

MICHAEL ANDERSON

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USA Repository Services LLC
1160 N. Town Center Drive
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CURRICULUM VITAE

SUMMARY

Twenty-eight years of experience in Nuclear and Mechanical Engineering, including work with two Nuclear Steam System Suppliers (NSSS) and nuclear fuel vendors. Experienced in thermal and structural analysis, design development and integration, and prototyping of storage canisters for nuclear waste. Also experienced in reactivity control and nuclear criticality analyses, ionizing radiation shielding analyses, radioactive nuclide inventory generation, nuclear core reload design, and BWR control blade design and analyses.

Extensive experience in managing resolution of challenging technical problems with teams of highly skilled engineers and analysts.

PROFESSIONAL EXPERIENCE

Yucca Mountain Project, Principal Engineer, Waste Package Design (USA Repository Services LLC), Responsible for maintaining the design and technical bases for the waste packages designs for the Yucca Mountain Project, as well as supporting responses to Requests for Additional information from the NRC for the Yucca Mountain License Application.

Yucca Mountain Project, Discipline Engineering Manager (Bechtel SAIC, LLC), Responsible for development of waste package designs for the Yucca Mountain Project, including demonstration of compliance to project requirements and interface with other design organizations. This includes technical supervision functions for as many as 15 to 20 design engineers, including structural, design, and thermal disciplines, and representing the project to both internal and external customers, including the NRC and Nuclear Waste Technical Review Board. Based on organizational structure, was also responsible for risk-informed, radionuclide source term and radiation shielding analyses.

Yucca Mountain Project, Advisory Engineer/Principal Engineer (Framatome Cogema Fuels), Served as Lead Engineer for waste package thermal analysis, including both in-package and extra-package thermal analysis. Led a team of five engineers, including all supervisory responsibilities. Prior to this was responsible for evaluations of PWR and BWR Critical Reactor Configurations to support Criticality Methodology Topical Report for Proposed Nuclear Waste Repository at Yucca Mountain.

GE Nuclear Energy, Principal Engineer/Senior Engineer, Acted as Responsible Engineer for Control Rod nuclear design and lifetime integration, including as primary contact for blade technical issues. Served as Responsible Engineer for a wide range of reactivity control issues, including new and spent fuel rack criticality margins, shipping container criticality compliance and Standby Liquid Control System (SLCS) margin requirements. Also involved in advanced conceptual core design. Prior to this, acted as technical lead with responsibility for BWR

Owners Group's Analytical Methodology for Detection and Suppression portion of Coupled Neutronic-Thermal-hydraulic Stability Long-term Solutions; served as liaison with BWROG Stability Committee, made presentation to ACRS, made presentations to NRC staff, supported preparation of Licensing Topical Reports; performed project management of resources and resource and schedule planning for the same. Exercised Reactivity Control Lead System Engineer responsibilities, including Reactivity Initiated Accidents (Control Rod Drop Accident and Control Rod Withdrawal Error), Scram Time Requirements, and Reactivity Control during Refueling.

Lockheed Aeronautical Systems Company, Senior Propulsion Engineer

S. Levy Incorporated, Senior Engineer

Portland General Electric, Associate Engineer

REGISTRATIONS AND CERTIFICATIONS

Professional Engineer: California, NU002285

U.S. PATENTS

5,742,651, "Method of Increasing Depletion Capacity of a Control Rod for a Nuclear Reactor"

6,226,340, "Hermaphroditic Absorber Loading for Higher Worth Control Rods"

EDUCATION

MSME, Stanford University, Stanford, CA

MSNE, Oregon State University, Corvallis, OR

BSNE, Oregon State University, Corvallis, OR

PROFESSIONAL AFFILIATIONS

American Society of Mechanical Engineers

American Nuclear Society

Tau Beta Pi

PUBLICATIONS

James, R. J., Jaquay, K. R., and Anderson, M. J., 2009. "Design by Analysis of Waste Packages at Yucca Mountain for Impact Loads," ICONE17-75355, *Proceedings of the 17th International Conference on Nuclear Engineering, ICONE17*, Brussels, Belgium, July 12-16, 2009.

Jaquay, K. R. and Anderson, M. J., 2008. "Yucca Mountain Project Structural Acceptance Criterion for Impact Loading of Waste Packages," IMECE2008-66537, *Proceedings of the 2008 ASME International Mechanical Engineering Congress & Exposition*, Boston, MA, October 31—November 6, 2008.

Jaquay, K. R. and Anderson, M. J., 2008. "Yucca Mountain Project Structural Fragility Estimates for Impact Loading of Waste Packages," IMECE2008-66538, Proceedings of the 2008 ASME International Mechanical Engineering Congress & Exposition, Boston, MA, October 31—November 6, 2008.

M. J. Anderson, et al., "Waste Package Design for License Application," 10th International High-level Waste Management Conference, Las Vegas NV, April 2003.

M. J. Anderson and D. P. Henderson, "BWR Benchmarking for Yucca Mountain Disposal Criticality Methodology," 1998 Winter Meeting of the American Nuclear Society, Washington, DC, November 1998.

D. P. Henderson and M. J. Anderson, "BWR Commercial Reactor Critical Benchmark Calculations using SAS2H and MCNP4A," 8th International High-level Waste Management Conference, Las Vegas NV, June 1998.

ROBERT ANDREWS

Personal

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Summary: Dr. Robert W. Andrews has over 30 years of project management and scientific geotechnical experience leading multidisciplinary groups of scientists and engineers in conducting site characterizations and evaluating the performance assessment of waste disposal sites and communicating these results and their bases to a range of stakeholders in a regulated setting.

Education:

- Ph.D., Geology, Hydrogeology, University of Illinois, Urbana-Champaign, Illinois
- M.S., Geology, Hydrogeology, University of Illinois, Urbana-Champaign, Illinois
- A.B. (Honors), Geology, Earlham College, Richmond, Indiana

Key Strengths:

- Exceptional written and oral communication skills including the synthesis of complex scientific understanding in regulatory documents and presenting results to external oversight boards
- Strong leadership and project management skills including the application of EVMS processes and process improvement techniques to scientific studies
- Extensive planning and implementation of site characterization testing and performance assessment models and analyses in a range of hydrogeologic settings
- Application of licensing and quality assurance requirements in a contentious regulated environment
- Integrator of scientific information to address design, performance assessment and licensing requirements
- Synthesize technically complex material related to groundwater contaminant fate and transport
- Develop conceptual approaches to model complex multidisciplinary physical-chemical processes related to waste management

Significant Accomplishments:

- Lead contributor to Yucca Mountain License Application, Site Recommendation Report, Final Environmental Impact Statement and Viability Assessment
- Lead integrator to ensure consistency and accuracy of performance assessment and related design technical documents supporting the Yucca Mountain License Application, successfully docketed by NRC in September 2008
- Led team of over 400 scientists and engineers from DOE national laboratories (Sandia, Berkeley, Livermore, Los Alamos and PNNL) and USGS in completing Yucca Mountain site characterization and performance assessment
- Published over 40 performance assessment articles and reports and represented DOE in presenting results to external review boards and regulators in over 20 public meetings.
- Published over 30 groundwater modeling and hydrogeologic data synthesis reports and articles
- Published over 20 hydrogeologic testing and data interpretation reports.

Honors/

Awards: DOE "Commitment to Performance Excellence" Award (2004, 2005)
DOE "Doer of Deeds" Award (2001)
Sandia National Laboratories Meritorious Achievement Award (1999)
DOE Outreach Program Awards (1996 – 1998)

Professional History:

- 2009** **Jason Associates** (part time) **Las Vegas, Nevada**
Nuclear and Regulatory Support Services, LLC (part time)
INTERA, Inc. (part time)
Scientific consulting
- Support review of responses to NRC requests for additional information on Yucca Mountain License Application, including Groundwater Supplement to the EIS. Support reviews of groundwater flow and contaminant transport boundary calculations at underground nuclear test sites on the Nevada Test Site.
- 2006– 2009** **Bechtel SAIC Company, LLC** **Las Vegas, Nevada**
Manager, Science Interface, Licensing and Nuclear Safety, Bechtel SAIC Company, LLC
- Responsible for ensuring accuracy and completeness of postclosure sections of Yucca Mountain License Application. Role includes ensuring consistency of repository design with postclosure design bases and integrating design and performance assessment.
- 2005-2006** **Bechtel SAIC Company, LLC** **Las Vegas, Nevada**
Project Manager, Performance Assessment Project, Licensing and Nuclear Safety, Bechtel SAIC Company, LLC
- Responsible for developing strategy, approach and technical plans to revise models and analyses to support the postclosure technical basis for the Yucca Mountain License Application. Responsible for ensuring plans were being effectively and efficiently implemented by the national laboratories to result in high quality products that were technically defensible and addressed regulatory acceptance criteria. Responsible for ensuring appropriate transition of work scope from M&O to Sandia.
- 2004-2005** **Bechtel SAIC Company, LLC** **Las Vegas, Nevada**
Senior Technical Staff, Licensing and Nuclear Safety, Bechtel SAIC Company, LLC
- Responsible for integrating and documenting post-closure safety case in the draft Safety Analysis Report and ensuring that the documented basis addressed all Nuclear Regulatory Commission acceptance criteria. Led BSC interactions with DOE and other government organizations in development and implementation of a peak dose performance assessment.
- 2001-2004** **Bechtel SAIC Company, LLC** **Las Vegas, Nevada**
Project Manager, Performance Assessment Project, Bechtel SAIC Company, LLC
- Responsible for scope, schedule and resources for all performance assessment activities to evaluate the potential high-level radioactive waste repository site at Yucca Mountain. Supervision/review of

technical work performed and earned value by staff and contractors including the national laboratories. Developed WBS dictionary and led performance reviews of over 4000 baseline activities. Managed and led the contribution of national laboratory and other subcontractor activities in support of Yucca Mountain performance assessment. Annual budget for total effort averaged about \$ 90 M, over 60% of which was with the four principal national laboratories (LBNL, SNL, LANL, and LLNL). Successfully led completion of postclosure portions of Yucca Mountain Site Recommendation Report and the Final Environmental Impact Statement as well as strategy to address NRC Key Technical Issue Agreements.

1995 - 2001 **Duke Engineering and Services, Inc. (parent of INTERA Inc)** **Las Vegas, Nevada**
High Level Waste Division Manager
Manager, Performance Assessment Department, Civilian Radioactive Waste Management System Management and Operating Contractor, TRW Environmental Safety Systems

Responsible for all performance assessment activities to evaluate the potential high-level radioactive waste repository site at Yucca Mountain. Supervision/review of technical work performed by other staff and contractors, notably Sandia to ensure completeness and quality. Management and integration of performance assessment activities with other M&O and DOE departments. Annual budget averaged about \$12 M during this time period.

1991 - 1995 **INTERA Inc.** **Vienna, Virginia**
High Level Waste Division Manager
Manager, Performance Assessment Branch, Civilian Radioactive Waste Management System Management and Operating Contractor, TRW Environmental Safety Systems

Responsible for M&O performance assessment activities to evaluate the potential high-level radioactive waste repository site at Yucca Mountain and potential Monitored Retrievable Storage designs. Supervision/review of technical work performed by about 15 FTE staff. Management and integration of all performance assessment activities performed by M&O including that performed by Sandia and other national lab staff. In 1995 INTERA Inc was purchased by Duke Engineering and Services, Inc.

