

ERIC L. SONNENTHAL, Ph.D. – Curriculum Vitae

Earth Sciences Division, 1 Cyclotron Rd., MS84R0171
Lawrence Berkeley National Laboratory, Berkeley, CA 94720
Phone: 510-486-5866 Email: elsonnenthal@lbl.gov
Fax: 510-486-5686

Research Interests And Activities

Investigation of geochemical and isotopic processes coupled to thermal, hydrological, and mechanical effects in geological and engineered systems. Development of reaction transport models for water-gas-rock interaction applied to geological emplacement of nuclear waste, environmental remediation, enhanced geothermal systems, hydrothermal processes, vadose zone transport, and CO₂ sequestration. Co-developer of the widely used multiphase reaction-transport code TOUGHREACT. Author of reaction-transport-mechanical codes for sedimentary basin compaction and multicomponent magma crystallization.

Professional Preparation

Pennsylvania State University	B.S. Geosciences, Geochemistry option, 1982
University of Oregon	Ph.D. Geological Sciences, 1990
Indiana University	Postdoctoral Fellow, Geochemistry, 1990-1993
French Institute of Petroleum	Postdoctoral Scientist, Geochemistry, 1993-1994

Appointments

Staff Geological Scientist, Lawrence Berkeley National Laboratory, Earth Sciences Division, 2004–. Associate Researcher, University of California, Berkeley, Earth and Planetary Science, 2009–2011. Geological Scientist, Lawrence Berkeley National Laboratory, Earth Sciences Division, 1996-2004. Visiting Instructor, Department of Geological Sciences, University of Oregon, 1995.

Current Projects

Sonnenthal E., J. Rutqvist, and S. Nakagawa. Coupled Thermal-Hydrological-Mechanical-Chemical Model And Experiments For Optimization Of Enhanced Geothermal System Development And Production.

Sonnenthal E., J. Christensen, S. Nakagawa, S. Brown. Integration of Nontraditional Isotopic Systems Into Reaction--Transport Models of EGS For Exploration, Evaluation of Water-Rock Interaction, and Impacts of Water Chemistry on Reservoir Sustainability.

Sonnenthal E., M. Kennedy, N. Spycher. Evaluation of Stimulation at the Newberry Volcano EGS Demonstration Site through Natural Isotopic Reactive Tracers.

Sonnenthal E., D. Elsworth, R. Lowell, K. Maher, B. Mailloux, and N. Uzunlar. NSF: *Collaborative Research: Coupled Thermal-Hydrological-Mechanical-Chemical-Biological Experimental Facility at DUSEL Homestake*.

AltaRock Energy (Lead), E. Sonnenthal (LBNL PI), J. Rutqvist. Geochemistry and THMC Models in Support of the Newberry EGS Demonstration Project.

Elsworth D. (Penn State Univ), J. Taron (USGS), and E. Sonnenthal (LBNL PI). THMC Modeling of EGS Reservoirs – Continuum through Discontinuum Representations: Capturing Reservoir Stimulation, Evolution and Induced Seismicity.

Spycher N., M. Kennedy, E. Sonnenthal. Integrated Chemical Geothermometry System for Geothermal Exploration.

Simmons S. (Colorado School of Mines), N. Spycher, E. Sonnenthal, P. Dobson. Advances in Hydrogeochemical Indicators for the Discovery of New Geothermal Resources in the Great Basin, USA.

Pau, G. S. Finsterle, E. Sonnenthal. LBNL Innovation Grant: New Parallel Software Framework For TOUGH Suite of Codes.

