

B. Mack Kennedy

EDUCATION:

Ph.D., Earth and Planetary Sciences and McDonnell Center for Space Sciences, Washington University, St. Louis, Missouri, 1981.

B.A., Earth and Planetary Sciences, Washington University, St. Louis, Missouri, 1974.

RESEARCH INTERESTS:

Application of isotope techniques to further our understanding of the origin, history, and current processes acting on the earth and solar system. Specifically, noble gas isotope geochemistry as applied to sources, geochemical evolution, transport processes, and flow rates of fluids in the crust, cosmogenic and radiometric dating techniques, tectano-magmatic processes, and paleoclimatology. Research areas of application include geothermal energy, fossil energy, and basic energy sciences.

PROFESSIONAL EXPERIENCE:

2001-present: Program Lead: Geothermal Energy Development, Earth Science Division, LBNL.

1999-present: Group Leader: Center for Isotope Geochemistry, Earth Science Division, LBNL.

1995-2001: Group Leader: Environmental Measurements Laboratory, Earth Science Division, LBNL.

1991-present: Staff Scientist, Earth Science Division, Lawrence Berkeley National Laboratory.

1990-1991; 2000-present: Lecturer, Department of Earth and Planetary Science, UC Berkeley.

1990-1992: Asst. Research Geophysicist V, Department of Physics, Univ. of California, Berkeley.

1985-1990: Asst. Research Geophysicist I-IV, Department of Physics, Univ. of California, Berkeley.

1981-1985: Post Doctoral Research Assistant, Department of Physics, Univ. of California, Berkeley.

1969-1971: United States Army; Honorable Discharge, June, 1971.

PUBLICATIONS

A. Journal Articles

1. Brown S.T., Kennedy B.M., DePaolo D.J. and Evans W.C. (2008) Isotopic constraints on the chemical evolution of geothermal fluids, Long Valley, CA. *Trans. Geothermal Res. Council*, 32, 269-272. (extended abstract). LBNL-2411E.
2. Dressel P.E., Olsen K.B., Hayes J.C., McIntyre J.I., Waichler S.R., Milbrath B.D, Cooper M., and Kennedy B.M. (2008), Environmental application of stable xenon and radioxenon monitoring. *Journal of Radioanalytical and Nuclear Chemistry*, v276, No.3, 763-769. LBNL# 61563.
3. Kennedy, B.M. and van Soest, M.C. (2007), Flow of mantle fluids through the ductile lower crust: helium isotope trends. *Science* 318, 1433-1436. LBNL# 63575.
4. Christenson, B.W., Kennedy, B.M., Adams, M.C., Bjornstad, S.C., and Buck, C. (2007), Chemical and isotopic characteristics of the Coso East Flank hydrothermal fluids: implications for the location and nature of the heat source. *Proceedings, 32nd Workshop on Geothermal Reservoir Engineering, Stanford Geothermal Program ReportSGP-TR-183*. LBNL# 62359.
5. Aciego, S.M., DePaolo, D.J., Kennedy, B.M., Lamb, M.P., Sims, K., and Dietrich, W. (2007), Combining [³He] cosmogenic dating with U-Th/He eruption ages using olivine in basalt. *Earth Planet. Sci Lett.*, doi:10.1016/j.epsl.2006.11.039. LBNL# 62379.
6. Kennedy, B.M. and van Soest, M. (2006), A systematic regional trend in helium isotopes across the northern Basin and Range Province, western North America. *Trans. Geothermal Res. Council, 2006 Annual Meeting, San Diego, CA*. (extended abstract). LBNL# 61338.
7. Dobson, P., Sonnenthal, E., Kennedy, B.M., van Soest, M., and Lewicki, J. (2006), Temporal changes in noble gas compositions within the Aidlin sector of The Geysers geothermal system. *Trans. Geothermal Res. Council, 2006 Annual Meeting, San Diego, CA*. (extended abstract). LBNL# 60159.
8. Dobson, P., Sonnenthal, E., Lewicki, J., and Kennedy, B.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. *Proc., TOUGH Symposium 2006, LBNL, Berkeley, CA, May 15-17, 2006* (extended abstract). LBNL# 60321.
9. Kennedy, B.M. and van Soest, M.C. (2005), A helium isotope perspective on the Dixie Valley, Nevada hydrothermal system. *Geothermics*, 35, 26-43. LBNL# 60930.

