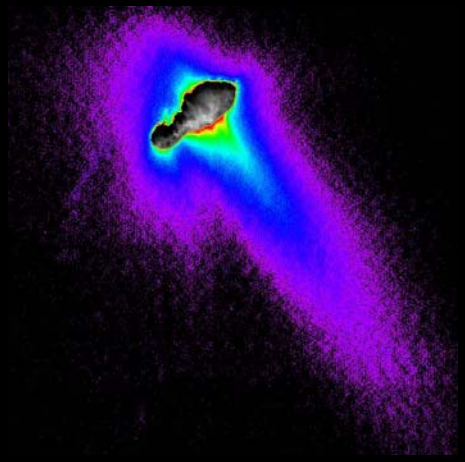

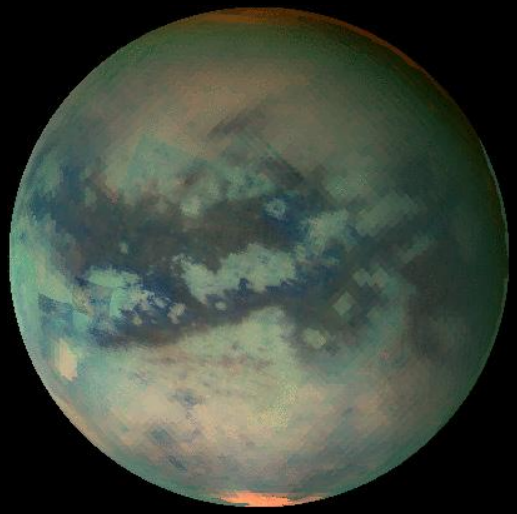

Hydrates as Planetary Materials

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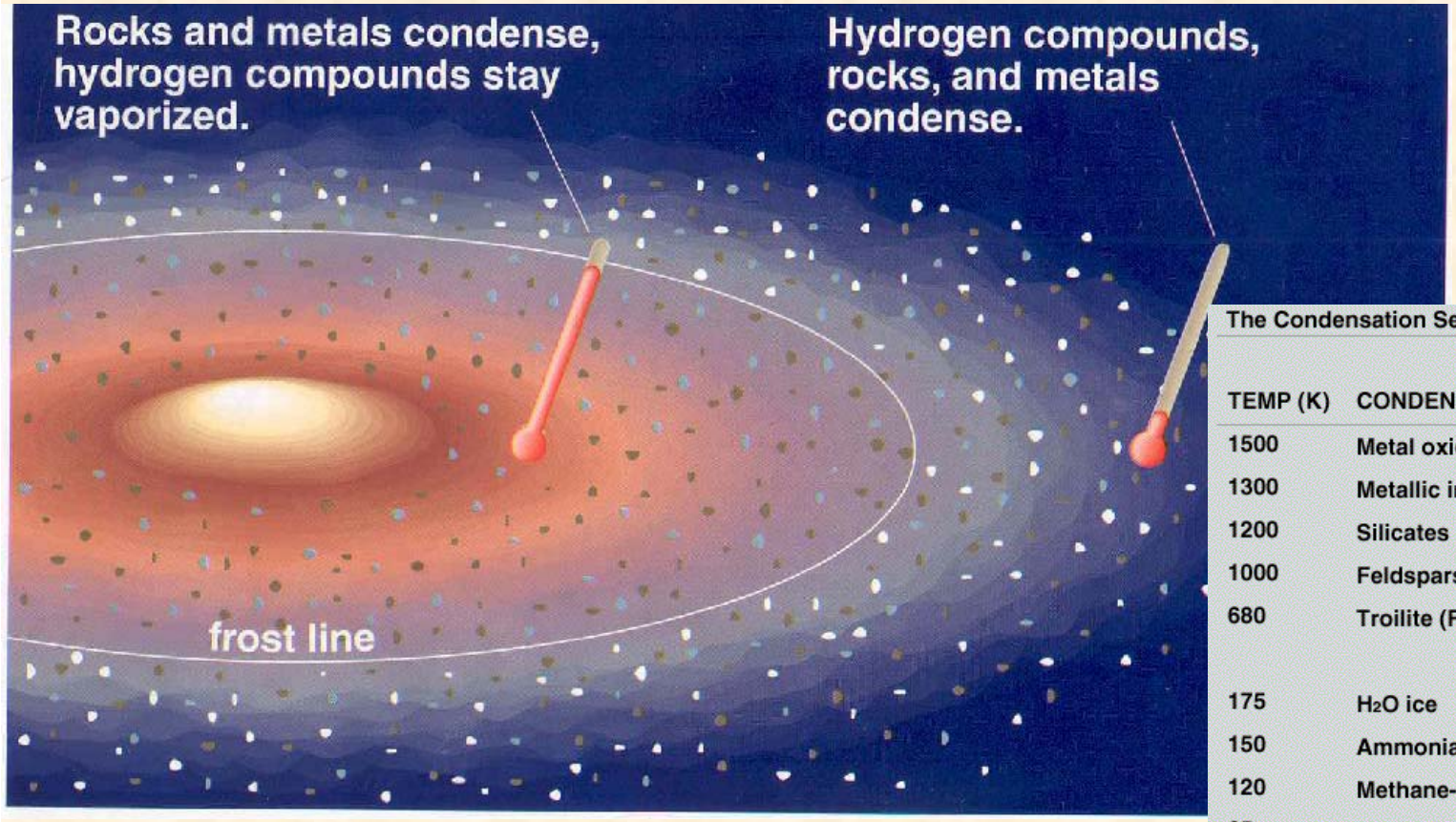
U. S. DEPARTMENT OF ENERGY

