Proceedings of the 5th Symposium of the Society of Avian Paleontology and Evolution, Beijing, 1-4 June 2000

Zhonghe Zhou and *Fucheng Zhang*

Editors

Science Press
Beijing, China

Proceedings of the 5th Symposium of the Society of Avian Paleontology and Evolution, Beijing, 1-4 June 2000

Zhonghe Zhou and *Fucheng Zhang*

Editors

Science Press

Beijing, China

Responsible Editor: Xiaochun Hu

Published by Science Press
http://www.sciencep.com
16 Donghuangchenggen North Street
Beijing, 100717
P.R.China

Printed in Beijing

ISBN 7-03-010551-6/P · 1338

Foreword

The fifth International Meeting of the Society of Avian Paleontology and Evolution and the Symposium on Jehol Biota were held at the Institute of Vertebrate Paleontology and Paleoanthropology of the Chinese Academy of Sciences (IVPP) in Beijing during 1-4 June 2000. I have been very pleased to learn that nearly all the participants I have met either at the meeting or afterwards regarded it as a successful one. First, I would like to take this opportunity to thank all the participants for their attending of the meeting as well as the various supports they had provided. Second, I wish to congratulate all members of the organizing committee for doing an excellent job in organizing a stimulating symposium, with a concurrent mini-exhibition of Chinese Mesozoic birds and the Jehol Biota, and further and probably the most impressive to many, a pre-meeting field trip to western Liaoning, where many people had experienced, for the first time in their whole life, the live excavation of a Mesozoic bird (*Confuciusornis*) at the famous Sihetun locality.

In the past decade, many interesting early birds have been discovered around the world, and particularly in northeast China. These finds and their studies have greatly improved our understanding of such issues as early evolution of birds and their flight. They have also furthered the discussion of the Mesozoic stratigraphy and biological diversity of this critical stage of the earth history. The discoveries of many small-sized theropod dinosaurs with feather-like integuments from the same horizon of *Confuciusornis* have stimulated the discussion on the origin of birds and brought the topic to an unprecedented high level of interest to both the scientific communities and the public. In a recent letter I received from Peter Wellnhofer, he has kindly commented "China has become a center of avian paleontology since 1995, when you first described *Confuciusornis sanctus*." As a veteran Chinese paleornithologist, I have a lot more to be proud of: among many of others, two young paleornithologists from the IVPP have now been increasingly active and playing a major role in the studies of Chinese Mesozoic birds. They are Dr. Zhonghe Zhou, who received his Ph.D. degree from the University of Kansas with Prof. Larry D. Martin, and Dr. Fucheng Zhang who graduated from the Beijing Normal University with Prof. Guangmei Zheng, chairman of the Chinese Ornithological Society.

Thanks to the contributions from the SAPE members, and the hard work by the co-editors (Zhonghe Zhou and Fucheng Zhang), the proceedings of the fifth International Meeting of the Society of Avian Paleontology and Evolution and the Symposium on Jehol Biota is finally published. Among the 23 contributors, I would like to mention two contributors and special guests of the meeting: Prof. Dongsheng Liu, a distinguished Quaternary geologist and member of the Chinese Academy of Sciences (CAS), who has provided a fresh view on the paleoenvironment of the Mesozoic birds in western Liaoning, China; and Prof. Zhiwei Gu, a pioneer worker on the Jehol Biota and distinguished invertebrate paleontologist, also member of the CAS, who has also kindly contributed a paper discussing the age of the bird-bearing deposit in western Liaoning. I would like to express my gratitude and appreciation of their enthusiasm and support toward the avian paleontological study in China.

The meeting and the proceedings would not be possible without the support of many of our international colleagues. In particular, I would like to thank Dr. Cécile Mourer-Chauviré, former secretary of the SAPE, who has contributed as much as anybody to the organization and helped to have the fifth SAPE meeting successfully held in China.

It is my belief that with the ongoing discoveries of new fossils and the publication of this proceedings, the golden age of the avian paleontology in China will continue for many years to come. I also believe with the founding of the first Executive Council of the Society of Avian Paleontology, presided by Dr. Kenneth Campbell, as a result of the Beijing meeting, the prospect of international collaboration and exchanges among paleornithologists in the world will be more bright, and the community of avian

paleontology will grow and contribute more to the paleontological study as well as our investigation of the biological complexity and diversity in the long history of earth evolution.

Lianhai Hou
Institute of Vertebrate Paleontology and Paleoanthropology
Chinese Academy of Sciences
Beijing, China

Preface

About the meeting

The fifth International Meeting of the Society of Avian Paleontology and Evolution and the Symposium on Jehol Biota (1-4 June 2000) marked the first SAPE symposium held outside Europe and North America. The meeting drew 110 registered participants representing 17 countries. The general scientific program comprised a total of 66 oral presentations and 8 posters, as well as a half-day round-table discussion on the origin and early evolution of birds. Traditionally, SAPE does not have concurrent sessions; this tradition has generally been kept except for a half-day's concurrent session on the Jehol Biota, which contains all the known Mesozoic birds and feathered dinosaurs in China.

A pre-meeting field excursion (28-31 May 2000) in western Liaoning Province, northeast China included visits to several Mesozoic bird and feathered dinosaur localities as well as local paleontological museums. One day's in-between-meeting trips to Zhoukoudian, the locality of the "Peking Man", and the National Museum of Geology in Beijing were also arranged for the meeting participants.

All 83 submitted abstracts were published in a special issue of the journal of *Vertebrata PalAsiatica* (2000: 38 suppl.), which also includes a field guide for the pre-meeting field trip. During the meeting in Beijing, a mini-exhibition of the Jehol Biota highlighting the recent discoveries of Mesozoic birds and feathered dinosaurs in China was displayed. A traditional SAPE auction was also successful as in the past thanks to the generous donations of the SAPE members. Two routes of a week long post-meeting travels were also provided for some participants to northern China and the southwestern China, respectively.

At the business meeting, the first Executive Council of the Society of Avian Paleontology was elected, with Dr. Kenneth Campbell as the president, Per Ericson the vice president, Gerald Mayr the secretary, and David Steadman the treasurer. The Executive Council comprises 7 members at large: Herculano Alvarenga, Walter Boles, Andrzej Elzanowski, Helen James, Alexander Karkhu, Claudia Tambussi and Zhonghe Zhou.

