

**KEVIN COPPERSMITH**



## **KEVIN J. COPPERSMITH**

Technical Decision Analysis  
Probabilistic Hazard Analysis  
Performance Assessment

### **EDUCATION**

University of California, Santa Cruz; Ph.D., Geology, 1979 (Thesis: Paleoseismology of the Zayante-Vergeles Fault Zone, Central California)  
Washington and Lee University, Lexington, Virginia: B.S., Geology, 1974

### **PROFESSIONAL HISTORY**

Coppersmith Consulting, Inc., President, 2000 to present  
Geomatrix Consultants, Inc., Principal and Vice President, 1985 to 2000  
Woodward-Clyde Consultants, Senior Project Geologist, 1978-1985  
University of California, Regents Fellow, 1974-1978  
Earth Sciences Board, University of California, Santa Cruz, Research Assistant and Teaching Assistant, 1974-1978

### **REPRESENTATIVE SKILLS AND EXPERIENCE**

Dr. Coppersmith has 30 years of consulting experience, with primary emphasis in probabilistic hazard analysis, decision analysis, and geo-hazard analysis. Dr. Coppersmith has pioneered approaches to characterizing earth sciences data, and their associated uncertainties and variabilities, for probabilistic hazard analyses. As manager of the Decision Analysis (DA) operating unit at Geomatrix, Dr. Coppersmith helped develop capabilities that integrate the fields of earth sciences, hazard analysis, and risk assessment. In his practice at Coppersmith Consulting, Dr. Coppersmith has worked with both clients and regulators to develop and implement decision analysis methodologies for quantifying uncertainties and structuring hazard assessments. Applications range from new and existing nuclear power plants to offshore platforms to nuclear waste repositories.

Dr. Coppersmith's representative project experience and clients are identified briefly below:

#### **Advisory Boards for Hazard Analysis and Design Development**

*Technical Advisory Panel for Volcanic and Seismic Hazard Analyses, Armenia Nuclear Power Plant, Georisk Inc., Yerevan, Armenia*

*Peer Review Panel, Seismic Hazard Analysis for the BC Hydro Service Area, BC Hydro, Vancouver*

*PG&E Seismic Advisory Board, Central Coastal California Seismic Hazards Update, Pacific Gas and Electric Company*

*SCE Seismic Advisory Board, Southern California Edison Company*

*Technical Advisory Group, Combined Operating License Application Site Investigation for Levy County Site, Florida, CH2M Hill/Progress Energy*

*Technical Advisory Group, Geotechnical and Seismic Hazards Analysis for Combined Operating License for Shearon Harris Nuclear Power Plant, CH2M Hill/Progress Energy*

*Technical Advisory Group, Seismic Design Criteria for Early Site Permit for Clinton Nuclear Power Plant, CH2M Hill/Exelon.*

*Logic Tree Review Panel, Waste Treatment Facility, Hanford, Washington, PNNL/Batelle Memorial Institute*  
*Seismic Review of Device Assembly Facility, Nevada Test Site, Lawrence Livermore National Laboratory*  
*Coronado Tunnel Technical Advisory Panel, Caltrans*  
*Peer Review Panel, Seismic Hazard Analysis for TVA Service Area, Geomatrix Consultants, Inc.*

### **Development of Hazard Methodologies and Uncertainty Treatment**

*Implementation Guidance for the SSHAC Methodology, Nuclear Regulatory Commission (NRC)*  
*Seismic Hazard in the Eastern United States, Electric Power Research Institute (EPRI) Seismicity Owners Group*  
*Maximum Earthquakes in the Eastern United States, EPRI*  
*Member of Senior Seismic Hazard Analysis Committee [SSHAC], Nuclear Regulatory Commission (NRC), U.S. Department of Energy (DOE), and EPRI*  
*Seismic Hazard Analysis Methodology Topical Report for Yucca Mountain, DOE*  
*Expert Elicitation Methodology Demonstration for Yucca Mountain Performance Assessment, EPRI*  
*Review of Methodologies for Probabilistic Flood Hazard Analysis, INEEL, DOE*

### **Hazard Analysis for Performance Assessment of Built Structures and Pipelines**

*Seismic Hazard Analysis of Gas Pipeline Papua New Guinea, ExxonMobil Development*  
*Seismic hazard at San Francisco Bay Area bridges, California Department of Transportation (Caltrans)*  
*Seismic hazard at Humboldt Bay bridges, Caltrans*  
*Regional seismic hazard analysis for Oregon bridges and transportation structures, Oregon Department of Transportation*  
*Seismic hazard and site response studies for K-reactor, Westinghouse Savannah River Company*  
*Seismic hazard analysis for Portugues Dam, Puerto Rico, U.S. Army Corps of Engineers*  
*Seismic hazard analysis of Southern Ontario, Atomic Energy Control Board, Canada*  
*Probabilistic Seismic Hazard Analysis for Nuclear Power Plants in Switzerland, NAGRA*

### **Technical Decision Making for Critical Facilities**

*License Application Design Selection for Yucca Mountain, TRW Environmental Safety Systems*  
*Performance Allocation for Viability Assessment at Yucca Mountain, TRW Environmental Safety Systems, DOE Office of Civilian Radioactive Waste Management*

### **Uncertainty Characterization for Performance Assessments and Risk Analyses**

*Update to Probabilistic Volcanic Hazard Analysis for Yucca Mountain, Bechtel SAIC, Sandia National Laboratories, DOE*  
*Demonstration of risk-based total system performance assessment, EPRI, DOE*  
*Probabilistic volcanic hazard analysis for Yucca Mountain, TRW, DOE*  
*Seismic hazard analysis for Yucca Mountain, USGS, DOE*  
*Expert Elicitations for Total System Performance Assessment at Yucca Mountain: Unsaturated zone flow; Near field/Altered Zone Coupled Effects; Waste Package Degradation; Waste Form Degradation Radionuclide Mobilization; Saturated Zone Flow and Transport, TRW, DOE*  
*Uncertainty Strategy for Total System Performance Assessment at Yucca Mountain High Level Waste Repository, Bechtel-SAIC, DOE*

### **Hazard Analyses for Development of Design Criteria, Design Review, and Licensing**

*SSHAC Level 3 PSHAs at the Proposed Thyspunt, Bantamsklip, and Duynefontein Sites, South Africa, Council for Geosciences, South Africa*  
*Licensing Support for NRC Review of License Application for Yucca Mountain, Nevada, Sandia National Laboratories*  
*Probabilistic Seismic Hazard Analysis for Nuclear Power Plants in Switzerland (PEGASOS), NAGRA, Switzerland*  
*Seismic Hazard Assessment for the New Production Reactor of Savannah River Site and Idaho National Engineering Laboratory, DOE*  
*WNP-1, 2, 4 Hanford and WNP-3,5 Satsop, WPPSS*  
*Diablo Canyon Power Plant, PG&E*

*Trojan Nuclear Power Plant, Portland General Electric*  
*San Onofre Nuclear Generating Station, SCE*  
*Palo Verde Nuclear Power Plant, APS*  
*Seismic Design Criteria for Oseberg and Troll Prospects, Norwegian North Sea, Det Norske Veritas*  
*Preclosure Seismic Design Strategy, Yucca Mountain, Bechtel-SAIC*  
*Seismic Hazard Analysis of Orlan Site, Sakhalin Island, Russia, ExxonMobil*  
*Seismic Hazard Analysis of Gas Terminals and Pipeline Papua New Guinea to Australia, ExxonMobil*

### **Seismic Source Characterization for Hazard Analysis**

*Central and Eastern United States Seismic Source Characterization for Nuclear Facilities NRC, several nuclear utilities (represented by EPRI), DOE*  
*Diablo Canyon Power Plant, PG&E*  
*Hanford Reservation, Westinghouse Hanford Company*  
*Darlington and Pickering Nuclear Generating Stations, AECB*  
*Nuclear Power Plants in Eastern Europe: Bohunice, Slovakia; Kozloduy and Belene, Bulgaria, Westinghouse Energy Systems; Paks, Hungary; Ove Arup and Partners*  
*San Onofre Nuclear Generating Station, Southern California Edison*  
*Device Assembly Facility, Nevada Test Site, Lawrence Livermore Nat'l Laboratory*

### **Geologic Field Studies**

*Humboldt Bay Nuclear Power Plant, PG&E*  
*Diablo Canyon Power Plant, PG&E*  
*Savannah River Site, South Carolina, Westinghouse Savannah River Company*  
*Rocky Flats Environmental Technology Site, EG&G*

### **AFFILIATIONS**

Geological Society of America  
Seismological Society of America  
American Geophysical Union  
Earthquake Engineering Research Institute

