APPLYING THE APOLLO BREAKTHROUGH IN FIELD WORK METHODOLOGY FOR PLANETARY SURFACES. P.E. Clark[1]; [1]CUA@NASA/GSFC, Greenbelt, MD 20771 (pamela.e.clark@nasa.gov).

Apollo Approach to Field Work: The extraordinary challenge field geologists faced in planning the first human expeditions to the surface of another solar system body led to the development of a new and distinctive approach to geological field work [1]. Not only did those involved deal effectively with the extreme limitation in access to and resources available for a target as remote as the lunar surface, but they developed a truly rigorous and effective approach to science activities ranging from geological field work to deploying field instruments. An extensive archive of the Apollo era science activity related documents [2] provides evidence of the principal aspects and keys to the success of the field work. The Apollo Surface Journal [3] allows analysis of the astronaut's actual performance in terms of capability for distance on foot, documentation and sampling of field stations, and manual operation of tools and instruments, all as a function of time. The application of these analysis as 'lessons learned' for planning the next generation of field science activities on the Moon and elsewhere are considered here as well.

Constraints and Requirements: The constraints imposed by the Apollo architecture, and, barring any major technology breakthroughs, by current architectures under consideration as well, are far more demanding than those placed on any geological expeditions on Earth, in terms of cost, logistical complexity, environmental extremes requiring life support, deliverable mass, volume, power, and bandwidth, mobility, access, and dexterity on location or between locations, and available time. Called for were extremely capable crew members with exquisitely good training in field geology, resourcefulness, extraordinary problem solving skills, and the ability to assess and articulate the big picture with the appropriate level of detail and clarity.

How could science requirements be met while dealing with severe, necessary constraints? That question drove the development of the unique Apollo Field Work Style, shaped by the realities that 1) Robotic precursors to provide 'on the ground' images and orbital coverage at up to 1 meter resolution for potential landing sites would be essential. 2) The astronauts would have to rely on intensive simulation and training to operate 'where no man had gone before' [e.g., 4] and the innovative use of a co-trained geological 'back room'. The astronauts had to be successful at capturing the geological character of the site accurately and succinctly the first and only time, despite the fact that they had very little time (3 EVAs of up to 24 hours in the field for the later J missions). 3) The astronauts were restricted to tens of kilometers in the rover and normally tens of meters on foot. Science objectives would be addressed by gathering samples of rock and regolith at accessible outcrops and determining their relationship to the surrounding terrain as keys to understanding the underlying structure and stratigraphy. These constraints affected every aspect of the approach to geological field work as well as field hardware design.

Reconnaissance: Apollo precursor missions, provided the reconnaissance data critical for planning, simulating, and executing Apollo field activities [e.g., 5,6,7]. The earliest, Ranger, established the basic capabilities for navigation, tracking, and communication from the Earth to the Moon. Orbiter confirmed the capability for orbital insertion and provided pictures of the potential landing sites at nominal resolution of 1 meter. Surveyor established that the regolith could support a lander and its crew, and provided the first pictures and compositional data of the lunar surface in situ. Aerial reconnaissance data with comparable resolution were obtained for selected terrestrial sites where simulation and astronaut training would be performed.

Specific landing sites and traverse routes were planned on the basis of minimizing required time, distance, and relief along the route, while allowing access to geological features of greatest interest in a landing site area. Visits to such 'field stations' would potentially allow characterization of the stratigraphy and geomorphological structure and sampling of composition using surface or near-surface exposures of underlying rock, and thus, potentially, determination of the site's origin. For the Apollo J mission training, terrestrial sites and routes were direct analogs in terms of distance covered and number of stations visited [2].

In the early stages of training, the astronauts were given photogeological unit maps derived as described above for field maps. a limit was found to the amount of data that was digestible and useful in real time [8]. Thus, the decision was made to supply the astronauts with photographic maps with traverses superposed and major landmarks identified.