Condensation of hydrates and ices within the Solar nebula

>4 AU: H_2O, CO_2, NH_3, and CH_4 ices and clathrates account for *more than half* of the condensed mass



The Condensation Sequence

TEMP (K)	CONDENSATE	PLANET (EST TEMP OF FORMATION; K)
1500	Metal oxides	Mercury (1400)
1300	Metallic iron and nickel	
1200	Silicates	
1000	Feldspars	Venus (900)
680	Troilite (FeS)	Earth (600) Mars (450)
175	H_2O ice	Jovian (175)
150	Ammonia-water ice	Pluto (65)
120	Methane-water ice	
65	Argon-neon ice	

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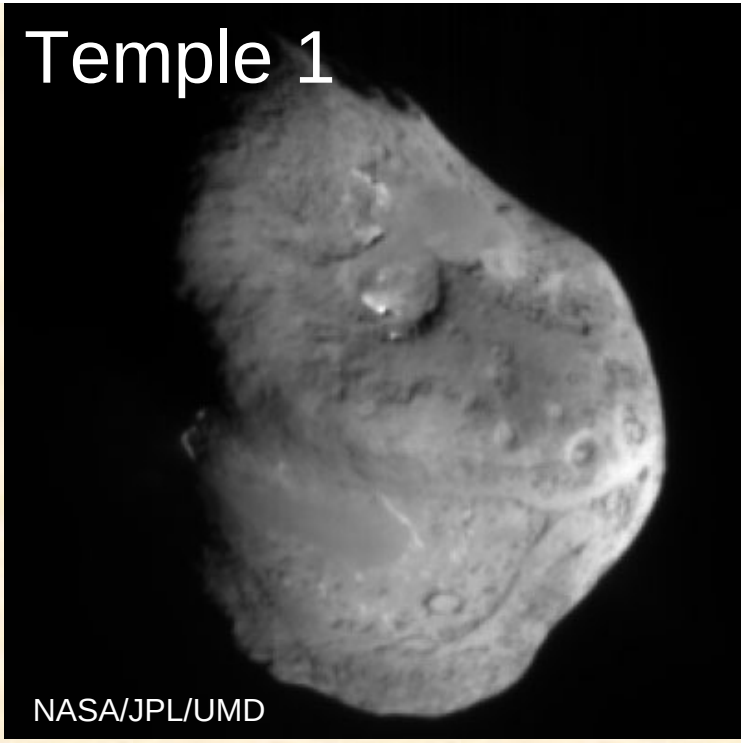
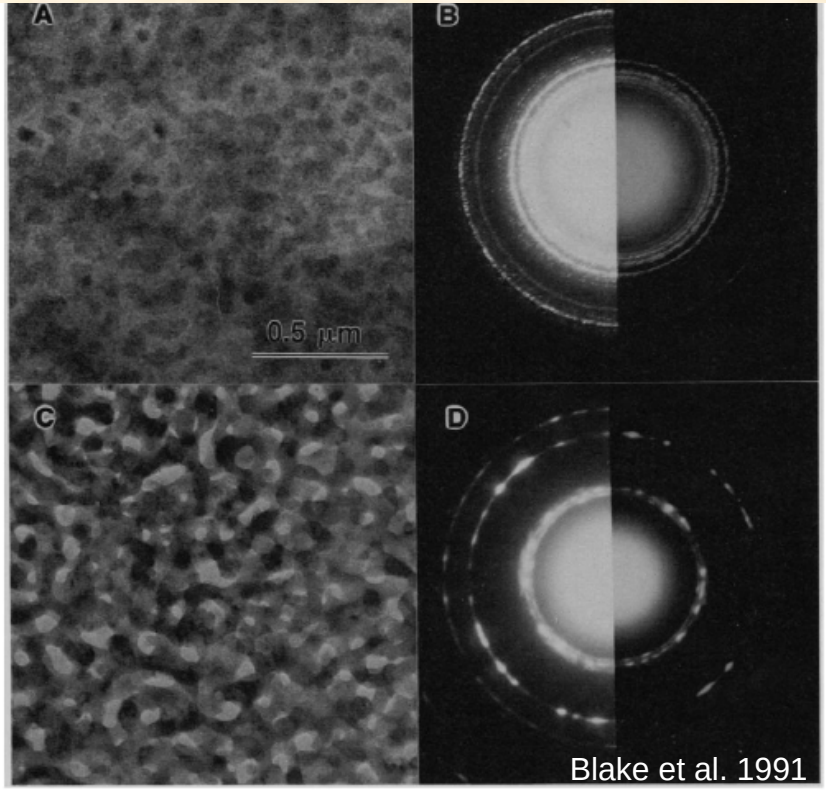
Comets

Formed in Kuiper Belt (30AU) or Oort Cloud (50-100k AU)

Water and clathrate forming gases are prevalent.



