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science for a changing world

Applying the USGS Resource Assessment Methodology to the Moon: Three Very Different Cases

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Outline

- The USGS “way”
- Solar Power
- Lunar Regolith
- Lunar Ice
- Discussion

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USGS: Doing resource assessments since 1879

REPORT

ON THE

LANDS OF THE ARID REGION

OF THE

UNITED STATES,

WITH A

MORE DETAILED ACCOUNT OF THE LANDS OF UTAH.

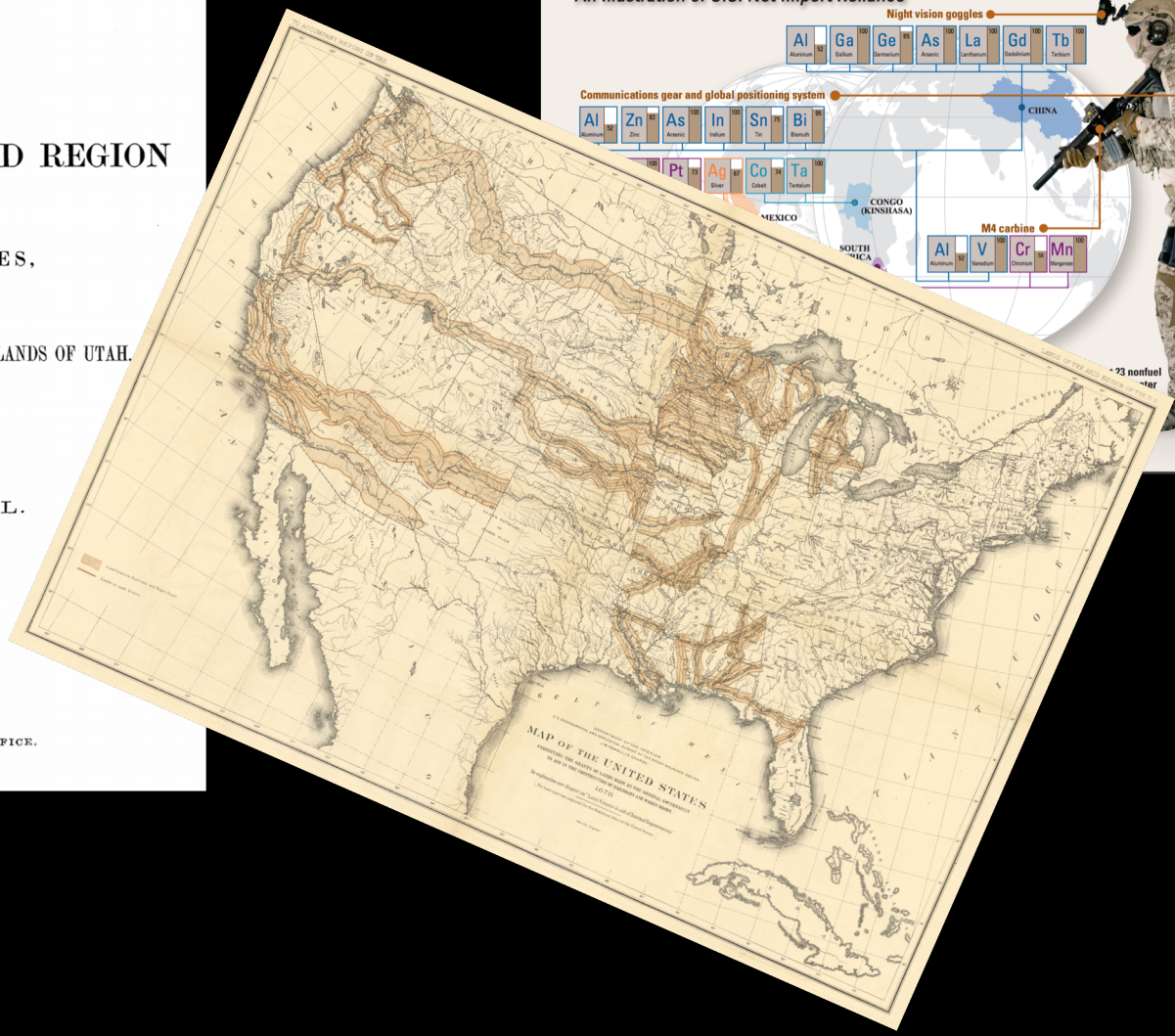
WITH MAPS.

