FIRST OCCURRENCE OF A HADROSAUR (DINOSAURIA) FROM THE MATANUSKA FORMATION (TURONIAN) IN THE TALKEETNA MOUNTAINS OF SOUTH-CENTRAL ALASKA

by
Anne D. Pasch [1] and Kevin C. May [1]

INTRODUCTION

The recent discovery of a hadrosaur (“Lizzie”) in the Talkeetna Mountains about 150 km northeast of Anchorage is of special interest for several reasons. It is the first known occurrence of a hadrosaur in south-central Alaska, adding a new high latitude locality (62°N) for dinosaurs (fig. 1). Lizzie is unique in that she represents the only association of dinosaur bones in Alaska that can be attributed to a single individual. A closely associated assemblage of marine invertebrates provides a reliable age of middle Turonian (early Late Cretaceous), making it one of the few well-dated early hadrosaurs known in the world. Its location in the Matanuska Formation makes it one of only four vertebrate fossils known from the Wrangellia composite terrane in south-central Alaska (fig. 2). Although dinosaur remains are uncommon in marine deposits, this hadrosaur is the second dinosaur to be found in the marine mudstones of the Matanuska Formation. The first, *Edmontonia*, a nodosaur recently described by Gangloff (1995), is of Campanian-Maastrichtian age, or at least 10 million yrs younger than the new find (fig. 3).

[1]Geology Department, University of Alaska Anchorage, 3211 Providence Drive, Anchorage, Alaska 99508-8338.

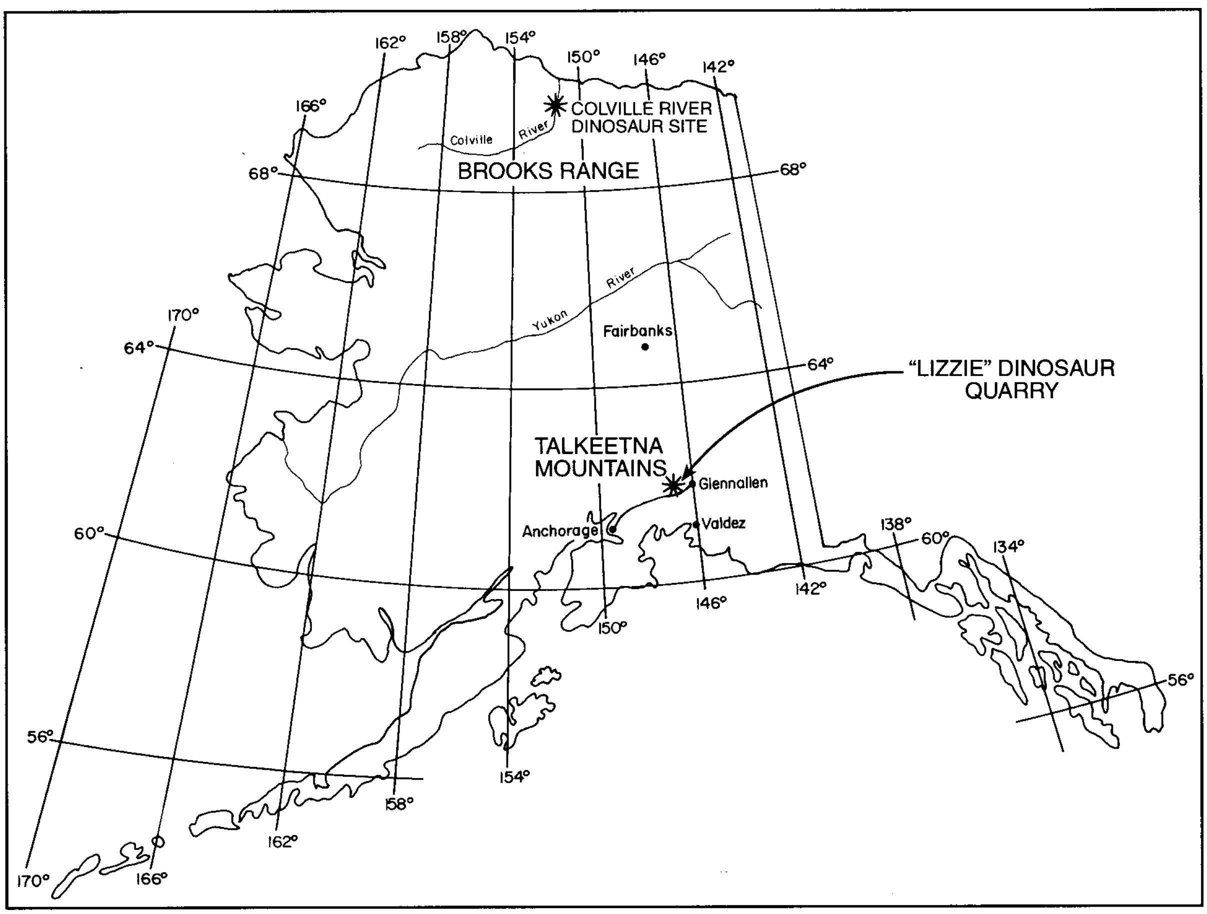

Figure 1.Map of Alaska showing location of the Lizzie quarry in the Talkeetna Mountains of south-central Alaska.

