

Supplemental Material: The geology and evolution of the Near-Earth binary asteroid system (65803) Didymos.

Olivier Barnouin^{1,*}, Ronald-Louis Ballouz¹, Simone Marchi², Jean-Baptiste Vincent³, Harrison Agrusa^{4,5}, Yun Zhang⁶, Carolyn M. Ernst¹, Maurizio Pajola⁷, Filippo Tusberti⁷, Alice Lucchetti⁷, R. Terik Daly¹, Eric Palmer⁸, Kevin J. Walsh², Patrick Michel^{4,9}, Jessica M. Sunshine⁵, Juan L. Rizos¹⁰, Tony L. Farnham⁵, Derek C. Richardson⁵, Laura M. Parro¹¹, Naomi Murdoch¹², Colas Q. Robin¹², Masatoshi Hirabayashi¹³, Tomas Kahout¹⁴, Erik Asphaug¹⁵, Sabina D. Raducan¹⁶, Martin Jutzi¹⁶, Fabio Ferrari¹⁷, Pedro Henrique Aragao Hasselmann¹⁸, Adriano Campo Bagatin¹¹, Nancy L. Chabot¹, Jian-Yang Li⁸, Andrew Cheng¹, Michael C. Nolan¹⁵, Angela M. Stickle¹, Ozgur Karatekin¹⁹, Elisabetta Dotto¹⁸, Vincenzo Della Corte²⁰, Elena Mazzotta Epifani¹⁸, Alessandro Rossi²¹, Igor Gai²², Jasinghege Don Prasanna Deshapriya¹⁸, Ivano Bertini²³, Angelo Zinzi²⁴, Josep M. Trigo-Rodriguez²⁵, Joel Beccarelli²⁶, Stavro Lambrov Ivanovski²⁷, John Robert Brucato²⁸, Giovanni Poggiali²⁸, Giovanni Zanotti¹⁶, Marilena Amoroso²⁴, Andrea Capannolo¹⁷, Gabriele Cremonese⁷, Massimo Dall'Ora²⁹, Simone Ieva¹⁸, Gabriele Impresario²⁴, Michèle Lavagn¹⁷, Dario Modenini²², Pasquale Palumbo²³, Davide Perna¹⁸, Simone Pirrotta²⁴, Paolo Tortora²², Marco Zannoni²², and Andrew S. Rivkin¹

¹Johns Hopkins University Applied Physics Laboratory, Laurel, MD
(olivier.barnouin@jhuapl.edu)

²Southwest Research Institute, Boulder, CO

³DLR Institute of Planetary Research, Berlin, Germany

⁴University of the Côte d'Azur, Observatory of the Côte d'Azur, CNRS,
Laboratory Lagrange, Nice, France

⁵University of Maryland, College Park, MD

⁶University of Michigan, Ann Arbor, MI

⁷INAF-Astronomical Observatory of Padova, Padova, Italy

⁸Planetary Science Institute, Tucson, AZ

⁹The University of Tokyo, Department of Systems Innovation, School of
Engineering, Tokyo, Japan

¹⁰ Institute of Astrophysics of Andalusia, CSIC, Granada, Spain

¹¹University of Alicante, Alicante, Spain

¹²Superior Institute of Aeronautics and Space, University of
Toulouse, Toulouse, France

¹³Daniel Guggenheim School of Aerospace Engineering, Georgia Institute
of Technology, Atlanta, GA

