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New features of the Moon revealed and identified by CLTM-s01

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Previous analyses showed a clear asymmetry in the topography, geological material distribution, and crustal thickness between the nearside and farside of the Moon. Lunar detecting data, such as topography and gravity, have made it possible to interpret this hemisphere dichotomy. The high-resolution lunar topographic model CLTM-s01 has revealed that there still exist four unknown features, namely, quasi-impact basin Sternfeld-Lewis (20°S, 232°E), confirmed impact basin Fitzgerald-Jackson (25°N, 191°E), crater Wugang (13°N, 189°E) and volcanic deposited highland Yutu (14°N, 308°E). Furthermore, we analyzed and identified about eleven large-scale impact basins that have been proposed since 1994, and classified them according to their circular characteristics.

Chang'E-1, laser altimeter, lunar topography, dichotomy, new feature

Previous global mapping missions have shown that the Moon is asymmetric between the nearside and the farside, as regards its figure, structure, crustal thickness and chemical composition. Topographic dichotomy is a fundamental characteristic of the lunar shape, represented by numerous smooth maria on the nearside and thousands of highlands and craters on the farside. Analyses of the lunar topography and gravity have shown that the lunar farside crust is thicker than the nearside[1−3], accounting for an approximately 2-km offset between the Moon's center of the mass (COM) and center of figure (COF)[1,4−9]. As the lunar surface is made up of various rocks of different types, ages and formations, the material compositions are obviously different between the farside and nearside. Maria regions are abundant in mare basalts, containing high level ilmenites, while the farside highlands are rich in feldspathic terrane[10]. The asymmetries in chemical composition may be better explained by an asymmetric crystallization of a primordial magma ocean. Long-wavelength analyses of the crustal structure have shown that lunar global dichotomy may be caused by asymmetric melt[11], asymmetric impact[12] or large-scale interior convection[13] of the Moon. Explanations of lunar dichotomy can help us to understand the lunar interior structure, origin and evolution.

Lunar detecting data, especially results from topography and gravity analyses, have made it possible to interpret these hemisphere dichotomies[7,14]. Numerous randomly distributed impact craters of various kinds are the most obvious topographic features of the Moon. Many impact craters, ancient volcanoes and tectonic basins exist on the Moon, but they are collectively referred to as impact craters owing to the fact that they cannot be readily distinguished and indentified on re-

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mote-sensing images alone. Generally we name a crater that has a multi-central structure, a central peak, and with a diameter greater than 300 km, as an impact basin[15,16]. The distribution and characteristics of these impact basins play an important role in understanding the evolution history of the Moon. Geological tectonic structures and terranes can be inversed from remote-sensing images, but as there are usually multiple solutions from an images inversion, a great deal of uncertainties may exist in the interpretation of the geological structures. Global laser altimetry data can help us to further identify the distribution and composition of the multi-ring impact basins and craters on the moon.

With the global laser altimetry data from Clementine LIDAR, Spudis[17−19] analyzed 21 multi-ring basins on the Moon, ranging in size from 326 to 2600 km, and evaluated the situation and configuration of the long-wavelength topographic features of the lunar crust. One of the most interesting discoveries was the description of some oldest and most degraded impact basins, such as Mendel-Rydberg, Mutus-Vlacq and Lomonosov-Fleming. Since Clementine was a large elliptical polar-orbit satellite, two months' laser altimetry measurements only covered the latitude range from 70°S to 70°N, with a spatial resolution of approximate 60 km along the equator. In order to get a global lunar topographic model, Margot et al.[20] used Earth-based radar interferometry data to obtain poleward ±87.5° topographic map with a spatial resolution of 150 m, and Cook et al.[21] made use of the Clementine stereo images (UV-VIS) to yield a paleward ±60° digital elevation model (with 1km spatial resolution). Based on the new stereo-derived DEM (Digital Elevation Model), Cook recognized several pre-Nectarian impact basins, such as Bailly-Newton, Schrodinger-Zeeman and Sylvester-Nansen. Although their results have provided important information on the relative topography in the lunar polar regions, estimates suggest that our knowledge of absolute elevations at the lunar poles remains uncertain. Elevations comparisons show that positional errors of several kilometers exist among the results derived from earth-based interferometry, Clementine laser altimetry and stereo-images[20−22]. Those errors will certainly affect the sizes and depths determination of the craters, and it is necessary to use high resolution topographic maps to confirm them.

