Distant Mirrors to illuminate our understandings of the Earth

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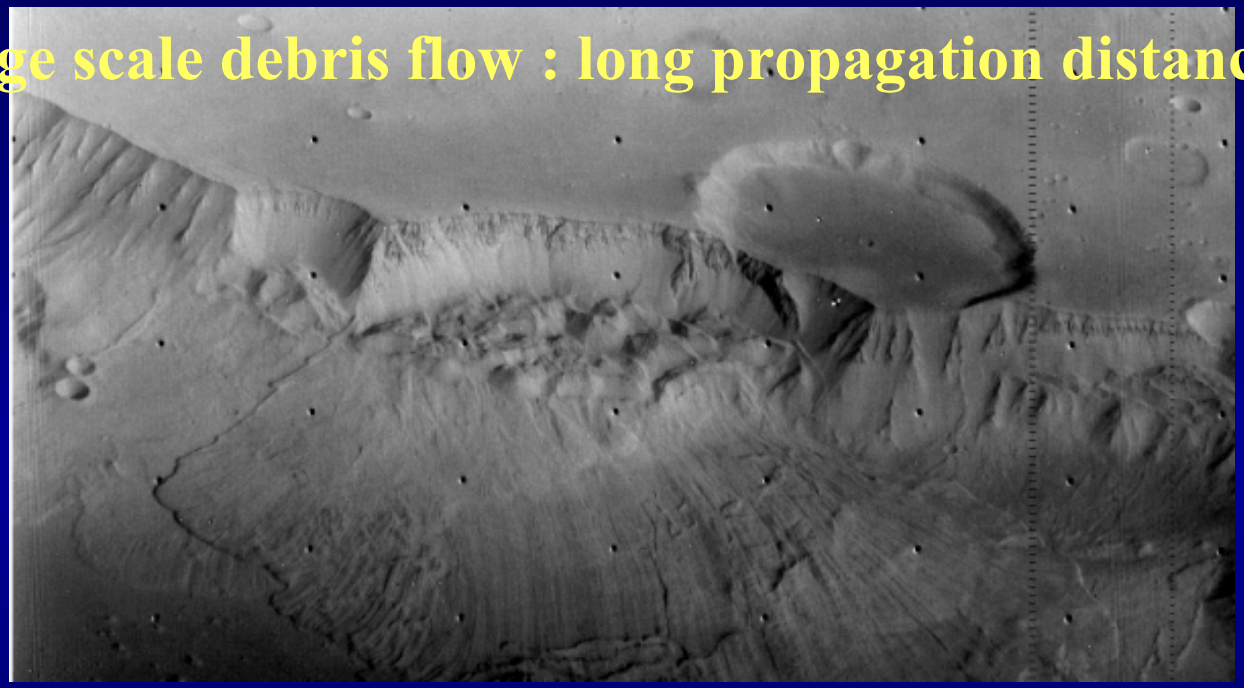
Subjects

- Part 1: Martian Debris Flow
- Part 2: Morphology of Martian Volcanoes
- Part 3: Evolution of Icy Satellites

Part 1:Martian Debris Flow

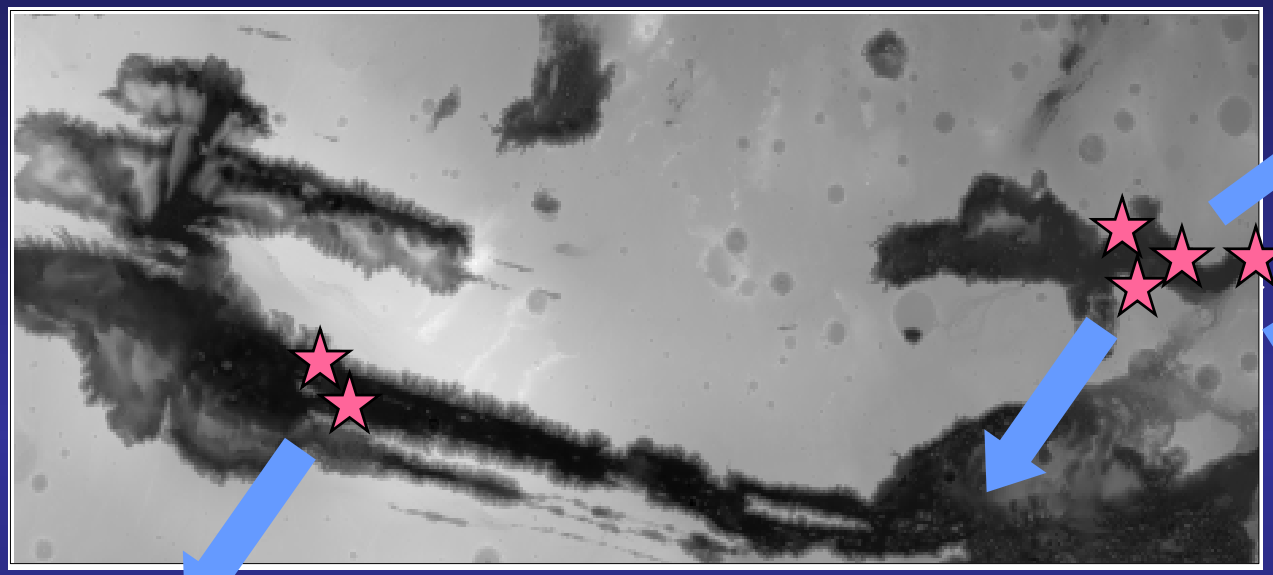
Large scale debris flow : long propagation distance

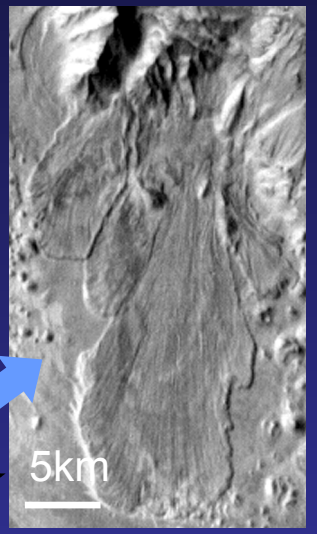


High mobility may indicate the role of volatiles in the debris.

To explore existence of volatiles in debris flow formation

Location Map





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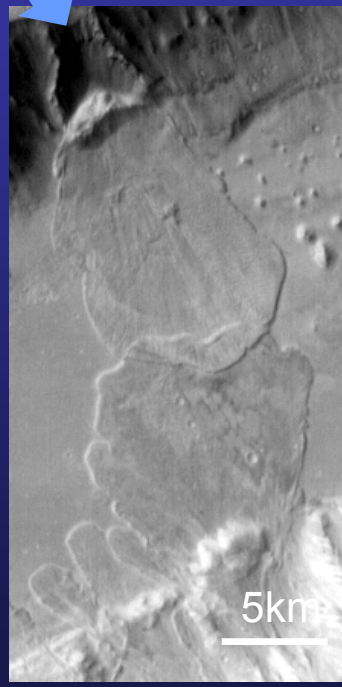
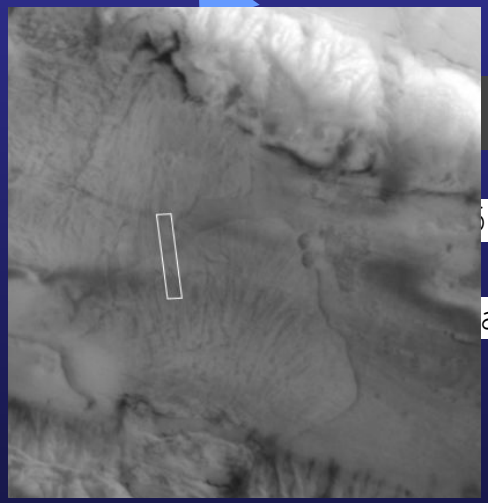
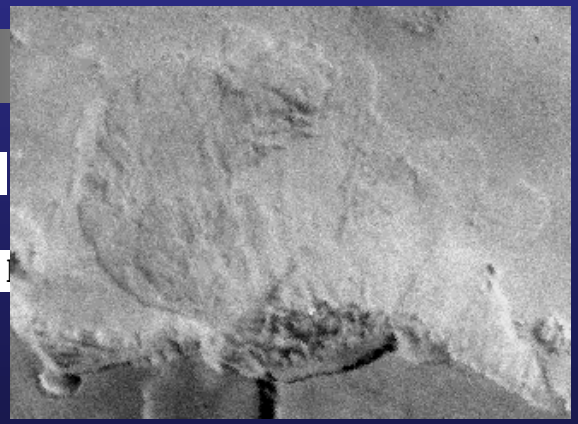
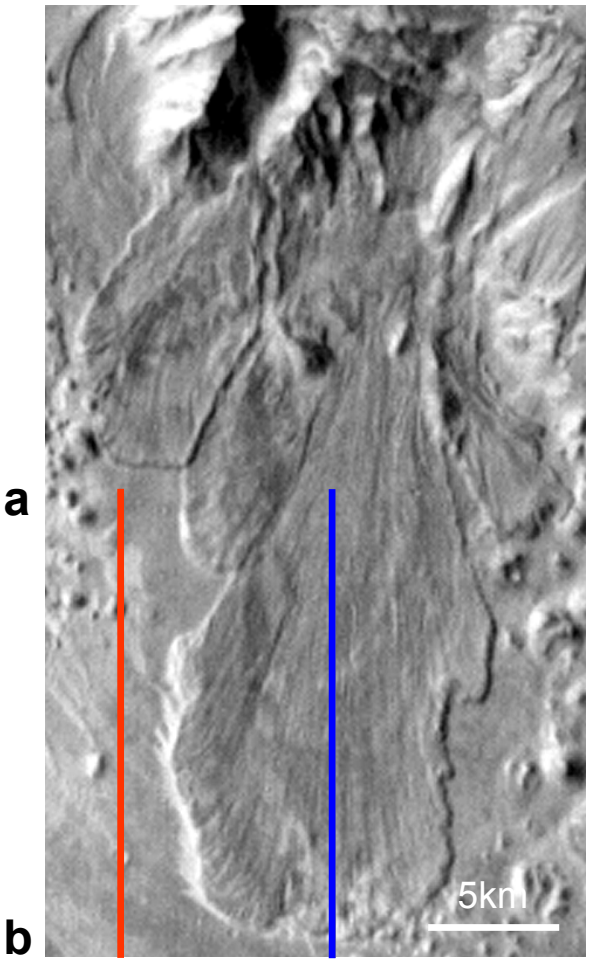






Viking

Morphology 1



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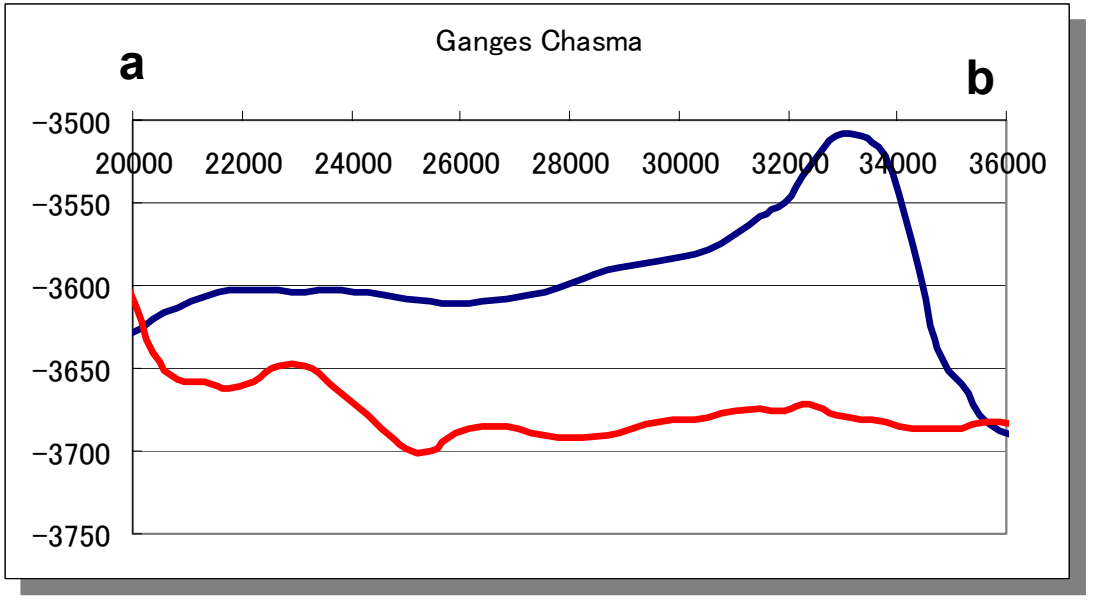
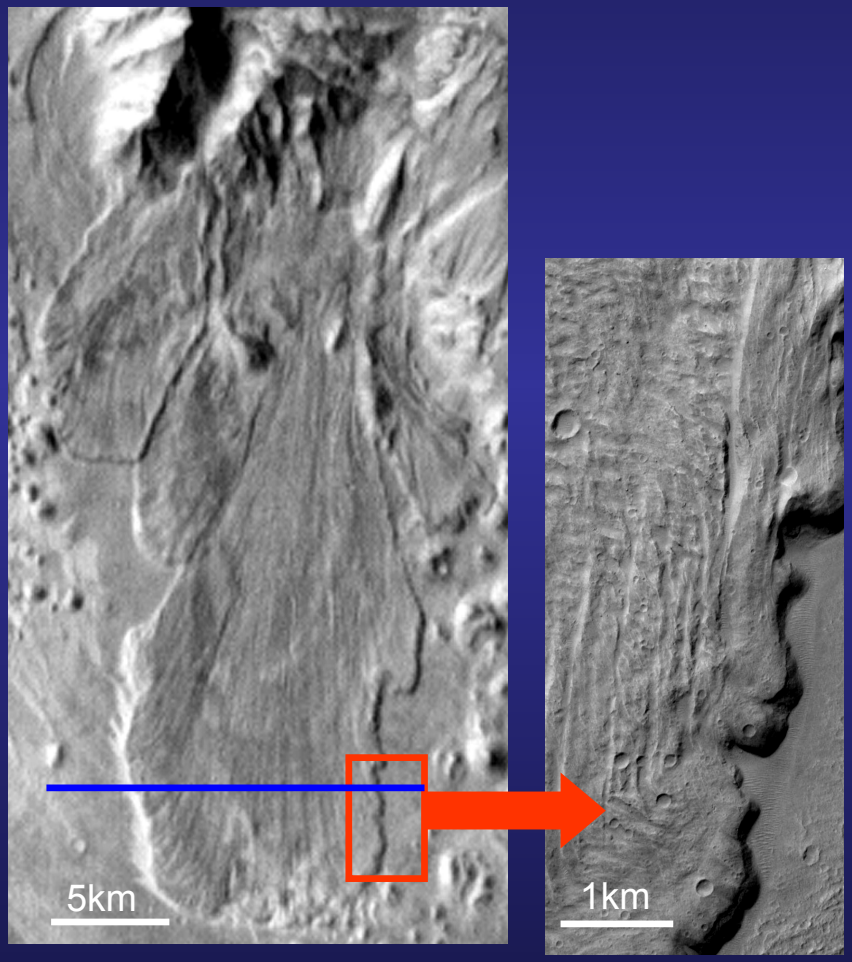
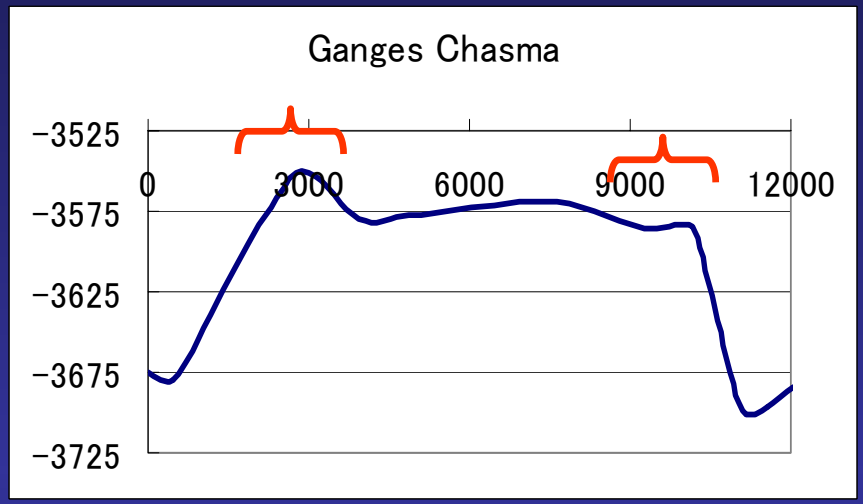