1989-1991 **INTERA Inc.** **Austin, Texas**
Group Manager

Supervise about 6 FTE technical staff conducting well-test interpretation and hydrogeologic modeling of various waste disposal sites under consideration by NAGRA. Coordinated and performed business development in radioactive waste management, including successful proposal with TRW as the management and operating contractor for DOE.

1988 - 1989 **INTERA Inc.** **Baden, Switzerland**
Manager, Group for In-Situ Testing (UGIV), a cooperative agreement between INTERA and Motor Columbus Engineers.

Supervised the design, analysis and interpretation of all hydraulic testing conducted by NAGRA. In particular, supervised the interpretation of testing performed in boreholes drilled from access tunnels at the Oberbauenstock and Piz Pian Grand sites. Staff included INTERA and Motor Columbus scientists and averaged about 10 FTE.

1985 - 1988 **INTERA Inc.** **Austin, Texas**

Project Manager, Salt Site Performance Assessment Contract, Office of Nuclear Waste Isolation, Battelle Memorial Institute and Technical Field Support Contractor, Stone & Webster Engineering Corporation.

Planned, coordinated and performed sensitivity and uncertainty analysis of ground-water flow in the vicinity of salt sites proposed for a high level waste repository. Evaluated key data required during site characterization and optimum borehole locations to minimize uncertainty. Supervised all ground-water travel time uncertainty analyses presented in Draft and Final Environmental Assessments for all salt sites under consideration by DOE for high-level radioactive waste disposal. Total staff managed averaged about 8 FTE during the time period.

1984 - 1985**INTERA Inc.****Baden, Switzerland**

Project Staff, NAGRA Nationale Genossenschaft fur die Lagerung radioactive Abfalle (Swiss Cooperative for the storage of radioactive wastes)

Responsible for coordinating performance assessments related to regional ground-water hydrology and coupled thermal-hydrologic modeling and providing an interface between ground-water flow and radionuclide transport modelers. Provided liaison between field data collection/interpretation group and performance assessment groups within NAGRA and NAGRA contractors..

1981 - 1984**INTERA Inc.****Houston, Texas**

Senior Staff Consultant

Application of numerical ground-water flow and transport models in the characterization of regional and local hydrogeologic flow regimes; development and application of sensitivity and uncertainty analysis techniques to ground-water flow and transport models.

1978 - 1981**University of Connecticut****Storrs, Connecticut**

Assistant Professor, Department of Geology and Geophysics

Taught graduate and undergraduate courses in hydrogeology and engineering geology as well as undergraduate environmental geology; supervised graduate students in hydrogeology and other related disciplines; conducted research on ground-water modeling, ground-water/ surface-water interaction, and organic contaminant transport.

1973 - 1977**University of Illinois****Urbana, Illinois**

Graduate Teaching Assistant, Department of Geology

Training:

Project Management Professional exam preparation review (October 2008)

Bechtel Project Management Workshop (March 2002)

Bechtel Project Controls Module of Project Management Tier II (Oct 2002)

Bechtel 6 Sigma Champions Training (2003)

Andrews, R.W., 1978. Digital Simulation of Areal Salt Transport in a Coastal Aquifer in Northwest Mexico. EOS, 59(12), p.1062.

Andrews, R.W., 1981. Salt Water Intrusion in the Costa de Hermosillo, Mexico: A Numerical Analysis of Water Management Proposals. Ground Water, Vol. 19, No. 6, pp.635-647.

Sykes, J.F., and R.W. Andrews, 1982. Application of Performance Assessment Technology to High-Level Radioactive Waste Site Characterization. Paper presented at American Nuclear Society Annual Meeting, November 1982.

Pearson, F.J., Jr., C.J. Noronha, and R.W. Andrews, 1982. Mathematical Modeling of the Distribution of Natural C-14, U-234 and U-238 in a Regional Groundwater System. Fourteenth International Radiocarbon Conference, Radiocarbon, Vol. 25, No. 2, pp.291-300.

Andrews, R.W. and F.J. Pearson, Jr., 1983. Transport of ¹⁴C and Uranium in the Carrizo Aquifer of South Texas: Geohydrology Surrounding a High-level Nuclear Waste Repository in the Palo Duro Basin, Texas. Scientific Basis for Nuclear Waste Management. MRS Symposium Proceedings, Vol. 26, pp.1085-1092.

Brandstetter, A., R.W. Andrews, L. Kroitoru, J.W. Thackston, 1983. Geohydrology Surrounding a High-Level Nuclear Waste Repository in the Paradox Basin, Utah. Scientific Basis for Nuclear Waste Management. MRS Symposium Proceedings, Vol. 26, pp.369-378.

Deyling, M.A., L. Picking, R.W. Andrews, L. Kroitoru, 1983. Geohydrology Surrounding a High-Level Waste Repository in the Palo Duro Basin, Texas. Scientific Basis for Nuclear Waste Management. MRS Symposium Proceedings, Vol. 26, pp.389-396.

Brandstetter, A. and R.W. Andrews, 1983. Ground-water Flow Modeling in Support of Salt Site Evaluation. Presented at the American Nuclear Society Annual Meeting, June, 1983, Transactions ANS, Vol. 44, pp.58-59.

Gupta, S.K., R.W. Andrews, C.R. Cole, J.F. Kircher, 1984. Site Characterization for Nuclear Waste Repository Ground-Water Modeling Demonstration Using Palo Duro Basin. Paper presented at Waste Management 1984, Tucson, AZ.

Andrews, R.W. and D.E. Metcalfe, 1984. First Status Report on Regional and Local Ground-water Flow Modeling for Richton Dome, Mississippi. ONWI-502, prepared for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH.

Pahwa, S.B. and R.W. Andrews, 1984. First Status Report on Regional and Local Ground-water Flow Modeling for Vacherie Dome, Louisiana. Prepared for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH.

Andrews, R.W. and M.T. Drahnak, 1984. First Status Report on Regional Ground-water Flow Modeling for the Paradox Basin, Utah. ONWI-503, prepared for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH.

Andrews, R.W., J.F. Sykes, and K.G. Carter, 1984. First Status Report on Regional Ground-water Flow Modeling for the Palo Duro Basin, Texas. ONWI-504, prepared for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH.

Andrews, R.W., S.K. Gupta and S.B. Pahwa, 1984. Sensitivity Analysis of Ground-water Flow in the Palo Duro Basin, Texas. NWWA Symposium on Practical Applications of Ground-Water Models, Columbus, OH.

Sykes, J.F., J.L. Wilson, R.W. Andrews, 1985. Sensitivity Analysis for Steady-State Ground-water Flow Using Adjoint Operators. *Water Resources Research*, Vol. 21, No. 3, pp.359-371.

Andrews, R.W., F. Kimmeier, P. Perrochet, and L. Kiraly, 1985. Validation of Hydrogeologic Models to Describe Ground-water Flow in the Crystalline of Northern Switzerland. *Scientific Basis for Nuclear Waste Management*, MRS Symposium Proceedings, Stockholm, Sweden.

Metcalf, D.E. and R.W. Andrews, 1985. Second Status Report on Regional and Local Ground-water Flow Modeling for Richton and Cypress Creek Domes, Mississippi. Prepared for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH.

Andrews, R.W., S.B. Pahwa, and M.T. Drahnak, 1985. Second Status Report on Regional Ground-water Flow Modeling for the Paradox Basin, Utah. ONWI-614, prepared for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH.

Johnson, C.L., J.L. Wilson and R.W. Andrews, 1985. Second Status Report on Regional Ground-water Flow Modeling for the Palo Duro Basin, Texas. Prepared for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH.

Kimmeier, F., P. Perrochet, R.W. Andrews, and L. Kiraly, 1985. *Modele Mathematique des Ecoulements Souterrains entre des Alpes et al Foret Noire*, NAGRA NTB 84-50, prepared for NAGRA, Baden, Switzerland.

Andrews, R.W., V.A. Kelley, J.A. McNeish, A.M. LaVenue, and J.E. Campbell, 1986. Travel Path/Travel Time Uncertainties at Salt Site Proposed for High Level Waste Repositories. Prepared for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH.

Andrews, R.W., D.W. LaFleur and S.B. Pahwa, 1986. Resaturation of Backfilled Tunnels in Granite. Technical Report 86-27, NAGRA, Baden, Switzerland.

McNeish, J.A. and R.W. Andrews, 1987. Synthetic Evaluation of Hydrogeologic Spatial Correlation Scale: A Methodology for Quantifying Variance Reduction Using Indirect Hydrogeologic Tests. Paper presented at IGWMC Modeling Conference, Amsterdam, Netherlands, October 1987.

Andrews, R.W., A.M. LaVenue, B.M. Thompson, and J.E. Campbell, 1987. Application of Uncertainty Analysis Techniques to Address NRC Travel Time Performance Measures at a Potential HLW Disposal Site in Deaf Smith County, Texas. Paper presented at NWWA Conference on Solving Ground Water Problems with Models, Denver, Colorado.

Andrews, R.W. and A.M. LaVenue, 1987. Comparison of Uncertainty Analysis Techniques Applied to the NRC Ground-Water Travel Time Performance Measure. Abstract presented at NWWA Conference on Solving Ground Water Problems with Models, Denver, Colorado.

Andrews, R.W., and S.B. Pahwa, 1987. Verification and Validation of a Two-Phase Flow Model. Paper presented at GEOVAL-87 Conference, Stockholm, Sweden.

LaVenue, A.M. and R.W. Andrews, 1987. Ground-Water Travel Time Uncertainty Analysis: A Comparison Between the Differential and Probabilistic Techniques. Poster presented at 1987 AGU Spring Meeting, Baltimore, MD.

Andrews, R.W., A.M. LaVenue, and J.A. McNeish, 1987. Evaluating the Effect of Sampling and Spatial Correlation on Ground-Water Travel Time Uncertainty: Coupling Geostatistical, Stochastic, and First-Order, Second Moment Methods. Paper presented at the DOE/AECL '87 International Conference on Geostatistical Sensitivity and Uncertainty Methods for Ground-Water Flow and Radionuclide Transport Modeling, San Francisco, California, September 1987.

LaVenue, A.M., R.W. Andrews, B.S. RamaRao, 1988. Ground-water Travel Time Uncertainty Analysis: A Comparison Between the Differential and Statistical Sampling Techniques. Water Resources Research.

Andrews, R.W., 1988. OBS: Preliminary Interpretation of Hydraulic Tests and Possible Conceptual Models for the Groundwater flow Regime Considering the Effects of Gas, NAGRA NIB 88-48, Baden, Switzerland.

Andrews, R.W., F.T. Blaskovich, J.M. Lavanchy, and J.A. McNeish, 1988. Final Interpretation of Selected Hydraulic Tests Performed During Oberbauenstock - Phase I, NAGRA Technical Report, NTB 88-16, Baden, Switzerland.

Lavanchy, J.M. and R.W. Andrews, 1988. Final Interpretation of Selected Hydraulic Tests Performed During Piz Pian Grand - Phase I, NAGRA Internal Report, NTB 88-49, Baden, Switzerland.

Lavanchy, J.M., J.A. McNeish, R.W. Andrews, 1988. Summary of Potentiometric Data of the Sedimentary Strata of Northern Switzerland with Emphasis on Drill Stem Tests. NAGRA Internal Report.

McNeish, J.A. and R.W. Andrews, 1988. Leuggern Tracer Dilution Testing Pre-Test Analysis. NAGRA Internal Report.

