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AGeS[3] Program Proposal

Intellectual Merit

- Project Title (up to 150 characters)

  LASS-ICPMS zircon petrochronology to investigate the connection between the Jackass Lakes pluton and adjacent porphyry and metavolcanic rocks

- Project supervisor at home institution

  California State University, Fullerton (CSUF); Dr. Memeti

- AGeS lab and lab director

  Laser-ablation split-stream petrochronology laboratory at the University of California Santa Barbara (UCSB); Dr. Andrew R.C. Kylander-Clark, Director of the LASS-ICPMS Facility

- State the geoscience question or hypothesis that this project will address. (Up to 1200 characters).

  Plutonic, hypabyssal porphyries, and volcanic rocks represent different vertical exposures of magma plumbing systems and distinct parts of different stages of their evolution (Bachmann et al., 2007; Glazner et al., 2015). This project examines the temporal and petrologic relationship of the different parts of the Jackass Lakes (JL) volcanic-porphyry-plutonic complex that are now juxtaposed to one another. Specifically, it will test the first hypothesis that the JL granodiorite is compositionally complementary to the more felsic Post Peak leucogranite porphyry (PPP) and rhyolites, which formed through melt-extraction from the plutonic magma reservoir that now is composed of remnant crystal cumulate materials (Fig. 1; Barnes et al., 2019; Werts et al., 2020). The second hypothesis tests whether the JL granodiorite and meta-dacitic lithic-bearing crystal tuff containing similar silica composition and mineralogy are temporally and compositionally equivalent and record the same or similar magma histories (Fig. 1). A comparison of all three units to one another may result in findings that both complementary and equivalent systems are formed together either concurrently or consecutively.

- Discuss the importance of the proposed study. (Up to 2500 characters).

The largely accepted status quo for pluton growth models is that magma batches are emplaced incrementally at depth. In especially large plutons, they can create large-scale magma mush zones (Bachmann et al., 2007; Gelman et al., 2013), which can be (re)-activated to feed subvolcanic plutons and volcanic eruptions. This view considers some (or all) plutonic rocks as representative of the residual crystal (cumulate) material that remains after melt is extracted from volcanic eruptions (Lipman, 2007; Barnes et al., 2019; Werts et al., 2020) and supports the idea of compositionally complementary volcanic-porphyry-plutonic systems (Fig. 1). The alternative end-member model supports an equivalent volcanic-porphyry-plutonic system, whereby plutons are comprised of dikes/intrusions of the compositionally same magma that passes through the crust without further modification at different crustal levels to erupt on the surface (Glazner et al., 2004, 2015; Fig. 1).

The optimal scenario for studying the physical and petrologic links between parts of a volcanic-porphyry-plutonic complex is where remnants of an intrusive body and its supposed porphyry/volcanic counterparts are exposed together (Bachmann et al., 2007; Deering et al., 2016). This is the case in the 99-97 Ma JL granodiorite situated in the central Sierra Nevada batholith (McNulty et al., 1996; Fig. 2). The JL represents a well-exposed example of a 175 km^2 resurgent pluton of largely granodiorite and minor diorite that intruded into contemporaneous dacitic and rhyolitic volcanic ejecta and subvolcanic granitic porphyries of the ca. 101-97 Ma Merced Peak Caldera sequence preserved in roof pendants (Peck, 1980; Pignotta et al., 2010; Pignotta pers comm., 2022; Fig. 2). Despite the temporal and spatial association between all units, the petrologic connections between them are unknown.

The relevance and motivation to study volcanic-plutonic connections are to assist volcanic hazard mitigation worldwide by adding to the understanding of the magma processes that can lead to volcanic eruptions by looking at extinct systems and implementing the knowledge to currently active systems. Since it is impossible to collect samples from magma chambers many miles deep beneath active volcanoes, studying uplifted and exposed plutonic bodies and their volcanic and hypabyssal counterparts can be used to investigate the physical and petrologic processes that are likely occurring in presently active magma systems.

- Briefly explain the relevance of your project to NSF-Division of Earth science goals, which are aimed at "...improving the understanding of the structure, composition, and evolution of the Earth, the life it supports, and the processes that govern the formation and behavior of the Earth's materials". (Up to 500 characters).

