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AN ANALYTIC SPHERICALLY SYMMETRIC *P*- AND *S*- WAVE VELOCITY MODEL

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The problem of the Earth's interior constitution is considered under the perspective of a spherically symmetric $P-$ and $S-$ wave velocity model. This model is derived from a guess function for the distribution of the density in the Earth's interior, $\rho(r) = \rho_0 + a_0 \cdot \log(\frac{R_0}{r})$, which depends only on the radial distance to each layer, and where a_0 is a parameter and (ρ_0, R_0) are the density and radius for the upper boundary of each layer. The analytical function for the velocity allows us to adjust the arrival times of the different seismic phases with a high precision, around the 99%, yielding a valid reference model since satisfies the most important classes of seismological observations. In this sense, we compare our results with the successive PREM, IASP91 and SP6 earth models. In addition, several calculations for the moment of inertia of Earth are performed, obtaining a precision upper than 99.5%.

Submittal Information

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4. slides
5. Oral presentation strongly preferred

AN ANALYTIC SPHERICALLY SYMMETRIC *P* - AND *S* - WAVE VELOCITY MODEL

The only guess fonction for the density in every layer i in the Earth's interior is:

layer i	ρ_i , a_i	R_i
fonction	$\rho_i(r) = \rho_i + a_i \cdot \log\left(\frac{R_i}{r}\right)$	
$R_i \geq r \geq R_j$	$j = i + 1$	R_j

where $\rho_i = \rho_i(R_i)$ and a_i

are constants to determine

with the help of the following guess relationship between density and P wave velocity

$$v_i(r) = \frac{r \cdot \rho_i(r)}{H}$$

where H is a general constant for the Earth

we may rewrite the velocity in the form

$$v_i(r) = r \cdot \left(B_i - A_i \cdot \log\left(r_i\right)\right)$$

where

$$B_i = \frac{\rho_i + a_i \cdot \log\left(R_i\right)}{H} \qquad A_i = \frac{a_i}{H}$$

they will be also constants of the layer i

and we will also have

$$\rho_i = H \cdot \left(B_i - A_i \cdot \log\left(R_i\right)\right) \qquad a_i = H \cdot A_i$$

Then, the problem is to find the constants

A_i and B_i for every layer i

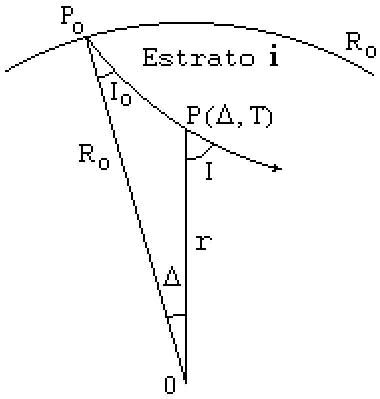
With the analytical velocity fonction
is very easy to obtain the formulas

Epicentral distance:

$$\Delta\left(P_o, P\right) = \frac{\cos\left(I_o\right) - \cos(I)}{A_i \cdot p_o}$$

Travel - time

$$T\left(P_o, P\right) = \frac{1}{A_i} \cdot \log\left[\frac{\tan\left(\frac{I}{2}\right)}{\tan\left(\frac{I_o}{2}\right)}\right]$$

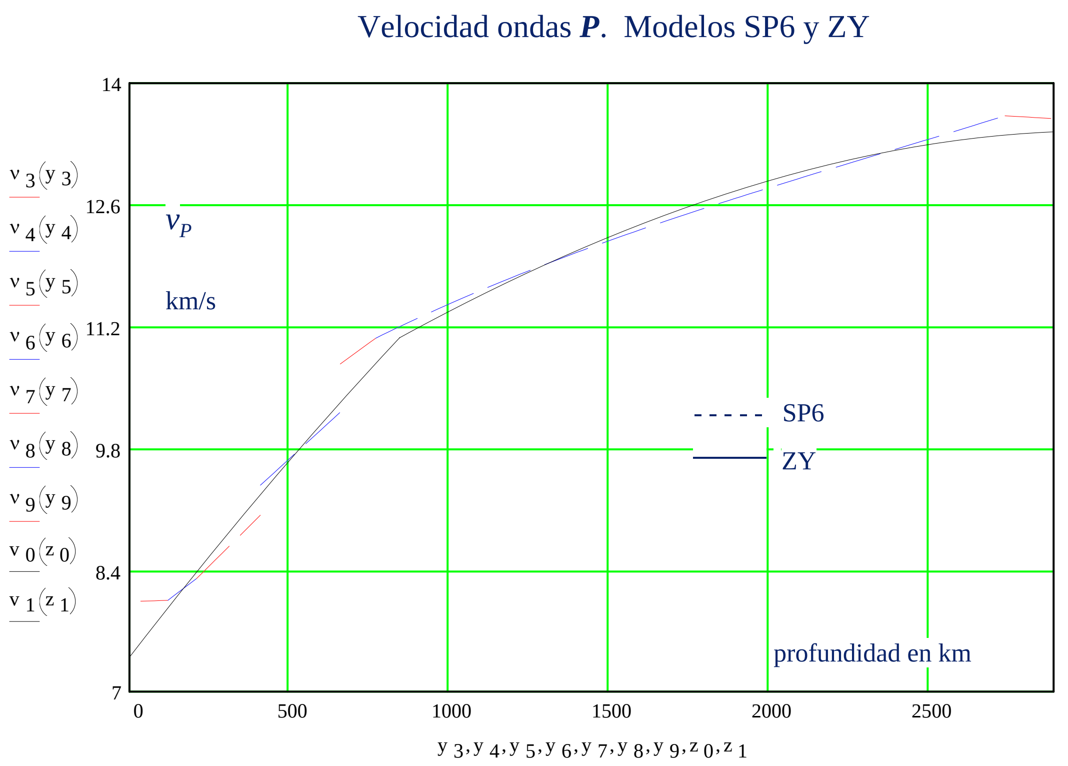


layer i

and many others

Working with observed travel times from "1968 seismological tables for P phase" in B.S.S.A and from the model SP6 (Morelli - Dziewonski,1993) for PKP and PKIKP phases, we have found the following structure of the Earth

