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Chemical heterogeneity on Mercury's surface revealed by the MESSENGER X-Ray Spectrometer

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Abstract

We present the analysis of spatially resolved measurements of Mercury's surface composition from MESSENGER's X-Ray Spectrometer, which reveal chemical differences between geological terrain types. High-Mg mafic minerals, plagioclase feldspar and lesser amounts of sulfides are likely to dominate Mercury's surface.

1. Introduction

Analysis of planetary X-ray fluorescence (XRF) data obtained by the MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) X-Ray Spectrometer (XRS) during 14 solar flare periods that occurred between orbit insertion on 18 March 2011 and the end of 2011 has revealed chemical heterogeneities across Mercury's surface that are related to the planet's diverse geological terrain types.

2. Methodology

The data periods chosen for this analysis were when MESSENGER was close to periapsis and the XRS data collection intervals were short (<100 s), resulting in spatially resolved measurements of Mercury's surface. We employ the forward modeling procedure of *Nittler et al.* [1] to fit the incident solar and planetary XRF spectra obtained by XRS and generate elemental abundances for the regions observed.

3. Results

The ~200 individual XRS measurements presented here have been split into three groups according to the geological terrain on which their corresponding footprints lie: (i) the northern volcanic smooth plains [2], (ii) the surrounding, older regions mapped from Mariner 10 images as intercrater plains and heavily cratered terrain (IcP-HCT) [3,4], and (iii) combinations of both. Derived Mg, Al, S, and Ca abundances, expressed as elemental weight ratios with respect to Si, are displayed in Figure 1. The data indicate that the surrounding IcP-HCT have, on average, higher Mg/Si, S/Si, and Ca/Si ratios, and a lower Al/Si ratio, than the northern plains.

4. Discussion

The high Mg/Si and low Fe/Si (see section 5) ratios indicate that Mg-rich silicate minerals (*e.g.,* enstatite, forsterite) dominate Mercury's surface. The strong Ca/Si–S/Si correlation is consistent for both northern plains and IcP-HCT material, and may be evidence of varying amounts of sulfides (*e.g.,* oldhamite) in different lithologies. However, this correlation could also result from variable abundances of CaS *and* mixing of different silicate minerals. The majority of Ca on Mercury's surface is contained in plagioclase feldspar [5], but it is also possible that some is found within non-aluminous phases such as diopside, as well as sulfides. The plagioclase feldspar composition is thought to be intermediate between anorthite and albite [5].

The lower Mg content of the northern plains indicates that its material was derived from a mantle source that was more evolved (and cooler) than the sources for the older IcP-HCT. This inference is consistent with the younger age of the smooth plains [2, 6]. From the direction of the trends between the two populations (Fig. 1), the northern plains do not appear to have been produced by remelting of IcP-HCT material.

5. Fe content

The lower Mg/Si of the northern plains compared with the IcP-HCT may be due in part to Fe substitution for Mg in mafic minerals. Although it has been demonstrated that Mercury's surface has a low Fe content (<4 wt% [1]), it has thus far not been possible to map the Fe abundance at the same spatial resolution as we have for lower-mass elements. Moreover, Fe is more susceptible to systematic errors in the XRS analysis than the other reported elements. Accurately estimating Fe heterogeneity on Mercury's surface requires the occurrence of strong solar flares occurring at or near MESSENGER periapsis, and detailed analysis and corrections for possible systematic effects related to detector backgrounds, observation geometry, and solar temperature. Such analyses are underway.

References

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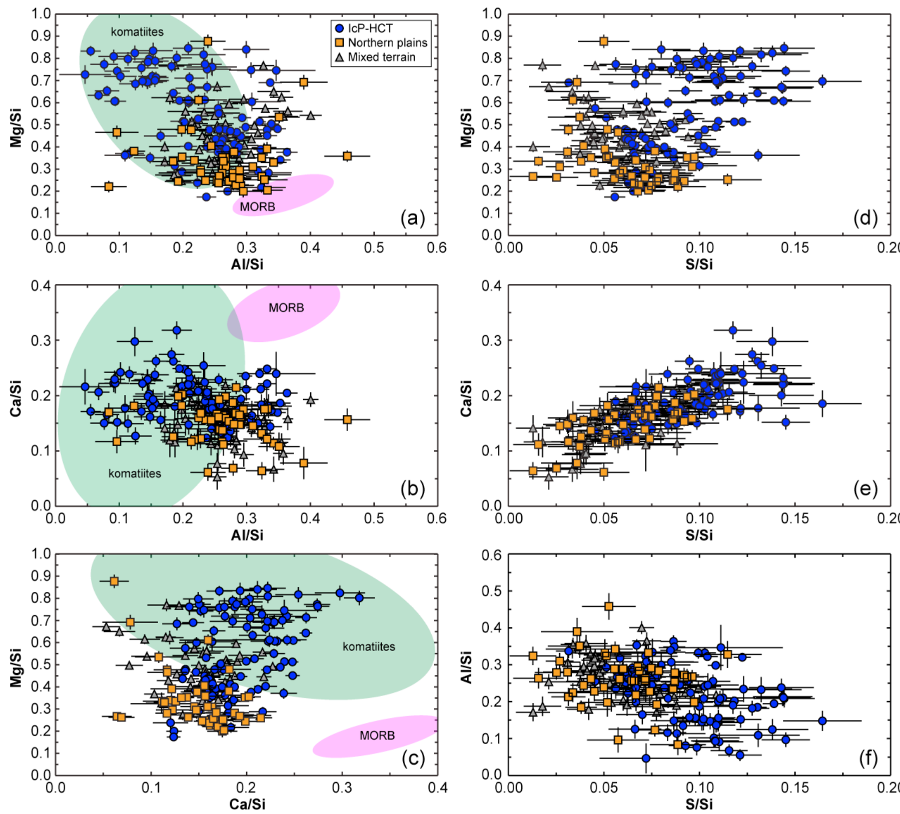

Figure 1: Elemental ratios, by weight fraction, for ~200 individual XRS footprints. Data are grouped according to the terrain on which their footprint lies. Also shown are compositional fields for terrestrial komatiites and mid-ocean ridge basalts (MORB).