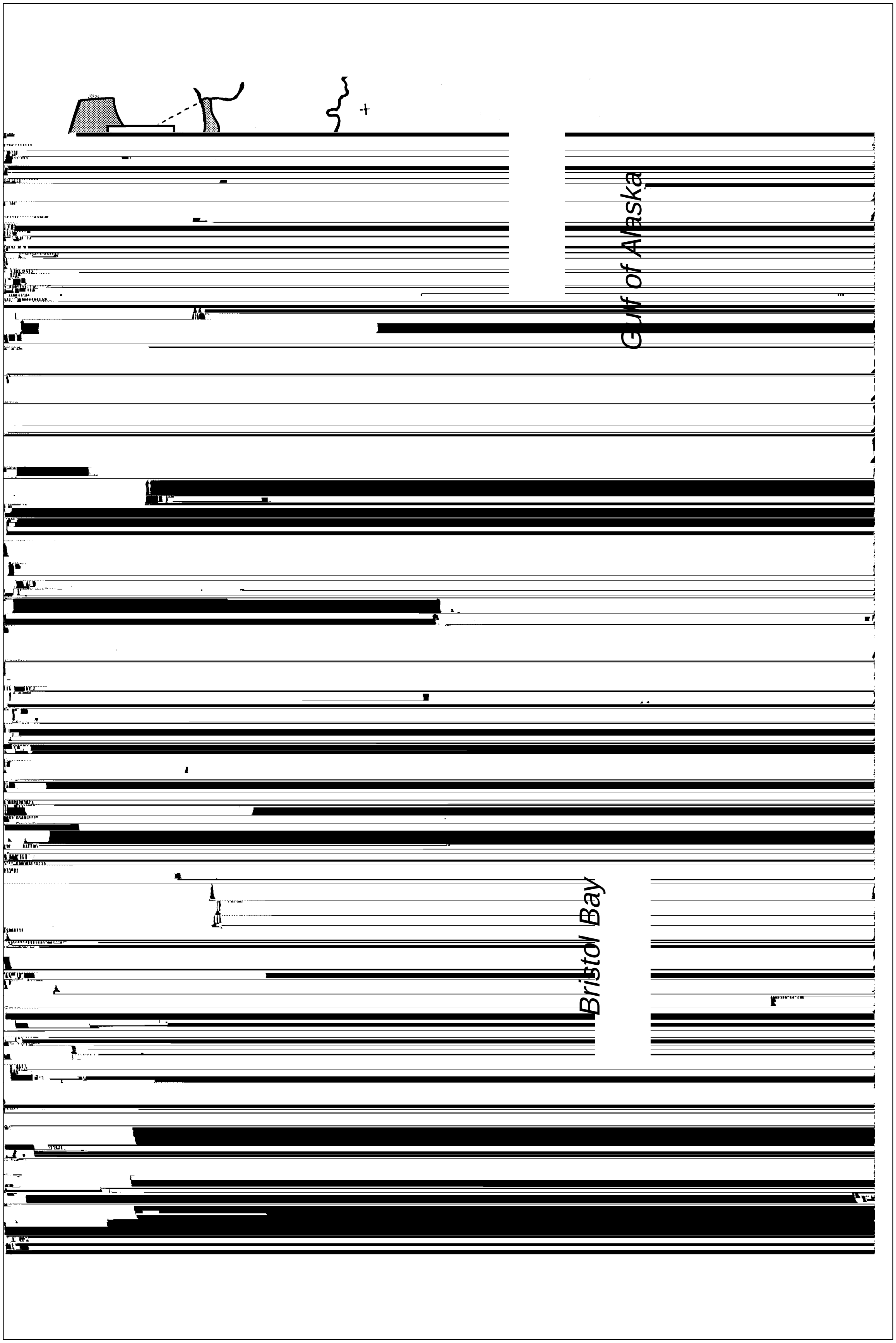

Figure 2.The four fossil vertebrate localities in the Peninsular terrane of south-central Alaska (modified from Wallace, 1992, p. 53).

BACKGROUND AND DISCOVERY

The hadrosaur fossil material was discovered by Virginia May in September 1994. Bone fragments lying in the rubble of a borrow pit led to the discovery of bone-bearing concretions in the bedrock. Centra of caudal vertebrae and distal elements of the limbs were later found in talus beneath the quarry face. During the summer of 1995 a quarry of 24 sq m was excavated. However, the main efforts were concentrated in a 4-sq-m quadrant containing a large concretion nearly 1 m long with bone fragments exposed along its edges. The alignment of the limb bones suggests that this concretion may contain pelvic bones. These would be the most diagnostic postcranial elements for identification to the generic level. Hundreds of invertebrate fossils were excavated along with the bone-bearing concretions.

Because of high public interest in this discovery, the fossil was given a popular name, Lizzie, after Kevin May's 12-yr-old daughter, who contributed many hours to the excavation project.

LOCATION AND GEOLOGIC SETTING

The privately owned borrow pit is situated in the Talkeetna Mountains in south-central Alaska near the Glenn Highway at about lat 61°52'N and long 147°21'W

