Particles from Ephemeral Plume Activities of Enceladus Deposit on Saturnian Satellites.

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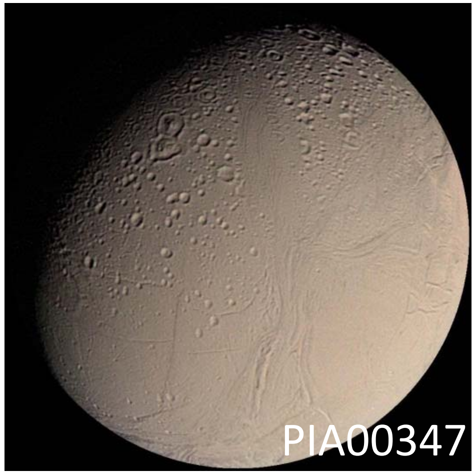
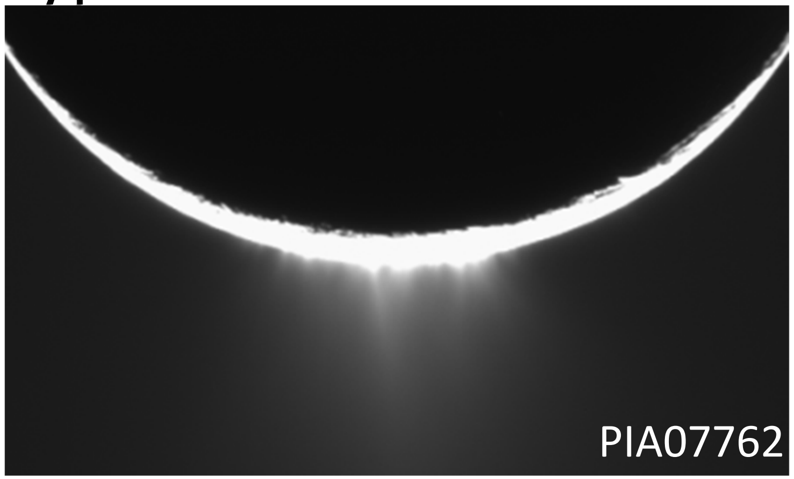
Background 1

- Enceladus is one of saturnian icy satellites
- Enceladus has the ocean in its sub-surface.
- Icy particles released from satellites form Ering

