J. Geophys. 44, 675–677, 1978

Journal of Geophysics

Short Communication

Anomalous *P*-Velocities in the Earth's Outer Core

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Key words: Earth's core – *P*-velocity.

Kind and Müller (1977) recently put forward a new model for the structure of the Earth's outer core based on SKS amplitudes and travel times. Specifically they used long period observations of SKS/SKKS amplitude ratios and travel time differences between SKS and SKKS from five deep-focus earthquakes in the Tonga-Fiji region, and obtained significant disagreements with conventional core models. Theyruled out near source effects as the cause of these disagreements which they believe are caused by anomalous conditions around a depth of 3750 km. Their *P*-velocity structure around this depth is reproduced in Figure 1. It is the purpose of this short note to explore whether any physical-chemical model of the outer core could explain such a velocity structure, the validity of which demands further confirmation.

Since a light alloying element is required to account for the density of the core, it is probable that the core has a melting interval rather than a well-defined melting temperature. The solidus, or eutectic, temperature of the core could be quite a bit lower than the melting point of pure iron or the liquidus temperature of the alloy. Moreover since the liquidus is pressure dependent, the composition of the core would vary with depth. If core temperatures are below the liquidus solid iron would coexist with an ironrich melt solution. The solid iron could either be held in suspension by turbulent convection or settle out. An explanation for the behaviour of Figure 1 is put forward based on the supposition that between L_1 and L_2 the actual temperature in the outer core falls below the liquidus, crossing the solidus at L_2. Between L_1 and L_2 there is then a slurry of solid iron particles. Between L_2 and L_3 the temperature falls below the solidus and the core is solid. At L_3 the temperature rises above the solidus again, crossing the liquidus at L_4. Between L_3 and L_4 we again have a slurry of solid iron particles. It is further assumed that there is no abnormal behaviour in the incompressibility k which increases smoothly with depth (Bullen, 1949).

Consider first the region $L_1 L_2$ where the gradient of the velocity v_p of P waves is reduced. It is suggested that this reduction arises from the increased

0340-062X/78/0044/0675/$01.00

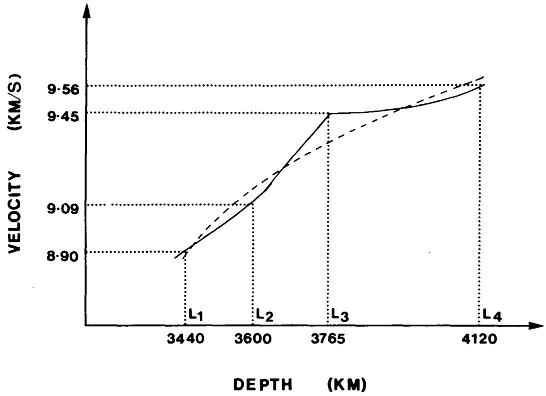

Fig. 1. Velocity of P waves versus depth in part of the outer core. Solid curve after Kind and Müller (1977), dashed curve, model 1066B (Gilbert and Dziewonski, 1975)

density in this region due to the solid iron particles in the slurry. Consider next the region $L_2 L_3$ where there is a rapid increase in v_p. This is accounted for by the elimination of a melt fraction in the core where the temperature has fallen below the solidus. If the material becomes sufficiently rigid, shear waves may be transmitted, and the abnormal increase in v_p given by $v_p^2 = k/\rho + \frac{4}{3} v_s^2$ where ρ is the density and v_s the velocity of shear waves. Taking the values of v_p from Kind and Müller (1977) and those of k and ρ from Model 1066B (Gilbert and Dziewonski, 1975) which Kind and Müller used for densities, values of v_s can be calculated throughout $L_2 L_3$. At L_3, $v_s = 1.60$ km/s. Finally in region $L_3 L_4$ the temperature has risen above the solidus and we again have a slurry. v_s is now zero and the increase in v_p is reduced below that of 'normal models'. If the increase in ρ (due to the presence of the solid iron particles) is approx. equal to that in k, then v_p is approx. constant as indicated in Figure 1. As L_4 is approached, the temperature exceeds the liquidus again and the material would begin to melt. The latent heat absorbed on melting would probably keep the temperature near the liquidus. The density gradient would decrease and approach its more 'normal' value leading to more 'normal' values of the velocity gradient, as observed.

It should again be emphasized that it is not suggested that the above thermal structure actually occurs in the core – it is only put forward as a possible explanation of the behaviour of the v_p depth curve in the outer core (Fig. 1) should this be substantiated by further work. For this model the core would be stably stratified at least over part of its depth. It is interesting in this regard to note that in some of the models that have been proposed for the outer core, we have found some indication that there may be a central stable region, i.e., a region where the stability parameter $\beta = 1 + \frac{k}{g \rho^2} \frac{d\rho}{dr}$ introduced by Pekeris and Accad (1972) is negative. However the degree of stability in such a region and the composition gradient across the core appear slight and it seems doubtful whether such an abnormal velocity region as found by Kind and Müller does in fact exist.

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Received April 14, 1978 / Revised version May 31, 1978