MAGNETIC POLARITY STRATIGRAPHY AND PALEOCENE-EOCENE BIOSTRATIGRAPHY OF POLECAT BENCH, NORTHWESTERN WYOMING

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Abstract.— Late Paleocene and early Eocene mammalian faunas are well represented in a 1500 m sequence of continental sediments exposed on the south side of Polecat Bench. This part of the Polecat Bench section includes faunas representing four of the five Tiffanian *Plesiadapis* zones, all three Clarkforkian zones, and the basal Wasatchian *Pelycodus ralstoni* zone. The entire sequence is of reversed polarity except for two normal polarity zones, one in the transition from the middle to late Tiffanian and the other in the transition from the Tiffanian to Clarkforkian. By comparison with the Cenozoic magnetic polarity time scale, these are interpreted as magnetic anomalies 26 and 25. The Paleocene-Eocene boundary in North American mammalian faunas is placed between the early and middle Clarkforkian, which our work indicates is just above anomaly 25 on the magnetic polarity time scale.

INTRODUCTION

Magnetostratigraphic studies of terrestrial sedimentary sequences containing important vertebrate faunas are of considerable importance in establishing the geochronology of land mammal ages. Early and middle Paleocene land mammal ages (Puercan and Torrejonian) are best known from continental sediments of the Nacimiento Formation in the San Juan Basin of New Mexico. The paleomagnetic stratigraphy of these beds has been studied recently (Butler et al., 1977; Lindsay, Jacobs, and Butler, 1978; Taylor and Butler, 1980; Lindsay, Butler, and Johnson, 1980; see also Tomida and Butler, 1980). Faunas of late Paleocene and early Eocene land mammal ages (Tiffanian, Clarkforkian, and Wasatchian) are best documented in the Clark's Fork and Bighorn basins. Here we present a preliminary report on the paleomagnetic stratigraphy of late Paleocene and early Eocene land mammal ages in the northern Bighorn Basin, with particular reference to mammalian faunas in the stratigraphic section exposed on the south side of Polecat Bench. A more extensive report on this work in the Clark's Fork Basin-Polecat Bench area is in preparation.

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BIOSTRATIGRAPHY

The Tiffanian Land-Mammal Age can be subdivided into five zones or biochrons in the Clark's Fork Basin-Polecat Bench area, based on the evolution of the archaic primate genus *Plesiadapis* (Gingerich, 1976). These are, in sequence, the *P. praecursor, P. anceps, P. rex, P. churchilli,* and *P. simonsi* zones, which we abbreviate Ti_1-Ti_5, respectively. The very latest Tiffanian and Clarkforkian can be subdivided into three zones, based on large *Plesiadapis* or its absence. These are, in sequence, the *P.* sp. nov., *P. cookei,* and *Phenacodus-Ectocion* zones (Rose, 1980), which we abbreviate Cf_1-Cf_3, respectively. Similarly, the Wasatchian of the Clark's Fork and Bighorn basins can be subdivided into five *Pelycodus* zones or

biochrons (Gingerich, 1980), only the first of which, the *Pelycodus ralstoni* zone (Wa_1), is present on Polecat Bench.

Tiffanian, Clarkforkian, and Wasatchian faunas occur through a 1500 m thick sequence of sediments in the Polecat Bench and Willwood formations on Polecat Bench (from approximately 100 m to 1600 m above the base of the Polecat Bench Formation; see Gingerich, Rose, and Krause, this volume). This sequence includes faunas of Tiffanian zones Ti_2-Ti_5, Clarkforkian zones Cf_1-Cf_3, and early Wasatchian zone Wa_1; that is, a complete sequence of late Paleocene and early Eocene faunas from zones Ti_2 through Wa_1.

The Paleocene-Eocene boundary in North America was previously placed between the Tiffanian and Clarkforkian land mammal ages, based on correlation of North American mammalian faunas with those of the Paris Basin in Europe using *Plesiadapis* (Gingerich, 1976). Recent work indicates the presence of a new species of *Plesiadapis* in North America temporally and phyletically intermediate between previously known *P. simonsi* and *P. cookei.* This latest Tiffanian-early Clarkforkian species is most similar to latest Thanetian *Plesiadapis* in Europe, indicating that the Paleocene-Eocene boundary recognized between the Thanetian and Sparnacian in Europe should be placed between the early and middle Clarkforkian in North America (Rose, 1980). In terms of the zonation used here, the Paleocene-Eocene boundary falls between biochrons Cf_1 and Cf_2.

