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# Analysis of lunar highland regolith samples from Apollo 16 drive core 64001/2 and lunar regolith simulants – an expanding comparative database

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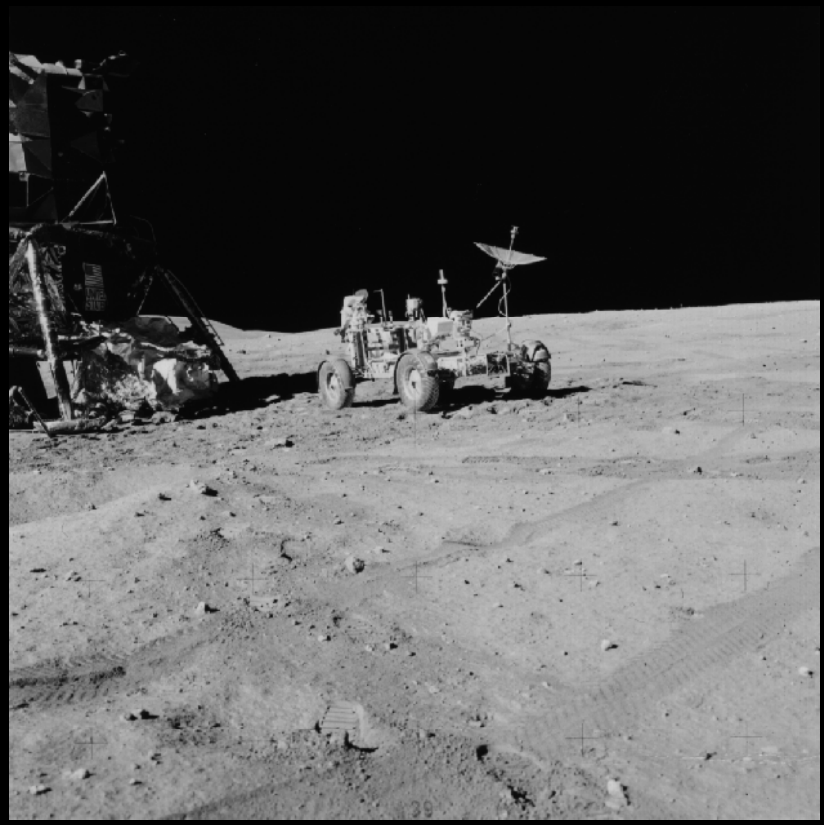
# Outline

- Background of the lunar regolith simulant effort
- Apollo site and sample selection
- Results of QEMSCAN® modal analysis of lunar material
  - change in major mineral modal% with size fraction
  - comparison of major/trace minerals in sieved vs. thin section samples

# Outline, cont.

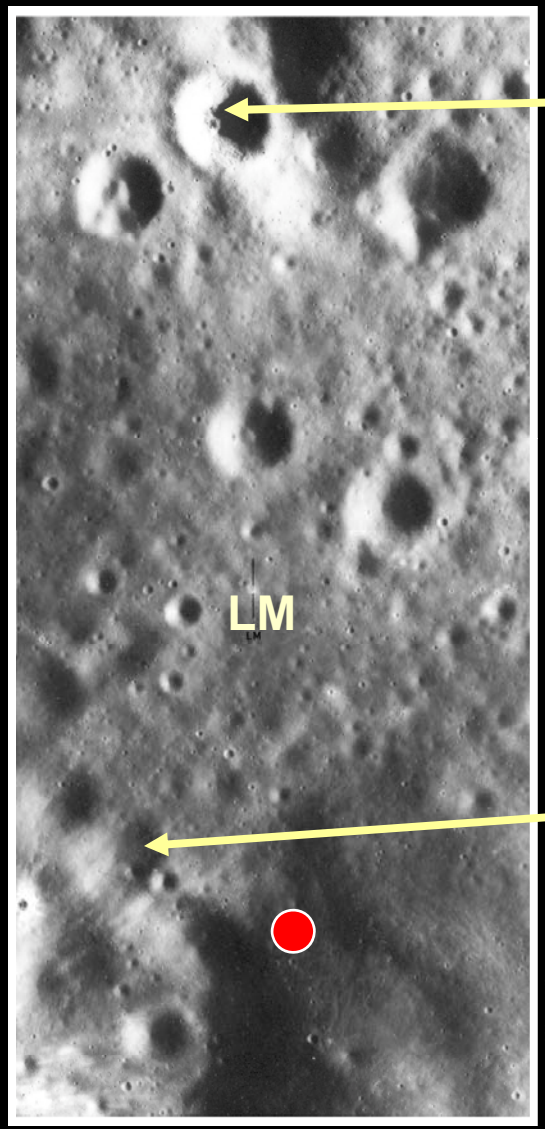
- Results of analysis of simulants vs. Apollo samples
- Future, ongoing, and parallel work

