

BIJLAGE 2 (behorend bij vraag 227)

Referenties geïnduceerde seismiciteit

In deze bijlage is een lijst opgenomen met publicaties en rapporten, waaraan medewerkers van TNO, KNMI, SodM, CBS en TUD hebben bijgedragen aan kennisontwikkeling rondom geïnduceerde seismiciteit en bodemdaling.

2014

Van Wees, J.D., Buijze, L., Van Thienen-Visser, K., Nepveu, M., Wassing, B.B.T., Orlic B., Fokker P.A., (2014) Geomechanics response and induced seismicity during gasfield depletion in the Netherlands, *geothermics*, 52, 206-219

Wassing, B., Van Wees, J.D., Fokker, P., 2014. Coupled Continuum Modeling of Fracture Reactivation and Induced Seismicity during Enhanced Geothermal Operations. *geothermics*, 52
Significance of trend changes in ground subsidence in Groningen. Phase 0, report 1., F.P.Pijpers, CBS, 2014
Significance of trend changes in tremor rates in Groningen. Phase 0, report 2., F.P.Pijpers CBS, 2014

2013

Dahm, T., D. Becker, M. Bischoff, S. Cesca, B. Dost, R. Fritschen, S. Hainzl, C. Klose, D. Kuehn, S. Lasocki, T. Meier, M. Ohrnberger, E. Rivalta, U. Wegler and S. Husen, 2013, Recommendation for the discrimination of human-related and natural seismicity (Letter to the Editor), *J. Seism.*, doi:10.1007/s10950-012-9295-6

Dost, B., M. Caccavale, T. van Eck and D. Kraaijpoel, 2013, Report on the expected PGV and PGA values for induced earthquakes in the Groningen area. KNMI publication, pp26.

Dost, B. and D. Kraaijpoel, 2013, The August 16, 2012 earthquake near Huizinge (Groningen) KNMI publication: TR, pp26.

Fokker, P.A., Wassing, B.B.T., Leijen, F.J. van, Hanssen, R.F. & Nieuwland, D.A. (2013). Data assimilation of PS-InSAR movement measurements applied to the bergermeer gas field. In International Workshop on Geomechanics and Energy: The Ground as Energy Source and Storage, 26 November 2013 through 28 November 2013, Lausanne (pp. 5p.). : European Association of Geoscientists and Engineers, EAGE.

Kraaijpoel, D.A. and B. Dost, 2013, Implications of salt-related propagation and mode conversion effects on the analysis of induced seismicity, *J. Seism.*, doi:10.1007/s10950-012-9309-4

Kraaijpoel, D., T. Kraft, A. Tramelli, G. de Natale, C. Troise, M. Orazi, V. Oye, D. Kuhn, B. Goertz-Allmann, J. Douglas and A. Jupe, 2013, *GEISER Deliverable D6.2 - Seismic Monitoring Strategies*, Deliverable D6.2, FP& Project GEISER, 2013.

Muntendam-Bos, A.G. and J.A. De Waal, Reassessment of the probability of higher magnitude earthquakes in the Groningen gas field, SodM technical report, 2013

Orlic, B. (2013). Site-specific geomechanical modeling for predicting stress changes around depleted gas reservoirs considered for CO₂ storage in the Netherlands. In 47th US Rock Mechanics / Geomechanics Symposium held in San Francisco, CA, USA, 23-26 June 2013 Alexandria, VA : ARMA, American Rock Mechanics Association.

Orlic, B., Wassing, B.B.T. & Geel, C.R. (2013). Field scale geomechanical modeling for prediction of fault stability during underground gas storage operations in a depleted gas field in the Netherlands. In 47th US Rock Mechanics / Geomechanics Symposium held in San Francisco, CA, USA, 23-26 June 2013 Alexandria, VA : ARMA, American Rock Mechanics Association.

