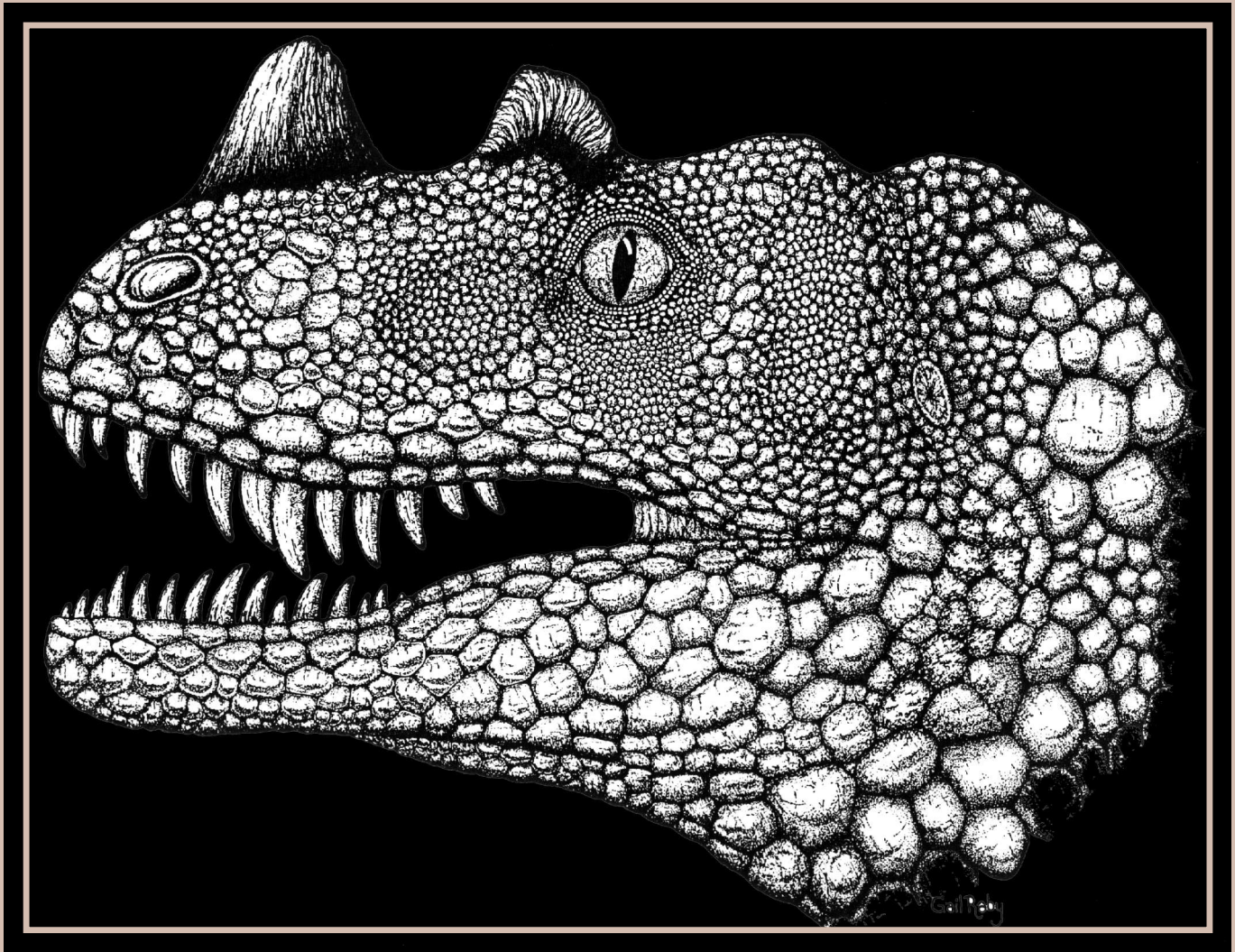


# CERATOSAURUS (DINOSAURIA, THEROPODA) A REVISED OSTEOLOGY

by

*James H. Madsen Jr., DINOLAB, Inc., Salt Lake City, Utah  
and*

*Samuel P. Welles, Museum of Paleontology, University of California, Berkeley, California*



2000

MISCELLANEOUS PUBLICATION 00-2  
UTAH GEOLOGICAL SURVEY  
*a division of*  
Utah Department of Natural Resources



# *CERATOSAURUS* (DINOSAURIA, THEROPODA) A REVISED OSTEOLOGY

by

*James H. Madsen Jr., DINOLAB, Inc., Salt Lake City, Utah*

and

*Samuel P. Welles, Museum of Paleontology, University of California, Berkeley, California*

**Cover:** sketch by Gail Raby  
of *Ceratosaurus* head based on MWC skull reconstruction.

ISBN 1-55791-380-3

The Miscellaneous Publication Series of the Utah Geological Survey provides non-UGS authors with a high-quality format for papers concerning Utah geology and paleontology. Although reviews have been incorporated, this publication does not necessarily conform to UGS technical, policy, or editorial standards.



MISCELLANEOUS PUBLICATION OO-2  
UTAH GEOLOGICAL SURVEY

*a division of*

2000 Utah Department of Natural Resources



**STATE OF UTAH**

*Michael O. Leavitt, Governor*

**DEPARTMENT OF NATURAL RESOURCES**

*Kathleen Clarke, Executive Director*

**UTAH GEOLOGICAL SURVEY**

*Kimm M. Harty, Acting Director*

**UGS Board**

<b>Member</b>	<b>Representing</b>
Craig Nelson (Chairman) .....	Civil Engineering
D. Cary Smith .....	Mineral Industry
C. William Berge .....	Mineral Industry
E.H. Deedee O'Brien .....	Public-at-Large
Robert Robison .....	Mineral Industry
Charles Semborski .....	Mineral Industry
Richard R. Kennedy .....	Economics-Business/Scientific
David Terry, Director, Trust Lands Administration .....	<i>Ex officio member</i>

**UTAH GEOLOGICAL SURVEY**

The **UTAH GEOLOGICAL SURVEY** is organized into five geologic programs with Administration, Editorial, and Computer Resources providing necessary support to the programs. The **ECONOMIC GEOLOGY PROGRAM** undertakes studies to identify coal, geothermal, uranium, hydrocarbon, and industrial and metallic resources; initiates detailed studies of these resources including mining district and field studies; develops computerized resource data bases, to answer state, federal, and industry requests for information; and encourages the prudent development of Utah's geologic resources. The **APPLIED GEOLOGY PROGRAM** responds to requests from local and state governmental entities for engineering-geologic investigations; and identifies, documents, and interprets Utah's geologic hazards. The **GEOLOGIC MAPPING PROGRAM** maps the bedrock and surficial geology of the state at a regional scale by county and at a more detailed scale by quadrangle. The **GEOLOGIC EXTENSION SERVICE** answers inquiries from the public and provides information about Utah's geology in a non-technical format. The **ENVIRONMENTAL SCIENCES PROGRAM** maintains and publishes records of Utah's fossil resources, provides paleontological and archeological recovery services to state and local governments, conducts studies of environmental change to aid resource management, and evaluates the quantity and quality of Utah's ground-water resources.

The UGS Library is open to the public and contains many reference works on Utah geology and many unpublished documents on aspects of Utah geology by UGS staff and others. The UGS has several computer data bases with information on mineral and energy resources, geologic hazards, stratigraphic sections, and bibliographic references. Most files may be viewed by using the UGS Library. The UGS also manages a sample library which contains core, cuttings, and soil samples from mineral and petroleum drill holes and engineering geology investigations. Samples may be viewed at the Sample Library or requested as a loan for outside study.

The UGS publishes the results of its investigations in the form of maps, reports, and compilations of data that are accessible to the public. For information on UGS publications, contact the Natural Resources Map/Bookstore, 1594 W. North Temple, Salt Lake City, Utah 84116, (801) 537-3320 or 1-888-UTAH MAP. E-mail: [nrugs.geostore@state.ut.us](mailto:nrugs.geostore@state.ut.us) and visit our web site at <http://www.ugs.state.ut.us>.

**UGS Editorial Staff**

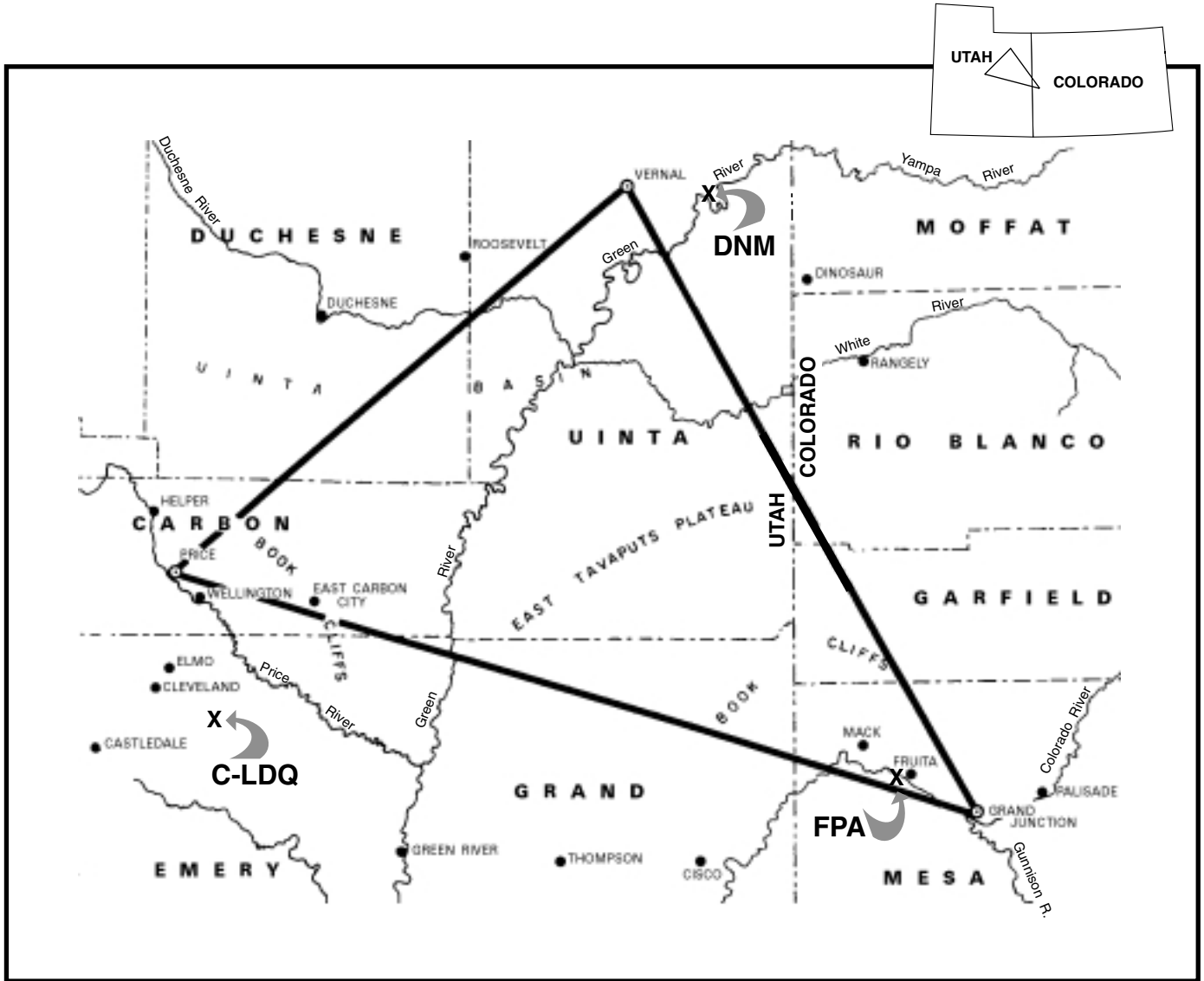
J. Stringfellow .....	Editor
Vicky Clarke, Sharon Hamre.....	Graphic Artists
Patricia H. Speranza, James W. Parker, Lori Douglas .....	Cartographers

---

*The Utah Department of Natural Resources receives federal aid and prohibits discrimination on the basis of race, color, sex, age, national origin, or disability. For information or complaints regarding discrimination, contact Executive Director, Utah Department of Natural Resources, 1594 West North Temple #3710, Box 145610, Salt Lake City, UT 84116-5610 or Equal Employment Opportunity Commission, 1801 L Street, NW, Washington DC 20507.*

---





The **Dinosaur Triangle** with the towns of Price and Vernal, Utah and Grand Junction, Colorado at the apices; and near to each, the Cleveland-Lloyd Dinosaur Quarry (C-LDQ), Dinosaur National Monument Quarry (DNM), and Fruita Paleontological Area (FPA) respectively.

## ABBREVIATIONS FOR INSTITUTIONS AND LOCALITIES

**AMNH** = American Museum of Natural History, New York city, New York  
**BYUVP** = Earth Science Museum, Brigham Young University, Provo, Utah  
**CEUPM** = College of Eastern Utah Prehistoric Museum, Price, Utah  
**C-LDQ** = Cleveland-Lloyd Dinosaur Quarry, Emery County, Utah  
**DM** = Dry Mesa Quarry, Montrose County, Colorado  
**DNM** = Dinosaur National Monument, near Jensen, Utah  
**FPA** = Fruita Paleontological Area, Mesa County, Colorado  
**HM** = Humboldt Museum, Berlin, Germany  
**MWC\*** = Museum of Western Colorado, Grand Junction, Colorado  
**UMNH** = Utah Museum of Natural History, University of Utah, Salt Lake City, Utah  
**USNM** = United States National Museum (Smithsonian Institution), Washington, D.C.  
**UUVP\*\*** = Utah Museum of Natural History, University of Utah, Salt Lake City, Utah  
**YPM** = Yale Peabody Museum, New Haven, Connecticut

\* The current catalog number for *Ceratosaurus magnicornis* n. sp., holotype, at the Museum of Western Colorado is MWC 1 and the locality number is MWC 1. Additionally, subnumbers and field numbers, e.g., MWC 1 and PF-QB-12, are included in the text, because some curation and cataloging issues had not been resolved at the last access to the MWC collection.

\*\* For continuity, this abbreviation, signifying University of Utah Vertebrate Paleontology, is used in the text. Furthermore, the specimen catalog number UMNH 5278 also appears on all elements of the holotype *Ceratosaurus dentisulcatus*, n. sp. The elemental UUVP numbers in the text identify those individual elements collected from the C-LDQ and curated in the UMNH collections.

**IN MEMORIUM**  
**Dr. Samuel Paul Welles**  
**9 November 1909 - 6 August 1997**

This publication is dedicated to Sam, not just for his contribution to the work, but for his impact on the science of Vertebrate Paleontology as a scientist and researcher, and also as a mentor, teacher, colleague, and friend.

## CONTENTS

Abstract	1
Introduction	1
General Geology	1
Systematics	2
Osteology	2
<i>Ceratosaurus magnicornis</i> , n. sp. holotype	2
Skull	3
Axial Skeleton	12
Appendicular Skeleton	18
<i>Ceratosaurus dentisulcatus</i> , n. sp. holotype	21
Skull	22
Axial Skeleton	24
Appendicular Skeleton	32
<i>Ceratosaurus</i> sp.	35
Dinosaur National Monument, Utah	35
Tendaguru Hills, Tanzania	35
Bern Jura, Switzerland	35
Cimarron Co., Oklahoma	36
Como Bluff, Wyoming	36
Mygatt-Moore Quarry, Colorado	36
Cleveland-Lloyd Dinosaur Quarry, Utah	36
Dry Mesa Quarry, Colorado	36
Bone Cabin Quarry, (west) Wyoming	36
Agate Basin Quarry, Utah	36
<i>Ceratosaurus ingens</i> Rowe and Gauthier	36
<i>Labrosaurus</i>	37
Acknowledgments	38
References and Associated Readings	39
Appendices	41
Glossary	47
Abbreviations used in text, figures, and plates	49

## FIGURES

Frontispiece. The Dinosaur Triangle	
Figure 1. Premaxillae from Dinosaur National Monument and the Fruita Paleontological Area	4
Figure 2. Stereo view of the anterior two teeth of the left dentary of <i>Ceratosaurus dentisulcatus</i> , n. sp. from the Cleveland-Lloyd Dinosaur Quarry	4
Figure 3. Left humeri of ceratosaurs from the FPA and the Cleveland-Lloyd Dinosaur Quarry	19
Figure 4. Ventral view of an anterior, caudal centrum of <i>Ceratosaurus dentisulcatus</i> , n. sp. from the C-LDQ showing the diagnostic ventral groove	30
Figure 5. The first two sets in a series of five articulated distal caudals and chevrons of <i>Ceratosaurus dentisulcatus</i> , n. sp.	31
Figure 6. Cross sections of distal caudal vertebrae from the C-LDQ	31
Figure 7. Theropod furculae from the C-LDQ	31
Figure 8. Dermal ossicles thought to be from the C-LDQ ceratosaur	32
Figure 9. Metacarpals and pedal phalanx from the C-LDQ ceratosaur	34
Figure 10. Left metatarsal IV of <i>Ceratosaurus dentisulcatus</i> , n. sp. from the C-LDQ	34
Figure 11. Theropod teeth from Janensch (1925, plate X)	35
Figure 12. Lingual view of cast tooth of type specimen of <i>Labrosaurus sulcatus</i>	36
Figure 13. Ceratosaur tooth from the Moore-Mygatt Quarry in western Colorado	36
Figure 14. Left scapula/coracoid of <i>Ceratosaurus</i> sp. from the Morrison Formation of Dry Mesa, Colorado	37
Figure 15. Medial view of a left dentary, the type of <i>Labrosaurus ferox</i>	37

## TABLES

Table 1. Ceratosaur Element Inventory, Fruita Paleontological Area	42
Table 2. Ceratosaur Element Inventory, Cleveland-Lloyd Dinosaur Quarry	43
Table 3. Ceratosaur Teeth, Dinosaur National Monument	45
Table 4. Ceratosaur Teeth, Fruita Paleontological Area	45
Table 5. Ceratosaur Teeth, Cleveland-Lloyd Dinosaur Quarry	46

## PLATES

Plate 1.	<i>Ceratosaurus magnicornis</i> , holotype.	Left lateral view of skull	52
Plate 2.	<i>Ceratosaurus magnicornis</i> , holotype.	Medial view of skull	53
Plate 3.	<i>Ceratosaurus magnicornis</i> , holotype.	Paired nasals and left quadrate	54
Plate 4.	<i>Ceratosaurus magnicornis</i> , holotype.	Cranium	55
Plate 5.	<i>Ceratosaurus magnicornis</i> , holotype.	Left postorbital, squamosal, ectopterygoid, and pterygoid/eipterygoid	56
Plate 6.	<i>Ceratosaurus magnicornis</i> , holotype.	Fifth cervical vertebra, fused ninth cervical and first pectoral vertebrae, and third dorsal vertebra	57
Plate 7.	<i>Ceratosaurus magnicornis</i> , holotype.	Posterior dorsal vertebra and anterior caudal vertebra	59
Plate 8.	<i>Ceratosaurus magnicornis</i> , holotype.	Right tibia, astragalus, and calcaneum	60
Plate 9.	<i>Ceratosaurus dentisulcatus</i> , holotype.	Paired premaxillae	61
Plate 10.	<i>Ceratosaurus dentisulcatus</i> , holotype.	Left maxilla	62
Plate 11.	<i>Ceratosaurus dentisulcatus</i> , holotype.	Coossified right quadrate and quadratojugal	63
Plate 12.	<i>Ceratosaurus dentisulcatus</i> , holotype.	Right pterygoid and right jugal	64
Plate 13.	<i>Ceratosaurus dentisulcatus</i> , holotype.	Left dentary, right angular, and left splenial	65
Plate 14.	<i>Ceratosaurus dentisulcatus</i> , holotype.	Atlantal intercentrum, axial intercentrum, axis and third, fourth, and fifth cervical vertebrae	66
Plate 15.	<i>Ceratosaurus dentisulcatus</i> , holotype.	Sixth, seventh, and ninth cervical vertebrae	68
Plate 16.	<i>Ceratosaurus dentisulcatus</i> , holotype.	First pectoral vertebra and seventh dorsal vertebra	70
Plate 17.	<i>Ceratosaurus dentisulcatus</i> , holotype.	Ninth dorsal vertebra and anterior caudal vertebra	72
Plate 18.	<i>Ceratosaurus dentisulcatus</i> , holotype.	Medial caudal vertebrae and chevrons, distal caudal vertebra, and proximal chevrons	73
Plate 19.	<i>Ceratosaurus dentisulcatus</i> , holotype.	Dorsal rib and cervical ribs	74
Plate 20.	<i>Ceratosaurus dentisulcatus</i> , holotype.	Right scapula-coracoid	75
Plate 21.	<i>Ceratosaurus dentisulcatus</i> , holotype.	Left femur	76
Plate 22.	<i>Ceratosaurus dentisulcatus</i> , holotype.	Left tibia, astragalus, and calcaneum	78
Plate 23.	<i>Ceratosaurus dentisulcatus</i> , holotype.	Right fibula	80





# **CERATOSAURUS (DINOSAURIA, THEROPODA) A Revised Osteology**

*James H. Madsen Jr., DINOLAB, Inc., Salt Lake City, Utah 84124*  
*Samuel P. Welles, Museum of Paleontology, University of California, Berkeley, California 94720*

## **ABSTRACT**

The Ceratosauria is modified to include two super families with one new subfamily. Two new species of *Ceratosaurus* are described, the first based on an articulated skeleton from the Fruita Paleontological Area (FPA) in western Colorado, and the second on skeletal elements of a single individual from the Cleveland-Lloyd Dinosaur Quarry (C-LDQ) in east-central Utah. A number of additional specimens, identifiable only to genus, have been found in North America and are mentioned or briefly described. Specimens from East Africa and Switzerland are also considered to be identifiable only to genus. The peculiar genus *Labrosaurus* is placed in synonymy with *Allosaurus*.

## **INTRODUCTION**

The Late Jurassic theropod dinosaur *Ceratosaurus nasicornis* Marsh was for many years the only species in this genus. It was known from the original description by Marsh (1884a) and was redescribed in detail by Gilmore (1920). Janensch (1925, p. 61) based a new species, *Ceratosaurus roechlingi*, on some presumably associated remains from the Tendaguru beds of East Africa, which may not be diagnostic to species. Other fragmentary finds have been identified as *Ceratosaurus* sp. by Janensch (1920, p. 230), by Stovall (1938, p. 596), by Madsen and Stokes (1963, p. 73; 1977, p. 69), by White (1964, p. 24), and by Brooks Britt (1993, personal communication).

During more than seventy years of discontinuous collecting from the Cleveland-Lloyd Dinosaur Quarry (C-LDQ) in east-central Utah, a significant number of bones have been excavated belonging to one of the two new species described below. In 1976 an almost complete theropod skeleton, obviously of this genus, and also a new species, was collected by the Museum of Western Colorado from the Fruita Paleontological Area (FPA) south of Grand Junction and near Fruita in western Colorado. This single specimen is also described in this paper. Over the last several decades many isolated finds have come to light, and we have attempted to make note and identify them as far as possible.

We originally intended to describe only the material from the Cleveland-Lloyd Dinosaur Quarry; but when the more complete, partially articulated, specimen (MWC 1) from the Fruita Paleontological Area became available, it

was evident that our work should be expanded into a review of the genus. As a result we concluded that at least three species are valid: *Ceratosaurus nasicornis* Marsh (holotype USNM 4735); *Ceratosaurus magnicornis* n. sp. holotype, the Fruita Paleontological Area specimen (holotype, MWC 1); and *Ceratosaurus dentisulcatus*, n. sp. the Cleveland-Lloyd Dinosaur Quarry specimen (holotype, UMNH 5278). The other, isolated finds cannot be assigned with certainty to any species at this time.

We describe the Fruita specimen first, because it is more complete. Next is the Cleveland-Lloyd specimen, and then the isolated finds. Lastly, a discussion of the genus *Labrosaurus* grew out of our studies, and it is also included here.

This work is intended to supplement the contributions of Gilmore (1920), and his paper is basic to any study of the genus *Ceratosaurus*.

## **GENERAL GEOLOGY**

The continental sediments of the Upper Jurassic Morrison Formation are of broad extent in the western United States, having temporal and lithologic equivalents as far north as southern Canada and extending far to the south in a broad band across much of Montana, North and South Dakota, Wyoming, Utah, and Colorado. They also touch Nebraska, Kansas, Oklahoma, and Texas, and the northern parts of New Mexico and Arizona.

In Utah, depending upon the author and the areas studied, the Morrison may be divided into a minimum of five members from youngest to oldest: Brushy Basin, Westwater Canyon, Recapture Creek, Salt Wash Sandstone, and Tidwell.

The uppermost member, the Brushy Basin, is the source of the most significant dinosaur discoveries in Utah, the two most prominent of which are the quarry at Dinosaur National Monument near Jensen, and the Cleveland-Lloyd Dinosaur Quarry south of Price.

The Cleveland-Lloyd Dinosaur Quarry bone bed lies approximately 150 feet below the contact of the Lower Cretaceous Cedar Mountain Formation and the underlying Brushy Basin. The fossil bones of the Cleveland-Lloyd Dinosaur Quarry are confined to the upper several feet of a bentonitic, blocky shale which is capped by a light-grey, dense, siliceous, freshwater limestone of limited areal extent. This geology and petrology are described in detail by Bilbey (1992).

Additional references to the Cleveland-Lloyd Dinosaur Quarry stratigraphy are by Stokes (1985, 1986) and the taphonomy by Dodson and others (1980a, b).

## SYSTEMATICS

The family Ceratosauridae was established by Marsh (1884b, p. 330) to include the genus *Ceratosaurus* and was placed in his Order Theropoda. The characteristics he listed were: horn on the skull, planoconcave cervical centra and biconcave post-cervicals, coossified pelvis, slender pubis, short dorsal process of the astragalus, and osseous dermal elements.

In review, Cope (1892, p. 241) cited *Megalosaurus nasicornis*, and wrote (p. 244, footnote), "It has been shown that the character on which Prof. Marsh relied to distinguish the genus *Ceratosaurus* and the family Ceratosauridae, viz. the confluent metapodials, is pathological. The keeled process on the nose is probably only a specific character." However Cope did not say where "it has been shown," so this is evidently the first suggestion of this pedal pathology. Matthew and Brown (1922, p. 370) thought there were no more than subfamilial differences between *Ceratosaurus* and *Allosaurus*, and therefore placed both genera in the Deinodontidae.

Later workers have included the family, variously, in the Megalosauridae (Lydekker, 1888, p. 157; Romer, 1956, p. 615), the Coelurosauria (Huene, 1932, p. 46; and later papers), the Carnosauria (Romer, 1945, p. 599), the Deinodontidae (Maleev, 1964, p. 537), and the Ceratosauria (Gauthier, 1984, p. 212, 448; Rowe and Gauthier, 1990, p. 151).

Welles (1984, p. 158) noted that *Dilophosaurus* and *Ceratosaurus* were more similar than either is to other theropods. Thus, there has been no consensus as to the relationship of this family. We now think that *Ceratosaurus* is quite different from the other genera included by Rowe and Gauthier in their Ceratosauria and so we divide the Ceratosauria into Ceratosauridae including only *Ceratosaurus* and possibly *Proceratosaurus*; and Dilophosauridae, including the rest of the Ceratosauria.

T.R. Holtz (1994, p. 1103) presented an extensive cladistic analysis of the Theropoda. He divided his Node Ceratosauria into the Node Coelophysoidea, n. tax., and Node Neoceratosauria (Novas, 1991). His Coelophysoidea includes the Coelophysidae, *Dilophosaurus*, and *Liliensternus*; while his Neoceratosauria includes *Ceratosaurus* and the Abelosauroidae, which includes *Elaphrosaurus* and the Abelosauridae. We concur in this general arrangement, but would agree with Colbert (1989, p. 28) in using Podokesauridae instead of Coelophysidae because of priority. It then follows that Podokesauroidae would replace Coelophysoidea. We also believe that *Dilophosaurus* is closely related to *Coelophysis*, yet is different enough to be placed in a separate subfamily. We would therefore change the Node 2 of Holtz to read Podokesauroidae, to include the Podokesauridae. This family would then include the subfamilies Podokesaurinae, with *Coelophysis*, *Liliensternus*, *Podokesaurus*, and *Syntarsus*; and the Dilophosaurinae n. tax. with only *Dilophosaurus*. We therefore classify the Ceratosauria as follows:

### Ceratosauria

**Podokesauroidae** (including only the family Podokesauridae)

#### Podokesauridae

##### Podokesaurinae

- small size
- skull long and low
- no crests on skull

- jugal low and slender
- parapophyses close to centra
- supraacetabular crest of ilium narrow and without anterior notch
- genera included:  
*Coelophysis*, *Liliensternus*, *Podokesaurus*, *Sarcosaurus*, and *Syntarsus*

### Dilophosauridae

#### Dilophosaurinae, n. tax.

- medium size;
- skull high;
- parasagittal crests present;
- jugal large and deep;
- parapophyses on short stems;
- supraacetabular crest of ilium broad, and notched anteriorly
- genus included: *Dilophosaurus*.

**Neoceratosauroidae** (including only the family Ceratosauridae)

### Ceratosauridae

- Ceratosaurus*
- Proceratosaurus*

Contrary to the statement by Rowe and Gauthier that there is a firm junction between the premaxilla and maxilla (1990, p. 154), the articulated specimens of *Dilophosaurus wetherilli* (UCMP 37303 and 77270) show that the postero-medial process of the premaxilla is transversely concave and rides smoothly over the anteromedial process of the maxilla, forming a rather weak connection. It does not interdigitate with the anteromedial process, but forms an arched cover over the latter. It is the anteromedial process of the maxilla that interlocks with its opposite by slightly arched anteroposterior tongues and grooves. As a further indication of the weak attachment of the premaxilla, the nasal process of the premaxilla rides smoothly over the nasal. Thus the premaxilla is loosely attached to both the maxilla and the nasal. This unusual articulation should have been fully described by Welles (1984, p. 144) and his omission is regrettable, possibly leading Rowe and Gauthier to their erroneous conclusion.

Rowe and Gauthier (1990) also suggested that the subnasal gap and pit accommodated an enlarged dentary tooth, but in neither of the two available specimens is an enlarged dentary tooth present or in evidence.

## OSTEOLOGY

### *Ceratosaurus magnicornis*, n. sp.

**Type:** Nearly complete skeleton curated in the Museum of Western Colorado, catalog number MWC 1. It is important to note that MWC 1 is the primary catalog number for this specimen, although variations and old numbers are also listed in the tables for some elements of this associated skeleton.

**Hypodigm:** Holotype only.

**Etymology:** *magnicornis*, this in reference to the proportionately larger nasal horncore.

**Locality:** Fruita Paleontological Area (FPA) near Fruita, in the SW<sup>1</sup>/<sub>4</sub>, Sec. 24, T1N, R3W, Ute Meridian, Mesa County, Colorado.

**Horizon:** Lower part of the Brushy Basin Member of the Morrison Formation.

**Age:** Late Jurassic.

**Description:** The individual is large, but not fully grown,

as indicated by the many open sutures on the skull. Significant missing elements include those of the mandible, lower arm, and gastralia.

**Diagnosis:** Differs from *Ceratosauros nasicornis* in being more massive; having a longer and lower skull (H:L ratio of 40 versus 47); the anterior border of the premaxilla is straighter; the maxilla is longer (412 versus 360 mm); its anterior edge is almost vertical, versus an anterior dip of about 50°; its lower border is more convex, its lateral face more deeply impressed by the recess, and its nasal process has a deep maxillary vacuity; the upper edge of the maxilla, below the antorbital fenestra, dips only 15° posteriorly versus 25°, and the anterior edge of the maxilla is lower at the front of the fenestra; the nasal horn core is longer and lower; the teeth are longer and stouter, especially posteriorly; the lacrimal is more massive, bears a high, rugose horn core with a longer base, and a much larger recess; the quadratojugal is more massive ventrally; the quadrate has a much larger, lower articular surface, and its pillar is more concave posteriorly; the dentary is much more concave dorsally and convex ventrally, the chin much more rounded with the bone more massive, becoming 148 mm high at the surangular contact at 546 mm from the chin, versus 92 mm at 320 mm; there are 11, possibly 12 alveoli versus 15.

The 6th cervical is 80 mm long versus 65 mm, and its neural spine is much higher (145 versus 120 mm) and is longer anteroposteriorly (52 versus 34 mm); the table slants up more steeply posteriorly; the posterior chonos is much shorter; the diapophysis is much higher above the parapophysis; there is a stout epiphysis.

The femur is 630 mm long versus 620 mm, its head 120 mm broad versus 150 mm, and the distal end of each is 135 mm broad; the shaft is 75 mm broad below the trochanteric shelf, versus 52 mm, and is much straighter.

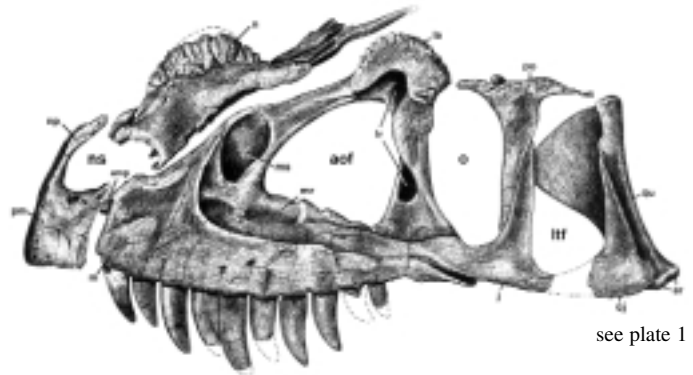
The tibia is 520 mm long versus 555 mm (T:F ratio of 83 versus 90) and the tuberosity is not so well developed; the proximal diameters are 135 and 180 mm, the distal are diameters 132 and 140 mm; the astragalar facet is similar, but the dorsal process of the astragalus completely fills the facet.

The calcaneum is broader anteriorly, occupying 43% of the astragalocalcaneal breadth, versus 28%, and the suture runs dorsolaterally; the calcaneum is also broader in lateral view. For differences from *Ceratosauros dentisulcatus*, n. sp. see the diagnosis for that species on page 21.

## Skull

The skull of *Ceratosauros magnicornis*, n. sp. (plates 1, 2) is compressed, the premaxillae and the right maxilla crushed upward, and the left side of the cranium is crushed downward 25 mm. The original length from snout to occipital condyle is estimated to be 600 mm and the breadth at the quadratojugals to be about 160 mm. The snout was only 60 mm wide. Measurements are of the left side, and where the right side differs significantly, its measure follows in italics inside parentheses. In this description the skull is oriented with the floor of the braincase horizontal. This makes the base of the horn core dip 20° anteriorly, and alveolar border of the maxilla dip 10° posteriorly.

**Premaxilla:** In lateral view (figure 1E) the body of the premaxilla, MWC 1, is 65 mm long. Only the base of the left premaxilla is preserved, so the rest of the description applies to the right side (figure 1). Its base is also 65 mm



see plate 1

long parasagittally, and it is 79 mm high at the bottom of the naris, the H:L ratio is 122, while its ends are parallel and dip 60° anteriorly. The surface is smooth except for a subnarial foramen (18 x 10 mm) just below the naris, and three small foramina that open anteroventrally. The anterior one is 7 mm from the front of the bone, and 3 mm above the base. The second is 10 mm posterodorsal to this, and the third is 15 mm behind the second. The posterodorsal tip of the body points up and back and overrides the maxilla, but below this the maxilla becomes the lateral element.

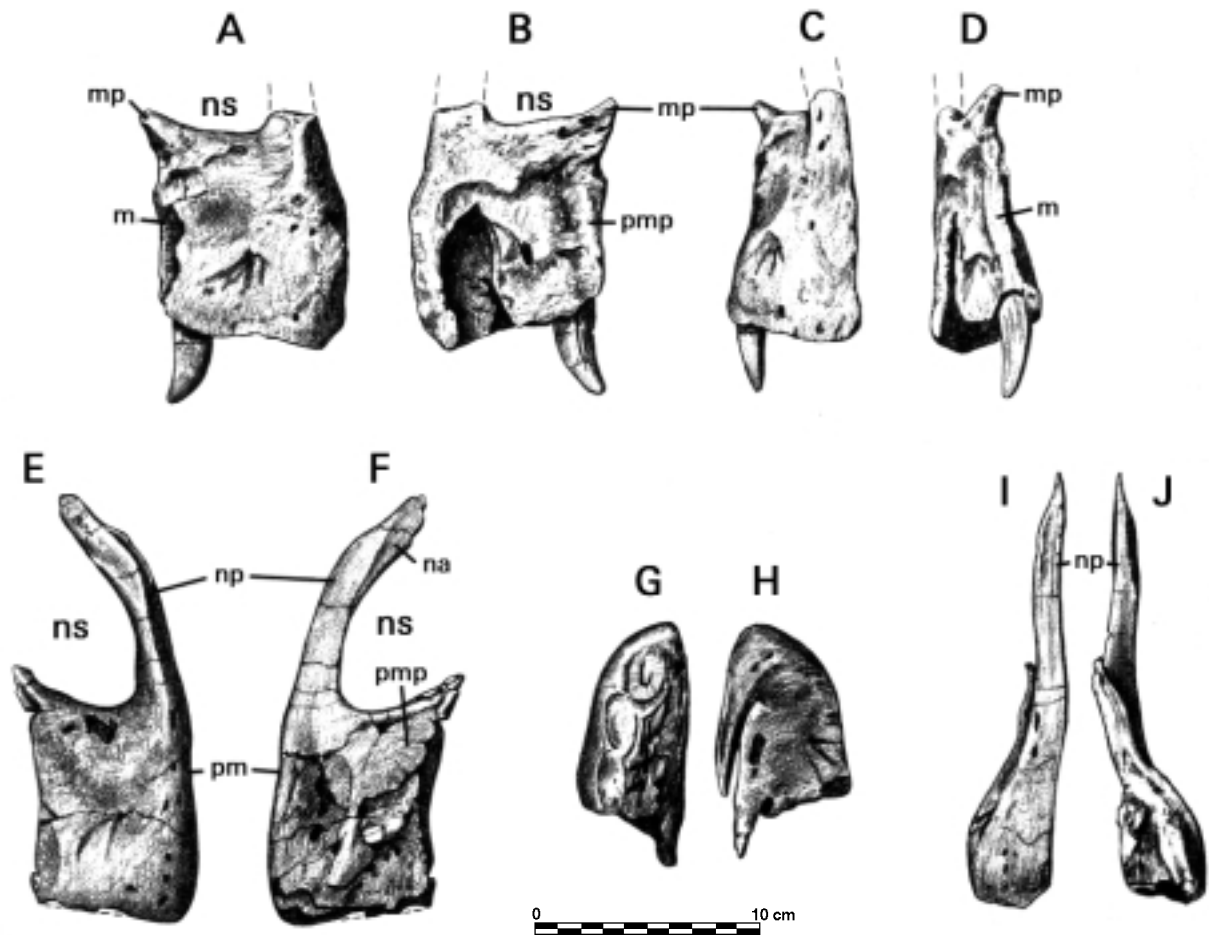
The nasal process rises to 157 mm above the posteroventral corner. The lower 70 mm of the process has a uniform, gentle anterior convexity that is continuous with the anterior edge of the body. At a height of 76 mm there is a bulge, and above this the upper 30 mm slopes less steeply forward. The smooth sulcus for the lateral overlap of the nasal is 54 mm long, and begins 105 mm above the base of the body of the bone.

In medial view (figure 1F) the medial sutural surface is 30 mm long ventrally and shortens dorsally to 29 mm at the base of the nasal process. The posteromedial process is entire, but very small. It begins 45 mm posterodorsal to its anteroventral tip, is 11 mm long, and ends 7 mm from the posterior edge of the premaxilla. Its medial surface dips 45° medially and its ventral edge meets its opposite at the midline. Its ventral surface curves posteroventrolaterally into the body of the bone. Immediately below this the alveolar surface is offset laterally 3 mm, and there is a nutrient groove 3 mm high. This extends up into the bone. The groove begins 25 mm above the posteroventral corner of the bone, curves anteroventrally, and ends at the midline 7 mm above the back of the first alveolus. The inner surface of the bone below the nutrient groove is concave both vertically and longitudinally.

In anterior view (figure 1I) the premaxilla flares out to 30 mm from the midline. The upper 50 mm of the nasal process is grooved for an overlap of the medial prong of the nasal.

In posterior view (figure 1J) the facet for the maxilla is concave transversely, 30 mm high, 6 mm wide, and dips 70° laterally. Lateral to this is a concavity for the lower, lateral overlap of the maxilla that widens to 13 mm near the alveolar border. Above 30 mm the surface for the maxilla curves posteromedially and overlaps the maxilla laterally. Above this is a depression in the posterodorsal projection of the body that received a projection from the maxilla as the upper, lateral overlap of the maxilla.

In ventral view the left premaxilla (not illustrated) is thicker than the right, although both are badly compressed.



**Figure 1.** Right premaxillae of *Ceratosaurus* sp. from Dinosaur National Monument (DNM 972) A,B,C,D, and *Ceratosaurus magnicornis*, n. sp. the holotype from the Fruita Paleontological Area (FPA) (MWC 1.1) E, F, G, H, I, J in lateral (A, E), medial (B, F), anterior (C, I), posterior (D, J), ventral (G), and dorsal (H) views. Abbreviations: na, nasal contact; np, nasal process; ns, external naris; m, maxillary suture; mp, maxillary process; pm, premaxilla; pmp, posteromedial process. Scale: one-third natural size.

On the right premaxilla there are three alveoli, en echelon, and overlapping. The first is 25 x 16 mm and contains a broken elliptical tooth 21 x 13 mm. The second alveolus is oval, 23 x 12 mm, narrowing posteriorly. The third is 23 x 10 mm. The crowns of the teeth are, presumably, longitudinally grooved on the lingual side as they are on other known species of the genus (figure 1). The same is true of the anterior three teeth of the dentary (figure 2).

**Maxilla:** In lateral view the maxilla (plate 1) of *Ceratosaurus magnicornis*, n. sp. is 395 mm long (385 mm), 95 mm high anteriorly, 105 mm high below the naris (100 mm), 117 mm high below the maxillary sinus, 105 mm high at the front of the antorbital fenestra, and only 56 mm high at the back of the fenestra. It tapers to a sharp tip below the center of the orbit.

At the back of the fourth tooth the maxillary recess is 60 mm above the alveolar border. Its anterior end is inset 10 mm, and it fades out posteriorly below the center of the lacrimal. On the right side the front of the recess is uncrushed. Here the recess expands anteriorly, ventrally, and posteriorly into the body of the bone, extending as a pocket into the face of the bone. Its anterior wall is divided at mid-height by a small, horizontal shelf. The upper edge of



**Figure 2.** Stereo view of the anterior two teeth of the left dentary (UUVP158) from the Cleveland-Lloyd Dinosaur Quarry *Ceratosaurus dentisulcatus*, n. sp. holotype in lingual view showing diagnostic longitudinal grooves. Scale: actual size.

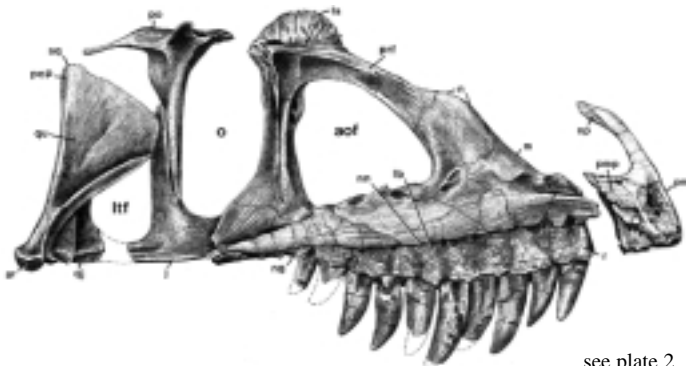
the maxilla, below the antorbital fenestra, is 125 mm long to its junction with the base of the lacrimal.

The lower edge of the alveolar recess of the left maxilla is evenly convex and arches down 31 mm at the center of the tooth row. A row of sixteen 2 mm foramina for the branches of the facial nerve lies on the lateral surface above

the alveolar border. Each foramen opens anteroventrally into a depressed area that widens ventrally into a band above the alveolar border. This band is 30 mm high anteriorly above the second alveolus, curves down to 20 mm above the third alveolus, then gradually up to 13 mm above the tenth alveolus, at 280 mm behind the front of the tooth row. The external surface of the right maxilla has a similar row of foramina and depressed band, but the band is 5 mm shorter.

The nasal process is 115 mm long at its base. Its anterior edge dips 30° anteriorly, 40° with respect to a chord across the alveolar border. At its anterior base the surface for the nasal broadens and curves laterally. At 190 mm above the alveolar border the dip lessens to 15° and the process continues back for another 105 mm below, then up, into a longitudinal socket in the lateral base of the lacrimal. The base of the process contains a large, inverted pyriform, preantorbital recess, 79 mm high, 18 mm long ventrally, and 43 mm long at midheight. Its anterior border is concave. Its posterior border is concave above and convex below. The base of the recess is 120 mm above the base of the maxillary recess, aligned with the base of the antorbital fenestra.

In medial view the maxilla (plate 2) is 95 mm high at the front of the antorbital fenestra, and 62 mm above the nutrient groove. The tooth row is 280 mm long and there are thirteen alveoli in each maxilla, the last four become shorter as the body of the maxilla decreases in height. The rugosae are fused to form a high wall, continuous except for the inverted triangular foramen between the summits. Each foramen reveals the tip of a replacement tooth, while the seventh also has a replacement tooth 13 mm high at its inner base. The anterior rugosae are 50 mm high (40 mm), and the height decreases gradually posteriorly to 5 mm, where the rugosae become separate. The nutrient groove is small and narrow, and the lingual bar is almost flat, probably an artifact of compression of the bone. The anteromedial process curves anteroventrally and extends 24 mm in front of the lateral border of the premaxillary suture. Its anteroventral edge descends to 44 mm above the ventral labial border. It curves gently posteriorly into the body of the bone, its base 5 mm above the nutrient groove, its top 30 mm above the groove. The dorsomedial edge of the left process is convex vertically and fits into a longitudinal groove in the right process. A parasagittal groove 13 mm wide runs between the top of the process and the inner wall of the maxilla, curving down anteriorly at the surface for the premaxilla. The fit of the two posteromedial processes fixes the breadth of the snout at the premaxillae suture at 60 mm.



see plate 2

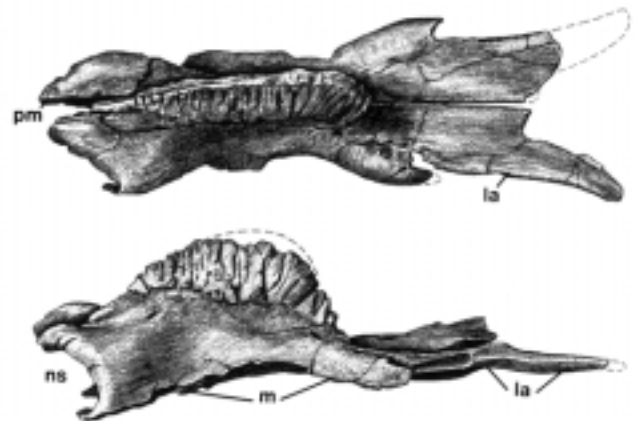
**Nasal:** In lateral view the nasal of *Ceratosaurus magnicornis*, n. sp. (plate 3) is 218 mm long (230 mm) from the front of the naris to the back of the posterolateral projection. The narial border is 55 mm long posteroventrally. The bone is 15 mm thick anteriorly, thins to 8 mm at the back of the naris, and is rugose. Its surface is convex anteriorly and becomes concave posteriorly below the horn core. It is 60 mm tall ventrolaterally at the front of the horn core, 35 mm at the back. The dorsal surface becomes increasingly convex laterally from 50 mm in front of the back of the horn core, and over the posterolateral projection.

The ventral edge of the nasal, below the horn cores, dips 30° anteriorly for 95 mm as it overrides the nasal process of the maxilla. Behind this it curves gently down and becomes horizontal as its lateral edge laps down 15 mm over the process.

The rugose area of the horn core is 120 mm long basally. Its summit is arched more steeply posteriorly than anteriorly. At 70 mm from the front it is 28 mm high. The rugosity is increased by grooves that radiate from the base at intervals of about 6 mm.

In anterior view (plate 3A) the fronts of the nasals are crushed up and to the right side, so the naris would originally have been about 45 mm high. Each flares out anteriorly above the premaxilla. The anterior edge is 14 mm high dorsally and thins to 5 mm near its base.

In dorsal view (plate 3B) the anterior 40 mm of the nasal are spread apart about 10 mm to accommodate the upper 60 mm of the processes of the premaxillae. The anterior base of the horn cores extends forward 9 mm into this gap. The horn core has a narrow crest and broadens ventrally to 50 mm. Its total length, including the anterior extension, is 144 mm. Its posterior base is off center slightly to the left side, probably caused by postdepositional distortion. The left nasal sends a wedge back 20 mm between the anterior ends of the frontals. The right wedge is 25 mm long. The posterolateral process begins 22 mm from the midline, where it is convex above and 20 mm broad. It narrows as it extends back beside the frontal, its side becoming vertical posteriorly.



see plate 3B, C

In ventral view (plate 3D) the nasal is 111 mm long (114 mm) to the front of the underlapping frontals. The nasals form a longitudinal arch 25 mm broad dorsally, its sides spreading ventrally. The ventral edge is about 6 mm broad anteriorly, and widens to 10 mm at 55 mm back,

where it becomes concave with thin edges that extend ventrally over the premaxilla. This concavity increases in depth to 6 mm at 11 mm from the front, then becomes shallow posteriorly and disappears at 142 mm from the front. The lateral wall becomes increasingly high posteriorly and, at 150 mm back, its posterolateral process laps down 29 mm over the top of the nasal process of the premaxilla, then continues back into a cavity in the anterodorsal face of the lacrimal.

**Frontal:** The cranial complex of *Ceratosaurus magnicornis*, n. sp., MWC 1 (plate 4A), is fairly complete but slightly distorted dorsoventrally by postdepositional compression.

In lateral view the anterior 15 mm of the frontal (plate 4) forms a flat sutural surface for the prefrontal that dips 45° medially and is grooved anterodorsally. Behind this the prefrontal surface continues into a socket 20 mm long. Its anterior end narrows upwards, its posterior end is sunk into the bone and is 8 mm high. Behind the prefrontal surface is the supraorbital notch, which is 20 mm long. At its center the frontal thins to 4 mm. The socket for the postorbital follows. It is 27 mm long, 4 mm high anteriorly, 10 mm posteriorly, and 5 mm deep. The frontal makes a continuous arch over the orbit with the prefrontal and the laterosphenoid. The frontal is underlain posteriorly by the lateral wing of the septosphenoid, and the inner part of its suture with the laterosphenoid is hidden. The lateral suture is just behind the postorbital pit and dips 40° anteriorly.

In dorsal view (plate 4D) the left frontal is 155 mm long, its front end broken. The two frontals are fused and their central 57 mm forms a table 70 mm broad at the front of the prefrontal sutures, and 110 mm above the front of the postorbital sutures. This table bears a low, sagittal arch, flanked by shallow depressions, which continues forward where it is overlain by spikes from the nasals. Each spike also forms a wedge into the frontal and is underlapped by a diverging projection from each frontal. The frontal table is 100 mm broad at the center of the supraorbital notch, which is 20 mm long.

