

VITA - DEREK ELSWORTH

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Professional Preparation

Portsmouth Polytechnic, England	Engineering Geology	B.Sc.(Honors)	1979
Imperial College, London	Engineering Rock Mechanics	M.Sc.(Distinction)	1980
University of California, Berkeley	Engineering	Ph.D.	1984

Professional Details

1997 - Pres. Professor, Energy and Mineral Engineering, Geosciences (2013-), Civil and Environmental Engineering (2015-), Pennsylvania State University

2017 – Adjunct Professor, Henan Polytechnic University, Jiaozhu, China

2016 – Adjunct Professor, Northeastern University, Shenyang, China

2016 – Adjunct Professor, Chinese Academy of Sciences, Wuhan, China

2014 – Guest Professor, China University of Petroleum (Huadong), Qingdao, China

2014 – Visiting Professor, China University of Mining and Technology (CUMT), Xuzhou, China

2000 - 2003 Associate Dean for Research, College of Earth & Mineral Sciences, Penn State University

1991 - 1997 Associate Professor, Mineral Engineering, Pennsylvania State University

1985 - 1991 Assistant Professor, Mineral Engineering, Pennsylvania State University

1990 - 1993 Research Assistant Professor, Adjunct Professor, Earth Sciences and WCGR, U. Waterloo

1984 - 1985 Visiting Assistant Professor, Civil Engineering, University of Toronto

1984 Research Associate, Lawrence Berkeley Laboratory

1980 - 1982 Engineer D.R. Piteau and Assocs., and Komex Consultants. Calgary, Canada

Current Interests and Past Activities

Derek Elsworth is a Professor of Energy and Geo-Environmental Engineering and former Associate Dean for Research in the College of Earth and Mineral Sciences at Penn State. He is the founding chair of the graduate programs in Geo-Environmental Engineering and in Energy and Geo-Environmental Engineering and co-developer of an international exchange program in Energy and Environment (ICEEIT) between universities in Europe and the United States. He is the co-founder of the Center for Geomechanics, Geofluids and Geohazards (G³) at Penn State – a center for multidisciplinary studies in rock and fluid physics.

He has 30 years of teaching, research and consulting experience in computational mechanics, flow and transport in fractured media and rock mechanics. In his role as a university administrator he was responsible for growing College research expenditures by one third to \$52M/year over his three year tenure.

His recent research interests have focused on understanding the role of fluids on natural and engineered processes in the Earth's crust, particularly in the evolution of transport and mechanical properties of fractured rocks under the complex action of stress, fluid pressures and chemistry. This work has elevated the state-of-science in the deep geological sequestration of radioactive wastes and of CO₂, mining, petroleum and geothermal engineering and of volcanic hazards. Principal activities include:

- Understanding the complex roles of stress and chemistry in mediating permeability and stress-state in geothermal and petroleum reservoirs, in repositories for the sequestration of energy by-product wastes such as HLW and CO₂ and for *in situ* mining and combustion (*Funded by: ARC, CSIRO, DOE-BES, DOE-OSTI, DOE-EERE, NSF-EAR, NSERC, Chevron and Halliburton*). This work has

demonstrated crucial feedbacks between stress-chemistry in enhanced dissolution and precipitation in controlling the evolution of permeability and strength in pressure sensitive (fractured) rocks with important influences on the performance of critical facilities, resource recovery from reservoirs, induced seismicity, seismicity-permeability coupling and the earthquake cycle and the potential for alternate working fluids such as CO₂ in EGS reservoirs (*Reported in: EPSL, GRL, IJNAMG, JGR, TIPM, WRR; Keynotes in: Stockholm, Berlin, Turin, Nanjing, Dalian, Shanghai, SedHeat, Jeju Island, ARMA*).