Thickening towards the head

Morphology 2

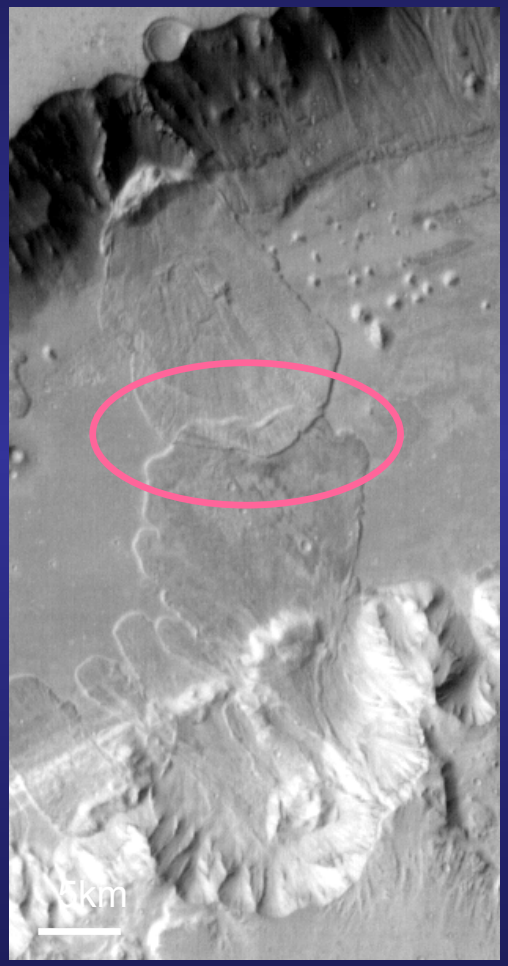




Existence of levee
Smooth on the levee
Wrinkled on the middle

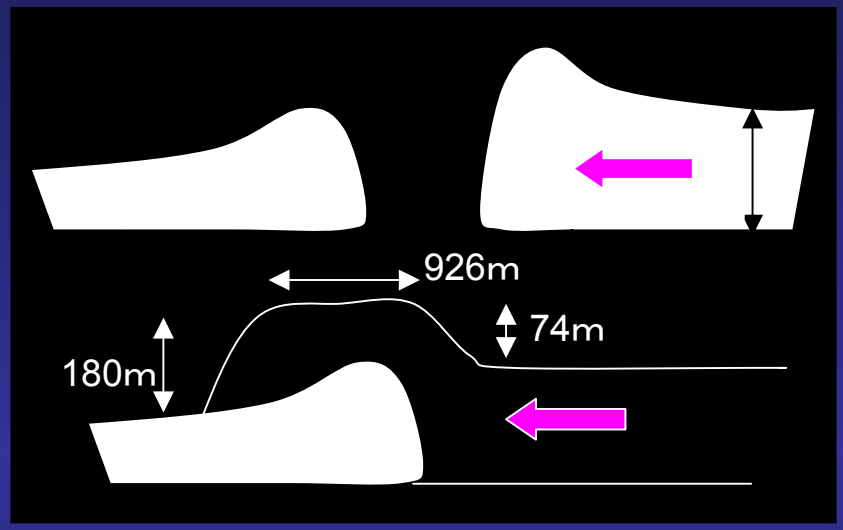
THEMIS day view:I01699006

Morphology 3



THEMIS dayview :I01699006

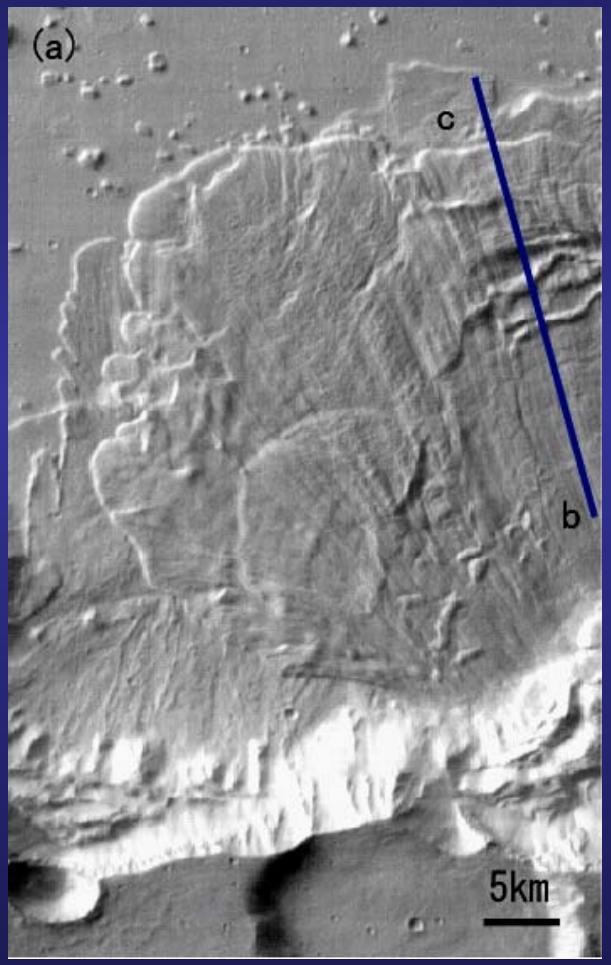
Overriding of debris flow



Solid-dominant flow may destroy the former front

Morphology 4

Overriding hill



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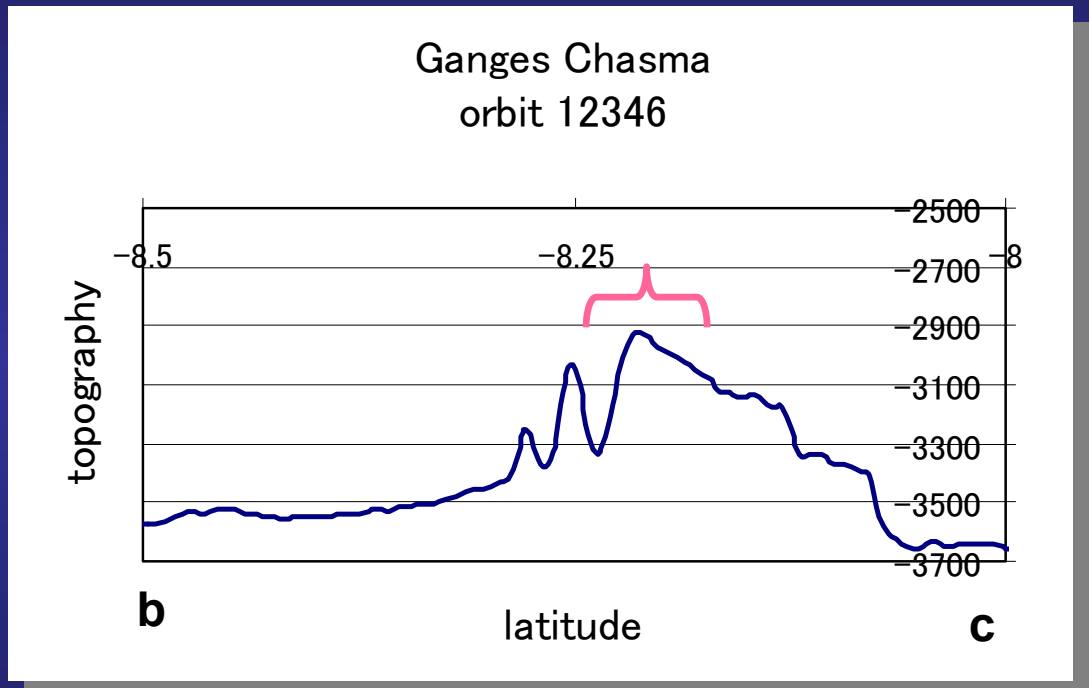
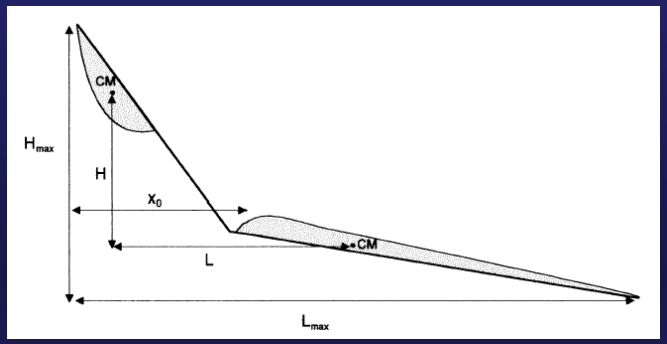
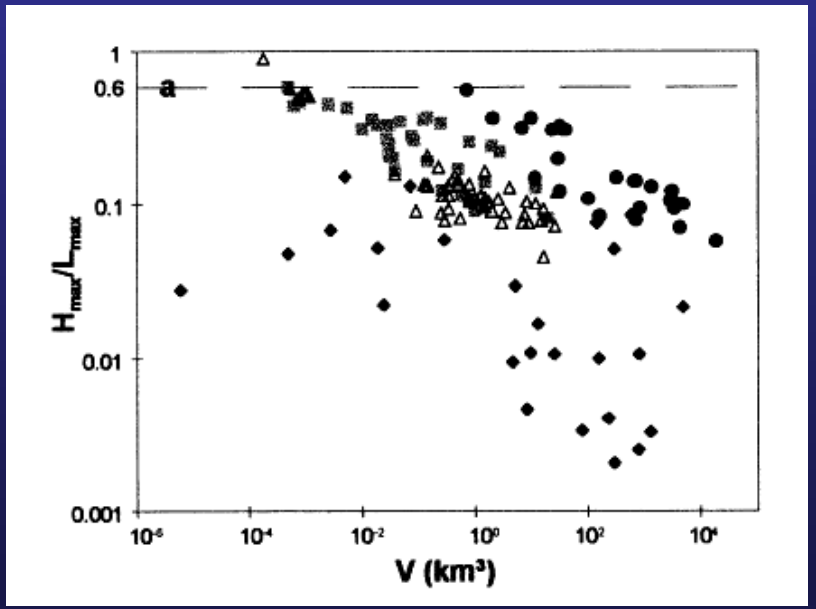


V≧56m/s

Volume vs frictional





△ Subaerial volcanic landslides. Data from Siebert (1984), Hazlett et al. (1991), Hayashi and Self (1992), Siebe et al. (1992).

⊠ Subaerial non-volcanic landslides. Data from Hayashi and Self (1992).

◆ Submarine landslides. Data from Lipman et al. (1988), Hampton et al. (1996).

● Martian landslides. Data from McEwen (1989).

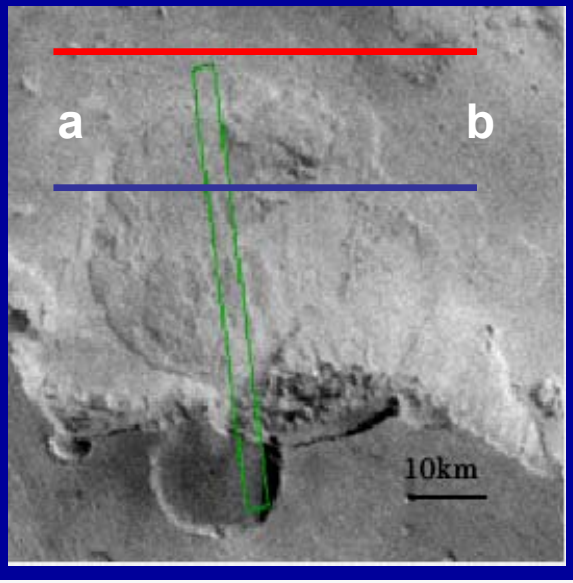
× Debris flows. Data from Pierson et al. (1990), Iverson (1997), Iverson et al. (1998), Mothes et al. (1998).

