Summer Faculty/Student Research Program Attachment

Frappier/Pinkey-Drobnis

2. Title: Calendar-year dating of pre-historic hurricanes in Yucatán, Mexico using fluorescence micro-imaging of an annually-layered stalagmite.

3. Abstract:

Hurricanes and other tropical cyclones are among Earth's deadliest and most costly natural hazards. Among many potential impacts of future climate change, changes to hurricane intensity, frequency, or tracks are of great interest to the public and decision-makers. A dearth of historical data has led to the emergence of paleotempestology, a rapidly changing field that aims to compile geo- and biological archives of past storm events to study hurricane-climate interactions. Our project would build on previous work that established mud layers in stalagmite CH-1 as a proxy for hurricanes over the last 2300 years. Ms. Pinkey-Drobnis would refine the age of pre-historic hurricane events to calendar-year precision by counting and measuring annual layers visible in fluorescent light, using digital photographic capabilities of Skidmore's new microsampler.

4. Faculty Statement:

This project will help advance our knowledge about past hurricane-climate interactions. For me, this summer research project has two important goals: It will provide one of our department's most talented sophomores, Ms. Aurora Pinkey-Drobnis, with valuable research experience that may help launch her into an exciting trajectory during her final two years on campus and beyond. The proposed project will also enable me to transform the existing body of work (on which Aurora's summer study is based) into a publishable paper with strong impact.

Aurora is the ideal student to take on this project, which will involve making careful observations of fine layers in a stalagmite using a digital microscopy imaging, analyzing that data using image processing software, and interpreting the results consistently in order to develop geologically significant information. Aurora took the initiative in approaching me about opportunities to get involved in my research. In the course of a month-long tree-ring laboratory project in Climatology last fall, she showed a special knack for counting thoughtfully and making careful measurements of tree-ring widths. Her innate patience and interest in tree-ring data collection made Aurora stand out as an unusual person who is very well-suited to working on stalagmite records of past climate. We have begun meeting regularly individually and with my research group for an informal seminar on cave systems and climate studies. She is thus perfectly prepared to take on this project, for which I propose to train her in more advanced techniques for high-resolution paleo-climate research.

I hope to have a few students working with me over the summer on this and related research, as I establish a new laboratory. In my line of work, laboratory techniques and theoretical discussions cannot be divested from understanding how cave formations grow in the field. Aurora would be expected to participate in a weekly seminar organized around cave- and climate-science readings from the peer-reviewed literature. We would include field training, culminating in a field trip to local caves in the Schoharie/ Schenectady area as part of the training regimen.

For geosciences majors, gaining research experience in the second year or summer after sophomore year is the ideal pathway toward future internships and research experiences. A MS degree is the optimal one for geoscientists, so Aurora will most likely return to school immediately or after working for a few years. If this project is approved, Aurora will gain significant research experience this summer, which will help her to crystallize her future career plans, and position her strongly for landing a competitive national summer experience the following summer.

5. Student Statement:

When I first heard about Professor Frappier's paleoclimatology research I was excited at the prospect of learning more and becoming involved. I am interested in her work with stalagmites as indicators of storm events and past climate because it is relevant to my passion for climatology as well as environmental issues involving the climate system.

Thus far, I have taken two lab classes (climatology and oceanography) with Professor Frappier. In order to become acquainted with the research she is doing, I have been working to learn more about cave dynamics and the data already taken from the tropical stalagmites. This semester we have begun to have regular individual and group meetings with other students involved to talk about projects involving dating the stalagmites, measuring mud layers, and creating an annual record.

I am excited for the opportunity to work together with Amy Frappier on a project we are both interested and engaged in that has practical applications to the environmental and climate problems we are facing today. The collaborative research experience will provide me with important lab experience that will expand my academic and career possibilities for the future. Working to find new data in order to better understand such a pressing issue as annual storm patterns would be an invaluable experience. As an undergraduate it is incredible to be at Skidmore because of the chance to do research with a professor and begin to explore a field I might be interested in as a career path. Throughout this project I hope to be inspired by the potential in the collected data and research and to learn from my professor in a dynamic and reciprocal context.

6. Goals, proposed activities, and format of final outcome expected

The immediate goals of this project are data collection:

- develop high-resolution fluorescence images of the lower 15cm of stalagmite CH-1,
- use image processing software such as ImageJ to convert fluorescence brightness data to annual layer counts,
- measure the thickness of each lamina and mud layer, and
- use the above data to extend the existing calendar-year age-depth model developed for the upper part of stalagmite CH-1 through the entire record.
- Interpretation of the results in terms of previous hurricane-climate research.

This project will result directly in a conference presentation and a journal article. I will encourage Ms. Pinkey-Drobnis to present at a national or regional professional conference, such as the Northeastern Section of the Geological Society of America annual meeting. She will be listed as the first author of the poster. I will be involved at every step with abstract writing and poster development and printing.

