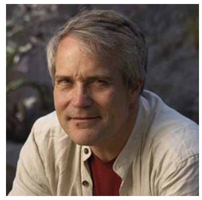
PLANETARY SCIENCE

Imagining a new era of planetary field geology



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July marked the beginning of a 3-year-long celebration of one of the most remarkable periods of human exploration in history: the Apollo missions to the Moon. Reflections on Apollo have inspired a renewed international interest in sustained lunar exploration. While there are many motivations for traveling to the surface of the Moon, experience shows that a sustained program of science activities on the lunar surface would yield unique and invaluable scientific data. Although the Apollo missions themselves ended nearly five decades ago, Apollo science continues today. Building on field scientific observations and sampling by the Apollo astronauts, we now know that the Moon is very old, forming perhaps only a few tens of million years after the 4.56-billion-year origin of Earth and the Solar System. Unfortunately, our planet preserves only sparse evidence of its own ancient history as a consequence of the continuous recycling of Earth's crust through plate tectonics. There are no plate tectonics on the Moon and none of the erosional effects of wind, water, and flowing ice that drive most of the surface evolution of Earth. As a consequence, the Moon represents an incredible archive of the early history of the inner Solar System, a billion-year period that included the stabilization of Earth into a world capable of sustaining life. We may never fully understand the evolution of environmental conditions in the inner Solar System that eventually made the origin of life on Earth possible without a more comprehensive understanding of the deep history of our nearest neighbor. It is precisely that level of scientific endeavor currently contemplated by space agencies worldwide. But will we be sufficiently prepared to take full scientific advantage of future voyages to the Moon and beyond?

Geologic research on the Moon must not be focused solely on the collection of lunar rocks and soil. Nearly 300 years of geoscience on Earth has taught us the importance of understanding the geologic context of samples so as to best interpret the data we obtain from them in the laboratory. This is no less important on the Moon. In the geosciences, the art and science of contextual awareness is the research domain of field geologists, and geologic field work on the Moon is unusually difficult. No part of the ancient lunar surface is truly pristine; observable geologic relationships are complicated by billions of years of space weathering, the combined effects of cosmic ray, solar wind, and meteorite bombardment. The last of these is especially problematic because meteorite impacts result in ballistic redistribution of material over great distances. These processes make it challenging to understand the geologic context of any sample collected without detailed geologic mapping. As is the case on Earth, remote-sensing data can help inform those mapping studies, but detailed on-site work will be necessary for adequate ground truthing.

Even the most basic geologic mapping competency requires extensive training, and the best geologic mappers are those who have spent years honing their skills through field research on Earth. Current astronaut training worldwide includes some geology, but the emphasis on developing and exercising field skills is low compared to the training program developed for the Apollo astronauts. Field geology was the single most emphasized type of scientific training for Apollo crews. Those realistic field exercises, amounting to many hundreds of hours and almost 25% of crew training time, were instigated and overseen by NASA's Astronaut Office and implemented by a broad spectrum of professional geologists and engineers from the U.S. Geological Survey, academia, and NASA itself. The success of the Apollo training hinged on planning and debriefing by geologists who were field-oriented earth scientists, not only planetary scientists, some of whom had decades of experience in both field research and teaching field geology in university settings. A similar emphasis on field geology training is required before we send astronauts to new targets for planetary exploration. In addition, including at least one classically trained field geologist as a crew member would maximize the quality and quantity of science that could be done.

Despite the value of training on Earth, field geology by humans on a planetary surface is very different from field geology as commonly practiced on Earth and not only because of the constraints of space suits and time. Although terrestrial field geologists increasingly use drone imagery and data from handheld analytical instruments to improve their observations, enabling technologies (e.g., augmented reality, position tracking, and mobile robotics with varying levels of autonomy) are advancing rapidly and show great promise for advancing field geology on Earth. It seems obvious that the high stakes of planetary field geology would merit a major investment in the design of innovative field research strategies that incorporate emerging new technologies. International space agencies, however, are spending very small proportions of their budgets on field science operations research today. Most of the funding that is available is focused on analog testing of established technologies and traditional research strategies. With the next opportunities for lunar field science likely to be less than a decade away, the time is right for space agencies to support the establishment of multiple task forces—each including a broad spectrum of field scientists from academia, as well as the agencies themselves—to design a range of novel approaches to planetary field geology and to conduct extensive comparative experiments at complex terrestrial sites before incorporating any of them in mission planning and mission-specific training. Otherwise, we will have squandered an unparalleled opportunity to improve the geoscience we do on the Moon and—eventually—on Mars.

– K. V. Hodges and H. H. Schmitt

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