

CHIN-FU TSANG

Energy Geosciences Division, Lawrence Berkeley National Laboratory
Berkeley, California, USA
cftsang@lbl.gov
Currently in residence at Department of Earth Sciences, Uppsala University
Uppsala, Sweden

EDUCATION

Ph.D., Physics, 1969, University of California at Berkeley, USA
B.Sc. (First Class Honours), Physics, 1964, University of Manchester, England.
Higgenbottom Prize (Top of class), 1962, University of Manchester, England.

PROFESSIONAL POSITIONS

Senior Scientist Emeritus, Lawrence Berkeley National Laboratory, July 2005 – present
Visiting Professor and Visiting Scholar, Department of Earth Sciences, Uppsala University, Sweden,
February 2008 – present
Visiting Professor of Hydrogeology, Department of Earth Science and Engineering, Imperial College
London, UK, September 2008 – July 2011
Chairman of Steering Committee of DECOVALEX project, an international cooperative research
program (involving about ten countries) on coupled thermomechanical-hydrochemical processes in
geological systems, 1992-2007.
Senior Scientist, highest level in Earth Sciences Division, Lawrence Berkeley National Laboratory,
May 1981 – June 2005
Head, Department of Hydrogeology and Reservoir Dynamics, Earth Sciences Division, Lawrence
Berkeley National Laboratory, June 1998 – May 2002
Director, LBL Russian-American Center for Contaminant Transport Studies, Lawrence Berkeley
National Laboratory, June 1993 – 1998
Various Group Leader positions in Earth Sciences, Lawrence Berkeley Laboratory, 1979–1996.
Scientist and Staff Scientist, Lawrence Berkeley Laboratory, July 1969 – May 1981.

RESEARCH INTERESTS

Coupled hydro-mechanical and thermo-hydro-mechanical processes in fractured rocks
Fluid flow and solute transport in fractured media and heterogeneous porous media
Site characterization methods and analysis
Hydrological and tracer field test analysis, and hydrologic borehole logging
Site-specific modeling of hydrogeological systems and performance assessment
Injection of liquids and CO₂ into deep underground formations

PROJECTS AND CONTRIBUTIONS

Dr. Tsang is principal investigator and project manager for a large number of projects at the Lawrence Berkeley National Laboratory. These include projects on groundwater contaminant transport; underground thermal energy storage; geothermal reservoir modeling; deep injection disposal of hazardous wastes; basic study of reservoir dynamics; technical issues and advanced modeling in geologic disposal of nuclear wastes, and CO₂ geosequestration regional studies and site characterization issues. He initiated a number of new research areas for the Berkeley Laboratory, such as underground thermal energy storage, borehole fluid logging methods, and coupled thermo-hydro-mechanical processes in fractured rocks.

