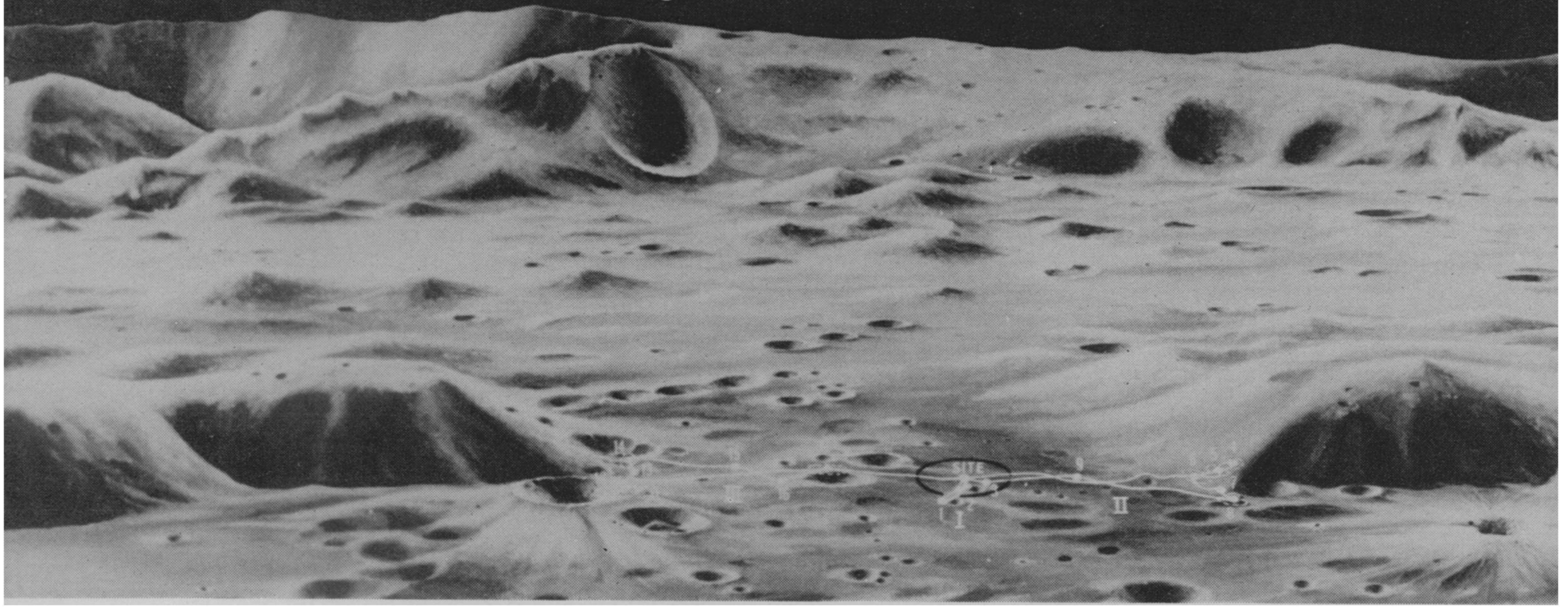
Journey to the Descartes highlands

Apollo 16's astronauts will explore a region of volcanic lunar terrae



Jerry L. Elmore/NASA

by Everly Driscoll

Early astronomers studying the moon through telescopes saw the near-side surface divided generally into two regions—the low, dark areas that they called seas (maria) and the lighter surrounding highlands they called "terrae." It was obvious, even then, that the highlands were not formed the way mountains were on earth. For this reason lunar scientists prefer still to call them terrae rather than highlands.

The National Aeronautics and Space Administration is scheduled to launch Apollo 16 next weekend to a region known as Descartes in the Central Highlands (SN: 6/12/71, p. 397). The landing site is named for the 48-kilometer-wide Descartes crater 60 kilometers to the south. The area is below and to the right of the center of the moon's disk as seen from earth. The mission will be the only Apollo flight to land on a terra.

There was considerable debate in lunar science circles about the site. For that matter, there is still debate about whether true terrae still exist in a pristine, undisturbed state on the moon.

The most widely accepted theory is that the terrae are what is left of the outer crust of the moon. This theory assumes that at one time, probably about 4.6 billion years ago, all of the moon's surface looked like the Central and Southern Highlands do today—minus a lot of the craters. The moon was subsequently bombarded by objects, some large enough to knock out the large circular basins such as Serenitatis and Imbrium (SN: 1/15/72, p. 38). Later these basins were flooded by melting, upwelling or volcanic activity.