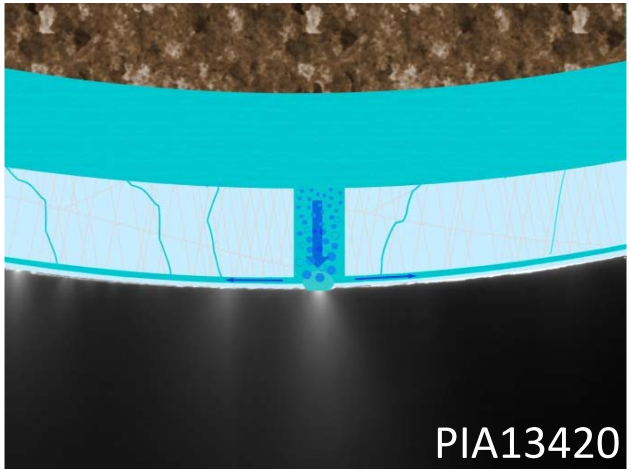
Enceladus



Icy particles released from Enceladus



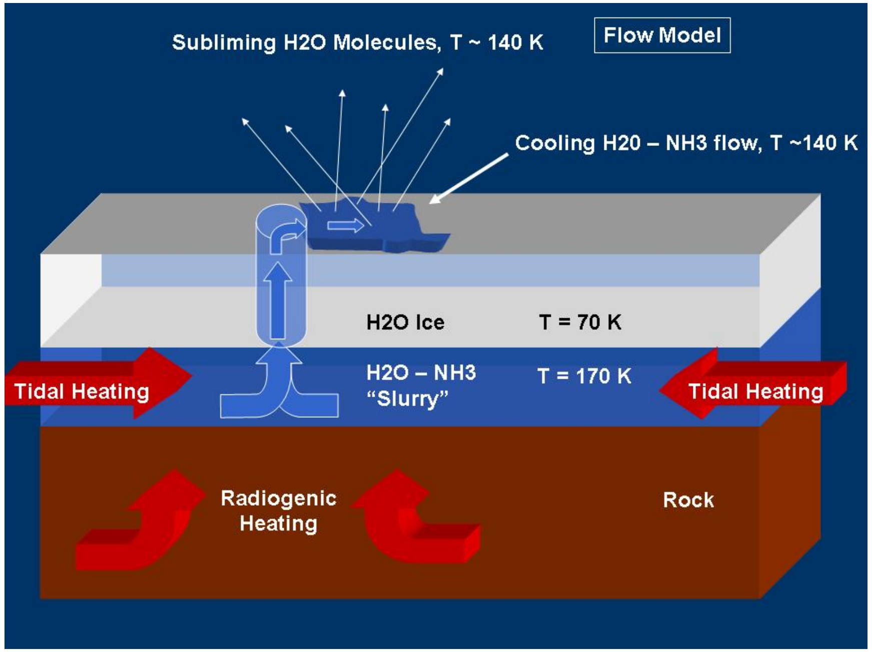
Interior structure



Background 2

The lifetime of the ocean is ***long*** or ***short***?

- Thermal source is not sufficient to maintain the subsurface ocean
  - the subsurface ocean must freeze over 30 My (Robert & Nimmo 2008)
- No geological evidence to support the large mass decreasing of Enceladus.
  - The current eruption rate is estimate to ~200kg/s (Hansen et al. 2006)
  - This rate should cause significant geological tectonics (Spencer et al. 2009)



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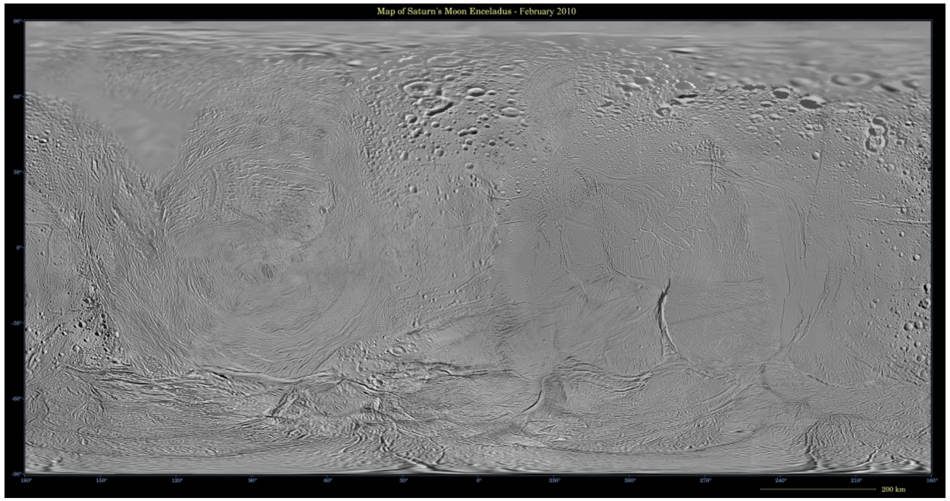

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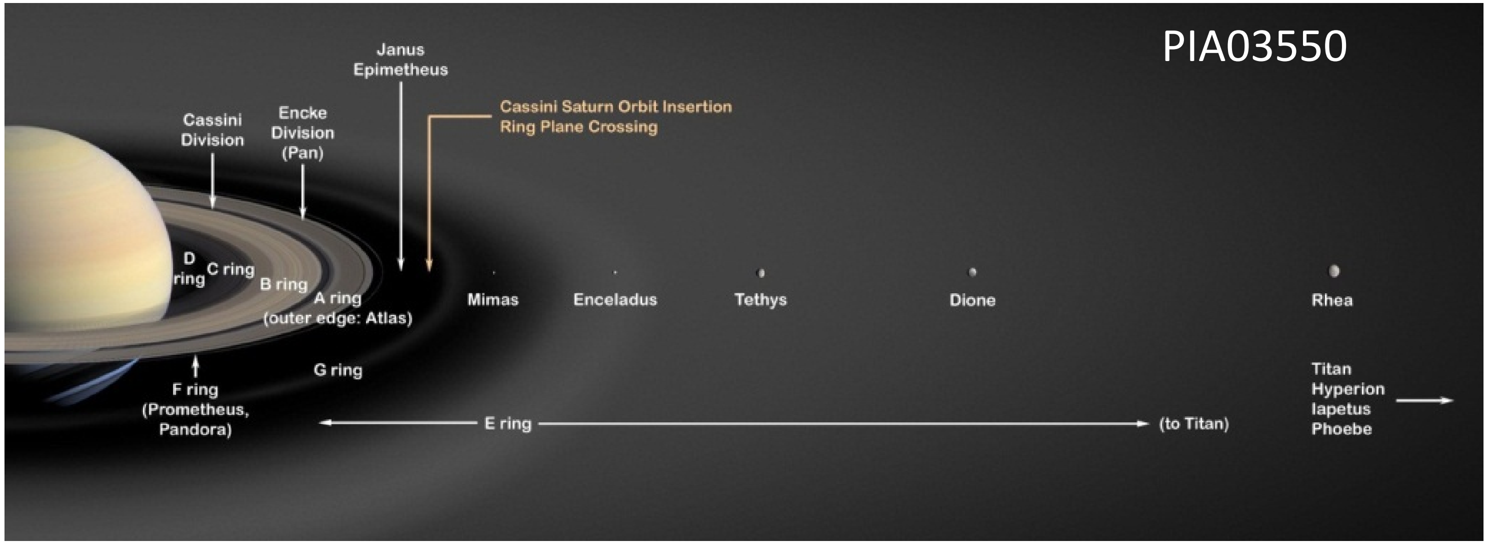
Short?

