

# **4th EAGE CO<sub>2</sub> Geological Storage Workshop 2014**

**Demonstrating Storage Integrity  
and Building Confidence in CCS**

**Stavanger, Norway  
22 - 24 April 2014**

**ISBN: 978-1-63266-538-6**

**Printed from e-media with permission by:**

Curran Associates, Inc.  
57 Morehouse Lane  
Red Hook, NY 12571



**Some format issues inherent in the e-media version may also appear in this print version.**

Copyright© (2014) by the European Association of Geoscientists & Engineers  
All rights reserved.

Printed by Curran Associates, Inc. (2014)

For permission requests, please contact by the European Association of Geoscientists & Engineers  
at the address below.

EAGE  
PO Box 59  
3990 DB Houten  
The Netherlands

Phone: +31 88 995 5055  
Fax: +31 30 634 3524

[eage@eage.org](mailto:eage@eage.org)

**Additional copies of this publication are available from:**

Curran Associates, Inc.  
57 Morehouse Lane  
Red Hook, NY 12571 USA  
Phone: 845-758-0400  
Fax: 845-758-2634  
Email: [curran@proceedings.com](mailto:curran@proceedings.com)  
Web: [www.proceedings.com](http://www.proceedings.com)

## TABLE OF CONTENTS

<b>A01 Keynote Speech - Large-Scale CO2 Storage - How.....</b>	1
<i>P. Ringrose</i>	
<b>B01 Keynote Speech - Technical Qualification of a Storage Site for Mongstad.....</b>	7
<i>H. Hoydalsvik</i>	
<b>B02 SiteChar - Workflow for Fit-For-Purpose Characterisation of CO2 Storage Sites in Europe .....</b>	10
<i>F. Delprat-Jannaud, J. Pearce, F. Neele, M. Akhurst, C. Nielsen, M. Mazurowski, A. Lothe, V. Volpi, S. Brunsting</i>	
<b>B03 The Barents Sea Storage Atlas .....</b>	15
<i>J. Mujezinovic, I. Gjeldvik</i>	
<b>B04 Simulating CO2 Injection in Depleted Gas Reservoirs .....</b>	20
<i>S. Mathias, J. Gluyas, R. Bissell, N. Muller</i>	
<b>B05 Fault Stability and Potential Fault Reactivation Analysis in Otway Basin, Australia .....</b>	25
<i>C. Aruffo, A. Henk</i>	
<b>B06 Generalized Cubic Equation of State .....</b>	29
<i>I. Aavatsmark</i>	
<b>B07 On the Dependence of Capillary Entry Pressure with Subsurface Depth in Geological CO2 Storage.....</b>	34
<i>Y. Zhou, J. Helland, D. Hatzignatiou</i>	
<b>B08 On Layer Specific CO2 Plume Distributions and Variability in Mineralization Potential.....</b>	40
<i>A. Sundal, H. Hellevang, R. Miri, P. Aagaard</i>	
<b>B09 Modeling Water Vaporization During CO2 Reinjection into a Sour Gas Reservoir.....</b>	45
