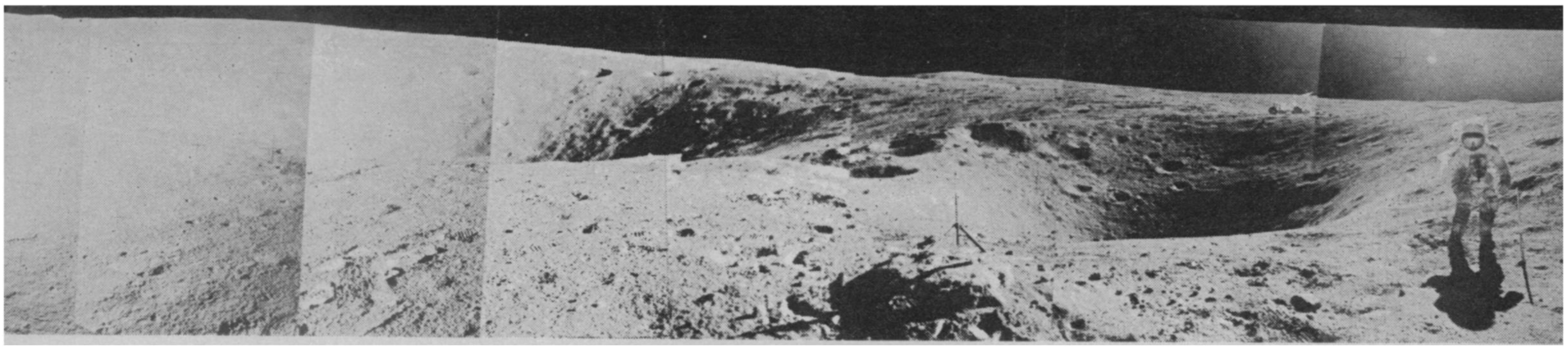


Bonanza from the highlands

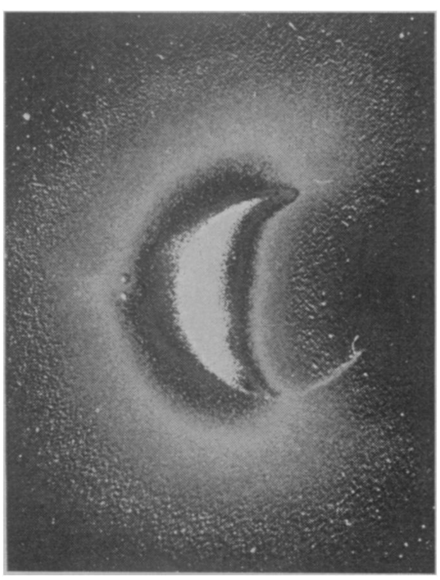
A first look at Descartes returns reveals a 65-kilometer-thick anorthositic crust

by Everly Driscoll

Getting samples from the moon's highlands had been the magnificent obsession of most lunar scientists, and now it appears that their anticipations were justified (SN: 4/8/72, p. 235). Last week at NASA's Manned Spacecraft Center (MSC) in Houston, scientists reported on their preliminary analyses of the Descartes highland material and interpertation of the seismic signals.

Scientists think that the highlands are what is left of the lunar crust. If so, Apollo 16 is a bonanza find. "The overriding fact about the chemical composition of the material," says Paul W. Gast of MSC, "is that it is rich in aluminum and calcium. The concentrations of these approach the composition of pure plagioclase [anorthosites] and are almost identical to the composition inferred [from orbital data] for large areas of the lunar highlands. If we don't have a Genesis Rock, we have lots of material that's been broken off of such rocks."

And, says Gary Latham of Columbia's Lamont-Doherty Geological Observatory, there is strong evidence that this crust, or outer shell is about 60 kilometers thick. "This is twice as thick as the average crustal continent on earth." The earth's crust varies from 5 kilometers under the oceans to about 35 kilometers under the continents.



NASA

A look at the earth's corona in UV.

