Correlation between plate motion and tomography

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The driving force of plate motions is considered to have a correlation with the upper mantle, but the correlation with the lower mantle is not clear. There might be a heat source in the lower mantle or on the top of the outer core, in addition to ridge spreading, or slab pull force that may originate in the upper mantle.

In this paper, seismic tomography at all depths, which represents the mantle heterogeneity and structure, and the plate velocities, crustal age and boundary spreading and convergence rate, which represent the plate motion, crustal thickness, and boundary position, respectively, are correlated in order to investigate the mechanism of the driving force of plate tectonics with respect to the mantle structure.

We used the method of Richards and Hager(1988) to obtain the correlations between two functions expanded with spherical harmonics.

Tanimoto(1990) model was used for the seismic tomography of the entire mantle. These data were expanded in terms of the spherical harmonics up to l=m=6 mode for 11 layers of the mantle.

For the correlation of plate velocity with tomography, we used the data of plate velocity of HS2-NUVEL1(Gripp and Gordon,1990). Vector direction of these data is ignored and this function is expanded up to l=m=6 with spherical harmonics(figure 1).

A high negative correlation in the lower mantle, a high negative correlation above 670km discontinuity and positive(above layer 5)-negative(layer 6,7)-positive(layer 10,11) correlation pattern in the lower mantle in l=4 are observed(figure 2). These results indicate that the lower mantle structure has also a correlation with plate motions, that 670km transitional boundary can be seen clearly in this correlation, and that there might be a three layers structure in the lower mantle in mode l=4.

For the correlation of crustal age with tomography, the crustal age of the oceans and the continents by Sclater et al.(1981) are used. Data points of crustal age are expanded with the same method as the case of the plate velocity(figure 3).

There is a high positive correlation in the upper mantle above the 670km discontinuity(figure 4). It might be related to the difference of mineralogy of continental and oceanic crust. The pattern of the positive correlation in l=3 and negative correlation in the higher modes in the lower mantle is somewhat opposite to the pattern in the upper mantle. This result might indicate the different pattern of the distribution of the horizontal anomaly of the compositional materials in the upper mantle from that in the lower mantle.

For the correlation of boundary rate with tomography, the spreading and convergence rate of NUVEL1 (DeMets et al. 1990) are used. The velocity is equal to zero at the non-boundary place, positive on the ridge, and negative on the trench, and absolute velocity is used to weight the boundary rate(figure 5).

A strong negative correlations in layer 4 which is the top of the lower mantle is observed(figure 6). There is also negative-positive-negative correlation in the lower mantle which can be seen in the case of the plate velocity in l=4. This might be related to the mantle convection structure as stated in the case of plate velocity.

From these analyses, three main results can be noted. One is a clear evidence of 670km discontinuity. The good correlation of the old crust and high seismic velocity in the upper mantle, the good correlation of slow plate velocity and high seismic velocity at the bottom of the upper mantle, and the high correlation of the boundary rate and tomography under the discontinuity support the existence of the 670km boundary of compositional material.

Secondary, the good correlation between the high seismic velocity and low plate velocity in the lower mantle suggests the existence of the correlation of the lower mantle to the plate motion.

Finally, in the lower mantle, three layers structure of the material anomaly can be seen with respect to the correlation of the plate velocity and the boundary rate with the tomography in $l = 4$. This indicates that the mantle convection might have three layers in the lower mantle with $l = 4$ mode.

References

DeMets et al.(1990) GJI, 101,425-478. Gripp and Gordon(1990) GRL, 17, 8, 1109-1112. Richards and Hager(1988) JGR, 93,7690-7708. Sclater et al.(1981) JGR, 86, 11535-11552. Tanimoto(1990) GJI, 100,327-326.

Figure Captions

Figure.1:Map of the plate velocity reconstructed from the coefficients of spherical harmonics up to $l = 6$.

