THE MORPHOLOGY AND ONTOGENY OF *Typothorax coccinarum* (ARCHOSAURIA STAGONOLEPIDIDAE) FROM THE UPPER TRIASSIC OF THE AMERICAN SOUTHWEST

by

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ABSTRACT

The aetosaur *Typothorax coccinarum* in known from abundant material from the Late Triassic Chinle Formation and Dockum Group of the American southwest, particularly in Arizona, New Mexico, and west Texas. *Redondasuchus reseri* is a smaller aetosaur taxon with several similarities to *Typothorax* that may indicate it is a juvenile. The purposes of this thesis are to provide a thorough, well-illustrated description of *Typothorax coccinarum*, describe the ontogeny of the taxon, and to determine if *Redondasuchus* is a valid taxon distinct from *Typothorax*.

The Canjilon Quarry (Upper Petrified Forest Formation, Chinle Formation, north-central New Mexico) *Typothorax* material includes three large concentrations of scutes and skeletal material (probably representing individuals) and other isolated elements, collected from two distinct stratagraphic layers. The original field maps and field numbers recorded on the bones allow the association of much of the material to be established. The Post Quarry (Cooper Canyon Formation, Dockum Group, west Texas) yielded a subadult specimen of *Typothorax* (TTUP 9214). Although detailed quarry maps and field notes for the Post Quarry are currently unavailable, the general consistency in the material supports its assignment to a single, unusually small individual of *Typothorax*. The Apache Canyon Quarry (Redonda Formation, Dockum Group, eastern New Mexico) material of *Redondasuchus* consists entirely of isolated scutes probably found in at least two different stratigraphic levels within the quarry.

The scutes of TTUP 9214 possess the diagnostic features of *Typothorax coccinarum*, while its small size and the incomplete ossification of some elements suggest it is a subadult. There are no major differences between the scutes of *Typothorax* and *Redondasuchus* apart from size; arching is seen in the presacral as well as caudal dorsal paramedian scutes of *Typothorax*, and the alleged down-turned lateral edge of the holotype scute of *Redondasuchus* is in fact is the medial edge, placing arching at the center of ossification as in *Typothorax*. *Redondasuchus reseri* is assigned to *Typothorax*,

but kept as a separate, smaller taxon, *Typothorax reseri*, due to the absence of *T. coccinarum* material from the Redonda Formation.

The only axial skeletal material described here is from TTUP 9214, which includes a squamosal, quadrate, braincase, dentary, and vertebrae from all regions of the column except for posterior caudals. The braincase has an incompletely enclosed trigeminal foramen and basal tubera that are deeply split by the basioccipital-basisphenoid suture. The dentary is extremely shallow, with ten aveoli. The transverse processes of the vertebrae grow extremely wide in the dorsal region. Appendicular skeletal material is well represented, and many areas of muscle attachment present in crocodilians can be plausibly inferred. The scapulocoracoid, clavicle, humerus, illium, pubis, ischium, femur, tibia, fibula, astragalus, calcaneum, metapodials, and phalanges are all known from the Canjilon Quarry material and/or TTUP 9214. The dorsal paramedian and lateral scutes of *Typothorax* are the best-known elements, and show variation relating to their anteroposterior placement on the body. The ordering of these scutes is inferred based on aetosaur specimens of other taxa with articulated scutes, and two blocks of articulated *Typothorax* scutes from the pelvic and caudal region of one of the Canjilon Quarry specimens. All dorsal paramedians have circular or oval ornamentation in a random pattern, a raised anterior bar, and most have a thick ventral keel and are extremely wide. The lateral scutes in the precaudal region are angulated, have a triangular dorsal flange, and lack a horn. In the caudal region the lateral scutes are flat plates with the flanges lying in roughly the same plane. Appendicular and ventral scutes of *Typothorax* are known, but their arrangement on the body is not understood due to the lack of articulated material.

Bivariate ontogenetic allometry was explored for the femur and tibia of *Typothorax coccinarum*. The femur of *Typothorax* may have lengthened more rapidly then the tibia. Log squared measurements of femur and tibia length were plotted against each other, yielding a good correlation, but failing to pass the p-test (probably due to the small sample size of individuals having both elements). Log-squared measures for the femur and tibia were then plotted against size scores on the first principal component

(PC1) to describe the relative growth of various dimensions of these bones. Several of the femur measures for *Typothorax coccinarum* have good correlation coefficients that pass the p-test for, generally indicating that the bone grew robust more rapidly distally and at the midshaft then it lengthened. All tibia measures showed good correlation coefficients that passed the p-test, generally indicating that the robustness of the tibia increased faster then its length in all areas of the bone, especially proximally and at the midshaft.

Many ontogenetic changes in *Typothorax coccinarum* seem to represent recapitulations, with likely plesiomorphic traits such as a less compact neck, slightly narrower transverse processes on the vertebrae, femora that are not so long relative to the crus, a narrower carapace, and a raised ridge on the dorsal paramedian scutes being lost with age and increase in size. The young of *Typothorax* may have been more active then the older individuals. There is insufficient evidence that posture became more erect in *Typothorax* ontogenetically, or between aetosaur taxa phylogenetically, as a graviportal adaptation. However, this possibility cannot be entirely ruled out for aetosaurs as a group, and it is possible that erect posture evolved in archosaurs in response to more then one selective pressure.

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FIGURES

ABBREVIATIONS

Institutional Abbreviations

AMNH: American Museum of Natural History, New York City, NY.
DMNH: Dallas Museum of Natural History, Dallas, TX
FMNH: Field Museum of Natural History, Chicago, IL.
MCZ: Museum of Comparative Zoology, Harvard University, Cambridge, MA.
NMMNH: New Mexico Museum of Natural History, Albuquerque, NM.
TTUP: Texas Tech Museum, Texas Tech University, Lubbock, TX.
UCMP: University of California Museum of Paleontology, Berkeley, CA.
USNM: United States National Museum (The Smithsonian), Washington DC.

Anatomical abbreviations

AAR = anterior ampullary recess
ac = acetabulum
af = astragalar fossa
ah = anterior hollow
bo = basioccipital
bt = basal tubera
btg = basipterygoid processes
cf = "crescentic facets"
clt = cultriform process
crp = crista prootica
da = dorsal articulation (astragalus)
dir = distal roller
dr = deltoid ridge
ds = dorsum sellae
dt4 = distal tarsal 4
ect = ectepicondylar flange
eo = exoccipital
ff = fibular facet
fos = fossae for menisci
gt = greater trochanter
ibb = buttresses on the iliac blade
ic = internal carotid
ilf = *M. illiofemoralis* attachment
it = internal tuberosity
lat = lateral distal condyle
ls = laterosphenoid
"lt" = "lesser trochanter"
mcv = middle cerebral vein
med = medial distal condyle
mk = Meckelian canal
mpr = medial pharyngeal recess
nf = nutrient foramen

ob = obturator flange
op = opisthotic
occ = osseus common crus
p = parietal
pad = primary adductor scar
PAR = posterior ampullary recess
pbs = parabasisphenoid
pcf = proximal condylar fold
pf = pubic foot
pg = posterior groove
pr = prootic
sa = surangular
sab = supracetabuluar buttress
sad = secondary adductor scar
sgp = subglenoid pillar
so = supraoccipital
sym = symphysis of pelvic bone with sister
t = calcaneal tuber
tf.l = lateral part of tibia articulation
tf.m = medial tibia articulation
tr = trochlea of the femur
tt = triceps tubercle
vr = ventral ramus of the opisthotic
4th = 4th trochanter of the femur
V = embayment for the trigeminal nerve
VI = foramen for the abductens nerve
VII = foramen for the facialis nerve
XII = floor or foramen for the hypoglosseal nerve

CHAPTER 1

INTRODUCTION

1.1. Stagonolepidids (aetosaurs)

Aetosaurs were heavily armored herbivorous archosaurs that lived during Late Triassic time (Carnian-?Rhaetian). Aetosaurs belong to the branch of crown-clade Archosauria (sensu Gauthier, 1984) consisting of all archosaurs closer to crocodilians than birds, properly called Pseudoscuhia[1] (Gauthier and Padian, 1985; Gauthier, 1986; Padian, 1997; Brochu 1997). They were common members of the herbivorous terrestrial fauna during Late Triassic time, and varied in length from less than a meter up to 5 meters or more. Aetosaurs are characterized primarily by their extensive covering of osteoderms.

Aetosaur remains are known from the Chinle Formation, Dockum Group, and related Upper Triassic strata of the American southwest (Long and Ballew, 1985; Long and Murry, 1995), but they are also known from the Newark Supergroup of the east coast of North America (Jepsen, 1948; Baird, 1986; Huber et al., 1993), and other Upper Triassic deposits in Greenland (Jenkins et al., 1994), South America (Casamiquela, 1961; Bonaparte, 1970, 1971; Rogers et al., 1993; Heckert and Lucas, 2002), Europe (Walker, 1961; Benton and Walker, 1985; Wild, 1989), Morocco (Lucas, 1998a), and India (Chatterjee and Roy-Chowdhury, 1974; Kutty and Sengupta, 1989).

Aetosaurs were extremely common members of the terrestrial herbivorous fauna across the world for most of Late Triassic time, and seem to have survived well enough in both wetter and drier climes. The genus *Stagonolepis* is known from the Chinle Formation (Long and Ballew, 1985), which was deposited in a climate that (at least seasonally) experienced high precipitation (Dubiel et al., 1991). It is also present in the

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[1] The name Crurotarsi was created by Sereno and Arcucci (1990) and Sereno (1991) as a node-based definition for essentially the same group, largely over semantic issues. Although defined as a stem, the name Pseudosuchia has priority over Crurotarsi since the membership of the clades is usually considered to be identical due to the basal position of Parasuchia.

Lossiemouth Sandstone of Scotland, which consists of eolian dune and interdune deposits probably representing a drier environment in which aquatic vertebrates such as phytosaurs and metoposaurs are unknown (Benton and Walker, 1985). However, the *Placerias* Quarry near St. Johns, Arizona, where mass vertebrate mortality likely resulted from drought conditions (Fiorillo et al., 2000), contains abundant aetosaur material belonging to *Stagonolepis* and *Desmatosuchus* (Long and Ballew, 1985; Long and Murry, 1995), suggesting that aetosaurs were not immune to extremely dry environmental conditions.

The osteoderms of aetosaurs are considered to be highly distinctive at least to the generic level. Scutes are the most frequently encountered and commonly used means of identifying aetosaur taxa (e.g., Long and Ballew, 1985; Heckert and Lucas, 2000), and probably have value as index fossils for Upper Triassic terrestrial deposits (e.g., Heckert and Lucas, 1996; Lucas, 1998b). However, many taxa have long stratagraphic ranges and/or limited geographic distribution, which reduce their biostratigraphic utility (Lehman and Chatterjee, in prep).

1.2 *Typothorax coccinarum*

Typothorax coccinarum is an abundant aetosaur in the Upper Triassic deposits of the American southwest, being known from the upper Petrified Forest and Owl Rock Members (Chinle Formation) of the Colorado Plateau, and the Trujillo and Cooper Canyon Formations (Dockum Group; sensu Lehman, 1994) of eastern New Mexico and west Texas (Long and Murry, 1995). Elsewhere in the world, the taxon is unknown, although material from the Maleri Formation of India may be referable to it (T. S. Kutty, personal communication, 2000).

The dorsal paramedian scutes of *Typothorax* are generally distinguished from those of other aetosaurs by the following combination of characters[2], some of which are

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[2] Aetosaur scutes are rarely distinguished by autapomorphies, but rather by *combinations* of characters which are usually shared individually with other aetosaur taxa (Martz and Small, in prep).

clearly illustrated by the incomplete holotype scute, USNM 2585 (Cope, 1887, plate I; Huene, 1915, fig. 5.):

1. They are highly expanded mediolaterally, with a width/length ratio in the widest scutes approaching or exceeding 4.0.
2. The dorsal surface is ornamented by random (non-radial) circular or subcircular pitting.
3. A boss on the dorsal surface of the scute is either absent or fairly small.
4. There is a thick keel extending the width of the scute on the ventral surface.
5. There is a raised bar extending the width of the anterior edge of the scute on the dorsal surface (Long and Ballew, 1985; Long and Murry, 1995; Heckert and Lucas, 2000).
6. Long and Ballew (1985) noted that the caudal dorsal paramedian scutes in the UCMP collections (mostly from Canjilon Quarry) are transversely arched. However, Long and Murry (1995) implied that in most dorsal paramedian scutes, this arching was due to post-mortem distortion.

Discussions of the taxonomic history of *Typothorax* may be found in Gregory (1953) and Long and Ballew (1985, pp. 61-62). Moreover, Long and Ballew (1985, pp. 58-64), Long and Murry (1995, pp. 215-220, 222, 234-235), and Hunt (2001, pp. 136-137) provide extensive listings of specimens they assigned to *Typothorax* and the localities from which they were derived. The more significant specimens, localities, and publications are reviewed below.

Typothorax coccinarum was the first stagonolepidid named in North America. Cope (1875) named the taxon for scrappy skeletal material (USNM 2585, later designated the holotype by Long and Ballew, 1985) he collected during the summer of 1874 while accompanying the Geographical Survey led by Lt. G. M. Wheeler. This material, excavated from the upper part of the Petrified Forest Member (Chinle Formation) at what is now referred to as the Cerro Blanco locality near Gallina Creek, in

Rio Arriba County, New Mexico (Cope, 1875; Camp, 1930, p. 143), consists of a jaw fragment, scutes, a partial vertebra, and the proximal end of a femur. It was later figured by Cope (1877, p. 29-30, pl. 22, figs 4, 5, 9) and in part by Huene (1915). Cope (1887) later amended USNM 2585, removing scutes lacking the pitted ornamentation, as well as the jaw fragment, which he recognized as probably being phytosaurian. Cope (1875) also referred a second specimen from Cerro Blanco to *T. coccinarum*. David Baldwin recovered more material for Cope from the Cerro Blanco type locality in 1881. Cope (1887) referred some of this material to *T. coccinarum* (AMNH 2710; see Cope, 1887, plate 1), and some to a new taxon, *Episcoposaurus horridus* (AMNH 2713). This new Cerro Blanco material was later re-described by Huene (1915), who also refigured the material assigned to *T. coccinarum* (Huene, 1915, figs. 1, 5, 6) and referred additional material to the specimen Cope (1887) had considered to be of uncertain association (Huene, 1915, figs. 2, 4). Huene (1915, figs. 12-15, 18-27) also figured the *Episcoposaurus horridus* material, though he doubted that all the material assigned to that specimen belonged to the same animal. Gregory (1953) later recognized that the type of *Episcoposaurus horridus*[3] probably represents a large individual of *T. coccinarum*. Lucas and Hunt (1992) referred several dorsal paramedian scute fragments from Cope's type locality at Cerro Blanco (NMMNH P-18197, 18199, 18201) as topotypes for the taxon.

In addition to the material collected by Baldwin, additional AMNH material referred to *Typothorax coccinarum* was collected by J. Rak in the Chinle Formation in or near Tucumcari in 1929, and by S.J. Olsen and A. Lewis in El Cobre Canyon of New Mexico in 1954. The latter includes AMNH 7634, articulated series of cervical and dorsal vertebrae figured by Long and Murry (1995, figs. 102, 103).

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[3] Gregory (1953) also referred *Episcoposaurus haploceros* to *Desmatosuchus*, which is also generally accepted. However, he continued to assign "*Typothorax*" *meadei* (Sawin, 1947) as a co-gener to *T. coccniarum*; this taxon is now generally considered to belong to a distinct genus, *Longosuchus* (Hunt and Lucas, 1990).

In 1933, Charles Camp of the University of California at Berkeley, with the assistance of Robert Ariss, Howard Anderson, George Barrington, Natasha Smith, and Samuel Welles, excavated Canjilon Quarry (UCMP locality V2816). This quarry is located in the upper part of the Petrified Forest Member of Rio Arriba County, New Mexico, not far from the famous Ghost Ranch *Coelophysis* ("Whittaker") quarry (Fig. 1.1). This locality is best known for its spectacular collection of phytosaur skeletons (Lawler, 1976), but it has also yielded excellent associated (though incomplete) material of *Typothorax coccinarum*. Camp recovered the remains of at least four individuals of that taxon, which include extensive associated and sometimes articulated scutes, and excellent appendicular material. This material was described and illustrated by Long and Ballew (1985) and Long and Murry (1995). Harvard University collected the posterior portion of a *Typothorax* skeleton (MCZ 1488, 1487) probably from the vicinity of Canjilon Quarry, which received only a very brief description by Gregory (1953, p. 13). The tarsus of the MCZ specimen was illustrated by Parrish (1986, fig. 28). The nearby Snyder Quarry, at roughly the same level in the Petrified Forest Member of Rio Arriba County, has yielded a similar but more diverse assemblage then that of Canjilon Quarry, including considerable *Typothorax* material (Zeigler, 2002).

A considerable amount of *T. coccinarum* material, mostly scutes, has been recovered from Petrified Forest National Park in Arizona (Long and Ballew, 1985). This material was found mostly in the northern part of the park, where the upper Chinle Formation is better exposed. FMNH PR 1562, the most complete specimen of *T. coccinarum* recovered from the park (Long and Murry, 1995), consists of disarticulated but associated material, mostly scutes in various states of completeness, and five or six unarticulated vertebrae (Bill Simpson, personal communication, 2001). Long and Ballew (1985, pp. 59-60) and Long and Murry (1995) referred several aetosaur lateral scutes found in the park to the cervical region of *T. coccinarum*, although this assignment is dubious (see below).

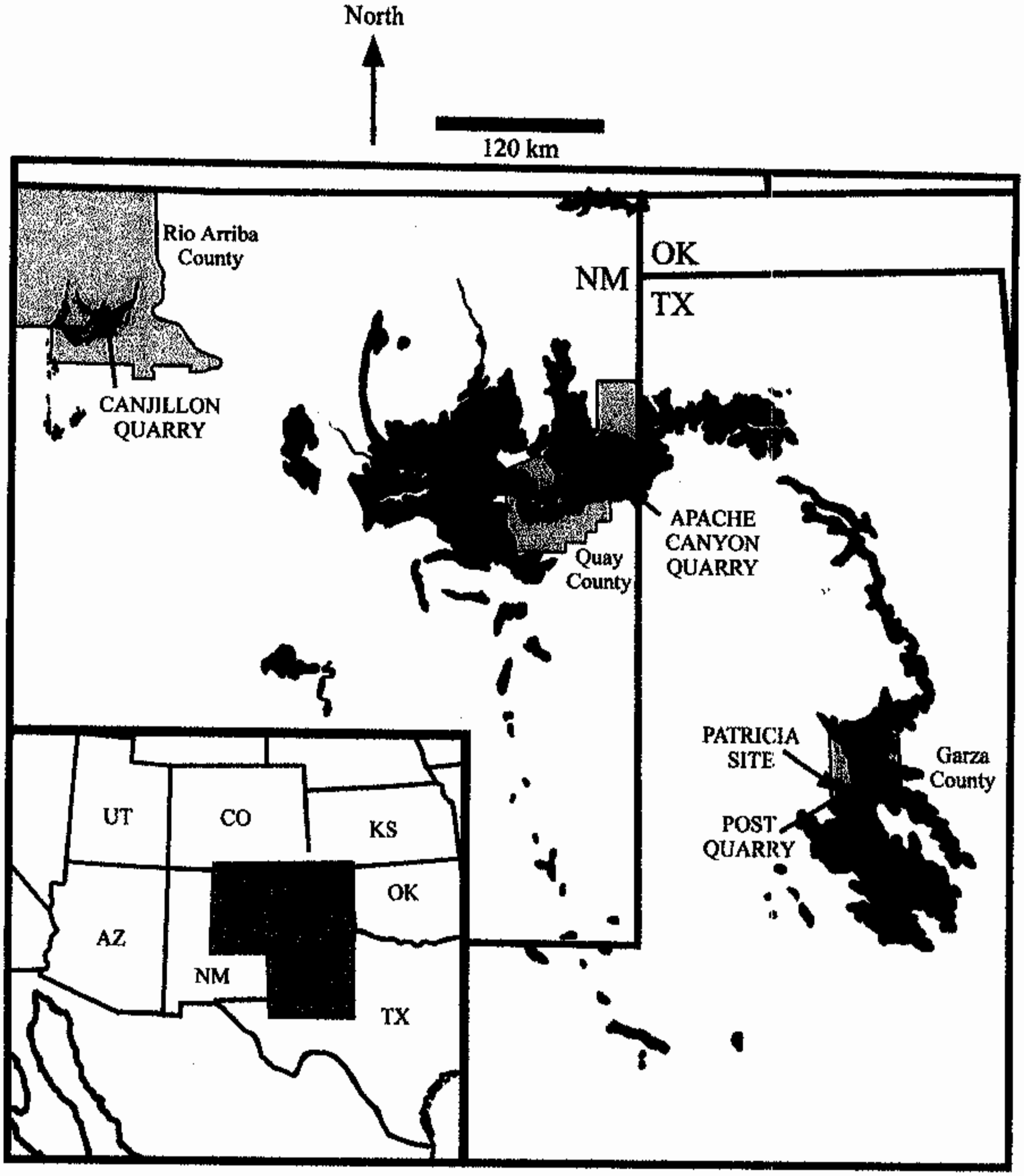

Figure 1.1 Map of outcrops of the Chinle Formation and Dockum Group in eastern New Mexico and west Texas; Chinle Formation exposures in purple, Dockum Group exposures in red. Key localities are indicated, and the counties in which they are located are outlined and shaded. The lower left insert shows the area of the American southwest covered by the map. Scale bar = 120 km

The Post Quarry (Fig. 1.1), in the Cooper Canyon Formation of the Dockum Group of Garza County west Texas, is one of the most productive vertebrate localities in the Dockum Group (Chatterjee, 1985; Small, 1989a, b; Lehman and Chatterjee, in prep). This site has produced excellent aetosaur material mostly referable to *Desmatosuchus* (Small, 1985, 2002), but has also produced extensive material of a small specimen[4] (TTUP 9214) probably representing a sub-adult of *Typothorax coccinarum* (Small, 1989b). The Patricia Site (Fig. 1.1), a new locality in the upper Cooper Canyon Formation in Garza County (Cunningham et al., 2002; Lehman and Chatterjee, in prep), has also produced *Typothorax* material housed at the Texas Tech Museum.

Hunt et al. (1993), and Hunt (2001) also provided a preliminary description of an almost complete and well-articulated specimen of *Typothorax coccinarum* from the Cooper Canyon Formation of eastern New Mexico (NMMNH P-12964). This specimen, probably the finest ever recovered, includes a complete skull and mandible (the only skull material known for this taxon other then TTUP 9214). The NMMNH collections also include the most extensive collection of *T. coccinarum* material outside of UCMP, mostly consisting of scutes collected in the Cooper Canyon Formation (Long and Murry, 1995; Hunt, 2001). Hunt (2001) also mentioned possibly juvenile *Typothorax* specimens in the NMMNH collections.

Typothorax has also been reported stratigraphically lower in the Dockum Group than the Cooper Canyon Formation, although this material is not well described. Long and Murry (1995) reported material from the "Garita Creek Formation" (=Tecovas Formation, sensu Lehman, 1994) and the Santa Rosa Sandstone. A specimen from the Los Esteros Member of the Santa Rosa Sandstone, possibly referable to a new species of *Typothorax*, is being described by workers at NMMNH (Adrian Hunt, personal communication 2001).

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[4] Small (1989b) erroneously gave the specimen number of this specimen as TTUP 9209, which refers to two adult dorsal paramedian scutes of *Typothorax* from a different locality.

1.3 *Redondasuchus reseri*

Hunt and Lucas (1991a) and Heckert et al. (1996) reported a new aetosaur, *Redondasuchus reseri*, from the Redonda Formation (Dockum Group) of Quay County, eastern New Mexico. This material, consisting entirely of isolated scutes, was collected from the Shark Tooth Hill locality for YPM by J.T. Gregory in 1947, and at nearby Apache Canyon locality (Fig. 1.1) for YPM and UCMP (the UCMP locality number is V6148) by Gregory or under his direction[5] between 1958 and 1961. A.P. Hunt collected additional material at these localities for NMMNH during the late 1980s (Hunt and Lucas, 1989; Hunt and Lucas, 1991).

The scutes of *Redondasuchus reseri* are very similar to those of *Typothorax coccinarum*, though considerably smaller. Similarities between these two taxa identified by Heckert et al. (1996) include a random pattern of pitted ornamentation on the dorsal surface of the scute, the absence of a raised boss, and a pronounced ventral keel. They also differentiated the scutes of the two taxa based on:

1. The presence of arching in the dorsal paramedians of *Redondasuchus* but its claimed absence in *Typothorax*.
2. The ventral keel terminating at the line of arching in the dorsal paramedians of *Redondasuchus* but allegedly being continuous across the ventral surface in *Typothorax*.
3. The inferred absence of lateral scutes in *Redondasuchus*. This claim was based on the edge of the scute they interpreted being lateral (which would make the scute a *left* dorsal paramedian) showing "no trace of an articulation with a lateral scute." This edge is the one closest to the arching (at least in the holotype; see Heckert et al., 1996, fig. 5C), and would give the scute a unique down-turned lateral edge. They suggested "the marked downward flexure…and the apparent

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[5] The 1961 field notes of J.W. Cosgriff, Gregory's student, indicate that Cosgriff and S.R. Leffler actually collected most or all of the Apache Canyon *Redondasuchus* material in the UCMP collections. Many of these scutes were identitified in the field as "amphibian clavicles," which they resemble.

absence of lateral scutes may be related. With this flexure the paramedian scutes may have given some of the lateral protection normally provided by the lateral scutes" (Hunt and Lucas, 1991a, p. 733). Their interpretation as to which edge was lateral would also place the discontinuous ventral keel *medial* to the line of arching.

In explaining why the scutes of *Redondasuchus* do not belong to a juvenile *Typothorax*, Hunt and Lucas (1991a, p. 732) claimed that "*Redondasuchus* scutes differ from juvenile *Typothorax* scutes in the same features that distinguish them from adult scutes", implying that the morphological differences could not be accounted for by ontogeny. However, they did not cite any juvenile specimens of *Typothorax* to support this claim. Long and Murry (1995) expressed the opinion that *Redondasuchus* does in fact represent a juvenile of *Typothorax coccinarum*, suggesting that any arching in the scutes of either taxon is the result of post-mortem distortion.

1.4 Methods and materials

With the exception of NMMNH P-12684 (Hunt et al., 1993), the UCMP Canjilon Quarry specimens (Long and Murry, 1995) and the subadult TTUP 9214 (Small, 1989b) probably represent the most complete specimens known that have been assigned to *Typothorax coccinarum*. The UCMP and TTUP specimens are re-described and illustrated here, with several objectives in mind:

1. To provide a thorough and well-illustrated reference on *Typothorax coccinarum*. In spite of a widespread interest in archosaurs, and the proposed and extensively published-on utility of aetosaur scutes in Late Triassic biochronology (e.g., Heckert and Lucas, 1996, 2000; Lucas, 1998b), a truly detailed and thoroughly illustrated description of the postcranial skeleton and osteoderms of *T. coccinarum* is lacking. Although Long and Ballew (1985) and Long and Murry (1995) provided important diagnostic information and fine illustrations

(particularly of the Canjilon Quarry material), I feel that considerably more can be said (and shown) on the anatomy of this taxon.

2. To describe ontogenetic change in *Typothorax coccinarum.* This will be done using quantitative bivariate allometry of the femur and tibia, and also examining other less quantifiable morphologic differences, between TTUP 9214 and larger (and presumably more mature) specimens of *T. coccinarum.* The latter will mostly consist Canjilon Quarry material, but other measurements of *Typothorax* specimens not examined by me are also available (Cope, 1887; Huene, 1915; Gregory, 1953). This work will be based on the assumption that TTUP 9214 truly represents a subadult of *T. coccinarum*; the evidence for this will be examined below.
3. To evaluate the validity of *Redondasuchus reseri* as a taxon distinct from *Typothorax coccinarum.* If TTUP 9214 is an immature specimen of *T. coccinarum*, it can be compared to *R. reseri* to determine if the latter is as well. However, an alternative possibility is that TTUP 9214 represents a distinct taxon from *T. coccinarum*, possibly assignable to *R. reseri.* In this case, it would provide a great deal of new information on the osteology of the latter taxon, which is otherwise known only from isolated dorsal paramedian scutes. These comparisons will be based primarily on the Apache Canyon Quarry material for *R. reseri* at UCMP, which has been examined.

CHAPTER 2

THE GEOLOGIC SETTING

2.1. The Upper Triassic strata of the American southwest

The Chinle Formation and Dockum Group (Fig. 2.1) of the Western Interior of North America consist of continental fluvial, paludal, lacustrine, and eolian sedimentary deposits of Late Triassic (Carnian-?Rhaetian) age (e.g., Lucas, 1998b). The Chinle Formation was deposited in two separate sedimentary depocenters, the largest of which was centered around the Colorado Plateau, although outcrops also extend throughout much of the Four Corners states of Utah, Colorado, Arizona, and New Mexico, and into Nevada (e.g., Stewart et al., 1972; Blakey and Gubitosa, 1983; Dubiel, 1994). Deposits also referred to the Chinle Formation are exposed in northwestern Colorado and northeastern Utah; these were probably separated from the more southern Chinle depocenter by the Ancestral Rocky Mountains and the Uncomphagre uplands (Stewart et al., 1972; Dubiel, 1991). The Dockum Group (Figs. 1.1, 2.1) was deposited primarily in west Texas and eastern New Mexico (McGowan et al., 1980; Lehman, 1994b; Lucas et al., 1994; Lehman and Chatterjee, in prep). Various deposits in parts of the four corners states, Wyoming, and Idaho (the Ankareh, Popo Agie, Jelm and Dolores Formations) are also of Late Triassic age (e.g., Dubiel, 1994). However, none of these latter formations, or the northwestern Colorado-northeastern Utah Chinle Formation, will be discussed further as *Typothorax* and *Redondasuchus* have not been reported from them.

Lucas (1993a) elevated the Chinle Formation to group status, and consequently elevated its constituent members to formations (e.g., the Petrified Forest Formation, the Rock Point Formation). However, Lucas's usage of the term "Chinle" differs greatly from its conventional usage in including not only those strata traditionally considered a part of the Chinle Formation, but all Upper Triassic strata of the American southwest, including the Dockum Group and other units such as the Dolores and Popo Agie

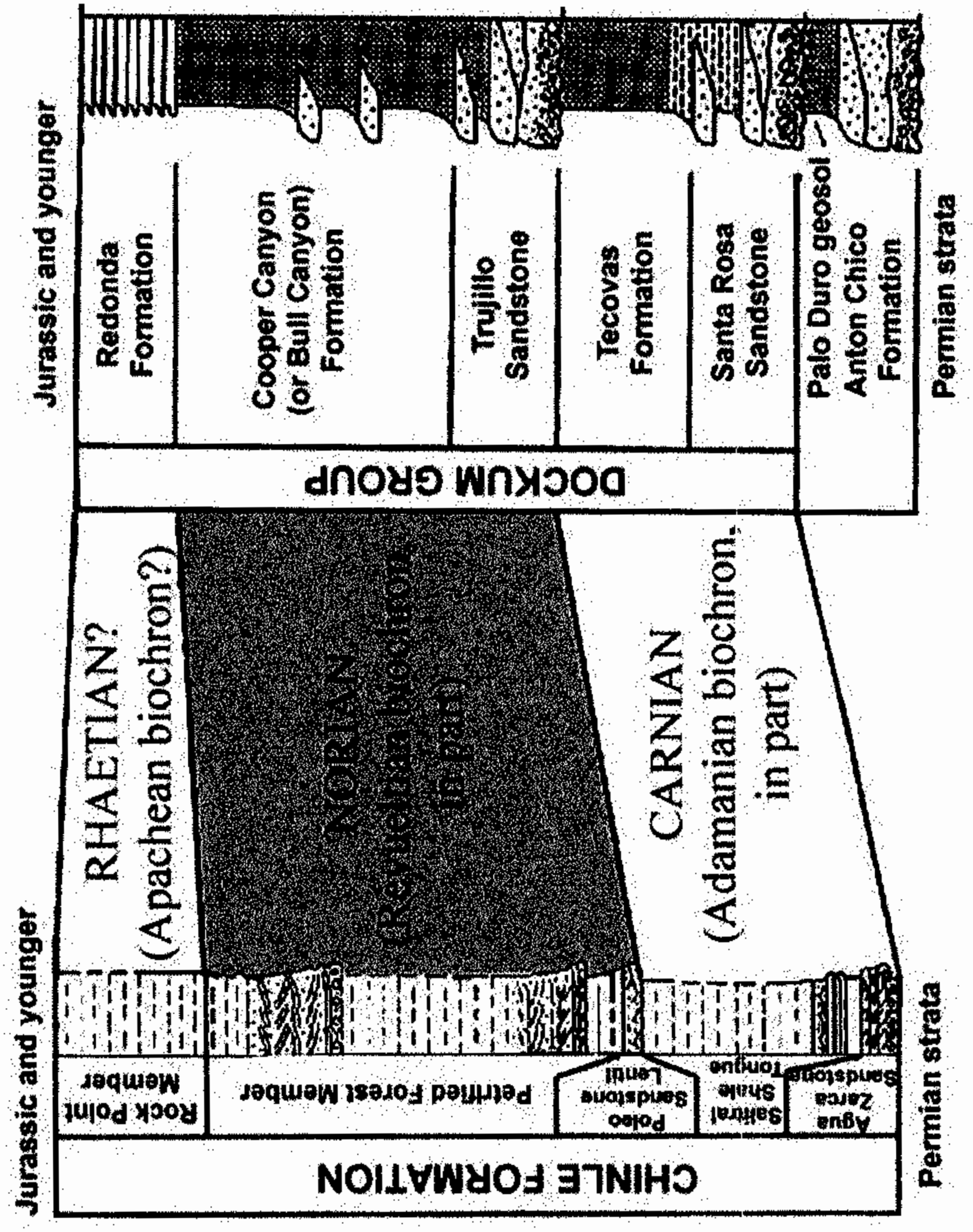

Figure 2.1 Stratigraphy of some *Typothorax*-bearing Upper Triassic strata; left stratigraphic column represents Chinle Formation near Canjilon Quarry, right stratigraphic column generalized for Dockum Group throughout west Texas and eastern New Mexico. Columns not to scale. Likely Late Triassic stages and "land vertebrate faunachrons" shown between columns. Modified from Dubiel, 1989, and Lehman et al., unpublished.

Formations. The more traditional usage, maintaining the Chinle as a formation and restricting its usage primarily to the Colorado Plateau is preferred here, for reasons discussed by Lehman (1994a), Dubiel (1994), and Carpenter (1997).

2.1.1. The Chinle Formation of north-central New Mexico

The stratigraphy of the Chinle Formation in the eastern San Juan Basin in north-central New Mexico, where Canjilon Quarry is located, was described by Stewart et al. (1972), Dubiel (1989), and Lucas and Hunt (1992). From lowest to the highest, the five members in the Chinle Formation (Fig. 2.1) are: the Agua Zarca Sandstone Member, Salitral Shale Tongue, Poleo Sandstone Lentil, Petrified Forest Member, and "siltstone member." The latter is probably assignable to the Rock Point Member (Lucas and Hunt, 1992), and contains the famous Ghost Ranch *Coelophysis* ("Whittaker") Quarry. The Early Jurassic Entrada Sandstone caps the Chinle Formation here.

Canjilon Quarry lies near the top of the upper part of the Petrified Forest Member, which is the thickest unit in the Chinle Formation at Ghost Ranch (and usually elsewhere). The Petrified Forest Member is a particularly important unit within the Chinle Formation, not only in being the most widespread geographically (Stewart et al., 1972), but the best described in terms of vertebrate fossils (e.g., Long and Murry, 1995). The member consists of fluvial and lacustrine variegated mudstones and sandstones with minor conglomeratic lenses, deposited in wetlands with an extensive meandering river system (Stewart et al., 1972; Blakey and Gubitosa, 1983; Dubiel et al., 1991). At Canjilon Quarry, the upper part of the member consists of muddy sandstone beds containing lenses of carbonate nodule conglomerate. The carbonate conglomerates and the coarser sandstones contain small to medium scale trough and tabular-planar crossbeds. The muddy interbedded sandstones, which are bentonitic and arkosic, were deposited on large-scale scour and lateral accretion surfaces. These interfinger with thin-bedded, ripple-laminated mudstones, bentonitic sandstones, and siltstones containing abundant vertebrate and unionid bivalve fossils. Dubiel (1989) interpreted the strata as representing a high sinuosity fluvial system, with channel deposits (the basal lag conglomerates, probably the coarse sandstones with planar or mild trough cross beds, and muddy sandstones showing the large scour and lateral accretion surfaces) interfingering with crevasse-splays grading into floodplain deposits (the ripple-laminated mudstones, bentonitic sandstones and siltstones).

2.1.2. The Dockum Group

Controversy exists regarding the nomenclature of the Upper Triassic strata of eastern New Mexico and west Texas (see particularly Lehman, 1994a, 1994b; and Lucas et al., 1994), a debate filled with hyperbole, subjectivity, self-contradiction and double standards as to the application of stratigraphic nomenclature. However, a thorough review of these nomenclatural problems is outside the scope of this paper. For the purposes of this thesis, I will use the traditional term "Dockum Group" to describe the Upper Triassic strata of this region, and Lehman (1994a, 1994b) and Lehman and Chatterjee's (in press) relatively simple nomenclature for the formations within the Dockum Group. In ascending order, these are the Santa Rosa Sandstone, Tecovas Formation, Trujillo Sandstone, Cooper Canyon Formation, and Redonda Formation (Fig. 2.1). The last is present only in eastern New Mexico; in west Texas, the Cooper Canyon Formation is the uppermost unit of the Dockum Group.

The Post Quarry lies in the lower part of the Cooper Canyon Formation of Garza county, west Texas. The Cooper Canyon Formation consists mostly of siltstone and mudstone, with interbedded lenses and sheet-like layers of micaceous, lithic-rich sandstones. These mostly consist of overbank deposits from meandering fluvial systems, although channel deposits and those formed in small, localized ponds are also present (Lehman et al. unpublished). The distribution of conglomerates and paleocurrent measurements suggest that by the time of Cooper Canyon deposition, the Dockum river system drained in a northerly direction, passing the Ancestral Rocky Mountains to the east (Frehlier, 1987; May, 1988; Schnable, 1994; Lehman et al., unpublished), rather than through the Chinle Formation depocenter as during Santa Rosa deposition (e.g., Riggs et al., 1996). If this is the case, then the Dockum and Chinle drainages were distinct during Cooper Canyon deposition (contra Lucas 1991, 1993a).

In eastern New Mexico, the Cooper Canyon Formation has a gradational contact with the overlying Redonda Formation (Fig. 2.1). In west Texas (where the Redonda Formation is absent), the top of the Cooper Canyon Formation is probably stratigraphically equivalent to it (Tom Lehman, personal communication, 2002). The Redonda Formation consists of cyclically deposited, laterally extensive sandstone, mudstone, and minor limestone beds deposited in a large, shallow lake. Laterally continuous sandstone beds indicate that eolian processes may have been present in the area (Hester, 1988; Lehman et al., unpublished).

2.2. Canjilon Quarry

2.2.1 The Berkeley collection

The most extensive collection of material from Canjilon Quarry resides in the University of California (Berkeley) Museum of Paleontology. The UCMP locality number for Canjilon is V2816, and the original field number was "70". This material was collected by Charles Camp, who first visited the site in 1928, and returned in 1930 and 1933 (Long et al., 1989). Although material was recovered in the earlier years, the 1933 excavation, lasting from May 23rd to July 27th, was a larger scale undertaking that recovered most of the UCMP material. This material can be referred almost entirely to the phytosaurs *Pseudopalatus buceros* and *P. pristinus*, and the aetosaur *Typothorax coccinarum*. Camp was assisted in this excavation by Howard Anderson, Robert Ariss, George Barrington, and Natasha Smith; in addition Sam Welles arrived at the end of June to participate. With the exception of Natasha Smith (whose notes, if any, are unknown), the field notes kept by these individuals during the excavation are housed at UCMP.

These are extremely informative, including inventories of the material collected (arranged by field number), and fairly detailed field maps for several of the grid squares making reference to the field numbers.

The 1933 excavation used a set of 20 grid squares, each 20 feet on a side (Fig. 2.2). These were given letters from A to X, omitting "I", "O" and "V" (grid "W" is also referred to as grid "X" by Camp). Grids A through T were roughly arranged in west to east rows that increased to the north; grids U and X were apparently added as an afterthought to two of the southern rows. The field maps make it clear that the eastern and western borders of these squares were not aligned perfectly north to south, but a few degrees to the west. At least some of these grid squares were further subdivided into smaller squares of various sizes, though most are four-foot squares. Field maps (in varying degrees of clarity) for squares B, C, F, H, J, K, L, and U are available in the field notes. Additionally, there is a larger quarry map, drawn (unfortunately in pencil) on rough brown paper in the UCMP collection. The "brown paper map" was apparently the basis for the quarry maps used by Long et al. (1989, fig. 1) and Lucas (1993b, fig. 10), and is also the basis for Fig. 2.2. The artist is unknown, but the map seems to be based at least partially on the field maps. However, grid squares not illustrated in the field notes *are* illustrated on the "brown paper map," which includes additional details not recorded on the field maps. Presumably, either the artist was present (and perhaps drew the map) firsthand during the excavation, or had access to field drawings not found at UCMP. The previously published versions of this map did not show several of the grid squares at the north and south ends of the quarry, probably because they were relatively un-fossiliferous. These squares have been added into the map presented here (Fig. 2.2).

The numbering system applied to the UCMP Canjilon Quarry material requires some discussion. The original field numbers given to the material (and used in the field notes and maps) give the locality number (70) over the grid squares the element was found in, usually followed by a more specific number for the specimen (e.g., 70/U80, 70/H8). These specific field numbers are applied in a variety of ways. They refer either

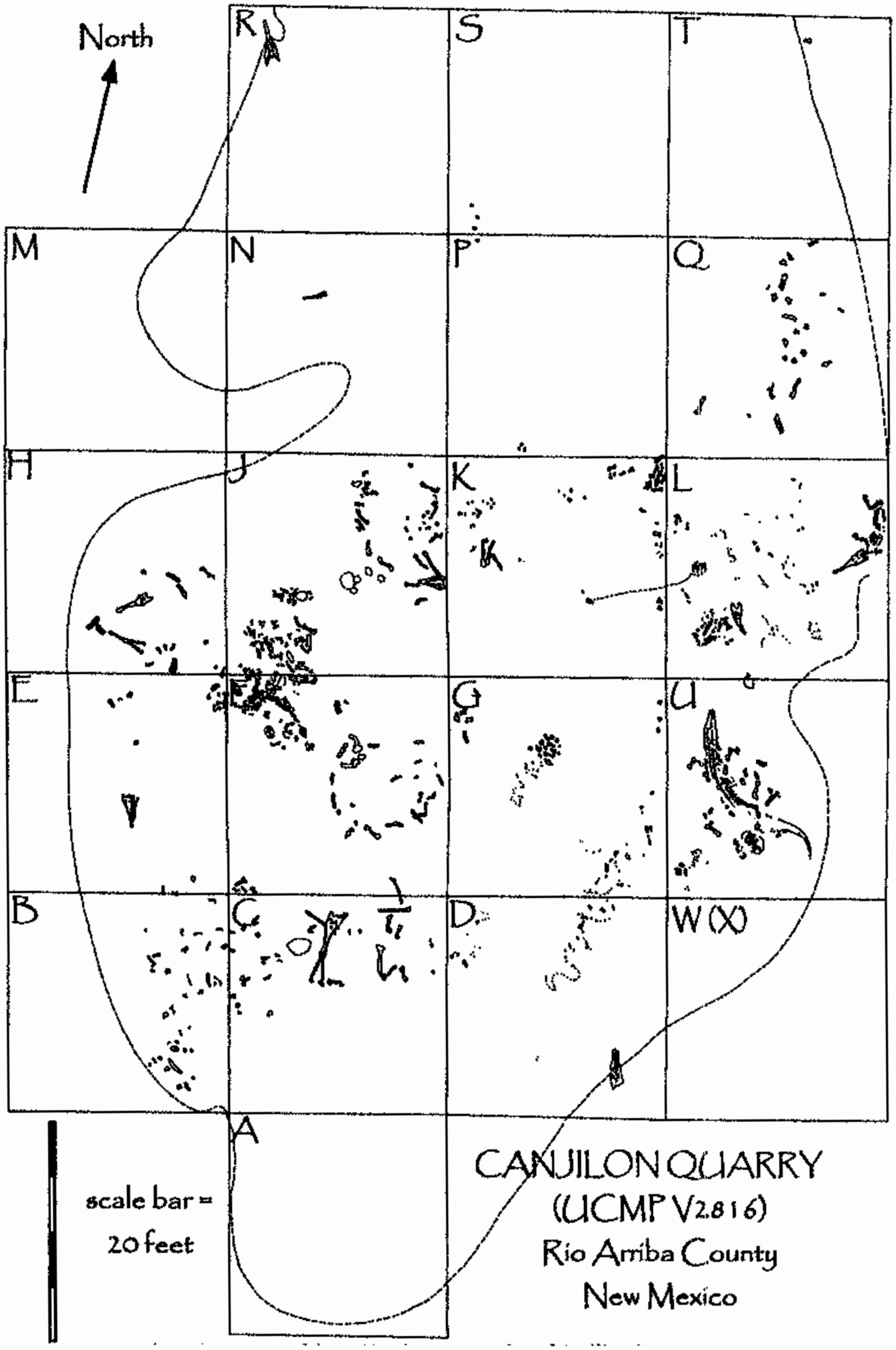

Figure 2.2 Map of the 1933 UCMP excavation of Canjilon Quarry. Revised and more detailed maps of the idividual grid squares are given in the Appendix. Scale bar = 20 feet.

to individual specimens and are applied roughly in the order they were found in the squares (for example, *Typothorax* scute 70/H8 was the eighth specimen found in grid square H), entire plaster blocks and all the material found within (70/U80 is applied to all material that was extracted from the block given that number), or the numbered subdivision of the grid square in which the element was found (phytosaur skull 34249 70/C31 was first uncovered in subdivision square 31 in the larger grid square C).

Axel Hungerbühler and I made a complete inventory of all the UCMP Canjilon Quarry material in the winter of 2001. Each individual element in the collection was identified to the best of our ability, and both the field number (usually written on the bone) and the specimen number were noted. The field numbers, combined with the field notes and maps, have allowed the placement of much of the material in the collections directly onto the field maps. This endeavor, supplemented by information in the field notes, has proven extremely beneficial. It allows the association of elements with particular concentrations of bone, and therefore (plausibly or probably) to individual animals.

Unfortunately, the specimen numbers later applied to the Canjilon Quarry material are considerably less informative. Generally speaking, specimen numbers have been applied based on the *type* of element, regardless of its location in the quarry. For example, 34227 contains almost exclusively scutes (mostly *Typothorax*) from all over the quarry, while 35235 was originally applied exclusively to femora, again from all over the quarry. Many individual bones initially lumped under a single specimen number have since been assigned their own numbers between 119338 and 137202, but this new numbering is just as uninformative about the association of material. In the cases of particular concentrations of bones, this has led to excessive specimen numbers applied to what was probably the same individual; the worst example is the "Fa" specimen (Table 2.1), which includes *15* different specimen numbers applied to a single concentration of bones! Therefore, the field numbers, rather then the specimen numbers, are consulted in order to extract information about the layout of the quarry.

Table 2.1. UCMP V2816 (Canjilon Quarry) *Typothorax coccinarum* material

Elements are ordered by: (1) concentration of skeletal material (e.g. the "Fa" specimen") or grid square for more isolated elements, (2) specimen number, and (3) field number. The word "unspecified" in parentheses following the grid number [e.g., 70/G (unspecified)] indicates a specimen for which the field number is only specific as to the grid square, so that its position cannot be determined on the maps. It should be noted that much of the unspecified material in squares 70/F, 70/G, and 70/U likely go with the skeletons in those grid squares.

70/C

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT
70/C17	34227		Dorsal paramedian and lateral scute fragments
70/C18	34227		Anterior caudal lateral acute
70/C1	122673		Femur (left, good condition); Long and Murry, 1995, fig. 110D-G
70/C (unspecified)	122677		Femur (right, badly mangled), probably the mate of 122673 70/C1

70/E

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT
70/E17	34227		Dorsal paramedian scute fragment, almost complete; Camp gave a "phytosaur tibia" this field number, possibly 122099
70/E (unspecified)	34227		Dorsal paramedian scute
70/E (unspecified)	34240		Fibula

"Fa" specimen (in 70/F and 70/J)

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT
70/Fa2	34227		Dorsal paramedian scutes (four, almost complete)
70/Fa9	34227		Caudal dorsal paramedian scutes
70/Fa15	34227		Scute fragments
70/Fa50	34227		Posterior dorsal paramedian scutes and a ventral scute
70/Fa52	34227		Posterior caudal dorsal paramedian scutes
70/Fa53	34227		Dorsal paramedian, lateral, possible ventral and appendicular scutes
70/Fa54	34227		Several dorsal paramedian and fragmentary lateral scutes
70/Fa55	34227		Dorsal paramedian scutes and a lateral scute
70/Fa53	122228		Calcaneum
70/Fa51	122277	34229	Cervical vertebra centrum
70/Fa51	122306		Sacral vertebra centrum
70/Fa2	122676	34240	Femur (left)
70/Fa2	122680		Tibia (middle section is missing and the ends are glued together)
70/Fa2	122682	34240	Fibula
70/Fa54	122683		Illium
70/Fa50	158668	34227	Posterior caudal dorsal paramedian scute, pelvic lateral scute, and caudal lateral scute
70/Fa52	158670	34227	Pelvic lateral scute and several ventral scutes
70/Fa52	158670	34227	Pelvic lateral scute and several ventral scutes
70/Fa53	158673	34227	Appendicular and ventral scutes

Table 2.1. Continued

"Fa" specimen (in 70/F and 70/J)

70/F59	34227		Anterior dorsal paramedian scute
70/J3	34227		Scutes (three, incomplete)
70/J4	34227		Dorsal paramedian scute, slightly warped, incipient boss
70/J5	34227		Dorsal paramedians scute
70/J8	34227		Dorsal paramedian scute, hemal arch on underside
70/J9	34227		Two partial dorsal paramedian scutes (one apparantly broken almost in half) and a lateral caudal (?) scute fragment
70/J9	34240		Humerus (small); Long and Murry, 1995, fig. 105C.
70/J36	34240		Scalpulocoracoid
70/J51	122679		Tibia
70/J70	34227		Dorsal paramedian scute
70/J77	34239		Rib
70/J78	?		Proximal rib fragments
70/J83	158672		Clavicle (left, incomplete)

70/F material outside the "Fa specimen" concentration, or of uncertain placement

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT
70/F (unspecified)	34227		Dorsal paramedian scute with boss and rib fragments
70/F53	34259		Dorsal paramedian and laterals scutes and toe bone in a large jacket
70/F (unspecified)	122255	34229	Cervical vertebra centrum

"G" specimen

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT
70/G6	34227		Lateral scute fragments and other bone fragments (smooth)
70/G3	34240		Humerus (distal end)
70/G7	34240		Ulna (small)
70/G6	34248		Dorsal paramedian and ventral scutes (more or less articulated), a chevron, and two caudal vertebrae, in a block; this is the main 70/G6 block
70/G7	34248		Dorsal paramedian scutes in contact
70/G7	34248		Dorsal paramedian scutes in a block; North arrow drawn
70/G7	34248		Tibia (right, proximal end)
70/G6	34248		Fibula (left)
70/G6(?)	34248		Pubis (left), Long and Murry, 1995, fig. 108
70/G6	122374	34229	Caudal vertebra centrum (small)
70/G6	122678	34248	Tibia (left), astragalus attached
70/G7	?		Femur distal end, rib and possible skull fragments; the femur has an arrow indicating it was oriented roughly N-S

Table 2.1. Continued

70/G material outside the "70/G specimen" concentration, or of uncertain placement

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT
70/G8	34227		Dorsal paramedian scute, almost complete
70/G (unspecified)	34227		Dorsal paramedian scute fragments
70/G (unspecified)	34227		Dorsal paramedian scutes (two, overlapping each other)
70/G (unspecified)	34240		Humerus (small)

70/H

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT
70/H2	34227		Dorsal paramedian scute, almost complete and in good condition *Typothorax coccinarum*
70/H8	34227		Dorsal paramedian scutes (two); only one is mentioned in the field notes.
70/H9	34227		Dorsal paramedian scute, almost complete
70/H11	34227		Scute
70/H (unspecified)	34231		Scapula fragment
70/H (unspecified)	?		Scute fragments

70/J material not part of the "Fa specimen" concentration, or of uncertain placement

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT
70/J10	34227		Dorsal paramedian scute, in good condition
70/J19	34227		Lateral scute fragment
70/J37	34227		Dorsal paramedian scute, good condition
70/J36	34230		Scapulocoracoid, incomplete; described as an "illium" in the field notes.
70/J46	122674	34240	Femur (complete)

70/K

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT
70/K12	34227		Dorsal paramedian scute; probably the best in the quarry

70/L

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT
70/L2	34227		Dorsal paramedian scute fragment
70/L3	34227		Appendicular(?) scute, rounded
70/L (unspecified)	12268		Fibula (distal end)
70/L (unspecified)	34227		Incomplete lateral scute
70/L1A	34253		Scute fragments (about a dozen)

Table 2.1. Continued

70/Q

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT
70/Q3	34227		Dorsal paramedian scute fragments (two, both large), may go together

"U specimen"

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT
70/U26	34227		Dorsal paramedian scute (incomplete)
70/U45	34227		Dorsal paramedian scutes (several large), lateral scutes, scute fragments
70/U75	34255		Articulated distal tail section, including dorsal paramedian, lateral, and ventral scutes, and some poorly exposed caudal vertebrae. There are also isolated scute fragments and a possible ischium (left)
70/U75	34255		Articulated distal tail section, including dorsal paramedian, lateral, and ventral scutes, and some poorly exposed caudal vertebrae. There are also isolated scute fragments and a possible ischium (left)
70/U80	34255		Articulated series of partial dorsal paramedian, lateral, and possible appendicular scutes, probably from the pelvic region.
70/U80	34227		Dorsal paramedian (large) and articulated lateral scute fragments, possible ventral and appendicular scutes, rib fragments.
70/U92	34227		Dorsal paramedian scute fragment, two articulated lateral scutes
70/U93	34240		Humerus fragment, distal end
70/U80	34255		Scapulocoracoid (left); Long and Murry, 1995, fig. 104, 105A-B
70/U80	34255		Illium (left); Long and Murry, 1995, fig. 106A, 107
70/U80	34255		Femur (left)
70/U80	34255		Tibia (left); Long and Murry, 1995, fig. 111D
70/U80	34255		Calcaneum (left)
70/U94	34258		Dorsal paramedian scute fragments
70/U95	?		Scute fragment

Material recovered before 1933

FIELD #	SPECIMEN #	ELEMENT
71/5	27232	Scutes
75	?	Scute fragments

Material of completely uncertain placement

SPECIMEN #	PREVIOUS #	ELEMENT
34240		Humerus (distal end)
34248		Femur
34248		Scute fragments
34248(?)		Semi-articulated foot material; Long and Murry, 1995, fig. 109 (in part)
34259		Scute fragments
122229	34248	Calcaneum (left)
122679	34240	Tibia (left), Long and Murry, 1995, fig. 111a-c
?		Sacrum (distorted)

Even more unfortunately, most of the bones either lack field numbers (because they were not written or subsequently removed) or (more commonly) identify the grid square but lack a more specific number. For example, of the 109 elements recorded in the inventory as having the field number "70/G", only 47 had a more specific number that could help place material more precisely. I refer to these specimens as "unspecified" in Table 2.1 and the Appendix. Much material is mentioned in the field notes but was not identified in the inventory, probably due to the removal of the field number from the specimen. Most likely much or all of this material lies in the "unspecified" material. Often the process of elimination using the field notes allowed elements to be placed on the field maps, albeit with strong uncertainty.

The Appendix presents all the available information about the 1933 Canjilon collection. It combines the 2001 inventory with the original field note inventories, and presents new maps for the individual grid squares. The spatial and stratagraphic distribution of the aetosaur and phytosaur material, as far as it can be discerned from the field notes, field maps, and new inventory, are discussed there. Table 2.1 lists only the *Typothorax* material identified in the 2001 inventory; all material from both *Typothorax* and *Pseudopalatus* found in the inventory *and* mentioned in the field notes is listed in the Appendix.

2.2.2. Stratigraphy of Canjilon Quarry

The field notes of Camp and his assistants indicate that the material in Canjilon Quarry was found primarily in two distinct levels. The upper layer consisted largely or entirely of blue-gray, gray-white, and pea-green carbonate conglomerate containing many concretions, often referred to by Camp as "the upper mortar layer" or 1" . Presumably this represented a channel lag deposit. Much of the material recovered from this level seems to have consisted of scraps of scutes and other small bones; Camp describes the material as "fresh-looking" but "soft and crumbly." The only really important material recovered from this layer were two excellent and largely articulated specimens, *Pseudopalatus buceros* (mostly UCMP V2816 34258) and *Typothorax coccinarum* (UCMP V2816 34255, the "U" specimen), found and mostly excavated by Natasha Smith, and possibly the *Pseudopalatus pristinus* skull found in 70/L by Camp.

Underneath the upper "mortar layer" conglomerate was a layer of blocky reddish mudstone (usually referred to in the field notes as "shale") varying from about one to two feet thick, containing common conglomeritic sandstone lenses (usually gray in color). Camp referred to this layer as 2". This mudstone layer probably represented one of Dubiel's (1989) crevasse splay and/or floodplain deposits. Bones were scattered throughout the thickness of this layer, but the base is the most fossiliferous, and was the primary bone producer in the quarry. Camp initially believed that this layer actually consisted of two separate levels (which he referred to as 2" and 3"), but later recognized they were part of a single continuous bone layer (2"). On the west side of the quarry, in sections 70/A, 70/C, 70/H, and 70/J, this layer was apparently "purple green... which contains much carbonaceous material." The layer contained abundant impressions of unionid clams and gypsum crystals according to Sam Welles, who expressed uncertainly as to if the latter were syngenetic with deposition. The base of the lower mudstone was described by Camp as "a blue-gray limestone concretionary," likely representing another channel lag. The main bone bed seems to have rested directly upon this lower concretion.

Before excavation began, the upper conglomeratic level was uncovered by plowing on 5/23/33 and 5/24/33 using mule teams on loan from Mrs. Stanley at Ghost Ranch. Later, this layer was itself plowed on 7/11/33 and 7/12/33 to expose the richer reddish mudstone layer underneath. However, the upper "mortar layer" was apparently not removed in all grid squares during this second plowing, as excavations in the upper conglomerate occur in some squares *after* the second plowing.

2.2.3. Association of *Typothorax* material

As noted by Long and Murry (1995, p. 234) there seem to be three major concentrations of *Typothorax* material in the quarry: one at the junction of grid squares 70/E, 70/F, and 70/J (referred to here as the "Fa" specimen), one in square 70/G (the "G" specimen) and one in square 70/U (UCMP V2816 34255, or the "U specimen"). A more detailed discussion of the distribution of material in these squares can be found in the Appendix.

Both the "Fa specimen" and the "G specimen" lay in the lower bone level, at the bottom of the reddish mudstone. The "U" specimen, the largest individual of *Typothorax* in the quarry, was lying across the backside of a large *Pseudopalatus buceros* specimen. It differs from most of the important material in the quarry in coming from the upper "mortar layer," and also in that most of the material was referred to a single specimen number (34255). Good field maps are available for the "Fa" and "U" specimens, but not unfortunately for the "G" specimen. All specimens were mostly removed in blocks, although most of the material was subsequently separated from the jackets. The "Fa" and "G" specimens were disarticulated but associated. However much of the "U" specimen was in articulation, notably an excellent string of dorsal paramedian and lateral scutes from the pelvic and caudal regions removed in two blocks.

Other *Typothorax* material found in the inventory, including much of the "unspecified" material, consists mostly of isolated elements. It is likely that some or most of this material belongs to the "Fa", "G", and "U" specimens, and was simply been more widely dispersed. The complete lack of identified *Typothorax* skull material in the quarry is disconcerting, and further scrutiny of the collection may identify some. Camp and his assistants also found additional material, not recognized in the inventory, that they suggested belonged to *Typothorax* or "*Episcoposaurus*"; this material is discussed in the Appendix.

2.3. The Post (Miller) Quarry

2.3.1. Material found in the Post Quarry

The Post Quarry, located in Garza County (Fig. 1.1) near the town of Post, was first worked by the Dallas Museum of Natural History in the 1970s. More extensive excavation was undertaken in 1980 by Texas Tech University under the supervision of Sankar Chatterjee, leading to an extensive collection of vertebrate material housed at the Texas Tech Museum. The quarry, which lies in the lower part of the Cooper Canyon Formation (Fig. 2.1), produced an extremely diverse collection of tetrapods, including a variety of small vertebrates, a phytosaur, rauisuchians, poposaurs, and aetosaurs (see Small, 1989a, and Lehman and Chatterjee, in prep, for a more thorough discussion of the history and fauna of the quarry). The aetosaur material is dominated by *Desmatosuchus*, but the taxa *Paratypothorax* and *Typothorax* are also present (Small, 1985, 1989b).

The Post Quarry represents floodplain overbank deposits, which probably formed some distance from the active river channel (Lehman and Chatterjee, in prep). The material from the quarry was found in a singe layer about 30 cm thick. Small (1989a, p. 147) reports "The bones of the larger specimens such as *Postosuchus* and *Desmatosuchus* are disarticulated but associated. There are many disassociated bones of smaller animals scattered throughout the quarry." Parts of the quarry map showing the distribution of material belonging to the rauisuchians *Postosuchus* and *Chatterjeea* may be found in Chatterjee (1985, fig. 22).

2.3.2. Association of *Typothorax* material

Material from TTUP 9214 includes parts of the cranium (including an almost complete braincase), a dentary, several vertebrae, rib fragments, a left ischium, right femur, right tibia and right astragalus, assorted toe bones, and extensive scute material. The latter consists mostly of dorsal paramedian and lateral scutes, but also several small odd osteoderms probably representing appendicular and ventral scutes.

Unfortunately, few quarry maps or detailed field notes are available for the Post Quarry showing the aetosaur material, and it is possible that not all material referred to TTUP 9214 comes from the same animal. However, Bryan Small (personal communication, 2000) who collected TTUP 9214, recalls that the material was all found within a very confined area. Moreover, examination of the material supports its assignment to the same individual. The scutes are all of a similar size and morphology suggesting they came from an unusually small specimen of *Typothorax coccinarum*. The other skeletal material is also consistent in size and morphology with an aetosaur of the same size, considerably smaller then any of the other aetosaur material described from the Post Quarry. It seems unlikely that so much aetosaur material of consistent morphology and unusually small size for *Typothorax* would be together by chance, although the possibility of more then one closely associated subadult specimens of *T. coccinarum* cannot be fully discounted.

2.4. The Patricia Site

The "Patricia Site" is a newly discovered locality (Fig. 1.1) in the upper part of the Cooper Canyon Formation stratagraphically higher then the Post Quarry, and is currently being worked by Texas Tech University. The site was located by museum volunteer Doug Cunningham (who has also prepared most of the phytosaur material recovered there) on property belonging to the Kirkpatrick family in Garza County. The Patricia Site has yielded an amazing quantity of isolated phytosaur skulls and postcranial material referable to *Pseudopalatus* and *Redondasaurus* (Cunningham et al., 2002; Lehman and Chatterjee, in prep).

Two anterior dorsal paramedian scutes, and a lateral scute articulated to the posterior of the two, are referable to *Typothorax coccinarum*. A scapulocoracoid identical to that of specimen "U" from Canjilon Quarry, and distinctly non-phytosaurian in possessing an enclosed coracoid foramen, was closely associated. The scutes and scapulocoracoid likely belong to the same individual, and are all under the same specimen number, TTUP 10070.

2.5. The Apache Canyon Quarry

2.5.1. Stratigraphy of the Apache Canyon Quarry

J.W. Cosgriff and S.R. Leffler collected the UCMP material of *Redondasuchus* from J. Gregory's Quarry 2 in north Apache Canyon in June and July of 1961. This locality was divided into five square "quads," each a meter square, lined up north to south, with Quad 1 and the north end and Quad 5 at the south end. Three stratagraphic units are suggested for the quarry in Cosgriff's field notes. From bottom to top, these are: a sandstone, a blue shale, and a brown pebble conglomerate. The thickness of these layers is not given, but Cosgriff's notes suggest that the conglomeratic layer was (at least in places) 14" thick or more. Nearly all the material recovered seems to have come out of the brown conglomeratic layer, and the upper few inches seem to have been the richest. The blue shale was particularly productive only in spots, and nothing was reported from the lower sandstone.

2.5.2. Association of *Redondasuchus* material

At least six specimens occur in the UCMP V6148 collections (Fig. 2.3; Table 2.2). By comparing his field notes with the specimen bag numbers provided for the scutes in the collection, some information on the stratagraphic and spatial distribution of the *Redondasuchus* scutes can be established. The *Redondasuchus* specimens collected by Cosgriff and Leffler were well spread out in the quarry, being recovered from all Quads except for Quad 5. Information on the stratigraphic position of the scutes is less clear, but they seem to have been found in both the blue mudstone and the brown conglomerate. Cosgriff is fairly explicit that UCMP V6148 65331 was collected in the blue mudstone, and it is strongly implied that at least some, if not most of the other

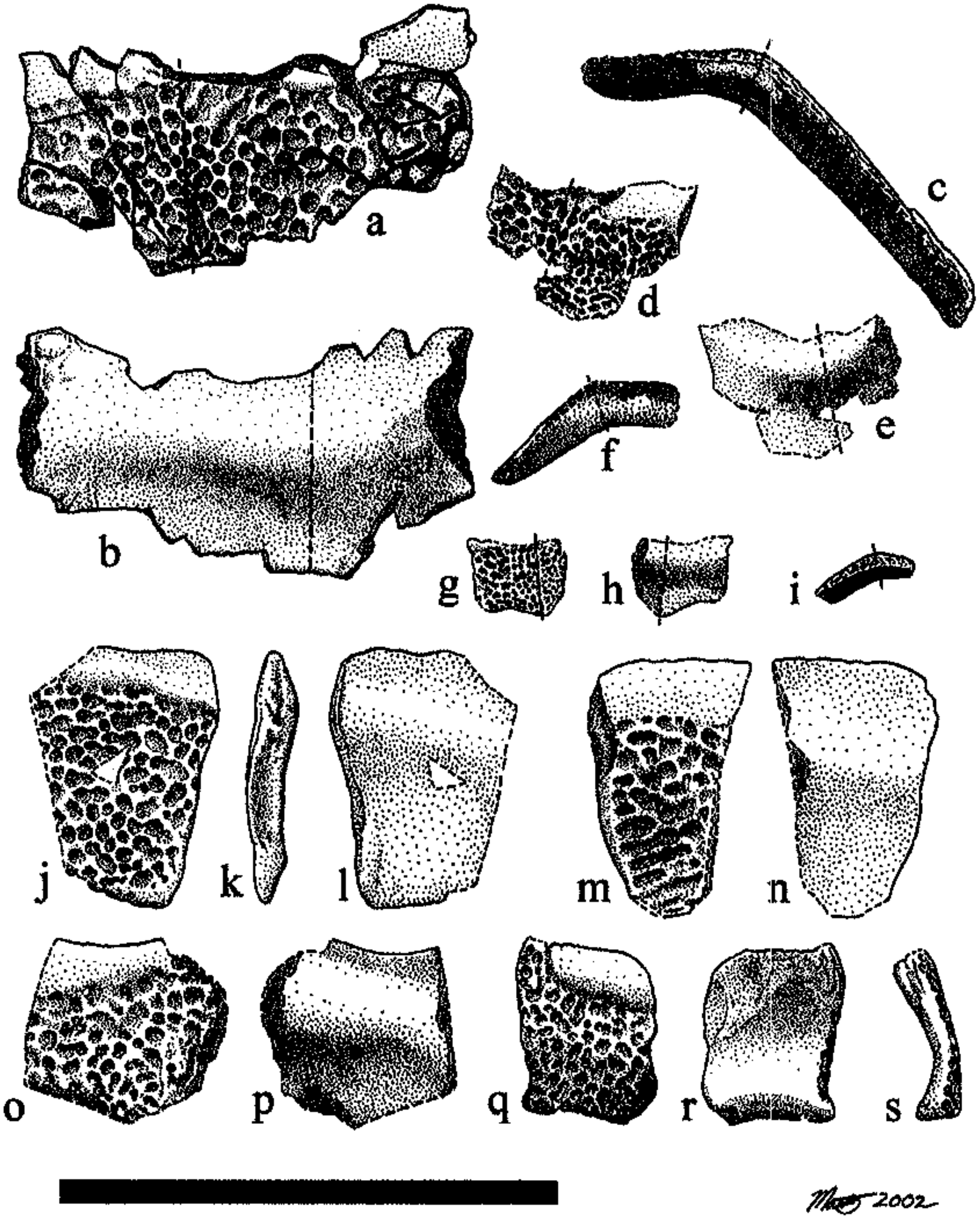

Figure 2.3 UCMP V6148 (Apache Canyon Quarry) dorsal paramedian scutes of *"Redondasuchus" reseri*; right dorsal paramedian 65415 (holotype) in (a) dorsal, (b) ventral, and (c) posterior views; right dorsal paramedian 173838 in (d) dorsal, (e) ventral, and (f) anterior views; left dorsal paramedian 65314 in (g) dorsal, (h) ventral, and (i) posterior views; left dorsal paramedian 65416-39 in (j) dorsal, (k) medial, and (l) ventral views; right dorsal paramedian 65416 in (m) dorsal, and (n) ventral views; right (?) dorsal paramedian 65416-74 in (o) dorsal, and (p) ventral views; possible cervical dorsal paramedian scute 65758 in (q) dorsal, (r) ventral, and (s) medial (?) views; dashed lines are drawn along the line of arching at the center of ossification and also indicate broken edges, shaded areas indicate broken bone surface. Scale bar = 10 cm.

scutes came from the conglomerate. No evidence exists that any of the *Redondasuchus* scutes were associated with each other, and it seems likely, based at least on their spatial distribution between quads and implied stratagraphic disparity, that none of them were.

Table 2.2. UCMP V6148 (Apache Canyon Quarry) *Redondasuchus reseri* scutes

All specimens listed here are dorsal paramedian scutes, and most are shown in Fig. 2.3. Scutes are ordered by (1) quad number, and (2) field number. Field numbers were assigned by Leffler and Cosgriff to bags of material, usually containing more then one specimen, collected in the same general area. UCMP V6148 65416 includes more than one scute fragment from different areas of the quarry.

QUAD	SPECIMEN #	FIELD #	DATE COLLECTED	COLLECTOR	LEVEL
1	65416	74	7/9/61	?	Brown conglomerate?
1	65415	76	7/9/61	?	Blue “shale”?
2	65416	39	6/29/61	Cosgriff	Brown conglomerate
2	173838	19	6/22/61	Cosgriff	Brown conglomerate?
3	65331	56	7/3/61	Leffler	Blue “shale”
4	65314	44	7/1/61	Leffler	Brown conglomerate?

CHAPTER 3

THE STATUS OF TTUP 9214 AND *REDONDASUCHUS RESERI*

3.1. TTUP 9214

The dorsal paramedian scutes of both TTUP 9214 and the Canjilon Quarry material have the diagnostic features of *Typothorax coccinarum*. The scutes have high mediolateral expansion, pitted, sub-circular ornamentation, a dorsal boss which is absent or present only in the posterior scutes, a thick ventral keel, and a raised anterior bar. Several features in TTUP 9214 that support its identification by Small (1989b) as an immature individual of *Typothorax coccinarum*:

1. TTUP 9214 is considerably smaller than the Canjilon Quarry material.
2. The neural arches are not completely fused to the vertebral centra. They are clearly separate in the anterior cervical vertebrae, and even in several more postrior vertebrae, the suture is still visible. In modern crocodilians, closure of the neurocentral sutures proceeds from the caudal vertebrae anteriorly, and is not complete until maturity (Brochu, 1996).
3. The laterosphenoid is incompletely ossified, so that the opening for the trigeminal (V) nerve is an embayment rather then an enclosed foramen, and the basal tubera also seem to be largely unossified. Hans Larsson (personal communication, 2002) indicates that in archosaurs, the laterosphenoid and basal tubera both ossify late in ontogeny.

The scutes of TTUP 9214 exhibit several slight morphological differences from the Canjilon Quarry material, which might best be explained as ontogenetic in nature. Skull and vertebral material is described here only for TTUP 9214. Consequently, with the exception of overall small size, the features in that specimen just listed that are most suggestive of immaturity cannot be compared with adult material from Canjilon Quarry to determine if the braincase ossification and nuerocentral suture fusion is more advanced in the latter, as would be expected.

Given the overall strong similarities between TTUP 9214 and adult material of *Typothorax coccinarum*, the features suggestive of immaturity in the former, and the fact that both occur in the Cooper Canyon Formation and equivalent strata (the upper Petrified Forest Member), it seems most reasonable to conclude that TTUP 9214 is an immature specimen of *T. coccinarum*. Consequently, the Canjilon Quarry material and TTUP 9214 will be discussed together in the description given below for the taxon. However, it should be noted that this is based on a small sample size of specimens, and must be considered tentative until more specimens of *Typothorax* are found to give a more thorough picture of variation in the taxon. Further work may well find that the differences between TTUP 9214 and other *Typothorax* material are taxonomic, and that the former represents a distinct species from *T. coccinarum*.

3.2. Is the arching in the dorsal paramedian scutes of *Typothorax coccinarum* real?

Long and Ballew (1985) identified transverse arching in the dorsal paramedian scutes of the caudal region in *Typothorax coccinarum*. However, Long and Murry (1995) suggested that the "flaring" seen in some of the dorsal paramedians from Canjilon Quarry was due to post-mortem distortion, and that the scutes were naturally flat. Examination of the Canjilon Quarry scutes does show that distortion occurs in many of the scutes.

However, with very few exceptions, arching almost always occurs *at the center of ossification* in most dorsal paramedians of both the Canjilon Quarry material and TTUP 9214 (Fig. 3.1a, b). The center of ossification in *Typothorax*, as in most aetosaurs, is considerably closer to the medial edge of the scute (in *Redondasuchus*, the arching allegedly occurs closer to the lateral edge). Several morphological indicators show where the center of ossification is located, though all may not be recognizable in the same scute:

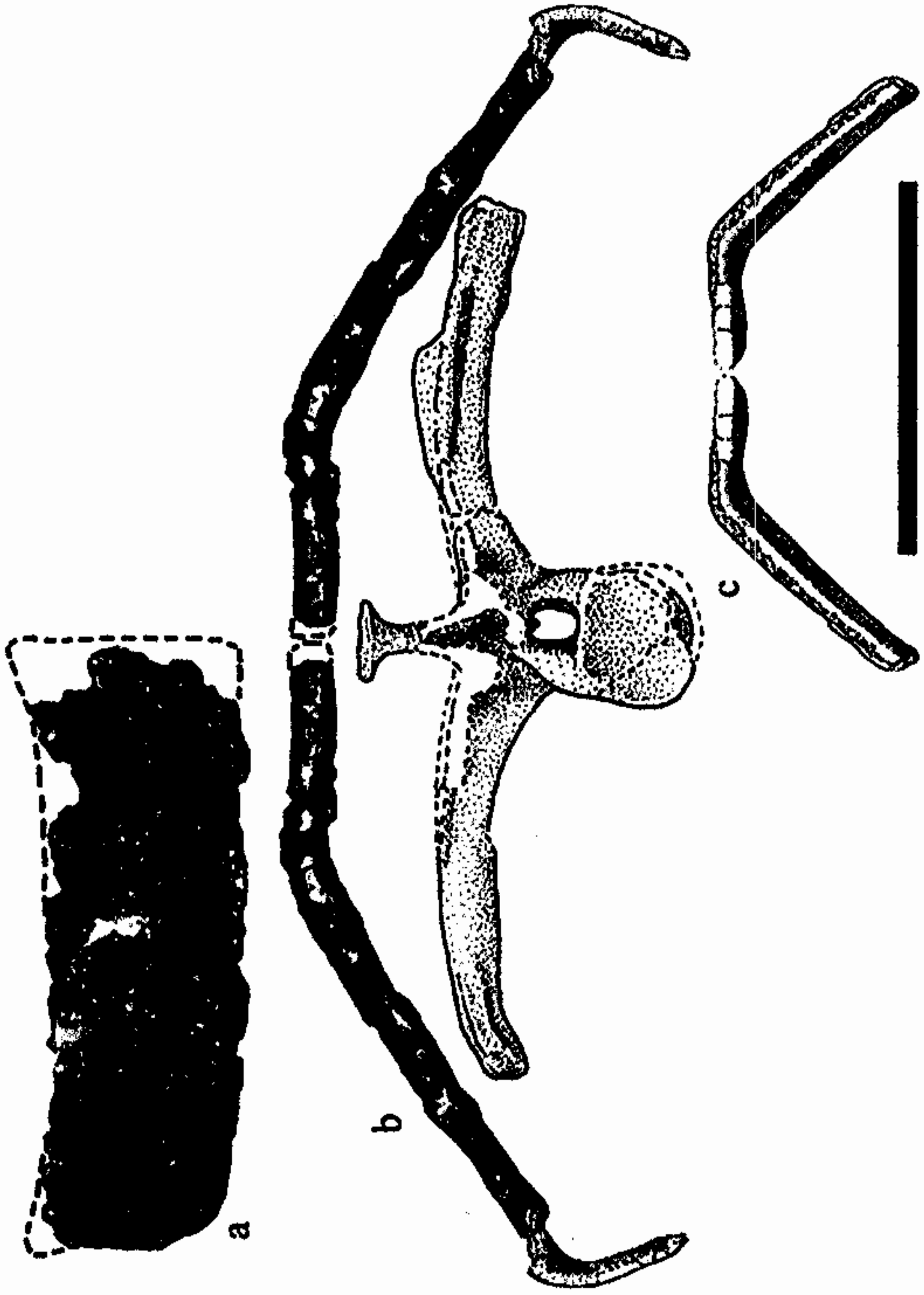

Figure 3.1 Comparison of dorsal paramedian scute arching between *Typothorax coccinarum* (TTUP 9214) and *"Redondasuchus" reseri*; (a) partially reconstructed left dorsal paramedian scute of TTUP 9214 in dorsal view, (b) same scute in posterior view with mirror image, lateral scutes, and dorsal vertebra added to give partial cross section through body. (c) *"Redondasuchus" reseri* UCMP V6148 65415 right dorsal paramedian scute with mirror image. Dashed lines indicate broken bone edges. Scale bar = 10 cm.

1. The pitting around this region is usually finer than on the surrounding dorsal surface of the scute. This is also evident in the holotype of *Redondasuchus* (UCMP 65415; see Fig. 2.3.a), and "*Tecovasuchus*", a new taxon being described by Martz and Small (in prep).
2. The dorsal boss, if present, is positioned there.
3. The ventral keel is usually thickest here, again as in *Redondasuchus* (Fig. 2.3.b). The keel flattens out gradually on the lateral side, and more abruptly on the medial side in both taxa.

It seems unlikely that arching would occur in this location so consistently through post-mortem deformation, especially considering the thickening of the ventral keel here. This arching is also clearly present in the Cope's (1887, plate I) and Huene's (1915, fig. 3) illustrations of the holotype of *Typothorax coccinarum* (USNM 2585). Weak arching at the center of ossification (usually between about 15° and 30° in the Canjilon material, and about 30° in TTUP 9214 as opposed to about 45° in *Redondasuchus*) is therefore a natural feature of the dorsal paramedian scutes of *T. coccinarum*, not only in the caudals, but also in much of the pre-caudal region.

3.3 The status of *Redondasuchus reseri*

Hunt and Lucas (1991a) and Heckert et al. (1996) have described the morphology of the dorsal paramedian scutes of *Redondasuchus*. As already noted, the scutes are distinctly similar to *Typothorax coccinarum*. However, most of the alleged *differences* between the taxa are considered to be dubious. Hunt and Lucas (1991a) and Heckert et al. (1996) interpreted the edge of the scute closest to the arching in the holotype scute (UCMP V6148 65415) *Redondasuchus* as being the *lateral* edge; in other words, that the scute is a left dorsal paramedian. In this orientation, the scute would have an unusual downturned lateral edge (see Heckert et al., 1996, fig. 5c), which is an alleged diagnostic character for this the taxon.

However, the edges of UCMP V6148 65415 are not well preserved enough to be certain which edge is medial and which is lateral (Fig. 2.3.a); the reason why Hunt and Lucas (1991a) and Heckert et al. (1996) assumed the orientation they did is not clear. However, if the scute is instead interpreted as a *right* dorsal paramedian scute, with the arching being present at the center of ossification, closer to the medial edge (Fig. 2.3.c), it more strongly resembles the dorsal paramedian scutes of *Typothorax coccinarum*, although with stronger arching (Fig. 3.1c). As noted above, the pitting at the region of arching is finer in UCMP V6145 65415, which is also often seen at the center of ossification in *T. coccinarum*. In narrower dorsal paramedian scutes of *Redondasuchus* (Fig 2.3.d-i; Heckert et al., 1996, fig. 5), the relative distance of the arching from the medial and lateral edges becomes more subequal. This is usual in aetosaurs as the width of the dorsal paramedians decreases posteriorly, including in the caudal dorsal paramedian scutes of *Typothorax coccinarum*.

Hunt and Lucas (1991a) and Heckert et al. (1996) described the ventral keel of the dorsal paramedians in *Redondasuchus* as being restricted to the medial side of the arching and terminating abruptly at it as a difference from *Typothorax*. If the scute is reoriented as a right dorsal paramedian, the keel is present on the lateral side, thickest adjacent to the line of arching, and flattens immediately on the medial side of the arching as in *Typothorax*.

Hunt and Lucas (1991a) and Heckert et al. (1996) also claimed that *Redondasuchus* differs from all other aetosaurs in lacking lateral scutes. This interpretation was based partly on their erroneous interpretation that the lateral edges of the dorsal paramedians are turned down, which they suggested was to compensate for the absence of lateral scutes. There is therefore no evidence to suggest that *Redondasuchus* lacked lateral scutes[6].

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[6] However, I strongly question Long and Murry's (1995) identification of UCMP V6145 173838 (Fig. 2.3.q-s) as a lateral scute of *Redondasuchus*. The scute does not resemble the lateral scute of any aetosaur. There is no sign of a raised ridge as in the lateral scutes of *Typothorax*, and if the odd, discontinuous bar across one edge is the anterior bar, flexion in the scute occurs *perpendicular* to its direction in the lateral scutes of other aetosaurs. The scute somewhat more closely resembles a dorsal

None of the scutes for *Redondasuchus reseri* possess pyramidal dorsal bosses, as are seen in the posterior dorsal paramedians of *Typothorax*. However, as will be discussed below, the bosses in TTUP 9214 are considerably more reduced than those seen in the larger specimens of *T. coccinarum*, and apparently more restricted as to which region of the carapace they occur. The presence and size of these bosses and their distribution between scutes is likely allometric.

In summary, all of the proposed differences between *Typothorax coccinarum* and *Redondasuchus reseri* are either due to erroneous interpretation, or only matters of size or degree:

1. *Redondasuchus* is smaller then *Typothorax* but otherwise similar.
2. Both taxa have arching at the center of ossification, although it is more pronounced in *Redondasuchus.*
3. Both have a ventral keel that is reduced abruptly medial to the center of ossification/arching, but it does so more sharply in *Redondasuchus.*
4. There is no reason to suspect that *Redondasuchus* lacked lateral scutes, which are present in all other aetosaurs.

