

**Award Number:** P13AC01391

**Project Number**: NAU-436

**CFDA #:** 15.945

**Park/NPS Unit: FLAG (SUCR)**

**Park internal control Number: FLAG13PR036**

**Title of Project:** Determine Accurate Date for the Sunset Volcanic Eruption, Using Tree Ring Chemical Analysis, Sunset Crater Volcano National Monument

**Administered through the:**  Colorado Plateau Cooperative Ecosystem Studies Unit Cooperative Agreement Number H1200-09-0005

**CESU Partner: Northern Arizona University, Flagstaff, Arizona**

**PROJECT CONTACTS:**

**Principal Investigator:** *Dr. Michael H. Ort, School of Earth Sciences and Environmental Sustainability, PO Box 4099, Northern Arizona University, Flagstaff, AZ, 86011 USA, phone: 928-523-9363, fax: 928-523-9220, michael.ort@nau.edu*

**Partner Administrative Contact*:*** *Cindy Judge, Grant and Contract Administrator, Office of Grant and Contract Services, Northern Arizona University, P.O. Box 4130, Flagstaff, AZ 86011, Phone: 928-523-6917, Fax: 928-523-1075*

*cindy.judge@nau.edu*

**NPS Certified ATR:** *Paul Whitefield, Natural Resource Specialist, North Central Arizona Monuments, 6400 N. Highway 89, Flagstaff, AZ 86004, Phone: (928) 526-1157 ext. 235, Paul\_Whitefield@nps.gov*

**FUNDING INFORMATION:**

**Amount Funded:** $8,285.00

**NPS Account Numbers (amounts in parentheses):** PPIMFLAGR1-133-PPMRSNR1Z.Y00000 ($7,285.00); PPIMIMR-03B-PPMRSNR1Y.Y00000 ($1,000)

**Fund Source (e.g., ONPS, FLREA, CRPP, CESU, etc.):** ONPS (FLAG Base); CPCESU Regional Base

NPS Funding

Is this funded using a reimbursable account number? If yes, IMR contracting needs a copy of the Interagency Agreement.

**PROJECT DATES:**

**Start Date:** September 1, 2013

**End Date:** November 30, 2015

**NPS Administrative Contacts**

**CESU Coordinator:** *Judy Bischoff, CPCESU Research Coordinator, NAU P.O. Box 5765, Flagstaff, AZ 86011, 928-523-6638, Fax: 928-523-2014,* [*judy\_bischoff@nps.gov*](mailto:judy_bischoff@nps.gov)

**Intermountain Region Administrative Contact:** Kelly Adams, Grants and Agreements Specialist, National Park Service, 12795 West Alameda Pkwy, Lakewood, CO 80228 Phone: 303-969-2392 Fax: 303-969-2992 Email: Kelly\_adams@nps.gov

**FEDERAL FINANCIAL REPORTS AND DRAWDOWN SCHEDULE:**

***Federal Financial Reports*** (Check as required for project based on spending plan, period of performance, risk, cooperator history, etc.)

{X} Quarterly { } Semi-annually { } Annually {X} Final

**Project SCHEDULE AND TECHNICAL REPORT DEADLINES:**

List all technical reports and products in sequential order as required in the scope (more lines and milestones can be added as needed):

*Project Start Date* – September 1, 2013

*Technical progress reports –* { } Quarterly {X} Semi-annually { } Annually

*Investigator’s Annual Report (IAR)* – Due February 1 each calendar year the Task Agreement is active

*Database, Collections/Specimens, Archives, and Maps provided to the NPS ATR or Technical Expert* – September 1, 2015

*Draft Final Report* – August 1, 2015

*Final Report* – September 1, 2015

*Project End Date* – November 30, 2015

*Final SF425 FFR* must be submitted within 90 days of project end date

**PAYMENTS**

**CFR PART 215.22*:*** Cash advance (drawdown) to recipient organization shall be limited to the minimum amounts needed and be timed to be in accordance with the actual immediate cash requirements of the recipient organization in carrying out the purpose of the approved program or project. The timing and amount of cash advances shall be as close as is administratively feasible to the actual disbursements by the recipient organization for direct program or project costs and the proportionate share of any allowable indirect costs.

