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Major Goals: The primary objectives during the budget period were: (1) to develop the California State University Northridge (CSUN) GeoAnalytical Center through the purchase and installation of the equipment described in the proposal, and to receive training on the use of the instrumentation as necessary, (2) initiate the use of the equipment for a variety of research projects, and (3) begin incorporating the equipment into teaching. The proposed instrumentation included: (a) an isotope ratio mass spectrometer (IRMS) with Conflo interface and gas bench and gas chromatograph peripherals, (b) an inductively coupled plasma mass spectrometer (ICP-MS), including autosampler, (c) an ion chromatograph, (d) a ground penetrating radar (GPR), and (e) an electrical resistivity system. Additional details regarding the equipment is provided in the attached PDF.

Accomplishments: The major instrumentation included in the grant (IRMS, ICP-MS, and IC) was ordered in Fall 2019 from Thermo Scientific; the GPR was ordered from GSSI in October 2019, and the purchase of the ER system from Advanced Geosciences was completed in October 2021, having been significantly delayed due to COVID-19-related supply issues. The IC and GPR were received later in Fall 2019 and the IC was installed by a Thermo technician by the end of the year. The IRMS and ICP-MS were received in February and October 2020, respectively. After lab preparation was completed, the ICP-MS and IRMS were installed in January 2021 and May-August 2021, respectively. Training was subsequently conducted in March 2021 for the ICP-MS and during the final weeks of installation (August 2021) for the IRMS. Further details are provided in the attached PDF document.

We have utilized the instrumentation for a number of research projects and have incorporated the equipment into teaching, including having students complete mini-research projects involving acquisition of data with the instrumentation. Descriptions of research projects and educational activities involving the equipment are provided in the attached PDF document.

Training Opportunities: Training for the ICP-MS and IRMS was provided to the PIs and other key users directly by representatives of Thermo Scientific, the instrument supplier. The PIs have trained eight undergraduate and eight graduate students on the use of the instrumentation and mentored them in conducting research projects using the equipment. Nearly an additional 100 students have been exposed to the equipment through coursework. Additional details are provided in the attached PDF.

Results Dissemination: The following scientific conference presentations incorporated data generated with the instruments acquired with this grant:

Ghosh, A., Cotton, J.M., Hauswirth, S.C., Hyland, E.G., Azmi, I., Raigemborn, M.S., Tineo, D., Hayduk, T.S., and Insel, N. (2021, October) Late Miocene-Pliocene Vegetation, Fire and Hydroclimate Dynamics in the Río Iruya Basin, Northwest Argentina. Oral presentation, Geological Society of America (GSA) Annual Meeting, Portland, OR.

Hauswirth, S.C., Kushner, M., Hoover, C., Ikeda, K., Jesmok, G., Estrada, A., and Ganguli, P. (2021, November) Wildfire-associated Organic Contaminants in a Coastal Watershed. Lightning talk, CSU Council on Ocean Affairs, Science & Technology (COAST) Annual Meeting (virtual).

Hauswirth, S.C., Kushner, M., Hoover, C., Ikeda, K., Jesmok, G., Estrada, A., Yunes Katz, B., and Ganguli, P. (2021, December) Monitoring Post-Wildfire Watershed Dynamics Through Analysis of Organic and Inorganic Geochemistry, Suspended Sediment Measurements, Hydrologic Data, and Soil Chemistry. Oral Presentation, American Geophysical Union (AGU) Annual Fall Meeting, New Orleans, LA.

Campos, G. J., Yunes Katz, b., Salek, s., Ikeda, K. H., Hoover, C. L., Kushner, M., Hauswirth, S., Odigie, K. and Ganguli, P. (2022, October) Transport and Fate of Metals Following The 2018 Woolsey Fire in Southern California: Geological Society of America Abstracts with Programs, v.54, no. 5, https://doi.org/10.1130/abs/2022AM-381368.

Campos, G., Yunes Katz, B., Salek, S., Ikeda, K. H., Hoover, C. L., Kushner, M., Hauswirth, S., Odigie, K., and Ganguli, P. (2022, December) Assessing Trends in Metals Transport and Fate Following the 2018 Woolsey Wildfire, Southern California, USA. Poster Presentation (virtual), American Geophysical Union (AGU) Annual Fall Meeting, Chicago, IL.