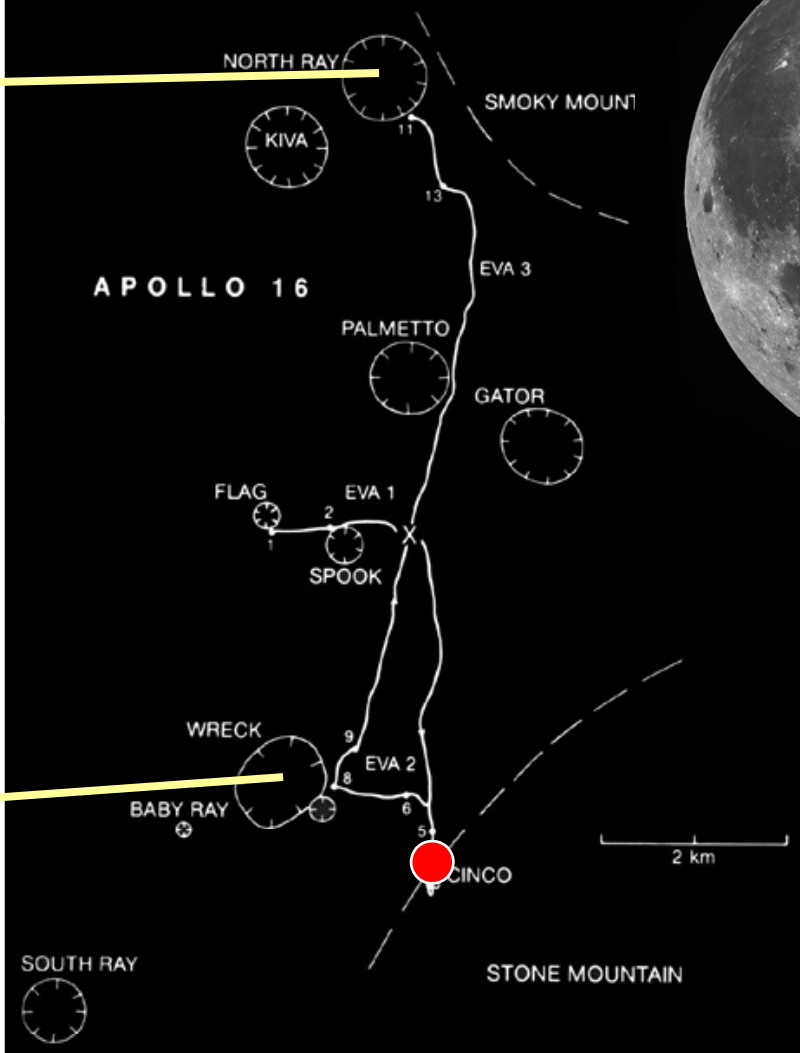


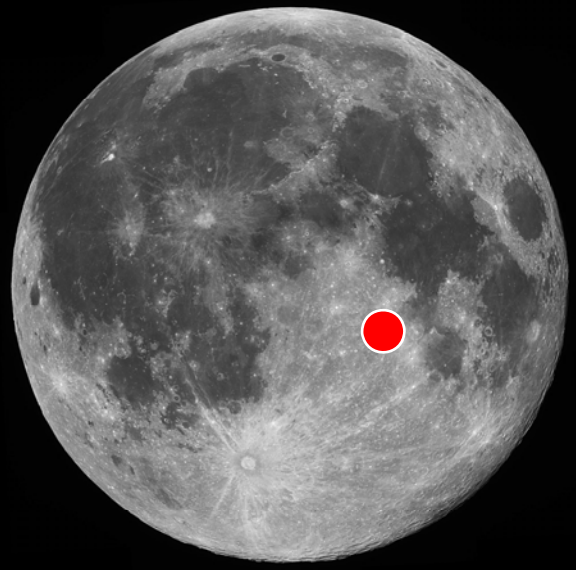
# In support of a future lunar outpost...

- This work is part of a larger effort to compile an internally consistent database on lunar regolith (Apollo samples) and lunar regolith simulants.
  - Characterize existing lunar regolith and simulants in terms of
    - Particle type
    - Particle size distribution
    - Particle shape distribution
    - Bulk density
    - Other compositional characteristics
  - Evaluate regolith simulants (Figure of Merit) by above properties by comparison to lunar regolith (Apollo sample)

