ABSTRACT

The Uinta Formation in northeastern Utah was the original basis of the Uinta and mammal "age." Magnetostratigraphic studies were conducted in four sections in the northeastern, north-central, and northwestern Uinta Basin. The uppermost Evacuation Creek Member of the Green River Shale, and all of varnished Uinta Formation unit "A," was of normal polarity. The normal interval probably correlates with Chron C7r (46.3-47.8 Ma), as originally suggested by Prothro and Sauvain (1992). Most of Uinta "B" was reversed (c Chron C20r, 43.8-46.3 Ma). A shorter normal zone spanning upper Uinta "B" and lower Uinta "C" probably correlates with Chron C20r (45.3-48 Ma). The upper part of the Uinta "C" and the lowermost portion of the Duchesne River Formation were also reversed (c C19r, 41.4-42 Ma), with normal (= C18r, 41.1-44.4 Ma) and reversed (= C18r, 40.4-41 Ma) magnetosteres in the higher part of the Eocene Basin Member.

Although the original magnetostratigraphic data for most Uinta Basin collections are very poor, distinctions between the faunas of Uinta "B1," "B2," and "C" are possible, Uinta "B1" (the "Mammalian zone" of Osborn, 1929) spans the interval 45-46 Ma, and is characterized by overlapping ranges of the brontothere Sphenacodon, Mesohippus, Entelodon, the chalicotheres Eomogopus, the horned Entelosaurus gracilis, the creodont Oxazoaemon, and the artiodactyl Diplopus, Oromeryx, and Leptorhinus. The temnospondyls (Styliodon), steiniheres (Urotherium and Entelodon), artiodactyls (Oonotherium), and protocylindroid rodent last appear in Uinta B2. Uinta "C" (the "Pleistocene vertebrate zone" of Osborn, 1929), including Mylon Pucked, Kenneth Hole, and Lena Quarry, spans the interval 42.3-45 Ma, and is characterized by the first occurrences of the brontothere Protorohippus, Mesotiloconodon, the leptomorph Mocheles, the primordial Mocheles, the rodent Lamia, and the last appearance of numerous taxa, including the temnospondyls, the chalicotheres, the artiodactyls, and the carnivores Procyonelobus and Uromeryx, the artiodactyls Protherium, Oromeryx, Acanthodon, Bunameryx, and Mysosaurus, and the rhynchozosteid Aymodon and Triplobus. The upper part of Uinta "C" (spanning the interval 42.0-42.5 Ma) is infan-
silisiferous. Sparse, but distinctive fossils characterize the latest Uinta Basina Basin Member and the Duchesnean Lapland Member of the Duchesne River Formation.

INTRODUCTION AND GEOLOGIC SETTING

The Uinta Basin is northeastern Utah (Dane, 1954; University of Utah, 1964, Cashion, 1967) is an asymmetrical synclinal structure about 7000 square miles in area (Fig. 1). Its axis trends roughly east-west, and the north limb is inclined more steeply than the shallow-dipping south limb. The Uinta Basin is about 135 miles wide along its east-west axis and 100 miles across in the north-south direction. It is bounded by the Uinta Mountains to the north, the Douglas Creek arch to the east (which separates it from the similar Pinecreek Basin of Colorado), the Wasatch Range on the west, and the Riona Cliffs to the south.

Thick sequences of fluvial and fan-deltaic rocks are found along the edges of the basin and plunge into the subsurface. These were deformed during the latest Creta-
cene-middle Eocene Laurasia Orogeny, which created the basin in its present configuration. During Laurasia orogeny, over 15,000 feet of Eocene sediments accumulated in this rapidly subsiding structure. The bulk of the sedimentary package consists of the fluvial lower Eocene Wasatch Formation (up to 4100 feet thick) and the lacustrine lower middle Eocene Green River Formation (up to 7000 feet thick). The latter is part of an extensive system of middle Eocene lakes that once covered much of northeastern Utah, southwestern Wyoming, and western Colorado. Because of its importance as source rock for oil and oil shale, the Green River Formation has been studied in great detail (see Bradley, 1929, 1931, 1964; Duke, 1954; Cashion, 1967, Ryder et al., 1976; Gradstein and Smith, 1979, 1980; Johnson, 1985; and Roehler, 1979, for some of the key features of the Green River lake systems).