Honors and Awards: Nothing to Report

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Partners

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I certify that the information in the report is complete and accurate:
Signature: Scott Hauswirth
Signature Date: 12/15/22 5:01PM

Final Report For: Development of a CSUN GeoAnalytical Center for Research, Teaching, and Outreach in Earth Systems Science

Department of Defense (DoD) Research and Education Program for HBCU/MI

Contract Number W911NF1910446

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I. Abstract

The aim of this project was to create a "GeoAnalytical Center" within the Department of Geological Sciences (DGS) at California State University, Northridge (CSUN) with the goal of expanding STEM research and educational opportunities in laboratory and computational settings. The GeoAnalytical Center consolidates existing CSUN DGS research facilities with the newly acquired instrumentation to create an exceptional state-of-the-art analytical center that stands out among similar institutions. The instrumentation in this proposal includes: (1) an isotope ratio mass spectrometer (IRMS) system for C, N, O, S and H stable isotope analysis, including compound-specific isotope analysis (CSIA) of C and H isotopes in organic compounds, analysis of C and O isotopes in carbonates and other solids, and O and H isotopes in water; (2) an inductively coupled plasma mass spectrometer (ICP-MS) for analysis of metals and metal isotopes in water and geologic media; (3) an ion chromatograph for analysis of environmentally relevant ions (e.g., nutrients, perchlorate, chloride), and; (4 & 5) ground penetrating radar (GPR) and electrical resistivity systems for characterizing subsurface features and groundwater fluxes and distributions. This equipment, combined with existing instrumentation, has expanded the breadth of the department's analytical capabilities and advanced it to the state-of-the-art. The purchased instruments will allow DGS to further integrate impactful, cutting-edge research directly into the educational framework of the department, including use in courses and in student research projects. As a result, the Center not only provides DGS students with exposure to the breadth of research conducted in the department, it also ensures that virtually all majors and graduate students gain hands-on experience conducting real-world analytical, geophysical, and/or computational science. Such hands-on experience allows students to directly engage with scientific ideas, garnering interest in STEM fields, while simultaneously practicing skills that will prepare them to succeed in those fields. The Center serves an interdisciplinary group of researchers including, but not limited to, the authors of this proposal. The research planned for the Center, some of which has already been initiated, focuses on interdisciplinary studies that incorporate environmental, geological, marine science, mathematical, and computational fields.

II. Objectives and Outcomes

The primary objectives during the budget period were: (1) to develop the CSUN GeoAnalytical Center through the purchase and installation of the equipment described in the proposal, and to receive training on the use of the instrumentation as necessary, (2) initiate the use of the equipment for a variety of research projects, and (3) begin incorporating the equipment into teaching and outreach. The proposed instrumentation included: (a) an isotope ratio mass spectrometer (IRMS) with Conflo interface and gas bench and gas chromatograph peripherals, (b) an inductively coupled plasma mass spectrometer (ICP-MS), including autosampler, (c) an ion chromatograph, (d) a ground penetrating radar (GPR), and (e) an electrical resistivity system. A description of our activities in advancement of the above objectives is provided in the sections below.

Equipment Acquisition, Installation, and Training

The acquired instruments were selected to supplement existing instrumentation, which includes gas and liquid chromatograph mass spectrometers (GC-MS and LC-MS), a high-resolution, laser ablation-inductively coupled plasma mass spectrometer (LA-ICP-MS), instruments for trace organic, inorganic, and gaseous mercury analyses, a scanning electron microscope (SEM), and a laser-based stable carbon isotope analyzer equipped with an elemental analyzer front-end. Brief descriptions of the equipment and instrumentation acquired with this grant are provided below.

