A MATURITY PARAMETER OF THE LUNAR REGOLTH FROM NEUTRON DATA.

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Introduction: The interaction of the lunar surface with interplanetary space causes the physical state of the regolith to evolve with exposure. The main changes are: grain size, reduction of iron oxides, implantation of solar wind, and production of glasses. Together, processes that induce these physical and chemical changes yield the concept of "maturation". Literature is rich of maturity indices for the lunar regolith. As a general rule, these indices are aimed at approximating the duration of exposure at the lunar surface, i.e. reflecting the age of given region. But the reality is that all indices are not equivalent because maturation processes evolve at different rates, over different depth, or depend upon the nature of the source material. Combining different indices is probably the best way to define maturity [1].

Most maturity indices have been determined from sample studies. I_s/FeO measures the ratio of fined grained iron metal measured by ferromagnetic resonance intensity to the abundance of the oxide [2]. It correlates reasonably well with other parameters, such as concentration of agglutinates, concentration of solar wind, and grain sizes. It is therefore accepted as a reference index for maturity.

At remote sensing scales, crater counts and OMAT are used as maturity indices. The former is tedious to establish and is used locally. The latter stands for optical maturity [3,4,5]. OMAT has been a major contribution from the Clementine UV-VIS experiment. It is derived from spectral reflectance at 950 and 750 nm. It has the advantage that it can also be measured from samples which serve as calibration of the technique. OMAT correlates well with other indices, including Is/FeO and crater counts. It shows minor contributions from soil composition control and a weak dependence on the geological setting. Here we introduce a new index of maturity at remote sensing scale from epithermal neutron measurements by the Lunar Prospector (LP) Neutron Spectrometer (NS).

Epithermal Neutron Data: Lunar Prospector orbited the Moon in a polar orbit from January 10th, 1998 to July 31st, 1999. The spacecraft mapped the entire Moon ~42 times. Epithermal neutrons were collected by the Neutron Spectrometer (NS), a Cd-covered proportional counter filled with ^{3}He pressurized at 10 atm [6]. We use an acquisition rate of 0.5 sec, re-binned in 8-sec packets. The spatial resolution of the maps is ~55 km (FHWM). The fractional error which comprises both systematic and statistical errors is typically 1.6% at the equator and less than 0.5% poleward of ±85°. Finally, the data have been smoothed by a two-dimensional, equal-area Gaussian (HWHM=18 km).

Epithermal neutrons result from the moderation of fast neutrons (> 100 keV) by the lunar regolith. Fast neutrons originate from the interaction of cosmic rays with the Moon. In the case of LP measurements, epithermal energies effectively extend from 0.3 to 100 eV. The information content [7] of the epithermal energy range is complex and reflects the composition of (1) the major oxides, (2) the trace rare earth elements, and (3) the hydrogen concentration.

We reduce the contribution of major oxides (and to some extent the rare earth elements) from our maturity index by constructing a hybrid neutron data set. In this hybrid data set, we subtract a fraction of our Sn-sensor count rate from the Cd-sensor count rate [8]. This is acceptable because both detectors have the same response function and are sensitive to the main oxides, predominantly FeO and TiO_2, in the same way. We then remove the signal from rare earth elements [9], mainly Sm and Gd, using the thorium abundances as measured by the LP gamma ray spectrometer.

The final signal, called NeMAT (Neutron Maturity) is valid over the whole Moon except poleward of ±85° (see next section). Main features of this map are high count rate "bright spots", e.g. far-side regions around Jackson (22.4°N, 163.10°E), Joule (27.3°N, 144.2°W), Korolev (4.0°S, 157.4°W), Bel'kovich (61.1°N, 90.2°E), and Shternberg (19.5°N, 116.3°W). We also "bright spots" in and around Mare Orientalis (19.4°S, 94.1°W), Tycho (43.4°S, 11.1°W) and Clavius (58.8°S, 14.1°W).

Relation to Solar Wind Implanted Hydrogen: Poleward of ±85°, excesses of hydrogen have been detected in permanently shaded craters; they are thought to be related to water deposits [8,10]. Equatorward of this latitude, the NeMAT parameter is related to hydrogen implanted by the solar wind. This interpretation for variations of epithermal neutron flux was reported earlier [11-12]. The authors indeed find that epithermal neutron fluxes are correlated to hydrogen content in soil samples.

In this study, we shall present the best resolution map of NeMAT improving by a factor 3 in spatial resolution to previous maps and by the same factor the ratio of signal-to-noise. The correction for rare earth elements also allow the use of NeMAT everywhere, including over KREEP rich terrains. Proving that a new quantity is a true measure of maturity is never easy, specially for NeMAT which cannot be tested against lunar samples. However, a map of this new index provides a credible global representation of lunar maturity.

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