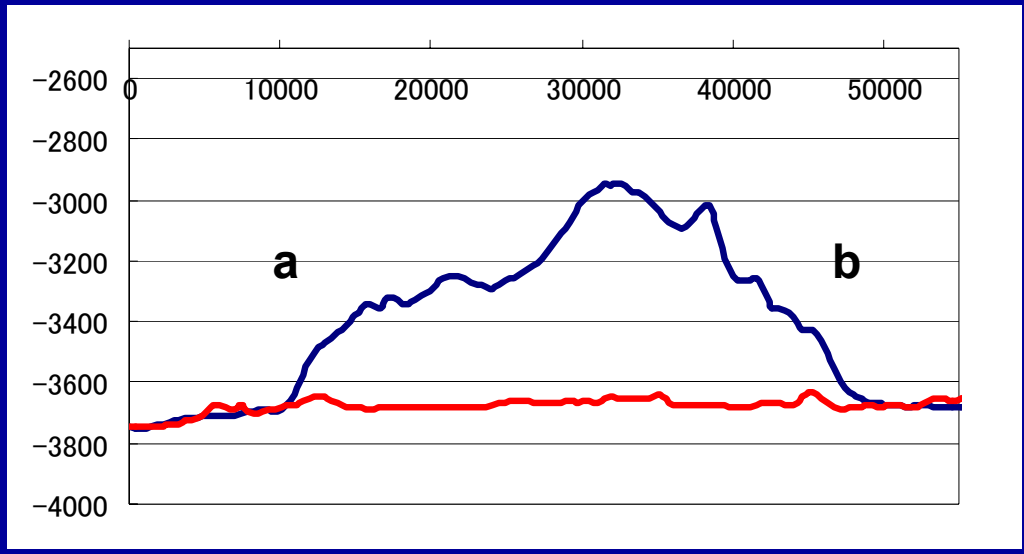
$$mgH = \mu mgL$$

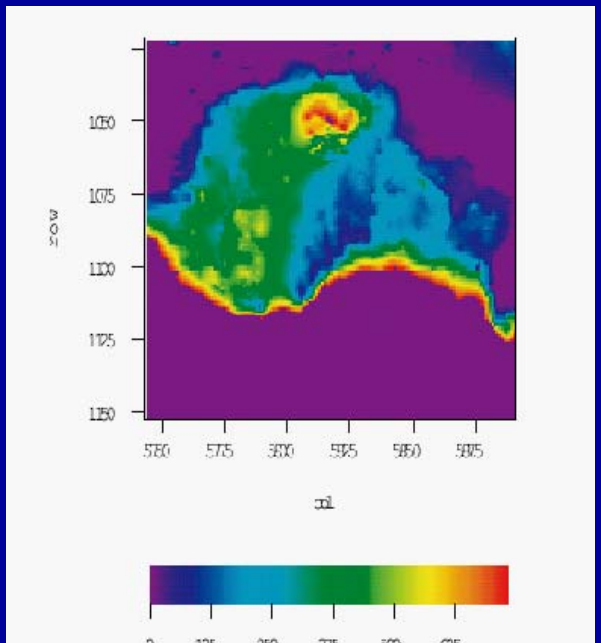
$$\mu = H / L$$

H/L; dry landslide>volcanic>submarine

Volume estimate



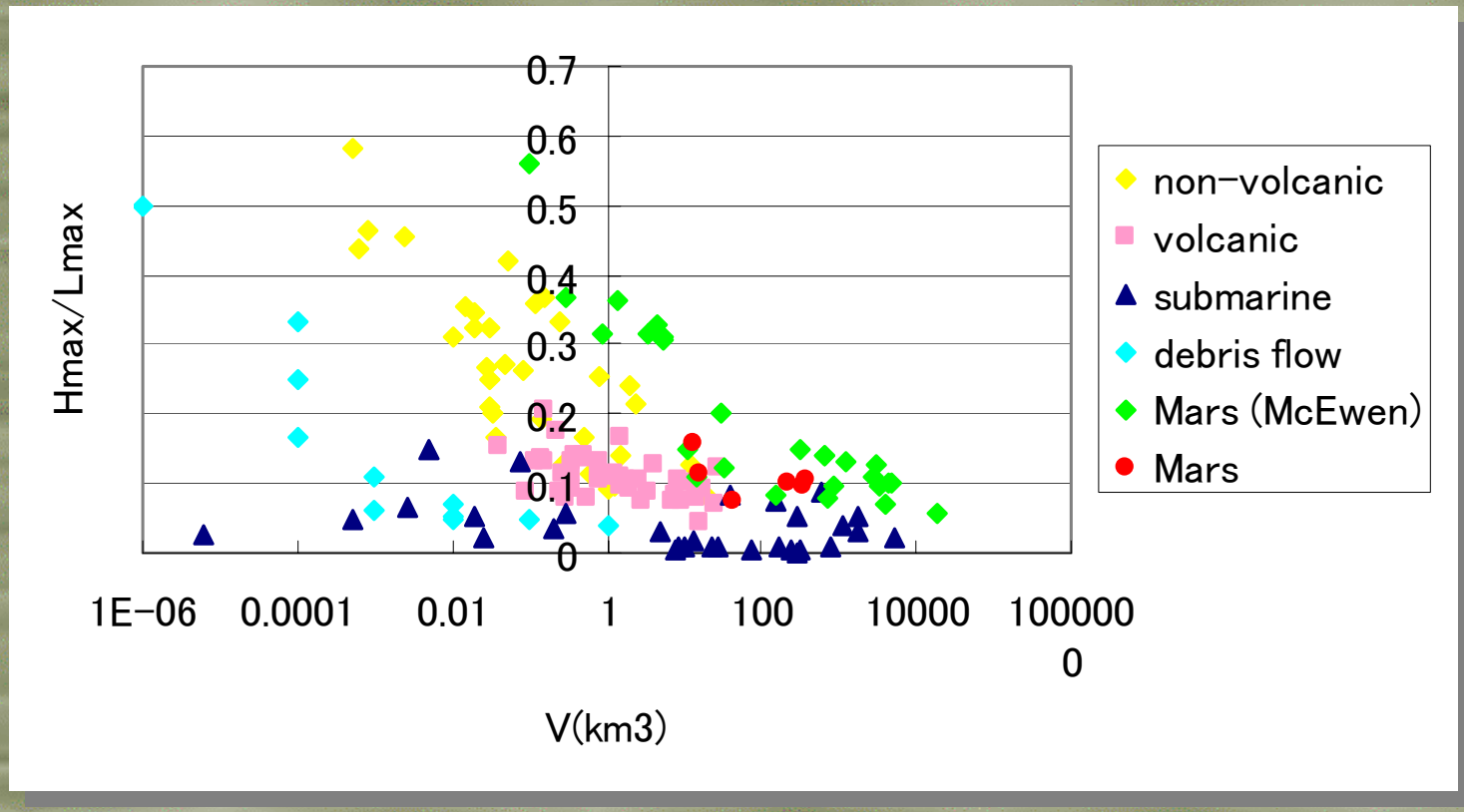




Martian debris flow

Landslide	Hmax[km]	Lmax[km]	μ =Hmax/Lmax	The elevation of	V[km3}
1	5.07	48.4	0.105	−3650	381
2	4.51	24.5	0.184	−3750	13.7
3	4.16	31.4	0.132		
4	4.8	42.7	0.112	−3700	16.1
5	4.1	41.7	0.099		
6	5.6	58.9	0.095	−4700	353
7	5.38	70.7	0.076	−4800	42.1

Size



Apparent friction coefficient

Martian landslide; comparable value with wet debris flow & volcanic

Existence of volatiles in debris material ?

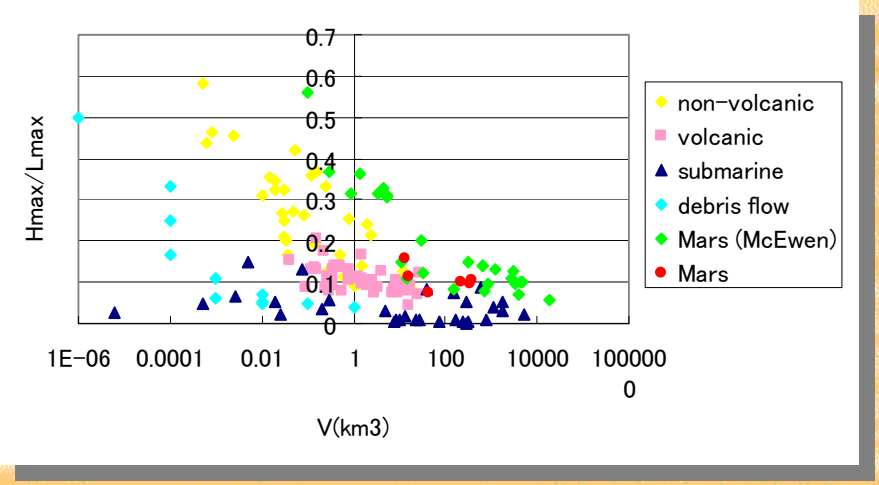
Problem

Is it possible to compare directly with the terrestrial cases ?

Difference in

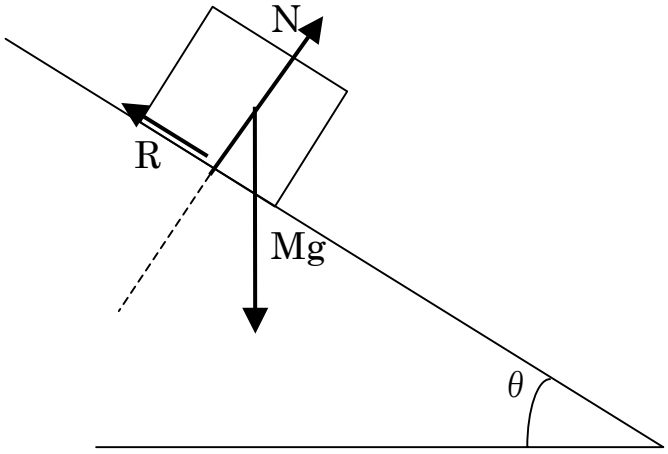
1:atmospheric pressure 6mb vs ~1000mb

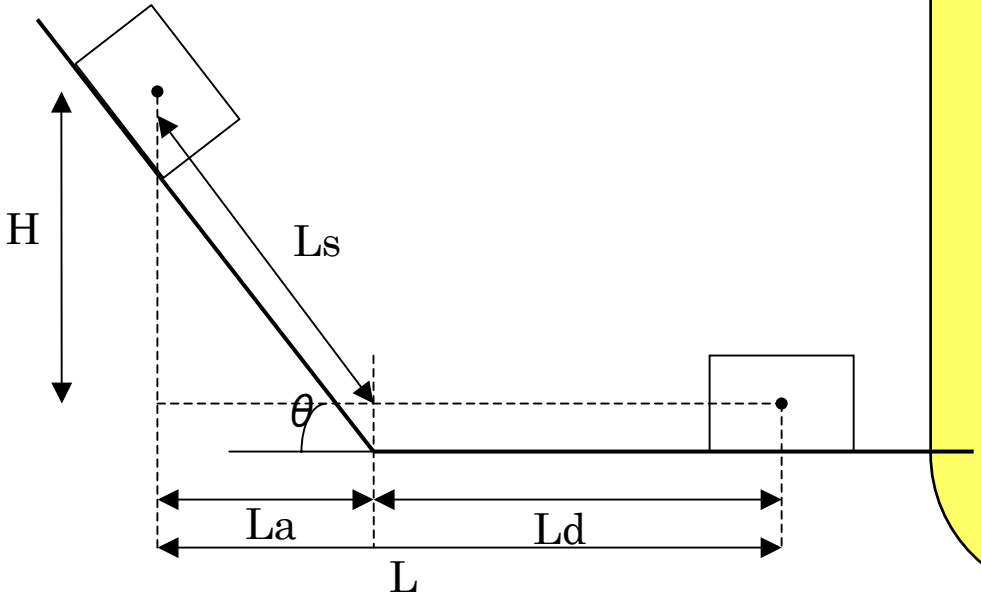
2:gravity 3.71 vs 9.78



How the gravity controls the apparent friction?

Friction control





$$MgH = RsLs + RdLd$$
$$= \mu Mg \cos\theta \, Ls + \mu MgLd$$
$$= \mu MgLa + \mu MgLd$$
$$= \mu MgL$$

$$\therefore \quad \mu = H/L$$

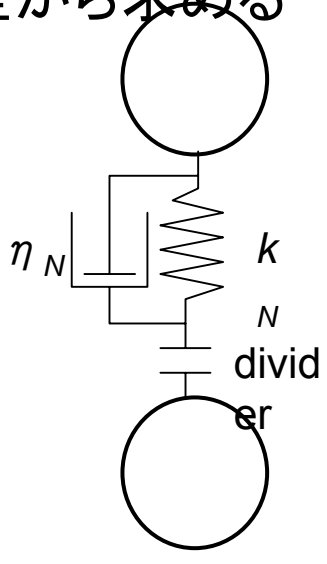
normal friction $\fallingdotseq 0.6$

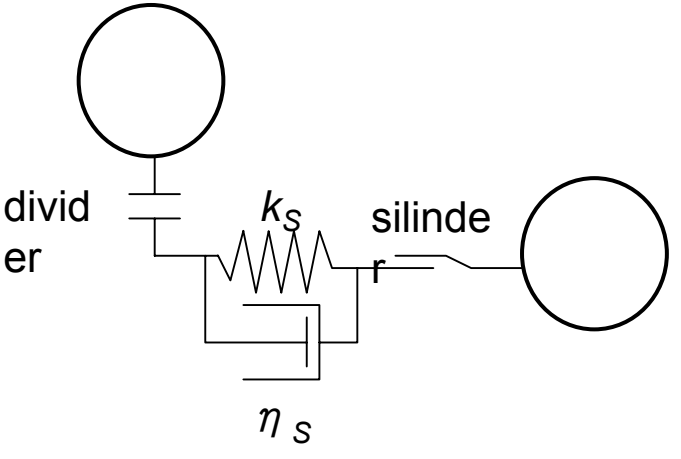
?

DEM simulation

粒子･･･球形の剛体（変形しないが少量の重なりを許す）

粒子間力･･･接触点の変形量と速度差から求める





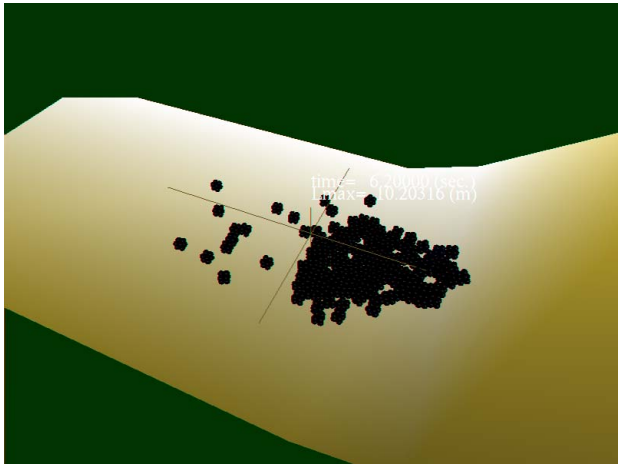
Tangential force

Normal force

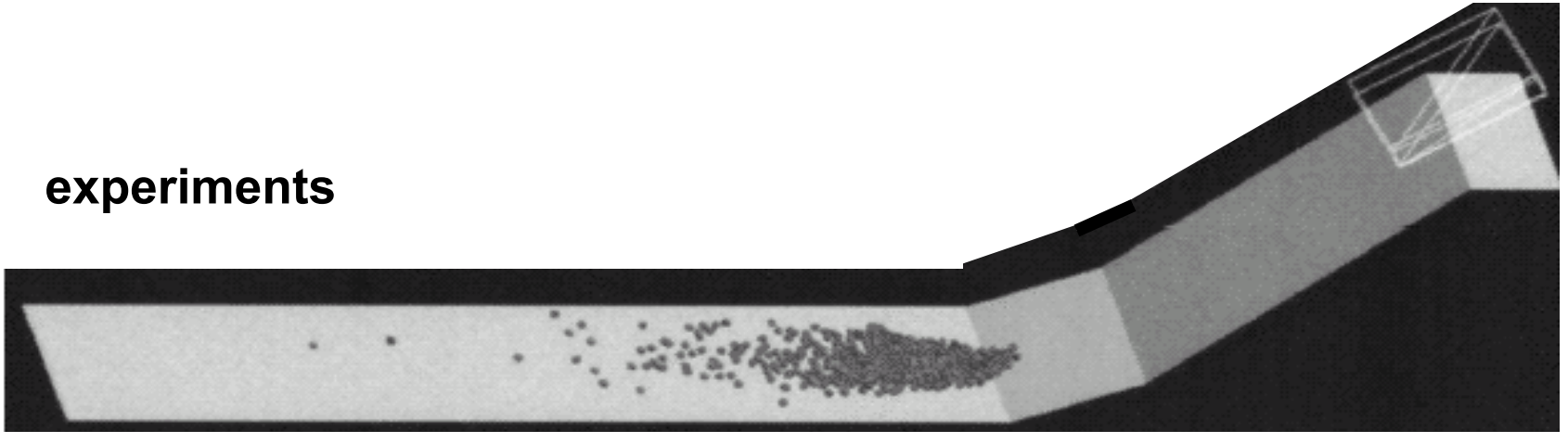
$$m \frac{\partial^2 x}{\partial t^2} = -kd - \eta v$$