  This project meets NSF-EAR goals as it will contribute to understanding the composition and evolution of the Earth’s crust through igneous processes. It will help better understand magma processes leading up to volcanic eruptions and aid in mitigating hazards and destruction caused by particularly large eruptions. This study specifically focuses on the nature of magma plumbing systems and their interconnectivity across vertical and thus usually rarely exposed 3D space and through time.

- Proposed work. Concisely state your research plan and how it will answer the question or test the hypothesis outlined above. (Up to 2500 characters).

As part of an USGS EDMAP-funded project, eight LA-ICPMS U-Pb zircon ages will already be acquired this spring at Arizona's LaserChron lab from samples of all three units collected in 2022 (Fig. 2). The preliminary ages will help narrow down which plutonic, porphyry, and volcanic rock units are of similar age (ca. 99-97 Ma) so they can be geochemically compared to one another. Sampling in summer 2023 will target all three units in the eastern JL (Fig. 2). Zircon separations will be done at CSUF.

Five samples of each of the three units will be analyzed with ~40 core and rim spots per sample to gain an appropriate data pool to test the hypotheses. Zircons will be analyzed using Laser-ablation split-stream inductively coupled plasma mass spectrometry (LASS-ICPMS) using both Nu Plasma HR MC-ICPMS and Nu AttoM SC-ICPMS and an Analyte laser-ablation system in the LASS lab at UCSB. LASS provides the ability to get precise ages and trace-element (TE) geochemistry of zircons simultaneously. Before LASS, zircons must be imaged via Cathodoluminescence to consider zircon zoning patterns during analyses and to avoid any inherited cores of significantly older age.

For the first hypothesis to be supported, TE and heavy rare earth elements (HREE) in zircons from the granitic PPP and rhyolitic volcanics need to show evidence of fractionation. Through substitution, zircons readily incorporate Zr, Hf, and HREE over lighter REE. Fractionated melts are signaled through low Zr/Hf ratios and depletion in HREE. Zircons grown in less fractionated melts have higher Zr/Hf ratios and higher HREE contents, which is to be expected for zircons in the JL granodiorite if it has complementary compositions to the PPP and rhyolites (Fig. 1). Petrography of the samples collected will be used in tandem to evaluate the zircon geochemistry results. Cumulate textures in granitoids are subtle but should be present if the zircon chemistry suggests a complementary relationship.

For the second hypothesis to be valid, the TE and HREE contents of the zircons should be the same in all three units (Fig. 1). In this scenario the JL magma was evacuated in bulk and was the source for the PPP and erupted metavolcanics (Fig. 1).

If the units are not coeval and neither hypothesis is validated via zircon geochemistry, a connection between the volcanic-porphyry-plutonic complex cannot be made. It might also be the case that the three units represent a complex combination of a complementary and equivalent system.

- Brief timeline (up to 500 characters)

  February 2023 – Zircon separations for 2022 samples

  April 2023 – U-Pb dating of 2022 samples at Arizona's LaserChron lab

July/August 2023 – Additional samples will be collected during field mapping. Ages of the 2022 samples will help determine what to sample further.

August/September 2023 – Zircon separations of summer 2023 samples

September 2023 – Epoxy rounds made at CSUF

October 2023 – CL imaging and LASS at UCSB

Winter/spring 2023/2024 – Data interpretation and manuscript preparation

- Figure(s) with caption(s). At least one figure is required, but the figure(s) should occupy no more than one page.

