PROCEEDINGS OF THE TWENTY-SIXTH ANNUAL KECK RESEARCH SYMPOSIUM IN GEOLOGY

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A PALEOMAGNETIC RECONAISSANCE STUDY OF THE POWDER RIVER VOLCANIC FIELD

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INTRODUCTION

The Powder River Volcanic Field (PRVF) consists of a series of Middle Miocene to Pliocene lava flows of unknown origin in northeastern Oregon (Ferns et al. 2010). Late Miocene to recent extensional faulting has separated these lavas, forming the Grande Ronde Valley. The PRVF rock types range from calc-alkaline to alkaline and basaltic to dacitic and are stratigraphically above the Grande Ronde Basalt Formation of the Columbia River Basalt Group (CRGB) (Ferns et al., 2010). In some outcrops, volcaniclastic deposits are located between the CRBG and PRVF with occasional paleosol development. The Wanapum Basalts and Saddle Mountains Basalts of the CRBG (15.6 Ma to 6 Ma) are contemporaneous with the PRVF (14.4 Ma to 2.1 Ma), but the PRVF are located primarily east of the Blue Mountains whereas young Saddle Mountains lavas erupted north and west of the PRVF.

Extensive paleomagnetic and geochronology studies have been done on the CRBG (e.g., Reidel, 1984; Sheriff, 1984; Hooper, 2002; Jarboe, 2011; Barry, 2012). The CRBG is well dated by a combination of $^{40}Ar/^{39}Ar$ and polarity determinations (Hooper, 2002; Barry, 2012). PRVF geochronology used K-Ar and Ar-Ar dating, which provided a large range of imprecise dates (Ferns et al., 2010). However, no paleomagnetic work has been done on the PRVF. The purposes of this project were to undertake such a study and to determine how paleomagnetism could be used to better understand the PRVF and subsequent extensional faulting. Two localities in the PRVF, Shaw Creek Drainage and Cricket Flat, were sampled.

REGIONAL TECTONICS AND GEOLOGY

The Upper Grande Ronde River basin covers 4200 km^2 of northeastern Oregon. The Grande Ronde flow marks the onset of flood basalt magnetism in the basin 17 Ma (Bailey, 1990; Ferns et al., 2010). An extensive ash-flow of unknown source was deposited during the Middle Miocene immediately preceding the onset of PRVF volcanism and is exposed at Cricket Flat (Mudd, Lopez-Maldonado, this volume). The earliest PRVF unit, consisting of at least three olivine basalt flows, erupted circa 14.5 Ma (Bailey, 1992) and one of these flows covers the Cricket Flat volcaniclastic deposit (Ferguson, Lopez-Maldonado, and Mudd, this volume). Multiple eruptions of olivine basalt were followed by a period of calc-alkaline volcanism (Bailey, 1990; Ferns et al., 2010). This volcanism has been attributed to back-arc extension rather than the Yellowstone hotspot (Hooper, 2002).

The Grande Ronde Valley formed from subsidence following uplift approximately 7 Ma. The valley was originally thought to be an extensional basin (Mann and Meyer, 1993), but a more recent model suggests it resulted from a combination of volcanic-induced uplift, extension, and subsidence (Ferns et al., 2010).

Publications indicate that the study area, the eastern block of the Grande Ronde River basin, has low tectonic activity (Ferns et al., 2010). However, the Mt. Harris Fault Zone runs along the eastern margin of the valley, west of the field sites. The fault zone incorporates northeast-trending folds and faults and northwest trending faults (Fern et al., 2010). Smaller fault zones are located in close proximity to both field sites. The Cricket Flat Fault Zone contains normal southwest-trending and northwest-trending faults (Ferns et al., 2010). The Shaw Creek Fault has been mapped, but not described. LIDAR viewer imaging indicates prominent lineations in the field area that were not included in past mapping and research publications (DOGAMI). This suggests that faulting could be more active in the region, then suggested by current research.

PALEOMAGNETISM

Ferromagnetic minerals are capable of recording and retaining the direction of an applied magnetic field. Thermal remanent magnetization (TRM) is the magnetization acquired when lava solidifies and then cools below the Curie point, the temperature at which magnetic grains are capable of holding a coherent magnetization. Chemical remanent magnetization (CRM) is the magnetization acquired when iron-bearing minerals form or are transformed as a result of chemical alteration (Butler, 1992). TRM and CRM are both relevant to this study.

