2013 SCEC Progress Report

Geochronology Infrastructure

Principal Investigator: Dr. Tom Guilderson, Lawrence Livermore National Lab
Principal Investigator: Dr. Tammy Rittenour, Utah State University
Principal Investigator: Dr. Lewis Owen, University of Cincinnati
Principal Investigator: Dr. John Southon, University of California, Irvine
Principal Investigator: Dr. Ed Rhodes, University of California, Los Angeles

Preparer: Dr. Michael Oskin, University of California, Davis

SUMMARY/ABSTRACT

The geochronology infrastructure provides a community resource for SCEC researchers to draw from for their dating needs. It provides laboratory support and access to expertise for ^{14}C, OSL (Optically Stimulated Luminescence) and cosmogenic ^{10}Be and ^{26}Al methods. By pooling resources, the infrastructure saves SCEC funds while simultaneously increasing flexibility. Researchers cannot precisely predict the amount of geochronology resources needed at the outset of a project. Instead, the SCEC RFP asks for an estimate of needs from each project, and then these needs are drawn from the infrastructure resources. The leader and co-leader of the Geology Disciplinary group coordinate these dating requests with the participating laboratories. This approach avoids wasting resources for the cases where a project ends up not needing as many dates as planned. Likewise, in other cases where important, higher-precision results could be obtained with more geochronology resources, the infrastructure budget allows SCEC to move quickly to take advantage the opportunity. Over the lifetime of SCEC3, funding of the geochronology infrastructure program at approximately 80% of requests was sufficient to meet the collective needs of the SCEC research program, ***yielding an estimated savings around $90,000.*** Another advantage of the geochronology infrastructure program is that it streamlines collaboration with participating laboratories. SCEC PIs do not need to pay to run samples. Instead, laboratories charge a single master SCEC account. Under SCEC4, the geochronology infrastructure program is keeping a more detailed record of the sample metadata for reporting purposes. Thus far we have carefully cataloged ^{14}C from the UCI/Keck lab. Cataloging of other laboratory data has yet to be completed.

INTELLECTURAL MERIT: The geochronology infrastructure provides a community resource for SCEC researchers to draw from for their dating needs. It provides laboratory support and access to expertise for ^{14}C, OSL (Optically Stimulated Luminescence) and cosmogenic ^{10}Be and ^{26}Al methods. By pooling resources, the infrastructure saves SCEC funds while simultaneously increasing flexibility. Researchers cannot precisely predict the amount of geochronology resources needed at the outset of a project. Instead, the SCEC RFP asks for an estimate of needs from each project, and then these needs are drawn from the infrastructure resources. This approach avoids wasting resources for the cases where a project ends up not needing as many dates as planned. Likewise, in other cases where important, higher-precision results could be obtained with more geochronology resources, the infrastructure budget allows SCEC to move quickly to take advantage the opportunity.

BROADER IMPACTS: Most laboratories offer opportunities for students to participate in sample preparation. Shared geochronology resources encourages collaboration and communication between SCEC researchers.

TECHNICAL REPORT

The following is a brief summary of each of the geochronology methods supported under the geochronology infrastructure program, including what costs are to be covered from infrastructure funds versus individual PI funds.

^{14}C: This technique is the workhorse of paleoseismic trenching. It uses the decay of ^{14}C in organic matter to determine the age of a host deposit. Modern accelerator mass spectrometer techniques allow for dating of minute samples (e.g. charcoal fragments the size of pin head) with high analytical precision (within a few years to decades). Because the production of ^{14}C in the atmosphere from cosmic-ray bombardment varies over time, as does the rate of carbon cycling within the biosphere, ^{14}C ages must be converted to calendar years with the aid of a calibration curve. The era from ~10,000 to 13,000 years before present can be difficult to date precisely due to changes in ocean circulation at that time. Dramatic changes to the carbon content of the atmosphere since the industrial revolution renders ^{14}C of little use for dating deposits formed after 1800 A.D. The upper limit for age-dating with ^{14}C is ~50,000 years. ***The geochronology infrastructure program supports sample preparation, measurement of ^{14}C concentration relative to stable ^{13}C, and optionally, the measurement of ^{13}C concentration relative to ^{12}C*** (this may assist with interpretation of some samples). Students are encouraged to participate in sample preparation at both the UCI and LLNL laboratories. ***Student participation lowers the cost per sample analysis at UCI.***