**CESU REQUIRED PRODUCTS (may be different from those products required by the ATR – See Statement of Work for Products required by the NPS unit):**

The Principal Investigator will prepare a brief report abstract suitable for public distribution and two hard copies and an electronic version (in PDF file format) of the final report and any subsequent reports, and mail all toJudy Bischoff, National Park Service, CPCESU, NAU P.O. Box 5765, Flagstaff, AZ 86011. Please be sure to include the project number (e.g.; NAU-###) and the P number on the cover page of the final report.

**PROJECT ABSTRACT:**

In 1958, Smiley reported the eruption of Sunset Crater Volcano as year A.D. 1064 using tree-ring dating of wood beams that were used in constructing the Wupatki Pueblo. The tree ring specimens had suppressed growth rings indicative of poor growing conditions starting at 1064 and continuing until their cutting dates 50-70 years later. The A.D. 1064 date has become entrenched in scientific literature but recent studies suggest the date may not be correct, and the eruption instead occurred about A.D. 1085. This new determination is based on tree-ring morphology and the dendrochemical analyses of tree rings using strontium isotopes and mass spectrometry for elements such as phosphorus and sulfur. Changes in relative amounts of these elements in affected tree ring tissues may provide evidence for direct dating of the eruption. While suggestive, the sample size is limited to four trees from Parícutin Volcano, which erupted in Michoacán, Mexico, in 1943-1952,four trees from Cinder Cone, Lassen Volcano National Park, California, and four wood specimens from the prehistoric site of Wupatki. Under this Task Agreement, additional wood samples from prehistoric sites in the Sunset Crater area will be examined using two methods of mass spectrometry, and additional strontium isotope data will be developed. Additional information may also be developed on soil chemistry changes in pre- eruptive soil (weathered) and post-eruptive soil (fresh cinder deposits), as these provide the source for uptake of these elements used in tree ring growth. The research is intended to enable definitive determination of the Sunset Eruption date, perhaps to a single year, along with more accurately dating the entire span of the eruption.

**Scope of Work:**

**Background.**

In 1958, Smiley reported the eruption of Sunset Crater Volcano as year A.D. 1064, based upon tree-ring dating of suppressed growth rings in wooden beams used in construction of the Wupatki Pueblo site. The A.D. 1064 date has become entrenched in scientific literature, and the NPS has long included this information in interpretive materials at both Sunset Crater Volcano and Wupatki National Monuments. However a series of studies over the last ten years suggests the date is not accurate, and the eruption occurred around A.D. 1085. This new determination is based on a wider analysis of tree-ring morphology data from numerous other study sites within the volcanic cinder and ash-fall zone around Sunset Crater Volcano. In addition, pilot dendrochemical analyses were recently completed on four structural wood specimens from the prehistoric archeological site of Wupatki, curated at the Laboratory of Tree-Ring Research at the University of Arizona, along with four tree ring samples from Parícutin Volcano in Michoacán, Mexico and four tree-rings samples from Cinder Cone, Lassen Volcano National Park, California. Parícutin erupted in 1943-1952, and the samples used in the analysis provided a modern control to identify which soil elements are affected by cinder cone eruptions. The Cinder Cone analyses showed an eruption date of 1661 AD using both ring-width and dendrochemical anomalies. The pilot analyses of samples from Wupatki measured strontium isotopes (87Sr/86Sr) using thermal-ionization mass spectrometry (TIMS), along with trace elements using inductively coupled plasma mass spectrometry (ICP-MS). The Sr isotopic ratios in water in the post-eruption soils drop dramatically after the eruption because the fresh cinders have much lower ratios than those of the pre-eruptive, weathered soils. Therefore, Sr isotope analysis on tree-ring tissues may provide evidence for direct dating of the eruption by measuring Sr isotopic differences in pre- and post-eruptive tree rings. In addition, increases in elements, such as phosphorous (P) and sulfur (S), were detected in the post-eruption tree ring samples from Parícutin.

