

A black and white photograph of an astronaut on the moon. The astronaut is wearing a full space suit and is standing on the lunar surface, which is covered in rocks and craters. The background shows the dark, cratered landscape of the moon under a bright sky.

Lunar Field Exploration Science

**Harrison H. Schmitt
(In Conjunction with FEAT)**

**Workshop on Science Associated with the
Lunar Exploration Architecture**

“The Tempe Conference”

February 26-March 2

What Lunar Field Exploration is Left to Do?

- **Unk-Unks (Unknown-Unknowns)***
- **Far-side and Polar Regions* Totally Unexplored on the Ground and Only Partially Explored, Remotely**
- **Global, Active and Passive Geophysical Networks***
- **Geochemical Characterization of Stratigraphic and Eruptive Sequences in the Crust**
- **Known Issues Defined by Current Knowledge***

* Outpost Compatible



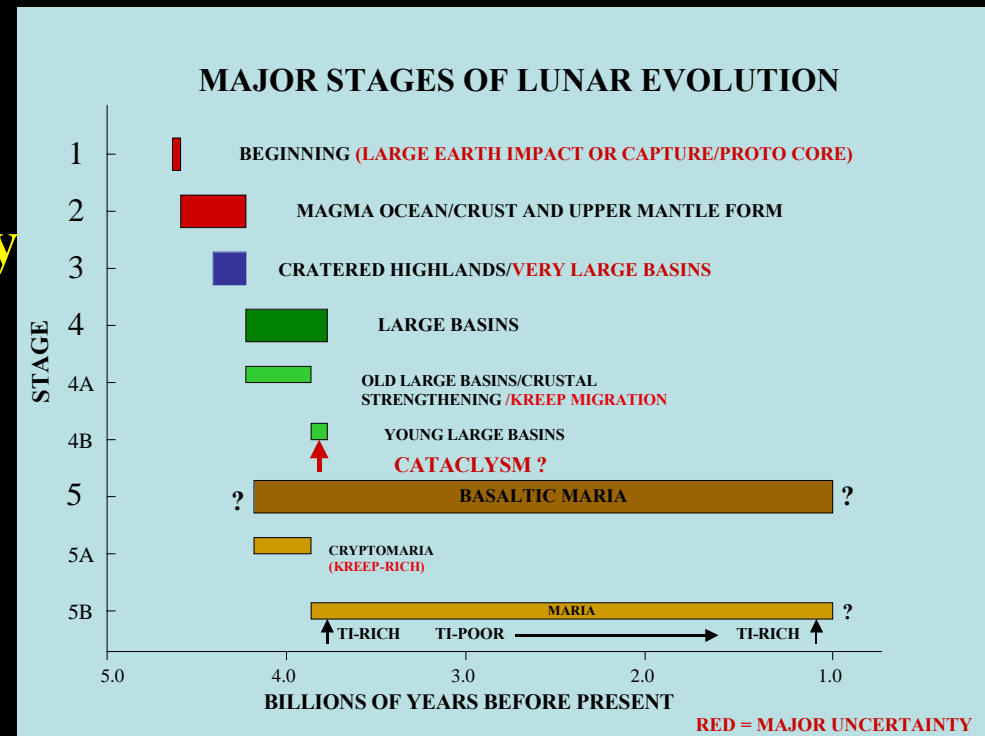
Important Problems: Provide Efficient Exploration Capabilities

- **Requirements and Implementation**
 - **Crew Experience**
 - **Crew Training**
 - **Sampling Tool/Container Suite**
 - **Sample Documentation (Rover/Crew)**
 - **Mobility (Dual Mode)**
 - **“Robotic” Assistance**
 - **Analytical Assistance**
 - **Site Selection**
 - **Exploration Planning**
- 
- A photograph of an astronaut in a white spacesuit standing on the lunar surface. The astronaut is wearing a large white backpack and is using a long-handled tool, possibly a shovel or a sampling tool, to interact with the dark, rocky ground. The background shows the dark, cratered landscape of the moon under a black sky.

