Oceanic Lithosphere: perspectives from Love wave phase velocity

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Global Love wave phase velocity variations are constructed for periods between 80 and 200 seconds by using approximately 9,000 paths from 971 events (with $M \geq 5.5$). The block parameterization approach ($5^o \times 5^o$ near equator) is used in this study. With improved resolution of about 1000 km, we attempt to study the oceanic lithosphere structure by using these results, because they are very sensitive to structure variation in the upper 200 km near the surface.

Using Sclater et al.'s oceanic age map (1981), we assigned an age to each 5 degrees by 5 degrees block in the Pacific, Atlantic and Indian oceans. We also corrected the age map based upon the resolution kernel at each block. Figure 1 shows the age versus Love wave phase velocity distribution for the Pacific Ocean at different periods. There is some scatter in the data, but the increase of phase velocity with age is apparent. There are similar features for the Indian and Atlantic oceans. The average phase velocities at ten million year intervals were calculated and plotted in Figure 2. One standard deviation is also shown in the figure. The number in parenthesis at the bottom is the number of blocks for a given age interval. In the conventional model, plates are believed to cool, subside and thicken during the first 60-80 Ma, but the development of secondary small scale convection or viscous shear stress heating below the lithosphere causes plate thickness to remain constant. On the contrary, our results indicate an increase in phase velocity for all oceans from the ridge to areas older than 100 Ma.

Using PREM as a starting model, we calculated theoretical phase velocity dispersion curves, and attempted to fit the observation by varying the thickness of the lithosphere and S-wave velocity of different layers. The final model for the Pacific Ocean is shown in Figure 3. Topography and crustal corrections are included in the analysis. Theoretical phase velocity variation curves are plotted with solid lines in Figure 2. They suggest that the lithosphere continuously thickens with age up to about 150 Ma, and does not stop thickening after 60-80 Ma.

Figure 4 is the age-phase velocity curves for the Pacific, Atlantic and Indian Oceans at period 100 s. There are two distinct features in these curves: (1) convergence of phase velocities for plate older than 100 Ma, and (2) systematic differences in plates of younger ages. The convergence of phase velocities beyond 100 Ma probably means that the lithospheric thicknesses are approximately the same for all oceans for old ages. The differences at younger ages implies a failure of scaling derived from a simple thermal boundary layer model for oceanic plates. Average heat flow data in young oceans decrease from the Pacific Ocean to the Indian Ocean, and then the Atlantic Ocean. They have been mainly explained by hydrothermal circulations. But our surface wave results indicate that the thermal differences in the mantle are required.

In order to understand the evolutions of lithosphere on different side of ridges, we examined the phase velocity variations. Figure 5 shows age-phase velocity curves on different sides of the Mid-Atlantic Ridge. We have added data from all areas of the Atlantic ocean. The phase velocity gradients are different for each side. Similar features occurred in other oceans, but the Atlantic Ocean shows this feature more clearly. Different hotspot concentrations is one possible explanation for the asymmetry. There are different thermal states on different sides of ridges, resulting perhaps in different lithospheric thickening rates.

