

Apollo 16 Sample 60635: Evidence for assimilated KREEP-rich material?

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Impact Processes in the Origin and Evolution of the Moon: New Sample Driven Perspectives



- Whole Rock
- Crystal Size Distributions (CSD)
- Mineral Composition

- Characterize impact melts using:
 1. CSDs
 2. Major element abundances; EMP-Washington Univ. @ St. Louis
 3. Trace element abundances; LA-ICP-MS, Internal Standard: Ca (EMP)
- Determine:
NIST-610
 - 1. Target lithologies
 - 2. Parental melt composition
 - 3. Crystallization method

2007 NRC Report

The Scientific Context for Exploration of the Moon

1. Lunar bombardment history
2. Structure and Composition of Lunar Interior
3. Crustal Rock Diversity
4. Lunar Poles and the Volatile Flux
5. Lunar Volcanism
6. Impact Processes
7. Regolith Processes
8. Atmosphere and dust Environment

Thin Sections Analyzed To Date



60635



67559

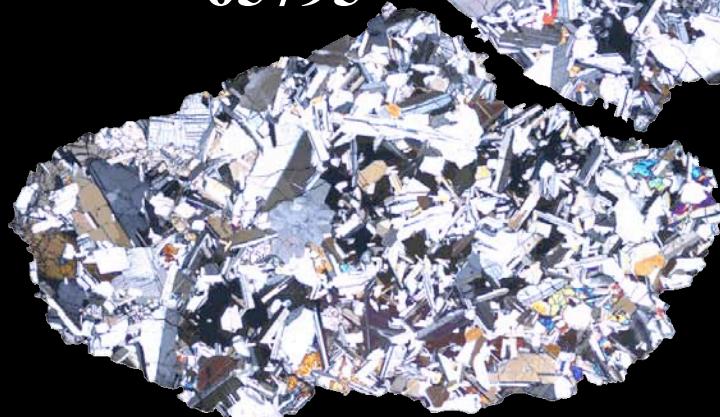


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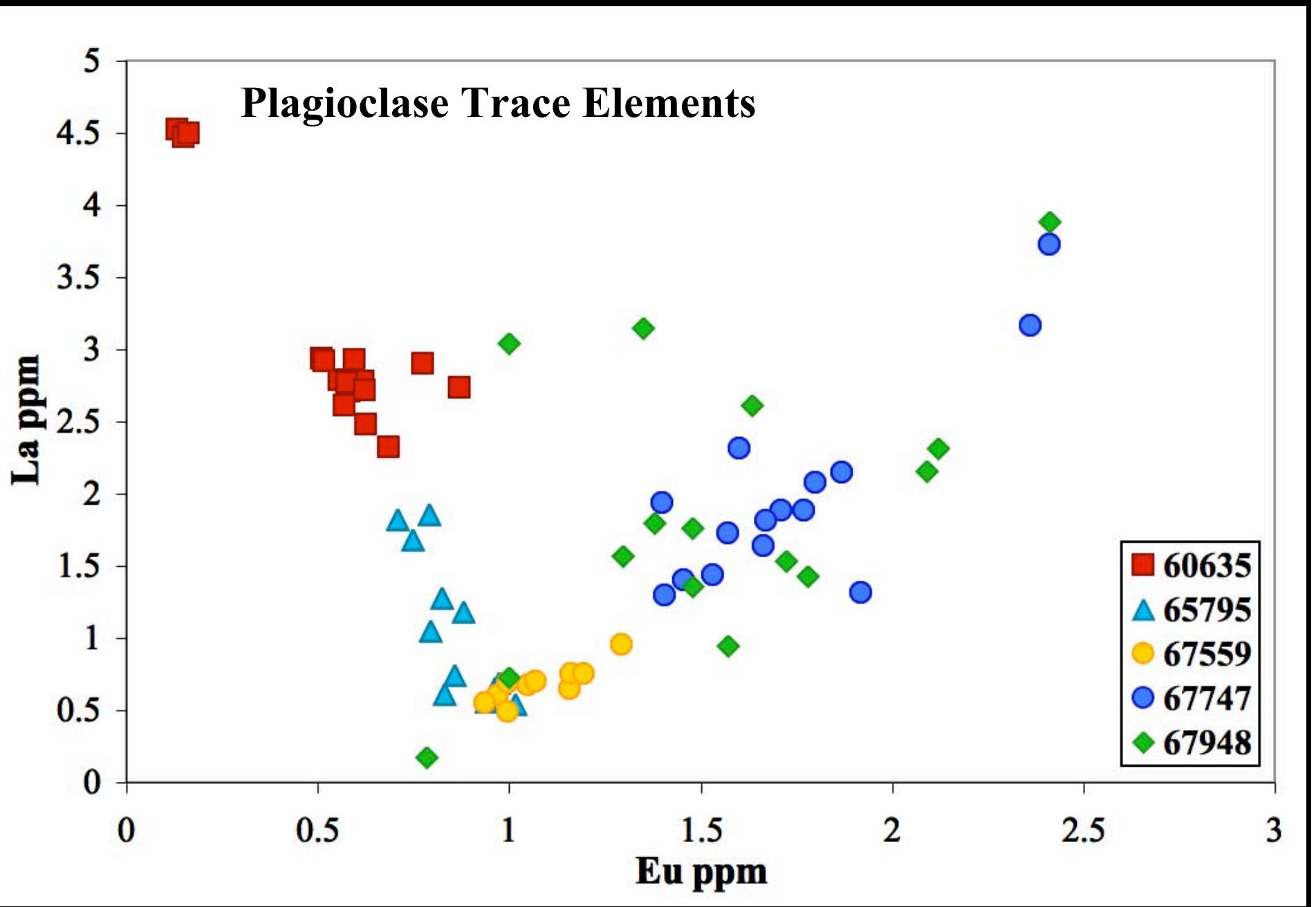
65795