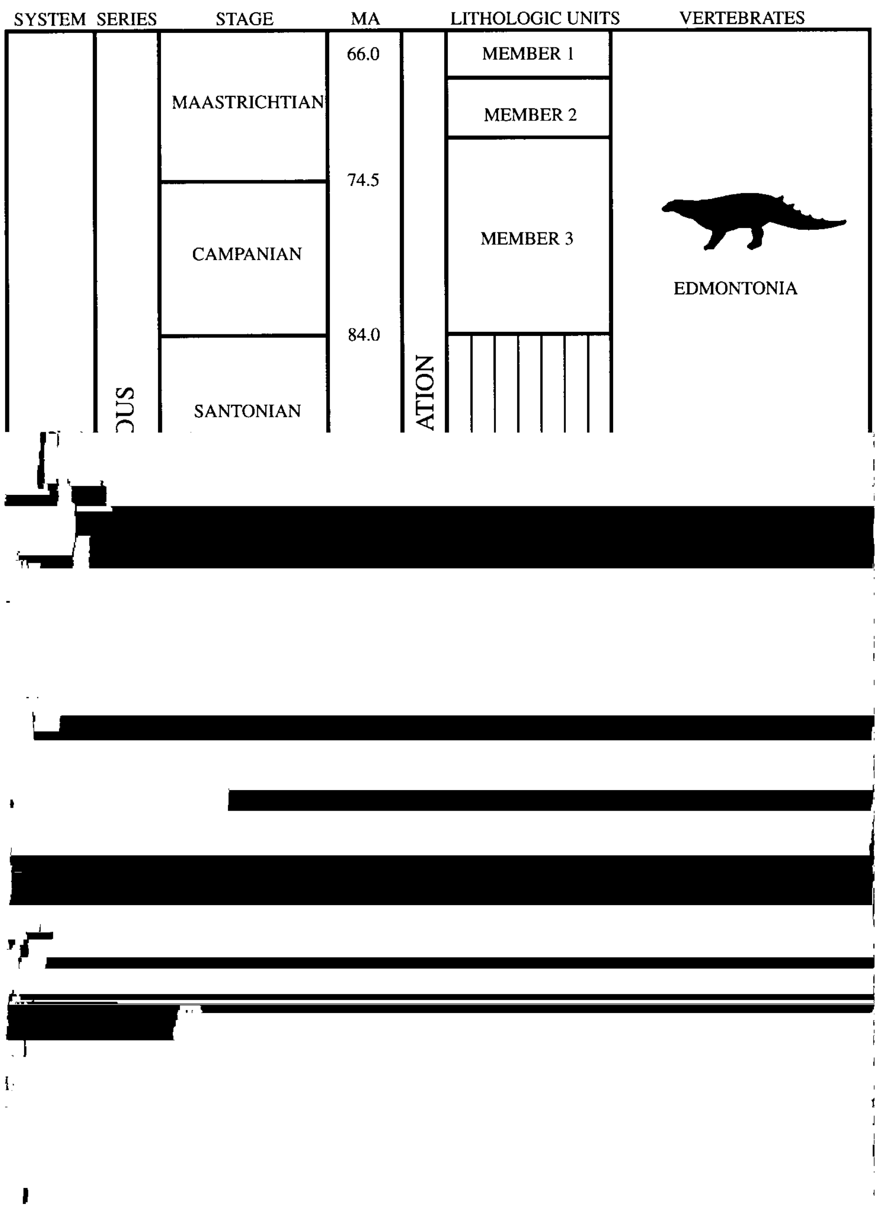

Figure 3. Schematic columnar section of the Matanuska Formation showing positions of the dinosaur fossils (from Jones, 1963; Jones and Grantz, 1967).

