References

Abelin, H., Birgersson, L., Gidlund, J., Neretnieks, I., and Tunbrandt, S. (1987). Results from some tracer experiments in crystalline rocks in Sweden. *Academic Press Inc*, **28**, 363–379.

Alexander, W., Frieg, B., Ota, K., and Bossart, P. (1996). Untersuchungen der Retardation von Radionukliden im Wirtgestein. *Nagra informiert*, **27**, 43–55.

Anderberg, M. R. (1974). *Cluster analysis for applications*. Academic Press Inc., New York.

Appelo, C. A. J. and Postma, D. (1993). *Geochemistry, groundwater and pollution*. Balkema, Rotterdam, Netherlands.

Baecher, G., Lanney, N., and Einstein, H. (1977). Statistical description of rock properties and sampling. Proc. of the 18th U.S. Symposium on Rock Mechanics. 5C 1–8.

Baehr, A. and Hult, M. (1991). Evaluation of unsaturated zone air permeability through pneumatic tests. *Water Resources Research*, **27**, 2605–2617.

Baraka-Lokmane, S. (2002a). *Determination of hydraulic conductivities from discrete geometrical characterisation of fractured sandstone cores*. Tübinger Geowissenschaftliche Arbeiten (TGA) C 51, Geowissenschaftliche Fakultät der Eberhard-Karls-Universität Tübingen.

Baraka-Lokmane, S. (2002b). Technical note. A new resin impregnation technique for characterising fracture geometry in sandstone cores. *Int. J. Rock Mech. & Mining Sciences*, **39**, 815–823.

Baraka-Lokmane, S., Teutsch, G., and Main, I. G. (2001). Influence of open and sealed fractures on fluid flow and water saturation in sandstone cores using magnetic resonance imaging,. *Geophys. J. Int.*, **147**, 263–271.

Baraka-Lokmane, S., Liedl, R., and Teutsch, G. (2003). Comparison of measured and modelled hydraulic conductivities of fractured sandstone cores. *Pure & Appl. Geophys.*, **160**, 909–927.

Barenblatt, G., Zheltov, I., and Kochina, I. (1960). Basic concepts in the theory of seepage of homogeneous liquids in fissured rocks (strata). *Journal of Applied Mathematics and Mechanics*, **24**, 1286–1303.

Barker, J. (1988). A generalized radial-flow model for pumping tests in fracured rock. *Water Resources Research*, **24**(10), 1796–1804.

Barlag, C. (1997). *Adaptive Methoden zur Modellierung von Stofftransport im Kluftgestein*. (Institut für Strömungsmechanik und Elektronisches Rechnen im Bauwesen Hannover, Bericht; 52) (Zugl.: Hannover, Univ., Diss., 1997). Eigenverlag, Hannover.

Barton, N. (1973). Review of a new shear-strength criterion for rock joints. *Eng. Geol.*, **7**, 287–332.

Barton, N. K. and Choubey, V. (1977). The shear strength of rock joint in theory and practice. *Rock Mechanics*, **10**, 1–54.

Bastian, P., Chen, Z., Ewing, R., Helmig, R., Jakobs, H., and Reichenberger, V. (1999). Numerical simulation of flow in fractured porous media. In Z. Chen, R. Ewing, and Shi, editors, *Numerical treatment of multiphase flows in porous media*, Lecture notes in physics, pages 1–18. Springer-Verlag, Berlin, Heidelberg.

Bastian, P. T. (1997). UG A flexible software toolbox for solving partial differential equations. *Computing and Visualization in Science*, pages 27–40.

Bear, J.and Tsang, C. F. and de Marsily, G. (1993). *Flow and contaminant transport in fractured rock*. Academic Press Inc., San Diego, California, USA,.

Bear, J. (1972). *Dynamics of Fluids in Porous Media*. (Environmental Science Series). American Elsevier Publ. Comp., New York.

Bear, J. (1993). Modeling flow and contaminant transport in fractured rocks. chapter 1.1.: Introduction. In *Flow and Contaminant Transport in Fractured Rock / Ed. by J.Bear*, pages 1–10. Academic Press, San Diego u.a.

Bear, J. and Bachmat, Y. (1990). *Introduction to Modeling of Transport Phenomena in Porous Media*. (Theory and Applications of Transport in Porous Media; 4). Kluwer, Dordrecht u.a.

Becker, L. and Yeh, W. (1972). Identification of parameters in unsteady open channel flows. *Water Resources Research*, **8**(4), 956–965.

Bengelsdorf, K. (1997). *Fazies- und Reservoirgeologie im Stubensandstein von Pliezhausen-Rübgarten*. Diplomarbeit, Geowissenschaftliche Fakultät der Eberhard-Karls-Universität Tübingen.

Berkowitz, B. (2002). Characterizing flow and transport in fractured geological media: A review. *Advances in Water Resources*, **25**, 861–884.

Berkowitz, B., Bear, J., and Braester, C. (1988). Continuum Models for Contaminant Transport in Fractured Porous Formations. *Water Resources Research*, **24**(8), 1225–1236.

Bertin, H. and Panfiloy, M.;Quintard, M. (2000). Two types of transient phenomena and full relaxation macroscale model for single phase flow through double porosity media. *Transport Porous Media*, **39**(1), 73–96.

Beyer, W. (1964). Zur Bestimmung der Wasserdurchlässigkeit von Sanden und Kiesen. *Z. Wasserwirt.-Wassertech.*, **14**, 165–168.

Billaux, D., Chiles, J., Hestir, K., and Long, J. (1989). Three-dimensional statistical modeling of a fractured rock mass – an example from the Fanay-Augre mine. *International Journal of Rock Mechanics and Mining Sciences and Geomechanics Abstracts*, **26**, 281–299.

Birgersson, N. and Neretnieks, I. (1990). Diffusion in the matrix of granitic rock: field test in the stripa min. *Water Resources Research*, **26**(11), 2833–2842.

Birkhölzer, J. (1994a). *Numerische Untersuchungen zur Mehrkontinuumsmodellierung von Stofftransportvorgängen in Kluftgrundwasserleitern*. (Technische Hochschule Aachen / Lehrstuhl und Institut für Wasserbau und Wasserwirtschaft: Mitteilungen; 93) (Zugl.: Aachen, T.H., Diss.). Eigenverlag, Aachen.

Birkhölzer, J. (1994b). *Programmdokumentation STRAFE4: Ein 3D Finite-Elemente-Programm zur Simulation von Strömungs- und Transportvorgängen in doppelt-permeablen Medien*. (unveröffentlicht). Lehrstuhl und Institut für Wasserbau und Wasserwirtschaft der RWTH, Aachen.

Bitton, G. and Gerba, C. P. (1984). *Microbiological polluants, their survival and transport pattern to groundwater, groundwater pollution microbiology*, pages 65–88. C.P. Gerba, Eds. John Wiley & Sons, New York.

Bloomfield, J. P. and Williams, A. T. (1995). An empirical liquid permeability – gas permeability correlation for use in aquifer properties studies. *Quaterly J. Engng. Geol.*, **28**, 143–150.

Bodvarsson, G., Ho, C., and Robinson, B. (2003). Yucca mountain projekt. *J. of Contam. Hydrology*, **62–63**, Special Issue.

Böttger, M. (1989). Die nutzbaren Gesteine Baden-Württembergs - ein überblick. *Oberrhein. Geol. Abh.*, **35**, 1–4.

Bourke, P. (1987). Channeling of flow through fractures in rock. Proc. GEOVAL-87, Swe. Nuc. Power Insp., Stockholm.

Brauchler, R., Liedl, R., and Dietrich, P. (2003). A travel time-based hydraulic tomographic approach. *Water Resources Research*, **39**(12), 1370 10.1029/2003WR002262.

Brenner, S. and Gudmundsson, A. (2002). Permeability development during hydrofracture propagation in layered reservoirs. Proc. of Nordic Workshop 2001, NGU, 439.

Bronstein, I. and Semedjajew (1977). *Taschenbuch der Mathematik*. Harri Deutsch.

Brown, J. A., Lee, F., and Jackson, J. A. (1981). NMR measurements on Western Gas sand cores, spe/doe 9861. Low Permeability Symp., Denver, Colorado.

Brown, R. J. S. and Fatt, I. (1956). Measurements of fractional wettability of oil field rocks by the Nuclear Magnetic Relaxation method. *Petrol. Trans. AIME*, **207**, 262–264.

Brown, S. R. (1987). Fluid flow through rock joints: The effect of surface roughness. *J. Geophys. Res.*, **92**(B2), 1337–1347.

Brown, S. R. and Scholz, C. H. (1986). Closure of rock joints. *J. Geophys. Res.*, **91**(B5), 4939–4948.

Brusseau, M. (1991). Transport of organic chemicals by gas advection in structured or heterogeneous porous media: development of a model and application to column experiments. *Water Resources Research*, **27**, 3189–3199.

Busch, K.-F., Luckner, L., and Tiemer, K. (1993). *Lehrbuch der Hydrogeologie - Geohydraulik*. Gebrüder Borntraeger, Berlin, Stuttgart.

Butler Jr., J., McElwee, C., and Bohling, G. (1999). Pumping tests in networks of multilevel sampling wells: Motivation and methodology. *Water Resources Research*, **35**(11), 3553–3560.

Cacas, M., Ledoux, E., Marsily, G. d., and Tillie, B. (1990). Modeling fracture flow with stochastic discrete fracture network: calibration and validation. 1: The flow model. *Water Resources Research*, **26**, 479–489.

Carman, P. (1956). *Flow of gases through porous media*. Butterworths scientific publications, London.

