REFLECTANCE SPECTRA OF METEORITES AND IMPLICATION FOR FEATURELESS E/M/B-TYPE ASTEROIDS

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Introduction: Generally, one type of asteroids links to a specific type of meteorites or represents a kind of stable mineral assemblages, for example S-type asteroid 25143 Itokawa matches well to ordinary chondrites [1]. However, for asteroids without any spectral features, it is difficult to accurately know surface composition or corresponding type of meteorites. Adopting only classic spectral parameters (e.g. geometric albedo) to compare spectra of featureless asteroids with candidate meteorites, would even link one type of asteroids to multiple kinds of possible meteorites. A representative example is that enstatite chondrites (ECs) and iron meteorites (IMs) [2-3] have always been thought daughters of Tholen M-type asteroids due to their featureless characteristic and very similar reflectance and slopes [4]. It is also controversial about composition of some featureless primitive or very dark asteroids, such as B-, D-types and others. In addition, because of existence of some alteration processes on surface such as space weathering [5], absorption characteristics of some asteroids may have been completely suppressed, leading to featureless spectra. Astronomers acknowledge that each of asteroid classes probably encompasses a wide variety of surface compositions [6-7] due to the complexity of the asteroids, yet planetary geologist always want to know more details about mineralogy. Hence, it is indeed necessary to develop a more efficient tool to describe these featureless asteroids' spectra, to update the existing classification schemes and perfect the asteroids-meteorites connection, in order to better speculate on composition of asteroids and meet the needs of the modified solar system evolution model currently in use.

Experiments: Here we show newest results of reflectance spectra of fourteen meteorites measured in laboratory, covering four types that are aubrites (Aubs) enstatite chondrites (ECs), iron meteorites (IMs) and carbonaceous chondrites (CCs). Spectral parameters e.g. reflectance at 0.55μm ($R_{0.55}$), slopes (S) in two visible bands (0.4-0.5 μm, S_1; 0.5-0.6 μm, S_2) and four near-infrared bands (0.8-0.9 μm, S_3; 1.1-1.2 μm, S_4; 1.1-1.4 μm, S_5; 1.6-1.8 μm, S_6) were calculated and compared respectively, aiming to develop a tool to identify types of meteorites by spectroscopy. We also counted and compared the geometric albedo (P_v) and slopes in five short bands (excluding 0.4-0.5 μm) among twenty-one asteroids (including E-, M- and B-type) to test whether it is effective to identify the types of featureless asteroids when using analog of divided methods of meteorites' types.

Results: We have found that each types of meteorites have almost completely independent range of values of $R_{0.55}$ and values of near-infrared slopes (S_3 to S_6), as shown in fig.1a. In summary, the method that plotted reflectance at 0.55 μm with slopes is effective to identify types of meteorites, and which works best when slopes were calculated in 1.1-1.4 μm band.

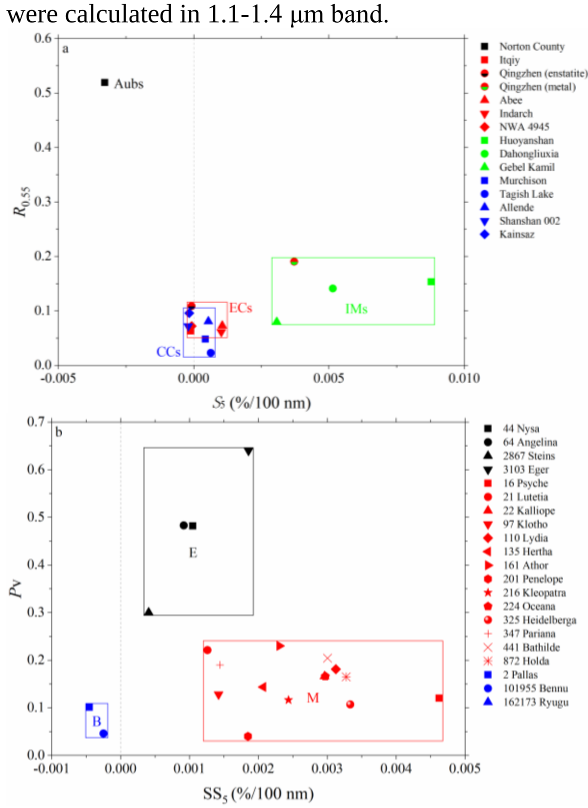

Fig.1 a) Orthogonal coordinate diagram plotted by reflectance at 0.55 μm and slope in 1.1-1.4 μm of 14 measured meteorites; b) Orthogonal coordinate diagram plotted by geometric albedo and slope in 1.1-1.4 μm of 21 asteroids.

