INTRODUCTION

In North America, the only practical method of correlation and dating of most Cenozoic terrestrial deposits has been with land mammals. As the turn of the century, William Diller Matthew and Henry Fairfield Osborn (Matthew, 1899; Osborn and Matthew, 1906; Osborn, 1907, 1910, 1929) attempted to create biostratigraphic zonations of the North American terrestrial sequence, based on principles followed by European stratigraphers at the time (see review by Telford, 1970). But the good beginning established by Osborn and Matthew was slow, since the next generation of vertebrate paleontologists virtually ignored their pioneering work.

Unlike most marine invertebrates, fossil mammals typically occur in localized fossiliferous horizons, or in isolated pockets or quarries, without the stratigraphic superposition. As a result, traditional biostratigraphic methods developed by European invertebrate paleontologists (based on detailed stratigraphy; ranges of fossils in measured sections) were not widely followed by North American vertebrate paleontologists until they were followed by European vertebrate paleontologists; then or now. In the Wood Committee (1941) Section of the Paleontological Society appointed a committee to clarify the confusion over correlation, and adopt a terminology that could be widely used. Known as the Wood Committee (Wood and others, 1941), it was chaired by Horace E. Wood and included four other vertebrate paleontologists (Edwin H. Colbert, John Clark, Glenn L. Jepsen, and Chester Stock), plus paleobotanist Ralph Chasey, and invertebrate paleontologist J. B. Reeside.

The Wood Committee’s “Provincial Ages” were a complex hybrid of local rock units and time units delineated by index taxa, characteristic taxa, and first and last occurrences of mammalian genera. As Telford (1950) and Woodburne (1977, 1987) have pointed out, these units were not true stratigraphic ages, which must be based on biostratigraphic zones and stages (assuming to western stratigraphic codes, such as the 1983 North American Code of Stratigraphic Nomenclature. Since they were not standard stratigraphic ages, the North American land mammal “ages” should properly be put in quotes in most publications. Instead, the Wood Committee’s methods resemble a system called “biochronology,” first proposed by H. S. Williams (1901), which attempts to reconstruct the sequence of occurrences of taxa without documenting every event in a local stratigraphic section. Demonstration of stratigraphic superposition was noted when available, but detailed biostratigraphic work in the tradition of European invertebrate paleontologists was not considered essential to their “provincial” system.

In spite of their loose characterization, the land mammal “ages” of the Wood Committee worked quite well for over forty years, mostly because mammals do evolve and disperse very rapidly (Savage, 1977). However, problems eventually arose. For example, the Chedaxon land mammal “age” was originally defined both on the co-occurrence of the horse-Mesopho- rus and bronchotheres, and also on the limits of the Chadron Formation. At the time, the last occurrence of bronchotheres was thought to coincide with the top of the Chadron Formation, so there was no conflict. When Merriam (1932) described the Bronchotherium specimens in rocks correlative with the overlying Orellia Member of the Brule Formation (which typified the Chadron), the difficulty of defining the Chadronian both biostratigraph- ically and lithostratigraphically became apparent (Entry and others, 1987; Prothro, 1982; Egloff and others, 1992). Yet many of Skinner’s contemporaries could not accept this evidence, since the misconception that rock units could be treated as time units was widespread among paleontologists of that generation.

Since the 1950s, a newer generation of paleontologists (for example, Savage, 1955, 1962, 1977; Telford, 1970; Woodburne, 1977, 1987) has tried to bring vertebrate paleontology back to more rigorous classical biostratigraphic methods. Trained in modern stratigraphic thinking, vertebrate paleontologists now appreciate the possibility that rock units can be time-transgressive over distance (Shaw, 1964; Prothro, 1990), and so they rarely collect rock units with time units. In addition, we have come to
to realize that detailed stratigraphic zonations of faunal fos-
sils provides much higher resolution of time than collections
whose only stratigraphic information is the formation they came
from. As discussed by Woodburne (1977), such detailed zo-
nation could potentially subdivide the Cenozoic Era into incre-
ments of time of 300,000 years or less. In recent years, portions
of the North American continental Tertiary have been formally
subdivided by proper biostratigraphic methods. However,
the zonation of the entire Cenozoic Era is still in progress, and
biostratigraphical methods are still widely used.