SOME HIGHLIGHTS OF PROFESSIONAL ACTIVITIES: 2005 – 2016

- Faculty Opponent of Ph.D. thesis on “Flow and Transport in rough-walled rock fractures: impact of surface roughness and asperity contacts,” School of Land and Water Technology, Department of Engineering Geology, Royal Institute of Technology (KTH), Stockholm, Sweden, November 2016.
- Invited Opening Session Lecture, HydroFrame Summer School on Nuclear Waste Disposal. Department of Earth Science and Engineering, Royal School of Mines, Imperial College London, London, UK. 8-12 August, 2016
- Board member for PhD Thesis, Department of Chemical Engineering, Royal Institute of Technology, Stockholm. Thesis title: “Solute Transport through Fractured Rocks: Influence of Geological Heterogeneity and Stagnant Water Zone.” Stockholm, Sweden, April 26, 2016.
- Member of Scientific, Industry and Regulatory Advisory Board, EU-FracRisk Project coordinated by University of Edinburgh, UK, and University of Goettingen, Germany, 2015-2018.
- Invited Review Paper for the Special 50th Anniversary Issue of Water Resources Research, on “Hydrologic issues associated with nuclear waste repositories,” 2015.
- Invited Concluding Summary Talk of the EU-Panacea Project, Final Meeting of the EU-Panacea Project 2012-2014, Paris, France, 18-19 December, 2014.
- Board member for PhD Thesis, School of Land and Water Technology, Department of Engineering Geology, Royal Institute of Technology, Stockholm. Thesis title: “Strength and deformability of fractured rocks.” Stockholm, Sweden, November 25, 2014.
- Member of International Advisory Committee, National Geosphere Laboratory, Sweden, coordinated by Stockholm University, Sweden, 2013-present.
- Invited to be Hydrogeology Principal Investigator for the Swedish Scientific Deep Drilling Program, COSC project (with first fully cored deep borehole drilled at Are, Sweden, in 2014), 2012-present.
- Co-Organizer, and Co-Chair of Scientific Committee, Deep Hydrogeology Workshop, Uppsala University, Sweden, September 20-22, 2011.
- Faculty Opponent of Licentious Thesis on “Escherichia coli transport and fate in unsaturated porous media.” School of Land and Water Technology, Royal Institute of Technology (KTH), Stockholm, Sweden, 2011.
- Keynote Lecture: “A discussion of Key Issues in Coupled THM Processes in Clays, Rock Salt and Crystalline Rock with Bentonite Buffer.” The Thirteenth International Conference on Environmental Remediation and Radioactive Waste Management, Tsukuba, Japan. October 3-7, 2010.
- Session Chair of the Session, Site Characterization and Modeling of Geological Environment.” The Thirteenth International Conference on Environmental Remediation and Radioactive Waste Management, Tsukuba, Japan. October 3-7, 2010.
- Faculty Opponent of Ph.D. thesis on “Numerical modeling of coupled Thermo-hydro-mechanical processes In geological porous media,” School of Land and Water Technology, Department of Engineering Geology, Royal Institute of Technology (KTH), Stockholm, Sweden, 2010.
- Keynote Lecture and General Rapporteur, EU International Coupled THMC Conference on THERESA and TIMODAZ multiple-year and multi-organization research programmes, Luxembourg, September 30 – October 2, 2009
- Keynote Lecture, Society of Core Analysis Conference and Workshop, 2009 Noordwijk, The Netherlands, September 27-29, 2009.
- 2009 *Applied Rock Mechanics Award*, American Rock Mechanics Association. For contributions in fractured rock hydrogeomechanics with applications ranging from pressure testing, tracer transport to CO₂ injection-storage, 2009.

