

MINERALOGY OF HED METEORITES AND V-TYPE ASTEROIDS BY MEANS OF THE MODIFIED GAUSSIAN MODEL

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Abstract: The correlation between specific meteorites and asteroids is a long-standing problem. The best-known correlation seems to be the HED-Vesta, although several problems still remain to be solved. We report the spectral reflectance analysis (0.4-2.5 μ m) of a set of HED meteorites, taken from the RELAB database and three V-type asteroids, taken from MIT-UH-IRTF Joint Campaign for NEO Reconnaissance. We used the Modified Gaussian Model to fit the spectra to a series of overlapping, modified gaussian absorptions. With spectral resolution extending to the near-infrared, we are able to resolve the presence of both high-calcium pyroxene (HCP) and low-calcium pyroxene (LCP) and, thus, use the HCP/(HCP+LCP) ratios to remotely trace igneous processing on the parent asteroids. A search of this mineral provides a useful probe of differentiation. The degree of melting obtained for the eucrites, using the former ratio, is comparable with that obtained for all the V-type asteroids here analyzed, suggesting a comparable geologic history.

Keywords: HED meteorites

1 Introduction

Most part of the extraterrestrial samples - the meteorites, has proven to be from small bodies of the solar system - the asteroids. Given these samples ancient radiometric ages indicating that their ages are very close to that of the solar system itself, their study supplies us with important key information connected to their initial composition and subsequent processes of chemical evolution, thermal and physical processes through which these samples evolved. These clues build up the basis to our understanding of the stages of solar system pre-planetary formation and subsequent evolution of smaller bodies [1]. One of the most interesting bodies among the asteroid population is Vesta. Detailed studies, combining remote sensing, modelling and density estimates, indicate that it is a differentiated object with crust, mantle, exposed

in a huge crater and core. But in order to achieve fully understanding of this asteroid fascinating geological history we can also rely on the study of the howardite-eucrite-diogenite meteorites (HEDs) which are believed to come originally from Vesta. These impact fragments composed of a large suit of differentiated basalts (eucrites), pyroxenites (diogenites), and breccia mixtures of mainly these two types (howardites) have suffered several changes and trough subsequent collisions and dynamical evolutions. We are therefore in the presence of samples from the Vesta family, like type V asteroids also found to have similarities with Vesta [2]. At visible and infrared wavelength (0.4-2.5 μm), mineral reflection spectra have absorption features that are typical of crystalline composition and structure of the absorption entity. So it's possible to use reflection spectra from remote sensing as a base to estimate the mineralogy of terrestrial as well of extraterrestrial surfaces. Through high signal to noise data and high spectral resolution data it is now possible to resolve the presence of both HCP and LCP and use HCP/(LCP+HCP) ratios to remotely trace igneous processes on asteroids [3].

2 Method

Modified Gaussian Model (MGM) arose from the necessity of a more general fitting method of analysis that resolve and allow distinguish spectra in individual absorption features representing these same absorption features with discrete mathematical distributions. The use of this quantitative correlation it is only dependent of the spectrum itself. MGM method supplies an objective and consistent tool to examine the individual absorption features of a spectrum. [5] Given a set of different input parameters on MGM and operating the first step of the fitting process we now must meet strict sequential steps in order to reach physical coherent results. The calibration procedures, to which all samples analyzed in the present study were submitted, can be summarized as follows. Given the initial parameters we first proceed to an initial fit. Once the fit result is obtained we then proceed to check the band width calibration and assure that it is within the tabulated values [4]. Band center calibration follows and again, comparing the results with the tabulated values, we then see if the LCP/HCP band ratio near the 1 and 2 μm region is acceptable. If all these conditions are met then we achieved the final result if not then a change in the parameters is needed and we restart the process. An important add to this procedure is to always mind the fit residual and keep its structures to a minimum.