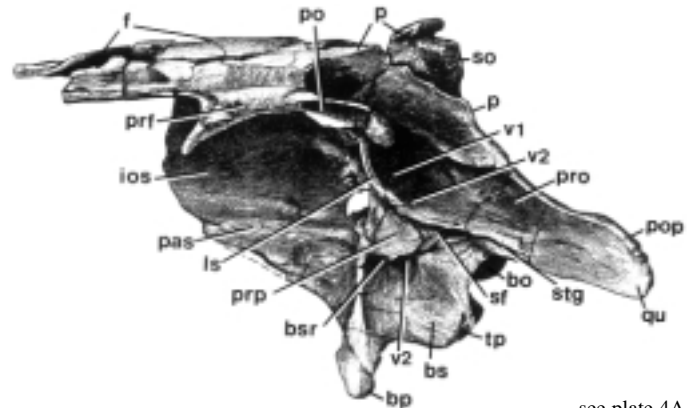
The posterolateral area of each frontal is depressed 20 mm and forms an anterior continuation of the lateral temporal fossa. This depression, the adductor fossa, allows the adductor muscles of the lower jaw to increase their area of origin. The fossa continues about 4 mm anteromedially into the back of the frontal table and the side of its posterior extension. Its anterior edge is 45 mm long. Its posterior edge ends abruptly at a sharp ridge, concave anteriorly, at the suture with the parietal. The posterior extension of the fused frontals is 30 mm broad at the transverse suture with the parietals.

In ventral view (plate 4E) the anterior projection of each frontal is 26 mm broad, and convex transversely, the two forming a midline groove. It sends a prong forward 60 mm beneath the nasal, its tip 13 mm from the midline. The frontal keel begins at the front of the prefrontal suture, 35 mm from the midline. Its anterolateral edge has a socket 25 mm long for the prefrontal. Its anterior 15 mm dips 45° medially, is grooved anterodorsally, and was covered by the prefrontal. The prefrontal is in place on the left side, and the anterior suture with the frontal runs 45° posteromedially; the posterior suture only runs 10°.

The supraorbital notch is 20 mm long and behind this is the socket for the postorbital. This is 33 mm long and

curves slightly posterolaterally. Behind this the frontal meets the laterosphenoid in a suture that continues anteromedially, but is underlain and hidden by the lateral wing of the septosphenoid.

**Parietal:** In lateral view the parietal of MWC 1 (plate 4) begins as a concave wall covering the anteromedial corner of the adductor cove of the frontal. It continues back into the supratemporal fossa. At the back of the adductor cove the upper 10 mm of the parietal dips ventrolaterally, and below this is a longitudinal concavity 15 mm long and 5 mm high. Its ventral surface curves laterally, with its anterior edge slightly elevated above the frontal, and running 45° posterolaterally. At the back of the adductor cove the parietal angles posteroventrally, then laterally in back of the laterosphenoid, forming a plate over the back of the laterosphenoid 10 mm high that reaches to about 40 mm from the midline. This plate continues medially and curves posteriorly to form the anterior and medial wall of the supratemporal fenestra. At the center of the fenestra the parietal is 45 mm high as it overrides the laterosphenoid, the prootic, and the middle cerebral vein foramen. Behind this the parietal curves posterolaterally into the posterolateral wing, so the supratemporal fenestra is about 35 mm wide, and dips 50° posteriorly with respect to the frontal plate. The posterolateral wing of the parietal begins 22 mm below the crest and 20 mm in front of its posterior end. It extends back for 78 mm to a ventrolateral tip above the prootic.



see plate 4A

In posterior view (plate 4C) the crushed condition of the specimen makes it impossible to be certain of all the details of the parietal.

In dorsal view (plate 4D) the parietals are fused, their midline length is 65 mm. Their anterior breadth is 36 mm, and this narrows to 9 mm at 30 mm back then, at 47 mm back, expands to 23 mm. The posterior 17-mm section rounds back into a blunt end; therefore the posterior half of the parietals is triangular.

**Prefrontal:** Only the left prefrontal of *Ceratosaurus magnicornis*, n. sp., MWC 1, remains (plate 4A). In lateral view it forms an arch 40 mm anteroventrally over the front of the orbit. It is 11 mm thick near its posterior end, then thickens to 14 mm medially as it curves down into an anteroventral process only 4 mm wide. This surface is rough and forms the sutural surface for the posteromedial end of the lacrimal. The bone thins posteriorly to 3 mm at the front of the supraorbital notch.

In dorsal view the back of the bone is 20 mm broad, and it is set about 5 mm into the frontal. The suture with the frontal runs posterolaterally at 40° from the parasagittal, the suture with the lacrimal is at 60° from midline.

In ventral view the inner end is bluntly rounded and the anterior suture with the frontal runs 45° posteromedially. The posterior suture makes an angle of 80° with the parasagittal line and is 24 mm long.

**Lacrimal:** In lateral view the lacrimal of MWC 1 (plate 1) expands posterodorsally into a massive horn core forming a crest 95 mm in maximum length and arching into a semicircle. The distal base of this horn core is slightly swollen and extends behind the semicircle. The peripheral 10 mm is very rough, with radial grooves. The lateral face of the crest is 87 mm long posteroventrally at its anterior base, 36 mm high at its center, and 44 mm long posteriorly. Its anteroventral surface is sunk 17 mm and forms the back wall of a huge pit, the lacrimal recess, that extends about 10 mm up and inside the bone. The inner wall of the recess reaches 33 mm anteroventral to the lateral wall and forms the posterodorsal edge of the antorbital fenestra. The lateral wall of the lacrimal extends forward about 40 mm in a groove in the dorsal process of the maxilla.

The ventral arm of the lacrimal is 130 mm high above the jugal suture. The top of the lateral face is inset 3 mm at the base of the horn core. The upper 90 mm of its anterior edge bows forward and the lateral face is 32 mm broad at the top, 33 mm at midheight, and 12 mm basally. Its surface is rugose. The internal edge of the ventral arm is separated from the lateral face by a deep recess in the anterior edge of the bone. This is separated from the upper recess by an anterodorsal bar that is part of the posterodorsal edge of the antorbital fenestra. The upper 60 mm of this lower recess is hidden by the lateral face of the bone, but below this it comes into view as a teardrop-shaped pit 35 mm high and 20 mm wide near its base. At the top of this pit the lacrimal is 29 mm broad, and it broadens ventrally to 90 mm at the jugal suture.

In anterior view (not illustrated) the base of the horn core is 18 mm thick. Its lateral face is slightly concave and dips medially. Its inner face is very rough, curves dorsolaterally into a narrow parasagittal crest. The upper 70 mm of the ventral arm is 19 mm broad. The ventral recess narrows anterodorsally under the back of the horizontal arm. At 25 mm from the top, the recess is 18 mm wide and extends about 20 mm back into the bone. At the base of this excavation is a horizontal floor 5 mm high, and below this the recess shallows and curves laterally into the teardrop-shaped pit on the lateral face of the bone. Below this the bone becomes very thin.

In posterior view (not illustrated) the base of the horn core is 20 mm thick. Its posterolateral end has a rough facet for the postfrontal that is 40 mm long. Its posterior 25 mm is 14 mm high, its anterior end is offset medially, faces ventromedially, and lessens in height anteriorly to 4 mm. It runs anteromedially, and at 20 mm it curves down 30 mm and is only 4 mm broad. Immediately above the prefrontal contact the lacrimal curves medially and forms a longitudinal facet for the frontal. This facet is 7 mm high, concave longitudinally and inset, so the lacrimal is 25 mm thick. The lacrimal is vertically concave both above and below the frontal and prefrontal facets.

**Postorbital:** In lateral view (plate 5B) the postorbital bone is T-shaped. Its dorsal edge is 127 mm long, slightly sigmoid, convex above the back of the orbit and also above the temporal fenestra, and concave above the anterior edge of the ventral process and above the squamosal process. The lateral face has a sharp anterior ridge that curves up and back and rounds into a bulging ridge over the squamosal process. Just inside the sharp ridge is a depression, and the frontal process leads anteromedially inside this depression, its surface rounded. The squamosal process begins as a bulge anterodorsal to the posterior edge of the bone, and it arches back about 60 mm. It is 17 mm high anteriorly, and its height decreases to about 6 mm posteriorly.

The ventral process is 135 mm high, 55 mm broad dorsally, and 4 mm at its ventral tip. Its anterior edge is smoothly concave as it forms the posterodorsal border of the orbit, and its lower 75 mm is straight. The posterior edge is more sharply concave at the top and bulges posteriorly at about 50 mm down, then is gently concave as it laps against the front of the jugal.

In medial view (plates 2, 5D) a frontal process 30 mm long extends medially and slightly anteriorly. This process is 13 mm broad near its base, and tapers to 9 mm medially. From its anterior base a rounded ridge curves back and down, strengthening the ventral process.

In anterior view (plate 5A) the upper 70 mm of the bone is concave, and below this it is straight. The edge is a rounded ridge that curves dorsomedially to a breadth of 30 mm, ending below the back of the frontal process. It forms a cavity with the lateral edge of the bone that is the posterodorsal part of the orbit.

In posterior view (plate 5C) the edge is very thin. The frontal process dips 30° laterally, and it is 8 mm thick. The internal rounded ridge begins 5 mm below the front of the process, its posterior face vertical. At 30 mm below the top, the posterior face of the ridge curves gradually back to the edge of the bone. At 75 mm below the top, the posterior edge of the ridge becomes grooved to receive the anterior edge of the jugal.

In dorsal view (not illustrated) the bone broadens to 10 mm at 20 mm from its pointed tip. At 30 mm from the front the frontal process extends 20 mm medially. This plate is 20 mm broad at its base and narrows medially to a rounded end. At the back of the process the bone is 12 mm thick.

**Squamosal:** In lateral view the left squamosal MWC 1 (plates E and F) forms an arch 110 mm long. It is 30 mm high anteriorly and its lower anterior 20 mm has a groove 30 mm long for the postorbital. The posteroventral end curves down over a socket 20 mm deep for the top of the quadrate. Behind the socket the squamosal is only 8 mm broad. In front of the socket the squamosal is convex, expanding to an anteroposterior length of 40 mm at the top of the socket, and extending down 70 mm.

The right squamosal of *Ceratopsaurus magnicornis*, n. sp., MWC 1 (not illustrated), is crushed down and in front of the quadrate approximately 80 mm. There is a notch 20 mm wide in the squamosal posterolateral to the quadrate socket and the head of the quadrate is extended up inside this notch. Above the notch the squamosal is 33 mm broad. A stout process arches down from the front of the notch for 32 mm and narrows to a blunt end, 9 mm in diameter, which evi-



dently capped the quadratojugal. This process is rounded and does not expand anteroposteriorly into the lateral temporal fenestra above the quadratojugal. The posteroventral process that undoubtedly extended down behind the paroccipital process and the top of the quadrate is hidden, pushed down in front of the quadrate and inside the quadratojugal. The socket for the head of the quadrate must have continued down the anterolateral face of the paroccipital process.

In dorsal view (plate 5E) the left squamosal of MWC 1 is triangular and 40 mm broad, with sides converging posteriorly at 70°. The dorsal surface is convex, with an anterior prong inside the postorbital and a posterior prong above and anterior to the lateral tip of the opisthotic and above the quadrate. A third prong runs anteromedially to override the posterolateral wing of the parietal.

In ventral view (not illustrated) the squamosal is concave transversely and anteroposteriorly. Its anterolateral edge is 16 mm thick at 45 mm in front of the quadrate socket and pinches out at 75 mm beneath the groove for the postorbital.

**Jugal:** In lateral view the lower edge of the jugal of *Ceratosauros magnicornis*, n. sp., MWC 1 (plates 1 and 2) is 225 mm long. Its anterior process ends beneath the center of the lacrimal, overlapping the maxilla. It is 35 mm high at the back of the lacrimal, 32 mm below the center of the orbit, rising to 155 mm along the back of the postorbital. Its posterior bar is 20 mm high with a narrow v-shaped socket for the quadratojugal.

**Quadratojugal:** In lateral view (plate 1) the left quadratojugal of MWC 1 has a convex lower edge, extending forward 155 mm where its pointed tip lies in a groove in the jugal. The vertical ramus is 30 mm broad below, 155 mm high, its summit rounded as determined from the right quadratojugal. Its upper half is convex anteriorly, its lower half slightly convex. At 113 mm above the ventral edge the vertical ramus is 20 mm broad. Above this its posterior edge is excavated by the dorsolateral expansion of the quadrate.

In posterior view (not illustrated) the base of the quadratojugal extends 30 mm posteromedially around the back of the quadrate and is 35 mm high. Above this the back of the lateral edge of the quadratojugal is a rounded ridge 75 mm high, its inner wall slanting anteromedially. This inner wall meets the quadrate in a vertical suture at the lateral edge of the great cavity in the latter. Near the top of this cavity the suture arches dorsolaterally, and the quadratojugal is hidden by the lateral expansion of the quadrate. The upper 40 mm of the suture is on the lateral surface, behind the quadratojugal. Both quadratojugals are present, but neither is complete.

**Quadrate:** In lateral view (plates 1,3F) the quadrate is 210 mm high, the upper third of the pillar is gently convex, the lower part concave to a depth of 16 mm. At 35 mm below the top, the quadrate sends out an anterolateral wing, 10 mm broad, over and into the quadratojugal.

In medial view (plates 2 and 3H) the pterygoid wing rises smoothly from the anteromedial edge of the pillar 74 mm above the condyle, its dorsal edge 8 mm below the top of the condyle, its ventral edge making an angle of 30° with the pillar. This edge is thickened to 20 mm by a medial flange extending to a point 110 mm from its base and underlying the base of the pterygoid. The thin dorsal blade

of the wing is 55 mm high anteriorly, where it lies alongside the pterygoid. Its anterodorsal edge is convex, its surface concave.

In posterior view (plate 3G) there is a concavity 120 mm high and 40 mm broad, lying lateral to the rather sharp vertical ridge at the back of the pillar. Above this concavity, and 35 mm below the top of the quadrate, is the thin anterolateral wing extending out over the quadratojugal. The upper edge of this wing is horizontal and the upper 35 mm extends above the top of the quadratojugal. The suture with the quadratojugal curves laterally as it descends, so that the quadrate has a breadth of 45 mm at 85 mm below the top. From there, the suture arches inward, then curves laterally to 40 mm above the base where the quadrate is 50 mm broad. Here the quadrate is overlapped by a process 30 mm long from the quadratojugal which curves around the back of the quadrate. The contact between the two bones is continuous and there is no quadrate foramen in evidence.

In dorsal view the head is 32 mm anteromedially, and 21 mm posteromedially, the thin pterygoid wing extending 108 mm anteromedially.

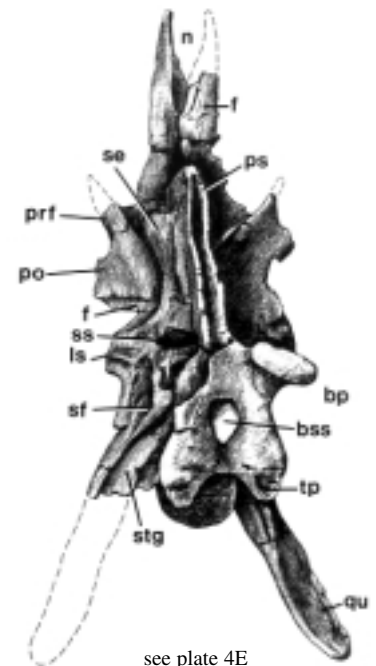
In ventral view (plate 3I), the condyles are 70 mm wide, separated by a broad, shallow groove that runs 15° anteriorly to the medial edge. The ectocondyle is smaller and lower; the two condyles converge anteromedially so that the ectocondyle is nearly transverse. From the lateral end of the ectocondyle a wing of the quadrate extends forward 35 mm inside the quadratojugal. The pterygoid wing is 15 mm broad and is grooved longitudinally.

**Sphenethmoid:** This element of MWC 1 (plate 4E) lies beneath the frontals and between their

keels. In lateral view (not illustrated) the suture with the frontal is horizontal to the broken front end, where it is 25 mm high. The sphenethmoid flares out anteriorly and has a median septum which projects 20 mm in front of the lateral wall. Its length is estimated to be 38 mm along the dorsal edge, but the suture with the septosphenoid is not certain. Its lateral face is concave both anteroposteriorly and dorsoventrally, forming the upper anterior inner wall of the orbit. From its dorsolateral corner a

groove runs posterolaterally and ventrally along its lateral wall. Its dorsolateral wall has a notch 10 mm deep. The sphenethmoid is continuous ventrally with the interorbital septum, which is, in turn, continuous ventrally with the parasphenoid; the three form a complete interorbital wall.

In anterior view the anterior end is 23 mm high and, although the right side is missing, the breadth is estimated



see plate 4E

at 44 mm. A groove runs posterolaterally and ventrally from its dorsolateral corner. It is very narrow below. The anterior foramina for the olfactory nerve are each 12 mm high and wide, separated by a vertical, midline septum. The septum has a horizontal shelf that partially separates each foramen into upper and lower parts. The upper part is elliptical and 14 mm ventromedially, the lower is circular and 9 mm in diameter. The dorsal surface of the sphenethmoid has a midline ridge and is concave lateral to this ridge, the whole fitting snugly under the frontals.

**Septosphenoid:** In right lateral view (not illustrated) the septosphenoid (plate 4E) arches laterally behind the sphenethmoid and is continuous with the latter, the suture obscure. The suture is vertical and lies 33 mm behind the notch at the front of the sphenethmoid. It forms the back of the upper orbital wall and, at its posterodorsal corner, it sends out a lateral wing which has a horizontal suture with the frontal and overlaps the front of the laterosphenoid. The suture with the laterosphenoid is 35 mm high.

In ventral view (plate 4E) the tip of the lateral wing can be seen extending laterally beyond the level of the end of the basiptyergoid process.

**Orbitosphenoid:** In right lateral view the orbitosphenoid underlies the laterosphenoid and the septosphenoid above the optic foramen. It has a concave anterior face that forms the posterodorsal wall of the orbit. The dorsal edge is 25 mm long. The posterior edge is concave so that the bone is constricted to 13 mm anteroposteriorly at midheight. Ventrally the orbitosphenoid expands to an indefinite continuation with the presphenoid. At 8 mm below the top, and at the center, is a 4 mm foramen, possibly for the oculomotor nerve.

The interorbital wall is completely ossified as far forward as at least 30 mm in front of the olfactory openings. The lowest element is the parasphenoid, and above it is the presphenoid. Above the sphenoid is a crushed, or possibly only partly ossified, vertical plate in front of the orbitosphenoid, which is continuous up to the sphenethmoid and septosphenoid.

**Basisphenoidal rostrum:** The basisphenoidal rostrum is the anterior projection of the basisphenoid (plate 4A, B, E) and extends forward 95 mm, its tip convex vertically. In lateral view it is 10 mm high at its broken anterior tip, the height increasing posteriorly to 24 mm. Its ventral edge is straight and dips 40° posteriorly with respect to the dorsal surface of the frontals, as does the grain of its bone.

In ventral view it is 11 mm broad, and channeled its entire length. The channel is 5 mm wide and 5 mm high anteriorly, increasing to at least 7 mm posteriorly where the lateral walls fuse with the sides of the subsellar pit. The channel probably continues into the pit, but this area is obscured by matrix.

**Presphenoid:** This is a very thin element that lies immediately above the basisphenoidal rostrum. It is broken anteriorly, its length 73 mm, and its maximum height 31 mm at midlength. It sends a thin buttress posteroventrally along the front of the basisphenoid. Its posterodorsal edge curves down and back and is evidently continuous with the edge of the sella turcica.

**Laterosphenoid:** Both laterosphenoids are crushed, and it is difficult to make out their relationships. The left dorso-

lateral boss is at least 70 mm from the midline, the right is 65 mm from the midline. It is 15 mm tall anteroventrally and 20 mm tall posteroventrally. In left lateral view (plate 4A) the dorsal surface is overlapped by the frontal. The anterior face curves posteroventrally beneath the transverse suture with the lateral wing of the septosphenoid. The surface is concave both transversely and posteroventrally, forming the posterior wall of the orbit. It continues anteroventrally over the top of the preotic pendant, lateral to and above the prootic. The bone forms a buttress below the dorsolateral boss, its lateral edge 5 mm thick. This buttress curves posteroventrally 30 mm and meets a rugosity on the anteroventral end of the preotic. There is a very weak anterior buttress but no concavity between the two.

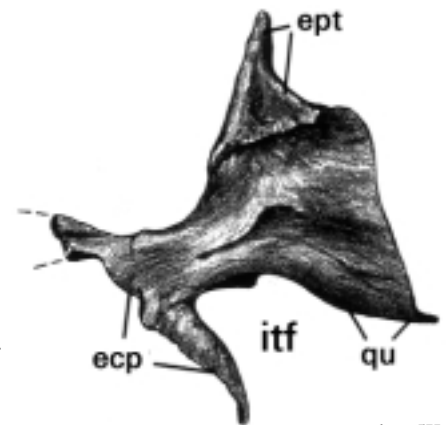
The upper 13 mm of the posterior face of the laterosphenoid is flat and dips 45° posteriorly. It is covered by a projection of the parietal out to 33 mm from the midline. Below the upper flat surface, the suture with the parietal is horizontal and curves back 10 mm, then down 5 mm to the foramen for the lateral head vein. Here it meets the front of the prootic, and the suture runs anteroventrally for 30 mm to the top of a boss in the latter bone. The posterior face of the laterosphenoid is concave and forms the lower 32 mm of the front of the lateral temporal fenestra.

**Vomer and Palatine:** Both the vomer and palatine are hidden by the compression of the skull and, therefore, cannot be described.

**Pterygoid:** The left pterygoid (plate 5J,K,L,M) is separate, and apparently uncrushed, but its anterior ramus is missing. In dorsal view the socket for the basiptyergoid process of the basisphenoid is oval, its upper opening 27 mm anteroposteriorly and 20 mm transversely.

The socket is roughened inside as though for a cartilage lining. Its anterior wall is 26 mm high, its posterior gap closed to 9 mm. The quadrate wing rises at the front of the socket, its base 116 mm long, extending posterolaterally. The wing has a rounded shelf along its inner base, extending 85 mm behind the basiptyergoid socket. There is a short, rounded posterolateral process medial to the socket. The ventrolateral base begins in a neck 20 mm anteroposteriorly, and ends in a blunt process 14 mm broad, convex above and concave below. This has a rounded end that seems to be natural, however, above it is a continuation that was broken and inset to overlap the lower process about 18 mm. When the two are juxtaposed, the ventrolateral process would have extended 88 mm laterally from the midline. Its outer end is expanded posteriorly to a length of about 63 mm with a convex dorsal surface and a blunt end. Its lateral surface evidently served to guide the lower jaw.

In lateral view (plate 5K) the base of the pterygoid forms an arch, with a neck rising posterodorsally from the



see plate 5K

center of the arch, inset about 25 mm from the lateral edge. The posterolateral end of the arch is a blunt process 17 mm across, convex above and concave below, overlapped by the ectopterygoid. The anterior extension has a thickened, roughened, medial border. The neck is 32 mm broad, its anterior edge concave and rising to 65 mm. Its upper 20 mm is overlapped by the epipterygoid and becomes very thin. The quadrate ramus is 111 mm high, its base is 95 mm long, and its lower edge concave.

In anterior view (plate 5J) the base is an arch, and its outer surface slants ventrolaterally. Its midline edge is a ridge 14 mm broad at its broken anterior end. A slight groove runs along the dorsal lateral edge of the ridge. The posterior end of this thickened ridge curves laterally and is separated from the raised anterior edge of the socket for the basiptyergoid process by a groove running posterolaterally.

In ventral view there is a socket centered 45 mm in front of the posterior tip, at the center of the facet for the ectopterygoid. Behind the socket a buttress runs ventrolaterally to form the floor of the socket for the basiptyergoid process.

**Ectopterygoid:** The left ectopterygoid of MWC 1 (plate 5G,H,I) is 138 mm along its inner edge. Its anterior surface slants 45°. Its anterior end is bluntly rounded. Some 60 mm back it develops a slight forward bulge, then curves back and out to a thin, conical process 59 mm long for the jugal. The posterior border is deeply concave to form the front of the subtemporal fenestra. The posterior ramus has a socket 26 mm long and 5 mm deep, its base extending medially for 8 mm as it is overlapped by the pterygoid.

**Epipterygoid:** The epipterygoid of *Ceratosaurus magnicornis*, n. sp., MWC 1 (plate 5J, K, L, M) is a thin, triangular plate, its upper end becoming rodlike, its base 43 mm long. Its anterior edge is straight, its posterior edge concave. It overlaps the dorsolateral surface of the pterygoid with a squamous suture. The position of the dorsal tip is not shown, but in the type of *Ceratosaurus nasicornis* it lies along the back of the laterosphenoid. Its inner surface has an arched facet that corresponds to the upper edge of the pterygoid.

**Basisphenoid:** In lateral view (plate 4A) the basisphenoid is 65 mm long from the top of the basiptyergoid process to the lateral base of the tuberosus process. It is 50 mm high to its eversion to form the foundation of the preotic pendant. It extends another 25 mm up medial to the prootic. It is 65 mm high at the stapedial fenestra. Its anterior edge continues into the rostrum. A vertical ridge 45 mm high and 5 mm broad runs down from the front of the preotic pendant and on to the side of the basiptyergoid process. Here it broadens and gradually decreases in height, then disappears 25 mm above the end of the process.

The basiptyergoidal recess begins immediately behind the anterior ridge and is 25 mm long. It is 8 mm deep dorsally, and a vertical bar separates off the anterior 5 mm. This bar has a foramen up under its top, not visible in lateral view, that allowed the carotid artery to enter the sella turcica. The posterior part of the recess continues, hidden under the preotic pendant. The ventral edge of the recess curves smoothly into the lower face of the bone. Posterodorsally, the basisphenoid forms the floor and posteroventral wall of the stapedial fenestra, and the inner wall of the facial foramen. The fenestra is crushed to a narrow, almost

vertical, slit 12 mm high, its inner surface dipping 70° laterally. A groove on the basisphenoid runs anteroventrally from the base of the front of the fenestra. The facial foramen is anterolateral to the stapedial fenestra, under the base of the prootic. The posteroventral base of the bone curves ventromedially into the basal process, and it is rugose.

On the right side the bone is badly broken, but the anterodorsal corner of the recess has two fenestrae, separated by an anteroventral bar. The dorsolateral is the larger, 10 mm in diameter, and is evidently a blind pit. The posteroventral is inset medially, is about 11 mm anteroventrally and 4 mm posteroventrally. It is partially divided, with an anterior opening at the level of the base of the infundibular foramen, which is probably for the internal carotid artery, and a posterodorsal opening that continues more dorsally into the bone.

In anterior view (plate 4B) the bone is about 18 mm thick at the front of the preotic pendant, including the anterior vertical ridge. Below this it narrows to 14 mm, then slants ventrolaterally to a breadth of 50 mm at the level of the crista basisphenoidalis. Here the basiptyergoid process is 16 mm anteromedially and thins distally to 12 mm. The subcellar pit is hidden by the rostrum.

In ventral view (plate 4E) the body of the basisphenoid is 70 mm long from the front of the basiptyergoid process to the posterolateral corner, 58 mm in the midline. It is 40 mm broad at the front of the crista basisphenoidalis, broadens to 46 mm at the back of the basiptyergoid processes, and to 62 mm posteriorly. The crista basisphenoidalis is 17 mm thick. The basicranial fontanelle is pyriform, 28 mm long, and 12 mm wide anteriorly, narrowing to 8 mm posteriorly. The medial face of its lateral wall is formed by the basisphenoid back for 20 mm, where it meets the basioccipital. The suture runs posteriorly for 10 mm, then curves posterolaterally about 45° over the base of the basal tuber.

**Prootic:** In lateral view the prootic (plate 4A) begins under the laterosphenoid-parietal arch, at the foramen for the medial cerebral vein. It is 95 mm long to its posterolateral end. It forms the lower half of the medial wall of the lateral temporal fenestra, below the parietal. The suture with the laterosphenoid runs anteroventrally from the foramen to the top of a boss on the prootic. The suture then curves anteromedially about 15 mm, then anteroventrally across the face of the preotic pendant. At the top of the stapedial fenestra, the prootic meet the opisthotic, and the suture runs back along the lateral top of the stapedial groove 75 mm where the end of the prootic curves dorsally.

There are two trigeminal foramina in the front of the prootic. The anterior foramen is below the front of the lateral temporal fenestra. It is an inverted triangle, its top 12 mm long and horizontal. Its anterior wall dips 45° posteriorly and is also 12 mm long. Its posterior wall is 8 mm high and dips 60° anteriorly. A broad groove runs anterodorsally from the foramen and carried the ophthalmic branch forward. The foramen opens posteroventrally into a concavity that broadens to 15 mm at a ledge above and in front of the stapedial fenestra. This carried the maxillary branch of the nerve. The second trigeminal foramen is 10 mm from the anterior one, in the center of the concavity, and is only 6 mm anteroventrally. It opens down along the concavity, and probably was for the mandibular branch.

The facial foramen is 14 mm directly below the top of

the second trigeminal foramen. It lies under the prootic, between it and the basisphenoid. From it a groove leads posterodorsally into the top of the stapedia fenestra. Another groove continues forward into the top of the basisphenoidal recess.

In ventral view the anteroventral projection into the preotic pendant is about 25 mm broad, and the pendant stands out about 5 mm from the basisphenoid. The suture with the opisthotic continues along the outer edge of the roof of the stapedia groove.

**Opisthotic:** In lateral view (plate 4A) the body of the bone is hidden by the parietal and the prootic, except for its posterolateroventral projection behind the prootic as the paroccipital process. It extends 80 mm beyond the end of the prootic, has a rounded end, and is about 40 mm high. Near the distal end is an indistinct hollow for the top of the quadrate. The anterior 60 mm of the lower surface is inset and its top arches out to form the inner roof of the stapedia groove. This is 50 mm long from the stapedia fenestra.

At 92 mm in front of the distal end, the paroccipital process sends down a thin plate that forms a buttress against the back of the basisphenoid. This is the crista tuberalis. Its anterior edge begins in the floor of the stapedia fenestra, then curves posteriorly as it descends along the back of the basisphenoid to 4 mm above the basal tuber (tuberous process). The posterior edge is concave and arches forward to the ventral tip.

In medial view the opisthotic is first visible between the wing of the parietal and the ventrolateral wing of the supraoccipital. It is 150 mm long and about 60 mm high to the top of its crista tuberalis. Its surface is convex vertically, and a pronounced swelling runs from the end of the supraoccipital wing diagonally down the end of the bone. Much of the surface below the parietal wing is covered by the lateral wing of the exoccipital.

In ventral view (plate 4E) the edge of the bone, including the crista tuberalis, is only 5 mm thick.

In posterior view (plate 4C) the dorsal surface is visible between the wings of the parietal and supraoccipital.

Below this the bone is hidden by the parietal wing and the exoccipital. The crista tuberalis curves anteromedially to meet the exoccipital above, and the basisphenoid below, forming the side wall and part of the anterior wall of the paracondylar pocket. Its posterior edge is only 2 mm thick. This pocket is compressed by the crushing, but apparently extends about 10 mm above the top of the condyle, and is confluent below with the subcondylar pocket in the basioccipital.

**Epiotic:** The epiotic is visible only in posterior view in a window between the supraoccipital and parietal. Crushing makes this whole region difficult to interpret, but the visible

part of the epiotic seems to be 11 mm high and 5 mm broad.

**Supraoccipital:** In lateral view (plate 4A) the supraoccipital summit extends 7 mm behind the parietals.

In posterior view (plate 4C) it is 60 mm high, ending at the exoccipitals, 5 mm above the foramen magnum. It expands dorsally to a breadth of 27 mm. The posterior edge is crushed into a vertical ridge 5 mm broad, that begins 13 mm above the foramen. The sutures with the parietal and opisthotic are obscure. The ventrolateral wing extends at least 40 mm from the midline. Its dorsomedial 10 mm are below the epiotic, and its posterolateral extension overlaps the opisthotic. The epiotic completely fills the area for the posttemporal fenestra, so there is no indication of an opening.

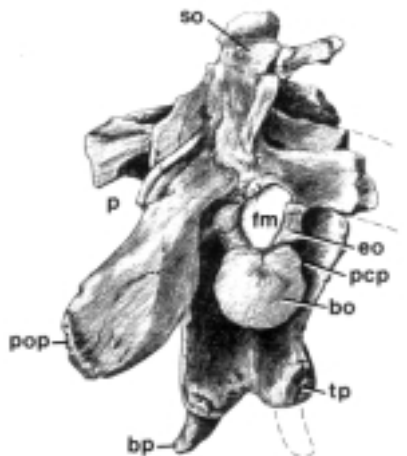
**Exoccipital:** In posterior view the exoccipital forms the dorsolateral quarter of the condyle (plate 4C), its base 21 mm long ventrolaterally. The two are 5 mm apart at their posterior base but meet anteriorly so as to cover the basioccipital. The dorsolateral stem is 10 mm broad. Its medial edge arches dorsomedially to the midline, where the bone is 5 mm high. The foramen magnum is pyriform, 31 mm high and 26 mm wide at midheight.

The dorsolateral stem broadens upward, and the bone curves posteriorly over the opisthotic at least 30 mm, where the suture is obscure. The lower edge of the stem arches forward to form the top of the paracondylar pocket. At the inner summit of the pocket the exoccipital is pierced by the 6 mm vagus foramen. The hypoglossal foramen is hidden by the crushing.

**Basioccipital:** In lateral view of the cranium (plate 4A) the posteroventral quarter of the occipital condyle projects 12 mm behind the crista tuberalis of the opisthotic.

In posterior view (plate 4C) the condyle is 31 mm high at the midline and 40 mm broad. The suture with the exoccipital dips 25° laterally from the midline. The condyle curves anteromedially into the neck, so that the neck, the medial part of the paracondylar pocket, and the top of the subcondylar pocket are hidden. The neck is 15 mm long ventrally, 36 mm broad, and has a ventral sagittal ridge that curves down anteriorly into the subcondylar pocket. About 7 mm in front of the condyle the exoccipital extends down vertically to the midheight of the neck. Below this the lower part of the neck curves out and meets the inner edge of the crista tuberalis, the two forming the front part of the paracondylar pocket. The pocket begins about 8 mm above the top of the condyle and is 70 mm high, ending at the base of the basal tuber. The subcondylar pocket is confluent with the paracondylar pocket, the two 50 mm wide ventrally near the base, and narrowing to 30 mm at the base of the tuberous process (basal tuber) of the basioccipital. A low, vertical midline ridge is continuous with the ridge on the neck. Lateral to the top of the ridge is a depression 4 mm deep. The basioccipital extends down, then curves laterally and posteriorly to form back of the basal tuber.

In ventral view (plate 4E) the basioccipital forms the entire crista basioccipitalis and is 10 mm thick. The basioccipital extends forward inside the basisphenoid and along the inner wall of the fontanelle and is visible for at least 15 mm. It disappears forward under the overhang of the basisphenoid, but probably extends to the front of the fontanelle. The suture with the basioccipital continues back posterolat-



see plate 4C

erally across the basal tuber. The basioccipital extends 27 mm posterolaterally from the crista, and it ends in a rough facet that faces posterolateroventrally.

### Axial Skeleton

**Cervical Vertebrae:** Typically, the cervical centra of *Ceratosaurus* are amphiplatyan as described by Gilmore (1920, p. 95) with nearly flat anterior ends and deeply concave posterior ends. The spines are quite thin and the prezygapophyses are large and dip about 45° medially. The table is unusual in the ventral flexure of the lateral half, such that the transverse process is oriented vertically. The posterior cervicals become very short anteroposteriorly.

The zygosphenes appear on the anterior cervicals as a slender, vertical bar directly above the neural canal (plate 6). This bar becomes larger and projects farther forward on the posterior cervicals, and on the dorsals it develops dorso-laterally-facing articular facets. A similar vertical bar, the hyosphene, projects back below the postzygapophyses and above the neural canal.

The atlas, axis, third and fourth cervicals are missing. The fifth centrum of the holotype, *Ceratosaurus magnicornis*, n. sp. (MWC 1; PF-QB-36A; plate 6A-C) in lateral view is 60 mm long dorsally and 65 mm ventrally. It is 60 mm high anteriorly, 77 mm posteriorly, and deeply concave laterally. Its ventral surface is arched asymmetrically, 15 mm high just behind the front. The front end dips 80° posteriorly with respect to the long axis of the centrum, the posterior end is vertical. The parapophysis is at the anteroventral edge of the centrum, 25 mm high and 15 mm long. The anterior pleurocoel is 12 mm long posteroventrally, its base 25 mm above the bottom of the parapophysis. The posterior pleurocoel is separated from the anterior one by a flat surface 14 mm long. Its axis dips more steeply posteriorly, and is 12 mm in major diameter. Its base is 21 mm above the bottom of the centrum. The arch is fused to the centrum, but is broken. The anterior chonos continues as a groove along the anterior face of the transverse process. The medial chonos is 32 mm long basally and 20 mm high. Its anterior and posterior walls meet at an angle of 55°. The posterior chonos is widely open, its anterior wall dipping 60° posteriorly.

In anterior view the centrum is flat, 80 mm broad, and 90 mm wide including the parapophyses. The zygosphenes are 11 mm high, 4 mm broad, and are flanked by small prechonos 13 mm high and 8 mm wide. The neural canal is 15 mm high and 18 mm wide.

In posterior view the centrum is 85 mm broad, and 21

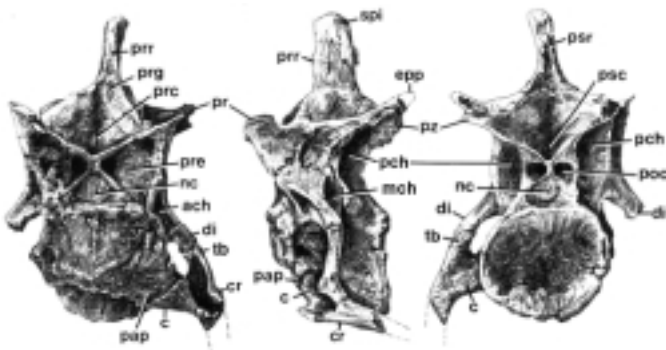
mm deep. The pedicle is 21 mm broad at the center of the canal, which is 18 mm high and 29 mm wide.

The sixth cervical centrum (MWC 1, PF-QB-43) is 80 mm long dorsally, its anterior end damaged. In lateral view it is 82 mm high posteriorly. The parapophysis is near the base of the centrum; it is 15 mm long and 30 mm high, and the ridge behind it extends back 35 mm. The anterior pleurocoel is 5 mm high and 8 mm wide, situated 10 mm above the top of the parapophysis and 18 mm behind the front of the centrum. The posterior pleurocoel is 9 mm high and 12 mm wide, and is 23 mm behind and 4 mm above the anteroventral corner of the centrum. The arch is fused to the centrum, its peduncle 70 mm long. Its anterior edge dips 70° posteriorly from the horizontal, its posterior edge is vertical. The anterior chonos is narrow and triangular. Its base is 12 mm long, 22 mm high anteriorly, and about 15 mm deep. Its posterior wall dips 60° posteriorly and the cavity extends 30 mm ventrolaterally along the diapophysis. The medial chonos is low, its base 35 mm long, and its summit extends along the ventral face of the diapophysis nearly to its end. The posterior chonos is 50 mm high, its posterior wall vertical. Its anterodorsal wall dips 50° anteriorly. The anteroventral wall is 27 mm deep, convex, and meets the anterodorsal wall at midheight. The table is 40 mm long above the prezygapophysis. At the line joining the zygapophysial surfaces, it bends steeply downward, where it is 70 mm long in front of the postzygapophysis. At 35 mm below the bend the table shortens to 35 mm, this occurs at the front of the posterior chonos. The diapophysis is on a transverse process reaching down to within 22 mm of the parapophysis. It is 17 mm long and 15 mm high. The lateral edge of the prezygapophysis is 55 mm above the centrum. The postzygapophysis is continuous with the chonos, its lateral edge 60 mm above the centrum. The ends of the zygapophyses and the spine are missing.

In anterior view the centrum is almost flat and is 60 mm broad. The neural canal is 28 mm high and 15 mm wide, narrowing dorsally. The pedicle is 20 mm broad, its face slanting posterolaterally. At 10 mm above the base a buttress runs up and out to form the anterior wall of the anterior chonos. The inner wall of the pedicle arches up and over the canal, 20 mm high, and above this is a zygosphenes 12 mm high and 7 mm broad. This is flanked by a triangular prechonos 25 mm in anterolateral height and 10 mm wide. Above the zygosphenes is a huge prespinal chonos 28 mm wide and continuous with a prespinal groove 10 mm wide at its base. The prezygapophysis dips 35° medially. The table dips 40° laterally down to a line joining the lateral edges of the zygapophyses, then it arches suddenly downward, its dip increasing to 80°. It is convex above the bend and below it, down to 10 mm from the diapophysis, where it becomes concave.

In posterior view the centrum is 76 mm broad and 20 mm deep. The pedicle curves far, 45 mm down over the centrum. It is 10 mm wide at the center of the canal. It is perforated by a postchonos 25 mm high and 10 mm wide, its center is opposite that of a hyosphene 10 mm high and 5 mm wide. The postspinal chonos is obscure, but is much smaller than the prespinal chonos.

The seventh cervical (MWC 1, PF-QB-12) is fairly complete. In lateral view its centrum is 70 mm long dorsal-ly, 75 mm ventrally. It is 55 mm high anteriorly, 70 mm



see plate 6A-C

posteriorly, and both ends dip 80° posteriorly from the horizontal. The ventral arch is but 7 mm high. The parapophysis extends as a buttress from its anteroventral edge, and is 18 mm high and 13 mm long. The anterior pleurocoel, lying just above the parapophysis, is very small, 5 mm long and 2 mm high. The posterior pleurocoel is a 5 mm circle, its edge 20 mm behind the former. The arch is fused, the pedicle 69 mm long. Its anterior and posterior edges are aligned with the ends of the centrum.

The anterior chonos is a very small depression 25 mm high, 7 mm wide, and 5 mm deep. The medial chonos is 20 mm long, about 10 mm high, and extends up under the table. The posterior chonos is a very large cavity opening posterolaterally. It is 55 mm high posterolaterally, 29 mm wide, and 25 mm deep. The edge of the prezygapophysis is 60 mm above the upper margin of the centrum. The wall beneath it is 60 mm long to the posterior chonos. It slopes steeply downward and shortens to 20 mm at the level of the top of the centrum. Here it gives off a process 12 mm across its top that extends 35 mm posterolateromedially to end in the diapophyseal facet. This is at about midheight of the centrum and the rib is fused to it. The table is short, 40 mm at the base of the spine, and concave transversely. The prezygapophysis has its edge 60 mm above the centrum with its tip 17 mm in front of the centrum. The spine is 52 mm long at its base and rises 80 mm above the table, 145 mm above the centrum. Its side becomes increasingly rough, vertically striated towards the top. The postzygapophysis rises to 60 mm above the centrum. Its inner face is 20 mm broad and is separated from the posterior chonos by a groove 5 mm wide along its anterior face. It is surmounted by an epiphysis 26 mm long.

In anterior view, the pedicle is 18 mm broad, arching inward over a canal 12 mm high and 20 mm wide. The waist is 12 mm broad and 5 mm high, and is 10 mm back of the front of the centrum. It is flanked by a prechonos 12 mm high and 9 mm wide. The prespinal trough is 15 mm long and 25 mm wide. The prespinal groove flares out into the trough. The lateral edge of the pedicle is a 7 mm broad buttress that runs up to the center of the zygapophysis. The prezygapophyses dip 30° medially, their central edges 30 mm apart.

In posterior view, the centrum is 80 mm broad and 31 mm deep, the pedicle is 9 mm broad, arching over a canal 15 mm high and 17 mm wide. The waist is 5 mm high and 11 mm broad. On either side is a postchonos 20 mm high and 13 mm wide. The postspinal trough is 30 mm long and flares out dorsally into a large cavity 70 mm high and 55 mm wide. The spine is 25 mm broad. The postzygapophyses dip 35° medially. The lateral wall of the pedicle is a thin (2 mm) buttress rising to the inner edge of the postzygapophysis. It forms the lateral wall of the postchonos and the inner wall of the posterior chonos.

In ventral view, the centrum is pinched to 53 mm in breadth and there is a faint remnant of a keel. In anterior view, the end is nearly flat, and 70 mm broad. Its upper edge is flat below the canal.

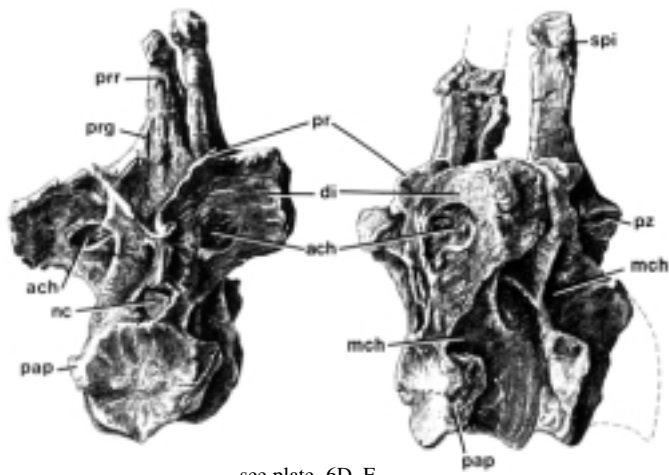
The eighth cervical (MWC 1, PF-QB-4) is mostly complete. In lateral view the centrum is 80 mm long dorsally, 60 mm ventrally. The anterior face dips 70° posteriorly with respect to the neural canal. The posterior edge is vertical and slightly concave. The lower edge arches up only 5

mm. The parapophysis is at the bottom of the front edge, 30 mm high and 15 mm wide. Immediately above it, at midheight of the centrum, is the anterior pleurocoel, 6 mm wide. The posterior pleurocoel is 22 mm behind this and slightly higher, but equally small. The arch is fused, as is the rib on the left side. The anterior chonos is very small, nearly hidden by the table. It is 12 mm high, 5 mm wide and continues as a groove for 30 mm along the diapophysis. The medial chonos is covered by the table, is 30 mm long and about 20 mm high. The posterior chonos is a huge opening 65 mm high, 35 mm wide, and 37 mm deep, facing posterolaterally. The table is very short at the base of the spine (30 mm) lengthening to 70 mm at the zygapophyses. Here it bends suddenly downward, and shortens to 30 mm at the top of the anterior chonos, then to 25 mm at the top of the diapophysis where it curves to face posterolaterally as a part of the pedicle.

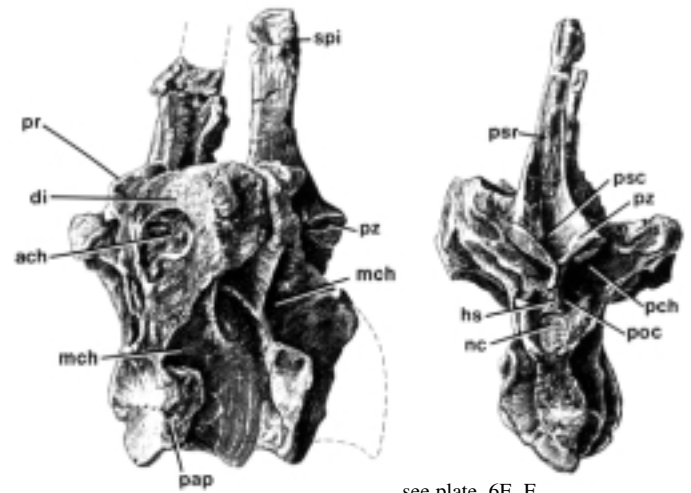
The prezygapophysis rises to 68 mm above the centrum, with a notch between it and the table. The postzygapophysis has a slight groove between it and the posterior chonos. Its tip is 65 mm above the centrum and it has an epiphysis, broken off. The spine is very short (28 mm) at its base and broken off at midheight. In anterior view the centrum is 75 mm wide and 60 mm high, its top straight. The breadth across the parapophyses is 95 mm. The pedicle is 25 mm wide, arching over a canal 22 mm high and 26 mm wide. The zygosphene is 9 mm high and 7 mm wide. The prechonos is 15 mm high, 12 mm wide, flaring out into a large, shallow depression. The whole is a triangle 40 mm high and 30 mm wide. The prespinal trough is 16 mm long, ending in a shallow chonos. The groove is indistinct, with the buttresses to the prezygapophyses flaring out to a breadth of 50 mm. The prezygapophysis has its inner edge 40 mm above the centrum, the two 50 mm apart and dipping 25° medially. The buttress below it, which is the front edge of the lower table, is 45 mm from the midline and nearly vertical. The diapophysis dips 50° laterally, with its lower edge 25 mm long. Its end is nearly horizontal and the rib is fused.

In posterior view, the centrum is 80 mm high, 90 mm broad, and 25 mm deep. The pedicle is 10 mm wide at midheight of the neural canal, which is 20 mm high and 20 mm wide. The hyposphene is 8 mm high. The postchonos is 28 mm high laterally and 14 mm wide. The postspinal trough is 22 mm long. The groove is indistinct, but about 10 mm wide. The entire cavity is large, with bulging dorso-lateral walls. The facets of the postzygapophyses dip 30° medially and extend to 60 mm from the midline. The lateral wall of the posterior chonos is 48 mm from the midline, the inner wall (the lateral wall of the prechonos) 20 mm.

The ninth cervical (MWC 1, PF-QB-1A, plate 6D,E), is joined by matrix to the first pectoral (PF-QB-1B). In lateral view (plate 6E) its centrum is 64 mm long dorsally, 68 mm ventrally. The anterior face is vertical, the posterior dips 80° posteriorly, and its dorsal 20 mm is vertical. The ventral surface arches up 12 mm. The parapophysis is low on the anterior edge, 40 mm high and 20 mm long. The anterior pleurocoel is 12 mm long, 10 mm high and continues laterally into a paracoel 6 mm high. The posterior pleurocoel is but 4 mm high and 2 mm long, situated 13 mm posterodorsal to the anterior. The arch is tightly fused. The anterior chonos is 40 mm high, 15 mm long, and opens lat-



see plate 6D, E



see plate 6E, F

erally. Behind it, and running out 30 mm below the top of the parapophysis, is an elliptical depression in the wall of the parapophysis, 27 mm long, 12 mm high, and 9 mm deep. The anterior wall of the anterior chonos dips 55° posteriorly. The medial chonos is 39 mm long and 40 mm high. Its inner wall is vertical and its top extends out 60 mm below the transverse process. The posterior chonos is 40 mm high and 12 mm long dorsally, pointed below. It opens laterally along the back of the transverse process and is continuous with the postzygapophysis.

The prezygapophysis rises to 95 mm above the centrum and extends 15 mm in front of it. The transverse process is massive, 45 mm high (70 mm medially) and extends to 90 mm from the midline. The diapophysis is 40 mm high and 30 mm long on the right, and 70 by 37 mm on the left. The postzygapophysis is 65 mm above the centrum. The tips of the pre- and postzygapophyses are 80 mm apart. The table is 35 mm long, the top of the transverse process 30 mm. The spine is 28 mm long at 20 mm above the table, and lengthens dorsally to 40 mm; its tip is gone.

