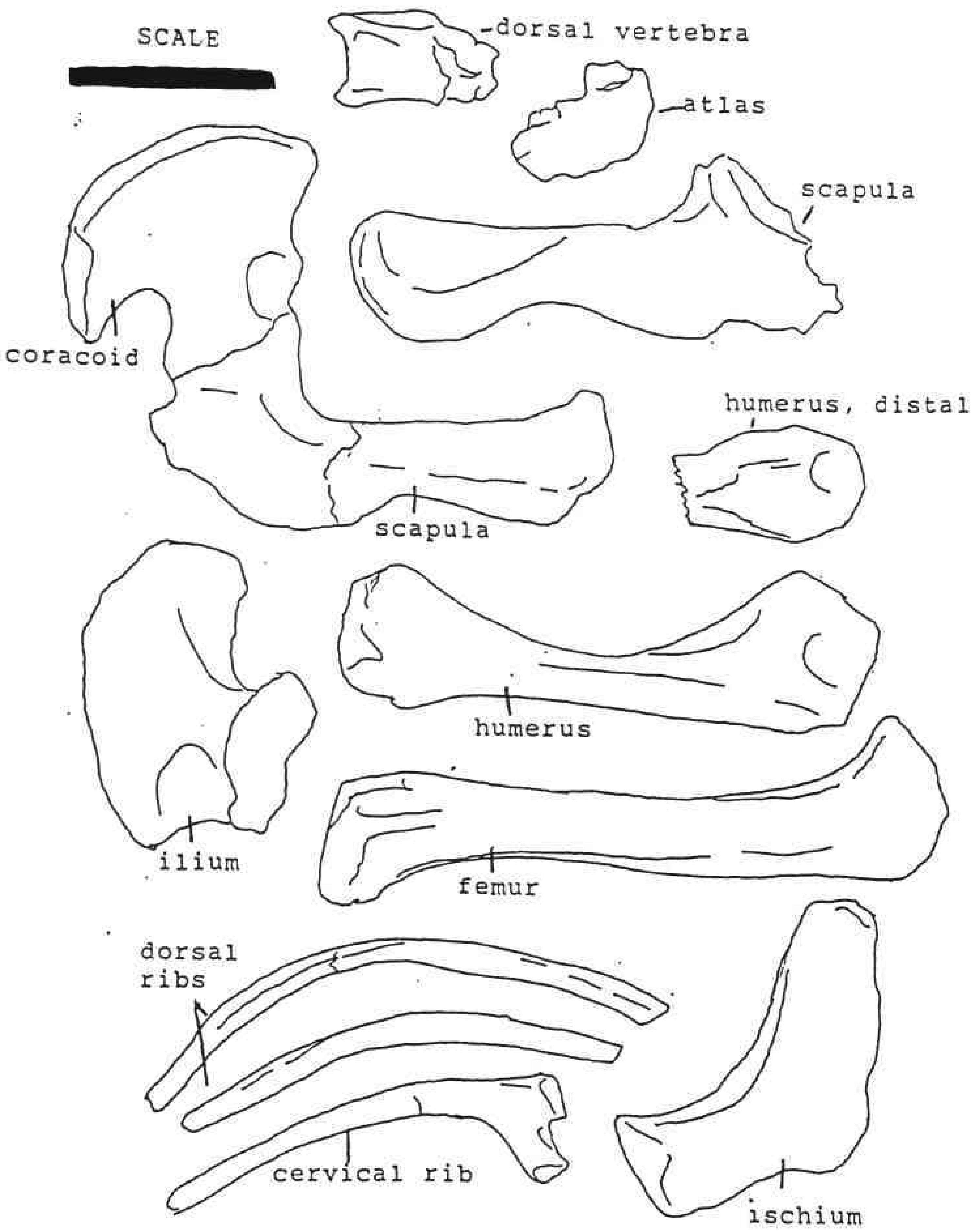


Figure 2.16. Shoulder girdle, pelvic girdle, and limb bones of *Macysuchus*. Scale equals 12 cm.

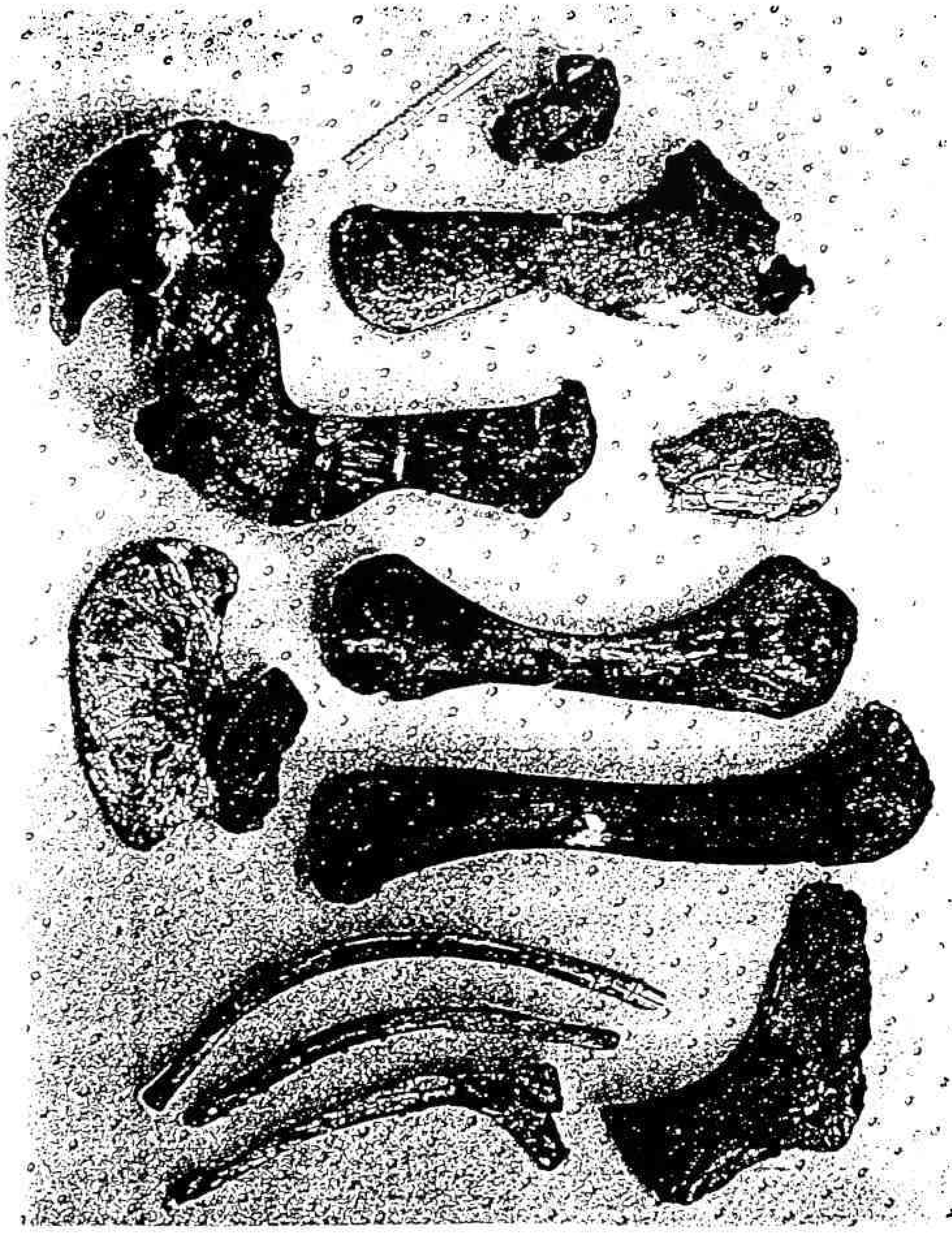


Figure 2.17. Photograph of Shoulder girdle, pelvic girdle, and limb bones of *Macysuchus*.

Ulna. The ulna is stouter and longer than the radius. It has a prominent olecranon process for the articulation with the humerus.

Pelvic girdle

The pelvic girdle is largely intact. The pelvis is primitive, plate-like, with an imperforated acetabulum.

Ilium. The ilium has a large iliac blade with anterior and posterior projections.

Pubis. The pubis has distinctive obturator foramen.

Ischium. The ischium becomes narrow and blade-like ventrally.

Hindlimbs

Elements of the hindlimbs include a pair of femora, a tibia, a fibula, and the ankle bones.

Femur. The femur is sigmoidal, and has proximal and distal expansions that do not lie in the same plane; they are twisted at an angle of 50 degrees. It is longer than the humerus. Below the head, there is a prominent fourth trochantor on the ventral surface of the femur. Distally, the femur is diverted into two condyles.

Tibia. This bone has an expanded proximal end with a cnemial crest.

Fibula. The fibula is a slim bone.

Astragalus and calcaneum. These form the proximal row of ankle bones, indicative of a peg and socket joint. The calcaneum has a prominent lateral process. The astragalus is massive.

2.3.3 Discussion

Macysuchus shares the following characters with other phytosaurs: external nares positioned dorsally near the top of the head rather than the tip of the rostrum; nasals extended anteriorly, completely encompassing the external narial openings; ossified septomaxillae sutured medially in the dermal skull roof and lateral displacement of the nasals; a braincase fused to the skull; subtriangular quadratojugal; and linguiform osteoderms with compressed central ridges and eminent radial ridges and grooves.

Macysuchus exhibits many derived features found in *Rutiodon* and *Nicrosaurus* (Figure 2.18). These are: margins of the external naris within the margin of the antorbital fenestra; depressed supratemporal fenestra; enlarged squamosal with a strong posterior and deep ventral process.

However, *Macysuchus* is distinctive from all other known phytosaur genera due to its highly abbreviated rostrum and three sacral vertebrae. The skull appears to be deep relative to its width, and the external nares seem larger than most known phytosaur genera (Figure 2.19).

The most striking autapomorphy displayed by *Macysuchus* is in its abbreviated rostrum; the snouts of phytosaurs are typically long. This begs the question of whether the shortened snout of *Macysuchus* is the result of breakage, although only the extreme tip of the snout is missing . Figure 2.20 shows reconstructions illustrating comparatively abbreviated rostrums for *Nicrosaurus* and *Rutiodon*. The premaxilla of *Nicrosaurus* is characteristically massive; much wider at its anterior articulation with the septomaxilla, and much wider and thicker at the correlative point of abbreviation. The premaxilla of

Rutiodon is more gracile, similar to that of *Macysuchus*, at both its articulation with the septomaxilla and its correlative point of abbreviation. However, the morphology of the lacrimal, jugal, and prefrontal bones, and the size of the naris, differs greatly between *Rutiodon* and *Macysuchus*.

Since, in phytosaurs the external nares are already decoupled with the size of the rostrum (Hunt, 1994), it is not unlikely to see a short-snouted phytosaur. Among modern crocodilians, both long and short-snouted variants are common, as seen in *Gavialis gangeticus* and *Crocodylus niloticus*. Additional analogies between crocodilians and phytosaurs exist in ankle structure and mode of life. As phytosaurs shared similar ecological niches, it is likely that they may also have given rise to these two distinct morphotypes. Until the discovery of *Macysuchus*, the short-snouted type was unknown.

In modern crocodilians, the morphology of the snout is linked with feeding habits (Neill, 1971). It is likely that phytosaur behavior was similarly linked with snout length. *Gavialis* and *Paleorhinus* exhibit strikingly similar cranial morphology (Figure 2.21). Both animals have long, slender snouts and homodont, to weakly heterodont, dentition; typical of piscivorous animals. Additional characters thought to be shared between *Gavialis*, *Paleorhinus*, and other piscivores include: slender dorso-ventral and transverse proportions of the snout end; slender mandible with parallel ventral and dorsal margins; and rostral tip turned ventrally (Hunt, 1994).

Short-snouted crocodiles, such as *Crocodylus niloticus* are typically generalist feeders, preying on large, terrestrial vertebrates (Neill, 1971). These hunters often lie in ambush, at the water's edge, and strike animals that have come to drink. *Macysuchus* would likely have filled a similar niche, and was probably an active predator. Analogies in snout-length between *Macysuchus* and *Crocodylus sp.* are seen in Figure 2.22.

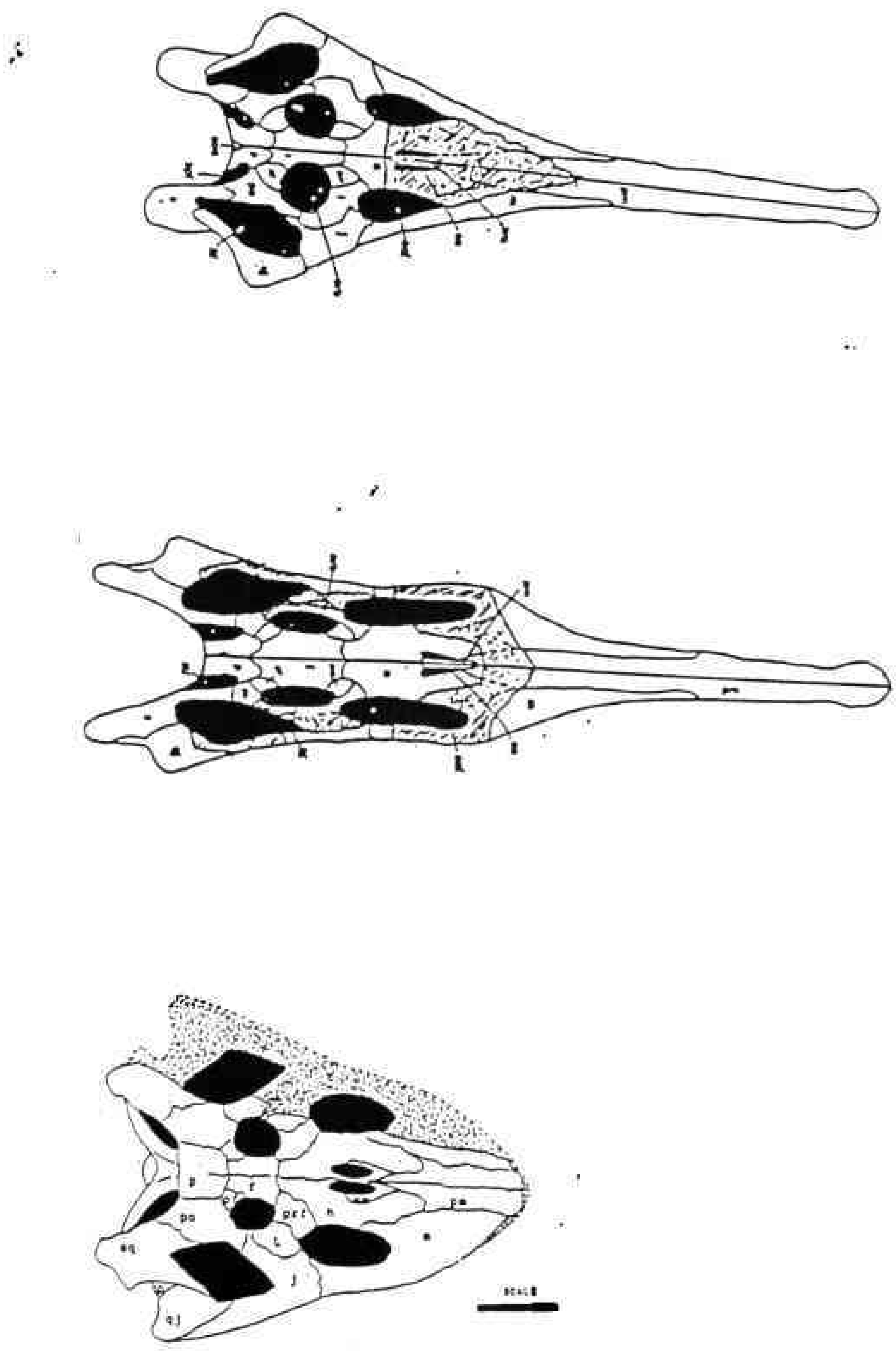


Figure 2.18. Comparisons of skull morphology between *Rutiodon*, *Nicrosaurus* (After Simpson, 1998), and *Macysuchus*. Scale equals 12 cm.

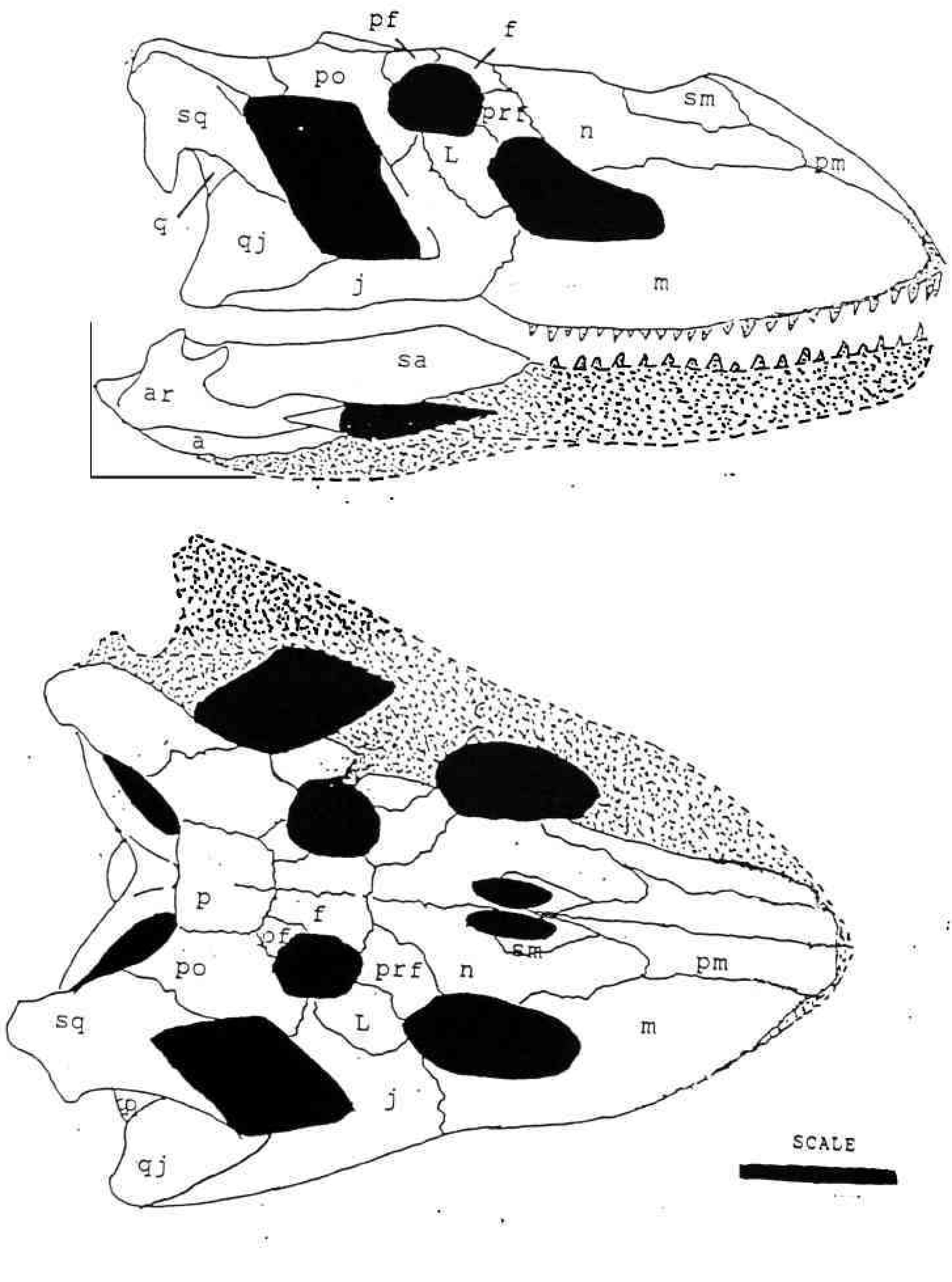


Figure 2.19 Reconstruction of *Macysuchus* skull. Scale equals 12 cm.