¹⁴Univ. of Helsinki, Helsinki, Finland

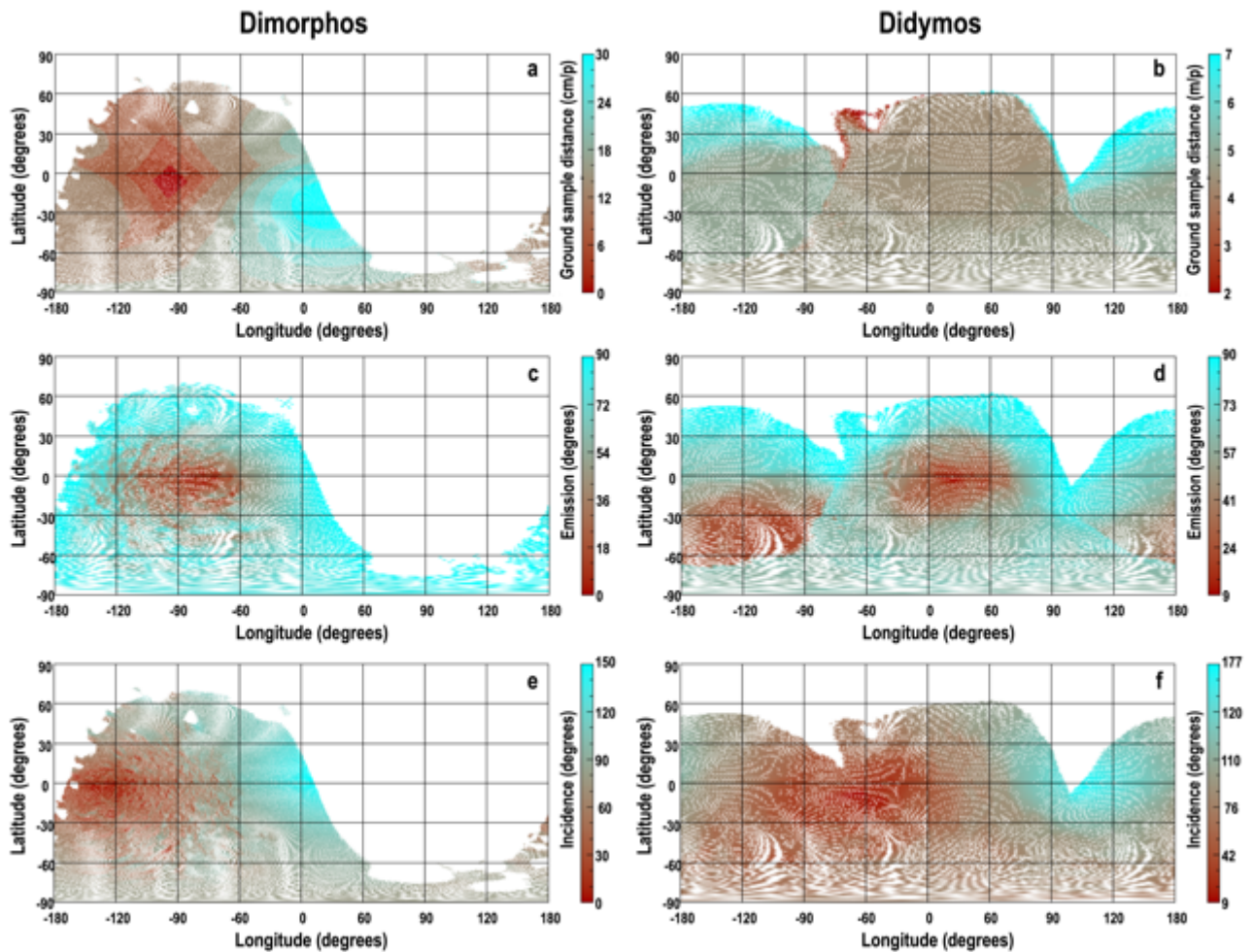
¹⁵Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ