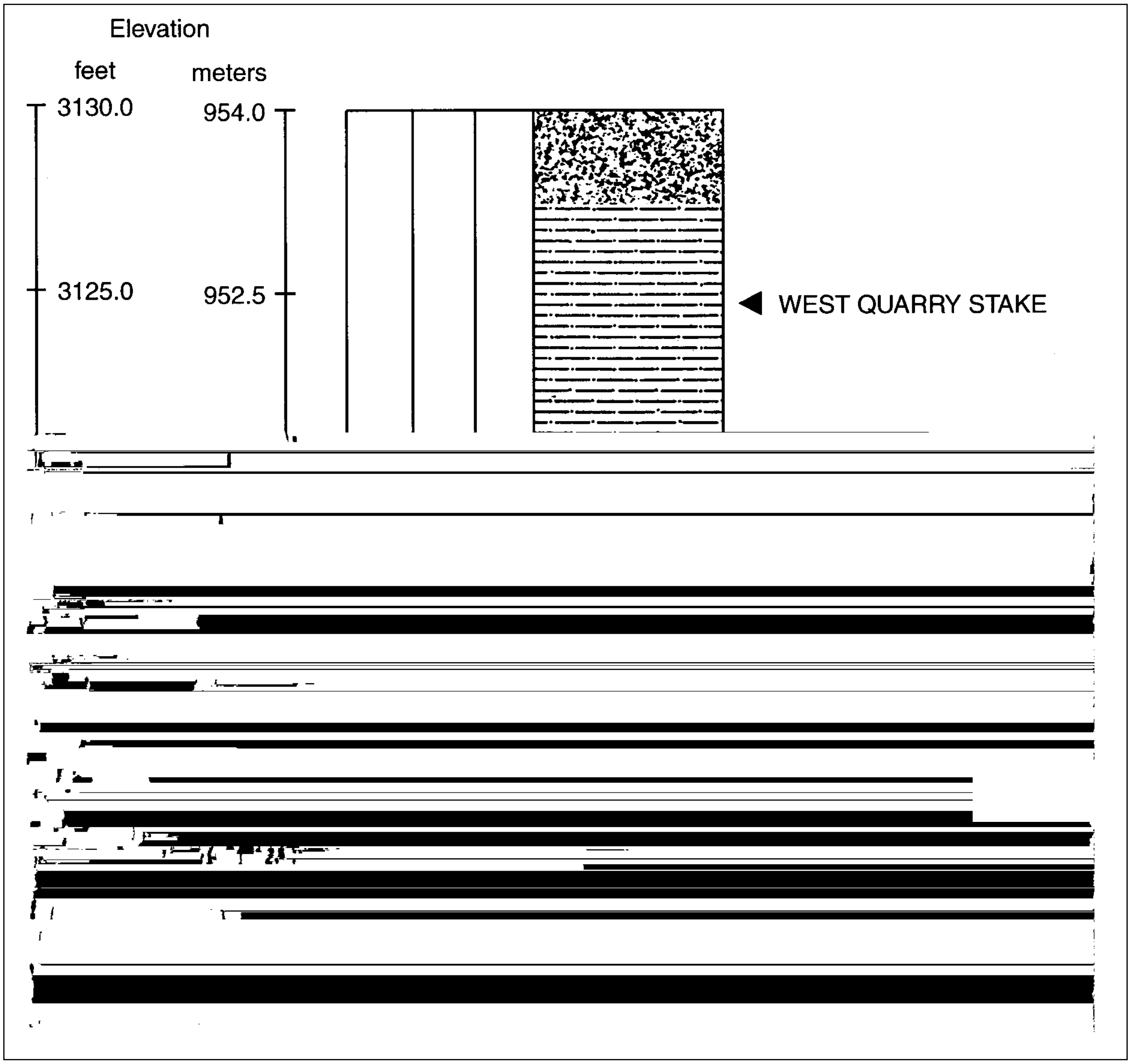

Figure 4. Stratigraphic section of the Lizzie quarry.

at an elevation of 950 m (fig. 1); the exact location is recorded at the Alaska Museum of Natural History in Anchorage. The nearest city is Glennallen.

The Mesozoic and Cenozoic sedimentary rocks underlying this region form an east-west-trending structural trough about 32 km wide and 112 km long northeast of Anchorage (Grantz, 1964). At the eastern margin of the trough Mesozoic rocks lie in an anticline that plunges to the northeast. The eastern end has been displaced along a north-south-trending fault. The Lizzie quarry lies in the Matanuska Formation on the southeast limb of the nose in the displaced part of the anticline (Grantz, 1961a, b). According to Jones and Grantz (1967) and Jones (1963), the Matanuska Formation sediments were derived from highlands to the north and deposited in a deep, subsiding, narrow trough. Their texture and mineralogy suggest deposition on a narrow shelf a few miles south of a shoreline to the north. Particles were rapidly buried and not subject to abrasion or winnowing by wave action.

The bone-bearing unit consists of an easily weathered dark-gray marine mudstone that contains highly indurated calcareous concretions and finely disseminated pyrite crystals (fig. 4). In outcrop it seems to be massive, lacking primary sedimentary features. However, fine laminations, possible ripples, and evidence of bioturbation are faintly visible on wet fresh surfaces. No rip-up clasts, graded beds, or sandstone units suggestive of classic turbidite deposits were noted at the site. The unit has been subject to postdepositional deformation as indicated by the joint sets, faults, secondary deposition of calcite, and degree of induration.

The beds in the quarry strike north; dip 22°00’ to 26°50’ east, and are cut by four joint sets. Two of the joint sets are planar and fairly well defined with steep dips of 50° to 70°; the other two are poorly defined and have undulating surfaces, one dipping steeply (40° to 89°), and one gently (6° to 35°). The latter set produces centimeter-scale offsets of the well-defined planar joints.

AGE

A well-preserved collection of fossil mollusks from the quarry provides a secure Turonian age and marine setting for the bone-bearing unit. The age was determined by Will P. Elder of the U.S. Geological Survey, who identified 7 species of ammonites, 6 species of bivalves, and 2 different gastropods. The presence of the ammonite *Muramotoceras* strongly suggests a Middle Turonian age, as this genus is known from only two species that occur in Middle Turonian sequences. This is the first noted occurrence of this unusual heteromorph outside of Japan (Matsumoto, 1977). The ammonite genus *Eubostrychoceras* is known from Japan, Germany, and Madagascar. *E. japonicum* is Turonian and probably Middle Turonian (Matsumoto, 1977). The inoceramids have a worldwide distribution and are used as guide fossils for the Late Cretaceous from the Albian through the Maastrichtian (Thiede and Dinkelman, 1977).

Other fossils include fish teeth, shark teeth, scaphopods, a solitary hexacoral, planktic forams, trace fossils, toredo-bored wood, and wood fragments. Both the lithology and the invertebrates of the bone-bearing unit strongly suggest that the quarry section belongs to the lower part of C-1, an informal stratigraphic unit of Turonian age in the lower half of the Matanuska Formation as defined by Jones and Grantz (1967), and Member 4 (Turonian), as defined by Jones (1963) (fig. 3). A comparison of fossils found in the Lizzie quarry with those in the equivalent units in the Matanuska Formation (Member 4 and C-1) is shown in table 1. Member 4 is estimated to be about 120 m thick and contains invertebrate fossils of the Indopacific faunal realm (Jones and Grantz, 1967; Matsumoto, 1988). The age of unit C-1 is based on the presence of the bivalve, *Inoceramus* aff. *I. cuvieri*, and the ammonite *Otoscaphites teshioensis* (Jones and Grantz, 1967; Jones, 1963).