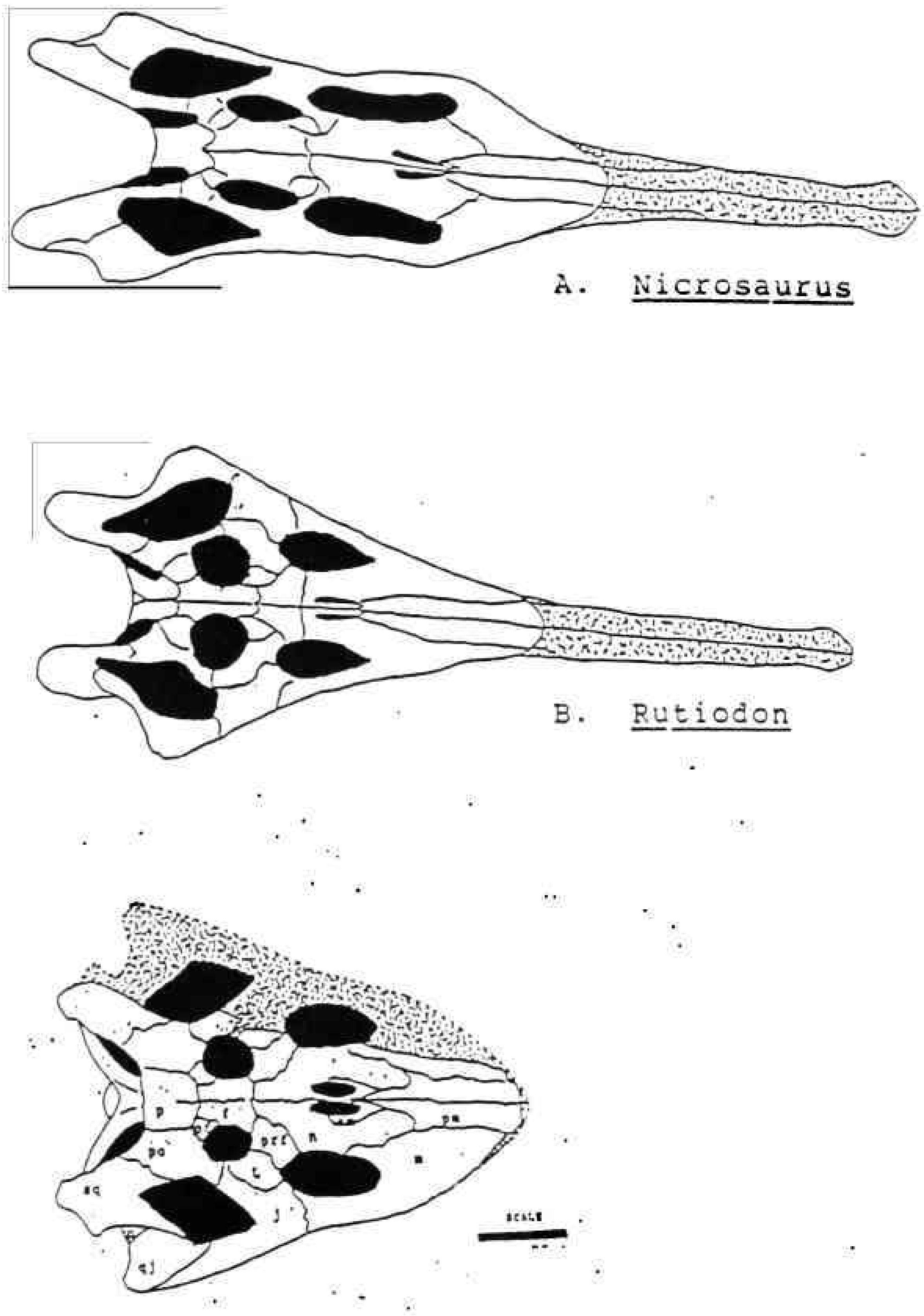


Figure 2.20 Reconstructions of *Nicrosaurus* and *Rutiodon* with abbreviated snouts. Scale equals 12 cm.

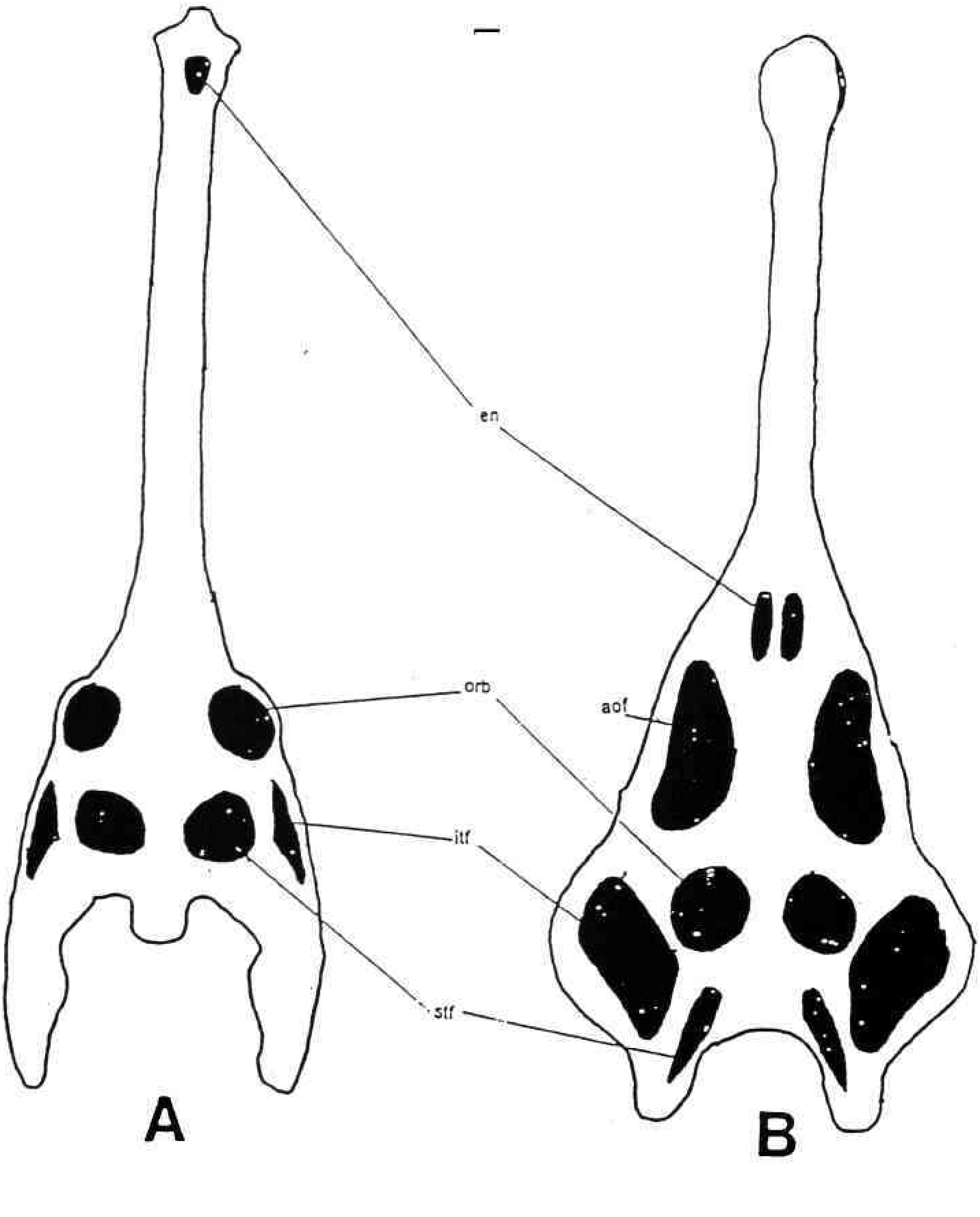
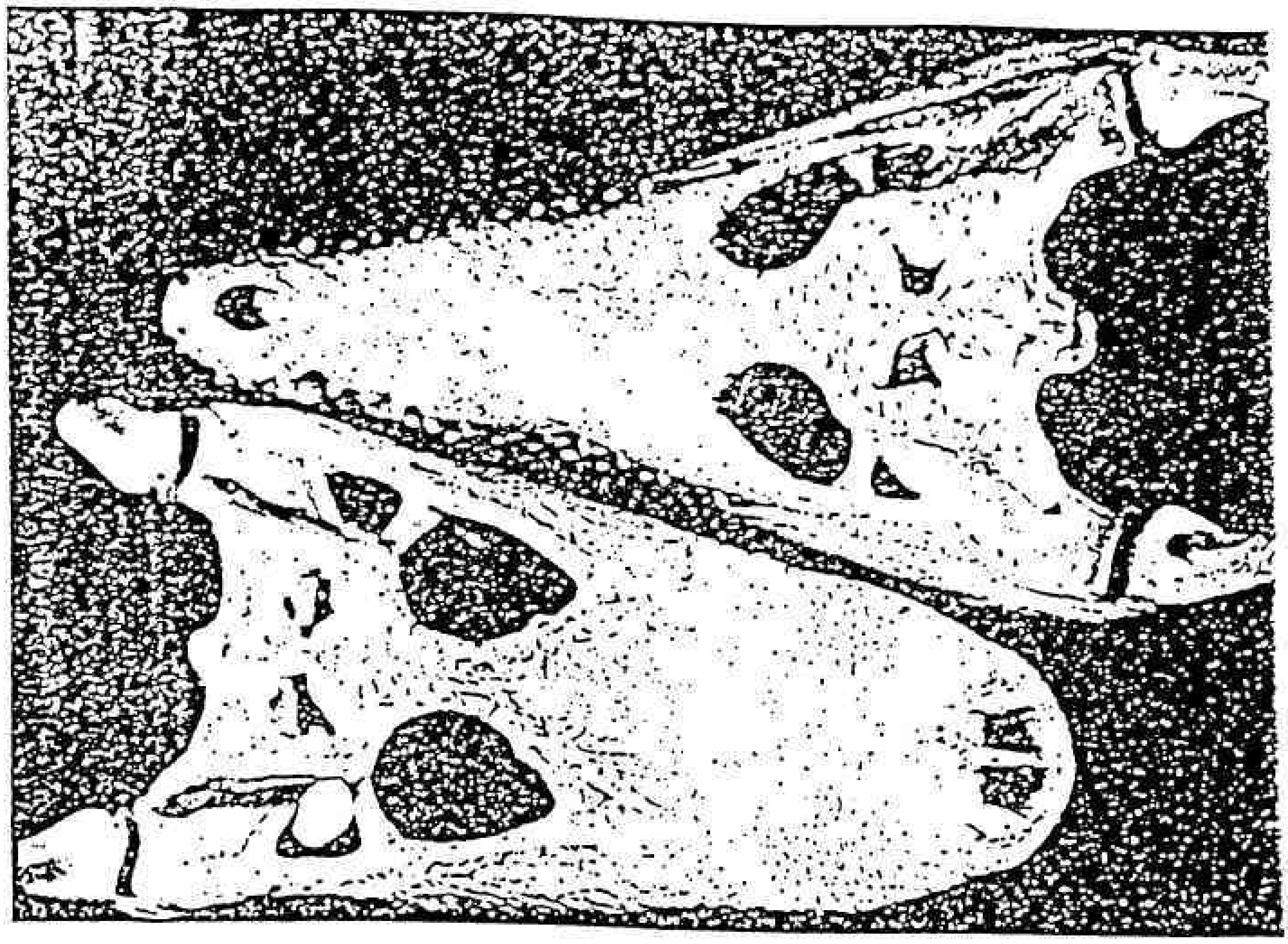
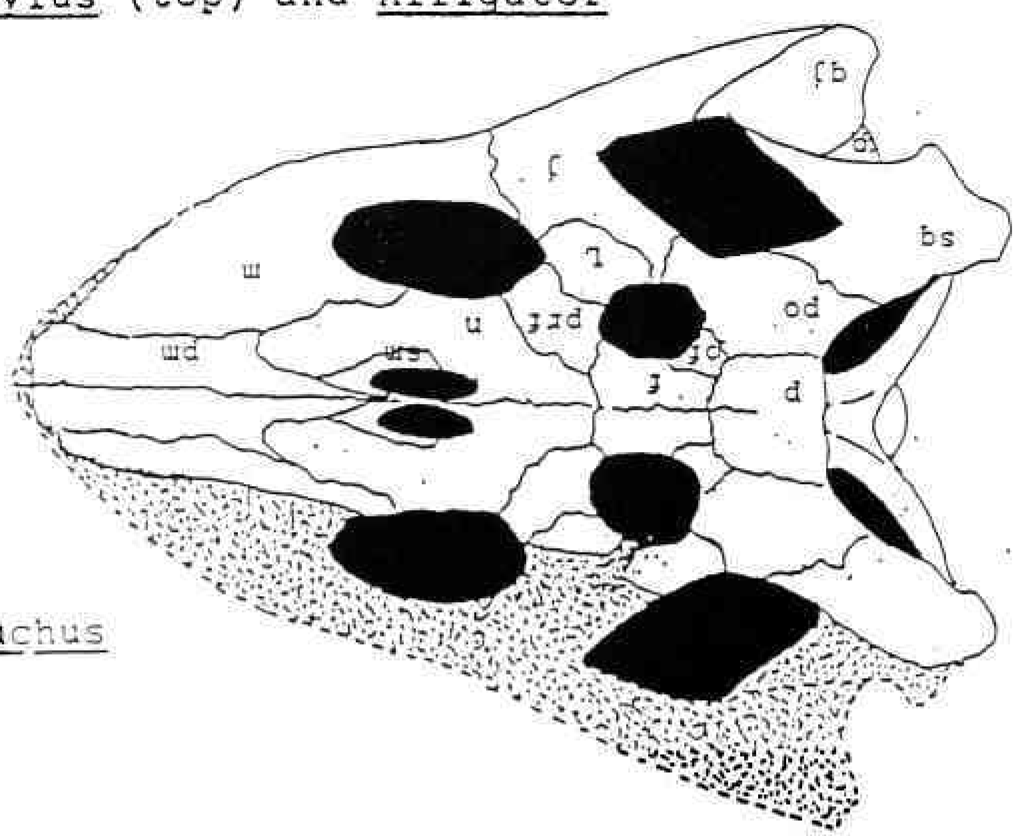


Figure 2.21 Comparisons between *Gavialis* and *Paleorhinus* (Simpson, 1998).



Crocodylus (top) and Alligator



Macysuchus

Figure 2.22 Comparisons between *Crocodylus*, *Alligator* (After Obst et al., 1988), and *Macysuchus*.

CHAPTER III

GEOLOGIC SETTING

Phytosaur material in the region around Lubbock, Texas is found in the Upper Triassic Dockum Group (Figures 3.1). These are continental red beds, exposed around the southern High Plains in Texas and eastern New Mexico (Chatterjee, 1997). The Dockum Group lies unconformably over Permian strata, and is overlain by Cretaceous, Tertiary, and Quarternary strata (Lehman, Chatterjee, and Schnable, 1992). In Texas, Dockum Group strata are assigned to four formations. These are, in ascending order, the Santa Rosa Sandstone, the Tecovas Formation, the Trujillo Sandstone, and the Cooper Canyon Formation (Lehman, 1994).

The Dockum is characterized by cross-bedded sandstones, conglomerates, siltstones, and mudstones that accumulated in a variety of fluvial, lacustrine, and floodplain environments. The mudstones and siltstones are prone to weather, producing characteristic "badlands" with sandstone ridges (May and Lehman, 1989).

The Dockum Group has produced an outstanding variety of Triassic vertebrate fossils. Since the early 1980's, Texas Tech University has conducted much field research, and collected specimens under the direction of Dr. Sankar Chatterjee. The Museum of Texas Tech University now houses one of the richest collections of Triassic vertebrate fossils in the world. Among these are many holotype specimens, such as *Protoavis, Postosuchus, Shuvosaurus,* and *Technosaurus.* The Museum also houses many fine phytosaur fossils, including all genera known from the Dockum Group. Other Dockum vertebrates include aetosaurs, metoposaurs, dicynodonts, and several undescribed fauna. The food chain of terrestrial Dockum vertebrates is shown in Figure 3.2.

The basal unit of the Dockum Group is the Santa Rosa Sandstone, a formation comprised of a quartzose sandstone with particles of quartzite, chert, and sedimentary rocks. Above the Santa Rosa Sandstone is the Tecovas Formation. It is largely a mudstone deposit that intertongues with the overlying Santa Rosa deposits. The Trujillo Sandstone overlies the Tecovas Formation. These are cliff-forming sandstones and conglomerates derived largely from metamorphic rocks. The Tecovas Formation was deposited by meandering streams creating a high-energy environment that was deleterious to fossilization. There are no known phytosaur skulls from the Trujillo Sandstone. Deposits of the Cooper Canyon Formation intertongue with those from the Trujillo Sandstone. Cooper Canyon deposits are primarily mudstone and siltstone derived from the erosion of metamorphic rocks (Simpson, 1998). There are many thin beds of carbonate granule conglomerates, many of which contain fossil shells and bivalves (Lehman et al., 1992; Lehman, 1994).

Recently, Simpson (1998) analyzed the biostratigraphic ranges of the Dockum phytosaur genera and found that *Paleorhinus, Angistorhinus,* and *Rutiodon* have overlapping ranges from the Carnian to the Norian. So far, *Nicrosaurus* appears to be restricted to the Norian stage and may be useful for subdivision of the Late Triassic continental rocks (Figure 3.3).

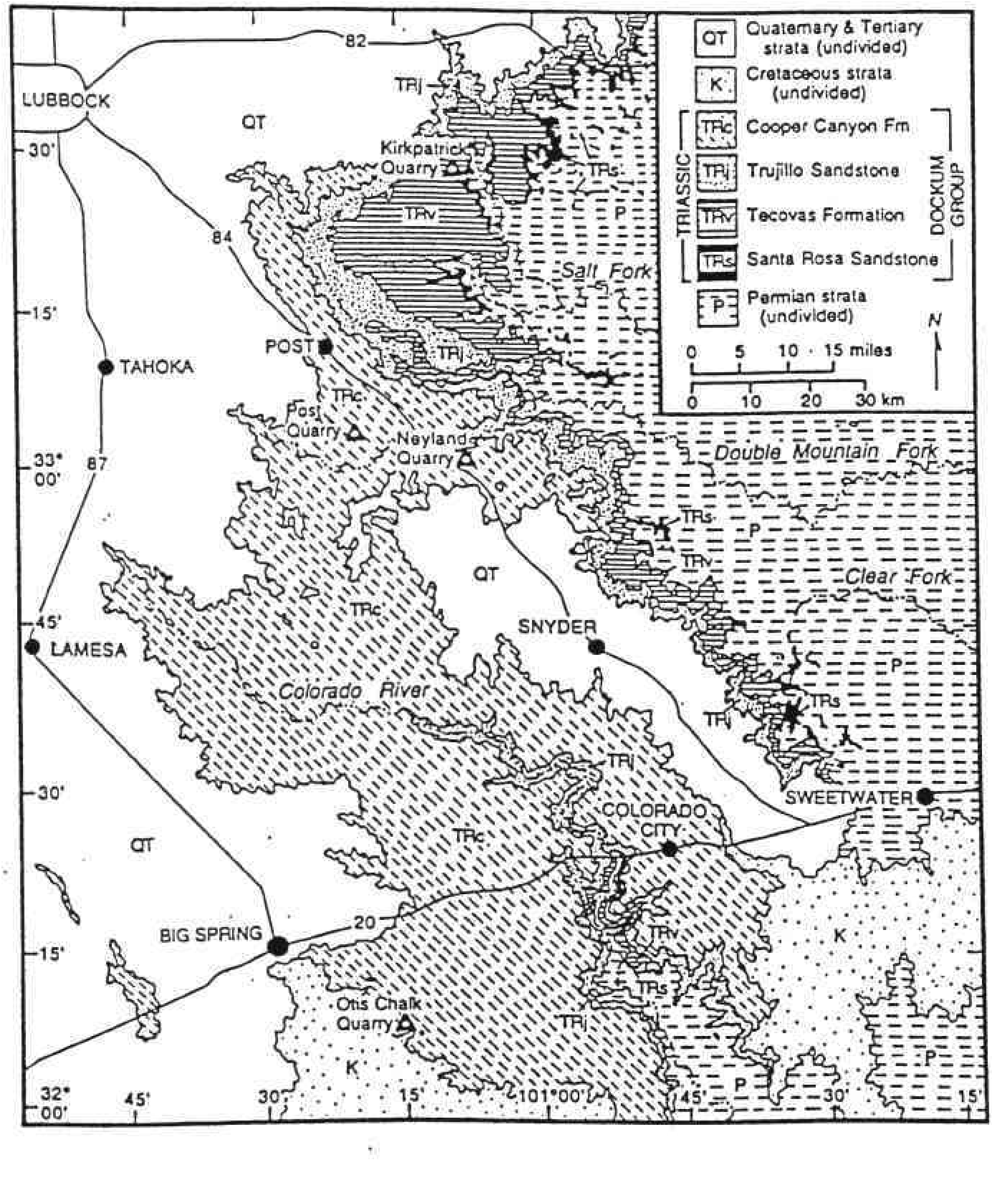


Figure 3.1. Exposures of the Dockum in West Texas (Chatterjee, 1997).