In 2007, China and Japan launched their lunar satellite Chang'E-1 and SELENE respectively. Both of them carried a laser altimeter that can be used to measure the lunar surface globally[8,9]. Using 3 million effective laser altimetry ranges obtained from the first forward flying phase of Chang'E-1, Ping et al.[8] obtained a global lunar topographic model (named CLTM-s01) with a spatial resolution of approximate 8 km. This model can help us to analyze and identify craters with a certain scale, which will be able to improve our knowledge of crater evolutions.

In this paper, we have produced a global gridded map with a resolution of 0.0625° from Chang'E-1 CLTM-s01 model. Comparison between ULCN2005[23] and CLTM-s01 showed that there still exist some middle-scale topographic features which were undiscovered by previous researchers. They are quasi-impact basin Sternfeld-Lewis (20°S, 232°E), confirmed impact basin Fitzgerald-Jackson (25°N, 191°), crater Wugang (13°, 189°E), and volcanic deposited highland Yutu (14°N, 308°E). Furthermore, we analyzed and identified about 11 large-scale impact basins which have been proposed since 1994, and reclassified them according to their circular characteristics.

1 New features revealed by CLTM-s01

The International Astronomical Union (IAU) has put out a list of all the up-to-date lunar features on the Gazetteer of Planetary Nomenclature website (http://planetarynames.wr.usgs.gov). According to the different physiognomy of the Moon, IAU divides the lunar surface into 18 main feature types, including Mare, Crater, Catena, Mons, Rima, Sinus etc. All the feature names permitted by IAU are delineated on its 1∶1 million shaded relief and color-coded topography maps (http://planetarynames.wr.usgs.gov/luna_ccsr.html). By far the on-line database has already published 8962 audited lunar names, among which 1521 are named impact craters[24].

The new global DEM (Digital Elevation Model) of Chang'E-1 has allowed the recognition of basins or craters previously not being identified. Expanded the CLTM-s01 model into 0.0625°×0.0625° gridded map, and assisted with a 1∶1 million topographic map, we analyze circle characteristics of the Moon with diameter bigger than 50 km. Comparison with previous laser altimetry result shows that there still have 4 obvious features not being revealed before. Table 1 enumerates 4 newest features with their recommended names, positions, diameters and ages. Figure 1 is the lunar global

Table 1 New features of the Moon revealed by CLTM-s01 a)

Code name	Features name	Latitude	Longitude	Diameter (km)	Type	Age
N1	Sternfeld-Lewis	20°S	232°E	840	Quasi-basin	pN
N2	Fitzgerald-Jackson	25°N	191°E	470	Impact basin	pN
N3	Wugang	13°N	189°E	190	Impact basin	pN
N4	Yutu	14°N	308°E	300	Volcano shield highland	LI

a) pN, pre-Nectarian; LI, low Imbrian.

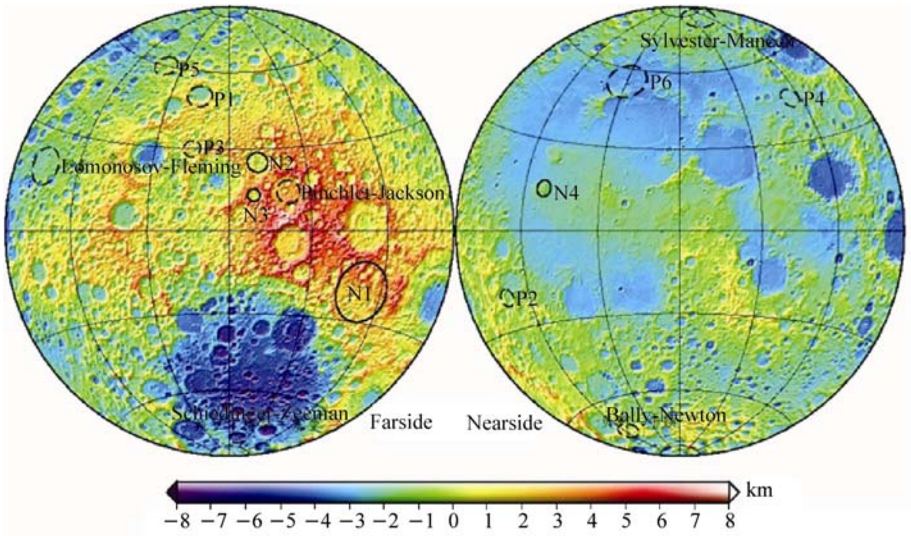

Figure 1 Topography of the Moon from CLTM-s01 (with resolution of 0.0625°). The map is a Lambert Azimuthal Equal-Area projection, with the farside on the left and the nearside on the right. The longitude and latitude grid lines are at 30° intervals. The new features revealed by CLTM-s01 are marked with solid black circles.

