The transition from the Eocene to the Oligocene epochs from approximately 47 to 27 million years ago was one of the most dramatic episodes of climatic and biotic change since the demise of the dinosaurs. The mild tropical climates of the Paleocene and early Eocene were replaced by modern climatic conditions and extremes, including glacial ice in Antarctica. The best terrestrial record of the Eocene-Oligocene transition is found in North America, including the spectacular cliffs and spires of Big Badlands National Park in South Dakota.

The first part of the book summarizes the latest information in dating and correlation of the strata of late middle Eocene through early Oligocene age in North America, including the latest insights from argon/argon dating and magnetic stratigraphy. The second part reviews almost all the important terrestrial reptiles and mammals found near the Eocene-Oligocene boundary in the White River Chronofauna, from the turtles, snakes, and lizards, to the common rodents, carnivores, artiodactyls, and perissodactyls.

This is the first comprehensive treatment of these rocks and fossils in over sixty years. The *Terrestrial Eocene-Oligocene Transition in North America* will be an invaluable resource to vertebrate paleontologists, geologists, mammologists, and evolutionary biologists.

Morris F. Skinner in the Big Badlands of South Dakota during the 1950s. (Photo courtesy Marie Skinner).

Morris F. Skinner
1906-1989

Our present understanding of the White River Group and its fossils would never have been possible without the enormous contributions of Morris Skinner. Although he was originally hired by Childs Frick in 1927 to collect late Cenozoic mammals of western North America, he spent much time in the White River Group as well. Beginning in 1938 and continuing through the 1940s and 1950s, Skinner made large, stratigraphically zoned collections from the Big Badlands of South Dakota. In the 1950s and 1960s, he made some of the most important collections from White River outcrops in Wyoming, Nebraska, and North Dakota as well. Unlike many collectors, however, Morris was a dedicated geologist and stratigrapher. He measured hundreds of stratigraphic sections, and made sure that every specimen he and his field parties collected had the best possible stratigraphic information. Thus, the Frick White River collections made by Skinner and parties have the best biostratigraphic data available (frequently zoned to the nearest foot from marker ashes), allowing the first detailed range-zone biostratigraphy after 150 years of study in the White River Group. Most of the systematic paleontological studies in this volume are based largely on the Frick Collections, and their insights would not be possible without the excellent stratigraphic data provided by Skinner and crew.

Skinner was more than one of the best fossil collectors of this century, however. He was also an excellent field geologist, and his many insights into White River stratigraphy were largely unappreciated because they remained in his field notebooks, unpublished. Only his brief summary of the North Dakota sequence (Skinner, 1951) was published in his lifetime, but his contributions to the stratigraphy of White River deposits at Flagstaff Rim (Emry, 1992) and the Lusk and Douglas areas of eastern Wyoming (see Evanoff et al., 1992; partially summarized in this volume, Chapter 13, and Prothero and Whittlesey, in press), have been the basis of many later publications by others. For example, Skinner recognized that the divisions of the Chadron Formation used by his contemporaries were inadequate, and described a latest Chadronian unit he called the "Trunk Butte Member." This concept was revived 30 years later as the Big Cottonwood Creek Member of the Chadron Formation (Terry et al., 1995). As early as 1953, Skinner collected brontothere bones from Brule Formation equivalents (see Prothero and Whittlesey, in press), and recognized that the classic definitions of the Chadronian and Orellan needed revision. This, too, is finally occurring 40 years after Skinner's insight. Based on his knowledge of biostratigraphy, Skinner realized that the Chadronian and earliest Orellan were poorly represented in the Big Badlands, but much thicker and more completely exposed in eastern Wyoming. This has major implications for interpretations of the Chadronian or Orellan based on the less complete Big Badlands sequence (e.g., Clark et al., 1967; Retallack, 1983). Skinner's stratigraphic concepts about the White River Group only reached print as an illustration in Mellett (1977, fig. 71, pp. 128-129). His profound understanding of White River stratigraphy and paleontology is finally being appreciated. At the White River Group symposium held at the North Central–South Central section meeting of the Geological Society of America in Lincoln, Nebraska, on April 27, 1995, the prevailing refrain from the speakers and all their "new" research was, "Morris Skinner knew this years ago!"

Much of the best science in this book represents Morris Skinner's collections or ideas finally seeing publication. It is appropriate that it be dedicated to his memory.

