
DONALD R. PROTHRO

ABSTRACT

Magnetographic sampling was conducted on key stratigraphic levels of the White River Group in the High Plains, in order to determine the tectonic history of the region. The results indicate that the area was characterized by multiple periods of magnetic activity, each associated with different tectonic events. The analysis of the magnetic stratigraphy provides insight into the geologic history of the region and its evolution over time.

INTRODUCTION

The rich fossiliferous and petrified fauna-bedecked sands of the White River Group in the High Plains (Fig. 1) have been a magnet to fossil hunters and paleontologists for over a century, as the White River sandstones and shale of this time span have long been a subject of scientific study. Many detailed paleontological studies have been published over the years (Cantino, 1931; Clark et al., 1967; Sengor and Picard, 1960; Reisch, 1965; Sengor, 1957, among others). Some areas have been reviewed by Scheckel et al. (1965). Despite the amazing variety and quantity of fossils, no comprehensive study has been made of the magnetic stratigraphy of the area. This study was undertaken with the goal of understanding the tectonic history of the region and its evolution over time.

Methods

As previously described in Prothro (1982) and Prothro (1983), all samples were collected with simple hand tools at horizontally orientated transverse sections of rock. Three samples were collected per site, and most sites were spaced 5.5 feet (1.7 m) apart. In the laboratory, the samples were treated into cored cores approximately 3.5 cm in length. Different techniques were used for the samples at different sites, and the procedures have evolved as necessary. For the sections that were sampled, the results indicate that the area was characterized by multiple periods of magnetic activity, each associated with different tectonic events. The analysis of the magnetic stratigraphy provides insight into the geologic history of the region and its evolution over time.

Figure 1. Magnetic stratigraphy of the White River Group in the High Plains.
Figure 2. Typical orthogonal demagnetization plane (\(C_{2}H_{2}\)) plane of demagnetization (AF demagnetization) of samples. 1 = NRM direction of inclination. Each diamond is 1 in. The smoothly deepens rapidly, showing an AF demagnetization in the primary carrier of the remanence.

Figure 3. Typical orthogonal demagnetization plane (\(C_{2}H_{2}\)) plane of remagnetization results. Convergences in the comparison of remagnetization and a fade residual component is present between 300-500°C. This component was used in further analysis.

Figure 4. IRM (inductive remanence magnetization) demagnetization over the range of 150°C to 550°C. A typical sample from the arm (black squares) and from the arm (black stars) is shown in the IRM demagnetization patterns (see Pickering et al., 1991, for details of the IRM).
Figure 3. Magnetic anisotropy of the "Little Badlands" (left) and "Fitterer Ranch" (center and right sections) in South County, North Dakota. Similar locations of sections given in text. Stratigraphic terminology follows Skoog (1973) and Storm (1972). Sections in parentheses are not entirely separated from the sections given in the text, and the distributions at the 95% confidence level. Triangles are class 3 sites, which could not be statistically analyzed because only two samples, instead of three, were lost or not collected. Open circles are class 3 sites, in which two samples showed a clear magnetic anisotropy. 3.4.4.4.$\sigma = 0.5\sigma, \sigma = 1.7$ within the unit area matrix. This positive remanent mean suggests that the magnetization is primary and not due to secondary overprinting. Most of the areas, so far not tested could be conducted. In some sections, it was not possible to completely remove the remanent magnetization, so that there are isolated single-site "polarity events." In most (such as single-member units within a long reversed interval), these are most likely due to normal overprinting. Consequently, the conclusions drawn below are based only on magnetizations that are at least as two or more sites; single-site "polarity events" are not considered a part of the normal overprinting. However, the possibility that these "events" are real cannot be ruled out, as detailed analysis of Oxfordian samples (Haq et al. 1993) has shown that there were a number of brief polarity events during the Oligocene and Miocene.

RESULTS
The magnetic polarity patterns of each of these regions is discussed below. Details of the magnetic analyses sections have already been published elsewhere (Skog et al. 1990, 1991).

White River Valley Magnetostratigraphy
The Rock Laboratory collecting in the area started in 1984. Skoog presented a detailed stratigraphic for the major collection areas in the Little Badlands and for the newly discovered fossil localities at Fitterer Ranch. Skoog (1987) presented a more detailed stratigraphy for the Rock Valley sections, containing several new names for the members to be recognized. However, those names are identical to those used in his study (Huggenberger, 1984; Murphy et al. 1985). Since the 1980s, the Upper Member of the Little Badlands and the North Dakota have been extensively studied and published by personnel of the North Dakota Field Geology Survey (Huggenberger, 1984; Huggenberger and Lawrence, 1984; Huggenberger, 1982). The White River Group in the region was refigured in detail by Murphy et al. (1991).

