Global Partial Melt Zone in Mars: Origin for Recent Volcanism?

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Cooling of a One-Plate Planet

- Present thermal evolution models suggest
  - Average upper mantle temperature above melting temperature in early evolution ➔ strong early crust formation
  - Present-day average mantle temperature below melting temperature
  - Present-day melt due to lateral temperature variations, e.g. plumes?

‘Stable‘ Plume Volcanism?

- Thermal boundary layer (tbl) is necessary e.g. at the bottom of mantle
  - Cooling of the core → rapid disappearance of tbl
- Stability of plumes possible with phase transitions close to core-mantle boundary
  - Phase transition may be not existent
  - Models with temperature-dependent viscosity do not show the stabilizing effect of plumes (Roberts and Zhong, 2004)

Alternative Model

- Origin of recent volcanism a consequence of the heat transport through the upper non-convecting layer?

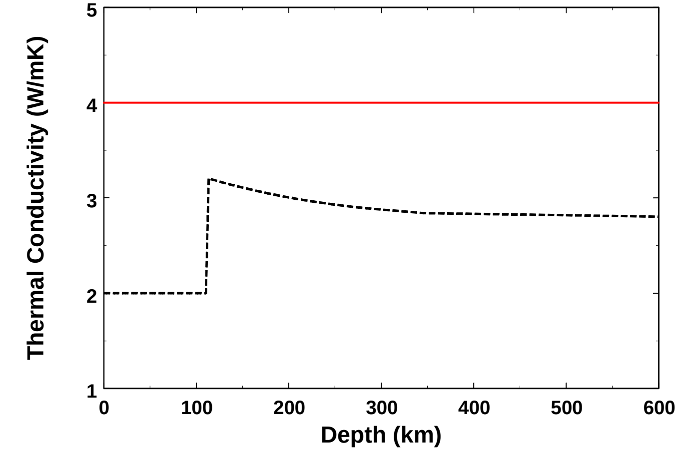
Thermal Conductivity

- Mantle material
  - Dependent on temperature and pressure
    ~ 3 – 4 W/(mK)

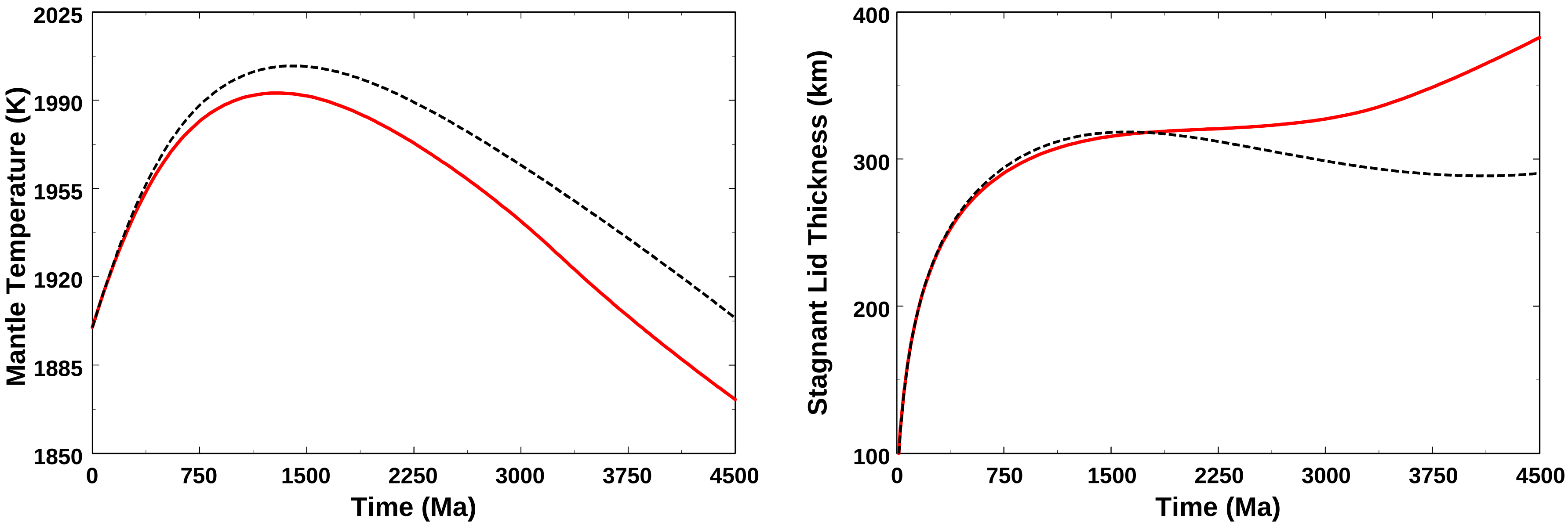
- Crustal material
  - ‘Compact‘ crust (e.g. basalt and andesite) ~ 2 W/(mK)
  - Fractured surface layer 0.01 – 0.5 W/mK