BY

J. W. POWELL.

SECOND EDITION.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1879.



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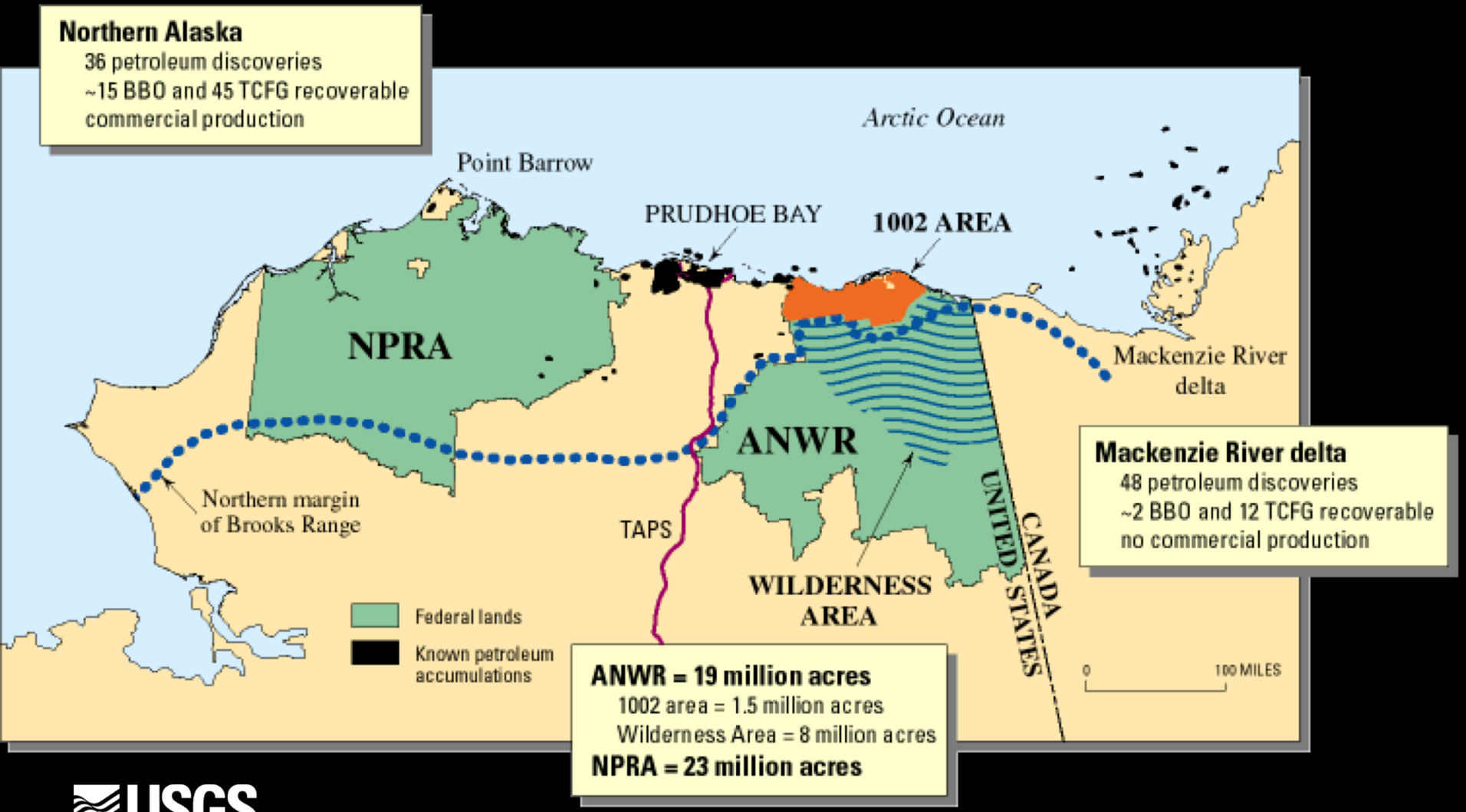
Allows evidence-based decisions