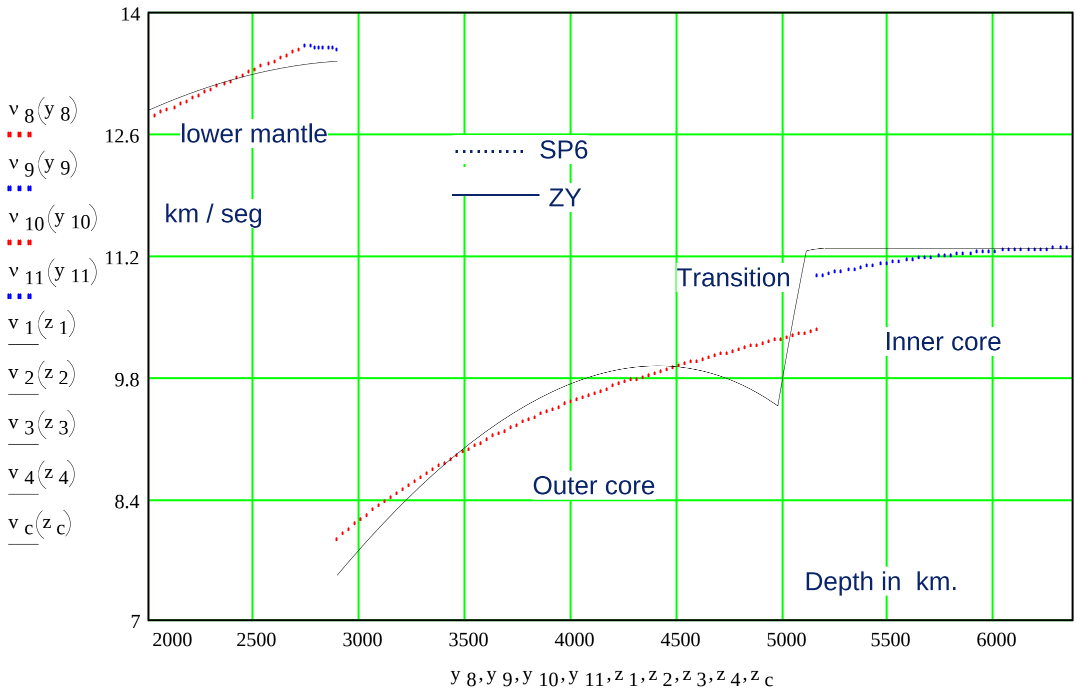
Depth	layers	Radius (km)
	Upper mantle	
846		5525
	Lower mantle	
2893		3478
	Outer core	
4977		1394
	Transition zone	
5111		1260
	Inner core	
5199		1172
	Inner core with density constant	
6371		0



P - wave velocity (km/s) in the Mantle

Comparison of models SP6 and ZY

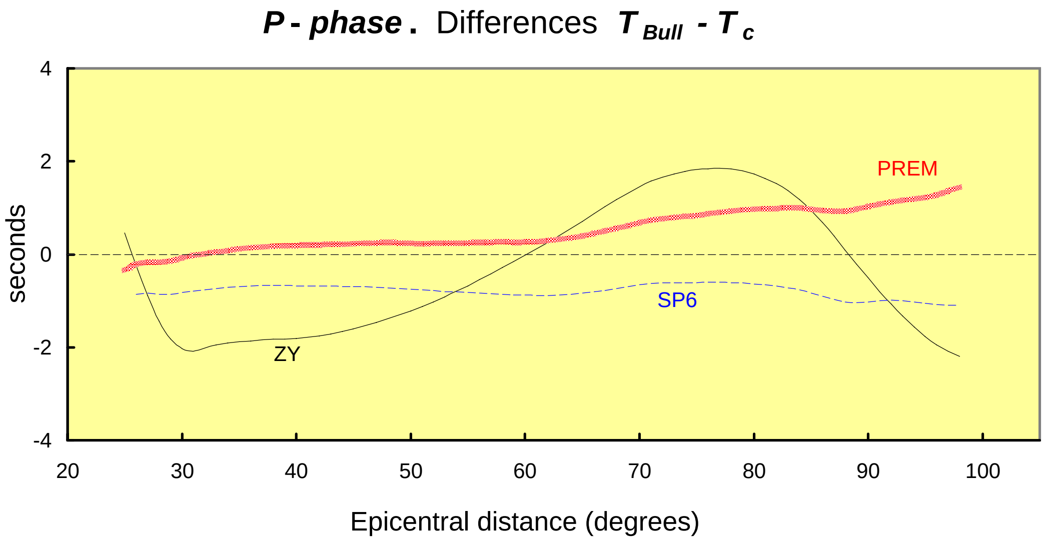
Velocidad ondas ***P***. Modelos SP6 y ZY



