MEGACRYSTIC POTASSIUM FELDSPAR MAGMATISM IN THE SOUTHERN MOJAVE DESERT, CALIFORNIA

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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 Pluton (SHP) in Southern California.

SHP 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 Or78-93 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 (An19-An34) and albite-rich rims (An3-An10).

Although SHP 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
Inclusion Identification using SEM Images
EDS Chemical Mapping of Mineral Inclusions

3) EPMA Analysis at LSU
Chemical Compositions of Mineral Phases

4) Synthesis & Conclusions

PETROGRAPHIC RESULTS

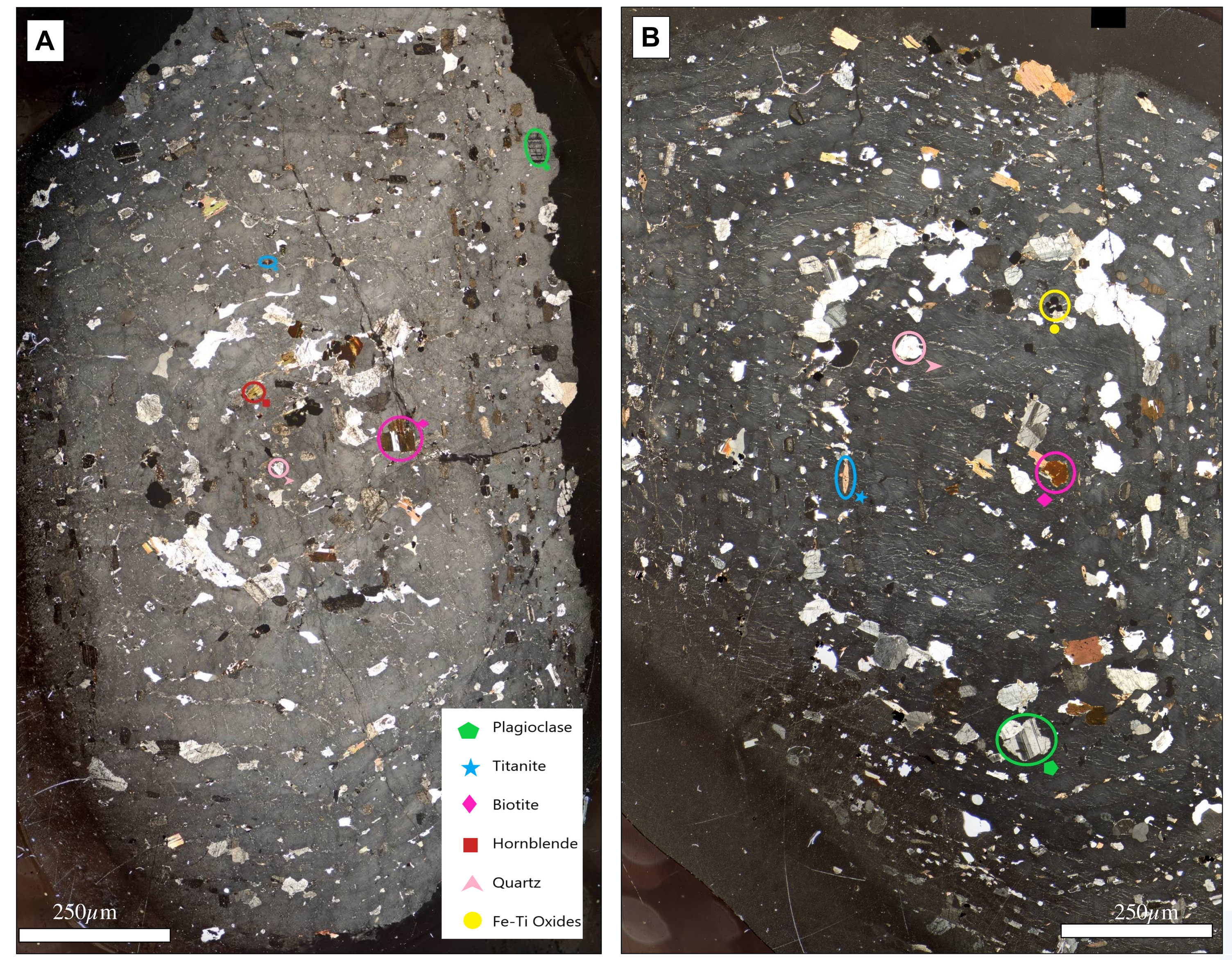
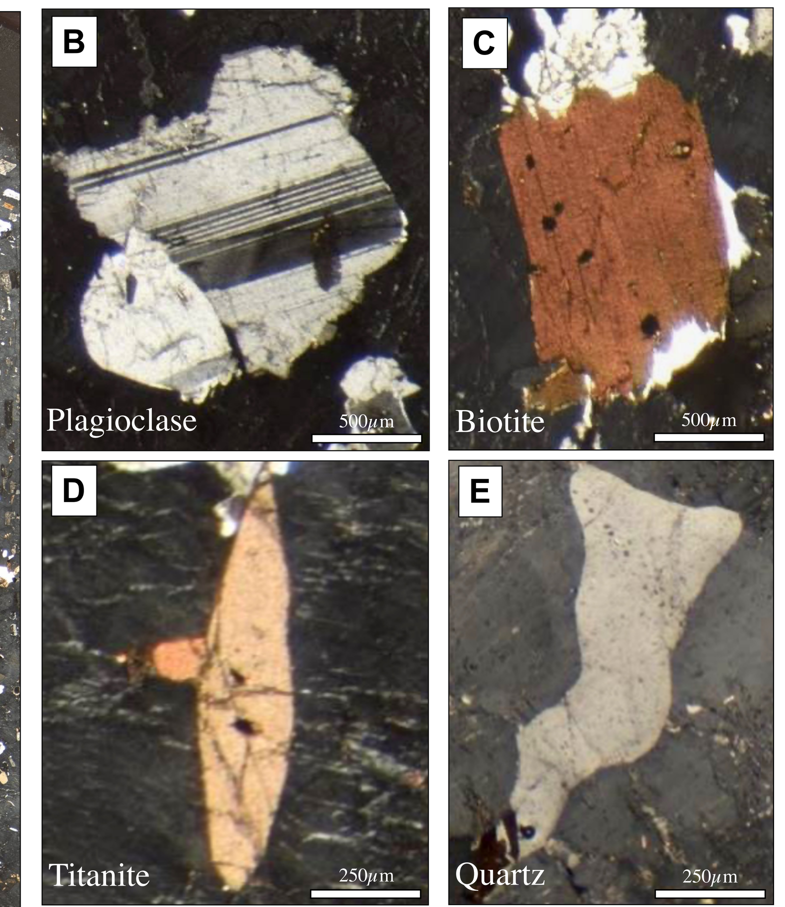