Model

- Stagnant lid parameterization
- Crust formation with redistribution of radioactive elements
- Composition, temperature- and pressure-dependent thermal conductivity



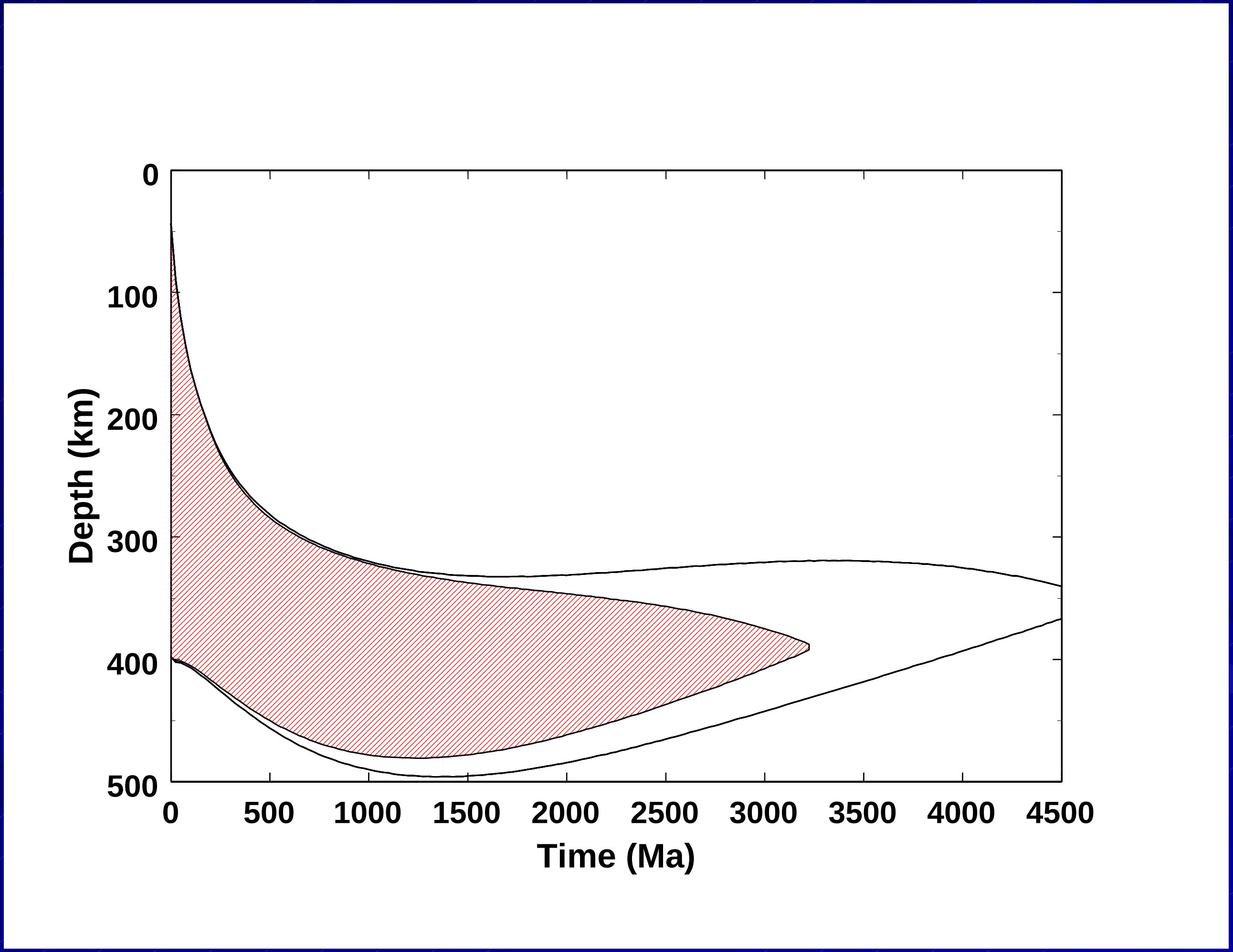
Results I



K = 4 W/(mK) in crust and mantle

K = 2 W/(mK) in crust and K(T,P) in mantle

Results II



0
100
200
300
400
500
Depth (km)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Time (Ma)