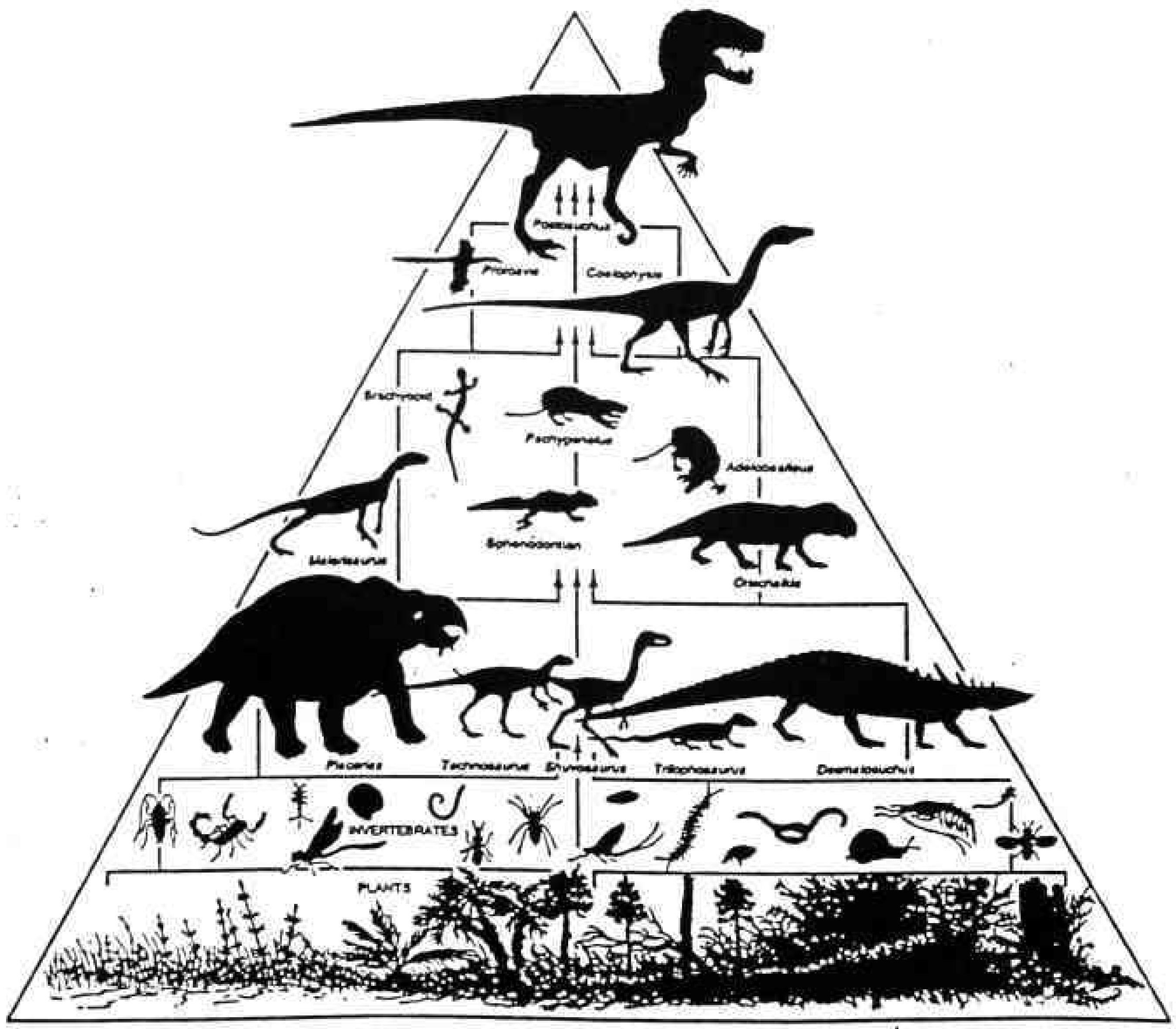


Figure 3.2. Terrestrial food chain of the Dockum (Chatterjee, 1997).

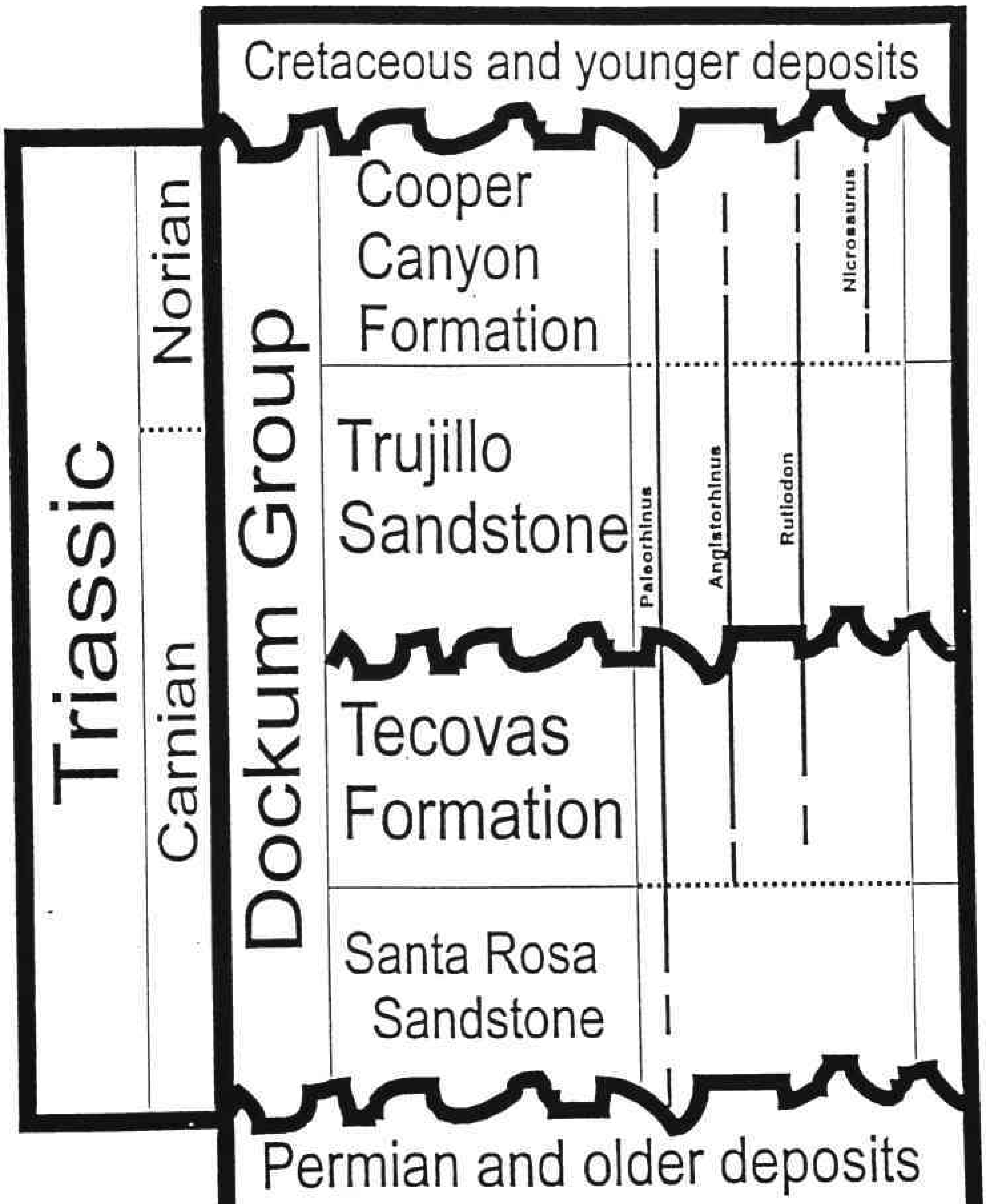


Figure 3.3. Revised stratigraphic ranges of the four genera of Dockum phytosaurs (Simpson, 1998).

CHAPTER IV

FIELD EXCAVATION

4.1 Introduction

Proper technique in the field is a necessary ingredient in the successful preparation and interpretation of fossil vertebrates. Techniques utilized in the field impact the long-term integrity of the specimen (Shelton, 1994). Considerations for the future integrity of the excavated fossil include proper site recording, examination of taphonomic data, careful selection of materials, and cautious excavation of the material.

Paleontological field work tends to be formation specific rather than site specific. As a result, archaeological methods are not necessarily mandated for removal of paleontological material (Shelton, 1994; Committee on Guidelines for Paleontological Collecting, 1987). However, careful site recording is essential.

Good planning is prerequisite to successful field collection. Materials used in the laboratory may need to be accommodated specifically for field use. Logistics, such as distance to the site, may impact the choice of materials used. Tools and materials should be chosen especially for the task at hand, insuring maximum protection for the fossil, and minimum stress for the collector.

Excavation techniques should insure that the fossil is returned intact to the museum. It is not imperative to expose the entirety of the specimen in the field, only that which is necessary to ensure safe removal. Detailed preparation and development of the specimen is best accomplished in the controlled environment of the laboratory.

4.2 Site Recording

The scientific value in a specimen is directly proportional to its provenance (Converse, 1984). Pertinent data includes site mapping, surveying, stratigraphic data, a record of materials used, and field notes. This information should be kept with collections records in the museum.

The use of United States Geological Survey (USGS) Quadrangle 7.5 minute 1:24000 scale topographical maps in conjunction with a site record allows for specific locality identification (Leiggi, Schaff, and May, 1994). These maps can be obtained through library loan, or purchased from a USGS office or a Public Lands District Office (Leiggi et al., 1994). The USGS section map, showing the *Macysuchus* quarry, follows as Figure 4.1.

A site record lists general data, pertinent to the specimen. This data includes locality, fossil type, geological information, collector's name, and any specific remarks (Figure 4.2). In general, a standardized form assures that all field participants record the same information.

The boundaries of the fossil bearing sediments should be determined, and marked with stakes and string. Screwdrivers, rock hammers, and other tools make handy stakes. Next, a grid is set up using one meter squares. The information is recorded into the field notes, either with sketches, photos, or both (Converse, 1984).

All specimens should be labeled, and corresponding data kept in the field notes (Figure 4.3). The label should include basic information, such as description, State, County, locality name, date, and collector's name (Converse, 1984). Labels can be placed in polyethylene bags along with the specimens, or placed inside field jackets. The jackets should be labeled, in waterproof pen, with similar information.

A log, separate from field notes, should be kept listing the materials and methods used in the excavation of fossil material (Shelton, 1994). This information should later be transferred to the collections records in the Museum.

Careful field notes should be kept by each member of the team. These should include locality information, excavation procedures, materials, logistics, and site drawings (Figures 4.4, 4.5). The following are paraphrased excerpts from field notes written by Chatterjee in reference to *Macysuchus*.

4.2.1 Field Notes for September 20 through October 12, 1996

Friday, September 20, 1996

We responded to a request by Bob Macy to examine some fossils he had found on his ranch. Mr. Macy showed us a mastodon skeleton he had discovered and took us to see what he believed to be a dinosaur track. It proved to be a trick of nature, a phenomenon of weathering. However, since the ranch had excellent exposures of the Dockum Group, we decided to do a little prospecting. Carter Keairns found a beautiful skeleton in a siltstone facies. The bones break easily into tiny flakes; they have probably been impregnated with gypsum.

The skeleton appears to be in bad shape. There are three teeth in position and what is possibly the palate exposed. Additionally, there appears to be three articulated cervical vertebrae. The braincase appears similar to that of a phytosaur, but somewhat different. We exposed beautiful, massive forelimbs.

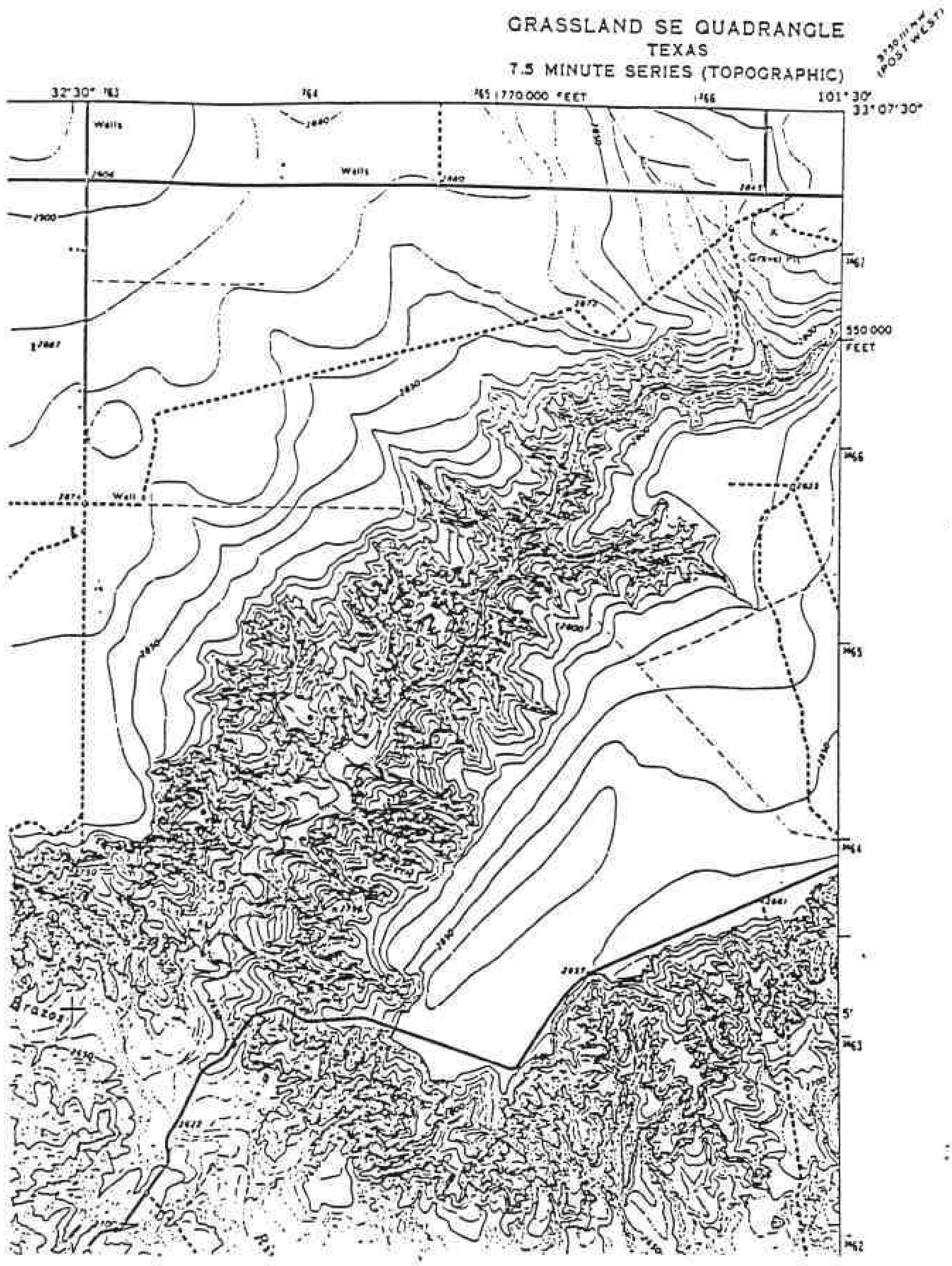


Figure 4.1. USGS Topographic Quadrangle map showing *Macysuchus* quarry.

Paleontological Resource Site Record

Resource Area: Macy Ranch

State: Texas County: Garza

Map (USGS Quad.) Grassland, SE, Latitude: 33° 00'-33°07'30"

Longitude: 101°37'30"- 101°30'

****

Description of fossil: Articulated phytosaur skeleton

Genus and species: *Macysuchus brevirostris*

Condition of fossil: A complete and articulated skeleton, including: the skull, cervical, dorsal, sacrum, and partial caudal vertebrae, shoulder and pelvic girdles, gastralia, and fore- and hind-limb elements

Condition of preservation: good

Collected by: Chatterjee and crew Date Collected: October 13, 1996

****

Sediment: mudstone

Formation: Cooper Canyon of the Dockum Group

Age: Late Triassic; Norian

****

Remarks: the skeleton was sectioned into four jackets and removed.

Field notes: yes Photographs: yes

Figure 4.2. Site record for *Macysuchus brevirostris.*

THE MUSEUM OF TEXAS TECH UNIVERSITY

Cat. No. .... Field No. ....

Name ....

Description of Material ....

....

....

Locality ....

....

Formation .... Age ....

Collector .... Date ....

Vertebrate Paleontology

Figure 4.3. Sample field label.

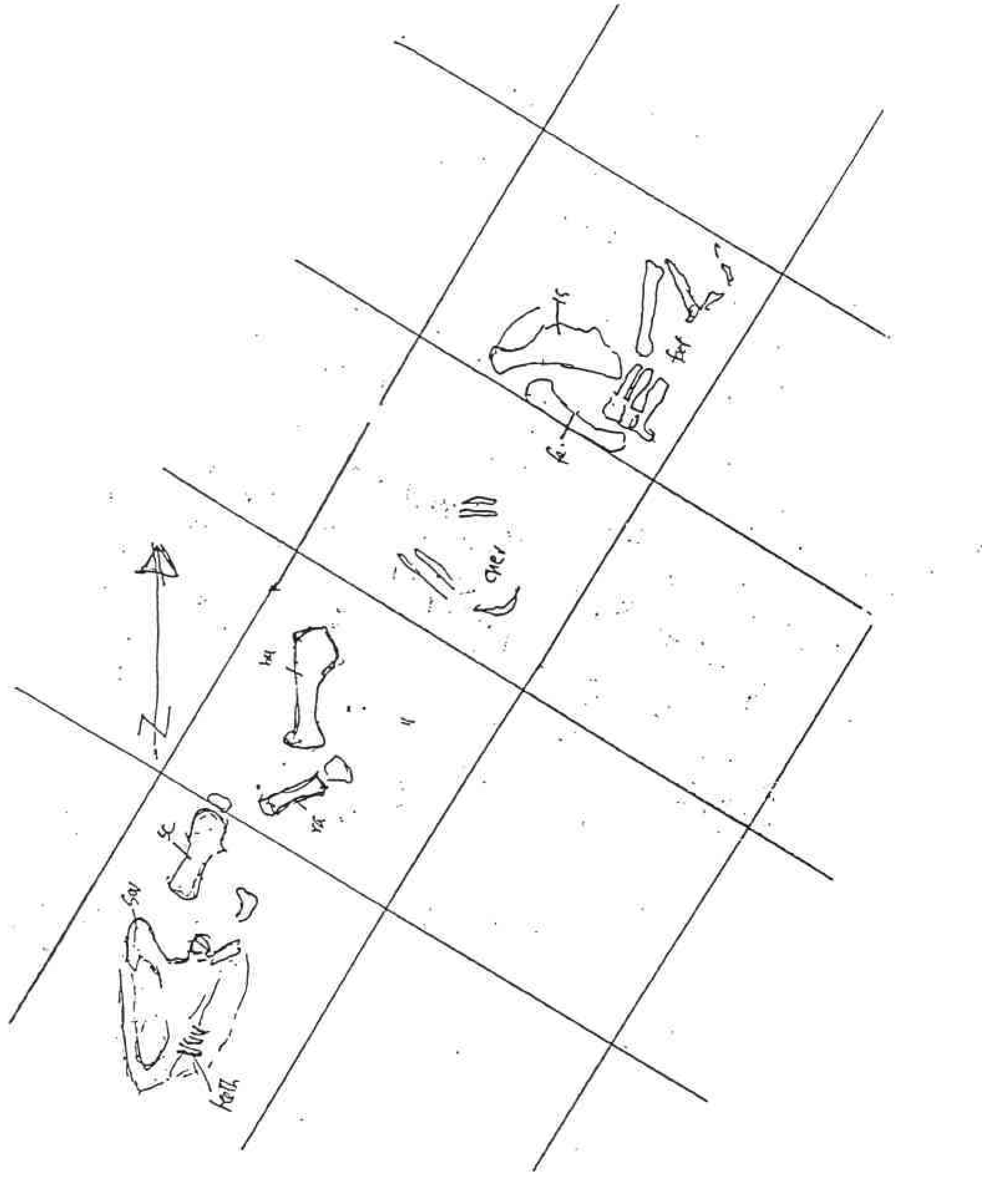


Figure 4.4. Field sketch of *Macysuchus*; cranial elements (Chatterjee, 1996).