McNeish, J.A., R.W. Andrews, and S. Vomvoris, 1989. Interpretation of the Tracer Testing Conducted in the Leuggern Borehole. NAGRA Technical Report, Baden, Switzerland.

Andrews, R.W., P. Brenner, and J. Kaelin, 1989. Investigation Concept for an Adit Sealing Test at the Wellenberg Rock Laboratory. NAGRA Internal Report NTB 89-60, Baden, Switzerland.

Low, S., J.A. McNeish, and R.W. Andrews, 1989. Final Interpretation of the Leuggern 1987 Fluid Logging. NAGRA Technical Report, Baden, Switzerland.

McNeish, J.A., J.P. McCord, and R.W. Andrews, 1989. Final Interpretation of the Leuggern Long-Term Monitoring Data. NAGRA Internal Report, Baden, Switzerland.

Hufschmied, P., M. Thury, S. Vomvoris, R.W. Andrews, and F. Herzog, 1989. Hydrologic Investigations of Low Permeability Rock in the NAGRA Program: From Methods Development to Site Characterization. Paper presented at International Geologic Congress, Washington, D.C.

Moe, H., J.A. McNeish, J.P. McCord, and R.W. Andrews, 1989. Final Interpretation of Selected Hydraulic Tests Performed in the Schafisheim Borehole. NAGRA Technical Report, Baden, Switzerland.

McNeish, J.A., J.P. McCord, and R.W. Andrews, 1990. Analyses of Long-Term Monitoring Data from the Schafisheim, Kaisten, and Leuggern Boreholes. NAGRA Internal Report, 90-11, Baden, Switzerland.

Andrews, R.W., P. Hufschmeid, S. Loew, J. Black, W.Dershowitz, 1990. Evaluation of Strategies for Hydrogeologic Characterization of a Repository Area in Marine and Fluvio-terrestrial Sedimentary Strata, paper presented at OECD/NEA Workshop, Paris, France.

McNeish, J.A., R.W. Andrews, S. Vomvoris, and F. Spane, 1990. Tracer Testing Within a Deep Borehole in Northern Switzerland. EOS Transactions, American Geophysical Union. 71(43), December (presented paper).

Lavanchy, J.M., J.A. McNeish, R.W. Andrews, and L. Calmbach, 1990. Critical Review of Head and Transmissivity Data from Oil and Gas Exploration Wells in Northern Switzerland. NAGRA Internal Report 89-04, Baden, Switzerland.

Andrews, R.W., W. Dershowitz, J. Black, P. Hufschmeid, 1992. Evaluation of Exploration Strategies for Hydrogeologic Characterization of a Repository Area: Example Application to the Opalinus Clay and the Lower Freshwater Molasse, NAGRA NTB 91-15, Baden Switzerland.

Vomvoris, S., O. Voborny, W. Wilson, R.W. Andrews, and W. Huerlimann, 1992. Hydrogeology of Crystalline Rocks of Northern Switzerland: Synthesis of results relevant to safety analysis, Reference Area West, NAGRA NIB 92-65, Baden, Switzerland.

Vomvoris, S., O. Voborny, W. Wilson, and R.W. Andrews, 1993. Hydrogeology of Crystalline rocks of Northern Switzerland: Synthesis of results relevant to safety analysis, Reference Area East, NAGRA NIB 92-126, Baden, Switzerland.

Vomvoris, S. and R.W. Andrews, Eds, R.W. Andrews, P. Blumling, A. Gautschi, W.H. Mueller, M. Thury, S. Vomvoris, 1993. Crystalline Explorability: Documentation of Key Assumptions, Questions, and Intermediate Synthesis of Results, NAGRA NIB 93-109, Baden, Switzerland.

Vomvoris, S., R.W. Andrews, P. Blumling, W.H. Mueller, M. Schindler, K. Takeuchi, H. Umeki, O. Voborny, W.W. Wilson, 1993. Northern Switzerland Crystalline Rocks: Preliminary Assessment of Changes in Groundwater Flow and their Implications to the Geodataset due to the Excavation Disturbed Zone around a Repository Tunnel, NAGRA NIB 93-115, Baden, Switzerland.

Andrews, R.W., 1993. Review and Evaluation of the Potential Effects of Gas Generation on the Performance of a High-Level Waste Repository in the Crystalline, NAGRA NIB 93-148, Baden, Switzerland.

Intera, Inc, 1993. A Comparative Application of the Repository Integration Program (RIP) to Total System Performance Assessment - 1991. Prepared for U.S. Department of Energy, Las Vegas, NV.

Andrews, R.W., T.F. Dale, and J.A. McNeish, 1994. Total System Performance Assessment - 1993: An Evaluation of the Potential Yucca Mountain Repository. Prepared for U.S. Department of Energy, Las Vegas, NV.

Andrews, R.W., and J. A. McNeish, 1995. Preliminary Evaluation of Predicted Peak Release Rates from the Engineered Barrier System for a Potential Repository at Yucca Mountain, Nevada. 1995 International High Level Radioactive Waste Management Conference, Las Vegas, Nevada, May.

Lee, J.H., J.E. Atkins, S. Lingineni, and R.W. Andrews, 1995. Stochastic Simulation of Pitting Degradation of Multi-Barrier Waste Container in the Potential Repository at Yucca Mountain, Scientific Basis for Nuclear Waste Management XIX,

Materials Research Society Symposium Proceedings, Vol. xxx, W.M. Murphy and D.A. Knecht (eds.), November 27-December 1, 1995, Boston, Massachusetts, Materials Research Society, Pittsburgh, Pennsylvania.

Lee, J.H., J.E. Atkins, and R.W. Andrews, 1995. Humid-Air and Aqueous Corrosion Models for Corrosion-Allowance Barrier Material, Scientific Basis for Nuclear Waste Management XIX, Materials Research Society Symposium Proceedings, Vol. xxx, W.M. Murphy and D.A. Knecht (eds.), November 27-December 1, 1995, Boston, Massachusetts, Materials Research Society, Pittsburgh, Pennsylvania.

Andrews, R.W., J.A. Atkins, J.O. Duguid, J.E. Houseworth, J.H. Lee, S. Lingineni, J.A. McNeish, S. Mishra, D.C. Sassani and S.D. Sevougian, 1995. Total System Performance Assessment - 1995 : An Evaluation of the Potential Yucca Mountain Repository, Civilian Radioactive Waste Management System, Management and Operating Contractor, Yucca Mountain Site Characterization Project, Las Vegas, NV, 702 pp.

Andrews, R.W., J.A. McNeish, and J.H. Lee, 1995. Preliminary Evaluation of Predicted Peak Release Rates from the Engineered Barrier System for a Potential Repository at Yucca Mountain, Nevada, Proceedings of the Sixth International Conference on High-Level Radioactive Waste Management, American Nuclear Society, La Grange Park, IL and American Society of Civil Engineers, New York, New York, pp. 397-399.

Atkins, J.E., S.D. Sevougian, J.H. Lee, R.W. Andrews, and J.A. McNeish, 1996. Important Parameters in the Performance of a Potential Repository at Yucca Mountain (TSPA-1995), in Proceedings of the Seventh International Conference on High-Level Radioactive Waste Management, American Nuclear Society, La Grange Park, IL and American Society of Civil Engineers, New York, New York

Sevougian, S.D., R.W. Andrews, J.A. McNeish, 1996. Total System Performance Predictions (TSPA-1995) for the Potential High-Level Waste Repository at Yucca Mountain, in Proceedings of the Seventh International Conference on High-Level Radioactive Waste Management, American Nuclear Society, La Grange Park, IL and American Society of Civil Engineers, New York, New York

Atkins, J.E., J.H. Lee, and R.W. Andrews, 1996. Impacts of Cathodic Protection on Waste Package Performance, in Proceedings of the Seventh International Conference on High-Level Radioactive Waste Management, American Nuclear Society, La Grange Park, IL and American Society of Civil Engineers, New York, New York

Sevougian, S.D., Lee, J.H., and R.W. Andrews, 1996. The Use of Performance Assessment to Prioritize Site and Design Information Needs for a High-Level Nuclear Waste Repository: Examples from the Potential Repository at Yucca Mountain, Nevada USA, in Proceedings of the Symposium on the Safety of Radioactive Waste Management, November 1996, Korean Institute of Nuclear Safety, Tae Jon, Korea.

Lee, J.H., P.L. Chambre, and R.W. Andrews, 1997. Mathematical Models for Diffusive and Advective Release from a Waste Disposal Container with Multiple Perforations, International Conference on Deep Geological Disposal of Radioactive Waste, September 16-19, Winnipeg, Canada, Canadian Nuclear Society.

RamaRao, B.S.; Mishra, S.; Sevougian, S.D.; and Andrews, R.W. 1998. "Uncertainty Importance of Correlated Variables in the Probabilistic Performance Assessment of a Nuclear Waste Repository." *SAMO '98: Second International Symposium on Sensitivity Analysis of Model Output, Venice, Italy, April 19-22, 1998*. Chan, K.; Tarantola, S.; and Campolongo, F., eds. Pages 215-218. Luxembourg, Luxembourg: Office for Official Publications of the European Communities.

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1982 – 1984: Shell Oil Company, Mining Division, Contract Geologist.

1978 – 1980: Uranengesellschaft, USA, Geologist. Uranium exploration.

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Patrick D. Mattie, Robert G. Knowlton, Bill W. Arnold, and Nengchuan Tien, 2006, Coupling legacy and contemporary deterministic codes to Goldsim for probabilistic assessments of potential low-level waste repository sites (abstract), American Geophysical Union 2006 Fall Meeting, December 11-15, 2006, American Geophysical Union, Washington, DC.

Eddebarh, Al-Aziz, Scott C. James, Bill W. Arnold, and George A. Zyvoloski, 2006, The site-scale saturated zone flow model for Yucca Mountain (abstract), American Geophysical Union 2006 Fall Meeting, December 11-15, 2006, American Geophysical Union, Washington, DC.

Kelkar, Sharad, Hari Viswanathan, Al Eddebarh, Mei Ding, Paul Reimus, Bruce Robinson, Bill Arnold, and Arend Meijer, 2006, An updated site scale saturated zone ground water transport model for Yucca Mountain (abstract), American Geophysical Union 2006 Fall Meeting, December 11-15, 2006, American Geophysical Union, Washington, DC.

Arnold, Bill W., Robert G. Knowlton, F. Joseph Schelling, Patrick D. Mattie, John C. Cochran, and Hong-Nian Jow, 2007, *Taiwan Industrial Cooperation Program Technology Transfer for Low-Level Radioactive Waste Final Disposal – Phase I*, SAND2007-0131, Sandia National Laboratories, Albuquerque, NM.

Mattie, Patrick D., Robert G. Knowlton, and Bill W. Arnold, 2007, *A User's Guide to the GoldSim/BLT-MS Integrated Software Package: A Low-Level Radioactive Waste Disposal Performance Assessment Model*, SAND2007-1354, Sandia National Laboratories, Albuquerque, NM.

Kelkar, Sharad, Mei Ding, Shaoping Chu, Bruce Robinson, Bill Arnold, and Arend Meijer, 2007, An updated site scale saturated zone ground water transport model for Yucca Mountain (abstract), American Geophysical Union 2007 Fall Meeting, December 10-14, 2006, American Geophysical Union, Washington, DC.

