Field and Remote Sensing Training for Human Exploration of the Planets

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Chaired by William R. Muehlberger

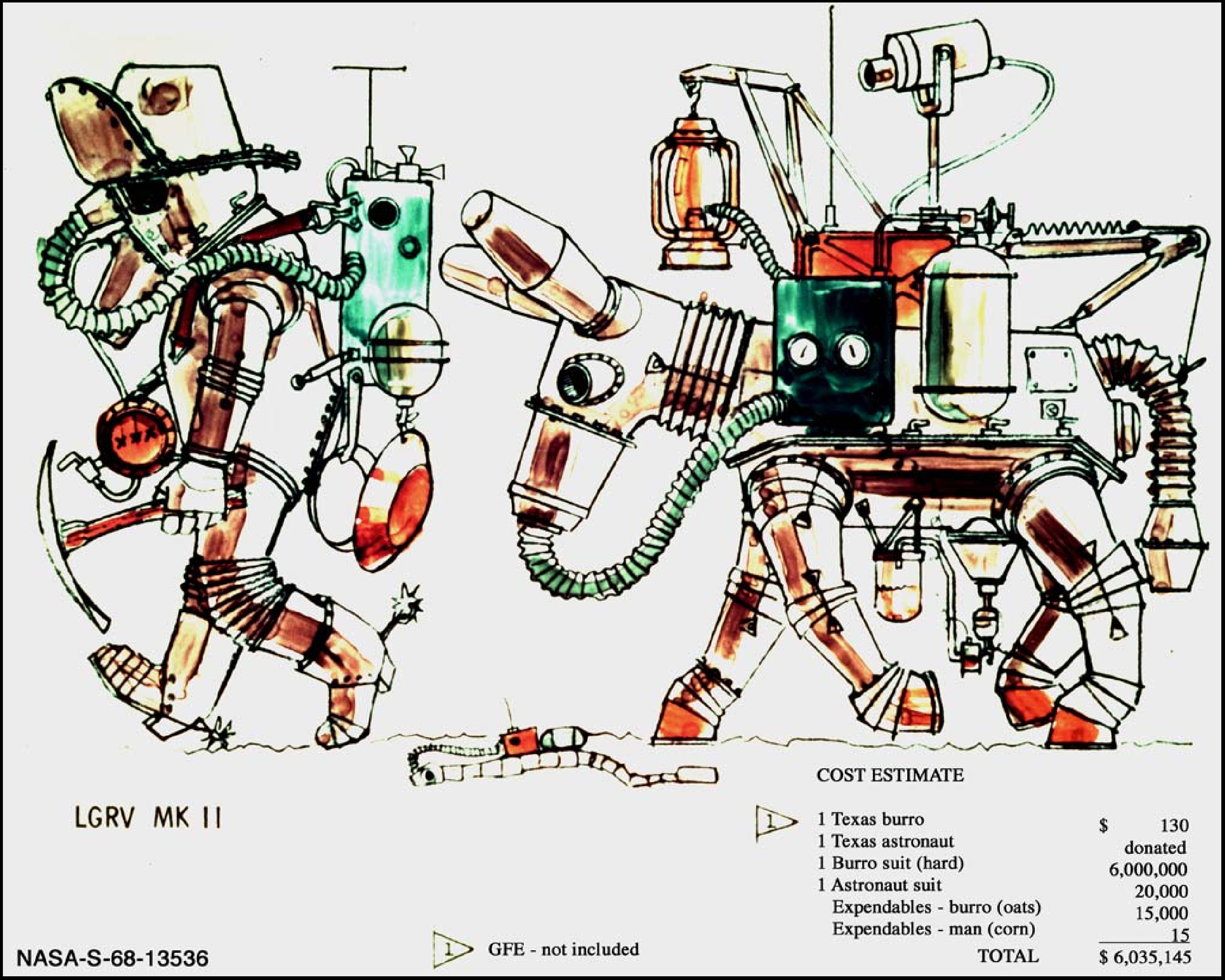
Abstract

In addition to geologic sampling, stereophoto interpretation, and descriptive techniques, in 1999 astronauts began to be trained in geophysical exploration methods. Thirty-one astronauts conducted gravity traverses – a technique employed by Apollo explorers on the Moon; they acquired ~10 miles of data and profiled a buried fault with displacement of thousands of feet.