Isotope ratio mass spectrometer (IRMS) system

An IRMS is used to determine the stable isotopic composition of light, non-metal elements (C, N, O, H, S). The highly sensitive instruments work by ionizing gaseous samples and then accelerating them down a flight tube, where the ions are focused into a beam by electrical lenses (Fig. 1). Centered around the flight tube is a magnet the deflects the path of the ion, depending on its mass to charge ratio (magnetic sector-IRMS). This deflection separates ions, which then pick up electrons at the collectors, creating a current. The intensity of the voltage produced is proportional to the quantity of ions measured. With multiple collection cups, ions of different masses can be measured at the same time. Modern IRMS systems use a continuous flow method, in which samples are delivered to the IRMS within a stream of helium carrier gas via a gas chromatograph. With this grant, we purchased a Thermo Scientific Delta V Advantage IRMS. We also purchased a Thermo ConFlo IV interface, which allows the integration of multiple online peripheral devices to the same IRMS instrument, thereby allowing analysis of multiple different isotope systems from a wide array of sample types. A total of four such peripherals were attached to the IRMS, three of which were purchased with this grant. The first peripheral is a Costech 4010 Elemental Analyzer (EA), which measures the elemental abundance of C, N, O, H and S in organic samples. This existing instrument is being used with the IRMS to allow isotopic analysis of these elements in bulk materials. For full capabilities, we also upgraded the autosampler on the Costech EA to the Zero-Blank autosampler, which is required for N-isotope analyses. The second peripheral is a Thermo Scientific Trace GC-1310 gas chromatograph (GC), interfaced to the IRMS through a Thermo Scientific GC-Isolink II. The GC/Isolink component allows for *compound specific* isotopic analysis (CSIA) of C and H isotopes (upgradeable to include N and O isotopes in the future). In the Trace GC-1310, liquid samples are vaporized, then chromatographically separated, such that compounds enter the IRMS at different times. The compounds are converted in the Isolink to form H_2 and CO_2 to allow direct measurement of C and H isotopes. The third peripheral is a Thermo Scientific Gasbench II universal online gas preparation and introduction system. The Gasbench II allows for the online analysis of C and O isotopes in solid carbonates and dissolved inorganic carbonate, and O and H isotopes in waters by automatically flushing, replacing, and then sampling the headspace of exetainers containing solid or liquid samples. Lastly, although not included in the proposal, we were able to negotiate pricing with the vendor and include a High Temperature Conversion Elemental Analyzer (TC/EA) as an additional peripheral while remaining within the original budget. The TC/EA performs high temperature pyrolysis of organic and inorganic compounds (including water) into H_2 and CO, allowing for direct measurement of H and O isotopes in a variety of solid and liquid samples. A PC was also provided with the instrument, including preloaded Isodat software for instrument control and data analysis.

Inductively coupled plasma mass spectrometer (ICP-MS)

The quadrupole ICP-MS allows for rapid and highly sensitive analysis of nearly all metals in liquid samples. In ICP-MS analysis, liquid (via autosampler) or gas samples (via the existing laser ablation system, as discussed further below) are injected into the system, where they are vaporized and then ionized in a plasma beam. The ionized metal species then enter the mass spectrometer where, as with the IRMS, they are separated by mass, allowing quantitation of specific metals and metal ions. The acquired instrument is a Thermo Scientific iCAP RQ single quadrupole ICP-MS equipped with a Cetac ASX560 autosampler and a dedicated chiller component. The system also included a PC with instrument control software and Thermo Qtegra software for mass spectrometric analysis and data management. Multiple sets of sample introduction parts, including nebulizers, spray chambers, and skimmer and sample cones are included in the system to allow for analysis via both the liquid autosampler and the laser ablation system, and for optimizing the analysis for variable sample types. The requested single-quadrupole ICP-MS can be used for analysis of a variety of geological media (water, soil, sediment, rock), extending DGS's ability to conduct metals-related research that currently requires having analyses performed at other universities or through commercial laboratories.

Ion chromatograph (IC)

ICs use liquid-phase chromatography to separate ions in solution, allowing simultaneous quantification of a number of species in aqueous solution. As the sample flows through an ion exchange column, the varying affinity of ions for the column packing material (typically silica or polymer-based), results in a chromatographic separation. For standard anion and cation analyses, the ions are detected by an electrochemical detector that measures an increase in the electrical conductivity of the solution, which is proportional to the concentration of the component. IC is currently the most widely used method for ion analysis, due to the short run times, precise results, and simultaneous determination of multiple species. IC is regularly used for analysis of a range of environmentally relevant anions, including nitrate, nitrite, phosphate, sulfate, chloride, bromide, and perchlorate. Common cations measured by IC include alkali and alkaline earth metals (e.g., Na^+, K^+, Ca^{2+}, Mg^{2+}) and ammonium. The system acquired is a single-channel Thermo Aquion IC equipped with a conductivity detector that will allow analysis of most anions and cations. The system included ion exchange columns and chemical suppressors for both anionic and cationic analysis. Suppressors use additional ion exchange cartridges to minimize the conductivity of the eluent and increase the conductivity of the analyte, greatly improving the signal to noise ratio of the instrument, and thereby improving the precision of the instrument. An autosampler was included for both convenience when analyzing large numbers of samples and to maximize repeatability. A PC system was also included with pre-installed chromatography software for instrument control, programming of methods, peak integration, and analyte quantitation.