~1mm
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67747





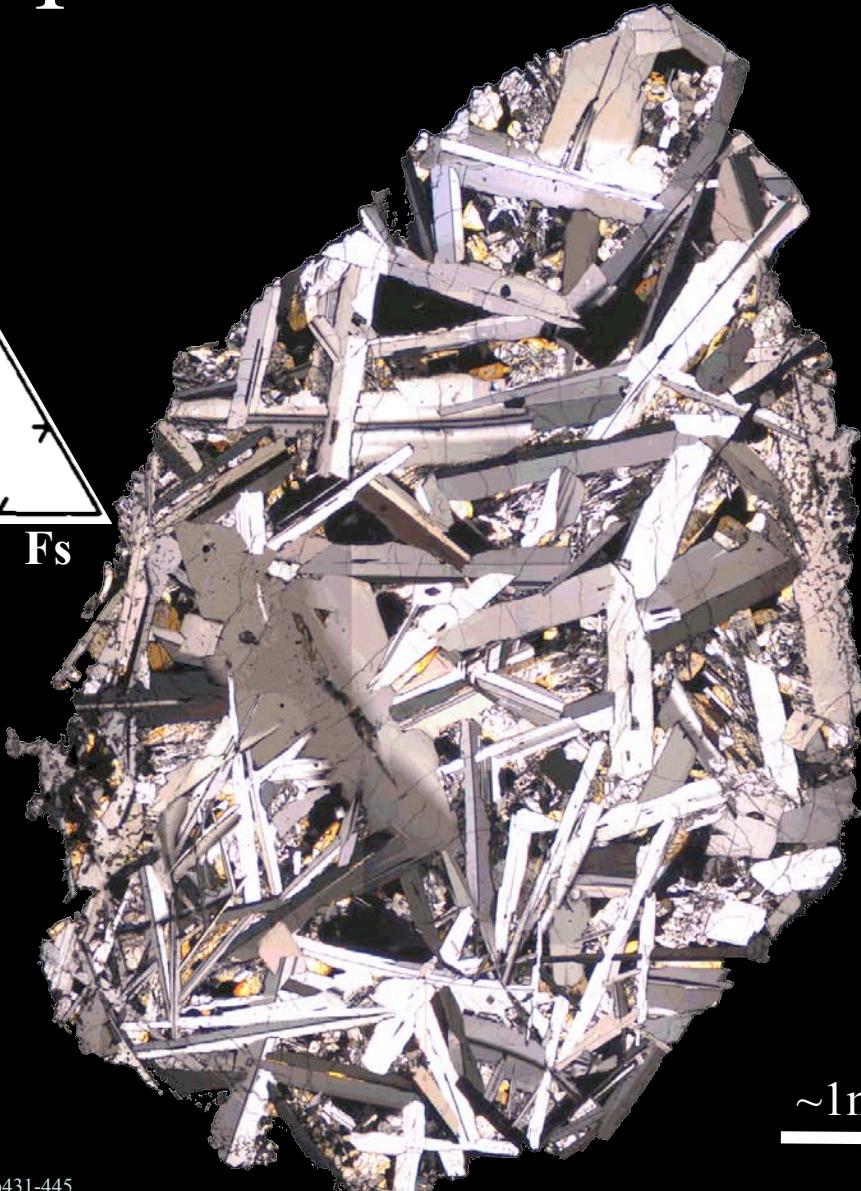
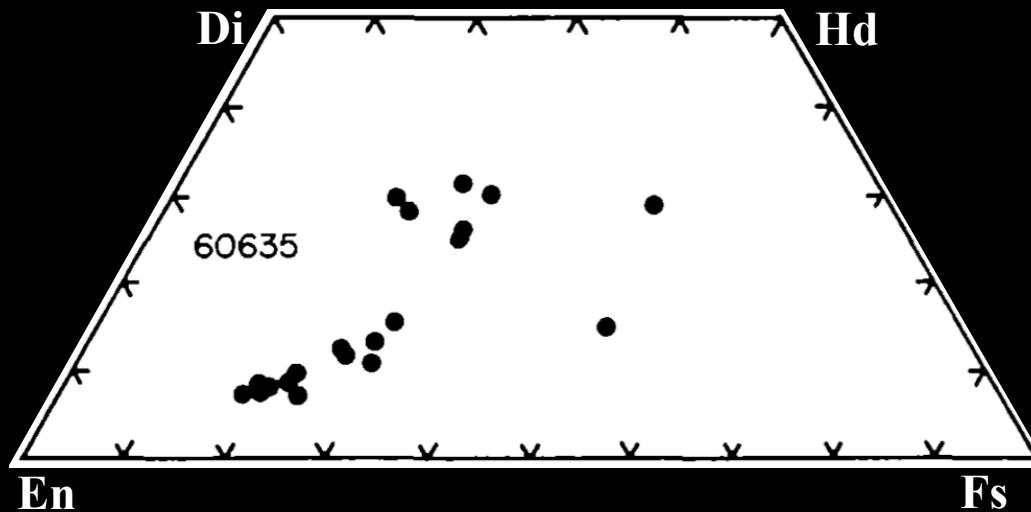
60635: Impact Melt