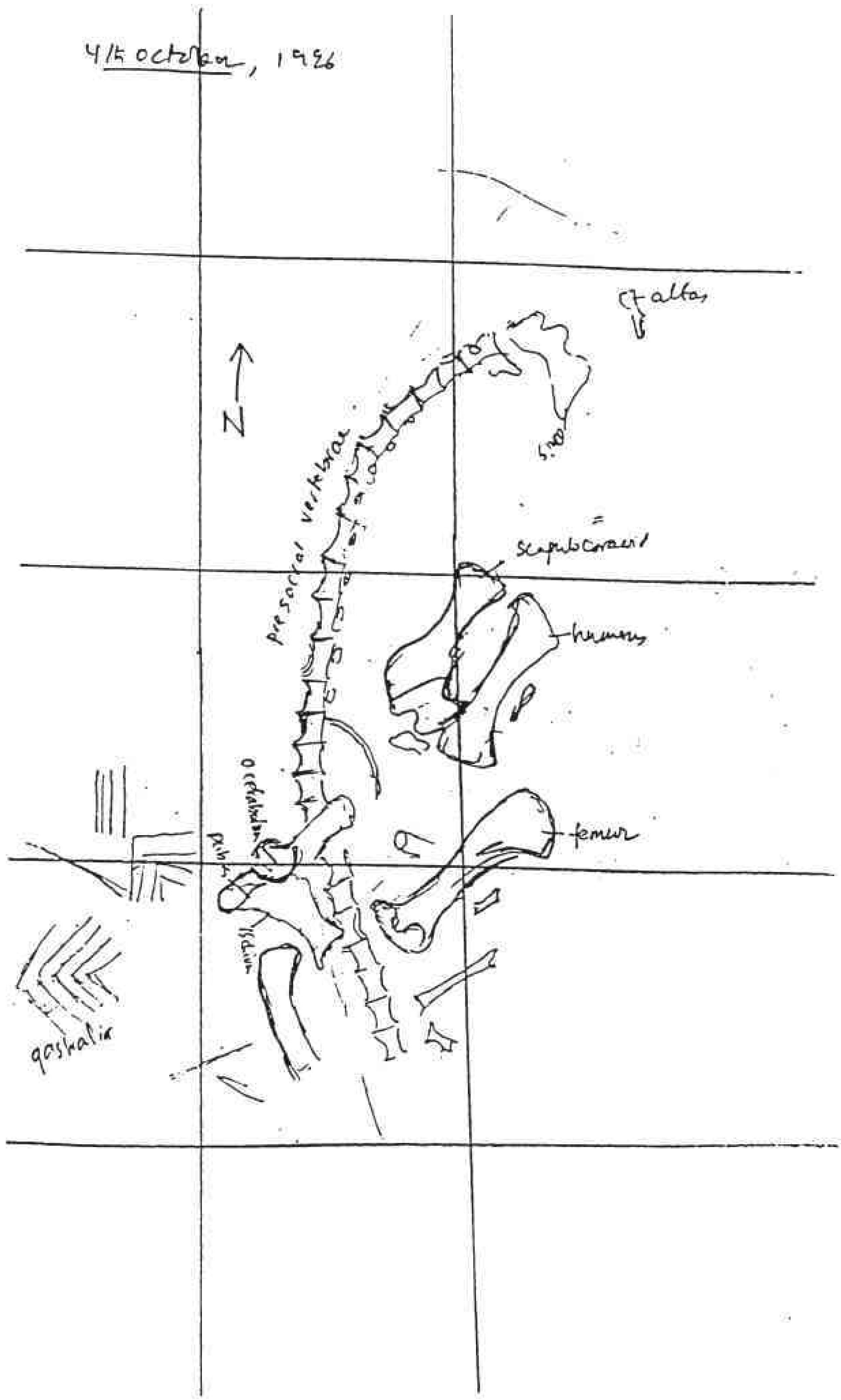


Figure 4.5. Field sketch of *Macysuchus*, postcranial elements (Chatterjee, 1996).

Saturday, September 21

Mr. Macy built a road by bulldozer so that we might reach the site more easily. The left, lateral side of the skull is now exposed and appears to be well preserved. The skull appears to be about the size of a large *Postosuchus*. At this point, it is apparent that the animal was a large, quadrupedal carnivore. The teeth and snout appear different than that associated with phytosaurs. The pubis is different than that for *Postosuchus*; it is not so elongated. The forelimbs are more massive than the hindlimbs unlike typical theropods. Is it a theropod or a new pseudosuchian?

A scapula and a long, isolated tooth were uncovered. Near the pelvis, articulated vertebrae were uncovered and an articulated hind limb. As we get down through the siltstone layer into mudstone, the bones are in better preservation.

Sunday, September 22

The site has been identified as Middle Creek. More information is needed from a topographical map. The skull was jacketed and returned to the Museum. Near the pelvis, associated sacral and caudal elements were uncovered.

Friday, September 27

It is essential to remove as much of the skeleton as quickly as possible. Mr. Macy agreed to remove some of the overburden with his bulldozer. The vertebral column appears to be nearly articulated and complete. A femur and tibia, some gastralia, and a series of scutes were found. The ilium is imperforated. It is certainly a pseudosuchian and not a theropod.

Saturday, September 28

Mr. Macy removed much of the overburden with his bulldozer. The vertebral column continues back and appears to be intact from sacrum to neck.

Sunday, September 29

Our main problem is to determine whether we are dealing with one animal or two. The skull, left scapula and coracoid, and left forelimbs are in one mass (Figure 4.4). The rest of the skeleton, including the skull, is slightly to the North, and approximately 20 feet away (Figure 4.5). In the late afternoon the atlas and axis vertebrae were uncovered. They will shed light on the question of one or two animals.

Friday, October 4

The entire skeleton has been uncovered. Additional digging near the skull has failed to turn up any postcranial material and excavation near the vertebral column has failed to produce a skull.

Saturday, October 5

A pedestal was dug around the skeleton. There is still no skull in direct association with the vertebral column. A humerus, femur, scapulocoracoid, and metatarsal were removed.

Sunday, October 6

To facilitate transportation, and to minimize the risk of dropping the fossil, it has been decided to split the skeleton into three parts. The gastralia block was removed in one piece.

Friday, October 11

We plastered the remaining two blocks. The anterior block contains mainly anterior vertebrae. The posterior block contains vertebral elements and the pelvis.

Saturday, October 12

The remaining two blocks were loaded into a truck and returned to the museum laboratory. The jackets were flipped and opened. The reverse sides appear to be in excellent condition.

4.3 Site Taphonomy

Taphonomy is the study of the processes, or laws, of burial and the impact these processes have on the preservation of organisms (Conroy, 1997). An understanding of the laws of taphonomy will help decipher the clues left behind in a burial. In turn, the interpretation of these clues helps shed light on the behavior of the animal, and the environment in which it lived and died.

Bone is, by nature, fragile and fossils are rare. As a result, the fossil record is quite incomplete, favoring large animals over small, and dry environments over moist. Some of the variables affecting an orgasm's chances of preservation include: cause of death, rapid burial, a dry environment, the size of the animal, and the diagenesis of the entombing matrix (Rogers, 1994).

Animals that die natural deaths or traumatic deaths in floods or deadfalls are more likely to be preserved than animals that fall victim to predators. Predators tend to scatter bones and to consume much of the skull and marrow-producing long bones (Conroy, 1997). Remains that are buried quickly are more likely to be preserved because they are less likely to be scavenged by other animals or to be scattered and trampled. Animals that are caught in floods, or that die in shallow ponds and swamps, tend to be interned more quickly than animals that die in terrestrial environments.

Rain forest animals are unlikely to be preserved due to constant, high humidity, increased rainfall, and an abundance of rodents that gnaw bones to sharpen their teeth. Large animals' skeletons are more likely to be fossilized than small animals' due to the sheer mass of the bone. However, complete skeletons are exceedingly rare no matter what size the animal, or where and how it died (Conroy, 1997).

Diagenesis refers to the physical, chemical, and biological changes that affect a fossil-bearing sediment (Conroy, 1997). These factors include the composition and dynamics of the deposits, as well as the period of time over which the fossils accumulated (Conroy, 1997). Measuring the stratigraphic sections associated with fossils provides clues as to the depositional nature of the sediment (Rogers, 1994).

The mudstone and siltstone of the Cooper Canyon Formation are indicative of a fluvial environment. As such, the Macy Ranch phytosaur probably died in a flood plain, along the banks of a meandering river, and was quickly buried by sediment. The distance separating the skull from the postcranial material indicates that the animal's remains were disturbed after death. Apparently, the skull was separated from the body, and moved by the paleo-current. The skull was found downstream, approximately 20 feet from the postrcranial material. The fact that the skeleton is nearly complete diminishes the possibility that this disturbance was caused by predators.

Tooth marks on the skull appear to show signs of healing, indicating that the animal survived an attack by a predator. *Postosuchus*, or similarly toothed animal, was the likely predator, because the toothmarks are not closely spaced and were probably produced by a caniniform tooth. An absence of similar marks on the postcranial material is further evidence that the carcass was not disturbed by scavengers.

The most likely conclusion is that the animal died in a flash flood and was quickly buried. A second flood event might have disarticulated some skeletal elements, transported the skull downstream, and buried the rest of the skeleton. The vertebral column lacks the degree of recurve associated with the classic "death pose. This recurve is the result of the tendons tightening and shrinking as the carcass dries. The degree of recurve seen indicates that the phytosaur was buried in damp sediment that prevented the drying of the tendons. However, for the bones to have been preserved, it was necessary for this sediment to have dried shortly after interning *Macysuchus*.

4.4 Materiel

4.4.1 Introduction

An important ingredient to successful paleontological excavation is proper planning prior to departure to the field (Leiggi et al., 1994). Much of the materiel used in the laboratory is acceptable for field work, but the less controlled environment of the field requires special consideration (Wolberg, 1989). Tools, adhesives, and related equipment appropriate for field work vary with weather, site topography, the size of the crew, and the consistency of the matrix.

Choices for glues and consolidants will be discussed in depth in Chapter V; however, several points are notable here. When considering an adhesive or consolidant for field work, it is important to consider the glass transition point of the glue, and its reversibility. Glass transition point (T_g) refers to the temperature at which a plastic begins to flow, and the correlative tendencies of that plastic to be brittle (Shelton and Chaney, 1994). Adhesives with a T_g of 50° C or greater can be brittle; those with a T_g of 20° C or less can soften at higher temperatures.

As stated earlier, techniques and materiel used in the field can impact the long-term stability of the fossil. As a result, it is advisable to use reversible adhesives whenever possible. This will ensure that methods used to stabilize a specimen in the field can be redone in the more controlled environment of the laboratory.

Hand tools for field work should be specific to the nature of the matrix, the terrain of the site, and the state of preservation of the specimen. Generally, the minimum necessary for the efficient removal of the specimen is advisable. This reduces transportation requirements in rough terrain, and eases stress on the field crew.

4.4.2 Adhesives and Consolidants

In the field, reconstruction and reinforcement of bone for *Macysuchus* was accomplished using Polyvinyl butyral (Butvar B-76), cyanoacrylates (super glues), and plaster. Butvar B-76 affords good adhesion and consolidation of bone and remains reversible in acetone. Butvar B-76 was carried to the field in premixed solution and used exclusively as a consolidant on exposed portions of the skeleton. Super glues are convenient for field work because they dry quickly and are easily transported. As a result, most field adhesion of broken bone in *Macysuchus* was accomplished using super glue. Plaster is generally carried to the field for the construction of field jackets, and is useful for gap filling. Portions of the *Macysuchus* skull, limb bones, and pelvic girdle that were poorly preserved were strengthened in the field using plaster. Although there are no suitable alternatives, these three materials are not without disadvantages.

Butvar B-76 has been used extensively as both consolidant and adhesive. While useful in the laboratory, Butvar B-76 may be less desirable in the field, as it has a tendency to become cloudy when applied to damp bone or in humid environments, and can become brittle at high temperatures. Polyvinyl acetate (Vinac B-15) and Polyethyl methacrylate/polymethyl methacrylate acrylic copolymer (Acryloid B-72) are two similar, acetone-soluble adhesives that are used for paleontological field work. Vinac B-15 remains clear in humid conditions and on wet bone, but it can soften at high temperatures (Johnson, 1994). Acryloid B-72 remains rigid at high temperatures, but it tends to be more brittle at room temperature than Vinac B-15.

The T_g for Butvar B-76 is 48-55° C (Elder et al., 1997). Acryloid B-72 is slightly less brittle, with a T_g of 40° C (Elder et al., 1997). Of the three adhesives, Vinac B-15 is the least brittle, possessing a T_g of 16-27° C (Elder et al., 1997). However, a T_g of less than 20° C can result in loss of bond strength, softening, and incorporation of dust particles into softened solutions at higher temperatures (Shelton and Chaney, 1994).

Many paleontologists prefer the quick adhesion and ease of transportation offered by cyanoacrylates (super glues). However, the permanence and reversibility of super glues is unknown, and as such, these materials should be used sparingly (Shelton and Chaney, 1994).

As the reversibility of adhesives is a priority concern, Butvar B-76, Vinac B-15, and Acryloid B-72 are preferred for field work. These three adhesives exhibit equally expedient reversibility in acetone (Elder et al., 1997). Although super glues can be softened with acetone, removal remains largely a manual process, and there is danger of breakage to the specimen. Similarly, plaster can be softened with acetone to ease removal. However, most of the removal must be done manually and there is threat of injury to the bone. Plaster and super glue applied to *Macysuchus* in the field proved exceedingly difficult to remove in the lab.

Advance planning can help the preparator determine which consolidant to use and accommodate transportation of the adhesive to the field. In the hot, dry conditions prevalent in West Texas, Butvar B-76 proved to perform satisfactorily for the field consolidation and adhesion of the Macy Ranch phytosaur. In cool, damp conditions, Vinac B-15 is favored (Croucher and Wooley, 1982); in hot, damp environments, Acryloid B-72 is a better choice.

Premixing acetone-based adhesives and carrying them to the field in manageable containers grants these materials the same convenience found in super glues. Consolidants can be carried in small squeeze bottles (Leiggi et al., 1994), and thicker adhesives can be carried in aluminum paint tubes (Kroehler, 1998; personal communication). The more accessible and efficient acetone-based adhesives are to use, the more likely they are to be chosen over cyanoacrylates.

4.4.3 Tools

Fossils should be worked as little as possible in the field and it is not advisable to expose the entire specimen (Croucher and Wooley, 1982). It is best to return the specimen to the controlled environment of the laboratory for full preparation (Leiggi et al., 1994). Therefore, field preparation of *Macysuchus* was kept to simple removal of the bone and transportation in a plaster jacket. Only enough bone was exposed in the field to ensure a safe and complete jacket.

The matrix entombing *Macysuchus* was relatively soft mudstone. As a result, much of the development in the field was accomplished with brushes, dental picks, and small chisels. However, there was considerable overburden concealing elements of the postcranial skeleton. The uppermost deposits of the overburden were removed by Mr. Macy, and the bulldozer used to construct the road to the site. A portable, electric jackhammer was used to clear overburden that was too close to the skeleton for the safe use of the bulldozer. Eventually, proximity to underlying bone necessitated that the final overburden be removed with shovels, rock hammers, and chisels.

On occasion, the use of a jack hammer for the removal of large amounts of overburden may be required. However, as the vibration of a jack hammer can cause injury to the bone, these tools should be used sparingly (Shelton, 1994). A jackhammer can also prove valuable for the initial digging of a pedestal trench.

4.5 Techniques

Traditionally, bone is returned to the museum by means of a protective plaster jacket built to encase the fossil. The jackets for *Macysuchus* were prepared by first digging a trench around each element of the specimen (Leiggi et al., 1994). A jackhammer was used to facilitate the digging of the trench, maintaining a safe distance between trench and fossil to protect against vibration. The trench was dug deep enough to ensure that it was deeper than the bone. The blocks were then trimmed with chisels and hammers, reducing excess matrix and undercutting the base of the pedestal (Greenwald, 1989).

Once the trench was dug, the specimen was covered with a layer of aluminum foil (Leiggi et al., 1994). This helps fill undercuts that may later catch on the jacket when it is opened. Additionally, the foil prevents glues and consolidants from adhering the fossil to the jacket, leading to breakage when the jacket is opened. Aluminum may not be suitable for molding into delicate undercuts, and dampened tissue is recommended for these instances (Shelton, 1994).

Next, the specimen was covered with damp paper to prevent the plaster from sticking to the bone (Leiggi et al., 1994). Traditionally, newspaper or toilet paper is used for this step. However, due to the length of time that fossils may be kept in their jackets, it is preferable to use an acid-free paper or a Japanese rice paper (Shelton, 1994; Greenwald, 1989). As this may be cost prohibitive, a dye-free, perfume-free toilet paper such as that sold for camping and septic tank use may be preferable.

Finally, the damp paper was covered with strips of burlap impregnated with plaster (Leiggi et al., 1994). Again, as many jackets remain unopened for years, it is preferable to use 100% cotton strips instead of burlap. Old tee-shirts, bed linens, and towels are handy sources of second hand cotton. Bandages used in the construction of casts are often made from cotton and are handy in the field, but may not be strong enough for heavy jackets.

The jacket was allowed to harden fully before it was removed from the ground. Removal was accomplished by simply breaking, or "popping," the jacket off at the strata beneath the deepest part of the fossil (Leiggi et al., 1994). When popping a jacket, care should be exercised to ensure that the block containing bone is removed intact. A pry-bar made from a flattened piece of metal will aid in the popping of the jacket (Leiggi et al., 1994). Generally, the strata separate nicely, and the action of flipping a jacket is similar to flipping a pancake.

To facilitate transporting the jacket to a vehicle, branches or poles can be woven into the jacket material to serve as carrying handles. However, branches collected on site may pose problems later; insects may be inadvertently carried into the Museum, and the bark may peel from the branch, tracking dust into the collections area. If possible, aluminum or stainless steel conduit can be carried to the field to serve as litter handles. Polyvinyl chloride (PVC) pipe should be avoided as it tends to release hydrochloric acid as it deteriorates (Shelton, 1994).

The use of a plaster field jacket facilitated the removal of the Macy Ranch phytosaur by preserving the orientation of the original in-situ articulation (Shelton, 1994). But, the size and weight of the block containing the skeleton necessitated that it be "blocked out"; that is, it was broken into pieces by removing a vertebra at a point where the least amount of damage would be incurred, and sectioning the vertebral column (Leiggi et al., 1994). The articulated postcranial material comprised a block nearly eight feet long and three feet wide. This would have been unmanageable in the field. The decision to remove the postcranial material in three blocks was made to simplify transportation to the Museum and reduce the risk of dropping and breaking the heavy jackets (Shelton, 1994). Additionally, the smaller blocks were easier to manipulate in the lab.