# Apollo 16 site



Station 4:
64001/64002

# Station 4 samples

## geochemical data from Korotev (1982) and Korotev et al. (1984)

**64002**
**(Houck, 1982)**

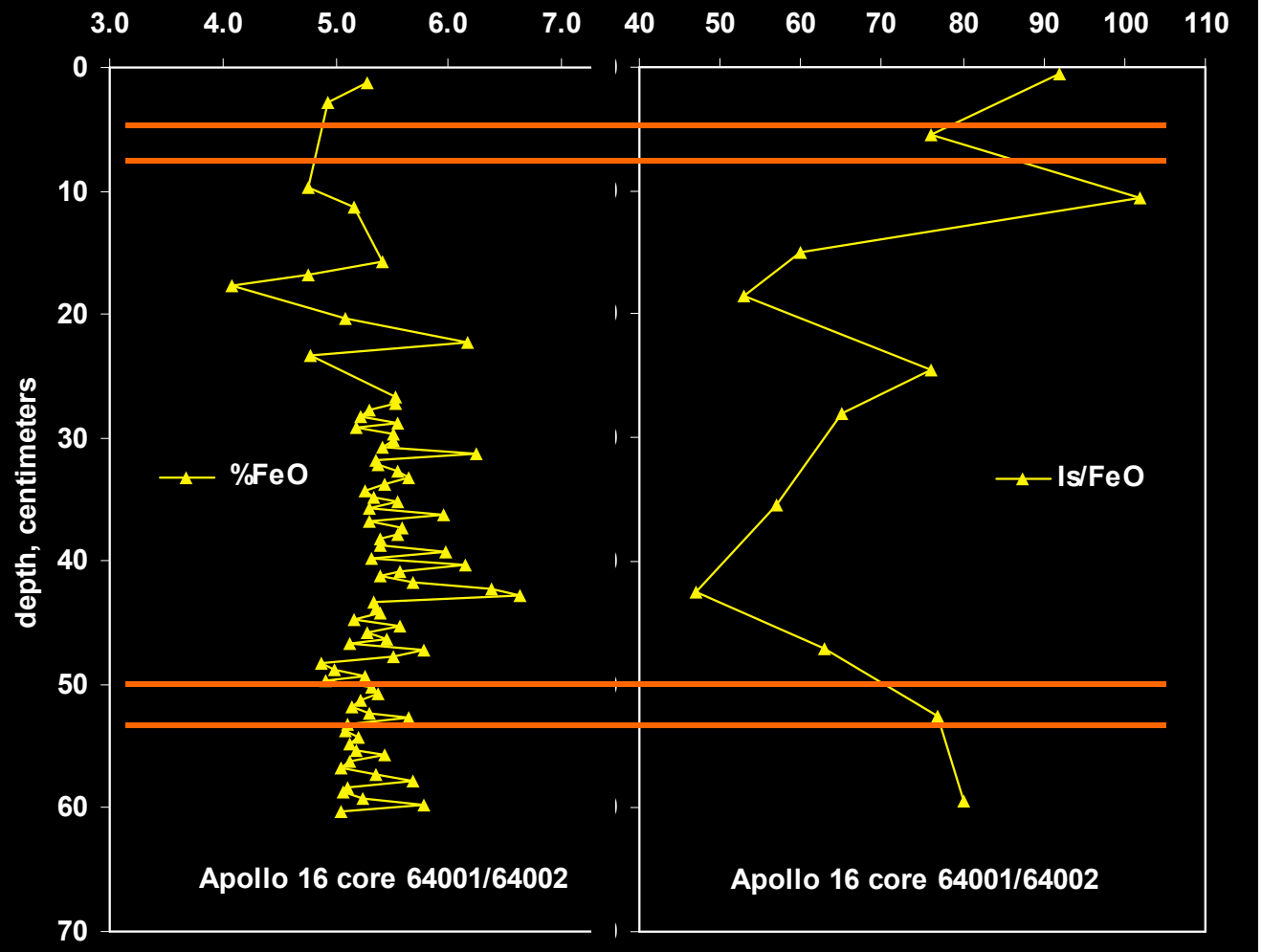
**One thin-section**
64002,6019: 5.0 – 8.0 cm