OSL: Optically stimulated luminescence dates the time since a sample of mineral grains has been exposed to light. The dating procedure uses light to stimulate the release of electrons trapped within flaws of a mineral structure. This procedure causes these electrons to emit light (luminescence), the intensity of which is then measured. Obtaining a date requires knowledge of the natural dosing rate of ionizing radiation (gamma rays) that dislodges electrons into these structural traps. Sampling for OSL requires that the sample is kept shielded from light, and that the natural dose rate be measured, preferably with a field gamma-ray dosimeter. The advantages of OSL are that it can date sediments that lack materials for ^{14}C, epochs where ^{14}C is not ideal, and materials older than 50,000 years. The disadvantages of OSL are lower precision (typical analytical uncertainties exceed 100 years), and anomalously old age-dates due to partial bleaching, where samples were incompletely reset by exposure to light prior to deposition. Partial bleaching is of little concern when dating fine windblown sediments but is a significant problem for dating coarse sandy alluvium. The upper age-limit for OSL depends on the sample and the local dose rate, but may typically range from 100,000 to 300,000 years. ***The geochronology infrastructure program supports sample preparation, analysis, and interpretation for OSL.*** PIs are encouraged to work closely with a chosen OSL lab, including support of field costs for proper sampling and in-situ measurement of gamma-ray dosing rate.

^{10}Be and ^{26}Al: In-situ cosmogenic ^{10}Be and ^{26}Al dates the exposure of surface materials to high-energy cosmic rays. This technique is well suited to dating geomorphic features offset by faults, and has become a common technique employed in slip-rate studies. Cosmic rays are not light rays, but rather protons and neutrons travelling at velocities sufficient split atomic nuclei. Cosmic-ray induced nuclear fission of an atom within a mineral grain generates two lighter nuclei, sometimes producing an isotope useful for age-dating. ^{10}Be and ^{26}Al are isotopes with half-lives of 1.3 and 0.7 million years, respectively. These half-lives are short compared to the formation of Earth, such that no primary ^{10}Be or ^{26}Al exists, but long compared to the lifetime of geomorphic features, making these isotopes ideal targets for exposure dating. The advantages of ^{10}Be and ^{26}Al are that these may be used to date exposure from one of the most common minerals, quartz. The disadvantages are that exposure dating is sensitive to nuclides formed prior to formation of a geomorphic feature (inheritance) and to subtly small rates of erosion these features. Uncertainty due to inheritance and erosion tends to be larger than typical analytical uncertainties of 3-5%. Though cosmogenic isotopes are theoretically capable of dating features millions of years old, erosion tends to limit the practical upper limit to around 100,000 to 200,000 years in most settings. Production rates of cosmogenic nuclides are measured in atoms per gram per year, thus large samples (~1 kg) and precise accelerator mass spectrometer measurements are required. ***The geochronology infrastructure program supports the accelerator mass spectrometer measurement of ^{10}Be and ^{26}Al.*** ^{10}Be is more commonly used than ^{26}Al because its measurements are more precise. ^{26}Al is useful for some specialized dating techniques. Sample preparation costs are typically covered under individual PI budgets. ***The UC lab also offers sample preparation through collaborations arranged with PIs***. These arrangements should be stated in individual grant proposals.

GEOCHRONOLOGY COSTS (PER SAMPLE): The table below summarizes these dating costs, on a per-sample basis, sorted by method and by laboratory.

Table 1. Overview of per-sample costs from collaborating geochronology laboratories.

Lab	Method	Base Cost / Sample	Overhead	Cost / Sample
LLNL	^{14}C	$350	(included in base cost)	**$350**
	^{14}C (with separate ^{13}C analysis)	$384		**$384**
	^{10}Be	$400		**$400**
	^{26}Al	$600		**$600**
UCI	^{14}C	$200	53%	**$306**
	^{14}C (self-prep at lab)	$80		**$122**
	^{14}C (with separate ^{13}C analysis)	$210		**$321**
UC	OSL	$500	56%	**$780**
	10Be sample preparation	$550		**$858**
UCLA	OSL	$487	54%	**$750**
	OSL single grain	$974		**$1500**
USU	OSL	$700	42.8%	**$1000**
	OSL single grain	$1500		**$2142**