CONTENTS

Programme	**Pages 2-4**
Oral abstracts (In programme order)	**Pages 5-26**
Poster abstracts (In programme order)	**Pages 27-30**
Fire safety information	**Pages 31-32**
Note pages	**Pages 33-35**

Programme

22nd November 2011	
09.00	**Registration & coffee**
09.30	**Welcome Address** Bryan Lovell, Geological Society/University of Cambridge & Dave Cook, AAPG
Session 1: Context for capture & storage	
09.45	**Deep geological storage of CO_2: challenges to development** Stuart Haszeldine, University of Edinburgh
10.15	**Carbon Capture: New materials for amine replacement** Peter Styring, University of Sheffield
10.45	**Tea & coffee**
11.05	**CO_2 sequestration** Mercedese Maroto-Valer, University of Nottingham
11.35	**Industry, clustering & CO_2 transport** Dermot Roddy, University of Newcastle
12.05	**Discussion**
13.00	**Lunch (provided for all delegates)**
Session 2: Capacity / Containment	
14.00	**Static CO_2 storage capacity estimation** Sam Holloway, BGS
14.20	**Discussion**
14.30	**Estimating dynamic CO_2 capacity of UKCS Deep Saline Aquifers** Eugene Balbinski, RPS
14.50	**Discussion**
15.00	**The impact of geological structure on CO_2 storage in the Bunter Sandstone, UK** Kate Thatcher & Amy Clarke, Durham University
15.20	**Discussion**
15.30	**Tea & coffee**
15.50	**Geological CO2 storage – how is CO2 trapped?** Martin Blunt, Imperial College London
16.10	**Discussion**
16.20	**CO_2 EOR & storage in the North Sea: A developer's perspective** James Lorsong, 2Co Energy Limited
16.40	**Discussion**

16.50	**Limited sequestration of CO_2 in natural analogue quantified by stepwise C & O stable isotope extraction** Mark Wilkinson, University of Edinburgh
17.10	**Discussion & Day 1 summary** Andy Woods, University of Cambridge
17.30	**Close of day and drinks reception**

23rd November 2011	
08.30	**Registration & coffee**
09.00	**Welcome Address** Jon Gluyas, Durham University
Session 3: Containment / Intergrity / Injectivity	
09.10	**Evaluating the structural integrity of fault-bound traps for CO_2 storage** Graham Yielding, Badley Geoscience Ltd
09.30	**Discussion**
9.40	**Structural uncertainty: Why it matters to Carbon Storage** Gareth Johnson, Midland Valley
10.00	**Discussion**
10.10	**Caprock and fault integrity: insights from experiments on Bunter and Rotliegend topseals**
10.30	**Discussion**
10.40	**Estimating injectivity for saline aquifers – The UKSAP method** Simon Mathias, University of Durham
11.00	**Discussion**
11.10	**Tea & coffee**
11.30	**Monitoring** Bernd Wiese, Potsdam
11.50	**Discussion**
12.00	**Monitoring subsurface CO_2 emplacement and security of storage using muon tomography** Jon Gluyas, Durham University
12.20	**Discussion**
12.30	**The framework for storage risks and risk assessment in geological storage** Bill Senior, Senior CSS Solutions
12.50	**Discussion**
13.00	**Lunch (provided for all delegates)**

Session 4: Current projects	
14.00	**CO_2 Management at ExxonMobil's LaBarge Field, Wyoming, USA** Jim Herbertson, ExxonMobil
14.20	**Discussion**
14.30	**Carbon capture and storage in the Cambrian and Ordovician strata of the Illinois Basin, USA** Hannes Leetaru, Illinois State Geological Survey
14.50	**Discussion**
15.00	**Learning by doing: CSS in Australia** Peter Cook, CO2CRC/University of Melbourne
15.20	**Discussion**
15.30	**Injectivity and storage update on the DOE-NETL Central Appalachia Southwest Virginia coal seam injection project for SECARB Partnership** Steve Carpenter, Advanced Resources International
15.50	**Discussion & conference summary** Max Coleman, NASA Jet Propulsion Laboratory
16.20	**Tea & coffee**
Session 5: CCS debate from 16.50	

Poster programme

Preliminary evaluation of offshore transport and storage of CO_2 Steve Carpenter, Advanced Resources International
Prospects for aquifer CO_2 storage in the Bunter Sandstone domes, UK Southern North Sea John Williams, British Geological Survey
CO_2 storage potential in reservoir – aquifer of Daqing Oil Field, Northeast China Rongshu Zeng, Institute of Geology and Geophysics
A case study on CO_2 EOR and storage potential in Shengli Oil Field, Jiyang Depression, China Shu Wang, Institute of Geology and Geophysics

ORAL ABSTRACTS

Deep geological storage of CO2: challenges to development

Stuart Haszeldine, Professor of Carbon Capture and Storage

SCCS, School of Geosciences, University of Edinburgh, Edinburgh. EH9 3JW
s.haszeldine@ed.ac.uk

If the evidence on ocean acidification and climate warming is credible, then capturing CO2 from combustion, and storage deep below ground, is seductively attractive. However, in spite of great ambitions, the rate of industrial-scaled storage development is minimal. Geological CO2 storage is presently visioned as assisting power plants. But storage for industry has hardly started development. And Climate Engineering to address negative emissions, with CO2 storage for air capture also needs to be developed. The geological record points to the alternative being a sixth Phanerozoic extinction.