Carter, R., Kemp, L., Pierce, A., and Williams, D. (1974). Performance matching with constraints. *Soc. Pet. Eng.*, **14**, 187–196.

Carter, R., Kemp, L., and Pierce, A. (1982). Discussion of comparision of sensitivity coefficient calculation methods in automatic history matching. *Soc. Pet. Eng.*, **22**, 205–208.

Chang, J. and Yortsos, Y. (1990). *Pressure transient analysis of fractal reservoirs*. SPE Formation Evaluation. SPE.

Chardaire, C. and Roussel, J. (1990). *Advances in core evaluation, accuracy and precision in reserves estimation*, chapter NMR imaging of fluid saturation distributions in core samples using a high magnetic field, pages 301–315. Gordon & Breach, Philadelphia, USA.

Chavent, G., Dupuy, M., and Lemmonier, P. (1975). History matching by use of optimal theory. *Society of Petroleum Engineers Journal*, **15**, 74–86.

Chen, G., Illman, W., Thompson, D., Vesselinov, V., and Neuman, S. (2000). Geostatistical, type-curve, and inverse analyses of pneumatic injection tests in unsaturated fractured tuffs at the apache leap research site near superior, arizona. In: Dynamics of Fluids in Fractured Rock. Geoph. Monograph, 122.

Chilès, J.-P. and de Marsily, G. (1993). Stochastic models of fracture systems and their use in flow and transport modeling. In J. Bear, C.-F. Tsang, and G. de Marsily, editors, *Flow and Contaminant Transport in Fractured Rock*, San Diego, California. Academic Press.

Cirpka, O. (1997). *Numerische Methoden zur Simulation des reaktiven Mehrkomponententransports im Grundwasser*. (Mitteilungen / Institut für Wasserbau, Universität Stuttgart; H. 95) (Zugl.: Stuttgart, Univ., Diss., 1997). Eigenverlag, Stuttgart.

Clement, T., Truex, M., and Hooker, B. (1997). Two-well test method for determining hydraulic properties of aquifers. *Ground Water*, **35**(4), 698–703.

Clifton, P. M. and Neumann, S. P. (1982). Effects of kriging and inverse modelling on conditional simulation of the Avra Valley aquifer in southern Arizona. *Water Resources Research*, **18**, 1215–1234.

Closmann, P. (1975). An aquifer model for fissured reservoirs. (4434). *Society of Petroleum Engineers Journal, Vol. 15, No. 5*, pages 385–398.

Cowgill, D. F., Pitman, J. K., and Seevers, D. O. (1981a). NMR and flow estimation. DOE Rep. N 810313, Tulsa.

Cowgill, D. F., Pitman, J. K., and Seevers, D. O. (1981b). NMR determination of porosity and permeability of western tight gas sands, spe/doe 9875. Low Permeability Symp., Denver, Colorado.

Cox, B. L., Pruess, K., and Persoff, P. (1990). A casting and imaging technique for determining void geometry and relative permeability behaviour of a single fracture specimen. Technical Report Int. Rep. 28485, 1–6, University of California, Berkeley, Int. Earth Sciences Division, Lawrence Berkeley Laboratory, University of California, Berkeley, USA.

Croisé, J. (1996). *Extraktion von leichtflchtigen Chemikalien aus porösen ungesättigten Zonen mittels erzwungener Luftströmung*. Ph.D. thesis, Universität Stuttgart, Germany.

Cunningham, R. and Williams, R. (1980). *Diffusion in gases and porous media*. Plenum press, New York and London.

Dagan, G. (1982). Stochastic modeling of groundwater flow by unconditional and conditional probabilities, 2, The solute transport. *Water Resources Research*, **18**, 835–848.

de Marsily, G. (1981). *Hydrogéologie quantitative*. Masson, Paris.

Dechter, J. J., Komoroski, R. A., and Ramaprasad, S. (1989). NMR chemical shift selective imaging of individual fluids in sandstone and dolomite cores. SCA Conf., paper N 8903.

Dershowitz, W. and Einstein, H. (1988). Charaterizing rock joint geometry with joint system models. *Rock Mechanics and Rock Engineering*, **21**, 21 – 51.

Desbarats, A. and Bachu, S. (1994). Geostatistical analysis of aquifer heterogeneity from the core scale to the basin scale, A case study. *Water Resources Research*, **30**(3), 673–684.

Deutsch, C. and Journel, A. (1992). *Geostatistical Software Library and User's Guide (GSLIB)*. Oxford Univ. Press, New York u.a.

Dietrich, P. (1992). *Impedanztomographie: Entwicklungeines Rechnerprogramms zur Bestimmung der Durchlässigkeitsverteilung des Untergrundes mittels hydraulischer Tomographie*. Diplomarbeit, Bergakademie Freiberg, Freiberg, Germany.

Dietrich, P. (1999). *Konzeption und Auswertung gleichstromgeoelektrischer Tracerversuche unter Verwendung von Sensitivitätskoeffizienten*. Tübinger Geowissenschaftliche Arbeiten (TGA) C 50, Geowissenschaftliche Fakultät der Eberhard-Karls-Universität Tübingen.

Dijk, P., Berkowitz, B., and Bendel, P. (1999). Investigation of flow in water-saturated rock fractures using nuclear magnetic resonance imaging (NMRI). *Water Resour. Res.*, **35**(2), 347–360.

Dines, K. and Lytle, R. (1979). Computerized geophysical tomography. *Proc. IEEE*, **67**(7), 1065–1073.

Doe, T. (2001). What do drops do? Surface wetting and network geometry effects on vadose-zone fractured flow. In: Conceptional Models of Flow and Transport in the Fractured Vadose Zone, National Research Council.

Dollinger, H., Bühler, C., and Bossart, P. (1994). Exkavationsprojekt: Epoxidharz-Imprägnations-Experimente (Excavation project: Epoxy resin impregnation experiments). Internal Report 92-24, Nagra.

Domenico, P. and Schwartz, F. (1990). *Physical and chemical hydrogeology*. John Wiley & Sons, New York, Chicester, Brisbane, Toronto, Singapore.

Dragila, M. I. and S. W. Wheatcraft, S. (2001). Free-surface films. In: Conceptional Models of Flow and Transport in the Fractured Vadose Zone, National Research Council.

Dullien, F. A. L. (1991). *Porous media: Fluid transport and pore structure*. Academic, New York, 2 edition.

Earlougher, R. (1977). Advances in well test analysis. Society of Petroleum Engineers, Dallas, Texas.

Einsele, G. and Agster, G. (1986). *Überblick zur Geologie und Morphologie des Schönbuchs*. Deutsche Forschungsgemeinschaft, Weinheim.

Essaid, H., Herkelrath, W., and Hess, K. (1993). Simulation of fluid distributions observed at a crude oil spill site incorporating hysteresis, oil entrapment, and spatial variability of hydraulic properties. *Water Resources Research*, **29**(6), 1753–1770.

Evans, D. and Nicholson, T. (1987). *Flow and Transport through Unsaturated Fractured Rock*, volume 42 of *Geophys. Monograph*. AGU, Washington D.C., 1 edition.

Evans, D., Nicholson, T., and Rasmussen, T. (2001). *Flow and Transport through Unsaturated Fractured Rock*, volume 42 of *Geophys. Monograph*. AGU, Washington D.C., 2 edition.

Everitt, R., Martin, C., and Thompson, P. (1994). An approach to the underground characterization of a disposal vault in granite. Technical Report AECL-10560, Atomic Energy of Canada Ltd., Whiteshell Laboratories, Pinawa, Manitoba, Canada.

Faybishenko, B., Witherspoon, P., and Benson, S. e. (2000). *Dynamics of Fluids in Fractured Rocks*, volume 122 of *Geophys. Monograph*. AGU, Washington D.C.

Fisher, N., Lewis, T., and Embleton, B. (1993). *Statistical analysis of spherical data*. Cambridge University Press, 2 edition.

Flint, S. and Bryant, I. e. (1993). *The Geological Modelling of Hydrocarbon Reservoirs and Outcrop Analogues*, volume 15 of *Spec. Publs.* Int. Ass. Sediment.

Flury, M. (1996). Experimental evidence of transport of pesticides through field soils – a review. *J. Env. Qual.*, **25**, 25–45.

Fondeur, C. (1964). Etude petrographique detaillee d' un gres a structure en feuillets. (a petrographic study of a sandstone with layered structure). *Revue de l'Institut Francais du Petrole*, **19**(7–8), 901–920.

Freeze, R. and Cherry, J. (1979). *Groundwater*. Prentice Hall, Englewood Cliffs, NJ.

Freig, B., Alexander, W., Dollinger, H., Buehler, C., Haag, P., Moeri, A., and Ota, K. (1998). In situ resin impregnation for investigating radionuclide retardation in fractured repository host rocks. *Journal of Contaminant Hydrology*, **35**(1–3), 115–130.

Frind, E., Sudicky, E., and Schellenberg, S. (1988). Micro-scale modelling in the study of plume evolution in heterogeneous media. In: Custodio, E. et al. (eds.), Groundwater FIow and Quality Modelling. Reidel, Dordrecht.

Fuchs, A. (1999). *Optimierte Delaunay-Triangulierungen zur Vernetzung getrimmter NURBS-Körper*. Ph.D. thesis, Universität.

Gale, J. E. (1987). Comparison of coupled fracture deformation and fluid flow models with direct measurements of fracture pore structure and stress-flow properties. Proc. 28th U.S. Symp. on Rock Mechanics.

Gallegos, D. P. and Smith, D. M. (1988). A NMR technique for the analysis of pore structure: Determination of continuous pore size distributions. *J. Colloid Interface Sci.*, **122**(1), 144–153.

