FACULTY SPONSOR
EASTERN ILLINOIS UNIVERSITY
UNDERGRADUATE RESEARCH AND CREATIVE ACTIVITY PROPOSAL

Name of Student Sponsored Olivia A. Barbee

Name of Faculty Sponsor Craig A. Chesner

Department Geology/Geography

Briefly provide your comments about the student's proposed research or creative activity, including an assessment of the validity of the project design.

Olivia's proposed research on identifying source areas for the Toba tuffs will be an important contribution to the body of information that is known about the development and evolution of the Toba Caldera Complex. Lithic fragment distribution analysis has proven to be a viable method for identifying vent areas for ash-flow tuffs at other calderas. Not only is it the best way to reconstruct this part of the eruptive history at calderas, it may be the only way. Furthermore, Olivia has already successfully applied this technique to constrain the source areas of two smaller tuff eruptions (HDT and MTT) at Toba. Expansion of her ongoing research to identify the source areas of the two largest eruptions (OTT and YTT) at Toba will employ the same sample preparation, data collection, and interpretation methods that she is already quite familiar with. In my opinion, this is a solid, tested, research plan that will generate the data needed to constrain the vent locations of the OTT and YTT. The study may even be able to determine if and how vent locations migrated during the YTT super-eruption.

Explain why you believe the student will be successful in carrying out this proposed project, bearing in mind that the student is primarily responsible for the actual execution of the activity and preparation of the Summary Reflection. Please include comments on the student's communication skills.

Olivia has an excellent work ethic and is extremely well organized, conscientious, and devoted to the study of Geology. This project will utilize her strong geological background gained from previous course work and Undergraduate Research. She has already acquired all the necessary skills and background to conduct this study including: completion of the literature review, classifying the pre-caldera basement rocks, learning sample preparation techniques, establishing a data collection strategy, and experience evaluating and interpreting the results. With this strong foundation to build upon, I am confident that Olivia will do an excellent job with all aspects of this study including preparation of a final report and presenting her findings at a professional conference. Her written communication skills are excellent; indeed she has written some of the best research papers that I have seen by undergraduate students. The few oral presentations that I have observed Olivia give have been organized, complete, well-illustrated, and to the point. This research experience will culminate an impressive undergraduate career, and will further prepare Olivia for graduate studies in Geology next Fall.

Please specify the account name and number into which faculty funds are to be deposited. *Cannot be a gift account*

Organization # [redacted]   Organization Title GEOLOGY/GEOGRAPHY

I understand that the funds awarded by the Undergraduate Research Council are for the exclusive use of the above named faculty member.

Department Chair Signature   Date 29-FEB-12

By signing this application, I agree to supervise the student, the proposed project, and monitor the ethics used in the proposed research. I also understand that the Undergraduate Research Council requires the student to submit a summary report of his/her research to the Honors College Office.

Craig A. Chesner

Faculty Sponsor Signature   Date 2/29/12

Return this application to Dr. John Paul Stimac, Dean of The Honors College, Booth House, Eastern Illinois University, Charleston, IL 61920. It is the responsibility of the student to inform the faculty sponsor of the proposal due date.

*********Note: It is the student's and the sponsor's responsibility to submit the summary reflection by the deadline. Failure to do so will result in the refusal of future undergraduate research grants for the applicant.*********

02-29-12 P03:19 IN

Constraining Vent Sources at the Toba Caldera, Sumatra, Indonesia

R1. Proposed Research

The Toba caldera formed 74,000 years ago when 2800 km^3 of silicic magma erupted explosively from a shallow magma body. This super-eruption is widely cited as the largest eruption on Earth in the past 2 million years, and left a 100 x 30 km (60 x 18 miles), steep sided crater that is now partly filled with Lake Toba. Geological evidence suggests that three smaller calderas formed prior to the Toba caldera and were all consumed by the cataclysmic eruption 74,000 years ago (Fig. 1). Each of the four caldera-forming explosive eruptions produced a rock unit known as a "tuff" consisting of fragmented magma (pumice and ash) plus ***lithic fragments*** torn from the underlying rocks during the eruption. The four Toba tuffs erupted at 1.2, 0.84, 0.50, and 0.074 million years (m.y.) ago and are respectively known as the Haranggaol Dacite Tuff (HDT), Oldest Toba Tuff (OTT), Middle Toba Tuff (MTT), and Youngest Toba Tuff (YTT).