Field Exploration Training

Pre-mission Assignment, Field-based Curriculum

- Principles of Observation, Sampling and Mapping
- Lunar Analog Igneous Geology
- Impact Crater Geology
- Regolith Geology
- Element and Isotope Geochemistry
- Planetary Geophysics
- Geology of the Moon (Integrated with Above)



Field Exploration Training

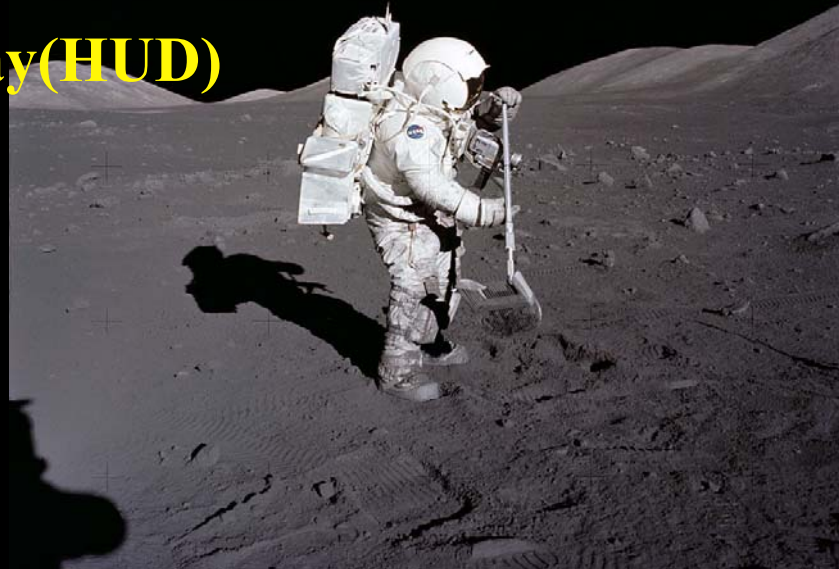
Apollo 15-17 Simulation Model

- **~One Week Per Month**
- **Relevant Analog Site**
- **Functional Mission Equipment**
- **One to Two, Pre-planned Traverses Per Day**
 - **Functioning “MCC / Science Room” Support**
 - **Debriefing Walk-over After Each Exercise**
 - **Observation, sampling and Documentation Critique**
- **One to Two, Integrated Mission Simulations before Flight**

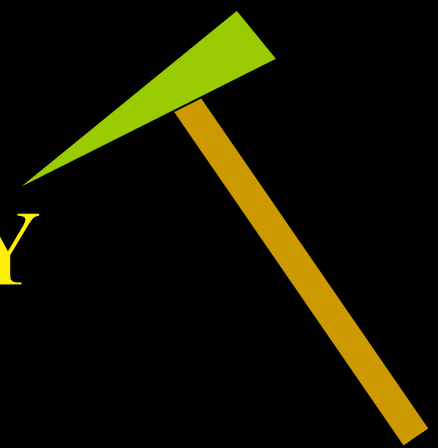
Lunar Exploration Preparation

Basic Exploration Equipment

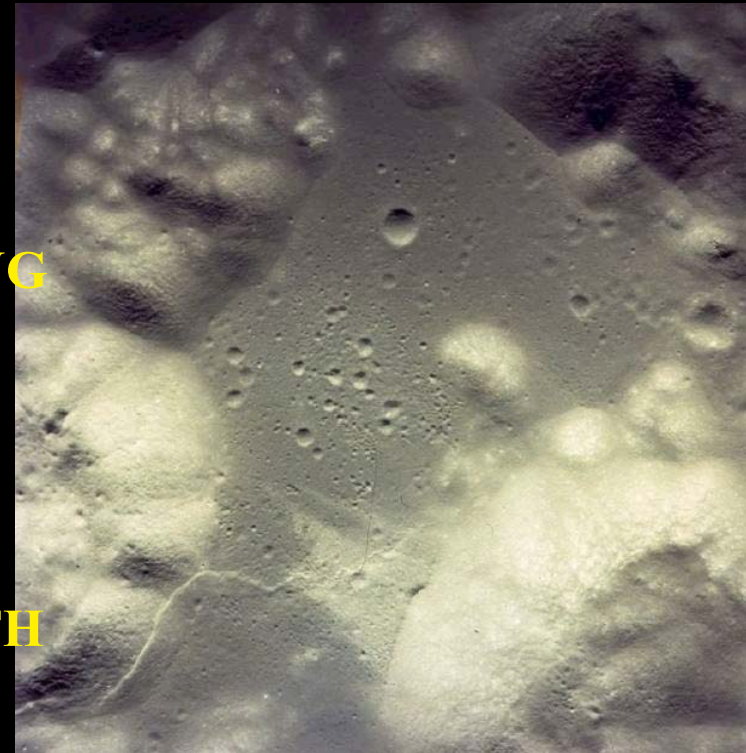
- **“Standard” Exploration & Sampling Tools**
 - Scoop, Hammer, Core-tubes, Drills, Bags, Rock Labels, etc.
- **Surveying - Mapping - Documentation**
 - Helmet-mounted Stereo-imaging & Ranging
 - Helmet-mounted 3D position determination
 - Chest-mounted Digital Camera
 - Voice-activated, Heads-up Display(HUD)
 - Exploration Data
 - ECS Data
 - Communications Modes
 - C&W System