Gallegos, D. P., Munn, K., Smith, D., and Stermer, D. (1987). A NMR technique for the analysis of pore structure: Application to materials with well-defined pore structure. *J. Colloid Interface Sci.*, **119**(1), 127–140.

Gentier, S. (1986). *Morphologie et comportement hydromécanique d' une fracture naturelle dans un granite sous contrainte normale*. Ph.D. thesis, Université d' Orléans, Orlans, France.

Gentier, S. and Billaux, D.and van Vliet, L. (1989). Laboratory testing of the voids of a fracture. *Rock Mech. Rock Engng.*, **22**, 149–157.

Gentier, S., Hopkins, D., and Riss, J. (2000). Role of fracture geometry in the evolution of flow paths under stress. In: Dynamics of Fluids in Fractured Rock. Geoph. Monograph, 122.

Gilbert, P. (1972). Iterative methods for three-dimensional reconstruction of an object from projections. *J. theor. Biol.*, **36**, 105–117.

Grader, A., Balzarini, M., Radaelli, F., Capasso, G., and Pellegrino, A. (2000). Fracture-matrix flow: Quantification and visualization using x-ray computerized tomography. In: Dynamics of Fluids in Fractured Rock. Geoph. Monograph, 122.

Grathwohl, P. (1998). *Diffusion in natural porous media: Contaminant Transport, Sorption/Desorption and dissolution kinetics*. Kluwer Academic Publishers.

Grimm, W.-D. (1990). *Bildatlas wichtiger Denkmalgesteine der Bundesrepublik Deutschland*. Bayerisches Landesamt für Denkmalpflege.

Gringarten, A. (1982). Flow-test evaluation of fractured reservoirs. In: T.N. Narasimhan, Recent trends in hydrogeology, GSA, Special Paper, 189.

Gudmundsson, A., Fjeldskaar, I., and Gjesdal, O. (2002). Fracture-generated permeability and groundwater yield in norway. Proc. of Nordic Workshop 2001, NGU, 439.

Gudmundsson, A., Gjesdal, O., Brenner, S., and Fjeldskaar, I. (2003). Effects of linking up of discontinuities on fracture growth and groundwater transport. *Hydrogeo. J.*, **11**, 84–99.

Gummerson, R. J., Hall, C., and Hoff, W. G. (1979). Unsaturated water flow within porous materials observed by NMR imaging. *Nature*, **281**.

GUS (1999). *Bericht der Georadar-Messungen auf dem Testfeld Pliezhausen*. GUS - Geophysikalische Untersuchungen Karlsruhe, Karlsruhe.

Güven, O., Falta, R., Molz, F., and Melville, J. (1986). A simplified analysis of two well tracer tests in stratified aquifers. *Ground Water*, **24**(1), 63–71.

Guzman, A., Geddis, A., Henrich, M., Lohrstorfer, C., and Neuman, S. (1996). Summary of air permeability data from single-hole injection tests in unsaturated fractured tuffs at the apache leap research site: Results of steady-state test interpretation. NUREG/CR-6360, U.S. Nuclear Regulatory Commission, Washington, D.C.

Gwo, J., Jardine, P., and Wilson, G. e. (1995). A multiple-pore-region concept to modeling mass transfer in subsurface media. *Journal of Hydrology*, **164**, 217–237.

Hagemann, B. (2001). *Untersuchung und Modellierung von Wasserdurchlässigkeit und Transporteigenschaften in gekläuftetem Gestein,*. Diplomarbeit, Geowissenschaftliche Fakultät der Eberhard-Karls-Universität Tübingen.

Hakami, E. (1988). *Water Flow in Single Rock Joints*. Licentiale thesis, Lulea University of Technology, Lulea Sweden.

Harter, T. and Yeh, T.-C. J. (1996). Conditional stochastic analysis of solute transport in heterogenous, variably saturated soils. *Water Resources Research*, **32**(6), 1597–1609.

Hartigan, J. A. (1975). *Clustering algorithms*. John Wiley & Sons. Inc., New York.

Hartung, J. (1995). *Lehr- und Handbuch der angewandten Statistik*. Oldenburg.

Hase, M. (2002). *Festgesteins-Aquiferanalog: Charakterisierung eines diskreten Modells und Entwicklung eines neuen Ansatzes der Mehrkontinuum Modellierung*. (Dipl.-Arbeit) (unveröffentlicht). Lehrstuhl und Institut für Wasserbau und Wasserwirtschaft der RWTH, Aachen.

Headley, L. C. (1973). NMR relaxation of ^{7}Li and ^{1}H in appalachian petroleum reservoir rocks containing licl solutions. *Nature Physical Science*, **242**, 87–88.

Helmig, R. (1993). *Theorie und Numerik der Mehrphasenströmung in geklüftet-porösen Medien*. (Institut für Strömungsmechanik und Elektronisches Rechnen im Bauwesen Hannover, Bericht; 34) (Zugl.: Hannover, Univ., Diss., 1993). Eigenverlag, Hannover.

Helmig, R. (1997). *Multiphase Flow and Transport Processes in the Subsurface*. Springer-Verlag, Heidelberg.

Helmig, R., Class, H., Huber, R., Sheta, H., Ewing, R., Hinkelmann, R., Jakobs, H., and Bastian, P. (1998). Architecture of the modular program system MUFTE UG for simulating multiphase flow and transport processes in heterogeneous porous media. *Mathematische Geologie*, **2**.

Hemminger, A., Neunhäuserer, L., Bardossy, A., and Helmig, R. (1998). Identification of equivalent parameters on different scales in fractured–porous media . In K. Holz, W. Bechteler, S. Wang, and M. Kawahara, editors, *Advances in Hydro–Science and –Engineering*, volume 3, page 205. 3rd International Conference on Hydroscience and Engineering, BTU Cottbus, Germany, Center for Computational Hydroscience and Engineering, The University of Mississippi. cdrom.

Himmelsbach, T. (1993). *Untersuchungen zum Wasser- und Stofftransportverhalten von Störungszonen im Grundgebirge Albtalgranit, Sdschwarzwald)*. Ph.D. thesis, Schr. Angew. Geol. Karlsruhe, 23.

Hinedi, Z., Chang, A., Anderson, M., and Borchardt, D. (1997). Quantification of microporosity by nuclear magnetic resonance relaxation of water imbibed in porous media. *Water Resour. Res.*, **33**(12), 2697–2704.

Hirsch, C. (1984). *Numerical computation of internal and external flows*, volume 2: Computational methods for inviscid and viscous flows. John Wiley & Sons Ltd., Chichester, England.

Hofmann, U., Schaller, D., Kottenhan, H., Dammler, I., and Morcos, S. (1976). Die adsorption von methylenblau an kaolin, ton und bentonit. *Giesserei*, **54**(1), 97–101.

Hölting, B. (1980). *Hydrogeologie: Einführung in die allgemeine und angewandte Hydrogeologie*. Enke, Stuttgart.

Hornung, J. (1998). *Dynamische Stratigraphie, Reservoir- und Aquifersedimentologie einer alluvialen Ebene: Der Stubensandstein in Baden-Württemberg*. Tübinger Geowissenschaftliche Arbeiten (TGA), Geowissenschaftliche Fakultät der Eberhard-Karls-Universität Tübingen.

Hornung, J. and Aigner, T. (1999). Reservoir and aquifer characterization of fluvial architectural elements: Stubensandstein, upper triassic, southwest germany. *Sedimentary Geology*, **129**, 215–280.

Horsfield, M. A., Fordham, E. J., Hall, C., and Hall, D. (1989). ^{1}H NMR imaging studies of filtration in colloidal suspensions. *J. Magnetic Resonance*, **81**, 593–596.

Hötzl, H., Bäumle, R., Thüringer, C., and Witthüser, K. (2000). Festgesteins–Aquiferanalog: Experimente und Modellierung, Teilprojekt 1: Feldexperimente zur Wasser– und Stoffausbreitung in Abhängigkeit von Kluft– und Gesteinsdurchlässigkeit . Technical report, Lehrstuhl für Angewandte Geologie , Universität Karlsruhe.

Hsieh, P. (2000). A brief survey of hydraulic tests in fractured rocks. In: Dynamics of Fluids in Fractured Rock. Geoph. Monograph, 122.

Huang, K., Tsang, Y., and Bodvardson, G. (1999). Simultaneous inversion of air-injection tests in fractured unsaturated tuff at Yucca Mountain. *Water Resources Research*, **35**(8), 2375–2386.

Huggenberger, P. and Aigner, T. (1999). Introduction to the special issue on aquifer-sedimentology: problems, perspectives and modern approaches. *Sed. Geol.*, **129**, 179–186.

Huggenberger, P., Siegenthaler, C., and Aigner, T. (1997). Quaternary fluvial sedimentation in northern Switzerland and southern Germany: an integrated approach of sedimentological analysis and ultra-high resolution geophysical techniques. *Gaea Heidelbergensis*, **4**, 141–157.

ICDD (1980). *Mineral Powder Diffraction File: Data Book*. Joint Committee on Powder Diffraction Standards, Swarthmore.

Illman, W., Thompson, D., Vesselinov, V., G., C., and Neuman, S. (1998). Single- and cross-hole pneumatic tests in unsaturated fractured tuffs at the apache leap research site: Phenomenology, spatial variabiity, connectivity and scale. NUREG/CR-5559, U.S. Nuclear Regulatory Commission, Wachington, D.C.

Jackson, M. and Tweeton, D. (1996). 3DTOM: Three-dimensional geophysical tomography. Report of Investigation 9617, United States Department of the Interior, Bureau of Mines.