Toward the end of the early middle Eocene
(Bridgeport, about 47°45' N lat, the Green River lake system began to recede. Lacustrine shales were replaced by fluvial-delta mudrocks and sandstones which succeeded many unconformable sandstones. The Bridgeport (Bridge Formation and Washakie Shale; Kimrey, 1977; Kimrey and others, 1981) began to dry up first, with Bridgeport-aged fluvial sediments covering and superposing with the Green River shales. Much of the fluvial sediments was supplied by a large delta of *Eocycloides* delta from the Abajo Formation (field of reconstruction Wyoming and the Chalky facies of Yada, forming the "valleymold" fluvial palaeohydrology of Rasmussen et al. (1979), 1980, and John Johnson, 1985). The Paradox Basin began to dry up slightly later as volcanic debris spilled south from the Washakie-basin Washakie and Bradley, 1979, 1980; (Schrader et al., 1982; see Stacey et al., this volume, Chapter 3). In the Uinta Basin, the Green River lake system was gradually replaced by the fluvial Uinta Formation providing a record of the west end of the basin (Fig. 2). Thus, the lower fluvial sediments of the eastern Uinta Basin are largely equivalent in facies and composition to the western Uinta Basin, with complex interfingerings between the two units (Don, 1954, 1975; Roy et al., 1956; Cahoon, 1967; Ryder et al., 1976). Most recent Uinta Formation sandstones have well-preserved paleosols (Cahoon, 1961, Cahoon, 1969), and apparently an arid climate area to the southeast in
the Lopudice subsite, especially the Unio compressus split in well-vascularized, and the Park Ranges of central Columbia (Ogden, 1914, Brooks et al., 1953), summarized by Deuve et al., 1998). By Deuve et al., 1998, they showed that the subsite samples from the Lopudice subsite were composed of the Lopudice subsite and the Park Ranges of central Columbia. The samples were taken from the Lopudice subsite and the Park Ranges of central Columbia.

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Figure 5: 14C activity in selected samples from the Uinta Formation (see text and Piper et al., 1981). For each sample, solid bars show 14C measurements on alkali dithionite-extractable carbon, open bars are 14C measurements on CO2 from the same sample. The insert shows a scatter diagram for the same samples, indicating that the major source of 14C contamination is soil, with somewhat smaller and less obvious contributions from vegetation and aquatic sources. The percentage of 14C contamination is essentially random with respect to the stratigraphic position of the sample. The 14C activity in the Uinta Formation is potentially important to the accuracy of radiocarbon dating because it is present in a significant proportion of the samples. In the modified Loveluck-Piper 14C dating curve (eq. 1), the 14C activity is shown to be negligible, but the 14C contamination is shown to be substantial.

Over 100 14C measurements (a minimum of three measurements per sample) were collected using a modified Loveluck-Piper technique, resulting in over 1200 individual measurements. The technique involves the extraction of organic material from the sample, combustion of the organic material to CO2, and measurement of the 14C content of the CO2. The 14C content of the CO2 is then compared to the 14C content of the standard material, which is the carbon-14 content of the atmosphere at the time the sample was formed. Any deviation from the standard 14C content is attributed to the presence of 14C contamination.

The 14C contamination is shown to be significant in the Uinta Formation, with over 1% of the samples showing a 14C content that is significantly different from the standard 14C content. The 14C contamination is shown to be caused by the presence of soil and vegetation, with smaller contributions from aquatic sources.

The present study was conducted by comparing the 14C content of the CO2 from the samples to the 14C content of the standard material. The 14C content of the CO2 is then compared to the 14C content of the standard material, which is the carbon-14 content of the atmosphere at the time the sample was formed. Any deviation from the standard 14C content is attributed to the presence of 14C contamination.

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PROTHEO

fossils in the Wasatch Basin; the sequence spans only the last 300 million years in Utina (Shrock, 1967), and early Utina (to Utina B). However, this is a minor point. The predominance of the evidence still favors the original conception of Prothero and Swindler that the Utina Basin sequence spans Cerato Chalk-Cretaceous (see Walsh, this volume, Chapter 4, and the summary chapter in this volume).

BIOSTRATIGRAPHY

Juggling from these calculations, the Utina is one of the longest of the North American land-based "ages." It spans 66 million years in Jurassic time (Prothero, 1967, a), with a duration of about 3.5 million years. Unfortunately, it has not been firmly placed in tectonostratigraphic records, but instead the lithostratigraphic base "zone" of Utina B-32.4 and "C" have been used. Oxford (1979, pp. 92-93) has been stratigraphic names in the Utina lithostratigraphic units. "B" was called the Miocene zone, "B-1" the Eocene-Oligocene zone, and "C" the Paleocene zone. Except for the detailed position of a few basaltic feldspars (Oxford, 1979, figs. 63, 66) and some other specimen, however, no detailed range information was provided to facilitate biastratigraphic subdivision of these units.

Utina's biastratigraphic zonal terminology was not adopted by later workers, including Kay and Prothero of the Carnegie Museum, who used stratigraphic terms, or Wood, who named the Wasatch and Miocene members. In spite of the fact that Oxford's zonal names were established long before, Gannett (1980) named two "zones" (C11, the Eocene-Oligocene "zone" and C12, the Cretaceous-Apennine "zone") for the early and late units. However, these are not based on recent biastratigraphic work, and simply denote the distinction between the faunas of Utina B and C. In addition, both names are now inappropiate, as discussed below.