Peer-Reviewed Publications

- Aradóttir, E.S.P., B. Sigfussen, E.L. Sonnenthal, G. Björnsson, & H. Jónsson (2013). Dynamics of basaltic glass dissolution - Capturing microscopic effects in continuum-scale models. *Geochimica et Cosmochimica Acta*, in press.
- Finsterle, S., Sonnenthal E.L., and N. Spycher, 2013. *Advances in subsurface modeling using the TOUGH suite of simulators*. Computers & Geosciences, in press.
- Wanner C. and E.L. Sonnenthal. *Assessing the control on the effective kinetic Cr isotope fractionation factor: A reactive transport modeling approach*, 2013. *Chemical Geology*, 337-338: 88-98.
- Aradóttir, E.S.P., E.L. Sonnenthal, G. Björnsson, & H. Jónsson, 2012. *Multidimensional reactive transport modeling of CO₂ mineral sequestration in basalts at the Hellisheidi geothermal field, Iceland*. *International Journal of Greenhouse Gas Control*, 9:24-40.
- Aradóttir, E.S.P., E.L. Sonnenthal, & H. Jónsson, 2012. *Development and evaluation of a thermodynamic dataset for phases of interest in CO₂ mineral sequestration in basaltic rocks*. *Chemical Geology*, 304-305:26-38.
- Kim J., E. Sonnenthal, & J. Rutqvist, 2012. *Formulation and sequential numerical algorithms of coupled fluid/heat flow and geomechanics for multiple porosity materials*. *Int. J. Numer. Meth. Engng.*, 92:425-456.
- Xu, T., N. Spycher, E. Sonnenthal, G. Zhang, L. Zheng, & K. Pruess, 2011. *TOUGHREACT Version 2.0: A simulator for subsurface reactive transport under non-isothermal multiphase flow conditions*. *Computers and Geosciences*, 37:763–774.
- Hazen T.C., E.A. Dubinsky, T.Z. DeSantis, G.L. Andersen, Y.M. Piceno, N. Singh, J.R. Jansson, A. Probst, S.E. Borglin, J. L. Fortney, W. T. Stringfellow, M. Bill, M.S. Conrad, L.M. Tom, K.L. Chavarria, T.R. Alusi, R. Lamendella, D.C. Joyner, C. Spier, J. Baelum, M. Auer, M. L. Zemla, R. Chakraborty, E.L. Sonnenthal, P. D'haeseleer, H-Y. N. Holman, S. Osman, Z. Lu, J.D. Van Nostrand, Y. Deng, J. Zhou, and O.U. Mason, 2010. *Deep-sea oil plume enriches indigenous oil-degrading bacteria*. *Science* [DOI: 10.1126/science.1195979].
- Zhang, G., N. Spycher, E. Sonnenthal, and C. Steefel, 2009. *Modeling acid-gas generation from boiling chloride brines*. *Geochemical Transactions*, 10 (11).
- Mukhopadhyay, S., E.L. Sonnenthal, and N. Spycher, 2009. Modeling of coupled heat transfer and reactive transport processes in porous media: Application to seepage studies at Yucca Mountain, Nevada. *Journal of Porous Media*, 12:725-748.
- Zhang, G., N. Spycher, E. Sonnenthal, C. Steefel, and T. Xu, 2008. *Modeling reactive multiphase flow and transport of concentrated solutions*. *Nuclear Technology*, 164:180-195.
- Lu, G., E.L. Sonnenthal, and G.S. Bodvarsson, 2008. *Multiple component end-member mixing model of dilution: hydrochemical effects of construction water at Yucca Mountain, Nevada, USA*. *Hydrogeology Journal*, 16:1517-1526.
- Mukhopadhyay S., E.L. Sonnenthal, and N. Spycher, 2006. *Modeling coupled thermal-hydrological-chemical processes in the unsaturated fractured rock of Yucca Mountain, Nevada: heterogeneity and seepage*. *Physics and Chemistry of the Earth*, 31:626-633.
- Xu, T., E. Sonnenthal, N. Spycher, and K. Pruess, 2006. *TOUGHREACT: A simulation program for non-isothermal multiphase reactive geochemical transport in variably saturated geologic media: Applications to geothermal injectivity and CO₂ geological sequestration*. *Computers & Geosciences*. 32:145-156.
- Sonnenthal, E., A. Ito, N. Spycher, M. Yui, J. Apps, Y. Sugita, M. Conrad, and S. Kawakami, 2005. *Approaches to modeling coupled thermal, hydrological, and chemical processes in the Drift Scale Heater Test at Yucca Mountain*. *International Journal of Rock Mechanics and Mining Sciences*, 42:698-719.
- Sonnenthal, E., T. Xu, and G. Bodvarsson, 2005. *Reply to "Commentary: Assessment of past infiltration fluxes through Yucca Mountain on the basis of the secondary mineral record – is it a viable methodology?"*, by Y.V. Dublyansky and S.Z. Smirnov. *Journal of Contaminant Hydrology*. 77: 225-231.
- Sonnenthal, E.L., N.F. Spycher, M. Conrad, and J. Apps, 2004. *A conceptual and numerical model for thermal-hydrological–chemical processes in the Yucca Mountain Drift Scale Test*. In: Stephansson, O., J.A. Hudson, and L. Jing, ed., *Coupled Thermo-Hydro-Mechanical-Chemical Processes in Geo-Systems, Fundamentals, Modelling, Experiments and Applications*. Elsevier Geo-Engineering Book Series, volume 2, p. 347-352.

