

Cotlow Award Application Form 2009

Department of Anthropology

The George Washington University

Washington, DC 20052

1. Personal Information

Applicant's name: Katherine E. Schroer

Degree sought: PhD

Field of study/major/minor/concentration: Hominid Paleobiology

Expected date of graduation: May 2013

Faculty Advisor(s) (who have served as your mentor or mentors for this proposal):

Dr. Bernard Wood, Dr. Brian Richmond, Dr. Matt Skinner (Max Planck Institute of Evolutionary Anthropology)

2. Language Skills

Does the proposed project involve the use of a "field language"? no

If yes, state what the language is and your degree of fluency in speaking, reading, and writing it:

3. Title of the Project and Abstract

Project Title: Developmental process of molarization in Pliocene hominins

Abstract of the Project (provide a summary description of the project's goals, location, methods, and relevance to anthropology) [80 word maximum]:

The "molarization" of premolar teeth in robust australopithecines is an important anatomical character defining the genus *Paranthropus*. However, this character may be convergent among *Paranthropus* taxa. This project (conducted at the Max Planck Institute for Evolutionary Anthropology) employs micro-computed tomography to image the internal structure of fossil hominin premolars and morphometric analyses to test the hypothesis that molarized premolars grow in the same way in all robust australopithecine species. Results will have implications for the monophyletic nature of *Paranthropus* and hominin phylogenetics.

4. Description of the Project (describe your overall research goals, what the project is generally about, and where you will conduct the research and why) [250 word maximum]:

Dental traits vary among even closely related species, making the identification of these traits highly useful for reconstructing phylogenetic relationships (Bailey 2000). Traditionally, these studies have been limited to traits on the external surface of the tooth crown. Recent high-resolution microCT analyses reveal variations in internal structures at the enamel-dentine junction (EDJ). This method permits analysis of two major growth processes responsible for forming crown shape: the formation of the EDJ and the deposition of enamel on the EDJ surface. Because of these separate processes, teeth with the same outer surface could show different development at the EDJ. Likewise, superficially dissimilar teeth may reveal the same internal structures. This project applies the microCT method employed by Skinner *et al.* 2008 in order to determine whether *Paranthropus* taxa from eastern and southern African molarize in the same way. The project will also assess the relative contribution of EDJ structures to the enamel crown. Finally, the study will characterize premolar shape and discrete dental traits, as these analyses have been useful for determining phylogeny (Wood *et al.*, Bailey, and Suwa). The project will be conducted in the Department of Human Evolution at the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany. The Virtual Paleoanthropology program within this department has amassed a large collection of dental CT scans belonging to a variety of extant primate and fossil hominin taxa. Analyzing these scans requires the technical expertise, specialized computer software, and powerful computer workstations available at the department.

5. Significance of the Project to Anthropology (in this literature review describe how the proposed research relates to other anthropological research on the topic, and/or region as relevant; use social science style citation--no footnotes) [400 word maximum]:

In the evolution of hominins, *Paranthropus* teeth have been called the “most distinctive” of any within the hominin clade (Bailey and Wood 2007). The unique characteristics of their teeth, particularly their robust premolars, provide a rich resource for determining phylogenetic relationships both between hominin clades and within the *Paranthropus* clade itself. Additionally, their highly derived premolars provide important implications for understanding hominin tooth development.

In terms of phylogeny, dental trait variance and frequency differs even between very closely related species (Bailey 2000). Variance in premolars during the 1980s specifically demonstrated that *Homo*, *Paranthropus robustus* (then called *Australopithecus robustus*), and *Australopithecus afarensis* could be considered separate taxa (Wood and Uytterschaut 1987). This dental research contributed to the modern paradigm that separates *Paranthropus* and australopithecines into different clades. *Paranthropus* premolars are highly “molarized;” they have a relatively large talonid and bear additional cusps (Wood and Uytterschaut 1987). The developmental process of molarization remains an anthropological mystery, as does the phylogenetic relationship of *Paranthropus* species to each other. Previous analysis of crown traits has demonstrated that australopithecines are more closely related to each other than to *Paranthropus* (Bailey and Wood 2007), but has not yet been applied to *Paranthropus* in comparison to other hominins. Additionally, the proposed monophyly of *Paranthropus* remains questionable; in fact, this clade may represent two different evolutionary histories (Wood 2007).

Extensive wearing on fossil teeth has traditionally been a hindrance to trait-oriented analysis. This project expands the sample size via microCT scanning to include teeth that exhibit wear, thus more clearly elucidating phylogenetic relationships both within *Paranthropus* and

between *Paranthropus* and other hominin clades. The analysis of internal structures will also specifically address how the enamel-dentine junction and enamel formation contribute to the crown shape of *Paranthropus* teeth. Characterizing this developmental process could reveal differences between the molarization of eastern and southern *Paranthropus* populations.

In summary, this project will accomplish three goals relevant to the subject of hominin dental analysis. First, it will demonstrate the utility of using partially worn teeth in the fossil record. This sample will reveal morphological similarities and differences present at the EDJ never before seen by dental researchers. Identifying these characteristics will further illuminate the developmental processes responsible for premolar molarization. Finally, determining these processes will contribute to current understanding of *Paranthropus* monophyly.