**Eight sieved samples**
64002,262: 5.0 – 5.5 cm

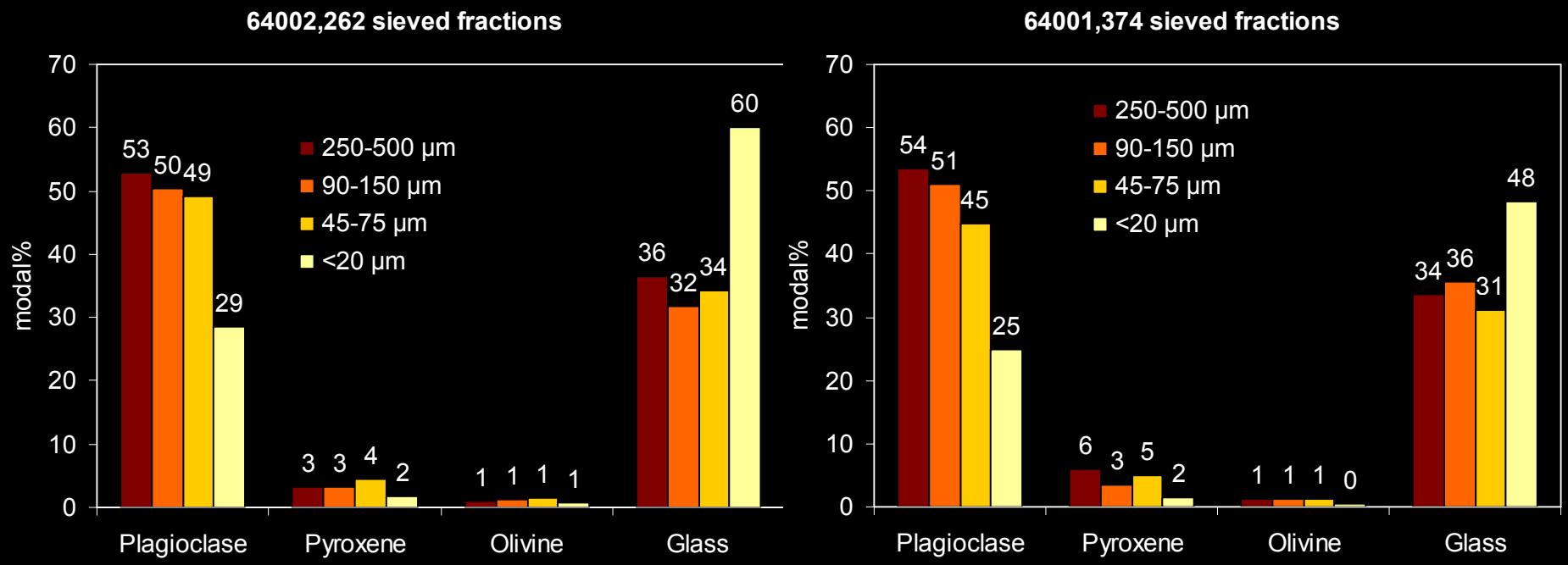
**64001**
**(Basu & McKay, 1984)**

**One thin-section**
64001,6031: 50.0 – 53.1 cm

**Eight sieved samples**
64001,374: 52.0 – 52.5 cm

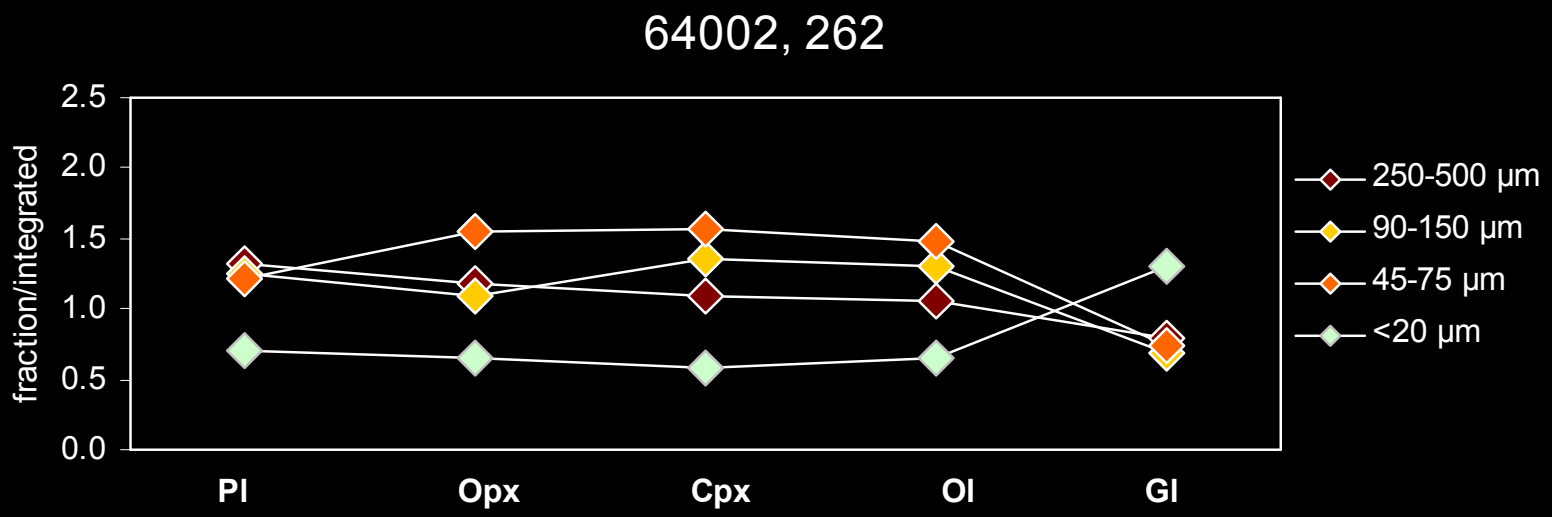


# Modal analysis of sieved grain mounts




As size decreases, glass modal% increases at the expense of mineral modal%.