Tuning the simulation with experiments

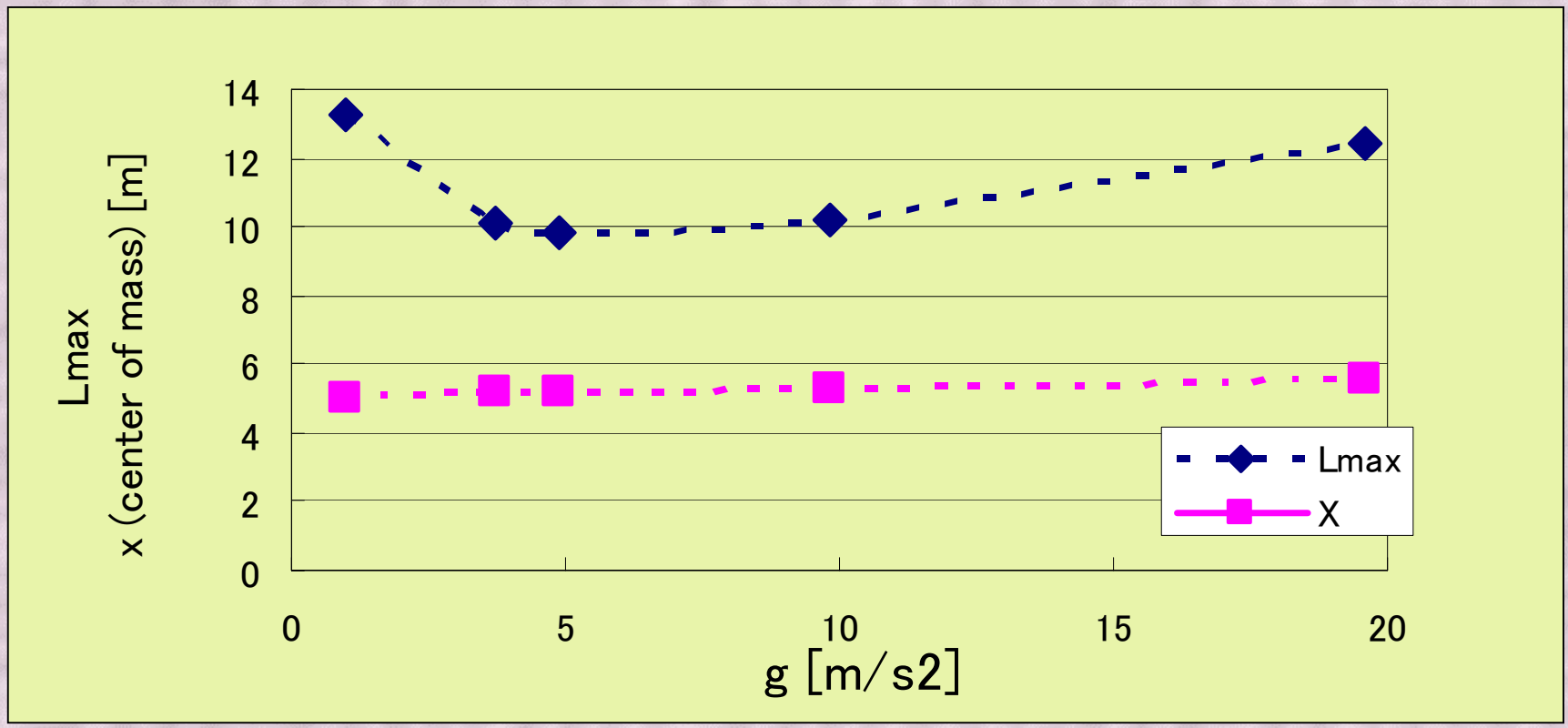
simulation



experiments



Effect of gravity

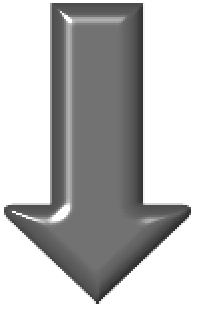


Two branches

Fortunately we can compare the Martian case with the terrestrial one!

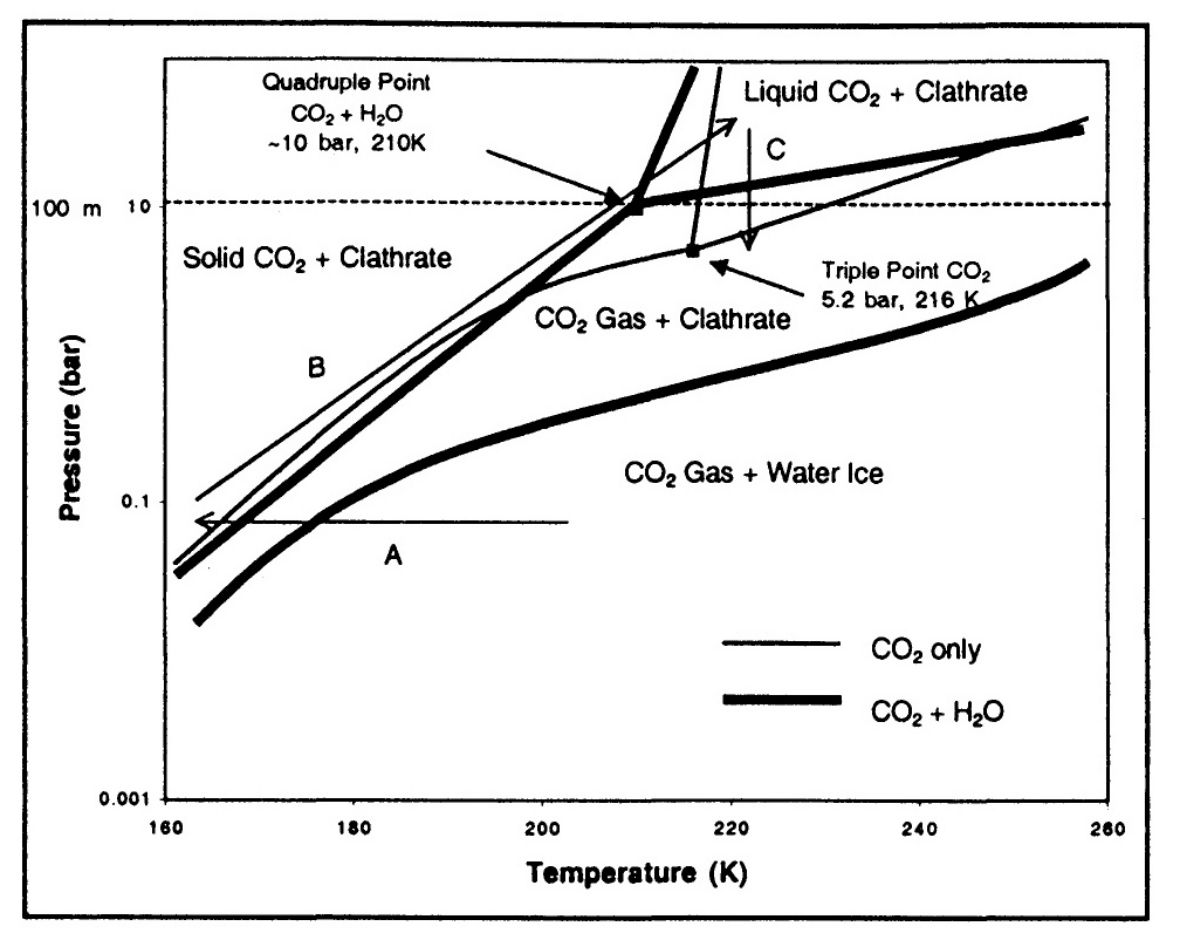
Mobility,fluid source

Smaller values of apparent friction coeff.



Existence of volatiles in debris materials

Importance of volatiles in Mars



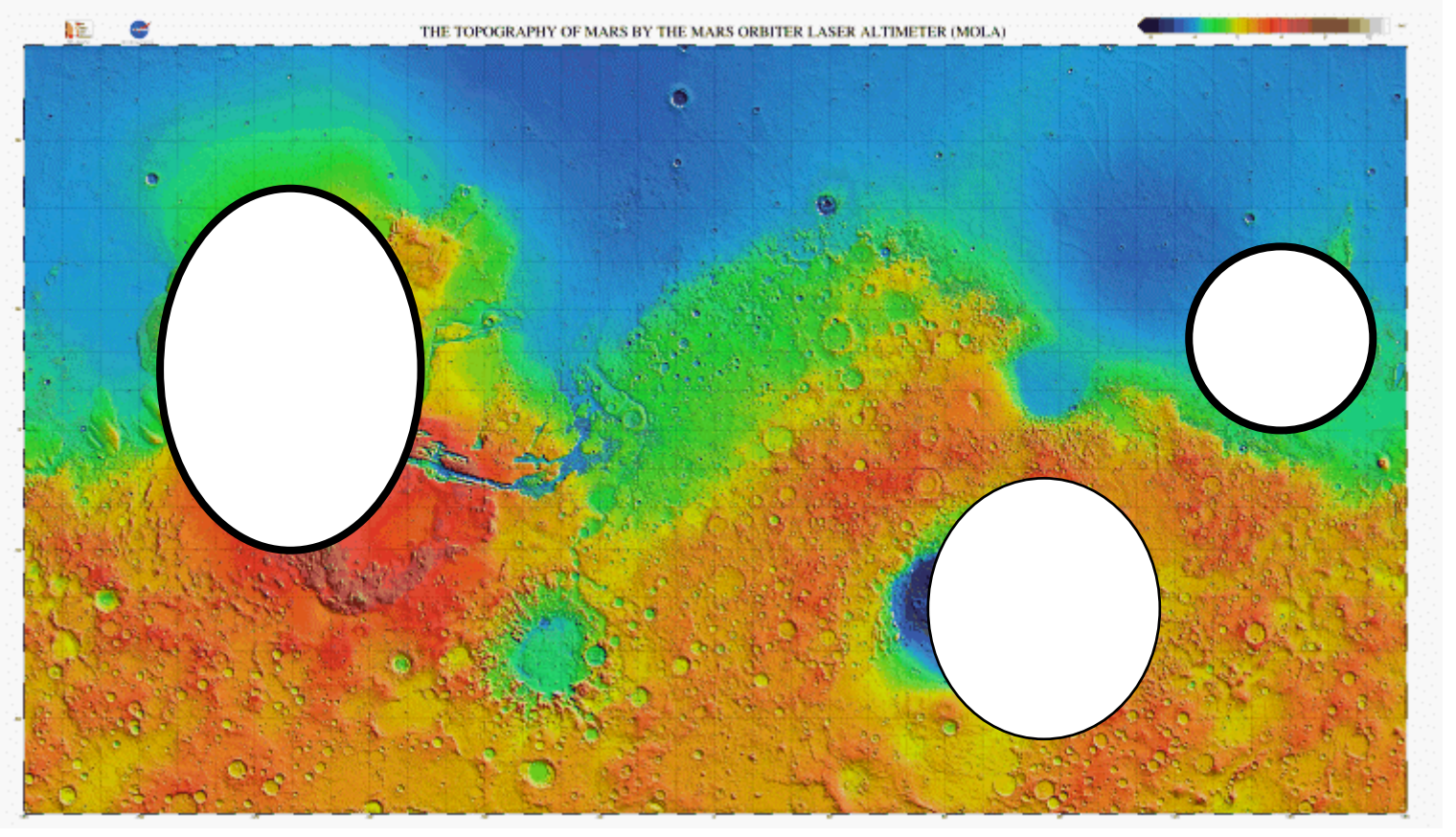
Decomposition of CO2 clathrate

Part2:Morphology of Volcanoes

Martian volcanoes

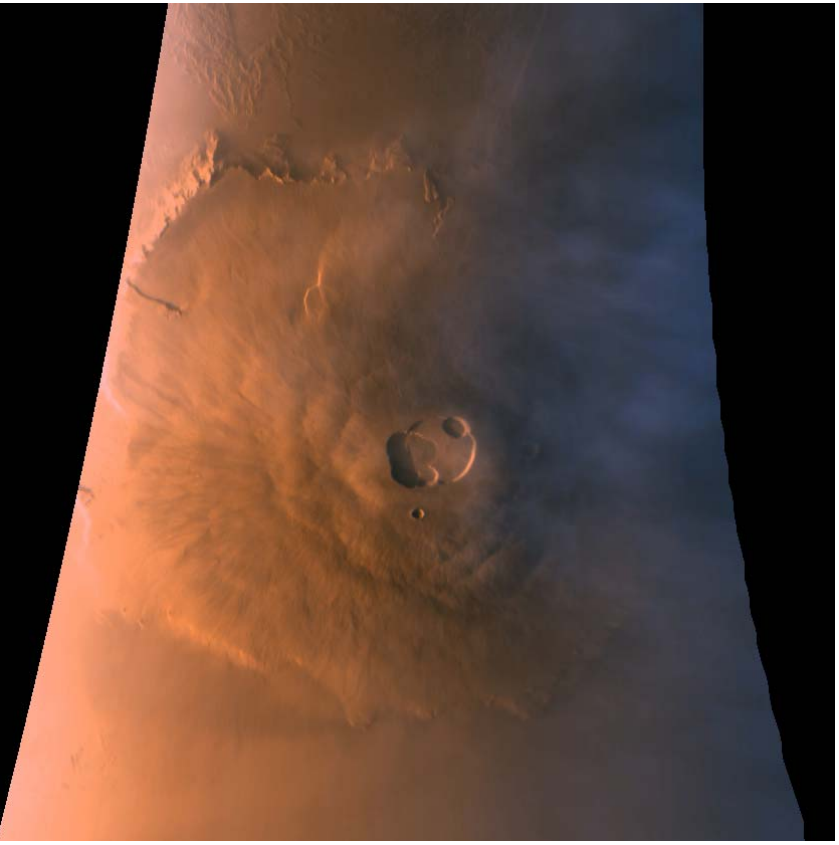
- Small number
- Localized into 3 region
- Large size
- Long life time
- Basaltic composition
- Lava flow