The Beijing meeting was extensively covered by both national and international media, reflecting the increasing impact of both the Chinese paleontology and the SAPE. Both *Nature* (2000: 405, 992; 406, 930-932) and *Science* (2000: 288, 1721) also published meeting reports highlighting the meeting's achievements while expressing their concerns over the issue of the illegal trading of Chinese fossils. One of the good news for all of us at the meeting was that the infamous composite '*Archaeoraptor*' specimen that had been smuggled to the United States was successfully repatriated to China right before the meeting thanks to the efforts of Mr. Stephen Czerkas, the National Geographic Society, and many of our respectable international colleagues.

In summary, it was both an honor and a challenge for us to host the first SAPE symposium in the new millennium. On behalf of the organizing committee, we can now proudly conclude that we have achieved more than we could have imagined, and some of them will be recorded in the history of the society: the attendance of the meeting exceeding that of previous meetings, the initiation of the Executive Council of the SAPE, pre-meeting field trip, post-meeting travels, official publications of the abstracts, and coverage of the meeting by such prestigious journals as *Nature* and *Science*.

About the proceeding

In this proceeding we have included 23 contributions with a wide range of interesting topics. In general, we try to keep the tradition of the SAPE proceedings in terms of format. All manuscripts were peer-reviewed by at least one and in most cases, by two or more referee(s).

However, we would like to express our regrets for the slight delay and changed avenue in its publication for various logistic reasons. Although it deviates from being published in the traditionally

established, peer-reviewed series publication, the proceeding is peer-reviewed and published with the same high standard by the Science Press of China, the most prestigious scientific publishing house in China and the publisher of *Vertebratea PalAsiatica*.

Acknowledgments

There are a lot more people who have contributed to the success of the meeting than we can possibly list here.

First of all, we thank Drs. Cécile Mourer-Chauviré and Storrs Olson who are mainly responsible for the selection of Beijing in hosting the 5th SAPE symposium, and Dr. Zhuding Qiu, the former director of the IVPP, for agreeing to have this meeting at the IVPP. Prof. Lianhai Hou had initially proposed the meeting in Beijing; we owe a great deal to him for this as well as his Foreword for the proceedings.

We wish to thank the members of the organizing committee: Meemann Chang, Peiji Chen, Fan Jin, Lianhai Hou, Qiang Ji, Jinlin Li, Yuanqing Wang and Zhonghe Zhou. In particular, we would like to thank Dr. Meemann Chang for being the chair of the organizing committee.

Many people have been involved in the organizing activities. Among them, we would like to specially mention the following individuals: Dr. Xiaolin Wang, the chief leader of the pre-meeting field excursion, did an excellent job in leading the trip that many participants regarded one of the most exciting field trips in their careers; Mss. Yi Zhang, Huilin Wu and Yonghong Zhang were the key staff members responsible for the registration, social activities, and logistics of the meeting, and largely through their efforts the meeting afforded to cover several international colleagues' costs of attending and waive the registration fees for several needy attendants: Xing Xu, Yuan Wang, Jiangyong Zhang and Hailu You were also the pre-meeting field trip leaders, their professional work have been highly commended by the participants. Yuan Wang also helped to set up a mini-exhibition of Mesozoic birds and the Jehol Biota during the meeting in Beijing.

We would like to thank Drs. Luis Chiappe and Jose L. Sanz for organizing and coordinating a very successful and stimulating symposium on "Feathered vertebrates form the Mesozoic of China: implications for the origin and early evolution of birds" as well as a round-table discussion. We also wish to thank all the invited speakers at the symposium for contributions and participations in the round-table discussion: Luis Chiappe, Chengming Chuong, Andrzej Elzanowski, Dominique G. Homberger, Lianhai Hou, Shu' an Ji, Richard Prum, Armand de Ricqles, Jose Luis Sanz, Johann Welman, Xing Xu and Fucheng Zhang.

Prof. Peiji Chen and Dr. Fan Jin coordinated and chaired the Jehol Biota symposium. Dr. Storrs Olson chaired the business meeting. Several people who chaired one of the other scientific sessions at the meeting were: Ken Campbell, Per Ericson, Anusuya Chinsamy-Tur, Andrzej Elzanowski, Cécile Mourer-Chauviré, Storrs Olson, Paul Sereno, and Zhonghe Zhou.

Mr. David Burnham was the auctioneer of the traditional SAPE auction, which proved to be a success as usual. Dr. Desui Miao provided invaluable helps during various stages of the meeting.

We would also like to thank the local government of Chaoyang and Jinzhou cities for making extraordinary efforts to ensure the success of our pre-meeting field excursion. In particular, we are grateful to the Chaoyang City government for a splendid evening performance for all the guests of the meeting. Many of the local officials were involved in the organizing activities, among them, we wish to pay our special regards to Mrs. Xiaokun Chen, Mochen Li, Hongxi Sun, Shusheng Gao, Wanlian Zhang, and Mss. Guichun Wang and Jing Zhang for their great passion and assistance with the meeting. We are also grateful to three local museums: Wenya Museum (Mr. Wenya Du), Yizhou Museum (Mr. Haichen Bo) and Beipiao Museum (Mr. Yibin Zhao) for their hospitality.