Jacquard, P. (1964). Théorie de linterprétation des mesures de pression. *Revue IFP*, **Vol. XIX**, 297–338.

Jacquard, P. and Jain, C. (1965). Permeability distribution from field pressure data. *Society of Petroleum Engineers Journal*, **5**, 281–294.

Jakobs, H. (2004). *Simulation nicht-isothermer Gas-Wasser-Prozesse in komplexen Kluft-Matrix-Systemen*. Ph.D. thesis, Institut für Wasserbau, Universität Stuttgart. To be published.

Jansen, D. (1999). *Identifikation des Mehrkontinuum-Modells zur Simulation des Stofftransportes in multiporösen Festgesteinsaquiferen*. (Technische Hochschule Aachen / Lehrstuhl und Institut für Wasserbau und Wasserwirtschaft: Mitteilungen; 118) (Zugl.: Aachen, T.H., Diss.). Eigenverlag, Aachen.

Jansen, D., Birkhölzer, J., and Köngeter, J. (1996). Contaminant transport in fractured porous formations with strongly heterogeneous matrix properties. In *Rock Mechanics: Tools and Techniques; Proceedings of the 2nd North American Rock Mechanics Symposium, NARMS '96, A Regional Conference of ISRM, Montral, Qubec, Canada, 19–21 June 1996 / Ed. by M. Aubertin [et al.]*, pages 1421–1428. Balkema, Rotterdam u.a.

Jansen, D., Forkel, C., Lagendijk, V., and Köngeter, J. (1998). Evaluating the capability of scale dependent multi-continuum modeling in fractured permeable formations based on field, laboratory and numerical experiments. In *Computational Methods in Water Resources XII : Twelth International Conference held in Crete, Greece, June 1998 / Ed. by V. N. Burganos. Vol 2.: Computational Methods in Surface and Ground Water Transport*, pages 93–100. Computational Mechanics Publ., Southampton u.a.

Jaritz, R. (1999). *Quantifizierung der Heterogenität einer Sandsteinmatrix am Beispiel des Stubensandsteins*. Tübinger Geowissenschaftliche Arbeiten (TGA) C 48, Geowissenschaftliche Fakultät der Eberhard-Karls-Universität Tübingen.

Jasmund, K. and Lagaly, G. (1993). *Tone und Tonminerale*. Steinkopff Verlag, Darmstadt.

Jöreskog, K. G., Klovan, J. E., and Reyment, R. A. (1976). *Geological Factor Analysis*. Elsevier, Amsterdam.

Jury, W. and Wang, Z. (2000). Unresolved problems in vadose zone hydrology and contaminant transport. In: Dynamics of Fluids in Fractured Rock. Geoph. Monograph, 122.

Kaiser, H. F. (1958). The varimax criterion for analytical rotation in factor analysis. *Psychometrika*, **35**, 187–200.

Karasaki, K., Long, J., and Witherspoon, P. (1988). Analytical models of slug tests. *Water Resources Research*, **24**, 115–126.

Karasaki, K., Freifeld, B., Cohen, A., Grossenbacher, K., Cook, P., and Vasco, D. (2000). A mulitidisciplinary fractured rock characterization study at Raymond field site, Raymond, CA. *Journal of Hydrology*, **236**, 17–34.

Kazemi, H. (1969). Pressure transient analysis of naturally fractured reservoirs with uniform fracture distribution. *Society of Petroleum Engineers Journal, December*, pages 451–462.

Kelley, V., Pickens, J., Reeves, M., and Beauheim, R. (1987). Double-porosity tracer-test analysis for interpretation of the fracture characteristics of a dolomite formation. Proc. Solving Ground Water Problems with models, Denver, Colorado.

Kendorski, F. and Bindokas, A. (1987). Fracture geometry characterisation for use in rock mechanics. Proc. of 28th US Sympos. Rock Mechanics/Tucson.

Kenyon, W. E., Day, P. I., Straley, C., and Willemsen, J. F. (1986). Compact and consistent representation of rock NMR data for permeability estimation, spe 15643. 61st Annual Technical Conf. and Exhibition of the SPE, New Orleans.

Kenyon, W. E., Howard, J. J., Sezginer, A.and Straley, C., Matteson, A., and Horkowitz, K.and Ehrlich, R. (1989). Pore-size distribution and NMR in microporous cherty sandstones. SPWLA Annual Logging Symp.

Kilbury, R., Rasmussen, T., Evans, D., and Warrick, A. (1986). Water and air intake to surface exposed rock fracture in situ. *Water Resources Research*, **22**, 1431–1443.

Kinzelbach, W. (1992). *Numerische Methoden zur Modellierung des Transports von Schadstoffen im Grundwasser*. R. Oldenburg Verlag, München Wien. 2. Auflage.

Kiraly, L. (1969). Statistical analysis of fractures (orientation and density). *Geol. Rundschau*, **59**.

Kleineidam, S., Rügner, H., and Grathwohl, P. (1999). Influence of petrographic composition/organic matter distribution of fluvial aquifer sediments on the sorption of hydrophobic contaminants. *Sed. Geol.*, **129**, 311–325.

Klingbeil, R., Kleineidam, S., Asprion, U., Aigner, T., and Teutsch, G. (1999). Relating lithofacies to hydrofacies: outcrop-based hydrological characterisation of Quaternary gravel deposits. *Sed. Geol.*, **129**, 299–310.

Klinkenberg, L. J. (1941). The permeability of porous media to liquids and gases. *Drill. Prod. Pract.*, pages 200–213.

Kolditz, O. (1997). *Strömung, Stoff– und Wärmetransport im Kluftgestein*. Gebr. Borntraeger, Berlin-Stuttgart.

Kozlov, G. A. and Ivanchuk, A. P. (1982). NMR study of the distribution of a liquid in a porous medium. *Kolloidnyi Zhurnal*, **44**(3), 574–577.

Krasny, J. (2002). Quantitative hardrock hydrogeology in a regional scale. Proc. of Nordic Workshop 2001, NGU, 439.

Krasny, J. and Mls, J. e. (1996). First workshop on "Hardrock hydrogeology of the Bohemian Massif", 1994. *Acta Universitatis Carolinae Geologica*, **40**(2), 115–122.

Kravaris, C. and Seinfeld, J. (1985). Identification of parameters in distributed parameter systems by regularization. *SIAM J. Control and Optimization*, **23**, 217–241.

Kröhn, K. (1991). *Simulation von Transportvorgängen im klüftigen Gestein mit der Methode der Finite Elemente*. (Institut für Strömungsmechanik und Elektronisches Rechnen im Bauwesen Hannover, Bericht; 29) (Zugl.: Hannover, Univ., Diss., 1990). Eigenverlag, Hannover.

Kruseman, G. and de Ridder, N. (1994). Analysis and evaluation of pumping test data. . ILRI publication, 47, Wageningen.

Kulatilake, P., Wathugala, D., and Stephansson, O. (1993). Joint network modelling with a validation exercise in stripa mine, sweden. *International Journal of Rock Mechanics and Mining Sciences*, **30**, 503–526.

Kulkarni, K., Datta-Gupta, A., and Vasco, D. (2000). A streamline approach to integrating transient pressure data into high resolution reservoir models,. Proceedings of the SPE European Petroleum Conference, Paris.

Kulke, H. (1967). *Petrographie und Diagenese des Stubensandsteins (mittlerer Keuper) aus Tiefbohrungen im Raum Memmingen*. Ph.D. thesis, Universität Tübingen.

Kumar, J., Fatt, I., and Saraf, D. N. (1969). Nuclear magnetic relaxation time of water in a porous medium with heterogeneous surface wettability. *J. Appl. Phys.*, **40**(10), 4165–4171.

Kundt, A. and Warburg, E. (1875). Über Reibung und Wärmeleitung verdünnter Gase (On friction and heat conduction of diluted gases). *Ann. Phys.*, **155**, 337–525.

La Pointe, P. (2000). Predicting hydrology of fractured rock masses from geology. In: Dynamics of Fluids in Fractured Rock. Geoph. Monograph, 122.

La Pointe, P. and Hudson, J. (1985). Characterization and Interpretation of Rock Mass Joint Patterns. Special paper 199, Geological Society of America.

Lagendijk, V. (1997). *Mehrkontinuum-Modellierung: Erstellung eines Modells zur Simulation der ungesttigten Strmung in doppelt-permeablen Grundwassersystemen*. (Dipl.-Arbeit) (unveröffentlicht). Lehrstuhl und Institut fr Wasserbau und Wasserwirtschaft der RWTH, Aachen.

Lagendijk, V. (2003). *Stofftransportvorgänge in Festgesteinsaquiferen: Analyse von Tracerdurchbruchskurven zur Identifikation eines geeigneten Mehrkontinuum-Ansatzes*. Electr. Ph.D. thesis. Lehrstuhl und Institut für Wasserbau und Wasserwirtschaft der RWTH, Aachen.

Lebbe, L., Tarhouni, J., Van, H., and De, B. (1995). Results of an artificial recharge test and a double pumping test as preliminary studies for optimizing water supply in the western Belgian coastal plain. *Hydrogeology Journal*, **3**(3), 53–63.

Lee, B. and Tan, T. (1987). Application of a multiple porosity/permeability simulator in fractured reservoir simulation. (SPE 16009). In *SPE Ninth Symposium on Reservoir Simulation held in San Antonio, Texas, February 1-4 1987*, pages 181–192. Society of Petroleum Engineers, Richardson.

Lenda, A. and Zuber, A. (1970). Tracer dispersion in groundwater experiments. *Isotope techniques in groundwater hydrology*, **2**, 619–641.