Although mammals and palaeontologists are increasingly mov-
ing toward classical biostratigraphical procedures, there are still
problems. For example, biostratigraphic "zonations" proposed by
do not meet all the criteria established by the North American
Code of Stratigraphic Nomenclature. Typically, these "zones"
do not have formally proposed type sections (required in Article
5(a)), and in some cases the actual local stratigraphic ranges of
tabulae are not clearly indicated. Consequently, they are still "biostratigraphic zones and stages, which must be based on local ranges of fossils in specific sections.

Even the reviews of the Palaeocene land mammal chronology
by Archibald and others (1987), which attempted to rigorously
date a number of different biostratigraphic zones, did not date
these to specific levels in a local biostratigraphic zonation.
Instead, these authors relied on the Wood Committee's practice of
referring a number of different localities to a specific "zone" and
listing taxa of biostratigraphical importance. Rather than
follow the stricter criteria of the North American Stratigraphic
Code, they adopted "zone"-zones and "stage"-zones in the
looser sense of the International Stratigraphic Guide (Heywood,
1976), which were not tied to local biostratigraphic conditions.
Archibald and others (1987, p. 255) acknowledge that "these ages
and zones are based on faunal content and in many in-
stances cannot be defined with precision in type sections... for
the most part these units cannot be regarded as stages. This is,
of course, one of the goals for the future."

In addition to higher-resolution biostratigraphic, other tech-
niques have come along to improve temporal correlation. The
original application of K-Ar dating by Evenden and others
(1964) to the North American terrestrial record provided an
independent test of the Wood Committee sequence and showed it
to be substantially correct. For over 25 years, K-Ar methods
continued to refine the chronology, and provided numerical esti-
mates of the age for most of the sequence (Savage and Russell,
1983, "Woodburne, 1983"). However, in the last five years, the development of high-precision single-crystal 
K-Ar dating (McDougall and Harrison, 1988; Swisher, this
volume) showed that many of the classical K-Ar dates must be
recalibrated. In some cases, they have significantly changed the
chronology that was accepted for decades (Swisher and Proctor,
1990; Prothero and Swisher, 1992; Berggren and others, this
volume).

Another breakthrough came from the application of magnetic
stratigraphy to terrestrial sections. Unlike any other method of
correlation, magnetic stratigraphy can supply non-temporally
synchronous, numerically dated time horizons to terrestrial sec-
sections (Lisboan and others, 1987; Prothero, 1988, 1990; Opdyke,
1990). The combination of both magnetic stratigraphy and 
K-Ar/ 

**The Wood Committee created the term mammalian "ages" for an interval they considered approximately equal to the Palaeocene Epoch (Fig. 1). The first two, the Fritsche and Eocene, were based on fossils from the San Juan Basin in **

![Figure 1](image-url)
New Mexico. The controversial Dragonian "age" was based on the limited Dragon Canyon local fauna from the North Horn Formation of Quevail, Utah. Although comparable faunas were later found in New Mexico (Tomida, 1987), most paleontologists now consider the Dragonian to be the beginning of the Torrejonian (Tomida and Butler, 1985; Tomida, 1981; Sloan, 1987; Archibald and others, 1987). The Tiffanian was originally based on faunas from the San Juan Basin in Colorado, but since then the Tiffanian has become much better known from faunas in Montana and Wyoming. The Clarkforkian last mammal "age" was originally based on faunas from the Clark Fork Basin on the Montana-Wyoming border. Originally considered latest Paleoecene age by the Wood Committee (1941), in recent years it was thought to span the Paleocene/Eocene boundary based on correlations of planktonic foraminifera from Europe and North America (Gingerich, 1976; Galtier and Rose, 1977; Rose, 1981). As we shall see in the next section, the Paleoecene/Eocene boundary is now thought to occur in the earliest Wasatchian, so not only the Clarkforkian but also the earliest Wasatchian are now considered Paleoene age.

