THE CENTRAL SYMMETRY ANALYSIS OF LINEAR FEATURES IN LUNAR MARE. Meijuan Yao[1] and Jianping Chen[1]. [1]Institute of High and New Techniques Applied to Land Resources, China University of Geosciences (Beijing), 29 Xueyuan Road, Haidian Distirct, Beijing, China (lyaomeijuan@163.com, 3s@cugb.edu.cn).

Introduction: Linear features are simply linear geological structures formed by tectonic, volcanic or a combination of these two processes, such as ridges or rilles. Previous mapping of linear features on the lunar surface shows that linear features are preferentially oriented in three main directions, N-E, NE-SW and NW-SE, with a distinctive lack of any E-W trend [1, 2]. However, the linear features not only have preferred orientations, but also more likely distributed in or around the lava-filled mare or basins with a certain regional characteristic of distribution: 1) parallel to each other and have a regionally uniform orientation in lunar mare; 2) concentric or radial to the corresponding center of a clear circular or elliptical mare; 3) geographically scattered or isolated on the lunar surface [3]. The regional distribution characteristics of linear features can indicate the tectonic pattern of the area and the force trend that formed these structures especially the concentric or radial group can reflect the lava intrusion center of study area. Usually, we qualitatively identify whether the linear features distributed in concentric or not. In order to analyze the degree of concentric by quantitative method, we introduce the central symmetry value to determine the linear features' distribution characteristic [4, 5].

Data and Method: In this study, we calculated the central symmetry value of Mare Serenitatis (28°N, 17.5°E) as an example to introduce the method that used to calculate the central symmetry value. A global mosaic images acquired by LROC WAC with a resolution of 100m/pixel were used to identify and map the linear features in study area. The identified and mapped linear features in the mare are demonstrated in Figure 1.

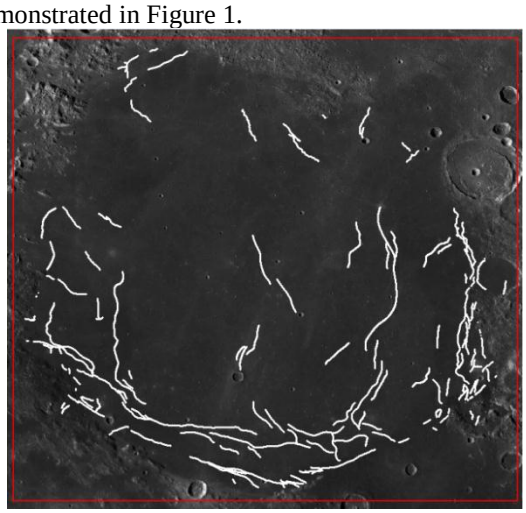

Figure 1. The distribution of linear features in Mare Serenitatis (red square is the grid size).

The equations that calculate the central symmetry value is:

$$\sigma = \left[\sum_{i=1}^{n} l_i \sin^2(\theta_i - \bar{\theta}) \Big/ \sum_{i=1}^{n} l_i \right]^{\frac{1}{2}}$$

$$\bar{\theta} = \sum_{i=1}^{n} l_i \theta_i \Big/ \sum_{i=1}^{n} l_i$$

where σ is central symmetry value, $\bar{\theta}$ is the average orientation of linear features, l_i is the linear features' length of i in each grid, i =1,2,3,…n; θ_i is the linear features' orientation of i in each grid, $-90° \le \theta_i \le 90°$.

In the equations, there are two important parameters of each linear feature need to be determined: orientation and length. Due to the results' accuracy of orientation and length are correlated with map projection, so for minimizing the distortion caused by map projections, linear features were map-projected according to the location of study area [6]. The length and orientation were both calculated automatically by ArcGIS after map-projected, but the orientation of each linear feature was determined using the latitude and longitude coordinates of the linear features' endpoints and its range between -90°– 90°. 0° refers to a northern direction, 90° refers to eastern direction while an orientation of -90° refers to western direction. Moreover, the precision of central symmetry value is associated with the grid size. When the grid scale that determined is too large or too small, the results will get a greater error, only the size of grid scale is matched with research area, the results that obtained can reflect the central symmetry degree of study area. Therefore, in order to reduce the results' error caused by grid size, a minimum bounding square of mare or basin according to its diameter was used to calculate the central symmetry value.