### **APPOINTMENTS**

- Advisory Committee for *Nuclear Energy: Balancing Benefits And Risks*, Council On Foreign Relations CSR No. 28, April 2007
- Editorial Board, *Earthquake Spectra*, Professional Journal of the Earthquake Engineering Research Institute (1991-2000)
- Board of Directors, Seismological Society of America (1996-1999)
- Senior Seismic Hazard Analysis Committee (SSHAC), sponsored by the Department of Energy, Nuclear Regulatory Commission, and Electric Power Research Institute (1994-1996), Treatment of uncertainties and expert elicitation for seismic hazard analysis
- Appendix A Expert Panel, providing advice to Nuclear Regulatory Commission regarding revision to 10CFR100 Appendix A of Geologic Siting Criteria and associated regulatory guidance (1991-1996)
- Geosciences Team Leader, Governor's Executive Order on the Implications of the 1993 Northridge Earthquake to Building Codes and Land Use Planning, sponsored by California Seismic Safety Commission and FEMA (1994)
- Seismic Hazard Team Leader, *Earthquake Risk Reduction in the United States, An Assessment of Selected User Needs and Recommendations for the National Earthquake Hazards Reduction Program*; conducted for Federal Emergency Management Agency (FEMA) (1994)
- Chairman, Task Group on Probabilistic Approaches to Geological Uncertainties Related to Seismic and Volcanic Hazards, International Lithosphere Program, Inter-Union Commission on the Lithosphere - Geodynamics of the Solid Earth (1991-1993)
- National Research Council/National Academy of Sciences:
  - Panel on Probabilistic Seismic Hazard Analysis (1987-1988)
  - Panel on Geological Hazards, Committee on Solid Earth Sciences - A Critical

- Assessment (1989-1990)
- Committee on Seismology (1988-1993)

## **INVITED LECTURES AND PRESENTATIONS**

- Implementation Guidance for a SSHAC Level 3 Process, 10<sup>th</sup> International Probabilistic Safety Assessment and Management Conference (June 2010)
- Moderator, Nuclear Waste Storage, The Role of Nuclear Power Workshop, Washington and Lee University and Council on Foreign Relations (June 20-24, 2007)
- Lessons Learned – The Use Of Formal Expert Elicitation in Probabilistic Seismic Hazard Analysis, First European Conference on Earthquake Engineering and Seismology, Geneva, Switzerland (September 2006)
- Expert Elicitation to Update Probabilistic Volcanic Hazard Analysis, Yucca Mountain, Nevada, American Geophysical Union Annual Meeting, San Francisco (December, 2005)
- Specialists Meeting on State of the Art in Seismic Hazard Evaluation Methodology—Insights and Lessons from the PEGASOS Project, Baden, Switzerland (November 2004)
- Recent Developments in Seismic Hazard Assessment, Co-Convener, European Seismological Commission XXIX General Assembly, Potsdam, Germany (September 2004)
- Relationships Between Fault Behavior and Seismicity, EGS/AGU Conference, Nice, France (April, 2003)
- A Methodology for Probabilistic Fault Displacement Hazard Analysis, Workshop on the Seismic Hazard Evaluation and Risk Mitigation for the Critical Facilities in Caucasus, U.S. Civilian Research and Development Foundation (CRDF), Yerevan, Armenia (October, 2002)
- Quantifying Epistemic Uncertainty and Aleatory Variability for Probabilistic Performance Assessments, Radioactive Waste Management and Risk Analysis Symposium, Las Vegas, NV (October, 2002)
- Incorporating Uncertainties in Seismic Hazard Analyses, Luncheon Address, Symposium on the Application of Geophysics to Environmental and Engineering Problems, Environmental and Engineering Geophysical Society (March, 1999)
- New Trends in the Use of Paleoseismic Data in Seismic Hazard Analyses, Keynote Speech Latin American Geological Congress, Buenos Aires (November, 1998)
- Use of Expert Judgments in Risk Analyses, Probabilistic Safety Analysis and Management Conference, New York (September, 1998)
- Examples of Seismic Source Characterization for Probabilistic Seismic Hazard Analysis, Symposium on Geologic Interpretation of Earthquake Hazards, Camerino, Italy (June, 1998)
- The Use of Expert Elicitation to Quantify Uncertainties in Inputs to Total System Performance Assessments at Yucca Mountain, Nevada; Nuclear Waste Technical Review Board (May, 1998)
- Improved Guidance on the Use of Experts - Probabilistic Seismic Hazard Analysis and Other International Topical Meeting on Probabilistic Safety Assessment (October, 1996)
- Expert Elicitation of Probabilistic Volcanic Hazard at Yucca Mountain, Nevada, International High Level Radioactive Waste Management Conference (May, 1996)
- Probabilistic and Deterministic Approaches to Seismic Hazard Analysis, Applied Technology Council (September, 1995)
- Experience Characterizing Earthquake Sources in the Central and Eastern United States; Canadian Atomic Energy Control Board (June, 1995)
- Emergency Response Planning for Gas Systems, Institute Gas Technology (May, 1994)
- New Directions in Geotechnical Engineering, American Society of Civil Engineers (April, 1994)
- Use of Paleoseismic Data in Hazard Analysis, International Conference on the Implications of the 1988 Spitak, Armenia Earthquake (October, 1993)
- Effects of the 1992 Nevada Earthquake, International High Level radioactive Waste Management Conference (April, 1993)
- Seismic Hazard Methodologies, Building Seismic Safety Council (January, 1993)
- Conference on Seismic Vulnerabilities, Nuclear Waste Technical Review Board (January, 1992)
- State-of-the-Art Lecture, International Conference on Seismic Zonation (August, 1991)
- Seismic Hazards in the Delta, San Francisco Bay Region, Association of California Water Agencies (November, 1990)
- Workshop on Probabilistic Seismic Hazard Methodology, California Department of Transportation (November, 1990)

- Institute of Gas technology, Disaster Relief Planning Meeting (April, 1990)
- Advancements in Seismic Hazards Analysis, Department of Energy, Natural Phenomena Hazards Mitigation Conference (October, 1989)
- International Geological Congress Symposium on Geological Hazards (July, 1989)
- National Academy of Sciences/National Research Council, Symposium on Opportunities in Seismology (May, 1989)
- National Earthquake Hazards Reduction Program Workshop of the Cascadia Subduction Zone (March, 1989)
- American Society of Civil Engineers, Earthquake Engineering and Soil Dynamics II Conference (June, 1988)
- NATO Advanced Research Workshop on Causes and Effects on Earthquakes at Passive Margins and in Areas with Post-glacial Rebound on both Sides of the North Atlantic (May, 1988)
- Seismogenesis in The Eastern United States, NSF Workshop (April, 1988)
- U.S. Geological Survey Workshop on Fault Segmentation (March, 1988)
- Geological Society of America, Neotectonics in Earthquake Evaluation (October, 1987)
- National Center for Earthquake Engineering Research, Symposium on Seismic Hazards, Ground Motions, Soil-Liquefaction, and Engineering Practice in Eastern North America (October, 1987)
- Geotechnical Considerations in Hazardous Waste Management, American Society of Civil Engineers (June, 1987)
- Seismic Source Characterization for Probabilistic Seismic Hazard Analysis, Earthquake Engineering Research Institute, Strong Ground Motion Seminar: San Francisco, CA (April, 1987), Los Angeles, CA (April, 1987), Charleston, SC (January, 1988)
- National Earthquake Prediction Evaluation Council, Cascadia Subduction Zone (April, 1987)
- University of California, Santa Cruz, Geology Seminar (March, 1987)
- Stanford University, Risk Analysis Seminar (March, 1987)
- University of South Carolina, Geology Seminar (September, 1986)
- Earthquake Engineering Research Institute Annual Seminar (February, 1986)

## PUBLICATIONS

“Methodology and Main Results of Seismic Source Characterization for the PEGASOS Project, Switzerland,” Coppersmith, K.J., Youngs, R.R., and Sprecher, C., *Swiss Journal of Geosciences* (in press, publication in 2009)

“Chapter 26, Lessons Learned—The Use of Formal Expert Assessment in Probabilistic Seismic and Volcanic Hazard Analysis,” Coppersmith, K.J., Perman, R.C., Jenni, K.E., and Youngs, R.R., in *Volcanism, Tectonism, and Siting of Nuclear Facilities*, edited by C. Connor and L. Connor, Cambridge University Press, p. 593-611, 2009

“Lessons Learned—The Use of Formal Expert Elicitation in Probabilistic Seismic Hazard Analysis” Coppersmith, K.J., Perman, R.P., Youngs, R.R., First European Conference on Earthquake Engineering and Seismology, Geneva, Switzerland, September 3-8, 2006

“Seismic Source Zones in PSHA: Aleatory or Epistemic?” Youngs, R.R., Coppersmith, K.J., First European Conference on Earthquake Engineering and Seismology, Geneva, Switzerland, September 3-8, 2006

