To: Joe Kosmo, Amy Ross
From: Dean Eppler
Subj: Geologic Field Work And General Implications For Planetary EVA Suit Design
Date: 7 February 1997

This is a brief discussion on the nature of geologic field work, and some general implications for suit design. It can serve as a start to this task, and can give you a flavor of the kinds of activities field geology entails. Hopefully, it won't be too pedantic, but if it is, my apologies.

INTRODUCTION

The objective of planetary exploration is to determine the physical makeup, history and the processes that have formed and modified a planet. While many techniques are applied to conduct this task, the most critical technique is geologic field work. Geologic field work can be loosely defined as the aggregate work to determine the spatial distribution and age of rock units and structures that cut or deform those rock units, and to determine the processes that led to their emplacement and subsequent modification. Geologic field work is perhaps the last bastion of descriptive, "semi-quantitative" data-gathering in our present science paradigm[1]. Although there has been a lot of ink spilled over the quantitative vs. qualitative nature of data-gathering, and the last 20-30 years have seen many efforts to introduce more quantitative data into the geologic sciences, field work still remains as much art as science, as much intuition as deduction. Further, geologic field work, with few exceptions, remains the primary source of data in the solution of geologic problems. This brief narrative is designed to give a non-geologist an understanding of what geologic field work entails, and the broad implications field work has on the design of EVA suits and tools.

There are a number of reasons that geologic field work remains the primary source of geologic data. The first is that, unlike more purely quantitative fields like physics, a geologist's primary data source remains the rocks, in the field, and their spatial distribution . While experimentation has achieved an important

[1]The value of field work has occasionally been disputed by geochemists and geophysicists who have failed to understand the underpinning field work gives to the Earth sciences. For example, Compton (1989) discussed Apollo program mission planning arguments between field geologists and other geoscientists who, "would scarcely classify field geology...as a science at all (Compton, 1989, pg. 169)." In contrast, Sharp (1988) pointed out that, "...exciting Earth science developments have recently come from experimental and theoretical work...but close inspection shows that many of these fruitful advances have depended upon complementary and cooperative field investigations."

place in a geologist's repertoire, particularly in fields like structural geology, the ultimate source of geologic data are the field distribution of rocks and the relationship of one rock unit to another. The second reason is that, with a few notable exceptions like the Arctic and alpine environments, there is always less data (i.e., fewer rocks showing through the surface cover and vegetation) than one would like to have for a complete understanding. Sharp (1988) noted that learning to arrive at workable conclusions, often on the basis of insufficient evidence, is part of doing geologic field work. In dealing with a limited data source, geologists are forced to leave no stone unturned in acquiring the basic data for developing models of geologic history and process, and, in contrast with many other sciences, to use a healthy dose of imagination in interpreting what is almost always an incomplete data set. The third reason is that models used to predict the behavior and condition of the natural world always have less fidelity than the real thing, because natural systems involve much more complexity than models can accommodate. Modeling of earthquake behavior, for instance, relies heavily on data from field sources to understand differences between the predictive capability of a particular model and a real event. Without such input, predictive models of the behavior of most geologic processes are, at best, limited[2].

THE NATURE OF GEOLOGIC FIELD WORK

Geologic field work involves collecting data about the spatial distribution of rock units and structures in order to develop an understanding of the geologic history and distribution of rock units in a particular region. The reasons for collecting field information, generally thought of as field mapping, can vary. A primary reason is to understand the geology of a particular unknown or poorly known area. Basic geologic exploration in order to establish a baseline of data remains important in many parts of the globe, including the United States. In addition to adding to general knowledge, understanding the spatial distribution and deformation of rock units at the surface is critical in order to develop 3-dimensional models of the subsurface geology. Mineral and oil exploration proceeds in this way, particularly when considering the siting of boreholes.

Another reason may be to understand a particular geologic process. Investigation of a host of volcanic phenomena, for instance, starts with an understanding of the distribution of units from a given eruption. Similarly, the first response to an earthquake is to identify and map the surface rupture of the fault which caused the earthquake, to understand the nature of the movement

---

[2]Robert P. Sharp, perhaps the most eminent U.S. field geologist of this century, commented in 1988, "Nature is a perverse ego humbler, and she exercises that trait freely in field geology. She delights in throwing spitball curves that send the overconfident neophyte, and the often hardened, experienced field mapper, back to the dugout muttering to themselves."

along the fault and the stresses that caused the earthquake. Such data can lead to the development of predictive models, which must be rooted in events that are correlatable and measurable.

A third reason may be to conduct sampling that is tied to a geographic base, so as to understand the variations in space and time, of a given parameter. Understanding the chemical evolution of a crystallizing magma body, for instance, is usually based on sampling the surface distribution of rock units within the body. Depending on the understanding of the event that produced the body, this may also lead to an understanding of the change through time of that body as well.

Lastly, the surface distribution and character of rock units becomes primary information to interpret geophysical data in a (relatively) unambiguous way. The nature of geophysical data-gathering is such that there are always more unknowns than there are equations. Useful and geologically valid interpretation of geophysical data requires a good founding in the local, spatial distribution of rock units and structures[3].