In 1980 I had only Skinner (1951) and Skinner's unpublished field notes on which to base a major stratigraphic analysis of the important Rock Valley section from which the magnetic data were collected. A magnetic section was taken in the main area of the Little Badlands (7 miles south of Saddle Butte) in the Rock Laboratory's "Peninsula Ranch" locality of Murphy et al. (1983, p. 35). The section (Fig. 4) began in SE NW SW Sec 23, and was completed in SW SW NW Sec 23. S1 E1, SW SW NW Sec 23, and included a transverse section across the early Cenozoic, normal magnetization (north throughout the White River Group. The rest of the section is of reversed polarity. Important collections were also made by the North Dakota at Fitterer Ranch. The measured section began in NW SW Sec 7, T1N NW NW, New England Township, Mountrail County, North Dakota. It is in the upper part of the section above Fitterer Ranch channel, which was taken in NW SW Sec 17. The sections and stratigraphic terminology shown in Figure 5 was developed by Skinner (1951), the section is as developed by Murphy et al. (1991, p. 37). In these sections, and of the upper part of the section is of normal polarity, as it is in the Little Badlands. However, unit 4H of is of normal polarity for the Little Badlands section. The lower part of the Fitterer Ranch section is of reversed polarity. The upper unit of the section begins at the top of the likely fossiliferous Fitterer Ranch channel, and unit 3D (10 feet thick) of Skoog (1951) are of reversed polarity. The rest of the section is through unit 6 of Skoog (1951) are of normal polarity. In the Rock Laboratory section, these areas as the White River, which is where it would make the normal magnetization curve, with the upper portion of normal magnetization (Problem and Murphy, 1992). Murphy et al. (1991, p. 106) confirmed the age of these areas, since it is diagnostic of the area. Placental mammals have been described from these areas. However, the major of the Rock collections from these beds have not yet been named. They may eventually substantiate the suggestions of Morris Skinner and the others in the Fitterer collecting parties.

Pine Ridge area, Sioux County, Nebraska
Outside the Big Badlands and the Little Badlands sections along the Pine Ridge in Wyoming, the most fossiliferous collecting areas occur along the Pine Ridge in Nebraska. The thickest and best exposed of these sections in the Transect Park-Rocky Ford sections described by Schulz and Stone (1955), fig. 3, sections 6-9, also shown in Schulz and Stone (1965), fig. 3, sections 6-9, and Schulz and Stone (1965). The revised magnetostratigraphy of the Transect Park-Rocky Ford section is shown by Duennebier and Sevacher (1952, 25). This has been used as the basis for a study of the University of Nebraska State Museum fossil collections section, fig. 3, fig. 4. The revised magnetostratigraphy of the Transect Park-Rocky Ford section is shown by Duennebier and Sevacher (1952, 25).
Figure 6. Magnetic stratigraphy of sections in western Iowa and eastern South Dakota, northwestern Nebraska. Key locations of sections described in text. Lithostratigraphy of section near South Dakota (unpublished data) in files in the Archives of the Department of Paleontology, American Museum of Natural History. Toadstool Park Channel section after Smith and Stark (1991); Raven Ranch section after Oonander (1984). All other symbols are in Figure 1.
River occurs in the Pinyon Dog Creek drainage, just east of the road from Harmon as it descends through Moonridge Creek Canyon. Known in the field literature as "Perforated Panorama," the original sections were discovered in the 1960s when Morris Skinner and Bob Ensz examined three sections, Skinner section 39a, "G" section 84a, and "H" section 92a. These sections are located in the foothills of the Sierra Nevada, approximately 15 miles northeast of Stockton and 5 miles south of the western edge of Yosemite National Park. The rock units in the sections are mostly sandstone, siltstone, and shale, with minor amounts of conglomerate and limestone. The rock units are characterized by a variety of sedimentary structures, including cross-stratification, ripple marks, and current bedding. The sections are important for understanding the depositional environments of the Cenozoic Era and the evolution of the Sierra Nevada Mountains. The sections are also significant for paleontology, with fossils of plants and animals preserved in the rock. The sections are protected under California State Parks, and visitors are encouraged to explore and learn about the natural history of the region. The significance of the sections has been recognized by the publication of scientific papers and reports, and their importance for research and education continues to be recognized today.
FIGURE 3. Magnetic stratigraphy of sections in northern Logan County, Colorado. Extent of sections described in text. Lithostratigraphy after Gehrels (1983). All symbols as in Fig. 2.
zone correlated with Chm C1r (35.5-30 Ma), which is calibrated by the Upper Whitney Ash Zone which occurs in 39-32 Ma. The Whitney-Arkoma boundary is a bit more difficult to define, but based on the criteria discussed by Tuttle et al. (at this volume, Chapter 13), it occurs in Chm C1r (30-30 Ma). The contact between the Whitney Member and "brown shale" at the base of the Bear Formation appears to be younger than C1r (about 30 Ma). The oldest beds of the Arkoma Group occur in C1r at about 28.3 Ma.

Based on the information presented above we and Tuttle et al. (1993) the Chotomlom apatite to the 316 Ma to about 33.8 Ma. This is slightly different from the calibrations proposed by Prothero and Swisher (1992), mostly due to new changes in the Berggren et al. (1995) data and the new dates reported by Chotomlom et al. (995).

Figure 9. Magnetic correlation of zones within the White River Group, based on zones presented in this paper, Prothero and Whithman (1980), Prothero and Protheroe (1990), and Prothero (1990). Dates for zones within the Chadron (Chm) come from the 
Penn.). Correlation to the time scale of Berggren et al. (1995) is based on dates presented in Prothero and Swisher (1992).

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White River Magnetoturbation

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