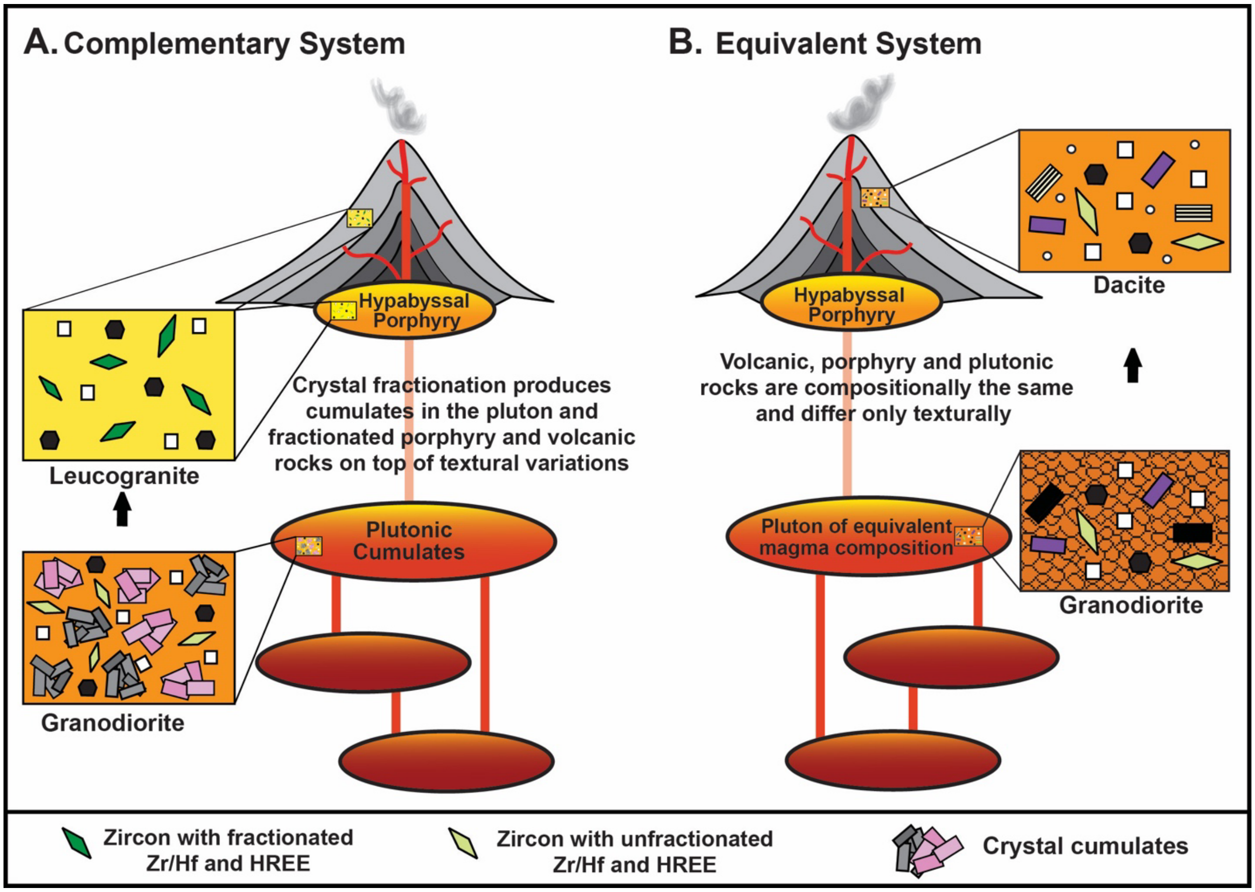

Figure 1: Schematic of a magmatic plumbing system. **A)** depicts the first hypothesis of a complementary relationship between the JL granodiorite and Post Peak leucogranite porphyry and rhyolitic volcanics. **B)** Depicts an equivalent relationship between the JL granodiorite, porphyry and the meta-dacite as suggested by the second hypothesis. The geometric shapes in the rectangles represent minerals typically found in an intermediate to felsic plutonic, porphyry, and volcanic rocks.

