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AN INITIAL PERSPECTIVE OF S-ASTEROID SUBTYPES WITHIN ASTEROID FAMILIES; M. S. Kelley and M. J. Gaffey, Dept. of Earth & Env. Sci., Rensselaer Polytechnic Institute, Troy, NY 12180-3590

Many main belt asteroids cluster around certain values of semi-major axis (a), inclination (i), and eccentricity (e). Hirayama [1,2] was the first to notice these concentrations which he interpreted as evidence of disruptions of larger parent bodies. He called these clusters "asteroid families". The term "families" is increasingly reserved for genetic associations to distinguish them from clusters of unknown or purely dynamical origin (e.g. the Phocaea cluster [3]). Members of a genetic asteroid family represent fragments derived from various depths within the original parent planetesimal. Thus, family members offer the potential for direct examination of the interiors of parent bodies which have undergone metamorphism and differentiation similar to that occuring in the inaccessible interiors of terrestrial planets. The condition that genetic family members represent the fragments of a parent object provides a critical test of whether an association (cluster in proper element space) is a genetic family. Compositions (types and relative abundances of materials) of family members must permit the reconstruction of a compositionally plausible parent body. The compositions of proposed family members can be utilized to test the genetic reality of the family and to determine the type and degree of internal differentiation within the parent planetesimal. The interpretation of the S-class mineralogy provides a preliminary evaluation of family memberships.

To date no detailed investigation of proposed genetic relationships using the specific mineralogy and petrology of family members has been published. The closest approximations to a genetic relationship study have been attempts to confirm logical family groups based upon taxonomic types of family members primarily from existing survey data [4-9]. While a valuable first step, such taxonomy-based approaches do not have the sensitivity nor the discriminability of a mineralogy-based approach. In particular, it is generally accepted that each asteroid started with some initial composition similar to one of the chondritic groups. The composition of the mafic silicates in a differentiated parent body can be related to the chondritic group from which it was derived. For example, any genetic affinity between two fragments in a nominal family would be precluded if their compositions differed in a manner which did not conform to some part of the chemical evolutionary sequence from a single initial composition.

Since Hirayama's pioneering work, the number of known asteroids has increased greatly, improved methods of calculating orbital elements have been devised [e.g. 10-13], and new methods of distinguishing statistically significant clusters have been utilized [e.g. 11, 12, 14-17]. All subsequent surveys have confirmed Hirayama's six original families, with additional members added as the known asteroid population has increased. However, there has been considerable disagreement among recent studies regarding the total number of families and the family memberships, including additions to the original six. The various approaches have different criteria for identifying a family and for including or excluding potential members. The detection of small families against high backgrounds is a particularly contested issue, with some investigators identifying large numbers of such families while others find few. The validity of such families could be tested by determining the compositions of members and establishing whether they represent plausible compositions for a single parent body.

Detailed mineralogical and petrological analysis has been done based on the reflectance spectra of 39 S-type asteroids [18]. The result is a division of the S-asteroid class into seven subtypes based on compositional differences. These subtypes, designated S(I) to S(VII), correspond to surface silicate assemblages ranging from monomineralic olivine (dunites) through olivine-pyroxene mixtures to pure pyroxene or pyroxene-feldspar mixtures (basalts). The most general conclusion of this study is that the S-asteroids cannot be treated as a single group of objects without greatly oversimplifying their properties. Each S-subtype needs to be treated as an independent group with a distinct evolutionary history.

Half of the objects in the Gaffey et al. [18] survey fall into Williams [12] families and 8 of the asteroids (4 pairs) fall into 4 families. 39 Laetitia, subtype S(II), and 264 Libussa, subtype S(V), are in family 67. Two subtype S(V) objects, 101 Helena and 389 Industria, are in family 144. Asteroid 115 Thyra is a borderline subtype S(III-IV) object and 584 Semiramis is a subtype S(IV), both fall within the family 163. Family 170 only contains two numbered objects, 9 Metis and 113 Amalthea, both of which are S-type asteroids. 113 Amalthea is a subtype S(I) object and 9 Metis is presently ungrouped, but appears to be related to the S(II) subtype. All of these pairings make compositional or petrographic sense based on current meteoritic and igneous petrogenic models. The probability of any of these compositional family pairings occurring in the surveyed S-asteroid population is on the order of only a few percent. The probability of all of these pairs occurring in this sample population is much less than one percent.

This study by Gaffey et al. [18] has provided tentative support for the Williams [12,16] family classifications.

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