DISSPLACEMENT-LENGTH RATIO AND CONTRACTIONAL STRAIN OF LUNAR WRINKLE RIDGES IN MARE SERENITATIS AND MARE TRANQUILLITATIS. Bo Li[1,2*], Jiang Zhang[1], Jian Chen[1]. 1 Shandong Provincial Key Laboratory of Optical Astronomy and Solar-Terrestrial Environment; Institute of Space Sciences, Shandong University, Weihai, China. 2 Key Laboratory of Lunar and Deep Space Exploration, Bejing, China. (libralibo@sdu.edu.cn)

Introduction

Statistical analysis of the geometric properties of the populations of the planetary tectonic structures (such as faults, joints, veins, dikes and deformation bands) can be used to understand the basic mechanical controls on the growth of a wide range of these geologic structures. Some previous studies showed a relationship between the maximum displacement (D_{max}) and length (L) of fault populations on terrestrial and planetary surfaces. The D_{max}-L scaling can be used to describe an average long-term equilibrium stress field.

Mare Serenitatis and Mare Tranquillitatis have similar perimeter and size. Mare Serenitatis formed in the Nectarian period, while Mare Tranquillitatis formed in the pre-Nectarian period. Mare Serenitatis is a mascon basin, and there is no mascon in Mare Tranquillitatis. Therefore, the wrinkle ridges in the two maria are good research subjects for comparing and contrasting the nature of the D_{max}-L scaling and local contractional strains of mare basins.

Method

The mechanical effects of fault linkage become evident if height profiles are constructed along the border fault systems by measuring the vertical offset (the throw) across the border fault at many individual positions. If there is a continuous increase of throw from the fault tip toward the area of maximum throw, which is located at or near the fault's midpoint, this fault is thought to be a single fault. We extract the single ridges from the identified wrinkle ridges in Mare Serenitatis and Mare Tranquillitatis, which are yellow lines shown in Fig.1.

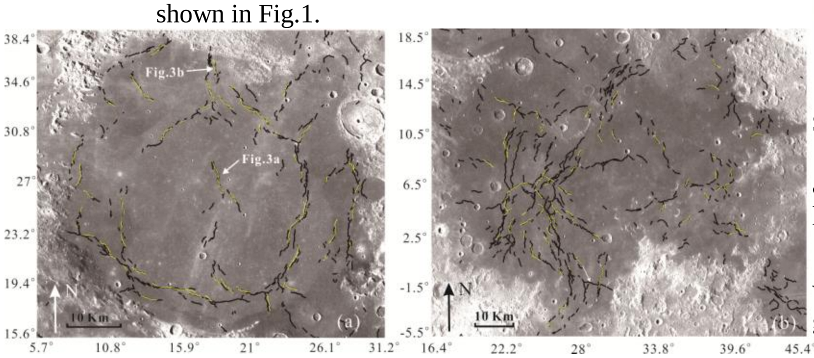

Fig.1 Identified wrinkle ridges (black lines) and selected single ridges (yellow colors, superposed on the black lines) in Mare Serenitatis and Mare Tranquillitatis.

Given the height (H) and dip angle (θ) of a wrinkle ridge, the displacement (D) to a planar surface can be given by:

$$D = H/\sin\theta.$$

Previous experiments suggest that thrust faults will be formed when dips range from 24° to 30°. Moreover, dip angles derived from field work for thrust faults are between 20° to 30°, consistent with laboratory results. In order to estimate the maximum total fault displacement recorded at each fault, we assume that the thrust faults had a dip of 25°.

***D-L* scaling of wrinkle ridge population**

The relationship between the maximum displacement and length of a fault population can be described as a linear formula:

$$D_{max} = \gamma L,$$

where γ is a constant determined by rock type and tectonic setting (where n = 1, $\gamma = c$).

The heights of 59 single wrinkle ridges in Mare Serenitatis are from 50 m to 650 m with an average of 174.1 m. A linear fit to D_{max}-L data for wrinkle ridge population in Mare Serenitatis yields a value of γ= 1.73×10^{-2} (Fig. 2a). While in Mare Tranquillitatis, we only calculate the γ value of the radial group. The heights of 39 wrinkle ridges in the radial group range from 60 m to 490 m with an average of 166.9 m. A linear fit to D_{max}-L data for them yields a value of γ = 2.13×10^{-2} for θ = 25° (Fig. 2b).

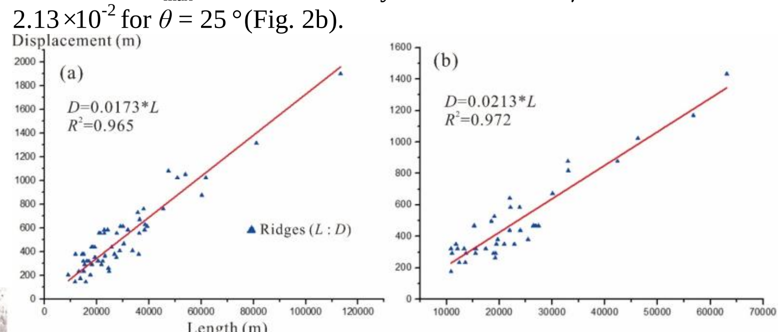

Fig.2 The D_{max}-L ratios of ridge populations in Mare Serenitatis (a) and the radial group in Mare Tranquillitatis (b).