MAGNETIC POLARITY STRATIGRAPHY

At least three oriented block samples were collected at each of 190 sites in the Polecat Bench section. Collection and sample preparation techniques are described in Lindsay, Butler, and Johnson (1980). Each paleomagnetic site was chosen to sample the finest lithology and least weathered outcrop available, and sites were spaced 20 ft (6 m) apart whenever suitable lithologies were present. Most sites were in dark claystone or fine siltstone, and red beds in the Willwood Formation were avoided. Measurements of remanent magnetization were made using a cryogenic magnetometer (Superconducting Technology, C-102) with noise level of approximately 1×10^{-7} gauss·cm^3. A Schonstedt GSD-1 single-axis demagnetizer was used for performing alternating-field (AF) demagnetization. Double demagnetizations were done for most AF treatments and no diverging directions or erratic behavior were observed.

Intensities of natural remanent magnetization (NRM) are low in both the Polecat Bench and Willwood formations. Mean NRM intensities following AF demagnetization in 300 oe peak field are 3×10^{-7} gauss in the Polecat Bench Formation and 6.5×10^{-7} gauss in the Willwood Formation. The AF demagnetization behaviors observed for these samples are quite similar to those observed for samples from the San Juan Basin (Lindsay, Butler, and Johnson, 1980). The carrier of the primary NRM has the characteristics of detrital magnetite or titanomagnetite, and there seems little doubt that the primary NRM is a depositional remanence acquired penecontemporaneous with deposition.

Site mean directions were calculated and a test for randomness was also performed. Statistical parameters of all sites were examined to establish which sites contained a grouping of sample NRM vectors exceeding that expected if the vectors were sampled from a random population ($p \leqslant 0.05$). Passage of this test requires $R \geqslant 2.62$ for $N = 3$ and is a rather stringent test for such weakly magnetized rocks. In the Polecat Bench section, 90 of the 128 sites in the Polecat Bench Formation passed this test, while 28 of the 40 sites in the Willwood Formation passed the test. No data were rejected as a result of this statistical analysis. However, we are more confident of polarity assignments for sites passing the test than for others. Accordingly, sites whose clustering is significantly different from random at the 95% confidence level are given more weight in our interpretation of the polarity zonation.

INTERPRETATION

Site mean virtual geomagnetic pole (VGP) latitudes following AF demagnetization are plotted for the Polecat Bench section in Figure 1. Also illustrated are positions of the principal fossil localities and the range of each of the Tiffanian, Clarkforkian, and Wasatchian mammalian biochrons, together with the interpreted magnetic polarity column. Negative VGP latitude indicates reversed polarity and positive VGP latitude indicates normal polarity. We have not designated polarity zones in the lower 100 m of this section because we do not believe that the results in this interval can be interpreted reliably. Lithologies in this stratigraphic interval are dominated by sandstones, and weathering of the outcrop is quite deep in this area. Also, we do not observe a coherent pattern of results distributed into stratigraphic intervals of positive and negative VGP latitudes. Above the 100 m level, we do observe coherent patterns of VGP latitudes that clearly define the polarity zonation.

