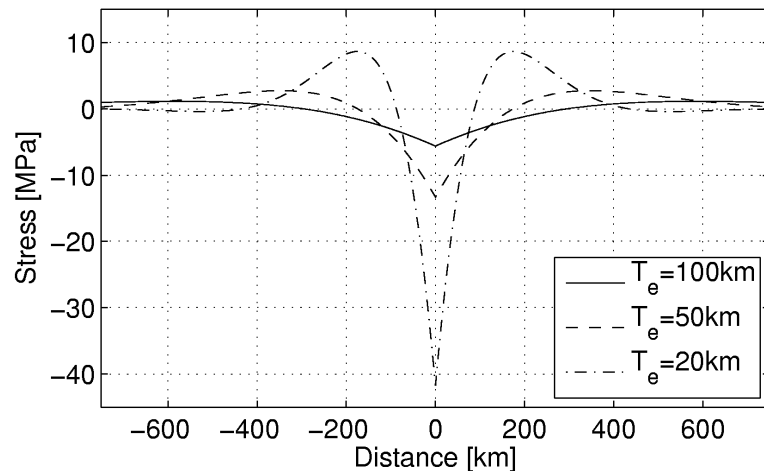
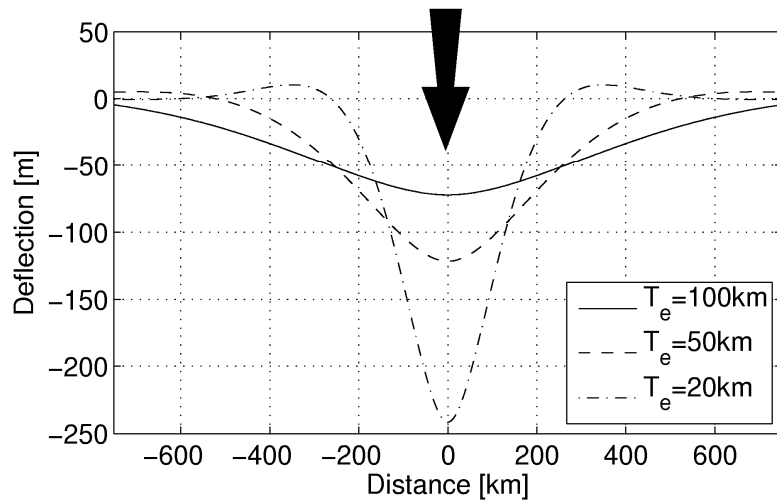


Tectonics on a one Plate Planet: The Spatial Variability of the Martian Elastic Lithosphere Thickness and a Comparison with Earth's Continents