Other geophysical techniques for eventual instruction include seismic profiling to reveal buried stratigraphic relations/structures, and possibly water and/or CO_2 ice. Magnetic surveys could help to distinguish among lava flows and lithic boundaries expressed in thermal emission spectrometric (TES) data. Geological and geochemical methods for distinguishing spring deposits, hydrate/clathrate accumulations, and macro/microbiological remains should be emphasized as well.

Lunar and Martian impact craters, volcanoes, and dunes exhibit analogous morphologies to terrestrial features and likely formed by processes similar to those that have operated on Earth. Forms of others, such as vast canyons and channels, fluid springs, and layered strata are similar, but modes of formation are vigorously debated. New data for both Moon and Mars enable comparison with astronaut-acquired photographs of Earth and investigation of planetary processes in advance of exploration.

Surface Exploration Readiness



Taos Plateau, NM – Geological Training Ground from Apollo to the Present

Taos Plateau

- Dave Scott and Jim Irwin train on the rim of the Rio Grande gorge, a 1:1 analogue to Hadley Rille, Apollo 15 exploration site. (Schaber, 2002)
- Field training continues here for Space Shuttle, International Space Station astronauts, some of whom may explore Mars or direct a Mars mission from the ground.

Sampling Techniques

Stereophoto Analysis

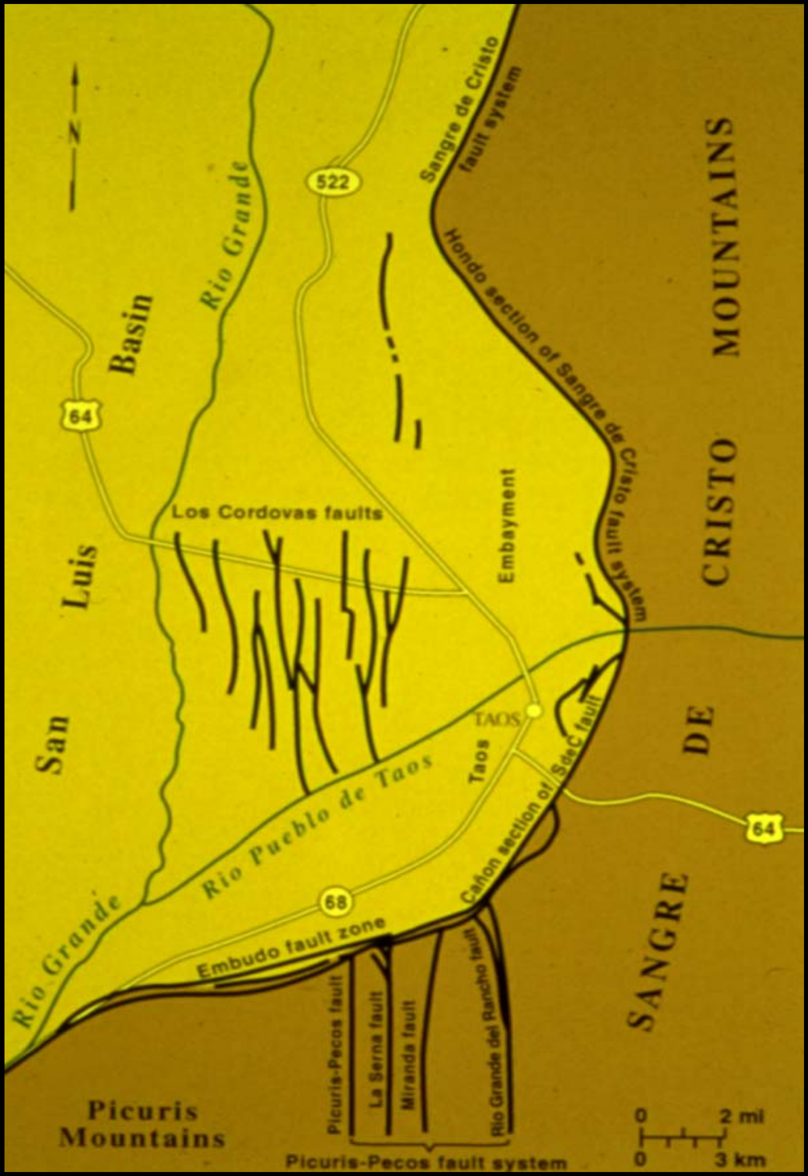
Geophysical Methods - Gravimetric Surveys

Training in gravity data acquisition to delineate buried structures began in 1999. Gravimetric surveying is nondestructive and requires no external energy input; the instrument is lightweight, portable, and flight-certified.

