REMOTE DETERMINATION OF LUNAR SOIL MATURITY. V.V.Shevchenko[1,2], P.C.Pinet[1], S.Chevrel[1], Y.Daydou[1], T.P.Skobeleva[2], O.I.Kvaratskhelia[3], C.Rosemberg[1]. [1]UMR 5562 "Dynamique Terrestre et Planetaire"/CNRS/UPS, Observatoire Midi-Pyrenees, Toulouse, 31400 France; [2]Sternberg Astronomical Institute, Moscow University, Moscow, 119992, Russia, [3]Abastumany Astrophysical Observatory, Georgian Academy of Sciences, Georgia. shev@sai.msu.ru

Introduction. The main spectral/optical effects of space weathering are a reduction of reflectance, attenuation of the 1-μm ferrous absorption band, and a red-sloped continuum creation [1]. Lucey et al. [2-4] proposed to estimate the maturity of lunar soils from Clementine UVVIS data using a method which decorrelates the effects of variations in Fe^{2+} concentration from the effects of soil maturity. The method calculates optical maturity defined as parameter OMAT [5].

Spectropolarimetric Maturity Index. Shevchenko et al. [6, 7], and Pinet et al. [8] developed the method to determine the maturity of lunar soil by using spectropolarimetric ratio $P_{max}(B)/P_{max}(R)$ for blue (B) and red (R) spectral regions. On the basis of known laboratory results and telescopic data, it was found that ratio Pmax(419nm)/Pmax(641nm) could be used as a remote sensing parameter of lunar soil maturity. This parameter does not correlate with the soil chemical composition (for example, with FeO content) but a good anticorrelation (r = -0.951) was found with I_s/FeO values for Apollo and Luna landing sites [7, 9, 10]. So, it is possible to consider the ratio mentioned above as an independent remote sensing index of the lunar soil maturity level.

Conformity between maturity parameters. A detailed remote sensing survey of ten lunar regions of mare and highland types has been carried out by means of Clementine spectro-imaging data with the purpose of establishing the regional distribution of the maturity state and weight percent of iron content in the lunar soils. The spectral dataset has been instrumentally calibrated and a radiometric calibration using previous telescopic spectra has been made, resulting in the production of absolute reflectance spectra organized in regional image cubes [11-13]. The data are used to obtain a scale of conformity between spectral index of maturity OMAT and spectropolarization index established by Shevchenko et al. [10]. A special optimization technique has been developed on the basin of maximal likelihood, to locate very precisely the spectropolarimetric telescopic observations available [14] in the Clementine regional mosaics. For example, in Figure 1, is shown the Clementine image of crater Proclus which is a very young lunar crater, with an extensive ray system. The boxes inside the crater

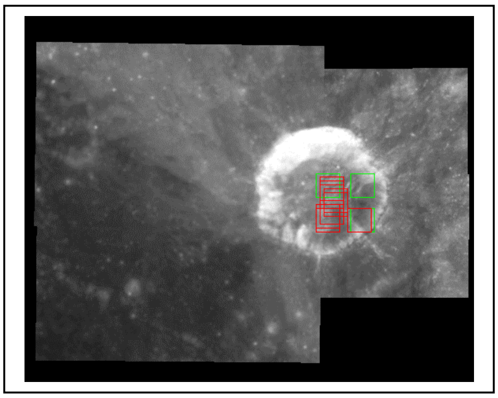

Fig. 1. Crater Proclus (Clementine image mosaic).

exhibit for the process for the search of the real site position operates from the reference catalog [10]. Size of the each box is 5.6x5.6 km that is resolution of the telescopic observations for these sites. Center of bright rays system – crater Proclus is probably very young lunar object. Given the likely recent origin of these features, one may consider the age of their formation as nearly equal as to the exposure age of their soils. On the other hand, soils of old formations such as highland craters have been exposed for an extended period of time. It means that most of the petrographic and chemical parameters of maturity should have reached steady-state values with exposure time. In that case, any local variation seen in the soil maturity should be explained as the result of space weathering process. As mentioned above, ten lunar surface zones are chosen for the purpose of this study. The list includes the highland crater Alpetragius, mare units in Mare Humorum and in Oceanus Procellarum near by Aristarchus, post-mare craters Aristarchus, Herodotus, and Reiner, which have different ages of emplacement. On the bases of these data, a scale of conformity between the two types of maturity parameters is obtained. The diagram, depicted in Figure 2, plots the ratio P_{max}(419nm)/P_{max}(641nm) versus the spectral index of maturity OMAT (Lucey's parameter).

