

MISSION TO THE RIMA BODE REGIONAL PYROCLASTIC DEPOSIT

Exploration for Science and Resources

Paul D. Spudis

Lunar and Planetary Institute and Moon Express Inc.

Robert D. Richards

Moon Express Inc.

Lunar Science for Landed Missions Workshop

January 11, 2018

Background

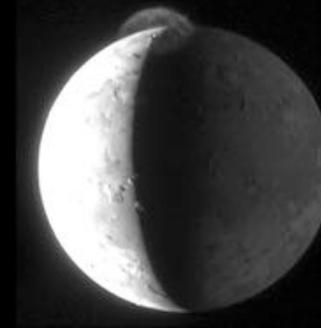
- Moon Express plans to launch its first lunar landing mission sometime this year
- Early lander missions to emphasize safety, simplicity, short mission duration, significance
- Desire mission profile that provides both important scientific and exploration (resource utilization) results



Lunar Pyroclastics

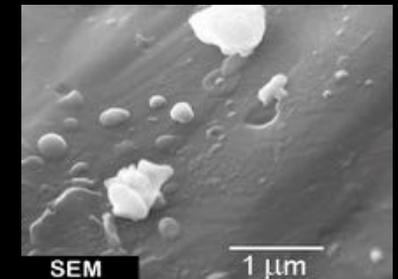
- **Scientific value**

- Primitive, unmodified magmas from the deep mantle
- Source regions contain volatiles
- Eruption mechanisms, dynamics - source of deep-seated rock fragments?



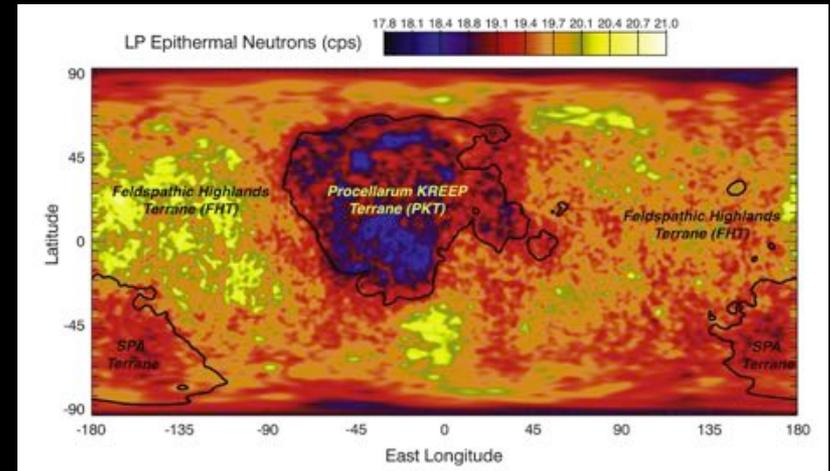
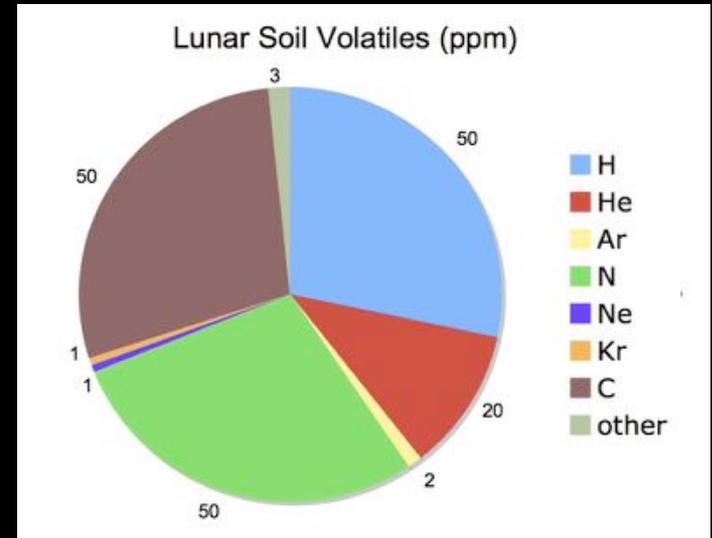
- **Resource value**

- Uniform, fine-grained deposits - easy feedstock for resource processing
- Solar wind gas content may be enhanced in pyroclastics; if so, a potential “ore” deposit for H₂ recovery

