

Carlé McGetchin Pieters

Department of Earth, Environmental, and Planetary Sciences [DEEPS]
Brown University, Providence, RI 02912
Email: Carle_Pieters@brown.edu

Education:

- Ph.D., Massachusetts Institute of Technology, Planetary Science, 1977
- M.S., Massachusetts Institute of Technology, Planetary Science, 1972
- B.S., Massachusetts Institute of Technology, Planetary Science, 1971
- B.A., Antioch College, Math-Education, 1966

Professional Positions:

2020 – present	Professor (Emeritus), Department of Earth, Environmental, and Planetary Sciences, Brown University
2010-2020	Professor (Research), Department of Geological Sciences (name changed to Earth, Environmental, and Planetary Sciences in 2014), Brown University.
1994-2010	Professor, Department of Geological Sciences, Brown University.
1983-1994	Associate Professor, Department of Geological Sciences, Brown University.
1980-1983	Assistant Professor (Research), Department of Geological Sciences, Brown University, Providence, Rhode Island.
1977-1980	Space Scientist, Lunar and Planetary Sciences Division, NASA Johnson Space Center, Houston, Texas.
1972-1975	Division of Sponsored Research Staff Scientist, Massachusetts Institute of Technology, Planetary Astronomy Laboratory, Department of Earth and Planetary Sciences.
1967-1969	Science teacher (Peace Corps), Sarawak, Malaysia.
1966-1967	High School. Math teacher, Somerville, Massachusetts.

Completed Research:

Publications: Over 300 research articles in peer-reviewed scientific journals, including a book *Remote Geochemical Analyses* (Cambridge University Press). In addition, numerous short and extended abstracts are presented each year at professional meetings and workshops. See attached for the last several years of peer-reviewed publications. Full publication list by date or by first author can be found at:

http://www.planetary.brown.edu/html_pages/pieters_refpubs_date.htm

Research:

- Moon Mineralogy Mapper (M³): Principal Investigator for an imaging spectrometer (0.4-3.0 μm) to characterize and map the mineralogy of the Moon at high resolution. M³ was launched on the Indian Chandrayaan-1 spacecraft to the Moon in October 2008 and acquired global compositional data until September 2009. Major accomplishments include discovering measurable OH/H₂O across the surface and a new rock type (Mg-spinel anorthosite) not recognized in returned samples. Analysis of the data continue to produce high quality science results.
- PI, NASA Solar System Exploration Research Virtual Institute (SSERVI) team: *SSERVI Evolution and Environment of Exploration Destinations* (SEEED) 2014-2020. Responsible

for leading a ‘virtual’ institute involving 24 CoI’s and 19 Collaborators focused on exploration and science issues for the Moon, asteroids and moons of Mars.

- Laboratory spectroscopy experiments: Measuring and modeling the interaction of visible to mid-infrared radiation with geologic materials. Includes extensive measurement and analyses of lunar samples and meteorites as well as terrestrial analogue materials.
- Lunar science: Remote compositional analysis using spectroscopic data integrated with a growing array of global lunar data. Science questions focus on formation and evolution of the lunar crust and character and diversity of mare basalt types. Craters and large basins are used as probes to the interior. Ongoing analyses identify and characterize potential resources in geologic context.
- Space weathering: Explore and understand processes responsible for altering materials in the space environment and measure the effects of these processes on geologic samples. Compositional applications for the Moon, asteroids, Mercury, Phobos/Deimos.
- Dawn Science Team. Science Co-Investigator to study the large asteroids Vesta and Ceres in detail. Principal responsibilities involved integration of remote measurements (multi-spectral imaging and spectroscopy) to understand surface composition in geologic context and infer implications for surface evolution. Dawn launched in 2007; arrived at Vesta in 2011 and remained a few years, and arrived at Ceres in 2015. The spacecraft ceased operation in November 2018.
- International collaboration: Promoting and assisting in planning international planetary exploration with colleagues from Europe, Japan, Russia, India, Korea, and Ukraine. Participate in integrated science and mission discussions with emphasis on the Moon.

