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SIR-2 as an important geological investigative tool.

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Abstract

The compositional relationship between silicate species tells us much about the thermal history of a given magmatic eruption, flow dynamics, depth of origin, volumetric output, and differentiation and fractionation mechanisms. This information, coupled with a plausible estimate of time of emplacement, can realistically contribute to the development of a reliable planetary evolution model and constrain the possible scenarios. The SIR-2 Point spectrometer on board of the Chandrayaan-1 mission, with a 200 m ground resolution and spectral resolution of 6 nm [1], can help investigate the key mineral species on a both local and planetary scale.

Introduction

In the last forty years with the help of returned Moon samples, the advance of remote sensing techniques, and the analysis of lunaites (lunar meteorites), we have progressively moved away from a relatively simple view of lunar crustal mineralogy to a more complex model of geochemical evolution and stratification. In particular, global electromagnetic studies have hinted at an even greater compositional heterogeneity of surface materials than previously suggested by direct analysis of lunar materials. Nevertheless, if we exclude the contribution of volatiles, most planetary bodies are built on a few mineralogical components: silicates (mostly), oxides and metals (mainly Fe-Ni). As it happens, key silicates minerals display strong absorption bands in the UV-VIS-NIR range [2], mainly due to the presence of iron within their crystalline lattices, hence enabling detection of each mineral phase and finer classification therein.

Scientific applications of SIR-2 data

Unlike the Earth and Mars [3], which compositions of most basalts reflect partial melting at depth of relatively uniform mantle materials (mainly peridotite, i.e. pyroxene- and olivine-rich rocks) and a consequent 4.5 Ga history of depletion and enrichment of key mineral phases, returned lunar samples have indicated a far greater mineralogical variability of source materials. In particular, the uniform depletion of the Rare Earth Element (REE) Europium in most lunar basalts and ultramafic glasses indicate an early segregation process of this element by Ca-rich plagioclase (anorthite), thus strengthening the evidence of an early Moon-wide fractionation process, the lunar magma-ocean model [4,5,6].

The melting and crystallisation behaviour of silicates is a function of composition (elemental population, volatiles content, etc.), Pressure-Temperature, and fugacity. In particular, key mineral phases crystallise/melt in a predictable sequence under given P-T conditions: on the Moon, for instance the Apollo 15 low-Ti basalt 15555 phase diagram [7] suggest a crystallisation sequence (from higher to lower P-T) as garnet-pyroxene-olivine-spinel-plagioclase (with some overlapping); Apollo 15 Red Glasses (high TiO_2 content) instead follow the general trend of mineral crystallisation (ortho)pyroxene-olivine [8]. Hence, the relative presence or absence of a particular mineral phase tells us much about the typology and origin of exposed lunar materials and their probable evolution. Consequently, being able to conduct a global survey of silicates distribution, in particular olivines and plagioclase, and differentiate between the Ca-poor and Ca-rich pyroxenes (if present) offers scientists the basis upon which to build plausible scenarios of crustal formation and evolution, including differentiation

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and segregation of diagnostic mineral phases [Fig.1].

Moreover, the high spatial resolution of the SIR-2 instrument should facilitate a detailed mineralogical survey of the central peaks of large lunar impacts, said to represent excavated materials from depth, i.e. potentially unearthed rock samples from the deeper strata, including bedrock and, in theory, even mantle materials [9]. Crater floor mineralogy would also be used to integrate and complement crater peak composition estimates, providing it has not being extensively reworked or contaminated by later impact ejecta [10]. Again, high-spatial and reflectance intensity resolution would allow for a closer inspection of visible ('bright', as in UV-VIS-NIR) ejecta rays, and, when used in conjunction with crater peak data (if present) and target material mineralogy, helping to understand the relationship between the stratigraphy of the impact area, composition, and time-dependent weathering rates of the rays themselves.

The spectrometer will also investigate the broad reflectance intensity and shape (slope) of chosen targets, since these characteristics are strongly related to surface maturity, i.e. how long the top soil has been exposed to the space elements [11,12,13]. Comparison with locally exposed 'fresh' soils, as for instance on craters' steep slopes, can help developing and restrain a new lunar surface maturity index, with implications for comparative and even absolute surface emplacement dating.

Conclusions

The ultimate goal of geology remote sensing is to develop an instrument that can be aimed at any planetary surface and obtain a reliable estimate of mineral composition. The SIR-2 instrument is a step forward towards this aspiration, especially when used in conjunction with data from similar and complimentary instruments.

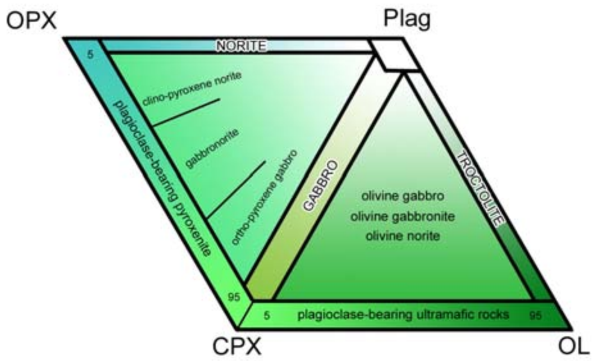

Figure 1: Combined Plag-Px-Ol phase diagrams

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