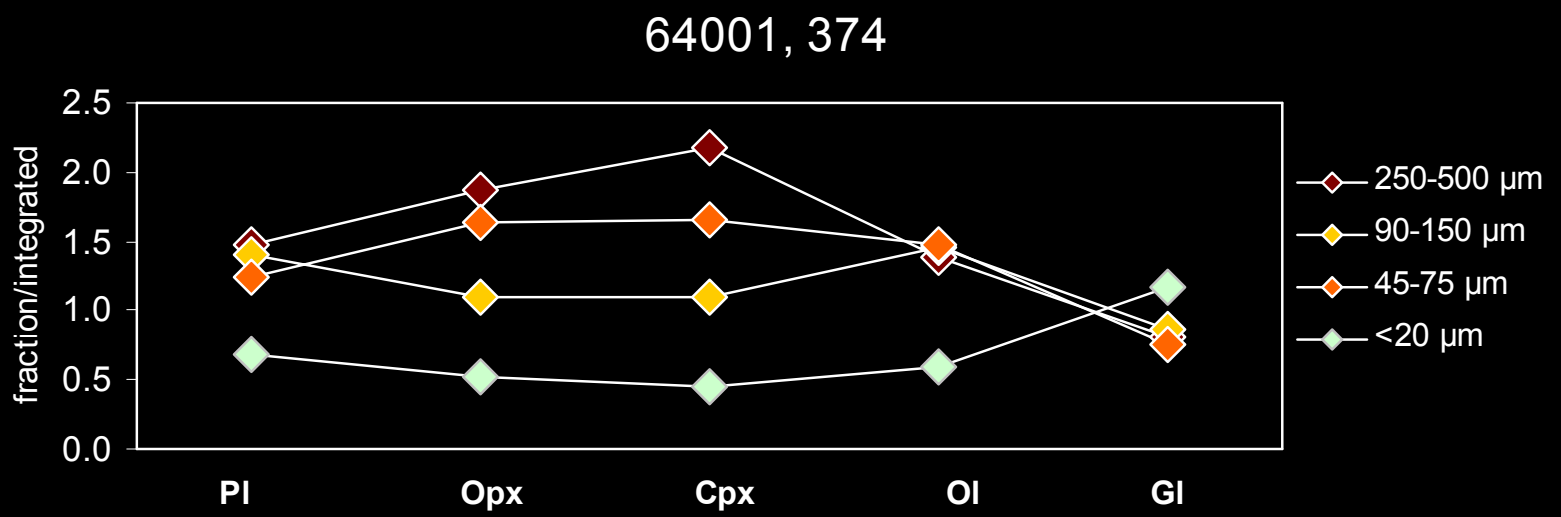
# Change in modal% by size fraction: 64002,262




<20 µm fraction: All minerals are depleted relative to bulk sample: 29-43%. Glass is enriched relative to bulk sample: 30%.

All fractions: Plagioclase is increasingly depleted as grain size decreases. The 250-500 µm fraction is less enriched in other minerals than in the 64001 sample.

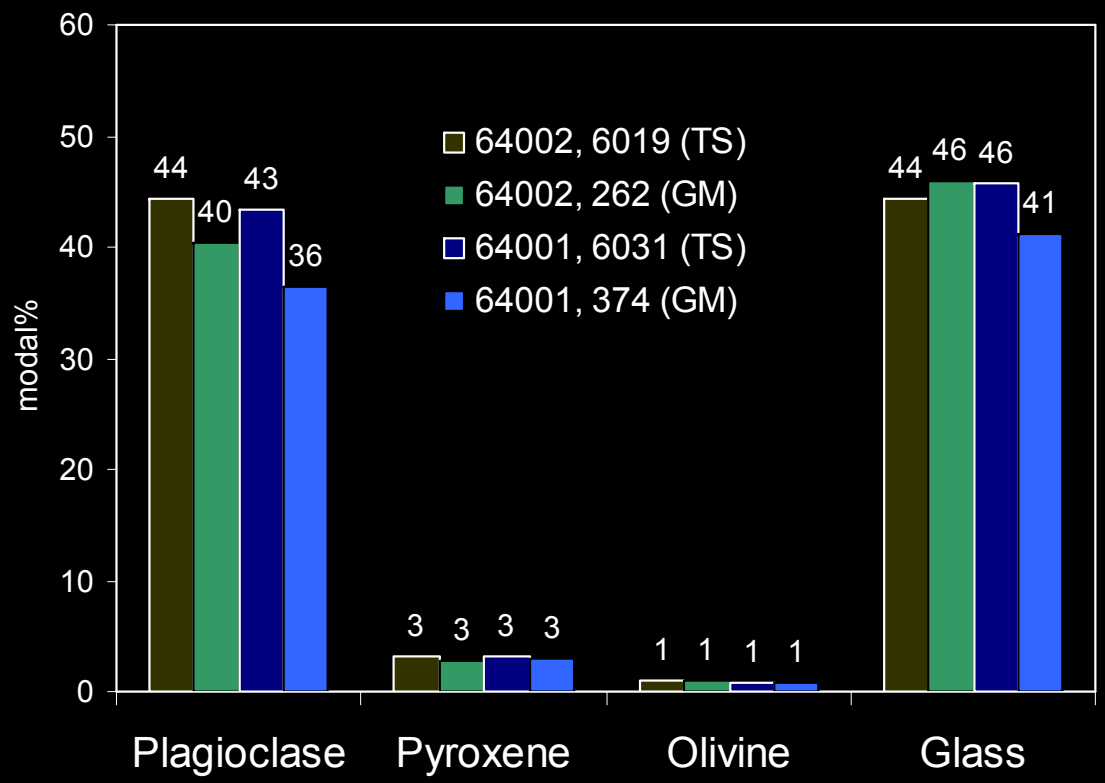
# Change in modal% by size fraction: 64001,374




<20 µm fraction: All minerals are depleted relative to bulk sample: 32-56%. Glass is enriched relative to bulk sample: 17%.

All fractions: Plagioclase, pyroxenes, and olivine are increasingly depleted as grain size decreases.

