CURRICULUM VITAE

ROMY D. HANNA

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RESEARCH STATEMENT

My research is driven by the desire to understand how the dust and gas surrounding the early proto-Sun evolved to form the solid objects we see in our Solar System today. I focus on primitive, undifferentiated material found in carbonaceous chondrites and on small bodies (asteroids, comets). I study this material both in the lab (electron microbeam techniques, X-ray computed tomography (XCT)) and remotely using spacecraft (visible to near infrared (VISNIR) and thermal infrared (TIR) spectroscopy). I am particularly interested in applying cutting-edge XCT techniques to study planetary materials and am the PI of the NASA Planetary Science Enabling Facilities (PSEF) award to UTCT to enable and support NASA planetary scientists who use our facility. I am also involved in efforts to develop XCT for use on landed and sample return missions, including for the Moon.

EDUCATION

2016 **Ph.D., Geosciences, University of Texas at Austin, TX.**
Advisor: Dr. Richard Ketcham
Dissertation*: CM Murchison: Nebular Formation of Fine-grained Chondrule Rims Followed by Impact Processing on the CM Parent Body*

2006 **M.S., Geology and Geophysics, University of Hawaii,** Honolulu, HI.
Advisor: Dr. Victoria Hamilton
Thesis: *Evidence for Locally-derived, Ultramafic Intracrater Materials in Amazonis Planitia, Mars*

1999 **B.S., Geophysics, with High Honors, University of Texas at Austin**, TX.
Advisor: Dr. William Carlson
Honors Thesis: *3-D Textural analysis of a garnet-amphibole rock from the Franciscan Complex of California: Nucleation and growth mechanism of porphyroblastic crystals using high-resolution X-ray computed tomography*

PROFESSIONAL EXPERIENCE

2024 – Pres. Research Scientist, University of Texas at Austin (UT Austin)
2016 – 2024 Research Associate, UT Austin
2013 – 2016 NASA Earth and Space Science Graduate Fellow, UT Austin
2009 – 2016 Research Engineering/Scientist Associate IV, UT Austin
2006 – 2009 Senior Visualization Specialist, Texas Advanced Computing Center, UT Austin
2003 – 2006 Graduate Research Assistant, University of Hawaii, Honolulu

2002 – 2003 Geophysical Software Developer, Landmark Graphics, Houston
2000 – 2002 Software Engineer, National Instruments, Austin

SCIENCE AND MISSION TEAMS

OSIRIS-REx Asteroid Sample Return Mission, Participating Scientist

Apollo Next Generation Sample Analysis (ANGSA), Science Team Member

Thermal Emission Imaging System (THEMIS) on Mars Odyssey, Graduate Student and Science Team Member

PROFESSIONAL SERVICE AND MEMBERSHIP

2023 – 2025 ***Chair,*** Meteoritical Society Membership Committee

2023 – Pres. *Member, Center for Planetary Systems Habitability Executive Committee*

2023 – Pres. *Member, NASA Antarctic Meteorite Allocation Panel*

2023 – Pres. *Member, NASA Working Group on Astromaterials Data Management and Archiving*

2022 – 2025 *Member, Non-Clinical Tomography Users Research Network (NoCTURN) Basic and Applied Research Working Group*

2022 *Member, Scientific Program Committee,* 84th Meteoritical Society Meeting Glasgow, UK

2021 – 2024 *Member, Meteorite Subcommittee of Extraterrestrial Materials Analysis Group (ExMAG)*

2021 *Member, Travel Award Committee*, 83rd Meteoritical Society Meeting Chicago, IL

2019 – 2022 ***Chair,*** Meteoritical Society McKay Award Committee

2019 – 2025 ***Secretary***, Tomography for Scientific Advancement (ToScA), North America

2015 – Pres. *Reviewer, Journals*: *Science, Nature Astronomy, Icarus, Meteoritics and Planetary Science, Earth and Planetary Science Letters, Geology, Computers & Geosciences, Physics & Chemistry of Minerals, Journal of Geophysical Research – Planets*

2017 – Pres. *Review Panel Member and/or External Reviewer* for NASA ROSES (Group Chief in 2023, 2024)

2023 – Pres. *Reviewer*, NASA Postdoctoral Program (NPP)

2014 – Pres. *Judge*, Lunar and Planetary Science Conference Dwornik Award (Annual Meeting Award for Best Student Oral and Poster Presentations)