P - wave velocity (km/s) in the Core

Comparison of models SP6 and ZY

Comparison amongst *PREM*, *SP6* and *ZY*

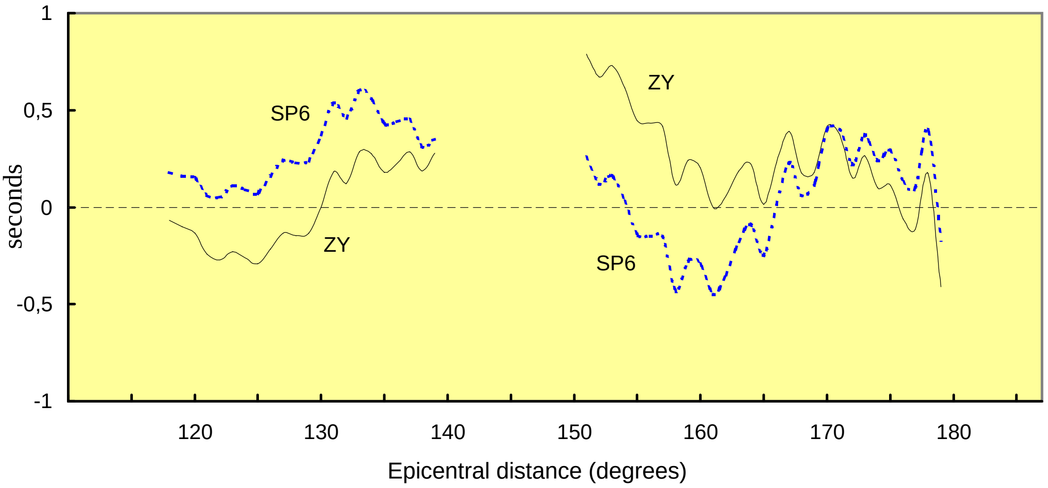


T_{Bull} : Observed times B.S.S.A. (1968) from E. Herrin

T_c : Calculated times

Comparison amongst *SP6* and *ZY*

***PKIKP - phase*.** Differences $T_o - T_c$



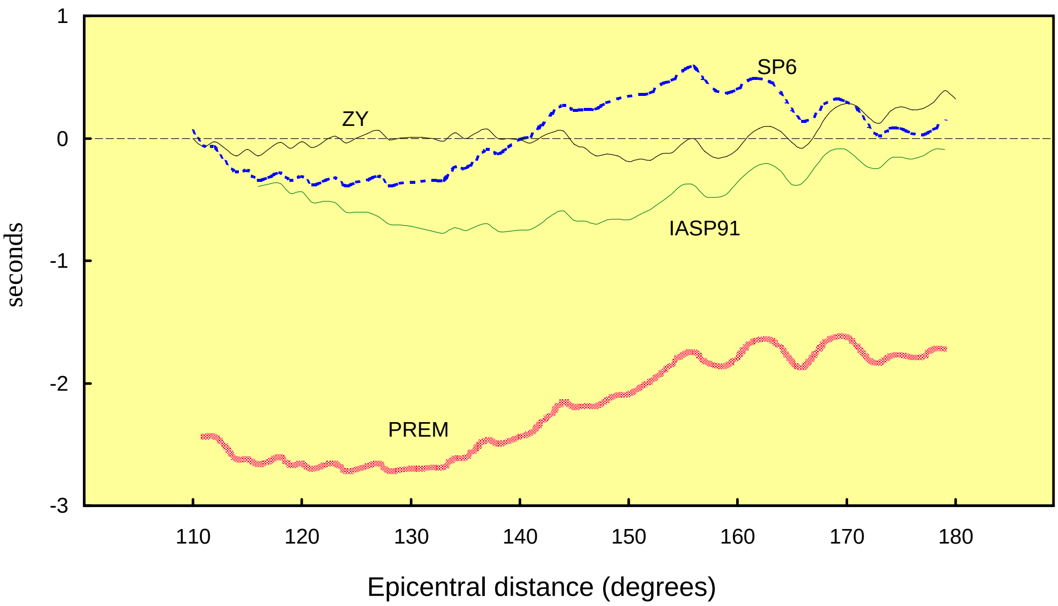
T_o : Observed times from Morelli-Dziewonski 1993

T_c : Calculated times

Comparison amongst

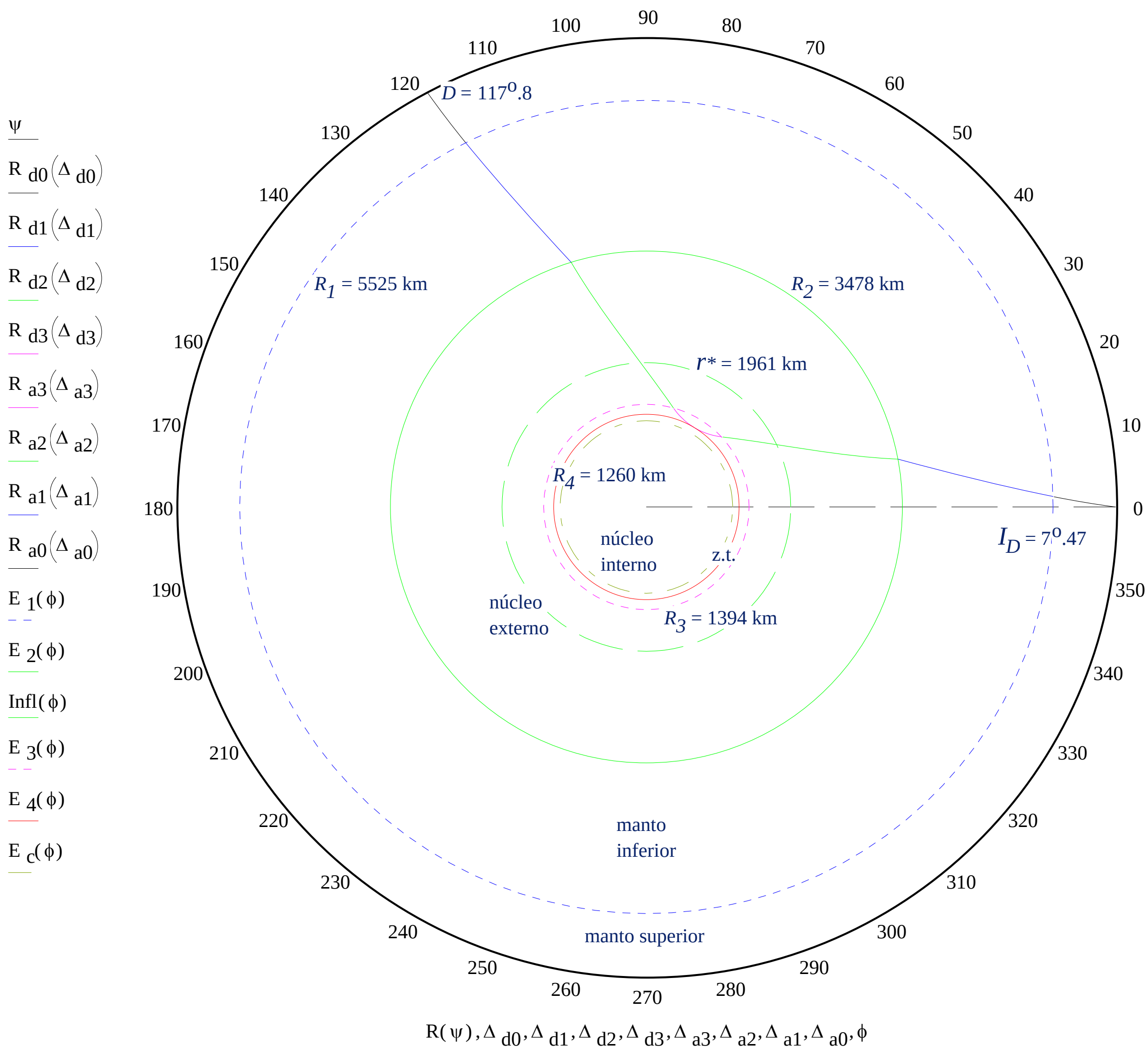
PREM (1981) ,   IASP (1991) ,   SP6 (1993)   and   ZY (1997)

