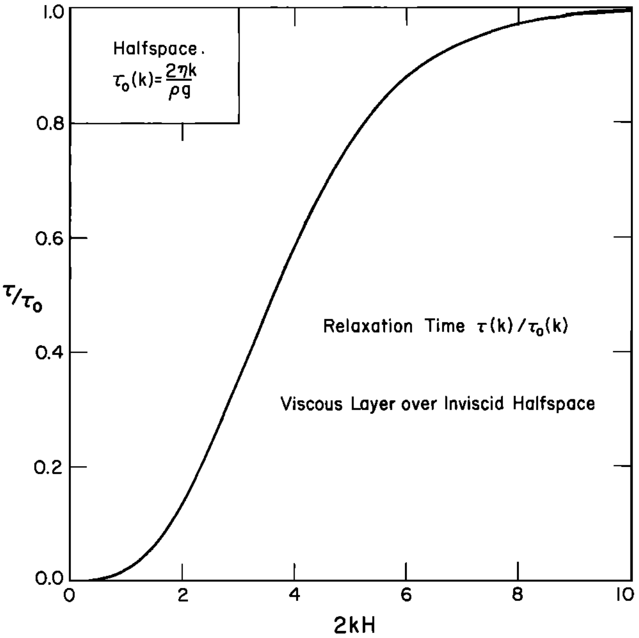

Fig. 4. Relaxation time τ versus wave number k for a viscous layer of thickness H over an inviscid half space. The relaxation time has been normalized by the relaxation time τ_0 for a uniform half space.

number of wave numbers, the quantity $|F(k)|$ in (7) is replaced by the coefficient of $J_0(kr)$ in the summation. For the Orientale profile in Figure 1*b*, the first inequality in (7) is easily satisfied for all k and all time t; i.e., topographic slopes are gentle. The second inequality is satisfied for all time t and for small k when H = 100 km; for H = 50 km and wavelengths $2\pi/k \geq 700$ km, however, the expressions on the two sides of the second inequality in (7) are comparable in magnitude at $t = 0$. For these long wavelengths also, as noted above, the neglect of the spherical geometry of the lunar lithosphere introduces further errors in the relaxation problem. The longest wavelength components of the relaxation displayed for these models, particularly in Figure 5, may require some modification once these additional aspects of the problem are incorporated in the analysis.

While the model of a viscous layer over a half space of much lower viscosity provides a simplified representation of a decreasing viscosity with temperature and therefore with depth, this model and the earlier half-space model ignore any isostatic compensation of the initial basin topography. Gravity anomalies over young basins indicate that the crustal thickness beneath basins is substantially less than beneath surrounding terrain [*Bowin et al.*, 1975; *Sjogren and Smith*, 1976; *Thurber and Solomon*, 1978]. Crustal thinning is presumably accomplished during basin formation by the combined effects of transient cavity excavation and mantle upwelling during inward collapse of the cavity and development of the outer ring scarp [*Head*, 1977; *Melosh and McKinnon*, 1978; *Phillips and Dvorak*, 1981]. Mantle uplift beneath the basin interior provides partial to complete compensation of the mass deficiency of the basin depression [*Bowin et al.*, 1975; *Sjogren and Smith*, 1976; *Phillips and Dvorak*, 1981]; this compensation can affect the viscous relaxation process substantially and should be included in any discussion of relaxation of impact basin topography.

Layer With Isostatic Compensation

The final analytical model we consider for lunar rheology is that of a layer of uniform viscosity η, density ρ, and thickness H overlying an inviscid half space of greater density $\rho_m = \rho + \Delta\rho$. For this model, the topographies at the surface and at the depth of the density contrast are coupled through the equations of motion and the boundary conditions; see the appendix. The topography at $t = 0$ at the mean depth H must be given as an initial condition; we assume a specified fraction c ($0 \leq c \leq 1$) of local Airy isostatic compensation in order to relate the initial depth of the density contrast to the initial surface topography. We are restricted with this model to have the depth of isostatic compensation coincide with the base of the high viscosity layer, but with this restriction we can obtain an analytical solution that permits a full exploration of the effects of both a decrease in viscosity with depth and initial isostatic compensation of topography on the viscous relaxation problem.

The solution for topography $h(r, t)$ at $t > 0$ is given, following the appendix, by

$$h(r, t) = \int_0^\infty [F_1(k)e^{-t/\tau_1(k)} + F_2(k)e^{-\tau_2(k)}]\, J_0(kr)\, k\, dk \qquad (8)$$

In this relation $F_1(k)$ and $F_2(k)$ are given by equations (A27), (A2), (A24), and (A26), and satisfy

$$F_1(k) + F_2(k) = F(k) \qquad (9)$$

where $F(k)$ by (5) is the Hankel transform of the initial topographic profile $f(r)$. The relaxation of a viscous layer overlying a half space of different density and viscosity has been treated in somewhat different form by *Ramberg* [1968] and by *Dvorak and Phillips* [1975]; the relaxation with time of a large lunar crater according to the Dvorak-Phillips treatment was displayed by *Phillips and Lambeck* [1980].

Two distinct time constants in (8), $\tau_1(k)$ and $\tau_2(k)$, govern the relaxation of topographic relief [cf. *Ramberg*, 1968]. The time constants are each proportional to η/g and are distinct functions of ρ, $\Delta\rho$, H, and k; see equations (A26) and (A24). The two time constants are plotted as functions of k in Figure 7 for the case ρ = 2.9 g/cm^3 and H = 50 km [*Toksöz et al.*,

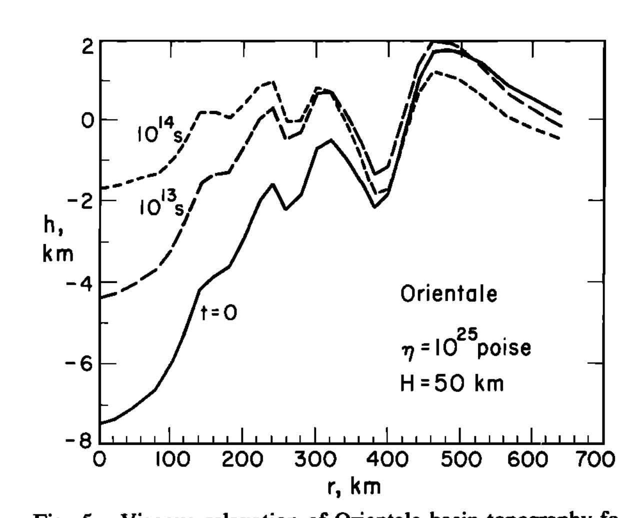

Fig. 5. Viscous relaxation of Orientale basin topography for a 50-km-thick layer of viscosity $\eta = 10^{25}$ P over an inviscid half space. Profiles are shown at t = 0, 10^{13} s (0.3 m.y.) and 10^{14} s (3 m.y.); these times scale linearly with the assumed layer viscosity.