Quantitative petrography of ilmenite in lunar mare basalts

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Overview

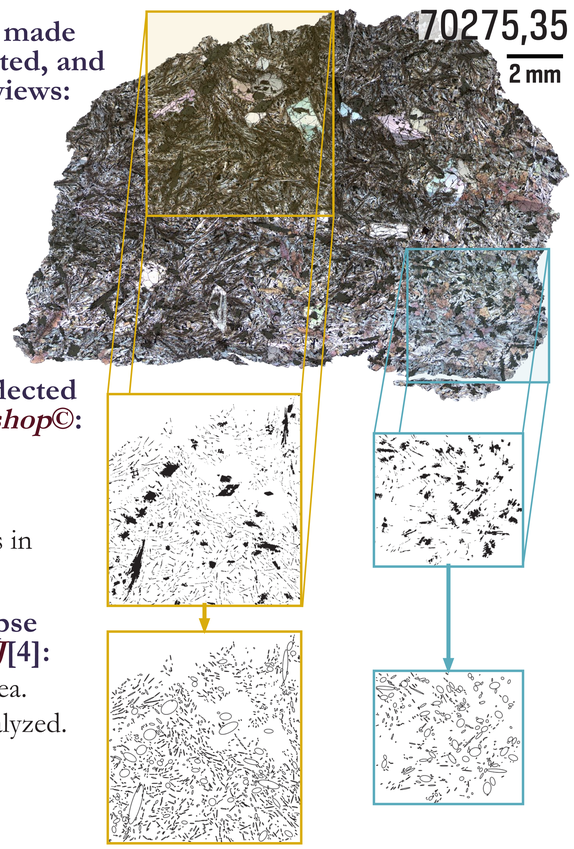
- Ilmenite is a major constituent in high-Ti lunar basalts.
- Early onset and prolonged crystallization records cooling history.
- Extend quantitative petrographic methods originally applied to Plagioclase [1] and Olivine [2] in mare basalts and impact melts.
- Apollo 17 high-Ti basalts are an ideal suite for this case study:
  - »Sampled multiple (at least five) eruptive events [3];
  - »Texture can vary from vitrophyric to equigranular within compositional suites.
- Combine quantitative textural analyses with experimental studies:
  - »Place samples in context of a lava flow.

Creating a Crystal Size Distribution

Thin section mosaics made for transmitted, reflected, and cross-polarized light views:

70275,35 example

- Two textural regions:
  - »"Fine" in yellow;
  - »"Coarse" in blue.



Traced ilmenite in reflected light in *Adobe Photoshop*©:

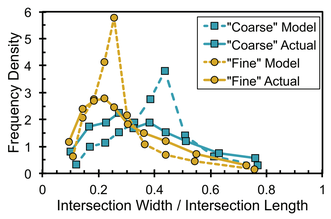
- Note similar size of largest crystals.
- Fewer small ilmenites in "Coarse" region.

Measured best-fit ellipse dimensions in *ImageJ*[4]:

- Length, width and area.
- Edge crystals not analyzed.

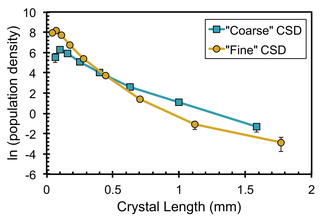
Estimated 3D crystal shape in *CSDSlice*[5]:

- "Fine" area:
  - »1:4:10, $R^2 = 0.84$.
- "Coarse" area:
  - »1:2.3:9, $R^2 = 0.74$.



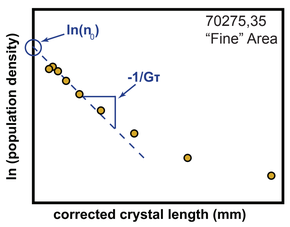
Generated CSDs in *CSDCorrections*[6]:

- Both concave up
- Similar slope at larger size bins.
- "Fine" area has steeper slope and higher intercept at small size bins.

