RSRead Consulting Inc.
Applied Rock Mechanics and Geotechnical Engineering

Curriculum Vitae

RODNEY STEWART READ, Ph.D., P.Eng., P.Geol., P.Geo.
Principal Geotechnical/Geological Engineer

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SYNOPSIS

Dr. R.S. (Rod) Read, P.Eng., P.Geol., P.Geo. is President and Principal Consultant of RSRead Consulting Inc., a Canadian engineering consulting firm specializing in geotechnical/geological engineering and applied rock mechanics. He has over 35 years of experience in projects related to pipeline geotechnics, geohazard assessment, transportation (railway and highway) systems, petroleum geomechanics, underground nuclear waste management research, and other civil/mining applications. This experience includes development and application of geohazard assessment approaches for pipelines and linear infrastructure, in situ geological/geotechnical characterization, instrumentation and monitoring system development, soil and rock laboratory testing program development, numerical analysis, and regulatory support. Dr. Read has authored over 100 publications and technical reports related to his work including several publications on the Turtle Mountain Monitoring Project at the site of the 1903 Frank Slide, and has acted as contributing author to the ASME book "Pipeline Geo-Environmental Design and Geohazard Management" (2008) and the book "Rock Mechanics and Engineering" (2017). He is co-editor and contributing author to the ASME book "Pipeline Geohazards: Planning, Design, Construction and Operation" (2019). He has co-chaired several geohazard sessions at the International Pipeline Conference and Banff Pipeline Workshop, and has served as an Adjunct Professor at the University of Calgary.

AREAS OF EXPERTISE

Geohazard assessment	Geotechnical engineering	Pipeline geotechnics
Rock mechanics	Geological engineering	Nuclear waste management R&D

EDUCATION

Ph.D. (1994), Civil & Geological Engineering, University of Manitoba, Winnipeg, MB, Canada

B.A.Sc. (1984), Geological Engineering, University of British Columbia, Vancouver, BC, Canada

PROJECT EXAMPLES

Eagle Mountain Pipeline Project | Fortis BC | Universal Pegasus International/Dynamic Risk
Natural gas pipeline project from Coquitlam to Squamish, BC

- Geotechnical SME technical review of geohazard assessment of pipeline (UPI)
- Geotechnical SME for review and input to QRA of tunnel segment (Dynamic Risk)

Trans Mountain Expansion Project | Trans Mountain | MSJV/Thurber Engineering Ltd.
Oil pipeline project from Edmonton, AB to Burnaby, BC twinning existing pipeline

- Geotechnical SME and manager supporting construction contractor (MSJV) for Spread 5B
- Geotechnical advisor supporting geotechnical team (Thurber) for Spreads 5A & 5B

Camisea Pipeline | Transportadora de Gas del Perú
Geohazard assessment approach development for existing Andean pipeline system, Perú

- Gap analysis of existing geohazard assessment approach (Subject Matter Expert, SME)
- Pipeline geohazard assessment approach development (Subject Matter Expert, SME)

Alaska LNG Project | ExxonMobil/BP/TCPL/ConocoPhilips | WorleyParsons
Arctic natural gas pipeline geotechnical engineering, Alaska, USA.

- Pipeline geohazard assessment (Subject Matter Expert, SME)
- Geotechnical quantities analysis for ROW preparation and footprint development
- Geotechnical characterization for strain-based design (SBD)

PROJECT EXAMPLES

Coastal GasLink Pipeline Project | Coastal GasLink Pipeline Ltd. | WorleyParsons
Natural gas pipeline geotechnical engineering in British Columbia, Canada.

- Pipeline geohazard assessment (Subject Matter Expert, SME)
- Geotechnical quantities analysis for ROW preparation and footprint development
- Detailed engineering of geotechnical mitigation

Mt. Shaughnessy Tunnel Remediation | Canadian Pacific Railway

- Geotechnical drilling, instrumentation and monitoring for the railway tunnel remediation

Westcoast Connector Gas Transmission | Spectra Energy | WorleyParsons
Natural gas pipeline geotechnical engineering in British Columbia, Canada.

- Pipeline geohazard assessment (Subject Matter Expert, SME)
- Geotechnical quantities analysis for ROW preparation and footprint development
- Regulatory support

Alaska Pipeline Project | ExxonMobil/TCPL | WorleyParsons
Arctic natural gas pipeline geotechnical engineering, Alaska, USA and Yukon/British Columbia, Canada.