“Update to the Probabilistic Volcanic Hazard Analysis, Yucca Mountain, Nevada” Coppersmith, K.J., Jenni, K., Nieman, T., Perman, R., Youngs, R., Perry, F., Cline, M., *Eos, Trans. AGU*, 85 (52), 2005

“Bounding Peak Ground Velocities for Seismic Events at Yucca Mountain, Nevada” King, J.L., Coppersmith, K.J., Quittmeyer, R.C., (abs), *Geological Society of America Abstracts with Programs*, v.36, no.5, p. 33, 2004

“A Methodology for Probabilistic Fault Displacement Hazard Analysis (PFDHA),” Youngs, R.R., Arabasz,

W.J., Anderson, R.E., Ramelli, A.R., Ake, J.P., Slemmons, D.B., McCalpin, J. P., Doser, D.I., Fridrich, C.J., Swan III, F.H., Rogers, A.M., Bruhn, R.L., Knuepfer, P.L.K., Smith, R.B., dePolo, C.M., O’Leary, D.W., Coppersmith, K.J., Pezzopane, S.K., Schwartz, D.P., Whitney, J.W., Olig, S.W., and Toro, G.R., 2003, *Earthquake Spectra*, The Professional Journal of the Earthquake Engineering Institute, vol. 19, no. 1, p. 191-219, 2003.

“Probabilistic Seismic Hazard Analyses for Ground Motions and Fault Displacement at Yucca Mountain, Nevada,” J.C. Stepp, I. Wong, J. Whitney, R. Quittmeyer, N. Abrahamson, G. Toro, R. Youngs, K. Coppersmith, J. Savy, T. Sullivan, and Yucca Mountain PSHA Project Members, *Earthquake Spectra*, v. 17, No. 1, p. 113-151, 2001

“Data Needs for Probabilistic Fault Displacement Hazard Analysis,” K. Coppersmith and R. Youngs, *Journal of Geodynamics*, v. 29, p. 329-343, 2000.

“Use of Technical Expert Panels: Applications to Probabilistic Seismic Hazard Analysis,” R. Budnitz, G. Apostolakis, D. Boore, L. Cluff, K. Coppersmith, C. Cornell, and P. Morris, *Risk Analysis*, v. 18, p. 463-470, 1998.

“Use of Expert Elicitation to Quantify Uncertainties in Process Models for Total System Performance Assessment,” K.J. Coppersmith, R.C. Perman, R.R. Youngs, and M. Pendleton, *International High Level Radioactive Waste Management Conference Proceedings*, p. 318-320, 1998.

“Use of Expert Elicitation for Modeling Waste Package Degradation at the Potential Yucca Mountain Repository,” J.H. Lee, K.J. Coppersmith, D. Stahl, R. Andrews, M. Pendleton, *International High Level Radioactive Waste Management Conference Proceedings*, p. 414-416, 1998

“Recommendations for Probabilistic Seismic Hazard Analysis—Guidance on Uncertainty and Use of Experts,” SSHAC ([Senior Seismic Hazard Analysis Committee], R.J. Budnitz, Chairman, G. Apostolakis, D.M. Boore, L.S. Cluff, K.J. Coppersmith, C.A. Cornell, and P.A. Morris), U.S. Nuclear Regulatory Commission, *NUREG/CR-6372*, Washington, D.C., 1997

“Characterizing seismic sources for design ground motions and fault displacement studies part of Los Angeles 2020 project,” L. S. Cluff, and K. J. Coppersmith, *Port of Las Angeles 2020 Project Earthquake Symposium*, p. 1-14, 1997.

“Performance Assessments for gas transmission systems,” K.J. Coppersmith, *Proceedings of the Disaster Relief Planning Symposium: Institute for Gas Technology*, May, 1997.

“Yucca Mountain Probabilistic Volcanic Hazard Analysis Project,” K.J. Coppersmith, *International High-Level Radioactive Waste Management Conference Proceedings*, 1996.

“New empirical relationships among magnitude, rupture length, rupture width, rupture area, and surface displacement,” D.L. Wells, K.J. Coppersmith, *Bulletin of the Seismological Society of America*, v. 84 #4, p. 974-1002, 1994.

“Modeling fault rupture hazard for the proposed repository at Yucca Mountain, Nevada,” K.J. Coppersmith, R. Youngs, *Proceedings Third International Conference High Level Radioactive Waste Management*, April 12-16, 1992.

“Demonstration of a decision analysis methodology for assessing the performance of the Yucca Mountain site in southern Nevada,” F. Schwartz, R. McGuire, D. Bullen, N. Cook, K. J. Coppersmith, J. Kemeny, A.

Long, F. Pearson Jr., M. Sheridan, and R. R. Youngs, *Waste Management*, v. II, p. 287-306, 1991.

“Seismic source characterization for engineering seismic hazard analyses,” K.J. Coppersmith, *Proceedings of the Fourth International Conference on Seismic Zonation: Earthquake Engineering Research Institute*, Oakland, California, v. 1, p. 1-60, 1991.

“Improved methods for seismic hazard analysis in the western United States,” R.R. Youngs, *Proceedings of the Fourth U.S. National Conference on Earthquake Engineering*, v. 1, p. 723-731, 1990.

“Incorporating seismotectonic data into seismic hazards analyses,” K.J. Coppersmith, *Second International High-Level Radioactive Waste Management Conference Proceedings*, 1990.

“Probabilistic Seismic hazard analysis using expert opinion: An example from the Pacific Northwest,” K.J. Coppersmith, R. Youngs, *Geological Society of America Memoir on Neotectonics in Earthquake Evaluation*, E. Krinitsky, and D.B. Slemmons (eds.), v. 8, p.27-46, 1990.

“New earthquake magnitude and fault rupture parameters: Part I Surface rupture length and rupture area relationships” (abs.), D.L. Wells, K.J. Coppersmith, X. Chang, and D.B. Slemmons, *Seismological Research Letters*, 1989.

“Paleoseismic history of the Meers fault, southwestern Oklahoma, and its implications to evaluations of earthquake hazards in the central and eastern United States,” F. H. Swan, K.J. Coppersmith, and K. I. Kelson, *Proceedings of the 17th Water Reactor Safety Information Meeting*, 1989.

“Keeping pace with the science: seismic hazard analysis in the western United States,” R.R. Youngs, K. J. Coppersmith, *Proceedings of the Second DOE Natural Phenomena Hazards Mitigation Conference*, 1989.

“Keeping pace with the science: seismic hazard analysis in the central and eastern United States,” K. J. Coppersmith, R.R. Youngs, *Proceedings of the Second DOE Natural Phenomena Hazards Mitigation Conference*, 1989.

“The impact of fault segmentation on estimates of earthquake recurrence and seismic hazard,” K.J. Coppersmith, R.R. Youngs, *Proceedings of the Fourth International Symposium on the Analysis of Seismicity and Seismic Risk*, 1989.

“Estimating maximum earthquakes for seismic sources in the central and eastern United States: A progress report,” K.J. Coppersmith, R.R. Youngs, A.C. Johnston, L.R. Kanter, J.F. Schneider, and W.J. Arabasz, *Proceedings of the Fourth International Symposium on the Analysis of Seismicity and Seismic Risk*, Bechyně Castle, Czechoslovakia, v.1, p.115-122, September 4-9, 1989.

“Issues regarding earthquake source characterization and seismic hazard analysis within passive margins and stable continental interiors,” K.J.Coppersmith, R.R. Youngs, *Earthquakes at North Atlantic Passive Margins: Neotectonics and Post-glacial Rebound*, S. Gregerson and P.W. Basham (eds.), Kluwer Academic publishers, v. 266, p.601-631, 1989.

“Temporal and spatial clustering of earthquake activity in the central and eastern United States,” K.J. Coppersmith, *Seismological Research Letters*, v. 59, p. no. 4, 299-304, 1988.

“Estimating future coseismic ruptures from fault segmentation data,” (abs.) K.J. Coppersmith, R.R. Youngs, *Geological Society of America Abstracts with Programs*, 20:151, 1988.



“The seismicity of stable continental interiors,” A.C. Johnston, K.J. Coppersmith, and A.G. Metzger, *Seismological Society of America*, Annual Meeting, 1987.

“Characteristics of the boundaries of historical surface fault ruptures,” P.L. Knuepfer, and K.J. Coppersmith, *Seismological Society of America*, Annual Meeting, 1987.

“Methods for assessing maximum earthquakes in the central and eastern United States,” K.J. Coppersmith, R. Youngs, A.C. Johnston, and L. Kanter, *Electric Power Research Institute, Palo Alto, California, Research Project RP-2556-12*, 1987.

“Seismic hazard methodology for the central and eastern United States, Volume 1: Methodology,” with Risk Engineering, Woodward-Clyde Consultants, and Cygna Corporation, *Electric Power Research Institute Publication NP-4726*, 1986.