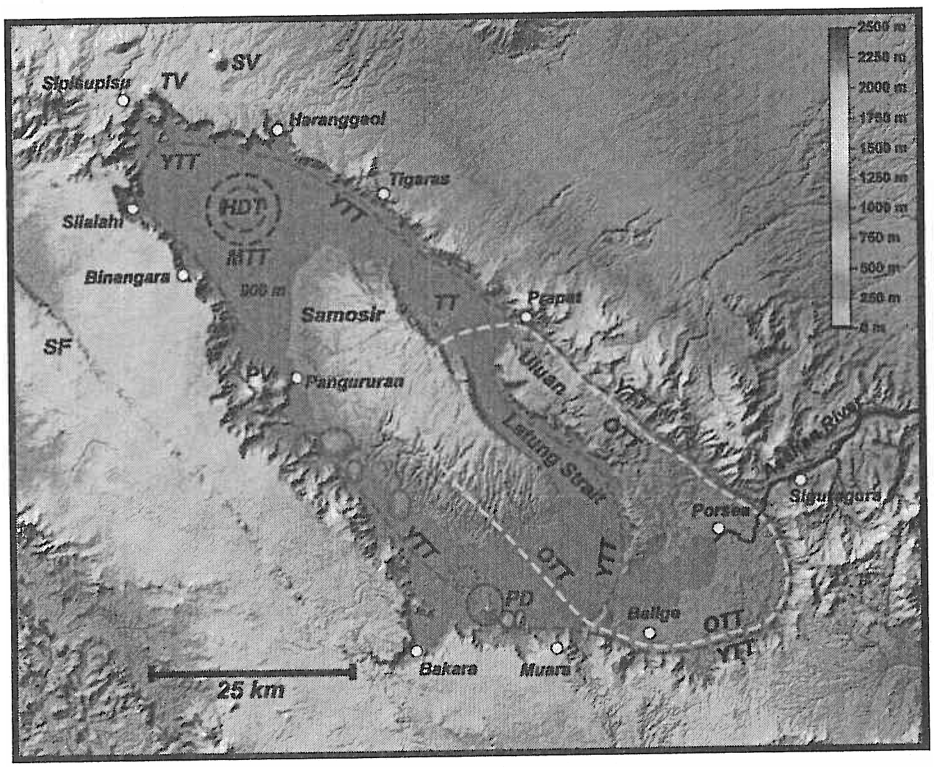

Figure 1. Location map of the Toba Caldera Complex (from Chesner, 2011). The colored dashed lines represent the tentative locations of the successively aged calderas that erupted the HDT, OTT, MTT, and YTT, respectively.

Prior to the explosive volcanic eruptions, the Toba area was underlain by a variety of much older metamorphic, sedimentary, and volcanic basement rocks. These rocks are now only exposed in the steep walls of the caldera because the surrounding terrain is completely covered by the younger Toba tuffs (Fig. 2). Detailed geologic maps show that different varieties of these pre-caldera basement rocks occur at widely separated locations within the caldera walls. The main premise of my proposed research is that by studying the lithic fragments contained within the four Toba tuffs, it will be possible to determine the source area (vent location) for each tuff.

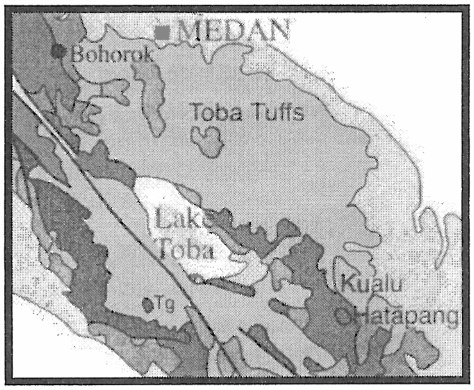

Figure 2. Simplified geologic map of the Toba caldera showing the YTT (pink) and pre-caldera basement rocks (brown = metamorphic rocks; orange and yellow = sedimentary rocks; gray = pre-caldera volcanic rocks). The HDT, OTT, MTT, and additional basement rocks exposed in the steep caldera walls are not shown on this simplified map. Modified from Stephenson and Aspden (1982).

Large caldera eruptions, like those at Toba, typically do not occur from a single central vent, but instead occur along localized linear vents around the perimeter of a caldera. These "ring fracture" eruptions can be likened to the foundering of the roof of a shallow magma body, whereby a coherent block of rock rapidly subsides into the magma chamber along arcuate faults. As the piston of rock drops into the magma chamber, magma is expelled explosively along segments of the caldera collapse faults. These explosive eruptions fragment the magma into a gas-charged mass of pumice and ash, and rip lithic fragments from the walls of the vents. This mixture of volcanic gases and clasts is highly mobile and can then flow great distances away from the vent as "pumice and ash-flows." The resultant deposits, known as "ash-flow tuffs," can cover vast areas outside the caldera, and also accumulate to great thicknesses inside the caldera. For these reasons, it can be difficult to determine where an ash-flow tuff originated, especially those that erupted from older calderas whose outlines are no longer visible. However, because ash-flow tuffs contain lithic fragments inherited from their vents, and the locations of different basement rocks exposed in the caldera walls are known, it then becomes possible to reconstruct vent locations for older eruptions (HDT, OTT, MTT), and even determine what portions of a visible ring fracture were active vents (YTT).