Natural remanent magnetism (NRM) is the naturally-occurring magnetization of a rock. Rocks can have both a primary and secondary NRM (Butler, 1992). Alternating-field demagnetization is a laboratory procedure designed to preferentially eliminate the secondary component in order to determine the primary (original) direction of magnetization. Volcanic rocks are ideal for paleomagnetic analysis because their magnetic grains are small and their magnetization is stable on the scale of geologic time (Butler, 1992).

The inclination and declination of a sample can be determined using a three-axis magnetometer. Each sample is exposed to steadily decreasing alternating magnetic fields of increasing peak intensities in order to dissect the magnetization. The data are then analyzed to discriminate between the primary and secondary NRM and to determine the best value for the primary NRM, using a process known as principal component analysis (Jolliffe, 2002).

METHODOLOGY

Paleomagnetic cores were collected using a gasoline-powered drill with a hollow 2.54 cm diameter diamond-rimmed drill bit. Water was used as a lubricant and coolant during the drilling process. Field orientations of the sample were measured using a Pomeroy orienting device. The azimuth, hade, sun reading, time of orientation, and description of each core were recorded. Thirty-seven oriented cores were drilled from three outcrops in the Powder River Volcanic Field: Cricket Flats, Shaw Creek Drainage Basin Outcrop 1, and Shaw Creek Drainage Basin Outcrop 2 (see Fig. 2 of Bader and Nicolaysen, this volume).

All samples were analyzed in the Paleomagnetism Laboratory of the University of California, Davis. Cores were cut into 2.54 cm lengths. One sample from each core was progressively demagnetized in peak alternating fields of 5 mT, 10 mT, 20 mT, 30 mT, 40 mT, 50 mT, 60 mT, 80 mT, and 100 mT using a 2G Enterprise Model cryogenic magnetometer. The sample coordinates for inclination and declination were converted to geographic coordinates using the values of azimuth and hade to get the true inclination and declination for the sample.

FIELD SITE DESCRIPTIONS

Cricket Flat

Cricket Flats is an east-facing road-cut located off Highway 82 in Union County, Oregon. The outcrop consists of five physically and chemically differentiable units and an overlying olivine basalt flow (Flow 1) (Fig. 1). Mudd and Lopez-Maldonado (this volume) discuss the stratigraphy and origin of the lower five units. The uppermost unit (cores 14A, 14C-J) is an olivine basalt flow (Ferguson, this volume) that provides a minimum age for the outcrop of 14.85 +/- 0.45 Ma.

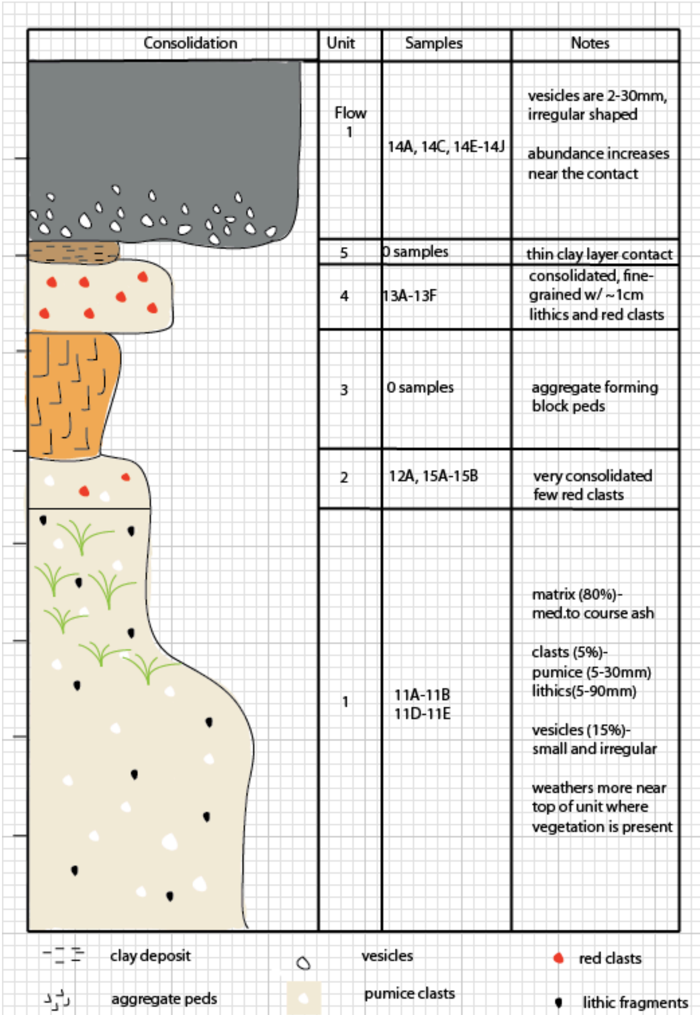

Figure 1-Stratigraphic column of Cricket Flat illustrating the chemically and texturally distinct volcaniclastic and pedogenic units and the overlying olivine basalt flow. Unit 1 is a volcaniclastic deposit and is the parent material for units 2-5. The overlying basalt flow is interpreted as baking the underlying units.

