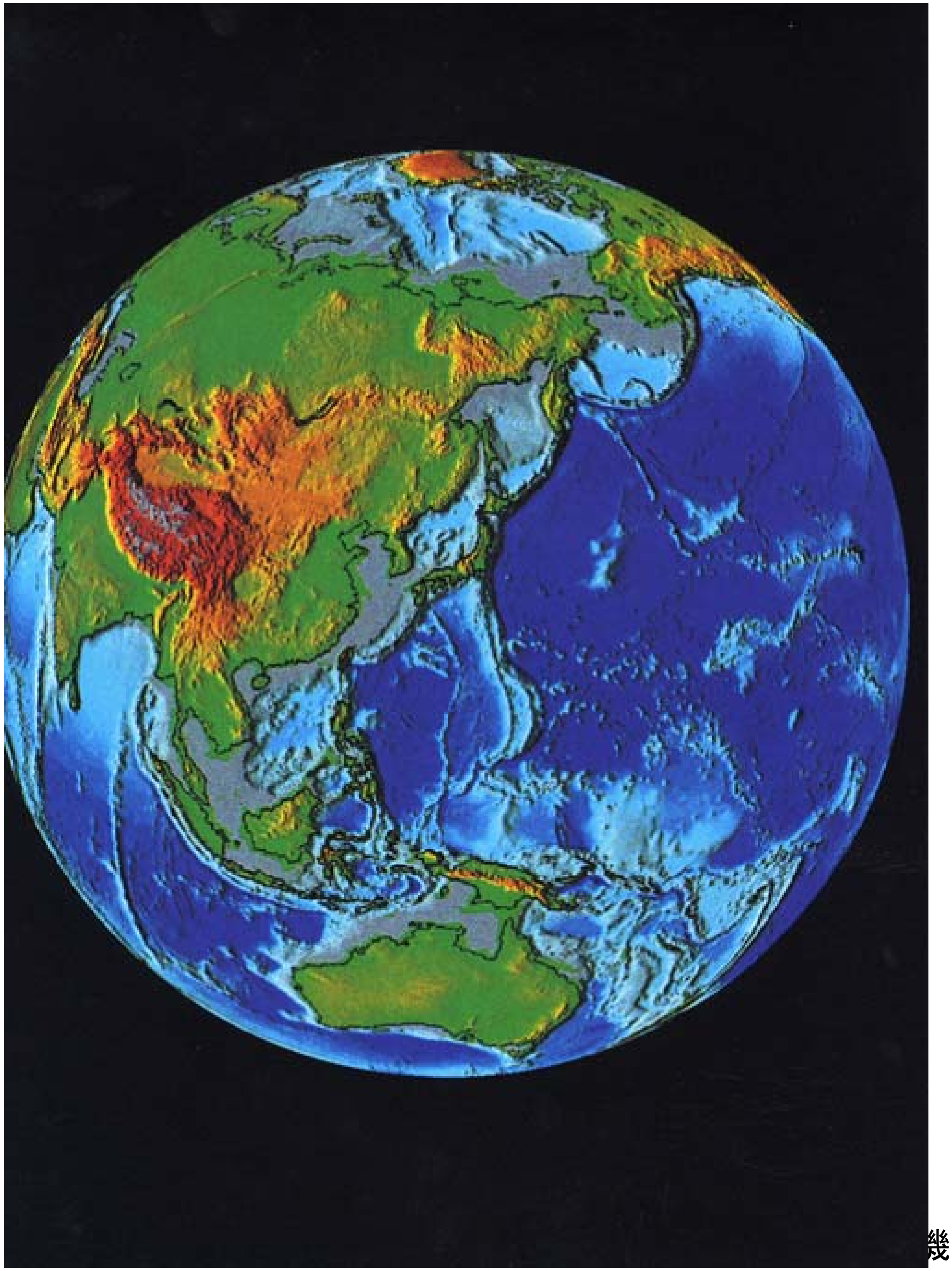

コアの話

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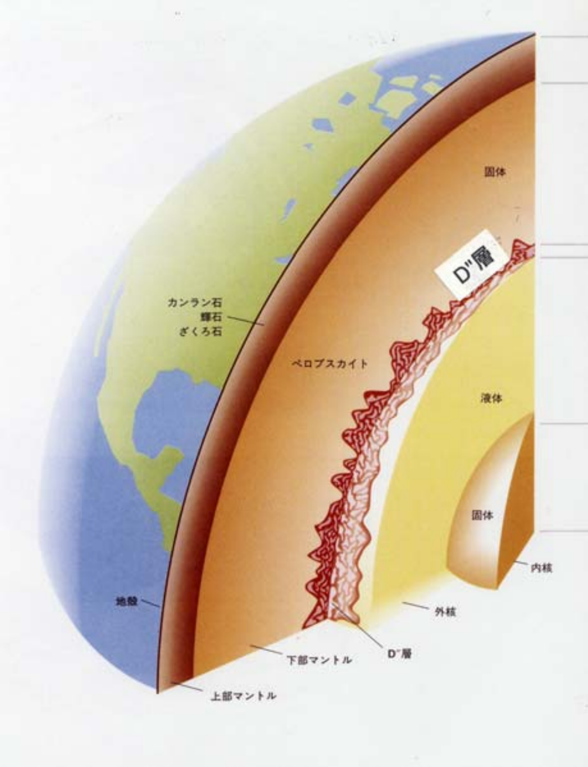
地震予知研究センター
川崎一朗

コアの基礎知識

- 1913年、グーテンベルグ.