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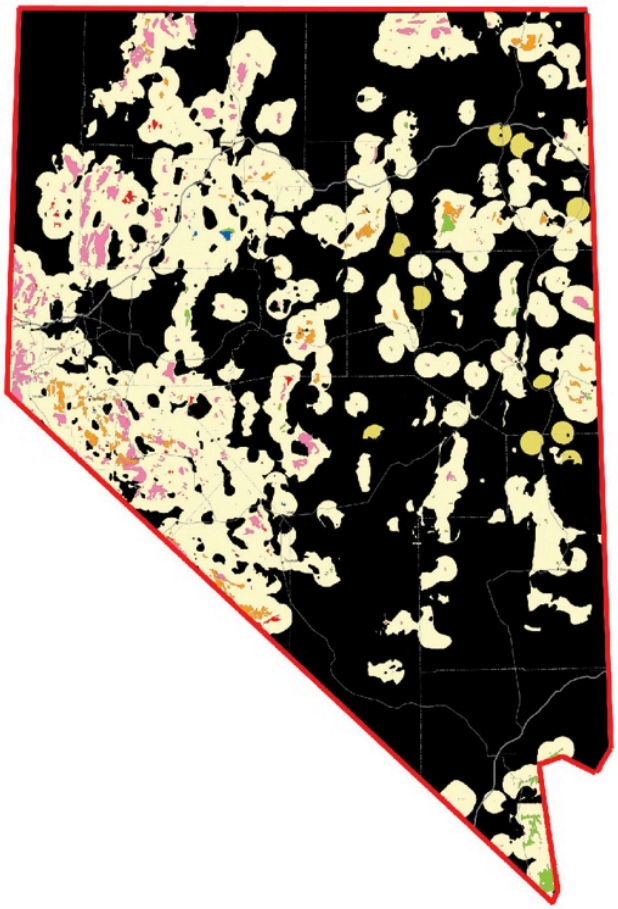
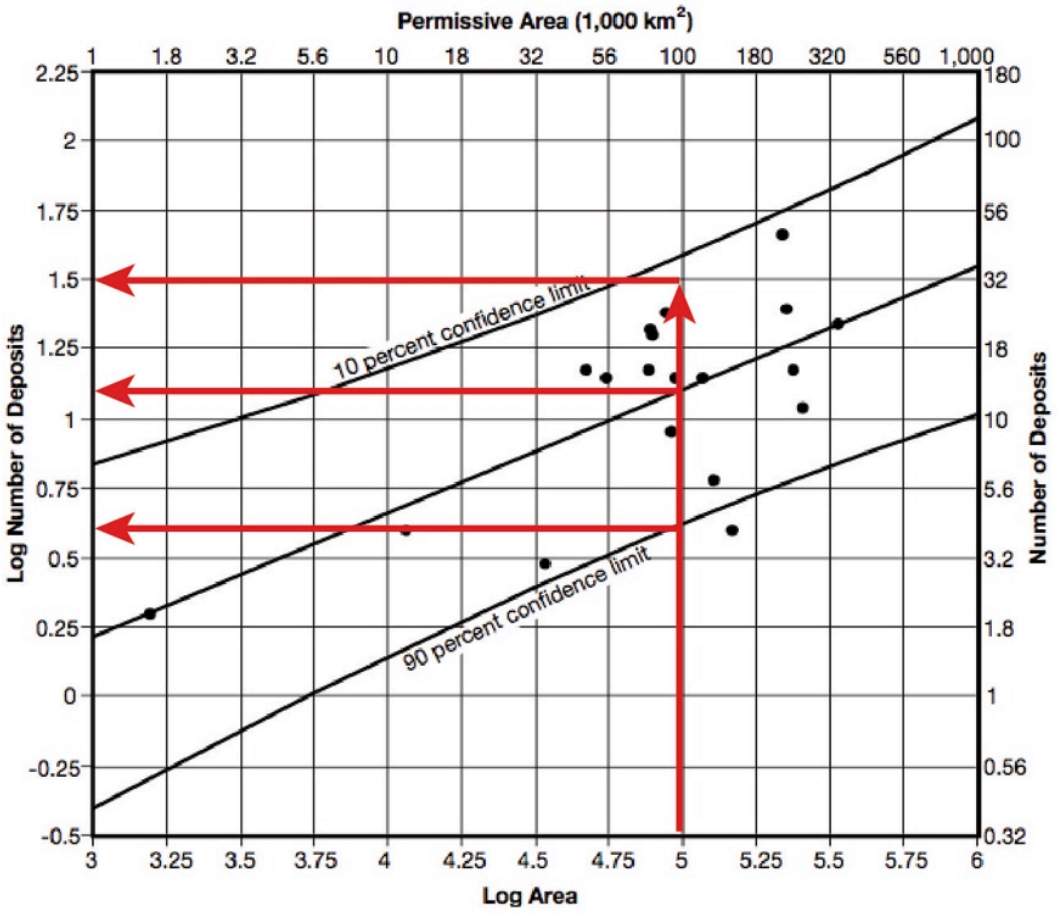
How does the USGS do resource assessments?