L - Gordon Cooper & Marty Kane read gravimeter, Apollo field training (Schaber, 2002).

R - Chris Ferguson, John Young and Barbara Morgan collect gravity and GPS data.

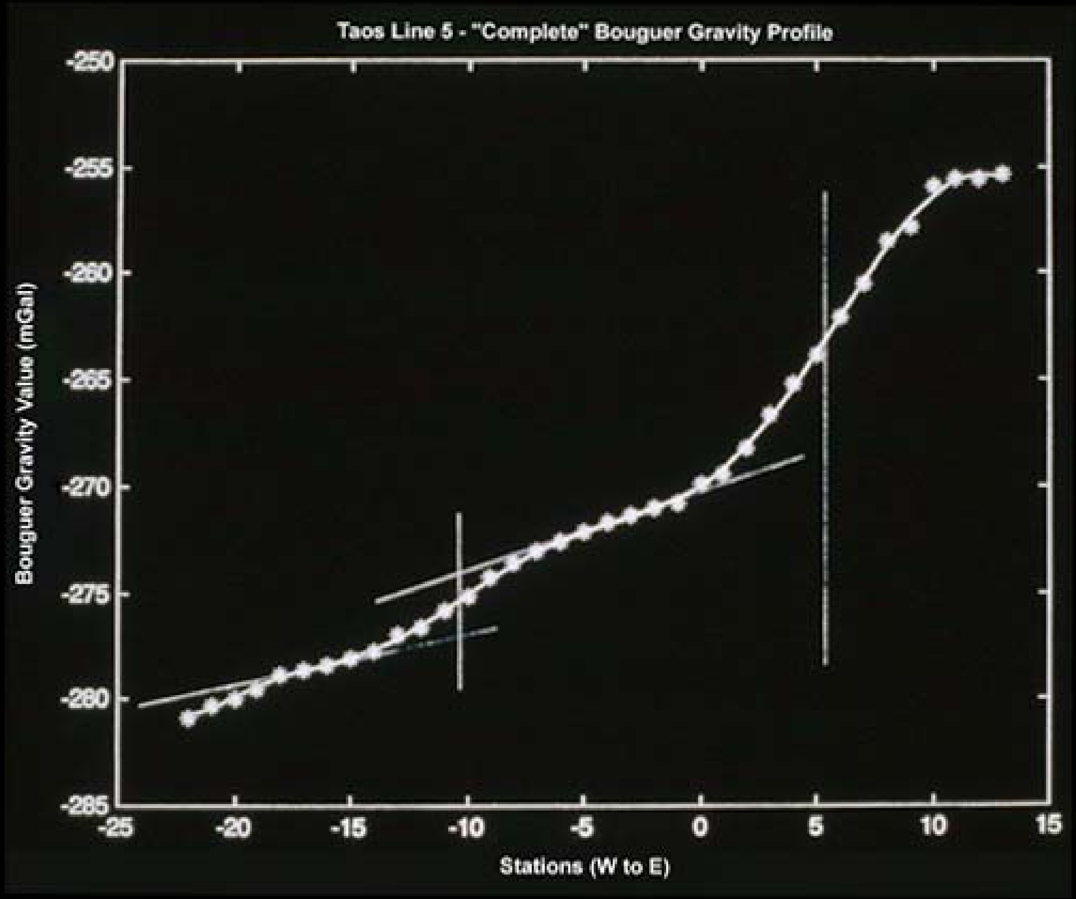
Taos Valley Ground-Water Assessment



- Faults influence ground-water distribution and flow paths in Taos Valley.
- Good bedrock/valley fill density contrast for gravity method; structural setting was ideal.
- Gravity data helped define faults buried beneath valley fill.
- Data were used by NM Bureau of Geology in water-resource assessment of fast-growing area.