In anterior view (plate 6D) the centrum is 72 mm high and 75 mm broad. The pedicle, 19 mm wide, arches over the neural canal which is 20 by 20 mm. The zygosphene is 27 mm high, 11 mm wide, and there was a very thin ventral continuation 5 mm wide dorsally that pinches out ventrally, as indicated by the broken surface. The prechonon is reduced to a circular pit 6 mm across. The buttresses to the zygapophyses are 55 mm apart. The prespinal trough is 20 mm long. The groove is 13 mm wide, but is filled by slightly roughened and vertically striated bone. The spine narrows to 13 mm dorsally. The prezygapophyses dip 45° medially.

The posterior end of the centrum is 75 mm high and only 63 mm wide, having been narrowed by crushing, and it is 15 mm deep. Ventrally it is pinched to 38 mm and a slight keel is present at each end.

**Pectoral vertebrae:** The first pectoral (MWC1.1, PF-QB-1B, plate 6E,F) lacks the posterior part of the centrum. In lateral view it is 76 mm high anteriorly. The parapophysis is 25 mm above the bottom, 50 mm high and 25 mm broad. It has a nearly vertical anterior edge that extends in front of the centrum and a convex posterior edge. The upper 17 mm of the parapophysis is formed by the arch. There is an anterior pleurocoel 60 mm above the front base

of the centrum, 8 mm from the end and half hidden by the reverted edge of the parapophysis. The pleurocoel is 9 mm long and 7 mm high. The arch is fused, its posterior base missing. The anterior edge of the pedicle rises vertically 13 mm then sends a buttress, dipping 50° posteriorly, up to the prezygapophysis. The wall of the pedicle is 46 mm long dorsally, 55 mm ventrally. The posterior edge of the pedicle is a thick buttress that dips 60° posteriorly and continues up as the anterior wall of the medial chonos. The anterior chonos begins 33 mm above the centrum, is 44 mm high and opens anteriorly and laterally. Its posterior wall dips 70° anteriorly, its top extending out 54 mm under the transverse process. The medial chonos is 31 mm high, its base 31 mm wide, and its inner wall is continuous with the face of the pedicle. The posterior chonos opens anterolaterally and is 43 mm high; it continues 67 mm laterally along the face of the transverse process nearly to its end.

The prezygapophysis is 60 mm above the centrum and extends 10 mm in front of it. Its lateral edge is horizontal. Behind it the platform arches up and out to the diapophysis. The platform ends posteriorly 14 mm above the postzygapophysis, which is 60 mm above the centrum. The spine is 53 mm long basally, shortening to 25 mm a third of the way up, and reaching 120 mm above the table. The diapophysis is a rounded, inverted triangle 37 mm high, and 30 mm long above. Its upper edge is convex, its anterior and posterior edges concave. It is 10 mm long ventrally.

In anterior view the prespinal trough is widely open (about 90°) and is 23 mm long. The groove is narrow below and widens to 15 mm at a height of 65 mm; it is replaced by a prespinal ridge for the upper 40 mm. The transverse process extends 85 mm from the midline and is almost horizontal.

In posterior view the pedicle narrows to 15 mm, then arches over the neural canal, which is 26 mm high and 18 mm wide. From its base a thin buttress runs out to below the end of the transverse process. This forms the front of the large posterior chonos. The hyposphene is 30 mm high. Its lower 9 mm is a thin vertical wall, above which it expands suddenly to a breadth of 12 mm. This narrows upward to 10 mm, then flares out to the postzygapophysis, which is 35 mm broad and slightly arched, dipping 35° medially.

The second pectoral (MWC 1, PF-QB-1C) and the first

dorsal (PF-QB-1D) are matrixed together. In lateral view the pectoral centrum is 170 mm long both dorsally and ventrally. There is no pleurocoel and it is crushed so that it is extremely narrow. The parapophysis is partly on the centrum, but its upper 20 mm are on the arch. It is 25 mm high and 10 mm long. The anterior face of the centrum is 81 mm high, 78 mm wide, and 8 mm deep. The arch is fused. The pedicle is 65 mm long, its anterior and posterior edges concave and dipping posteriorly. The anterior chonos is 35 mm high and continues laterally at least 70 mm along the transverse process. Its posterior wall dips 50° anteriorly. The medial chonos is a widely open triangle, its base 50 mm long and its height 30 mm. It extends 50 mm out under the transverse process. Its posterior wall is transverse and dips 60° posteriorly. The posterior chonos is 50 mm high and opens posteriorly. Its roof is the back of the table, 6 mm above the postzygapophysis. The table is 60 mm long and arches anteroposteriorly.

The prezygapophyses are 60 mm above the centrum and extend 30 mm in front of it. The postzygapophyses are 45 mm above the centrum. The spine is 60 mm long at the base, 38 mm dorsally, and 124 mm above the table.

In anterior view the pedicle is broadened to reach 62 mm from the midline where its end forms the upper part of the parapophysis, dipping 55° medially. The canal is 15 mm high, and 23 mm wide. The zygosphenes are 14 mm high and very narrow. The prechonos is 17 mm high and 5 mm wide. The prespinal trough is 15 mm long and ends at the base of the groove, which is very poorly defined, being filled with bone. The spine is 25 mm wide near the base and narrows dorsally to 12 mm. The facets of the prezygapophyses dip 30° medially.

**Dorsal Vertebrae:** These are distinctive in that both the parapophyses and diapophyses project far laterally on separate processes, so there is a deep concavity between them. Thus, in dorsal view the sides of the tables are deeply concave.

The first dorsal (MWC 1, PF-QB-1D), is crushed so that the spool is narrowed to 12 mm, but must have originally been quite pinched. In lateral view, the centrum is 70 mm long dorsally, 75 mm ventrally. It is 90 mm high at each end. The arch is fused, the pedicle 70 mm long at the base. The parapophysis is on a long process that has its summit 25 mm above the centrum. It is supported by a thin buttress rising from the anterior edge of the centrum. The anterior chonos is above the base of the parapophyseal process. It is 30 mm high at its posterolateral wall, and 12 mm wide at its center. The posterior wall of the chonos rises above the process and dips 80° anteriorly. The median chonos is widely open, its base 50 mm long. It is interrupted by a flange that extends back, and up, into the chonos and separates the anterodorsal half of the chonos. This part of the chonos extends as a groove out the posterodorsal edge of the process. The transverse process extends as a wing over the medial chonos. The posterior chonos faces posteriorly, continuing out along the back of the transverse process. The base of the spine is missing but it is 55 mm long at the summit. In anterior view the end is hidden. The strut for the parapophyseal stem dips 15° laterally, extends 66 mm from the midline, and is 20 mm high.

The facet of the prezygapophysis dips 40° medially. Viewed posteriorly, the pedicle is 13 mm wide. The neural

canal is 10 mm high and 12 mm broad. The hyposphene projects back 20 mm to above the back of the centrum, with dorsolateral facets dipping 50° laterally. They are 5 mm apart dorsally, 17 mm ventrally. Their lower surfaces are concave. A narrow keel 25 mm high extends down to the canal. The postzygapophysal facet dips 35° medially. The transverse process extends dorsolaterally to 75 mm from the midline, buttressed by the posterior wall of the median chonos.

The second dorsal (MWC 1, PF-QB-2) has a centrum 65 mm long dorsally and ventrally. In lateral view there is no pleurocoel. The ventral surface arches up 25 mm. The sides are very concave, the spool pinched to 27 mm. The neural arch is fused, the pedicle is 65 mm long. Its anterior base is vertical and its posterior base dips 30° posteriorly. The anterior chonos is 40 mm above the centrum and is 20 mm high and 10 mm wide, opening anterolaterally. The parapophyseal stem is 40 mm high at its base, centered on the anterior chonos. A process along the back of the stem curves down and thickens into the base of the medial chonos. This divides the chonos into a small, ventral pocket below the base of the strut, and a large, laterally facing upper part which is 40 mm high and 30 mm long. It is roofed by the table and its posterior wall is a great buttress arching forward, up, and out below the transverse process. This buttress has a bulge on its anterior face on its lateral third. The posterior chonos is 50 mm high to the inner base of the postzygapophysis and extends forward beyond the middle of the arch and continues as a concavity dorsolaterally 95 mm along the face of the transverse process. This face of the process is also swollen and at the middle of the swelling, 30 mm from the midline, is a large foramen. This foramen is 15 mm high, 5 mm wide, and opens laterally. The postzygapophysis is 65 mm above the centrum, 5 mm below the table and separated from the table by a longitudinal groove that curves up around the front of the table. The top of the table is highly arched anteroposteriorly and is 65 mm long. The end of the transverse process is an inverted triangle, its top 35 mm long. It is 25 mm high, the sides concave.

In anterior view the centrum is 82 mm high, 90 mm broad, and flat. The pedicle is 16 mm wide at its narrowest. The canal is 14 mm high and 18 mm broad. There is a slight zygosphenes 30 mm high. The prechonos is between 35 to 40 mm above the centrum.

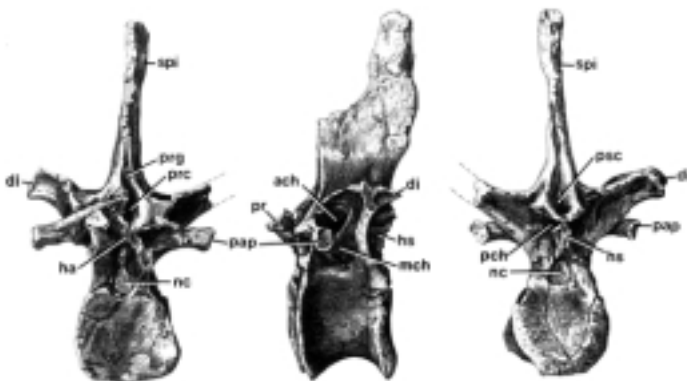
The prezygapophysis dips 15° medially, its inner edge 50 mm above the centrum. The two are separated by a vertical gap, a small hypantrum, 2 mm wide and 20 mm long. The surfaces for the zygosphenes dip 55° laterally. The lateral edge of the pedicle curves dorsolaterally to form a buttress under and along the front of the parapophyseal stem. At a height of 35 mm the front face of the pedicle gives off a thick (9 mm) buttress that dips 45° laterally and braces the zygapophysis. The parapophyseal stem has a base about 40 mm high, centered on the anterior chonos. It dips 15° laterally and reaches 77 mm from the midline. There is no prespinal trough, and the lower 55 mm of the groove is a narrow cleft. Lateral to the crest the wall is convex, curving anterolaterally, its breadth diminishing from 20 mm at the base to a pointed top. A slight groove marks the upper edge of this convex wall; dorsolateral to the groove is the base of the spine, 10 mm wide. The front edge of the transverse process and table curves down 35 mm to the top of



the parapophyseal stem. The top of the table dips 20° medially and extends to 95 mm from the midline.

In posterior view the end of the centrum is 80 mm high, 75 mm broad, and 4 mm deep. The pedicle is 18 mm broad, arching over the canal 24 mm high and 18 mm wide. Above this is a complicated hyposphene 40 mm high and 17 mm broad that fills the center of the posterior chonos. This includes a midline keel 17 mm high and 3 mm thick. Above the keel the dorsolateral facets dip 40° laterally, their anterior ventral surfaces curving down and back like the upturned prow of a boat. The hyposphene extends 10 mm from the midline ventrally and narrows above to a vertical process 6 mm high and 3 mm wide that reaches up to the base of the postspinal trough. Here the postzygapophysis meets the midline, dipping 20° medially. The trough is 63 mm above the centrum, 20 mm long, ending at the base of a deep, narrow groove without a chonos. The spine is 30 mm wide at its base. In ventral view the sides of the centrum are pinched to a 27 mm transverse diameter.

The third dorsal (MWC 1, PF-QB-44, plate 6G-I) is almost complete. In lateral view its centrum is 70 mm long dorsally, 65 mm ventrally. The ventral border is arched 16 mm. The pedicles are fused to the centrum, their bases 70 mm long. The sides are imperforate. The anterior chonos is squeezed upward by the dorsal migration of the parapophyseal stem so that its base is 35 mm above the centrum. It is 15 mm high and opens laterally. The medial chonos is 20 mm long and 35 mm high. It is divided almost equally by a shelf that runs posterodorsally from the back of the stem. Its posterior wall is a buttress, 10 mm thick, up from the posterior lappet to beneath the center of the transverse process. The posterior chonos opens laterally and posteriorly, its top the front of the table. It is separated from the postzygapophysis by a groove down and around the side of the table. Its roof is 9 mm above the lateral edge of the postzygapophysis. On the right side a vertical wall separates a lateral third of the chonos. The chonos extends dorsolaterally beyond this wall nearly to the end of the transverse process. The prezygapophysis is almost horizontal laterally, with its tip 52 mm above and 10 mm in front of the end of the centrum. The table arches back from behind the prezygapophysis, giving off the parapophyseal stem 10 mm back. The spine is 70 mm long and 57 mm broad near the base, expanding to 72 mm near the summits then narrowing. It reaches 135 mm above the table and there is a pit at its central base.



see plate 6G-I

In anterior view the centrum is 63 mm high, 75 mm broad, and 8 mm deep. The pedicle is 12 mm broad at the center of the neural canal. The canal is oval, broader below, 22 mm high and 13 mm wide. Above it is a narrow vertical zygosphene 12 mm high, flanked by very small prechonos. The area above is damaged, but the base of the spine broadens to enclose a prespinal chonos and groove, the two 72 mm high. The parapophyseal stem is quite different on the two sides. On the left it is concave at its base as the anterior chonos continues out its edge. On the right it is flat and dips 40° posteriorly. It extends nearly horizontally to 68 mm from the midline. The front of the table arches up and back to the top of the diapophysis. The summit of the table dips 20° medially. The spine is 14 mm wide near its base, 6 mm dorsally.

In posterior view the centrum is 75 mm high and 70 mm broad. The pedicle is 10 mm wide, the canal 12 mm high and 20 mm wide. Above it is a complex hyposphene with a narrow vertical ridge 25 mm high. The hyposphene is 15 mm wide at its base, and narrows to 7 mm at the center. On the left it expands 9 mm to a poorly developed articular surface, then narrows immediately below the zygapophysis. On the right the articular surface failed to develop. The postzygapophysis dips 15° medially and is 22 mm long by 22 mm broad. The postspinal trough is 18 mm long, curving upward into the groove. The left posterior chonos is open, but its anterior wall has a slight horizontal bulge at midheight. The right chonos is 42 mm deep and has a vertical buttress 5 mm thick rising 20 mm from the midline. In ventral view the centrum is pinched to a transverse width of 25 mm.

Dorsals 5, 6, and 7 are matrixed in sequence, the gaps between centra 7 mm and 6 mm. The centrum of 5 (MWC 1, PF-QB-3A) is broken and 110 mm long. In lateral view the arch is fused, the pedicle 110 mm long, shortening to 70 mm at midheight. The anterior pleurocoel begins 40 mm above the centrum and is 22 mm high, its posterior edge is formed by the front of the parapophyseal stem, in line with a ridge that forms a slight buttress to the front of the stem. The medial chonos is separated into a smaller upper part 30 mm long and 10 mm high, all above the posterior shelf from the stem, and a very large open cavity anteroventral to the transverse process. From the posteroventral lappet a thin buttress arches up, out, and back under the transverse process. The lappet divides the medial chonos from the posterior. The posterior chonos is 80 mm high posteriorly and is widely open. It extends to 17 mm above and beside the postzygapophysis. The inner wall extends back to at least above the end of the centrum, its upper part evidently extending as an hyposphene between the succeeding prezygapophyses. The table is nearly flat anteroposteriorly, but curves down over the top and front of the parapophyseal stem. The diapophysis is a 25 mm circle. The diapophysis is 35 mm long, 9 mm high anteriorly and 25 mm posteriorly. The prezygapophysis is 60 mm above the centrum and extends to its front. The spine is 92 mm long at its base, expanding to 95 mm at 55 mm above the table.

In dorsal view the transverse process has a notch above the parapophyseal stem where it is 35 mm wide. From here it arches back to the rear of the diapophysis where it is 80 mm from the midline. The stem is 60 mm long from the midline, and is 20 mm wide, projecting below the level of

the table.

In anterior view, the pedicle has a very thin base, and the canal is a triangle 30 mm high with its base 30 mm broad. Above its center, a groove rises 35 mm and curves back into the prespinal groove. Lateral to it a buttress 10 mm wide runs up beneath the transverse process. The prezygapophyses are nearly horizontal, 3 mm apart, and their inner upper faces form hypocentral facets that dip 60° laterally. The prespinal trough is 15 mm long and the groove is very narrow, broadening ventrally. The parapophyseal stem dips 15° laterally, is 22 mm high and the parapophysis dips 55° medially. The transverse process dips 30° medially.

The sixth dorsal (MWC 1, PF-QB-3B) also has a damaged centrum. It is 100 mm long dorsally, its sides deeply pinched and imperforate. The arch is fused, the pedicle as long as the centrum. The pedicle shortens to 65 mm at midheight. The anterior chonos is 20 mm high and 15 mm wide. The medial chonos is 45 mm long, its base open and continuous with the wall of the arch. A broad swelling runs back from the parapophyseal stem to the back of the chonos. Above this swelling is a small conical recess. The posterior chonos is widely open, its posterior roof 75 mm above the centrum. The prezygapophysis is 60 mm above the centrum and is nearly horizontal. The front of the pedicle forms a buttress, dipping 50° posteriorly, that rises under the zygapophysis. The lateral edge of the pedicle has a 3 mm buttress up to the anterior edge of the parapophyseal stem. The parapophysis is 25 mm above the centrum, is 25 mm high and 14 mm long. It faces posteroventrally. The diapophysis is an inverted triangle, 30 mm long and 35 mm high. The table is nearly flat, curving down anteriorly. It is 90 mm long. The spine is 100 mm long at the base, shortens to 90 mm, then expands dorsally to 100 mm. The top is 120 mm high above the table.

The seventh dorsal centrum (MWC 1, PF-QB-3C) is 85 mm long, and 85 mm high anteriorly. In lateral view, the ends are finely rugose, the ventral arch 20 mm high. The arch is tightly fused, the pedicle 95 mm long, overhanging the centrum. It shortens to 75 mm at midheight. Its anterior edge dips 70° anteriorly, its lateral edge forming a thin buttress for the parapophyseal stem. Medial to this it sends a 10 mm buttress up to the zygapophysis. The anterior chonos is hidden by the strut, but is about 25 mm high. The stem is quite massive, 20 mm in diameter, and dips ventrolaterally and somewhat anteriorly. The parapophysis is the same diameter and its summit has a thin crest running up to the front of the table. The medial chonos is 35 mm wide from the back of the stem. It opens laterally and its base is continuous with the wall of the pedicle. The posterior chonos is very shallow and is divided by a buttress slanting ventrolaterally.

The prezygapophyses are hidden in lateral view. The transverse process reaches 90 mm from the midline and ends in a large diapophysis. This is an inverted triangle 40 mm long and 30 mm high. The postzygapophysis is 80 mm above the centrum and extends 40 mm behind it. Below it is the hyposphene, damaged, but 16 mm wide and reaching back below the ends of the zygapophyses. There is no postspinal trough and the groove is narrow. In ventral view the centrum is pinched to 26 mm medially and is 68 mm broad anteriorly, 75 mm posteriorly.

The eighth dorsal (MWC 1, PF-QB-14A) is the last of the series preserved. In lateral view its centrum is 120 mm long dorsally, 95 mm ventrally. The anterior end is vertical, the posterior dips 85° ventrally. The arch is fused, the pedicle 106 mm long. Its anterior edge dips forward 60° and at its base gives off a 3 mm buttress to the parapophyseal strut. The lower edge of the strut is 13 mm above the centrum. The parapophysis is an ellipse 20 mm high and 18 mm long. The table curves down from 30 mm above it to the top of the facet. The anterior chonos is barely visible in lateral view. The medial chonos is 70 mm long at the top of the centrum and 55 mm high, its summit rounded. Its anterior wall has a rounded swelling leading posterodorsally from the parapophysis. The posterior chonos is wide open, 50 mm high and 40 mm wide along the face of the transverse process. The diapophysis is a rounded knob 30 mm long, and from its back the table curves down and into the parapophysis, the two facets 18 mm apart. The posterior base of the pedicle is concave, forming a semicircle 20 mm deep, arching over the canal and up to the zygosphenes.

In anterior view, the pedicle is 15 mm wide, the canal 27 mm high and 27 mm broad. The outer buttress to the parapophysis originates at the base of the pedicle. This buttress forms the back of the anterior chonos which is 40 mm high and 50 mm wide. It is about 35 mm deep. The parapophysis is 75 mm from the midline, the diapophysis 90 mm. From the level of the center of the canal a thicker (7 mm) buttress runs dorsomedially to below the prezygapophysis. The zygapophysis is 55 mm above the centrum and overhangs it by 6 mm. Its facet dips 25° medially. A narrow (2 mm) groove separates the two facets. The inner wall has a hypantrum facet dipping 65° laterally. Above the zygapophysis is a large triangular prespinal chonos, but the extent of the prespinal groove and trough cannot be determined. The table dips 20° laterally. The base of the spine is 50 mm broad, its upper part missing.

In posterior view the base of the pedicle is 15 mm wide, the canal is 20 mm high and 20 mm wide. Above it the hyposphene is 35 mm high to the postspinal trough. The base of the hyposphene is 15 mm wide. It narrows to 8 mm at a height of 27 mm, the base of the zygapophysis, and overhangs the centrum by 15 mm. The zygapophysis has a convex lateroventral facet 30 mm long. The postspinal trough is 45 mm long and dips 40° posteriorly. The groove is 15 mm wide at its base. The posterior chonos has two successive vertical lamina that enclose parts of the cavity. The more posterior is 30 mm in front of the tip of the hyposphene; it is 6 mm lateral to the median wall and is 20 mm high. The second meets the posterior one at the top, arches out 5 mm, and rests on the buttress to the diapophysis 12 mm in front of the base of the first. Each encloses a vertical arched opening about 20 mm high.

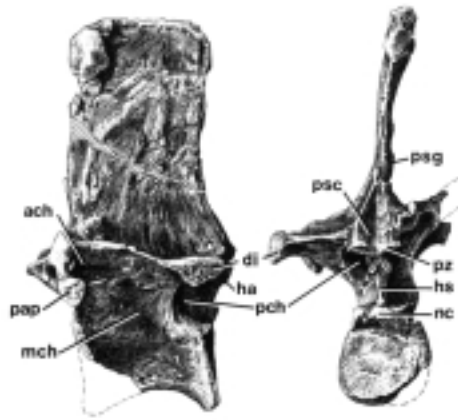
A posterior dorsal (MWC 1, PF-QB-34, plate 7A-C) centrum is 98 mm long dorsally. In lateral view its anteroventral corner is missing. The arch is fused, the pedicle base 95 mm long. The anterior chonos is 18 mm high and 10 mm wide, opening anterolaterally. In front of the anterior chonos the buttress to the prezygapophysis dips 30° posteriorly. A sharp vertical ridge rises from the front edge of the pedicle to the front of the parapophyseal stem. This stem has a base about 25 mm high, and from its center a shelf runs back across the medial chonos to its posterior

wall. This shelf walls off an anterior part of the medial chonos that is 18 mm high. The posterior wall of the chonos is a gentle arch that buttresses the center of the transverse process. The posterior chonos expands to a height of 45 mm posteriorly. Its general cavity extends out below the table for 50 mm, but it has a smaller anterior continuation 18 mm high and 15 mm wide. The parapophysis is 20 mm high and 15 mm long, and extends back beyond the centrum. The diapophysis is 40 by 20 mm and extends beyond the front of the centrum. The spine is a great, nearly rectangular, vertical plate 150 mm high, 111 mm long at the base, and shortening to 93 mm at 39 mm above the postzygapophyses.

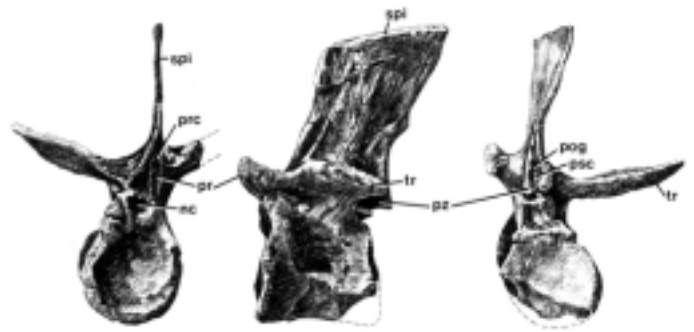
In anterior view each pedicle narrows to 10 mm then arches over the canal 15 mm high and broad. Above the canal is a junction 7 mm high, but no zygosphene. Above this and between the buttresses to the prezygapophyses is a hypantrum 21 mm high and 20 mm wide. The prespinal chonos is very shallow and narrow, and above it is a rough boss rather than a prespinal groove. From the front of the pedicle, a buttress 8 mm thick rises to the front of the prezygapophysis. The prezygapophysis is 20 mm wide and dips 15° medially. The two prezygapophyses are now together as preserved, but could have been separated in life. The parapophyseal stem dips 25° medially and is 15 mm high, expanding distally to 20 mm.

In posterior view, the centrum is 60 mm high and broad, and 5 mm deep. The pedicle is 10 mm broad, the canal 12 mm high and 18 mm wide. Above it for 25 mm is a hyposphene composed of a narrow (2 mm) basal 10 mm that reaches back 14 mm to overhang the back of the centrum. Above this the dorsolateral facets widen to 13 mm, then narrow to 1 mm at the base of the zygapophyses. The lateral edge of the hyposphene dips 55° laterally and is 12 mm long. The postzygapophysis is 20 mm wide, horizontal, and reaches 15 mm behind the centrum. The postspinal chonos is 39 mm high, and the groove (2 mm wide) above it extends only halfway up the spine. In ventral view the spool is pinched to an estimated 29 mm transverse diameter, its left side crushed in.

**Caudal Vertebrae:** An anterior caudal (MWC 1, PF-QB-8, plate 7D-F) lacks the posteroventral corner. In lateral view it is 70 mm long dorsally, its base weakly arched, and its side deeply concave. The pedicle is fused, its base as long as the centrum, its anterior edge gently concave and rising to the prezygapophysis, where the outline becomes convex. The posterior edge is much more sharply concave, leading up and out to the transverse process. The right



see plate 7B, C



see plate 7D-F

process extends horizontally and is 66 mm broad anteroposteriorly, with a posteromedial slant. The prezygapophysis extends 27 mm in front of the centrum and rises to 131 mm above its base. The postzygapophysis reaches to 12 mm behind the centrum, its base 11 mm above the centrum. The spine is 73 mm long anteroposteriorly at its shortest, 47 mm above the postzygapophysis. The anterior edge of the spine is slightly concave, and dips 70° anteriorly. The summit of the spine is 100 mm long and dips 15° anteriorly. The posterior edge is almost vertical for 45 mm, then curves back into a 6 mm projection, and above this continues to the top.

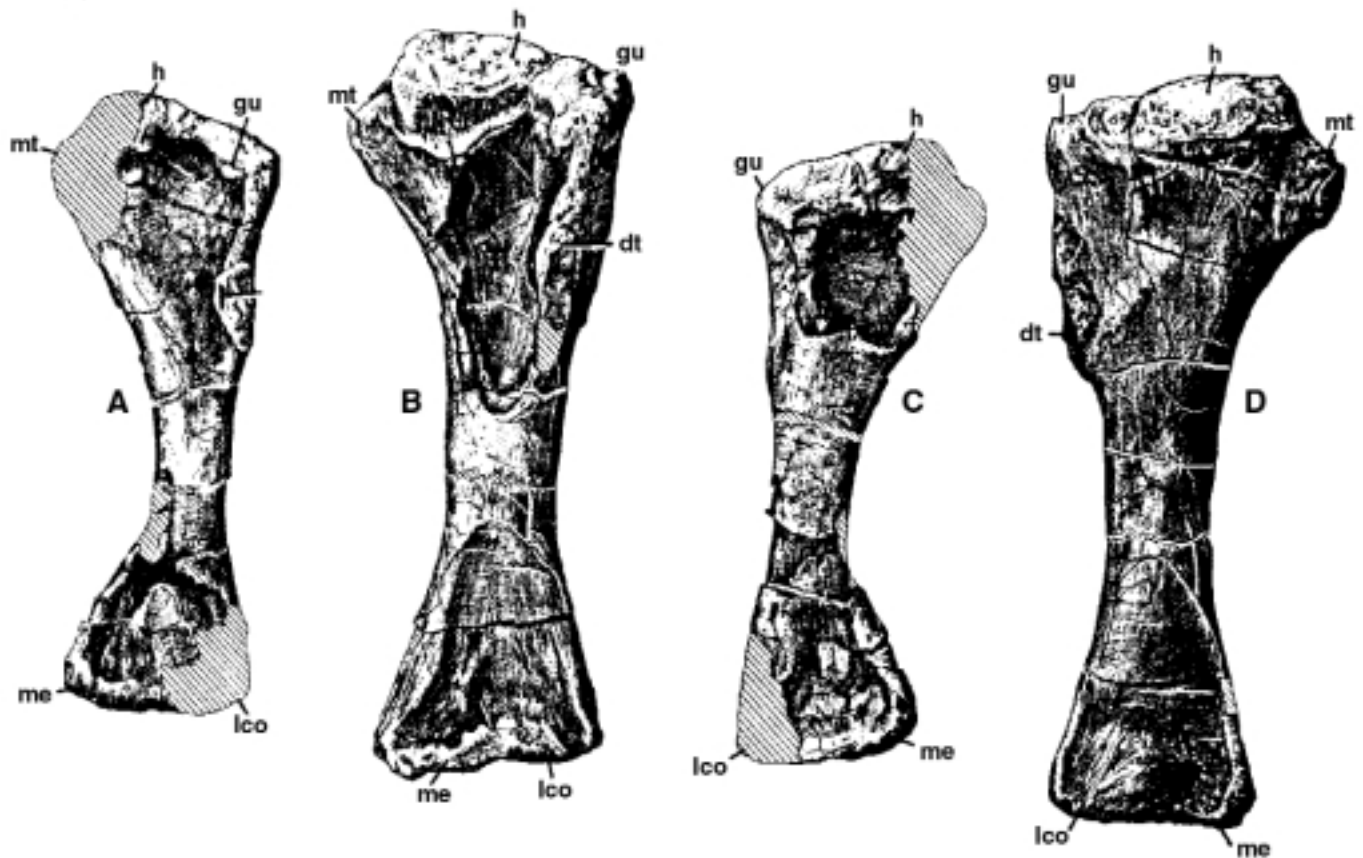
In anterior view (plate 7D) the centrum is concave, an estimated 78 mm high and broad, its edge broken away. The pedicle is 17 mm broad, the two 44 mm across their narrowest part. The canal is 13 mm in diameter. Above it is a prespinal chonos and groove that extends only 30 mm above the base of the chonos. The anterior edge of the spine is only 6 mm broad.

In posterior view (plate 7F) the centrum is slightly concave, 81 mm broad, its lower edge missing. Its upper edge forms a table 9 mm high and 47 mm broad, partly including the bases of the pedicles. The canal is 15 mm high and wide. The postspinal chonos is only 6 mm high. The bases of the postzygapophyses are 28 mm above the floor of the canal, and between them a narrow postspinal groove extends 57 mm above the base of the chonos.

Viewed from below, the centrum exhibits the characteristic anteroposterior sulcus, which persists through most of the caudal series of vertebrae.

## Appendicular Skeleton

**Humerus:** The left humerus (MWC 1, PF-QB-21; figure 3A,C), lacks the proximomedial and distolateral corners. It is 292 mm long and the width of the head is estimated at 90 mm. The medial tuberosity is 103 mm from the greater trochanter and 30 mm below the head. The head is 30 mm thick and curves 32 mm down the shaft. The head curves forward laterally, retaining its thickness nearly to the edge. The deltoid tuberosity is 84 mm long. It begins 7 mm below the edge of the greater tubercle where it is 6 mm wide. This width continues for 35 mm, then widens to 15 mm, then the tuberosity narrows to 9 mm and merges into the shaft 110 mm below the top of the tubercle. Its greatest height is at its thickest part where it is 41 mm from the back of the shaft, 25 mm from its front. The shaft narrows to 35 mm broad and 29 mm long. The distal end is crushed, but was probably 85 mm wide.



**Figure 3.** Left humeri from the FPA (A, C) holotype, *Ceratosaurus magnicornis*, n. sp., MWC 1.1.30 and the Cleveland-Lloyd Dinosaur Quarry (UUVP 549) (B, D) holotype, *Ceratosaurus dentisulcatus*, n. sp. in anterior (A, B) and posterior (C, D) views. Abbreviations: *dt*, deltoid tuberosity; *gu*, greater tubercle; *h*, head; *lco*, lateral or radial condyle; *me*, medial or ulnar condyle; *mt*, medial tuberosity; *rc*, radial condyle; *uc*, ulnar condyle. Scale: one-third natural size.

**Femur:** The right femur (MWC 1, PF-QB-31) lacks the anteromedial corner. It is 630 mm long to the ectocondyle. In anterior view the head slants laterally 20° from the upper shaft, its medioventral diameter 120 mm. The anterior trochanter is 90 mm below the head and is merely a low process that does not extend above the notch. A trochanteric shelf extends anteriorly at its base to form a projection at the angle of the shaft. This shelf has a socket at its top 35 mm wide and 7 mm deep. Below this socket the shaft is 75 mm across. It thins to 60 mm some 250 mm above the end, then expands to a distal breadth of 135 mm. The lateral distal edge is flattened and slants anteromedially. The shaft is gently sigmoid, convex medially above.

In lateral view the head is crushed. The bone is 75 mm thick at the anterior trochanter and the base of the trochanteric shelf curves upward and forward. The fourth trochanter begins 20 mm below the shelf and extends 20 mm from the shaft, merging gently into the shaft above, and again 110 mm below its top. Here the shaft is 65 mm broad. The shaft is convex anteriorly. The distal end is crushed, but the ectocondyle is 70 mm wide, its base curving posterodorsally so that its posterior corner is 25 mm above the anterior. The tuberous process extends 25 mm behind the groove down its lateral edge. The tuberous process is 50 mm high, sloping with a concave dorsal edge up into the ridge.

In posterior view, the shaft arches laterally. The fourth

trochanter is centered 50 mm from the lateral edge, 35 mm from the medial. It is about 10 mm thick and not very prominent. The back face of the shaft is 75 mm broad at the top of the tuberous process. The entocondyle is oval, 38 mm in distomedial diameter, and 75 mm high. Its axis is inclined 25° proximomedially. The ectocondyle is 50 mm broad distally, its posterior face curving 37 mm up the shaft. A groove runs anteromedially to separate the condyle from the intercondylar fossa. Its posterolateral end continues up into the groove in front of the tuberous process. The groove is 15 mm wide and is overhung 15 mm by the wall of the tuber. Its distal end is separated from the condyle by a slight transverse groove. The tuberous process is 35 mm wide, 50 mm high, and its medial edge slants forward into the intercondylar groove.

In medial view the neck is 45 mm thick. The anterior trochanter extends the thickness to 75 mm and the shaft is concave posteroventrally below the trochanter and neck. The fourth trochanter is not prominent. It has a slightly concave inner wall and in the center of the shaft there is a large depression. The ridge which divides the trochanter from the depression swells dorsally into a boss in line with the base of the neck. The entocondyle is semicircular below, its posterior edge straight for the dorsal 40 mm.

In distal view, the ectocondyle is elliptical, 70 mm long, and 50 mm wide, its axis oriented 30° posterolaterally. The

tuberous process curves posterolaterally. The intercondylar groove is 30 mm wide. The entocondyle is 83 mm long, its anterolateral face missing. It is 40 mm broad posteriorly and extends 25 mm behind the groove, its lateral wall overhanging the groove to form a vertical channel 13 mm in diameter.

The left femur (MWC 1, PE-QB-25) lacks its distal end. In anterior view, the head is 95 mm wide. The caput curves down sharply so that its medial face dips 5° laterally. The anterior trochanter is 88 mm below the tuberosity and does not rise above the notch. It has a rounded posterior face 40 mm wide. The trochanteric shelf is broken away, but there is a lateral swelling of the shaft that would mark its edge. This is 55 mm below the notch. The greater trochanter continues downward 75 mm as a ridge 25 mm wide, then gradually merges with the shaft. The shaft is concave laterally, its diameter 65 mm.

In lateral view the greater trochanter is 30 mm broad and its dorsal surface curves posteroventrally. The neck curves forward into the anterior trochanter, which extends 48 mm from the shaft. A prominent bulge is centered on the shaft 70 mm below the notch. This is at the base of the anterior trochanter and the top of the fourth trochanter. The fourth trochanter extends 25 mm behind the shaft so that the entire bone is 90 mm wide.

In posterior view the inner, lower part of the caput is missing, but there is the dorsal end of a groove down its lateral edge. The upper articular face curves ventrolaterally leaving a rounded dorsal extension of the caput 50 mm broad. There is no notch at the base of the caput, which is 85 mm high. The neck gradually thins below the caput to 73 mm. Here it is thickened by the boss at the base of the trochanteric shelf. The fourth trochanter is about 110 mm long, very massive, and merges very gradually into the shaft above and below.

In medial view the caput is 55 mm wide, ending below in a point so that a sharp ridge curves down into the neck. The caput occupies the posteromedial third of the head, and is separated from the greater trochanter by a broad groove across the top so that it stands 3 mm higher than the trochanter. The neck thins to 50 mm then expands at the anterior trochanter. The bone is somewhat crushed opposite the top of the fourth trochanter. A wide (35 mm) groove curves anterodistally from the notch of the anterior trochanter.

**Tibia:** The right tibia (MWC 1, PF-QB-26A, plate 8) has the astragalocalcaneum fused to its base. It is 520 mm long, medially. In anterior view, the tuberosity extends only 7 mm above the entocondyle (medial condyle). It is a large process 74 mm in laterodistal diameter with a bluntly rounded end. It extends anterolaterally to outside the lateral edge of the shaft. The tuberosity merges into the medial side of the shaft 150 mm below the crest. At the level of the base of the tuberosity the fibular flange arises on the lateral side of the shaft. This flange extends upward to 15 mm below the crest, a total length of 100 mm, its upper half missing. The shaft is 67 mm broad, the distal end expanding rather suddenly to 132 mm. The astragalal facet is about 60 mm high and quite deep. The overhang dips 30° medially and is fairly straight. The distal, medial end of the overhang is bluntly rounded, with a posteromedial swelling and a weak shoulder. The astragalus is completely buried

in its socket and there is a swelling on the tibia, immediately medial to the top of the socket, that bulges a few millimeters in front of the astragalus. The distal end thins laterally into a postfibular plate 40 mm broad that faces about 20° anterolaterally. It has a slight shoulder 65 mm high.

In medial view the bone is 520 mm long. The tuberosity projects anterodorsally, its anterior end convex and 185 mm around its surface, its anterodistal diameter is 135 mm. The anteromedial face of the tuberosity is bevelled. The shaft narrows rapidly, and at 175 mm below the head its section is ovoid, the anterior face nearly flat, and the diameters 48 mm and 70 mm, respectively. The shaft is slightly convex anteriorly, the curvature increasing distally. The distal end is 60 mm wide.

In posterior view (plate 8C) the tibia is 95 mm across the condyles and dips 15° laterally across their tops. The entocondyle (medial condyle) extends 15 mm above the ectocondyle (lateral condyle). The intercondylar groove ends 20 mm below the top in a rough area. This rough area extends laterally around the back of the condyles. It is 33 mm high below the ectocondyle and it reaches much farther, 70 mm, down the back of the endocondyle. The medial surface of this rough surface is vertically concave so that the medial edge of the bone curves posterolaterally into the rough area. The lateral edge of the bone is concave immediately below the ectocondyle, and there is a concavity below this condyle and lateral to the ventral projection of the entocondyle. At about 100 mm below the top of the ectocondyle the shaft narrows to 60 mm. The posterolateral half of the shaft is rough and striated opposite the lower part of the fibular flange. The striations make a series of arches with increasing sharpness proximally. The lower half of the shaft curves slightly medially and expands distally to 110 mm. Here it is fused to the calcaneum and astragalus, the midpart of the suture obliterated. The distal 80 mm of the bone is slightly concave both vertically and transversely.



see plate 8A, B



see plate 8C, D

In lateral view (plate 8B) the head of the tibia is 130 mm from ectocondyle to tuberosity. The tuberosity has a massive upper process, 35 mm across, extending anteroproximally. This process is concave behind and ends as a rounded surface, the crest of the tuberosity. This is excavated deeply (40 mm) by a great sulcus 37 mm wide that begins 30 mm below the head of the tuberosity and curls posteroventrally to within 150 mm of the top. Its summit is aligned with the head of the tuberosity and dips 50° anteriorly. This sulcus is partly overlapped by the fibular flange. The posterodorsal edge of the ectocondyle arches down anteriorly, then up, to form a notch 15 mm wide so that the ectocondyle is 30 mm long at its base. The edge then slopes up and forward with a dip of 40° to the summit of the tuberosity. The fibular flange ends 115 mm below the notch and below this the edge of the shaft is 50 mm broad.

In proximal view the lateral edge curves around 140 mm to the top of the tuberosity, 190 mm to its base. The edge arches 42 mm medially. The tuberosity is 35 mm broad, its lateral face concave for 45 mm, 18 mm deep. At the back of this concavity the bone thickens to 80 mm, and is 85 mm broad at the back. The upper surface is crushed down, but slants laterally.

**Astragalus:** The right astragalus (MWC 1, PF-QB-26B, plate 8) is fused to the calcaneum, and both are fused to the tibia. They are slightly broader than the tibia, and form a transverse, nearly hemicylindrical, distal condyle 127 mm broad. In anterior view (plate 8A), the astragalus is 72 mm wide below. There is a very weak horizontal groove on the medial half of the astragalus that becomes fairly deep and curves dorsally 35 mm from the medial edge. The dorsal process rises 73 mm above the ventral surface, its peak 74 mm lateral to the medial edge. Its dorsomedial edge is slightly more concave than the convexity of the astragalar shelf of the tibia, so there is a 4 mm gap at the center. The upper horizontal groove is very slight. At 52 mm out from the medial edge there is a vertical groove in the dorsal process 15 mm wide. This groove has a sharp lower edge that dips 30° laterally. The groove is 5 mm deep and opens into a small foramen at its ventrolateral corner. The suture with the calcaneum is concave 8 mm.

In medial view (plate 8D) the bone is 32 mm high at the center and rises 50 mm in front of, and 45 mm behind, the tibia to form a deep cup 56 mm wide.

In posterior view, (plate 8C) the suture line with the tibia curves down from its medial height of 45 mm in a sigmoid flexure to 12 mm at the astragalo-calcaneal suture. From here it curves up to 37 mm at the back of the calcaneum. The astragalus is 85 mm wide along its posterior crest. Its medial edge slants posterolaterally and also ventrolaterally so that the bone is narrower posteriorly and ventrally. In distal view, the condyle is not smoothly rounded but has a slight central transverse crest. The part formed by the anterior faces of the calcaneum and lateral astragalus is flattened.

**Calcaneum:** The right calcaneum (MWC 1, PF-QB-26C, plate 8), in anterior view is 20 mm wide dorsally, curves into the astragalus to a breadth of 37 mm, then out to a ventral breadth of 27 mm. In posterior view, the breadth increases to 37 mm to the tibial suture, then decreases in a quarter circle to 10 mm at its top. In dorsal view, it forms the lateral 30 mm of the base of the fibular socket. The

entire socket is triangular, 45 mm wide anteriorly, its lateral wall 45 mm long and its posterolateral tip the apex. In lateral view the calcaneum is 50 mm long dorsally, crescentic, with the anterior crest 37 mm high, the posterior 43 mm. It is 37 mm high at the center.

**Metatarsals:** The left metatarsal III (MWC 1, PF-QB-47) is 234 mm long. Its head is somewhat crushed, but measures about 45 by 30 mm. The proximal 90 mm of the lateral face of the shaft is flat, and only 24 mm wide. It widens laterally to 30 mm just above the condyle, where it is circular. The distal condyle is broken and offset medially on its anterior surface. The condyle is 40 mm wide and faces anteromedially. Its dorsal edge rounds 22 mm up the shaft. In lateral view, the distal condyle is 47 mm wide and above it is a deep, collateral ligament pit 18 mm in diameter. In medial view the ligament pit is shallower. The posteromedial process is missing. In posterior view the distal end is deeply notched for its posterior half. The notch is 19 mm from the lateral edge, 12 mm wide, and it extends proximolaterally 15 mm up the shaft. The posterior edge of the shaft is rough and 10 mm wide down to about 65 mm from the distal end.

### *Ceratosaurs dentisulcatus*, n. sp.

**Holotype:** Disarticulated, skeletal elements belonging to a single individual, now curated in the Utah Museum of Natural History, University of Utah, Salt Lake City, Utah. Most bones have separate catalog numbers, but the entire skeleton has the number UMNH 5278.

**Hypodigm:** Holotype only.

**Etymology:** *dentisulcatus*, with reference to the persistent, parallel grooves on the medial surfaces of the premaxillary teeth and the anterior three teeth of the dentary.

**Locality:** Cleveland-Lloyd Dinosaur Quarry, Emery Co., Utah, latitude 39° 19' 00" N., longitude 110° 41' 15" W.

**Horizon:** 150 feet below the top of the Brushy Basin Member of the Morrison Formation and its contact with the Cedar Mountain Formation.

**Diagnosis:** In addition to significantly larger size, the largest ceratosaurs of record differs from *Ceratosaurs nasicornis* in the following: subnasal border of premaxilla arched and almost horizontal versus straight and dipping forward; nasal process lower; body of premaxilla longer, and with several large foramina; maxilla more massive, alveolar border more concave, and recess more pronounced; posterior edge of nasal process rises more steeply; front of antorbital fenestra more open; three large openings into body of maxilla at front of maxillary recess and base of nasal process; 12 alveoli versus 15; teeth more massive and more strongly recurved; dentary more massive and more upturned from tooth 6 forward; dentary teeth more massive, and only 11 versus 15; atlas-axis 100 mm long versus 84; odontoid more prominent, axial centrum much shorter, its ventral edge less downcurved, its spine higher and very much shorter anteroposteriorly, its anterior edge dipping 70° anteriorly versus 20°; the edge of its table much steeper and straighter, there is no prezygapophysis and there is an epiphysis extending far behind the spine; third centrum shorter, its ends almost vertical, its spine shorter and almost vertical rather than strongly recurved, its epiphysis very

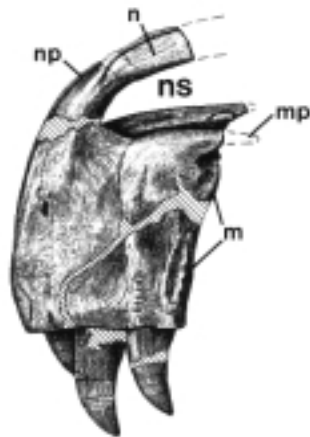
much larger; tibia longer (594 versus 554 mm) and more massive; the tuberosity heavier, as is the shaft; the astragalus overhang dips only 5° versus 28°; the distal end is 165 mm broad versus 140 mm; there is a weak horizontal groove across the front of the astragalus, and its dorsal process is ossified; the fibula is longer (564 versus 502 mm); in lateral view its upper end is vertical, rather than dipping 70° anteriorly, and is broader; the tibial flange dips posteriorly versus anteriorly, and its upper edge versus lower edge projects anteriorly; the distal end is broader (81 versus 53 mm) and is convex, evenly rounded versus truncated.

It differs from *Ceratosaurus magnicornis*, n. sp. in having a much more massive premaxilla; the muzzle is more rounded and the nasal process curves back more sharply, making the snout and naris lower; the lower border of the naris is convex behind an anterior concavity, as opposed to smoothly concave; the maxilla is about the same length, but has a steeper nasal process with a straight posterior border so the antorbital fenestra has a more open anterior border; there are three additional openings into the maxilla at the front of the recess and the base of the nasal process; the lateral face of the bone is higher above the first three teeth; the lower half of the anterior border dips steeply posteriorly, versus anteriorly; the alveolar border is slightly more convex; the foramina in the row above the alveolar border are larger, and the grooves below them deeper; the anterior three teeth are more recurved, and the posterior teeth more vertical. The 5th cervical vertebra has a similarly downset centrum, but is shorter; the transverse process ends with the diapophysis higher above the parapophysis; the table is shorter; the epipophysis much smaller; the spine is lower, shorter, and the shoulder weaker. The humerus is longer (333 versus 292 mm) and is much more massive; the head dips only 10° laterally versus 20° and the anteroventral process of the greater tuberosity is much larger; the deltoid tuberosity is 93 mm long, versus 84 mm, and is thinner; the shaft is 63 mm broad versus 35 mm.

The C-LDQ ceratosaur is a single skeleton, although almost completely disarticulated and moderately scattered in the quarry. For this reason multiple quarry numbers were assigned in the field, which are also used in the text even though the single catalog number of UMNH 5278 would be more conventional for an individual skeleton.

## Skull

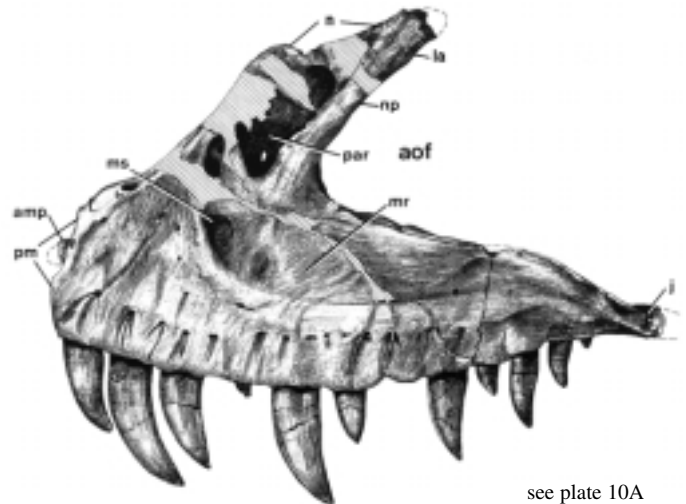
**Premaxilla:** The premaxillae of *Ceratosaurus dentisulcatus*, n. sp. (UUVP 674, plate 9) are fused, the right lateral surface crushed. In left lateral view the anterior convexity extends gently upward and onto the base of the nasal process. This process then curves more sharply back, and from 17 mm above the floor of the naris it dips 45° anteriorly. The lateral nasal suture begins 19 mm above the nasal floor. The body is 64 mm long dorsally, 53 mm



see plate 9A

along the lower edge, and is 63 mm high below the depression at the front of the naris. The lower narial border is concave for its anterior third, convex posteriorly, and ends in a blunt projection 52 mm behind the front of the naris. The lower border of this projection is concave, and forms the anterior border of the subnarial foramen.

**Maxilla:** The left maxilla (UUVP 674, plate 10) in lateral view is 400 mm long at the ventral edge of the jugal overlap. It is 110 mm high below the naris, 132 mm below the recess in the nasal process, 124 mm at the front of the antorbital fenestra and 68 mm at the front of the lacrimal suture. The alveolar border is 347 mm long in a straight line, the border convex and bowing down 35 mm at the center. The nasal process is 73 mm transversely just above the base and has two openings into the central cavity at its lateral base. The anterior opening is 31 mm high and 11 mm wide, almost vertical, its anterior border continuing the curvature of the front of the maxillary recess. The posterior opening extends 87 mm up the process. Evidently, this is the opening labeled maxillary depression by Gilmore (1920, figure 54). Its upper anterior edge is broken away, but its lower edge is an open V. The posterior edge of the nasal process dips 60° anteriorly. The upper part of the maxilla and most of the nasal process are inset into a maxillary recess. The recess becomes shallower posteriorly and fades out below the front of the lacrimal facet. At the anteroventral edge of the recess is another opening, 41 mm high and 21 mm wide dorsally. Its anterior edge is that of the recess, and its posterior edge is vertical. This may be the precursor of the preantorbital fenestra. The area in front of and below the recess is pierced by a row of large foramina subparallel to the alveolar border. These foramina are from 5 to 6 mm in diameter, and each opens ventrally into a large groove that continues nearly to the edge of the bone.