Leven, C. (2002). *Effects of Heterogeneous Parameter Distributions on Hydraulic Test - Analysis and Assessment*. Tübinger Geowissenschaftliche Arbeiten (TGA) C 65, Geowissenschaftliche Fakultät der Eberhard-Karls-Universität Tübingen.

Leven, C., McDermott, C. I., Baraka-Lokmane, S., Sauter, M.and Liedl, R., and Teutsch, G. (2000). Festgesteins-Aquiferanalog: Experimente und Modellierung – Laborexperimente und Entwicklung neuer Untersuchungsmethoden,. 3. Workshop Kluftaquifere – Gekoppelte Prozesse, Institut fr Strömungsmechanik im Internationalen Zentrum für Computergestützte Ingenieurwissenschaften (ICCES) der Universität Hannover.

Lever, D., Bradbury, M., and Hemingway, S. (1985). The effect of dead-end porosity on rock matrix-diffusion. *J. Hydrol.*, **80**, 45–76.

Long, J. (1983). *Investihation of equivalent porous medium permeability in networks of discontinuous fractures*. Ph.D. thesis, Berkeley.

Long, J. and Billaux, D. (1987). From field data to fracture network modeling: An example incorporating spatial structure. *Water Resources Research*, **23**(7), 1201–1216.

Long, J. and Billaux, D. (1987). From field data to fracture network modeling: An example incorporatingspatial structure. *Water Resources Research*, **23**(7), 1201–1216.

Long, J. and Witherspoon, P. (1985). The relationship of interconnection to permeability in fracture networks. *Journal of Geophysical Research*, **90**, 3087–3098.

Long, J., Remer, J., and Wilson, C. e. (1982). Porous media equivalents for networks of discontinuous fractures. *Water Resources Research*, **18**(3), 645–658.

Lovelock, P. E. R. (1977). Aquifer properties of Permo-Triassic sandstones in the United Kingdom. *Bull. Geol. Survey of Great Britain*, **56**, 1–40.

Lowry, T., Allen, M., and Shive, P. (1989). Singularity removal: A refinement of resistivity modeling techniques. *Geophysics*, **54**(6), 766–774.

Luckner, L. and Schestakow, W. (1986). *Migrationsprozesse im Boden- und Grundwasserbereich*. Verlag für Grundstoffindustrie, Leipzig.

Lunn, R. and Mackay, R. (1996). Geostatistical Analysis of Fractured Rock Characteristics. In A. Soares, J. Gomez-Hernandez, and R. Froidevaux, editors, *geoENV I – Geostatistics for Environmental Applications*, Proceedings of the Geostatistics for Environmental Applications Workshop, Lisabon, Portugal, 18.–19. November 1996. Kluwer Academic Publisher.

Majer, E., Myer, L., Peterson, J., Karasaki, K., Long, J., Martel, S., Blumling, P., and Vomvoris, S. (1990). Joint seismic, hydrogeological and geomechanical investigations of a fracture zone in the grimsel rock laboratory, switzerland. Technical Report NAGRA TR 90–94, Swiss National Cooperative for Radioactive Waste Disposal (NAGRA), Wettingen, Switzerland.

Malmgrem, B. A. and Haq, B. U. (1982). Assessment of quantitatives techniques in paleobiogeography. *Marine Micropaleontology*, **7**, 213–236.

Maloszewski, P. and Zuber, A. (1990). Mathematical modeling of tracer bahavior in short-term experiments in fissured rocks. *Water Resources Research*, **26**(7), 1517–1528.

Matthess, G. and Ubell, K. (1983). *Lehrbuch der Hydrogeologie*. Gebrüder Borntraeger, Berlin, Stuttgart.

Matthews, C. and Russel, D. (1967). Pressure build-up and flow tests in wells. Society of Petroleum Engineers, Dallas, Texas.

McDermott, C. (1999). *New Experimental and Modelling Techniques to Investigate the Fractured Porous System*. Tübinger Geowissenschaftliche Arbeiten (TGA) C 52, Geowissenschaftliche Fakultät der Eberhard-Karls-Universität Tübingen.

McDermott, C., Sauter, M., and Liedl, R. (1998). Investigating fractured-porous systems - The aquifer analogue approach. In Rossmanith, editor, *Mechanics of Jointed and Faulted Rock, Balkema, Rotterdam*, pages 607–612.

McDermott, C., Sauter, M., and Liedl, R. (2003a). New experimental techniques for pneumatic tomographical determination of the flow and transport parameters of highly fractured porous rock samples. *Journal of Hydrology*, **278**(1-4), 51–63.

McDermott, C., Sinclair, B., and Sauter, M. (2003b). Recovery of undisturbed highly fractured bench scale samples (diameter 30cm x 35cm) for laboratory investigation. *Engineering Geology*, **69**(122), 161–170.

McQueen, J. (1967). Some methods for classification and analysis of multivariate observations. *5th Berkeley Symposium on Mathematics, Statistics and Probalility*, **1**, 281–298.

Meier, D. and Kronberg, P. (1989). *Klüftung in Sedimentgesteinen*. Enke Verlag, Stuttgart.

Meng, S. X. and Maynard, J. B. (2001). Use of statistical analysis to formulate conceptual models of geochemical behavior: Water chemical data from the Botucatu aquifer in Sao Paulo state, Brazil. *Journal of Hydrology*, **250**, 78–79.

Mertz, J. P. (1991). Structures de porosité et propriétés de transport dans les grs.

Miall, A. (1985). Architectural element analysis: a new method of facies analysis applied to fluvial deposits. *Earth Sci. Rev.*, **22**, 261–308.

Militzer, H., Schön, J., and Stötzner, U. (1986). *Angewandte Geophysik im Ingenieur- und Bergbau*. Deutscher Verlag für Grundstoffindustrie, Leipzig.

Miller, S., McWilliams, P., and Kerkering, J. (1990). Ambiguities in estimating fractal dimensions of rock fracture. Proc. of 31. Symp. Rock Mech., Golden, CO, Balkema, Rotterdam.

Moench, A. and Ogata, A. (1981). A numerical inversion of the Laplace transform solution to radial dispersion in a porous medium. *Water Resources Research*, **17**(1), 250–252.

Molz, F., Güven, O., Melville, R., Crocker, R., and Matteson, K. (1986). Performance, analysis, and simulation of a two well tracer test at the Mobile site. *Water Resources Research*, **22**(7), 1031–1037.

Moreno, L., Neretnieks, I., and Eriksen, T. (1985). Analysis of some laboratory tracer runs in natural fissures. *Water Resources Research*, **21**, 951–958.

Morin, R., Hess, A., and Paillet, F. (1988). Determining the distribution of hydraulic conductivity in a fractured limestone aquifer by simultaneous injection and geophysical logging. *Ground Water*, **26**, 587–595.

Moyne, C. (1997). Two-equation model for a diffusive process in porous media using the volume averaging method with an unsteady-state closure. *Advances in Water Resources*, **20**(2-3), 63–76.

Müller, T. (1997). Teil B: Bestimmung der Gesteins- und Kluftgeometrie eines Stubensandsteinhorizontes. Diplomarbeit, Geologisches Institut, Lehrstuhl für Angewandte Geologie, Universität Karlsruhe (TH).

Murawski, H. (1998). *Geologisches Wörterbuch*. dtv, Ferdinand Enke Verlag, Stuttgart, 10 edition.

Naceur, B. and Economides, M. (1988). Production from naturally fissured reservoirs intercepted by a vertical hydraulic fracture. Proc. - Society of Petroleum Engineers of AIME. California Regional Meeting.

Narr, W. and Suppe, J. (1991). Joint spacing in sedimentary rocks. *J. Struct. Geol.*, **13**, 1037–1048.

Neretnieks, I. (1985). Transport in fractured rocks. *Mem. Int. Assoc. Hydrogeol.*, **17**, 301–318.

Neretnieks, I., Abelin, H., and Birgersson, L. (1987). Some recent observations of channeling in fractured rocks – its potential impact on radionuclide migration. Proc. of Geostat. Sens. Uncert. Methods Groundwater Flow and Rad. Transport Modelling, Battelle Press.

Neuman, S. and Federico, V. d. (2003). Multifaceted nature of hydrogeologic scaling and its interpretation. *Reviews of Geophysics*, **41**(3), DOI 10.1029/2003RG000130.

Neunhäuserer, L. (2003). *Diskretisierungsansätze zur Modellierung von Strömungs- und Transportprozessen in geklüftet-porösen Medien*. Ph.D. thesis, Institut für Wasserbau, Universität Stuttgart.

Novakowski, K. and Lapcevic, P. (1994). Field measurement of radial solute transport in fractured rock. *Water Resources Research*, **30**, 37–44.

NRC (1996). *National Research Council: Rock Fractures ans Fluid Flow - Contemporary Understanding and Applications*. National Academy Press, Washington D.C.

NRC (2001). *National Research Council: Conceptual Models of Flow and Transport in the Fractured Vadose Zone*. National Academy Press, Washington D.C.

Ochs, S., Hinkelmann, R., Neunh"auserer, L., Suess, M., Helmig, R., Gebauer, S., and Kornhuber, R. (2002). Adaptive methods for the equidimensional modelling of flow and transport processes in fractured aquifers. In *5th International Conference on Hydro-Science & -Engineering*, Warsaw, Poland.

Odling, N. (1995). The development of network properties in natural fracture patterns: An example from the Devonian sandstones of western Norway. In L. Myer, C. Tsang, N. Cook, and R. Goodman, editors, *Fractured and jointed rock masses*, Proceedings of the conference on fractured and jointed rock masses, Lake Tahoe / California / USA / 3–5 June 1992. A.A. Balkema / Rotterdam / Brookfield.