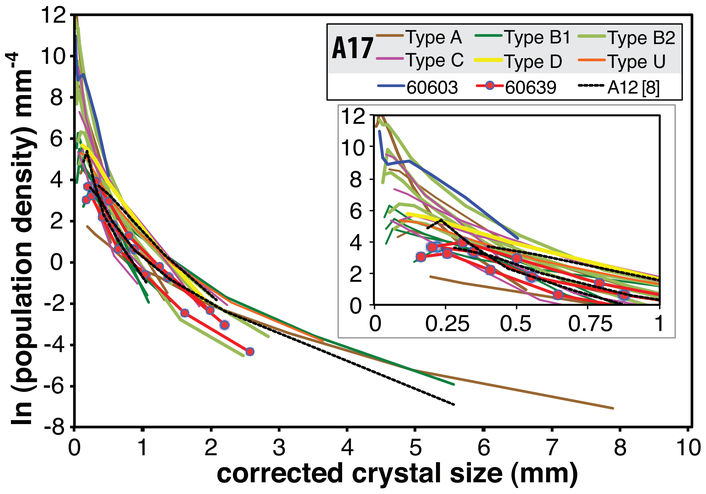


Quantified CSD to utilize slope-intercept relationships:

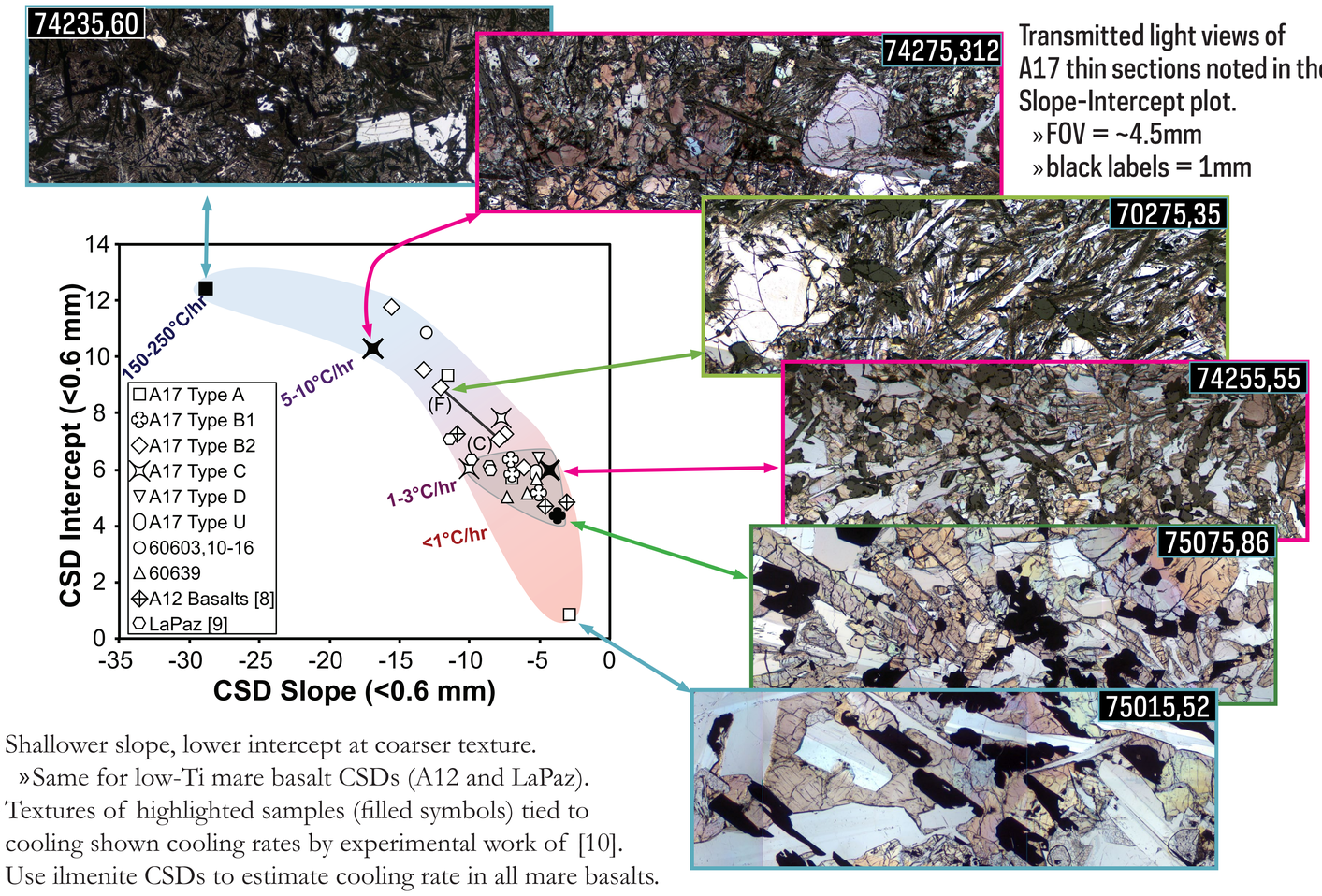
- Y-intercept a function of nucleation density [7].
- Slope is a function of growth rate (G) and residence time (τ).
- Downturn at smallest size likely an artifact of intersection effects.