M. Grott¹, D. Breuer¹

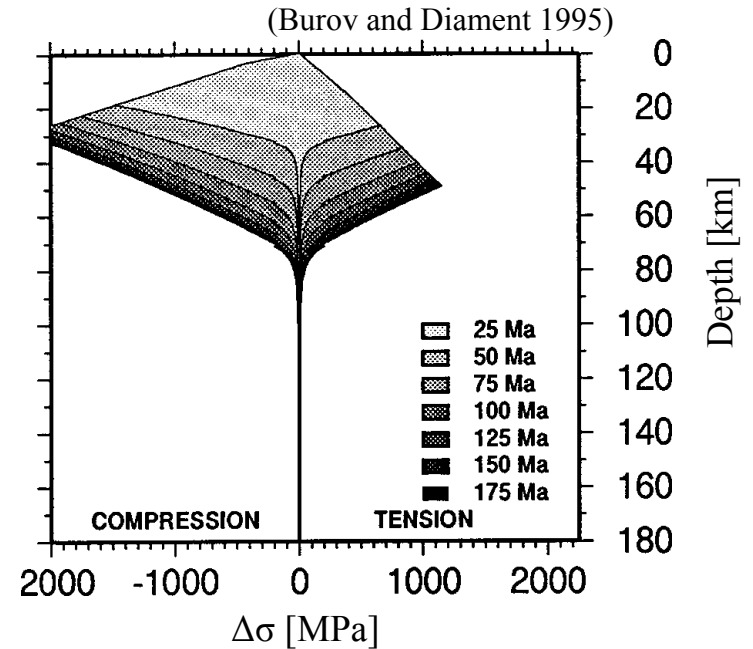
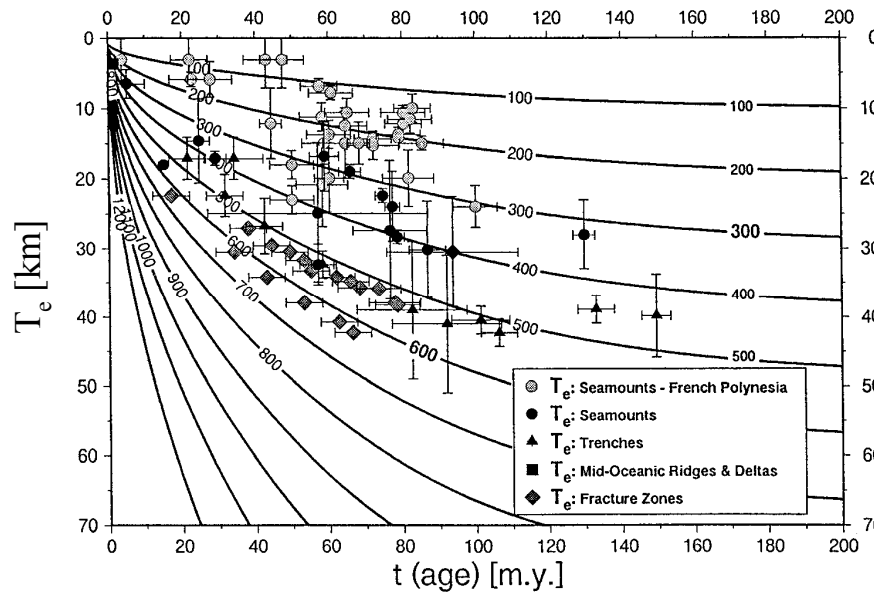
¹Institute of Planetary Research, German Aerospace Center (DLR)

Effective Elastic Lithosphere Thickness



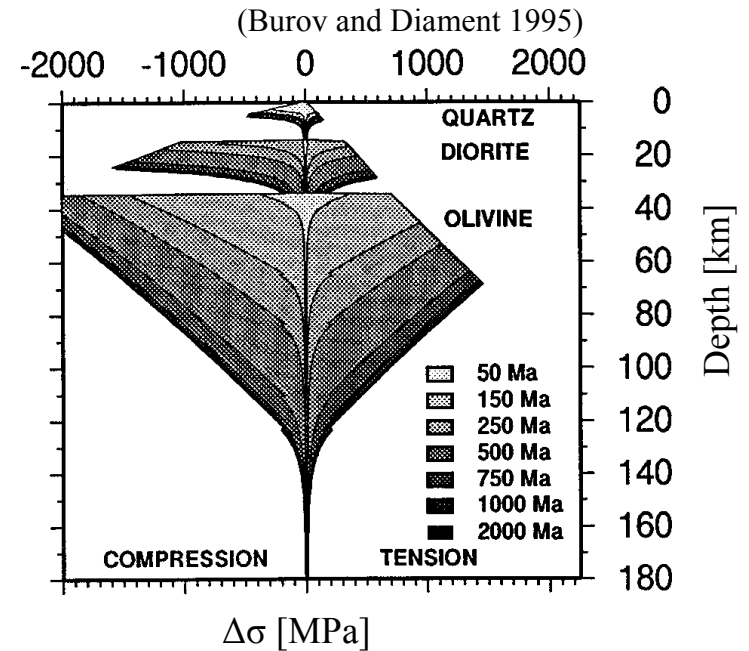
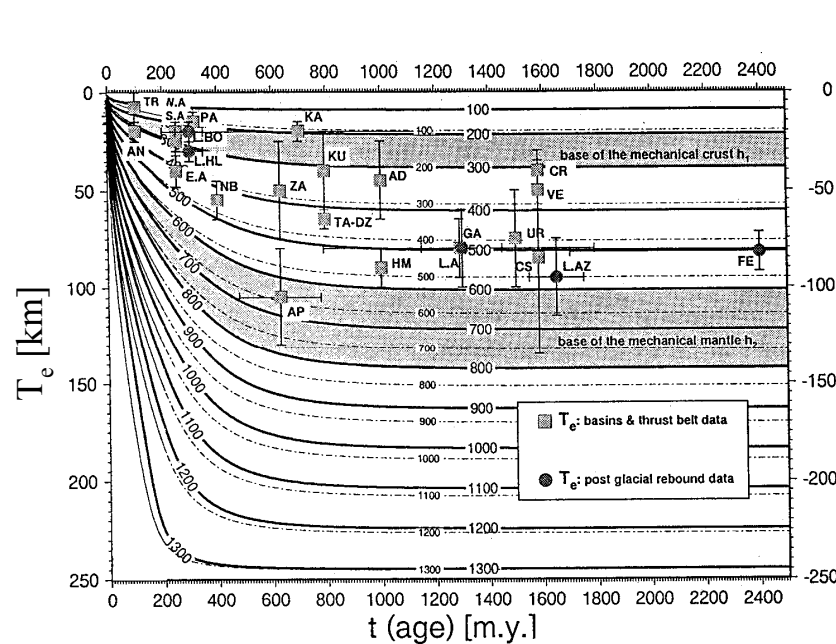
- T_e determines the response of an elastic plate to loading, i.e.:
 - deflection wavelength
 - deflection amplitude
 - stress distribution
- T_e can be estimated by modeling gravity and/or topographic data