Lateral Variations in Crustal Thickness

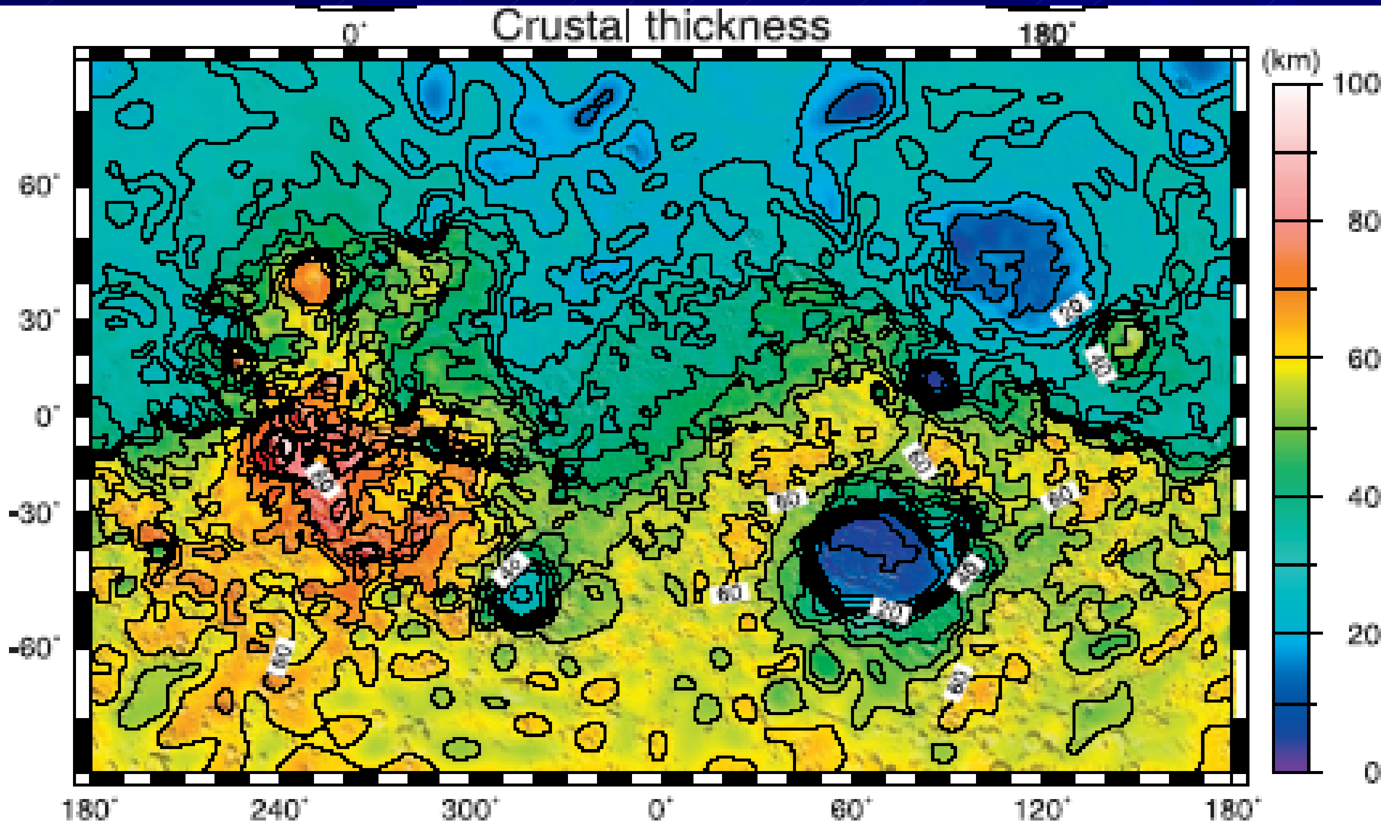
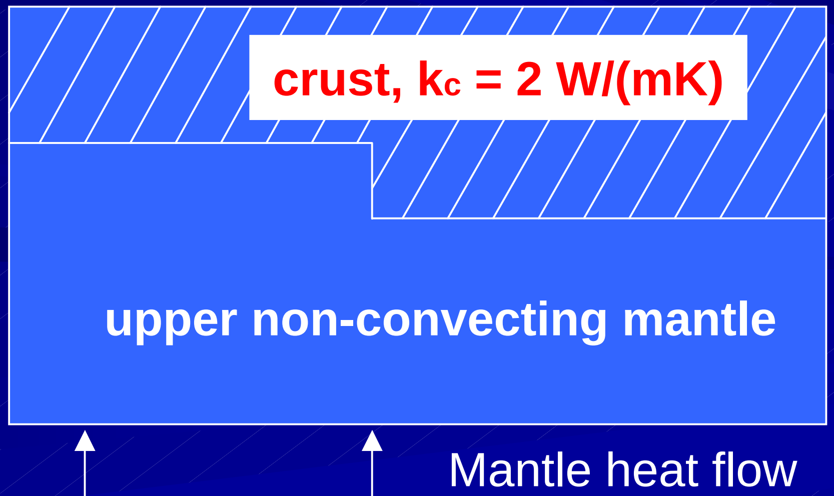


