

## THOMAS ROBERT WATTERS

### Address:

Center for Earth and Planetary Studies  
National Air and Space Museum  
Smithsonian Institution  
P. O. Box 37012, Washington, DC 20013-7012

### Education:

George Washington University, Ph.D., Geology (1981-1985).  
Bryn Mawr College, M.A., Geology (1977-1979).  
West Chester University, B.S. (*magna cum laude*), Earth Sciences (1973-1977).

### Experience:

Senior Scientist, Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution (1998-present).  
Chair, Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution (1989-1998; 2011-2015).  
Research Geologist, Center for Earth and Planetary Studies, Smithsonian Institution, Planetary Geology and Tectonics, Structural Geology, Tectonophysics (1981-1989).  
Research Assistant, Department of Terrestrial Magnetism, Carnegie Institution of Washington, Chemical Analysis and Fission Track Studies of Meteorites (1980-1981).  
Research Fellowship, American Museum of Natural History, Electron Microprobe and Petrographic Study of Aubrites and Related Meteorites (1978-1980).  
Teaching Assistant, Bryn Mawr College (1977-1979), Physical and Historical Geology, Crystallography and Optical Crystallography.  
Undergraduate Assistant, West Chester University (1973-1977), Teaching Assistant in General and Advanced Astronomy, Physical and Historical Geology.

### Honors:

William P. Phillips Memorial Scholarship (West Chester University); National Air and Space Museum Certificate of Award 1983, 1986, 1989, 1991, 1992, 2002, 2004; American Geophysical Union Editor's Citation for Excellence in Refereeing - Journal Geophysical Research-Planets, 1992; Smithsonian Exhibition Award - Earth Today: A Digital View of Our Dynamic Planet, 1999; Certificate of Appreciation, Geological Society of America, 2005, 2006; Elected to Fellowship in the Geological Society of America, 2007. The Johns Hopkins University Applied Physics Laboratory 2009 Publication Award - Outstanding Research Paper, "Return to Mercury: A Global Perspective on MESSENGER's First Mercury Flyby (S.C. Solomon lead author). Secretary's Research Prize for 2010, "Evolution of the Rembrandt Impact Basin on Mercury" (T.R. Watters lead author). Elected to Fellow in the American Association for the Advancement of Science, 2012. ESA Outstanding Contribution Certificate: Mars Express 2003-2013, 2013. NASA Group Achievement Award: LRO Science Mission Team, 2013, 2015. NASA Group Achievement Award: MESSENGER Project Team, 2017. Smithsonian Distinguished Scholar in the Sciences Award, 2019. NASA Planetary Science Division Award, Director Regional Planetary Image Facility Node, 2020.

### **Professional Activities:**

Developing the Lunar Geophysical Network (LGN) Mission, Co-Investigator, 2019-  
 Lunar Reconnaissance Orbiter Camera (LROC) Co-Investigator, 2012-.

Participating Scientist, Mars Advanced Radar for Subsurface and Ionospheric Sounding  
 (MARSIS), Mars Express Mission, 2003-.

Collaborator, Geophysical Exploration of the Dynamics and Evolution of the Solar System,  
 Solar System Exploration Research Virtual Institutes (SSERVI) program, NASA, 2021-.

Participating Scientist, Mercury Surface Environment, Geochemistry, and Ranging  
 (MESSENGER) Mission, 2007-2016.

Participating Scientist, Lunar Reconnaissance Orbiter (LRO) Mission, 2008-2012.

Director, Smithsonian Regional Planetary Image Facility, NASA, 2002-present.

Graduate Faculty, Department of Geology, University of Maryland, 2012-2015.

Review Panel Member, Planetary Cartography Working Group, NASA, 2007-2011.

Guest Editor (with P.J. McGovern), Crustal Dichotomy on Mars Special Section, *Geophysical  
 Research Letters*, 2005.

Convener (with P.J. McGovern), Workshop on Hemispheres Apart: The Origin and Modification  
 of the Martian Crustal Dichotomy, Lunar and Planetary Institute, 2004.