North American Paleoecene chronology was most recently summarized by Archibald and others (1987). Most of the Paleoecene Epoch has now been subdivided into a series of biostratigraphic "zones," abbreviated "Pu1, Pu2, Pu3, Tol" ("Puer- can 1, 2, 3, Torrejonian 1") and so on (Fig. 2). This scheme was originally introduced by Gingerich (1976, 1980, 1983) based on a local zonation of adapted primates and planktonic foraminifera from Tiffanian and Clarkforkian of the northern Big Horn Basin in Wyoming, and expanded to the Puercan and Torrejonian strata by Archibald and others (1987) and by Sloan (1987).

Archibald and Loefgren (1990) added an additional "interval-specific" zone, Pu0, for the earliest Paleocene beds above the K/T boundary in eastern Montana, as "the "Buryatian" by Sloan and others, 1985). As noted above, these "zones" do not meet the criteria of the North American Code of Stratigraphic Nomenclature since they lack type sections. Though there are some difficulties with this zonation (see Schankler, 1980, 1981), the scheme has been modified with additional mammalian groups and has been widely adopted (Archibald and others, 1987). There are four Puercan "zones," three Tiffanian "zones," and three Clarkforkian "zones" (plus Wasatchian 0, which is also latest Paleocene).

Relatively few Paleoecene radiometric dates are available. The most recent dates on the Cretaceous/Tertiary boundary place its age at 65 Ma (Berggren and others, 1984). Revisions to the dating of the magnetic polarity time scale and new dates on the Eocene (Berggren and others, this volume) place the Puercan/Paleocene boundary at about 55 Ma. Magnetic polarity stratigraphy (Fig. 2) has been studied in the key sections of the Big Horn Basin of Wyoming and Montana (Butler and others, 1985; 1984; 1988; Cory and others, 1994; Sloan and others, 1995), the Crazy Mountain Basin in Montana (Butler and other, 1987), the San Juan Basin in New Mexico and Colorado (Butler and others, 1977; Lindsay and others, 1978, 1981, Taylor and others, 1980; Butler and Lindsay, 1985; Butler and others, 1987), and the Big Bend region in Texas (Kapp and others, 1983).

Based on magnetic stratigraphy from the San Juan and Crazy Mountain Basins, Butler and Lindsay (1985) and Butler and others (1987) squeezed the Eocene from Chron C22n (65-64 Ma), so Puercan "zones" Pu0-Pu3 are each about 250,000 years in duration. In the San Juan and Crazy Mountain Basins, Torrejonian "zone" Tol occurs in Chron C22n 62.5-63.5 Ma, Tol in C22n 61.3-62.5 Ma, and Tol in Chron C22n 61.4-61.3 Ma, so the three Torrejonian "zones" Tol-Tol range from 0.3-1.2 million years in duration. The Torrejonian/ Tiffanian boundary occurs early in Chron C22r, about 66 Ma. Based on magnetic stratigraphy from the northern Big Horn Basin, Butler and others (1984) showed that T2 occurs early in Chron C22r (about 59-60 Ma) and T0 in late Chron C22r and C21n 57.5-58.5 Ma). T4 occurs in earliest Chron C22r (57.5-57.3 Ma) and T5 in early Chron C22r (56.1-56.3 Ma). The Tiffanian/Clarkforkian boundary occurs in Chron C22n, about 56.2 Ma, so the five Tiffanian "zones" range from 0.2-1.0 million years in duration. The Clarkforkian/ Wasatchian boundary occurs in the middle of Chron C22n, about 55.5 Ma, so the three Clarkforkian "zones" are each about 200,000 years in duration.

**Eocene Epoch**

The major difficulty in establishing the correlation of the North American terrestrial chronology with the marine-based global time scale is the lack of direct correlation of mammalian-bearing terrestrial deposits with marine sequences. Fortunately, the type areas of many of the European marine stages intertongue with mammalian-bearing beds in both the Paris and London Basins (Savage and Russell, 1983). This allows direct correlation of the European Eocene mammalian chronology with the global time scale. During intervals of faunal interchange with North
America (such as in the early Eocene, but not the middle or late Eocene), we can correlate the North American sequence with the epoch stratotype sequences based in Europe. We also have magnetic stratigraphy and a large number of radiometric dates for many areas in the North American Eocene sequence. New radiometric dates, however, have greatly changed our notions of the temporal correlation of the North American sequences of middle and late Eocene age (Swisher and Prothero, 1990; Prothero and Swisher, 1992).

