F. Detailed Modeling + Implications

Now that we have a pretty good idea that the mantle has a fairly constant ~10^{21} Pa·s viscosity (except for a very fluid asthenosphere), we can refine our estimate by more sophisticated calculations.

- Viscoelastic propagator system for sphere with fluid core — Fig 1. Note gravitational perturbation caused by elastic strain are included in the elastic system. Buoyant force result from fluid flow only of $(P_r P_0)_{MA}$, to non-adiabatic density gradient, $\omega \neq 0$.

Mention again

- For a 10^{21} Pa-s mantle decrease in log amplitude of each load harmonic plotted vs. time. Note effect of core on very low order harmonics. — Fig 2

- Explanation of change in slope of $n = 2$ harmonic — Fig 3

- Decay times vs order number. Effect of lower mantle viscosity and asthenosphere/lithosphere combination shown. — Fig 4. Central uplift suggests ~10^{21} Pa-s (10^{22} poise) mantle

START →

Critical observations

- Fig 5 — central uplift
  — peripheral bulge

- Fig 6 — Cylindrical ½ space calculation
  * ⇒ uplift → subsid. uff $\eta \sim$ vary $\sim 10^{21}$ Pa s

  Cent uplift > near edge no spread of just one hemisphere

- Fig 7 — Marine limit

Building a full model

- Fig 8 — construction

- Fig 9 — Sea level calibration

- Fig 10 — detailed check on E coast peripheral bulge

Fig 11 — Observed bulge behavior

Fig 12 — Calculated bulge behavior

Fig 13 — Geoid — eg. gravity change included + synopt

1. Conclusions – Fig 14

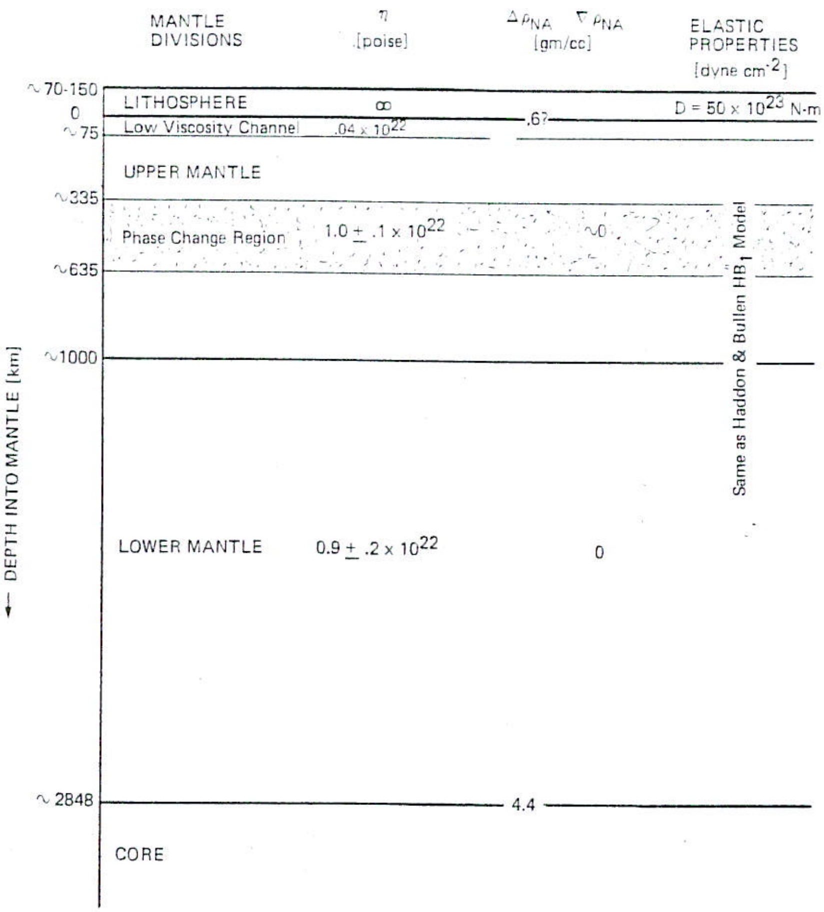

Figure IV-69. Summary of earth parameters determined or used in this study.

$$Ra = \frac{\alpha \rho g d^3 \Delta T}{k \eta}$$

$$= 21{,}600\ \Delta T$$

$$\boxed{\frac{Ra}{Ra_c} = 21.6\ \Delta T}$$

$$Ra_c = 1000$$

Coef Thml expansion

$\alpha = 2 \times 10^{-5}\ {}^\circ K^{-1}$

$\rho = 4000\ kg/m^3$

$g = 10\ m/sec^2$

$d = 3000 \times 10^3\ m$

$\eta = 10^{21}\ Pa \cdot s$

k = Thml diffusivity

$= 10^{-6}\ m^2/sec$

This indicates very strong mantle convection.