EPO Team Member, Mercury Surface Environment, Geochemistry, and Ranging  
 (MESSENGER) Mission, 1999-2007.

Chair and Officer, Planetary Geology Division, Geological Society of America, 2003-2007.

Member, Planetary Geology and Geophysics Management Operations Working Group, NASA,  
 2003-2004.

Group Chief, Planetary Geology and Geophysics Program Review Panel, NASA, 2003.

Review Panel Member, Planetary Geology and Geophysics Program, NASA, 2002.

Review Panel Member, Mars Odyssey Participating Scientist Program, NASA, 2001.

Scientific Organizing Committee Member, Mercury: Space Environment, Surface, and Interior,  
 2001.

Review Panel Member, Pluto-Kuiper Belt Mission Technical, Management, Cost and Other  
 Factors Evaluation, NASA, 2001.

Review Panel Member, Mars Global Surveyor Data Analysis Program, NASA, 2001.

American Geophysical Union Representative on the American Institute of Physics Award for  
 Science Writing Aimed at Children Committee, 1998-2001.

Editorial Board Member, the journal *GEOLOGY*, Geological Society of America, 1993-1999.

Review Panel Member, Processing of the Clementine imaging data sets, NASA, 1994.

Co-Convener, Mars: Evolution of Volcanism, Tectonics and Volatiles (MEVTV) Workshop on  
 “Tectonic Features on Mars”, 1989.

### **Museum Exhibit Activities:**

Curator, A New Moon Rises: New Views from the Lunar Reconnaissance Orbiter Camera, with  
 M.S. Robinson and E. Speyerer, 2016-2017.

Unit Updates, Exploring the Planets Gallery, 2008-.

Curator, *Earth Today*, 1998-2006.

Curator, HoloGlobe, National Museum of Natural History, 1996-1997.

Curator, Monitoring Amazonia from Space (mini-exhibit), with F. Engle, 1993.

A Piece of Mars, with S. Soter, Exploring the Planets Gallery, 1990.

Curator, Space Science 1986 (mini-exhibit), 1986.  
 Viking View of Mars, with T. Maxwell, Exploring the Planets Gallery, 1983.