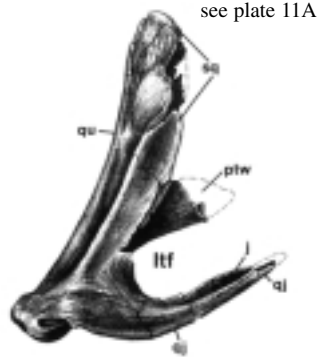
see plate 10A

In medial view (plate 10B) the rugosae form a continuous wall. There are large nutrient notches above the middle of the 1st and 2nd teeth, and the front of the 3rd and 5th. This wall is 48 mm high anteriorly and decreases to 8 mm posteriorly. Its upper edge is the nutrient groove, inset above. There is no obvious lingual bar, but the surface of the maxilla rounds smoothly up to its dorsal edge. The anteromedial process arches inward to form a midline su-

ture with its opposite. This suture has only a single groove along its upper edge. The process is 33 mm high posteriorly below the back of the naris, and 17 mm at its broken anterior tip. It reaches 20 mm in front of the body of the maxilla. There are 12 alveoli, with teeth in 1 to 3, 5, 6, 8 to 12. The 4th is broken, the 6th, 9th, and 12th about half erupted. The 7th is missing. The mature teeth are massive, their bases about 29 mm anteroposteriorly. The 2nd has the highest crown (93 mm), the 5th is next at 85 mm. The anterior teeth are more recurved, the 2nd most strongly so, and their posterior concavity decreases toward the rear.

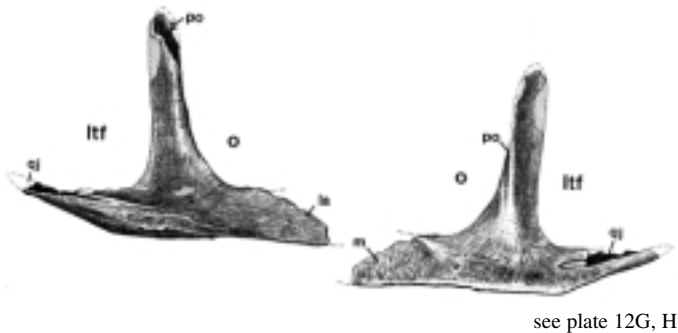
**Quadrate/quadratojugal:**

The right quadratojugal and quadrate (UUVP 1646) are completely fused along their contact, so there is little trace of the suture. The quadratojugal is L-shaped with the vertical ramus 180 mm high and the horizontal or jugal ramus subequal to it in length (UUVP 1646, plate 11).

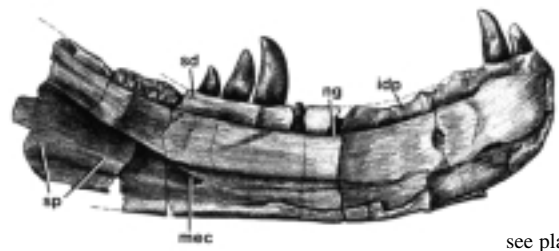


**Pterygoid:** The right pterygoid, UUVP 1646 (plate 12A-F), is a complex element with a subtriangular pterygoid wing 172 mm long from the posterior point of the quadrate contact forward to the nearly vertical anterior edge; the vertical height of the wing is 90 mm. The lateral bar is excavated ventrally to receive the medial margin at the ectopterygoid. Medial to the lateral bar lies the concave socket for the basiptyergoid process. The anterodorsal margin of the pterygoid blade is distinctly scarred, marking the contact of the epiptyergoid process.

**Jugal:** A right jugal, (UUVP 1646, plate 12G, H) from the C-LDQ differs little morphologically from MWC 1, however, the greater size is consistent with the larger specimen from Utah. Although incomplete, the anteroposterior length is 247 mm and the maximum height from the ventral bow to the top of the postorbital process is 179 mm.



**Dentary:** This element, a left dentary, (UUVP 158, plate 13A-D) is incomplete posteriorly, not reaching the external mandibular foramen. In lateral view the alveolar border dips anteriorly for the first three alveoli, then becomes deeply concave posteriorly. A row of foramina up to 4 mm in diameter lies at midheight and begins 140 mm from the front. These are widely and irregularly spaced and open forward into shallow grooves. The ventral border is very convex for the anterior 200 mm, and behind this it becomes straight. It is less curved than the alveolar border, so the



height of the dentary gradually increases from 93 mm at the 3rd tooth to an estimated 100 mm at the surangular suture.

In medial view (plate 13A) the pronounced upturn of the front is evident, the bone bulging in front of the 1st alveolus. There is no obvious symphyseal surface. The supradentary is missing except for a segment from the 7th tooth to the back of the 11th. The segment is a fragment 106 mm long that is continuous with an impression in matrix that is 64 mm in length. The effective, total length then is 170 mm running from the diastema at the fifth alveolus to the center of the twelfth alveolus. The complete supradentary likely would span the entire length of the tooth row.

The rugosae are fused into a solid wall that begins at the front of the 2nd tooth. Here it is 9 mm high. Its ventral border is lowered at the 3rd tooth, and the wall becomes 16 mm high, retaining this height to the end of the tooth row. The nutrient groove is shallow, and there are no nutrient foramina. The lingual bar is flat, 64 mm high below the 2nd alveolus and it gradually decreases in height to 46 mm behind the last tooth. It then shortens to 32 mm as it rises above the opening into the meckelian canal. The area below the lingual bar is slightly offset labially, increasing in height from its upturned tip at the front of the jaw to 44 mm below the last tooth, at the front of the opening into the meckelian canal.

In dorsal view (plate 13D) there are 11 alveoli, with a possible 12th. Teeth are present in 1, 2, 9, 10, and 11. Broken roots are in 3, 4, and 7, and there is an erupting tooth in 8. The teeth are less massive and narrower than the upper teeth of the maxilla and are less recurved, especially in the front of the jaw. The dentary is about 36 mm thick, swelling slightly from the center of the second alveolus to the fourth.

There is a diastema in place of the fifth alveolus and it is interpreted as having pathological rather than taxonomical significance.

**Angular:** The right angular of *Ceratosaurus dentisulcatus*, n. sp., UUVP 5911, (plate 13E, F), though incomplete, is 305 mm long and 45 mm dorsoventrally at midlength. The bone is plate-like, laterally compressed, having a broad, uniformly bowed ventral margin which curves under, medially along its posterior half.

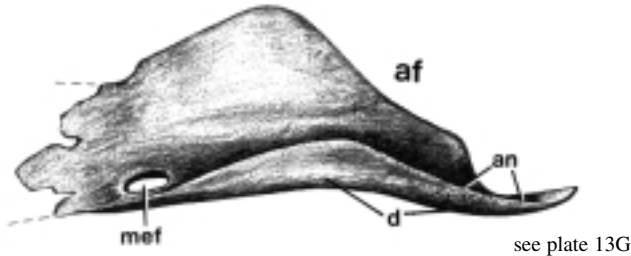


see plate 13E



**Splénial:** The left splénial, UUVP 157, (plate 13G, H), is a subtriangular plate-like element 298 mm long, 99 mm high at midlength, but lacking the complete anterior end. Anteriorly, the splénial is perforated near the ventral margin by the anteroposteriorly elongate meckelian foramen, which is completely enclosed unlike the ventrally open counterpart in *Allosaurus*. The foramen is 7 mm dorsoventrally and 17 mm anteroposteriorly. The posterior end of the splénial is scoop-shaped to receive the anterior end of the angular in a joint that appears to have allowed dorsoventral flexion of the mandible near midlength.

The right splénial, UUVP 156, is 326 mm long, anteroposteriorly, and 102 mm in height at midlength.



### Axial Skeleton

The atlas, axis, and third cervical were in a horizontal position in life, but the posterior face of the fourth cervical is extended downward, marking the beginning of the downward curvature of the neck. The following centra through at least the seventh continue this downset. The vertebra we identify as the tenth, (8 and 9 are missing) has no posterior downset, so we assume that the neck straightened at or near the two missing vertebrae, which is at the cervical/pectoral transition.

The centra become progressively shorter posteriorly, and the first dorsal is the shortest of all. The parapophyses retain their position on the anteroventral edge of the centrum throughout the cervical series, and on pectoral 1. On pectoral 2 they are found on the pedicle just below the zygapophyses. The diapophysis is first far down on a long projection of the front of the transverse process, close to the parapophysis. It climbs higher down the column as the transverse process broadens and shortens, and by cervical 10 it is higher than the centrum, and the ventral edge of the transverse process is horizontal.

The zygapophyses are wide apart, and buttresses run from the prezygapophyses to the front of the spine, and also from the postzygapophyses to back of the spine, enclosing pre- and postspinal chonoses. The epiphysis is largest on cervical 3, becomes smaller down the column, and is lost by cervical 10. The spine is short anteroposteriorly, shortest on cervical 10, and about as high as the combined centrum and pedicle. It has weak shoulders at the top of pre- and postspinal ridges, best developed on cervical 7.

**Cervical Vertebrae:** The atlantal intercentrum (UUVP 1053, plate 14D-F) is free. In lateral view (plate 14E) it is 28 mm long ventrally, and 57 mm high. The posterodorsolateral corner is bevelled 21 mm for the pedicle. The posterior base has a bulge on the lateral face that projects slightly posteroventrally. The anterolateral edge is concave, the center of the anterior face is concave below, and convex above, so the length at midheight is 33 mm.



see plate 14D-F

In anterior view the end is 52 mm broad ventrally, 66 mm dorsally, and 36 mm high in the center. Its dorsal surface is transversely concave to a depth of 9 mm.

In posterior view it is 40 mm high at the center, and its dorsolateral corners rise to 50 mm above the base at the dorsolateral bulge.

The odontoid, axial intercentrum, axis, and third cervical of *Ceratosaurus dentisulcatus*, n. sp. (UUVP 1053, plate 14A-C) are fused. In lateral view, the odontoid projects 30 mm in front of the top of the intercentrum, its base 36 mm high, and its anteroventral face convex. In anterior view it is 39 mm broad, and its surface a longitudinal trough 24 mm wide. Its ventral edge is a semicircle 39 mm broad.

The intercentrum is 42 mm long ventrally, its side smoothly rounded and concave below. Its posterior midline descends into a boss which is fused to the front of the keel of the axis.

The combined axial intercentrum and centrum is 72 mm long dorsally and 89 mm ventrally. A parapophyseal socket 21 mm long opens 33 mm from the front of the intercentrum and 18 mm above its basal boss, on the line of fusion of the two elements.

In lateral view the axis has a lateral ridge that extends back from the upper edge of the parapophyseal socket. There is a 10 mm pleurocoel 18 mm above the socket, its anterior edge above the center of the socket. The centrum develops a boss posteroventrally, and its ventral edge is arched 6 mm. A very narrow downcurved transverse process, 21 mm long, ends in a diapophysis 5 mm broad at the level of the pleurocoel. The edge of the table dips 45° anteriorly and it is 119 mm long back and up to the tip of the epiphysis. Its lower edge, continuous with the back of the table, is arched 18 mm in the 85 mm span from the diapophysis to the back of the postzygapophysis. The postzygapophysis extends 12 mm behind the top of the centrum, its top 45 mm above the centrum, its edge slightly arched, its facet curving gently ventromedially. Above this is a large epiphysis that extends 30 mm behind the top of the centrum. The front of the spine is convex, its dip 75° anteriorly. It rises 120 mm above the centrum and is massive. Its posterior top sends down a thick 15 mm posterolateral wing to the top of the base of the epiphysis.

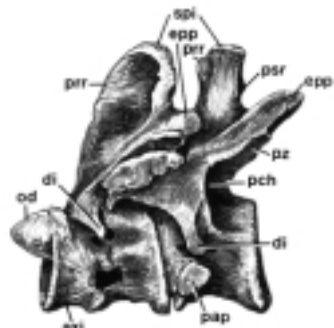
In anterior view the neural canal is 13 mm wide. The lateral walls of the pedicles are 42 mm apart, overhung by the downbent table.

In posterior view the axis is 76 mm broad and 78 mm high, including the ventral extension.

In dorsal view, the anterior edge of the spine becomes 15 mm thick above and very rugose. Its summit immediately diverges into the posterolateral wings, and between them is a central concavity 30 mm wide. Each wing increases in thickness as it arches posteroventrally and laterally and its surface is rugose down to the notch. The

wings, including the coextensive epiphyses, spread apart to enclose a cavity 95 mm wide at their base. A postspinal ridge runs down the center of the front of this cavity, its face dipping 80° anteriorly.

The third cervical (UUVP 1053, plate 14A-C), in lateral view, has a centrum 70 mm long dorsally, and 65 mm ventrally. Its anterior edge dips 80° posteriorly and is 74 mm high. Its posterior edge dips 85° posteriorly. The ventral arch is 12 mm high, the peak 20 mm behind the front. The parapophysis is 7 mm from the front of the centrum, 8 mm above the ventral edge, and is an oval 30 by 19 mm which narrows anteroventrally. The edges are raised and it is on a short pedestal, especially anteriorly and dorsally. The anterior pleurocoel is at midheight of the centrum, 15 mm from the front. The posterior pleurocoel is 30 mm above the ventral arch and 28 mm from the back. This is 6 mm high and opens posteroventrally.



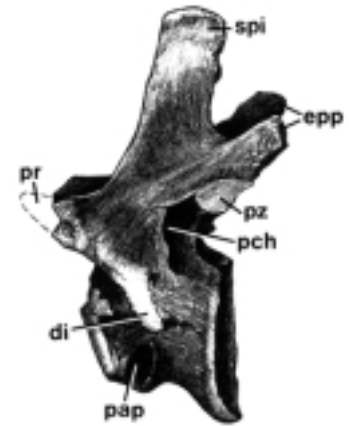
see plate 14B

The arch is fused, the base of its pedicle 48 mm long. Its anterior edge arches anterodorsally and forms a buttress under the prezygapophysis. At a height of 12 mm it joins the downturned process to the diapophysis. The anterior and medial chonoses are covered by matrix. The lateral wall of the posterior chonos is 45 mm high and at 51 mm above its base the transverse process extends ventrolaterally and ends in a diapophysis 15 mm long. The anterior edge of the transverse process ends under the front of the prezygapophysis. Here the downturned face of the table is 45 mm long and its flexure is aligned with the edge of the postzygapophysis. From the flexure down to the diapophysis is 53 mm so that the diapophysis is just 9 mm above the parapophysis. The tip is 5 mm below the top of the axis, and just in front of its center. The prezygapophysis curves down 60 mm under the axial postzygapophysis. The lateral edge of the prezygapophysis is expanded into a large, roughened face, 20 mm high at its center, arched above and convex below in front, concave posteriorly. The anterior end is 15 mm high, and its posterior end 10 mm. The spine is 30 mm long near the base, its posterior edge vertical. Its top is 100 mm above the centrum and is 27 mm long. There is an anterior shoulder 7 mm below the top.

In posterior view the centrum is 84 mm high, 84 mm wide and 24 mm deep. Its upper edge folds down into a central concavity 31 mm wide. The canal is 18 mm high and wide. It is enclosed by the narrow (6 mm) pedicles that converge to 27 mm opposite the hyposphene, then run up under the zygapophyses. The hyposphene is a V-shaped extension reaching back 7 mm over the canal. Its center is 2 mm high; its posterior edges run dorsolaterally to just inside the tips of the zygapophyses. The zygapophyses are 15 mm apart. Each forms a huge surface 45 mm wide, slightly arched laterally, and dipping 22° medially. The epiphysis extends dorsolaterally so that the tips of the two are 108 mm apart and 78 mm above the centrum. The

postspinal trough is about 25 mm long and V-shaped. It continues anteriorly into a large postspinal chonos 22 mm high and 10 mm wide. The postspinal ridge begins at the top of the chonos, and at midheight of the spine it extends abruptly posteriorly for 3 mm.

The fourth cervical of *Ceratosaurus dentisulcatus*, n. sp. (UUVP 6963, plate 14 G-I) is extended posteroventrolaterally. In lateral view the anterior face of the centrum is 63 mm high and dips 70° posteriorly. The posterior edge is 84 mm high and dips 85° posteriorly with respect to the canal. The anterior pleurocoel is very small on the left, 3 mm in diameter and 17 mm behind the anterior face



see plate 14H

and is absent on the right. The posterior pleurocoel is 34 mm back, 6 mm high, and opens posteroventrolaterally. The lower face arches up 9 mm and the parapophysis, its center 18 mm back, extends as a bulge below the ventral edge of the centrum. The parapophysis is a pit 25 by 13 mm lying 9 mm behind the anterior edge. The arch is fused to the centrum, and its pedicle is 62 mm long, shortening to 39 mm before expanding dorsally. The transverse process curves down sharply, becoming vertical, thereby bringing the diapophysis close to the parapophyseal pit. The table is not sharply defined, but dips 30° anteriorly. The anterior chonos is very small and hidden by the vertical wall of the transverse process. The median chonos is also hidden. The posterior chonos is a large opening, 40 mm high, its lateral edge vertical and 18 mm in front of the back of the pedicle. The top of the prezygapophysis is 37 mm above the centrum and its tip is restored to extend 33 mm in front of it. The postzygapophysis is 42 mm above the centrum. Its lower edge dips 15° anteriorly, in line with the top of the prezygapophysis. It is covered by an epiphysis extending 30 mm posterodorsally and 15 mm high at its center. Its dorsal edge dips 30° anteriorly. A break on the right side shows this to have been hollow with walls 5 mm thick. The spine is 35 mm long at its base, 33 mm at the summit, reaches 138 mm above the centrum, and dips 80° anteriorly.

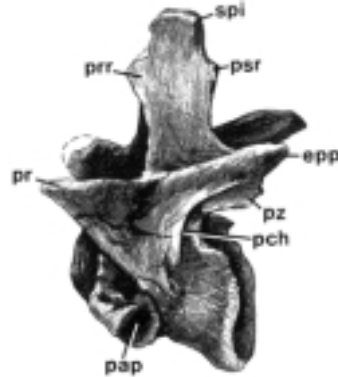
In anterior view (plate 14G) the centrum is 75 mm broad, nearly flat, and the parapophysis extends 3 mm below the rim. The pedicles span 36 mm at their narrowest. The canal is 15 mm high and 18 mm wide. The zygosphene is 8 mm high and 14 mm broad. The prechonos is very small, 14 mm high and 6 mm wide. The tips of the prezygapophyses are 36 mm above the centrum, 114 mm apart, and their facets dip 20° medially. The prespinal trough is 22 mm above the base of the canal, and is widely open. The prespinal ridge begins just above the trough and is 31 mm high.

In posterior view, the centrum is 87 mm broad, 24 mm deep and slightly concave below the canal, so that it sinks slightly into the posterior concavity of the centrum. The

pedicle is 7 mm broad, slants dorsomedially over a circular canal 18 mm in diameter. The hyposphene is V-shaped, 5 mm high, and above it is a V-shaped postspinal trough 22 mm long. There are no postchonos. The postzygapophysis is 35 mm above the centrum medially, dips 20° medially, and is 33 mm broad. The epipophysis rises posterolaterally to 75 mm above the centrum. The spine is 15 mm wide at its base. The posterior chonos opens almost directly posteriorly. It is 35 mm high laterally, and 20 mm wide at midheight. The pedicles arch inward, where the distance across the two is 25 mm.

In ventral view there is an anterior keel leading forward to the boss. The centrum is pinched to 62 mm in transverse breadth.

The fifth cervical centrum (UUVP 6965, plate 14J-L) is badly crushed. In lateral view (plate 14K) the centrum is 75 mm long dorsally, 90 mm ventrally. Its lower edge dips 30° posteriorly, and its anterior and posterior edges are vertical. The neural arch is fused and the pedicle is broken at its base. The pleurocoels are similar to those of the sixth cervical as nearly as can be determined. From the top of the prezygapophysis to that of the epipophysis is 141 mm.



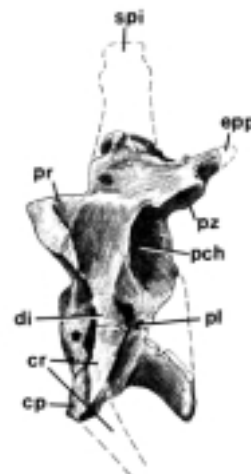
see plate 14K

The faces of the zygapophyses are parallel and strike anteroposteriorly. The table rises gently from behind the prezygapophysis to 25 mm above the postzygapophysis. The transverse process is almost vertical, and ends below in a small diapophysis just above and behind the parapophysis. Its anterior edge dips 45° posteriorly from the front of the prezygapophysis. Its posterior edge is vertical, and 12 mm in front of the back of the pedicle. The base of the spine is 39 mm long and enlarges to 50 mm at an anterior height of 60 mm and a posterior one of 50 mm, thus marking the heights of the shoulders and the tops of the pre- and postspinal troughs. The cap extends to 75 mm above the table and is 30 mm long with a rounded summit.

In anterior view (plate 14J), the centrum is convex. The prezygapophysis is 33 mm broad wide and dips 20° medially. There is a small prespinal chonos and a narrow prespinal groove that runs to 78 mm above the trough. The base of the spine is 11 mm broad.

In posterior view (plate 14L), the postzygapophysis dips 20° medially and is 45 mm broad. The epipophysis reaches 30 mm above the end of the zygapophysis, and is 65 mm from the midline. The base of the spine is about 11 mm broad, narrows dorsally to 10 mm, then expands at the top to 15 mm. The groove is 5 mm wide, has a rough wall, and extends to the shoulder, 90 mm above the trough. There is a wide posterior chonos, and the circular neural canal is 15 mm in diameter.

The sixth cervical centrum of *Ceratosaurus dentisulcatus*, n. sp. (UUVP 6964, plate 15A-C) is 72 mm long dorsally and 75 mm ventrally. In lateral view (plate 15B) it is



see plate 15B

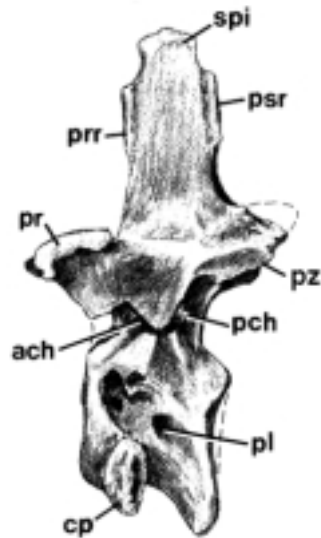
arched 18 mm ventrally with the posteroventral edge greatly extended. The anterior edge is 75 mm high, slightly convex and vertical. The posterior edge is 84 mm high and also vertical. The parapophysis is at the anteroventral corner, its base level with the centrum. It is 26 mm high, 18 mm broad, elliptical, and faces 45° ventrolaterally. The anterior pleurocoel is 27 mm high. The posterior pleurocoel is a 5 mm circle, directly behind the parapophysis. The arch is fused, as is the rib. The pedicle is 60 mm long. The anterior chonos is 28 mm high, opening below the level of the top of the centrum and

extending 20 mm up and under the downbent lateral part of the table. The medial chonos is 23 mm long, very low, and covered by the table. The posterior chonos is 25 mm high, 30 mm wide, and opens posterolaterally. It was evidently about 35 mm deep. The transverse process is 18 mm long at the level of the top of the centrum and expands dorsally to 67 mm along the side of the prezygapophysis. The end of the prezygapophysis is 53 mm above, and 18 mm in front of the centrum. The downbent of the table behind it is 71 mm long and ends in a diapophysis 18 mm broad. From the front of the prezygapophysis to the back of the postzygapophysis is 108 mm and the epipophysis extends another 21 mm. The spine is broken off just above the base, where it is 39 mm long.

In anterior view (plate 15A) the centrum is 75 mm broad, with a dorsal depression 50 mm wide. The parapophyses are 78 mm apart dorsally, 60 mm ventrally. The pedicle is 8 mm broad and broadens dorsally as a buttress to the prezygapophysis. The canal is 18 mm high and 9 mm wide. The zygosphene is 8 mm high and broad, flanked by 6 mm prechonos. The prespinal trough is open about 90° and is 14 mm long. The posterior wall of the concavity is vertical, its breadth 67 mm at midheight. The prespinal ridge begins at the trough, is 6 mm broad, and broadens to 12 mm at a height of 54 mm.

In posterior view (plate 15C) the centrum is 82 mm high, its breadth estimated at 90 mm, and it is 30 mm deep. The neural canal is 18 mm high, 13 mm wide below, narrowing above, and sinks 6 mm into the centrum. The pedicle is 15 mm broad at its base and gives off a supporting strut to the base of the hyposphene; and another lateral to the postchonos. The hyposphene is 6 mm high and 10 mm broad. The postchonos is 14 mm high and 5 mm wide. The postspinal trough is a 30° V in cross section so that the postspinal cavity is narrow. The zygapophysis is 42 mm above the centrum medially, with its face 27 mm broad, and dipping 30° medially. The epipophysis rises to 20 mm above it and has a 4 mm groove running around its posterior base. The apices of the epipophyses are 105 mm apart and 70 mm above the centrum. The neural spine is broken at its base and has a circular cavity 6 mm wide at its center. The postspinal ridge begins at the level of the top of the postzygapophysis.

The seventh cervical centrum (UUVP 1615, plate 15D-F) is 64 mm long dorsally and ventrally. In lateral view the posteroventral corner is greatly extended. The anterior and posterior ends are both vertical. The parapophysis is a large process facing ventrolaterally, with the left rib fused to it. It is level with the bottom of the centrum, its base 30 mm high and 15 mm broad. The anterior pleurocoel is 20 mm above it and 9 mm from the front of the centrum. It is 7 mm long and 18 mm high, with 6 mm



see plate 15E

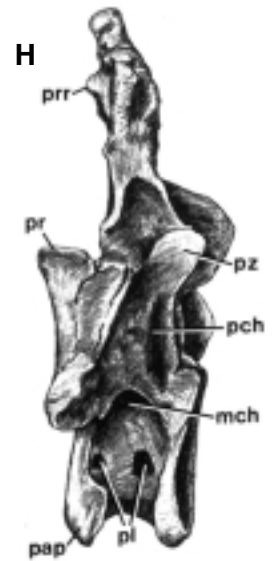
foramina at its top and bottom. The posterior pleurocoel is a 9 mm circle 21 mm from the front of the centrum, and there is a 6 mm opening just above it. The arch is fused, the base of the pedicle broken. The anterior chonos is hidden by the downturned transverse process, as is the medial chonos. The posterior chonos reaches 33 mm above the centrum, its base is open and curves down over the centrum. The back edge of its inner wall, the side of the pedicle, is parallel to that of the outer wall and is 10 mm behind it.

The tip of the prezygapophysis is 45 mm above and 29 mm in front of the centrum. Its edge dips 10° forward, aligned with a ridge up to the top of the epiphysis. The top of the postzygapophysis is 54 mm above the centrum, is 33 mm long laterally and 24 mm broad. The transverse process is 75 mm long to the tip of the prezygapophysis. Its lower end is broken on both sides showing a large central cavity. The epiphyses are broken off and missing. The spine is 42 mm long 30 mm above the table. Here the anterior edge extends forward 7 mm as a prespinal ridge 33 mm high, and the posterior edge curves back into a postspinal ridge that continues upward for 33 mm. The tops of the ridges form shoulders, and above there the spine shortens to 27 mm anteroposteriorly and ends above in a rounded, slightly swollen cap.

In anterior view (plate 15D), the centrum is nearly flat, 60 mm high and 78 mm broad. The pedicle is 18 mm broad, arching around a canal 22 mm high and 21 mm wide near the base. A lateral buttress rises to the inside of the front of the downturned table forming the lateral wall of a prechonos 12 mm high and 10 mm wide, below and medial to the zygapophysis. The waist is 13 mm high and 15 mm broad, the anterior chonos is 27 mm high and 12 mm wide. The tips of the prezygapophyses are 108 mm apart, their bases 48 mm, and they dip 35° medially, each face 36 mm broad. Above the zygosphene is a large, rhomboid, prespinal chonos 46 mm high and 54 mm wide, its posterior wall nearly vertical. The prespinal ridge begins at the base of the trough and extends upward 94 mm, its edge quite rough. The spine is 15 mm broad near its base.

In posterior view (plate 15F), the height of the centrum is 81 mm, the breadth 85 mm, and the depth 31 mm. The center of the upper edge is concave below the canal. The pedicle is 12 mm broad and walls a triangular canal 18 mm high and 15 mm wide at the base. The lateral edge of the pedicle narrows to within 15 mm of the midline, then curves dorsolaterally under the inner edge of the postzygapophysis. The hyposphene is 6 mm high and broad, the postchonos 18 mm high and 11 mm wide. The postspinal trough is 16 mm long. The zygapophyses flare out to enclose a postspinal chonos 60 mm wide. The postspinal ridge is a rugose area in the front of the chonos that continues up 72 mm. It is narrow below, broadens to 14 mm and is replaced dorsally by the postspinal groove. The groove ends 104 mm above the trough, and above this the ridge projects 5 mm behind the spine, forming the posterior shoulder. The postzygapophysis is 20 mm from the midline, dips 30° medially, and is 45 mm wide. The epiphysis is broken, but there is a groove around its posterior base.

The ninth cervical of *Ceratosauros dentisulcatus*, n. sp. (UUVP 562, plate 15G-I) in lateral view has a centrum only 66 mm long, both dorsally and ventrally. The side is deeply concave anteroposteriorly and vertically, and is perforated by two pleurocoels at midheight. The anterior is 6 mm in diameter, the posterior 10 mm. The ventral edge is arched 20 mm. The parapophysis is at the anteroventral corner, and is an ellipse 32 mm high and 15 mm broad, dipping 75° anteriorly. The anterior chonos is hidden by the transverse process. The medial chonos runs up under the process, and the posterior chonos is 36 mm high. The pedicle ends 15 mm in front of the back of the centrum, its posterior edge almost vertical. The transverse process is 57 mm broad dorsally and narrows to 34 mm at the diapophysis, its top at the level of the top of the centrum. The prezygapophysis has a straight upper edge that dips slightly posteriorly. The postzygapophysis projects dorsally as a semicircle, its top 75 mm above the centrum. The ends of the two zygapophyses are 93 mm apart. The spine is very short, 45 mm at the base, and 25 mm at its lower third. There is a strong anterior shoulder, a 29 mm high narrow cap, and no posterior shoulder.



see plate 15H

In anterior view (plate 15G) the centrum is 93 mm in diameter, the end almost flat. The parapophysis is 33 mm high and dips steeply medially, its edge projecting just beyond that of the centrum. The pedicles are 60 mm across, and arch up and out as they form the inner walls of the anterior chonos. They enclose a canal 18 mm in diameter, above which is a zygosphene 6 mm high and 12 mm broad. On the left side, the anterior chonos meets the zygosphene; but on the right side there is a triangular prechonos 9 mm wide at the base, with its top dipping 45° lat-

erally. The anterior chonoses have moved up and are large triangles above the centrum and in the front of the transverse processes. The right anterior chonos is lateral to the prechonos, and is much narrower than the left.

The prezygapophyses are 120 mm apart dorsally, and 79 mm above the centrum. They arch gently ventromedially 78 mm to the top of the zygosphene, forming the sides of the prespinal chonos and the floor of the prespinal trough. The left transverse process is 104 mm from the midline, while the right has an upper extension that adds another 11 mm. The left diapophysis is 22 mm high, the right 36.

In posterior view (plate 15I) the centrum is 99 mm high and 104 mm broad. The pedicles are 26 mm across and enclose a triangular canal 21 mm wide at the base, and 22 mm high. Above the canal is a hyposphene 5 mm high and 7 mm broad. The region dorsolateral to the hyposphene is crushed on the right, but on the left is a postchonos 21 mm high and 12 mm wide. Its lateral wall is the pedicle, which dips steeply laterally and is 42 mm high. Here it continues dorsolaterally as a buttress to the postzygapophysis, the whole forming the inner wall of the posterior chonos. The postzygapophyses reach 93 mm above the centrum, where they are 111 mm apart. They dip 45° medially for 78 mm, including their buttresses, and enclose a large postspinal chonos and trough. There is no trace of an epipophysis. The spine is 24 mm broad, and a rough postspinal ridge begins 75 mm above the trough. A buttress runs from the tip of the postzygapophysis to the side of the spine.

**Pectoral Vertebrae:** In describing the osteology of *Dilophosaurus*, Welles (1984, p. 103) followed Seeley (1877, p. 545) in identifying some vertebrae as pectorals, axial elements which are transitional from cervical to dorsal vertebrae. Simply stated, in the axial cervicodorsal section of a theropod skeleton the transitional position of parapophyses from centrum to neural arch is used to make the determination. The position of the parapophysis on a centrum or neural arch indicates dorsal or cervical vertebra, respectively. When the parapophyses includes the cervicodorsal suture, it denotes pectoral and this interpretation is applied in the following descriptions.

The first pectoral vertebra (UUVP329, plate 16) is crushed anteroposteriorly, in lateral view the centrum is 50 mm thick and there is a single pleurocoel 9 mm in diameter just above midheight, with a smaller foramen just 3 mm behind. The parapophysis arises from the anterior margin of the centrum largely below midline, 39 mm high and 25 mm wide. There is slight evidence of a keel above the posteroventral margin of the centrum, but crushing masks anterior development, if any.

The anterior chonos is subtriangular viewed from the front, most deeply excavated dorsally where it terminates in a deeper concavity beneath the prezygapophysis. The medial chonos terminates in a pit angling dorsomedially beneath the transverse process. The dorsal surface of the transverse process is 35 mm wide at the prezygapophysis, narrowing to 25 mm at the termination of the diapophysis.

The prezygapophysis is broader than deep, the articular surface uniformly flattened. The postzygapophyses meet ventrally at a right angle, their articular faces diverging dorsally to a maximum of 90 mm at the upper margin and 22 mm ventrally.

The anterior surface of the centrum is flattened, slightly

oval in outline with the parapophyses projecting laterally, the horizontal width 123 mm and the vertical 91 mm to the floor of the neural canal. The vertical diameter of the neural canal is 19 mm and the horizontal is 21 mm. The maximum width across the diapophyses is 253 mm. The height of the neural spine is 191 mm from the top of the neural canal. At their thinnest development, the laminae between the anterior and posterior chonos, and the prespinal and postspinal chonos, are less than 3 mm.

The prezygapophyses are 109 mm apart at their dorsal margins and an estimated 35 mm ventrally. On the anteroventral margin of the centrum to the left of center there is a thin layer of bone from the posterior margin of the last cervical centrum at the point where they were found matrixed together.

Posteriorly, the centrum is 103 mm wide and 93 mm high. The pedicals are 30 mm at their greatest width and they meet the contact with the centrum at 45 degrees. The neural canal is 20 mm wide and 21 mm high. The total height of the vertebra is 305 mm.

**Dorsal vertebrae:** The anterior dorsals have the same peculiar parapophyses as in *Ceratosaurus magnicornis*. They are born at the end of a downcurved, extended, anterior part of the transverse process, a stem that is quite separate from the process to the diapophysis. The parapophysis climbs suddenly higher behind the cervicals, until it reaches the level of the postzygapophyses. In dorsal view the table is deeply concave between the parapophysis and the diapophysis.

The fifth dorsal of *Ceratosaurus dentisulcatus*, n. sp. (UUVP 1229, plate 16A-C) in lateral view has an extremely short centrum, 66 mm dorsally and 63 mm ventrally. It is deeply concave both anteroposteriorly and dorsoventrally, and is pierced by two pleurocoels at midheight, the posterior the larger at 12 mm. The ventral border arches up 21 mm. The parapophysis dips 45° anteriorly, and is 45 mm high and 18 mm broad. From its anterior summit a narrow (8 mm) buttress continues up to the base of the transverse process. The base of the pedicle is as long as the centrum, but it narrows to 25 mm at a height of 24 mm. The prezygapophysis rises 96 mm above the centrum, its front directly above the front of the centrum. Its upper edge is 25 mm long, and behind this it dips 9 mm, then rises to the side of the spine. The postzygapophysis is very short, its top 69 mm above the centrum. The spine is 27 mm long and rises 219 mm above the centrum. At 144 mm above the centrum the prespinal ridge juts forward. The postspinal ridge juts backward at 147 mm, the two bulges increasing the anteroposterior length to 42 mm.

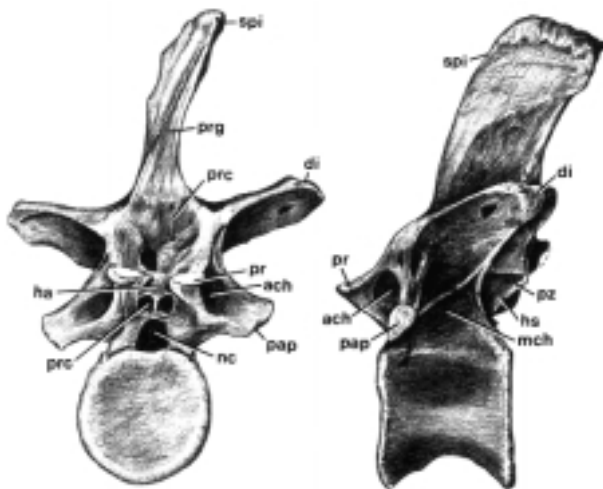
In anterior view the centrum is 87 mm high and 129 mm broad. The pedicles are 78 mm broad at their bases and enclose a neural canal 18 mm high and 24 mm wide. Above the canal is a zygosphene 16 mm high and 9 mm broad, which floors the prespinal trough. Flanking the zygosphene are the prechonos, the left crushed, the right 26 mm high and 12 mm wide. Above the zygosphene rise the buttresses to the prezygapophyses, dipping 40° medially. The summits of the prezygapophyses are 116 mm apart. They form the lateral walls of the large prespinal trough, and the inner walls of the anterior chonos. The diapophyses are 216 mm apart at their tops, 198 mm at their bases, and the transverse processes dip 20° laterally. The pre-

spinal ridge begins at the top of the small prespinal chonos and ends 132 mm above the trough, with a projection from 98 to 132 mm.

In posterior view the centrum is 93 mm high and 105 mm broad. The pedicles are 75 mm across their bases, narrow to 72 mm dorsally, and then flare out beneath the transverse processes. The canal is 27 mm high and 21 mm wide. Above it is a greatly reduced hyposphene 14 mm high and only 6 mm broad, flanked by very small (5 mm) postchonoses. Here the breadth of the back of the pedicles, between the posterior chonoses, is 18 mm. Immediately above is the floor of the postspinal trough, above which the sides of the trough continue dorsolaterally into the postzygapophyses. These dip 32° medially, their upper edges 97 mm apart. The postspinal ridge is 18 mm broad and rises to 162 mm above the centrum, its upper 16 mm projecting back.

The seventh dorsal (UUVP 1231, plate 16D-F), is so identified because the parapophysis is on a stem on a level above the centrum, and below the zygapophysis. However, it differs much more from dorsal 1 than we expected. In lateral view (plate 16F) the centrum is 94 mm long dorsally and ventrally, its side concave in both directions, and there is no pleurocoel. The parapophysis is oval, 28 mm high, and 18 mm posteroventrally. The anterior chonos is on the front face of the parapophyseal stem, lateral to the prezygapophysis. The medial chonos runs up beneath the transverse process, divided by a strut rising posterodorsally from the posterodorsal edge of the parapophyseal stem. This strut fuses with the posterolateral edge of the pedicle at 59 mm above the centrum. The top of the prezygapophysis is 39 mm above the centrum, the postzygapophysis 51 mm, that of the diapophysis 117 mm, and it projects 24 mm behind the centrum. The spine is 72 mm broad, its posterior edge overhanging the centrum by 22 mm. It arches backward and its summit dips 20° posteriorly.

In anterior view (plate 16D) the centrum is 96 mm high and 93 mm broad, its top slightly concave. The neural canal is 21 mm high and 24 mm wide. The pedicles span a breadth of 66 mm, and just above the centrum they flare out into the parapophyseal stem. The two parapophyses are 162 mm apart, their anterior faces excavated by the anterior chonos. Above the canal is an extremely narrow (3 mm) zygosphene, flanked by prechonoses 12 mm in diameter. At this level a buttress descends from the prezygapophysis



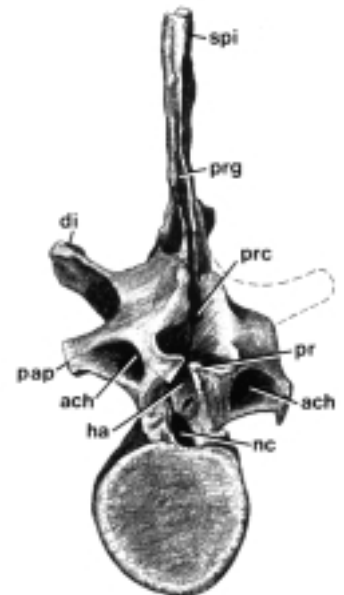
see plate 16D, F

and continues out to the transverse process. The distance across the two buttresses is 60 mm. The prezygapophyses are horizontal, their tops 70 mm across, and 17 mm apart. The upper edge of the process to the parapophysis is vertical to about 78 mm above the centrum, there it curves backward and laterally to the transverse process. At the junction the breadth is 79 mm. The top of the transverse process dips slightly medially, and the diapophyses are 222 mm apart. The prezygapophyses do not continue ventromedially to form a prespinal trough, but between them is a hypantrum that extends as a prespinal chonos into the base of the neural spine. The spine narrows dorsally from 51 mm to 18 mm at its top, 237 mm above the centrum. A prespinal groove rises to within 25 mm of the top.

In posterior view (plate 16E) the centrum is 93 mm high and 90 mm broad, the central 60 mm of its top horizontal. The pedicles occupy this entire breadth and enclose a canal 15 mm high and 30 mm wide. Above this the hyposphene has extended back and become larger, with a central chonos at its base. The postzygapophyses are horizontal and span 69 mm, their lateral edges running forward, then curving out to the back of the transverse process. The postspinal groove runs up to 216 mm above the centrum.

The ninth dorsal, (UUVP 48, plate 17A-C), in lateral view (plate 17B) is 105 mm long dorsally, 99 mm ventrally, its side pinched, its ventral edge arched 25 mm. There is no pleurocoel. The pedicle is as long as the centrum, and becomes slightly concave anteriorly, and deeply so posteriorly at a length of 78 mm. The anterior chonos is high up on the front of the parapophyseal stem. The medial chonos extends 48 mm above the centrum, and has a foramen 9 mm high and 27 mm long near its summit. The posterior chonos begins near the centrum and continues far out the back of the transverse process. The parapophysis is on a horizontal stem, centered at the level of the prezygapophysis. Its posterodorsal edge bows in, then out along the posterior prong to the diapophysis, forming the lateral edge of the table. The upper surface of the parapophyseal stem dips 20° laterally, that of the transverse process dips 30° medially and ends 117 mm above the centrum. The spine is rectangular, 94 mm long and 237 mm above the centrum, its top gently arched.

In anterior view (plate 17A) the centrum is 89 mm high and 90 mm broad. The pedicles are 49 mm across and enclose a canal 18 mm high and 12 mm wide. Above the canal the buttress to the zygapophysis arches out, up, and in, to enclose a hypantrum 21 mm wide. At the back of this is a small zygosphene 12 mm high, flanked by small prechonoses. The hypantrum opens above this and behind the zygapophysis. There is no prespinal trough, and the dorsal lateral edges of the zygapo-



see plate 17A

physes curve out 39 mm, then back in, to buttress the spine. The prespinal groove is very narrow, as is the spine.

In posterior view (plate 17C) the centrum is 102 mm high and 90 mm broad, narrowing at the top to 48 mm. Here it is concave below the canal, which is 13 mm high and 21 mm wide. Above the canal is a diamond-shaped hyposphene 27 mm high and 19 mm broad at 10 mm above the base. It tapers to a rounded point both dorsally and ventrally. Above the hyposphene the zygapophyses send processes in and forward to meet and form the floor of the postspinal trough. The two zygapophyses span a breadth of 55 mm, each dipping 30° medially. The pedicles span 45 mm at their bases, narrow to 39 mm dorsally, then flare out under the diapophyses. The spine is 33 mm broad at its base, and is excavated by a postspinal groove from the trough to a height of 111 mm. Above this the posterior edge of the spine narrows to 6 mm, its top 245 mm above the floor of the canal.

**Sacral Vertebrae:** No sacral vertebrae of *Ceratosaurus* were identified in the Cleveland-Lloyd Dinosaur Quarry collection.

**Caudal Vertebrae:** An anterior caudal of *Ceratosaurus dentisulcatus*, n. sp. (UUVP 6961, plate 17D-F) has a centrum that, in lateral view (plate 17E), is 102 mm long, and 92 mm high. The lower two-thirds of its anterior end is vertical, but the upper part curves forward. The side is pinched and without pleurocoels. The posterior end is slightly convex. The lower edge is arched 12 mm, and the posteroventral corner is bevelled, but does not show chevron facets. The pedicle contracts to 73 mm just above the centrum, then expands dorsally into the buttresses for the pre- and postzygapophyses. The prezygapophysis overhangs the front of the centrum about 5 mm, and from its tip to that of the postzygapophysis is 111 mm. The transverse process is a flat plate 69 mm broad proximally, and 44 mm distally. It has a ventral thickening just behind its center. The spine is rectangular, 60 mm broad just above the transverse process, and increases gradually to 72 mm near the top, which is 240 mm above the centrum. The posterodorsal corner is bevelled.

In anterior view (plate 17D) the centrum is 102 mm broad at its lower third, and narrows dorsally to 30 mm at the pedicle base. The pedicles span 37 mm opposite the canal, which is 16 mm high and 19 mm wide. The prezygapophyses almost meet above the canal, are 34 mm high, and concave, dipping 60° medially. The transverse process rises slightly to 87 mm from the midline, then dips 20° laterally for another 40 mm. Between the zygapophyses is a prespinal chonos. The spine is 18 mm broad, and a prespinal ridge begins 57 mm above the floor of the canal and extends up to 120 mm, where it arches forward to 6 mm in front of the general edge of the spine.

In posterior view (plate 17E) the centrum is 84 mm broad. The pedicles are 39 mm across at their base, and enclose a canal 15 mm high and 24 mm wide. Above this they contract to span 27 mm. A triangular hyposphene, its base 7 mm broad, projects just above the canal. Dorsolateral to it are postchonoses 21 mm high and 7 mm wide. The postzygapophyses are weak, their lateral walls 3 mm apart at their bases, and 21 mm above. They enclose a postspinal chonos 4 mm wide that extends up to 67 mm above the floor of the canal.

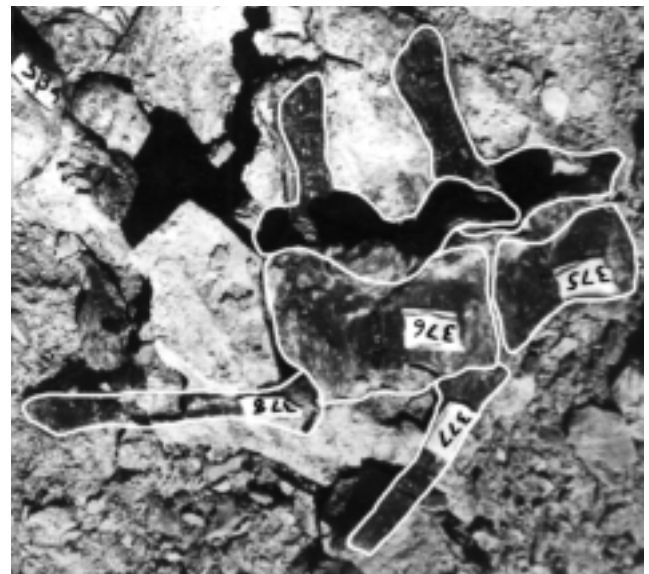
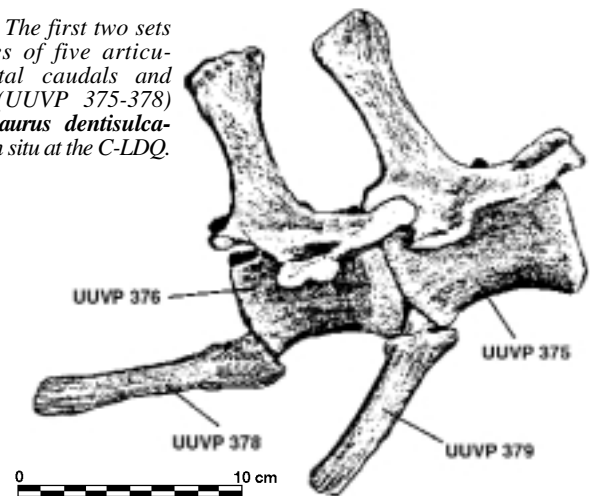
The ventral surface of the caudal centrum, UUVP 6305, has a shallow, uniformly narrow, anteroposterior groove (figure 4). The anteroposterior, ventral groove is most evident as a diagnostic feature in all but the most distal caudal vertebrae.

Two medial caudals (UUVP 375-376, plate 18A-C and figure 5) are joined in articulation, including chevrons, and were prepared without separation. The anterior centrum is

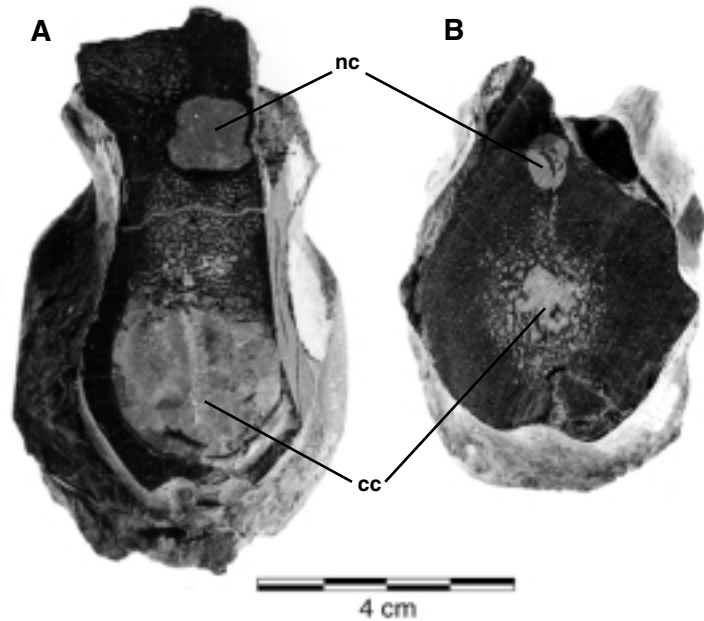


**Figure 4.** Ventral view of an anterior, caudal centrum (UUVP 6305) of *Ceratosaurus dentisulcatus*, n. sp. holotype, from the C-LDQ showing the diagnostic ventral groove.

**Figure 5.** The first two sets in a series of five articulated distal caudals and chevrons (UUVP 375-378) of *Ceratosaurus dentisulcatus*, n. sp. in situ at the C-LDQ.



