ON THE ORIGIN AND EVOLUTION OF DIFFERENTIATED PLANETESIMALS. W.F. Bottke[1], E. Asphaug[2]. [1]Southwest Research Institute, Boulder, CO, USA (bottke@boulder.swri.edu) [2]School of Earth and Space Exploration, Arizona State University, Tempe, AZ, USA (easphaug@asu.edu).

Introduction. The origin and evolution of differentiated planetesimals is intimately tied to several challenging planet formation questions: How, where, and how fast do planetesimals grow? How are they affected by collisional evolution within a primordial disk that also contains protoplanets? How did the differentiated fragments of these collisions survive to the present? The constraints available to solve these problems [1] include meteorite samples (e.g., irons, HEDs), remote observations of unusual asteroids like (16) Psyche, which may be an exposed core of a Vesta-like asteroid, and in situ studies of (4) Vesta and the weird asteroid (21) Lutetia.

What We Think We Know. Consider that most iron meteorites are pieces from the cores of distinct, differentiated asteroids [2]. Core formation for these bodies was nearly contemporaneous with the origin of the CAI inclusions and likely predated the birth of most chondrules by 1-3 My [3,4]. Iron meteorites also represent two-thirds of the 100-150 unique asteroid parent bodies sampled among all meteorites [1]. Both factors suggest that differentiated parent bodies and their fragments are common in the main asteroid belt.

Evidence supporting this idea, however, is meager. Spectroscopic observations of many tens of asteroid families show few signs that their parent bodies once had distinct iron cores nor mantles/crusts derived from melted rock [6]. Instead, we see the opposite: most asteroid families investigated to date are made up of members with remarkably similar spectroscopic signatures and albedos. There is also a paucity of olivine-rich asteroids that would be derived from the exposed mantles of disrupted differentiated bodies.

Even studies of M-type asteroids, long thought to be simple exposed iron cores, have become complicated. Rosetta observations of (21) Lutetia, an asteroid probably representative of this class, indicates it is an enstatite or CV chondrite with perhaps a small iron core [7,8]. Perhaps only M-types like (16) Psyche and (212) Kleopatra can still be considered exposed iron cores from the interpretation of radar observations [9].

Cores may be hidden. Not that magnetic field traces in the Allende CV chondrite may be telling us that some primitive- and not so primitive-looking main belt asteroids experienced partial differentiation [10]. Regardless, we have a conundrum. We need to make lots of differentiated bodies, extract material from their deep interiors, yet hide or eliminate most of the expected traces that would come from extraction.

Pathway to a Solution. To solve this problem, consider that planetesimals are predominantly heated, overall, by the decay of short-lived radionuclides like ^{26}Al [13]. This means that only the fastest and/or largest growing bodies have a chance to melt globally [14]. According to planetesimal formation models, in the inner solar system, the faster-growing bodies are closer to the Sun. It may then be deduced that most iron meteorite parent bodies formed in the terrestrial planet region [1]. Second, consider that differentiated planetesimals in the terrestrial planet region evolved side-by-side with larger and similar-sized protoplanets. Collisions between these bodies were inevitable, and their accretion was inefficient [15]. Hit and run collisions were common, with the fragments often forming core-enriched bodies. Repeated hit and run collisions could leave naked molten cores or core fragments buried by remnant mantle and crustal silicates [16]. Collisional evolution in the terrestrial region was also intense [1], and only the largest, strongest, or most fortunate bodies survived for very long.

Capturing Objects in the Main Belt. From this, we argue that only a modest number of fully and partially differentiated bodies were indigenous to the main belt, and most of these (like Vesta) were large enough to survive intact to recent times. The rest may be hit and run byproducts from the terrestrial planet region that were captured in the main belt region by early dynamical processes. This could explain why the asteroid belt has a number of sizable fragments that look like they came from differentiated protoplanets.

In our talk, we will discuss the origin and evolution of this putative population of exposed cores (e.g., Psyche) and "hodge-podge" worlds made of leftover debris (e.g., Lutetia) that may exist in the main belt today.

References: [1] Bottke, W. F. et al. (2006) Nature 439, 821. [2] Burbine, T.H. et al. (2002) Asteroids III (U. Arizona Press), 657; [3] Halliday, A.N. & Kleine, T. (2006) MESS II (U. Arizona Press), 775. [5] Baker, J., et al. (2005) Nature 436, 1127. [6] Cellino, A. et al. (2002) Asteroids III (U. Arizona), 632; [7] Barucci, M. A. et al. (2012) Planet. Space. Sci. 66, 23. [8] Weiss, B. P. et al. (2012) Planet. Space. Sci. 66, 137. Sheppard, M. K. et al. (2010) Icarus 208, 221. [10] Carporzen, L. et al. (2011) PNAS 108, 6386. [13] Srinivasan, G. et al. (1999) Science 284, 1348. [14] Grimm, R.E. & McSween, H.Y. (1993) Science 259, 653. [15] Asphaug, E. et al. (2006) Nature 439, 155. [16] Asphaug, E., et al. (2011) Earth Planet. Sci. Lett. 308, 369.