Ground penetrating radar (GPR)

GPR broadcasts radio waves that travel through the top several meters of the earth to an antenna to detect the presence and location of objects and structures. The selected GPR model was a GSSI UtilityScan Pro, which includes a SIR 4000 Data Acquisition System, a Model 350 HyperStacking Antenna, and a Model 624 3-wheel Cart. The RADAN data processing and imaging software (with 3D module) was also purchased. The data acquisition unit allows real-time visualization as data is being collected for preliminary analysis, quality control, and trouble-shooting, and is compatible with several GPR antennas and antenna configurations that allow it to be used for a wide range of applications, ensuring that the system remains relevant to research at CSUN for many years. The included digital hypo-stacking antenna allows surveying of depths up to 12 meters with good data resolution, especially in unconsolidated sediments which will often be present in landslide and shallow fault applications. The purchased system allows two antenna configurations: 1) a 3-wheel cart that may be used off-road in a variety of terrains in natural field sites, and 2) a handle, harness, and external encoder wheel for especially rough terrain. Additional batteries were purchased to allow use at remote field sites.

Electrical resistivity (ER) system

Electrical resistivity involves injecting direct current into the ground and measuring the voltage difference between electrodes. Collecting data over an area (typically along one or more transects) allows differentiation between, for example, saltwater and freshwater, or saturated and unsaturated soils, providing valuable data regarding the distribution and movement of water in the subsurface. The purchased system was an Advanced Geosciences, Inc. SuperSting R1/IP/SP Wi-Fi console with data acquisition software, a 28 electrode SSR8 SwitchBox, and a FlexLite Marine cable with 28 graphite electrodes. Earthimager 2D software with the Time Lapse option and an academic classroom module (to allow in-class use of the software) was also purchased for analyzing and visualizing the data.

The major instrumentation (IRMS, ICP-MS, and IC) was ordered in Fall 2019, after working with the vendor (Thermo Scientific) to modify and optimize the configuration based on currently available instrument models and pricing. The GPR was ordered from GSSI in October 2019. The purchase of the ER system from Advanced Geosciences was completed in October 2021, having been significantly delayed due to COVID-19-related supply issues. The IC and GPR were received later in Fall 2019 and the IC was installed by a Thermo technician by the end of the year. The IRMS and ICP-MS were received in February and October 2020, respectively.

The labs for the IRMS and ICP-MS required preparation, which was significantly delayed due to the onset of the COVID-19 pandemic in Spring 2020. CSUN campus was closed from March to August 2020, with limited access through the 2020-2021 academic year. The installation of the ICP-MS involved making a hole in an interior lab wall to allow the new instrument to be interfaced directly to the existing laser ablation system, and the installation of two 208V outlets for the instrument and associated chiller. Additionally, exhaust lines were connected to the instrument from the pre-existing exhaust system in the room. These aspects of the installation were performed by CSUN Physical Plant Management (PPM). Installation of the instrument by a Thermo technician was performed in January 2021. During the installation, the new iCAP ICP-MS was interfaced with the existing laser ablation system to allow simultaneous determination of trace element composition (via iCAP) and U/Pb age (via the existing high-resolution ICP-MS) from a single ablated sample. Training was subsequently conducted in March 2021 via a hybrid in-person/remote approach that allowed four of the PIs, as well as other users, to participate.