- Keynote Lecture, Rock Mechanics Analysis Workshop, Mont Terri Project, NAGRA, Unterageri, Switzerland, June 3-5, 2009
- Invited Speaker at Science Colloquium for celebration of 50th Anniversary of the Federal Institute for Geosciences and Natural Resources (BGR). Lecture title: Thermo-Hydro-Mechanics of Geological Systems: Advances, Challenges, and Limits. Hannover, Germany, November 25, 2008.
- Visiting Professor of Hydrogeology, Department of Earth Science and Engineering, Imperial College London, UK, September 2008 – July 2011 (in residence at Imperial College, September 2008 – July 2010).
- Expert member of INSITE Core Group to advise the Swedish government authority, Swedish Nuclear Power Inspectorate (SKI) on Swedish site investigation program for siting nuclear waste repository in Sweden being conducted by Swedish Nuclear Fuel and Waste Management Company (SKB), 2002 – 2009
- Expert member of International Review Team to advise Finnish Government authority, STUK, in their review of TKS2006, “Posiva’s Research Programme for 2007-2009,” January-May, 2007.
- Chairman of Steering Committee, DECOVALEX Project, a ten-nation international cooperative research program on Coupled Thermo-Hydro-Mechanical-Chemical (THMC) Process Model Development and Validation against Experiments, managed by Swedish Nuclear Power Inspectorate, with Secretariat at Royal Institute of Technology, Stockholm, Sweden, 1992-2007.
- Faculty Opponent of Ph.D. thesis on “Modelling long-term redox processes and oxygen scavenging in fractured crystalline rocks,” by Magnus Sidborn, School of Chemical Science and Engineering, Royal Institute of Technology (KTH), Stockholm, Sweden, 2007.
- Keynote Lecture, *Coupled Hydromechanical Processes in Crystalline Rock and in Plastic and Indurated Clays – a Comparative Discussion*. Second International Conference on Coupled Thermo-Hydro-Mechanical-Chemical Processes in Geosystems, GeoProc2006, Nanjing, China, May 22-24, 2006.
- 2006 *Rock Mechanics Case History Award*, American Rock Mechanics Association. Awarded for contributions to the field of rock mechanics as a co-investigator in coupled thermo-hydrological-mechanical analysis of the Yucca Mountain Drift Scale Heater Test, which was the largest heater test in geological formation to-date with four-year heating period followed by an equal period of cooling. 2006.
- Opening Keynote Speaker, *Studies in Fractured Rock Hydromechanics: from Borehole Testing, Solute Transport, to CO₂ Storage*. Euro-Conference 2005 on Rock Physics and Geomechanics, Saint-Pierre d’Oléron, France, 18-22 September, 2005.
- Invited Speaker, International Workshop on: “Practical Experience and Results of Research for Deep Well Injection,” Dimitrovgrad, Yliankov Region, Russia Federation, August 23-25, 2005.
- 2005 *Applied Rock Mechanics Award*, American Rock Mechanics Association. Awarded for seminal contributions in the field of rock mechanics by conducting a comparative evaluation of geohydromechanical processes in the excavation damaged zone in crystalline rock, rock salt, and indurated and plastic clays – in the context of radioactive waste disposal, 2005.

PUBLICATIONS

Dr. Chin-Fu Tsang has over 400 research reports, papers, book chapters, and invited or keynote presentations, including 185 papers in refereed scientific journals. In addition, he is the co-author and co-editor of 13 books or special issues of scientific journals.

SPECIAL PUBLICATIONS IN 2005 – 2015:

Book: Underground Injection Science and Technology, C.-F. Tsang and J. Apps, editors. Elsevier Science Publishers, Developments in Water Science, Volume 52, 2005.

Special Issue, Journal of Environmental Geology, on Site Characterization for CO₂ Storage,” Jens Birkholzer and C.-F. Tsang, Guest Editors. Springer Verlag, Germany, 2008.

Special Issue, Journal of Environmental Geology, on Coupled Thermo-hydro-mechanical-chemical (THMC) Processes, Chin-Fu Tsang, Guest Editor, Springer Verlag, Germany, 2009.

Proceedings of Deep Hydrogeology Workshop, Chin-Fu Tsang, Auli Niemi and Martin Larsson, Editors, Department of Earth Sciences, Uppsala University, September 20-22, 2011.

SELECTED PAPERS IN REFEREED JOURNALS IN 2005 – 2016:

Tsang CF, Rosberg JE, Sharma P, Berthet T, Juhlin C and Niemi A. Hydrologic testing during drilling: application of the flowing fluid electrical conductivity (FFEC) logging method to drilling of a deep borehole. DOI 10.1007/s10040-016-1405-z. Hydrogeology Journal, 24(6), 1333-1341, 2016.

Figueiredo, B., Tsang, C.-F., Rutqvist, J., Niemi, A. (2015). A study of changes in deep fractured rock permeability due to coupled hydro-mechanical effects. DOI. 10.1016/j.ijrmms.2015.08.011. International Journal of Rock Mechanics and Mining Sciences 79C: 70-85, 2015.

Figueiredo B, Tsang CF, Niemi A and Lindgren G. A review of the state-of-art of sparse channel models and their applicability to performance assessment of radioactive waste repositories in fractured crystalline formations. Hydrogeology Journal, DOI 10.1007/s10040-016-1415-x. March 2016.