- Key properties of USGS assessments:
  - Unbiased
  - Quantitative
  - Easy to understand by non-scientists
- Composed of 5 parts (called 3-part)
  - Descriptive Model of resource deposits
  - Spatial Model of study area
  - Deposit-Density Model of deposits in study area
  - Grade-Tonnage Model of deposit population
  - Economic Model

How does the USGS do resource assessments?





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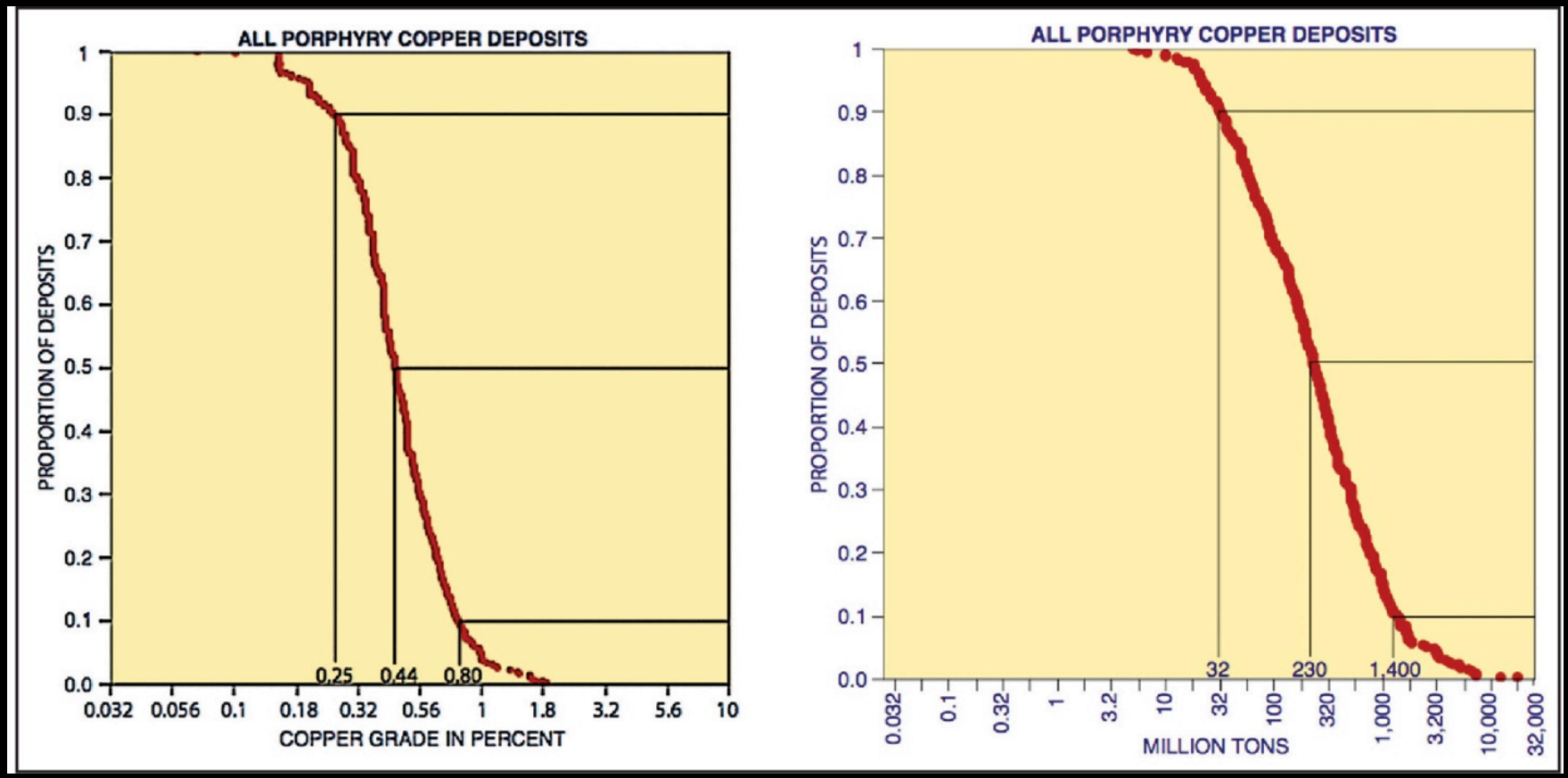

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Solar Power at the Moon

- **Descriptive Model**: *where the sun shines*
- **Spatial Model**: *the whole Moon*
- **Deposit Density Model**: *the whole Moon*
- **Grade-Tonnage Models**: *#hours a month the sun shines at a given location, the angle the sun rises above the horizon*
- **Economic Model**: *Design of the solar array (dimensions, can it rotate, quantum efficiency, energy storage, temperature tolerance, etc.)*

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Solar Power at the Moon