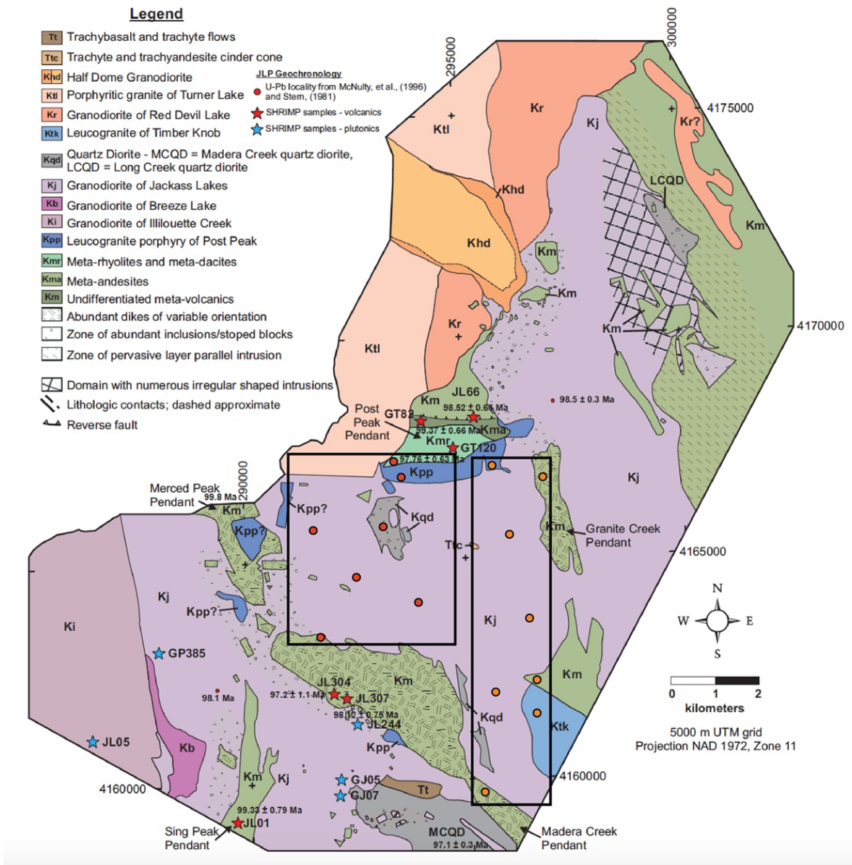

Figure 2: Geologic map adapted from Pignotta et al., 2010. The map includes U-Pb zircons ages of the JL granodiorite taken from McNulty et al., 1996, and unpublished ages of the JL metavolcanics (pers. comm. Geoff Pignotta, 2022). The box (left) with the red dots shows the approximate location of samples collected in 2022 and the box (right) shows approximated locations where samples will be collected this summer.

- References Cited.

Bachmann, O., Miller, C.F., and de Silva, S.L., 2007, The volcanic–plutonic connection as a stage for understanding crustal magmatism: Journal of Volcanology and Geothermal Research, v. 167, p. 1–23, doi: 10.1016/j.jvolgeores.2007.08.002.

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Deering, C. D., Keller, B., Schoene, B., Bachmann, O., Beane, R., and Ovtcharova, M., 2016, Zircon record of the plutonic-volcanic connection and protracted rhyolite melt evolution: Geology, v. 44, no. 4, p. 267-270.

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Glazner, A. F., Bartley, J. M., Coleman, D. S., Gray, W., and Taylor, R. Z., 2004, Are plutons assembled over millions of years by amalgamation from small magma chambers?: GSA today, v. 14, no. 4/5, p. 4-12.

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Lipman, P. W., 2007, Incremental assembly and prolonged consolidation of Cordilleran magma chambers: Evidence from the Southern Rocky Mountain volcanic field: Geosphere, v. 3, no. 1, p. 42-70.

McNulty, B.A., Tong, W., and Tobisch, O.T., 1996, Assembly of a dike-fed magma chamber: The jackass lakes pluton, Central Sierra Nevada, California: Geological Society of America Bulletin, v. 108, p. 926–940, doi: 10.1130/0016-7606(1996)108<0926:aoadfm>2.3.co;2.

Peck, D., 1980, Geologic map of the Merced Peak quadrangle, central Sierra Nevada, California: U.S. Geological Survey Geologic Quadrangle Map GQ-1531, scale 1:62 500.

Pignotta, G.S., Paterson, S.R., Coyne, C.C., Anderson, J.L., and Onezime, J., 2010, Processes involved during incremental growth of the jackass lakes pluton, central Sierra Nevada Batholith: Geosphere, v. 6, p. 130–159, doi: 10.1130/ges00224.1.

Werts, K., Barnes, C. G., Memeti, V., Ratschbacher, B., Williams, D., and Paterson, S. R., 2020, Hornblende as a tool for assessing mineral-melt equilibrium and recognition of crystal accumulation: American Mineralogist: Journal of Earth and Planetary Materials, v. 105, no. 1, p. 77-91.

- Available funds. Please explain if you currently have any funds available for the proposed geochronology work. Is your project unlikely to occur without AGeS support? If you require more money than AGeS can support, then where will those additional funds come from? (Up to 500 characters).