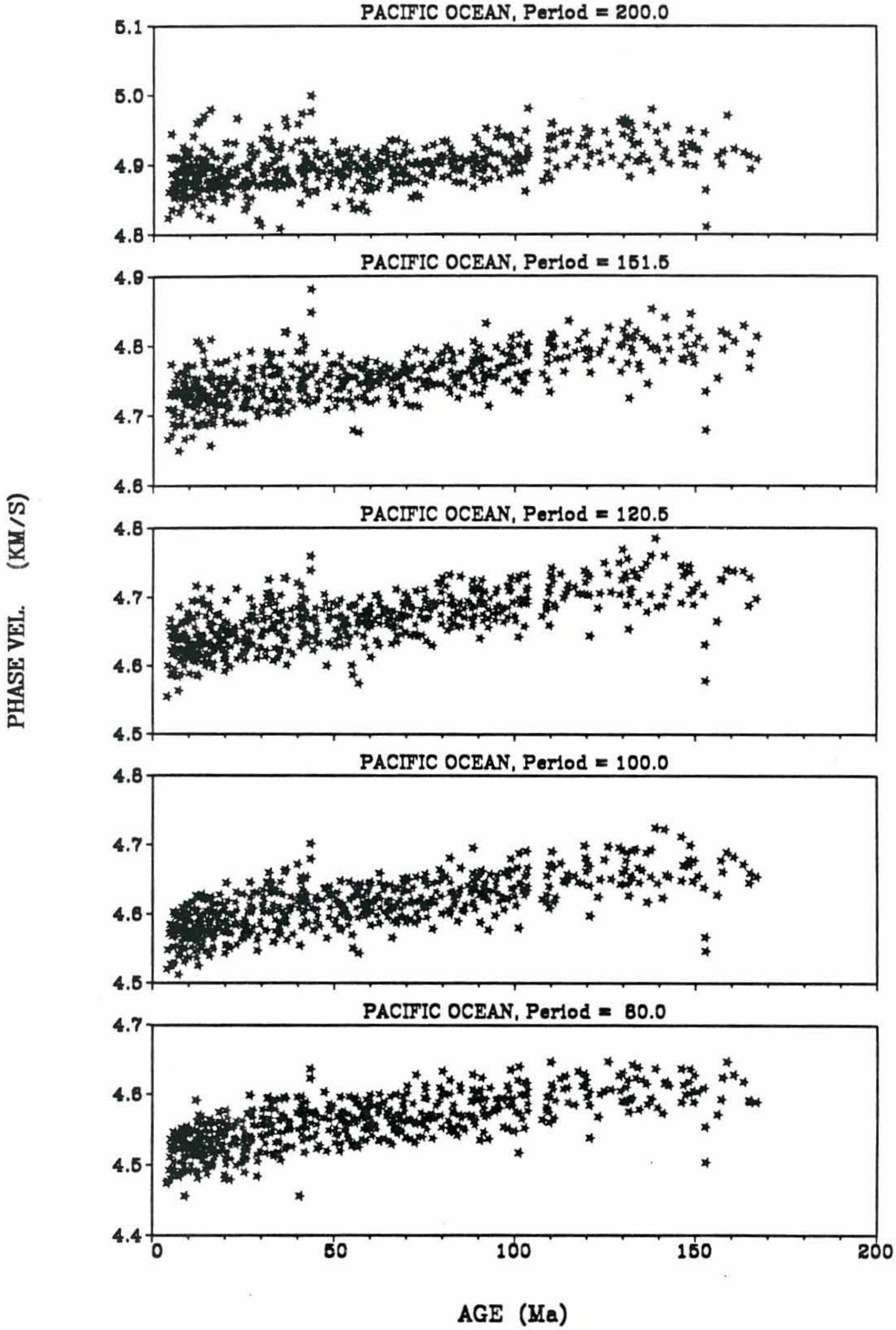

Fig. 1. Velocity distributions in the Pacific Ocean for periods from 80 to 200 s.

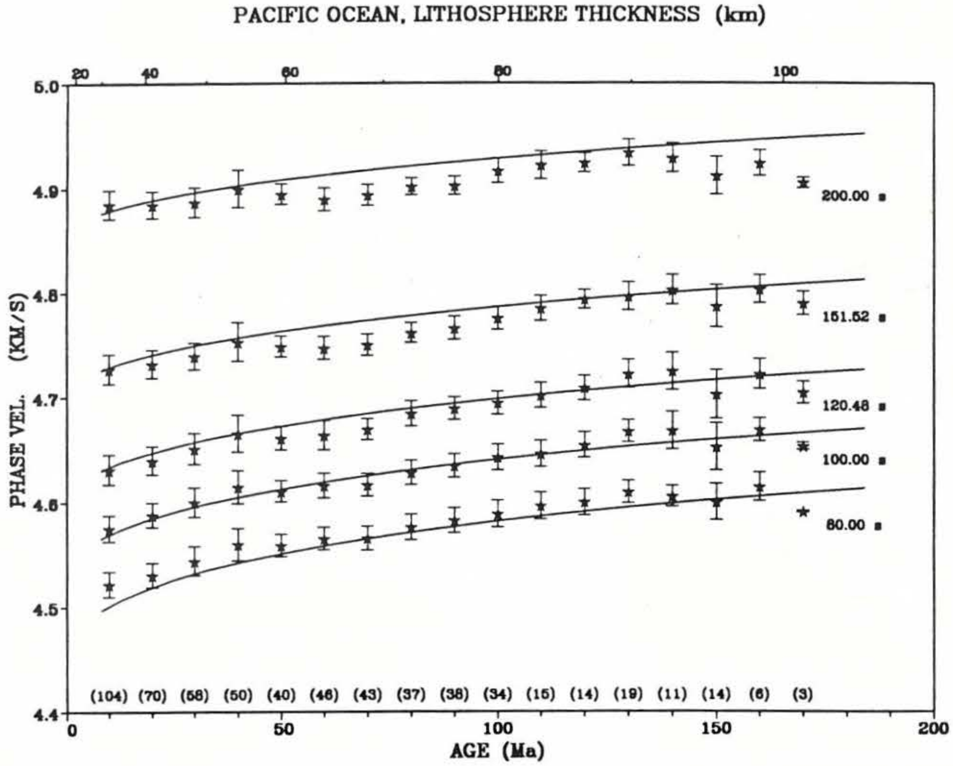

Fig. 2. Average phase velocity at ten million year intervals with one standard deviation for the Pacific Ocean. Solid lines are theoretical phase velocity curves for model in Figure 3.