The Beijing meeting was supported by the National Natural Science Foundation of China, the Special Funds for Major State Basic Research Projects of China (G2000077700), and the Chinese

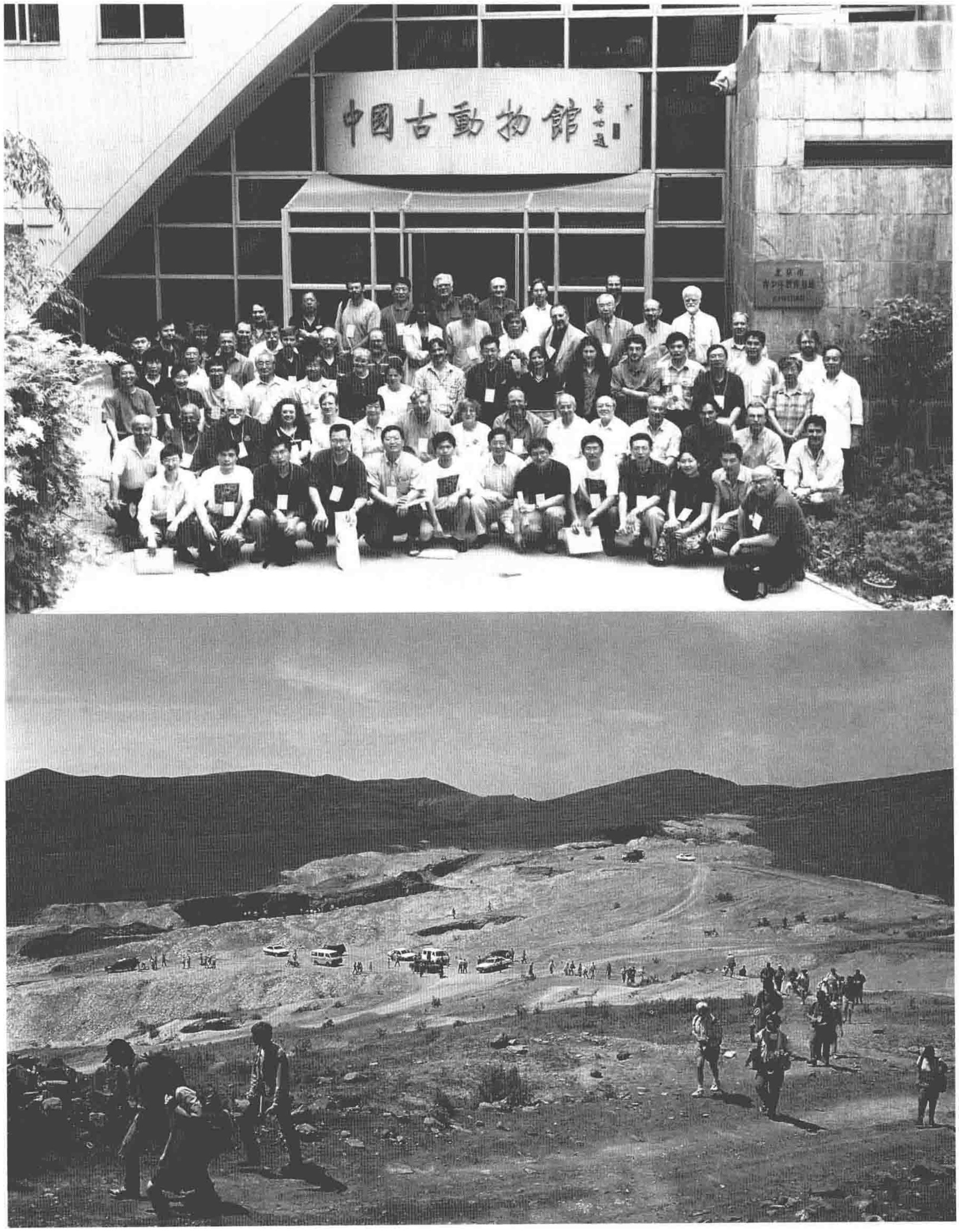
Academy of Sciences. The Jurassic Foundation also kindly provided support for the meeting, for which we are especially grateful to Dr. Phil Currie.

We thank Mr. Rex Dalton of *Nature* and Mr. Dennis Normile of *Science* for their extensive and timely reports of the meeting. We also wish to pay special respect to Mr. Dalton for his series of reports on the illegal fossil trading that has perplexed Chinese paleontology for years, his reports undoubtedly have helped to raise the awareness of international scientific community.

Dr. Min Zhu, director of the IVPP and Dr. Junshe Dong, deputy director of the IVPP, showed a strong support for the meeting. For the publication of the abstracts, we owe a lot to Prof. Jinlin Li and Ms. Liqun Shi of the *Vertebrata PalAsiatic* for their assistance. Many more people from the IVPP assisted with the meeting in different ways: Huaquan Shou, Yan Li, Qiang Li, Yushan Sheng, Min Liu, Liliu Wu, Yulong Huo, Zhao Wang, Wenhua Du, Weimin Zhen, and Jie Zhang.

Finally, we thank the following people for reviewing one or more manuscripts submitted to this proceedings: Ken Campbell, Sankar Chatterjee, Luis M. Chiappe, Joel Cracraft, Per Ericson, James Farlow, Alan Feduccia, Sylvia Hope, Louis L. Jacobs, Helen Jame, Martin Lockley, Larry D. Martin, Gerald Mayr, Cécile Mourer-Chauviré, Storrs Olson, Rick O. Prum, Kyle McQuilkin, Jose L. Sanz, John R. Stewart, Tommy Tyrberg, Xiaolin Wang, Lawrence Witmer, and Zhonghe Zhou

Zhonghe Zhou and Fucheng Zhang
Institute of Vertebrate Paleontology and Paleoanthropology
Chinese Academy of Sciences
Beijing, China



Proceedings of the 5th Symposium of the Society of Avian Paleontology and Evolution, Beijing, 1- 4 June 2000. The participants (top) and pre-meeting excursion at the Sihetun locality (bottom). Photograph by Jie Zhang.

Contents

Controversial Birds

Form and Function

Feather and Flight

Species and Evolution

Paleogeography and Stratigraphy

A New Teratorn (Aves: Teratornithidae) from the Upper Pleistocene of Oregon, USA

***Kenneth E. Campbell, Jr.* and *Alison T. Stenger*[1]**

Natural History Museum of Los Angeles County, 900 Exposition Boulevard, Los Angeles, California 90007 USA; email: kcampbel@nhm.org
[1] Institute for Archaeological Studies, 4235 S.W. Westdale Drive, Portland, Oregon 97221. USA

Abstract

An associated partial skeleton recovered from a paleo-/archaeological test trench in the Willamette Valley is the first record of the family Teratornithidae from the state of Oregon. Recovered elements include both cranial and postcranial bones and a number of vertebrae. The elements fall with the range of size variation of *Teratornis merriami* from Rancho La Brea, California, but they have several unique features that indicate that they represent a new species of teratorns. The inferred age of the specimen is approximately 12,000 yrBP, and it is associated with archaeological and micro- and megafaunal remains. *Teratornis* have not previously been reported from north of central California, although they have been reported from as far east as Florida. Based on their large wingspans, which were in excess of 4 m, teratorns have been interpreted as primarily birds of semi-open terrain where they would not have had trouble maneuvering. From this it may be inferred that such habitats were available in the Willamette Valley 12,000 years ago. The only other reported occurrence of teratorns in proximity to archaeological remains is at Rancho La Brea, California.

