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A New Late Cretaceous Paleomagnetic Pole from the Adel Mountains, West Central Montana

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North America's apparent polar wander path has been poorly defined between the mid-Cretaceous and Paleocene reference pole positions. Existing data allowed 13° of apparent polar motion over about 22 m.y. (87–65 Ma) roughly coinciding with the beginning of Laramide deformation (~80 Ma). We report on a paleomagnetic study of the Adel Mountain Volcanic rocks to refine the North American apparent polar wander path for this interval. The shonkinite rocks of the Adel Mountain Volcanic field are on the eastern edge of the Cretaceous-Paleocene fold and thrust belt; some of these structures disturb the western edge of the volcanic pile. We obtained two new K-Ar dates from the Adel rocks. One date, on biotite (from a shonkinite dike that crosscuts most of the volcanic rocks, is 71.2 ± 2.7 Ma. The other, a whole rock date from a flow deep in the volcanic pile, is 81.1 ± 3.5 Ma. We collected six to nine paleomagnetic samples from each of 34 sites in roadcuts and natural outcrops of flows, dikes, and laccoliths. Positive fold and conglomerate tests, along with alternating field and thermal demagnetization, indicate that our characteristic remanent directions are primary magnetizations acquired before Late Cretaceous to Paleocene thrust belt deformation. Averaging the virtual geomagnetic poles from 26 reliable sites, all of normal polarity, yields a paleopole at 82.2°N, 209.9°E ($\alpha95$ = 6.80°, k = 18.38). This pole is concordant with the Paleocene reference pole (82.0°N, 170.2°E, $\alpha95$ = 3.5°, k = 18.6 (Diehl et al., 1983)) and is 11.6° from the Globerman and Irving (1988) mid-Cretaceous pole at 71°N, 196°E. The youngest information in the Cretaceous stillstand pole is from the Niobrara Formation (Shive and Frerichs, 1974) at about 85–89 Ma. If we take the average age of the Adel Mountain Volcanics to be 76 Ma, then ~12° of apparent polar motion occurred between 87 Ma and 76 Ma. Thus, rapid apparent polar motion correlates well with the onset of Laramide deformation.

INTRODUCTION

Paleomagnetic pole positions and apparent polar wander (APW) paths for stable cratons provide an unequaled reference frame for delineating large-scale relative motions and tectonic histories of crustal fragments. This reference frame requires precise APW paths assembled from a series of accurate reference poles with well known ages. Although North American reference poles for the mid-Cretaceous and Early Tertiary are well established, the Late Cretaceous segment of the APW path for North America is poorly defined.

Cusps in APW paths separate smooth tracks representing uniform plate motion. Cusps are manifestations of major plate interactions [*Gordon et al.*, 1984; *May and Butler*, 1986] which may be correlated with specific orogenic events [*Irving and Park*, 1972; *Coney*, 1972, 1978]. The youngest well-defined APW track for North America, the J2-K track of *May and Butler* [1986], records rapid plate motion from the Late Jurassic to the Early Cretaceous (ca. 150–130 Ma). The J2-K track is punctuated by a mid-Cretaceous stillstand pole located at 71°N, 196°E, $\alpha95$ = 4.9° [*Globerman and Irving*, 1988] (Figure 1). Current data also indicate a Tertiary APW track with a different trend than the J2-K track. *Diehl et al.* [1983] provide high-quality reference pole positions for the Paleocene (67–55 Ma) (81.5°N, 192.6°E, $\alpha95$ = 3.2°) and Eocene (54–44 Ma) (82.8°N, 170.4°E, $\alpha95$ = 3.0°). However, these two poles along with the mean Oligocene–Miocene (40–20 Ma) pole [*Diehl et al.*, 1988] at (81.5°N, 147.3°E, $\alpha95$ = 2.4°) have minimal angular separation (Figure 1). Because the Early Tertiary reference poles are not significantly different from each other, this APW track is not particularly well defined. Regardless, the Paleocene and Eocene paleomagnetic poles are well removed (~11°) from the mid-Cretaceous reference pole.

The cusp between the J2-K track and the Early Tertiary track/poles coincides with many interesting geologic developments in North America. These include (1) the beginning of Late Cretaceous–Eocene (Laramide) folding and thrusting about 80 Ma [*Coney*, 1972, 1978], (2) the end of major magmatism and volcanism extending from the Northern Rocky Mountains to the Sierra Nevada, (3) a decrease in the subduction angle of the Farallon Plate [*Engebretson et al.*, 1984], and (4) an increased rate of convergence between the North American and Farallon plates [*Engebretson et al.*, 1984]. Refining the APW path for this crucial interval, thereby accurately locating the cusp, is necessary for an accurate tectonic history of the western Cordillera.

The youngest poles included in the mid-Cretaceous stillstand pole [*Globerman and Irving*, 1988] are from the 88–100 Ma alkalic intrusives of Arkansas and the 85–89 Ma Niobrara Formation of Wyoming, Colorado, and Kansas [*Shive and Frerichs*, 1974]. The oldest of *Diehl et al.'s* [1983] Paleocene poles are from the 67–62 Ma Moccasin Mountains and Judith Mountains of north central Montana. Using *Globerman and Irving's* [1988] preferred mid-Cretaceous pole position and *Diehl et al.'s* [1983] Paleocene pole, about 11° of apparent motion of North America occurred over a minimum of 18 m.y. during the Late Cretaceous. This period covers the link between the J2-K track and the Tertiary poles. Alternatively, *Swenson and McWilliams* [1989] contribute two new Late Cretaceous–Paleocene poles from the Maudlow and Livingston formations of Montana and suggest that the Jurassic–Cretaceous APW path continued farther to the present-day south and east than indicated by previous workers [*Diehl et al.*, 1983; *Gordon et al.*, 1984; *May and Butler*, 1986]. To delineate between these two proposals and to better understand

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