- Pipeline geohazard assessment (Subject Matter Expert, SME)
- Geotechnical quantities analysis for ROW preparation and footprint development
- Regulatory support

Northern Gateway Pipeline Project | Northern Gateway Pipelines Inc. | WorleyParsons
Geotechnical engineering support for oil pipeline from Alberta to British Columbia west coast, Canada

- Review of geohazard assessment methodology (Subject Matter Expert, SME)
- Field validation of geohazard mitigation strategy
- Regulatory support

Gasoducto Andino del Sur | Odebrecht Perú Ingenería y Construcción | WorleyParsons

- Geotechnical engineering support for Peruvian pipeline geohazard assessment, Peru
- Review of geohazard assessment methodology (Subject Matter Expert, SME)

Mackenzie Gas Project | Imperial Oil Resources Ventures Limited, ConocoPhillips Canada (North) Limited, Shell Canada Limited, ExxonMobil Canada Properties | WorleyParsons
Arctic natural gas pipeline geotechnical engineering, Northwest Territory, Canada.

- Development and application of geohazard assessment methodology
- Geotechnical quantities analysis for ROW preparation and footprint development
- Regulatory support
- Analysis of trencher trials
- Frost heave and uplift resistance testing stewardship
- Numerical modelling of uplift resistance
- Drilling specification development

Turtle Mountain Monitoring Project | Alberta Government | Various ministries
Applied rock mechanics and geotechnical engineering related to geohazard assessment of the 1903 Frank Slide site

- Geotechnical hazard assessment of the south flank of Frank Slide (Alberta Environment)
- Development of a monitoring framework for Turtle Mountain (Alberta Municipal Affairs)
- Planning and implementation of a monitoring framework on Turtle Mountain (Emergency Management Alberta)
- Monitoring data review and analysis from early warning system, Turtle Mountain (Alberta Geological Survey)

TransCanada Realignment, Kickinghorse Pass | BC Ministry of Highways
Value analysis of realignment of TransCanada Highway through Kickinghorse Pass, BC

- Rock mechanics review and input to design process

PROFESSIONAL AFFILIATIONS

2017 – present	Registered Professional Engineer and Geoscientist, Saskatchewan (APEGS)
2013 – present	Registered Professional Geoscientist, British Columbia (APEGBC)
2002 – present	Registered Professional Geologist, Alberta (APEGA)
2002 – present	Registered Professional Engineer, British Columbia (APEGBC)
1997 – present	Registered Professional Engineer, Alberta (APEGA)
1987 – present	Registered Professional Engineer, Manitoba (APEGM)
2019 – present	Member, CSA Z662 Risk Assessment Task Force
2012 – present	Member, American Society of Mechanical Engineers
2000 – present	Member, Society of Petroleum Engineers
1989 – present	Member, Tunnelling Association of Canada (TAC)
1999 – present	Member, American Rock Mechanics Association
1998 – present	Member, International Society for Rock Mechanics (ISRM)
1998 – present	Member, Canadian Geotechnical Society (CGS)
1998 – 1999	Adjunct Professor, Dept. of Civil Engineering, University of Calgary
1998 – 1999	Committee Member, Calgary Chapter of CGS
1984 – 1987	Engineer-in-training, (APEBC); Member, Vancouver Geotechnical Society

EXPERIENCE HIGHLIGHTS

Geohazard assessment - Subject Matter Expert (SME) in the development and application of geohazard assessment approaches for several major pipeline projects in western and northern Canada, Alaska, Peru, Colombia, Ecuador and others. Geotechnical engineering lead on the Turtle Mountain Monitoring Project at the site of the 1903 Frank Slide in southern Alberta, Canada. Ongoing development of pipeline geohazard assessment methodologies, software and supporting data management systems.

Geomechanical analysis of pipeline and petroleum-related processes – analysis of uplift resistance and geomechanical testing of frozen soil, right-of-way preparation methods and quantities, Arctic trenching trials, pipeline deformations due to slope movement, potential karst collapse under pipelines, gas storage feasibility and associated applications of microseismic monitoring, water disposal issues related to oil sands development, borehole stability analysis of petroleum wells and horizontal directional drillholes, and drilling/laboratory testing program planning.

Surface and underground instrumentation and monitoring systems – planning and installation of geotechnical monitoring systems for underground nuclear waste management research, railway tunnel stability assessment, and landslide monitoring and early warning system development as part of the Turtle Mountain Monitoring Project in Crowsnest Pass, Alberta – the site of the 1903 Frank Slide. Analysis of data from complex monitoring systems to assess stability conditions and to back analyze fundamental geomechanical response characteristics was the basis for Doctoral Thesis "Interpreting Excavation-Induced Displacements around a Tunnel in Highly Stressed Granite" (University of Manitoba, 1994).