“Seismic hazard: new trends in analysis using geologic data,” D.P. Schwartz, K.J. Coppersmith, *Active Tectonics: National Academy of Sciences*, National Academy Press, pgs. 215-230, 1986.

“Capturing uncertainty in probabilistic seismic hazard assessments within intraplate tectonic environments,” K.J. Coppersmith, R.R. Youngs, *Proceedings Third U.S. National Conference on Earthquake Engineering*, v. 1, p.301-312, Charleston, South Carolina, Aug.24-28, 1986.

“Advances in tectonic and seismic hazard studies in the eastern United States,” K.J. Coppersmith, *Earthquake Engineering Institute Annual Seminar*, Seismic Hazard and Vulnerability, February 6, 1986.

“Seismic hazard assessment at the Hanford region, eastern Washington state,” R.R. Youngs, K.J. Coppersmith, M.S. Power, and F. Swan, *Proceedings of the DOE Natural Phenomena Hazards Mitigation Conference*, p.169-176, 1985.

“Implications of Fault slip rates and earthquake recurrence models to probabilistic seismic hazard estimates,” R.R. Youngs, K.J. Coppersmith, *Bulletin of the Seismological Society of America*, #4 v. 75, p.939-964, August, 1985.

“Tectonic framework methodology for developing seismic source zones in the eastern United States,” J.C. Stepp, K.J. Coppersmith, J.L. King, *International ANS/ENS Topical Meeting on Probabilistic Safety Methods and Applications Proceedings*, p.49-1 – 49-8,1985.

“Methods for estimating maximum earthquake magnitude,” D.P. Schwartz, K.J. Coppersmith, and F.H. Swan, III, *Proceedings of the Eighth World Conference on Earthquake Engineering*, v.1, p.279-286, 1984.

Special Issue “Journal of Geophysical Research Special Issue on Fault Behavior and the Earthquake Generation Process,” D.P. Schwartz and K.J. Coppersmith, Associate Editors, *Journal of Geophysical Research*, v. 89, no. B7, 1984.

“Fault behavior and characteristic earthquakes: examples from the Wasatch and San Andreas fault zones,” D. P. Schwartz, and K. J. Coppersmith, *Journal of Geophysical Research*, v. 89, no. B7, p.5681-5698, July 10, 1984.

“Assessment of confidence intervals for results of seismic exposure analysis,” R.B. Kulkarni, R.R. Youngs, and K.J. Coppersmith, *Proceedings of the Eighth World Conference on Earthquake Engineering*, San Francisco, California, v. 1, p.263-270, 1984.

- “Introduction to the Special Section on fault behavior and the earthquake generation process,” K. J. Coppersmith, and D. P. Schwartz, *Journal of Geophysical Research*, v. 89, no. B7, p. 5669-5673, July 10, 1984.
- “Source characterization for seismic hazards analyses within intraplate tectonic environments” (abs.), K.J. Coppersmith and R.R. Youngs, *Earthquake Notes*, v. 54, no. 1, 1983.
- “Probabilistic evaluation of earthquake hazards,” K.J. Coppersmith, *California Division of Mines and Geology, Special Publication 62*, 1982.
- “Probabilistic earthquake source definition for seismic exposure analyses” (abs), R. R. Youngs and K.J. Coppersmith, *Earthquake Notes*, v. 53, no. 1, 1982.
- “Probabilities of earthquake occurrence on the San Andreas fault based on geologic data”, (abs.) K.J. Coppersmith and L. S. Cluff, *International Association of Seismology and Physics of the Earth’s Interior*, 21st General Assembly, A2.17, 1981.
- “A new approach to seismic hazards analysis: Classifying faults based on their relative degree of activity,” L.S. Cluff, K.J. Coppersmith, and P.L. Knuepfer, *Structural Engineers Association of California, 50th Annual Convention Proceedings*, v. 4, 1981.
- “Near-surface behavior of thrust faults in the Humboldt Bay Area, California” (abs.), K.J. Coppersmith, *Earthquake Notes*, Seismological Society of America, v. 52, no. 1, 1981.
- “Estimating the probability of occurrence of surface faulting earthquakes on the Watsatch Fault Zone, Utah,” L.S. Cluff, A.S. Patwardhan, K.J. Coppersmith, *Bulletin of the Seismological Society of America*, v. 70, no. 5, p.1463-1478, 1980.
- “Morphology, recent activity, and seismicity of the San Gregorio fault zone,” K.J. Coppersmith and G.B. Griggs, *California Division of Mines and Geology, Special Report 137*, 1978.

### **Pertinent Recent Publications: Dr. Kevin J. Coppersmith**

Coppersmith, K.J., Youngs, R.R., and Sprecher, C., (in press, publication in 2009), Methodology and Main Results of Seismic Source Characterization for the PEGASOS Project, Switzerland, *Swiss Journal of Geosciences*

Coppersmith, K.J., Perman, R.C., Jenni, K.E., and Youngs, R.R., (in press, publication in 2009), Chapter 26, Lessons Learned—The Use of Formal Expert Assessment in Probabilistic Seismic and Volcanic Hazard Analysis, in *Volcanism, Tectonism, and Siting of Nuclear Facilities*, edited by C. Connor and L. Connor, Cambridge University Press

Coppersmith, K.J., Perman, R.P., Youngs, R.R., 2006, Lessons Learned—The Use of Formal Expert Elicitation in Probabilistic Seismic Hazard Analysis, First European Conference on Earthquake Engineering and Seismology, Geneva, Switzerland, September 3-8, 2006

Youngs, R.R., Coppersmith, K.J., 2006, Seismic Source Zones in PSHA: Aleatory or Epistemic?, First European Conference on Earthquake Engineering and Seismology, Geneva, Switzerland, September 3-8, 2006

Coppersmith, K.J., Jenni, K., Nieman, T., Perman, R., Youngs, R., Perry, F., Cline, M., 2005, Update to the Probabilistic Volcanic Hazard Analysis, Yucca Mountain, Nevada, *Eos, Trans. American Geophysical Union*, 85 (52).

King, J.L., Coppersmith, K.J., Quittmeyer, R.C., 2004, Bounding Peak Ground Velocities for Seismic Events at Yucca Mountain, Nevada” (abs), *Geological Society of America Abstracts with Programs*, v.36, no.5, p. 33

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**BRANKO DAMJANAC**

Itasca Consulting Group  
111 Third Avenue South, Suite 450  
Minneapolis, MN 55401

**Geotechnical Engineering**

**Expertise** Rock Mechanics, Hydro-Mechanical Coupling, Dynamics in Geotechnical Engineering, Tool-Rock Interaction

**Education** Ph.D. (Civil Engineering), 1996  
M.S.C.E. (Civil Engineering), 1992  
University of Minnesota  
B.S.C.E. (Civil Engineering), 1984  
Belgrade University (Yugoslavia)

**Professional Experience**

*2000 - Present* *Itasca Consulting Group, Inc., Minneapolis, Minnesota*  
*Principal*  
*1996 - Present* *Geotechnical Engineer*  
*1991-1996* *University of Minnesota, Department of Civil Engineering*  
*Research Assistant/Post-Doctoral Associate*  
*1991 - 1993* *Itasca Consulting Group, Inc., Minneapolis, Minnesota, Staff Engineer*  
*1984 - 1991* *Energoprojekt Consulting Company, Belgrade, Yugoslavia*  
*Consulting Engineer*

**Project Experience**

*Design and Analysis of Geological Radioactive Waste Disposal:* Since 1991, involved in different aspects of the U.S. program for geological disposal of high-level radioactive waste at Yucca Mountain, Nevada. Starting in 2001, manager of Itasca's long-term project with Bechtel-SAIC Company, U.S. Department of Energy (DOE) contactor for Yucca Mountain Project. Among other issues, the project involves: (a) stability analyses of the emplacement drifts and non-emplacement excavations at the Yucca Mountain site for different loading conditions, including in-situ stresses, thermally induced stresses, seismic ground shaking, and time-dependent strength degradation; and (b) investigations of the mechanics of dike propagation and the interaction between the dike and the emplacement drifts in case of volcanic intrusion into the repository. Previous work on the Yucca Mountain Project involves: (a) investigation of effect of thermo-mechanical-hydrological coupling on conditions of water percolation in an unsaturated rock mass around the emplacement drifts and the potential for water seepage into the drifts; (b) simulation of the Heated Drift Test (a large scale experiment involving heating a 50-m long tunnel) and analysis of the effects of large-scale heating on deformation of a rock mass and changes in rock-mass permeability; and (c) investigations of the influence of local seismicity, due to slip on the faults in vicinity of the repository, on variation of groundwater levels at the proposed Yucca Mountain site.

