JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 102, NO. B9, PAGES 20,259–20,268, SEPTEMBER 10, 1997

Geomagnetic fluctuations during a polarity transition

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Abstract. The extensive Roza Member of the Columbia River Basalt Group (Washington State) has intermediate paleomagnetic directions, bracketed by underlying normal and overlying reverse polarity flows. A consistent paleomagnetic direction was measured at 11 widely distributed outcrops; the average direction has a declination of 189° and an inclination of –5°, with greater variation in the inclination [*Rietman*, 1966]. In this study the Roza Member was sampled in two Pasco Basin drillcores, where it is a single cooling unit and its thickness exceeds 50 m. Excellent core recovery allowed uniform and dense sampling of the drillcores. During its protracted cooling, the Roza flow in the drillcores recorded part of a 15.5 Ma geomagnetic polarity transition. The inclination has symmetric, quasi-cyclic intraflow variation, while the declination is nearly constant, consistent with the results from the outcrops. Thermal models of the cooling flow provide the timing for remanence acquisition. The inclination is inferred to have progressed from 0° to –15° and back to –3°over a period of 15 to 60 years, at rates of 1.6° to 0.5°/yr. Because the geomagnetic intensity was probably weak during the transition, these apparently high rates of change are not significantly different from present-day secular variation. These results agree with the hypothesis that normal secular variation persists through geomagnetic transitions. The low-amplitude quasi-cyclical fluctuations of the field over tens of years, recorded by Roza, suggest that the geomagnetic field reverses in discrete steps, and that more than 15–60 years were required to complete this reversal.

Introduction

The *Earth's* magnetic field is usually in one of two stable polarity states, superimposed by modest secular fluctuations. During polarity transitions the geodynamo appears to be unstable, possibly exposing more of its underlying dynamics. Therefore analyzing the field's characteristic timescales during transitions may aid in constraining mechanisms for geomagnetic field generation and causes of reversals. Studies of fundamental geomagnetic rates of change are complementary to analyzing the morphology and intensity fluctuations of the field during transitions.

The present understanding of geomagnetic transitions is incomplete; only a coarse description of first-order features is known, and many details appear inconsistent between records, even of the same transition. Details of geomagnetic transitions come primarily from lava sequences, rapidly deposited sediments and intrusives, each expressing different details of the paleofield. Sediments and slowly cooled magmatic bodies typically represent an integrated and relatively continuous time series of the field. However, these records often miss higher frequency geomagnetic fluctuations, due to inherent smoothing during remanence acquisiton, potential complexities in the recording material, as well as post-deposition and postacquisition alteration. Lava successions often reliably record the paleomagnetic vector at discrete times, but lavas typically erupt at irregular and unknown time intervals. In this paper we report results from a partial polarity transition recorded in a single thick lava flow with a protracted cooling history.

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Paper number 96JB02534.
0148-0227/97/96JB-02534$09.00

Geology and Paleomagnetism of the Roza Member

The Columbia River Basalt Group in the northwest United States is an extensive succession of basaltic lavas (Figure 1), spanning 17 to 6 Ma (million years before present) and several magnetic polarity chrons [e.g., *Swanson et al.*, 1979; *Hooper*, 1982]. The Roza Member of the Wanapum Basalt erupted about 15.5 Ma [*Baksi*, 1988] and recorded intermediate magnetic polarity; it is underlain by the normal polarity Frenchman Springs units and overlain by the reverse polarity Priest Rapids flows [e.g., *Beeson et al.*, 1985]. The Roza Member originally extended over about 40,000 km^2 and had a volume in excess of 1500 km^3 [*Swanson et al.*, 1975]. In the western part of the plateau the Roza Member is present as one flow, but in the eastern part two flows are common [*Mackin*, 1961; *Bingham and Walters*, 1965; *Bingham and Grolier*, 1966]. *Shaw and Swanson* [1970] suggested that the main flow of the Roza Member was extruded in a matter of days.

Rietman [1966] sampled the Roza Member for paleomagnetism at 11 widely separated sites and measured approximately the same transitional directions, declination D = 189.0° and inclination I = –4.8°, with α_{95} = 7.0° for N = 9 sites. Rietman's results show that the range of the site-mean inclinations (–21° to +8°) is approximately twice the variation of the declinations (180° to 196°).

The thickness of the Roza Member often exceeds 50 m in the Pasco Basin and 30 m over a large area of the western plateau. *Audunsson and Levi* [1988] calculated that cooling of the flow everywhere to below about 300°C would require tens of years. Therefore, a continuous record of the geomagnetic field is expected to have been recorded in the cooling Roza flow, as the blocking temperature isotherms traversed the flow.

The consistent intermediate paleomagnetic direction of the Roza Member, its stratigraphic position between underlying normal and overlying reverse polarity units and its extended cooling history suggest that the Roza Member recorded part of a