Sharma P, Tsang CF, Kukkonen IT, Niemi A. Analysis of 6-year uid electric conductivity logs to evaluate the hydraulic structure of the deep drill hole at Outokumpu, Finland. Int J Earth Sci (Geol Rundsch) DOI 10.1007/s00531-015-1268-x. International Journal of Earth Sciences, 105(5), 1549-1562, 2015.

Figueiredo, B., Tsang, C., Rutqvist, J., Bensabat, J., Niemi, A. (2015). Coupled hydro-mechanical processes and fault reactivation induced by CO₂ Injection in a three-layer storage formation. International Journal of Greenhouse Gas Control, vol. 39, ss. 432-448. doi:10.1016/j.ijggc.2015.06.008, 2015.

Tsang, CF, Neretnieks I and Tsang Y (2015), Hydrologic issues associated with nuclear waste repositories, Water Resour. Res., 51, doi:10.1002/2015WR017641 [Invited review paper for the Special 50th Anniversary Issue of Water Resources Research]. 2015.

Figueiredo, B., Tsang, C.-F., Rutqvist, J., Niemi, A., 2015. A study of changes in deep fractured rock permeability due to coupled hydro-mechanical effects. International Journal of Rock Mechanics and Mining Sciences 79C: 70-85, 2015.

Lei, Q., J.-P. Latham, C.-F. Tsang, J. Xiang, and P. Lang, 2015. A new approach to upscaling fracture network models while preserving geostatistical and geomechanical characteristics, J. Geophys. Res. Solid Earth, 120, doi:10.1002/2014JB011736, 2015.

Lei Q, Latham J-P, Xiang J, Tsang C-F. 2015. Polyaxial stress-induced variable aperture model for persistent 3D fracture networks. DOI:10.1002/2014JB011736. Geomechanics for Energy and the Environment 1, 34–47, 2015