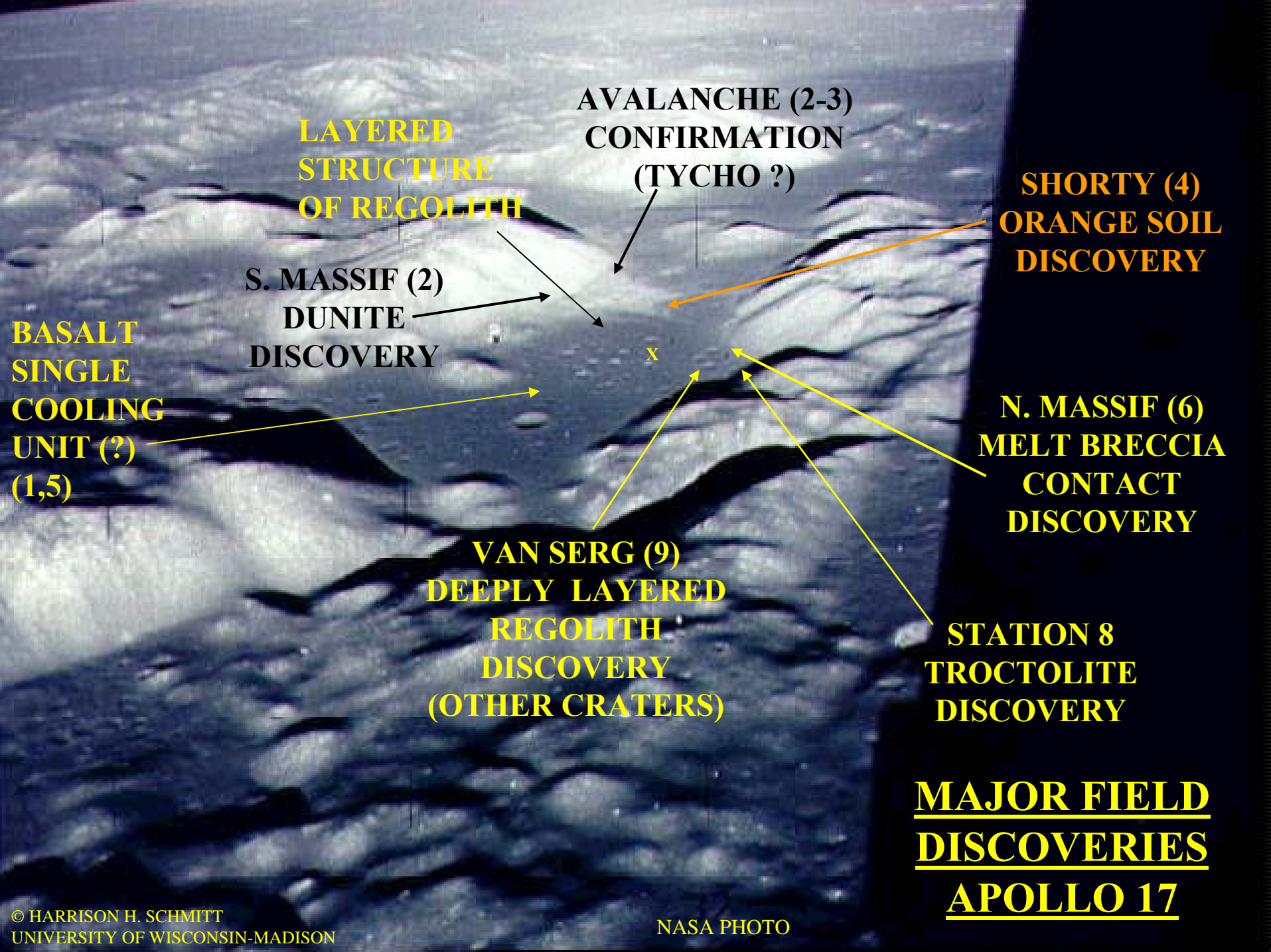


NATURAL AIDS TO LUNAR FIELD GEOLOGY



- **YOUNG IMPACT CRATERS**
 - **OVERTURNED STRATIGRAPHY IN EJECTA BLANKET**
 - **POSSIBLE VOLATILE ACTIVATION IN TARGET ROCKS**
- **EJECTA FROM DISTANT IMPACT CRATERS**
 - **SELECTIVE AND RANDOM SAMPLING OF CRUST AND MANTLE**
- **GRABEN FAULT SCARPS / IMPACT CRATER WALLS**
