MEGACRYSTIC POTASSIUM FELDSPAR MAGMATISM IN THE SOUTHERN MOJAVE DESERT, CALIFORNIA

Wolfe, Claire[1] (*clairewolfe_2024@depauw.edu*), Brown, K.[1], Loocke, M., [2], McLeod, C. L.[3]

(1) Department of Geology & Environmental Geoscience, DePauw University, U.S.A; (2) Department of Geology & Geophysics, Louisiana State University, U.S.A; (3) Department of Geology & Environmental Earth Science, Miami University

ABSTRACT

Investigating the textural, chemical, and chronological records preserved within crystal populations can provide insight into the processes which operate during magma ascent, emplacement, and crystallization. K-feldspar megacrysts offer an excellent opportunity to explore these records, particularly in chemically-evolved systems. Understanding megacryst formation bears on a fundamental issue in granite petrogenesis, namely whether the textural and chemical features preserved within granitoid intrusions reflect primary magmatic processes or late-stage crystallization and subsolidus reorganization. To expand our understanding of megacryst formation, we investigated a suite of K-feldspar megacrysts from the Sheep Hole Mountains Pluton (SHMP) in Southern California.

SHMP megacrysts are euhedral, ranging from 1-8cm in length. Petrographic analysis and SEM/EDS mapping reveals abundant plagioclase (~40%), quartz (~35%), biotite (~10%), titanite (~10%), and hornblende (~5%) inclusions. Other accessory phases include Fe-Ti oxides, apatite, allanite, and zircon. Many of these inclusions, especially euhedral plagioclase, biotite, and titanite, are preferentially orientated along diffuse oscillatory zoning boundaries in the host megacryst. EPMA analyses collected along megacryst core-to-rim traverses reveal Or_{78-93} compositions with dramatic fluctuations in Ba concentrations (0.89-2.73 wt%). Core and rim analyses of plagioclase inclusions were also collected via EPMA. These analyses reveal that plagioclase inclusions contain oligoclase to andesine cores (An_{19}-An_{34}) and albite-rich rims (An_3-An_{10}).

Although SHMP megacrysts are much older than megacrysts described in previous studies, the textural and chemical observations are strikingly similar. We favor a magmatic origin for these megacrysts and interpret these similarities to suggest that a common magmatic process is responsible for K-feldspar megacryst formation.

METHODS

K-feldspar megacrysts were collected from four outcrops in southern California during the GEOS 183 course: Field Experience-Mojave Desert (Fig. 2). From these outcrops, four megacryst samples were selected for investigation. The methods used in this study are briefly summarized in the flow chart below.

1) Petrographic Analysis
Thin Section Creation
Photomicrograph Composite Images
Modal Mineralogy Observations
Textural Observations
Grain Size Observations

2) SEM & EDS Analysis
Identification of Inclusions using SEM Images
EDS Chemical Mapping of Mineral Inclusions

3) EPMA Analysis at LSU
Chemical Compositions of Mineral Phases

4) Synthesis & Conclusions

PETROGRAPHIC RESULTS

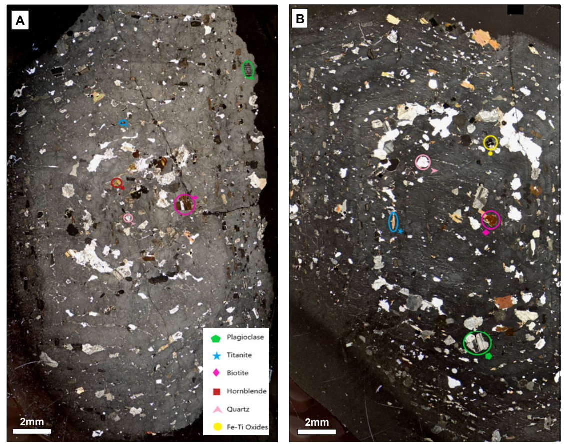

Fig. 4: A) Composite photomicrograph of a K-feldspar megacryst. Note the spatial distribution of the mineral inclusions: Plagioclase, Biotite, Titanite, and Fe-Ti Oxides. **(B)** Composite photomicrograph of a K-feldspar megacryst. Note the spatial distribution of the mineral inclusions: Plagioclase, Biotite, Titanite, and Fe-Ti Oxides as well as the oscillatory zoning.

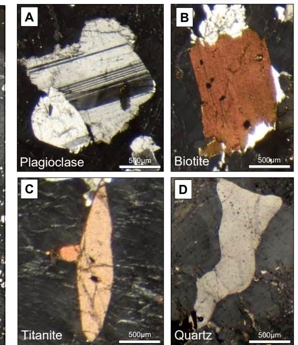

Fig. 5: (A, B, C, and D) Photomicrographs of common mineral inclusions found in all four megacrysts. The table below summarizes the primary inclusions observed in these megacrysts.