The Wood Committee recognized four land mammal "ages" in North America (Figs. 1-3), which they thought were approximately correlative with the European Eocene sequence. The Wasatchian land mammal "age" was named for the Wa- satch Formation in basins of southern Wyoming. The Bridgerian land mammal "age" got its name from the fauna of the Bridger Formation in southwest Wyoming, and the Uintan and Duchesnean land mammal "ages" were named for the Uinta and Duchesne River Formations in the Uinta Basin of northeast Utah. The Wood Committee thought that the Wasatchian was early Eocene, the Bridgerian middle Eocene, and the Uintan and Duchesnean were late Eocene age. The next "age," the Chadronian (named after the Chadron Formation in the High Plains, especially Nebraska and South Dakota), was considered early Oligocene age.

As mentioned in the previous section, the Wood Committee and most subsequent authors placed the Paleocene/Eocene boundary within or at the end of the Clarkforkian in North America (Gingerich, 1976; Gingerich and Rose, 1987; Rose, 1981; Gunnell, 1989). However, a number of recent lines of evidence suggest that the boundary actually falls within the ear- liest Wasatchian. The original correlations of Gingerich and Rose were based primarily on the interpretation of adipod pri- mates and plesiadelphoids. Other taxa, such as pachycentrotids (Lucas, 1984, 1985; 1993; Rea and others, 1990) and ommatid pri- mates (Beard and Tabrum, 1991) suggested that the boundary occurs in the earliest Wasatchian. Another datum is the first appearance of Planocarpus pollen in the earliest Wasatchian of the northern Bighorn Basin (Wing, 1984; Wing and others, 1991). This palynological datum occurs at the NPS/NP10 nan- nofossil zone boundary in the Gulf Coast (Federer, 1980), which is 300,000 years older than the Paleocene/Eocene bound- ary (Berggren, 1993). These correlations were borne out by the recent detection of the striking carbon isotopic event near the Paleocene/Eocene boundary (Rea and others, 1990; Kenneth and Stott, 1991) in earliest Wasatchian terrestrial carbon iso- topes extracted from palynos and mammal teeth and bones (Koch and others, 1992).

Yet some mammalian paleontologists (Gingerich, 1989; Gunnell and others, 1993) continue to place the Paleocene/Eocene boundary at the Clarkforkian/Wasatchian boundary. The key to the entire controversy lies in the interpretation of the Spasmian mammalian faunas of Europe. In the past, European mammalian paleontologists had considered the Spasmian the beginning of the Eocene Epoch, because its mammals were more similar to later Eocene faunas, and differed radically from the underlying upper Paleocene Thetisian faunas (Savage and Russell, 1983). The discovery of a new earliest Wasatchian fauna (Wau) in North America with strong similarities to the Spasmian in Europe supported that correlation (Gingerich, 1989, p. 83-87); Gunnell and others (1993) argued that the beginning of the Clarkforkian/Wasatchian transition was the time of greatest faunal turnover, and therefore it seemed to be the best place to mark the boundary.

But the Paleocene/Eocene boundary is defined on the basis of marine taxa in European type sections, not on the basis of North American or European mammalian faunas. Where the Clarkforkian/Spasmian boundary in North America (or the Thetisian/Spasmian boundary in Europe) falls in relation to marine stratotypes must be demonstrated, not asserted. One cannot assume the coincidence of mammalian faunal turnover and European epoch boundaries. For instance, the "Grande Coupure" in Europe was long thought to represent the Eocene/Oligocene boundary because of the great faunal turnover, but recent work (Hooker, 1992) has demonstrated that it actually occurred in the early Oligocene, about 1 my after the Eocene/Oligocene boundary.

Marine stratigraphers have long ago shown that the European Spasmian correlates with late Paleocene nanofossil zone: NP9 (Costa and Downie, 1976; Costa and others, 1978; Berg- gren and others, 1985, this volume; Aubry and others, 1988). It is at least one or two sequences lower (and about 1 million years older) than the Paleocene/Eocene boundary as denoted by the base of the London Clay or the Argille d'Ypres (Berggren, 1993), long recognized as the base of the Ypresian and therefore the base of the Eocene Epoch (Berggren and others, 1985; Aub- ry and others, 1988).