<i>S. Thibeau, M. Cardinal</i>	
<b>B10 Modelling Carbon Transformation at the Sediment-water Interface.....</b>	50
<i>E. Yakushev, E. Protsenko</i>	
<b>B11 Modelling the Influence of Two-phase Properties on CO2 Sequestration in Faulted Saline Aquifers .....</b>	54
<i>I. Tsiantis, T. Manzocchi</i>	
<b>B12 H-CUBE Project - Hydrodynamics, Heterogeneity, and Homogenization in CO2 Storage Modeling.....</b>	59
<i>P. Audigane, D. Guerillot, S. Viseur, E. Mouche, J. Rohmer</i>	
<b>B13 Changes of Deep Saline Aquifer Samples Due to Long Term Exposure to SpCO2.....</b>	65
<i>V. Havlova, V. Kolejka, V. Vrbova, R. Cervinka</i>	
<b>C01 Keynote Speech - Making Fossil Energy more Sustainable.....</b>	70
<i>D. Nummedal</i>	
<b>C02 Resistivity and Ultrasonic Velocity Measurements During CO2-brine Drainage and Imbibition .....</b>	72
<i>O. Johnsen, M. Soldal, J. Park, N. Mondol, B. Alemu</i>	
<b>C03 The Impact of Reservoir Conditions on the Measurement of Multiphase Flow Properties for CO2-Brine Systems.....</b>	77
<i>B. Niu, S. Krevor</i>	
<b>C04 Pore-Scale Modelling to Simulate Reactive Flow in Porous Media .....</b>	82
<i>S. Bekri, S. Renard, F. Delprat-Jannaud</i>	
<b>C05 Developments in SAFT EOS for Carbon Capture and Storage (CSS) .....</b>	87
<i>R. Miri, H. Hellevang</i>	
<b>C06 Geomechanical Characterization of Storage Reservoirs by Assimilation of Surface Displacements.....</b>	92
<i>C. Zoccarato, A. Alzraiee, D. Bau, M. Ferronato, G. Gambolati, C. Janna, P. Teatini</i>	
<b>C07 Fast Evaluation of Fluid-Rock Coupling in CO2 Storage .....</b>	97
<i>T. Bjornara, S. Mathias, J. Nordbotten, J. Park</i>	
<b>C08 InSAR Monitoring Leads to Improved Understanding of Flow and Pressure Behaviour During CO2 Injection at In Salah .....</b>	102
<i>J. Guzman, J. Shi, S. Durukan, A. Korre</i>	
<b>C09 Risk Assessment-Led Pre-Characterisation of a Site for Commercial-Scale Storage of CO2.....</b>	107
<i>M. Akhurst, M. Quinn, F. Delprat-Jannaud, D. Bossie-Codreanu, S. Hannis, J. Lecomte, M. McCormac, P. Frykman</i>	
<b>C10 Mature Oilfields Screening for CO2 EOR Utilization and Storage – A Case Study .....</b>	112
<i>D. Hatzignatiou, I. Fjelde</i>	
<b>C11 Fault Zone Development with Temporal Impact on Fluid Flow - Example from Navajo Sandstone, Utah .....</b>	117
<i>E. Skurtveit, A. Torabi, A. Braathen, R. Alikarami</i>	