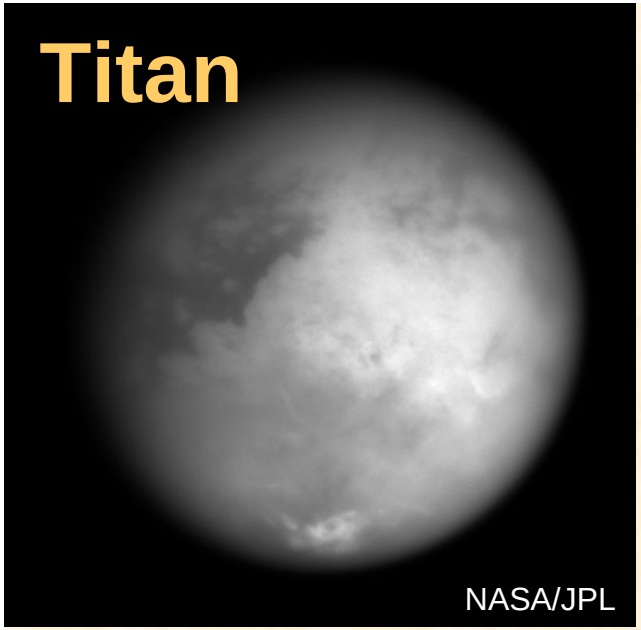


Clathrate dissociation may account for anomalous gas release at higher than expected AU

Formation of methanol hydrate at low pressures- recrystallization of amorphous ice