Nuclear waste management research - Principal Investigator/Experiment Manager at Atomic Energy of Canada Limited's (AECL's) Underground Research Laboratory for large multi-disciplinary in-situ investigations, including the Mine-by Experiment, Heated Failure Tests, Excavation Stability Study, and Thermal-Mechanical Stability Studies, addressing fundamental issues related to rock mass response to excavation and heating, tunnel instability and excavation damage zone (EDZ) development. Consultant to AECL, Ontario Power Generation, Nuclear Waste Management Organization, and several international organizations regarding geomechanics and monitoring issues associated with nuclear waste management research.

AWARDS

1997	Association of Professional Engineers of the Province of Manitoba's Early Achievement Award
1995	First Prize in Tunnelling Association of Canada (TAC) Graduate Student Thesis Award competition
1983	George E. Winkler Memorial Scholarship

PERSONAL

Nationality Canadian
Birthplace Revelstoke, BC, Canada

WORK EXPERIENCE

2000 – Present

President and Principal Consultant,
RSRead Consulting Inc., Okotoks, AB, Canada
Principal consultant focused on geohazard assessment, geotechnical engineering related to pipeline and railway geotechnics, instrumentation, geomechanical analysis, slope stability analysis, rock mechanics research and development, project/program planning and management, and technical peer review of issues related to international nuclear waste disposal. Involved in geotechnical design, geohazard assessment and engineering for the Mackenzie Gas Project, the Alaska Pipeline Project, Alaska LNG Project the Camisea Pipeline, Coastal GasLink and other major pipeline projects. Consultant to WorleyParsons/Advisian and other clients (see website www.rsrci.com for more information on specific projects).

2000 – 2001

Senior Geomechanics Engineer / Manager, Geotechnical
Advanced Geotechnology Inc., Calgary, AB, Canada
Senior geomechanics engineer and geotechnical engineering manager specializing in project planning, analysis, and numerical modelling related to petroleum production, heavy oil extraction using SAGD and other thermal processes, borehole stability, in situ stress determination, site characterization, and application of microseismic and geotechnical monitoring technology.

1998 – 2000

Senior Geotechnical Engineer,
BGC Engineering Inc., Calgary, AB, Canada
Senior geotechnical engineer specializing in geomechanics-related projects. Typical projects: coordination and technical direction of thermal-mechanical stability studies at AECL's Underground Research Laboratory; geotechnical engineering gap analysis and project planning for Ontario Power Generation's Used Fuel Disposal Technology Program; numerical analysis of slope stability and soil/pipeline interaction; stability assessment of directionally-drilled boreholes; railway rock slope stabilization; foundation investigation and evaluation of stability of South Peak of Turtle Mountain – the site of the 1903 Frank Slide.

1997 - 1998

Senior Geotechnical Engineer,
Klohn-Crippen Consultants Ltd., Calgary, AB, Canada
Senior geotechnical engineer specializing in rock mechanics-related projects. Typical projects: analysis and interpretation of results from geotechnical research at AECL's Underground Research Laboratory; assessment of instrumentation and rock bolt performance in spillway replacement project at St. Mary dam; analysis of drain design criteria; project management of geo-technical site investigations.

1987- 1997

Senior Geomechanics Research Engineer,
AECL, Underground Research Laboratory, MB, Canada
Senior rock mechanics engineer for AECL's Geotechnical Science & Engineering Branch. Design, project management/ coordination, contract administration, analysis and reporting related to geomechanics research conducted to support the Canadian Nuclear Fuel Waste Management Program and Ontario Hydro's Used Fuel Disposal Project. Experiment Manager and Principal Investigator for the Mine-by Experiment, one of the world's foremost rock mechanics experiments addressing issues related to the Canadian concept for nuclear fuel waste disposal. Specialist in fundamental rock mechanics research related to tunnel design and excavation-induced damage for

WORK EXPERIENCE (cont.)

several large experiments, including the Tunnel Sealing Experiment, Excavation Stability Study, Heated Failure Tests and In Situ Characterization program.

1985 - 1987 **Geotechnical Engineer (EIT),**
Golder Associates, Vancouver, BC, Canada
Geotechnical engineer (EIT) on various geotechnical projects including the Oldman River Dam site investigation and test diversion tunnel project in southern Alberta; quarry investigation in the NWT; Cigar Lake mine study in Saskatchewan; and other civil projects.