PKIKP - phase. Differences T_c - T_{JB}



T_{JB} : Observed times from Jeffreys - Bullen (1958)

T_c : Calculated times



Point D. Ray path tangent to inner core for P wave

tra0123D.mcd

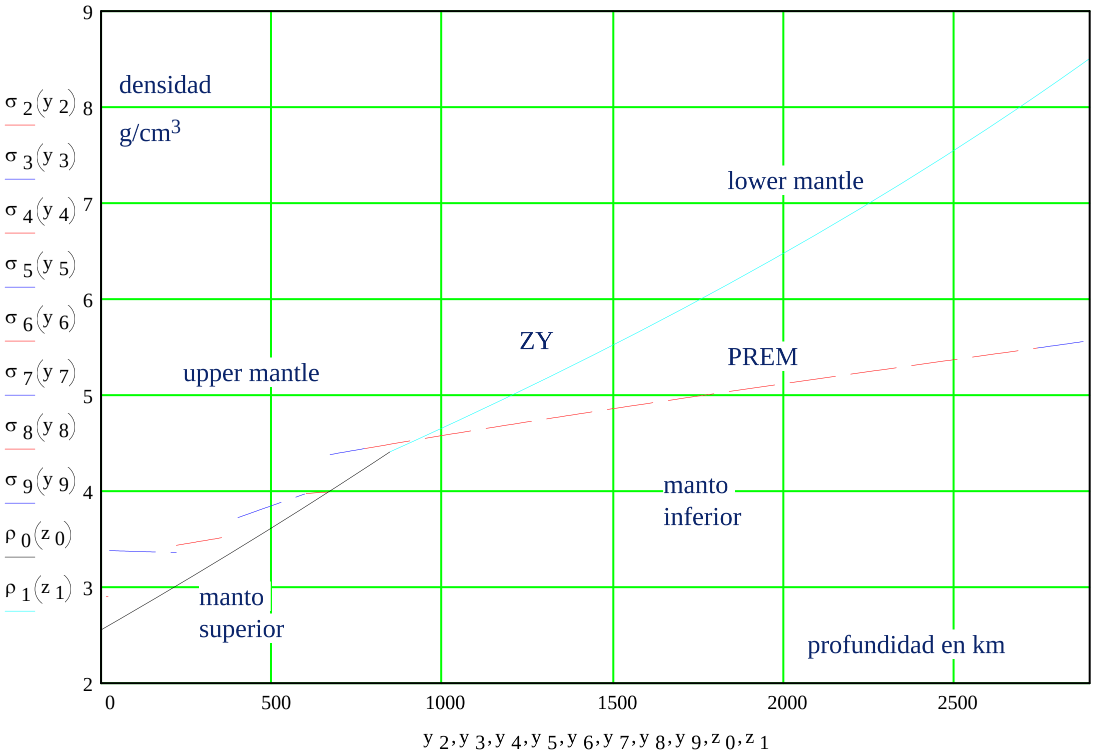


Figura 6.1: Distribución de densidades en el manto de los modelos PREM y ZY

Density in the mantle

Comparison of models PREM and ZY

Archivo PREMG1

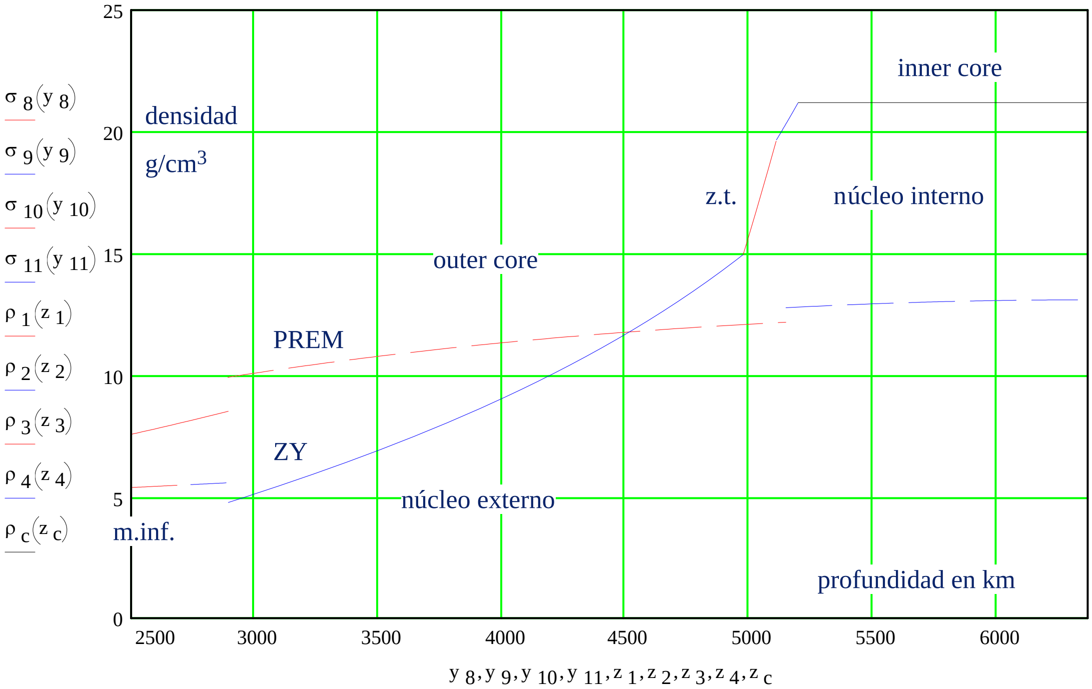


Figura 6.2: Distribución de densidades en el núcleo de los modelos PREM y ZY

Density in the core