### Journal Articles:

- Watters, T.R. and M. Prinz, Aubrites: Their Origin and Relationship to Enstatite Chondrites, *Proc. Lunar and Planet. Sci. Conf. 10th, Geochimica et Cosmochimica Acta, Suppl. 11*, v. 1, p. 1073-1093, 1979.
- Rajan, R.S., T.R. Watters, and B.K. Kothari, Variation of Fission Tracks on the surfaces of olivines from Murchison Carbonaceous Chondrite, *Carnegie Institution of Washington Annual Report 1979-1980*, p. 551-553, 1980.
- Watters, T.R. and T.A. Maxwell Cross-cutting relations and relative ages of ridges and faults in the Tharsis region of Mars, *Icarus*, v. 56, p. 278-298, 1983.
- Watters, T.R. and T.A. Maxwell, Orientation, relative age and extent of the Tharsis Plateau ridge system, *J. Geophys. Res.*, v. 91, p. 8113-8125, 1986.
- Watters, T.R., Wrinkle ridge assemblages on the terrestrial planets, *J. Geophys. Res.*, v. 93, p. 10236-10254, 1988.
- Watters, T.R. Periodically spaced anticlines of the Columbia Plateau, in *Geological Soc. Am. Sp. Paper No. 239: Volcanism and Tectonism in the Columbia River Flood-Basalt Province*, S.P. Reidel and P.R. Hooper eds., p. 283-292, 1989.
- Watters, T.R., The origin of periodically spaced wrinkle ridges on the Tharsis Plateau of Mars, *J. Geophys. Res. (Planets)*, v. 96, p. 15,599-15,616, 1991.
- Watters, T.R., A system of tectonic features common Earth, Mars and Venus, *Geology*, v. 20, (with cover), p. 609-612, 1992.
- Watters, T.R., Compressional tectonism on Mars, *J. Geophys. Res. (Planets)*, 98, p. 17,049-17,060, 1993.
- Watters, T.R., and D.M. Janes, Coronae on Venus and Mars: Implications for similar structures on Earth, *Geology*, v. 23, (with cover) p. 200-204, 1995.
- Schultz, R.A., and T.R. Watters Elastic buckling of fractured basalts on the Columbia Plateau, Washington State, *35th U.S. Symposium on Rock Mechanics*, p. 885-860, 1995.
- Watters, T.R., and M.S. Robinson, Radar and Photoclinometric Studies of Wrinkle Ridges on Mars, *J. Geophys. Res.*, v. 102, p. 10,889-10,903, 1997.
- Watters, T.R., M.S. Robinson, and A.C. Cook, Topography of lobate scarps on Mercury: New constraints on the planet's contraction, *Geology*, v. 26, p. 991-994, 1998.
- Watters, T.R., and M.S. Robinson, Lobate Scarps and the martian crustal dichotomy, *J. Geophys. Res. (Planets)*, 104, 18981-18990, 1999.
- Cook, A.C., T.R. Watters, M.S. Robinson, P.D., Spudis, and D.B.J. Bussey, Lunar polar topography derived from Clementine stereoimages, *J. Geophys. Res. (Planets)*, 105, 12023-12033, 2000.
- Watters, T.R., R.A. Schultz, and M.S. Robinson, Displacement-length relations of thrust faults associated with lobate scarps on Mercury and Mars: Comparison with terrestrial faults, *Geophys. Res. Lett.*, 27, 3659-3662, 2000.
- Watters, T.R., and A.S. Konopliv, The topography and gravity of Mare Serenitatis: Implications for subsidence of the mare surface, *Planet. Space Sci.*, 49, 743-748, 2001.
- Watters, T.R., M.S. Robinson, and A.C. Cook, Large-scale lobate scarps in the southern hemisphere of Mercury, *Mercury Special Issue - Planet. Space Sci.*, 49 (14-15), 1523-1530, 2001.