3 Results

Given the high number of fitted eucrites we only present the obtained plot of one of them. We find that with the residual line kept to a minimum of structures we can fit

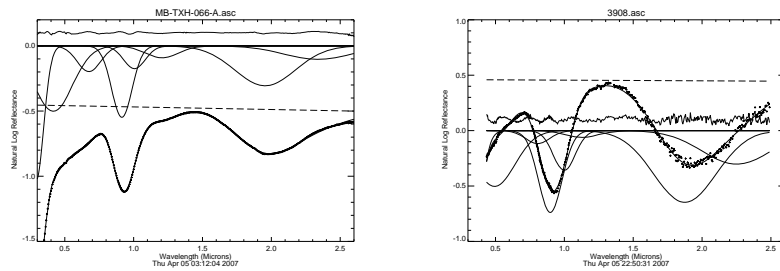


Figure 1: A example of an MGM fit of the MB-TXH-066-A eucrite (left panel). A MGM fit of the V type asteroid (3908) Nix, is shown as an example of one of the three fitted asteroids(right panel).

the two main absorption features near 1 and 2 μm . We can see band I and II with band centers 0.916 μm and 1.964 μm for LCP and 1.010 μm and 2.309 μm for HCP. We also present the plot for one of the fitted V-type asteroid as an example of the MGM fitting process here applied.

In the present work we used as a input model parameters of absorption bands in the MGM fit listed [4]. First we started with a set of orthopyroxene (LCP) only and observed an non conformity in the obtained results which mean we did not manage to attain all the given constrictions. We did not manage to explain the full width of the second combined band therefore we needed to address the problem with an additional individual band which could explain the results. Therefore a second analysis was proceeded changing the input parameters to an also given percentage of clinopyroxenes (HCP) (75/25 LCP/HCP). [4] derived a relationship from spectra of a set of powders of known proportions of high and low calcium pyroxene. We proceed to the comparison of our results against these tabulated values. Once obtained the ratios between LCP/HCP bands from our fitted samples and once performed a logarithmic transformation we can determine HCP/(HCP+LCP) ratio. Therefore based on this systematic variation in the relative strength of pyroxene absorption function of HCP/(HCP+LCP) ratios which are also function of melting percentage and using calculations of melting with the MELTS program [3] we determined the correspondent values of degree of melting of our samples.

4 Discussion and Conclusions

In this study we analyzed a set of 10 eucrites and 3 type V asteroids with Modified Gaussian Model (MGM) which has been shown to accurately model the shape of isolated absorptions and thus provides a high degree of confidence in resolving overlapping absorption bands. Eucrites are enriched in high calcium pyroxene, consistent with their origin by crystallization of partial melts. Calculations suggest that the HCP/(HCP+LCP) ratio is a sensitive indicator of the degree of partial melting of a chondritic precursor and could be an important tool for deciphering the igneous history of differentiated asteroids [3].

Analyzing the data obtained for the percentage of melting for the eucrites we can see that the degree of melting varies from 21.1% to 23.9% corresponding to an HCP/(LCP+HCP) ratio of 0.46 to 0.55. For the results obtained of the three V type asteroids we found 18 - 19% of melting with a ratio of HCP/(LCP+HCP) 0.59 - 0.66. As a whole, the parent body of the howardite-eucrite-diogenite (HED) meteorites would exhibit lower values, consistent with the inclusion of orthopyroxene-rich, augite-poor diogenitic material with HCP/(HCP+LCP) ratios approaching zero [3]. The rates of HCP/(HCP+LCP) found, assert an extensive differentiation of their parent body. The degree of melting obtained to the eucrites using the quoted ratio can be comparable yet not quite similar to asteroids V analyzed but still suggest a geological comparable history. Theoretical predictions expecting asteroid and meteorite differentiation to produce changes in high calcium pyroxene abundances is clear, the strongest evidence still lies in the study and analysis of both meteorites and remote sensing observed asteroid spectra which experienced various degrees of differentiation and its study stands as an important path to follow in present and future researches.

Acknowledgements: Part of the data utilized in this work were obtained and made available by the The MIT-UH-IRTF Joint Campaign for NEO Reconnaissance. The IRTF is operated by the University of Hawaii under Cooperative Agreement no. NCC 5-538 with the National Aeronautics and Space Administration, Office of Space Science, Planetary Astronomy Program.

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