10. Kennedy, B.M. and van Soest, M. (2005), Regional and local trends in helium isotopes, Basin and Range Province, western North America: evidence for deep permeable pathways. Trans. Geothermal Res. Council, 2005 Annual Meeting, Reno, NV. (extended abstract). LBNL# 59811.
11. Patterson, L.J., Sturchio, N.C., Kennedy, B.M., van Soest, M.C., Sultan, M., Lehmann, B., Purtschert, R., El Alfy, Z., El Kaliouby, B., Dawood, Y., and Abdallah, A. (2005), Cosmogenic, radiogenic, and stable isotopic constraints on groundwater residence time in the Nubian Aquifer, Western Desert of Egypt. *Geochem., Geophys., Geosystems*, v.6, 1-19. LBNL# 57471
12. Barker, B., Kennedy, M., Hoversten, M., van Soest, M.C., and Williams, K. (2005), Geothermal exploration at Fort Bidwell, California. Proceedings, 30th Workshop on Geothermal Reservoir Engineering, Stanford Geothermal Program ReportSGP-TR-176. LBNL# 57275.
13. Torgersen, T., Kennedy, B.M., and van Soest, M.C. (2004), Diffusive separation of noble gases and noble gas abundance patterns in sedimentary rocks. *Earth Planet. Sci. Lett.*, v226, 477-489. LBNL# 55507
14. Aciego, S., Kennedy, B.M., DePaolo, D.J., Christensen, J.N., and Hutcheon, I. (2003). U-Th-He age of phenocrystic garnet from the 79AD eruption of Mt. Vesuvius. *Earth Planet. Sci. Lett.*, v216, 209-219. LBNL# 53622
15. Kennedy, B.M., Torgersen, T., and van Soest, M.C. (2002), Multiple atmospheric noble gas components in hydrocarbon reservoirs: a study of the Northwest Shelf, Delaware Basin, SE New Mexico. *Geochim. Cosmochim. Acta*, v.66, 2807-2822. LBNL# 47387
16. Evans, W.C., Sorey, M.L., Cook, A.C., Kennedy, B.M., Shuster, D.L., Colvard, E.M., White, L.D., and Huebner, M.A. (2002), Tracing and quantifying magmatic carbon discharge in cold groundwaters: lessons learned from Mammoth Mountain, USA. *J. Volc. Geotherm. Res.*, v.114, 291-312. LBNL# 50610
17. Christenson, B.W., Mrocek, E.K., Kennedy, B.M., van Soest, T., Stewart, M.K., and Lyon, G. (2002), Ohaaki reservoir chemistry: Characteristics of an arc-type hydrothermal system in the Taupo Volcanic Zone, New Zealand. *J. Volc. Geothermal. Res.*, v.115, 53-82. LBNL# 48570
18. Evans, W.C., Sorey, M.L., Kennedy, B.M., Stonestram, D.A., Rogie, D.L., and Shuster, D.L. (2001), High CO₂ emissions through porous media: transport mechanisms and implications for flux measurement and fractionation. *Chemical Geology*, 177, pp. 15-29. LBNL# 46482