CHAPTER V

LABORATORY TECHNIQUES

5.1 Introduction

The paleontological preparator must remember that the integrity of the fossil is the foremost consideration. In order to maintain this integrity, the preparator must first become familiar with the anatomy of the specimen or similar specimens, the mode of preservation, the chemistry of the encasing matrix, and the final disposition of the fossil (Feldmann, 1989)

Reference to anatomical drawings published with original descriptions can greatly aid the preparator in understanding that which lies hidden within matrix. For holotypic specimens, such as *Macysuchus*, descriptions of similar genera are most helpful.

The mode of preservation, and the chemistry of matrix, aid in the decision as to which method of extraction is preferable. Experimentation on non-fossiliferous matrix will provide clues as to whether acid, manual, or mechanical preparation technique is advisable.

The final disposition of the specimen is an important consideration that will impact the amount of restoration and reconstruction completed. Preservation techniques should utilize reversible materials and incorporate the least invasive techniques available for stabilization of the fossil. Restoration, or reconstruction, often relies on a myriad of chemicals and techniques that are often irreversible. Therefore, it is best to reconstruct only those specimens that are specifically intended for exhibition. Otherwise, it is preferable to merely stabilize the specimen, and to only reconstruct those areas that are in immediate peril of breakage. The use of casts for exhibition is the best means of protecting the integrity of the specimen, as many reconstructions can be made directly to the cast rather than to the fossil, and the amount of change necessary for casting is often less injurious than that required for full reconstruction (Shelton, 1994).

5.2 Preparation

5.2.1 Introduction

Preparation, or development of the fossil, is the process of removing the matrix from the bone. This can be a tedious process, requiring patience, skill, and a knowledge of a broad spectrum of techniques. Although techniques utilized vary from specimen to specimen, the preparator's foremost concern should be rendered to the safety of the specimen.

The decision as to which method of development to employ varies according to the specific matrix involved, the size of the specimen, and the quality of preservation of the fossil. In general, it is important to use the least invasive technique available to insure the safety of the fossil. Softer matrices can often be developed with small, dental picks and brushes. Harder matrices are more difficult to remove, and may require the use of power tools, such as air abrasives, vibro-tools, and rotary grinders. Calcareous matrices can be developed in weak, acidic solution. Small specimens may require the use of microscope and pin vise, while larger fossils may need to be supported in a sand table, and developed by mechanical means. Specimens in poor preservation may require manual means of development as mechanical means may introduce excessive vibration.

The Macy Ranch phytosaur was found in relatively soft mudstone that was not responsive to acids. Therefore, all development was performed using manual and mechanical means. Tools selected included: pin vises; dental picks; fine chisels; light rock-hammers; a magnifying light; and a Chicago Pneumatic Air Scribe. These tools were selected over the use of air abrasives and rotary grinders because they pose less threat to the fossil (May et al., 1994).

5.2.2 Manual Preparation

Although time consuming, manual preparation is still the best method for many types of preparation in the laboratory. The term "manual preparation" refers to the use of hand tools rather than power tools for fossil development. The most common tools used are hammers, chisels, dental picks, and pin vices. Many of these tools can be modified by the preparator to best suit the task at hand. Picks and pins can be ground or sanded into miniature gouges, chisels, and scoops (Sohl, 1989). A good magnifying light is also an essential piece of equipment in the laboratory. This is especially true when doing delicate work with a pin vise (Croucher and Wooley, 1982).

The advantage of manual preparation over many other methods is that broken bone can be repaired. Breaks due to overstrike should be repaired immediately to ensure that the bone fragments are returned to their proper places. If immediate restoration of a broken piece places the fragments in danger of continued stress, the pieces should be labeled, and marked with registration marks. This will assure the proper replacement of the fragments following the preparation of contiguous bone. Acid preparation, air abrasive preparation, and rotary grinders do not allow for this type of repair. Material lost to any of these methods cannot be repaired as it is often reduced to dust (Chaney, 1994).

Much preliminary work, and the finishing of fine detail on *Macysuchus* was done using manual techniques. The jackets were supported in a sandbox to absorb some of the vibrations resulting from hammer strikes (Converse, 1984). Large areas of loose stone were first consolidated with Butvar B-76, then worked with light hammer and chisel. This consolidation of matrix helped to limit the amount of stone removed with each strike. Matrix was left intact if its removal endangered the stability of the fossil, or the unity of the slab.

As the matrix was reduced, the tools utilized were reduced in size, ending with fine dental picks. Finishing detail was completed with the aid of a magnifying light. This was particularly helpful for final development of the skull; for identifying sutures; and for differentiating matrix from bone in the delicate recesses of the rugose surface of the skull.

Simple acids, such as coffee (Kroehler, 1998; personal communication) and vinegar, work well to loosen mudstone matrix, and are not deleterious to the bone. Mudstone matrix can also be softened with water or acetone. However, both methods present problems for the preparator. Bone dampened with water can develop a haze when consolidated with Butvar B-76 (Converse, 1984), and the use of acetone to soften matrix can also loosen adhesives.

5.2.3 Mechanical Preparation

A variety of power tools are useful for the mechanical preparation of paleontological material. These include: grinders; air-abrasives; and vibro-tools (air scribes). Grinders are rotary tools, such as Dremmel tools, and Foredom drills. Air-abrasives are miniature sandblasting units that power matrix from bone by disintegrating matrix with a fine stream of powder. Vibro-tools, or air scribes, are pneumatic, impact tools with tips that vibrate rapidly, crumbling matrix from bone. While each of these tools may be useful for mechanical preparation, air scribes are less injurious to the bone. As with manual preparation, fossil breakage from air scribes can be easily repaired and there is not the loss of bone associated with acid preparation, air abrasive preparation, or from grinding tools.

Air scribes are excellent for many types of preparation. The tip of an air scribe vibrates rapidly and loosens matrix at the point of contact with bone. The speed of the vibration can be controlled with air pressure, allowing for fine tuning of the tool for detail work. A stream of compressed air is released near the tip, blowing loose matrix away from the work area, and increasing visibility.

Air scribes are a good alternative to manual development. They are more efficient and often less damaging to bone. Loose matrix can be consolidated while overhanging bone is developed and there is less chance of breakage to overstrike. Often with manual preparation, hammer-strike vibrations cause loose matrix to break free from beneath the bone and can weaken the fossil.

The consolidation of matrix can be limiting to the use of hand tools. The toughened matrix adheres to the bone and is difficult to remove. With the air scribe, the bone can be more easily consolidated as it is developed, and the matrix is still easily separated from the bone. Even crumbling bone can be developed if it is first consolidated with either Butvar B-76, or a cyanoacrylate such as Paleo-Bond Penetrant, and then worked with an air scribe. However, the use of super glues entirely negates the use of hand tools for further development. Because the glue is often stronger than the bone, a hammer strike is more likely to break bone than to remove matrix.

There are certain health concerns associated with the use of an air scribe. These tools tend to produce a lot of noise and dust (Croucher and Wooley, 1982). It is therefore essential that these tools be used with proper ventilation. It is also recommended that the preparator wear a dust mask and ear protection.

Much of the development of the Macy Ranch phytosaur was done using a Chicago Pneumatic Air Scribe, and it compared favorably to the quality of work produced by hammer and chisel. However, the air scribe worked much more quickly.

Following final development of the facing side of the block, the specimen was "flipped" so that the reverse could be prepared (May et al., 1994). This was accomplished by means of a second jacket built to sandwich the fossil. The specimen was then flipped over onto the new jacket, and the original jacket was removed.

It is at this point that the skeletal elements are generally freed completely from the matrix. However, it was decided to leave *Macysuchus* in its articulated death-pose. Therefore, it was essential to remove enough matrix to fully expose the skeleton without weakening the structure of the block. The air scribe proved particularly valuable for the exposure of the bone in such bas relief. This was because there was less damage to the matrix from the percussion of hammer-strike. Additionally, many of the zygopotheses, which were very difficult to expose using hand tools, were cleanly exposed using the air scribe.

The air scribe also proved to be a convenient source of air. This greatly facilitated the cleaning of the specimen prior to its being consolidated with Butvar B-76. The low-pressure stream of air emanating from the tip of the scribe worked well to blow dust away without blowing larger fragments of the fossil away. The stream of air generated by the air scribe meant that this tool could not be used in conjunction with a sand box, as the scribe would have blown sand into the air. As a result, the *Macysuchus* jackets were supported with small sand bags (Sohl, 1989).

5.3 Glues and Consolidants

A myriad of adhesives and consolidants have been used in the preparation of paleontological material. These include cyanoacrylates (super glues), polyvinyl acetate (PVA), polyvinyl butyral (Butvar B-76), Acryloid B-72, white glues such as Elmer's Glue-All, cellulose nitrates, and epoxy resins. None have been in use long enough to affirm their categorical stability or reversibility. However, some have been around long enough to affirm their instability or irreversibility. Of the adhesives listed, Butvar B-76, super glue (Paleo Bond), and epoxy resins were used in the preparation of *Macysuchus*.

Elmer's Glue-All, while handy for the amateur, has been shown to be highly deleterious to fossils. White glues such as this are cross-linked polyvinyl acetone emulsions that are not directly reversible. Although partially responsive to acetone, these adhesives can be very difficult to remove. Additionally, these glues are known to become brittle with age and exposure to ultraviolet (UV) light, and can off-gas acetic acid (Shelton and Chaney, 1994).

Cellulose nitrates, such as Ducco Cement, are similarly flawed for paleontological preparation. These materials are known to be particularly unstable. Deterioration of the polymer is seen as enbrittlement, shrinkage, and yellowing (Johnson, 1994).

Epoxies form a very strong bond and are an accessible means of repairing heavy bone. In the preparation of *Macysuchus*, epoxy putties were used primarily to fill cracks and gaps because, prior to the development of Paper Pulp Epoxy, there was no suitable alternative. However, epoxies are very unstable and only partially reversible. These adhesives degrade under UV light, tend to turn yellow and brittle, and can stain the specimen (Shelton and Chaney, 1994). Epoxy can be softened with a hot air gun but removal is still largely manual and damaging to the fossil. Additionally, the heat of the air gun can weaken other adhesives and consolidants such as PVA.

Cyanoacrylates (super glues) are used quite extensively in paleontological preparation. A fossil-specific brand, Paleo Bond, was used in the preparation of *Macysuchus*, and is in use at major museums, including the Smithsonian Institution's National Museum of Natural History (NMNH), and the Denver Museum of Natural History (DMNH). This super glue comes in several viscosities. The least dense is sold as a consolidant and marketed as a "penetrant." The thickest viscosity is meant as a gap filler, however the tubes in which this mixture is marketed tend to clog irreversibly, leading to much waste. The company also sells a solvent.

The manufacturer of Paleo Bond claims that the glue remains stable, and can be reversed completely with the solvent, and that tests in a vacuum accelerator confirm this for a projected 1750 year period (Mason, 1996; personal communication). However, in order to remove the penetrant, the fossil must be immersed in the solvent for up to 24 hours (Mason, 1996; personal communication). This procedure could be quite injurious to the fossil as the solvent would weaken other adhesives. Acetone can also be used to soften super glues, but the procedure remains largely manual. It is nearly impossible to fully remove super glue from a fossil without breaking some bone.

Additionally, Paleo Bond and other super glues represent an unnecessary health hazard to workers. Fumes from the penetrant are visible as the glue cures and organic filters are insufficient for protection against cyanoacrylates. These adhesives are also very difficult to remove from skin and clothing. The use of rubber surgical gloves eliminates this problem; however, gloves reduce fingertip sensitivity and can be awkward to wear.

There are some instances when the Paleo Bond penetrant is invaluable. For dusty, crumbling bone nothing works as well. It then becomes a decision between loss of reversibility and loss of a fossil. In this case, it is certainly more important to preserve the bone than it is to reverse it later on. The Macy Ranch phytosaur has several caudal vertebrae in which preservation was particularly poor, reducing these bones to dust. Since the vertebrae had been fixed in the field with Butvar B-76, they were reduced to mud when an attempt was made to further clean them with acetone. The Paleo Bond penetrant proved to be the only way to stabilize these elements, allowing for the cleaning of contiguous bone without reversing the consolidant.

The sparing use of super glues is recommended for bone that cannot be conserved any other way. In these situations it is advisable to consolidate the bone with a coating of Butvar B-76 or Vinac B-15 on top of the super glue. However, these glues have not been in use much longer than super glues. At this point, it is not really known if any are stable and reversible indefinitely (Shelton and Chaney, 1994).

Vinac B-15, Butvar B-76, and Acryloid B-72 are widely used, and preferred, for adhesive needs in paleontological preparation. They are stable, and have good, long-term reversibility (Johnson, 1994). These glues are made from polyvinyl plastic, or acrylic beads that are dissolved in acetone. The low viscosity of acetone makes it an excellent vehicle for bone consolidation. The proportion of acetone to plastic can be varied to yield viscosities applicable for consolidants and adhesives. As mentioned earlier, these glues are not without potential problems. Butvar B-76 can become cloudy when used under humid conditions or on wet bone (Croucher and Wooley, 1982). Vinac B-15 can soften under high temperature, and Acryloid B-72 tends to be somewhat brittle.

Butvar B-76 was used for consolidation and adhesion of the *Macysuchus* specimen. For all but the most poorly preserved bone, Butvar B-76 proved satisfactory. As mentioned earlier, although Butvar B-76 successfully consolidated the bone, the use of acetone on adjacent bone reversed the Butvar B-76 and damaged the bone. Thicker mixtures of Butvar B-76 tended to form air bubbles upon curing, but applied in thin layers, thick viscosities produced a strong gap filler.

In the case of any adhesive, it is advisable to support the fossil with a jacket or armature. The preparator should not attempt to secure heavy bone with adhesives alone. No glue or epoxy will form a bond strong enough to ensure the safety of the specimen if a break appears between two pieces of heavy, load bearing bone.

5.4 Epoxies, Plaster, and Paper Maché

In addition to adhesives used to join bone are those used to fill gaps and in the reconstruction of missing parts. Polyvinyl plastics do not lend themselves well to this task because thick mixtures tend to produce bubbles upon curing. As a result, preparators have turned to epoxy, plaster, and paper maché.

As previously stated, epoxies are unstable and irreversible. Plaster or Hydrocal can be very difficult to remove from bone and do not have the tensile strength necessary to bridge a sizable gap (Wolberg, 1989). Plaster can often be weakened with acetone, but full removal requires manual preparation (Croucher and Wooley, 1982). Hydrocal does not respond to acetone and requires manual removal.

A 1:1 mixture of paper maché and plaster provides more tensile strength than plaster alone. Although irreversible, a paper maché and plaster mixture is useful for reconstruction (Converse, 1984) and for the sculpting of faux-matrix in the final exhibit (Kroehler, 1998; personal communication).

Paper maché is a useful alternative. However, commercial paper machés are wood pulp in composition. Since calcareous fossils and pyritic material can deteriorate in the presence of many acids, it is advisable to avoid the use of commercial paper maché. Additionally, commercial water-based paper maché cannot be reserved, and responds only to manual removal.

Mixing Butvar B-76 with the paper maché pulp produces a reversible material that is strong and easily sculpted (Jabo, 1998; personal communication). However, this mixture tends to produce air bubbles as it cures and the voids can be difficult to detect and fill. Additionally, the use of Butvar B-76 as a consolidant weakens the paper maché as the consolidant cures. Any cleaning of the fossil, or the contiguous use of acetone, can reverse the paper maché and threaten the structural integrity of the fossil.

5.5 Paper Pulp Epoxy

An alternative to commercially produced paper machés is a paper pulp epoxy made from 100% cotton paper pulp and a reversible, water-based, polyvinyl acetate glue. No long-term studies are available as the use of this material has been short-term. Paper Pulp Epoxy will be referred to as PPE in this thesis.

The paper pulp component in PPE can be obtained commercially as 100% cotton rag paper that is sold for intaglio or paper casting. This paper is sold in sheets that can be saturated with water and broken up with a toothed, metal stir-rod. A more cost-efficient solution is to make the pulp from scratch in the lab. While any cotton rag paper is suitable, blue-board scrap is readily available in most museums and often discarded as waste. This board is acid free, buffered, 100% cotton rag and contains very little sizing. The lack of appreciable sizing is an additional advantage over other rag papers. The paper, or blue-board, can be cut into pieces, placed in a blender full of water, and ground to the desired consistency. The wet pulp can be spread over a screen, or microwaved to dry.

Finely ground pulp is more workable than coarse ground pulp. However, coarse ground paper affords a stronger matrix for the epoxy. The longer cotton fibers offer a stronger weave. An initial coat of coarse pulp covered with a second layer of fine pulp yields a strong, workable epoxy. Additionally, pieces of unpulped paper can be cut to fit holes and to bridge gaps in the specimen, offering an even stronger bond (Figure 5.1).

The glue used in PPE is Lineco's pH neutral water-based glue. It is commercially available from most art supply stores and through wholesale catalogs. This glue is a PVA based white glue and is of archival quality. Lineco products, such as linen tape, are commonly used by paper artists and art galleries and will not stain paper as some other adhesives can. The Lineco pH neutral, water-based glue has been in use at the Smithsonian Institution's National Museum of Natural History for a number of years, primarily by the staff taxidermist, Frank Greenwell. Greenwell (1998, personal communication) recommends the product for its long-term reversibility, its archival ingredients, and for its nontoxic binder. Additionally, this glue has proven to be stable, and safe to use on even the most delicate specimen. Since Lineco's glue is PVA based, it is not prone to degradation under UV light.

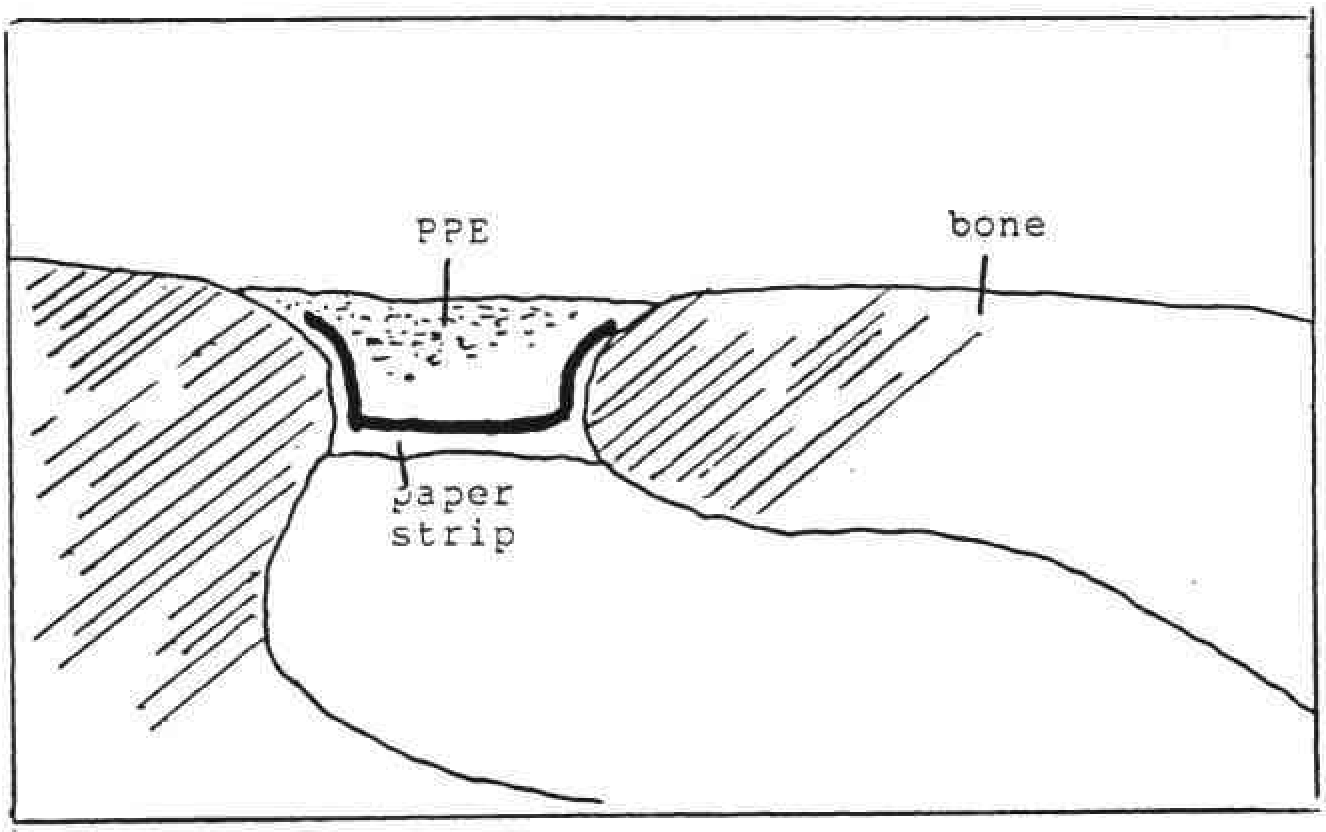


Figure 5.1. Paper Pulp Epoxy reconstruction strengthened with paper.