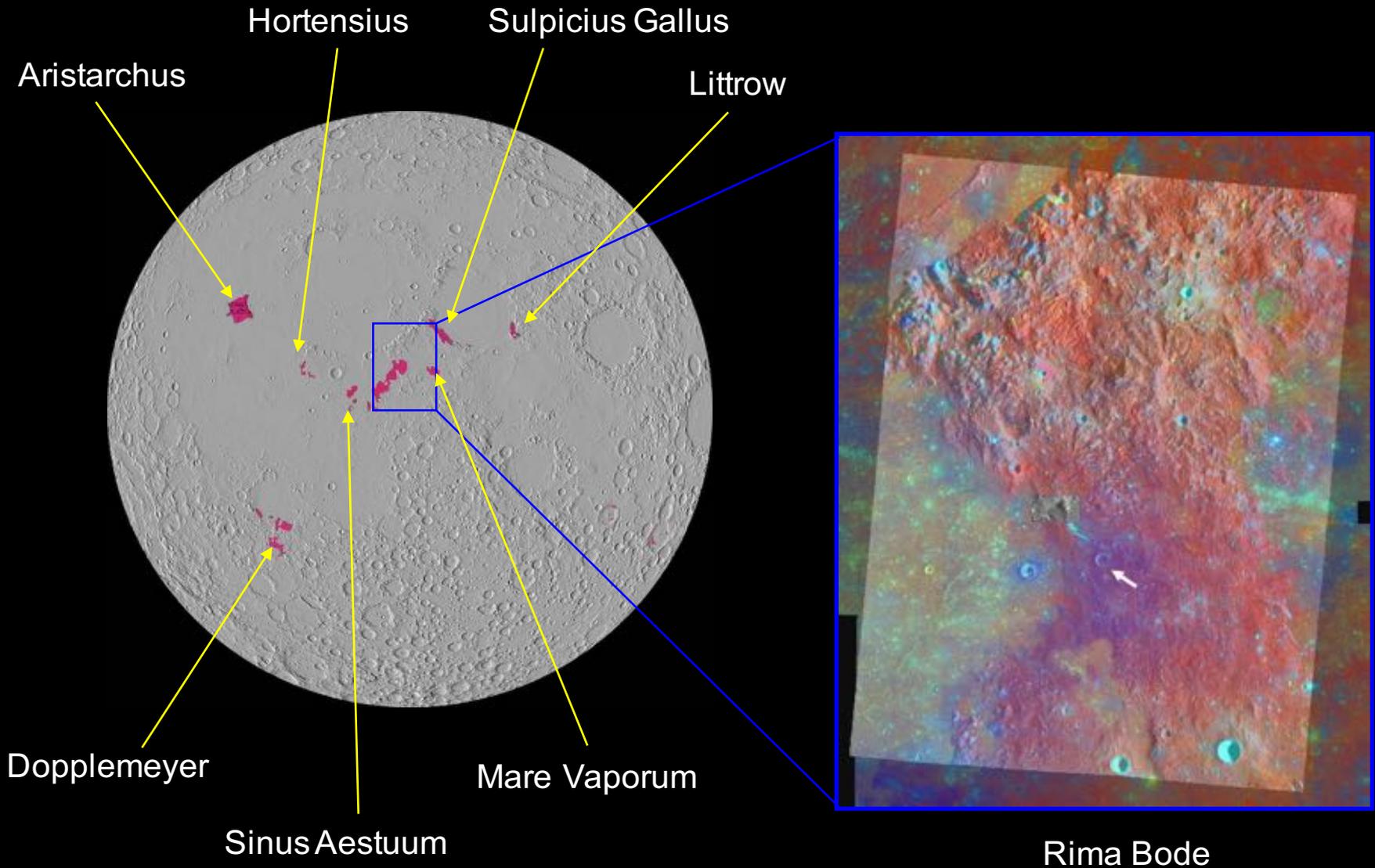


The Premise

- Quantity of solar wind implanted H_2 in lunar soils is positively correlated with:
 - Smaller median grain size
 - Fe-Ti (ilmenite) content
 - Soil maturity
- These properties suggest highest solar wind H_2 should be found in mature, high-Ti pyroclastic glasses
- Pyroclastics sampled by Apollo were either wrong composition (VLT green glass) or immature (High-Ti orange-black glass; buried)
- High-Ti, mature regional pyroclastic deposits should be best non-polar locales to process for hydrogen and oxygen production