CSD Profiles and Cooling Rate



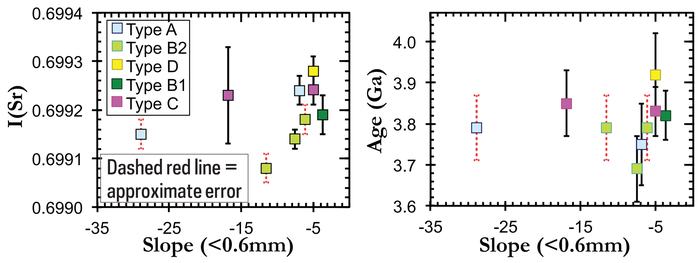
- CSDs are (sub)linear (n=12) or concave up (n=15):
  - »Subparallel at large crystal lengths;
  - »Fanning-out pattern below ~0.6mm (inset plot).
- Much like the 70275 example, finer-grained samples have steeper profiles (and thus higher intercepts).
- Larger crystals formed at shallow depths pre-eruption or at slow cooling rates.
- Smaller crystals (groundmass phase) affected by post-eruption crystal nucleation and growth:
  - »High nucleation rate raises population density.
- To investigate further, we calculate CSD profile slope and intercept for <0.6mm size bins (below).



Transmitted light views of A17 thin sections noted in the Slope-Intercept plot.
- »FOV = ~4.5mm
- »black labels = 1mm

- Shallower slope, lower intercept at coarser texture.
  - »Same for low-Ti mare basalt CSDs (A12 and LaPaz).
- Textures of highlighted samples (filled symbols) tied to cooling shown cooling rates by experimental work of [10].
- Use ilmenite CSDs to estimate cooling rate in all mare basalts.

Relative Timing of High-Ti Volcanism



- Initial-Sr [11-19] increases with decreasing slope in Types A and B2:
  - »Multiple source regions produced multiple flows.
- Two Type C basalts have same I(Sr), different cooling rate:
  - »Single Type C flow sampled?
  - »If so, samples from different locations within flow.

Conclusions

- **Petrography of ilmenite is a powerful tool in reconstructing high-Ti basalt crystallization:**
  - » Combine CSD and experimental data to estimate cooling rate in high-Ti basalts;
  - » Combine with isotope data to discern whether suites represent single or multiple flows.
- **Implications for relative timing of volcanism:**
  - » Type A: Two samples from different flows;
  - » Type B2: At least two flows sampled;
  - » Type C: Sampled two regions of a single flow.

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References

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