Grace, M.D., S.C. James, T.S. Lowry, B.W. Arnold, and G.A. Gray, 2008, Development of an iterative site characterization using multimodel ranking and inference (abstract), Computation Methods in Water Resources, XVII International Conference, June 6-10, 2008, San Francisco, CA.

Arnold, Bill W., Teklu Hadgu, and Cedric J.M. Sallaberry, 2008, Sensitivity analyses of radionuclide transport in the saturated zone at Yucca Mountain, Nevada, Proceedings of the 12th International High Level Radioactive Waste Management Conference, Las Vegas, Nevada, September 7-11, 2008, American Nuclear Society, La Grange Park, IL.

Ho, Clifford K., Bill W. Arnold, and Susan J. Altman, 2008, Dual permeability modeling and evaluation of drift-shadow experiments, Proceedings of the 12th International High Level Radioactive Waste Management Conference, Las Vegas, Nevada, September 7-11, 2008, American Nuclear Society, La Grange Park, IL.

Arnold, Bill W. and Sharad Kelkar, 2008, Conceptual model of potential radionuclide transport in the saturated zone at Yucca Mountain (abstract), 2008 Joint Meeting of the Geological Society of America, Soil Science Society of America, American Society of Agronomy, Crop Science Society of America, Gulf Coast Association of Geological Societies with the Gulf Coast Section of SEPM, October 5-9, 2008, Houston, TX.

Patrick V. Brady, Bill W. Arnold, Geoff A. Freeze, Peter N. Swift, Stephen J. Bauer, Joseph L. Kanney, Robert P. Rechar, and Joshua S. Stein, 2009, *Deep Borehole Disposal of High-Level Radioactive Waste*, SAND2009-4401, Sandia National Laboratories, Albuquerque, NM.

JACK BAILEY

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CURRICULUM VITAE

SUMMARY

Technical manager experienced in design, construction, start-up and operation of nuclear facilities. Performed activities as a design engineer, project manager and licensing manager, as well as an executive manager involved in technical evaluations and decision making.

PROFESSIONAL EXPERIENCE

Beckman & Associates, Inc. (Civilian Radioactive Waste Management System, Management & Operating Contractor), Las Vegas, NV **2002-Present**

Served in assignments including Staff Assistant to the Repository Project Manger, Project Manager for CD-1 Design Alternative Selection, and License Application (LA) Subsurface and Waste Package Licensing Group Lead.

Directed the preparation and approved the technical content of the Yucca Mountain Project (YMP) LA and responses to requests for additional information for LA Sections reviewed and related to:

- 1.) Subsurface design and overall repository operations including retrieval and closure,
- 2.) Waste form description and receipt
- 3.) Design of the waste package and drip shield
- 4.) EBS components and integration with postclosure analysis

Managed the development of a systems solution for the design of the repository facilities to support the CD-1 decision to implement the mostly canistered spent nuclear fuel approach.

Directed integration of Design, Total System Performance Assessment and Licensing Department activities for the subsurface and waste package areas.

TRW (Civilian Radioactive Waste Management System, Management & Operating Contractor), Las Vegas, NV **1995-2002**

Director, Regulatory & Licensing responsible for directing policy and strategy; utilizing resources from more than twenty companies, responsible for technical development of products to provide safety analysis.

Deputy Engineering Manager responsible for directing activities for development of component and facility designs and specialized analytical tools including those for the project's underground environment to support preclosure and postclosure operations.

S. Levy Incorporated, Campbell, CA

1992 -1994

Project Manager–Directed technical and management activities to resolve utility operating issues that included evaluation of the issue, development of design solutions and associated design criteria and licensing bases.

Arizona Public Service Company, Phoenix, AZ.

1989 -1992

Vice President, Nuclear Safety & Licensing responsible for directing regulatory compliance practices for a three-unit nuclear station of 2800 employees. Directed root cause analyses programs for station events and headed self-assessment of station technical and management activities.

Houston Lighting & Power Company, Houston, TX

1977 -1989

Project Engineer, Manager Engineering and Licensing responsible for directing the activities of (up to) 120 engineers to perform the technical and regulatory activities necessary to engineer, start-up and license the South Texas Project Electrical Generating Station.

United States Navy (Lieutenant)

1972 -1977

Officer responsible for managing the training program at one of the Navy's prototype (hands-on) nuclear training units.

Division Officer on the USS Long Beach (CGN-9) responsible for directing the activities of Machinist Mates and Electronics Technicians to operate and maintain nuclear plant equipment.

EDUCATION

Bachelors of Electrical Engineering, Georgia Institute of Technology, 1972

RONALD BALLINGER

TO BE SUPPLIED LATER

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CURRICULUM VITAE

SUMMARY

Over 40 years experience in the development, implementation, and oversight of nuclear programs at Department of Energy (DOE) and commercial nuclear facilities. His experience includes nuclear operations, maintenance, testing, design engineering, safety analysis, quality assurance, management oversight and nuclear licensing.

PROFESSIONAL EXPERIENCE

Beckman and Associates, Inc., 1985 to Present

Owner and principal consultant managing and personally providing engineering and technical consulting to nuclear industry clients. (Note: Operated with co-owner as Prisuta Beckman Associates, Inc. from 1985-89)

Supported the Yucca Mountain Project in several line management and support roles from 1994 to present. Initially provided regulatory and quality program consulting directly to the Department of Energy. From 1999-2004, managed various nuclear licensing related efforts including development of Technical Basis Documents in response to US Nuclear Regulatory Commission (NRC) Key Technical Issues; managed pre- and post-closure safety analysis activities associated with various technical and regulatory initiatives and early (2003-04) drafts of the License Application.

Nuclear utility engagements have been directed at senior management services, business planning, and oversight, including senior management support; management mentoring; development and oversight of nuclear organization performance improvement initiatives and related business plans; development and delivery of staff and management training for nuclear safety, safety culture and safety conscious work environment, and assessment skills and techniques. Customers included Duquesne Light Company, Nebraska Public Power District, Commonwealth Edison, Arizona Public Service, Vermont Yankee, Maine Yankee Atomic Power Company, Carolina Power and Light, Public Service Electric and Gas of NJ, and others.

Other consulting engagements with DOE have included evaluations and support for improvement initiatives of safety analysis, engineering, design control, and quality assurance performance, facility readiness evaluations, and oversight of operations, maintenance, nuclear safety, design/engineering, construction and modifications, and testing. Engagements have included support to the Y-12 Site Office, the Rocky Flats Complex (during restart and decommissioning), Idaho National Laboratory, Oak Ridge National Laboratory, Oak Ridge Operations Office, and Oak Ridge Institute for Science and Education.

Since 1985 has also provided the NRC Office of Nuclear Reactor Regulation support of nuclear power plant inspections and licensing reviews in the areas of engineering and plant modification, operations, maintenance, testing, quality assurance, safety conscious work environment issues, and related areas. In addition to direct performance of these tasks, provided executive management for twenty to fifty NRC tasks per year.

Energy Consultants - Vice President, Engineering Division, 1982 to 1984

Responsible for Division level technical and fiscal management of the Design and Consulting Engineering Department, Operations Support Services Department and Quality Assurance Services Department. Directly involved in day-to-day technical activities, including plant modification engineering and construction support including system and subsystem design, installation, testing, and documentation; Nuclear Quality Assurance and Control services to utility and utility contractors; Nuclear licensed operator and plant staff training programs, including development of training material, training administration, classroom and simulator training; Industrial and construction training programs and materials; Nuclear plant licensing and regulatory affairs, including strategic planning, staff training, and technical problem resolution; Plant startup and operations support including control room operations, maintenance, and pre-operational testing; Organizational studies and management consulting for utility and other clients; and; Consulting services to NRC for Shoreham diesel generator problems.

U.S. Nuclear Regulatory Commission, Region I, 1977-82

Chief, Plant Systems Section, 1982

Supervised specialist reactor inspectors and license reviews in all phases of nuclear, electrical, instrument and control engineering, HVAC and atmosphere cleanup systems engineering, maintenance and construction; fire prevention and protection systems engineering, maintenance, and construction, and fluid systems design, maintenance and construction.

Responsible for the conduct of specialized technical inspections, review of operating reactor license amendment proposals, and resolution of technical issues, including enforcement of NRC regulations. Reviews/inspections included assessment of management and quality assurance programs applied to power reactor activities.

Senior Resident Inspector, 1979 to 1982

Was responsible for the administration and performance of the NRC inspection program at Beaver Valley Power Station, Unit 1. Reviewed all phases of power reactor operation, maintenance, modification, facility management, quality assurance program implementation, health physics, plant security, and utility company performance relating to safe facility operation.

Reactor Inspector, 1977 to 1979

Conducted power reactor quality assurance program inspections, plant staff training program inspections, and was eventually responsible for the administration and performance of the NRC inspection program at the Beaver Valley Power Station and the R. E. Ginna Nuclear Station as lead inspector responsible for routine inspection of operations, maintenance, and management.

Burns and Roe, Inc. - Operations/Test Supervisor, 1976 to 1977

Responsible for overall balance of plant preoperational and startup test program development, scheduling, and execution; preparation of station manual procedures; performance of operability, maintainability, and testability reviews of plant design and management of home office and field personnel for the Clinch River Breeder Reactor Plant and various fossil fueled generating stations. Involved extensive integration of plant and system design characteristics with operating characteristics. Produced and implemented design changes for improvement in plant operations and operational safety.

Newport News Shipbuilding and Dry Dock Company - Submarine Reactor Plant Test Supervisor, 1971 to 1976

Responsible for coordination of construction, testing, operations, and maintenance efforts including procedure development, administration of support activities and direct supervision of shipboard testing and personnel.

First Atomic Ship Transport, Inc. - Nuclear Operator/Shift Supervisor/Marine Engineer, Nuclear Ship Savannah, 1969 - 1971

USAEC licensed operator for commercial shipboard reactor. Responsibility for on-shift supervision and operation and maintenance of reactor and propulsion plant. Performed on-shift and outage health physics and chemistry duties. Responsible for hands-on operation and maintenance of ship's systems.

REGISTRATIONS AND CERTIFICATIONS

U.S. Atomic Energy Commission Operator's License, Nuclear Ship Savannah

EDUCATION

B.S., Marine Engineering, U.S. Merchant Marine Academy, 1969

JENS BIRKHOLZER

INFORMATION JENS BIRKHOLZER

AFFILIATION AND ADDRESS

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EDUCATION

1982-1985 University of Technology, Aachen. B.Sc. in Civil Engineering, 1985.
1985-1988 University of Technology, Aachen. M.Sc. in Water Resources, Hydraulic Engineering, Soil and Rock Mechanics, 1988.
1989-1994 University of Technology, Aachen. Ph.D. in Subsurface Hydrology, 1994.

RESEARCH INTERESTS

Subsurface hydrology with emphasis on fluid, gas, solute and heat transport in complex subsurface systems such as saturated and unsaturated porous or fractured media. Current work includes:

- Temperature-driven processes in geologic repositories for radioactive waste (experiments and predictive modeling)
- Assessment of CO₂ sequestration in deep geological formations (leakage pathways, impact on groundwater, geomechanical changes).