Unit 1 (cores 11A-11E) is a volcaniclastic deposit containing pumice and lithic clasts in a medium to coarse ash matrix. Unit 2 (cores 12A and 15A-15B) appears compositionally similar to Unit 1. However, it is more consolidated with red clasts in the matrix. Unit 3 consists of aggregated peds. It is approximately 30 cm-50 cm thick and is interpreted as the Bt horizon of a paleosol (Mudd, this volume). Unit 4 (cores 13A-13F) sits immediately above the peds. Unit 5 is a thin clay layer located immediately beneath the olivine basalt. The working hypothesis is that Unit 1 was the parent material of Units 2, 3, and 4, and that soil processes and baking by the olivine basalt have significantly altered the physical and chemical properties, creating multiple units . Drilling and core collection was difficult in Units 1-5 due to high clay content. Samples were not obtained for Units 3 and 5.

Shaw Creek Drainage Basin

Shaw Creek Drainage Basin (SCDB) Outcrop 1 is located off Shaw Creek Road, 20 km southeast of Elgin, OR. The outcrop contains three different flow types. Cores 6A-6H were collected from the lowermost flow (designated Flow 2), with the exception of 6B interpreted as from the middle flow.

SCDB Outcrop 2 is located 150 m NW of SCDB Outcrop 1. The outcrop is a multiple-flow exposure with up to four different flows. Based on hand sample descriptions, three of the four flows appear to correlate with the SCDB Outcrop 1 flows. Cores 7B-7E (Flow 3), 8A (Flow 4), 9A (Flow 5), 10A-10B (Flow 6) were collected from this site.

RESULTS

Paleomagnetic Behavior

Samples from Flow 2 demagnetized smoothly, but resisted full demagnetization (Fig. 2). The average maximum intensity is 1.88 A/m and median destructive field (MDF) is 27.9 mT. The z-plots generally indicate a small secondary NRM. The samples have normal inclinations (~73.5˚) but southerly declinations (~190˚). This behavior is representative of Flow 5 as well. However, Flow 5 demagnetized less than Flow 2 and has a MDF of 50mT.

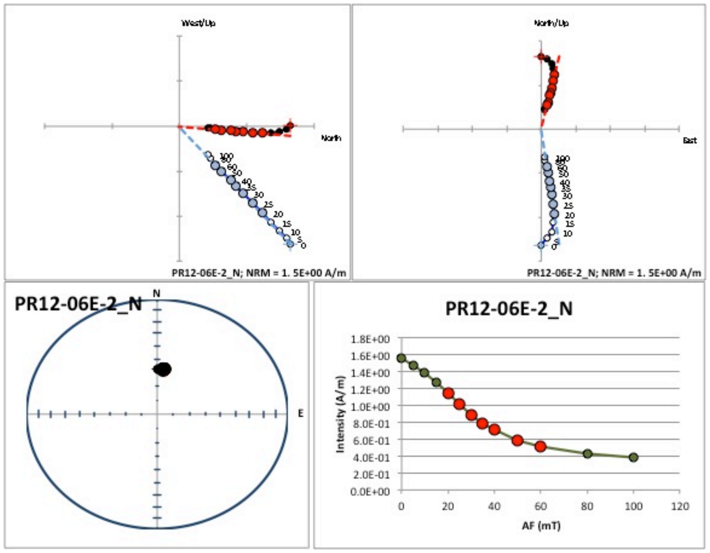

Figure 2-Z-plots, equal-area projection, and demagnetization curve for sample 6E-2. Sample 6E-2 was sampled from Flow 2 at SCDB Outcrop 1. The paleomagnetic behavior is typical of Flow 2, as well as Flow 5. Sample 7C-2 was sampled from Flow 3 at SCDB Outcrop 2. The paleomagnetic behavior is typical of Flows 3, 4, and 6.