Recent Mission Involvement:

Chandrayaan-1 (a mission to the Moon launched by the Indian Space Research Organization in October 2008): Pieters was Principal Investigator (PI) of a US guest instrument, the Moon Mineralogy Mapper (M³), selected by NASA’s Discovery Program after an intense peer-review process. She had overall responsibility for the success of this instrument and M³ Science Team activities. M³ was built by the Jet Propulsion Laboratory.

Dawn (a Discovery mission launched in 2007): Co-Investigator. Participation in planning the mission to study the large asteroids Vesta and Ceres in detail. Principal responsibilities involved oversight and integration of remote compositional measurements and development of links to meteorites and understanding of early solar system processes. Dawn evaluated Vesta from orbit for more than a year starting mid-2011 and later studied Ceres from orbit starting in 2015 and continued for almost 3 years.

Co-Investigator on several Discovery missions formulated and submitted to NASA in 2019.

Service to the Profession:

- Associate Editor, *Meteoritics and Planetary Sciences*, 1998-present
- Member (and Vice-Chair), NASA Advisory Council Science Committee 2013 – 2017
- Member, OSIRIS-Rex Standing Review Board 2013 – 2016
- Chair, AGU Fellows Committee 2013-2014
- Member, AGU Honors and Recognition committee 2010-2014
- Science Manager, NASA Reflectance Experiment Laboratory (RELAB) [1980-2014]
- Member, Planetary Protection Subcommittee [2002 to 2013, although the name varied]

- Chair, Awards Committee, AGU, Planetary Sciences Section (2006 to 2009)
- Chair, MoonLITE Science Evaluation Board, NASA-UK (2008)
- Co-Chair, National Academies, NRC Space Studies Board, Committee on Scientific Context for Exploration of the Moon (2006-2007)
- Member, AGU Fellows Committee [2001 to 2006]
- Member, Visiting Committee, MIT Department of Earth, Atmosphere, and Planetary Sciences [2000-2008]
- Chair, Solar System Exploration Survey, Inner Planets Panel, NAS/NRC [2001/2]

Honors and Awards

- Elected Fellow of American Astronomical Society, 2020
- Elected Fellow of Meteoritical Society, 2016
- Presented SSERVI Shoemaker Medal and Lecturer 2015
- Presented International Cooperation Medal, Committee on Space Research (COSPAR) 2014
- Elected Fellow of Geological Society of America, 2011
- Shoemaker Lecturer, American Geophysical Union, 2010 Fall Meeting
- Presented GSA G. K. Gilbert Award, 2010.
- Presented NASA Exceptional Scientific Achievement Medal 2010
- Elected Fellow of American Association for the Advancement of Science (2007)
- Elected member of International Academy of Astronautics (2006)
- Presented Gerard P. Kuiper Prize, American Astronomical Society, Division for Planetary Sciences, 2004
- Elected President, ILEWG (International Lunar Exploration Working Group) 2002-2004
- Elected Chair, American Association Advancement of Science, Astronomy Section 2002/3
- Elected Fellow, American Geophysical Union, 2001
- Elected President, Planetary Sciences Section, American Geophysical Union, 1998 - 2000

Carlé M. Pieters

Publications in peer-reviewed journals, articles, or books, **2012 to 2019**.
For full list of publications prior to 2012 as well as links to manuscripts:
http://www.planetary.brown.edu/html_pages/pieters_refpubs_date.htm