- Reservoir geomechanics of unconventional reservoirs including gas shales and coalbed methane (*Funded by: ARC, DOE, ConocoPhillips, ExxonMobil, Chevron*). In particular the poromechanics of sorbing media and physicochemical controls on sorption and permeability evolution in coalbed methane (CBM) and gas shales together with gas fracturing of shales and enhanced methods of recovery using surrogate gases including CO₂ and N₂ (*Reported in: Int. J. Coal Geol., IJRM, J. Greenhouse Gas; Keynotes in Sapporo, Wuhan, Suzhou, Melbourne*).
- Fundamental studies of landslide dynamics on volcanoes including the roles of magmatic and meteoric fluids (*Funded by: NSF-CD, NSF-CMS, NERC, NASA*). These studies have defined the crucial role of hot and gas-charged magmatic fluids and their interaction with ground- and meteoric-water in triggering and sustaining giant landslides with long-reach, including those capable of generating dangerous ocean-traversing tsunami and hurricane-speed pyroclastic flows (*Reported in: Geology, GRL, JVGR, Science, BBC-Horizon & Discovery Channel; Keynotes in: Martinique, Azores*).
- Development of advanced profiling methods for the real-time determination of mechanical and transport properties of soils (*Funded by: NSF-CMMI, NSF-IREE*). This work has provided the only current method of recovering continuous profiles of permeability and of cyclic mobility in soils accommodating important roles of penetration rate and drainage effects (*Reported in: CGJ, Geotechnique, JGGE, JEM*).

He is the author of ~240 publications in refereed journals, ~120 in conference proceedings, one authored book and two edited books. In the last five years he has given numerous (~100) invited, plenary and keynote addresses, worldwide. His work has been excerpted and abstracted in the general press including in *Science, Nature, New Scientist* and in a popular *BBC-Horizon* documentary. Over the prior decade his research has been supported by competitive grants from government and industry totaling ~\$16M with current support of ~\$6M.

Alumni from these research programs are university faculty in Australia, China, France, Japan and Korea populating programs in mechanical, mining, petroleum, and geological engineering, and in volcanology, with others working in research laboratories and for resource and consulting companies. Their scholarship has been rewarded with the most prestigious awards in their field – the NRC-USNCRM Thesis Award, ARMA's N.G.W. Cook Award, and ISRM's Rocha Medal.

He is an active consultant and advisor to government and industry. These assignments relate to understanding the consequences of complex coupled processes on the long-term performance of radioactive waste repositories (*DOE, NRC-ACNW, NRC-CNWRA*), of high-pressure high-temperature conventional and unconventional petroleum reservoirs and geothermal reservoirs (*ExxonMobil, Halliburton, ChevronTexaco, W. Australia Parliamentary Committee, Australian Federal Government*) and the potential impacts of volcanic intrusion (*NWTRB, NRC-ACNW*) on the catastrophic disruption of radioactive waste repositories. He currently serves (2016-2018) on the National Academy Committee on Geotechnical and Geological Engineering (COGGE).

An elected board-member of ARMA, he served as treasurer and chaired the 38th U.S. Symposium on Rock Mechanics. He serves on the editorial boards of various national and international journals. From 2002-2010 he was an ardent advocate and leader in an effort to establish a deep underground science laboratory

(DUSEL) for subsurface research in astrophysics and engineering geoscience. In this pursuit he co-authored numerous reports developing the science-case (*NSF-ARMA*, *NSF-Earthlab*, *NSF-SI*), convened workshops and served as co-chair of the science program advisory committee for the successful laboratory site. Since then he has been involved in projects on reactivated fault slip and hydraulic fracturing using gases in underground laboratories in Europe.

Elsworth is the 2011 recipient of an ARMA Basic Research Award, a 2010 ARMA Case Study Award and a 1987 ISRM Manuel Rocha Medal and the first honoree to advise a student similarly awarded (Hideaki Yasuhara in 2007). In 2008 he was a Gledden Senior Visiting Fellow at the University of Western Australia, returning in 2009-2012 as Professor-at-Large. He was a JSPS Fellow at Kyoto University in 2010 and Darcy Professor at Utrecht University in 2016.