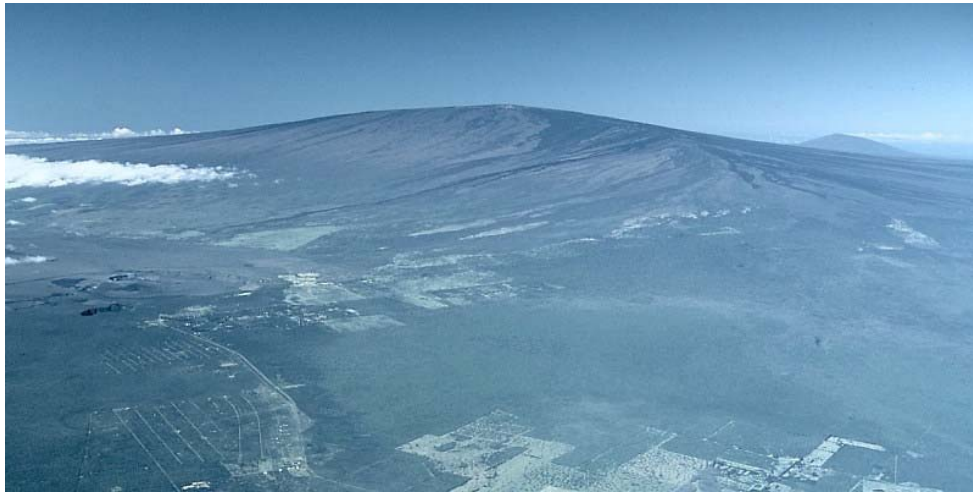
distribution



Tharsis, Elysium and circum-Hellas

Mars & Earth





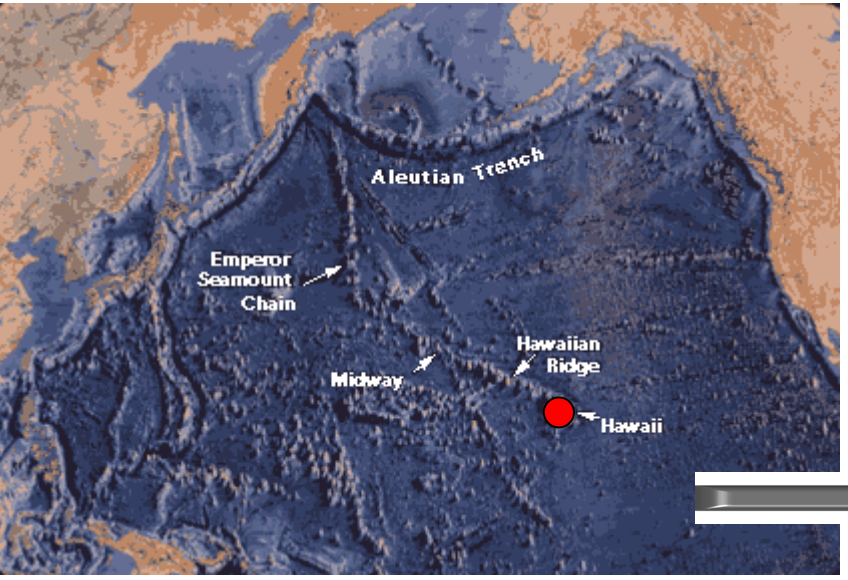
Mauna Loa

height : 5+4 km
base : 150 km

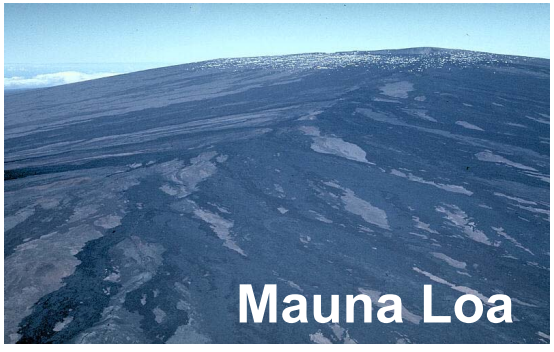
Olympus Mons

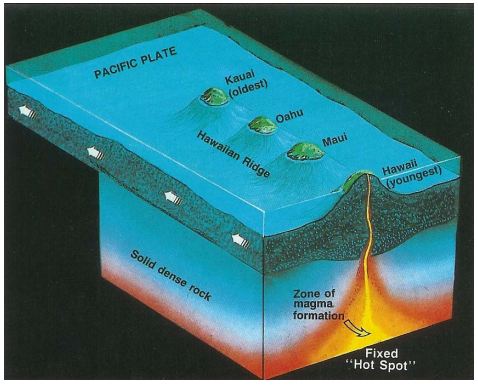
height : 27 km
base : 800 km

Total volume

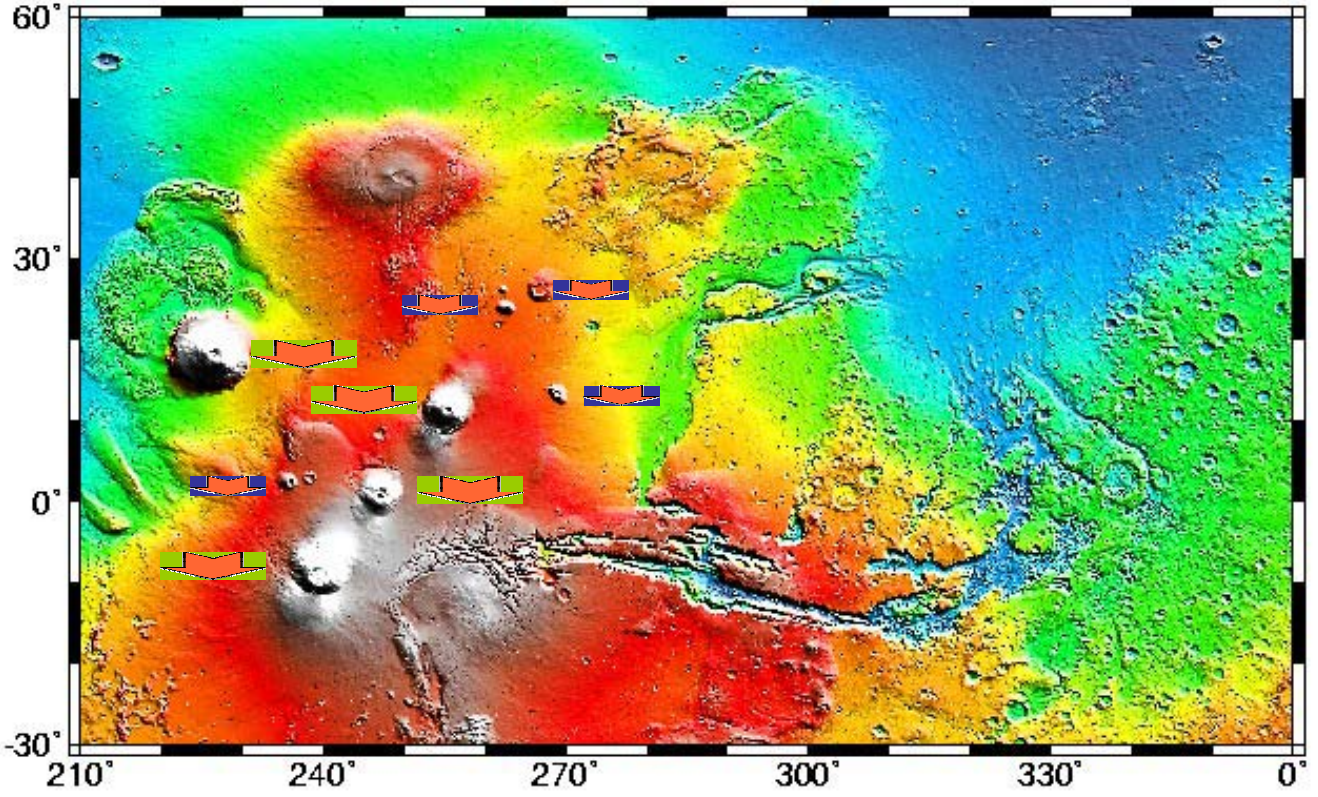


Total volume of Hawaiian hot spot is comparable to that of Olympus





Tharsis region



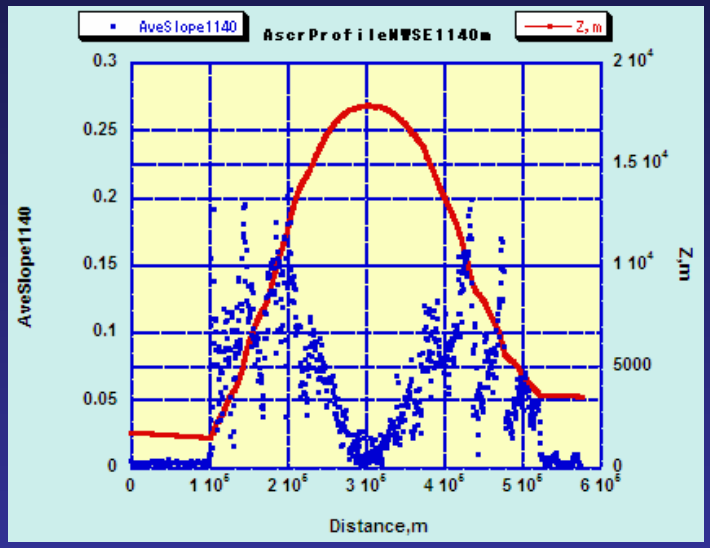
Two types of volcano;