Fig. 3: A) Composite photomicrograph of a K-feldspar megacryst. Note the spatial distribution of the mineral inclusions: Plagioclase, Biotite, Titanite, and Fe-Ti Oxides. B) Composite photomicrograph of a K-feldspar megacryst. Note the spatial distribution of the mineral inclusions: Plagioclase, Biotite, Titanite, and Fe-Ti Oxides as well as the Barium zoning.



Images B, C, D, and E contain photomicrograph images of common mineral inclusions found in all four megacryst. The table below summarizes which inclusions are found in the four selected megacryst samples.

Sample ID	Plag	Bt	Fe-Ti Oxides	Hbl.	Qtz.	Titan.	Musc.
IB	~30%	~10%	~10%	~10%	~30%	~10%	~0%
IA	~30%	~15%	~10%	~14%	~25%	~5%	~1%
IC	~40%	~5%	~10%	~5%	~30%	~10%	~0%
IF	Yes	Yes	Yes	Yes	Yes	Yes	No

SEM & EDS RESULTS

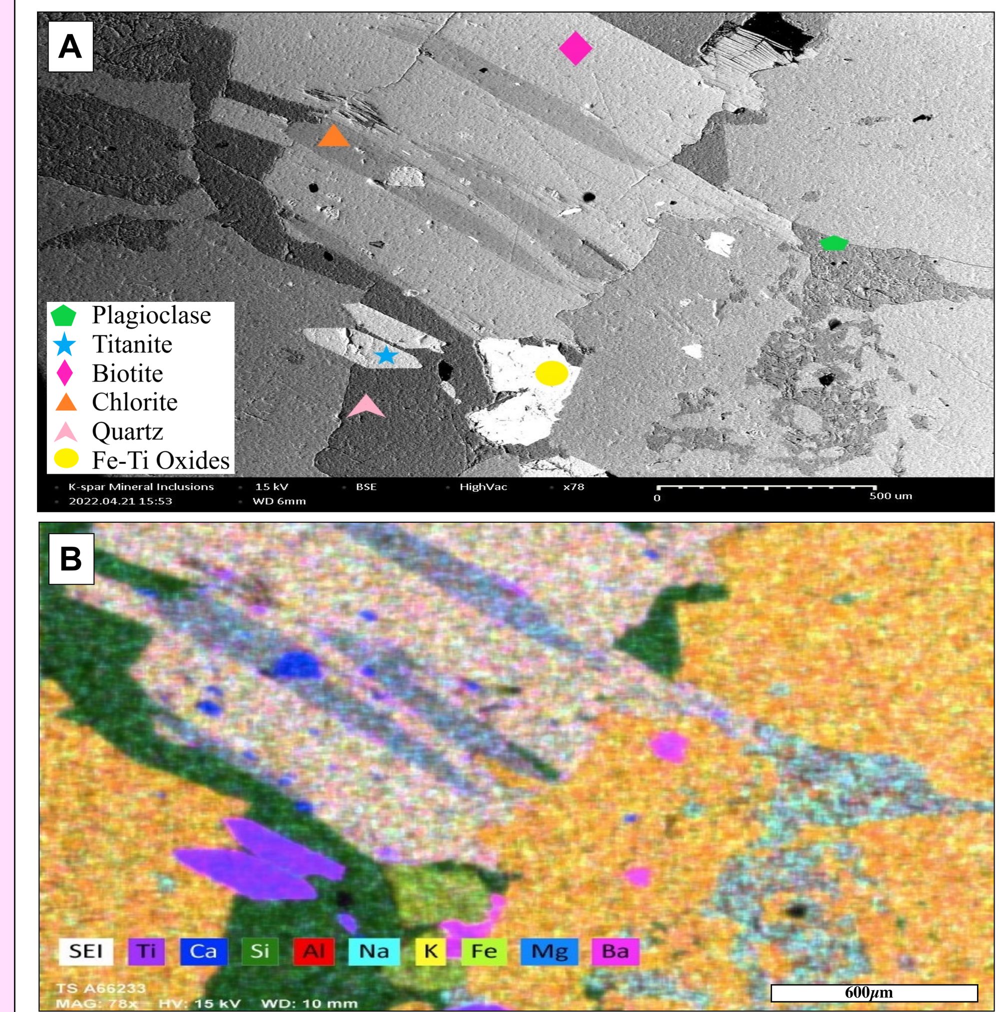


Fig. 4: A) Backscatter electron (BSE) image collected using DePauw's Scanning Electron Microscope (SEM). The image shows an array of mineral inclusions found within one of the K-feldspar megacrysts. These include: Na-rich plagioclase, biotite, titanite, quartz, and Fe-Ti oxides. B) False color Energy Dispersive Spectroscopy (EDS) image showing the spatial distribution of chemical components in the thin section. This chemical mapping confirms SEM and petrographic observations.