It would be expected that the 6.5 million years of the Utina should be divisible by biastratigraphic zones into more than three zones. However, in most cases the original collections do not have adequate stratigraphic data, since the collectors (mostly Prothero, Kay, Clark, Elzeg, and other early twentieth-century period) rarely recorded the position of fossils found within Utina B or C. I have not an extensive survey of the collections and field notes (especially in the Carnegie Museum and American Museum) and it is clear that more detailed information cannot be extracted from most of these old collections. Unfortunately, the best specimens that had weathered out over the centuries from the Utina Formation were removed by these early collectors, and museum quarries since then have not obtained significant new collections that would help refine the biastratigraphy, Only Mylo Pockey (Hambly, 1987), and occasionally some of the other classic localities, such as White River Pocket (e.g., Dawson, 1966), are still producing Tag Ruminators (personal communication) has recently col-


Table 1. Paleogeographic distribution of mammals from the Wasatch Basin. Most ranges after Osborne (1929), Pearson (1909), Pearson and Kay (1951), Kay and Osborne (1954), and Stucky (1966), and Mylo Pockey (1987). Stucky (1966), and Mylo Pockey (1987).

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Schoenstedt, quoted from the Flowing Formations of York (Wilson, 1970) is not relevant to this genus. A few taxa (sphenops rovetii, Pseudorhynchites shawae) first appeared at the B level, and a few taxa (Pseudorhynchites shawae, Pseudorhynchites rovetii, Pseudorhynchites kingi) appeared at this level. Osburn (1970) noted that the "immediate" Lutetian zone of this level was a fauna from the Eocene, but this has since been corrected by Wilson et al. (1980), who showed that the Lutetian zone should be referred to the assistant genus. The data presented in the figure are based on the ichnotaxonomic classification presented by Wilson et al. (1980), and the data are given in the figure.
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REFERENCES

Basin, the fluvial sandstones and mudstones are replaced by the eolian lacustrine facies of Eleven Lake Unita. Instead of the Unita "A" sandstones, the Escalation Creek Member of the Green River Formation is overlain by the "saline facies" and "sandstone and limstone facies" of the Unita Formation (Dane, 1954, 1955; Ray et al., 1956). The most complete section through the region is in Indian Canyon, southwest of Duchesne, in Duchesne County, Utah. A brief sketch of the section was published by Dane (1954, fig. 2, column 5), and the stratigraphic relationships were summarized by Prayzhek et al. (1989, fig. 14). A detailed, unpublished stratigraphic section through Indian Canyon made by J. R. Dyke and W. B. Cashin was generously provided for our research by Dr. Dyke, and our stratigraphic sections followed theirs closely. This section and its nomenclature are also cited by Maguer (1977), who attempted to date pre-Cretaceous layers in the Indian Canyon.

The section begins on the distinctive "Horse Bench Sandstone Bed" (w41.21) of Dyke and Cashin of Dane (1954, 1955), which can be traced northwest through the Escalation Creek Member across most of the basin, and is apparently equivalent to the base of Unita "A" in the east (Prayzhek et al., 1989, fig. 14). The first sequence (section 6 of Dyke and Cashin) was located in west side of the left fork of Indian Canyon, east half of the NW Sec. 21, T65S R7W, Jones Hollow 7.5' quadrangle, Duchesne County, Utah.

This section ran from the Horse Bench Sandstone to the base of the saline facies of the Unita Formation (unit 297 of Dyke and Cashin), covering the upper 460 feet of the Escalation Creek Member. The second section (Dyke and Cashin, section 7, units 298-350) along the bluffs on the west side of Indian Canyon, was located in NW SW Sec. 12 in the same map; it covered 300 feet of the lower saline facies. The third section (section 8 of Dyke and Cashin), also on the west side of the left fork of Indian Canyon in SE SE Sec. 1, T65S R7W, Lance Canyon 7.5' quadrangle, covered units 351-390 of Dyke and Cashin. The fourth segment (Dyke and Cashin section 9, units 390-428) was located in the NW SW Sec. 22, T65S R7W, Buck Knoll 7.5' quadrangle; units 428-450 were collected in SW NE Sec. 22. The fifth segment (Dyke and Cashin, section 10, units 457-488) covers the uppermost 320 feet of the saline facies, and was located in NW NW Sec. 28, T65 S R7W, Duchesne 7.5' quadrangle. The sixth segment covered the basal 200 feet of the limstone and sandstone facies of the Unita Formation (units 485-503 of Dyke and Cashin), and was located in a west-flowing dry wash 1 mile east of Indian Canyon in NE SW Sec. 14, T65 S R7W, Duchesne 7.5' quadrangle. The remaining portion of the sandstone and limstone facies was not sampled because of difficulty of access and poor continuity of exposures.