¹⁶Univ. of Bern, Bern, Switzerland

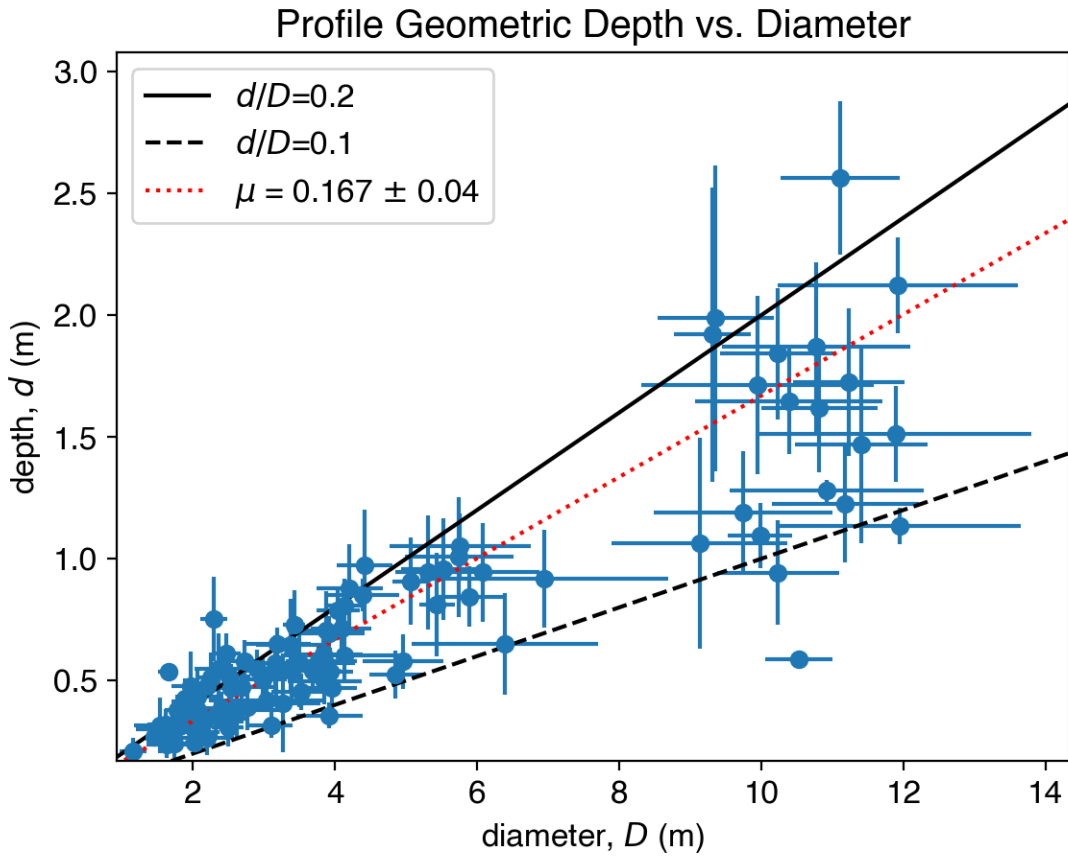
- ¹⁷Politechnic University of Milan, Milan, Italy
- ¹⁸INAF- Astronomical Observatory of Rome, Rome, Italy
- ¹⁹Royal Observatory of Belgium, Brussels, Belgium
- ²⁰INAF-Institute of Space Astrophysics and Planetology, Rome, Italy
- ²¹Institute of Applied Physics "Nello Carrara", CNR, Florence, Italy
- ²²University of Bologna, Bologna, Italy
- ²³University of Parthenope, Parthenope, Italy
- ²⁴ASI, Rome, Italy
- ²⁵Institute of Space Sciences (CSIC-IEEC), Barcelona, Catalonia, Spain
- ²⁶Univ. of Padova, Padova, Italy
- ²⁷INAF- Astronomical Observatory of Trieste, Trieste, Italy
- ²⁸INAF- Astronomical Observatory of Arcetri, Arcetri, Italy
- ²⁹INAF- Astronomical Observatory of Capodimonte, Capodimonte, Italy
- *Corresponding author: Olivier Barnouin, olivier.barnouin@jhuapl.edu

This supplementary materials section possesses the figures and table referenced in the Method section of the main paper. It also has a section on the unpublished geometric diameter-depth measurements for Bennu, that were used as comparison with the craters measured on Dimorphos. It provides the data used to make Main Fig. 7. All the other data are available in the PDS.

Supplementary Figures



Supplementary Figure 1. Ground sample distance (a,b), emission (c,d) and incidence (e,f) coverage of DRACO data collected at Dimorphos (left-column:a,c,e), and combined DRACO and LUKE data collected at Didymos (right-column:b,d,f).



Supplementary Figure 2. The geometric shapes of craters on Bennu with $D < 12\text{m}$. They compare favorably to the geometric shapes of all craters measured on Dimorphos, the largest of which has a $D \sim 11.1\text{m}$. These crater shapes were collected while preparing Daly et al. (2020)²⁸ but were not published before because measurements that use surface elevation (which include the effects of gravity) are more useful for understanding and comparing the geological processes responsible for crater formation and modification on asteroids and planets, especially given recent findings that asteroid surface are very weak (see main manuscript for more details). Surface elevation was not computed for Dimorphos because of the challenges the proximity of Didymos poses to define a reasonable reference geoid. The Bennu data used to make this figure are available in the source data file of the main article.