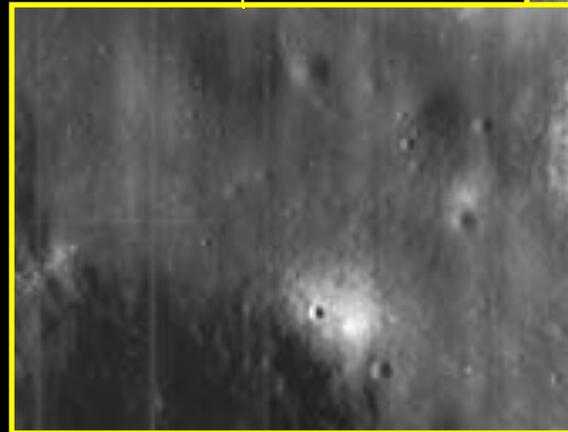
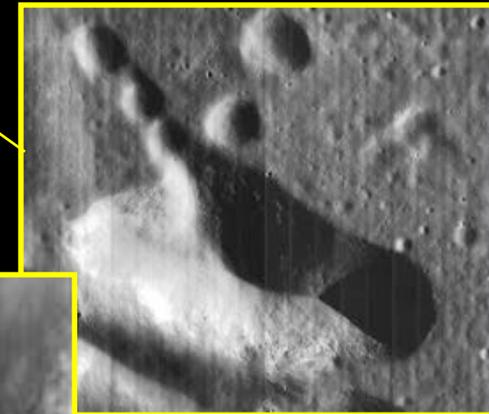
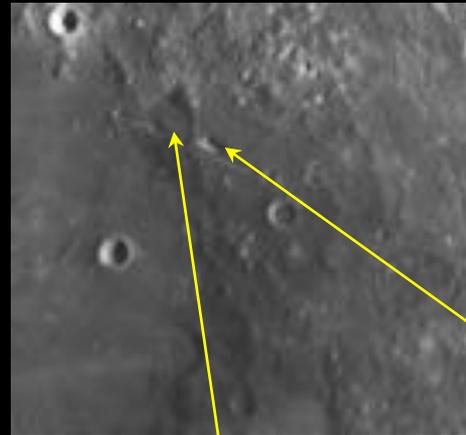


Distribution of Regional Pyroclastics

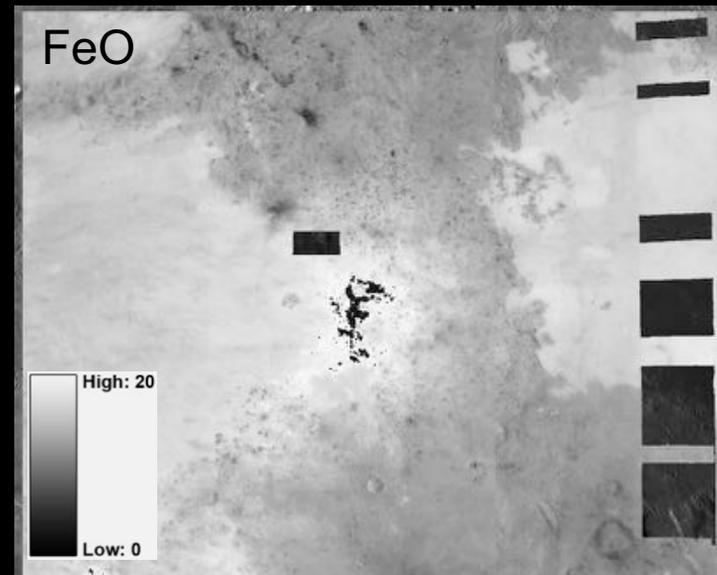
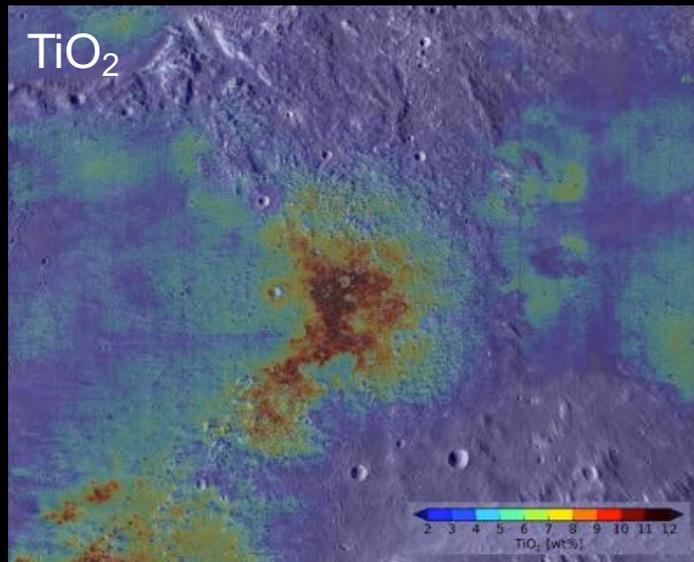
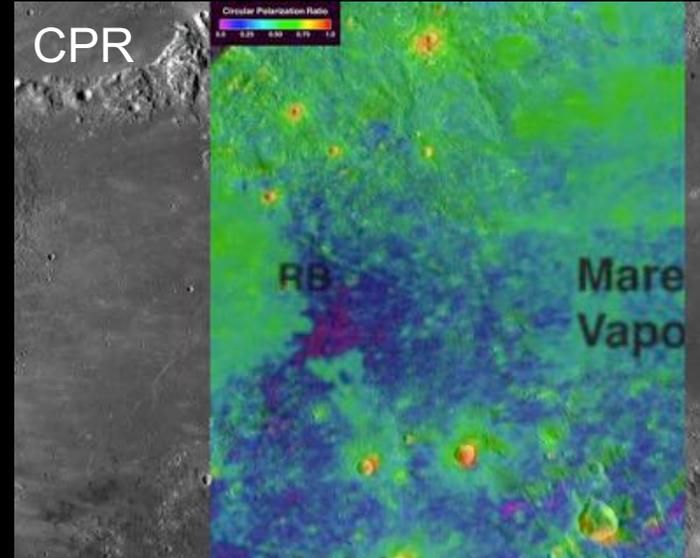


