A preliminary study of classification method on lunar topography and landforms

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Abstract— **The article first reviews the lunar topographic types and classifying methods. Then, a matrix combining multi-stage classification method is put forward based on the characteristics of topography, material and geologic age. The test mapping method is addressed in Sheet H010, showing that the combination classification method is reasonable.**

I. INTRODUCTION

Moon, the only satellite of the earth, is first celestial body for deep space exploration. Lunar morphologic characteristics is a best window for direct observation[1]. Researchers studied lunar morphology from different angles and levels[2], but lunar morphologic types division has not attracted much attention. At the same time, compared to the whole lunar scale morphologic analysis, more and more scholars tend to study typical lunar morphology. This paper first analyzes the research about lunar morphology types. Then, a lunar morphology classification method involved multi-level index is proposed, putting H010 as a case.

II. EXPRESSION AND EXTRACTION METHODS OF LUNAR TOPOGRAPHY

Lunar surface topography studies rolling topography, distribute law, material structure, development history, exploitation and utilization of the lunar surface. Dividing lunar morphology types is a basis work for studying lunar morphology[1,3]. In 1978, NASA announced lunar terrain orthophoto map[4-7]. In 1982, Andersson and Whitaker divided the lunar morphology into three major types including impact craters, non-impact craters, and other geomorphic features[4-7]. Based on the classification of 1982, IAU divided lunar morphology into two levels. In 2013, zhou et al classified the typical lunar morphology based on remote sensing image interpretation[3,8].

In the 1970s, USGS had compiled a 1:5 000 000 whole moon geological map[9]. Geological information includes three layers: geological age, geological unit material, geological unit topography features. The geological information is expressed by the matrix structure of the combination of matter, age and landform.

In addition to the traditional terrain factors, some scholars interpreted lunar morphology by using roughness. As a terrain factor, topographic curvature is selected to extract the surface linear feature. This method provided an important reference for the interpretation of the lunar surface linear structure. Image-based automatic classification of craters can be divided into the three categories including edge detection, Hough transform, machine learning. Besides, many achievements in extracting the lunar typical morphologic features have been made through artificial interpretation.

III. A NEW CLASSIFICATION SCHEME

A. Classification principle

- Dominant factor principle. The dominant factor of lunar surface morphology classification should be the surface morphological features. The surface material and geological age are auxiliary indicators of classification[1,3,9,10,11].
- Logical principle. Consistent with the earth's geomorphological classification, lunar morphological

classification should follow the logical principle. The four basic lunar surface morphology forms include mare, highland, crater and basin that can reflect the macroscopic characteristics of the moon[1,3,9,10,11].

- Quantitative principles. The indicators of lunar morphology types can be quantified based on DEM, remote sense data and other massive data.
- Completeness principle. Classification methods require a variety of elements, and can continue to expand the classification indicators.

B. Classification method

- Grade classification. The classification adopts the class classification method, that is, according to group then individual, entirety then single, big then small, primary then secondary, and other classification order.
- Matrix combination method. In order to make the the classification hierarchical and logical, the matrix combination method is proposed as the classification method.