On the basis of these similarities, it seems most reasonable to assign *Redondasuchus reseri* to *Typothorax*, and it may well represent a juvenile of *T. coccinarum*, as suggested by Long and Murry (1995). Certainly, if "*Redondasuchus*" scutes were found in the Cooper Canyon Formation or the Petrified Forest Member, I would have little doubt in assigning them to *T. coccinarum.*

However, the fact that *only* the small scutes of "*Redondasuchus*" are known from the Redonda Formation provides circumstantial evidence that "*Redondasuchus*" *reseri* actually represents a distinct taxon from *Typothorax coccinarum.* Although many "*Redondasuchus*" scutes have been collected from the Redonda Formation, no larger

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paramedian, so Heckert et al.'s (1996) identification of the scute as a cervical dorsal paramedian may be more reasonable, although the arching is still in the wrong direction.

Typothorax coccinarum scutes are known from the same strata. It would seem odd for the latter to be totally absent if it represented an adult of the same species. I therefore tentatively retain "*Redondasuchus*" *reseri* as a separate, smaller species of *Typothorax*, *T. reseri*.

3.4 Revised diagnosis of *Typothorax*

Typothorax: Aetosaur with dorsal paramedian scutes having a high width/length ratio (as in *Paratypothorax* and "*Tecovasuchus*"), random sub-circular ornamentation that is finer, more densely spaced, and shallower than in *Desmatosuchus*, arching about 15°-45° at the center of ossification in most of the post-cervical region, straight, anterolaterally sloping lateral margins in the posterior dorsal (region) dorsal paramedian scutes in adults (autapomorphy), a raised anterior bar, thick rounded ventral keel more prominent lateral and immediately adjacent to center of ossification (as in "*Tecovasuchus*") and flattens out both sides of the line of arching, lack beveling of the dorsal posterior margin (unlike *Paratypothorax* and "*Tecovasuchus*.")

T. coccinarum: Larger size relative to *T. reseri*, a higher width/length ratio of the dorsal paramedian scutes ($\geq$4.0) as in *Paratypothorax* and "*Tecovasuchus*", arching in the dorsal paramedians usually 15°-30°, less pronounced ventral keel, low, pyramidal dorsal boss present in the posterior dorsal (region) and caudal dorsal paramedian scutes. Other diagnostic features that cannot be assessed for *T. reseri*: absence of premaxillary teeth (as in *Desmatosuchus*), an extremely shallow dentary (autapomorphy) with ten teeth, dorsal vertebrae with greatly expanded transverse processes, extremely gracile humerus relative to *Desmatosuchus* and *Longosuchus*, humerus with enclosed ectepicondylar foramen as in *Desmatosuchus* and *Neoaetosauroides*, illium with a greatly elongate preacetabular process and strong constriction above the acetabulum (autapomorphies), extremely shortened distal pubis (autapomorphy), angulated lateral scutes with reduced dorsal flanges having pitted ornamentation as in *Paratypothorax* and "*Tecovasuchus*", dorsal flange triangular in adults (autapomorphy), raised ridge at the line of angulation, no lateral horn, large lateral flange bearing fine pitting posterodorsally, but elongate grooves radiating from the region on rest of the flange.

T. reseri: Smaller size relative to *T. coccinarum*, dorsal paramedian scutes with greater degree of arching (45°), prominent ventral keel relative to size of scute, keel more abruptly flattened medial to the line of arching, absence of dorsal boss in all dorsal paramedian scutes.

3.5. The Otischalkian, Revueltian, and Apachean land vertebrate faunachrons

Lucas (e.g., 1998b) and his colleagues (e.g., Lucas and Hunt, 1993; Heckert and Lucas, 2000) have proposed and made extensive use of a system of biochronological correlation using terrestrial vertebrates for strata of Late Triassic age. They have divided Late Triassic time into four "land vertebrate faunachrons," the Otischalkian, Adamanian, Revueltian, and Apachean (Fig. 2.1), based on the representative vertebrate fossils, especially phytosaurs and aetosaurs. *Typothorax coccinarum* and the phytosaur *Pseudopalatus* are considered in this system to be index fossils of the Revueltian (which is approximately equivalent to the Norian), and encompasses both the upper Petrified Forest Member and the Cooper Canyon Formation. *Typothorax reseri* and the phytosaur *Redondasaurus* are index fossils for the Apachian (which may be equivalent to the late Norian and/or Rhaetian), which includes the Redonda Formation.

As discussed Lehman (1994b) and Lehman and Chatterjee (in prep), the restriction of the Otischalkian fauna (which includes the phytosaur *Paleorhinus* and the aetosaur *Longosuchus*) to strata older than that of the Revueltian is questionable. Strata containing *Paleorhinus* (including the type Otischalkian locality and more northerly sites currently being worked by Texas Tech University) have been identified using lithostratagraphic correlation as being part of the Cooper Canyon Formation (Lehman, 1994b; Lehman and Chatterjee, in prep), which also contains a Revueltian fauna. The Otischalkian fauna therefore occurs at the same stratigraphic level as faunas considered under Lucas's system to be younger, although *Paleorhinus* at least probably does indeed also extend downward into the Carnian (Hunt and Lucas, 1991b).

The recognition of the Apachean is also somewhat problematic, partly due to two of its defining and diagnostic taxa, the phytosaur *Redondasaurus*, and the aetosaur *Typothorax reseri*. *T. reseri* is of extremely dubious use as an index fossil, for two reasons:

1. *T. reseri* is much more similar to *T. coccinarum* then has generally been acknowledged. Determining if a small *Typothorax* scute is referable to a juvenile of *T. coccinarum* or an adult of *T. reseri* is problematic.
2. *T. reseri* is so far known only from the Redonda Formation, which is restricted to eastern New Mexico. It is certainly premature to consider a taxon with such a (currently) restricted geographic range to be a useful index fossil, as it cannot be used for correlation.

Additionally, the phytosaur *Redondasaurus* is now known from the upper Cooper Canyon Formation, in association with both *Pseudopalatus* and *Typothorax coccinarum* (Cunningham et al., 2002), so the Apachean fauna, like that of the Otischalkian, partly overlaps stratigraphically with the Revueltian fauna. Moreover, stratagraphic units have been assigned to the Apachean (such as the Los Colorados Formation of Argentina) often due solely to the presence of prosauropod dinosaurs (Lucas, 1998b), even if they contain none of the index fossils from the type locality of the Apachean (in the Redonda Formation). This assignment is apparently based on an *ad hoc* assumption that Late Triassic prosauropod dominated faunas *must* be younger worldwide than those of the Revueltian, and not on genuine correlation using diagnostic index fossils. Even if this assumption is true, there is no evidence that all strata assigned to the Apachean are precisely the same age within the late Norian-Rhaetian, even if they are younger then the Revueltian faunas.

CHAPTER 4

DESCRIPTION OF *TYPOTHORAX COCCINARUM*

4.1. Introduction

The following description of *Typothorax coccinarum* is based almost entirely on the Canjilon Quarry, Post Quarry, and Patricia Site specimens. Direct comparisons were made primarily with Texas Tech's *Desmatosuchus haploceros* material, although UCMP's and TMM's fine collections of *Desmatosuchus haploceros*, *Stagonolepis wellesi*, *Longosuchus meadei*, and *Lucasuchus hunti* were also examined by the author. Other comparisons are mostly based on the literature, particularly Sawin (1947), Walker (1961), Small (1985), Long and Murry (1995), and Heckert and Lucas (1999, 2000).

Recently, the terms "anterior" (referring to the 'forward' direction along the midline axis of the skeleton toward the skull) and "posterior" (referring to the 'backward' direction toward the tip of the tail) have fallen into disfavor in the literature. The terms "rostral" and "caudal" have been proposed as replacements for skull and mandible description, and "cranial" and "caudal" for postcranial material, and are now commonly applied. However, the modern day application of the terms "anterior" and "posterior" for vertebrate anatomy are well understood and applied consistently, and the alleged confusion caused by these terms is more imagined then real. Moreover, the proposed replacement terms also carry unfortunate anatomical connotations, which can lead to terminology more confusing then caused by the traditional terms. In particular, this is a problem in the case of the paired rows of scutes running along the dorsal midline in aetosaurs, usually referred to as "dorsal paramedian scutes." Using the terms "cranial" and "caudal" leads to unfortunate anatomical concoctions such as "caudal cervical dorsal paramedians" (which would refer to these scutes from the rear part of the neck region); the substitution of the traditional terms gives the somewhat more manageable "posterior cervical dorsal paramedians." The traditional terms "anterior" and "posterior" will be used here.

"Dorsal," "ventral," "medial," and "lateral" are used here conventionally. The terms "proximal" and "distal" also carry their conventional meanings. Additionally, the terms "internal" and "external" are occasionally used (especially for scutes) when describing respectively the sides of an element facing towards or away from the mid-line of the body.

4.2 Cranial skeleton

Good aetosaur skull material is relatively rare, but at least partial descriptions have been provided for *Aetosaurus, Stagonolepis* (Walker, 1961; Gower and Walker, 2002), *Desmatosuchus* (Case, 1922; Small, 1985, 2002), *Longosuchus* (Sawin, 1947; Parrish, 1994), and *Coahomasuchus* (Heckert and Lucas, 1999). Direct comparisons were mostly made with *Desmatosuchus* and *Longosuchus* cranial material at TTUP and TMM. It is important to remember the braincase and dentary descriptions given here for *Typothorax* are based on TTUP 9214, which is immature and may differ ontogenetically from adult material. NMMNH P-12964 (Hunt et al., 1993; Hunt, 2001) possesses the only complete skull and mandible known for *Typothorax coccinarum*, and hopefully a detailed description of this material will eventually clarify the adult cranial morphology of this taxon.

4.2.1 Parietal

The roof of the parietal is not preserved, but the thick, ventrally descending processes contacting the braincase laterally and forming much of the dorsal part of the occipital face are still in place. The lateral processes thin as they descend to the braincase, and their lateral surfaces are concave (Fig. 4.2.b). Ventrally, they meet the prootic, and in life were probably wedged between that element and the (mostly unossified) laterosphenoid. Parrish (1994) described this part of the parietal as being part of the laterosphenoid in *Longosuchus*.

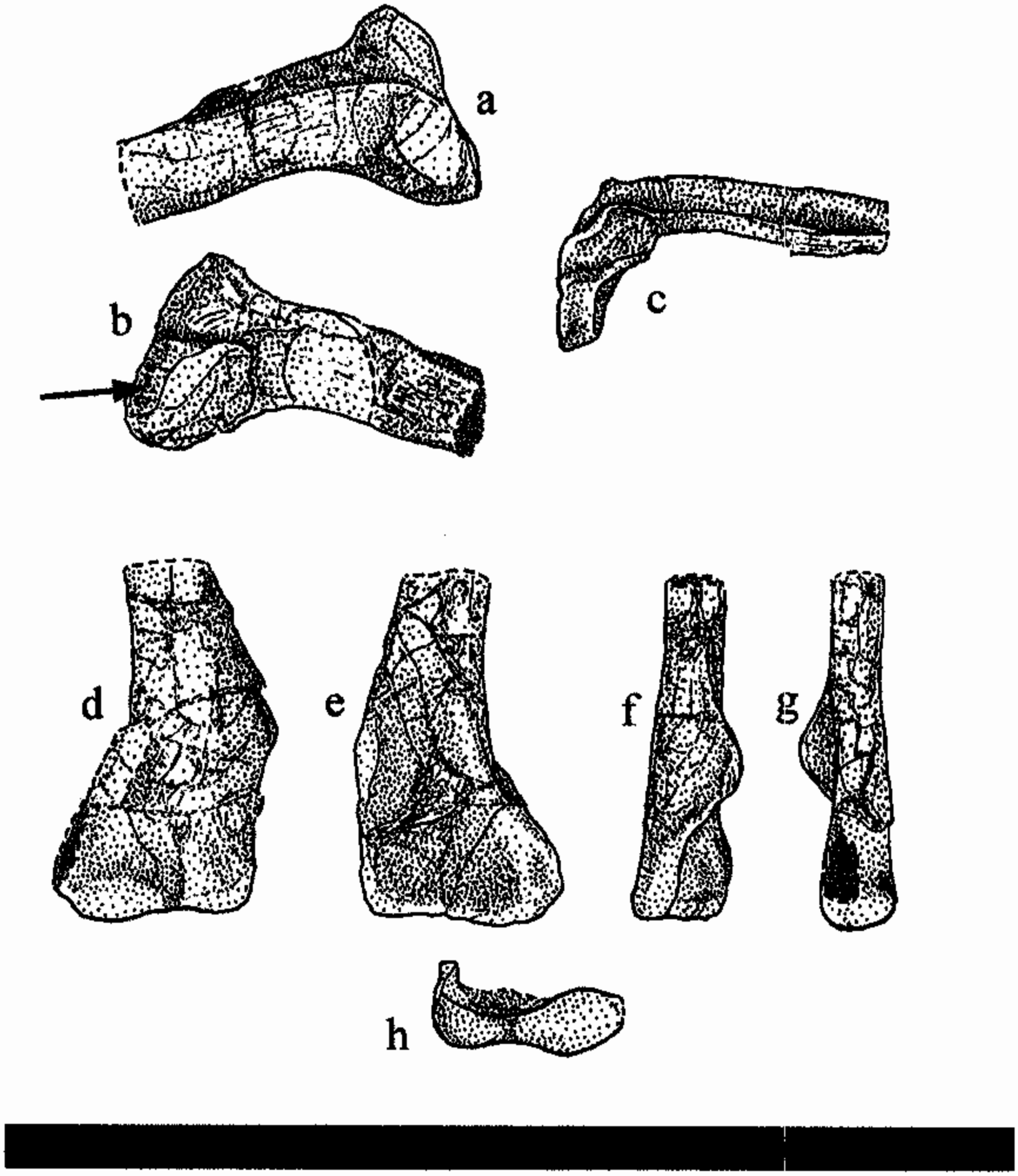
On the occipital face of the braincase (Fig. 4.2.c), the parietal contacts the dorsal edge of the supraoccipital, and the suture between the two elements cannot be discerned. Unlike *Desmatosuchus* and *Stagonolepis* (Walker, 1961, fig. 4d), this part of the occiput does not seem to have been slightly concave in *Typothorax*. Like the supraoccipital, the element is mostly missing along the midline above the foramen magnum. The posterolateral extent of the parietal (forming the dorsal border of the posterior temporal fenestrate and contacting the squamosal) and the posterodorsal flanges that supported the first dorsal paramedian scutes are also not preserved.

4.2.2. Squamosal

An incomplete element possibly representing the posterior end of a left squamosal is known from the TTUP 9214 (Fig. 4.1a-c). The element is mediolaterally flattened, though still fairly thick. The posterior end curves medially (Fig. 4.1c). The medial end of this curved section is a smooth articular surface (indicated by an arrow in Fig. 4.1b), which would have contacted the paroccipital process. On the dorsal side of the curved region is a thin lamina which would have formed the ventral border of the supratemporal fenestra (which faces laterally in aetosaurs).

4.2.3 Quadrate

TTUP 9214 preserves most of the right quadrate (Fig. 4.1d-h), missing the head (which articulated with the squamosal and the paroccipital process) and the pterygoideus ramus. The distal end articulated with the mandible, and is divided into two condyles separated by a slight constriction (Fig. 4.1h). The medial condyle is much more inflated and broadly rounded then the lateral condyle, and also relatively more inflated then in *Desmatosuchus*. In posterior view the shaft of the quadrate curves gently medially (Fig. 4.1d), as in *Desmatosuchus*. The body of the bone is anteroposteriorly flattened, the posterior side is faintly convex (Fig. 4.1d), and the anterior side is faintly concave (Fig. 4.1e). As with the condyles, the medial edge is thicker (Fig. 4.1g). About half way up



Martz 2002

Figure 4.1 Skull bones of *Typothorax coccinarum* (TTUP 9214); left squamosal in (a) lateral, (b), medial, and (c) dorsal views; right quadrate in (d) posterior, (e) anterior, (f) lateral, (g) medial, and (h) distal views. Broken edges are indicated by dashed lines, broken bone surface by shading. Scale bar = 5 cm.

the preserved section of the lateral edge is a small, flat, anteriorly extending triangular ramus (Fig. 4.1f), which articulated with the squamosal. The pterygoideus ramus (which is broken off) would have extended off the thicker medial edge (Fig. 4.1g), and was probably overlapped by the pterygoid (Small, 2002). The quadrate foramen cannot be discerned on the posterior side of the bone in *Typothorax* and *Desmatosuchus* (Small, 1985).

4.2.4. Braincase

TTUP 9214 includes an excellent and almost complete braincase, including most or all of the basioccipital, exoccipitals, parabasisphenoid, opisthotics, and prootics, and part of the laterosphenoid (Fig. 4.2). During preparation, part of the left lateral wall of the braincase broke away, allowing preparation and description of the inner surface. The braincase is of similar size to the much less complete braincase of TTUP 545 ("*Tecovasuchus chatterjeei*"; Martz and Small, in prep). The morphology of the internal surface of the braincase is discussed separately from the descriptions of the individual elements.

4.2.4.1. Basioccipital and parabasasphenoid

The basioccipital forms most of the occipital condyle, which is hemispherical in posterior view (Fig. 4.2c); Walker (1961, fig. 4d) shows it as being more circular in *Stagonolepis*. The neck of the condyle is convex ventrally (Fig. 4.2b), smoothly merging with the very broad, roughly vertical, occipital face of the basioccipital. On this face, below the occipital condyle, weakly developed pillars connect the neck of the condyle to the basal tubera. The posterior face of the basioccipital is not nearly as broad, and the pillars are leading to the basal tubera are even less distinct (or absent), in "*Tecovasuchus*," *Desmatosuchus*, *Postosuchus*, and phytosaurs.

The basal tubera of the basioccipital are faintly rugose thickenings separated by a smooth sulcus on the ventral edge of the occipital face of the basiocciptial (Fig. 4.2c).

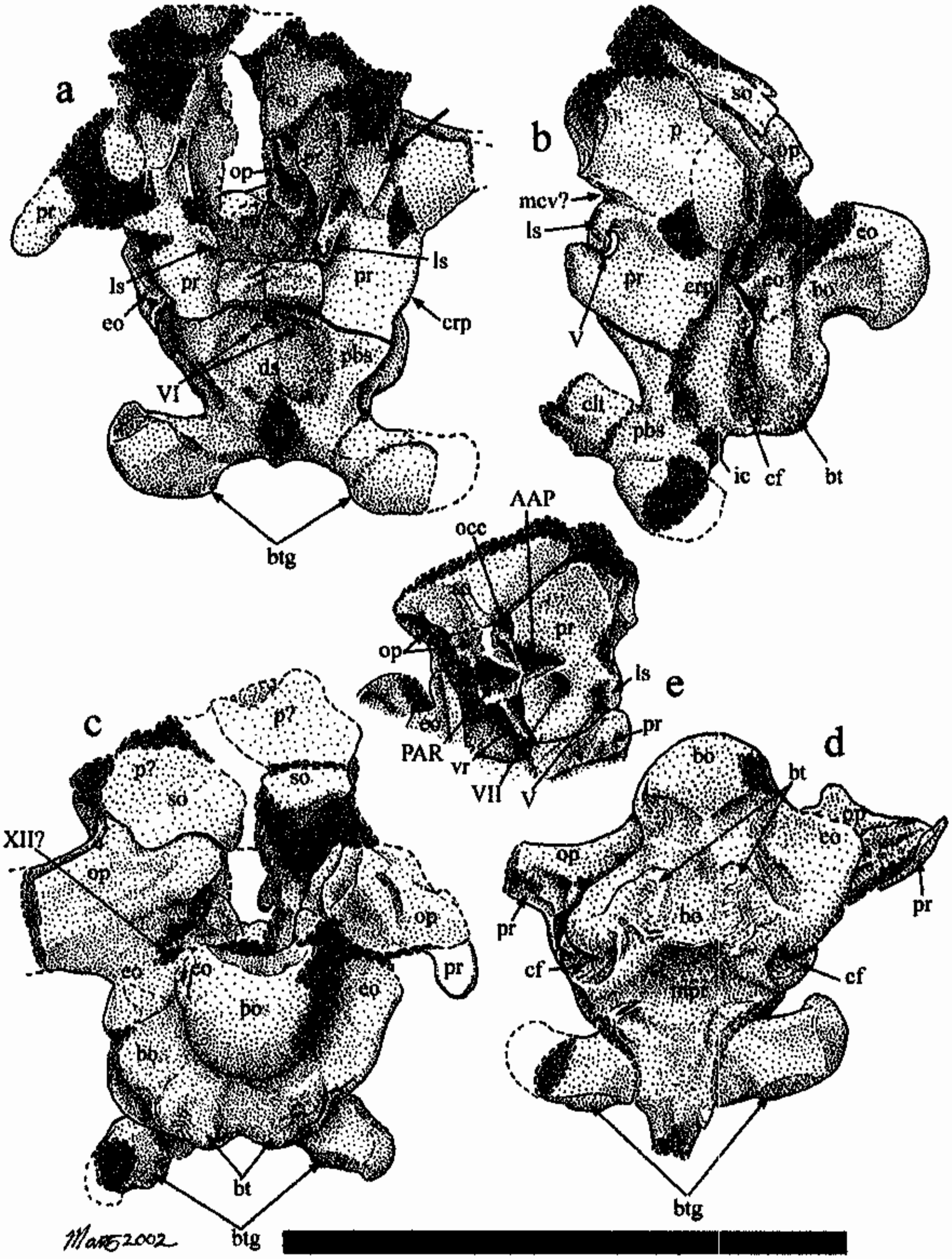


Figure 4.2 Braincase of *Typothorax coccinarum* (TTUP 9214) in (a) anterior, (b) left lateral, (c) posterior, (d) ventral views, and (e) the left inner surface. Dashed lines represent broken bone edges, shaded areas broken bone surface. Scale bar = 5 cm.

The tubera face posteriorly and slightly ventrally (Fig. 4.2b); this is also the case in "*Tecovasuchus*." In both *Desmatosuchus* and "*Tecovasuchus*," the tubera are more closely spaced then in *Typothorax*. In *Stagonolepis* they form a "chevron shaped mass, the apex of which points forward" (Walker, 1961, p. 124), which implies that they are joined. This is not the case in any pseudosuchian braincases examined by the author.

Paired broad, crescentic facets border the parabasisphenoid-basioccipital suture anteriorly on the ventrolateral surface of the parabasisphenoid (Fig. 4.2b). The posterior surface of these facets, facing the suture, is slightly rugose. The same facets are present and *extremely* rugose in "*Tecovasuchus*" and were also described by Walker (1961) in *Stagonolepis*. The facets may become part of the basal tubera at a later stage of ontogeny. It is very common, and possibly the norm in archosauriformes, for both the basiocciptial and parabasisphenoid to participate in the basal tubera, with the suture between the two bones running through the middle of the tubera. This has been noted in basal archosauriformes (e.g., Gower, 1997), phytosaurs (Chatterjee, 1978; Hungerbühler, 2002), *Postosuchus* (Chatterjee, 1985), and *Desmatosuchus* (Small, 1985, 2002).[7] As TTUP 9214 is probably immature, in life the basal tubera of the basiocciptial and the crescentic facets may have been covered with a cartilage cap that ossified with maturity into a single, massive pair of basal tuber spanning the two bones, as seen in *Desmatosuchus* (Small, 2002). Hans Larsson (personal communication, 2002) indicates that in archosaurs, the basal tubera usually ossify very late in ontogeny; this might explain the unossified state of the tubera even in an animal approaching adult size. Alternately, these separate basal tubera and crescentic facets may have been retained into maturity, and have some phylogenetic significance.

On the ventral surface of the parabasisphenoid (Fig. 4.2d), directly anterior to the basal tubera, and posterior to the basipterygoid processes, is a broad, shallow, roughly

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[7] Some of these authors describe the basal tubera as being part of the basioccipital and supported by processes from the parabasisphenoid, others as being part of the parabasisphenoid and supported by a process from the basioccipital. However, their descriptions and figures indicate that they are all describing essentially the same condition.

circular depression lying at the posterior end of a shallow trough leading anteriorly between the basipterygoid processes. It is also present in *Stagonolepis*, *Aetosaurus*, *Desmatosuchus*, *Longosuchus*, "*Tecovasuchus*," and *Coahomasuchus* (Walker, 1961; Small, 1985; Parrish, 1994; Heckert and Lucas, 1999; Martz and Small, in prep). This depression was described as the "hemispherical sulcus" by Parrish (1994) and the "hemispherical fontanelle" by Heckert and Lucas (1999) and Small (2002). The term "medial pharyngeal recess" was proposed by Witmer (1997), who also noted that the recess is filled by an (possibly pneumatic) outgrowth from the throat region, and certainly not associated with the eustacian system as implied by Parrish (1994). Witmer's term is preferred here. The median pharyngeal recess is also very wide and shallow in *Desmatosuchus* as in *Typothorax*, but in "*Tecovasuchus*" (and possibly *Stagonolepis*; see Walker, 1961, fig. 5a), it is a narrower but very deep pit[8].

On the ventral surface of the braincase (Fig. 4.2d), the basioccipital-parabasisphenoid suture is mostly closed but appears to run between the basal tubera and the median pharyngeal recess. It moves dorsally and slightly posteriorly up the lateral side of the braincase (Fig. 4.2b), passing posterior to the crescentic facets, toward the stapedial groove (the deep depression under the paroccipital process shared by the foramen ovale, meitotic foramen, and ventral ramus of the opisthotic).

The basipterygoid processes are elongate, project laterally and slightly ventrally (Fig. 4.2a, c), and are slightly curved posteriorly. Contrary to Gower and Walker (2002), who suggested that the basipterygoid processes in all aetosaurs was roughly level with the basal tubera, they descend slightly below the tubera in TTUP 9214. They have a

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[8] Heckert and Lucas (1999) coded the presence or absence of the median pharyngeal recess as a phylogenetically significant character among aetosaurs (their character 7), which is absent plesiomorphically. However, it is probably present to some extent in most basal archosaurs (e.g., Chatterjee, 1978, 1985; Gower, 1997; Witmer, 1997), and is therefore almost certainly plesiomorphic for aetosaurs. Contra Heckert and Lucas (1999), it is also present in *Aetosaurus* according to Walker (1961), as well as the *Typothorax* specimen described here, and is therefore present in all aetosaurs for which its presence can be determined; only its exact form varies (Gower and Walker, 2002). Moreover, development of the recess shows intraspecific variation in *Desmatosuchus*. The recess is therefore probably unreliable as phylogenetic character (Small, 2002).

dorsoventrally compressed neck and thicken distally, with convex, anteriorly facing facets that contacted the pterygoid. The processes are also elongate in *Stagonolepis* (Walker, 1961), but in *Desmatosuchus* (and in phytosaurs) they are shorter and thicker. In lateral view, the basal tubera are very close to the basipterygoid processes in *Desmatosuchus* (especially in UMMP and UCMP material; Small, 2002) as in phytosaurs, but they are somewhat more widely separated in *Typothorax*.

A deep trough, which conducted the internal carotid artery, runs ventroanteriorly from beneath the paroccipital processes behind the crista prootica on the lateral side of the parabasisphenoid before tunneling medially into the hypophyseal fossa above the basipterygoid processes (Fig. 4.2a, b). The hypophyseal fossa (or sella turcica), which held the pituitary, is well concealed behind the base of the cultriform process. It is bordered posteriorly by a tall, slightly concave wall, the dorsum sellae, which is penetrated near its top by the paired openings for the abductens (VI) nerve (Fig 4.2a).

The cultriform rostrum of the parabasisphenoid arises between the anterior edges of the basipterygoid processes, and projects anterodorsally (Fig. 4.2.b). Only the base is preserved and it appears to be fused indistinguishably with the basisphenoid (hence the combined term, "parabasisphenoid"). The process in more or less diamond-shaped in cross section (Fig. 4.2a), with thin, sharp ventral and dorsal edges; this is also the case in *Desmatosuchus*.

4.2.4.2. Exoccipital

Both exoccipitals are partially preserved, though both are missing most of the pillars forming the lateral borders of the foramen magnum. The left exoccipital is slightly more complete then the right (which is missing most of its contact with the opisthotic). The right exoccipital is more or less in its natural position, but part of the left has been slightly broken loose from the basioccipital and displaced into the brain cavity.

The preserved bases of the exoccipital pillars form the dorsolateral corners of the occipital condyle. The exoccipitals also overlap the condyle dorsally, cutting it off from the medullary cavity, unlike *Desmatosuchus* (Small, 2002). The sutural union with the basioccipital in this area is almost indistinguishably fused on the dorsal surface of the occipital condyle, but further inside the foramen magnum the displaced left exoccipital is partly telescoped over the right. One or two channels for the hypoglosseal (XII) nerve passed laterally through the exoccipital in life, but these were mostly lost with the dorsal parts of the bones. However, the bottom of the channel (its roof removed) is still present on the displaced left exoccipital. Just inside the foramen magnum, the exoccipital sends up a thin, dorsally rounded lamina partially overlapping part of the internal surface of the opisthotic (visible in Fig. 4.2c, e).

Lateral to the occipital condyle, the exoccipital forms part of the broad posterior occipital face as a tall, thin wall that borders the meitotic foramen posteriorly. The lateral edge of the lamina thickens and bifurcates ventrally (Fig. 4.2b) where it contacts the basioccipital, sending a small process anteriorly beneath the meitotic foramen. On the right side, the ventral suture with the basioccipital on the occipital face is indistinguishable (Fig. 4.2c). However, the displaced left exoccipital apparently broke loose along the suture, which is probably represented by a straight crack running ventrolaterally along the occiput from the occipital condyle to the bifurcation (Fig. 4.2.c).

4.2.4.3. Supraoccipital

The supraoccipital in TTUP 9214 (Fig. 4.2c) was probably roughly diamond shaped or triangular, with the ventral point of the bone forming the dorsal border of the foramen magnum as in *Longosuchus* (Sawin, 1947), *Stagonolepis* (Walker, 1961), and *Desmatosuchus* (Small, 1985, 2002). The dorsal point of the supraoccipital would have been directed dorsally along the midline of the skull. However, the midline of the occipital face above the foramen magnum is missing. Consequently, the middle of the supraoccipital is also missing, and only the lateral apices and a bit of the ventral apex are preserved. The lower suture of each lateral contact with the opisthotic is a thin lamina partially overlying that bone. This suture descends medially to the ventral apex, and then curves slightly laterally again before contacting the foramen magnum. Contra Small (2002), who was examining the more indiscernibly fused sutures of *Desmatosuchus*, the buttresses for the proatlas are *below* the suture and consequently part of the opisthotic rather then the supraoccipital.

4.2.4.4. Opisthotic

The opisthotic-prootic suture emerges dorsally from the foramen ovale and moves out between the lateral wings of the bones forming the paroccipital process. The suture is clearly visible on the process as a wide gap along both the dorsal (Fig. 4.2b) and ventral edges (Fig. 4.2d) of the process. On the dorsal edge of the process, the suture ends proximally at the parietal-opisthotic junction. The opisthotic contribution to the process is thicker then that of the prootic (Fig. 4.2.b). The dorsal edge of the opisthotic wing is sharp. The ventral edge is thicker, and also slightly embayed by the stapedial groove. The ventral ramus of the opisthotic,[9] a thin lamina separating the foramen ovale and meitotic foramen and connecting with the basioccipital (Fig. 4.2b, e), is preserved on both sides. It is deeply recessed within the stapedial groove as in other aetosaurs, but the foramen for the perilymphatic duct (Gower and Walker, 2002) cannot be discerned.

The occipital side of the opisthotic wing of the paroccipital process is not flat, but separated into dorsally and ventrally inclined surfaces (see left process on Fig. 4.2c). The suture with the exoccipital probably would have been located somewhere on the latter. Medial to the paroccipital process on the occipital face of the opisthotic, a smooth, slightly beveled buttress, which contacted the proatlas, forms the dorsolateral border of the foramen magnum.

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[9] This ramus has been called the "crista paroccipitalis" by Chatterjee (1978) and the "crista interfenestralis" by Chatterjee (1991) and Parrish (1994).

4.2.4.5. Prootic and laterosphenoid

Anteriorly, the base of the prootic is thick along its suture with the parabasisphenoid. The suture is open and runs across the top of the dorsum sellae (Fig. 4.2a). It then turns posteroventrally along the lateral surface of the braincase (Fig. 4.2b), ending at the crista prootica. At the ventroanterior extremity of the prootic, resting on the suture above the dorsum sellae, is a dorsally curving buttress that floored the exit for the trigeminal (V) nerve.

Posteroventrally, the thin flange of the crista prootica overhangs part of the canal for the internal carotid and the stapedial groove. The crista is thin edged and runs posterodorsally at a steep angle of about 50° from the horizontal (Fig. 4.2b). The external opening for the facialis (VII) nerve is concealed beneath. In at least some basal archosaurs (Chatterjee, 1978, 1985; Gower, 1997; Hungerbühler, 2002), the opening for the facialis (VII) nerve opens onto the crista rather then underneath it. However, the facialis (VII) nerve opens underneath the crista not only in *Typothorax* TTUP 9214, but apparently in *Longosuchus* (Parrish, 1994, fig. 5). This concealed opening for the facialis nerve may therefore characterize some aetosaurs. However in at least one specimen of *Desmatosuchus* (TTUP 9208), and apparently *Stagonolepis* (Gower and Walker, 2002), the facialis opens on the outside of the crista as in most pseudosuchians.

Dorsally and posteriorly to the crista prootica, the prootic sends out laterally extending wings that formed the anterior face of the paroccipital process. As with the opisthotic, the dorsal edge of the wing is sharp. Only the right side preserves the distal end of the wing (Fig. 4.2a), which seems to not have extended as far laterally as the opisthotic, so the distal end of the process was probably formed entirely by the opisthotic. The prootic wing is also markedly thinner than that of the opisthotic (Fig. 4.2b).

One of the more striking features of the TTUP 9214 braincase is that the notch for the trigeminal (V) nerve is not entirely closed off anteriorly by the laterosphenoid. A thin projection of that bone curves down from above, but does not touch the prootic buttress below the trigeminal opening, leaving the latter as an embayment rather then an enclosed foramen as is typical of archosauriformes (Fig. 4.2b). This projection of the laterosphenoid, extending from the anterodorsal edge of the prootic just below the parietal suture, seems to represent the only part of the laterosphenoid that is ossified. The rest of the laterosphenoid, which was presumably still cartilaginous at the time of death, would have sat anterior to the ossified projection and anteroventral to the parietal. Above this small ossification, what is interpreted as the anterior edge of the prootic is thick, with an odd football-shaped tuber visible on both sides in anterior view (indicated on the left side by a thick, un-labeled arrow in Fig. 4.2a). This surface probably contacted the still unossified portion of the laterosphenoid. The incomplete ossification of the laterosphenoid is likely due to the specimen's immaturity. Hans Larsson (personal communication, 2002) indicates that the laterosphenoid, like the basal tubera, ossifies late in ontogeny in archosaurs. The notch directly above the trigeminal may represent the opening for the middle cerebral vein (Fig. 4.2b) also seen in *Stagonolepis* and *Desmatosuchus*[10] (Walker, 1972; Small, 2002).

4.2.4.6. Internal surface of the braincase

The posterior floor of the braincase is slightly distorted by the displaced left exoccipital. The meitotic foramen and the foramen ovale both enter at the floor just anterior to the exoccipital, and the meitotic foramen is directly bordered posteriorly by the thin, rounded flange of the exoccipital just inside the foramen magnum (Fig. 4.2e). The ventral end of the ventral ramus of the opisthotic, which contacted the basioccipital, is not clearly visible. On the right side of the braincase, where the inner wall of the prootic has been partially removed, the foramen ovale can be seen to open into a posteriorly facing sulcus inside the prootic behind the facialis nerve, which presumably contained part of the inner ear.

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[10] Walker (1961) and Small (1985) initially identified this second opening as being for one of the branches of the trigeminal nerve.

Just above the meitotic foramen and foramen ovale are the three openings interpreted as being for the joined ends of the semicircular canals and their associated ampullae. The posterior of these openings is a posterolaterally-constricting funnel, the internal opening of which is circular. The funnel is apparently contained entirely within the opisthotic, directly above the descending ramus. This is interpreted as the posterior ampullary recess, the combined opening for the ventral end of the posterior vertical semicircular canal, the posterior ampulla, and the posterior end of the external (horizontal) semicircular canal (Gower and Weber, 1998). The opening just anterior to this is triangular, bordered anteriorly by the prootic and posteriorly by the opisthotic. This is interpreted as the anterior ampullary recess, the combined opening of the ventral end of the anterior vertical semicircular canal and anterior opening of the external semicircular canal (Gower and Weber, 1998). On the right side, the anterior ampullary recess can be seen to invade the prootic as a posteriorly facing embayment. This contains a tiny, posteriorly pointed flange of bone. Ventrally, it is continuous with the embayment in front of the foramen ovale. The third opening is slightly smaller then the other two, and sits just dorsal and intermediate to the first two openings, at the junction of the prootic, opisthotic, and supraoccipital. This is probably the osseous common crus, opening of the joined dorsal ends of the vertical semicircular canals (Gower and Weber, 1998).

Just posterior to the embayment for the trigeminal (V) nerve on medial wall of the prootic and just anterior to the anterior ampullary recess and the foramen magnum, is a small, narrow foramen. This is probably the internal opening for the facialis (VII) nerve. The facialis is also located between the trigeminal foramen and the foramen magnum in *Stagonolepis*, though in that taxon it is reported as being "on the floor of the endocranial cavity" (Gower and Walker, 2002, p.13). The nerve probably would have had to pass through or near the inner ear to exit the braincase behind the crista prootica. Chatterjee (1978) interpreted what may be the same foramen as a pit for the endolymphatic sac.

4.2.5 Dentary

The lower jaw of *Typothorax* is described only for the right dentary of TTUP 9214 (Fig. 4.3a-c), which is almost complete, though lacking its posterior extremity. The dentary is most distinctive in being extremely slender; Hunt et al. (1993) also described the dentary of NMMNH P-12964 as being "shallow." This is apparently a unique feature of *Typothorax* (particularly compared to the relatively robust lower jaws of *Desmatosuchus*, *Longosuchus*, and *Neoaetosauroides*), and the only proposed cranial autapomorphy not involving the teeth proposed for an aetosaur taxon known to me.

The tip of the dentary is an edentulous beak, as is characteristic of aetosaurs. The very tip is missing, so it is not clear how elongate it was in life; in *Stagonolepis*, *Desmatosuchus*, and *Longosuchus* it extends into a long, sharp tip. The edentulous tip is triangular in cross section as in other aetosaurs, with the lateral (external) side forming the broad base of the triangle, and the apex pointing medially. The ventromedial edge of the triangle is the mandibular symphysis, which is rugose in other aetosaurs but smoother in TTUP 9214, probably due to overpreparation. The symphysis in TTUP 9214 is not nearly as broad as seen in other aetosaurs due to the slenderness of the bone (Fig. 4.3b). The dorsomedial side of the "triangle" forms dorsal surface of the beak. The lateral edge of the beak (the dorsal corner of the "triangle") is a raised sharp edge. Posteriorly, this raised edge slightly borders the row of aveoli, partly concealing them from lateral view (Fig. 4.3b), though not as strongly as in other aetosaurs.

The lateral surface of the rostral end of the dentary is not preserved well enough preserved to identify the nutrient foramina seen in other aetosaurs (Fig. 4.3a). The anteroventral margin of the dentary (the "chin"), where the bone begins to rise anterodorsally to taper to a beak, is unusual among aetosaurs in being a smoothly curving surface (Fig. 4.3a, b). In *Stagonolepis*, the transition is more angular (Fig. 4.3e), and in *Desmatosuchus*, *Longosuchus*, and *Neoaetosauroides*, the "chin" is so pronounced that it dips downward (Fig. 4.3f-h).

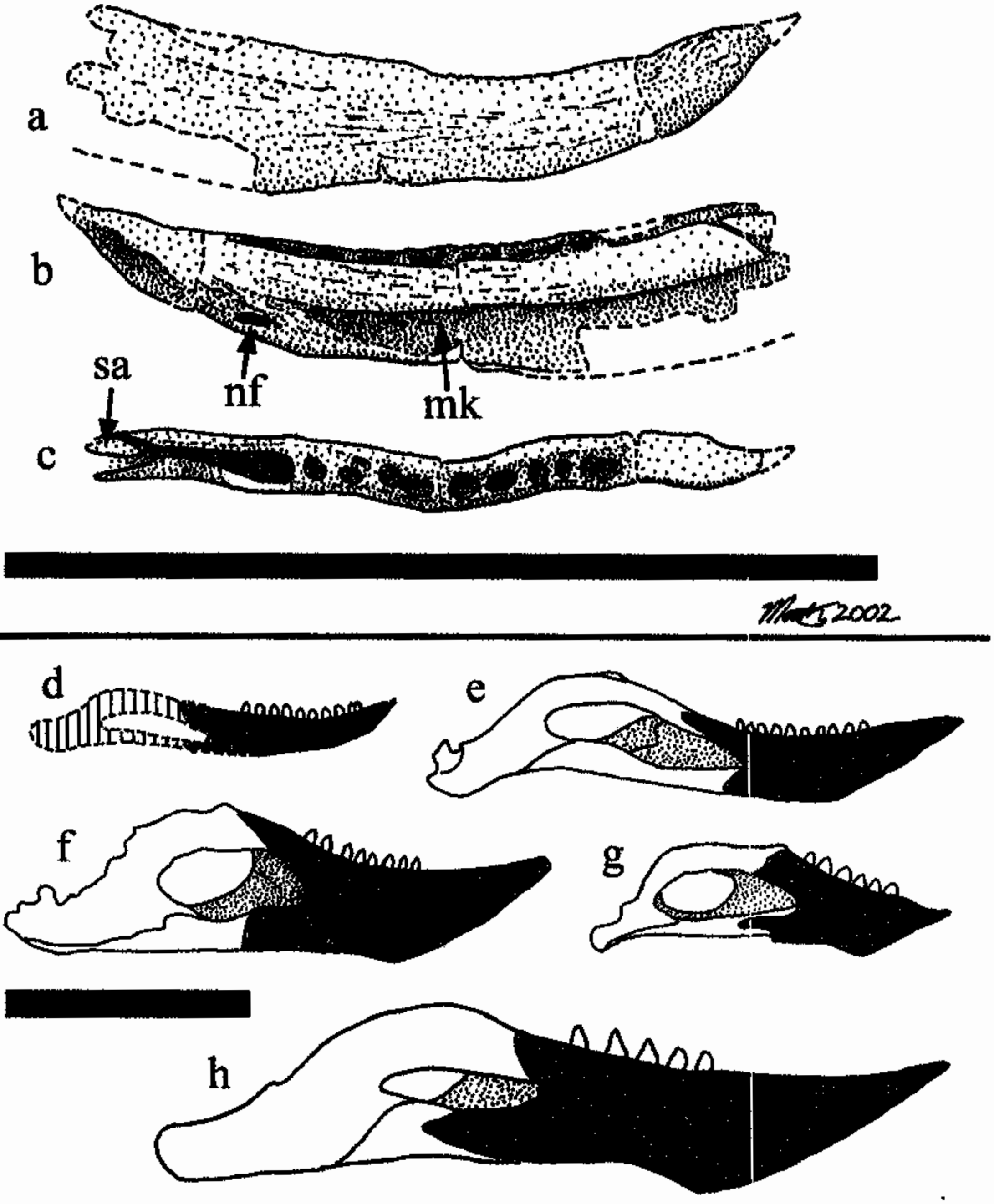

Figure 4.3 Aetosaur mandibles; right dentary of *Typothorax coccinarum* (TTUP 9214) in (a) lateral, (b) medial, and (c) dorsal views; aetosaur mandibles with the dentary shaded, (d) *Typothorax coccinarum* TTUP 9214 (largely reconstructed), (e) *Stagonolepis robertsoni* (after Walker, 1961, fig. 6a), (f) *Longosuchus meadei* (after Parrish, 1994, fig. 6a), (g) *Neoaetosauroides engaeus* (after Bonaparte, 1971, fig. 34), and (h) *Desmatosuchus haploceros* (after Small, 1985, fig. 6a). Dashed lines indicate broken edges. Scale bar = 10 cm.

The row of aveoli is complete, although none contain teeth. Ten aveoli seem to be represented (Fig. 4.3c), as was reported for *Typothorax* by Long and Murry (1995; probably based on NMMNH P-12698). Ten aveoli are also present in *Stagonolepis* (Walker, 1961). Seven aveoli are present in both *Desmatosuchus* (Small, 2002; Long and Murry, 1995) and *Longosuchus* (Sawin, 1947; Parrish, 1994). The first two aveoli in TTUP 9214 seem to be joined, but otherwise there are definite interdental septa, as in all other aetosaurs for which the dentary is known.[11]

Just behind the symphysis, at the front of the Meckelian canal, is a deep nutrient foramina (Fig. 4.3b), which was probably partly overlapped by the splenial as in *Stagonolepis* (Walker, 1961), *Longosuchus* (Parrish, 1994), and *Desmatosuchus* (Small, 1985, 2002). The splenial is absent, so the Meckelian canal is fully exposed. The canal originates about the level of the fourth tooth, farther posteriorly then in *Stagonolepis* (Walker, 1961), and grows taller posteriorly. Due to the shallowness of the dentary, the groove appears deceptively elongate compared to *Stagonolepis*.

Dorsally, above the Meckelian canal and behind the tooth row, the dentary divides into medial and lateral processes enclosing the anterior end of the surangular, of which only a tiny fragment is preserved (Fig. 4.3c). The medial process is complete. It is confluent with and basically and extension of the medial side of the dentary above the Meckelian groove, extending farther posteriorly then in other aetosaurs and maintaining an almost constant thickness almost to its end, where it tapers abruptly as it contacts the surangular (Fig. 4.3b). The dorsal lateral branch is much deeper (Fig. 4.3a), although part of its ventral margin is not preserved, and in fact it is remarkably deeper then the process in other aetosaurs. It also seems to extend further posteriorly then in other aetosaurs, well past the end of dorsal medial process. It is not clear if the mandibular fenestra began below the preserved segment of the process, or more posteriorly (Fig. 4.3d).

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[11] Small (1989b) reported that the dentary of *Paratypothorax* (TTUP 9215) lacks interdental septa and a median symphysis. However, the element he identified as a dentary is in fact the horn of a lateral scute, which bears a strong resemblance to the dentary of *Desmatosuchus*. This is made clear by examination of the more extensive *Paratypothorax* material from Post Quarry at DMNH (Long and Murry, 1995, fig. 113b-e). The "tooth row" lacking septa is the hollow on the posterior side of the horn.

Ventrally, below the Meckelian groove, aetosaurs also possess another process extending posteriorly along the ventral margin of the dentary (Fig. 4.3e-h). The ventral process is not preserved behind the Meckelian groove in TTUP 9214, but judging by how shallow the dentary is below the groove, it was probably very delicate.

4.3. Vertebrae

TTUP 9214 has good vertebral material (Figs. 4.4-4.7; Tables 4.1-4.2), though almost none is recognized for the Canjilon Quarry material aside from a few incomplete caudals identified as *Typothorax* mostly through association with the concentrations of scute material. However, there are seven vertebrae for TTUP 9214 that are complete or mostly complete, many vertebral fragments (including centra, zygapophyses, neural spines, and transverse processes), and at least three incomplete chevrons. All the vertebrae are amphicoelous or slightly platycoelous (sensu Romer, 1954). Incomplete ribs were also associated with TTUP 9214, but are too fragmentary to describe here.

4.3.1. Cervical vertebrae

The only part of the atlas-axis complex recognized is a right atlas neural arch (Fig. 4.5a, b), which was not fused to the centrum. The element is mediolaterally flattened. It consists of a strongly mediolaterally flattened base (which contacted the atlas intercentrum), connected by a short neck to an elongate process. The base is inclined medially and tapers posteriorly. The medial side of the base is deeply concave, with an overhanging lip just below the neck (Fig. 4.5b). The posterior part of the elongate process is longer then the anterior part. It is thicker along its ventral edge and has a sharp dorsal edge. The posterior process is slightly inclined posteromedially, and bears a zygopophyseal facet on the posterior end for articulating with the axis.

Parts of at least five cervical vertebrae are preserved, three of which are mostly complete. These vertebrae can be identified as cervicals by the presence of both

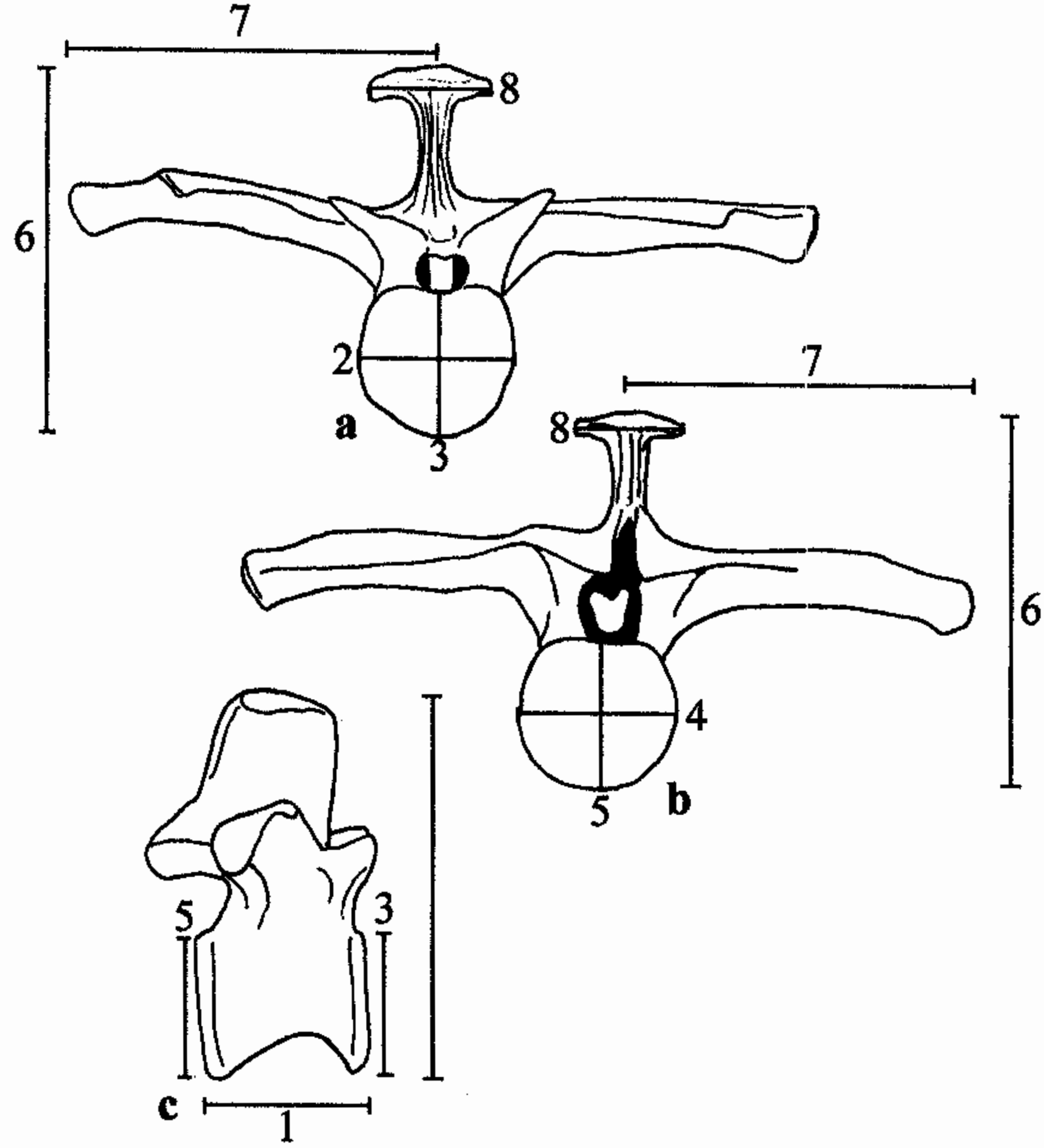

Figure 4.4 Vertebrae measurements given in Tables 4.1-4.2; (a) anterior view, (b) posterior view, (c) left lateral view.

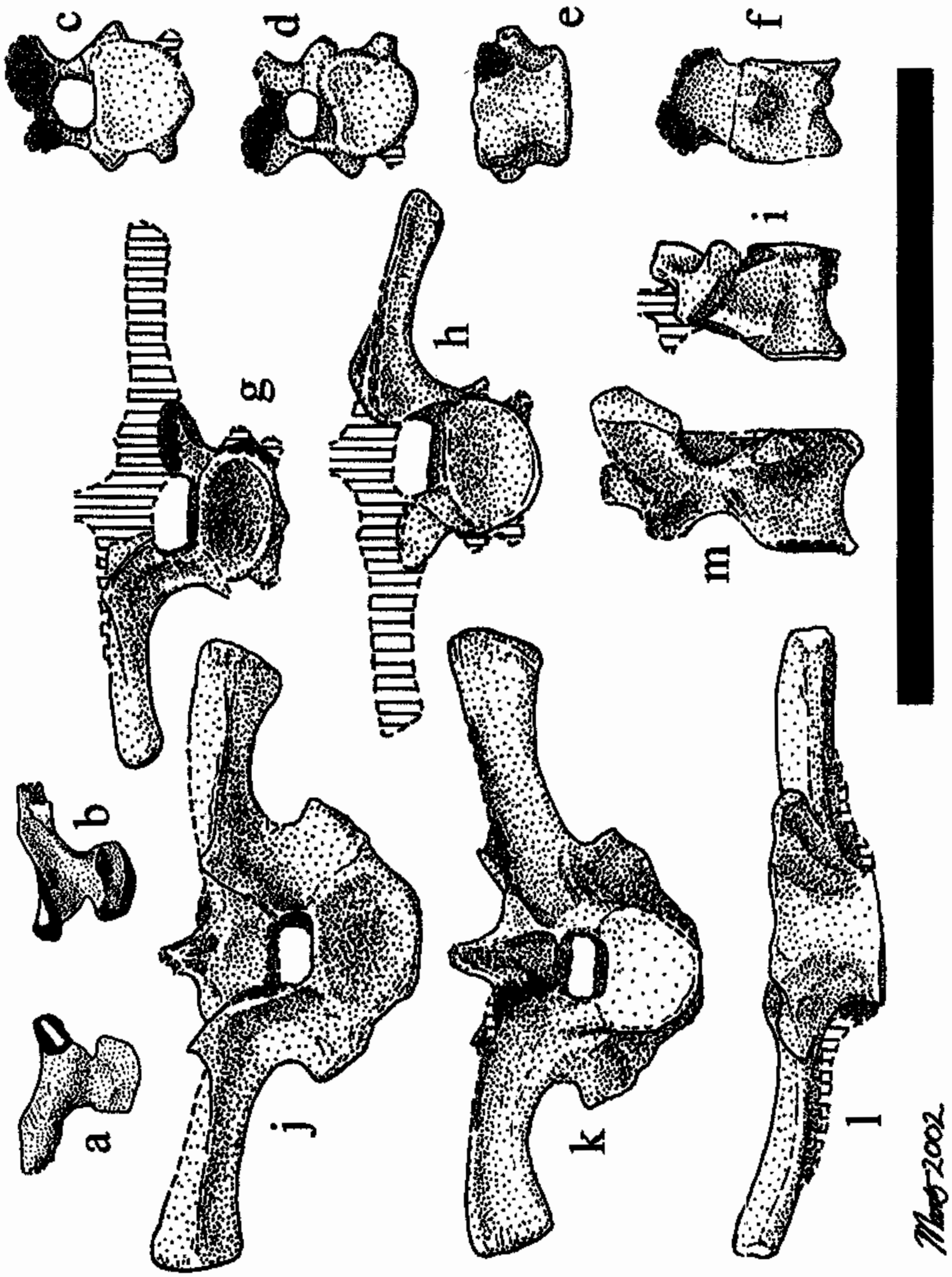

Figure 4.5 Cervical vertebrae of *Typothorax coccinarum* (TTUP 9214); right atlas neural arch in (a) lateral and (b) medial views; anterior cervical vertebra in (c) anterior, (d) posterior, (e) ventral (anterior side up), and (f) right lateral views; mid-cervical vertebra in (g) anterior, (h) posterior, and (i) right lateral views; posterior cervical vertebra in (j) anterior, (k) posterior, (l) ventral (anterior side up) and (m) right lateral views. Dashed lines represent broken bone edges, shading broken bone surface, and hatching reconstructed parts. Scale bar = 10 cm.

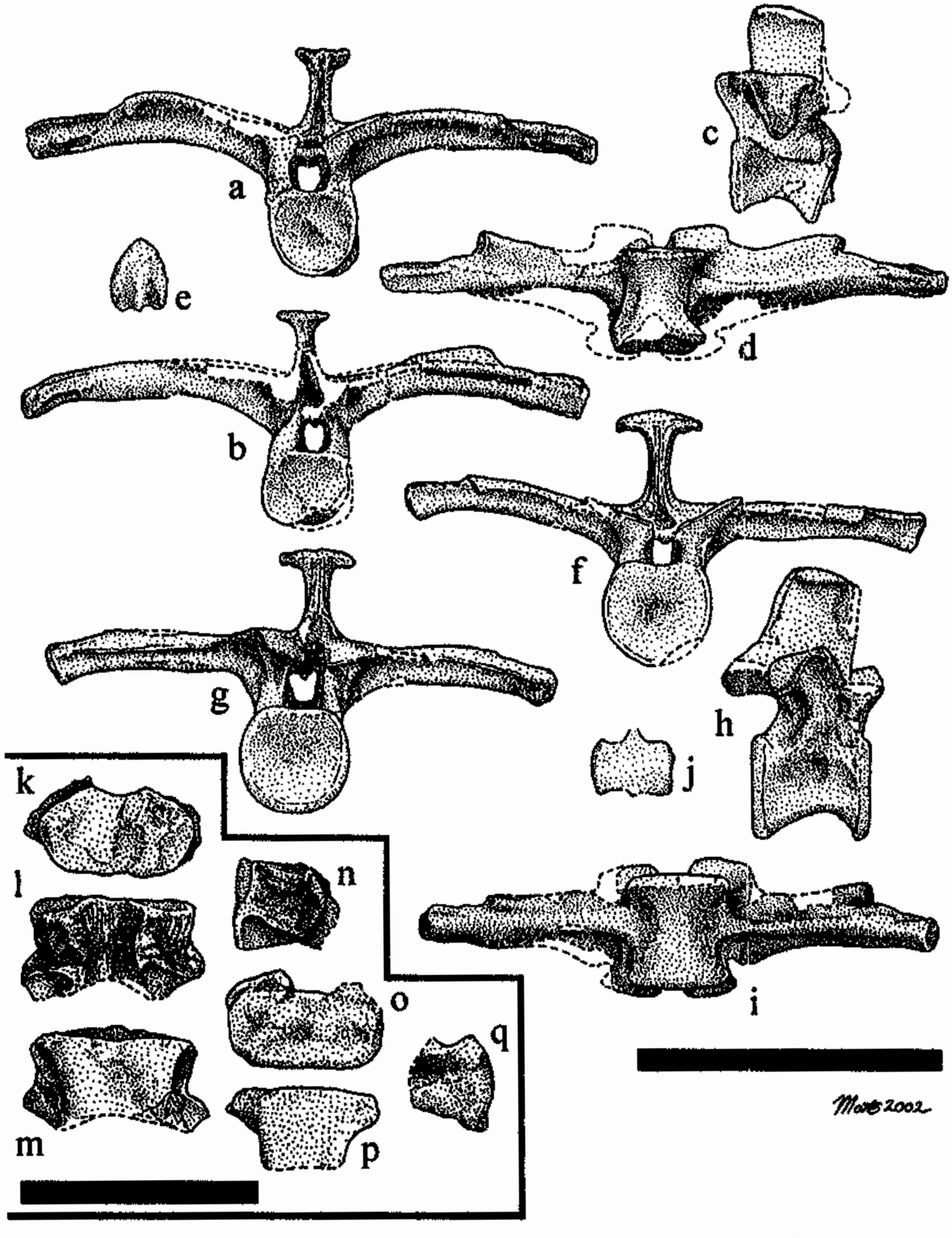

Figure 4.6 Dorsal and sacral vertebrae of *Typothorax coccinarum* (TTUP 9214); middle or posterior dorsal vertebra in (a) anterior, (b) posterior, (c) left lateral, and (d) ventral views, (e) spine table in dorsal view; more posterior dorsal vertebra in (f) anterior, (g) posterior, (h) right lateral, and (i) ventral views, (j) spine table in dorsal view; in lower left hand corner insert, half a sacral vertebra centrum in (k) anterior?, (l) dorsal, (m) ventral, and (n) left? lateral views; half another sacral vertebra centrum in (o) anterior?, (p) ventral, and (q) right? lateral views. Dashed lines represent broken bone edges. Both scale bars = 10 cm.

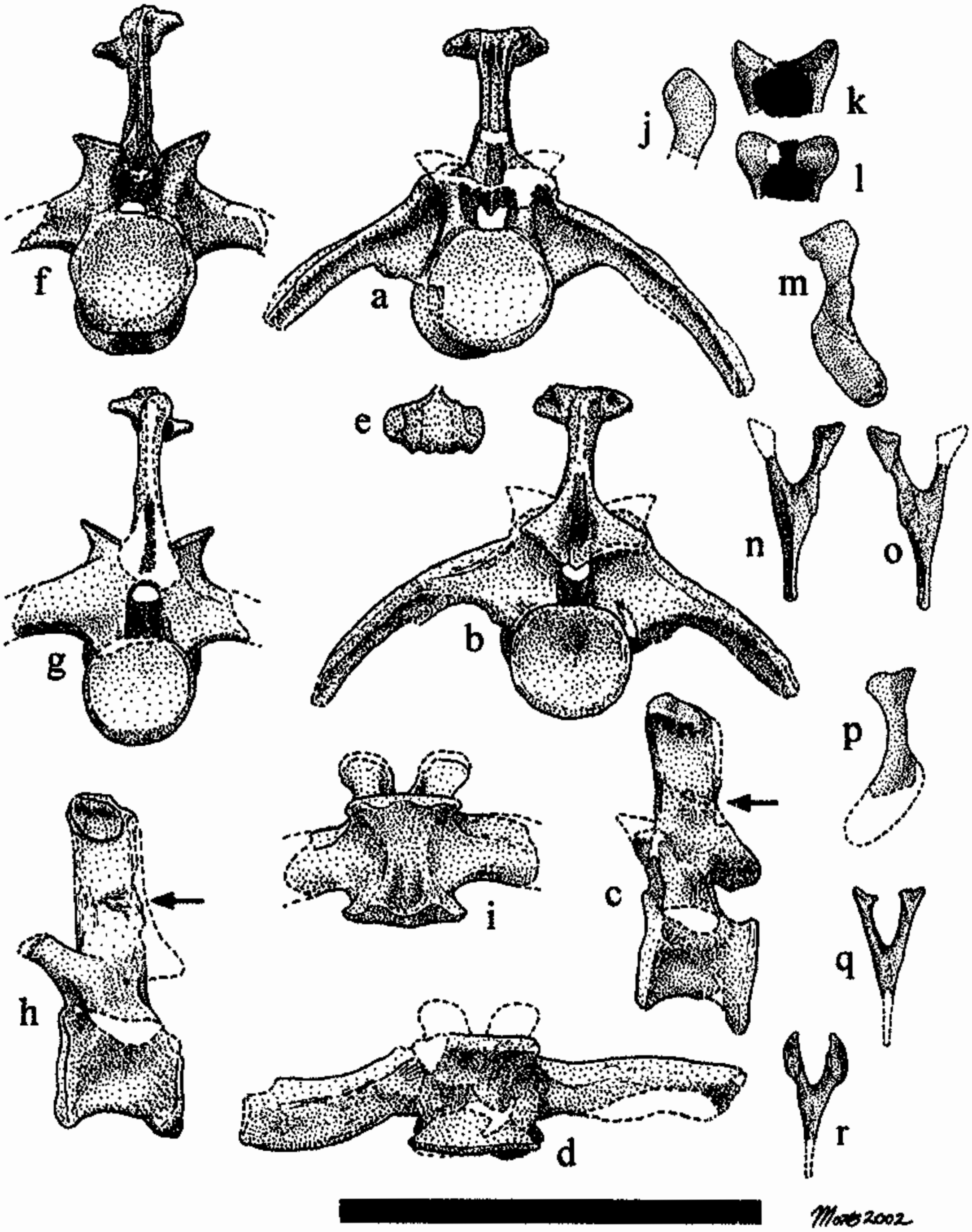

Figure 4.7 Anterior caudal vertebrae and chevrons of *Typothorax coccinarum* (TTUP 9214); first or second caudal vertebra in (a) anterior, (b) posterior, (c) left lateral (the base of the transverse process is cut back to show the side of the centrum), and (d) ventral views, (e) spine table in dorsal view; next caudal vertebra in (f) anterior, (g) posterior, (h) left lateral, and (i) ventral views; "fat" chevron in (j) lateral, (k) posterior, and (l) proximal views; "slim" chevron in (m) left lateral, (n) anterior, and (o) posterior views; incomplete "slim" chevron in (p) right lateral, (q) posterior, and (r) proximal views. Healed breaks on neural spines indicated by arrows. Dashed lines represent broken bone edges. Scale bar = 10 cm.

Table 4.1. Cervical and dorsal vertebrae measurements for TTUP 9214

All measurements are in millimeters, and were rounded off to the nearest millimeter. "NA" refers to measurements that could not be taken due to the vertebra being incomplete. The measurements are explained graphically in Fig. 4.4, numbered as below.

	Anterior cervical (Fig. 4.5.d-g)	?Mid-cervical (Fig. 4.5.h-j)	Posterior cervical (Fig. 4.5.k-n)	More anterior dorsal (Fig. 4.6.a-e)	More posterior dorsal (Fig. 4.6.a-e)
1. Centrum length	14	16	17	31	26
2. Centrum width (anterior face)	16	21	23	29	22
3. Centrum height (anterior face)	15	14	16	27	22
4. Centrum width (posterior face)	17	19	19	30	22
5. Centrum height (posterior face)	13	15	15	27	23
6. Vertebra height (base of anterior face to top of spine)	NA	NA	NA	72	59
7. Width of transverse process	NA	41	50	70	76
8. Width of spine table	NA	NA	NA	21	14

Table 4.2. Anterior caudal vertebrae measurements for TTUP 9214

All measurements are in millimeters, and were rounded off to the nearest millimeter. "NA" refers to measurements that could not be taken due to the vertebra being incomplete. For the transverse process width of the first dorsal, the ">" indicates that the measures process is not complete. The measurements are explained graphically in Fig. 4.4, numbered as below.

	?First caudal (Fig. 4.7.a-e)	?Second caudal (Fig. 4.7.f-i)
1. Centrum length	27	30
2. Centrum width (anterior face)	30	28
3. Centrum height (anterior face)	28	27
4. Centrum width (posterior face)	30	26
5. Centrum height (posterior face)	28	24
6. Vertebra height (base of anterior face to top of spine)	77	77
7. Width of transverse process	>67	NA
8. Width of spine table	25	20

the parapophyses and diapophyses on the centrum and the absence of chevron facets. The three best preserved are interpreted as being from the anterior, middle, and posterior parts of the vertebral column based on their overall size and morphology (Fig. 4.5c-m). The anterior cervical has a complete centrum, but the neural arch is poorly preserved and the transverse processes, zygopophyses, and neural spine are not preserved at all (4.5c-f). The middle cervical also has an almost complete centrum, but only preserves one of the parapophyses (the left); the other rib articulations have apparently been destroyed. It also preserves parts of the neural arches, and the left transverse process and prezygapophysis (4.5g-i). The posterior cervical is almost complete except that it lacks the top of the neural spine and one of the postzygapophyses (Fig. 4.5j-m).

The anterior cervical has the smallest centrum of any of the vertebra, and the articular faces are both roughly circular (Fig. 4.5c, d). The more posterior cervicals have larger, more dorsoventrally compressed, and slightly concave anterior articular faces (Fig. 4.5g, j), while the posterior faces remain more circular and flattened (Fig. 4.5h, k). However, the length of the centra does not increase significantly in the cervical series, and the articular faces are wider then the length of the centra (Table 4.1), though not by 200% as in the *Typothorax* cervicals described by Long and Murry (1995). Some of the articular faces are embayed on the dorsal surface by the neural canal (Long and Murry, 1995, p. 104, described them as "crescent shaped"). No ridge occurs on the bottom of the centrum as reported by Long and Murry (1995), just a lip on the ventral edge of the posterior articular face, which is present only in the anterior and middle cervicals.

Both sets of apophyses are situated closer to the anterior then posterior articular face (Fig. 4.5f, i, m), and the bases of the parapophyses touch the anterior articular surface. The parapophyses in the anterior and middle cervicals project distinctly laterally and just slightly ventrally, and are slightly dorsoventrally compressed, with round rib articulations. The parapophysis in the posterior cervical differ in being almost indiscernible, extremely faint bumps on the anterior articular face (Fig. 4.5j, l). The diapophyses in both the anterior and posterior cervical are more strongly developed then the parapophyses, and are oriented somewhat more ventrally, though they are on a much shorter stem than in the cervicals of *Stagonolepis* (Walker, 1961, fig. 7b) and *Desmatosuchus* (Case, 1922, fig. 11a-d). In the anterior cervical, the diapophysis is slightly dorsoventrally compressed with a round rib facet. However, in the posterior cervical, the diapophyses are very different in being extremely anteroposteriorly flattened flanges with elongate, lateroventrally facing facets level with anterior articular face, and are dorsally confluent with the strut of the "T-beam" of the transverse process (Fig. 4.5j-m). In the middle cervical, the diapophyses cannot be discerned, apparently having been destroyed by the displacement of the neural arch.

In the anterior and middle cervicals, the neural arch is unfused to the centrum, with the suture being clearly distinct all the way around. In the middle cervical, the neural arches have been displaced slightly (Fig. 4.5.g). As noted by Long and Murry (1995), the transverse processes of *Typothorax* are extremely wide compared to other aetosaurs, and this is clear even in the posterior cervical, the processes of which are noticeably wider than in the middle cervical. They probably widened steadily into the dorsal series. In the middle cervical, ridges arise from the anterior and posterior ends of the neural arch and converge to support the base of process, which is roughly round in cross section, and does not show a distinct "T-beam" described by Case (1922). However, the "T-beam" does appear weakly in the posterior cervical, with the dorsal edge of the process being flat with a rounded strut supporting it (Fig. 4.5l, m).

All preserved cervical zygapophyses are oriented at about 45°. The prezygapophyses do not appear as discrete processes (at least in the posterior cervical, the only cervical preserving them), but are part of an "H"-shaped bridge of bone over the neural canal (Fig. 4.5j). The shelf of bone forming the middle of the "H" covers the neural canal dorsally. Descending laterally from this shelf to the anterior articular surfaces along the neural arch are two laminae forming the lower arms of the "H". Two much larger laminae extend dorsolaterally from the shelf at about 45°, protruding slightly above the transverse processes; these are the prezygapophyses. The only preserved postzygapophysis in the cervical series is the right on the posterior cervical (Fig. 4.5k). There the horizontal shelf above the neural canal is present, but the descending laminae are gone, and the postzygapophysis itself is a more stout, narrow processes.

The only cervical neural spine is also on the posterior cervical. The spine has only its base, which appears to have not been nearly as long as the centrum, and in fact not much longer then wide (Fig. 4.5.m; Long and Murry (1995) described it as "rod-like" in their specimen, although in TTUP 9214 at least it is still slightly mediolaterally compressed. The base of the neural spine is deeply cleft posteriorly (Fig. 4.5k).

A partial vertebra similar to, but larger then, the posterior cervical of TTUP 9214 is known from the isolated Patricia Site material, and likely belongs to an adult *Typothorax coccinarum*. Meyer (1865, plate 27, fig. 1-3) figured a very similar vertebra from the Stubensandstein of the German Keuper, currently housed at SMNS, which differs primarily from the posterior cervical of TTUP 9214 in having the anteroposteriorly flattened diapophyses positioned slightly higher, encroaching onto the transverse process. Such a difference would be expected from a slightly more posterior vertebra, as the apophyses move onto the transverse processes in the dorsal series. The vertebra may belong to *Paratypothorax*.

4.3.2. Dorsal vertebrae

Two almost complete vertebrae (Fig. 4.6a-j) are referable to the dorsal region by their extremely wide transverse processes (Table 4.1) bearing both the diapophyses and parapophyses, and the absence of chevron facts. The more massive of the two is presumed to be more posterior. Both dorsals are nearly complete, except that the anterior of the two lacks all zygopophyses except for the left prezygapophysis.

In the dorsals, the articular faces are all platycoelous (sensu Romer, 1954), and their dorsal surfaces are slightly flattened by the neural canal. The articular faces are roughly circular in both vertebrae. However, in the anterior dorsal, the anterior face (Fig.

4.6a) is very slightly laterally compressed. The anterior face of the more posterior dorsal bears a trace of the notochordal pit (Fig. 4.6f).

The zygapophyses are very broad, and oriented at roughly 20° from the horizontal, more shallowly then in the cervicals (Fig. 4.6a, f, g). The prezygapophyses are supported ventrally by stout pillars flanking the neural canal on either side, which are roughly flush with the anterior articular face of the centrum in lateral view (Fig. 4.6e, h). In contrast, in lateral view a deep embayment occurs between the postzygapophyses and the centrum, so that the former hang out over the latter. A deep cleft between the postzygapophyses cuts into the back of the neural spine (as in the posterior cervical); this cleft is deeper in the posterior vertebra (Fig. 4.6b, g).

The transverse processes are extremely elongate, much more so then in *Desmatosuchus* (Case, 1922), *Longosuchus* (Sawin, 1947), or *Stagonolepis* (Walker, 1961), and oriented almost horizontally. The "T-beam" is well developed. The wide, flat dorsal surfaces of the processes, forming the cross bar of the "T-beam," are slightly dorsally convex, and tilt slightly posteriorly. The ventral strut of the "T-beam" divides the cross bar into an anterior and a posterior flange. The anterior flange of the "T-beam" cross bar is broader then the posterior flange, and the difference is more pronounced in the anterior dorsal. The ventral strut of the "T-beam" becomes thicker and more rounded distally (Fig. 4.5d, i). Both rib facets lie distally on the transverse process. The anterior flange terminates sharply at the parapophysis (Fig. 4.5a, f), but a much thinner flange continues past it to merge with the distal end of the process (which is the diapophysis). In the more anterior dorsal, this thin flange curves ventrally so that it almost reaches the underside of the distal end of the process (Fig. 4.5a; especially visible on the left side), but in the posterior dorsal it stays in the same plane so that it merges with the top of the process (Fig. 4.5f). The posterior flange of the "T-beam" also dies out distally, essentially leaving only the thickened strut of the "T-beam" to form the distal end of the process. Shallow pockets that lie between the prezygapophyses and transverse processes are deeper in the more posterior dorsal.[12]

The neural spines are short dorsoventrally, but much more elongate anteroposteriorly then in the cervicals, running the length of the centrum; as noted by Long and Murry (1995), they are much more plate-like then the cervical neural spines. The anterior edge is vertical, but the posterior edge slopes posteroventrally in lateral view (Fig. 4.5c, h). Both dorsals have wide spine tables, though they differ slightly in form. In the anterior dorsal, the table is more heart-shaped in dorsal view, with the wider end anterior (Fig. 45.e). Similar heart-shaped tables are observed in the dorsal vertebrae of *Desmatosuchus*. In the posterior dorsal, the table is subrectangular (Fig. 4.5j).

4.3.3. Sacral vertebrae

Probably only two sacral vertebrae were present in *Typothorax*, as in most pseudosuchians. TTUP 9214 preserves parts of both sacral centra, although neither is complete (Fig. 4.6k-p). The centra are broken in the middle, and two of these broken ends probably belong to a single sacral, though there is bone missing in between, while the second larger sacral is represented only by one end of the centrum. The sacral ribs and neural spines are missing, although two of the sacral fragments preserve the bases of the neural arch (on is shown in Fig. 4.6k-n). It is not clear how to orient these centra (which end was anterior); examination of other pseudosuchian sacrals suggests that the neural arches attach closer to the anterior side of the anterior sacral, and the posterior side of the posterior sacral. However, it is unclear which half-centrum preserving the arches is which.

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[12] Slightly shallower depressions are also seen in the dorsal vertebrae of *Desmatosuchus*. Gower (2000) identified similar pockets in the dorsal vertebrae of basal archosauriformes and some pseudosuchians, and suggested they indicated postcranial pneumaticity. If correct, this is significant because it suggests that pneumaticity is a plesiomorphic for crown-clade archosaurs, and that its absence in crocodilians is a secondary loss; however, O'Connor (2002) doubts that these depressions indicate true postcranial pneumaticity based on his observations of extant archosaurs.

The centra are extremely peculiar compared to the other TTUP 9214 vertebrae in having flattened bottoms (Fig. 4.6m, p); this is also the case of the sacrals in phytosaurs (Axel Hungerbühler, personal communication, 2002). The articular faces are strongly dorsoventrally compressed then those of any of the other vertebrae (Fig. 4.6k, o), though they are roughly as *wide* as the adjacent posterior dorsals and anterior caudals. The bases of the neural arches extend far down the centrum, almost to the ventral edge. The ribs appear to have been incompletely ossified to the centrum, leaving only part of the arch and an extremely rugose suture behind (Fig. 4.6.l, n).

4.3.4. Caudal vertebrae

Two vertebrae are referable to the anterior caudal region (Fig. 4.7a-i; Table 4.2). They articulate with each other well enough that they may have been adjacent in life, probably representing the first and second or second and third caudals. The larger vertebra is probably more anterior, and it is fairly complete except for the prezygapophyses and the distal ends of the transverse processes (Fig. 4.7a-e). The smaller, more posterior caudal (Fig. 4.6f-i) lacks the postzygapophyses and most of the transverse processes. They can be identified as caudals by the way the centra dip posteriorly, with the posterior face set lower the anterior face; in the posterior dorsals, the centra slope up (see Sawin, 1947, fig. 9.2, 9.6; Walker, 1961, figs. 10b, e). The caudals can be identified as coming from the extreme anterior part of the caudal series due to the absence of chevron articular facets in the more anterior caudal, and the weakly developed ones of the more posterior caudal.

The articular faces of these vertebrae are almost circular (as in the dorsals), although the anterior face in both shows subtle lateral bulges where the inflated neural arches contact it (Fig. 4.6a, b, f, g). Although no chevron facets are visible on the anterior centrum, the posterior centrum shows a faint trace of chevron facets on the ventral edge of the *anterior* articular surface, for the chevron wedged between it and the more anterior dorsal, in addition to the chevron facets on the posterior articular surface.

The base of the anterior face of the more posterior caudal appears flat due to the chevron facets, making the articular face almost hexagonal (Fig. 4.7f). The underside of the more anterior caudal centrum is fairly well rounded (Fig. 4.7d; this is hard to tell from the figure due to distortion), but that of the more the posterior centrum has faint, paired ridges leading anteriorly from the posterior chevron facets (Fig. 4.7i).

The transverse processes curve strongly ventrolaterally (evident even in the smaller of these vertebra, even though only the bases are present). The processes in the more anterior vertebrae are slightly constricted proximally, but broaden slightly not far from the centrum to about the same width as in the dorsal vertebrae (Fig. 4.7d). The "T-beam" is still developed in the anterior caudals, but the posterior flange of the cross beam of the transverse process is not very distinct from the strut, as can be seen in the broken cross sections of the processes (Fig. 4.7c, h). Distally, the strut is less thick than in the dorsals, but proximally it becomes dramatically thickened, greatly inflating the base of the neural arch, which extends almost half way down the sides of the centrum; the neural arch is especially inflated in the more anterior vertebra (Fig. 4.7a, b). At least in the larger vertebra, the suture of the arch is visible, and seems to be incompletely fused to the centrum. The transverse processes and neural arch are both set slightly anteriorly on the centrum (Fig. 4.7c., h). The neural canal slopes posteroventrally with the centrum. Anteriorly, the opening is sub-circular (Fig. 4.7a, f); posteriorly, it is more dorsoventrally elongate (Fig. 4.7b, g).

The prezygapophyses continue the shallowing angle trend seen in the cervicals and dorsals, being set at about 10° from the horizontal (Fig. 4.7b, f). In the more anterior caudal, the postzygapophyses are considerably larger, and their articular surfaces are slightly concave (Fig. 4.7b). As with the dorsals, the bases of the prezygapophyses are confluent with the anterior face of the centrum (Fig. 4.7c, h). In the posterior of the two vertebrae, the prezygapophyses extend strongly anterodorsally. The anterior flange of the transverse process merges smoothly with the prezygapophyses.

The neural spines differ from those of the dorsals in being taller and not as anteroposteriorly elongate as the centra (Fig. 4.7c, h). On the left lateral surface of both neural spines is a rugose region less then half the distance up the spine (indicated with arrows in Fig. 4.7c, h), which is roughly level on both spines when the vertebrae are in articulation. These rough areas are interpreted as being pathological, possibly representing a healed break. The table of the anterior caudal is better preserved; it is subrectangular as in the posterior dorsal (Fig. 4.7e), though wider then seen in that vertebra, and it slopes posteriorly. One striking thing about the table is that the wings seem to be unfused to the neural spine; in the more posterior dorsal, one of the wings is partly displaced down the spine (Fig. 4.7f, g).

4.3.5. Chevrons

At least four chevrons are recognized, though they appear to be two distinct types. It is possible that at least one of these types of chevrons does not belong with TTUP 9214. The best-preserved chevrons are referred to here as "slim" (Fig. 4.7n-r). The articular branches are mediolaterally flattened (Fig. 4.7n, o, q). The facets pinch anteriorly (Fig. 4.7r), and tilted just slightly medially (Fig. 4.7n, o, q). The surfaces of the facets are faintly concave. The distal ends of the chevrons are also laterally compressed, and in lateral view are smoothly rounded, resembling the ends of a hockey stick (Fig. 4.7m). The chevrons of the Canjilon Quarry "U" specimen tail block (Fig. 4.24d) appear to be similar, but are more flattened ventrally.

Some incomplete chevrons differ from the "slim" type and are described here as "fat". The articular facets are very wide, sub-circular in proximal view (Fig. 4.7.l), and strongly inclined medially (Fig. 4.7k). The flattened necks are much broader anteroposteriorly then the slim type in lateral view (Fig. 4.7j). Where the branches meet, the anterior edge of the chevron is thicker then the posterior edge, which is sharp. The "fat" chevron is also oriented posteroventrally, but the shape of the end of the blade is unknown.

4.4 Appendicular skeleton

The primary purpose of this paper is descriptive, but some discussion of myology and functional morphology will be included where they seem to show variation within or between taxa, or particular functional inferences for *Typothorax* might be made. Meers (1999) described the myology and functional morphology for the crocodilian forelimb, and his terminology and interpretations are applied here. Romer (1923), Rowe (1986), and Brochu (1992) described the muscles of the hind limb in *Alligator* and other crocodilians, and their terms are likewise used. Additional insights of the functional morphology of the hind limb in basal archosaurs, extrapolated largely from extant crocodilians and birds, were provided by Charring (1972) and Parrish (1986). These comparisons, made almost entirely with crocodilians, are extremely tentative, and should be approached with caution given the morphological and probable functional differences between crocodilians and other pseudosuchians (Parrish, 1986). Following Romer (1954), the terms "anterior" and "posterior" (rather then "dorsal" and "ventral") are used as with the other elements to describe respectively the sides of the humerus and the femur facing the skull and the tail.