 - **BOULDERS AT BASE OF CLIFTS WITH TRACKS TO SOURCE CROPS**





**LAYERED
STRUCTURE
OF REGOLITH**

**AVALANCHE (2-3)
CONFIRMATION
(TYCHO ?)**

**SHORTY (4)
ORANGE SOIL
DISCOVERY**

**S. MASSIF (2)
DUNITE
DISCOVERY**

**BASALT
SINGLE
COOLING
UNIT (?)
(1,5)**

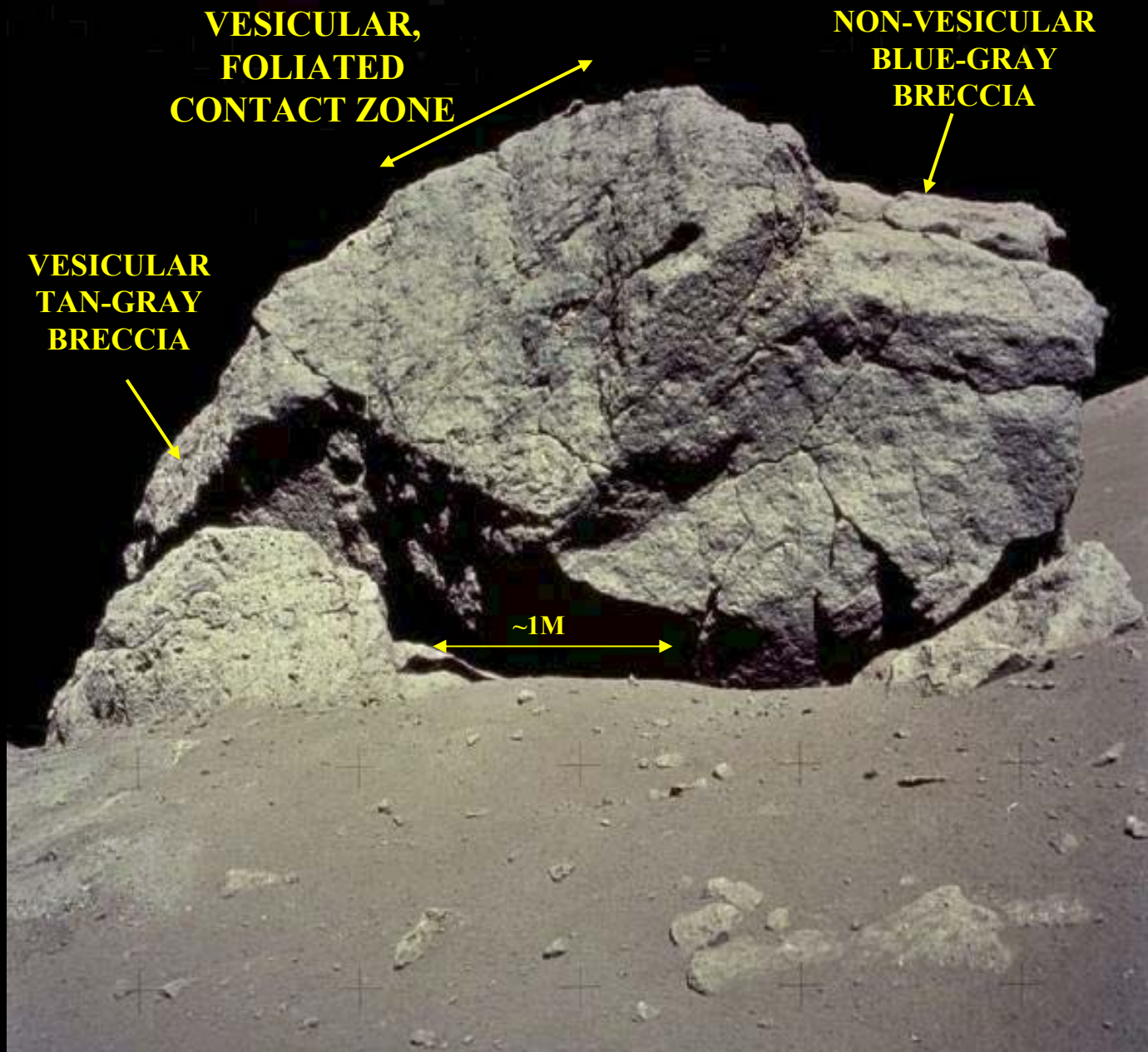
**N. MASSIF (6)
MELT BRECCIA
CONTACT
DISCOVERY**