Introduction

Buried bogs dating from the late Pleistocene are common in the Willamette Valley of Oregon, and they have been known to produce fossils for over 150 years (Orr and Orr, 1999). The Woodburn Bog is one of these fossiliferous bogs, and it comprises a buried network of ancient wetlands within the City of Woodburn, Oregon. The flood plain of the Mill Creek drainage, a seasonal tributary of the Willamette River, commonly overlies the Woodburn Bog (Balster and Parsons, 1968). Sewer line construction near Mill Creek close to Woodburn High School in the 1950's resulted in the discovery of Pleistocene megafaunal remains, and similar excavations in 1987 produced additional fossils. These finds, along with other reported finds along Mill Creek, prompted the City of Woodburn to initiate the Woodburn Paleo-Archaeology Project in 1996 to ensure minimal impact on other remains by future utility construction. This project was undertaken by the Institute for Archaeological Studies, in conjunction with Oregon State University and the

Condon Museum of Geology, University of Oregon. A completely unexpected discovery in the course of this project was an associated partial skeleton of a new species of teratorn.

Material and Methods

The Woodburn Paleo-Archaeology Project tested four sites in the Mill Creek flood plain, all on undeveloped land and at elevations of 45-50 m above mean sea level. Auger probes to 5± m depth were used to determine site stratigraphy. These tests were then followed by trench excavation at three sites (Mammoth Park, Legion Park, and Stafek; Fig. 1) using a backhoe. Hand excavation and direct inspection of the stratigraphic profiles were prevented by a high water table and slumping. However, expert trenching work and careful separation of stratigraphic horizons did allow for minute scrutiny of all sediments removed from the trenches. The stratigraphy at all of the sites proved to be similar, and all of the sites produced both fossil vertebrates and archaeological remains. The oldest beds producing remains have been ^{14}C dated to >12,000 yrBP.

The Legion Park site produced the teratorn remains reported on here. Field tests at this site were first undertaken in 1999, and included nine auger probes and three trenches. The first two trenches, A and B, were at opposite ends of the site, approximately 226 m apart. Trench C, from which came the teratorn, was

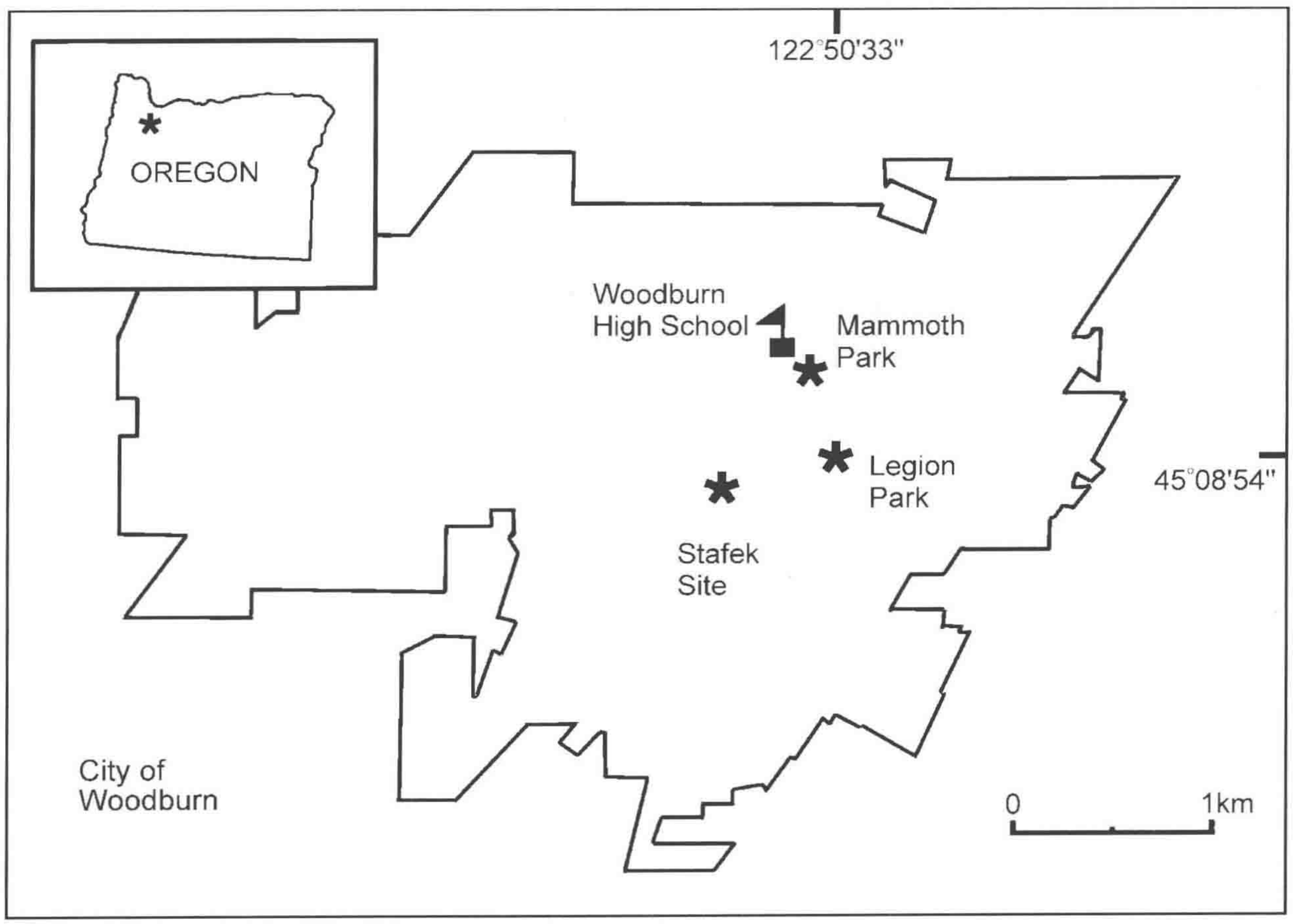


FIGURE 1. Map of the City of Woodburn showing the location of the three sites trenched during the 1999 Woodburn Paleo-Archaeology Project. Inset map shows state of Oregon, with location of City of Woodburn indicated by asterisk.