Orlic, B., Mazurowski, M., Papiernik, B. & Nagy, S. (2013). Assessing the geomechanical effects of CO₂ injection in a depleted gas field in Poland by field scale modelling. In Kwasniewski & Lydzba (Eds.), *Rock Mechanics for Resources, Energy and Environment* (pp. 969-975). London : Taylor & Francis Group.

Trani, M., Arts, R. & Leeuwenburgh, O. (2013). Seismic history matching of fluid fronts using the ensemble kalman filter. *SPE Journal*, 18(1), 159-171.

Urpi, L., Blöcher, G., Zimmermann, G., Wees, J.D. van & Fokker, P. (2013). Coulomb stress change during and after tensile fracture opening in a geothermal reservoir. In 47th US Rock Mechanics / Geomechanics Symposium 2013, 23 June 2013 through 26 June 2013, San Francisco, CA (pp. 969-974).

Van Wees, J.D., Buijze, L., Van Thienen-Visser, K., Wassing, B., Fokker, P., Nepveu, M., Orlic, B., 2013. Natural stress and fault controls in induced seismicity: what can we learn from gas depletion in the Netherlands? European Geothermal Congress, Pisa, Italy.

2012

Cesca, S., B. Dost and A. Oth, 2012, Preface to the special issue -Triggered and induced seismicity: probabilities and discrimination. *J. Seism.*, 2012, doi:10.1007/s10950-012-9338-z.

Dost, B., F. Goutbeek, T. van Eck and D. Kraaijpoel, 2012, Monitoring induced seismicity in the North of the Netherlands: status report 2010 KNMI publication: WR-2012-03, pp39.

Fokker, P.A., Visser, K., Kunakbayeva, G. & Muntendam-Bos, A.G. (2012). Inversion of Surface Subsidence Data to Quantify Reservoir Compartmentalization: A Field Study. *Journal of Petroleum Science and Engineering*, 96-97, 10-21. doi:http://dx.doi.org/10.1016/j.petrol.2012.06.032

Muntendam-Bos, A.G., Seismic Risk: Assessment, mitigation, and management, Injection Induced Seismicity workshop, Banff, Alberta, Canada, 15-18 September, 2014

Orlic, B. & Wassing, B.B.T. (2012). A study of stress change and fault slip in producing gas reservoirs overlain by elastic and visco-elastic caprocks. *Rock Mechanics and Rock Engineering*, 15p. doi:http://dx.doi.org/10.1007/s00603-012-0347-6

Orlic, B. & Wassing, B.B.T. (2012). Modeling stress development and fault slip in producing hydrocarbon reservoirs overlain by rock salt caprocks. In *Proceedings of the 46th US Rock Mechanics / Geomechanics Symposium (ARMA)Chicago* : ARMA.

Van Thienen-Visser, K., Nepveu, M. & Hettelaar, J.M.M. (2012). Deterministische hazard analyse voor geïnduceerde seismiteit in Nederland. (TNO 2012 R10198). Utrecht: TNO. http://nlog.nl/resources/Seismic_Risk/TNO-rapport_202012_20R10198.zip

Waal, J.A. de, Roest, J.P.A., Fokker, P.A., Kroon, I.C., Breunese, J.N., Muntendam-Bos, A.G., Oost, P.A. & Wirdum, G. van (2012). The effective subsidence capacity concept: How to assure that subsidence in the Wadden Sea remains within defined limits?. *Netherlands Journal of Geosciences - Geologie en Mijnbouw*, 91(3), 385-399.

Wassing, B.B.T. & Dost, B. (2012). Seismisch hazard van geïnduceerde aardbevingen: integratie van deelstudies. (TNO 2012 R11139). Utrecht: TNO ; KNMI. http://nlog.nl/resources/Seismic_Risk/TNO-KNMI_integratie-studie_2012_final.pdf

Zhang, X., Santonico, D., Meekes, J.A.C., Verdel, A.R. & Arts, R.J. (2012). Passive and Active Seismic Monitoring of CO₂-Storage at Ketzin. In *Proceedings European Geosciences Union (EGU) General Assembly Conference Abstracts*

2011

Baker-Hughes, Dynamic Geomechanical Modelling of the Bergermeer Underground Gas Storage, Netherlands-Part 1: Base Case Modelling, 2011.

