BULK COMPOSITIONAL TRENDS IN METEORITES: A GUIDE FOR ANALYSIS AND INTERPRETATION OF NEAR XGRS DATA FROM ASTEROID 433 EROS. L. R. Nittler,[1] P. E. Clark,[1,2] T. J. McCoy,[3] M. E. Murphy,[1,2] and J. I. Trombka[1], [1]*Laboratory for Extraterrestrial Physics, NASA's Goddard Spaceflight Center, Greenbelt MD 20771, USA (nittler@lepvax.gsfc.nasa.gov)* [2]*Physics Dept., Catholic University of America, Washington, DC 20064 USA.,* [3]*Dept. of Mineral Sciences, Smithsonian Institution, Washington, DC 20560 USA, mccoy.tim@nmnh.si.edu.*

The Near Earth Asteroid Rendezvous (NEAR) spacecraft is to orbit the S-class asteroid 433 Eros for about one year beginning on February 14, 2000. The X-ray/gamma-ray spectrometer (XGRS) on NEAR will determine the surface elemental composition (e.g., O, Mg, Al, Si, Fe, and K; possibly H, Ca, S, Ti, and Th) of Eros with a spatial resolution ranging from a few km for X-rays to ~25% of the asteroid's surface for γ-rays [1]. The major scientific goals for the NEAR XGRS are to relate the composition of Eros to known classes of meteorites, to assess compositional heterogeneity and to identify geological processes that have occurred on the asteroid.

Comparing remote-sensing data from asteroids to laboratory data from meteorites requires that the latter be well-determined and understood. How well particular classes of meteorites can be identified as analogues of Eros depends not only on the error of the XGRS measurement, but also on the spread in abundances observed among different members of a given meteorite class. To prepare for the return of XGRS data from Eros, we have compiled a large database of bulk elemental compositions of meteorites, using data from a wide variety of published and unpublished sources (including [2–5]). Custom software was developed to easily extract statistical information and make plots of data from different meteorite classes.

Here we use the meteorite compositional database to investigate which abundances and abundance ratios, of those measureable by the NEAR XGRS, are most diagnostic for distinguishing meteorite classes and identifying geological processes that have occurred on the samples' parent asteroids. We initially consider the meteorite classes most likely related to Eros, including ordinary chondrites (OC), achondrites (*e.g.*, eucrites, diogenites), primitive achondrites (*e.g.*, acapulcoites, lodranites) and stony-irons (pallasites, mesosiderites). Other classes (carbonaceous and enstatite chondrites, aubrites) are poor spectral matches for Eros and are given less attention here. These classes are present in the database, however, and will be considered in the future if spacecraft data indicates this is warranted.

The elements Mg and Si, plotted in Figure 1 for fourteen meteorite classes, provide a useful example of major elements measureable by the NEAR XGRS. These elements distinguish some, but not all, meteorite classes and geological processes. Some classes are clearly separated due of the effects of differentiation. For example, the basaltic eucrites are strongly enriched in Si and depleted in Mg relative to their chondritic precursors while the ureilites are enriched in Mg, relative to OCs. The OC sub-classes H, L, and LL clearly have distinct average Mg and Si abundances, but there is some overlap in the observed ranges. Hence distinguishing OC sub-class solely by Mg and Si abundances is not unambiguous. Pallasites define a linear trend because their Mg and Si are contained in a single mineral, olivine, with a relatively constant Mg/Si ratio; the position along the trend of any given meteorite depends on the metal:silicate ratio.