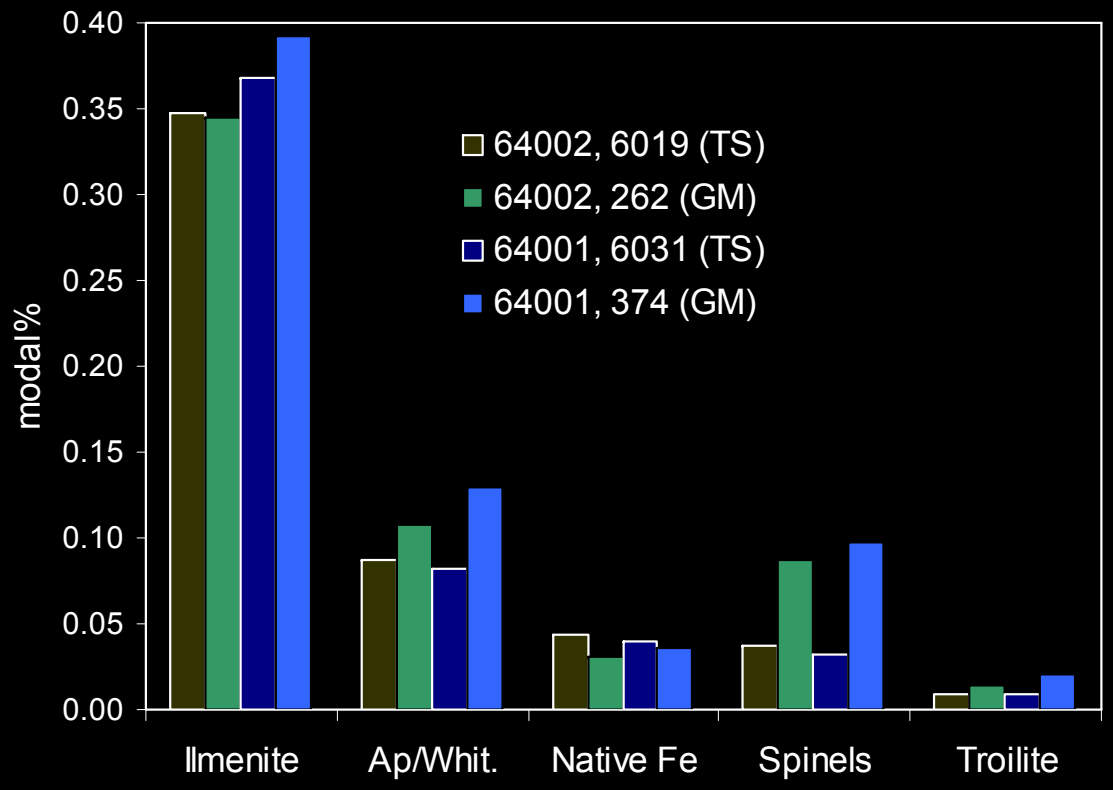
# Modal analysis: thin sections versus integrated bulk grain mounts




- Minerals report as higher in thin section than in corresponding integrated grain mounts.
  - Edge effects/mixed phases in thin sections report as minerals?
  - Real effect from missing fractions in grain mounts?
  - Sampling error from sieving?

Glass shows less regular pattern.

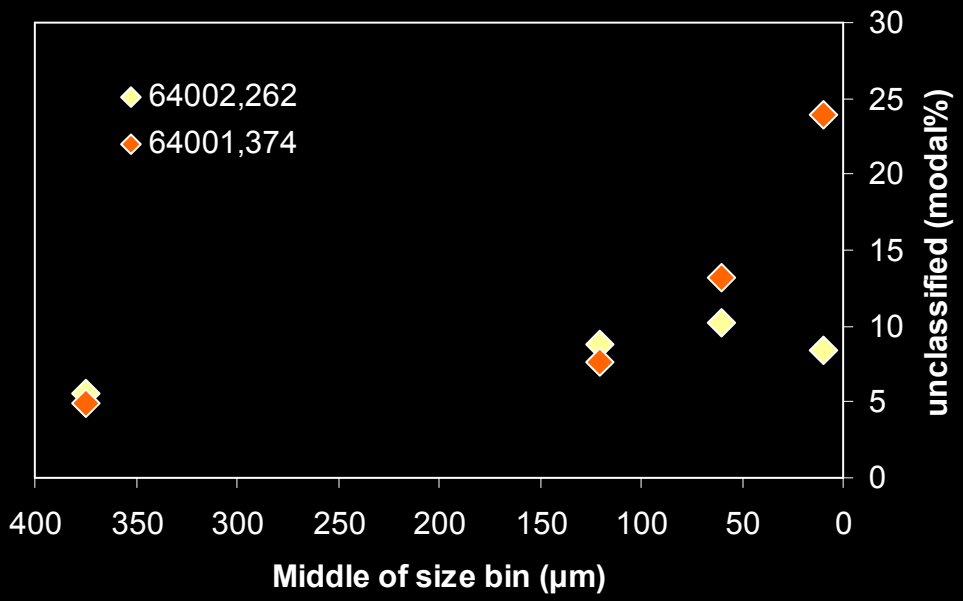
# Modal analysis: thin sections versus integrated bulk grain mounts




Trace Minerals:

- Given, the very low amounts of some trace minerals (<0.01 modal%), the consistency is encouraging.
- Some of these are especially important to *In Situ* Resource Utilization (ISRU) on the moon.