- **Uncertainties are small:** *ephemerides of Moon, Sun very well known, topography well known*
- **Resource extraction technology is TRL9/10:** *most issues are tied to landing and deploying the solar arrays, connecting to a power system, and delivering to the end user*
- **Summary:** *Assessment can be done today; problem is so deterministic that it can be inverted to define requirements for the landed system*

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Lunar Regolith (radiation shielding)

- **Descriptive Models:** *wherever impacts disrupt and garden the surface. Maria and highlands could be split because of age differences*
- **Spatial Model:** *the whole Moon*
- **Deposit Density Model:** *the whole Moon*
- **Grade-Tonnage Models:** *tonnage tied to regolith thickness, grade to mean atomic mass, lack of boulders*
- **Economic Model:** *bulldoze over a habitat.*

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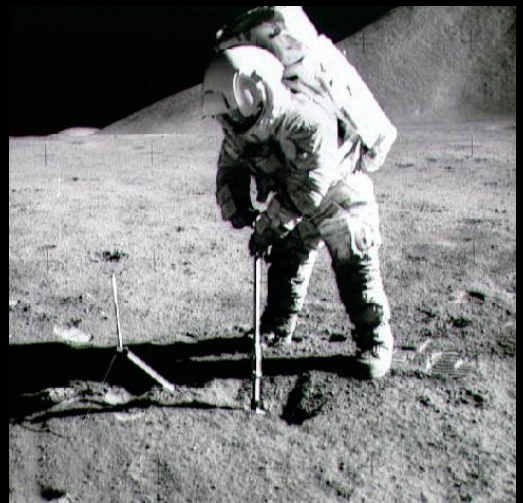
Lunar Regolith (radiation shielding)

