MUKUL SHARMA

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Education

Ph.D. Geology, University of Rochester, Rochester, New York (1993).
Advisor: Asish R. Basu
M.S. Geology, University of Rochester, Rochester, New York (1989).
M.Sc. Applied Geology, Indian Institute of Technology, Bombay, India (1985)
B.Sc. (Honors) Applied Geology, University of Delhi, Delhi, India (1983).

Professional Experience

Professor, Department of Earth Sciences, Dartmouth College
(July 2014–present)
Associate Professor, Department of Earth Sciences, Dartmouth College
(July 2007–June 2014)
Assistant Professor, Department of Earth Sciences, Dartmouth College
(January 2001–June 2007)
Staff Scientist Max-Planck Institute for Chemistry, Mainz, Germany
(January 2000-December 2000)
Max-Planck Fellow, Max-Planck Institute for Chemistry, Mainz, Germany.
(April 1997–December 2000)
Supervisor: Albrecht Hofmann
Visiting Associate in Geochemistry**,** California Institute of Technology, Pasadena, California.
(March 1998–May 1998)
Associate Scientist, California Institute of Technology, Pasadena, California.
(December 1995 – April 1997)
Research Fellow in Geochemistry, California Institute of Technology, Pasadena, California.
(December 1992–December 1995).
Supervisor: Gerald J. Wasserburg

Research Interests

Origin and evolution of early Earth
Platinum Group Element chemistry of natural waters
Large igneous provinces
Generation of oceanic lithosphere
Ion transport during weathering
Solar magnetism and terrestrial climate
Meteorite impacts
Evolution of early solar system—irradiation history of early formed solids
Marcellus Shale diagenesis and hydraulic fracturing
Carbon sequestration in geological record

Professional Society Memberships
American Geophysical Union
Geochemical Society

Professional Activities:
(1) Reviewer for (a) professional papers in Geochimica et Cosmochimica Acta, Earth and Planetary Science Letters, Journal of Petrology, Science, Journal of Atmospheric and Terrestrial Physics, Proceeding of Royal Society and (b) research proposals for the National Science foundation, NASA, National Research Council, UK, and Swedish National Science Research Council.

(2) Co-organizer of an international workshop called GEOTRACES in Toulouse, France with about 85 participants to plan the future of trace element and isotope investigations in oceans. (13-16 April, 2003). Other organizers are Bob Anderson (Lamont Doherty Earth Observatory of the Columbia University), Roger Francois (Woods Hole Oceanographic Institution), Gideon Henderson (Oxford Univ.), Catherin Jeandel (CNRS, Toulouse), and Martin Frank (ETH, Zuerich). Associate member of GEOTRACES Planning Group, Scientific Committee on Oceanic Research.

Invited Lectures:
Caltech (1992), Max Planck Institute for Chemistry, Mainz (1996), Scripps (1997), ETH, Zuerich (1998), University of Maryland, College Park (1999), University of Rochester (1999), Yale (March 4, 2002), Woods Hole Oceanographic Institution (April 19, 2002), Boston University (March 27, 2003), University of Colorado (Sept 2005), Dartmouth College (Physics & Astronomy Colloquium, Oct 2005); University of Vermont (Nov 2005), Yale University (June 2006), Norwich University (Oct 2006), Woods Hole Oceanographic Institution (June 12, 2007), Delhi University, India (Dec., 2007); Physical Research Laboratory, Ahmedabad, India (Jan 22, 2008). Yale University (Feb 2009). AGU (Dec. 2010). Genesis Science Meeting in Houston, Texas (March 2015, 2016, 2017, 2018).

HONORS AND AWARDS

1. **Dartmouth College.** Herris Petit Fellowship (2014)
2. **Dartmouth College:** Douglas C. Floren Fellowship (Aug. 2007).
3. **Dartmouth College:** Junior Faculty Fellowship (Fall, 2005).
4. **Max-Planck Gesellschaft:** Max-Planck Fellowship, 1996-1999.
5. **Geological Society of America:** Penrose Grants for field work in the East Indian Craton, 1988 and 1989.
6. **Indian Institute of Technology, Bombay:** Institute Silver Medal (Institute's highest award given to the student at the top of the graduating class). November 1985.
7. **Ministry of Education and Culture, Government of India:** National Merit Scholarship, 1983-1985.