However, observational facts are not obtained yet

Point of this study

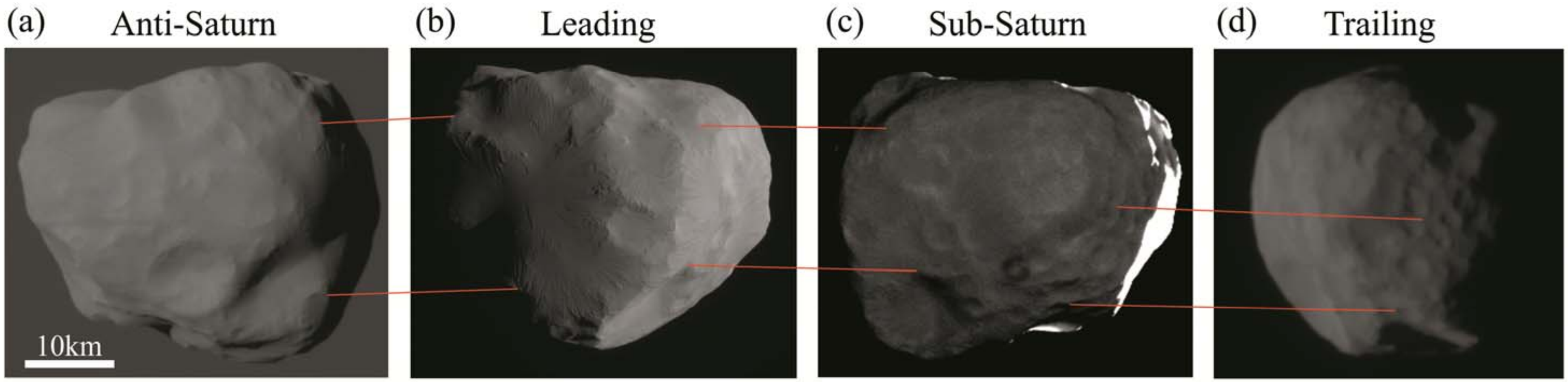
- Addressing this issues,
  - we point out the coefficients between rings and satellites



- Materials erupted from Enceladus form the E ring
- The E ring materials should affect the surrounding satellites.
- Based on this view, we investigate 5 mid-sized and 7 small satellites.

Finding

We found Helene has the obviously deposits originated from E ring.



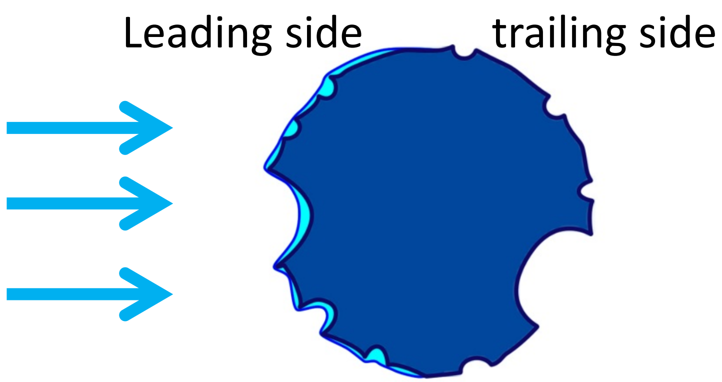
(右からN1646319549,N1687121104,N1646315085,N1563643679)