6. Methods (clearly outline or list your research questions; describe the data you will collect and how you will collect it; discuss your analytical methods; and show how the data will address the research questions) [300 word maximum]:

Research questions:

- What is the contribution of the EDJ to premolar morphology among fossil hominins?
- How do the EDJ and enamel cap contribute to molarization?
- Does premolar structure support or reject *Paranthropus* monophyly?

Study sample

The fossil sample includes mandibular and maxillary premolars attributed to *Paranthropus robustus*, *Paranthropus boisei*, *Australopithecus africanus*, and *Australopithecus anamensis*. An extant hominoid sample provides additional context for morphological variation.

Methods

Dentine and enamel tissues will be segmented from CT scans of each premolar and surface models will be created using computer software (Figure 1). General premolar shape will be assessed using geometric morphometric methods. These measurements will capture the size and shape of the crown and the placement of major cusps (Figure 2). Specimens will be adjusted for location, orientation, and size. The degree of shape similarity between *Paranthropus* taxa will be assessed using principal component and discriminate analyses. These analyses will demonstrate whether premolars of *Paranthropus* species are more similar to each other than either species is to other hominin taxa.

Figure 1: CT-scan images of the EDJ (left) and enamel cap (right) of a hominin molar.

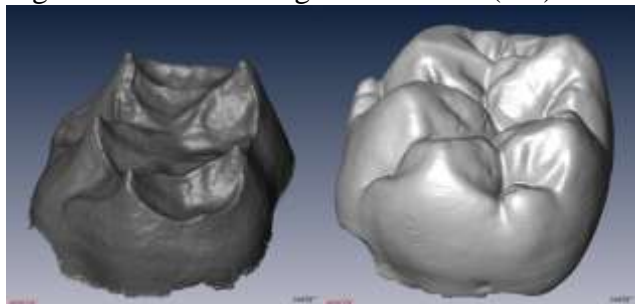
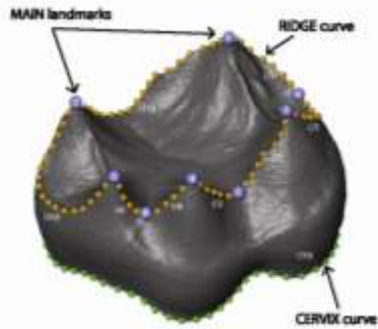
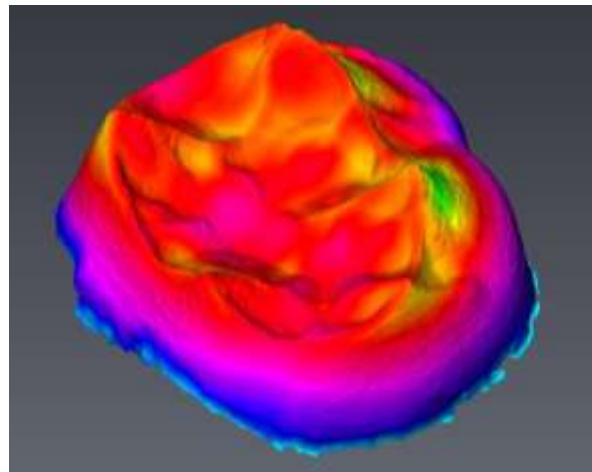


Figure 2: Landmark analysis on an EDJ image.



Skinner *et al.* 2008a, 2008b, and 2009 demonstrate that examination of the EDJ can reveal differences in trait expression not evident at the enamel surface. The contribution of the EDJ and enamel cap to discrete trait presence will be assessed visually from surface models generated from the segmented CT scans. Visual inspection of each surface will also be used to determine whether particular traits are contributing to the molarization of premolars in the study sample. Additionally, the creation of 3D enamel distribution maps will show how enamel is distributed across the EDJ (Figure 3). These analyses will characterize molar development and again demonstrate whether the premolars of *Paranthropus* belong to the same evolutionary lineage.

Figure 3 Enamel thickness distribution across the EDJ



7. Research Ethics (describe how you will ensure that your research project is conducted in accordance with anthropology guidelines and the guidelines of your particular field within anthropology, and in the case of “Human Subjects Research,” according to the criteria of GW’s Institutional Review Board. For the former, consult the Web site of the American Anthropological Association (<http://www.aaanet.org>). For the latter, discuss requirements with your faculty mentor and/or with Professor Barbara Miller, the IRB rep in the Anthropology Department. Most student projects involving living humans fit in the IRB category of “excluded,” meaning that IRB forms do not need to be submitted, if they follow AAA ethical guidelines in terms of informed consent and avoidance of harm to participants, do not involve

medical topics and do not identify particular individuals. In some instances, the IRB approval does need to be sought, usually in the “expedited” category.” Information on these categories is also available at <http://www.gwumc.edu/research/human/aboutus/html> [150 word maximum]:

The samples for this analysis are skeletal materials; no living human subjects will be involved. All methods employed in this research will adhere to laboratory and ethical guidelines set forth by the George Washington University, the American Anthropological Association, and the Max Planck Institute.