- Singleton, M.J., E.L. Sonnenthal, M.E. Conrad, D.J. DePaolo, and G.W. Gee, 2004. *Multiphase reactive transport modeling of stable isotope fractionation in unsaturated zone pore water and vapor: Application to seasonal infiltration events at the Hanford Site, WA*. *Vadose Zone Journal*, 3: 775-785.
- Dobson, P.F., S. Salah, N. Spycher, and E.L. Sonnenthal, 2004. *Simulation of water-rock interaction in the Yellowstone geothermal system using TOUGHREACT*. *Geothermics* 33: 493-502.
- Lu, G., E.L. Sonnenthal, and G.S. Bodvarsson, 2003. *Implications of halide leaching on chlorine-36 studies at Yucca Mountain, Nevada*. *Water Resources Research*, 39(12): 1361, 3-1-15.
- Xu, T., E. Sonnenthal, and G.S. Bodvarsson, 2003. *A reaction-transport model for calcite precipitation and evaluation of infiltration fluxes in unsaturated fractured rock*. *Journal of Contaminant Hydrology*, 64:113-127.
- Dobson, P.F., T.J. Kneafsey, E.L. Sonnenthal, N.F. Spycher, and J.A. Apps, 2003. *Experimental and numerical simulation of dissolution and precipitation: Implications for fracture sealing at Yucca Mountain, Nevada*. *Journal of Contaminant Hydrology*. 62-63: 459-476.
- Liu, J., E. Sonnenthal, and G.S. Bodvarsson, 2003. *Modeling of porewater chloride data to calibrate flow and transport processes in the unsaturated Zone at Yucca Mountain, Nevada*. *Journal of Contaminant Hydrology*. 62-63: 213-235.
- Spycher, N., E. Sonnenthal, and J. Apps, 2003. *Prediction of fluid flow and reactive transport around potential nuclear waste emplacement tunnels at Yucca Mountain, Nevada*. *Journal of Contaminant Hydrology*, 62-63: 653-673.
- Bodvarsson, G.S., H.H. Liu, C.F. Ahlers, Y.S. Wu, and E.L. Sonnenthal, 2001. *Parameterization and upscaling in modeling flow and transport at Yucca Mountain*. In: *Conceptual Models of Flow and Transport in the Fractured Vadose Zone*, Chapter 11. National Academy of Sciences, National Academy Press, Wash. D.C., 335-365.
- Xu, T., E. Sonnenthal, N. Spycher, K. Pruess, G. Brimhall, and J.A. Apps, 2001. *Modeling multiphase fluid flow and reactive geochemical transport in variably saturated fractured rocks: 2. Applications to supergene copper enrichment and hydrothermal flows*. *American Journal of Science*, 301: 34-59.
- Bodvarsson, G.S., S. Finsterle, H.H. Liu, C.M. Oldenburg, K. Pruess, E. Sonnenthal, and Y-S. Wu, 2000. *Flow and Transport Modeling of Subsurface Systems*. In: *Vadose Zone Science and Technology Solutions*, Chapter 5. B.B. Loomy and F.W. Faltz, eds. Battelle Press: Columbus, Ohio, 2: 591-784.
- Sonnenthal, E.L. and G.S. Bodvarsson, 1999. *Constraints on the hydrology of the unsaturated zone and infiltration at Yucca Mountain, Nevada from three-dimensional models of chloride and strontium geochemistry*, *Journal of Contaminant Hydrology*, 38: 107-156.
- Sonnenthal, E.L. and A.R. McBirney, 1998. *The Skaergaard Layered Series. Part IV. Reaction-transport simulations of foundered blocks*. *Journal of Petrology*, 39(4): 633-661.
- Sonnenthal, E.L. and P.J. Ortoleva, 1994. *Numerical simulation of overpressured compartments in sedimentary basins*. In: *Basin Compartments and Seals*, American Association of Petroleum Geologists Memoir 61, 403-416.
- Sonnenthal, E.L., 1992. *Geochemistry of dendritic anorthosites and associated pegmatites in the Skaergaard Intrusion, East Greenland: Evidence for metasomatism by a chlorine-rich fluid*. *Journal of Volcanology and Geothermal Research*, 52: 209-230.
- McBirney, A.R. and E.L. Sonnenthal, 1990. *Metasomatic processes in the Skaergaard Intrusion: preliminary observations*. *Chemical Geology*, 88: 245-260.
- Roy, D.M., E. Sonnenthal and R. Prave, 1985. *Hydrocalcite observed in mortars exposed to sulfate solutions*. *Cement and Concrete Research*, 15: 912-916.