(map from Bauer *et al.*, 1999)

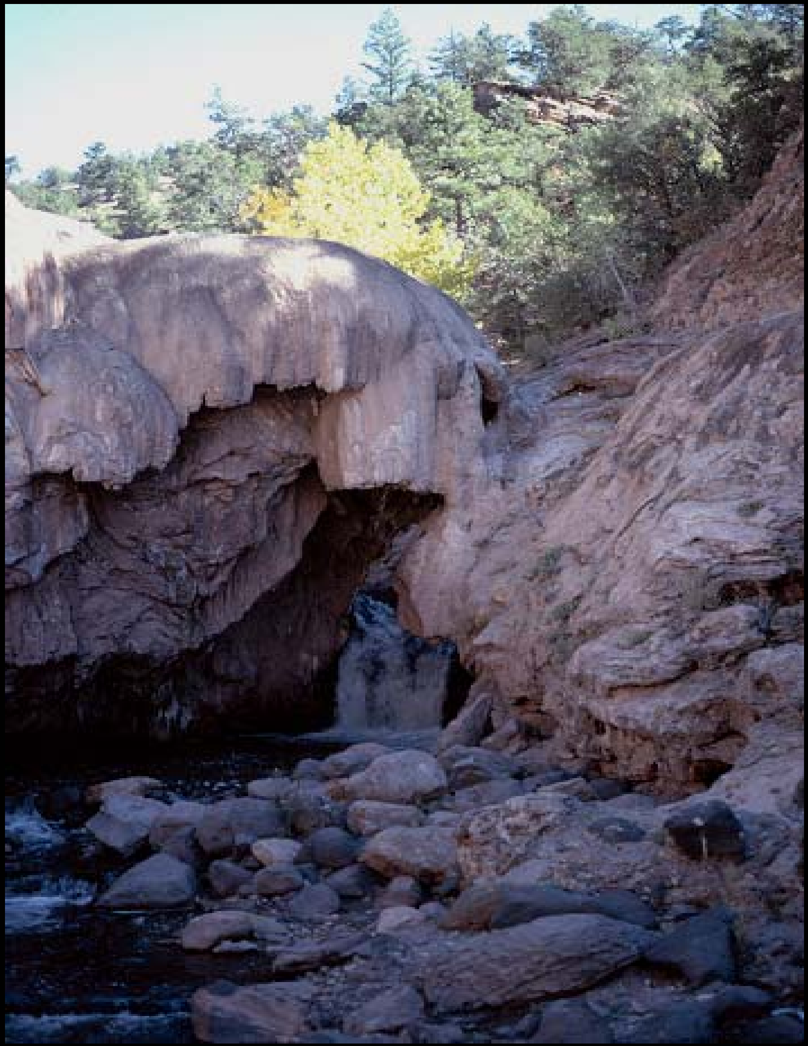
Bouguer Gravity Profile - Buried Fault Influencing Ground-Water Movement



The sharp inflection at the right (E) end of the Bouguer gravity profile marks a buried fault with no surface expression; displacement measures thousands of feet. (NM Bureau of Geology & Mineral Resources, 2000)

Field Trials Have Been Conducted for Shallow-Target Seismic Reflection Exercises

Future Training in Sampling Techniques – Spring Waters, Sedimentary Deposits, Organic Material



Integrative Interrogation - Preceding and Throughout Surface Exploration

- Observe, map, and interpret planetary surfaces and processes - Earth, her Moon, Mars, Phobos, Deimos, Europa...
  - *Satellite images - Clementine, Viking, Galileo, Landsat, SPOT, Ikonos, Mars Global Surveyor (more detailed coverage for much of Mars than for most of Earth at present)...*
  - *Astronaut-acquired photos (>450,000 images, including stereophoto mapping suites; some taken specifically for comparison with lunar, martian images); SRTM data*
- Integrate relevant observations/interpretations; compare analogous data for the several planetary bodies

Similar Features Formed by Processes Like Those on Earth

ASTRONAUT-AQUIRED PHOTOS AND SATELLITE DATA PERMIT DETAILED COMPARISONS OF:

- Great volcanoes (Mars, Jupiter’s moon Io)
- Dunes (possibly finer sediment on Mars)
- Layered strata of varied origins (extrusive igneous, volcaniclastic, sedimentary)
- Meteor impact structures on Moon and Mars
- Glacially carved valleys, moraines

Emi Koussi Volcanic Crater, Tibesti Massif, Chad

Olympus Mons, Mars

- Constitutes most of the Tharsis Bulge
- 27 km high – 3 times the height of the island of Hawaii (9 km from subsea base to summit)
- Like Hawaii and Tibesti Massif, may have formed over a mantle hotspot

MOC2-69

Shifting Sands

(Greeley, 1987)

Longitudinal (parallel to dominant wind direction), transverse (perpendicular), and star dunes (variable wind directions) are known on Earth and Mars.