4.4.1 Scapulocoracoid

An excellent *Typothorax* left scapulocoracoid is known for the Canjilon Quarry "U" specimen (UCMP V2816 34255 70/U80; Fig.4.9a-e), though no others are known from either the Canjilon or Post Quarries. The Patricia Site left scapulocoracoid associated with the scutes of TTUP 10070 is identical. Both are almost complete, clearly non-phytosaurian in having an enclosed coracoid foramen, and distinctly aetosaurian in the blade having an expanded apex (Long and Murry, 1995). The anterior edge of the coracoid is missing in both specimens. Measurements of the scapula of *Typothorax* and *Desmatosuchus* are given in Table 4.3, and explained graphically in Fig. 4.8.

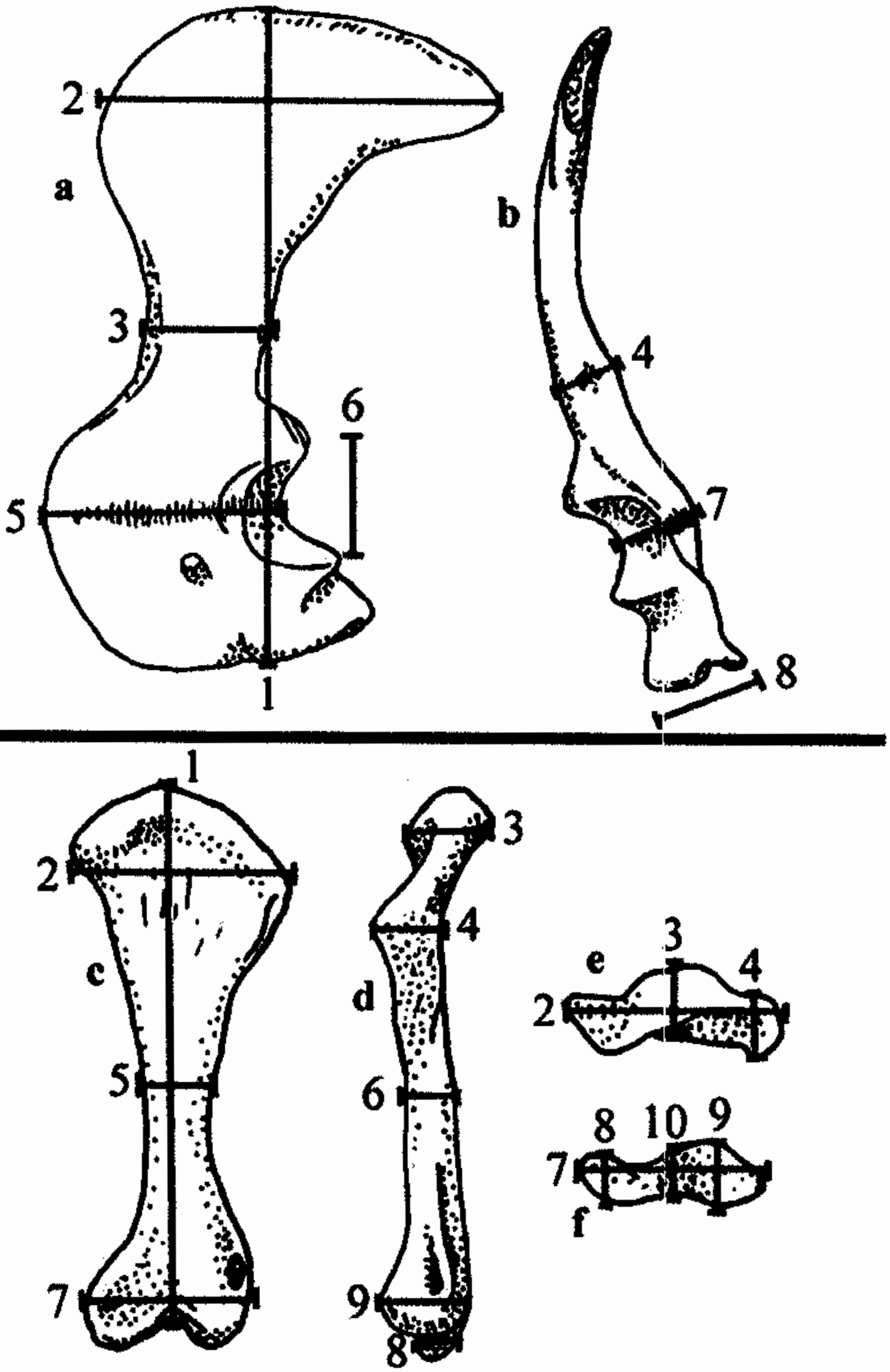

Figure 4.8 Appendicular skeleton measurements given in Tables 4.3-4.4; scapulocoracoid measures (Table 4.3) in (a) lateral, and (b) posterior views, humerus measures (Table 4.4) in (c) anterior, (d) lateral, (e) proximal, and (f) distal views.

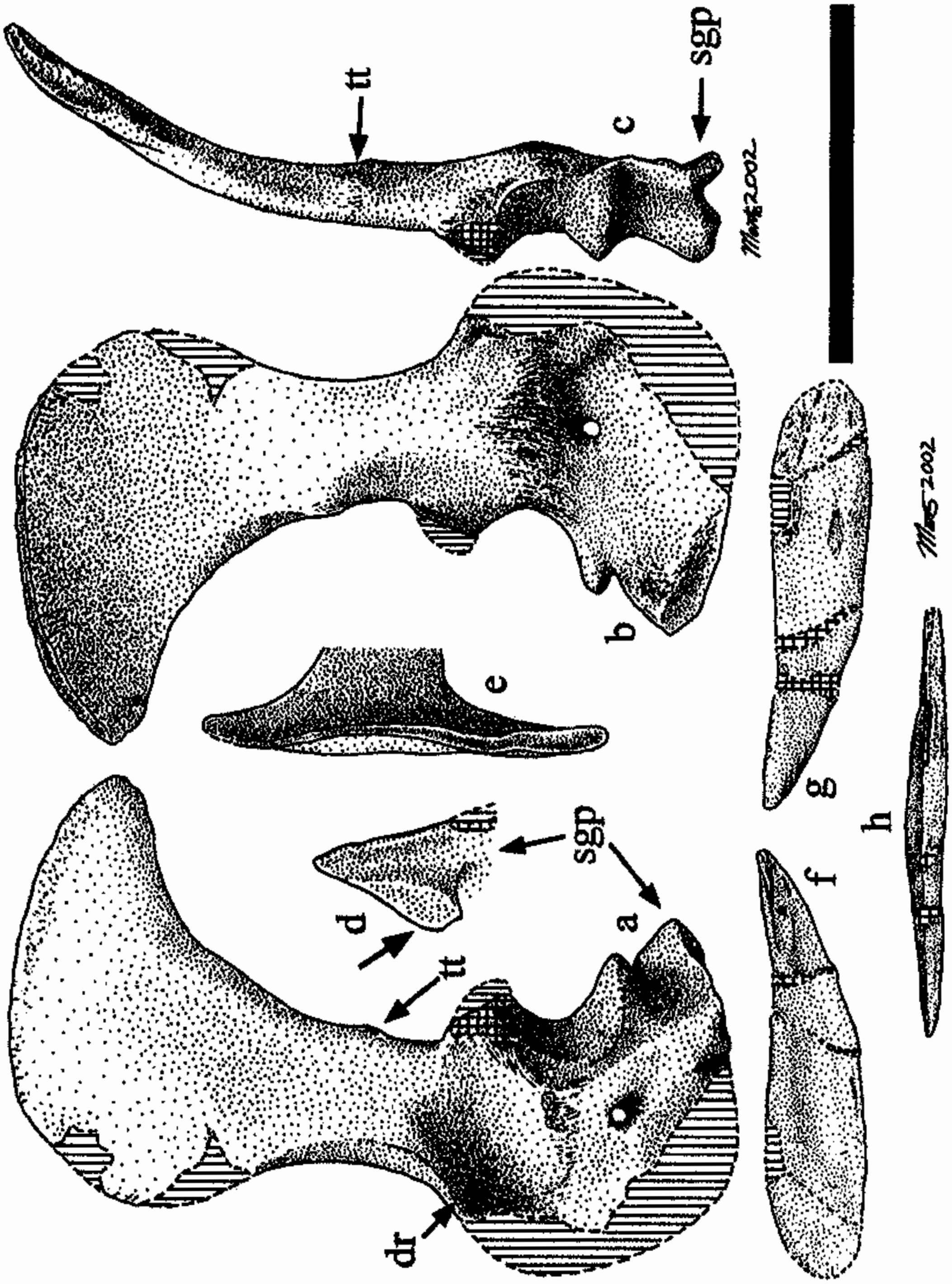

Figure 4.9 Pectoral material of *Typothorax coccinarum* from Canjilon Quarry; left scapulocoracoid UCMP V2816 34255 70/U80 in (a) lateral, (b) medial, (c) posterior views, (d) ventral view of subglenoid pillar (unlabelled arrow points to the rounded knob), (e) dorsal view of scapular blade; left clavicle UCMP V2816 158672 70/J83 in (f) lateral, (g) medial, and (h) dorsal views. Dashed lines indicate broken bone, cross hatching broken bone surface, and hatching reconstructed areas. Scale bar = 10 cm.

Table 4.3. Aetosaur scapulocoracoid measurements

All measurements are in millimeters. "NA" refers to measurements that could not be taken due to the scapulocoracoid being incomplete. For height of the TTUP 10070, the ">" indicates that the top of the blade is incomplete, so the actual height was larger then the measured. The presence of a (l) or (r) after specimen number indicates if the femur was left or right. The measurements are explained graphically in Fig. 4.10, numbered as below.

	Typothorax UCMP V2816 34255 70/U80 (l) (Fig. 4.9.a-c)	TTUP 10070 (l)	*Desmatosuchus* TTUP 9023 (r) (Small, 1985, fig. 7)
1. Height of bone from base of glenoid pillar to apex of blade	203	>200	413
2. Length of apex	119	NA	NA
3. Length of blade at triceps tubercle	38	40	91
4. Thickness of blade at triceps tubercle	15	14	26
5. Length along scapulo-coracoid suture	NA	NA	155
6. Height of glenoid	40	NA	76
7. Thickness of glenoid	24	27	42
8. Width of pillar	29	29	34

The dorsal apex of the blade projects more strongly posteriorly then anteriorly (Fig. 4.9a, b). The expanded anterior part of the apex is a gently rounded crest that extends some distance down the shaft, and is much thinner then the posterior edge. As noted by Long and Murry (1995), the anterior apex appears to be more angular in lateral view in *Stagonolepis robertsoni* (Walker, 1961, fig. 12a) and *Neoaetosauroides* (Bonaparte, 1971, fig. 36). As in crocodilians, the anterior edge of this expansion may have provided the attachment site of muscles that served as anterior rotators of the scapula during locomotion (the *m. levatator scapulae* and *m. trapezius*). However, most of the lateral surface of this anterior expansion was probably occupied by the *m. deltoideus scapularis*, which in crocodilians serve primarily to stabilize the shoulder, and also participates in humeral adduction (Meers, 1999).

The posterior edge of the scapula blade, including the apex, is much thicker in *Typothorax* then the anterior edge (Fig. 4.9c). This is the usual case in tetrapods (Romer, 1954), but not in *Desmatosuchus* and *Longosuchus*, where both the anterior and posterior edges of the blade are sharp, and the shaft is thickest along its middle. The expanded posterior apex of the scapula is oriented more or less horizontally and ends fairly acutely in *Typothorax* (Fig. 4.9a, b). In *Desmatosuchus*, *Longosuchus*, and *Lucasuchus*, the posterior apex is oriented more posterodorsally and is more broadly rounded (see Small, 1985, fig. 7a; Long and Murry, 1995, figs. 62A, 66D). Walker (1961) noted that larger (and possibly male) specimens of *Stagonolepis* have a less acute posterior apex than the smaller (and possibly female) specimens, which he suggested was due to an ossified suprascapula in the former. The dorsal edge of the apex in UCMP V2816 34255 70/U is faintly sulcate and rugose (Fig. 4.9e), suggesting that an unossified suprascapula was present, consistent with Walker's suggestion. However, this sulcate and rugose dorsal edge is also present in *Lucasuchus* (TMM 31100-2), which has a broader posterior apex, indicating that the latter condition is not necessarily due to ossification of the suprascapula. Both the medial and lateral surfaces of the posterior apex are strongly striated in TTUP 10070. This is not apparent in the "U" scapula, but the absence may be due to overpreparation. By comparison with crocodilians, the lateral surface of the posterior apex was probably the attachment site of *M. teres major*, and the thickened posterior edge of the blade below the apex was the attachment site of the *m. scapulohumeralis caudalis*. Both serve to elevate the humerus and flex and stabilize the glenohumeral joint in crocodilians (Meers, 1999). However, the posterior edge of the scapula is the attachment site of branches of the *m. serratus ventralis*, and so it is likely that the posterior expansion served primarily to provide more attachment area for that muscle. The function of *m. serratus ventralis* was not discussed by Meers (1999), but its position opposite *the m. levator scapulae* and *m. trapezius* suggests it may also rotate the scapula. The fact that the anterior and posterior edges of the apex of the scapular blade, which are expanded in aetosaurs, provide attachment sites for muscles that may serve in rotating the scapula during locomotion in crocodilians (Meers, 1999) suggests that rotation of the scapulocoracoid may also have taken place during locomotion in aetosaurs.

A fairly smooth surfaced and barely discernible bump is located above the glenoid on the posterior edge of the blade, less than a third of the distance between the supraglenoid buttress (about 4 cm above it) and the tip of the posterior tip of the apex. This may have been the triceps tubercle, the origin of a branch or branches of the *M. triceps brachii* (Meers, 1999). In *Desmatosuchus*, this tubercle is sharp edged, like the rest of the posterior edge.

A laterally projecting shelf extends anteriorly from the anterior base of the shaft of the scapula. Brochu (1992) referred to this shelf in *Alligator* as the "deltoid ridge," noting that its homology with the acromion process of mammals is doubtful (Fig. 4.9a). The ridge is nearly as prominent (relative to the scapula) in *Typothorax* as it is in *Desmatosuchus*. By analogy with crocodilians, the "deltoid ridge" and the laterally beveled anterior edge of the blade (below the apex) probably provided the origin of the *m. deltoideus clavicularis*, and the concave area beneath the deltoid ridge probably provided the origin of the *m. coracobrachialis*. Both the muscles are important in humerus protraction and stabilizing the shoulder joint in crocodilians (Meers, 1999). On the medial side of the scapula, opposite the tip of the deltoid ridge is a tuberosity that may have helped stabilize the clavicle (Fig. 4.9b).

The suture between the scapula and coracoid is discernible, and is conspicuously thickened on both the medial and lateral sides. The suture runs roughly through the center of the glenoid, so that the latter is almost evenly shared between the scapula and coracoid. The "ridge" on the glenoid reported by Case (1922) and Walker (1961) probably refers to the suture.

The coracoid foramen is roughly the same absolute size in *Typothorax* as in *Desmatosuchus* in spite of the overall size difference between the bones. The foramen is located just anterior to the lower lip of the glenoid, and runs ventrolaterally through the bone, entering on the medial side of the coracoid, just below the medial swell of the scapulocoracoid suture (Fig. 4.9b), and exiting slightly below this on the lateral side (Fig. 4.9a).

The glenoid fossa in *Typothorax* faces posterolaterally as in other aetosaurs. The lower lip of the glenoid (on the coracoid) projects more strongly posteriorly than the supraglenoid buttress (the upper lip, on the scapula). Viewed posteriorly (Fig. 4.9c), the lower lip of the glenoid does not project medially in *Typothorax* as indicated for *Stagonolepis* by Walker (1961, fig. 12b).

The subglenoid pillar in *Typothorax* is about as prominent (relative to the overall size of the scapulocoracoid) as in *Desmatosuchus*. The lateral surface of the pillar, just below the glenoid, may have been the origin of the *mm. costocoracoideus*, which is probably a rotator of the scapula in crocodilians (Meers, 1999). The pillar projects backward as a tapering process (Fig. 4.9a, b), apparently more sharply then in most other aetosaurs (Walker, 1961, fig. 12c; Small, 1985, fig. 7a; Long and Murry, 1995, figs. 62a-8, 66c) except for *Neoaetosauroides* (Bonaparte, 1971, fig. 36), which has an extremely well developed pillar. Viewed ventrally, (Fig.4.9d), the pillar in *Typothorax* is strongly triangular. As noted by Long and Murry (1995, p. 104), it has a distinct "rounded knob which flares laterally from the main body of the coracoid" rather then merging smoothly with the rest of the lateral surface of the coracoid (the left corner of the "triangle", indicated by an unlabeled arrow in Fig. 4.9d). This "knob," apparently absent in other aetosaurs, may have provided additional surface area for the *mm. costocoracoideus*, possibly assisting the rotation of the scapulocoracoid in aetosaurs during locomotion. In ventral view the pillar is longitudinally grooved, also noted by Long and Murry (1995). The ventromedial edge of the pillar has a striated site of tissue attachment, possibly to bind the bone to the interclavicle (Fig. 4.9b).

4.4.2 Clavicle

UCMP V2816 34228 70/J83 is an enigmatic element found in "Fa" *Typothorax* concentration in square 70/J. It resembles slightly a phytosaur clavicle (the only other common vertebrate in Canjilon Quarry), but differs somewhat in being more flattened (Axel Hungerbühler, personal communication, 2001). Based on this slight similarity, and its association with material of the "Fa" specimen, the element is tentatively identified as a left clavicle of *Typothorax* (Fig. 4.9f-h). However, some other material found in the vicinity is clearly phytosaurian (see Appendix), so this identification is debatable.

The clavicle has a fairly straight and laterally compressed body, which is slightly convex laterally, and slightly flatter medially (Fig. 4.9h). In lateral and medial views, the end interpreted as being proximal tapers to a sharp point, with the dorsal edge being straight and the ventral edge curving upwards to meet it (Fig. 4.9f, g). The curved ventral edge would have rested on the deltoid crest. As in phytosaurs (Camp, 1930; Lawler, 1974), deep striations on the lateral side on the scapular end run parallel to the long axis of the element. The ventral end of the element, which would have contacted the interclavicle, is missing and it is difficult to know how much is gone. In both phytosaurs and *Stagonolepis*, the only aetosaur for which the clavicle is described (Walker, 1961, fig. 12a), the clavicle appears to be more continuously curved throughout its length, and at least in phytosaurs, it is much thicker and not very laterally compressed.

4.4.3 Humerus

The UCMP Canjilon Quarry material includes several partial and mostly complete humeri, all under the specimen number 34240 (Tables 2.1, 4.4). Two fairly complete and well-preserved right humeri are from the "Fa" (34240 70/J9[13]; Fig. 4.10a-e) and "G" specimens (34240 70/G; Fig. 4.10f-j). Four other humerus fragments are also referable to *Typothorax*, a proximal end (34240 70/G3) and three distal ends (34240 70/E, 34240 70/U93, and a third 34240 without a field number). TTUP 9214 includes the proximal end and most of the shaft of the right humerus (Fig. 4.10k-n), but is missing its distal end. The humerus assigned by Cope (1887) to AMNH 2713 (the holotype of "*Episcoposaurus horridus*") appears phytosaurian as figured by Huene (1915, fig. 25), and he was probably correct in removing it from "*Episcoposaurus*" (contra Gregory, 1953).

The proximal end of the humerus curves very slightly backwards (Fig. 4.10c, d, m, n), and the peak of the strongly convex proximal edge is greatly thickened where it articulated with the glenoid of the scapulocoracoid, more notably so on the posterior side (Fig. 4.10b, l). Both conditions are typical of basal archosaurs (Romer, 1954). The articular thickening is greater in 34240 70/J9 than in TTUP 9214 (measured as "head thickness" in Table 4.4), but is more pronounced still in *Desmatosuchus*. The surface of the thickening is faintly rugose in TTUP 9214, but smooth in the Canjilon Quarry humeri. The latter condition is almost certainly due to overpreparation, especially in UCMP 34240 70/G, where the head has been largely re-shaped.

As noted by Long and Murry (1995), the anterior surface of the head of the humerus of *Typothorax* is more or less flat (Fig. 4.10a, k), rather then broadly concave as in *Desmatosuchus*, *Longosuchus*, and apparently *Stagonolepis* (Walker, 1961, fig. 14b). In crocodilians, this region is the attachment site of the *m. coracobrachialis brevis ventralis* (which partially extends onto the deltopectoral crest), a versatile muscle that

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[13] Long and Murry, 1995, fig. 105C. Long and Murry, 1995, fig. 105D-E probably belongs to a phytosaur.

Table 4.4. Aetosaur humerus measurements

All measurements in millimeters, except for the ratio of length to proximal head width. "NA" refers to measurements that could not be taken due to the humerus being incomplete. The presence of an (l) or (r) after specimen number indicates if the humerus was left or right. Measurements for MCZ 1448 come from Gregory (1953). The measurements are explained graphically in Fig. 4.8, numbered as below.

	Typothorax TTUP 9214 (r) (Fig. 4.10.k-m)	MCZ 1448	UCMP V2816 34240 70/J9 (l) (Fig. 4.10.a-e)	UCMP V2816 34240 70/G (r) (Fig. 4.10.f-k)	UCMP V2816 34240 70/G3
1. Length	NA	175	158	157	NA
2. Head width	52	NA	68	NA	NA
3. Head thickness	15	NA	17	NA	NA
4. Deltopectoral crest thickness	16	NA	14	NA	NA
5. Mid-shaft width	14	NA	21	19	NA
6. Mid-shaft thickness	15	NA	13	14	NA
7. Distal end width	NA	NA	50	55	62
8. Medial condyle thickness	NA	NA	15	13	15
9. Capitellum (lateral condyle) thickness	NA	NA	26	21	19
10. Trochlea thickness	NA	NA	16	19	14

Table 4.4. Continued

	Typothorax UCMP V2816 34240 70/U93	UCMP V2816 ?	*Desmatosuchus* TTUP 9170 (r) 25831 C65 (Small, 1985, fig. 8)	UCMP A269 32184 CF48	UCMP A269 (L& M, 1995, fig. 81C)
1. Length	NA	NA	323	223	232
2. Head width	NA	NA	156	128	141
3. Head thickness	NA	NA	52	31	37
4. Deltopectoral crest thickness	NA	NA	54	44	41
5. Mid-shaft width	NA	NA	48	33	31
6. Mid-shaft thickness	NA	NA	34	26	25
7. Distal end width	63	55	123	96	99
8. Medial condyle thickness	23	19	61	40	39
9. Capitellum (lateral condyle) thickness	34	28	48	42	30
10. Trochlea thickness	24	14	34	32	36

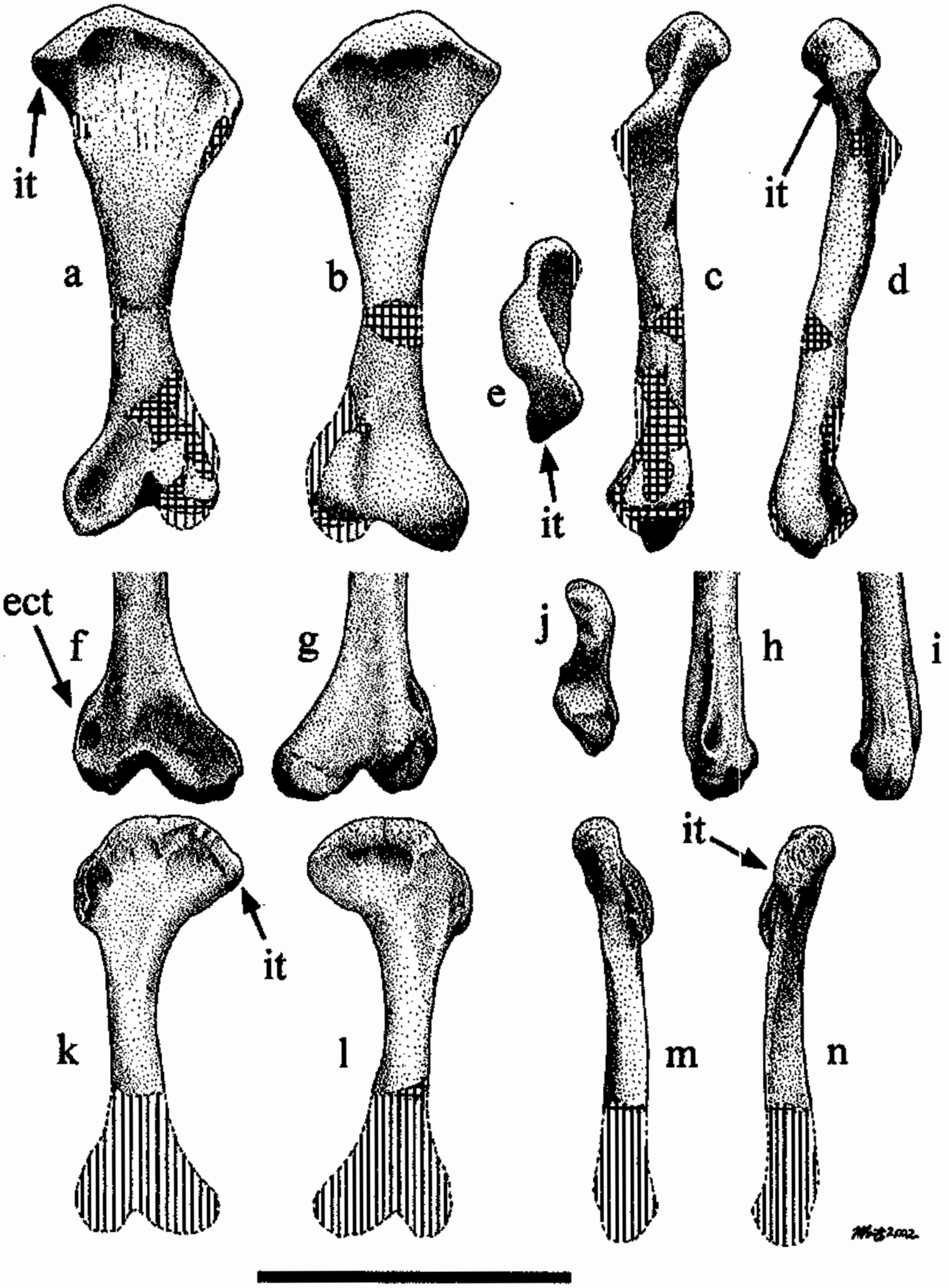

Figure 4.10 Humeri of *Typothorax coccinarum*; left humerus UCMP V2816 34240 70/J9 in (a) anterior, (b) posterior, (c) lateral, (d) medial, and (e) proximal (anterior side facing right) views; distal end of right humerus UCMP V2816 34240 70/G in (f) anterior, (g) posterior, (h) lateral, (i) medial, and (j) distal (anterior side facing left) views; right humerus of TTUP 9214 in (k) anterior, (l) posterior, (m) lateral, and (n) medial views. Dashed lines represent broken bone, cross hatching broken bone surface, and hatching reconstructed parts. Scale bar = 10 cm.

may serve to flex, retract, or adduct the humerus in the various postures adopted by crocodilians (Meers, 1999). This muscle may have been more weakly developed in *Typothorax* than in other aetosaurs. However, since aetosaurs probably had a more consistently upright posture then crocodilians (Parrish, 1986), it is unclear what the primary function of this muscle was in *Typothorax*.

The medial edge of the head is almost as robust as the articular thickening (Fig. 4.10c-e, n), and this is apparently what Romer (1956, p. 357) referred to as the "internal tuberosity." In *Typothorax*, the articular thickening and internal tuberosity are smoothly continuous along the proximal edge of the head (Fig. 4.10a, k). In contrast, a pronounced indentation separates them in *Desmatosuchus* (Small, 1985, fig. 8a), as in *Alligator* (Brochu, 1992). The internal tuberosity protrudes anteriorly and posteriorly (Fig. 4.10e), more strongly in UCMP 34248 70/J9 than in TTUP 9214. The tuberosity is distinctly cleft on its anterior side in *Desmatosuchus* and *Longosuchus*, though apparently not in *Typothorax*.

The head of the humerus in *Typothorax* appears asymmetric in anterior view, with the medial side being distinctly more expanded then the lateral side. This is the typical archosaur condition (Romer, 1956). This greater medial expansion is more pronounced in TTUP 9214 (Fig. 4.10k) than in the Canjilon Quarry material (Fig. 4.10a, f), but this may be partially due to the over preparation of the latter specimens. This asymmetry is present in *Stagonolepis* (Walker, 1961, fig. 14), and at least one specimen assigned to *Longosuchus* (TMM 31185-84b; Long and Murry, 1995, fig. 62c-d).

The thin and anteriorly curving deltopectoral crest is more mediolaterally expanded in *Desmatosuchus* (Small, 1985, fig. 8; Long and Murry, 1995, figs. 89C and 90) and one specimen assigned to *Longosuchus* (TMM 31185-84 43[14]; Long and Murry, 1995, fig. 62e-f), than in *Typothorax*, causing the head to appear more symmetrical in

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[14] The other humerus referred to *Longosuchus* (TMM 31185-84b), not only lacks the enclosed ectepicondylar foramen, but has a less laterally expanded deltopectoral crest (and therefore a more asymmetric head). I suspect therefore that TMM 31185-84 43 may belong to a small individual of *Desmatosuchus* rather then *Longosuchus*.

former taxa. Since head symmetry is increased by lateral expansion of the crest, the ratio of the total length of the humerus to the head (or proximal) width (l:hw) is tied to it. The humerus of 34240 70/J9 has a l:hw of 2.3, and is as or more gracile in *Coahomasuchus* (l:hw = 3.0), *Aetosaurus*, and *Stagonolepis* (Heckert and Lucas, 1999). It is more robust in *Longosuchus* (Heckert and Lucas, 1999), although the degree of expansion of the proximal end is variable in referred specimens (Long and Murry, 1995). The relative proximal expansion is greatest in *Desmatosuchus* (l:pw ≈ 2.0 or less), as noted by Long and Murry (1995).

The deltopectoral crest itself is poorly preserved in the Canjilon Quarry specimens, but is distinct in TTUP 9214. In the Canjilon Quarry *Typothorax* humeri, the crest seems to be restricted to between the proximal 1/3 and 2/5 of the humerus, whereas it extends farther distally in *Desmatosuchus* (Long and Murry, 1995), *Longosuchus* (Sawin, 1947; Long and Murry, 1995), and *Stagonolepis* (Walker, 1961). The crest does not curve as tightly in *Typothorax* as in *Desmatosuchus* and *Longosuchus*. The edge of the crest is rugose in TTUP 9124; it is apparently smoother in the Canjilon specimens, probably due to overpreparation. The base of the deltopectoral crest is beveled laterally (Fig. 4.10c, m), much more distinctly in the Canjilon Quarry material then in TTUP 9124. This beveled surface in crocodilians serves primarily as the insertion of the *m. deltoideus clavicularis* and more distally the origin of the *m. humeroradialis* (which is found only archosaurs), which are respectively a protractor of the humerus, and a fast flexor of the forelimb during locomotion (Meers, 1999).

Distal to the deltopectoral crest, the lateral edge of the shaft is rounded and the medial edge (distal to the internal tuberosity) seems to be slightly more pinched in some specimens of *Typothorax*. The anterior side of shaft is flatter than the more convex posterior side in both *Typothorax* and *Desmatosuchus*.

The distal end of the humerus is absent in TTUP 9214, but in the Canjilon Quarry material it is well represented. The width of the distal end is about 1/3 of the shaft length (contra Long and Murry, 1995, who claimed it was 2/5); it is slightly more in

Desmatosuchus. Torsion between the distal and proximal end is not evident in any aetosaur humeri examined by the author, though Walker (1961) claims it is present in *Stagonolepis*.

As in most archosaurs, the two distal condyles are separated by a groove. The lateral of these condyles, the capitellum, articulated with the radius. The groove, called the trochlea, and the medial condyle articulated with the ulna (Romer, 1954). Both condyles are very flattened anteroposteriorly in *Typothorax* relative to other aetosaurs. The capitellum is notably thicker then the medial condyle, and it thickens medially where it meets the trochlea. The trochlea is the thickest part of the distal end, actually projecting anteriorly beyond the condyles (Fig. 4.10j), unlike *Desmatosuchus*. The medial condyle is much more anteroposteriorly flattened then the capitellum, and projects more strongly medially and distally (Fig. 4.10.a, f) as noted by Long and Murry (1995), as well as curving slightly anteriorly (Fig. 4.10.j). Its anterior surface is concave, also as noted by Long and Murry (1995); this concavity is much weaker in *Desmatosuchus*.

A thin ectepicondylar flange is on the medial edge of the capitellum (Fig. 4.10f-h). The flange was probably the origin of the *m. supinator*, as in modern reptiles (Romer, 1954; Meers, 1999). In most archosaurs, only an uncovered ectepicondylar groove is present on the capitellum, but in *Typothorax* the flange is pieced by a true, roofed ectepicondylar foramen that trends anteriorly and distally (Fig. 4.10f-h). Among aetosaurs, an enclosed ectepicondylar foramen is also present in *Neoaetosauroides* (Bonaparte, 1971), *Desmatosuchus* (Small, 1985) and *Longosuchus*(?) humerus TMM 31185-84 (Long and Murry, 1995).

4.4.4. Illium

The UCMP Canjilon Quarry material includes two excellent *Typothorax* illia referable to the “Fa” specimen (122683 70/Fa54; Fig. 4.12a-e) and “U” specimen (34255 70/U80; Fig. 4.11a; also see Long and Murry, 1995, figs. 106A, 107). Another illium

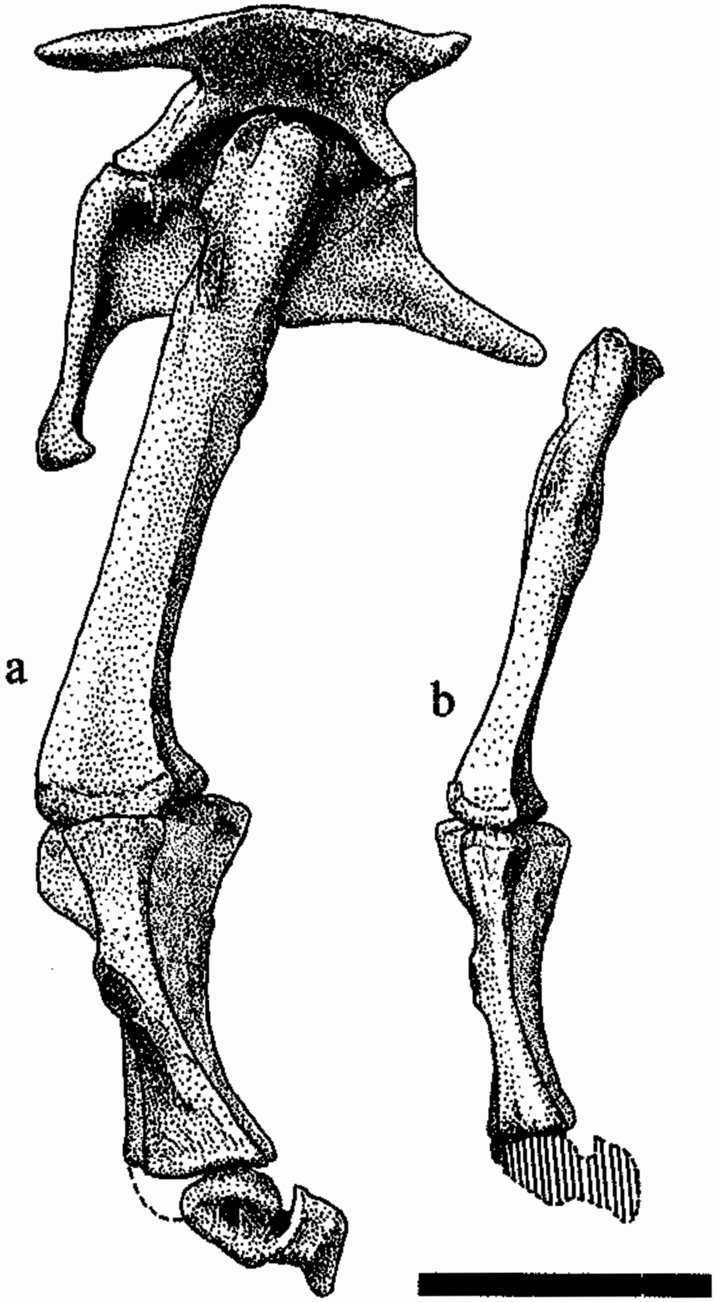

Figure 4.11 Partial reconstructions of left hind limb of *Typothorax coccinarum* in left lateral view; (a) adult specimen, illium, femur, tibia, and calcaneum based on UCMP V2816 34255, fibula after UCMP V2816 12268 70/L (all U specimen), pubis based on UCMP V2816 34248 70/G6 (enlarged), ichium based on TTUP 9214 (enlarged); (b) subadult TTUP 9214 (pelvis excluded). Scale bar = 10 cm.

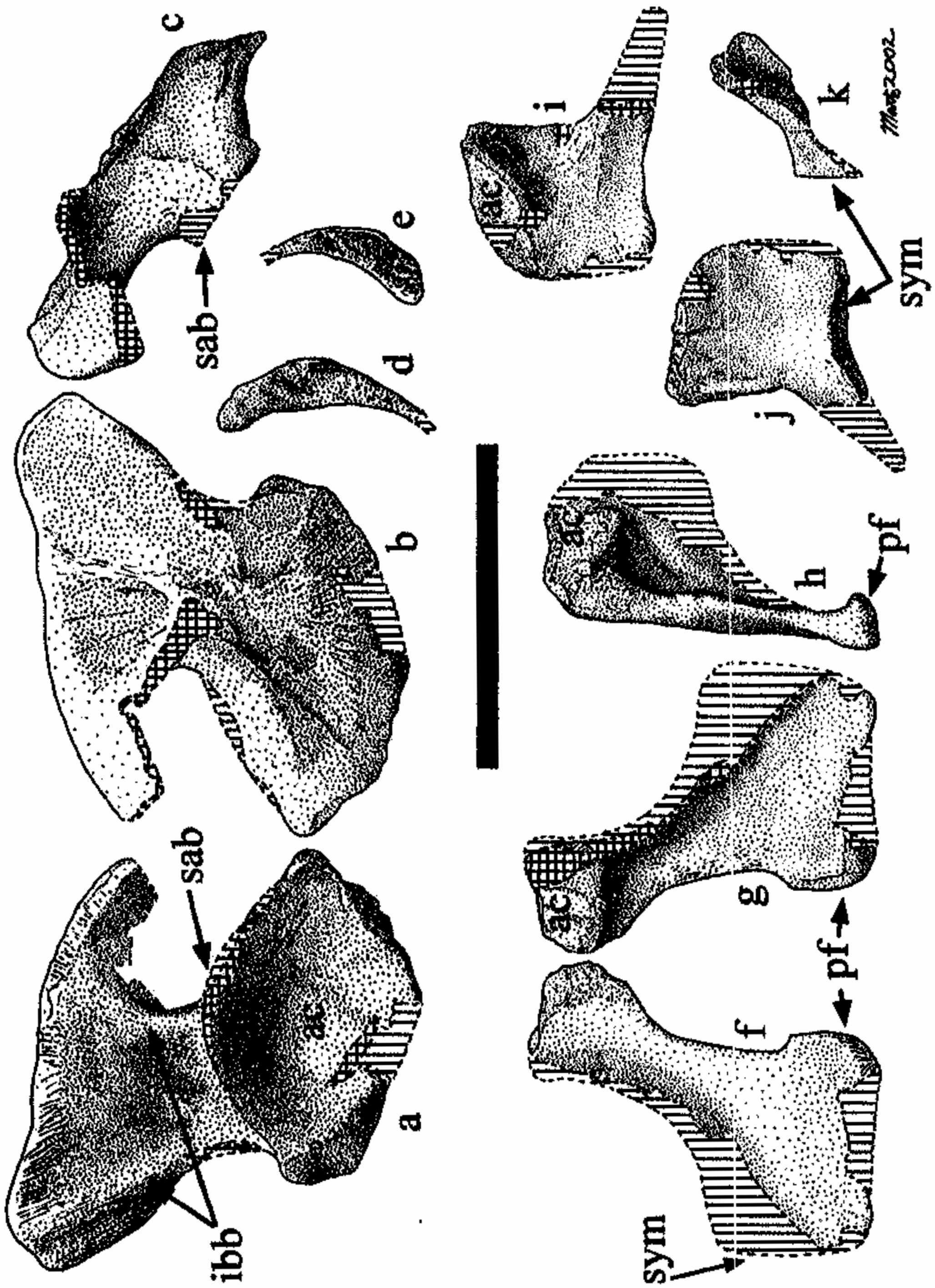

Figure 4.12 Pelvic material of *Typothorax coccinarum*; right illium UCMP V2816 122683 70/Fa54 in (a) ventrolateral, (b) dorsomedial, and (c) anterior (in life orientation) views, d) articular surface for pubis in anteroventral view, (e) articular surface for ischium in posteroventral view; left pubis UCMP V2816 34248 in (f) anterior, (g) posterior, and (h) left lateral views; left ischium of TTUP 9214 in (i) ventrolateral, (j) dorsomedial, (k) anterior (in natural orientation) views. Scale bar = 10 cm.

with a sacral rib attached (UCMP V2816 15867) but lacking a field number is also probably referable to *Typothorax* based on the shape of the blade, but is too badly distorted to provide much information. The illia are not known from TTUP 9214. The illium may be divided into the body (which includes the acetabulum and the articular surfaces for the pubis and ischium) and a thinner and more dorsal blade connected by an anteroposteriorly constricted neck.

The iliac blades of aetosaurs were strongly oriented horizontally so that the acetabulum faced downwards as much or more then it faced laterally, an adaptation that may have served to support the carapace (Parrish, 1986). This was especially pronounced in *Typothorax* (Fig. 4.11a; 4.12e; Long and Murry, 1995). This is important to keep in mind when examining the illium, as in most other archosaurs (for example, in dinosaurs) the blade is oriented roughly vertically. Therefore, what would be the lateral side of the blade in dinosaurs is ventrolateral in aetosaurs, and the medial side (facing directly toward the sacrum in archosaurs with an upright blade) is dorsomedial. As recognized by Long and Murry (1995), the illium of *Typothorax* differs in many ways from those of other aetosaurs.

The preacetabular process of the blade is extremely elongated, much more so than in other aetosaur taxa (Long and Murry, 1995) and archosaurs in general (Romer, 1923), and slightly curved medially and ventrally (Fig. 4.12.a, e). In birds, and probably among other archosaurs with an erect posture, elongation of the anterior process of the blade indicates the movement of the *M. iliofemoralis* (an important femoral protractor), and the *M. iliotibialis* (a crural extensor), anterior to the acetabulum, reducing or eliminating their role as rotators of the hind limb in sprawling reptiles (Parrish, 1986; Pettingil, 1985). The anterior process is flattened dorsoventrally, and thickens toward its lateral edge (Fig. 4.12e). The thin medial edge of the anterior process of the iliac blade was probably continuous with the dorsal edge of the anterior sacral rib (see Walker, 1961, fig. 17). The branches of the *M. iliotibialis* attach all along the dorsolateral edge of the blade in *Alligator* (Romer, 1923), and this edge is strongly striated in *Typothorax* (Fig. 4.12a).

The striations are particularly rugose just before the posterior process, and this region may have been the origin of the *M. iliofibularis* as in crocodilians (Brochu, 1992). The iliac blade is thickened by two buttresses, which extend along its ventrolateral surface from the dorsal rim of the acetabulum to the dorsolateral edge of the blade. The anterior of these buttresses arises from the lateral rim of the supracetabular buttress, and the preacetabular process of the iliac blade extends off of it.

The posterior process of the iliac blade in *Typothorax* does not project nearly far posteriorly as in other aetosaurs (as noted by Long and Murry, 1995), and the posterior tip ends very bluntly (Fig. 4.12a). The posterior buttress of the iliac blade runs along the posterior process to its tip, thickening dorsolaterally. A slightly thinner flange behind the posterior buttress forms the posterior edge of the blade, and was likely the origin of the *M. coccygeo-femoralis brevis* as it is in *Alligator* (Romer, 1923; Brochu, 1992).

The ventrolateral face of the iliac blade between the buttresses is much more deeply concave than in most other aetosaurs as noted by Long and Murry (1995), with the concavity deepest on the neck just above the acetabulum (Fig. 4.12a). In *Alligator*, this region is the site of attachment of the *M. illiofemoralis* (Romer, 1923). The neck of the iliac blade, just above the acetabulum (the "supracetabular buttress" of Long and Murry, 1995), is much more strongly constricted anteroposteriorly in *Typothorax* than in other aetosaurs (Long and Murry, 1995). The bases of the buttresses on the blade form the anterior and posterior edges of the neck.

The supracetabular buttress (the ridge of bone between the acetabulum and the neck) is sharp edged. The acetabulum is deepest below the anterior buttress of the iliac blade. The anterior part of the body of the illium, the "preacetabular buttress," projects more strongly anteriorly then in other aetosaurs, as far or farther then the preacetabular process of the blade (Fig. 4.12a, b). The articular faces for the pubis and ischium are similar in form, rugose-surfaced crescents, which taper toward each other (Fig. 4.12c, d).

The medial side of the illium is not well preserved in 34255 70/U80, but it is in 122653 70/Fa65 where the sacral vertebrae seem *not* to have been fused to the illium and the sutures where the ribs attached are still visible (Fig. 4.12b). The sutures lie on the body of the illium opposite the acetabulum, and did not extend onto the blade, where the dorsal musculature probably attached (Romer, 1923). Judging by the size of the sutures, the sacral ribs expanded broadly across the body of the illium.

4.4.5. Pubis

No pubis is known for TTUP 9214 except for a possible fragment, but Long and Murry (1995) assigned a left pubis, UCMP V2816 34248 to *Typothorax* (Fig. 4.12f-h). The specimen label identifies it as coming from square 70/G6. At first glance it resembles a quadrate (though one too large to belong to *Typothorax*). However, what would be the mandible articulation is not nearly a constricted as in phytosaurs and aetosaurs, a distinct acetabular buttress can be identified, and the general form of more flattened part of the element is more consistent with a pubic apron then the dorsal part of a quadrate. The element does not appear to be a phytosaur pubis (Axel Hungerbühler, personal communication, 2002), and the author therefore tentatively supports Long and Murry's (1995) assignment of the element as a pubis of *Typothorax*. If the field number 70/G6 is correct, the taxon assignment is strengthened, as that number refers to one of the main blocks of the "G" specimen of *Typothorax*.

The proximal end of the pubis, which would have met the illium, is very thick and has a rugose surface. A thick, posterolaterally facing lip, the acetabular buttress (Fig. 4.12g, h), formed the anteroventral border of the acetabulum. The acetabular buttress appears to be somewhat more compressed in *Stagonolepis* (Walker, 1961, fig. 16). Just above where the symphysis with the right pubis would have been, the medial edge of the proximal end curves posteriorly, forming a thin flange that would have run along the ventral edge of the illium to contact the ischium. The region on this flange where the pubic foramen or foramina would have been located is not preserved, so it is unclear if there was a single foramen as in *Longosuchus* and *Desmatosuchus* (Sawin, 1947; Small, 1985), or two foramina as in *Stagonolepis* (Walker, 1961).

As noted by Long and Murry (1995), the distal part of the pubis (including the pubic apron) is extremely short, and their claim that the entire pubis is only about half the length of the femur is probably accurate (Fig. 4.11a). The lateral edge is thicker then the rest of the apron. In anterior view it curves slightly medially just ventral to the proximal end then swells laterally again (Fig. 4.12f, g), ending in a modest pubic foot, which differs from other aetosaurs in being an odd, posteriorly curving hook-like process (Fig. 4.12h). The distal surface of the foot is rugose, as in other aetosaurs (Walker, 1961; Long and Murry, 1995). The thin medial edge of the apron that formed the symphysis with the right pubis is not preserved.

4.4.6. Ischium

TTUP 9214 has an almost complete left ischium (Fig. 4.12i-k), though none is recognized for the Canjilon Quarry material. As with the illium, the ischium was inclined dorsolaterally. This orientation is supported by the orientation of the symphysis with that of the right ischium, which is vertical when the ischium is inclined at about 45° (Fig. 4.12k).

The ischium includes the posteroventral part of the acetabulum. The rim of the acetabulum is not sharp as in *Stagonolepis* (Walker, 1961, fig. 16), but this may be due to damage. The articulation with the illium is rugose. In proximal view, the articulation is wide posteriorly and tapers anteriorly, curving around the hollow of the acetabulum, mirroring the shape of the articular surface on the illium (Fig. 4.12c).

Posteriorly on the surface of the illium, just below the rim of the acetabulum, are two deep sub-parallel scratches (Fig. 4.12i). These may have formed before burial, possibly representing tooth marks, as they appear to have been filled with matrix. The posterior edge of the ischium is thick, but the ischium thins anteriorly toward the pubis, though the meeting with that bone is not preserved. The posterior process of the ischium is broken off near the base, but seems to have been trended almost horizontally and was laterally compressed (Fig. 4.11a). Just above the ventral edge, the ventrolateral surface of the ischium is distinctly concave (Fig. 4.12i). By analogy with *Alligator* (Romer, 1923), this region was likely the attachment site for the *M. pubo-ischiofemoralis externus*.

The symphysis with the right ischium is preserved as a thick, rugose suture, which is faintly concave and curves dorsally (Fig. 4.12j). It appears to have been much thicker in *Stagonolepis* (Walker, 1961, fig. 15d). The ventrolateral surface of the ischium along the edge of the suture is distinctly striated (Fig. 4.12i).

4.4.7. Femur

The UCMP material includes several excellent femora: 34248 70/G7 (and another from 70/G7 lacking a specimen number), 34255 70/U80, 122673 70/C1, 122674 70/J46, 122676 70/Fa2, and 122677 70/C, most of which can be paired up using the field numbers and similarities in size and morphology. Measurements are given in Table 4.5 and explained graphically in Fig. 4.13. 34248 70/G7 (Fig. 4.15) is probably the best-preserved overall. The distal ends of 34255 70/U80 (Fig. 4.14; the largest *Typothorax* femur from the quarry) and TTU 9214 (Fig. 4.16) are badly crushed, but the proximal halves are in somewhat better shape. This crushing has probably distorted the torsion between the long axes of the proximal and distal ends measured for these femora, which can be determined more reliably for most of the Canjilon material (measure 12 in Table 4.5).

All *Typothorax* femora show a distinct, medially developed head as is typical in aetosaurs and other archosaurs with an erect posture (e.g., Charig, 1972; Parrish, 1986), but its degree of development varies between specimens. The femoral head width/total femur length ratio is 1.33-1.38 in *Typothorax*. Among the Canjilon specimens, the head appears to be especially prominent in 34255 70/U80, but it is even more distinct in TTUP 9214. At the anterolateral corner of the articular head is a thickened buttress. This is probably the "proximal condylar fold" of Brochu (1992), although it is more robust then seen in *Alligator*. The dorsal surface of the head is highly rugose (Figs. 4.15e, 416.e),

Table 4.5. Aetosaur femur measurements

All measurements are in millimeters, and were rounded off to the nearest millimeter, except for torsion and the distal angle, which are in degrees. The presence of a (l) or (r) after a specimen number indicates if the femur was left or right. Italicized measurements were reconstructed using the expectation maximization method in order to calculate the femur PC1 (see Chapter 5). The measurements are explained graphically in Fig. 4.13, numbered as below. Measurements for USNM 2585 and AMNH 2713 are from Cope (1887) and Von Huene (1915). Measurements for MCZ 1488 are from Gregory (1953).

	Typothorax					
	USNM 2585	AMNH 2713	MCZ 1488	UCMP V2816 122677 70/C (r)	UCMP V2816 122673 70/C1 (l)	UCMP V2816 70/G7 (l)
1. Length	220	315	258	272	254	*166*
2. Distance from head to 4th trochanter	60	76	NA	104	99	NA
3. Head width	60	50	NA	70	69	NA
4. Head length	35	24	NA	34	36	NA
5. Thickness across 4th trochanter	NA	NA	NA	37	40	36
6. Mid-shaft length	30	52	NA	28	25	25
7. Mid shaft width	22	41	NA	37	35	22
8. Distal width	80	*360*	NA	*98*	79	74
9. Medial condyle thickness	40	NA	NA	NA	50	35
10. Lateral condyle thickness	54	NA	NA	39	55	51
11. Intercondylar thickness	34	NA	NA	NA	35	40
12. Torsion	NA	NA	NA	NA	66°	NA
13. Distal angle	NA	NA	NA	NA	10°	24°
14. Size score on PC1	7.1919	8.4993	NA	7.5737	7.3163	6.9979

Table 4.5. Continued

	Typothorax				
	AMNH 2710	UCMP V2816 122676 70/Fa2	UCMP V2816 34248 70/G7 (r) (Fig. 4.15)	UCMP V2816 122674 70/J46 (r)	UCMP V2816 34255 70/U80 (l) (Fig. 4.16)
1. Length	220	*248*	NA	233	257
2. Distance from from head to 4th trochanter	NA	NA	NA	96	101
3. Head width	NA	NA	NA	59	77
4. Head length	NA	NA	NA	36	43
5. Thickness across 4th trochanter	NA	36	NA	31	40
6. Mid-shaft length	NA	27	NA	27	29
7. Mid shaft width	NA	34	NA	28	33
8. Distal width	NA	*92*	NA	83	91
9. Medial condyle thickness	NA	NA	NA	30	52
10. Lateral condyle thickness	NA	NA	NA	43	31
11. Intercondylar thickness	NA	NA	NA	20	NA
12. Torsion	NA	NA	NA	52°	38°
13. Distal angle	NA	NA	NA	20°	16°
14. Size score on PC1	NA	7.4533	NA	7.2856	7.4669

Table 4.5. Continued

	Typothorax TTUP 9214 (l) (Fig. 4.14)	*Longosuchus* TMM 31185-84b 57	TMM 31185-84b 88	*Desmatosuchus* TTUP 9204 (r)	UCMP V269 27988 (r)
1. Length	178	29	32	490	377
2. Distance from head to 4th trochanter	69	NA	NA	202	153
3. Head width	54	91	86	121	101
4. Head length	26	45	34	63	50
5. Thickness across 4th trochanter	23	NA	NA	64	57
6. Mid-shaft length	22	39	40	67	36
7. Mid shaft width	18	29	29	53	56
8. Distal width	37	89	92	148	124
9. Medial condyle thickness	NA	60	53	83	NA
10. Lateral condyle thickness	NA	69	55	76	NA
11. Intercondylar thickness	20	40	38	50	NA
12. Torsion	33°	NA	NA	34°	35°
13. Distal angle	20°	NA	NA	25°	NA
14. Size score on PC1	6.3175				

Table 4.5. Continued

	Desmatosuchus		*Stagonolepis*		PCA loading
	UCMP A269 25911 CF1 (l)	UCMP V269 25907 C75W (l)	UCMP A269 25916 CF1 (l)	UCMP V269 25912 CH2 (l)	
1. Length	NA	NA	308	403	.2449
2. Distance from head to 4th trochanter	NA	NA	123	120	NA
3. Head width	NA	NA	NA	80	NA
4. Head length	NA	NA	NA	49	NA
5. Thickness across 4th trochanter	NA	NA	49	51	NA
6. Mid-shaft length	NA	NA	37	NA	.3232
7. Mid shaft width	NA	NA	36	NA	.3419
8. Distal width	155	111	90	104	.8477
9. Medial condyle thickness	62	58	52	56	NA
10. Lateral condyle thickness	89	72	71	68	NA
11. Intercondylar thickness	NA	50	49	47	NA
12. Torsion	35°	NA	51°	42°	NA
13. Distal angle	10°	13°	16°	76°	NA

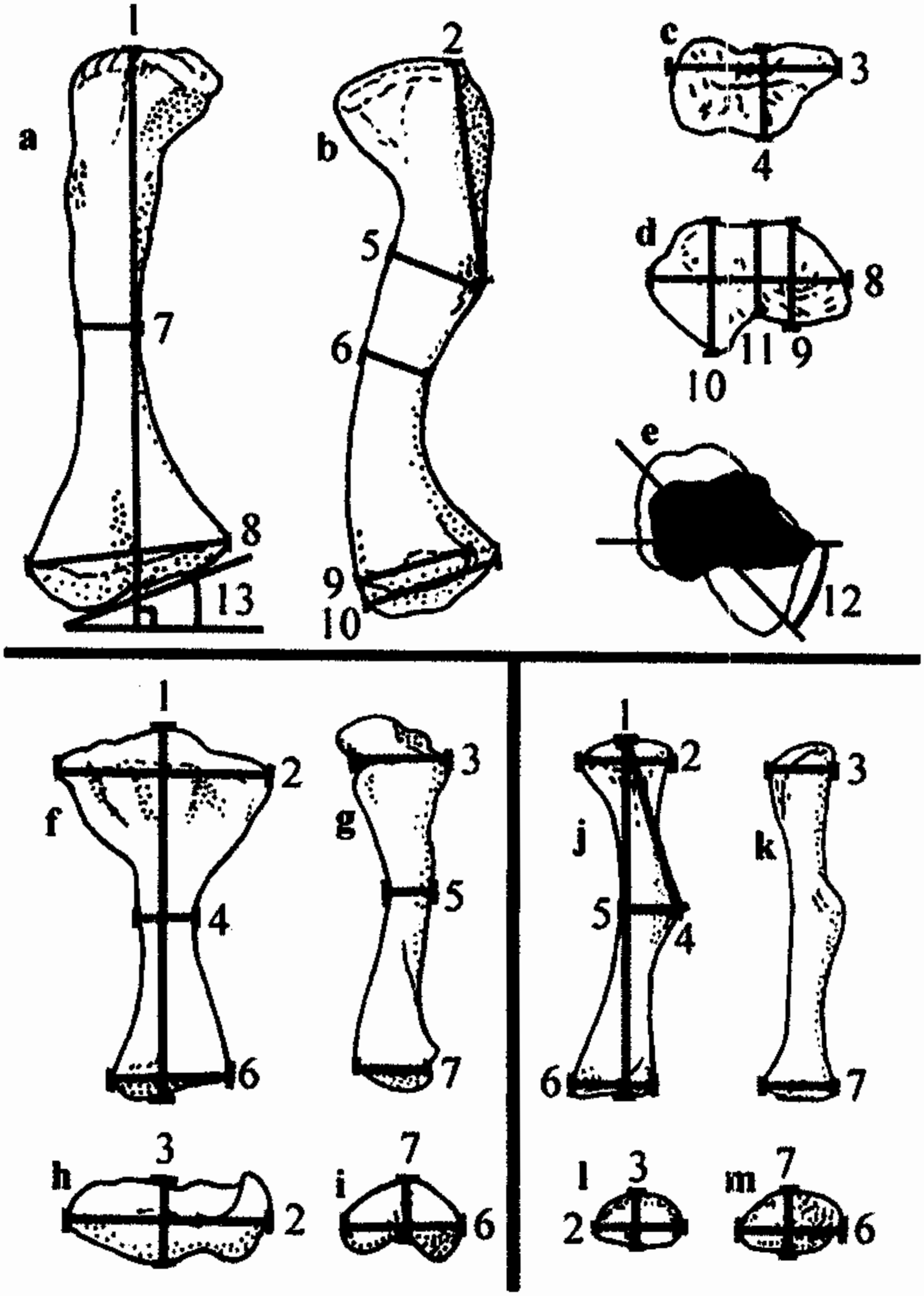

Figure 4.13 Appendicular measurements given in Tables 4.5-4.7; femur measures in (Table 4.5) in (a) anterior, (b) medial, (c) proximal, (d) distal views, and (e) showing torsion (the proximal and distal ends are superimposed as though viewed distally with lines drawn through the long axes); tibia measures (Table 4.6) in (f) anterior, (g) medial, (h) proximal, and (i) distal views; fibula measures (Table 4.7) in (j) medial, (k) anterior, (l) proximal, and (m) distal views.

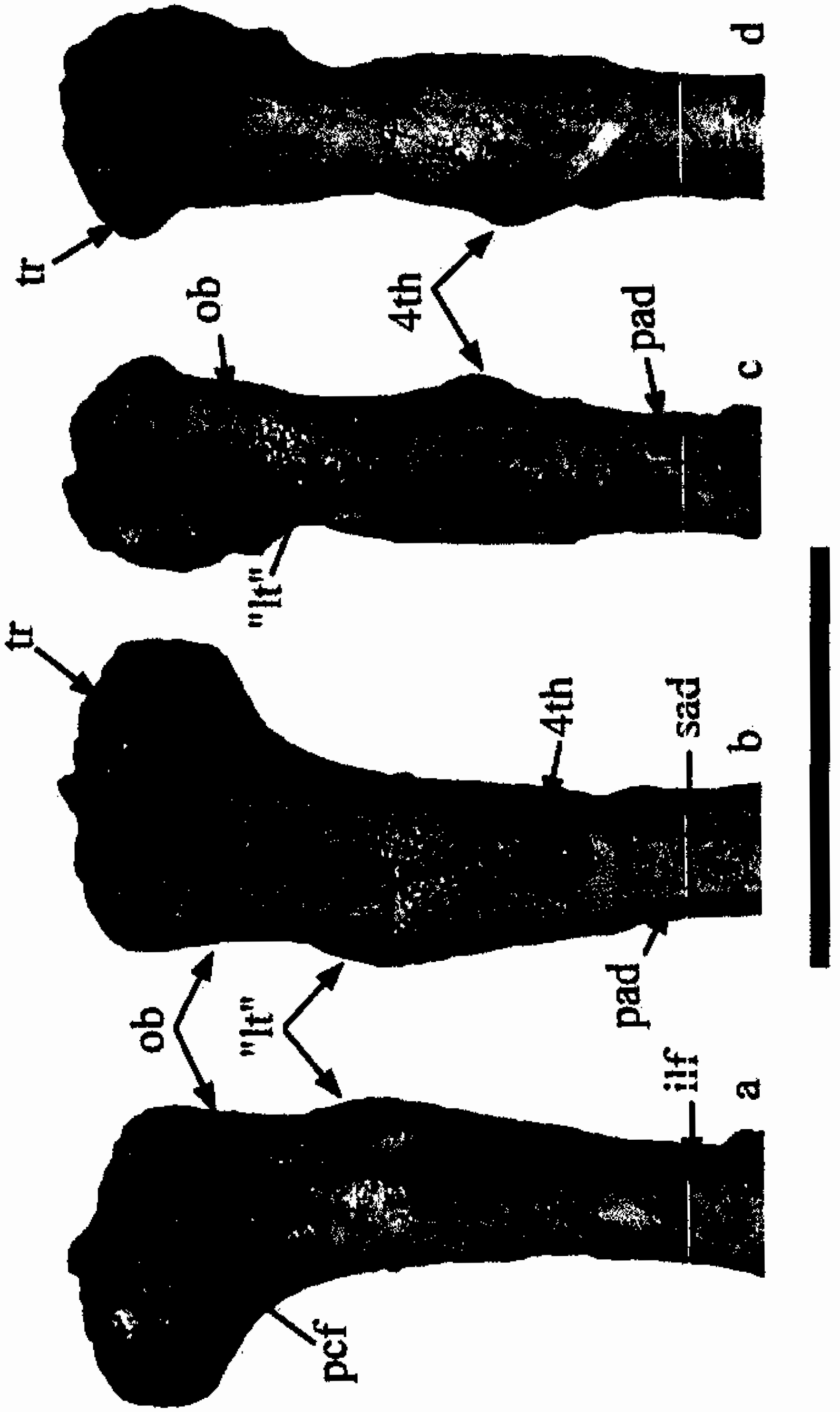

Figure 4.14 Proximal end of left femur of *Typothorax coccinarum* (UCMP V2816 34255 70/U80) in (a) anterior, (b) posterior, (c) lateral, and (d) medial views. Scale bar = 10 cm.

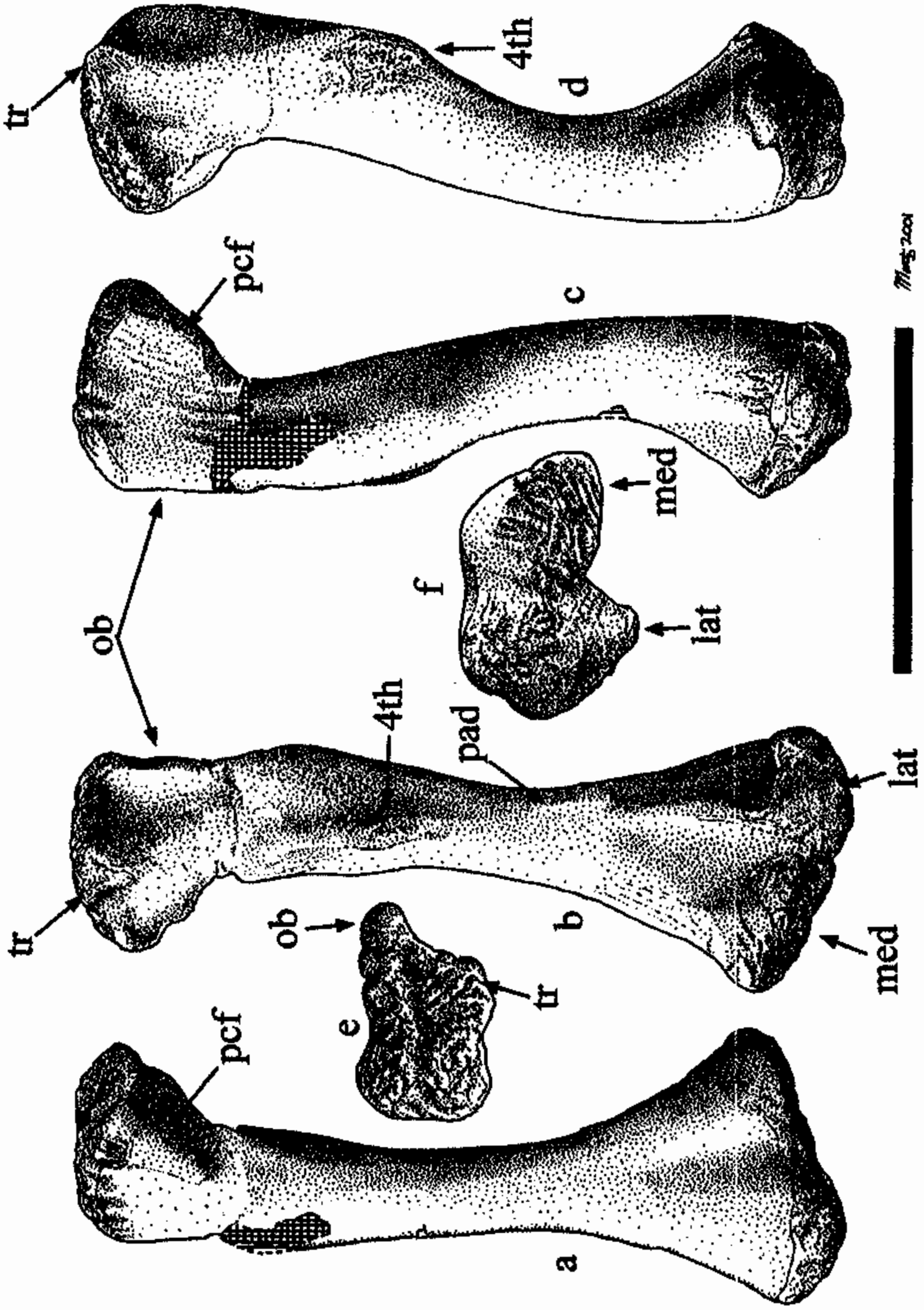

Figure 4.15 Right femur of *Typothorax coccinarum* (UCMP V2816 34248 70/G7); in (a) anterior, (b) posterior, (c) lateral, (d) medial, (e) proximal, and (f) distal views. Dashed lines represent broken bone, cross hatching broken bone surface. Scale bar = 10 cm.

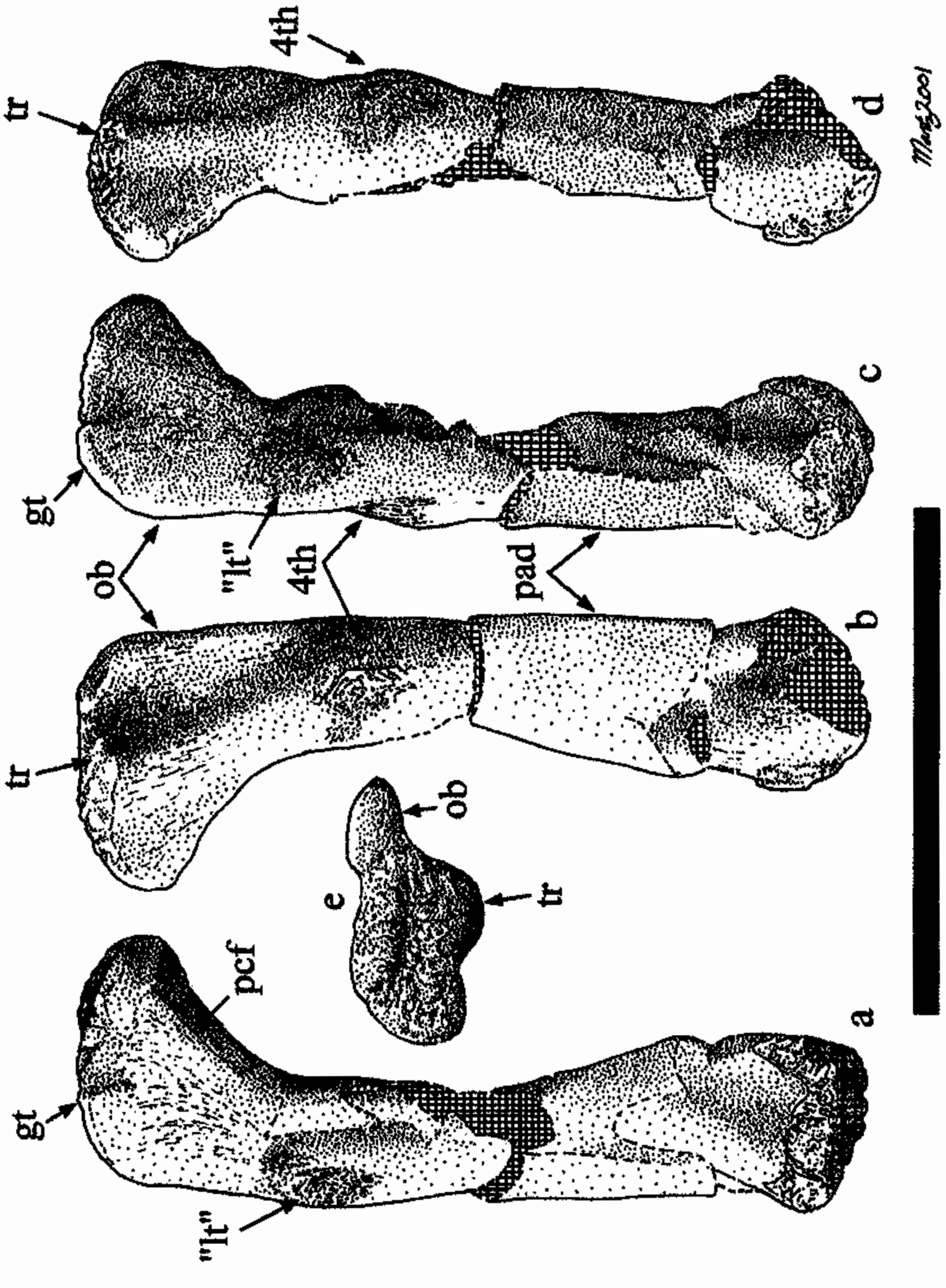

Figure 4.16 Right femur of *Typothorax coccinarum* (TTUP 9214); (a) anterior, (b) posterior, (c) lateral, (e) medial, and (f) proximal views. Dashed lines represent broken bone edges, cross hatching broken bone surface. Scale bar = 10 cm.

with a shallow sulcus running anteromedially along the long axis of the head, not quite extending onto the obturator flange. In *Alligator*, a cartilage cap covers the entire proximal end. A large knob, the trochlea, is present on the posteromedial side of the head and confluent with its dorsal edge. The trochlea is most prominent in UCMP 34255 70/U80 (Fig. 4.14b, d). The posterior side of the head is swollen below the trochlea down towards the 4th trochanter (Figs. 4.15d, 4.16d).

The anterior side of the head has very faint striations running subparallel to the long axis of the bone (Figs. 4.15c, 4.16a), though they are difficult to see in some specimens (probably due to overpreparation). Laterally, the head is pinched into the obturator flange. The top of the obturator flange is the greater trochanter, which is indicated by a slight prominence (Fig. 4.16a, c) or at least coarse grooves (Fig. 4.15c). In *Alligator*, the rest of the obturator flange is the attachment site of the second branch of the *M. pubo-ischio-femoralis externus* (sensu Romer, 1923).

Anterolaterally on the shaft is the roughened area noted by Long and Murry (1995). This area isn't well preserved in 34248 70/G7, but the rugosity can be discerned in most of the other specimens (including TTUP 9214), and is marked by an extremely prominent scar in 34255 70/U80 (clearest in Fig. 4.11a). This region is also slightly swollen, not only in *Typothorax*, but also in *Longosuchus* and *Stagonolepis* (Walker, 1961). As suggested by Long and Murry (1995) the region may be homologous to the lesser trochanter of dinosaurs, as the *M. pubo-ischio-femoralis internus pars dorsalis* (which is homologous with the muscle attaching at the greater trochanter in birds) attaches in this region in crocodilians (Romer, 1923; Rowe, 1986; Brochu, 1992). However, it is possible that this rugose region is instead homologous with the "proximal dorsal tuberosity" of Brochu (1992).

The mid-shafts of all the femora of *Typothorax* are subtly compressed mediolaterally, so that most they are relatively narrow in anterior and posterior views compared to medial and lateral views. This compression is most pronounced below the 4th trochanter. This is also true of *Longosuchus*, but not *Desmatosuchus*, which has a femur shaft that is thicker mediolaterally (Table 4.5). In lateral view, the shafts of the femora from 70/G7 (Fig. 4.15c, d) and 122673 70/C1 are vaguely sinuous, with the proximal and distal ends curving subtly anteriorly and posteriorly respectively. In the case of the latter, the sinuosity seems to be the result of crushing, but it appears natural in the former. Most of the other femora however are straight shafted relative to phytosaurs, as noted by Lawler (1976). The shaft of TTUP 9214 is also fairly straight (Fig. 4.15c, d), as noted by Small (1989), but is too badly crushed to determine if this is natural.

Below the 4th trochanter, the shaft becomes slightly "pinched" longitudinally along both its anterior and posterior surface. In most of the Canjilon femora, the longitudinal pinching on the anterior side of the shaft flattens out more distally. This slight pinching or ridge probably represents the attachment for the *M. iliofemoralis* (Romer, 1923; Brochu, 1992). In 34248 70/G7, the pinching is more broadly rounded then in most of the femora. In 34255 70/U80, the pinching is extremely pronounced, so that there is a very distinct ridge (Fig. 4.14a) that angles off proximally toward the scar for the *M. pubo-ischio-femoralis internus pars dorsalis* ("lesser trochanter"). A somewhat sharp ridge also lies here in *Longosuchus*. The condition cannot be determined in TTUP 9214 due to crushing.

On the posterior side, the obturator flange is continuous with another longitudinal pinching that weakens as it passes the fourth trochanter laterally, then tightens again and becomes a pronounced ridge leading onto the lateral condyle. A much more distinct ridge is present in 34255 70/U80 and apparently TTUP 9214 than in most of the Canjilon femora (Fig. 4.14b; 4.16b, c). This pinching or ridge probably represents the "primary adductor scar" of Brochu (1992), which separates the longitudinal insertions of the *M. femoro-tibialais externus* and the branches of the *M. adductor femoralis* (Romer, 1923). In 34255 70/U80, a second distinct ridge is present medial to and paralleling the primary adductor scar (Fig. 4.14b), leading distally from the fourth trochanter. This is probably the "secondary adductor scar" of Brochu (1992), which separated the insertions of the *M. adductor femoralis* from that of the *M. femoro-tibialis internus*. This secondary adductor scar cannot be discerned on any of the other *Typothorax* femora besides 34255 70/U80. The "tertiary muscle scar" of Brochu (1992) cannot be discerned on any of the femora.

The fourth trochanter is located on the posterior side of the shaft, less then half way down the shaft (Table 4.5). It is a mediolaterally compressed swelling in TTUP 9214 and most of the Canjilon femora (Figs. 4.15d, 4.16d). In 34255 70/U80, and even more so in *Desmatosuchus*, the trochanter is more of a bulbous knob (Fig. 4.14b), a morphology which may be attained with large size. The trochanter is also figured as being somewhat bulbous in *Neoaetosauroides* by Bonaparte (1971, fig. 39). The surface of the shaft immediately around the 4th trochanter is rugose, and the areas on the medial and lateral sides of the trochanter are, respectively, the insertion of the *M. coccygeo-femoralis (=caudifemoralis) longus* and *M. coccygeo-femoralis brevis* (Romer, 1923; Rowe, 1986; Brochu, 1992). When mediolaterally compressed, the trochanter runs roughly parallel to the long axis of the shaft in *Typothorax*; in *Longosuchus*, it twines slightly around the femur shaft.

The distal end of the femur is strongly expanded, particularly in larger individuals (Table 4.5). The articular surface, like on the proximal end of the head, is rugose (Fig. 4.15f). A suture separating the rugose cap from the rest of the head is discernible in TTUP 9214, 34248 70/G7, and several of the other Canjilon femora, although this region is prone to overpreparation. The cap seems to extend far up the front of the distal end on the medial condyle in TTUP 9214. Torsion of the distal end relative to the proximal end and the angle between the long axis of the shaft and the distal end (measures 12 and 13 in Table 4.5) are both often slightly more pronounced in *Typothorax* than in *Desmatosuchus*, but this is not consistent.

The lateral condyle is thicker anteroposteriorly than the medial condyle, but more pinched mediolaterally (Fig. 4.15f). The "primary adductor scar" continues onto its ventral side as a highly pronounced ridge (Fig. 4.15b), which can be faintly discerned in TTUP 9214 even as badly crushed as the distal end of that femur is. Unlike the lateral condyle, which projects straight back, the medial condyle in *Typothorax* projects posteromedially. In *Desmatosuchus* and *Longosuchus*, the condyles appear to be more similar to each other in size and morphology. The medial condyle projects straight back and comes to a point as prominent as on the lateral condyle.

4.4.8. Tibia

Several tibiae are known from the Canjilon material, UCMP V2816 34248 70/G7, 34255 70/U80 (Fig. 4.17), 122678 70/G6, 122679 (no field number; Fig. 4.18), 122679 70/J51, and 122680 70/Fa2; measurements are given in Table 4.6. In its natural orientation, the tibia rotated anteromedially so that the widest surfaces (Figs. 4.17a; 4.18a, b; 4.19a, b) face anterolaterally and posteromedially. These sides are generally referred to as the anterior and posterior sides, and these will be used here for the sake of simplicity. The narrower anteromedial and posterolateral sides (Figs. 4.17b; 4.18c, d; 4.19c, d) will therefore be referred to as medial and lateral respectively.

As noted by Lawler (1976), the tibia is considerably shorter compared to the femur than in phytosaurs. The compactness of the tibia appears to vary ontogenetically as well as taxonomically. It is a relatively squat element in the Canjilon *Typothorax* material and *Desmatosuchus*, but more elongate and slender in TTUP 9214 (Fig. 4.19), *Longosuchus*, *Stagonolepis*, and especially *Neoaetosauroides* (Bonaparte, 1971).

The head of the tibia is much more strongly expanded in aetosaurs then in other pseudosuchians (Parrish, 1986). Among the *Typothorax* specimens, the head of the tibia is least expanded relative to the rest of the bone in TTUP 9214 (Fig. 4.19a, b), but considerably more expanded in the UCMP material, especially 122679 (Fig. 4.18a, b). Except when overprepared, the proximal surface of the head is strongly rugose and can be divided into two barely discernable shallow fossae (Fig. 4.17c), one medial and one lateral. The fossae are most distinct in 34255 70/U80 and indiscernible in TTUP 9214. The lateral fossa is usually larger, and slopes posteriorly. These fossae housed menisci that met the femoral condyles and reinforced the knee (Parrish, 1986). The anterior side of the head of the tibia is convex, and swells strongly in the middle, especially in UCMP

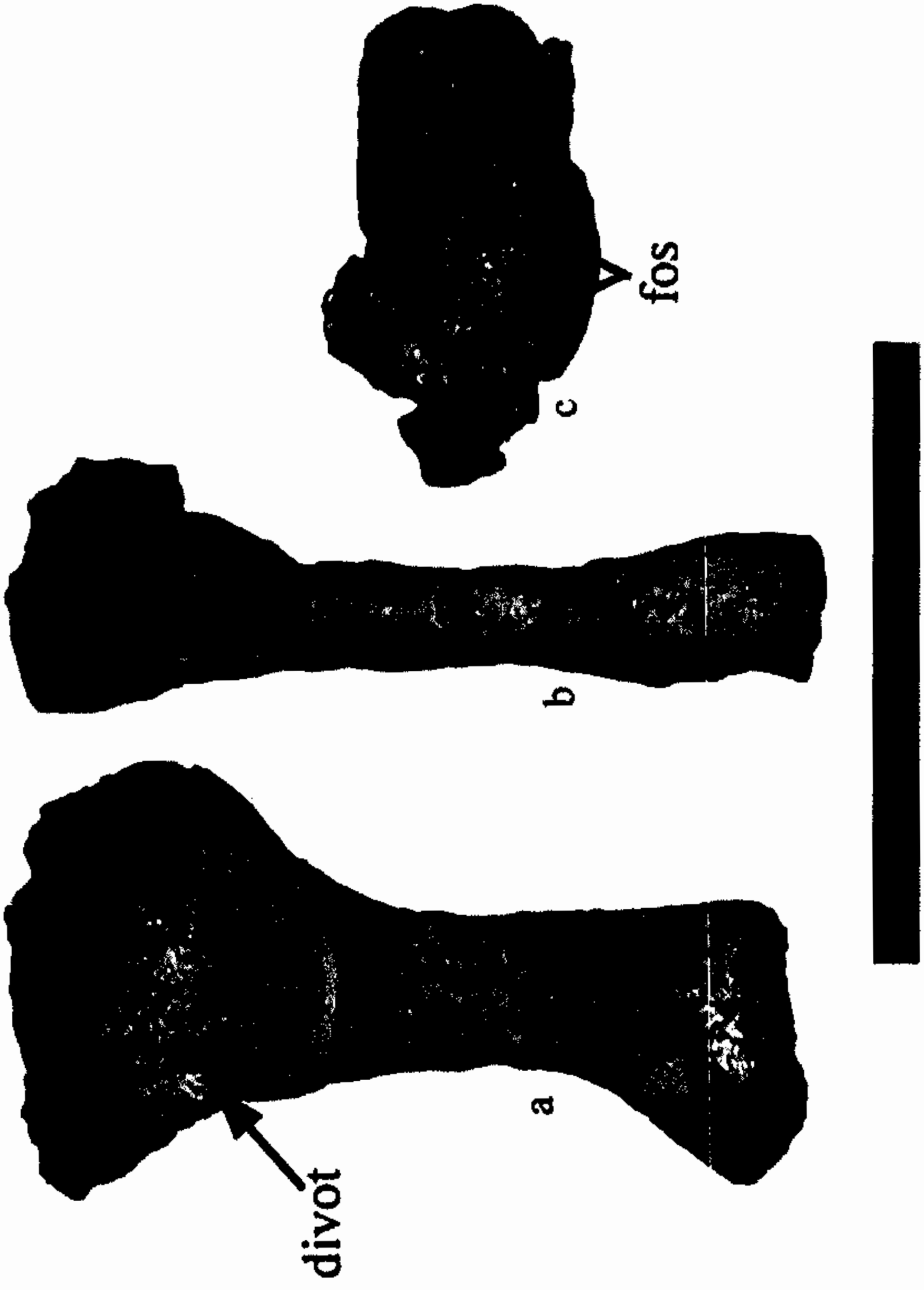

Figure 4.17 Left tibia of *Typothorax coccinarum* (UCMP V2816 34255) 70/U80: in (a) anterior, (b) medial, and (c) proximal views. Blackened areas indicate matrix. Scale bar = 10 cm.