2017 – Pres. *Judge*, Meteoritical Society Gordon A. McKay Award (Annual Meeting Award for Best Student Oral Presentation)

AWARDS AND HONORS

2025 Asteroid named 41003 Romy in honor of work on OSIRIS-REx mission

2015 Pellas-Ryder Award for Best Student Paper in Planetary Sciences

2015 Vargas Endowed Presidential Scholarship, Jackson School of Geosciences

2014 Gordon A. McKay Award for best student oral presentation at 77th Annual Meteoritical Society Meeting

2013 NASA Earth and Space Science Fellowship (NESSF)

2013 Marshall Endowed Presidential Scholarship, Jackson School of Geosciences

2011 Jackson School of Geosciences First Year Graduate Fellowship

2004 National Science Foundation Graduate Fellowship Program Honorable Mention

1998 University of Texas College Scholar

1997 MSA American Mineralogist Undergraduate Award

1996 University of Texas Natural Sciences Endowed Presidential Scholarship

TEACHING, MENTORSHIP, AND OUTREACH ACTIVITIES

2011 – Pres. *Lead Instructor and Organizer,* Fundamentals of 3D Quantitative Analysis of Geological Materials using CT, short course held at University of Texas High-Resolution X-ray Computed Tomography Facility (UTCT). Annual summer course.

2021 – 2024 *Champion of Diversity (CD) Participant & Mentor*, Jackson School of Geosciences, Program funded by NSF GOLD-EN EAGER award to PI Ginny Catania (UT Austin)

2023 *Guest Lecturer*, "XCT in Planetary Sciences" for '3D Analysis of Volumetric Data', UT GEO 393D, Instructor Rich Ketcham

2023 *Guest Lecturer,* "XCT in Planetary Sciences" for 'Laboratory Analysis of Earth and Planetary Materials' at Purdue University, Instructor Michelle Thompson

2019 – 2022 *Guest Lecturer,* "The OSIRIS-REx Mission, Bennu, and Spectral Results" for 'Introduction to Remote Sensing for Geoscientists', UT GEO 455S/485S, Instructor Tim Goudge

2016 – Pres. *Tour Lead,* UTCT Facility, various groups of students (high school age through graduate student level)

STUDENT ADVISING

2024 – 2025 Paul Redman, Master of Geological Sciences, Graduated August 2025. Thesis Title: *XCT, SEM, And LA-ICP-MS Map Investigation of Chondrule FGRs in CM2 Aquas Zarcas.*

2022 – 2023 Jordan Jee, Undergraduate Research Project funded under NSF CD program. Work presented at the Tomography for Scientific Advancement North America Meeting, Austin, TX, May 2023. Title: *Deep Learning Segmentation of Chondrules Using Dragonfly*

2019 – 2022 Bailey Glenewinkel, Undergraduate Research Project. Work presented at 84th Annual Meeting of the Meteoritical Society, Glasgow, UK, August 2022. Title: *Investigation of Fabric in CO Chondrite MIL 05024 using XCT and EBSD*

2016 – 2017 Megan Hoffman, Undergraduate Honors Research Project (UT Astronomy Dept.)

PhD COMMITTEE MEMBERSHIP

2025 *(Examinatrice)* Léna Jossé, Université Paris-Saclay, Advisor Rosario Brunetto, Graduation December 2025. Dissertation Title: 3D Detection of Mineral

Assemblages in a Ryugu Asteroid Sample Using SR-µXCT: A Multi-Analytical Study of Their Formation and Evolution

2023 – 2024 *(committee member)* Zoe Wilbur, University of Arizona, Advisor Jessica Barnes, Graduation December 2024. Dissertation Title: *New Insights into Lunar Basaltic Magmatism: A Study Of Volatiles, Vesicles, and Volcanics*

2023 Trygve Prestgard, Université Grenoble Alpes, Institut de Planétologie et d'Astrophysique de Grenoble, Advisors (Joint) Pierre Beck and Lydia Bonal. Expected graduation December 2023. Dissertation Title: *The Parent Bodies of Carbonaceous Chondrites and their Secondary History*

TECHNICAL SKILLS AND KNOWLEDGE

Remote sensing data analysis: visible to near-infrared (VIS-NIR) spectroscopy, thermal infrared (TIR) spectroscopy, multi-band thermal and visible imagery