Tables

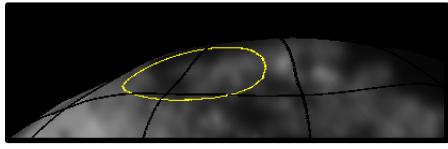
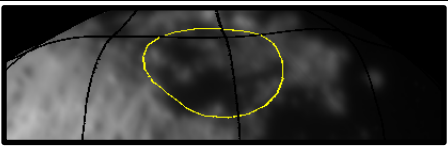
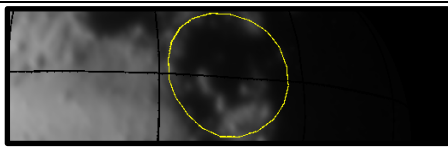
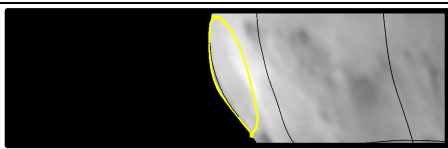
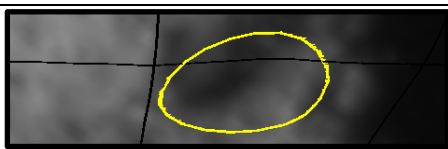
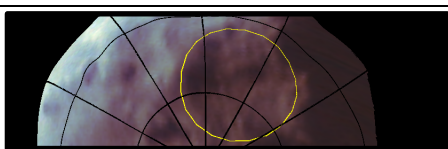
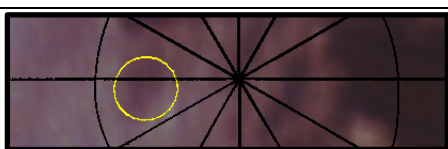
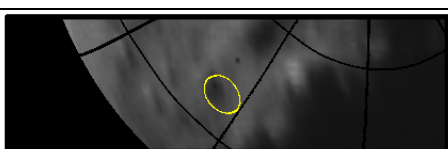
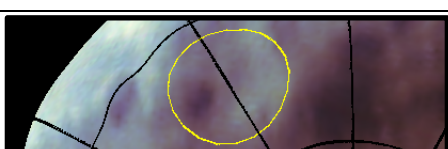
Supplementary Table 1. Didymos Global Digital Terrain Model


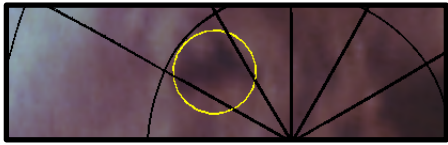
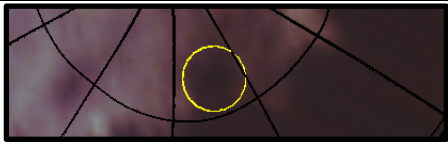
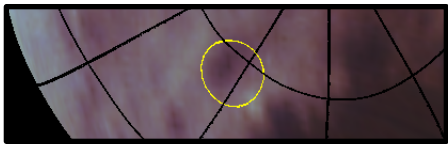
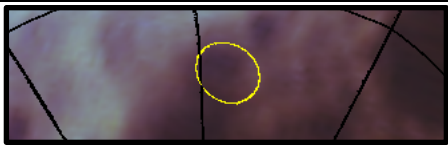
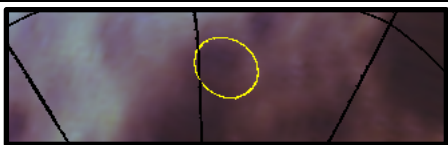

Parameter	Value
Volume (km ³)	0.203 ± 3.4%
Surface area (km ²)	1.729732 ± 3.3%
Extent	
x (m)	819 ± 14
y (m)	801 ± 14
z (m)	607 ± 14
Best fit ellipsoid semi-major axes	
a (m)	409 ± 7
b (m)	398 ± 7
c (m)	295 ± 7
Equivalent radius (m)	365 ± 4
Density (kg/m ³)	2800 ± 280
Average slope (degrees)	34.0 ± 15.0
Median slope (degrees)	33

