6

Back at the Main Event

1965

PROGRESS ON ALL FRONTS

Some cautious or overextended scientists had criticized NASA's rush to place people on the Moon before precursor probes could gather more data and prepare the way. Ranger was expected to provide information about the surface material that could help in designing the Surveyor and Apollo landing vehicles. However, Thomas Gold made his input before Ranger could. In 1963 Grumman Aircraft (now Aerospace) Corporation increased the size of the LEM's footpads from 22 to 91 cm because MSC had listened to Gold's worries about surface dust.[1] Grumman also reduced the number of the LEM's legs from five to four to save weight and simplify construction. Ranger finally did provide reassurance that the surface was not a quagmire and that the LEM design was adequate. Mobile dust had not obliterated the surface, at least not within a dangerously recent time. There was no shortage of craters, but the greatest concentrations were unevenly distributed and could be avoided by intelligent mapping and avoiding the rays.

Anyway, both the United States and the Soviet Union[2] were preparing to place humans in space whether they were going to land on the Moon or whether they were planning to do any science while there. A series of 10 suborbital tests of the Saturn 1 launch vehicle, which was never rated for manned flight, was conducted between the early dates of 27 October 1961 and 30 July 1965.[3] These tests, named Saturn-Apollo 1–10, are not the missions known to most of the world as Apollos 1–10. Overlapping at the end of this test series was Project Gemini, an intermediate stage between Mercury and Apollo that had been initiated in December 1961.[4] Geminis were launched by Titans, which are far more powerful than Mercury's Redstone and Atlas rockets but three times less powerful than Apollo's Saturn 1, not to mention the later Saturn 5, the Moon rocket.

Unlike the passive Mercury capsules, Geminis could change their orbits precisely and were designed to test the rendezvous technique, life-support systems for missions the length of a lunar flight, and the human crews themselves. After two unmanned tests in April 1964 and January 1965, Gus Grissom and John Young flew the first manned Gemini, Gemini-Titan 3, in March 1965 and landed the day before Ranger 9 crashed on the Moon. Gemini never flew to the Moon, but both Robert Gilruth and George Mueller in mid-1965 endorsed a plan for it to do just that.[5] Although this "Large Earth Orbit" plan was squelched by James Webb and Congress, preparation for a Moon trip by Apollo was clearly the reason for Gemini's existence.

Trips to the Moon, of course, required more than rockets and spacecraft; they required committees. To coordinate the various contemporaneous spaceflight projects in OSSA and OMSF, Homer Newell created in May 1965 the first of the committees that would assume central roles in the site-selection process: the Surveyor/Orbiter Utilization Committee (SOUC). Chaired by Newell's deputy in OSSA, aeronautical engineer Edgar Cortright, SOUC would coordinate the Surveyor and Lunar Orbiter programs for the benefit of Apollo and for each other; its members included directors or high-level representatives of the Apollo, Surveyor, and Lunar Orbiter projects and program offices.[6] The committee's task was to gather engineering and science information and pass judgment on proposed Surveyor landing sites and Lunar Orbiter photographic targets. In so doing they created the methodology for Apollo site selection. Another key committee, with overlapping membership, was established in July 1965 by George Mueller of OMSF, at Bellcomm's suggestion, and was even more portentous: the Apollo Site Selection Board.[7] The ASSB was chaired by the Apollo program director, who between October 1964 and August 1969 was the Mueller appointee and former director of development of the Minuteman ICBM, Air Force Brigadier General Samuel Cochran Phillips (1921–1990). In chapters 10–17 we shall have cause to rejoice or mourn as the ASSB delivers seven successive fateful pronouncements about where astronauts will set foot on the Moon.

The astronaut-training program also continued and in June 1965 entered its third "academic term," which we thought of as phase 3. Between 30 June and 2 July, Bob Smith guided us to another region of the silicic ashflow tuffs about which he is an expert. The ashflows in the Valley of Ten Thousand Smokes on the Katmai Peninsula of Alaska are not degraded, faulted, overgrown, or desert-varnished but were born yesterday — in Ralph Baldwin's birth year of 1912 — and were still smoking. Spurr had been at the place before the eruption and had walked on ground now deeply buried by the flows.[8] If the Moon had ashflow tuffs, then the draped topography, fumaroles (vents for remnant gases), channels, and other landforms like the ones we saw there should show up on photographs and could be explored effectively by the prepared astronauts. The simulation of missions was part of the purpose of phase 3. Pairs of astronauts and their instructors, learning together, communicated by radio and recorded their observations and discussions in a first approximation of the way it would be done for real not too many years later.

