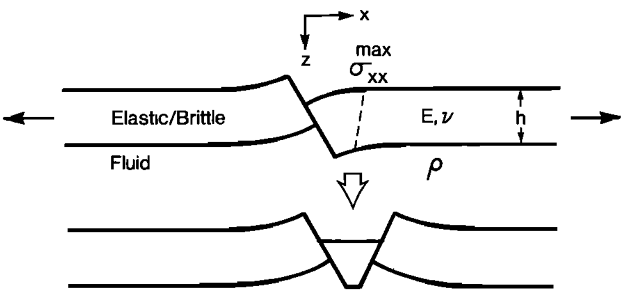

Fig. 6. The *Vening Meinesz* [1950] model for graben formation. Once a throughgoing normal fault forms in an extended elastic-brittle layer, then slip on that fault leads to additional bending stress in the layer. Under further extension, the preferred site for formation of the next failure plane will be where the surface bending stress σ_{xx} has its maximum extensional magnitude.

overlies an inviscid incompressible fluid of density ρ, and both are in a uniform gravitational field of acceleration g. The plate has been subjected to horizontal extension until failure, producing a normal fault that extends through the full thickness of the elastic layer. Slip on the fault leads to bending of the plate on either side (Figure 6, top).

If the fault is assumed to be stress free and to be located at $x = 0$, the vertical displacement for $x > 0$ is given by

$$w = w_0 e^{-x/\alpha} \cos (x/\alpha) \tag{27}$$

where w_0 is the vertical component of fault slip at $x = 0^+$, α is the flexural parameter

$$\alpha = (4D/\rho g)^{1/4} \tag{28}$$

and D is the flexural rigidity as given by (2) [e.g., *Turcotte and Schubert*, 1982, p. 127]. On the uplifted side of the plate ($x < 0$), (27) also holds if the signs are changed for both x and w_0.

The surface of the plate will be subjected to an additional horizontal stress σ_{xx} (positive in extension) caused by bending. The *Vening Meinesz* [1950] hypothesis is that the next normal fault to form under continued lithospheric extension will be located where σ_{xx} is largest (Figure 6). The bending stress at the surface is given by

$$\sigma_{xx} = \frac{E}{1 - \nu^2} \frac{h}{2} \frac{d^2w}{dx^2} \tag{29}$$

so for $x > 0$, σ_{xx} is a maximum where $(d^3w/dx^3) = 0$. By (27) this occurs at $x = \pi\alpha/4$. Assuming that this seond normal fault dips toward the first, a graben will form with width

$$b = \frac{\pi\alpha}{4} = \frac{\pi}{4}\left(\frac{4D}{\rho g}\right)^{1/4} \tag{30}$$

This equation as been used to predict the widths of continental rift valleys [*Vening Meninesz*, 1950; *Bott*, 1976]. Bott has also shown that if the region near $x = 0$ acts as a continuous elastic plate rather than as a stress-free fault, then b is larger by a factor of 2 than the value predicted by (30).

In order to apply this theory to banded terrain on Venus we must extend it to the situation where continued lithospheric extension gives rise to a sequence of alternating horst and graben structures. To do so, we must assume a relationship between band spacing λ and graben width. We explore several alternative assumptions for this relationship. The first is that graben width equals the half spacing between bands, i.e., each bright band is a graben (or horst) and the intervening material of lesser radar reflectivity is the opposite structure. With this assumption, (30) and (2) give

$$h = 4\left(\frac{\gamma}{B}\right)^{1/3}\left(\frac{\lambda}{2\pi}\right)^{4/3} \tag{31}$$

where γ and B are as defined in (12) and (13). This relation is shown in Figure 7 for $E = 10^{12}$ dyn/cm^2, $\nu = 0.25$, and $\rho = 3$ g/cm^3. For $\lambda = 15$–20 km, (31) gives $h = 2$–3 km.

Equation (31), except for the factor of 4, is identical to (14), expressing the relation between h and λ for the case of folding of an elastic layer. This similarity arises because bending of an elastic plate is involved both in the folding case and in the model for graben formation adopted here.

An alternative assumption for the interpretation of band spacing is that the bright bands are regions of steep slopes and rough surfaces and that the darker interventing regions are topographically flatter and smoother. By this assumption, graben width equals band spacing, and the inferred thickness of the brittle layer is larger than that given in (31) by a factor of 2.5.

A third possible assumption for the spacing between adjacent graben may be formulated by an examination of the bending stress σ_{xx}. Immediately outward of the graben (Figure 6, bottom), the bending stress at the surface is compressional. We may postulate that the preferred site for the next normal fault after the first graben has formed will be where σ_{xx} is most extensional. Consider the region $x < 0$ in Figure 6. From (27) and (29), σ_{xx} is most compressional (i.e., has a minimum) at $x = -\pi\alpha/4$, equals zero where $d^2w/dx^2 = 0$ at $x = -\pi\alpha$, and has a maximum where $d^3w/dx^3 = 0$ at $x = -5\pi\alpha/4$. However, the magnitude of σ_{xx} at $x = -5\pi\alpha/4$ is smaller by a factor of $e^\pi = 23$ than the magnitude at $x = -\pi\alpha/4$ (i.e., the stress invoked to explain the width of the initial graben), so the effect of bending stress at this distance from the graben may well be too small to exert an important control. If even this small extensional stress is sufficient to localize further normal faulting, however, this hypothesis predicts that the spacing between graben is about a factor of 6 larger than the width of each graben. If we equate the spacing between graben to the spacing λ between adjacent bands, then

$$h = 4\left(\frac{\gamma}{B}\right)^{1/3}\left(\frac{\gamma}{6\pi}\right)^{4/3} = 0.92\left(\frac{\gamma}{B}\right)^{1/3}\left(\frac{\lambda}{2\pi}\right)^{4/3} \tag{32}$$

a relation formally indistinguishable from (14). For Venus, if we put $\lambda = 15$–20 km, then (32) gives $h = 0.4$–0.6 km (Figure 7).

Imbricate normal faulting. The Vening Meinesz hypothesis for graben formation, depicted in Figure 6, is based on the assumption that the second normal fault to form will dip toward the first. On the other hand the conventional (i.e., Mohr-Coulomb) failure criterion does not distinguish between two alternative failure planes. By such a criterion the second fault could equally well have the same orientation as the first. Continued application of this latter scenario leads to a situation with imbricate normal faults. Imbricate faulting may be accompanied by rotation of crustal blocks as well as extension [e.g., *Wernicke and Burchfiel*, 1982], but significant block rotation may not be required in regions of steep long-wavelength surface slopes such as the mountains of Ishtar Terra.

Equations (27)–(29) still hold for the imbricate normal faulting model. The hypothesis that this model can explain banded terrain on Venus, however, requires that the spacing between