- Schultz, R.A., and T.R. Watters, Forward mechanical modeling of the Amenthes Rupes thrust fault on Mars, *Geophys. Res. Lett.*, 28, 4659-4662, 2001.
- Watters, T.R., R.A. Schultz, M.S. Robinson, and A.C. Cook, The mechanical and thermal structure of Mercury's early crust, *Geophys. Res. Lett.*, 29, (with cover) 4659-4462, 2002.
- Watters, T.R., Lithospheric flexure and the origin of the dichotomy boundary on Mars, *Geology*, 31, 271-274, 2003.
- Watters, T.R., Thrust faulting along the dichotomy boundary in the eastern hemisphere of Mars, *J. Geophys. Res. (Planets)*, 108, 5055, 10.1029/2002JE001934, 2003.
- Watters, T.R., M.S. Robinson, C.R. Bina, and P.D. Spudis, Thrust faults and the global contraction Mercury, *Geophys. Res. Lett.*, 31, (with cover) L04701, 10.1029/2003GL019171, 2004.
- Nimmo, F. and T.R. Watters, Depth of faulting on Mercury: Implications for heat flux and crustal and effective elastic thickness, *Geophys. Res. Lett.*, 31, L02701, doi: 10.1029/2003GL018847, 2004.
- Watters, T.R., Elastic dislocation modeling of wrinkle ridges on Mars, *Icarus*, 171, 284-294, 2004.
- Irwin, R.P., T.R. Watters, A.D. Howard, and J.R. Zimbelman, Sedimentary resurfacing and fretted terrain development along the crustal dichotomy boundary, Aeolis Mensae, Mars, *J. Geophys. Res. (Planets)*, 109, E09011, doi:10.1029/2004JE002248, 2004.
- Watters, T.R., F. Nimmo, and M.S. Robinson, Extensional troughs in the Caloris Basin of Mercury: Evidence of lateral crustal flow, *Geology*, 33, 669-672, 2005.
- André, S.L., T.R. Watters, and M.S. Robinson, The long wavelength topography of Beethoven and Tolstoj basins, Mercury, *Geophys. Res. Lett.*, 32, L21202, doi:10.1029/2005GL023627, 2005.
- Picardi, G., J.J. Plaut, O. Bombaci, D. Calabrese, M. Cartacci, A. Cicchetti, S.M. Clifford, P. Edenhofer, W.M. Farrell, C. Federico, A. Frigeri, D.A. Gurnett, T. Hagfors, E. Heggy, A. Herique, R.L. Huff, A.B. Ivanov, W.T.K. Johnson, R.L. Jordan, D.L. Kirchner, W. Kofman, C.J. Leuschen, E. Nielsen, R. Orosei, E. Pettinelli, R.J. Phillips, D. Plettemeier, A. Safaeinili, R. Seu, E.R. Stofan, G. Vannaroni, T.R. Watters, E. Zampolini, The First Radar Soundings of the Subsurface of Mars, *Science*, 310, 1925-1928, 2005.
- Watters, T.R., and P.J. McGovern, Lithospheric flexure and the evolution of the dichotomy boundary on Mars, *Geophys. Res. Lett.*, 33, L08S05, doi:10.1029/2005GL024325, 2006.
- Watters, T.R., and P.J. McGovern, Introduction to special section: The Hemispheric Dichotomy on Mars, *Geophys. Res. Lett.*, 33, L08S01, doi:10.1029/2006GL025755, 2006.
- Watters, T.R., C.J. Leuschen, J.J. Plaut, G. Picardi, A. Safaeinili, S.M. Clifford, W.M. Farrell, A.B. Ivanov, R.J. Phillips, and E.R. Stofan, MARSIS radar sounder evidence of buried basins in the northern lowlands of Mars, *Nature*, 444, doi:10.1038/nature05356, 2006.
- Plaut, J.J., G. Picardi, A. Safaeinili, A.B. Ivanov, S.M. Milkovich, A. Cicchetti, W. Koofman, J. Mouginot, W.M. Farrell, R.J. Phillips, S.M. Clifford, A. Frigeri, R. Orosei, C. Federico, I.P. Williams, D.A. Gurnett, E. Nielsen, T. Hagfors, E. Heggy, E.R. Stofan, D. Plettemeier, T.R. Watters, C.J. Leuschen, and P. Edenhofer, Subsurface Radar Sounding of the South Polar Layered Deposits of Mars, *Science*, 316, doi:10.1126/science.1139672, 2007.