The origin of the low areas such as Oceanus Procellarum that don't look like the circular basins is more difficult to explain. Harold Masursky of the U.S. Geological Survey believes that Oceanus Procellarum represents an area where not much crustal differentiation took place, or if it did, it is missing now.

The most up-to-date information about terrae has come from Apollo orbital data, the unmanned Surveyor lander data and from study of what is believed to be fragments of terra material mixed in with samples from the lunar maria. Most recently Luna 20 landed on a terra north of Mare Fecunditatis and brought back samples of it (SN: 3/4/72, p. 149). (The Soviets have prepared a sample of the Luna 20 material for U.S. lunar scientists and are awaiting a representative to pick it up.) Apollos 11 and 12 landed in maria. Apollos 14 and 15 were billed as missions to hilly, mountainous regions, but those areas were not regarded as true terrae. The Apollo 14 hills resulted from ejecta thrown out by the Imbrium impact (SN: 4/4/70, p. 353). The Apennine Mountain range of Apollo 15 was formed by the Imbrium impact and subsequent faulting (SN: 7/10/71, p. 28). Although the material at both sites was originally crustal, it has since been altered, and geologists don't know how similar the material is to true terrae.

Orbital data indicate that the outer crust in the maria is thinner than it is in the terrae. The data also show that terrae have high percentages of aluminum. This supports the theory that as the crust differentiated, lighter-weight materials came to the surface and that the terrae are what is left of the stages of differentiation. Orbital measurements show that the chemical composition of the maria correlates well with the composition of heavy, iron-rich basalts.

Astrogeologists recognize two broad classes of highland terrain. One kind is described by John A. Wood of the Smithsonian Astrophysical Observatory and other geochemists as "typical highlands." These are areas mainly in the Southern Highlands away from impact basins but where the local geology is all messed up and confused because of smaller impacts. But there is no apparent melting or volcanism in these regions. And they believe these areas would be the places to find 4.6-billion-year-old crustal rocks.

About 12 percent of the near-side highlands represent the second class of terrae. These are highlands that appear to have been filled with later melting or volcanism. The Descartes site falls into this category. Since Descartes is not typical of the near-side highlands, it is not a good place to sample the crust, Wood believes.

Masursky disagrees. He believes that the highland fill areas represent "a more refined and evolved lunar crust" and thus they are the best example of the processes that formed the crust to begin with. He thinks older-looking areas in the highlands would yield rocks so complicated by shock metamorphism that geologists would be unable to ascertain what they were before they had been battered about for 4 billion years. At Descartes, Masursky thinks the astronauts will find rocks similar to those that would have been found on the surface 4 billion years ago. The rocks will be younger, because the crustal evolution continued at Descartes longer, but in his view they will demonstrate how the crust evolved.

The Descartes highland site is at the west edge of the Kant plateau, topographically the highest region on the near side of the moon. Tracking data show that there is not a large positive gravity anomaly there (such as mascons in the maria). "These two facts together say that there must be a very thick layer of differentiated, less-dense crust in the region," says Masursky. "The site represents the continental divide on the near side of the moon. Whatever process led to the development of the light-weight crust . . . continued in this region longer, and is better developed than any place else on the near side."

What kind of rocks will be found? Probably felsites—a high silicon, high aluminum-extrusive volcanic rock equivalent to extrusive anorthosites, says Masursky.

Astronauts John W. Young and Charles M. Duke will spend 73 hours at Descartes while Thomas (Ken) Mattingly is orbiting the moon. Young and Duke will spend 21 hours outside the lunar module (LM) sampling the surface and setting up scientific instruments. They will sample largely two kinds of this highland fill—the Cayley formation and the Descartes formation.

Mapping work and interpretation by Daniel J. Milton, Carroll Ann Hodges, Donald P. Elston, E. L. Boudette, J. A. Schafer and William R. Muehlberger of the USGS have resulted in detailed outlines of the interrelationships of the two kinds of highland fill at Descartes. The Cayley is the plains-forming fill unit that is scattered throughout the entire Central Highlands. It is characterized by mostly smooth to undulating terrain. "The Cayley must be volcanic, because it fills in like bathtub rings," says Muehlberger. "In other words, they were relatively fluid, or very fluid materials. Their light albedo tells us they are not mare basalts."