Large shield volcanoes

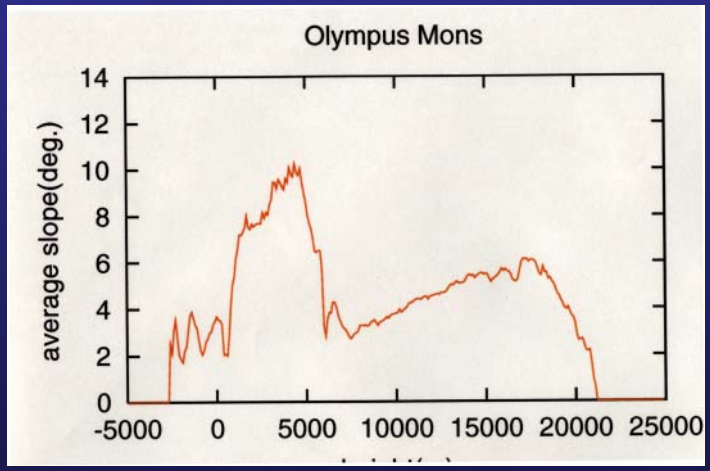
Medium sized volcanoes

Large shield volcano

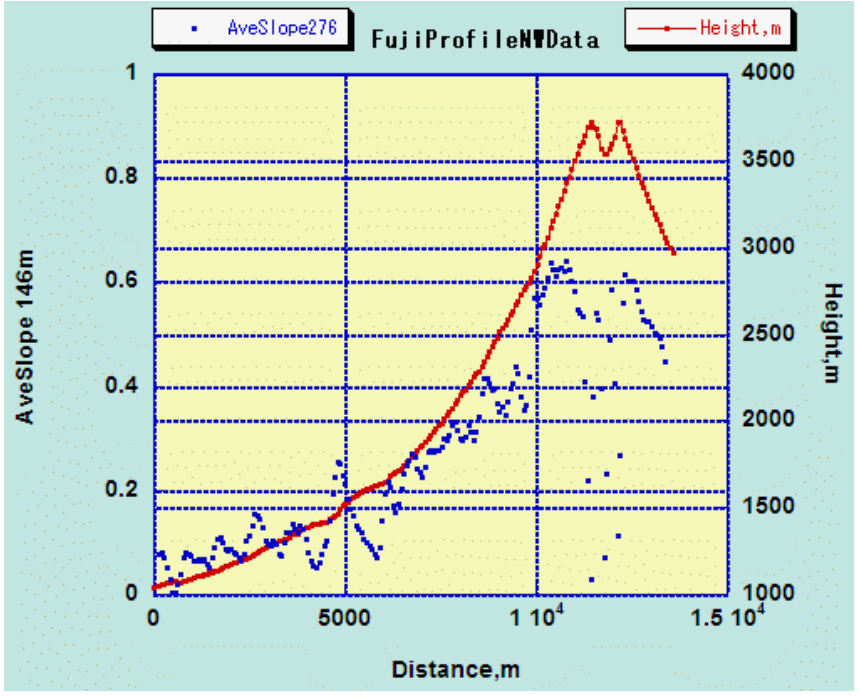
Lava flows

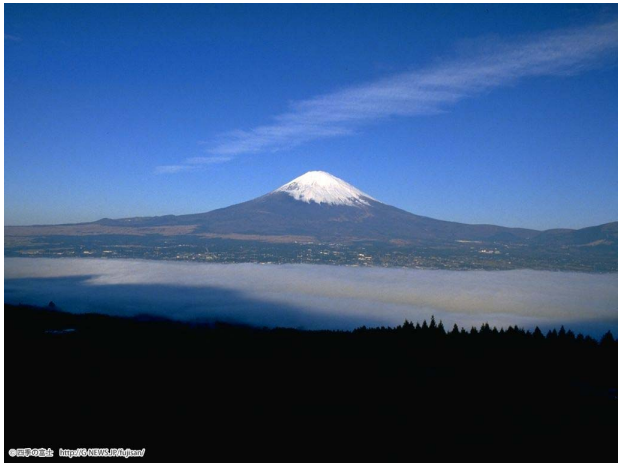


Variable slope



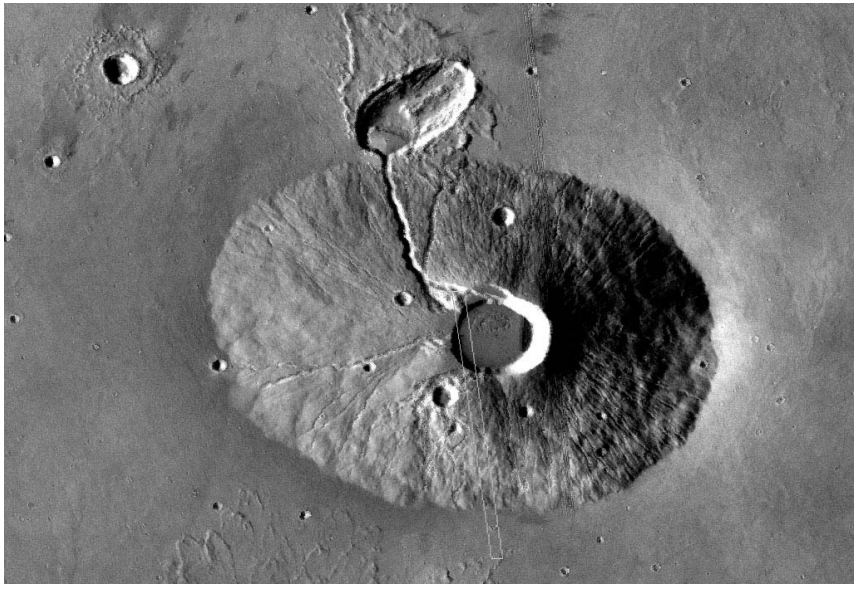
Slope morphology#1 Earth

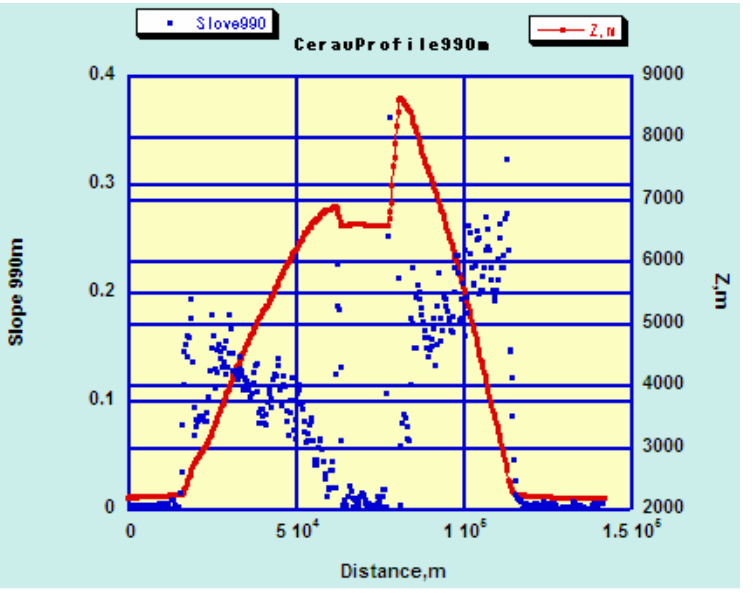


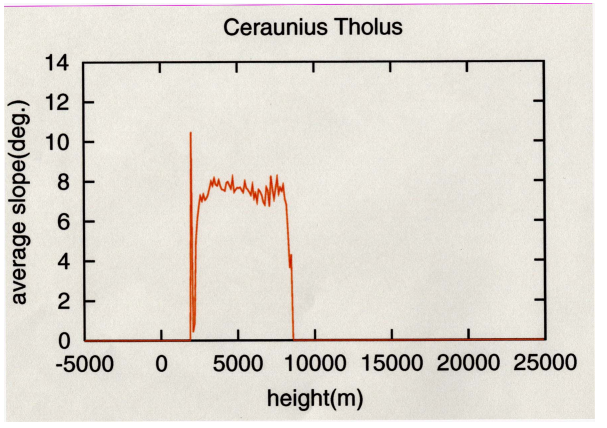


Variable slope type

Ceraunius

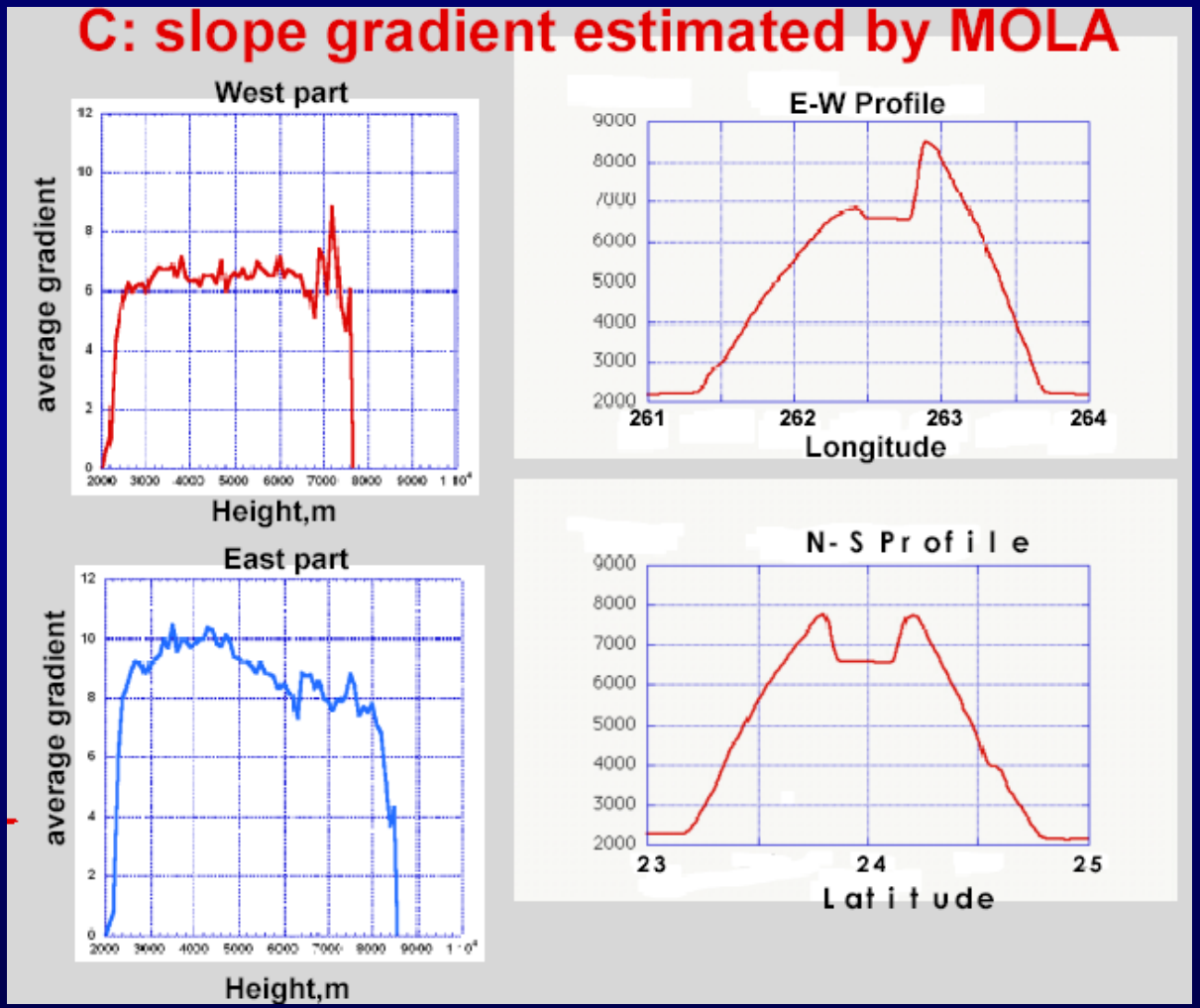






Constant slope type

Ceraunius NS vs EW

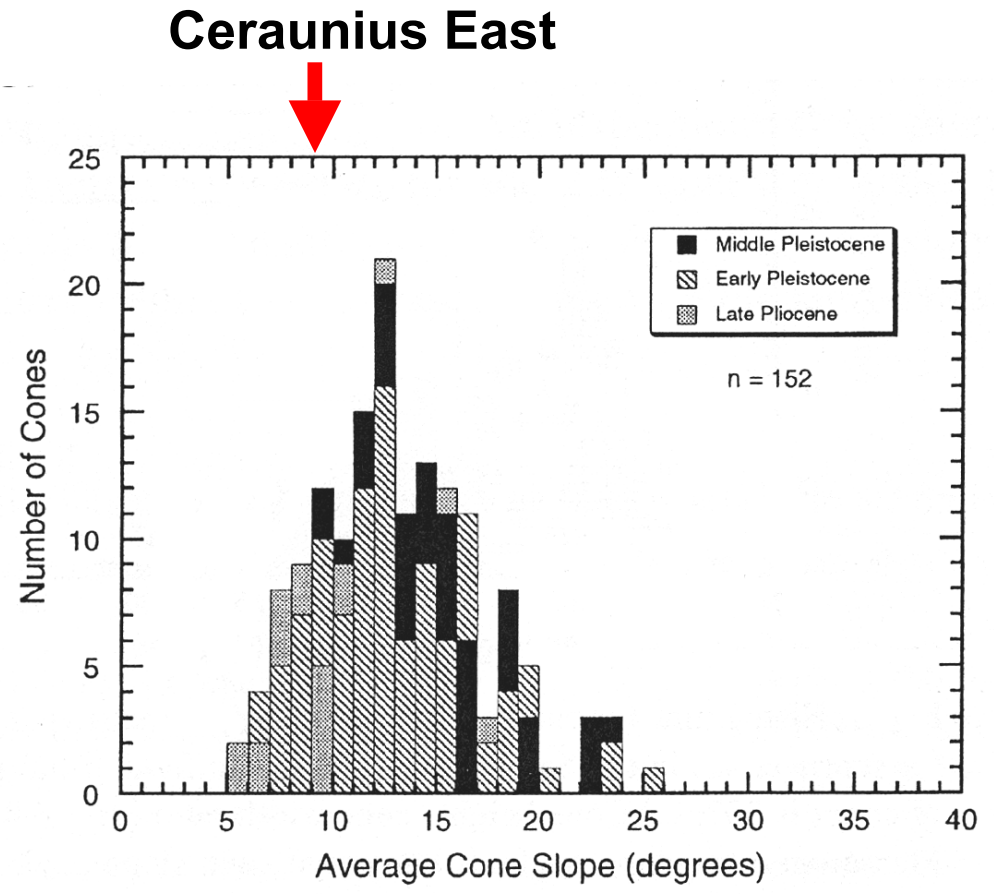


ScoriaCone

- Constant slope (>7 deg.)
- Small size (mostly 5km)

Constant,high slope represents the repose angle of air fall pyroclasts.

Slope of Scoria Cones



Problem

- Does Ceraunius belong to scoria cone?
  - The size is much larger (5km vs. 100km)
- Scoria Cone is formed by air fall deposits.
  - Is it possible to throw pyloclasts to >50km
  - Martian conditions: low atmospheric P & low gravity

If YES, explosive volcanism at the early stage

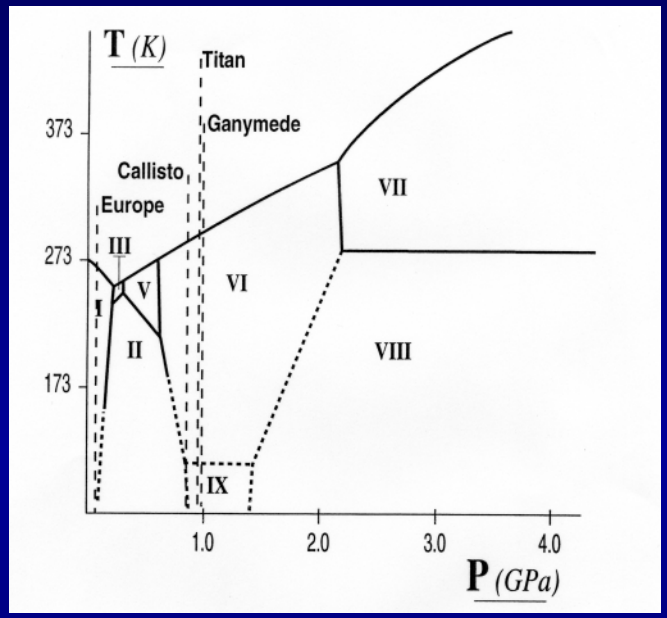
?

Part 3:icy satellites

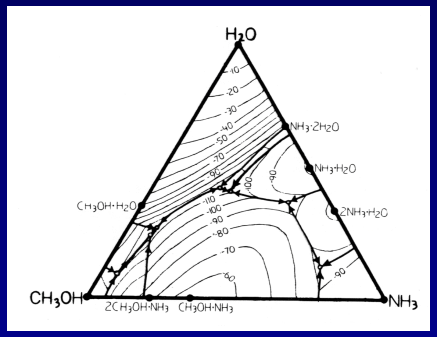
Similarity between Earth and Icy Satellites

- Lithosphere-asthenosphere structure
  - Brittle-ductile transition
- Temperature-sensitive rheology
- Melting relationship
  - Negative & positive slope,eutectic
- Existence of phase changes
  - Negative & positive Clapeyron slopes

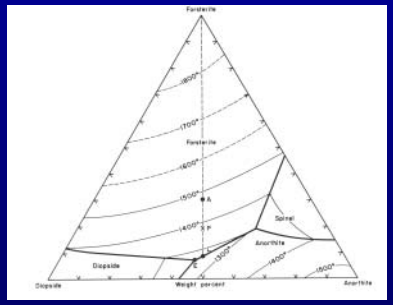
Ice vs. rocks

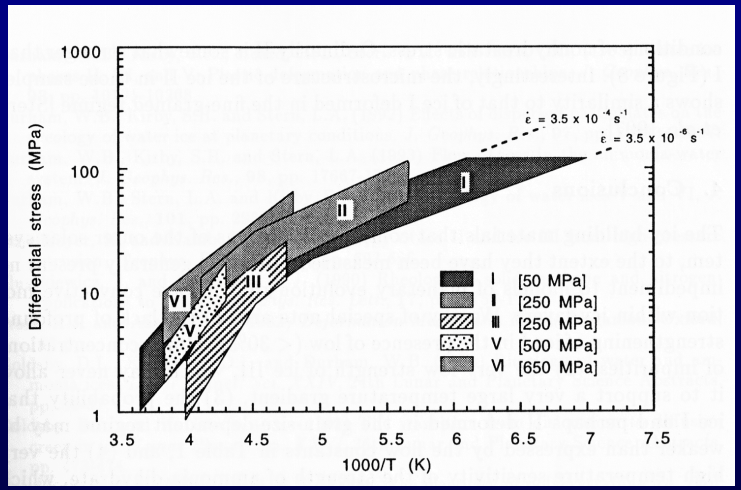


Phase change



Melting relation





rheology

Evolution & size

Basic principle

Heat production & initial heat is proportional to the volume, R^3

Cooling(heat transfer) is proportional to the surface are,R^2

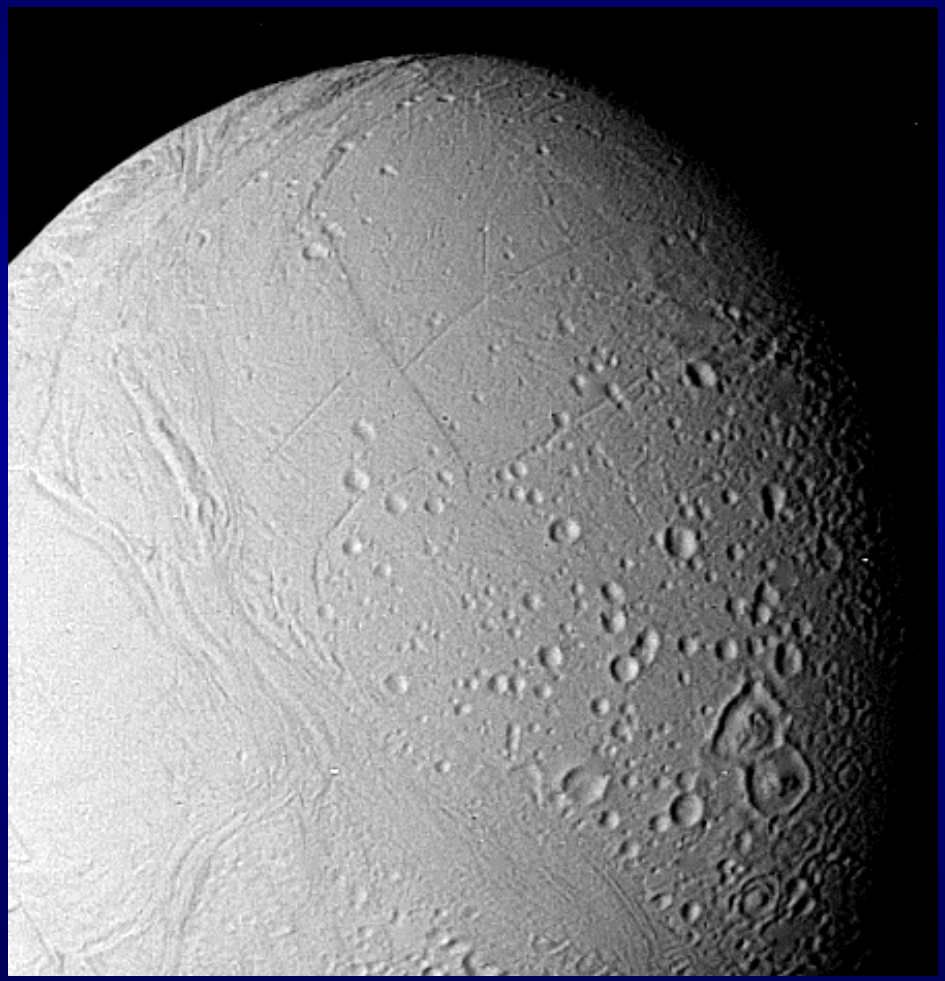
The larger the size, more active the interior.

But there are so many exceptions!

Problem: diversity

- Enceladus (251km, ρ=1.25)
- Moon & Mars has no dynamo because of small size. Then why smaller Ganymede ?
- Why smaller Europa is more active than Ganymede ?

Enceladus (251km 1.24)



Trace of “recent activity” on Enceladus

Surface extension and tectonics

【Europa】 [Sullivan et al. 1998]

Extensional features

- subparallel margins.
- ambient terrain is reconsructive

No compressional features exist

➔ internal expansion.