Sample #	Plag	Qtz	Biotite	Hbl.	Fe-Ti Oxides	Titanite
IB	30%	30%	10%	10%	10%	10%
IA	30%	25%	15%	14%	10%	5%
IC	40%	30%	5%	5%	10%	10%
IF	45%	20%	10%	5%	15%	5%

SEM & EDS RESULTS

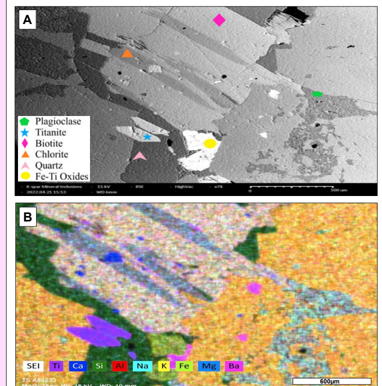

Fig. 6: A) Backscatter electron (BSE) image showing common mineral inclusions found within one of the K-feldspar megacrysts. These include: Na-rich plagioclase, biotite, titanite, quartz, and Fe-Ti oxides. **(B)** False-color Energy Dispersive Spectroscopy (EDS) image showing the spatial distribution of mineral phases. This chemical mapping confirms SEM and petrographic observations.

INTRODUCTION

K-feldspar megacryst formation has long been a controversial topic in igneous petrology. Given their large size and euhedral shape, one model hypothesizes that these megacrysts crystallized early in a melt-dominated system (e.g., Vernon and Paterson, 2008). However, an alternative model hypothesizes that megacrysts form by textural coarsening late in the magma's history when it is mostly solid (e.g., Glazner and Johnson, 2013). Understanding megacryst formation bears on a fundamental issue in granite petrogenesis, namely whether the textural and chemical features preserved within granitoid intrusions reflect primary magmatic processes or late-stage crystallization and subsolidus reorganization. This project aims to characterize a suite of potassium feldspar megacrysts from southern California in order to identify petrographic and geochemical evidence that can be used to constrain which model is responsible for megacryst formation. Careful examination of these megacrysts can help us constrain the timing of their formation.

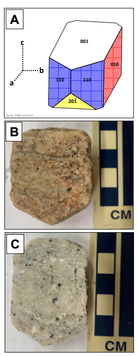

Fig. 1: A) Model of K-feldspar showing Miller indices. **(B & C)** K-feldspar megacrysts showing euhedral shape, monoclinic form, and internal features.

BACKGROUND & FIELD AREA

To evaluate the two competing hypotheses, this project focuses on a suite of K-feldspar megacrysts collected from the Sheep Hole Mountains Pluton (SHMP) in Southern California (Fig 2). The SHMP is a porphyritic, medium- to coarse-grained biotite granodiorite with abundant K-feldspar megacrysts (2–10 cm long) (Howard, 2002). The SHMP is located in the southern Mojave desert along a series of NW-SE trending faults. To the south, these faults intersect the Eastern Transverse Ranges (Joshua Tree area).

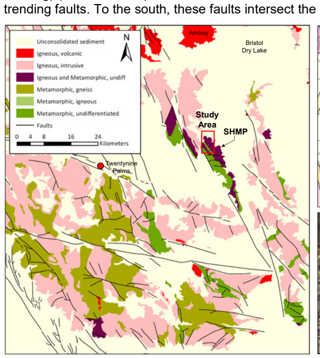

Fig. 2: Simplified geologic map of Southern California showing the study area location. Map data from USGS Data Series 1052 (Horton, 2017).

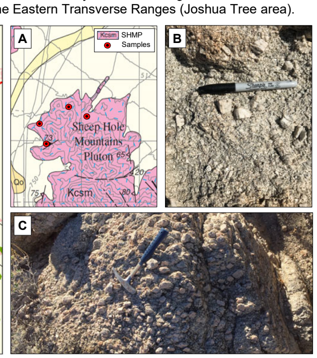

Fig. 3: A) Geologic map of the NW corner of the SHMP (from Howard, 2002). **(B & C)** Outcrop images of the SHMP showing K-feldspar megacrysts.

EPMA RESULTS

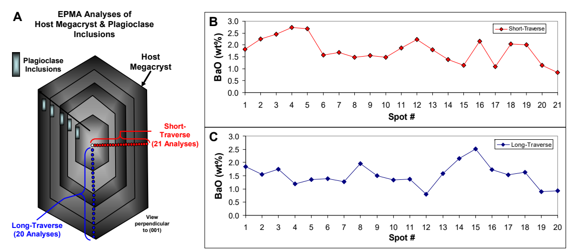

Fig. 7: A) Two EPMA core to rim traverses were completed on a host megacryst sample. Plagioclase inclusions were also analyzed along a core-rim traverse. **(B & C)** Host megacryst core-rim traverses reveal BaO (wt%) fluctuations, ranging from 0.89 to 2.73 wt%.

