

MINERALOGICAL EVOLUTION OF METEORITE PARENT BODIES. J. F. Bell, Planetary Geosciences Division, Hawaii Institute of Geophysics, Honolulu, HI 96822

INTRODUCTION: A tremendous amount of research has been and is being carried out on meteorites. Simultaneously, a large body of remote sensing data has been obtained for the putative asteroidal parent bodies of meteorites with optical, infrared, and radar telescopes. However, this tremendous mass of raw data has not resulted in a comprehensive, generally accepted view of the evolutionary history of meteorites and asteroids. Recent work in asteroid spectroscopy has made it possible to associate most meteorite types with specific narrow zones in the solar system (and in a few cases specific objects). The petrological and isotopic composition, inferred condensation temperatures, and metamorphic heating of those meteorites then can be fitted into a "big picture" of the early solar system. This abstract attempts to do so while overturning the minimum necessary number of sacred truths.

NEW SPECTRAL OBSERVATIONS AND METEORITICAL INTERPRETATIONS: The largest coherent body of asteroid spectra is the Arizona 8-color survey (1) of 589 objects. D.J. Tholen has used a cluster analysis of this data to divide the asteroids into 14 "taxonomic types" or "spectral classes" (2). The distribution in space of these classes is highly nonuniform, with each class clustering around a characteristic distance from the sun (3). Recent near-IR observing programs have resolved the characteristic spectral features of olivine, pyroxene, plagioclase, and bound/adsorbed water in at least a few asteroids of most of these classes (4,5). These new spectral databases, when combined with recent laboratory studies of simulated asteroidal regoliths give us a much improved ability to assign meteorites to their parent asteroid classes. Table 1 summarizes the author's current belief system, which is generally similar to those of most other workers in the field. I will argue that the main features of this distribution can be explained by A.) condensation of all known chondrite types between 1.7 and 3.5 AU plus "ultracarbonaceous chondrites" farther out; B.) intense metamorphic heating which declined rapidly with increasing solar distance and smaller planetesimal size; C.) incomplete differentiation in many inner belt objects; D.) collisional fragmentation controlled by large internal strength gradients.

CONDENSATION LOCATIONS: Carbonaceous chondrites are concentrated near 3.0 AU, but are replaced at greater distances by types spectrally inconsistent with known meteorites. These appear to be lower-temperature materials rich in complex organics. Basaltic achondrites, petrologically derivable from H-like material, are at 2.3 AU. Aubrites at 1.9 AU suggest an identical location for E chondrites. The full chondrite sequence is thus compressed into an embarrassingly small space. If the belt is a dumping ground for material dynamically swept in, why is the sequence preserved across resonances and gaps?

ASTEROID SUPERCLASSES: From the table it appears that Tholen's 15 classes can be grouped into three larger associations according to the degree of metamorphic heating they have undergone. These three "superclasses" are the primitive objects which have undergone little or no heating, the metamorphosed objects which have been heated sufficiently to exhibit spectral changes, and the igneous objects whose current surfaces were formed from a melt. A plot of the distribution of the superclasses shows that the igneous types dominate the belt sunward of 2.7 AU, the metamorphosed types lie in a narrow zone around 3.2 AU, and the primitive types are dominant outside 3.4 AU. It appears that the heating mechanism which metamorphosed the chondrites and melted the achondrites was one which rapidly declined in efficiency with solar distance. Al-26 decay can explain this striking pattern only if planetesimal formation began close to the sun, and slowly spread outward to reach the region of Jupiter over many half-lives of Al-26. Most models of planetesimal formation do in fact predict such a pattern, but the time required seems excessive. Alternatively, magnetic induction heating would produce exactly the pattern seen. Whatever the cause, it is clear that the asteroid belt preserves a transition between unaltered nebular condensate and highly evolved igneous materials, and this pattern must be disentangled from original differences.

