WATER EJECTA OF MARINE IMPACTS AND ICE METEORITES. H Hargitai Eötvös Loránd University Cosmic Materials Space Research Group 1117 Budapest, Pázmány P. sétány 1/a Hungary hargitai@emc.elte.hu.

Introduction: Marine impacts may produce an ejecta curtain with jets, made of water ("wave crown"). If parts of the high speed jets of this water ejecta are not vaporized, they may reach above the higher atmosphere and freeze. When they fall back, ablation may not destroy the whole part and they may reach the surface as ice meteorite. Although this event is not very probable, the existence of such secondary crater producing exotic ice bodies may not be impossible. Extraterrestrial ice meteorites may also produce crater on ths surfaces of inner Solar System bodies.

Water ejecta: Earlier works focused on the evaporation effect of such large impacts: a large enough impactor may be able to evaporate an ocean. The temperature may exceed 1000 C above the impact site. However, similarly as in the case of silicate target impacts, unmelted (here: not vaporized) ejecta may be ejected from the crater to great distances: in this case the first contact – especially if the impact is oblique – may throw large amounts of water to large distances in a ballistic orbit.

Marine and oceanic impacts have been modelled by several authors. According to the model of the Eltanin impact made by V. Shuvalov, the rebounded water column created by a 500 m diameter impactor may have reached 20 km, well above the stratosphere [1].

Surface features: Maximal amount of pure water is ejected if the transient cavity is made wholly of water; and its depth is on the same order of magnitude as the depth of the water body. Secondary craters may be produced by ejected materials which are mostly composed of water; large part of which is evaporated (in the central plume region which has the highest temperature; and those parts heated during atmospheric travel) but some may be impacted as liquid water bodies. What kind of surface features, ejecta blanket types are made by a water ejecta? It is hard to observe, since it may not survive for a long time. If the primary (water-) crater is surrounded by large water body, liquid water in the ejecta will fall into water, creating no lasting features. If the impact is near the land, secondary "craters" (or features) will be created but washed away immediately by megatsunamies (and waves created by other impacting water bodies). Closer the impact to the land is, larger the tsunami will be. If the impact is large, ejecta reaches farther, but tsunami waves even farther. Ejected water collides with the ocean itself, creating waves moving hundreds of kms/sec in the model of the Chicxulub impact [2]

If the material of the ejecta curtain is water and the impact is oblique, the first jets has the chance not to be vaporized by the heat generated at the impact site. These may reach above the atmosphere (as vapor or liquid), freeze in space and re-enter the atmosphere as ice meteorites which may even reach the ground farther away. Models of a Chicxulub scale impact show that the maximum height of material is no more than 80 km [3]

Ballistic orbit of the water ejecta: If the impact is very large (transient cavity depth is more than ~6 km), water is mixed with porous sediments or basaltic materials. But the ejecta reaches higher: the water component - as the sicilate component - may enter a new orbit around the Earth. If enough water/silicate particle is present, a temporary ice/sicilate ring may be formed or it may leave Earth's gravitational field. In the later case it may impact the Moon producing sesquinary craters, where – if impacted to the permanently shadowed polar areas – its debris may survive for long time. Ice meteorites has little survival time in space because of sublimation (a 10-m diameter ice-block would disappear within about 4 orbits of the Sun – a timescale of about 20 years [4].) Therefore these "locally made" blocks of ice must re-enter the atmosphere in relatively little time which is the case here.

Atmospheric passage: A 11.5 km/s ice-meteoroid of mass ~50,000-kg (diameter ≈ 4.8-m) is required to produce a 2-kg meteorite on the ground [4]. Bérczi and Lukács calculates that the total mass loss of ices and silicates during fall is roughly similar [5]. Models of an Eltatin type impact give that less than 10% of the ejecta is faster that 1 km/s. Typical ejecta speed for a Chicxulub scale impact (10 km diam., 20 km/s vertical impact) is ~5 km/s [3]. At such speed atmospheric ablation from 80 km height (max. height at Chicxulub) is much more reduced. Water may travel in ballistic orbit at high altitude for several, even tens of minutes. However, water may not freeze but be in a supercritical fluid state during the event. Model calculations are needed to prove or disprove if such event can occur.

Extraterrestrial ice meteorites: Meteorites made of water ice are exotic features where ice is volatile, and not a planet-forming material as in the outer Solar System. Therefore ice meteorites in the outer Solar

System (like those producing secondaries on Europa which are certainly made of ice meteorites) are not discussed here; only those which produce primary craters in the inner Solar System.

The followings are possible indicators of an ice meteorite impact in inner solar system conditions.

Lobate ejecta. Vapour plume interacting with ejecta curtain or melted ice component of the target material (in the presence of an atmosphere) may have produced lobate ejecta blankets on Mars and on Earth in the past. Material from the impactor makes up only ~1% of the total mass ejected from either a large continental or oceanic crater [6]. This means that even a large ice meteorite (of extraterrestrial - cometary - origin) may not provide enough material to fluidize the ejecta blanket of a dry target material.

Frost. If an ice meteorite impacts a planet with no atmosphere at the dark side, instant evaporation of the ice meteorite debris would create a temporary vapor atmosphere which instantly would freeze and precipitate later as a thin frost layer on the surface. If such frost would be found on the Moon, it may reveal the occurrence of an ice meteorite impact.

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