RECENT RESEARCH GRANTS

Awarded

1. Novel Methods to Clean Hydraulic Fracturing Wastewater, Dartmouth, Scholarly Innovation and Advancement Award ($35,000, 2-year award beginning July 1, 2013).
2. Collaborative Research: Investigating Hypothesized Bolide Signatures in Greenland Ice at the Younger Dryas Onset. NSF Polar Program. M. Sharma (PI), E. Osterburg (co-PI), Paul Mayewski (PI), A. Kurbatov (co-PI). $224,582 (7/1/14—6/30/16).
3. Determination of Osmium Concentration and Isotope Composition of Solar Corona using Genesis-a pilot study. NASA LARS Program. M. Sharma (PI). $42,491 (1/21/15-1/20/16).
4. Determination of Osmium Concentration and Isotope Composition of Solar Corona using Genesis. M. Sharma (PI). $283,240 (3/17/16-2/16/19).

TEACHING & MENTORING

Dartmouth

Courses Taught

1. EARS 2: Earth History
1. EARS 7: From Big Bang to Planet Earth: How did we get here?
2. EARS 8/Human Biology 1/CoCo-4: Life on Mars? (co-taught with J. Buckey, Professor of Medicine, and L. Davies, Professor of Literature) (*The Chronicle of Higher Education, May 18, 2001*)
3. EARS 9: Earth Resources
4. EARS 19/ASTR 19: Habitable Planets (co-taught with Ryan Hickox, Professor of Astronomy)
5. EARS 62: Geochemistry
6. EARS 69: Igneous and Metamorphic Petrology
7. EARS 108: Radiogenic Isotope Geochemistry
8. EARS 202: Geochemical Tracers

Max-Planck-Institut für Chemie

1. Kompaktkurs Geochemie, October 1997 and 1999. Lectured on the Geochemistry of the Earth's Mantle and supervised a group of graduate students in ultra-clean laboratory methods and mass spectrometry.
2. Supervised two postdoctoral fellows (1. Dr. M. Benoit CNRS, Brest, France; 2. Dr. K. Balakrishna, Mysore, India) and a doctoral candidate (Dr. Jürgen Eisele, Mainz, Germany).

California Institute of Technology

Guest lecturer in Geochemistry for a Graduate Class offered by Dr. G. J. Wasserburg. Spring 1996. Lectured on the Geochemistry of Pb.

Students Advised

1. Emily Schaller (Senior Thesis; now finished her Ph.D. from Caltech): co-advisor with Leslie Sonder. Title: **Consequences of rotational bursting for the terrestrial accretion of the ^{3}He retentive interplanetary dust (2002).**
2. Jonathan Lu (Senior Thesis; now finished his Medical degree at Yale Univ). Title: **An isotopic study of cosmic spherules from the South Pole water well (2002)**