A large suite of Toba samples consisting of the HDT, OTT, MTT, and YTT, and many basement rock samples collected from the walls of the caldera is housed at EIU and available for this study. Using the basement rocks as a reference suite, I plan to study the lithic fragments contained within the four tuffs to constrain the vent area(s) of each tuff. I am presently nearing completion of a lithic distribution study of the two smaller Toba tuffs (HDT and MTT). Due to the success of that study (Barbee and Chesner, 2012), I propose to apply the same lithic-distribution method to identify the vent areas of the much larger OTT and YTT. Incorporating the results of the OTT and YTT lithic study with those of the HDT and MTT will complete my overall goal of identifying the vent locations for all four Toba tuffs.

R2. Research Methods

In order to successfully conduct my proposed research there are several steps and methods that I will be applying. Each of these components is discussed below:

Toba Literature Review: Due to my previous and ongoing research on the HDT and MTT, I have read all the available literature regarding the evolution and eruption of the Toba caldera. Particular attention was paid to field descriptions of the pre-caldera metamorphic, sedimentary, and volcanic basement rocks exposed in the northern walls of the caldera. For my proposed study of the OTT and YTT, I will revisit the papers that discuss basement rocks exposed in the southern caldera walls, as this is a likely source area for the OTT and a significant portion of the YTT. I am also quite familiar with the geologic maps of the caldera, but will also re-examine them with a focus on the southern caldera walls. Understanding the distribution of the various pre-caldera basement rocks as explained in the literature, on geologic maps, and from rocks collected from actual exposures is an essential element of this study.

Lithic Fragment Distribution Literature Review: The inspiration for this study stemmed from classic studies at two well-known calderas (Long Valley, CA and Taupo, New Zealand) that demonstrated the utility of using lithic fragments in ash-flow tuffs to constrain vent areas. I have read these papers and expect to continue consulting them as I apply their methods to collect and interpret data on the OTT and YTT.

Sample Preparation: Ash-flow tuff samples occur in two distinct forms. If a pumice and ash-flow is hotter than 500°C when it comes to rest, it will weld into a dense rock. However, those that are emplaced below 500°C remain loose and unconsolidated. The OTT is entirely a welded tuff, whereas the YTT is mostly a non-welded tuff. As a result, sample preparation techniques for the OTT and YTT are quite different. For the welded OTT samples, lithic fragments are studied by examining "thin sections" of these rocks with the petrographic microscope. Lithic fragments in the non-welded YTT are collected by hand-picking them from the loose sample with tweezers. Thin sections of the hand-picked lithic fragments are then made for detailed petrographic analysis. Most of the OTT samples and many of YTT hand-picked lithic samples have already been prepared as thin sections. Although a few additional samples of the OTT and YTT will need to be made for this study, I have already learned the techniques to prepare both types of samples.

Recording Lithic Distribution Data: Because I prepared and studied thin sections of the basement rocks that surround the caldera during the HDT/MTT study, I am familiar with the reference set to which the lithic fragments found in the OTT and YTT will be compared. Using the variety of lithologies encountered in the reference set, I developed a detailed lithic classification scheme that provides for general rock types and specific sub-divisions. Each sample has a master chart depicting all classification possibilities. As I systematically work through each thin section, the rock type classification of each lithic fragment is recorded as specifically as possible on the chart. During this process, I also map the location of each lithic within the thin section, sketching its relative size and shape. Upon completion of this step, every lithic has been categorized and mapped, and their qualitative abundances are clearly depicted on each sample's chart.

Matching Lithics to Basement Rocks: In order to make precise correlations between the categorized lithics, and their potential basement source rocks, each lithic fragment will be photographed using a digital camera integrated with the petrographic microscope. These images can then be compared side by side against digital images of the basement rock samples. Furthermore, lithics can be compared within the same sample, or between different samples, and even different tuffs. Another useful parameter that can be precisely determined from the digital images is the area of each lithic fragment which can eventually be used to determine quantitative abundances for each lithic type.