According to the previous studies, the strain (ε) of a study area containing tectonic features can be calculated by [1]:

$$\varepsilon = \frac{\cos(\theta)}{A}\sum_{K=1}^{n} D_k L_k$$

where θ is the fault dip, A is the area of the study region, n is the total number of tectonic features.

The contractional strains for wrinkle ridge population in Mare Serenitatis and Mare Tranquillitatis are estimated to be ~0.36% and ~0.14% (for θ = 25°).

Discussions and implications

(1) Compared to the previous results, the contractional strains for the wrinkle ridges in Mare Serenitatis and Mare Tranquillitatis appear to be nearly one order of magnitude bigger than the strain from the

small scarps on the Moon. Young lobate scarp thrust faults indicate late-stage and smaller compression of the lunar crust. While wrinkle ridges suggest a long history of contractional deformation with higher strain value resulting from mare basalts emplacements.

(2) The values of free-air gravity anomalies [2] in Mare Serenitatis range from -18 to 358 mGal with an average of 250 mGal, higher than those of the gravity anomalies in Mare Tranquillitatis which range from -70 to 120 mGal with an average of 30 mGal. We think that the contractional strains derived from the wrinkle ridges in mare basins may be affected by the existence of the mascon and the quantity of gravity anomalies in the mare basins. The Mare Serenitatis has obvious positive and negative gravity anomalies, and its concentric wrinkle ridges around the mare boundary can penetrate up to kilometer-scale in depth. Thus, Mare Serenitatis has a larger contractional strain for wrinkle ridge population than the strain in Mare Tranquillitatis.

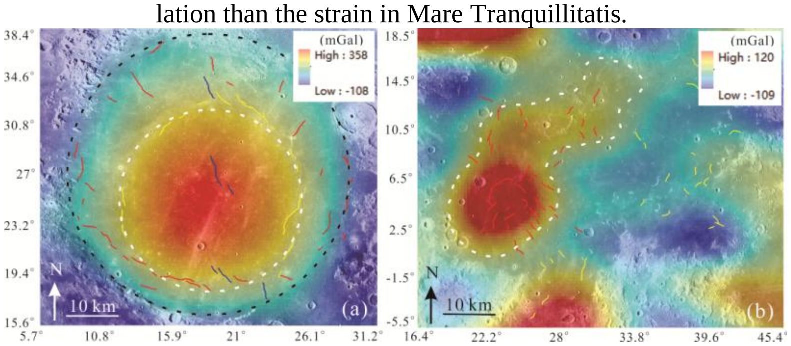

Fig.3 Free-air gravity anomalies in Mare Serenitatis (a) and Mare Tranquillitatis (b).

Models for the origin of stresses in mascons suggest that the spatial distribution of the wrinkle ridges is best fit by a relatively uniform thickness of mare basalts [3]. The average of basaltic thickness in Mare Tranquillitatis is 400 m determined by the widely distributed craters [4]. While the average basaltic thickness in Mare Serenitatis is 798 m from 31 craters [5]. Thus, the higher value of free-air gravity anomalies and thicker basaltic emplacement in Mare Serenitatis may result in the higher contractional strain than the strain in Mare Tranquillitatis, although the formation of the Tranquillitatis basin is earlier than that of the Serenitatis basin.

Except for the ridges in mare Tranquilitatis, the ridge groups formed with average ages between 3.5 and 3.1 Ga ago, or 100-650 Ma after the oldest observable erupted basalts where they are located [6]. But, the ridge system in Tranquilitatis yields an average formation time of 2.4 Ga, which is 1.4 Ga after its oldest surface lavas, a significantly longer period than for any other basin. Although, Mare Tranquillitatis (pre-Nectarian period) is older than Mare Serenitatis (Nectarian period), the formation time of the ridge group in Mare Tranquillitatis is earlier than that of the ridge group in Mare Serenitatis. The formation of ridge group in Mare Serenitatis takes longer time than that in Mare Serenitatis, therefore, the average length (28.82 Km) and height (174.1 m) of ridge in Mare Serenitatis is bigger than the average length (23.04 Km) and height (163 m) of ridge in Mare Tranquillitatis. And the contractional strain of wrinkle ridge populations in Mare Serenitatis is ~0.36%, which is also bigger than the contractional strain (~0.14%) in Mare Tranquillitatis.

Therefore, we think the higher value of gravity anomalies, thicker basaltic units and longer formation time for wrinkle ridge in Mare Serenitatis maybe result in the higher value of contractional strain, although the formation of Tranquillitatis basin is earlier than that of Serenitatis basin.

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