Layered Rocks of Varied Origins - Grand Canyon

- Sequences of layers of varied origins are common on Earth.
- The Grand Canyon has been carved through marine limestones, desert dune deposits, and ancient lava flows.

Layered Rocks on Mars - Coprates Chasma

- Viking images (1970s) first revealed layered strata on Mars.
- Mars Orbital Camera (MOC) data provide more detailed views.

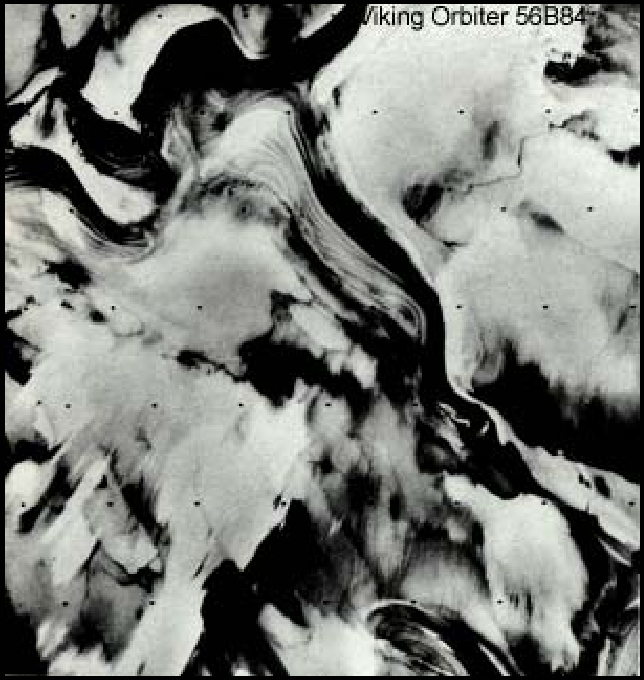
MOC2-29

Complex Impact Craters

Manicouagin, Quebec

Copernicus, Earth's Moon

Glaciers - Earth and Mars



(Greeley, 1987)

Southern Andes, Chile

North Pole, Mars

Similar Features Formed by Potentially Different Processes

- Canyons that appear to be river-carved –
  - No surface water and little water ice on Mars now
  - Flow conditions at 1/3 the Earth's gravitational acceleration? At subzero temperatures?
  - Long-lived water supply?

- Apparent springs and seeps –
  - Source of water? Other fluid?
  - Melted subsurface ice (H_2O, CO_2)? Methane clathrate?

- Possible shorelines –
  - Bodies of standing water — lakes and seas?
  - Lava-filled basins?

Catastrophic Flood? Candor Chasma

(USGS, 1992, detail)

- Abrupt breaks in walls of Valles Marineris
- Apparent scours extend out several kilometers
- Tremendous erosive power required
- Possible mechanism - Sudden release of large volume of glacial meltwater in response to volcanic heating?

Details of Possible Flood Erosion - Candor Chasma, Mars

- Deep scouring of valley floors
- Undercut valley walls
- Slumps and landslides
- Blocky deposits on valley floor