Bruhn, D., Huenges, E., Ágústsson, K., Zang, A., Kwiatak, G., Rachez, X., Wiemer, S., Wees, J.D.A.M. van, Calcagno, P., Kohl, T., Dorbath, C., Natale, G. de & Oye, V. (2011). Geothermal engineering integrating mitigation of induced seismicity in reservoirs - The European GEISER project. In *Geothermal Resources Council Annual Meeting 2011, Geothermal 2011*, 23 October 2011 through 26 October 2011, San Diego, CA(Vol. 35 2, (pp. 1623-1626).

Giger, S.B., Clenell, M.B., Harbers, C., Clark, P., Ricchetti, M., Ter Heege, J.H., Wassing, B.B.T., Orlic, B. (2011). Design, operation and validation of a new fluid-sealed direct shear apparatus capable of monitoring fault-related fluid flow to large displacements. *International Journal of Rock Mechanics & Mining Sciences*, 48, 1160-1172.

Kanten-Roos, W. van. Dost, B., Vrouwenfelder, A.C.W.M., Eck, T. van, Maximale schade door geïnduceerde aardbevingen: inventarisatie van studies met toepassingen op Bergermeer, TNO-KNMI rapport, mei 2011 http://nlog.nl/resources/Seismic_Risk/Max_schade_Bergermeer_2011.pdf

Orlic, B., Heege, J.T. ter & Wassing, B.B.T. (2011). Assessing the integrity of fault- and top seals at CO₂ storage sites. In 10th International Conference on Greenhouse Gas Control Technologies, 19 September 2010 through 23 September 2010, Amsterdam. Conference code: 84600(Vol. 4, (pp. 4798-4805).

Orlic, B., Heege, J.T. ter & Wassing, B.B.T. (2011). Assessing the short-term and long-term integrity of top seals in feasibility studies of geological CO₂ storage. ARMA 11.

Ouboter, T., Wassing, B.B.T., & Fokker, P.A. (2011). Coupled continuum modeling of flow and mechanics in a natural fracture network. In Flows and mechanics in natural porous media from pore to field scale. Pore2Field 16-18 November 2011, IFP Energies nouvelles (France)

Petrat, L., Fokker, P.A., Zschocke, A., & Petrat, K. (2011). Surface Movements derived from Space: Valuable Information for Underground Reservoir and Geomechanical Processes!. In (pp. 13 p.).

Vlieg, D.J.J. de, Muntendam-Bos, A.G. & Breunese, J.N. (2011). Induced (Micro-) Seismicity during underground gas storage. (TNO-060-UT-2011-02199). Utrecht: TNO.

Wassing et al, 3D Geomechanical Modelling of Fault stability in the Bergermeer Field During Underground Gas Storage Operations, TNO-report TNO-060-UT-2011-01388/C, 2011;

Wassing, B.B.T., Wees, J.D. van & Fokker, P.A. (2012). Coupled continuum modeling of fracture reactivation and induced seismicity during enhanced geothermal operations. In 46th US Rock Mechanics, Geomechanics Symposium held in Chicago, IL, USA, 24-27 June.

Wilschut, F., Peters, E., Visser, K., Fokker, P.A. (2011). Joint history matching of well data and surface subsidence observations using the Ensemble Kalman Filter. SPE reservoir simulation symposium, Woodlands, Texas, February 2011.

Zhang, X., Brouwer, J.H., Meekes, J.A.C. & Arts, R.J. (2011). Passive seismic monitoring in two carbon sequestration sites, a data driven approach. In 73rd European Association of Geoscientists and Engineers Conference and Exhibition 2011 - Incorporating SPE EUROPEC 2011, 23 May 2011 through 26 May 2011, Vienna(Vol. 6, (pp. 4054-4058).