Comparison of models PREM and ZY

Archivo PREMG1

Precision for the

moment of inertia

of the Earth

99.87 %

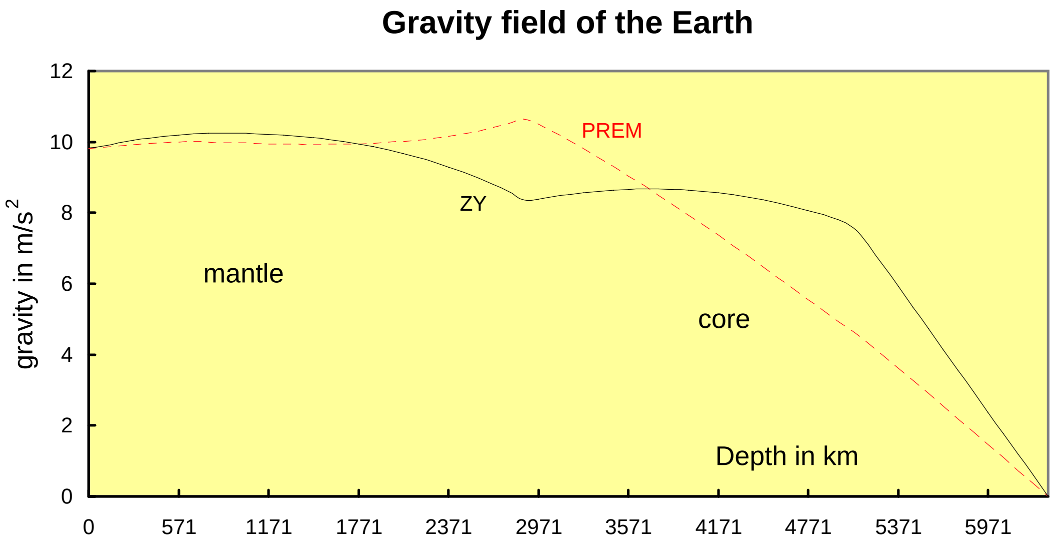


Figura 6.10: Gravedad en el interior de la Tierra según los modelos PREM y ZY.

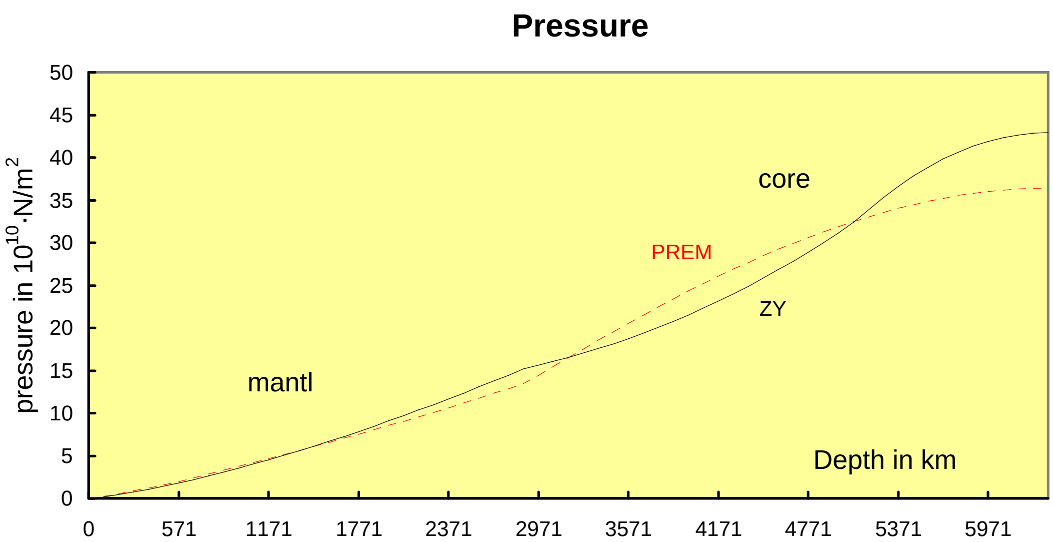
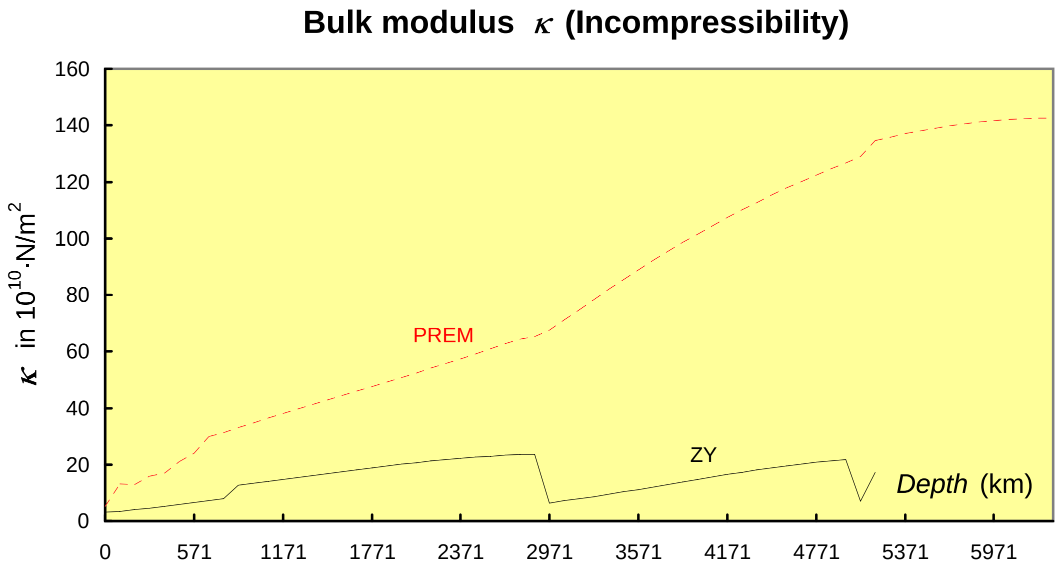


Figura 6.11: Presion en el interior de la Tierra según los modelos PREM y ZY.



PREM: Hard model

ZY: Soft model

Figura 6.12: Módulo κ en función de la profundidad z (km) según los modelos PREM y ZY.

