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Magnetostratigraphy of the early Oligocene Pipestone Springs locality, Jefferson County, Montana

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ABSTRACT

A classic early Oligocene (Chadronian) mammal locality, the Pipestone Springs local fauna of Jefferson County, Montana, was paleomagnetically sampled. 24 sites, spanning 43 m of section, were treated by thermal demagnetization. The lower 25 m showed a predominantly normal polarity; the upper portion of the section showed reversed polarity. Faunal correlations and magnetostratigraphic work on other Chadronian sections suggest that the Pipestone Springs sequence correlates with Chron 13 and Chron 12r of the magnetic polarity timescale, or approximately 35 to 36 mybp.

INTRODUCTION

The early Oligocene Pipestone Springs local fauna (l.f.) is considered one of the most important North American Oligocene mammal localities outside the High Plains. Despite the limited outcrop, this locality provides a diverse fauna (especially of small mammals) that allows comparison of montane basin Early Oligocene faunas with the High Plains Chadronian faunas. Many of the taxa in this fauna are unique to Pipestone Springs. Since it was first discovered by Earl Douglass in 1899, Pipestone Springs has been extremely productive, and has generated a large literature, which was reviewed by Tabrum and Fields (1980). The geology of Pipestone Springs and other nearby Oligocene localities in the Jefferson River Valley was described by Kuenzi and Fields (1971). Tabrum and Fields (1980) have revised and updated the faunal list. There are now 55 species of mammals reported from the Pipestone Springs l.f.

PALEOMAGNETIC STRATIGRAPHY

The main fossiliferous exposures are part of the Climbing Arrow Member of the Renova Formation (Kuenzi and Fields, 1971). They are located in the NW 1/4, NW 1/4, SW 1/4, sec. 29, T.2N R.5W, Delmoe Lake 7.5-minute quadrangle, Jefferson Co., Montana (Fig. 1). The Climbing Arrow Member at this locality consists of about 60 m of volcaniclastic and montmorillonitic pumiceous mudstones and immature vitric siltstone. The outcrops are fresh and well-exposed, and soft enough to collect with simple hand tools. The magnetostratigraphic section was begun at the first good exposures above the unconformable contact with the underlying Cretaceous Boulder Batholith. The section trended northeasterly (downdip) along the ridge indicated by the 4760 foot contour (Fig. 1) from the NW 1/4, NW 1/4, SW 1/4 of section 29, to the SE 1/4, SW 1/4, NW 1/4 of the same section (shown as localities MV 5902, 5811, and 5901 in Kuenzi and Fields, 1971, Fig. 3). Due to the local strike and dip of N5OW, 25N, section was measured with a Brunton transit using the Hewett method. Samples were taken every 1.3 meters, resulting in 24 levels, or sample sites. Three oriented samples were taken at each site, using simple hand tools. In the laboratory, the samples were trimmed with a tungsten carbide-tipped band saw.