19. DePaolo, D.J., Bryce, J.G., Dodson, A., Shuster, D.L., and Kennedy, B.M. (2001), Isotopic evolution of Mauna Loa and the chemical structure of the Hawaii plume. *Geochemistry, Geophysics, Geosystems*, v2, U1-U32. LBNL# 50611
20. Ping, Z., Kennedy, B.M., Shuster, D., Ji, D., Ejun, X., and Shaoping, D. (2001), Implications of noble gas geochemistry in the Yangbajing geothermal field, Tibet. *Proc. 10th Water-Rock Interaction Symposium (WRI-10), Villasimius, Italy*, v. 2, pp. 947-950.
21. Moore, J.N., Norman, D.I., and Kennedy, B.M. (2001), Fluid inclusion gas compositions from an active magmatic hydrothermal system: a case study of The Geysers geothermal field, USA. *Chemical Geology*, V173, p. 3-30.
22. Preuss, K., O'Sullivan, M.J., and Kennedy, B.M. (2000), Modeling of Phase-Partitioning Tracers in Fractured Reservoirs. Proceedings, 25th Workshop on Geothermal Reservoir Engineering, Stanford Geothermal Program ReportSGP-TR-165, pp. 167-173.
23. Kennedy, B.M., Fischer, T.P., and Shuster, D.L. (2000), Heat and Helium in Geothermal Systems. Proceedings, 25th Workshop on Geothermal Reservoir Engineering, Stanford Geothermal Program ReportSGP-TR-165, pp. 167-173.
24. Kennedy, B.M. and Shuster, D.L. (2000), Noble gases: sensitive natural tracers for detection and monitoring injectate returns to geothermal reservoirs. *Geothermal Res. Council. Trans.*, V24, p. 247-252.
25. Sorey, M., Evans, B., Kennedy, B.M., Rogie, J. and Cook, A. (1999), Magmatic gas emissions from Mammoth Mountain. *California Geology*, September/October, pp. 4-16.
26. Torgersen, T. and Kennedy, B.M. (1999), Air-Xe enrichments in Elk Hills oil field gases: role of water in migration and storage. *Earth Planet. Sci. Lett.*, 167, pp. 239-253.
27. Kennedy, B.M., Janik, K., Benoit, D., and Shuster, D. (1999). Natural geochemical tracers for injectate fluids at Dixie Valley. *Proc. 24th Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, California, January 25-27, 1999*, 108-115.
28. Dodson, A., DePaolo, D.J., and Kennedy, B.M. (1998), Helium isotopes in lithospheric mantle: evidence from Tertiary basalts of the Western U.S.. *Geochim. Cosmochim. Acta*, 62, pp. 3775-3788.

