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2009-2010 PROJECTS

SE ALASKA - EXHUMATION OF THE COAST MOUNTAINS BATHOLITH DURING THE GREENHOUSE TO ICEHOUSE TRANSITION IN SOUTHEAST ALASKA: A MULTIDISCIPLINARY STUDY OF THE PALEOGENE KOOTZNAHOO FM.
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Keck Geology Consortium: Projects 2009-2010
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EXHUMATION OF THE COAST MOUNTAINS BATHOLITH DURING THE GREENHOUSE TO ICEHOUSE TRANSITION IN SOUTHEAST ALASKA: A MULTIDISCIPLINARY STUDY OF THE PALEOGENE KOOTZNAHOO FORMATION

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TIM WHITE, Pennsylvania State University

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LEONARD ANCUTA: Union College
Research Advisor: John Garver

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TIFFANY HENDERSON: Trinity University
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JULIA NAVE: The Colorado College
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PALEOMAGNETIC STUDY OF THE PALEOGENE KOOTZNAHOO FORMATION, SOUTHEAST ALASKA

MARIA PRINCEN: Macalester College
Research Advisor: Karl Wirth

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PALEOMAGNETIC STUDY OF THE PALEOGENE KOOTZNAHOO FORMATION, SOUTHEAST ALASKA

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Reserach Advisor: Karl Wirth

INTRODUCTION

The Kootznahoo Formation of southeast Alaska is a sedimentary deposit formed during the Paleogene in a time of great geologic change including major climate episodes (Zachos et al., 2003), volcanism (Courtillot & Renne, 2003), and tectonic activity (Gehrels et al., 2009). Constraining ages for these significant events is an imperative step for understanding this dynamic time period. However, determining depositional age can be difficult using techniques such as paleomagnetic dating. This study attempts to determine the depositional age of the Kootznahoo using paleomagnetic analysis through magnetostratgraphic and paleolatitude evidence. The Kootznahoo consists of conglomerate, shale and sandstone (Lathram etal., 1965; Dickinson et al., 1990). It is underlain by the Alexander-Wrangellia terrane and was likely deposited between 55-25 Ma (Ancuta, this volume). If this depositional range is correct, then the Kootznahoo should reflect paleolatitudes of the North American continent during the early Tertiary. Magnetic polarity should also correlate with the geomagnetic polarity time scale of Cande and Kent (1995). Initially, the goals of this project were to re-construct the paleomagnetic history of the Kootznahoo Formation. Much of the resulting polarity data are scattered and I am thus unable to present conclusive data for normal or reversed polarities. However, some paleopole data yield relatively consistent results that reflect the expected paleomagnetic directions of North America during the Late Cretaceous to early Paleogene.

METHODS

FIELD WORK

I collected 84 samples from 23 sites of the Kootznahoo Formation exposed between Hamilton Bay and Big John Bay (See stratigraphic section in Fig. 2, Davidson, et al., this volume) spanning about 250 m of section. These samples were cut using a portable drill and oriented using a magnetic compass and inclinometer in the field. The strike and dip of bedding was measured. Samples were most often drilled parallel to bedding. Most sedimentary layers at each sample site in the Kootznahoo Formation did not yield coherent cores, and those that remained the most intact during drilling were from sample areas of concretions and well-cemented sandstone.

LAB METHODS

Before measuring the magnetism of the samples, it was necessary to remove remanent magnetic fields. Some samples may have overprinted the natural remanent magnetization (NRM) at the time of deposition. These remanent magnetic fields were removed through alternating field (AF) demagnetization or thermal demagnetization.

I initially used AF demagnetization to strip away secondary NRM. The resulting paleopole data were scattered and I chose to continue using thermal demagnetization. I thus conducted thermal demagnetization from 100 ^{0}C to 400 ^{0}C. After each heating step (100, 150, 200, 300, and 400), I measured the magnetism of the samples using a Superconducting Rock Magnetometer (SRM). The SRM measures NRM of cores and is useful for both weak and normal samples. My samples are primarily coarse grained and are known to have weaker magnetic signals (Butler, 1998). To account for the potential weak magnetism, I conducted more rotation measurements per individual sample to obtain a consistent magnetic signal.

