Observing distinctive geologic features on asteroid Toutatis

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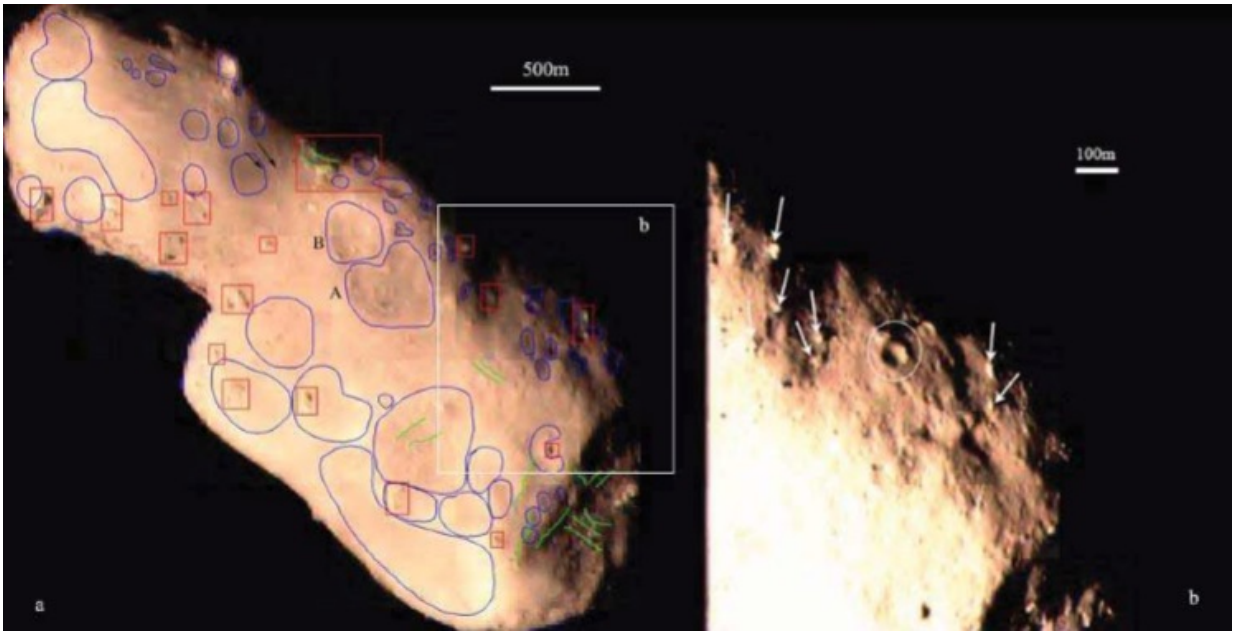

Various geological features on the surface of Toutatis. (a) Craters (blue circles),boulders (red squares), lineaments (green lines) as well as the flow direction of regolith (blackarrows) are outlined. (b) A morphological-integrity crater shows a sharp bowl shape, with dozens of boulders distributing around. This figure is reproduced from Huang et al. (2013a).

(Phys.org)—Asteroid (4179) Toutatis, an Apollo-type near-Earth object (NEO) was thoroughly studied by Chinese Chang'e-2 spacecraft in 2012, when the space rock flew by Earth at a distance of 18 lunar distances.

The probe, imaging the asteroid in high-resolution, has provided compelling information regarding Toutatis' geological structure. Now, a team of researchers from the Chinese Academy of Sciences has published a paper on *arXiv* that sums up the findings about the asteroid's distinctive geologic features.

The Chang'e-2 spacecraft completed a successful flyby of the Toutatis at a closest distance of 770 meters from the asteroid's surface. The observations show that Toutatis has an irregular surface and its shape resembles a ginger root, with a smaller lobe (head) and a larger lobe (body).