29. Sorey M.L., Evans W.C., Kennedy B.M., Farrar C.D., Hainsworth, H.A., and Hausback, B. (1998), Carbon dioxide and helium emissions from a reservoir of magmatic gas beneath Mammoth Mountain, California. *J. Geophys. Res.*, 103, pp. 15,303-15,323.
30. Evans, W.C., Sorey, M.L., Michel, R.L., Kennedy, B.M., and Hainsworth, L.J. (1998), Gas-water interaction at Mammoth Mountain, California. *Water-Rock Interaction* (Aerhart and Hulston, eds.), 9, pp. 443-446.
31. Kharaka, Y.K., Thordsen, J.J., Evans, W.C., and Kennedy, B.M. (1998), Fluids and faults: the chemistry, origin and interactions of fluids associated with the San Andreas fault system, California, USA. *Water-Rock Interaction* (Aerhart and Hulston, eds.), 9, pp. 781-784.
32. Pili, E., Kennedy, B.M., Conrad, M.S., Gratier, J.-P., and Poitrasson, F. (1998), Isotope constraints on the involvement of fluids in the San Andreas fault system, California. *Proc. Goldschmidt Conference*.
33. Dickens, G.R. and Kennedy, B.M. (1998), Noble gases in methane hydrate from the Blake Ridge. *Proc. of the Ocean Drilling Program, Scientific Results*, v164, pp.165-170.
34. Kennedy B.M., Kharaka Y.K., Evans W.C., Ellwood A., DePaolo D.J., Thordsen J., Ambats G., and Mariner R.H. (1997), Mantle fluids in the San Andreas fault system, California. *Science* 278, pp. 1278-1281.
35. Dodson A., Kennedy B.M., and DePaolo D.J. (1997), Helium and neon isotopes in the Imnaha Basalt, Columbia River Basalt Group: Evidence for a Yellowstone Plume Source. *Earth Planet. Sci. Lett.* 150, pp. 443-451.
36. Kennedy B.M. and Truesdell A.H. (1996), The Northwest Geysers high-temperature reservoir: Evidence for active magmatic degassing and implications for the origin of The Geysers Geothermal Field. *Geothermics* 25 (3), pp. 365-387.
37. Kennedy B.M., Benoit D., and Truesdell A.H. (1996), A preliminary survey of noble gases at Dixie Valley, Nevada. *Trans. Geotherm. Res. Council* 20, pp. 815-820.
38. Farrar C.D., Sorey M.L., Evans W.C., Howle J.F., Kerr B.D., Kennedy B.M., King C.-Y., and Southon J.R. (1995), Forest-killing diffuse CO₂ emission at Mammoth Mountain as a sign of magmatic unrest. *Nature* 376, pp. 675-678.
39. Kennedy B.M. and Truesdell A.H. (1994), Active magmatic degassing in the NW Geysers high-temperature reservoir. *Trans. Geotherm. Res. Council* 18, pp. 325-330.
40. Fournier R.O., Kennedy B.M., Aoki M., and Thompson J.M. (1994), Correlation of gold in siliceous sinters with ³He/⁴He in hot spring waters of Yellowstone National Park. *Geochim. Cosmochim. Acta* 58, pp. 5401-5419.
41. Goff, F., Evans, W.C., Gardiner, J.N., Adams, A., Janik, C.J., Kennedy, B.M., Trujillo, P.E., and Counce, D. (1994), Interpretation of *in-situ* fluid samples from geothermal wells: example from hole VC-2B, Valles Caldera, New Mexico. *Geotherm. Sci. & Tech.*, 4(2), pp. 97-128.
42. Sorey M.L., Kennedy B.M., Evans W.C., Farrar C.D., and Suemnicht G.A. (1993) Helium isotope variations associated with crustal unrest in Long Valley Caldera, California, in 1989-1992. *J. Geophys. Res.* 98, 15871-15889.
43. Goff F., Kennedy B.M., Adam A.I., Truillo P.E., and Counce D. (1993), Hydrogeochemical evaluation of conventional and hot dry rock geothermal resource potential in the Clear Lake region, California. *Trans. Geotherm. Res. Council* 17, pp. 335-342.
44. Truesdell A.H., Walters M., Kennedy B.M., and Lippmann M. (1993), An integrated model for the origin of The Geysers geothermal field. *Trans. Geotherm. Res. Council* 17, pp. 273-280.
45. Hiyagon H. and Kennedy B. M. (1992), Noble gases in CH₄-rich gas fields, Alberta, Canada. *Geochim. Cosmochim. Acta*. 56, pp. 1569-1589.
46. Kennedy B.M., Hiyagon H., and Poths J. (1992), Anomalous ³He contents of CH₄-rich gases in sedimentary basins. *Proc. Int. Symp Water-Rock Interaction* 7, pp. 947-950.
47. Kharaka Y.K., Mariner R.H., Evans W.C., and Kennedy B.M. (1992). Composition of gases from the Norris-Mammoth corridor, Yellowstone National Park, USA; evidence for a magmatic source near Mammoth Hot Springs. *Proc. Int. Symp. Water-Rock Interaction* 7, pp. 1303-1307.
48. Kennedy B.M., Hiyagon H., and Reynolds J.H. (1991), Noble gases from Honduras geothermal sites. *J. Volcanology Geothermal Res.* 45, N1-2, pp. 29-39.
49. Kennedy B.M., Hiyagon H., and Reynolds J.H. (1990), Crustal neon: A striking uniformity. *Earth Planet. Sci. Lett.* 98, pp. 277-286.

