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Laboratory spectroscopy of rocks and data analysis: a fundamental tool for understanding the planetary geology

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Acquiring information about the surface composition of bodies in the Solar System is essential in order to model their origin, evolution and internal structure, and to understand how our own Earth formed as well.

During the last decades, the technological improvement of remote sensors and the subsequent implications for planetary studies have encouraged the scientific community to address both laboratory and field spectroscopy researches to model the spectral behavior of terrestrial analogues for planetary surfaces. The surfaces of terrestrial planets are composed of solid rocks which eventually can be partially or totally covered by particulate materials, the so-called regolith, as for the Moon, Mars and Mercury. Compositional, as well as textural, characteristics have to be taken into account when attempting to model remote-acquired spectra. Nevertheless, the natural complexity is so variable and difficult to reproduce in laboratory experiments that further and more detailed studies are required to better understand the relationships between spectra of pure mineral mixtures and solid rocks.

Several approaches to the qualitative and quantitative analysis of remotely-acquired spectra have been developed and successfully used to infer the presence and abundance of minerals with distinctive spectral signatures and to discover spectral trends attributable to compositional features (Hapke et al., 1975; Rava and Hapke, 1987; Lucey et al., 2000). A simple technique to qualitatively evaluate remote spectra is to compare them with laboratory reference spectra (Gaffey et al., 1993). This empirical approach, even if highly subjective, has produced encouraging results, both qualitative and quantitative, when applied to terrestrial and extraterrestrial surfaces. Other approaches are mainly based on mathematical and statistical analyses, but again they cannot be considered as completely objective techniques. Two known and applied models allow prediction of the compositional information using theoretical calculations (e.g. Hapke, 1981; Hapke and Wells, 1981), and Gaussian distributions (Modified Gaussian Model, Sunshine et al. 1990).

Nevertheless, there are still some open questions regarding the ability of the models developed for spectral analysis to understand rock spectral behavior. The present investigation tested MGM applicability to solid mafic rock spectral modeling, in order to resolve the presence of the most common iron-bearing silicates. For this purpose, we have chosen two rock types with different textural characteristics: an intrusive cumulate rock (melanorite) and an effusive rock (basalt). The spectroscopic measurements were performed directly on slightly polished rock slab surfaces. The spectral analysis revealed that the MGM decomposition of solid rock samples can be used with caution, at least to obtain qualitative estimates of the main composition, in the case of intrusive rocks not strongly affected by textural complications. Further work is still required in order to understand texture and its implications for spectral analysis. In addition, the statistical and thus objective evaluation of spectral models in the case of solid rocks is complicated by the increased observational error due to the homogeneity characteristics of the surfaces.

Moving to the larger viewing scale of the remote observations, again compositional and surface textural features become relevant to the spectral analysis, either merging or interfering with each other. The stronger the compositional signal, the more effective the spectral modeling is. Nevertheless, an increase in both the amount and the quality of spectroscopic observations is needed in order to interpret more numerous ambiguous spectral morphologies. Therefore, our recommendation is to improve the spectral modeling of bulk rocks and in situ-acquired spectra. Hopefully, once the spectral modeling has provided qualitative information about composition at least, then it should be possible to arrange laboratory experiments and simulate the spectral behavior of different textural rock-bearing components, in an extraterrestrial environment.

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