- **Tonnage (regolith depth):** *reasonably well constrained by age, Apollo, penetrating impacts*
- **Grade (boulders):** *reasonably well constrained by radar, thermal inertia, topographic roughness*
- **Grade (amu):** *reasonably well constrained by spectroscopy (IR, gamma ray, etc.) + Apollo samples*



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Lunar Regolith (radiation shielding)

- **Assessment possible and useful:** *Deposit formation process understood, requisite global and in situ data exist, uncertainties appropriate for USGS statistical methods*
- **Extraction technology is the big unknown:** *will define what is an ore*

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Lunar Ice

- **Descriptive Models:** *regions that stay cold enough to trap the water for billions of years*
- **Spatial Model:** *permanently shadowed regions (and friends)*
- **Deposit Density Model:** *how patchy is the ice*
- **Grade-Tonnage models:** *fraction of regolith that is ice, contaminants (e.g., sulfur), thickness and depth of ice layer*
- **Economic Model:** *?? extraction technology*

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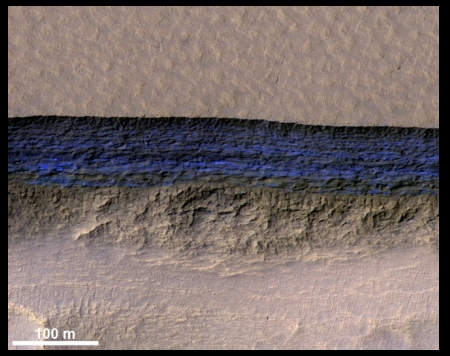
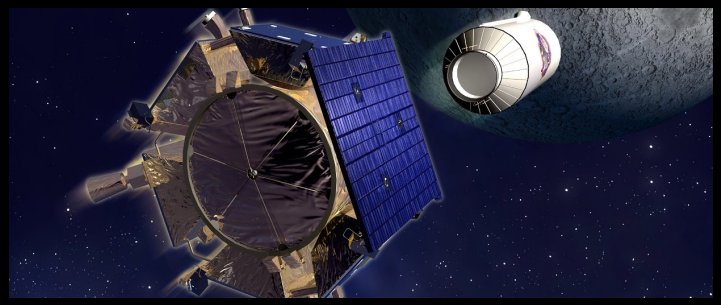
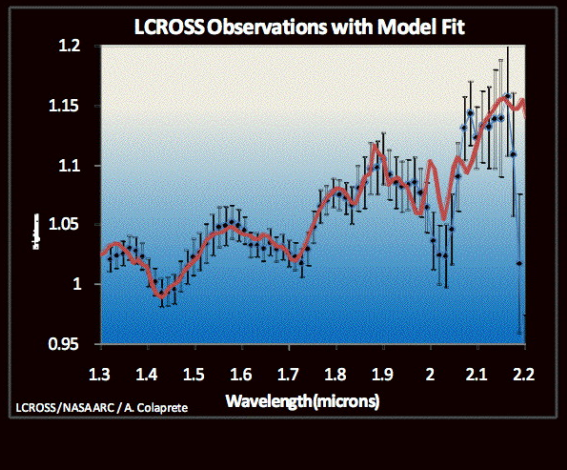
Lunar Ice



- **<u>Descriptive Models</u>:** *we do not know the source of the water (impactors vs volcanism); the conditions that trap water for Ga are still debated; quantifying the results of the in-situ observation (LCROSS) are debated – in short, we don't know enough to write a proper descriptive model for how lunar ice deposits form*