Stress sources for the tectonics

- Tidal deformation < 0.1 MPa
- Solid-state convection < 0.01 ~ 0.1 MPa

- Tensile strength of ice 1~10 MPa

➔ Insufficient to the tectonics.
There must be other sources.

- Internal differentiation
- Thermal expansion

Both are the processes in the early stage of satellite history,
and should not remain as the present surface features.

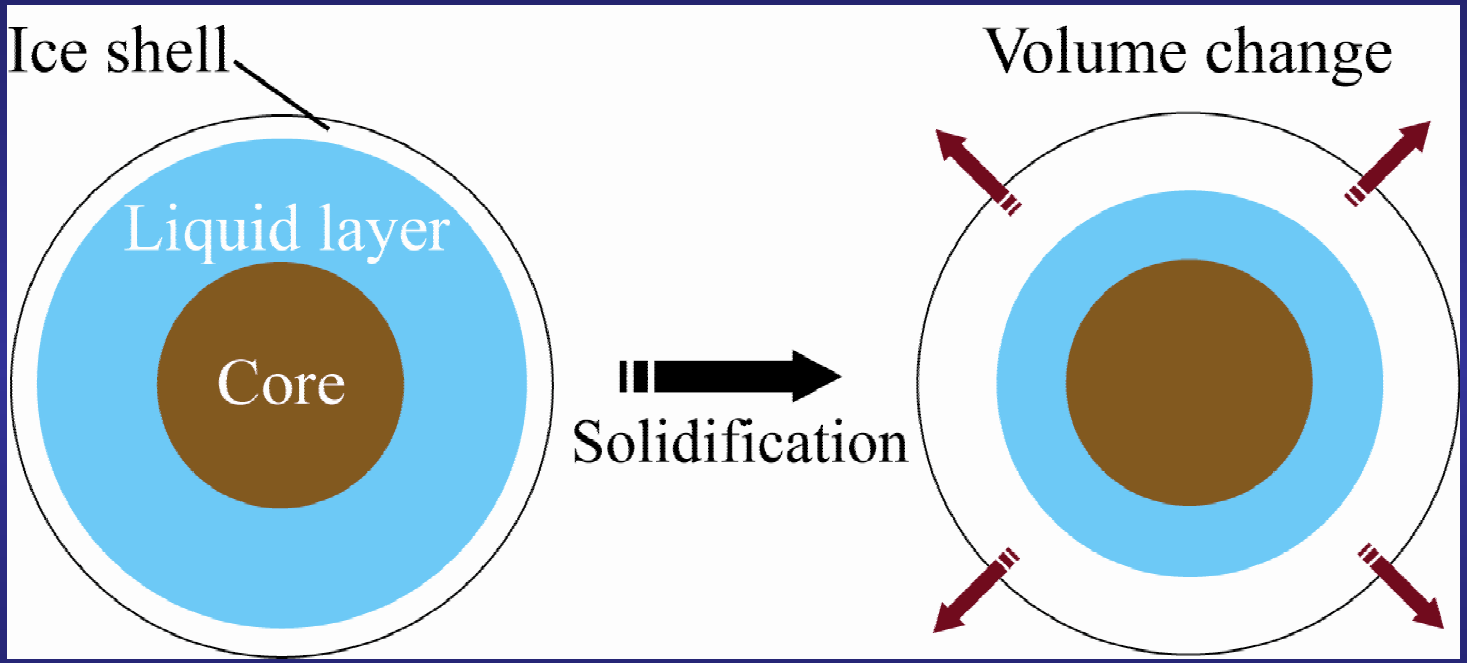
- Solidification of liquid H_2O

ex. Liquid H2O → low-pressure ice ・・・

$$\frac{\Delta V}{V} \approx 10\%$$

solidification and volume chage

Solidification of liquid H_2O



Icy satellites (radius>700km) initially have an ocean.

(e.g. Consolmagno and Lewis [1978], Lunine and Stevenson [1982])

➔ With the satellite cooling, the liquid layer solidifies.

Framework

① Calculation of thermal history

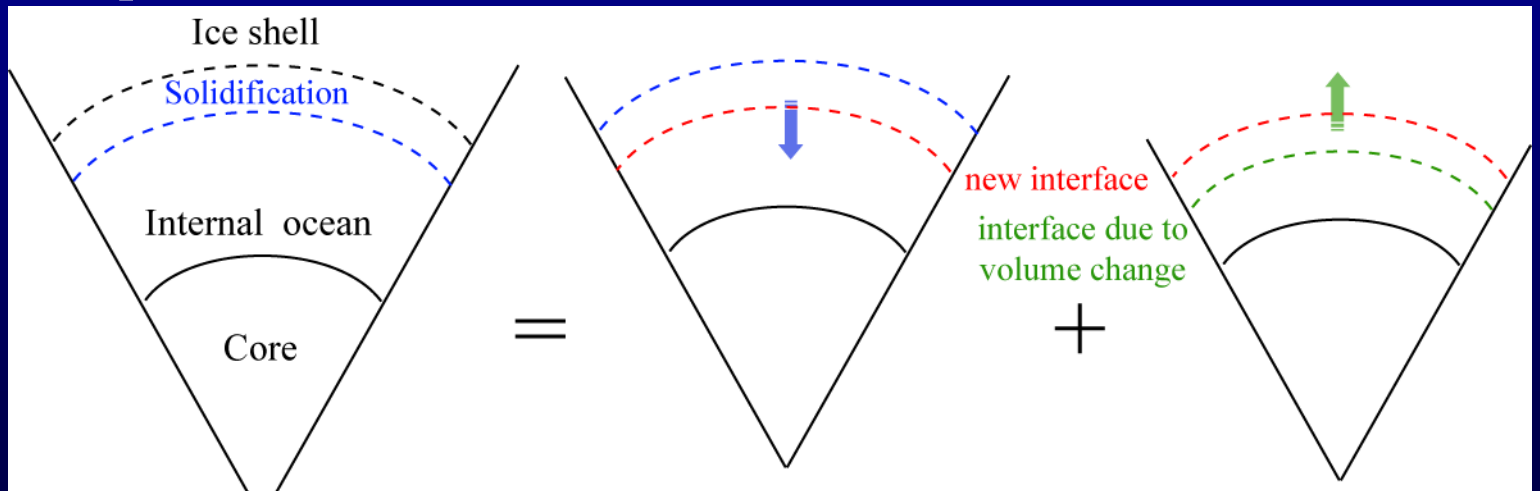
--- Solve the heat transfer equation for each layer numerically.

--- Decide the growth rate of the ice shell.

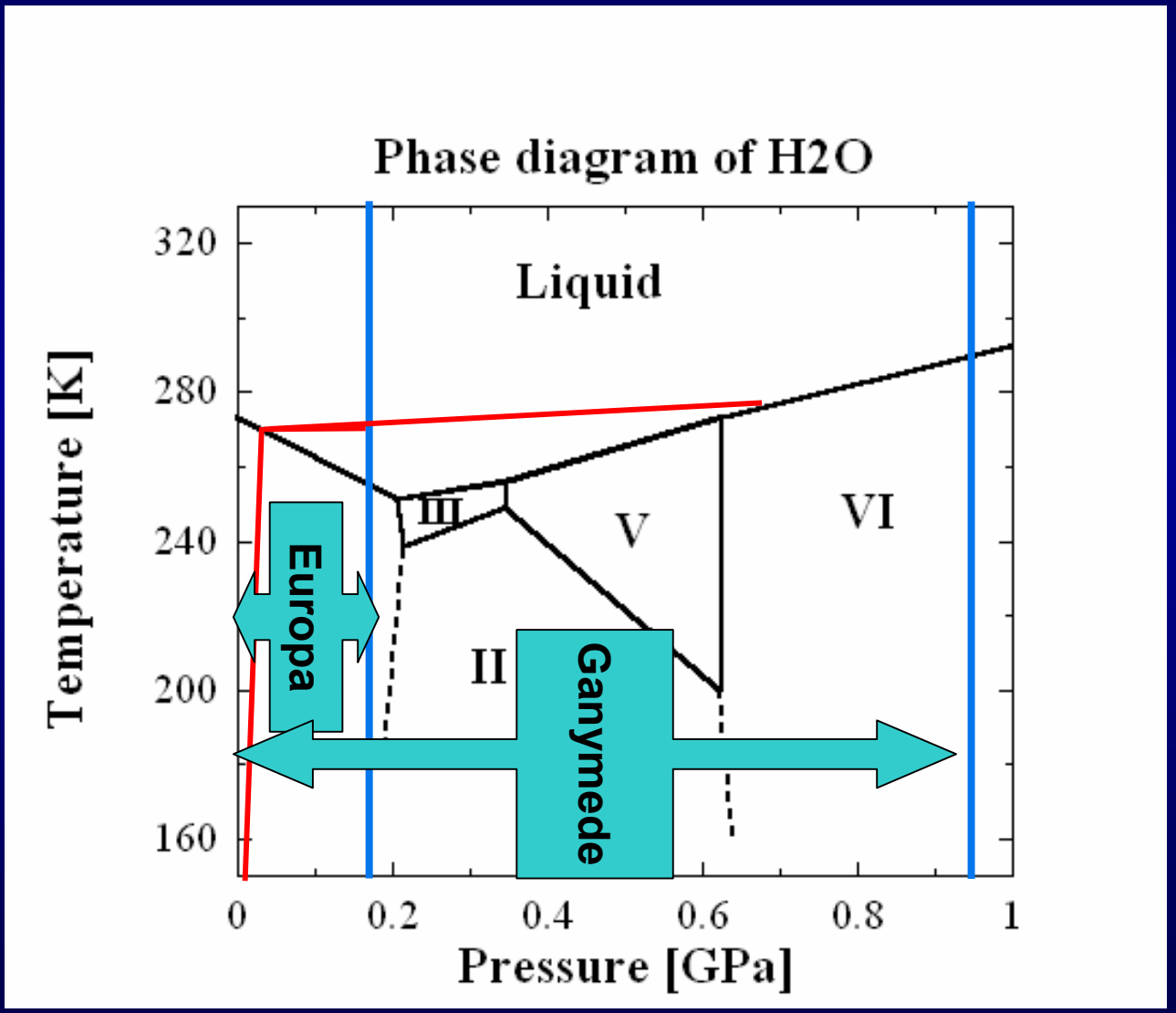
② Evaluation of stress produced in the shell

--- From the volume of solidification per unit time, find the position that balanced the pressure at the phase boundary.

--- Calculate the stress field in the viscoelastic ice shell and its temporal variation.

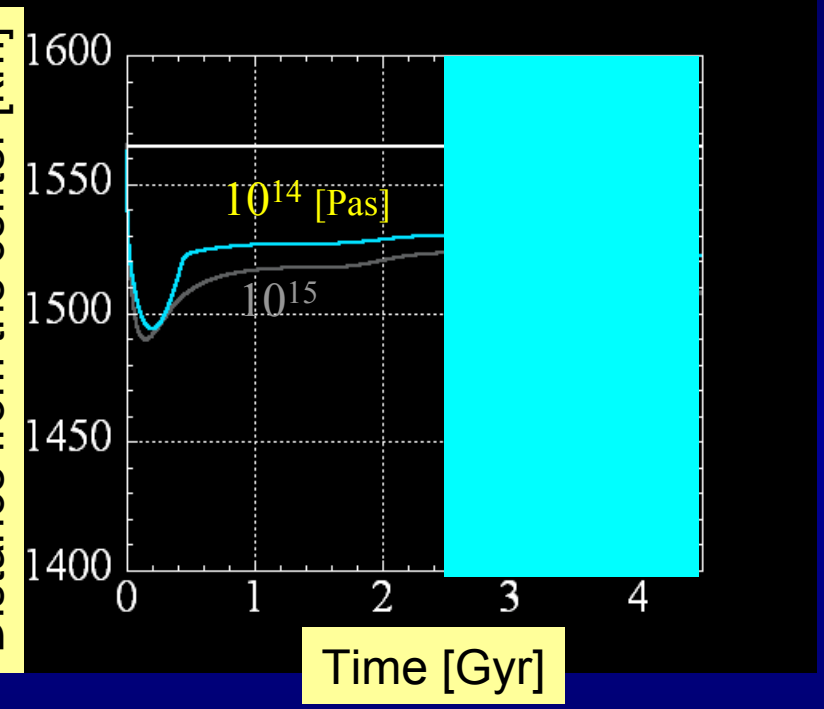


Solidification of liquid layer



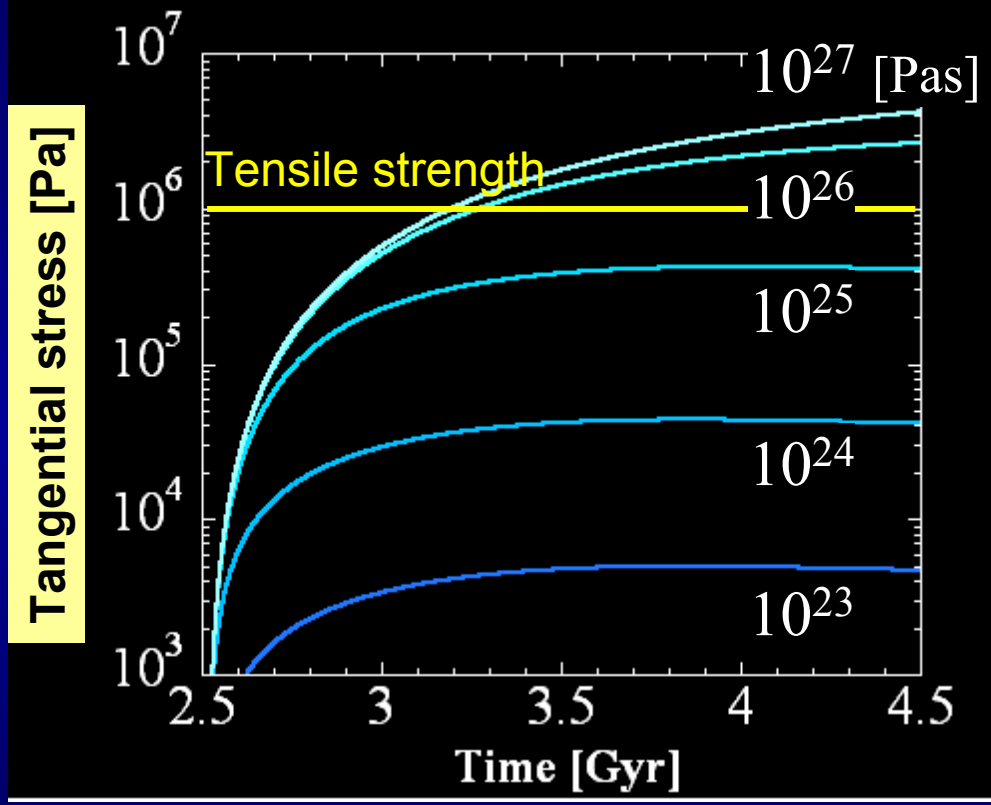
Results （Europa）

Evolution of icy plate



$\eta_m = 10^{14}$ [Pas]