Recent Honors

- 2017 [Keynote Addresses] NSF SedHeat Workshop, Salt Lake City; YSRM Conference, Jeju, Korea; ARMA Symposium, San Francisco; 14th Young Scholars Conference, Northeastern University; 4th Int. Conf. Unconventional Geomechanics, Shenyang, China; 15th IACMAG Conference, Wuhan.
[Invited Addresses] Interpore 2017; Chinese Academy of Sciences, Wuhan; Henan Polytechnic, China; Int. Workshop on Grand Challenges in Mining Engineering, CUMT-B; Engineering Geology 50, Portsmouth; Int. Conf. Shale Gas Engineering Geomechs., CNPC, Beijing;
- 2016 **Darcy Professor, Utrecht University**
International Advisory Board, China JinPing Laboratory (particle physics and geomechanics)
[Keynote Addresses] 2nd Conf. on Rock Dynamics, 3rd Workshop on Unconventional Geomechanics, Wuhan; 2nd Darcy Symposium, Eindhoven; Int. Conf. Geomechanics and Geophysics for Georesources, Melbourne; 2nd Sustainability Conference, Utrecht; 3rd Int. Conf. on Multiscale Geomechanics and Geo-Engineering, Tongji University.
- 2015 **Member, US National Academy of Engineering**
[Keynote Addresses] CEDAR Workshop, Muroran, Japan; China Engineering, Science and Technology Forum, Chinese Academy of Engineering, Xuzhou, China. China Shale Gas 2015, Wuhan, China.
[Plenary Addresses] 7th Int. Conf. on Mining Sci. and Tech. Xuzhou, China.
[Invited Addresses] 7th Int. Conf. on Mining Sci. and Tech. Xuzhou, China. China Engineering, Science and Technology Forum. URL Networking Commission Workshop, ISRM, Montreal, Canada.
Korean Society of Civil Engineers - Springer Award – Most cited paper in *J. of KSCE*
- 2014 **President, ARMA Foundation (2014-)**
Elected Member, ARMA Board (2014-2016)
[Keynote Address] Asian Rock Mechanics Symposium, ARMS8, Sapporo, Japan
[Invited Addresses] Workshop on Unconventional THMC Processes, Chinese Academy of Sciences, Wuhan, Northeastern University (China), Harvard SEAS, ETH, Zurich, AGU.
Guest Professor, China University of Petroleum (Huadong), Qingdao, China
Visiting Professor, China University of Mining and Technology (CUMT), Xuzhou, China
Chinese Academy of Sciences – Masterclass, Wuhan.
- 2013 Co-convenor Penrose Conference on Predicting and Detecting Natural Flow Paths for Geothermal Fluids in Deep Sedimentary Basins. Park City, UT.
[Keynote Address] Penrose Conference, Park City, UT
[Invited Addresses] SPE/AAPG Regional Meeting, Chinese Academy of Sciences (Beijing & Wuhan), Tsinghua University, CUMT (Beijing and Xuzhou), JASON EGS Study, ARMA Unconventional Geomechanics Workshop, AGU.
Inaugural Rio Tinto – UWA Masterclass. University of Western Australia. 2013

- 2012 **Wilson Research Award, EMS, PSU**
 [Plenary Addresses] Water Dynamics, Tohoku, Japan; US-New Zealand Joint Geothermal Workshop, Rotorua, New Zealand
 [Invited Addresses] EnergyPath 2012, Allentown, Pennsylvania.
- 2011 [Keynote Address] GeoProc2011. Int. Conf. on Coupled Processes in GeoSystems, Perth.
ARMA Basic Research Award
Chair of Fellows, American Rock Mechanics Association
- 2010 **Fellow, Japan Society for the Promotion of Science**
ARMA Case Studies Award
 [Invited Plenary] 44th US-Canada Rock Mechanics Symposium
 [Invited Addresses] AGU (2), EGU, NRC and ~20 others.
- 2009 **Fellow, American Rock Mechanics Association**
Professor at Large, Institute of Advanced Study, University of Western Australia (2009-2012)
 [Keynote Address] Inaugural MTS Lecturer, ARMA.
 [Keynote Address] 7th Int. Conf. on Rockbursts and Seismicity in Mines, China (with J. Liu).
 [Invited Address] European Geophysical Union Meeting, Vienna.
 [Invited Address] Batsheva de Rothschild Workshop on Shear Physics, Ein Gedi, Israel.
TUBITAK Fellow, Istanbul Kultur University and Sakarya University, Turkey
- 2008 **Gledden Senior Visiting Fellow, University of Western Australia**
 [Invited Theme] 12th International Conference of IACMAG, Goa, India.
 EMS Faculty Mentoring Award
- 2007 [Invited Plenary] IODP Workshop on Geohazards.
 [Keynote Address] ISRM Workshop on Volcanic Rocks, Lisbon.
 [Invited Address] North American Symposium on Rock Mechanics, Vancouver, Canada.
- 2006 [Keynote Address] GeoProc 2006. Nanjing. China.
 [Keynote Address] R.E. Goodman Colloquium, Berkeley.
- 2005 [Keynote Address] 11th International Conference of IACMAG, Turin.
- 2004 [Keynote Address] Euro-Conference on Rock Physics and Geomechanics, Berlin.
 [Invited Plenary] DUSEL Workshop, Berkeley.
- 2003 [Keynote Address] GeoProc 2003. KTH. Stockholm. Sweden.
 [Invited Address] NSF-ARMA Workshop on Geothermal Systems, US R. Mech. Symp, MIT.
- 2002 [Keynote Address] IAVCEI Conference on Explosive Volcanism, Martinique.
- Recent Committees and Advising**
- 2016- US National Academy Committee on Geotechnical and Geological Engineering
- 2011-Pres. DOE Committee on the Potential of EGS Geothermal Energy
- 2011-2014 Mine Safety and Health Research Advisory Committee, US DHHS.
- 2002-2010 Deep Underground Science and Engineering Laboratory
- 2010-2011 DUSEL Users' Research Association (DuRA) Exec. Comm. Member.
 - 2008-2010 DUSEL Experiment Development Committee. Chair.
 - 2006 NSF-S1 Report. Co-Author.
 - 2006 Homestake Program Advisory Committee. Co-chair.
 - 2004 NSF-S1 Inaugural Workshop. Plenary Address.
 - 2003 Workshop on DUSEL, Johannesburg, SA. Convener.
 - 2002 NSF-NESS Study. Co-Author. [www.earthlab.org]
 - 2002 NSF-ARMA Study. Co-Author.
- 2001-05 Consequences of Igneous Intrusion at Yucca Mountain. NWTRB and NRC-ACNW
- 1997-98 Yucca Mountain Near Field and Altered Zone. Expert Elicitation. DOE