Tate and others (1995) described the magnetic stratigraphy of the Willwood Formation in the northern Bighorn Basin of Wyoming, and also argued that the Paleocene/Eocene boundary...
might correlate with the Clarkforkian Wasatchian boundary. The only direct evidence to support their argument is that the Plateau was not apparently occupied 35 meters below the first occurrence of a Wa7 fauna in the southern Bighorn Basin, although it occurs 160 meters above the Wa7 mammals in the northern Bighorn Basin. Thus, Taxa and others (1989) suggest that the range of Plateau morality and the Paleocene/Eocene boundary has been extended downward. However, as we saw above, the Plateau was not occupied by the N6/P7 boundary and it was not evident in the Paleocene/Eocene boundary, but about 300,000 years older (Rogers, 1982).

The most recent summary of most of the Eocene North American land mammal "ages" (Krishna and others, 1987) did not attempt to formally divide the entire interval into biostatigraphic stages. However, biostatigraphic zonations for the Wasatchian and Bridgerian have been proposed by Savage (1977), Gingerich (1976, 1980, 1983), Gingerich and Simmons (1977), Schnakker (1980), Stocky (1984), and Gunnell (1989). Some of these biostatigraphic schemes (especially those of Savage, 1977, Schenkler, 1980, and Stocky, 1984) follow the 1983 North American Stratigraphic Code in specifying type sections, but others do not. Currently, the Wasatchian is divided into eight "zones," labeled Wa7 to W9. (Gingerich, 1983, 1989). Clyde and others (1994) found that W9 was the lowest Wa9 occurred in the Bridgerian (57.3-55 Ma) in the northern Bighorn Basin, and that upper Wa8 and Wa7 correlates with C24n (52.5-53.3 Ma). Wa8 occurred in Cr2n (51.6-52.3 Ma). These ages are in good agreement with a new "G" date on Wa7 of 52.8 ± 0.2 Ma (Woodburne and Swisher, this volume).

No magnetic stratigraphy for the Wasatchian-Bridgerian transition has ever been published. Good sections are available in the Wind River, Green River, and Shoshone Basins (Krishna and others, 1989, p. 471), so eventually it should be possible to tie these to the geomagnetic polarity time scale. Based on F-A dates of 53.5 Ma on the latest Wa7 and 50.3 Ma on the earliest Bridgerian in the Wind River Formation (Kremer and others, 1964; Krishna and others, 1987, p. 93, Rame and Uch, this paper) probably occur around 50.4 Ma, or within Cr2n (Woodburne, this volume). Recently, Clyde and others (1995) reported on the magnetic stratigraphy of the Wasatchian-Bridgerian transition in the Green River Basin, Wyoming. They found this transition in Cr2n and suggested that it occurs between 49.7 Ma and 50.7 Ma.

After the Wasatchian, North America was separated from direct faunal interchange with Europe, and the correlative evidence becomes more indirect. At a result, the most effective technique has been radiometrically dated stratigraphy. The magnetic stratigraphy of the type Bridgerian in the Bridger Basin of Wyoming has been studied, but not published (Jervis, pers. comm., 1981), and is now being restudied (Fry, pers. comm., 1994). The magnetic stratigraphy of the classic Ulanian and Duchesnean sections in the Uinta Basin of Utah was described by Prothero and Swisher (1991) and Prothero (1992a). Bridgerian and Uintian beds have been studied in California and Wyoming by Fry (1984) and by McConnell and others (1993), and in Texas by Walton and Prothero (1992). Ulanian-Duchesnean beds in the Sand Wash Basin of Colorado (Stocky and others, 1991), the Sespe Formation of the Central County, California (Prothero and others, 1993), the Poway Group in San Diego County, California (Walsh and others, 1995), the Gallovo Formation in central New Mexico (Prothero and Lucas, 1995) and several units in western Montana (Thurman and others, 1995) have also been sampled.