Supplementary Table 2. Crater candidate confidence criterion

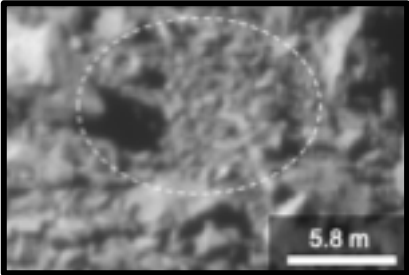
Confidence Rating	Criteria
1	Circular uplifted rim, bowl shape
2	Partial circular rim; accumulation of boulders, some bowl shaped appearance, crushed interior
3	Circular structure, central depression present
4	Circular flat facet*

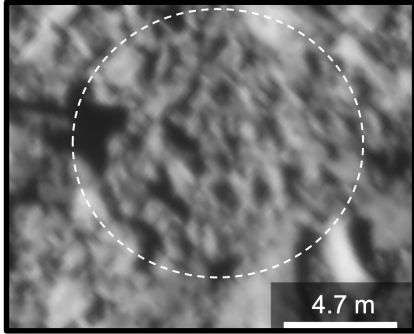
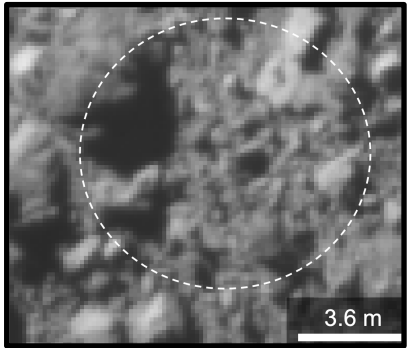
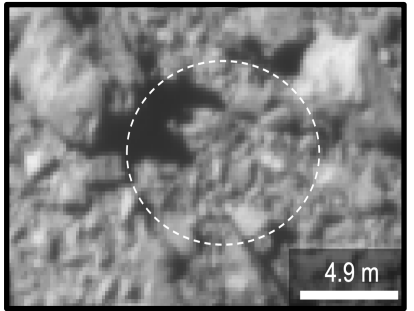
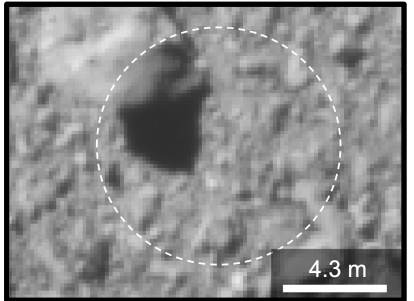
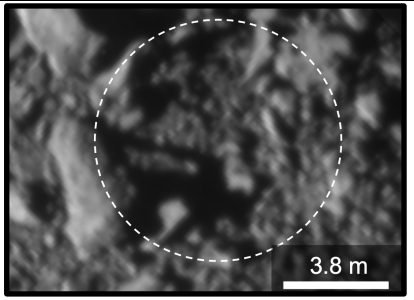
Supplementary Table 3. Candidate craters identified on Didymos.