UT-BATTELLE

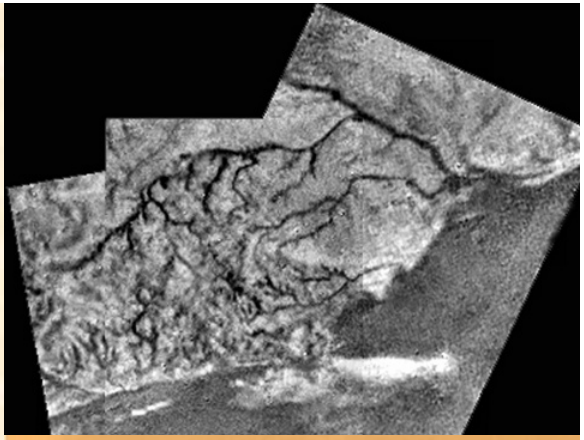
Titan

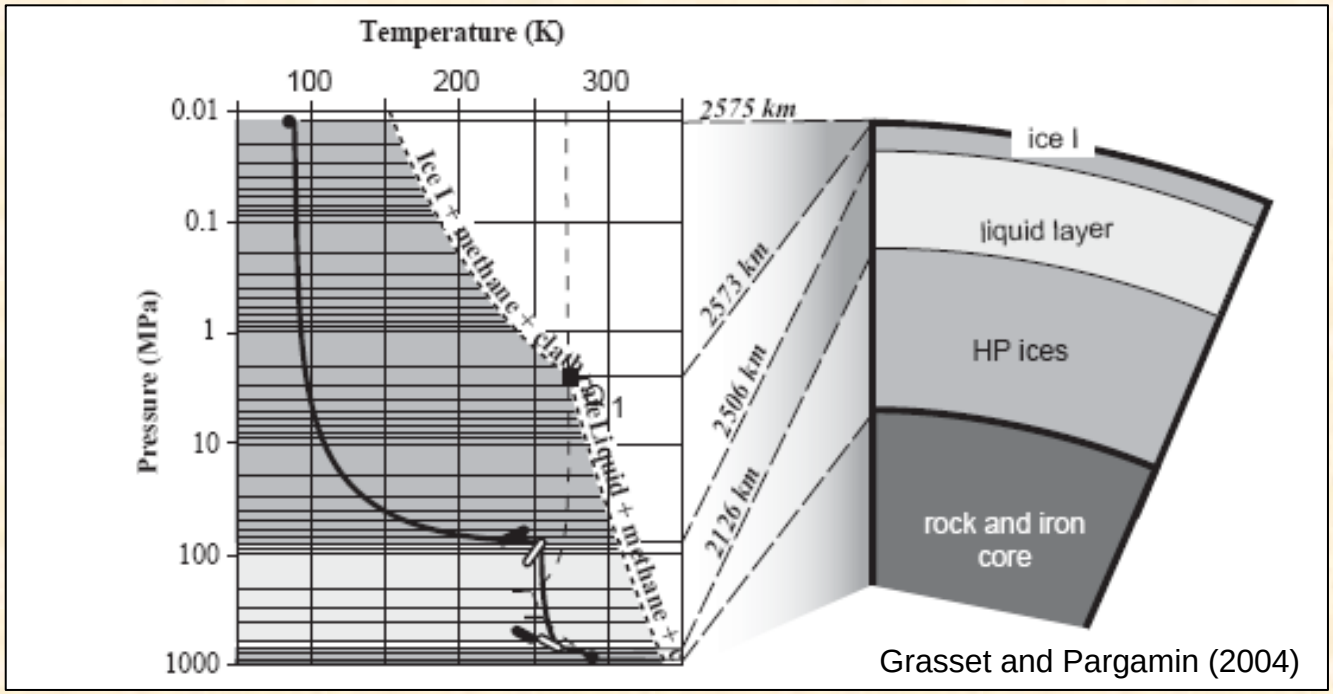


Surface : T~100 K
P~1.5 bars

Methane, ethane, ammonia

Water-limited



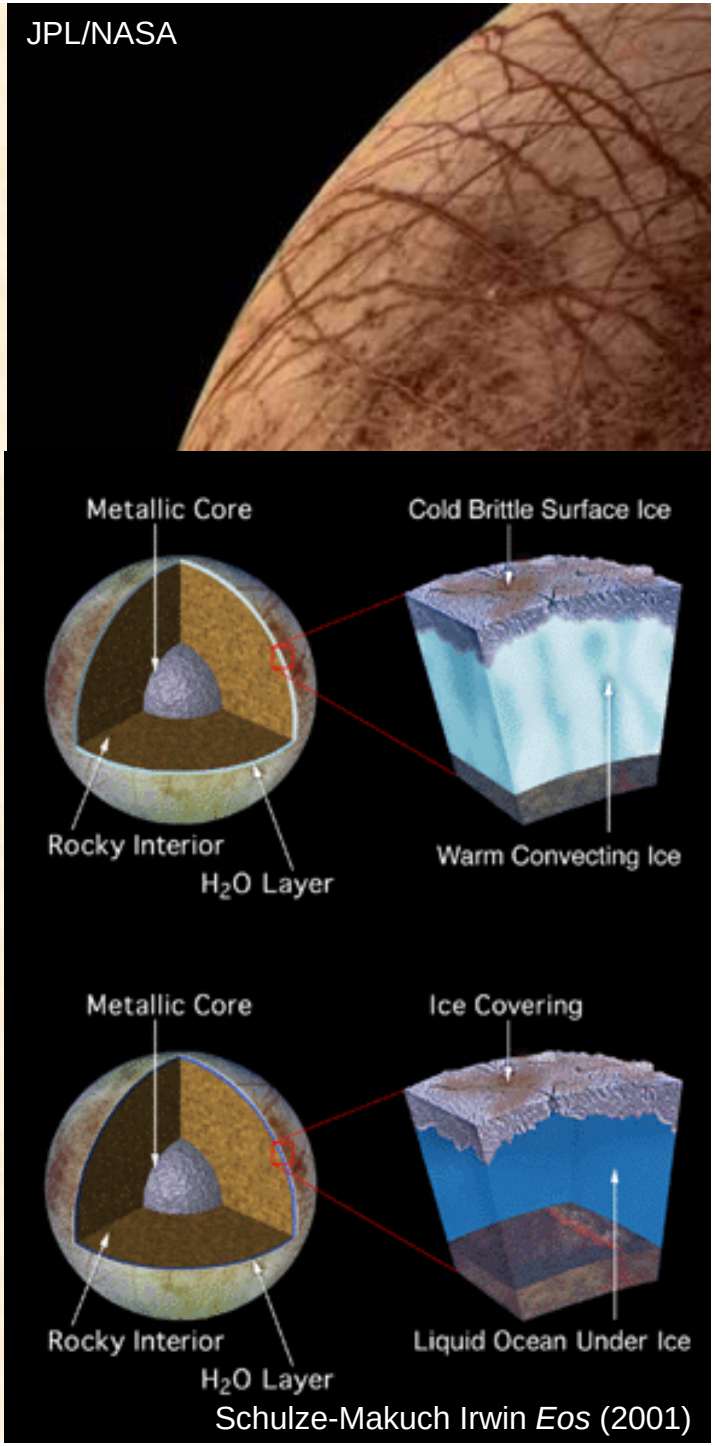


Grasset and Pargamin (2004)