- Lorenz, H., J-E. Rosberg, C. Juhlin, L. Bjelm, B.S.G. Almqvist, T. Berthet, R. Conze, D.G. Gee, I. Klonowska, C. Pascal, K. Pedersen, N.M.W. Roberts and C.-F. Tsang (2015): COSC-1 – drilling of a subduction-related allochthon in the Palaeozoic Caledonide orogen of Scandinavia, *Sci. Dril.*, 19, 1-11, doi:10.5194/sd-19-1-2015.
- Rasmusson, K., Tsang, C.-F., Tsang, Y., Rasmusson, M., Pan, L., Fagerlund, F., Bensabat, J. and Niemi, A. Distribution of injected CO₂ in a stratified saline reservoir accounting for coupled wellbore-reservoir flow. *Greenhouse Gas Sci Technol*, 5: 419–436. doi: 10.1002/ghg.1477, 2015
- Prabhakar Sharma, Chin-Fu Tsang, Christine Doughty, Auli Niemi, and Jacob Bensabat. Feasibility of Long-term Monitoring of Deep Hydrogeology with Flowing Fluid Electric Conductivity Logging Method. 2014. AGU/Wiley Monograph “Dynamics of Fluids and Transport in Fractured-Porous Media,” edited by Faybishenko, B., J. Gale, and S.Benson. December 2014.
- Yves Guglielmi, Frederic Cappa, Herve Lancon, Jean Bernard Janowczyk, Jonny Rutqvist, C.-F. Tsang and J.S.Y. Wang. ISRM Suggested Method for Step-Rate Injection Method for Fracture In-Situ Properties (SIMFIP) Using a 3-Components Borehole Deformation Sensor. DOI 10.1007/s00603-013-0517-1. *Rock Mechanics and Rock Engineering*, 47(1), 303-311, 2014.
- Qinghua Lei, John-Paul Latham, Jiansheng Xiang, Chin-Fu Tsang, Philipp Lang, and Liwei Guo (2014). Effects of geomechanical changes on the validity of a discrete fracture network representation of a realistic two-dimensional fractured rock. DOI 10.1016/j.ijrmms.2014.06.001. *International Journal of Rock Mechanics & Mining Sciences*, 70, 507–523, 2014.
- Chin-Fu Tsang and Auli Niemi Deep Hydrogeology: A Discussion of Issues and Research Needs. *Hydrogeological Journal*. Issue Paper, DOI 10.1007/s10040-013-0989-9. *Hydrogeology Journal* 21-08: 1687–1690, 2013.
- Doughty, C., C.-F. Tsang, S. Yabuchi, and T. Kunimaru, Flowing fluid electric conductivity logging for a deep artesian well in fractured rock with regional flow. DOI:10.1016/j.jhydrol.2012.04.061. *Journal of Hydrology*, Vol. 482, pp. 1–13, 2013.
- Latham J-P, Xiang J, Belayneh M, Nick HM, Tsang C-F, Blunt MJ. 2013. Modelling stress-dependent permeability in fractured rock including effects of propagating and bending fractures. *International Journal of Rock Mechanics and Mining Sciences* 57: 100-112, 2013.
- Larsson, M., C. Doughty, C.-F. Tsang, and A. Niemi (2013), Understanding the effect of single fracture heterogeneity from single well injection withdrawal (SWIW) tests. DOI 10.1007/s10040-013-0988-x. *Hydrogeology Journal* 21-08: 1691–1700, 2013.
- Larsson, M., M. Odén, A. Niemi, I. Neretnieks, and C.-F. Tsang, A new approach to account for fracture aperture variability when modeling solute transport in fracture networks. doi:10.1002/wrcr.2013. *Water Resour. Res.*, 49, 2241–2252, 2013.
- Jonny Rutqvist and Chin-Fu Tsang. Multiphysics processes in partially saturated fractured rock: Experiments and models from Yucca Mountain. *Reviews of Geophysics*, Vol. 50, RG3006, 30 pp., doi:10.1029/2012RG000391. 2012. (Cover article for this issue of *Review of Geophysics*).
- Tsang C.-F., Barnichon J.D., Birkholzer J., Li X.L., Liu H.H., Sillen X. Coupled thermo-hydro-mechanical processes in the nearfield of a high-level radioactive waste repository in clay formations. DOI: 10.1016/j.ijrmms.2011.09.015. *International Journal of Rock Mechanics & Mining Sciences* 49, 31–44, 2012.
- Jens Birkholzer, James Houseworth and Chin-Fu Tsang. Geologic Disposal of High-Level Radioactive Waste: Status, Key Issues, and Trends. Invited paper. *Annual Review of Environment and Resources*. Volume 37, DOI: 10.1146/annurev-environ-090611-143314, 2012.