Isolated Iceland, with its fresh basaltic lavas and landforms, was an even more relevant spot. By "fresh" I mean still forming. Iceland is an exposed part of the mid-Atlantic ridge along which new volcanic rock periodically rises from the mantle to be added to the oceanic crust. Though the ridge is decidedly nonlunar, Iceland has lunar-type maars and chain and fissure craters. We saw plenty of these under the guidance of the Icelandic experts, led by Sigurdur Thorarinsson, when we visited in July 1965. We trekked way into the interior of the barren but beautiful island to view the spectacular young Askja caldera, part of which had gushed out vast quantities (2.0–2.5 km^3) of coarse fragments in 1875 and had erupted several times since then, including in 1961.

A major milestone of a different type was reached at the same time. Among the many bones of contention between science and NASA was who should go to the Moon, scientists or test pilots? Dating from Eugene Shoemaker's flash of insight in 1948, scientists had thought scientists should go. The Space Science Board of the National Academy of Sciences had vigorously promoted this view. As astronaut Walt Cunningham put it, "The Academy's position seemed to be that anyone with a yen for adventure could be a pilot, but only God could make a scientist."[9] Many scientists — though definitely not we geologist instructors — did look down their noses at the astronauts as "dumb fighter jocks," just as they looked down their noses at the Apollo program in general. In opposition was most of NASA, which thought the test pilots already in the program, or other men very much like them, should become the lunar astronauts. Quoting Cunningham again: "The real clash in our space world, though it existed largely behind the scenes, was between the pilots and the scientists — the goals of technology against those of science."

As early as September 1963 a compromise had begun to take shape whereby scientists could apply for the astronaut program if they trained in the piloting aspects of lunar exploration. Harry Hess established and Shoemaker chaired an ad hoc committee of the Space Science Board to define the scientific qualifications of a "scientist-astronaut" and to evaluate the expected flood of applications.[10] A recruiting call went out in October 1964 and elicited over 1,000 applications, of which 400 survived the preliminary screening by NASA during the next two months. The USGS was represented by Dan Milton, Jack Schmitt, and Mike Duke, at that time with Astrogeology in Washington but since the spring of 1970 at MSC. Dan and Mike were among the great majority who washed out somewhere during the tortures of physical and psychological testing that NASA inflicted on the candidates; passengers in automobiles driven by Dan are sure they know what eliminated him. Shoemaker's committee nominated only 16 survivors of the testing. The size of the final crop disappointed him even more: only 6 ended up occupying offices in Building 4 at MSC after their selection was announced in June 1965. This would be the fourth group of astronauts after the Mercury 7 and the 9-man "Gemini" and 14-man "Apollo" groups. They were not another bunch of red-hot test pilots with the Right Stuff.[11] All 6 held M.D.s or Ph.D.s. One, physician Duane Graveline, resigned two months after the group's selection because of a domestic dispute. Another, Curt Michel, had gone as far as the geologic fieldwork with Dan Milton at the Henbury Craters, but he never really warmed to the program and resigned in August 1969 in the face of the low likelihood of flying anytime soon.[12] Three others survived the Apollo era to fly in the three manned Skylab missions in 1973 and 1974: Joe Kerwin, Owen Garriott, and Edward Gibson.

The sixth was Jack Schmitt. Among all us USGS astrogeologists, which he had been for a year, only Jack had the required combination of good health, good eyesight, good hand-eye coordination, and the potential ability to fly a jet. So in July 1965 the one geologist who would both prepare and execute a lunar mission transferred from the USGS to NASA and began 53 weeks of jet pilot training at Williams Air Force Base in Arizona.

WOODS HOLE AND FALMOUTH

As Jack was entering flight school, the second summer study addressing the role and goals of science in lunar exploration took place in Massachusetts. A first, more general, segment was sponsored for NASA by the Space Science Board and was held at the Woods Hole Oceanographic Institute under the chairmanship of Harry Hess. The convened scientists looked much more benignly on manned spaceflight than had the generally hostile physicist-dominated crowd at Iowa City in 1962 and outlined some general goals for lunar exploration.