While suggestive, the total sample size of only twelve trees cannot be considered statistically robust. Up to 80 prehistoric wood specimens from the Sunset Crater area that could yield dendrochemical signatures indicative of the actual eruption date have been identified in the existing Tree Ring Lab collections. Under this Task Agreement, the cooperators will initiate additional dendrochemical analysis of available specimens for Sr isotope ratios using TIMS and relative P and S concentrations using laser-ablation ICP-MS. The results will be used to evaluate which method provides more consistent results, along with increasing the current sample size for eventual statistical analysis. Most wood specimens will be from pine and fir trees that were growing at higher elevation sites in proximity to Sunset Crater Volcano, where trees would more likely have been affected by the eruption and show differences in chemical compositions. A few specimens may be selected from curated samples collected from archeological sites within Wupatki National Monument.

The resulting data may enable determination of the Sunset Eruption date to a single year. However, based upon the results, additional funding may be sought to further increase the dataset and statistical confidence in the results. More wood specimens may eventually be analyzed using dissolution of the sample flowed by ICP-MS analysis, which is more conventional but more expensive. Additional data may also be developed on soil chemistry changes in pre-eruptive soil (weathered) and post-eruptive soil (fresh cinder deposits), as these are the sources for uptake of the elements used in tree ring growth. Soil chemistry profiles would be developed from field samples of Sunset Eruption tephra deposits of varying depth, along with underlying, pre-eruptive soils. Nutrient availability in soil samples can readily be processed at NAU using published methods, such as the Olsen method, that are widely accepted by the scientific community.

The greater community of geologic scientists, educational institutions, and the NPS would benefit from the research. The study would greatly improve scientific understanding of the timing of the entire Sunset Volcano eruption sequence, including an improved understanding of pioneering ecological succession within the very young volcanic terrain – the stages of soil genesis and natural vegetation recovery. An accurate revision of the eruption date and duration will also provide crucial information for anthropologists and archeologists to reinterpret prehistoric settlement/abandonment patterns in the Flagstaff area, including at nearby Wupatki and Walnut Canyon National Monuments. A short duration eruption may have caused different adaptation by local peoples compared to a long term eruption event. The development of a dendrochemical method to date prehistoric volcano eruptions will be considered of great scientific value, and applicable to dating cinder-cone volcanoes in forested environments around the world. The NPS would be able to use the results to update visitor information in the current interpretive exhibits at the Sunset Crater Visitor Center, Lava Flow Trail, and Wupatki Visitor Center. Lastly, the data developed by the cooperators provide an excellent educational opportunity to communicate about the scientific method and the iterative scientific process used in dating the Sunset Eruption over the last 50 years.

**Objectives.** The proposed study is intended to address interdisciplinary scientific questions in both the geologic and anthropological sciences. The primary objectives for this project include:

(1) Test at least two tree-ring chemistry analysis methods, and evaluate the results to identify the optimum method for detecting changes caused by recent basaltic volcanic eruptions;

(2) Develop a statistically robust dataset by analyzing up to 80 tree-ring samples from existing museum specimen collections to more accurately determine the year that Sunset Crater Volcano began erupting;

(3) Develop related soil chemistry data from pre- and post-eruptive soil deposits to test for: (1) alteration of Sr isotope ratios and (2) increases in elements such as P and S; and

(4) Use the resulting datasets to determine if the Sunset Eruption was a sort-duration or long-duration event;

**Tasks and Schedule.**

**Task A: Initial Meeting of Cooperators (September 2013):** NAU and NPS cooperators will meet in order to discuss data availability, proposed methods, and timelines associated with the study.

**Task B: Laboratory Analysis of Tree Ring Specimens (September 2013 – August 2014):**  The Investigator will select and submit wood samples from prehistoric sites in the Sunset Crater-Wupatki area for Sr isotopic and mass spectrometry analysis.

**Task C: Evaluate Dendrochemisty Data (September 2014 – October 2014 ):** The Investigator will compile and organize the results into a format suitable for evaluating their usefulness, statistical variation, and potential sources of error. The Investigator and ATR will meet to evaluate the results, and determine if additional specimens should be analyzed, along with the preferred method for analysis.