**VAN SERG (9)
DEEPLY LAYERED
REGOLITH
DISCOVERY
(OTHER CRATERS)**

**STATION 8
TROCTOLITE
DISCOVERY**

**MAJOR FIELD
DISCOVERIES
APOLLO 17**

THE BOULDER AT STATION 6



**VESICULAR,
FOLIATED
CONTACT ZONE**

**NON-VESICULAR
BLUE-GRAY
BRECCIA**

**VESICULAR
TAN-GRAY
BRECCIA**

~1M

**FELDSPATHIC
OLIVINE NORITE**



**NON-VESICULAR
BLUE-GRAY
BRECCIA**

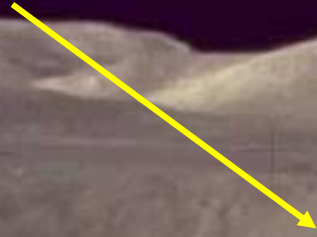
~20CM



NASA PHOTO

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UNIVERSITY OF WISCONSIN-MADISON

**VESICULAR
TAN-GRAY
BRECCIA**



VESICULE



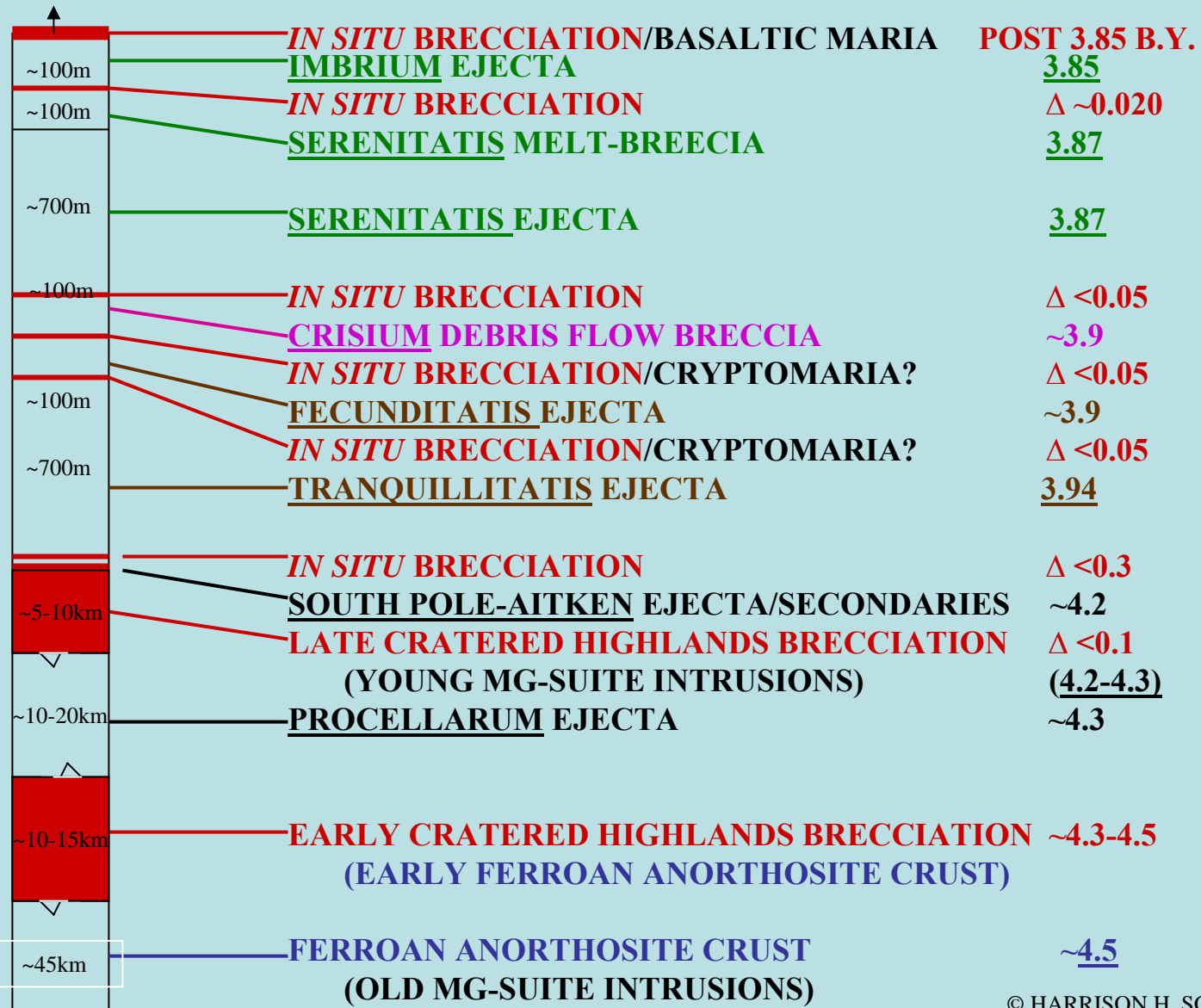
CLAST



~20CM



PRE-MARE TIME-STRATIGRAPHIC SEQUENCE VALLEY OF TAURUS-LITTROW



**SHORTY CRATER
ORANGE "SOIL"
(PYROCLASTIC
GLASS)**

**FRACTURED
BASALT
BOULDER**