The second segment was held between 19 and 31 July under the auspices of an OSSA committee established by Homer Newell to advise his Manned Space Science Division under Willis Foster. Both the committee and the conference were chaired by geophysicist Richard J. Allenby, Foster's deputy.[13] The 123 conferees assembled at a high school in Falmouth, the town surrounding Woods Hole, to get down to details.[14] They were divided into seven working groups: bioscience, particles and fields (sky science par excellence, chaired by Wilmot Hess), lunar atmospheres (not actually at the meeting but represented by Curt Michel), geodesy/cartography, geophysics, geochemistry, and, last but not least, geology. The geophysics group was chaired by Frank Press, who had recently moved from Caltech to head the geology department at rival MIT and create a new focus on the Moon and planets.[15] The geochemistry group's chairman was James Richard Arnold (b. 1923) and the secretary was Paul Lowman, both early entrants into lunar science.[16] Jim Arnold had been advocating orbital gamma-ray spectrometers at least since the founding of NASA, although he has disclaimed complicity in the first-priority "A" ranking this experiment received. An eighth discipline was astronomy, which for the moment met only as a study group convened by NASA astronomer Nancy Roman.

The conference came at the right time to influence what later happened and decided much that actually came to fruition. In the preceding months the concept of a package of geophysical instruments to be taken to the Moon and emplaced by the astronauts had been taking shape. This was the *Lunar Surface Experiments Package,* to which was added the name *Apollo* six months later and so known forevermore by the acronym ALSEP.[17] The geophysics group dug into the job of defining tasks and instruments for the ALSEP. They expressed surprise that operational restrictions on weight and space did not appear likely to keep *them* from doing everything they wanted—emphasis on "them," for they did envision possible conflicts with the atmosphere group's wishes. Central to the planning was the design of the ALSEP as *modular,* that is, different instruments could easily be plugged in and unplugged as appropriate for each mission. The items on their wish list, all of which were granted more than once on Apollos 12–17, after five more years of fiddling and chiseling on concepts and designs, consisted of a magnetometer, gravity meter, passive seismometer, active seismometer, and heat-flow probe. They seem to have worried most about the drill for the heat-flow experiment, demonstrating a certain ability to foretell the future.

The geology working group was chaired, as might be expected and hoped, by Shoemaker. Geology's secretary was Don Beattie of OMSF, an able geologist to whom the manned-investigations group in Flagstaff reported. Also in the geology group were Bill Fischer, Edward Goddard, Harry Hess, Hoover Mackin, Jack Schmitt, Aaron Waters, and Bob Wallace. Fischer, the chief of the USGS Photogeology Branch, had participated in early studies of lunar photometry for the Astrogeologic Studies Group. (We met him in chapter 2 as one of the promoters of the Hackman-Mason *Engineer Special Study.*) Bob Wallace was one of the top-notch non-Astrogeology geologists recruited by Hal Masursky from the old guard at Menlo Park. Astronaut and physicist Walt Cunningham was there to warn the geologists in sharp terms about the formidable difficulties imposed by factors beyond their control like the space suit and available oxygen. A number of astrogeologists served as "rapporteurs": Al Chidester, Don Elston, Hal Masursky, Jack McCauley, Joe O'Connor, Gordon Swann, and Spence Titley, then on temporary duty with the USGS. Rapporteurs theoretically served to keep track of the proceedings and keep work flowing toward a final report. Actually, their purpose was to stack the deck in favor of the geology team's recommendations. Falmouth was the first major entry of the USGS geologic mappers into the public arena, and their influence was considerable.[18]

The geology group had a straightforward concept of the three major classes of lunar terrains: maria, cratered highlands, and large craters. Their interest in craters stressed the then-popular notion that many craters were hybrids which remained thermally active long after their formation by impacts and thus became the sites of all sorts of volcanic modifications. The Ranger 9 mission had ended only five months before, and they had in mind that constant companion of mission planning, Alphonsus.