2019

- Pieters, C. M., R. L. Klima, and R. O. Green (2019), Compositional Analysis of the Moon from the Visible and Near-infrared, in *Remote Compositional Analysis: Techniques for Understanding Spectroscopy, Mineralogy, and Geochemistry of Planetary Surfaces*, edited by J. L. Bishop, J. E. Moersch and J. F. Bell III, in press, Cambridge University Press, Cambridge, UK.
- Pieters, C. M., R. M. Canup, D. A. Kring, J. W. Head III, and D. R. Scott (2018), Transformative lunar science, SSERVI White Paper, 1-8. <http://www.planetary.brown.edu/pdfs/5480.pdf>
- Prettyman, T. H., N. Yamashita, E. Ammannito, B. L. Ehlmann, H. Y. McSween Jr., D. W. Mittlefehldt, S. Marchi, N. Schörghofer, M. J. Toplis, J. Y. Li, C. M. Pieters, J. C. Castillo-Rogez, C. A. Raymond, and C. T. Russell (2019), Elemental composition and mineralogy of Vesta and Ceres: Distribution and origins of hydrogen-bearing species, *Icarus*, 318, 42-55, doi: 10.1016/j.icarus.2018.04.032.
- Raponi, A., F. G. Carrozzo, F. Zambon, M. C. De Sanctis, M. Ciarniello, A. Frigeri, E. Ammannito, F. Tosi, J.-P. Combe, A. Longobardo, E. Palomba, C. M. Pieters, C. A. Raymond, and C. T. Russell (2019), Mineralogical mapping of Coniraya quadrangle of the dwarf planet Ceres, *Icarus*, 318, 99-110, doi: 10.1016/j.icarus.2017.10.023.
- Shkuratov, Y., Y. A. Surkov, M. A. Ivanov, V. V. Korokhin, V. G. Kaydash, G. Videen, C. M. Pieters, and D. Stankevich (2019), Improved Chandrayaan-1 M3 data: A northwest portion of the Aristarchus plateau and contiguous maria, *Icarus*, 321, 34-94. Doi: 10.1016/j.icarus.2018.11.002.
- Tosi, F., F. G. Carrozzo, F. Zambon, M. Ciarniello, A. Frigeri, J.-P. Combe, M. C. De Sanctis, M. Hoffmann, A. Longobardo, A. Nathues, A. Raponi, G. S. Thangjam, E. Ammannito, K. Krohn, L. A. McFadden, E. Palomba, C. M. Pieters, K. Stephan, C. A. Raymond, C. T. Russell, and the Dawn Science Team (2019), Mineralogical analysis of the Ac-H-6 Haulani quadrangle of the dwarf planet Ceres, *Icarus*, 318, 170-187, doi: 10.1016/j.icarus.2017.08.012.

2018

- Krohn, K., R. Jaumann, K. A. Otto, F. Schulzeck, A. Neesemann, A. Nass, K. Stephan, F. Tosi, R. J. Wagner, F. Zambon, I. von der Gathen, D. A. Williams, D. L. Buczkowski, M. C. De Sanctis, E. Kersten, K.-D. Matz, S. C. Mest, C. M. Pieters, F. Preusker, T. Roatsch, J. E. C. Scully, C. T. Russell, and C. A. Raymond (2018), The unique geomorphology and structural geology of the Haulani crater of dwarf planet Ceres as revealed by geological

mapping of equatorial quadrangle Ac-6 Haulani, *Icarus*, 316, 84-98, doi: 10.1016/j.icarus.2017.09.014.

McSween Jr., H. Y., J. P. Emery, A. S. Rivkin, M. J. Toplis, J. C. Castillo-Rogez, T. H. Prettyman, M. C. De Sanctis, C. M. Pieters, C. A. Raymond, and C. T. Russell (2018), Carbonaceous chondrites as analogs for the composition and alteration of Ceres, *Meteoritics and Planetary Science*, 53, 1793-1804, doi: 10.1111/maps.12947.

Moriarty III, D. P., and C. M. Pieters (2018), The character of South Pole-Aitken Basin: Patterns of surface and sub-surface composition, *J. Geophys. Res.*, 123, 729-747, doi: 10.1002/2017JE005364.

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Wu, Y. Z., L. Li, X. Luo, Y. Lu, Y. Chen, C. M. Pieters, A. T. Basilevsky, and J. W. Head III (2018), Geology, tectonism and composition of the northwest Imbrium region, *Icarus*, 303, 67-90, doi: 10.1016/j.icarus.2017.12.029.