Evolution of surface tensile stress



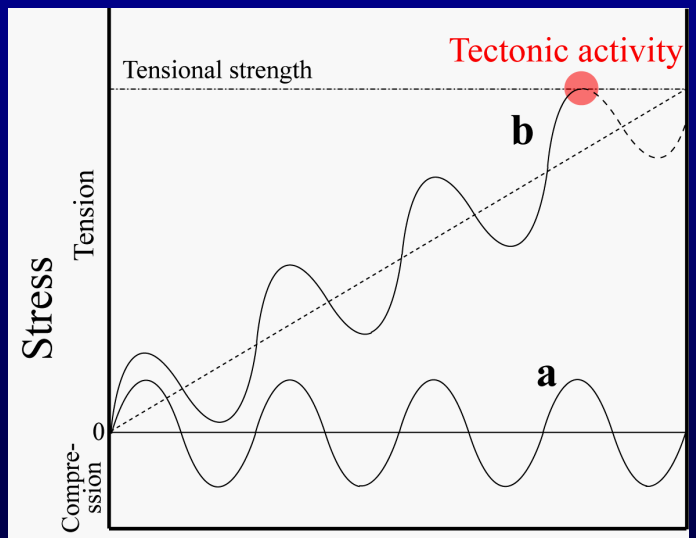
As a function of surface viscosity

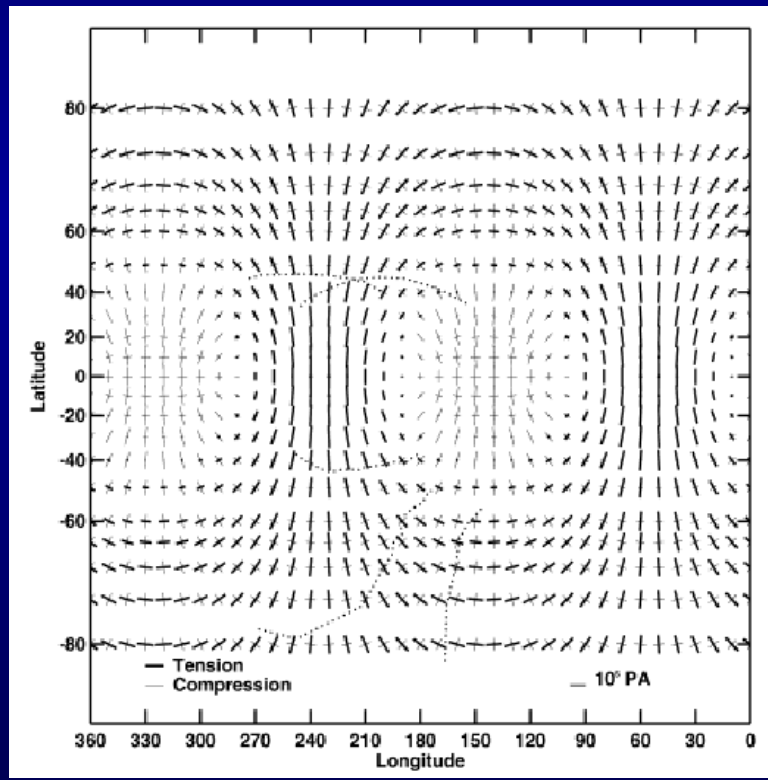
result: stress sources

stress sources

solidification・・・isotropic
surface pattern indicates tidal stress

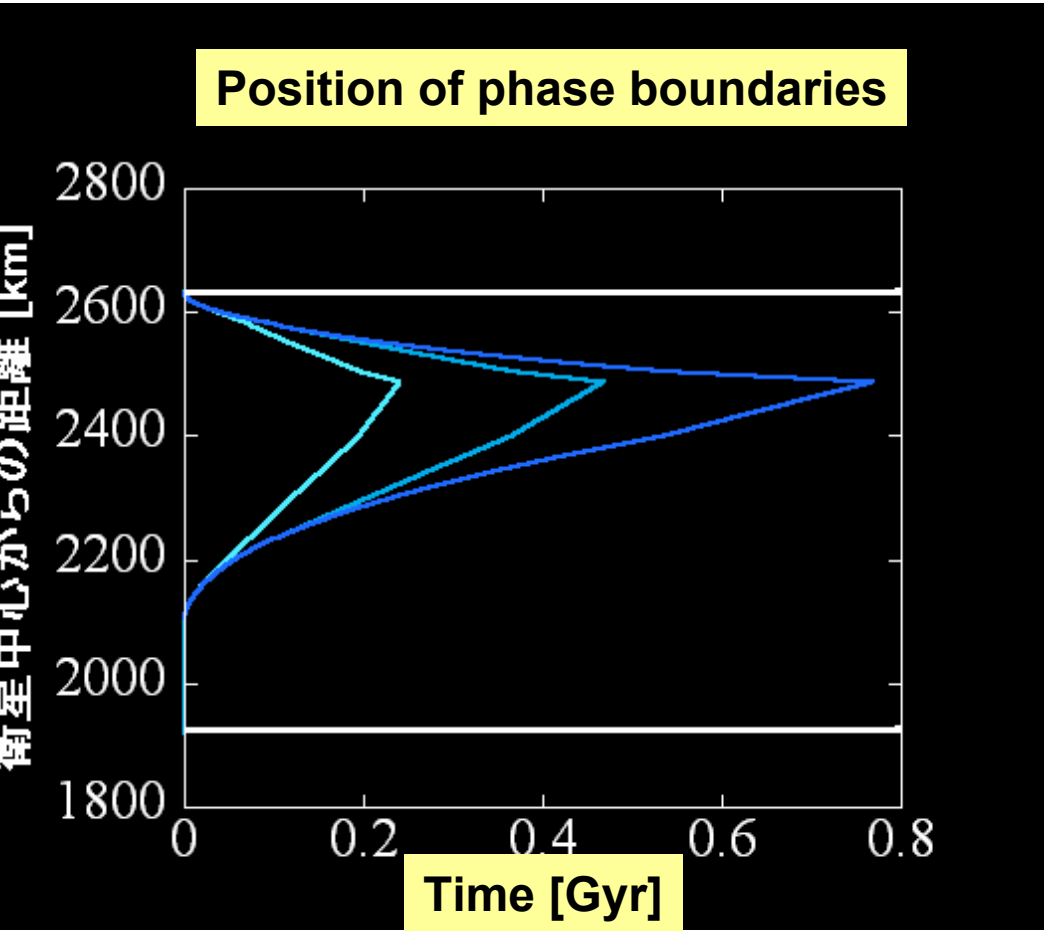
- background stress level
  ・・・・・・solidification
- triggering fracture
  ・・・・・・tidal stress





[Greenberg et al. 199

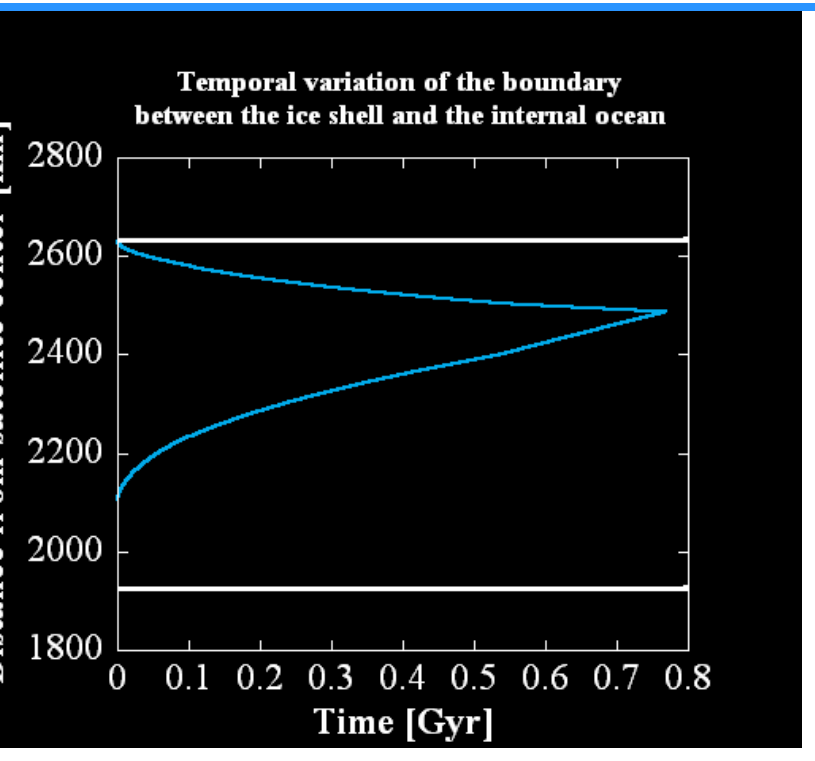
Ganymede



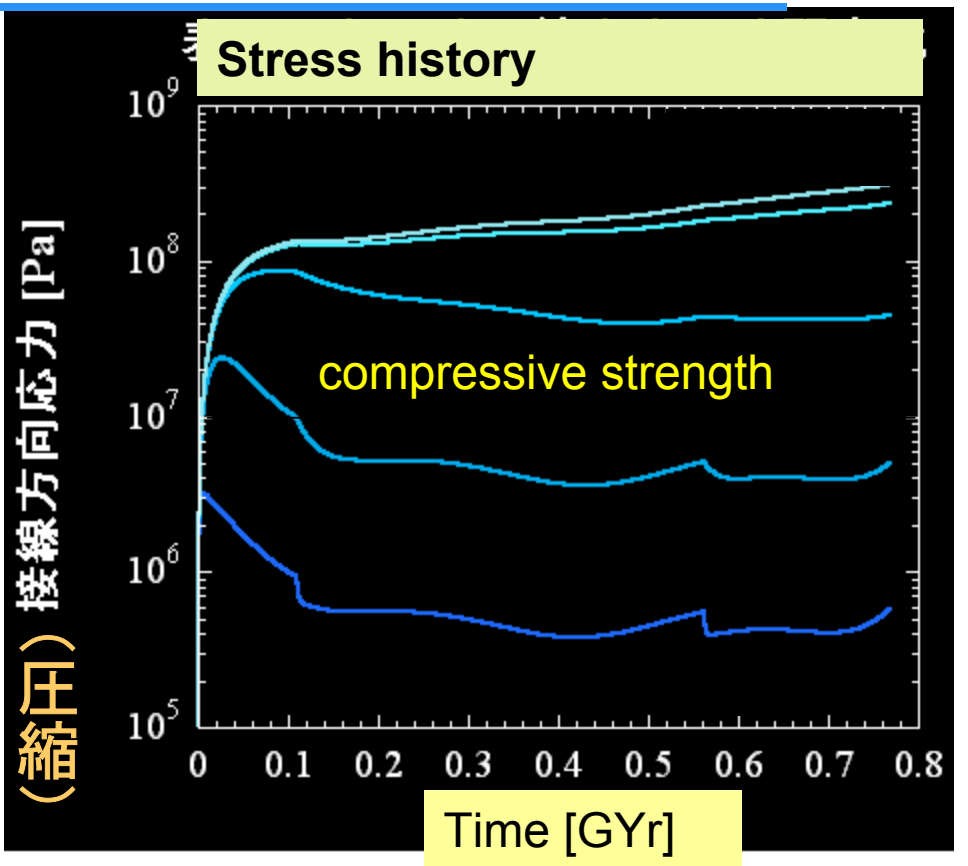
1. Growth of high P ice to induce adiabatic gr.

2. Weak convection during growt

Stress history Ganumede

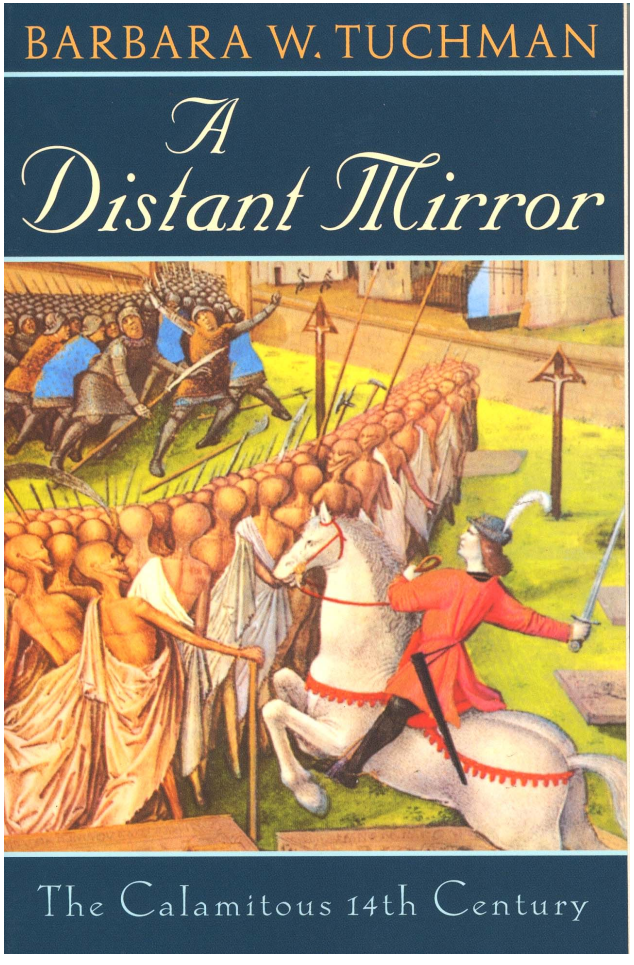


Visco-m = 10^{15} [Pas]



Terrestrial magma ocean

A Distant Mirror



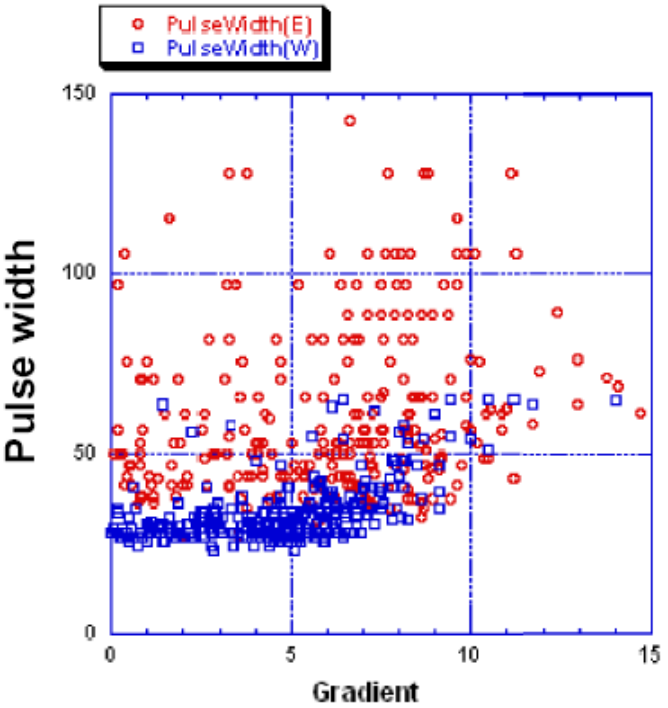
This book deals with the Black-Death plague of 1348-50, which killed 1/3 of people lived between Istanbul and Iceland.

Comparative planetology

井の中の蛙(ino nakano kawazu): **a frog who lives in a small pond can not recognize whole world. As for the frog the world is just his pond.**

If we study the Earth without diverse knowledge of planets & satellites, we are unconsciously constrained by the Earth's situations. We may miss essential part. By placing the Earth in diverse realm of planets & satellites, we can reach deeper understandings.

PulseWidth


PulseWidth(E)
PulseWidth(W)
150
100
50
0
Pulse width
0
5
10
15
Gradient

PulseWidth2