INTRODUCTION

There has been a long-standing debate about what stage of the cooling of granitic to granodioritic magma does megacrysts of potassium feldspar form. Given the size and euhedral shape of these megacrysts, one model hypothesizes that these megacrysts crystallized early in the magma's evolution when the system was mostly liquid (Vernon and Paterson, 2008). However, an alternative model hypothesizes that megacrysts crystallize late in the magma's history when it is mostly solid (Glazner and Johnson, 2013). 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 identify which model is responsible for megacryst formation. Careful examination of these megacrysts can help us constrain the timing of their formation. Evidence such as euhedral mineral inclusions, Barium (Ba) zoning, and the compositions of plagioclase inclusions have been used to support early formation (Moore and Sisson, 2008).

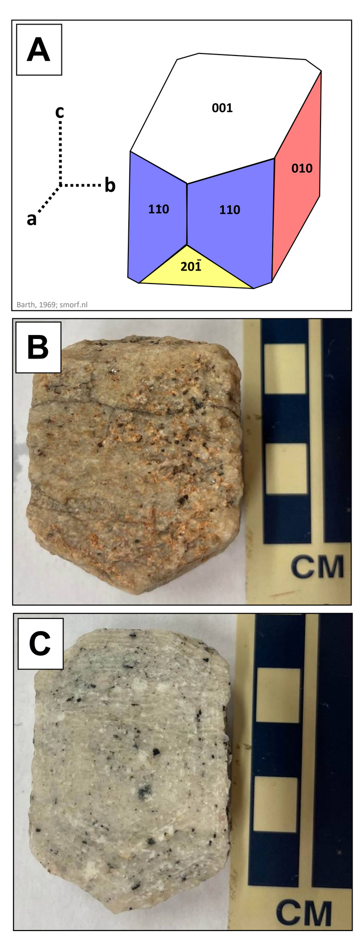


Fig. 1: A) Monoclinic model of K-feldspar, including its Miller indices. (B & C) K-feldspar megacrysts showing euhedral shape, monoclinic form, and interior.