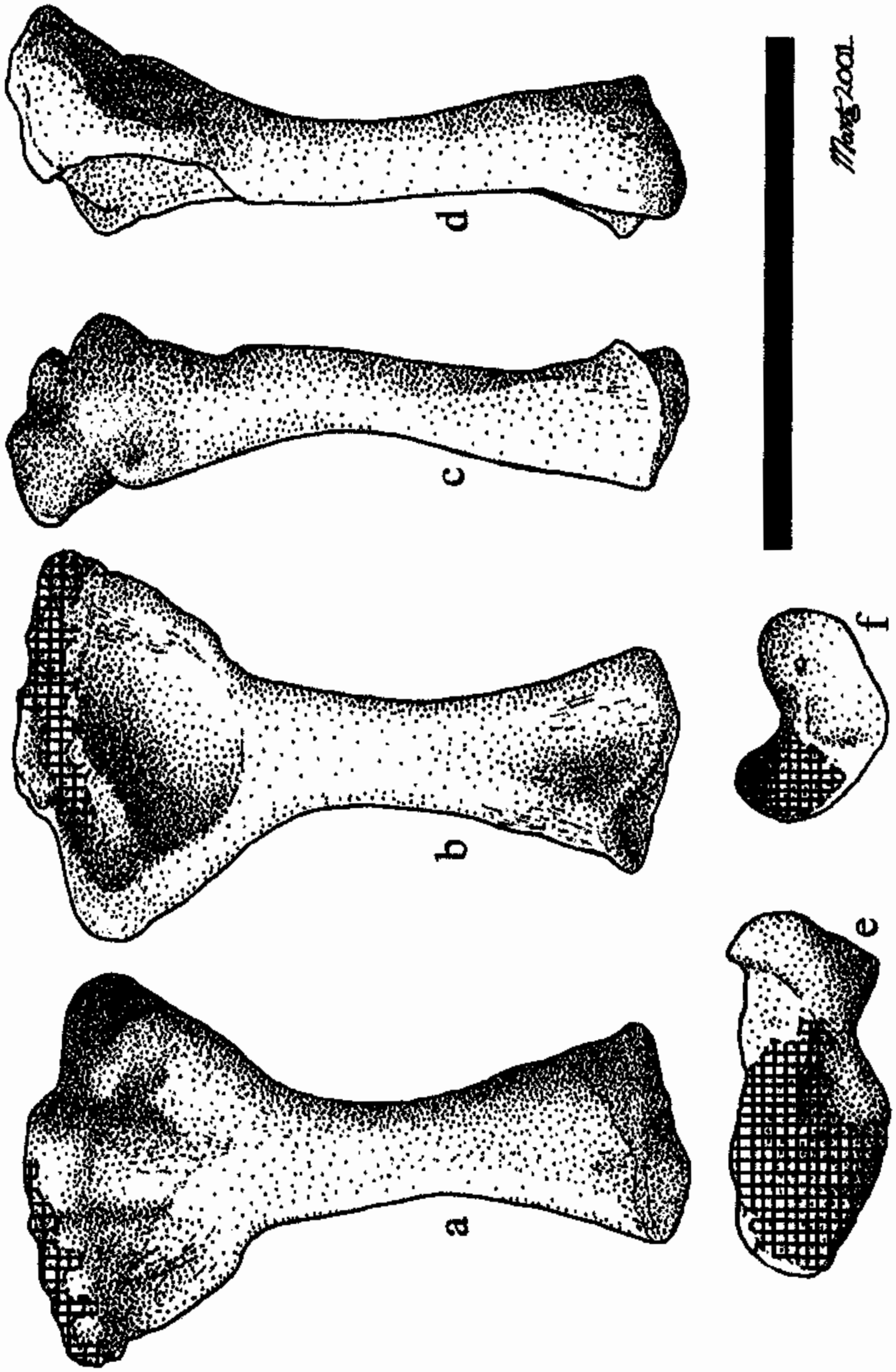

Figure 4.18 Left tibia of *Typothorax coccinarum* (UCMP V2816 122678); in (a) anterior, (b) posterior, (c) medial, and (d) lateral (posterolatetral) views. Dashed lines represent broken bone edges, cross hatching broken bone surface. Scale bar = 10 cm.

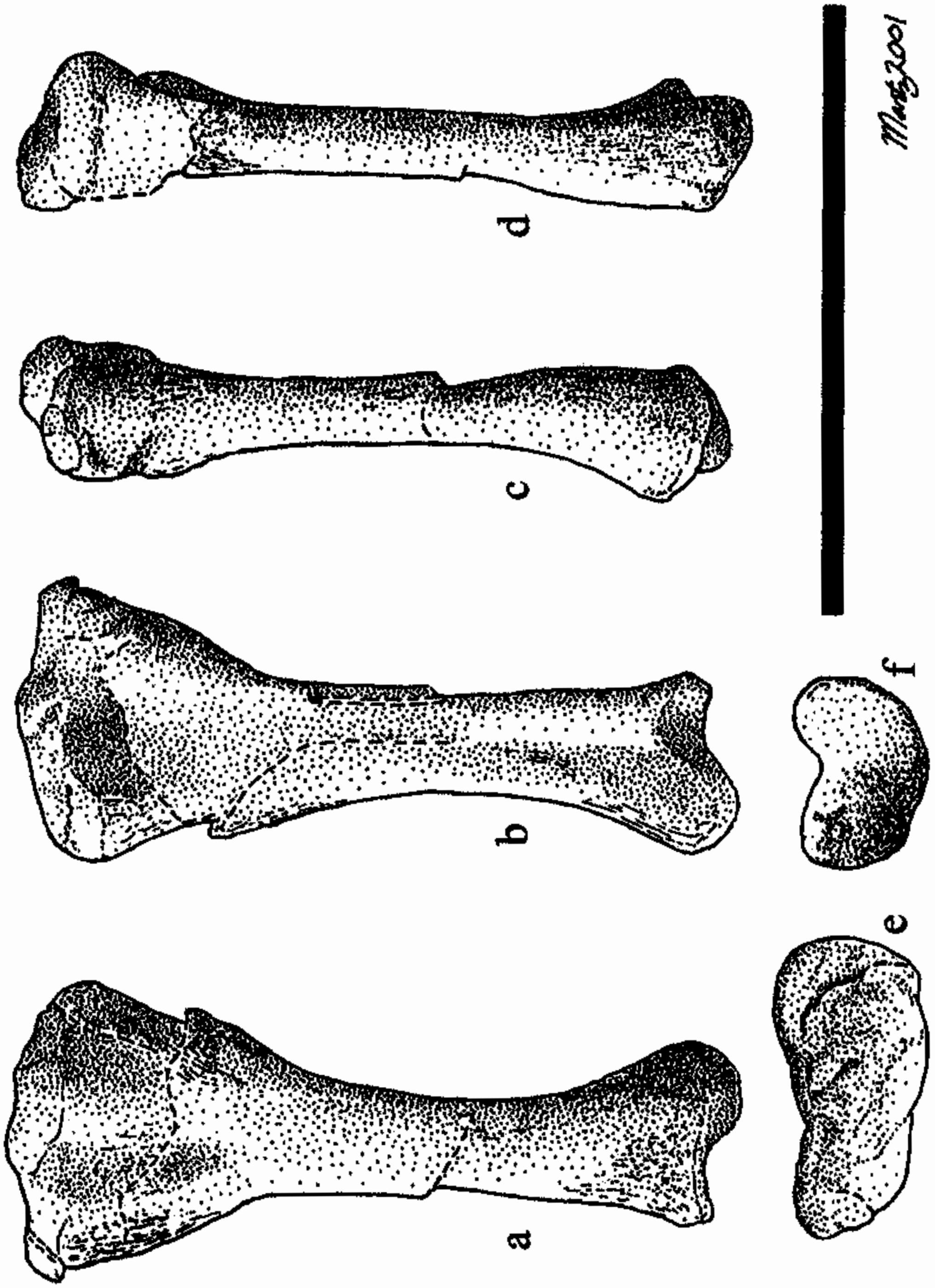

Figure 4.19 Right tibia of *Typothorax coccinarum* (TTUP 9214); in (a) anterior, (b) posterior, (c) medial, and (d) lateral views. Dashed lines represent broken bone edges. Scale bar = 10 cm.

Table 4.6. Aetosaur tibia measurements

All measurements are in millimeters, and were rounded off to the nearest millimeter. Italicized measurements were reconstructed using the expectation maximization method in order to calculate the tibia PC1. The measurements are explained graphically in Fig. 4.13, numbered as below. Measurements for USNM 2585 and AMNH 2713 are from Cope (1887) and Von Huene (1915).

	Typothorax					
	UNSM 2585	AMNH 2713	UCMP V2816 122680 70/Fa2	UCMP V2816 34248 70/G6	UCMP V2816 122678 70/G6	UCMP V2816 34255 70/U80 (Fig. 4.17)
1. Length	*108*	*183*	104	*128*	125	139
2. Proximal width (mediolateral)	55	107	57	62	61	7
3. Proximal thickness (anteroposterior)	33	73	31	33	35	36
4. Mid-shaft width (mediolateral)	33	43	21	22	22	27
5. Mid-shaft thickness (anteroposterior)	18	32	14	16	15	26
6. Distal width (mediolateral)	*31*	*71*	40	*43*	42	50
7. Distal thickness (anteroposterior)	NA	NA	20	NA	NA	24
8. Size score on PC1	8.404	9.8904	8.2202	8.3959	8.3685	8.9170

Table 4.6. Continued

	Typothorax TTUP 9214	*Longosuchus* TMM 31185- 84b "xa"	TMM 31185- 84b "left"	*Desmatosuchus* UCMP V269 25877 CD1	Loadings
1. Length	118	193	198	210	.2117
2. Proximal width (mediolateral)	48	83	82	99	.3721
3. Proximal thickness (anteroposterior)	21	49	42	70	.5146
4. Mid-shaft width (mediolateral)	18	34	29	41	.3779
5. Mid-shaft thickness (anteroposterior)	11	20	23	26	.5080
6. Distal width (mediolateral)	30	52	55	70	.3885
7. Distal thickness (anteroposterior)	17	29	34	34	NA
8. Size score on PC1	7.6494	NA	NA	NA	

V2816 122679 (Fig. 4.18a). This area may have been the attachment site for the internal lateral ligament, as in crocodilians (Brochu, 1993). The posterior side of the head is concave, much more deeply in the Canjilon specimens then in TTUP 9214 (Figs. 4.18b, 4.19b). In anterior and posterior view, the medial side of the head is often distinctly thicker and blunter then the more pinched and pointed lateral side (especially in 34255 70/U80; Fig. 4.17a). This is also often the case in *Desmatosuchus*, and to a lesser extent in *Longosuchus* and *Stagonolepis*. The thicker medial side was probably the attachment site for the *M. tibialis anterior*, as in crocodilians (Brochu, 1993). On the lateral side of the head is a rugose area (in specimens which are not overprepared) for the attachment of a muscle or ligament; a divot is present in this area in 34255 70/U80 (labeled in Fig. 4.17a).

The shaft of the tibia is anteroposteriorly compressed, flatter on the posterior side and more convex anteriorly. In the Canjilon material, the shaft is most robust relative to the head in 34255 70/U80 (Fig. 4.17, Table 4.6), which is also the largest *Typothorax* tibia overall. The tibia is relatively more slender, longer compared to the femur, and has a less expanded head in TTUP 9214 then in the Canjilon material, resembling the more gracile tibiae of *Stagonolepis*, *Longosuchus*, and *Neoaetosauroides*.

The distal end of the tibia is expanded mediolaterally as is typical in crocodile-normal archosaurs, though not as much as the head. Neither the distal end nor the head are as expanded in TTUP 9214 as in the Canjilon material (Figs. 4.17a; 4.18a; 4.19a). The divided facet for the astragalus characteristic of pseudosuchians is present (Fig. 4.18f; 4.19f); the medial part of the facet is flat and projects slightly posteriorly (see especially 4.18b, c; 4.19c). The lateral facet is more convex and projects downward, meeting the concave lateral surface of the astragalus. When not smoothed by overpreparation, the anterior side of the distal end is rugose, probably for the medial tibioastragalar ligament as in crocodilians (Brochu, 1992).

4.4.9. Fibula

Several fibulae are known from the Canjilon material (Table 4.7): UCMP 34240 70/E, 34248 70/G6 (Fig. 4.20), 12268 70/L (the most massive), and 122682 70/Fa2. 12268 70/L was found in the adjacent grid square to the "U" specimen, and may be referable to it. As with the other "U specimen" limb elements, pronounced muscle scars on the 70/L fibula are not visible in the other specimens. An incomplete left fibula is known from TTUP 9124 (Fig. 4.21). The distal end is absent, and a short section of shaft is probably missing between the illiofibularis trochanter and the broken-off proximal end. The midshaft section bearing the trochanter is appressed to an unidentifiable mass of bone (not shown in Fig. 4.21).

The proximal articular surface of the fibula is slightly convex. The head is slightly mediolaterally compressed, making it oval in proximal view (Fig. 4.20e), more so in the Canjilon specimens than in TTUP 9124. The proximal end is striated all the way around, especially on the medial side in TTUP 9124 (Fig. 4.21a), and probably also the Canjilon fibulae, although the latter are generally too overprepared to be certain. The anterior side of the proximal end is rounded (Figs. 4.20c, 4.2.c), but the posterior side is flattened (Figs. 4.20d, 4.21d), with the flattened surface tapering proximolaterally. This flattened surface is bounded laterally by a pinched ridge, which is very prominent and extends some distance down the shaft distally in 12268 70/L.

The shaft of the fibula appears more or less straight viewed anteriorly or posteriorly (Fig. 4.20c, d; 4.21c, d). In medial or lateral view however, the shaft is distinctly bowed so that the proximal and distal ends are inclined posteriorly (Fig. 4.20a, b; 4.21a, b). This bowing is due to the huge illio-fibularis trochanter[15], which is characteristic of pseudosuchians but particularly massive in aetosaurs (Parrish, 1986; Long in Murry, 1995). The trochanter projects slightly anterolaterally. In anterior view,

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[15] This trochanter has been termed the "lateral trochanter" by Walker (1961), and the "anterolateral process" by Heckert and Lucas (1999). The term "illio-fibularis trochanter" was used by Parrish (1986), noting its probable homology with the much smaller trochanter in crocodilians, and this term is preferred here.

Table 4.7. Aetosaur fibula measurements

All measurements are in millimeters, and were rounded off to the nearest millimeter. The measurements are explained graphically in Fig. 4.13, numbered as below. Measurements for AMNH 2713 are from Cope (1887) and Von Huene (1915).

	Typothorax AMNH 2713	UCMP V2816 122982 70/Fa2	UCMP V2816 122681 70/L	TTUP 9214 (Fig. 4.21)
1. Length	NA	126	NA	NA
2. Proximal width	80	34	NA	25
3. Proximal thickness	48	24	NA	19
4. Distance, proximal end to trochanter	NA	25	23	54
5. Thickness at trochanter	NA	13	18	18
6. Distal width	NA	40	45	NA
7. Distal thickness	NA	17	24	NA

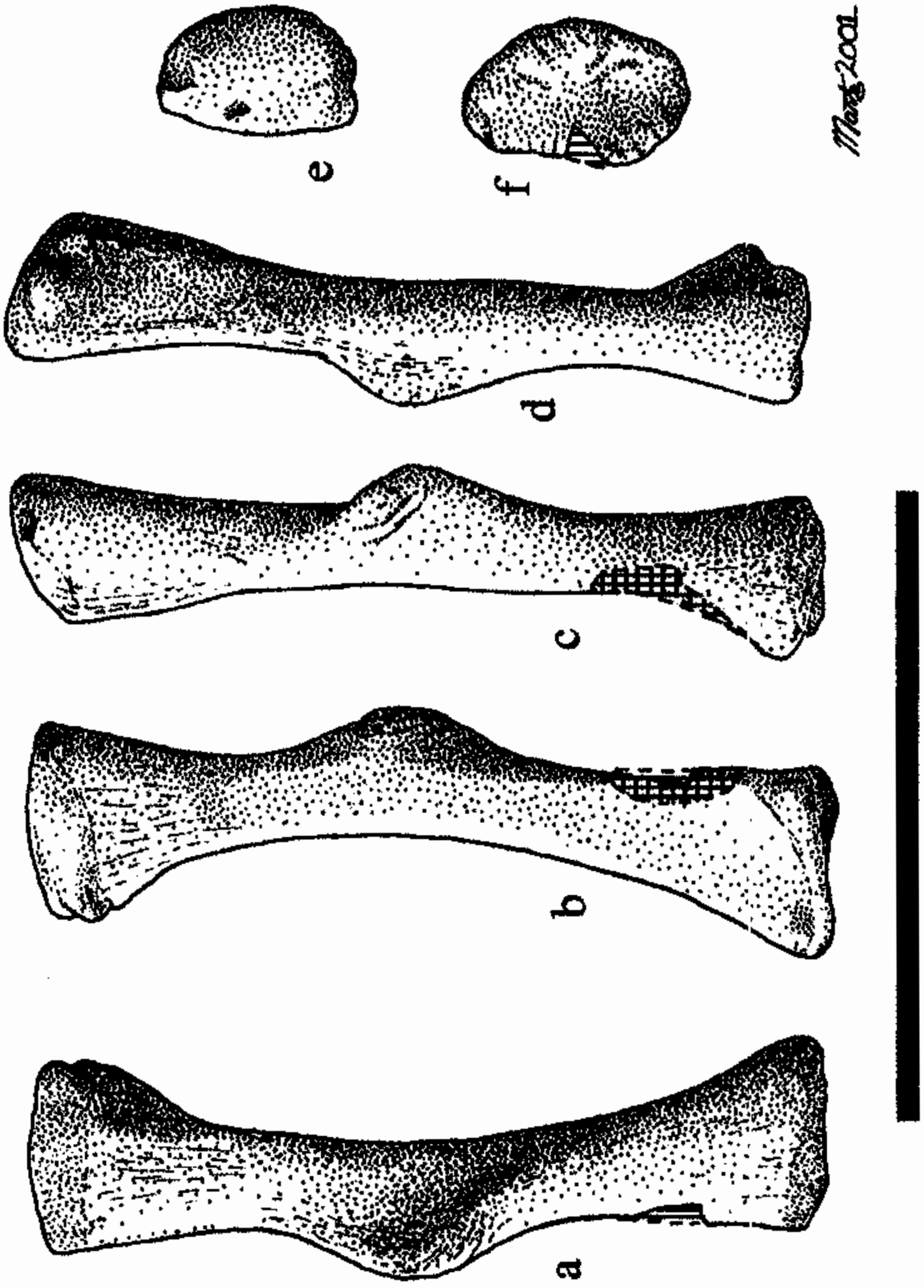

Figure 4.20 Left fibula of *Typothorax coccinarum* (UCMP V2816 34248 70/G6); in (a) lateral, (b) medial, (c) anterior, (d) posterior, (e) proximal, and (f) distal views. Dashed lines represent broken bone edges, cross hatching broken bone surface, and hatching reconstructed parts. Scale bar = 10 cm.

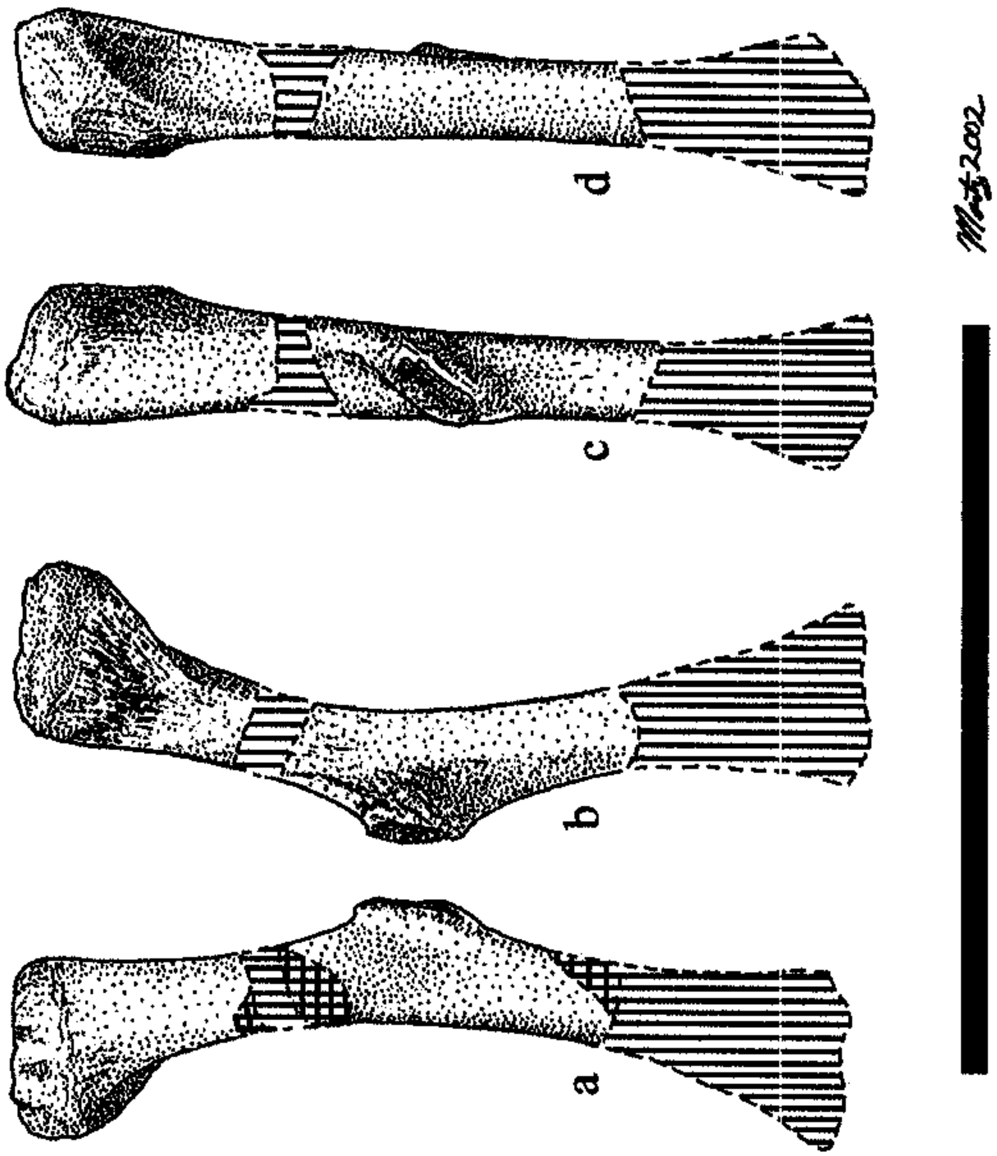

Figure 4.21 Partially reconstructed right fibula of *Typothorax coccinarum* TTUP 9214; in (a) lateral, (b) medial, (c) anterior, and (d) posterior views. Dashed lines represent broken bone, cross hatching broken bone surface, and hatching reconstructed parts. Scale bar = 10 cm.

the trochanter twists around distally toward the lateral side of the shaft, most strongly in 122681 70/L, and most weakly in TTUP 9214 (Fig. 4.21c). The surface of the trochanter is rugose, and in 122681 70/L and TTUP 9214, it has a deep sulcus; the absence of this sulcus in 34248 70/G6 (Fig. 4.20) may be due to overpreparation. On the lateral side of the fibula in 122681 70/L, two distinct ridges lead away from the trochanter posteroventrally along the lateral side of the shaft. In crocodilians, these ridges are the origin of the *M. peroneus longus* (Brochu, 1992).

The distal end of the fibula in the Canjilon material is much more strongly compressed mediolaterally than the proximal end (Fig. 4.20f). The posterior edge is rounded, but the anterior edge is more pinched, especially in 122681 70/L. The lateral side is faintly concave, the medial side convex. The distal articular surface (Fig. 4.20f), which met the tarsus, has two distal facets for the astragalus and calcaneum in erect archosaurs (Parrish, 1986) that can be barely distinguished in the Canjilon *Typothorax* specimens, except for 122681 70/L (not figured). The posterior of the two facets, which is for the calcaneum, is larger and faintly convex. The anterior facet, which is for the astragalus, is smaller.

4.4.10. Astragalus

The traditional importance of the tarsus in archosaur taxonomy, phylogeny, and functional morphology has been reviewed extensively elsewhere (e.g., Chatterjee, 1982; Cruickshank and Benton, 1985; Thulborn, 1980; Sereno and Arcucci, 1990; Sereno, 1991; Dyke, 1998). The tarsus of *Typothorax*, as with all aetosaurs and most other pseudosuchians, has a crocodile normal (CN) rotary ankle joint with two astragalo-calcaneal articulations. The ventral of these consists of a peg on the astragalus, which fits into a socket on the calcaneum.[16] The dorsal articulation of the CN ankle is a sliding joint, in which a process from the astragalus slides over a ball on the calcaneum.

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[16] In crocodile reverse ankles, the peg is on the calcaneum and the socket on the astragalus.

Two *Typothorax* astragali are recognized in the Canjilon material, 122678 70/G6 (attached to the end of the tibia from the same jacket; see Table 1), and 122230, but both are too poorly preserved to describe. A nearly complete right astragalus, which fits perfectly on the end of the right tibia, is known for TTUP 9214 (Fig. 4.22), and is a fairly typical pseudosuchian crocodile-normal element. It is compared with astragali assigned to *Desmatosuchus* (UCMP V269 34493), *Stagonolepis* (UCMP A269 34485), and *Postosuchus* (TMM 3110-513), and is generally similar to these taxa in form. However, it differs distinctly from that of *Alligator* in several ways.

The ventral articulation peg is pointed in anterior and posterior views, with a swollen and convex ventral surface, more amorphous then in *Alligator*, which is part of the the huge distal roller on the anterior side (Fig. 4.22a). The distal roller articulated with metatarsals I and II and the third distal tarsal. On the posterior side, the roller sharply borders the posterior groove, and lacks the curling scroll-shape seen in *Alligator*. A short, thick neck extends from the astragalus, and the dorsal articulation with the calcaneum is its smooth ventral surface, the "articulating channel" of Brochu (1993). In medial view (fig. 4.22c), the neck is curved slightly posteriorly. In posterior view, a strong concavity lies between the neck and the peg, which Sereno (1991) referred to as the posterior groove in crocodilians. The neck is only slightly longer in *Desmatosuchus* than in *Typothorax*, but in *Postosuchus*, the neck is considerably longer then in either aetosaur and the posterior groove is much more pronounced.

On the dorsomedial surface of the neck is another facet at about 90° to the calcaneum articular surface on its underside, which articulated with the fibula. The surface of the fibular facet is faintly concave. The facet is vaguely square in medial view (not terribly evident from Fig. 4.22c), though the ventroposterior corner is slightly more prominent. The shape of the facet is similar in *Desmatosuchus* and *Alligator*, although the ventroposterior corner is extremely elongate in *Postosuchus*, making the facet slightly more rhombohedral in shape. This corner in crocodilians in the attachment site of the fibular-astragalus ligament (Brochu, 1992).

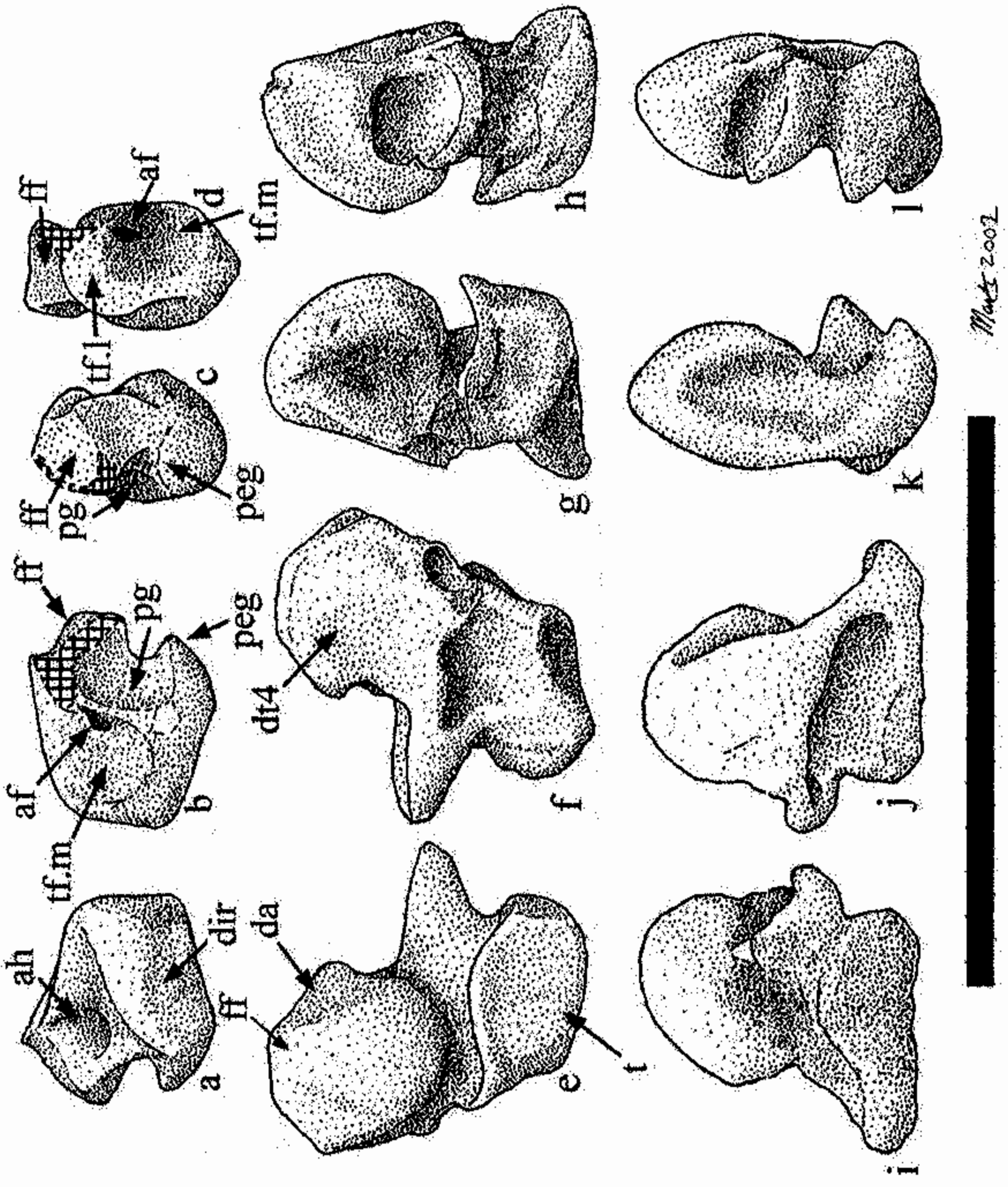

Figure 4.22 Tarsus of *Typothorax coccinarum*; TTUP 9214 right astragalus in (a) anterior, (b) posterior, (c) lateral, and (d) dorsal views; UCMP V2816 left calcanea, 122228 Fa53 in (e) dorsal, (f) ventral, (g) lateral, and (h) medial views; 34253 70/U80? in (i) dorsal, (j) ventral, (k) lateral, and (l) medial views. Dashed lines represent broken bone edges and cross hatching broken bone surface. Scale bar = 10 cm.

Anteriorly, the neck is hollowed by a hemispherical concavity (the anterior hollow), which does not quite contact the distal roller. The hollow is not as deep but much broader in *Desmatosuchus* and *Alligator*, contacting the distal roller and in *Alligator* being especially large and extending down to the peg. The hollow also seems to contain a foramen in *Desmatosuchus* and *Alligator* not evident in *Typothorax*.

The tibia articulation is of the typical pseudosuchian ("divided," "strap-shaped," "saddle-shaped," "U-shaped," or "screw") type, with two distinct, but smoothly joined facets. The medial facet is larger, concave, faces somewhat posteriorly, and is bounded by a buttress separating it from the posterior groove (Fig. 4.22.b). A pit is present on the edge of the medial facet, entering the buttress. One is not clearly evident in *Desmatosuchus*, but a large foramen is also preserved here in *Postosuchus*, and a very deep funnel-shaped pit is present in *Alligator* (see Parrish, 1986, fig. 28). This is the astragalar fossa, which at least in crocodilians is the area of attachment for the posterior and internal tibial-astragalar ligaments (Brinkman, 1980). The flatter lateral facet is smaller and more level then the medial facet.

4.4.11. Calcaneum

Three reasonably good calcanea (all left) are known from the Canjilon *Typothorax* material: 34255, 122228 Fa33, (Fig. 4.22e-i), and 122229; the label for 34255 gives the field numbers "U75, [and] U80", so it probably went with the "U specimen." 34255 is in excellent condition, but 122228 seems to have been badly overprepared, and perhaps distorted by crushing. However, some of the perceived differences between these two calcanea may be natural.

The ventral articulation with the astragalus is a deep socket (Fig. 4.22h, l), supported from below by a broad, protruding, dorsally concave lip, which held the ventrally convex peg of the astragalus. The lip is twisted slightly posteriorly, but is still more symmetrical in *Typothorax*, *Desmatosuchus*, and *Postosuchus* then in *Alligator*.

The dorsal articulation with the astragalus is on an enormous, curving, posteriorly facing hemisphere, the anterior ball, the bottom of which is about level with the lip of the ventral articulation in anterior view (Fig. 4.22e, i). In both *Typothorax* and *Desmatosuchus*, this is clearly divided into two facets. The medial of these, overhanging the articular socket, is the dorsal articular surface over which the neck of the astragalus slid. The lateral part of the ball contacted the fibula, and this part of the ball is much larger then the facet for the astragalus. The astragalus and fibula facets are almost indistinguishable on the ball in *Postosuchus* or *Alligator*, and the distinct facets may be an aetosaur feature. The ventral side of the anterior ball is flattened (Fig. 4.22f, j.), and articulated with the fourth distal tarsal. The lateral side of the ball (Fig. 4.22g, k) is more distinctly sulcate in *Typothorax* and *Desmatosuchus* then in *Postosuchus* or *Alligator*, where it is flatter. In UCMP 34255, there is what appears to be a foramen in this concavity that cannot be clearly discerned in *Desmatosuchus* or *Postosuchus*; however, in *Alligator* there is a foramen present slightly lower, on the neck of the calcaneal tuber.

The most distinctive aspect of the aetosaur calcaneum is the greatly compressed calcaneal tuber, which was the attachment site of the gastronemeus. The dorsal side of this tuber is distinctly curled anteriorly in *Desmatosuchus*, *Typothorax*, and to a lesser extent, *Postosuchus*, though not in *Alligator*. The tuber is badly preserved and overprepared in UCMP 122228, but in UCMP 34255 the curling is so pronounced that it forms a strong, dorsally oriented lip (Fig. 4.22e, g, h). In UCMP 122228 and *Desmatosuchus* the lip does not curl so strongly, and descends and thickens to project medially (the projection is indicated by an un-labeled arrow in Fig. 4.22i). On the ventral side of the calcaneum, directly beneath the fourth distal tarsal articulation, the neck of the tuber is deeply concave (Fig. 4.22f, j); this is not the case in *Alligator*. The posterior side of the tuber in *Alligator* bears a groove that guides the Achilles tendon; only a trace of this groove is visible in *Typothorax* and *Desmatosuchus*.

4.4.12. Metapodials and phalanges

Three metapodials and several phalanges are known for TTUP 9214. The only complete metapodial of the three is a left that is 47 mm long, with proximal and distal ends that are respectively 23 mm and 18 mm wide (Fig. 4.23a). Based on its size compared to that of the other appendicular material, it is most likely a metatarsal (probably II, III, or IV), as it seems to be to too large and too slender to have come from the manus (Sawin, 1945, fig. 5B; Walker, 1961, fig. 19f). It is faintly dorsoventrally flattened, giving it an oval cross section. The wide proximal end projects medially, where it would have been overlapped by the adjacent metatarsal. The dorsal side of the distal end is depressed, and pits for tendon insertions are present on the lateral and medial sides of the same. A small foramen is present on the ventral side of the distal end.

There are several phalanges of various sizes. It is unclear if these belong to the manus or the pes, but the largest at least (Fig. 4.23c-d) are likely to be from the pes. Other then size, little appears to distinguish the phalanges of the manus and pes in aetosaurs. In most, the proximal articular surfaces are concave and faintly pyramidal or diamond-shaped when viewed proximally. The distal end is either as broad as the proximal end or nearly so, and lateral tendon pits occur as in the metapodial. Most of the phalanges are at least slightly asymmetrical in dorsal and ventral views, indicating that the digits curved either medially or laterally (depending on which side they came from). One of the larger phalanges is unusual in having a proximal end that is roughly oval rather than pyramidal, and has an unusually swollen-looking distal end (Fig. 4.23c), which may be pathological.

A single ungal is known for TTUP 9214 (Fig. 4.23h). It is strongly curved, laterally compressed, and has a blunt tip. Single grooves run near the ventral edge on both sides (probably for blood vessels), deeper near the tip. Faint pitting is visible along the dorsal edge. The proximal end is concave as in the other phalanges.

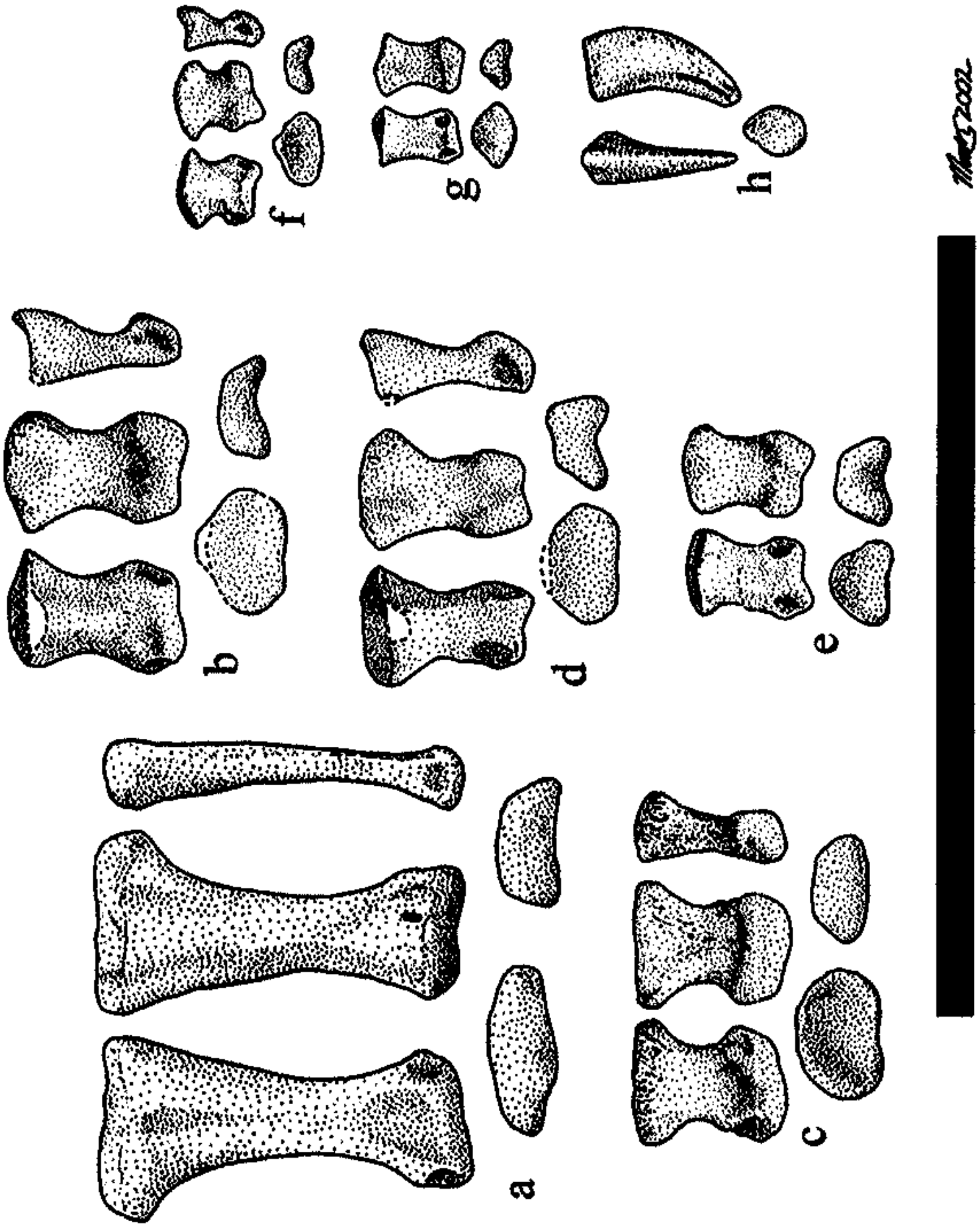

Figure 4.23 Metapodial and phalanges of *Typothorax coccinarum* (TTUP 9214); (a) probable left metatarsal in (clockwise starting from the upper left) dorsal, ventral, right lateral, proximal, and distal views; (b)-(d), (f) phalanges in (clockwise starting from the upper left) dorsal, ventral, left lateral, distal, and proximal views; (e) and (g) phalanges in (clockwise starting from the upper left) dorsal, ventral, distal, and proximal views; h) ungal in (clockwise starting from the upper left) dorsal, right lateral, and proximal views. Dashed lines represent broken edges and reconstructed areas. Scale bar = 10 cm.

4.5 Osteoderms

The excellent description of the dorsal paramedian and lateral scutes of *Typothorax coccinarum* by Long and Ballew (1985) was based largely on the Canjilon Quarry material, and it should be noted that a repeat of their work forms the skeleton of the following discussion. However, enough new observations of the Canjilon Quarry and Post Quarry *Typothorax* scutes were made by the author to warrant an expanded description.

Several different types of scutes occur in aetosaurs. The most commonly described are the dorsal paramedian and lateral scutes, which are therefore the best-known elements of aetosaur anatomy (e.g., Long and Ballew, 1985; Long and Murry, 1995; Heckert and Lucas, 2000). The dorsal paramedian scutes are arranged in two columns[17] running down the back. Each dorsal paramedian articulates with its fellow dorsal paramedian along its medial edge, and a lateral scute along its lateral edge. Lateral scutes are usually flexed, extending partly down the sides of the animal. Usually (except in the cervical region of some taxa), each row of scutes corresponds to a single vertebra. Therefore, each row along the back consists of two dorsal paramedians and two lateral scutes overlying a single vertebra. Ventral scutes form an equally extensive carapace covering the underside of the body, and appendicular scutes covering the limbs are also described for some aetosaur taxa (e.g., Walker, 1961; Heckert and Lucas, 1999). However, the morphology, variation, and exact distribution of ventral and appendicular scutes on the body are generally not as well understood, and the dorsal paramedians (and to a lesser extent, the laterals) are far better known. Aetosaur taxa are generally diagnosed almost entirely on dorsal paramedian scute morphology.

Determining which scutes come from which area on the body is problematic, and depends on rare specimens in which the scutes are still articulated. Such specimens provide a Rosetta Stone for interpreting the scutes of less well-articulated specimens,

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[17] Following Heckert and Lucas (2000), the term "column" refers to a line of consecutive scutes running antero-posteriorly down the length of the body (referred to as "rows" by Walker, 1961), wheras a "row" is a series of scutes running medio-laterally (Sawin, 1947 referred to these as "bands").

even ones from different taxa. The interpretation of the placement of scutes on the body for *Typothorax* given here is based mostly on information from articulated material for *Aetosaurus*, *Stagonolepis* (Walker, 1961; Case, 1922), and *Coahomasuchus* (Heckert and Lucas, 1999). Additionally, the Canjilon Quarry "U" specimen of *Typothorax* includes two blocks of roughly articulated scutes (Fig. 4.24), showing the antero-posterior change in the morphology of dorsal paramedian and lateral scutes in the pelvic and caudal regions. Some additional hints are also provided by the brief summary of Hunt et al. (1993) of *Typothorax* specimen NMMNH P-12964.

The anterior of the two blocks of roughly articulated scutes belonging to the Canjilon "U" specimen (34255 70/U80; Fig. 4.24a, b) is interpreted as representing the left side of the pelvic region. It consists primarily of a string of six mostly complete lateral scutes, with the lateral ends of the articulating dorsal paramedians (the medial ends are missing) still more or less in place, though all scutes have been very slightly displaced from their original position. At the posterior end of this string of scutes is a jumbled mass of scutes and other bone fragments. Facing the same side as the ventrolateral flange of the lateral scutes is a mass of five scutes interpreted as probably representing ventral scutes (Fig. 4.24b). This mass of scutes was probably slightly displaced from its natural position before burial. A possible thigh-region appendicular scute faces outward on the opposite side of the block (indicated by an arrow in Fig. 4.24a). The rest of this mass of bone seems to consist mostly of fragmentary dorsal paramedian scutes, although a caudal vertebra and another small scute (not figured) probably representing a ventral scute are also present.

The posterior of the articulated scute blocks, representing the middle and posterior part of the tail, is more complete (UCMP V2816 34255 70/U75; Fig. 4.24c, d). Both the left and right columns of dorsal paramedian and lateral scutes are at least partially preserved and in articulation, and ventral scutes are also in place. Twelve right side dorsal paramedian scutes are almost perfectly articulated, while at least parts of

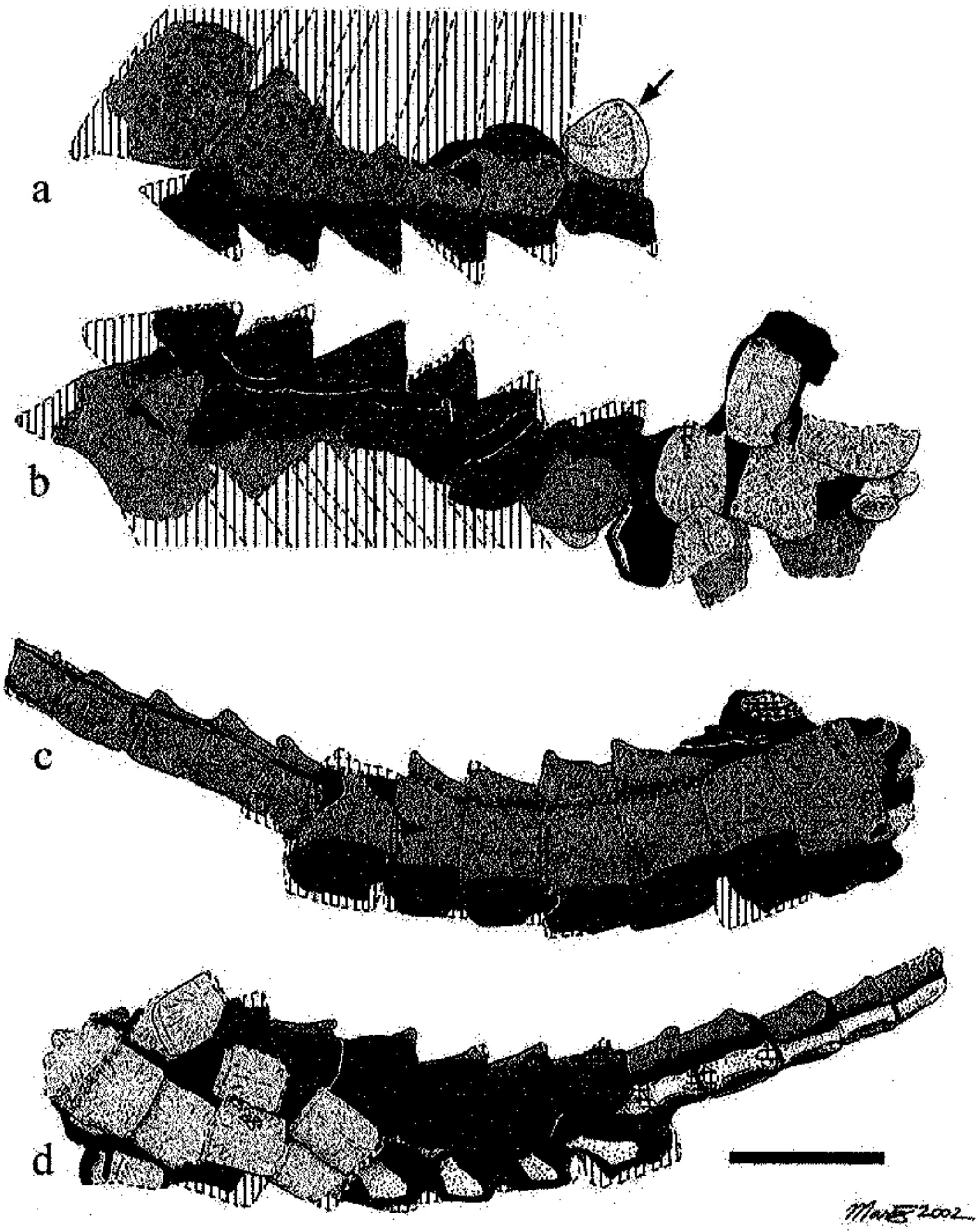

Figure 4.24 Blocks with articulated *Typothorax coccinarum* "U specimen" scutes (UCMP V2816 34255); pelvic region scute block 34255 70/U80 in (a) dorsal and (b) left ventromedial views; caudal region scute block 34277 70/U75 in (c) right dorsolateral and (d) left ventrolateral views. Dashed lines indicate broken edges, cross hatching broken bone surface, and hatching missing bone. Caudal vertebrae and chevrons are white, dorsal paramedian scutes medium gray, lateral scutes dark gray, ventral and appendicular scutes light gray (the possible thigh region appendicular scute is indicated by an un-labeled arrow), and matrix is black. Scale bar = 10cm.

eleven of the adjacent left dorsal paramedians are preserved. Six right laterals and six or seven left laterals are at least partly preserved; those adjacent to the posteriormost five dorsal paramedians are absent on both sides. In dorsal view (Fig. 4.24c), the left dorsal paramedians are partly displaced over the right dorsal paramedians, and the lateral scutes are displaced over their adjacent dorsal paramedians on both sides. Only the proximal-most ventral scutes are preserved, apparently representing two columns (Fig. 4.24d). The right column preserves five articulated scutes, the left only three; all of the latter are slightly displaced from their natural position. The ventral surfaces of the posterior nine caudal vertebrae are exposed, and the anterior four of these have chevrons still in place.

4.5.1 Dorsal paramedian scutes

The dorsal paramedian scutes of *Typothorax coccinarum* are characterized by ornamentation on the dorsal surface that is usually roughly circular or oval, and arranged randomly rather then in a radiating pattern as in most aetosaurs. The pitting around the center of ossification is often finer and denser then elsewhere on the scute; this is also evident in other aetosaurs (including *Typothorax reseri*; Fig. 2.4). A raised anterior bar occurs in all the dorsal paramedians, which is broadest (anteroposteriorly) at the anterolateral and anteromedial corners of the scute. Anterolaterally, the bar projects past the ornamented region of the dorsal surface; anteromedially, it forms an anteriorly pointed tip along the straight medial edge. A bar of this form is typical in aetosaurs, and was overlapped by the proceeding dorsal paramedian. The ornamentation is more weakly incised or entirely absent just behind the anterior bar. This region is also often faintly depressed. The medial and lateral edges of the scute do not show the extremely pronounced tongue and groove articulations seen in the dorsal paramedians of *Desmatosuchus*, *Longosuchus*, and *Lucasuchus* (Long and Ballew, 1985; Long and Murry, 1995; Heckert and Lucas, 2000). The dorsal side of the posterior edge is never beveled or tapering as seen in *Paratypothorax* and "*Tecovasuchus*" (Martz and Small, in prep), although faint beveling of the *ventral* side of the posterior edge (where it overlapped the anterior bar of the following scute) is usually present. This beveled surface is covered with grooves inclined toward the center of ossification.

The widest scutes in *Typothorax* have a width/length ratio approaching or exceeding 4.0, which is unusually wide in aetosaurs (Heckert and Lucas, 2000; Fig. 4.25; Table 4.8), giving the articulated carapace a discoid outline in dorsal view shared only by *Paratypothorax* (Long and Ballew, 1995; Heckert and Lucas, 2000) and "*Tecovasuchus*" (Martz and Small, in prep). None of the dorsal paramedian scutes from any region of the body are as wide in TTUP 9214 as in the corresponding region of the Canjilon specimens (Table 4.8). It appears that the carapace of the smaller specimen was not as wide as seen in the larger individuals, probably a feature of ontogeny. The term "width" refers to the mediolateral long axis of a scute, whereas its "length" is in the antero-posterior direction. For consistency, the width is always measured just behind the anterior bar, and the length is always measured along the medial edge (Table 4.8). For the sake of clarity, presacral dorsal paramedian scutes posterior to the cervical region will be referred to as "dorsal (region) dorsal paramedian scutes".

In *Aetosaurus*, *Stagonolepis* (Walker, 1961), and *Coahomasuchus* (Heckert and Lucas, 1999), several patterns can be seen in the antero-posterior variation in dorsal paramedians scute morphology that may be plausibly applied here to *Typothorax*:

1. The dorsal paramedian scutes become increasingly wide (mediolaterally) posteriorly into the dorsal region, then narrow again into the caudal region, eventually becoming longer (antero-posteriorly) than wide.
2. Posteriorly, the dorsal paramedians also develop more deeply incised ornamentation, which becomes deepest over the pelvic region.
3. In *Aetosaurus* and *Stagonolepis*, the dorsal bosses also become more pronounced posteriorly.

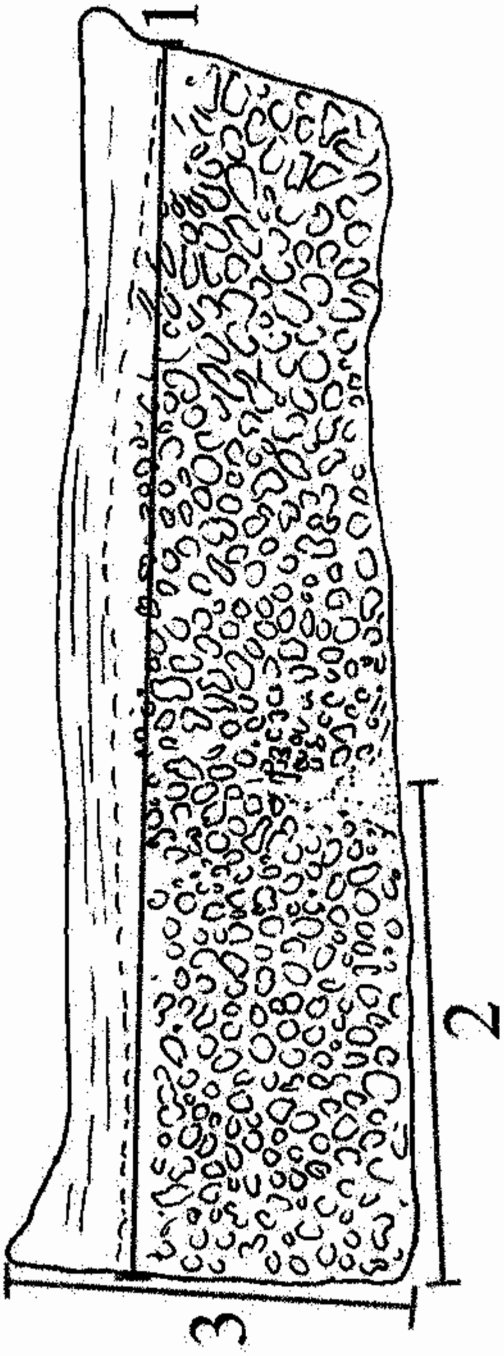

Figure 4.25 Dorsal paramedian scute measures given in Tables 4.8; measure 4, the thickness across the center of ossification, is not shown but was taken using calipers from the anterior edge of the scute so as to avoid the boss on the posterior edge (if present).

Table 4.8. Dorsal paramedian scute measurements for *Typothorax coccinarum*

All measurements are in millimeters, and were rounded off to the nearest millimeter. The measurements are explained graphically in Fig. 4.25, numbered as below. An ">" indicates that the scute is incomplete, but the preserved section is at least that length.

	UCMP V2816 34227 70/Fa55 (Fig. 4.25.a)	34227 70/F59 (Fig.4.25.b, c)	34227 70/H8 (Fig. 4.28.d-h)	34227 70/J8 (Fig. 4.29)	33227 70/Fa5 (Fig. 4.32.a, b)
1. Width behind anterior bar	128	302	353	322	194
2. Distance to center of ossification from medial edge	NA	120	145	140	69
3. Length along medial edge	>50	>74	~95	>116	>68
4. Thickness at center of ossification	8	12	15	19	6

	UCMP V2816 34255 70/U75 (Fig. 4.32.c, d)	158670 70/Fa52 (Fig. 4.32.e, f)	TTUP 9214 (Fig. 4.27.a, b)	(Fig. 4.27.c, d)	(Fig. 4.28.a, c)
1. Width just behind anterior bar	~88	40	80	100	162
2. Distance to center of ossification from medial edge	41	17	?	39	66
3. Length along medial edge	61	~56	40	~48	>53
4. Thickness at center of ossification	4	4	6	8	10

	TTUP 9214 (Fig. 4.30.a)	(Fig. 4.33.a)	(Fig.4.33.b-d)	(Fig4.33.e)	(Fig.4.33.i)
1. Width just behind anterior bar	129	116	91	51	30
2. Distance to center of ossification from medial edge	?	46	40	?	?
3. Length along medial edge	?	~58	>49	~29	~27
4. Thickness at center of ossification	8	7	7	5	4

These changes can be applied to interpreting the antero-posterior placement of un-articulated *Typothorax* scutes. Long and Ballew (1985) assigned the dorsal paramedians of *Typothorax* in the same order favored here, presumably based on the same reasoning:

1. Scutes with weak ornamentation and no bosses are interpreted as cervical and anterior dorsal (region) dorsal paramedians.
2. Scutes with the deepest ornamentation, bosses, and greatest width are interpreted as mid-dorsal (region) and pelvic dorsal paramedians.
3. For the caudal scutes, more direct evidence of change in the caudal series in *Typothorax coccinarum* comes from the posterior articulated tail block of the "U" specimen (UCMP V2816 34255 70/U75; Fig. 36), and the discussion of caudal scutes is based mostly on that specimen. These show the expected narrowing of the dorsal paramedians and weakening of the ornamentation.

4.5.1.1 Anterior cervical dorsal paramedian scutes

The first few cervical dorsal paramedian scutes for *Typothorax*, including the modified first pair that contacted the back of the skull, are unknown (Long and Ballew, 1985). Although there are a few scutes for TTUP 9214 that seem to be the right size and shape to have come from the anterior cervical region, they are unlikely to be cervicals due to the coarseness of the ornamentation compared to those of the posterior cervical-anterior dorsal region; they are believed to be instead posterior caudal dorsal paramedian scutes and ventral scutes.

Hunt et al. (1993, p. 209) reported that in NMMNH P-12964, "the neck is extremely short… The gradual transition between the dorsal and cervical armor by Long et al. (1989, Fig. 3A) is erroneous… the carapace narrows rapidly in the shoulder region." As the dorsal paramedian scutes described below from the posterior cervical and anterior dorsal region probably were not that far behind the skull, the first cervical paramedians were probably also anterolaterally curved with extremely faint ornamentation. Long and

Ballew (1985) suggested that the cervical dorsal paramedians were probably thin rather then thickened as in *Desmatosuchus*, and this is supported by the fact that the posterior cervical and anterior dorsal (region) dorsal paramedians are thinner then those behind.

4.5.1.2 Posterior cervical and anterior dorsal (region) dorsal paramedian scutes

Unlike those from the posterior part of the column, the dorsal paramedians which probably covered the posterior cervical and anterior dorsal region (Figs. 4.26, 4.27) curve anterolaterally. This curvature is likely responsible for the rapid anterior tapering of the carapace noted by Hunt et al. (1993) in NMMNH P-12964. The two dorsal paramedian scutes found at the Patricia Site (TTUP 10079) are of this type.

The pitting in these scutes is finer, more weakly incised, and more nearly circular then in the rest of the presacral dorsal paramedians (Figs. 4.26a, b; 4.27a, c). In at least one of the TTUP 9214 scutes (Fig. 4.27c), the pitting is more deeply incised medial to the center of ossification then lateral to it; this is not clearly evident in the Canjilon Quarry or Patricia Site scutes. The ornamentation is also less distinct laterally on the scute.

There is no sign of arching at the center of ossification in the narrower (and probably therefore more anterior) of these scutes in TTUP 9214. However, some of the Canjilon scutes (e.g., 34227 70/F59) do seem to show weak arching. In TTUP 9214, there is a faint hint of the longitudinal ridge seen at the center of ossification seen in the more posterior scutes.

The anterior bar is strongly thickened and elevated above the ornamented region of the scute, more so then in the more posterior dorsal paramedians. A strong ventral keel is present in these scutes (Figs. 4.26c; 4.27b, d), though not quite as thick as in the dorsal region. The lateral edges of the scutes are constricted compared to the medial edges in at least some of the Canjilon Quarry scutes (Fig. 4.26b, c), probably to help the anteriorly curving scutes fit within the rapidly narrowing carapace. The lateral articular edge is perpendicular to the anterior and posterior edges of the scute.

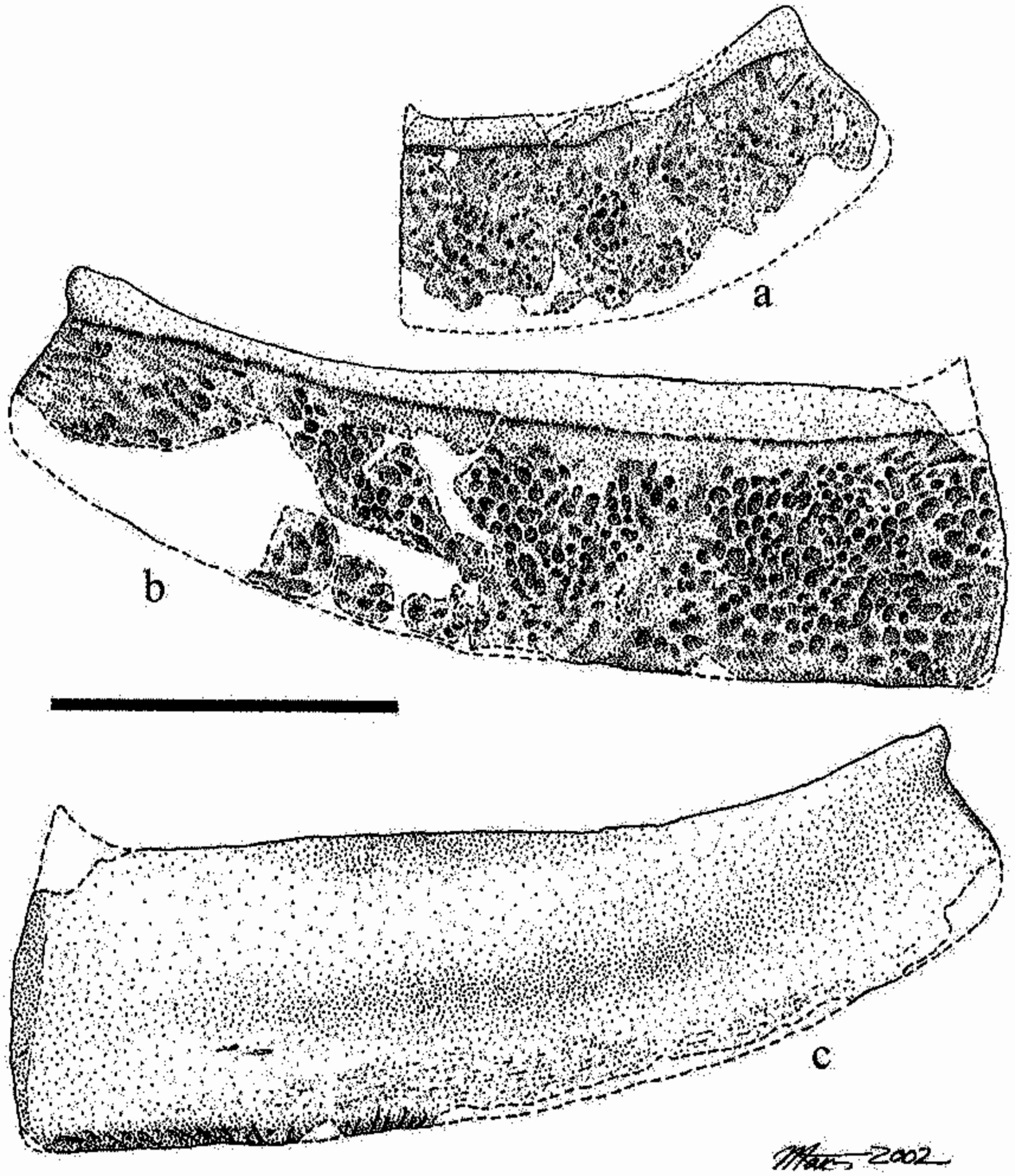

Figure 4.26 Posterior cervical-anterior dorsal (region) dorsal paramedian scutes of *Typothorax coccinarum* from Canjilon Quarry (UCMP V2816); (a) right cervical dorsal paramedian 34227 70/Fa55 in dorsal view; left anterior dorsal 34227 70/F59 in (b) dorsal and (c) ventral views. Dashed lines represent broken edges and reconstructed areas. Scale bar = 10 cm.

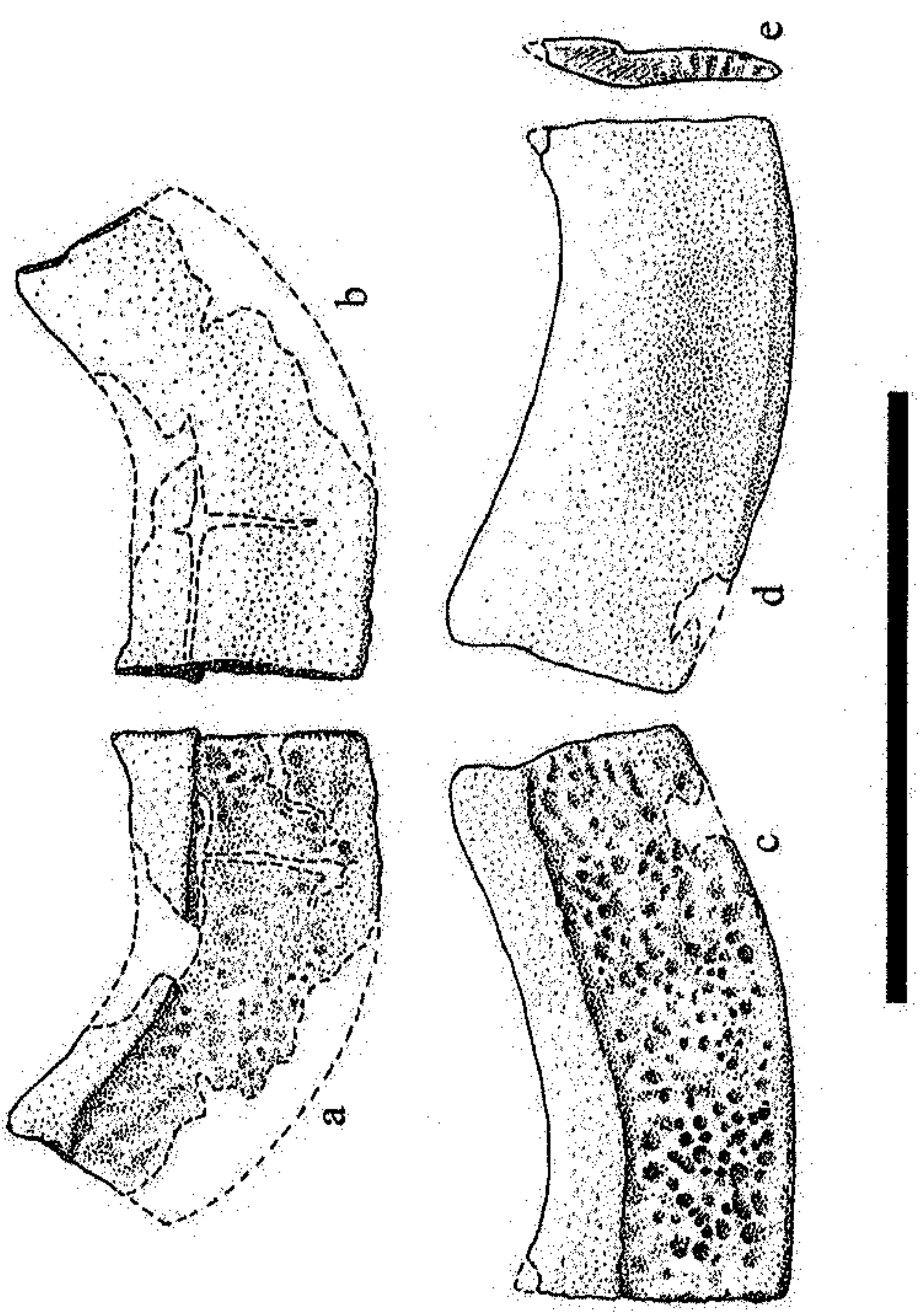

Figure 4.27 Posterior cervical-anterior dorsal (region) dorsal paramedian scutes of *Typothorax coccinarum* (TTUP 9214); left cervical dorsal paramedian in (a) dorsal and (b) ventral views; right cervical or anterior dorsal in (c) dorsal, (d) ventral, and (e) medial views. Dashed lines represent broken edges and reconstructed areas. Scale bar = 10 cm.

4.5.1.3 Mid-posterior dorsal (region) and pelvic dorsal paramedian scutes

Posteriorly, the dorsal paramedian scutes become noticeably wider, and lose the anterolateral curvature so that the long axis of the scutes is more or less straight (Figs. 3.1, 4.28). These scutes show slight arching at the center of ossification in both the Canjilon Quarry and TTUP 9214 material. However, this arching is more pronounced in the latter, though not as strongly as in *Typothorax reseri* (Fig. 3.1). As argued previously, this arching is believed to be natural (contra Long and Murry, 1995), and the decrease in arching between smaller and larger individuals may represent allometric change.

The pitting on the dorsal surface becomes larger, slightly less circular, and deeper than in the more anterior scutes. In TTUP 9214, the pits appear to be relatively large compared to the size of the scute than in both the Canjilon Quarry material (Fig. 4.28c, d) and *Typothorax reseri* (Fig. 2.3). In TTUP 9214 the pitting is slightly elongate near the lateral edge, and in the Canjilon Quarry material the pits are subtly larger and more irregular in form laterally (Figs. 3.1a; 4.28 c, d).

In TTUP 9214, the faint longitudinal ridge hinted at in the more anterior scutes is distinctly present at the center of ossification in the dorsal (region) dorsal paramedian scutes. This ridge resembles that present in *Aetosaurus ferratus* (Wild, 1989). As the presence of such a longitudinal ridge may be plesiomorphic for aetosaurs (Heckert and Lucas, 1999, 2000), the ridge may represent an ancestral feature present in young animals that is lost through ontogeny. In the Canjilon Quarry material, a distinctly raised boss develops for the first in scutes of the dorsal and pelvic region. In some of the Canjilon scutes, a slightly thickened region or very weakly developed knob is set slightly anterior to the posterior margin of the scute (as coded in the phylogeny of Heckert and Lucas, 1999). However, in other scutes (e.g., Fig. 4.28d) the boss is slightly more strongly pronounced and in the form of a weak asymmetric pyramid, with the two sides facing anteriorly and a flat, vertical, posterior side sitting directly on the posterior margin of the scute (as noted by Long and Ballew, 1985; contra the character coding in Heckert and

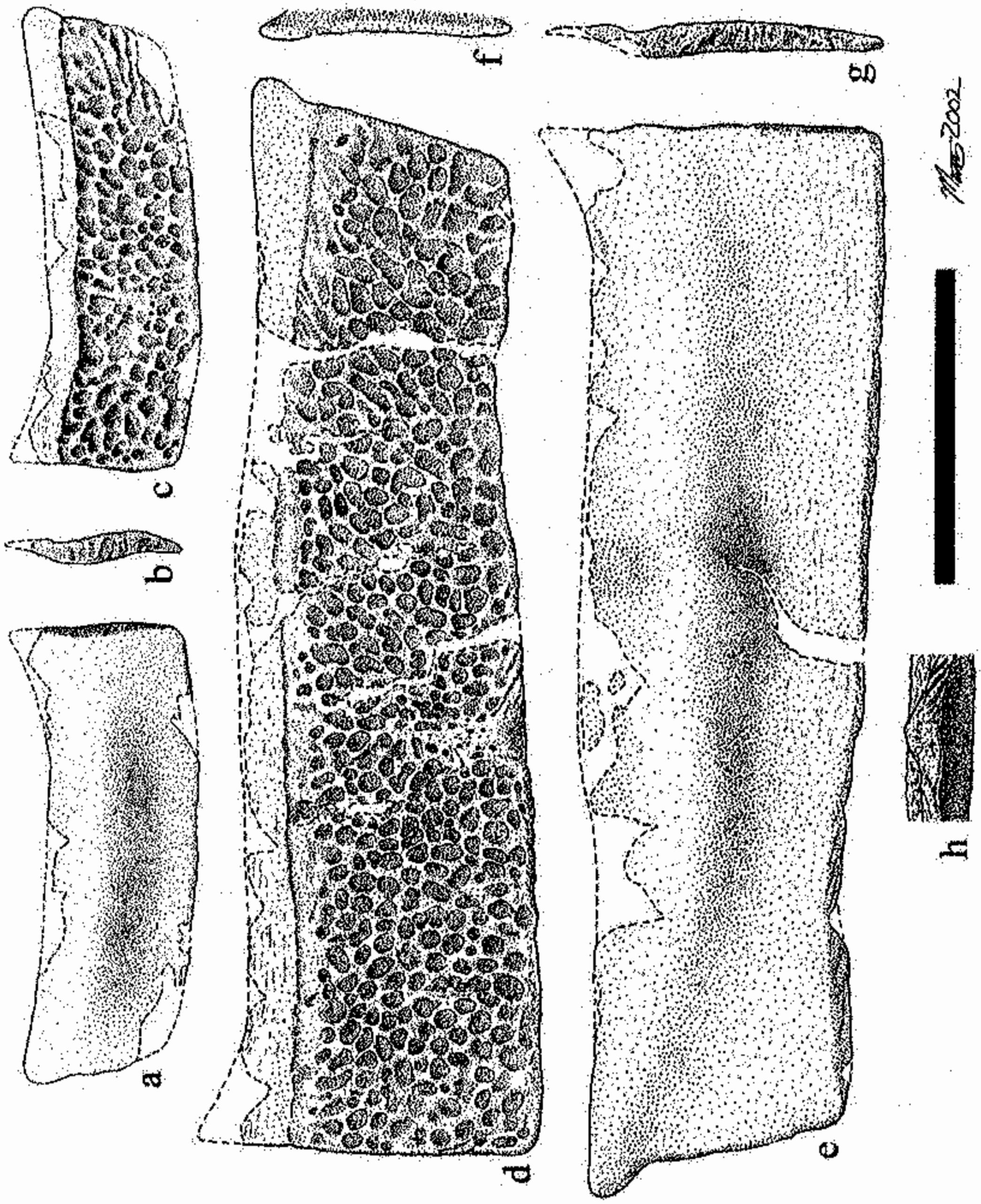

Figure 4.28 Mid-dorsal (region) dorsal paramedian scutes of *Typothorax coccinarum* TTUP 9214 in (a) ventral, (b) medial, and (c) dorsal views; UCMP V2816 34227 70/H8 in (d) dorsal, (e) ventral, (f) lateral, (g) medial views, and (h) posterior edge at center of ossification, showing boss. Dashed lines represent broken edges and reconstructed areas. Scale bar = 10 cm.

Lucas, 1999).[18] This difference in boss form and placement between the Canjilon scutes probably represents change from more anterior to more posterior dorsal paramedians.

The lateral ends of the scutes of the dorsal and pelvic regions are not constricted as in the more anterior dorsal paramedians, and the lateral edge is not perpendicular to the anterior and posterior edges. In the Canjilon Quarry material, this edge is straight and angles posteromedially (Figs. 4.28d, 4.29a). However, in TTUP 9124, it is slightly more laterally convex (Fig. 4.30c) as in *Paratypothorax* and "*Tecovasuchus*" (Martz and Small, in prep).

In the Canjilon material, some of the scutes have both a particularly strongly anterolaterally projecting anterior bar, and a lateral edge which slopes more steeply posteromedially then in the other scutes (Fig. 4.29; compare with Fig. 4.28). These are interpreted as representing the posteriormost dorsal (region) or pelvic dorsal paramedians, placed where the discoid carapace constricts toward the caudal region. Although only preserving the lateral edges, the dorsal paramedians in the Canjilon "U" specimen pelvic block (UCMP V2816 34255 70/U80; Fig. 4.24a, b) seem to be of this type. In TTUP 9214, some dorsal paramedians exhibit the deep ornamentation and rounded lateral edges seen in the mid-dorsal region, but are narrower then the widest scutes. These are also interpreted as being posterior dorsals (Fig. 4.30.a, b). These also have a pointed anterior bar (Fig. 4.30.b).

The ventral keel reaches its greatest thickness in the posterior dorsal (region) and pelvic dorsal paramedian scutes (Fig. 4.28a, e; 4.29b). The keel is thickest just lateral to the line of arching, and flattens out slightly medially and laterally. The condition is similar in *Typothorax reseri*, although the reduction of the keel at the line of arching is more abrupt in that taxon. The keel also behaves similarly in *Stagonolepis* (it is present in this taxon, although much less pronounced) and "*Tecovasuchus*."

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[18] The boss is also of this latter form and placement (a pyramid sitting on the posterior margin of the scute) in *Longosuchus* and at least some scutes of *Stagonolepis wellesi*, although it is much more pronounced those taxa. The boss in never really "conical" in *Typothorax* as described by Long and Murry (1985), although in *Lucasuchus* and *Paratypothorax* it may be more cone-shaped.

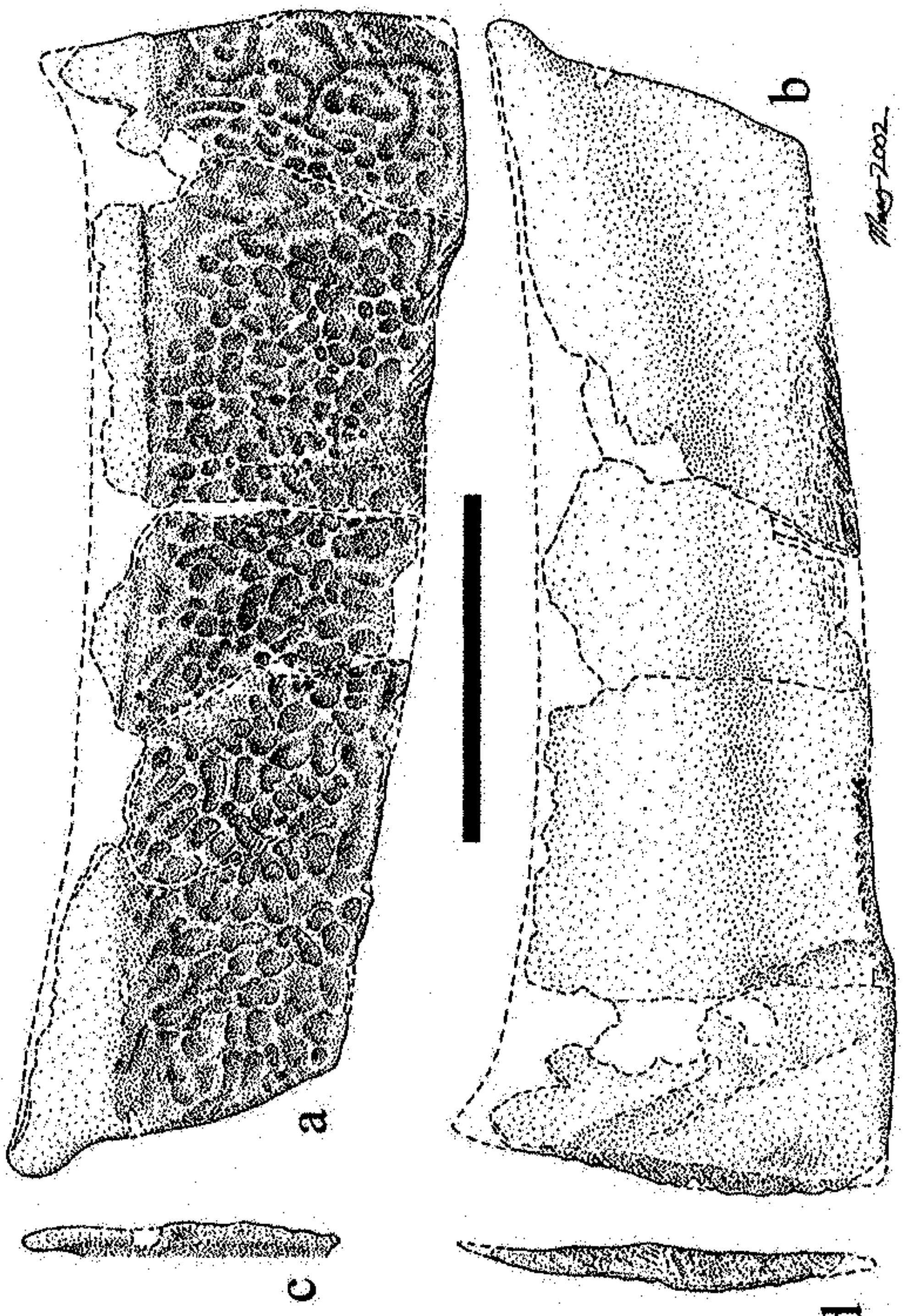

Figure 4.29 Posterior dorsal (region) dorsal paramedian scutes of *Typothorax coccinarum* (UCMP V2816 34227 70/J8) in (a) dorsal, (b) ventral, (c) lateral, and (d) medial views. Dashed lines represent broken edges and reconstructed areas. Scale bar = 10 cm.