"Such bilobate shape is indicative of a contact binary origin for Toutatis. In addition, the high-resolution images better than three meters provide a number of new discoveries about this asteroid, such as an 800-meter depression at the end of the large lobe, a sharply perpendicular silhouette near the neck region, boulders, indicating that Toutatis is probably a rubble-pile asteroid," Jianghui Ji of the Chinese Academy of Sciences, one of the co-authors of the paper, told Phys.org.

The observations revealed that Toutatis is covered by abundant concavities indicating that impact cratering may play an important role in shaping the asteroid's present surface. Most large craters show shallow depths and obscure shapes, which may result from a resetting process. For instance, seismic shaking from subsequent impacts can cause regolith displacement to erase craters' rims.

For researchers, the most interesting feature on Toutatis is the previously mentioned giant 800-meter depression. It is estimated that the energy of the impactor for this depression would be 500 GJ. This result is fairly greater than the energy required for breaking up a bulk rock with the same size of Toutatis. Therefore, they infer that this asteroid might not bear a monolithic structure but a rubble pile with fragments accreted.

"The present investigation shows that Toutatis, like many other asteroids, may bear a rubble-pile structure rather than a monolithic rock, providing abundant information of this kind of asteroids," Ji said.

In addition, they calculated the seismic attenuation factor for the largest depression of Toutatis, which is higher than those of other porous asteroids. This may greatly attenuate the heavy shock wave so that abundant large craters are unlikely to lead to global disruption of the asteroid.

The researchers have also identified more than 200 boulders scattered across the asteroid's surface. They have dimensions ranging from 10 to 61 meters, with an average size of 22 meters, and as the scientists noted, 90 percent of them are less than 30 meters wide. The two largest boulders are located in the Toutatis' "neck" region. According to Ji and his colleagues, most of the asteroid's boulders are probably fragments from the parent body but are not generated by impact cratering.

Chang'e-2 has also provided detailed images of linear structures like troughs and ridges. The scientists believe that the origin of the troughs on the surface may arise from the impact of other asteroids.

Chang'e-2, the second Chinese spacecraft dedicated for lunar exploration, was launched on Oct. 1, 2010. It orbited the moon for six months and after the successful lunar mission, the spacecraft was sent to the sun-Earth Lagrangian point (L2) to explore the space environment. After an over 230-day stay at L2, the probe started its mission to Toutatis on June 1, 2012 and on Dec. 13, 2012, it made the closest approach to the asteroid. The spacecraft obtained a total of 425 images of Toutatis.

Encouraged by the success of Chang'e-2 mission, Ji would like to see more spacecraft exploring this geologically interesting asteroid.

"Sending another probe to Toutatis may entirely reveal its detailed information, which was not exposed by ground-based radar measurements and Chang'e-2 flyby mission," he said.

Meanwhile, China is planning an asteroid mission, named Multiple Asteroids Rendezvous and in-situ Survey (MARS) that will visit three NEOs. Asteroid (99942) Apophis and (175706) 1996 FG3 are the potential candidates. MARS' main goals will be to provide insights on the formation of planets, the evolution of the solar system and the origin of life on Earth.

More information: Chang'e-2 spacecraft observations of asteroid 4179 Toutatis, arXiv:1511.02131 [astro-ph.EP]
arxiv.org/abs/1511.02131

Abstract
On 13 December 2012, Chang'e-2 completed a successful flyby of the near-Earth asteroid 4179 Toutatis at a closest distance of 770 meters from the asteroid's surface. The observations show that Toutatis has an irregular surface and its shape resembles a ginger-root of a smaller lobe (head) and a larger lobe (body). Such bilobate shape is indicative of a contact binary origin for Toutatis. In addition, the high-resolution images better than 3 meters provide a number of new discoveries about this asteroid, such as an 800-meter depression at the end of the large lobe, a sharply perpendicular silhouette near the neck region, boulders, indicating that Toutatis is probably a rubble-pile asteroid. Chang'e-2 observations have significantly revealed new insights into the geological features and the formation and evolution of this asteroid. In final, we brief the future Chinese asteroid mission concept.