MOC2-105

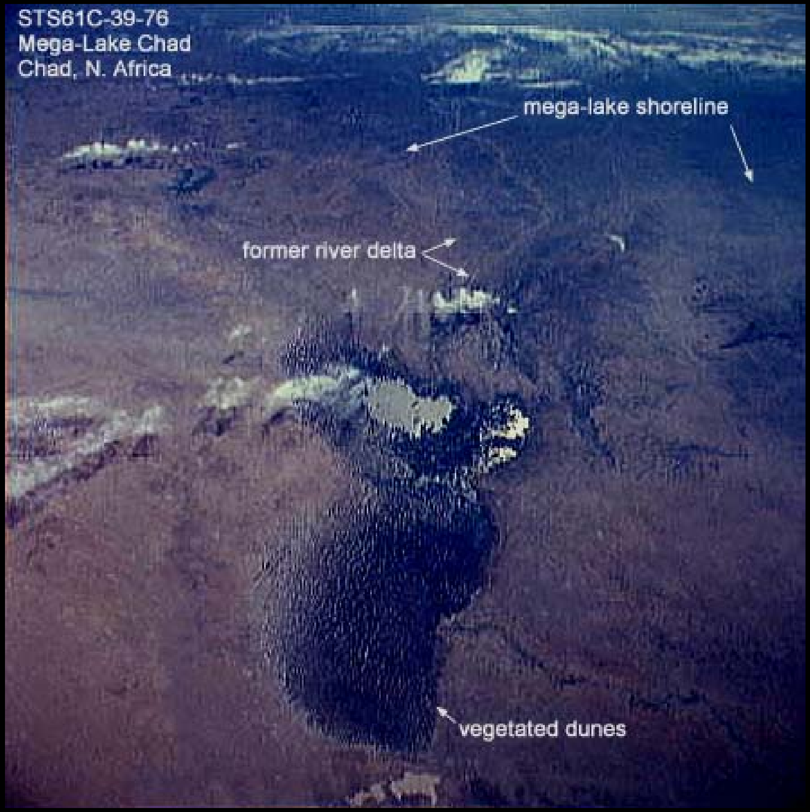
Cascade Range,
Eastern Washington State

- Channeled Scablands, along the Columbia River east of the Cascade range, are possible analogue for large-scale breaches of canyon walls on Mars.
- Bedrock scours resulting from ice-dam burst and abrupt release of great volumes of water.

Moses Lake and Coulees

- Glacial ice dams broke between 18,000 and 13,000 years ago, in response to volcanism near modern Lake Pend Oreille, ID.
- 500 mi^3 of melt water stripped away the glacial soil and carved deep valleys (coulees) into the bedrock.
- The coulees were formed in five catastrophic events; glacial Lake Missoula was the source of the flood waters.

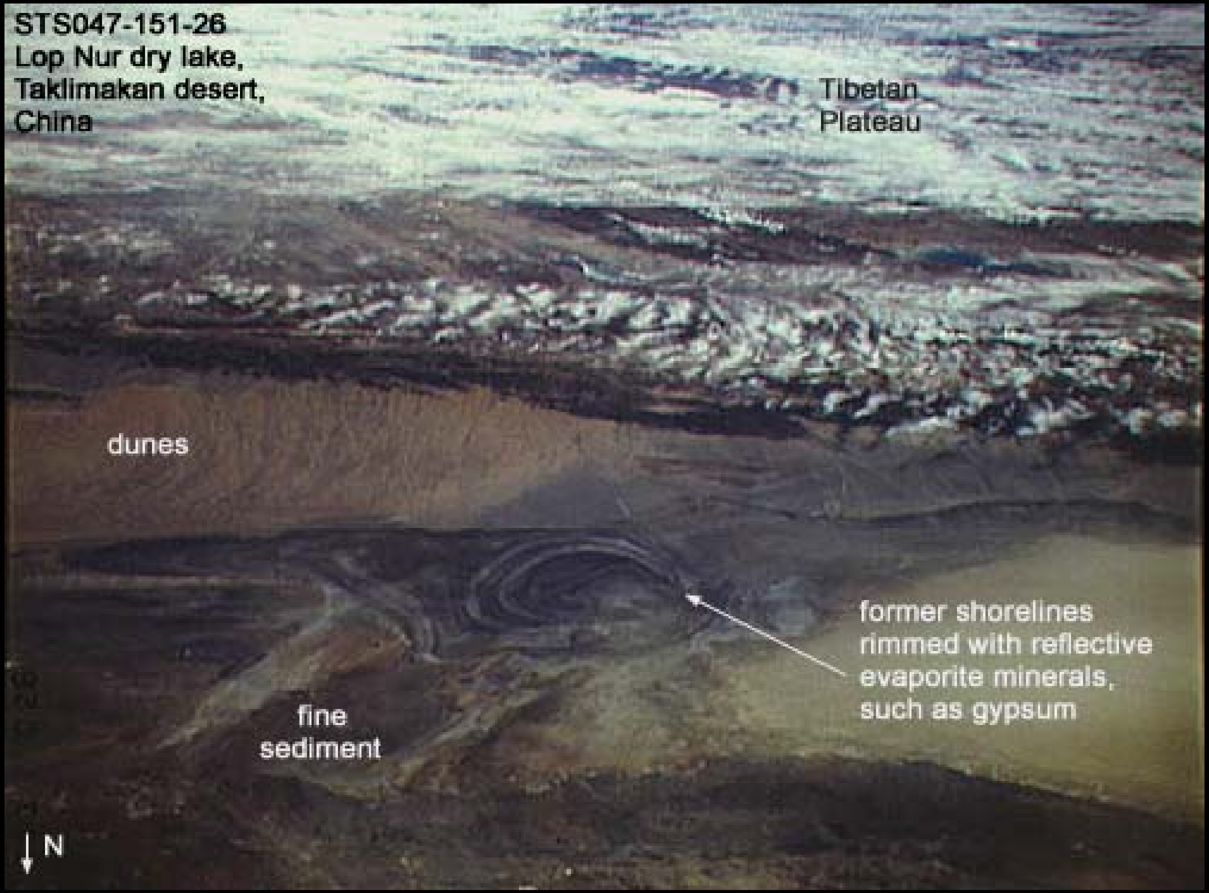
Large Lake Basin, Old Shorelines: Mega-Lake Chad