RESULTS

For each site, Zijderveld diagrams, equal area plots (paleopoles), and J/J0 intensity plots (removal of remanence magnetism through each temperature step) were constructed. The Zidjerveld diagrams illustrate the complexity of the magnetic properties of the Kootznahoo Formation through varying polar directions for each demagnetization step (Fig. 1a). If the trend did not pass linearly through the origin, I assumed a great circle trend instead of fitting a line trend. For samples that showed a linear trend towards the origin, I manually cleaned the paleopole data by eliminating points that did not fit the linear trend (typically, these were at low thermal demagnetization temperatures). Figure 1b shows a linear trend without data cleaning.

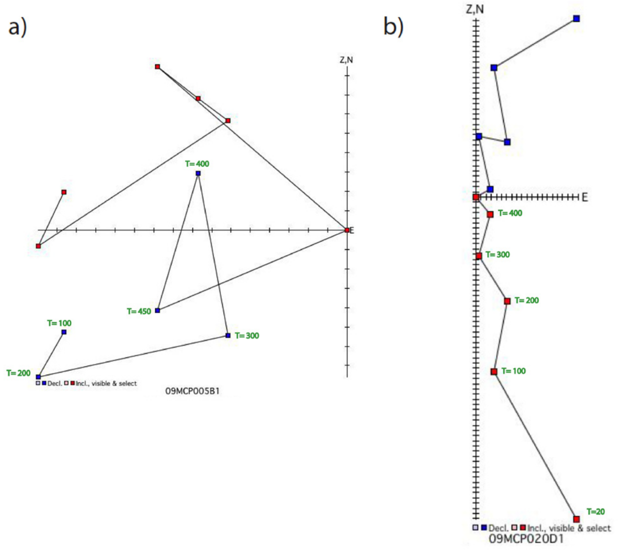

Figure 1. Typical thermal demagnetization behavior from the Kootznahoo Formation represented on Zijderveld diagrams. (a) Non-linear progressions of demagnetization steps toward the origin show different polar directions for each step and are thus inconsistent and unreadable (Sample 09MCP002). (b) Trends that are linear and towards the origin show a single characteristic magnetization component and are thus interpretable for paleopole direction.

Using both AF and thermal demagnetization data, I determined average pole directions for 17 of the total 23 sample sites (For sample locations, see Fig. 2 in Davidson et al., this volume). These orientations are represented in Fisher diagrams that include both the average pole and an error interval, called α95 (Fig. 2). AF demagnetization procedures produced inconsistent paleopole data and thermal demagnetization results were only slightly more consistent. Ultimately, the analyzed samples did not yield consistent normal or reverse polarity results. Furthermore, because of the large error associated with each paleopole result, it was not possible to resolve changes in paleopole mean directions with regards to stratigraphic height.

The inconsistency of paleomagnetic data is also evident in paleopole coordinates but it is still possible to attribute a general direction to the Kootznahoo paleopoles. This is reflected in equal area plots of the mean polar directions for each sample site. For example, sites from the lower Kootznahoo display scattered paleopole data with large error estimates (Fig. 2). A number of sites, including 09MCP009 (Fig. 3a), yield large α_{95} values but the indicated paleopole orientations are consistent with the expected poles for that time (Early Tertiary) and location. After combining paleopole data from nearby sites (within 5-20 m of section of each other), the error estimates are greatly decreased (Fig. 3b).

A representative paleopole coordinate for the entire formation is determined to be declination= 349.6 and inclination= 70.5. This coordinate is an average of the sites represented in Figure 4. By mid-section, poles shift to higher inclinations (Table 1) and rotate slightly counter clockwise to declination= 299. The paleopole data from the upper Kootznahoo (best reflected in Sites 20 and 21) are the least complex data and yield a paleopole with declination= 10.0 and inclination= 75.0 (Table 1).