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- Taylor, T.R. Watters, and B. Williams, The Mercury Dual Imaging System (MDIS) on the MESSENGER spacecraft, *Space Sci. Rev.*, *131*, 247-338, 2007.
- Head, J.W., C.R. Chapman, D.L. Domingue, S. E. Hawkins, W. E. McClintock, S.L. Murchie, L.M. Prockter, M.S. Robinson, R.G. Strom, T.R. Watters, The geology of Mercury: The view prior to the MESSENGER mission, *Space Sci. Rev.*, *131*, 41-84, 2007.
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- Watters, T.R., B.A. Campbell, L. Carter, C.J. Leuschen, J.J. Plaut, G. Picardi, R. Orosei, A. Safaeinili, S.M. Clifford, W.M. Farrell, A.B. Ivanov, R.J. Phillips, and E.R. Stofan, MARSIS radar sounding of the Medusae Fossae Formation: A unique deposit on Mars, *Science*, *318*, 1125-1128, 2007.
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- Head, J.W., S.L. Murchie, L.M. Prockter, M.S. Robinson, S.C. Solomon, R.G. Strom, C.R. Chapman, T.R. Watters, W.E. McClintock, D.T. Blewett, J.J. Gillis-Davis, Volcanism on Mercury: Evidence from the First MESSENGER Flyby, *Science*, *321*, 69-72, 2008.
- Murchie, S.L., T.R. Watters, M.S. Robinson, J.W. Head, R.G. Strom, C.R. Chapman, S.C. Solomon, W.E. McClintock, L.M. Prockter, D.L. Domingue, D.T. Blewett, Geology of the Caloris Basin, Mercury: A New View from MESSENGER, *Science*, *321*, 73-76, 2008.
- Robinson, M.A., S.L. Murchie, D.T. Blewett, D.L. Domingue, S.E. Hawkins, J.W. Head, G.M. Holsclaw, W.E. McClintock, T.J. McCoy, R.L. McNutt, L.M. Prockter, S.C. Solomon, T.R. Watters, Reflectance and Color Variations on Mercury: Indicators of Regolith Processes and Compositional Heterogeneity, *Science*, *321*, 66-69, 2008.
- Solomon, S.C., R. L. McNutt, T.R. Watters, D.J. Lawrence, W.C. Feldman, J.W. Head, S.M. Krimigis, S.L. Murchie, R.J. Phillips, J.A. Slavin, M.T. Zuber, Return to Mercury: A Global Perspective on MESSENGER's First Mercury Flyby, *Science*, *321*, 59-62, 2008.
- André, S.L., T.C. André, T.R. Watters and M.S. Robinson, Application of an adaptive least squares correlation algorithm for stereo matching planetary science images, *J. Geophys. Res. (Planets)*, *113*, E11006, doi:10.1029/2008JE003080, 2008.
- Watters, T.R., J.W. Head, S.C. Solomon, M.S. Robinson, C.R. Chapman, B.W. Denevi, C.I. Fassett, S.L. Murchie, R.G. Strom, Evolution of the Rembrandt Impact Basin on Mercury, *Science*, *324*, (with cover) 618-621, 2009.
- Denevi, B.W., M.S. Robinson, S.C. Solomon, S.L. Murchie, D.T. Blewett, D.L. Domingue, T.J. McCoy, E.M. Ernst, J.W. Head, T.R. Watters, N.L. Chabot, The evolution of Mercury's crust: a global perspective from MESSENGER, *Science*, *324*, 613-618, 2009.
- Watters, T.R., S.C. Solomon, M.S. Robinson, J.W. Head, S.L. André, S.A. Hauck and S.L. Murchie, The Tectonics of Mercury: The View after MESSENGER's First Flyby, *Earth. Planet. Sci. Lett.*, *285*, 283-296, 2009.
- Watters, T.R., S.L. Murchie, M.S. Robinson, S.C. Solomon, B.W. Denevi, S.L. André, J.W. Head, Emplacement and tectonic deformation of smooth plains in the Caloris basin, Mercury, *Earth Planet. Sci. Lett.*, *285*, 309-319, 2009.

