

COMPARATIVE STUDY OF PIT CRATERS ON ASTEROIDS (951) GASpra, (243) IDA, (433) EROS AND THE MARTIAN MOON PHOBOS. M. de Luis¹ and L. M. Parro^{2,3,4}, ¹Universidad de Alcalá de Henares, Spain, ²Instituto de Física Aplicada a las Ciencias y las Tecnologías, Universidad de Alicante, Sant Vicent del Raspeig, Spain, ³Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ, USA, ⁴Universidad Complutense de Madrid, Madrid, Spain (lmparro@ucm.es).

Introduction: The study of asteroids has become extremely relevant due to their risk of collision with our planet. This knowledge of their external and internal characteristics is essential to design effective planetary defense strategies. In this sense, it is important to know the mechanical and dynamical properties of such objects in order to understand and evaluate the efficiency of momentum transfer in the event of an attempt to deflect them employing impacts [1]. Asteroids could also be used as a source of resources, for gravitational assistance or as intermediate stations in interplanetary missions. Furthermore, they provide us with key data on the origin of life and our Solar System [2].

The small bodies studied in this research occupy different regions of the Solar System and appear to be mostly monolithic bodies covered with regolith. The pit craters on them could have formed by the drainage of overlying loose material into internal fractures [3].

In the present work, a catalogue of possible pit craters on the surfaces of (951) Gaspra, (243) Ida, (433) Eros and Phobos has been compiled and their sizes compared. We also explore possible correlations with different parameters of these bodies such as the average body size, density, composition, etc.

Methods: Images taken in Galileo, NEAR Shoemaker and other space missions were analyzed, mainly using the Small Body Mapping Tool [4]. SBMT provides images, spectra and other data related to the small bodies of the solar system that can be accessed in a user-friendly way. Thanks to the large catalogue of three-dimensional models of numerous moons and asteroids allow us to locate images, radar altimetry data or spectra in the databases compiled by different space missions and project them onto the three-dimensional model (Fig. 1).

Exploratory analyses and comparisons of pit crater diameters were made using Analysis of Variance, and possible correlations were studied. In this work, the ANOVA technique is used to compare the means of the diameters of pit craters detected on the different celestial bodies studied. Among them, we have two asteroids of the main belt (951) Gaspra and (243) Ida, one NEO (433) Eros, and one of the moons of Mars, Phobos. An ANOVA test is a type of statistical test that can be used to determine whether there is a statistically

significant difference between the means of two or more groups. This is achieved by analyzing the levels of variance within groups across samples taken from each group [5].

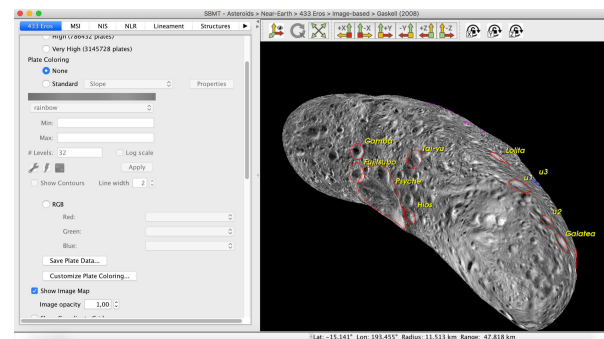


Figure 1. Example of SBMT session where various geological features have been marked on the surfaces of the asteroid (433) Eros.

Results: A total of 195 pit craters have been catalogued and distributed as follows: 52 on (243) Ida, 58 on (433) Eros, 28 on (951) Gaspra and 57 on Phobos. First, an exploratory analysis of the data obtained was carried out. A statistical study has been performed for each of the bodies and for the whole pool of detected craters. The smallest pit craters are detected in (433) Eros, probably because the resolution of the images used is much higher than that used for the other objects studied.

In general, the diameters range from a few tens of meters to a maximum of almost 1 km. The mean of the total group of features would be almost 200 m with a median of about 150 m (Fig. 2). On (931) Gaspra and (243) Ida seem to have a similar mean and the largest ones are found on Phobos. It is important to keep in mind that the Phobos measurements present a large uncertainty given the difficulty of distinguishing chains of subsidence craters with chains of sesquinary impact craters. This could be reflected in a high dispersion (Fig. 2) of the values as shown by their standard deviation.