near the middle of the site, and it was about 2 m long by 1 m wide. This trench collapsed during excavation and was immediately backfilled with non-productive higher-level strata while the samples of extracted older strata were being examined for remains. The collapse was fortuitous because it brought a halt to the backhoe work after enough of the teratorn had been brought up to indicate that there was a good possibility that an entire associated skeleton was present, but before the specimen had actually been detected in the sediment. A return excavation in July 2000, however, failed to recover additional remains.

Except for being broken in excavation, the bones of the Woodburn teratorn are in good condition, with excellent preservation of osteological characters. Elements of the new specimen were compared with those of *Teratornis merriami* Miller, 1909 in the extensive collections from Rancho La Brea housed in the George C. Page Museum of La Brea Discoveries, a branch of the Natural History Museum of Los Angeles County. In the course of this work several specimens in the La Brea collections were identified as belonging to the second, little known teratorn species from that site, *Cathartornis gracilis* Miller, 1910.

Osteological terminology is primarily from Baumel (1993) and Howard (1980). Measurements were taken with dial calipers accurate to 0.05 mm.

Systematic Paleontology

Class Aves

Order Ciconiiformes

Family Teratornithidae Miller, 1909

Genus *Teratornis* Miller, 1909

Teratornis woodburnensis n. sp.

Holotype Partial skeleton of one individual, including right and left quadrates, right pterygoid, right palatine, partial left and right mandibular rami, anterior end of sternum, almost complete left humerus, distal end of right tibiotarsus, and axis, 3rd, 9th-11th, 13th cervical and 3rd thoracic vertebrae; Condon Museum of Geology, University of Oregon, catalogue number F36468.

Diagnosis The specimen is diagnosed as a member of the family Teratornithidae by the enlarged great tuberosity on anterior face of bicipital crest of the humerus and the tall, thin Pars intermediae of the Rami mandibulae that bear anterior suture scars. It agrees with *Teratornis*, and differs from *Cathartornis*, by having humerus with caput humeri more rounded proximally and less set off ventrally, in anterior view; facies bicipitalis more deeply channeled; epicondylus ventralis more pronounced and more angular; tuberculum supracondylare ventrale more prominent, highly elevated, and angular.

The holotypical specimen differs from *Teratornis merriami* by having crista deltopectoralis with prominent ridge on anterior surface of bone, with attachment of M. pectoralis superficialis consisting of two parts: a very long, greatly elevated, proximal portion for insertion of M. pectoralis superficialis, superficial layer; and a shorter, much less elevated, but still prominent distal portion for attachment of M. pectoralis superficialis, deep layer, with elevated ridge narrowing considerably where the attachment scars for deep and superficial layers meet, but with no hiatus between the two (proximal elevated portion shorter and distal elevated portion longer in *Teratornis merriami*, with a hiatus between the attachment scars associated with the two areas); great tuberosity on anterior face of bicipital crest long, at less of an angle to long axis of shaft, in ventral and anterior view; epicondylus ventralis prominent, less rounded, maximum ventral extension positioned distal to tuberculum supracondylare ventrale (not positioned quite as far distally in *T. merriami*); epicondylus dorsalis extending farther dorsad, less rounded. Tibiotarsus with condylus lateralis, in anterior view, at a greater angle to long axis of shaft, with antero-proximal corner protruding more laterad; in distal view, not protruding as far anteriad, giving more flattened appearance. Ossa quadratum with processus oticus with medial portion, or pars squamosum, extending farther dorsad, and with condylus squamosum larger, longer, and more bulbous at medial end.

Type Locality Legion Park, City of Woodburn, Oregon. Lat. 45° 08' 54" N; Long. 122° 50' 33" W; University of Oregon locality number UO3038 (Fig. 1).

Type Horizon and Age Stratum 4 (= uppermost, transitional horizon capping Willamette Silts) of the Woodburn Bog deposits (Fig. 2); at an approximate depth of 2.8-3.0 m below the surface. The stratigraphic record at the three trenched sites in the Mill Creek