Samples from Flow 3 demagnetized smoothly and showed uni-vectorial decay to the origin (Fig. 3). The average maximum intensity is 1.21 A/m and the average MDF is 17.5 mT. The z-plots indicate a small secondary NRM. The samples have normal inclinations (~65.1˚) and southerly declinations (~249) similar to Flows 2 and 5. Flows 4 and 6 have similar paleomagnetic behavior as Flow 3.

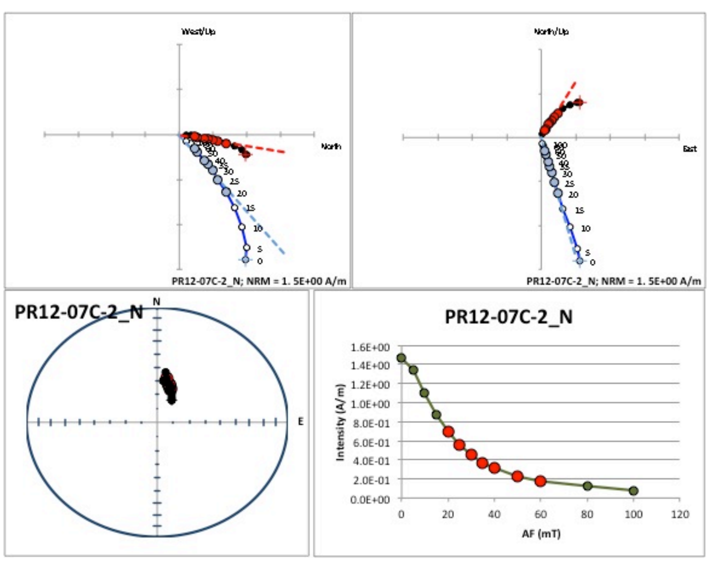

Figure 3-Z-plots, equal-area projection, and demagnetization curve for sample 7C-2. Sample 7C-2 was sampled from Flow 3 at SCDB Outcrop 2. The paleomagnetic behavior is typical of Flows 3, 4, and 6 from SCDB Outcrop 2.

Unit 1 did not demagnetize smoothly and the demagnetization curves were inconsistent in the sample suite (Fig. 4). The z-plots indicate a large secondary NRM. However, best fit direction for the primary NRM were obtained for only two of the four samples. Sample 11D-2 underwent rapid demagnetization from 0mT to 10mT and then resisted demagnetization. Sample 11B-2 also resisted demagnetization and underwent an initial rapid demagnetization. The samples have reverse inclinations (~-62.0˚) and southerly declinations (~200˚). Unit 2 has relatively similar paleomagnetic behavior. Samples resist demagnetization like sample 11B-2. The paleomagnetic directions were consistent with Unit 1.

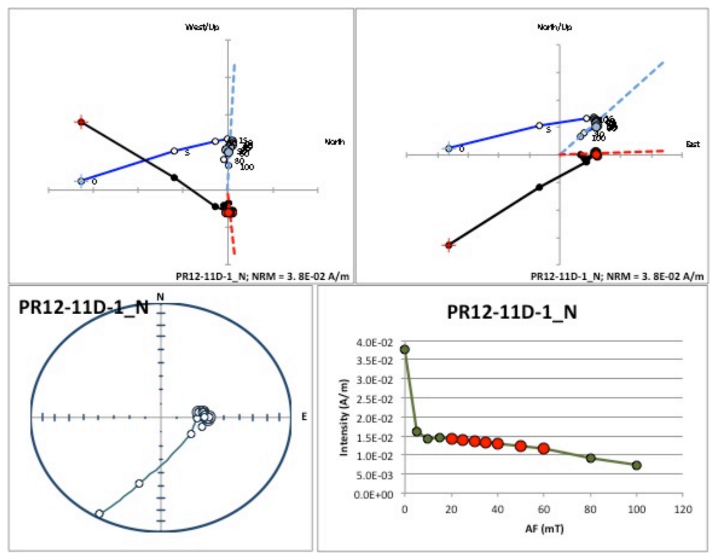

Figure 4- Z-plots, equal-area projection, and demagnetization curve for sample 11D-1. 11D-1 was sampled from a volcaniclastic deposit (unit 1) at Cricket Flat. The paleomagnetic behavior is typical of units 1 and 2, the volcaniclastic and alterated volcaniclastic.