- Present Lake Chad occupies only a small portion of a far larger basin.
- Former shorelines, cut by waves, and abandoned river deltas are visible in surrounding topography.
- Possible analogues for N. Highlands features, Mars?

Lake Chad -
Details of Old Shorelines and River Delta

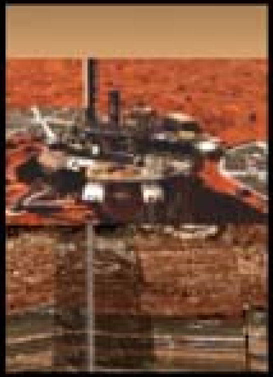
Lop Nur, China - Evaporite Minerals Marking Old Shorelines



Exploration Progression

INTEGRATIVE INTERROGATION

Satellite observations, imaging, mapping, systematic scientific comparison with terrestrial and known lunar sites



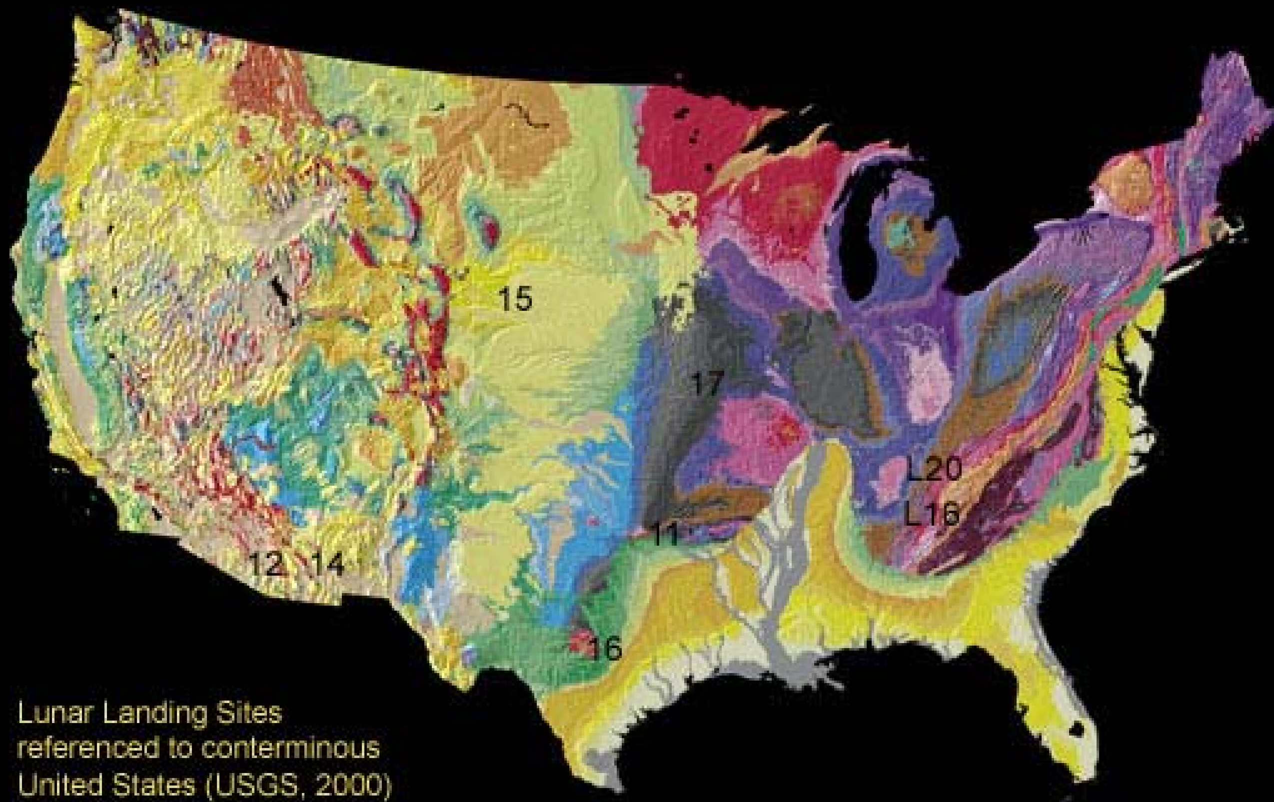
ENLIGHTENED RECONNAISSANCE

Testing complex robotic (with/without humans) systems on the Moon before going to Phobos, Deimos, Mars...

TIGHTLY TARGETED INQUIRY

Applying the investigative/integrative power of human explorers in concert with intelligent robots

Your Mission:



Characterize the geology of Earth

and discuss the origin and evolution of the planet

Acknowledgments

Astronaut-acquired photographs of Earth are made available to the public by the Earth Science & Image Analysis Laboratory (http://eol.jsc.nasa.gov), NASA-Johnson Space Center. Mars Orbital Camera (MOC) images from Mars Global Surveyor are made available by Malin Space Systems/NASA http://www.msss.com). Apollo 17 photographs are made available by NASA-Johnson Space Center (http://images.jsc.nasa.gov/iams/html/pao/as17.htm).

References

Bauer, P. W., Johnson, P. S., and Kelson, K. I., 1999, Geology and hydrogeology of the southern Taos valley, Taos County, New Mexico: Socorro, New Mexico Bureau of Geology and Mineral Resources, Final Technical Report to New Mexico Office of the State Engineer, 56 p., 4 pl.