Figure.2:The correlation between the plate velocity and the tomography. Horizontal axis is l mode and Vertical axis is the depth layer of the mantle(from 1:surface to 11:CMB). High positive correlations(high plate velocity and high seismic velocity, and vice versa) are expressed with the dotted area and negative correlations(high plate velocity and low seismic velocity, and vice versa) are expressed with the shaded area.

Figure.3:Map of the crustal age reconstructed from the coefficients of spherical harmonics up to $l = 6$.

Figure.4:The correlation between the crustal age and the tomography. High positive correlations(old crust and high seismic velocity, and vice versa) are expressed with the shaded area, and negative correlation (new crust and low seismic velocity, and vice versa) are expressed with the dotted area.

Figure.5:Map of the boundary velocity reconstructed from the coefficients of spherical harmonics up to $l = 6$.

Figure.6:The correlation between the boundary velocity and the tomography. The representations are the same as figure 5.

Figure.1

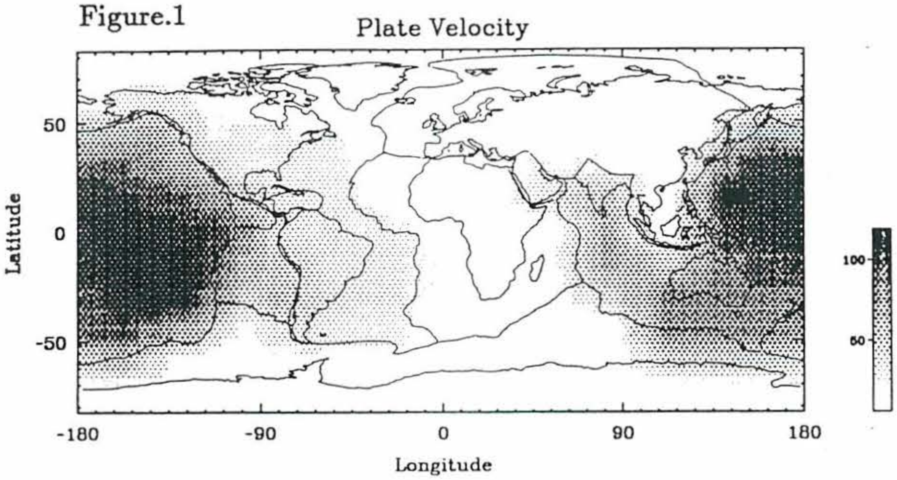


Figure.2

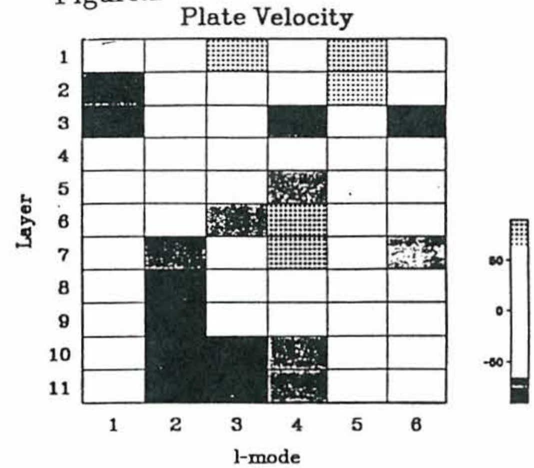


Figure.3

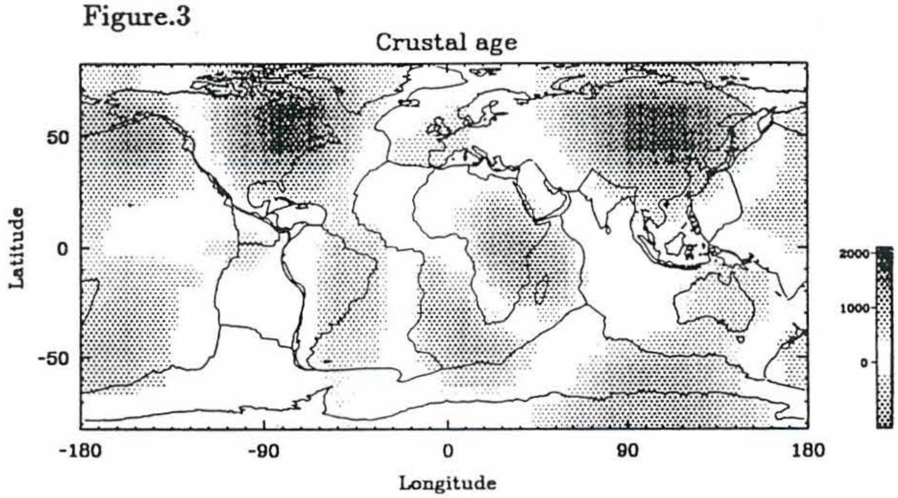


Figure.4

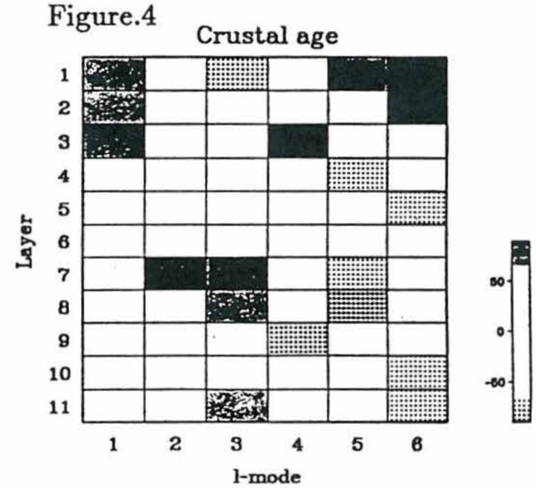


Figure.5

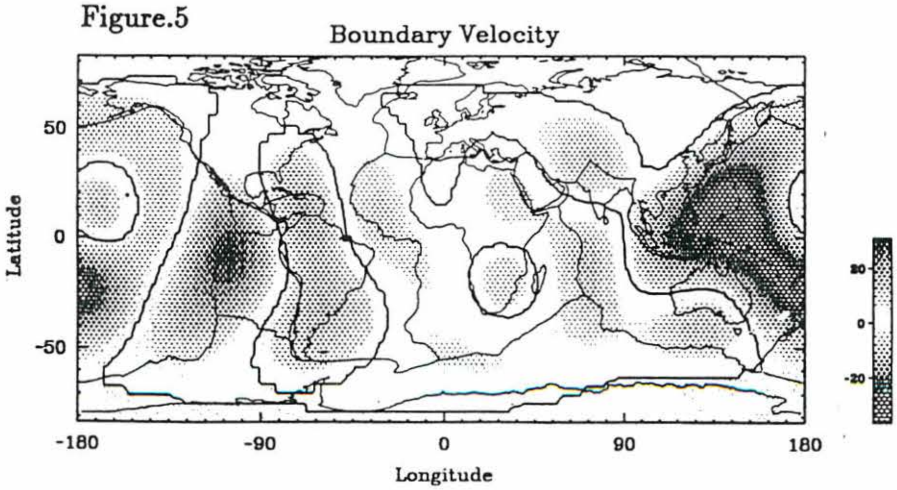
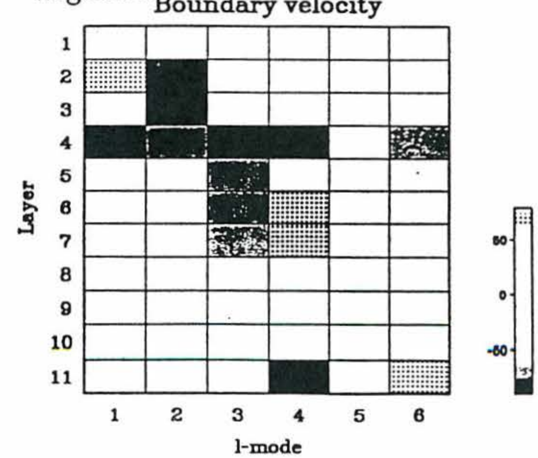


Figure.6



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