3. David Zylberberg (Senior Thesis; now finished his MS from Lamont and J.D. from Columbia): Title: **High resolution record of seawater osmium isotopes over the last 100,000 years (2004)**
4. Ross Markwort (Senior Thesis; now finished his PhD from Boston College; co-advisor with Xiahong Feng and Jim Aronson) Title: **$\delta^{18}O$ in Early Holocene Gastropods from Lake Galana Boi, Kenya: Characterizing the African Humid Period (2004)**
5. Evelyn Mervine (Senior Thesis; now finished his PhD MIT/WHOI): **Petrogenesis of alkaline lavas associated with Deccan flood basalts (2006)**
6. Erin Rosenberg (M.S.): **The osmium budget of the oceans from the off-axis hydrothermal fluid flux (2004)**
7. Chris Oze (Obering Postdoctoral Fellow; now a Professor at University of Canterbury, New Zealand).
8. Rasmus Andreasen (Ph.D.; now a Research Assistant Prof., Univ. Houston): **Early earth and solar system evolution: insights from strontium, barium, neodymium, and samarium isotopes** (May 2007).
9. Elena Ramirez (M.S.; now a Ph.D. from University of British Columbia): **Eolian-derived Osmium inputs to the Surface Waters of the Sargasso Sea: Impact of Seasonal Saharan Dust.** (Dec. 2007).
10. Erich Osterberg (Obering Postdoctoral Fellow; now an Assistant Prof in Earth Sciences, Dartmouth)
11. Cynthia Chen (Ph.D.): **Osmium geochemistry of natural waters** (March 2009; now with Halliburton, Denver, CO).
12. Katie Bono (Senior Thesis; now Mountain Guide at RMI Expeditions): **Osmium contributions to seawater by island arc volcanism: an initial assessment from Guatemala.**
13. Elizabeth Varner (Independent Study, Chemistry Dept): **High Precision Samarium Isotopes: Implications on Lunar Composition.**
14. Yingzhe Wu (M.S.): **Origin an dprovenance of magnetic spherules at the Younger Dryas Boundary** (June 2011; now a PhD student at Columbia University).
15. Tim Blazina (M.S. Aug 2011; Ph.D. from EAWAG Zuerich, Switzerland): **The impact of arc terrain weathering on the global cycles of C, Sr and Os as deduced from the North Island of New Zealand**.
16. Carl Symcox (Senior Thesis): **An assessment of the redistribution of Barium during diagenesis of Marcellus Shale** (June 2012) (co-advisor: Devon Renock).
17. Hannah Hallock (M.S.): **Variations in Os/Ir and $^{187}Os/^{188}Os$ ratios across the K-Pg boundary from Stevns Klint and Hell Creek - Implications for the global iridium distribution** (Fall 2012)
18. Kelly Landau (M.S.): **Insights into the behavior of osmium in the oceans** (June 2013).
19. Ying Qi Wong (Senior Thesis): **Measurement and Separation of Precious Metals from the Wastewater of Hydraulic Fracturing** (June 2014)
20. Ben Bauer (Senior Thesis; 2015)
21. Zach Murphy (Senior Thesis; 2015)

At present, he is advising the following students:

1. Danielle Niu (Ph.D.) co-advisor: Devon Renock
2. Ji-Hye Seo (Ph.D.)
3. Gayathri J.P. (MS.; defended Nov., 2017)
4. Jessica McDaniel (MS)

The following students have worked in his laboratory as research assistants:

1. Jamie deLemos (Graduate student)
2. Gretchen Gehrke (Undergraduate researcher)
3. Zhaohui Zhang (Graduate Student)
4. Kevan Grimaldi (Undergraduate researcher)
5. Carmen Springer (Undergraduate researcher)
6. Evelyn Mervine (Undergraduate researcher)
7. Lauren Edgar (Undergraduate researcher NASA NH Space Grant)
8. Laura Kehrl (WISP Intern)
9. Dominique Winski (undergraduate researcher)
10. Sarah Stern (undergraduate researcher)
11. Bridget Alex (undergraduate researcher NASA NH Space Grant)
12. Elise Wilkes (WISP Intern)
13. Thomas Robbins (undergraduate researcher NASA NH Space Grant)
14. Carl Symcox (NSF, Younger Dryas Grant)
15. Isaac Takushi (undergraduate researcher)
16. Katherine Lindzey
17. Ying-Qi Wong
18. Ivy Shen (WISP intern)
19. Ying-Qi Wong ’14 (Senior Thesis)
20. Aditya Natarajan (Hanover High)
21. Dylan Cahill’18 (Sophomore Scholar) & undergraduate researcher
22. Emma Rieb’18 (Sophomore Scholar) & undergraduate researcher

PUBLICATIONS

1. A. R. Basu, M. Sharma, and P.G. DeCelles (1990) Nd-Sr isotopic provenance and trace element geochemistry of Amazonian Foreland Basin Sands, Bolivia and Peru: implications for ensialic Andean orogeny. *Earth Planet. Sci. Lett*. **100**, 1-17.

2. M. Sharma, A. R. Basu, and R. B. Cole (1991) Bimodal Volcanism by MORB-Continental Crust Interaction: Nd, Sr-isotopic and geochemical evidence from Southern San Joaquin Basin, California. *Contrib. Mineral. Petrol.* **109**, 159-172.

3. M. Sharma, A. R. Basu, and G. V. Nesterenko (1991) Nd-Sr isotopes, petrochemistry, and origin of the Siberian Flood Basalts, USSR. *Geochim. Cosmochim. Acta* **55**, 1183-1192.