The conferees were considering an elaborate 10-year program of exploration starting with the first manned landing. There were to be five classes of missions. The first type, to be gotten out of the way as fast as possible, consisted of the first one to three landings—whatever it took to fulfill Kennedy's goal for Apollo. This phase was usually called early Apollo; sometimes it was called simply Apollo and everything afterward was post-Apollo. The geology group thought that the maria could be left behind and the highland plains explored as early as the third landing. Our telescopic work had led us to think that these plains were of two types, the volcanic Cayley Formation and an older smooth variant (facies) of the impact-created Fra Mauro Formation; exploration of both was desirable. The group wanted the diverse, laterally and vertically variable surficial debris examined in detail by trenching and coring, showing clear evidence of Shoemaker's interest and an understanding of what could and should be done. Crater ejecta would be traversed and sampled carefully because each blanket probably represents the entire stratigraphic section of debris or rock penetrated by the crater; for example, they suggested that a Copernican crater superposed on the Fra Mauro Formation would fulfill a wide range of objectives—as Cone Crater in fact did at the Apollo 14 site only five and a half years later. Stereoscopic photographs would, and often did, document each sample before and after its collection. The group devoted much attention to hand tools, as would NASA, contractors, and scientists for several more years.

The second type of mission was the unmanned Lunar Orbiter, which also flew much as the conferees thought it should. The first Orbiter was to search for early Apollo sites in the equatorial belt, but the geoscience working groups agreed that the later flights should go into polar orbit.

The third class of mission suffered a less happy fate. At the time of the conference, the later Apollo, or post-Apollo, program was called Apollo Extension System (AES). One type of AES was the manned lunar orbiter. There were to be five or six thorough manned exploration missions from orbit, each spacecraft equipped with all the cameras and remote-sensing devices needed to gladden the heart of every earth and sky scientist. The astronaut could switch on high-resolution multiband cameras when he saw something interesting, while synoptic multiband cameras surveyed the big picture. The orbiting and landing missions would overlap so that the surface analyses could be calibrated with units mapped and characterized from aloft. Calibration would also be achieved by dropping off hard-landing or soft-landing probes. The Moon would be mapped geologically at scales of 1:2,500,000, 1:1,000,000, and, eventually, 1:250,000. Still larger scales would be needed for special purposes. An enormous effort by geologists in mapping and geologic analysis was projected, peaking at 333 man-years in the single year of 1970 and totaling 1,679 man-years! Apparently the conferees — more specifically photogeologist Bill Fischer, according to Hal Masursky — had not quite absorbed the recent lesson of Ranger that the Moon's geologic units are so severely blurred by impact tilling at the fine scale that most detailed lunar photogeology is futile. The actual synoptic mapping scale turned out to be 1:5,000,000. "Only" the 44 1:1,000,000-scale near-side quadrangles were completed, and "only" 29 maps at scales of 1:250,000 or larger were published (mainly for Ranger postflight and Apollo preflight analysis); "only" because this was still a hell of a lot of maps and was the tip of the iceberg of many additional preliminary versions.[19] The manned orbiter never flew, and a quarter century later the chemistry and physics of most of the Moon have *still* not been explored from orbit.

Some of the instruments planned for the AES manned orbiters actually flew in orbit with Apollo, including a laser altimeter and a number of the nonimaging remote sensors. So did metric cameras for accurate mapmaking and panoramic cameras for high-resolution studies, thanks in no small part to Hal Masursky's untiring promotional efforts. The fourth class of mission, the AES surface missions, also left some legacy. These were thought of as continuations of the early Apollo missions but with longer stay times (up to 14 days), longer traverses (up to 15 km), and larger scientific payloads (many instruments and 200–250 kg of samples returned). There were to be at least three and possibly as many as six through 1974. Except for such items as the 14-day stay time, this is a rough approximation of what was actually flown in 1971 and 1972 by Apollos 15, 16, and 17. Drills that could penetrate 3 m and a good roving vehicle were carried as proposed at Falmouth. However, a surveying staff that would carry a video camera, a film camera, and a laser tracker to locate the astronauts during their traverses never went to the Moon. A good working model was built, but the idea was fought by Cunningham and others at MSC as being unwieldy.[20]

The fifth type of mission came nowhere near fruition, although something like it is now being reproposed for lunar exploration in the twenty-first century, and an offshoot is being proposed for Mars. In 1965 it was called post-AES. Unmanned and manned traverses would extend hundreds of kilometers across the surface, passing by caches that had been left by unmanned Saturn 5 rockets and not necessarily taking off from the landing point. Dual launches to support a single mission were in the plans not only of 1965 but for several more years, and the immense Vertical (later, Vehicle) Assembly Building at the Kennedy Space Center had been built to hold four Saturn 5s simultaneously. Finally, a lunar base would be emplaced. This science fiction would begin in 1975 and proceed at the rate of one mission per year through the far-off date of 1980.