1984 - 1985 **Geotechnical Engineer (EIT),**
CP Rail Special Projects, Revelstoke, BC, Canada
Construction inspection of twinning of the Rogers Pass section of the CPR mainline including aspects of rock and soil engineering, grade design, concrete testing, and contract administration.

1979 - 1984 **Summer Student,**
BC Hydro, BC Ministry of Highways, CP Rail, Revelstoke, BC
Various engineering-related positions to support undergraduate studies, including surveying and railway grade construction.

CONFERENCE VOLUNTEER

2013-2021 Banff Pipeline Workshop, Banff, Alberta. Co-chair Geohazards working session.

2014 International Pipeline Conference, Calgary Alberta. Chair, Session 6-3-1: Weather Related & Outside Forces— Water Hazard

PUBLICATIONS

Books and Journal Publications

Rizkalla, M. and R.S. Read (eds.). 2019. Pipeline Geohazards: Planning, Design, Construction and Operations. ASME, 800 p.

Rizkalla, M. and R.S. Read. 2019. Pipeline geohazard assessment – reducing risk to linear infrastructure. Geotechnical News 7(4): 46-50, December 2019, BiTech Publishers Ltd.

Read, R.S. 2017. Excavation response studies at AECL's Underground Research Laboratory – 1982 to 2010. Chapter in Rock Mechanics and Engineering, CRC Press/Balkema.

Rizkalla, M., R.S. Read, and G. O'Neil. 2008. Pipeline Geo-Environmental Design and Geohazard Manage-ment. Chapter 6 Geohazard Management. ASME, 352 pp.

Read, R.S. 2004. 20 years of excavation response studies at AECL's Underground Research Laboratory. Int. J. Rock Mech. & Min. Sci. 41: 1251-1275.

Eberhardt, E., D. Stead, B. Stimpson, and R. Read. 1998. Identifying crack initiation and propagation thresholds in brittle rock. Can. Geotech. J., 35(2): 222-233.

Read, R.S., N.A. Chandler, and E.J. Dzik. 1998. In situ strength criteria for tunnel design in highly-stressed rock masses. Int. J. Rock Mech. & Min. Sci., 35(3): 261-278.

Maxwell, S.C., R.P. Young, and R.S. Read. 1998. A microvelocity logging tool to assess the excavation damaged zone. Int. J. Rock Mech. & Min. Sci., 35(2):235-247.

Eberhardt, E., D. Stead, B. Stimpson, and R.S. Read. 1997. Changes in acoustic event properties with progressive fracture damage. Int. J. Rock Mech. & Min. Sci., 34:3-4, Paper No. 071B.

Martin, C.D., R.S. Read, and J.B. Martino. 1997. Observations of brittle failure around a circular test tunnel. Int. J. Rock Mech. & Min. Sci., 34(7): 1065-1073.

Martin, C. Derek, Neil A. Chandler, and Rodney S. Read. 1996. The role of convergence measurements in characterizing a rock mass. Can. Geotech. J., 33: 363-370.

Martino, Jason B., and Rodney S. Read. 1996. An overview of AECL's Heated Failure Tests. ISRM Newsjournal, 4(1): 24-31.

PUBLICATIONS (cont.)

Read, R.S. 1994. Interpreting excavation-induced displacements around a tunnel in highly stressed granite. PhD thesis, Department of Civil and Geological Engineering, University of Manitoba, Winnipeg, MB.

Read, R.S., and C.D. Martin. 1991. The Underground Research Laboratory Mine-by Experiment - A research perspective on tunnel design. Canadian Tunnelling, 7:75-88.

Conference Publications

Read, R.S. 2021. Pipeline geohazard target susceptibility threshold – a reliability-based rationalization. Proceedings of the ASME-ARPEL 2021 International Pipeline Geotechnical Conference IPG2021, June 21-22, 2021, Virtual, Online, Paper IPG2021-65935.

Read, R.S. 2018. Pipeline geohazard assessment - Bridging the gap between integrity management and construction safety contexts. Proceedings of the 2018 12th International Pipeline Conference IPC2018, September 24-28, 2018, Calgary, Alberta, Canada, Paper IPC2018-78225.

Read, R.S., J. E. Malpartida Moya, and G. Massucco de la Sota. 2017. Framing uncertainty in pipeline geohazard assessment for integrity management and iterative risk assessment. Proceedings of the ASME 2017 International Pipeline Geotechnical Conference, IPG2017, July 25-26, 2017, Lima, Peru. Paper IPG2017-2505

Read, R.S. and M. Rizkalla. 2015. Bridging the gap between qualitative, semi-quantitative and quantitative risk assessment of pipeline geohazards – the role of engineering judgment. Proceedings of the 2nd ASME International Pipeline Geotechnical Conference IPG2015, July 15-17, 2015, Bogotá, Colombia, Paper IPG2015-8523.