角距離103° より遠方ではP波もS波も来なくなることを示した
- 半径3,400km
- 外核：液体金属鉄（軽元素を含む）
- 内核：柔かい固体金属鉄
- 基本的な構造で一番解けていない問題
内核の密度



コア・マントル境界（CMB）

- 扁平率1/400（地球表面より球に近い）
- 凸凹あり、異常な層あり
- D”層：マントル最下部約200kmの不均質層
- ULVZ, CRZの存在
- 調べ方：

(1) 反射・屈折された地震波の走時差

(2) CMB Stoneley modes の splitting

外核

- 粘性係数は水程度
- 金属鉄、ニッケル、少量の軽元素
- 熱対流・組成対流（軽元素の放出）
- 地球磁場の発生源（ダイナモ作用）
- 磁場の西方移動（毎年0.2-0.3°）

  からわかる外核表面の水平流

内核

- 内核表層付近の極と赤道の不均質
- 内核内部の異方性（堆積・圧密過程を反映）
- 異方軸は自転軸から１０度ずれている
- 異方軸の経年変化より、内核の差分回転
- ダイナモ作用に密接に関わっている？

地球振動によるコアの探求

- CMB Stoneley modes のスプリッティング

  ⇔ CMBの水平不均質構造

- コアモードによる内核の不均質と異方性

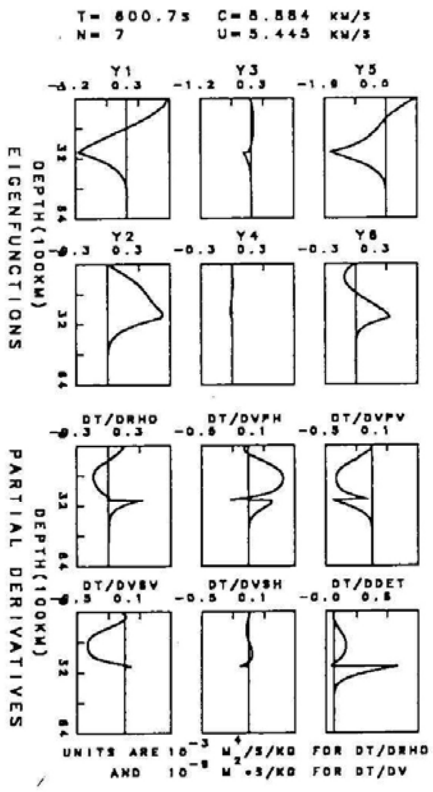
- 内核の浮力振動 Slichter mode

  周期約5.4時間. 内核と外核の密度差に依存.