2017

Ciarniello, M., M. C. De Sanctis, E. Ammannito, A. Raponi, A. Longobardo, E. Palomba, F. G. Carrozzo, F. Tosi, J. Y. Li, S. E. Schröder, F. Zambon, A. Frigeri, S. Fonte, M. Giardino, C. M. Pieters, C. A. Raymond, and C. T. Russell (2017), Spectrophotometric properties of dwarf planet Ceres from the VIR spectrometer on board the Dawn mission, *Astronomy & Astrophysics*, 598, A130, 131-114, doi: 10.1051/0004-6361/201629490.

Dhingra, D., J. W. Head III, and C. M. Pieters (2017), Geological mapping of impact melt deposits at lunar complex craters Jackson and Tycho: Morphologic and topographic diversity and relation to the cratering process, *Icarus*, 283, 268-281, doi: 10.1016/j.icarus.2016.05.004.

Donaldson Hanna, K. L., B. T. Greenhagen, W. R. Patterson III, C. M. Pieters, J. F. Mustard, N. E. Bowles, D. A. Paige, T. D. Glotch, and C. Thompson (2017), Effects of varying environmental conditions on emissivity spectra of bulk lunar solis: Application to Diviner

thermal infrared observations of the Moon, *Icarus*, 283, 3326-3342, doi: 10.1016/j.icarus.2016.05.034.

- McSween Jr., H. Y., J. P. Emery, A. S. Rivkin, M. J. Toplis, J. C. Castillo-Rogez, T. H. Prettyman, M. C. De Sanctis, C. M. Pieters, C. A. Raymond, and C. T. Russell (2017), Carbonaceous chondrites as analogs for the composition and alteration of Ceres, *Meteoritics and Planetary Science*, doi: 10.1111/maps.12947.
- Schröder, S. E., S. Mottola, U. Carsenty, M. Ciarniello, R. Jaumann, J.-Y. Li, A. Longobardo, E. E. Palmer, C. M. Pieters, F. Preusker, C. A. Raymond, and C. T. Russell (2017), Resolved spectrophotometric properties of the Ceres surface from Dawn Framing Camera images, *Icarus*, 288, 201-225, doi: 10.1016/j.icarus.2017.01.026.
- Zambon, F., A. Raponi, F. Tosi, M. C. De Sanctis, L. A. McFadden, F. G. Carrozzo, A. Longobardo, M. Ciarniello, K. Krohn, K. Stephan, E. Palomba, C. M. Pieters, E. Ammannito, C. T. Russell, and C. A. Raymond (2017), Spectral analysis of Ahuna Mons from Dawn mission's visible-infrared spectrometer, *Geophysical Research Letters*, 44, 97-104, doi: 10.1002/2016GL071303.

2016

- De Sanctis, M. C., A. Raponi, E. Ammannito, M. Ciarniello, M. J. Toplis, H. Y. McSween Jr., J. C. Castillo-Rogez, B. L. Ehlmann, F. G. Carrozzo, S. Marchi, F. Tosi, F. Zambon, F. Capaccioni, M. T. Capria, S. Fonte, M. Formisano, A. Frigeri, M. Giardino, A. Longobardo, G. Magni, E. Palomba, L. McFadden, C. M. Pieters, R. Jaumann, P. Schenk, R. Mugnuolo, C. A. Raymond, and C. T. Russell (2016), Bright carbonate deposits as evidence of aqueous alteration on (1) Ceres, *Nature*, 536, 54-57, doi: 10.1038/nature18290.
- Moriarty III, D. P., and C. M. Pieters (2016), Complexities in pyroxene compositions derived from absorption band centers: Examples from Apollo samples, HED meteorites, synthetic pure pyroxenes, and remote sensing data, *Meteoritics & Planetary Science*, 51, 207-234, doi: 10.1111/maps.12588.
- Pieters, C. M. (2016), The inspiring 50++ years of lunar exploration, in *Space Research Institute in Times of Change: Glimpses of the Past and Visions of the Future*, Selected Papers from Space Science Forum: Yesterday, Today and Tomorrow, 30 September - 2 October 2015, Moscow, edited by L. M. Zelenyi, pp. 70-84, Space Research Institute of the Russian Academy of Sciences (IKI RAN), Moscow, Russia.
- Pieters, C. M., and S. K. Noble (2016), Space weathering on airless bodies, *J. Geophys. Res.*, 121, 1865-1884, doi: 10.1002/2016JE005128.
- Schwadron, N. A., J. K. Wilson, M. D. Looper, A. P. Jordan, H. E. Spence, J. B. Blake, A. W. Case, Y. Iwata, J. C. Kasper, W. M. Farrell, D. J. Lawrence, G. Livadiotis, J. Mazur, N. Petro, C. M. Pieters, M. S. Robinson, S. Smith, L. W. Townsend, and C. Zeitlin (2016),