  Currently, no funds are available to complete the proposed geochronology/petrochronology work. Although LA-ICPMS U-Pb zircon ages of eight samples will be acquired at Arizona’s Laserchron lab this spring through USGS EDMAP funding, trace elements of zircons are not part of the plan and cannot be done there with LASS. My proposed LASS-ICPMS petrochronology work cannot be completed without an AGeS grant. If I receive the AGeS grant, the data I will collect will be a major component of my MS thesis.

- Detailed budget and budget justification. Budgets may include funds for travel to and from the AGeS lab where you propose to work, food and lodging while visiting the lab, analytical and training fees, equipment or consumables required for analysis, and sample preparation fees (including mineral separation accomplished at another facility if necessary). Requested budgets may not exceed $10,000 per proposal (Up to 1200 characters)

  LASS-ICPMS at UCSB costs $3,580/day, and I will require two days to analyze my 15 samples (I intend to analyze ~40 core and rim spots per zircon) for a total of $7,160. The time is calculated to account for the time it takes to analyze a single zircon (unknown) and test a reference material (known) for recalibration purposes. Cathodoluminescence imaging (CL) will also be completed at UCSB on all samples to visualize zircon zoning patterns and inherited cores. CL imaging will take two days to complete and costs $75/hour; estimating one sample per hour, equals 15 hours multiplied by $75 per sample, for a total of $1,125. Zircon separation and mounting will be done at CSUF in my advisor's lab, requiring LST heavy liquid to complete the separation process. A bottle of LST costs $800. Lodging will be needed for the three nights accounting for the two days of CL imaging and two days of LASS, ca. ~$150/night, for a total of $450. Travel to UCSB is calculated roundtrip from CSUF to UCSB which is 168 miles multiplied by the California standard mileage reimbursement of $0.625/mile equaling $105. Parking fees for guests on the UCSB campus are $8/day, and food for the four days will cost ~$150.

Budget Item	**Total Amount Budgeted**	**Amount Requested AGeS Program (maximum of $10,000)**
LASS-ICP Petrochronology at UCSB 2 days: ~ 15 samples (40 spots/zircons per sample)	$3,580/day	$7,160
Cathodoluminescence imaging at UCSB 2 days for CL imaging $75/hour, 1-samples/hour 15 samples = 15 hrs x $75	$1,125	$1,125
Bottle of LST heavy liquid	$800	$800
Food - 4 days	$150	$150
Travel to UCSB Mileage: 168 miles roundtrip Standard mileage reimbursement = $0.625/miles	$105	$105
Parking fees $8/day	$32	$32
Hotel (3 nights)	$450	$450
Total		9,822

Broader Impacts

- Previous AGeS award? (yes/no)

  No

- Geochronology Experience. List what geochronology experience you already have. Be specific. Enter "None" if you have no geochronology experience at all.

  None at the time of writing this proposal.

- Geochronology Opportunities. Explain what geochronology opportunities that you already have through your existing thesis research. Do you have local access to geochronology facilities and expertise? Does your advisor direct a geochronology lab? Does your advisor's research group regularly use the technique you propose to use in this project? (Up to 500 characters).

  Funded by a USGS EDMAP grant, my advisor, myself, and two fellow students will go to the University of Arizona LaserChron lab to use LA-ICPMS U-Pb zircon geochronology to date different units of the JLP plutonic-porphyry-volcanic complex in April 2023.

  Besides the geochronology facility at UCSB, I do not have any local access to a geochronology lab. My advisor does not direct a geochronology lab. My advisor's research group has never used LASS-ICPMS for petrochronology analysis before.

- New Collaborations. Explain the extent to which this project represents a new collaboration with the host geochronology lab. Has your advisor's research group previously interacted or collaborated with this lab? If so, is this a new or existing research topic of investigation? Are there ways in which your project and your experience address and support BAJEDI values? Be specific. (Up to 500 characters)

  My advisor's research group has no previous collaboration with UCSB's petrochronology lab. The project involves a new pluton and is a new research direction for my advisor and me.

  As a master's degree pursuing woman, I represent young women in STEM. I will attend conferences to present this research and write a publication. I am also part of the CSUF geology department's inclusivity forum that supports BAJEDI values and is actively making DEI changes in the department.