According to Flynn (1986), the Bridgerian-Ulanian transition occurs early in Chron C28n, about 64 Ma. However, recent studies of the critical sections in San Diego suggest that the transition might lie within Chron C27n, about 47 Ma (Walsh, 1995; Walsh et al., 1999). The Ulanian-Duchesnean transition occurs within Chron C18n, about 40 Ma (Prothero and Swisher, 1992; Prothero, 1995b, 1995c; Prothero and others, 1995). The latest biostatigraphic correlations of the middle Eocene Bartonian and late Eocene Priabonian stages in Europe (Berggren and others, 1985; Aubry and others, 1988) place the Priabonian/Bartonian boundary in Chron C14n (Berggren and others, this volume), so that the middle Eocene includes not only the Bridgerian, but also the Ulanian and Duchesnean (Figs. 1, 3).

Gossell (1989) named two "zones" (U11, the Eupodophus assemblage zone, and U12, the camelid-carnivore assemblage zone) for the early and late Ulanian. However, unlike earlier Eocene zones, these are not based on recent detailed biostatigraphic work, but simply formalized the distinction between the faunas of Ulanian Formation Member "B" (upper part of the Wasatchian Woodbine Member of Wood, 1934) and Member "C" (Myton Member of Wood, 1934). More detailed biostatigraphic work to subdivide the seven million years of the Ulanian would be valuable, but the stratigraphic data on the existing collections from the Ulanian Basin are too incomplete, and the area is too poorly fossiliferous to make significant new collections with good stratigraphic data (Prothero and Swisher, 1992; Prothero, 1995a). The biostatigraphy of existing Ulanian Formation collections was summarized by Prothero (1995a). Ultimately, it would be better to subdivide the Ulanian by precisely dating stratigraphically superposed faunas in Texas (from the Weswa and Buck Hill Groups in the Big Bend region, Colorado (the Sand Wash Basin), Wyoming (the Washakie Basin), and California (the Sespe and San Diego sections). However, this effort is also hampered by the high degree of endemism of Ulanian faunas, making true first and last occurrences difficult to distinguish from local geographic effects (Lillegraven, 1979; Flynn, 1986; Krishna and others, 1987).

The Duchesnean has always been the most controversial land mammal "age" of the Eocene Epoch (Fig. 1). Originally considered the last of the Eocene ages by Wood and others (1941), opinions have fluctuated from placing it in the early Oligocene (Scott, 1945) or back to the late Eocene (Grimo, 1946), and built and forth several times since then. Gazzin (1955, 1959) assigned the faunas from the lower Duchesne River Formation (Lambert and Halfway faunas) to the late Ulanian. The poor quality of the overlying Lapeo Point fauna (the "classic" Duchesnean) and its similarity to some Chadronian faunas led several workers to reduce the Duchesnean to a stage of the Chadronian, or drop it altogether (Wilson, 1982, 1979, 1984, 1991). In recent years, opinions have swung back toward recognizing a distinct Duchesnean, with important correlations in Swinhoe, South Dakota, Wyoming, Montana, Texas, New Mexico, Oregon, and California (Krishna and others, 1987; Kelly, 1995; Lucas, 1992).

Even though the Duchesnean spans almost three million years, efforts to subdivide it into biostatigraphic zones have been controversial since the faunas are so sparse and often endemic to the many scattered localities (Lucas, 1992). Several authors have attempted to recognize an early and late Duchesnean in Texas (Wilson, 1984, 1986) and California (Kelly, 1995).
1990). Further radiometric dating and magnetic stratigraphy will probably provide the best test of the age of these faunas, and may eventually help establish a biostratigraphic zonation for the Duchesnean.

The most surprising conclusion of recent dating, however, concerns the Chadronian land mammal “age.” Considered early Oligocene age by the Wood Committee, it was K-Ar dated by Evernden and others (1964) at between 32 and 36 Ma. Since the Eocene/Oligocene boundary was generally placed around 36.5 Ma (Berggren and others, 1985), the correlation of the Chadronian with the early Oligocene seemed secure. However, the European Eocene/Oligocene boundary has been recently redated at 33.2 Ma (Berggren and others, this volume). At the same time, redating of K-Ar-dated ashes by *Ar*Ar methods have shown that the Chadronian spans an interval from 35-37 Ma (Swisher and Prothero, 1990; Prothero and Swisher, 1992). This places the Chadronian in the late Eocene, and the Eocene/Oligocene boundary appears to fall just below the Chadronian/Orellan boundary, not at the Duchesnean/Chadronian boundary, as long thought.