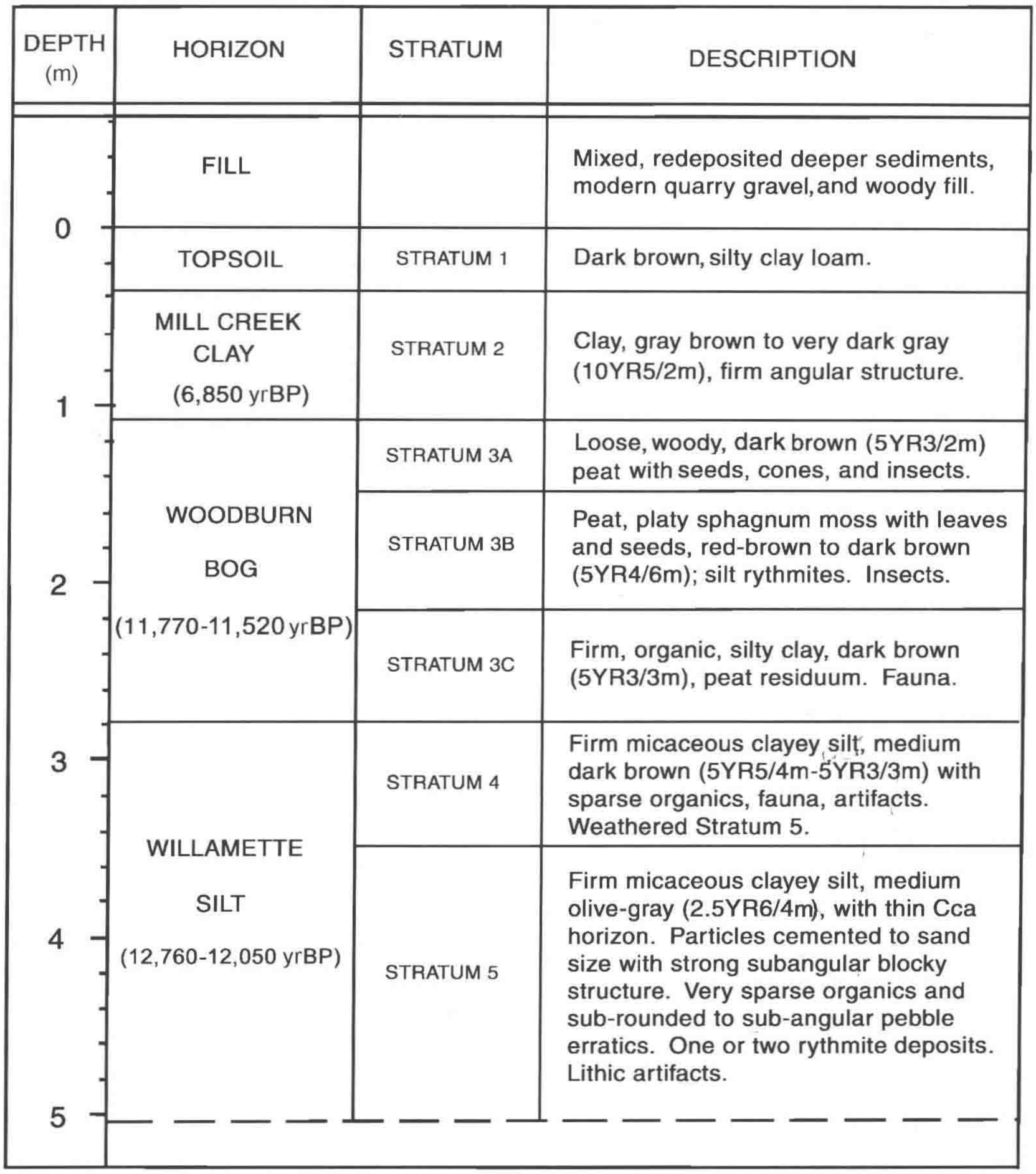


FIGURE 2. Chart showing the interpretation of the stratigraphy at Legion Park, the type locality for *Teratornis woodburnensis* n. sp. The stratigraphy at this site is comparable to that at the other two sites in Woodburn that were trenched in 1999.

floodplain spans the Pleistocene-Holocene boundary (Fig. 2). The Willamette Silts (Stratum 4 and Stratum 5), which were deposited by the last episode of the late Pleistocene Bretz floods (Balster and Parsons, 1968; Allen, 1986), comprise the base of the section exposed. The excavations did not reach the base of these silts. Stratum 4 is the uppermost, transitional horizon of the Willamette Silts. An organic silty clay, it appears to represent a period of weathering of the original deposit, with only light accumulation of sediment.

The teratorn specimen itself has not been dated, but an age of approximately 12,000 yrBP is inferred based on a ^{14}C sediment date from the deep part of Stratum 4 at the Legion Park site (12,050±50; Beta

146470). At the Mammoth Park site, sediment from Stratum 4 has been ^{14}C dated to 12,200 ± 100 yrBP (Beta 96399). Stratum 4 is also bracketed by older dates on Stratum 5 samples from the Mammoth Park (12,310 ± 80 yrBP; Beta 96400) and Stafek (12,760 ± 110 yrBP; Beta 133022) sites and younger dates on Stratum 3 samples at Legion Park (11,520 ± 70 yrBP; Beta 136265) and the Mammoth Park site (11,770±70 yrBP; Beta 96403).

Etymology This species is named for the city in which it was found, Woodburn, Oregon.

Collector Collected by Alison Stenger, Charles Hibbs, and William T. Orr on 29 September 1999.

Description In addition to the diagnostic characters listed above, the following comparative descriptive comments illustrate differences from comparable features in *Teratornis merriami*. The size of the comparative sample is different for each bone because of differential preservation of fossils at Rancho La Brea. For those elements with only a small number of comparative bones the diagnostic value of the characters listed below is unknown.

Ossa quadratum Right and left, complete, except for procesus orbitalis (Fig. 3). Corpus ossis quadrati more lightly built overall. Sulcus pneumaticus less excavated, with small, as opposed to large, foramen pneumaticum. Condylus lateralis narrower antero-posteriorly, with lateral portion extending farther posterolaterad relative to medial portion, in ventral view, and with medial flange at a greater angle to long axis of bone and not extending as far ventrad, in posterior view, which gives a shallower "saddle" between the lateral and medial portions of the condylus lateralis. Condylus oticum shorter along long axis; more bulbous, particularly on external end, where its facies articularis extends farther ventrad. Incisura intercondylus narrower. Condylus pterygoideus slightly convex at anterior end, much more convex at posterior end (variable in *Teratornis merriami*, from slightly concave to moderately convex). Comparative material consisted of 5 left and 5 right quadrates of *T. merriami*.

Measurements (mm; *T. merriami* in parentheses): Right and left quadrates in that order; not separated to side for *T. merriami*. Length through condylus medialis and medial portion of condylus lateralis, 25.7, 25.3 (24.5-27.1, $\bar{x}$ =25.9, n = 8); length through condylus lateralis, 16.4, 16.1 (15.1-17.6, $\bar{x}$ = 16.3, n = 7); height through lateral portion of condylus posterior and condylus squamosum, 31.9, 32.0 (31.0-34.0, $\bar{x}$ = 32.4, n = 8); width through condylus oticum and condylus squamosum, 18.9, 19.1 (18.1-20.0, $\bar{x}$ = 19.1, n = 8).