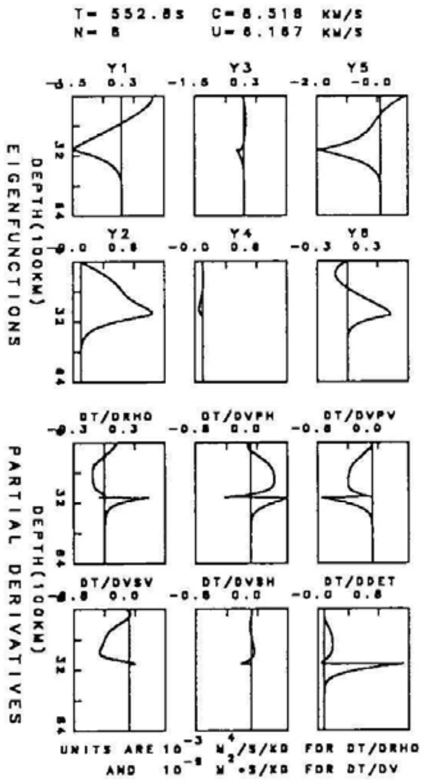
  ⇔ 内核の密度

CMB Stoneley mode

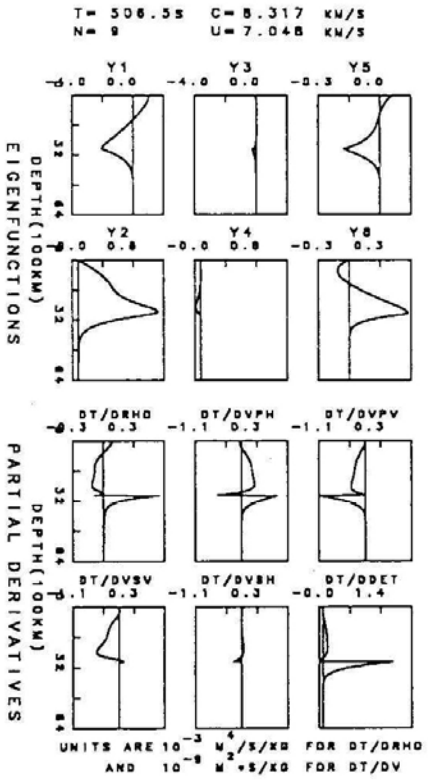
$_1S_7$

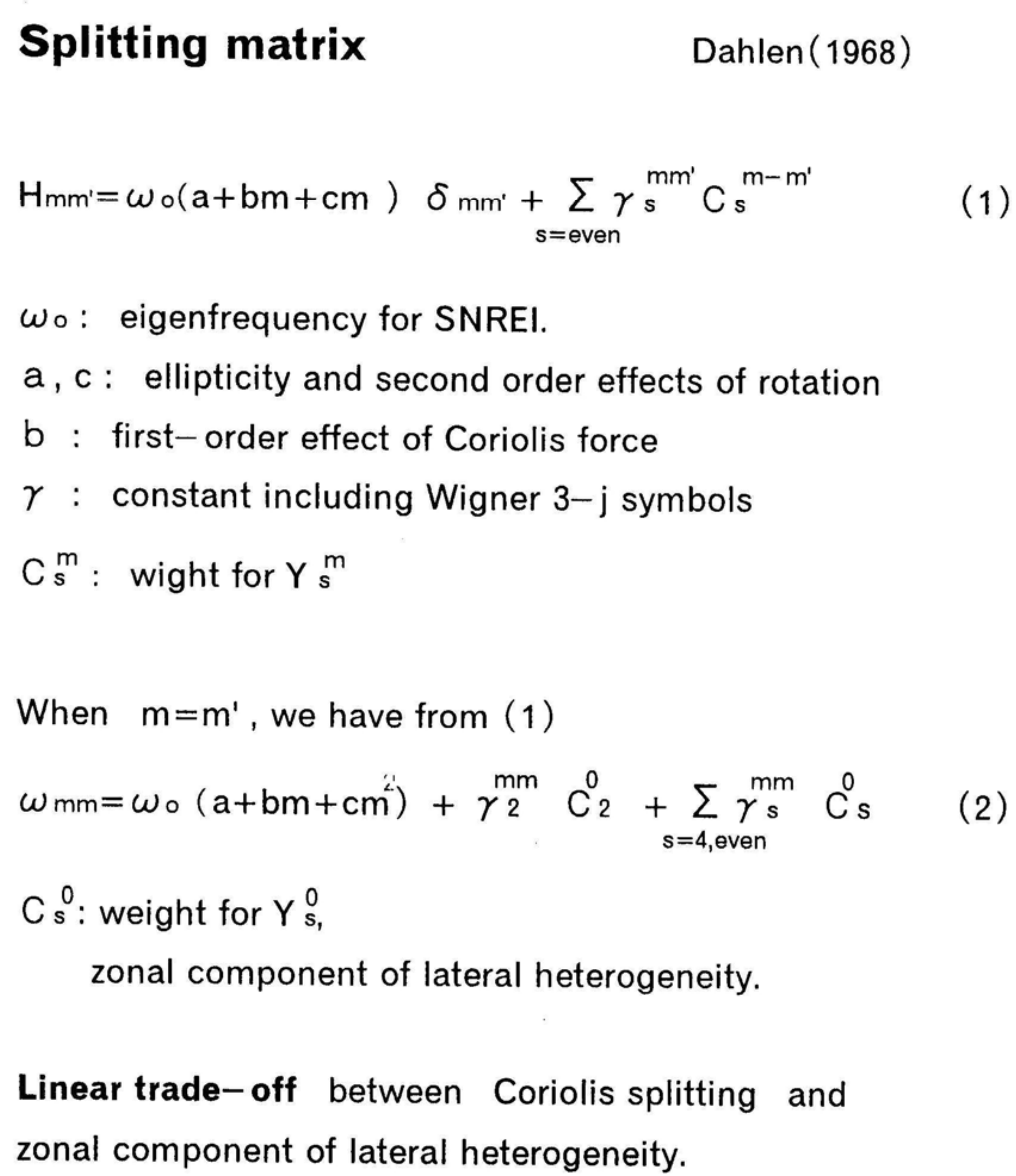


$_1S_8$



$_1S_9$





Splitting matrix

Dahlen (1968)

$$H_{mm'} = \omega_o(a + bm + cm\ )\ \delta_{mm'} + \sum_{s=\text{even}} \gamma_s^{mm'} C_s^{m-m'} \qquad (1)$$

ω_o : eigenfrequency for SNREI.

a , c : ellipticity and second order effects of rotation

b : first-order effect of Coriolis force

γ : constant including Wigner 3-j symbols

C_s^m : wight for Y_s^m

When m=m' , we have from (1)

$$\omega_{mm} = \omega_o\ (a + bm + cm^2) + \gamma_2^{mm}\ C_2^0 + \sum_{s=4,\text{even}} \gamma_s^{mm}\ C_s^0 \qquad (2)$$

C_s^0: weight for Y_s^0,

zonal component of lateral heterogeneity.

Linear trade-off between Coriolis splitting and zonal component of lateral heterogeneity.