BACKGROUND

The two opposing models argue that either potassium feldspar megacrysts were one of the first crystallizing phases formed during the magma's cooling (Moore and Sisson, 2008) or one of the last (e.g., Glazner and Johnson, 2013). Early crystallization is supported by petrographic evidence such as the megacryst's euhedral shape and the alignment of its mineral inclusions within the megacryst. Geochemical patterns (Ba-zoning) have also been used to support early crystallization, as these zoning patterns suggest the presence of an evolving magmatic system (Moore and Sisson, 2008). Compositional changes within plagioclase inclusions have also been used to indicate an evolving melt-rich system. The opposing hypothesis argues that the large size and euhedral shape of these megacrysts is due to textural coarsening caused by late-stage thermal cycling near the system's solidus (Johnson and Glazner, 2009).

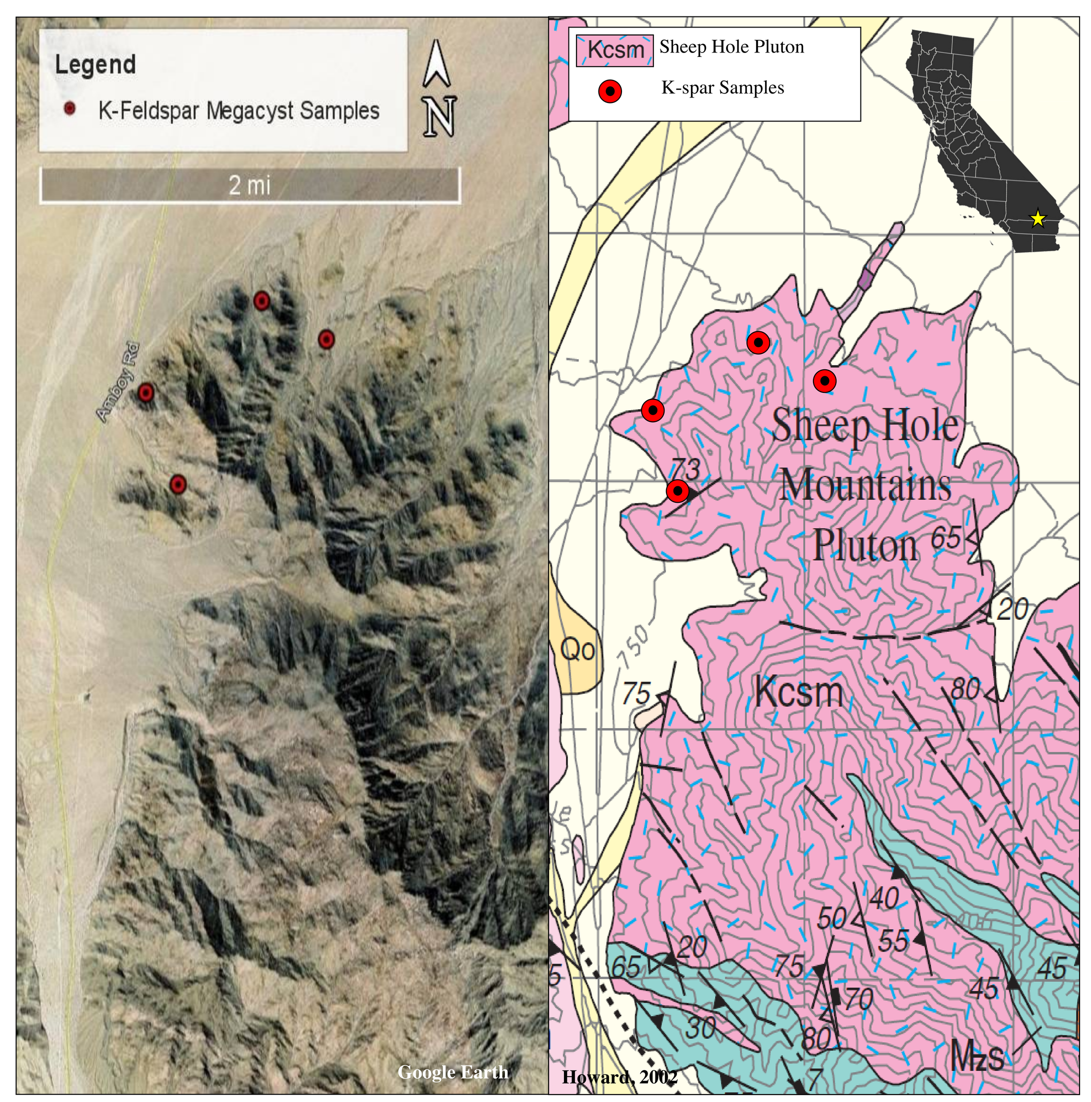


Fig. 2: A satellite image (left) and geologic map (right) of the Sheep Hole Mountains Pluton in Southern California. These maps show the location of megacryst collection sites.

EPMA RESULTS

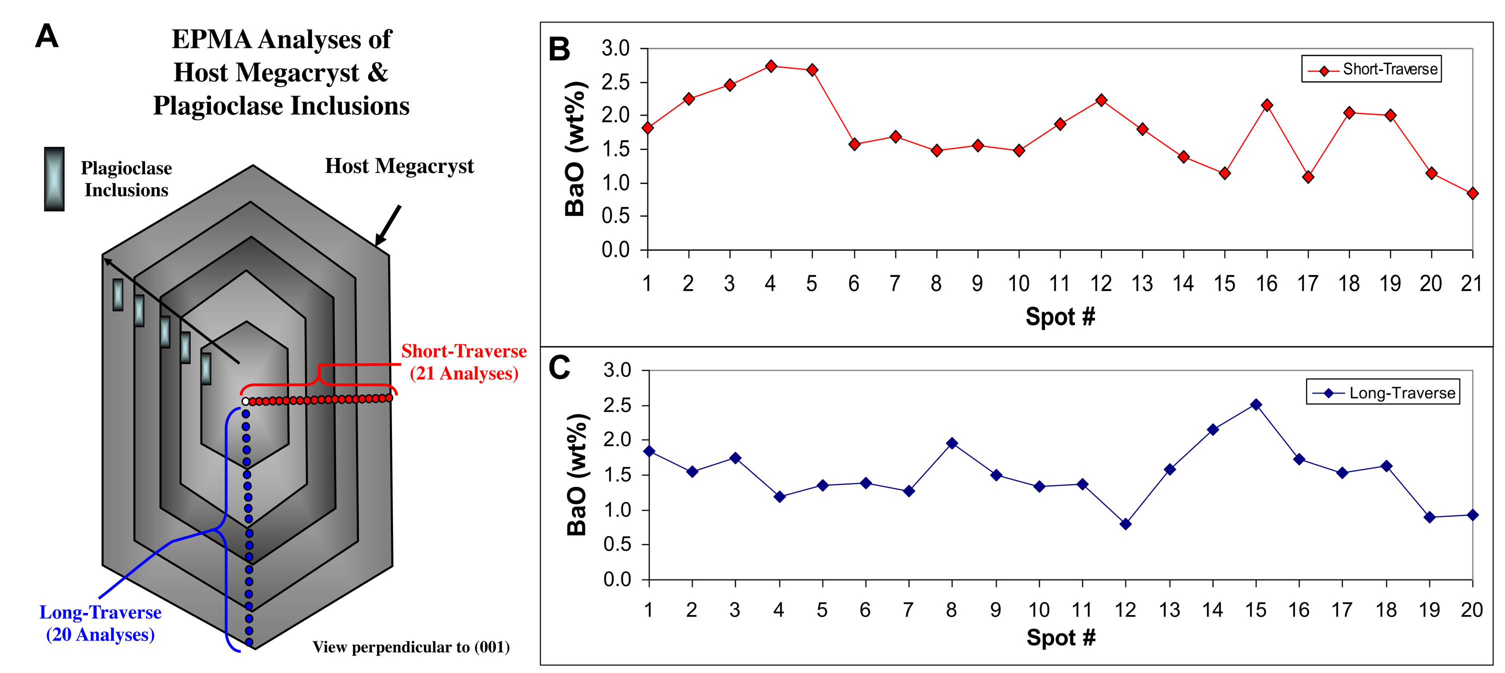


Fig. 5: A) Two EPMA core to rim traverses were completed on a host megacryst sample. Plagioclase inclusions were also analyzed along a core-rim traverse. B & C) Barium zones reveal BaO (wt%) fluctuations, ranging from 0.89 to 2.73 wt%.