Paper Pulp Epoxy offers several advantages over conventional epoxies. First, it is fully reversible in water. A few drops of water on PPE softens it sufficiently that it can be removed. Additionally, these pieces of PPE can be reconstituted, making this material exceptionally cost efficient.

Paper Pulp Epoxy's second advantage over Butvar B-76-based paper maché is that it reverses in water rather than acetone. For the preparator, this diminishes exposure to harmful vapors and ameliorates cleanup. Additionally, applying Butvar B-76 over PPE does not weaken the structural integrity of the reconstruction, nor does the application of PPE weaken contiguous areas of the specimen that have been consolidated with Butvar B-76.

Third, paper maché fixed with Butvar B-76 tends to form air bubbles as it cures. Undetected air bubbles can weaken the bond and endanger the specimen. Paper Pulp Epoxy does not form air bubbles because of the slower drying rate of the water-based glue. However, this slower rate can lead to less efficient adhesion.

Fourth, areas strengthened with epoxy or Butvar B-76-based paper maché must be painted with acrylic, enamel spray paints, or oil paints. Each of these paints can be difficult to remove from bone, and acrylic and oil paints tend to scratch easily when applied over a plastic or epoxy resin. However, water based PPE can be painted with watercolor paints that will not flake or scratch, and can be easily cleaned from the bone.

Finally, PPE can be premixed and stored in vials, increasing the accessibility of the epoxy. This allows for more frequent application of the epoxy as the specimen is prepared, rather then waiting until the end of the day to mix and apply two-part epoxy resins. Butvar B-76-based paper maché tends to dry too quickly to be premixed, and two-part epoxy resins remain pliable for short periods of time. However, the slow cure time of PPE necessitates overnight drying for it to fully cure.

An advantage of epoxy resins and Butvar B-76-based paper maché is found in their workability. Both adhesives can be smoothed to an aesthetic finish and are easily sculpted. Paper pulp epoxy is less easily sculpted and the finished product tends to have a lumpy, pulpy finish. However, with practice the results are acceptable. Additionally, epoxy resin can be smoothed over the PPE without threatening the reversibility of the PPE, and provides a more aesthetic finish.

Since PPE utilizes a water-reversible glue, it is hygroscopic. Therefore, it is sensitive to fluctuations in relative humidity (RH). Since many museums maintain an RH level of 50%, there is little danger of loss of adhesion in PPE. Additionally, it is recommended that paleontological collections be maintained at 45-55% RH (National Park Service, 1991). Therefore, normal museum environments are within parameters appropriate for the use of PPE.

Experiments were conducted to determine the effect of high humidity on PPE. For approximately three weeks, pellets of PPE were subjected to varying RH levels. The pellets were placed into containers with damp paper, and the RH levels were monitored with Artenmeter hygrometers. The RH was varied by increasing and decreasing airflow, and by altering the water content of the paper placed within the containers. Since Artenmeter hygrometers are only accurate to within 5%, the results indicated should be considered as such.

Under experimental conditions, PPE exhibited no loss of strength at constant RH levels below 65%. Paper pulp epoxy also demonstrated consistent durability in variable humidity levels as disparate as 40% to 80%. However, sustained exposure of humidity levels above 65% resulted in a softening of the PPE. There was no dissolution of the PPE, even up to 94% RH .

At the Museum of Texas Tech, the humidity is kept at a constant 50% RH, with minimal fluctuations of ± 5%. During the three weeks that the experiment was conducted, actual RH levels never exceeded 40%, as recorded by the hygrometers used. At these levels, PPE showed no signs of softening.

Pellets of PPE were then confined to constant RH levels varying between 60% and 90%, and the RH was monitored. Under these conditions, minor softening was noted at sustained levels above 65% RH. Mold growth was noted at constant levels above 75% RH. Paper pulp epoxy was also tested for softening under fluctuating RH levels. Pellets were move from 40% to 80% RH, in one hour increments. Under these conditions, no softening of the PPE was noted.

Air circulation also played a role in the effect humidity levels had on PPE. A sample of PPE and a hygrometer were placed on a window sill, outdoors during a rainstorm. The ambient RH was recorded at 80%, and no softening of the PPE was noted after exposure of eight hours. In a more confined environment, PPE softened in one hour at this RH level.

At normal museum humidity levels, PPE shows no loss of structural integrity. There may be some concerns about the use of PPE in the field, particularly in tropical locations, and under damp conditions. Museums with poor humidity control, and those that regularly see constants above 65% RH, should avoid the use of PPE. However, at these levels, objects made of wood, paper, metal, and fiber may be in jeopardy as well. Any RH level that is unsafe for PPE is also unsafe for other museum objects.

In the above experiment, pellets of PPE were coated with Butvar B-76, and exposed simultaneously to the same humidity levels as the uncoated pellets. The pellets coated with Butvar B-76 were resistant to sustained RH levels of up to 75%. However, even these coated pellets softened at sustained levels of over 75% RH. Although the use of Butvar B-76 diminishes the health benefits of using a water-based epoxy, the quantity of acetone utilized is much less for a coating of Butvar B-76 than for an entire reconstruction made from an acetone-based epoxy.

If the need for a waterproof epoxy outweighs health concerns, then a mixture of Butvar B-76 and the paper pulp component of PPE offers a strong, reversible, archival material. The benefit to this mixture, as opposed to that made from a commercial paper maché, is that the paper pulp used is 100% acid-free.

5.6 Reconstruction

It may be necessary to reconstruct missing pieces of bone, or to strengthen areas of the fossil. As stated above, PPE is recommended for such reconstruction. Paper Pulp Epoxy can be forced into gaps or cracks in the bone preventing further breakage. As the paper pulp is pressed into the cracks, glue is forced into the bone thereby strengthening the bond. Epoxy resins do not bond internally with the bone and therefore form a weaker adhesion.

Initial reconstruction of the Macy Ranch phytosaur was done using plaster and epoxy resins. Much of this was done hastily in the field, and these materials proved exceedingly difficult to remove or modify in the lab. In many instances, the plaster could be softened with acetone to facilitate removal, but final cleanup was by manual preparation. Major cracks, missing pieces, and gaps were filled with epoxy putty. The epoxy proved to be exceedingly difficult to remove. Instead, the epoxy was ground with a Foredom drill, and reduced in mass as much as possible.

Paper Pulp Epoxy was used exclusively following its formulation. For example, the crumbling caudal vertebrae mentioned above were strengthened and reconstructed with PPE to satisfactory results. A through and through hole in the neural spine of one of these vertebra was repaired by first cutting a piece of cotton rag paper to fit the hole (Figure 5.2). This piece of paper was dampened with Lineco glue and held in place with a layer of PPE. Additional layers of PPE were added after the initial application had cured, and the patch was built up until it approximated flush with the surrounding bone.

It is important that reconstructed areas be readily apparent. It is not advisable to sculpt or paint the PPE to an exact match to surrounding bone. This is to ensure that the integrity of the specimen be preserved for morphometric study, and that no attempt be made to fool the viewer into believing that reconstructed areas are scientifically accurate.

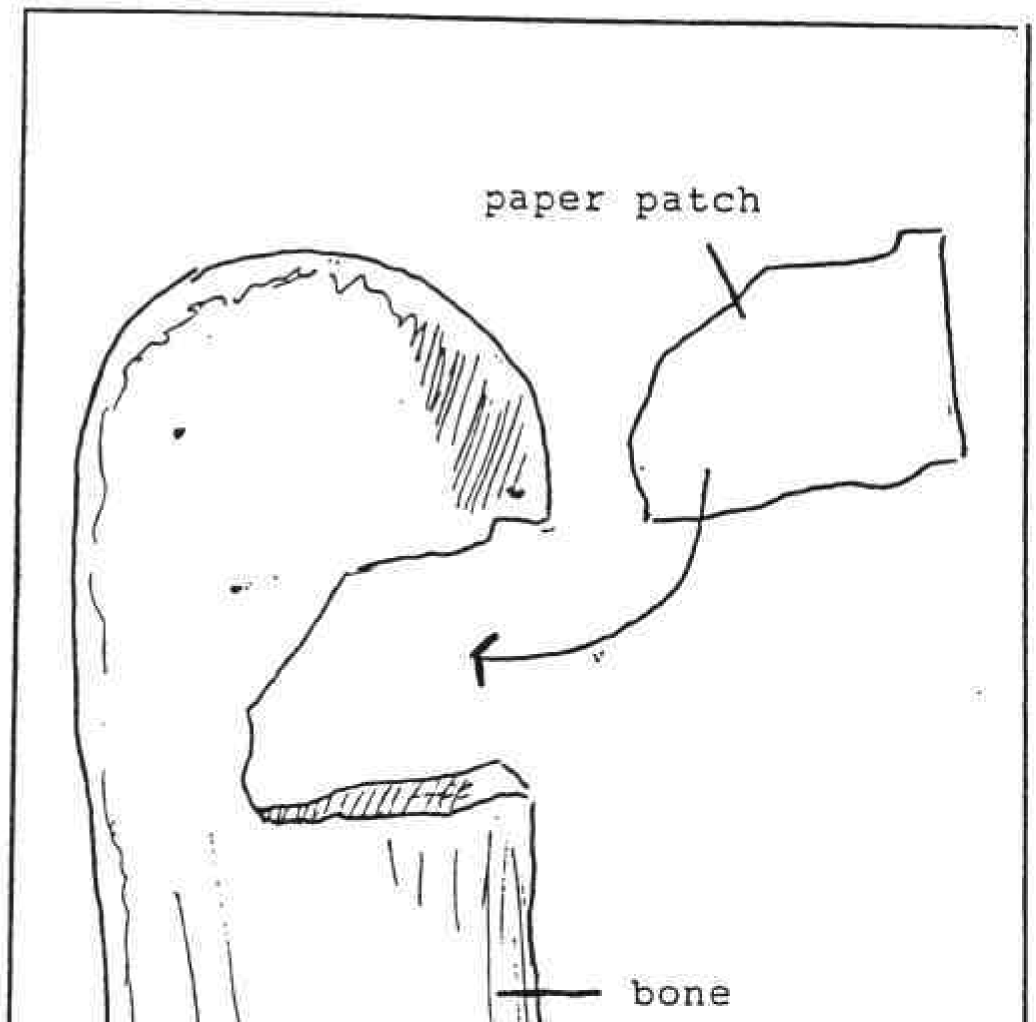


Figure 5.2. Repair of a through and through hole using PPE and a paper patch.

5.7 Supporting Armatures

As previously stated, no adhesive will form a bond strong enough to hold two pieces of heavy bone. In this case, it may be necessary to build a supporting armature. Simple armatures can be constructed without welding equipment, and provide the support needed to ensure the safety of the specimen.

Stainless steel wire, available commercially through taxidermy supply companies, can be used with Butvar B-76 to create strong, reversible armatures. The braincase and palate of the Macy Ranch phytosaur were supported using this technique. Pieces of wire were cut to length and bent as the letter "Z" (Figure 5.3). These wires were then glued in place using a thick mixture of Butvar B-76 and the bone was supported while the glue cured. The results are such that the armatures are capable of supporting the entire weight of the skull.

The gastralia block of *Macysuchus*, and similarly delicate specimens, are best supported with a galvanized, ¼ inch wire, such as rat wire. This wire can be cut to shape, bent, and glued to the fossil using Butvar B-76. Again, the results are strong and reversible. It is advisable that the wire be used sparingly to maintain the aesthetics of the both sides of the specimen.

For long term storage and exhibition, it is recommended to support the specimen with a plaster jacket. A form-fitted, padded jacket (Figure 5.4) is preferable to those used for field transportation. Padded jackets are in use at NMNH and provide secure, acid-free housing for fossils (Jabo, 1998; personal communication).

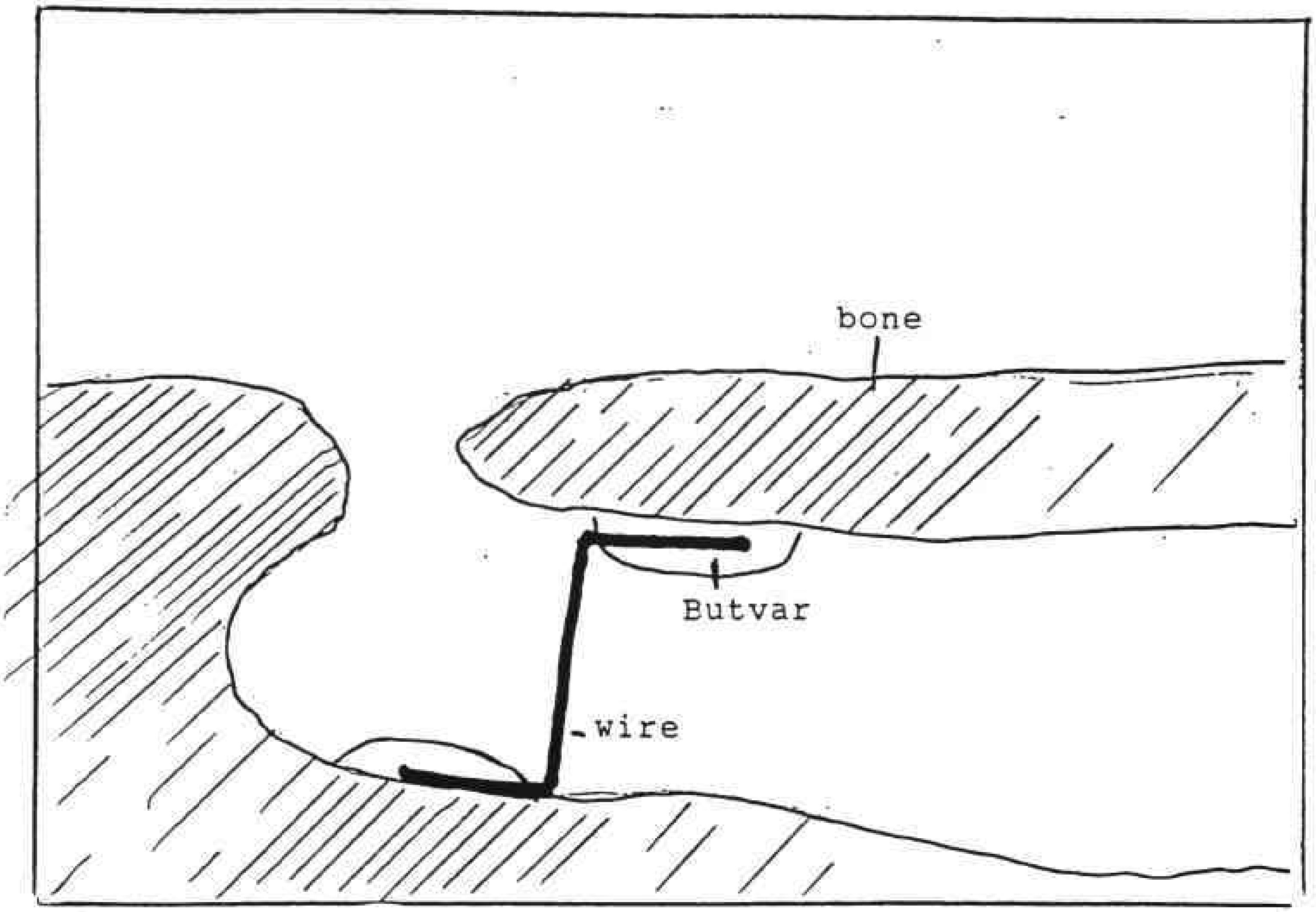


Figure 5.3. Armature made from stainless steel wire and Butvar B-76.

Padded jackets are made using Hydrocal Gypsum Cement (FGR-95), fiberglass sheeting (Sur-mat), and a polyethylene foam (Etha-foam). First, the specimen must be divided in half along an imaginary midline to determine the size and shape of the two halves of the jacket. The specimen is then covered with a layer of aluminum foil to keep the fossil clean and to fill undercuts that might otherwise catch on the jacket. Next, the specimen is wrapped in a layer of clay that has been pressed to the same thickness as the polyethylene foam. Clay is used initially because it can be readily molded to fit the specimen. The clay is then covered with a layer of plastic wrap to keep it clean of plaster (Jabo, 1998; personal communication).

Hydrocal is layered over the clay and interwoven with layers of Sur-mat. A thickness of 15 mm works well for the fiberglass, and this combination of Hydrocal and Surmat makes for an exceptionally strong, lightweight jacket. After curing, the plaster jacket is removed, excess fiberglass is burned off with a propane torch, and the jacket is lined with polyethylene foam. This foam can be adhered to the jacket using a spray mount adhesive. Next, the clay, plastic wrap, and aluminum foil are removed from the specimen. The fossil can then be positioned into the jacket (Jabo, 1998; personal communication).

For exhibition, only one-half of a jacket is necessary. However, for storage it is recommended that the jacket be completed in the round. The second side of the jacket can be built following the above instructions and the two halves can be secured with bolts and wing nuts. This allows for the jacket to be readily flipped, and for both sides of the specimen to be studied without removing the fossil from the jacket, thus reducing handling and diminishing the chances of breakage (Jabo, 1998; personal communication).

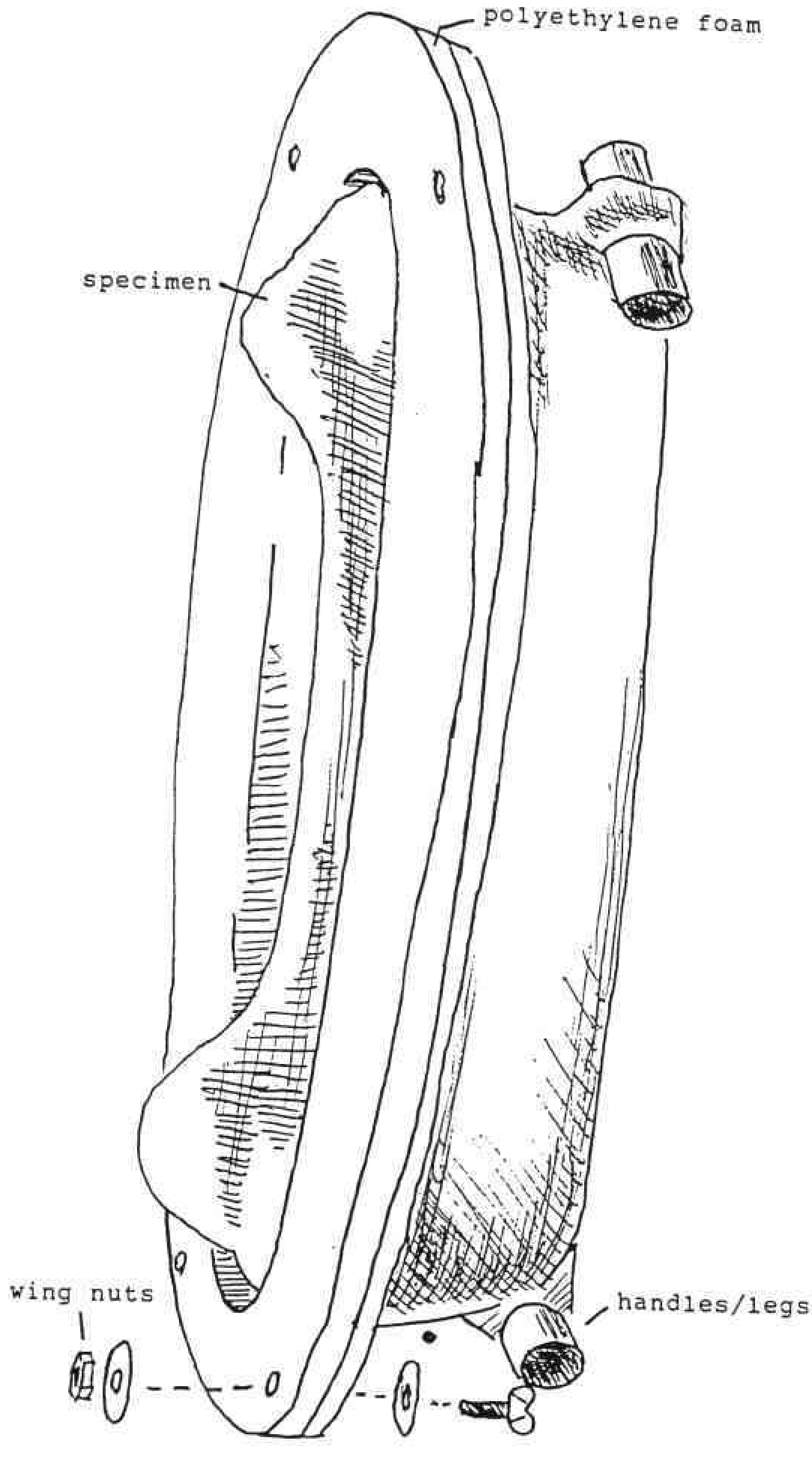


Figure 5.4. Form-fitted, padded jacket.