Reflected Light

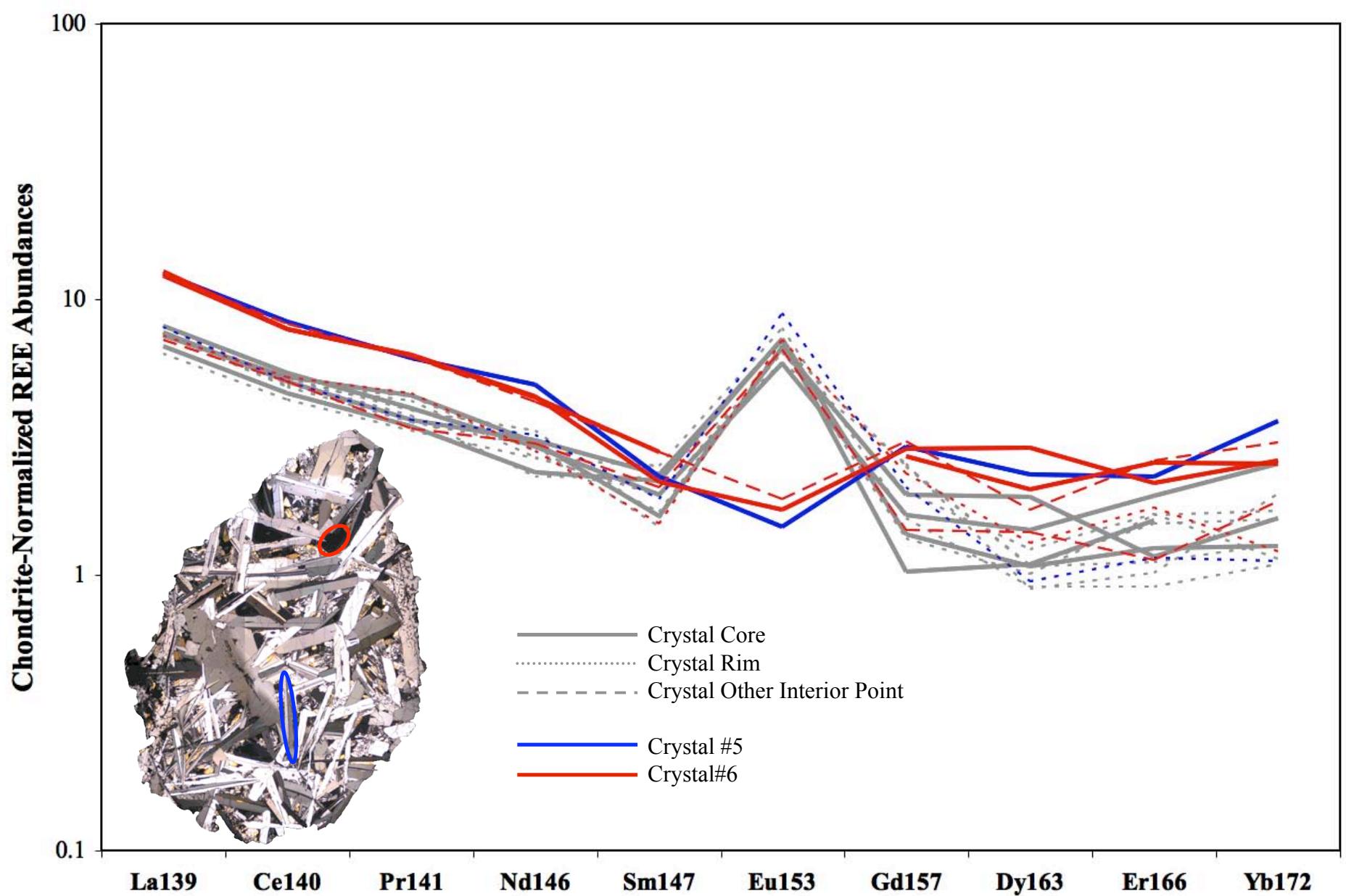


60635: Impact Melt



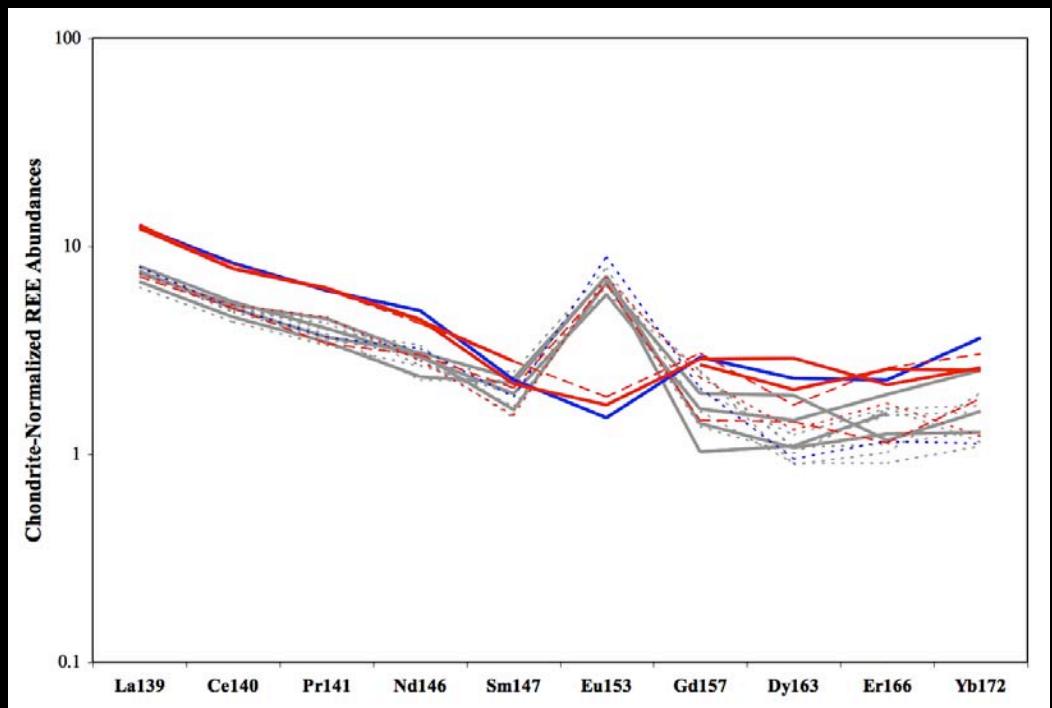
Dowty et al., 1974

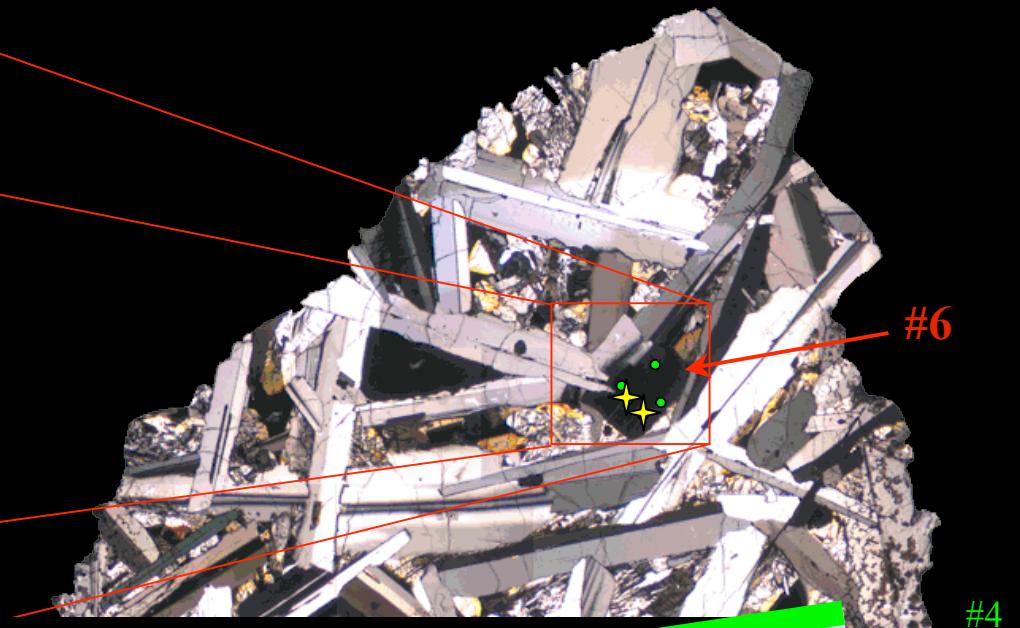
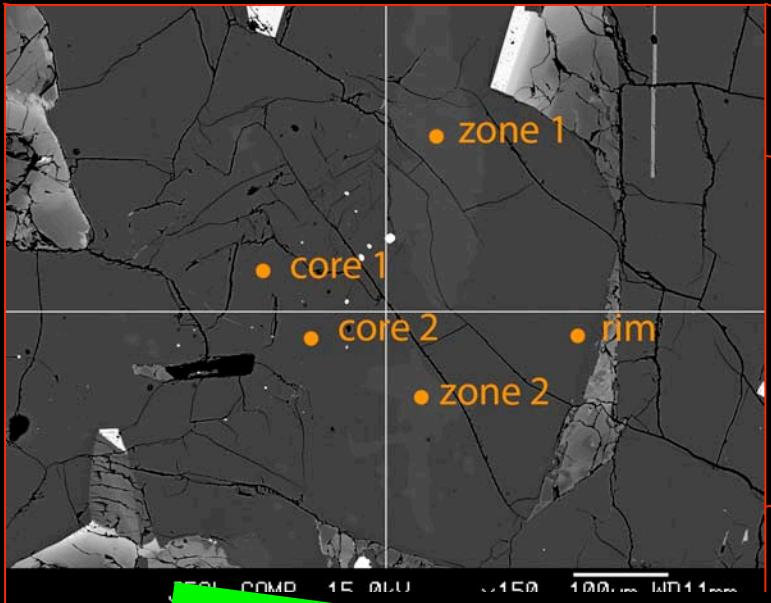
- An_{94}
- No olivine
- Nearly pure ulvöspinel
- Some troilite
- Traces of K-feldspar