CURRENT POSITION AND PROFESSIONAL EXPERIENCE

Since 2008 Program Lead, Nuclear Waste, Earth Sciences Division, Lawrence Berkeley National Laboratory
Since 2001 Staff Scientist and Group Leader, Earth Sciences Division, Lawrence Berkeley National Laboratory
1999 - 2001 Chief Engineer and Project Manager, Construction of the New International Airport in Dusseldorf, HOCHTIEF AG, Germany
1994 - 1998 Geological Scientist, Earth Sciences Division, Lawrence Berkeley National Laboratory
1989 - 1994 Research Associate (since 1993 Group Leader), Institute of Hydraulic Engineering and Water Resources Management (IWW), University of Technology, Aachen, Germany

Honors and Awards:

2007, 1997 Outstanding Performance Award, by LBNL
1995 - 1996 Postdoctoral fellowship granted by the Humboldt-Stiftung
1995 Friedrich-Wilhelm Award for Summa Cum Laude Ph.D. Thesis
1995 Borchers Award for Summa Cum Laude Ph.D. Thesis
1994 - 1995 Postdoctoral fellowship granted by the DAAD
1989 Research-fellowship granted by the DAAD
1989 Springorum Award for Summa Cum Laude M.Sc.
1989 Hünnebeck Award for best Master Thesis
since 1986 Studienstiftung des Deutschen Volkes, Scholarship for Excellent Students

Publications

Dr. Birkholzer has over 150 scientific publications, about 40 of which are in peer-reviewed journals, in addition to numerous research reports (see partial publication list below).

LIST OF RELEVANT PUBLICATIONS (LAST TEN YEARS)

1. TSANG, Y.W., BIRKHOZLER, J.T., MUKHOPADHYAY, S. (2009): Modeling of Thermally-Driven Hydrological Processes in Partially Saturated Fractured Rocks, *Rev. Geophys.*, 47, RG3004, doi:10.1029/2008RG000265.
2. LIU, X.Y., ZHANG, C.Y., LIU, Q.S., BIRKHOZLER, J.T. (2009): Multiple-Point Statistical Prediction on Fracture Networks at Yucca Mountain, *Journal of Environmental Geology*, 57(6), pp. 1361-1370.
3. RUTQVIST, J., BARR, D., BIRKHOZLER, J.T., FUJISAKI, K., KOLDITZ, O., LIU, Q., FUJITA, T., WANG, W., ZHANG, C. (2009): A comparative simulation study of coupled THM processes and their effect on fractured rock permeability around nuclear waste repositories, *Journal of Environmental Geology*, 57(6), pp. 1347-1360.
4. BIRKHOZLER, J.T. (2008), Recent Advances in Nuclear Waste Isolation through Simulations with the TOUGH Code, *Journal of Nuclear Technology*, 164(2), pp. 153-154.
5. KOWALSKY, M.B., BIRKHOZLER, J.T., PETERSON, J., FINSTERLE, S., MUKHOPADHYAY, S., TSANG, Y.W. (2008): Sensitivity Analysis for Joint Inversion of Ground-Penetrating Radar and Thermal-Hydrological Data from a Large-Scale Underground Heater Test, *Journal of Nuclear Technology*, 164(2), pp. 169-179.
6. CORTIS, A., BIRKHOZLER, J.T. (2008): Continuous Time Random Walk Analysis of Solute Transport in Fractured Porous Media, *Water Resources Research*, 44(6), W06414, doi:10.1029/2007WR006596.
7. BIRKHOZLER, J.T., HALECKY, N., WEBB, S.W., PETERSON, P.F., BODVARSSON, G.S. (2008): A Modeling Study Evaluating the Thermal-Hydrological Conditions in and Near Waste Emplacement Tunnels at Yucca Mountain, *Journal of Nuclear Technology*, 163(1), pp. 147-164.
8. DANKO, G., BIRKHOZLER, J.T., BAHRAMI, D. (2008): Coupled In-Rock and In-Drift Hydrothermal Model Study for Yucca Mountain, *Journal of Nuclear Technology*, 163(1), pp. 110-128.
9. RUTQVIST, J., BARR, D., BIRKHOZLER, J.T., CHIJIMATSU, M., KOLDITZ, O., LIU, Q., ODA, Y., WANG, W., ZHANG, C. (2008): Results from an International Simulation Study on Coupled Thermal, Hydrological, and Mechanical (THM) Processes near Geological Nuclear Waste Repositories, *Journal of Nuclear Technology*, 163(1), pp. 101-109.
10. RUTQVIST, J., BIRKHOZLER, J.T., TSANG, C.-F. (2008): Coupled Reservoir–Geomechanical Analysis of the Potential for Tensile and Shear Failure Associated with CO₂ Injection in Multilayered Reservoir–Caprock Systems, *International Journal of Rock Mechanics and Mining Sciences*, 45(2), pp. 132-143.
11. TSANG, C.-F., BIRKHOZLER, J.T., RUTQVIST, J. (2008): A Comparative Review of Hydrologic Issues Involved in Injection Storage of CO₂ and in Injection Disposal of Liquid Waste, *Journal of Environmental Geology*, 54(8), pp. 1723-1737.
12. MUKHOPADHYAY, S., TSANG, Y.W., BIRKHOZLER, J.T. (2007): Estimation of Field-Scale Thermal Conductivities of Unsaturated Rocks from In Situ Temperature Data, *Water Resources Research*, 43, W09418.
13. RUTQVIST, J., BIRKHOZLER, J.T., CAPPA, F., TSANG, C.-F. (2007): Estimating Maximum Sustainable Injection Pressure during Geological Sequestration of CO₂ using Coupled Fluid Flow and Geomechanical Fault-Slip Analysis, *Energy Conversion and Management Journal*, 48(6), pp. 1798-1807.
14. BIRKHOZLER, J.T., WEBB, S.W., HALECKY, N., PETERSON, P.F., BODVARSSON, G.S. (2006): Evaluating the Moisture Conditions in the Fractured Rock at Yucca Mountain – The Impact of Natural Convection in Heated Emplacement Drifts, *Vadose Zone Journal*, 5(4), pp. 1172-1193.
15. BIRKHOZLER, J.T. (2006): Estimating Liquid Fluxes in Thermally Perturbed Fractured Rocks Using Measured Temperature Profiles, *Journal of Hydrology*, 327(3-4), pp. 496-515.
16. BIRKHOZLER, J.T. (2006): A Temperature-Profile Method for Estimating Flow in Geologic Heat Pipes, *Journal of Contaminant Hydrology*, 85(3-4), pp. 89-117.

17. BIRKHOLZER, J.T., ZHANG, Y. (2006): The Impact of Fracture-Matrix Interaction on Thermal-Hydrological Conditions in Heated Fractured Rock, *Vadose Zone Journal*, 5(2), pp. 657-672.
18. BIRKHOLZER, J.T., MUKHOPADHYAY, S., TSANG, Y.W. (2004): The Impact of Preferential Flow on the Vaporization Barrier above Waste Emplacement Drifts at Yucca Mountain, *Journal of Nuclear Technology*, 148(2), pp. 138-150.
19. BIRKHOLZER, J.T., MUKHOPADHYAY, S., TSANG, Y.W. (2004): Modeling Seepage into Heated Waste Emplacement Tunnels in Unsaturated Fractured Rock, *Vadose Zone Journal*, 3(3), pp. 819-836.
20. BIRKHOLZER, J.T., HO, C.K. (2003): A Probabilistic Analysis of Episodic Preferential Flow into Superheated Fractured Rock, *Journal of Hydrology*, 284(1-4), pp. 151-173.
21. BIRKHOLZER, J.T. (2003): Penetration of Liquid Fingers into Superheated Fractured Rock, *Water Resources Research*, 39(4), pp. 9-1 through 9-21.
22. BIRKHOLZER, J.T., TSANG, Y.W. (2000): Modeling the Thermal-Hydrologic Processes in a Large-scale Underground Heater Test in Partially Saturated Fractured Tuff, *Water Resources Research*, 36(6), pp. 1431 -1447.
23. WANG, J.S.Y., TRAUTZ, R.C., COOK, P.J., FINSTERLE, S., JAMES, A.L., BIRKHOLZER, J.T. (1999): Field Tests and Model Analyses of Seepage into Drifts at Yucca Mountain, *Journal of Contaminant Hydrology*, 38 (1-3), pp. 323-348.
24. BIRKHOLZER, J.T., LI, G., TSANG, C.F., TSANG, Y.W. (1999): Modeling Studies and Analysis of Seepage into Drifts at Yucca Mountain, *Journal of Contaminant Hydrology*, 38 (1-3), pp. 349-384.
25. TSANG, Y.W., BIRKHOLZER, J.T. (1999): Predictions and Observations of the Thermal-hydrologic Conditions in the Single Heater Test, *Journal of Contaminant Hydrology*, 38 (1-3), pp. 385-426.
26. BIRKHOLZER, J.T., TSANG, C.F. (1997): Solute Channeling in Unsaturated Heterogeneous Porous Media, *Water Resources Research*, 33(10), pp. 2221-2238.

MARK BOARD

Itasca Consulting Group
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Expertise	Geotechnical and Mining Engineering
Education	Ph.D. (Geological Engineering), 1994 M.S. (Geological Engineering), 1977 B.S. (Geological Engineering, with High Honors), 1975 University of Minnesota
Honors	Applied Rock Mechanics Award, American Rock Mechanics Association, 2003 Rocha Medal, International Society for Rock Mechanics, 1995 Award for Research in Rock Mechanics, US National Committee on Rock Mechanics, 1976
Professional Experience	
2005 – Present	<i>Principal Engineer - Itasca Consulting Group, Denver, Colorado</i>
2001 - 2005	<i>Bechtel SAIC Company, LLC, Las Vegas, Nevada, Yucca Mt. Project Engineer Subsurface Design/Manager of Seismic Studies</i>
1982 – 2001	<i>Itasca Consulting Group, Inc., Minneapolis, Minnesota Senior Mining/Geotechnical Engineer</i>
1981 – 1982	<i>Science Applications, Inc., Salt Lake City, Utah, Mining Engineer</i>
1978 - 1981	<i>TerraTek, Inc., Salt Lake City, Utah, Mining Engineer</i>
1977 - 1978	<i>Rockwell Hanford Operations, Richland, Washington, Mining Engineer</i>
1974 - 1977	<i>Hecla Mining Company, Wallace, Idaho/Case Grande, Arizona Mining and rock mechanics engineer at the Star, Lucky Friday and Lakeshore Mines. (Completed MS degree, Univ. of Minnesota during this time period)</i>

Mr. Board is a geotechnical engineer with over 30 years experience in ground support specification, mine planning and design, underground mine stability assessments, backfill specification, open pit slope stability assessments, field geotechnical characterization, rock instrumentation and numerical modeling. Underground mining experience includes work in block and panel caving, blasthole open stoping, cut and fill, room and pillar, and longwall in base metals, evaporites, stone and coal.

Summary of Mine Design and Rock Engineering Experience

In the past 20+ years at Itasca, has been involved in numerous mine design projects world-wide from short-term stability assessments to feasibility and conceptual design studies. The following are examples of some of the significant projects conducted in the past 10 years:

- *Bingham Canyon Mine, Keystone Project, Rio Tinto* – Geotechnical manager for the prefeasibility studies for long-term underground mining at the Bingham Canyon Mine. Work includes study of major open pit expansions that will take the pit to 1200m depth as well as mining of several orebodies beneath the pit by block caving and sublevel open stoping. The work includes geotechnical characterization and development of a 3D geotechnical block model, rock properties assessments, stability assessment of the ultimate pit slopes, detailed interaction of the pit and underground during

the transition, including cave growth prediction, slope subsidence, design of the cave mine production and undercut levels, and placement of permanent infrastructure. As manager of the project, leads interaction with an international geotechnical review board as well as Rio Tinto management.