# Unclassified material in QEMSCAN® modal analysis




Thin sections
64002,6019: 6.6% unclassified
64001,6031: 6.4% unclassified

Integrated grain mounts
64002,262: 8.4% unclassified
64001,374: 16.9% unclassified

The modal% of unclassified material:

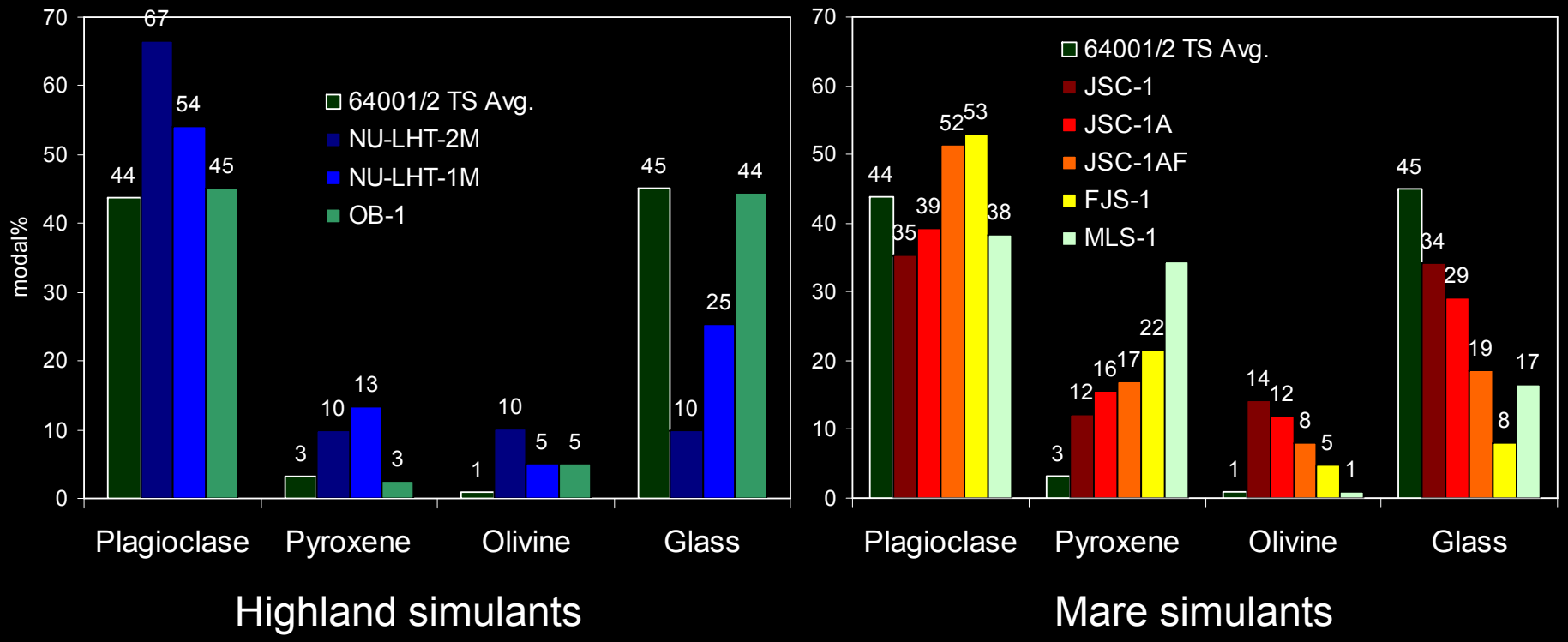
- ranges from ~5-24% in any one analysis;
- *tends* to increase as size fraction decreases in grain mounts;
- is higher in integrated grain mounts than in thin sections
  - (is more material *mis*classified due to edge effects and phase mixing?)
  - (is this from another, unknown effect?)