Most of the 1500 m thick stratigraphic sequence

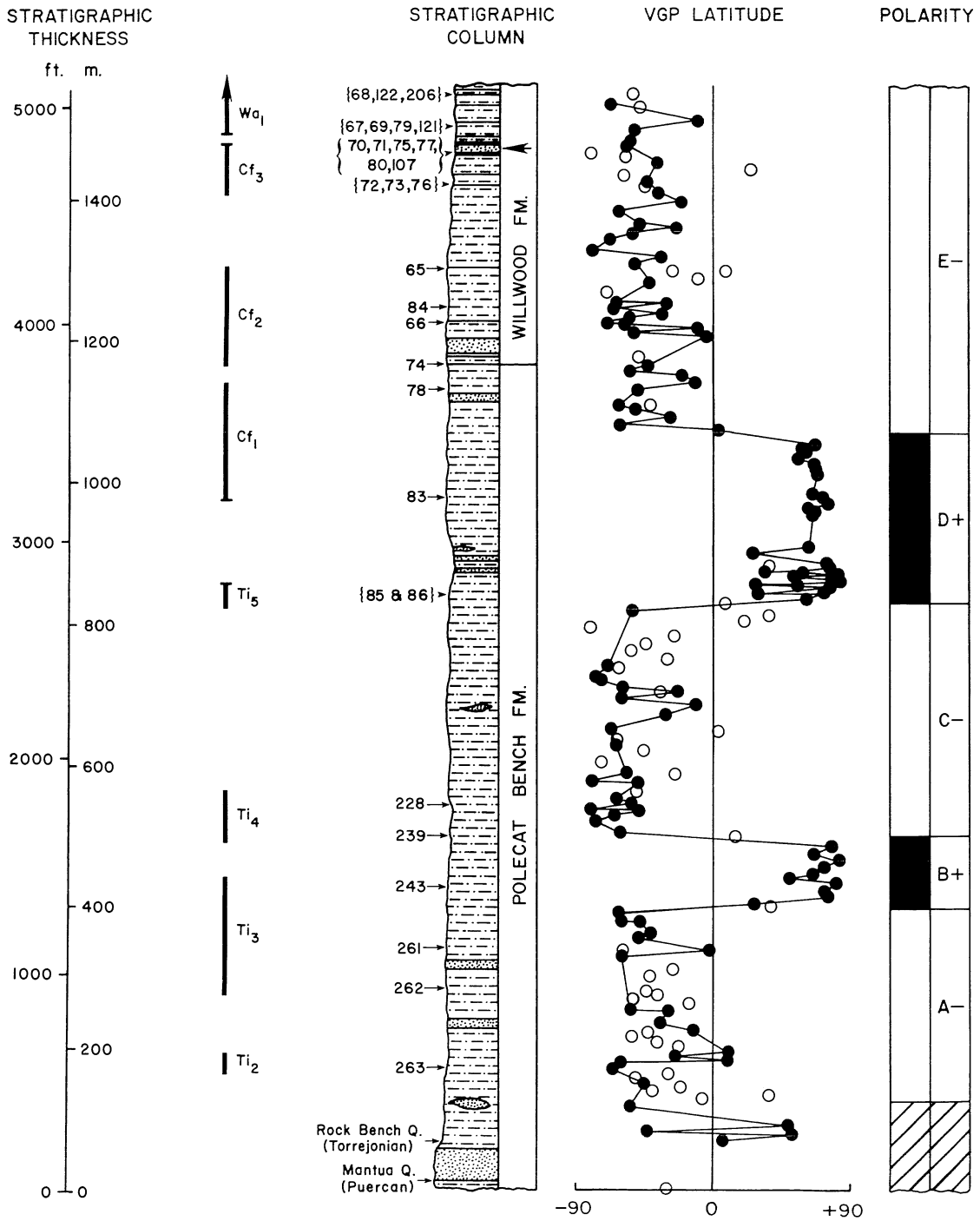

Figure 1. Stratigraphic section on the south side of Polecat Bench, showing the position of each of the principal University of Michigan fossil locations (numbered) in the drab Polecat Bench and red-banded Willwood formations. Biochrons abbreviated Ti_{2-5}, Cf_{1-3}, and Wa_1 are explained and discussed in the text. Mean virtual geomagnetic pole (VGP) latitudes for each site in the Polecat Bench section are illustrated together with our interpreted polarity column. Normal polarity zones B+ and D+ are interpreted as magnetic anomalies 26 and 25, respectively. The Paleocene-Eocene boundary between biochrons Cf_1 and Cf_2 is just above the top of anomaly 25.

above the 100 m level in the Polecat Bench section is of reversed magnetic polarity. There are two significant normal polarity zones in this sequence, one from level 400 m to 500 m, and the other from level 820 m to 1070 m. As shown in Figure 1, the first normal polarity zone (B+) occurs at the transition between the *Plesiadapis rex* (Ti_3) and *P. churchilli* (Ti_4) zones, which is also the transition from middle to late Tiffanian. The second normal polarity zone (D+) occurs at the transition from the latest Tiffanian *Plesiadapis simonsi* Zone (Ti_5) to the early Clarkforkian *Plesiadapis* sp. nov. zone (Cf_1). Most of the early Clarkforkian falls within this second normal polarity zone.