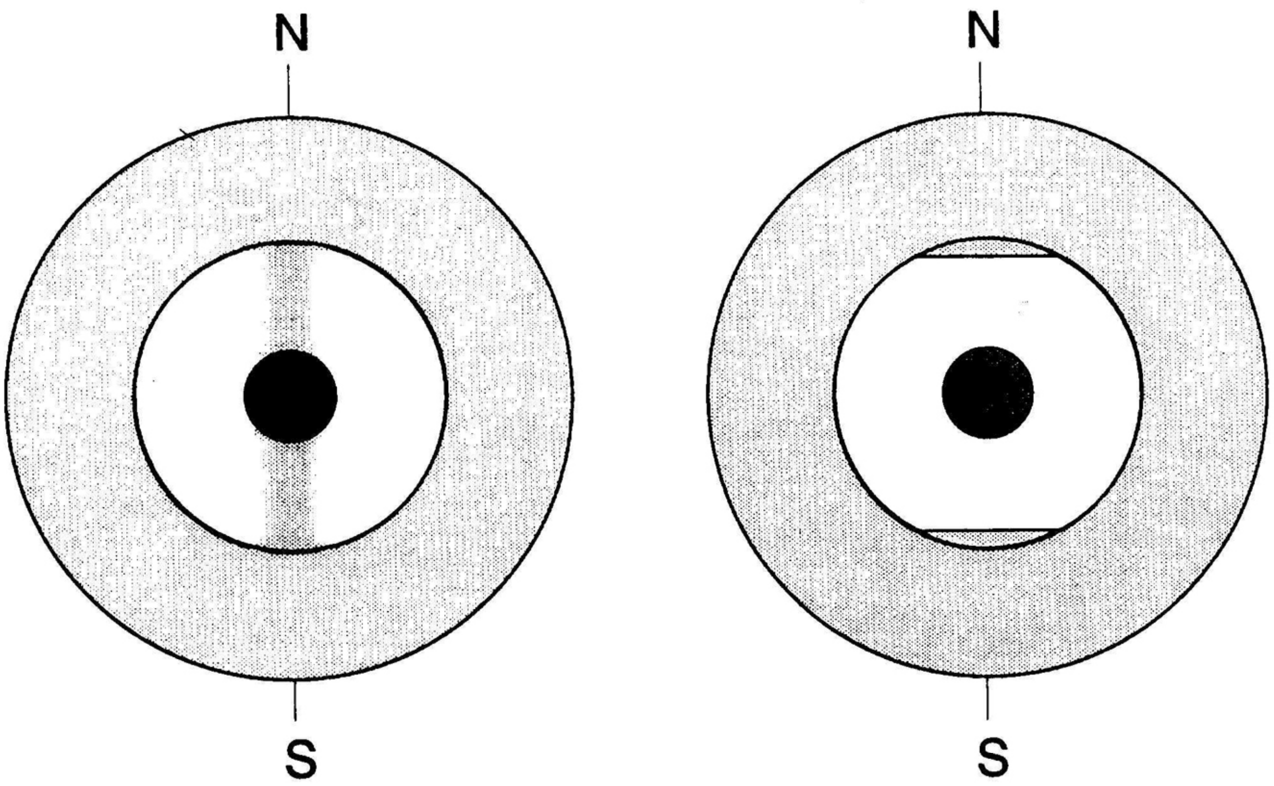


Figure 13. Conceptual sketches showing the two alternative outer core models discussed in the text: a) heterogeneity confined to the Taylor cylinder tangent to the inner core; (b) stagnant polar "caps" in the outer core.