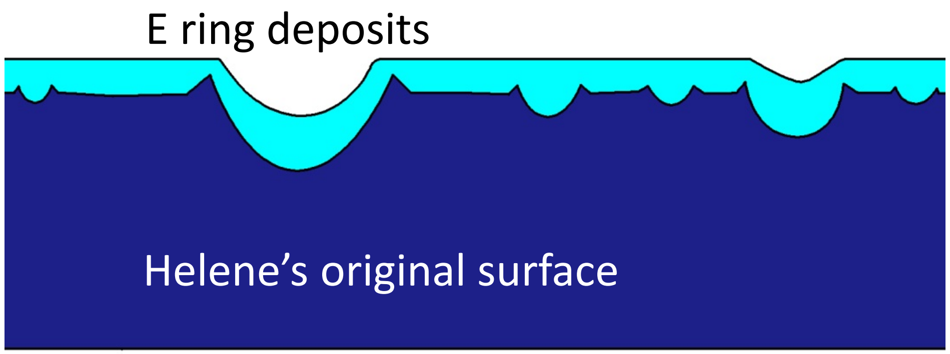
This satellite is located at L4 point of Dione
Its mean diameter is ~30 km

We find
Helene has the unusual smooth surface and streaky depression.
These features is formed by the depositions of E ring materials

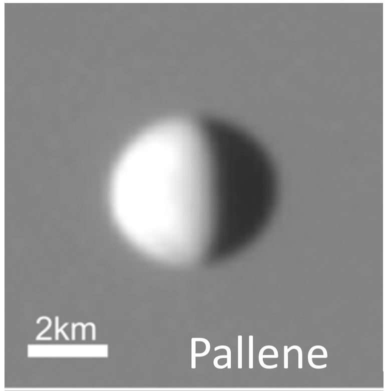
Discussion

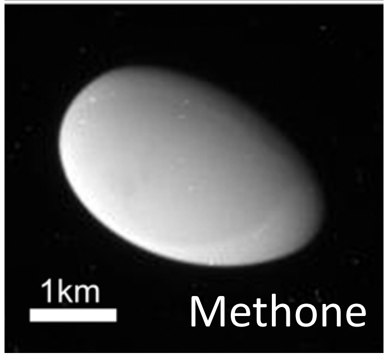
- These features can be explained by the depositions of E ring materials
  - Concentration to the leading side.
    - E ring particles tend to collide to the leading side of the satellite
    - In fact, Dione's leading side is more strongly contaminated than its trailing side. (Hamilton & Burn 1994)
    - Helene's Bimodal appearance may be explained
  - This phenomena makes the slope unstabilize and small craters erase
  - Spectral features of leading side is similar to that of E ring



