Space Weathering Trends on the Moon Based on Statistical Analysis of Spectral Parameters

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INTRODUCTION

Space weathering causes continuous changes of spectral and compositional properties of airless planetary bodies. The main changes include:

- albedo reduction,
- diminution of mineral absorption bands,
- and slope reddening.

Individual components causing space weathering are:

- solar wind,
- galaxy radiation, and
- impacts of small bodies, so-called microimpacts.

Currently, the way each of these three effects influences the final state of a weathered surface remains unknown. In this research, we study spectra of lunar swirl areas on the Moon, where different contribution of these effects, due to locally higher magnetic field, is expected to uncover varying trends.

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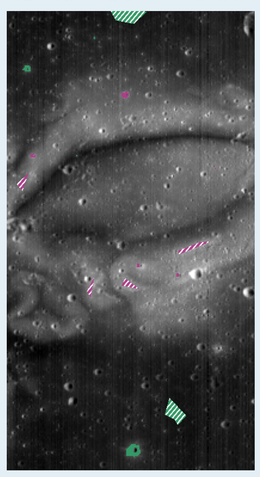
By analysis of lunar swirl areas, we found that in Reiner Gamma swirl, weathered (mature) swirl material exhibits intermediate depths of 1 and 2 μm absorption band, and intermediate slope compared to the fresh and mature material outside the swirl.

This trend seems to comply for 1 μm band in all swirls we have examined.

1 M3 SPECTRA

Fig.: Selected spectra in Reiner Gamma swirl.



Our data come from the Moon Mineralogy Mapper (M3), a spectrometer that was carried by Chandrayaan-1 probe.
We have chosen four different swirls on the Moon:

- Mare Ingenii,
- Mare Marginis,
- Rima Sirsalis, and
- Reiner Gamma swirl.

In each of them, we selected several tens to hundreds spectra from four distinct regions:

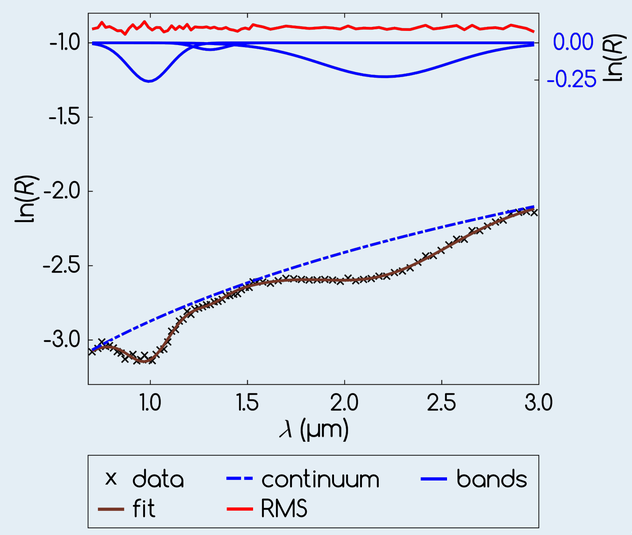
a) fresh crater outside the swirl (fresh - out),
b) fresh crater in the swirl (fresh - in),
c) mature material in the swirl (mature - in), and
d) mature material outside swirl (mature - out).

2 MGM FITS

We treat the spectra with the Modified Gaussian Model (MGM) by Sunshine et al. (1990). To manipulate sets of several hundreds spectra, we wrote a routine that pre-estimates spectral parameters. This allows us to use MGM in cycles. It is done by:

- estimation of number of absorption bands,
- fitting absorption bands by quadratic functions, and
- fitting continuum by a linear function.

Fig.: Sample output of our MGM modification.



3 RESULTS

STACKING & HISTOGRAMS

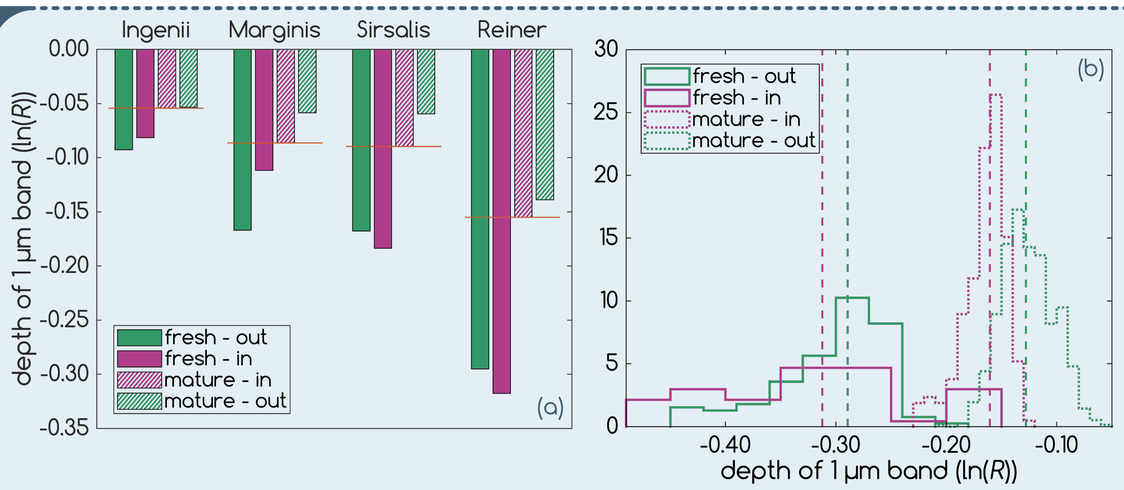


Fig.: (a) results of spectral stacking for different swirls and 1 μm band, (b) an example of a histogram plot for Reiner Gamma swirl.

Some of our results:

- when we stack all the spectra from a given region, and then evaluate them with MGM, mature swirl material seems to have intermediate depth of 1 μm absorption band between fresh and mature off-swirl material in all swirls (see figure (a) on left),

- when we apply MGM on all spectra individually, and then make histogram plots of all the parameters, 1 μm band also exhibits this trend (see fig. (b) on left),

- 2 μm band and spectral slope follow the trend only in some cases (see Table). Reiner Gamma has the trend in all three parameters.

Table: Does the spectral parameter follow the trend (mature - swirl - fresh)? In each case: left mark is the result of stacking, right of histograms.

	Mare Ingenii	Mare Marginis	Rima Sirsalis	Reiner Gamma
Depth of 1 μm	∼ ∼	✓ ✓	✓ ∼	✓ ✓
Depth of 2 μm	✗ ✗	✓ ✓	✓ ✗	✓ ✓
Spectral slope	✗ ✗	✗ ✗	✗ ✓	✓ ✓

∼ : trend is present but is below 5% significance level

To conclude:

- when comparing the depth of 1 μm band, all swirls seem to exhibit described trend (swirl material is intermediate between mature and fresh material),
- Reiner Gamma is the only swirl that follows the trend in all three main parameters (depths of 1 and 2 μm band, and spectral slope),
- in other spectral parameters, different swirls behave differently.

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