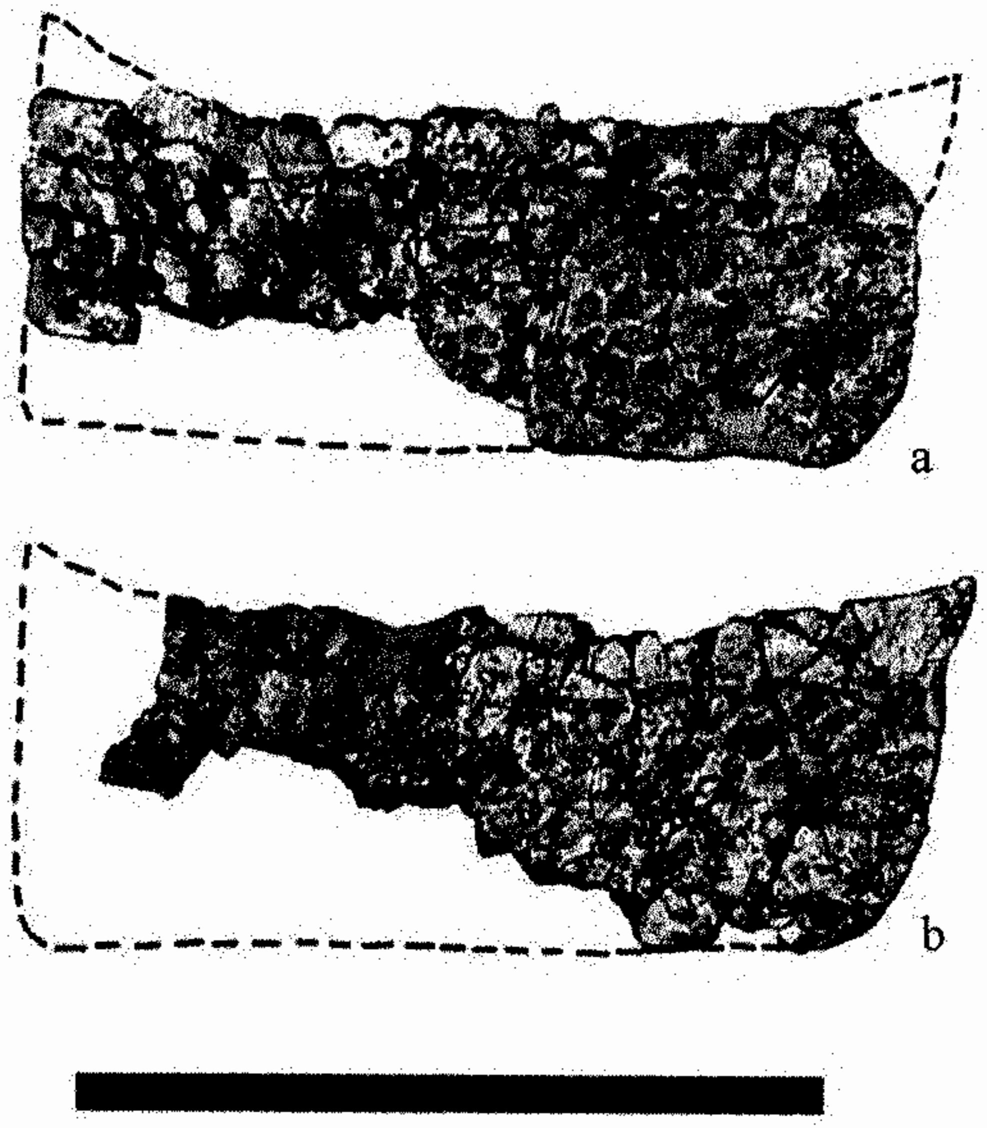

Figure 4.30 Posterior dorsal (region) dorsal paramedian scutes of *Typothorax coccinarum* (TTUP 9214) in dorsal view; (a) almost complete dorsal paramedian scute, (b) dorsal paramedian scute missing most of its medial end. Scale bar = 10 cm.

Two of the widest dorsal paramedians of TTUP 9214 (Fig. 4.31) seem to be pathologically fused. In dorsal and medial view (Fig. 4.31a), they can be seen to be two separate, strongly superimposed dorsal paramedians. Dorsally, they are fused only at the center of ossification. However, ventrally, they are almost totally fused (Fig. 4.31b), and only part of the anteromedial corner of the overlapped scute is distinct. They seem to share a single ventral keel, probably belonging to the anterior (overlapping) scute. In some ankylosaurs, the scutes of the cervical region usually form "cervical rings" in a similar manner by fusing the internal surfaces with a thin ossified layer (e.g., Carpenter, 1997a). As this condition has not been reported in other aetosaur scutes, the fused scutes in TTUP 9214 are believed to be pathological. The only other reported pathological aetosaur scute known to me is SMNS 12958, a specimen of *Paratypothorax* (Lucas, 2000). This pathology also involves fusion of the dorsal paramedians, although massive bony overgrowth occurs on the dorsal surfaces of that specimen, possibly due to infection, that is lacking in TTUP 9214. Lucas (2000) suggested the pathology was a response to some sort of injury, and this is also a possibility for TTUP 9214; the evidence of healed fractures in the neural spines of the anterior caudal vertebrae has already been mentioned.

4.5.1.4 Anterior caudal dorsal paramedian scutes

The caudal dorsal paramedian scutes probably coming from immediately behind the pelvis are narrowed (mediolaterally) compared to those from more anteriorly, though they are still wider then long (Figs. 4.32a, 4.33a). The arching at the center of ossification is well pronounced (Fig. 4.32b). In TTUP 9214, the anterolateral corner of the anterior bar is pointed rather then rounded, and the anterior edge of the bar flares out there (best seen in Fig. 4.33b). The ventral strut is reduced or entirely absent in the caudal paramedians (Fig. 4.33c), and the scutes are thinner overall then the more anterior scutes (Fig. 4.33d; Table 4.8). The lateral edge of the anterior caudals is straight in both

Figure 4.31 Pathological dorsal paramedian scutes of *Typothorax coccinarum* (TTUP 9214) in (a) dorsal and (b) ventral views. The edges where the scutes are distinct have been emphasized with a bold black line, and in ventral view post-mortem cracks in the scutes have been slightly obscured. Scale bar = 10 cm.

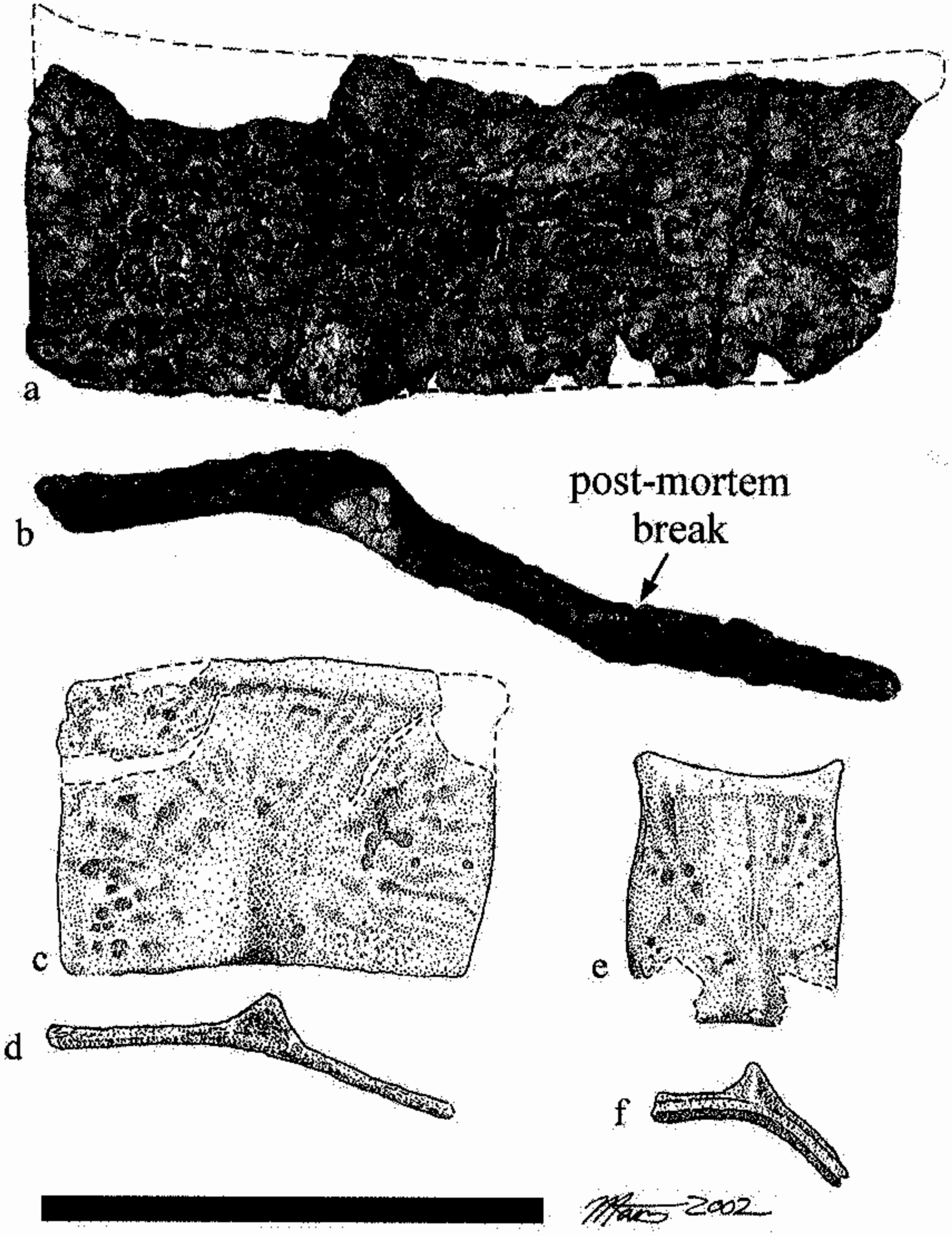

Figure 4.32 Caudal dorsal paramedian scutes of *Typothorax coccinarum* from Canjilon Quarry; pelvic or anterior caudal dorsal paramedian UCMP V2816 34227 70/Fa55 in (a) dorsal, and (b) posterior views; caudal dorsal paramedian 34255 70/U75 (from tail block) in (c) dorsal and (d) posterior views; posterior caudal dorsal paramedian UCMP V2816 158670 70/Fa52 in (e) dorsal, and (f) posterior views. Dashed lines represent broken edges and reconstructed areas. Scale bar = 10 cm.

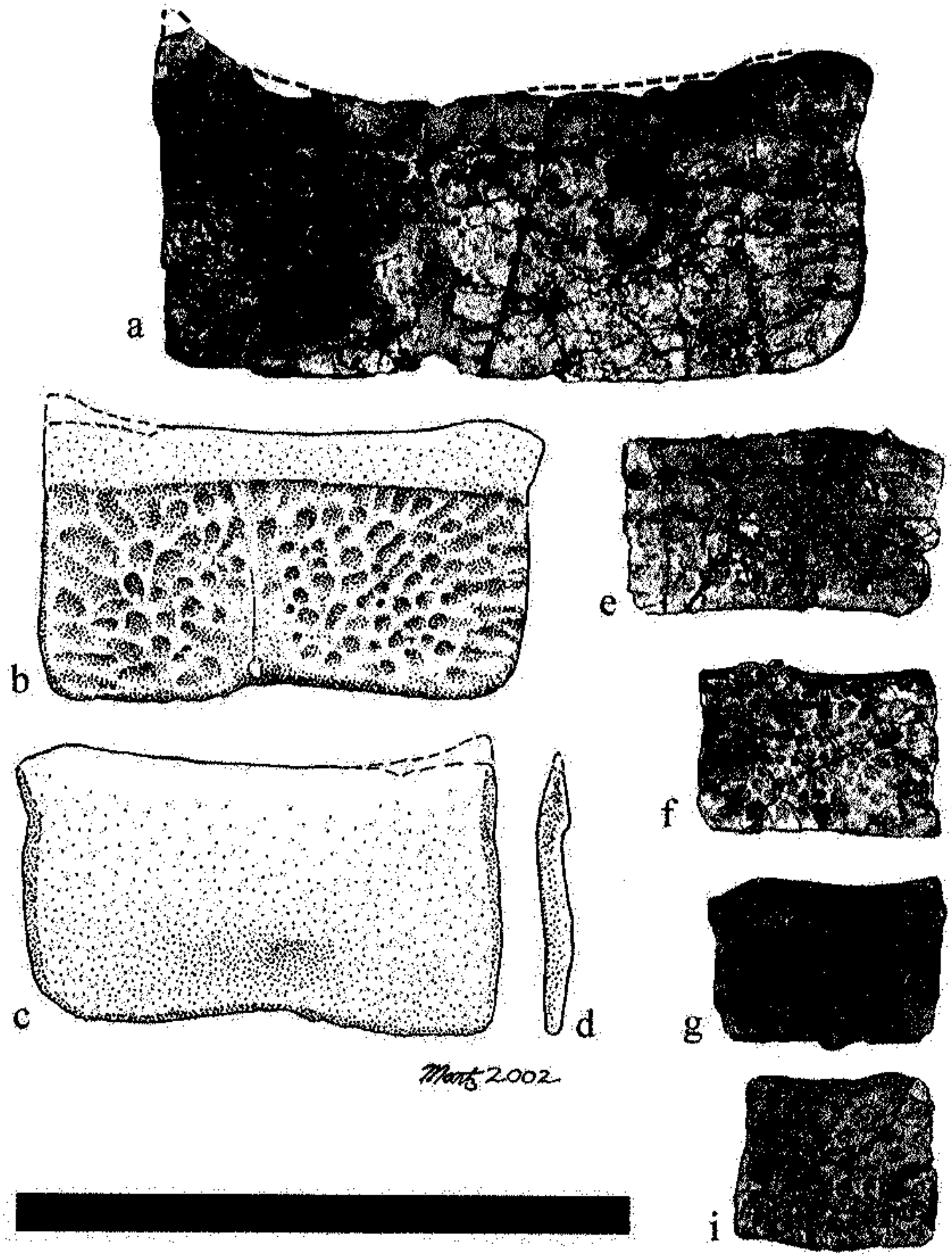

Figure 4.33 Caudal dorsal paramedian scutes of *Typothorax coccinarum* (TTUP 9214); (a) right pelvic or anterior caudal dorsal paramedian in dorsal view; a more posterior right caudal dorsal paramedian in (b) dorsal, (c) ventral, and (d) medial views; (e) probable posterior right caudal dorsal paramedian in dorsal view; probable increasingly posterior caudal dorsal paramedians, (f) and (g) left, (i) right. Dashed lines represent broken edges and reconstructed areas. Scale bar = 10 cm.

the Canjilon and Post Quarry scutes and is neither posteromedially sloping or convex, making these anterior caudals more subrectangular in shape. In one of the TTUP 9214 anterior caudals, the posterior edge seems to be emarginated at the center of ossification and boss (Fig. 4.33b); this is not recognized in any others.

In the Canjilon Quarry scutes, the boss is most pronounced and distinctly triangular in the caudals (Fig. 4.32b, d, f). In TTUP 9214, this boss appears for the first time in these scutes, being entirely absent in the dorsal region; the bar is generally similar those in the Canjilon Quarry material in being roughly pyramidal, although the pyramid is not as pronounced in TTUP 9214. In TTUP 9214, the pyramid grows off the posterior end of the longitudinal ridge seen in the dorsal region (Fig. 4.33b). The ridge is otherwise reduced compared to the dorsal region. On the ventral surface of the scutes, a depression lies immediately ventral to the boss (Fig. 4.33c). This is also usually seen in other aetosaur scutes when a raised boss is present. The ornamentation is sparser, weaker and more subcircular than in the scutes of the dorsal and pelvic regions. In TTUP 9214 the ornamentation is faintly radial toward the medial and lateral edges of the anterior caudals (Fig. 4.33b).

4.5.1.5 Posterior caudal dorsal paramedian scutes

The posterior of the two Canjilon Quarry "U" scute blocks (34255 70/U75) clearly shows the changes in the dorsal paramedian scutes posteriorly within the caudal series. These are interpreted as beginning just behind the scutes described above, perhaps near the middle of the caudal series (Figs. 4.24, 4.32c). Posterior caudal dorsal paramedians are not identified with certainty for TTUP 9214, as the best candidates (Fig. 4.33e-i) differ in several ways from those of the Canjilon scute blocks.

The first scutes in block UCMP V2816 34255 70/U75 are almost square (Fig. 4.32c), only slightly wider then long, and the lateral edge is perpendicular to the anterior and posterior edges. The scutes continue to narrow posteriorly, and eventually become longer then wide (Fig. 4.32e, f), as is typical in aetosaurs (e.g. Walker, 1961). Some of these scutes are arched sharply at the center of ossification as in the proceeding dorsal paramedians (Fig. 4.32d), but the more posterior and narrow scutes appear to be more smoothly dorsally convex (Fig. 4.32f).

The ornamentation in the Canjilon posterior caudals grows increasingly fainter posteriorly. Although circular pits are distinct, they become less prominent, and faint elongate grooves become visible. The triangular boss still is very distinct in these scutes (Fig. 4.32d, f), though it seems to become somewhat reduced in the posteriormost scutes. The side of the scute lateral to the center of ossification reduces more rapidly then the medial side, so that the boss becomes more and more evenly centered on the scute.

Scutes possibly representing the posterior caudal dorsal paramedians of TTUP 9214 (Fig. 4.33e-i) differ from those just described. These have straight lateral edges and laterally flaring anterior bars as in the anterior caudal dorsal paramedians of the same specimen. One has narrowed to become roughly square, and may be from more posteriorly then the others (Fig. 4.33i). However, these scutes lack any trace of arching or a boss. An alternate possibility is that these represent ventral scutes.

4.5.1.6 Summary of anterior-posterior changes in the dorsal paramedian scutes

As with other aetosaurs, the dorsal paramedians of *Typothorax coccinarum* are wider than long in the pre-caudal region, and widen gradually posteriorly until reaching their maximum width around the mid-dorsal region. They then narrow through the posterior dorsal, pelvic, and caudal regions, eventually becoming longer than wide somewhere in the caudal series.

Arching is absent in the anteriormost dorsal paramedians, which are flat, but curve anterolaterally when viewed dorsally. Arching at the center of ossification begins in the dorsal region. The arching continues into the caudal series, until the scutes start to narrow, at which point they either loose the arching or reduce it to a gentle transverse curvature. A ventral keel is present and fairly prominent in the anterior dorsal paramedians, and it thickens into the posterior dorsal region. The caudal scutes reduce or eliminate the ventral keel entirely.

The lateral edges of the anterior dorsal paramedians are roughly perpendicular to the anterior and posterior edges of the scute. In the Canjilon material, they begin to slope posteromedially into the dorsal series, with the slope being the greatest in the posterior dorsal (region) dorsal paramedians; however, in TTUP 9214, the lateral edges instead become convex in this region. In the caudal series, the lateral edge returns to being straight and roughly perpendicular to the anterior and posterior edges in all specimens.

The pitted ornamentation is extremely faint and roughly circular in the anterior dorsal region, and deepens and becomes somewhat more chaotic posteriorly. The ornamentation is deepest around the pelvic region. Posteriorly into the caudal region, the ornamentation becomes faint again, and is almost absent in the posterior caudals. A raised boss is absent anteriorly, but develops gradually posteriorly (beginning somewhere in the posterior dorsal region), and reaches a raised pyramidal form by the anterior caudals.

4.5.2 Lateral scutes

Three basic types of lateral scute are recognized in the Canjilon Quarry and Post Quarry *Typothorax coccinarum* specimens. Lateral scutes from the pelvic and caudal regions are known from the articulated scute blocks for the Canjilon Quarry "U" specimen (Fig. 4.24). The lateral scutes represented in the anterior of these blocks (34255 70/U80, Fig. 4.24a, b) are considered to be pelvic and immediately pre-pelvic for reasons discussed below, and those of the following block (34255 70/U75; Fig. 4.24c, d) are caudals. A third type of lateral scute found in the Canjilon material is unfortunately known only from disarticulated elements. However, as the pre-pelvic and caudal regions are accounted for, these are assigned by default to the more anterior dorsal and possibly cervical regions. The TTUP 10070 lateral scute found articulated with the two anterior dorsal (region) dorsal paramedians is of this last type, supporting the identification.

Since none of the TTUP 9124 scutes are articulated, they are assigned to various parts of the body based on their closest resemblance to the three general types of Canjilon Quarry laterals.

Several general remarks can be made about all lateral scutes of *Typothorax coccinarum* known from Canjilon Quarry and the Texas localities. The scute can be divided into two flanges, usually at an angle to each other; one that faces dorsally, and another that faces laterally or ventrolaterally depending on how tightly angulated the scute is. The exceptions to this are the caudal lateral scutes, which are almost completely flat, with both flanges in the same plane. This difference was also noted by Hunt et al. (1993, p. 209) for NMMNH P-12964, in which "Lateral scutes are flat in the caudal region and highly arched in the dorsal region". Between the flanges is a sharp-edged, dorsally raised ridge, which never forms a laterally projecting horn as in *Desmatosuchus*, *Longosuchus*, *Paratypothorax*, and "*Tecovasuchus.*"

The dorsal flange is usually very reduced compared to the lateral flange. Except in the caudal region, it is also roughly triangular in shape. The adjacent dorsal paramedian scute articulated with the anterior side of this triangle, while the rest of the scute posterior to this would have overlapped the following lateral scute. The length of this anterior articular edge relative to the rest of the dorsal flange tends to increase posteriorly, meaning the amount of overlap between lateral scutes probably *decreased* posteriorly in *Typothorax*. The dorsal flange has broader pits then the lateral flange.

On the larger lateral flange, a raised anterior bar is present along the anterior edge (as in most aetosaurs), which extends only a little or not at all onto the dorsal flange. This bar is usually oriented more or less vertically (as in most aetosaurs) or slopes slightly ventroanteriorly. This differs from *Paratypothorax* and *Tecovasuchus*, in which the lateral flange is extremely elongate and the anterior edge slopes ventro*posteriorly.* The posterior edge of the lateral flange in *Typothorax* usually slopes at least slightly posterodorsally, so that in lateral view the scute seems to point posteriorly. Ornamentation on the lateral flange is faintly pitted posterodorsally on the "pointed" region, and usually along the posterior edge, with elongate grooves (which may be very faint) radiating anteriorly and anteroventrally away from this area across the rest of the flange. This is contrary to Long and Ballew (1985, p. 51) who stated that the ornamentation shows "little or no radiating pattern." The grooves are much more prominent in TTUP 9214 than in the Canjilon material. These grooves sometimes contain deeper and more rounded pits set within them, as seen in *Stagonolepis* and "*Tecovasuchus*."

4.5.2.1 Cervical lateral scutes

No articulated cervical lateral scutes are known with certainty for *Typothorax*, but several isolated aetosaur lateral scutes were tentatively assigned to that region by Long and Ballew (1985) and Long and Murry (1995). However, at least one of these fragmentary "cervical" lateral scutes, UCMP V82271 126862 from Petrified Forest National Park, is clearly the boss of a pre-pelvic lateral scute of *Typothorax*.

The best preserved of these "cervical" lateral scutes, UCMP V82240 126809 (Long and Murry, 1995, fig. 101), is distinctly different from any of the lateral scutes known from Canjilon Quarry. It most closely resembles the lateral scutes of *Paratypothorax* and "*Tecovasuchus*" in having a very prominent laterally projecting horn, a dorsal flange that is a dorsoposteriorly projecting tongue, and *very* tight flexion between the flanges. Incidentally, these same features are found in MNA Pl. 3000, assigned by Long and Murry (1995) to the cervical region of *Stagonolepis wellesi*. Heckert and Lucas (1999) questioned the association of these scutes with *Stagonolepis* material, and until the locality data for these types of lateral scutes can be scrutinized more carefully, their assignment to *Paratypothorax*, "*Tecovasuchus*," or a closely related taxon seems most likely (Martz and Small, in prep). It is also suggestive that no lateral scutes of this type are known from the Canjilon Quarry material or TTUP 9214. The TTUP 10070 lateral scute, probably from the posterior cervical or anterior dorsal region, fits the description of a typical dorsal region lateral given below. It seems unlikely that the scute morphology would shift so drastically from the first few laterals. The anterior cervical lateral scutes of *Typothorax* were likely similar to those of the dorsal region.

4.5.2.2 Anterior dorsal (region) lateral scutes

The lateral scutes in the Canjilon Quarry material and TTUP 10070 assigned to the dorsal (and possibly cervical) region are fairly consistent in form (Fig. 4.34, 4.35). The angulation between the dorsal and lateral flanges is at about 90 degrees, forming an inverted "L" when viewed anteriorly or posteriorly (Fig. 4.34d, h). In TTUP 9214, the contact between the flanges is more smoothly curving rather then sharply flexed, so that the scute resembles a an inverted "J" instead of "L" (Fig. 4.35d, g).

In the Canjilon Quarry dorsal region laterals, and most of those of TTUP 9214, the dorsal flange is in the form of a triangle, which is often nearly symmetrical (Fig. 4.34c, g; 4.35c). The line of angulation forms the wide base of the triangle, and the apex of the triangle points medially. The articulation with the adjacent dorsal paramedian is the anterior edge of this triangle and is straight, as noted by Long and Ballew (1985).

The lateral flange is quadrilateral in lateral view (Fig. 4.34a, e; 4.35a, e), though none of the sides are exactly parallel. The dorsal edge is formed by the line of angulation. The posterodorsal sloping of the posterior edge is very pronounced, particularly in the Canjilon Quarry material. The ventral edge is usually almost horizontal, and the anterior edge (bearing the anterior bar) is roughly vertical. In TTUP 10070, the anterior bar of the lateral scute is very thick compared to the Canjilon material. It is not clear if this is a feature of variation along the column, or variation between individuals. The ornamentation on the lateral flange is fainter in the dorsal (and immediately pre-pelvic) laterals then in the caudal laterals in the Canjilon Quarry scutes (Fig. 4.34a, e). However, it is just as strong as in the same region in TTUP 9214, and the lateral flange is also distinctly more elongate (Fig. 4.35a, e).

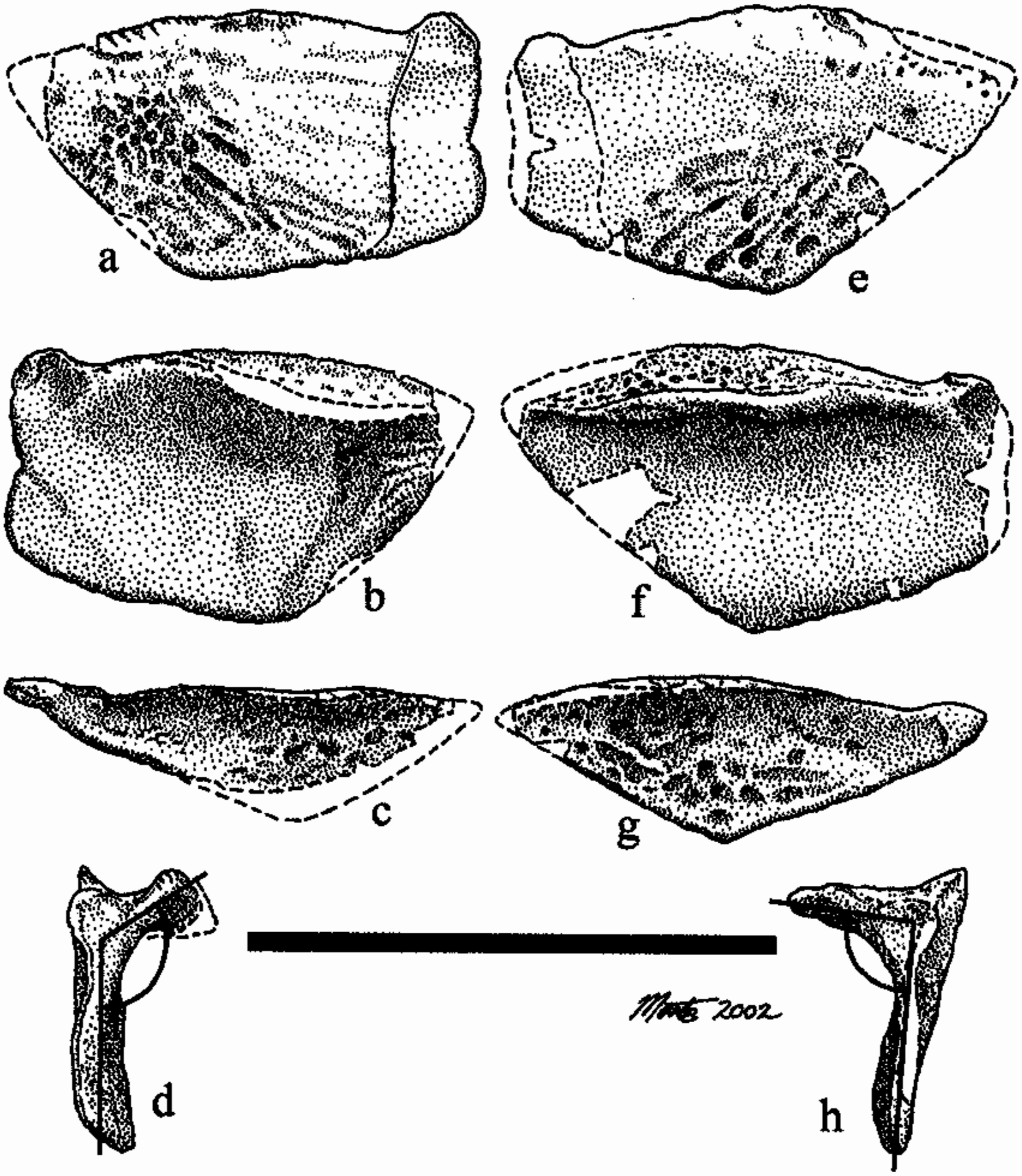

Figure 4.34 Dorsal region lateral scutes of *Typothorax coccinarum* from Canjilon Quarry; right lateral UCMP V2816 34227 70/Fa53 in (a) lateral, (b) medial, (c) dorsal, and (d) anterior views; left lateral 34227 70/Fa55 in (e) lateral, (f) medial, (g) dorsal, and (h) anterior views. Dashed lines represent broken bone edges and reconstructed areas. Scale bar = 10 cm.

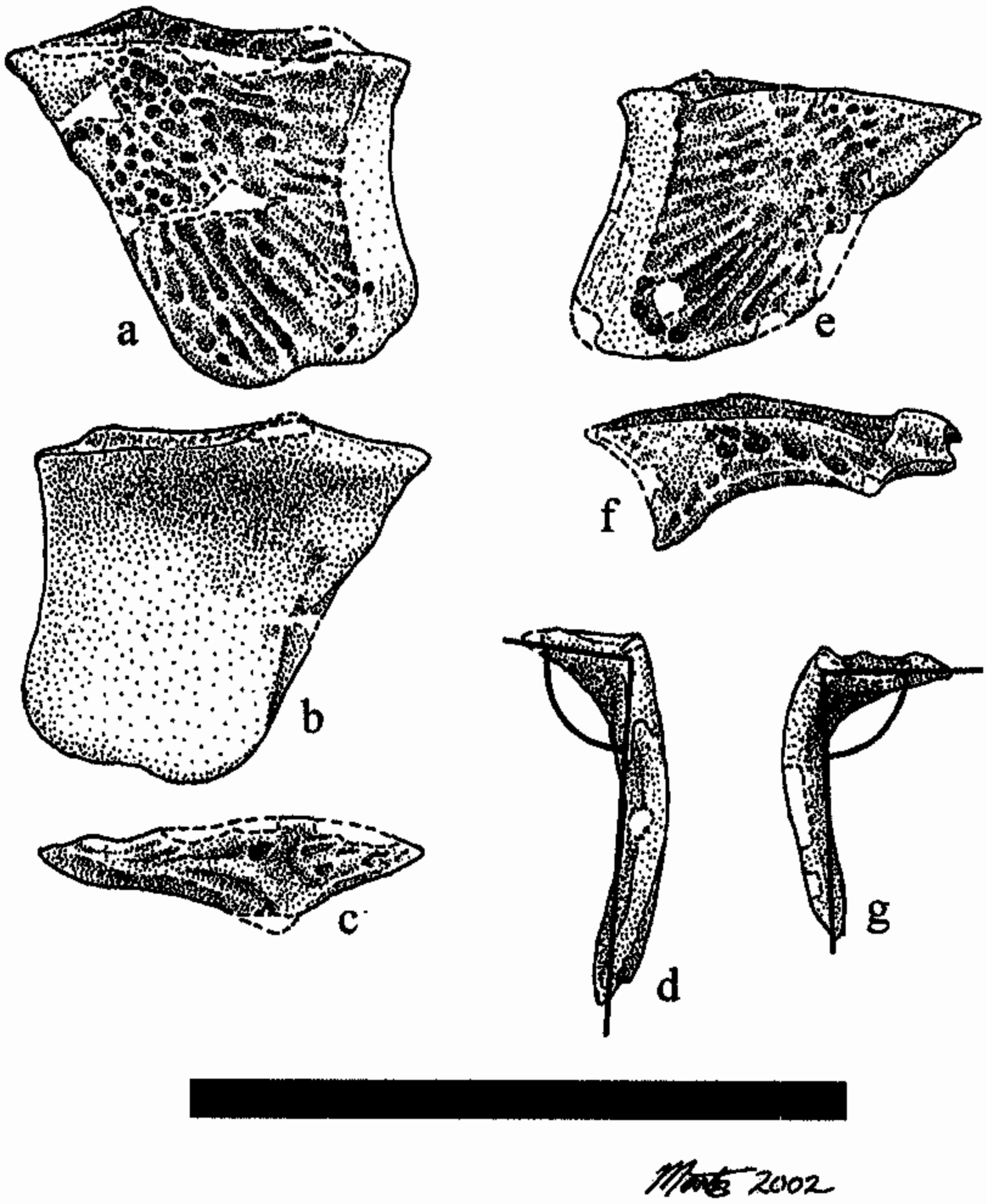

Figure 4.35 Dorsal lateral scutes of *Typothorax coccinarum* (TTUP 9214); right lateral scute in (a) lateral, (b) medial, (c) dorsal, and (d) posterior views; more posterior left lateral scute in (e) lateral, (f) dorsal, and (g) posterior views. Dashed lines indicate broken bone surface and reconstructed areas. Scale bar = 10 cm.

In the Canjilon Quarry material, the ridge at the line of angulation is distinct and sharp-edged, rising to become most prominent about mid-way along the length of the scute before subsiding to the posterior edge (Fig. 4.34a, b, e, f). The ridge is oriented vertically, in the same plane as the lateral flange (Fig. 4.34d). The ridge is less prominent and not as sharp in TTUP 9124 (Fig. 4.35d, g).

In the 70/U80 material are several isolated lateral scutes, which have greatly enlarged triangular dorsal flanges with prominent ornamentation at the line of angulation as in the immediately pre-pelvic laterals, but lateral flanges more like those just described. Presumably these are intermediates between the anterior dorsal and immediately pre-pelvic lateral scutes. These scutes, as well as the pre-pelvic laterals, probably articulated with the posterior dorsal (region) dorsal paramedians (Fig. 4.29); the dorsal flange would need to be enlarged to lengthen its articular edge to match that of the dorsal paramedian of that region. Some lateral scutes from TTUP 9214 are likewise probably intermediate between the anterior dorsal and pre-pelvic regions (Fig. 4.35e-g), with a slightly reduced lateral flange and a more tongue-like dorsal flange (see below), although the flexion between flanges is still about 90° (Fig. 4.35g)

4.5.2.3 Pre-pelvic lateral scutes

In *Stagonolepis* and *Aetosaurus*, the lateral scutes of the posterior dorsal region, immediately before the pelvis, have lateral flanges that are "contracted", so that the two flanges are of almost equal size, and the angulation between the flanges also becomes tightest (Walker, 1961). In the first lateral scutes of the Canjilon "U" *Typothorax* specimen proximal tail block (Fig. 4.24a, b), and other isolated Canjilon scutes, the lateral flange is strongly reduced, and there is much tighter angulation than both the anterior dorsal region lateral scutes and the following caudals (Fig. 4.36). They are therefore inferred to also represent immediately pre-pelvic laterals. This assignment is supported by the fact that these scutes articulate with posterior dorsal (region) dorsal paramedians with very elongate and strongly sloping lateral edges (Fig 4.24a), and the

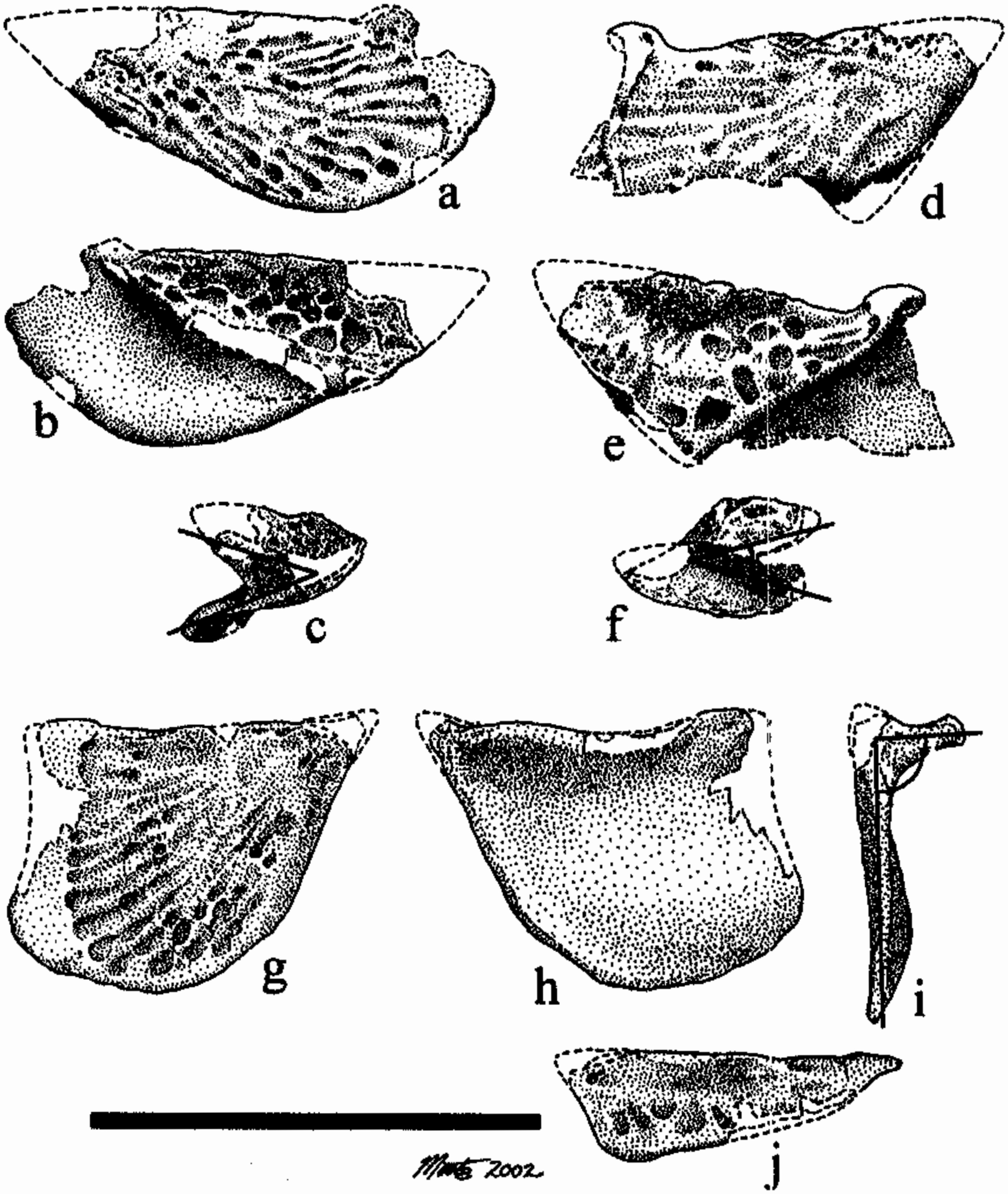

Figure 4.36 Pelvic area lateral scutes of *Typothorax coccinarum* from Canjilon Quarry; right immeditely pre-pelvic lateral scute UCMP V2816 34227 70/Fa54 in (a) ventrolateral, (b) dorsal, and (c) anterior views; incomplete left immediately pre-pelvic lateral scute (missing most of lateral flange) in (d) ventrolateral, (e) dorsal, and (f) anterior views; thigh? region lateral scute 34227 70/Fa53 in (g) lateral, (h) medial, (i) anterior, and (j) dorsal views. Dashed lines indicate broken bone surface and reconstructed areas. Scale bar = 10 cm.

block (70/U80) exhibiting this type of lateral scute also contained the left illium and hind limb (Table 2.1). Some of the TTUP 9214 laterals show a similarly reduced lateral flange (Fig. 4.37), and are interpreted as being from the same region although there are important differences.

In the Canjilon Quarry pre-pelvic laterals, the dorsal flanges are extremely large (almost as large as the lateral flange), strongly triangular, extremely thick, and covered with very broad pitted ornamentation (Fig. 4.36b, e). The anterior edge of the triangle, which met the dorsal paramedian, is faintly beveled. These scutes are so tightly angulated that the dorsal flange approaches being parallel to the lateral flange, making the scute resemble a "V" in posterior view rather then an "L" as in the dorsal region (Fig. 4.36e, f). However, in TTUP 9214 the dorsal flange differs in form and orientation. Rather then being large and roughly triangular, the dorsal flange is a thick, posteromedially projecting tongue, with the articular surface being concave rather then straight and running most of the length of the scute (Figs. 4.35f, 4.37b); a dorsal flange of similar form is found in *Paratypothorax* and "*Tecovasuchus*" (Martz and Small, in prep). Also, in TTUP 9214 the tight angulation between the pre-pelvic lateral scute flanges is not seen, and the angulation is actually more obtuse than seen in the dorsal region lateral scutes (Fig. 4.37d).

In the Canjilon Quarry pre-pelvic laterals, the lateral ridge at the line of flexion is more pronounced and sharp-edged than anywhere in the column. The ridge thickens posteriorly, forming a posteriorly flattened boss not dissimilar to the pyramidal bosses on the dorsal paramedians. These bosses project posterolaterally when the lateral scutes are in articulation (Fig. 4.24a, b). The boss is not posteriorly emarginated as the horns of *Paratypothorax* and *Longosuchus* are (Long and Murry, 1995). Neither the ridge nor the boss is as pronounced in TTUP 9124.

In addition to the lateral flange being reduced, the ventral and posterior edges are not distinct, but form a smooth, continuous curve that slopes strongly posterodorsally in both the Canjilon and Post Quarry material (Figs. 4.36a, b; 4.37a, c). In the Canjilon

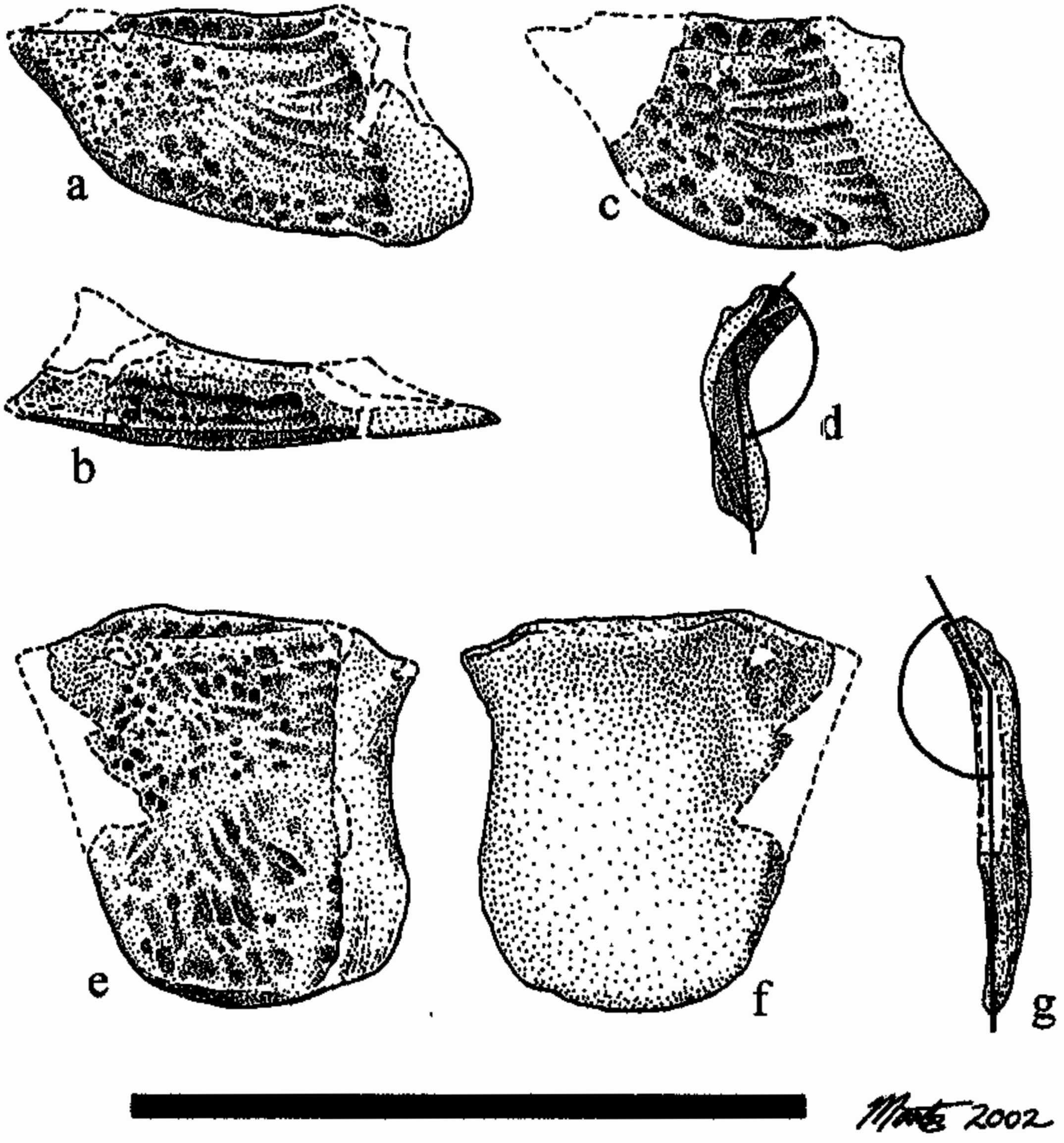

Figure 4.37 Pelvic area lateral scutes of *Typothorax coccinarum* (TTUP 9214); right immediately pre-pelvic lateral scute in (a) lateral, and (b) dorsal views; another right immediately pre-pelvic lateral in (c) lateral, and (d) anterior views; thigh? region right lateral scute in (e) lateral, (f) medial, and (g) posterior views. Dashed lines represent broken bone edges and reconstructed areas. Scale bar = 10 cm.

material, the lateral flange has radiating grooved ornamentation that is more deeply incised than in the more anterior lateral scutes (and often contains deeper pits set within them), and these deep grooves continue into the caudal laterals. The ornamentation is also strongly incised in TTUP 9214 (though as already noted, the ornamentation in the more anterior laterals is just as deep). In both the Canjilon Quarry material, the anterior edge (and anterior bar) is greatly shortened (Fig. 4.36a). However, in TTUP 9214 the bar is not oriented vertically, but projects antero-ventrally (Fig. 4.37a, c) as in *Stagonolepis* (Walker, 1961, fig. 20h).

Lateral scutes transitional between those of the pre-pelvic and anterior caudal regions can be observed in the "U" specimen pelvic region block (Fig. 4.24b; indicated with an arrow), and in isolated Canjilon scutes (Fig. 4.36g-j). These are interpreted as coming from about the thigh region. In the Canjilon material thigh scutes, the arching between the flanges is reduced, so that the angle between them is back to being about 90° as in the dorsal region. The dorsal flange is still triangular in form, but the triangle is strongly asymmetric, with the anterior (articular) edge being much longer and steeply inclined (Fig. 4.36j). The lateral flange becomes enlarged again, approaching the more equant shape seen in the caudals, but the corner between the ventral and posterior edges are still smoothly rounded. The anterior bar is taller then in the pre-pelvic region and projects slightly anteroventrally. TTUP 9214 also has at least one scute probably preserved from this region (Fig. 4.37e-g), which is basically similar to that just described except that the lateral flange is taller, and the angle between the flanges is very obtuse (Fig. 4.37g).

4.5.2.4 Caudal lateral scutes

The caudal lateral scutes are similar to those seen in most aetosaurs, and are more similar between the Canjilon Quarry and TTUP 9124 material than the other laterals (Fig. 4.38). There is almost no flexion between the dorsal and lateral flanges. The flanges are at almost 180° to each other, essentially forming a nearly flat plate (Fig. 4.38d, f, h, j).

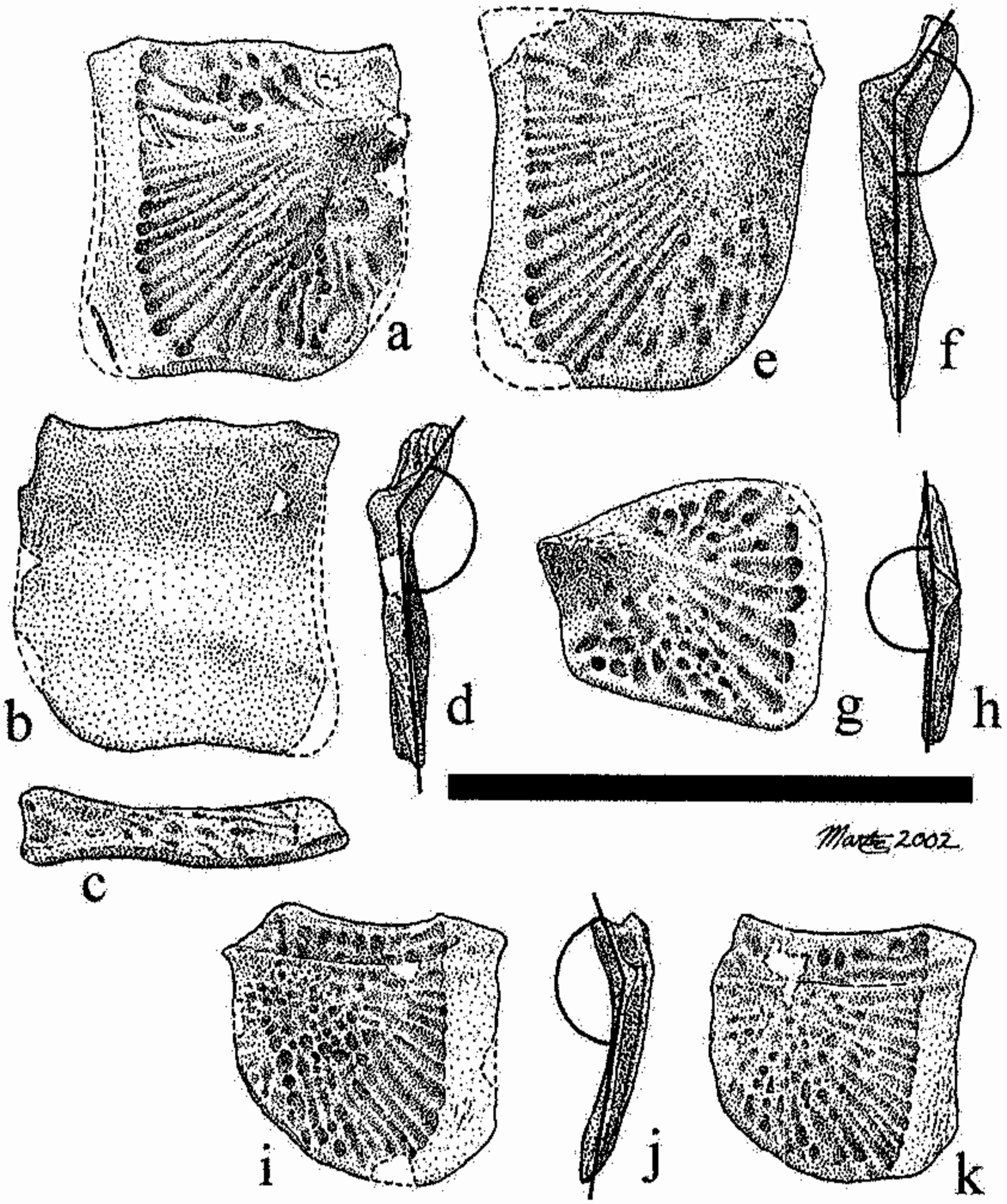

Figure 4.38 Caudal lateral scutes of *Typothorax coccinarum*; left lateral caudal scute UCMP V2816 34227 70/C18 in (a) lateral, (b) medial, (c) dorsal, and (d) posterior views; left lateral caudal scute 158668 70/Fa50 in (e) lateral, and (f) posterior views; posterior right lateral? caudal scute 158670 70/Fa52 in (g) lateral, and (h) posterior views; TTUP 9214 caudal lateral scute in (i) lateral and (j) posterior views; (k) another TTUP 9214 right lateral caudal scute in lateral view. Dashed lines indicate broken bone edges and reconstructed areas. Scale bar = 10 cm.

Consequently, *both* flanges face laterally (Fig. 4.38a, e, g, i, k); however, the flange that articulates with the dorsal paramedian will still be referred to as the "dorsal" flange for consistency. The caudal lateral scutes are almost quadrangular in lateral view.

The dorsal flange in the caudal laterals is a roughly vertical, anteroposteriorly elongate rectangle rather then triangular, with the articular edge for the dorsal paramedian running the length of the scute, parallel to the line of angulation (Fig. 4.38a, e, g, i, k). Consequently, the laterals probably did not overlap strongly. The anterior bar continues smoothly onto the dorsal flange. The ornamentation is still distinctly pitted on the dorsal flange, although it is fainter than seen in the sacral region, and some faint and posterodorsally trending grooves may also be seen in the Canjilon Quarry material (4.38a, e, g). On an isolated lateral scute that may be from very far posterior on the caudal series (Fig. 4.38g), both flanges slope posteriorly to meet the boss.

The ridge extending between the flanges is still present. However, it is not as pronounced or sharp edged as seen in the pre-pelvic and dorsal lateral scutes, being much fainter in the Canjilon caudal lateral scutes then in those of TTUP 9214 (Fig. 4.38i, k). Posteriorly, the ridge still thickens into a pointed boss, though the boss is not as pronounced as in the pre-pelvic scutes. On the posterior caudal lateral scute (Fig. 4.38g, h), the boss is very prominent, like the pyramidal bosses on the posterior dorsal paramedians.

The lateral flange is broad and almost square or rectangular, except that the anterior and ventral edges are still joined by a rounded corner, more strongly in TTUP 9214 then the Canjilon scutes (Fig. 4.38a, b, e, i, k). On the lateral flange, the ornamentation is extremely distinct, with strong, deeply incised arcuate grooves curving away from the boss anteroventrally. The area around the boss and the posterior margin of the flange is pitted, with the pits around the boss being very fine.

4.5.2.5. Summary of anterior-posterior changes in the lateral scutes

The dorsal flange is triangular in the pre-caudal lateral scutes of *Typothorax coccinarum*. In adult material, it is roughly a symmetrical triangle in both the dorsal and immediately pre-pelvic region. However, in TTUP 9214, it becomes more of an asymmetric, posteriorly projecting tongue to fit the convex lateral edges of the dorsal paramedians. In the caudals, the dorsal flange becomes more of an elongate rectangle. This change has the effect of consistently decreasing the degree to which the laterals overlapped those immediately behind them from the more anterior to more posteriorly laterals. The dorsal flange also grows somewhat larger and thicker posteriorly into the immediately pre-pelvic series, then reduces and thins again in the caudals.

Angulation between the dorsal and lateral flanges is at about 90° in the dorsal laterals. This angle becomes much more acute in the immediately prepelvic laterals of adult material, but more obtuse in TTUP 9214. In the caudals, the angle is almost 180°, so that the entire scute is basically a flat plate. The ridge at the line of angulation is distinctly sharp edged and parallel to the lateral flange in the pre-caudal laterals; it becomes the most prominent in the immediately pre-pelvic lateral scutes. In the caudals, it becomes a much weaker ridge.

The lateral flange is larger than the dorsal flange in the anterior dorsal region, where it is quadrilateral, with a sharp corner between the ventral and dorsoposteriorly inclined edges. The lateral flange is strongly reduced in the immediately pre-pelvic region, and the ventral and posterior edges become a single, smoothly curving, steeply inclined edge. The lateral flange then grows again into an almost square plate in the caudals, though the corner between the ventral and now nearly vertical posterior edges is still well rounded. As with the dorsal paramedians, the ornamentation becomes increasingly deeply incised posteriorly, being the deepest in the caudal scutes in the Canjilon material (in TTUP 9214, it remains deep throughout).

4.5.3. Appendicular scutes

As mentioned previously, adequate descriptions and illustration of appendicular and ventral scutes are relatively uncommon. At least some information is provided for *Longosuchus* (Sawin, 1947), *Stagonolepis* (Walker, 1961), and *Coahomasuchus* (Heckert and Lucas, 1999), and the interpretations here are based largely on those taxa. However, these interpretations should be taken with extreme caution, especially since little or no information is available on the position of these scutes in-situ in *Typothorax* itself. Although none of these osteoderms are likely to be dorsal paramedians or laterals, some scutes identified as being appendicular may be ventral, and vice versa. Certainly, many of the scutes tentatively assigned to one category resemble others assigned to the second. Hopefully, information on better-articulated material (e.g., Hunt et al., 1993; Hunt, 2001) will shed light on the placement of these scutes in *Typothorax*.

Several scutes are known for the UCMP material that are probably appendicular (Fig. 4.39d-h). They are identified as such by being rounded or faintly polygonal, with little or no trace of anterior bar, suggesting they were probably "free floating" in the skin and not articulating with other scutes. The ornamentation on the external surface of these scutes is deeply pitted, as with the dorsal paramedians. One of these found in grid square 70/L, possibly belonging to the large "U" specimen (Fig. 4.39.h), is especially thick.

Possible appendicular scutes for TTUP 9215 (Fig. 4.39i-l) also have irregular shapes implying they were not in close contact with other scutes, though they are generally less rounded then the Canjilon Quarry scutes. These TTUP 9214 scutes have a longitudinal raised ridge similar to those seen on the dorsal paramedian scutes of the same specimen, often drawing the posterior edge of the scute into a sharp point. These scutes are somewhat similar to the thigh region scutes described for *Stagonolepis* by Walker (1961, fig. 20m-o), and may be from that region.

Other scutes with odd shapes may also be interpreted as appendicular scutes of the thigh region, if only because they taper slightly posteriorly. The only scute of this

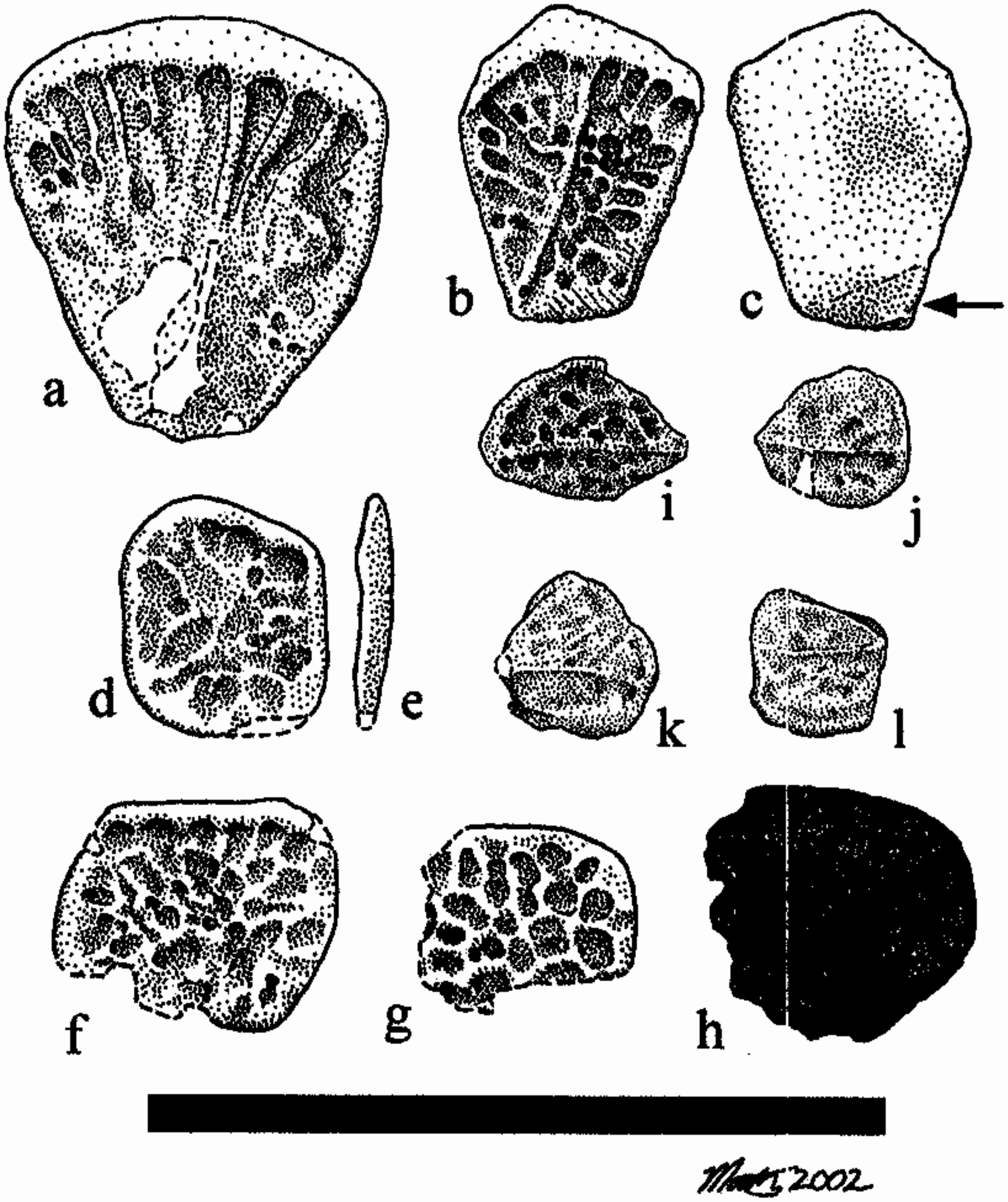

Figure 4.39 Appendicular scutes of *Typothorax coccinarum*; possible thigh appendicular scutes in external view (f) 34255 70/U80 (indicated by an arrow in Fig. 4.24.a), and TTUP 9214 in (b) external and (c) internal views; free-floating appendicular scute UCMP V2816 158675 70/Fa53 in (d) external, and (e) edge-on views; other UCMP V2816 free-floating appendicular scutes, all in external view: (f) and (g) both 158675 70/Fa53, h) 34227 70/L3; i-l) possible free-floating appendicular scutes from TTUP 9214 in external view. Dashed lines indicate broken bone edges. Scale bar = 10 cm.

form recognized in the Canjilon material is part of the anterior articulated scute block from the "U" specimen (Fig. 4.39a; indicated with an arrow in Fig. 4.24a). This scute has strongly radiating ornamentation anteriorly, and a ridge that originates slightly off center at the anterior bar and grows into a prominent boss at the tapered posterior edge of the scute.

A possibly homologous scute from TTUP 9214 (Fig. 4.24b, c) has an anterior edge that tapers to a point rather then being smoothly rounded, and does not taper as strongly posteriorly. The ornamentation is more distinctly pitted, and a raised ridge also originates slightly off center on the anterior bar, and trends somewhat diagonally to one of the posterior corners of the scute. On the internal side of the scute is a strongly depressed triangular area on the same corner (indicated by an arrow in Fig. 4.24c), which may have overlain part of the anterior bar of a similar scute.

4.5.4. Ventral scutes

Ventral scutes from the caudal region are in place in the tail blocks of UCMP V2816 34255 (Fig. 4.24c, d), and other isolated scutes of the same form are known for the UCMP material (Fig. 4.40b, c) and TTUP 9214 (Fig. 4.40a). These scutes are almost square and gently curved transversely. The anterior bar is thin, more so in the Canjilon scutes then in TTUP 9214. A faint hint of a longitudinal ridge extends down the middle of the scutes. The ornamentation is very faint and almost completely indiscernible in the Canjilon scutes, consisting of a few fine pits, set within faint grooves; the ornamentation is similar but somewhat more deeply incised in TTUP 9214. In the tail block (Fig. 4.24d), there appear to be four columns of ventral scutes; two along the midline in which the scutes are roughly square, and two with slightly narrower scutes on either side. These did not appear to have made contact with the caudal lateral scutes, though the more posterior ventral scutes may have as in *Stagonolepis* (Walker, 1961).

Other probable isolated ventral scutes occur in the Canjilon material. One, resembling the ventral caudals just described in being almost square and having a very

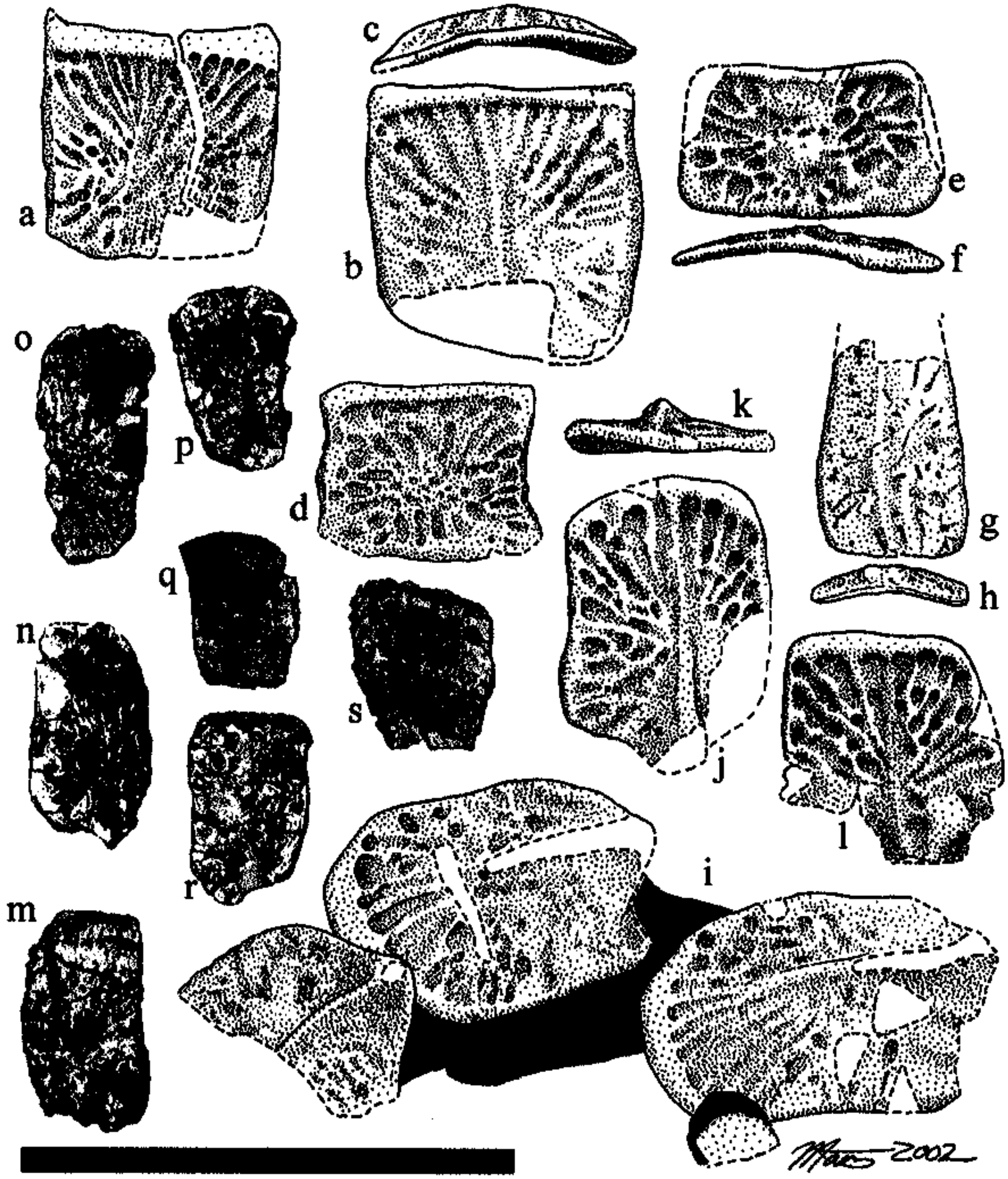

Figure 4.40 Ventral scutes of *Typothorax coccinarum*. Ventral caudals (a) TTUP 9214; UCMP V2816 34227 70/F50 in (b) external, and (c) anterior views; other likely ventral scutes from UCMP V2816, (e) 158675 70/Fa53 in external, and (f) posterior views, (g) 158670 70/Fa52 in external and (h) posterior views; possible ventral scutes from the perimeter of the ventral carapace, all in external view, (i) 34255 70/U80, (j) 158670 70/Fa52, (k) 158675 70/Fa53, (l) and (m) both TTUP 9214; (o)-(r) are other weird TTUP 9214 ventral? scutes, all in external view. Dashed lines indicate broken bone edges, blackened areas represent matrix. Scale bar = 10 cm.

thin anterior bar and faint ornamentation radiating from the middle of the scute (Fig. 4.40d), was found associated with the anterior articulated scute block and may be from the belly or cloacal region. Another (Fig. 4.40e, f) is wider with slightly deeper ornamentation and a thickening in the middle, but also has a very thin anterior bar. Yet another (Fig. 4.40g, h), which is much longer then wide, has *extremely* faint ornamentation and a barely discernable longitudinal ridge, and may be a ventral scute from the extreme posterior end of the tail.

Other odd scutes from both the Canjilon and Post Quarry specimens are harder to identify, but they do not appear to be recognizably dorsal paramedian, lateral, or appendicular scutes and so may be ventral by default. One variety of these is seen in the anterior "U specimen" tail block (Fig. 4.40i and on the far right of Fig 4.24b) and other isolated fragmentary scutes (Fig. 4.40j-l) may be of the same type. These are longer then wide, with a rounded anterior edge, radiating and pitted ornamentation, and a strong ridge that rises posteriorly from the anterior bar, drawing the posterior edge into a slightly pointed tip. At least some (Fig. 4.40i) seem to be asymmetrical, faintly convex on one side and faintly concave on the other, which is nearest the ridge. Possibly homologous scutes from TTUP 9214 (Fig. 4.40m, n) share this odd asymmetry. Walker (1961, fig. 21) illustrates the scutes forming the perimeter of the ventral carapace as having a roughly similar shape, and these scutes may be from this region.

Many other odd scutes are known from the TTUP 9214 (Fig. 4.40o-s), which somewhat resemble the asymmetric ones just described in being longer then wide and in having a raised ridge that runs close to one edge, although in some it cuts diagonally across the external surface of the scute. One type (Fig. 4.40o) is *extremely* elongate compared to its width; it is about as long as the asymmetric scutes just described, and may have articulated with them. These odd scutes are likely to be ventral scutes as well. Another possibility is that some are dorsal paramedians from the extreme posterior end of the tail.

4.6 Skeletal and carapace reconstructions

Figure 4.41a shows a composite skeletal reconstruction of *Typothorax coccinarum*, mostly modeled (and scaled) after TTUP 9214. Material from TTUP 9214 is light gray, material based on other *Typothorax* specimens is dark gray, and blackened areas are based entirely on other aetosaurs. This reconstruction gives some idea of how much material is known for *Typothorax coccinarum* between the Canjilon Quarry and Post Quarry material. Most of the skull is unknown, but based on the slenderness of the dentary the snout is shown as being similarly gracile. The vertebral counts are estimated for the cervicals (9), dorsals (16), sacrals (2), and caudals (~30-40) based on *Stagonolepis* (Walker, 1961), *Longosuchus* (Sawin, 1947), and *Coahomasuchus* (Heckert and Lucas, 1999). The length of the tail is based on the statement by Hunt et. al (1993) that the tail in NMMNH P-12964 is about half the total length of the animal; the resultant estimated total length for TTUP 9214 is just under two meters. Ribs are known for TTUP 9214, but are extremely fragmentary.

The armor reconstructions for TTUP 9214 (Fig. 4.41b, c) are based on considerably more extensive material. Assuming that each pair of dorsal paramedian and lateral scutes corresponded to a single vertebra, and the assignment of the different scute morphologies to different areas of the body is correct, the shape of the carapace (Fig. 4.41c) is not much more expanded then that of *Stagonolepis* (Walker, 1961), or *Coahomasuchus* (Heckert and Lucas, 1999), although it has been reconstructed without a waist. In lateral view (Fig. 4.41b), the arching of the dorsal paramedians is more evident, and the changes in lateral scute morphology (including the reduction in overlap), can be seen. The rest of the lateral view life reconstruction must be taken with a grain of salt; little is known about the distribution of ventral and appendicular scutes at this time, and their placement is mostly hypothetical.

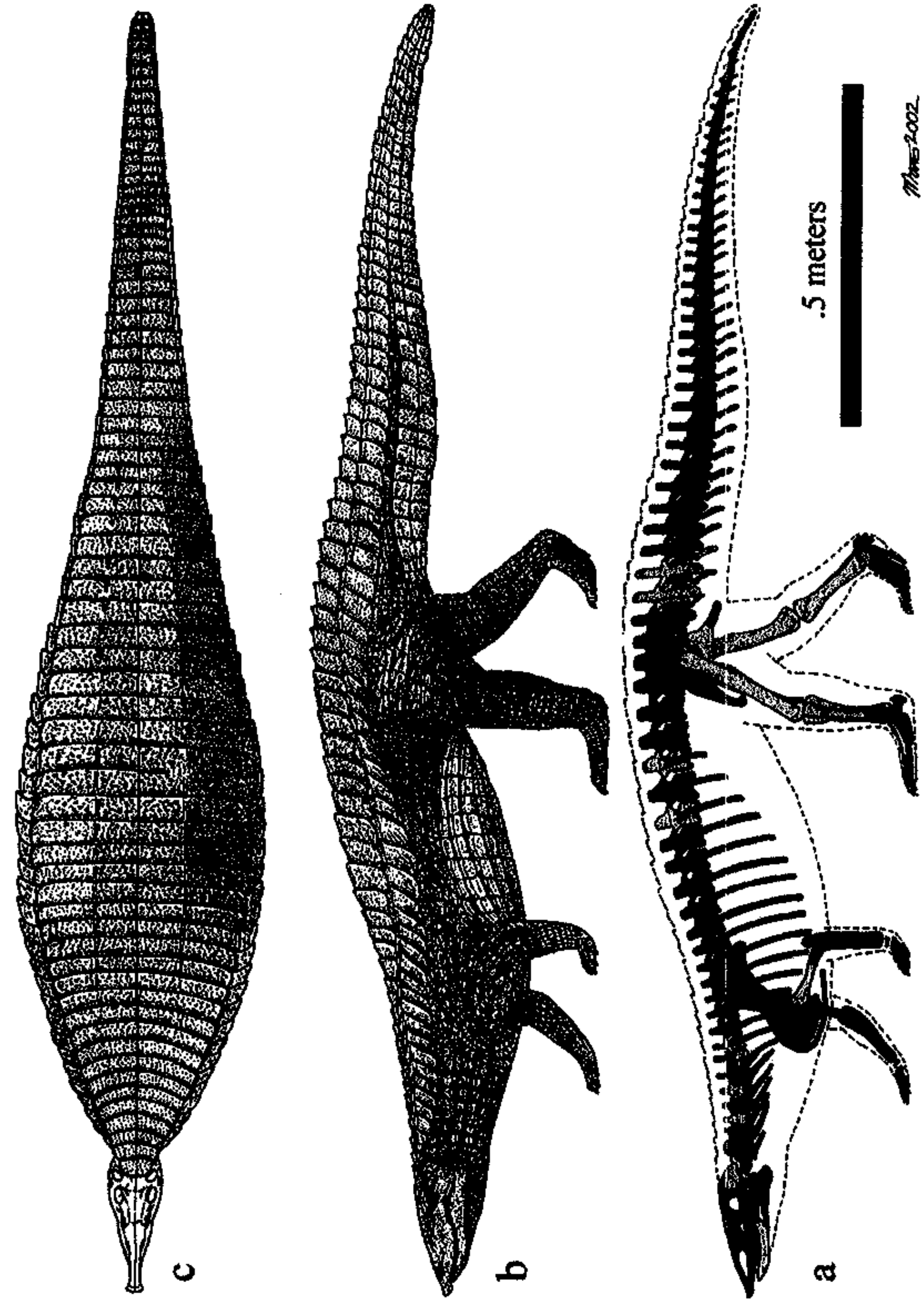

Figure 4.41 Reconstructions of *Typothorax coccinarum* (TTUP 9214); (a) skeletal reconstruction, elements in light gray present in TTUP 9214, elements in dark gray based on adult material from Canjilon Quarry, elements in black based only on other aetosaur taxa; (b) lateral view of ife reconstruction, (c) dorsal view of reconstructed carapace. Scale bar = .5 meters.

CHAPTER 5

ONTOGENETIC CHANGE IN *TYPOTHORAX COCCINARUM*

5.1 Ontogenetic versus static allometry

As noted by Gould (1971 p. 116) and Chevaud (1982), when looking at individuals assumed to belong to the same species, it is important to distinguish between ontogenetic and static allometry. A *static* allometric regression includes only information on animals at *the same stage of growth* (such as fully grown adults). Static allometry for animals in the *same* species (intraspecific static allometry) may be used to establish or describe sexual or population differences.[19] However, a static intraspecific allometric regression may fall along a different trajectory than the allometric path taken by the *same animals as they matured*, referred to as *ontogenetic* allometry. Variation occurs in the ontogenetic slopes and intercepts of different individuals, and the ontogenetic path of the larger adult individuals in a population did not necessarily pass through forms identical to the smaller adults in the population. Ontogenetic allometry may be procedurally distinguished from static allometry in that the former includes measurements of *all* known individuals in a population, and therefore should more closely approximate the average ontogenetic path of its individuals, then the latter (Chevaud, 1982).

In the case of *Typothorax*, distinguishing fully mature from immature animals is difficult or impossible. The primary reason for this (small sample size aside) is that that aetosaurs, like most reptiles, probably had indeterminate growth. Therefore, barring sexual differences, all scaling differences within a species with indeterminate growth should be more or less ontogenetic, as "fully grown" individuals do not exist. Given the small available sample size of specimens with good skeletal material, it is not currently feasible to explore the possibility of sexual dimorphism using statistical techniques. The

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[19] Static allometry describing individuals at the same stage of growth in *different* species is referred to as *static interspecific* allometry.

assumption that sexual dimorphism is not potentially responsible for scaling differences in *Typothorax* is a serious one, especially considering that size-related sexual dimorphism has been reported or suggested for other pseudosuchians, including extant crocodilians, phytosaurs (Zeigler et al., 2001), rauisuchians (Jonathan Weinbaum, personal communication, 2002), and the aetosaur *Stagonolepis* (Walker, 1961).

5.2 Bivariate allometry

Simple bivariate allometry is a common tool in the study of both extinct (e.g., Brower and Veinus, 1981; Gatesy, 1991; Brochu, 1992) and extant vertebrates (Dodson, 1978; Chevaud, 1982), but multivariate techniques (e.g., Houk et al., 2000; Strauss et al., in press) have only recently become commonly utilized. Multivariate techniques (such as principal component or discriminate analyses) have an advantage over bivariate techniques in that they can consider the interrelationships of *several* variables simultaneously, unlike bivariate analyses, which can only compare two at a time. However, when the number of variables measured is greater then the sample size (as is often the case with extinct vertebrates), this advantage is strongly curtailed, and the results less reliable then those obtained using bivariate techniques (Rich Strauss, personal communication, 2001).

Bivariate analyses make use of Huxley's equation

$$Y = aX^k$$

where Y and X are two variables whose *relative* growth is being considered, and k is the *allometric coefficient* that determines which variable increases at the greater rate. A value of "1" for the allometric coefficient represents isometry, meaning the X and Y variables grow at the same rate. If the Y variable grows more slowly. then the X variable, the allometric coefficient is less then 1. If the Y variable grows more quickly, the allometric coefficient is greater then one. A *negative* allometric coefficient indicates that the Y variable is actually *decreasing* in size.[20]

Huxley's equation can be log transformed to linearize it, becoming:

$$\log Y = (\log a)\,(k)(\log X)$$

Making the equation represent a straight line is useful, as the *slope* of the regression represents the allometric coefficient, k. This study will use bivariate analysis of log-transformed data, with the allometric coefficient extracted from the linearized equation.

The largest number of measurements available for any elements in *Typothorax coccinarum* is for the femur and tibia (Tables 4.5. and 4.6, Fig. 4.13). Two types of bivariate analysis were conducted using these elements. In both types, the R^2 values (representing the correlation between the variables) measure how well the points fit the regression, and these results were tested at the 95% significance level (p-value = .05).

In the first plot, (log squared) lengths of the femur and tibia were plotted against each other. The regression considered the relative change in length between these two elements. The tibia was chosen as the X variable, so the allometric coefficient is a reflection of the rate at which the femur increases relative to the tibia. The second type of regression considered bivariate allometry of various log-squared measurements *within* the femur and tibia. However, since the two bones were not to be plotted against each other (as in the first regression), a new X variable or variables needed to be selected.

5.3 Size scores of the first principal component as the bivariate X variable

For the regressions only considering measures for the femur *or* tibia, an X variable that is unique for each specimen needed to be selected. This X variable is usually meant to represent some overall measure of body size. Examples in the literature

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[20] The exact meaning of "a" is not agreed upon, although Gould (1971) emphasizes that it is not size independent as is often claimed, and actually represents a size factor.

include skull length (Dodson, 1978), total hind limb length (Gatesy, 1991), femoral length (Houck et al., 1989; Gatesy, 1991), the mass of the living animal (Brower and Veinus, 1981), the geometric mean[21] (Brochu, 1992), and first principal component, or "PC1" (Houck et al., 1989). Of these, the geometric mean and PC1 are the best estimates of overall body size, as they are composites of several different measures.

Principal component analysis (PCA) is essentially an extension of bivariate regression, except that while in bivariate analysis only a single axis is found for a *single* pair of variables, in PCA a separate axis is found for every possible pair of *multiple* variables. PC1 is the axis representing the maximum amount of variance in the data (successive PCs are ranked in order of the remaining variance that they account for). In PCA, the loadings of each character on the PCs are used directly to describe variance. As previously mentioned, PCA is less reliable then bivariate regression when the number of variables considered exceeds the sample size. However, the PC1 can still be calculated, and the size scores on it *for each specimen* applied to *bivariate* analysis as the X variable representing overall body size. Essentially, a single measurement (such as femur length) used as the X variable in most bivariate analyses is combined with other measures to give this composite X variable.

An important difference between using the PC1 in multivariate and bivariate analysis needs to be clarified. In multivariate analysis, it is important to report the PCs *accurately*, using *all* available character measurements, as information regarding variance is extracted from them. However, as the X value in bivariate analysis, the PC1 is merely a standard size measure, and it is more important that the PC1 account for as high a percentage of the total variance as possible. Therefore, it is acceptable to drop characters from being calculated in the PC1 in order to boost its percentage of the total variance.

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[21] The geometric mean for a specimen is the nth root of the product of n measurements: $gm = {}^{n}\sqrt{[(m_1)(m_2)(m_3)\ldots(m_n)]}$ (Brochu, 1992).

Gatesy (1991, p. 84) noted that "…a multivariate estimate of size would require the preservation of other skeletal elements in fossil taxa that would severely limit the data set." This is often the case in fossil vertebrates, which are usually so incomplete that a limited number of skeletal elements are available. However, this difficulty can be reduced by applying regressions to a single *type* of element (as is done here using only the femur and tibia), and using only the PC1 calculated using measurements for those characters only. For example, if allometric growth is only considered for measures of a humerus in a taxon, the PC1 can be calculated by combining only the humerus measures for all specimens. In this way, it doesn't matter if other elements for the various specimens examined are missing, or even if some bones are isolated elements. However, it is required that *all* the *same* humerus measures be used for all the specimens in calculating the PC1, which can still be problematic if the elements themselves are incomplete.

Allometric growth is described here for each of the different dimensions of the femur and tibia, plotted against the size scores for each element on the PC1 for the femur or tibia. In calculating the first principal components for the two bones, certain measures were omitted to raise the PC1s as high as possible. Then, for each character, the size scores for each specimen on the PC1 value were plotted against the actual (log transformed) measures to obtain a major axis regression. Again, the slope represents the allometric coefficient, the R^2 values measure how well the points fit the regression, and the results were tested at the 95% significance level (p-value = .05).