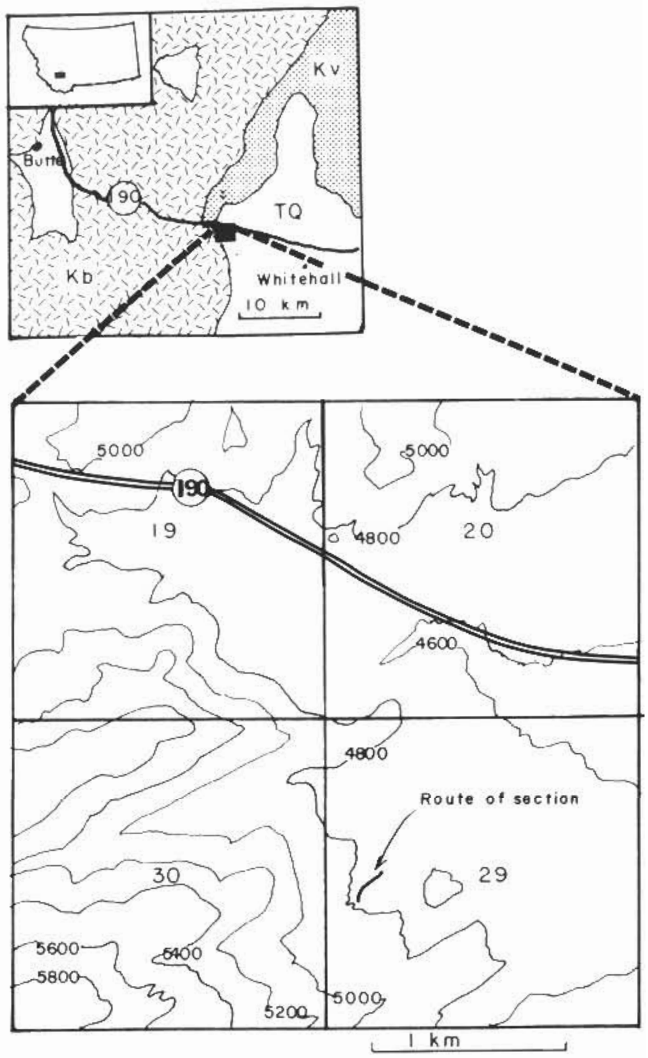

Figure 1. Location map (modified from Kuenzi and Fields, 1971, and the Delmoe Lake 7½-minute quadrangle) showing route of magnetostratigraphic section in Section 29, T2N, R5W. Abbreviations: Kb = Cretaceous Boulder Batholith; Kv = Cretaceous volcanics; TQ = Tertiary and Quaternary valley deposits (including the Oligocene Renova Formation).

Samples were measured on a CTF Systems, Inc., cryogenic magnetometer at the South Dakota School of Mines and Technology. Mean NRM (natural remanent magnetization) intensity was 6.47 x 10^{-6} Gauss. Since many White River Oligocene rocks of similar lithology have proven difficult to demagnetize with alternating field treatment due to chemical overprinting from goethite (Prothero, *in review*), all samples were thermally demagnetized. Progressive thermal demagnetization showed a rapid decrease in intensity at higher cleaning temperatures. By 500 °C, the mean intensity had dropped to 8.16 x 10^{-7} Gauss. At 600 °C (above the Curie point of magnetite), the intensity was much less than 5% of NRM, indicating that the primary carrier of the remanence is detrital magnetite. Most samples showed a single characteristic component of normal polarity when analyzed on a Zijderveld plot (Fig. 2). A few samples showed clear reversed directions at demagnetization temperatures of 150-300 °C. All samples which had not given stable, clustered directions at 300 °C were demagnetized again at 500 °C to see if their directions improved. Sample directions were then averaged for each site, and rotated to correct for strike and dip. Standard site statistics (Fisher, 1953; Irving, 1964) were then calculated.