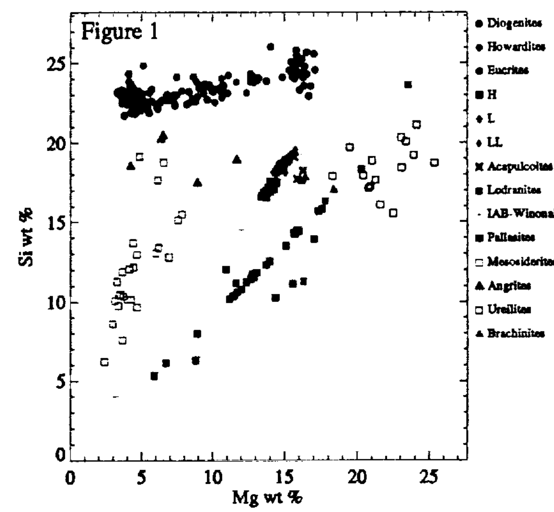


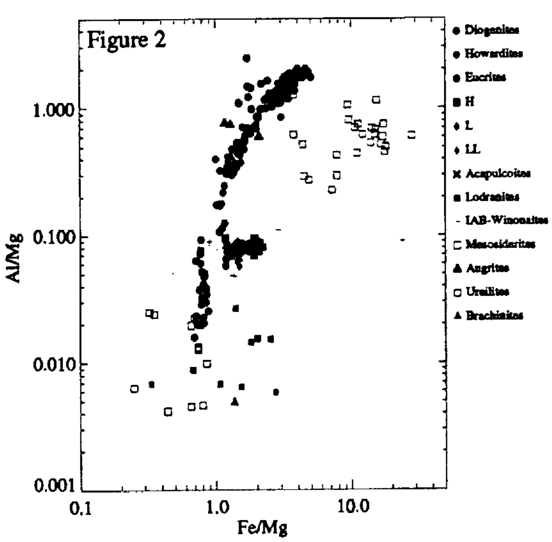
Figure 1

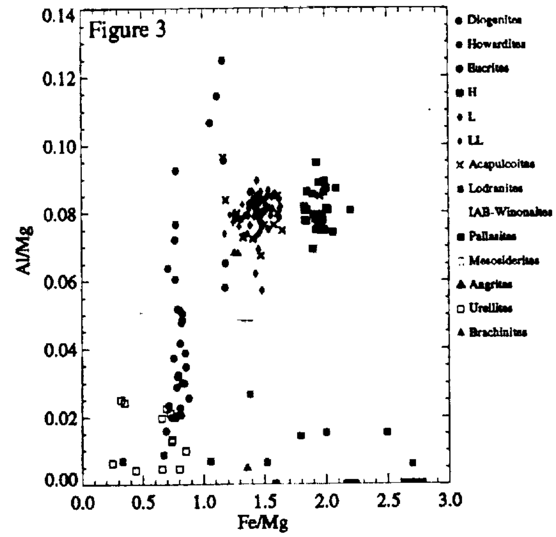
Accurate abundance ratios will be easier to obtain from the XGRS spectra than absolute abundances because ratioing eliminates many of the geometrical factors which affect the production of X- and γ-rays from the asteroid's surface. Shown in Figure 2 are Al/Mg and Fe/Mg ratios plotted for several meteorite classes; Figure 3 shows a restricted range of the same data. A number of interesting features are apparent on these plots. Many classes can be distinguished. The H, L and LL sub-classes of the ordinary chondrites have overlapping ranges of Al/Mg, but are separated according to their Fe/Mg ratios. As in Figure 1, the effects of igneous processing are clearly visible. For example, Al-rich, Mg-poor basalts (eucrites, angrites) are clearly distinguished from Mg-rich residues (ureilites, lodranites). Similar ranges in these ratios might be observed at the surface of Eros, if the asteroid has undergone igneous differentiation.

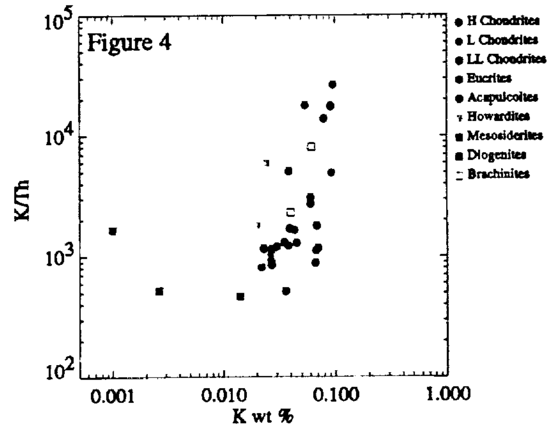
The figures indicate the importance of a multicomponent approach. Some meteorite classes (and hence the geological histories that have produced them) are distinguishable in some abundances but not in others. For example, the unusual basalts, angrites, overlap the eucrite field in Figure 2, but have clearly lower Si abundances in Figure 1. Angrites also have much higher Ca and Ti abundances than eucrites. Note also that in Figures 1–3, the primitive achondrite acapulcoites are indistinguishable from OCs. However, lodranites, which are believed to originate from the same parent asteroid as acapulcoites, are quite distinct, reflecting their probable origin as residues of partial-melting. Hence, taken as a class, acapulcoites and lodranites are distinguishable from OCs. In fact, as discussed by [6], if Eros has undergone partial melting and melt migration to the extent inferred for the parent body of the acapulcoites and lodranites, we should expect strong elemental heterogeneity on a scale of km, with some regions appearing chondritic and others appearing similar to igneous rocks.

In addition to major rock-forming elements, some trace elements, including K and Th, should be observable by their γ-ray emissions. Figure 4 shows the K/Th ratio plotted against K abundance for several classes. The ratio of volatile K to refractory Th should reflect the thermal history of planetary bodies. For example, the unmelted chondrites have high K/Th ratios, the fully melted eucrites have lower ratios, and the partially melted acapulcoites and brachinites have intermediate ratios.

Clearly, careful examination of the elemental trends observed in asteroidal samples –meteorites– on earth is essential for any understanding of remote-sensing elemental abundance data from asteroids. However, our ultimate understanding of the composition, structure and geological history of Eros will require careful consideration not only of the elemental abundance data determined by the XGRS, but also the information returned by other instruments on the NEAR spacecraft, for example topographic and mineralogical data from the multispectral imager and near-infrared spectrometer.







Thanks: We are very grateful to D. Bogard, E. Jarosewich, G. Kallemeyn, D. Mittlefeldht and T. Murakami for making data available to us in computer-readable form.

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