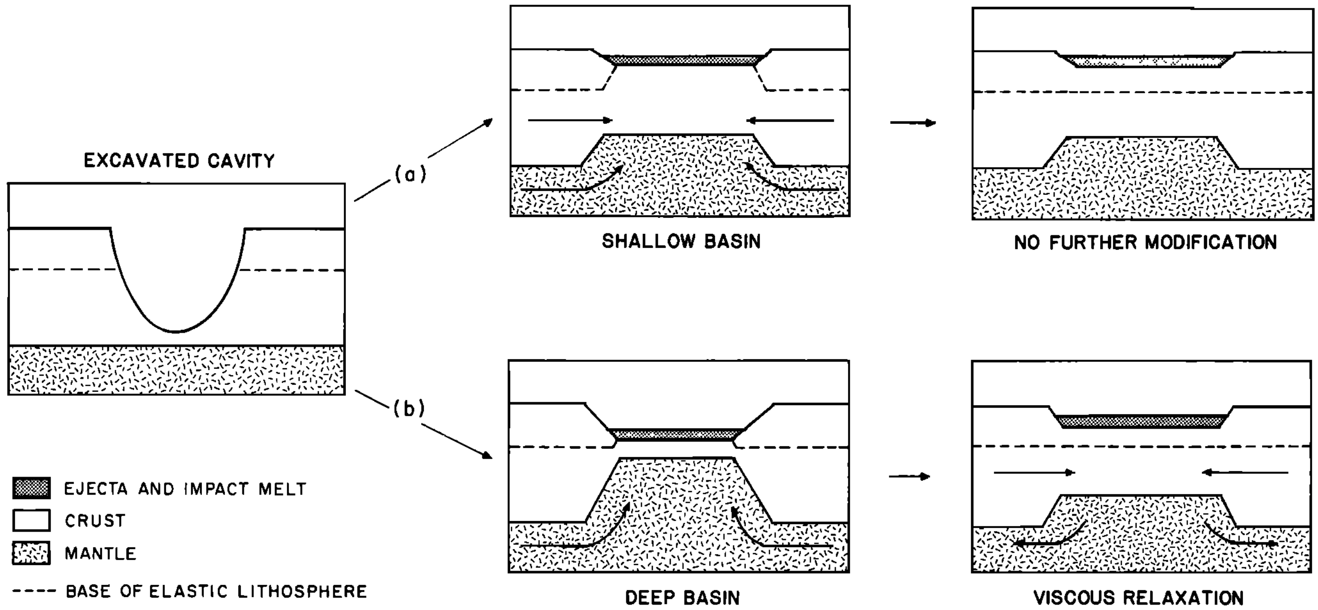

Fig. 12. Two possible scenarios to account for the structure of older lunar basins (e.g., Figures 10*g*–10*i*). (*a*) Because of the high crustal temperatures and thin elastic lithosphere at the time of impact, flow of both the crust and the mantle accompany transient cavity collapse, leading to a structure similar to that presently observed. (*b*) The collapse of the transient cavity at left is accomplished primarily by uplift of mantle material contemporaneously with the return of impact ejecta and melt to the basin, yielding an initial structure similar to that of younger basins. Because of high near-surface temperatures this initial structure undergoes long-term viscous relaxation of both topographic and Moho relief [*Solomon et al.*, 1982].

vation depths rarely exceeded the Moho depth by any significant amount. We therefore favor the first explanation.

Basin Modification

One of the principal results of this paper is that the extent of apparent mantle uplift or crustal thinning preserved beneath large lunar basins generally decreases with increasing basin age. The cross sections shown in Figure 10 illustrate this trend. We have attributed this variation to more extensive modification of older basins than younger ones. The time scale for this modification is highly uncertain and may range from the time scale of cavity collapse to the time interval between basin formation and one or more major episodes of mare basalt volcanism. In this section we consider the modification processes that can act to reduce basin topographic and Moho relief, and we evaluate the implications of our structural models for the variation of these processes with time on the moon.

A significant element of all endogenic basin modification processes is the additional heating at depth that accompanies basin formation [*Bratt et al.*, 1981]. Both ductile flow and magma genesis can be expected to be enhanced by this type of deep heating. Because the outer portions of the moon have generally cooled with time, the effects of such temperature-dependent processes might be enhanced for basins formed at an early stage in lunar history. Older basins are also more likely to sense the lingering effects of the formation of large, preexisting basins in the same region.

We consider four principal basin modification processes for young and old lunar basins: (1) ejecta from younger basins, (2) ductile flow of the crust, (3) nonmare volcanic activity, and (4) more volcanism.

Basin ejecta. The topographic relief of an older basin is reduced by the infill of ejecta deposits from younger basins. This effect probably constitutes only a minor contribution, however, to the topographic modification of most lunar basins. The difference in the amount of crustal thinning between the youngest nearside basins (e.g., Orientale, Serenitatis, Crisium) and older basins of comparable diameter (Nubium, Fecunditatis, Tranquillitatis) is several tens of kilometers. The accumulated thickness of younger basin ejecta deposits in these older basins is not likely to exceed a few kilometers [*McGetchin et al.*, 1973].

Ductile flow. Viscous relaxation of an impact basin by ductile flow of crustal material can reduce both topographic and Moho relief [*Solomon et al.*, 1982]. Because of the strong dependence of effective viscosity on temperature, viscous relaxation was likely to have been a more important modification process for older basins formed when near-surface temperatures on the moon were relatively high and the elastic lithosphere was thin. In particular, the premare topography and the crustal thickness in the Tranquillitatis region are both consistent with viscous relaxation from an initial structure similar to the present structure of Orientale [*Solomon et al.*, 1982]. It is, of course, uncertain whether the oldest basins actually had initial structures similar to that of Orientale or, perhaps because of a different thermal state at the time of basin formation, never displayed the topographic relief and extent of crustal thinning now observed for young lunar basins; the structural models derived from present gravity and topography cannot distinguish between these alternatives (Figure 12).

The formation of the Nubium, Fecunditatis, and Tranquillitatis basins, not resolvably different in age [*Wilhelms*, 1981], may have occurred over a sufficiently short interval of time following the formation of the 3200-km-diameter Procellarum basin [*Whitaker*, 1981] so that the thermal effects of the Procellarum impact on the creep rates in the crust were still im-