PALEOGEOGRAPHY

The paleogeography of the quarry site is somewhat uncertain because of discrepancies between various models of the accretionary history of the tectonostratigraphic terranes in the southern Alaska margin. The Matanuska Formation lies within the Peninsular terrane (Grantz, 1964). In their overview of the tectonic history of Alaska, Plafker and Berg (1994) include it in the allochthonous Wrangellia composite terrane (WCT), a long narrow unit parallel to the southern curved shoreline of Alaska that lies between the Denali and Border Ranges faults (fig. 2). In both the Hillhouse (1987) and Plafker and Berg (1994) models, Turonian rock units were deposited prior to the counterclockwise rotation of southwestern Alaska and carried northward along the continental margin by oceanic plate motion. However, neither the mid-Cretaceous paleolatitude nor the time of accretion of the WCT have been firmly established. Plafker and Berg (1994) place the WCT close to its present latitude by Late Jurassic time and close to its present configuration in the Turonian. This would make the paleolatitude of

Table 1.Comparison of the fauna of the Lizzie Quarry with that of Member 4 and the Turonian part of unit C-1 of the Matanuska Formation

summer of 1995 to recover a large concretion that may contain pelvic elements. To date, 2 scapulae, 2 humeri, 2 ulnae, 1 radius, 6 rib fragments, parts of a femur, tibia, fibula, astragalus, 5 metatarsals, and 14 pedal phalanges from the appendicular skeleton have been identified along with 23 caudal centra, 2 chevrons, and a few centimeters of ossified tendon from the axial skeleton. They are shown diagrammatically in figure 6. All elements are closely associated and some are articulated. No elements are duplicated and the identified bones all fall within a narrow size range, suggesting they represent a single individual. Preliminary comparisons with other specimens suggest the animal was a juvenile about 3 m long. However, the possibility remains that she was an

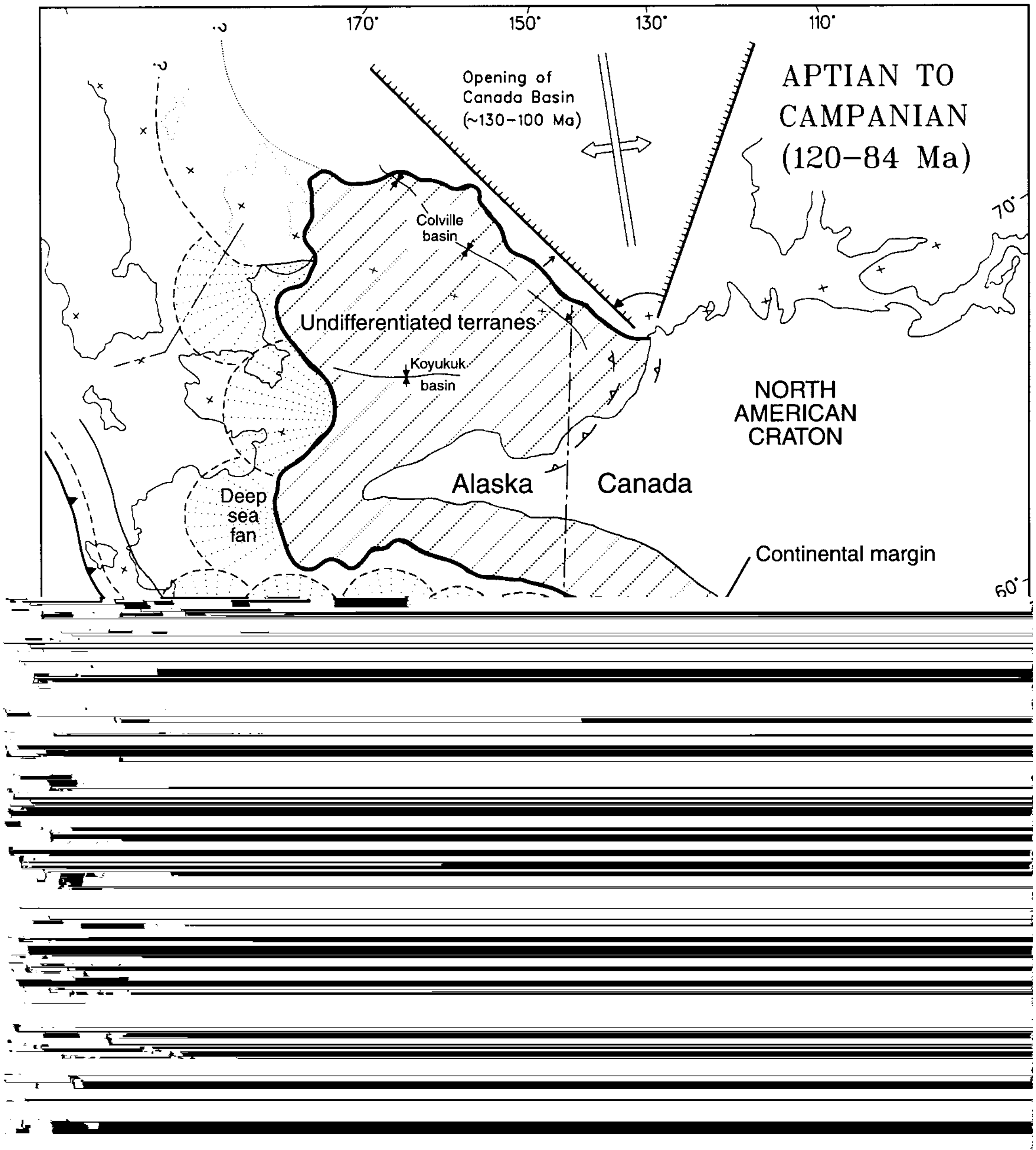

Figure 5. Paleogeography of Alaska during the Aptian-Campanian (120-84 Ma) interval showing a possible configuration of the Wrangellia Composite Terrane and paleoposition of the Lizzie Quarry. It includes the Peninsular terrane and Wrangellia terranes (modified from Plafker and Berg, 1994, fig. 5E).