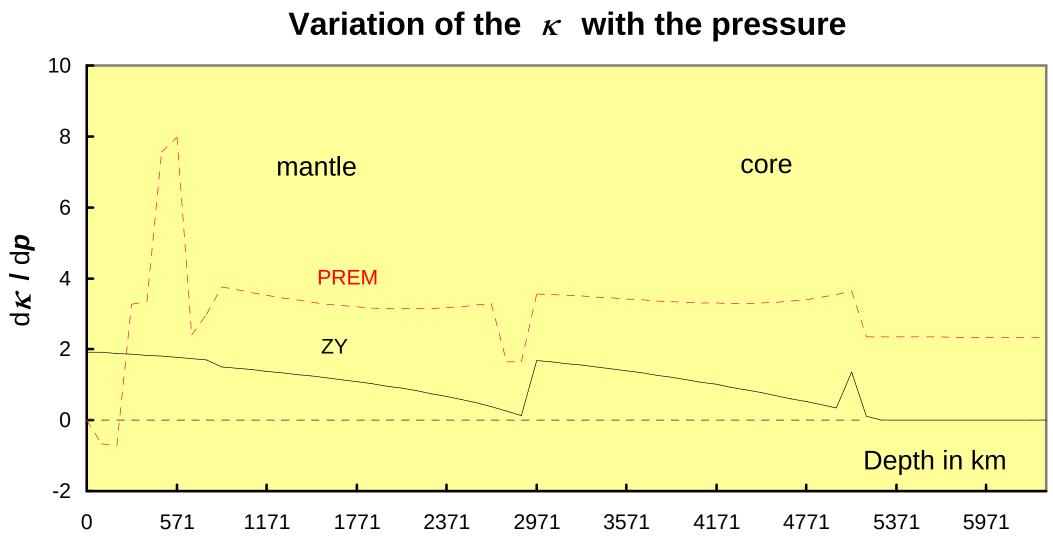


Figura 6.15: Variación del modulo κ respecto a la presión. Modelos PREM y ZY.

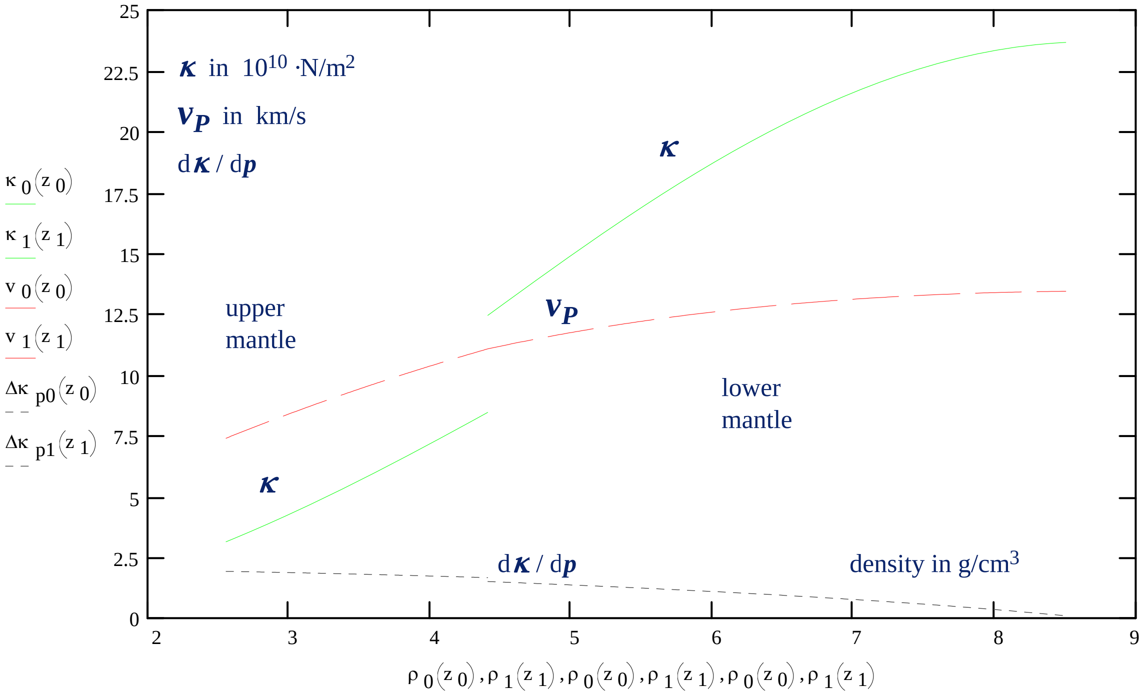


Figura 6.16: Modelo ZY. Módulo de compresibilidad ***κ***, velocidad de las ondas ***P*** y variación de ***κ*** con la presión en el manto en función de la densidad.

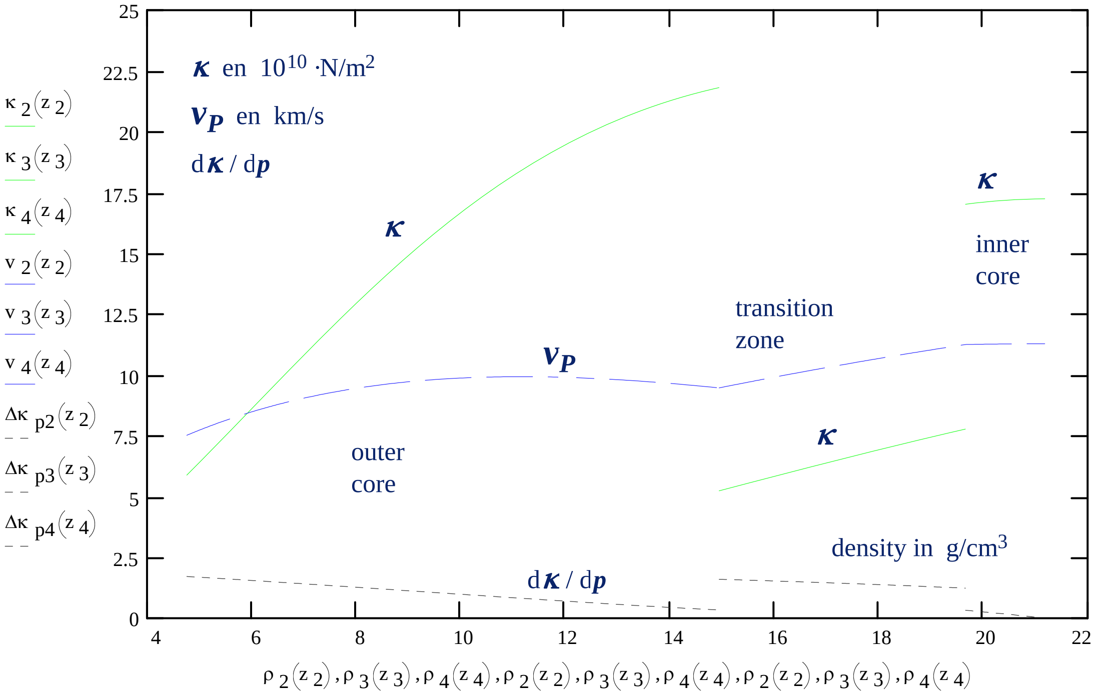


Figura 6.17: Modelo ZY. Módulo de compresibilidad ***κ***, velocidad de las ondas ***P*** y variación de ***κ*** con la presión en el núcleo en función de la densidad.