As Ra/Ra_c becomes large, upwelling zones narrow + downwelling enlarge. This is because the fluid must lose its heat in the time it transits across the surface. As Ra/Ra_c increases the rate of overturn increases and the fluid spends less time at the surface. The near-surface thermal boundary layer is thin, and the upwelling must also be thin.

- plume heads — flood basalts
- plume tracks — explain most of topography of oceans, <u>except</u> for mid ocean Ridges.

Fig 1

The Viscoelastic Propagator System III-64RK

$$
\tilde{r}\partial\tilde{r}\begin{bmatrix} \frac{\mu^* U_E}{r^*} \\ \frac{\mu^* V_E}{r^*} \\ P \\ Q \\ \phi_1 \\ r^*\hat{g}_1 \end{bmatrix} = \begin{bmatrix} -2\tilde{\lambda}\tilde{\beta}^{-1} & -\tilde{\lambda}\tilde{\beta}^{-1}\nabla_1^2 & \tilde{\beta}^{-1}\tilde{r} & 0 & 0 & 0 \\ -1 & 1 & 0 & \tilde{r}\tilde{\mu}^{-1} & 0 & 0 \\ 4\left(\tilde{r}^{-1}\tilde{\gamma} - \frac{\rho_0 g_0 r^*}{\mu^*}\right) + \frac{4\pi G\rho_0^2 r r^*}{\mu^*} & \left(2\tilde{\gamma}\tilde{r}^{-1} - \frac{\rho_0 g_0 r^*}{\mu^*}\right)\nabla_1^2 & -4\tilde{\mu}\beta^{-1} & -\nabla_1^2 & 0 & +\tilde{r}\rho_0 \\ -2\tilde{r}^{-1}\tilde{\gamma} + \frac{\rho_0 g_0 r^*}{\mu^*} & -\tilde{r}^{-1}[(\tilde{\gamma} + \tilde{\mu})\nabla_1^2 + 2\tilde{\mu}] & -\tilde{\lambda}\tilde{\beta}^{-1} & -3 & +\rho_0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \tilde{r} \\ \frac{-4\pi G r^{*2}}{\mu^*}[\tilde{r}\partial_{\tilde{r}}\rho_0 + 4\tilde{\mu}\tilde{\beta}^{-1}\rho_0] & \frac{-8\pi G\rho_0 r^{*2}}{\mu^*}\tilde{\mu}\tilde{\beta}^{-1}\nabla_1^2 & \frac{-4\pi G\rho_0 r\tilde{\beta}^{-1}r^*}{\mu^*} & 0 & -\tilde{r}^{-1}\nabla_1^2 & -2 \end{bmatrix}\begin{bmatrix} \frac{\mu^* U_E}{r^*} \\ \frac{\mu^* V_E}{r^*} \\ P \\ Q \\ \phi_1 \\ r^*\hat{g}_1 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ -g_0\tilde{r}[\partial_{\tilde{r}}\rho_0]_{NA} U_V \\ 0 \\ \tilde{r}(\phi_1(r))_V \\ -4\pi G\tilde{r}r^*[\partial_{\tilde{r}}\rho_0]_{NA} U_V + n(\phi_1(r))_V \end{bmatrix}
$$

note $\tilde{\lambda}\tilde{\beta}^{-1} - 1 = -2\tilde{\mu}\tilde{\beta}$

$$
\tilde{r}\partial\tilde{r}\begin{bmatrix} \frac{\eta^* V_U}{r^*} \\ \frac{\eta^* V_V}{r^*} \\ P \\ Q \end{bmatrix} = \begin{bmatrix} -2 & -\nabla_1^2 & 0 & 0 \\ -1 & 1 & 0 & \tilde{r}\tilde{\eta}^{-1} \\ 12\tilde{r}^{-1}\tilde{\eta} & 6\tilde{r}^{-1}\tilde{\eta}\nabla_1^2 & 0 & -\nabla_1^2 \\ -6\tilde{r}^{-1}\tilde{\eta} & -2\tilde{r}^{-1}\tilde{\eta}(2\nabla_1^2 + 1) & -1 & -3 \end{bmatrix}\begin{bmatrix} \frac{\eta^* V_U}{r^*} \\ \frac{\eta^* V_V}{r^*} \\ P \\ Q \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ r\rho_0\hat{g}_1 - g_0 U_V\tilde{r}[\partial_{\tilde{r}}\rho_0]_{NA} - 4\rho_0 g_0 U_E - \rho_0 g_0\nabla_1^2 V_E + 4\pi G\rho_0^2 U_E r \\ \rho_0\phi_1 + \rho_0 g_0 U_E \end{bmatrix}
$$