EVIDENCE FROM MAGELLAN DATA FOR STRIKE-SLIP FAULTING WITHIN FREYJA MONTES OROGENIC BELT; *J. W. HEAD and L. S. CRUMPLER*, *Department of Geological Sciences, Brown University, Providence, RI 02912*

INTRODUCTION. The mountain belts surrounding Lakshmi Planum have been interpreted previously to represent orogenic belts on Venus[1]. A major question that remains is how much crustal shortening has been accomodated [2] by the mountain belt formation and whether they are supported isostatically by great crustal thickening associated with convergence and horizontal surface movement [3] or whether they are the result of crustal thickening associated with mantle convective drag and sub-lithospheric piling up of a deformable lithosphere with little surface motion [4,5]. The convergent model was supported in previous studies and interpreted as orogenic belts because a number of discontinuities are associated with apparent large-scale offset of structural fabrics [1,3]. The large scale of these offsets (>100 km locally) was interpreted as the result of large scale horizontal motions of the crust.

Magellan images across Freyja Montes [6,7] yield significant resolution improvements over previous data sets and may potentially address the question of the length scale of horizontal surface motions, the amount of crustal shortening that has taken place, and the presence or absence of large-scale strike-slip faulting in general. Several discontinuities may be resolved in the Magellan images which cut across the regional structure of Freyja Montes and are interpreted to represent large faults, many of which are potential strike-slip faults based on previous predictions about the regional kinematics [1]. In this initial study, we focus on the identification and determination of the the sign and magnitude of displacement associated with one discontinuity. Many other features with similar characteristics occur throughout Freyja Montes, but the purpose here is to establish the criteria for recognition of the sign of the deformation. Later analysis will assess its regional significanece and overall contribution to the question of the length scale of crustal deformation and transport.

CHARACTERISTICS OF A SINGLE DISCONTINUITY. In order to illustrate the individual characteristics and detailed structure associated with faulting within the mountain belts, we focus on the nature of a single generally linear fault (Figure 1) forming a nearly east-west oriented discontinuity along the crest of Freyja Montes [Feature location: Lat 74.0 N / Long 330-331]. In regional view, Magellan images show a single lineament approximately 1 to 2 km wide, 100 km in length, and characterized along most of its length as a discontinuity identified as a narrow trough with intersecting northwest-southeast oriented scarps and graben a few kilometers wide. Locally the lineament flares in width to form polygonal basins from several hundred meters to two kilometers wide, the margins of which are consistently oriented on a regional scale.

Detailed mapping of the variety of topographic characteristics and nature of individual discontinuous features throughout the length of the linement all imply a history of deformation acting along a relatively narrow trace. Referring to reference numbers on the map in Fig. 1, the charcateristics include: (1) a wide trough with a relatively flat floor bounded on both north and south sides by surfaces of disparate regional surface topographic fabric (kilometer-scale polygonal plateaus to the north, 100 m-scale narrow furrows on the south); (2) abrupt terminations of numerous small regional scarps and graben from both the north and south sides of the linement; (3) "S"-shaped graben pierced by the lineament in which a 90° change in stike of the graben axis occurs across the discontinuity trace; (4) termination of a large graben at the discontinuity; (5) 2 km wide, polygonal or rhomboidal basin joining ends of two offset strike graben; (6) series of small scarps, basins, and mostly ridges oriented east-northeast to west-southwest obliquely with respect to the disconinuity trace; (7) change of discontinuity from generally a linear trough to a single north-facing scarp with superimposed scarps as noted at 6; (8) discontinuity continues as single faint lineament; and (9) discontinuity characterized by scarps oriented alternately in oblique west-northwest and east-northeast directions.

ANALYSIS AND INTERPRETATION. The variety of discontinuous structures and topographic elements across this lineament are consistent with a long, linear fault paralleling the general east-west orientation of the mountain belt and disrupting the more northerly oriented secondary structural fabric consisting dominantly of numerous parallel graben. The extreme topographic gradients and high elevations thoughout the mountain belts around Lakshmi Planum are potential sites for crustal deformation associated with gravitational self-stresses [6] and associted "gravitational relaxation" of topographic highs. If so, a number of large scale and dominantly normal (vertical displacment) faults might occur in the central massifs. In addition, the interpreted presence of crustal shortening associated with the formation of the mountain belts (i.e., orogenic belts), implies that large scale thrust faults may also be common. Some of the largest faults to occur in orogenic settings are, however, commonly strike slip faults, suggesting that this fault may also represent strike slip. On the basis of the above characteristics we assess whether it represents a normal fault or thrust fault (indicative of vertical disaplacement), or a stike-slip fault (indicative of horizontal displacement).

Evidence for sign and direction of displacement. The strike of both normal and thrust faults are sensitive to variations in local stress because of the influence of the orientation of the principal stress orientations on the corresponding azimuthal deflection of the surface intercept with the fault plane (lateral location of the fault trace);

extremes in topographic gradients, pervasive regional cross-fabrics (graben), and similar influences on local stressfield in the upper crust are examples of important influences in the strike of fault traces for normal and thrust faults. As a result, the strike of normal and thrust faults typically vary greatly over large distances (distances > regional scale of topography or structural fabric, i.e., >100 kms). The fault trace of normal and thrust faults are for these reasons variously complex, sinuous, arcuate, and even discontiuous. The fault examined here appears not to have been deflected or modified in response to regional slopes, is unaffected by shallow structure, is extremely linear and narrow, and in this respect implies the behavior associated with strike-slip faulting.

