AN OCEANIC SOURCE OF ICY, HYDROSILICATE AND ORGANIC GRINDED MATERIALS AS ONE OF THE MAIN FACTORS SCULPTURED THE EARLY ASTEROID BELT. V. V. Busarev, Sternberg Astronomical Institute, Moscow Lomonosov State University, Moscow, Russian Federation, E-mail: busarev@sai.msu.ru

Introduction: According to a traditional point of view, asteroids of the main belt originated in the early Solar System (ESS) *in situ*, due to collisional disruption of asteroid parent bodies (APBs) [1]. Very close positions of heliocentric distributions of igneous and primitive asteroid types may be explained by zoning action of APBs' heating by the short-lived radionuclides (generally ^{26}Al) [2]. But this structure could also be distorted by other factors. As modeling show, the heating was less on APBs which accumulated some water ice in the outer asteroid belt [2]. Melting water ice in interiors of such APBs would lead to formation of a temporal aqueous medium. For the same reasons, extensive internal water oceans could form and exist for some time on many rock-ice bodies in the ESS outside the "snow-line". Internal water oceans on Edgeworth-Kuiper objects (EKOs) and a great number of proto-planetary bodies in the formation zones of giant planets were probably additional sources of icy and/or rock-icy fragments after breaking up the bodies at collisions. Intensive fluxes of the materials might have considerably influence chemical and mineralogical content of APBs at the time of their accretion and shortly thereafter.

Results and discussion: As a limiting case, the possibility of formation of internal water oceans on the EKOs at the periphery of the ESS was shown [3]. The analytical calculations were inspired by discoveries of absorption bands at 0.5-0.9 µm [4] and 0.43 µm [5] in reflectance spectra of some EKOs similar to those of carbonaceous chondrites and terrestrial phyllosilicates (e. g., [6-8]). The available observational data on comets, carbonaceous chondrites, IDPs and modeling heliocentric distribution of matter make it possible to estimate composition of pristine EKOs and the content of ^{26}Al, the most abundant short-lived radionuclide [9]. According to the data (e. g., [10-13]), early EKOs could contain nearly equal proportions of ices (including 80% of water ice), organics (mainly CHON) and rocks (mainly of magnesium and iron silicates, FeS and metallic iron). At chondritic (solar) abundances of refractory elements, the rock component contains 1.3 wt. % of aluminum [10]. Taking into account the probable accretion time of 100-km EKOs at their heliocentric distances, about 1.5 Myr after the collapse of the protosolar cloud [14], the ^{26}Al/^{27}Al ratio of 1×10^{-5} was derived [3] from the "canonical" initial value 5×10^{-5} determined in calcium-aluminum inclusions (CAIs) of the Allende meteorite [15]. A thermal balance calculation for the large bodies (R>100 km) shows that ^{26}Al decay in the first several million years of their existence produced sufficient amount of heat to fully melt the water ice [3]. The lifetime of the water ocean in large EKOs' interiors was estimated to be ~5 Myr before its complete freezing. If the parent EKOs similarly to comet nuclei consisted of "dirty" ice, sedimentation of solid particles with a density of >1 g/cm^3 (silicates and heavy organics of kerogen or bitumen type) in the water ocean was accompanied by phyllosilicate formation (mainly serpentinization). These processes could lead to accumulation of silicate-organic cores in the bodies. During this time, only a surface layer with a thickness of about 10 km could remain frozen on the large EKOs [3]. The results are in accordance with numerical modeling that additionally showed possibility of higher temperatures (up to several hundred degrees) into silicate-organic cores of the bodies (e. g., [16]). Later mutual collisions could lead to cracking the ice mantle and excavation of phyllosilicates observed on some of the bodies [4, 5]. An intense release of H_2 and CH_4 at serpentinization of silicates [17, 18] in internal water oceans of the bodies might have a similar effect.

Similar rock icy bodies existed in the formation zones of all giant planets at the time of their growth. A high surface density of ices in the zones (especially, in Jupiter's one) outside the "snow line" [19] was probably a main reason of runaway accretion of the bodies. Lifetimes of liquid water oceans on large Jupiter zone bodies (JZBs) could be estimated ~10 Myr. If these bodies were not devoured by proto-Jupiter, they had been thrown out of the zone at velocities (2-3 to 10-15 km s^{-1}), in particular, to the main asteroid belt (MAB) [19, 20].