90 mm long, 160 mm high, and 45 mm broad, and has a chevron facet 24 mm long. The prezygapophysis extends 18 mm in front of the centrum, its front round, and 12 mm high. The transverse process is behind the middle of the centrum, and opposite the canal. It is a thin plate 30 mm anteroposteriorly, and reaches 54 mm from the midline. The postzygapophysis is very small, and extends just beyond the centrum. The spine is concave anteriorly and posteriorly, shortening to 21 mm at midheight and expanding to 39 mm near the top. The medial caudals are readily identified in contrast with those of *Allosaurus* by the enlarged marrow cavity in the centrum (figure 6).



**Figure 6.** Cross sections of distal caudal vertebrae from the C-LDQ contrasting the cavernous marrow cavity (centrocoel) of *Ceratosaurus* (A) (UUVP 5960) with the more restricted counterpart in *Allosaurus* (B). Abbreviations: nc-neural canal; cc-centrocoel.

A caudal from near the end of the tail (UUVP 6953, plate 18D-F), is 72 mm long, 43 mm high and broad. The transverse process is broken, but begins at midheight of the centrum. The spine rises to 36 mm above the centrum, and is 15 mm long with its posterior edge above the back of the centrum.

**Chevrons:** The chevrons of *Ceratosaurus* are ordinary (plate 18), differing from their counterparts in *Allosaurus* by having shafts that are slightly more cylindrical in cross section rather than more laterally compressed. Additionally, the paired anterior processes are more abbreviated and the articular surfaces are better defined than in *Allosaurus*, suggesting less flexibility with the two adjoining caudal centra.

The few posterior chevrons of *Ceratosaurus* recovered from the C-LDQ were a rarity, having been collected as part of an articulated, distal segment of the tail in a quarry that has yielded few articulated or associated elements of any individual skeleton.

An anterior chevron (UUVP 272, plate 18G-J) is 276 mm long, its shaft 24 mm long anteroposteriorly and 15 mm broad. The line of fusion of the two halves is evident to 189 mm from the top. The top is 66 mm broad, has a wedge shape, with two processes extending anterodorsally.

The haemal canal is 24 mm wide anteriorly and 12 mm posteriorly.

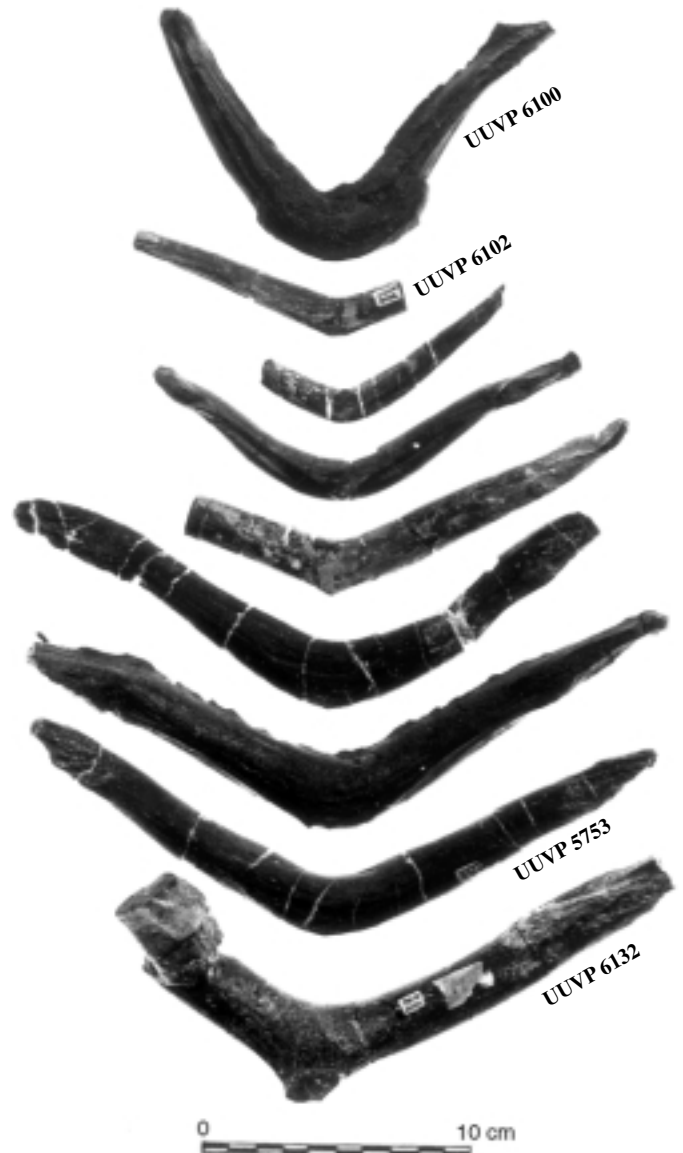
**Ribs:** Only five isolated ribs of *Ceratosaurus* have been recovered from the C-LDQ, three dorsal and two cervical.

The cervical ribs UUVP 2172 and 6520 (plate 19) are incomplete, but were readily identified by comparison with the sixth cervical vertebra, UUVP 6964 (plate 15), which retained part of the right rib.

The three dorsal ribs, UUVP 548, UUVP 316, and UUVP 610 are incomplete, but UUVP 548 is the best example measuring 846 mm in length and 152 mm across the proximal end. These elements are long, relatively heavy, and only slightly bowed along the proximal third of their length. Their configuration suggests a slab-sided body cavity for *Ceratosaurus*.

A common character of these few ribs, cervical and dorsal, is a pneumatic cavity (plate 19).

**Furcula:** A collection of medial elements, furculae, from the Cleveland-Lloyd Dinosaur Quarry (figure 7), were speculatively identified as abdominal ribs by Madsen (1976),



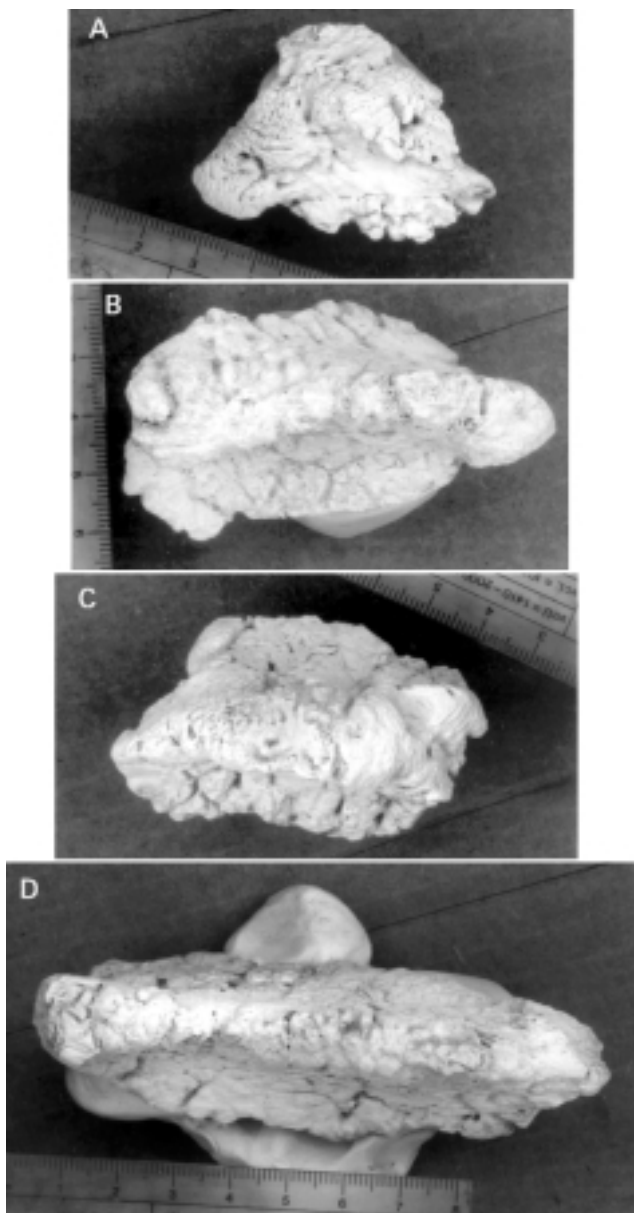
**Figure 7.** Theropod furculae from the C-LDQ (see Chure and Madsen, 1996).



but subsequent work by Thulborn (1984), Bryant and Russell (1993), and Chure and Madsen (1996), makes a strong argument for their identification as furculae. Such an interpretation would not support their assignment exclusively to *Ceratosaurus*, but to several of the C-LDQ theropod dinosaurs instead, for example *Allosaurus* and *Torvosaurus*.

**Dermal Ossicles:** These bones were first reported by Gilmore (1920) having been recovered along the dorsal margin of the anterior axial elements of USNM 4735, the type of *Ceratosaurus nasicornis*. Although similar ossifications were collected from the C-LDQ, none were found in immediate association with any vertebrae, pre- or post-sacral.

The unusual bones in figure 8 are amorphous in shape which, together with their limited number in the C-LDQ, supports their supposed origin from a single taxon. In addition they all share a common surface texture which is typically rough and pitted with a textile-like appearance.



**Figure 8.** Dermal ossicles thought to be from the C-LDQ ceratosaur, UUVP 433 (A), UUVP 6788 (B), UUVP 677 (C), UUVP 80 (D).

Additional, unfigured dermal ossicles, likely assignable to *Ceratosaurus dentisulcatus*, n. sp., are UUVP numbers 25, 93, 102, 113, 208, 236, 351, 361, 367, 469, and 507. Most of these enigmatic bones fall within a circle 5 meters in diameter in the Cleveland-Lloyd Dinosaur Quarry from which other ceratosaur elements were collected.

### Appendicular Skeleton

**Scapulocoracoid:** The right scapulocoracoid (UUVP 317, plate 20A-C) (see also *Ceratosaurus* sp., Madsen, 1976, figure 23B,D) is 405 mm long. The scapula in lateral view is 335 mm long to the coracoid suture. The blade is 54 mm concave along its anterior edge, its posterior edge convex at the center, gently concave in its upper third, and rather sharply concave just above the glenoid. The upper end is 78 mm broad, narrowing to 51 mm at midheight, and expanding to 122 mm at the top of the glenoid. The anterior edge of the blade is very thin, and the blade thickens to 21 mm near the posterior edge. The upper edge of the glenoid dips 40° anteriorly, and is 30 mm long. The glenoid is 40 mm high and 36 mm deep. The suture with the coracoid begins at the lower edge of the glenoid, runs forward to just above the coracoid foramen where it arches up halfway to the top of the preglenoid fossa. It then continues forward horizontally and is lost about 43 mm from the anterior border. The anterodistal edge of the scapula has a sharp projection that extends 5 mm in front of the smooth curvature of the bone, just above the level of the top of the glenoid. The lower part of the scapula has a preglenoid ridge that arches up and forward from the front of the glenoid, then continues horizontally to the anterior edge. Below this the scapula is concave, as a preglenoid fossa, to its junction with the coracoid.

The ventral edge of the coracoid and the lower anterior edge of the scapula make a semicircle 150 mm in diameter that is slightly flattened anteriorly. In lateral view the glenoid lip is 17 mm long, and the concavity below it is shallow. The biceps tubercle is horizontal and from it a dorsal buttress runs up to the ventral lip of the glenoid. The foramen is 12 mm wide and 6 mm high, and leads dorsomedially, opening into vertical groove on the medial face that runs up to the scapular suture.

**Humerus:** The left humerus (UUVP 549, figure 3B,D) is 333 mm long and, in anterior view, the proximal end is 135 mm from medial tuberosity to the greater tubercle. The head is 90 mm broad and dips 10° laterally. Its medial end curves down 44 mm to a fairly sharp point, then up and laterally to 29 mm below the top. From here this lower edge of the head curves up laterally to 18 mm from the top. Here it curves down and anteriorly to join the greater tubercle. The greater tubercle is 16 mm broad and curves anteroventrally around the outer edge of the head. The medial tubercle projects 16 mm medially to the head, its upper edge dipping 43° medially for 26 mm. Below, it curves laterally into the shaft. The upper anterior face of the bone is hollowed out below the head, between its medial ventral projection and the greater tubercle, the breadth is 63 mm. The shaft narrows to 63 mm at 130 mm below the head, then to a minimum of 50 mm at 219 mm. The deltoid tuberosity begins 21 mm below the top of the greater tubercle, where it is 9 mm broad. It gradually increases in breadth, until at 90 mm below the top of the tubercle it is 18 mm broad. Below this it narrows gradually to a rounded

base 138 mm below the tubercle, then blends into the shaft. The distal end broadens to 134 mm. The medial condyle is 23 mm broad and arches up 12 mm. The lateral condyle is 48 mm broad and arches up 16 mm.

In posterior view the head is an ellipse 29 mm high and 98 mm broad. The medial tubercle has a rough surface and is a stout medial projection below the head. The greater tubercle extends 15 mm lateral to, and just below, the head.

**Femur:** The left femur (UUVP 56, plate 21A-D) in lateral view is 759 mm long. The greater trochanter is only 33 mm broad, but the lateral face of the bone expands to 120 mm at the top of the anterior trochanter. At the base of the trochanter the shaft is 102 mm broad, then narrows to 79 mm at midheight. It is narrowest (60 mm) at 80 mm above the distal end. Just below this is an anterior projection that extends 12 mm in front of the edge of the femur. At the top of the tuberos process the bone expands to 84 mm. Below this is a notch 51 mm high and 9 mm deep in the posterior edge of the femur. The distal end is the smoothly rounded lateral condyle. The anterior trochanter has a horizontal top 30 mm broad, without a notch at its junction with the base of the greater trochanter. Its anterior edge is 60 mm long and dips 54° anteriorly. Below this it continues 43 mm into the shaft, dipping 56° posteriorly. There is a faint trochanteric shelf at its base that extends back to the middle of the shaft. The fourth trochanter begins 195 mm below the crest of the greater trochanter and expands gradually to 39 mm from the shaft at 243 mm down. The tuberos process has a horizontal top 105 mm above the base of the condyle, and extends 27 mm behind the shaft. The lateral condyle has a rounded anteroventral corner, a vertical anterior edge and a horizontal base. Its maximum breadth is 87 mm where its posteroventral end rounds up to 54 mm above its base. Above the back of the condyle is a concavity 57 mm high and 6 mm deep that separates the condyle from the shaft. The medial condyle is missing, but it evidently extended farther back than the lateral condyle.

In anterior view the head is 180 mm broad, including the greater trochanter. It is 126 mm high at its medial projection. Its proximomedial surface is flattened, and its lower end is separated from the shaft by a notch 6 mm high. Above this notch the anterior face is excavated into an arch 30 mm high and 39 mm wide. Above and lateral to the arch the bone is flat. From the base of the notch the edge of the bone dips 60° laterally for 75 mm where it meets the shaft. The upper lateral edge is gently convex for 147 mm below the greater trochanter, dipping 60° laterally. Here it slants ventrolaterally for 15 mm to the top of the shaft. This also marks the base of the anterior trochanter, which is 78 mm broad. The trochanter is 81 mm high, its lateral edge straight and dipping 80° laterally. The trochanteric shelf extends medially 54 mm. The top of the shaft is 99 mm broad, narrowing to 93 mm at midheight, and expanding to 198 mm at 51 mm above the distal end of the ectocondyle. Here the medial face curves medially for 12 mm, then continues vertically for 111 mm as the entocondylar ridge. Below this it curves smoothly into the entocondyle. The entocondyle extends laterally to 90 mm from the ridge, and above it the bone is rough and depressed to a height of 177 mm, the upper medial edge of this roughening arched. Lateral to this the shaft curves slightly laterally to the ectocondyle. The top of the tuber-

ous process projects 26 mm laterally from the edge of the shaft, and is 123 mm above the base of the condyle.

In posterior view the greater trochanter curves down laterally to 28 mm from the top. The trochanter begins near the lateral edge, continues medially for 81 mm, then arches up to 12 mm from the top where it joins the top of the head. The area below the trochanter is excavated and the excavation continues medially into a deeper hollow proximolateral to the head. The head has two faces, the upper of which is dorsolateral to the excavation, is 12 mm broad, and 81 mm long, dipping 68° medially. Below this the head enlarges, its surface rolled back 27 mm, its medial edge convex, and its lateral edge almost straight and dipping 40° laterally. Below the head is a short neck, or notch, and below this the shaft curves down laterally for 90 mm. The inner edge of the shaft is vertical and straight for 345 mm to the top of the entocondylar ridge. Here the edge slants medially for 45 mm, then again becomes vertical alongside the ridge and in front of the condyle. The proximal 156 mm of the lateral edge is slightly convex, and dips 76° laterally. At 156 mm below the top of the trochanter the lateral edge curves laterally for 12 mm, thickening the base of the anterior trochanter. The bone above this has a dorsomedial slant, while below this the shaft is nearly vertical, its lateral edge slightly concave. The tuberos process is rectangular with rounded corners. It is 78 mm high, 51 mm broad, and dips 77° medially so that its anterolateral corner extends 21 mm beyond the general curvature of the bone. Below it is a horizontal groove separating it from the ectocondyle. The entocondyle is broken, but is 111 mm high and 84 mm broad. The intercondylar groove is 15 mm wide below, increasing to 48 mm at the top of the tuberos process. The ectocondyle is only 30 mm high, but is 81 mm broad.

In medial view the head curves down for 87 mm. Its summit angles posteroventrally, its maximum breadth 60 mm at midheight. Below the head and just at the top of the anterior trochanter the bone is 60 mm broad. The anterior trochanter is 64 mm high, with a horizontal top and an anterior edge that dips 66° anteriorly. It extends the breadth of the bone to 108 mm at its base. Below this the bone curves gently into the shaft, which is 96 mm broad. The anterior face of the shaft is straight and vertical for 348 mm, then is slightly everted, then continues down to the entocondyle. The fourth trochanter begins just below the level of the base of the anterior trochanter and increases the breadth of the shaft to 105 mm for some 45 mm. The posterior edge of the shaft then bends forward so the shaft is 63 mm broad at midheight. It then curves back to increase the breadth to 81 mm just above the condyle. The medial face of the condyle is slightly sunken, its lower edge extended, then curves anterodorsally into the entocondylar ridge, which blends into the shaft at a height of 201 mm.

**Tibia:** The left tibia (UUVP 5681, plate 22A-D) is 594 mm long at the medial condyle. Oriented with the distal end transverse, in anterior view the head is 180 mm across from the medial condyle to the end of the tuberosity. The tuberosity is massive, its ventrolateral diameter 102 mm, its upper and lower edges parallel and dipping 25° medially. It extends to 21 mm above the condyle. Its lower edge curves into the front of the shaft, forming a band 60 mm wide that continues down to the midheight of the shaft. This constitutes the medial two-thirds of the shaft, and the lateral third

is set back, its lateral edge extended into the fibular flange. The shaft is slightly concave medially, and varies in breadth from 90 to 99 mm, including the flange. The distal end broadens to 165 mm, including a medial enlargement and a postfibular plate 51 mm broad. The astragalus overhang is low, dips 5° medially, and its center arches down to almost touch the body of the astragalus, almost enclosing the dorsal process.

In lateral view the head is 171 mm broad and the out-curved tip of the tuberosity is 52 mm broad anterodistally. The condyle is 66 mm broad and it continues down into the shaft which narrows to 45 mm just above the top of the astragalus overhang. It then broadens to 66 mm as it becomes convex posteriorly continuing the curvature of the calcaneum and forming the postfibular plate. The fibular flange begins 51 mm below the condyle and extends to within 137 mm of the distal end. The depression for the dorsal process of the astragalus is half as deep as the breadth of the tibia, shallow dorsally, and is 69 mm high.

In posterior view the lateral condyle is 87 mm broad and 54 mm high, its ventral edge almost a semicircle. The intercondylar notch is 30 mm wide, and the medial condyle is 27 mm broad behind the notch and extends about 18 mm above the medial condyle. The tuberosity curves anterolaterally to 69 mm lateral to the condyle. The lateral condyle has a rounded buttress below that is concave laterally and curves out to the lateral edge of the shaft at 240 mm below the top of the condyle.

**Astragalus and Calcaneum:** The astragalus and calcaneum are fused, and so tightly locked to the tibia as to form a tibiotarsus. In anterior view they are 57 mm high medially and 50 mm laterally. They are 165 mm broad and a weak horizontal groove transverses the face at midheight. The dorsal process is only 33 mm high (H:B index 20), and is deeply embedded in the tibia. Its lateral edge is vertical, but concave, and its dorsal tip is blunt.

In medial view the anterior edge of the astragalus is almost vertical and is 48 mm high. Its posterior edge dips 50° anteriorly and reaches up the back of the tibia for 69 mm.

In lateral view the calcaneum is 66 mm high anteriorly and 48 mm posteriorly. The lateral edge of the dorsal process arches forward to a height of 99 mm above the rounded base of the calcaneum.

In posterior view the astragalocalcaneum curves slightly up around the base of the tibia, its height 21 mm medially, dropping to 7 mm for 36 mm, then to 10 mm for 60 mm where it curves up to 39 mm behind the fibular socket.

**Fibula:** The left fibula (UUVP 56, plate 23A-D) is 564 mm long, its head 150 mm broad anteroposteriorly, and concave medially and convex laterally. It is thicker posteriorly where it curves slightly up to form a condyle. In lateral view this condyle curves down 21 mm onto the shaft, and is deepest at 51 mm from the posterior edge. The shaft narrows to 70 mm at 105 mm below the head, the anterior edge dipping a little more steeply than the posterior edge. This upper part of the fibula is aligned with the shaft. At 135 mm below the top the tibial flange juts forward, making the shaft 67 mm broad. The flange is rough, 72 mm long, and dips 70° posteriorly. At the lower end of the flange the fibula is 45 mm broad, and it narrows ventrally to 30 mm at 114 mm above the end. The distal condyle is rounded, and expands to a breadth of 81 mm.

In anterior view the head is 63 mm broad and dips slightly medially. The shaft narrows rather uniformly to 28 mm at 114 mm above the base, then broadens to 48 mm distally. The base is a condyle that curves 24 mm proximolaterally and dips 30° laterally. Its medial edge is vertical for 78 mm up the shaft to where the shaft is 39 mm broad. Here the edge of the shaft suddenly steps in, narrowing the shaft to 34 mm. The tibial flange is from 135 to 228 mm below the top, aligned with the shaft, and about 16 mm broad.

In medial view the posterior proximal condyle extends to the posterior edge and rolls down 22 mm from the top. From its anterior base a strut runs ventromedially, dipping 37° and joining the top of the tibial flange. Behind the flange and below the strut is a cavity in the upper posterior part of the fibula. The flange is 27 mm broad ventrally where it causes a swelling on the anterior edge of the shaft, centered 165 mm below the top.

In posterior view the head is 51 mm broad, and the shaft narrows gradually to 22 mm at 105 mm above the end. Below this the edge thins to 12 mm as a ridge, expanding to 25 mm at the distal end.

There was only one tarsal and one metatarsal collected with other appendicular elements of *Ceratosaurus dentisulcatus* from the C-LDQ including two metacarpals, and a single pedal phalanx (figures 9 and 10).

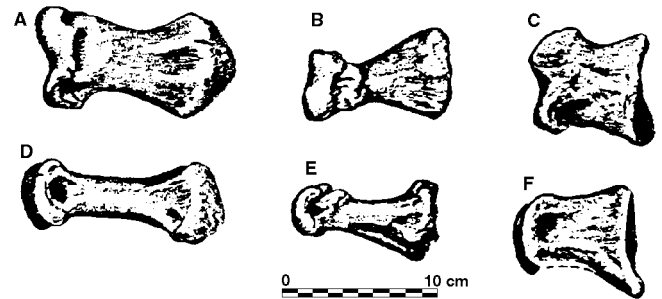


Figure 9. Metacarpals (UUVP 1979 and 47) (A,B) and pedal phalanx (UUVP 3729) (C) from the C-LDQ ceratosaur in dorsal (A,B,C) and lateral (D,E,F) views.

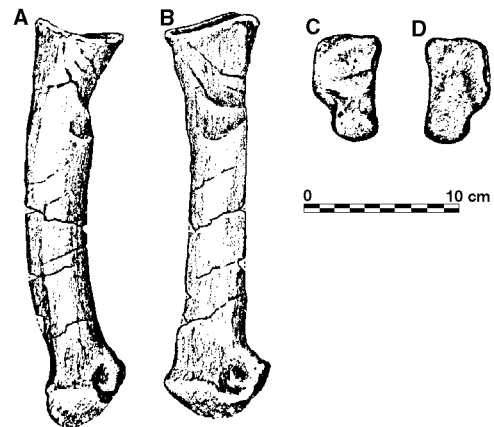


Figure 10. Left metatarsal IV (UUVP 5683) of *Ceratosaurus dentisulcatus*, n. sp. holotype, from the C-LDQ in anterior (A) and medial (B) views, and the tarsal IV (UUVP 327) in dorsal (C) and ventral (D) views.

## Ceratosaurus, sp.

### Dinosaur National Monument, Utah

A right premaxilla, (DNM 972, figure 1, A-D) was identified by comparison with the type, the Fruita, and the Cleveland-Lloyd specimens as belonging to this genus. Although this specimen differs in some details, we do not believe an isolated premaxilla such as this is adequate for specific determination and, therefore, it is identified as *Ceratosaurus* sp.

In lateral view it is rectangular, 154 mm long and 162 mm high below the naris. The dorsal edge curves up posteriorly to form the maxillary process. Below it is an indentation for the subnarial foramen.

In anterior view it is 108 mm broad at the base, narrowing dorsally to 67 mm at the base of the maxillary process. With the medial surface vertical, the base dips 15° medially and the lateral face dips 75° laterally and is almost straight, with a slight mid-height concavity.

In medial view some bone is missing over the first alveolus, and the anteromedial process is either missing or was not developed.

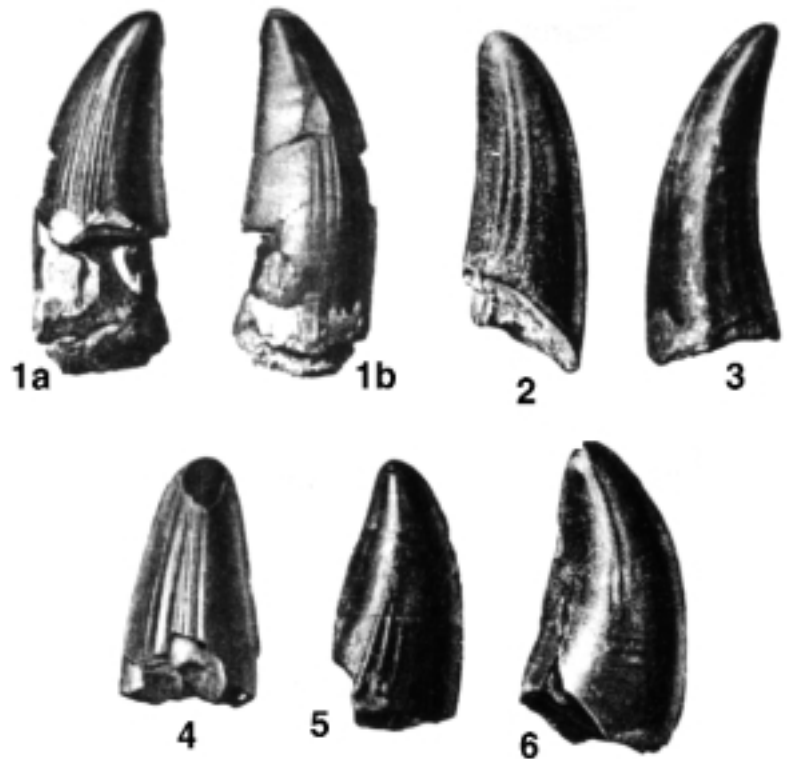
Only the third tooth remains. It extends 64 mm below the bone, and is 33 mm broad at its base. It is recurved so that its tip is directly below the back of its base and it exhibits characteristic longitudinal grooves on the lingual surface which are peculiar to the genus.

Although White (1964, p. 24) identified the premaxilla (DNM 972) and a maxilla from Dinosaur National Monument, the premaxilla is described in this paper (figure 1), but the maxilla is of a small specimen of *Allosaurus*, (compare with *Allosaurus fragilis*).

### Tendaguru Hills, Tanzania

*Ceratosaurus roechlingi* Janensch (1925, p. 61, figures 19, 20) was based on a left quadrate and a left fibula from the upper Saurian Bed of Tendaguru (MW Quarry). The quadrate is here designated the type as it is generically diagnostic. It is 130 mm broad distally, versus 78 mm for *Ceratosaurus magnicornis*, but it is not possible to distinguish it at the specific level from other known quadrates. The quadrate (MW 2, Janensch's figure 19) is from a large theropod, but is not diagnostic of a species. It is almost twice as large as that of *Ceratosaurus magnicornis*. The fibula (MW 1, Janensch's figure 20) is only the proximal half, and is not diagnostic. The anterior caudal (MW 3) is 106 mm high, while that of *C. magnicornis* is only 76 mm. These specimens probably represent one or more individuals of a large species of *Ceratosaurus*, but at the present state of our knowledge they are not further diagnostic.

A number of theropod teeth (figure 11) were described by Janensch (1920, p. 232, figures 7, 8; 1925, p. 86, plate 10, figures 1-6) as *Labrosaurus* (?) *stechowi*. The type has finely serrated edges, and heavy ridges that converge apically on the labial side. These teeth are recurved and longitudinally grooved as in the known species of *Ceratosaurus* and, together with the bones, confirm the presence of a large *Ceratosaurus* in the Tendaguru fauna. However, the



**Figure 11.** Theropod teeth from Janensch (1925, plate X). The lingual grooves are diagnostic of the premaxillary and anterior three teeth of the *Ceratosaurus dentary*. Scale: actual size.

material is scattered, and is not diagnostic to species. The name is probably a junior synonym of *Ceratosaurus roechlingi*, and each is a nomen vanum. We classify this material as *Ceratosaurus* sp.

*Ceratosaurus* sp. Janensch (1920, p. 230) was based on three, small, dorsal vertebrae from the third reptile level of Tendaguru identified by Janensch in 1925 (p. 78) as Quarry TL. These are described as juvenile, and lack their arches. They are plano-concave, the ends circular, the sides strongly pinched, sloping ventromedially, and there is a deep sagittal keel. There is a deep pleurocoel on the front of the lateral face above midheight. The parapophysis is on the anterior border above midheight. The length is 65 mm dorsally and 73 mm ventrally, the height 69 mm.

Janensch also referred to a mid-dorsal from the same locality. It is longer, 89 mm dorsally, its ends compressed, and the keel very weak. He also added a posterior dorsal 86 mm long dorsally, its ends circular and weakly concave. It is pinched to 41 mm, and above midheight is a long, deep concavity. None of this Tendaguru material is specifically diagnostic, and we agree with Janensch in referring it all to *Ceratosaurus* sp.

### Bern Jura, Switzerland

*Labrosaurus meriani* Janensch (1920, p. 233) was based on a tooth with weak grooves on the lateral surface from the Malm, near Moutier, Savoy, in the Bern Jura. This was originally described and illustrated by Greppin (1870, p. 339, plate 1, figure 1) as *Megalosaurus meriani*. Huene (1926, p. 40; 1932, p. 59) noted that it came from Moutier

in the Swiss Jura, the Upper Jurassic Virgulla beds. Molnar and others (1990, p. 192) listed it as a nomen dubium. The lingual grooves are characteristic of the anterior teeth of *Ceratosaurus*, but teeth are not necessarily specifically diagnostic, so the tooth should be labeled *Ceratosaurus* sp.

### Cimarron County, Oklahoma

Stovall (1938, p. 596, figure 3[5-9]) described a number of bones that suggested to him an animal the size and character of *Ceratosaurus*. In brief review, his figure 3(5) shows one of several teeth that average 51 mm high. The illustration shows it recurved and serrated, but not longitudinally grooved as in *Ceratosaurus*. The metatarsals of figure 3(6) are indeterminate. The cervical vertebra of figure 3(7) is described as plano-concave, and 89 mm long. It is of a size appropriate for a large theropod, but is indeterminate. The dorsal vertebra of figure 3(8) was described as having its centrum deeply concave both laterally and ventrally, and with a large internal concavity. It is 124 mm long, the illustration showing its breadth greater than its height, again indicating a large theropod, but indeterminate.

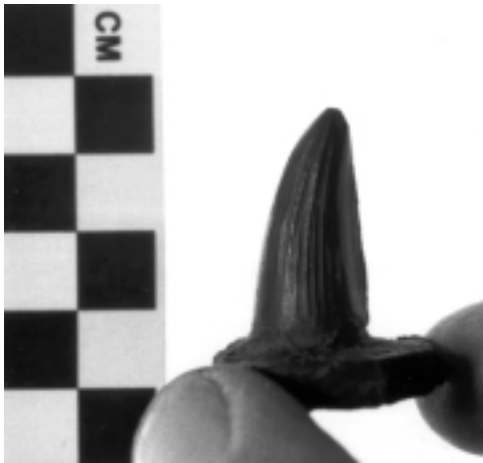
Unfortunately, none of these elements is adequate for specific, or even generic determination at this time, and the material should be referred to as Theropoda indet.

Stovall mentioned a number of bones, still unprepared, that may some day permit a proper identification of this theropod.

### Como Bluff, Wyoming

The Nail Quarry has yielded, among other important fossils, a very large, fused scapula and coracoid. They were reported by Robert Bakker (1991, personal communication).

Quarry Nine at Como Bluff was the site from which a single *Ceratosaurus* tooth was collected, to be named *Labrosaurus sulcatus* (figure 12), which taxon is discussed in more detail below.



**Figure 12.** Lingual view of a cast of the type specimen of *Labrosaurus sulcatus* (YPM 1936). Scale: actual size.

### Mygatt-Moore Quarry, Colorado

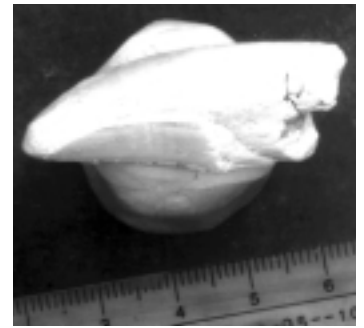
This site, also called the Rabbit Valley Quarry, has yielded postcranial parts of a typical Morrison Formation fauna including *Apatosaurus*, *Allosaurus*, and a number of theropod teeth tentatively assigned to *Allosaurus* (Mygatt, 1991).

Recently, some other theropod teeth informally report-

ed earlier have been identified as *Ceratosaurus* sp. (figure 13) by James Kirkland (1992, personal communication).

### Cleveland-Lloyd Dinosaur Quarry, Utah

*Ceratosaurus* sp. Madsen and Stokes (1963, p. 90) mentioned the material which is described in this paper as *Ceratosaurus dentisulcatus*, n. sp.



**Figure 13.** *Ceratosaurus* tooth from the Mygatt-Moore Quarry in western Colorado (photo courtesy Jim Kirkland). Scale: actual size (centimeter bar shown).

### Dry Mesa Quarry, Colorado

*Ceratosaurus* sp. This undescribed specimen (BYUVP 13024), (figure 14) is based on a complete, coossified, left scapula and coracoid, as well as some axial and appendicular elements collected from the Dry Mesa Quarry near Delta, Colorado (Britt, 1991, p. 69-70).

### Bone Cabin Quarry (west), Wyoming

An associated, juvenile skeleton of *Ceratosaurus* sp. has been collected from this historic locality by Western Paleontological Laboratories, Orem, Utah. This remarkable skeleton is currently under preparation and is being studied by Brooks Britt, Clifford Miles, and Jim Madsen (Clifford Miles, 1999, personal communication).

### Agate Basin Quarry, Utah

*Ceratosaurus* sp. This important specimen (BYUVP 12893) is also in the collections of the Earth Science Museum at Brigham Young University. It includes a complete cranium, partial nasal horn cores, distal fragment of a quadrate, seven fragmented dorsal vertebrae, and incomplete elements of the pelvic girdle, including the ischium and pubis. It was collected in 1992 in the Agate Basin area on the west flank of the San Rafael Swell southeast of Moore, Emery County, east-central Utah.

Representing one of the two largest skeletons of *Ceratosaurus* known at this time, this incomplete, but associated, adult theropod is almost fully prepared and will be studied and described by Brooks Britt, Ken Stadtman, Dan Chure, and Jim Madsen (Brooks Britt, 1999, personal communication).

### *Ceratosaurus ingens* Rowe & Gauthier

Rowe and Gauthier (1990, p. 165) attributed this name to Janensch, 1920. However, Janensch (1920, p. 232, figure 6) actually described a gigantic theropod tooth (150 mm high) from Tendaguru as *Megalosaurus(?) ingens*, not *Ceratosaurus ingens*. In 1925 Janensch, (p. 90, plate 9, figure 7) again described this tooth, and again as *Megalosaurus(?) ingens*, and derived it from the Upper Saurian level, Quarry B. It appears too large to belong to any described species of *Ceratosaurus*, and the name is likely a lapsus.



**Figure 14.** Left scapula/coracoid of *Ceratosaurus* sp. BYUVP 13024, from the Morrison Formation of Dry Mesa, Colorado in medial (A) and lateral (B) views. Scale: one-fifth actual size (bar is in centimeters).

### *Labrosaurus*

The genus *Labrosaurus* was established by Marsh in the Allosauridae (1879, p. 91) based on the vertebrae and forelimbs (YPM 1931) that he had described earlier as *Allosaurus lucaris* (Marsh, 1878; 242). The type name is, thus, *Labrosaurus lucaris* (Marsh) Marsh. It came from Reed's YPM Quarry 3, Como Bluff, Wyoming, and has never been illustrated in print. Marsh described the species *Labrosaurus lucaris* as smaller than *Allosaurus fragilis*, the cervicals short and strongly opisthocoelous, the dorsals moderately so. All have very large centrocoels which connect with the exterior by small foramina on each side. The dorsal spines are high and do not show a zygosphenal articulation. The forelimbs are quite small, the humerus curved and with a large crest. This diagnosis is not definitive.

Marsh (1882, p. 84) created the family Labrosauridae for this genus. He characterized it (Marsh, 1884b, p. 337) as having lower jaws edentulous anteriorly, a character based upon his *Labrosaurus ferox* that he described in the same paper. Hay (1902, p. 489) placed *Labrosaurus lucaris* in the genus *Antrodemus*, and later (Hay, 1908, p. 352) restricted the type to the dorsal vertebrae. Ostrom and McIntosh (1966, p. 52) place it in the genus *Antrodemus*. It is not diagnostic, and *Labrosaurus lucaris* is a nomen vanum.

*Labrosaurus ferox* Marsh (1884b, p. 333, plate 9, figures 4-6) was based on a left dentary (USNM 2315, on figure 15) from Felch's Quarry 1, Garden Park, Colorado. It is edentulous in

front, and highly arched ventrally, and Marsh described the teeth as more triangular than in other genera. Hay (1908, p. 352) could not verify the condition of the teeth since the crowns were missing and the roots buried in matrix. One of us (Madsen) has studied this specimen and concluded that it is an aberrant, pathological left dentary of *Allosaurus fragilis*. The downcurved, posterior one-third is partly due to over-preparation and partly to postmortem distortion. This ventral curvature has been interpreted as natural by some other workers. The edentulous section is rare, but plate 13B in this paper illustrates the dentary of *Ceratosaurus dentisulcatus* n. sp. with a similar diastema. We also place *Labrosaurus ferox* in synonymy of *Allosaurus fragilis*.

*Labrosaurus fragilis* Marsh (1896, plate 13, figure 5) was the label for the illustration of a pelvis. Hay (1908, p. 352) wrote that this was a slip of the pen for *Labrosaurus ferox*.

*Labrosaurus medius* Marsh (1888, p. 93) was based on material from the Jurassic of Potomac, Maryland. Matthew and Brown (1922, p. 378) transferred it to the genus *Dryptosaurus* as *D. medius*.

*Labrosaurus huene* Huene (1956, p. 481) was a nomen nudum, based on a tooth from the upper Jurassic deposits of Szechuan, China. Huene (1958, p. 205) again listed it as a nomen nudum.

*Labrosaurus stehowi* Janensch (1920, p. 232, figures 7, 8) was based on a tooth from Tendaguru, and he mentioned 9 similar teeth from the middle reptile level. We identify these as *Ceratosaurus*, sp. (see above).

*Labrosaurus sulcatus*, figure 12, was based by Marsh (1896;270, plate 13, figure 1) on a single tooth (YPM 1936) that he illustrated, but did not describe. Hay (1908, p. 352) described the tooth from Marsh's figure as 30 mm high, its base 12.5 by 12 mm, its posterior face concave, and its lat-



**Figure 15.** Medial view of a left dentary, USNM 2315, the type of *Labrosaurus ferox*. Scale: approximately one-fourth actual size.

eral face crenelated with 8 ridges, reduced to 3 at the apex. Gilmore (1920, p. 125) noted that it was probably a pre-maxillary tooth, but one of us (Madsen) has identified it as an anterior tooth, probably of the dentary, of *Ceratosaurus* sp. Hay (1930, p. 174) listed it as being from the Morrison Formation of Colorado.

In review of the species placed in the genus *Labrosaurus*, the type-species, *Labrosaurus lucaris*, is here identified as *Allosaurus fragilis*, thus placing the genus in synonymy. *Labrosaurus ferox* was based on an aberrant and damaged left dentary that we also identify as *Allosaurus fragilis*. The *Labrosaurus fragilis* pelvis of Marsh was, according to Hay, a slip of the pen for *Labrosaurus ferox*. *Labrosaurus medius* Marsh was transferred to the genus *Dryptosaurus* by Matthew and Brown (1922). Huene's (1958, p. 205) *Labrosaurus* sp. is transferred to *Ceratosaurus* sp., as are *Labrosaurus stechowi* Janensch, and *Labrosaurus sulcatus* Marsh.

### ACKNOWLEDGMENTS

In 1975 and 1976 Mr. Lance Eriksen, then Curator of Paleontology at the Historical Museum and Institute of Western Colorado (now the Museum of Western Colorado),

collected and prepared a fairly complete skeleton of *Ceratosaurus* from the Morrison Formation near Fruita, Colorado. It was originally thought that Mr. Eriksen would be a co-author of this paper, but his other duties precluded this. We deeply appreciate his efforts in collecting and preparing the Colorado specimen.

We thank Mr. Michael Perry and Dr. Beverly Goodrich, former Directors of the Museum of Western Colorado, and most recently, Dr. Brooks Britt, formerly of that institution, for their support and cooperation in making fossil material of *Ceratosaurus* in their museum collection available for this study.

We also extend our thanks and appreciation to Dr. Jack McIntosh and Dr. Dan Chure, who took the time to read the paper and offer constructive suggestions during preparation. Dr. David Gillette contributed with thoughtful and timely editing of the final draft for which we thank him as well.

The final and finished drafts of the paper were typed by Ms. Lisa Anne Madsen. All of the plates and most of the illustrated figures were prepared by Mr. Merrill Hamilton. Ms. Gail Raby prepared the sketch of the *Ceratosaurus* head based on the MWC skull reconstruction.

The order of authorship records the order of involvement in this paper and is not intended as a measure of individual contribution.

## REFERENCES AND ASSOCIATED READINGS

- Barsbold, Rinchin, 1983, Khischnyye dinosavry mela Mongolii (Carnivorous dinosaurs from the Cretaceous of Mongolia): Moscow, Trudy Sovmestnaya, Sovetsko-Mongol'skaya Paleontologicheskaya Ekspeditskaya, v. 19, p. 5-117
- Bilbey, S.A., 1992, Stratigraphy and sedimentary petrology of the Upper Jurassic-Lower Cretaceous rocks at Cleveland-Lloyd Dinosaur Quarry with a comparison to the Dinosaur National Monument Quarry, Utah: Salt Lake City, University of Utah Ph.D. dissertation, 295 p.
- Britt, B.B., 1991, Theropods of Dry Mesa Quarry (Morrison Formation, Late Jurassic), Colorado, with emphasis on the osteology of *Torvosaurus tanneri*: Provo, Utah, Brigham Young University Geology Studies, v. 37, p. 1-72.
- Bryant, H.N., and Russell, A.P., 1993, The occurrence of clavicles within Dinosauria: implications for the homology of the avian furcula and the utility of negative evidence: Journal of Vertebrate Paleontology, v. 13, no. 2, p. 171-184.
- Camp, C.L., 1942, California mosasaurs: Memoirs of the University of California, v. 13, 68 p., 6 pl.
- Chure, D.J., and Madsen, J.H. Jr., (1996), On the presence of furculae in some non-maniraptoran theropods: Journal of Vertebrate Paleontology, v. 16, no. 3, p. 573-577.
- Colbert, E.H., 1989, The Triassic dinosaur *Coelophysis*: Museum of Northern Arizona Bulletin, v. 57, 160 p.
- Cope, E.D., 1885, Marsh on the Jurassic Dinosauria, Part VIII: American Naturalist, v. 19, p. 67-68.
- 1892, On the skull of the dinosaurian *Laelaps incassatus* (Cope): Proceedings of the American Philosophical Society, v. 30, p. 240-245.
- Dodson, Peter, Behrensmeyer, A.K., Bakker, R.T., and McIntosh, J.S., 1980a, Taphonomy and paleoecology of the dinosaur beds of the Jurassic Morrison Formation: Paleobiology, vol. 6, no. 2, p. 208-232.
- Dodson, Peter, Behrensmeyer, A.K., and Bakker, R.T., 1980b, Taphonomy of the Morrison Formation (Kimmeridgian-Portlandian) and Cloverly Formation (Aptian-Albian) of the western United States: Mémoire de Société Géologique de France (N.S.), vol. 59, no. 139, p. 87-93.
- Gauthier, J. A., 1984, A cladistic analysis of the higher systematic categories of the Diapsida: Berkeley, University of California, Ph.D. dissertation, 564 p.
- 1986, Saurischian monophyly and the origin of birds, in Padian, Kevin, editor. The origin of birds and the evolution of flight: Memoirs of the California Academy of Science, v. 8, p. 1-55.
- Gilmore, C.W., 1914, Osteology of the armored Dinosauria in the United States National Museum, with special reference to the genus *Stegosaurus*: Bulletin of the United States National Museum, v. 89, 136 p., 37 pl.
- 1915, On the fore-limb of *Allosaurus fragilis*: Proceedings of the United States National Museum, v. 49, p. 501-513.
- 1920, Osteology of the carnivorous Dinosauria in the United States National Museum, with special reference to the genera *Antrodemus* (*Allosaurus*) and *Ceratosaurus*: Bulletin of the United States National Museum, v. 110, 154 p., 35 pl.
- Greppin, J.B., 1870, Description géologiques du Jura bernois et de quelques districts adjacents: Beitrage Geologie Karte Schweiz, v. 8, 357 p., 8 pl.
- Hay, O.P., 1902, Bibliography and catalogue of the fossil vertebrata of North America: U.S. Geological Survey Bulletin 179, 868 p.
- 1908, On certain genera of carnivorous dinosaurs, with special reference to *Ceratosaurus nasicornis* (Marsh): Proceedings of the United States National Museum, v. 35, p. 351-366, 4 figs.
- 1930, Second bibliography and catalogue of the fossil vertebrates of North America, Volume 2: Washington, Carnegie Institute Publication 390, 1074 p.
- Holtz, T.R., 1994, The phylogenetic position of the Tyrannosauridae: implications for theropod systematics: Journal of Paleontology, v. 68, no. 3, p. 1100-1117.
- Huene, F. von, 1926, The carnivorous Saurischia in the Jura and Cretaceous formations principally in Europe: Revista del Museo de La Plata, v. XXIX, no. 35, 167 p.
- 1932, Die fossile Reptil-Ordnung Saurischia, ihre Entwicklung und Geschichte: Monographien zur Geologie und Paleontologie, v. 1, no. 4, p. 1-361, 56 pls.
- 1956, Paläontologie und Phylogenie der Niederen Tetrapoden: Jena, Gustav Fischer, 716 p.
- 1958, Pre-Tertiary saurians of China: Vertebrata Palasiatica, v. 2, no. 4, p. 201 - 207 (Chinese and English).
- Janensch, Werner, 1920, Ueber *Elaphrosaurus bambergi* und die Megalosaurier aus den Tendaguru-Schichten Deutsch Ostafrikas: Sitz..Ber. Naturforsch. Fr. Berlin, p. 225-235.
- 1925, Die Coelurosauria und Theropoden der Tendaguru-Schichten Deutsch-Ostafrikas, Palaeontographica Supplement, v. VII, p. 1-99, 10 pls.
- Lambe, L.M., 1904, On *Dryptosaurus incassatus* (Cope) from the Edmonton series of the Northwest Territory: Geological Survey of Canada, Contributions to Canadian Paleontology, v. 3, no. 3, p. 1-27, 9 pl.
- Lydekker, Richard, 1888, Catalogue of the fossil Reptilia and Amphibia in the British Museum, Part 1: Containing the orders Ornithosauria, Crocodilia, Dinosauria, Squamata, Rhynchocephalia, and Proterosauria: London, British Museum, 309 p.
- Madsen, J.H. Jr., 1976, A second new theropod dinosaur from the Late Jurassic of east central Utah: Utah Geological and Mineral Survey, Utah Geology, v. 3, no. 1, p. 51-60.
- 1976, *Allosaurus fragilis*: a revised osteology: Utah Geological and Mineral Survey, Bulletin 109, 163 p., 54 pl.
- Madsen, J.H. Jr., 1987, the dinosaur department store: Grand Junction Geological Society, Guidebook for the Dinosaur Triangle paleontological field trip, p. 65-74.
- Madsen, J.H. Jr., and Stokes, W.L., 1963, New information on the Jurassic dinosaur *Ceratosaurus*: Geological Society of America, Special Paper 73, p. 90 (abs.).
- 1977, University of Utah Dinosaur Project: a final report, 1971-1977. Encyclia, v. 54, no. 2, p. 68-70.
- Maleev, E.A., 1964, Megalosauridae, in Orlov, J.A., editor, Fundamentals of paleontology, Volume XII: Moscow, Nauka Press, p. 537.
- Marsh, O.C., 1878, Notice of new dinosaurian reptiles: American Journal of Science, Third Series, v. XV, no. 87, p. 241-244.
- 1879, Principal characters of American Jurassic dinosaurs, Part II: American Journal of Science, Third Series, v. XVII, no. 97, p. 86-92.
- 1882, Classification of the Dinosauria: American Journal of Science, Third Series, v. XVIII, p. 81-86.
- 1884a, Principal characters of American Jurassic dinosaurs,



- Part 8, The order of Theropoda: American Journal of Science, Third Series, v. 27, no. 38, p. 329-340, pls. 8-14.
- 1884b, On the united metatarsal bones of *Ceratosaurus*: American Journal of Science, Third Series, v. 28, p. 161-162, 2 figures.
- 1888, Notice of a new genus of Sauropoda and other new dinosaurs from the Potomac Formation: American Journal of Science, Third Series, v. XXXV, p. 89-94.
- 1896, The dinosaurs of North America: U.S. Geological Survey 16th Annual Report (1894-95), p. 133-414, 84 pl.
- Matthew, W.D., and Brown, B., 1922, The family Deinodontidae, with notice of a new genus from the Cretaceous of Alberta: American Museum of Natural History, Bulletin XLVI, p. 367-385.
- Miller, W.E., Horrocks, R.D., and Madsen, J.H. Jr., 1996, The Cleveland-Lloyd Dinosaur Quarry, Emery County, Utah: A U.S. Natural Landmark (including history and quarry map): Brigham Young University Geology Studies, v. 41, p. 3-24.
- Molnar, R.E., Kurzanov, J.M., and Zhiming, Dong, 1990, Carnosauria, in Weishampel, D. B., Dodson, Peter, and Osmólska, Halszke, editors, The Dinosauria: Berkeley, University of California Press, p. 169-209.
- Mygatt, Peter, 1991, The Mygatt-Moore Quarry, Rabbit Valley, Mesa County, Colorado: Guidebook for dinosaur quarries and tracksites tour: Grand Junction Geological Society Publication, p. 57.
- Ostrom, J.H., and McIntosh, J.S., 1966, Marsh's dinosaurs, the collections from Como Bluff: New Haven, Yale University Press, 388 p.; Sauropod pl. 1-91; Stegosaur pl. 1-4, 7-9, 14-18, 20-65.
- Padian, Kevin, editor, 1986, The origin of birds and the evolution of flight: Memoirs of the California Academy of Science, v. 8, 98 p.
- Romer, A.S., 1945, Vertebrate Paleontology (2nd edition): Chicago, University of Chicago Press, 687 p.
- 1956, Osteology of the reptiles: Chicago, University of Chicago Press, 772 p.
- Rowe, T., and Gauthier, J.A., 1990, Ceratosauria, in Weishampel, D. B., Dodson, Peter, and Osmólska, Halszke, editors, The Dinosauria: Berkeley, University of California Press, pp 151-168, fig 5-1 to 5-10.
- Seeley, H.G., 1877, On *Mauisaurus gardneri* (Seeley), an elasmosaurian from the base of the Gault Folkestone: Quaternary Journal of the Geological Society of London, vol. 33, p. 541-546, 1 pl.
- Stokes, Wm. Lee, 1985, The Cleveland-Lloyd Dinosaur Quarry: Window to the past: U.S. Government Printing Office, 27 p.
- Stokes, W.L., 1986, Geology of Utah: Utah Museum of Natural History, Occasional Paper no. 6, 280 p.
- Stovall, J.W., 1938, The Morrison of Oklahoma and its dinosaurs: Journal of Geology, v. 46, no. 4, p. 583-600.
- Thulborn, R.A., 1984, The avian relationships of *Archaeopteryx*, and the origin of birds, in Patterson, Colin, editor, Vertebrate structure and history: Linnean Society of London, Zoological Journal, v. 82, no. 1 & 2, p. 119-158.
- Weishampel, D.B., Dodson, Peter, and Osmólska, Halszke, editors, 1990, The Dinosauria: Berkeley, University of California Press, 733 p.
- Welles, S.P., 1984, *Dilophosaurus wetherilli* (Dinosauria, Theropoda) osteology and comparisons: Palaeontographica Abteilung A, v. 185, no. 4-6, p. 85-180.
- White, T.E., 1964, The Dinosaur Quarry, in Sabatka, E.F., editor, Guidebook to the geology and mineral resources of the Uinta Basin: Intermountain Association of Petroleum Geologists, 13th Annual Field Conference, p. 21-28.