Elastic Thickness – Earth's Oceans



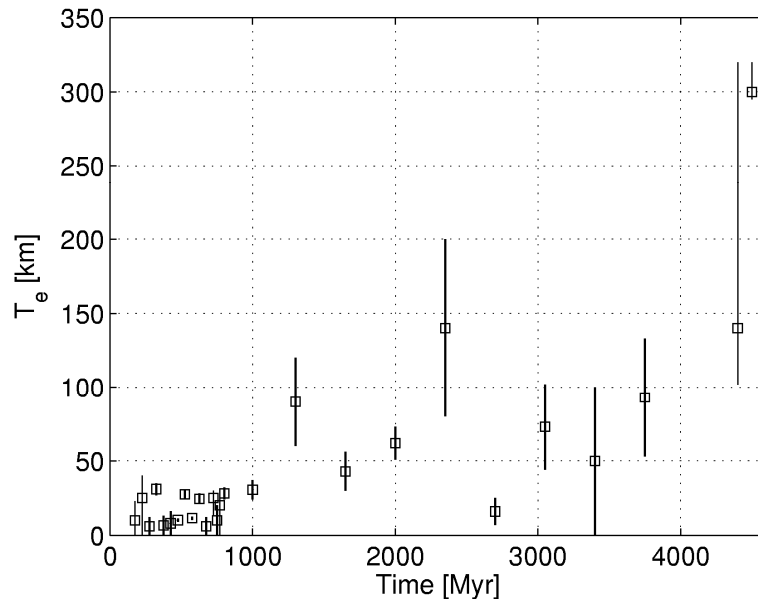
- T_e in the oceans is described by a single isotherm
- Oceanic lithosphere has a single-layer rheology
- T_e grows as the lithosphere cools
- T_e in the oceans has a unimodal distribution

Elastic Thickness – Earth's Continents



- T_e on the continents is not described by a single isotherm
- Continental lithosphere has a multilayer rheology
- Decoupling depth for $t > 750$ Myr is 35 – 40 km
- T_e on the continents has a bimodal distribution

Elastic Thickness Estimates - Mars



Time	T_e
100-800 Myr	16±9 km
600-900 Myr	19±12 km
800-1200 Myr	30 km
900-2400 Myr	84±42km
1200-4500 Myr	78±53 km

- T_e during the Noachian / Early Hesperian ~ 15 km
- T_e during the Amazonian between 30 and 300 km
- General trend follows planetary cooling *but*
- Large T_e variations in the Amazonian