I expect that Ms. Pinkey-Drobnis' results will provide the missing data that I need in order to produce a publishable paper from Mr. James Pyburn's master's thesis. The paper we intend to write has the working title "2,305 years of hurricane activity in Yucatán, Mexico from mud layers within an annually-laminated calcite stalagmite." If Aurora is interested in participating with the writing process, particularly for the sections relevant to this proposed summer research, then she would be included as a co-author. I will encourage her to become involved in scientific publication through this process.

7. Budget

This project will require $600 in financial support above the given faculty and student salaries:

1. Funds for field trip vehicle rental and fuel costs are requested at $100
2. Training - $500 is requested to help defray the cost of installing the microsampling system in the new lab space, including a training session for both faculty and student from the OEM, Carpenter Microsystems.
3. Analysis – no additional funds are needed for analysis, because the samples, instrumentation, and software required for this project are already in-house, and can be obtained simply with time and effort.

8. Complete Description

Hurricanes and other tropical cyclones are among Earth's deadliest and most costly natural hazards (e.g. Emanuel, 2003). Among many potential impacts of future climate change, changes to hurricane intensity, frequency, or tracks are of great interest to the public and decision-makers. Understanding variability in the frequency and intensity of TCs is important for development of coastal human settlements and evaluating the need for better warning systems and evacuation infrastructure (Nott et al., 2007), as well as evaluating the correlation between climate change and TC activity. A dearth of historical data has led to the emergence of paleotempestology, a rapidly changing field that aims to compile geo- and biological archives of past storm events to study hurricane-climate interactions.

Cave formations such as stalagmite are rapidly emerging as important sources of information about past tropical climate change (e.g. Frappier et al., 2002; Wang et al., 2005). Previous work by Prof. Frappier and James Pyburn, a former Master's student at Boston College, has established that a stalagmite collected in 2007 from a cave in Yucatán, Mexico contains annual layers over the last 2300 years, as well as mud layers deposited by hurricanes (Pyburn, 2010). The mud layers in stalagmite CH-1 (Fig. 1) thus provide a proxy record of hurricane activity over the last 2300 years, including a dramatic decline during the Little Ice Age, ~1350-1800AD. However, Mr. Pyburn was unable to complete high-resolution imaging of the entire stalagmite before starting his job in Houston. Before this important work can be published, the lower portion of the stalagmite requires high-resolution image analysis to match the dating precision of the top section of the stalagmite. Ms. Pinkey-Drobnis is ideally situated to perform this work, and would spend the summer refining the age of pre-historic hurricane events to calendar-year precision by counting and measuring annual layers visible in fluorescent light, using digital photographic capabilities of Skidmore's new microsampler.

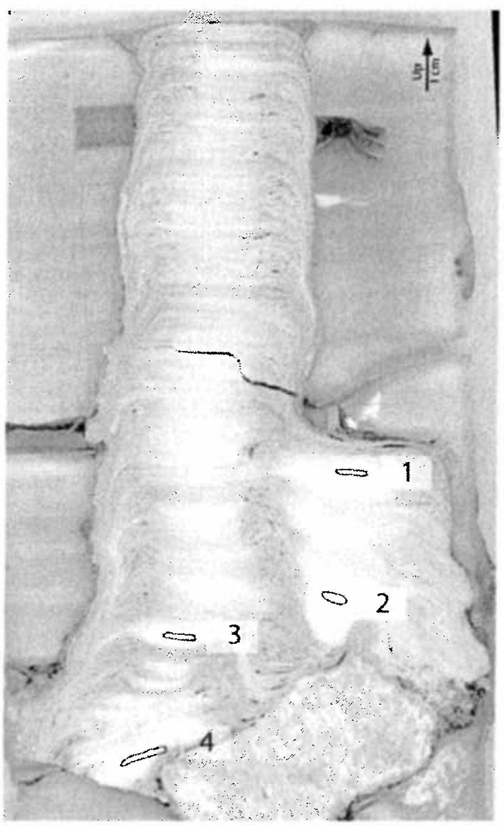

Fig. 1. Polished cross-section of CH-1 showing the 4 locations of radiometric dates.

Layer counting is a visual stratigraphic technique for recognizing annual laminae (analogous to varves or tree-rings) based on the variations in calcite deposition between the wet and dry seasons, which are very pronounced in the Yucatán Peninsula. Typically, in such seasonal climates, stalagmites develop annual layers (Baker et al., 2008). Each year two layers are deposited: one layer of opaque calcite, sometimes called white porous calcite (WPC), coupled with a clear layer of dark compact calcite (DCC) (Kendall and Broughton, 1978). The differences in color are due to the different morphologies of the calcite crystals deposited under different hydrological regimes (Baker et al., 2008). Each calcite couplet should thus represent one hydrological year. In addition to visible couplets, annual variations in fluorescent humic acids flushed into the cave system by rainwater can be seen and measured using a mercury light source to excite the intrinsic fluorescence of these organic substances (Sharp, 2007). Brighter excitation seen in the calcite of stalagmites is normally due to higher rainfall, and darker, less fluorescent material is deposited during the dry season.