Olofsson, B. (2002). Estimating groundwater resources in hardrock areas – a water balance approach. Proc. of Nordic Workshop 2001, NGU, 439.

Olsson, O. e. ((1992)). Site characterization and validation - final report: Stripa project. Technical Report TR 92–22, Swedish Nuclear Fuel and Waste Management Co., Stockholm.

Ostensen, R. (1998). Tracer test and contaminant transport rates in dual-porosity formations with application to the wipp. *Journal of Hydrology*, **204**(1–4), 197–216.

Paillet, F., Hess, A., Cheng, C., and Hardin, E. (1987). Characterisation of fracture permeability with high resolution vertical flow measurements during borehole pumping. *Ground Water*, **25**, 28–40.

Peters, R. and Klavetter, E. (1988). A continuum model for water movement in an unsaturated fractured rock mass. *Water Resources Research*, **24**, 416–430.

Plummer, C., McGeary, D., and Carlson, D. (2002). *Physical Geology*. McGraw-Hill Science/Engineering/Math, Sacramento.

Pointe, P. and Hudson, J. (1985). *Characterization and interpretation of rock mass joint patterns*, volume 199. Geological Society of America, Wisconsin.

Pollard, D. and Aydin, A. (1988). Progress in understanding jointing over the past century. *Geol. Soc. Am. Bull.*, **100**, 1181–1204.

Pollock, D. (1988). Semianalytical computation of path lines for finite-difference models. *Ground Water*, **26**(6), 743–750.

Press, W. e., Teukolsky, S., Vetterling, W., and Flannery, B. (1996). *Numerical recipes in Fortran 90: The art of parallel scientific computing*. Cambridge University Press, Cambridge.

Priest, S. and Hudson, J. (1976). Discontinuity spacings in rock. *Int. Journal of Rock Mechanics and Mining Sciences*, **18**, 135–148.

Priest, S. e. (1993). *Discontinuity Analysis for Rock Engineering*. Chapman & Hall, London.

Pruess, K. (1999). A mechanistic model for water seepage through thick unsaturated zones in fractured rocks of low matix permeability. *Water Resources Research*, **35**, 1039–1051.

Pruess, K. and Karasaki, K. (1982). Proximity functions for modeling fluid and heat flow in reservoirs with stochastic fracture distributions. In *Proceedings of the Eighth Workshop on Geothermal Reservoir Engineering, held at Stanford, California, December 14–16, 1982*, volume 8 of *Workshop on Geothermal Reservoir Engineering*, pages 219–224. Univ., Stanford, CA.

Pruess, K. and Narasimhan, T. (1985). A practical method for modeling fluid and heat flow in fractured porous media. *Society of Petroleum Engineers Journal*, **25**(1), 14–26.

Pyrak-Nolte, L. J., Myer, L. R. O., Cook, N. G. W., and Witherspoon, P. A. (1987). Hydraulic and mechanical properties of natural fractures in low permeability rock. Proc. 6th Int. Congr. on Rock Mechanics, Montreal, Canada.

Quintard, M. and Whitaker, S. (1996). Transport in chemically and mechanically heterogeneous porous media ii: Theoretical development of region-averaged equations for slightly compressible single-phase flow. *Advances in Water Resources Research*, **10**(1), 29–47.

Rasmussen, T., Evans, D., Sheets, P., and Blanford, J. (1993). Permeability of Apache Leap Tuff: Borehole and core measurements using water and air. *Water Resources Research*, **29**, 1997–2006.

Rats, M. and Chernyashov, S. (1967). Statistical aspects of the problem on the permeability of the jointy rocks. In *Hydrologie des roches fissurées: Hydrology of Fractured Rocks. Dubrovnik Symposium 1965. Organis par l'Unesco. Vol. 1*, (International Association of Scientific Hydrology; 73), pages 227–236. Unesco, Paris.

Raven, K. and Gale, J. (1985). Water flow in a natural rock fracture as a function of stress and sample size. *Int. J. Rock Mech. Min. Sci. & Geomech. Abstr.*, **22**, 251–261.

Rawnsley, K., Rives, T., Petit, J.-P., Hencher, S., and Lumsden, A. (1992). Joint development in perturbed stress fields near faults. *J. Struct. Geol.*, **14**, 939–951.

Reichenberger, V. (2003). *Multiphase flow in fractured porous media*. Ph.D. thesis, Interdisziplinäres Zentrum für Wissenschaftliches Rechnen, Universität Heidelberg.

Reid, R., Prausnitz, J., and Poling, B. (1987). *The properties of gases and liquids*. McGrawHill.

Rives, T., Razack, M., Petit, J.-P., and Rawnsley, K. (1992). Joint spacing: analogue and numerical simulations. *J. Struct. Geol.*, **14**, 925–937.

Rohr-Torp, E. and Roberts, D. (2002). Hardrock hydrogeology - proceedings of a nordic workshop. Oslo August 2001, NGU, 439.

Romm, E. (1966). *Flow characteristics of fractured rocks (in Russian)*. Nedra, Moscow.

Rutqvist, J. and Stephansson, O. (2003). The role of hydromechanical coupling in fractured rock engineering. *Hydrogeo. J.*, **11**, 7–40.

Ryan, T., Farmer, I., and Kimbrell, A. (1987). Laboratory determination of fracture permeability. Proc. of 28th Symp. Rock Mech., Tucson, AZ.

Sachs, L. (1997). *Angewandte Statistik*. Springer-Verlag, Berlin, 8 edition.

Sahimi, M. (1995). *Flow and transport in porous fractured media and fractured rock: From classical methods to modern approaches*. VHC Verlagsgesellschaft, Weinheim.

Sampath, K. and Keighin, C. W. (1982). Factors affecting gas slippage in tight sandstones of Cretaceous age in the Uinta Basin. *J. Petrol. Technol*, pages 2715–2720.

Saraf, D. N. and Fatt, I. (1966). *Measurement of fluid saturations by Nuclear Magnetic Resonance and its application to three-phase relative permeability studies*. Phd dissertation, Univ. of California, Berkeley.

Saraf, D. N. and Fatt, I. (1967). Three-phase relative permeability measurement using a Nuclear Magnetic Resonance technique for estimating fluid saturation. *Soc. Petrol. Eng. J.*, **7**, 235–242.

Schachtschabel, P., Blume, H.-P., Brümmer, G., Hartge, K.-H., and Schwertmann, U. (1992). *Lehrbuch der Bodenkunde*. Enke, Stuttgart.

Schad, H. and Teutsch, G. (1994). Effects of the investigation scale on pumping test results in heterogeneous porous aquifers. *Journal of Hydrology*, **159**, 61–77.

Schafmeister, M. (1999). *Geostatistik für die hydrogeologische Praxis*. Springer.

Scheidegger, A. (1961). General theory of dispersion in porous media. *Journal of Geophysical Research*, **66**(10), 3273–3278.

Schrauf, T. and Evans, D. (1986). Laboratory Studies of Gas Flow Through a Single Natural Fracture. *Water Resources Research*, **22**(7), 1038–1050.

Schwarzenbach, R., Gschwend, P. M., and Imboden, D. M. (1993). *Environmental organic chemistry*. John Wiley & Sons, New York.

Seevers, D. O. (1966). A nuclear magnetic method for determining the permeability of sandstones. Trans. 7th Ann. SPWLA Logging Symp., Tulsa, Oklahoma, USA.

Silberhorn-Hemminger, A. (2002). *Modellierung von Kluftaquifersystemen: Geostatistische Analyse und deterministisch-stochastische Kluftgenerierung*. (Mitteilungen / Institut für Wasserbau, Universität Stuttgart; H. 114) (Zugl.: Stuttgart, Univ., Diss., 2002). Eigenverlag, Stuttgart.

Silliman, S. E. (1989). An interpretation of difference between aperture estimates derived from hydraulic and tracer tests in a single fracture. *Water resour. res.*, **25**(10), 2275–2283.

Skagius, K. and Neretnieks, I. (1986). Porosities and diffusivities of some nonsorbing species in crystalline rocks. *Water Resources Research*, **22**, 389–398.

Snow, D. (1965). *A parallel plate model of fractured permeable media*. Ph.D. thesis, Univ. of California, Berkeley.

Snow, D. (1969). Anisotropic permeability of fractured media. *Water Resources Research*, **5**(6), 1273–1289.

Snow, D. T. (1968). Hydraulic character of fractured metamorphic rocks of the Front Range and implications to the Rocky Mountains Arsenal well. *Colo. Sch. Mines*, **63**(1), 201–244.

Streltsova, T. (1988). *Well testing in heterogeneous formations*. Exxon monographs, John Wiley & Sons,.

Sun, N. (1994). *Inverse problems in groundwater modeling*. Kluwer Acad. Publ., Dordrecht.

Sundaram, P., Watkins, D., and Ralph, W. (1987). Laboratory investigations of coupled stress-deformation-hydraulic flow in a natural rock fracture. Proc. of 28th Symp. Rock Mech., Tucson, AZ.

Süß, M. (2004). *Analysis of the influence of structures and boundaries on flow and transport processes in fractured forous media (preliminary title)*. Ph.D. thesis, Universität Stuttgart, Germany. To be published.

Tang, D., Frind, E., and Sudicky, E. (1981). Contaminant transport in fractured porous media: Analytical solution for a single fracture. *Water Resources Research*, **17**(3), 555–564.