4. M. Sharma, A. R. Basu, and G. V. Nesterenko (1992) Temporal Sr-, Nd- and Pb-isotopic variations in the Siberian Flood Basalts: implications for the plume-source characteristics. *Earth Planet. Sci. Lett.* **113**, 365-381**.**

5. M. Sharma, A. R. Basu, and S. L. Roy (1994) Sm-Nd isotopic and geochemical study of the Archean tonalite-amphibolite association from the eastern Indian Craton. *Contrib. Mineral. Petrol.* **117**, 45-55.

6. M. Sharma, D.A. Papanastassiou, G.J. Wasserburg and R.F. Dymek (1994) The problem of high precision measurements of $^{142}Nd/^{144}Nd$: the terrestrial record of ^{146}Sm. *Lunar Planet. Sci. Conf.* **XXV**, 1253-1254.

7. M. Sharma, G. J. Wasserburg, D. A. Papanastassiou, J.E. Quick, E.V. Sharkov and E.E. Laz'ko (1995a) High $^{143}Nd/^{144}Nd$ in extremely depleted mantle rocks. *Earth Planet. Sci. Lett.* **125**, 101-114.

8. M. Sharma, D.A. Papanastassiou and G.J. Wasserburg (1995b) Sm-Nd systematics of a large eucrite clast in the Vaca Muerta mesosiderite and initial solar system ^{146}Sm abundance. *Lunar Planet. Sci. Conf.* **XXVI**, 1271-1272.

9. M. Sharma, G.J. Wasserburg, D.A. Papanastassiou, J.E. Quick, E.V. Sharkov and E.E. Laz'ko (1995c) Extreme Sm-Nd fractionation due to melting in the oceanic upper mantle: evidence from Polar Urals Ophiolite. *Lunar Planet. Sci. Conf.* **XXVI**, 1273-1274.

10. A. R. Basu, M. Sharma, and W. R. Premo (1996) U-Pb age of an Older Metamorphic Group mica schist: earliest terrain of the Eastern Indian Craton. In: *Recent Researches in Geology and Geophysics of the Precambrians*, Ed. A. K. Saha, Recent Researches in Geology, Volume 16, p 93-102, Hindustan Publishing Corporation (India), New Delhi.

11. M. Sharma, D. A. Papanastassiou, G. J. Wasserburg and R.F. Dymek (1996a) The issue of the terrestrial record of ^{146}Sm. *Geochim. Cosmochim. Acta* **60**, 2037-2047.

12. M. Sharma, D. A. Papanastassiou, G. J. Wasserburg and R.F. Dymek (1996b) Reply to the Comment on "The issue of the terrestrial record of ^{146}Sm" by S.B. Jacobsen and C.L. Harper Jr. *Geochim. Cosmochim. Acta* **60**, 3751-3754.

13. M. Sharma and G.J. Wasserburg (1996c) The neodymium isotopic compositions and rare earth patterns in highly depleted ultramafic rocks. *Geochim. Cosmochim. Acta* **60**, 4537-4550.

14. M. Sharma, D.A. Papanastassiou and G.J. Wasserburg (1997a) The osmium isotopic compostion and concentration in the oceans: terrestrial and extraterrestrial sources. *Lunar Planet. Sci. Conf.* **XXVIII**, 1281-1282.

15. M. Sharma, D. A. Papanastassiou, and G. J. Wasserburg (1997b) The concentration and isotopic composition of osmium in the oceans. *Geochim. Cosmochim. Acta* **61**, 3287-3299.

16. M. Sharma (1997) Siberian Traps. In: *Large Igneous Provinces: Continental, Oceanic, and Planetary Flood Volcanism.* Eds. J. J. Mahoney and M. Coffin, AGU Monograph, Volume 100, p 273-295, American Geophysical Union, Washington D.C.

17. M. Sharma and G. J. Wasserburg (1997) Osmium in the rivers. *Geochim. Cosmochim. Acta* **61**, 5411-5416.

18. M. Sharma, G. J. Wasserburg, A. W. Hofmann, and G. J. Chakrapani (1999) Himalayan uplift and osmium isotopes in oceans and rivers, *Geochim. Cosmochim. Acta,*. **63**, 4005-4012.

19. M. Sharma, G. J. Wasserburg, A. W. Hofmann, and D. A. Butterfield (2000) Osmium Isotopes in Hydrothermal Fluids from the Juan de Fuca Ridge. *Earth Planet. Sci. Lett.*, 179: 139-152.