Investigated the effects of incidental borehole intrusion into Waste Isolation Pilot Plant, New Mexico, including analysis and modeling of the expulsion of granular material due to gas migration caused by intrusion of the borehole into the waste repository; analysis of coupled, fluid flow-deformation; analysis of the conditions for erosion of the granular material, in which erosion as a manifestation of local (sanding) and

global (plastic flow) instability was considered, as well as transition conditions between two modes of instability.

*Numerical Modeling of Underground Nuclear Explosions.* Acted as a consultant to International Geological Commission established by French government to investigate effects of underground nuclear testing on the structural stability of atolls of Mururoa and Fangataufa, French Polynesia. Responsible for numerical simulations related to deformation and stability of rock mass including: (a) near-field effects — predictions of cavity size and extent of different modes of damage in the rock mass, which involved development of the numerical model for and simulation of shock-wave propagation caused by nuclear explosion; and (b) far-field effects — effects of elastic waves caused by nuclear explosion on stability of atoll flanks and subsidence of the atoll rim.

*Code Development:* Involved in the development of different Itasca codes including a fully coupled 3D model of fluid flow through the joints in deformable media (3DEC), a new algorithm (fast flow) for simulating hydro-mechanical coupling in porous media (FLAC), and mixed discretization in 3DEC; continuum and micro-mechanical constitutive models (FLAC, PFC).

*Rock Mechanics Applied to Underground Mine Design:* Involved in the investigation of mechanism of large-scale panel collapses at room-and-pillar trona mines in Green River, Wyoming. Developed a methodology that can be used to provide guidelines for safe mine design (i.e., panel spans, extraction ratio, pillar widths) accounting for interaction between pillars and overburden. Investigated using three-dimensional models of the mechanisms of movement of large blocks formed by faults at Kidd Creek Mine (Falconbridge, Timmins, Canada) and its consequences on mine operation. Suggested measures (mining sequence) to reduce the risk of additional movement and potential disruption of mine operation. Analyzed mine-scale convergence rate due to salt creep at Sifto Mine (Goderich, Canada). Involved in the design of an optimal mining methodology at De Beers' Snap Lake operation. Analyses of mine-scale deformation (looking at potential consequences of permeability change) due to different level of extraction were conducted. Effects of different pillar extraction schemes were investigated using pillar-scale models.

*Tool-Rock Interaction:* Theoretical and numerical analyses of rock cutting; determination of cut-ability criterion as a function of the material properties of the rock, geometry of the tool and cutting disposition; determination of ductile to brittle transition; prediction of force required to induce fracturing of the rock during tool indentation (University of Minnesota, Department of Civil Engineering).

*Underground Storage of Hydrocarbons:* U.S. DOE review of new technology for the underground storage of gas under large pressure into lined rock caverns (LRC). New technology promises to provide additional flexibility in meeting seasonal fluctuations in energy demands. Complex three-dimensional structure-rock interactions were investigated to determine the most unfavorable conditions for the operation of the structure.

Design and consulting related to aqua-type underground oil-storage facilities: analytical and numerical analysis of the stability of caverns; design of primary and permanent support of underground excavations; simulation of the influence of underground storage systems on regional groundwater conditions during construction and operation. (Energoprojekt).

*Design of Dams:* Consultant to the project manager for the stability of slopes and underground excavations during construction at the Bekhme Dam, Iraq; development and programming of analytical and numerical procedures (finite-element method) used in analysis of stability and design of support of slopes and underground excavations in rock (Energoprojekt).



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Damjanac, B., P. A. Cundall and T. Brandshaug. “Itasca Presentations at the Menlo Park Workshop, August 23-24, 2004,” in *Report of the Workshop on Extreme Ground Motions at Yucca Mountain, August 23-25, 2004*, U.S. Geological Survey, USGS Open-File Report 2006-1277. T. C. Hanks et al., Eds. Reston, Virginia: USGS, 2006.

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Lin, M., M. P. Board, D. C. Kicker, J. Leem, B. Damjanac and D. C. Buesch. “Assessment of Drift Stability with Consideration of Spatial Variation of Lithophysal Cavities at Yucca Mountain,” in *Proceedings of Alaska Rocks 2005 — Rock Mechanics for Energy, Mineral and Infrastructure Development in the Northern Regions (CD)*. University of Alaska-Anchorage, June 2005, Paper No. ARMA/USRMS 05-802. G. Chen et al., Eds. ARMA, University of Alaska-Fairbanks, 2005.

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Fairhurst, C., B. Damjanac and R. Hart. "Numerical Analysis As a Practical Design Tool in Geo Engineering," in *Slope Stability 2000*, Geotechnical Special Publication No. 101, Proceedings of Sessions of Geo-Denver 2000 (August 2000, Denver), pp. 169-183. D. V. Griffiths, Ed. Reston, Virginia: ASCE, 2000.

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Damjanac, B., E. Detournay and H. Huang. "Effects of Underground Nuclear Tests in French Polynesia On the Stability of Atoll Flanks," in *FLAC and Numerical Modeling in Geomechanics (Proceedings of the Conference, Minneapolis, September 1999)*, pp. 23-31. C. Detournay and R. Hart, Eds. Rotterdam: Balkema, 1999.

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Smiljkovic, Z., and B. Damjanac. "Some Design Aspects of Large Rock Caverns for Storing Petroleum Products," in *Proceedings of the International Congress on Progress and Innovation in Tunnelling (Toronto, 1989)*, pp. 419-426. K. Y. Lo et al., Eds. Toronto: Tunnelling Association of Canada/National Research Council of Canada/International Tunnelling Association, 1989.

**DAVID ENOS**

## **David G. Enos, Ph.D.**

Sandia National Laboratories  
Materials Reliability Department  
P.O. Box 5800, MS 0888  
Albuquerque, NM 87185-0888  
E-Mail: dgenos@Sandia.gov

### ***Education***

*University of Virginia*, Ph.D., Materials Science and Engineering, August 1997

Thesis: The Long Term Effects of Cathodic Protection on Corroding, Pre-Stressed Concrete Structures: Hydrogen Embrittlement of Pre-Stressing Steel

*University of Virginia*, M.S., Materials Science and Engineering, January 1994

Thesis: The Influence of Sulfate Reducing Bacteria on Alloy 625 and a Series of Austenitic Stainless Steel Weldments

*Rensselaer Polytechnic Institute*, B.S., Materials Engineering, May 1991

### ***Professional Experience***

*Principal Member, Technical Staff* 4/02-present

Sandia National Laboratories, Materials Reliability Dept. – Albuquerque, NM

Corrosion scientist within the primary materials research group. Current projects range from fundamental research in the area of atmospheric corrosion of electronics, to failure analysis, to materials based safety assessments of critical systems.

Projects have included assessment of atmospheric corrosion of noble metal plated connector materials; Evaluation of the corrosion performance of a Ni-Cr-Mo superalloy under various conditions of importance during the thermal pulse within the proposed high level nuclear waste repository at Yucca Mountain; Development of a fundamental understanding of the corrosion of microelectronic materials (aluminum bondpads and gold wirebonds); Basic research on the environmentally assisted cracking of LIGA materials; and Materials aging assessments (involving both safety and functional aspects) of various high consequence systems. During the course of the aforementioned projects I was responsible for the design and construction of several complex mixed flowing gas exposure chambers, a novel mechanical testing apparatus, and a differential-imaging optical analysis system. Development of each of the aforementioned devices included hardware selection and assembly, control system construction, and control algorithm development. Responsible for providing technical direction to a team of technologists and several student interns.

*Research Specialist* 2/01-5/02

*Senior Research Scientist* 9/97-2/01

3M, OptoElectronic Packaging Systems Technology Center - Austin, TX

Current role is as the Electrochemistry/Corrosion Science technology application leader within a corporate research and development laboratory. Responsibilities include (1) Serving as a general corrosion consultant to divisions throughout the company (Interactions have included automotive products, medical specialties, sintered abrasives, telecommunications, corrosion protection products, etc.), assisting individuals and groups with failure analyses, general questions/problems, etc. which involve electrochemistry/corrosion science (2) Interact with divisions to assist with material development and selection, as well as identification of promising R&D areas; (3) Develop and implement electrochemical test procedures as appropriate to meet divisional and research needs; (4) Maintain electrochemical and corrosion testing capabilities of the OPSTC – including specification and purchasing of equipment and software. Major projects include (1) Process refinement in flexible circuit manufacture; (2) Development of a self-healing coating system (patent issued); (3) Corrosion inhibitor selection/development; (4) Assessment of technologies offered to 3M; (5) Served as corporate technical liaison to external consortium focused on protective coating development; and (6) Extensive customer/division interaction to brainstorm corrosion issues with product. In addition, have supervised 8 Co-op and summer intern students.