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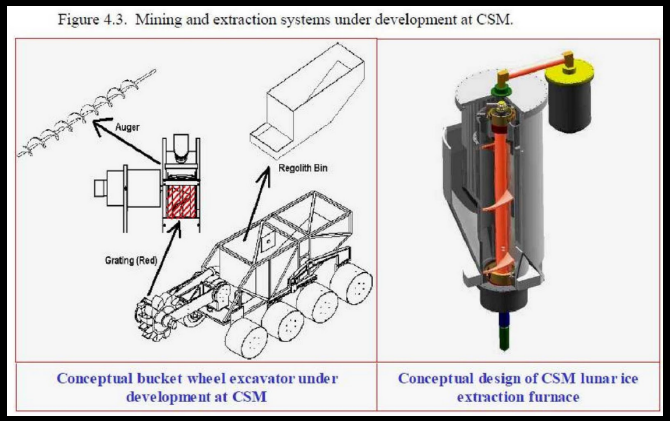
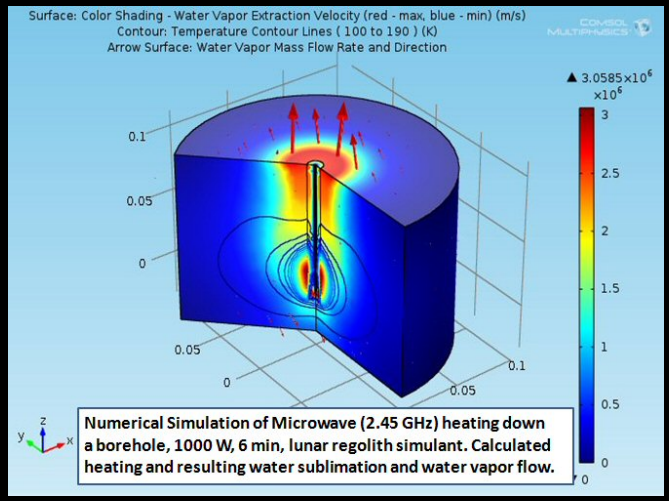
Lunar Ice

- **<u>Quantitative Models</u>:** *we do not have the ability to reliably convert orbital data into maps of ice quantity with rigorously computed uncertainties to feed into a statistical model*
- **<u>Economic Model</u>:** *we do not have any high TRL technologies to extract the water leaving critical questions unanswered*





Lunar Ice

- **<u>Rigorous assessment is not yet possible</u>:** *until more basic research is completed, any assessment will have massive uncertainty.*
- **<u>Still worth doing</u>:** *Even such an assessment would identify the measurements that are most needed and would serve as a useful benchmark to measure our increasing knowledge against.*

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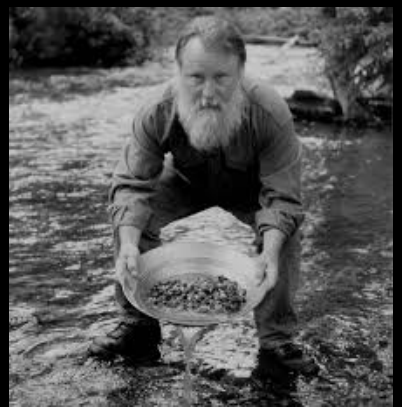

Lunar Ice

- **<u>Sampling mission a priority</u>:** *this is the most direct way to build the foundational "descriptive model" needed to start a quantitative assessment. Sample return is not required.*
- **<u>Investigate a statistically relevant number of sites</u>:** *The uncertainties in the assessment will be reduced most effectively with more detailed investigations of both typical (type) localities and special areas.*

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Results

- **Solar power, regolith, and ice demonstrate the range of situations the USGS methods could be used for**
  - *Solar power assessment can be inverted to identify the requirements for the lander to provide a given quantity/quality of power*
  - *Regolith is ready for a classic USGS assessment*
  - *Ice assessment would highlight what we still need to learn before we are ready to conduct extraction*

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