But back to mid-1960s reality. Apparently somebody in NASA did not like the idea, implied by the name AES, that Apollo would be extended, so in August 1965 George Mueller formalized the follow-on program under the name Apollo Applications Program (AAP).[21] AAP would "apply" the Apollo and Saturn equipment to other uses, including more science. AAP would be the bridge from Apollo to ambitious future undertakings. It was not to be; all lunar landings eventually were considered part of the Apollo program. Nevertheless, this history will have much to say about AAP while discussing the planning for Lunar Orbiter and late Apollo landings conducted during 1967.

THE APOLLO ZONE

The immediate site-selection challenge for geologists and terrain analysts was to recommend landing sites for early Apollo. At the time of the Falmouth conference this entailed picking landing sites for Surveyor and photographic targets for Lunar Orbiter.[22] Knowledge of the Moon's surface derived from direct observation and geologic inference guided the pinpointing of specific target spots or areas. As always, however, the requirements imposed by Apollo's spacecraft, rockets, and launch and flight operations established the basic ground rules. To make sense of later discussions of site selection, we need to understand the concept of the *Apollo zone,* devised by Bellcomm to simplify and unify the planning process.[23] At first the Apollo zone shrank and expanded like an accordion, but by 1965 it had settled down as a strip 10° wide and 90° long between 5° north and south latitudes and 45° east and west longitudes, or 300 by 2,700 km. These were simplified boundaries for planning purposes; the actual zone of accessibility was pinched in the middle, a little wider in the east than in the west, and different for each launch month.

For a number of reasons, MSC and Bellcomm had decided that early Apollos should try to land only in this near-equatorial belt of the central near side.[24]

Less fuel was consumed in approaching equatorial than nonequatorial sites. A spacecraft could return to Earth from the equatorial belt in a so-called free return if its main engine malfunctioned—a major worry for the early missions. The lunar equatorial zone was accessible throughout the year from injections of the Saturn third stage and the attached spacecraft from over the Atlantic or the Pacific. The launch window for a given launch date was longest for near-equatorial sites.

The longitude restriction to the central near side also had multiple reasons. The far side was excluded from the beginning because radio communication with the astronauts could not pass through the Moon, and no repeater satellite was planned. Moreover, positions of lunar features were so poorly known, especially on the far side and limbs, that the orbiting astronauts had to sight navigational landmarks and communicate their positions to the navigation and guidance computer on Earth in order to update the spacecraft's orbits. This took time and could only be achieved while the spacecraft was in view of Earth, so landing sites could not be located near the limbs even on the near side. One more consideration was time of splashdown on Earth: lunar blast-off from the wrong spot would bring the astronauts back at night or over land.

Spacing of potential landing sites within the Apollo zone was determined by a combination of modern and old-fashioned factors. A major modern worry was reliability of the launches, a vexing problem throughout the Space Age. Slippage beyond a launch window of a few hours might cause slippage by two full Earth days because the recycle time for a scrubbed Saturn 5 launch was about 44 hours.[25] NASA could not command the Sun to stand still during a launch hold, and so the old astronomical concern of lighting became decisive even in this age of high technology. Each Earth day the Sun would get 12° higher over a given point on the Moon. At one time engineers who looked more closely at their graphs than at the Moon had calculated that a Sun elevation between 30° and 45° should impart the optimum illumination to a lunar scene. Astronomers and geologists who had actually looked at the Moon knew that those Sun angles would result in bland images and that lower angles of 5°–20° were required to bring out topographic detail. Eventually this bit of experience carried the day over theory. Bellcomm's new calculations showed that the Sun should be no lower than about 5° and no higher than about 13° above the horizon behind (east of) a descending lunar module. Shadows would obscure the landing site if the Sun angle were below 5°. Sun angles higher than 13° might place the astronauts in the equally bad predicament of looking at a bright spot that appears along the Sun's rays opposite the Sun (*zero phase* point), for approach angles of about 16° were being planned for early Apollos. This narrow lighting range meant that the original landing site could not be used if a launch slipped by an

Earth day. Therefore, if no escape hatch awaited about 24° farther west (about 720 km at the lunar equator), the launch would have to be postponed a full month. The longer the hold, the greater the cost. As we will see, the backup requirement called many a shot in the site-selection battles until NASA thought up ways around it.