One distinction that needs to be emphasized is the difference between field mapping and pure sampling. A popular misconception is that geologists conduct field work purely for the purposes of sampling rock units. Sampling *is* an important part of field mapping, but sampling in the absence of the spatial information that field mapping provides leads to, at best, a limited understanding of the geology of a particular area. Having said that, the nature of the rock exposure in a given area can limit the amount of field mapping that can be done, and *can* drive field work efforts to conducting a sampling program that, with some ingenuity, can provide the basics for understanding the broad geologic context of a particular locality. The Apollo expeditions, for example, conducted a highly successful sampling program on the lunar surface that was not necessarily field mapping. Two things drove this. The first was that the dominance of meteorite impact on lunar surface processes leads to a chaotic, jumbled regolith many meters deep over much of the lunar surface. This regolith covers up much of the bedrock, except in places where slopes allow the regolith to move downslope and continually expose bedrock. The second driver was that mission safety constraints limited landing areas to relatively safe, relatively flat areas away from terrain that would most likely have held bedrock exposures. The samples acquired during each mission were tied to a geographic data base

[3]Interpretation of a host of geophysical data requires a model based on the likely subsurface geology. Such a model cannot be conjectured without a basic understanding of surficial geology. There remains an apocryphal story from my undergraduate years about a team of geophysicists who explained a set of gravity anomalies in the Canadian shield as salt domes, not a bad hypothesis on the Gulf coast, but totally innappropriate for some of the oldest metamorphic rocks in the world.

using real time visual and audio communications, making them extremely useful from a geologic standpoint, but the fragmented nature of lunar surface units did not allow geologic mapping of rock units in the conventional sense.

FIELD DATA COLLECTION

Given the nature of geologic field work, it is possible to break down the activity into a general list of the kinds of data collected. Again, the first and foremost, the information collected during field work is the spatial distribution of rock units at the surface. This requires determining what rock units are exposed where on the surface, and tying that data to a geographic data base, usually a topographic map or aerial photograph. This also requires determining the general composition of each rock type by visual identification. For most rock types, it is possible to visually identify the minerals and other components using either the naked eye or a hand-held 10x pocket magnifier.

A second type of data collected are the effects of the deformation that the geologic section may have been subjected to - specifically folding and fracturing. This type of data, generally referred to as structural data, allows a geologist to understand the nature and magnitude of the stresses the rocks have been exposed to after deposition. Understanding deformational stresses and history begins with measuring the orientation of planar or linear elements that have been oriented by the deformational stresses. These measurements include the spatial orientation of fracture planes, fold axes, the preferred orientation of either planar or cylindrical minerals, or the orientation of planes formed by bedded rock units.

The third type of data collected are actual samples of the different rock units encountered. Samples provide the ability to take the field units back into the laboratory, and to conduct more detailed examinations on the composition and texture of the maps units seen in the field. To emphasize what was said above, pure sampling is rarely the goal of a field investigation, but rock samples collected as part of a field mapping exercise invariably lead to a more complete understanding of the geology of a particular locality.

GENERAL IMPLICATIONS FOR DESIGN OF EVA SUITS

There are a number of general implications that drive EVA suit design for geologic field work. The first is ability for suited crew members to observe the environment around them. First and foremost, geologic field work is an exercise in seeing rocks and structures. The accommodations that allow observation must allow as wide a field of view as possible. A good exercise to understand this is to compare the view of a particular terrain through a camera viewfinder and then with unencumbered vision. A cogent understanding of the spatial distribution of rocks in an area requires as wide a view as possible. Further, the visibility provided must be as free of optical distortion and preferably without degradation of color vision. In particular, seeing colors allows discrimination between otherwise similar rock units. Discrimination of minerals and other components in samples is also often based on discrimination of the color of individual grains.

The second major implication is that EVA suits and other exploration accommodations must allow as much mobility as possible, both in terms of suit mobility and the ability to see as much countryside as possible. It is an oft-stated but correct maxim that the best field mappers are the ones who have seen the most rocks. Geologic field work on the planets, if it is to be worth the significant cost needed to get the geologists there, will require both EVA suits that will allow EVA crew to walk comfortably for hours at a time, and rovers that will allow the crew to see as much terrain as possible. Where suit mobility is difficult or disallowed by the mechanics of inflated suits (e.g., bending and squatting down), an easily used suite of tools should compensate for the lack of mobility, so rock samples and dropped tools can be picked up with as little effort as possible. There are a number of examples during Apollo where the simple act of picking up a dropped tool took a supreme effort by the crew member to overcome the limitations of the suit mobility.

The third major implication is that individual elements of the suit, such as gloves, will need to allow for the grasping and manipulation of both rock samples and hand tools. The need to pick up a rock and look at it closer is one of the basic requirements in developing adequate documentation of rock units. Also, in spite of the advent of a whole suite of sensitive laboratory instruments, the primary tools for the field geologist remains a hammer and a shovel. The ability to manipulate these types of devices will be of paramount importance in planetary geologic exploration.

Lastly, there will be a need to document the spatial data on rock units and structures as they are developed in the field. In terrestrial studies, this is typically done on either a topographic or air photo base. It is unclear at this time how this documentation will take place in a planetary setting; however, the need will exist to document this kind of geographically based data.

CONCLUSIONS

The primary source of geologic data on the terrestrial planets is likely to be the collection of spatially based data on the distribution of rock units and structures. This data source remains primary in terrestrial geologic studies, and future human missions to the moon and Mars will rely heavily on geologic mapping to achieve science goals. In order to conduct field work, planetary EVA suits will need to allow wide-view, distortion-free observation of the terrain and the rock units, and provide adequate mobility to allow minimally-encumbered walking, reaching and grasping. In addition, mobility elements must be provided that will allow transport of the crew to a wide variety of terrain , to see as much of the geology as possible.

REFERENCES CITED

Compton, W. D., 1989, Where No Man Has Gone Before: A History of the Apollo Lunar Explorations: Natl. Aeron. Space Admin. Spec. Publ. SP-4214, 415 pp.

Sharp, R. P., 1988, Earth Science Field Work: Role and Status, *Ann. Rev. Earth. Planet. Sci.,* v. 16, pp. 1-19.