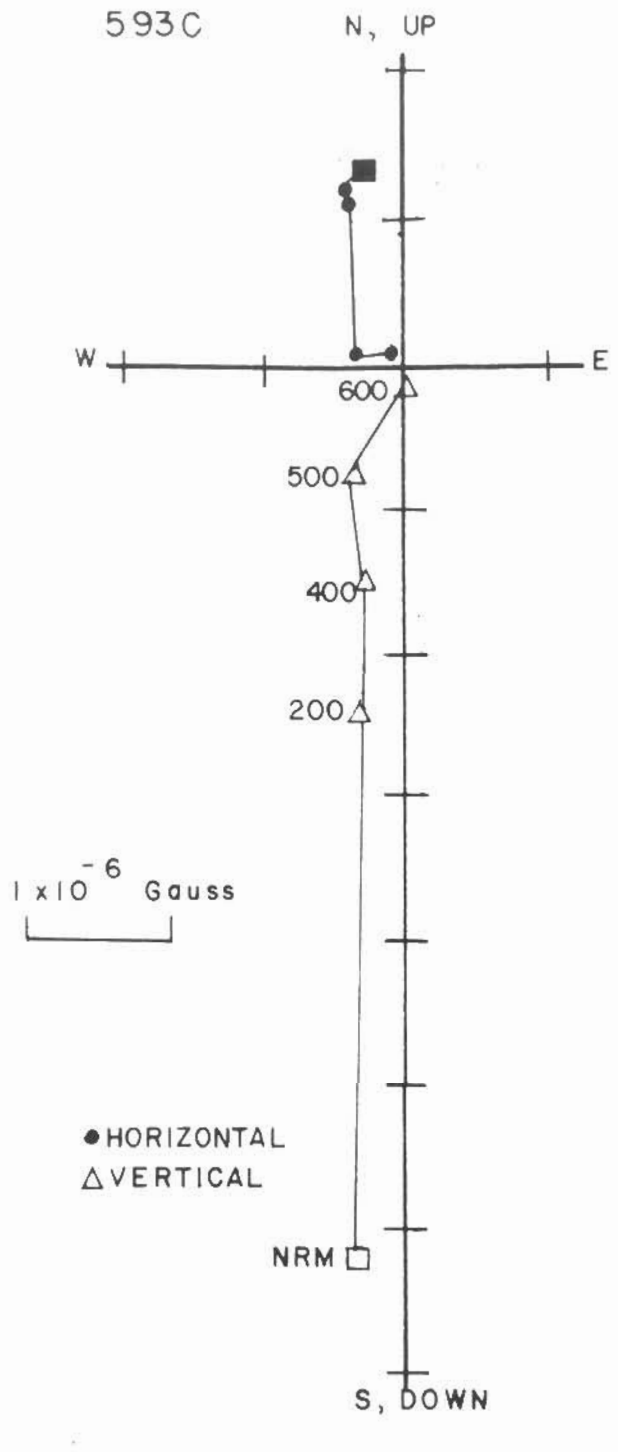

Figure 2. Vector demagnetization (Zijderveld) plot of normal sample 593C. Each step is demagnetization temperature in degrees centigrade.

Five of the 24 sites were significantly separated from a random distribution at the 95% confidence level. These are Class I sites of Opdyke and others (1977), and are indicated by a solid circle in Figure 3. In four sites, one sample was lost during preparation, but the other two samples gave clear concordance of directions. These are Class II sites of Opdyke and others (1977), indicated by the open square in Figure 3. Class III sites of Opdyke and others (1977) have two samples which are concordant, but the third is divergent. These are shown by open circles in Figure 3. One site was considered indeterminate (shown by an "x" in Fig. 3). VGP (virtual geomagnetic pole) latitudes were calculated for each site and plotted

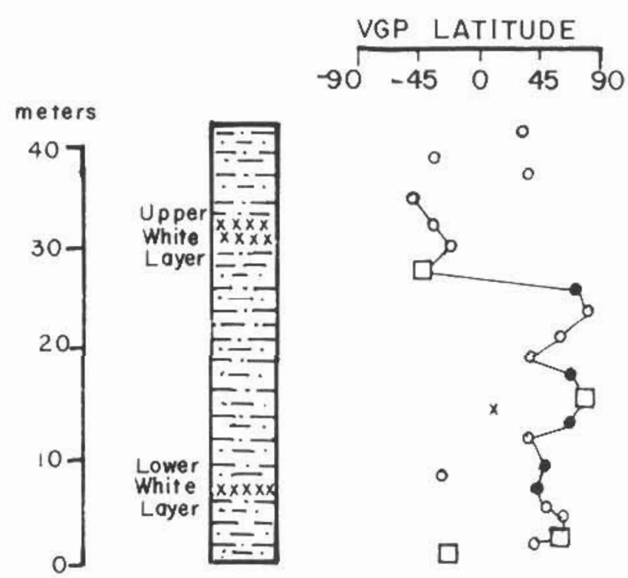

Figure 3. Magnetic polarity stratigraphy of the Pipestone Springs section. Positive virtual geomagnetic pole (VGP) latitudes are normal; negative VGP latitudes are reversed. Site classification (after Opdyke et al., 1977) is as follows: solid circle—Class I (significant); open square—Class II (sample lost, not significant); open circle—Class III (divergent sample, not significant); "x" = indeterminate polarity. Only polarity zones established by two or more sequential sites of similar polarity are connected by the solid line.