CHAPTER VI

CASTING TECHNIQUES

6.1 Introduction

Casting and molding skills are invaluable to the paleontological preparator. The casting of fossils allows for copies to be shared with other institutions for study and exhibition. The exhibition of casts protects the original specimen from unnecessary exposure to agents of deterioration, such as vandalism, theft, pollutants, UV radiation, and temperature and humidity fluctuations (Shelton, 1994). . As original fossil material tends to be exceedingly fragile, rare, and heavy, the exhibition of cast bone ensures the safety of the original, extends public access to more species, and requires less intricate armature. The exhibition of casts also allows for holotype specimens to remain in collections storage for scientific study (Converse, 1984).

However, the molding process can be injurious to the fossil and careful consideration should be given as to when and how a specimen is cast. This injury can be both to the physical and intrinsic nature of the specimen. The decisions as to which mold material is used, how many pieces the mold will comprise, which casting material is used, and how copies are disseminated should be made carefully, and with foremost concern given to the integrity of the fossil (Goodwin and Chaney, 1994).

Cost of materials is often a prohibitive reality for museums. Therefore, planning should include the necessary cost of appropriate materials for the molding and casting of each individual fossil (Goodwin and Chaney, 1994). No single method or material will suffice for all casting needs. A cast of a composite skeleton comprised of real bone and sculpted elements may in itself require a myriad of techniques and materials.

The disposition of copies should be made exclusively to other museums and universities of honorable reputation. Care should be taken to ensure that casts do not appear on the commercial market, as this damages the intrinsic and scientific integrity of the fossil. Museums have the responsibility to ensure a scientifically-accurate presentation of objects, and therefore have the responsibility to ensure that reproductions from their collections are handled ethically.

6.2 Molds

The molding of a fossil poses serious threats to the safety of the specimen. The preparator should consider this when planning the logistics of the mold. It is essential to consider the least invasive method for molding each, individual specimen.

When planning a mold, the preparator must consider the final dispensation of the cast (Iwama, 1993). If the cast is intended for scientific study, the mold may need to be more complicated, reproducing more detail. The more complicated a mold becomes, often the more stress is suffered by the fossil. If the cast is intended solely for exhibition, less detail may be necessary, and therefore, a less complicated mold. It may not be necessary to duplicate all fenestrae and fossae (Iwama, 1993). It may be possible to plug such openings with clay, thereby reducing the risk to the original. For exhibits purposes, these fenestrae can be ground out in the cast, replicating the original opening (Goodwin and Chaney, 1994).

As it may not be necessary to capture all detail from every specimen, considering the minimally sufficient quality needed from each cast will help minimize injury to the fossil. This will also assure that each specimen is subjected but once to the rigors of the molding process. If multiple copies are needed from the mold, it is advantageous to retain a good, first generation cast. Since the mold will deteriorate with age and use, duplicate molds can be made from this cast without redundant stress to the original fossil.

All specimens should first be reinforced and hardened before they are molded. Deep, undiagnostic fossae, cracks and undercuts should be sealed with either clay or polyethylene glycol (Carbo-wax). The decision as to which material is used depends on the mold material selected and the nature of the crack filled. Clay is more difficult to remove from the specimen after it is demolded; however, Carbo-wax can react with latex rubbers causing them to become brittle (Goodwin and Chaney, 1994). Room Temperature Vulcanizing (RTV) rubbers are compatible with Carbo-wax, but are by nature sensitive to contamination, particularly by sulfur and tin. Therefore, any clay used with RTV should be silicon based and free from sulfur compounds.

In some cases, it may be advisable to complete reconstructions with clay prior to molding (Converse, 1984). Minor reconstructions, and those that bear little weight, can be made at this time. However, sculpted clay may not retain its shape during the molding process if it is used to reconstruct delicate detail, or major, weight-bearing areas. Additionally, it is important to retain the scientific integrity of the fossil. Since any reconstruction is largely conjecture, it should be held to a minimum in the preparation of a study cast (Converse, 1984).

Major reconstructions, and those that bear weight, are better made following casting. This permits the production of study casts and exhibition casts from the same mold. Depending on the casting material used, major reconstructions can be made from either plaster, Hydrocal, or a two-part epoxy putty. If necessary, this cast can then be remolded, allowing additional copies to be made with the incorporated reconstructions.

Following reinforcement and reconstruction, the specimen must be hardened with Butvar B-76 or Vinac B-15. Several coats must be applied in thin, even layers to ensure that detail is maintained, that the mold material will not adhere to the bone, and that the fossil will withstand the rigors of molding (Converse, 1984). Generally, the hardener is left on the fossil, and although the long-term stability of these adhesives is undetermined, they remain the best available choices. Additionally, removal of the hardener would expose the bare bone to agents of deterioration.

Consideration as to how many pieces comprise the mold must include the material used, the intricacy of the specimen, and the accuracy of the finished cast (Iwama, 1993). A simple, one-piece peel mold may be appropriate for bas-relief casts and for those specimens that are largely two dimensional. However, for complicated fossils and those casts intended for scientific study, a multi-piece mold may be necessary (Smith and Latimer, 1989).

Room Temperature Vulcanizing rubber is preferred for extremely delicate fossils, for finished casts of scientific quality, and for long lasting molds from which many casts are anticipated. The flexibility of RTV makes it the best choice for delicate specimens because it is less abrasive to the fossil (Smith and Latimer, 1989). Additionally, it can be applied in thin, strong layers that are more easily removed from intricate surface detail. The detail required for study quality casts necessitates the use of RTV. Long lasting, epoxy casts can be made from RTV molds without the use of a separator that may potentially reduce surface detail (Goodwin and Chaney, 1994).

The proposal for the exhibition of *Macysuchus* is that it be presented in situ, so only one side of the skull will be visible. Therefore, a simple, one-piece, peel mold will suffice. A one-piece mold would also be less injurious to the specimen. Since the presentation of a cast means that the original skull will be retained in collections storage for study, it may not be necessary to produce a study cast. However, if it is decided to disseminate study casts, then a multi-piece mold will be necessary.

Latex rubber molds offer a cost-efficient alternative to RTV molds and are a good solution for fossils that are to be cast in plaster or Hydrocal, and for those casts intended solely for exhibition. However, latex molds have a limited shelf life and require the use of a separator in conjunction with epoxy casting resins. Latex also has a tendency to shrink excessively (Goodwin and Chaney, 1994).

Since the *Macysuchus* skull is to be presented in situ, the casts will not be required to support any weight. Therefore, Hydrocal or plaster would provide an inexpensive solution. However, epoxy casts are stronger and reproduce a more accurate surface quality; epoxy casts resemble bone more than plaster casts do. Therefore, an RTV mold is recommended whether a one-piece or a multi-piece mold is selected, because the mold will last longer, be less injurious to the fossil, and can be more efficiently used in conjunction with either Hydrocal or epoxy casting resins (Iwama, 1993).

Figure 6.1 illustrates the preparation of *Macysuchus* prior to molding as a one-piece peel. A clay base is built, enclosing the skull. Clay is also used to fill the orbit, nasal openings, and cranial fenestrae. This not only prevents mold material from fully encasing the skull, but it also replicates the matrix that once filled these openings. The mold material will be painted over the skull and clay base so that the finished cast includes the rectangular base, similar to the illustration.

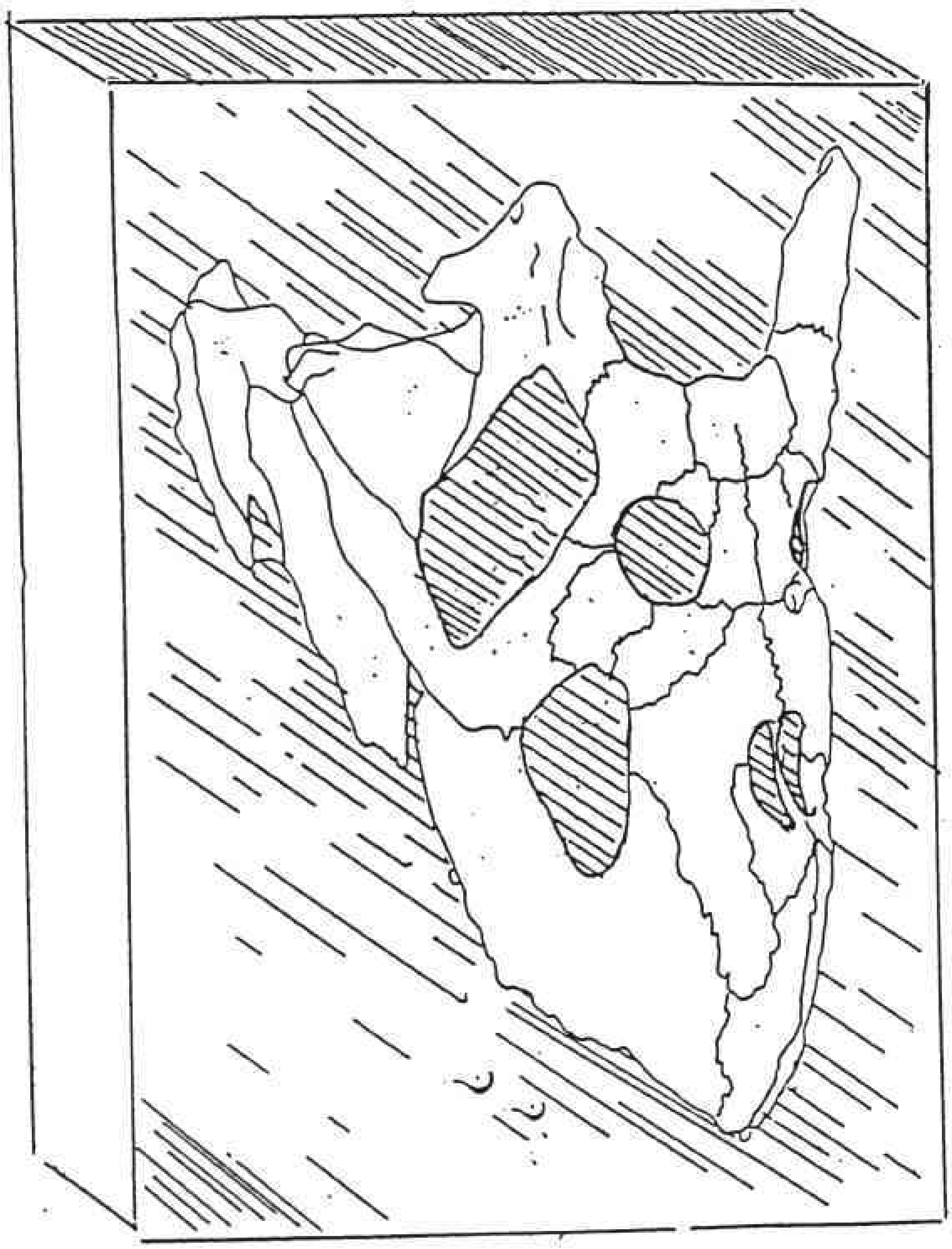


Figure 6.1. Preparation of *Macysuchus* prior to molding in a one-piece peel.

6.3 Pour Spouts

Traditionally, molds incorporate a pour spout to assist in the evacuation of air bubbles from the casting material (Iwama, 1993). It is still extremely difficult to remove all air bubbles from a cast. Molds constructed without pour spouts (lay-up molds) allow for the casting material to be painted into the mold. This is advantageous for several reasons. First, the absence of a pour spout negates the necessity of grinding the spout from the finished cast, thereby producing a more accurate copy. Second, the laying up of the casting material within the mold allows for a lightweight, hollow cast to be produced, thereby reducing both the weight and the cost of the cast. Finally, brushing the casting compound into the mold removes more air bubbles than pour spouts and vents. Even the use of a vacuum cannot assure that the casting material will find its way into undercuts, thin passages, and deep recesses. Brushing the casting material into the mold assures that all surfaces will be coated (Converse, 1984; Schrimper, 1973).

Lay-up molds are prepared by painting the casting material within the mold in thickened solution. Fumed colloidal silicone (Cab-O-Sil) is a convenient thickening agent (Goodwin and Chaney, 1994). For a hollow mold, this first layer is allowed to dry, taking precaution that no casting material is allowed to dry beyond the edges of the image, as this will hinder a tight seal once the two halves of the mold are joined. A second, thickened layer is painted over the edges and the two halves of the mold are pressed together. Solid casts can be made in one step. The mold is simply painted with thickened casting material to destroy surface bubbles, filled with casting material, and the two halves of the mold are joined (Goodwin and Chaney, 1994; Schrimper, 1973).

6.4 Casts

A variety of casting compounds are available commercially including Water Extended Polyester (WEP), plaster, epoxy resins, polyurethane, and Hydrocal. While all of these compounds produce satisfactory casts, epoxy resins and Hydrocal are recommended for the casting requirements associated with *Macysuchus*.

Hydrocal is preferable to plaster simply because it is stronger and more resistant to chipping (Goodwin and Chaney, 1994). In Chapter Seven, the advantages to casting postcranial elements of the *Macysuchus* skeleton will be discussed. These casts are intended to preserve information obscured on the reverse side of the in-situ presentation. Due to the size of the casts necessary, latex peel-molds cast in Hydrocal provide an inexpensive means of replicating the image.

Plastics provide a more aesthetic surface texture to the cast than either Hydrocal or plaster (Smith and Latimer, 1989). Of these, epoxy resin is selected over WEP and polyurethane for several reasons. First, it is less toxic than WEP. Second, epoxy produces less heat during cure than either WEP or polyurethane, thereby reducing stress to the mold. Third, the slower cure time of epoxy than either WEP or polyurethane allows for a better lay-up of the material within the mold.

Water Extended Polyester is used extensively in paleontological casting because it is less expensive than many alternative casting compounds (Goodwin and Chaney, 1994). However, NMNH does not use WEP for any of its casting due to the tendency of WEP to leach its water over time (Grady, 1998; personal communication). This leaching of water can cause the cast to deform and to lose its rigidity. Relaxation of the WEP requires that the cast be heated with a hot air gun and reshaped. However, the hot air gun can weaken adhesives and cause paint to bubble and blister. Water Extended Polyester can eventually lose its elastic memory and the specimen will have to be recast.

The use of WEP requires that the preparator wear an organic filter respirator. However, it is doubtful that the respirator removes all contaminates. Long-term exposure to harmful vapors is a concern for preparators, and as less toxic casting materials are available, it is recommended that WEP be avoided (Goodwin and Chaney, 1994).

The use of polyurethane requires a hood for extrication of harmful vapors (Smith and Latimer, 1989). Additionally, polyurethane tends to heat as it cures and can damage the mold after repeated casting (Goodwin and Chaney, 1994). Also, polyurethanes have a fast cure time, setting in under five minutes. As a result, polyurethanes are not suitable for lay-up molds.

The use of epoxy resins in conjunction with lay-up molds produces a long lasting, highly detailed cast (Smith and Latimer, 1989). As previously stated, epoxies can be cast from RTV molds without the use of a separator, thereby producing a more detailed cast (Goodwin and Chaney, 1994). Additionally, the use of a simple, hand-operated centrifuge will remove air bubbles and produce an even coating of epoxy over the surface of the mold. Larger specimens can be spun in an electric, omni-directional centrifuge (Figure 6.2) (Schrimper, 1973). However, these machines are space consumptive, and largely impractical in deference to hand-painted, lay-up casts (Kroehler, 1998; personal communication). In order to prepare the mold for use in a centrifuge, the mold is first secured with rubber bands, and spun in the centrifuge forcing the epoxy to the surface of the mold. This process reduces the time spent casting a hollow lay-up because it is no longer necessary to let the first layer cure before coating the seams and pressing the two halves of the mold together (Schrimper, 1973).

Hydrocal lay-up casts can also be used in conjunction with a centrifuge. However, since the *Macysuchus* is to be molded in a one-piece peel, the use of a centrifuge is both unnecessary and impractical. The Hydrocal can be painted within the mold, and any remaining air bubbles can be evacuated simply by shaking, tapping, and vibrating the mold (Babcock, 1989).

Casting compounds can be dyed to produce a more aesthetic result. Powder pigments work rather well (Converse, 1984). These pigments are available from art supply stores, come in a variety of colors, and can be mixed to duplicate the color of the bone. A less expensive alternative is cement dye that can be purchased at hardware and masonry stores (Converse, 1984). A complete palate, including blues, greens, and earth tones, will enable the preparator to produce an attractive replica.

These pigments tend to be somewhat transparent and it is advisable to first mix the epoxy with an opaque white, such as that marketed for casting, in more traditional liquid or paste form. These liquid and paste dyes tend to be messy and more difficult to work with than dry pigments. The dry pigment can be then added to the white resin to approximate the color of the bone (Goodwin and Chaney, 1994).

Dry pigment can also be dusted into the mold prior to the addition of the casting compound (Kroehler, 1998; personal communication). This pigment will be incorporated into the finished cast, producing a mottled coloration that closely duplicates the original fossil. Since the pigment tends to be somewhat transparent, darker colors tend to work better than lighter colors. Therefore, for *Macysuchus*, the casting compound should be dyed to a light color, and the detail dusted in darker tones. The advantage to this process, is that when carefully done, the need for painting the cast is reduced to simple touchup, and the finished product is more durable.

Oil paints generally produce the best results for any touchups needed. These colors tend to be more vibrant than watercolors or acrylics, are available in high-quality, fade-resistant brands, and adhere better to plastic casting compounds (Goodwin and Chaney, 1994). Drying time of oil paint can be decreased by mixing a small amount of cobalt dryer with the paints. These paints can be thinned with turpentine, and applied in a series of thin washes, highlighting the detail of the cast. Both oil paints and turpentine are compatible with the plastics mentioned (Goodwin and Chaney, 1994).