Recent Educational Activities

- 2017 Sustainable Energy in New Zealand
http://www.ems.psu.edu/~elsworth/courses/egee_497/egee_497.pdf
- 2015 Sustainable Energy in Scandinavia – One Region, Many Choices
www.ems.psu.edu/~elsworth/courses/cause2015/
- 2013 Energy, Environment and Society – The “Energy” New Deal – Down Under
www.ems.psu.edu/~elsworth/courses/cause2013/
- 2012+ Online courses, e.g. Fluid Mechanics: www.ems.psu.edu/~elsworth/courses/eme_303/
YouTube Channel: <https://www.youtube.com/derekelsworth>
- 2000-2007 Intra-College Graduate Programs in Geo-Environmental Engineering and in Energy and Geo-Environmental Engineering. Founding chair
- 2001 US Department of Education-funded consortium between Universities in the US, France, Italy and Portugal www.ems.psu.edu/ICEEIT/ [Co-proponent]
- 2000-03 Undergraduate research classes and travel to western US, Iceland, and UK:
- 2003 Energy and Society: Energy Choices for the New Millennium
www.ems.psu.edu/~elsworth/courses/cause2000/
- 2000 Energy and Society: Industrial Revolution to Industrial Ecology
www.ems.psu.edu/~elsworth/courses/cause2003/

Recent Papers [2015—present] [www.ems.psu.edu/~elsworth/publications/pubs.htm]