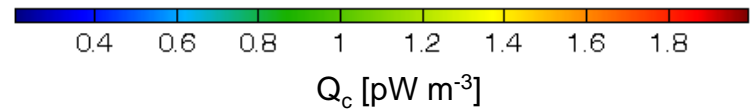
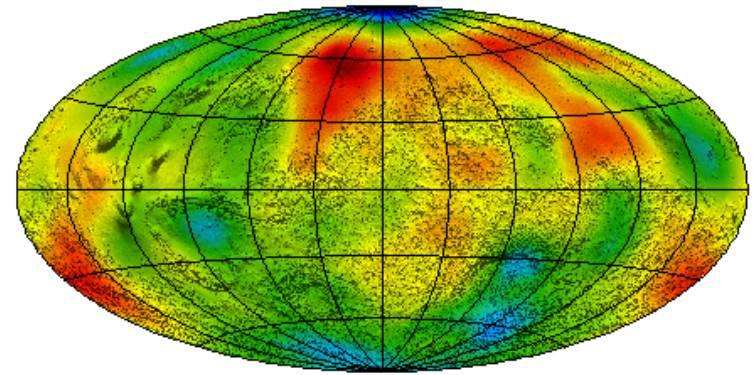
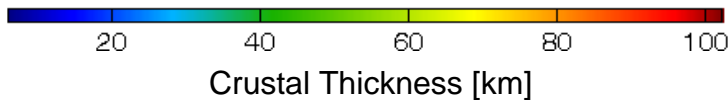
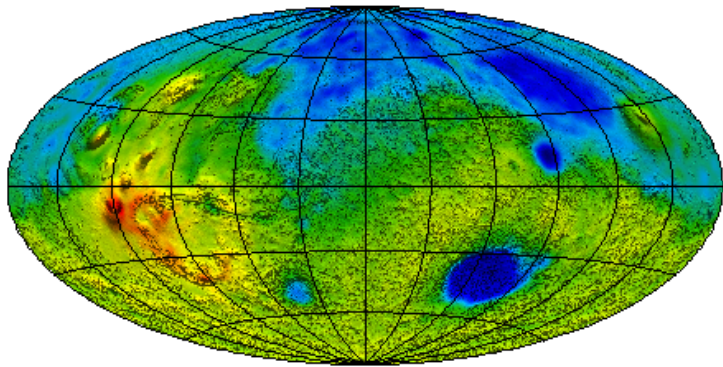
Amazonian Elastic Thickness Estimates

Feature	Age	T_e [km]
North Pole	Recent	>300
South Pole	Recent	>275 >102
Olympus Mons	Amazonian	93 ± 40
Ascraeus Mons	Amazonian	2 – 80 105 ± 40
Pavonis Mons	Amazonian	<100 >50
Arsia Mons	Amazonian	<35 >20

- T_e at the north pole is > 300 km
- T_e at the south pole is not well constrained
- T_e at the volcanoes ranges from ~30 km to ~140 km

- Small T_e at the volcanoes *may or may not* be connected to recent volcanic activity

Lithospheric Modeling – Spatial Heterogeneity



- Do not consider hot spots
- Use constant background heat flow F_l and lid thickness D_l
- Include varying crustal thickness [Neumann et al. 2004]
- Include varying abundance of HPE [Taylor et al. 2006]

Modeling – Lithospheric Temperature Profile

- $D_l(t)$ and $F_l(t)$ are taken from thermal evolution models
- Calculate mantle and surface heat flow:

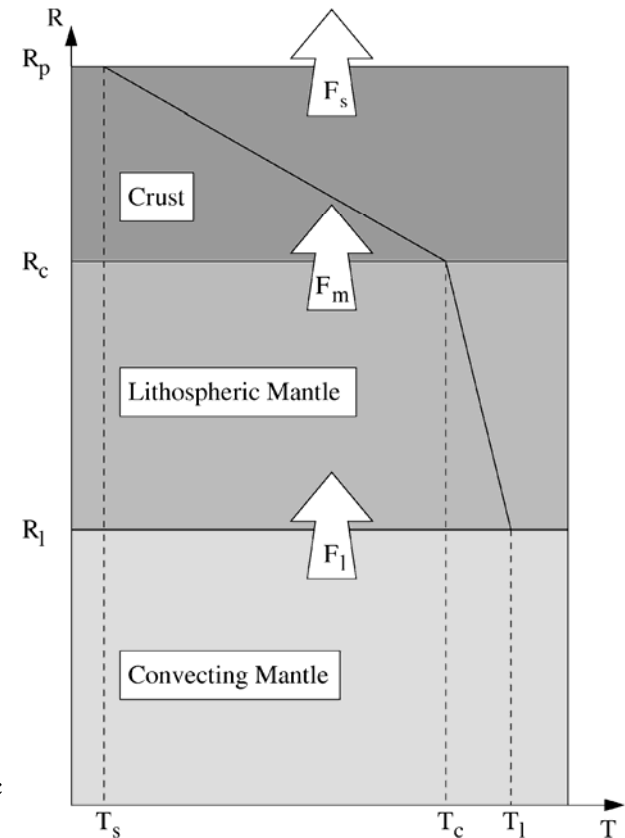
$$F_m(\theta, \phi) = F_l + Q_m(R_c - R_l)$$