Analytical instruments: scanning electron microscope (SEM), electron backscatter diffraction (EBSD), electron probe microanalysis (EPMA), x-ray computed topography (XCT), Fourier transform infrared spectroscopy (FTIR)

Programming/scripting: C/C++, Fortran, IDL, Python, LabVIEW, shells/scripting

Software/libraries: : IDL/ENVI, Matlab, JMars, JAsteroid, SBMT, ImageJ, Dragonfly, Avizo, ISIS, GDAL, VTK, MTEX

SYNERGISTIC ACTIVITIES

Development of numerous, freely available X-ray computed tomography (XCT)-related software tools to process and analyze XCT data https://www.ctlab.geo.utexas.edu/software/

Development of XCT movie of Apollo 17 tube 73002 for NASA Press Release (2019)

INVITED PRESENTATIONS AND SYMPOSIA

2023 3D Submicron Porosity in Meteorites: A Noble (Gas) Pursuit or a Fool's Errand? ***Invited Keynote Speaker*** Tomography for Scientific Advancement North America Meeting, Austin, TX.

2023 High Porosity Fine-grained Rims in CM Murchison via XCT Imaging with Xe gas, ASU Buseck Center for Meteorite Studies Virtual Seminar

2017 Nebular Formation and Parent Body Modification of Chondrule and Their Rims: Center for Astrophysics, Space Physics, and Engineering Research (Baylor University, TX) Colloquia

2016 Joint US-Japan workshop for Science in Japan Forum 2016 "US-Japan Collaboration in Space Sciences", hosted by Japan Society for the Promotion of Science, Cosmos Club, Washington D.C.

2015 Impact-induced Brittle Deformation, Porosity Loss, and Aqueous Alteration in CM Murchison: Implications for OSIRIS-REx, Southwest Research Institute (SwRI), Boulder, CO Colloquia

PEER-REVIEWED PUBLICATIONS

33. **Hanna R.D.,** Ketcham R.A., Edey D.R., Avice G., Miller K., Whittington A. ***(in review at the Planetary Science Journal)*** Impact-generated porosity gradients controlled fluid flow and aqueous alteration on the CM parent body

32. Ryan AJ, Ballouz RL, Macke RJ, Ishizaki T, Alasi A, Biele J,Eckley SA, Hoover CG, Jardine KJ, King AJ, Opeil CP, Pajola M, Tusberti F, Barnes JJ, Bates HC, Berger EL, Bierhaus EB, Calva C, Cambioni S, Cheng F, Delbo M, DellaGiustina DN, Dworkin JP, Elder CM, Emery JP, Freemantle J, Fujita R, Glavin DP, Gonzalez C, Haenecour P, Hamilton VE, **Hanna R** + 24 coauthors ***(in press at Nature Communications)*** Low Thermal Inertia of Carbonaceous Asteroid Bennu Driven By Cracks Observed in Returned Samples*,*

31. Eckley S., Zeigler R., Ketcham R., Edey D., **Hanna R**. Gross J., O'Neal E., McCubbin F., Shearer C. and the ANGSA Science team (2025) Utilization of X-Ray Computed Tomography During the Preliminary Examination of Unopened Apollo Drive Tube Samples 73001 and 73002 *Journal of Geophysical Research: Planets 130, 8, e2024JE008583. https://doi.org/10.1029/2024JE008583*

30. Neuman M., Jolliff B., Wang K., Petro N. + 34 coauthors + **Hanna R.**, Edey D.R., and the ANGSA Science team (2025) Revealing the Moon's Taurus‐Littrow Landslide via Integrated Analysis of Pristine Apollo 17 Soil Core 73001/2, *Journal of Geophysical Research: Planets* 130, 4, e2024JE008556. https://doi.org/10.1029/2024JE008556

29. Gross J., Zeigler R., Mosie A., Krysher C., Eckley S., Ketcham R., **Hanna R**. + 12 coauthors (2025) Apollo Next Generation Sample Analyses (ANGSA) samples: Preliminary Examination of Double Drive Tube Samples 73001 and 73002 and Lessons Learned for Returning to the Moon with Artemis*, Journal of Geophysical Research: Planets* 130, 1, e2024JE008585. https://doi.org/10.1029/2024JE008585