内核の異方性

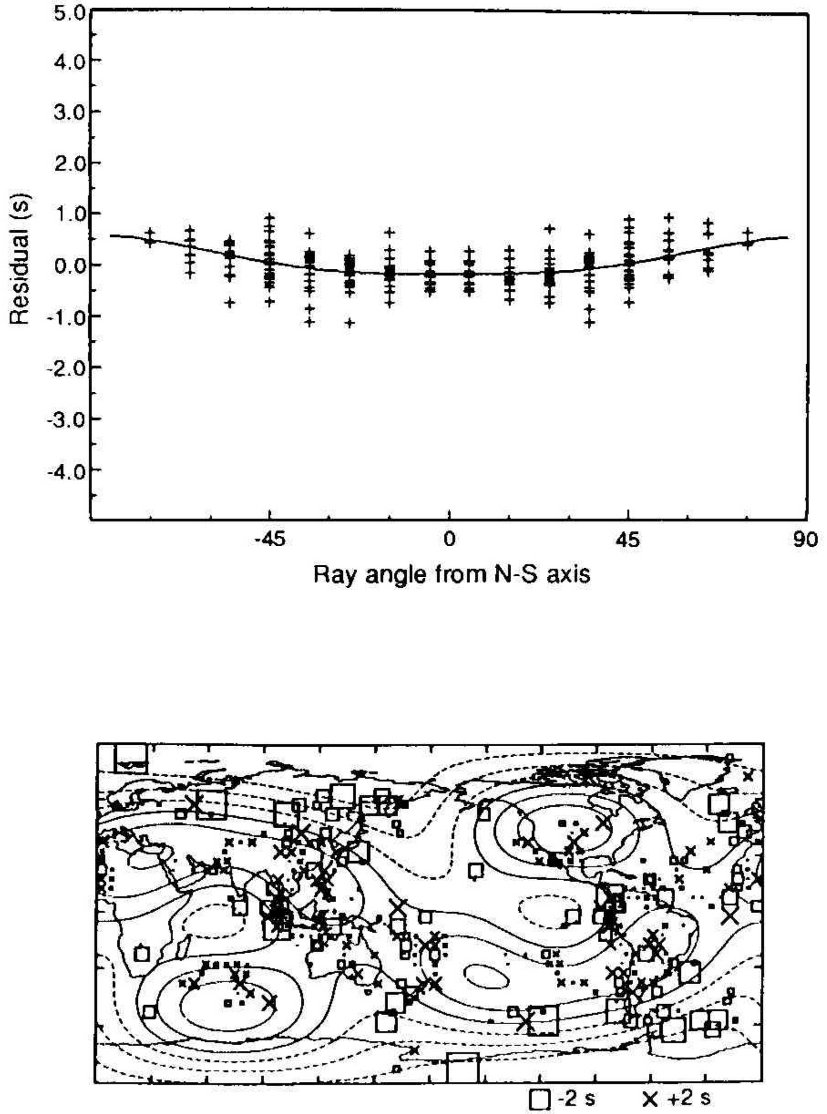


FIGURE 7.B4.1 Two separate analyses of *PKIKP* travel time anomalies, revealing a pattern of more negative anomalies (faster velocities) for paths along the polar direction. The top plot shows the residuals as a function of azimuth from the axis. The lower plot is a map of the anomalies at the source and receiver locations, with a low-order degree-4 expansion of the pattern. (Top from Shearer and Toy, *J. Geophys. Res.* **96**, 2233–2247, 1991; © copyright by the American Geophysical Union. Bottom from Morelli *et al.*, *Geophys. Res. Lett.* **13**, 1545–1548, 1986; © Copyright by the American Geophysical Union.)

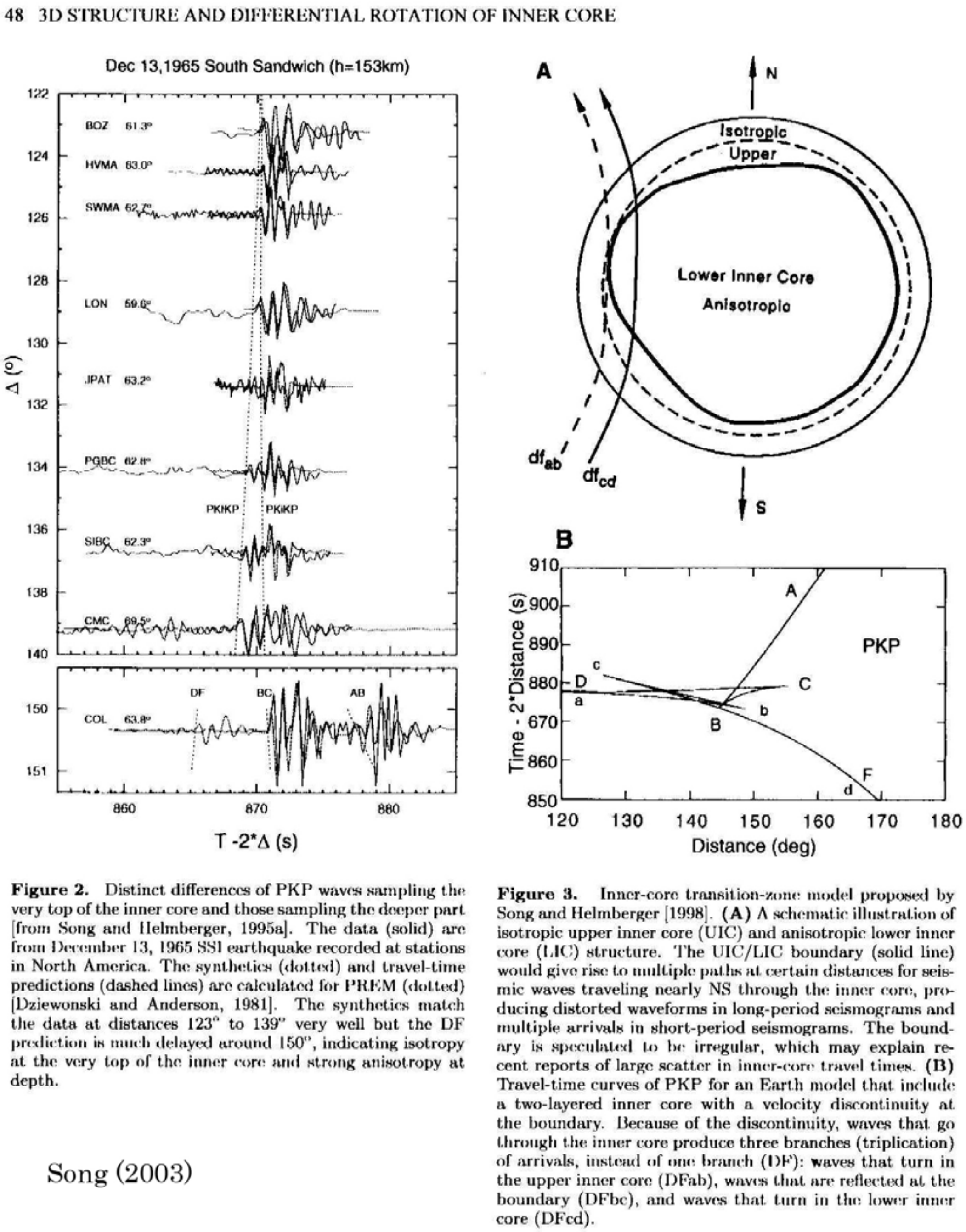
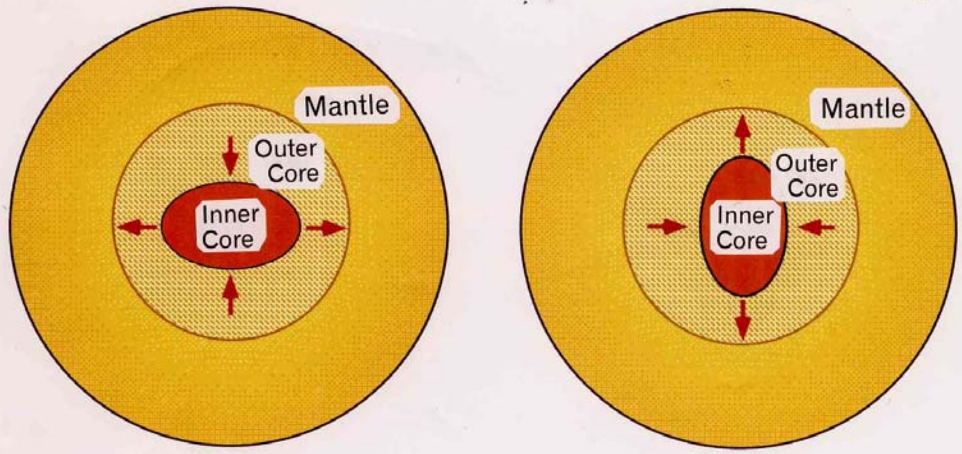


