Cyrena Anne Goodrich
Senior Staff Scientist
Science Manager for Geochemistry and Petrology Group
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Education:

- Ph.D, Geology: Cornell University, 1983 (Petrogenesis of Fe-C Alloys, Disko Island).
- B.A., Russian Language and Literature: Cornell University, 1977.

Principal Research, Service, and Managerial Responsibilities:

- Research in petrology & geochemistry of meteorites and asteroid-meteorite connections.
- Associate Editor for *Meteoritics & Planetary Science*.
- Member and Special Editor of the Nomenclature Committee of the Meteoritical Society.
- LPI Science Manager for Geochemistry/Petrology Group; Supervisor to eight LPI staff scientists and/or LPI-ARES postdoctoral fellows.
- Mentor to summer interns at LPI.
- Science Co-Editor for LPI/USRA's *Planetary News*.
- Laboratory manager for LPI SEM Facility.
- LPI lead for XSPACE (joint LPI-ARES meteorite curatorial facility).
- Reviewer for *GCA, M&PS, EPSL*, and other journals.
- Reviewer/panel member for NASA, DFG, and Leverhume Foundation Research Programs.
- Member of program committee for LPSC, MSM, and other meetings/workshops.
- Chairman of organizing committee for LPI-ARES Mini Science Symposium, 1920-present.

Recent Research Grants and Awards:

- NASA Planetary Science Enabling Facilities (2023-2026): Augmentation of the LPI SEM-Facility.
- NASA Emerging Worlds PI (2019-2023): Physical and Compositional Structure of Heterogeneous Asteroid 2008 TC_3 from New Samples of the Almahata Sitta Meteorite.
- NASA Emerging Worlds PI (2017-2021): Petrologic, Oxygen and Chromium Isotope, and Ar-Ar Studies of Non-Ureilitic Materials in Polymict Ureilites.
- NASA Emerging Worlds PI (2016-2018): Nature and Origin of Asteroid 2008 TC_3 from petrologic, oxygen isotope, and other studies of new samples from the Almahata Sitta Meteorite Fall.
- NASA Cosmochemistry PI (2012-2015): Analytical and Theoretical Studies of Ureilites.
- NASA Origins of Solar Systems PI (2012-2015): Origin and Dynamical Evolution of Ureilites and 2008 TC_3/Almahata Sitta.
- NASA Mars Fundamental Research Co-I (2011-2012): Melt Inclusions in Olivine in Nakhla as Probes of the Martian Mantle.
- NASA Cosmochemistry PI (2011-2012): Differentiation of Primitive Achondrite Parent Bodies, Extending the Lessons from Ureilites.
- NASA Cosmochemistry PI (2008-2011): Thermal Evolution, Aqueous Alteration and Differentiation of the Ureilite Parent Body).

- NASA Cosmochemistry PI (2005-2008): The Ureilite Parent Body: Thermal Evolution and Differentiation of a Carbonaceous Chondrite-Like Asteroid.
- NASA Cosmochemistry major equipment Co-I (2006) for purchase of SEM at KCC.
- Asteroid 6762 named CyrenaGoodrich (2006).
- Professional Staff Congress-City University of New York grants (2004, 2005, 2007).

Research Interests:

- Geological and chemical evolution of the terrestrial planets and asteroids.
- Petrology, geochemistry, and reflectance spectroscopy of meteorites.
- Asteroid-meteorite connections.

Previous Employment:

- Senior Visiting Scientist: Lunar and Planetary Institute (2015-2016)
- Senior Scientist: Planetary Science Institute (2009-2016)
- Assistant Professor: Kingsborough Community College, CUNY (2004-Feb. 2009).
- Senior Research Fellow: Hawaii Institute of Geophysics and Planetology (2002-2004).
- Research Scientist: Max-Planck-Institut für Chemie (1997– 2001).
- Research Consultant: Lunar and Planetary Laboratory, University of Arizona (1994-1995).
- Research Associate: Scripps Institution of Oceanography, San Diego (1993).
- Senior Research Associate: Lunar and Planetary Lab, University of Arizona (1988-1993).
- Research Associate: Lunar and Planetary Lab, University of Arizona (1986-1988).
- Research Fellow: The Institute of Meteoritics, University of New Mexico (1983-1986).

Professional Societies:

- Member and Elected Fellow of the Meteoritical Society
- Member of the Geochemical Society

Publications

Papers:

GOODRICH C.A., DOWNES H., GREENWOOD R., ROSS A., FIORETTI A.M., ALEXANDER L., KITA N.T., BUTLER J., JERCINOVIC M.J., JENNISKENS P. and SHADDAD M.H. (2023) Enstatite meteorite clasts in Almahata Sitta and other polymict ureilites: Implications for the formation of asteroid 2008 TC_3 and the history of enstatite meteorite parent asteroids. *Meteoritics & Planetary Science, submitted.*

TURRIN B. D., LINDSAY F., DELANEY J. S., PARK J., HERZOG G. F., SWISHER C., Jr., and **GOODRICH C. A.** (2022) $^{40}Ar/^{39}Ar$ ages of L4, H5, EL6 and feldspathic ureilitic clasts from the Almahata Sitta polymict ureilite (asteroid 2008 TC_3). *Meteoritics & Planetary Science* **58**, 304-327.