<b>C12 The Dynamic Stability of Chalks During Flooding of Non-Equilibrium Brines and CO<sub>2</sub> .....</b>	122
<i>A. Nermoen, R. Korsnes, S. Haug, A. Hiorth, M. Madland</i>	
<b>C13 A Comparison of Volumetric and Dynamic CO<sub>2</sub> Storage Resource Estimation Methodologies in Deep Saline Formations .....</b>	127
<i>C. Gorecki, G. Liu, J. Braunberger, R. Klenner, S. Ayash, N. Dotzenrod, E. Steadman, J. Harju</i>	
<b>C14 Capillary Pressure Measurements for CO<sub>2</sub>, Brine and Berea Sandstone at Reservoir Conditions.....</b>	132
<i>M. Sarmadivaleh, S. Iglauer</i>	
<b>D01 Keynote Speech - Corrective Measures for CO<sub>2</sub> Storage - the MiReCOL Project .....</b>	137
<i>F. Neele</i>	
<b>D02 Utilising Spectral Decomposition to Determine Distribution of Injected CO<sub>2</sub> at the Snohvit Field .....</b>	141
<i>J. White, G. Williams</i>	
<b>D03 Use of the Panarea Natural Test Laboratory for Offshore CO<sub>2</sub> Leakage Monitoring and Impact Studies.....</b>	146
<i>S. Beaubien, C. Vittori, D. Viezzoli, A. Annunziatellis, S. Bigi, M. Celussi, S. Colella, C. Comici, S. Graziani, A. Karuza, M. Kralj, S. Lombardi, M. Pacciaroni</i>	
<b>D04 Integrating Rock-Physics Models and 3D VSP Data to Model Injected CO<sub>2</sub> and Porosity at Cranfield Field, Mississippi, USA.....</b>	151
<i>R. Carter, K. Spikes</i>	
<b>D05 The Application of Muon Tomography to Carbon Storage Monitoring .....</b>	156
<i>L. Thompson, C. Benton, S. Clark, M. Coleman, J. Gluyas, V. Kudryavtsev, J. Klinger, C. Mitchell, S. Pal, S. Paling, N. Spooner, S. Telfer</i>	
<b>D06 MVA Techniques and Application at the Citronelle SECARB Phase III site, Alabama .....</b>	160
<i>G. Koperna, S. Carpenter, R. Rhudy, R. Trautz, R. Esposito, G. Hill</i>	
<b>D07 In Situ Resistivity of CO<sub>2</sub> Plume at Sleipner from CSEM and Gravity Data.....</b>	164
<i>J. Park, M. Vanneste, B. Bohloli, I. Viken, T. Bjornara</i>	
<b>D08 Progress in CO<sub>2</sub> Storage and EOR Application Technologies in CNPC.....</b>	169
<i>Y. Hu, M. Hao, X. Liu, X. Yang, Y. Zhou</i>	
<b>E01 Keynote Speech - Managing CO<sub>2</sub> Storage, Are we Ready?.....</b>	174
<i>E. Halland</i>	
<b>E02 Acoustic Waveform Modelling to Improve Confidence in Wellbore Integrity Assessments Across the Utsira Formation .....</b>	176
<i>S. Hannis, G. Williams</i>	
<b>E03 Evaluation of Storage Capacity and Maturity of Potential Storage Sites in the Norwegian Continental Shelf (NCS).....</b>	181
<i>F. Riis, E. Halland, I. Gjeldvik, C. Magnus, J. Mujezinovic, V. Pham, R. Rod, I. Tappel</i>	
<b>E04 Indications of a Gravity-Dominated Dynamic Equilibrium for the Sleipner CO<sub>2</sub> Plume from Benchmark Reservoir Simulations.....</b>	186
<i>A. Cavanagh</i>	
<b>E05 A Case Study of CO<sub>2</sub> Storage in Southwestern Spain .....</b>	191
<i>B. Gonzalez, J. Navarro, A. Alaminos, M. Bozorgzadeh</i>	
<b>E06 Keynote Speech - Can we get CCS Back on Track?.....</b>	196
<i>S. Eggen</i>	
<b>E07 Effect of Reactive Surface Area of Minerals on Mineralization Due to CO<sub>2</sub> Injection in a Depleted Gas Reservoir .....</b>	198
<i>P. Boulourinejad, P. Omrani, R. Herber</i>	
<b>E08 Snohvit CO<sub>2</sub> Monitoring Using Well Pressure Measurement and 4D Seismic.....</b>	203
<i>B. Osdal, H. Zadeh, S. Johansen, R. Gonzalez, G. Waerum</i>	
<b>P02 Utilizing CO<sub>2</sub> for Oil Recovery in the Barents Sea.....</b>	208
<i>V. Pham, I. Gjeldvik, J. Mujezinovic, F. Riis</i>	
<b>P03 The Importance of Poromechanics for CO<sub>2</sub> Storage Integrity.....</b>	213
<i>L. Rass, V. Yarushina, N. Simon, Y. Podladchikov</i>	
<b>P04 Deformation of Porous Sandstone and its Implication for CO<sub>2</sub> Storage .....</b>	218
<i>A. Torabi</i>	
<b>P05 Interpretation of Microseismicity from Hydraulic Fracture Modelling.....</b>	222
<i>M. Wangen, V. Oye, A. Wuestefeld, B. Goertz-Allmann, A. Souche</i>	
<b>P06 Reservoir Compaction and Fluid Leakoff During Fluid Injection Operations .....</b>	227
<i>V. Yarushina, D. Bercovici</i>	
<b>P07 Structural Characterization of the Longyearbyen CO<sub>2</sub> Lab Reservoir-Caprock Succession .....</b>	231
<i>K. Ogata, K. Senger, A. Braathen, S. Olaussen, J. Tveranger</i>	
<b>P08 Communication between Reservoir and Surface -Sub-Seismic Deformation Prediction as Tool for Leakage Assessment .....</b>	236
<i>C. Krawczyk, D. Tanner</i>	