ZOND 3 AND THE ORIENTALE CRATER CHAINS

As the scientists were meeting at Woods Hole and Falmouth, Mariner 4 showed a moonlike surface as it flew by Mars on 14 July, and Zond 3 looped past the Moon on 20 July—a date destined to be famous in space exploration.[26] This first lunar Zond was launched on 18 July into a parking orbit and then shot to the Moon in the very fast time of 33 hours.[27] Zond began a 68-minute photographic run at 0124 GMT on 20 July when it was 11,570 km above the west limb, then dipped to 9,220 km on the far side before climbing back up relative to the Moon and heading off into space. It dumped its data back to Earth on 29 July when it was 2.2 million km away, apparently because it was originally intended as a planetary probe designed to operate from great distances.[28] The haul was about 25 photographs of western Oceanus Procellarum, the west limb, and the far side, including a previously unseen region as far west as the terminator at longitude 166°. Zond's camera system was similar to that of Luna 3 but showed more detail because of the lower Sun angle. The resolution was about the same as would be obtained by an astronomical telescope if a telescope could see the far side. Overlap of adjacent frames provided stereoscopy, and three filters were used. With Zond 3 the Soviets had almost completed the photographic coverage of the Moon begun by Luna 3. Lipskiy noted that the far side has many of the ringed structures that we call basins and the Russians called *thalassoids*—"sea-like" features without the dark filling.[29]

The star of the coverage was the Orientale basin, which was known from telescopic observations at favorable orientations of the Moon (librations) but had never been seen in its entirety. Its concentric ring structure is clearly visible; so also is a distinct system of radial chains visible on the far side beyond the rings. At this point most astrogeologists realized that the basin itself was created by an impact, but some thought that the chain craters originated internally. We have seen that the hybrid-origin notion of "impact-triggered" faulting was running rampant in the mid-1960s for basin radial "sculpture" and craters, even though the notion was subsiding for secondary craters of Copernicus-type primaries. One view supposed that the Orientale chain craters were volcanic craters that grew along the faults.

Exploration and reality have been especially unkind to all internal interpretations of special features in the lunar terrae, and none more so than the chains and clusters of craters surrounding ringed basins. Gilbert and Baldwin knew that the sculpture was created by flying ejecta. However, I doubt that anybody in the early 1960s realized how many craters around basins are related to the basins and created by secondary impacts of the basin ejecta. The Zond 3 pictures fixed the first problem; very many craters as large as 10–20 km across are indeed related to basins.

As for the secondary-impact interpretation, I know of only one early astrogeologist who realized that basins might have secondaries like those of Copernicus. In a USGS monthly report with the incredibly early date of February 1963, Dick Eggleton accurately suggested that most near-side chains and grooves originated through the secondary impact of Imbrium ejecta, down to correctly (I believe) specifying their probable diameters (10–45 km, typically 20 km). Bill Hartmann identified some circum-Orientale craters as secondaries but ascribed the majority around Orientale and other basins to the impact-induced mechanism.[30] Newell Trask and I may have been the next to suspect the secondary-impact origin. During good nights with the telescope Newell recognized fields of pits around the Orientale and Humorum basins as a pitted type (facies) of basin material, entertaining both impact and volcanic hypotheses.[31] By comparing the radial ejecta and secondaries of the crater Aristoteles with the peripheries of basins, I concluded that basins have secondaries 1–3 km wide and 8 km long[32] — having overlooked, forgotten, or ignored Eggleton's conclusion that the basin secondaries would be still larger. In mid-1965 Newell and I collaborated on the first regional compilation of lunar geology.[33] Newell concentrated on the Orientale-Humorum region where he first saw the pitted terrain, and we identified similar terrain around other near-side basins as well. Later, most USGS astrogeologists and almost all newcomers to lunar geology ascribed the pits and craters clustered around basins to volcanism. They did not change their minds until Apollo 16 touched down near some typical pits.