topographic map of CLTM-s01. New features with code name from N1 to N4 are marked with black circles on the map, among which N1—N3 are located on the farside and N4 on the nearside. Figures 2 and 3 compare the topographic characteristics of N1—N4 between CLTM-s01 and ULCN2005. Figure 4 delineates the topography and gravity information of region N4 respectively.

Figure 5 shows the topographic profiles of the new features N1—N4. The profile in Figure 5(a) shows that the ring diameter of N1 is about 840 km, though without enough circular structure information; the profile in Figure 5(b) represents that N2 has a very obvious depressed characteristic, from east to west showing a rim diameter of about 470 km; Figure 5(c) delineates the profile of region N3, revealing a clear impact feature and from east to west with a rim diameter of about 190 km; The profile of N4 in Figure 5(d) indicates a highland with a diameter of approximately 300 km.

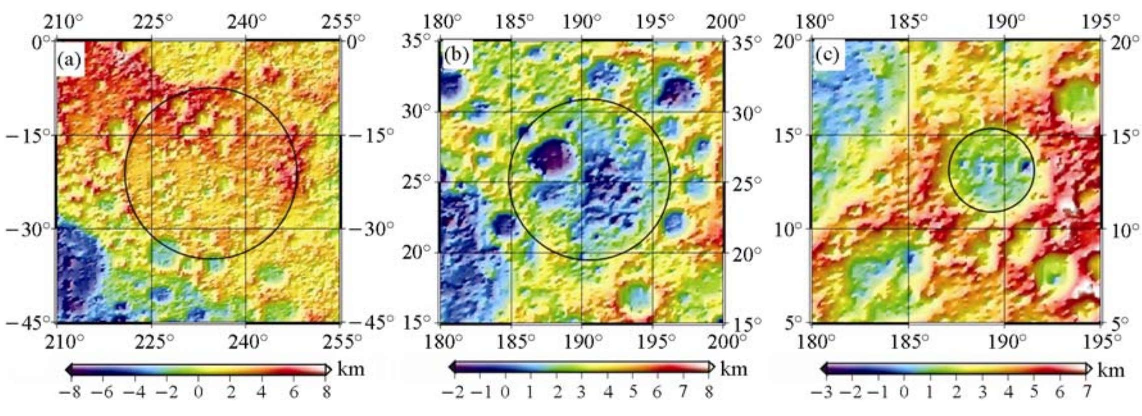

Figure 2 Regional topography of the Moon showing the new features revealed by CLTM-s01. (a) N1 (20°S, 232°); (b) N2 (25°N, 191°E); (c) N3 (13°N, 189°E).