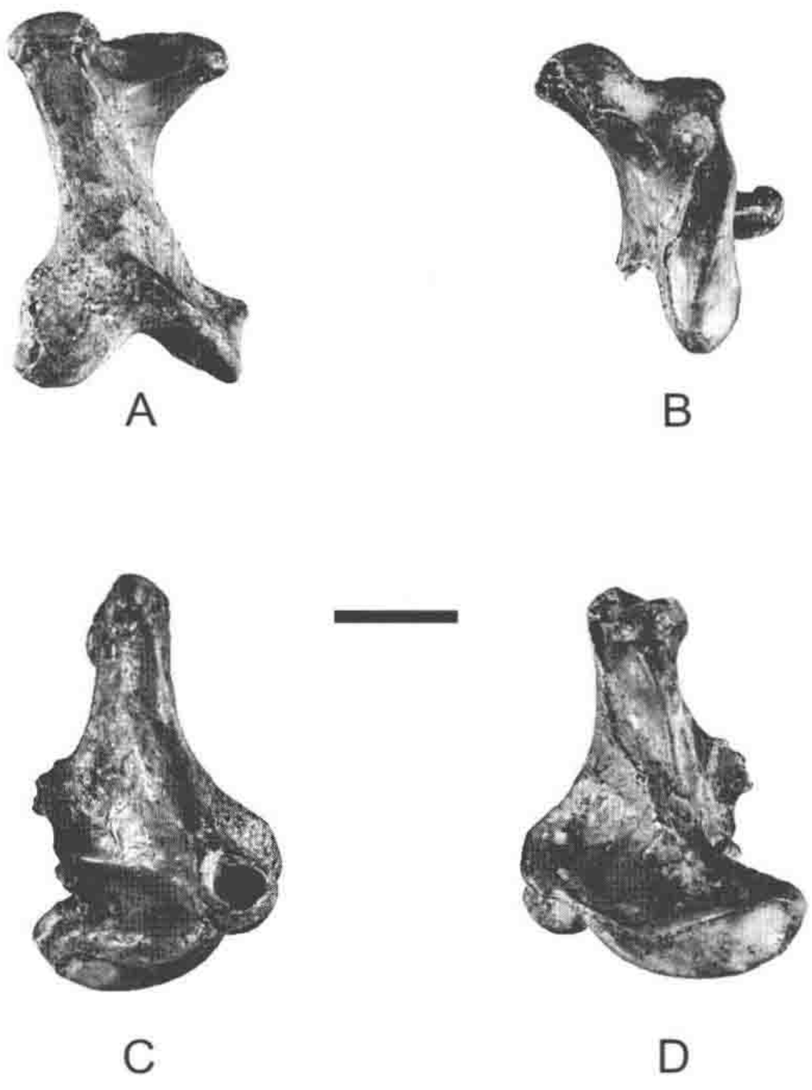


FIGURE 3. Left quadrate of *Teratornis woodburnensis* n. sp. in posterior (A), ventral (B), lateral (C), and medial (D) views. Scale bar = 1 cm.

Ossa mandibulae The mandibles of teratorns are long, thin, and blade-like, with a highly developed flexure zone where the pars posterior joins the pars intermedia. The pars symphysialis of teratorns has yet to be identified.

Ramus mandibulae, pars posterior Left, fragment (Fig. 4). This fragment consists of part of the mandible immediately posterior to the zona flexoria intramandibularis posterior, and it includes the posterior portion of the fenestra rostralis mandibulae. An overall similarity to *T. merriami* can be noted, including the dorsolateral flare of the occusal edge, but this specimen is too fragmentary to provide details. Comparative material included 8 left and 7 right specimens of *T. merriami.*

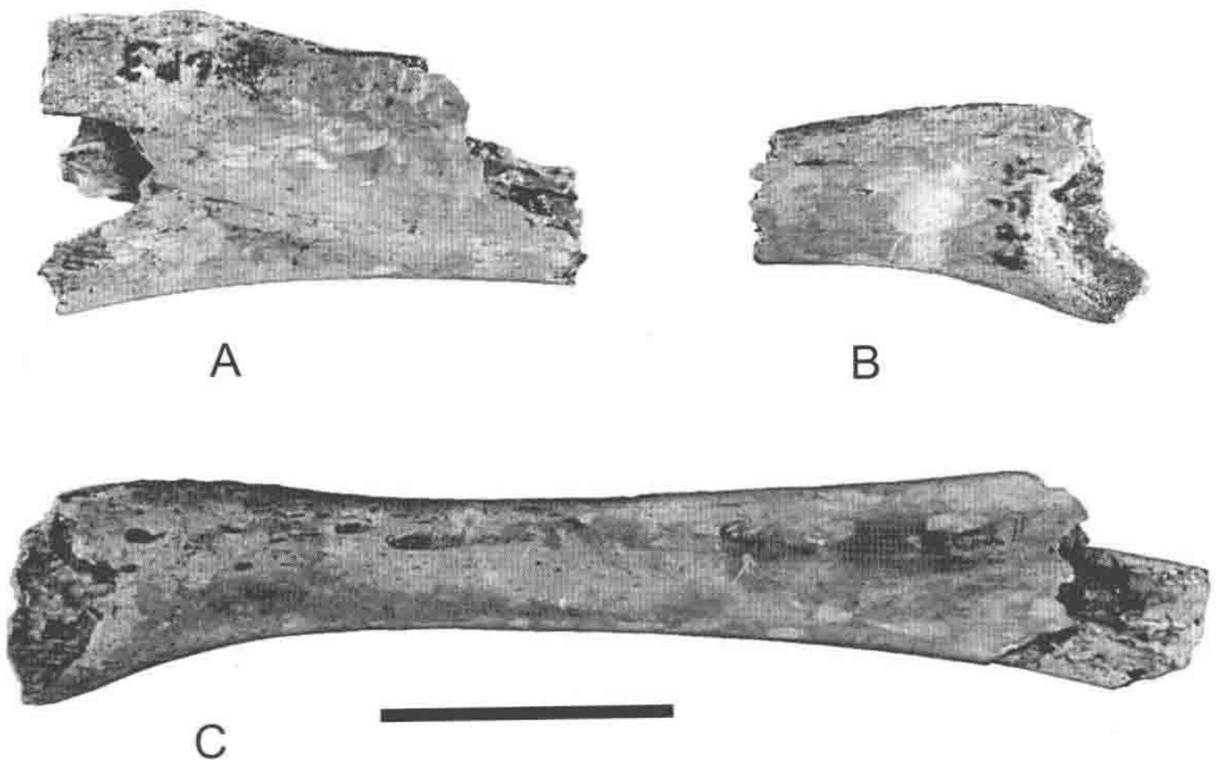


FIGURE 4. Partial mandibular rami of *Teratornis woodburnensis* n. sp. (A), anterior portion of left ramus mandibulae, pars posterior, in lateral view; (B), anterior portion of right ramus mandibulae, pars intermedia, in lateral view; (C), almost complete left ramus mandibulae, pars intermedia, in lateral view. Scale bar = 2 cm.