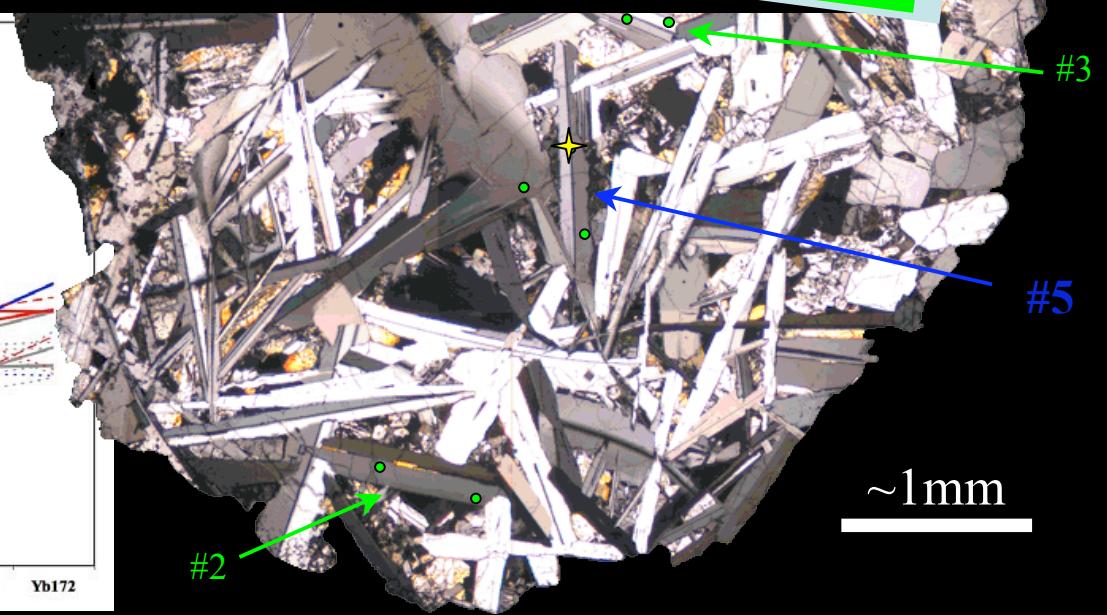
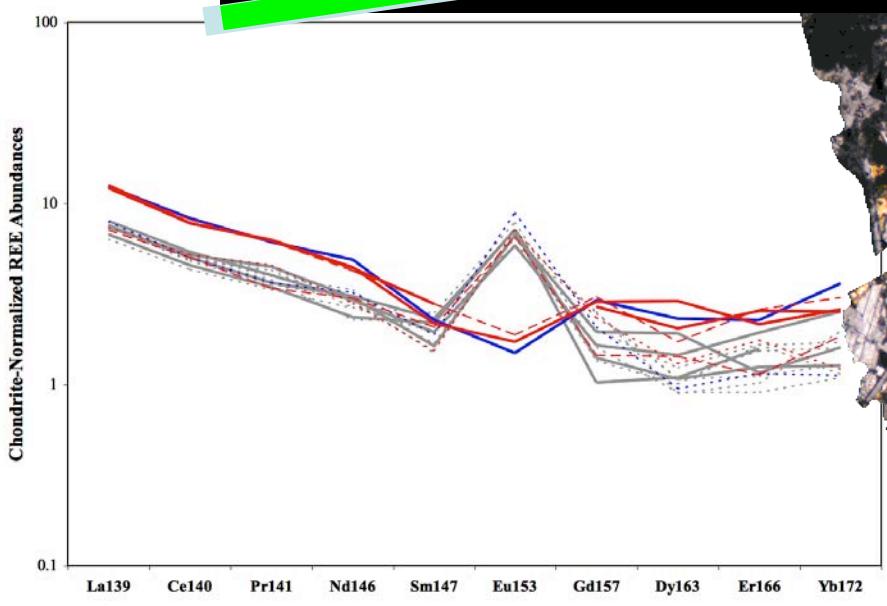
Plagioclase & Europium

- Plagioclase ❤ Eu 2+
 - Size and charge → Ca
 - Expect positive anomaly
- Negative Anomaly???
 - Later crystallization?
 - Crystallized via Assimilation Fractional Crystallization (AFC)
 - KREEP-rich lithologies