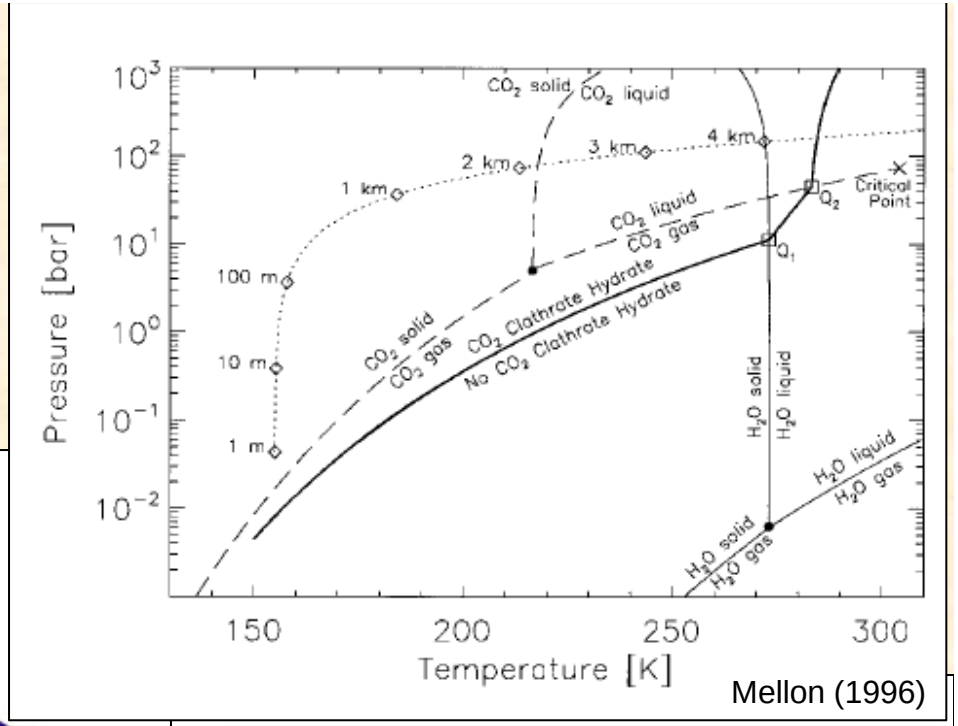
Europa

CO_2 or methane hydrate in icy shell

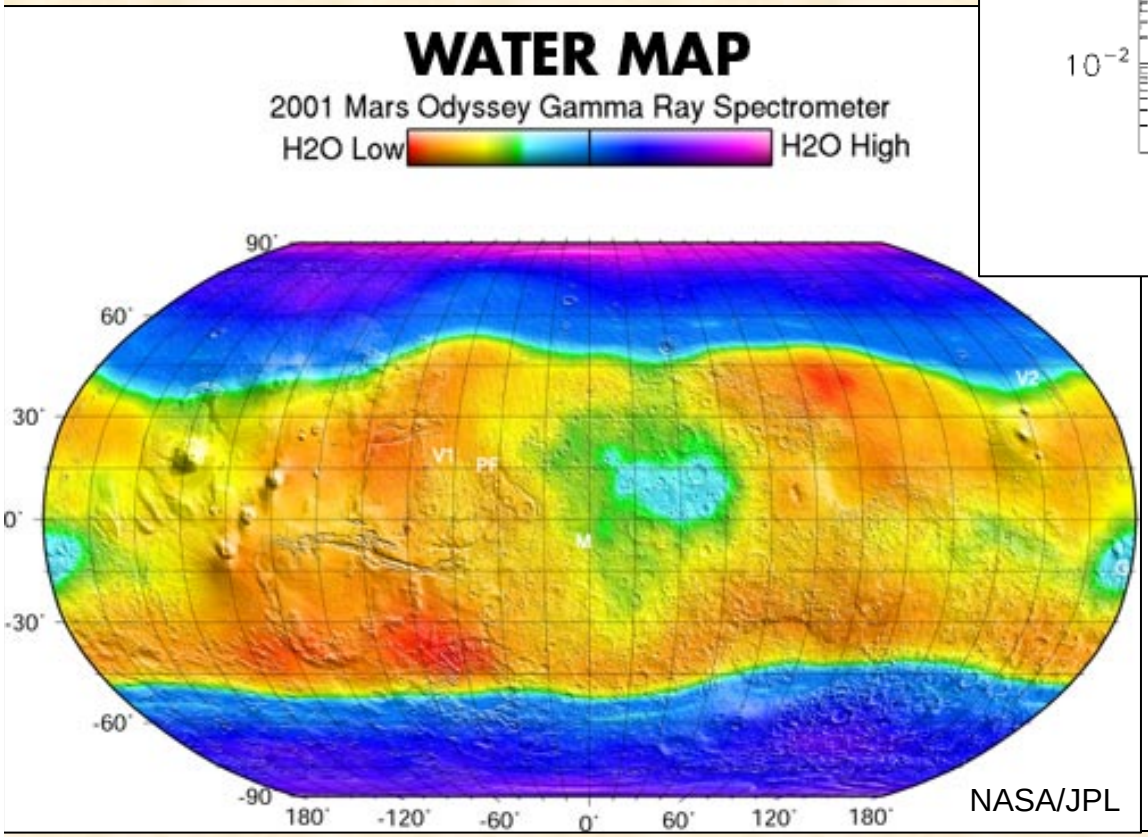
Possibility of gas venting at rock/fluid interface, similar to terrestrial ocean environments



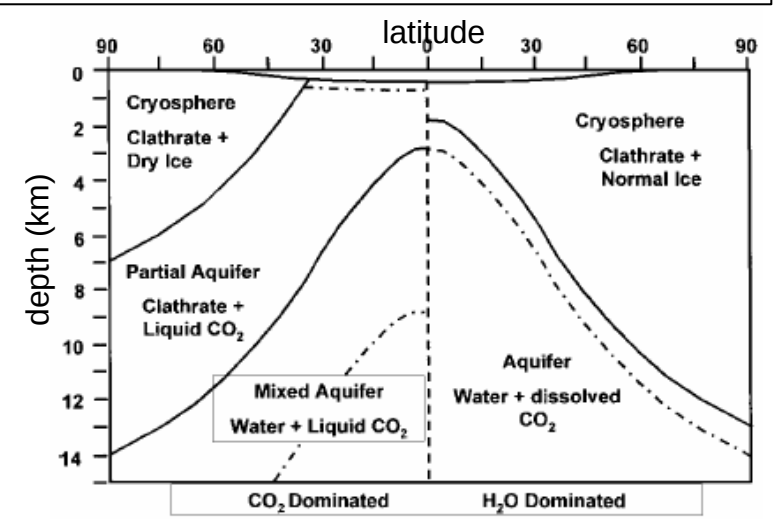
Water (hydrate?) distribution on Mars



Mellon (1996)