The Descartes formation, the second fill, is also believed to be the result of highland volcanics. The entire formation extends over an area 100 kilometers by 60 kilometers and is made up of hilly, mountainous terrain that forms domes and furrows. Several mountain-type formations of Descartes fill are found in the landing area. "Descartes is of significant importance in terms of the volcanic or petrochemical evolution of the moon," says Muehlberger. The fill materials form high relief units. "They not only fill in craters, they fill in the uplands and flow over the uplands and down into the lowlands. They make topographic escarpments hundreds of meters high." From this evidence geologists assume the material was extremely viscous volcanics.

The LM will land on the Cayley plains between two bright craters named North and South Ray that fence the landing area to the north and south. They are about a kilometer in diameter. Both are about 900 million years old and probably cut through the volcanic fills to the material below. The astronauts will sample volcanic formations and ejecta from the craters during three seven-hour periods outside the LM.

When exactly did the highland fill at Descartes occur? The geologists are not sure. "The fill is of a wide range of ages," says Muehlberger. Some of the heavily cratered Cayley in the Central Highlands appears to be Pre-Imbrium in age (older than 3.9 billion years). Where the Cayley formation fills Imbrium impact sculpture, it is younger than 3.9 billion years. Elston and Boudette believe that Cayley and Descartes fills are contemporaneous events in some places. Both Cayley and Descartes are stratified, says Elston, and the stratification units range from 10 meters to 40 meters in thickness.

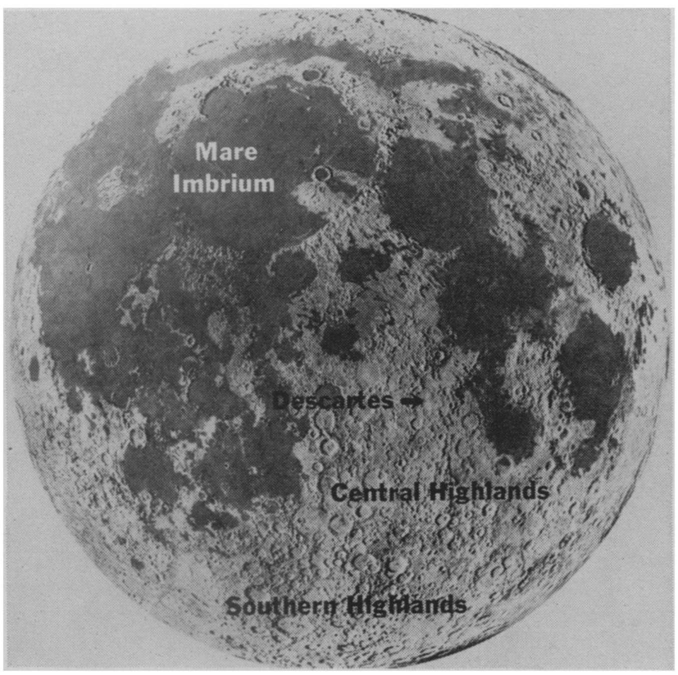
The astronauts will set up instruments to obtain data about the depth of the regolith, the structure and materials of the highlands, the magnetic properties of the site and the heat flow from the interior to the surface.

They will deploy two instruments not flown before. One is an ultraviolet spectographic camera (SN: 10/9/71, p. 249). The astronauts will photograph the earth, galaxies and other celestial objects in the far ultraviolet wavelength range from 500 to 1,600 angstroms.

The other new instrument is a cosmic-ray detector that should tell scientists something about the points of origin or sources of cosmic rays. It should also produce evidence about how cosmic rays are accelerated and something about the medium through which they are accelerated. The instrument consists of plates of solid materials that will record the tracks of charged particles. The package is positioned on the side of the LM's descent stage.

In all there are some 21 experiments that will be used in lunar orbit or on the surface during Apollo 16.

Whether or not Duke and Young bring back samples that will help solve the rather basic questions of the history and evolution of the lunar terrae may not be answered for some time. Duke characterizes the trip as "a mission to volcanic highlands." And 16 is the only Apollo mission that will land in the highlands. "Since we haven't really sampled the highlands yet, we don't know what has happened in the global thermal evolution of the moon," says Noel W. Hinners of Bellcomm. "Descartes will give us our first good chance —and our last for some time to come." □



Lunar scientists hope the Descartes site, although not "typical terrae," will provide evidence about how the lunar crust evolved.

Rendering by USGS artist