Where Some Asteroid Parent Bodies

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Summary: From analysis of observational data and results of contemporary cosmogonic models a hypothesis is propounded on intensive production of dust in the asteroid belt during a postaccretionary period. A consequence of this may be a settling of the dust on asteroid parent bodies in the form of a layer with atypical content. It could make them inaccessible in some cases for remote investigations.

Introduction: As follows from the well-known cosmogonic models [12, 18, 19, 24, 25], accumulation of the asteroid parent bodies was stopped by the gravitational influence of Jupiter's growing embryo and smaller Jupiter zone bodies (JZBs) penetrating through the asteroid belt. Fast growth of Jupiter's nucleus was provided by the increased surface density of solid material in its zone owing to condensation of water vapor from the internal parts of the solar system [21] and freezing of H_2O, NH_3, and CH_4 at the heliocentric distances [12]. After Jupiter's embryo reached ~5 masses of Earth [18, 19], accretion of JZBs onto it was replaced by their ejection far out of the zone. The JZBs thrown by Jupiter in the directions of the asteroid belt could have high velocities (to a few kms per sec) to reach its internal edge [17]. Because of the increased surface density of solid matter in Jupiter's zone, some JZBs penetrating the asteroid belt could have sizes and masses considerably bigger than these of the asteroid parent bodies [17, 18]. For these reasons, JZBs invading the asteroid belt could gravitationally perturb the movement of approaching asteroid bodies or collide and crash with some of them. In this process a large number of asteroid parent bodies or fragments were probably swept out of the asteroid belt [17, 24]. A considerable part of colliding bodies were possibly shattered to small fragments or dust remaining and moving amongst the asteroid parent bodies for a long time.

Observational data: There is almost no doubt that early thermal evolution of asteroid parent bodies and other small planets (up to ~1000 km in diameter) could take place because of their heating by short-living ^{26}Al [9, 13]. The discovery of ^{26}Mg, a sub-product of ^{26}Al decay, in differentiated meteorites may be considered as a direct proof of it [14, 20]. Moreover, as shown in space measurements, ^{26}Al is widespread in the plane of our Galaxy as a remnant of nova and super-nova explosions in concentration (^{26}Al/ ^{27}Al ~ 10^{-5}) similar to that in CAIs of the Allende meteorite [23]. The high efficiency of ^{26}Al in heating of asteroid parent bodies is explained by its initial abundance in the protoplanetary nebula and also by the closeness of its half-life (7.2 x 10^5 yr) to the shortest age of the bodies' formation (ab. 3-4 x 10^6 yr) [6]. As follows from a distribution of high-temperature asteroid spectral types (E, M and S) [8] (Fig. 1), it may be true at least for asteroid parent bodies which originated at the inner border to middle of the asteroid belt.

A distribution of asteroid spectral types with the heliocentric distance over 2-4 AU [8] (Fig. 1) shows a relatively sharp transition from high-temperature differentiated E-M-S-type bodies (or probably recovered in collisions nuclei of differentiated asteroid parent bodies) to primitive C-P-D-ones at the outer edge of the asteroid belt. As noted before, the feature of the asteroid belt structure may be connected with a restricted action of the asteroid parent bodies' heating [1]. Some strange details of the structure are the all-embracing distribution of C-type asteroids and the proximity of the largest asteroids 1 Ceres, 2 Pallas and 10 Hygiea having spectral characteristics of primitive bodies to 4 Vega being probably highly differentiated [e. g., 7]. It is possible that Ceres, Pallas, Hygiea or some other asteroids may have different interiors and surface layers. For instance, the interiors of the asteroids may be differentiated due to their heating by ^{26}Al in the past. Then it should be explained why their external layers remained primitive.