20. M. Sharma, M. Polizzotto, and A.D. Anbar (2001) Iron Isotopes in Hot Springs along the Juan de Fuca Ridge. *Earth Planet. Sci. Lett.*, 194, 39-51.

21. J. Eisele**, M. Sharma, J. Blichert-Toft, C. Devey, S. Galer, and A. W. Hofmann (2002) The role of sediment recycling in EM-1 inferred from Os, Pb, Hf, Nd, Sr isotope and trace element systematics of the Pitcairn hotspot. *Earth Planet. Sci. Lett.*, 196 (3-4): 197-212.

22. M. Sharma (2002) Variations in Solar Magnetic Activity during the last 200,000 years: Is there a Sun-Climate Connection? *Earth Planet. Sci. Lett.*, 199 (3-4): 459-472.

23. D.A. Papanastassiou, M. Sharma, H. H. Ngo, G. J. Wasserburg, R. F. Dymek (2003) No ^{142}Nd excess in early Archean Isua gneiss IE 715-28. *Lunar Planet. Sci. Conf.* **XXXIV**, #1851.

24. LEXEN Scientific Party (2003) Probing for life in the ocean crust with the LEXEN Program, *Eos*, Transactions, American Geophysical Union, **84**, pp.109, 112, 25 Mar 2003.

25. M. Frank, C. Jeandel, R. F. Anderson, G. Henderson, R. Francois, M. Sharma (2003) GEOTRACES: Studying the global marine biogeochemistry of trace elements and isotopes, *Eos*, Transactions, American Geophysical Union, **84**, pp. 327, 330, 26 Aug 2003.

26. M. Sharma and C. Chen** (2004) Neodymium isotope fractionation in the mass spectrometer and the issue of ^{142}Nd anomalies in the early Archean rocks. *Precambrian Research* 134: 315-329.

27. C. Chen**, S. Taylor, and M. Sharma (2005) Iron and Osmium Isotopes from stony micrometeorites and implications for the Os budget of the ocean. *Lunar Planet. Sci. Conf.* **XXXVI**, #2134.

28. C. Oze and M. Sharma (2005) Have olivine, will gas: Serpentinization and the abiogenic production of methane on Mars. *Geophys. Res. Lett.* 32 (10): Art. No. L10203 MAY 26.

29. R. Andreasen** and M. Sharma (2006) Solar nebula heterogeneity in p-process Sm and Nd isotopes. *Science*. 314: 806-809 (doi: 10.1126/science.1131708).

30. C. Chen**, M. Sharma and B. Bostick (2006) Lithologic controls on the Os isotopic composition in the Rio Orinoco. *Earth Planet. Sci. Lett.* 252 (1-2): 138-151.

31. C. Oze and M. Sharma (2007) Serpentinization and the Inorganic Synthesis of H_2 in Planetary Surfaces. *Icarus.* 186: 557-561 (doi:10.1016/j.icarus.2006.09.012).

32. K. Turekian, M. Sharma and G. Williams (2007) The behavior of natural and anthropogenic osmium in the Hudson River-Long Island Sound Estuarine Systems. *Geochim. Cosmochim. Acta,* 71: 4135-4140.

33. M. Sharma, E. R. Rosenburg**, and D. A. Butterfield (2007) Search for the proverbial mantle osmium sources to the oceans: Hydrothermal alteration of mid-ocean ridge basalt. *Geochim. Cosmochim. Acta,* 71: 4655-4667.

34. R. Andreasen** and M. Sharma (2007) Decoupling of the Barium and Lanthanide r-process nuclide sources: constraints on the origin of ^{142}Nd anomalies. *Lunar Planet. Sci. Conf.* **XXXVIII**, #2242.

35. M. Sharma, K. Balakrishna, A. W. Hofmann, R. Shankar (2007) The behavior of osmium and strontium isotopes through a tropical estuary. *Geochim. Cosmochim. Acta.* 71**:** 4856-4867**.**

36. R. Andreasen** and M. Sharma (2007) Mixing and Homogenization in the Early Solar System: clues from Sr, Ba, Nd, and Sm isotopes in meteorites. *The Astrophysical J.* 665: 874-883.

37. SCOR Working Group (2007) GEOTRACES - An international study of the global marine biogeochemical cycles of trace elements and their isotopes. *Chemie der Erde-Geochemistry.* 67: 85-131.