At the time of the Wood Committee report, the biostratigra phy of the Chadronian was very poorly understood. Many of the taxa (especially brontotheres and ceroodonts) were badly over-rich taxonomically, and the stratigraphic data on the fossils from the classic collections in the Chadron Formation were inadequate (Emery and others, 1987). Attempts to divide the Chadronian based on biostratigraphic evidence in the Chadron Formation in Nebraska (Schultz and Stout, 1955) or South Dakota (Clark, 1937, 1954; Clark and others, 1967) were unsuccessful (Emery, 1973; Emery and others, 1987). Since that time, however, Emery (1973, 1992) has carefully documented the mammalian biostratigraphy in the thickest and most fossiliferous Chadronian sequence at Flagstaff Rim, Wyoming. Based on this work, Emery (1992) identified criteria for recognizing early, middle, and late Chadronian, but no formal biostratigraphic zonation was proposed. Such a zonation is now in progress (Prothero and Emery, 1995).

**Oligocene Epoch**

The biochronology of the Eocene/Oligocene boundary has long been controversial. For decades, the dates produced by K-Ar methods on volcanics and by various isotopes in marine conchostracans produced highly contradictory estimates ranging from 32 to 38 Ma (Hardenbol and Berggren, 1978; Berggren and others, 1985; Berggren, 1986; Ausbruch and others, 1988; Chi radovich, 1988; Odin, 1978, 1982; Curry and Odin, 1982; Odin and Curry, 1985; Glass and Crook, 1982; Glass and others, 1986; summarized in Prothero, 1990, 1994), and Berggren and others, 1992). However, new *Ar*Ar dating of volcanic ashes in the deep marine sections in Gubbio and Massingno, Italy, directly tied to marine microfossils and magnetic stratigraphy (Montanari, 1988, 1990; Montanari and others, 1985, 1988; Odin and others, 1988, 1991) and of terrestrial volcanic ashes in North America (Swisher and Prothero, 1990; Prothero and Swisher, 1992) have resolved the controversy by eliminating many erroneous age estimates. The emerging consensus places the Eocene/Oligocene boundary at about 33.5 Ma (Berggren and others, this volume).

In addition to recalibrating the Eocene/Oligocene boundary, new *Ar*Ar methods provided radiometric dates on much of

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detailed itzation was proposed. Thanks to decades of work by Morris Skinner, Bob Emry, and collectors of the Frick Laba-
ory, however, there are now large collections of White River mammals with stratigraphy delineated to the nearest foot for ronicic isches. These collections allowed Prothero (1982) to
propose a preliminary biostratigraphy which divided the Orel-
ian into four zones, and recognizing one zone for the earilv Whit-
neyan. North (1989) also proposed a biostratigraphic zonation for the Orellan, but it is based on University of Nebraska col-
lections which do not have the resolution to subdivide the lith-
oolstratigraphic units. Hence, Knight's (1989) "faunal zones" are
really based on lithostratigraphic boundaries.
A finely resolved biostratigraphy for the Orellan and Whit-
nynian has long been in preparation, but the publication has
been delayed by the lack of up-to-date systematic revisions of many of the key taxa, especially rodents, lagomorphs, and ichn-
y Throndness. Such revisions are now in press various papers
in Prothero and Emery, 1995), and that volume suggests a formal
biostratigraphic zonation for the Chadianian through early Ar-
kareian (Prothero and Emery, 1995).
Rensberger (1971, 1973, 1983; Fisher and Rensberger, 1972) pro-
posed a formal biostratigraphic zonation of rodents from the
late Oligocene-Miocene Miocene John Day Formation of central
Oregon. The magnetostratigraphy of these beds has also been
published (Prothero and Rensberger, 1985), although it may need
further revision when new "m""""A""""A"""" data are analyzed by Carl
Swisher. Unfortunately, some of the key taxa used in
Rensberger's zonation do not occur in the classic Arikaree fauna
in the High Plains, so his biostratigraphic zones have been
proven useful only in Oregon, Montana, and South Dakota
(Telford and others, 1987). When the magnetic stratigraphy of
the American west is fully resolved and compared with the
magnetostratigraphy of the "other" western United States, it
will be possible to overcome these difficulties, and establish
biostratigraphic zones for the Arikareean throughout the west-
ern United States.
CONCLUSION