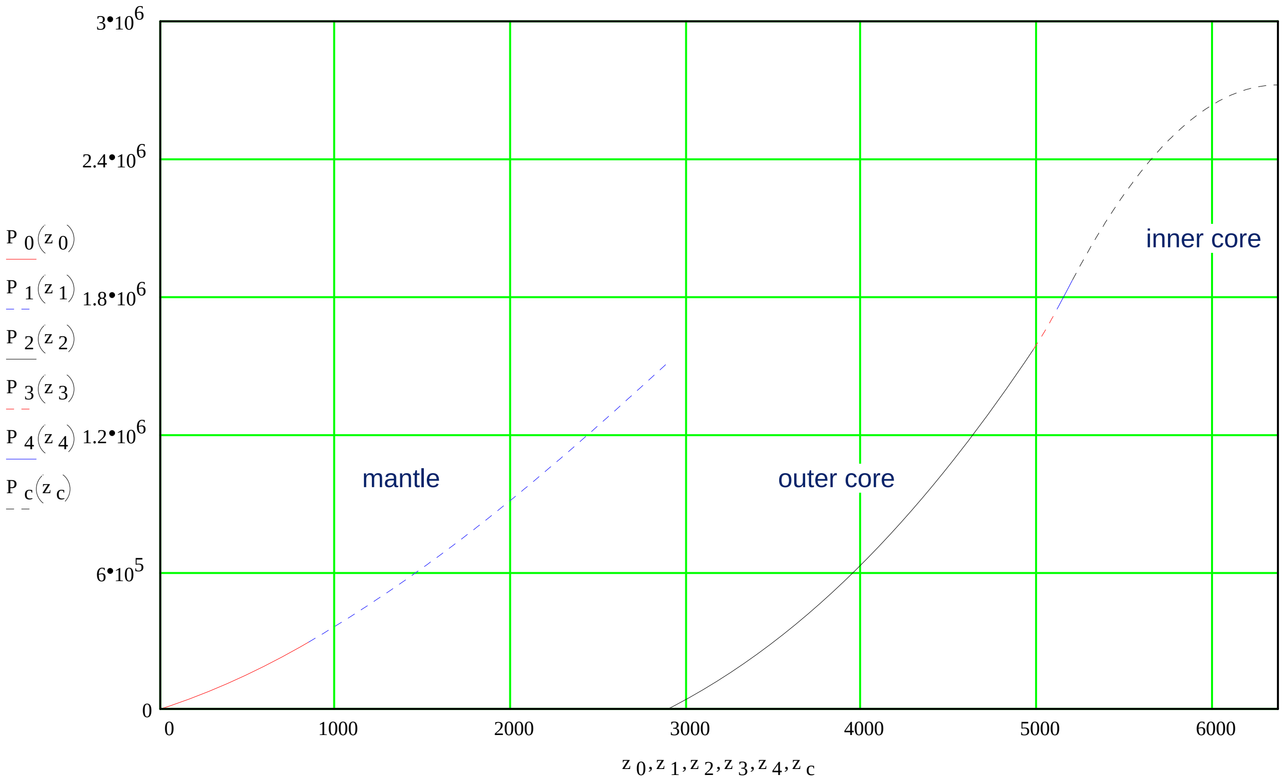
Vault model

Graphical representation of the pressure in the interior of the Earth considering that is a discontinuity. We considered that the mantle is self-resistence, and that the pressure in the beginning of the outer core is zero.

in where the constant H of the Earth takes the value: $H = 2.200965143272 \cdot 10^{15} \frac{kg}{km^3} \cdot sec$

Axe OX: depth z in km.

Axe OY: Pressure P(z) in Atmospheres



Pressure $P_i(r)$ in the interior of the layer E_i:

$P_{i0}(R_i)$ = Pressure in the beginning of the layer

$$P_i(r) = P_{i0}(R_i) + P_{i1}(r) + P_{i2}(r) + P_{i3}(r)$$

$$P_{i1}(r) = 2 \cdot \pi \cdot G \cdot \left(\rho_i(R_i)^2 \cdot R_i^2 - \rho_i(r)^2 \cdot r^2 \right)$$

$$P_{i2}(r) = A_i \cdot H \cdot \left(g_i(R_i) \cdot R_i - g_i(r) \cdot r \right)$$

