2020 SCEC Progress Report

Geochronology Infrastructure

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SUMMARY

The geochronology infrastructure provides a community resource for SCEC researchers to draw from for their C-14 and cosmogenic exposure age-dating needs. 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. Geochronology infrastructure is now embedded into the proposal submission process. The leader and co-leader of the Geology Disciplinary group coordinate these dating requests with the participating laboratories. The infrastructure program also enables centralized accounting of geochronology results, allowing SCEC to archive its geochronology data in community repositories and enabling data re-use and re-analysis in the future.

The 2020-2021 COVID19 pandemic severely impacted fieldwork timelines and lab operations. These delays meant that the 2020 geochronology funds were carried over into 2021. Funds are now expended at LLNL, and some funds remain allocated for ^{14}C at UC Irvine.

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 and cosmogenic ^{10}Be and ^{26}Al methods. 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: Shared geochronology resources encourages collaboration and communication between SCEC researchers. Students are encouraged to participate in the preparation and analysis of their samples. This is very convenient at the UCI ^{14}C facility, and also possible at Lawrence Livermore National Laboratory once clearance is granted. This experience has proven valuable for early-career SCEC researchers. The shared geochronology model has helped spawn similar initiatives elsewhere, such as the Earthscope AGeS program.

TECHNICAL REPORT

^{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.***

Cosmogenic Isotopes: In-situ cosmogenic ^{10}Be, ^{26}Al, and ^{36}Cl 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, ^{26}Al, and ^{36}Cl are isotopes with half-lives of 1.3, 0.7, and 0.3 million years, respectively. These half-lives are short compared to the formation of Earth, such that no primary reservoirs of these isotopes exist, 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. Recently, there has been increasing interest within SCEC of dual isotope techniques to date young, deformed sedimentary deposits. In particular, the combination of ^{36}Cl and ^{10}Be may be used to date strata less than one million years old. 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, ^{26}Al, and ^{36}Cl.*** Sample preparation costs must be covered under individual PI budgets.

Luminescence Dating: Support for luminescence dating was removed from the geochronology infrastructure program in SCEC5. Luminescence methods (OSL, IRSL, etc.) requires close collaboration between the lab scientists and other PIs, and the cost of the technique varies considerably in practice according to the materials measured, sample age, and sample quality. These situation-specific factors prove to be too unpredictable for the shared infrastructure approach. Rather, SCEC PIs wishing to use luminescence dating are encouraged to collaborate with participating lab facilities as co-investigators.

Data Reporting Requirement: New to SCEC5 is an online data reporting requirement. This form collects site information, sample purpose, and individual sample metadata before analyses are completed. All of the information to reproduce an age and its scientific context are archived and held confidential for a period of one year.