*Consultant* 1/95-5/97

Cahen Consulting - Charlottesville, VA

Conducted failure analyses of tube sheet heat exchangers, evaluating corrosion issues as well as new production procedures.

*Consultant*

10/94-5/97

Scribner Associates, Inc. - Charlottesville, VA

Developed diagnostic software to assist calibration of a multi-channel potentiostat. Composed application notes outlining specific electrochemical techniques (AC Impedance, DC Polarization) for a major equipment manufacturer. Edited a series of software instruction manuals.

*Co-op Engineer*

5/91-8/91

Texas Instruments, New Business Development - Attleboro, MA

Conducted research on the properties of a plasma deposited ceramic as a potential substrate material for the electronics industry. Areas explored included phase composition and stability, moisture resistance and dielectric performance. Developed and executed appropriate materials test procedures.

*Co-op Engineer*

5/90-8/90

GE Aircraft Engines, Thompson Laboratory - Lynn, MA

Assisted materials application engineers conducting gas turbine failure analyses. Performed comprehensive metallographic analyses and environmental exposure testing on a variety of superalloys.

*Co-op Engineer*

5/89-1/90

Arthur D. Little, Materials and Applied Physics - Cambridge, MA

Aided in the refinement of a coal cleaning process, operating a pilot plant and conducting data analysis. Instrumental in the development of a small scale aluminum refining furnace, which included monitoring and maintaining the furnace as well as assisting in the design certain aspects of the system. Conducted a series of literature searches and market analyses.

***Academic Experience***

*Research Assistant*

10/93-8/97

University of Virginia - Charlottesville, VA

Quantified positional and temporal variations in the local electrochemical conditions present at the steel/concrete interface within a steel reinforced, marine bridge pile. Implemented constant extension rate testing to establish the fracture initiation stress and the micromechanisms of failure of the pre-stressing steel as a function of hydrogen concentration. Laboratory scale pilings and hydrogen permeation measurements were employed to determine the hydrogen concentrations anticipated within a cathodically protected structure. The aforementioned information was then combined to obtain an understanding of safe cathodic protection limits for a pre-stressed concrete structure. Laboratory techniques implemented included slow strain rate testing, Devanathan/Stachurski hydrogen permeation studies, thermal desorption spectroscopy, local pH measurement, as well as a series of AC and DC electrochemical techniques.

*Teaching Assistant*

9/94-12/94, 1/97-5/97

University of Virginia

Conducted review sessions, laboratories, and grading for several undergraduate level materials science courses.

*Laboratory Instructor*

8/94, 7/96

University of Virginia

Prepared and supervised laboratories and review sessions for an Electrochemical Impedance Spectroscopy short course offered to industry by the Center for Electrochemical Science and Engineering at the University of Virginia.

*Research Assistant*

8/91-10/93

University of Virginia

Evaluated the corrosion performance of alloy 625 as well as a series of austenitic stainless steels within a biologically active environment simulating a service water system. Addressed both general and microbiologically induced corrosion, focusing on the behavior of weldments of the aforementioned materials. Laboratory techniques implemented included a series of AC (electrochemical Impedance Spectroscopy) and DC (polarization, zero resistance ammetry) electrochemical experiments, as well as both optical and scanning electron microscopy.

***Awards***

NACE A.B. Campbell Award, 1999

NACE Mars Fontana Award for Corrosion Engineering (*First Place*), 1996

### ***Professional Societies***

Member: NACE

Chair, NACE A.B. Campbell Awards committee (2002-present)

Vice-Chair, NACE Research Committee

Member, NACE Awards committee

Vice-Chair, Corrosion in Electronics

In addition, have chaired numerous technical symposia at the NACE annual Corrosion conference

### ***Selected Publications and Presentations***

1. D.G. Enos, D.J. Giersch, R.E. Heintzleman "A Materials Ageing Assessment of the MC1828, MC2807, MC3280 Tube Radars for the B61 ", SAND2009-4098
2. C.D. Mowry, D.G. Enos, R.P. Grant "Final Report: Powder Analysis for Team Technologies, Inc.", SAND2009-0062
3. H.K. Moffat, D.G. Enos, L.M. Serna, N.R. Sorensen, A.C. Sun "Modeling Pore Corrosion in Normally Open Gold Plated Copper Connectors", SAND2008-5737
4. D.G. Enos "Understanding the Atmospheric Degradation of Noble Metal Plated Connector Materials ", SAND2009-1704C (Presented at NACE Corrosion/09 Conference)
5. D.G. Enos, S.J. Lucero, F.D. Wall, "Generating and Performing Experiments within the In-Drift Environments Anticipated in the Proposed Yucca Mountain Repository", SAND2008-1044A, (Presented at NACE Corrosion/08 Conference)
6. D.G. Enos, H.W. Papenguth, G.A. Knorovsky, V.M. Loyola, T.M. Massis, R.L. Carlson "A Materials Aging Assessment of the MC4698 CoS<sub>2</sub> Based Thermal Battery", SAND2008-3290.
7. A.C. Sun, H.K. Moffat, D.G. Enos, C.S. George "Pore Corrosion Model for Gold Plated Copper Contacts", SAND 2007-3233J, IEEE Transactions on Components and Packaging Technologies, Vol. 30, No. 4 (2007), pp. 796-804.
8. N.R. Sorensen, J.R. Brown, T.E. Buchheit, D.G. Enos, S.L. Monroe, S.M. Thornberg "Summary of the B61 enhanced surveillance campaign MC2911 material evaluation", SAND2007-2796
9. T.D. Hund, D.G. Enos, T.T. Borek, J.A. Van Den Avyle "Characterization of positive strap corrosion products from NIFE cells in the PREPA Sabana Llana BESS", WFO final report # F1062060510, SAND2007-2507
10. D.G. Enos, S.H. Goods "Development of a Novel Technique to Assess the Vulnerability of Micro-mechanical System Components to Environmentally Assisted Cracking", SAND2006-7573
11. N.J. Dhooge, D.G. Enos, T.J. Garino, G.M. Jamison, E.P. Lopez, S.V. Prasad, D.R. Tallant "Investigation of the Effects of Material Aging on the Nuclear Detonation Safety Characteristics of the W78 (U)", SAND2007-2093.
12. D.G. Enos, F.D. Wall, B.Bullard, C.R. Bryan, G. De, R.L. Jarek, K. Mon, R. Rebak "Corrosion Performance of the Engineered Barrier in the Yucca Mountain Repository", SAND2007-2578C (Invited presentation at Third International Workshop on Long-Term Prediction of Corrosion Damage in Nuclear Waste Systems, 2007)
13. D.G. Enos, H.K. Moffat, A.C. Sun "Atmospheric Degradation of Connector Materials", SAND2007-1410C (Presented at NACE Corrosion/07 Conference)
14. D.G. Enos, S.L. Robinson, "A Materials Aging Assessment of the MC3473 Electronic Sequencer", SAND2006-5274
15. D.G. Enos, D. Ingersoll, N.H. Clark "A Materials Aging Assessment of the Li(Si)/FeS<sub>2</sub> Based Thermal Batteries in the B61", SAND2006-5144

