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

![Graph showing thermal conductivity vs depth](image)
Results I

- Mantle Temperature (K)
- Stagnant Lid Thickness (km)

- \( K = 4 \text{ W/(mK)} \) in crust and mantle
- \( K = 2 \text{ W/(mK)} \) in crust and \( K(T, P) \) in mantle
Results II

![Graph showing the relationship between time (Ma) and depth (km). The graph includes a shaded area and several lines, indicating changes over time.]
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 assumptions**

- Steady state heat conduction
- No lateral heat flow
- Constant mantle heat flow

**Crust,** $k_c = 2 \text{ W/(mK)}$

**Upper non-convecting mantle**

Mantle heat flow
Results

![Graph showing the relationship between lateral temperature variation at 300 km and crustal thickness variation](image)

- Lateral temperature variation at 300 km (K)
- 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)