Figure 7. Degree 1-85 crustal thickness model (5 km contours), in Mercator and polar stereographic projections as in Figure 3.

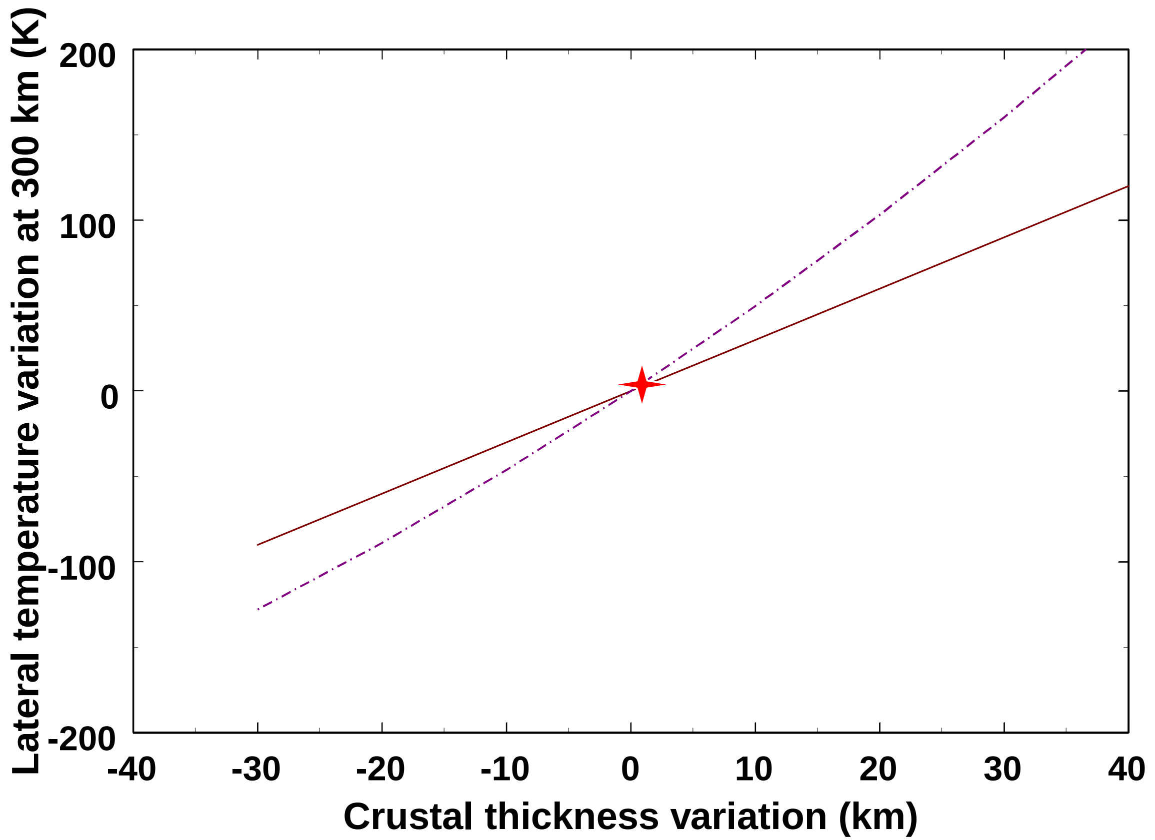
Neumann et al, 2004

Expected Lateral Temperature Variations at 300 km Depths

- Estimate from simple assumtions
  - Steady state heat conduction
  - No lateral heat flow
  - Constant mantle heat flow



Results



Lateral temperature variation at 300 km (K)
200
100
0
-100
-200
-40
-30
-20
-10
0
10
20
30
40
Crustal thickness variation (km)

Conclusions

- Recent volcanic activity difficult to explain with present-day plume(s)
- Low conducting crust is responsible for recent volcanic activity
  - Zone with partial melt in about 300 km depth can be the source region
  - Lateral thickness variations in the crust increase locally the melt content and may favour the rise of melt in those regions (e.g. Tharsis)