Tang, D., Frind, E., and Sudicky, E. (1981). Contaminant transport in fractured porous media: Analytical solution for a single fracture. *Water Resources Research*, **17**(3), 555–564.

Terzaghi, R. (1965). Sources of error in joint surveys. *Geotechnique*, **15**(3), 287–304.

Teutsch, G. and Sauter, M. (1992). Groundwater modeling in karst terranes: Scale effects, data aquisition and field validation. In *Proceedings of the Third International Conference on Hydrogeology, Ecology, Monitoring and Management of Groundwater in Karst Terranes, December 4–6, 1991 Nashville, USA*, volume 10 of *Ground Water Management*, pages 17–35. Water Well Journal Publishing, Dublin, Ohio.

Theis, C. (1935). The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage. *Transactions, American Geophysical Union*, **16**, 519–524.

Thielen, A. (2002). *Entwicklung und Verifikation eines Modellansatzes zur numerischen Simulation von Stofftransportvorgängen in ungesättigten doppelt-permeablen Grundwassersystemen*. (Dipl.-Arbeit) (unveröffentlicht). Lehrstuhl und Institut für Wasserbau und Wasserwirtschaft der RWTH, Aachen.

Thorez, J. (1975). *Phyllosilicates and clay minerals*. Dison, Belgium.

Thorez, J. (1976). *Practical identification of clay minerals*. Dison, Belgium.

Thunvik, R. and Braester, C. (1990). Gas migration in discrete fracture networks. *Water Resources Research*, **26**(10), 2425–2434.

Thüringer, C. (2002). *Untersuchungen zum Gastransport im ungesättigten, geklüftet-porösen Festgestein*. (Schriftenreihe Angewandte Geologie Karlsruhe). Lehrstuhl für Angewandte Geologie, Karlsruhe.

Tidwell, V. and Wilson, J. (1997). Laboratory method for investigating permeability upscaling. *Water Resources Research*, **33**(7), 1607–1616.

Timur, A. (1969). Pulsed Nuclear Magnetic Resonance studies of porosity, movable fluid, and permeability of sandstones. *J. Pet. Tech.*, **246**, 775–786.

Tokunaga, T. and Wan, J. (1997). Water film flow along fracture surfaces in porous rock. *Water Resources Research*, **36**, 1287–1295.

Tsang, C., Hufschmied, P., and Hale, F. (1990). Determination of fracture inflow parameters with a borehole fluid conductivity logging method. *Water Resources Research*, **26**(4), 561–578.

Tsang, C., Tsang, Y., and Hale, F. (1991). Tracer Transport in Fractures: Analysis of Field Data Based on a Variable–Aperture Channel Model. *Water Resources Research*, **27**(12), 3095–3106.

Tsang, Y. (1992). Usage of "equivalent" apertures for rock fractures as derived from hydraulic and tracer tests. *Water Resources Research*, **28**(5), 1451–1455.

Tsang, Y. and Tsang, C. (1987). Channel model of flow through fractured media. *Water Resources Research*, **23**(3), 467–479.

Tsang, Y., Tsang, C., Neretnieks, I., and Moreno, L. (1988). Flow and transport in fractured media: a variable aperture channel model and its properties. *Water Resources Research*, **24**(12), 2049–2060.

Tsang, Y., Tsang, C., Hale, F., and Dverstorp, B. (1996). Tracer transport in a stochastic continuum model of fractured media. *Water Resources Research*, **32**(10), 3077–3092.

Tsang, Y. W. and Tsang, C. F. (1987). Channel model of flow through fractured media. *Water Resources Research*, **23**(3), 467–479.

Tsang, Y. W. and Tsang, C. F. (1989). Flow channelling in a single fracture as a two dimensional strongly variable heterogeneous medium. *Water Resources Research*, **25**(9), 2076–2080.

Ufrecht, W. (1987). *Zur Hydrogeologie und Hydrochemie des SAndsteinkeupers in Mittel- und Ostwürttemberg*. Ph.D. thesis, Universität Stuttgart.

Van Genuchten, M. and Dalton, F. (1986). Models for simulating salt movement in aggregated field soils. *Geoderma*, **38**, 165–183.

Vandergraaf, T. T., Drew, J., Archambault, D., and Ticknor, K. (1997). Transport of radionuclides in natural fractures: some aspects of laboratory migration experiments. *Journal of Contaminant Hydrology*, **26**(1–4), 83–95.

Vasco, D., Keers, H., and Karasaki, K. (2000). Estimation of reservoir properties using transient pressure data: An asymptotic approach. *Water Resources Research*, **36**(12), 3447–3465.

Vesselinov, V., Neuman, S., and Illman, W. (2001). Three-dimensional numerical inversion of pneumatic cross hole tests in unsaturated fractured tuff: 1. Methodology and borehole effects. *Water Resources Research*, **37**(12), 3001–3018.

Vogelsang, D. (1991). *Geophysik an Altlasten - Leitfaden für Ingenieure, Naturwissenschaftler und Juristen*. Springer, Berlin, Heidelberg, New York.

Voos, C. and Shotwell, L. (1990). An investigation of the mechanical and hydraulic behavior of tuff fractures under saturated conditions. Proc. of High Level Rad. Waste Managem., Am. Nuc. Soc.

Wallbrecher, E. (1986). *Tektonische und gefügeanalytische Arbeitsweisen*. Enke Verlag, Stuttgart.

Wang, J. (1991). Flow and transport in fractured rocks. In: Review of Geophysics, Supplement, U.S. National Report to International Union of Geodesy and Geophysics (1987-1990), Contributions in Hydrology.

Wang, J. and Narasimhan, T. (1985). Hydrologic mechanism governing fluid flow in saturated, fractured porous media. *Water Resources Research*, **21**, 1861–1874.

Wang, Y. and Dusseault, M. (1991). The effect of quadratic term on the borehole solution in poroelastic media. *Water Resources Research*, **27**, 3215–3223.

Wang, Y., Luo, T., and Z., M. (2001). Geostatistical and geochemical analysis of surface water leakage into groundwater on a regional scale: a case study in the liulin karst system, northwestern china.

Warren, J. and Root, P. (1963). The behaviour of naturally fractured reservoirs. (spej 426). *Society of Petroleum Engineers Journal*, pages 245–255.

Washburn, E. (1941). Note on a method of determining the distribution of pore sizes in porous media. *Nat. Acad. Sci. Proc.*, **7**, 115 pp.

White, F. (1999). *Fluid Mechanics*. McGraw-Hill, USA, 4th edition edition.

Whittaker, J. and Teutsch, G. (1996). The simulation of subsurface characterisation methods applied to a natural aquifer analogue. Proc. of IAHS, Modelcare 96, Golden, Colorado, USA.

Wichter, L. and Gudehus, G. (1976). Ein Verfahren zur Entnahme und Prüfungen von geklüfteten Grobohrkernen. Proc. 2 Nat. Taguung ber Felsmechanik, Aachen.

Wikberg, P. e., Gustafson, G., Rhén, I., and Stanfors, R. (1991). Äspö Hard Rock Laboratory. Evaluation of conceptual modelling based on the preinvestigations 1986-1990. SKB Technical Reports 91–22, Swedish Nuclear Fuel and Waste Management Company, Stockholm.

Williams, C. E. and Fung, B. M. (1982). The determination of wettability by hydrocarbons of small particles by deuteron T1 measurement. *J. Magnetic Resonance*, **50**, 71–80.

Wilson, M. (1987). *A Handbook of Determinative Methods in Clay Mineralogy*. Chapman and Hall, Glasgow - New York.

Wollrath, J. (1990). *Ein Strömungs- und Transportmodell für klüftiges Gestein und Untersuchungen zu homogenen Ersatzsystemen*. (Institut für Strömungsmechanik und Elektronisches Rechnen im Bauwesen Hannover, Bericht; 28) (Zugl.: Hannover, Univ., Diss., 1990). Eigenverlag, Hannover.

Wollrath, J. (1990). Ein Strömungs- und Transportmodell für klüftiges Gestein und Untersuchungen zu homogenen Ersatzsystemen. Technical Report 28, Institut für Strömungsmechanik und Elektronisches Rechnen im Bauwesen, Universität Hannover.

Yeh, T.-C. J. and J., Z. (1996). A geostatistical inverse method for variably saturated flow in the vadose zone. *Water Resources Research*, **32**(9), 2757–2766.

Yeh, W. (1986). Review of parameter identification procedures in groundwater hydrology: The inverse problem. *Water Resources Research*, **22**(2), 95–108.

Zhu, W. and Wong, T. (1996). Permeability reduction in a dilating rock; network modelling of damage and tortuosity. *Geophys. Res. Lett*, **23**(22), 3099–3102.

Zimmermann, R. and Yeo, I.-W. (2000). Fluid flow in rock fractured: From the navier-stokes equations to the cubic law. In: Dynamics of Fluids in Fractured Rock. Geoph. Monograph, 122.

Zimmermann, R., Chen, G., and Hadgu, T. (1993). A numerical dual-porosity model with semianalytical treatment of fracture/matrix flow. *Water Resources Research*, **29**(7), 2127–2137.

Zlotnik, V. and Ledder, G. (1996). Theory of dipole flow in uniform anisotropic aquifers. *Water Resources Research*, **32**(4), 1119–1128.