Rima Bode Pyroclastic Deposits

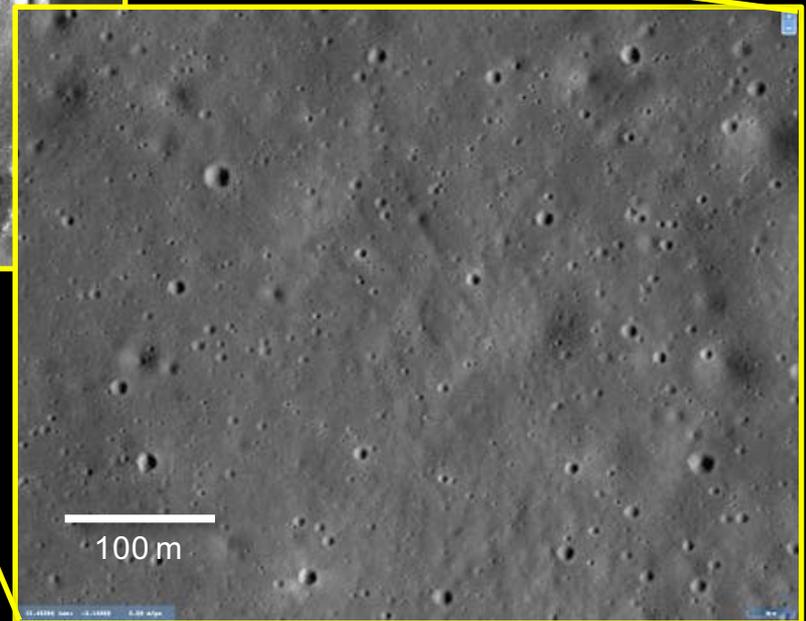
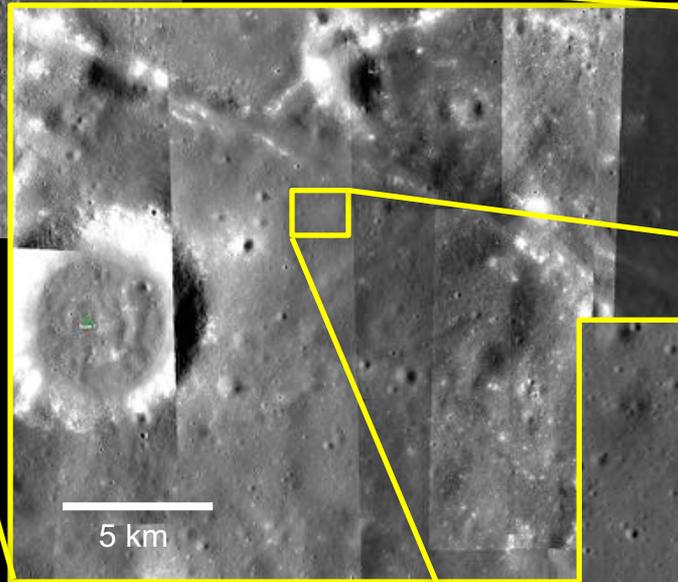
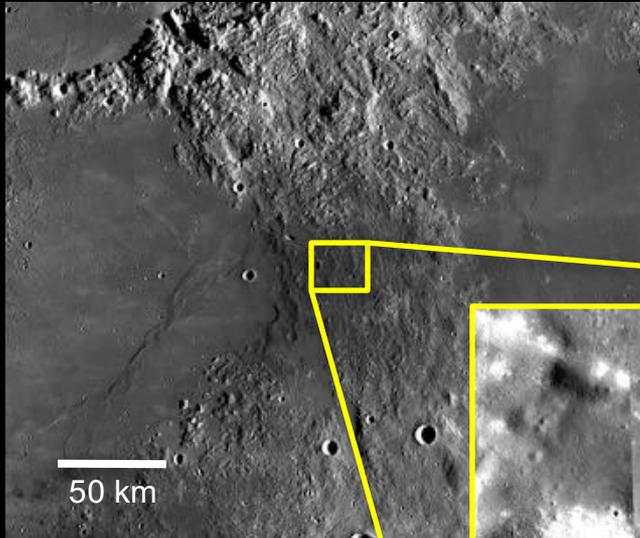
- Extensive, regional dark mantling deposit ($\sim 7000 \text{ km}^2$)
- Very low albedo (0.075-0.089; black glass?)
- Embayed by (older than) maria 3.5 billion years old
- Complex vent and rille system associated with eruption
- Near center of near side (12°N , 3°W); smoothed terrain of lunar ash beds
- Xenoliths from deep in the Moon may be found near vent