$$F_s(\theta, \phi) = F_m(\theta, \phi) + Q_c(\theta, \phi)(R_p - R_c)$$

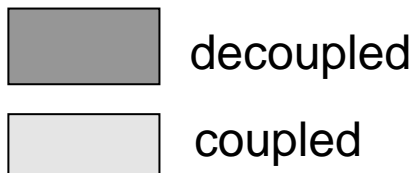
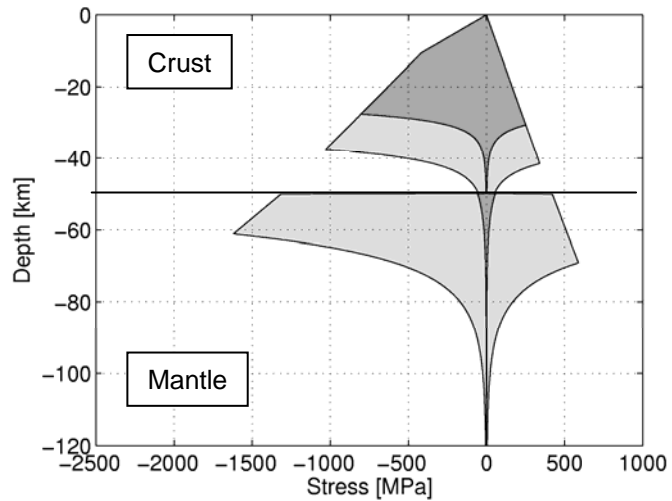
- Calculate temperature profile

$$T(\theta, \phi, z) = T_s + \frac{F_s(\theta, \phi)z}{k_c} - \frac{Q_c(\theta, \phi)z^2}{2k_c} \quad \text{for } z \leq D_c$$

$$T(\theta, \phi, z) = T_c(\theta, \phi) + \frac{F_m(\theta, \phi)(z - D_c)}{k_m} - \frac{Q_m(z - D_c)^2}{2k_m} \quad \text{for } z > D_c$$



Modeling – Elastic Thickness



- Calculated using strength envelopes
- Elastic thickness T_e
 - Decoupled:

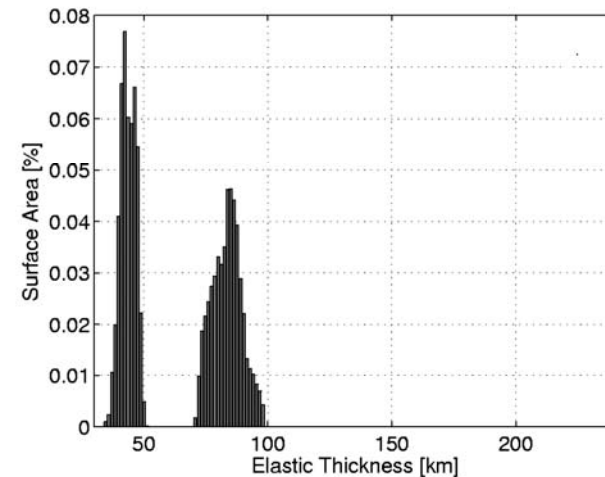
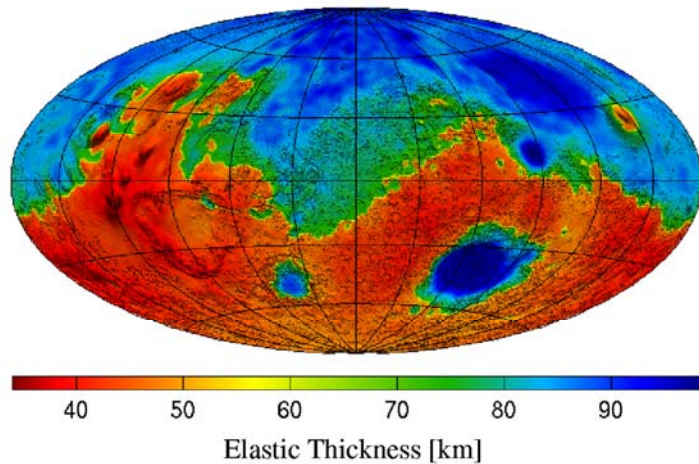
$$T_e = (T_{e,m}^3 + T_{e,c}^3)^{\frac{1}{3}}$$