### Oral Communications

- Robert Bakker (1991) Tate Museum, Casper, WY
- Brooks Britt (1993) Museum of Western Colorado, Grand Junction, CO
- James Kirkland (1992) Dinamation International Society, Fruita, CO (currently, Utah Geological Survey)
- Clifford Miles (1999) Western Paleo Labs, Orem, UT
- Brooks, Britt (1999) Eccles Dinosaur Park, Odgen, UT

## **APPENDICES**

Table 1

**CERATOSAUR ELEMENT INVENTORY**  
**Fruita Paleontological Area, Quarry B, MWC 1**  
*Ceratosaurus magnicornis*, n. sp., holotype  
 (elements in the order of description)

New MWC#'s	Old #'s	Description	Illustration (* = illus. in this paper)	
1.1.14	PF-QB-24I	premaxilla, left	Figure 1	*
	PF-QB-24J	premaxilla, right		
	PF-QB-24L	premaxilla (?), fragment & tooth		
1.1. 8	PF-QB-24A	maxilla, left	Plate 1	*
1.1.13	PF-QB-24K	maxilla, right		
1.1. 3	PF-QB- 24C	nasals	Plate 1 & 3	*
1.1. 1	PF-QB-24E	frontals	Plate 4	*
1.1. 2	PF-QB-24B	lacrimal, left	Plate 1 & 2	*
1.1.40	PF-QB-24M	squamosal, right		
	PF-QB-24T	squamosal, left	Plate 5	*
1.1.10	PF-QB-24F	jugal, left	Plate 1 & 2	*
1.1	PF-QB-24H	jugal, right(?)		
1.1.41	PF-QB-24G	quadrate/quadratojugal, right(?)		
	PF-QB-24N	quadrate/quadratojugal, left	Plate 2 & 3	*
	PF-QB-24D	pterygoid/eipterygoid, left	Plate 5	*
	PF-QB-24N	ectopterygoid, left	Plate 5	*
	PF-QB-24O	paroccipital, left		
1.1. 5	PF-QB-24P	postorbital, left	Plates 1, 2 & 5	*
1.1. 1	PF-QB-24P	cranial elements	Plate 4	*
	PF-QB-24R	tooth, premaxillary (?)		
	PF-QB-24S	tooth, maxillary		
	PF-QB-18	tooth, premaxillary or dentary		
1.1	PF-QB-36A	vertebra, cervical (fifth)	Plate 6	*
	PF-QB-43	vertebra, cervical (sixth)		
	PF-QB-12	vertebra, cervical (seventh)		
	PF-QB-4	vertebra, cervical (eighth)		
	PF-QB-1A	vertebra, cervical (ninth)	Plate 6	*
	PF-QB-1B	vertebra, pectoral (first)	Plate 6	*
	PF-QB-1C	vertebra, pectoral (second)		
	PF-QB-2	vertebra, dorsal (second)		
	PF-QB-44	vertebra, dorsal (third)	Plate 6	*
	PF-QB-3A	vertebra, dorsal (fifth)		
	PF-QB-3B	vertebra, dorsal (sixth)		
	PF-QB-3C	vertebra, dorsal (seventh)		
	PF-QB-14A	vertebra, dorsal (eighth)		
	PF-QB-34	vertebra, dorsal (posterior)	Plate 7	*
	PF-QB-8	vertebra, anterior caudal	Plate 7	*
	PF-QB-14B	vertebra, median caudal		
	PF-QB-16	vertebra, posterior caudal		
	PF-QB-17	vertebra, posterior caudal		
	PF-QB-30	vertebra, posterior caudal		
	PF-QB-35	vertebra, posterior caudal		
1.1.32	PF-QB-24Q	rib, cervical		
	PF-QB-36B	chevron, median		
1.1.15	PF-QB-33A	dermal ossicle		
1.1.16	PF-QB-33B	dermal ossicle		
1.1.17	PF-QB-33C	dermal ossicle		
1.1.18	PF-QB-33D	dermal ossicle		
1.1.30	PF-QB-46	dermal ossicle		
	PF-QB-21	humerus, left	Figure 3	*
	PF-QB-19	ungual, manus		

Table 1 (continued)

New MWC#	Old #	Description	Illustration (* = illus. in this paper)	
	PF-QB-25	femur, left		
	PF-QB-31	femur, right		
	PF-QB-42	tibia, left		
	PF-QB-26A	tibia, right	Plate 8	*
	PF-QB-26B	astralgus, right	Plate 8	*
	PF-QB-26C	calcaneum, right	Plate 8	*
	PF-QB-27	metatarsal-II, left		
	PF-QB-37	metatarsal-II, right, distal end		
	PF-QB-6	metatarsal-III-1 (?)		
	PF-QB-47	metatarsal-III, left		
	PF-QB-28	pes, left D-II-1		
	PF-QB-38	pes, right D-II-1		
	PF-QB-32	pes (?), left, D-III-2 (?)		
	PF-QB-7	pes, left, D-IV-1		
	PF-QB-45	pes, right, D-IV-1		
	PF-QB-40	pes, right, D-IV-1 (?)		

**Note:** At our last access to MWC 1 from the Fruita Paleontological Area, there was some confusion of catalog data. As a consequence, an attempt is made in this report to tabulate all numbers evident in the initial study and they all appear in these tables to facilitate future correlation with any other surviving maps or field notes. There is a single, associated skeleton however, and all elements bear the Catalog Number MWC 1.

Table 2

**CERATOSAUR ELEMENT INVENTORY**  
**Cleveland-Lloyd Dinosaur Quarry**  
*Ceratops dentisulcatus* n. sp., holotype  
 (elements in the order of description)

**Note:** the individual ceratops carries the catalog number UMNH 5278, although separate pieces have their own field number (UUVP)

UUVP#	Description	Illustration (* = illus. in this paper)	
674	premaxillae, right and left	Plate 9	*
674	maxilla, left	Plate 10	*
1646	quadrate/quadratojugal, right	Plate 11	*
1646	jugal, right	Plate 12	*
1646	pterygoid, right	Plate 12	*
158	dentary/supradentary, left	Plate 13	*
155	dentary, right		
5911	angular, right	Plate 13	*
156	splenial, right		
157	splenial, left	Plate 13	*
1053	atlantal intercentrum	Plate 14	*
1053	atlas/odontoid/axial intercentrum/axis	Plate 14	*
1053	vertebra, cervical (third)	Plate 14	*
6963	vertebra, cervical (fourth)	Plate 14	*
6965	vertebra, cervical (fifth)	Plate 14	*
6964	vertebra, cervical (sixth)	Plate 15	*
1615	vertebra, cervical (seventh)	Plate 15	*
1035	vertebra, cervical (eighth)		
562	vertebra, cervical (ninth)	Plate 15	*
329	vertebra, pectoral (first)	Plate 16	*
49	vertebra, pectoral (?)	Plate 16	*
66	vertebra, pectoral (third)		
1229	vertebra, dorsal (fifth)		

Table 2 (continued)

UUVP#	Description	Illustration (* = illus. in this paper)	
1231	vertebra, dorsal (seventh)	Plate 16	*
6938	centrum, dorsal (eighth)		
48	vertebra, dorsal (ninth)	Plate 17	*
170	vertebra, anterior caudal, sectioned		
81	vertebra, anterior caudal, sectioned		
365	neural arch, anterior caudal		
6961	vertebra, anterior caudal	Plate 17	*
6305	vertebra, anterior caudal	Figure 4	*
53 (6939)	vertebra, anterior caudal		
438	vertebra, anterior caudal		
439	vertebra, anterior caudal		
5960	vertebra, medial caudal with chevron	Figure 6	*
5959	vertebra, distal caudal		
375	vertebra, medial caudal (see UUVP 377 & 378)	Figure 5	*
376	vertebra, medial caudal	Figure 5	*
534	vertebra, distal caudal		
532	vertebra, distal caudal		
530	vertebra, distal caudal		
6958	vertebra, distal caudal with chevron (6957)		
212	vertebra, distal caudal		
6952	vertebra, distal caudal		
6953	vertebra, distal caudal	Plate 18	*
6954	vertebra, distal caudal		
6955	vertebra, distal caudal		
6956	vertebra, distal caudal		
6951	vertebra, distal caudal		
272	chevron, anterior	Plate 18	*
6941	chevron, anterior		
6949	chevron, medial		
234	chevron, medial		
377	chevron, distal (see UUVP 375 & 376)	Figure 5	*
378	chevron, distal (see UUVP 375 & 376)	Figure 5	*
531	chevron, distal		
533	chevron, distal		
6948	chevron, distal		
6945-46	chevrons, distal		
2172	rib, cervical, left (fifth)	Plate 19	*
6520	rib, cervical, right (fourth)	Plate 19	*
548	rib, anterior dorsal, right	Plate 19	*
316	rib, dorsal, right		
610	rib, anterior dorsal, left		
80	dermal ossicle	Figure 8	*
433	dermal ossicle	Figure 8	*
677	dermal ossicle	Figure 8	*
6788	dermal ossicle	Figure 8	*
317	scapula/coracoid, right	Plate 20	*
549	humerus, left	Figure 3	*
47	phalanx, (?) manus	Figure 9	*
1979	MC-II, right manus	Figure 9	*
56	femur, left	Plate 21	*
5681	tibia, astragalus, and calcaneum, left	Plate 22	*
5682	tibia, right		
56	fibula, right (reversed for illustration)	Plate 23	*
173	fibula, left		
5683	metatarsal-IV, left	Figure 10	*
327	tarsal - IV	Figure 10	*
3729	phalanx	Figure 9	*

**Table 3**

**Teeth of *Ceratosaurus* sp.  
Dinosaur National Monument**

**DNM Right Premaxilla (DNM 972)  
(measurements in millimeters)**

	1	2	3
H	—	—	31
W	—	—	17
T	—	—	11

**Table 4**

**Teeth of *Ceratosaurus magnicornis*, n. sp., holotype  
Fruita Paleontological Area**

**MWC Premaxillae/maxillae**

The left maxilla (MWC 10.1.8) has 10 emergent teeth followed by 3 vacant alveoli.

The largest teeth are below the anterior margin of the antorbital fenestra.

(measurements in millimeters)

**Left Premaxilla (MWC 1.1.14)**

	1	2	3
H	—	—	—
W	—	—	—
T	—	—	—

**Right Premaxilla (MWC 1.1)**

	1	2	3
H	—	—	—
W	18.5	—	—
T	12.0	—	—

**Left Maxilla (MWC 1.1.8)**

	1	2	3	4	5	6	7	8	9	10	11	12	13
H	60	55	78	71	80	67	63	62	—	30	—	—	—
W	23	26	28	28	29	31	26	26	23	18	—	—	—
T	11	12	12	11	11	9	11	10	8	8	—	—	—

**Right Maxilla (MWC 1.1.13)**

	1	2	3	4	5	6	7	8	9	10	11	12	13
H	—	—	—	—	10	69	48	36	50	—	10	—	—
W	—	—	—	—	15	33.5	27	28	26	—	9	—	—
T	—	—	—	—	6	16	8	9	9	—	m	—	—

Height (H) is measured from the tip to the center of the base at the labial alveolar margin.

Width (W) is anteroposterior measurement at midlength.

Thickness (T) is labial/lingual measurement taken at midlength of the tooth.

m = bone missing or incomplete; — = tooth missing

Table 5

**Teeth of *Ceratosaur dentisulcatus*, n. sp., holotype  
Cleveland-Lloyd Dinosaur Quarry**

**C-LDQ Specimens**

**Note:** the individual ceratosaur carries the catalog number UMNH 5278, although separate pieces are listed below.

Left Premaxilla (UUVP 674)				Right premaxilla (UUVP 674)			
	1	2	3		1	2	3
H	35	48	49	H	38	63e	46
W	24	25	25	W	19	29e	23
T	17	18	15	T	16	16e	13

Left Maxilla (UUVP 674)												
	1	2	3	4	5	6	7	8	9	10	11	12
H	68	93e	68	13	85	39	—	62	22	53	22e	9
W	27	30	30	14	33	27	—	27	17	22	16	9
T	16	15	14	8	14	10	—	12	7	10	6	5

Left Dentary (UUVP 158)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
H	30e	42	—	—	d	—	—	7	51	42	25	—	d	—	—
W	17	22	—	—	d	—	—	10	21	18	17	—	d	14	11
T	14	13	—	—	d	—	—	5	11	9	7	—	d	3	4

Right Dentary (UUVP 155)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
H	18	40	—	45e	—	—	33	—	40e	7e	—	—	m	m	m
W	15	25	—	27	22	—	21	—	23	9	19	—	m	m	m
T	12	12	—	12	9	—	10	—	10	7	8	10	m	m	m

Height (H) of tooth is measured from the tip to the center of the base at the labial, alveolar margin.

Width (W) is anteroposterior measurement at midlength.

Thickness (T) is labial/lingual measurement taken at midlength of the tooth.

Measurements in millimeters. m = bone missing or incomplete; e = estimated; d = diastema; — = tooth missing.

## GLOSSARY

- adductor fenestra** - opening at top and rear of lower jaw in front of the articular and between the surangular and the prearticular, af.
- alveolus** - tooth socket
- anterior chonos** - conical recess lateral to the pedicle and below the prezygapophysis and the table, ach.
- anterior trochanter** - dorsally projecting process on the anterior or anterolateral face of the upper shaft of femur, at.
- anteromedial process** - projection on the lingual face of the maxilla that forms a tongue-and-groove articulation with its counterpart on the opposite side, amp.
- astragalar overhang** - crest on the tibia above the ascending process of the astragalus, a.
- basisphenoidal recess** - opening in the upper lateral wall of the basisphenoid, bsr.
- basisphenoidal rostrum** - anterior projection of basisphenoid (= parasphenoid = presphenoid, in use by other authors), br.
- basisphenoid sinus** - cavity in the ventral body of the basisphenoid, closed posteriorly by the basioccipital, bss.
- biceps tubercle** - process on the posterior lower margin of the coracoid, bi.
- cap** - top of the spine of a vertebra above and between the shoulders, cap.
- centrocoel** - cavity inside the centrum of a vertebra, ccl.
- chonos** - a conical recess or indentation
- condyle** - a rounded articular surface
- crista prootica** - anteroventral projection of lateral wall of prootic, cp.
- crista supravenosa** - process of basisphenoid overhanging basisphenoidal recess, cs.
- deltoid tuberosity** - process on the proximolateral edge of the humerus (= deltoid crest, = deltopectoral crest), dt.
- ectocondylar tuber** - process on the posterior face of the distal end of the femur, above the ectocondyle, ect.
- eminentia medullaris** - sagittal ridge on the anterodorsal surface of the basioccipital, em.
- entocondylar ridge** - vertical ridge above entocondyle of the femur on the posterior face of the base of the shaft, er.
- epipophysis** - posterodorsal projection above the postzygapophysis of a cervical vertebra, epp.
- external mandibular foramen** - opening enclosed by the angular, surangular, and dentary, or in the surangular on the lateral face of the mandible, fem.
- fenestra ovalis** - see vestibular foramen
- fibular flange** - flange on the fibular face of the tibia, ff.
- greater trochanter** - process on the lateral side of the proximal end of the femur, opposite and continuous with the head, gt.
- glenoid** - shallow socket or cavity
- greater tubercle** - swelling at the proximolateral surface of the humerus, gu.
- hypantrum** - cavity on the anterior face of the arch, below the prezygapophyses and above the neural canal, ha.
- hyposphene** - posteriorly projecting sagittal wedge, below the zygapophyses and above the neural canal, hs.
- infundibular foramen** - opening near the top of the dorsum sellae for the infundibulum, fin.
- intercondylar fossa** - groove on the posterodistal face of the femur, between the condyles, in.
- interdental plate** - see rugosa
- interorbital septum** - vertical sagittal plate between the orbits, above the parasphenoid, ios.
- labial parapet** - wall on the upper labial edge of the dentary, along the tooth row, lp.
- lacrimal recess** - excavation below the crest, continuing down the anterior edge of the lacrimal, lr.
- lateral chonos** - conical recess up under the table of a vertebra, between the medial and posterior chonoses, lc.
- lateral temporal fenestra** - opening in the skull roof surrounded by the postorbital, squamosal, quadratojugal, and jugal, ltf.
- lingual bar** - horizontal ridge along the lingual wall of the maxilla, (or dentary), above, (or below) the nutrient groove, lb.
- maxillary recess** - depressed area of the maxilla in front of, and below, the antorbital fenestra, mr.
- medial chonos** - conical recess up under the middle of the table, mc.
- medial tuberosity** - projection internal to the head of the humerus, mt.
- metotic fissure** - gap between the otic capsule and the occipital bones, mf.
- nutrient groove** - groove along the bases of the rugosa, ng.
- nutrient notch** - opening from the nutrient groove into an alveolus, between the rugosae, nn.
- palatine fenestra** - opening in palate lateral to pterygoid, and between palatine and ectopterygoid, plf.
- paracoel** - cavity extending laterally from anterior pleurocoel into the parapophysis, pa.
- paracondylar pocket** - cavity lateral to the occipital condyle, in the basioccipital, opisthotic, and exoccipital, pcp.
- parapophyseal stem** - elongate process to support parapophysis, pat.
- pedicle** - side wall of the neural canal, pe.



**pyriform** - pear shaped

**pleurocoel** - cavity in the upper, lateral wall of a centrum, pl.

**popliteal surface** - area above the condyles in the center of the posterior face of the femoral shaft, ppp.

**postchonos** - conical recess dorsolateral to the neural canal and medial to the posterior edge of the pedicle, poc.

**posterior chonos** - conical recess lateral to the pedicle and below the postzygapophysis and the table, pch.

**posteromedial process** - posterior extension of the premaxilla that overrides the anteromedial process of the maxilla, pmp.

**postfibular plate** - flange on the distolateral edge of the tibia, lying behind the fibula, ppl.

**postspinal chonos** - conical recess at the posterior base of the neural spine, psc.

**postspinal groove** - vertical groove on the posterior surface of a neural spine, psg.

**postspinal ridge** - vertical ridge on the posterior surface of a neural spine, psr.

**postspinal trough** - horizontal trough between the bases of the postzygapophyses, and above the neural canal, pst.

**preantorbital fenestra** - opening in the maxilla in front of the antorbital fenestra, paf.

**preantorbital recess** - cavity in the nasal process of the premaxilla, par.

**prechonos** - conical recess lateral to hyosphene, pre.

**preglenoid fossa** - transverse depression in the lateral face of the ventral end of the scapula, pgf.

**preglenoid ridge** - transverse ridge on the ventrolateral face of the scapula at the level of the glenoid top, pgr.

**preotic pendant** - posteroventrally projecting process overhanging the basisphenoidal recess, prp.

**prespinal chonos** - conical recess at the anterior base of a vertebral spine, prc.

**prespinal groove** - groove on the anterior edge of a neural spine, prg.

**prespinal ridge** - ridge on the anterior edge of a neural spine, prr.

**prespinal trough** - horizontal trough between the bases of the prezygapophyses, above the canal, prt.

**rugosa** - plate on the lingual face of the maxilla or dentary, lingual to the alveolar septum, (= interdental plate), r.

**septosphenoid** - bone below the parietals, and behind the sphenethmoid, forms the posterior floor of the olfactory tract, ss.

**shoulder** - anterior or posterior edge of the summit of the neurospine, above which the spine narrows anteroposteriorly, sh.

**sphenethmoid** - bone below the frontals, forming the anterior floor of the olfactory tract, se.

**subarcuate fossa** - cavity in the top of the prootic and opisthotic, capped by the epiotic, extends back inside the semicircular canals, sbf.

**subnarial foramen** - opening between the premaxilla and the maxilla, just below the naris, fsn.

**subnarial gap** - gap between the premaxilla and the maxilla on the side of the face, sg.

**subnarial pit** - cavity inside the subnarial gap, extending into the premaxilla and the maxilla, spt.

**subsellar pit** - cavity in the front of the basisphenoid below the sella turcica, ssp.

**subtemporal fenestra** - opening in the palate inside the quadratojugal and lateral to the pterygoid, stf.

**supradentary** - thin plate, usually missing, along the lingual faces of the rugosae of the dentary, sd.

**supratemporal fenestra** - see temporal fenestra.

**table** - platform lateral to the base of the neural spine, ta.

**temporal fenestra** - opening in the skull roof surrounded by the frontal, parietal, squamosal, and postorbital, tf.

**tibial flange** - flange on the tibial side of the fibula, tfl.

**trochanteric shelf** - shelf at the anterior base of the anterior trochanter of the femur, ts.

**tuberosity** - anterodorsal projection of the tibia, tu.

**tuberous process of basioccipital** - ventral projection of the basioccipital, behind the basisphenoid, tp.

**tuberous process of femur** - rounded posterior projection above the ectocondyle of the femur, tpf.

**vestibular foramen** - opening occupied by the foot of the stapes, (= fenestra ovalis), fv.

**zygantrum** - midline cavity in the posterior end of the arch below and between the bases of the postzygapophyses, za.

**zygosphene** - vertical, sagittal bar projecting forward from the arch above the neural canal, zs.

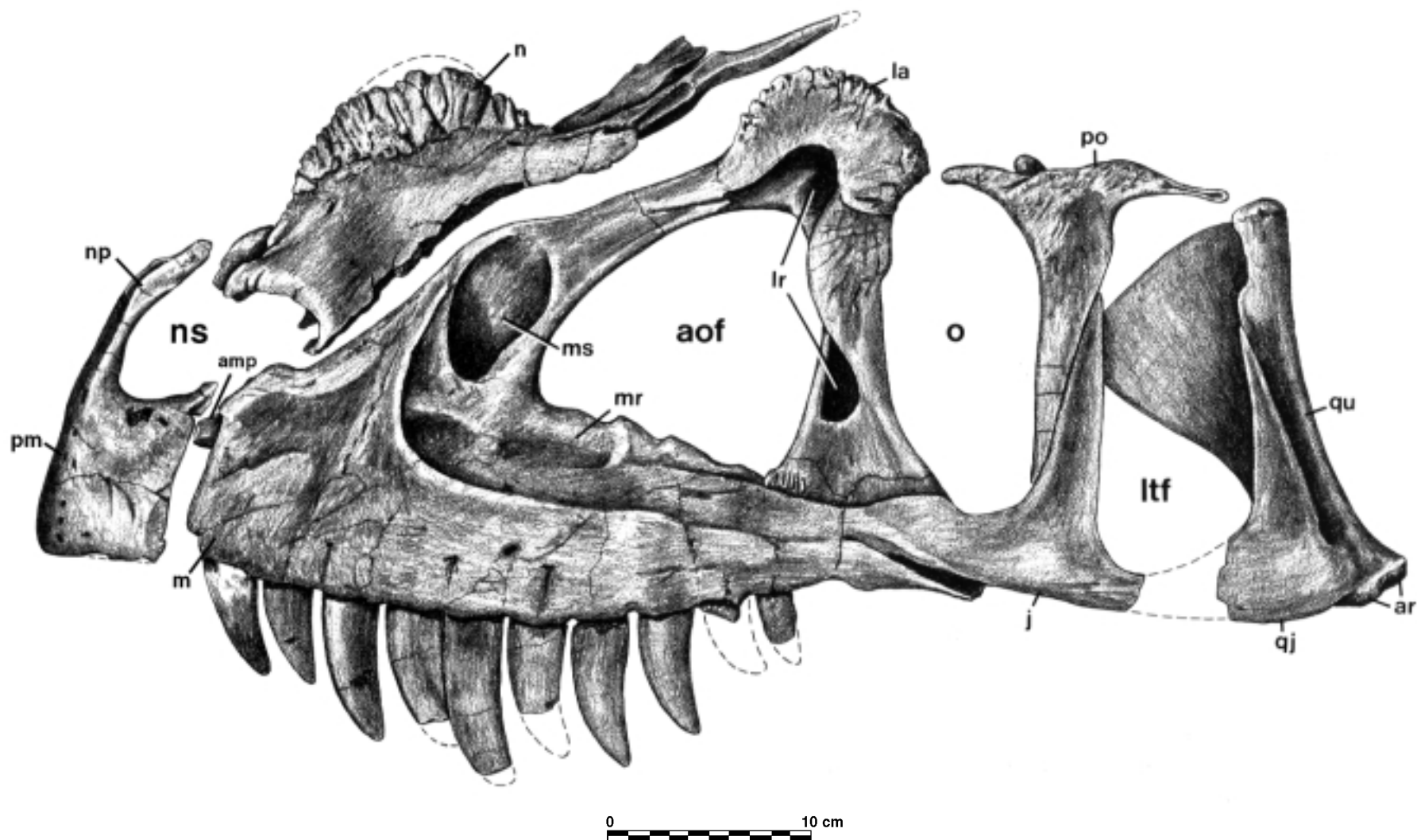
## ABBREVIATIONS FOR ILLUSTRATIONS

An abbreviation can identify the bone or a contact for the bone.

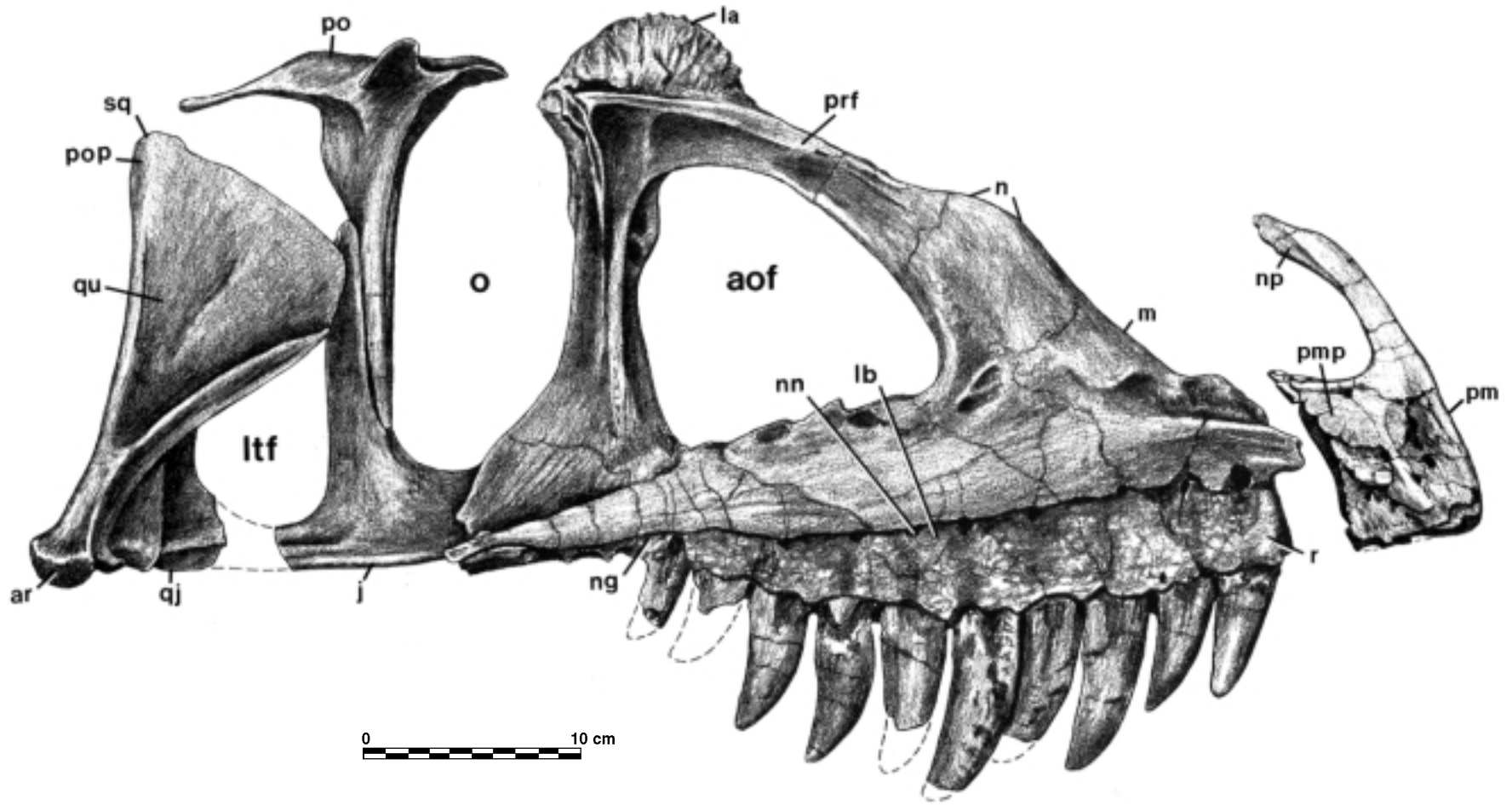
<b>A</b>	astragalus	<b>fj</b>	jugular foramen
<b>a</b>	astragular overhang	<b>fm</b>	foramen magnum
<b>ab</b>	anterior blade	<b>fmi</b>	internal mandibular foramen
<b>ach</b>	anterior chonos	<b>fn</b>	nutrient foramen
<b>act</b>	acetabulum	<b>fob</b>	obturator foramen
<b>af</b>	adductor fenestra	<b>fq</b>	quadrate foramen
<b>amp</b>	anteromedial process	<b>fsn</b>	subnarial foramen
<b>an</b>	angular	<b>fv</b>	vestibular foramen
<b>ao</b>	astragalar overhang	<b>g</b>	glenoid fossa
<b>aof</b>	antorbital fenestra	<b>gt</b>	greater trochanter
<b>ap</b>	ascending process	<b>gu</b>	greater tubercle
<b>ar</b>	articular	<b>H</b>	humerus
<b>at</b>	anterior trochanter	<b>h</b>	head
<b>ati</b>	atlantal intercentrum	<b>ha</b>	hypantrum
<b>ax</b>	axis	<b>hc</b>	haemal canal
<b>axi</b>	axial intercentrum	<b>hs</b>	hyposphene
<b>bi</b>	biceps tubercle	<b>I</b>	ilium
<b>bo</b>	basioccipital	<b>ic</b>	intercentrum
<b>bp</b>	basipterygoid process	<b>idp</b>	interdental plate
<b>br</b>	basisphenoidal rostrum	<b>Im</b>	intermedium
<b>bs</b>	basisphenoid	<b>in</b>	intercondylar fossa
<b>bsr</b>	basisphenoidal recess	<b>ios</b>	interorbital septum
<b>bss</b>	basisphenoidal sinus	<b>ip</b>	ischial peduncle
<b>bt</b>	basal tuberosity	<b>iptv</b>	interpterygoid vacuity
<b>C</b>	calcaneum	<b>Is</b>	ischium
<b>cap</b>	cap	<b>it</b>	internal tuberosity or trochanter
<b>cc</b>	centrocoel	<b>it</b>	inferior temporal fenestra
<b>ch</b>	choana = internal naris	<b>j</b>	jugal
<b>Co</b>	coracoid	<b>la</b>	lacrimal
<b>co</b>	coronoid	<b>lb</b>	lingual bar
<b>cp</b>	capitulum	<b>lc</b>	lateral chonos
<b>cp</b>	crista prootica	<b>lco</b>	lateral condyle = ectocondyle
<b>cr</b>	cervical rib	<b>lf</b>	lateral mandibular fenestra
<b>cs</b>	crista supraventricosa	<b>lp</b>	labial parapet
<b>cv</b>	chevron	<b>lr</b>	lacrimal recess
<b>d</b>	dentary	<b>ls</b>	laterosphenoid
<b>des</b>	dentary symphysis	<b>ltf</b>	lateral temporal fenestra
<b>di</b>	diapophysis	<b>m</b>	maxilla
<b>dia</b>	diastema	<b>Mc</b>	metacarpal
<b>do</b>	dorsum sellae	<b>mch</b>	medial chonos
<b>dt</b>	deltoid tuberosity	<b>me</b>	medial condyle = ectocondyle
<b>ec</b>	ectocondyle	<b>mec</b>	Meckelian canal
<b>ecp</b>	ectopterygoid	<b>mef</b>	Meckelian foramen
<b>ect</b>	ectocondylar tuber	<b>mf</b>	metotic fissure
<b>em</b>	eminentia medullaris	<b>mp</b>	maxillary process
<b>en</b>	entocondyle	<b>mr</b>	maxillary recess
<b>eo</b>	exoccipital	<b>ms</b>	maxillary sinus
<b>ep</b>	epiotic	<b>Mt</b>	metatarsal
<b>epp</b>	epipophysis	<b>mt</b>	medial tuberosity
<b>ept</b>	epipterygoid	<b>na</b>	nasal
<b>er</b>	entocondylar ridge	<b>nc</b>	neural canal
<b>F</b>	femur	<b>ne</b>	neurapophysis
<b>f</b>	frontal	<b>ng</b>	nutrient groove
<b>fC</b>	coracoid foramen	<b>nn</b>	nutrient notch
<b>fem</b>	external mandibular foramen	<b>np</b>	nasal process
<b>ff</b>	fibular flange	<b>nr</b>	nasal ramus
<b>Fi</b>	fibula	<b>ns</b>	naris
<b>fin</b>	infundibular foramen	<b>o</b>	orbit

<b>oc</b>	occipital condyle	<b>Pu</b>	pubis
<b>od</b>	odontoid	<b>pz</b>	postzygapophysis
<b>oo</b>	opisthotic	<b>qj</b>	quadratojugal
<b>os</b>	orbitosphenoid	<b>qu</b>	quadrate
<b>P</b>	pubis	<b>R</b>	radius
<b>p</b>	parietal	<b>r</b>	rugosa
<b>pa</b>	paracoel	<b>rc</b>	radial condyle
<b>paf</b>	preantorbital fenestra	<b>Re</b>	radiale
<b>pal</b>	palatine	<b>rp</b>	retroarticular process
<b>pap</b>	parapophysis	<b>S</b>	scapula
<b>par</b>	preantorbital recess	<b>s</b>	stapes
<b>pat</b>	parapophyseal stem	<b>sa</b>	surangular
<b>pb</b>	posterior blade	<b>san</b>	stapedial antrum
<b>pch</b>	posterior chonos	<b>sb</b>	supraglenoid buttress
<b>pcp</b>	paracondylar pocket	<b>sbf</b>	subarcuate fossa
<b>pfl</b>	pterygoid flange	<b>sd</b>	supradentary
<b>pgf</b>	preglenoid fossa	<b>se</b>	sphenethmoid
<b>pgr</b>	preglenoid ridge	<b>sf</b>	stapedial fenestra (or foramen?)
<b>pl</b>	pleurocoel	<b>sg</b>	subnarial gap
<b>plf</b>	palatine fenestra	<b>sh</b>	shoulder
<b>pm</b>	premaxilla	<b>so</b>	supraoccipital
<b>pmp</b>	posteromedial process	<b>sp</b>	splénial
<b>pn</b>	pneumatic foramen	<b>spi</b>	spine
<b>po</b>	postorbital	<b>spt</b>	subnarial pit
<b>poc</b>	postchonos	<b>sq</b>	squamosal
<b>pof</b>	postfrontal	<b>ss</b>	septosphenoid
<b>pog</b>	postspinal groove	<b>ssp</b>	subsellar pit
<b>pop</b>	paroccipital process	<b>st</b>	sella turcica
<b>pp</b>	pubic peduncle	<b>stf</b>	supratemporal fenestra
<b>ppl</b>	postfibular plate	<b>stg</b>	stapedial groove
<b>ppp</b>	popliteal surface	<b>sub</b>	subglenoid buttress
<b>ppp</b>	popliteal area	<b>suf</b>	subtemporal fenestra
<b>pr</b>	prezygapophysis	<b>T</b>	tibia
<b>pra</b>	prearticular	<b>t</b>	tuberosity
<b>prc</b>	prespinal chonos	<b>ta</b>	table
<b>pre</b>	prechonos	<b>tb</b>	tuberculum
<b>prf</b>	prefrontal	<b>tf</b>	tibial flange
<b>prg</b>	prespinal groove	<b>tp</b>	tuberous process
<b>pro</b>	prootic	<b>tpf</b>	tuberous process of femur
<b>prp</b>	preotic pendant	<b>tr</b>	transverse process
<b>prr</b>	prespinal ridge	<b>trf</b>	fourth trochanter
<b>prt</b>	prespinal trough	<b>ts</b>	trochanteric shelf
<b>psc</b>	postspinal chonos	<b>tu</b>	tuberosity
<b>psg</b>	postspinal groove	<b>U</b>	ulna
<b>psr</b>	postspinal ridge	<b>uc</b>	ulnar condyle
<b>pst</b>	postspinal trough	<b>Ue</b>	ulnare
<b>pt</b>	pterygoid	<b>v</b>	vomer
<b>ptf</b>	posttemporal fenestra	<b>za</b>	zygantrum
<b>ptw</b>	pterygoid wing	<b>zs</b>	zygosphenone

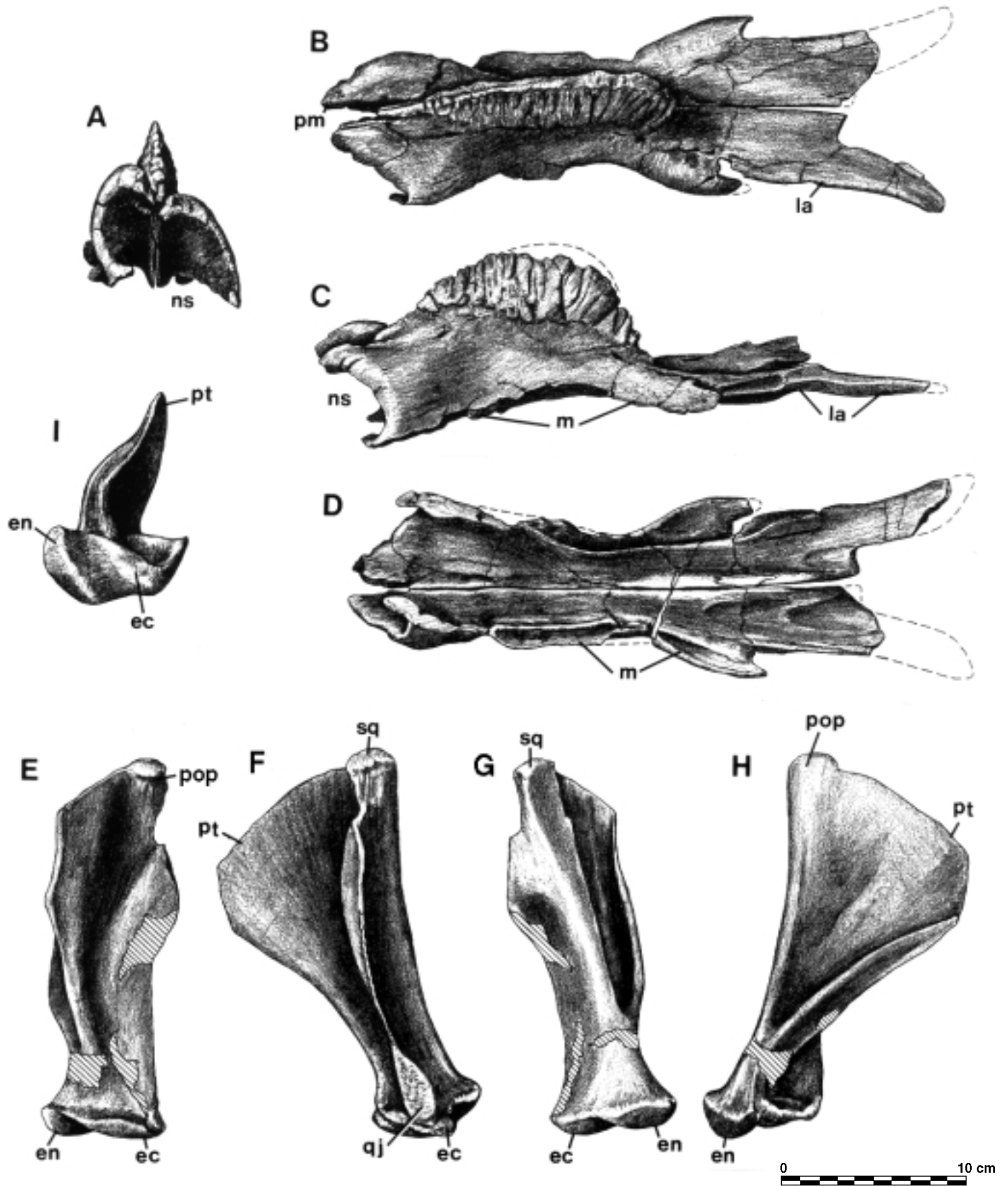
## **PLATES**



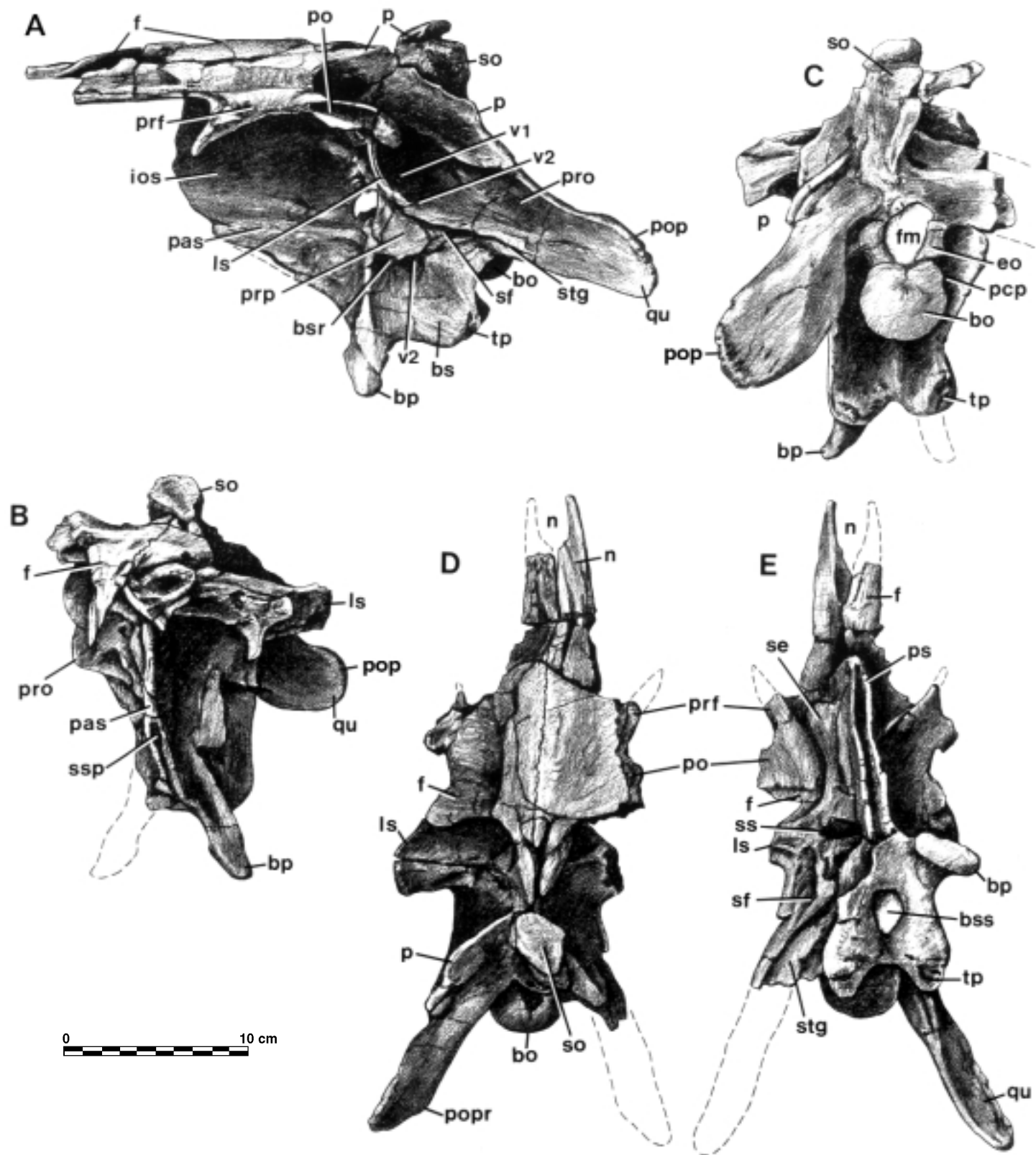
**Plate 1.** *Ceratosaurus magnicornis*, n. sp., holotype. Left lateral view of premaxilla (reversed right premaxilla), maxilla, paired nasals, lacrimal, jugal, postorbital, quadratojugal, and quadrate, MWC 1. **amp**, anteromedial process; **aof**, antorbital fenestra; **ar**, articular; **j**, jugal; **la**, lacrimal; **lr**, lacrimal recess; **ltf**, lateral temporal fenestra; **m**, maxilla; **mr**, maxillary recess; **ms**, maxillary sinus; **n**, nasal; **np**, nasal process; **ns**, nasus; **o**, orbit; **pm**, premaxilla; **po**, postorbital; **qj**, quadratojugal; **qu**, quadrate. Scale: one-third natural size.



**Plate 2.** *Ceratosaurus magnicornis*, n. sp., holotype. Medial view of reversed right premaxilla, left maxilla, lacrimal, postorbital, jugal, quadratojugal, and quadrate, MWC 1. **aof**, antorbital fenestra; **ar**, contact for articular; **j**, jugal; **la**, lacrimal; **lb**, lingual bar; **lbf**, lateral temporal fenestra; **m**, maxilla; **n**, contact for nasal; **ng**, nutrient groove; **nn**, nutrient notch; **np**, nasal process; **ns**, naris; **o**, orbit; **pm**, premaxilla; **pmp**, posteromedial process; **po**, postorbital; **pop**, contact for paroccipital; **prf**, contact for prefrontal; **qj**, quadratojugal; **qu**, quadrate; **r**, rosgosa; **sq**, contact for squamosal. Scale: one-third natural size.

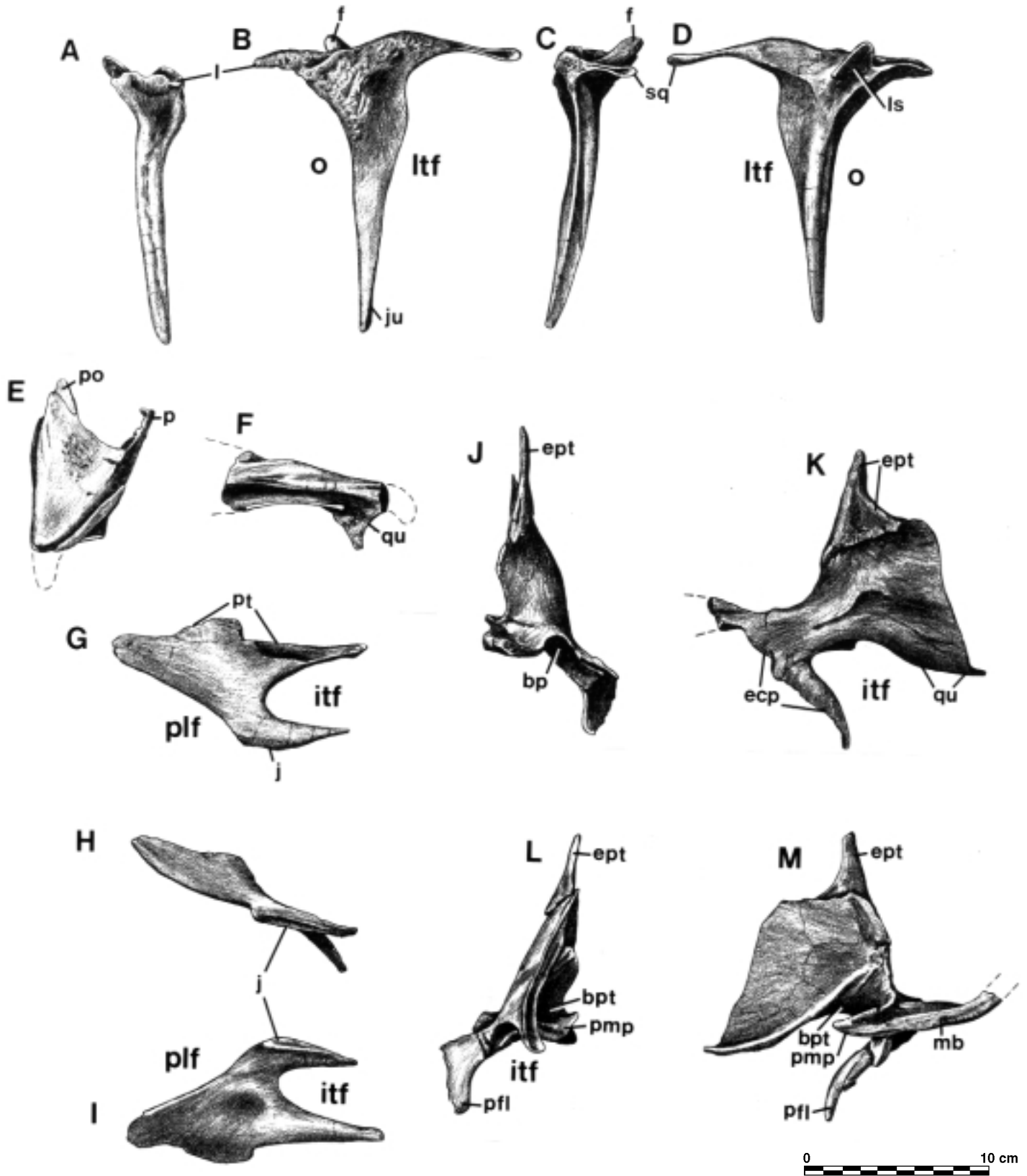


**Plate 3.** *Ceratosaurus magnicornis*, n. sp., holotype. Paired nasals and left quadrate (restored), MWC 1, in anterior (A,E), dorsal (B), left lateral (C,F), posterior (G), medial (H), and ventral (D,I) views. **ec**, ectocondyle; **en**, entocondyle; **la**, contact for lacrimal; **m**, contact for maxilla; **ns**, naris; **pm**, contact for premaxilla; **pop**, contact for paroccipital process; **pt**, contact for pterygoid; **qj**, quadratojugal; **sq**, contact for squamosal. Scale: one-third natural size.