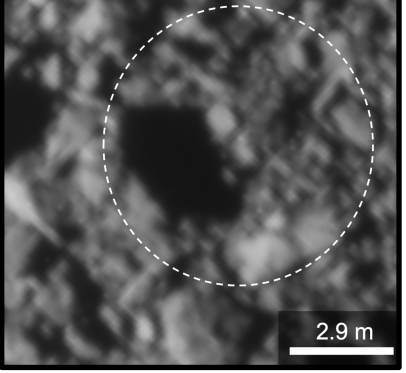
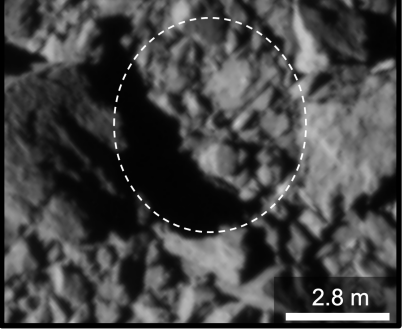
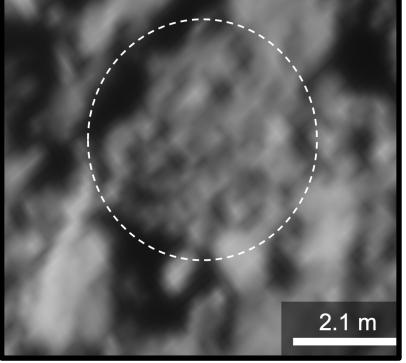
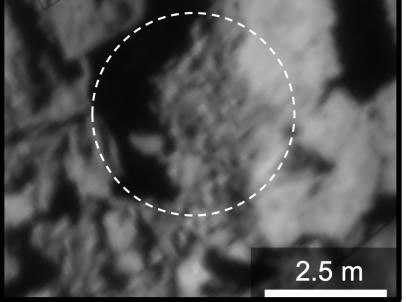
Crater Candidate	Image	Location	Diameter (km)	Confidence
Dcrt01		39.6N 2.8E	0.167	2
Dcrt02		20.6N 25.9E	0.198	2
Dcrt03		1.0N 44.5E	0.188	2
Dcrt04		16.6S 309.1E	0.154	3
Dcrt05		33.6S 40.7E	0.109	2
Dcrt06		53.6S 21.9E	0.268	3
Dcrt07		70.40S 263.8E	0.072	2
Dcrt08		39.5S 215.4E	0.048	3
Dcrt09		43.1S 330.2E	0.140	4

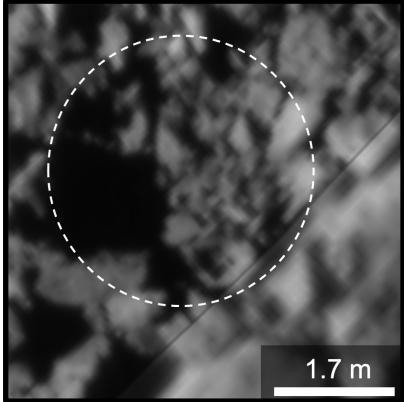
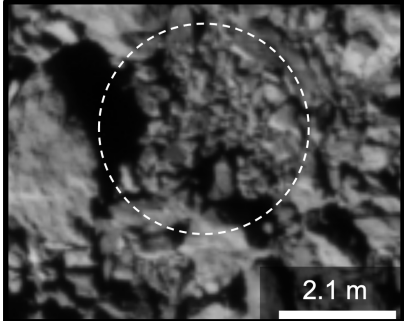
Dert10		63.3S 85.3E	0.128	2
Dert11		68.3S 312.9E	0.09	3
Dert12		65.9S 162.4E	0.07	2
Dert13		56.2S 212.9E	0.08	2
Dert14		35.8S 12.9E	0.05	2
Dert15		43.9S 5.3E	0.06	2
Dert16		77.7S 152.6E	0.03	3

Supplementary Table 4. Candidate craters identified on Dimorphos.

Crater Candidate	Image	Location	Diameter (m)	Depth (m)	Confidence
crt02		20.3N 247.7E	11.1 ± 2.1	1.9 ± 0.2	2

crt04		8.8N 254.2E	10.9 ± 2.1	1.4 ± 0.2	1
crt05		31.4S 263.3E	7.1 ± 0.7	1.3 ± 0.3	2
crt06		10.5S 241.6E	8.5 ± 0.9	1.3 ± 0.3	4
crt07		26.9S 230.8E	8.8 ± 1.1	1.6 ± 0.2	1
crt08		3.1N 284.7E	9.0 ± 1.4	0.99 ± 0.04	4

crt10		6.1S 283.3E	8.3 ± 0.5	0.8 ± 0.1	3
crt11		9.9S 266.5E	4.7 ± 0.3	0.8 ± 0.1	3
crt12		24.8S 271.9E	4.7 ± 0.7	0.7 ± 0.1	1
crt15		24.7 263.7E	5.6 ± 0.5	1.3 ± 0.2	1

crt17		17.2S 275.1E	5.2 ± 0.5	0.7 ± 0.2	1
crt19		12.0S 271.2E	2.9 ± 0.5	0.3 ± 0.1	1