Measurements (mm; *T. merriami* in parentheses): Height at posterior end of fenestra rostralis, 20.1 (20.4-23.3, $\bar{x}$ = 21.3, n = 10); maximum width at posterior end of fenestra rostralis, 5.4 (4.6-6.0, $\bar{x}$ = 5.4, n = 11).

Ramus mandibulae, Pars intermedia Left, almost complete, and right, anterior end (Fig. 4). Both fragments display the typical teratorn suture zone at the anterior end. Numerous small foramina occur in the dorsolateral quadrant, and the occusal edge is roughened anteriorly. Dorsoventral depth much greater at proximal suture zone than for some distance posterior to suture zone. No characters can be noted that distinguish the pars intermedia of *Teratornis woodburnensis* from that of *T. merriami*. Comparative material included four pars intermedia of *T. merriami* in good condition and six badly worn or broken specimens.

Measurements of left specimen (mm; *T. merriami* in parentheses): Vertical height at shallowest point distal to anterior suture, 9.4 (8.1-9.1, $\bar{x}$ = 8.6, n = 4); width at shallowest point, 3.1 (3.2-4.1,$\bar{x}$ = 3.7, n = 4).

Os pterygoideum Right, complete (Fig. 5). Facies articularis quadratica larger, more rectolinear, with broad dorsal extension onto processus quadraticus (extension absent in *Teratornis merriami*, but may be a variable character); at greater angle to long axis of bone, in medial view; and more prominently set off from shaft in medial view. Processus quadraticus much broader, in dorsal view, with larger foramen in distal portion. Facies articularis basipterygoidea a shorter,

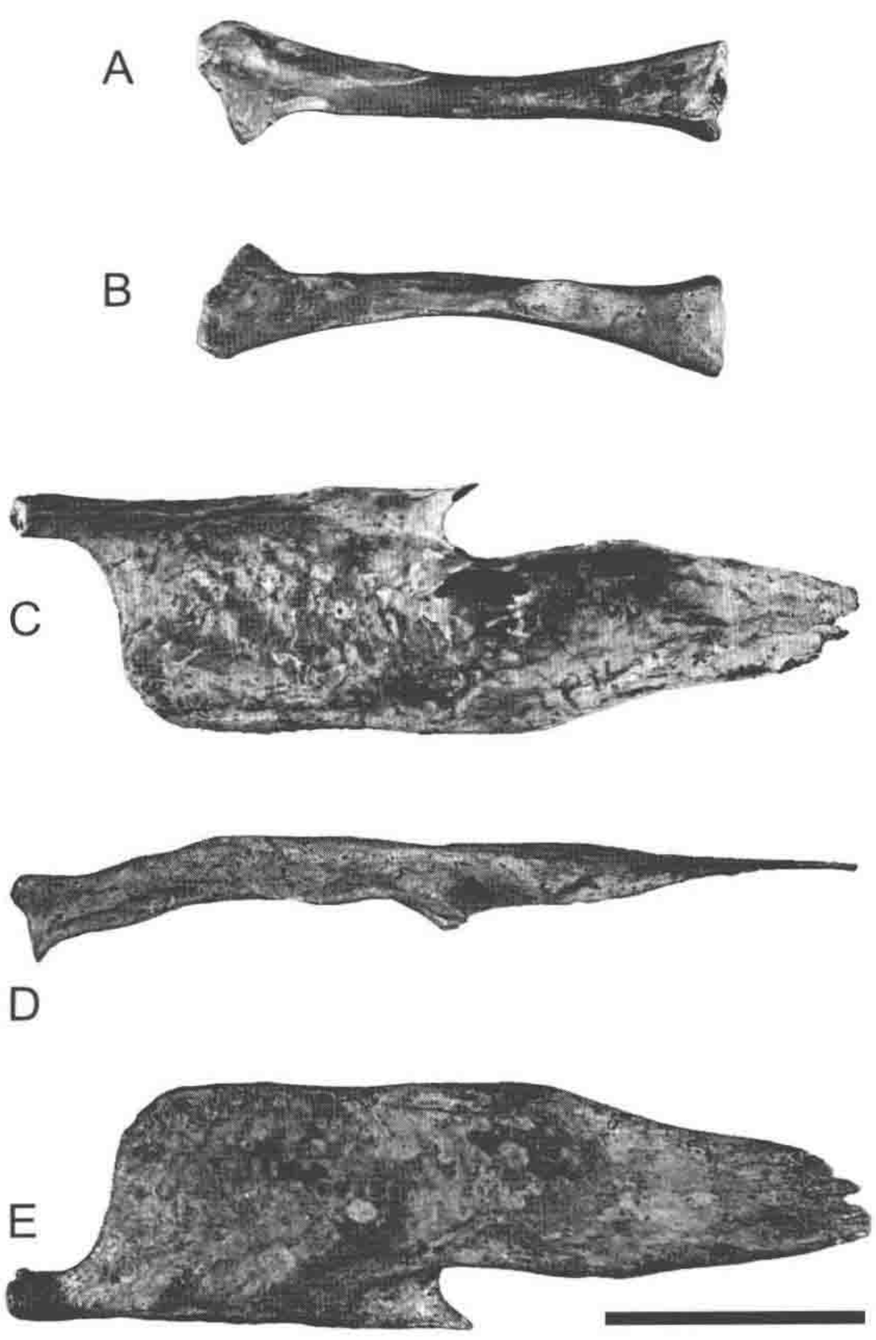


FIGURE 5. Right pterygoid (A, B) and right palatine (C-E) of *Teratornis woodburnensis* n. sp., in ventral (A, C), dorsal (B, E), and medial (D) views. Scale bar = 2 cm.