Proceedings Papers (since 2006)

- Peiffer, L., Wanner, C., Spycher, N., Sonnenthal, E., 2013. *Multicomponent vs. Classical Geothermometry: An Evaluation using Reactive Transport Modeling*. *Procedia Earth and Planetary Science*, 7:665-668.
- Wanner, C., Peiffer, L., Sonnenthal, E., Spycher, N., 2013. *On the use of Chemical Geothermometry: A Reactive Transport Modeling Study of the Dixie Valley Geothermal Area*. *Procedia Earth and Planetary Science*, 7:884-887.
- Aradóttir, E.S.P., I. Gunnarsson, B. Sigfússon, G. Gunnarsson, E. Gunnlaugsson, H. Sigurðardóttir, E.J. Ásbjörnsson, and E. Sonnenthal, 2012. *Towards Cleaner Geothermal Energy Utilization: Capturing and Sequestering CO₂ and H₂S Emissions From Geothermal Power Plants*. *Proceedings, TOUGH Symposium 2012*, Lawrence Berkeley National Laboratory, Berkeley, CA.

- Keen, N., G. Pau, J. Johnson, E. Sonnenthal, S. Finsterle, 2012. A New Library to Improve TOUGH Parallel Performance. *Proceedings, TOUGH Symposium 2012*, Lawrence Berkeley National Laboratory, Berkeley, CA.
- Kim J., E. Sonnenthal, and J. Rutqvist, 2012. A Sequential Implicit Algorithm Of Chemo-Thermo-Poro-Mechanics For Fractured Geothermal Reservoirs. *Proceedings, TOUGH Symposium 2012*, Lawrence Berkeley National Laboratory, Berkeley, CA.
- Rinaldi A.P., J. Rutqvist, E.L. Sonnenthal, and T.T. Cladouhos, 2012. TOUGH-FLAC Coupled THM Modeling Of Proposed Stimulation At The Newberry Volcano EGS Demonstration. *Proceedings, TOUGH Symposium 2012*, Lawrence Berkeley National Laboratory, Berkeley, CA.
- Sonnenthal E., N. Spycher, O. Callahan, T. Cladouhos, and S. Petty. A thermal-hydrological-chemical model for the Enhanced Geothermal System Demonstration Project at Newberry Volcano, Oregon., 2012. PROCEEDINGS, Thirty-Seventh Workshop on Geothermal Reservoir Engineering Stanford University, Stanford, California, January 30 - February 1, 2012 SGP-TR-194.
- Spycher N., Sonnenthal, E.L., Kennedy, B.M., 2011. Integrating multicomponent chemical geothermometry with parameter estimation computations for geothermal exploration. *Geothermal Resource Council Transactions*. **35**, 663-666.
- Palguta J., C.F. Williams, S.E. Ingebritsen, S.H. Hickman, and E. Sonnenthal, 2011. *An approach to modeling coupled thermal-hydraulic-chemical processes in geothermal systems*. PROCEEDINGS, Thirty-Sixth Workshop on Geothermal Reservoir Engineering Stanford University, Stanford, California, January 31 - February 2, 2011 SGP-TR-191.
- Aradottir, E.S.P., E. Sonnenthal, G. Bjornsson, E. Gunnlaugsson, and H. Jonsson, 2009. *Development of a coupled reactive fluid flow model for mineral CO₂ capture in Hellisheidi, Iceland*. TOUGH Symposium 2009.
- Druhan, J., E. Sonnenthal, and D. DePaolo, 2009. *Investigation of strontium isotopic exchange in single and dual continua using TOUGHREACT*. TOUGH Symposium 2009.
- Gupta, I., G. Jones, and E. Sonnenthal, 2009. *Reaction transport models of structurally controlled hydrothermal dolomite in carbonate reservoirs*. TOUGH Symposium 2009.
- Pau, G.S.H., A.S. Almgren, J.B. Bell, M.J. Lijewski, E. Sonnenthal, N. Spycher, T. Xu, and G. Zhang, 2009. *A parallel second-order adaptive mesh algorithm for reactive flow in geochemical systems*. TOUGH Symposium 2009.
- Xu, T., E. Sonnenthal, N. Spycher, G. Zhang, L. Zheng, and K. Pruess, 2009. *TOUGHREACT Version 2.0*. TOUGH Symposium 2009.
- Birkholzer, J.T., D. Barr, J. Rutqvist, E. Sonnenthal, 2006. *Motivation, description, and summary status of geomechanical and geochemical modeling studies in Task D of the international DECOVALEX-THMC project*. In: Advances on Coupled Thermo-Hydro-Mechanical-Chemical Processes in Geosystems and Engineering, Proceedings of the GEOPROC2006 International Symposium, Nanjing, China. 91-96.
- Dobson, P., Sonnenthal, E., Kennedy, M., Van Soest, T., and Lewicki, J., 2006. *Temporal changes in noble gas compositions within the Aidlin sector of The Geysers geothermal system*. Transactions, Geothermal Resources Council, 2006 Annual Meeting.
- Dobson, P., Sonnenthal, E., Lewicki, J., and Kennedy, M., 2006. *Evaluation of C-14 as a natural tracer for injected fluids at the Aidlin sector of The Geysers geothermal system through modeling of mineral-water-gas reactions*. Proceedings, TOUGH Symposium 2006, LBNL, Berkeley, CA, May 15-17, 2006.
- Hubbard, S., J. Chen, Y. Fang, K. Williams, S. Mukhopadhyay, E. Sonnenthal, K. McFarlane, N. Linde and T. Scheibe, 2006. *Improved parameterization of hydrological models and reduction of geophysical monitoring data ambiguity through joint use of geophysical and numerical modeling methods*. Invited Keynote Speaker, CWMR, Copenhagen, June 19-23, 2006.
- Rutqvist, J., X-T Feng, J. Hudson, L. Jing, A. Kobayashi, T. Koyama, P-Z Pan, H-S Lee, M. Rinne, E. Sonnenthal, and Y. Yamamoto, 2006. *Multiple-code benchmark simulation of coupled THMC processes in the excavation disturbed zone associated with geological nuclear waste repositories*. In: Advances on Coupled Thermo-Hydro-Mechanical-Chemical Processes in Geosystems and Engineering, Proceedings of the GEOPROC2006 International Symposium, Nanjing, China. 397-402.
- Xie, M., E. Sonnenthal, W. Wang, O. Kolditz, J.T. Birkholzer, J. Rutqvist, Y. Oda, and M. Chijimatsu, 2006. *Geochemical predictions for a hypothetical repository located in crystalline rock – comparative*