DISCUSSION

MAGNETIC POLARITY RESULTS

I was unable to constrain magnetic polarity of the Kootznahoo because the majority of data consists of complex magnetizations without distinct polarity patterns. This is mostly a result of insufficient number of samples taken and the type of sediment collected. According to Butler (1998), fine-grained

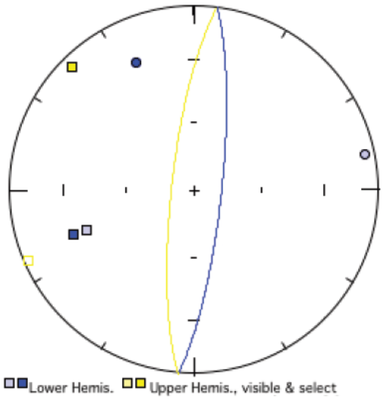

Figure 2. Equal area projection of paleopoles for Site 018 showing substantial scatter that typifies many sites. Paleopole data from this site plot in both the lower and upper hemispheres of the equal area plot.

Site	*N*	*D*	*I*	α_{95}
005-006	9	36.4	61	35.9
008	3	299.7	74.5	37.9
009-010	3	17	73.7	28.7
019	6	318.7	62.4	28.9
020	5	9.3	76.2	41.6
021	6	11.3	75.1	37.6
022	7	297.5	59	56.9

Table 1. Paleomagnetic poles for selected sites of the Kootznahoo based on cleaned data. N is the number of samples used in the equal area plot, D is in-situ declination, I is in-situ inclination, and a_{95} *is error estimate. Site 005-006 is located in lower section Dakaneek Bay, Sites 008-009-0010 are located in mid Dakaneek Bay, Site 019 is located in lower Big John Bay, Site 020 is located in upper Big John Bay, Site 021 is located in lower Big John Bay South, and Site 022 is located at the top of Big John Bay South (See stratigraphic section in Fig. 2, Davidson, et al., this volume).*

lithologies are preferred for quality polarity data because fine-grained sediments acquire detrital remanent magnetization (DRM) more efficiently than coarse-grained. They are also less susceptible to secondary chemical remanent magnetization (CRM). For rocks of the Kootznahoo age and location, poles with normal polarities have mean directions of about 60-70 degrees inclination (northward and down) while reversed polarities are south and up (M. Jackson, personal communication, 2010). My samples, being medium to coarse grained, produced scattered inclination directions most likely from carrier instability. In addition, the samples could have been affected by more recent affects such as local rotations, drilling in the field or sawing during preparation for analysis.

MEAN PALEOPOLE DIRECTIONS

Most paleopoles measured from the Kootznahoo plot in the lower hemisphere on an equal-area diagram and are consistent with paleopoles determined for that time and geographic region. Paleomagnetic data from the Alexander Terrane demonstrate mean pole directions of 20 degrees declination and 75 degrees inclination during the late Cretaceous (Haeussler et al., 1992). Samples from the lower Kootznahoo sections Hamilton Bay and lower Dakaneek Bay (See stratigraphic section in Fig. 2, Davidson, et al., this volume) produce mean paleopoles in the lower hemispheres, northeast quadrants of equal area plots with declination= 17 and inclination= 73.7(Fig. 3b).

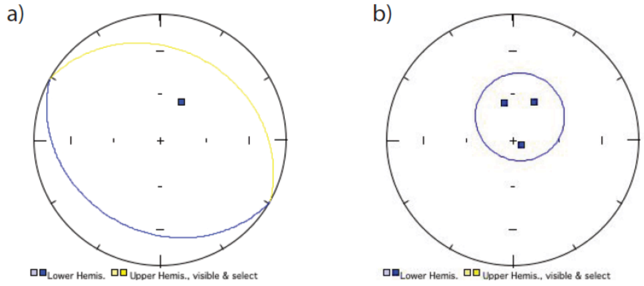

Figure 3. Equal area projections for (a) Site 009 and (b) the combined Sites 009 and 010; mean pole orientation, declination= 17 degrees and inclination= 62 degrees.

Since the Alexander-Wrangellia terrane arrived at its present position with relation to North America by 50 Ma (Hauessler and Coe,1992), the mean paleopole directions of the Kootznahoo should be consistent with the mean directions of North America after 50 Ma. Indeed, data from the mid and upper sections of the Kootznahoo are similar to other data from the Late Cretaceous in the Keku Strait region (Fig. 4).