5.4 Reconstructing missing data

Before calculating the PC1s for the femur and tibia, one final problem had to be addressed. As previously mentioned, calculating the PC1 for each bone requires using all the same measures for all specimens. Since many of the specimens used were incomplete, this is a problem. For example, one of the measures used in calculating the femur PC1 was the width of the distal end, which was not preserved in some specimens.

Additionally, several of the elements were only known from previously published measurements, which were not as numerous as those made by the author for the Canjilon and Post Quarry material, and consequently missing some of the measures used for the PC1. In order to find the first principal components, it was therefore necessary to plausibly *reconstruct* the missing values.

By far the most effective and reliable method for doing this is the expectation-maximization method (e.g., Strauss et al., in press), which was utilized here. The reconstructed values were found using a Matlab macro using the expectation-maximization method created for the purpose by Dr. Richard Strauss of TTU. The reconstructed values are given in italics on Tables 4.5 and 4.6.

5.5 Results

5.5.1. Femur-tibia length allometry

Relatively few specimens of *Typothorax* have both the femur and tibia known reliably for the same individual. Only the Canjilon Quarry "Fa specimen" (femur: 122674 70/J46, fibula: 122682 70/Fa2[22]), "G specimen" (femur: 34248 70/G6, tibia: 122678 70/G6) "U specimen" (34255 70/U80), and TTUP 9214, have both elements (a total sample size of four). The results are shown in Fig. 5.1.

The allometric coefficient obtained by plotting the long-transformed femur length values against log transformed tibia values is 2.05, which indicates that femur length increases at approximately twice the rate that tibia length does. The R^2 value for this regression is high, suggesting the femur and tibia lengths correlate well. However, the p-value fails to pass the 95% test of significance, and the results are suspect. A larger sample size will hopefully eventually make for a more strongly supported correlation. Faster femoral growth may be weakly supported by the greater allometric coefficient of the femur length then that of tibia length (discussed below). However, since these

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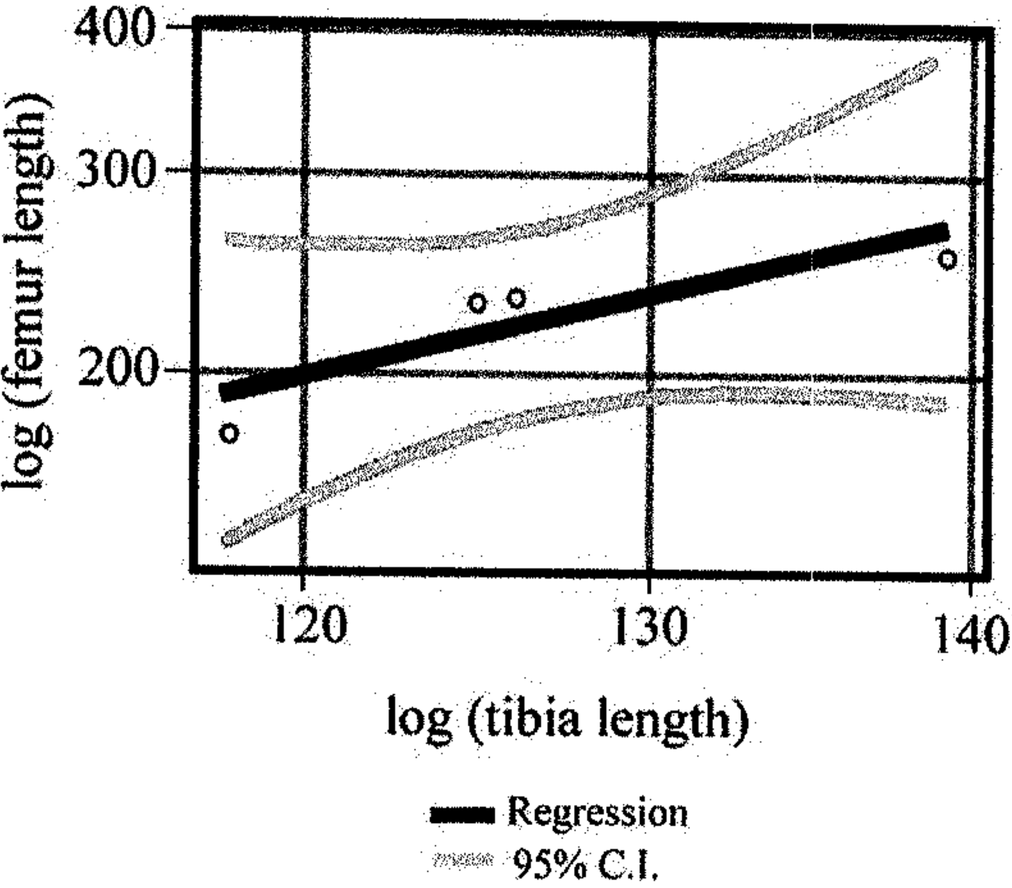
[22] Since the only good tibia for this individual, UCMP 122689 79/Fa2, is missing much of the shaft, the length is based on the fibula instead, making the assumption that the two bones were of approximately the same length.



log femur length = -1.97 + 2.05 log tibia length

$r2 = .789$ $p = .112$

Figure 5.1 Bivariate plot of log-transformed femur and tibia lengths. The slope of the regression, correlation coefficient, and p-value are also given.

coefficients are in reference to overall size values found separately for different elements, they cannot really be compared directly.

5.5.2. The first principal components

For femoral allometry, AMNH 2710 and MCZ 1488 were removed before reconstructing the missing values, and consequently do not contribute to the femur PC1. Only measurements for femur length are known for these specimens, so reconstructing all the other missing measures was considered too unreliable. For the remaining femora, values were only reconstructed for four variables to obtain as high a PC1 as possible while at the same time avoiding characters in which the measures would have to be reconstructed for too many specimens. The characters used were (1) femur length, (6) the anteroposterior thickness at the midshaft, (7) the mediolateral thicknesses at mid-shaft, and (8) the width of the distal end. This combination yielded a fairly high PC1 of 89.1724% of the total variance. The loadings of the individual characters on the PC1, and the (log-transformed) size scores on the PC1 for the individual specimens are given in Table 4.4.

For tibia allometry, few of the specimens had measurements for the mediolateral thickness of the distal end. Consequently, that character was not used to calculate the PC1. The resultant PC1 calculated with all six of the remaining characters (for all specimens) accounted for 88.4628% of the total variance. The loadings of the individual characters on the PC1, and the (log-transformed) size scores on the PC1 for the individual specimens are given in Table 4.5.

5.5.3 Femur allometry

The allometric coefficients, correlation coefficients (R^2 values) and p-values for the regressions of log-squared femur measurements against the specimen size scores are given in Table 5.1, and displayed in Figs. 5.2 and 5.3. Discussion here will mostly be limited to variables with R^2 values greater then 0.5, which only includes six (roughly

Table 5.1. Allometric coefficients, R^2 values, and p-values for femur plots

	Allometric Coefficient	R^2	p-value
1. Length	0.749	0.904	0.001
2. Distance from head to 4th trochanter	0.758	0.273	0.131
3. Head width	0.530	0.551	0.034
4. Head length	0.702	0.670	0.015
5. Thickness across 4th trochanter	0.885	0.689	0.013
6. Mid-shaft length	0.443	0.381	0.045
7. Mid shaft width	1.360	0.682	0.004
8. Distal width	1.778	0.947	0.000
9. Medial condyle thickness	1.850	0.201	0.208
10. Lateral condyle thickness	-1.733	0.382	0.082
11. Intercondylar thickness	0.793	0.000	0.382
12. Torsion	0.798	0.024	0.409
13. Distal angle	0.159	0.000	0.458

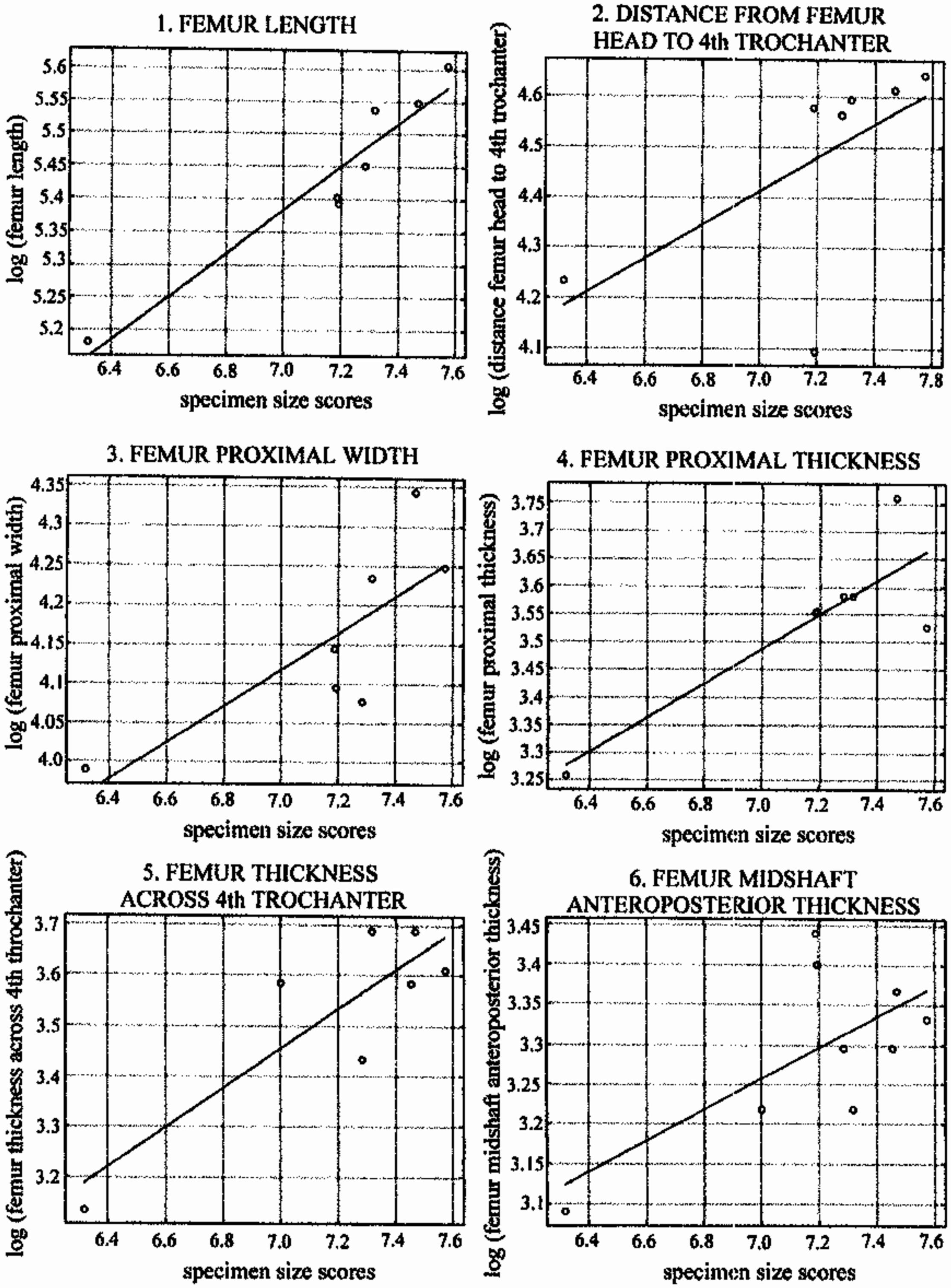


Figure 5.2 Bivariate plots of log-transformed measures and PC1 size scores for femur measures 1-6.

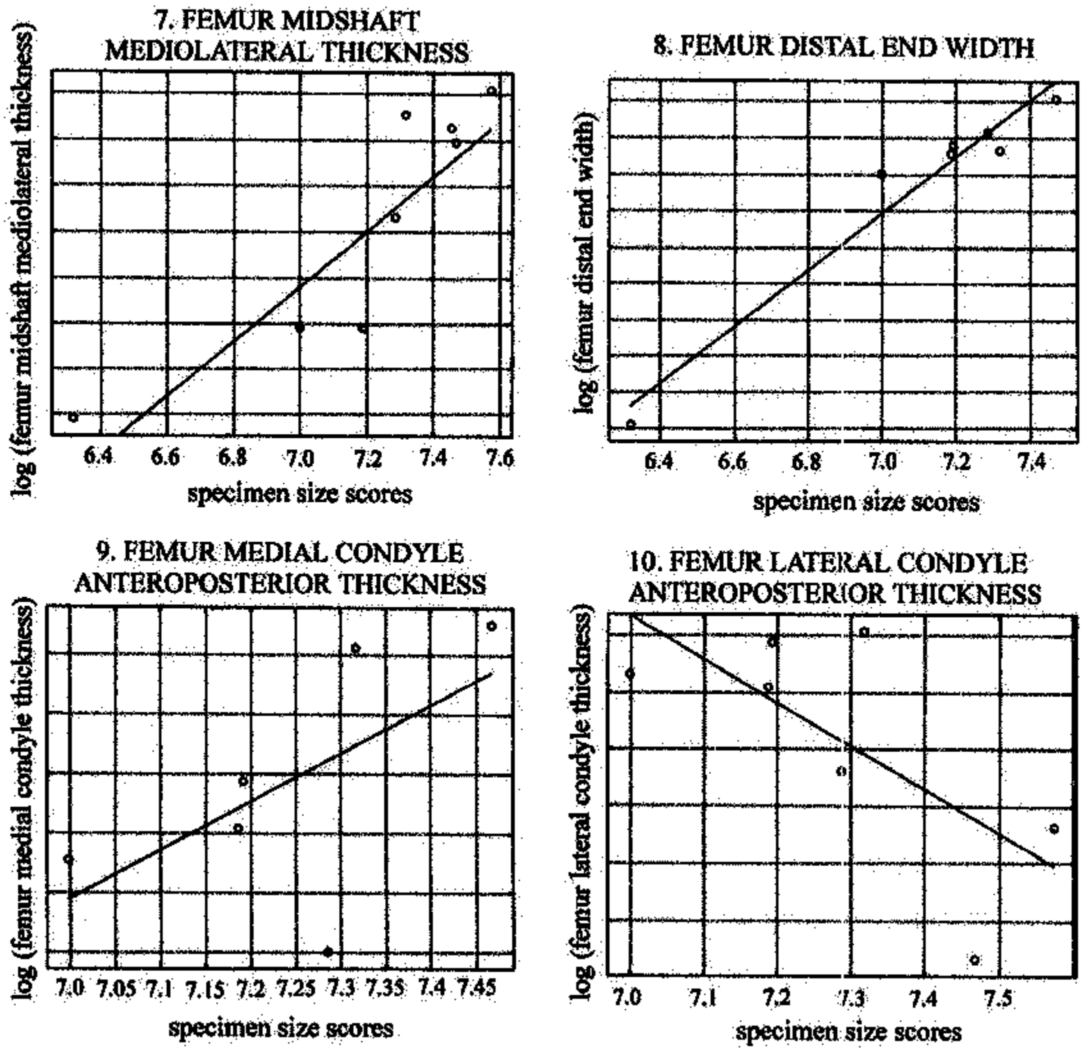


Figure 5.3 Bivariate plots of log-transformed measures and PC1 size scores for femur measures 7-10.

half). All six of these variables also pass the p-test. In the *Typothorax* specimens examined, the femur characters with good correlation coefficients, in order starting with the fastest growing (possessing the highest allometric coefficient) are: (8) mediolateral width of the distal end, (7) mediolateral thickness of the shaft at mid-length, (5) antero-posterior thickness of the femur across the 4th trochanter, (1) the length of the entire femur, (4) the antero-posterior thickness of the head, and 3) the mediolateral width of the head. For the most part therefore, overall robustness of the femur increases more rapidly then the femur length, though only distal to the head.

Based on their low R^2 values, the other variables are not considered to increase at a consistent rate with overall growth of the femur, or at least this is not apparent with the current sample size. These variables include: (1) the distance of the 4th trochanter from the proximal end of the femur, (2) the degree of torsion between the proximal and distal ends, and (3) the angle of the distal end to the long axis of the shaft. The possible importance of these latter variables *not* being correlated to overall size will be discussed below.

5.5.4. Tibia allometry

The allometric coefficients, correlation coefficients (R^2 values) and p-values for the regressions of log-squared tibia measurements against the specimen size scores are given in Table 5.2 and displayed graphically in Figs. 5.4 and 5.5. All of the regressions had correlation coefficients much higher then 0.7, and all passed the p-test. The tibia measures are therefore correlated well with the overall size of the bone.

The tibia measures, listed with the variable with the highest allometric coefficient first, are (3) the (anteroposterior) thickness of the head, (5) (anteroposterior) thickness at midshaft, (6) (mediolateral) width of the distal end, (4) (mediolateral) midshaft width, (2) (mediolateral) width of the head, (3) (anteroposterior) thickness of the distal end, and (1) overall length of the tibia. The tibia therefore thickens proximally and along its shaft

Table 5.2. Allometric coefficients, R^2 values, and p-values for tibia plots

	Allometric Coefficient	R^2	p-value
1. Length	0.316	0.913	0.029
2. Proximal width	0.941	0.959	0.000
3. Proximal thickness	1.301	0.931	0.000
4. Mid-shaft width	0.956	0.722	0.010
5. Mid-shaft length	1.285	0.897	0.001
6. Distal width	1.018	0.969	0.010
7. Distal length	0.687	0.999	0.015

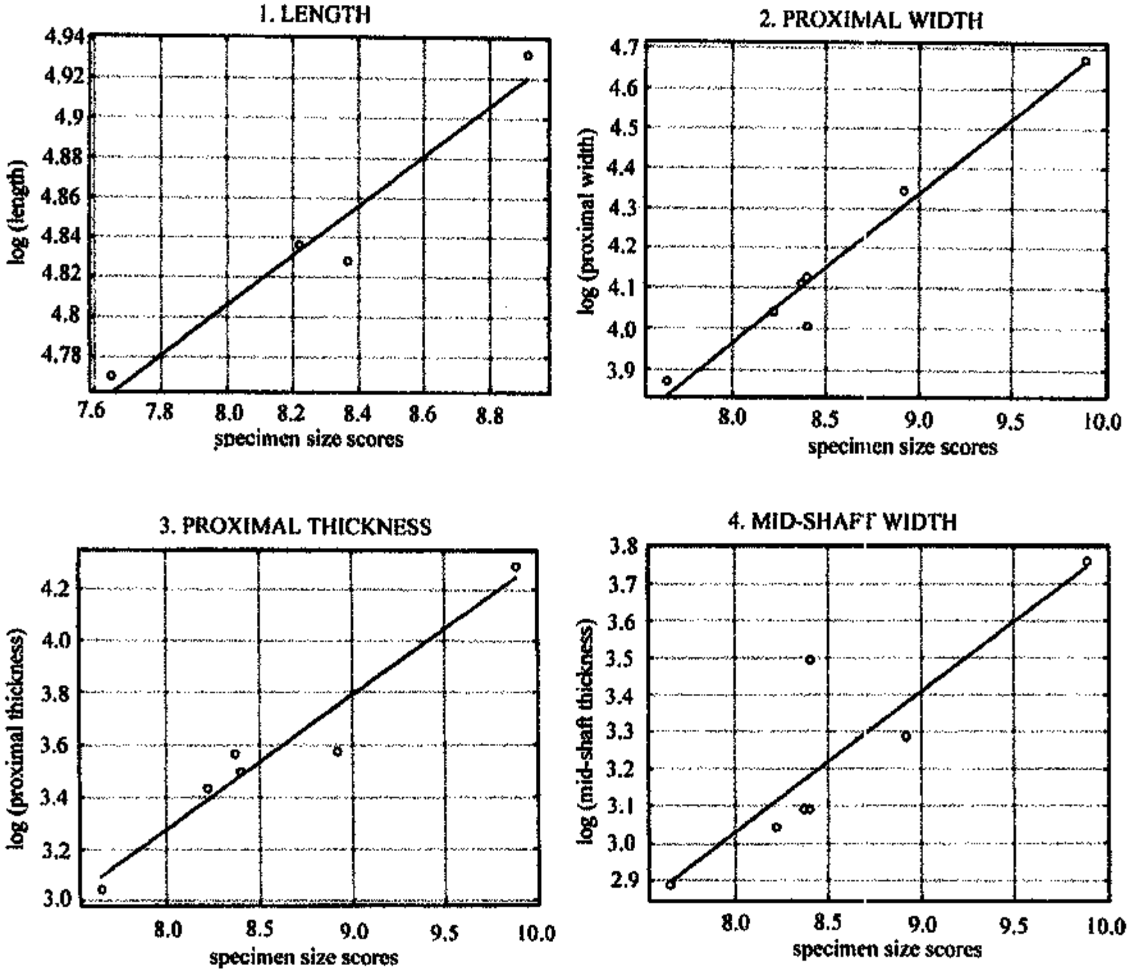


Figure 5.4 Bivariate plots of log-transformed measures and PC1 size scores for tibia measures 1-4

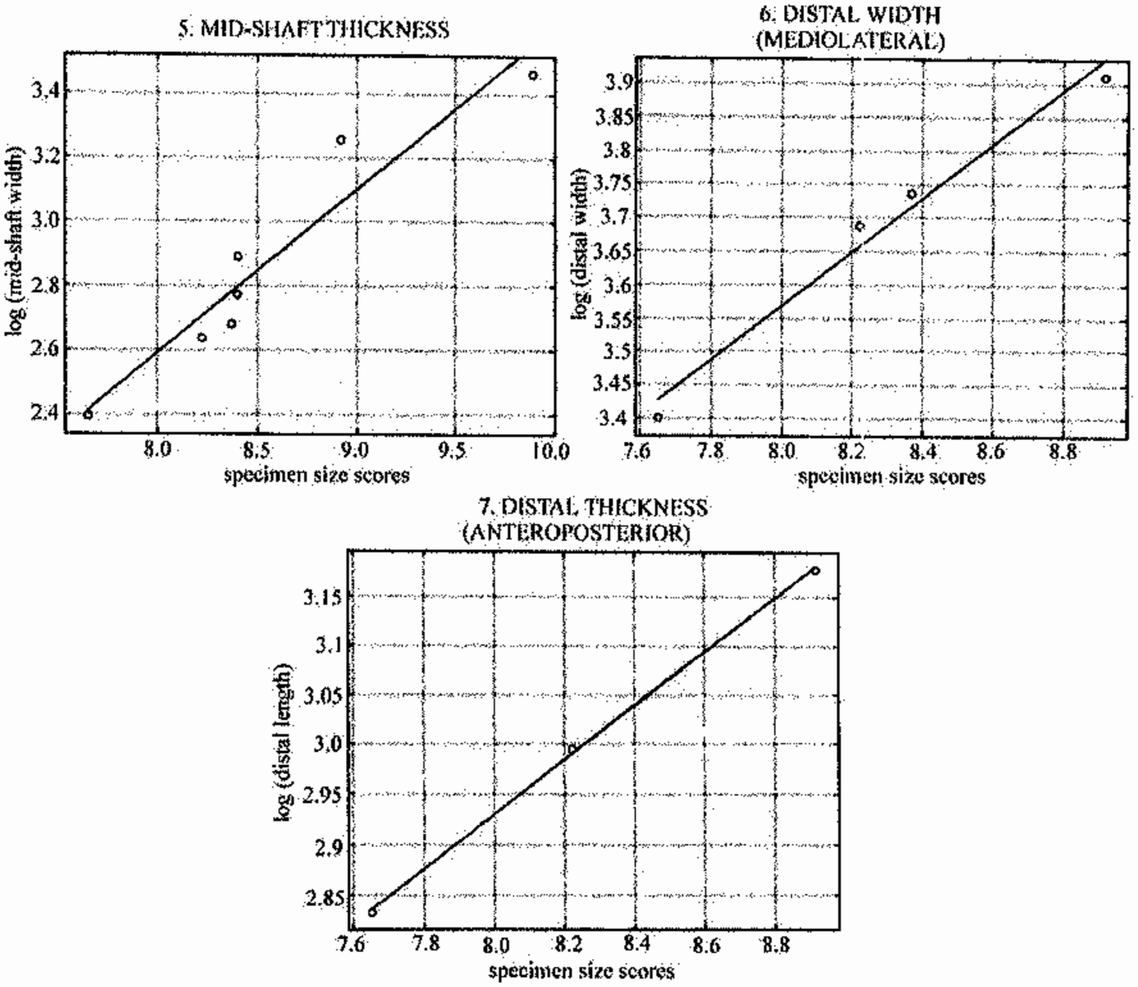


Figure 5.5 Bivariate plots of log-transformed measures and PC1 size scores for tibia measures 5-7

faster than it expands mediolaterally in those areas, although the reverse is true at the distal end. The slow increase in length is consistent with the hypothesis that femur length increases much more quickly then tibia length.

CHAPTER 6
DISCUSSION

6.1 Assumptions

Much of the following discussion depends heavily on several assumptions, listed below, which have already been discussed and defended in Chapters 2, 3, and 5. It should also be borne in mind that these interpretations are based on an extremely small sample size for *Typothorax*.

1. The material described here has been correctly assigned to the various specimens, so that material treated as coming from the same individual is correctly associated.
2. TTUP 9214, the Canjilon Quarry specimens, and other material discussed housed at AMNH (including the holotype) all belong to the same species, *Typothorax coccinarum*.
3. The differences between TTUP 9214 and the other specimens represent ontogenetic change within *Typothorax coccinarum*; in other words, TTUP 9214 represents a sub-adult of the species rather then (for example) one of the sexes while the larger specimens represent the other sex.

6.2 Summary of ontogenetic changes in *Typothorax coccinarum*

Nothing can be said about ontogenetic change in the skull, pectoral girdle, and pelvic girdle of *Typothorax*, as these elements are known from either TTUP 9214 or the Canjilon Quarry material, but not both. Little can also be said about the vertebrae, which were only described and illustrated in brief for probable adult specimens of *Typothorax* by Long and Murry (1995; figs. 102-103 show articulated cervicals of AMNH 7634). Long and Murry (1995) noted that the cervical vertebrae in *Typothorax* were very short, with the centra being twice as wide as long. This is not the case in TTUP 9214 (Table

4.1), in which the cervical centra are only slightly wider then long. Long and Murry (1995 p. 104) also note that in *Typothorax* "the ventral surfaces of the [cervical] centra bear a faint to moderate ridge" which is shared with *Stagonolepis* (Walker, 1961; Long and Murry, 1995). These ridges are absent in TTUP 9214, in which there is only a lip on the ventral edge of the anterior articular face. Long and Murry (1995) also described the width of the centra of the dorsal vertebra as being 3/5 their length (whereas it is about 4/5 in TTUP 9214), and that the transverse processes of the same reached more then three times the length of the centrum. Assuming they are referring to individual transverse process (and not the total width across both), TTUP 9214 has processes that are less expanded, little more than twice the length of a centrum. In summary, *shortening* of the cervical vertebra centra, development of ridges on the underside of the cervical vertebra centra, *lengthening* of the dorsal vertebra centra, and widening of the dorsal vertebrae transverse processes, all apparently occurred during ontogeny in *Typothorax*. The greatly shortened cervical centra and widened transverse processes are derived for *Typothorax* among aetosaurs (Long and Murry, 1995), so the development of these features ontogenetically may represent recapitulation.

The humerus of TTUP 9214 is more asymmetric than that of the Canjilon Quarry specimens, with greater lateral expansion (making the humerus head slightly more symmetrical) present in the latter. As noted by Romer (1956), most archosaurs have a relatively asymmetric head, which is likely the plesiomorphic state. The lateral expansion of the humerus head during ontogeny may also represent recapitulation.

Within the hind limb, the length of the tibia and fibula seem to grow slower relative to the length of the femur, so that the crus becomes shorter relative to the thigh in adults compared to the subadult. As discussed above, this is difficult to prove statistically by directly comparing femur length to tibia length in the same specimen given the currently small samply size. On the femur, several muscle scars are particularly prominent in the largest *Typothorax* specimen examined by the author (UCMP V2816 34255 70/U80). The fourth trochanter in this specimen is also bulbous rather then a crest (also seen in the large aetosaur *Desmatosuchus*), and the *M. iliofemoralis* muscle scar on the anterior side of the shaft, and the "primary and secondary muscle scars" on the posterior side are all particularly distinct ridges that may become prominent with increased size. Among the aspects of femur growth tested statistically, the distal end of the femur in *Typothorax* grows distinctly wider, and both the femur and tibia grow more robust.

One of the most striking differences between TTUP 9214 and the other *Typothorax* specimens examined is the size of the dorsal paramedian scutes, which are apparently much more enlarged and expanded relative to the body size in the adults compared to the subadult. The extreme expansion of the "discoid" carapace of *Typothorax* seems to take place relatively late in ontogeny. Also, the lateral edges of the dorsal paramedian scutes from the mid-dorsal region go from being convex in the subadult to straight in the adult, an elongate ridge at the center of ossification is lost, the pyramidal bosses become more prominent (and perhaps extend more anteriorly and posteriorly from the anterior caudal scutes), and the degree of arching at the center of ossification becomes less pronounced. The discoid carapace with greatly widened dorsal paramedian scutes in unusual in aetosaurs (most have relatively narrow bodies), and the elongate ridge at the center of ossification may be plesiomorphic for the group (Heckert and Lucas, 1999). The widening of the scutes and the replacement of a ridge at the center of ossification with a pyrimidal boss may therefore both represent ontogenetic recapitulations.

The dorsal flange of the lateral scutes in the middle and probably posterior dorsal region in TTUP 9214 (probably articulating with the dorsal paramedians with the convex lateral edges) differ from those of the adult specimens in not being straight-edged triangles, but instead being medially concave, posteromedially projecting tongues, similar to those of *Paratypothorax* and "*Tecovasuchus*." The change of this type of dorsal flange into a more triangular one may again represent recapitulation; such a flange is not seen in other aetosaurs besides TTUP 9214, *Paratypothorax*, and "*Tecovasuchus*," and may imply a close relationship between these taxa with wide dorsal paramedian scutes as suggested by Parrish (1994), contra Heckert and Lucas (1999, 2000). The angulation between the dorsal and lateral flanges in TTUP 9214 in never less then 90°, but much tighter flexion develops in the immediately presacral laterals in the adult material. The lateral flange of the lateral scutes from the dorsal (and possibly cervical) region becomes shorter, and the ornamentation of the same region grows fainter, though it remains deeply incised in the pelvic and caudal laterals.

The ventral and appendicular scutes of *Typothorax* are too poorly understood for much comment to be made on ontogenetic variation. However, in TTUP 9214, most of these scutes possess a longitudinal ridge similar to those seen in the dorsal paramedians of the same specimen. This ridge is seen in the few of the Canjilon Quarry scutes. Also, for the possible thigh (Fig. 4.31), and laterally placed ventral scutes (Fig. 4.32), there are prominent bosses at the posterior margins, as in the dorsal paramedians. It seems therefore that the bosses of at least some ventral and appendicular scutes change in the same manner as the dorsal paramedians, which a ridge being replaced by a more prominent and posteriorly positioned boss.

6.3. Ontogeny and locomotion

6.3.1. Ontogeny and cursorial ability

Faster moving terrestrial vertebrates have crus (tibiae and fibulae), which are relatively long compared to the femur (e.g., Maynard Smith and Savage, 1954; Garland and Janis, 1993). As noted above, TTUP 9214 seems to have had a more elongate tibia compared to the femur then the larger Canjilon specimens, although this is difficult to confirm statistically given the small sample size. It is possible therefore that younger *Typothorax* were more active cursors then the adults. This suggestion is also supported by the great increase in the width of the dorsal paramedian scutes during ontogeny, which, it seems logical, would increase the weight and unwieldiness of the carapace. It may be speculated that *Typothorax* was relatively active as a juvenile, perhaps using concealment and retreat as means to escape predation. As growth progressed and the animal adopted a more sedentary lifestyle with the enlargement of the carapace and shortening of the crus, it would have relied more heavily on its armor for defense.

6.3.2. Ontogenetic variation in posture?

Charig (1972) and Parrish (1986) discussed in detail on how characters of the pelvis, femur, and tibia differ between archosaurs exhibiting a plesiomorphic sprawling posture (basal archosauriformes, phytosaurs, and some crocodylomorphs), and a more derived upright posture (ornithosuchians, including dinosaurs, rauisuchians, and poposaurs). Aetosaurs as a group show greater development of these features than in full sprawlers, yet were not as fully erect (Parrish, 1986). The reasons *why* some archosaurs evolved a less sprawling posture has received considerable discussion, but the most common explanations relate to an inferred increase in locomotor speed, stamina, and/or maneuverability (Bakker, 1971; Bakker and Galton, 1974; Parrish, 1986; Carrier, 1987), although some authors (e.g., Benton, 1984; Sereno, 1991) question whether an upright posture provided any significant competitive advantage.

Large animals exhibiting graviportal adaptations also tend to have limbs that are pillar-like and held vertically, which is better for supporting increased mass (e.g., McGowan, 1992). Therefore, the possibility might be entertained that upright posture, in at least in the case of the heavily armored and probably not terribly fleet footed aetosaurs, may be tied to an increase in body size rather then a way of increasing locomotor efficiency. Ironically, these proposed explanations for upright posture essentially opposed, as graviportal locomotion imply a relatively sedentary gait, while previous suggestions involve *increased* activity correlated with erect posture. As already discussed, cursorial activity may have decreased with ontogeny in *Typothorax*, so it is worth exploring the possibility that growing individuals may have developed an increasingly upright graviportal posture.

Among the characters tied to upright posture by Charig (1972) and Parrish (1986), the femora of upright archosaurs tend to move the 4th trochanter farther distally down the shaft, decrease torsion between the distal and proximal ends, and decrease the angle between the distal articular surface and the long axis of the femur. As discussed above, these characters are not correlated to overall size, which suggests that there is no evidence to favor a more upright posture in larger individuals of *Typothorax* compared to smaller individuals.

Another character cited by Parrish (1986) that is related to an increase in upright posture is the width of the distal end, which tends to *decrease* with a more upright stance. As noted above, the width of the distal end of the femur in *Typothorax* instead *increases* with greater size. However, when it relates to posture, a wider distal width is usually tied to a large angle between the distal end and the long axis of the shaft (Parrish, 1986). This is not the case in *Typothorax*. It is unlikely that the increasing width of the distal end has anything to do with larger individuals having a *more* sprawling posture. In summary, although adults of *Typothorax* were more massive then the juveniles, they did not appear to have a distinctly different posture.

6.3.3. Taxonomic variation in posture?

This analysis only considered ontogenetic allometric change *within* a single taxon, *Typothorax*. However, even if there is no evidence that upright posture develops as a graviportal adaptation ontogenetically *within* a taxon, may it have done so phylogenetically *between* aetosaur taxa of different sizes? Although this was not tested statistically here, judging by measurements taken for other aetosaur taxa (Table 4.4), no evidence seems to support this suggestion. The distance the fourth trochanter moves down the shaft (relative to total shaft length), the degree of torsion, and the distal angle, do not seem to vary in any sort of consistent pattern between *Typothorax*, *Desmatosuchus*, *Longosuchus*, and *Stagonolepis*.

One interesting feature of the hind limb of *Typothorax* that *does* seem to differ from other taxa is the pubis and ischium. Another feature Charig (1972) and Parrish (1986) correlated with upright posture in pseudosuchians is that the pubis and ischium extend distally (ventrally), to allow the muscular connections between those bones and the femur to remain level. This distal extension is seen in *Stagonolepis* (Walker, 1961), *Longosuchus* (Sawin, 1947) and *Desmatosuchus* (Small, 1985). However, the single pubis described for *Typothorax*, UCMP V2816 34248, is only about half as long at the femur (Long and Murry, 1995), and the posterior process of the ischium of TTUP 9214 is oriented horizontally rather then posteroventrally (Fig. 4.11). As the femur of *Typothorax* shows no more evidence of a sprawling posture then other aetosaurs, the significance of this ventrally shortened pelvis is not clear.

A final possibility is that even if there is not evidence of variation in posture *within* aetosaurs, adaptations to a sedentary lifestyle with a massive carapace may be responsible for the development of an upright posture in aetosaurs as a group. Interestingly, Bonaparte (1984) in comparing the adaptations for an upright posture of rauisuchians (which, like aetosaurs, did so through having a laterally oriented illium that maintained an imperforate acetabulum) to those of dinosaurs, referred to the adaptations of the former as "graviportal" to distinguish them from the latter, although his inferred functional significance of this distinction was not made clear. It seems unlikely that such apparently small and active bipedal archosaurs such as dinosaurs, ornithosuchids, and poposaurs developed erect posture as a weight-bearing adaptation. For these small bipeds, the author particularly prefers the explanation of Carrier (1987) for upright, and especially bipedal posture as a way of circumnavigating the constraints imposed on respiration by quadrupedal locomotion with unilateral movements of the body. However, it may be that the aetosaurs, large heavily armored, and apparently not particularly active quadrupeds, may have reduced their sprawling posture for very different reasons related to supporting their mass; as noted by Carrier (1987, p. 335), "the initial shifts toward upright posture may well have occurred in response to more then one selective agent".

REFERENCES

Baird, D. 1986. Some Upper Triassic reptiles, footprints, and an amphibian from New Jersey. The Mosasaur, vol. 3, pp. 125-153.

Bakker, R. T. 1971. Dinosaur physiology and the origin of mammals. Evolution, vol. 25, pp. 636-658.

Bakker, R.T., and Galton, P.M. 1974. Dinosaur monophyly and a new class of vertebrates. Nature, vol. 248, pp. 168-172.

Benton, M. 1984. Rauisuchians and the success of dinosaurs. Nature, vol. 310, p. 101.

Benton, M. J., and Walker, A. D. 1985. Palaeoecology, taphonomy, and dating of Permo-Triassic reptiles from Elgin, north-east Scotland. Palaeontology, vol. 28, no. 2, pp. 207-234.

Blakey, R. C., and Gubitosa, R. 1983. Late Triassic paleogeography and depositional history of the Chinle Formation, southern Utah and northern Arizona. *In* Reynolds, M. W., and Dolly, E. D. (eds.), Mesozoic Paleogeography of West-Central United States. Rocky Mountain Section, Society of Economic Paleontologists and Mineralogists, Rocky Mountain Paleogeography Symposium 2, pp. 57-76.

Bonaparte, J. F. 1970. Annotated list of the South American Triassic tetrapods. Second Gondawana Symposium Proceedings and Papers, pp. 665-682.

Bonaparte, J. F. 1971. Los tetrapodos del sector superior de la Formacion Los Colorados, La Rioja, Argentina (Triásico Superior), parte I. Opera Lilloana, vol. 22, pp. 1-183.

Bonaparte, J. F. 1984. Locomotion in rauisuchid thecodonts. Journal of Verebrate Paleontology, vol. 3, no. 4, pp. 210-218.

Brinkman, D. 1980. The hind limb step cyle of *Caiman sclerops* and the mechanics of the crocodile tarsus and metatarsus. Canadian Journal of Zoology, vol. 58, pp. 2187-2200.

Brochu, C. A. 1992. Ontogeny of the postcranium in crocodylomorph archosaurs. Master's thesis, University of Texas, Austin, TX, 340 pp.

Brochu, C. A. 1996. Closure of neurocentral sutures during crocodilian ontogeny: Implications for maturity assessment in fossil archosaurs. Journal of Vertebrate Paleontology, vol. 16, no. 1, pp. 49-62.

Brochu, C. A. 1997. Synonymy, redundancy, and the name of the crocodile stem-group. Journal of Vertebrate Paleontology, vol. 17, no. 2, pp. 448-449.

Brower, J. C., and Veinus, J. 1981. Allometry in pterosaurs. The University of Kansas Paleontological Contributions, no. 105. 32 pp.

Camp, C. L. 1930. A study of the phytosaurs with description of new material from western North America. Memoirs of the University of California 10, 161 pp.

Carpenter, K. 1997a. Ankylosauria. *In* Currie, P. J., and Padian, K. (eds.), Encyclopedia of Dinosaurs. Academic Press, San Diego, CA, pp. 16-20.

Carpenter, K. 1997b. A giant coelophysoid (Ceratosauria) theropod from the Upper Triassic of New Mexico, USA. Neus Jahrbuch für Geologie und Paläontologie, Monatschefte, vol. 205, no. 2, pp. 189-208.

Carrier, D. R. 1987. The evolution of locomotor stamina in tetrapods: circumnavigating a mechanical constraint. Paleobiology, vol. 13, no. 3, pp. 326-341.

Casamiquela, R. M. 1961. Dos nuevos estagonolepoideos Argentinos (de Ischigualasto, San Juan). Revista de la Asociacion Geologica Argentina, vol. 16, pp. 4-203.

Case, E. C. 1922. New reptiles and stegocephalians from the Upper Triassic of western Texas. Carnegie Institution of Washington Publication 321, 84 pp.

Charig, A. J. 1972. The evolution of the archosaur pelvis and hind-limb: an explanation in functional terms. *In* Joysey, K. A., and Kemp, T. S. (eds.), Studies in Vertebrate Evolution. Oliver and Boyd, Edinburg, pp. 121-151.

Chatterjee, S. 1978. A primitive parasuchid (phytosaur) reptile from the Upper Triassic Maleri Formation of India. Paleontology, vol. 21, no. 1, pp. 83-127.

Chatterjee, S. 1982. Phylogeny and classification of thecodontian reptiles. Nature, vol. 295, pp. 317-320.

Chatterjee, S. 1985. *Postosuchus*, a new thecodontian reptile from the Triassic of Texas, and the origin of tyrannosaurs. Philosophical Transactions of the Royal Society of London B, vol. 309, pp. 395-460.

Chatterjee, S. 1991. Cranial anatomy of new Triassic bird from Texas. Philosophical Transactions of the Royal Society of London, Series B, vol. 332, pp. 277-346.

Chatterjee, S., and Roy-Chowdhury, T. 1974. Triassic Gondwana vertebrates from India. Indian Journal of Earth Sciences, vol. 1, no. 1, pp. 96-112.

Chevaud, J. M. 1982. Relationships among ontogenetic, static, and evolutionary allometry. American Journal of Physical Anthropology, vol. 59, pp. 139-149.

Cope, E. D. 1875. The geology of New Mexico. Philadelphia Academy of Natural Sciences Proceedings, pp. 263-267.

Cope, E. D. 1877. Report upon the extinct Vertebrata obtained in New Mexico by portions of the expeditions of 1874. Report of the Geographical Survey west of the 100th meridian by Lt. G. M. Wheeler, vol. 2, no. 2, pp. 1-365.

Cope, E. D. 1887. A contribution to the history of the vertebrata of the Trias of North America. Proceedings of the American Philosophical Society, vol. 24, no. 126, pp. 209-228.

Cruickshank, A. R. I., and Benton, M. J. 1985. Archosaur ankles and the relationships of the thecodontian and dinosaurian reptiles. Nature, vol. 317, pp. 715-717.

Cunningham, D. P, Hungerbühler, A., Chatterjee, S., and McQuilkin, K. 2002. Late Triassic vertebrates from the Patricia Site near Post, Texas. Journal of Vertebrate Paleontology, vol. 22, (supplement to no. 1), p. 47A.

Dodson, P. 1978. Functional and ecological significance of relative growth in *Alligator*. Journal of Zoology (London), vol. 175, pp. 315-355.

Dubiel, R. F. 1989. Depositional environments of the Upper Triassic Chinle Formation in the eastern San Juan and vicinity, New Mexico.

Dubiel, R. F. 1991. Sedimentology and depositional history of the Upper Triassic Chinle Formation in the Uinta, Piceance, and Eagle Basins, northwestern Colorado and northeastern Utah.

Dubiel, R. F. 1994. Triassic deposystems, paleogeography, and paleoclimate of the western interior. *In* Caputo, M. V., Peterson, J. A., and Franczyk, K. J. (eds.), Mesozoic Systems of the Rocky Mountain Region, USA, pp. 133-168.

Dubiel, R. F., Parrish, J. T., Parrish, J. M., and Good, S. C. 1991. The Pangaean megamonsoon-evidence from the Upper Triassic Chinle Formation, Colorado Plateau. Palaios, vol. 6, pp. 347-370.

Dyke, G. J. 1998. Does archosaur phylogeny hinge on the ankle joint? Jounral of Vertebrate Paleontology, vol. 18, no. 3, pp. 558-562.

Fiorillo, A. R., Padian, K., and Musikasinthorn, C. 2000. Taphonomy and depositional setting of the *Placerias* Quarry (Chinle Formation: Late Triassic, Arizona). Palaios, vol. 15, pp. 373-386.

Frelier, A. P. 1987. Sedimentology, paleohydrology, and paleogeomorphology of the Dockum Formation (Triassic), West Texas. Master's thesis, Texas Tech University, Lubbock, TX, 198 pp.

Garland, T., Jr., and Janis, C. M. 1993. Does metatarsal/femur ratio predict maximal running speed in cursorial mammals? Journal of Zoology, vol. 229, pp. 133-151.

Gatesy, S. M. 1991. Hind limb scaling in birds and other theropods: implications for terrestrial locomotion. Journal of Morphology, vol. 209, pp. 83-96.

Gauthier, J. 1984. A cladistic analysis of the higher systematic categories of Diapsida. Unpublished Ph.D dissertation, University of California, Berkeley, CA, 564 pp.

Gauthier, J. 1986. Saurischian monophyly and the origin of birds. *In* Padian, K. (ed.), The origin of birds and the evolution of flight. Memoirs of the California Academy of Sciences 8, pp. 1-55.

Gauthier, J., and Padian, K. 1985. Phylogenetic, functional, and aeodynamic analyses of the origin of birds and their flight. *In* Hecht, M. K., Ostrom, J. H., Viohl, G., and Wellnhofer, P. (eds.), The Beginnings of Birds. Freude des Jura-Museums, Eichstatt, pp. 185-197.

Gould, S. J. 1971. Geometric similarity in allometric growth: a contribution to the problem of scaling in the evolution of size. The American Naturalist, vol. 105, no. 942, pp. 113-136.

Gower, D. J. 1997. The braincase of the early archosaurian reptile *Erythrosuchus africanus*. Journal of Zoology, London, vol. 242, pp. 557-576.

Gower, D. J. 2000. Possible postcranial pneumaticity in the last common ancestor of birds and crocodilians: evidence from *Erythrosuchus* and other Mesozoic archosaurs. Naturwissenschaften, vol. 88, pp. 119-122.

Gower, D. J., and Walker, A. D. 2002. New data on the braincase of the aetosaurian archosaur (Reptilia: Diapsida) *Stagonolepis robertsoni* Agassiz. Zoological Journal of the Linnean Society, vol. 136, pp. 7-23.

Gower D. J.,and Weber, E. 1998. The braincase of *Euparkeria*, and the evolutionary relationships of birds and crocodilians. Biological Reviews, vol. 73, pp. 367-411.

Gregory, J. T. 1953. *Typothorax* and *Desmatosuchus*. Postilla, no. 16, 27 pp.

Heckert A. B., and Lucas, S. G. 1996. Late Triassic aetosaur biochronology. Albertiana, vol. 17, pp. 57-64.

Heckert, A. B., and Lucas, S. G. 1999. A new aetosaur (Reptilia: Archosauria) from the Upper Triassic of Texas and the phylogeny of aetosaurs. Journal of Vertebrate Paleontology, vol. 19, no. 1, pp. 50-68.

Heckert, A. B., and Lucas, S. G. 2000. Taxonomy, phylogeny, biostratigraphy, biochronology, paleobiogeography, and evolution of the Late Triassic Aetosauria (Archosauria: Crurotarsi). Zentralblatt für Geologie und Paläontologie Teil I1998 Heft 11-12, p. 1539-1587.

Heckert, A.B., and Lucas, S. G. 2002. South American occurrences of the Adamanian (Late Triassic: Latest Carnian) index taxon *Stagonolepis* (Archosauria: Aetosauria) and their biochronological significance. Journal of Paleontology vol. 76, no. 5, pp. 852-863.

Heckert, A. B., Hunt, A. P., and Lucas, S. G. 1996. Redescription of *Redondasuchus reseri*, a Late Triassic aetosaur (Reptilia: Archosauria) from New Mexico (U.S.A.), and the biochronology and phylogeny of aetosaurs. Geobios, vol. 29, no. 5, pp. 619-632.

Hester, P. M. 1988. Depositional environments in an Upper Triassic lake, east-central New Mexico. Master's thesis, University of New Mexico, Albuquerque, NM, 154 pp.

Houk, M. A., Gauthier, J. A., and Strauss, R. E. 2000. Allometric scaling in the earliest fossil bird, *Archaeopteryx lithographica*. Science, vol. 247, pp. 195-198.

Huber, P., Lucas, S. G., and Hunt, A. P. 1993. Vertebrate biochronology of the Newark Supergroup Triassic, eastern North America. *In* Lucas, S. G., and Morales, M. (eds.), The Nonmarine Triassic. New Mexico Museum of Natural History and Science Bulletin 3, pp. 179-186.

Huene, F. von. 1915. On reptiles of the New Mexico Trias in the Cope collection. American Museum of Natural History Bulletin, vol. 34, pp. 485-507.

Hungerbühler, A. 2002. The Late Triassic phytosaur *Mystriosuchus westphali*, with a revision of the genus. Paleontology, vol. 45, part 2, pp. 377-418.

Hunt, A. P. 2001. The vertebrate fauna, biostratigraphy and biochronology of the type Revueltian land-vertebrate faunachron, Bull Canyon Formation (Upper Triassic), east-central New Mexico. New Mexico Geological Society Guidebook, vol. 52, pp. 123-152.

Hunt, A. P., and Lucas, S. G. 1990. Re-evaluation of "*Typothorax*" *meadei*, a Late Triassic aetosaur from the United States. Paläontologische Zeitschrift, vol. 64, no. 3/4, pp. 317-328.

Hunt, A. P., and Lucas, S. G. 1991a. A new aetosaur from the Redonda Formation (Late Triassic: Middle Norian of east-central New Mexico, USA. Neus Jahrbuch für Geologie und Paläontologie, Monatschefte, no. 12, pp. 728-736.

Hunt, A. P., and Lucas, S. G. 1991b. The *Paleorhinus* biochron and the correlation of the non-marine Upper Triassic of Pangea. Paleontology, vol. 34, part 2, pp. 487-501.

Hunt, A. P., Lucas, S. G., and Reser, P. K. 1993. A complete skeleton of the stagonolepidid *Typothorax coccinarum* from the Upper Triassic Bull Canyon Formation of east-central New Mexico, USA. *In* Lucas, S. G., and Morales, M. (eds.), The nonmarine Triassic. New Mexico Museum of Natural History and Science Bulletin 3, pp. 209-212.

Jenkins, F. A., Jr., Shubin, N. H., Jr., Amaral, W. W., Gatesy, S. M., Schaff, C. R., Clemmensen, L. B., Downs, W. R., Davidson, A. R., Bonde, N., and Osbaeck, F. 1994. Late Triassic continental vertebrates and depositional environments of the Fleming Fjord Formation, Jameson Land, East Greenland. Meddeleser om Grønland, Geoscience, vol. 32, pp. 3-25.

Jepsen, G. L. 1948. A Triassic armored reptile from New Jersey. State of New Jersey Department of Conservation, miscellaneous geologic paper, 20 pp.

Kutty, T. S., and Sengupta, D. P. 1989. The Late Triassic formations of the Pranhita-Godavari Valley and their vertebrate faunal succession-a reappraisal. Indian Journal of Earth Sciences, vol. 16, no. 3-4, pp. 189-206.

Lawler, D. A. 1976. Osteological variation in the phytosaur *Rutiodon tenuis* from Ghost Ranch, New Mexico. Master's thesis, University of California, Berkeley, CA, 140 pp.

Lehman, T. M. 1994a. Save the Dockum Group! West Texas Geological Society Bulletin, vol. 34, no. 4, pp. 5-10.

Lehman, T. M. 1994b. The saga of the Dockum Group and the case of the Texas/New Mexico boundary fault. New Mexico Bureau of Mines and Mineral Resources Bulletin 150, pp. 37-51.

Lehman, T., Frelier, A., May, B., Fritz, T., and Schnable, J. Unpublished. Sedimentation and tectonism in the Triassic Dockum Basin, southern High Plains of Texas and New Mexico.

Long, R. A., and Ballew, K. L. 1985. Aetosaur dermal armor from the Late Triassic of southwestern North America, with special reference to material from the Chinle Formation of Petrified Forest National Park. Museum of Northern Arizona Bulletin 54, pp. 45-68.

Long, R. A., and Murry, P. A. 1995. Late Triassic (Carnian and Norian) tetrapods from the southwestern United States. New Mexico Museum of Natural History and Science Bulletin 4, 245 pp.

Long, R. A., Lucas, S. G., Hunt, A. P., and McCrea, R. T. 1989. Charles Camp: collecting Late Triassic vertebrates in the American Southwest during the 1920's and 1930's. *In* Lucas, S. G., and Hunt, A. P. (eds.), Dawn of the age of dinosaurs in the American Southwest. New Mexico Museum of Natural History and Science, Albequerque, NM, pp. 65-71.

Lucas, S. G. 1991. Correlation of Triassic strata of the Colorado Plateau and southern High Plains, New Mexico. New Mexico Bureau of Mines and Mineral Resources Bulletin 137, pp. 47-56.

Lucas, S. G. 1993a. The Chinle Group: revised stratigraphy and biochronology of Upper Triassic nonmarine strata in the western United States. *In* Morales, M. (ed.), Aspects of Mesozoic Geology and Paleontology of the Colorado Plateau. Museum of Northern Arizona Bulletin 59, pp. 27-50.

Lucas, S. G. 1993b. The Upper Triassic Chinle group, western United States. *In* Lucas, S. G., and Morales, M. (eds.), The nonmarine Triassic. New Mexico Museum of Natural History and Science Bulletin 3, pp. G2-G12.

Lucas, S. G. 1998a. The aetosaur *Longosuchus* from the Triassic of Morocco and its biochronological significance. Compte Rendus de l'Académie des Science Paris, vol. 326, pp. 589-594.

Lucas, S. G., 1998b. Global Triassic tetrapod biostratigraphy and biochronology. Palaeogeography, Palaeoclimatology, Palaeoecology, vol. 143, pp. 347-384.

Lucas. S. G. 2000. Pathological aetosaur armor from the Upper Triassic of Germany. Stuttgarter Beiträge zur Naturkunde, Serie B (Geologie und Paläontologie), no. 281, 6 pp.

Lucas, S. G., and Hunt, A. P. 1992. Triassic stratigraphy and paleontology, Chama Basin and adjacent areas, north-central New Mexico. New Mexico Geological Society Guidebook, vol. 43, pp. 151-171.

Lucas, S. G., and Hunt, A. P. 1993. Tetrapod biochronology of the Chinle Group (Upper Triassic), western United States. *In* Lucas, S. G., and Morales, M. (eds.), The nonmarine Triassic. New Mexico Museum of Natural History and Science Bulletin 3, pp. 327-329.

Lucas, S. G., Anderson, O. J., and Hunt, A. P. 1994. Triassic stratigraphy and correlations, southern High Plains of New Mexico-Texas. New Mexico Bureau of Mines and Mineral Resources Bulletin 150, pp. 105-126.

May, B. A. 1988. Depositional environments, sedimentology, and stratigraphy of the Dockum Group (Triassic) in the Texas Panhandle. Master's thesis, Texas Tech University, Lubbock, TX, 180 pp.

Maynard Smith, J. and Savage, R. J. G. 1954. Some locomotory adaptations in mammals. Zoological Journal of the Linnean Society, vol. 43, pp. 603-622.

McGowan, C. 1991. Dinosaurs, Spitfires, and Sea Dragons. Harvard University Press, Cambridge, MA. 384 pp.

McGowan, J. H., Granata, G. E., and Seni, S. J. 1983. Depositional setting of the Triassic Dockum Group, Texas panhandle and eastern New Mexico. *In* Reynolds, M. W., and Dolly, E. D. (eds.), Mesozoic Paleogeography of West-Central United States. Rocky Mountain Section, Society of Economic Paleontologists and Mineralogists, Rocky Mountain Paleogeography Symposium 2, pp. 13-38.

Meers, M. B. 1999. Evolution of the crocodilian forelimb: anatomy, biomechanics, and functional morphology. Unpublished Ph.D dissertation, John Hopkins University, Baltimore, MD, 435 pp.

Meyer, H. von. 1865. Reptilien aus dem Stubensandstein des oberen Keupers, Dritte Folge [third paper]. Palaeontographica, vol. 14, no. 3, pp. 14-124.

O'Connor, P. 2002. Pulmonary pneumaticity in non-dinosaurian archosaurs with comments on *Erythrosuchus* and distal forelimb pneumaticity in pterosaurs. Journal of Vertebrate Paleontology, vol. 22, (supplement to no. 1), p. 93A.

Padian, K. 1997. Pseudosuchia. *In* Currie, P. J., and Padian, K. (eds.), Encyclopedia of Dinosaurs. Academic Press, San Diego, CA, pp. 608-611.

Parrish, J. M. 1986. Locomotor adaptations in the hindlimb and pelvis of the Thecodontia. Hunteria, vol. 1, no. 2, 35 pp.

Parrish, J. M. 1994. Cranial osteology of *Longosuchus meadei* and the phylogeny and distribution of the Aetosauria. Journal of Vertebrate Paleontology, vol. 14, no. 2, pp. 196-209.

Pettingil Jr., O. S. 1985. Ornithology in laboratory and field. Academic Press, San Diego, CA. 403 pp.

Riggs, N. R., Lehman, T. M., Gehrels, G. E., and Dickinson, W. R. 1996. Detrital zircon link between headwaters and terminus of the Upper Triassic Chinle-Dockum paleoriver system. Science, vol. 273, pp. 97-100.

Rogers, R. R., Swisher, C. C., III., Sereno, P. C., Monetta, A. M., Forster, C. A., and Martinez, R. N. 1993. The Ischigualasto tetrapod assemblage (Late Triassic, Argentina) and ^{40}Ar/^{39}Ar dating of dinosaur origins. Science, vol. 260, pp. 794-797.

Romer, A. S. 1923. Crocodilian pelvic muscles and their avian and reptilian homologues. Bulletin of the American Museum of Natural History, vol. 48, pp. 533-552.

Romer, A. S. 1956. Osteology of the Reptiles. University of Chicago Press, Chicago, IL. 772 pp.

Rowe, T. R. 1986. Homology and evolution of the deep dorsal thigh musculature in birds and other Reptilia. Journal of Morphology, vol. 189, pp. 327-346.

Sawin, H. J. 1947. The pseudosuchian reptile Typothorax meadei. Journal of Paleontology, vol. 21, no. 3, pp. 201-238.

Schnable, J. P. 1994. Sedimentology of the Upper Triassic Dockum Group in the Canadian River Valley of Texas and New Mexico. Master's thesis, Texas Tech University, Lubbock, TX, 423 pp.

Sereno, P. C. 1991. Basal archosaurs: phylogenetic relationships and functional implications. Journal of Vertebrate Paleontology (Memoir 2), vol. 11, supplement to no. 4, 53 pp.

Sereno, P. C., and Arcucci, A. B. 1990. The monophyly of crurotarsal archosaurs and the origin of bird and crocodile ankle joints. Neues Jahrbuch für Geologie und Palaontologie Abhandlungen, vol 180, pp. 21-52.

Small, B. J. 1985. The Triassic thecodontian reptile *Desmatosuchus*: osteology and relationships. Master's thesis, Texas Tech University, Lubbock, TX, 83 pp.

Small, 1989a. Post Quarry. *In* Lucas, S.G., and Hunt, A. P. (eds.), Dawn of the age of dinosaurs in the American southwest. New Mexico Museum of Natural History, Albequerque, NM, pp. 145-148.

Small, B. J. 1989b. Aetosaurs from the Upper Triassic Dockum Formation, Post Quarry, west Texas. *In* Lucas, S.G., and Hunt, A. P. (eds.), Dawn of the age of dinosaurs in the American southwest. New Mexico Museum of Natural History, Albequerque, NM, pp. 301-308.

Small, B. J. 2002. Cranial anatomy of *Desmatosuchus haplocerus* (Reptilia: Archosauria: Stagonolepididae). Zoological Journal of the Linnean Society, vol. 136, pp. 97-111.

Stewart, J. H., Poole, F. G., and Wilson, R. F. 1972. Stratigraphy and origin of the Chinle Formation and related Upper Triassic strata in the Colorado Plateau region. Geological Survey Professional Paper 690, 336 pp.

Strauss, R. E., Atanassov, M. N., and de Oliviera, J. A. In press. Evaluation of the principal-component and expectation-maximization methods for estimating data in morphometric studies. Journal of Vertebrate Paleontology.

Thulborn, R. A. 1980. The ankle joints of archosaurs. Alcheringa, vol. 4, no. 261-274.

Walker, A. D. 1961. Triassic reptiles from the Elgin area: *Stagonolepis*, *Dasygnathus* and their allies. Philosophical Transactions of the Royal Society of London B, vol. 244, no. 709, pp. 103-204.

Walker, A. D. 1972. New light on the origin of birds and crocodiles. Nature, vol. 237, pp. 257-263.

Wild, R. 1989. *Aëtosaurus* (Reptilia: Thecodontia) from the Upper Triassic (Norian) of Cene near Bergamo, Italy, with a revision of the genus. Revista del Museo Civico di Scienze Naturali "Enrico Caffi," vol. 14, pp. 1-24.

Witmer, L. M. 1997. Craniofacial air sinus systems. *In* Currie, P. J., and Padian, K. (eds.), Encyclopedia of Dinosaurs. Academic Press, San Diego, CA, pp. 151-159.

Zeigler, K. E. 2002. A taphonomic analysis of a fire-related Upper Triassic fossil assemblage. Masters Thesis, University of New Mexico, Albuquerque, NM, 124 pp, 4 maps

Zeigler, K. E., Lucas, S. G., and Heckert, A. B. 2001. Varaiation in the Late Triassic Canjilon Quarry (Upper Chinle Group, New Mexico) phytosaur skulls: sexual dimorphism in phytosaurs. Journal of Vertebrate Paleontology, vol. 21, supplement to no. 3, p. 117A.

APPENDIX

THE 1933 UCMP V2816 (CANJILON QUARRY) COLLECTION: REVISED INVENTORY AND QUARRY MAPS

This Appendix makes use of the field notes and field maps of Charles Camp and his assistants (Robert M. Ariss, Howard T. Anderson, George W. Barrington, and Sam Welles) during the 1933 excavation of Canjilon Quarry, as well as the revised inventory made in 2001 by Axel Hungerbühler and myself of the UCMP V2816 collection.

The grid squares are examined individually. The first part of each section discusses the field record of the excavation for each square, tying this information in as much as possible to both the field maps (when available) and the collection inventory. This discussion is organized according to the different levels in which material was found (as can best be determined), starting with the upper conglomerate (referred to here following Camp as "layer 1"), followed by the thick red mudstone ("layer 2") which contained the most productive bone bed at its base, and then material of uncertain distribution. Material recovered early in the excavation, before the second plowing, is sometimes presumed to be from the upper layer 1. When a specimen found in the inventory is mentioned in this discussion, it is underlined. However, Camp and his assistants also made note, both in the field notes and field maps, of field numbers that were *not* recognized in the inventory, and these are in quotation marks. When passages are quoted from the field notes, the citation following gives the initials of the note taker, and the page number in their field notes. Comments by the author of this thesis made *within* these quotes are in brackets.

The next part of each grid square discussion gives the 2001 inventory of the material found in that grid square. This is arranged first by the field number, and secondly by the specimen number. For specimens assigned a new specimen number, the previous specimen number is also recorded. Field numbers from the field notes and maps not recognized in the inventory are included (they were left out in Table 2.1), with both the field number itself, and the field identification of the element both in quotation marks. It should be noted that the assignment of the material is fairly conservative, but that most or all of the phytosaur material is probably assignable to *Pseudopalatus buceros* or *P. pristinus*, and material which cannot be assigned with certainty (indicated by a question mark) probably belongs to either these two taxa or *Typothorax coccinarum*. Due to an oversight on the part of the author, much material in the UCMP collections probably identifiable as phytosaurian is listed as unidentified here.

The word "unspecified" in parentheses following a field number indicates that no more specific field number was given, so that the element can only be placed somewhere within that grid square. A field number followed by a question mark indicates that the number may be in error; many are difficult to read off the bones. Material figured in Long and Murry (1995) is identified here below the entry, as are any other notes of interest about the specimen. The final section, "homeless specimens", refers to specimens for which no field number (and sometimes no specimen number) was found. Much of this material may belong to the field numbers mentioned in the field notes but not found in the inventory, or have been recovered during Camp's previous visits to the quarry in 1928 and 1930.

Quarry maps for many of the grid squares are also given. Most of these are redrawn directly from the original field maps, although features in the "brown paper map" not noted on the field maps are included. Field numbers in quotation marks represent specimens not found in the inventory. Generally, only the field numbers are given on the maps, and the reader may refer to the specimen tables to identify the material.

70/A

Robert Ariss and Natasha Smith worked grid square 70/A from 5/24/33 until 5/26/33, probably in the upper conglomeratic layer 1. The square was extremely barren. Ariss, presumably working the northern half of the square, found "a few scraps and two vertebrae" (RMA, 5/25/33), possibly 34229 70/A12 and 122395 70/A12, (since both have the same field number). Camp dug down below upper layer 1 without success. Smith came up with "a bit more" (RMA, 5/25/33) in the southern half of the square. On

7/24/33, after the second plowing, Barrington found a "stubby" femur (CLC, 7/24/33) in lower mudstone level 2 at the north end of the square. Field numbers in the notes identified none of the 70/A material, and no elements at all are drawn in the grid square on the brown paper map. Oddly, no mention is made in the field notes of the *Pseudopalatus* mandible 34245 70/A25, which presumably came from this square.

Table A.1. 1933 UCMP V2816 (Canjillon Quarry) material from grid square 70/A

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
70/A12	34229	34229	Atlas fragment	?
70/A12	122395	34229	Anterior caudal vertebra	?
70/A25	34245		Mandible (complete); in oversize cabinets	*Pseudopalatus pristinus*
70/A26a (?)	34258		Rib fragment; field number almost illegible and probably wrong	?
70/A (unspecified)	34229		Neural spine	?
70/A (unspecified)	34238		Radius	?
70/A (unspecified)	119375	34230	Coracoid articular end (left)	?
70/A (unspecified)	122207	34581	Clavicle fragment	?
70/A (unspecified)	122264	34229	Vertebral centrum	?

70/B

Charles Camp worked grid square 70/B (Fig. A.1) from 5/24/33 to 5/26/33, probably upper layer 1. Camp found a partial basioccipital of "a small reptile resembling *Episcoposaurus*" which he suggested might be referable to *Typothorax*; unfortunately, this piece was not recognized in the inventory. He also found the distal end of a humerus (which he suggested was the other half of a proximal end located the same day by Robert Ariss in 70/E), and various scrap; "small broken fragments of plate and small scutes, along with rib fragments, teeth, a few vertebrae etc…" (CLC, 5/24/33). Camp did not make a field map for his collection.

George Barrington worked the main bone bed at the bottom of layer 2 after the second plowing, from 7/13/33 to 7/15/33. The bone bed was about 27 inches below the upper (CLC, 7/8/33) and the bone was heavily coated with concretion, "apparently of a ferrous nature" (GWB, 7/13/33), which often made field identification of the bones

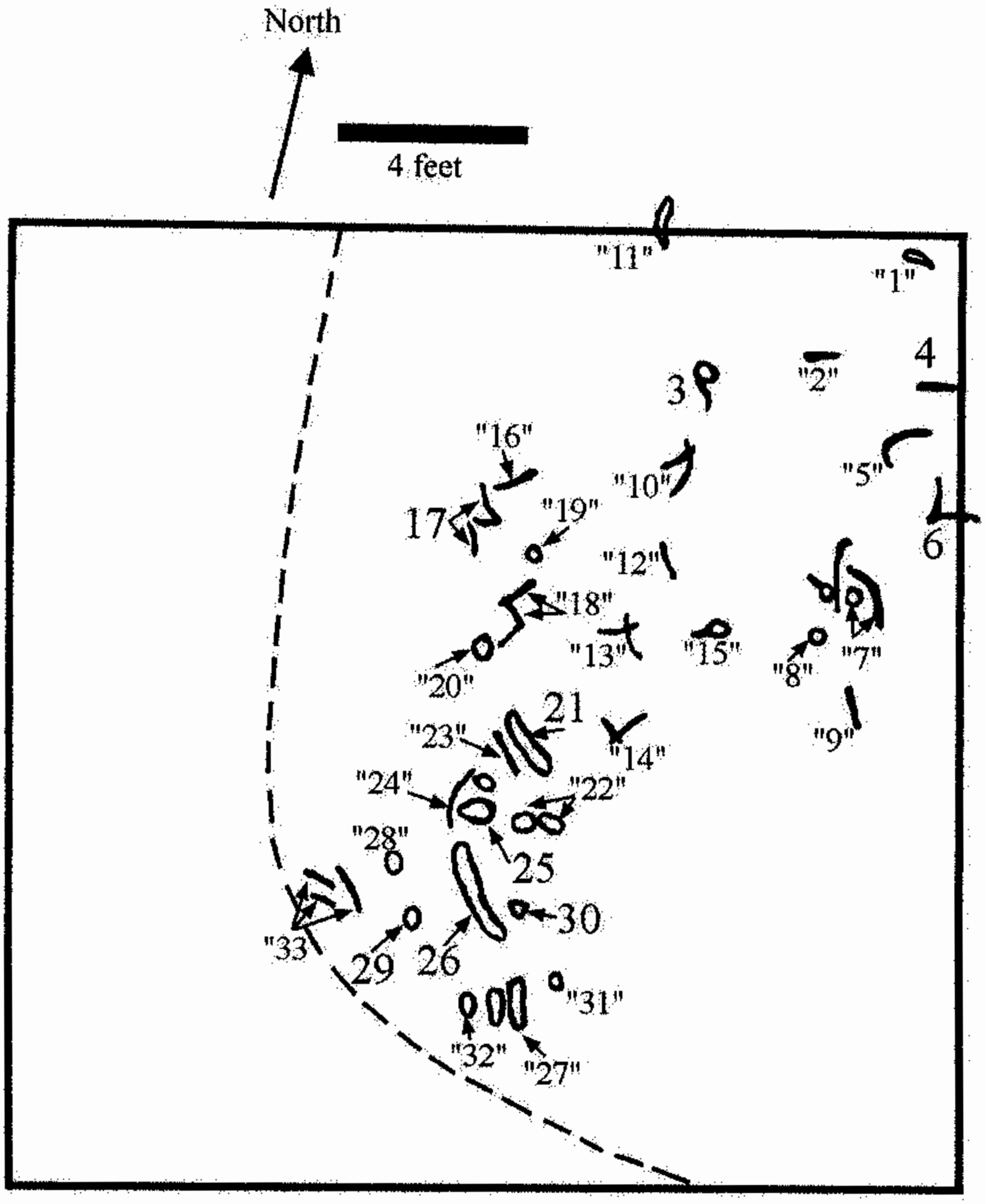


Figure A.1 Canjilon Quarry 1933 excavation grid square 70/B difficult. Barrington made a field map for the layer 2, which was the basis for the brown paper map. 70/B lower layer 2 material seems to have been completely disarticulated. Nearly all the material Barrington collected apparently consisted of ribs (though oddly, only one rib, 34249 70/B6, was recognized in the inventory), though he also found vertebrae. Several are drawn more clearly on the "brown paper map" then they appear on Barrington's field map, but the only two vertebrae noted in the inventory are both "unspecified". Barrington also found "possibly an ischium" (possibly 119334, a left ischium figured by Long and Murry, 1995, fig. 34D-E), and the "one ramus of the lower jaw" (GWB, 7/13/33). The latter is almost certainly 32228 70/B26, a small left mandible referable to *Pseudopalatus pristinus*.

Camp recorded that Barrington collected a total of thirty-three field numbers, which is consistent with his map. No information is given on these numbers in the notes other then to say they were "mostly ribs".

Table A.2. 1933 UCMP V2816 (Canjillon Quarry) material from grid square 70/B

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
70/B3	34227		Scute	Phytosaur
70/B3	122085	34236	Tibia (small, right)	Phytosaur?
70/B4	34238		Phalanx	?
70/B6	34249		Rib	?
70/B17	122661	34236	Tibia (left)	Phytosaur?
70/B21	122208	34230	Interclavicle	?
70/B25	119334	34236	Ischium (left); Long and Murry, 1995, fig. 34D-E	Phytosaur
70/B26	34228		Mandible (left ramus, juvenile?); label misidentifies as 34227	*Pseudopalatus pristinus*
70/B26	122213	34230	Scapula (?) blade fragment; label misidentifies as interclavicle	?
70/B29	122250	34229	Dorsal (?) vertebra neural spine	?
70/B30	34227		Scutes (three)	Phytosaur
70/B (unspecified)	34227		Scute (small)	Phytosaur
70/B (unspecified)	34230		Scapula fragment	?
70/B (unspecified)	34238		Metapodial	Phytosaur
70/B (unspecified)	121946	34232	Humerus (small, right)	?

Table A.2. Continued

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
70/B (unspecified)	122297	34229	Vertebra centrum	?
70/B (unspecified)	122381	34229	Caudal vertebra centrum	?

70/C

Grid square 70/C (Fig. A.2) was not worked on until August. Robert Ariss worked the eastern part of the square from about 7/15/33 until 7/26/33, and George Barrington worked mostly the western side from 7/17/33 until 7/26/33; both drew field maps. The grid was divided into twenty-five smaller squares four feet on a side, numbered from 21 to 45. Ariss (7/22/33) states that numbering in each row increased to the south, with the numbering starting at the northwest corner (21), and finished on the southeast corner (45). This is consistent with Ariss' map, but Barrington's grid is upside down and backwards of the actual layout. It is assumed that Barrington's bones are in the drawn in their correct relative positions with only the grid numbering in error, which was also the assumption apparently made for the "brown paper map". Field numbers 70/C1 through 70/C17, mostly found by Barrington on the western side of 70/C, appear to all be numbered independently of the grid, as were Ariss's 70/C18 through 70/C20. However, the rest of Ariss's field numbers mostly identify the smaller grid squares the elements came from.

Robert Ariss noted that the upper layer 1 conglomerate here was green in color, with bone "abundant but fragmentary, very hard to remove intact" (RMA 7/1/33). Work began after the second plowing, in which apparently layer 1 of 70/C was left intact (presumably because it had not yet been worked), as Ariss notes that he began in the "upper gravel layer". There he found "a wealth of small limb bones, mostly fragmentary" (RMA 7/17/33, erroneously dated the 16th), before proceeding to the lower layer. Ariss later found "the quadrate bone of a large phytosaur…just grazed by the last scraper on the last cut" (RMA 7/18/33) toward the west side of the square, so this was also likely found in upper layer 1.

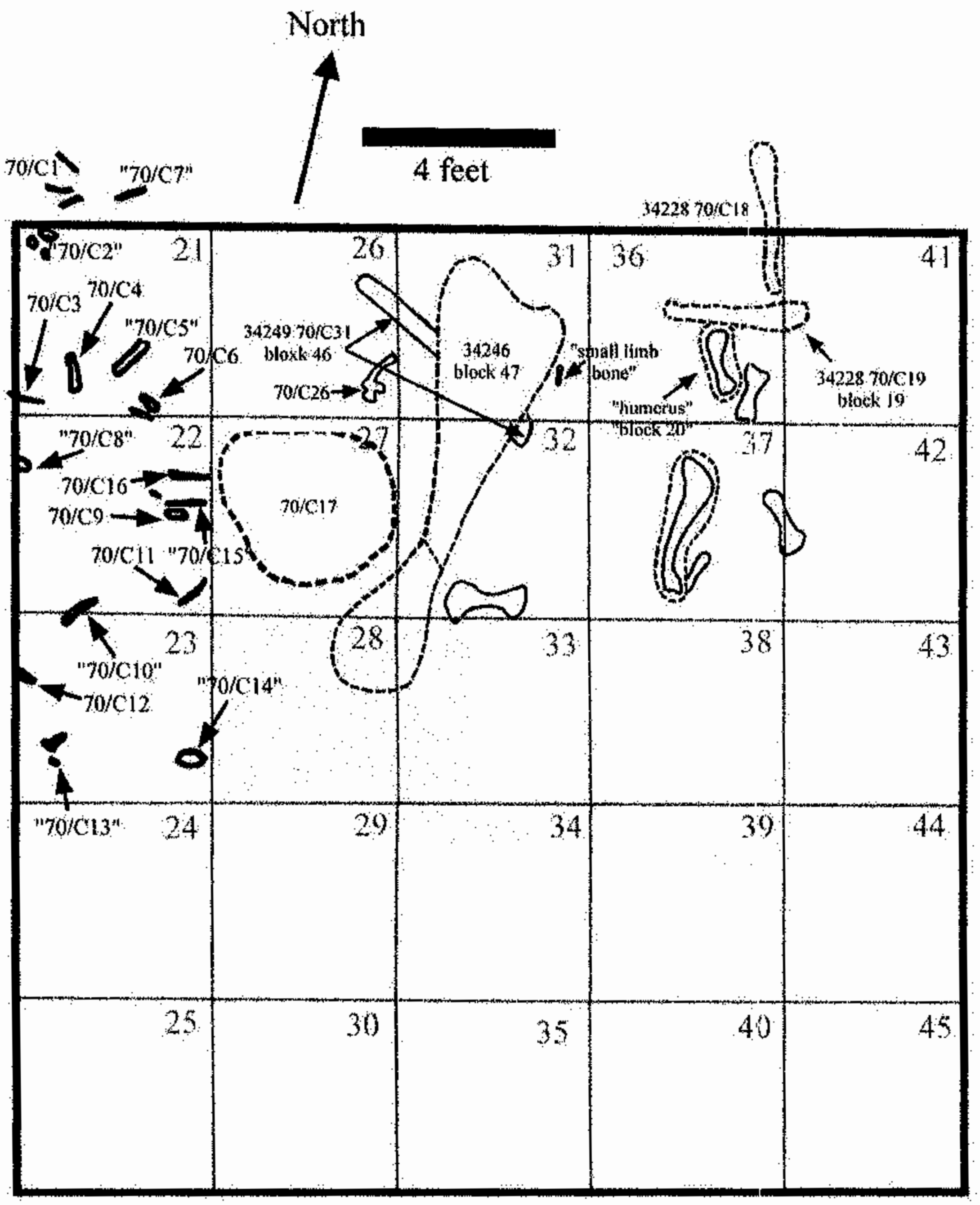


Figure A.2 Canjilon Quarry 1933 excavation grid square 70/C

All other material recorded and mapped by Ariss in the *east* side apparently came from lower layer 2. The first bones recovered by Ariss were probably those shown on his field map in grid squares 36 and 37; "a tibia [probably 122079 70/C37, a large phytosaur tibia], then a fibula, a femur, [both of these bones in grid 37 were not recognized in the inventory] and then to the north of these another tibia" (RMA 7/17/33). This last was probably 122660 70/C36; though the proximal end of a right tibia 122091 70/C36, was also found in this square. Ariss notes that these bones were "in fine preservation, though in some instances slightly covered with nodule." Next to these he found the end of a lower jaw, probably 34228 70/C18 (it is identified on the field map as "Block #18"), a partial left *Pseudopalatus* mandible. The right mandible, 34228 70/C19 (identified on the field map as "Block #19") lay immediately adjacent and perpendicular to it. These probably belong to the *P. pristinus* skull 34249 70/C31, just a few feet away to the east. A *Typothorax* lateral caudal scute (34227 70/C18) may have been found nearby, perhaps in the phytosaur lower jaw block with the same field number.

Ariss later found two phytosaur skulls just a few feet to the east; one of these was 34246 (removed in block 47; the specimen number is actually given in Ariss's notes), the largest *Pseudopalatus buceros* skull known from the quarry, which was found lying palate side up "but tilted a bit obliquely to the horizontal". Its complete lower jaws, rami attached (also 34246 C/31, removed in block 48) slightly displaced "alongside and in front of the rostrum" (RMA 7/18/33). Ariss noted that the quadrates of this skull were coated with concretion, "Then [underneath the quadrates?] comes a bit of red clay interspersed with a layer of green gravel" (RMA 7/19/33), apparently at the base of lower layer 2. Underneath 34246 was a smaller but still large *Pseudopalatus pristinus* skull, 34249 70/C31, also lying palate up. These skulls were blocked and removed by Ariss with the assistance of Sam Welles, Barrington, Anderson, and Smith. The "very large humerus" found by Ariss (RMA 7/19/33) adjacent to the rostrum of 34246 was not recognized in the 2001 inventory.

Barrington's notes for the west side of the grid square are unfortunately not very thorough, and more information can be derived from his map then his notes. It is not even clear from which layer his material was recovered. He mostly notes the scarcity of material, not giving field numbers or even identifying what he found; all information comes from comparing his field map with the inventory field numbers. One important exception is a block, 70/C17 (the material was removed and split into several specimen numbers), which contained quite a bit of material, apparently a jumble of *Typothorax* and phytosaur.

Several other items in the inventory, 34228 70/C29 (a possible skull fragment), 34238 70/C34 (a metapodial), 122391 70/C34 (a dorsal vertebra centrum), 122367 70/C35 (a mid-caudal vertebra), 122452 70/C39 (a caudal vertebra), and 34238 70/C42 (a metapodial or fibula) were not mentioned by Ariss or plotted on the map, but presumably found in the grid squares bearing those field numbers, possibly also in lower mudstone layer 2. Several specimens from the inventory bear field numbers read as 70/C46, 70/C47, 70/C66, and 70/C87; these are complete mysteries, falling well outside both Ariss's and Barrington's numbering.

Table A.3. 1933 UCMP V2816 (Canjillon Quarry) material from grid square 70/C

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
70/C1	34230		Scapula fragment	?
70/C1	121959	34232	Humerus (left)	Phytosaur?
70/C1	122096	34236	Tibia (left)	Phytosaur?
70/C1	122103		Tibia (distal end, left)	?
70/C1	122673		Femur (left, good condition); Long and Murry, 1995, fig. 110D-G	*Typothorax coccinarum*
70/C3	34238	34236	Phalanx	?
70/C4	34238		Metapodial	?
70/C6	34239		Ribs (four) and a scute	Phytosaur
70/C9	122358	34229	Mid-caudal vertebral centrum, preserves base of neural arch	?
70/C11	34239		Rib	?
70/C11	34239		Rib	?
70/C11	121982	34234	Ulna (right, distal end)	?
70/C12	34238		Metapodial; shipped in box 8	?

Table A.3. Continued

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
70/C16	34227		Scute (large)	Phytosaur
70/C16	34239		Ribs (two)	?
70/C16	34249		Rib	?
70/C17	34227		Scutes (five, one particularly large)	Phytosaur
70/C17	34227		Dorsal paramedian and lateral scute fragments	*Typothorax coccinarum*
70/C17	34229		Neural spine (top)	?
70/C17	34238		Metapodial (small)	?
70/C17	34239		Ribs (five)	?
70/C17	34249		Ribs (five)	?
70/C17	34249		Rib head	?
70/C17	122095	34236	Tibia (left, small)	?
70/C17	122259		Dorsal vertebra centrum, unfused neural arches and high-oval articular faces	?
70/C17	122371	34229	Posterior caudal vertebrae (two), one lacks neural spine	?
70/C17	122373	34229	Posterior caudal vertebra (small), lacks neural spine	?
70/C18	34227		Scute (anterior caudal lateral)	*Typothorax coccinarum*
70/C18	34228		Mandible (left) missing articular section, probably goes with 34228 70/C19 and 34249 70/C31; in oversize cabinets	*Pseudopalatus pristinus?*
70/C19	34228		Mandible (right); mostly complete, missing articular section, probably goes with 34228 70/C18 and 34249 70/C31; oversize cabinets	*Pseudopalatus pristinus?*
70/C26	34238		Metapodial	Phytosaur
70/C26	34239		Rib	?
70/C29	34228		Skull (?) fragment kept with 34228 70/G	?
70/C31	34229		Thoracic vertebra transverse process	Phytosaur?
70/C31	34246		Mandible (complete, huge), probably goes with 34246 skull; oversize cabinets	*Pseudopalatus buceros?*
70/C31 (probably)	34246		Skull; the largest *P. buceros* skull in the quarry; no field number is recorded, but Ariss recorded the specimen number and its location; almost certainly goes with the 34246 70/C31 mandible; oversize cabinets	*Pseudopalatus buceros*
70/C31	34249		Skull (large, complete); in oversize cabinets	*Pseudopalatus pristinus*
70/C31	122453	34229	Caudal vertebra, missing neural arch, circular centrum	?
70/C32	122451	34229	Caudal vertebra, missing neural arch, centrum circular	?
70/C34	34238		Metapodial (right, possibly the fourth)	?
70/C34	122391	34229	Dorsal vertebra centrum	?