The IRMS was originally planned to be installed in co-PI Cotton's TRACE lab (1223 Live Oak Hall), however, electrical power, space, and safety restrictions required us to identify an alternate location. A DGS computer lab was relocated to create a dedicated isotope analytical laboratory in an adjacent building (2027 Eucalytpus Hall). The new laboratory was furnished with repurposed lab furniture. Gas cylinder cradles and a gas line system were installed by the CSUN Science Shop to house and distribute seven different gases (He, H_2, N_2, O_2, CO, CO_2, Ar) to the IRMS and peripherals as required for operation. A 208V outlet and 230V power conditioner/transformer required for the instrument were installed by CSUN PPM. Due to the change in the lab location to a room without house compressed air, it was necessary to purchase and install an air compressor to provide pressurized clean air required for instrument operation. Installation of the instrument and peripherals, and attachment to the existing Costech EA, was performed by Thermo technicians between May and August 2021, requiring a total of nearly five weeks to complete. We had initially budgeted for a stand-alone training course for the IRMS, however, the two primary PI users of the instrument (Hauswirth and Cotton) received substantial training during the last two weeks of the installation, which was deemed sufficient to successfully operate the IRMS and peripherals.

Use of Equipment in Research

In the year since most of the equipment was installed/acquired, we have begun to utilize the equipment for a number of research projects, a selection of which are highlighted below.

South American Paleoclimate and Potential Relationship to the Spread of C4 Grasses
Researchers: PI Cotton, PI Hauswirth, Adit Ghosh (CSUN graduate student), Shelby Littleton (CSUN graduate student), Ryan Kellis (CSUN graduate student), Gregory Guajardo (CSUN undergraduate student), Brooklyn Dib (CSUN undergraduate student)
Instruments Used: IRMS

Dr. Cotton is using the new instruments with current master's student Shelby Littleton and previous master's student Adit Ghosh to measure the $d^{13}C$ of Miocene-Pliocene aged paleosols from Argentina. This project is focused on using the $d^{13}C$ values of paleosols to constrain the timing of the expansion of C_4 grasses in South America to determine if the vegetation transition was caused by the strengthening of the South American summer monsoon. So far, we have analyzed samples from four different sites, and have a manuscript being prepared for publication. In the winter of 2023, new master's student Ryan Kellis and undergraduate student Gregory Guajardo will also be working with Cotton and PI Hauswirth to extract preserved plant leaf waxes from these paleosol samples to analyze for d^2H and $d^{13}C$. These analyses will allow us to link the change in vegetation cover to hydrologic change through time. Cotton is also currently working with undergraduate student Brooklyn Dib on a senior thesis project aimed at determining if the $d^{13}C$ values of California black oak trees can be used to reconstruct drought frequency and intensity. Dib and Cotton will be analyzing tree ring cellulose for $d^{13}C$ in the winter of 2023.

Assessing the Toxicity, Transport, and Fate of Organic and Inorganic Compounds Following Wildfires

Researchers: PI Hauswirth, PI Ganguli, Danielle Bram (CSUN Dept. of Geography), Kyle Ikeda (former CSUN student), Kingsley Odigie (UC Riverside), Judy Campos (CSUN Graduate Student), Felipe Ribelo (CSUN undergraduate student), Brooklyn Dib (CSUN undergraduate student)

