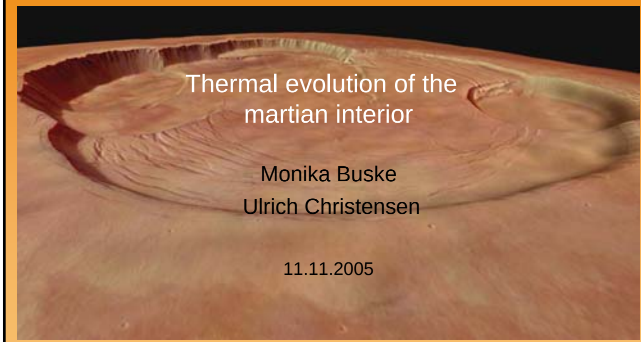
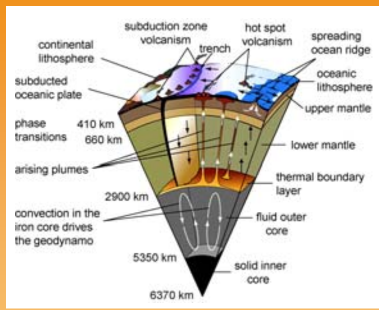


Thermal evolution of the martian interior

Monika Buske
Ulrich Christensen

11.11.2005

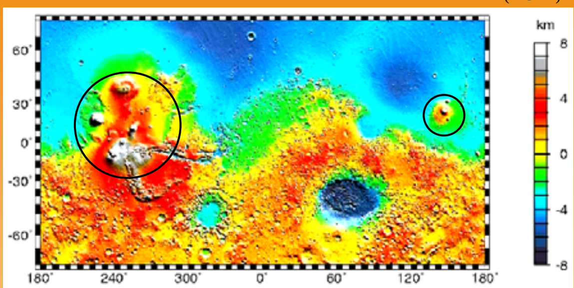
Internal structure of terrestrial planets



pressure and mechanical stress deform the solid mantle material:
➔ creeping motion of rocky material (“very viscous fluid”)
➔ convective flow in the mantle

Volcanism on Mars

(MOLA)

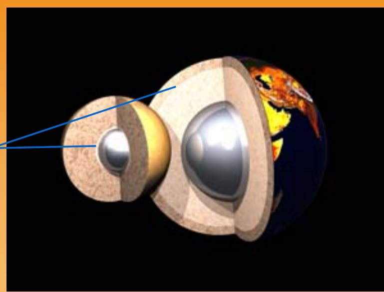


Volcanic structures are concentrated in **only two** areas:
Tharsis region and Elysium region
↓
Convection pattern in Mars is dominated by a **few strong plumes**

Comparison of the interior structure of Mars and Earth

change in mineral structure:

phase transition
(γ-spinel – perovskite)
↓
weakens convection



- on Mars the convection weakening phase transition might exist close to the core mantle boundary (CMB)
- there it impedes thermal instabilities or small plumes to arise

Questions addressed by thermal evolution models

- How does the convection pattern change during the thermal evolution of the planet?
  Do plumes still exist today? How many are there?
- How does the heat flux at the CMB evolve with time?
  How long can a thermally driven dynamo work?
- Does Mars have an inner core?
- How thick is the martian lithosphere and how did it grow with time?

. . .

Model for mantle convection

3-D spherical model for convection of an incompressible fluid

- conservation of energy:

  advection, diffusion, internal heating (^{238}U, ^{235}U, ^{232}Th, ^{40}K)

- conservation of momentum (Stokes equation)

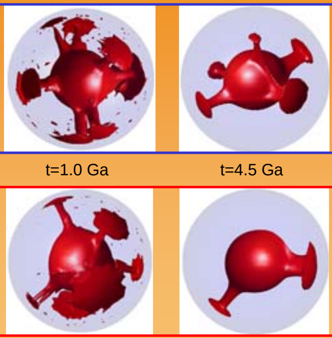
  - viscous forces, viscosity: $\eta(r) = \eta_0 \cdot \exp\left(\frac{E + pV}{\langle T \rangle}\right)$

  - buoyancy forces due to thermal expansion and phase boundary deflection

Isosurfaces of the temperature field

without a phase transition

several concentrated plumes

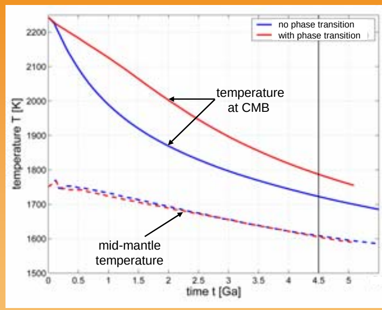


t=1.0 Ga   t=4.5 Ga

including a phase transition

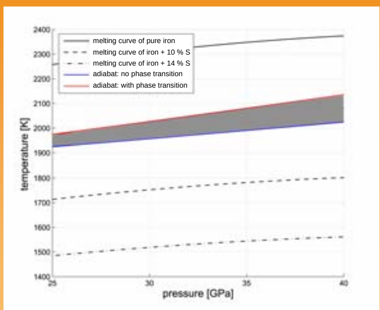
reduction to only two plumes

The influence of the phase transition on the cooling rate of the core and the mantle



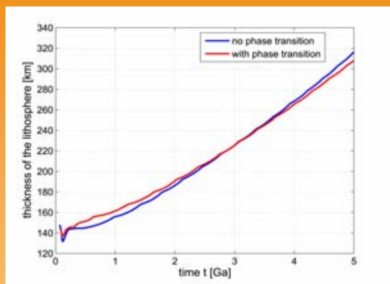
- lower cooling rate of the core including the phase transition
- smaller effect on the temperature at mid-depth

Existence of a solid inner core in Mars ?



- if the core contains some sulphur then the temperature in the core will be too high to freeze out a solid inner core

The thickness of the lithosphere



- lithosphere: velocity vanishes because of high viscosity
- phase transition hardly influences thickness of lithosphere
- thickness increases from less than 150 km to about 290 km after 4.5 Ga

Conclusions:

- After 4.5 Ga the temperature contrast at the CMB is sufficient to allow plume-like structures to arise.
- The spinel-perovskite transition close to the CMB reduces the number of plumes also when a variable viscosity is taken into account.
  The reduction could explain the strong concentration of young volcanism on Mars.
- The core cools down slower in the presence of the phase boundary. In both cases the temperatures are too high to freeze out an inner core.
- The variable viscosity allows to simulate the growth of the lithosphere. After 4.5 Ga its thickness is about 290 km.