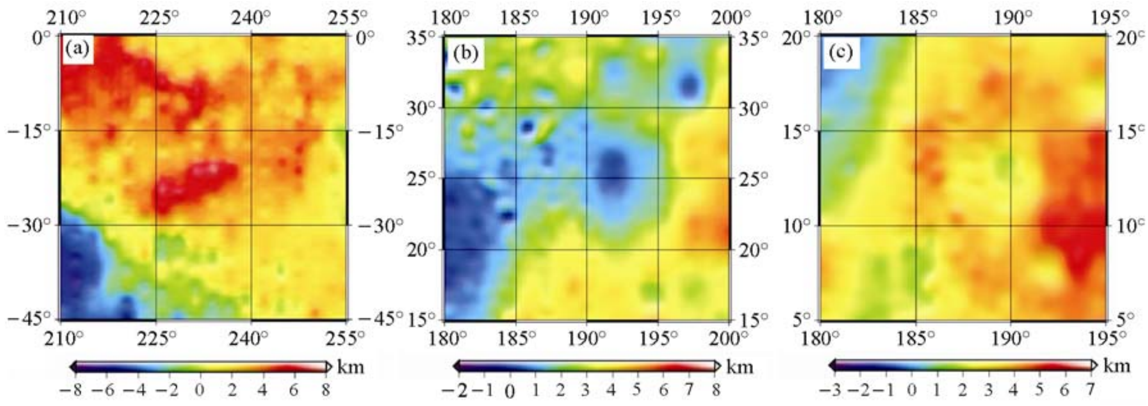

Figure 3 Regional topography of the new features from ULCN2005. The map here is corresponding to Figure 2 with (a) N1; (b) N2; (c) N3.

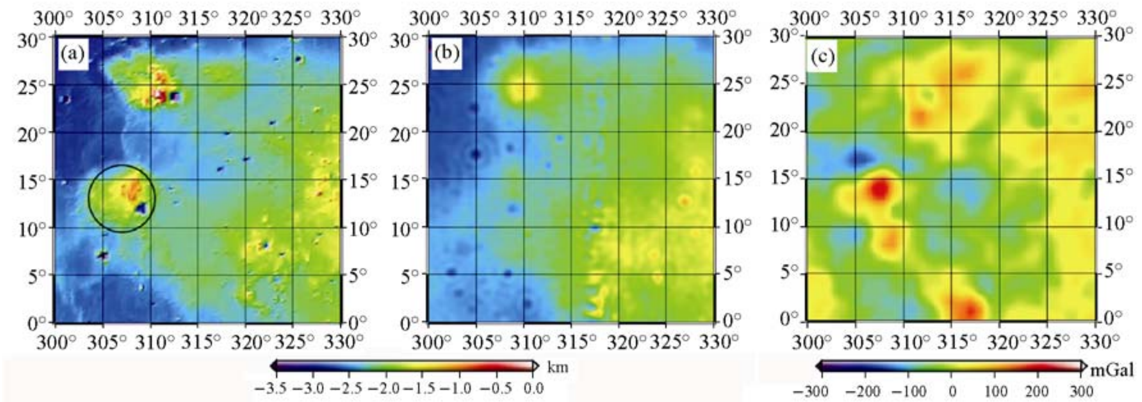

Figure 4 Regional topography and gravity map of N4. (a) CLTM-s01 topography; (b) ULCN2005 topography; (c) LP150Q free-air gravity anomaly.

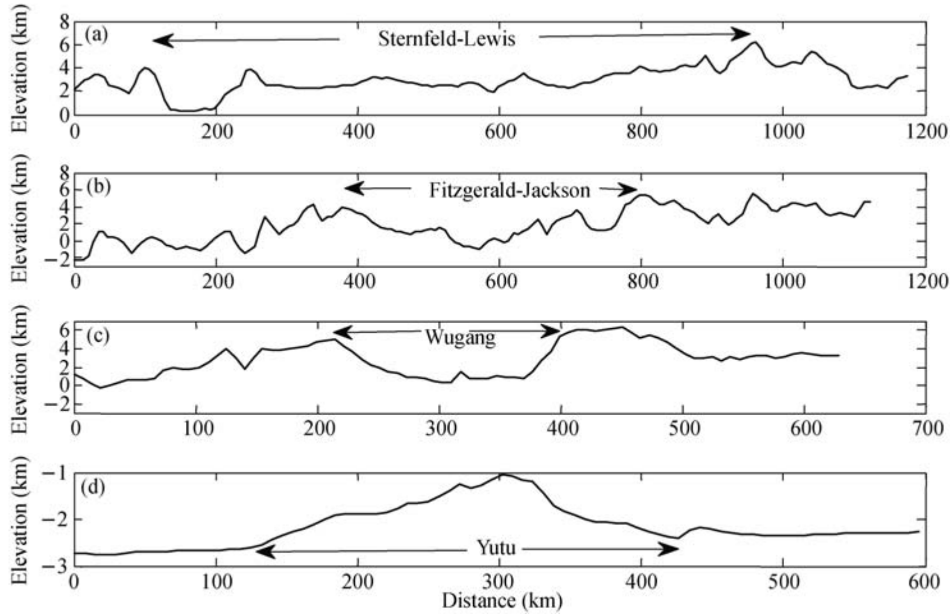

Figure 5 Topographic profiles of N1—N4. (a) N1 (20°S, 212°E to 20°S, 252°E); (b) N2 (25°N, 171°E to 25°N, 211°E); (c) N3 (13°N, 179°E to 13°N, 199°E); (d) N4 (14°N, 298°E to 14°N, 318°E).