- Larsson, M., A. Niemi, and C.-F. Tsang, A study of flow-wetted surface area in a single fracture as a function of its hydraulic conductivity distribution, *Water Resour. Res.*, 48, W01508, doi:10.1029/2011WR010686, 2012.
- Larsson, Martin, Auli Niemi and Chin-Fu Tsang, An observed error in PMPATH particle tracking algorithm for MODFLOW in case of varying porosity and a proposed correction. DOI:10.1016/j.cageo.2012.03.001. *Computers & Geosciences*, 45, 1–3, 2012.
- Zhou, Quanlin, Birkholzer, Jens T. and Tsang, Chin-Fu. Reply to Comments by Veling on “A Semi-Analytical Solution for Large-Scale Injection-Induced Pressure Perturbation and Leakage in a Laterally Bounded Aquifer–Aquitard System” by Zhou, Birkholzer, and Tsang. *Transp Porous Media*, 86:327–328. DOI 10.1007/s11242-010-9680-y, 2011.
- Mathias, Simon A., Jon G. Gluyas, Curtis M. Oldenburg and Chin-Fu Tsang. Analytical solution for Joule–Thomson cooling during CO₂ geo-sequestration in depleted oil and gas reservoirs. *International Journal of Greenhouse Gas Control*, 4 (5), 806–810, 2010.
- Fransson A, C.-F. Tsang, J. Rutqvist and G. Gustafson. Estimation of deformation and stiffness of fractures close to tunnels using data from single-hole hydraulic testing and grouting. *International Journal of Rock Mechanics & Mining Sciences* 47, 887–893, 2010.
- Mathias, Simon A., Chin-Fu Tsang and Maarten van Reeuwijk. Investigation of hydromechanical processes during cyclic extraction recovery testing of a deformable rock fracture. *International Journal of Rock Mechanics and Mining Sciences*, 47(2010) 517–522; 2010.
- Wessling, Stefan; Ralf Junker, Jonny Rutqvist, Dmitriy Silin, Hans Sulzbacher, Torsten Tischner, Chin-Fu Tsang. Pressure analysis of the hydromechanical fracture behaviour in stimulated tight sedimentary geothermal reservoirs, *Geothermics* 38, 211–226, 2009.
- Zhou, Quanlin; Jens T. Birkholzer and Chin-Fu Tsang, A semi-analytical solution for large-scale injection-induced pressure perturbation and leakage in a laterally bounded aquifer–aquitard system, *Transp Porous Med* 78:127–148, DOI 10.1007/s11242-008-9290-0, 2009.
- Tsang, C.-F., O. Stephansson, L. Jing and F. Kautsky, DECOVALEX Project: from 1992 to 2007. *Journal of Environmental Geology*, Vol. 57, No. 6, pp 1221–1238, 2009.
- Tsang, C., C. Doughty, and M. Uchida. Simple model representations of transport in a complex fracture and their effects on long-term predictions, *Water Resour. Res.*, Vol. 44, W08445, doi:10.1029/2007WR006632, 2008.
- Odén, M.; Niemi, A., Tsang C.-F. and Öhman J, Regional Channelized Transport in Fractured Media with Matrix Diffusion and Linear Sorption. *Water Resources Research*, Vol. 44, W02421, doi:10.1029/2006WR005632, 2008.
- Guglielmi, Y., F. Cappa, J. Rutqvist, C.-F. Tsang, and A. Thoraval, Mesoscale characterization of coupled hydromechanical behavior of a fractured-porous slope in response to free water-surface movement. *International Journal of Rock Mechanics and Mining Sciences*, 45, 862–878, 2008.
- Zhou, Q., J. Birkholzer, C.-F. Tsang, and J. Rutqvist, A method for quick assessment of CO₂ storage capacity in closed and semi-closed saline aquifers. *International Journal of Greenhouse Gas Control*, 85, doi:10.1016/j.ijggc.2008. 02.004, 2008
- Cappa, F., Y. Guglielmi, J. Rutqvist, C.-F. Tsang, and A. Thoraval, Estimation of fracture flow parameters through numerical analysis of hydromechanical pressure pulses. *Water Resour. Res.*, 44, W11408, doi:10.1029/2008WR007015, 2008

