

STATISTICAL ANALYSIS OF SPATIAL DISTRIBUTION OF CRATERS
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Using the images obtained from planetary explorations, many important informations on tectonic evolution of planets and satellites have been derived. However, usages of the imaging data seem not to be satisfactory and more effective usage is expected to be performed judging from the recent situations of the planetary exploration program. In this paper, we report a new method to analyse the spatial distribution of craters. It is promising that new informations on past exo- and endo-genetic process occurred on planetary surfaces are derived by this analysis.

Method of analysis: At first, we define three fundamental patterns of the spatial distribution of craters. (1) Random pattern (Fig. 1). Craters are distributed randomly in the area. (2) Regular pattern (Fig. 2). Craters are distributed evenly in the area. Distance from one crater to another crater are almost same in all pairs. (3) Group pattern (Fig. 3). The area can be divided into some sub-areas, in which craters are distributed either regularly or randomly. Sub-areas with equal crater density and distribution pattern are considered to be a part of one sub-area. Therefore, even if sub-areas are located separately, they are considered to be one sub-area. In Fig. 3 are shown an example of the case of the two sub-areas. In order to classify the above patterns statistically, we used the Morishita's index (Morishita, 1959), I_δ , defined by

$$I_\delta = Nq \frac{\sum N_i(N_i-1)}{Np(Np-1)},$$

where,

$$Np = \sum N_i, \text{ and } Nq$$

is the number of the quadrates which are square blocks taken randomly within the area (see Fig. 4),

and N_i is the number of craters in the i -th quadrate. I_δ has the following characteristics; $I_\delta \sim 1$ for the random distribution, $I_\delta < 1$ for the regular distribution and $I_\delta > 1$ for the group distribution. I_δ varies with q ($=Q_s/L$), where Q_s and L are side lengths of the quadrate and the area, respectively (see Fig. 4). As shown in Fig. 5, I_δ approaches 1 with increase in q . Using $D (=I_\delta(Np-1)+Nq-Np)$, we can determine whether or not the distribution is random. Because D is shown to follow the χ^2 distribution with $(Nq-1)$ degrees of freedom.

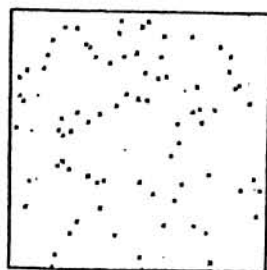


Fig. 1

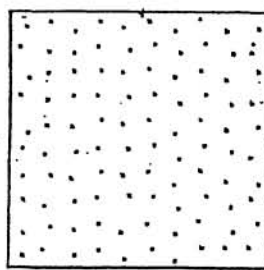


Fig. 2

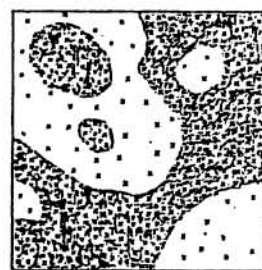


Fig. 3

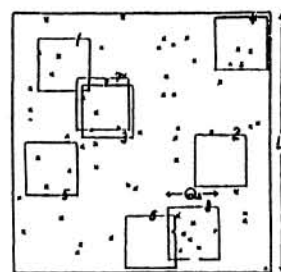


Fig. 4

Result: We analysed two areas on the Moon, Mare Imbrium and Orientale Basin, just for testing this analysis. Mare Imbrium The side length of the area is ~ 30 km. The number of the crater with the diameter larger than 120 m is 675. $Nq = 80$. I_δ for this area shows the distribution to have the group pattern (Fig. 6). It may be ascribed to that the craters of this size range are mostly secondary origin.

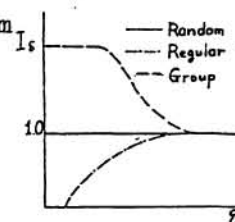


Fig. 5

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Orientele Basin The side length of the area is $\sqrt{500}$ km. The number of the craters with the diameter larger than 5 km is 376. $N_q = 80$. As shown in Fig. 7, I_δ suggests that the distribution has the group pattern.

Numerical simulation: To investigate I_δ 's behaviour more quantitatively, we calculated I_δ for several models and studied characteristics of their I_δ 's patterns. Size distribution of craters is assumed to follow $N \propto d^{-2}$, where N is the cumulative number of the craters with the diameter of d or larger. Locations of the craters are given at random and the number of the craters is assumed to be the same as that of the Orientele Basin. Numerical results for three models are shown here as an example. In all models, $N_q = 80$.

Model 1 Spatial distribution of the craters is influenced by later impacts. Therefore, we introduced the parameter, x , which represents the size of the region influenced by a later impact event. That is, the region as large as x times the diameter of the crater formed by later impact is assumed to be influenced by the impact event. I_δ for the three models ($x = 1.5, 2.0$ and 3.0) are shown in Fig. 8.

Model 2 x is fixed in this model ($x = 1.5$). However, flux of infalling bodies are changed. It is shown that the group pattern becomes dominant when larger bodies impact more frequently than smaller bodies at later stage, as shown in Fig. 9.

Model 3 Instead of the exponent, $\alpha = 2$ of the size distribution, we used 1.5, 1.625 and 1.75 in this model. I_δ s for the different α are shown in Fig. 10. It is found that I_δ is significantly influenced by the exponent of the size distribution.

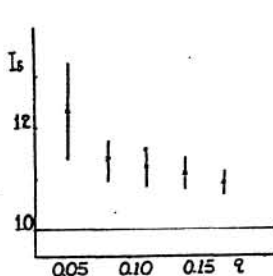


Fig. 6

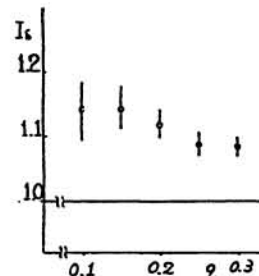


Fig. 7

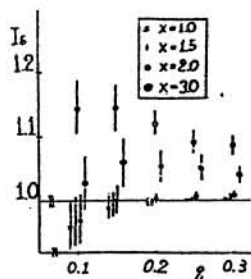


Fig. 8

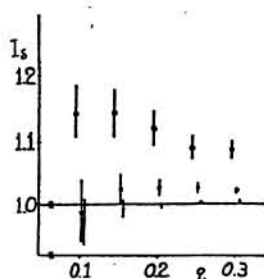
 I_δ for the model 1.

Fig. 9

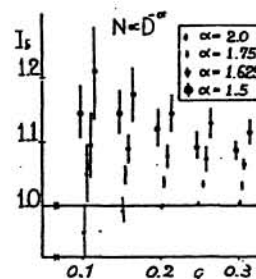
 I_δ for the model 2.

Fig. 10

 I_δ for the model 3.

It is very difficult to construct the model whose I_δ pattern is similar to the observed one although we can construct the group pattern models. Therefore, the deviation of the observed pattern from the regular and random distributions is considered to be due to the original nature, that is, meteorite shower-like nature of infalling bodies. Although the analysis is rather preliminary, application of this analysis to more complete imaging data set seem to promise derivation of new informations on exo- and endo-genetic processes occurred on planetary surface.

Reference: Morishita, M. (1959) Mem. Fac. Sci. Kyushu Univ. Ser. E. (Biol.) 2, 215-235.