A histogram has been generated for the total number of craters (Fig. 3). In it is easy to detect outliers. In the case of Phobos, the maximum values of the whole set are obtained. It may be that Phobos suffers an intense fracturing due to its position with

respect to the Roche limit of Mars, although the maximum outlier could also be a consequence of a large old impact.

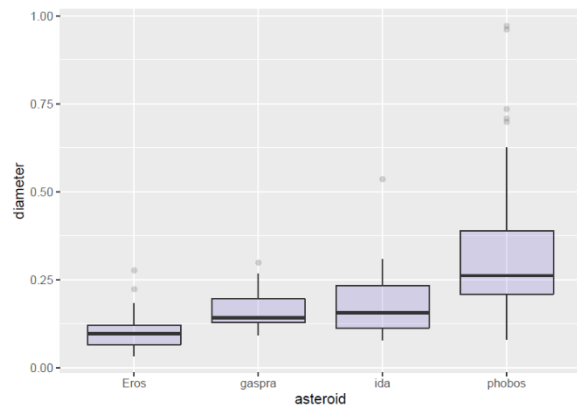


Fig. 2. Comparison of pit crater dimensions between the four bodies studied. Diameter in Km.

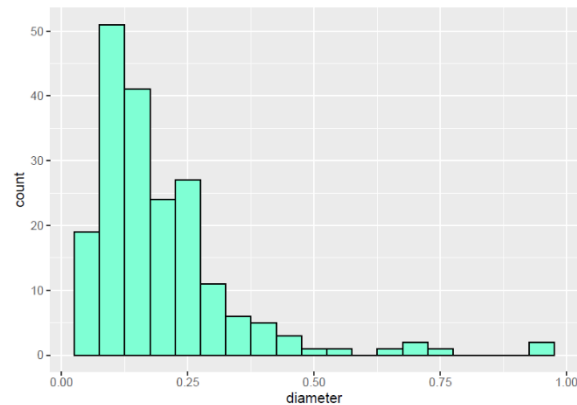


Fig. 3. Histogram for the set of all measured pit craters. Diameter in Km.

Discussion: It is assumed that (951) Gaspra is a fragment that originated when a catastrophic impact destroyed the parent body between 500 and 200 million years ago. This event also produced the entire Flora family, whose main representative is this asteroid of 140 km in diameter. This family occupies a region near the inner edge of the main asteroid belt (semi-major axis 2.2 AU) [6].

Asteroid (243) Ida appears to be older than the previous one. May it originate about 2 billion years ago in the catastrophic collision that gave rise to the Koronis family, which occupies the outer region of the belt (semi-major axis 2.86 AU). This is a region with few objects, given its proximity to the 5.2 resonance distance to the planet Jupiter [7].

Eros (semi-major axis 1.4 AU) also appears to be a fragment originating from the destruction of a larger parent body. It appears to be a coherent object under a layer of loose material, as there is evidence of efficient transmission of seismic waves. Impact events would generate waves with a very significant effect on a surface composed of loose, low-cohesion material. In this scenario, crater erasure would be very efficient, something that would affect current chronologies based on crater density [8].

The case of Phobos (semi-major axis of Mars 1.5 AU) is very different from the previous ones. It lies close to the Roche limit of Mars and seems clear to show signs of strong tidal stress. The origin of the Mars satellites is uncertain. They may be captured asteroids or have originated after the impact of an object on Mars. The composition of both moons remains unknown, although both appear to share spectral characteristics [9].

If pit craters originate from the drainage of regolith into internal fractures, the differences observed between these objects could be related to their degree of internal fracturing. Furthermore, although it is not easy to relate the observed differences to what is known about the collisional histories of these bodies, mapping and describing these structures on the surfaces of these asteroids could help us to understand their geological evolution.

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References: [1] Bruck Syal, *et al.* (2016), Icarus, 269, 50-61. [2] Zinner (2003), Treatise on Geochemistry 1st Edition, 711. [3] Horstman *et al.* (1989), Journal of Geophysical Research: Solid Earth 94(B9), 12433 [4] Ernst, C. M., et al (2018). 49th LPSC #1043. [5] Heumann *et al.* (2016), Introduction to statistics and data analysis, Springer. [6] Veverka *et al.* (2000), Science 289(5487), 2088. [7] Belton *et al.* (2000), Advances in Space Research 26(10), 1641. [8] Buczkowski *et al.* (2008), Icarus 193(1), 39 [9] Gartrelle (2019), Ph.D. thesis, The University of North Dakota