Rizkalla, M. and R.S. Read. 2013. Overview of pipeline geohazard assessment approaches and strategies. Paper No. IPG2013-1950, ASME 2013 International Pipeline Geotechnical Conference, Bogotá, Colombia, July 24-26, 2013.

Read, R.S., Birch, K. 2008. The role of rock engineering in developing a deep geological repository in sedimentary rocks. ROCKENG09: Proceedings of the 3rd CANUS Rock Mechanics Symposium, Toronto, May 2009 (Ed: M. Diederichs and G. Grasselli), Paper 4146.

Read, R.S., Birch, K. 2008. Reasoned argument why large-scale fracturing will not be induced by a deep geological repository. ROCKENG09: Proceedings of the 3rd CANUS Rock Mechanics Symposium, Toronto, May 2009 (Ed: M. Diederichs and G. Grasselli), Paper 4147.

Rizkalla, M., and R.S. Read. 2007. The assessment and management of pipeline geohazards. Paper IBP1205_07. In Proc. Rio Pipeline 2007 Conference and Exposition, Rio de Janeiro, Brazil.

Read, R.S, W. Langenberg, D. Cruden, M. Field, R. Stewart, H. Bland, Z. Chen, C.R. Froese, D.S. Cavers, A.K. Bidwell, C. Murray, W.S. Anderson, A. Jones, J. Chen, D. McIntyre, D. Kenway, D.K. Bingham, I. Weir-Jones, J. Seraphim, J. Freeman, D. Spratt, M. Lamb, E. Herd, D. Martin, P. McLellan, & D. Pana. 2005. Frank Slide a Century Later: The Turtle Mountain Monitoring Project. In Proc. of the International Conference on Landslide Risk Management, Vancouver, B.C. Canada. Balkema Publishers, Netherlands. pp. 713-723.

Froese, C.R., Murray, C.M., Cavers, D.S., Anderson, W.S., Bidwell, A.K., Read, R.S., Cruden, D.M., & Langenberg, W. 2005. Development and implementation of a warning system for the South Peak of Turtle Moun-tain. Proceedings of the International Conference on Landslide Risk Management, Vancouver, B.C. Canada. Balkema Publishers, Netherlands. pp. 705-712.

Read, R.S. 2003. A framework for monitoring the South Peak of Turtle Mountain - the aftermath of the Frank Slide. In Proc. 3rd Canadian Conference on Geotechnique and Natural Hazards, Edmonton, Alber-ta, Canada, June 9 - 10, 2003. pp 261-268.

Read, R.S. 2003. The role of tunnel design in controlling excavation damage development. Presented at EURATOM CLUSTER Conference, Nov 2004, Luxembourg.

Read, R.S. and J.B. Martino. 2002. To arch or not to arch – the role of tunnel design in controlling excava-tion damage development. In Proc. of the EDZ Workshop, NARMS-TAC 2002, July 6, 2002, Toronto, On-tario, Canada.

Chandler, N.A., J.B. Martino, and R.S. Read. 2002. The EDZ exists – So what? In Proc. of the EDZ Workshop, NARMS-TAC 2002, July 6, 2002, Toronto, Ontario, Canada.

Isherwood, A., K.W. Savigny, A. Samchek and R.S. Read. 2002. Deformation analysis of a pipeline river crossing. Proc. IPC 2002: International Pipeline Conference, Sept 29 – Oct 3, 2002, Calgary, Alberta, Canada.

PUBLICATIONS (cont.)

Chandler, N.A., R.S. Read, D. Potyondy, R.P. Young, and J. Hazzard. 2002. Computing brittle rock fracture and excavation stability using the Particle Flow Code. In Proc. 2nd Canadian Specialty Conference on Computer Applications in Geotechnique, April 28-30, 2002. Winnipeg, Manitoba, Canada.