<b>P09 Impact on Storage Complex Delineation from Injection-induced Pressure Propagation .....</b>	240
<i>C. Nielsen, P. Frykman, F. Dallhoff</i>	
<b>P12 CO2 Storage in the Utsira-Skade Aquifer in the Norwegian North Sea .....</b>	244
<i>I. Gjeldvik, F. Riis</i>	
<b>P13 Experimental Characterization of Clay-rich Shales Dehydration by Dry ScCO2 .....</b>	249
<i>A. Souche, O. Brandvoll, N. Simon, H. Johansen</i>	
<b>P14 Comprehensive Study of a Natural CO2 Reservoir in Hungary .....</b>	253
<i>C. Kiraly, A. Szamosfalvi, E. Sendula, G. Falus, C. Szabo</i>	
<b>P15 On the Sensitivity of CO2 Injectivity to Reservoir Facies Architecture .....</b>	257
<i>M. Jin, E. Mackay, S. Mathias, J. Gluyas, W. Goldthorpe, G. Pickup</i>	
<b>P17 Characterization of a Potential CO2 Storage Site in a Carbonate Aquifer - Example From the South Adriatic Offshore .....</b>	262
<i>V. Volpi, E. Forlini, A. Baroni, A. Estublier, F. Donda, F. Delprat-Jannaud, D. Civile, O. Vincke</i>	
<b>P19 Building Confidence in Transnational CCS Projects .....</b>	267
<i>J. O'Neill, R. Vernon</i>	
<b>P20 VIRCOLA - A Tool for Visualization and Crossdiscipline Collaboration Related to CO2 Storage .....</b>	270
<i>S. Tavakoli, T. Langeland</i>	
<b>P22 The Plains CO2 Reduction (PCOR) Partnership Program - Addressing CO2 Storage Through Enhanced Oil Recovery .....</b>	275
<i>C. Gorecki, J. Hamling, S. Ayash, E. Steadman, J. Harju</i>	
<b>P24 Carbon Capture and Storage at the Lacq Pilot - Microseismic Monitoring .....</b>	279
<i>C. Maisons, X. Payre</i>	
<b>P25 Models for CO2 Injection with Coupled Thermal Processes .....</b>	281
<i>B. Kometra, S. Gasda, I. Avatsmark</i>	
<b>P26 Communicating your Technological Readiness Level - Can we Really Halt Climate Change Without Using Pilots? .....</b>	286
<i>A. Kvassnes, A. Sweetman</i>	
<b>P28 Groundwater Changes Caused by Flow through Naturally Occurring Gas (<math>\pm</math>water) Leakage Points .....</b>	289
<i>S. Beaubien, S. Bigi, S. Lombardi, P. Sacco, M. Tartarello</i>	
<b>P29 Could Leakage from Sub-sea Storage of CO2 Affect Marine Invertebrate Behaviour? .....</b>	294
<i>S. Bamber</i>	
<b>P30 In-situ H2 Generation from Hydrocarbons and CO2 Storage in the Reservoir .....</b>	299
<i>L. Surguchev, R. Berenblyum</i>	
<b>P31 Seismic and Electromagnetic Tomography to Image the CO2 Plume in a Cross-Well Synthetic Experiment .....</b>	304
<i>S. Picotti, G. Bohm, D. Gei, J. Carcione, A. Michelini</i>	
<b>P32 A New Sampling Method for Collecting Fluids at Depth .....</b>	309
<i>F. Gal, M. Brach, H. Pauwels</i>	
<b>P33 4D Seismic Feasibility Study for Enhanced Oil Recovery (EOR) with CO2 Injection in a Mature North Sea Field .....</b>	313
<i>H. Amini, E. Alvarez, D. Wilkinson, J. Lorsong, J. Slater, G. Holman, O. Timofeeva</i>	
<b>P34 Detection, Location and Characterisation of CO2 Releases in Near Surface Regions Using a Hierarchical Monitoring Concept .....</b>	318
<i>C. Schuetze, U. Sauer, P. Dietrich</i>	
<b>P35 CCS Monitoring with Time-Lapse VSP in China Northwest .....</b>	322
<i>Y. Chen, Y. Li, J. Wu, J. Du, X. Li, Y. Wang</i>	
<b>P37 Microseismic Monitoring in Carbon Capture and Storage Projects .....</b>	327
<i>J. Albaric, V. Oye, D. Kuhn</i>	
<b>P38 CO2 Storage Atlas Norwegian Sea - A Case Study from the Froan Basin .....</b>	332
<i>R. Roed, V. Pham</i>	
<b>P40 Interaction of CO2 Storage System Materials with SpCO2 .....</b>	336
<i>V. Havlova, V. Kolejka, V. Vrbova</i>	
<b>P42 Geochemical Evaluation of the Potential CO2 Geological Storage and Caprock Formations in Hungary .....</b>	340
<i>E. Sendula, Z. Szabo, C. Kiraly, H. Hellevang, V. Forray, G. Falus, C. Szabo</i>	
<b>Author Index</b>	