COLOR REFERENCE

CRATER RIM

**70CM CORE
UPPER 20CM ORANGE
LOWER 50 CM BLACK**

~20CM

RED CORE

ORANGE INNER ZONE

YELLOW OUTER ZONE

LIGHT-GRAY

OUTER WALL MATERIAL

Lunar Exploration Preparation

Basic Exploration Equipment - 1

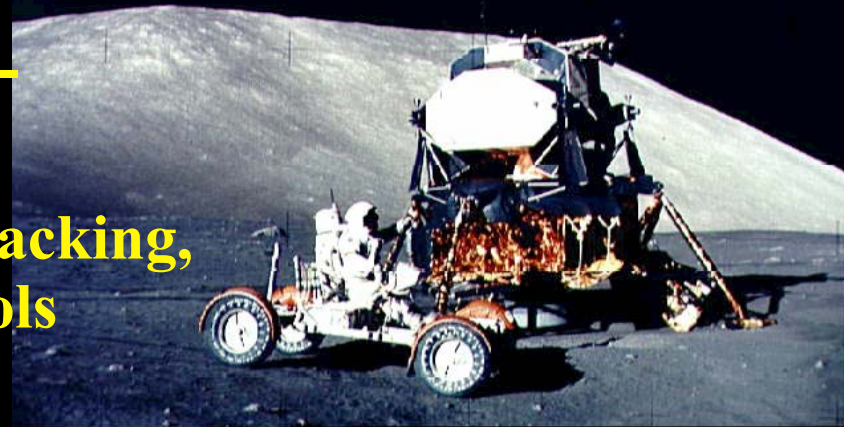
- **Exploration Pressure Suit**
 - **4X General Mobility Improvement vs. A7LB**
 - **>10X Improved Glove Dexterity**
 - **Routine EVA Consumables Recharge**
 - **Indefinite Life Design / Maintenance Concept**
 - **3D Position Determination, Tracking Stereo-imaging**
 - **Helmet-Mounted Photo Stereo Sample Documentation**
- **Layered Defense Against Dust Penetration, e.g.,**
 - **Dust Repulsion Design**
 - **Suits Remain External to Habitats**
 - **“L. Taylor” Magnetic Filters, etc.**