McLellan, P.J., C.D. Hawkes, and R.S. Read. 2000. Sand production and control in horizontal wells for gas-storage reservoirs. In Proc. 4th International Conference and Exhibition on Horizontal Well Technology, Nov. 6-8, Calgary AB. Paper SPE 65510/PS2000-149

McLellan, P.J., R.S. Read, and K. Gillen. 2000. Assessing caprock integrity for steam assisted gravity drainage projects in heavy oil reservoirs. In Proc. 4th International Conference and Exhibition on Horizontal Well Technology, Nov. 6-8, Calgary AB. Paper SPE 65521

Chandler, N.A., R. Read, P. Cundall, D. Potyondy, E. Detournay, R.P. Young, and J.S.O. Lau. 2000. An integrated approach to excavation design – a project within Canada's used fuel disposal program. In Pacific Rocks, Proc. 4th North American Rock Mechanics Symposium, Seattle, WA, pp. 1271-1278.

Read, R.S., and N.A. Chandler. 2000. Linkage between performance assessment, repository design and site characterization – a Canadian perspective. In Proc. 2nd International Workshop on Geomechanics of Nuclear Waste Repositories, July 2000, Seattle, WA.

Read, R.S., K.W. Savigny, F. Oboni, D.M. Cruden, and W. Langenberg. 2000. Geotechnical hazard assessment of the south flank of Frank Slide. In Proc. GeoCanada 2000, Calgary, AB.

Read, R.S., and N.A. Chandler. 1999. Excavation damage and stability studies at the URL - rock mechanics considerations for nuclear fuel waste disposal in Canada. In Proc. 37th US Rock Mech. Symp., Vail, CO: Balkema: Rotterdam, pp. 861-868.

Chandler, N.A. and R.S. Read. 1998. The long-term behaviour of excavations in granite - In situ evidence from Canada's URL and implications for waste retrieval. In Proc. International Workshop on Reversibil-ity, Paris, ANDRA.

Leite, Maria Helena, Robert Corthèsy, Denis E. Gill, and Rodney Read. 1997. Some aspects of a stress calculation model for deep measurements using the modified doorstopper cell. In Proc. Int. Symp. on Rock Stresses, Kumamoto, Japan: Balkema: Rotterdam, pp. 65-70.

Read, R. S., and N. A. Chandler. 1997. Minimizing excavation damage through tunnel design in adverse stress conditions. In Proc. 23rd General Assembly - Int. Tunnel. Assoc., World Tunnel Congress `97, Vien-na. Balkema: Rotterdam, pp. 23-28.

Read, R. S. 1996. Characterizing excavation damage in highly-stressed granite at AECL's Underground Research Laboratory. In Proc. Int. Conf. on Deep Geological Disposal of Radioactive Waste, EDZ Workshop, Winnipeg, pp. 35-46.

Martin, C. D., E. J. Dzik, and R. S. Read. 1996. Designing an effective excavation damaged zone cut-off in high stress environments. In Proc. Int. Conf. on Deep Geological Disposal of Radioactive Waste, EDZ Workshop, Winnipeg, pp. 155-164.

Read, R. S. 1996. Rock mechanics research at AECL's Underground Research Laboratory - An overview. In Prog. Symp. on Contributions to Geology by the Canadian Nuclear Fuel Waste Management Program, Winnipeg, p. A-78.

Read, R. S., and J. B. Martino. 1996. Effect of thermal stresses on progressive rock failure at AECL's Underground Research Laboratory. In Proc. Int. Conf. on Deep Geological Disposal of Radioactive Waste, Winnipeg, pp. 7-43 - 7-53.

Read, Rodney S., and Jason B. Martino. 1996. In situ thermal testing at AECL's Underground Research Laboratory. In M. Aubertin, F. Hassani and H. Mitri, editors, Proc. 2nd North American Rock Mech. Symp., Mon-treal: Balkema: Rotterdam, pp. 1487-1494.

Martin, C. Derek, and Rodney S. Read. 1996 AECL's Mine-by Experiment: A test tunnel in brittle rock. In M. Aubertin, F. Hassani, and H. Mitri, editors, Proc. 2nd North American Rock Mech. Symp., Montreal: Balkema: Rotterdam, pp. 13-24.

Chandler, Neil A., Rodney S. Read, and C. Derek Martin. 1996. In situ stress measurements for nuclear fuel waste repository design. In M. Aubertin, F. Hassani and H. Mitri, editors, Proc. 2nd North American Rock Mech. Symp., Montreal: Balkema: Rotterdam, pp. 929-936.

Chandler, Neil A., Rodney S. Read, and Alan W. L. Wan. 1996. Implications of the results of URL experiments on the design of repository seals in granite. In Proc. Int. Conf. on Deep Geological Disposal of Radioactive Waste, Winnipeg, pp. 7-1 - 7-10.

PUBLICATIONS (cont.)