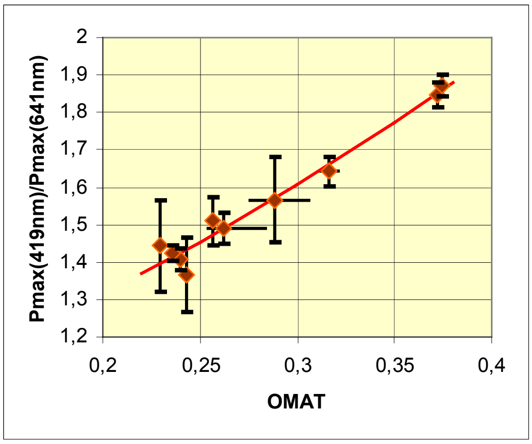

Fig. 2. Conformity between maturity parameters.

The interval of maturity index covers the geological formation time span from recent impact to old highland craters. These quantities display a good correlation (exponential regression) with a correlation coefficient r = 0.980 for the interval of spectral index of maturity, ranging from 0.22 to 0.38. Shevchenko et al. [10] shows that the spectropolarization index represented, as ratio P_{max}(419nm)/P_{max}(641nm), correlates directly with maturity index I_s/FeO established by Morris [15-16]. The correlation coefficient between the average values of Morris' parameter for Apollo and Luna landing sites and the P_{max}(419nm)/P_{max}(641nm) values for the same places derived from telescopic observations is $r = -0.951$. Making use of the dependence mentioned above it is then possible to build a graph of maturity index I_s/FeO versus the spectral index of maturity. Fig. 3 shows the type of relationship between I_s/FeO and OMAT. The Apollo and Luna landing sites data, combined with the ten selected lunar features data, are used to establish the graph in the interval of OMAT from about 0.23 to 0.38. The data concerning the most mature surface soils arise from the individual sample stations at the Apollo-17 landing site and are used to establish the graph in the range from 0.12 to 0.23. The estimates of parameter OMAT are derived from Clementine UV-VIS reflectance values for Apollo 17 landing-site sample stations published by Jolliff [5]. Average values of I_s/FeO for the sample stations are compiled by Jolliff from Morris' data. Part of the plot from 0 to 0.12 is extrapolated from the linear trend observed data of Apollo 17 stations. It is needed to point out that value OMAT = 0 (Lucey's "optimized origin") asymptotic behavior only. As it follows from the plot in Fig. 3, a significant inflection of the curve is seen for values of I_s/FeO ~ 70 – 75. As revealed by Fisher and

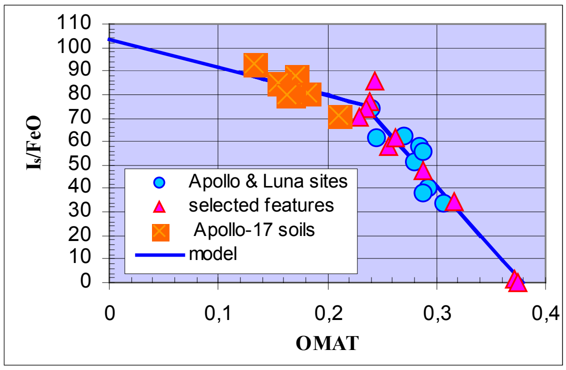

Fig. 3. Relationship between I_s/FeO and OMAT values.

Pieters [1], when a soil reaches maturity, exposure.

Conclusions. The trend shown in Fig. 3, isoptical properties no longer change with further consistent with this effect which is accounted here by the curve flattening of the spectral index of maturity values at I_s/FeO > 70 – 75. Shevchenko [7] and Pinet et al. [8] from correlation between maturity index and exposure age of a collection of lunar samples found that exposure age of 100 Myr corresponds to maturity index value of I_s/FeO ~ 75. The present results suggest, that the slope in flexion detected for I_s/FeO values around 75 is indicative of the beginning of the asymptotic behavior expected for a lunar regolithic soil when it reaches maturity steady-state. The implication is that one should be careful when interpreting OMAT relative estimates less than 0.22 +/-0.02 in terms of local variations of maturity in the lunar regolith, at the 100 – 200 m resolution available with Clementine.

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