The pattern of reversals observed in the Polecat Bench section is one of a relatively long early and middle Tiffanian reversed interval (A-), a relatively short normal interval (B+), a short late Tiffanian reversed interval (C-), a moderate early Clarkforkian normal interval (D+), then a long reversed interval (E-) extending through the middle and late Clarkforkian and early Wasatchian (our results indicate that all of the early Wasatchian in the Clark's Fork Basin to the west of Polecat Bench is also of reversed magnetic polarity). This signature matches that of anomalies 25 and 26 on recently published magnetic polarity time scales (Tarling and Mitchell, 1976; La Brecque, Kent, and Cande, 1977; Hardenbol and Berggren, 1978; and others). Furthermore, anomaly 26 corresponds to the *Planorotalites pseudomenardii* (P4) planktonic foraminiferal zone, which is mid-Thanetian in age (Berggren et al., 1978), corroborating our interpretation here.

In Europe, the Paleocene-Eocene boundary is usually drawn between the Thanetian and Sparnacian ages (Gingerich, 1975; Berggren et al., 1978). By comparison with mammalian faunas of the Paris Basin, the Paleocene-Eocene boundary in North America appears to correspond to the early Clarkforkian-middle Clarkforkian boundary (Rose, 1980). The transition from the early to middle Clarkforkian occurs between localities SC-78 and SC-74, which is just above magnetic polarity zone D+ (Figure 1). In other words, the Paleocene-Eocene boundary appears to fall just above anomaly 25 in the Polecat Bench section. The Paleocene-Eocene boundary on Polecat Bench corresponds closely to the Polecat Bench-Willwood formational boundary, but this correspondence appears to be largely accidental since the formational boundary is clearly time transgressive in other areas of the Clark's Fork and Bighorn basins.

Magnetic stratigraphy and its correlation with mammalian biostratigraphy during most of the Eocene has not yet been studied, and a number of questions in the Paleocene remain to be clarified. For example, we are not yet able to make an unambiguous paleomagnetic and biostratigraphic correlation between the San Juan Basin and the Polecat Bench area. However, it is becoming increasingly clear that magnetostratigraphy can and will make a very important contribution to understanding the geochronology of the Paleocene-Eocene transition and other important events of Cenozoic faunal evolution.

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LITERATURE CITED

BERGGREN, W. A., M. C. McKENNA, J. HARDENBOL, and J. D. OBRADOVICH. 1978. Revised Paleogene polarity time scale. Jour. Geol., 86:67-81.

BUTLER, R. F., E. H. LINDSAY, L. L. JACOBS, and N. M. JOHNSON. 1977. Magnetostratigraphy of the Cretaceous-Tertiary boundary in the San Juan Basin, New Mexico. Nature, 267:318-323.

GINGERICH, P. D. 1975. What is type Paleocene?-Discussion. Amer. Jour. Sci., 275:894-895.

GINGERICH, P. D. 1976. Cranial anatomy and evolution of early Tertiary Plesiadapidae (Mammalia, Primates). Univ. Michigan Pap. Paleont., 15:1-140.

GINGERICH, P. D. 1980. Evolutionary patterns in early Cenozoic mammals. Ann. Rev. Earth Planet. Sci., 8:407-424.

HARDENBOL, J. and W. A. BERGGREN. 1978. A new Paleogene numerical time scale. Amer. Assoc. Petrol. Geol., Stud. Geol., 6:213-234.

LaBRECQUE, J. L., D. B. KENT, and S. C. CANDE. 1977. Revised magnetic polarity time scale for late Cretaceous and Cenozoic time. Geology, 5:330-335.

LINDSAY, E. H., R. H. BUTLER, and N. M. JOHNSON. 1980. Biostratigraphy and magnetic polarity stratigraphy of upper Cretaceous and Paleocene terrestrial deposits, San Juan Basin, New Mexico. Amer. Jour. Sci., 280:in press.

LINDSAY, E. H., L. L. JACOBS, and R. F. BUTLER. 1978. Biostratigraphy and magnetostratigraphy of Paleocene terrestrial deposits. San Juan Basin, New Mexico. Geology, 6:425-429.

ROSE, K. D. 1980. Clarkforkian Land-Mammal Age: revised definition, zonation, and tentative intercontinental correlations. Science, in press.

TARLING, D. H. and J. G. MITCHELL. 1976. Revised Cenozoic polarity time scale. Geology, 4:133-136.

TAYLOR, L. H. and R. F. BUTLER. 1980. Magnetic polarity stratigraphy of Torrejonian sediments, Nacimiento Formation, San Juan Basin, New Mexico. Amer. Jour. Sci., 280:97-115.

TOMIDA, Y. and R. F. BUTLER. 1980. Dragonian mammals and Paleocene magnetic polarity stratigraphy, North Horn Formation, central Utah. Amer. Jour. Sci., 280: in press.