C. Classification index

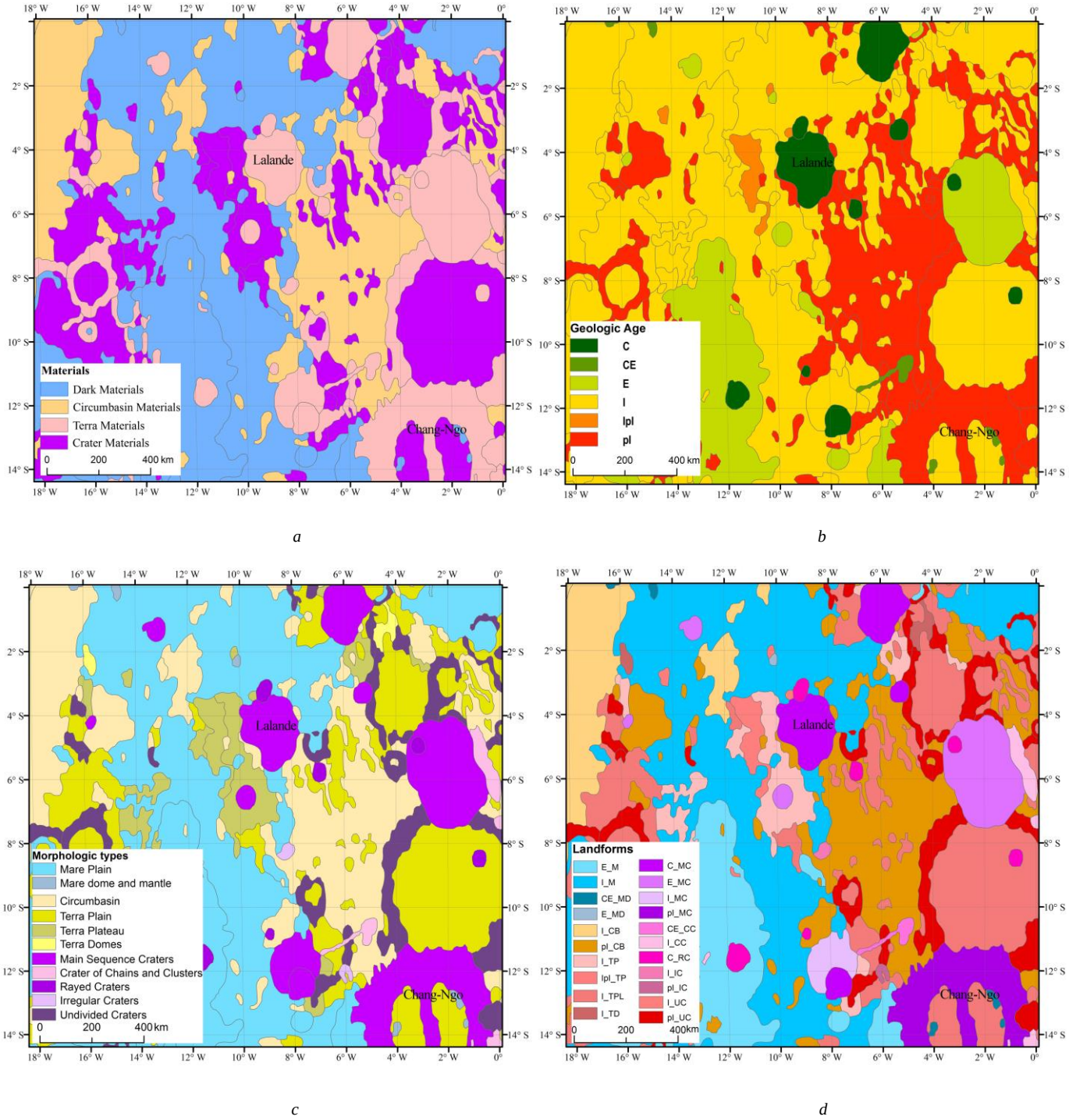
- Geological age. The geological age can be divided into seven periods: Copernican (C), Copernican-Eartosthenian (CE), Eartosthenian (E), Eartosthenian-Imbrian (EI), Imbrian (I), Imbrian-PreImbrian (IPI), PreImbrian (P) (Table 1).
- Material difference. Drawing on the classification of materials in American Geological Map in 1970s, lunar material can be divided into four types: dark materials, basin materials, terra materials, crater materials in this classification system[1,3,9,12,13] (Table 1).
- Morphological parameter. The mare can be divided into plain, dome and mantle; basin can be divided into plain and circumbasin; highland can be divided into plain, plateau, dome; crater can be divided into main sequence craters, crater plain, secondary craters, crater chains and clusters, rayed craters, irregular craters, undivided craters (Table 1).

D. Classification scheme

Classification system of lunar landform that using three indicators of the matrix combination form based on geology age, surface materials and morphologic feature. Table 1 is a matrix table of lunar landform classification based on the above three indicators. Based on the above matrix combination classification scheme, taking H010 as an example, elements of the lunar morphology type diagram and lunar morphology type diagram had been made (Figure 1).