Methodlogy - The photography for the analysis will be taken with the CM-2 microsampling system with stalagmite option, epifluorescence imaging, transmitted light base, and horizontal drill micromilling assembly to be installed at Skidmore College in March, 2010. A series of high-resolution images of the polished surface of CH-1 will be collected using the CM-2 epifluorescence microscopy module with a broadband fluorescence excitation lamp and a Chroma 49000 series CFP filter at 6x magnification. Layer counting, will be performed following the methodology of Pyburn (2010) using the above high-resolution digital photographs in plain white light and fluorescent light. Layer counting and stratigraphic mapping will be performed using the software packages Adobe Illustrator and Image J 64. Fluorescent light has more distinct variation (Fig. 2), and therefore will be the preferred light for layer counting. The next section provides further detail on the methodology.

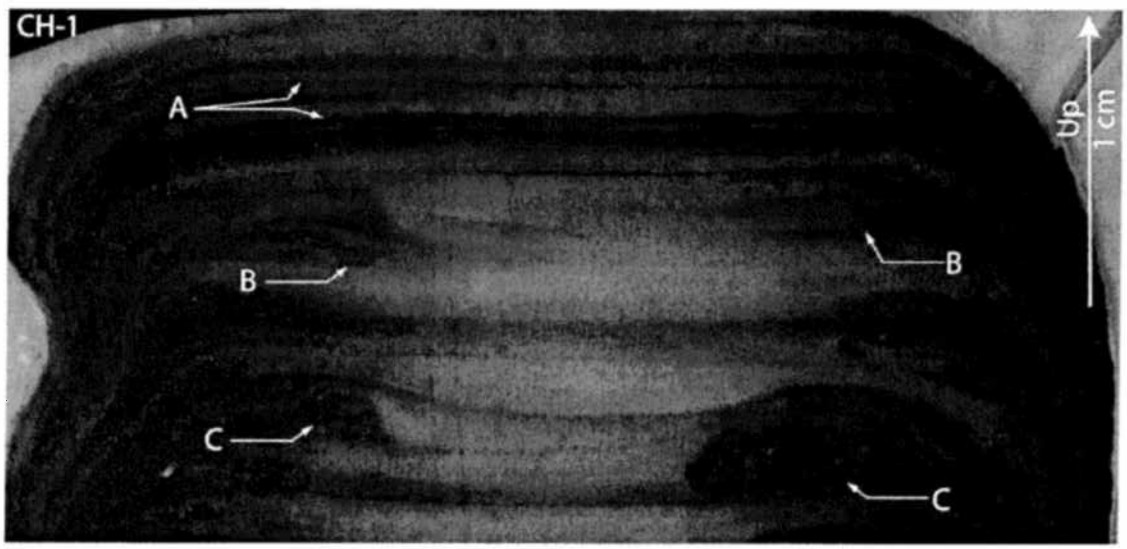

Figure 2. Top two centimeters of CH-1 in fluorescent light, showing mud layers.

Using Image J64, four adjacent gray scale measurements will be taken along transects drawn perpendicular to the laminae in the center of CH-1 and parallel to the growth axis. These grayscale transects are averaged and plotted as a function of depth below the growth surface. A 3-point (3-pixel) running mean is then applied to remove high frequency noise, revealing cycles of grayscale brightness that reflect fluorescence intensity. The cycles resulting from variations in fluorescence are assumed to represent one hydrological year, and the peaks are manually counted. In order to account for the flood-deposited mud layers that also generated low fluorescence layers, we systematically remove the clastic layers from the counts of annual laminae in the following manner: Mud layers that have measurable thicknesses observed in plain and fluorescent light that are present across the entire width of the CH-1 crosssection are assumed to cause a false cycle in the fluorescence data. Each fluorescence cycle whose depth matches the depth of a mud layer will be subtracted from the final cycle count. This procedure results in an adjusted count of the number of cycles (interpreted as hydrological years) in the CH-1 stratigraphic record. Furthermore, by subtracting the adjusted number of cycles stratigraphically above each mud layer from 2007.5, the time of stalagmite collection, it is possible to determine the calendar year of each mud layer's deposition. Using these layer-counting-derived dates for each mud layer, we will calculate growth rates for each section between mud layers. This has been done for the top 56 mud layers (Pyburn, 2010), but another ~200 mud layers remain to be dated by Aurora Pinkey-Drobnis in this proposed project.

A complete chronology will pave the way for publication. In the broader scientific context, the proposed work will help advance the scientific training of a promising young female scientist, and will contribute to revealing the potential for paleotempestology approach to yield long records of landfalling hurricanes to sample past hurricane-climate interaction outcomes, and to test theoretical and modeling predictions relevant to projecting the changing character of hurricane risk in a warming world.

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