Identification to the family level is based on three nearly complete phalanges (II-1, III-1, IV-1) of the right pes, which were compared with material at the University of Alaska Museum in Fairbanks and the Royal Tyrrell Museum of Palaeontology in Alberta, Canada. It is not known if this is a hadrosaurid (noncrested) or lambeosaurid (crested) duckbill. Pelvic bones or skull, if present, could allow assignment to the subfamilial and possibly the generic level.

PALEOECOLOGIC CONTEXT

Although dinosaur remains situated in rocks of marine origin are unusual, there are numerous reports of such finds. From a list of 95 individual dinosaurs found in marine Upper Cretaceous rocks in North America, 54 are hadrosaurs and the ratio of hadrosaurines (noncrested types) to lambeosaurines (crested types) in this setting is 17:1. About half of these

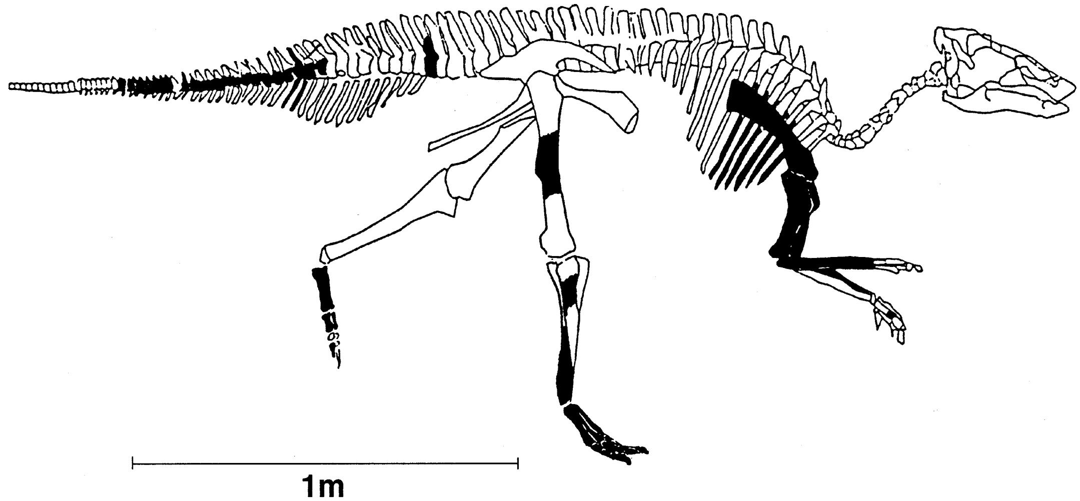

Figure 6. Postcranial skeletal elements retrieved from Lizzie to date (modified from Norman, 1985, p. 118-119).

hadrosaurs are young or juvenile individuals (Horner, 1979; Fiorillo, 1990). Nearly all were found articulated and in one case the animal was entombed in skin. Lizzie's skin and soft tissue may have controlled the formation of the concretions.

Deposition in a middle to outer shelf or upper bathyal environment below wave base appears to be suggested by the invertebrate assemblage, which is dominated by ammonites and inoceramid bivalves. The thin-shelled heteromorphic ammonites were probably inhabitants of the outer shelf (36 -183 m) (Tasch, 1973). Inoceramids are thought to have inhabited a wide range of depths, but seem to be confined to the upper bathyal and neritic environments close to continental or island margins (Thiede and Dinkelman, 1977). The lack of heavy-shelled, shallow-water pelecypods also suggests an outer neritic zone or deeper water location for the quarry (Jones, 1963).

The density of the invertebrates suggests that this was an environment where organisms were either very rare or arrived only after death. The preservation suggests rapid burial. The shells lack signs of postmortem biological activity such as borings or encrustations. They show no signs of abrasion, and broken surfaces are fresh. Some are nearly whole and undeformed, whereas others are fragmented, crushed, and greatly compressed. The orientation of the large planar valves (up to 20 cm in diameter) in the quarry was always parallel to bedding. The lack of abrasion and the recovery of fragile heteromorph ammonites suggest that the invertebrates could not have been reworked. The proximity of the hadrosaur bones to each other implies that they were not disturbed a great deal by scavengers. The occurrence of pyrite suggests the organisms were buried in an anoxic environment. The lack of oxygen, low temperatures, and lack of scavengers provided excellent conditions for preservation.

Whether the fossil assemblage represents a living assemblage that can be used for the reconstruction of specific paleoecologic conditions is an open question. The muddy substrate may have been unstable and subject to submarine slides and slumps. Elder (written commun.) states that transport of delicate and complete shells in this type of environment is very common. The organisms, whether transported or not, show some ecological affinities to each other. Ecological interpretation is confounded by the possibility that ammonite shells can float long distances after death. This may be true for pelagic genera with normal planispiral shells such as *Mesopuzosia*, but it may not be true for the heteromorphs. In their recent paper, Seilacher and Labarbera (1995) suggest that the septum closing off the living chamber of heteromorph ammonites was not calcified and that it decomposed with other soft parts, thus limiting the drift of the shell. A benthic mode of life that has been suggested for heteromorphs of this type would also have placed limits on the distance of transport after death. Obviously heteromorph morphology is not conducive to a pelagic mode of life requiring the rapid locomotion of a predator. Matsumoto

(1977) suggests that *Eubostrychoceras*, with its open coiling, was not adapted for rapid swimming but for a benthic lifestyle and may even have been partly embedded in the substrate. The spinose flared ribs of the shell may have been used to stabilize the animal as it sat on the bottom. Ammonites were thought to live in marine vegetation or on a loose clay mud substrate (Tasch, 1973). Seilacher and Labarbera (1995) suggest the helical coil may have been covered by living tissue or another organism such as a sponge. They also suggest that heteromorph ammonites were "Cartesian divers" living as suspension feeders rather than active predators such as nautiloids. Their arms made up a delicate filter fan that removed small particles from the water more analogous to the feeding behavior of graptolites.