ADVANCING THE APPROACH

Due to the inconsistency of this study's paleopole results and the lack of normal/reversed polarity data, later studies would benefit from a number of project

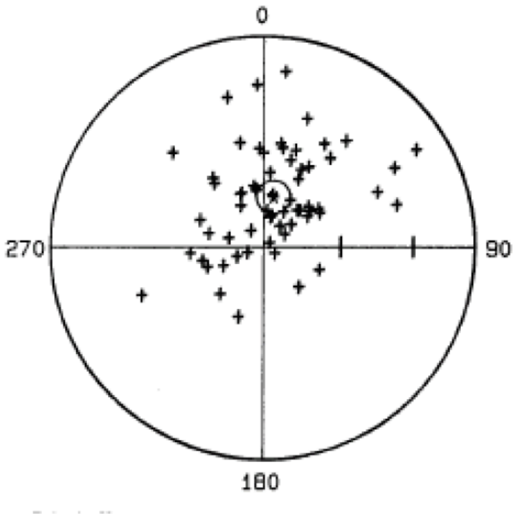

Figure 4. Mean paleopole directions of Hound Island Volcanics from the Late Cretaceous (Hauessler et al., 1992). The expected early Late Cretaceous direction (Declination= 329.4, Inclination= 80.2) is shown by the α_{95} in the northeast quadrant of the equal area plot. Site averaged Kootznahoo declinations range from 299 to 17 degrees, while inclinations average about 70 degrees.

improvements. This project would have benefited greatly from a larger number of core samples. The resulting paleopoles are inconsistent primarily because there were not enough points to determine a true trend. More samples per site would increase the likelihood of having more useable data. Similarly, normal and reversed polarity could have been distinguished using a more detailed approach to the stratigraphic height, such as increasing the total number of sites per section and focusing on fine-grained lithologies.

The lack of consistent paleopole results is largely a function of the type of sediment sampled. In the field, it was difficult to preserve cores in one piece and to find sediments that can withstand drilling. While drilling concretions produced intact cores, the resulting paleomagnetic data are still scattered. The upper section concretions of the Kootznahoo demonstrated clearer patterns than concretions located in the lower sections. Concretions may yield unreliable data because they form post-deposition and do not necessarily represent the bedded layer in which they are found. Additionally, there may be significant mineralogical differences between the initially deposited bed and the concretion that formed after, including cement type or strength or type of ferromagnetic minerals present. Finally, while it is understood that coarse-grained sediments are less likely to preserve a strong primary magnetization (Butler, 1998), many of the Kootznahoo samples that yielded consistent paleopole data are from coarse sandstone. In fact, at the very bottom of the section, a fine-grained sandstone produced some of the most scattered results of all the data. From this data, it is unclear whether the grain size impacted the accuracy of paleomagnetic analysis.

Finally, most paleomagnetic studies utilize the fold test and tilt correction techniques. Since the Kootznahoo strike and dip does not change significantly within the formation, the tilt corrections (applied to the entire formation in all directions in the same way) would not alter the data. There is also no evidence of major offset or transport within the Keku Strait after the deposition of the Kootznahoo (Hauessler and Coe, 1992). Thus a fold test would be ineffective in producing cleaner results.

I recommend that future paleomagnetic studies of the Kootznahoo do the following: 1) increase the number of cores taken at each site, 2) increase the number of total sites to better detail the entire Kootznahoo stratigraphy, 3) focus on well-cemented sediment types for drilling, 4) avoid drilling concretions, and 5) increase the number of thermal demagnetization temperature steps beyond 400 degrees.

CONCLUSION

The inconsistencies of this paleomagnetic data demonstrate the difficulties associated with age dating marginal marine sediments using paleomagnetic analysis. Much of the Kootznahoo Formation was complex and difficult to interpret. While paleomagnetic mean directions were obtained, this study would have benefited greatly from substantive normal/reversed polarity data. Such data would be best used to constrain times in which deposition occurred and assist in determining a comprehensive depositional history.

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