Due to low strength and porosity (for an intense release of H_2 and CH_4 at serpentinization of silicates [17, 18]) of heterogeneous JZBs, they could crush predominantly into fragments of different sizes up to small particles at collisions with mainly rocky APBs. This is supported by experimental studies of breaking up solid bodies with different strength at collisions. The disruption of hydrated silicate targets requires less specific energy than that of anhydrous ones [21]. The scenario of a post-accretional dusty period of MAB's evolution was already discussed [22]. If it is so, the MAB could play a role of "crusher" for a considerable part of JZBs. Their largest fragments might have remained in the MAB adding to the families of primitive bodies. Then many of contemporary asteroids (C- and partly D- and P- types) could be remnants of JZBs. It is interesting to examine a possible evolution of a considerable cloud of icy and silicate-icy small debris and dust originated at the collisions. First, preserving a predominant direction of the velocity vector of their parent bodies (namely, JZBs thrown by Jupiter's embryo inwards the ESS) the larger debris should also move in the direction. Second, velocities of the dust particles had to effectively decrease by interaction with a gas environment of the ESS. It was probably the main reason of a safe fall of a prevalent part of the dust (including hydrosilicates and organic compounds) at low velocities on the surfaces of close asteroids. Additionally, Poynting-Robertson effect accelerates movement of the smallest particles in the direction of the Sun. Drifting into the inner part of the ESS, a large part of the dust cloud settle on the surfaces of all planetary bodies being in the path of the motion. During these events, surfaces of large neighboring asteroids and inner planetary bodies could be covered with a substantial layer of icy, hydrosilicate and CHON particles. As a depth of the dust layer on a particular body is a function of gravitational acceleration on its surface, larger bodies could have thicker dust layers. The delivery of considerable quantities of icy, hydrated and organic materials on planetary bodies at the time or soon after their magmatic differentiation should noticeably change their native surface chemistry and mineralogy. A reality of such events in the history of the MAB is probably confirmed by discoveries of atypical hydrated silicates on asteroids of igneous M-, S-, E- and V-types [23-28]. The results and numeric simulations of dust particles' transport from the EKBs' region to the inner ESS due to the action of gravitation and radiative effects (e. g., [29]) could explain presence of hydrated silicates on the lunar surface [30, 31] and delivering water (in a bound state) and pre-biotic organics to the early Earth (e. g., [32, 33]).

Hydrodynamical simulations show that embryos of Jupiter and Saturn experienced inward migration (because of exchange of their angular momentums to that of a massive gas-disk of the ESS) and then a rapid outward migration and mutual orbital separation on a time scale of no more than 5 My in all after CAIs' formation [34-36]. For uncertainty of the gas-disk parameters, the minimal heliocentric distance of Jupiter at the end of the inward migration is unknown, though the value may be in the range from 4-5 [35] to 1.5 AU [36]. The last scenario could explain the small mass of Mars and early repopulation of the MAB from two very different parent populations of planetesimals (from Mars' and Jupiter's zones) [37]. Regardless of whether or not this very early stage of the MAB repopulation was realistic, the described above delivery of primitive matter from neighboring formation zones of giant planets to the MAB was probable.

Conclusions: Thus, it was possible: (1) origin of global internal water oceans on proto-planetary bodies (R>100 km) at the periphery of the ESS and in the formation zones of all giant planets in times of their growth, (2) accumulation of silicate-organic cores, formation of hydrosilicates and organic compounds in the water oceans of the bodies, (3) intensive ejections and collisional disruption of the bodies originated in the neighboring zones of giant planets (and, especially, in the Jupiter's one) to the early MAB, (4) falling the grinded materials of JZBs on the surfaces of APBs led to formation of 1 Ceres, 2 Pallas and the largest of C-type asteroids, and (5) the most part of C-type asteroids and carbonaceous chondrites are native fragments of JZBs.

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