The most abundant bivalves in the borrow pit are inoceramids, an extinct group of bivalves thought to be related to modern oysters. An important guide fossil for the Late Cretaceous, they were benthic with large, relatively flat shells typical of species on soft, muddy substrates. They are characterized by large robust valves with lengths that can exceed 27 mm and thicknesses of 2 to 3 mm. The shells have multiple ligamental pits, which provided anchorage for threadlike ligaments that attached it to the substrate. They are common constituents of dark-gray calcareous laminated mudstones, which indicate reducing conditions below the sediment-water interface (Thiede and Dinkelman, 1977). They were probably filter feeders living below wave base, which harbored chemosynthetic symbionts to supplement their diet (MacLeod and Hoppe, 1992).

Nucula, represented by several specimens, is a ubiquitous genus of an infaunal detritus feeder often found in organic muds. It is an important component of ancient and modern deep-water communities. It is indicative of a low-diversity assemblage in a soft, water-saturated substrate, rich in organic matter with abundant hydrogen sulfide somewhat depleted in oxygen. Nine typical extant deep-water species live below bottom waters with temperatures from 2.3°C to 9.2°C (Kauffman, 1976).

Whether transported or not, the heteromorphs, inoceramids, and nuculids all indicate that Lizzie was buried at a paleodepth greater than 35 m.

EARLY HADROSAURS

Generally, hadrosaurs are a large, diverse, and well-known group of dinosaurs that were the dominant herbivores of the Campanian-Maastrichtian stages of the Late Cretaceous period. Their appearance is well documented in North and South America, Europe, and Asia. Most taxa are described from several individuals, including both juveniles and adults (Weishampel and Horner, 1990). However, hadrosaurs from pre-Campanian rocks are quite rare. In their summary of known hadrosaurs, Weishampel and Horner (1990) list 42 taxa. Of these, 35 species are Campanian-Maastrichtian. Of the seven taxa older than that, the ages of five are uncertain. Until recently, there were almost no well-dated hadrosaurs of early Late Cretaceous age. Now, however, early hadrosaurs are known from at least nine sites in Asia and North America (table 2). Systematic study of these new specimens may show evolutionary relationships between these widely separated fossils. Hadrosaurs are thought to have evolved in Asia from iguanodontids and spread to Europe and North America (Weishampel and Horner, 1990). Work from the recent Sino-Canadian Dinosaur Project showed there are striking similarities between the dinosaur faunas of Asia and North America (Currie, 1995). Lizzie provides a geographic link between Asia and North America for these faunas during the Turonian. Because she is younger than most iguanodontids and older than most hadrosaurines, Lizzie should contribute to the understanding of the relationship between these two groups.

CONCLUSIONS

Lizzie is the first hadrosaur to be found in south-central Alaska and one of the earliest hadrosaurs known in the world. This fossil has the potential to contribute to our understanding of the timing and direction of the spread of this group of ornithopods and of the evolutionary relationships between hadrosaurids and their iguanodontid ancestors. This discovery may also help place constraints on the timing of the docking of the Wrangellia composite terrane with the North American craton. Future work will include micro-osteological and systematic analysis of the postcranial skeleton to determine this hadrosaur's developmental stage and its affinities to known genera.

ACKNOWLEDGMENTS

We are especially indebted to Will Elder of the U.S. Geological Survey, who recognized the rare heteromorph ammonites and identified the invertebrates. We offer a special thanks to Roland A. Gangloff of the University of Alaska Museum, who reviewed the manuscript; this project could not have succeeded without his generous assistance over the past 3 yr. Art Grantz provided expert editorial comments as well as important questions in his thorough review of the manuscript. We thank Phil Currie and Darren Tanke of the Royal Tyrrell Museum of Palaeontology, Steve Nelson and George Plafker of the U.S. Geological

Survey, David Stone of the University of Alaska Fairbanks, Jim Kirkland of Dinamation, Sabra Reid of the Alaska Museum of Natural History, Jack Miller of MB Construction, Pat Murray, and the members of the Kevin May family. We also thank David Gillette for his encouragement and Jim Clough and an anonymous reviewer, who suggested important revisions. Lastly, we thank the Dinosaur Society, the Eagle River Parks and Recreation Board, and the Joe Kapella Memorial Fund for grants and the University of Alaska Anchorage, which supported this work.

REFERENCES CITED

Brazzatti, T., and Calligaris, R., 1995, Studio preliminare di reperti ossei di dinosauri del Carso Triestino: Atti del Museo Civico di Storia Naturale di Trieste [Italy], v. 46, p. 221-226.

Currie, P.J., 1995, Wandering dragons, the dinosaurs of Canada and China: Sixth Symposium on Mesozoic Terrestrial Ecosystems and Biota, Short Papers, Sun, Ailing, and Wang, Yuanqing, eds., Beijing, China Ocean Press, p. 101.

Currie, P.J., and Eberth, D.A., 1993, Paleontology, sedimentology and palaeoecology of the Iren Dabasu Formation (Upper Cretaceous), Inner Mongolia, People's Republic of China: Cretaceous Research, v. 14, p. 127-144.