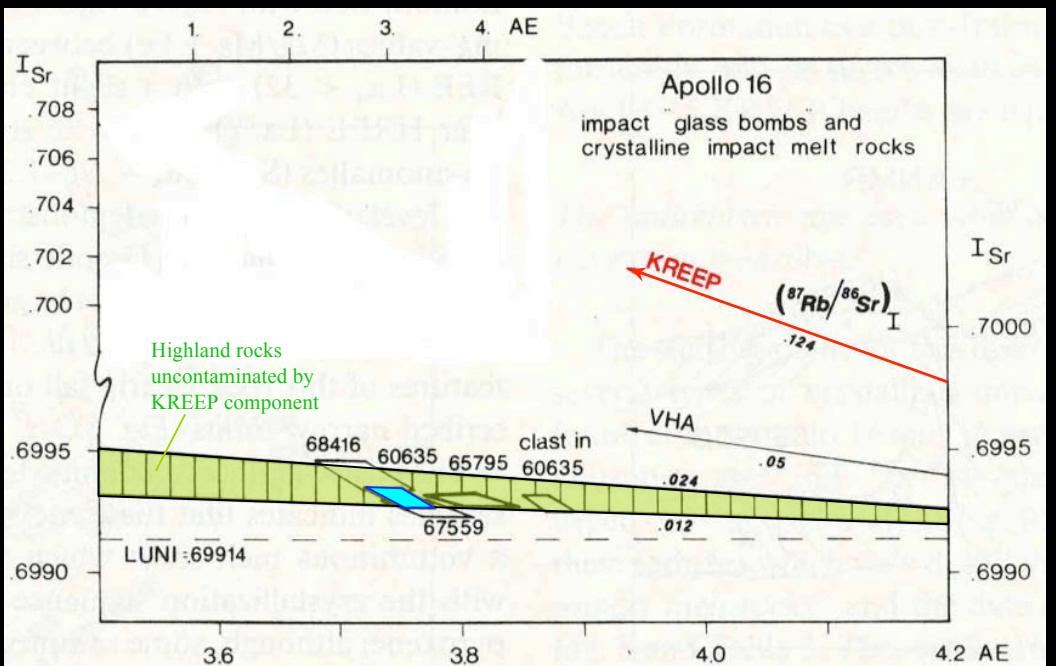
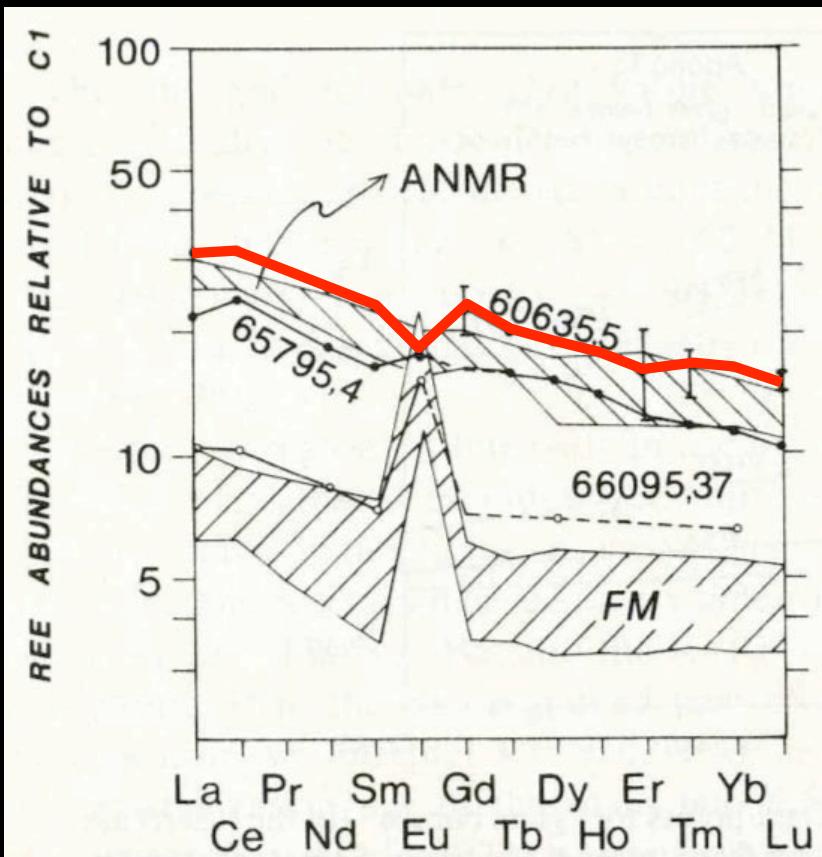




Astrophyllite Stabilization



KREEP or no KREEP?



Upper Bound: Sr-isotope evolution of pristine norite 78236
(Nyquist *et al.*, 1981)
Lower Limit: subophitic IM 67559 (Reimold *et al.*, 1985)

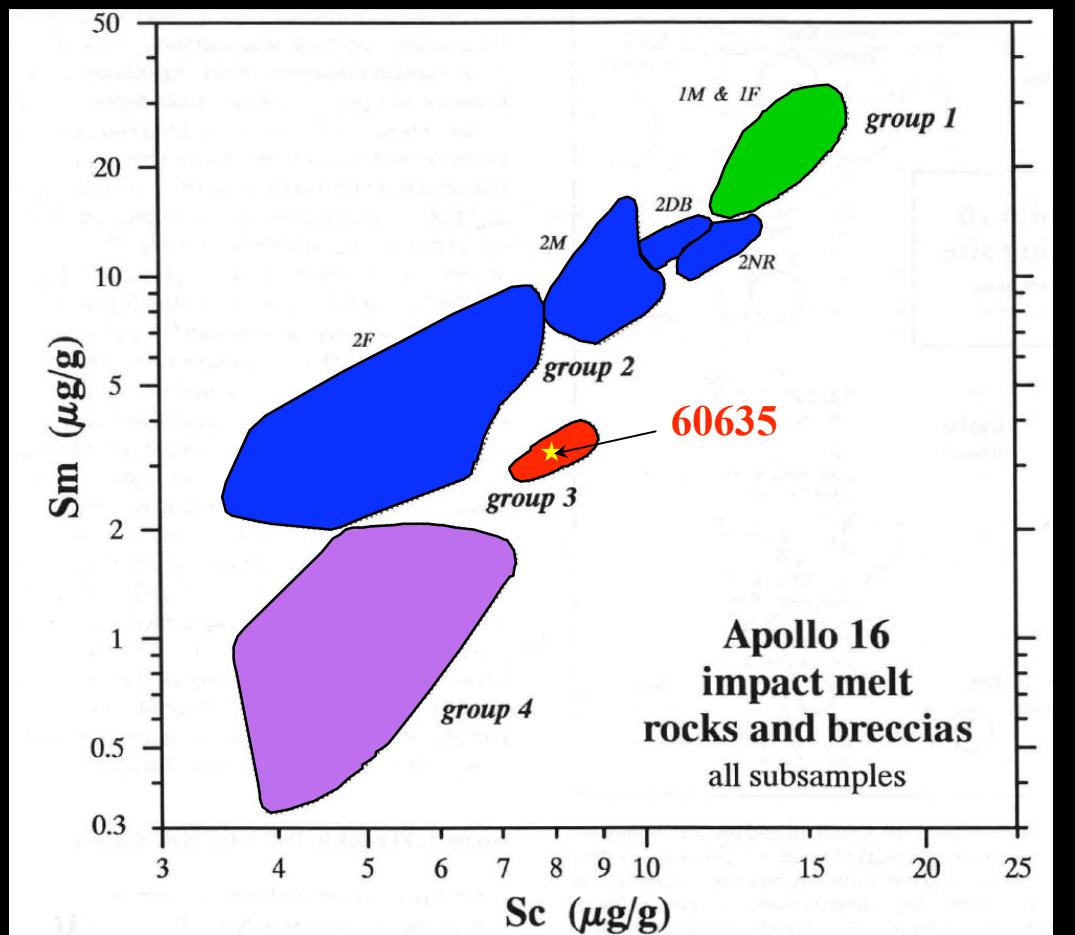
Deutsch, A. and D. Stoffler (1987), Rb-Sr-analyses of Apollo 16 melt rocks and a new age estimate for the Imbrium basin: Lunar basin chronology and the early heavy bombardment of the moon, *Geoch. Cosmo. Acta*, **51**, 1951-1964.