**Task D: Prepare and Submit Draft Final Report (October 2014 - August 2015):** The Investigator will prepare a Draft Report on accomplishments with the available funding, and provide to the NPS ATR for at least 30 days for review and comment. The report should be organized and adhere to accepted scientific reporting format, including: review of pertinent literature and identification of research questions/objectives; describe tree-ring specimen selection criteria; describe laboratory analysis and statistical analysis methods; present results of analysis; and discuss the results.

**Task E: Prepare and Submit Final Report and Other Identified Products (September 2015):** The Investigator will consider any review comments and prepare a Final Report, and provide copies and other products to the NPS.

**Task F: Present Study Results to NPS Staff (September - November 2015):** The NAU Investigators and NPS ATR will coordinate a time and location for a presentation to NPS staff with the Flagstaff Area National Monuments. The presentation will be based upon the Final Report, but intended for a non-technical audience.

**Optional Future Tasks.**

Based upon the results of the currently funded Tasks described above, and should the cooperators decide to pursue and secure additional funding, the following additional Tasks may be completed:

**Task G:** Develop additional dendrochemical data for the identified wood specimens in the Tree Ring Lab collection, including the optional use of methods such as: 87Sr/86Sr ratios, inductively coupled plasma mass spectrometry (ICP-MS), laser-ablation mass spectrometry (ICP-OES), and possibly others.

**Task H:** Develop soil chemistry profiles in pre- eruptive soil (weathered) and post-eruptive soil (fresh cinder deposits) from the area surrounding Sunset Crater Volcano to test whether there are distinct signatures in 87Sr/86Sr ratios, and elements such as P. Soil chemistry profiles would be developed from field samples of Sunset Eruption tephra deposits of varying depth, along with underlying, pre-eruptive soils. Soil samples can readily be processed at NAU using published methods that are widely accepted by the scientific community.

**Task I:** The Investigator will prepare a Draft Report that synthesizes the results from Tasks A – C above, with those accomplished with subsequent funding. The Draft Report will be provided to the NPS ATR for at least 30 days for review and comment. The report should be organized and adhere to accepted scientific reporting format, including: review of pertinent literature and identification of research questions/objectives; describe tree-ring specimen selection criteria; describe laboratory analysis and statistical analysis methods; present results of analysis; and discuss the results.

**Task J:** The Investigator will consider any review comments and prepare a Final Report, and provide copies and other products to the NPS.

**Cooperation**.

The NPS and NAU will cooperate on the following to meet the objectives under this Task Agreement:

* Organize and participate in at least three meetings to: (1) discuss wood specimen availability, proposed methods, and timelines associated with the study; (2) evaluate the results of tree ring Sr isotope and element analysis, and adjust methods, project area, and/or wood samples, if needed; and (3) present the study results to NPS staff with the Flagstaff Area National Monuments.
* Ensure that NPS research permitting and pertinent environmental compliance reviews and consultations are completed for any field data collection activities at SUCR and WUPA.
* Establish a format and content for the project report and any subsequent synthesis reports, and ensure reports and other related data products are reviewed, finalized, and provided within the established time frame.
* Pending evaluation of the results of tasks A – C above, seek additional funding as needed to increase the amount of chemical analyses and resulting data on tree ring specimens and soils that were affected by the Sunset Eruption.

**COOPERATIVE AGREEMENTS OR TASK AGREEMENTS INVOLVING COOPERATORS WORKING ON-SITE**

**Background.**

In cooperative agreements or task agreements with universities where the university utilizes interns, student employees, research associates (RAs) or cooperators on-site (hereafter called “cooperator personnel”), these cooperator personnel sometimes work on government sites in close proximity to federal employees. It is illegal (without specific statutory authority) for federal employees to directly supervise the cooperator personnel or any university employees or for the students or other university employees to supervise federal employees. When cooperator personnel are working on an NPS site, it is important that there is a clear distinction between students and federal employees.