in Figure 3. The polarity pattern thus produced shows that the lowest well-exposed sampling level is of reversed polarity, but there are about 20 m of poorly exposed Oligocene rocks below this level. Strata 25 m thick with a predominantly normal polarity occur above this basal site. In the middle of this zone, one site, near the "lower white layer," is of reversed polarity. The upper 15 m of section is of reversed polarity, except for two sites near the top which appear to be of normal polarity.

CORRELATION

The polarity pattern at Pipestone Springs is not diagnostic by itself. Mammalian biostratigraphy, however, makes a correlation with the polarity timescale possible. Clark and Beerbower (in Clark, Beerbower, and Kietzke, 1967, p. 56-59) correlated the Pipestone Springs l.f. with the upper part of the Chadron Formation (the "Peanut Peak" Member) in the Big Badlands of South Dakota. Emry (1973, p. 34-41) thoroughly reviewed the arguments of Clark and Beerbower and showed that the Pipestone Springs l.f. was not late Chadronian, but as old as medial Chadronian in age. Emry, Bjork, and Russell (*in press)* correlated Pipestone Springs with the interval between Ash B and Ash F at Flagstaff Rim, Natrona County, Wyoming. This was based on strong similarities of the entire fauna. In particular, the large species of *Leptomeryx, L. mammifer (Leptomeryx* species "C" of Emry, 1973) was shown to be restricted to this interval at Flagstaff Rim. It also occurs abundantly at Pipestone Springs. Thus, the biostratigraphic evidence places the age of the Pipestone Springs l.f. between the dates of 34.6 (Ash F) and 36.1 (Ash B) at Flagstaff Rim (Fig. 4).

In the Chadronian, the polarity timescale shows only two short episodes of normal polarity within one of the longest episodes of reversed polarity in the Tertiary. The Pipestone Springs normal magnetozone could be correlated with either of these two normal magnetochrons, Chron 12 (32.5-32.9 mybp, according to Berggren, Kent, and Flynn, 1984) or Chron 13 (35.3-35.9 mybp). As is