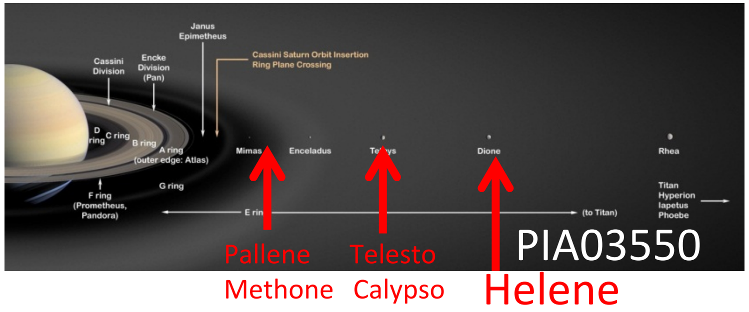


Other small satellites of E ring region

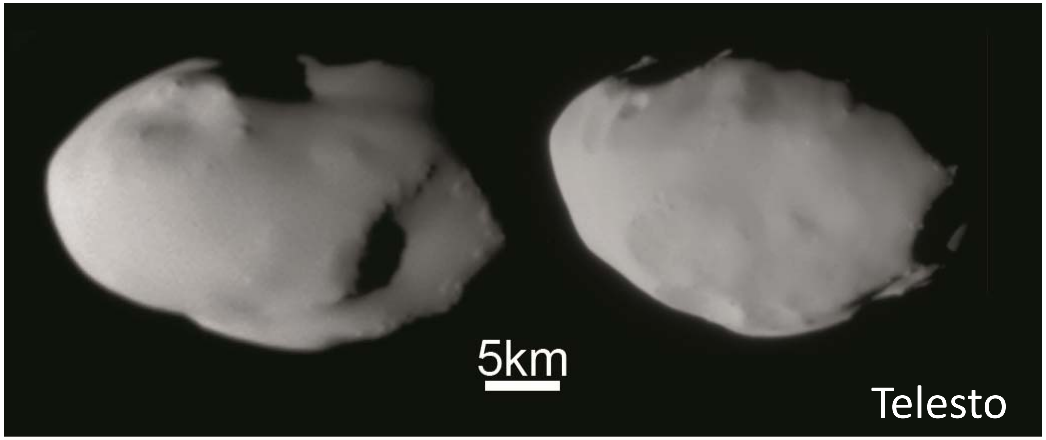


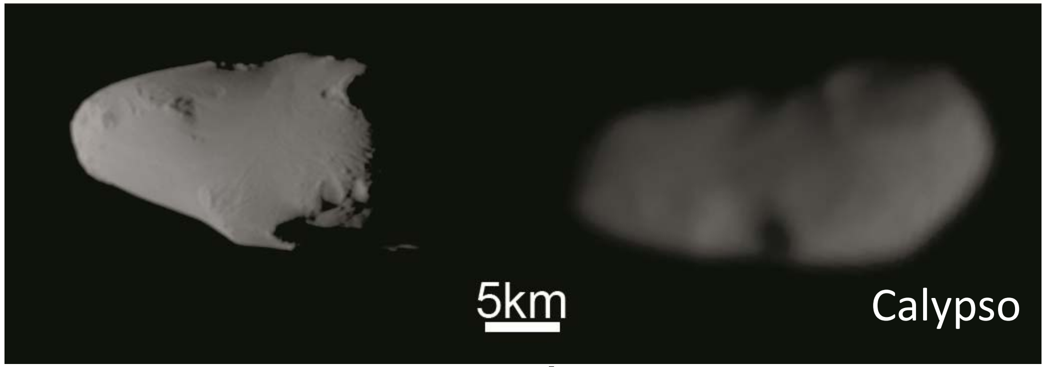


Pallene's mean diameter is 4 km
Methone's mean diameter is 3 km
Located within the orbit of Mimas
Spherical shape and
Quite smooth surface



Upper N1665947247
Lower N00189072





Upper N1630076968, N1514163666, lower N1644754662, N1506184171

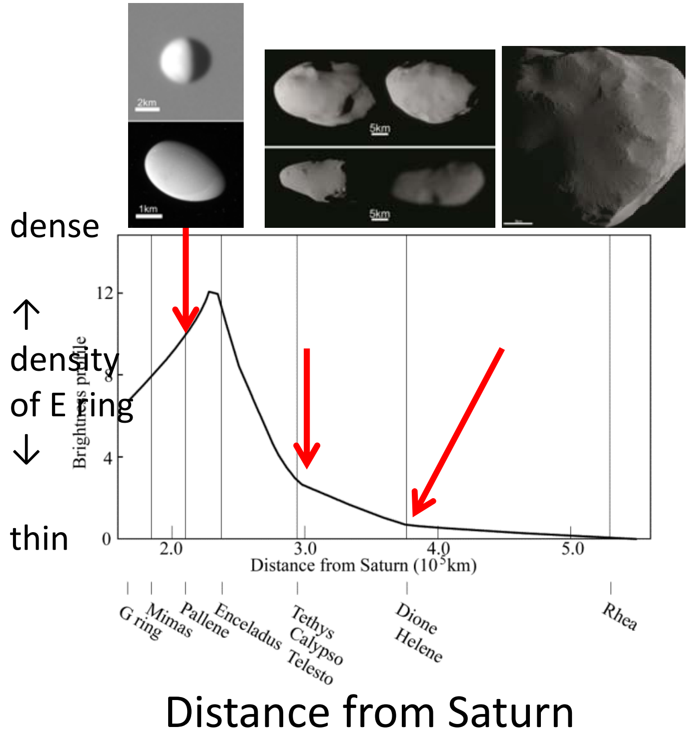
- Located at the L4 and L5 points of the orbit of Tethys
- There are a lot of large craters while there are few small craters
- Surface is somehow smooth
- Streaky depressions can be identified on Calyspo

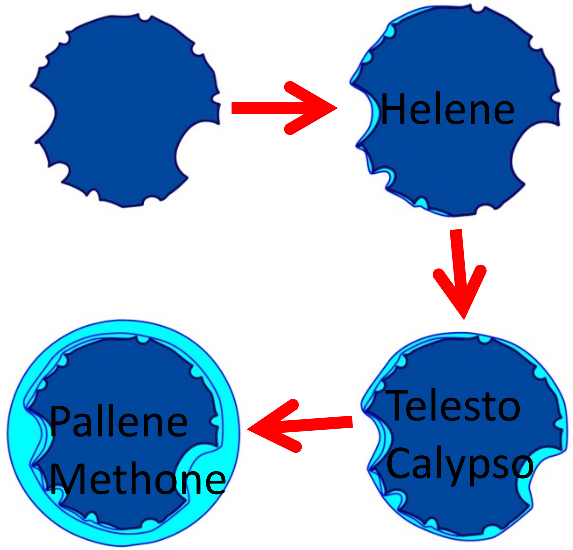
Irregular features of these Small satellites can be explained by the depositions of E ring