28. **Hanna R. D.,** Hamilton V. E., Haberle C. H., Kaplan H. H., Lantz C., Christensen P. R., Simon A. A. and Reuter D. C. (2024) Phyllosilicate decomposition on Bennu due to prolonged surface exposure. *Icarus* 408, 115809. https://doi.org/10.1016/j.icarus.2023.115809

27. Carballido A., Matthews, L., **Hanna, R.D.,** Hyde, T. (2023) Mechanical modification of chondrule fine-grained rims by dusty nebular shocks. *Planetary Science Journal* **4,** 113. https://iopscience.iop.org/article/10.3847/PSJ/acd758

26. Pressley L. A., Edey D., **Hanna R**., Chae S., Heron J. T., Khan M.A. and McQueen T. M. (2022) Informing quantum materials discovery and synthesis using X-ray micro-computed tomography. *NPJ Quantum Materials* 7, 121. https://doi.org/10.1038/s41535-022-00527-6

25. Kerrouch, I., Y. Kebukawa, A. Biscoff, M. Zolensky, E. Wolfer, J. Hellman, M. Ito, A. King, M. Trieloff, J. Barrat, P. Schmitt-Kopplin, A. Pack, M. Patzek, **R. D. Hanna**, T. Fockenberg, Y. Marrocchi, M. Fries, J. Mathurin, E. Dartois, J. Duprat, C. Engrand, A. Deniset, A. Dazzi, K. Kiryu, M. Igisu, T. Shibuya, D. Wakabayashi, S. Yamashita, Y. Takeichi, Y. Takahashi, T. Ohigashi, Y. Kodama and M. Kondo (2022) Heterogeneous nature of the carbonaceous chondrite breccia Aguas Zarcas - Cosmochemical characterization and origin of new carbonaceous chondrite lithologies, *Geochimica et Cosmochimica Acta,* 334 155-186*.* https://doi.org/10.1016/j.gca.2022.07.010

24. Kramer-Ruggiu L., B. Devouard, J. Gattacceca, L. Bonal, H. Leroux, J. Eschrig, D. Borschneck, A. J. King, P. Beck, Y. Marrocchi, V. Debaille, **R. D. Hanna**, O. Grauby (2022) Detection of

Incipient Aqueous Alteration in Carbonaceous Chondrites, *Geochimica et Cosmochimica Acta,* 336, 308-331. https://doi.org/10.1016/j.gca.2022.09.020