According to the naming rules of impact basins proposed by the IAU Lunar Task Group (LTG), we temporarily name N1 Sternfeld-Lewis, N2 Fitzgerald-Jackson, N3 WUGANG and N4 YUTU respectively, which are in accordance with a Chinese ancient legend of Chang'E. We have analyzed the regional topographic characteristics of the four newly revealed features and proposed possible geological ages of them.

1.1 Quasi-impact basin N1 (Sternfeld-Lewis)

Using about 700,000 Clementine UV-VIS stereo photo pairs and assisted with JPL Clementine SPICE data, Cook[25] produced a global Digital Elevation Model (DEM) with the resolution of 1 km. He pointed out that there is an unusual highland block to the west of Orientale basin, with an elevation of +5—8 km. The block shows a structure similar to a basin, but it need to be proved by further information. In this research, we analyzed this region using the CLTM-s01 topographic model. Figures 2(a) and 3(a') are comparative maps for region N1 (0°—45°S, 210°—255°E) from CLTM-s01 and ULCN2005 respectively. Figure 3(a) clearly shows a highland block centered at (25°S, 230°E), with longitude from 225°E to 238°E and latitude from 30°S to 20°S, with an elevation uplift of about +6—8 km. However, in Figure 2(a), the relief is much smoother than Figure 3(a) and without any obvious topographic jump. More importantly, there is not any visible gravity anomaly blocks in the lunar gravity maps of LP165P[26] and SGM90d[27]. It is confirmed that such a convex feature in that region does not exist. This unusual appearance may be caused by measuring errors in the raw data or the uncertainties in the Clementine LIDAR data. There may exists a potential impact basin with a diameter of about 900 km in the CLTM-s01 map Figure 2(a), and located to the west of Orientale and the south of Hertzprung, with center at 20°S, 232°E. That basin belongs to the Feldspathic Highlands Terrane (FHT)[10]. The northern part of the basin has been squeezed by the out rim of Hertspung basin, while the eastern part was covered by the ejecta of Oriental basin. The entire basin is tilted from the upper north-east to the lower south-west. Although the impact basin has certain ring-edge features, the so-called uplift edge rim may be caused by squeeze as it is surrounded by a series of impact craters. On the one hand, we can say that this region may be just an ordinary highland on the farside, having a similar edge of a basin formed by impact extrusion; on the other hand, as the basin is quite old and extensively degraded by overlying younger craters and deposits, the basin floor is not obvious to the human eyes. It is necessary to use more scientific data such as stereo-photos to ascertain whether it is an impact basin.

According to the IAU naming method, we use the craters on opposite sides to name this suggested basin as Sternfeld-Lewis temporarily. From the overlap relationship of the edges, we may suggest that this region has a geological age older than its surrounding basins (such as Hertspung), and therefore we can interpret it as pre-Nectarian in age.

1.2 Impact basin N2 (Fitzgerald-Jackson) and crater N3 (Wugang)

Frey[28] has used the Quasi-Circular Depressions(QCDs) technique in analyzing the Mars Orbiting Laser Altimeter(MOLA) data, and discovered a large population of apparently buried craters on Mars. In order to further determine whether there are still unrecognized impact features on the Moon, Frey searched the Unified Lunar Control Network (ULCN)[23,29] and indentified all roughly circular features with the diameter bigger than 300 km. The search results show that in the vicinity of Freundlich- Sharonov and Korolev basins on the lunar farside are a number of well-defined circular depressions with strong basin-like characteristics. In that region there is a gap of about 10° (~300 km) in the Clementine laser altimeter coverage along the longitude, making it difficult to directly indentify detailed features by laser altimetry results. With high-precision and resolution, CLTM-s01 of Chang'E-1 has given us an opportunity to make sound judgments on the impact basins or craters that may exist in this region.