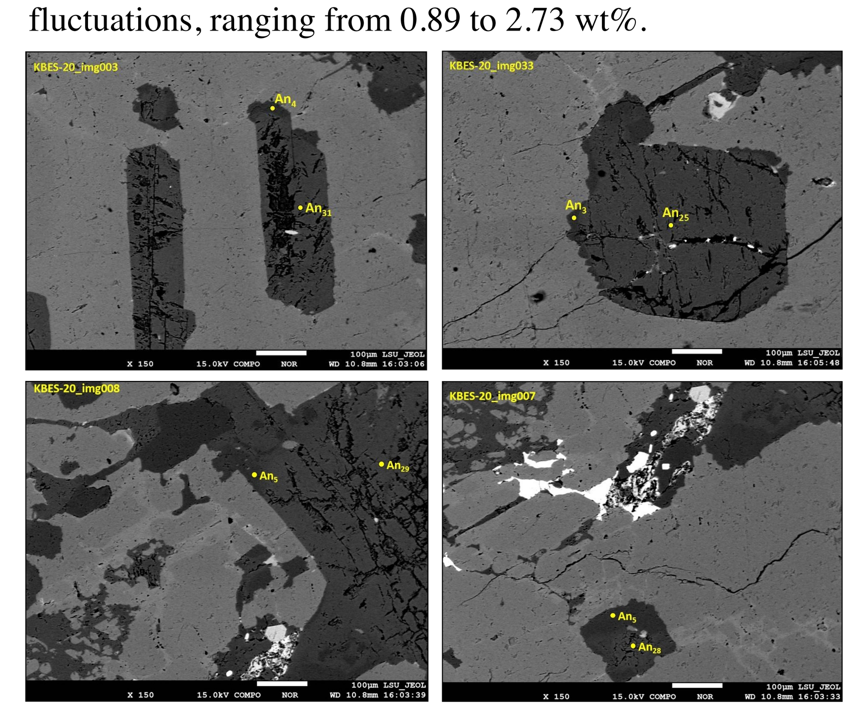


Fig. 6: Plagioclase inclusions were more Anorthite-rich (An) at the core compared to the rims. Average Plagioclase cores are An_{27}, while the rim's are An_{10}.

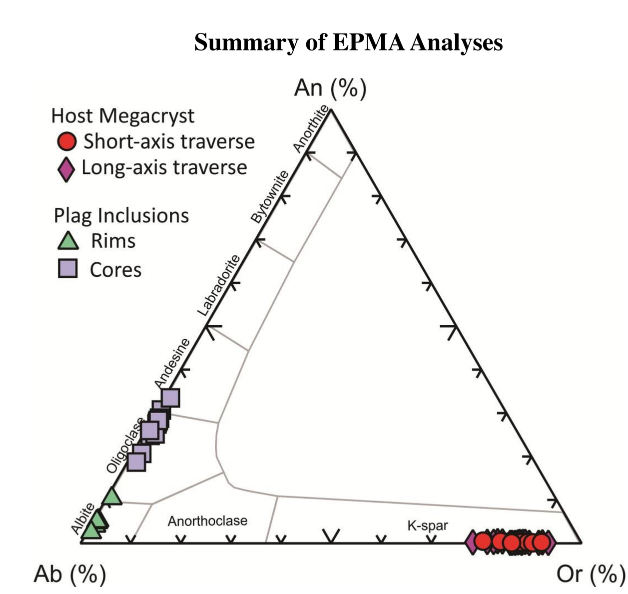


Fig. 7: EPMA analyses reveal that the host megacrysts are orthoclase (Or_{78}-Or_{93}). The plagioclase inclusions contain oligoclase to andesine cores (An_{19}- An_{34}) and albite-rich rims ($An_3 - An_{10}$).

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, biotite, titanite, and quartz.
- 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 magma-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% (Fig. 6). 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 was not obvious nor was it 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 grew in an evolving liquid.

Something to potentially do future work on is the degradation of barium zoning in potassium feldspars over time. The barium zoning in the samples used for this project was much less distinct than other research done on younger potassium feldspar samples. It would be interesting to look at both how the barium zones' composition changes with time, and how quickly the zones begin to decrease in barium levels. Another piece of future work would be to analyze the rare earth element patterns to figure out when they were incorporated into the megacrysts.

ACKNOWLEDGEMENTS AND REFERENCES

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