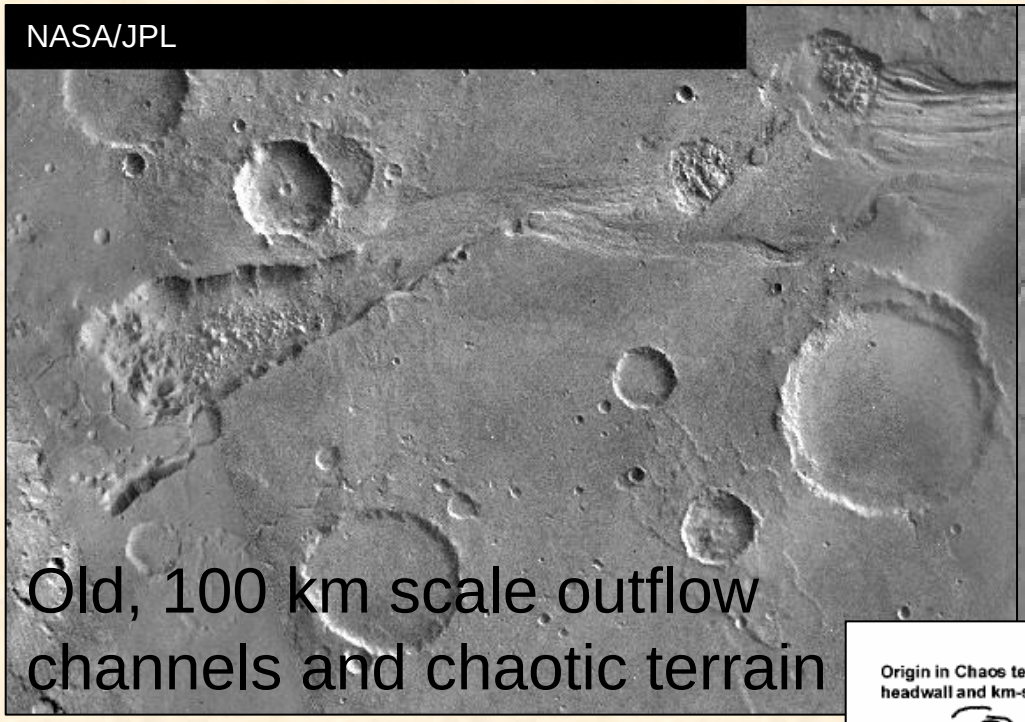


NASA/JPL

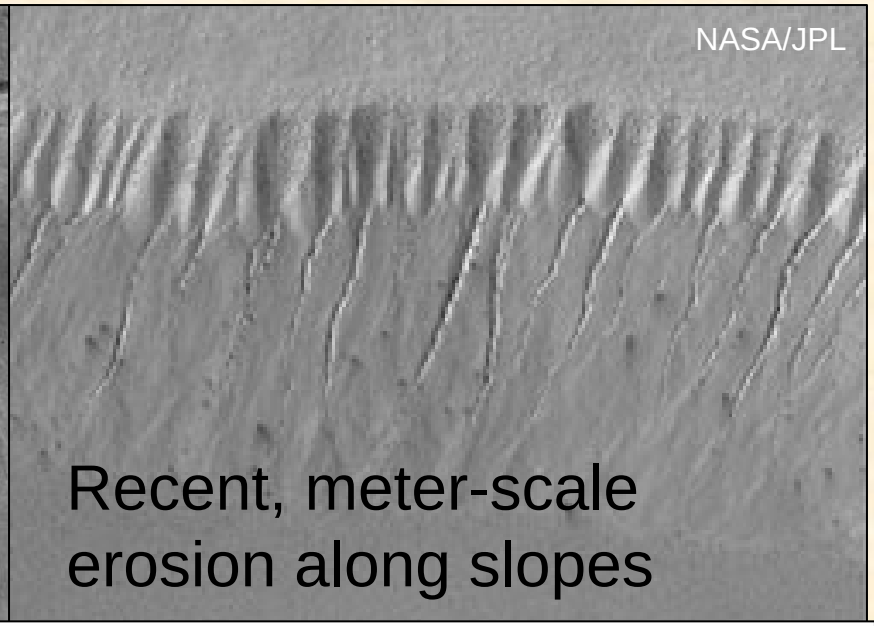


Hoffman (2000)