Evaluation and Interpretation of Data: Once classification, basement rock matching, and quantitative abundances of the lithic types in each sample has been determined, this data will then be plotted onto the base geologic map in the form of pie charts. The geographic distribution of the lithic proportion pie-charts and the pre-caldera basement rocks should then allow me to constrain the vent location for each sample site. For example, should an OTT sample contain 80% pre-caldera volcanic lithic fragments, 20% metamorphic rock fragments, and virtually no sedimentary rock fragments, this would indicate that it erupted from a narrowly confined region in the southwest part of the caldera where this combination of basement rocks exists (Fig. 2). Collectively evaluating the results of all individual samples should then greatly constrain the vent locations for each tuff. Finally, it will be possible to determine if widely spaced samples of the same tuff erupted from the same vent, or whether multiple vents were active during the eruption. The OTT and YTT results will then be combined with the findings from my HDT and MTT study, providing a comprehensive assessment of vent locations for all four Toba tuffs.

Project Completion Schedule: Should this project be funded, I will enroll in 3 credit hours of Undergraduate Research in Geology (GEL 4430) during the 2012 Summer session. Since this will be the only course that I enroll in during Summer session, I plan to devote my full attention to the execution and completion of this research. The abstract deadline for the professional meeting that I intend to submit the results of this study to is August 8, 2012, and I am confident that I can meet that goal.

R3. Contributions to Existing Knowledge

Presently, the general vent locations for the Toba tuffs are based primarily on the geographic distribution pattern of each ash-flow tuff deposit. Furthermore, because the YTT eruption has engulfed the 3 older calderas, the outlines and locations of these calderas is highly conjectural. Although the location of the YTT ring fracture is known, the segments of this nearly 250 km long fracture that erupted the YTT have yet to be established. The results of this study, combined with my ongoing HDT and MTT vent location study, will provide new, important constraints for the source locations of all tuffs that erupted from the Toba Caldera Complex. In addition to the primary goal of constraining vent sites for the tuffs, it is likely that supplementary information regarding the unexposed subsurface geology beneath the calderas will also be generated by this study. Collectively, the results from this study will contribute significantly to the overall understanding and evolution of the Toba Caldera Complex. Ultimately, an increased understanding of the nature of ring-fracture eruptions from giant silicic calderas will be an important component for volcanologists to consider when evaluating the volcanic hazards for the next super-eruption on Earth.

R4: Background and Skills

In order to complete this project, I will use the knowledge and skills I have acquired through several geology courses that I have taken at EIU, especially Mineralogy, Optical Mineralogy, Petrology, and Volcanology. Both Mineralogy and Petrology have given me the ability to identify various properties of minerals and rocks in both hand sample and thin section. Optical Mineralogy and Petrology have provided the necessary skills and experience to use the petrographic microscope to analyze thin sections of all rock types, especially volcanic rocks. Volcanology was also an important course in strengthening my background in volcanic processes and features. During my present undergraduate research project to constrain the vent areas of the HDT and MTT, I have read all the pertinent literature on Toba, learned how the methods and techniques that I will be applying to Toba were used at other calderas, characterized the pre-caldera metamorphic, sedimentary, and volcanic basement rocks at Toba, learned to prepare thin sections and lithic-fragment mounts for the tuff samples, and collected data on 20 tuff samples. In the next 2 months, I will continue to collect and evaluate data on the HDT and MTT and prepare my interpretations for presentation at the regional Geological Society of America meeting in Dayton, Ohio on April 23. Thus, I feel well prepared to extend this study to evaluate the source areas for the OTT and YTT, and believe that the background and experience that I bring to this project will result in its successful completion. Receiving this award will provide funds that enable me to enroll in EIU this summer and provide living expenses while I conduct my research here on campus. Remaining funds will be used to support my travel to present this research.

R5. Criteria/Techniques used to Analyze/Evaluate the Data

This lithic fragment distribution study will be modeled after similar studies conducted at the Long Valley caldera in California (Hildreth and Mahood, 1986) and the Taupo caldera in New Zealand (Cole et al., 1998; Krippner et al., 1998). In all of these studies, vent locations were clearly identified using the populations and distributions of lithic fragments, as well as information regarding shifting of vents during an eruption, and identification of sub-volcanic rock types not visible on the surface. I expect that the application of their methods, combined with the data collection techniques that I have developed, will be equally successful at Toba. The data that I gather and the interpretations that follow will be analyzed in conjunction with the known geographic patterns of the tuffs, available tuff thickness data, general concepts of the pre-eruption topography, and the present state of knowledge regarding ring fracture eruptions at silicic calderas to develop a new vent location model for the Toba tuffs.

R6: Dissemination of Results

I plan to present the results of this research at the Fall meeting of the American Geophysical Union held in San Francisco, CA, December 6-10, 2012. A poster presentation will be produced to serve as a visual aid that displays my findings. All research will be completed prior to the abstract deadline of August 8, 2012.

References Cited

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