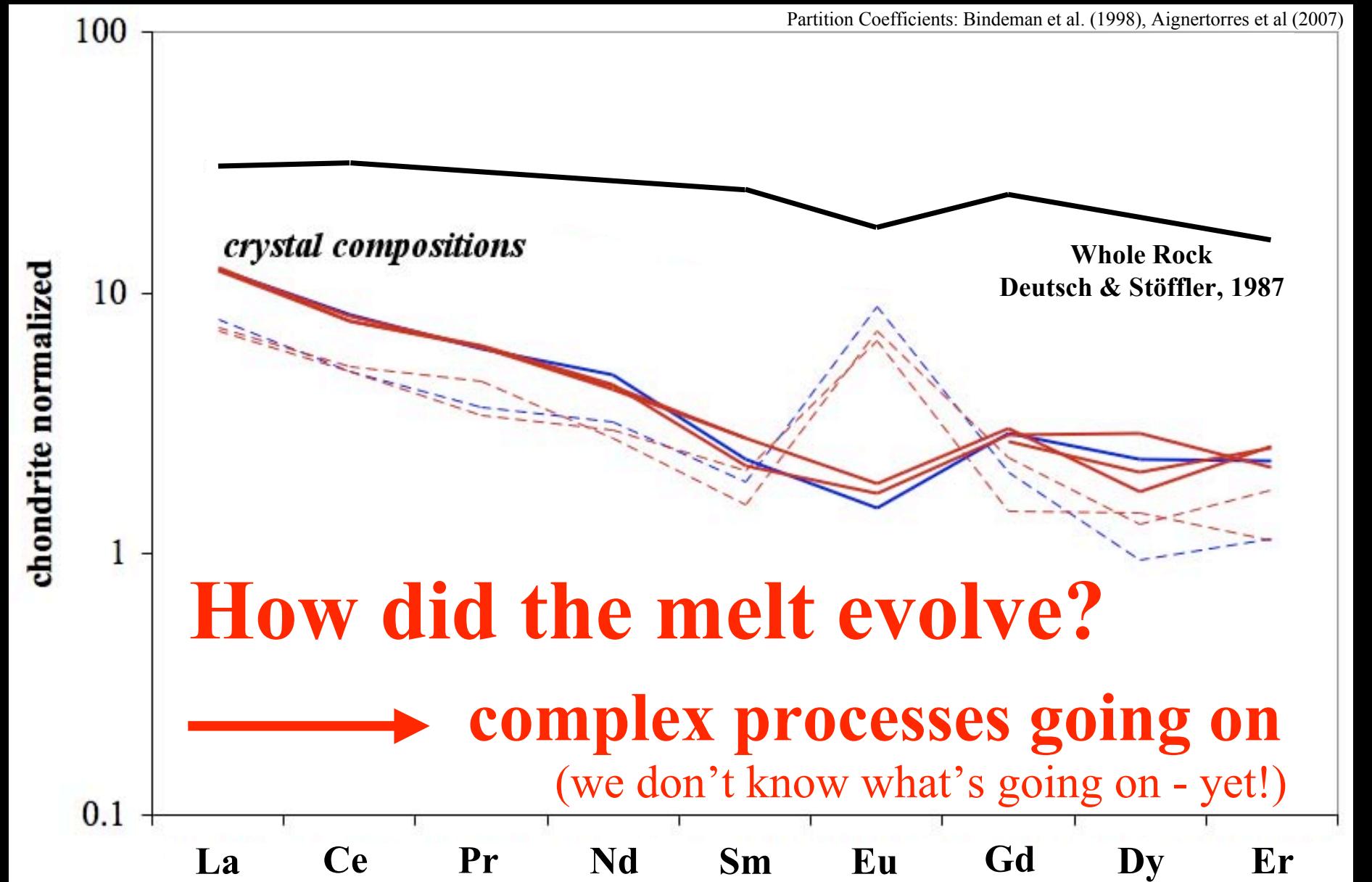
Nyquist *et al.* (1981), A comparative Rb-Sr, Sm-Nd, and K-Ar study of shocked norite 78236: evidence of slow cooling in the lunar crust?, *Proc. Lunar Planet. Sci. Conf. 12th*, 67-97.

Reimold *et al.* (1985), Isotope analyses of crystalline impact melt rocks from Apollo 16 stations 11 and 13, North Ray crater, *Proc. Lunar Planet. Sci. Conf. 15th; J. Geophys. Res.*, **90**, C431-C448.

KREEP or no KREEP?

- Korotev, 1994
 - ANMR
 - Compositional Group 3
 - Lower absolute incompatible trace element conc. than Groups 1 & 2
 - Corresponds to old, KREEP-free “Eastern” rocks (Stöffler *et al.*, 1985)





Bindeman et al. (1998), Ion microprobe study of plagioclase-basalt partition experiments at natural concentration levels of trace elements, *GCA*, 62, 1175-1193.