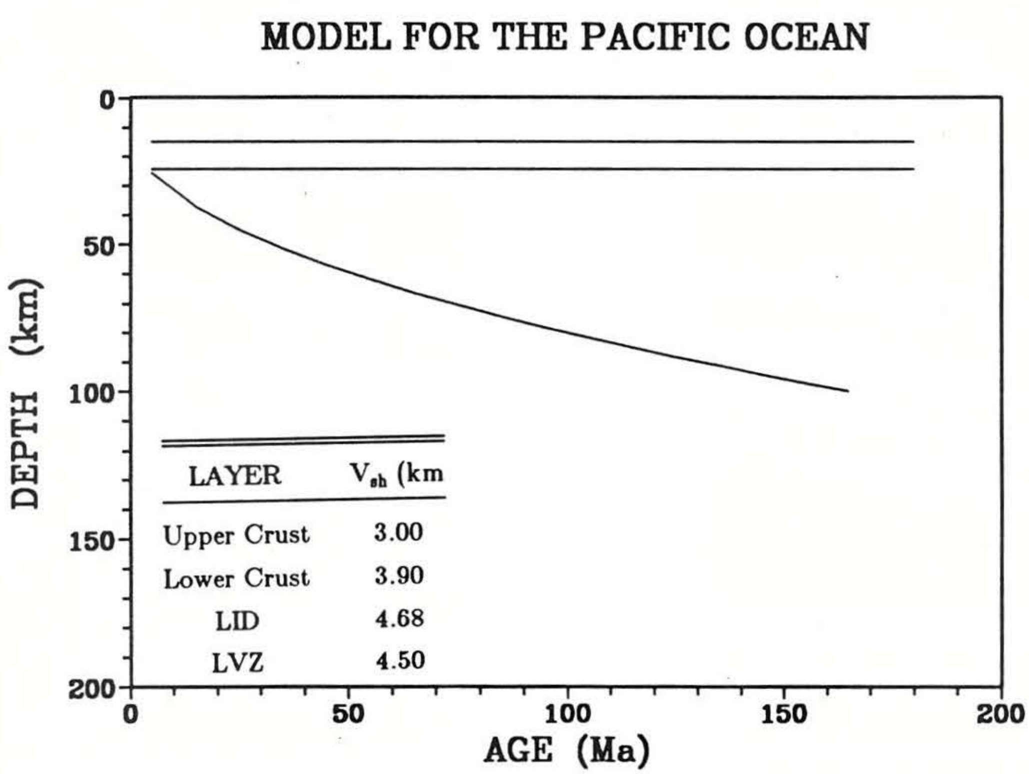

Fig. 3. Model for the Pacific plate. The thickness of the lithosphere is proportional to the square root of the age. The corresponding velocities for each layer are also given in the figure.