2010

Dahm, T., S. Hainzl, D. Becker, M. Bischoff, S. Ceska, B. Dost, R. Fritschen, D. Kuhn, S. Lasocki, C.D. Klose, T. Meier, M. Ohrnberger, E. Rivalta, S. Shapiro and U. Wegler, 2010, How to discriminate induced, triggered and natural seismicity, EGCS workshop on Induced Seismicity, 15/11/2010-17/11/2010, J. Ritter and A. Oth (Ed), Luxemburg, ECGS, ISBN 978-2-91989-709-4, 69-76.

Douglas, J., B. Edwards, V. Convertito, N. Sharma, A. Tramelli, D. Kraaijpoel, B. Mena Cabrera, N. Maercklin and C. Troise, 2013, Predicting ground motion from induced earthquakes in geothermal areas, *Bulletin of the Seismological Society of America*, 103: 1875-1897, doi:10.1785/0120120197.

Fokker, P.A., Visser, K., Peters, E., Kunakbayeva, G., Muntendam-Bos, A.G. (2010). Inversion of surface subsidence data to quantify reservoir compartmentalization: a field study. SPE annual technical conference and exhibition, Florence, Italy, 19-22 September 2010.

Van Thienen-Visser, K., Muntendam-Bos, A.G., Peters, L., Leeuwenburgh, O., Fokker, P.A. (2010). Undepleted pockets of gas detected using coupled modeling of subsidence and reservoir depletion processes. Geo 2010 – 9th Middle East geosciences conference & exhibition, Manama, Bahrein.

Visser, K., Muntendam-Bos, A.G., Kunakbayeva, G., Leeuwenburgh, O., Peters, E., Fokker, P.A. (2010). Inverting subsidence data to detect possible compartmentalization in a gas reservoir in the Netherlands. Proceedings of the eighth international symposium on land subsidence, Querétaro, México, 17-22 October.

Wassing, B., P. Waarts, A.G. Muntendam-Bos, M. Nepveu, W. van Kanten-Roos, and T. van Eck, Seismic risk analysis of small earthquakes induced by hydrocarbon production in the Netherlands, SPE – 72nd EAGE Conference and Exhibition, Barcelona, Spain, June 2010.

2009

Borsje, H., S.A.J. de Richemont, W. Roos, Methodiek voor onderzoek naar de oorzaak van gebouwschade in de provincie Groningen, TNO rapport 2008-D-R13322/B, september 2009

Fokker, P.A., Muntendam-Bos, A.G., Orlic, B., Van Thienen-Visser, K., Abbink, O.A. (2009). Detecting remaining gas reserves based on coupled modelling of subsidence and reservoir depletion processes. 4th EAGE North African/Mediterranean Petroleum and Geosciences Conference & Exhibition, Tunis, Tunisia, 2009.

Muntendam-Bos, A.G. and P.A. Fokker, Unraveling reservoir compaction parameters through the inversion of surface subsidence observations, Computational Geosciences 13(1), 43-55, 2009.

Muntendam-Bos, A.G., M.H.P. Kleuskens, M. Bakr, G. de Lange, and P.A. Fokker, Unraveling shallow causes of subsidence, Geophysical research Letters, 36(10), 2009.

Roos, W., Waarts, P.H., Wassing, B.B.T. (2009). Kalibratiestudie schade door aardbevingen. TNO-rapport: TNO-034-DTM-2009-04435.

Samiei-Esfahany, S., Van Thienen-Visser, K., Muntendam-Bos, A.G., Hanssen, R.F. (2009). Complex subsidence signal induced by gas and salt production in Friesland, The Netherlands, observed by persistent scatterer interferometry. ESA Fringe 2009 Workshop, Frascati, Italy.

Samiei-Esfahany, S., Hanssen, R.F., Van Thienen-Visser, K., Muntendam-Bos, A.G. (2009). On the effect of horizontal deformation of InSAR subsidence estimates. Proceedings of Fringe 2009, Frascati, Italy, 30 November – 4 December 2009.