Equipment Used: ICP-MS, IRMS, IC

This project seeks to understand the generation, mobilization, persistence, and transport of polycyclic aromatic hydrocarbons (PAHs), aliphatic compounds, metals, nutrients, and suspended material associated with wildfires. The project to date has involved collection of nearly 100 soil samples from eight different Southern California wildfires and background locations. The soil samples support multiple project goals, including identifying chemical differences among fires and how organic compound concentrations change over time. A major component of the project includes a focused study on the long-term effects of the 2018 Woolsey Fire on the Malibu Creek watershed, located about 20 miles northwest of Los Angeles. We have collected water samples at ten locations within the Malibu Creek watershed monthly and during/after significant precipitation events since November 2018 (a total of 25 sampling events have been conducted). We have analyzed nearly 200 samples from the Malibu Creek watershed for anions (Br^-, Cl^-, F^-, NO_2^-, NO_3^-, $PO4^{3-}$, $SO4^{2-}$) using the IC acquired with this grant. The results showed limited impact of the wildfire on anion concentrations, however, one of the tributaries in the system has a sulfur spring with very high $SO4^{2-}$ concentrations near the headwaters. This has allowed the use of $SO4^{2-}$ as a tracer to evaluate relative inputs from the main tributaries. Graduate student Judy Campos has focused on the trace metals component of the project. To date she has developed procedures for analysis of filtered and non-filtered water samples and has analyzed over 100 samples for trace metals using the iCAP ICP-MS. While the analyses are ongoing, initial results indicate significant increases in some metals, including environmentally relevant metals such as lead and cadmium, during rain events within burned areas of the watershed. An unburned section of the watershed serving as a control site shows significantly lesser increases for most metals (arsenic is a notable exception), suggesting that the wildfire has played a role in increasing metal fluxes in the watershed. Ms. Campos has presented the preliminary results at a Geological Society of America (GSA) conference and will be presenting at the American Geophysical Union (AGU) 2022 Annual Fall Meeting. Once all analyses are complete (expected Spring 2023), we anticipate the data providing critical insight into spatial and temporal trends in wildfire-associated transport of metals in burned watersheds. We will further be combining the trace metals results with other already completed analyses, including suspended particulate matter (SPM) concentrations and organic compound analysis (primarily alkanes and polycyclic aromatic hydrocarbons; PAHs) to improve understanding of post-wildfire sediment and contaminant transport and recovery mechanisms, and intend to submit a manuscript in progress for publication. We have also begun to use the GC-IRMS to measure compound specific C and H isotope ratios in organic extracts from the wildfire samples. This analysis requires careful sample processing (e.g., multiple column chromatography separations and subsequent concentration of samples by up to 1000-10,000x), which is still being optimized. However, we have successfully determined C-isotope ratios for a suite of alkanes and PAHs for a number of samples. Once completed, the CSIA results will be used to probe fire-driven changes to organic compounds in soil and water, provide a means of distinguishing various sources (e.g., vegetation versus fire-derived versus anthropogenic) of those organic compounds.

Organic and Inorganic Geochemistry Associated with Natural Oil Seeps in Terrestrial Watersheds

Researchers: PI Hauswirth, PI Ganguli, Alfredo Estrada (CSUN graduate student), Kyle Ikeda (former CSUN student), Denise Berg (CSUN undergraduate student)
Equipment Used: ICP-MS, IRMS, IC

Although substantial attention has been paid to marine oil seeps and oil spills, petroleum in terrestrial watersheds has received relatively little study. This project addresses the potential for contamination of soil and surface water associated with natural oil seeps and improperly decommissioned oil wells in Southern California. The study sites are in the vicinity of Santa Clarita, Simi Valley, Ojai, and Santa Paula, CA. We have conducted several sampling events and optimized analytical procedures for crude oil analysis. Results to date indicate that oil primarily impacts only the immediate vicinity of the seeps during low-flow conditions, but that large amounts of oil are transported far downstream during rain events. Besides analysis of organic oil components, water samples have been analyzed for anions via IC and water samples are currently being processed for trace metal analysis by ICP-MS. As with the wildfire study, we have also begun preparing and analyzing samples for CSIA and several preliminary samples have been analyzed. In addition to source identification, CSIA results for this project will also be used to compare crude oils from the study sites and from other marine and terrestrial sources. Funding for the project comes in part from a grant from California State University Council on Ocean Affairs, Science & Technology (COAST).

Assessing Contaminant Distributions and Sources in Castaic Lake, a Mercury-impacted Reservoir in Los Angeles County, CA

Researchers: PI Ganguli, PI Hauswirth, Greg Jesmok (CSUN graduate student), Scott Jedrusiak (CSUN graduate student)
Equipment Used: IC, ICP-MS

Lead by Dr. Ganguli, this project, which was recently funded by the California Institute of Water Resources, primarily investigates mercury sources and transformations in Castaic Lake, but has an additional component to assess inputs of other contaminants associated with area wildfires. Several sampling events have been conducted, including conducting multiple depth profiles of the >300 ft deep lake, surveying the lateral extent of the lake, and collecting inlet stream water and sediment samples. Water samples have been analyzed for PAHs (using existing instrumentation) and anions by IC, and are being prepared for trace metal analysis by ICP-MS. The anion analysis is especially important for this project since anionic nutrients play important roles in mercury methylation processes.