Despite its limitations, correlation by fossil mammals is still
the only practical method of dating most Oligocene terrigenous
deposits. In retrospect, the pioneering work of the Wood Com-
mittee (1943) was remarkably accurate in most of its correla-
tions; however, it may have been over-zealous in the use of what
are now known as "m""""A""""A"""" dates. The last decade have sig-
hnificantly changed some of the important cor-
relations. In particular, the Paleocene/Eocene boundary has
been moved to the middle of the Clackamasian into the early
part of the Wasatchian, and the Eocene/Oligocene boundary
shifted from the base to the top of the Chadianian. The Oli-
gocene/Miocene boundary has moved toward the middle most of the
Arikareean. Although these revisions may seem minor to the
non-specialist, they require major adjustments in the thinking
of several generations of paleontologists who were trained to
"equate" Chadianian with early Oligocene, Arikareean with early
Miocene, and so on. Those who have long talked about huge
"Oligocene" biostratigraphers must now get used to the fact that
there are probably no Oligocene biostratigraphers at all (not even in
Asia, see Berggren and Prothero, 1993). As uncomfortable as
that may be, it is required by the data that have now emerged.
More importantly, such major shifts in the time scale strongly
affect all studies of evolutionary patterns, rates of sedimen-
lation, climatic changes, and other geologic processes that depend
upon a particular correlation scheme or version of the time scale
(e.g., Berggren and Pagano, 1985; Prothero and others, 1985).
In the past, some vertebrate paleontologists have tried to sal-
vage their unmodified concepts by referring to the Duchesnean
as the "North American early Miocene," or, the Arikareean as
"North American early Miocene," or similar evolutions. This
is indefensible, since the Eocene epochs are strictly a European
marine concept, and the global time scale is based on European,
not North American, chronostratigraphy. The duration of the
epochs in North America is only known by correlation to an
independent North American chronology, and not by redefining
the European epochs in North American terms to reach ob-
solete notions. Indeed, the strength of the original North Amer-
ican latal mammal chronology lies in its independence. The
relative sequence of land mammal "ages" remains the same,
regardless of "where" the European epoch boundaries fall, as the
Wood Committee (1941) realized.
Although North American vertebrate paleontologists are
making encouraging attempts to construct formal biostratigra-
phies consistent with standard biostratigraphic methods, some
problems remain. Considering all the detailed work done by
some paleontologists to construct their "zonations," it is rather
surprising that they did not finish the job and propose their
"zones" in compliance with the North American Stratigraphic
Code. These same palaeontologists would be appalled if some-
one did not follow the International Code of Zoological No-
mbers and proposed taxa that had no type specimen and
became "nomen nudum" yet they have done something analogous
with their "biological zonation." In some places where the fossils
are abundant, there is much vertical bio-
stratigraphic range, the reason for this non-compliance with the
North American Stratigraphic Code is prohibitive excusable.
However, Gingerich (1976: Gingerich and Rose, 1977), Stein
(1987), and Archibald and others (1987) abandantly document
much of the stratigraphic detail necessary for formal type sec-
tons, yet do not take this final step.
With the detailed documentation now available, we should
soon be able to replace the informal biostratigraphic schemes
used by Archibald and others (1987), and Enry and others (1987)
with formal range-zone biostratigraphy. When a formal biostratigraphic basis for all the North American land mammals "ages" is published, these zones will
become true biostratigraphic stages. At that point, we will no
longer need to apologize for our system with the ubiquitous
quote around the word "age." More importantly, tying the in-
formal biostratigraphic to specific sections will make our work
of locating magnetic polarity zones and radiometric dates much
easier. Half a century of ignoring standard biostratigraphic prac-
tice is enough.

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