– Telesto and Calypso
  - E ring of their orbits is denser than that of Helene's orbits

    which means the accumulations is stronger
  - Their shapes may bury their ordinary surface
– Pallene and Methone
  - E ring of their orbits is much denser than that of Telesto's or Calypso's orbits

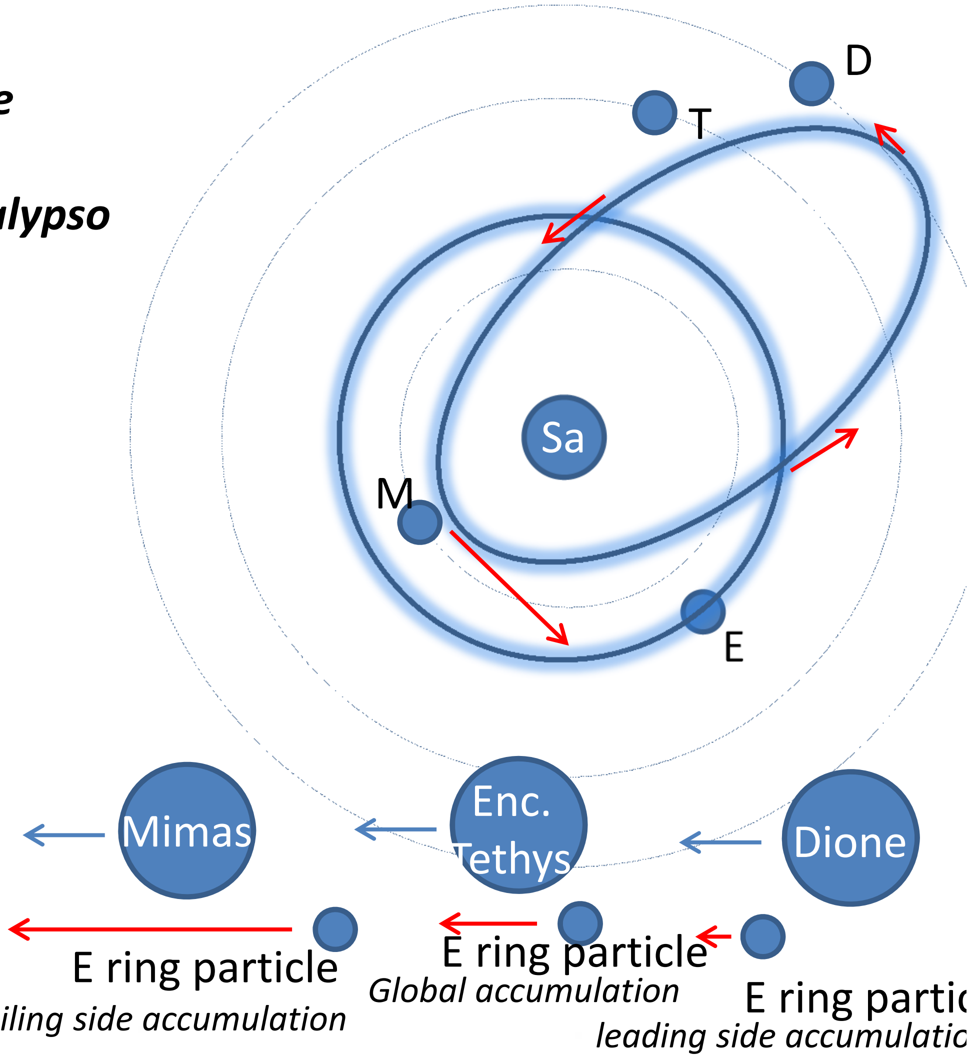
    which means the accumulations is much stronger
  - The large amount of E ring materials may completely bury their ordinary surface and their shape may be near-spherical ones