1. Fang, Y., Elsworth, D., Cladouhos, T.T. (2018) Permeability mapping using microearthquake data. *Geothermics*. Vol. 72, pp. 83-100. <http://dx.doi.org/10.1016/j.geothermics.2017.10.019>
2. Cui, G., Liu, J., Wei, M., Shi, R., Elsworth, D. (2018) Why shale permeability changes under variable effective stresses: new insights. *Fuel*. Vol. 213, pp. 55-71. <http://dx.doi.org/10.1016/j.fuel.2017.10.068>
3. Im, K.J., Elsworth, D., Marone, C., Leeman, J. (2017) The impact of frictional healing on stick-slip recurrence interval and stress drop: implications for earthquake scaling. *J. Geophys. Res.*. Vol. 122. <https://doi.org/10.1002/2017JB014476>
4. Zhang, F., Fang, Y., Elsworth, D., Wang, C., Yang, X. (2017) Evolution of friction and permeability in a propped fracture under shear. *Geofluids*. Vol. 2017, 13 pp. <https://doi.org/10.1155/2017/2063747>
5. Sang, G., Elsworth, D., Liu, S., Harpalani, S. (2017) Characterization of swelling modulus and effective stress coefficient accommodating sorption-induced swelling in coal. *Energy and Fuels*. Vol. 31, No. 9. pp 8843-8851. <http://dx.doi.org/10.1021/acs.energyfuels.7b00462>
6. White, M., Fu, P., McClure, M., Danko, G., Elsworth, D., Sonnenthal, E., Kelkar, S., Podgorney, R. (2017) A suite of benchmark and challenge problems for enhanced geothermal systems. *Geomech. Geophys. Geoenviron. Geo-resour.*. Vol. 3, No. 2. pp. 189-198. <http://dx.doi.org/10.1007/s40948-017-0076-0>
7. Wang, C., Elsworth, D., Fang, Y. (2017) Influence of weakening minerals on the ensemble strength and slip stability of faults. *J. Geophys. Res.* Vol. 122. pp 7090-7110. <http://dx.doi.org/10.1002/2016JB013687>
8. Hao, S., Yang, H., Elsworth, D. (2017) An accelerating precursor to predict “time-to-failure” in creep and volcanic eruptions. *J. Volc. Geotherm. Res.* Vol. 343. pp. 252-262. <http://dx.doi.org/10.1016/j.jvolgeores.2017.07.009>
9. Zhang, Q., Dong, Y., Liu, S., Elsworth, D., Zhao, Y. (2017) Shale pore characterization using NMR cryoporometry with octamethylcyclotetrasiloxane as the probe liquid. *Energy and Fuels*. Vol. 31, No. 7. pp 6951-6959. <http://dx.doi.org/10.1021/acs.energyfuels.7b00880>
10. Wang, J., Elsworth, D., Wu, Y., Liu, J., Zhu, W., Liu, Y. (2017) The influence of fracturing fluids on fracturing processes: a comparison between water, oil and sc-CO₂. *R. Mech. and R. Eng.* <http://dx.doi.org/10.1007/s00603-017-1326-8>