8. Research Product (discuss how you will use and present your findings including, for example, a presentation at a professional meeting, a film, a museum exhibit, a publishable paper, a thesis) [150 words maximum]:

Findings from this research experience will be published in a peer-reviewed journal. Dr. Skinner has targeted the Journal of Human Evolution as a likely publication source. The research product will also be presented at Anthropology Student Research Conference in 2009 and as a poster at the American Association of Physical Anthropology (AAPA) meetings in 2009. Finally, the research experience will greatly enhance our knowledge of how hominin teeth evolved and will be used as part of my thesis in australopithecine dental development.

9. Timetable (provide a brief description of the schedule of your research activities week-by-week or as appropriate):

May – mid-June 2009: Primary research will be conducted at the MPI-EVA supervision of Matt Skinner. Previously scanned fossil specimens will be segmented and analyzed.

June – August 2009: Analysis will continue on previously imaged fossil teeth and a primarily publication draft composed.

September 2009: Submission of publication to relevant journals. Data will also be prepared for both electronic and poster presentations. An abstract of the publication will be submitted to the AAPA for presentation in the spring.

October 2009: Presentation at the Anthropology Student Research Conference.

April 2010: Poster presentation at the AAPA meetings.

10. Budget Amount and Projected Expenditures

Total Amount Requested: \$1800

Projected Expenditures (list the expenditure categories for your project, for example, transportation--international, domestic, local; room and board; and research supplies). Funds from a Cotlow award cannot be used for tuition, academic fees, or for purchasing equipments such as a laptop or camera [awards range from a few hundred dollars to \$1800]

Roundtrip flight from Washington DC to Leipzig, Germany: \$1100

Apartment in Leipzig for 6 weeks: \$640

Roundtrip from Leipzig to Berlin for museum visit: \$80 dollars

Tram pass in Leipzig for 6 weeks: \$100 dollars

The total research cost is \$1920. I am therefore requesting \$1800 from the Lewis N. Cotlow Field Research Fund to defray these costs.

11. Staff (if others are to participate in the project as researchers or research assistants, please give their name and qualifications):

Dr. Matt Skinner of the Max Planck Institute will be the lead researcher. He is a specialist in the field of hominin dentition and a graduate of GWU's Hominid Paleobiology program. Dr. Jean-Jacques Hublin, director of the Department of Human Evolution, MPI-EVA, has agreed to make available the study sample and resources necessary for the completion of this project.

12. Outside Financial Support (list any other sources of funding for the project, either obtained or applied for, with amounts and restrictions):

My IGERT NSF Fellowship provides some livelihood expenses and will be used to purchase food and personal supplies.

13. References Cited/Select Bibliography (list the sources you have cited in the proposal and/or used as background research. Use the style defined by the American Anthropological Association [see <http://aaanet.org>]; list a minimum of 10 sources to a maximum of one page).

Bailey SE

- 2000 Dental morphological affinities among late Pleistocene and recent humans. *Dental Anthropology* 14(2): 1-8.

Bailey SE and Wood BA

- 2007a Trends in postcanine occlusal morphology within the hominin clade: The case of *Paranthropus*. In *Dental Perspectives on Human Evolution*. Bailey SE and Hublin J-J, eds. New York: Springer.
- 2007b The evolution of premolar and molar crown morphology within the hominid clade. In *Dental Perspectives on Human Evolution*. Bailey SE and Hublin J-J, eds. New York: Springer

Skinner MM *et al.*

- 2009 Protostylid expression at the enamel-dentine junction and enamel surface of mandibular molars of *Paranthropus robustus* and *Australopithecus africanus*. *Journal of Human Evolution* 56: 76-85.
- 2008a Dental trait expression at the enamel-dentine junction of lower molars in extant and fossil hominoids. *Journal of Human Evolution* 54: 173-186.
- 2008b Enamel-dentine junction (EDJ) morphology distinguishes the lower molars of *Australopithecus africanus* and *Paranthropus robustus*. *Journal of Human Evolution* 55: 979-988

Suwa G *et al.*

- 1991 A phylogenetic analysis of Pliocene Hominidae based on premolar morphology. *Primate Today*: 509-512.
- 1984 Further analysis of mandibular molar crown and cusp areas in Pliocene and early Pleistocene hominids. *American Journal of Physical Anthropology*.

Wood BA *et al.*

- 2007 Are "Robust" Australopithecines a Monophyletic Group? In *Evolutionary History of the Robust Australopithecines*. Grine F, ed. New York: New York.
- 1987 Analysis of the dental morphology of Plio-Pleistocene hominids. III. Mandibular premolar crowns. *Journal of Anatomy* 154: 121-156.

14. Permits (demonstrate that you have, or are seeking, any necessary permits such as a research permit, a research visa, an antiquities permit, letter of welcome from an institution, etc. Attach copies to this proposal).

A permit is not necessary for this project, and my passport to Germany has been processed.

15. Transcript (submit a copy of your transcript with this proposal; it can be either official or unofficial. Without a transcript, your proposal is incomplete and will not be considered).