Table A.3. Continued

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
70/C35	122367	34229	Mid-caudal vertebra (lacks neural spine)	?
70/C36	122091	34236	Tibia (right, proximal end)	Phytosaur?
70/C36	122660	34236	Tibia (large, right); Long and Murry, 1995, fig. 52.	Phytosaur?
70/C37-1	122079	34236	Tibia (large, left), shipped in box 20.	Phytosaur
70/C39	122452		Caudal vertebra with round centrum, missing most of neural arch	?
70/C42	34238		Metapodial (?) or fibula (?) (weathered)	?
70/C46 (?)	34236		Tibia (right)	Phytosaur
70/C46 (?)	34239		Rib	?
70/C47 (?)	34227		Scute; possibly a lateral scute, looks superficially like *Typothorax*	Phytosaur?
70/C47 (?)	119338	34230	Pubis (right)	?
70/C66 (?)	?		Rib head (?)	?
70/C87 (?)	122444	34229	Caudal vertebra (round centrum)	?
70/C (unspecified)	34228		Skull (?) fragments (three)	?
70/C (unspecified)	34229		Neural arch base	?
70/C (unspecified)	34231		Skull fragment	?
70/C (unspecified)	34238		Limb bone fragment	?
70/C (unspecified)	121979	34234	Ulna proximal end (right)	?
70/C (unspecified)	122257	34229	Dorsal vertebra centrum, unfused neural arch	?
70/C (unspecified)	122363	34229	Mid-caudal vertebra (small, complete)	?
70/C (unspecified)	122439		Caudal vertebra, round centrum, rugose neural arch suture	?
70/C (unspecified)	122677		Femur (right, badly mangled), probably the mate of 122673 70/C1	*Typothorax coccinarum*
70/C (unspecified)	?		Scutes	Phytosaur

70/D

Very little is known of what came out of grid square 70/D. Most material recorded was found during by Robert Ariss during prospecting on 6/19/33 and 6/20/33 before the second plowing, and during and after plowing on 7/12/33 and 7/15/33. The inventory yielded almost nothing.

The upper conglomerate layer 1 was is green, and Ariss found there "several rib fragments, two good toe bones, a vertebra, and a tooth" (RMA 6/19/33). Of these, only the ribs may have been found in the 2001 inventory. Later, during plowing, Ariss uncovered "a lot of bone…mostly scrap and a broken segment of phytosaur upper and lower jaws in 70/D" (RMA 7/12/33) in the upper layer, probably representing the northward pointing partial phytosaur skull seen in the southeast corner of the grid square on the "brown paper map" (Fig. 2.2). These were not recognized in the 2001 inventory, and are probably somewhere in the homeless specimens. The bone bed at the bottom of layer 2 lay about 1 ½ feet below upper layer 1. Ariss notes only that there was "a good showing on bone in the prospect hole" (RMA 6/20/33).

Only one rib 34239 70/D70, has a specific field number. No field map is known for the grid square, and the source of the information for the "brown paper map" drawing is unknown. In addition to the phytosaur jaws in the southeast, the "brown paper map" also shows a sparse concentration of bones in the northwest corner, and a trail of bones to the northeast east continuous with that of the "partial skeleton" of 70/G1.

Table A.4. 1933 UCMP V2816 (Canjillon Quarry) material from grid square 70/D

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
70/D70	34239		Rib	?
70/D (unspecified)	34228		Basioccipital (small)	Phytosaur?
70/D (unspecified)	34229		Neural spine fragment	?
70/D (unspecified)	34239		Rib	?
70/D (unspecified)	34249		Gastral? rib (large)	?
70/D (unspecified)	34249		Rib fragment	?
70/D (unspecified)	122204	34230	Clavicle fragment	?

70/E

Grid square 70/E (Fig. A.3) is poorly documented. Even though twenty-five field numbers were recorded during the excavation, these are not recognized for most of the specimens from 70/E in the 2001 inventory, and most of the elements that *were* recorded in the inventory for 70/E are unspecified. Additionally, many of the elements given field numbers conflict with the actual elements found under those field numbers in the inventory. There are no detailed field maps drawn, and the "brown paper map" is not very helpful except for the phytosaur skull. 70/E appears to have not been plotted with much of the material.

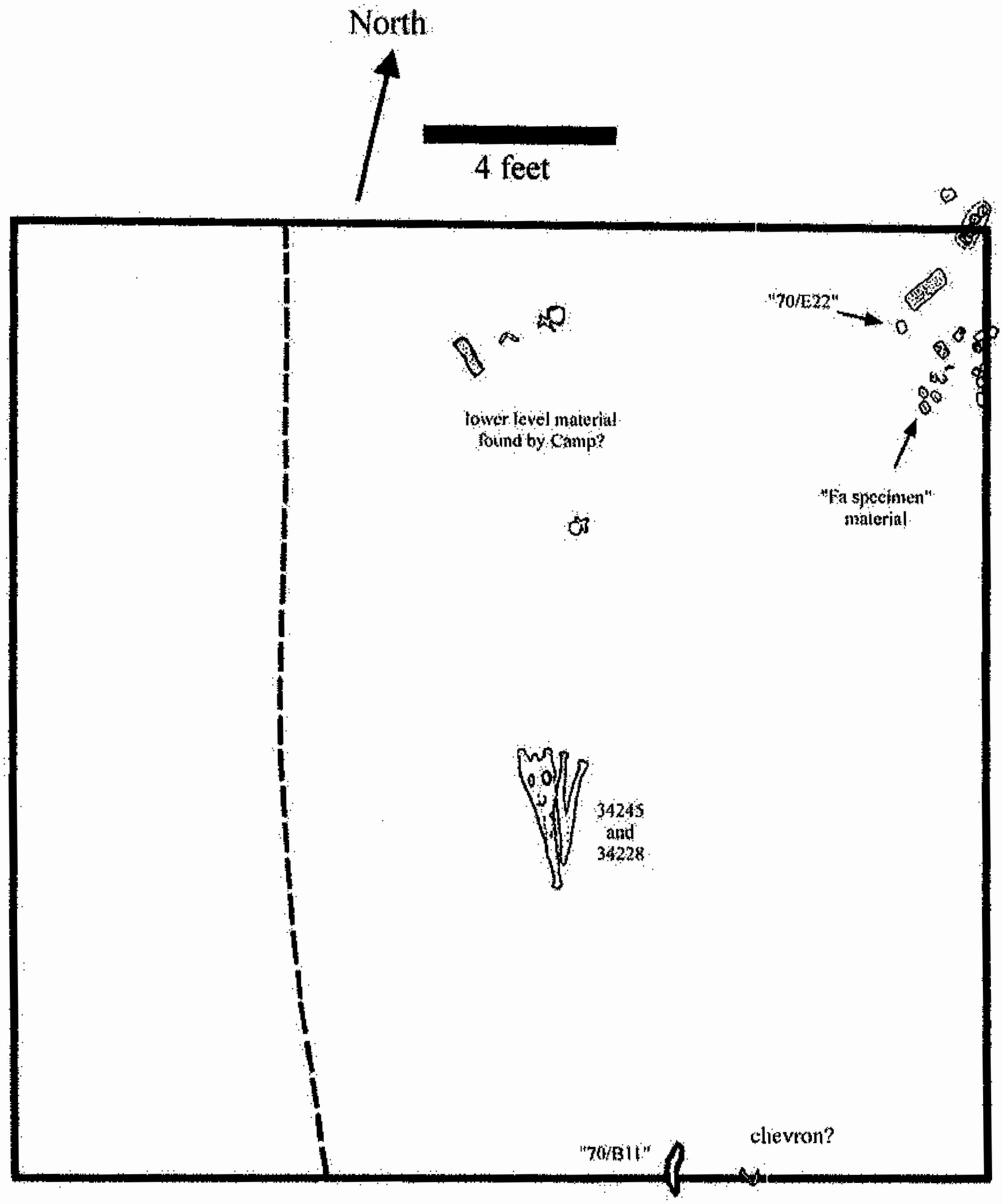


Figure A.3 Canjilon Quarry 1933 excavation grid square 70/E

Upper conglomeratic layer 1 of grid square 70/E is described as bluish or grayish in color, and was worked by Howard Anderson from 5/24/33 to 6/6/33. Anderson apparently began work near the southern edge of the square, as one of the first bones he found was the proximal humerus "70/E5" (not found in the inventory, thought it may be 34240), that Camp suggested might belong to the distal humerus he recovered in 70/B. Presumably in this same area, Anderson also found "several small fragments of bone and skin plates…one chevron [two chevrons are identified in the inventory without field numbers, both 34229]…and several fragmentary teeth" (HTA 5/24/33). Anderson later found "two foot bones and several fragments as head of rib" (HTA 5/25/33). One of these elements (perhaps the chevron) may be represented by the "U"-shaped element drawn on the south edge of the grid in the brown paper map. In upper layer 1 of the northern part of 70/E, adjacent to 70/H, Anderson found a "phytosaur-like foot" (RMA 5/26/33), which he took as a plaster block. He mentions the field numbers "70/E1" and "70/E2" for "toe bones" and "foot bones" respectively in his inventory of both material collected in 70/E; it is not clear if one or both of these refer to the aforementioned block. There are two more or less articulated foot blocks in the inventory (158674 under homeless specimens), which may be the same specimen.

The positions of the following elements in the grid square is not certain, but many are specifically referred to upper layer 2, and most or all of them were probably derived from it. Anderson found several scutes, possibly phytosaur scutes found in the inventory (all 34227). Anderson also found a several vertebrae. One was described as "very badly decomposed" (HTA 5/29/33), another as "small" ("70/E21" HTA 6/5/33), another as a thoracic, and one as "*Typothorax* (?)-like" ("70/E20"; HTA 6/6/33). Anderson identified two gastralia and a cervical rib, neither with a field number. A "head of a scapula" ("70/E3"; HTA 5/30/33) is possibly 119363. Anderson found "a pelvis about five feet from the scapula" (70/E10; HTA 6/1/33), which was taken out as two packages, one paper wrapped and one plastered. A left phytosaur illium 199325 70/E10 was found in the inventory, and a right ischium (119332) may also belong to this pelvis. Anderson later found, apparently not closely associated, "fragments of a pubis or pubis-like bone of a phytosaur" ("70/E19"; HTA 6/5/33), possibly 34230. The field number 70/E18, which Anderson assigned to a calcaneum, belongs to a rib in the inventory. A phalanx was found "in immediate proximity" to the scapula head ("70/E3"; HTA 5/30/33), and another toe bone was given the number 70/E16. The inventory designates the latter field number as a calcaneum, 122672 70/E16. Three "ends of limb bones" were designated "70/E13", "70/E14", and "70/E15", none found in the inventory.

Anderson worked lower mudstone layer 2, which he described as the "brown shale", on 6/6/33 and 6/7/33. A phytosaur tibia was found about six inches below the upper layer. He assigned the field number "70/E17", but in the inventory, this field number is applied to an almost complete *Typothorax* dorsal paramedian scute 34227 70/E17; there is only one tibia in the inventory, a left (122099). In the northeast corner of the grid, about 18 inches below upper layer 1 (in what he called "a deep level"), Anderson found " a wafer plate" ("70/E22"), "one very large plate somewhat narrower then the typical *Typothorax* plate with a tit at the apex of its curvature [probably an anterior caudal dorsal paramedian]" (HTA 6/7/33), and a "*Coelophysis* vertebra" ("70/E23"; all from HTA 6/7/33). This material probably belongs to the "Fa" *Typothorax* specimen, and the probable proximal caudal paramedian is likely the one shown on the northeast corner of the map. Camp also worked the lower layer 2 bone bed after the second plowing from 7/13/33 to 7/19/33. He located "two *Typothorax* plates, vertebrae, and gastralia" (HTA 7/13/33), which may refer to the the scute, U-shaped bone, and two vertebrae shown close north of the skull on the brown paper map. The skull itself, 34245 70/E25 belongs to *Pseudopalatus pristinus*. It was found palate side up with the snout facing south, resting on the basal concretion at the bottom of layer 2, but encased in the reddish mudstone. The lower jaws (at least partly represented by 34228 70/E25) lay underneath, "buccal side up along right side of shale and pointing in same direction…with tips of muzzle inserted beneath the anterior rostrum of the skull" (CLC 7/15/33). Camp took the skull and jaws out in two blocks, "70/E24" and 70/E25. He noted only that the latter "contains tips of rostrum of lower and upper jaws". "70/E24" is not noted in the inventory, and its contents may have been erroneously labeled 70/E25.

Table A.5. 1933 UCMP V2816 (Canjillon Quarry) material from grid square 70/E

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
"70/E1"	?	33-16 (field #)	"Toe bones"; may be referable to a plastered block of toe bones recovered by Anderson (158674)	?
"70/E2"	?	33-17 (field #)	"Foot bones"; may be referable to a plastered block of toe bones removed by Anderson (158674)	?
"70/E3"	?		"Scapula and phalanx"	Phytosaur?
=70/E (unspecified)?	119363	34230	Scapula dorsal end (left)	Phytosaur?
"70/E4"	?		"Three phalanges"	?
"70/E5"	?		"Head of humerus"	Phytosaur?
=70/E (unspecified)?	34240		Humerus (proximal end); the distal end of this humerus may have been recovered in square 70/B by Camp	Phytosaur
"70/E6"	?		"Pubis"	Phytosaur?
70/E7	34238		Phalanx; several toe bones were originally collected under this field number	?
"70/E8"	?		"Caudal vertebra"	?
"70/E9"	?		"Caudal vertebra"	?
70/E10	119325	34231	Illium (left); this was part of a pelvis taken in two packages, sent in "Box 2"	?
70/E11	34238		Phalanx; several other toe bones were also collected under this field number	Phytosaur
70/E11	122354	34229	Caudal vertebra with neural arch	?
70/E12	34238		Metapodial	?
70/E12	121995	34236	Radius (distal end)	?
"70/E13"	?		"End of limb bone"	?
"70/E14"	?		"End of limb bone"	?
"70/E15"	?		"End of limb bone"	?
70/E16	122672	34238	Calcaneum; Anderson gave this field number to "toe bones"	?
70/E17	34227		Dorsal paramedian scute fragment, almost complete; Camp gave a "phytosaur tibia" this field number, possibly…	*Typothorax coccinarum*
=70/E (unspecified)	122099	34236	Tibia (left)	Phytosaur
70/E18	34239		Rib; Anderson listed this field number for a "calcaneus"	?
"70/E19"	?		"Pubis"	Phytosaur?
"70/E20"	?		"Vertebra"	"*Typothorax*?"
"70/E21"	?		"Vertebra, very small fragments"	?
"70/E22"	?		"Wafer plate fragments"	*Typothorax coccinarum*?

Table A.5. Continued

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
"70/E23"	?		"Vertebra"	"*Coelophysis*"
"70/E24"	?		Part of skull and jaws	*Pseudopalatus pristinus*?
70/E25	34228		Mandible; large, lacks free ramus, in oversize cabinets	*Pseudopalatus pristinus*
70/E25	34228		Mandible (articular end)	Phytosaur
70/E25	34245		Skull (large, complete)	*Pseudopalatus pristinus*
70/E (unspecified)	34227		Scutes (five)	Phytosaur
70/E (unspecified)	34227		Dorsal paramedian scute	*Typothorax coccinarum*
70/E (unspecified)	34229		Chevrons (two)	?
70/E (unspecified)	34230		Appendicular fragment (pelvis?)	?
70/E (unspecified)	34233		Radius (proximal end)	?
70/E (unspecified)	34238		Phalanx	?
70/E (unspecified)	34238		Metapodial	?
70/E (unspecified)	34240		Fibula	*Typothorax coccinarum*
70/E (unspecified)	34240		Rib head	?
70/E (unspecified)	34249		Rib	?
70/E (unspecified)	119332	34231	Ischium (right, small); may go with "70/E10" pelvis	?
70/E (unspecified)	121996	34233	Radius (distal end)	?
70/E (unspecified)	122222	34238	Calcaneum (left)	?
70/E (unspecified)	122223	34238	Calcaneum (left, moderate size)	?
70/E (unspecified)	122422	34229	Caudal vertebra centrum fragments	?
70/E (unspecified)	?		Limb bone fragment	?

70/F

Grid square 70/F (Fig. A.4) is one of the more productive and well documented squares, including one of the most important *Typothorax* concentrations in the quarry, mostly bearing the field number "Fa" (Fig. A.5). *Typothorax* material outside this concentration was mostly labeled "F", but some material labeled "F" probably came from the "Fa" concentration. Although more then half the material from this grid square recognized in the inventory is "unspecified", nearly all this "unspecified" material consists of vertebrae and ribs; most of the important material found in the 2001 inventory could be plotted.

Howard Anderson worked upper level 1 in the northwestern area of the square on 6/7/33, mostly in the process of getting down to the "Fa" *Typothorax* specimen in the

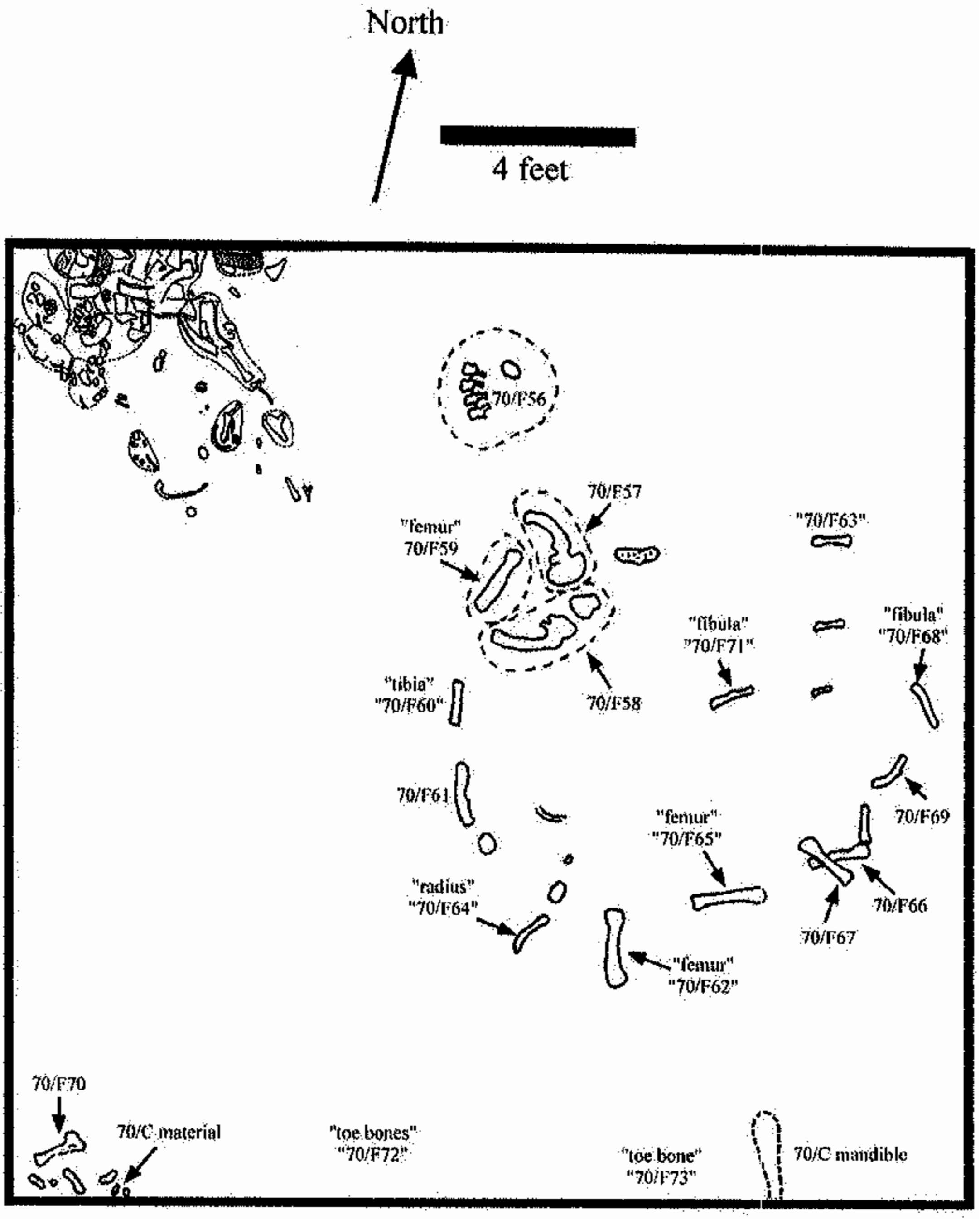


Figure A.4 Canjilon Quarry 1933 excavation grid square 70/F; the northwestern area is shown in detail in Fig. A.5.

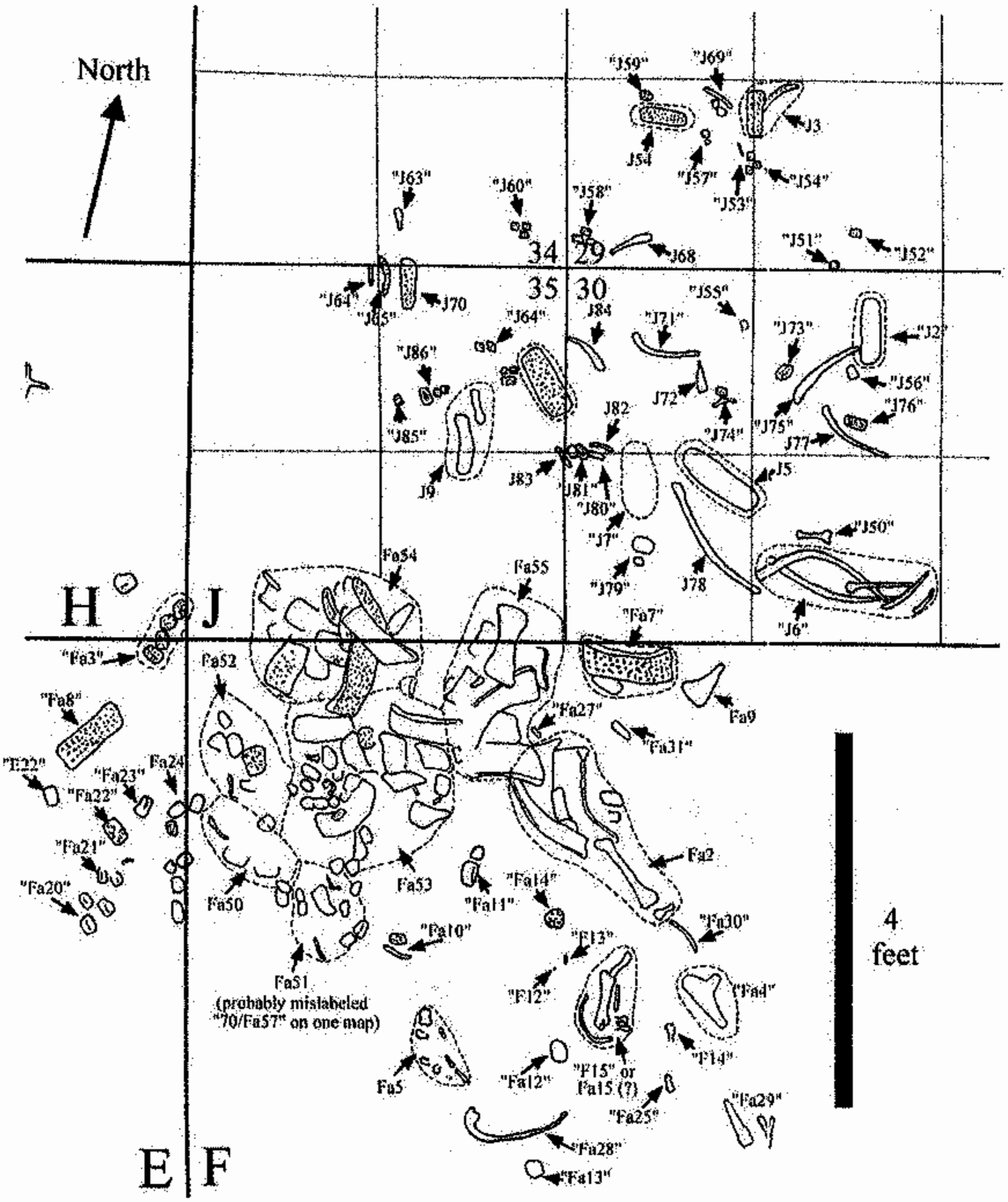


Figure A.5 Canjilon Quarry 1933 "Fa specimen" of *Typothorax coccinarum* lower level 2 bone bed. Conglomerate level 1 here was bluish. He collected three phalanges, “70/F1”, “70/F3”, and “70/F4”, and a vertebra he assigned to *Coelophysis*, “70/F2”, from the western half of the square. Also noted in Anderson’s catalogue is “70/F16, nodules containing end of limb bone” from layer 1. None of these specimens were recognized in the inventory, or marked on field map. While digging through the red mudstone to get to the bottom bone bed, Anderson found a left tibia (122097 70/F5) about ten inches below layer 1.

Anderson worked on the “Fa” *Typothorax* specimen at the bottom of the lower layer mudstone in the northwest corner from 6/9/33 until 7/8/33, working out from the scutes uncovered in 70/E. Camp (6/20/33) noted that the total concentration of the *Typothorax* bones, including what was in grid square 70/J, was about 300 square feet. The lower level bone bed was about 18 inches below layer 1. Anderson described a color change within the layer 2 mudstone. While most of the layer was reddish, at the main bone bed it turned “mottled with brown and blue” with a lot of “carbonaceous matter”. The “wafer plates [were]…so thickly embedded…that the corners overly. In some places, plates may be as many as three deep.” Some of the scutes had a raised “tit” indicating they were posterior dorsals or caudals; these he described as “intermediate between the [‘wafer plates’] and more typical *Typothorax* plate”. Camp (6/14/33) indicates that plates from the dorsal as well as caudal regions were being found, which was also noted in the 2001 inventory. Scutes were removed individually, as well as in blocks. Field numbers “70/Fa3” (a block of several plates), “70/Fa8-70/Fa18”, “70/Fa20-70/Fa24”, “70/Fa30-70/Fa31”, “70/Fa48 (removed from between blocks 70/Fa50 and 70/Fa51)-70/Fa49” apparently all belonged to individual scutes, but only two of these, 34227 70/Fa15 (consisting of scute fragments) and 34227 70/Fa24 (a small round scute with a ridge on it, probably not belonging to *Typothorax*), were recognized in the inventory. The scutes removed in the blocks, most of which seemed to have been adjacent, are better represented. Block 70/Fa2 includes four almost complete dorsal paramedians (all 34227). Blocks 70/Fa50-70/Fa55 were broken up from what Anderson apparently originally intended to take out as a single block, and material from all five was recognized. Block 70/Fa50 (containing posterior caudals under 34227) was removed "breaking a single wafer plate and clean break, loosing no pieces". Scutes from block 70/F51 are conspicuously absent in the inventory, although vertebra from that block were found. Other blocks of scutes, "70//Fa7" and "70/Fa57" (HTA 7/2/33) were not found in the inventory at all.

Vertebrae and ribs were also found in the "Fa" concentration. Anderson (6/19/33) found a caudal vertebrae (122384 70/Fa5); this field number suggests it was part of a block of foot bones. A "minute vertebra" ("70/F12") was apparently (HTA 6/19/33) found in a gravel lens about 4 inches across at the same level. A neural spine "70/Fa29" was found. Anderson (6/30/33) noted that block 70/Fa51 contained "certain small bones"; all recognized from the inventory were vertebrae. At least one un-numbered chevron was found in the concentration (HTA 6/28/33). Anderson found several ribs as well. One ("70/F9") found in the lower level 2 bone bed about 18 inches from the nearest *Typothorax* scute, and another ("70/F10") apparently adjacent or underneath (for the latter field number, the inventory gives two metapodials, 34238 70/F10). Another rib, "70/Fa28" was also found in this concentration. Other "Fa" axial material is listed in the inventory. However, most of the vertebrae and ribs removed from the lower level "Fa" concentration are probably in the "unspecified" material.

Quite a bit of appendicular material also came from the "Fa" concentration. A coracoid, "70/Fa6" was taken out in a block. A pubis was also found according to Anderson, but no further mention is given anywhere (a pubis fragment, 119340, and an ischium, 119347, are in the 70/F "unspecified material)". Several limb bones were recovered, the head of at least one actually was protruding from under the plates. A humerus and toe bones were removed in a block "70/Fa4". At least the phalanx may have been associated with one of the Fa2 limb bones. A tiny humerus ("70/F13") less then an inch long was found. A tiny tibia "70/F15" was found near block "70/Fa4". Several toes bones 70/Fa25-70/Fa27, were also not found in the inventory. The big scute blocks (70/Fa2 and 70/Fa50-70/Fa55) contained the best limb material in the quarry, mostly from the pelvis and hind limbs. Other material that may or may not have in the "Fa" bone concentration was catalogued by Anderson, including two phalanges ("70/F7" and "70/F8"), ribs, a "fish nodule '*Typothorax* coprolite'" ("70/F14").

Sam Welles began work with in 70/F on 7/13/33 at clearing out the rest of the square southeast of the "Fa" *Typothorax* concentration, and was joined by Anderson on 7/15/33. At least Anderson stayed in the square until 7/22/33. Anderson notes in his catalogue (7/8/33) that this material was in the main bone bed at the bottom of leayer 2, at the same level as the "Fa" skeleton. Most or all of this material seems to be phytosaurian. The field numbers for all this material bears the letter "F" instead of "Fa", starting with 70/F56. This was a block, containing six phytosaur cervical vertebrae, 34260 70/F56, still in articulation. This block apparently also contained cervical ribs (34260 70/Fa56) and a few phytosaur scutes (34227 70/Fa56). Just south of these were magnificent left and right phytosaur scapulocoracoids, apparently also taken out as blocks, 119364 70/F57 and 119355 70/F57. The coracoid for the latter was apparently separated (or broken off) and in the same block (119373 70/Fa58), as was a large tibia (122669 70/Fa58). Several limb bones noted in the field notes and map were located in the inventory.

Most of the other material noted in the field notes by Anderson and Welles was not recognized in the inventory, and much was not even assigned a field number. Both the position and layer of this material is uncertain, although it probably comes from layer 2. Both Anderson and Welles are rather superficial in their descriptions of the material and their location. These included neural spines, thoracic vertebrae (one of these may have been an un-numbered dorsal vertebrae with the field number 70/F59), caudal vertebrae, a cervical rib, gastralia, a small right scapulocoracoid (119366 70/F70, found on the south side of the square), and two right humeri "70/F61" (HTA 7/15/33; there is some confusion here; the inventory found a femur 122071 70/F61, and a humerus 121943 70/F66; Welle's map agrees better with the inventory, so Anderson's identification is probably wrong). Also, an ulna ("70/F64") tibia ("70/F60"), "two foot bones" ("70/F72", found on the south side of the square), "toe bones" (including "70/F73", also found on the south side of the square, and a metapodial 34238 70/F74). Again, much of the unrecognized field numbers may be with the "unspecified" material.

Table A.6. 1933 UCMP V2816 (Canjillon Quarry) material from grid square 70/F

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
"70/F1"			"Phalanx"	?
"70/F2"			"Vertebra"	"*Coelophysis*"
"70/F3"			"Phalanx"	?
"70/F4"			"Phalanx"	?
70/F4 B24	122296		Cervical vertebra centrum; the meaning of the odd field number is unclear; this specimen may have been found in 70/B	?
70/F5	122097	34236	Tibia (left); found in red mudstone directly above the "Fa" skeleton	?
"70/F7"			"Phalanx V"	?
"70/F8"			"Phalanx"	?
"70/F9"			"Rib"	?
"70/F10"			"Rib"	?
70/F10	34238		Metapodials (two)	?
"70/F11"			"Rib"	?
"70/F12"			"Caudal vertebra (minute)"	?
"70/F13"			"Humerus (minute)"	?
"70/F14"			"Fish nodule"; originally identified as a "*Typothorax* coprolite"	?
"70/F15"			"Tibia (minute)"	?
"70/F16"			"Ends of limb bones" (encased in nodule)	?
70/F47	34249		Rib (rather thin)	?
70/F53	34259		Scutes (dorsal paramedians and laterals) and toe bone in a large jacket Almost certainly mislabeled, should be "70/Fa53"	*Typothorax coccinarum*
70/F56	34227		Scutes (two, fairly large)	Phytosaur
70/F56	34260		Cervical ribs and other fragments	?
70/F56	34260		Cervical vertebrae (first six in articulation)	Phytosaur
70/F56	34260		Scutes (two; one is two scutes fused)	Phytosaur
70/F57	119364	34230	Scapulocoracoid (right); Long and Murry, 1995, fig. 48	Phytosaur
70/F58	119355	34230	Scapula (left)	Phytosaur
70/F58	119373	34230	Coracoid (left), parts of scapula (probably 119355) attached	Phytosaur
70/F58	122669	34237	Tibia (right, large)	Phytosaur?
70/F59	?		Anterior dorsal vertebra (good condition)	?

Table A.6. Continued

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
70/F59	34227		Anterior dorsal paramedian scute	*Typothorax coccinarum*
"70/F60"	?		"Tibia"	?
70/F61	122071	34235	Femur (right)	?
"70/F64"	?		"Ulna"	?
70/F66	121943	34232	Humerus (right)	Phytosaur
70/F67	121942		Humerus (right, huge)	Phytosaur
70/F69	122107		Fibula (left, large)	?
70/F70	119366	34230	Scapula (right, small)	Phytosaur
"70/F72"			"Two toe bones in a series"	?
"70/F73"			"Toe bone"	?
70/F74	34238		Metapodial	?
"70/Fa1": Originally a single block, broken up into blocks 70/Fa50-70/Fa55				
70/Fa2	34227		Scutes (four dorsal paramedians)	*Typothorax coccinarum*
70/Fa2	122676	34240	Femur (left)	*Typothorax coccinarum*
70/Fa2	122680		Tibia (middle section is missing and the ends are glued together)	*Typothorax coccinarum*
70/Fa2	122682	34240	Fibula	*Typothorax coccinarum*
"70/Fa3"			"Block, small skin plates"	*Typothorax coccinarum*?
"70/Fa4"			"Block, humerus and toe bones"	*Typothorax coccinarum?*
"70/Fa5"			"Block of foot bones"	*Typothorax coccinarum*?
70/Fa5	122384	34229	Caudal vertebra centrum	?
"70/Fa6"			"Block coracoid"	?
"70/Fa7"			"Block…large skin plate"	*Typothorax coccinarum*?
"70/Fa8"			"Plate with spine"	*Typothorax coccinarum?*
70/Fa9	34227		Caudal dorsal paramedian scute	*Typothorax coccinarum*
"70/Fa10"			"Wafer plates"	*Typothorax coccinarum?*
"70/Fa11"- "70/Fa14"			"Wafer plates"	*Typothorax coccinarum?*
70/Fa15	34227		Scute fragments	*Typothorax coccinarum*
"70/Fa16"-"70/Fa18", "70/Fa20", "70/Fa21"			"Wafer plates"	*Typothorax coccinarum*?
70/Fa24	34227		Small round osteoderm with a ridge	?
"70/Fa25"			"Phalanx"	?
"70/Fa26"			"End of phalanx"	?
"70/Fa27"			"Phalanx"	?
"70/Fa28"			"Rib"	?
"70/Fa29"			"Neural spine"	?
"70/Fa30", 70/Fa31"			"Skin plates"	*Typothorax coccinarum*?
70/Fa44	34238		Metapodial; 70/Fa44 consists of fragments found between blocks 70/Fa53 and 70/Fa55; this was the only found in the inventory	?
"70/Fa45"			"Fragments"; found between 70/Fa53 and 70/Fa54	?

Table A.6. Continued

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
"70/Fa46"			"Fragments"; found between blocks 70/Fa51, 70/Fa52, and 70/Fa53	?
"70/Fa47"			"Fragments"; found between 70/Fa52 and 70/Fa53	?
"70/Fa48"			"Fragments"; found between blocks 70/Fa50 and 70/Fa51	?
"70/Fa49"			"Skin plate"	*Typothorax coccinarum*?
70/Fa50	34227		Posterior dorsal paramedians and ventral scute.	*Typothorax coccinarum*
70/Fa50	158668	34227	Posterior caudal dorsal paramedian and pelvic and caudal lateral scutes	*Typothorax coccinarum*
70/Fa51	122251	34229	Vertebra centrum (small with round articular faces)	?
70/Fa51	122277	34229	Cervical vertebra centrum	*Typothorax coccinarum*
70/Fa51	122306		Sacral vertebra centrum (small)	*Typothorax coccinarum*
70/Fa52	34227		Scutes (posterior caudal dorsal paramedians)	*Typothorax coccinarum*
70/Fa52	158670	34227	Posterior lateral caudal and posterior ventral scutes	*Typothorax coccinarum*
70/Fa53	34227		Scutes (Dorsal paramedians, laterals, possible ventral and appendicular)	*Typothorax coccinarum*
70/Fa53	122228		Calcaneum	*Typothorax coccinarum*
70/Fa53	158675	34227	Appendicular and ventral scutes	*Typothorax coccinarum*
70/Fa53	?		Metapodial proximal end	?
70/Fa54	34227		Scutes (several dorsal paramedians and fragmentary laterals)	*Typothorax coccinarum*
70/Fa54	122683		Illium	*Typothorax coccinarum*
70/Fa55	34227		Scutes (dorsal paramedians)	*Typothorax coccinarum*
70/Fa88	?		Gastal rib (has an irregular groove); the field number is almost certainly an error; nothing collected was given a number that high	
70/F (unspecified)	34227		Scute (dorsal paramedian scute with boss) and rib fragments	*Typothorax coccinarum*
70/F (unspecified)	34229		Neural spines (top, three); at least one shipped in box 20	?
70/F (unspecified)	34229		Neural spines (base, three)	?
70/F (unspecified)	34229		Caudal neural spine (complete); shipped in box 20	?
70/F (unspecified)	34229		Neural arch (base)	?
70/F (unspecified)	34229		Neural spine	?
70/F (unspecified)	34238		Metapodial (four, and fragments)	?
70/F (unspecified)	34239		Rib (ten); at least two shipped in box 20	?
70/F (unspecified)	34239		Rib, expanded type (two)	?
70/F (unspecified)	34249		Rib, expanded type (three); at least one shipped in box 20	?

Table A.6. Continued

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
70/F (unspecified)	34249		Rib	?
70/F (unspecified)	34249		Rib heads (two)	?
70/F (unspecified)	35239		Rib, shipped in box 20	?
70/F (unspecified)	35239		Two cervical ribs	?
70/F (unspecified)	119340	34231	Pubis fragment (left)	?
70/F (unspecified)	119347	34231	Ischium (right)	?
70/F (unspecified)	119360	34230	Scapula (left, proximal end)	Phytosaur?
70/F (unspecified)	119372	34230	Coracoid (left)	Phytosaur
70/F (unspecified)	119376	34230	Coracoid (left)	Phytosaur
70/F (unspecified)	121969	34240	Ulna (right, tiny)	?
70/F (unspecified)	121976	34234	Ulna (left, proximal end)	?
70/F (unspecified)	121977	34234	Ulna (left, small proximal end)	?
70/F (unspecified)	122106	34237	Fibula (right)	?
70/F (unspecified)	122206	34581	Clavicle (left)	?
70/F (unspecified)	122234	34229	Cervical vertebra (no spine)	?
70/F (unspecified)	122238	34229	Cervical vertebra (good condition)	?
70/F (unspecified)	122240	34229	Cervical vertebrae (two, lack spines)	?
70/F (unspecified)	122244	34229	Complete cervical vertebra	?
70/F (unspecified)	122248	34229	Cervical vertebra, no spine	?
70/F (unspecified)	122255	34229	Cervical vertebra centrum	*Typothorax coccinarum*?
70/F (unspecified)	122260	34229	Complete dorsal vertebra	?
70/F (unspecified)	122278	34229	Cervical vertebra centrum	*Typothorax coccinarum*
70/F (unspecified)	122344	34229	Caudal vertebra centrum	?
70/F (unspecified)	122359	34229	Caudal vertebra centrum	?
70/F (unspecified)	122361	34229	Small caudal vertebra centrum	?
70/F (unspecified)	122382	34229	Caudal vertebra centrum	?
70/F (unspecified)	122386	34229	Caudal vertebra centrum	?
70/F (unspecified)	122389	34229	Caudal vertebra centrum	?
70/F (unspecified)	122416	34229	Dorsal vertebra centrum	?
70/F (unspecified)	122424	34229	Dorsal vertebra centrum	?
70/F (unspecified)	122437	34229	Vertebra centrum (circular articular faces; rugose unossified neural arch sutures)	?
70/F (unspecified)	122446	34227	Cervical? partial vertebra	?
70/F (unspecified)	122447	34229	Vertebra centrum (circular articular faces; rugose unossified neural arch sutures)	?
70/F (unspecified)	?		Fragments; mostly ribs, part of a radius, a possible sacral rib	?

70/G

The field data for grid square 70/G (Fig. A.6) is extremely poor, and the field notes are almost non-existent. This is unfortunate considering the square contains one of the important concentrations of *Typothorax* material. The most informative document is a single page, apparently written by Camp, describing where certain field numbers were located in the square. Combined with the bones drawn on the brown paper map, this can be used to approximate the location of some material in the square.

Ariss worked in 70/G from 7/6/33 to 7/8/33, apparently entirely in the upper layer and possibly in gravels in the upper part of red mudstone layer 2, before the second plowing. He notes (7/7/33) that "there is some good bone in the gravels, but it is next to impossible to get the bone clear of the matrix". He found "a section of jaw and a mass of adjoining bone which is blocked and labeled '70/G Lower jaw (?)". Ariss also worked in 70/U on 7/6/33, so it is likely that this first material came from the eastern part of the square. This is consistent with Camp's notes, which note that 70/G1 (presumed to be the first field number assigned) consists of "parts of skull about eight feet from the skeleton in 70/U. In southeast corner of G." There is no labeled 70/G1 phytosaur skull material, but quite a lot of it is probably in the "unspecified" material. <u>34228</u> especially (which consists of a great deal of phytosaur skull material probably belonging to *Pseudopalatus buceros*), likely represents Ariss's skull material.

Possibly in the same area, Ariss next removed "bone that was relatively free of matrix, including two large teeth [one of which may be phytosaur tooth <u>34228 70/G1</u>], a large limb bone [there is none labeled 70/G1, but there are several large phytosaur limbs in the "unspecified material"], a vertebra" (in the 2001 inventory there is a cervical vertebra centrum, <u>122432 70/G1</u> and the bases of two neural spines, both <u>34229 70/G1</u>; however, there are also quite a few vertebrae in the "unspecified" material). Ariss later (7/8/33) found more "good material" in what he called "the gravel lens", so it is unclear if he has been referring to the layer 1 conglomerate or gravel lenses in the layer 2 red mudstone. This latter "good material" consisted of "a complete vertebra, and a complete

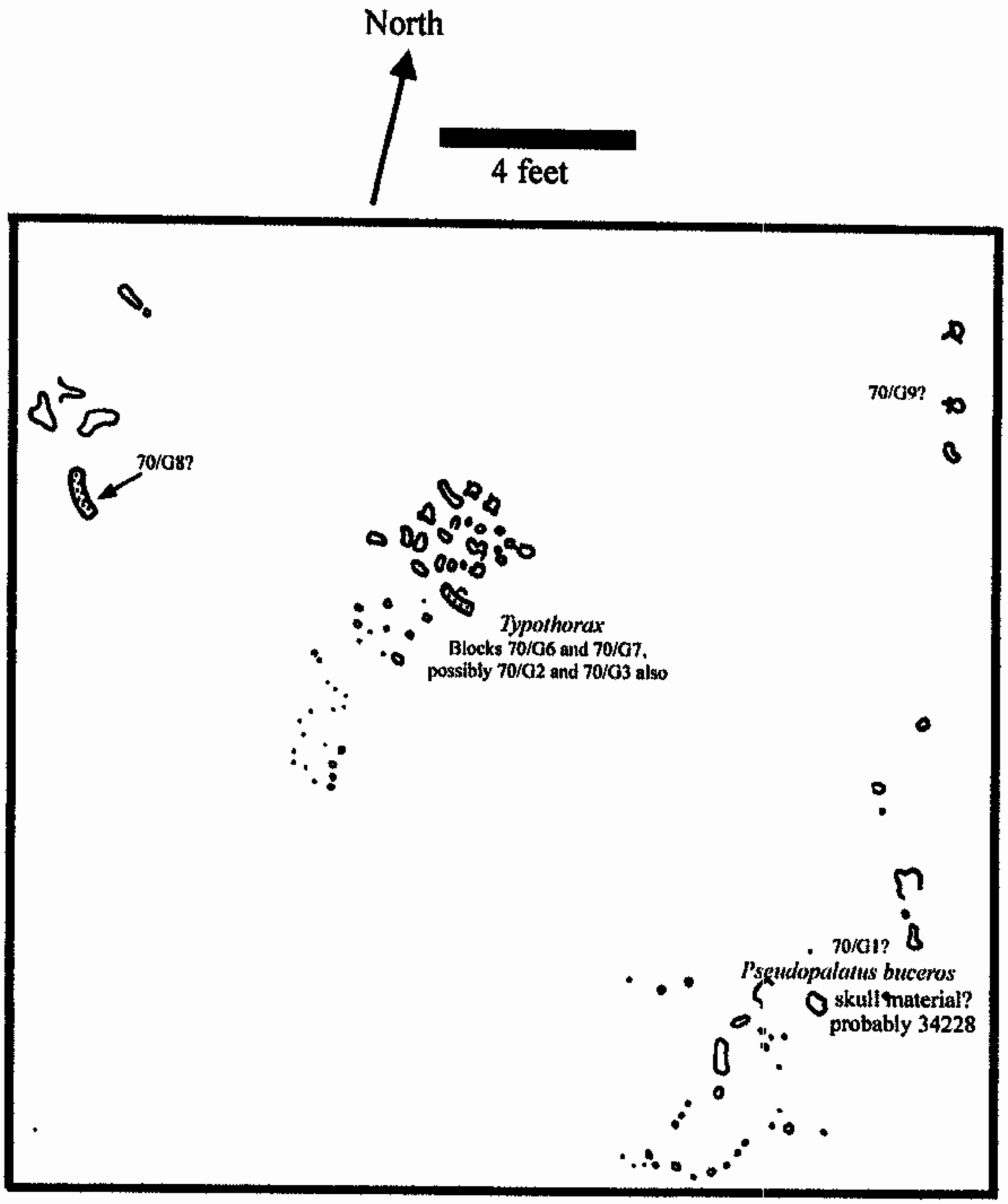


Figure A.6 Canjilon Quarry 1933 excavation grid square 70/G lower jaw, very short and thick". There are several phytosaur jaw fragments from 70/G, though none are complete. Ariss states, "The lens graded into red shale shortly after finding the jaw, so I went over to 70/K and finished it up."

After the plowing, Camp (7/13/33) notes that Welles and Smith worked the square. Welles was in the northwest corner; looking at the brown paper map the material there might have been a continuation of the phytosaur material in level 2 of 70/F, but no other record is made of his finds. Camp started work in 70/G from 7/19/33 until 7/21/33, finding "a chevron, a small one from the tail, also two *Typothorax* plates and a large vertebra." One of these plates may have been 34227 70/G8. Camp later found "four toe bones together", though it is not clear where. Howard Anderson (7/24/33) "picked up a few specimens from 70/G9" which Camp's page indicates was in the northeast part of the quarry. The brown paper map seems to show several vertebrae there, and several vertebrae bear that field number in the inventory.

The brown paper map shows a large concentration of material near the center of the square. Camp's page notes that material from 70/G2 consisted of "scrap turned up by the plow [in the second plowing, presumably within layer 1]. In center of section", and that 70/G3 material was also from the same area. Material recognized in the collection consists only of a phytosaur scute (34229 70/G2) and un-numbered skeletal fragments. Camp noted later that "Natasha has a pile of plates and limb bones near me". Smith worked in what Camp called 'the upper [layer 1] and 2" beds', so apparently she was finding material in both the upper conglomerate layer 1 and the layer 2 red mudstone; this material consisted of "broken pieces of lower jaws and other frags." Natasha's material was almost certainly the main *Typothorax* concentration, 70/G6 and 70/G7, which Camp's page indicates were "blocks from the center of the section". These blocks contain not only extensive scute material, but other skeletal material as well.

Besides 70/G8, other field numbers encountered in the inventory that were not mentioned in the field noted are 70/G4, 70/G5, 70/G14, 70/G31, and 70/G82. All consist of scrappy material, and the last two numbers are suspect, being so much higher then the others.

Table A.7. 1933 UCMP V2816 (Canjillon Quarry) material from grid square 70/G

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
70/G1(?)	34228		Quadrate (left) and posterior mandible; the field number is actually not specified beyond "70/G", but it has "block 1" written on it.	Phytosaur
70/G1	34228		Tooth; in a box of about two dozen 34228 teeth	Phytosaur
70/G1	34229		Thoracic vertebra neural spine base	?
70/G1	34229		Vertebra neural spine base	?
70/G1	122432	34229	Cervical vertebra centrum	?
70/G1	?		Rib and gastral rib fragments, with other fragments	?
70/G2	34229		Scute, neural spine table attached.	Phytosaur
70/G2	?		Scapula blade and gastral rib fragments, other fragments	?
70/G3	34240		Humerus (distal end)	*Typothorax coccinarum*
70/G3	119343	34231	Pubis (left, distal end)	?
70/G3	121989	34233	Radius (left)	?
70/G3	122100	34236	Tibia (left, lacking trochanter)	?
70/G3	?		Rib head, scute, and caudal vertebra centrum (small) fragments, as well as other fragments	?
70/G4	34238		Metapodial	?
70/G4	34238		Phalanx	?
70/G4	34249		Rib (two, both rather thin)	?
70/G4	?		Unidentifiable fragments (two)	?
70/G5	?		Unidentifiable bone fragments	?
70/G6	34227		Lateral scute fragments and other bone fragments (smooth)	*Typothorax coccinarum*
70/G6	34229		Neural spine top, with small table	?
70/G6	34239		Cervical rib	?
70/G6	34248		Fibula (left)	*Typothorax coccinarum*
70/G6	34248		Scutes (dorsal paramedians and ventral scutes, more or less articulated), a chevron, and two caudal vertebrae, in a block; this is the main 70/G6 block	*Typothorax coccinarum*
70/G6	122352	34229	Dorsal vertebra (small)	?

Table A.7. Continued

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
70/G6	122353	34229	Dorsal vertebra (fragmentary)	?
70/G6	122374	34229	Caudal vertebra centrum (small)	*Typothorax coccinarum*
70/G6	122418	34229	Caudal vertebra centrum (half)	?
70/G6	122678	34248	Tibia (left), astragalus attached	*Typothorax coccinarum*
70/G6	?		Unidentifiable fragments	?
70/G7	34229		Neural spine base	?
70/G7	34240		Ulna (small)	*Typothorax coccinarum*?
70/G7	34240		Ulna (complete)	?
70/G7	34248		Dorsal paramedian scutes in contact	*Typothorax coccinarum*
70/G7	34248		Dorsal paramedian scutes in a block; North arrow drawn	*Typothorax coccinarum*
70/G7	34248		Tibia (right, proximal end)	*Typothorax coccinarum*
70/G7(?)	122221	34238	Calcaneum (left, large); the field number may be wrong	?
70/G7	?		Femur distal end, rib and possible skull fragments; the femur has an arrow indicating it was oriented roughly N-S	*Typothorax coccinarum*
70/G8	34227		Dorsal paramedian scute, almost complete	*Typothorax coccinarum*
70/G9	34238		Metapodial	?
70/G9	34238		Radius	?
70/G9	34238		Ungal	?
70/G9	122299	34229	Vertebra centrum (small, with round articular faces)	?
70/G9	122364	34229	Caudal vertebra (small, lacking spine).	?
70/G9	122379	34229	Posterior caudal vertebra centrum (extremely small)	?
70/G9	?		Metapodial(?); a very strange bone)	?
70/G14	122258	34229	Dorsal vertebra centrum	?
70/G31	122332	34229	Mid-caudal vertebra, no neural spine; shipped in box 20	?
70/G82	34228		Tooth.	?
70/G (unspecified)	34227		Dorsal paramedian scute fragments	*Typothorax coccinarum*
70/G (unspecified)	34227		Dorsal paramedian scutes (two, overlapping each other)	*Typothorax coccinarum*
70/G (unspecified)	34228		Snout fragment; probably part of 70/G1	*Pseudopalatus*
70/G (unspecified)	34228		Basicranium (badly weathered); probably part of 70/G1	Phytosaur
70/G (unspecified)	34228		Quadrate (left), with posterior mandible articulated; probably part of 70/G1	Phytosaur
70/G (unspecified)	34228		Skull fragments, including part of a small mandible (16 pieces total); no particular evidence of association; probably part of 70/G1	Phytosaur
70/G (unspecified)	34228		Tooth; probably part of 70/G1	Phytosaur

Table A.7. Continued

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
70/G (unspecified)	34228		Skull fragments (from a large skull), three scutes; probably part of 70/G1	Phytosaur
70?G (unspecified)	34228		Skull fragments: anterior rim of nares with crest, quadrate (right) mandible (right, posterior); all probably associated, and probably part of 70/G1	*Pseudopalatus buceros*
70/G (unspecified)	34229		Chevron (excellent condition)	?
70/G (unspecified)	34229		Caudal rib fragments	?
70/G (unspecified)	34229		Vertebra (small)	Strange; not phytosaurian
70/G (unspecified)	34230		Scapula fragment	?
70/G (unspecified)	34238		Metapodial, and several unidentifiable fragments	?
70/G (unspecified)	34238		Metapodial	?
70/G (unspecified)	34238		Phalanx	?
70/G (unspecified)	34238		Metapodials (three)	?
70/G (unspecified)	34238		Metapodial	Aetosaur?
70/G (unspecified)	34238		Metapodial (?)	?
70/G (unspecified)	34240		Humerus (small)	?
70/G (unspecified)	34240		Humerus (small)	*Typothorax coccinarum*
70/G (unspecified)	34240		Fibula (proximal end)	?
70/G (unspecified)	119336	34230	Ischium peduncle (right)	?
70/G (unspecified)	119337	34230	Ischium (right, small)	?
70/G (unspecified)	121949	34232	Humerus (right, large, proximal end)	?
70/G (unspecified)	121963	34232	Humerus (left, distal end)	?
70/G (unspecified)	121967	34234	Ulna (right, huge)	Phytosaur?
70/G (unspecified)	122051	34235	Femur shaft	?
70/G (unspecified)	122052	34235	Femur fragment	?
70/G (unspecified)	122053	34235	Femur shaft (right)	?
70/G (unspecified)	122057	34235	Femur (left, proximal end)	?
70/G (unspecified)	122059	34235	Femur (right, distal end)	?
70/G (unspecified)	122060	34235	Femur (right, distal end)	?
70/G (unspecified)	122069	34235	Femur shaft (left)	?
70/G (unspecified)	122090	34236	Tibia (right, distal end)	?
70/G (unspecified)	122092	34236	Tibia (right, proximal end)	?
70/G (unspecified)	122094	34236	Tibia (right, proximal end)	?
70/G (unspecified)	122098	34236	Tibia (right), with possible bite mark	?
70/G (unspecified)	122101	34236	Tibia (left, proximal end)	?
70/G (unspecified)	122102	34236	Tibia (left, distal end)	?
70/G (unspecified)	122104	34236	Tibia (left, proximal end)	?
70/G (unspecified)	122111	34237	Fibula (right)	?
70/G (unspecified)	122237	34229	Vertebra (?) fragment	?

Table A.7. Continued

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
70/G (unspecified)	122242	34229	Cervical spine	?
70/G (unspecified)	122247	34229	Cervical vertebra centrum	?
70/G (unspecified)	122274	34229	Dorsal vertebra centrum	?
70/G (unspecified)	122275	34229	Dorsal vertebra centrum	?
70/G (unspecified)	122282	34229	Cervical vertebra (half, small)	?
70/G (unspecified)	122329	34229	Caudal vertebra centrum, neural arch base attached	?
70/G (unspecified)	122340	34229	Caudal vertebra centrum	?
70/G (unspecified)	122349	34229	Dorsal vertebra (small, transverse process intact)	?
70/G (unspecified)	122355	34229	Caudal vertebra centrum (small)	?
70/G (unspecified)	122364	34229	Caudal vertebra centrum	?
70/G (unspecified)	122378	34229	Caudal vertebra centrum (small)	?
70/G (unspecified)	122383	34229	Caudal vertebra centrum	?
70/G (unspecified)	122399	34229	Anterior caudal vertebra centrum.	?
70/G (unspecified)	122430	34229	Vertebra centrum	?
70/G (unspecified)	122675		Femur (weathered distal end)	?
70/G (unspecified)	?	34229	Neural spine top (with table); kept with 122421	?
70/G (unspecified)	?		Unidentifiable fragments	?
70/G (unspecified)	?		Rib, vertebra, splenial, and radius fragments	?

70/H

70/H (Fig. A.7) was worked by Barrington from 5/24/33 until 6/9/33. He recovered material in both the conglomerate layer 1 and the layer 2 red mudstone. Most of the lower field numbers (70/H1-70/H10) were assigned in the order the material was found, but the higher numbers (mostly not mentioned in the field notes) probably refer to the smaller grid square subdivisions. These subdivision squares were four feet on a side, and numbered starting with 70/H11. Camp (6/6/33) notes that the material recovered from 70/H was relatively free of concretion.

After the first plowing, there was apparently still a little red mudstone left on top of the upper layer 1; Barrington indicates that the conglomerate was blue or gray in color, averaged about two inches in thickness, and contained abundant concretions. Some of the concretions contained scute fragments. Apparently in upper layer 1, Barrington

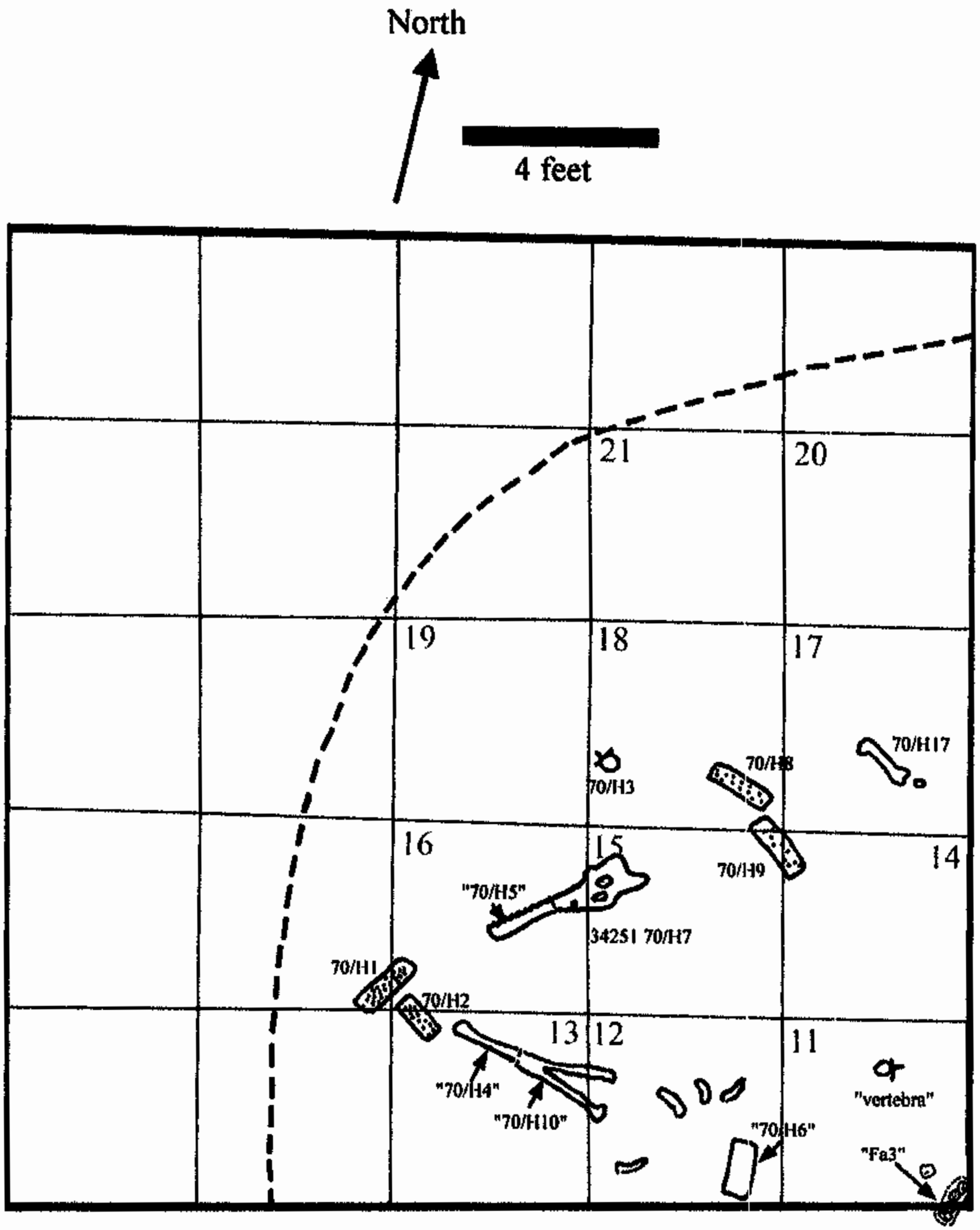


Figure A.7 Canjilon Quarry 1933 excavation grid square 70/H

(5/25/33) found " a small limb bone, about three inches long, which appeared to have epiphyses on the distal end". There are a few limb bones noted in the inventory, one of which might refer to this specimen; the lowest field number among these (which was therefore probably the first found), is a left fibula 122112 70/H7.

The rest of the material was found after Barrington "cleared off most of the gray layer", and so was probably all found in the red mudstone layer 2. However, it is implied that all the material derived from the latter was found fairly high up. Therefore, none of the 70/H material may have been derived from the main bone bed at the bottom of layer 2. The red mudstone consisted of a "mixed red shale and gray gravel complex." The mudstone was "blocky" and the gravel hard, making excavation difficult, at least in places. Barrington describes a "gray gravel lens" in the red mudstone, which was in contact with all the material first recovered from this layer. First, he found two excellent *Typothorax* plates, both lying right side up. The first ("70/H1") is not noted in the inventory. The other plate is probably 34227 70/H2. A complete skull lying on its left side (34251 70/H7) is referable to *Pseudopalatus pristinus*. It is currently missing its snout, which Camp (5/27/33) indicates had "a large tooth in the tip" and was removed as a separate piece ("70/H5"), although this number was not noted in the inventory. A complete lower jaw, probably belonging to the skull was found nearby right side up, but not noted in the inventory; this was apparently also removed as two pieces, the distal end (probably "70/H4") and the posterior part (probably "70/H10"). A limb bone was found "very close to the dorsal side of the skull", which Camp indicates was a humerus. An astragalus (likely 122218 70/H) was also found.

Other material in the red mudstone was found *after* Barrington indicated (5/26/33) that all material found "so far" was in contact with a gray gravel lens, so it is unclear if that is also the case for the following material. Apparently in the process of jacketing plate 34227 70/H2, Barrington found "smaller plates and one rib" (Barrignton, 5/27/33); the latter is likely rib 34239 70/H17, which was probably found in the same grid square as 70/H1; the "smaller plates" may refer to several "unspecified" 70/H phytosaur scutes (all 34277). Several fine dorsal paramedian plates of *Typothorax* were found. The field numbers indicated for the two dorsal paramedian scutes just north of the skull are "8" and "9"; these do indeed refer to dorsal paramedian scutes in the inventory (34227 70/H8 and 34227 70/H9 although the former includes *two* plates), but the field map indicates another was found nearby, probably "70/H6", which was not recorded in the 2001 inventory. The field notes are vague as to which is which, but the plate described as "upside down" (GWB 5/29/33) probably refers to "70/H6"; these plates all appear to have been removed in jackets. Barrington also found two vertebrae (one is apparently 122261 70/H3; another found in square 11 may be one of the vertebrae in "unspecified" 70/H), and several small ribs ("70/H13") and rib fragments. A phytosaur humerus was removed in a jacket (121952 70/H17). An "amphibian cervical vertebra", probably 122456 or 122457 (see "homeless specimens"), was found in square 20.

Table A.8. 1933 UCMP V2816 (Canjillon Quarry) material from grid square 70/H

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
"70/H1"			"Skin plate"	*Typothorax coccinarum?*
70/H2	34227		Dorsal paramedian scute, almost complete and in good condition	*Typothorax coccinarum*
70/H3	122261	34229	Dorsal vertebra	?
"70/H4"			"Lower jaw, anterior end"; probably the snout of 34251 70/H7	*Pseudopalatus pristinus?*
"70/H6"			"Skin plate"	*Typothorax coccinarum?*
70/H7	34251		Skull lacking most of rostrum	*Pseudopalatus pristinus*
70/H7	122112	34237	Fibula (left)	?
70/H8	34227		Dorsal paramedian scutes (two); only one is mentioned in the field notes.	*Typothorax coccinarum*
70/H9	34227		Dorsal paramedian scute, almost complete	*Typothorax coccinarum*
"70/H10"			"Lower jaw", probably just posterior end.	*Pseudopalatus pristinus?*
70/H11	34227		Scute	*Typothorax coccinarum*
70/H14	34253		Gastral rib (flattened)	?
70/H15	34227		Scutes (large)	Phytosaur
70/H15	122093	34236	Tibia distal end (right)	?
70/H16	34227		Scute (large)	Phytosaur
70/H17	121952	34232	Humerus (left)	Phytosaur
70/H17(?)	34239		Rib	?

Table A.8. Continued

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
70/H (unspecified)	34227		Scutes (three)	Phytosaur
70/H (unspecified)	34231		Indeterminate scrap	?
70/H (unspecified)	34231		Scapula fragment	*Typothorax coccinarum*?
70/H (unspecified)	34238		Metapodial	?
70/H (unspecified)	34239		Gastral rib	?
70/H (unspecified)	34253		Flattened element (odd)	?
70/H (unspecified)	34253		Gastral fragments (two)	?
70/H (unspecified)	34253		Rib distal end	?
70/H (unspecified)	119369	34230	Coracoid articular end (right)	Phytosaur?
70/H (unspecified)	122218	34238	Astragalus (right)	?
70/H (unspecified)	122253	34229	Posterior dorsal vertebra	?
70/H (unspecified)	122270	34229	Dorsal vertebra centrum	?
70/H (unspecified)	122273	34229	Dorsal vertebra centrum	?
70/H (unspecified)	122455		Vertebrae	Temnospondyl?
70/H (unspecified)	?		Scute fragments	*Typothorax coccinarum*

70/J

70/J (Fig. A.8) was divided into smaller squares four feet on a side, numbered east to west starting from the northeast corner with "11". Nearly all specimens however seem to have individual numbers, probably assigned in the order they were found, rather then being numbered for the squares. All the material recovered in 70/J seems to have come from the main bone bed in the lower mudstone layer 2, and work in the square was completed before the second plowing. The color change at the bone bed at the bottom of layer 2 noted in 70/F is also noted here; the base of the bone layer was "greenish-gray" and containing abundant "carbonaceous material none of which… has been identifiable" (GWB 6/19/33). Ariss notes that material was also derived from "green gravels", although it is not clear if he is referring to lenses within the layer 2 mudstone, or the upper conglomeratic layer 1.

About a quarter of the "Fa" Typothorax skeleton extends into the southwest corner of the square, mostly in sub-squares 30 and 35, but also running slightly into squares 29 and 34. These four sub-squares were apparently subdivided further into four two foot squares judging by one of Barrington's maps. The "Fa" *Typothorax* material

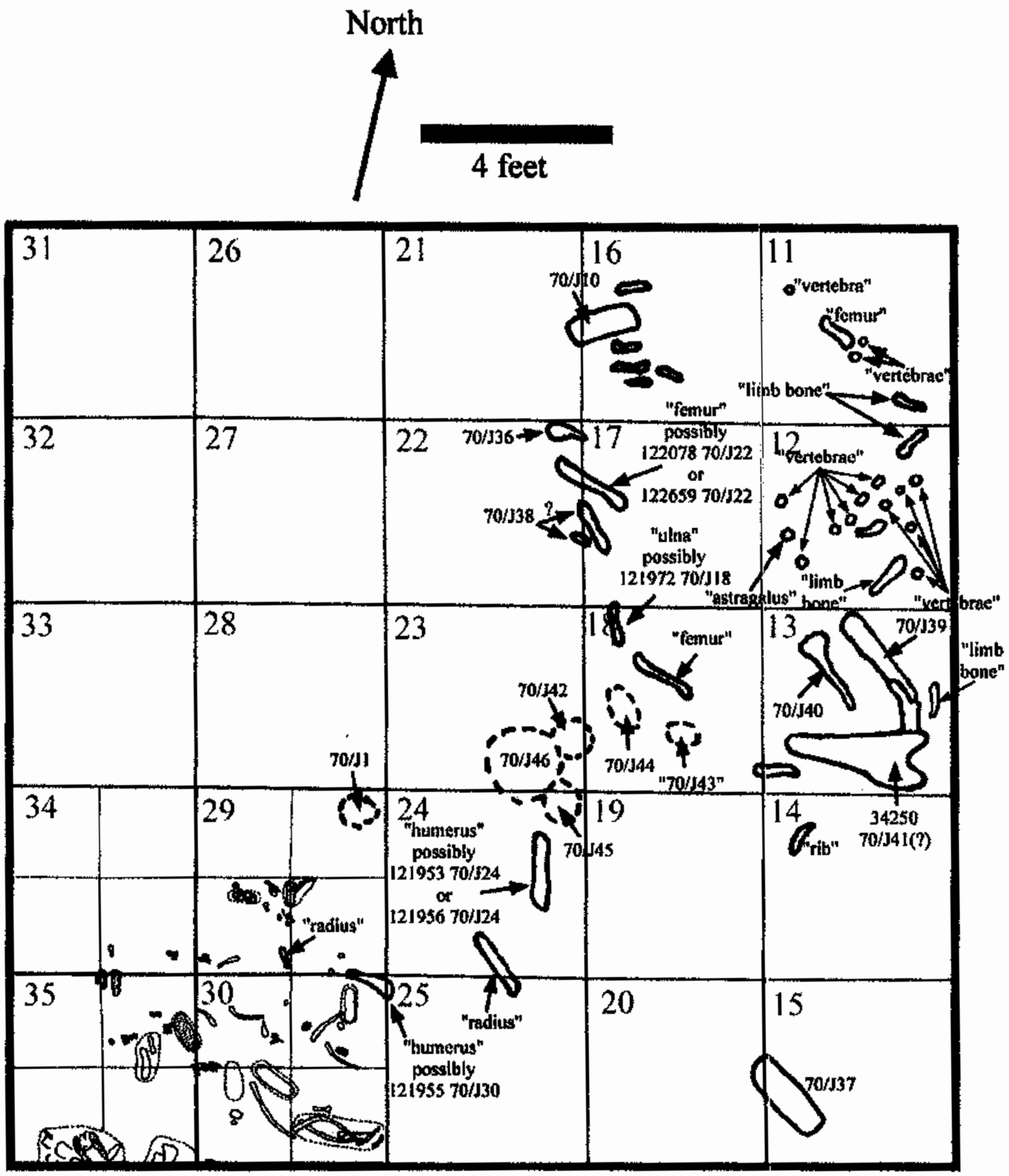


Figure A.8 Canjilon Quarry 1933 excavation grid square 70/J; southeastern area detailed in Fig. A.5.

recovered here consisted of plates in "an almost continuous sheet. There was very little order, some of the plates being overturned and some on edge as well as right side up... [but] mostly... horizontal"; as also suggested by the field map, they seem to have been more spaced out and more disordered then in 70/F, and Barrington (6/19/33) notes that "only four small wafer plates seem to have been in approximately natural position". The scutes came in a variety of sizes, including large dorsal paramedians, "small wafer plates, and a squarish plate intermediate in size". All the 70/J scutes recognized in the 2001 inventory under 34227. Scute "70/J2", also taken out in an individual block, was not recognized in the 2001 inventory.

Several other bones were found within the vicinity of the *Typothorax* plates, presumably also within the layer 2 bone bed. A large phytosaur tooth (34228 70/J3), a large left ulna (121978 70/J4), a large left radius (121987 70/J5), a dorsal vertebrae centrum (122267 70/J8), and two humeri (both 34240 70/J9), one of which is *Typothorax*, may have come from the "Fa" blocks. Most of this is probably phytosaurian material washed in. These include "a small limb bone" (GWB 6/10/33), "a large rib and several bones in concretion... a few inches below the general level of the plates" (GWB 6/12/33), "a few ribs" (GWB 6/13/33), and "a large phytosaur humerus, a phytosaur radius, and a small limb bone" (GWB 6/14/33). These last seem to have come from near the eastern edge of boundary of squares 29 and 30, and the humerus may be 121955 70/J30, an enormous left phytosaur humerus (in which case, the field number is based on the squares for this particular specimen). In "another part of the section", Barrington made a small block, "70/J1" in the northeast corner of subsquare 29 for a concentration of small bones; a large phytosaur (possibly *Pseudopalatus buceros*) maxilla is the only inventoried item with this field number, 34228 70/J1, and may have come from the block. A block of ribs, "70/J6" from subsquare 30 were not recognized in the 2001 inventory. A block of "unidentified bones (70/J7)" and several "small wrapped specimens" with the field numbers "70/J56" -"70/J65" were also not found in the 2001 inventory. However, at least some of the "small specimens" with the field numbers

"70/J66"-"70/J87" came from the "Fa specimen" concentration, and some were noted in the 2001 inventory. At least some of this material is probably phytosaurian, notably a large tooth (34228 70/J83). Other material collected by Barrington, the position of which is not clear, but which he found at the time he was working around in the southwestern corner, includes the "distal end of a humerus, several ribs, and a femur, all in one small area." He also found "a small humerus, about 1" long, complete with a broken shaft" (GWB 6/21/33).

Ariss began work in 70/J on 6/24/33 in the eastern part of 70/J, mostly in subsquares 11-14 (RMA 6/27/33), finding material in both the reddish and greenish mudstones in layer 2. He claimed that the bone bed here was 15 inches below that in 70/K, but this is probably based on the erroneous belief that there were two primary bone layers. He also noted that the layer 2 bone bed seemed to "slope up slightly to the North" (RMA 6/28/33). Both Ariss and Barrington mapped this region, though there are differences. In Ariss's map it is often difficult to tell which elements are labeled as vertebrae, and which as limb bones, and only Barrington's maps give field numbers. Ariss first found a "large group of bones in [the] right quarter section of 70/J. In an area about 2 feet square, there were four limb bones with many ribs and skin plates associated".

Ariss soon after found a *Pseudopalatus buceros* skull and much of the jaws just to the north of it, all under 34250 (though the field numbers are not written on the specimens in the collections, the field labels identify these as Ariss's skull), in subsquare 13. Although the field numbers were not noted in the 2001 inventory, the maps give them as "70/J39" and "70/J40" for the jaws, and "70/J41" for the skull. The 2001 inventory also found two jaw fragments and two maxillae (34228 70/J40) and other jaw and bone fragments (34253 70/J40), which might go with the specimen. There is also a lot of skull and jaw material under 34253 without specific field numbers identified as having come from blocks 39 and 41, so probably belong under 34250; material with the label reading "block 39" came from underneath the skull and jaws.

Ariss (6/26/33) noted, "front limb bones are scattered about the skull". One of these limb bones found with the skull might be small left humerus 121957 70/J13 (Camp's notes confirm that this field number was applied to material from block 39), but none of the others can be identified with certainty. Also, "above the lower jaw rami lie some bone of an animal much smaller then the phytosaur. There are several vertebrae and what seems to be a small femur. Dr. Camp thinks that the bones may be those of *Typothorax* ". This femur may be right femur 122072 70/J12, which is probably a phytosaur. Above the "*Typothorax*" femur was a small vertebra (RMA 6/29/33). Several scutes were also found scattered around the jaws, probably including phytosaur scutes 34227 70/J12, and also there was "another good bit of material". Camp (6/27/33) noted that Ariss also found "small vertebrae nearby [that] do not belong with skull", probably referring to the concentration of material shown on the field maps in square 70/J12 to the north of the skull. A considerable amount of material with this field number was found in the 2001 inventory, most of which are indeed vertebrae. A right astragalus, 122227 70/J12, is probably the one shown on Aris's map toward the west side of the subsquare.

Barrington seems to have worked the rest of the northern area of 70/J, recovering a *Typothorax* scute "70/J10" (not found in 2001 inventory) in subsquare 16, and what he identified as an "illium", but may actually have been a partial scapulocoracoid belonging to *Typothorax* (34230 70/J36), "several smaller specimens", and an ulna (121973 70/J38). Barrington also worked the area just west of skull (subsquares 18, 19, 23, and 24). These included a block of ribs "70/J43" (not found in the 2001 inventory) and another with a left pubis (34231 70/J44), a large left femur (122070 70/J44) and apparently a few scutes (34227 70/J44). Material in blocks 70/J42, 70/J45, and 70/J46 was taken out last, and material from all (various vertebrae, ribs and appendicular material) was found in the collections.

The southeast area of 70/J (including squares 15, 20, and 25) was worked by Ariss, who notes that here "the level seems to dip down very rapidly so as to make 70/J a sort of depression" (RMA 6/29/33). Ariss (RMA 6/30/33) found "very little bone" here.

In subsection 20, he found “two ribs and a fairly complete vertebra”. In subsection 15, there was an excellent *Typothorax* scute (34227 70/J37) and “a bone mass which is seemingly a vertebra”. Nothing was found in subsquare 25, although “only a small strip was worked”.

Table A.9. 1933 UCMP V2816 (Canjillon Quarry) material from grid square 70/J

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
“70/J1”			“Block”	?
70/J1	34228		Maxilla fragment (large)	*Pseudopalatus buceros?*
“70/J2”			“Skin plate”	*Typothorax coccinarum?*
70/J3	34227		Scutes (three, incomplete)	*Typothorax coccinarum*
70/J3	34228		Tooth (large)	Phytosaur
70/J4	34227		Dorsal paramedian scute, slightly warped, incipient boss	*Typothorax coccinarum*
70/J4	121978	34234	Ulna (left, large)	?
70/J5	34227		Dorsal paramedians scute	*Typothorax coccinarum*
70/J5	121987	34233	Radius (left, large)	?
“70/J6”			“Ribs”	?
“70/J7”			“Unidentified”	?
70/J8	34227		Dorsal paramedian scute, chevron on underside	*Typothorax coccinarum*
70/J8	122267	34229	Dorsal vertebra centrum	?
70/J8	34227		Clavicle(?)	?
70/J9	34227		Two partial dorsal paramedian scutes (one apparently broken almost in half) and a lateral caudal (?) fragment	*Typothorax coccinarum*
70/J9	34240		Humerus (small)	Phytosaur?
70/J9	34240		Humerus (small); Long and Murry, 1995, fig. 105C.	*Typothorax coccinarum*
70/J10	34227		Dorsal paramedian scute, in good condition	*Typothorax coccinarum*
70/J11	34229		Neural arch base	Phytosaur?
70/J12	34227		Scutes (two)	Phytosaur
70/J12	34227		Scute	Phytosaur
70/J12	34239		Rib	?
70/J12 *goes with 34250 70/J39-41 skull and jaws.	34250		Unprepared fragments, including gastrals, scutes, possibly jaw elements; associated note reads “transverse bar under rami of skull, blocks 39 and 42”	Phytosaur?
70/J12	122072	34235	Femur (right), lacking proximal end	?
70/J12	122227	34238	Astragalus (right)	?
70/J12	122266	34229	Dorsal vertebra centrum	?

Table A.9. Continued

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
70/J12	122298	34229	Dorsal vertebra centrum (small)	?
70/J12	122300	34229	Vertebra centrum, possibly a sacral	?
70/J12	122305	34229	Sacral vertebra centrum (small)	?
70/J12	122388	34229	Caudal vertebra centrum	?
70/J12	122414	34229	Caudal vertebra centrum (small)	?
70/J12	122422	34229	Caudal vertebra centrum	?
70/J12	122448	34229	Caudal vertebra centrum	?
70/J12	122454	34229	Caudal vertebra; similar to 122447 and 122437	?
70/J12	122665	34236	Tibia (right)	?
70/J13	121957	34232	Humerus (left, small); Camp's notes indicate this was part of "block 39".	?
70/J15	34227		Scute	Phytosaur
70/J16	34229		Terminal end of a vertebral centrum	Phytosaur?
70/J16	34238		Astragalus (left); Long and Murry, 1995, fig. 54D-H	Phytosaur
70/J16	34238		Ungals	Phytosaur?
70/J17	34227		Scute	Phytosaur
70/J18	34227		Scute?	Phytosaur?
70/J18	119361	34230	Scapula (left, proximal end)	Phytosaur?
70/J18	121972	34234	Ulna (right)	?
70/J18	?		Bone fragments	?
70/J19	34227		Scutes (two)	Phytosaur
70/J19	34227		Lateral scute fragment	*Typothorax coccinarum*
70/J19	34239		Rib	?
70/J22	122078	34235	Femur (left, large)	?
70/J22	122659	34235	Femur (right)	?
70/J24	34227		Scutes (five) of moderate size	Phytosaur
70/J24	34238		Metapodial or rib end	Phytosaur?
70/J24	34238		Metapodial	Phytosaur?
70/J24	34238		Unidentifiable bone; shipped in block 27	?
70/J24	34239		Rib; shipped in box 17	?
70/J24	121953	34232	Humerus (left)	?
70/J24	121956	34232	Humerus (left)	?
70/J24	121970	34234	Ulna (right)	?
70/J24	122108	34237	Fibula (right)	?
70/J24	122294	34229	Dorsal vertebra centrum	?
70/J24	?		Vertebra (?) fragments	?
70/J25	34227		Scutes (five)	Phytosaur
70/J25	34229		Neural arch, almost complete	Phytosaur?