11. Zhao, Y., Xue, S., Han, S., Cheng, Z., Liu, S., Elsworth, D., He, L., Cai, J. Liu, Y., Chen, D. (2017) Effects of microstructure on water imbibition in sandstones using X-ray computed tomography and neutron radiography. *J. Geophys. Res.* Vol. 122, pp. 4963-4981. <http://dx.doi.org/10.1002/2016JB013786>
12. Ma, C., Elsworth, D., Dong, C., Lin, C., Luan, G., Chen, B., Liu, X., Muhammad, J.M., Muhammad, A.Z., Shen, Z., Tian, F. (2017) Controls of hydrocarbon generation on the development of expulsion fractures in organic-rich shale: based on the Paleogene Shahejie formation of the Jiyang depression, Bohai Bay, east China. *Marine and Petrol. Geol.* Vol. 86. pp. 1406-1416. <http://dx.doi.org/10.1016/j.marpetgeo.2017.07.035>
13. Liu, J., Yao, Y., Elsworth D., Liu, D., Cai, Y., Dong, L. (2017) Vertical heterogeneity of the shale reservoir in the Lower Silurian Longmaxi Formation: a case study of Well-WQ2 in the Northeastern Sichuan Basin, SW China. *Minerals*, Vol. 7, No. 151. <http://dx.doi.org/10.3390/min7080151>
14. Im, K.J., Elsworth, D., Guglielmi, Y., Mattioli, G. (2017) Geodetic imaging of thermal deformation in geothermal reservoirs – production, depletion and fault activation. *J. Volc. Geotherm. Res.* Vol. 338. pp. 78-91. <http://dx.doi.org/10.1016/j.jvolgeores.2017.03.021>
15. Zhang, R., Liu, S.M., Bahadur, J., Elsworth, D., Wang, Y., Hu, G.L., Liang, Y.N. (2017) Changes in pore structure of coal caused by coal-to-gas bioconversion. *Nature Scientific Reports.* Vol. 7, No. 3840. <http://dx.doi.org/10.1038/s41598-017-04110-z>
16. Li, X., Feng, Z., Han, G., Elsworth, D., Marone, C., Saffer, D., Cheon, D.S. (2017) Permeability evolution of propped artificial fractures in Green River Shale. *R. Mech. and R. Eng.* Vol. 50, No. 6. pp. 1473-1485. <http://dx.doi.org/10.1007/s00603-017-1186-2>
17. Liu, J., Yao, Y., Liu, D., Elsworth, D. (2017) Experimental evaluation of CO₂ enhanced recovery of adsorbed-gas from shale. *Int. J. Coal. Geol.* Vol. 179. pp. 211-218. <http://dx.doi.org/10.1016/j.coal.2017.06.006>
18. Liang, S., Elsworth, D., Fu, X., Li, X., Yao, Q. (2017) Influence of stratigraphic conditions on the deformation characteristics of oil/gas wells piercing longwall pillars and mining optimization. *Energies*, 10, 775.
19. Liang, S., Elsworth, D., Li, X.H., Fu, X.H., Sun, B., Yao, Q.L (2017) Key strata characteristics controlling the integrity of deep wells in longwall mining areas. *Int. J. Coal Geol.* Vol. 172, pp. 31-42. <http://dx.doi.org/10.1016/j.coal.2017.01.012>
20. Li, X., Wang, J., Elsworth, D. (2017) Stress redistribution and fracture propagation during restimulation of gas shale reservoirs. *J. Pet. Sci. and Eng.* Vol. 154, pp. 150-160. <http://doi.org/10.1016/j.petrol.2017.04.027>
21. Fang, Y., Elsworth, D., Wang, C., Ishibashi, T., Fitts, J.P. (2017) Frictional stability-permeability relationships for fractures in shales. *J. Geophys. Res.* , Vol. 122, pp. 1760-1776. <http://dx.doi.org/10.1002/2016JB013435>
22. Cai, J.C., Ghanbarian, B., Xu, P., Elsworth, D., Wang, M.R., Zhang, Z.E., Wood, D. (2017) Virtual special issue: Advanced theoretical and numerical approaches and applications to enhanced gas recovery. *J. Nat. Gas Sci. Eng.*, Vol. 37, pp. 579-583. <http://dx.doi.org/10.1016/j.jngse.2016.12.006>
23. Wang, T., Hu, W.R., Elsworth, D., Zhou, W., Zhou, W.B., Zhao, X.Y., Zhao, L.Z. (2017) The effect of natural fractures on hydraulic fracture propagation in coal seams. *J. Pet. Sci. and Eng.* Vol. 150, pp. 180-190. <http://dx.doi.org/10.1016/j.petrol.2016.12.009>
24. Fang, Y., Wang, C., Elsworth, D., Ishibashi, T. (2017) Seismicity-permeability coupling in the behaviour of gas shales, CO₂ storage and deep geothermal energy. *Geomech. Geophys Geo-energ. Geo-resour.* Vol. 3, No. 2. pp. 189-198. <http://dx.doi.org/10.1007/s40948-017-0051-9>
25. Elsworth, D., Spiers, C.J., Niemeijer, A.R. (2016) Understanding induced seismicity. *Science* 354 (6318) pp. 1380–1381. <http://dx.doi.org/10.1126/science.aal2584>
26. Tang, S., Zhan, J., Elsworth, D., Tang, X., Li, Z.M., Du, X.R., Yang, X. (2016) Lithofacies and pore characterization of the Lower Permian Shanxi and Taiyuan shales in the southern North China Basin. *J. Nat. Gas Sci. and Eng.*, Vol. 36, pp. 644-661. <http://dx.doi.org/10.1016/j.jngse.2016.11.013>

