Geological Mapping of Sinus Iridum Area of the Moon Based on the Chang'E-I Data of China

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1 Introduction

Based on CCD image, Imaging Interferometer(IIM) data, DEM data, contents of minerals and elements obtained by the Chang'E-I lunar exploration project of China in 2007, a study for 1:2.5M-scale digital geological mapping around Sinus Iridum area was conducted. The purpose of the study is to apply these data and information and analytic results to carrying out tentative geological mapping (1:2.5 M) of the Sinus Iridum area, setting up a spatial database and preliminarily formulate the technical specification, procedure and method for lunar geological mapping through the division of stratigraphic and tectonic units, classification of rock types, integrated analysis of chronology and lunar evolution history, so as to lay a foundation for digital geological mapping of the global Moon and future compilation of geological maps of other planets. This study will also provide data and materials for selecting the landing site of Chang'E-III in the 3rd-phase lunar exploration project of China. This is of great significance for the future manned Moon mission, site-selection and construction of working bases on the Moon surface.

2 Regional Geological Setting

The geological mapping area is located at the northwestern part of the north hemisphere on the near-side of the Moon: 30°–65°N, 0°–60°W. According to elevation difference and rocky distribution, three types of regional geological landforms are defined: (1) Mare basalt plains, including mainly Sinus Iridum, Mare Imbrium, Oceanus Procellarum, Sinus Roris and Mare Frigoris; (2) Crater accumulative hills, including mainly the region from Montes Jura in the northwest of Sinus Iridum in the central part of research area to Montes Alpes in the east; (3) Terra plagioclase plateaus, which mainly refers to the terra region in the northern area. Besides, there are more large impact craters in this area, such as craters Plato, Harplus, Sharp, Mairan, Bianchini, South, J. Herschel and Fontenelle, which constitute the major circular geological structure of the mapping area. The image synthesized with the 2c-class data of Chang'E-I CCD image was used as the base map for the geological mapping. The spatial resolution of the image is 120m. Multi-stage geological events took place in the preImbrian, Imbrian, Eratosthenian and Copernican periods in the study area. The division of strata or geological bodies reflects the topographical features (crater, et al), types of accumulative materials (ejecta, et al), relations of each other's coverage and spectral features of different regions. The geological times of strata and geological bodies include the pre-Imbrian (PI), consisting of the pre-Nectarian(PN) and the Nectarian (N); the Imbrian (I), consisting of the Early Imbrian (I_1) and Late Imbrian (I_2); the Eratosthenian (E) and the Copernican(C). This typically summarizes the evolutional history of the lunar regional geology.

As regards the age of Mare Imbrian, Liu et al(2010) performed high-precision zircon SHRIMP dating for the samples of impact melting debris in front of the southern part of the study area obtained by Apollo 12, 14 and lunar meteorites SaU169, and accurately ascertained the ages of some early events on the Moon. For instance, the age of strong impact event of Imbrian Period is 3.92 Ga. This conclusion was commonly accepted at the 32nd Lunar and Planetary Science Conference in Huston in 2010, so as to change the traditional cognition among scientists in the world that this event occurred at 3.85 Ga, thus making a significant contribution to the study of the early lunar evolution history (Liu et al., 2011). In the same way, SIMS Pb-Pb dating was conducted on zircons in impact melt breccia and fine-grained matrix of the most K-rich KREEP of lunar meteorite SaU 169 by Lin et al. (2012), The comprehensive petrographic, mineral chemistry and SIMS study analyses consider the main age peak at 3921±3 Ma and the smaller one at 4016±6 Ma represent the latter crystallizing age of KREEP magma and the age of a catastrophic shock event in Nectarian. As a sequence, this age (39.2 Ma) was adopted as the lower limit of the Imbrian Period for the geological mapping in this study.

3 Characteristics and Evolution of Regional Tectonics

Many researchers developed detailedly the study about the lunar regional tectonic characteristics, main structural forms, genesis and evolution with Chang'E-I CCD image data(Zhang et al., 2010, Wang et al., 2011). Diverse structures are characteristic of the mapping area, including lineaments such as faults, rimae and montes, as well as some ring structures. Regionally, circular and arcuate faults are distributed on the bottom of craters, and moreover faulted structures are extensively developed in basalt and ejecta accumulative areas in lunar maria. These structures have approximately parallel lineaments, striking dominantly NE, NW and NS with limited extent, 2.5 km±, in general. Their ages, however, are difficult to determine. Persistence and consistence of the regional lineaments suggest that they have had stable regional stress fields for quite a long period. Therefore, we think that the stresses responsible for the formation of the regional faulted structures are mainly related to a secular and stable longitudinal compression stress field resulting from the spinning of the Moon, that is, the lunar surface structural lines were formed due to long-range continual compression stresses from the poles towards the equator.

3.1 Division and features of regional structure

The fault structure in the mapping quadrangle can be divided into 4 basic types based on their distribution and features: (1) Regional effusive faults in maria, (2) regional faults in crater accumulation, (3) regional faults in terrae, and (4) crater fault systems, which are further divided into 3 subtypes: crater ring faults, arcuate faults inside craters and “tortoise-shell-pattern” faults.

3.2 Division of tectonic units

In view of fault feature and spatial distribution, landforms and rock types in the study area, the mapping quadrangle is divided into 3 structural zones: (1) the regional effusive fault zone in mare plains, (2) the regional fault zone in monte-hill areas (in basalt-plagioclase accumulation) and (3) the regional fault zone in plagioclasite in plateaus.

3.3 Development and evolution of regional tectonics

Four evolution stages can be defined for the regional tectonics in the mapping area according to the features and distribution of different faults, as well as the covering relationships of crater accumulative materials.

3.3.1 Formation stage of pre-Imbrian ring faults

Pre-Imbrian ring structures are distributed mainly in the northwestern part and are all covered by Nectarian ejacta accumulative materials, thus having become buried craters. The inside of dike-like accumulation is an area of ring faults, which are not exposed due to coverage of accumulation of Nectarian craters. Now, we are not certain whether regional faults are developed here. The ring faults can be very large, whose diameters are mostly larger than 100 km, since the buried craters are fairly large.

3.3.2 Formation stage of Imbrian regional effusive faults

This is a stage that the regional faults wrer the most active. After the formation of Mare Imbrium, a considerable quantity of basalt magma surged upwards along ring faults and radial faults caused by meteorite impact, not only filled up Mare Imbrium and also violently eroded and contaminated surrounding rocks. As a result, the previously formed craters and secondary ejecta craters were subjected to serious disruption to form filling craters, incomplete craters and residual craters. At the late stage, high-Ti basalt magma of the Eratosthenian was erupted extensively along N-S-stretching tensional faults.

3.3.3 Formation stage of Eratosthenian regional faults and crater ring faults

Along with the formation and consolidation of a large amount of crater ejecta accumulations, NE- and NW-trending conjugate faults and nearly SW-trending tensional faults were formed by strong nearly SW-directed compression stress fields from the two poles to the equator due to the revolution and rotation of the Moon. In the Eratosthenian, meteorite impact was significantly weakening and ring faults were small, generally tens of kilometers in length, suggesting weaker and weaker faulting activity during this period.

3.3.4 Formation stage of Copernican crater ring faults

In the Copernican, regional basalt magmatism was basically terminated. Therefore, few filling process occurred in Copernican craters. Craters due to meteorite impact in this period usually have small sizes with diameters no larger than tens of kilometers in general.

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