Hayles, J.G., M.H. Serzu, G.S. Lodha, and R.S. Read. 1996. Cross-hole seismic tomography for the Mine-by Experiment. In Proc. Soc. Expl. Geophysicists Int. Exposition, Denver, Vol. 1, pp. 904-907.

Lodha, G.S., J.G. Hayles, G.W. Kuzyk, and R.S. Read. 1996. Review of geophysical techniques used for understanding rock mass damage with examples from controlled experiments at the Underground Research Laboratory, Pinawa, Manitoba, Canada. Presented at FRAGBLAST `96 Conference, Montreal.

Read, Rodney S., C. Derek Martin, and Edward J. Dzik. 1995. Asymmetric borehole breakouts at the URL. In J. Daemen and R. Schultz, editors, Proc. 35th U.S. Rock Mech. Symp., Lake Tahoe: Balkema: Rotterdam, pp. 879-884.

Martin, C.D., R.S. Read, and E.J. Dzik. 1995. Near-face cracking and strength around underground openings. In H. P. Rossmanith, editor, Proc. 2nd Int. Conf. on Mechanics of Jointed and Faulted Rock, Vienna: Balkema: Rotterdam, pp. 747-752.

Martin, C.D., N.A. Chandler, and R.S. Read. 1994. The role of convergence measurements in characterizing a rock mass. In Proc. 47th Can. Geotech. Conf., Halifax, pp. 408-417.

Read, R.S., and C.D. Martin. 1992. Monitoring the excavation-induced response of granite. In J. R. Tillerson and W. R. Wawersik, editors, Proc. 33rd U.S. Symp. on Rock Mech., Santa Fe: Balkema: Rotterdam, pp. 201-210.

Martin, C.D., and R.S. Read. 1992. The in situ strength of massive granite around excavations. In P. K. Kaiser and D. McCreath, editors, Proc. 16th Can. Rock Mech. Conf., Sudbury, pp. 1-10.

Thompson, P.M., B.H. Kjartanson, and R.S. Read. 1992. Design and construction of two major experiments at the URL. In Proc. 1992 International High-Level Radioactive Waste Management Conference, Las Vegas, NV, Vol. 1, pp. 1082-1089.

Onagi, D.P., R.S. Read, and G.W. Kuzyk. 1991. AECL's Mine-by Experiment - from concept to construction. In Proc. SME Conference, Denver.

Read, R.S., and C.D. Martin. 1990. The Underground Research Laboratory Mine-by Experiment - A research perspective on tunnel design. In Proc. 8th Canadian Tunnelling Conf., Vancouver, BC: BiTech: Vancouver, pp. 213-226.

Martin, C.D., R.S. Read, and P.A. Lang. 1990. Seven years of in situ stress measurements at the URL - An overview. In W. A. Hustrulid and G. A. Johnson, editors, Proc. 31st U.S. Symp. Rock Mech., Golden, CO: Balkema: Rotterdam, pp. 15-26.

Martin, C.D., R.S. Read, and N.A. Chandler. 1990. Does scale influence in situ stress measurements? - Some findings at the Underground Research Laboratory. In A. Pinto da Cunha, editor, Proc. 1st Int. Workshop on Scale Effects in Rock Masses, Loen, Norway, Balkema: Rotterdam, pp. 307-316.

CNL, NWMO, AECL, SKB and Other Publications

McCrank, G.F., Campbell, K., Everitt, R.A., Priyanto, D.G., Pucciarelli, D.M., Read, R.S., Sharp, K.J., Siddiqui, J.A., Stephenson, K., Stroes-Gascoyne, S., Thompson, P.M., Vilks, P. 2016. Geologic Waste Management Fa-cility Descriptive Geosphere Site Model Report: Phase I. Canadian Nuclear Laboratories (CNL) Report No. 361101-10260-REPT-005, Chalk River, Ontario, Canada.

McCrank, G.F., Campbell, K., Chshyolkova, T., Everitt, R.A., Kitson, C., Priyanto, D.G., Pucciarelli, D.M., Read, R.S., Sharp, K.J., Siddiqui, J.A., Stephenson, K., Stroes-Gascoyne, S., Thompson, P.M., and Vilks, P. 2016. Geologic Waste Management Facility Integrated Geosynthesis Report: Phase I. Canadian Nuclear Laboratories (CNL) Report No. 361101-10260-REPT-004, Chalk River, Ontario, Canada.

Read, R.S. 2011. Effects of earthquake induced rock shear on containment system integrity. Laboratory testing plan development. Swedish Nuclear Fuel and Waste Management Company Report SKB R-11-21.