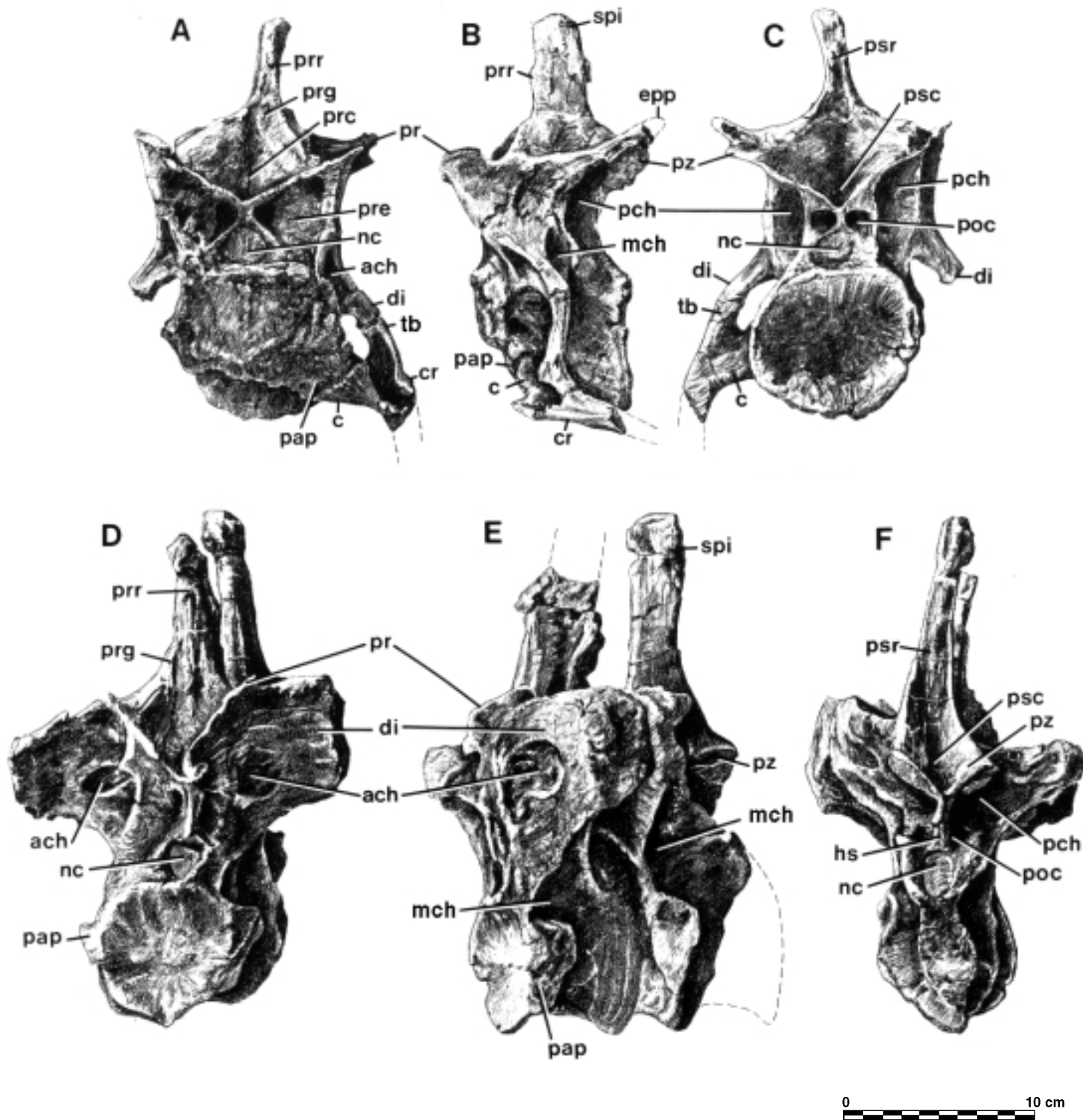


**Plate 4.** *Ceratosaurus magnicornis*, n. sp., holotype. Cranium, MWC 1, in left lateral (A), anterior (B), posterior (C), dorsal (D), and ventral (E) views. **bo**, basioccipital; **bp**, basipterygoid process; **bs**, basisphenoid; **bsr**, basisphenoid recess; **bss**, basisphenoid sinus; **eo**, exoccipital; **f**, frontal; **fm**, foramen magnum; **ios**, interorbital septum; **ls**, laterosphenoid; **n**, contact for nasal; **p**, parietal; **pcp**, paracondylar pocket; **po**, contact for post-orbital; **pop**, paroccipital process; **prf**, prefrontal and contact for prefrontal; **pro**, prootic; **prp**, preotic pendant; **qu**, contact for quadrate; **se**, sphenethmoid; **sf**, stapedia fenestra; **so**, supraoccipital; **ss**, septosphenoid; **ssp**, subsellar pit; **stg**, stapedia groove; **tp**, tuberous process (basal tuberosity); **v**, vomer. Scale: one-third natural size.



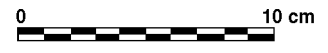
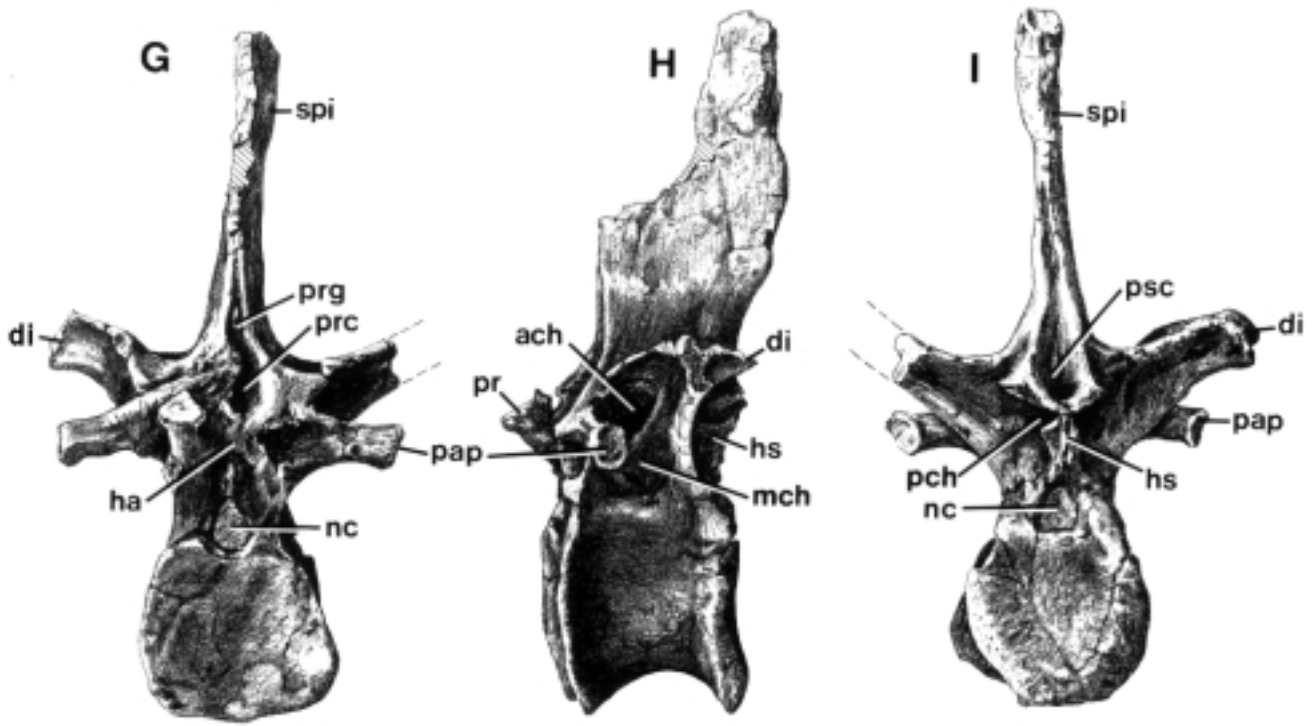


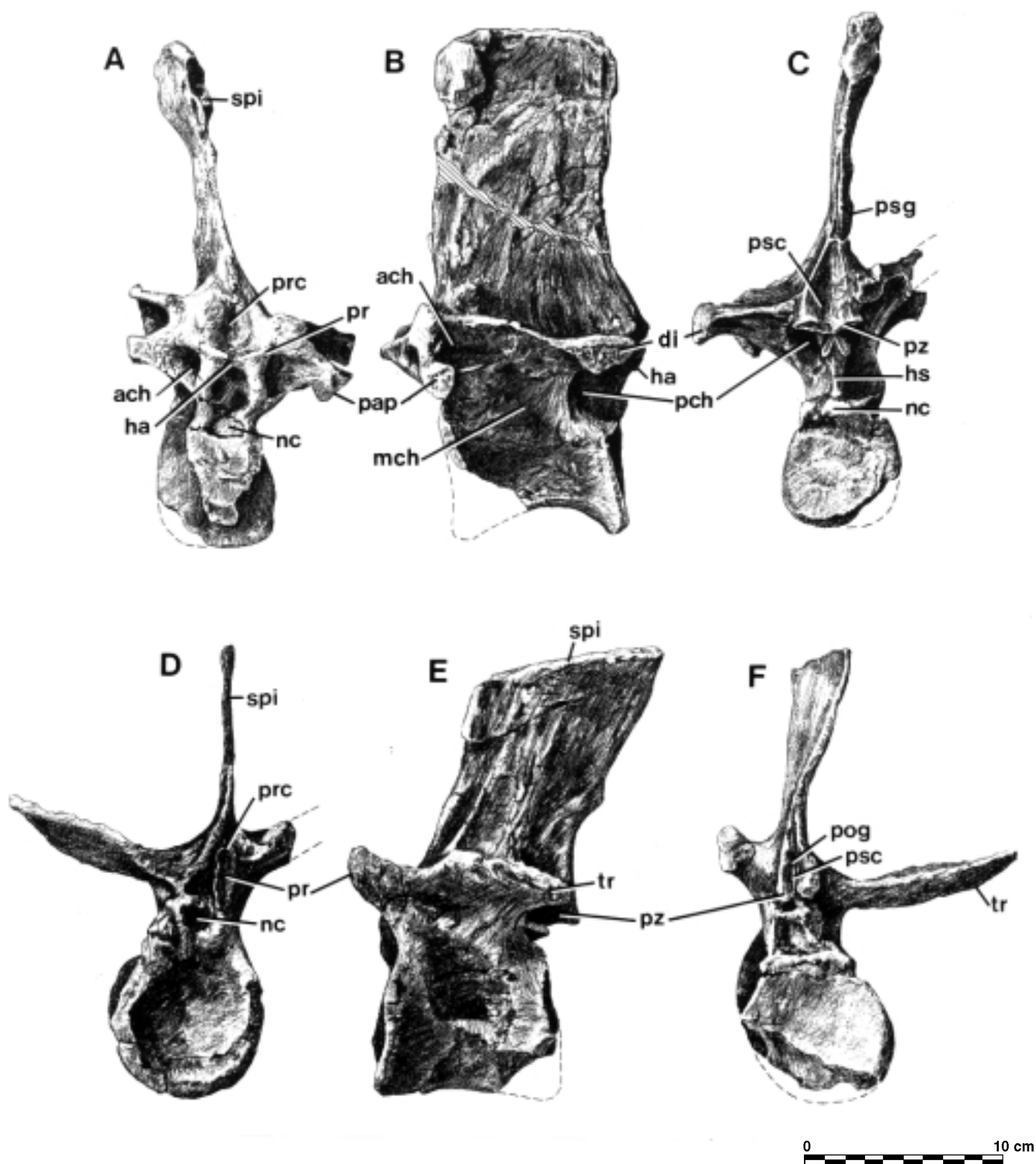
**Plate 5.** *Ceratosaurus magnicornis*, n. sp., holotype. Left postorbital (A,B,C,D), squamosal (E,F), ectopterygoid (G,H,I), and pterygoid/epipterygoid (J,K,L,M), MWC 1, in anterior (A,J), lateral (B,F,H,K), posterior (C,E,L), medial (D,M), dorsal (G), and ventral (I), views. **bp**, contact for basiptyergoid process; **ecp**, contact for ectopterygoid; **ept**, epiptyergoid; **f**, frontal; **itf**, inferior temporal fenestra; **j**, contact for jugal; **la**, contact for lacrimal; **ls**, contact for laterosphenoid; **ltf**, lateral temporal fenestra; **o**, orbit; **p**, contact for parietal; **pch**, posterior chonos; **pfl**, pterygoid flange; **plf**, palatine fenestra; **pmp**, posteromedial process; **po**, contact for postorbital; **pt**, contact for pterygoid; **qu**, socket for quadrate. Scale: one-third natural size.



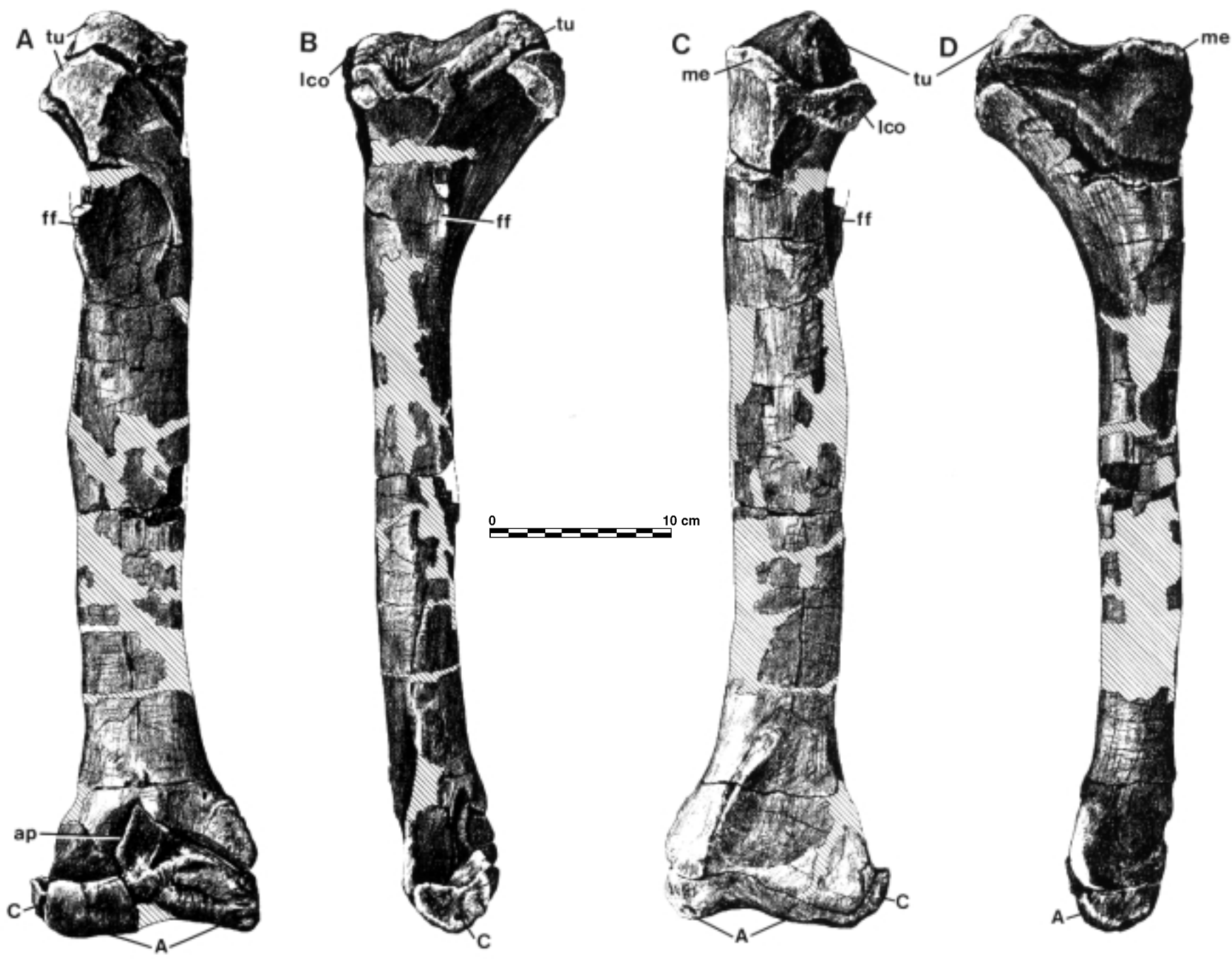
**Plate 6.** *Ceratosaurus magnicornis*, n. sp., holotype. Fifth cervical vertebra, MWC 1, PF-QB-36A (A,B,C), fused ninth cervical and first pectoral vertebrae, MWC 1, PF-QB-1A&B (D,E,F), and third dorsal vertebra, MCW 1, PF-QB-44 (G,H,I), in anterior (A,D,G), left lateral (B,E,H), and posterior (C,E,I) views. **ach**, anterior chonos; **c**, capitulum; **cr**, cervical rib; **di**, diapophysis; **epp**, epiphysis; **ha**, hypantrum; **hs**, hyosphene; **mch**, medial chonos; **nc**, neural canal; **pap**, parapophysis; **pch**, posterior chonos; **poc**, postchonos; **pr**, prezygapophysis; **prc**, prespinal chonos; **pre**, prechonos; **prg**, prespinal groove; **pr**, prespinal ridge; **psc**, postspinal chonos; **psr**, postspinal ridge; **pz**, postzygapophysis; **spi**, spine; **tb**, tuberculum. Scale: one-third natural size.

Plate 6 (continued)

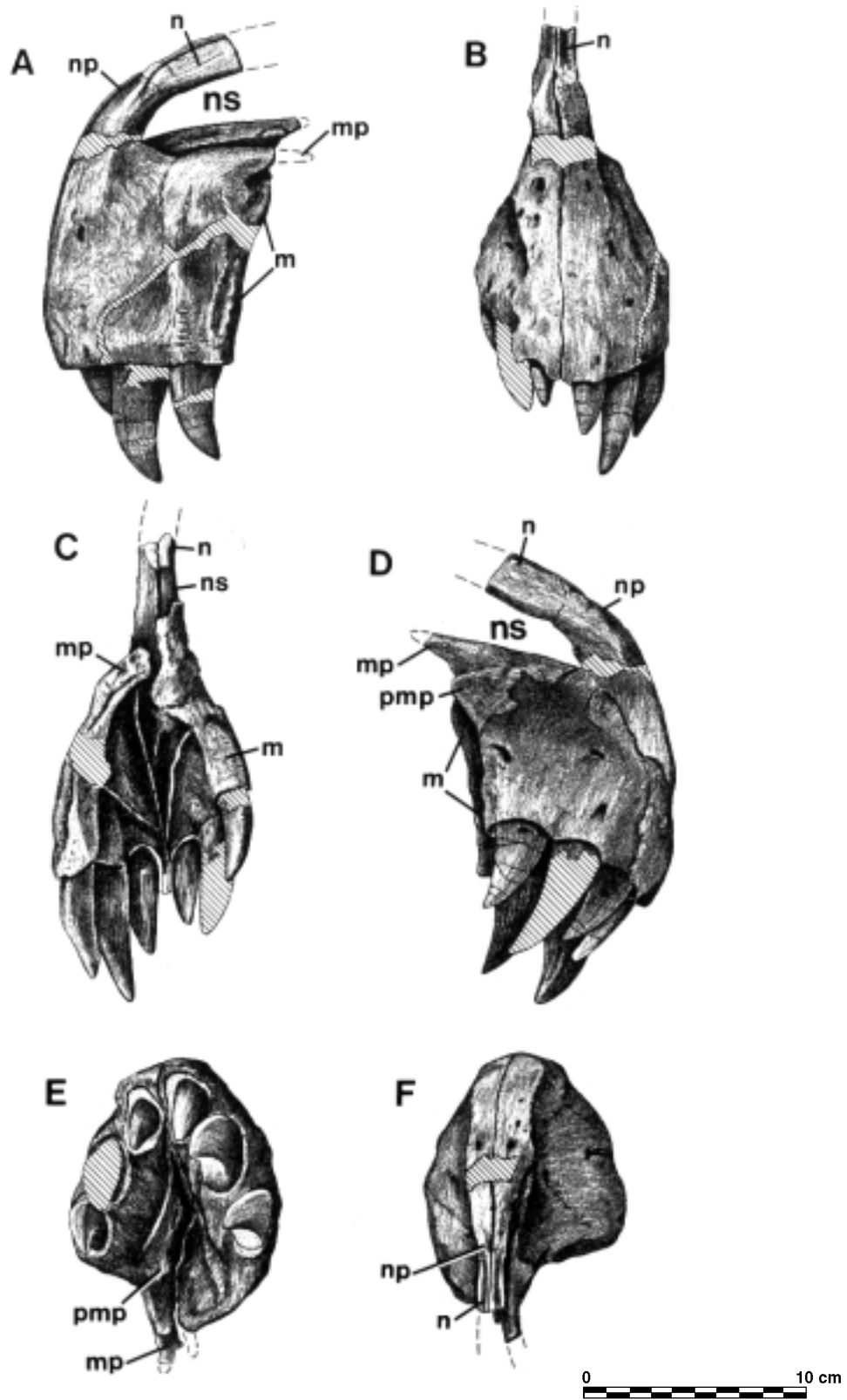




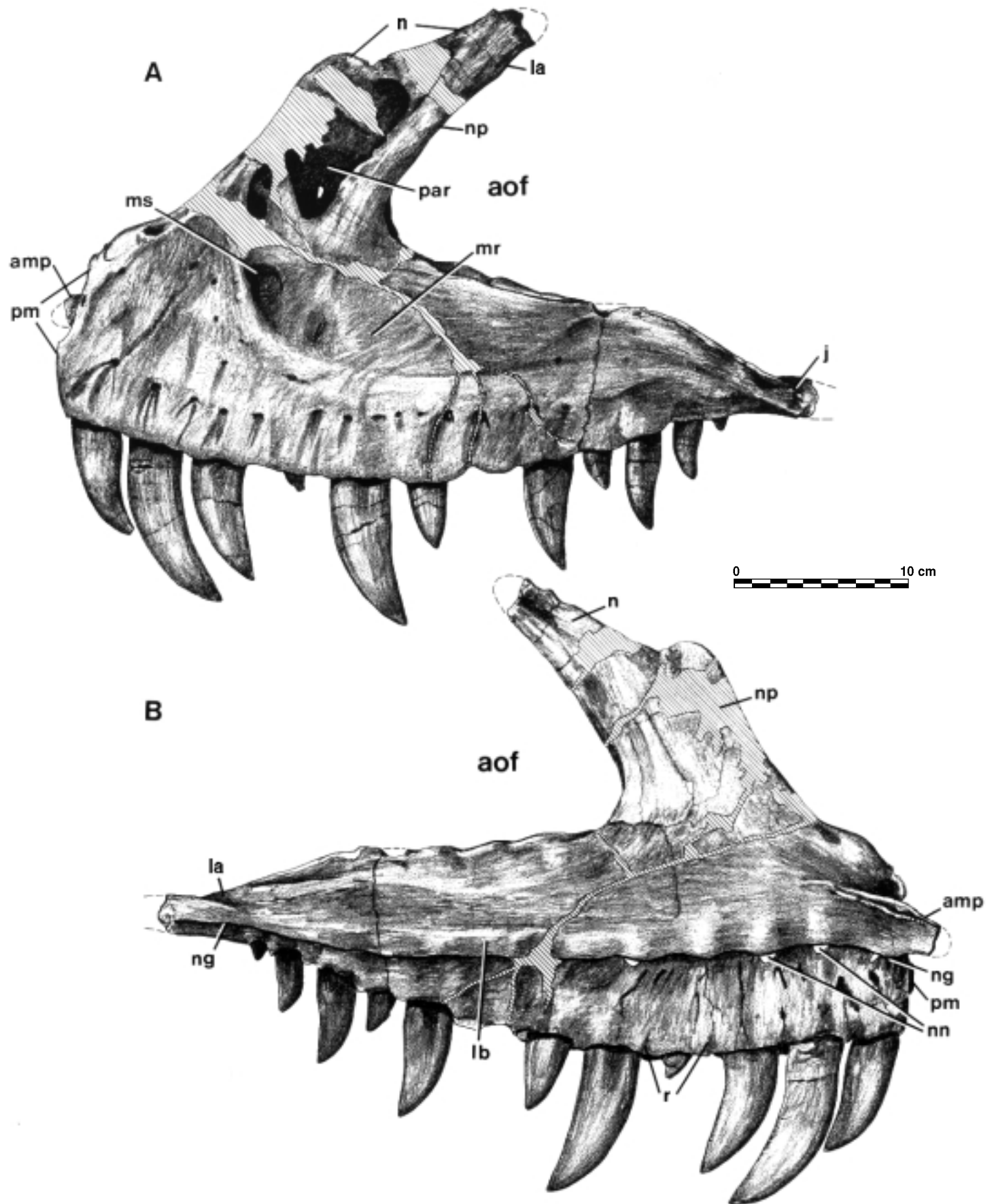
**Plate 7.** *Ceratosaurus magnicornis*, n. sp., holotype. Posterior dorsal vertebra MWC 1, PF-QB-34 (A,B,C), and anterior caudal vertebra MWC 1, PF-QB-8 (D,E,F), in anterior (A,D), left lateral (B,E), and posterior (C,F) views. **ach**, anterior chonos; **di**, diapophysis; **ha**, hypantrum; **hs**, hyposphene; **mch**, medial chonos; **nc**, neural canal; **pap**, parapophysis; **pch**, posterior chonos; **pog**, postspinal groove; **pr**, prezygapophysis; **prc**, prespinal chonos; **psc**, postspinal chonos; **psg**, postspinal groove; **pz**, postzygapophysis; **spi**, spine; **tr**, transverse process. Scale: one-third natural size.



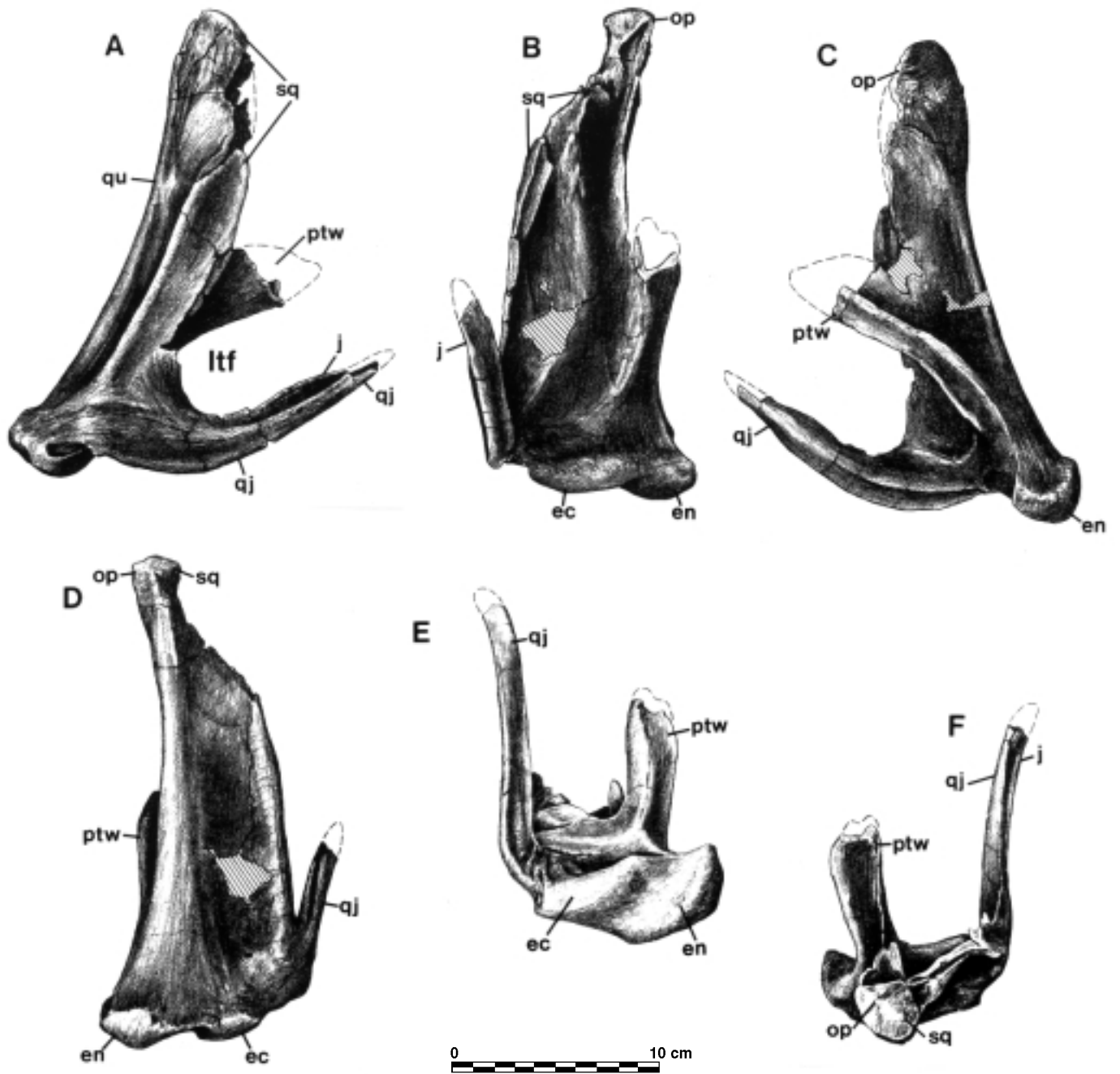
**Plate 8.** *Ceratosaurus magnicornis*, n. sp., holotype. Right tibia, astragalus, and calcaneum, MWC 1, PF-QB-26A,B,C, in anterior (A), lateral (B), posterior (C), and medial (D), views. **ap**, ascending process; **A**, astragalus; **C**, calcaneum; **ff**, fibular flange; **lco**, lateral condyle; **me**, medial condyle; **tu**, tuberosity. Scale: one-third natural size.



**Plate 9.** *Ceratosaurus dentisulcatus*, n. sp., holotype. Paired premaxillae, UUVP 674, in left lateral (A), anterior (B), posterior (C), right lateral (D), ventral (E), and dorsal (F) views. **m**, contact for maxilla; **mp**, maxillary process; **n**, contact for nasal; **np**, nasal process; **ns**, naris; **pmp**, posteromedial process. Scale: one-third natural size.

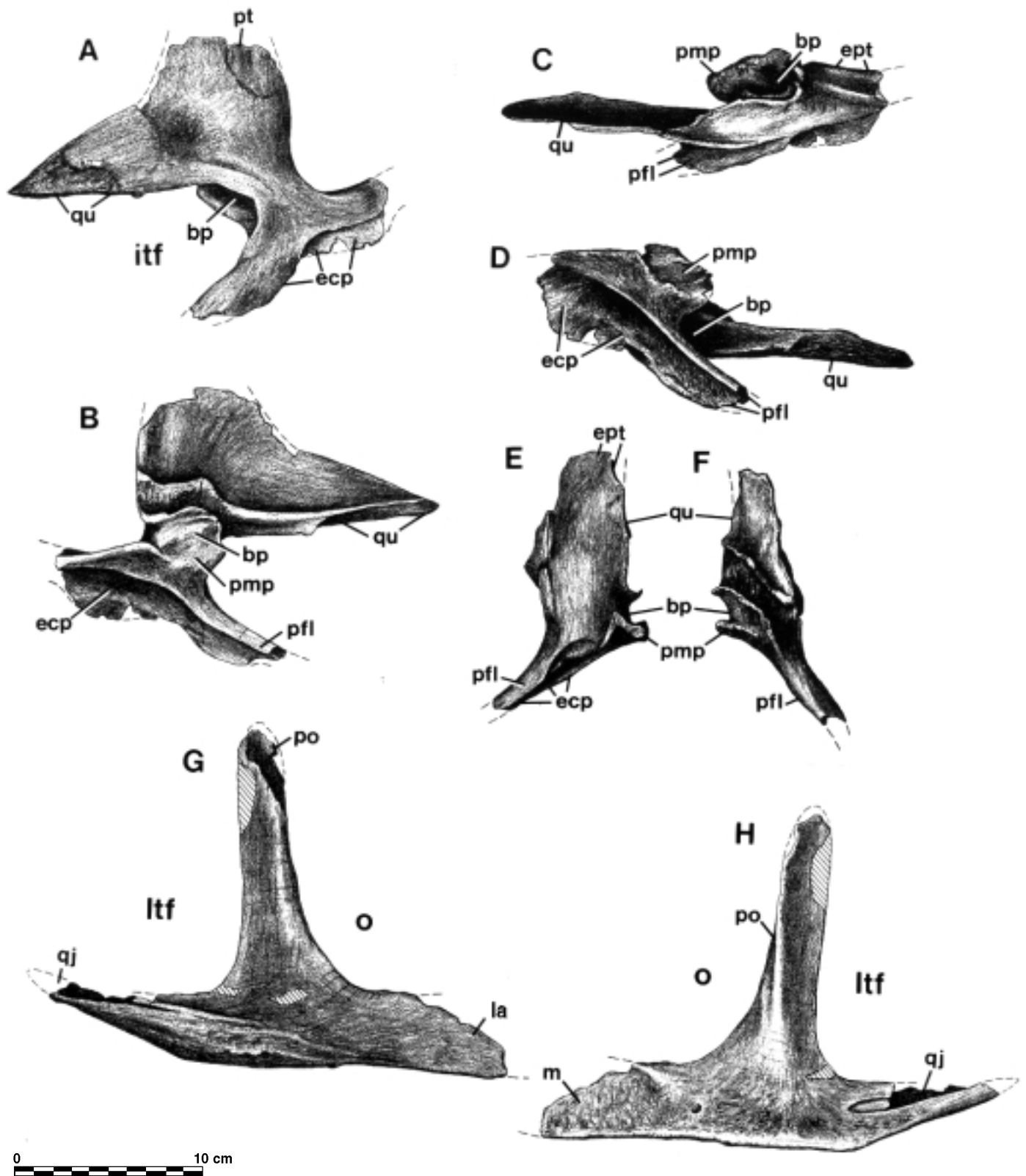


**Plate 10.** *Ceratosaurus dentisulcatus*, n. sp., holotype. Left maxilla, UUVP 674, in lateral (A), and medial (B) views. **amp**, anteromedial process; **aof**, antorbital fenestra; **j**, contact for jugal; **la**, contact for lacrimal; **lb**, lingual bar; **mr**, maxillary recess; **ms**, maxillary sinus; **n**, contact for nasal; **ng**, nutrient groove; **nn**, nutrient notch; **np**, nasal process; **par**, preantorbital recess; **pm**, contact for premaxilla; **r**, rugosa. Scale: one-third natural size.

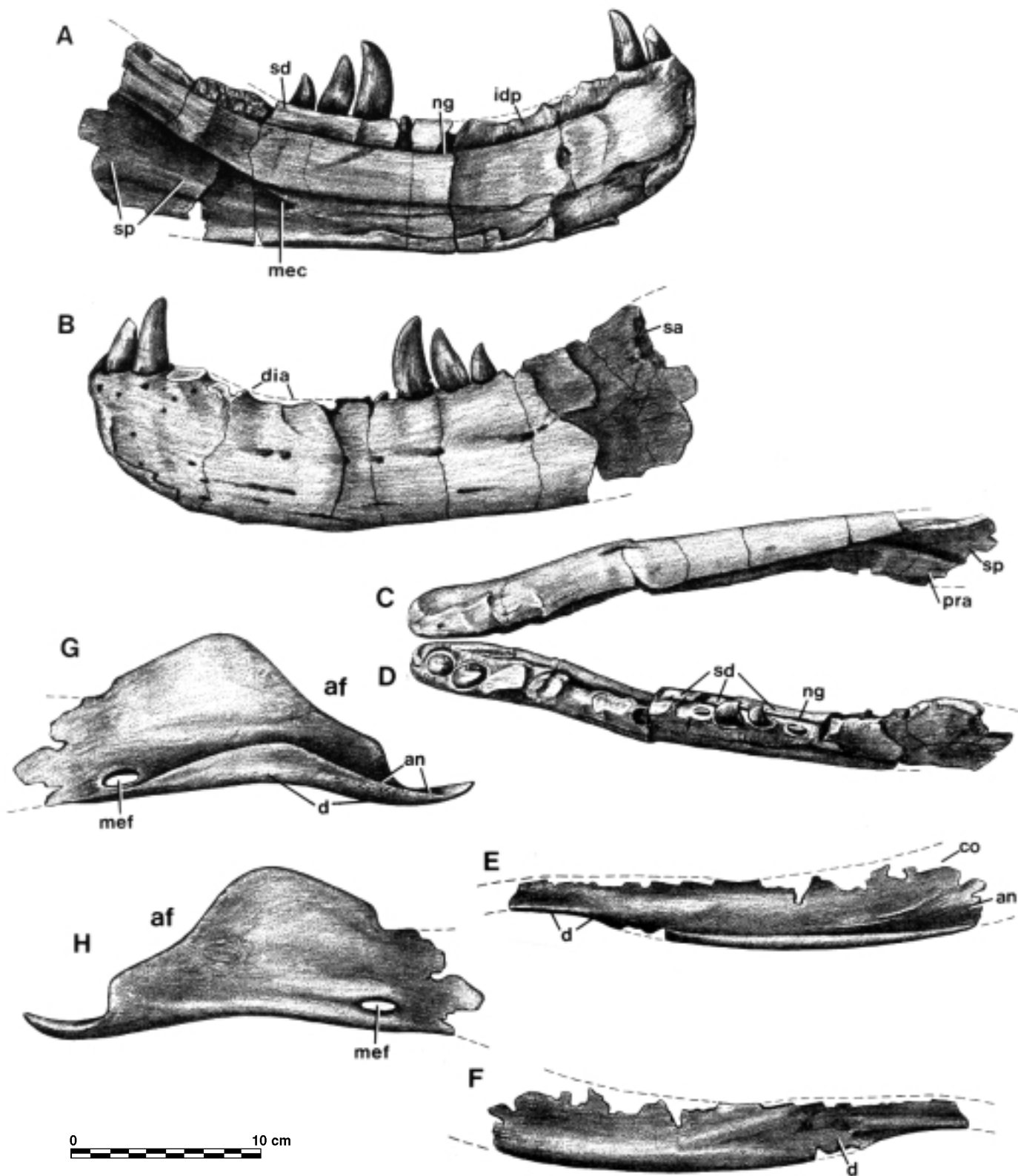


**Plate 11.** *Ceratosaurus dentisulcatus*, n. sp., holotype. Coossified right quadrate and quadratojugal, UUVP 1646, in lateral (A), anterior (B), medial (C), posterior (D), ventral (E), and dorsal (F) views. **ec**, ectocondyle; **en**, entocondyle; **j**, contact for jugal; **ltf**, lateral temporal fenestra; **op**, contact for opisthotic; **ptw**, pterygoid wing; **qj**, quadratojugal; **qu**, quadrate; **sq**, contact for squamosal. Scale: one-third natural size.

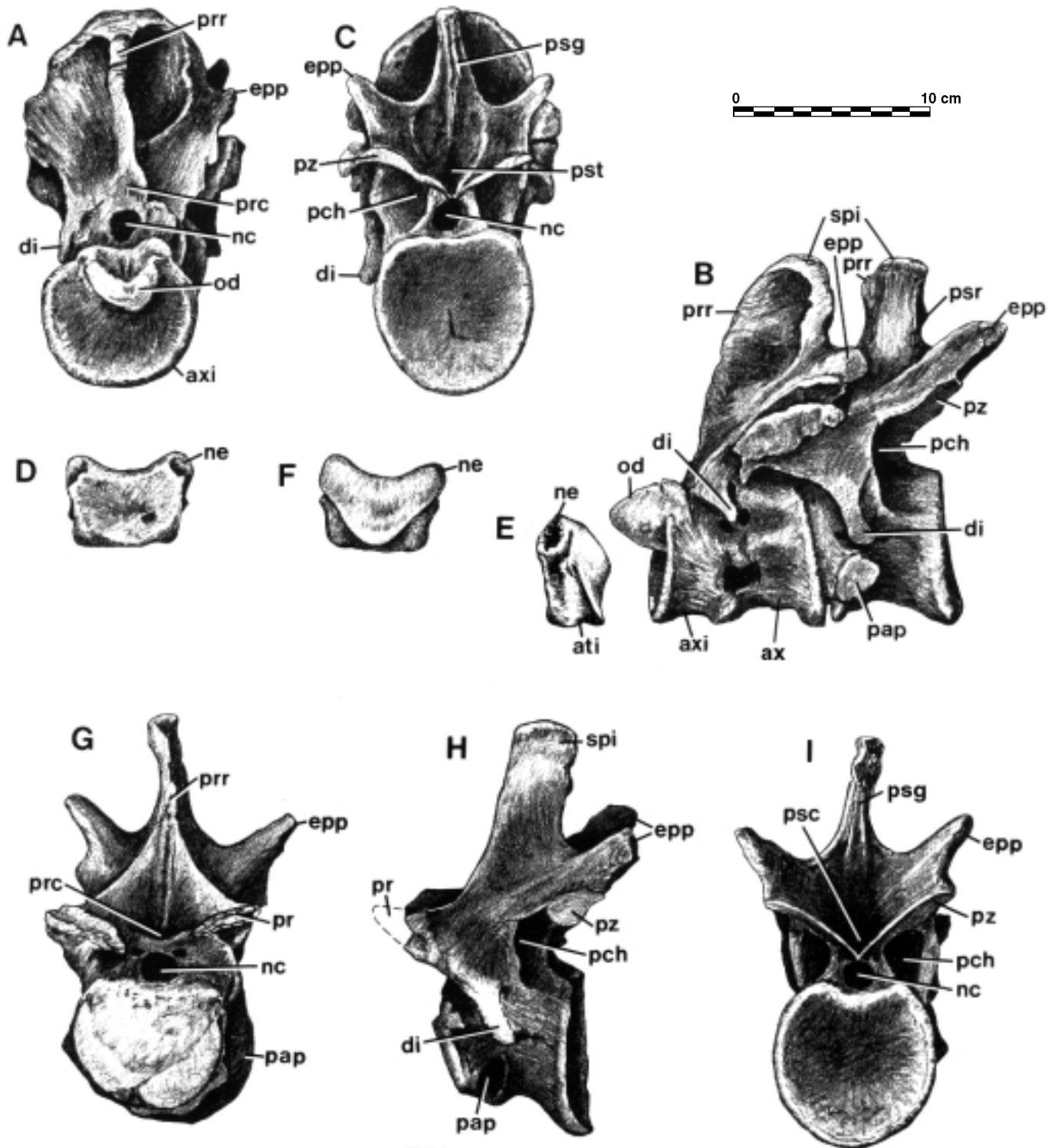




**Plate 12.** *Ceratosaurus dentisulcatus*, n. sp., holotype. Right pterygoid, UUV 1646 (A-F), and right jugal UUV 1646 (G,H), in lateral (A,G), medial (B,H), dorsal (C), ventral (D), anterior (E), and posterior (F) views. **bp**, contact for basipterygoid process; **ecp**, contact for ectopterygoid; **ept**, contact for epipterygoid; **la**, contact for lacrimal; **ltf**, lateral temporal fenestra; **m**, maxilla; **o**, orbit; **pfl**, pterygoid flange; **pmp**, posteromedial process; **po**, contact for postorbital; **qj**, contact for quadratojugal; **qu**, contact for quadrate. Scale: one-third natural size.

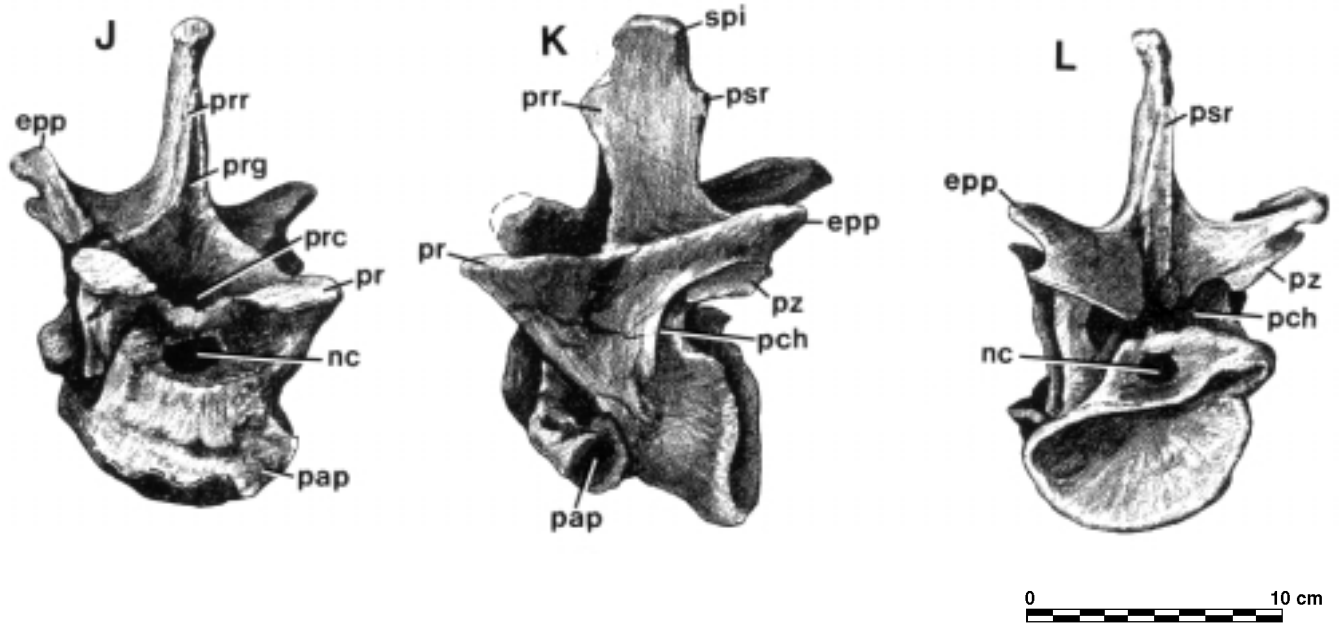


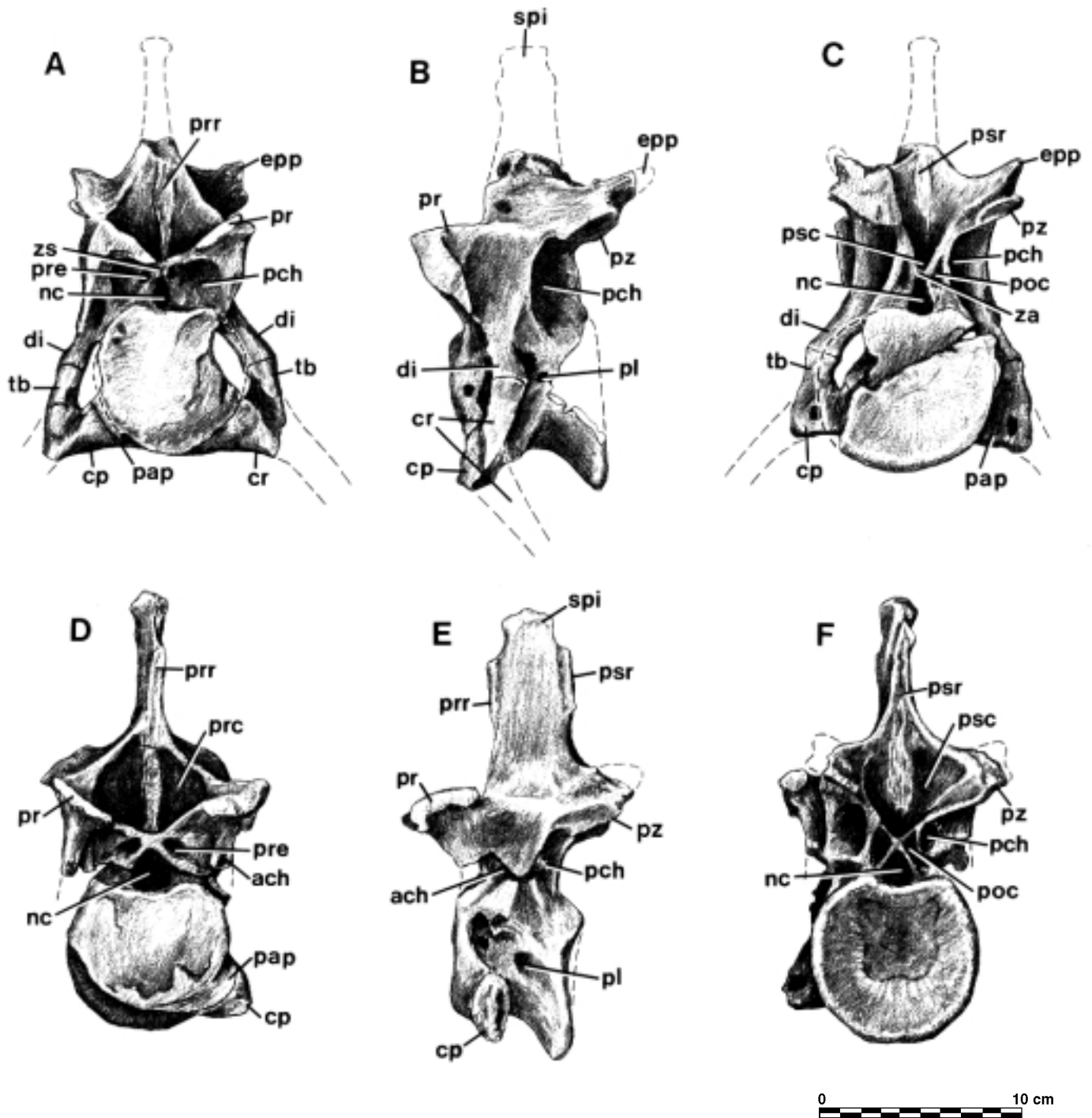
**Plate 13.** *Ceratosaurus dentisulcatus*, n. sp., holotype. Left dentary, UUV 158 (A,B,C,D), right angular, UUV 5911, (E,F), and left splenial, UUV 157 (G,H), in lateral (B,F), ventral (C), dorsal (D), medial (E,H) and internal (E,G) views. **af**, adductor fenestra; **an**, angular; **co**, coronoid; **d**, contact with dentary; **dia**, diastema; **idp**, interdental plate; **mec**, meckelian canal; **mef**, meckelian foramen; **ng**, nutrient groove; **pra**, prearticular; **sa**, surangular; **sd**, supradentary; and **sp**, splenial. Scale: one-third natural size.