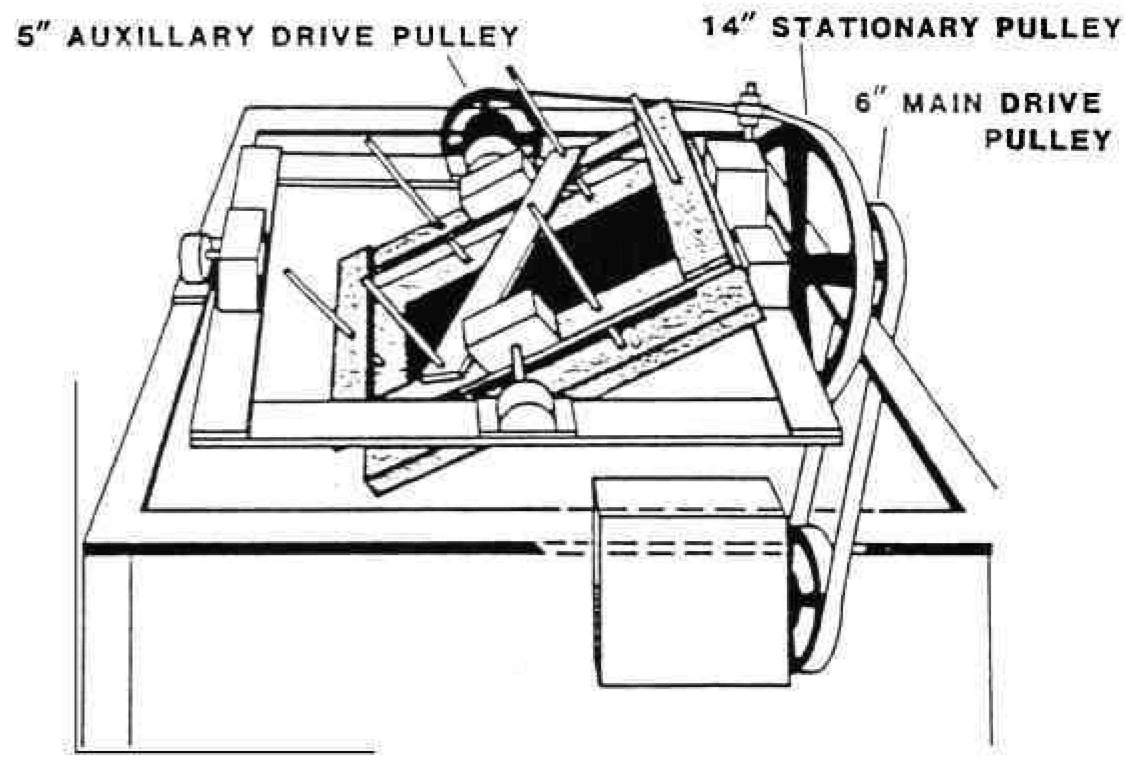


Figure 6.2. Omni-directional, electric centrifuge (After Smith and Latimer, 1989).

CHAPTER VII

EXHIBITION

7.1 Introduction

The exhibition of paleontological specimens subjects the material to increased stress over those levels usually associated with collections storage. The affecting agents of deterioration include: vandalism, theft, vibration, temperature and humidity fluctuation, ultraviolet radiation, and pollutants. The preparator's role in exhibition is to protect the fossil, as much as possible, from undue injury; to prepare the specimen for exhibition, including necessary reconstruction and casting; and to work with the exhibits team towards a unified exhibit composition.

The exhibits team should work with the preparator in assessing when a specimen should be cast, and when the original specimen can be displayed. This is because the preparator is often the most intimately knowledgeable about the condition of a fossil. The decision to cast a fossil should include a budget, a time line, and the specific materials and methods used.

The exhibits team should function as a unified whole, assuring a cohesive exhibit composition. For the preparator, this means an understanding of the overall design of the exhibit in which a specimen is to be used. Discourse between the preparator and exhibits staff will ensure a collaborative concern for the safety of the specimen, the materials used, and the accurate presentation of the material. The preparator must work within the constraints of space imposed by the exhibit design. The installation of the fossil should compliment the other elements of the case including text, additional paleontological specimens, and elements of the diorama.

In this thesis, examination of exhibition concerns is limited to preventive conservation issues associated with *Macysuchus*. Since this is merely a proposal, there will be no discussion of text, space design, construction design, or other related exhibits issues specific to the presentation of *Macysuchus*. These are beyond the scope of duties of the preparator outside the forum of the exhibits team.

7.2 Presentation Proposal

Macysuchus is to be exhibited in an in-situ presentation. The elements of the skeleton will be rearticulated and shown in a death pose. Although the pose will approximate the aesthetics of the original discovery, the skeleton will be flipped over from its original orientation. This is because the reverse of the skull is the most complete side. Additionally, concerns for space within the display dictate that the skull be joined to the skeleton, closing the 20 foot gap that originally separated these two elements. This gap can be hinted at, and the taphonomic story illustrated, by disarticulating the skull from the body by a few inches (Figure 7.1).

The separation of the skull from the body is useful in illustrating the taphonomy associated with *Macysuchus*. Specifically, the disarticulation of the skeleton is the result of flood activity. Therefore, the orientation of the specimen, and the degree of disarticulation of the skeleton, should coincide with the design of the rest of the exhibit case, and with any illustrations or dioramas. Figure 7.1 represents a proposal for the

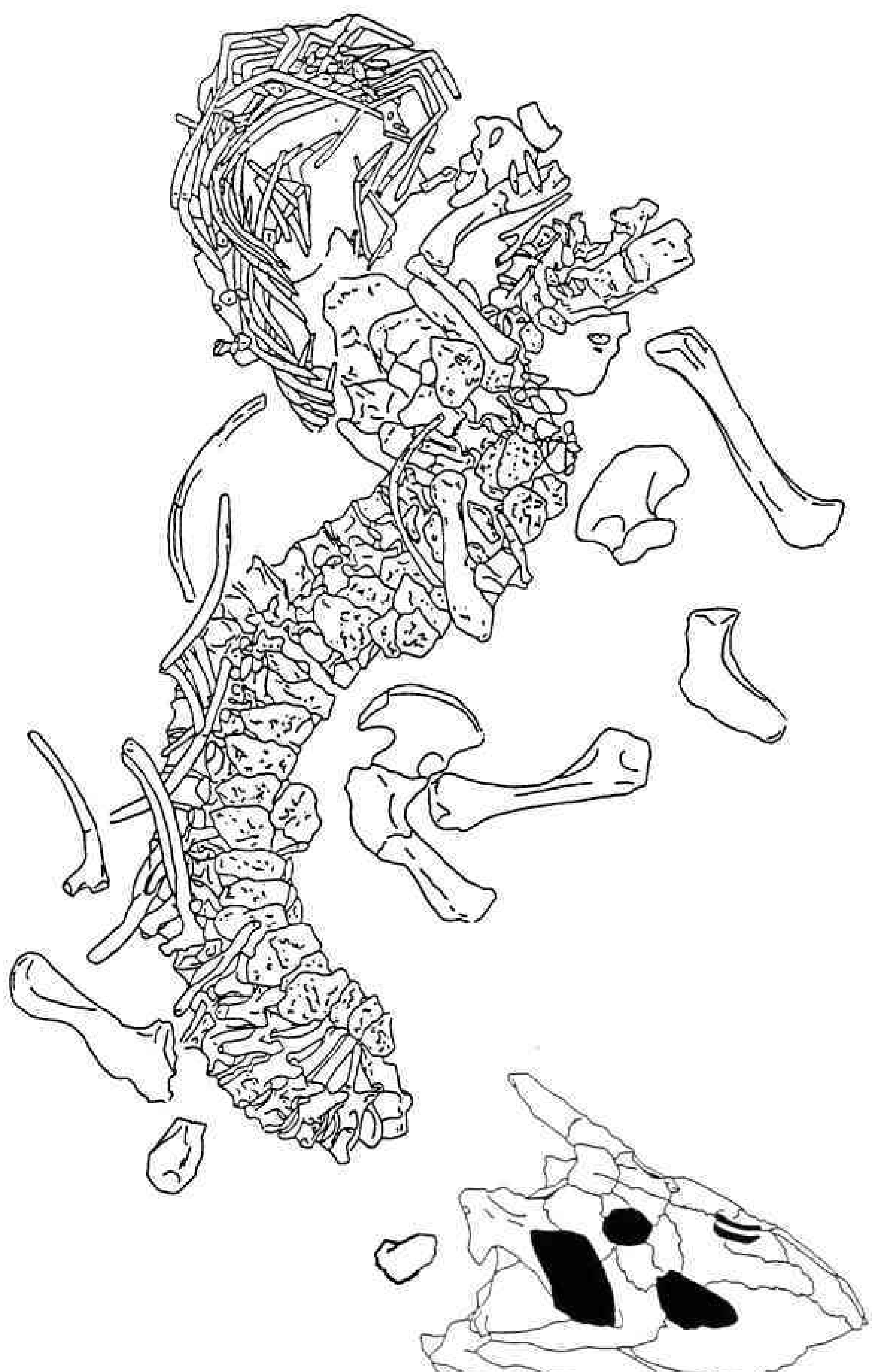


Figure 7.1. Exhibit proposal for *Macysuchus*, plan elevation.

exhibit of *Macysuchus* that approximates, as much as possible, the aesthetics of the original discovery.

The issue arises of whether or not to exhibit a cast in favor of the original specimen. Since *Macysuchus* is a holotype, there are several preventive conservation concerns related to its exhibition. These include loss of scholarly access, and increased threat of injury. The presentation of a cast ameliorates these concerns. However, the public has a desire and a right to see the "real thing."

Since *Macysuchus* is to be presented in an enclosed case, the threats of theft, vandalism, and pollutants are diminished. The light levels can be mediated with concern for the fossil, and the case glass can be lined with UV tempered film. Temperature and humidity control are largely constant, and regulated through the Museum's HVAC system. Breakage due to vibration, and loss of scholarly access, are the only two conservation concerns that pose a real threat to *Macysuchus*. Therefore, with modification, the original specimen can be safely displayed, attending to the needs of both the public and the fossil. A composite skeleton, composed of both original and cast elements, would satisfy the conservation needs of the specimen.

7.3 Casting the Skull

Since *Macysuchus* is a holotype, the skull should be cast so that the original fossil can be kept in collections storage for study. If the original is kept, the cast can be a simple, one-piece peel. The choice of materials used will be dependent on budget constraints, and other concerns voiced by the exhibits committee. It is recommended that the skull of *Macysuchus* be molded in RTV rubber, and cast in epoxy resin. This process will produce the strongest, most aesthetic, most detailed copy, and the longest-lasting, least invasive mold. The epoxy resin can be dyed to match the original skull, and detail can be dusted into the mold with cement dye. Any touch-ups needed can be applied with oil paints.

However, RTV rubber will be expensive for a mold this size, and a latex mold offers a less expensive alternative. The use of epoxy resin in a latex mold will require the use of a separator, but any detail lost will be negligible in an exhibits cast. If mandated by budget constraints, Hydrocal offers a less expensive alternative to epoxy.

It is also advisable to cast several postcranial elements. Since the specimen is to be exhibited in-situ, the underside of the skeleton will be hidden beneath the flooring. In order to preserve this information, the underside of the skeleton should be cast. This cast would be only for study purposes, and its size mandates that it be produced cheaply. A simple, latex peel, cast in Hydrocal, would suffice. Also, the sacrum and any postcranial elements deigned diagnostic, such as vertebrae, limb elements, and scutes should be cast for study. All of these can be cast in Hydrocal from latex molds.

7.4 Installation

An additional threat to the fossil on exhibition is that of breakage, and the primary cause of breakage is from vibration. To minimize this threat, the gastralia block and the two vertebral sections should be exhibited in a form-fitted, padded jacket (as discussed in

Chapter V; Figure 5.4). Such a jacket will not be necessary for the skull since it is to be exhibited as a cast.

Since the skeleton is to be rearticulated, the elements should be contained within one jacket. This will simplify the aesthetic joining of the skeleton later. To build the new jacket, the three elements should be laid out in their lab jackets, reverse side up, in a sand box, or supported with sandbags on the floor. The flanges of the old jackets will need to be cut off to facilitate a flush articulation of the skeleton. The sides of the jackets should be cut down below the intended seam line of the finished jacket. This will allow for a layer of clay to be built up, encasing the skeleton as if it were to be cast, and providing an even surface upon which to construct the new jacket.

A flange of cardboard or clay should be made, encircling the three blocks. This will accommodate the six inch flange on the finished jacket. At this time, the specimen can be molded in latex, since the procedure used for the jacket mirrors that by which the specimen would be molded. Once the latex peel is removed, the specimen can be reinforced and the jacket constructed as described in Chapter V. After the new jacket has been built, the lab jackets can be strapped to the padded jacket, and the unit flipped. The specimen is now nestled, face up, in a padded jacket.

In order for the skeleton to appear to be imbedded in matrix, a platform must be built up, raising the floor to accommodate the depth of the jacket. A paper stencil, outlining the shape of the jacket, can be used to mark a hole in the platform. The hole cut should be 5 inches inside the edge of the jacket so that the flange will rest on the platform of the flooring (Figure 7.2). Depending on the thickness of the flooring, the jacket can be

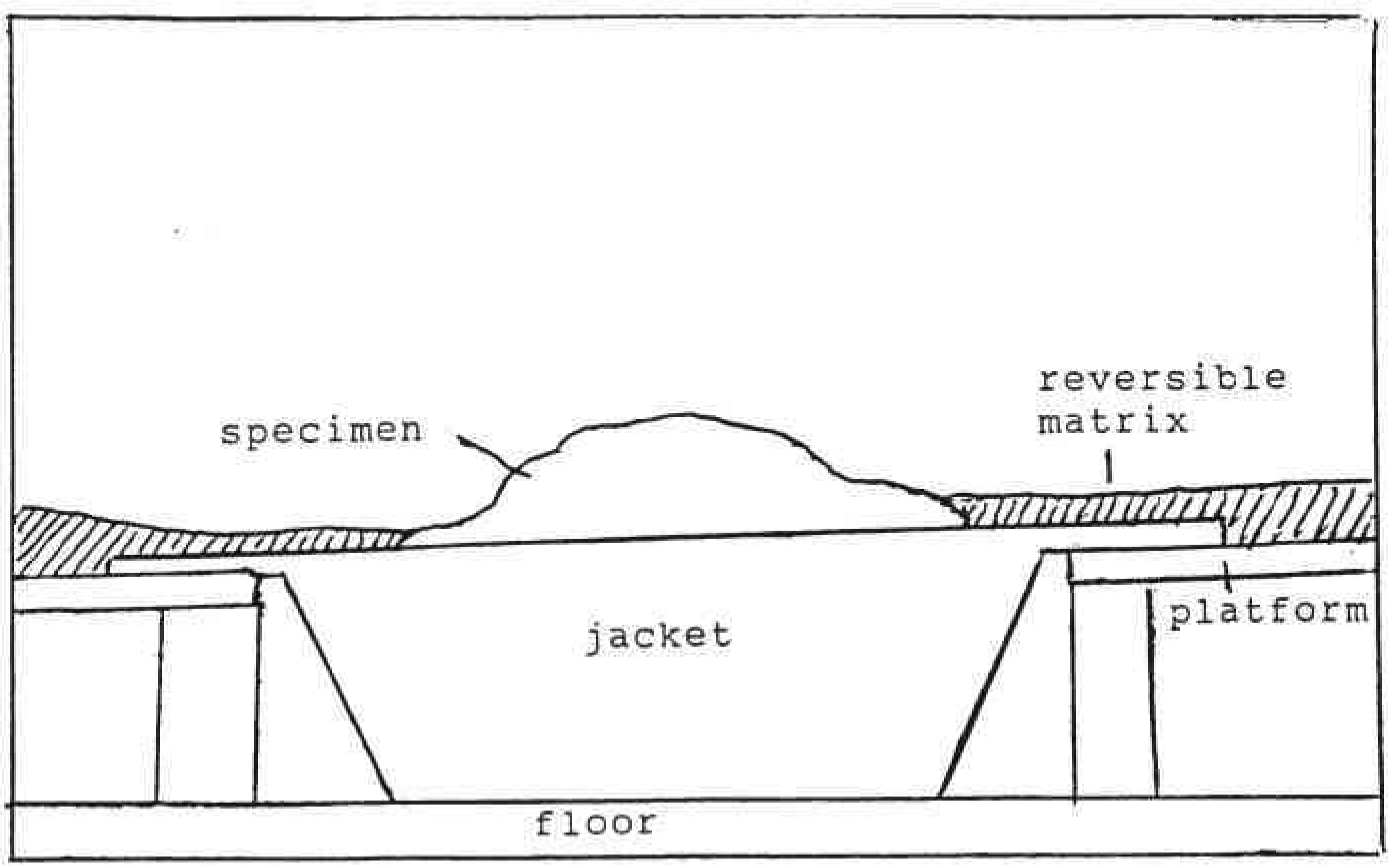


Figure 7.2. Jacket imbedded in platform; side elevation.

designed to rest on the floor, with its flange on the platform. If the flooring built is significantly thicker than the jacket, then its base may need to rest on a support.

The flooring will be covered with a ground, simulating the original matrix. A mixture of plaster and paper maché is generally used for such matrix (Converse, 1984; Kroehler, 1998; personal communication). Dirt can also be mixed with glue, but this concoction often cracks as it cures. The paper maché and plaster mixture will not crack; however, it is not reversible.

As *Macysuchus* is a holotype, the skeleton must be retrievable. It is suggested that a reversible matrix be used in contact with the bone, and covering the scar where the flange of the jacket overrides the platform. Paper pulp epoxy, stained with actual matrix, with food coloring, or with cement dyes, would provide a good, reversible matrix. If a hygroscopic material is undesirable, Butvar B-76 mixed with the paper pulp component of PPE could be similarly stained, and would provide a satisfactory, reversible matrix. If the matrix covering the platform is done using a mixture of dirt and glue, the matrix contacting bone should be done using dirt and a reversible glue, such as Butvar B-76, or Lineco's reversible, water-based glue.

CHAPTER VIII

CONCLUSION

Phytosaurs have been known to science for over 100 years; however, all previous genera have been in long-snouted form. The discovery of *Macysuchus brevirostris* is significant because it questions the ubiquity of long snouts for all phytosaur genera. Additionally, there are only two other complete, articulated phytosaur skeletons in the world. As such, *Macysuchus* is a priceless accession to the Museum of Texas Tech.

Macysuchus' abbreviated snout is a significant autapomorphy, for which the naming of a new taxon is warranted. However, *Macysuchus* shares many synapomorphies with other phytosaur genera. Dominant among these are placement of the external nares near the top of the head; a prominent squamosal process; and depressed upper temporal fenestrae. Therefore, *Macysuchus* is a phytosaur.

Although all other phytosaur genera are long-snouted, it is not unlikely that a short-snouted morphotype should exist. Modern crocodilians, the extant analogs of phytosaurs, are found in both long- and short-snouted forms.

The rarity and importance of *Macysuchus* mandated its careful treatment in the field and in the lab. Proper field methods included good field notes, a site record, and meticulous excavation technique. Great concern was given in the field to ensure that that which was done could be undone in the lab.

In the lab, every effort was made to ensure the perpetuity of the fossil. The least invasive techniques available for the development of the matrix were used, including manual preparation, and mechanical preparation using an air scribe. Glues, consolidants, and epoxies were chosen for their strength, stability, and reversibility. To this end, PPE was formulated. Epoxies used traditionally for fossil reconstruction are largely unstable and irreversible. Paper Pulp Epoxy offers an inexpensive, stable, and reversible alternative to these traditional materials.

More research is needed concerning PPE. A long-term study of the reversibility of Lineco's pH neutral, PVA glue is essential. Exploration into alternative water-based glues would be helpful. A repetition of the RH experiment discussed would be valuable in the assessment of these other adhesives.

Preventive conservation concerns for the exhibition of *Macysuchus* include damage from vibration and loss of scholarly access. The presentation of casts ameliorates both of these problems. Since *Macysuchus* is to be presented in-situ, the underside of the skeleton will be hidden beneath the matrix. Additionally, *Macysuchus* is a holotype and should be kept in collections storage for study. The casting of the skeleton will assure that access is not diminished, and that information is not lost.

Additional research is necessary for the full description of the *Macysuchus* specimen. Careful morphometric study should be published allowing for scrutiny by the scientific community. It is essential that this publication precede the public exhibition of the specimen to ensure an accurate presentation to both the public and to the scientific community.

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APPENDIX

LIST OF ABBREVIATIONS

a:	articular
an:	angular
aof:	antorbital fenestra
en:	external nares
f:	frontal
j:	jugal
L(l):	lacrimal
m:	maxilla
mf:	mandibular fenestra
n:	nasal
orb:	orbit
p:	parietal
pf:	postfrontal
pm:	premaxilla
po:	postorbital
prf:	prefrontal
pt:	pterygoid
ptf:	postemporal foramen
q:	quadrate
qj:	quadratojugal
s:	squamosal
sa:	surangular
sm:	septomaxilla
sp:	splenial
stf:	supratemporal fenestra

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