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Enceladus: a vanishing satellite

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Enceladus, a satellite of Saturn, is the smallest celestial body in the Solar System where volcanic activity is observed. Every second, the mass of ∼200 kg is ejecting into space.

The size of the satellite directly after accretion (this body is referred here as proto-Enceladus) is unknown. It can be estimated in two ways. First, if the average mass outflow is equal to the present rate then the satellite's original mass was ∼30% bigger than today. Second, we assume here that density of proto-Enceladus was equal to the present density of Mimas because they were formed in the same part of the nebula. Mimas is dead, so it preserves original composition. Both approaches give similar initial Enceladus' radius (∼296 km) and its surface area ($\sim 1.1\times 10^6$ km^2). The present values are: 252 km and 7.99×10^5 km^2.

The loss of matter should lead to global compression of the crust. Typical effects of compression are: thrust faults, folding, and subduction. However, such forms are not dominant on Enceladus. We propose here special tectonic model that could explain this paradox.

The volatiles escape from the hot region through the fractures forming plumes in the space. The loss of the volatiles results in a void, an instability, and motion of solid matter into hot region to fill the void *in statu nascendi*. The motion includes:

1. Subsidence of the lithosphere of SPT.
2. Flow of matter in the mantle.
3. Motion of lithospheric plates adjacent to SPT towards the active region.

If emerging void is being filled by the subsidence of SPT only, then the velocity of subsidence is ∼0.05 $mm\cdot yr^{-1}$. However, all three types of motion are probably important, so the subsidence is slower but mantle flow and plates' motion also play a role in filling the void.

Note that in our model reduction of the crust area is not a result of compression but it is a result of the plate sinking. Therefore the compressional surface features do not have to be dominant.

Note also that we do not know the present age of the satellite surface. Age assessment depends on the assumed model of the flux of meteorites. For the lunar-like flux, cratered plains of Enceladus are 4.2 Gyr old, and only 1.7 Gyr old, if cometary impact rates are used $(1, 2)$. If 'cometary' chronology is correct then we have no data concerning 2/3 of Enceladus history. During that time there could be a number of activity cycles, and the total decrease of the surface area could be 300,000 km^2.

If our hypothesis is confirmed, then Enceladus will be an exceptional body, possibly representing a new class of celestial bodies: bodies decreasing as a result of endogenic activity. Are other bodies similar to Enceladus? Dione seems be a good candidate. Its activity is predicted and observed$(3, 4)$. Its gravity is too low to retain gases. Its present high density could be a result of partial loss of volatiles in the past. Moreover, it is in orbit-orbit resonance, so substantial tidal heating is possible.

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References and Notes:

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