TABLE I. MATRIX COMBINATION CLASSIFICATION SYSTEM OF LUNAR MORPHOLOGY BASED ON GEOLOGIC AGE, SURFACE MATERIALS AND MORPHOLOGIC FEATURE

Materials	**Dark materials**		**Basin materials**		**Terra Materials**			**Crater materials**							**Geologic Age**
Morphologic Types	***Mare Plain (M)***	***Dome and Mantle (MD)***	***Basin Plain (B)***	***Circum-basin (CB)***	***Plain (TP)***	***Plateau (TPL)***	***Dome (TD)***	***Main Sequence Craters (MC)***	***Crater Plain（CP）***	***Secondary Craters (SC)***	***Craters of Chains and Clusters (CC)***	***Rayed Craters (RC)***	***Irregular Craters (IC)***	***Undivided Craters (UC)***	
Geologic Age-Morphologic Types						C_TPL		C_MC	C_CP	C_SC	C_CC	C_RC			***Copernican System (C)***
		CE_MD					CE_TD				CE_CC		CE_IC		***Copernican-Eartosthenian System (CE)***
	E_M	E_MD						E_MC		E_SC	E_CC				***Eartosthenian System (E)***
	EI_M	EI_MD													***Eartosthenian-InbrianSystem（EI）***
	I_M	I_MD	I_B	I_CB	I_TP	I_TPL	I_TD	I_MC	I_CP	I_SC	I_CC		I_IC	I_UC	***Imbrian System (I)***
				IpI_CB	IpI_TP	IpI_TPL	IpI_TD		IpI_CP				IpI_IC		***Imbrian-PreImbrian System(IpI)***
			pI_B	pI_CB	pI_TP	pI_TPL		pI_MC	pI_CP	pI_SC	pI_CC		pI_IC	pI_UC	***Pre-Imbrian System (pI)***



a *b*

c *d*

Figure 1. Maps of materials(a), geologic age(b), morphologic types(c) and landforms(d) of Sheet H010

IV. DISCUSSION

The exogenic force and endogenic force way is great difference to shape the surface morphology between lunar and earth[1,3,9,11], so the classification method of lunar morphology can't completely used the method that combine the morphology and genetic like dividing earth geomorphic types. Under the control of lunar mare basalt, lunar highland crystalline suite, impact crater special morphology and material, it is proposed that the morphological types of the lunar surface are classified by the combination of morphology and material to highlight the special morphological features of the lunar surface.

Morphological map should represent a various types of landform, and need overlay many information of basic geography. So far lunar basic geographical names on different scale had been setted, that is similar to earth morphology naming system. Therefore, in the detailed classification of morphological types, it can be divided into a certain area of the mapping spot, and in the basic geographic information, it also reflects the corresponding name.

V. CONCLUSION

Considering the present situation of lunar morphology, pattern and action of macro geologic agent, morphological variation, combination feature, and so on, a matrix combination classification method of lunar morphology initially puts forward based on geologic age, surface materials and morphologic feature.

Material characteristics can be divided into dark materials, basin materials, terra materials and crater materials. Geological age can be divided into Copernican System (C), Copernican-Eartosthenian System (CE), Eartosthenian System (E), Eartosthenian-InbrianSystem(EI), Imbrian System(I), Imbrian-PreImbrian System (IpI), Pre-Imbrian System (pI). As to topographic types, the first class can be divided into lunar mare, lunar basin, lunar terra and lunar crater. As to their second class according to morphological differences, the lunar basin can be divided into basin plain and circumbasin, lunar mare can be divided into mare plain and mare dome; lunar terra can be divided terra plain, plateau and hill, and craters can be divided into main sequence crater, crater plain, secondary crater, crater chains and clusters, rayed craters, irregular crater and undivided crater. Thus, 46 subclasses including geologic, lunar surface material and morphologic features are obtained in this classification system.

Taking H010 as a case, the combination of morphological types and the three indexes of material, age and morphological types were tested. This study will have a certain role in the division and mapping of full moon morphology.

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