Erosion agents on Mars

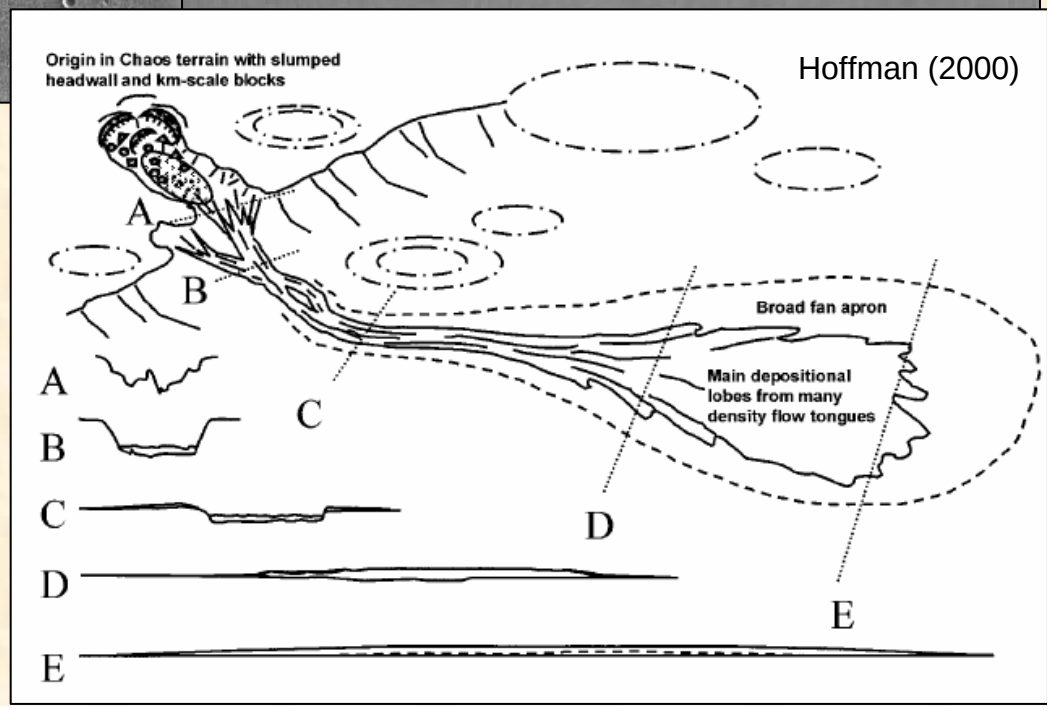


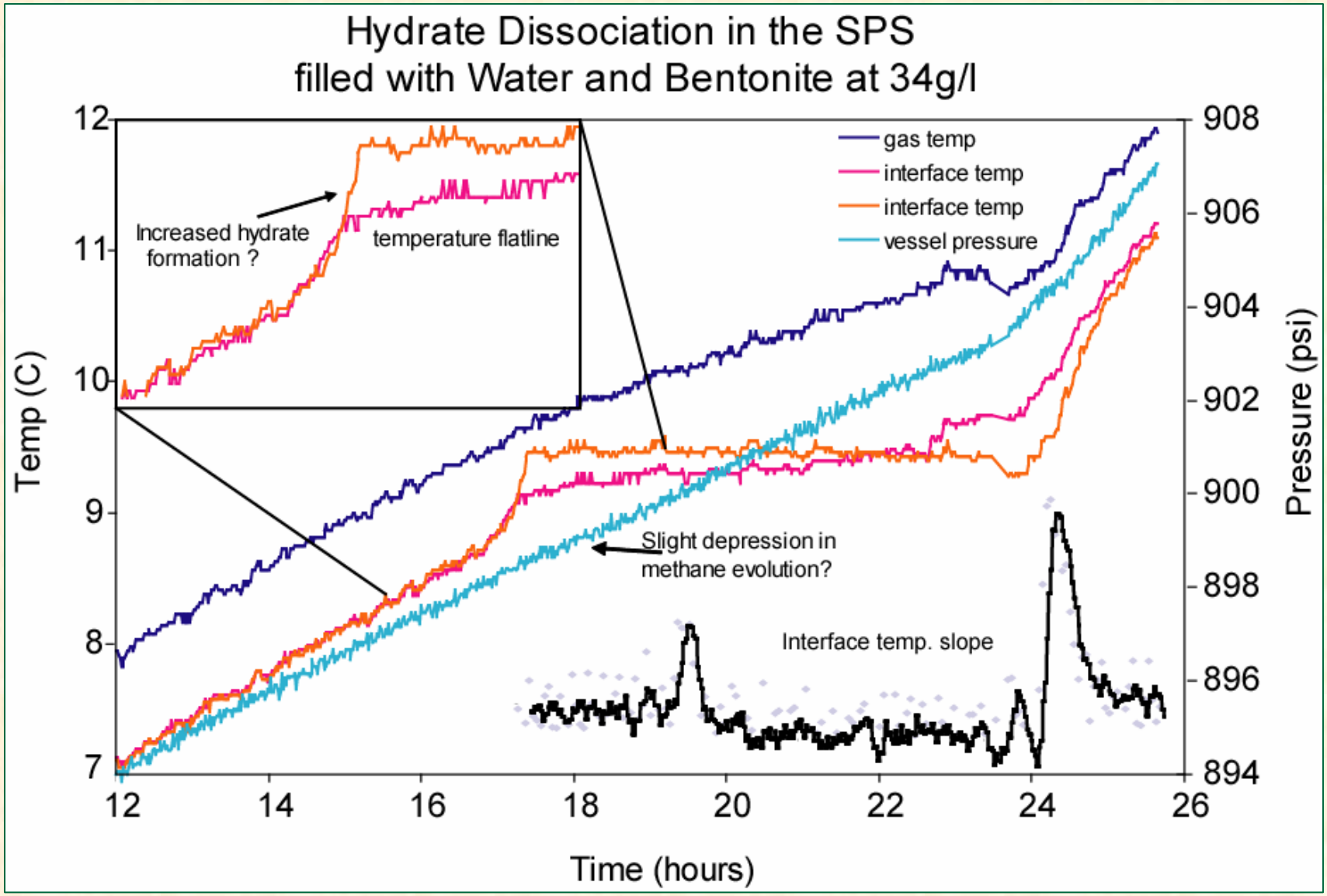
Old, 100 km scale outflow channels and chaotic terrain



Recent, meter-scale erosion along slopes

Hydrate dissociation driven cryoclastic flows?