38. R. Andreasen**, M. Sharma, K.V. Subbarao, S.G. Viladkar (2008) Where on Earth is the enriched Hadean reservoir? *Earth Planet. Sci. Lett.*: 266: 14-28.

39. C. Chen**, P. Sedwick, and M. Sharma (2009) Anthropogenic osmium in rain and snow reveals global-scale atmospheric contamination. *Proceedings of the National Academy of Sciences:* 106:7724-7728.

40. R. Andreasen** and M. Sharma (2009) Fractionation and mixing in a thermal ionization mass spectrometer source: implications and limitations for high-precision Nd isotope analyses. *International Journal of Mass Spectrometry & Ion Processes:* doi:10.1016/j.ijms.2009.04.004.

41. C. Chen** and M. Sharma (2009) High precision and high sensitivity measurements of osmium in seawater. *Analytical Chemistry:* doi:10.1021/ac900600e.

42. R. Andreasen** and M. Sharma (2009) Technical comment on 'Neodymium-142 Evidence for Hadean Mafic Crust' by Jonathan O'Neil, Richard W. Carlson, Don Francis, and Ross K. Stevenson. *Science* 325, 267-a. doi: 10.1126/science.1169604

43. M. Sharma (2011) Applications of Osmium and Iridium as Biogeochemical Tracers in the Environment. *Handbook of Environmental Isotope Geochemistry,* Advances in Isotope Geochemistry (ed: M. Baskaran), DOI 10.1007/978-3-642-10637-8_11. Springer-Verlag.

44. M. Sharma, C. Chen** and T. Blazina** (2012) Osmium contamination of seawater samples stored in polyethylene bottles. *Limnology & Oceanography Methods*. 10, 618–630.

45. B. Peucker-Ehrenbrink, M. Sharma and L. Reisberg (2013) Recommendations for Analysis of Dissolved Osmium in Seawater. *Eos*, 94 (7), 73.

46. J.R. Moore, H. Hallock**, J. W. Chipman, and M. Sharma (2013) Iridium and Osmium Fluences Across the K-Pg Boundary Indicate a Small Impactor, *Lunar and Planet Sci Conf.* [#2405]

47. Moore J. R. and Sharma M. (2013) The K-Pg Impactor was likely a High Velocity Comet. *Lunar and Planet Sci Conf.* [#2431].

48. Y. Wu, M. Sharma, M. LaCompte, M. Dimitrioff (2013) The origin and provenance of magnetic sphereules at the Younger Dryas Boundary. *Proceedings of the National Academy of Sciences Early Edition. www.pnas.org/cgi/doi/10.1073/pnas.1304059110.*

49. T. Blazina** and M. Sharma (2013) The impact of arc terrain weathering on the global cycles of Sr, Os and C as deduced from the North Island of New Zealand. *G^3 doi: 10.1002/ggge.20222.*

50. J. Moore, G.P. Wilson*, H. Hallock**, M. Sharma, D. R. Braman (2014) Characterization of the Hell Creek–Fort Union contact, Cretaceous-Paleogene boundary and impact-derived "pink" clay horizon at the type section of the Hell Creek Formation, Montana, *U.S.A. Geological Society of America (Hell Creek Special Volume)*

51. B. P. Bauer*, E. E. Meyer, J. R. Moore, M. Sharma (2015) Investigating a Burning Question: Search for a Pyrometamorphic Mineral (Esseneite) at the K-Pg Boundary, *Lunar and Planet Sci Conf.* [#2836]

52. M. Sharma, A. Jurewicz, D. Burnett (2015) The Problem with the Estimated Re/Os Ratio of the Solar Nebula. *Lunar and Planet Sci Conf.* [#2361]

53. J. Noordmann, S. Weyer, B. Georg, S. Rausch, and M. Sharma (2015) $^{238}U/^{235}U$ isotope ratios of crustal material, rivers and products of hydrothermal alteration: New insights on the oceanic U isotope mass balance, *Isotopes in Environmental and Health Studies*. 52: 141-163, DOI: 10.1080/10256016.2015.1047449

54. C. Almécija-Pereda, M. Sharma, A. Cobelo-García, J. Santos-Echeandía, and M. Caetano (2015) Osmium and Platinum Decoupling in the Environment: Evidences in Salt Marsh Sediments (Tagus Estuary, SW Europe). *Environmental Science and Technology* 49: 6545−6553.