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Taylor, L. A., C. M. Pieters, and D. Britt (2016), Evaluations of lunar regolith simulants, *Planetary and Space Science*, 126, 1-7, doi: 10.1016/j.pss.2016.04.005.

Williams, K., C. R. M. Jackson, L. Cheek, K. L. Donaldson Hanna, S. W. Parman, C. M. Pieters, M. D. Dyar, and T. C. Prissel (2016), Reflectance spectroscopy of chromium-bearing spinel with application to recent orbital data from the Moon, *American Mineralogist*, 101, 726-734, doi: 10.2138/am-2016-5535.

2015

Basilevsky, A. T., A. M. Abdrakhimov, J. W. Head III, C. M. Pieters, Y. Z. Wu, and L. Xiao (2015), Geologic characteristics of the Luna 17/Lunokhod 1 and Chang'E-3/Yutu landing sites, *Planetary and Space Science*, 117, 385-400, doi: 10.1016/j.pss.2015.08.006.

Blewett, D. T., B. W. Denevi, L. Le Corre, V. Reddy, S. E. Schröder, C. M. Pieters, F. Tosi, F. Zambon, M. C. De Sanctis, E. Ammannito, T. Roatsch, C. A. Raymond, and C. T. Russell (2015), Optical space weathering on Vesta: Radiative-transfer models and Dawn observations, *Icarus*, 265, 161-174, doi: 10.1016/j.icarus.2015.10.012.

De Sanctis, M. C., E. Ammannito, A. Raponi, S. Marchi, T. B. McCord, H. Y. McSween Jr., F. Capaccioni, M. T. Capria, F. G. Carrozzo, M. Ciarniello, A. Longobardo, F. Tosi, S. Fonte, M. Formisano, A. Frigeri, M. Giardino, G. Magni, E. Palomba, D. Turrini, F. Zambon, J. P. Combe, W. C. Feldman, R. Jauman, L. A. McFadden, C. M. Pieters, T. H. Prettyman, M. Toppis, C. A. Raymond, and C. T. Russell (2015), Ammoniated-phyllsilicates on dwarf planet Ceres with a likely outer solar system origin, *Nature*, 528, 241-244, doi: 10.1038/nature16172.

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McFadden, L. A., J.-P. Combe, E. Ammannito, A. Frigeri, K. Stephan, A. Longobardo, E. Palomba, F. Tosi, F. Zambon, K. Krohn, M. C. De Sanctis, V. Reddy, L. Le Corre, A. Nathues, C. M. Pieters, T. H. Prettyman, C. A. Raymond, and C. T. Russell (2015), Vesta's Pinaria region: Origin basaltic achondrite material derived from mixing upper and lower crust, *Icarus*, 2015, 150-161, doi: 10.1016/j.icarus.2015.07.003.

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Moriarty III, D. P., and C. M. Pieters (2015), The nature and origin of mafic mound in the South Pole-Aitken Basin, *Geophysical Research Letters*, 42, 7907-7915, doi: 10.1002/2015GL065718.