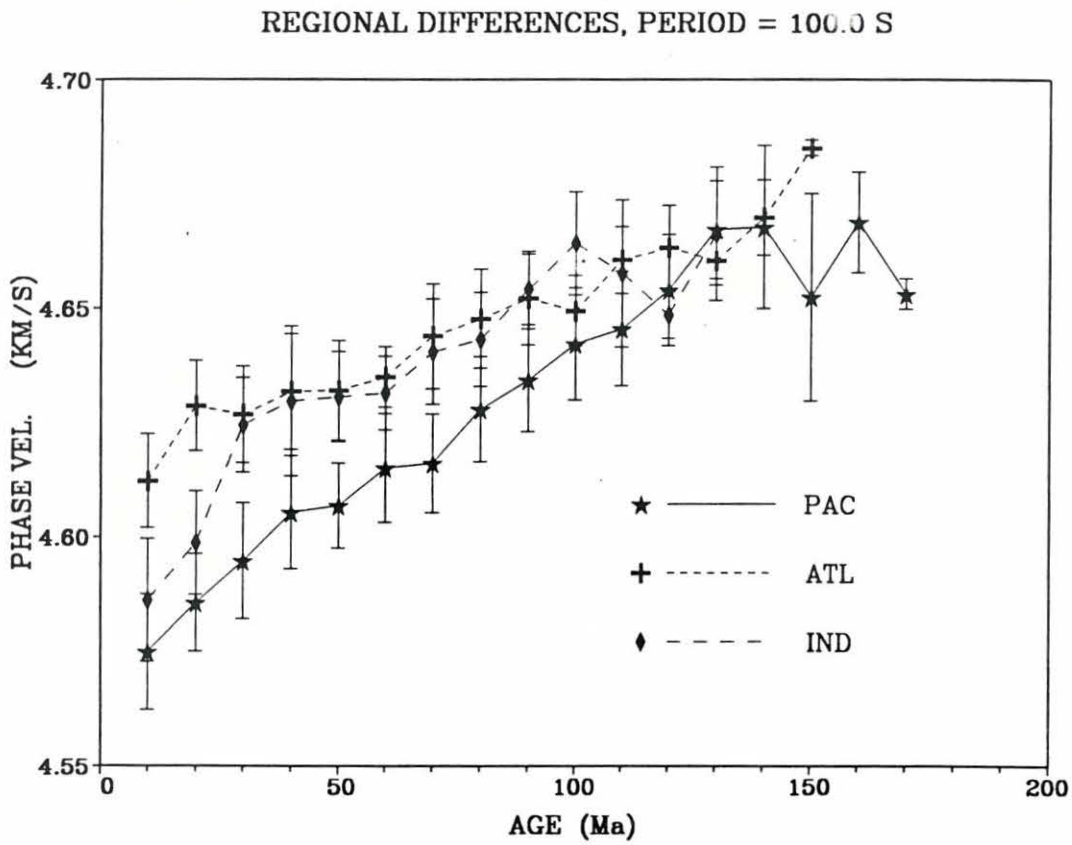

Fig. 4. Average phase velocity and one standard deviation in every ten million years for three oceans at period 100 s.

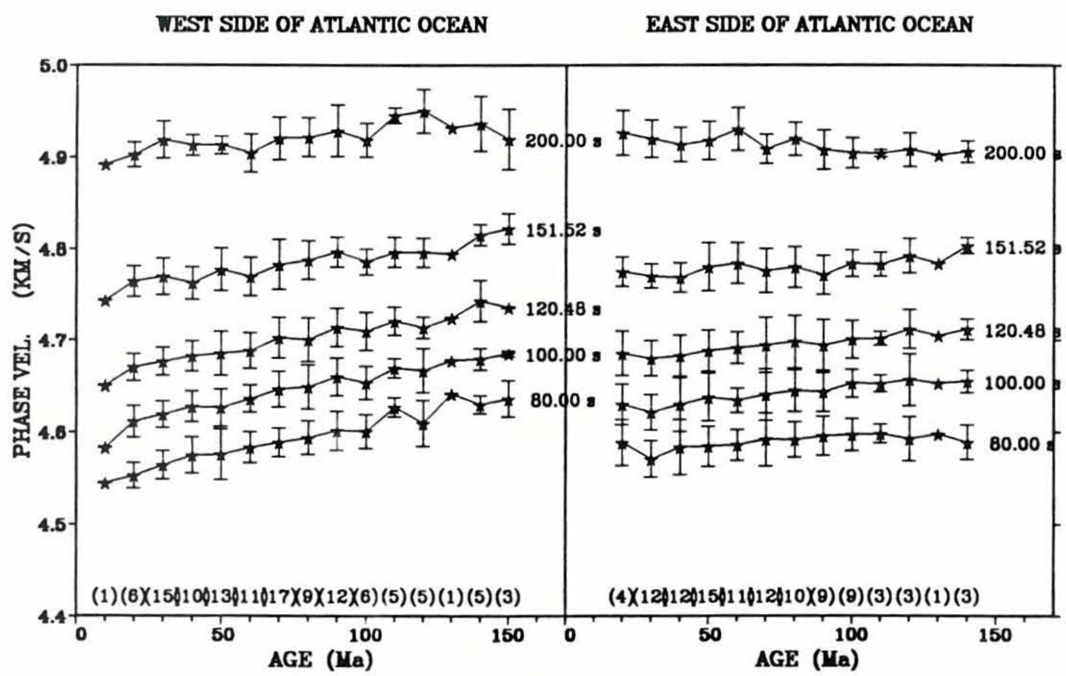

Fig. 5 Age-phase velocity curves on both sides of Mid-Atlantic Ridge. The velocity gradients are different on each side.

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