We also chosen 21 representative asteroids that include E-type, M-type and B-type to analyze their spectral parameters. Particularly, we are concerned about their geometric albedo (P_v) and spectral slopes (SS) in the six bands. Similar to meteorites, SS_1 to SS_2 represent visible slopes calculated in the 0.4-0.5 μm and 0.5-0.6 μm reprehensively, while SS_3 to SS_6 refer to near infrared slopes in 0.8-0.9 μm, 1.1-1.2 μm, 1.1-1.4 μm, and 1.6-1.8 μm in turn. The fig.1b show that the asteroids have similar trends on brightness and slopes when compared with meteorites. B-types show the lowest Pv (lower than 0.101) and weakly negative slope (-0.000453 to -0.002468); E-types occupy region with relatively highest Pv (larger than 0.3) and weakly positive slope (0.000409 to 0.001857); M-types have moderate Pv (0.04 to 0.23) and intense positive slope (0.001261 to 0.004624). It is worth noting that the asteroids do not show exactly the same slope change as meteorites: 1) in fig.1b, B-type have the lowest slope value, but for meteorites in fig.1a, the type with lowest slope of is aubrite; 2) E-type asteroids all show positive slope while aubrite show negative slope; 3) the slope range of E-type overlap with some M-type asteroids.

Discussion: Fig.2 shows transformation of $R_{0.55}$ and S_5 before and after irradiation. It suggests that space weathering will significantly alter the original location of meteorites in fig.1a. The stronger the degree of space weathering, the stronger the spectral alteration. In fig.2, if the degree of space weathering is stronger, for aubrite, the value of S_5 is very likely to turn positive and finally completely falls into range of E-types. For CM2 Murchison, after irradiation, the value of S_5 is closer to the SS_5 of B-type than before (fig.1b). In other words, the space weathering indeed is an important reason for the difference between fresh meteorites classification (fig.1a) and asteroids classification (fig.1b). Hence, without space weathering, the distribution of E-, M-, and B-type asteroids should be very likely to be consistent with distribution of Aubs, ECs, IMs and CM2 in fig.1a. However, after space weathering, the original E-type asteroids will darken and redden, original M-type asteroids will brighten and redden, and original B-type asteroids will brighten in visible region and show bluer near-infrared slope, in this way, the distribution of E-, M-, and B-type asteroids will become to the results in fig.1b. In this case, the B-type asteroids will have the lowest negative SS_5, the E-type asteroids will have positive SS_5, and part of E-type asteroids undergone intense space weathering are likely to overlap with enstatite-richer M-type asteroids undergone less space weathering.

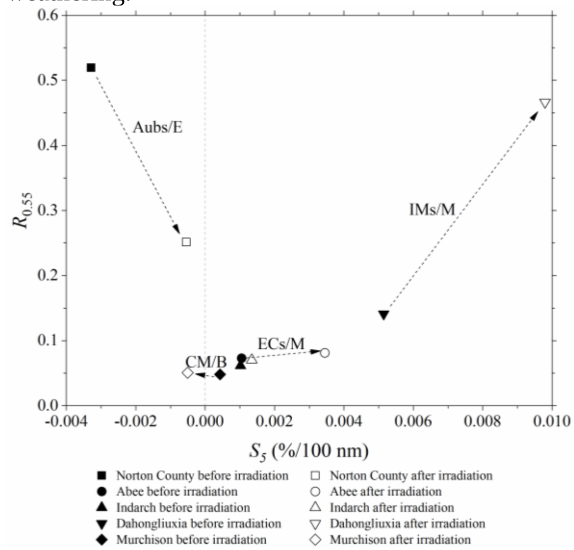

Fig.2 Spectral characteristics of 5 meteorites before and after irradiation.

Conclusion: For featureless asteroids, The near-infrared slope is important for identifying types of asteroids and analyzing surface composition. Especially, space weathering plays an important role in alteration of original spectral characteristics even classification of asteroids.

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