Equipment: Although the astronauts had to perform field work that would involve using their hands, with a heavy emphasis on sampling, they would be in spacesuits with arms and gloves of limited flexibility at the joints. Fortunately, geological surface sample collection tools [9], including rock hammer and chisel, tongs, rake and shovel, lend themselves to easy handling, but even these were optimized for use in the gloved hand of the astronaut. Scoops were added for the collection of representative regolith samples. One tool, a scoop with a handle extendable over a range of angles and lengths, was specifically designed for quickly obtaining a sample from the rover without dismounting. Most problematic were the subsurface sampling devices, including manual shallow drive tubes (20-30 centimeters) and the powered regolith drill (up to 2 meters in 40 cm stem sections) and designs were modified subsequent to first use on the Moon. Also included as standard equipment were site characterization instruments, including an active seismic experiment, gravimeter, and magnetometer.

Documentation: Obviously, the indispensable geological field notebook, requiring use of a writing implement and both hands, was not practical [10]. What was needed was articulate streaming of detailed yet comprehensible information. In order to be clearly understood by everyone, descriptions of would have to be very systematic, logical, flexible as opposed to dogmatic in interpretation, and thus highly disciplined. Obviously, training played a crucial role here. In fact, systematic oral description of sites and samples was a critical part of Apollo documentation, accompanied with panoramic/portrait photos to confirm position and context of collected samples numbered for later use.

Sampling and Site Characterization: Sampling accompanied by documentation was the primary geological activity. Between major stations, traverse samples would be collected on the scale of tens to hundreds of meters, sometimes without even getting out of the rover. Sampling was a systematic yet flexible activity. Stations along the route were selected in advance on the basis of the apparent availability of exposures of underlying strata, typically boulders [2]. Even though sampling activities at a given station were typically described in terms of allotted time and site geology in the planning documents, a pattern in sampling activities is discernable and a technique for selecting sampling sites within a station is implicit in the Apollo Lunar Surface Journals [1,3].

Astronauts had been trained to minimize the time required for sample collection during their training, which involved time motion studies [8]. At a typical station, 3 to 4 prime sampling sites were reachable on foot from the rover, separated by tens of meters. Sampling at a site typically took 15 to 20 minutes and was repeated for each sampling site [1]. Systematic sampling typically involved sampling soils and rock fragments around and under a boulder as well as obtaining chips of the boulder or rocks on the ground that apparently originated from it. During the course of each of the day's traverse, astronauts typically gathered 30 to 35 kg of samples from 4 to 5 major stations, averaging between 7 and 8 kg per station. The Apollo astronauts used an unpressurized rover to travel distances of up to 25 to 30 km during the course of a traverse during an EVA. They spent about half of their time at the stations, and the rest driving. This pattern was developed during their training with a simulated rover [3,8].

Application for Future Field Work: What can we apply for use in future field expeditions to the Moon or elsewhere [1]? Our areas of uncertainty are more focused. Requirements for landing sites are thus far more specific, and involve more inaccessible geological features in many cases. A much more comprehensive and detailed basemap can be created because a number of lunar orbital missions have flown in the interim, resulting in greater resolution maps of compositional variations, topography and underlying structure, and greater high resolution photographic coverage. We certainly have a greater capability for streaming audio, video, and instrument feeds, and for hands free operation. In addition, greatly resource-minimized experiment packages are available. Rover-mounted ground penetrating radar could provide detailed in situ sensing of underlying structure along traverses. Handheld multi-spectrometers could provide preliminary compositional analysis of samples in situ. In fact, we could easily generate too much information for anyone to process in real time, as indicated by the Apollo experience. None of these capabilities mitigate the need for efficient, systematic documentation and sampling methodology, as used on Apollo. In fact, the need is more critical, because of the limited mass available for sample return, still between 100 and 200 kg with any current architecture, despite the fact the much longer expeditions are planned. This translates into the need for down-selecting samples of potential interest in situ, through the use of new portable analysis tools, as an additional step in the sampling and site characterization process developed for the Apollo J missions.

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