Aignertorres et al. (2007). Laser Ablation ICPMS study of trace element partitioning between plagioclase and basaltic melts: an experimental approach, *Contrib. Min. Pet.* 153, 647-667.

Preliminary Conclusions

- Detailed crystal stratigraphy of samples is imperative!
- Plagioclase crystals with negative Eu anomaly
 - NOT inherited
 - Cores with “KREEPY” signature
 - Not the rims
 - Crystals seeing different melts
- Highlands assimilant?
 - Problematic-thermodynamics
- Incredible intricacies in impact melt processes
 - Flow, mixing
 - Trying to explain with igneous processes isn’t working
- Can’t explain melt evolution at this time

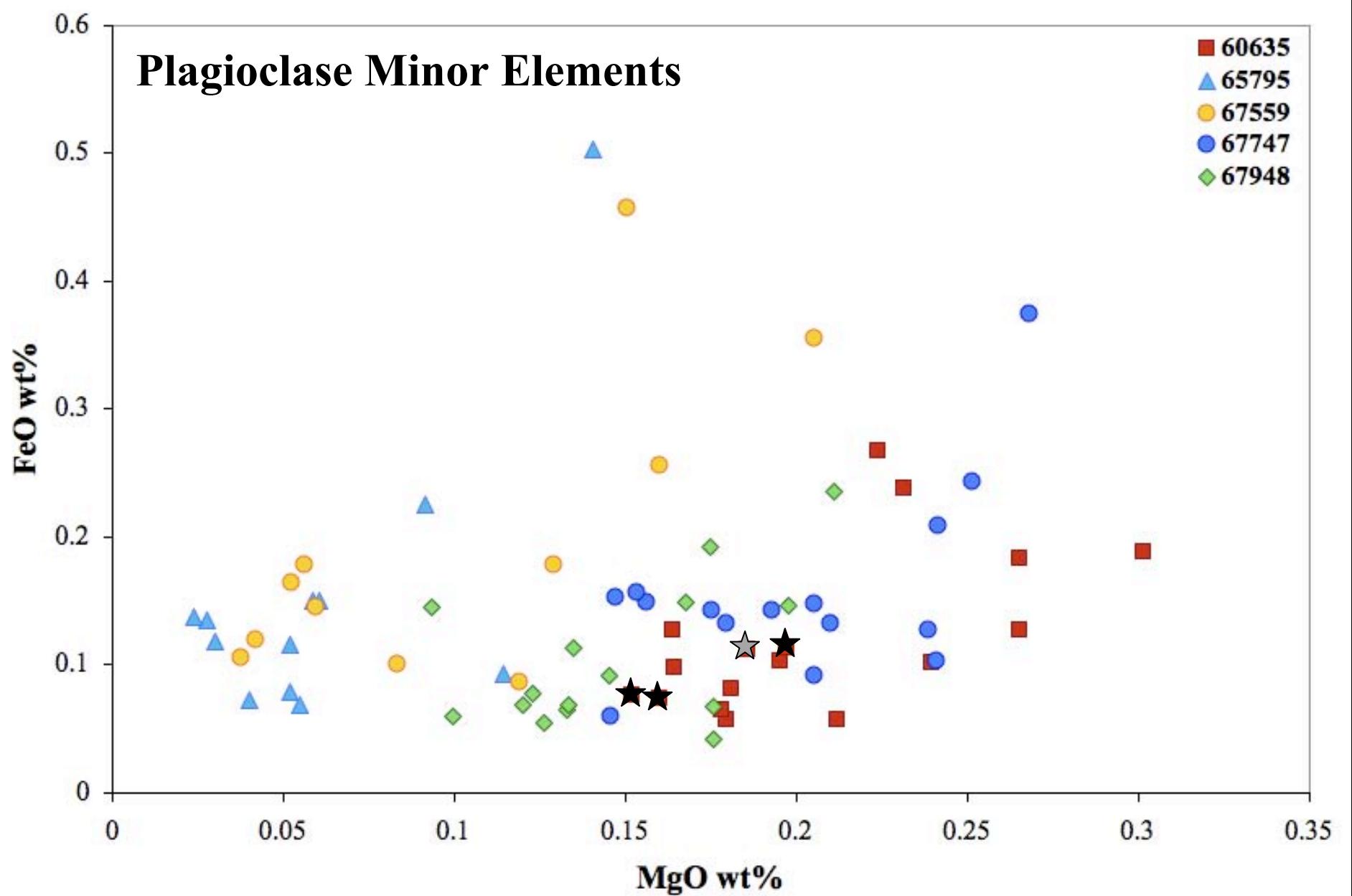


Future Work & Acknowledgements



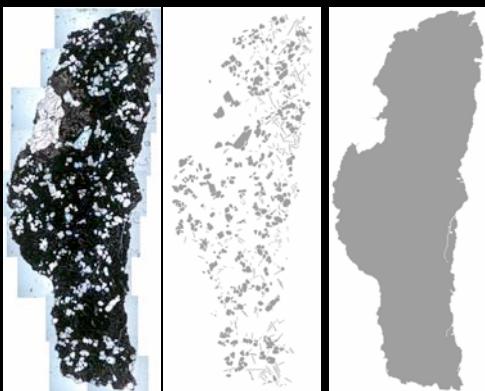
- EMP & ICP-MS
 - More plagioclase data
 - More crystals
 - More variety in crystal size
 - Pyroxene data
 - X-ray maps of plagioclases with -Eu anomaly
- Examine detailed impact processes
- Funding:
 - Univ. Notre Dame Lilly Fellowship
 - NASA Lunar Science Institute subcontract 02713-05
- Special Thanks:
 - Dr. Paul Carpenter
 - Dr. Tony Simonetti

Contact: abacasto@nd.edu



Textural Analysis: Crystal Size Distributions (CSD)

Photoshop



ImageTool [Higgins, 2000]