Comparing with the ULCN2005 topography map, we found that in the CLTM-s01 map, obvious impact depressions (see Figures 2(b) and 2(c)) exist in the regions of (15°N—35°N, 180°E—200°E) and (5°N—20°N, 180°E—195°E). The impact basin centered at (25°N, 191°E) in Figure 2(b) has a topographic ring of about 470 km in diameter and a ring elevation of –1—4 km above the exterior terrain. Because the north-eastern rim is covered by a series of impact craters, entire original edge of the basin cannot be discerned clearly. However, its impact depression structures can still be determined, albeit with a certain degree of degradation.

Since the most obvious craters around this impact basin are Fitzgerald and Jackson, here we name it Fitzgerald-Jackson. Based on a comparative analysis of the surrounding relative structures, we may conclude that the Fitzgerald-Jackson basin predates the Freundlich-Sharonov basin and is in the pre-Nectarian age.

We have also discovered an obvious impact crater (see Figure 2(c)) centered at (13°N, 189°E), which is south to the impact basin Fitzgerald-Jackson and west to Dirichlet- Jackson. This crater is just vaguely visible but is not clearly shown in the ULCN2005 map (see Figure 3(c). We propose to name this crater Wugang, which has a ring with a diameter of about 190 km and a rim with a height of about 4 km (see Figure 5(c)). In Figure 5(c) the impact depression of Wugang can be clearly seen with a small central peak. Geological relationship with its neighboring features suggests that Wugang is in the same pre-Nectarian age as the Freundlich-Sharonov basin.

1.3 Volcanic shield highland N4 (Yutu)

From the comparison map[8] between CLTM-s01 and ULCN2005, we find an elevation anomaly on the lunar nearside centered at (14°N, 308°E) and to the east of Oceanus Procellarum, with a height of about 2 km.

Area of (0°N—30°N, 300°E—330°E) in the Oceanus Procellarum (see Figure 4(a) and 4(b)), among which two highlands are clearly visible in the western region from Figure 4(a)) of CLTM-s01 topographic map. The northern one, hereafter called Highland One, is centered at (25°N, 310°E) with a diameter of about 250 km and a 3-km height above surrounding maria, which can be identified in the ULCN2005 map (see Figure 4(b)). Highland Two, which is to the south of Highland One, is centered at (14°N, 308°E), across an area of about 300 km in diameter and about 2—3 km above the surrounding maria.

Comparison between the 1∶1 million-scale shaded relief and the color-coded topography map derived from stereo-photos shows that the plateau characteristics of Highland One are much clearer than those of Highland Two. There are numerous feature types around Highland One, including the radial impact craters Aristarchus and Herodotus, as well as vallis Schroteri. Strangely, the obvious highland shown in Figure 4(a) with a solid black circle only represents a slight topographic disorder in the stereo-photos and is almost at the same topographic level of the surrounding maria. Previous lunar gravity model LP150Q[26] in Highland Two shows a very distinct positive gravity anomaly with about 300mgal higher than the lunar maria region. The 1∶10 million lunar chart supplied by LPI (Lunar and Planetary Institute) reveals complicated relief characteristics (such as radiation lines, mons, impact craters, vallis, sinus and etc.) in Highland One. However, the whole physiognomy is much smoother in the vicinity of Highland Two, in which the crater Marius and Rima Marius have been identified and named. Previous photographic analysis have shown that there are many hills around Marius and name them Marius hills, but from CLTM-s01 topography we can see that it is a whole mountain with many small raised relieves.

Most authors agree that the maria on the nearside represent volcanic rocks. The dark domes and plateaus closely associated with the maria are commonly interpreted as shield volcanoes. The crystalline rocks returned from Mare crystalline by Apollo 11 have igneous textures, and compositions similar to the terrestrial basalts but enriched in some refractory elements (particularly Ti and Zr) and depleted in alkalied and some volatile constituents. The nearly uniform appearance of the various maria suggest they are similar in origin and composition, and an approximately basaltic composition for all mare rocks is supported by remote sensing. Thus accumulated evidences indicate that the maria are volcanic fills of basalt-like composition[14].

Based on the above information, we argue that both Highland One and Highland Two are probably shield volcanoes. Highland Two has an obvious circular topographic uplift which is similar to the mouth of ancient volcano. It seems that Highland Two belongs to the geological age of Lower Imbrium. Inspired by an ancient Chinese legend, we temporarily name it YUTU Mountain. Topography in this region is much more complex than we have ever experienced, and it is necessary to use higher resolution camera results for further confirmation.

