LINKING ASTEROIDS AND METEORITES TO PRIMORDIAL "PARENT BODIES". Richard C. Greenwood[1], Thomas H. Burbine[2] and Ian A. Franchi[1] , [1]Planetary and Space Sciences, School of Physical Sciences, The Open University, Walton Hall, Milton Keynes MK7 6AA, United Kingdom, r.c.greenwood@open.ac.uk, [2]Department of Astronomy, Mount Holyoke College, South Hadley, MA 01075, USA.

Introduction: Meteorites provide us with a great diversity of extraterrestrial materials. However, to interpret this record effectively we need to link these meteorites to their source asteroids and ultimately relate both to the original asteroidal population. This involves addressing a number of key issues: i) how many asteroids/parent bodies are represented in the worldwide meteorite collection? [1,2]; ii) how well can we link meteorites to particular asteroids [3]; (iii) how useful are contemporary meteorites and asteroids as indicators of the composition and structure of the first-generation of planetesimals, those that accreted very early in the evolution of the Solar System? [4, 5]. Relevant to this final point are the proposals that giant planet migration was a major control on the structure of the main belt [6]. Understanding the compositional diversity of the original planetesimals is a crucial step in constraining the composition of the building blocks of the terrestrial planets [7].

Here we discuss the results of a survey assessing the likely number of "parent bodies" sampled by meteorites. We have also attempted to link meteorites with their potential source asteroids and try to relate both to the primordial planetesimal population [8].

What are "parent bodies? When linking meteorites to their asteroidal sources the term "parent body" is almost universally invoked. The SAO/NASA Astrophysics Data System returned 21,700 entries for the period 1953 to present, in which the words "Parent Body" or "Parent Bodies" had been used in the text. However, these terms are generally loosely used to designate "a body that supplies meteorites to Earth." This concept could be rendered more meaningful by discriminating between primary and secondary parent bodies. A primary parent body is the source asteroid from which the meteorite is ultimately derived, and a secondary parent body is an asteroid derived through impact or break-up of a primary body (Fig. 1). A clear example of this usage is provided by (4) Vesta, with the main asteroid being the primary parent body and the Vestoids representing secondary parent bodies [9,10,11].

Defining parent body relationships: The breakup of a lithologically diverse asteroid potentially results in the formation of a compositionally diverse suite of secondary asteroids (Fig. 1). This raises the important issue of what are the best geochemical tools to link these apparently disparate fragments and hence try to "rebuild" their source asteroid. Clearly, there is no "magic bullet" that can be used to undertake this task. Characterizing and classifying meteorites requires a detailed assessment of evidence from a wide range of techniques [12,13]. However, as a result of the pioneering studies of Robert Clayton and co-workers, oxygen isotope analysis has proved to be a particularly effective tool in establishing potential links between seemingly unrelated groups. In this study considerable use has been made of the results of whole rock oxygen isotope analysis as a means of defining the number of parent bodies represented in our meteorite collections.

Oxygen isotope analysis is a particularly powerful technique when applied to meteorite groups that have experienced large-scale melting and homogenization. The groups concerned include the HEDs, mesosiderites, angrites, aubrites, pallasites, magmatic irons, lunar and Martian rocks [14]. Such samples often show limited $\Delta^{17}O$ variation, rarely exceeding ±0.02 ‰ (2σ) [14]. Where less extensive melting and differentiation took place, as in the case of the primitive achondrites, the use of $\Delta^{17}O$ as a means of defining parent body sources is less clear-cut and a range of evidence is required in such cases [15]. For chondrites, which generally show significant levels of oxygen isotope variation, defining the number of parent bodies that are the sources for these meteorites is not straightforward [8].

Parent body numbers: The results of this survey indicate that there are between 95 and 148 parent bodies represented in our sample collections [8]. This number is steadily increasing as new "anomalous" meteorites are characterized. Full details given in [8].

	N_{min}	**N_{max}**
Grouped chondrites	15	20
Ungrouped chondrites	11	17
Grouped prim. achon.	4	5
Ungrouped prim. achon.	23	23
Diff. achond and stony irons	11	12
Anomalous basaltic achondrites	5	11
Irons	26	60
TOTALS	**95**	**148**

Linking meteorites to asteroids: Attempts to link these parent bodies to identified asteroids has so far been of limited success, due to the non-unique reflectance spectra of almost all known asteroids [16]. Asteroid (4) Vesta and the HEDs (howardites, eucrite, diognite) meteorites is the best example of a relatively non-disputed asteroid-meteorite linkage [9,10.11].

Chondrites as secondary parent bodies: The concept of primary vs. secondary parent bodies may have important implications for early Solar System evolution [8]. Chondritic parent bodies are known to have accreted between 1 and 4 Myr after CAIs [17]. The study of meteoritic breccias demonstrates that chondritic parent bodies underwent significant modification in this time interval, with many of the "first generation parent bodies" being destroyed [18]. It is entirely conceivable that all of the chondrites arriving on Earth today are sourced from asteroids that have undergone multiple breakup and reassembly events and hence are secondary parent bodies.

Why so few parent bodies? The number of parent bodies represented by meteorites (95 to 148) appears low when compared to the estimated number of asteroids in the main belt (> 100,000 with diameters exceeding ~2 km, but only about 200 with diameters exceeding 100 km). If meteorites were just coming from these larger bodies this mismatch would not be significant. However, preferential sampling of just larger bodies is unlikely.

A range of potential reasons may explain this apparent mismatch: i) meteorites provide an unrepresentative sampling of the main belt, ii) the belt may only contain a limited number of primary parent bodies, iii) meteorites may be preferentially derived from the ~120 identified asteroid families, iv) loosely consolidated types are filtered by Earth's atmosphere, v) multiple, near-identical, "clone" parent bodies may be present in the belt. At present, it is not possible to determine which of these mechanisms are dominant and all may operate to a greater or lesser extent.

Linking meteorites to primordial planetesimals: Based on classical accretion models [19] the meteorite record appears to be highly unrepresentative of the primordial asteroid population. In contrast, pebble accretion models [20] suggest that these primordial bodies may have been relatively large, in which case meteorites may provide a more unbiased record of early Solar System processes.

Conclusions: A clear implication of this survey is that although the number of parent bodies represented in our sample collections is steadily increasing, the mismatch with the numbers of asteroids present in the main belt remains large. To better resolve the question of how representative meteorites are of the current main belt further detailed work is required. In particular, sample return from key main belt objects would greatly help in matching up asteroids with meteorites.

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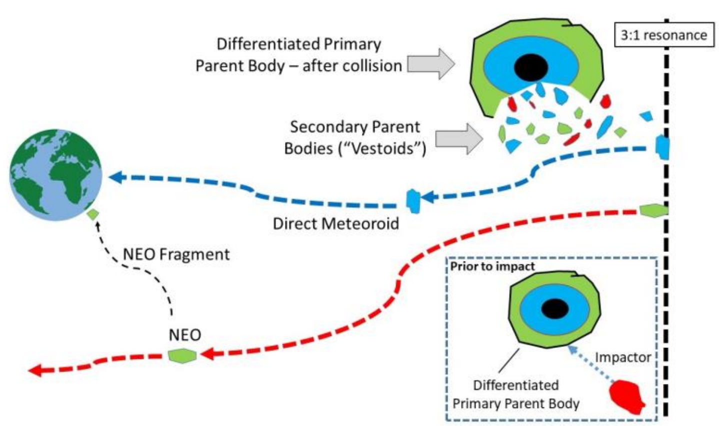

Figure 1 Meteoroid delivery routes from the main belt. Diagram based on Vesta – Vestoid relationship [9,10,11]