GOODRICH C.A., COLLINET M., TREIMAN A., PRISSEL T.C., PATZEK M., JERCINOVIC M.J., EBERT S., BISCHOFF A., PACK A., BARRAT J-A. and DECKER S. (2022) The first main-group ureilite with primary plagioclase: A missing link in the differentiation of the ureilite parent body. *Meteoritics & Planetary Science* **57**, 1589-1616.

HAMILTON V.E., CONNOLLY H.C., Jr, **GOODRICH C.A**., ABREU N.M., KAPLAN H.H. and SIMON A.A. (2022) GRO 95577 (CR1) as a mineralogical analogue for asteroid (101955) Bennu. *Icarus*, 383, 1 Sept. 2022, 115054.

SABBAH H., CARLOS M., JENNISKENS P, SHADDAD M., DUPRAT J., **GOODRICH C.A.** and JOBLIN C. (2022) Detection of cosmic fullerenes in the Almahata Sitta meteorite: Are they stardust? *Astrophysical Journal* 931:91 (12 pp) 2022 June 1.

JENNISKENS P., ROBERTSON D., **GOODRICH** C.A., SHADDAD M.H., KUDODA A., FIORETTI A.M., and ZOLENSKY M.E. (2022) Bolide fragmentation: What parts of asteroid 2008 TC_3 survived to the ground?" *Meteoritics & Planetary Sciences*, **57**,1641-1664.

GOODRICH C.A., KRING D.K. and GREENWOOD R. (2021) Xenoliths in ordinary chondrites and ureilites: Implications for early solar system dynamics. *Meteoritics & Planetary Sciences* **56**, 1949-1987.

GOODRICH C.A., NESTOLA F. and JAKUBEK R.S. (2021) Diamonds in ureilites: The never-ending story. *Elements* **17**, no. 4, 292-293.

HAMILTON V.E., CHRISTENSEN P.R., KAPLAN H.H., HABERLE C.W., ROGERS A.D., GLOTCH T.D., BREITENFELD L.B., **GOODRICH C.A.,** SCHRADER D.L., McCOY T.J., LANTZ C., HANNA R.D., SIMON A.A., BRUCATO J.R., CLARK B.E., and LAURETTA D.S. (2021) Evidence for limited compositional and particle size variation on asteroid (101955) Bennu from thermal infrared spectroscopy. *Astronomy & Astrophysics*, published April 16, 2021. 13 pp.

HAMILTON V.E., **GOODRICH C.A.**, TREIMAN A.H., CONNOLLY H.C., Jr, ZOLENSKY M.E. and SHADDAD M.H. (2020) Meteoritic evidence for a Ceres-sized water-rich carbonaceous chondrite parent asteroid. *Nature Astronomy Letters*, 21 December, 2020. https://doi.org/10.1038/s41550-020-01274-z. LPI publication #2546.

HAMILTON V.E., **GOODRICH C.A.**, TREIMAN A.H., CONNOLLY H.C., Jr, ZOLENSKY M.E. and SHADDAD M.H. (2021) Addendum: Meteoritic evidence for a Ceres-sized water-rich carbonaceous chondrite parent asteroid. *Nature Astronomy Letters*, October 25, 2021. https://doi.org/10.1038/s41550-021-01496-9.

GOODRICH C.A., SANBORN M.E., YIN Q-Z., KOHL I., FRANK D., DALY R.T., WALSH K.J., ZOLENSKY M.E., YOUNG E.R.D., JENNISKENS P. and SHADDAD M.H. (2021) Cr Isotopic Evidence for Mixing of NC and CC Reservoirs in Polymict Ureilites: Implications for Early Solar System Dynamics. *Planetary Science Journal*, Volume 2, Issue 1, id.13, 15 pp. LPI publication #2581.

KEBUKAWA Y., ZOLENSKY M.E., **GOODRICH C.A.**, ITO M., OGAWA N.O., TAKANO Y., OHKOUCHI N., KIRYU K., IGISU M., SHIBUYA T., MARCUS M.A., OHIGASHI T., MARTINEZ J., KODAMA Y., and SHADDAD M.H. (2021) Organic matter in carbonaceous chondrite lithologies of Almahata Sitta: Incorporation of previously unsampled carbonaceous chondrite lithologies into ureilitic regolith. *Meteoritics & Planetary Sciences* **56**, 1311-1327.

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BARBARO A., DOMENEGHETTI M.C., **GOODRICH C.A.**, MENEGHETTI M., LITTI L., FIORETTI A.M., JENNISKENS P., SHADDAD M.H. and NESTOLA F. (2020) Graphite-based geothermometry on Almahata Sitta ureilite meteorites. *Minerals* 2020, 10, 1005. LPI publication #2569.