Bauer, P. W., Read, A.., and Johnson, P. S., 2000, Astronaut geophysical training, Taos, New Mexico, Summer 1999: New Mexico Bureau of Geology and Mineral Resources, http://geoinfo.nmt.edu/penguins/summary.html

References, *continued*

Dickerson, P. W., Muehlberger, W. R., and Bauer, P. W., 2000, Astronaut training in field geophysical methods: Albuquerque, AIAA Space 2000 conference proceedings, 7 p.

Greeley, R., 1987, Planetary Landscapes: Boston, Allen & Unwin, 275 p.

Schaber, G. G., 2002, The U.S. Geological Survey's Role in Man's Greatest Adventure (The Apollo Expedition to the Moon): USGS Planetary Geology Branch, unpublished photo CD for dedication of Shoemaker building (September, 2002), 93 figures.

U.S. Geological Survey, 2000, A tapestry of time and terrain: U. S. Geological Survey, http://tapestry.usgs.gov/Default.html

U.S. Geological Survey, 1992, Valles Marineris: U.S. Geological Survey, Mars [color] Digital Image Mosaic disks, volume 13. Electronic version available from Malin Space Science Systems -- http://www.msss.com/mars/pictures/usgs_color_mosaics/usgs-color.html

Willis, K., Dickerson, P. W., and McRay, B. H., 1998, Canyons, craters and drifting dunes — Terrestrial analogues on Earth's Moon and Mars: NASA-Johnson Space Center, Office of Earth Sciences, http://eol.jsc.nasa.gov/newsletter/planetary/sld001.htm

Man must rise above the Earth – to the top of the atmosphere and beyond – only thus will he fully understand the world in which he lives.

Socrates, 500 B.C.