ELECTRICAL CONDUCTIVITY OF LUNAR SURFACE ROCKS: LABORATORY MEASUREMENTS AND IMPLICATIONS FOR LUNAR INTERIOR TEMPERATURES. F. C. Schwerer,* G. P. Huffman,* and T. Nagata**. *U. S. Steel Research, Monroeville, Penna. 15146. **National Institute of Polar Research, Tokyo, Japan.

Laboratory Measurements - The electrical conductivity of six Apollo lunar rocks with Fe^{2+} contents from 4 to 20 wt.% has been measured in the temperature range 20 C to 1000 C. Both d-c and low frequency a-c (nominally 5 Hz) measurements were made using a three-electrode technique. For all samples studied, the electrical conductivity was observed to depend in a complex fashion on the furnace atmosphere and on prior thermochemical treatments; however, reproducible data could be obtained for specified sets of conditions. This dependence was most severe for the more porous or cracked samples and was apparently associated with chemical alteration of sample surface regions. Mossbauer spectroscopy corroborated the expectation[2,3] that the changes in conductivity were associated with changes in the valence and distribution of iron.[1] The conductivity was lowest for samples measured in reducing atmosphere (He-H_2 mixtures) and after reduction at high temperatures. Furthermore, data obtained under these conditions were very similar to data obtained during the initial heating of samples and are considered to be most representative of pristine lunar samples.[1] These data can be described analytically by one or two exponential terms. The parameters obtained by a least squares fit are presented in Table I and the results are shown in Figure 1. (The dashed portions of the curves represent extrapolations of the data beyond the actual measured range using parameters from Table I.) Data reported by Olhoeft et al[4] are in reasonable agreement with these results.

Petrographic analyses of lunar samples indicate that the bulk d-c electrical conductivity will be determined by the silicate phases, in particular, by minerals from the pyroxene and feldspar series. The data in Figure 1, particularly when compared with results for other silicates,[5,6] indicate that the dependence of the electrical conductivity on iron content is sufficiently strong that it makes any dependence on structure of secondary importance. (Iron contents are denoted by the parenthetical numbers in Figure 1.) This observation suggests that these results can be used in conjunction with lunar conductivity profiles to estimate lunar interior temperatures.

Implications for Lunar Interior Temperatures - The electromagnetic response of the moon as measured by surface and orbiting magnetometers has been analyzed to yield electrical conductivity profiles of the lunar interior.[6,7] The most detailed of these recent profiles is from an analysis by Dyal et al.[6] of nightside data. The temperature band shown dotted in Figure 2 was obtained by a comparison of the error limits of the nightside conductivity profile with lunar sample conductivity data from Figure 1. (The lower temperature values in Figure 2 correspond to data for the samples with the larger Fe contents.) From whole-moon magnetization measurements, Parkin et al.[8] have deduced that for a lunar interior composed of pyroxene (olivine) the iron content is approximately 13 (5) wt.%. The cross-hatched region in Figure 2 was obtained by comparing the logarithmically averaged error limits from the

ELECTRICAL CONDUCTIVITY OF LUNAR SURFACE ROCKS

Schwerer, F. C., et al

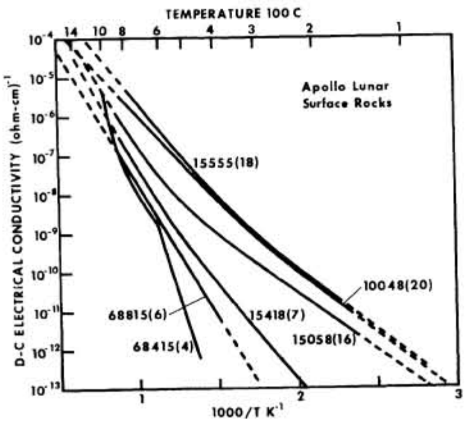

Figure 1.

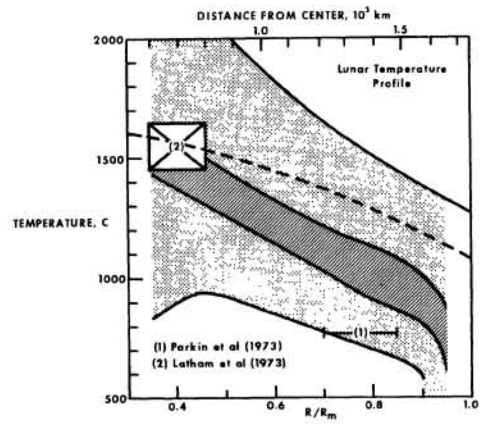

Figure 2.

nightside profile[6] with the conductivity data for lunar samples 15418 and 15058 (7 and 16 wt.% Fe, respectively). Also shown in Figure 2 are the temperature-depth points established by Parkin et al.[8] from whole-moon magnetization data and by Latham et al.[9] from seismic data assuming a partially molten zone for the lunar asthenosphere. (The dashed line in Figure 2 is the solidus for an anhydrous basalt.[10]) Similar analyses of two-shell conductivity profiles produce estimates of temperatures for $0.55 \leq R/R_m \leq 0.9$ of 1000 to 1200 C when conductivity data for the two samples named above were used and of 900 to 1400 C when data of all samples were used. Except for the lowest part of each band, these temperatures involve extrapolation of measured data and are most consistent with recent "hot" moon models.[10]

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TABLE I. ELECTRICAL CONDUCTIVITY PARAMETERS FOR LUNAR SAMPLES

LRL Sample Number	Fe^{2+} (a) Wt. %	Test Frequency Hz	Conductivity Parameters (b)				$\Delta\sigma/\sigma$ (c)	Points Fitted	Temperature Range (°C)
			$\sigma_o^{(1)}$	$E^{(1)}$	$\sigma_o^{(2)}$	$E^{(2)}$			
10048	19.8	5	5.18 10^{-5}	0.533	5.09 10^{-2}	0.867	0.037	14	210–850
		DC	2.66 10^{-5}	0.559	3.50 10^{-2}	0.896	0.054	15	160–850
15058	16.4	5	6.97 10^{-5}	0.624	1.30 10^{1}	1.570	0.075	16	320–880
		DC	2.78 10^{-5}	0.593	1.34 10^{0}	1.374	0.089	22	150–880
15418	6.7	5	4.39 10^{-7}	0.514	1.35 10^{-1}	1.260	0.055	20	280–860
		DC	9.84 10^{-4}	0.971	1.37 10^{0}	1.509	0.106	24	195–860
15555	17.6	5	3.18 10^{-6}	0.420	2.16 10^{-1}	0.993	0.050	21	170–800
		DC	1.27 10^{-4}	0.604	3.68 10^{-1}	1.040	0.059	21	170–800
68415 (d)	4.3	DC	4.73 10^{-3}	1.138	4.78 10^{+8}	3.554	0.126	23	610–1000
		DC			1.27 10^{+6}	2.640	0.160	11	460–625
68815 (d)	6.3	5			1.65 10^{-1}	1.340	0.126	25	470–885
		DC			1.42 10^{-1}	1.366	0.217	30	385–885

(a) Analyses from high field magnetic susceptibility at 300 K.

(b) Data fitted to $\sigma(T) = \sum_{i=1}^{2} \sigma_o^{(i)} \exp(-E^{(i)}/kT)$.

(c) Root mean square value of $1 - \sigma_{calculated}/\sigma_{measured}$.

(d) Includes data from two sets of measurements.