Nathues, A., M. Hoffman, M. Schaefer, L. Le Corre, V. Reddy, T. Platz, E. A. Cloutis, U. Christensen, T. Kneissl, J. Y. Li, K. Mengel, N. Schmedemann, T. Schaefer, C. T. Russell, D. M. Applin, D. L. Buczkowski, M. R. M. Izawa, H. U. Keller, D. P. O'Brien, C. M. Pieters, C. A. Raymond, J. Ripken, P. M. Schenk, B. E. Schmidt, H. Sierks, M. V. Sykes, G. S. Thangjam, and J. B. Vincent (2015), Sublimation in bright spots on (1) Ceres, *Nature*, 528, 237-240, doi: 10.1038/nature15754.

Tosi, F., A. Frigeri, J.-P. Combe, F. Zambon, M. C. De Sanctis, E. Ammannito, A. Longobardo, H. Hoffmann, A. Nathues, W. B. Garry, D. T. Blewett, C. M. Pieters, E. Palomba, K. Stephan, L. A. McFadden, H. Y. McSween Jr., C. T. Russell, C. A. Raymond, and the Dawn Science Team (2015), Mineralogical analysis of the Oppia quadrangle of asteroid (4) Vesta: Evidence for occurrence of moderate-reflectance hydrated minerals, *Icarus*, 259, 129-149, doi: 10.1016/j.icarus.2015.05.018.

2014

Buczkowski, D. L., D. Y. Wyrick, M. Toplis, R. A. Yingst, D. A. Williams, W. B. Garry, S. C. Mest, T. Kneissl, J. E. C. Scully, A. Nathues, M. C. De Sanctis, L. Le Corre, V. Reddy, M. Hoffman, E. Ammannito, A. Frigeri, F. Tosi, F. Preusker, T. Roatsch, C. A. Raymond, R. Jaumann, C. M. Pieters, and C. T. Russell (2014), The unique geomorphology and physical properties of the Vestalia Terra plateau, *Icarus*, 244, 89-103, doi: 10.1016/j.icarus.2014.03.035.

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Domingue, D. L., C. R. Chapman, R. M. Killen, T. H. Zurbuchen, J. A. Gilbert, M. Sarantos, M. Benna, J. A. Slavin, D. Schriver, P. M. Travnicek, T. M. Orlando, A. L. Sprague, D. T. Blewett, J. J. Gillis-Davis, W. C. Feldman, D. J. Lawrence, G. C. Ho, D. S. Ebel, L. R. Nittler, F. Vilas, C. M. Pieters, S. C. Solomon, C. L. Johnson, R. M. Winslow, J. Helbert, P. N. Peplowski, S. Z. Weider, N. Mouawad, N. R. Izenberg, and W. E. McClintock (2014), Mercury's weather-beaten surface: Understanding Mercury in the context of lunar and asteroidal space weathering studies, *Space Science Reviews*, 181, 121-214, doi: 10.1007/s11214-014-0039-5.

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- Jackson, C. R. M., L. C. Cheek, K. B. Williams, K. L. Donaldson Hanna, C. M. Pieters, S. W. Parman, R. F. Cooper, M. D. Dyar, M. Nelms, and M. R. Salvatore (2014), Visible-infrared spectral properties of iron-bearing aluminate spinel under lunar-like redox conditions, *American Mineralogist*, 99, 1821-1833, doi: 10.2138/am-2014-4793.
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- Pieters, C. M., S. L. Murchie, N. Thomas, and D. Britt (2014), Composition of surface material on the moons of Mars, *Planet. Space Sci.*, 102, 144-151, doi: 10.1016/j.pss.2014.02.008.
- Pieters, C. M., K. L. Donaldson Hanna, L. C. Cheek, D. Dhingra, T. C. Prissel, C. R. M. Jackson, D. P. Moriarty III, S. W. Parman, and L. A. Taylor (2014), The distribution of Mg-spinel across the Moon and constraints on crustal origin, *American Mineralogist*, 99, 1893-1910, doi: 10.2138/am-2014-4776.
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