- *Ernest Henry Mine, Cloncurry, Australia, Xstrata Copper* – Conducting geotechnical studies supporting feasibility of a proposed sublevel caving operation beneath a 500 m deep open pit. Work includes assessment of geotechnical model and rock mass properties, numerical stress analysis for simulation of cave propagation, impact on pit slope stability and subsidence. Layout and stability assessment of production level excavations and infrastructure. Assessment of geotechnical hazards including seismicity. Interaction with international geotechnical and mining review board.
- *Mt. Isa Mine, Mt. Isa, Australia, Xstrata Copper* – Performing mining methods and geotechnical scoping studies for mining of the 1100 Halo copper orebody. The orezone lies above the previously-mined excavations that consist of backfilled sublevel stopes. Examined the depth of failure above existing stopes, and developed a mining strategy for taking the orebody above it using either sublevel open stoping or sublevel caving.
- *Chuquicamata Mine, Calama Chile, Codelco (2005 to present)* – Geotechnical studies supporting feasibility assessment for a proposed 140,000 tpd caving operation beneath the Chuquicamata pit. Job duties involve the planning and coordination of the geotechnical activities in support of the feasibility study for the caving operation. Work included specification of underground mapping for exploration of the orebody, analysis and interpretation of geotechnical characterization for rock properties estimation and design input. Numerical assessment of caving and subsidence of rock slopes, stability assessment of the undercut and production levels, assessment of infrastructure stability and setback. Optimization of caving method using macro-block caves. Currently consulting on geotechnical exploration activities for construction of 3 shafts, approximately 50km of ventilation, conveyor and men/materials declines from the surface to underground.
- *Henderson Mine, Empire, Colorado, Freeport-McMoran (2005 to present)* – Assessments of cave propagation and cave front advance shape and directions for 7210 production level. Three-dimensional numerical modeling of panel caving alternatives and prediction of stresses and stability of production level; specification of ground support. Conduct annual or semi-annual mine geotechnical inspection and review.
- *Yucca Mountain Project, Bechtel (2001 - 2005)* – Acted as project engineer for mining and geotechnical engineering for the Yucca Mt as well as managed the seismic studies program.
- *Solvay Mine, Green River, Wyoming, Solvay Minerals (1995 to present)* – Design of longwall panels and pillaring geometries for large trona mines in the Green River Basin. Investigated large panel collapse and developed methodology for assessing collapse potential and design of room and pillar panels. Currently assessing solution mining of previously-mined room and pillar panels.
- *Onaping Depth Project, Sudbury, Ontario, Falconbridge, Ltd. (1997 to 2000, current)* – Geotechnical lead on prefeasibility design of a new nickel mine at great depth below the Onaping-Craig operations. Worked with a team to develop a mechanized undercut and fill operation to mine wide, high grade zone under high stress conditions at 7500 to 10,000' depth. Currently act on a geotechnical and mining review board for the prefeasibility of the project.
- *Mine D, Kidd Division, Timmins, Ontario, Falconbridge, Ltd (1997 to 2001)* – Geotechnical lead for mine planning, layout and economic assessment for deep extensions of the Kidd Mine. Design of a blasthole stope and pillar layout and extraction scheme for mining of orebody from 6000 to 10,000' depth.
- *Other major mine planning/geotechnical assessment projects with include:*
 - *El Teniente Mine, Chile, Codelco (caving)*
 - *Andina Mine, Chile, Codelco (caving)*
 - *Esperanza Project, Chile, Antofagasta Minerals (open pit)*

- *Snap Lake Project, DeBeers, NW Territories, (room and pillar)*
- *Orapa and Letlakhane Mines, Debswana, Botswana (open pit)*
- *Myra Falls Mine, Campbell River, BC, Boliden Mineral (cut and fill and blasthole)*
- *Kristineberg, Garpenberg, Renstrom and Garpenberg North Mines, Boliden, Sweden, Boliden Mineral (cut and fill)*
- *Premier and Bultfontein Mines, South Africa, DeBeers (panel and block caving)*
- *Brunswick and Heath Steele Mines, Bathurst, NB, Noranda, Ltd (blasthole)*
- *Onaping, Craig, TL, Frasier and Strathcona Mines, Onaping, Ont., Falconbridge, Ltd (blasthole)*
- *Buffelsfontein Mine, Klerksdorp, SA, GENMIN, (deep narrow reef gold)*
- *Western Deep Levels, Freddie's, Saplus Mines, Careltonville and Welkom, SA, Anglo (deep narrow reef gold)*
- *Thabazimbi Mine, Thabazimbi, SA, Yskor (Open pit and sublevel caving)*
- *K2 Mine, Esterhazy, Sask., IMC (room and pillar)*
- *Retsoff Mine, New York, Akzo Salt (room and pillar)*
- *Varangeville Mine, France, CSM (room and pillar)*
- *Sifto Salt, Goderich, Ont., Sifto Salt Company (room and pillar)*
- *Troy Mine, Troy, Montana, Revett Minerals (room and pillar)*
- *Campbell Mine, Red Lake, Ont., Campbell Mining (cut and fill, narrow vein blasthole)*
- *Dennison Mine, Elliot Lake, Ont., Dennison Mining (room and pillar)*
- *Macassa Mine, Kirkland Lake, Ont., Kinross Mining (cut and fill)*
- *Laronde Mine, Cadillac, Quebec, Agnico-Eagle (blasthole)*
- *Hope Brook Mine, Stephenville, NF, Royal Oak (blasthole)*
- *Star and Lucky Friday Mines, Burke, Idaho, Hecla Mining (cut and fill, undercut and fill)*
- *Galena/Coeur Mine, Wallace, Idaho, Coeur d'Alene Mining (cut and fill)*
- *Secunda Mine, Secunda SA, AMCOAL (longwall coal)*

Summary of Rock Instrumentation and Field Experience

Extensive work in planning, installation and analysis of data from most types of rock instrumentation, including: TDR cables, rock stress change, concrete stress and strain, displacement, tilt, temperature, groundwater pressure and flow, cross-hole acoustic measurements and seismic instruments. Have conducted numerous in situ stress measurements by hydraulic fracturing and overcoring. Installed several microseismic monitoring systems for rockburst monitoring and control. Conducted numerous field projects in geotechnical characterization including detail line mapping, core logging, etc., and estimation of in situ rock mass properties. Installed instrumentation and conducted field tests for major waste disposal projects in Sweden, Colorado and Nevada Test Site. Have worked on construction and instrumentation of several circular, concrete-lined shafts, including the Silver Shaft at the Lucky Friday Mine, Mullan, Idaho (6200' depth), Solvay and General Chemical Mines in Wyoming. Developed undercut and fill mining method for rockburst control for the Star Mine in Burke, Idaho (7900' depth), and supervised the mining trials of this method.

Currently perform due diligence reviews of ground conditions and ground support at several mines in the U.S. and Canada. These reviews involve inspection of mine workings, specification of ground remediation, examination of seismic conditions and mine layouts, and recommendation of mining layout and sequence revisions to minimize ground problems.

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Education - Bachelors - Geology, University of California-Berkeley (1984); Ph. D. Geochemistry, Northwestern; 1990 - Thesis Topic: *Chemical Controls over Silicate Weathering*. Post-doc, ETH-EAWAG, Dübendorf, Switzerland.

Background

Brady is a Senior Scientist at Sandia National Laboratories and has authored or co-authored several dozen peer-reviewed journal articles, books, book chapters, and 9 patents, in the fields of water treatment, contaminant chemistry, and climate change. He's been at Sandia since 1993 and has also been adjunct Assistant Professor of Civil and Environmental Engineering at New Mexico Institute of Mining and Technology, Socorro, New Mexico since 1998. Before Sandia he was an Assistant Professor in the Department of Geological Sciences at SMU in Dallas, Texas.

Brady has written, edited, or co-edited books on Soil Radiochemistry, Desalination and Water Treatment, Mineral Surface Chemistry, and Natural Attenuation of Groundwater Contaminants. He has briefed the National Academy of Sciences twice on waste disposal and advised the National Academy of Engineering on arsenic removal in developing countries. He is on the Research Advisory Committee of the WasteReuse Foundation, the editorial board of *Chemical Geology*, the Goldschmidt Award committee of the Geochemical Society, the Science Advisory Board of the Association for the Environmental Health of Soils, and leads Sandia's Truman Distinguished Scholar Selection Committee.

Recent Projects/Duties

- Lead Geochemist for Yucca Mountain Nuclear Waste Repository/Near Field (2006-present) who: 1. Wrote the waste package degradation/radionuclide transport chapter of the Yucca Mountain license application that was submitted to NRC in Spring, 2008; 2. Is addressing legal contentions filed against the license application.
- Leader of Sandia's Advanced Water Treatment & Desalination Programs (2004-2007): Periodically briefed congressional sponsors (US Senators Domenici and Bingaman).
- Technical Advisor to US EPA (2001-2003). Co-wrote several chapters of EPA's guidelines for natural attenuation of contaminant metals and radionuclides in soils and groundwaters.

Awards

Football scholarship to the University of California at Berkeley (1980-1983); 3-year letterman, 2 year starter at offensive center, and Bob Tessier Award winner (1982).

PUBLICATIONS:

*** As of January, 2009 ***

BOOKS/EDITED VOLUMES

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- Krumhansl J. L., Brady; P. V., Teter; D. M., and McConnell, P. (2007) US PATENT 7,271,310. Cask Weeping Mitigation.
- Teter D. M., Brady P. V., and Krumhansl J. L. (2007) US PATENT 7,244,359 Inorganic ion sorbents method.
- Teter D. M., Brady P. V., and Krumhansl J. L. (2006) US PATENT 7,074,336 Inorganic ion sorbents and method for using same.
- Teter D. M., Brady P. V., and Krumhansl J. L. (2006) US PATENT 7,122,502. Inorganic ion sorbents.
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- Brady P. V., Khandaker N. R., Krumhansl J. L., and Teter D. M. (2004) US PATENT 6,830, 695 B1 In-Situ Remediation Process Using Divalent Cations..
- Khandaker N. R., Brady P. V., Teter D. M., Krumhansl J. L., (2004) US PATENT 6,802,980 Arsenic Removal in Conjunction with Lime Softening.
- Lindgren, E. R. and Brady P. V. (1997) US PATENT 5,676,819 In Situ Removal of Contamination from Soil.

TECHNICAL PUBLICATIONS

- Optimized ferrozine micro-method for determination of ferrous and ferric iron in minerals. by Husler, John; Ferriss, Elizabeth; Helean, Katheryn; Bryan, Charles; Brady, Patrick. Geostandards and Geoanalytical Research (Submitted).
- Uraninite corrosion studies using small mockup experiments. B.E. Anderson, K.B. Helean, C.R. Bryan, P.V. Brady and R.C. Ewing. J. Nuclear Materials (in press).