23. Yang X., **Hanna R. D.**, Davis A. M., Neander A. I. and Heck P. R. (2022) A record of post-accretion asteroid surface mixing preserved in the Aguas Zarcas meteorite. Nature Astronomy, 6, 1051-1058. https://doi.org/10.1038/s41550-022-01746-4
22. **Hanna R. D**., Ketcham R. A., Edey D.R. and O'Connell J. (2022) 3D porosity structure of the earliest solar system material. *Scientific Reports* 12, 8369. https://doi.org/10.1038/s41598-022-11976-1
21. Gawronska A. J., McLeod C. L., Blumenfeld E. H., **Hanna R. D.** and Zeigler R. A. (2022) New interpretations of lunar mare basalt flow emplacement from XCT analysis of Apollo samples. *Icarus* 388, 115216. https://doi.org/10.1016/j.icarus.2022.115216
20. Rowe T. B., Stafford T. W., Fisher D. C., Enghild J. J., Quigg J. M., Ketcham R. A., Sagebiel J. C., Hanna R. and Colbert M. W. (2022) Human Occupation of the North American Colorado Plateau ~37,000 Years Ago. *Frontiers in Ecology and Evolution* 10. https://doi.orig/10.3389/fevo.2022.903795
19. Kerraouch, I., Bischoff, A., Zolensky, M.E., Pack, A., Patzek, M., **Hanna, R.D.**, Fries, M.D., Harries, D., Kebukawa Y., Le, L., Ito, M., Rahman, Z. (2021) The polymict carbonaceous breccia Aquas Zarcas: A potential analogue to samples being returned by the OSIRIS-REx and Hayabusa2 missions, *Meteoritics & Planetary Science*, https://doi.org/10.1111/maps.13620
18. Hamilton, V.E., P.R. Christensen, H.H. Kaplan, C.W. Haberle, A.D. Rogers, T.D. Glotch, L.B. Breitenfeld, C.A. Goodrich, D.L. Schrader, T.J. McCoy, C. Lantz, **R.D. Hanna,** A.A. Simon, J.R. Brucato, B.E. Clark, and D.S. Lauretta (2021) Evidence for limited compositional and particle size variation on asteroid (101955) Bennu from thermal infrared spectroscopy, *Astronomy & Astrophysics*, https://doi.org/10.1051/0004-6361/202039728
17. B. Rozitis, A. J. Ryan, J. P. Emery, P. R. Christensen, V. E. Hamilton, A. A. Simon, D. C. Reuter, M. Al Asad, R.-L. Ballouz, J. Bandfield, O. S. Barnouin, C. A. Bennett, M. Bernacki, K. N. Burke, S. Cambioni, B. E. Clark, M. G. Daly, M. Delbo, D. N. DellaGiustina, C. M. Elder, **R. D. Hanna**, C. W. Harbele, E. S. Howell, D. R. Golish, E. R. Jawin, H. H. Kaplan, L. F. Lim J. L. Molaro, D. Pino Munoz, M. C. Nolan, B. Rizk, M. A. Siegler, H. C. M. Susorney, K. J. Walsh, and D. S. Lauretta (2020) Asteroid (101955) Bennu's Brittle Boulders and Thermally Anomalous Equator , *Science Advances 6, eabc3699. 6, eabc3699.* DOI: 10.1126/sciadv.abc3699
16. Kaplan H. H., Lauretta D. S., Simon A. A., Hamilton V. E., DellaGiustina D. N., Golish D. R., Reuter D. C., Bennett C. A., Burke K. N., Campins H., Connolly H. C., Dworkin J. P., Emery J. P., Glavin D. P., Glotch T. D., **Hanna R.,** Ishimaru K., Jawin E. R., McCoy T. J., Porter N., Sandford S. A., Ferrone S., Clark B. E., Li J. Y., Zou X. D., Daly M. G., Barnouin O. S., Seabrook J. A. and Enos H. L. (2020) Bright carbonate veins on asteroid (101955) Bennu: Implications for aqueous alteration history. *Science*, eabc3557. DOI: 10.1126/science.abc3557
15. Lindgren, P., M.R. Lee, R. Sparkes, R.C. Greenwood, **R.D. Hanna**, I.A. Franchi, A.J. King, C. Floyd, P. Martin, V.E. Hamilton, C.H. Haberle (*2020)* Signatures of the post-hydration heating of highly aqueously altered CM carbonaceous chondrites and implications for

interpreting asteroid sample returns, *Geochimica et Cosmochimica Acta* https://doi.org/10.1016/j.gca.2020.08.021