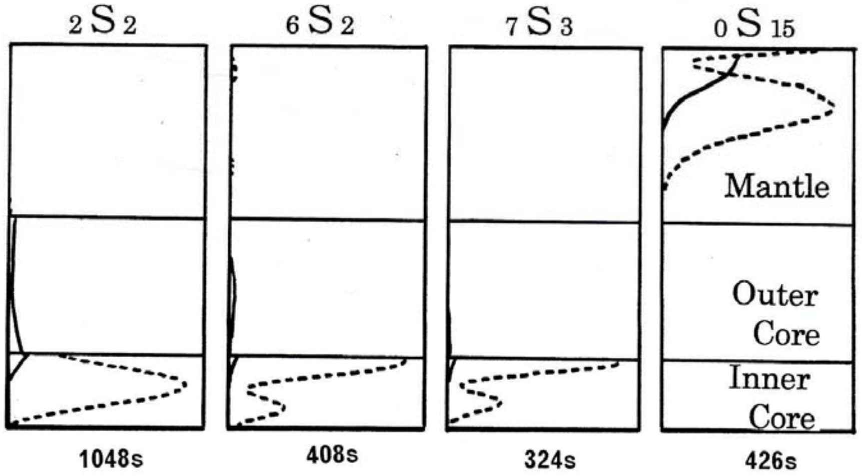
Figure 2. Distinct differences of PKP waves sampling the very top of the inner core and those sampling the deeper part [from Song and Helmberger, 1995a]. The data (solid) are from December 13, 1965 SSI earthquake recorded at stations in North America. The synthetics (dotted) and travel-time predictions (dashed lines) are calculated for PREM (dotted) [Dziewonski and Anderson, 1981]. The synthetics match the data at distances 123° to 139° very well but the DF prediction is much delayed around 150°, indicating isotropy at the very top of the inner core and strong anisotropy at depth.

Figure 3. Inner-core transition-zone model proposed by Song and Helmberger [1998]. **(A)** A schematic illustration of isotropic upper inner core (UIC) and anisotropic lower inner core (LIC) structure. The UIC/LIC boundary (solid line) would give rise to multiple paths at certain distances for seismic waves traveling nearly NS through the inner core, producing distorted waveforms in long-period seismograms and multiple arrivals in short-period seismograms. The boundary is speculated to be irregular, which may explain recent reports of large scatter in inner-core travel times. **(B)** Travel-time curves of PKP for an Earth model that include a two-layered inner core with a velocity discontinuity at the boundary. Because of the discontinuity, waves that go through the inner core produce three branches (triplication) of arrivals, instead of one branch (DF): waves that turn in the upper inner core (DFab), waves that are reflected at the boundary (DFbc), and waves that turn in the lower inner core (DFcd).

Song (2003)



Schematic pattern of the core mode $_2S_2$ (1048s)



(Suda et al., 1989)