- Experimental study of the effect of pH and temperature on the kinetics of montmorillonite dissolution. M. Luisa Rozalén, F. Javier Huertas, and Patrick V. Brady. *Geochim Cosmochim. Acta* (submitted).
- Experimental study of the effect of pH on the kinetics of montmorillonite dissolution at 25°C. M. Luisa Rozalén, F. Javier Huertas, Patrick V. Brady, Jordi Cama, Susana García-Palma, and José Linares. *Geochim. Cosmochim. Acta* (in press).
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CHARLES BRYAN

Curriculum Vitae

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EDUCATION

Ph.D., Earth and Planetary Sciences, University of New Mexico, 1995

M.S., Geology, University of New Mexico, 1988

B.A., Geology, Texas A&M University, 1981

Academic Awards: National Science Foundation fellowship (UNM)
Caswell Silver fellowship (UNM)
National Merit Scholar (Texas A&M)
Outstanding student in the Geosciences, 1981 (Texas A&M)

PROFESSIONAL EXPERIENCE

Current Position (2003-present): Geochemist for the Yucca Mountain Project, Sandia National Laboratories. I have taken a lead role with respect to near-field and in-drift chemistry, primarily geochemical modeling of the effect of mineral dissolution/precipitation reactions on pore water chemistry as waters percolate through the unsaturated zone above the emplacement drifts, and modeling of evaporated and deliquesced brine compositions within the drifts. I have led or contributed to several high-profile assignments, including:

- With respect to the *Yucca Mountain License Application Safety Analysis Report (LA-SAR)*, currently the lead for near-field and in-drift chemistry, and worked to develop the response plans for seventeen NRC requests for additional information (RAIs) on those subjects; author of five of the responses, and contributed text and calculations to several others. Also, author of three unrelated RAI responses dealing with barrier capability, UZ flow, and performance confirmation activities. In addition, provided the technical bases for responses to thirteen of the State of Nevada's contentions to the license application on near-field and in-drift chemistry and on waste package corrosion, as well as contributing to several others. I will be an expert witness when these contentions are litigated.
- Co-author of Chapter 2.3.5, In-Drift Physical and Chemical Environment, of the *Yucca Mountain License Application Safety Analysis Report (LA-SAR)*. Authored about half this chapter, documenting project models for near-field and in-drift water chemistry, and continue to work to keep the text current as license review proceeds.
- Took a lead role in developing Feature, Event, and Process screening justifications for the near-field environment, taking over authorship, at some point during the development process, of over forty near-field FEP screening justifications (more than half of the total), as well as writing and contributing to FEPS in other areas.
- Led the small team which developed, validated and implemented the near-field chemistry model in five months to replace the THC seepage model (once again, behind schedule and suffering major technical issues) in performance assessment calculations. The near-field chemistry model predicts potential seepage water compositions, evaluating changes in water chemistry due to

water-rock interactions as the water moves downwards to the emplacements drifts. I documented the near field chemistry model in the project report *Engineered Barrier System: Physical and Chemical Environment*.

- Acted as work plan manager for the near field chemistry and dust localized corrosion technical work plans during Sandia's transition to Lead Lab status, developing work plans and writing, compiling, and integrating sections written by several other authors.
- Principal authorship of *Analysis of Dust Deliquescence for FEP Screening*, a high-profile, multi-lab effort to assemble and document arguments for screening deliquescence of salts in dust on waste package surfaces from performance assessment calculations. Both contributed to the technical arguments and compiled the work of other contributors. Presented this work at an international conference in Ghent, Belgium in 2005, and to the Nuclear Waste Technical Review Board (NWTRB).
- Authorship of *Drift-scale THC Seepage Model*, and of the data qualification document for the associated thermodynamic database. Personnel and quality assurance issues had pushed these documents far behind schedule when I took over and finished them on time.
- Co-authorship of Chapter 5, "Conditions and Processes Affecting Radionuclide Transport" of the *Yucca Mountain Site Description*. An important step in the regulatory process, the site description summarizes decades of site characterization activities.
- As lead checker, oversaw the checking and repair of *Engineered Barrier System: Physical and Chemical Environment*. This document was behind schedule and poorly written when I was given the position of lead checker. Led a large group of reviewers who thoroughly scrubbed and rewrote the document.

I have represented the Yucca Mountain project many times to DOE, to the Nuclear Waste Technical Review Board (NWTRB), to the NRC, and at public meetings and conferences. Presented the in-drift chemistry model to the director of OCRWM (M. Chu) in 2004. Presented the screening arguments for dust deliquescence, and the chemical environment on the waste package surface, to the NWTRB at public meetings (Nov. 2005 and Sept. 2006, respectively), and participated on a panel at an NWTRB workshop on localized corrosion (Sept., 2007), as well meeting with the NWTRB at numerous informal information exchange meetings. In addition, prepared presentation materials and responded to questions at the NWTRB meeting on the near-field chemistry model (May, 2007), but did not actually present at that meeting. Participated in meetings with the NRC, including a clarification meeting on the near-field chemistry model (Appendix 7 meeting, April 2008), and clarification meetings for requests for additional information (RAIs) (spring-summer, 2009).

In the past several years, I have received at least 5 Employee Recognition Award Team Nominations for Yucca Mountain work, and several SPOT awards.

Other projects:

2009—Participated in a small LDRD project to evaluate the potential use of thermal diffusion to separate CO₂ from air or flue gas for carbon capture and sequestration.

2006—Geochemist/instrument expert on the Independent Review Team for the Mars Science Laboratory, a mobile chemistry laboratory for Mars exploration scheduled for launch in 2011. The independent review team, a group of well-known scientists and engineers, ran instrument review meetings at the NASA Jet Propulsion Laboratory and NASA-Goddard, evaluating every piece of instrumentation to be used on the mission.

2004–2007—Co-principle investigator (with Pat Brady) of an Office of Science and Technology project to evaluate the effects of corrosion of waste package and waste form components on in-package chemistry and radionuclide mobility. I wrote the test plan, designed the waste package mockups and had them built, informally mentored the experimental lead (Kate Helean) and the student intern, and contributed heavily to the several papers and presentations that resulted from this work.

2003-2004—Principal investigator in a work-for-others project to characterize the speciation and distribution of uranium in aquifer sediments from the DOE site at Fernald, Ohio. The study included sequential leaching of soil samples, mineralogical and microanalytical characterization, and uranium sorption studies. This work supported an evaluation of the effectiveness of the pump-and-treat remediation strategy at Fernald, which has pumped almost twenty billion gallons of water to date.

2002—Participated in a New Mexico Small Business project to evaluate the effect of adding polyacrylamide polymer (PAM) to soils in an effort to improve water infiltration during irrigation. Performed column experiments evaluating changes in soil wetting rates and clumping properties upon addition of PAM.

2001-2003—Co-principal investigator on an LDRD to investigate potential application of nanostructured materials to nuclear waste management and environmental remediation, with emphasis on anion getters. This effort resulted in several publications, technical advances, and a patent. Also participated in a second LDRD on developing microsensors for volatile organics.

2000-2002—As part of the DOE Lead Lab Program, acted as outside expert for the Hanford Area 300 remediation program, reviewing the results of site characterization activities and experimental studies and providing input for the remediation plan for the site.

1999-2003—Geochemist for the Waste Isolation Pilot Plant (WIPP) Project, performing experimental work evaluating cement-brine interactions; investigation of brine and waste interactions with MgO (the engineered barrier in the WIPP); studying the development of the disturbed rock zone (DRZ), the zone of deformation in the wall rocks surrounding the repository; performing modeling and experimental investigations into actinide transport in the Culebra Dolomite (involved determining matrix diffusion parameters for a multi-rate transport model); and carrying out a mineralogical investigation of fracture coatings to evaluate the potential effects of such coatings on actinide transport. A major part of this effort involved obtaining permitting for and designing and equipping a large laboratory facility (~5500 ft²) for geochemical research for the SNL/Carlsbad office. This included, (1) developing all necessary ES&H paperwork for the facility, including NEPA checklists, sanitary sewer discharge permits, contracts for hazardous waste disposal, and all necessary SNL ES&H documents (PHS, HA, SOPs); (2) designing the laboratory facilities (to the point of specifying which electrical outlets would be on which breakers, air conditioning needs, and sizing ventilation fans), and (3) writing specifications for and purchasing all furniture and all basic equipment and specialized instruments, including a SEM with EDS, an XRD, an ICP, a BET surface area analyzer, a UV-visible spectrophotometer, a carbon analyzer, and a GC-MS. Once the laboratory had been built, I was lab manager, training peers, technicians, and interns in ES&H procedures and in equipment use.

Earlier work at Sandia—As a student and post-doctoral researcher, performed laboratory studies of irreversible adsorption of uranium onto iron oxyhydroxides and its application to natural attenuation of uranium contaminant plumes and batch adsorption and column transport experiments investigating the efficiency of zero-valent iron and other substrates in removing U, Tc, Sr, and Eu radionuclides from a concentrated, chemically reactive brine. Also performed experiments supporting a geochemical transport validation study funded by the Yucca Mountain Site Characterization Project; this project involved developing techniques for measuring the extent of adsorption and adsorption rate constants in batch systems under a wide range of pH and atmospheric conditions and carrying out column transport experiments with sorbing and non-sorbing tracers.

Skills and Capabilities:

Extensive experience modeling aqueous solutions with the geochemical speciation code EQ3/6, especially complex brines formed by evaporation and deliquescence (co-taught a class on EQ3/6 at Sandia in 2005). Experience in surface complexation modeling with HYDRAQL and PHREEQC. Experience with transport codes, including STAMMT-L (a linear multi-rate transport code), CXTFIT (a column transport code); and TOUGHREACT (a reactive transport code).

Extensive experience in experimental work, especially characterization of natural materials and performing sorption experiments with a wide range of substrates. Wide range of experience with analytical equipment and techniques, including radiochemistry (INAA, LSC, and gamma spectroscopy), batch adsorption and column transport experiments, bulk whole rock and liquid chemical analysis (AA, GFAA, ICP, ICP-MS, GC-MS, XRF, mass spectrometry, pulse-stripping polarography, and colorimetric and spectrofluorometric techniques), and textural and mineralogical characterization of natural and man-made materials (XRD, BET surface area analysis, SEM, and electron microprobe). Experienced in laboratory design and development; in addition to the Carlsbad laboratory already discussed, developed a laboratory for performing radiological work at SNL/Albuquerque (B59/823), obtaining all necessary ES&H permits. As lab manager, I directed work in the facility for several years without incident.

