THE IDENTIFICATION OF LUNAR ROCK TYPES VIA ORBITAL GAMMA RAY SPECTROSCOPY; A. E. Metzger, Jet Propulsion Laboratory, Pasadena, CA 91109

A planetary gamma-ray spectrometer can measure the elemental abundance of surface constituents by detecting their natural and induced gamma-ray emission. It cannot determine mineralogy directly, but through a comparison with known or inferred rock type compositions, petrologic information can be derived. The returned samples provide such a data base for the Moon. In this manner, orbital chemical data can be transformed into regional petrological distributions. An early result from the Apollo experiment was the mapping of KREEP over that part of the Moon overflown by Apollo 15 and 16 (1, 2). Recently, Davis and Spudis (3) have used the Apollo Fe, Ti and Th gamma-ray data in combination to map observed regions in terms of their proportions of ferroan anorthosite, KREEP-rich or norite-troctolite rocks, and mare basalt end member rock types.

The extent to which rock types may be distinguished depends on the range of variation in their composition together with the sensitivity of the measurement. The greater the compositional contrast and the more sensitive the measurement, the better this can be done. Sensitivity depends on the quality of the instrument and the conditions of observation, specifically counting time and spacecraft altitude.

In this study I have used the compositions of 9 highland and 16 mare rock types as compiled for the LGO Science Workshop report (4). Calculations of the expected elemental sensitivity of the gamma-ray spectrometer were based on an instrument with a high resolution germanium detector similar to that under development for the Mars Observer mission (5). Application of these sensitivities to each rock type composition provides the time required to determine each component element to a specified precision and confidence level. These times may vary over several orders of magnitude for a single element. For example, K in KREEP basalt can be detected in less than a minute with 20% precision at the 2 sigma confidence level, but more than 200 hours are required to detect the very low K concentration in dunite.

By comparing and combining element sensitivies in the form of measurement times, with the contrasts in composition among members of the highland and mare rock type suites, it is possible to identify the most useful elements with which to discriminate among the highland and mare rock types, and to calculate the observing time required to uniquely identify each type within its set. Results for the highland set are given in Table 1. For two of the rock types, the determination of a single element (Mg in dunite, K in granite) is sufficient. In other cases, two or three elements are necessary. The most useful elements are Mg, Al, K, Fe, Th and U, and the observing times to uniquely identify each type within the set with 2 sigma confidence range from less than a minute to about 1.5 hours. Results for the 16 mare rock types are shown in Table 2. In this case, five elements, K, Fe, Mg, Ti and Th, provide the discrimination, with observing times for unique identification extending from 0.05 hrs to about 2 hrs. Including other elements which make lesser contributions to rock type identifiability would lower these times by an estimated 10-20%, while the presence of two or more rock types in comparable abundance in the field of view will increase the required observing time.

The results presented in Tables 1 and 2 show that, if dominant to an area, all the listed rock types, highland and mare, are distinguishable by the high resolution gamma-ray spectrometer with accumulation times of 2 hrs or less. This instrument must be operated at 100 K or less, a capability which can be provided by radiative cooling to space as designed for the Mars Observer instrument, or by taking advantage of recent advances in the development of active refrigerator systems for space use. With the latter it becomes possible to also accommodate the experiment on small spacecraft which cannot provide the fixed orientation needed by a passive radiator.

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Table 1: Highland Rock Type Identification

Type	Distinguishing Elements	Observing Time (hr)#
Ferroan Anorthosites	Al+K+U	1.3
Norites	Mg+Fe	0.5
Troctolites	Mg+Fe	0.7
Gabbro Norites	K+Fe	0.13
Dunite	Mg	0.13
KREEP Basalts	K+Th	0.02
Alkali Anorthosites	K+Al	0.5
Magnesium Anorthosites	Al+K+U	1.3
Granites	K	<0.001

Table 2: Mare Rock Type Identification

Type	Distinguishing Elements	Observing Times (hr)#
Very Low Ti: Luna 24	K+Fe+Mg	1.3
" " Ti: Apollo 17	K+Fe+Ti+Mg	1.3
Low Ti: Apollo 12 pig.	Ti+Th	1.8
" Ti: " 12 oliv.	Ti+Th+Mg	1.0
" Ti: " 12 ilm.	Ti+Th	1.0
" Ti: Apollo 15 pig.	Ti+Fe+Th	0.9
" Ti: " 15 oliv.	Fe+Ti+Th	1.3
High Ti: Apollo 11 low K	Ti+Th+Mg	0.6
" Ti: " 11 high K	K	0.02
" Ti: Apollo 17	Ti+Th	1.0
" Ti: " 17 v. high Ti	Ti	1.8
Aluminous: Apollo 14 low REE	Fe+Ti+K	1.0
" : " 14 high REE	Th+K	0.05
" : Luna 16	K+Th	0.05
Volcanic Glasses: Apollo 15	Mg+K	1.2
" " " 17	Fe+Ti	1.0

To uniquely identify each type within its set with two sigma confidence