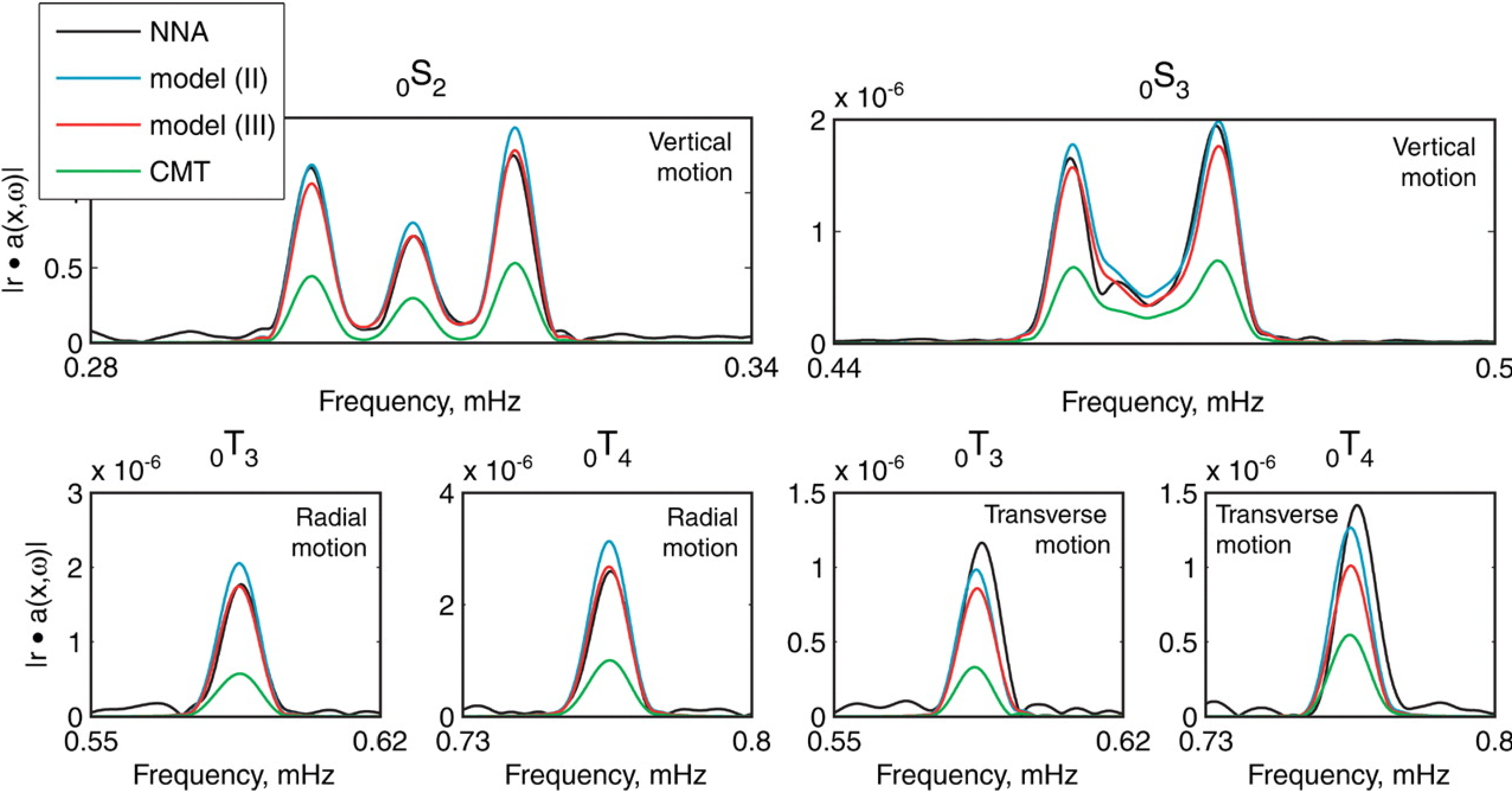
コアモードは何故検出困難か？

(1)M8クラスの地震の場合ですら、
地表での振幅が極小（10(-12)strain）
(2) ほぼ同じ周波数の基本モードがある

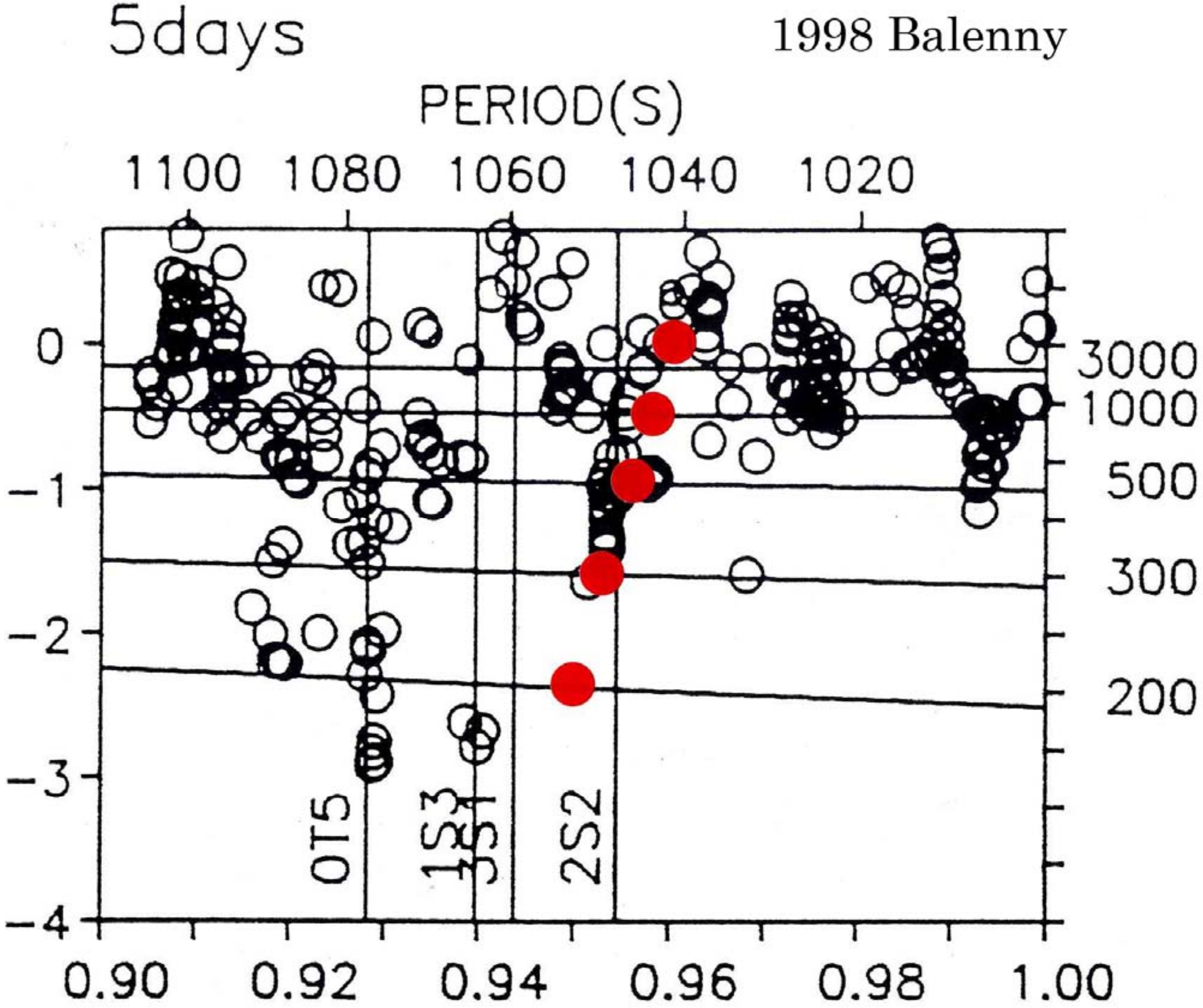
では、どうしたらいいの？

(1) **超巨大**な地震の記録。
(2) FFTやMEM では基本モードから分離不可能