<u>Near surface fault-driven deformation on the central San Andreas fault</u>
<u>Researchers:</u> PI Evans, Josie Nevitt (USGS), Timothy Clarke (CSUN undergraduate student)
<u>Equipment Used:</u> GPR

How faults slip and distribute deformation near Earth's surface (<100 m depth) is poorly understood, leaving open fundamental questions in earthquake science and seismic hazard analysis. This project targets a study site along the San Andreas fault in central California, where an alignment array has recorded continuous fault slip ("creep") at Earth's surface over the last 50 years. In recent years, the site has been resurveyed using modern geodetic techniques (GPS, UAVSAR, lidar). We aim to determine the fault zone structure and mechanical properties using ground penetrating radar (GPR) and an active source seismic survey. The GPR and seismic imagery will later guide the installation of a borehole inclinometer and creepmeter, which will monitor fault slip at depth and at Earth's surface over time. Undergraduate student Tim Clarke participated in the USGS active source seismic survey and performed several GPR surveys at the study site. He processed and interpreted the GPR data to locate the fault and associated structures. Tim Clarke presented his work at the USGS and in the DGS Honors Seminar in April 2022. In the summer of 2022, Dr. Evans submitted an NSF CAREER proposal to continue GPR surveying of the San Andreas fault, coupled with dense geodetic imaging with Global Navigation Satellite Systems (GNSS), including the Global Positioning System (GPS), and mechanical modeling. This project would include additional surveys on the Hayward fault in the San Francisco Bay area for comparison between two mechanically distinct creeping faults to illuminate the mechanics of near-surface deformation due to faulting.

<u>Future Applications and Other Research-Related Uses</u>

Since installation, much of our effort has been focused on development of methods and standard operating procedures for the use of the equipment. For example, we are currently optimizing methods for splitting a single, laser ablated sample to both the new iCAP and the existing HR-ICP-MS to allow simultaneous determination of U-Pb age-dates and trace element composition. This capability, once developed, represents a cutting-edge approach allowing geochemical investigation of, for example, specific zones on zoned zircons, to study magmatic processes including magma mixing and assimilation. Another example includes development of methods for extraction and precipitation of nitrates from water samples for analysis by EA- and TC/EA-IRMS analysis of N and O isotopes. Once developed, the method will provide a means of distinguishing nitrate derived from atmospheric sources, synthetic fertilizers, and human/animal waste. Nitrate is a ubiquitous contaminant in surface and groundwaters, and identifying the source is often a challenge. The capability of nitrate isotope determination provides a valuable tool with many opportunities for application, including pinpointing sources and understanding geochemical dynamics in, for example, coastal zones.

The GeoAnalytical Center has also been highly beneficial in applying for research funding. For example, the awarded COAST and CIWR grants, and Dr. Evans' pending CAREER grant mentioned above, all incorporated use of the Center. Dr. Ganguli is currently working toward a large-scale, multi-institution grant proposal to investigate geochemical cycling in coastal lagoons along the West Coast of the U.S., which will likewise highlight the Center and its analytical capabilities. The planned coastal lagoon studies would involve use of all of the acquired instrumentation: IC for measuring nutrient concentrations, ICP-MS for measuring major elements and trace metals, IRMS for tracking food web dynamics, GPR for identifying paleochannels, and the ER for investigating subsurface salt-fresh water interface dynamics. PIs Ganguli and Hauswirth, along with other members of the Department and faculty at UCLA, Arizona State University, and UC Merced developed multiple large-scale proposals to address both inequality in STEM fields and environmental justice issues. A major component of the work would involve collaborating with local environmental justice groups (e.g., The Better Watts Initiative) to investigate citizens' environmental concerns from a scientific perspective. The GeoAnalytical Center would serve a major role in the work, including for analysis of lead and other toxic metals in soil and water at sites within the affected communities. Although the submitted proposals were not funded, the group intends to submit a revised proposal within the next year.

The following scientific conference presentations incorporated data generated with the instruments acquired with this grant:

Ghosh, A., Cotton, J.M., Hauswirth, S.C., Hyland, E.G., Azmi, I., Raigemborn, M.S., Tineo, D., Hayduk, T.S., and Insel, N. (2021, October) Late Miocene-Pliocene Vegetation, Fire and Hydroclimate Dynamics in the Río Iruya Basin, Northwest Argentina. Oral presentation, Geological Society of America (GSA) Annual Meeting, Portland, OR

Hauswirth, S.C., Kushner, M., Hoover, C., Ikeda, K., Jesmok, G., Estrada, A., and Ganguli, P. (2021, November) Wildfire-associated Organic Contaminants in a Coastal Watershed. Lightning talk, CSU Council on Ocean Affairs, Science & Technology (COAST) Annual Meeting (virtual).