Read, R.S. 2010. Rock mechanics features, events, and processes for a used fuel deep geologic repository in crystalline rock. Nuclear Waste Management Organization Technical Report NWMO TR-2010

Read, R.S. 2009. Implications of excavation damage for design and performance of repository excavations and sealing systems. Nuclear Waste Management Organization Technical Report NWMO TR-2009

Read, R.S. 2008. Developing a reasoned argument that no large-scale fracturing or faulting will be induced in the host rock by a deep geological repository. Nuclear Waste Management Organization Technical Report NWMO TR-2008-14.

Read, R.S. 2008. The role of rock engineering in developing a deep geological repository in sedimentary rock. Nuclear Waste Management Organization Technical Report NWMO TR-2008-16.

PUBLICATIONS (cont.)

Read, R.S. 2008. Laboratory testing of rock shear effects on containment system integrity (2008 update). Nuclear waste Management Organization Technical Memorandum, November 2008 (R0)

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PH.D. THESIS SUMMARY

Interpreting Excavation-Induced Displacements around a Tunnel in Highly Stressed Granite (R.S. Read, 1994)

In Canada, as in many countries that employ nuclear power, the current concept for dealing with used nuclear fuel waste is deep underground disposal in crystalline rock such as granite. One of the primary concerns in this concept is the development of damage, or cracking, around excavations, which can potentially contribute to the migration of radionuclides. To address this concern, the fundamental response of the rock mass to excavating underground openings such as shafts and tunnels must be understood. The measurement and interpretation of excavation-induced displacements, i.e., movements of the rock mass as it adjusts to the introduction of a tunnel, play a key role in this respect. For example, in the absence of appreciable damage around a tunnel, measured displacements have been used to calculate the initial stresses in the rock mass. In rock damaged during excavation, displacements measured around a tunnel in known stress conditions have been used to determine the extent and characteristics of the damaged zone. These two applications tend to be mutually exclusive.

This thesis addresses the problems associated with interpreting displacements caused by excavating a cylindrical tunnel in conditions where the stresses concentrated near the opening are sufficient to damage the rock. A new technique using displacements measured near the tunnel face is developed to calculate the initial stresses in the rock mass, and is applied to a test tunnel in granite at AECL's Underground Research Laboratory (URL), where extensive damage is evident in parts of the tunnel. The displacements measured around this tunnel constitute a data set unparalleled anywhere in the world in terms of precision and quantity. The stresses estimated from these data are, in turn, used in conjunction with results from a field investigation and computer modelling to determine the extent and characteristics of damage around the tunnel, and the processes responsible for its development. It is concluded that both the initial stress state, and the extent and characteristics of damage around the excavation, can be interpreted from displacements measured around a single tunnel.

There are several original contributions to the field of rock mechanics represented by this thesis. In terms of analytical approaches, the method used to determine the initial stresses from displacements measured near the tunnel face has not been covered in the literature to this time. This approach is shown to be important in highly stressed rock masses where other stress measurement techniques do not work. The results at the 420 Level of the URL, for example, are significant in that they represent a refinement of previous stress estimates. The mathematical functions associated with this method are also new. In particular, the equations relating stresses and displacements for a cylindrical tunnel represent a significant improvement over previous relationships used for such purposes as designing tunnel support. Curvature of the tunnel face and stepped longitudinal tunnel geometry are two aspects of real tunnels that are generally overlooked in interpreting measured displacements. Both are addressed in the thesis and are shown to be important considerations. Finally, instruments installed from within a tunnel to measure rock displacements are shown to have several limitations that have not been considered in the literature. The method of interpretation presented in the thesis accounts for these limitations.

The specific interpretation, based on the estimated initial stresses, of the extent and characteristics of the damaged zone around the AECL's Mine-by Experiment test tunnel considerably enhances the fundamental understanding of the response of highly stressed granite to excavation. First, it suggests that there is a relationship between the stresses concentrated ahead of the advancing tunnel face and the eventual development of asymmetric patterns of large-scale damage, or breakouts, inside a tunnel. Second, it shows that the grain size and grain structure of the rock mass significantly influence the development of damage. Finally, it shows that excavation damage in zones of tensile stresses around the tunnel accounts for larger than expected displacements in these regions. It is of considerable interest that this tensile damage is not visible with the naked eye, but could, nonetheless, increase the potential for transport of radionuclides, either by diffusion or by groundwater flow. Identification of these regions of damage is therefore important in designing future experiments to assess the issue of radionuclide transport along engineered openings.