THE ORDINARY-CHONDRITE/CLASS-Q MYSTERY: For many years the principal problem in asteroid spectroscopy has been the location of the ordinary chondrite parent bodies. The best observed member of Tholen's Class Q (1862 Apollo) is indistinguishable from an L- or LL-chondrite (6). About 15% of the Earth-crossing population appears to be of this class. However, no examples are found among the over 500 main-belt objects observed! Instead, the only main-belt class which could remotely be OC parents, the S-class, fail every test so far applied: their metal component has a red spectrum unlike the flat spectrum of OC metal(7), many of them have no 2-micron pyroxene band (i.e. grossly non-chondritic pure-OL silicate component), and even 8 Flora which has about the right OL/PYX ratio has surface variations difficult to reconcile with well-known chondritic trends

Meteorite Parent Bodies

Bell, J.F.

- 2 -

(8). This seemingly conflicts with a variety of chemical evidence that OCs formed between the enstatite chondrites/achondrites and the carbonaceous chondrites -- which is exactly where many S-types, but no Q-types, are found in the asteroid belt! This mass of paradoxes can be resolved by remembering that Earth-crossers are much smaller than any main-belt objects yet observed. Small asteroids lose heat much more readily than large ones, so there was a lower limit to the size of differentiation at any given solar distance. Above this limit all large OC-like objects were melted to become the parents of today's various differentiated types, while below it they survived to become Q-types. These small Q-class objects have been found first in the Earth-crossing population merely because this is the only place where the surveys have reached their size range.

WHY SO FEW ROCKY ASTEROIDS? The heating episode as described above cannot explain the rarity of metal-free achondritic asteroids (classes V,R,A,E) relative to metal-rich objects (classes S and M) in the inner belt. An answer is suggested by the fact that the meteorites associated with the S-class are composed of discrete regions of silicates in a continuous metal matrix ("stony-irons" instead of "irony-stones") and presumably are much stronger than stony meteorites. A differentiated or semi-differentiated parent body will be rapidly stripped of its weak outer silicate layers; once a metal-dominated layer is reached, fragmentation will proceed more slowly. Only a lucky few inner-belt objects have retained their basalt/dunite surfaces. This "armour-deck" model is supported by the large difference in exposure ages between stony and irons. However, it creates a serious problem in explaining the survival of many large C-type asteroids slightly farther out.

PREDICTIONS FOR THE FUTURE: The model outlined here predicts: 1) The small-diameter inner-belt population will contain Q-class objects and in general resemble the Earth-crossers, while in the outer belt the large and small asteroids will not differ in type distribution; 2) A few very small objects at the inner edge of the belt will be found to be enstatite chondrites and enstatite stony irons; 3) New classes of chondritic material richer in complex organic compounds will be found, probably in meteorite breccias or cosmic dust collection experiments.

REFERENCES: (1) B. Zellner *et al.*, *Icarus*, 61, 355-416. (2) D. J. Tholen, thesis, Univ. of Arizona, 1984. (3) J. C. Gradie and E. Tedesco, *Science*, 216, 1405-1407. (4) J.F. Bell *et al.*, *BAAS* 17, 729. (5) M.A. Feierberg *et al.*, *BAAS* 17, 730. (6) L.A. McFadden, thesis, Univ. of Hawaii, 1983. (7) M.J. Gaffey, *Icarus*, submitted. (8) M.J. Gaffey, *Icarus*, 60, 83-114.

TABLE 1:
RELATIONSHIP OF ASTEROID AND METEORITE CLASSIFICATION SYSTEMS:

BELL SUPERCLASS	THOLEN CLASS	INFERRED MINERALS	METEORITES	SOLAR DISTANCE (AU)
PRIMITIVE	D	CLAYS, ORGANICS	(NONE)	5.2
	P	CLAYS, ORGANICS	(NONE)	4.0
	C	CLAYS, C, ORGANICS	CARBONACEOUS CHONDRITES	3.0
METAMORPHIC	B+G+F	CLAYS, OPAQUES	METAMORPHOSED CCs	3.0
	Q	PYX, OL, Grey-NiFe	ORDINARY CHONDRITES	???
IGNEOUS	V	PLG, PYX, OL	BASALTIC ACHONDRITES	2.3
	R	OL, PYX	OL-RICH ACHONDRITES ?	2.9
	S	PYX, OL, Red-NiFe	PALLASITES, LODRAN, STEINBACH	2.3
	T	?	URELITES ??	
	A	OL	(BRACHINA)	2.3
	M	NiFe	IRONS	2.8
E	Fe-free PYX	AUBRITES	1.9	