Department of Earth and Planetary Sciences
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

FINAL REPORT

Submitted to: National Aeronautics and Space Administration

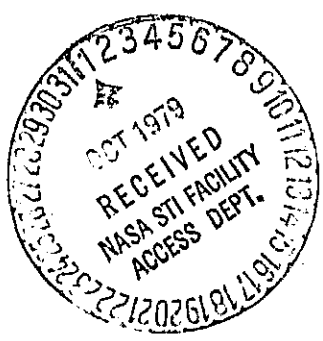
Grant Title: Microcracks in Lunar Rocks

Grant Number: NGR 22-009-540

Period Covered by Grant: 1 February 1971-30 June 1979

Principal Investigator: Gene Simmons
Professor of Geophysics
Department of Earth and Planetary Sciences
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

Date Submitted: 25 September 1979



INTRODUCTION

The purpose of this project was to examine the microcracks that are present in lunar samples and to use data that can be obtained from the microcracks for the purpose of constraining models of the processes that have operated on lunar rocks. During the contract period, we have learned how to prepare specimens for examination with the petrographic microscope and with the scanning electron microscope in such a way that we do not produce new cracks in the samples. We have also developed methods of specimen preparation, measurements, and interpretation that allow us to measure the volume of open microcracks present in a sample and to measure the strain as a function of pressure due to the complete mechanical closure of microcracks; the method has been termed differential strain analysis (DSA). We applied our techniques to the study of microcracks in a few lunar samples and in several terrestrial analogue samples that had been exposed to a wide variety of shock environments. Our methods and the results of our using them have been described in detail in several published manuscripts; the manuscripts are listed in Table 1.

Table 1.

Manuscripts on Microcracks

Authors	Title	Year	Where Published
Simmons, Todd, and Baldridge	Toward a quantitative relationship between elastic properties and cracks in low porosity rocks	1975	American Journal of Science, 275, 318-345.
Simmons, Siegfried, and Richter	Characteristics of microcracks in lunar samples	1975	Proceedings Sixth Lunar Science Conference, 3, 3227-3254.
Simmons and Richter	Microcracks in rocks	1976	The Physics and Chemistry of Minerals and Rocks, Wiley-Interscience, 105-137.
Richter, Simmons, and Siegfried	Microcracks, micropores, and their petrologic interpretation for 72415 and 15418	1976	Proceedings Seventh Lunar Science Conference, 2, 1901-1923.
Richter and Simmons	Microscopic tubes in igneous rocks	1977	Earth and Planetary Science Letters, 34, 1-12.
Siegfried and Simmons	Characterization of oriented cracks with differential strain analysis	1978	Journal of Geophysical Research, 83, 1269-1278.
Siegfried, Simmons, Richter, and Hörz	Microfractures produced by a laboratory scale hypervelocity impact into granite	1977	Proceedings Eighth Lunar Science Conference, 1, 1249-1270.

Table 1 (continued).

Authors	Title	Year	Where Published
Siegfried, McQueen, and Simmons	Shock-induced microfractures in six terrestrial igneous rocks characterized with differential strain analysis	1979	Journal of Geophysical Research, revised.
Batzle, Simmons, and Siegfried	Microcrack closure in rocks under stress: part 1, direct observation	1979	in preparation.
	Other Manuscripts Supported by this Grant		
Wang and Simmons	Elasticity of some mantle crystal structures. 3. spessartite-almandine garnet	1974	Journal of Geophysical Research, 79, 2607-2613.
Richter and Simmons	Thermal expansion behavior of igneous rocks	1974	Int. Journal of Rock Mech. Min. Sci., 11, 403-411.

SUMMARY OF RESULTS

Lunar samples contain abundant open microcracks that have closure characteristics completely unlike any shocked terrestrial rock. The differences are described in detail by Simmons *et al.* (1975), Richter *et al.* (1976), Feves *et al.* (1977), and Siegfried *et al.* (1977). However, the microcracks present in the lunar rocks before the rocks reached the surface of the moon were likely similar to the microcracks in the shocked terrestrial rocks. Because the microcracks present in the lunar rocks *in situ* inside the moon were different, radically different, from the microcracks present today in returned lunar samples, any property that is sensitive to microcracks measured on the returned lunar samples is inappropriate for predicting that property as a function of depth in the moon. Therefore, many data that have been measured already on lunar samples simply do not apply to rocks *in situ inside* the moon.

Batzle and Simmons (1979) showed that a plausible mechanism with which to account for the difference in microcrack characteristics of lunar samples on the surface of the moon and the microcrack characteristics of lunar rock *in situ* inside the moon is thermal cycling during residence on the moon's surface.

DISPOSITION OF LUNAR SAMPLES

The project to study microcracks in lunar samples was terminated for NASA funding after the Proxmire proclamation, but the project was continued with funding from the National Science Foundation under grant no. 79-07033 EAR. A lunar samples security plan was included in the NSF grant that was identical in all respects to the lunar samples security plans that had been in operation previously. Therefore, the lunar samples are not being returned to NASA at the present time. Formal notification has been received by MIT that all government property acquired under the NASA contract, including lunar samples, has been transferred to the NSF grant.

REFERENCES

Batzle, M. and G. Simmons, Effects of diurnal temperature variations on lunar rocks, Lunar Science X, 78-79, 1979.

Feves, M., G. Simmons, and R. Siegfried, Microcracks in crustal igneous rocks: physical properties, in The Earth's Crust: Its Nature and Physical Properties, edited by J.G. Heacock, AGU, Washington, DC, 95-117, 1977.

Richter, D., G. Simmons, and R. Siegfried, Microcracks, micropores, and their petrologic interpretation for 72415 and 15418, Proc. Lunar Sci. Conf. 7th, 1901-1923, 1976.

Siegfried, R., G. Simmons, D. Richter, and D. Hörz, Microfractures produced by a laboratory scale hypervelocity impact into granite, Proc. Lunar Sci. Conf. 8th, 1249-1270, 1977.

Simmons, G., R. Siegfried, and D. Richter, Characteristics of microcracks in lunar samples, Proc. Lunar Sci. Conf. 6th, 3227-3254, 1975.