The Terrestrial Eocene-Oligocene Transition in North America

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Front cover caption: The strata of the Big Badlands of South Dakota preserve one of the best terrestrial records of terrestrial Eocene-Oligocene transition in North America. This rendition is from Henry Fairfield Osborn's 1929 titanothere monograph, showing the upper Eocene Chadron Formation overlain by the lower Oligocene Brule Formation. Superimposed on this figure are side views of the skulls of three of the most common oreodonts from the Eocene-Oligocene transition (from bottom to top): the middle Chadronian *Merycoidodon presidioensis,* the late Chadronian – early Orellan *Merycoidodon culbertsoni,* and the late Orellan *Merycoidodon bullatus* (from Stevens and Stevens, this volume, Chapter 25).

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PREFACE

The transition from the Eocene to the Oligocene epochs (from about 47 to 27 million years ago) was one of the most dramatic episodes of climatic and biotic change since the demise of the dinosaurs. The mild tropical climates that characterized the Paleocene and early Eocene were replaced by the beginning of modern climatic extremes, including glacial ice in Antarctica and modern deep-water oceanic circulation (summarized in Prothero, 1994). These changes were seen in plants and animals worldwide, both in the oceans and on land. Land floras changed from dense forests (found even at polar latitudes) to a mixture of woodland and scrubland. The land faunas responded with extinction of many forest-dwelling and leaf-eating animals, and replacement by snails, reptiles, and mammals tolerant of drier conditions and the more open vegetation.

The best terrestrial record of the Eocene-Oligocene transition is found in North America, in deposits which include the spectacular cliffs and spires of Big Badlands National Park in South Dakota, world-famous for its scenery and abundant fossils. Although the fossils and deposits have been studied since 1846, much critical new information has accumulated in the last twenty years. Enormous collections of fossil mammals from these beds were made by the Frick Laboratory of the American Museum of Natural History in New York, but only a small fraction of the studies on these fossils has been published. On the 150th anniversary of the discovery and description of the first fossil mammal from the Badlands, we hope to bring the subject up to date. The last comprehensive monographs on the White River mammals were published in 1936-1941 by William Berryman Scott, Glenn Lowell Jepsen, and Albert E. Wood, and many of these mammals have not been reviewed since then. This volume is, in part, a long-overdue update of the classic White River monographs.

There has also been a vast improvement in our chronological understanding of these beds. With the new tools of magnetic stratigraphy and $^{40}Ar/^{39}Ar$ dating, we are gaining our first high-resolution correlation of the terrestrial North American section with the global climatic record. New correlations have already radically changed our understanding of the time scale, and even changed the position of the North American Eocene-Oligocene boundary itself. Uintan and Duchesnean fossils, long thought to be late Eocene, are now considered middle Eocene; Chadronian fossils, long thought to be early Oligocene, are now considered late Eocene; the Orellan and Whitneyan land mammal "ages," once thought to be middle and late Oligocene, are now considered early Oligocene. As important as these new data are, very little was published in sufficient detail. In addition to correlations of the classic White River and Uinta Basin deposits, this volume also summarizes the geology of relevant deposits in Saskatchewan, Montana, Oregon, Texas, New Mexico, and California, with detailed faunal lists, magnetics, and geochronology not previously published.

Contrary to widespread misconceptions, there was no singular, catastrophic "Terminal Eocene Event." Instead, the transition was marked by a series of extinctions, beginning at the end of the middle Eocene (about 37 Ma). Consequently, our stratigraphic coverage spans about 20 million years (47-27 Ma), beginning with the late middle Eocene (Uintan and Duchesnean, from 47-37 Ma) through the late Eocene (Chadronian, 37-33.5 Ma), and the early Oligocene (Orellan-Whitneyan-earliest Arikareean, from 33.5-27 Ma). The chapters in the first part of the book review the chronostratigraphy of nearly all the important areas where terrestrial mammal fossils of these ages are found.

The second part of the book summarizes the systematic paleontology of nearly all the common land vertebrates of the White River Chronofauna. These include the most common mammalian taxa, as well as the reptiles (turtles, lizards, snakes, and amphisbaenians). Unfortunately, it was not possible to include every taxon. Some have been recently revised elsewhere (hyaenodonts by Mellett, 1977; horses by Prothero and Shubin, 1989; rabbits by Korth and Hageman, 1988). The taxonomy of other groups (e.g., brontotheres, entelodonts) was not ready for publication. Nevertheless, the updated systematics of the mammals in this volume covers all the taxa which are critical to the biostratigraphy of the Chadronian through Whitneyan interval.

In the final chapter, we summarize the chronostratigraphic and biostratigraphic information presented in this book, and suggest outlines of a biostratigraphic zonation for the entire interval. Much work remains to be done, of course, but this summary presents a framework for further refinement of the chronostratigraphy, biostratigraphy, and systematic paleontology of this important interval in Earth history.

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