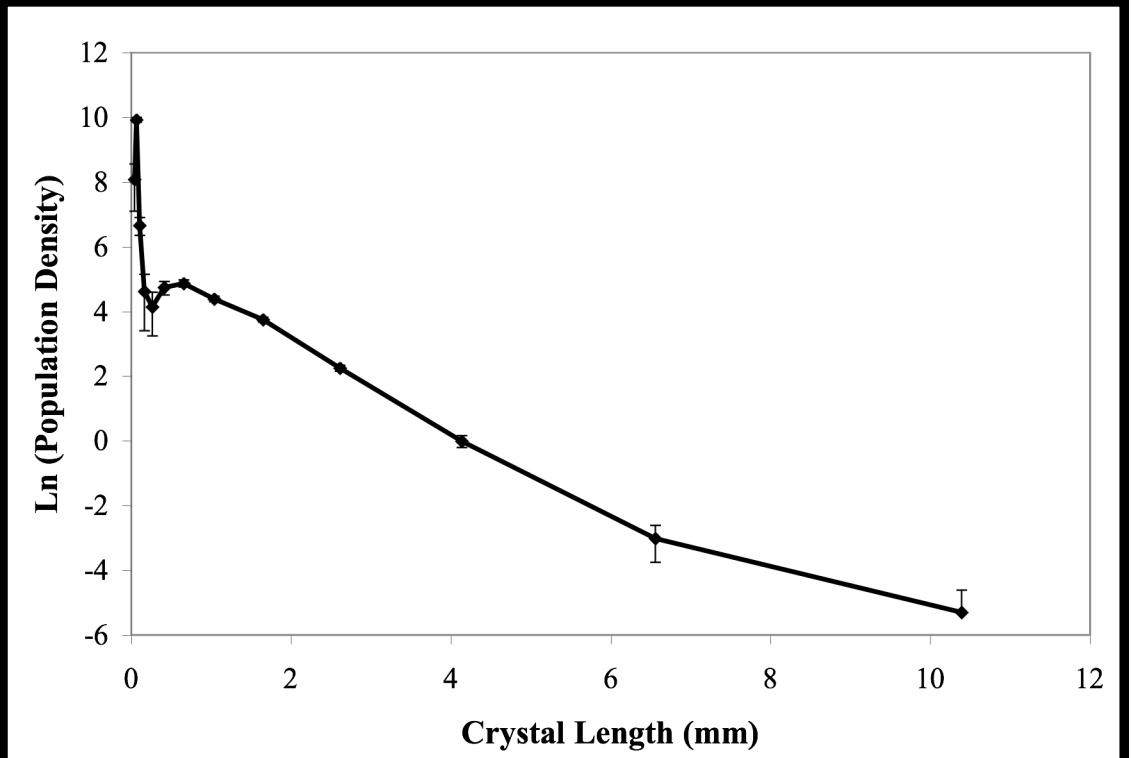
- Major and minor axes
- Roundness
- Area

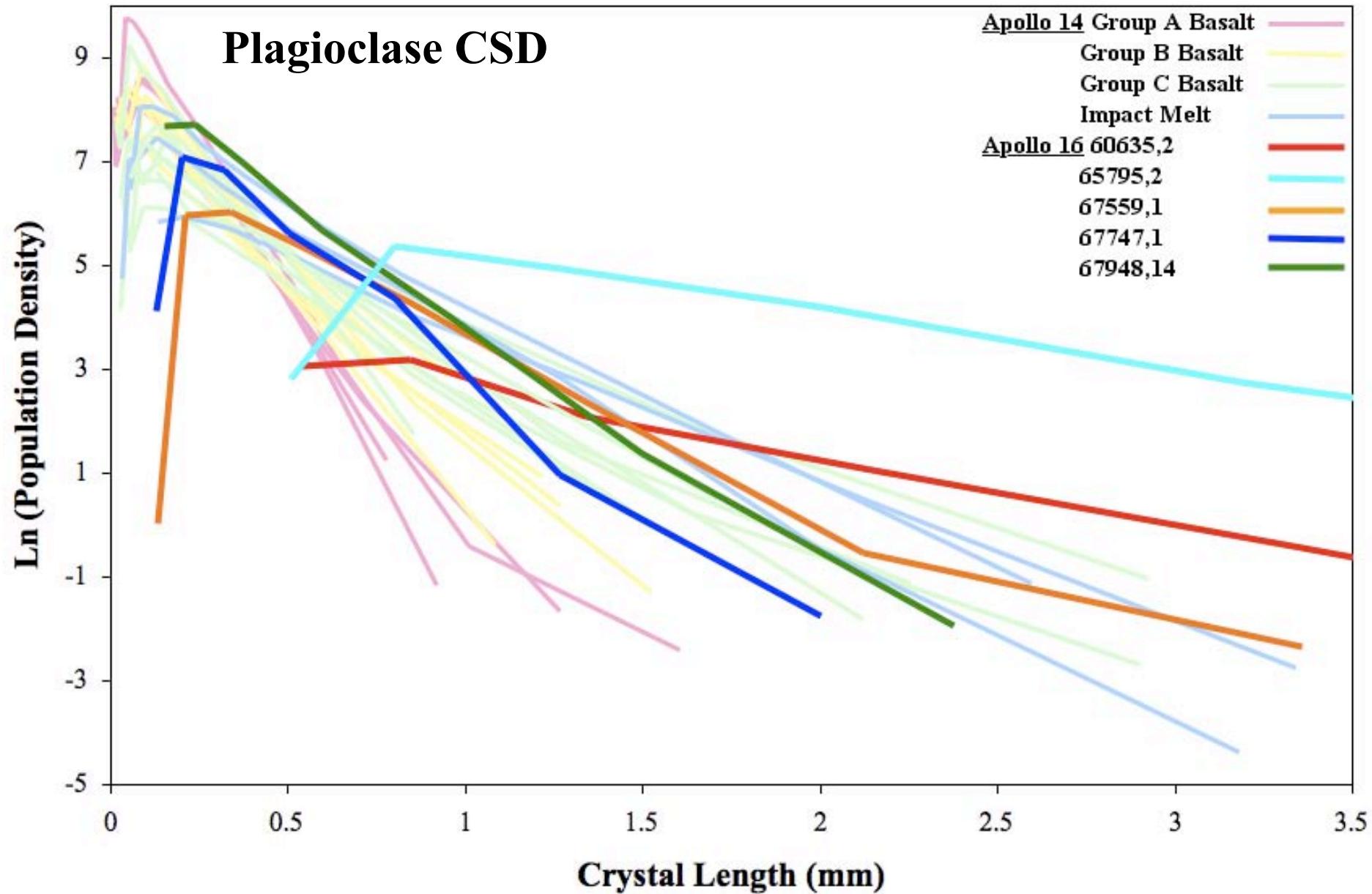
CSDslice [Morgan and Jerram, 2006]

- 3-D crystal habit
 - short
 - intermediate
 - long

CSDcorrections [Higgins, 2000]

- 3-D crystal size distribution





Field Site