2 Impact basins identified by CLTM-s01

Impact basins are the most important landforms on the Moon. Few are well known, but many exist. However, IAU did not make a distinction between impact craters and impact basins. Wood has summarized almost all the confirmed and proposed impact basins from historical data (see website: http://www.lpod.org/cwm/DataStuff/Lunar%20Basins.htm) and listed about 57 impact basins, which he classified into 4 grades. Some impact basins are well defined with multiple rings, central depressions, and surrounding ejecta deposits. Most basins lack some of these characteristics, but can still be classified as basins with relatively high confidence. Older and more obscure features have greater uncertainties, and the Clementine altimetry data have led to the tentative identification of some possible basins that are defined solely as depressions. Based on those analyses, impact basins are classified either as certain (1), probable (2), uncertain (3), or proposed (4). Here grade (4) represents some recently proposed basins that have not yet been examined carefully, but will ultimately be upgraded or removed from the list.

Table 2 lists the 11 impact basins in grade (4), five of which are definitely named. Here we code those six unnamed basins as P1—P6. All the basins have been delineated with black dotted circles in Figure 1, with six on the farside and five on the nearside. Based on the CLTM-s01 high-resolution topographic map, we have analyzed the characteristics of those grade(4) impact basins, and then reclassified accordingly.

2.1 Main impact basins identified by CLTM-s01

In the CLTM-s01 topographic map, Bailly-Newton shows obvious southern and western rims. The rim of the ancient SPA basin can be seen bisecting not only the rim but also cutting across the floor of the Bailly-Newton basin. Since they are also multi-mixture materials in this region, it is a little difficult to accurately discern ring of the basin. Based on the arguments of Cook[21], we conclude that Bailly-Newton is an impact basin. As the out rim of Bailly-Newton seems to be not too clearly discernable, we reclassify it as grade 3.

The Dirichlet-Jackson basin, located on the lunar farside, represents a very clear impact out rim in Figure 1. Compared to impact craters Korolev and Hertzspung, Dirichlet-Jackson is suffering from more secondary impacts. The newest gravity model SGM90d[27] shows an apparent circular signature corresponding to the topographic structure in Dirichlet-Jackson. Since we hold that this basin has a significant impact basin characteristic, we reclassified it as grade 1.

Lomonosov-Fleming is a relatively flat terrain, showing only a certain degree of depression. It has a circular out rim, with the inner part and the internal edge being covered by all kinds of impact craters. Giguere[30] has used the UV-VIS digital image model to generate both 1 km and 100 m resolution images for this region. Numerous dark halo impact craters have been identified and mapped in this region. Such widespread distribution of the dark halo craters indicate that the mare material is not confined to small areas and indeed represents a large cryptomare. Due to the fact that the characteristics of the basin have certain degradations and its edge features are not so obvious, here we believe that Lomonosov-Fleming should belong to grade 3.

Schrodinger-Zeeman has a double-ring structure, with a complete and obvious inner ring and a less intact outer ring (see Figure 1). The topographic feature of this region shows a high correlation with its gravity anomaly[27,31]. Although this basin appears highly degraded[21], we can still indentify its basin structure. We intend to classify it as a grade 2 basin.

Sylvester-Nansen is almost centered on the lunar north pole. It is a shallow basin, and its rim and interior are extensively degraded by overlying craters and deposits. Gravity anomaly map shows that it has a negative central gravity feature[27,31]. Accordance to the above-mentioned characteristics, we reclassified Sylvester-Nansen as a grade 2 basin.

2.2 Other impact basins identified by CLTM-s01

The basins numbered P1—P6 in Table 2 were all proposed by Spudis[17,18]. All of these potential basins were identified with the Clementine laser altimetry data, but have never been named before. Referring to Spudis' descriptions, we have analyzed the basins and reclassified them again with the CLTM-s01 model.