- Coupled:

$$T_e = T_{e,m} + T_{e,c}$$

Results – Elastic Thickness Distribution

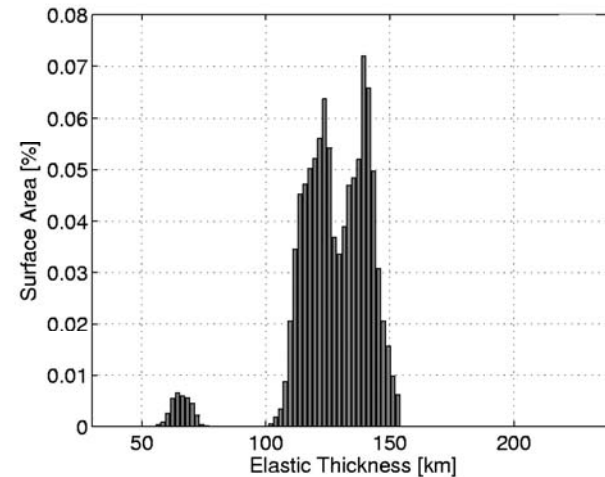
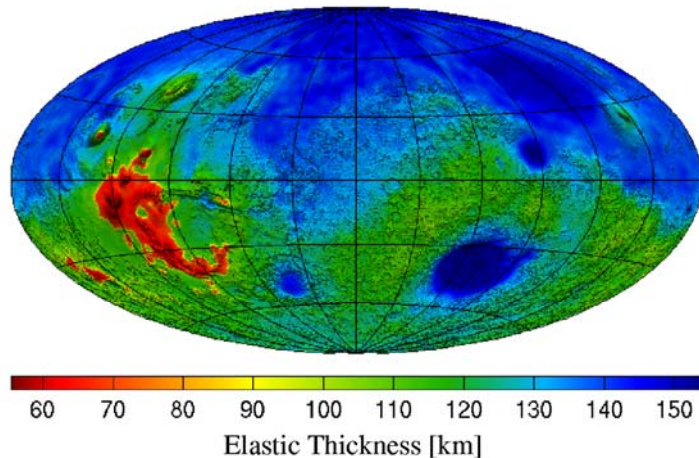
Early Amazonian



- T_e is small for large crustal thicknesses
- Q_c distribution has little influence on the results
- T_e distribution is bimodal, caused by rheological decoupling
- $30 \text{ km} < T_e < 100 \text{ km}$

Results – Elastic Thickness Distribution

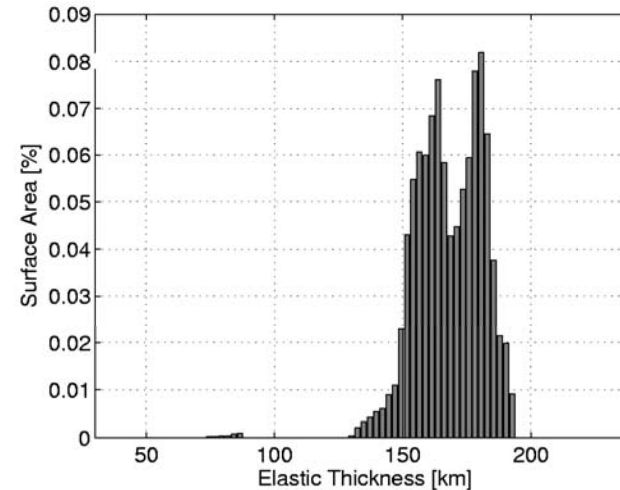
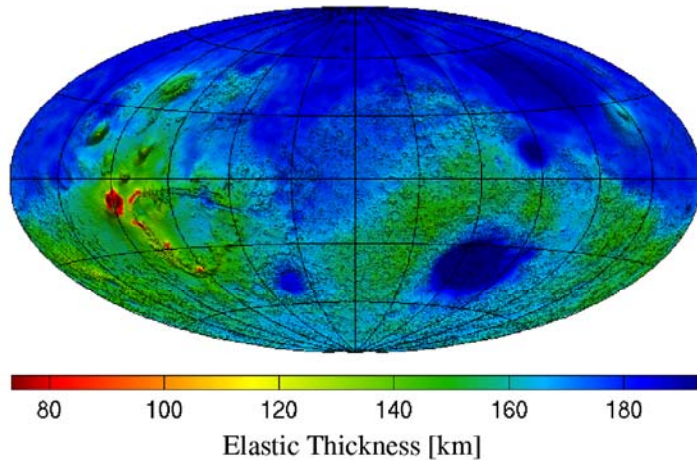
Mid Amazonian