According to previous study [3], when the central symmetry value is greater than 0.70, the distribution of linear features are close to completely symmetry; when the central symmetry value is greater than 0.65, the distribution of linear features has reached a high degree of concentric.

Results and Discussion: Using the equations mentioned above, we calculated the central symmetry value of Mare Serenitatis, the related parameters and result are shown in Table 1. The central symmetry

value is 0.56, which demonstrated that linear features distributed in this study area have a good degree of symmetry. About the reason that formed the distribution characteristic of linear features, previous work suggested that it was mainly caused by gravitational readjustments of the mare basalt flows [7].

Table 1 The central symmetry statistical parameters and preliminary result of linear features in Mare Serenitatis

Parameter	Result
Latitude [°]	28
Longitude [°]	17.5
Diameter (km)	740
Average orientation [°]	-23.75
Central symmetry value	0.56
Grid size (km × km)	740×740

In order to contrast the value with other mares, we also have calculated the central symmetry value of linear features in other lunar mares using WAC image (Table 2). From the table we can see that, Mare Imbrium has the highest degree of central symmetry values, followed by mare Mare Nubium, Orientale and Tranquillitatis. Although the linear features distributed in other mares showed a concentric circle or radial trend, but its central symmetry value is lower compared with these mares mentioned above.

It is worth noting that, when we analyze the central symmetry value of linear features, the accuracy of the result is not only affected by the grid size, but also affected by the interpretation of linear features, as well as the method to calculate the orientation and length of each linear feature. Therefore, the result of central symmetry value can be different after improving the method to interpret and calculate the length, orientation of each linear feature.

Conclusions and Future work: The degree of central symmetry value has a good reflection of the lava intrusion and evolution in study area, and the region with high central symmetry degree shows that the linear features in the area have good symmetry which means it more likely formed by volcanic process. However, due to we only mapped partial linear features in lunar mare as well as limited by the resolution of LROC, there may be have mistakes or missing some linear features when we identify and map them. For future study, we will use more high resolution images (e.g. SELENE TC images) to extract linear features and calculate the central symmetry value of linear features that distributed in lunar mare.

Acknowledgements: This research was funded by the National Natural Science Foundation of China (41473065), National Science and Technology Infrastructure Work Projects (2015FY210500).

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Table 2 The central symmetry statistical parameters and preliminary results of linear features in lunar mare

Location	Mare name	Latitude [°]	Longitude [°]	Diameter (km)	Average orientation [°]	Central symmetry	Gird size (km × km)
Nearside	Imbrium	32.8	-15.6	1160	7.31	0.68	1160×1160
	Crisium	17	59.1	1060	-12.24	0.45	1060×1060
	Nectaris	-15.2	35.5	860	13.95	0.44	860×860
	Humorum	-24.4	-38.6	820	-16.23	0.44	820×820
	Smythii	1.3	87.5	840	6.17	0.40	840×840
	Tranquillitatis	8.5	31.4	800	-4.63	0.60	800×800
	Fecunditatis	-7.8	51.3	990	-3.68	0.50	990×990
	Nubium	-21.3	-16.6	690	0.48	0.63	690×690
	Cognitum	-10.0	-23.1	376	-6.20	0.55	376×376
	Insularum	7.5	-30.9	513	11.47	0.54	513×513
	Vaporum	13.3	3.6	245	-22.31	0.52	245×245
Farside	Orientale	-19.4	-92.8	930	4.77	0.61	930×930
	Moscoviense	27.3	147.9	840	3.62	0.46	840×840