55. D. Renock, J. Landis, and M. Sharma (2016) Reductive weathering of black shale and release of barium during hydraulic fracturing. *Applied Geochemistry* 65: 73-86

56. D. Niu**, D. Renock, M. Whitehouse, J. Leone, Harry Rowe, J. Landis, K. Hamren*, C. W. Symcox*, and M. Sharma (2016) A relict sulfate–methane transition zone in the mid-Devonian Marcellus Shale. *Geochimica et Cosmochimica Acta* 182: 73–87

57. M. Sharma (2016) Determination of high precision isotope ratios in returned samples using multi-ion counting. *Lunar and Planet Sci Conf*. [#2679].

58. P. Cohen, J. Strauss, A. Rooney, M. Sharma & N. Tosca (2017) Controlled hydroxyapatite biomineralization in an ~810 million year old unicellular eukaryote. *Science Advances*. 2017;3: e1700095 28 June 2017.

59. J-H Seo, C. Han, J. P. Steffensen, S. Hong, and M. Sharma (2017) Osmium isotopes at the onset of Younger Dryas using the GRIP ice core. *Lunar and Planet Sci Conf.* [#3005].

60. J. D. Landis, M. Sharma, D. Renock, and D. Niu. (2018) Rapid desorption of radium isotopes from black shale during hydraulic fracturing. 1. Source phases that control the release of Ra from Marcellus shale. (Revision in review): *Chemical Geology*.

61. D. Landis, M. Sharma, and D. Renock (2018) Rapid desorption of radium isotopes from black shale during hydraulic fracturing. 2. A model reconciling radium extraction with Marcellus wastewater production. (Revision in review): *Chemical Geology*.

62. G. Janakiraman Paramasivan, M. Sharma, A. Jurewicz, D. Burnett (2018) A Procedure to Cleanly Separate Solar Wind Osmium Embedded in Genesis Silicon Collectors. *Lunar and Planet Sci Conf.* [#2886].

63. J. Seo, E. Osterberg, B.P. Jackson, and M. Sharma. (2018) Determination of Osmium concentration and isotope composition at ultra-low level in polar ice and snow. (being revised) *Analytical Chemistry.*

64. W.F. Bottke, D. Vokrouhlický, J.R. Moore, M.Sharma, S. Robbins, M. Banks, and H. Hallock (2018) Empirical Crater Scaling Laws and the Projectile Sizes Needed to Make Large Craters. (To be Submitted to *Icarus).*

ABSTRACTS

1. A.R. Basu, B.E. Faggart, Jr., and M. Sharma (1988) Sm-Nd isotopic study of wollastonite skarn and garnet-amphibolite metamorphism in the Adirondack Mountains, New York. *Trans. Amer. Geophys. Union* **69** (16), 468.

2. A.R. Basu, B.E. Faggart, Jr., and M. Sharma (1989) Implications of Nd-Isotopic study of Proterozoic Garnet Amphibolites and Wollastonite Skarns from the Adirondack Mountains, New York. *Inter. Geol. Congr. Washington, D.C.* **1**, 95-96.

3. M. Sharma, A.R. Basu, and P.G. DeCelles (1989) Nd-Sr isotopes and trace element geochemistry of Amazonian fluvial sands from Bolivia and Peru: Implications of magma contamination in Central Volcanic Zone (CVZ) and tectonics of the Andes. *Geol. Soc. America Abstr. with Programs*, A-190.

4. M. Sharma, R.B. Cole, P.G. DeCelles, and A.R. Basu (1990) Basalt-Dacite Volcanism by MORB-Continental Crust interaction: Sr-Nd isotopic and trace element evidence, Tecuya volcanics, Southern California. *Trans. Amer. Geophys. Union* **71** (17), 665.

5. A.R. Basu and M. Sharma (1990) Hotspots, Mantle Plumes, and the origin of Continental Flood Basalts. *Trans. Amer. Geophys. Union* **71** (43), 1669.

6. M. Sharma, A.R. Basu, and G.V. Nesterenko (1990) Nd, Sr-Isotopic geochemistry and petrogenesis of the Siberian Flood Basalts. *Trans. Amer. Geophys. Union* **71** (43), 1669.

7. M. Sharma and A.R. Basu (1991) Continental Flood Basalt Volcanism: a general model. *Geol. Soc. America Abstr. with Programs*, A-331.

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