16. D.G. Enos, E. Schexnayder "A Materials Aging Assessment of the MC3043 and MC3043A Firing System Assemblies", SAND2005-3611.
17. D.G. Enos, S.L. Robinson "A Materials Aging Assessment of the MC3152-101/-102 and MC3637 Programmers", SAND2005-4068
18. D.G. Enos, B.L. Levin, T.E. Hinkebein "Laboratory Based Evaluation of Corrosion Mitigation Strategies for Large Scale, Once-Through Heat Exchangers", Materials performance
19. D.G. Enos, B.L. Levin, T.E. Hinkebein "The Evaluation of Several Corrosion Mitigation Strategies for Oil Coolers Used by the Strategic Petroleum Reserve", SAND2004-4852
20. D.G. Enos, S.D. Dalton, B.L. Levin, T.E. Hinkebein "The Evaluation of Heat Exchanger Materials in High Chloride Solutions", SAND2004-1453C (Presented at NACE Corrosion/04 Conference)
21. D.G. Enos, C.S. George, N.R. Sorensen "The Atmospheric Degradation of Gold and Nickel-Gold Electroplated Copper Connectors", SAND2003-3835P, (Presented at the Fall 2003 meeting of the Electrochemical Society)
22. D.G. Enos, J.R. Scully, "A Critical Strain Criterion for Hydrogen Embrittlement of Cold Drawn, Ultra Fine Pearlitic Steel", Metallurgical Transactions A, Vol. 33A, No.4, pp1151-1166. (2002)
23. D.G. Enos, C.R. Guilbert, J.A. Kehr, "Improving the Damage Tolerance, and Extending the Service Life of Fusion-Bonded Epoxy Coatings" (Presented at the NACE Corrosion/01 Conference)
24. C.R. Guilbert, D.G. Enos, C.E. Boyer, "Latent Coating for Metal Repair", US Patent #6,075,072 (2000)
25. R.S. Lillard, D.G. Enos, J.R. Scully, "Calcium Hydroxide as a Promoter of Hydrogen Absorption in 99.5% Fe and a Fully Pearlitic 0.8% C Steel During the Electrochemical Reduction of Water", Corrosion, Vol. 56, No. 11, (2000)
26. J.A. Kehr, D.G. Enos "FBE, A Foundation for Pipeline Corrosion Coatings" (Presented at the NACE Corrosion/00 Conference)
27. 9/99 South Texas Chapter of the ECS invited talk "Fusion Bonded Epoxy Coatings: Past, Present, and Future"
28. J.R. Scully, D.G. Enos, G.G. Clemen, "Cathodic Protection of Steel Reinforced Concrete Pilings: Determining Safe Cathodic Protection Limits Using a Diffusible Hydrogen Criterion", Corrosion/99 Research Topical Symposium, Cathodic Protection: Modeling and Experiment
29. D.G. Enos, J.A. Kehr, C.R. Guilbert, "A High Performance, Damage Tolerant, Fusion-Bonded Epoxy Coating", BHR 13<sup>th</sup> International Conference on Pipeline Protection, Edinburgh, Scotland (1999)
30. D.G. Enos, C.R. Guilbert, C.F. Norman, J.A. Kehr, C.E. Boyer, "Improving the Damage Tolerance and Extending the Service Life of FBE Coatings", 1999 Protective Coatings Europe Conference, Brighton, England (1999)
31. D.G. Enos, C.R. Guilbert, J.A. Kehr, "Improving the Damage Tolerance and Extending the Service Life of FBE Coatings", International Conference on the Corrosion and Rehabilitation of Reinforced Concrete Structures, Orlando, FL (1998)
32. D.G. Enos, A.J. Williams, Jr., G.G. Clemen, J.R. Scully, "Impressed Current Cathodic Protection of Steel Reinforced Concrete Pilings: Protection Criteria and the Threshold for Hydrogen Embrittlement", Corrosion, Vol. 54, no. 5 (1998).
33. D.G. Enos, A.J. Williams, Jr., G.G. Clemen, J.R. Scully, Corrosion 97, paper no. 241.
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39. D.G. Enos, S.R. Taylor, "The Influence of Sulfate Reducing Bacteria on Alloy 625 and Austenitic Stainless Steel Weldments", Presented at NACE Corrosion/93 Conference.



**CHARLES FAIRHURST**

## ***Charles Fairhurst***

- ***Affiliation;*** Retired from University of Minnesota; Minneapolis MN  
Senior Consultant (Part –time), Itasca Consulting Group Inc.
- ***Address*** 417, Fifth Avenue North  
South Saint Paul  
Minnesota, 55075-2035

### □ ***Curriculum vitae***

***Expertise*** Rock Mechanics, Mining Engineering, Geological Isolation of Nuclear Waste

***Education*** Ph.D. (Mining Engineering), 1955, Sheffield University, England.  
B.Eng. (Mining Engineering, with First-Class Honours), 1952  
Sheffield University, England

### ***Professional***

***Affiliations*** Member: American Rock Mechanics Association (ARMA), American Institute of Mining Engineers (AIME), American Society of Civil Engineers (ASCE), American Underground Construction Association, International Society of Rock Mechanics (ISRM), Sigma XI, U.S. National Committee on Rock Mechanics

***Honors*** Member: U.S. National Academy of Engineering (1991); Royal Swedish Academy of Engineering Sciences (1979 Honorary Doctorates: University of Sheffield, England (1997); National Institute of Lorraine, France (1996); St. Petersburg Mining Academy & Technical University, Russia (1996); University of Minnesota (May 2000)

Professor Emeritus, University of Minnesota (1997); Advisory Professor, Tongji University, Shanghai, China (1995); Distinguished Professor of Mining Engineering & Rock Mechanics, University of Minnesota (1982)

Member, Science and Technology Review Panel, U.S. Department of Energy; Board of Governors, Geo-Institute of the ASCE (1998-2001);

President, ARMA (1995-1997); President, ISRM (1991-1995); Member, “Salzburg Circle” (predecessor to ISRM, 1962-1966); Corresponding Member, International Büro of Rock Mechanics, Berlin, Germany (1963-1970); Chair, U.S. National Committee on Rock Mechanics (1972-1974); President, American Underground Space Association (1976–1977)

Leopold Muller Award, ISRM (2003); U.S. National Committee on Rock Mechanics, Special Award: 25 Years of Distinguished Achievements (1983); American Underground Space Association 1981 Pergamon Medal; AIME Outstanding Achievement Award, Rock Mechanics (1972); Inter-Society Committee on Rock Mechanics Medal, Best Rock Mechanics Research Paper (with B. Haimson, 1970)

### ***Professional Experience***

<i>1997 – Present</i>	<i>Itasca Consulting Group, Inc., Minneapolis, Minnesota, Senior Consultant</i>
<i>1981 – 1999</i>	<i>Itasca Consulting Group, Inc., Minneapolis, Minnesota, Chairman</i>
	<i>University of Minnesota</i>
<i>1991 – 1997</i>	<i>T. W. Bennett Professor of Mining Engineering &amp; Rock Mechanics</i>
<i>1983 – 1991</i>	<i>E.P. Pfeleider Professor of Mining Engineering &amp; Rock Mechanics</i>
<i>1972 – 1987</i>	<i>Department of Civil &amp; Mineral Engineering, Head</i>
<i>1948 – 1956</i>	<i>National Coal Board, England, Mining Engineer Trainee</i>

### ***Project Experience.***

Dr Fairhurst has supervised 20 Ph.D. students at the University of Minnesota on a variety of topics in basic and applied rock mechanics. As a private consultant and Senior Consultant with Itasca, Dr Fairhurst has more than 50 years of experience in mining rock mechanics and has consulted on rock stability problems for tunnels, dams, mines, and excavations throughout the world. He has also been actively engaged internationally for more than 30 years in the problems of geological isolation of high and intermediate-level nuclear waste.

### ***Civil Engineering***

Laboratoire Mixte (Application of Mathematics and Physics to Civil Engineering), CNRS/LCPC, Marne La Vallée, France —Member, Conseil Scientifique (1993–1997)

National Science Foundation — Member: Division of Applied Research Review Panel (1978-1980); Conference Steering Committee, Initiatives in the States Program (1985-1986); Engineering Advisory Board (1982-1985); Division of Policy and Analysis Review Panel (1978-

1979); U.S. Centrifuge Facility Selection Panel (1977-1978); U.S. NSF/AIME Delegation to the Soviet Union (1977); Advisory Panel on Engineering Mechanics (1976). Chair: Advisory Sub-Committee on Civil and Environmental Engineering (1982-1984);

Spie Batignolles, France, Member, Board of Experts, Guavio Hydroelectric Project, Colombia (1985-1989)

U.S. Army Corps of Engineers — Consultant, R. D. Bailey Dam (1977-1981)

U.S. Army Corps of Engineers — Consultant, Niagara Falls Preservation Project (1968-1974)

U.S. Geological Survey — Member, Advisory Panel on Earthquake Research (1973-1977)

### ***Mining***

Mines Dominiiale de Potasse d'Alsace, Thailand — Potash Mine Design (1981 - 1983)

Martin Marietta Corporation — Consultant, Lunar Drilling and Rock Blasting Programs (1973-1975)

National Academy of Science/National Research Council — Chair, Committee on Feasibility of Returning Coal Mine Wastes to Underground (1973-1974)

Petrobras Mineracao Corporation, Brazil — Consultant, Potash Mine Design (1975-1989)

American Institute of Mining Engineers — Member, Committee on Rock Mechanics (1969-1973)

### ***Nuclear Testing & Waste Isolation***

Chairman, IAEA (Vienna) International Centres of Excellence Network –Waste Disposal Technologies (2003-2007)

Member, Science and Technology Panel, Office of Civilian Radioactive Waste Management, U.S. Department of Energy (2002–2006)

Member, Monitored Geological Repository (MGR) Advisory Board, Yucca Mountain (1999-2001)

Atomic Energy of Canada Limited (AECL) — Chair, Peer Review on the Tunnel Sealing and Mine-by Experiments at the Underground Research Laboratory, Pinawa (1995–2004)

ANDRA (French Radioactive Waste Agency) — Member, Conseil Scientifique (1993–2005)

International Stripa Project, Sweden: Member, Project Overview Committee (1993)

Ecole Polytechnique, Palaiseau, France — Member, Conseil Scientifique de G.3S, Groupement pour l'Etude des Structures Souterraines de Stockage (Underground Waste Storage Group) (1992-2003)