- Doughty, C., C.-F. Tsang, K. Hatanaka, S. Yabuuchi, and H. Kurikami. Application of direct-fitting, mass integral, and multirate methods to analysis of flowing fluid electric conductivity logs from Horonobe, Japan, *Water Resour. Res.*, Vol. 44, W08403, doi:10.1029/2007WR006441, 2008.
- Tsang C.-F., Birkholzer J., and Rutqvist J. A Comparative Review of Hydrologic Issues Involved in Geologic Storage of CO₂ and Injection Disposal of Liquid Waste. *Journal of Environmental Geology*, 54 (8), 1723–1737, 2008.
- Tsang C.-F., Rutqvist J., and Min K.B. Fractured Rock Hydromechanics: from Borehole Testing, Solute Transport, to CO₂ Storage, In: *Rock Physics and Geomechanics in the Study of Reservoirs and Repositories*, David, C. and Le Ravalec-Dupin, M. Editors. Geological Society of London Special Publication 284, pp. 15-34, 2007.
- Fransson Å, Tsang C.-F., Rutqvist J. and Gustafson G. A New Parameter to Assess Hydromechanical Effect in Single-hole Hydraulic Testing and Grouting. *Int. J. Rock mech. & Min. Sci.*, Vol. 44(7), 1011-1021, 2007
- Tsang, C.-F., C. Doughty, J. Rutqvist, and T. Xu, Modeling to understand and simulate physico-chemical processes of CO₂ geological storage. LBNL-59068. In: *Carbon Capture and Sequestration-Integrating Technology, Monitoring, Regulation*. E. Wilson and D. Gerard, eds., Blackwell Publishing, Ames, Iowa, pp. 35–72, 2007.
- Rutqvist, J., Birkholzer J.T., and Tsang C.-F. Coupled Reservoir-Geomechanical Analysis of the Potential for Tensile and Shear Failure Associated with CO₂ Injection in Multilayered Reservoir-Caprock Systems. *Int. J. Rock mech. & Min. Sci.*, Vol. 45(1), 132-143, 2007.
- Lewicki, J.L., Birkholzer, J., and Tsang, C.-F. Natural and Industrial Analogues for Leakage of CO₂ from Storage Reservoirs – Identification of Features, Events, and Processes and Lessons Learned, *Journal of Environmental Geology*, 52(3), pp. 457-467, 2007.
- Rutqvist J., Birkholzer J., Cappa F., and Tsang C.-F. Estimating Maximum Sustainable Injection Pressure during Geological Sequestration of CO₂ using Coupled Fluid Flow and Geomechanical Fault-slip Analysis. *Energy Conversion and Management* 48, 1798–1807, 2007.
- Cappa F., Guglielmi Y., Rutqvist J., Tsang C.-F., and Thoraval A. Hydromechanical modeling of pulse tests that measure both fluid pressure and fracture-normal displacement at the Coaraze Laboratory site, France. *Int. J. Rock mech. & Min. Sci.*, 43(7), 1062-1082, 2006.
- Tsang, C.F: Is Current Hydrogeologic Research Addressing Long-Term Predictions? *Journal of Ground Water*, 43, No. 3: 296–300, June, 2005.
- Öhman J., A. Niemi and C.-F. Tsang. Probabilistic estimation of fracture transmissivity from wellbore hydraulic data accounting for depth-dependent anisotropic rock stress, *International Journal of Rock Mechanics and Mining Sciences*, Volume 42, Numbers 5, 793-804, 2005.
- Chin-Fu Tsang, Lanru Jing, Ove Stephansson and Fritz Kautsky The DECOVALEX III project: A summary of activities and lessons learned. *International Journal of Rock Mechanics and Mining Sciences*, Volume 42, Numbers 5-6, 593-610, 2005.
- Min, K.B., Rutqvist J., Tsang C.-F. and Jing L. Thermally induced mechanical and permeability changes around a nuclear waste repository – a far-field study based on equivalent properties determined by a discrete approach. *Int. J. Rock mech. Min. Sci.*, Volume 42, Numbers 5, 765-780, 2005.
- Öhman, J., A. Niemi, and C.-F. Tsang, A Regional-Scale Particle-Tracking Method for Nonstationary Fractured Media, *Water Resources Research*, Volume 41, W03016, doi:10.1029/2004WR003498, 2005.

Rutqvist, Jonny and Chin-Fu Tsang. Coupled Hydromechanical Effects in CO₂ Injection. In: *Underground Injection Science and Technology, Developments in Water Science, Volume 52*. C.-F. Tsang and J.A. Apps, Editors, Elsevier Science Publishers, pp. 649-679, 2005.

Chin-Fu Tsang, F. Bernier and C. Davies. Geohydromechanical processes in the Excavation Damaged Zone in crystalline rock, rock salt, and indurated and plastic clays—in the context of radioactive waste disposal. *International Journal of Rock Mechanics and Mining Sciences*, Volume 42, No. 1, Pages 109-125, 2005 (This paper received the 2005 *Applied Rock Mechanics Award*, American Rock Mechanics Association).