TNO. (2009). Geïnduceerde aardtrillingen in of nabij het Groningen gasveld; een aanzet tot een geomechanische verklaring.", Brief TNO 27 oktober 2009.

Visser, K., Muntendam-Bos, A.G., Fokker, P.A. (2009). Inversion of surface subsidence data for detection of undepleted reservoir compartments: a field study. General Assembly of the European Geosciences Union (EGU), Vienna, Austria, 2009.

2008

Kroon, I.C., B-L. Nguyen, P.A. Fokker, A.G. Muntendam-Bos, and G. de Lange, Disentangling shallow and deep processes causing surface movement, Mathematical Geosciences, 41(5), 571-584, 2008.

Muntendam-Bos, A.G., Wassing, B.B.T., Geel, C.R., Louh, M., Van Thienen-Visser, K. (2008). Bergermeer seismicity study. TNO report 2008-U-R1071/B, 95pp. (zie ook Massachusetts Institute of Technology, Technical review of Bergermeer Seismicity study TNO report 2008-U-R0871/B, 2008.

Muntendam-Bos, A.G., I.C. Kroon, and P.A. Fokker, Time-dependent inversion of surface subsidence due to dynamic reservoir compaction, Mathematical Geosciences, 40(2), 159-177, 2008.

2007

Dost, B. and H.W. Haak, 2007, Natural and induced seismicity, in Th. E. Wong, D.A.J. Batjes and J. de Jager, eds., Geology of the Netherlands, Royal Netherlands Academy of Arts and Sciences: 223-229.

Eck, T. van, F.H. Goutbeek and B. Dost, 2007, Site specific hazard estimates for the NUON energy plant in the Eemshaven, KNMI publication: IR-2007-02, pp17.

Fokker, P.A., A.G. Muntendam-Bos, and I.C. Kroon, inverse modelling of surface subsidence to better understand the Earth's subsurface, *First Break*, 25, 101-105, 2007.

TNO rapport 2007-CI-M0033; Response spectra for the NUON Eemshaven energy plant under induced earthquake loading, A. Vrouwenvelder, September 2007

TNO rapport 2007-U-R0407/B; Kalibratie van hazard- en schademodelle, Seismisch risico geïnduceerde aardbevingen, B.B.T. Wassing, P.H. Waarts, W. Roos, april 2007

2006

Eck, T. van, F.H. Goutbeek, H.W. Haak and B. Dost, 2006, Seismic hazard due to small-magnitude, shallow-source, induced earthquakes in the Netherlands, *Engineering Geology*, 2006, 87, 105-121.

Van Eijs, R.M.H.E., Mulders, F.M.M., Nepveu, M., Kenter, C.J., Scheffers, B.C. (2006). Correlation between hydrocarbon reservoir properties and induced seismicity in the Netherlands. *Engineering Geology*, 84, 99-111.

2004

Dost, B., T. van Eck and H. Haak, 2004, Scaling of peak ground acceleration and peak ground velocity recorded in the Netherlands. *Bulletino di Geofisica Teorica e Applicata (special issue)*, vol 45, 153-168

Eck, T. van, F.H. Goutbeek, H.W. Haak and B. Dost, 2004, Seismic hazard due to small shallow induced earthquakes KNMI publication: WR-2004-01, ISBN 90-369-2248-8.

Van Eijs, R.M.H.E., Mulders, F.M.M., Nepveu, M. (2004). Deterministische hazard analyse voor geïnduceerde seismiciteit. TNO-rapport NITG 04-171-C.