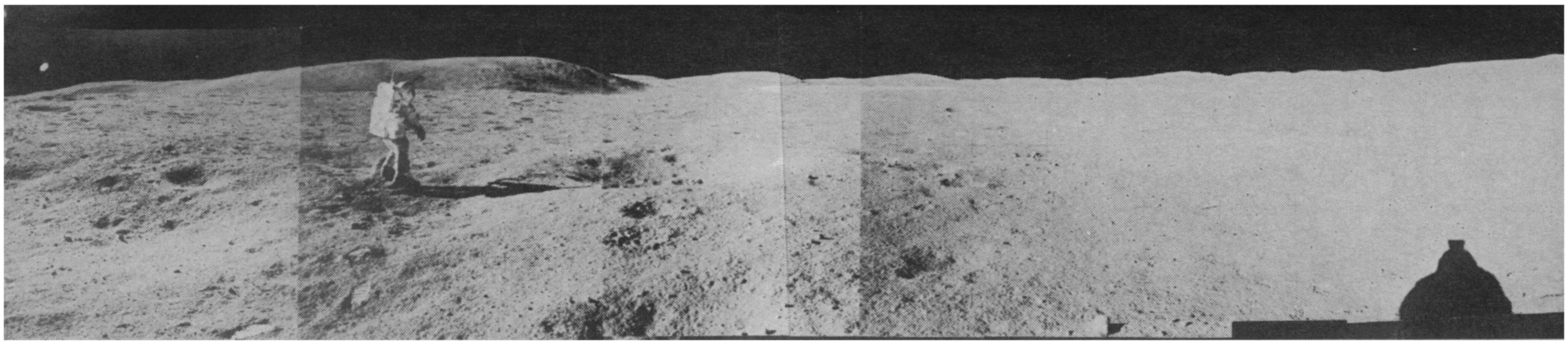
The verification of the crust's thickness (SN: 9/11/71, p. 167) came as a result of the "whopper"—a meteroid that slammed into the moon May 13 with an energy equivalent to about 200 tons of TNT. "The impact waited until we had the fourth [and last] passive seismometer set up and lunar night came," says Latham. "It was a miracle of the first magnitude." Geophysicists had long been awaiting such an impact so they could determine the structure of the moon's interior. The seismic velocities for the crust are equivalent to those for anorthositic material. At about 60 to 65 kilometers depth there is a change in velocity, which Latham interprets as the beginning of the moon's mantle. "It is a velocity of 8.1 kilometers per second, precisely the same velocity for that of the earth's mantle." Rocks rich in ferromagnesian minerals such as olivine and pyroxene would produce such seismic velocities.

These analyses of the depth and composition of what is believed to be the lunar crust are happy surprises to those scientists who wanted to go to a typical highland site. (The highlands comprise 70 percent of the total surface of the moon, while lava-filled basins and lowlands comprise the rest.) Premission photographic interpretation of the site had indicated that Descartes might not be a typical site. The crust appeared to be covered by material from a later volcanic event, called the Cayley formation. Geologists still are not sure what makes Cayley look so different, but says Gast, "We can generalize with some confidence that Cayley is not volcanic."

"The fact that Descartes is not volcanic is happy news," says one geochemist. Scientists have long wanted pristine samples of the lunar highlands, which they assumed to be the older regions of the surface and thus to contain the best clues about the evolution of the moon. The first tantalizing information about the composition of the crust had come from Surveyor 7, which landed on the north rim of Tycho crater in the Southern Highlands (SN: 9/19/70, p. 247) in January 1968. Anthony L. Turkevich, who was in charge of the geochemical analyzer aboard, reported the soil high in aluminum and calcium.

The second hint came from the Apollo 11 soils. In the soil were one-to-two millimeter-sized rocks that were anorthositic in composition. This meant they contained 75 to 85 percent of the mineral anorthite or calcic plagioclase ($CaAl_2Si_2O_8$). These were definitely the oddballs of the first return, as most of the material was basaltic—high in iron, magnesium and titanium. John A. Wood of the Smithsonian Astrophysical Observatory reported at the first lunar science conference that he believed the anorthositic fragments came from the highlands and theorized that all of the lunar highlands might have a similar composition. But that the moon could be covered with a thick layer of anorthositic material seemed rather far out. Anorthosites are relatively rare on earth, and while the crust has a few anorthositic outcrops, most of it is composed of metamorphized granitic rock and a thin coating of sedimentary and basaltic rocks. But subsequent Apollo soil returns also had a few anorthositic fragments and served to whet the appetite for genuine highland material. On Apollo 15, John W. Young found the first large anorthositic rock, dubbed "Genesis Rock" (SN: 8/21/71, p. 122). The orbital data recorded high concentrations of aluminum and silicon in the farside and nearside highlands, similar to the composition of the anorthosite.

Now that there is evidence that the crust is anorthositic and comprises 7 to 10 percent of the moon in volume



(the earth's crust makes up less than one-half percent of the earth), scientists have to explain how this could happen. How does one get a 65-kilometer-thick crust that is 50 to 85 percent plagioclase without melting most of the moon? And if melting occurred, how could the moon's interior be relatively cool today (800 to 1,000 degrees C.)?

Latham speculates that half the moon would have to be melted (down to about 1,000 kilometers) "in order for this light stuff to flow up as slag." Gast thinks that the moon would have to be melted down only to a depth of 200 kilometers, if the composition were homogeneous but moderately high in concentrations of aluminum and calcium (about 10 percent). Wood believes that if a melt occurred down to at least 150 kilometers, such a crust could differentiate out through crystal fractionation. In crystal fractionation, the crystals forming in a magma have different specific gravities than the surrounding liquid and the lighter crystals (such as plagioclase) go to the top and the heavier to the bottom. Wood would have the outer portion of the moon melt from the heat of rapid accretion. But, he says, "The picture of a vast magma ocean on the surface of the early moon is an extravagantly exciting state of affairs, and most people are reluctant to accept this yet."