Rima Bode



Rima Bode



MX-1 Lander

Mission to a Regional Pyroclastic Deposit



First lander could be outfitted with only two instruments

Alpha particle backscatter (Surveyor) - determine chemical composition of pyroclastic deposit

NS - measure bulk H_2 in upper meter of regolith



Instruments mounted underneath spacecraft (close contact with lunar surface desired)

Measurements (2) complete within ~ 1-2 hours

Measurements at a second point (after hop) desired but not critical

First direct measurement of the composition of a mature high-Ti pyroclastic deposit

Possible Instruments

| Instrument | Information | Mass (kg) | Power (W) | Volume (cm) | Comments/Heritage |
|----------------------|--------------------------|-----------|-----------|--------------|---|
| APX | Major and minor elements | 0.5 | 3 | 5 x 5 x 5 | Low data rate, analysis time; MER |
| MS imager | Mineralogy | 2 | 2 | 7 x 7 x 2 | 5 bands @ 410, 750, 900, 950, 1000 nm, high rate; Clementine, LROC |
| EGA | Solar wind gas content | 4 | 8 | 10 x 10 x 8 | Need soil sampler (surface only), low rate; Mars Phoenix lander |
| Neutron spectrometer | Total hydrogen | 0.5 | 2 | 20 x 5 x 5 | Passive; ~10 min. integration time, low rate; Lunar Prospector, Mars Odyssey |
| Imaging lidar | Topography | 4 | 10 | 50 x 30 x 30 | Navigate and topographic mapping, high data rate; terrestrial models |
| Magnets | Magnetic properties | < 0.5 | -- | 5 x 5 x 2 | Study magnetic properties of dust, resource and utilization properties; Viking, MER |

Conclusions

- First Moon Express landed mission will likely go to a site selected for safety and operational ease of use, yet desired to be scientifically significant and useful for exploration
- Rima Bode meets these requirements. Analysis of surface materials serves both scientific and resource utilization strategic knowledge needs
- Mission operations are simple and of short duration (results within a couple of hours after landing)
- Lunar pyroclastics offer a significant non-polar resource for ISRU processing for propellant and life support consumables