THE LUNAR FIELD GEOLOGISTS

A trip in September 1965 to the very young volcanic terrain of the Medicine Lake Highlands of northeastern California ended my participation in, and direct knowledge of, the field phase of astronaut training.[34] The Highlands are a broad shield volcano with still another caldera (8 km in diameter) and such features as obsidian domes and flows. The section of the trip I was on, which had to be curtailed so the astronauts could hurry home to beat a hurricane approaching Houston, was led by the former (1959–1964) USGS chief geologist, Charles Anderson, who had presided over the founding of the Astrogeology Branch. I dropped out of the training program because I felt I would be more useful as a full-time lunar geologist than as a teacher. More geologists wanted to go on astronaut-training trips than wanted to map the Moon. The manned-studies group in Flagstaff was coming into full flower and would soon be devoting all its time to detailed training and mission-simulation exercises. Still, like the other instructors, I enjoyed associating with the astronauts and learned a lot of geology on the trips. How much geology a geologist knows depends very much on the amount he or she sees firsthand.

Strangely, the trips also provided unique social opportunities for the astronauts. Usually they were split into small training groups, but on the geology trips most of them were together. Buzz Aldrin, for one, valued this aspect of the trips and generally enjoyed them.[35] Their interest in the subject matter varied greatly. Dave Scott became deeply interested and knowledgeable in geology. I recall an occasion in New Mexico when Richard Doell of the USGS at Menlo Park was pointing out superposed lava beds that recorded reversals of the polarity of Earth's magnetic field that he had been studying.[36] Scott's comment, "Gee, learn something new every day!" showed that he, and I think only he, realized the profound importance of this idea. A dozen other astronauts were also good and interested students, although the articulate Mike Collins tells us that the laboratory work bored many of them.[37] He and Frank Borman thought that some geology was alright, but the 58 hours they were getting was too much.[38] Alan Shepard exhibited open disdain for the whole notion of looking at rocks. Most of the astronauts in the first three groups were pilots first, second, and third, and scientists only by necessity. They had a fierce desire to fly, to achieve, and to surpass their peers. With few exceptions they were first or only sons from the midwestern and southern American heartland. They knew that they were at least as specially skilled as any scientist. Although they did not originate the term *Right Stuff,* they had it, and most scientist-astronauts and other "hyphenated astronauts" (Walt Cunningham's term) did not. Most test pilot–astronauts, I believe, regarded space and even the Moon not as new realms for the exploring urge of mankind but as new places to fly new machines. However, because they would do anything to get a lunar-landing assignment, especially that all-important first one, most of them did their very best in geology and concealed any lack of interest just in case it counted.

Their obvious vitality, alertness, and competence, not to mention their reputation, made us think at first that they were supermen able to absorb everything about all subjects. We piled on textbooks and equipment as if we were teaching advanced university students majoring in geology. One of Collins's complaints was having to learn the formula for turquoise, hardly expectable on the Moon but included by the MSC instructors in their mineralogy course. He might also have mentioned Chidester's teaching of the use of the aneroid barometer (dependent on air pressure) in measuring altitudes. Learn they did; totally retain they did not, any more than normal humans could have done. And as it turned out, the naysayers proved right: except for the special case of Schmitt, skill in geology was almost certainly not a factor in crew selection, as some astronauts feared and others hoped.

The cornball image that many astronauts projected in their "air"-to-ground communications and public utterances did not appear in person. They included swingers and straight arrows, teetotalers and borderline drunks, political conservatives and liberals, evangelists and atheists. They received no examinations, quizzes, grades, or even formal evaluations from the instructors in any of their courses; all were considered intrinsically equal. However, we concentrated special instruction on some who seemed either especially interested in geology or competent in science in general. Among these I remember Neil Armstrong (under Dale Jackson's wing), Buzz Aldrin (under mine), Charlie Bassett, Roger Chaffee, Walt Cunningham, Rusty Schweickart, Dave Scott, and Elliot See; there were probably others. We liked Scott Carpenter and Gordon Cooper because they were independent spirits—unfortunately to the extent of getting themselves eased out of the astronaut corps before they had a chance to fly an Apollo mission.[39]

The training continued for the next few years, then heated up after the Apollo 11 landing in July 1969 to become an intensive course of mission-related expert instruction. In later chapters we shall see how the students of the course performed as field geologists on the Moon when the chips were down.