Table A.9. Continued

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
70/J25	122322	34229	Caudal vertebra centrum	?
70/J25	122419	34229	Dorsal vertebra centrum (small, incomplete)	?
70/J25	122449	34229	Cervical vertebra centrum	?
70/J30	121955	34232	Humerus (huge, left)	Phytosaur
70/J36	34230		Scapulocoracoid, incomplete; described as an "illium" in the field notes.	*Typothorax coccinarum*?
70/J37	34227		Dorsal paramedian scute, good condition	*Typothorax coccinarum*
70/J38	121973	34234	Ulna (right)	?
70/J38	?		Rib scraps	?
70/J (unspecified)	34250		Mandible articular section (right, large), with one tooth; 70/J39 or 70/J40; shipped in box 13	*Pseudopalatus buceros* (?)
70/J (unspecified)	34250		Mandible (left), postsymphysial section; 70/J39 or 70/J40.	*Pseudopalatus buceros*(?)
70/J40	34228		Mandible fragments (two) and maxillae (two); shipped in box 13	Phytosaur
70/J (unspecified)	34250		Skull (average size); probably 70/J41	*Pseudopalatus buceros*
70/J41	34253		Jaw fragments and other bone fragments	Phytosaur
70/J (unspecified)	34253		Jaw fragments, mostly premaxilla, at least one mandible; from "block 41" (belongs with 34250 skull).	*Pseudopalatus buceros (?)*
70/J (unspecified)	34253		At least three jaw fragments; symphysis, posterior section, part of angular, one very fat tooth; "block 41" and "block 39" material; go with 34250 skull and jaws, some running underneath them.	*Pseudopalatus buceros (?)*
?	?		Mandible (right), postsymphyseal fragment; no specimen or field number, but may go with the skull and mandibles	Phytosaur
70/J42	122116	34237	Fibula (right, large, distal end)	?
70/J42	?		Rib fragments and other fragments	?
"70/J43"			"Ribs"	?
70/J44	34227		Scutes (two)	Phytosaur
70/J44	34231		Pubis (left); shipped in box 17	Phytosaur
70/J44	122070	34235	Femur (left, large), with scute attached; Camp's note misidentifies as a humerus, but Barrington identifies correctly.	?
70/J45	34238		Metapodial	Phytosaur
70/J45	34238		Ungal	Phytosaur?
70/J45	34239		Rib	?
70/J45	121993	34233	Radius (right)	?
70/J45	122113	34237	Fibula (right, proximal end)	?
70/J45	122394	34229	Caudal vertebra centrum	?
70/J45	?		Rib fragments (three)	?

Table A.9. Continued

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
70/J46	34227		Scute	Phytosaur
70/J46	34239		Rib	?
70/J46	122074	34235	Femur (right, large); shipped in box 17	?
70/J46	122245	34229	Cervical vertebra lacking spine	Phytosaur
70/J46	122674	34240	Femur (complete)	*Typothorax coccinarum*
"70/J50"			"Humerus"	?
"70/J51"			"Skin plate"	?
70/J51	122679		Tibia	*Typothorax coccinarum*
"70/J52"			"Skin plate"	?
"70/J53"			"Small rib (1 ¼")"	?
"70/J54"			"Skin plate"	?
"70/J55"			"Vertebra"	?
"70/J56"			"Skin plate"	?
"70/J57"			"Intercentrum"	?
"70/J58"			"Skin plates"	?
"70/J59"			"Skin plates"	?
"70/J60"			"Skin plate"	?
"70/J61"			"Rib and vertebra"	?
"70/J62"			"Rib"	?
"70/J63"			"Vertebra"	?
"70/J64"			"Skin plate"	?
"70/J65"			"Skin plate"	?
70/J66	34239		Rib	?
"70/J67"			"Skin plate"	?
70/J68	34231		Transverse process of vertebra	Phytosaur?
"70/J69"			"Skin plates"	?
70/J70	34227		Dorsal paramedian scute	*Typothorax coccinarum*
"70/J71"			"Rib"	?
70/J72	122320		Caudal centrum	?
70/J72	122320	34229	Caudal centrum	?
"70/J73"			"Skin plate"	?
"70/J74"			"Skin plate and gastralium"	?
"70/J75"			"Rib"	*Typothorax coccinarum*?
"70/J76"			"Skin plate"	*Typothorax coccinarum*?
70/J77	34239		Rib	*Typothorax coccinarum*?
70/J78	?		Proximal rib fragments	*Typothorax coccinarum*?
"70/J79"			"Skin plate"	*Typothorax coccinarum*?
"70/J80"			"Rib"	?
"70/J81"			"Skin plate"	?

Table A.9. Continued

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
70/J82	119327	34231	Illium (small, right)	?
70/J83	34227		Clavicle?	?
70/J83	34228		Large fang	Phytosaur
70/J84	122203		Clavicle (large, right); Camp identified as a rib.	?
"70/J85"			"Skin plate"	?
"70/J86"			"Skin plates"	?
"70/J87"			"Skin plates"	?
70/J (?)	122293	34229	Sacral centrum	?
70/J (unspecified)	34228		Snout	*Pseudopalatus pristinus*
70/J (unspecified)	34228		Braincase (incomplete)	Not phytosaur, possibly aetosaur
70/J (unspecified)	34232		Humerus (proximal end)	Probably not phytosaur
70/J (unspecified)	34238		Metapodial	Phytosaur?
70/J (unspecified)	34238		Ungal	Phytosaur?
70/J (unspecified)	34239		Rib	?
70/J (unspecified)	119326	34231	Illium (right, small); shipped in box 17	?
70/J (unspecified)	119339	34231	Pubis fragment	Phytosaur?
70/J (unspecified)	122058	34235	Femur (left, proximal end)	Phytosaur?
70/J (unspecified)	122065	34235	Femur (right, distal end)	Phytosaur?
70/J (unspecified)	122066	34235	Femur (left, lacks distal end)	Phytosaur?
70/J (unspecified)	?		Thoracic vertebra fragment	?
70/J-A	?		Rib fragment and flat piece of blade	?
70/JL4	?		Worn down gastral rib	?

70/K

70/K (Fig. A.9) was not subdivided, and the only field maps made were by Camp, both of which were quite poor. The "brown paper map" was used as the template for the map drawn here, though it has been modified slightly using Camp's maps. The vast majority of the specimens found in the 2001 inventory lack a specific field number. Nearly all material was recovered after the second plowing, and probably comes from the lower bone bed in the reddish mudstone. Both the upper layer 1 and lower conglomerate at the bottom of layer 2 were greenish; Anderson's first forays into 70/K, before the second plowing, found material "a foot or more below the [upper level?] gravels" (RMA 6/17/33), which he later described as green in color. Ariss (7/13/33), notes that the

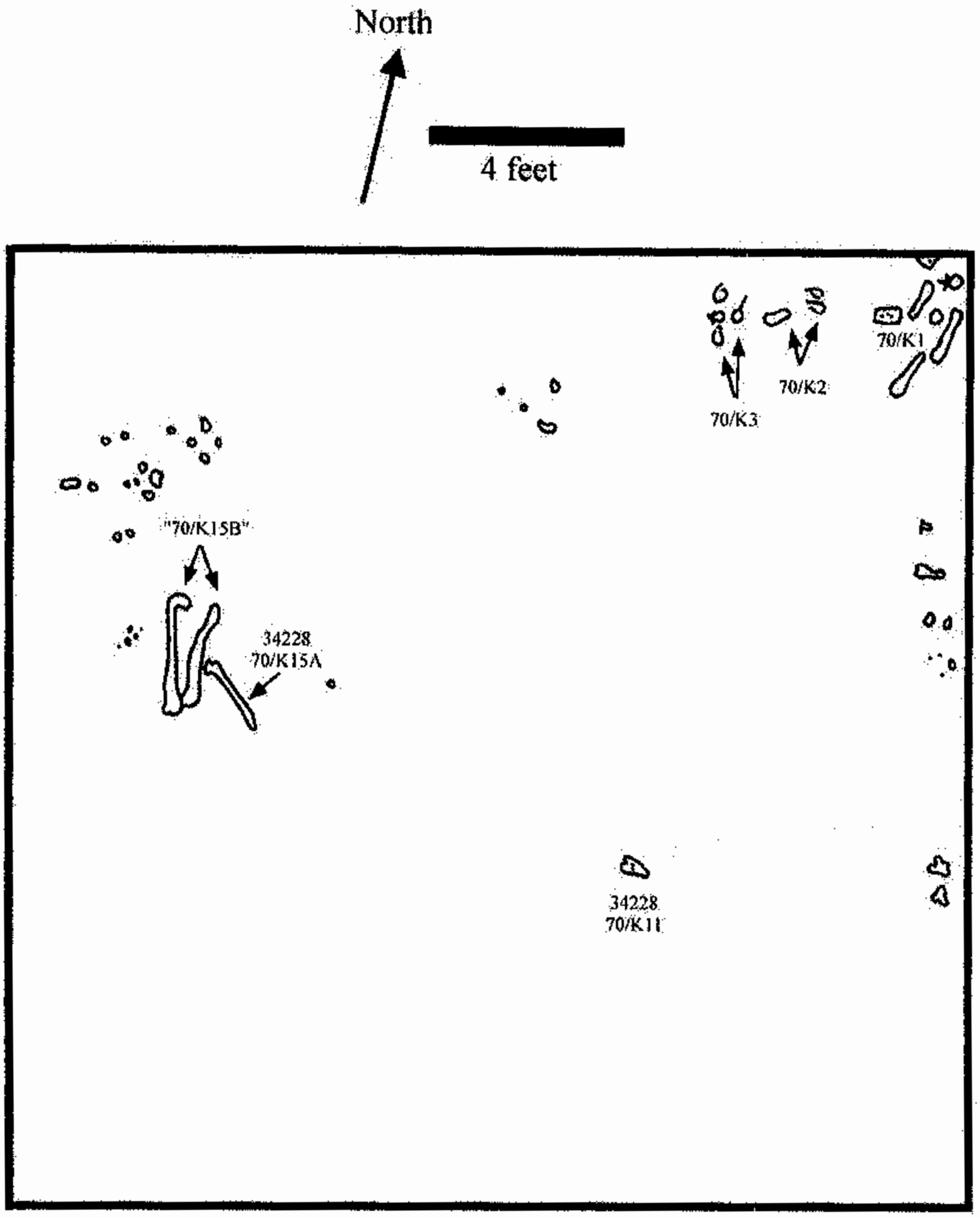


Figure A.9 Canjilon Quarry 1933 excavation grid square 70/K material recovered rests "on and slightly above a green gravel lens" which may be the same one he mentioned earlier as a "green gravel lens above the red shale level". Although most material in 70/K was recovered in the layer 2, additional material was removed from the "third level" *after* the second plowing. Although Camp makes clear that the main bone level for all squares was the same, and that his earlier suggestion that there were two separate main bone layers were erroneous, it seems that in this case material was indeed found below the layer 2 bone bed after plowing removed what was probably the lower conglomeratic bed.

The first serious excavation in 70/K was by Camp, in the eastern part of the square "near (within two feet) of the 70/L3 *Coelophysis* material" (CLC 6/19/33). This material consisted of "a small scapulocoracoid, a long complete rib, skin plate of *Typothorax*, several toe bones, and scrap". He soon after found somewhere in 70/K "two large phytosaur vertebrae, both cervicals, within an inch of each other" (CLC 6/20/33). Anderson (presumably working south of Camp's spot) found virtually nothing in the eastern part of 70/K.

In the northeast corner Camp found a large limb bone, which was labeled 70/K1. Quite a bit of material with this field number is present in the collections, although which is Camp's first large limb bone is not clear. Camp also found scapulocoracoid material, which he split into two packages labeled "coracoid/scap", and "a number of small things, including very small humerus, large slender ulna, plates, vertebra, teeth as ususal" (CLC 6/21/33). It is not clear, but all this material probably also came from the northeast part of the square, as Camp then found a "femur and a few plates with the larger vertebrae in extreme northeast corner" (CLC 6/23/33). Later, he found "a few small bones" (CLC 6/26/33). Camp divided up the material in the northeast corner into three field numbers; from east to west, 70/K1, "70/K2" (for which no material was recognized in the 2001 inventory), and 70/K3. The first number seems to have contained most of the material, and within it he made two jackets. 70/K1A "contains limbs, vertebrae, and a plate." Some of this material, including a fibula (<u>122670 70/K1A</u>) was found in the inventory.

"Alongside it [70/K1A] lay a humerus and an ulna, a femur, and many other bones including vertebrae and plate" (CLC 6/30/33). It is not clear if the latter material was in the jacket 70/K1A, or just nearby; in the latter case, this material is probably among the 70/K1 material found in the 2001 inventory. Jacket 70/K1B, just to the northeast of the first block, contained "a small scapula and a thin plate"; a small ischium (119348 70/K1B) may represent the latter. Camp also notes that "between the two blocks was a small limb bone, of which ½ is in a package, and the other half remains on the north side of the 70/K1A block"; this element was not recognized in the inventory.

Howard Anderson's first finds were on the western edge of 70/K, in layer 2 about "a foot or more" below the layer 1 concretion, consisted of "two nice limb bones, a toe bone, several plates and some teeth" (RMA 6/17/33). Anderson (7/12/22) later found a pair of phytosaur jaws in the lower bone level about three feet from the western edge and 10 feet from the southern edge, which he gave the number 70/K15 (the mandible to the east is 34228 70/K15A; the pair of jaws west, "70/K15B", could not be found). These jaws were oriented roughly north-south and heavily coated in concretion. Concretions in the vicinity of the jaws contained a variety of fragments, especially gastralia. Anderson found little else in 70/K.

Barrington found a small skull of *Pseudopalatus pristinus* (34228 70/K11) lacking the snout and apparently lying on the right side, apparently not far from the middle of the section. Camp believed this to be a *Coelophysis* skull, and the "brown paper map" shows a dashed line running from the skull to a concentration of bones in 70/L (see below), probably to imply that they go together. Barrington (7/7/33) notes that there were "a few phalanges and other small bones", possibly meaning in the vicinity of the skull, and Camp noted that there were many "*Coelophysis* vertebrae" surrounding the skull.

Material found by Anderson (7/5/33, 7/7/33) somewhere in 70/K but not given a specific location include a left calcaneum, (122224 70/K5) a metapodial (34238 70/K6), "some caudal vertebrae 70/K7" (not recognized in 2001), "a phytosaur intercentrum of atlas 70/K8" (possibly 122232), and "a toe bone K/9" (not recognized in 2001).

Table A.10 1933 UCMP V2816 (Canjillon Quarry) material from grid square 70/K

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
70/K1	34238		Ungal	?
70/K1	34239		Rib	?
70/K1	34239		Rib	?
70/K1	121968	34234	Ulna (right)	?
70/K1	122239	34229	Cervical vertebra; "vert 2" written on	?
70/K1	122249	34229	Cervical vertebra centrum; shipped in "box 8"	Phytosaur
70/K1	?		Miscellaneous bone fragments	?
70/K1 "V"	34238		Fifth metatarsal (left?)	Phytosaur
70/K1 "IV"	34238		Metapodial	?
70/K1-1	122427	34229	Dorsal vertebra centrum (incomplete) with base of spine	?
70/K1(?)	122668	34237	Tibia (left)	?
70/K1A	122251	34229	Dorsal vertebra	?
70/K1A	122286	34229	Anterior caudal vertebra	?
70/K1A	122670	34237	Fibula (right)	?
70/K1A	?		Ribs	?
70/K1B	119348	34231	Ischium (left, fairly small)	?
70/K3	34238		Metapodial (proximal end)	?
70/K3	34239		Rib	?
70/K3	?		Bone fragments	?
70/K5	122224	34238	Calcaneum (left), no heel	?
70/K6	34238		Metapodial, shipped in box 10	Phytosaur
"70/K7"			"Three caudal vertebrae-not associated"	?
"70/K8"			"Intercentrum-phytosaur atlas"	"Phytosaur"
"70/K9"			"Toe bone"	?
70/K10	119358	34230	Scapula (left, small)	Phytosaur
70/K11	34228		Skull, lacking snout; the field number is not written directly on the specimen, but it is probably the 70/K11 specimen	*Pseudopalatus pristinus*
70/K12	34227		Dorsal paramedian scute; probably the best in the quarry	*Typothorax coccinarum*
70/K15A	34228		Mandible (left)	Phytosaur
70/K15A	34228		Mandible fragment	Phytosaur
"70/K15B"			"Phytosaur pair of lower jaws"; collected by Barrington	"Phytosaur"
70/K (unspecified)	34239		Rib	?

Table A.10 Continued

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
70/K (unspecified)	34239		Rib (expanded type)	?
70/K (unspecified)	34240		Limb bone fragments	?
70/K (unspecified)	34229		Neural spine (base)	?
70/K (unspecified)	34231		Ischium(?)	Phytosaur?
70/K (unspecified)	34238		Tarsal or carpal; blocks of some kind?	?
70/K (unspecified)	34238		Phalanx	?
70/K (unspecified)	34238		Metapodial	?
70/K (unspecified)	34238		Phalanx	?
70/K (unspecified)	34238		Metapodial	?
70/K (unspecified)	34238		Calcaneal tuber	Probably phytosaur
70/K (unspecified)	34227		Scute (odd with weird, pinched boss); superficially resembles *Typothorax*	Phytosaur?
70/K (unspecified)	119359		Scapula (left); shipped in box 3(?)	Phytosaur
70/K (unspecified)	119356	34230	Scapula (left, small)	Phytosaur
70/K (unspecified)	119365	34230	Scapula (right, small)	Phytosaur
70/K (unspecified)	119374	34230	Coracoid (left)	Phytosaur
70/K (unspecified)	121945	34232	Humerus (right)	Phytosaur
70/K (unspecified)	121947	34232	Humerus (right, distal end); shipped in box 10	Phytosaur
70/K (unspecified)	121951	34232	Humerus (right, proximal end)	Phytosaur
70/K (unspecified)	121960	34232	Humerus (left, proximal end, tiny)	?
70/K (unspecified)	121964	34232	Humerus (right, proximal end)	?
70/K (unspecified)	121965	34232	Humerus (right, small)	?
70/K (unspecified)	121966	34232	Humerus (left)	?
70/K (unspecified)	121975	34234	Ulna (left)	?
70/K (unspecified)	122050	34235	Femur shaft	?
70/K (unspecified)	122073	34235	Femur (right, lacking proximal end)	?
70/K (unspecified)	122061	34235	Femur (right, distal end)	?
70/K (unspecified)	122062	34235	Femur (right, small, distal end)	?
70/K (unspecified)	122068	34235	Femur (left), pathological and probably broken	?
70/K (unspecified)	122075	34235	Femur (right)	?
70/K (unspecified)	122083	34236	Tibia (right, small)	?
70/K (unspecified)	122082	34236	Tibia (right)	?
70/K (unspecified)	122086	34236	Tibia (right, small)	?
70/K (unspecified)	122088	34236	Tibia (right, distal end)	?
70/K (unspecified)	122209	34230	Interclavicle; shipped in box 22	?
70/K (unspecified)	122218	34238	Calcaneum fragment (right)	?
70/K (unspecified)	122232	34229	Atlas (large, complete); shipped in box 22	?
70/K (unspecified)	122246	34229	Cervical vertebra lacking spine	Phytosaur

Table A.10 Continued

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
70/K (unspecified)	122254	34229	Dorsal vertebra lacking spine	Phytosaur
70/K (unspecified)	122256	34229	Dorsal vertebra centrum	?
70/K (unspecified)	122263	34229	Dorsal vertebra centrum	?
70/K (unspecified)	122283	34229	Cervical vertebra centrum (small); has "1" written on it, possibly part of the K1 group	?
70/K (unspecified)	122376	34229	Caudal vertebra centrum (small)	?
70/K (unspecified)	122398	34229	Dorsal vertebra centrum	?
70/K (unspecified)	122406	34229	Caudal vertebra centrum (small)	?
70/K (unspecified)	122421	34229	Anterior caudal vertebra with base of neural arch	?
70/K (unspecified)	122425	34229	Cervical vertebra centrum (incomplete)	?
70/K (unspecified)	122429	34229	Vertebra centrum (incomplete)	?
70/K (unspecified)	122434	34229	Caudal vertebra centrum	?
70/K (unspecified)	122671	34238	Calcaneum heel	?
70/K (unspecified)	?		Rib fragments and other bone fragments	?
70/K (?)	34238		Metapodial	?
70/K (?)	34229		Thoracic vertebra	?

70/L

As noted by Camp (5/26/33), 70/L (Fig. A.10) is adjacent to his 1931 70/10 locality, where the 27235 *Pseudopalatus pristinus* skeleton was recovered. This previously recovered skeleton is included in both Camp's field map and the brown paper map. Work in 70/L was completed before the second plowing, and the material all seems to have come from upper conglomerate layer 1, which is a blue-gray color here. The 27235 skeleton and other material recovered from 70/L were "heavily coated with lime nodule" (CLC 6/6/33). Camp's initial finds were "two toe bones and part of a radius, possibly also belonging to 70/10" (CLC 5/29/33), and later "a small vertebra, several small plates, toe bones; all scattered throughout the blue-gray gravel" (CLC 5/30/33).

The skull for the "broken and battered" *Pseudopalatus pristinus* skull 34253 was found "palate down about 10 feet southwest of the old 70/10 [27235] specimen", as shown on the map. The skull was removed in block 70/L1A. Some vertebrae were "in a heap nearby" (CLC 5/31/33), and working around the skull Camp found "a quantity

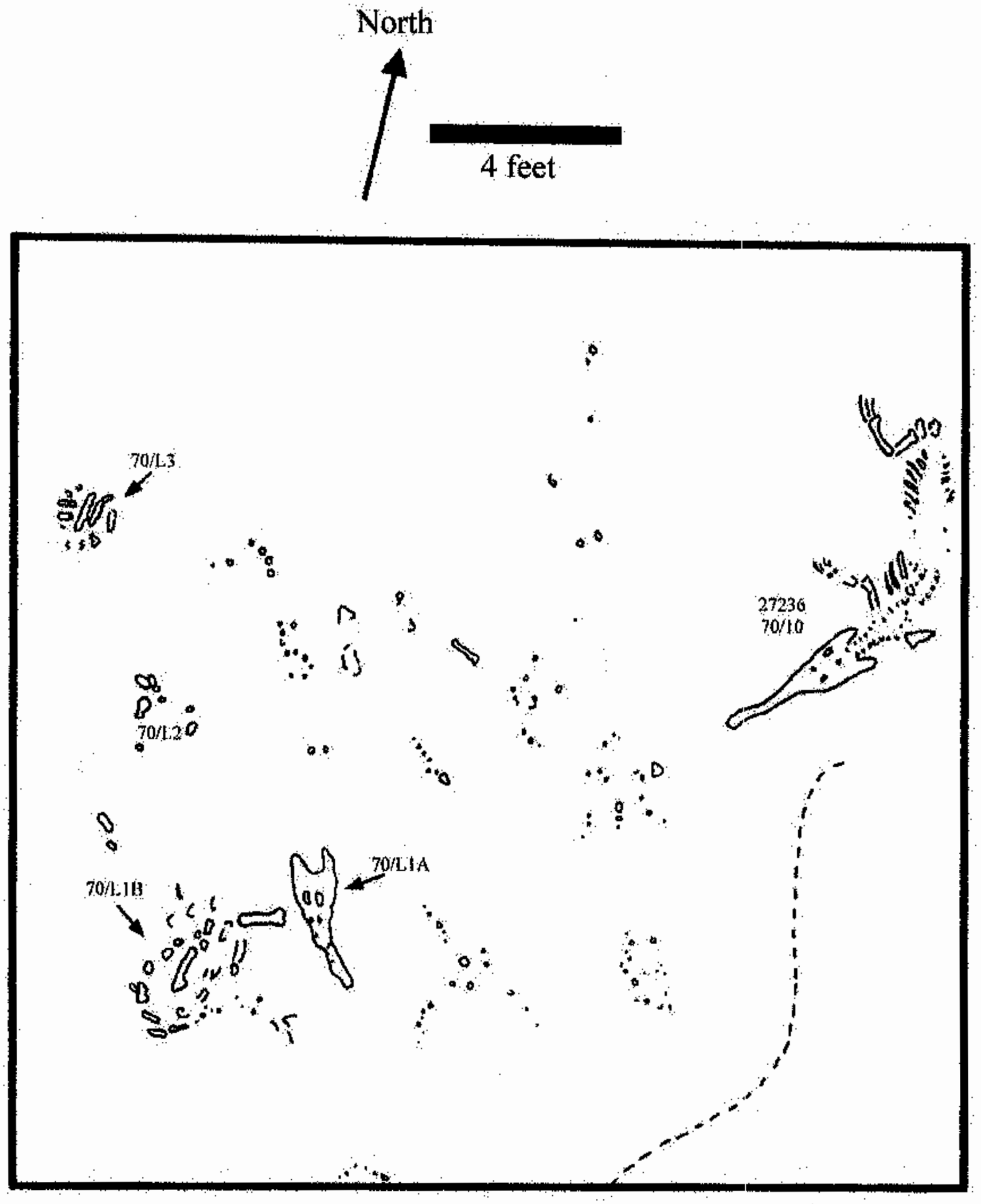


Figure A.10 Canjilon Quarry 1933 excavation grid square 70/L (perhaps 150) fragments of *Typothorax* plate scattered through the blue-gray gravel. Saved but little of this scrap plate. An occasional fragment of hind [limb?] bone with the plates and one or two elongate caudals were found mixed with the plate"(CLC 6/1/33). "I mined around my skull-skeleton block and found a number of complete gastralia adjoining it. Also, a number of phytosaur plates in very thick nodule underlie the skeleton and were taken up adjacent to it in the northwest" (CLC 6/2/33). Phytosaur scutes were also found between the 70/L1A and 70/L1B blocks (CLC 6/5/33). Most of the skeletal material was apparently removed in block 70/L1B (partly also under 34243) which is actually represented by at least *four* blocks, and includes not only articulated vertebrae but both pairs of ischia and pubes, and also an ulna and fibula which Camp may have mistakenly identified as "end of humerus and radius (or femur and tibia?)" (CLC 6/2/33). However, various other skeletal material was removed in the 70/L1A block, or listed under the field number 70/L1, presumably representing material from the same concentration. The *Typothorax* plate fragments probably are in 34253 70/L1A; as noted by Camp, none are complete. The caudal vertebrae 122370 70/L1 and 122411 70/L1 may be those found with the scute scraps. There are also many phytosaur scutes under 70/L1 and 70/L1A.

70/L2, "a mass of gastralia and other bones" was found "just to the north two feet" of the 70/L1 skull and skeleton. No gastralia were found in the 2001 inventory, but there is much appendicular material. Camp believed that this material belonged to the 70/L1 specimen. Block 70/L2A included a "large limb bone" (possibly humerus 121958) found about a foot from the 70/L1 specimen.

70/L3 was a concentration of material Camp identified as belonging to *Coelophysis*, but most identifiable material found in the 2001 inventory is *Pseudopalatus pristinus*; Camp was likely deceived by the appearance of the small, slender, and toothy jaws. Camp also believed that the small *Pseudopalatus* skull found in 70/K (34228 70/K11) belonged with this material, which is highly tenuous given the distance between them but a possibility given the similarity in size and the fact that both include *P.*

pristinus material. The 70/L3 concentration included "several vertebrae, small skin plates, and ribs" (CLC 6/7/33). An "ischium" (CLC 6/8/33) came out as its own block "70/L3C", but was not recognized in the inventory. However, there are two ischia with odd and possibly erroneous field numbers (34229 70/L11 and 119335 70/LB) which may be this element. The rest of the material apparently came out as block 70/L3B, which includes jaw material found in "one side" of the jacket (CLC 6/9/33); the anterior ends were packed in jacket 70/L1B, and may include the snout tip 34228. *Typothorax* plate was also found with 70/L3; probably not 34227 70/L3, as Camp would probably not recognize this as a potential *Typothorax* scute.

The brown paper map is used as a template for the map presented here (Fig. A.10), but some changes have been made. On the brown paper map, the concentration of bones immediately to the northwest of the 70/L1 specimen is connected by a dotted line to the small *Pseudopalatus* skull in 70/K, and may represent 70/L3, as Camp thought that this concentration and the skull actually belonged to *Coelophysis*. However, it is about where the 70/L2 concentration should be, based on Camp's notes and field map. Therefore, the mass of bone shown there and one further to the northwest on the brown paper map (where the 70/L3 concentration should be) have been switched in Fig. A.10 from the brown paper map.

On 7/11/33, Camp, Smith, and Anderson returned to 70/L, and Camp found the "tip of squamosal and fragment of lower jaw" at the east edge of the square given the field number 70/L5. An angular, splenial, and caudal vertebra were found under this number in the 2001 inventory. Anderson mentions a package of associated fragments, 70/L5B, which was not found.

Table A.11. 1933 UCMP V2816 (Canjillon Quarry) material from grid square 70/L

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
70/L1	34228		Mandible symphysis fragment	*Pseudopalatus*
70/L1	34253		Scute fragments	Phytosaur
70/L1	119371	34230	Coracoid (left, tiny)	Phytosaur?

Table A.11. Continued

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
70/L1	122370	34229	Posterior caudal vertebrae (four articulated)	Phytosaur
70/L1	122411	34229	Posterior caudal vertebra centrum (small, half)	Phytosaur
70/L1A	34253		Skull (cut transversely)	*Pseudopalatus pristinus*
70/L1A	34253		Mandible (right, mid section, vertebrae, ulna (incomplete), radius (incomplete), femur, tibia, metapodials, phalanges, scutes one expanded rib; label reads "phytosaur skull and skeleton, two blocks"	*Pseudopalatus pristinus*?
70/L1A	34253		Scute fragments (about a dozen)	*Typothorax coccinarum*
70/L1A	34227		Scute fragments; has small "I" on one side	Phytosaur?
70/L1B	34238		Ungal	?
70/L1B	34249		Rib	?
70/L1B	34253		Vertebra in articulation (including axis), in four blocks: V2-8, V9-14, V21-27, V15-20; Long and Murry, 1995, fig. 47A-C	Phytosaur
70/L1B	119324	34231	Ischium (left), parts of sacral ribs still attached, shipped in box 6	Phytosaur?
70/L1B	119324	34231	Ischium (right), has ischium peduncle and probably had both sacral ribs in articulation, though they are missing (fresh breaks)	Phytosaur?
70/L1B	119341	34235	Pubis (right)	Phytosaur?
70/L1B	119342	34231	Pubis (left)	Phytosaur?
70/L1B	121985	34234	Ulna (right, distal end)	?
70/L1B	122115	34237	Fibula (right, distal end)	Phytosaur?
70/L1B	122225		Astragalus (right)	?
70/L2	34227		Dorsal paramedian scute fragment	*Typothorax coccinarum*
70/L2	34238		Phalanx	?
70/L2	122064	34235	Femur (left, distal end); weird square outline in distal view	?
70/L2	122210	34230	Interclavicle	?
70/L2	122408	34229	Caudal vertebra centrum (small)	?
70/L2	?		Unidentifiable fragments	?
70/L2A	121958	34232	Humerus (left)	?
70/L2A	121974	34234	Ulna (left); Long and Murry, 1995, fig. 50A-D	?
70/L2A	121988	34233	Radius (left)	?
70/L3	34228		Squamosal (?) fragment, the right posterior process of a large individual	Phytosaur
70/L3	34228		Quadrate (right) of moderate size	Phytosaur
70/L3	34238		Phalanx	?

Table A.11. Continued

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
70/L3	34227		Appendicular (?) scute, rounded	*Typothorax coccinarum*
70/L3	121960	34232	Humerus (left, proximal end), shipped in box 2	Phytosaur?
70/L3	121961	34232	Humerus (left, proximal end), shipped in box 2	Phytosaur?
70/L3	122666	34236	Tibia (right, proximal end)	?
70/L3	?		Fragments (large)	?
70/L3	?		Astragalus (?) and calcaneum (?) in articulation, tibia and astragalus in articulation, other scrap	?
70/L3	158671	34227	Scute	Phytosaur
70/L3B	34228		Mandible (right), very small, probably a juvenile	*Pseudopalatus pristinus*?
70/L3B	34228		Snout (right side, snout and mandible appresed) with nares and part of jugal	*Pseudopalatus pristinus*?
70/L3B	34228		Mandible, partial right ramus	Phytosaur
70/L3B	34238		Metapodial (?) proximal end	?
70/L3B	?		Scutes in a block, kept with 34253 material	Phytosaur
70/L3B	119370	34230	Coracoid (right)	Phytosaur
70/L3B	122284	34229	Cervical vertebra centrum (small), has "V11" written on it	?
70/L3B	122280	34229	Cervical vertebra centrum (small)	?
70/L3B	122436	34229	Caudal vertebra centrum	?
70/L5	34228		Angular and splenial	Phytosaur
70/L5	34228		Vertebrae (?), possibly caudal	?
70/L11(?)	34229		Ischium (distal end)	Phytosaur?
70/L14 (?)	?		Scrap	?
70/L17 (?)	?		Jaw (?) fragments and other scrap	?
70/L38 (?)	34228		Jaw element; possibly 70/L3B?, juvenile	Phytosaur
70/L38 (?)	34228		Tooth; possibly L/3B?, in a box of about two dozen teeth	Phytosaur
70/LB(?)	34239		Rib	?
70/LB(?)	34238		Metapodial	?
70/LB(?)	34225		Posterior caudal vertebra	?
70/LB(?)	119335	34231	Ischium (left)	?
70/L (unspecified)	12268		Fibula (distal end)	*Typothorax coccinarum*
70/L (unspecified)	34228		Quadrate (left, incomplete)	Phytosaur
70/L (unspecified)	34229		Scute with vertebra spine table (?) attached	Phytosaur
70/L (unspecified)	34229		Neural arch base	?
70/L (unspecified)	34231		Skull bone fragments	Phytosaur?
70/L (unspecified)	34227		Incomplete lateral scute	*Typothorax coccinarum*

Table A.11. Continued

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
70/L (unspecified)	34240		Fibula (?) (large)	?
70/L (unspecified)	34240		Radius (half)	?
70/L (unspecified)	119362	34230	Scapula (left, small, proximal end)	Phytosaur?
70/L (unspecified)	121950	34232	Humerus (right, small, proximal end); shipped in box 12	Phytosaur?
70/L (unspecified)	122118	34237	Fibula (right, very small)	?
70/L (unspecified)	122205	34581	Clavicle (left)	?
70/L (unspecified)	122269	34229	Dorsal vertebra centrum	?
70/L (unspecified)	122345	34229	Mid-caudal vertebra centrum (large)	?
70/L (unspecified)	122346	34229	Caudal vertebra centrum	?
70/L (unspecified)	122362	34229	Caudal vertebra centrum (small)	?
70/L (unspecified)	122412	34229	Caudal vertebra centrum with base of neural arch (small)	?
70/L (?)	34228		Snout tip (right), juvenile	Phytosaur

70/M & 70/N

Both of these grid squares were virtually barren. Smith worked 70/N on 5/26/33 (presumably in upper layer 1, as this was before plowing) and found only "fragments". Camp worked both squares on 7/24/33, finding only " a toe bone and a few scraps". This may have been in lower level 2, as the second plowing took place earlier that month. The toe bone probably came from 70/N, as the only material from either square that was noted in the inventory were two phalanges from that square. The brown paper map shows what appears to be a mandible or limb bone in 70/N, but the identity of this element is a complete mystery.

Table A.12. 1933 UCMP V2816 (Canjillon Quarry) material from grid square 70/N

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
70/N1	34238		Phalanx	?
70/N (unspecified)	34238		Phalanx	?

70/P

70/P was also fairly barren. Smith worked the square on 5/30/33, and Ariss prospected and did some excavating there from 6/20/33 till 6/23/33. Ariss alludes to finding material in "70/P1" and "70/P2", so apparently the square was divided up into smaller squares, although there is not field map to show the layout or number of these subdivisions. However, he calls 70/P1 a "quarter section", so there were presumably four total.

Smith worked the square on 5/30/33, almost certainly in the upper layer 1, but found "little" according to Camp. On 6/20/33, Ariss prospected the square, according to Camp finding "little except fragments" in the layer 1. According to Ariss, he found "two skin plates, one lying in a vertical position" toward one of the edges of the square. He later (6/21/33) alludes to "finding nothing further in 70/P1", so presumably the scutes came from that square. No scutes were noted in the inventory.

Ariss spent the remainder of that day removing the "overburden", probably meaning layer 1, as his subsequent finds all came from the "top layer of red shale". Here he found "a very large tibia", probably 122081 70/P2, and soon after one end of a limb bone, probably 122055 70/P, a femur head. After this find, he dug only in "the quarter section next to 70/K", finding scarce bone material in "two levels" (levels 1 and 2?).

The brown paper map shows only what look like one of a string of vertebrae at the north end of the square leading into 70/S, and nearly all the 70/P material in the inventory consists of vertebrae. However, none are specified in the field notes.

Table A.13. 1933 UCMP V2816 (Canjillon Quarry) material from grid square 70/P

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
70/P1	34238		Metapodial	?
70/P2	122081	34236	Tibia (right); shipped in box 10	Phytosaur?
70/P (unspecified)	34229		Chevron (proximal end)	?
70/P (unspecified)	122055	34235	Femur (right?, proximal end)	Phytosaur?
70/P (unspecified)	122272	34229	Dorsal vertebra (articular end)	?
70/P (unspecified)	122325	34229	Caudal vertebra centrum (very large)	?

Table A.13. Continued

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
70/P (unspecified)	122327	34229	Caudal vertebra centrum (large, with base of neural arch)	?
70/P (unspecified)	122357	34229	Caudal vertebra centrum	?
70/P (unspecified)	122420	34229	Vertebra fragment	?
70/P (unspecified)	122423	34229	Vertebra centrum (only half, very large)	?
70/P (unspecified)	?		Thoracic vertebra fragment	?

70/Q

70/Q (Fig. A.11) was divided into four quadrants ten feet square (Fig. A.11), named 70/Q1-70/Q4, and the field numbers for material from 70/Q seem to all derive from the subdivisions in which it was found. The only map of 70/Q was made by Ariss, and identifies the types of elements plotted. This is roughly consistent with the brown paper map, but elements are spaced a little bit differently. The brown paper may was used as the template for the map given here, but elements have been shifted in position to be more consistent with Ariss's map.

Ariss first comment is that "I found more bone in place [in 70/Q] then in all of 70/A" (RMA 5/26/33). The material in 70/Q1 Ariss worked 70/Q from 5/26/02 until 6/9/33. Camp (CLC 5/26/33), who was working on the eastern side of 70/L indicates that Ariss began "next to me", probably in 70/Q1. The material recovered in 70/Q1 probably came from below layer 1. Ariss found all bone in 70/Q1 in gravel lenses (RMA 6/1/33) throughout the layer 2 red mudstone having pebbles "1/4 to 1 ½ inches in diameter" (RMA 5/30/33); the "green matrix" mentioned to by Ariss probably refers to these lenses (RMA 5/31/33). He also states that "the lensing showed up very plainly toward the boundary of the section…there was very little crystalline gypsum" (RMA 6/1/33). He notes that "the depths at which the bone lies varies from 6" to 1' below the last cut of the scraper (RMA 5/30/33). Ariss found a partial ulna (probably that plotted on the map) "in fine condition and rather softer then the material at St. John's [*Placerias* Quarry], Arizona" (RMA 5/27/33). The same day, he found "the heads of some small limb bones", though it is unclear is he is referring to elements plotted on the map. The

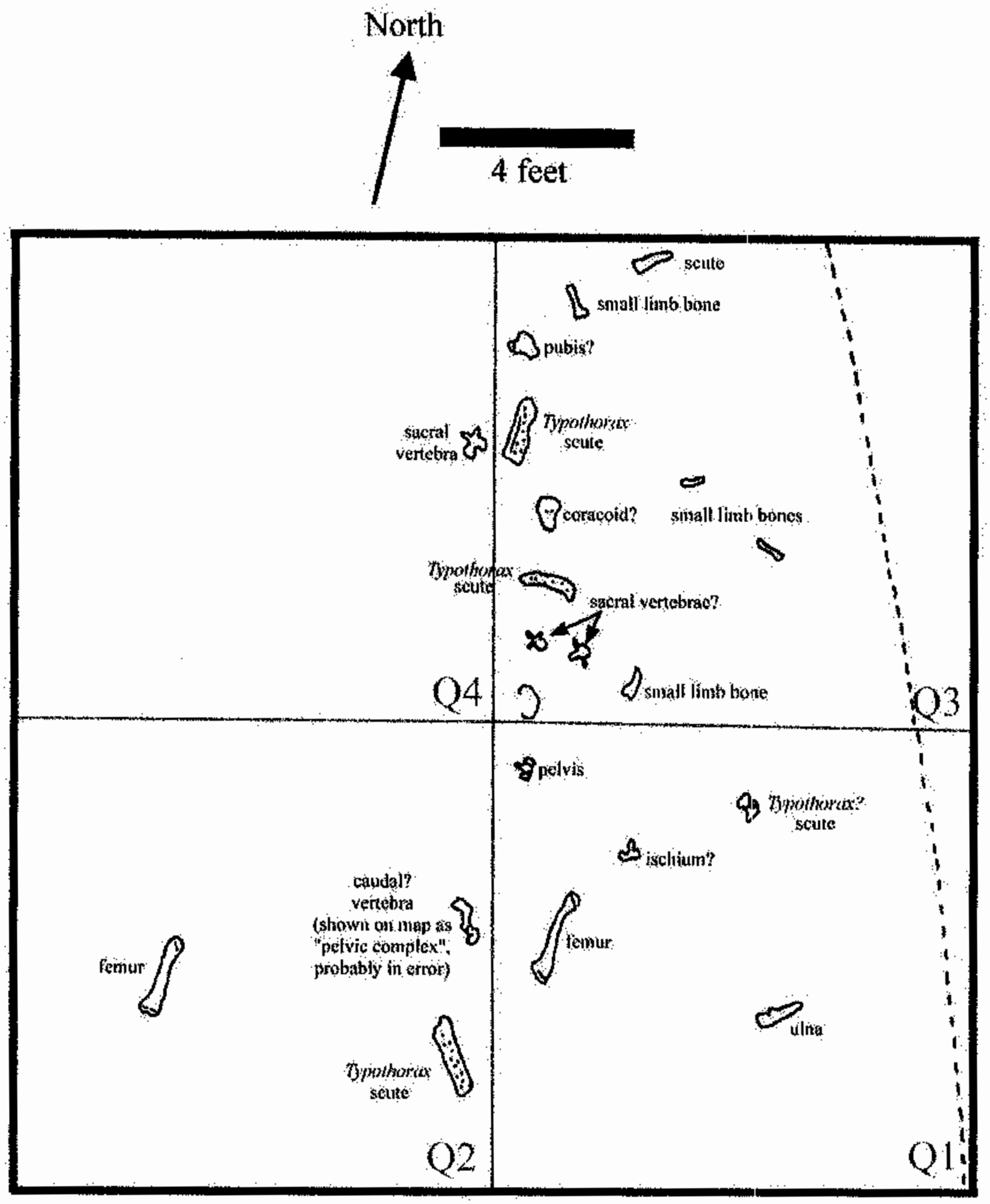


Figure A.11 Canjilon Quarry 1933 excavation grid square 70/Q femur plotted in 70/Q1 was probably "a large phytosaur femur about 1 ¼ feet long" (RMA 5/29/33). Camp suggested this was part of the 27235 70/10 skeleton (CLC 5/29/33). Ariss then notes "no sooner had I dug around the large one then I hit into a small shiny black femur no longer then 1 ½ inches…I lost the proximal end of it" (RMA 5/29/33). This smaller femur is not plotted on the map, but it is conceivable Ariss is referring to the 34238 metapodial. None of the 70/Q1 material mentioned above was identified in the 2001 inventory. A "phytosaur ischium and [another] femur" were found the next day, with "two digital bones" associated with the femur, and "two thecodont teeth". None of these seem to be plotted. Ariss found "a dermal plate…probably a *Typothorax* plate" near the south end of 70/Q1 (RMA 5/30/33). Pelvic material that "may be *Typothorax*" (CLC 5/31/33) was found and plotted in the northwest corner of 70/Q1, including "illium, ischium and pubis" (RMA 5/31/33); the ischium plotted just to the east probably refer to different elements, as Ariss afterwards mentions finding an ischium "a bit to the east of the pelvis" (RMA 6/1/33) which was labeled "CLC/RMA: 70/Q1 ischium" (RMA 6/2/33). Ariss also mentions an "easternmost dermal plate [which] is lying vertically; this may refer to the scute plotted on his map. Near this plate were two phytosaur caudal vertebrae. One of these, in a green matrix, has a high neural arch" (RMA 5/31/33). Finally, "At the very [north] edge of 70/Q1, I found a limb bone…in the red shale. It had plant roots penetrating it and it seemed a lot softer then the bones in the gravels. In the marrow, tissue had been replaced by calcite crystals" (RMA 6/6/33). This last seems therefore to be the only 70/Q1 bone not found in a gravel lens. None of this latter material mentioned after the ischium is plotted. The fibula (122109 70/Q1) found in the 2001 inventory is a complete mystery.

In 70/Q2, the material was found above a "gravel layer…dipping to the west" in the eastern part of the subsquare (RMA 6/3/33). This layer was probably a lens within the red mudstone, as Ariss also mentions, "the red shale contains some crystalline gypsum and a good deal of fossil charcoal" which yielded "no black streak when rubbed". Ariss began in 70/Q2 on 6/2/33, and found "a complete phytosaur caudal vertebra. The neural spine fell off at the centrum. South of this vertebra about one foot I uncovered a small *Typothorax* plate about 14 inches long, 5 inches wide, and ½ inch thick. It is very complete, the right hand corner being chopped off a bit." (RMA 6/2/33) It was removed in a jacket, and labeled "70/Q2 CLC RMH 6-3-33 DERM PLATE 70/Q2." (RMA 6/3/33) These elements are probably those shown at the east edge of 70/Q2. The "large phytosaur femur" was found on 6/5/33, missing its distal end. "The break was heavily coated in limestone concretion." As with the 70/Q1 fibula, the only specimen recorded from 70/Q2 in the 2001 inventory (tibia <u>122087 70/Q2</u>) is a mystery.

Ariss started in 70/Q3 on 6/6/33, noting "this bone lies in the red shale as it did in the lower part of 70/Q1. I shall go up into the greenish gravels however in case they might also contain bone." Apparently then, the initial material is from the red mudstone below the conglomeratic lenses. Ariss found "four small limb bones," (RMA 6/7/33) scattered throughout the subsection, one of which may be the tibia <u>122662 70/Q3</u>. Oddly, he also says that the first two he found were "similar to the ones marked 'L' in subsection 70/Q1," (RMA 6/6/33) even though there are no small limb bones marked thus in 70/Q1 on his map. "Toward the upper [northern?] end of 70/Q3 I found a *Typothorax* dermal plate." On the day he completed the subsection (RMA 6/7/33), Ariss notes "the general level of the green gravel is dipping westward in the section much faster then in the southern half section. All that I have found yet [in the gravels?] as yet is a fragmentary neural spine. In addition to the above bones in 70/Q3, I found another *Typothorax* plate" (RMA 6/7/33) which was "very close to the upper [northern?] edge of the subsection," (RMA 6/8/33) and was removed in a jacket labeled "70/Q3 CLC/RMA 6-8-33." One or both of these scutes are probably the <u>34227 70/Q3</u> fragments. Ariss also found "a phytosaur radius [not shown], and a complex of bones which are of uncertain nature," (RMA 6/7/33) which he later states "were very likely sacral vertebrae" which could not be identified. "A phytosaur coracoid and pubis also came from this area," (RMA 6/7/33) but the element identified as a pubis on his map may be "the group of bone right above [north of?] the plate [which] may belong to *Typothorax*, for as of yet no one has identified it. The bone resembles a phytosaur pubis in being rather flattish, with what appears to be heads upon it."

No material is mentioned by Ariss as having come from 70/Q4 in his field notes. Ariss's map shows it as being empty except for a sacral vertebra found at the very eastern edge. No 70/Q4 material was recorded in the 2002 inventory.

Table A.14. 1933 UCMP V2816 (Canjillon Quarry) material from grid square 70/Q

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
"70/Q1"			"Ischium"	?
70/Q1	122109	34237	Fibula (left)	?
"70/Q2"			"Dermal plate"	?
70/Q2	122087	34237	Tibia (right, small)	?
70/Q3	34227		Dorsal paramedian scute fragments (two, both large), may go together	*Typothorax coccinarum*
70/Q3	122662	34236	Tibia (left)	?
70/Q6?	34238		Metapodial? (fragmentary); the field number is probably a typo	?
70/Q (?)	34229		Vertebral spine base (probably thoracic)	?

70/R, 70/S, 70/T

Nothing is mentioned in the field notes regarding any of these squares, and the inventory produced only one specimen each for the first two squares. Both field numbers are hard to read, and may be in error. The brown paper map shows a phytosaur skull in 70/R missing the snout, a string of possible vertebrae in 70/S leading into 70/P, and what may be a single vertebra in 70/T. None were recognized in the inventory, and their identity is a mystery.

Table A.15. 1933 UCMP V2816 (Canjillon Quarry) material from squares 70/R and 70/S

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
70/R?	122667	34237	Fibula (left)	Phytosaur?
70/S24	34228		Basioccipital (tiny)	Phytosaur?

70/U

The material from 70/U (Fig. A.12) belongs almost entirely to two skeletons, *Typothorax coccinarum* and *Pseudopalatus buceros*, which lay together (Fig. A.13), although some skull material probably belonging to a *P. pristinus* specimen is also within the concentration. The *Typothorax* "U" specimen is the largest individual of that taxon in the quarry, the least disarticulated (it includes the two tail blocks described previously), and is also unique in that nearly all material identified as belonging to it share a single specimen number, 34255. The *P. buceros* material is probably represented by multiple specimen numbers, but the best material from the skull and anterior part of the skeleton is mostly under 34258. Both specimens were discovered and mostly excavated by Natasha Smith, whose notes unfortunately could not be located at UCMP. However, Camp, Ariss, and Sam Welles, all of whom assisted her, kept some notes, although there are unfortunately no field inventories giving field numbers not recognized in the 2001 inventory. These two skeletons have the best field map (Fig. A.12), which is remarkably detailed. Comparison of these field numbers with those of the inventory indicated that the *Typothorax* material lies to the south side of the concentration, and the *Pseudopalatus* material mostly to the north. On the brown paper map, it appears as though only a single phytosaur skeleton is present, but the posterior region and tail belong to the *Typothorax*. Moreover, the phytosaur skull itself is mostly disarticulated, although the skull material is associated. 70/U was subdivided into grids about 5 feet square (Figs. A.11, A.12), with the grid lines (rather then the squares themselves) being lettered. Most of the material was collected in blocks.

These specimens are also unusual in that they both occur in the upper conglomeratic level 1, as is stated explicitly by Camp (CLC 6/30/33, 7/21/33), which also probably contained all of the other 70/U material "in the vicinity." Camp also specifically noted (7/13/33) that the lower level in 70/U was barren; however, material was found after the skeletons had been blocked and the second plowing, and may therefore come from the lower mudstone level 2. The upper conglomerate layer 1 in

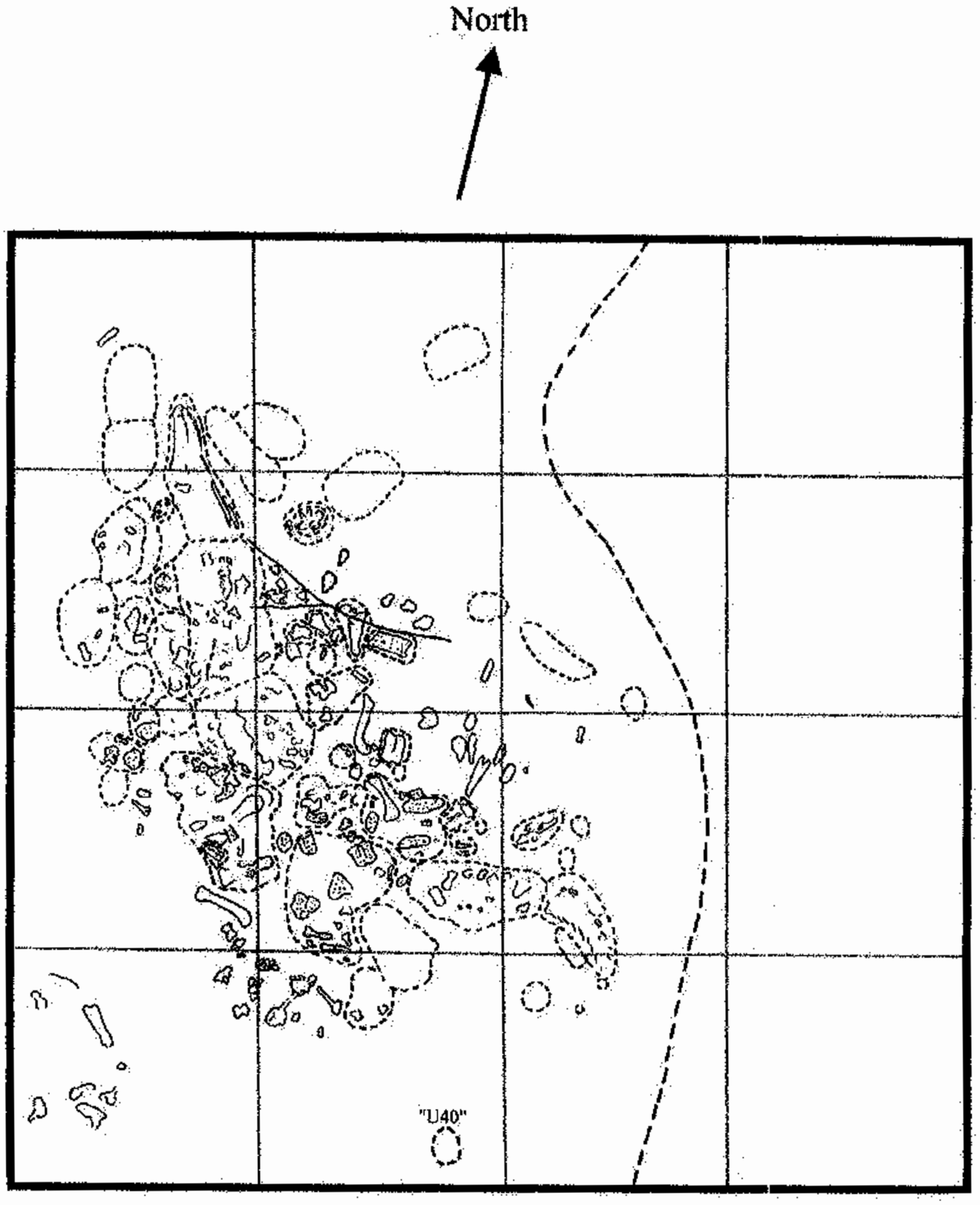


Figure A.12 Canjilon Quarry 1933 excavation grid square 70/U

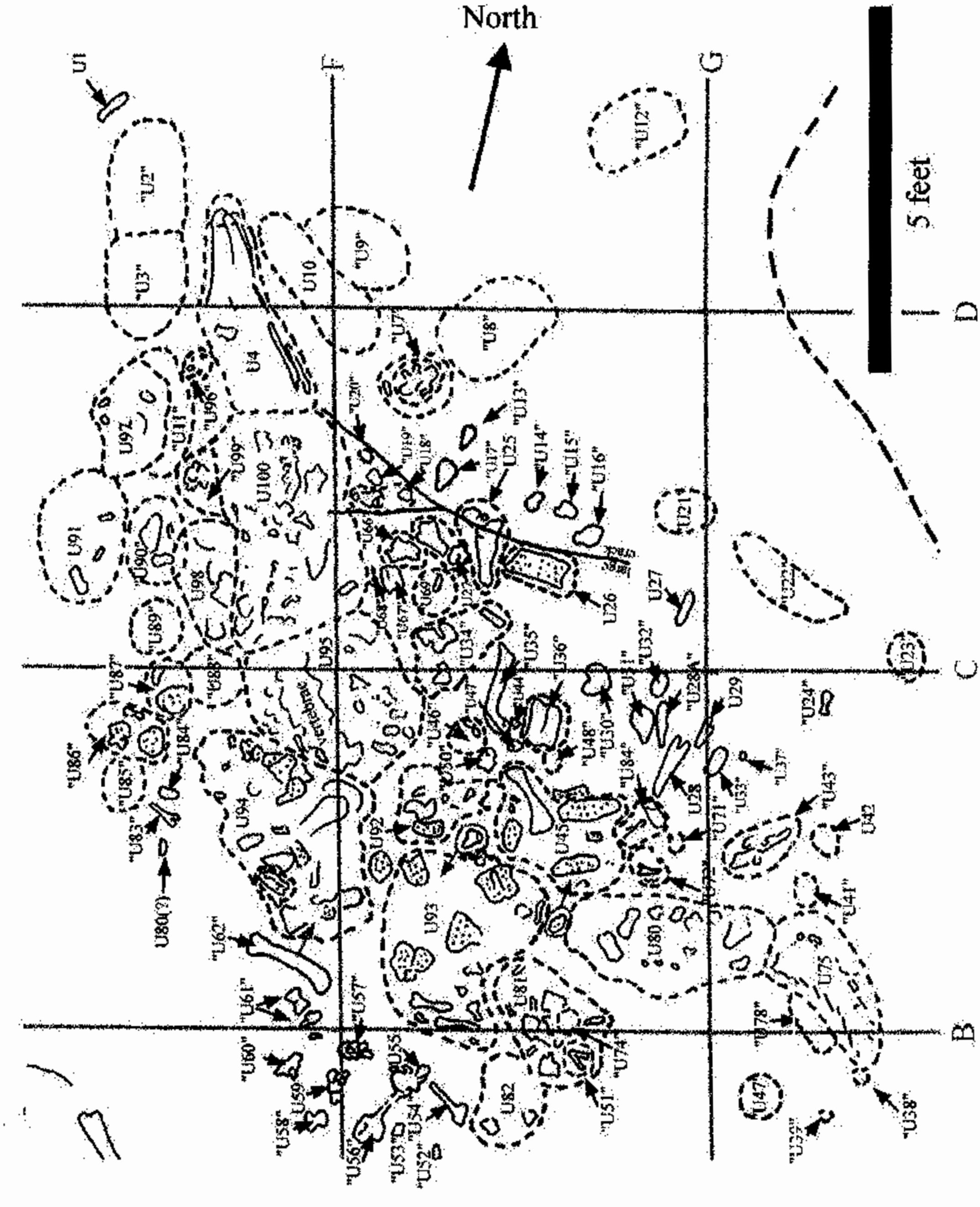


Figure A.13 Canjilon Quarry 1933 excavation "U specimen" (34255) of *Typothorax coccinarum*, and 34258 (and other numbers) *Pseudopalatus buceros*.

70/U may have been a gray in color here (Camp talks about material in "gray matrix"), but Ariss (7/5/33) describes it as green. Ariss (RMA 6/12/33) notes that the skeletons were "on a slight rise. Where I am working, the level dips rapidly away to the north." Ariss (RMA 6/14/33) also notes "the material toward the eastern edge of the section [close to the edge of the quarry] is very much weathered that it crumbles easily."

Smith's first find in70/U consisted of "a tibia, a phytosaur vertebra, and a few fragments." (CLC 6/2/33) The skull and anterior vertebral column of the *P. buceros* were found shortly thereafter (CLC 9/9/33), [with] several small plates *Typothorax* plates scattered throughout the pelvic region." (CLC 6/12/33) The skull and anterior vertebral column lies in block <u>70/U4</u> and <u>70/U100</u>, and the posterior presacral and pelvic region latter seems to have lain in blocks <u>70/U94</u> and <u>70/U95</u>; the latter do indeed do include some *Typothorax* scute fragments. "These plates are not found elsewhere in the immediate vicinity except as scrap fragments in the gray matrix." Camp (6/12/33) describes the limb material as including "a very elongate tibia, femur, and distal end of tibia which is provided with ridged, striated bone surfaces as in *Episcoposaurus* [*Desmatosuchus*] from St. John's [the *Placerias* Quarry]." The latter may belong to *Typothorax*, although the only tibia of that specimen recognized in the inventory was complete. Ariss (RMA 6/12/33) also found a tibia working on the skeleton; "Dr. Camp thinks that the foot will most likely be in place," but he only found a calcaneum slightly to the east (RMA 6/13/33); these may be those elements belonging to the *Typothorax* skeleton, but this is not clear. The tail of the *Pseudopalatus* specimen is probably represented by the vertebra in <u>70/81</u>, which are probably the "(about 14 [caudals] that were previously hidden)" mentioned by Camp (CLC 6/27/33), and also material included in <u>70/U82</u> and <u>70/U93</u>.

Material was also found in the southwest corner of 70/U (Fig. A.11). Ariss (6/12/33) notes "A little to the southwest of the skeleton proper I found what seems to be an occipital condyle amongst other skull elements." This latter is likely <u>34228 70/U</u> (unspecified), a partial occipital condyle and right exoccipital of a phytosaur. Probably also referring to this material, Ariss (6/13/33) notes "About 3' from the south boundary of 70/U were two vertebrae. On the very edge was a crushed vertebra and a limestone [concretion] encased toe bone." This material, if in the collections, is probably part of the 70/U (unspecified) material.

Sam Welles "uncovered some large Typothorax plates and left half on shoulder girdle of a large phytosaur... [the next day] uncovered the other half of his shoulder girdle with a portion of the interclavicle lying between." (CLC 7/14/33-7/15/33) This was recovered after the jackets for the skeletons were completed and the second plowing, so it is likely this was found in the lower level. However, none of this pectoral material was recognized in the 2001 inventory.

Table A.16. 1933 UCMP V2816 (Canjillon Quarry) material from grid square 70/U

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
70/U1	34258		Scute	Phytosaur
70/U4	34258		Mandible (left) and maxilla	*Pseudopalatus buceros*
70/U4	34258		Jaw fragment	*Pseudopalatus buceros*
70/U4	34258		Ectopterygoid	*Pseudopalatus buceros*
70/U4	34258		Mandible (missing left ramus and part of right ramus); in oversize cabinets	*Pseudopalatus buceros*
70/U4	122233	34229	Atlas fragment	*Pseudopalatus buceros*
70/U4	122235	34228	Unidentifiable bone fragment	?
70/U4	?		Rib	?
70/U10	122417	34229	Mid-caudal vertebra centrum (parts of neural arch attached)	Phytosaur?
70/U10	122428	34229	Dorsal centrum	Phytosaur?
70/U25	34231		Probable scapula	Phytosaur?
70/U25	34235		Femur (left, distal end)	Phytosaur?
70/U25	34238		Ungal	?
70/U26	34227		Dorsal paramedian scute (incomplete)	*Typothorax coccinarum*
70/U27	122211	34230	Interclavicle (fragment)	?
70/U28	34228		Snout (posterior part)	*Pseudopalatus pristinus*
70/U29	34228		Snout (anterior part)	*Pseudopalatus pristinus?*
70/U29(?)	34228		Snout fragment	*Pseudopalatus pristinus*?
70/U42	34238		Metapodial	?
70/U42	34238		Proximal radius?	?
70/U45	34227		Dorsal paramedian scutes (several large), lateral scutes, scute fragments	*Typothorax coccinarum*
70/U45	34238		5th metatarsal	?

Table A.16. Continued

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
70/U45	122080	34236	Tibia (right)	Phytosaur?
70/U55	34238		Rib	?
70/U55	34238		Metapodial; based on the field map, this and the following seem to be a single mass of foot bones.	?
70/U55	34238		Phalange	?
70/U55	34239		Cervical rib	?
70/U55	122217	34238	Calcaneum (right, large)	?
70/U55	122336	34229	Caudal centrum	?
70/U59	122335	34229	Caudal centrum	?
70/U75	34255		Articulated distal tail section, including dorsal paramedian, lateral, and ventral scutes, and some poorly exposed caudal vertebrae. There are also isolated scute fragments and a possible ischium (left).	*Typothorax coccinarum*
70/U80	34255		Articulated series of partial dorsal paramedian, lateral, and possible appendicular scutes, probably from the pelvic region.	*Typothorax coccinarum*
70/U80	34227		Dorsal paramedian (large) and articulated lateral scute fragments, possible ventral and appendicular scutes, rib fragments.	*Typothorax coccinarum*
70/U80	34255		Scapulocoracoid (left); Long and Murry, 1995, fig. 104, 105A-B	*Typothorax coccinarum*
70/U80	34255		Illium (left); Long and Murry, 1995, fig. 106A, 107	*Typothorax coccinarum*
70/U80	34255		Femur (left)	*Typothorax coccinarum*
70/U80	34255		Tibia (left); Long and Murry, 1995, fig. 111D	*Typothorax coccinarum*
70/U80	34255		Calcaneum (left)	*Typothorax coccinarum*
70/U81	34229		Caudal vertebra; this and the following may have been in articulation due to the numbering.	Phytosaur
70/U81 “#2”	34229		Caudal vertebra; larger then that just listed, but smaller then “#4”	Phytosaur
70/U81 “#3”	122315	34229	Caudal vertebra (complete)	Phytosaur
70/U81 “#4”	34229		Caudal vertebra	Phytosaur
70/U81 “#5”	122318	34229	Caudal centrum, no spine	Phytosaur
70/U81 (?)	122313	34229	Caudal vertebra (anterior); the field number on this and the following caudals is hard to read, but based on the specimen number the “U/81” is probably correct	phytosaur?
70/U81 (?)	122314	34229	Caudal vertebra, complete	phytosaur?
70/U81 (?)	122333	34229	Caudal vertebra centrum	?
70/U82	34229		Caudal vertebra neural spine	?
70/U82	122312	34229	Caudal vertebra, complete	?

Table A.16. Continued

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
70/U91	122289	34229	Sacral vertebra centrum (left)	?
70/U92	34227		Dorsal paramedian scute fragment, two articulated lateral scutes with huge anterior bars.	*Typothorax coccinarum*
70/U92	122287	34229	Sacral vertebra centrum (left)	?
70/U92	122287	34229	Sacral rib (left)	?
70/U93	34238		Phalange	?
70/U93	34238		Metapodial	?
70/U93	34240		Humerus fragment, distal end	*Typothorax coccinarum*
70/U93	122117	34237	Fibula (left, proximal end)	?
70/U93	122331	34229	Mid-caudal vertebra, lacking neural spine	?
70/U93	122348	34229	Mid-caudal vertebra centrum	?
70/U94 (?)	34258		Tibia (right)	Phytosaur
70/U94	34258		Illium (distal part), phalanx, fibula	Phytosaur
70/U94	34258		Illium (left acetabulum), fragments of illium (right)	Phytosaur
70/U94	34258		Unidentifiable bone fragment	?
70/U94	34258		Vertebra centrum, scute, metapodial	Phytosaur?
70/U94	34258		Vertebra (?) fragments (five)	?
70/U94	34258		Metapodials (two), numerous teeth	Phytosaur
70/U94	34258		Dorsal paramedian scute fragments	*Typothorax coccinarum*
70/U94	34238		Femur (left, large); possible "U62", which was placed inside the U/94 jacket.	Phytosaur
70/U95	34239		Rib	?
70/U95	34258		Thoracic dorsal vertebrae	Phytosaur?
70/U95	34258		Scute, with fragment of other element attached	Phytosaur
70/U95	34258		Central gastral ribs	Phytosaur?
70/U95	34258		Vertebra	Phytosaur?
70/U95	34258		Rib fragments	Phytosaur?
70/U95	119344	34231	Pubis fragment (left)	Phytosaur
70/U95	?		Various fragments, mostly scutes	Phytosaur mostly, one *Typothorax coccinarum*
70/U97 (?)	34228		Snout fragment	*Pseudopalatus buceros*?
70/U97	34258		Rostral crest fragment	*Pseudopalatus buceros*?
70/U98	121981		Ulna (right, distal end, very large)	Phytosaur
70/U98	121994	34233	Radius (distal end)	Phytosaur
70/U98	137201	122098, 34235	Femur (proximal end, large)	Phytosaur
70/U100	34258		Articulated vertebrae (posterior cervical and anterior dorsals), ulna, interclavicle, much of the shoulder girdle (damaged), part of humerus; in oversize cabinets	*Pseudopalatus buceros*
70/U100	34229		Neural arch base (fragmentary)	Phytosaur?

Table A.16. Continued

FIELD #	SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
70/U100	34258		Ulna (proximal end, very large)	Phytosaur?
70/U100	34258		Articulated vertebra centra (two)	Phytosaur?
70/U100	34258		Neural spine with table	Phytosaur?
70/U100	34258		Scute	Phytosaur
70/U100?	34258		Miscellaneous skull fragments, vertebra fragments, six large posterior cervicals with attached ribs, articulated with anterior dorsals, in-situ scutes; associated notes unclear, says "w U100"	Phytosaur
70/U (unspecified)	34228		Snout tip fragment	Phytosaur?
70/U (unspecified)	34228		Occipital condyle fragment with exoccipital (right) attached	Phytosaur?
70/U (unspecified)	34238		Metapodial (robust)	?
70/U (unspecified)	34238		Ungal	?
70/U (unspecified)	121948	34232	Humerus (right, distal end)	Phytosaur
70/U (unspecified)	121971	34234	Ulna (right)	Phytosaur?
70/U (unspecified)	121986	34234	Ulna (right shaft)	Phytosaur?
70/U (unspecified)	122084	34236	Tibia (right, small)	Phytosaur?
70/U (unspecified)	122110	34237	Fibula (left)	Phytosaur?
70/U (unspecified)	122317	?	Caudal vertebra centrum	?
70/U (unspecified)	122319	34229	Caudal vertebra centrum	?
70/U (unspecified)	122321	34229	Caudal vertebra centrum	?
70/U (unspecified)	122328	34229	Caudal vertebra centrum	?
70/U (unspecified)	122330	34229	Cervical vertebra centrum	?
70/U (unspecified)	122337	34229	Caudal vertebra centrum	?
70/U (unspecified)	122343	34229	Caudal vertebra centrum	?
70/U (unspecified)	122433	34229	Vertebra centrum (half)	?
70/U (?)	119333	34231	Ischium peduncle (right)	Phytosaur?
70/U (?)	122212		Scapula blade	Phytosaur?
?	34255		Metapodials (two), labeled "III" and "IV"; assigned to 70/U based on specimen number alone	?
?	?		Quadrate (left, large distal part), large radius with scute; probably go with 70/U *Pseudopalatus*	Phytosaur

70/W (X)

70/W and 70/X refer to the same grid square; Ariss's notes (6/15/33) note that "70/W is the northwest corner of 70/X of C.L.C. notes." Ariss worked the square with Smith from 6/14/33-6/15/33, finding only "four teeth and one vertebra in the entire plot," probably in the upper layer, and possibly in the northeast corner of the square. Later excavations by Ariss (7/13/33) yielded nothing at any level in the square. No material from 70/W (X) was noted in the 2001 inventory.

Material probably recovered in 1928 and 1930

The field notes by Camp and his assistants from these earlier years has not yet been examined in detail by the author. Unlike the 1933 excavation, material recovered during 1928 and 1930 has the locality number (70 or 71) over a number rather then a grid letter (e.g. 70/10). This material will not be discussed in detail here.

Table A.17. 1928 and 1930 UCMP V2816 (Canjillon Quarry) material

FIELD #	SPECIMEN #	ELEMENT	I.D.
70/3	34227	Vertebral fragments and other fragments, in a box	?
70/3(?)	34238	Phalanx	?
70/5-1	?	Limb bone and vertebra fragments	?
70/6	?	Splenial fragment, other mandible fragments, unidentifiable float scrap	Phytosaur
70/7	27234	Skull, largely reconstructed	*Pseudopalatus pristinus*
70/7	?	Humerus (proximal end), other fragments	Phytosaur?
70/7	?	Unidentifiable bone fragments	?
70/10	27235	Skeleton; on display, badly damaged. In or near grid square 70/L	*Pseudopalatus pristinus*
70/10	27235	Fragments from the east of the skull; includes mandible fragments, thoracic and caudal vertebrae	*Pseudopalatus pristinus*?
70/10	27235	Incomplete thoracic and caudal vertebrae, ribs, gastral ribs, other mostly unidentifiable scrap. "Block 3 fragments" include limb bone fragments, vertebrae, isolated neural spines, a scute. "Block 6 and 7 fragments" include small	Phytosaur?
		vertebral fragments, unidentifiable rib fragments, small gastral ribs; this material probably goes with the skeleton	
70/10	34227	Scute	Phytosaur
70/10	?	Mandible fragment, very fragmentary vertebra, sacral rib, eroded sacral rib fragment, found "just west of skull"	Phytosaur?
70/8	?	Unidentifiable bone fragments	?
70/9	?	Unidentifiable bone fragments	?
70/70	121992, 24223	Radius (right)	?
70/524	122410, 34229	Mid-caudal vertebra (small)	Phytosaur?

Table A.17. Continued

FIELD #	SPECIMEN #	ELEMENT	I.D.
71	?	Miscellaneous fragments, including a large triangular scute boss, possibly an aetosaur (resembles *Desmatosuchus*), a vertebral centra	?
71/1	27228	Dorsal vertebrae (four), unidentifiable bone fragments (identified previously as "*Typothorax* skull fragments"), 1928 collection	Phytosaur
71/2	27229	Mandible (?) fragments	Phytosaur?
71/2	?	Skull (?) fragment	?
71/3	27230	Palate, lacks dorsal skull and snout	Phytosaur
71/4	27231	?; Only known from note in drawers saying kept in oversize cabinets, but not located there	?
71/5	27232	Scutes	*Typothorax coccinarum*
71/5	27232	Ischium or pubis fragments, tibia (proximal end), vertebra (large)	Phytosaur?
72	?	Ischium (peduncle)	?
75	?	Mandible and vertebra fragments, scute fragments from *Typothorax*	?
75/2	?	Femur (proximal end), humerus (proximal end), femur (distal end), vertebra fragments, other scrap	?
75/3	?	Mostly limb bone fragments, other scrap	?

Material without any field numbrers

Some material lacking any field number can still be plotted to some extent in unusual cases then the same specimen number is mentioned in the field notes (as with the 34246 *Pseudopalatus* skull from 70/C), or is consistently associated with material from a certain area (as with 34255, which is restricted to the "U" *Typothorax* specimen). Such specimens are listed with the material they are probably associated with.

Table A.18. UCMP V2816 (Canjillon Quarry) material without field numbers

SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
27231		Skull, oversize cabinets; Long and Murry, 1995, fig. 40A-41A	*Pseudopalatus pristinus*
27232		Vertebrae (some small), sacral ribs (two), coracoid fragments, humerus (distal end, small), radius fragments, probably not associated with the humerus due to size difference, pubis fragment, tibiae (two, fragments, fairly small), other limb bone fragments; this material may go with 71/5	Phytosaur
27233		Premaxilla (badly eroded), humerus (proximal end), natural cast of "*Typothorax* olfactory tract" (uncertain of true identification); all apparently 1928 float.	Phytosaur
27235		Rib, mandible fragment, various unidentifiable fragments	?
34227		Scute, collected by RMA	Phytosaur
34227		Scutes (three, two of the fragments are large)	Phytosaur
34227		Scute (unprepared)	Phytosaur
34227		Mandible fragments (one collected by RMA), dorsal vertebrae	Phytosaur
34228		Mandible symphysis fragment	Phytosaur
34228		Mandible (?) fragment (small)	Phytosaur?
34228		Splenials (two), other mandible fragments	Phytosaur
34228		Quadrate (left)	Phytosaur
34228		Mandible fragments	Phytosaur
34228		"Thecodont skull and jaws"	?
34229		Vertebra fragment (small, possible juvenile)	Phytosaur?
34229		Thoracic neural spine bases (three)	?
34229		Neural spine top, with table	?
34229		Neural spine bases (two)	?
34229		Neural spine top	?
34229		Neural spine	?
34229		Chevron fragments (two)	?
34229		Neural arch bases (two)	?
34229		Neural arch top	?
34229		Chevron bases (two)	?
34230		Ischium or pubis (articulated)	?
34230		Vertebra centra (two)	?
34230		Ischium, including pubis symphysis	?
34235		Cervical vertebra centrum, collected by RMA	Phytosaur?
34235		Hyoid (?)	?
34237		Fibula (?) proximal end	?
34238		Unidentifiable bone fragment	?
34238		Fifth metacarpal (right)	?
34238		Phalanx (in good condition)	?
34238		Fifth metatarsal (tiny)	?
34238		Phalanges (about two dozen), and four ungals	?
34238		Carpal or tarsal block (?)	?

Table A.18. Continued

SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
34238		Metapodials and ungals (about three dozen)	?
34238(?)		Metapodial with another bone attached; labeled "II"	?
34238(?)		Pelvic bone, very odd, not phytosaur; labeled "V"	?
34239		Rib fragments	?
34239		Rib (expanded type)	?
34239		Rib (expanded type broken tip), probably goes with one of the others	?
34240		Ulna (proximal end, fairly large)	Phytosaur?
34240		Humerus (distal end)	*Typothorax coccinarum*
34240		Ulna (?)	?
34240-1		Humerus (distal end)	?
34248		Femur	*Typothorax coccinarum*
34248		Scute fragments	*Typothorax coccinarum*
34248(?)		Semi-articulated foot material; Long and Murry, 1995, fig. 109 (in part)	*Typothorax coccinarum*?
34249		Cervical rib	Phytosaur?
34250		Mandible fragments (left and right, juvenile)	Phytosaur
34252		Mandible ramus (right); in oversize cabinets	*Pseudopalatus pristinus*?
34252		Mandible ramus (left) with part of another left (?) ramus attached	Phytosaur
34252		Mandible ramus	Phytosaur
34253		Rib and gastral rib fragments	?
34253		Ribs fragments and other fragments	?
34258		Pelvic bone (very large)	Phytosaur?
34258		Vertebra? fragments, probably cervical	?
34258		Rib, various fragments	?
34258		Fragments, mostly scutes	Phytosaur
34259		Scute fragments	*Typothorax coccinarum*
119331	34231	Ischium (articular end)	?
119346		Ichium (right, acetabulum)	?
119367	34230	Scapula (right); has "G" or "K" written on it	Phytosaur
119368	34230	Coracoid (right)	Phytosaur
121944		Humerus (large, damaged), associated fragments	Phytosaur
121953	34232	Humerus (left)	Phytosaur?
121980	34234	Ulna (right, proximal end)	?
121983		Ulna (distal end)	?
121984		Ulna (distal end)	?
121991	34233	Radius (right)	?
121997		Radius (distal end)	?
122046	34235	Femur (right, distal end)	Phytosaur?
122054	34235	Femur (right, proximal end)	Phytosaur?
122067	34235	Femur (left, very large, lacks distal end)	Phytosaur?
122076	34235	Femur (right)	Phytosaur
122077	34235	Femur (right)	Phytosaur?
122089	34236	Tibia (right, distal end)	Phytosaur?
122214	34230	Scapula blade	?

Table A.18. Continued

SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
122215	34230	Clavicle blade fragment	?
122219	34238	Calcaneum (right, lacks heel)	Phytosaur?
122220	34238	Calcaneum (right, lacks heel)	Phytosaur?
122229	34248	Calcaneum (left)	*Typothorax coccinarum*
122230		Astragalus (?)	?
122234	34229	Atlas centrum fragment	?
122236	34229	Atlas (?) fragment	?
122252	?34229	Dorsal vertebra (complete)	Phytosaur?
122265	34229	Dorsal vertebra centrum	?
122268	34229	Caudal vertebra centrum	?
122269	34229	Caudal vertebra (small)	?
122276	34229	Dorsal vertebra centrum (small)	?
122277	34229	Dorsal vertebra centrum (small)	?
122278	34229	Dorsal vertebra centrum	?
122279	34229	Cervical vertebra centrum (small)	?
122281	34229	Cervical vertebra centrum and transverse process; labeled "V7"	?
122285	34229	Dorsal vertebra centrum (small); labeled "V11"	?
122288	34229	Cervical vertebra (complete)	?
122290	34229	Sacral vertebra centrum	?
122291	34229	Caudal vertebra (anterior)	?
122293	34229	Caudal vertebra centrum	?
122295	34229	Vertebra centrum	?
122301	34229	Sacral vertebra (small)	?
122304	34229	Vertebra centrum (small)	?
122307	34229	Caudal vertebra (anterior)	?
122308	34229	Sacral centrum (small)	?
122309	34229	Sacral centrum (small)	?
122310	34229	Sacral centrum (small)	?
122311	34229	Vertebra centrum (small); labeled "V24"	?
122316	34229	Caudal vertebra, no neural spine	?
122323	34229	Caudal vertebra centrum (large)	?
122324	34229	Caudal vertebra with transverse process (large)	?
122326	34229	Cervical vertebra centrum (large)	?
122334	34229	Mid-caudal vertebra (complete); U93 or J93?	?
122338	34229	Caudal vertebra centrum	?
122339	34229	Caudal vertebra centrum	?
122341	34229	Caudal vertebra centrum	?
122342	34229	Dorsal vertebra centrum	?
122347	34229	Posterior caudal vertebra	?
122350	34229	Posterior caudal vertebra	?
122351	34229	Posterior caudal vertebra	?
122356	34229	Caudal vertebra centrum (small)	?
122360	34229	Caudal vertebra centrum, with base of neural arch	?
122366	34229	Caudal vertebra (small, complete)	?
122368	34229	Caudal vertebra (small, lacking spine)	?

Table A.18. Continued

SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
122372	34229	Caudal vertebra centrum (small)	?
122375	34229	Caudal vertebra centrum	?
122376	34229	Caudal vertebra centrum	?
122386	34229	Caudal vertebra centrum	?
122387	34229	Caudal vertebra centrum (small)	?
122390	34229	Caudal vertebra centrum	?
122392	34229	Caudal vertebra centrum	?
122393	34229	Dorsal vertebra centrum (half)	?
122396	34229	Anterior caudal vertebra	?
122397	34229	Caudal vertebra centrum	?
122400	34229	Caudal vertebra centrum	?
122401	34229	Mid-caudal vertebra centrum	?
122402	34229	Caudal vertebra centrum (half)	?
122403	34229	Mid-caudal vertebra centrum	?
122404	34229	Posterior caudal vertebra centrum (small)	?
122405	34229	Caudal vertebra centrum (small)	?
122407	34229	Anterior caudal vertebra centrum (small)	?
122409	34229	Mid-caudal vertebra centrum	?
122413	34229	Caudal vertebra centrum (half, small)	?
122426	34229	Dorsal vertebra centrum (incomplete)	?
122431	34229	Dorsal vertebra centrum (half)	?
122435	34229	Vertebra centrum (half)	?
122438	34229	Dorsal vertebra centrum	?
122440	34229	Caudal vertebrae (round articular faces)	?
122441	34229	Caudal vertebrae (round articular faces); shipped in box 11	?
122443	34229	Vertebra centrum	?
122445	34229	Caudal vertebrae (round articular faces)	?
122450	34229	Caudal vertebrae (round articular faces)	?
122456		Vertebrae (two); kept with 122455 70/H vertebrae, possibly associated	Temnospondyl?
122457		Vertebrae (two, one incomplete); kept with 122455 70/H vertebrae, possibly associated	Temnospondyl?
122658	34236	Femur (right, big, missing distal end); Long and Murry, 1995, fig. 51)	*Pseudopalatus*
122663	34236	Tibia (left, proximal end)	?
122664	34236	Tibia (right, distal end)	?
129927		Ungal	?
137200	12228, 34229	Caudal vertebra (round articular faces); labeled "V11"	?
137202		Phalanx or limb bone (extremely tiny)	?
158673		Pelvis (incomplete)	*Typothorax coccinarum*
158674		Articulated metapodials and phalanges	?
"36/26"		Caudal dorsal paramedian scute	Aetosaur
?		Clavicle and other unnumbered fragments	Phytosaur
?		Mandible symphysis (anterior 2/3)	Phytosaur

Table A.18. Continued

SPECIMEN #	PREVIOUS #	ELEMENT	I.D.
?		Posterior mandible (right)	Phytosaur
?		Sacrum (distorted)	*Typothorax coccinarum*?
?		Mandibular fragment (large)	Phytosaur
?		Skull fragments (cheek region, paroccipital process and upper temporal bar), large endocast (?); miscellaneous appendicular float; humerus (distal end), ulnae (three proximal ends), femora (shaft, distal end), tibiae (proximal end, distal end), tibia or fibula (distal end, small), metatarsal fragments, other limb fragments much of which is small	Phytosaur
?		Mandible (right tip); unprepared, kept with 34228 (mostly 70/G) skull fragments, probably not associated	Phytosaur