The general topographic and morphologic characteristics by which a strike-slip fault may be identified include [8]: (1) great linearity, narrow width, and great length; (2) zone of complex and variable surface deformation which trends linearly across regional structures; (3) associated and consistently oriented en echelon arrays of fractures, pressure ridges, and sag, rhomb, or pull-apart basins; and (4) systematically deflected or offset cross-strike (piercing) geologic and topographic features. In terms of the characteristics outlined above, this fault is extre,mely linear and long compared to many linemaents in the orogenic belts of Venus as it may be traced for 100 km in length, but nowhere exceeds 2 km in width despite linearly traversing a variety of crossing graben and regional surface fabrics, extremes elevations associated with the mountain belts, and otherwise crosses structurally complex areas. The varied fault expression, along-trace structures such as rhomboidal basins, evidence for lateral offsets of graben, and consistent sense of offset implied bny these criteria all suggest that this fault is the result of strike-slip. Right lateral strike-slip of few kilometers locally could account for "S"-shaped graben. The regional orientation of small polygonal basins along the fault are consistent in dimension, in aspect ratio, and in orientation with local crustal pull-apart basins resulting from right lateral shear.

Evidence for the magnitude of the strain responsible for the displacement. The displacenment implied by the piercing (cross-strike) structures (graben) are small ~2 km). Two types of shear environments may be defined [8]: pure (Coulomb-Anderson) shear and simple (Reidal) shear. Limited strike-slip is predicted for the first type, and correspondingly limited crustal motion, whereas large horizontal crustal motion is predicted for the simple (Reidal) shear. Is this small displacement evidence that the faults are pure (Coulomb-Anderson) shear originating from regional compression? Previous models for the sense of strain within the central Freyja Montes [1] imply considerable simple (Reidal) shear across east-west oriented strike-slip faults.

Deformation by simple shear occurs from horizontal motion acting locally with a rotational component and results in multiple (up to five sets) of often obliquely crossing directions of local fracture along a given fault trace. In contrast, faults resulting from pure or Coulomb-Anderson type shear are characterized by fewer fractures and absence of complex multiple olbiquely oriented fracture sets typical of simple shear. The variable morphology of the fault trace suggests that simple (Reidal) shear has been dominant. The abundance and variable orientation of fractures and associated structural patterns along the length of the fault, the occurrence of fracture orientation sets, confinement to a relatively narrow zone relative to the length of the fault, and characteristic morphology of structures associated with strike-slip faulting all suggest that the fault is the result of right lateral simple strike-slip shear.

CONCLUSIONS. Analysis of the detailed geologic and topographic characteristics along a single linear fault trace within Freyja Montes suggests that this fault represents evidence for right lateral strike-slip motion parallel to the general trend of the orogenic belt. The variety of structures occurring along the fault trace suggest regional simple strike-slip shear rather than pure shear resulting from north-south crustal shortening along Freyja Montes.

REFERENCES. [1] Crumpler et al., 1986, Geology, 14, 1031. [2] Head, 1990 Geology, 18, 99. [3] Vorder Bruegge, et al. 1990, JGR, 95, 8357. [4] Bindschadler et al., 1990, GRL, 17, 1345. [5] Grimm and Phillips, 1990, GRL, 17, 1349. [5] Solomon et al.,1991, submitted to *Science*. [7] Saunders et al, 1991, submitted to *Science*. [8] Sylvester, GSABulletin, 100, 1666.

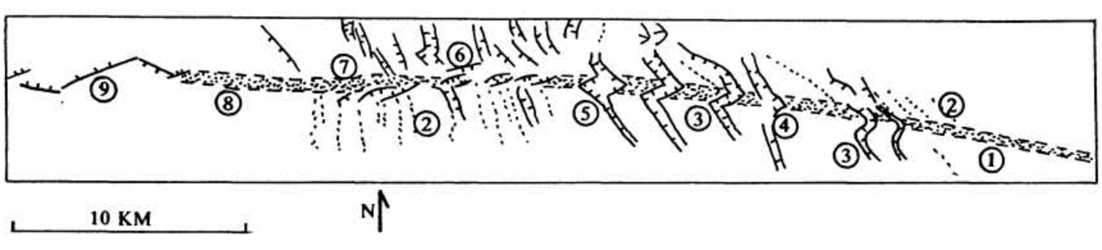

Figure 1. Physiographic sketch map of a lineament (dashed line enclosing shaded area) along the crest of Freyja Montes (centered at approximately Lat 74.0N / Long330.0-331.0; FMIDR 75N332). Numbers refer to observations noted in text. The great length, linearity, close association of numerous consistently oriented structures (rhomboidal basins and similarly-oriented oblique ridges), and apparent right lateral offset or termination of several pre-dating graben suggest that this lineament represents a right lateral strike-slip fault associated with simple trace-slip shear within Freyja Montes.