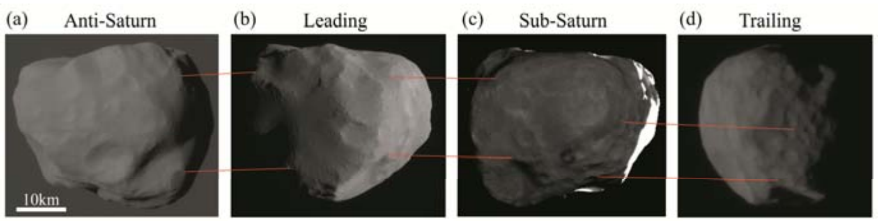


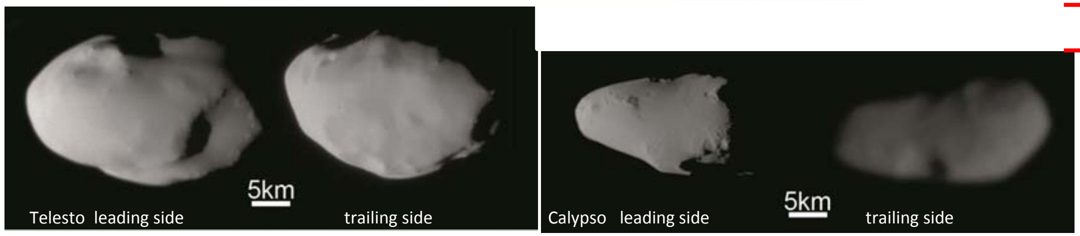


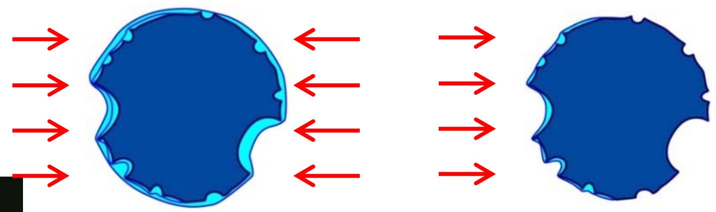
E ring accumulations concentrate to
the leading side in the case of ***Dione*** and ***Helene***
the trailing side in the case of ***Mimas***
the global in the case of ***Tethys, Telesto,*** and ***Calypso***

- Icy particles emitted from Enceladus has the same orbital velocity with that of Enceladus
- After that, the eccentricity of these particles increase
- Then, eccentric orbits cause
  - The angular velocity decrease in apoapsis
  - The angular velocity increase in periapsis
- Inner region of E ring, ring particles exceed satellites and collide with trailing side of the satellites
- Surrounding region of Enceladus, particles collide anywhere of satellites
- Outer orbit of E ring, ring particles are exceeded by satellites and collide with leading side of the satellites
- In fact, this nature was occurred on Mimas, Tethys, Dione
  - Based on the albedo, spectral features, and radar reflectance
- This view has the good agreement with the appearances of small satellites of E ring region.