Cook[25] has proposed an impact basin named Cruger-Sirsalis, which is centered at (15^{o}S, 66^{o}W) and with a diameter of 400 km. Hikida[32] has calculated the crustal thickness of the Moon using polyhedral shape models to inverse the gravity, and has thereby changed the central position of Cruger-Sirsalis to (16°S, 65°W). Wieczorek et al.[33] in his paper suggested the geological age of Cruger-Sirsalis as Imbrium to pre-Nectarian. Comparing the descriptions of Cook and Spidus, we conclude that P2 in Table 2 is the Cruger-Sirsalis basin mentioned by Cook. In the CLTM-s01 topographic map, the Cruger-Sirsalis basin represents an obvious impact depression. In this paper, we have determined that P2 is certainly an impact basin properly named Cruger-Sirsalis, and reclassified it as grade 1.

The P1 region depicted by Spudis is almost in a superposition with crater D'Alemebert (50.8°N, 163.9°E, 255 km in diameter), but in a range of 450 km mentioned by Spudis, non-depressed region exists. It is still difficult to clearly identify the basin characteristics of P3—P6 in the CLTM-s01 topographic map, as they do not

Table 2 Proposed impact basins (Wood, 2004)[a)]

Basin name	Latitude (deg.)	Longitude (deg.)	Diameter (km)	Age	Discoverer	Identified grade (this research)
Bailly-Newton	–73	–57	330	pN	Cook 2000	3
Dirichlet-Jackson	14	–158	470	pN	Cook 2000	1
Lomonosov-Fleming	19	105	620	pN	Wilhelms &ElBaz 1977[34]	3
Schrodinger-Zeeman	–81	–165	250	pN	Cook 2000	2
Sylvester-Nansen	83	45	500	pN	Cook 2000	2
P1	50	165	450		Spudis 1995	4
P2 (Cruger-Sirsalis)	–20 (–16)	–70 (–65)	300 (400)	I-pN	Spudis 1994	1
P3	30	165	330		Spudis 1995	4
P4	45	55	350		Spudis 1995	4
P5	60	130	400		Spudis 1995	4
P6	55	–30	700		Spudis 1995	4

a) The latitude and longitude ranges from –180—180 deg. and –90—90 deg., respectively. pN is pre-Nectarian; I is Imbium.

show any depressed features. We can only confirm that P2 is an exact impact basin, but P1 and P3—P6 can only stay in grade 4 or might be removed later according to the CLTM-s01 topographic maps. As uncertainties still exist, we believe classification of these regions merits further careful consideration that will be based on the latest camera results from Chang'E-1 and SELENE.

3 Discussion and conclusions

The dichotomy of the lunar surface and geology is controlled either directly or indirectly by the 50 or so impact basins that have been recognized with varying degrees of confidence from photogeology and orbital geophysical mappings[35]. The characteristics of large impact basins play an important role in understanding the early thermal and magnetic state of the Moon. Furthermore, it has implications for the theory of Late Heavy Bombardment on the Moon, and use of the Moon as a standard for estimating crater retention ages throughout the solar system.

Early analyses of Clementine laser altimetry and stereo-photographic results have provided us with very important information for understanding the distribution, composition and characteristics of the lunar impact basins. However, due to the constraints of the dada spatial resolution, our knowledge about the formation of those impact basins is still quite poor.

In this research, we analyzed the CLTM-s01 lunar topographic model in detail, and proposed four features which have never been confirmed before. They are the quasi-impact basin Sternfeld-Lewis, impact basin Fitzgerald-Jackson, crater Wugang and volcanic shield highland Yutu. Furthermore, we also identified several large-scale impact basins proposed before, and reclassified them into different grades according to their circular characteristics.

Dichotomy is the main factor for understanding the internal structure, origin and evolution of the Moon. Small-scale topographic features and high-resolution gravity data provide an important clue to interpreting such dichotomy phenomena. The high-resolution topographic map from Chang'E-1 has provided a certain amount of lunar surface information for studying the characteristics of small-scale features, but there are still restrictions on interpreting the geological structures and terrain types of those topographic features. Early research of lunar geology was almost entirely based on remote sensing inversion. As a result of getting multiple solutions from inversing remote sensing images, we are faced with a lot of uncertainties in interpreting the geological structures of the Moon. It is necessary to use high-resolution remote sensing data (such as the CCD images from Chang'E-1) in our future analysis of those proposed impact basins and special features.

As the task of naming features on the Moon following strict rules which are managed initially by the Lunar Task Group (LTG) of the International Astronomical Union (IAU) Working Group for Planetary System Nomenclature (WGPSN), we will submit an official proposal to LGT on the formal names we have proposed for the four new lunar features.

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