Fiorillo, A.R., 1990, The first occurrence of hadrosaur (Dinosauria) remains from the Marine Claggett Formation, Late Cretaceous of south-central Montana: Journal of Vertebrate Paleontology, v. 10, no. 4, p. 515-517.

Gangloff, R.A., 1995, *Edmontonia* sp., the first record of an ankylosaur from Alaska: Journal of Vertebrate Paleontology, v. 15, no.1, p. 195-200.

Grantz, Arthur, 1961a, Geologic map and cross sections of the Anchorage (D-2) Quadrangle and northeasternmost part of the Anchorage (D-3) Quadrangle, Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-342, scale 1:48,000.

———1961b, Geologic map of the north two-thirds of Anchorage (D-1) Quadrangle, Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-343, scale 1:48,000.

Horne, G.S., 1994, A Mid-Cretaceous ornithopod from central Honduras: Journal of Vertebrate Paleontology, v. 14, no. 1, p. 147-150.

Horner, J.R., 1979, Upper Cretaceous dinosaurs from the Bearpaw Shale (marine) of south-central Montana with a checklist of Upper Cretaceous dinosaur remains from marine sediments in North America: Journal of Paleontology, v. 53, no. 3, p. 566-577.

Jacobs, Louis, 1995, Lone star dinosaurs: College Station, Texas, A & M University Press, 160 p.

Jones, D.L., 1963, Upper Cretaceous (Campanian and Maestrichtian) ammonites from southern Alaska: U.S. Geological Survey Professional Paper 432, 53 p., 41 pls.

Jones, D. L., and Grantz, Arthur, 1967, Cretaceous ammonites from the lower part of the Matanuska Formation, southern Alaska: U.S. Geological Survey Professional Paper 547, 49 p., 9 pls.

Kauffman, E.G., 1976, Deep-sea Cretaceous macrofossils: hole 317A, Manihiki Plateau, *in* Jackson, E.D., and others, Initial reports of the Deep Sea Drilling Project: Washington, U.S. Government Printing Office, v. XXXIII, p. 503-535, 3 pls.

Kirkland, J.T., 1994, A large primitive hadrosaur from the lower Cretaceous of Utah: Journal of Vertebrate Paleontology, v. 14, supplement to no. 3, p. 32A.

MacLeod, K.G., and Hoppe, K.A., 1992, Evidence that inoceramid bivalves were benthic and harbored chemosynthetic symbionts: Geology, v. 20, p. 117-120.

McClelland, W.G., Gehrels, G.E., and Saleeby, J.B., 1992, Upper Jurassic-Lower Cretaceous basinal strata along the cordilleran margin: Implications for the accretionary history of the Alexander-Wrangellia-Peninsular terrane: Tectonics, v. 11, no. 4, p. 823-835.

Matsumoto, Tatsuro, 1977, Some heteromorph ammonites from the Cretaceous of Hokkaido: Memoirs of the Faculty of Science, Kyushu University, Fukuoka, Japan, Series D, Geology, v. XXIII, no. 3, p. 303-366.

———1988, A monograph of the Puzosiidae (Ammonoidea) from the Cretaceous of Hokkaido: Palaeontological Society of Japan, Special Papers, no. 30, 82 p.

Norman, David, 1985, The illustrated encyclopedia of dinosaurs: New York, Crescent Books, 208 p.

Pasch, A.D., and May, K.C., 1995, The significance of a new hadrosaur (Hadrosauridae) from the Matanuska Formation (Cretaceous) in southcentral Alaska: Journal of Vertebrate Paleontology, Abstracts of Papers, v. 15, supplement to no. 3, p. 48A.

Plafker, George, and Berg, H.C., 1994, Overview of the geology and tectonic evolution of Alaska, *in* Plafker, George, and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America, v. G-1, p. 989-1018.

Rozhdestvenskii, A.K., 1968, Hadrosauridae of Kazakhstan: "Nauka" Publishing House, Moscow, [English translation from Russian] *in* Tatarinov, L.P., and others, eds., Upper Paleozoic and Mesozoic Amphibians and Reptiles: Akademia Nauk S.S.S.R. Moscow, 120 p.

Seilacher, A., and Labarbera, M., 1995, Ammonites as cartesian divers, Palaios, v. 10, p. 493-506.

Tasch, Paul, 1973, Paleobiology of the invertebrates: New York, John Wiley & Sons, Inc., 946 p.

Thiede, J., and Dinkelman, M.G., 1977, Occurrence of *Inoceramus* remains in late Mesozoic pelagic and hemipelagic sediments, *in* Supko, P. R., and others, eds., Intitial Reports of the Deep Sea Drilling Project: Washington, U.S. Government. Printing Office, v. XXIX, p. 899-910.

Wallace, W.K., and Stone, D.B., 1992, Tectonic evolution of Alaska, Alaska Geological Society Short Course notes, Anchorage, Alaska, University of Alaska Fairbanks.

Weishampel, D.B., and Horner, J.R., 1990, Hadrosauridae, *in* Weishampel, D.B., Dodson, P., and Osmolska, H., eds., The Dinosauria: Berkeley, University of California Press, p. 534-561.

Weishampel, D.B., Norman, D.B., and Grigorescu, D., 1993, *Telmatosaurus transsylvanicus* from the Late Cretaceous of Romania: The most basal hadrosaurid dinosaur: Palaeontology, v. 36, pt. 2, p. 361-385.