**Office Environment and Vehicles.**

* The office space of the cooperator personnel and NPS personnel should be clearly labeled (Name and NPS or University affiliation on office or cubicle space).
* Cooperator personnel should be listed separately from NPS personnel in telephone lists, other identification or organizational rosters, and publication credits.
* Cooperator personnel should not receive “all-employee” e-mail or other communications intended for NPS personnel (unless it relates directly to the work the cooperator is doing for the NPS). When the e-mail does relate to the work being done, a copy of the same e-mail message should be sent to the University or cooperator’s supervisor.
* Cooperator personnel may use NPS e-mail systems when the communication relates directly to the work the cooperator is doing for the NPS. The e-mail addresses of the cooperator personnel must include a label associated with their NPS e-mail address that identifies the cooperator’s status (i.e., “Linda Webb, Cooperator” would be the label associated with the e-mail address, linda\_webb@contractor.nps.gov). Doing so clearly identifies this individual each time they send an e-mail message using the NPS system, and it identifies their status as a research associate, student intern or student employee in the e-mail directory.
* Unless stipulated in the agreement, cooperator personnel should not drive government vehicles.
* Unless stipulated in the agreement, cooperator personnel should not ride as a passenger in a government vehicle. When this is planned as part of the agreement, an appropriate amount of liability insurance should be negotiated.
* Prior written approval by the Park Superintendent or Center Manager must be obtained in order for a task to allow cooperator personnel to drive or ride in government vehicles.

**Supervision and Scheduling.**

* Each task must specify the university’s/cooperator’s supervisor for the cooperator personnel.
* Unless stipulated in the agreement, NPS staff should not set hours for cooperator personnel, specify where the work should be done, or conduct performance appraisals. National Park Service staff may give performance feedback to the cooperator personnel supervisor.
* Cooperator personnel should report leave, scheduling, and other related issues to the university or cooperator’s supervisor, not to NPS employees. The supervisor of the cooperator personnel should then communicate with the NPS. National Park Service employees cannot directly supervise cooperator personnel on a day-to-day basis. Work should be given to the cooperator personnel (via the cooperator’s supervisor) on a “task basis.” Cooperators should work without NPS supervision to accomplish each task, although technical consultations and cooperation is permissible.
* The Cooperator will be responsible for any disciplinary action needed to correct student employee conduct or performance problems. The NPS agreements technical representative will inform the university/cooperator’s supervisor of any conduct or performance problems.
* The Cooperator will remove student employees from their positions if they fail to improve performance or address conduct issues.
* The NPS will review and provide feedback to students or interns regarding work assignments.
* The NPS will inform the cooperator of conduct or performance problems with cooperator personnel so that the university can counsel employees and correct the performance problems.
* The NPS will recommend to the cooperator dismissal of cooperator personnel based on conduct or performance issues.
* The Cooperator will hire students, interns or RAs to work on NPS tasks identified in the agreement. Hiring will be conducted in consultation with the NPS Agreements Technical Representative (ATR).
* The Cooperator will: pay students, interns or RAs for hours they have worked in support of the agreement.

**Representation and Communication.**

* Cooperator personnel cannot in any way represent themselves to the public as NPS employees.
* Cooperator personnel are required to wear visible identification at all times.

**Other Issues.**

* Cooperator personnel should not list an NPS affiliation on publications, but rather should list the cooperative agreement under which the work was performed.
* Cooperator personnel should not be invited to official NPS “social” events.
* Cooperator personnel are not authorized to purchase property and supplies with government funds.
* Cooperator personnel will follow the local policy of the facility when federal facilities are closed due to early release for holidays, snow days, etc.

**PRODUCTS:**

Upon completion of the Work Tasks specified above, the Investigators will deliver the following to the NPS:

1. Draft Report: A near-final draft of the report will be submitted to the Technical Representative for review and comment for a period of at least 30 days prior to the final report.

2. Final Report: Three bound hardcopies of the final report.

3. Pertinent Supporting Data: A copy of specimen analysis results, GIS files, and/or pertinent electronic datasets resulting from the work will be provided to the ATR/Natural Resource Specialist, Flagstaff Area National Monuments.

4. Other Publications: Reprints or copies of other academic, scientific, or technical publications resulting from this study should be provided to the NPS ATR.

**BUDGET:***(Provided as a spreadsheet)*