- Freed, A.M., S.C. Solomon, T.R. Watters, R.J. Phillips, M.T. Zuber, Could Pantheon Fossae be the result of the Apollodorus crater-forming impact within the Caloris basin, Mercury? *Earth Planet. Sci. Lett.*, 285, 320–327, 2009.
- Fassett, C.I., J.W. Head, D.T. Blewett, C.R. Chapman, J.L. Dickson, S.L. Murchie, S.C. Solomon, T.R. Watters, Caloris Impact Basin: Exterior Geomorphology, Stratigraphy, Morphometry, Radial Sculpture, and Smooth Plains Deposits, *Earth Planet. Sci. Lett.*, 285, 297–308, 2009.
- Head, J.W., S.L. Murchie, L.M. Prockter, S.C. Solomon, R.G. Strom, C.R. Chapman, T.R. Watters, D.T. Blewett, J.J. Gillis-Davis, C.I. Fassett, J.L. Dickson, D.M. Hurwitz, L.R. Ostrach, Evidence for intrusive activity on Mercury from the first MESSENGER flyby, *Earth Planet. Sci. Lett.*, 285, 251–262, 2009.
- Head, J.W. S.L. Murchie, L.M. Prockter, S.C. Solomon, C.R. Chapman, R.G. Strom, T.R. Watters, D.T. Blewett, J.J. Gillis-Davis, C.I. Fassett, J.L. Dickson, G.A. Morgan, L. Kerber, Volcanism on Mercury: Evidence from the first MESSENGER flyby for extrusive and explosive activity and the volcanic origin of plains, *Earth Planet. Sci. Lett.*, 285, 227–242, 2009.
- Carter L.M., B.A. Campbell, T.R. Watters, R.J. Phillips, N.E. Putzig, A. Safaeinili, J.J. Plaut, C.H. Okubo, A.F. Egan, R. Seu, D. Biccari, R. Orosei, Shallow radar (SHARAD) sounding observations of the Medusae Fossae Formation, Mars, *Icarus*, 199, 295–302, 2009.
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- Zuber, M.T., L.G.J. Montési, G.T. Farmer, S.A. Hauck II, J.A. Ritzer, R.J. Phillips, S.C. Solomon, D.E. Smith, M.J. Talpe, J.W. Head III, G.A. Neumann, T.R. Watters, C.L. Johnson, Accommodation of lithospheric shortening on Mercury from altimetric profiles of ridges and lobate scarps measured during MESSENGER flybys 1 and 2, *Icarus*, 209, 247–255, 2010.
- Oberst, J., F. Preusker, R.J. Phillips, T.R. Watters, J.W. Head, M.T. Zuber, S.C. Solomon, The morphology of Mercury's Caloris basin as seen in MESSENGER stereo topographic models, *Icarus*, 209, 230–238, 2010.
- Schultz, R.A., E. Hauber, S.A. Katternhorn, C.H. Okubo, T.R. Watters, Interpretation and analysis of planetary structures, *J. Struct. Geol.*, 32, 855–875, 2010.
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- Watters, T.R., M.S. Robinson, R.A. Beyer, M.E. Banks, J.F. Bell, M.E. Pritchard, H. Hiesinger, C. van der Bogert, P.C. Thomas, E.P. Turtle, N.R. Williams, New evidence of recent thrust faulting on the Moon revealed by the Lunar Reconnaissance Orbiter Camera, *Science*, 329, 936–940, 2010.
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- Klimczak, C., T. R. Watters, C. M. Ernst, A. M. Freed, P. K. Byrne, S. C. Solomon, D. M. Blair, and J. W. Head, Deformation associated with ghost craters and basins in volcanic smooth plains on Mercury: Strain analysis and implications for plains evolution, *J. Geophys. Res.*, 117, doi:10.1029/2012JE004100, 2012.
- Watters, T.R., S.C. Solomon, C. Klimczak, A.M. Freed, J.W. Head, Carolyn M. Ernst, D.M. Blair, T.A. Goudge, P.K. Byrne, Extension and Contraction within Volcanically Buried Impact Craters and Basins on Mercury, *Geology*, 40, (with cover) 1123–1126, 2012.
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- Williams, N.R., T.R. Watters, M.E. Pritchard, M.E. Banks, J.F. Bell III, T. Tran, Fault Dislocation Modeled Structure of Lobate Scarps from Lunar Reconnaissance Orbiter Camera Digital Terrain Models, *J. Geophys. Res.*, doi: 10.1002/jgre.20051, 2013.
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Principal Investigator, Lunar Reconnaissance Orbiter Camera Co-Investigator, ASU/NASA LRO-LROC, 2008-2020.

Principal Investigator, Mercury Surface Environment, Geochemistry, and Ranging (MESSENGER) Mission, Participating Scientist Program, NASA, 2007-2020.

Principal Investigator, Smithsonian Regional Planetary Image Facility, Planetary Geology and Geophysics Program, NASA, 2013-2020.

Co-Investigator, Developing the Lunar Geophysical Network (LGN) Mission, NASA, 2019-2020.

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