27. Liu, J. Yao, Y.B., Elsworth, D., Pan, Z.J., Sun, X.X., Ao, W.H. (2016) Sedimentary characteristics of the Lower Cambrian Niutitang shale in the southeast margin of Sichuan Basin, China. *J. Nat. Gas Sci. and Eng.*, Vol. 36, pp. 1140-1150. <http://dx.doi.org/10.1016/j.jngse.2016.03.085>
28. Ma, C.F., Dong, C.M., Luan, G.Q., Lin, CY., Liu, XC., Elsworth, D. (2016) Types, characteristics and effects of natural fluid pressure fractures in shale: a case study of the Paleogene strata in Eastern China. *Petroleum Expl. And Development*, Vol. 43, No. 4, pp. 634-643.
29. Li, X., Feng, Z., Han, G., Elsworth, D., Marone, C., Saffer, D., Cheon, D.-S. (2016) Breakdown pressure and fracture surface morphology of hydraulic fracturing in shale with H₂O, CO₂ and N₂. *Geomech. Geophys. Geo-energ. Geo-resour.*, Vol 2, pp. 63-76. <http://dx.doi.org/10.1007/s40948-016-0022-6>
30. Zhi, S., Elsworth, D. (2016) The role of gas desorption on gas outbursts in underground mining of coal. *Geomech. Geophys. Geo-energ. Geo-resour.*, Vol 2, pp. 151–171. <http://dx.doi.org/10.1007/s40948-016-0026-2>
31. Vogler, D., Amann, F., Bayer, P., Elsworth, D. (2016) Permeability evolution in natural fractures subject to cyclic loading and gouge formation. *Rock Mech. and Rock Eng.* <http://dx.doi.org/10.1007/s00603-016-1022-0>
32. Sang, G., Elsworth, D., Miao, X., Mao, X., Wang, J. (2016) Numerical study of a stress-dependent triple porosity model for shale gas reservoirs accommodating gas diffusion in kerogen. *J. Nat. Gas Sci. and Eng.*, Vol. 32, pp. 423-438. <http://dx.doi.org/10.1016/j.jngse.2016.04.044>
33. Benato, S., Hickman, S., Davatzes, N.C., Taron, J., Spielman, P., Elsworth, D., Majer, E.L., Boyle, K. (2016) Conceptual model and numerical analysis of the Desert Peak EGS project: Reservoir response to the shallow medium flow-rate hydraulic stimulation phase. *Geothermics*, Vol. 63, pp. 139 – 166. <http://dx.doi.org/10.1016/j.geothermics.2015.06.008>
34. Fang, Y., den Hartog, S.A.M., Elsworth, D., Marone, C., Cladouhos, T. (2016) Anomalous distribution of microearthquakes in the Newberry geothermal reservoir: mechanisms and implications. *Geothermics*. Vol. 63, pp. 62-73. <http://dx.doi.org/10.1016/j.geothermics.2015.04.005>
35. Gan, Q. and Elsworth, D. (2016) Production optimization in fractured geothermal reservoirs by coupled discrete fracture network modeling. *Geothermics*. Vol. 62, pp. 131-142. <http://dx.doi.org/10.1016/j.geothermics.2016.04.009>
36. Hao, S.W., Liu, C., Lu, C.S., Elsworth, D. (2016) A relation to predict the failure of materials and potential application to volcanic eruptions and landslides. *Nature Scientific Reports*. Vol. 6, Article no. 27877. <http://dx.doi.org/10.1038/srep27877>
37. Kumar, H., Elsworth, D., Mathews, J.P., Marone, C. (2016) Permeability evolution in sorbing media: analogies between organic-rich shale and coal. *Geofluids*, Vol. 16, No., 1, pp. 43-55. <http://dx.doi.org/10.1111/gfl.12135>
38. Gan, Q. and Elsworth, D. (2016) A continuum model for coupled stress and fluid flow in discrete fracture networks. *Geomech. Geophys. Geo-energ. Geo-resour.*, Vol 2, pp. 43-61. <http://dx.doi.org/10.1007/s40948-015-0020-0>
39. Wang, T., Xu, D., Elsworth, D., Zhu, W. (2016) Distinct element modelling of strength variation in jointed rock masses under uniaxial compression. *Geomech. Geophys. Geo-energ. Geo-resour.*, Vol 2, pp. 11–24. <http://dx.doi.org/10.1007/s40948-015-0018-7>
40. Sun, X, Yao, Y., Liu, D., Elsworth, D., Pan, Z. (2016) Interactions and exchange of CO₂ and H₂O in coals: an investigation by low-field NMR relaxation. *Nature Scientific Reports*. Vol. 6, Article no. 19919. <http://dx.doi.org/10.1038/srep19919>
41. Pogacnik, J., Elsworth, D., O’Sullivan, M., O’Sullivan, J. (2016) A damage mechanics approach to the simulation of hydraulic fracturing/shearing around a geothermal injection well. *Computers & Geotechnics*, Vol, 71, pp. 338-351. <http://dx.doi.org/10.1016/compgeo.2015.10.003>

42. Zhong, Z., Elsworth, D., Hu, Y. (2016) Evolution of strength and permeability in stressed fractures with fluid-rock interactions. *Pure and Applied Geophys.*, Vol. 173, No. 2, pp. 525-536. <http://dx.doi.org/10.1007/s00024-015-1099-5>
43. Zhang, R., Liu, S.M., Bahadur, J., Elsworth, D., Melnichenko, Y., He, L.L., Wang, Y. (2015) Estimation and modelling of coal pore accessibility using small angle neutron scattering. *Fuel*. Vol. 161. pp. 232-332. <http://dx.doi.org/10.1016/j.fuel.2015.08.067>
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