14. **Hanna R.D.**, V.E. Hamilton, C.W. Haberle, A.J. King, N.M. Abreu, J.M. Friedrich, (2020) Distinguishing Relative Aqueous Alteration and Heating among CM Chondrites with IR Spectroscopy *Icarus.* 326, 113760. https://doi.org/10.1016/j.icarus.2020.113760.
13. J.L. Molaro, C.W. Hergenrother, S.R Chesley, K.J. Walsh, **R.D. Hanna**, C.W. Haberle, S.R. Schwartz, R-L. Ballouz, W. F. Bottke, and D. S. Lauretta (*2020*) Thermal fatigue as a driving mechanism for asteroid activity *Journal of Geophysical Research – Planets.* https://doi.org/10.1029/2019JE006325
12. J.L. Molaro, K.J. Walsh, E.R. Jawin, R.-L. Ballouz, C. A. Bennett, D. R. Golish, C. Drouet d'Aubigny, D. N. DellaGuistina, B. Rizk, S. R. Schwartz, M. Delbo, **R.D. Hanna**, M. Pajola, H. Campins, A. J. Ryan, W. F. Bottke, and D. S. Lauretta. (*2020*) In Situ Evidence of Thermally Induced Rock Breakdown Widespread on Bennu's Surface *Nature Communications*, 11, 2913 https://doi.org/10.1038/s41467-020-16528-7
11. V. E. Hamilton, A. A. Simon, P. R. Christensen, D. C. Reuter, B. E. Clark, M. A. Barucci, N. E. Bowles, W. V. Boynton, J. R. Brucato, E. A. Cloutis, H. C. Connolly Jr, K. L. Donaldson Hanna, J. P. Emery, H. L. Enos, S. Fornasier, C. W. Haberle, **R. D. Hanna**, E. S. Howell, H. H. Kaplan, L. P. Keller, C. Lantz, J.-Y. Li, L. F. Lim, T. J. McCoy, F. Merlin, M. C. Nolan, A. Praet, B. Rozitis, S. A. Sandford, D. L. Schrader, C. A. Thomas, X.-D. Zou, D. S. Lauretta & the OSIRIS-REx Team (2019) Evidence for widespread hydrated minerals on asteroid (101955) Bennu, *Nature Astronomy* https://doi.org/10.1038/s41550-019-0722-2**.**
10. Xiang C., Carballido A., **Hanna R.D**., Matthews L.S., Hyde T.W. (2019) The initial structure of chondrule dust rims I: electrically neutral grains, *Icarus,* 321, 99-11 https://doi.org/10.1016/j.icarus.2018.10.014.
9. **Hanna R. D.** and Ketcham R.A. (2018) Evidence for accretion of fine-grained rims in a turbulent nebula for CM Murchison, *Earth and Planetary Science Letters*, 481, 201-211. https://doi.org/10.1016/j.epsl.2017.10.029.
8. **Hanna R. D.** and Ketcham R.A. (*2017; **Invited Review***) X-ray computed tomography of planetary materials: A primer and review of recent studies, *Chemie der Erde Geochemistry*, https://doi.org/10.1016/j.chemer.2017.01.006.
7. **Hanna R. D.,** Hamilton, V.E., and Putzig, N.E. (2016) The complex relationship between olivine abundance and thermal inertia on Mars, *Journal of Geophysical Research-Planets*, 121, 7, 1293-1320. doi:10.1002/2015JE004924.
6. **Hanna R. D.,** Ketcham R. A., Zolensky M. and Behr W. (*2015*) Impact-induced brittle deformation, porosity loss, and aqueous alteration in the Murchison CM chondrite, *Geochimica et Cosmochimica Acta*, 171, 256-282, doi:10.1016/j.gca.2015.09.005.
5. Lindgren, P., **R.D Hanna**, K. J. Dobson, T. Tomkinson, and M. R. Lee (2015) The paradox between low shock-stage and evidence for compaction in CM carbonaceous chondrites explained by multiple low-intensity impacts, *Geochimica et Cosmochimica Acta*, 148, 159-178, doi:10.1016/j.gca.2014.09.014.
4. Zolensky, M., Mikouchi, T., Fries, M., Bodner, R., Jenniskens, P., Yin, Q., Hagiya, K., Ohsumi, K., Komatsu, M., Colbert, M., **Hanna, R.**, Maisano, J., Ketcham, R., Kebukawa, Y. Nakamura, T., Matsuoka M., Sasaki, S., Tsuchiyama, A., Gounelle, M., Le, L., Martinez, J., Ross, K. and Rahman, Z. (2014), Mineralogy and petrography of C asteroid regolith: The

Sutter's Mill CM meteorite, *Meteoritics & Planetary Science*, 49: 1997-2016. doi: 10.1111/maps.12386.

3. Ketcham, R.A. and **R.D Hanna** (2014) Beam hardening correction for X-ray computed tomography of heterogeneous natural materials, *Computers & Geosciences*, 67: 49-61. doi:10.1016/j.cageo.2014.03.003.
2. Zolensky, M., Herrin, J., Mikouchi, T., Ohsumi, K., Friedrich, J., Steele, A., Rumble, D., Fries, M., Sandford, S., Milam, S., Hagiya, K., Takeda, H., Satake, W., Kurihara, T., Colbert, M., **Hanna, R.**, Maisano, J., Ketcham, R., Goodrich, C., Le, L., Robinson, G., Martinez, J., Ross, K., Jenniskens, P. And Shaddad, M. H. (2010), Mineralogy and petrography of the Almahata Sitta ureilite, *Meteoritics & Planetary Science*, 45: 1618–1637. doi: 10.1111/j.1945-5100.2010.01128.x.
1. **Schneider, R.D. (now Hanna)** and V.E. Hamilton (2006) Evidence for Locally-derived, Ultramafic Intracrater Materials in Amazonis Planitia, Mars, *Journal of Geophysical Research*, Volume 111, Issue E9, doi: 10.1029/2005JE002611.