Lunar Exploration Preparation

Basic Exploration Equipment - 2

- **Roving Vehicle (Apollo LRV-Enhanced-Dual Mode)**
 - 3D Position Determination, Tracking, Stereo-imaging, Analytical Tools
 - Recharge Consumables
 - Solar Battery Recharge
 - Radiation Protection Provisions
- **Communication System**
 - Prime and Back-up, Two-way, Crew-to-Crew, Crew-to-Earth
 - High Data Rate Telemetry, Crew-to-Earth
 - High Data Rate Telemetry, Planning Information, Earth-to-Lander



Lunar Field Exploration Science

A black and white photograph of an astronaut in a full space suit walking across the lunar surface. The astronaut is positioned in the middle ground, moving away from the viewer towards the horizon. The terrain is covered in dark, jagged rocks and a fine layer of regolith. In the background, the dark, cratered surface of the moon extends to the horizon under a black sky.

*Time to Prepare a New Generation
for the Field Trip of a Lifetime!*

**To Join FEAT: Contact Mark Helper
<helper@mail.utexas.edu>**

Issues Defined by Current Knowledge - 1

- **Test Giant Impact Hypothesis - Whole Moon Effects**
 - Investigate Pyroclastic Strata of SW Serengetatis
 - Investigate and Identify Deep Floor / Ejecta from South Pole-Aiken
- **Test “Cataclysm” Hypothesis - If True, A Lot Happened in Short Time!**
 - Investigate, Identify and Date Syn-genetic Samples from Old, Non-Mascon Basins
 - South Pole-Aiken and Procellarum
 - Tranquillitatus, Fecunditatis, etc.

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

Issues Defined by Current Knowledge - 2

- **Calibration of the End of Large Impacts in the Hadean**
 - Identify and Date Syn-genetic Samples from Orientale Basin
- **Calibration of Episodes of Large Impacts in the Hadean**
 - Identify and Date Syn-genetic Samples from South Pole-Aitken and a Range of Younger Basins
- **Role of Pressure Release in Mare Basalt Magma Generation**
 - Investigate Mare Basalt Units in Orientale



Issues Defined by Current Knowledge - 3

- **Global Geophysical Delineation of Internal Structure -1**
 - **Depth of Magma Ocean**
 - **Lateral Extent and Vertical Depth of Upper Mantle Cumulate Sub-units**
 - **Original, 3D Distribution of urKREEP Residual Liquid**
 - **Distribution of Parent Bodies of Mg-Suite Samples**

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are needed to see this picture.