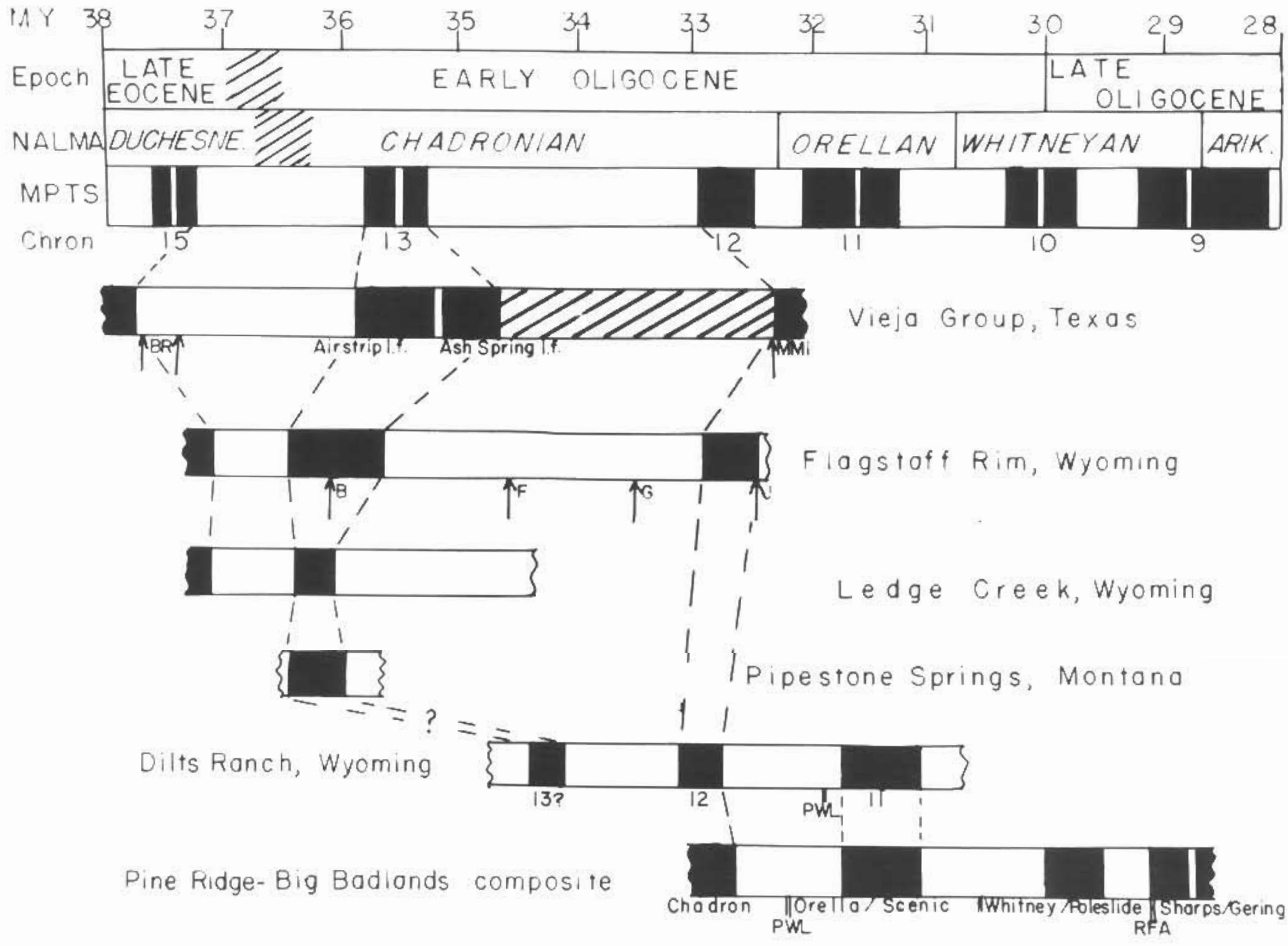

Figure 4. Correlation of the Pipestone Springs magnetostratigraphy with other Oligocene magnetostratigraphies (Prothero, in review) and with the polarity timescale of Berggren, Kent and Flynn (1984). Abbreviations: NALMA = North American land mammal "ages"; ARIK. = Arikareean; DUCHESNE. = Duchesnean; MPTS = magnetic polarity timescale; BR = Bracks Rhyolite; MMI = Mitchell Mesa ignimbrite (dates on both shown by arrows); l.f. = local fauna; PWL = Persistent White layer; RFA = Rockyford Ash. Thickness of magnetostratigraphic sections is based on geochronologic positions of radiometrically-dated ashes.

clear from Figure 4, correlation with Chron 13 is far more reasonable since:

1) it accords with the biostratigraphic evidence which places the Pipestone Springs local fauna between Ashes B and F at Flagstaff Rim. Chron 13 is recognized from about 11 m below Ash B to 10 m above Ash B at Flagstaff Rim (Prothero, *in review;* see Fig. 4).

2) correlation of the Pipestone Springs magnetostratigraphy with Chron 12 (the only other Chadronian normal magnetochron) would grossly conflict with the biostratigraphic evidence. In addition, the Pipestone Springs magnetostratigraphy shows some tentative evidence of a short reversed excursion within the long normal magnetozone. This is observed in Chron 13, but not in Chron 12 (Berggren and others, 1984).

Thus, the combined biostratigraphic and magnetostratigraphic evidence suggests that the Pipestone Springs sequence ranges from 35 to 36 mybp, so that the Pipestone Springs l.f. is of earliest Oligocene (early medial Chadronian) age.

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Cover Illustration:
Geologic map of part of the Wyoming thrust belt (see paper by Evans and Spang).

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