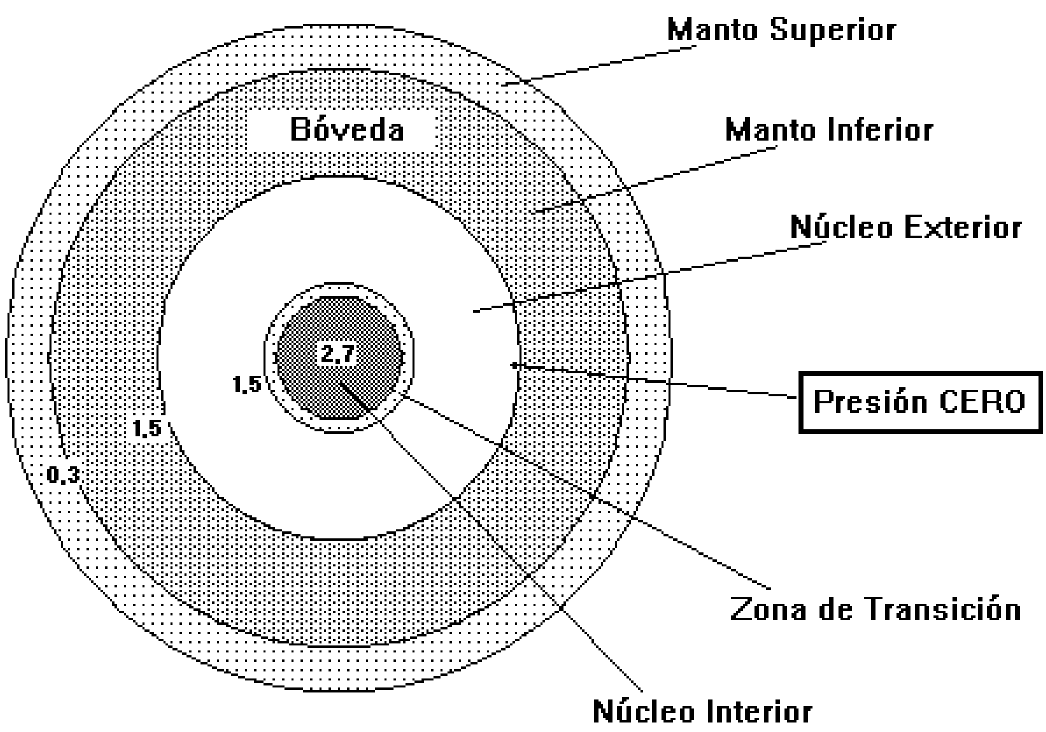
$$i = 0, 1, 2, 3, 4$$

$$P_{i3}(r) = \rho_i(r) \cdot g_i(r) \cdot r - \rho_i(R_i) \cdot g_i(R_i) \cdot R_i$$

Continuity: $P_i(R'_i) = P_j(R_j)$ $\quad j = i + 1$ $\quad$ **and** $R'_i = R_j$ $\quad$ except in R_2

Pressure $P_c(r)$ in the inner core - E_c: $P_c(r) = P_{c0}(R_c) + \frac{2}{3} \cdot \pi \cdot G \cdot \rho_c^2 \cdot \left(R_c^2 - r^2 \right)$

Modelo "BÓVEDA"



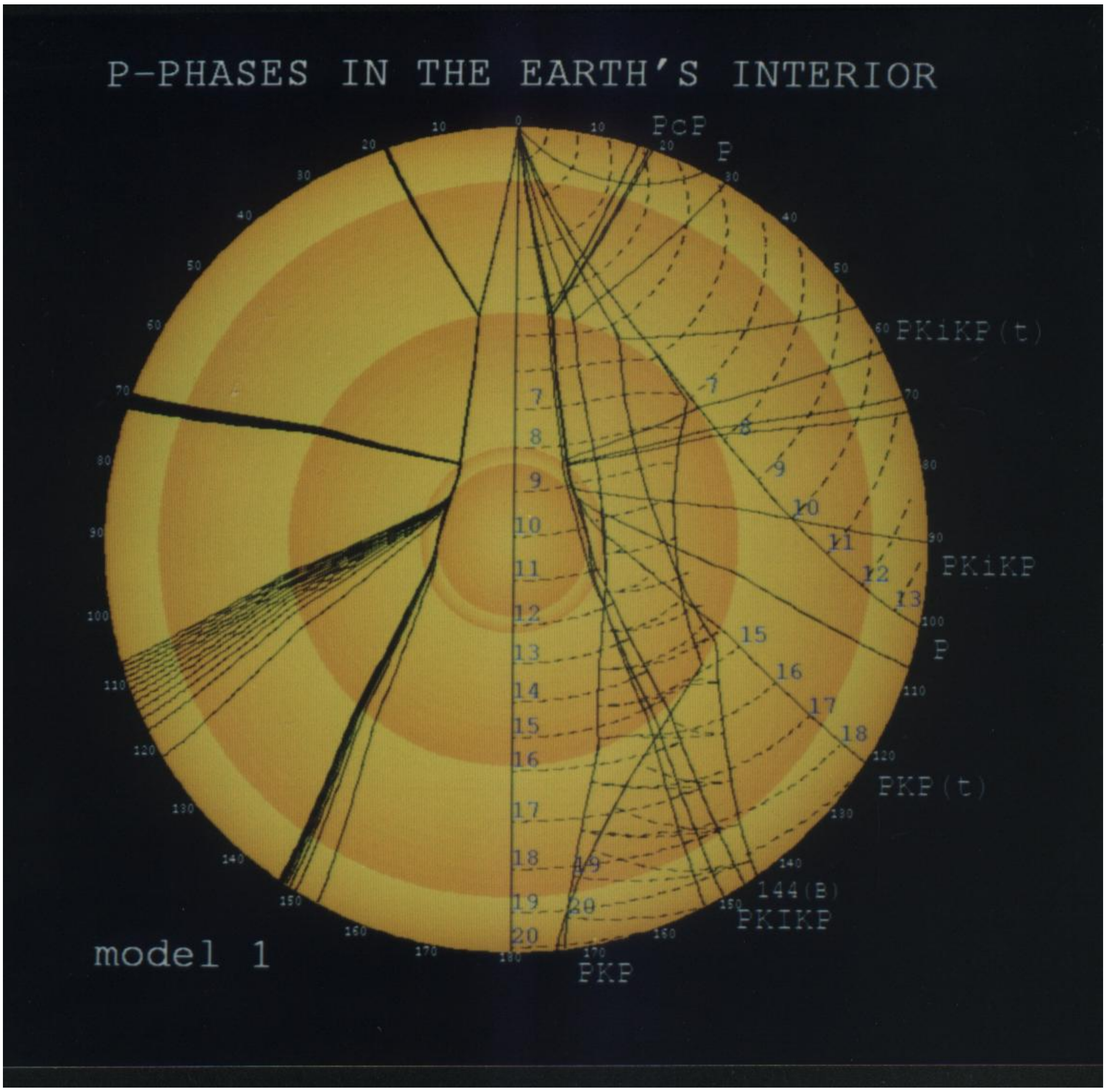
LA TIERRA. Presión en millones de Atmósferas

Conclusions Earth model G1(ZY)

- Fully analytic and algebraic
- Earth divided into 6 layers
- P-phases match observed travel times with high accuracy
- G1 yields into a different density distribution
    - high density in lower mantle and inner core
    - low density in outer core
    - negative jump in boundary mantle-core

- Precision for the moment of inertia. 99.87 %
- Density of the Earth surface 2.55 g/c.c.
- Mantle mass: 75 %
- low K ⇒ a soft Earth
- likely: negative jump in boundary mantle-core for pressure

⇒
  - mantle self-resistence
  - low pressure in the core
  - more stability



P-PHASES IN THE EARTH'S INTERIOR
PcP
P
PKiKP(t)
PKiKP
P
PKP(t)
144(B)
PKIKP
PKP
model 1