- T_e distribution is essentially trimodal, caused by the crustal dichotomy and rheological decoupling
- Rheological decoupling is limited to central Tharsis
- $55 \text{ km} < T_e < 160 \text{ km}$

Results – Elastic Thickness Distribution

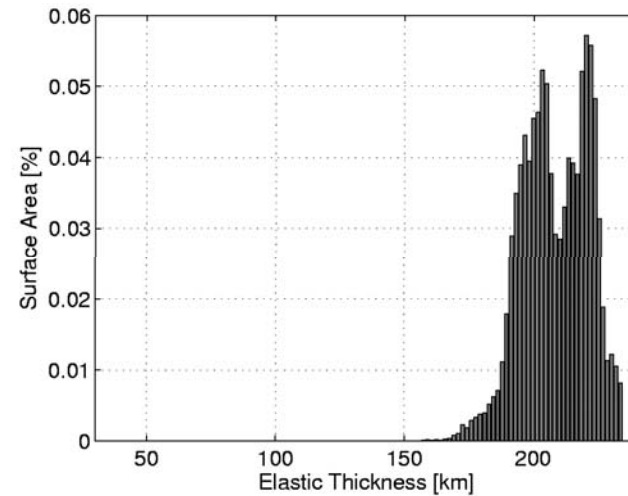
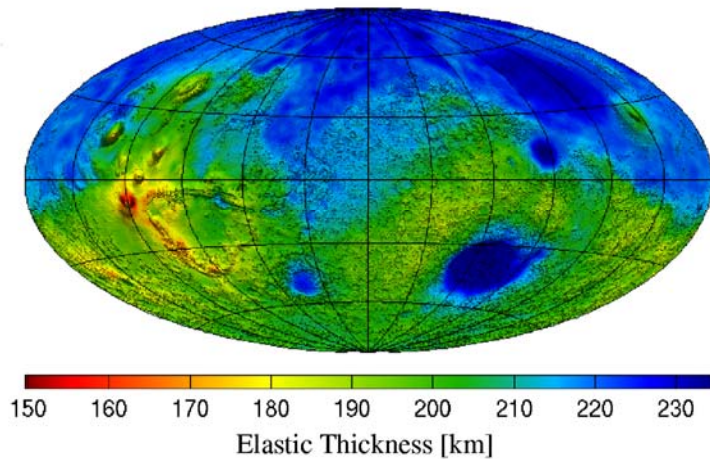
Late Amazonian



- T_e distribution is essentially bimodal, caused by the crustal dichotomy
- $75 \text{ km} < T_e < 190 \text{ km}$

Results – Influence of Strain Rate

Late Amazonian



- Fast deformation results in larger T_e
- $\dot{\epsilon} = 10^{-14} \text{ s}^{-1}$ appropriate for polar-cap deposition
- $150 \text{ km} < T_e < 235 \text{ km}$ (20% increase)

Elastic Thickness Estimates

Feature	Age	T_e [km]	T_e [km]	T_e [km]	T_e [km]
			Early Amaz.	Mid Amaz.	Late Amaz.
North Pole	Recent	>300	111	177	226
South Pole	Recent	>275 >102	79	155	202
Olympus Mons	Amaz.	93 ± 40	40	93	147
Ascraeus Mons	Amaz.	2 – 80 105 ± 40	39	77	142
Pavonis Mons	Amaz.	<100 >50	38	65	140
Arsia Mons	Amaz.	<35 >20	35	58	81

- Generally good agreement with the observations, *but*
- $T_e > 300$ km requires $F_l = F_l(\theta, \phi)$

Conclusions

- Rheological decoupling important up to the Amazonian (maybe today)
- Lithospheric structure similar to a two layer continental lithosphere on Earth
- D_c , Q_c and $\dot{\epsilon}$ variations result in spatial variations of $80 \text{ km} < T_e < 230 \text{ km}$.
- Maximum modeled T_e is inconsistent with $T_e > 300 \text{ km}$.
- Spatially variable mantle heat flow $\pm 10 \%$ is required