50. Abrajano T.A., Sturchio N.C., Kennedy B.M., Lyon G.L., Muehlenbachs K., and Bohlke J.K. (1990), Geochemistry of reduced gas related to serpentinization of the Zambales Ophiolite. *Applied Geochemistry* V, pp. 625-630.
51. Hearn L., Kennedy B.M., and Truesdell A.H. (1990), Coupled variations in helium isotopes and fluid chemistry: Shoshone Geysers Basin, Yellowstone National Park. *Geochim. Cosmochim. Acta.* 54, pp. 3103-3113.
52. Torgersen T., Kennedy B.M., Hiyagon H., Chiou K.Y., Reynolds J.H., and Clarke W.B. (1989), Argon accumulation and the crustal degassing flux of ^{40}Ar in the Great Artesian Basin, Australia. *Earth Planet. Sci. Lett.* 92, pp. 43-46.
53. Kennedy B.M., Reynolds J.H., and Smith S.P. (1988), Noble gas geochemistry in thermal springs. *Geochim. Cosmochim. Acta* 52, pp. 1919-1928.
54. Kennedy B.M. (1988), Noble gases in vent water from the Juan de Fuca Ridge. *Geochim. Cosmochim. Acta* 52, pp. 1929-1935.
55. Kennedy B.M., Hudson B., Hohenberg C.M., and Podosek F.A. (1988), $^{129}\text{I}/^{127}\text{I}$ Variations among Enstatite Chondrites. *Geochim. Cosmochim. Acta.*, 52, pp. 101-112.
56. Hudson G.B., Kennedy B.M., Podosek F.A., and Hohenberg C.M. (1988), The early solar system abundance of ^{244}Pu as inferred from the St. Severin chondrite. *Proc. Lunar Planet. Sci. Conf XIXth, J. Geophys. Res.*, pp. 547-557.
57. Kennedy B.M., Reynolds J.H., Smith S.P., and Truesdell A.H. (1987), Helium isotopes: Lower Geysers Basin, Yellowstone National Park. *J. Geophys. Res.*, 92, pp. 12,477-12,490.
58. Kennedy B.M., Lynch M.A., Reynolds J.H., and Smith S.P. (1985), Intensive sampling of noble gases in fluids at Yellowstone: I. Early overview of the data; regional patterns. *Geochim. Cosmochim. Acta* 49, pp. 1251-1261.
59. Bernatowicz T.J., Kennedy B.M., and Podosek F.A. (1985), Xe in glacial ice and the atmospheric inventory of noble gases. *Geochim. Cosmochim. Acta* 49, pp. 2561-2564.
60. Smith S.P. and Kennedy B.M. (1985), Noble gas evidence for two fluids in the Baca (Valles Caldera) geothermal reservoir. *Geochim. Cosmochim. Acta* 49, pp. 839-902.
61. Smith S.P. and Kennedy B.M. (1982), The solubility of noble gases in water and NaCl brine. *Geochim. Cosmochim. Acta* 47, pp. 503-515.
62. Caffè M., Hohenberg C.M., Horz F., Hudson B., Kennedy B.M., Podosek F.A., and Swindle T. (1982), Shock disturbances of the I-Xe system. *Proc. Lunar Planet. Sci. Conf. 13th, J. Geophys. Res., Suppl.* 87, pp. A318-A330.
63. Hohenberg C.M., Hudson B., Kennedy B.M., and Podosek F.A. (1981), Noble gas retention chronologies for the St. Severin meteorite. *Geochim. Cosmochim. Acta* 45, pp. 535-546.
64. Hohenberg C.M., Hudson B., Kennedy B.M., and Podosek F.A. (1981), Xenon spallation systematics in Angra dos Reis. *Geochim. Cosmochim. Acta* 45, pp. 1909-1915.
65. Hohenberg C.M. and Kennedy B.M. (1981), I-Xe dating: Intercomparisons of neutron irradiations and reproducibility of the Bjurböle standard. *Geochim. Cosmochim. Acta* 45, pp. 251-256.
66. Bernatowicz T.J., Hohenberg C.M., Hudson B., Kennedy B.M., Laul J.C., and Podosek F.A. (1980), Noble gas component organization in 14301. *Proc. Lunar Sci. Conf. 11th, Geochim. Cosmochim. Acta, Suppl.* 14, pp. 629-668.
67. Hohenberg C.M., Hudson B., Kennedy B.M., and Podosek F.A. (1980), Fission xenon in troctolite 76535. *Proc. Lunar Highlands Conf., Geochim. Cosmochim. Acta, Suppl.* 12, pp. 419-439.
68. Bernatowicz T.J., Hohenberg C.M., Hudson B., Kennedy B.M., and Podosek F.A. (1978), Excess fission xenon at Apollo 16. *Proc. Lunar Sci. Conf. 9th, Geochim. Cosmochim. Acta, Suppl.* 10, pp. 1571-1597.
69. Bernatowicz T.J., Hohenberg C.M., Hudson B., Kennedy B.M., and Podosek F.A. (1978), Argon ages for lunar breccias 14064 and 15405. *Proc. Lunar Sci. Conf. 9th, Geochim. Cosmochim. Acta, Suppl.* 10, pp. 905-919.
70. Drozd R.J., Kennedy B.M., Morgan C.J., Podosek F.A., and Taylor G.J. (1976), The excess fission xenon problem in lunar samples. *Proc. Lunar Sci. Conf 7th, Geochim. Cosmochim. Acta, Suppl.* 7, pp. 599-623.