Hauswirth, S.C., Kushner, M., Hoover, C., Ikeda, K., Jesmok, G., Estrada, A., Yunes Katz, B., and Ganguli, P. (2021, December) Monitoring Post-Wildfire Watershed Dynamics Through Analysis of Organic and Inorganic Geochemistry, Suspended Sediment Measurements, Hydrologic Data, and Soil Chemistry. Oral Presentation, American Geophysical Union (AGU) Annual Fall Meeting, New Orleans, LA.

Campos, G. J., Yunes Katz, b., Salek, s., Ikeda, K. H., Hoover, C. L., Kushner, M., Hauswirth, S., Odigie, K. and Ganguli, P. (2022, October) Transport And Fate Of Metals Following The 2018 Woolsey Fire In Southern California: Geological Society of America Abstracts with Programs, v.54, no. 5, https://doi.org/10.1130/abs/2022AM-381368.

Campos, G., Yunes Katz, B., Salek, S., Ikeda, K. H., Hoover, C. L., Kushner, M., Hauswirth, S., Odigie, K., and Ganguli, P. (2022, December) Assessing Trends in Metals Transport and Fate Following the 2018 Woolsey Wildfire, Southern California, USA. Poster Presentation (virtual), American Geophysical Union (AGU) Annual Fall Meeting, Chicago, IL.

Incorporation of Equipment into Teaching and Outreach

The acquired equipment and instrumentation has been directly incorporated into teaching in the department. The use in teaching has ranged from giving tours of the facilities (e.g., in Dr. Ganguli's The World Ocean and Hydrogeochemistry courses) to involving students in sample analysis using the instrumentation. Dr. Hauswirth's Hydrogeology (GEOL 575) course required that students complete mini-research projects, and a number of student groups used GeoAnalytical Center equipment in the process of completing their projects. For example, one group analyzed tap water samples collected from various locations in Southern California for O and H isotopes with the IRMS and attempted to determine (1) the proportion of groundwater in the local water supply and (2) the amount of evaporation occurring during water transport in California's aqueduct system. Another group analyzed a selection of bottled waters for O and H isotopes and for trace metals and major elements with the ICP-MS to evaluate the truthfulness of the suppliers' provided source and water quality information. A third group used the IC to measure nitrate concentrations in river and coastal water samples to identify nitrate "hotspots" along the Southern California coast.

The Spring 2022 offering of Dr. Cotton's Geochemistry and Biogeochemistry course (GEOL 552), included a similar project. Twenty-one students were enrolled in the senior undergraduate and masters level course, and these students were split into groups of 3 to design a research project and carry out a project from start to finish, analyzing the samples in the new stable isotope facility. Example projects included analysis of vegetable matter from various plant species to find the signal of carbon and nitrogen air pollution, determining the source of drinking water from tap water samples across the Los Angeles basin, and analysis of isotopes in wines to determine sources of the irrigation water used during the growing of the grapes and if the wine had been adulterated (i.e. by cane sugar).

In Dr. Evans' Applied Geophysics course, which provides an overview of Near-surface and Exploration Geophysics methods that are commonly applied in Geophysical and Environmental consulting, students used the GPR to survey the top ~5m of the subsurface at a local park to compare with a previous seismic survey. Students were responsible for preparing a full consulting-style report describing the GPR method and interpreting the data.

These examples were conducted in just the first academic year since the equipment was acquired and installed. DGS was recently approved to offer a new B.A. in Environmental Science, which will greatly increase the number of students in the department and result in expanding our course offerings. For example, new courses in Environmental Science, Environmental Hydrogeology, and Field Sampling and Analysis will be initiated next year and all will involve activities incorporating the Center. The Center has already become a major focus of the Department's research and, as a result, we have trained numerous graduate and undergraduate students on the use of the equipment, providing them with key analytical skills that will greatly benefit their future careers in academia or the private sector.