**Plate 14.** *Ceratosaurus dentisulcatus*, n. sp., holotype. Atlantal intercentrum, axial intercentrum, axis, and third cervical vertebra, UUV 1053 (A-F), fourth cervical vertebra, UUV 6963 (G,H,I), and fifth cervical vertebra, UUV 6965 (J,K,L), in anterior (A,D,G,J), lateral (B,E,H,K), and posterior (C,F,I,L) views. **ati**, atlantal intercentrum; **ax**, axis; **axi**, axial intercentrum; **di**, diapophysis; **epp**, epiphysis; **nc**, neural canal; **ne**, neuropophysis; **od**, odontoid; **pap**, parapophysis; **pch**, posterior chonos; **pr**, prezygapophysis; **prc**, prespinal chonos; **prg**, prespinal groove; **prp**, prespinal ridge; **psc**, postspinal chonos; **psg**, postspinal groove; **psr**, postspinal ridge; **pst**, postspinal trough; **pz**, postzygapophysis; **spi**, spine. Scale: one-third natural size.

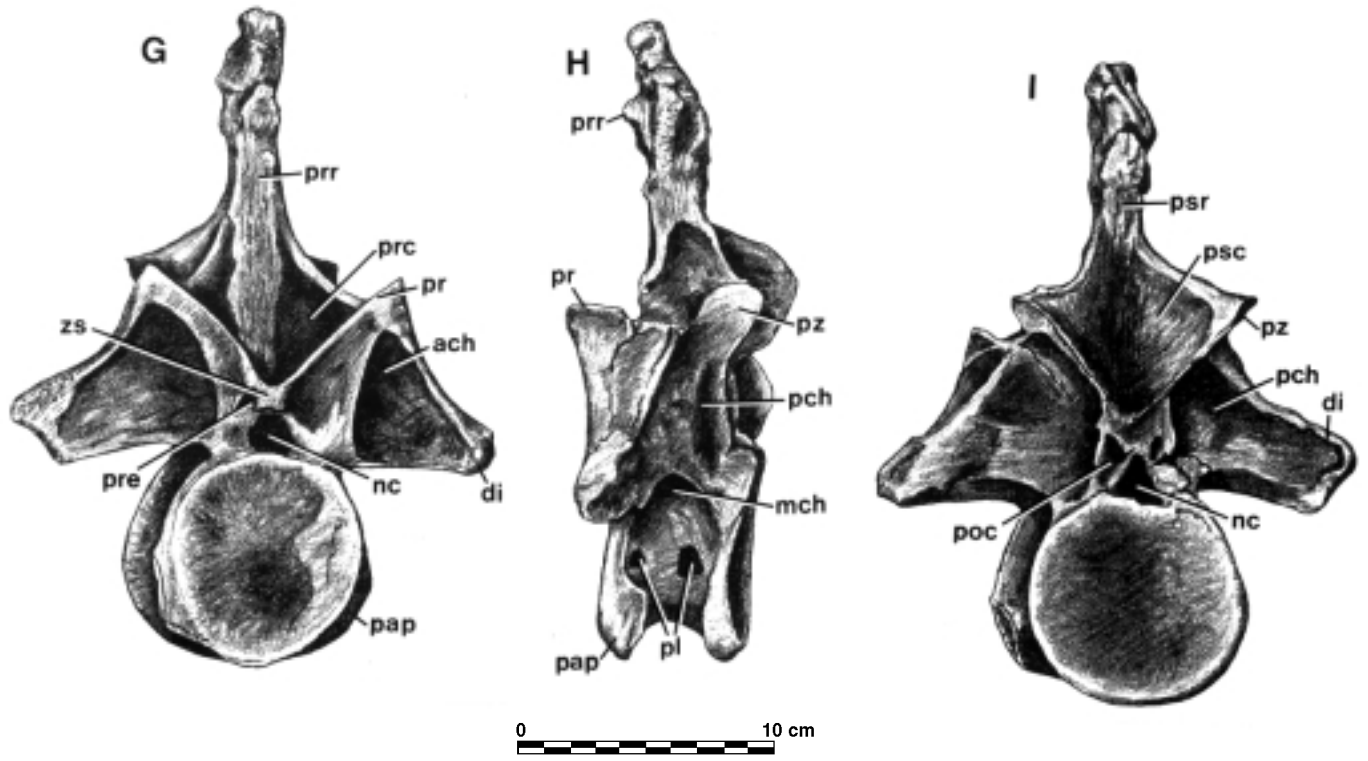
Plate 14 (continued)

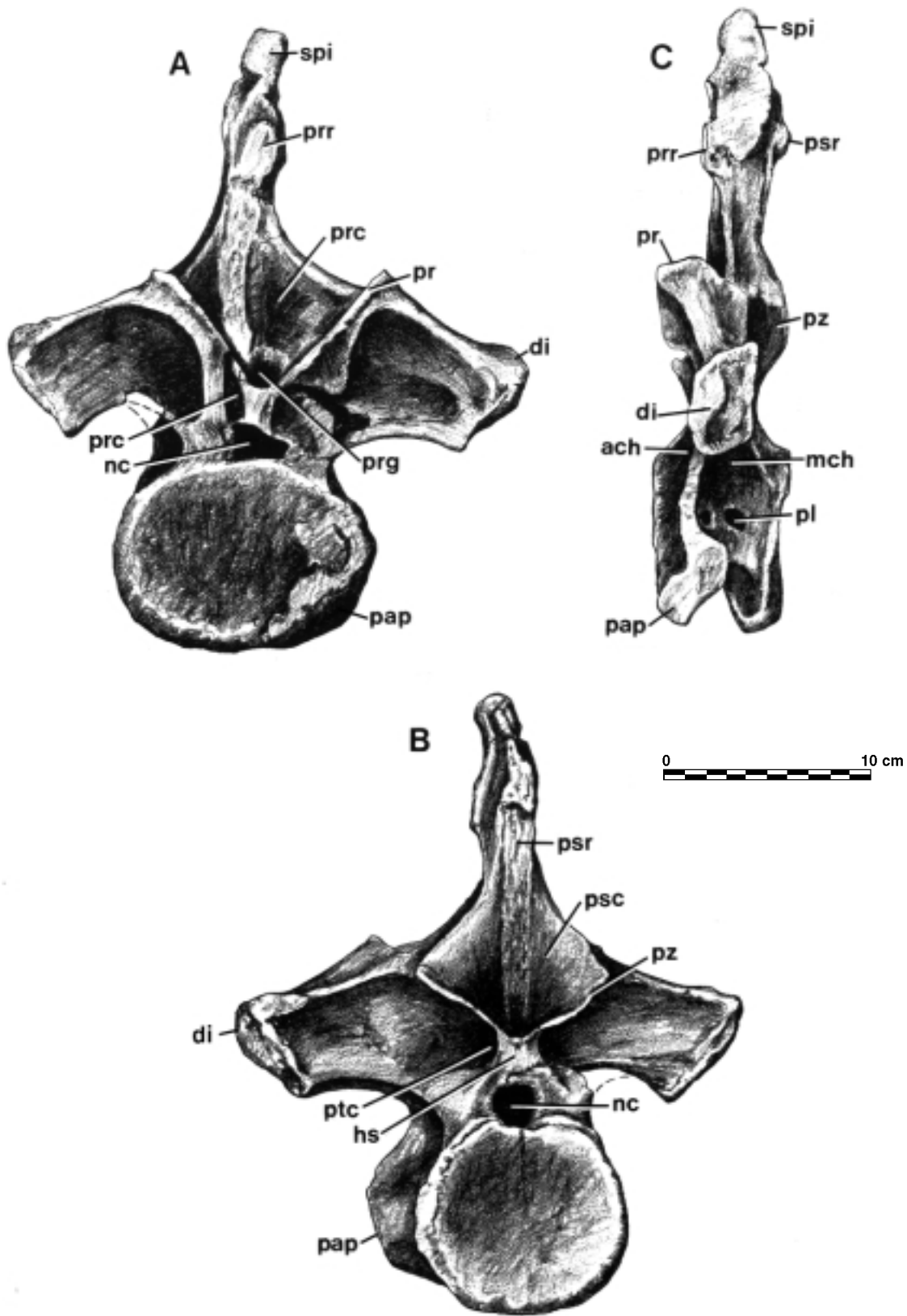




**Plate 15.** *Ceratosaurus dentisulcatus*, n. sp., holotype. Sixth cervical vertebra, UUVP 6964 (A,B,C), seventh cervical vertebra, UUVP 1615 (D,E,F), and ninth cervical vertebra, UUVP 562 (G,H,I), in anterior (A,D,G), lateral (B,E,H), and posterior (C,F,I) views. **ach**, anterior chonos; **cp**, capitulum; **cr**, cervical rib; **di**, diapophysis; **epp**, epipophysis; **mch**, medial chonos; **nc**, neural canal; **pap**, parapophysis; **pch**, posterior chonos; **pl**, pleurocoel; **poc**, postchonos; **pr**, prezygapophysis; **prc**, prespinal chonos; **pre**, prechonos; **pr**, prespinal ridge; **psc**, postspinal chonos; **psr**, postspinal ridge; **pz**, posterior zygapophysis; **spi**, spine; **tb**, tuberculum; **za**, zygantrum; **zs**, zygosphen. Scale: one-third natural size.

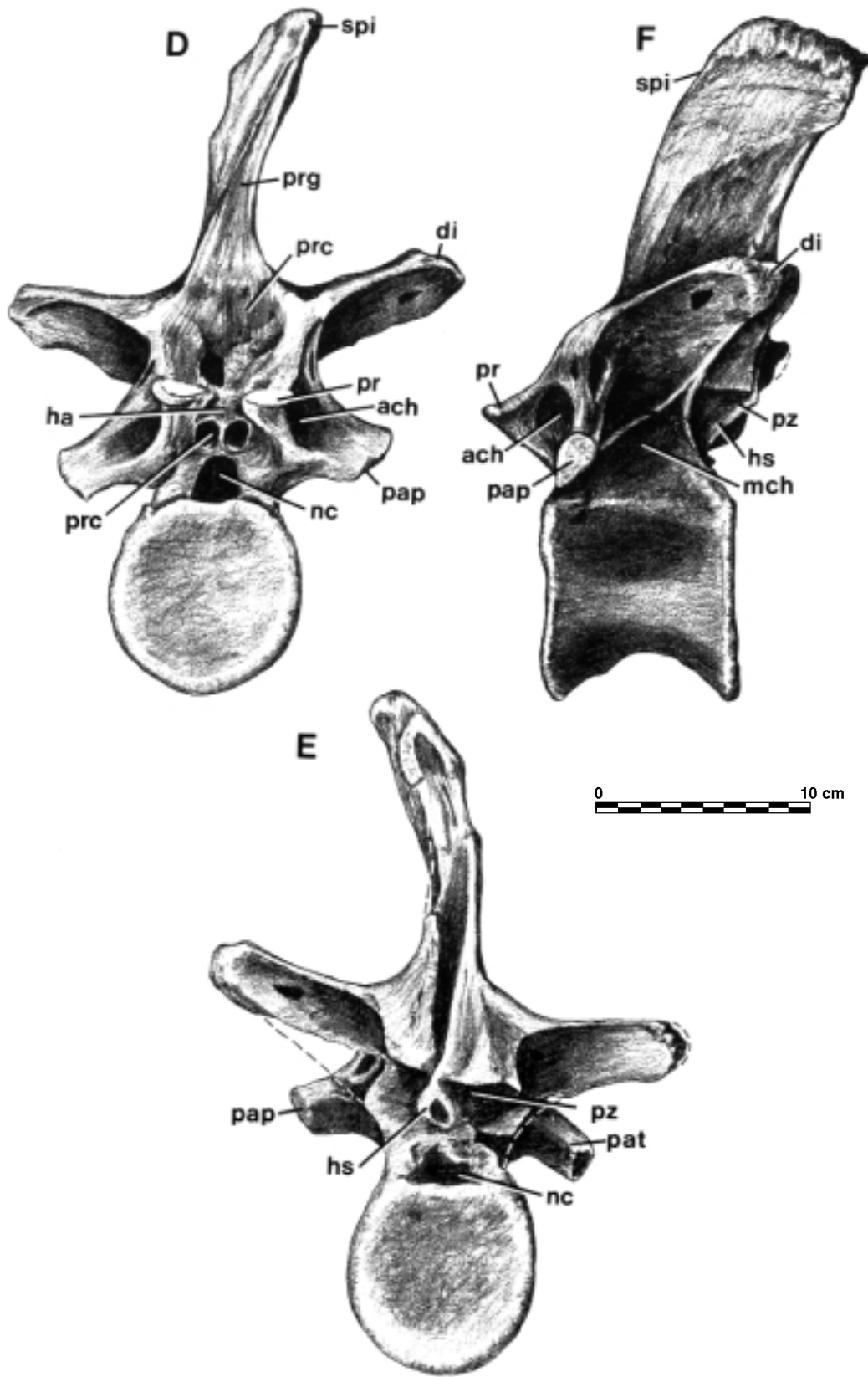
Plate 15 (continued)



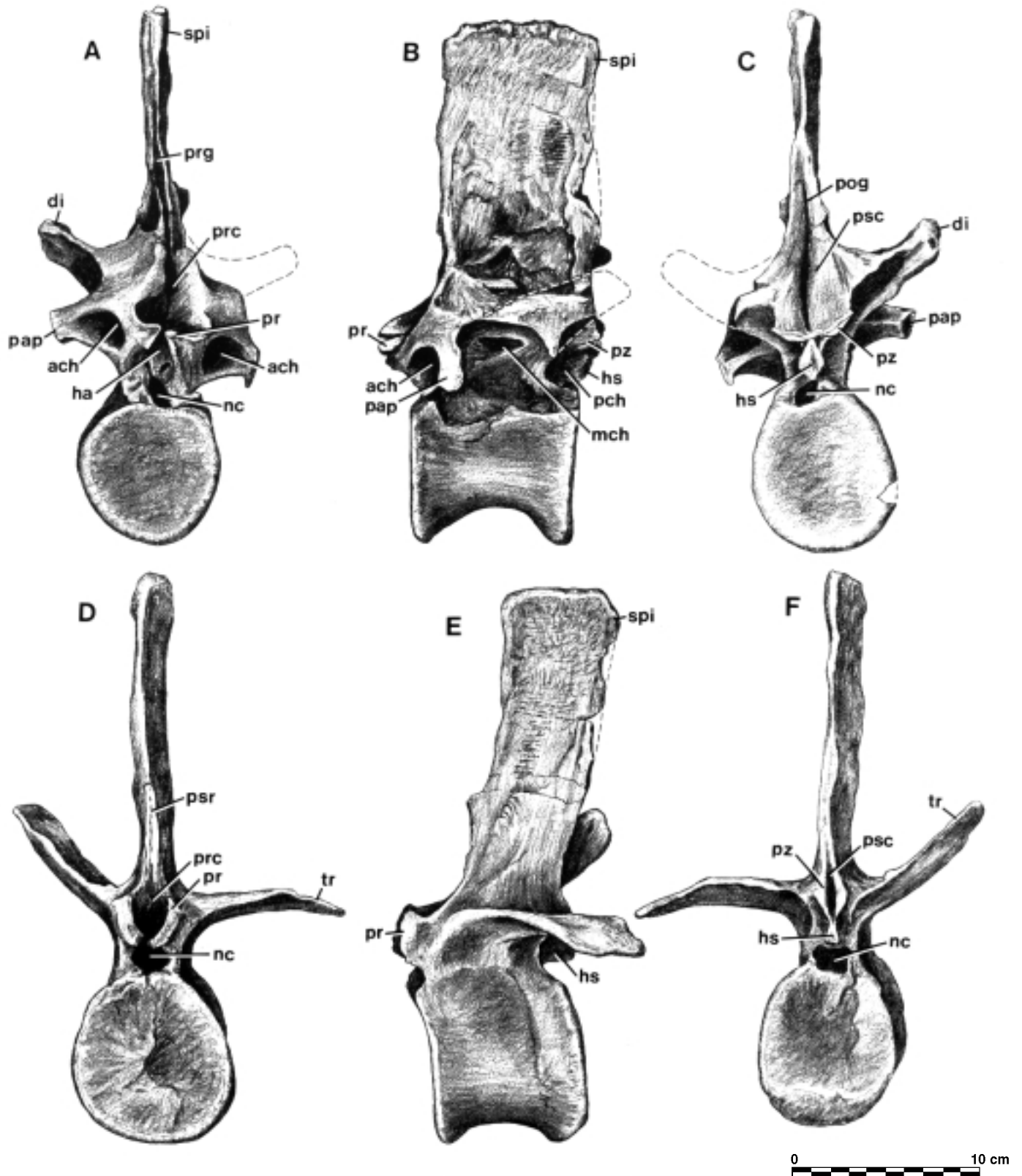


**Plate 16.** *Ceratosaurus dentisulcatus*, n. sp., holotype. First pectoral vertebra, UUV 329 (A,B,C), and seventh dorsal vertebra, UUV 1231 (D,E,F), in anterior (A,D), left lateral (C,F), and posterior (B,E) views. **ach**, anterior chonos; **di**, diapophysis; **ha**, hypantrum; **hs**, hyposphene; **mch**, medial chonos; **nc**, neural canal; **pap**, parapophysis; **pat**, parapophyseal stem; **pl**, pleurocoel; **pr**, prezygapophysis; **prc**, prespinal chonos; **pre**, prechonos; **prg**, prespinal groove; **prp**, prespinal ridge; **psc**, postspinal chonos; **psr**, postspinal ridge; **ptc**, posterior chonos; **pz**, postzygapophysis; **spi**, spine. Scale: one-third natural size.

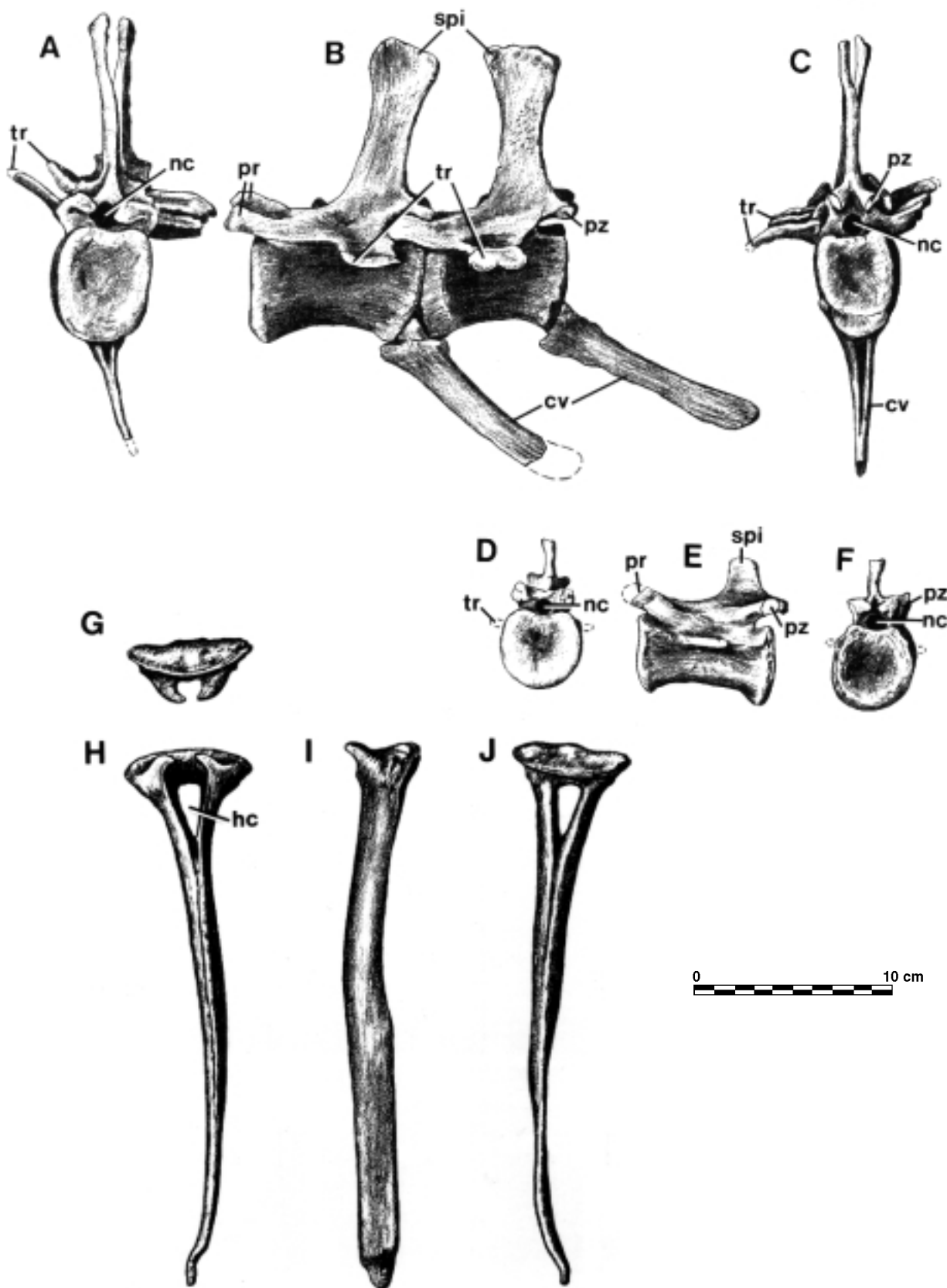
Plate 16 (continued)



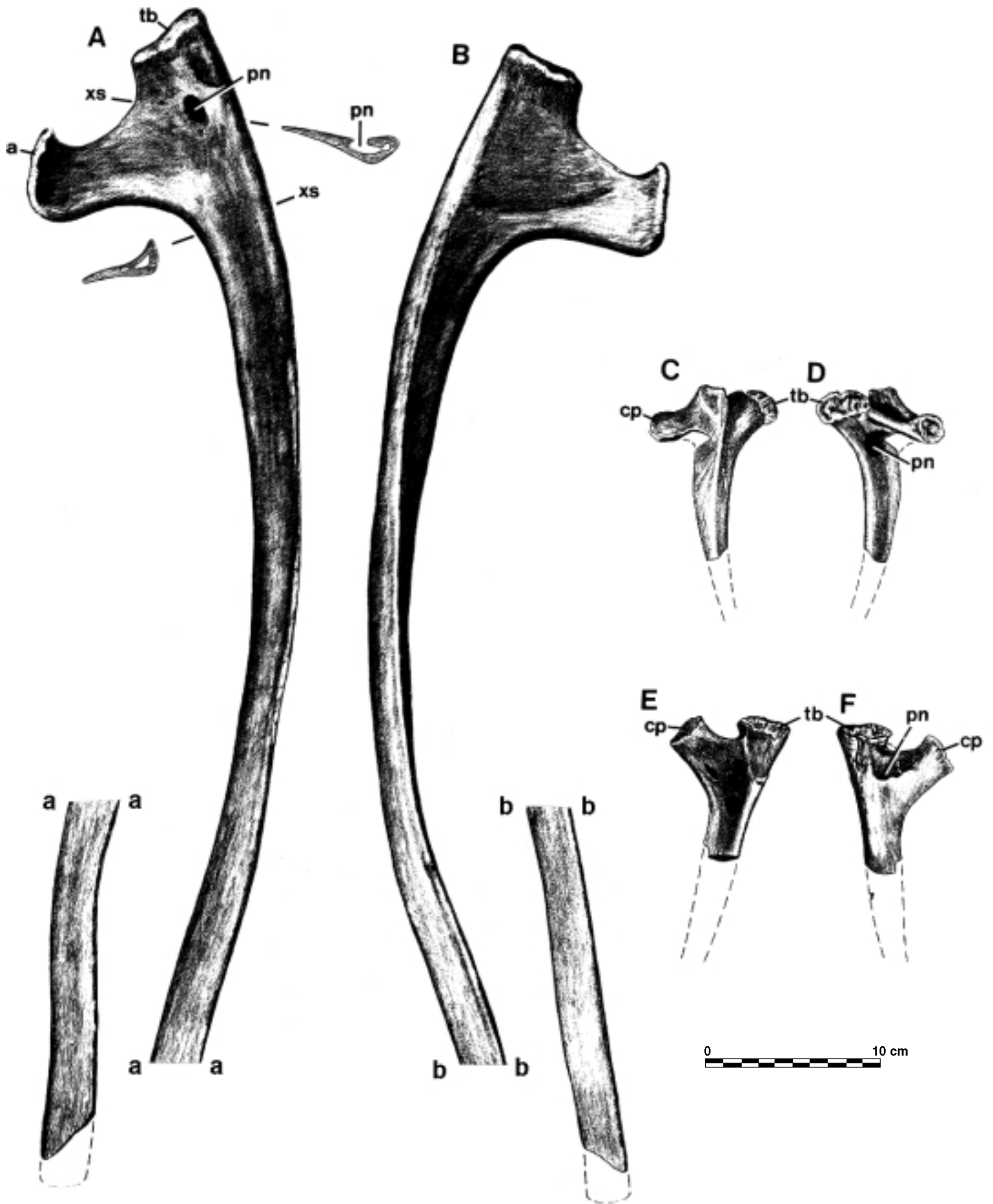




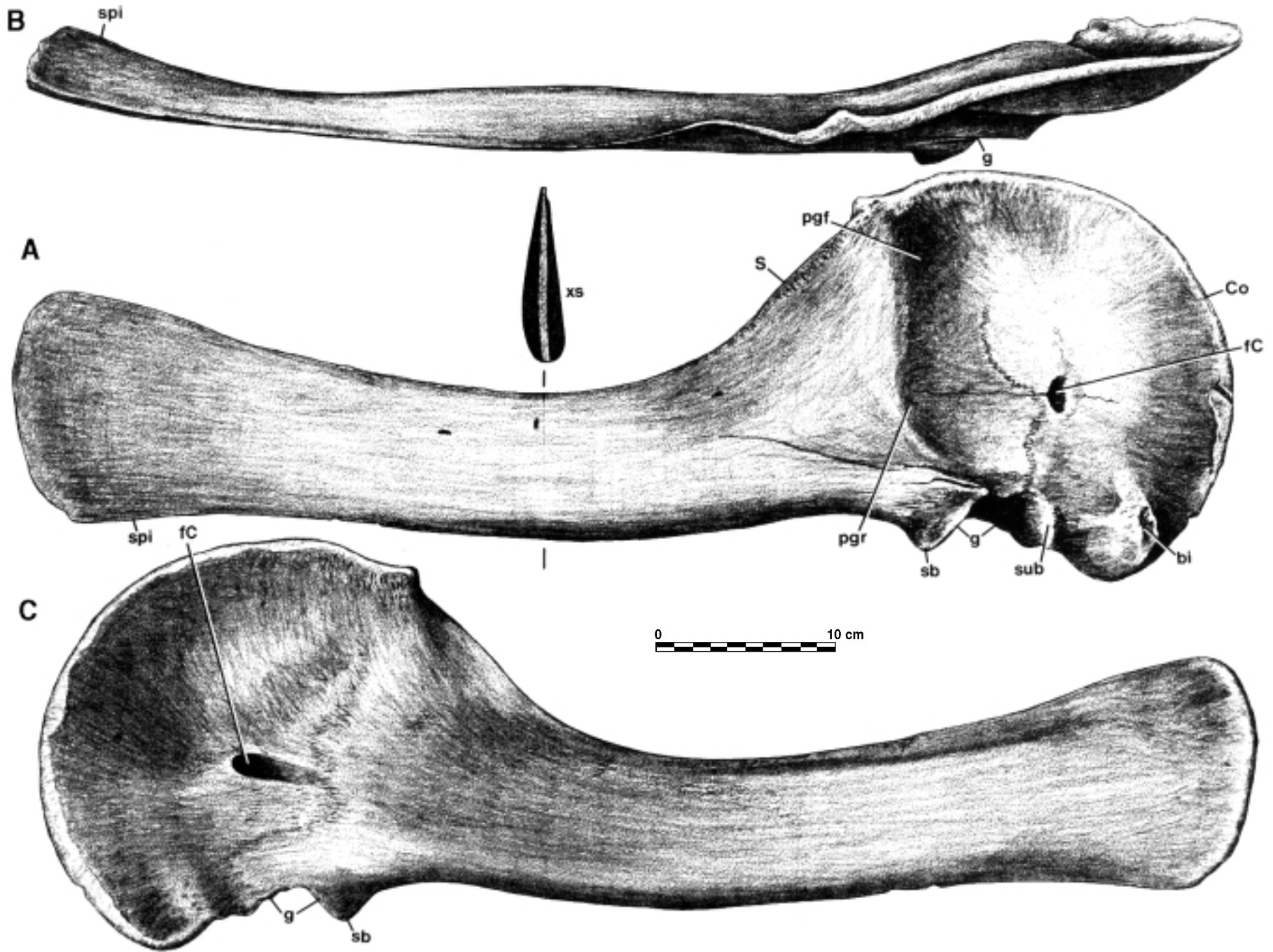
**Plate 17.** *Ceratosaurus dentisulcatus*, n. sp., holotype. Ninth dorsal vertebra, UUVP 48 (A,B,C), and anterior caudal vertebra, UUVP 6961 (D,E,F), in anterior (A,D), left lateral (B,D), and posterior (C,F) views. **ach**, anterior chonos; **di**, diapophysis; **ha**, hypantrum; **hs**, hyposphene; **mch**, medial chonos; **nc**, neural canal; **pap**, parapophysis; **pch**, posterior chonos; **pog**, postspinal groove; **pr**, prezygapophysis; **prc**, prespinal chonos; **prg**, prespinal groove; **psc**, postspinal chonos; **psr**, postspinal ridge; **pz**, postzygapophysis; **spi**, spine; **tr**, transverse process. Scale: one-third natural size.



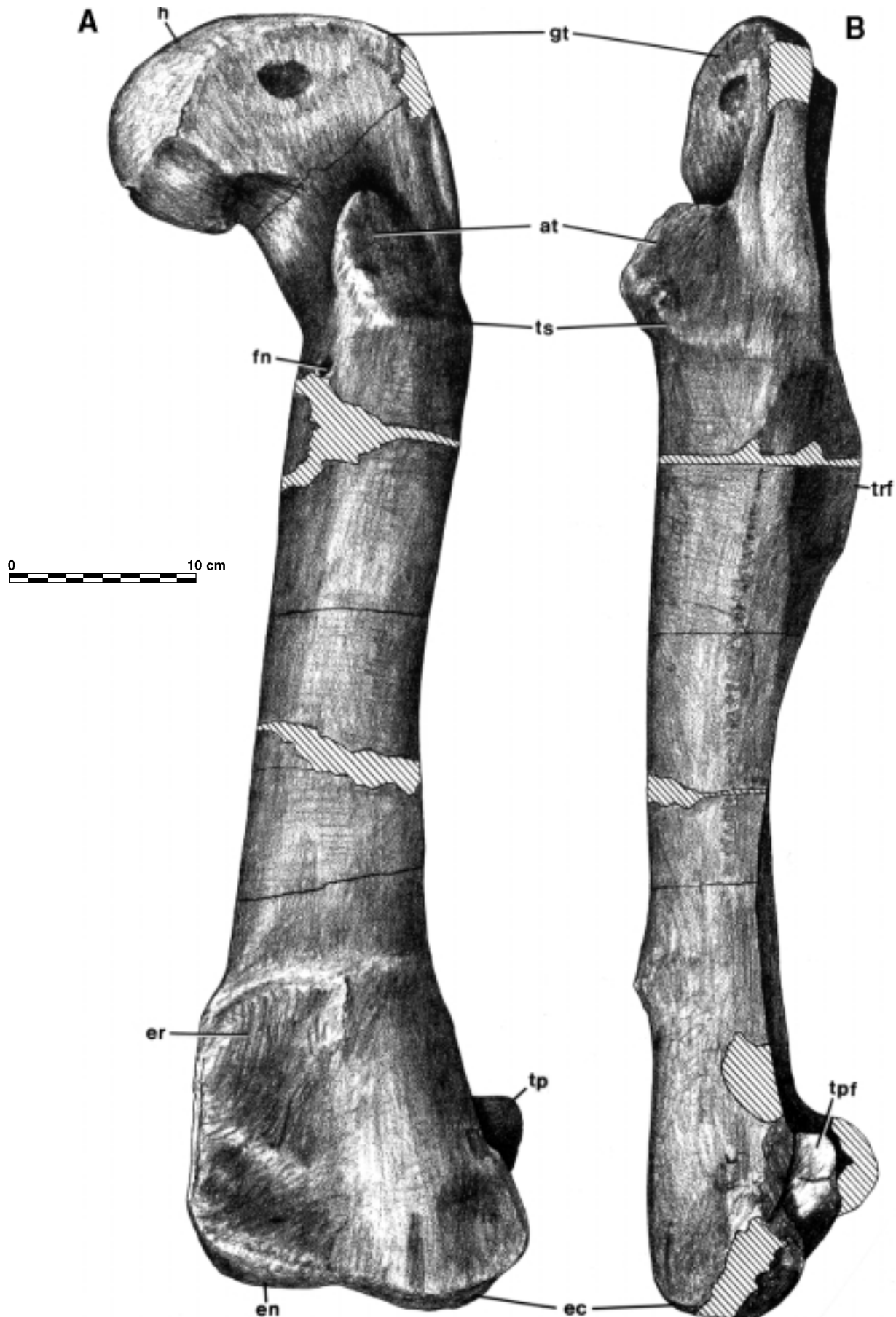
**Plate 18.** *Ceratosaurus dentisulcatus*, n. sp., holotype. Medial caudal vertebrae and chevrons, UUV 375-378 (A,B,C), distal caudal vertebra, UUV 6953 (D,E,F), and proximal chevrons, UUV 272 (G,H,I,J), in anterior (A,D,H), left lateral (B,E,I), posterior (C,F,J), and proximal (G) views. **cv**, chevron; **hc**, haemal canal; **nc**, neural canal; **pr**, prezygapophysis; **pz**, postzygapophysis; **spi**, spine; **tr**, transverse process. Scale: one-third natural size.



**Plate 19.** *Ceratosaurus dentisulcatus*, n. sp., holotype. Right dorsal rib, UUV 548 (A,B), and cervical ribs, UUV 6520 (C,D), UUV 2172 (E,F), in anterior (B), posterior (A), lateral (C,E), and medial (D,F) views. **cp**, capitulum; **pn**, pneumatic foramen; **tb**, tuberculum; **xs**, cross section. Scale: one-third natural size.

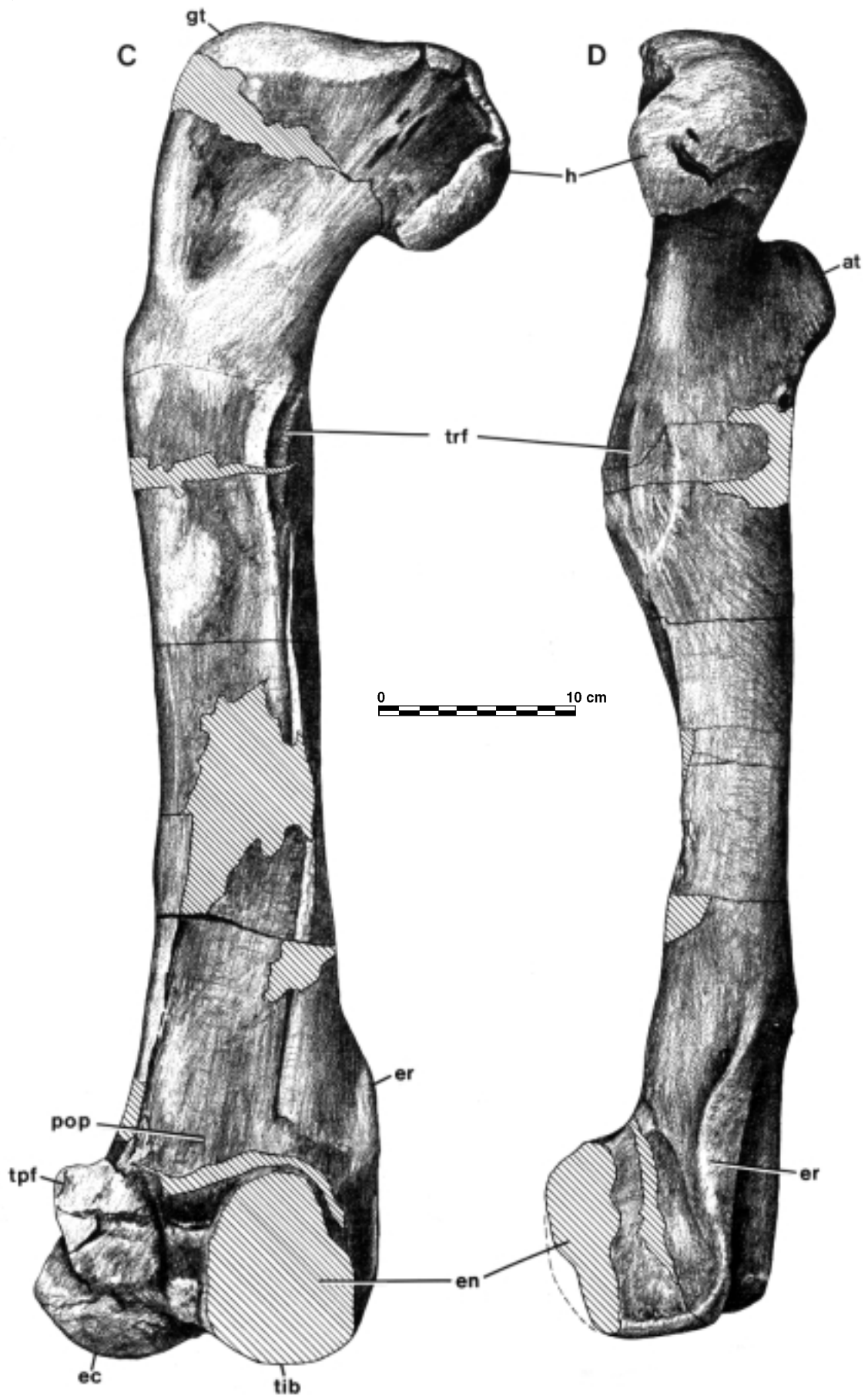


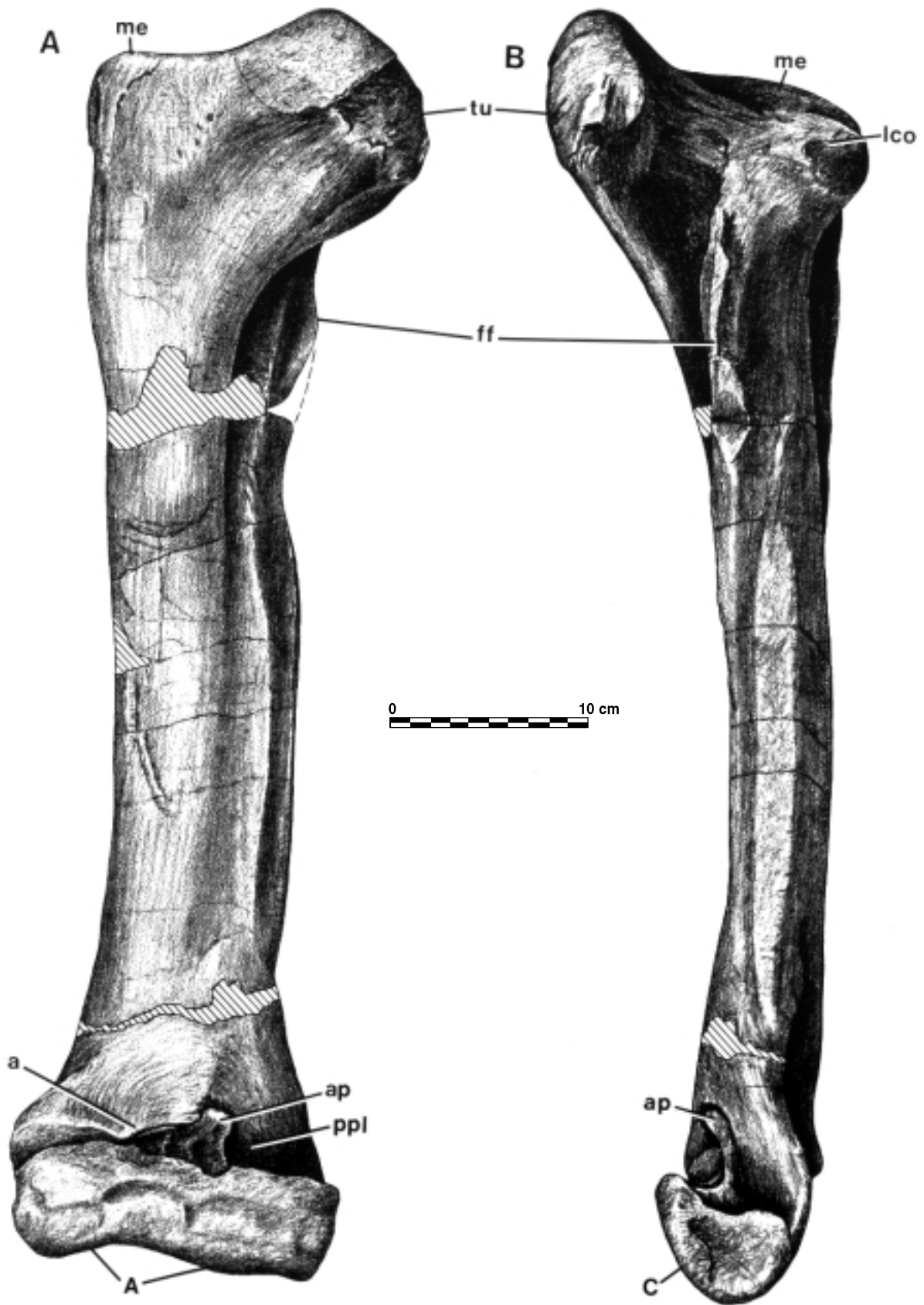
**Plate 20.** *Ceratosaurus dentisulcatus*, n. sp., holotype. Right scapula-coracoid, UUV 317, in lateral (A), dorsal (B), and medial (C) views. **bi**, biceps tubercle; **Co**, coracoid; **fc**, coracoid foramen; **g**, glenoid; **pgf**, preglenoid fossa; **pgr**, preglenoid ridge; **S**, scapula; **sb**, supraglenoid buttress; **sub**, subglenoid buttress; **xs**, cross section. Scale: three-tenths natural size.



**Plate 21.** *Ceratosaurus dentisulcatus*, n. sp., holotype. Left femur, UUVP 56, in anterior (A), lateral (B), posterior (C), and medial (D) views. **at**, anterior trochanter; **ec**, ectocondyle; **en**, entocondyle; **er**, entocondylar ridge; **fn**, nutrient foramen; **gt**, greater trochanter; **h**, head; **ppp**, popliteal surface; **tp**, tuberos process; **tpf**, tuberos process of femur; **trf**, fourth trochanter; **ts**, trochanteric shelf. Scale: one-third natural size.

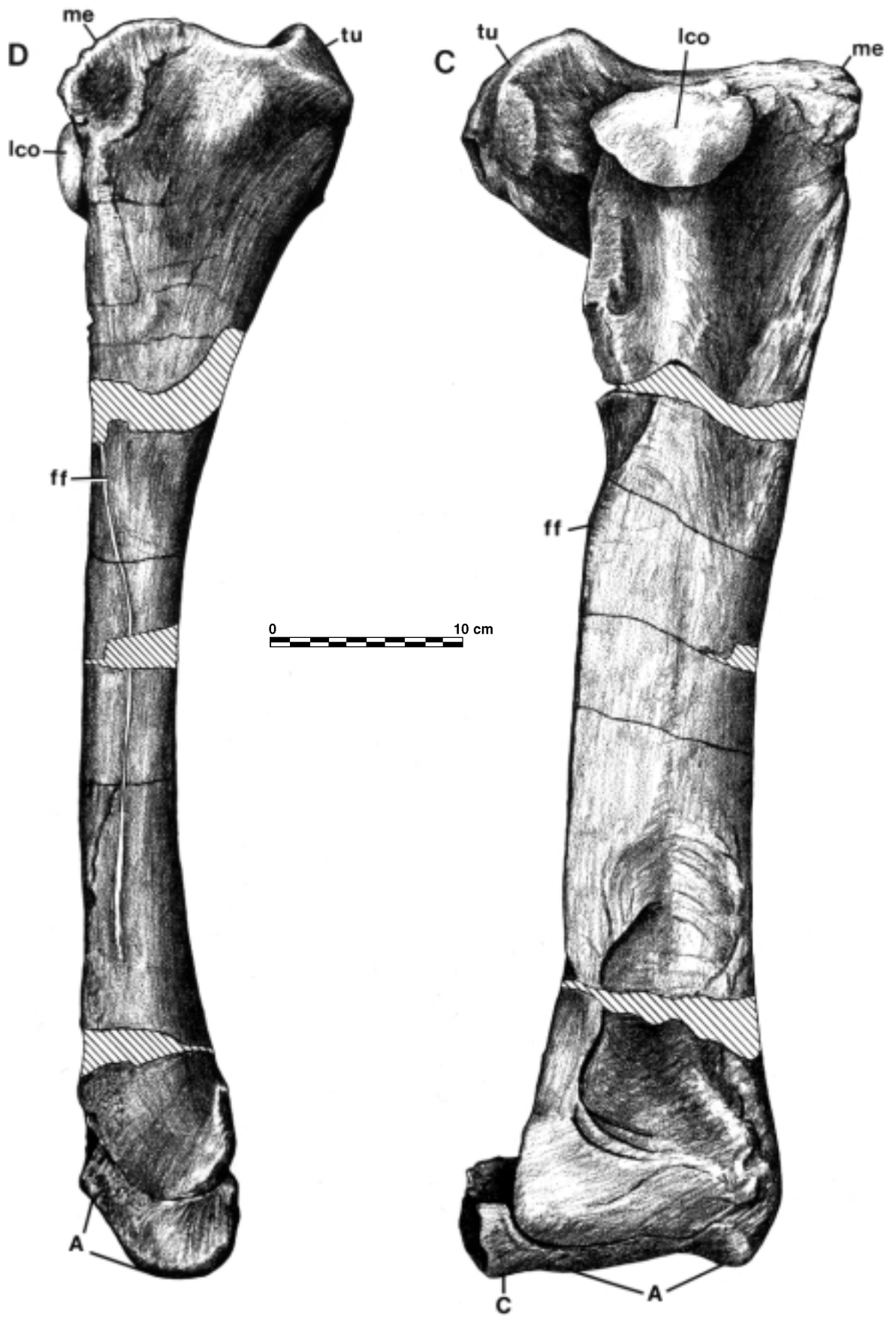
Plate 21 (continued)



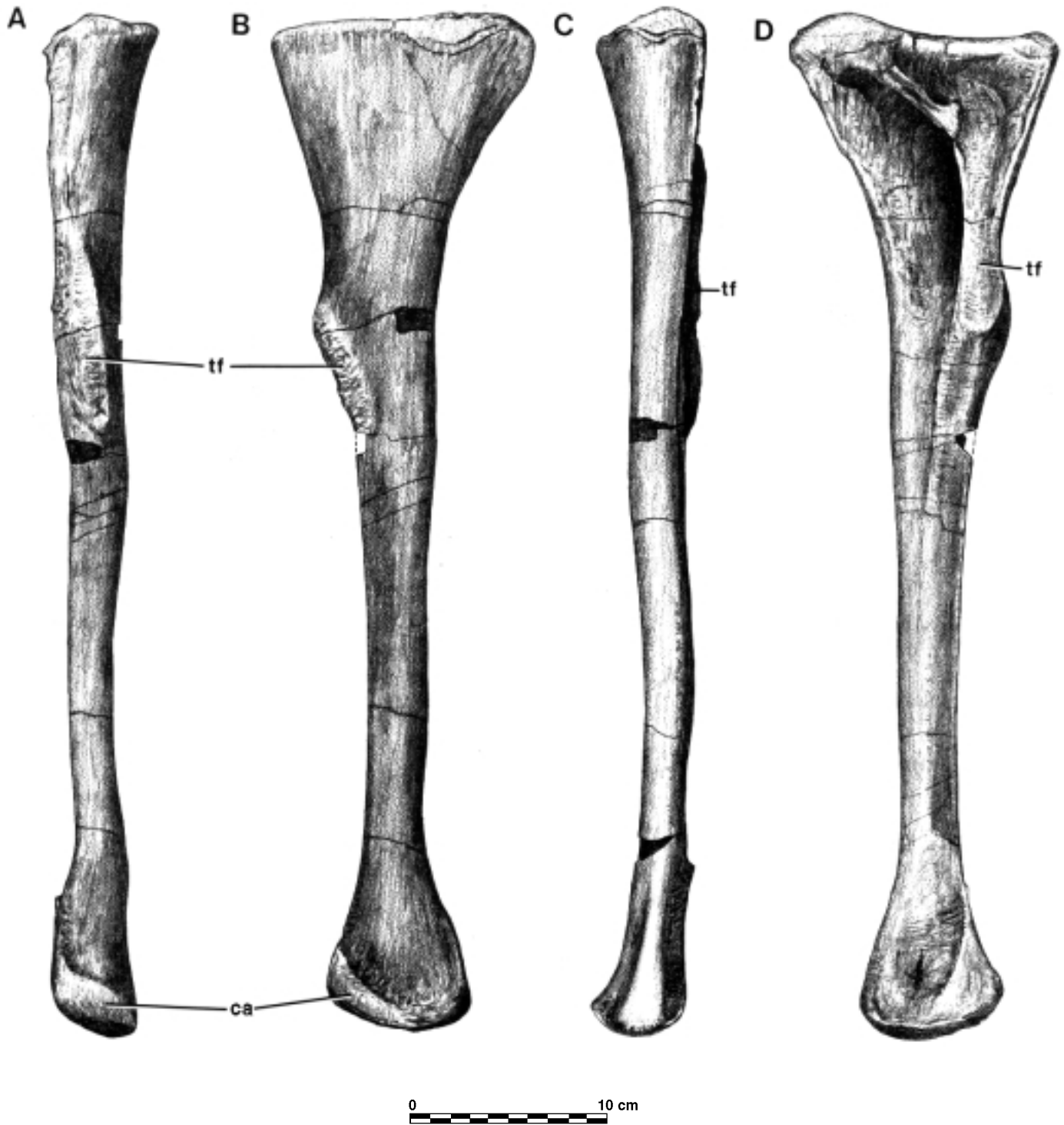


**Plate 22.** *Ceratosaurus dentisulcatus*, n. sp., holotype. Left tibia, UUV 5681, in anterior (A), lateral (B), posterior (C), and medial (D) views. A, astragalus; a, astragalus overhang; ap, ascending process; C, calcaneum; ff, fibular flange; lco, lateral condyle (ectocondyle); me, medial condyle (endocondyle); ppl, postfibular plate; tu, tuberosity. Scale: one-third natural size.

Plate 22 (continued)







**Plate 23.** *Ceratosaurus dentisulcatus*, n. sp., holotype. Right fibula, UUVP 56, reversed for left side illustration in anterior (A), lateral (B), posterior (C), and medial (D) views. **ca**, contact with calcaneum; **tf**, tibial flange. Scale: one-third natural size.