B. Books/Book Chapters

1. Kharaka, Y.K., Thordsen, J.J., Evans, W.C., and Kennedy, B.M. (1998), Geochemistry and hydromechanical interactions of fluids associated with the San Andreas fault system, California. In,

“Faults and Subsurface Fluid Flow”, Geophysical Monograph 113, Am. Geophysical Union, pp. 129-148.

2. Goff F., Gardner J.N., Hulen J.N., Nielson D.L., Charles R., WoldeGabriel G., Vuataz F.-D., Musgrave J.A., Shevenell L., and Kennedy B.M. (1991), The Valles caldera hydrothermal system, past and present, New Mexico, USA. Deep Drilling in Crystalline Bedrock, Vol. 3, Springer-Verlag, Berlin, 43 p.
3. Kharaka Y.K., Mariner R.H., Bullen T.D., Kennedy B.M., and Sturchio N.C. (1991) Geochemical investigations of hydraulic connections between the Corwin Springs Known Geothermal Resources Area and adjacent parts of Yellowstone National Park. In M.L. Sorey (ed.) U.S.G.S. Water Res. Invest. Rept. 91-4052, F1-F38.

C. Other

1. Kennedy, B.M. (2003), Book Review: “Noble Gases in Geochemistry and Cosmochemistry”, Reviews in Mineralogy and Geochemistry, v. 47. Porcelli, D. Ballentine, C.J., and Weiler, R. (editors). In EOS Trans. Am. Geophys. Un, Dec. 2003.

OPTIONAL

A. Honors

Outstanding Performance Award, Lawrence Berkeley National Laboratory, 1997.

B. Professional Service:

Member, California Geothermal Energy Collaborative (CGEC) Steering Committee

Co-Chair CGEC Geothermal Resource Committee

Co-Chair DOE Geothermal Technologies Program Committee on Reservoir Creation for Enhanced Geothermal Systems

Member: Safety Review Committee, LBNL (2000-2006).

Member: Safety Committee, Chemical Hazards, Earth Science Division, LBNL (1999-2006).

Lecturer, Department of Earth and Planetary Science, UC Berkeley.

IGPP Proposal Review Committee: 1996, 1997, 1999, 2001, 2003, 2004, 2006.

Chairman, IAEA Advisory Group Meeting: “State of the Art and Development Needs for Noble Gas Isotope Applications in Geothermal Reservoir Exploration and Monitoring”, Vienna, Austria, June, 2001.

Co-chairman, Scientific Program Committee, Eighth International Conference on Geochronology, Cosmochronology, and Isotope Geology.

C. Active Research Projects

1. Integrated Isotopic Studies of Geochemical Processes. Co-PI with Prof. D.J. DePaolo, Dept. of Geology and Geophysics, UC Berkeley and Drs. M.S. Conrad and John Christensen, Earth Science Division, LBNL. DoE Office of Energy Research, Office of Basic Energy Sciences, Engineering and Geosciences Division.
2. Air-Derived Noble Gases In Sediments: Sites for Acquisition of Trapped Components. Co-PI with Prof. Tom Torgersen, Dept of Marine Sciences, University of Connecticut. DoE Office of Energy Research, Office of Basic Energy Sciences, Engineering and Geosciences Division.
3. Development of Isotopic Techniques for Reservoir and Aquifer Characterization. PI, DoE Office of Energy Research, Office of Basic Energy Sciences, Engineering and Geosciences Division.
4. International Partnership for Geothermal Technology (IPGT) Support and Collaborative Research on Chemical and Isotopic Signatures of High Temperature Geothermal Systems, Iceland. PI, DoE, Energy Efficiency and Renewable Energy, Office of Geothermal Technologies.
5. Impact of Fluid Injection on Natural Isotopic Systems at EGS Sites. PI, DoE, Energy Efficiency and Renewable Energy, Office of Geothermal Technologies.
6. Integrated Approach to Use Natural Chemical and Isotopic Tracers to Estimate Fracture Spacing and Surface Area in EGS Systems. Co-PI, DoE, Energy Efficiency and Renewable Energy, Office of Geothermal Technologies.
7. Development of fluid injection strategies for optimizing steam production at The Geysers geothermal field, California. PI, PIER Research and Development Grant, California Energy Commission.