# Lunar simulants: Mare and Highlands

**NU-LHT-1M lunar highlands simulant**

**JSC-1A lunar mare simulant**

# Overview: Major mineral modal comparison between simulants and 64001/64002

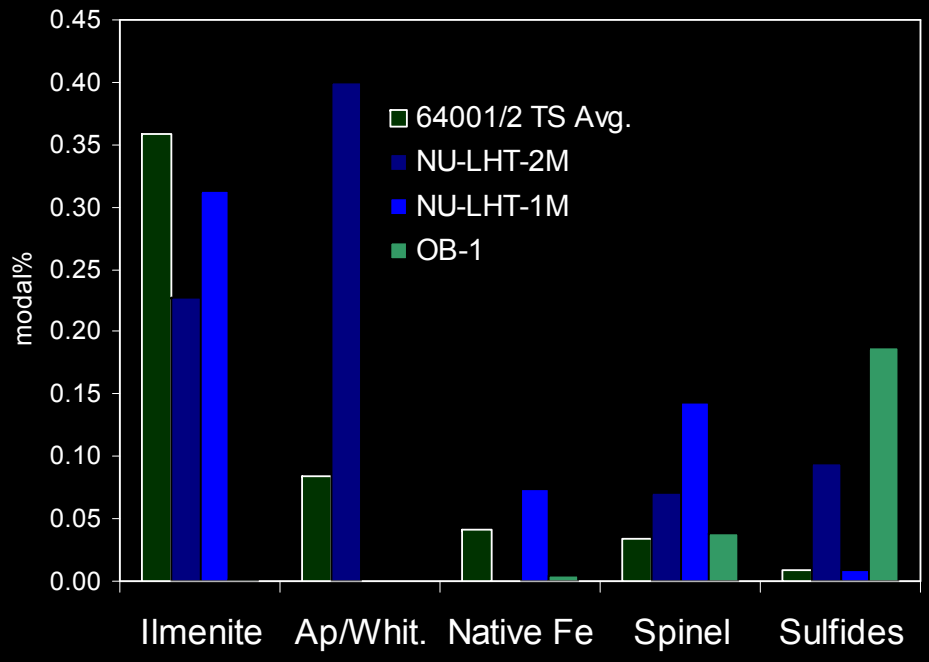



Highland simulants

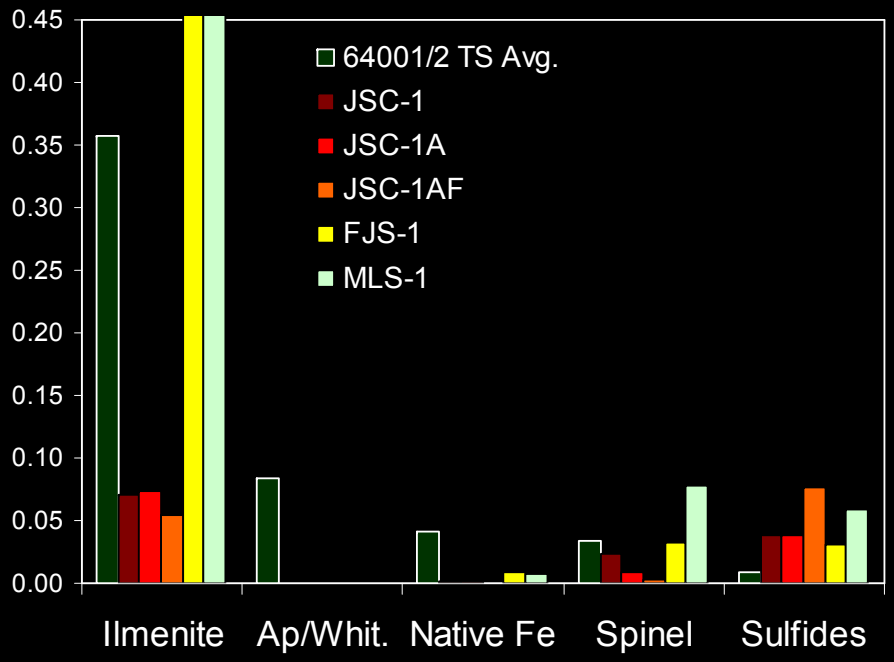
Mare simulants

We are incorporating particle type data (e.g., the presence of agglutinates) and phase chemistry into these comparisons.

# Overview: Trace mineral modal comparison between simulants and 64001/64002




Highland simulants




Mare simulants

We are incorporating particle type data (e.g., the presence of agglutinates) and phase chemistry into these comparisons.

# Further and ongoing work

- Continue to analyze Apollo samples by total phase modal%.
- Incorporate particle type modal analysis by determining which phases are present in lithics, breccias, agglutinates, etc.
- Incorporate phase chemistry.

- Analyze simulants by these same techniques for comparison by Figure of Merit algorithms.

# Parallel work

Characterizing particle size and shape distributions and bulk densities of lunar regolith and simulants for comparison by FoM.

# References


Basu, A. and Mckay, D.S., “Petrologic Profile of Apollo 16 Regolith at Station 4”, *Proceedings of the 15th Lunar and Planetary Science Conference*, Part 1, *Journal of Geophysical Research*, Vol. 89, Supplement, 1984, pp. C133-C142.

Houck, K.J., “Modal Petrology of Six Soils from Apollo 16 Double Drive Tube 64002”, *Proceedings of the 13th Lunar and Planetary Science Conference*, Part 1, *Journal of Geophysical Research*, Vol. 87, Supplement, 1982b, pp. A210-A220.

Korotev, R.L., “Comparative Geochemistry of Apollo 16 Surface Soils and Samples from Cores 64002 and 60002 through 60007”, *Proceedings of the 13th Lunar and Planetary Science Conference*, Part 1, *Journal of Geophysical Research*, Vol.. 87, Supplement, 1982, pp. A269-A278.

Korotev, R.L., Morris, R.V., and Lauer, H.V., Jr., “Stratigraphy and Geochemistry of the Stone Mountain Core (64001/2)”, *Proceedings of the 15th Lunar and Planetary Science Conference*, Part 1, *Journal of Geophysical Research*, Vol. 89, Supplement, 1984, pp. C143-C160.