evaluation of different research teams. In: Advances on Coupled Thermo-Hydro-Mechanical-Chemical Processes in Geosystems and Engineering, Proceedings of the GEOPROC2006 International Symposium, Nanjing, China. 403-410.

Zhang, G., N. Spycher, Sonnenthal, E., and C. Steefel, 2006. *Implementation of a Pitzer Activity Model into TOUGHREACT for Modeling Concentrated Solutions.* Proceedings, TOUGH Symposium 2006, LBNL, Berkeley, CA, May 15-17, 2006.

Invention Disclosures

1. Toughreact V2.2G_OMP: Shared-Memory Parallel Version of Toughreact with New Features for Enhanced Geothermal Systems, 2013. E. Sonnenthal, N. Spycher, T. Xu, and N. Miller (Software disclosure submitted).

2. GeoT: A Computer Program for Multicomponent Geothermometry and Geochemical Speciation, 2013. N. Spycher, L. Peiffer, and E. Sonnenthal (<http://esd.lbl.gov/research/projects/geot/>).

3. Toughreact V2, 2012. T. Xu, N. Spycher, E. Sonnenthal, G. Zhang, and L. Zheng.

Recent Awards

2012 Director's Award for Exceptional Achievement in Tech Transfer

Recent Synergistic Activities

TOUGH Symposium 2012, 2009 co-organizer

DOE Geothermal Reservoir Modeling Working Group 2012-current.

Invited Presentations: Virginia Tech Geosciences Lecturer Series, April 12, 2013; UC Berkeley Earth and Planetary Science Dept. Fall Colloquium, Fall 2008; International Workshop on Modelling Reactive Transport in Porous Media, Strasbourg, France, Jan. 21-24, 2008; Global Nuclear Energy Partnership: Waste Form S&T and Modeling & Simulation Workshop, Univ. of Michigan, Ann Arbor, MI, Jan. 29-31, 2008.

TOUGHREACT Training Course Development and Instruction (courses in 2007, 2008, 2009, 2012, 2013).

TOUGHREACT Reaction-transport code co-developer (Xu, T., E. Sonnenthal, N. Spycher, and K. Pruess). Available from Dept. of Energy Software Center and LBNL Tech Transfer, and widely used internationally in universities, national laboratories, and industry.

Working Group Leader – Deep Underground Science and Science and Engineering Laboratory (DUSEL) Induced Flow, Transport, and Activity, (2004-2006, 2008)

International DECOVALEX-THMC Project: Coupled Thermal-Hydrological-Mechanical-Chemical processes, Lead for THC tasks, 2005-2007.

Recent Student Mentoring

Amelia Paukert, 2012-current. Ph.D. student, Columbia University.

Edda Aradottir, 2007-2011. Ph.D. dissertation committee. University of Iceland.