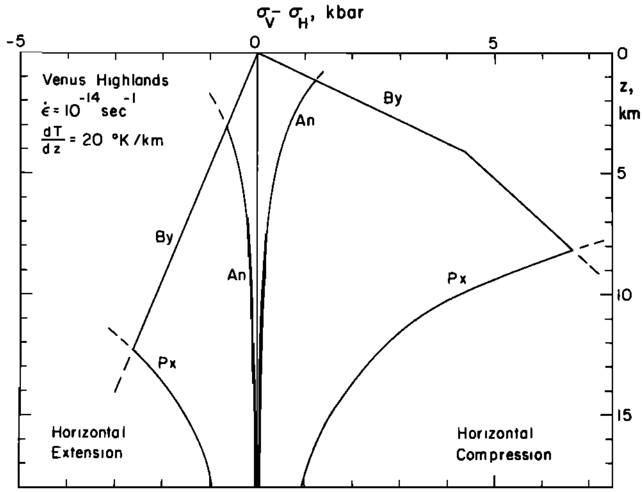

Fig. 8. Difference between vertical stress σ_V and maximum or minimum horizontal stress σ_H as a function of depth in Venus highland terrain. All stresss components are positive in extension. Thus for $\sigma_V - \sigma_H > 0$ the quantity σ_H is the least horizontal (most compressional) principal stress, and horizontal compression is implied, while for $\sigma_V - \sigma_H < 0$ the quantity σ_H is the greatest (least compressional) horizontal principal stress and horizontal extension is implied. Following *Brace and Kohlstedt* [1980], the stress difference is assumed to be limited by Byerlee's law (marked By) at shallowest depths and by an appropriate ductile flow law at greater depths. Flow laws for dry anorthosite [*Shelton and Tullis*, 1981] and for dry websterite (68% cpx, 32% opx) [*Avé Lallemant*, 1978] are shown (as An and Px, respectively), both assuming a strain rate of 10^{-14} s^{-1}, a surface temperature of 700°K, and an average crustal thermal gradient of 20°K/km.

thrust belt. Finally, while the bands generally strike parallel to the topographic contours of mountainous terrain, they may be seen to continue downslope without significant change in strike in several regions at the ends of mountain ranges (e.g., northwestern Maxwell Montes), contrary to the expected behavior if the bands originated by normal faulting in a massif spreading under its own gravity-generated internal stress.

There is a growing body of evidence from radar images and topographic profiles to indicate the characteristic style of extensional tectonics elsewhere on Venus. Lithospheric extension in other highland areas, including Beta Regio and Aphrodite Terra, appears to be manifested by the formation of great rift valleys and associated fault systems [*McGill et al.*, 1981; *Schaber*, 1982; *Campbell et al.*, 1984]. These rift valleys differ fundamentally, in both topographic form and radar image characteristics, from banded terrain units in Ishtar Terra. Ishtar, in fact, is the only major highland area lacking rift systems, consistent with the view that the most recent tectonic activity in that region has been dominantly compressional.

We therefore favor the hypothesis that banded terrain in Ishtar Terra formed concurrently with mountainous topography by folding, perhaps accompanied by thrust faulting, in response to lithospheric compression. While the alternative hypothesis—that the bands are secondary features associated with post-formational modification of the mountain ranges by extensional faulting—cannot be completely excluded, its likelihood is lessened by the length and linearity of individual bands, the relationship between band strike and topographic contours at the ends of linear mountain ranges, and the different tectonic response to extension in other major highland regions on Venus.

RELATIONSHIP OF TECTONIC MODELS TO VENUS THERMAL STRUCTURE

A common requirement of all of the best fitting models for band formation considered in this paper is that the surficial layer of elastic-brittle or high-viscosity behavior be no more than a few kilometers in thickness. Since this result holds whether the banded terrain is a product of compressional or extensional tectonics, we explore in this section the relationship of this surficial layer to the thermal structure of the Venus lithosphere. On the basis of laboratory measurements of the mechanical properties of likely crustal materials, the lithosphere of Venus may be shown on independent grounds also to be more than a few kilometers in thickness. We therefore suggest that the surficial high-strength layer invoked in tectonic models for band formation may in fact be the elastic lithosphere of the Venus highlands.

The simple analytical treatments we have followed for folding and extensional failure involve mechanical models that are abstractions of the actual mechanical behavior of rocks as measured in the laboratory. The relationship between laboratory observations and simple mechanical representations of the rheology of the lithosphere has been discussed at length for terrestrial tectonic problems by *Goetze and Evans* [1979], *Chapple and Forsyth* [1979], and *Brace and Kohlstedt* [1980], among others. We follow Brace and Kohlstedt in applying these same ideas to Venus.

At low temperatures the maximum stress difference that can be supported in fractured rock is governed by frictional resistance at fracture surfaces. As demonstrated by *Byerlee* [1968], frictional resistance can be described by a piecewise linear function of the normal stress across such surfaces, a relation largely independent of rock type. The form of Byerlee's law given by *Brace and Kohlstedt* [1980] provides a simple yet general limit to differential stress under both horizontal compression and horizontal extension. With the assumption that pore pressure on Venus is negligible, these limits are shown as functions of depth in Figure 8.

At elevated temperatures the maximum stress differences are controlled by ductile behavior. The relationship is usually cast in the form of a flow law, an expression for the stress difference as a function of temperature, strain rate, and rock type. Unfortunately, none of these parameters are well known for Venus, with the important exception of temperature at the planetary surface, which is sufficiently high that flow laws for many geological materials predict geologically rapid rates of strain for comparatively modest stress differences [*Weertman*, 1979].

Figure 8 shows the maximum stress difference as a function of depth for those portions of the Venus crust in the ductile fields of dry anorthosite [*Shelton and Tullis*, 1981] and dry websterite [*Avé Lallemant*, 1978], both for horizontal compression and horizontal extension. The temperature at the surface is taken to be 700°K, appropriate to an elevation about 5 km above the mean planetary radius [*Seiff et al.*, 1980] or approximately the elevation at the base of the mountain ranges of Ishtar Terra [*Masursky et al.*, 1980]. For Figure 8 we have also made the somewhat arbitrary assumptions that the strain rate $\dot{\epsilon}$ is 10^{-14} s^{-1} and the average vertical thermal gradient in the Venus highland crust is 20°K/km. The depth scale for the curves showing stress difference in the ductile field is inversely proportional to the adopted thermal gradient; e.g., all depths would be twice as great if dT/dz were 10°K/km. The indicated stress difference also depends on the