GOODRICH C.A., ZOLENSKY M., FIORETTI A.M., SHADDAD M.H., DOWNES H., HIROI T., KOHL I., YOUNG E., KITA N., HAMILTON V.E., RIEBE M., BUSEMANN H., MACKE R.J., FRIES M., ROSS D.K. and JENNISKENS P. (2019) The first samples from Almahata Sitta showing contacts between ureilitic and chondritic lithologies: implications for the structure and composition of asteroid 2008 TC_3. *Meteorit. Planet. Sci*. 54, 2769-2813. LPI contribution #2212.

GOODRICH C.A., KITA N.T., YIN Q-Z., SANBORN M.E., WILLIAMS C.D., NAKASHIMA D., LANE M.D. and BOYLE S. (2017) Petrogenesis and provenance of ungrouped achondrite Northwest Africa 7325 from petrology, trace elements, oxygen, chromium and titanium isotopes, and mid-IR spectroscopy. *Geochim. Cosmochim. Acta* **203**, 381-403. LPI contribution #1996. PSI contribution #630.

GOODRICH C.A., KITA N.T., SUTTON S.R., WIRICK S. and GROSS J. (2017) The Miller Range 090340 and 090206 meteorites: New brachinite-like achondrites with implications for the diversity and petrogenesis of the brachinite clan. *Meteorit. Planet. Sci*. 52, 949-978. LPI contribution #1998. PSI contribution #634.

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GOODRICH C.A., ASH R.D., Van ORMAN J.A., DOMANIK K. and McDONOUGH W.F. (2013) Metallic phases and siderophile elements in main group ureilites: Implications for ureilite petrogenesis. *Geochim. Cosmochim. Acta* **112**, 340-373.

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KROT A.H., KEIL K., SCOTT E.R.D., **GOODRICH C.A.** and WEISBERG M.K. (2013) Classification of meteorites and their genetic relationships. *In* Treatise on Geochemistry, Vol. 1, Meteorites, Comets and Planets. (A.M. Davis, Ed.), revised edition, Elsevier.

DAY J.M.D., WALKER R.J., ASH R.D., LIU Y., RUMBLE III D, IRVING A.J., **GOODRICH C.A.**, TAIT K., McDONOUGH W.F., TAYLOR L.A. (2012) Origin of felsic achondrites Graves Nunataks 06128 and 06129, and ultramafic brachinites and brachinite-like achondrites by partial melting of volatile-rich primitive parent bodies. *Geochim. Cosmochim. Acta* **81**, 94-128.

GOODRICH C.A., KITA N.T., SPICUZZA M.K., VALLEY J.W., ZIPFEL J., MIKOUCHI T. and MIYAMOTO M. (2011) The Northwest Africa 1500 meteorite: Not a ureilite, maybe a brachinite. *Meteorit. Planet. Sci.,* **45**, 1906-1928.

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GOODRICH C.A., HUTCHEON I.D., KITA N.T., HUSS G.R., COHEN B.A. and KEIL K. (2010) ^{53}Mn-^{53}Cr and ^{26}Al-^{26}Mg ages of a feldspathic lithology in polymict ureilites. *Earth Planet. Sci. Lett.* **295**, 531-540.

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GOODRICH C.A., FIORETTI A.M. and Van ORMAN J.A. (2009) Petrogenesis of augite-bearing ureilites Hughes 009 and FRO 90054/93008 inferred from melt inclusions. *Geochim. Cosmochim. Acta*, **73**, 3055-3076.

WILSON L., **GOODRICH C.A.** and Van ORMAN J. (2008) Thermal evolution and physics of melt extraction on the ureilite parent body. *Geochim. Cosmochim. Acta* **72**, 6154-6176.

GOODRICH C.A., Van ORMAN J. and WILSON L. (2007) Fractional melting and smelting on the ureilite parent body. *Geochim. Cosmochim. Acta* **71**, 2876-2895.

VAN NIEKERK D., **GOODRICH C.A**., TAYLOR G.J. and KEIL K. (2007) The lithological contact in the shergottite Elephant Moraine A790091 – A record of igneous differentiation processes on Mars. *Meteorit. Planet. Sci*. **42**, 1751-1762.

GOODRICH C.A., WLOTZKA F., ROSS D.K. and BARTOSCHEWITZ R. (2006) NWA 1500: Plagioclase-bearing monomict ureilite or ungrouped achondrite? *Meteorit. Planet. Sci.* **41**, 925-952.

BISCHOFF A., SCOTT E.R.D. and **GOODRICH C.A**. (2006) Nature and Origin of Meteoritic Breccias. In *Meteorites and the Early Solar System II* (eds D.S. Lauretta and H.Y. McSween). University of Arizona Press.

GOODRICH C.A., SCOTT E.R.D. and FIORETTI A.M. (2004) Ureilitic Breccias: Clues to the petrologic structure and impact disruption of the ureilite parent asteroid. *Chemie de Erde* **64**, 283-327.

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KROT A.N., LIBOUREL G., **GOODRICH C. A**. and PETAEV M.I. (2004) Silica-rich igneous rims around magnesian chondrules in CR carbonaceous chondrites: Evidence for fractional condensation during chondrule formation. *Meteorit. Planet. Sci.* **39**, 1931-1956.

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Abstracts:

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