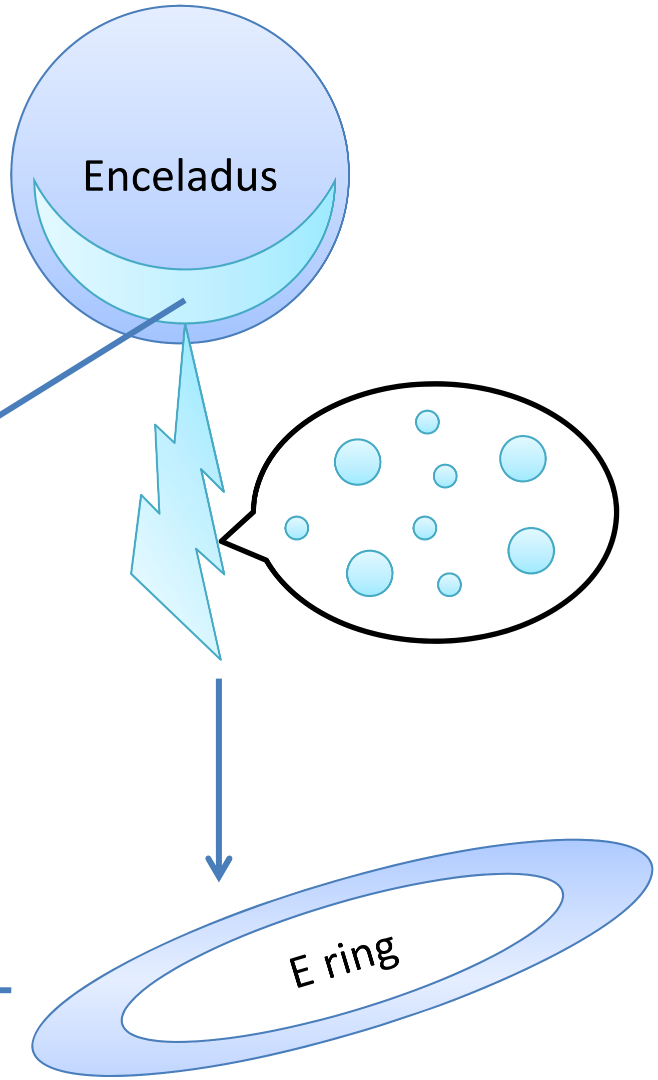


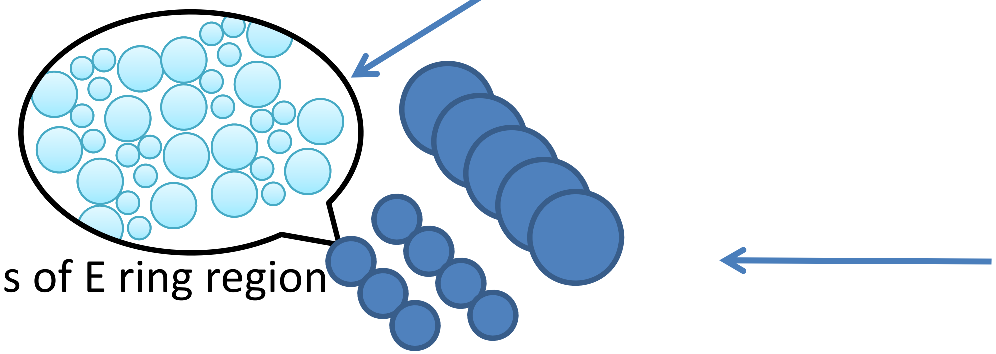
Telesto, Calypso (occupy the same orbit of Tethys) Global

Helene (occupies the same orbit of Dione) Leading side

Implications 1

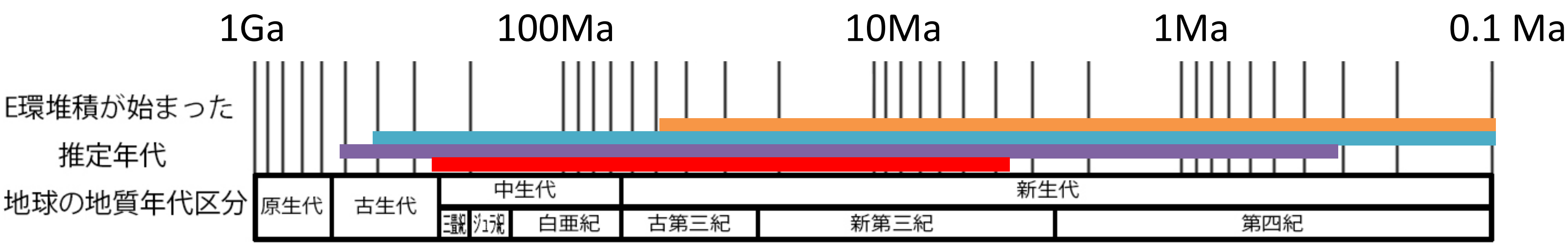
- Streaky depressions indicate
  - The friction angle of E ring particles is low, lower than 10 degree
  - the friction coefficient between E ring particles is quite small
  - E ring particles may have a spherical shape with a smooth surface
  - A particle attains a spherical shape due to the surface tensional force of a droplet emitted from Enceladus before frozen as a particle
  - If so, almost all E ring particles are originated from the subsurface ocean (not surface regolith layer)
- Sample return mission
  - A future sample return mission might consider utilizing small landers to obtain a sediment core to help reveal the activity of Enceladus





Implication 2

- Cratering age of the deposit of E ring on Helene is
  - Less than 50 My, if the cratering rate is the same as the case of Dione
  - Less than 400 My, if the trailing hemisphere was formed at 4 Ga
  - From 3 My to 500 My if I use the cratering estimate of Zahnle et al. 2003
  - The deposits of other small satellites also show the same result
- Based on the eruption rate
  - the mass of solid material per second escaping from Enceladus is most likely ~5 kg/s, currently
  - Assuming that 10 to 100% of particles ejected from Enceladus would be lost by collisions to satellites
  - the total volume of the E ring deposits on satellites would accumulate in only 3.8 My to 270 My
- there is the possibility that the accumulations of the E ring material on satellites began several My ago
- the initiation of cryovolcanism on the surface of Enceladus is also the same age?
  - This result is consistent with the theoretical study of Robert and Nimmo (2008)
    - the subsurface ocean must freeze over 30 My
  - ***This result is the first one indicating the geologic age of the cryovolcanism on Enceladus***



Conclusion

- The surfaces of small satellites is strongly affected by the cryovolcanism in Enceladus
- The accumulations due to E ring may have began at a few million years ago
- The lifetime of subsurface ocean of Enceladus may be also limited to a few million years