International Geomechanical Commission — Chair, invited by the French Government to study the effects of underground nuclear tests in French Polynesia on the stability and hydrology of the atolls Mururoa and Fangataufa (1995-1999)

U.S. Atomic Energy Commission (AEC)— Member, Oak Ridge National Laboratory Advisory Panel on Radioactive Waste Disposal in Lyons Salt Mine, Kansas (1971)

U.S. National Academy of Sciences — Vice Chair: Board on Radioactive Waste Management (BRWM) (1989-1995); BRWM Waste Management; Chairman, Waste Isolation Pilot Project (WIPP) Committee (1989-1997). Senior Advisor, WIPP Advisory Panel (1985-1989)

U.S. National Academy of Sciences/National Research Council — Member, Committee on Technical Bases for Yucca Mountain Standards (1993-1995); NAS/NRC Committee on Rethinking High Level Waste Disposal [Report 1990]; NAS/NRC Panel on the Savannah River (Nuclear) Plant (1978); NAS/NRC Advisory Panel on Bedrock Disposal (Underground Disposal of Radioactive Wastes) (1971)

U.S. Nuclear Regulatory Commission (NRC) — Member, Advisory Committee on Nuclear Waste (1997–1999)

U.S. Office of Science and Technology (OST) — Member, Policy Panel on U.S. Radioactive Waste Management Program (1978)

### ***Rock Mechanics***

American Society for Testing and Materials — Member, Subcommittee on Rock Mechanics (1966-1969) American Society of Civil Engineers — Chair: Committee on Rock Mechanics (1978 1980); ASCE/AIME Underground Construction Research Council (1974-1975)

Third International Congress on Rock Mechanics — Chair, Technical Program (1974)

Los Alamos Scientific Laboratory, New Mexico — Member, Hydraulic Fracturing, Geothermal Energy, and Rock Blasting Studies (1975-1981)

National Science Foundation (2004 –present). Advisor on Geoscience and Engineering (S1 et seq.). DUSEL (Deep Underground Science and Engineering Laboratory)

□ ***Brief statement(s) of the subject matters on which you are qualified and that are relevant to the indicated contention(s)***

Rock Mechanics issues in general e.g. Drift Degradation: In situ Stress State at Yucca Mountain. Seismic Effects on Stability of Excavations

□ ***List of all relevant publications authored in the previous 10 years***

Damjanac, B., and C. Fairhurst. “Evidence for a Long-Term Strength Threshold in Crystalline Rock,” submitted to *Rock Mech. & Rock Eng.* (Springer Verlag), 2009

Elsworth, D., and C. Fairhurst. “Some Opportunities for Science and Engineering at DUSEL,” in ***Rock Mechanics: Meeting Society's Challenges and Demands (1st Canada-U.S. Rock Mechanics Symposium, Vancouver, May 2007)***, Vol. 2: *Case Histories*, pp. 1085-1090, E. Eberhardt et al., Ed. London: Taylor & Francis Group, 2007.

Fairhurst, C., B. Damjanac and T. Brandshaug. “Rock Mass Strength and Numerical ‘Experiments’,” in ***Publications of the Geotechnical Institute No. 2006-5, Proceedings 35 (Geomechanics Colloquium, November 2006)***, pp. 1-20. Freiberg, Germany: Technical University Mining Academy Freiberg, 2007.

Mas Ivars, D., N. Deisman, M. Pierce and C. Fairhurst. “The Synthetic Rock Mass Approach — A Step Forward in the Characterization of Jointed Rock Masses,” in ***The Second Half Century of Rock Mechanics (11th Congress of the International Society for Rock Mechanics, Lisbon, July 2007)***, Vol. 1, pp. 485-490, L. Ribeiro e Sousa, C. Olalla, and N. Grossmann, Eds. London: Taylor & Francis Group, 2007.

Fairhurst, C. “Nuclear Waste Disposal and Rock Mechanics: Contributions of the Underground Research Laboratory (URL), Pinawa, Manitoba, Canada,” *Int. J. Rock Mech. Min. Sci.*, **41**, 1221-1227 (2004).

Fairhurst, C. “Radioactive Waste Isolation — One Small Step for Geology; One Giant Leap for Rock Mechanics.” Leopold Muller Award Presentation. 10th International ISRM Congress, Johannesburg, September 2003.

Fairhurst, C. “Stress Estimation in Rock: A Brief History and Review,” *Int. J. Rock Mech. & Min. Sci.*, **40**, 957-973 (2003).

Fairhurst, C., and C. Carranza-Torres. “Closing the Circle — Some Comments on Design Procedures for Tunnel Supports in Rock,” in ***Proceedings of the University of Minnesota 50th***

*Annual Geotechnical Conference (February 2002)*, pp. 21-84. J. F. Labuz and J. G. Bentler, Eds. Minneapolis: University of Minnesota, 2002.

Carranza-Torres, C., and C. Fairhurst. “Aplicación del Método de Convergencia-Confinamiento al Diseño de Túneles en Macizos Rocosos Que Satisfacen el Criterio de Rotura de Hoek y Brown,” in *IngeoTÚNELES*, pp. 69-123. C. López-Jimeno, Ed. Tunnelling Engineering Series, Vol. 4. Madrid: Escuela Técnica Superior de Ingenieros de Minas, 2001.

Fairhurst, C. “Rock Mechanics of Underground Nuclear Explosions,” *ISRM News J.*, **6**(3), 21-27 (2001).

Carranza-Torres, C., and C. Fairhurst. “Analysis of Tunnel Support Requirements Using the Convergence-Confinement Method and the Hoek-Brown Rock Failure Criterion,” in *GeoEng 2000 (Proceedings of the International Conference on Geotechnical & Geological Engineering, Melbourne, November 2000)*, Paper UW1244. Lancaster, Pennsylvania: Technomic Publishing, 2000.

Carranza-Torres, C., and C. Fairhurst. “Application of the Convergence-Confinement Method of Tunnel Design to Rock Masses That Satisfy the Hoek-Brown Failure Criterion,” *Tunn. & Underground Space Tech.*, **15**(2), 187-213 (2000).

Carranza-Torres, C., and C. Fairhurst. “Some Consequences of Inelastic Rock-Mass Deformation on the Tunnel Support Loads Predicted by the Einstein and Schwartz Design Approach,” in *Trends in Rock Mechanics (Proceedings of Sessions of Geo-Denver 2000)*, pp. 16-49. J. F. Labuz et al., Ed. Reston, Virginia: ASCE, 2000.

Damjanac, B., C. Fairhurst and T. Brandshaug. “Numerical Simulation of the Effects of Heating on the Permeability of a Jointed Rock Mass,” in *Proceedings of the 9th ISRM Congress on Rock Mechanics*. Paris, Vol. 2, pp. 881-885. Rotterdam: Balkema, 1999.

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International Geomechanical Commission (C. Fairhurst et al.). *Underground Nuclear Testing in French Polynesia* Damjanac, B., and C. Fairhurst. “Ecoulement Tri-Dimensionnel d’Eau Sous Pression dans les Milieux Fracturés,” in *La Sécurité Des Grands Ouvrages, Hommage À Pierre Londe*, pp. 5-19. Paris: Presses Pontes et Chauseés, 2000.

Hart, R., and C. Fairhurst. (2000) “Application of Discontinuum Modeling in Geotechnical Studies for Nuclear Waste Isolation,” in *Geocology and Computers (Proceedings of the 3rd*



*International Conference on Advances of Computer Methods in Geotechnical and Geoenvironmental Engineering, Moscow, February 2000*), pp. 15-28. S. A. Yufin, Ed. Rotterdam: Balkema, 2000.

Fairhurst, C. “Structural and Hydrological Consequences of Underground Nuclear Testing on the Atolls of Mururoa and Fangataufa, in French Polynesia,” presented at the GeoEng 2000, Melbourne, Australia, November 2000.

Fairhurst, C., B. Damjanac and R. Hart. “Numerical Analysis as a Practical Design Tool in Geo Engineering,” in *Slope Stability 2000 (Proceedings of Sessions of Geo-Denver 2000)*, pp. 169-183. D. V. Griffiths, G. A. Fenton, and T. R. Martin, Eds. Reston, Virginia: ASCE, 2000.

Carranza-Torres, C., and C. Fairhurst. “Elasto-Plastic Analysis of Elliptical Cavities in Rock Subject to Non-Hydrostatic Loading,” in *FLAC and Numerical Modeling in Geomechanics (Proceedings of the Conference, Minneapolis, September 1999)*, pp. 215-223. C. Detournay and R. Hart, Eds. Rotterdam: Balkema, 1999.

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December 7-9, 1999, pp. 463-480. Les Ulis: EDP: *Stability and Hydrology Issues*. Paris: La Documentation Française, 1999.