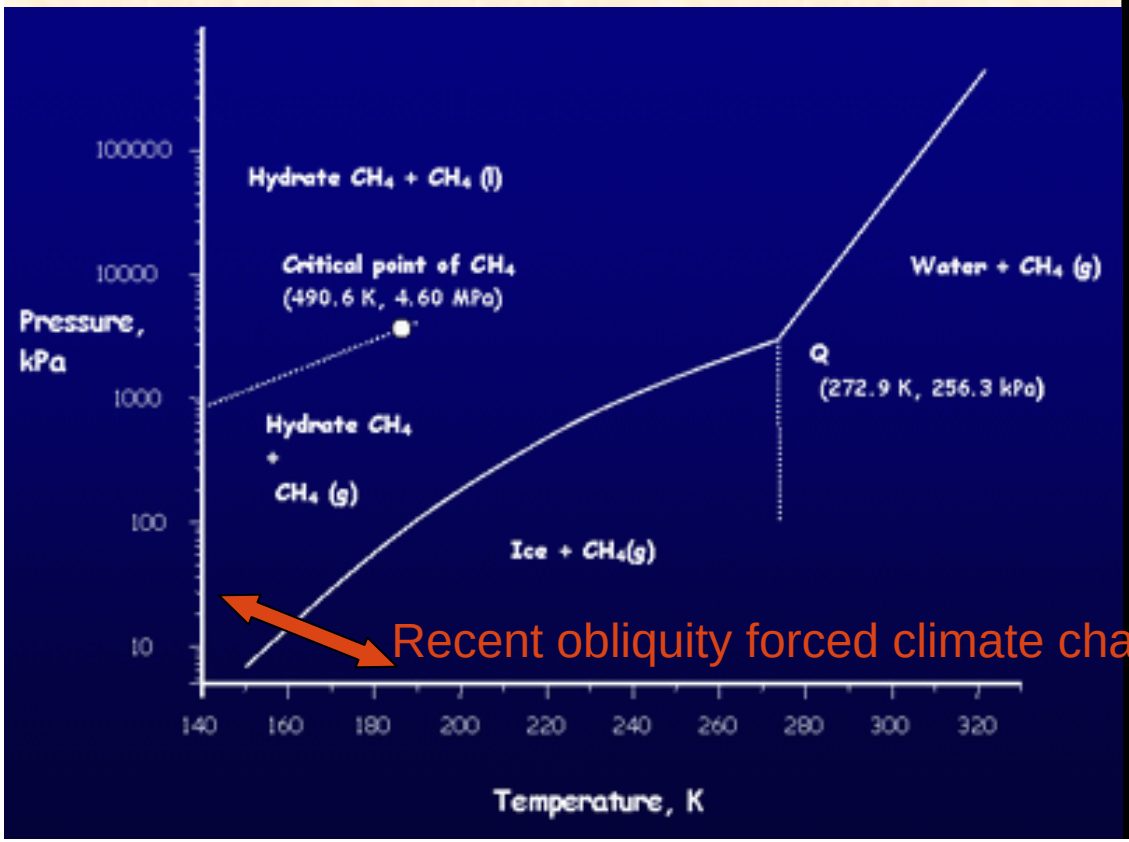



Hydrate Dissociation in the SPS
filled with Water and Bentonite at 34g/l
gas temp
interface temp
interface temp
vessel pressure
Increased hydrate formation ?
temperature flatline
Slight depression in methane evolution?
Interface temp. slope
Temp (C)
Pressure (psi)
Time (hours)
12
11
10
9
8
7
908
906
904
902
900
898
896
894
12
14
16
18
20
22
24
26

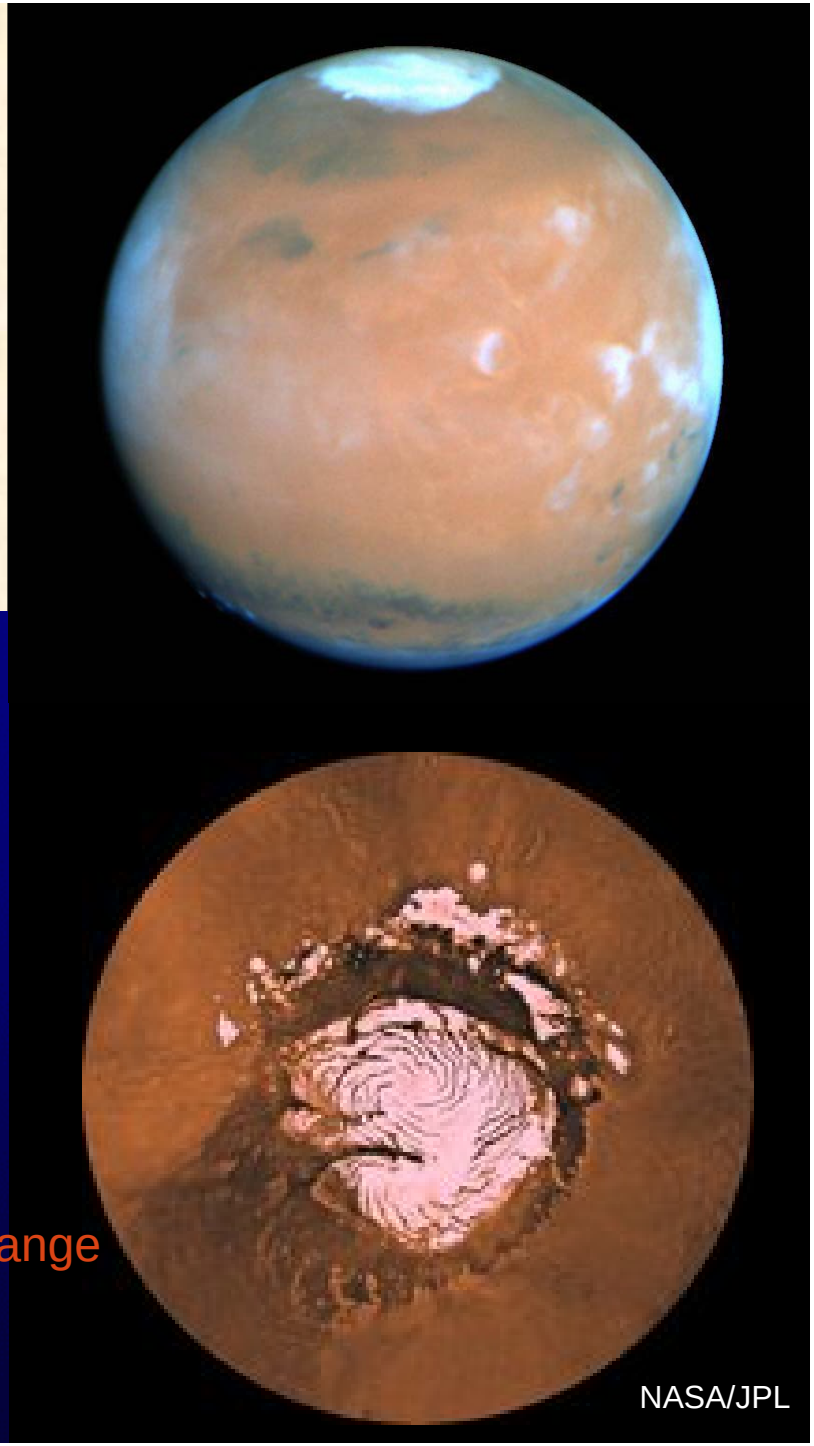
Mars- mysterious methane

Formisano et al. (2004)

- Short lifetime in atmosphere
- Source: biogenic, water-rock interactions, comet impacts?
- Methane hydrate reservoirs?



Recent obliquity forced climate change



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