Unit 4 demagnetized smoothly and showed uni-vectorial decay to the origin similar to Flow 3 (Fig. 5). The z-plots and demagnetization curve shows a strong normal secondary NRM. The average intensity is $1.25E^{-1}$ A/m. The unit shows reverse inclinations (~-73.6˚) with southerly declinations (~163˚). Flow 1 has similar paleomagnetic behavior and directions as this unit. However, Flow 1 samples tend to demagnetize more rapidly than Unit 4. The average intensity for Flow 1 is 5.12 A/m.

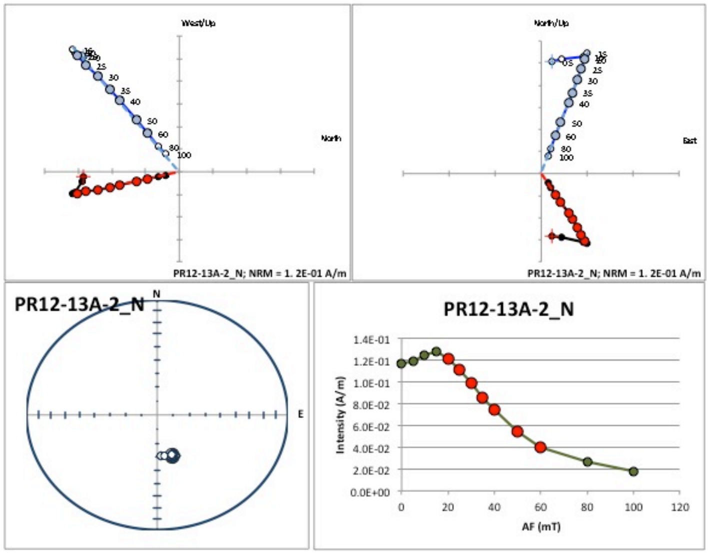

Figure 5-Z-plots, equal area projection, and demagnetization curve for sample 13A-2. Sample 13A-2 was sampled from the paleosol (Unit 4) baked by the overlying basalt at Cricket Flat. The paleomagnetic behavior is typical of Unit 4 and the overlying olivine basalt (Flow 1). The paleosol shows magnetic behaviors similar to that of the basalt indicating the unit was baked.

Summary of Paleomagnetic Behavior

Flows 2-6 are from the SCDB outcrops. In general, the samples tend to demagnetize smoothly, similar to an ideal demagnetization of a lava flow. Certain flows resist demagnetization more than other flows. The average intensity is approximately 1.5 A/m. The flows have normal inclinations, but anomalous declinations.

Units 1-5 and Flow 1 are from Cricket Flat. The paleomagnetic behavior of these units is more diverse. Units 1 and 2 resist demagnetization. Best-fit directions were less precise for these units. Unit 4 and Flow 1 demagnetize smoothly, much like the SCDB units. The units show reverse inclinations and southerly declinations.

CONCLUSIONS

Cricket Flat

A baked-contact test was performed at Cricket Flat in order to determine whether the paleosol was baked by the overlying basalt flow. The volcaniclastic, paleosol, and the olivine basalt show reverse directions. Therefore, the classic baked-contact test could not be done. However, the significant difference in paleomagnetic behavior of the volcaniclastic and paleosol beneath the basalt flow indicate that the paleosol was baked. The baked paleosol (Unit 4) demagnetized in the same manner as the basalt flow (Flow 1). Neither of these units resisted demagnetization. The volcaniclastic unit severely resisted demagnetization. The difference in the demagnetization curves is attributed to a difference in the magnetic phases of each unit. The basalt and the baked paleosol main magnetic phase is likely magnetite, while the volcaniclastic magnetic phase is hematite. The change in paleomagnetic behavior near the contact indicates that Unit 13 had been heated above the Curie temperature by the overlying flow.

Shaw Creek Drainage Basin

Miocene lava flows are expected to have declinations of 355˚ and inclinations of 65˚. The samples from this site have the expected inclinations, but have anomalous southerly declinations. Anomalous declinations were determined at sites in the Frenchmans Springs member of the Wanapum Basalt Formation. The Wanapum Basalt Formation declinations were approximately 149˚ (Sheriff, 1984). The Wanapum Basalt Formation is older than the flows at SCDB outcrop, but Sheriff's study indicates that other Miocene flows show anomalous directions as well. One possible explanation for the anomalous directions is that the flows were deposited during a geomagnetic reversal or excursion of the magnetic field. Another possibility is that we sampled a significantly rotated small tectonic block. More work could resolve the origin of the anomalous direction. The main paleomagnetic result of this study is that the PRVF is suitable for further paleomagnetic study.

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