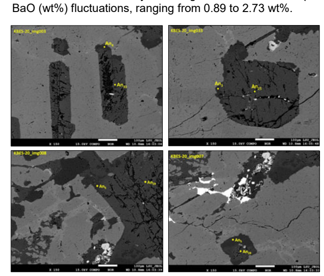

Fig. 8: Plagioclase inclusion cores were more anorthite-rich (An) compared to the rims. Average plagioclase cores are An_{27}, while the rims are An_{10}.

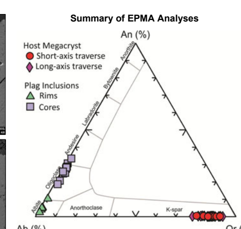

Fig. 9: EPMA analyses reveal that the host megacrysts are orthoclase (Or_{78}-Or_{93}). The plagioclase inclusions contain oligoclase to andesine cores (An_{19}- An_{34}) and albite-rich rims (An_3 – An_{10}).

CONCLUSIONS & FUTURE WORK

The goal of this project was to place important constraints on the timing for potassium feldspar megacryst formation. This research has produced the following conclusions:

- Petrographic and SEM/EDS analyses reveal a large number of mineral inclusions such as plagioclase, quartz, biotite, minor hornblende and titanite, and accessory phases (Fe-Ti oxides, zircon, apatite).
- Many of the inclusions are euhedral and are aligned parallel to the crystallographic faces of the host megacryst. These observations support that these grains grew in a melt-rich environment before being incorporated into a growing megacryst host. We also argue that it is unlikely that these inclusions would be euhedral if they grew within a crystal mush with a high proportion of crystals.
- EPMA core to rim traverses of the host megacryst reveal Ba zoning, ranging from 0.89 to 2.73 wt%. This is consistent with previous megacryst studies (e.g., Moore and Sisson, 2008). We interpret the Ba zoning to reflect a dynamic, melt-rich environment.
- While Ba zoning was present in the host megacryst, it is not as pronounced as Ba zoning found in other megacystic intrusions.
- EPMA analysis of plagioclase inclusions reveal oligoclase to andesine cores (An_{19} – An_{34}) and albitic rims (An_3 – An_{10}) (Fig. 8). This data suggests that the plagioclase likely grew in an evolving liquid.

Compared to previous studies, the barium zoning observed within these megacryst samples is much less distinct (sharp). It would be interesting to compare barium zoning patterns as a function of emplacement age. Because REE are less fluid mobile than Ba, mapping REE concentrations may provide new constraints on the formation of these megacysts.

ACKNOWLEDGEMENTS AND REFERENCES

We would like to thank GSA's OTF program and the DePauw FDC Student Research and Artistic Grant for helping fund this presentation. We would also like to thank Dipson Pradhan, the DePauw Buehler Biomedical Imaging Center, and DePauw's Geology and Environmental Geoscience Department for helping support the laboratory components of this project.

- Glazner, A., Johnson, B., 2013, Late crystallization of K-feldspar and the paradox of megacrystic granites: *Contrib Mineral Petrol*, vol. 166, p. 777-799,
- Gualda, G., 2019, On the origin of alkali feldspar megacrysts in granitoids: the case against textural coarsening: *Contrib Mineral Petrol,* vol. 174, p. 88,
- Horton, J.D., 2017, The State Geologic Map Compilation (SGMC) geodatabase of the conterminous United States: USGS data releasehttps://doi.org/10.5066/F7WH2N65
- Howard, K., A., 2002, Geologic map of the Sheep Hole Mountains 30' x 60' quadrangle, San Bernardino and Riverside Counties, California, http://ngmdb.usgs.gov/Prodesc/proddesc_51545.htm: U.S. Geological Survey, Miscellaneous Field Studies, Map MF-2344, scale 1:100,000
- Johnson, B., and Glazner, A., 2009, Formation of K-feldspar megacrysts in granodioritic plutons by thermal cycling and late-stage textural coarsening: *Contributions to Mineral Petrology*, vol. 159, pgs. 599-619,
- Moore, J., and Sisson, T., 2008, Igneous phenocrystic origin of K-feldspar megacrysts in granitic rocks from the Sierra Nevada batholith: *Geosphere*, vol. 4, no. 2, p. 387-400,
- Nekvasil, H., 1992, Feldspar crystallization in felsic magmas- a review: *Transaction of the Royal Society of Edinburgh*, vol. 83, pgs. 399-407,
- Slaby, E., Galbarczyk-Gąsiorowska, L., Seltmann, R., Müller, A., 2006, Alkali feldspar megacryst growth: Geochemical modelling: *Mineralogy and Petrology*, vol. 89, p. 1-29,
- Vernon, R., Paterson, S., 2008, How late are K-feldspar megacrysts in granites?: *Lithos,* vol. 104, p. 327-336,
- Whitney, J., 1988, The origin of granite: The role and source of water in the evolution of granitic magmas: *GSA Bulletin,* vol. 100, no. 20, 1886-1897