Wassing, B.B.T., Maljers, D., Westerhoff, R.S., Bosch, J.H.A., Weerts, H.J.T., Koopman, A., Dullemond, A., Roos, W. (2004). Seismisch hazard van geïnduceerde aardbevingen. Rapportage fase 2. TNO-rapport NITG 03-186-C. http://nlog.nl/resources/Seismic_Risk/NITG-03-186-C-def-v3-CD.zip

Wassing, B.B.T., Waarts, P.P.H. (2004). Seismisch hazard van geïnduceerde aardbevingen. Aanpassing dempingsfunctie. TNO-rapport NITG 04-223-C.

Wassing, B.B.T., T. van Eck and R.M.H.E. van Eijs, 2004, Seismisch risico van geïnduceerde aardbevingen; Integratie van deelstudies, *KNMI publication*: WR-208 2004.

2003

Wassing, B.B.T., Maljers, D., Westerhoff, R.S., Bosch, J.H.A., Weerts, H.J.T. (2003) Seismisch hazard van geïnduceerde aardbevingen Rapportage fase 1. TNO-rapport NITG 03-185-C http://nlog.nl/resources/Seismic_Risk/NITG-03-185-C-def.pdf

Mulders, F.M.M., Modelling of stress development and fault slip in and around a producing gas reservoir. Dissertatie Technische Universiteit Delft, 2003

2001

Gussinklo, H.J., H.W. Haak, R.C.H. Quadvlieg, P.M.F.M. Schutjens and L. Vogelaar, Subsidence, 2001, Tremors and Society, *Geologie en Mijnbouw*, 80, 1, 121-135.

Haak, H.W., B. Dost and F.H. Goutbeek, 2001, Seismische analyse van de aardbevingen bij Alkmaar op 9 en 10 september en Bergen aan Zee op 10 oktober 2001, *KNMI publication*: TR-239, ISBN 90-369-2203-8, 11/2001.

1999

J.P.A.Roest, F.M.M.Mulders & W.Kuilman, Delft University of Technology. Data-limited geomechanical modelling for investigating induced seismicity mechanisms, proceedings ISRM congress, 1999

1998

De Crook, Th, H.W. Haak and B. Dost, 1998, Seismisch risico in Noord-Nederland, KNMI- Technisch rapport; TR-205, pp23.

1997

Logan et al, Seismic risk assessment of a possible gas storage project in the Bergermeer field, Bergen concession, 1997;

Nagelhout, A.C.G.& Roest, J.P.A., Geomechanical modelling of the Norg gas field, 1997; TU-Delft. TA/IG/97.51 Centre of Technical Geoscience.

Nagelhout, A.C.G.& Roest, J.P.A., Investigating fault slip in a model of an underground gas storage facility, International Journal of Rock Mechanics and Mining Science, 34, 212, 1997;

1995

De Crook, Th., B. Dost and H.W. Haak, 1995, Analyse van het seismische risico in Noord Nederland, KNMI-Technisch rapport; TR-168, pp30.

1994

Haak, H.W. and T. de Crook, 1994, Seismische analyse van aardbevingen in Noord-Nederland : bijdrage aan het multidisciplinaire onderzoek naar de relatie tussen gaswinning en aardbevingen, *KNMI publication: WR-94-01, 1/1/1994.*

Logan et al, A review of hydrocarbon-operations induced seismicity and its relevance to the Alkmaar PGI project, 1994; met Nederlandse samenvatting: onderzoek naar geïnduceerde seismiciteit bij de exploitatie van koolwaterstofhoudende reservoirs en de invloed daarvan op de bedrijfsvoering van het PGI Alkmaar project, 1994

Roest, J.P.A., Kuilman W. 1993. *Geomechanische analyse van de lichte aardschokken in het Eleveld reservoir*. Faculteit der Mijnbouwkunde en Petroleumwinning, TUD, Delft. (onderdeel BOA)

Roest, J.P.A.& W. Kuilman, Geomechanical analysis of small earthquakes at the Eleveld gas reservoir, ISRM-SPE 28097, Delft, 1994;

1990

Roest, J.P.A. Mogelijkheden van kleine zettingen bij de winning van gas. Symposium Bodemdaling in Nederland, 1990 Technische Universiteit Delft.