VOLUNTEER WORK

- Member of Engineers without Borders, participating in a project to evaluate well water quality on the Ramah Navajo Reservation (2008-present).
- Guest lecturer at the University of New Mexico/Gallup campus, giving lectures on radioactive waste disposal (2005 to present)
- New Mexico regional science fair judge (~1986 to present)
- Volunteer for Upward Bound; acted as a geology teacher/counselor on field trips to National Parks in the western U.S. for high school students from Plattsburgh, NY (2001-2002)

TECHNICAL ADVANCES AND PATENTS:

- SD 6221: Use of Iron Filings as a Packed Bed Material to Remove Europium (M. Siegel, R. Moore, C. Bryan, W. Wanger)
- SD 6250: Technetium Sorber in Alkaline Waste Stream Fluids and Groundwaters (J. Krumhansl, M. Molecke, H. Westrich, C. Bryan, C. Smith, P. Brady, H. Anderson)
- SD 6793: Control of Layered Double Hydroxide Morphology by Surfactants (J. Brinker, Y. Yang, C. Bryan, A. Hurd, P. Braterman, K. Yu)
- SD 7040: Use of Activated Layered Double Hydroxides to Remove/Immobilized Anion (Y. Wang, C. Bryan, H. Xu)
- SD 7304: Synthesis and Applications of Oxide-Carbon Nanocomposite (H. Gao, Y. Wang, C. Bryan, Z. Xu, P. Braterman)
- SD 7305: Surface Modified Mesoporous Trivalent Metal Oxides as an Anion Sorbent (H. Gao, Y. Wang, C. Bryan, H. Xu)

- SD 7353: Stabilization of Hanford Tank Waste Slurry by In-Situ Formation of Layered Double Hydroxides (H. Gao, Y. Wang, C. Bryan)
- SD 11388: Thermal Non-chemical Separation of CO₂ from the Atmosphere or Flue Gas (J. Torczynski, M. Gallis, D. Rader, C. Brooks, S. Kearney, P. Brady, C. Bryan)
- U.S. Patent No. 7,238,288: Method for Absorbing an Ion from a Fluid (H. Gao, Y. Wang, C. Bryan)

PUBLICATIONS

Yucca Mountain Project documents

Author or Co-author

- US DOE 2008. In-Drift Physical and Chemical Environment, Chapter 2.3.5 of *Yucca Mountain License Application, Yucca Mountain Repository Safety Analysis Report*. DOE/RW-0573 (chapter length 254 p.)
- SNL (Sandia National Laboratories) 2008. *Use of Strontium Isotopic Data to Constrain Percolation Fluxes through the Unsaturated Zone*, LSA-AO-002. Las Vegas, Nevada: Sandia National Laboratories. 38 p.
- SNL 2008. *Evaluating the Role of Sorption onto Corrosion Products with Respect to Releases from the EBS*, LSA-AR-006. Las Vegas, Nevada: Sandia National Laboratories. 189 p.
- SNL 2007. *Engineered Barrier System: Physical and Chemical Environment*. ANL-EBS-MD-000033 REV 06. Las Vegas, Nevada: Sandia National Laboratories. 456 p.
- SNL 2006. *Technical Work Plan for: Experimental Work to Support Evaluation of Dust Deliquescence-Induced Screening Localized Corrosion of Alloy 22*. TWP-MGR-PA-000040 REV 01. Las Vegas, Nevada: Sandia National Laboratories. 44 p.
- BSC (Bechtel SAIC Company) 2006. *Technical Work Plan for: Revision of Model Reports for Near-Field and In-Drift Water Chemistry*. TWP-MGR-PA-000038 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. 88 p. (also authored REV00)
- BSC 2006. *Response to the Additional Information Need (AIN) for Key Technical Issue (KTI) Agreement TSPAI 3.30: Inconsistency between the colloid stability implemented in the colloid source term abstraction and the results of miniature waste package corrosion experiments conducted by Zarrabi, et al., 2003*. (Prepared at DOE request) Las Vegas, Nevada: Bechtel SAIC Company. 8 p. (RISweb CCU.20060914.0001)
- BSC 2005. *Drift-Scale THC Seepage Model*. MDL-NBS-HS-000001 REV 04. Las Vegas, Nevada: Bechtel SAIC Company. 366 p. (also authored REV03)
- BSC 2005. *Analysis of Dust Deliquescence for FEP Screening*. ANL-EBS-MD-000074 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. 274 p. (also authored REV00).
- BSC 2005. *Technical Work Plan for: Near-Field Environment and Transport: Coupled Processes (Mountain-Scale TH/THC/THM, Drift-Scale THC Seepage, and Post-Processing Analysis for THC Seepage) Report Integration*. TWP-MGR-PA-000017 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. 50 p. (also authored REV00)
- BSC 2005. *Technical Work Plan for: Near-Field Environment Thermal Properties Model and Analysis Reports Integration*. TWP-MGR-PA-000019 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. 32 p.

BSC 2004. *Data Qualification for Thermodynamic Data Used to Support THC Calculations*. ANL-NBS-HS-000043 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. 190 p.

BSC 2004. Conditions and Processes Affecting Radionuclide Transport, Chapter 5 of *Yucca Mountain Site Description* TDR-CRW-GS-000001 REV 02 . Two volumes. Las Vegas, Nevada: Bechtel SAIC Company. (chapter length 347 p.)

Contributing author

SNL 2008. *Postclosure Analysis of the Range of Design Thermal Loadings*. ANL-NBS-HS-000057 REV 00. Las Vegas, Nevada: Sandia National Laboratories. 262 p.

SNL 2008. *Features, Events, and Processes for the Total System Performance Assessment: Analyses*. ANL-WIS-MD-000027 REV 00. Las Vegas, Nevada: Sandia National Laboratories. 2042 p.

SNL 2007. *EBS Radionuclide Transport Abstraction*. ANL-WIS-PA-000001 REV 03 (also REV 02). Las Vegas, Nevada: Sandia National Laboratories. 752 p.

BSC 2006. *Evaluation of the Effects of Incorporating Backfill and Alternative Drip Shield Designs in the Yucca Mountain Repository*. 800-30R-SSE0-00100-000-000. US DOE, Las Vegas, Nevada. 273 p.

Hardin, E., Bryan, C., and Buscheck, T., 2006. *Response to Nye County Report NWRPO-2006-05 Vapor Transport, Performance, and Design*, (Prepared at DOE request), Las Vegas, Nevada. 11 p. (RISweb CCU.20060720.0022).

Publications Outside of Yucca Mountain

Bryan, C.R., B.D. Marshall, D. Shields, and E.L. Hardin. Geochemistry of Topopah Spring Tuff Pore Waters, Yucca Mountain, Nevada, in prep.

Husler, J.W., Ferriss, E.D.A., Helean, K., **Bryan, C.R.**, and Brady, P.V. Optimized ferrozine method for determination of ferrous and ferric iron in minerals. *Geostandards and Geoanalytical Research*, submitted.

Bryan, C.R., K.B. Helean, B.D. Marshall, and P.V. Brady. Field-based Feldspar Dissolution Rates in the Topopah Spring Tuff, Yucca Mountain, Nevada, *Applied Geochemistry*, in publication.

Ferriss, E. D. A., Helean, K. B., **Bryan, C. R.**, Brady, P. V., and Ewing, R. C. (2009) UO₂ corrosion in an iron waste package, *Scientific Basis for Nuclear Waste Management XXXII, Proceedings of the Materials Research Society*, in publication.

Torczynski, J.R., Gallis, M.A., Brooks, C.F., Brady, P.V., and **Bryan, C.R.**, 2009. *Computational Investigation of Thermal Gas Separation for CO₂ Capture* SAND2009-5705. Sandia National Laboratories, Albuquerque, NM.

Ferriss, E.D.A., Helean, K.B., **Bryan, C.R.**, Brady, P.V., and Ewing, R.C. (2009) UO₂ corrosion in an iron waste package. *Journal of Nuclear Materials*, 384, 130-139.

Anderson, B.E. (former name), Helean, K.B., **Bryan, C.R.**, Brady, P.V., and Ewing, R.C., 2008. Waste package corrosion studies using small mockup experiments. *Scientific Basis for Nuclear Waste Management XXXI, Proceedings of the Materials Research Society*, 519-526.

Enos, D., D. Wall, K. Mon, G. De, B. Bullard, R. Rebak, **C. Bryan**, and R. Jarek, 2007. Corrosion Performance of the Engineered Barrier in the Yucca Mountain Repository, *Abstracts of the Third*

International Workshop on Long-Term Prediction of Corrosion Damage in Nuclear Waste Systems, May 14-18, 2007, p. 7.

- Bryan, C.**, R. Jarek, T. Wolery, D. Shields, M. Sutton, E. Hardin, and D. Barr, 2005, Evaluation of the Corrosivity of Dust Deposited on Waste Packages at Yucca Mountain, Nevada, *Scientific Basis for Nuclear Waste Management XXIX, Proceedings of the Materials Research Society*, Warrendale, PA, p. 191-198.
- Cygan, R. T., P.V. Brady, M.D. Seigel, C. F. Jove Colon, and **C.R. Bryan**, 2005. Geochemistry at U.S. National Labs: Sandia National Laboratories, *The Geochemical News*, 123, p. 12-17.
- Bryan, C.R.**, M. Spilde, Y. Xu, C. Schloesslin, and K. M. Davis, 2004, *Results of Uranium Adsorption/Desorption Experiments and Microanalytical Studies Characterizing Sediment Samples from the Great Miami Aquifer, Fernald DOE Site, Ohio*, SAND2004-4085, Sandia National Laboratories, Albuquerque, NM, 76 p.
- Siegel, M.D., and **C.R. Bryan**, 2003: *Environmental Geochemistry of Radioactive Contamination*, SAND2003-2063, Sandia National Laboratories, Albuquerque, NM. 114 pp.
- Wang, Y., **C. Bryan**, H. Gao, P.I. Pohl, C.J. Brinker, K. Yu, H. Xu, Y. Yang, P.S. Braterman, and Z. Xu, 2003: *Potential Applications of Nanostructured Materials in Nuclear Waste Management*, SAND2003-3313, Sandia National Laboratories, Albuquerque, NM. 95 pp.
- Bryan, C.R.**, S. A. Du Frane, D. Moir, C. Schloesslin, and K. M. Davis, 2003, *Selective Sequential Extraction Analysis of Uranium in Great Miami Aquifer Sediment Samples, Fernald DOE site, Ohio*, SAND2003-0192P, Sandia National Laboratories, Albuquerque, NM, 51 p.
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- L.H. Brush, A.C. Snider, **C.R. Bryan**, and Y. Wang, 2002: "The Use of MgO as an Engineered Barrier in the WIPP," *Sixth International Workshop on Design and Construction of Final Repositories: Backfilling in Radioactive Waste Disposal, Brussels, 11-13 March 2002*. Brussels, Belgium: Belgian Agency for Radioactive Waste and Enriched Fissile Materials (ONDRAF/NIRAS). SAND2001-3941C.
- Wang Yifeng, Xu H., **Bryan C.**, Snider A., 2001: Prediction of metal partitioning between minerals and aqueous solutions: An implication to containment materials selection for radioactive waste disposal. *Material Research Society Meeting*, Boston, Massachusetts, Nov. 26 - 30, 2001.
- Wang Yifeng, Xu, Huifang, and **Bryan, Charles**, 2001: Formation of Petrified Woods - An Organic Molecule-Templated Silica Mineral Precipitation in Nature. *American Geological Society*, Boston, Massachusetts, Nov. 1-10, 2001.
- Brush, L.H., **C.R. Bryan**, L.C. Meigs, H.W. Papenguth, and P. Vaughn, 2001. The Consideration and Representation of Retention Processes in the WIPP Performance Assessment: Justification of Adopted Approaches and Interaction with the Regulator. Part 1. Chemical Retardation of Dissolved Actinides. *Radionuclide Retention in Geologic Media: Workshop Proceedings, Oskarshamn, Sweden, 7-9 May 2001*. Paris, France: Organization for Economic Cooperation and Development/Nuclear Energy Agency. Albuquerque, NM: Sandia National Laboratories. 179-186.
- Brush, L.H., **Bryan, C.R.**, Dotson, L.J., Papenguth, H.W., and Vaughn, P., 2001: (Chemical) Retention Processes in WIPP PA, Presentation at the GEOTRAP 5 Workshop, Äspö, Sweden, May 8, 2001.
- Bryan, C.R.**, Hansen, F.D., Chapin, D.M., and Snider, A.C., 2001: Characteristics of the Disturbed Rock Zone, *Proceedings of the 38th U.S. Rock Mechanics Symposium: Rock Mechanics in the National Interest, Volume 1*, Elsworth, D., Tinucci, J.P., and Heasley, K.A., eds. July, 2001, Washington D.C., p. 511-516.
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