Another set of strange observational data is our reflectance spectra of hydrated E-, M- and S-type asteroids [2-5]. Their albedos and overall shape of reflectance spectra correspond to bodies compounded by high-temperature silicates (pyroxenes, olivines, etc.) or even metals in accordance with the present taxonomic classification [22]. At the same time there are subtle (but wide) absorption bands present in the reflectance spectra of the asteroids at 0.43-0.46 and 0.60-0.90 µm (Fig. 2). The bands are typical for hydrated silicates or carbonaceous chondrites having a considerable fraction of such silicates [5, 10]. It is noteworthy that bound H_2O is detected in the surface matter of about 25% of known M-type asteroids [16]. It may be supposed that the spectral characteristics are indications of a combination of high-temperature and hydrated silicates on the asteroid surfaces (as a mixture or an interchange of different units). In this case a mechanism responsible for the composition origin on asteroids could exist.

A hypothesis on dust evolution in the asteroid belt: From the mentioned observational data and cosmogonic models we assume that unusual combinations of different materials on present asteroids could be a result of collisions between asteroid parent bodies and JZBs for a postaccretionary period. In the time of large-scale penetration of JZBs into the asteroid belt, the relative velocity of asteroid parent bodies arose from dozens of meters per second to the present value, ~5 km/sec. Therefore, the relative velocities of JZBs might have been about that value or more. Obviously, for direct collisions of JZBs and asteroid parent bodies at such velocities, most of the primitive materials incorporated in the bodies could be heated to high temperatures and completely dehydrated.

Similarly to matter incoming to Jupiter's nucleus [15], JZBs could consist of nearly equal proportions of water-ice, silicate dust and hydrocarbons (CHON). From our estimates, considerable heating of JZB interiors was possible up to the temperature of water-ice melting due to decay of ^{26}Al over a time sufficient to transform silicates to hydrosilicates (serpentines, chlorites, etc.). After the thermal source was exhausted, subsequent freezing could turn the porous JZBs to fragile icy objects. (However, the problem should be specially investigated.) Collisions of the heterogeneous JZBs with stronger silicate asteroid bodies probably led to a high degree of fragmentation of the former. For these reasons, most of the fragments and dust produced at such collisions might have originated from JZBs broken by shock-waves and having avoided considerable heating. The ice fraction of the fragments could evaporate at the lesser heliocentric distances of the asteroid belt, and the remaining silicate-organic fraction should be similar in content to carbonaceous chondrites. As a result, the surface of most asteroid parent bodies might have been covered with a layer of settled dust similar to carbonaceous chondrites. It could make the asteroid parent bodies invisible to remote methods if the atypical dust layer was not removed in subsequent collisional events.