Nomenclature

Coordinates, indices, conventions

$\overline{\overline{\square}}$	Equivalent parameter after averaging over the REV and averaging over single fractures or matrix blocks	
$\overline{\square}$	Equivalent parameter after averaging over the REV	-
$\square_\alpha$, $\square_\beta$	Parameters of a joint face	
$\square_\alpha$, $\square_\beta$	Number of a continuum for the multi continuum modelling	
$\square_{\mathrm{a}}$	Property associated with air	
$\square_{\mathrm{hydr}}$	Derived from hydraulic test	
$\square_{\mathrm{i}}$	Index of rectangles	
$\square_{\mathrm{n}}$	Property associated with non wetting phase	
$\square_{\mathrm{ow}}$	Property associated with observation well	
$\square_{\mathrm{pneu}}$	Derived from pneumatic test	
$\square_{\mathrm{pw}}$	Property associated with pumping well	
$\square_{\mathrm{sh}}$	Property associated with the shell model	
$\square_{\mathrm{w}}$	Property associated with water/wetting phase	
$\square_{\mathrm{z}}$	Index of slices	
$\square_F$	Fracture continuum (regarding fracture-matrix-systems)	
$\square_{ij}$	Tensor indices	
$\square_M$	Matrix continuum (regarding fracture-matrix-systems)	
$\square_T$	Parameter of an interface	
s	Local coordinates of the matrix blocks	m
x′, y′	Normalized coordinates	-
x, y, z	Carthesian coordinates	m

Scalar quantities

α	Θ-pole coordinate (colatitude) of the main direction (FISHER distr.)	-
α_Q	Exchange coefficient flow	$\mathrm{m\,s^{-1}}$
α_{c}	Exchange coefficient transport	$\mathrm{m^2\,s^{-1}}$
α_{l}	Longitudinal dispersivity	m
α_{t}	Transversal dispersivity	m

β	ϕ-pole coordinate (longitude) of the main direction (FISHER distr.)	-
δ	DIRAC function	
γ	Angle of flow direction	$^\circ$
γ	Surface tension	$\mathrm{kg\,m\,s^{-2}\,m^{-1}\,s^{-2}}$
κ	Concentration parameter (FISHER distr.)	-
λ	Mean free path of air molecules	m
μ	Dynamic viscosity	$\mathrm{kg\,m^{-1}\,s^{-1}}$
ω	Geometry coefficient	-
ω	Spherical aperture(FISHER distr.)	*TODO*
Ω_0	Specific surface	$\mathrm{m^{-1}}$
Ω_j	Subdomain j	
Ω_W	Specific fracture area	$\mathrm{m^{-1}}$
Φ	Relative volume	-
σ^2	Variance	(unit of the variable)^2
τ, ω	Integration variables	
θ	Angle of incidence	$^\circ$
θ_C	Contact angle	$^\circ$
ε	Absolute roughness	m
ρ	Density	$\mathrm{kg\,m^{-3}}$
A	Cross-sectional area	$\mathrm{m^2}$
a	Diffusion parameter	$\mathrm{s^{-\frac{1}{2}}}$
a	Half height of an experimental cell	m
a_r	Length parameter (variogram)	m
A_s	Azimuth	$^\circ$
b	Aquifer thickness	m
b	Diameter of an experimental cell	m
b	Distance from center port configuration	m
b	Fracture aperture	m
b_k	KLINKENBERG factor	-
C	Proportionality factor	-
c	Solute concentration	$\mathrm{kg\,m^{-3}}$
C_0	Nugget effect	(unit of the variable)^2
c_R	Concentration of boundary flow	$\mathrm{kg\,m^{-3}}$
D	Diffusivity	$\mathrm{m^2\ s^{-1}}$
d	Pore diameter	m
D^*	Pore diffusion coefficient	$\mathrm{m^2\ s^{-1}}$
d_1	Linear fracture density	$\mathrm{m^{-1}}$
d_2	Area related fracture density	$\mathrm{m\,m^{-2}}$
d_3	Volumetric fracture density	$\mathrm{m^2\,m^{-3}}$
D_m	Molecular diffusion coefficient	$\mathrm{m^2\,s^{-1}}$
D_P	Pore diffusion coefficient	$\mathrm{m^2\,s^{-1}}$
D_p	Dip angle	$^\circ$
d_p	Effective pore diameter	m
D_l	Longitudinal dispersion coefficient	$\mathrm{m^2\,s^{-1}}$

$D_{\mathrm{m,e}}$	Effective diffusion coefficient	$\mathrm{m^2\,s^{-1}}$
D_{t}	Transversal dispersion coefficient	$\mathrm{m^2\,s^{-1}}$
d_{ij}	Distance along trajectory i in voxel j	m
e_{RMSE}	Root mean square error	unit of the variable
e_q	Direction of flow	-
F	Mass flux	$\mathrm{kg\,m^{-2}\ s^{-1}}$
G	Continuous source	
g	Gravitational acceleration	$\mathrm{m\,s^{-2}}$
H	HEAVISIDE function	
h	Distance between two points (variogram)	m
h	Piezometric head	m
h_n	Maximum distance of n^{th} shell to center of flow	m
I	Hydraulic gradient	-
I	Normalized sensitivity coefficient	-
I_j	Sensitivity coefficient of subdomain j	s
K	Hydraulic conductivity (isotropic)	$\mathrm{m\,s^{-1}}$
k	Permeability (isotropic)	$\mathrm{m^2}$
k_{eff}	Effective permeability	$\mathrm{m^2}$
k_r	Permeability ratio	-
L	Typical length scale, length of sample	m
l	Length	m
L^*	Loss of identity length	m
L_z	Thickness of slice z	m
M	Injected tracer mass	kg
m_z	Number of slices	-
$MCor$	Maximum correction in the multi-shell model	-
n	Total porosity	-
N_M	Mobility number	-
n_{e}	Effective porosity	-
p	Pressure	$\mathrm{kg\,m^{-1}\,s^{-2}\,m^{-2}}$
Pe	PECLET number	-
pv	Number of pore volumes	-
pv_b	pv assymmetric port configurations	-
pv_{norm}	pv normalized curve	-
pv_{ref}	pv reference curve	-
Q	Volume discharge	$\mathrm{m^3\,s^{-1}}$
q_{s}	Source and sink term	$\mathrm{kg\,m^{-3}s^{-1}}$
q_{M}	Tracer mass flux	$\mathrm{kg\,s^{-1}}$
q_{m}	Tracer mass source/sink term	$\mathrm{kg\,m^{-2}s^{-1}}$
$Q_{Q,S}$	Volume discharge due to sources/sinks per unit volume	$\mathrm{s^{-1}}$
r	Distance	m
R_a	Core radius	m
r_n	Radius of the n^{th} shell	m
R_r	Relative roughness	-

R_i	Individual gas constant	$\mathrm{J\ kg^{-1}\,K^{-1}}$
Re	REYNOLDs number	-
S	Depth of flow system	m
S^2	Variance (variogram)	(unit of the variable)^2
S^*	Spherical variance	TODO
S_t	Strike angle	$^\circ$
S_S	Specific storage coefficient	$\mathrm{m^{-1}}$
$SCor$	Shell correction in the multi-shell model	-
T	Temperature	K
t	Time	s
T^*	Loading time	s
t_0	Mean transit time	s
t_i^e	Estimated travel time	s
t_i^m	Measured travel time	s
tr	Tracer recovery	-
u	Integration variable	-
u	Solution of groundwater flow equation	m
V	Volume	$\mathrm{m^3}$
v	Absolute velocity value	$\mathrm{m\,s^{-1}}$
v	Solution of adjoint groundwater flow equation	m
v_a	Mean velocity	$\mathrm{m\,s^{-1}}$
W_Al	Mass exchange per unit volume (by local advection)	$\mathrm{kg\,m^{-3}\,s^{-1}}$
W_Ar	Mass exchange per unit volume (by regional advection)	$\mathrm{kg\,m^{-3}}\,s^{-1}$
W_c	Mass exchange per unit volume	$\mathrm{kg\,m^{-3}\,s^{-1}}$
W_D	Mass exchange per unit volume (by diffusive exchange)	$\mathrm{kg\,m^{-3}\,s^{-1}}$
W_Ql	Fluid exchange per unit volume (by local pressure gradient)	$\mathrm{s^{-1}}$
W_Qr	Fluid exchange per unit volume (by regional pressure gradient)	$\mathrm{s^{-1}}$
x	Distance	m
x_n	Length of the outer edge of n^th shell	m

Tensor quantities

$\Omega_{W,ij}$	Tensor of specific fracture area	$\mathrm{m^{-1}}$
$D_{\mathrm{d},ij}$	Dispersion tensor	$\mathrm{m^2\,s^{-1}}$
D_{ij}	Hydrodynamic dispersion tensor	$\mathrm{m^2\,s^{-1}}$
$FF(x_i)$	Fracture frequency	-
$I(x_i)$	Indicator variable	-
J_i	Total mass flux vector	$\mathrm{kg\,m^{-2}\,s^{-1}}$
$J_{\mathrm{a},i}$	Advective mass flux vector	$\mathrm{kg\,m^{-2}\,s^{-1}}$
$J_{\mathrm{d},ij}$	Dispersive mass flux tensor	$\mathrm{kg\,m^{-2}\,s^{-1}}$
$J_{\mathrm{hd},i}$	Hydrodynamic dispersion mass flux vector	$\mathrm{kg\,m^{-2}\,s^{-1}}$
$J_{\mathrm{m},i}$	Diffusive mass flux vector	$\mathrm{kg\,m^{-2}\,s^{-1}}$
K_{ij}	Hydraulic conductivity tensor	$\mathrm{m\,s^{-1}}$
k_{ij}	Permeability tensor	$\mathrm{m^2}$

q_i	DARCY velocity vector	$\mathrm{m\,s^{-1}}$
R_i	Main orientation (FISHER distr.)	-
v_i	Seepage velocity vector	$\mathrm{m\,s^{-1}}$