存否法(Sompi-method)を使って、Qの違いを利用する。

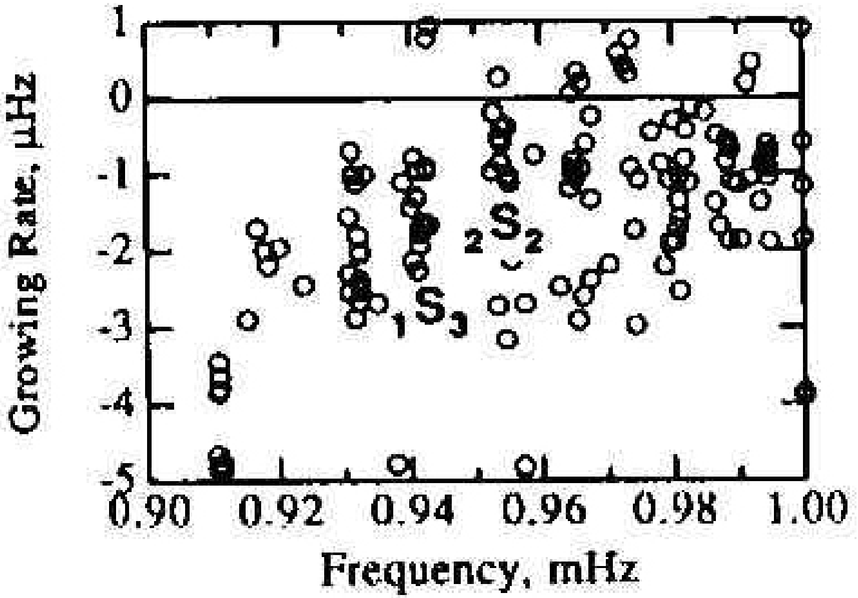
スマトラ地震 splitting Park(2005)



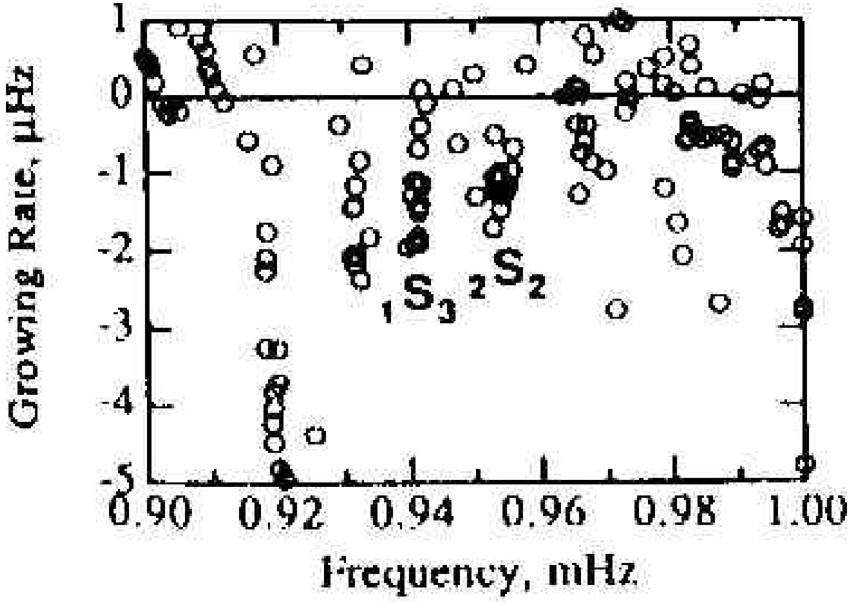
F-g diagram of Sompi-method



(b) 3 d



(c) 4 d



Imanishi
et al.(1990)