References: [1] Binzel, R. P. (1989), In *Asteroids II* (R. P. Binzel et al., Eds), 3-18, Univ. of Arizona Press, Tucson. [2] Busarev, V. V. (2000), *LPSC XXXI*, abs. 1428. [3] Busarev, V. V. (2001), *LPSC XXXII*, abs. 1927. [4] Busarev, V. V. (2002), *Solar Sys. Res. 36*, 35-42. [5] Busarev, V. V. and M. N. Taran (2002), *Proc. of ACM 2002*, 933-936, Technical Univ. Berlin, ESA-SP-500, Berlin. [6] Cameron, A. G. W. (2002), *Nature 418*, 924-925. [7] Gaffey, M. J. et al. (1989), In *Asteroids II* (R. P. Binzel et al., Eds), 98-127, Univ. of Arizona Press, Tucson. [8] Gradie, J. and E. Tedesco (1982), *Science 216*, 1405-1407. [9] Grimm, R. E. and Jr. H. Y. McSween (1993), *Science 259*, 653-655. [10] King, T. V. V. and R. N. Clark (1989), *JGR 94*, B13,997-B14,008. [11] Mahoney, W. A. et al. (1984), *AphJ 286*, 578-585. [12] Makalkin A. B., Dorofeeva V. A. (1996), *Solar Sys. Res. 30*, 440-455. [13] McSween, Jr. H. Y. et al. (2003), In *Asteroids III* (Eds W. Bottke et al.), 559-571, Univ. of Arizona Press, Tucson. [14] Nyquist, L. E. et al. (2001), *Meteoritics & Planet. Sci. 36*, A151-A152. [15] Pollak, J. B. et al. (1996), *Icarus 124*, 62-85. [16] Rivkin, A. S. et al. (200), *Icarus 145*, 351-368. [17] Ruskol, E. L. and V. S. Safronov (1998), *Solar Sys. Res. 32*, 255-263. [18] Safronov, V.S. (1969), *Evolution of the Protoplanetary Cloud and the Formation of the Earth and Planets*, Moscow: Nauka Press [NASA TTF-667 (Engl. transl.), 1972]. [19] Safronov, V.S. (1979), In *Asteroids*, (T. Gehrels, Ed.), 975–991, Univ. of Arizona Press, Tucson. [20] Srinivasan, G. et al. (1999), *Science 284*, 1348-1350. [21] Stevenson, D. J. and J. I. Lunine (1988), *Icarus 75*, 146-155. [22] Tholen, D. J. and M. A. Barucci (1989), In *Asteroids II* (R. P. Binzel et al., Eds), 298-315, Univ. of Arizona Press, Tucson. [23] Wasserburg, G. J. and D. A. Papanastassiou (1982), In *Essays in Nuclear Astrophysics*, (C. A. Barnes, D. D. Clayton and D. N. Schramm, eds.), 77, Cambridge Univ. Press, Cambridge, UK. [24] Weidenschilling, S. J. (1977), *Astrophys. Space. Sci. 51*, 152-158. [25] Wetherill, G. W. (1989), In *Asteroids II* (R. P. Binzel et al., Eds), 661-680, Univ. of Arizona Press, Tucson.

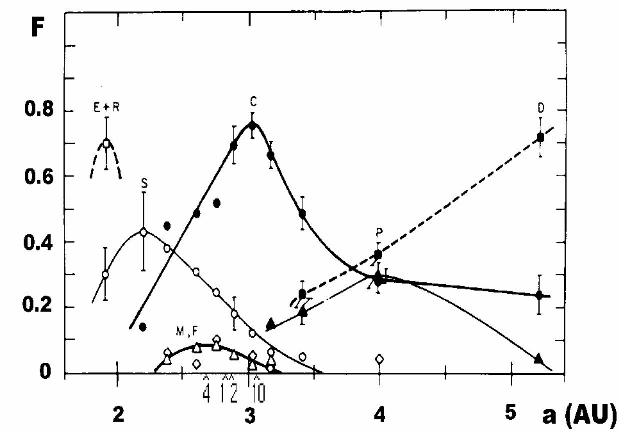

Fig. 1. Observed distribution of the main asteroid taxonomic classes with heliocentric distance taken from [8]. Heliocentric positions of 1 Ceres, 2 Pallas, 4 Vesta and 10 Hygiea are marked by ticks.

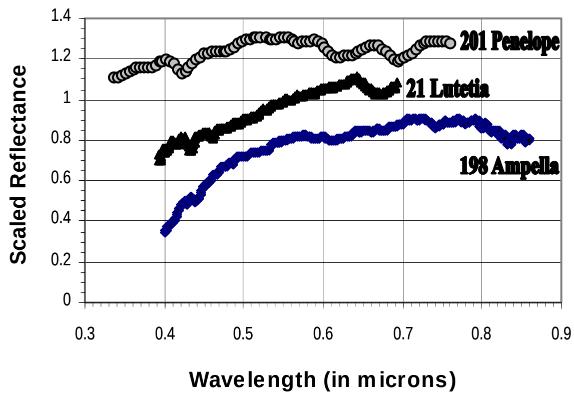

Fig. 2. Examples of reflectance spectra of some hydrated asteroids, 201 Penelope (M-type) (08/25.1865/93, obtained by a scanning spectrophotometer at 1.25-m telescope), 21 Lutetia (M-type) (09/01.2039/00, a CCD-spectrograph at 0.6-m telescope), and 198 Ampella (S-type) (08/18.1538/99, a CCD-spectrograph at 0.6-m telescope).