Gast has another explanation—a moon that accreted from partially differentiated material (SN: 1/22/72, p. 53). "The more calcium and aluminum you put into the outer portion of the moon to begin with, the easier it is to get such a crust without such a deep melt." If the moon started out with 50 to 60 percent plagioclase in the first 100 kilometers, it could end up with a crust that has consistently 80 percent plagioclase now, he speculates.

There is evidence from Type III carbonaceous chondrite meteorites that material of high aluminum and calcium concentrations (30 percent aluminum and 26 percent calcium) was around in the early solar system, says Wood. But these are highly refractory materials. (They condense from relatively high temperatures.) According to current theory these refractory materials would have condensed out of the solar nebula first and thus formed the cores and not the outer shells of planets.

Gast agrees that this is a problem. But he adds, "We don't really know all that much about the history of the sun and the conditions in the solar system at the time the moon was formed."

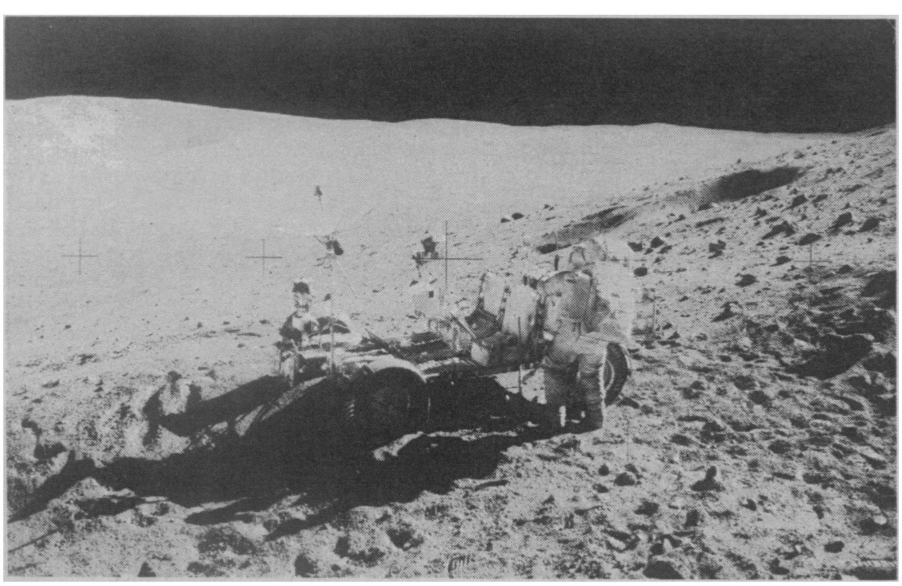
There are many questions of lunar history that the Apollo 16 data do not answer. One is the question of a core (SN: 5/22/72, p. 346). Scientists were hoping that an impact as large as the "whopper" would have indicated reflections from a core. But, says Latham, "This is one find that can't be confirmed or rejected at this point without corroborative data. We have been searching for a signal—energy which would have gone down to the core and bounced back up as a reflector. There is only a suggestion—a hint of such a signal," says Latham. "The reflector would have to be about 1,000 kilometers deep."

One international argument about the moon was settled by Apollo 16 orbital photography. Farouk El-Baz of Bellcomm, Inc. in Washington has located a second three-ringed impact basin on the far side (the only other is Orientale). The basin is more than 1,000 kilometers wide. It is ringed by one-kilometer-high mountains to the east and two-kilometer-high mountains to the west. This finding, says El-Baz, vindicates an earlier claim by Soviet scientists who first discovered the eastern mountains and named them the "Soviet Mountains." The name was later removed from international maps due to an American claim that the area was not mountainous at all, but consisted merely of highly reflective ejecta debris. Now El-Baz proposes returning the Russian name to the eastern range and naming the western range the "American Mountains."

Another mystery was opened up by the Apollo 16 return—a rock that appears to be rusty. The rock looks like rusted iron, says Gast. Although metallic iron is present in larger quantities in some rocks from the Apollo 16 site than others, how the iron could be rusted without the presence of water on the moon is a puzzle. Gast says the rusting is definitely of lunar origin.

One question about the earth has been answered by photography from the ultraviolet camera of Apollo 16. The geocorona is a halo of low density hydrogen that surrounds the earth. One picture shows that it extends out from the earth about 64,000 kilometers away from the sun and from 28,000 kilometers to 160,000 kilometers toward the sun, says Thorton Page of MSC.

Only one more manned lunar landing remains—Apollo 17, in December. It will land in a valley called Taurus Littrow (SN: 2/19/72, p. 120). The task now is to find all the missing pieces of the lunar story with just one landing left. □



NASA

A look at Smoky Mountain from the crater-marked slopes of Stone Mountain.