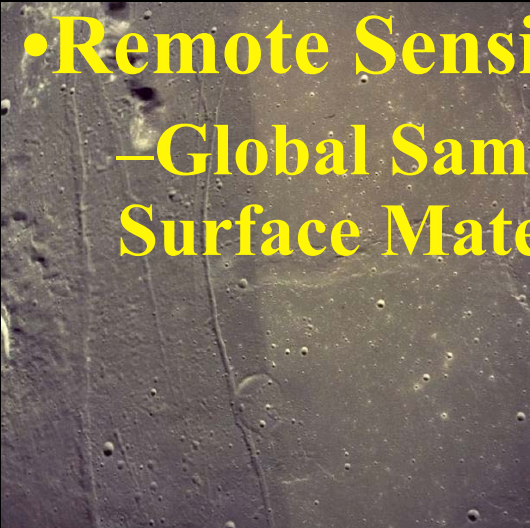
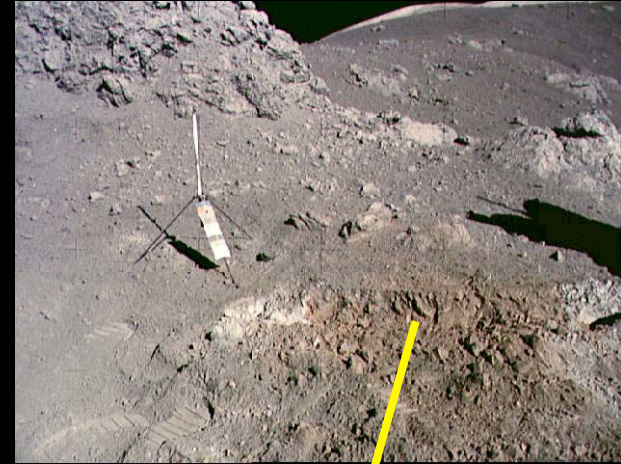
Issues Defined by Current Knowledge - 4

- **Global Geophysical Delineation of Internal Structure - 2**
 - **Structure / Composition of Transition Zone Between Lower and Upper Mantles**
 - **3D Nature of the Core and the Core-Mantle Boundary**
- **Timing of Core Formation and Core Dynamo Activity**
 - **Global mapping of Datable Remnant Magnetism**

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

Issues Defined by Current Knowledge - 5

- **Magma Generation in the Upper and Lower Mantles**
 - Investigation of Procellarum Volcanic Centers
 - Investigation of Mare Basalt / Pyroclastic / Other Eruptive Centers
- **Remote Sensing Ground Truth***
 - Global Sampling of Relevant Surface Materials



* Outpost Compatible

QuickTime™ and a
TIFF (Uncompressed) decompressor
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Issues Defined by Current Knowledge - 6

- **Distribution, Deposition and History of Polar Volatiles***

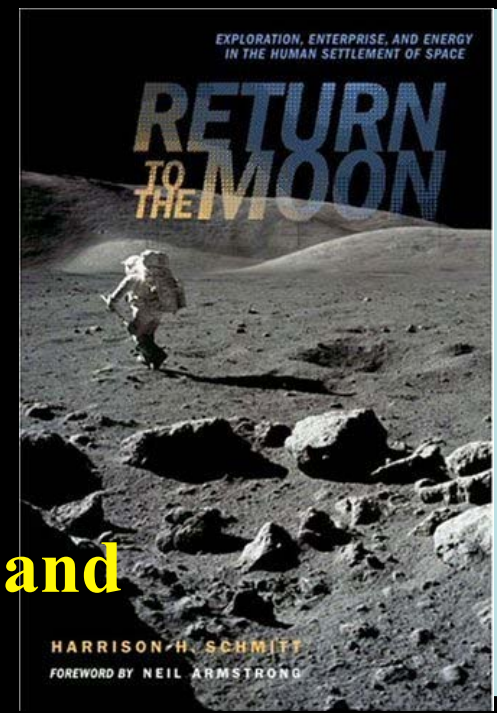
 - **Investigate Regolith Stratigraphy in and near Permanent Shadow**

- **Define the Economic Geology of Volatile Resources***

 - **Map 3D, *In Situ* Grade and Distribution in Ti-rich and Polar Regolith**

 - **Hydrogen, Helium 4&3,
Carbon, Nitrogen, Water(?)**

* **Outpost Compatible**



Issues Defined by Current Knowledge - 7

- **Gather Less Site-specific Geological Knowledge**
 - **Structural, Petrological and Dynamical Aspects of Large Impact Basins of Relevance to the Hadean**
 - **Broad Geological and Geotechnical Aspects of the Regolith***
 - **Structural and Geophysical Properties of the Mega-regolith**
 - **Geotechnical Support for Large Facility Construction***

* **Outpost Compatible**

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

Issues Defined by Current Knowledge - 8

- **Lunar Specific Phenomena**
 - **Global Stress-Strain History**
 - **Sinuuous Rilles**
 - **Mass Wasting**
 - **Recent Releases of Internal Volatiles**