Geological CO2 storage cannot be moved. Power plants and industries can be relocated across countries, pipes can be built for hundreds of kilometres, or emissions permits transferred internationally. But porous rocks stay in place. Carbon capture and storage for power plant has abundant attention and expenditure focused on the expense and difficulty of engineering capture. That is the current expensive step. But it can be expected that the cost and energy penalty of capture will both decline. By contrast, storage is sometimes regarded as cheap and generally available. Nonetheless, lack of verifiable storage has been the downfall of several CCS projects globally, and poor public perception of storage onshore is now a fundamental political blockage to CO2 storage.

Globally, there appears to be a lot of storage. How much is hard to tell, because of different assessment methods, and different vintages of studies. Storage assessment is initially too optimistic, and then can become pessimistic to the point of extinction.

The UK is lucky, several extensive and detailed evaluations have demonstrated a storage resource (at around 50% probability) of 30-70 Gt CO2 around the UK. Compared to annual emissions of 0.2Gt from power generation, this is optimistic that the UK has plenty of domestic storage, which is technically excellent, and could offer storage services to less fortunate nations from the EU or globally. But development of commercially bankable storage is hampered by stringent legislation on site performance, by fear of open-ended liability, the difficulty of licensing discrete subsurface zones, and by the expense of investigating and proving saline formations before CO2 revenue flows.

Without a much stronger commercial attraction, it is hard to predict that technically viable geological storage will be rapidly developed. Acceleration of storage development needs to include aspects such as: offshore injection and monitoring validation; licensing using hydrogeological principles; reduced liability timescales; capital grants for appraisal of storage; and greater profit returns. These aims could be achieved by a combination of a much higher market value for decarbonized electricity, state-led appraisal of storage, and extra revenue from Improved Oil Recovery. The alternatives impale governments of a dilemma of failed climate policy, investing in carbon-negative technologies, or diversifying out of carbon combustion energy.

Carbon Capture: New Materials for Amine Replacement

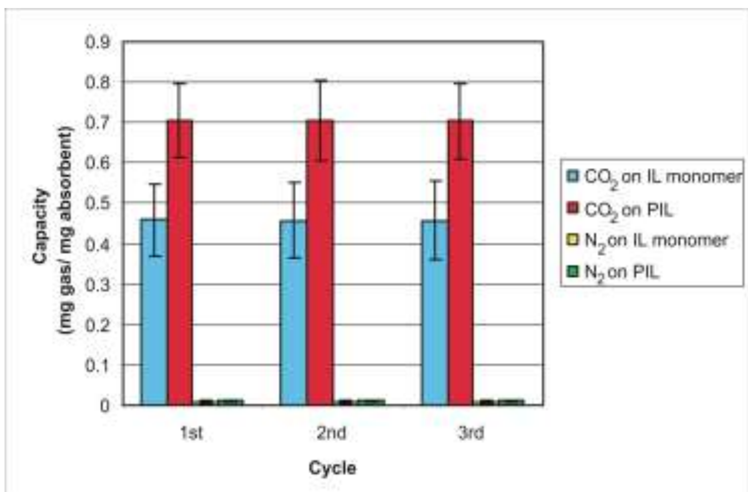
Peter Styring

Department of Chemical & Biological Engineering, Sir Robert Hadfield Building, The University of Sheffield, Sheffield S1 3JD, UK

Current carbon capture technologies use amine solvents to chemisorb the CO_2 emissions. However, there are a number of problems associated with amine use such as toxicity of the amine and its by-products, the large volumes required to accommodate amine solutions and the high energy penalty associated with temperature swing adsorption-desorption cycles. Other alcohol-based solvents have also been used but these tend to have lower performance specifications[1].

Recently we described some new carbon capture solvents based on ionic liquids and poly(ionic liquid)s.[2] These are low vapour pressure[3] solvents (or solids) that can capture CO_2 using chemisorption and/or physisorption. The benefit of the latter interaction is a lower energy penalty in the operational cycle. The nature of the associations between CO_2 in the anion and cation in the ionic liquid have been investigated and a conclusion reached that it is the nature of the substituents on the anionic motif that have the greatest influence on activity and selectivity. Furthermore, the ionic liquids are used in their pure form, rather than diluted in aqueous solution like the amine capture agents, and so occupy less plant volume and hence can reduce capital costs in post-combustion capture units.

Because of their low vapour pressures and stability at operational temperatures, ionic liquids do not contaminate the liquid or vapour phases and can be used in Carbon Capture and Utilisation (CCU)[4] applications.



1. O. Aschenbrenner and P. Styring, Energy Environ. Sci., 2010, 3, 1106-1113.
2. O. Aschenbrenner. S. Supasitmongkol, M. Taylor and P. Styring, Green Chem., 2009, 11, 1217-1221.
3. S. Supasitmongkol and P. Styring, Energy Environ. Sci., 2010, 3, 1961-1972.
4. P. Styring, D. Jansen, H. de Coninck, H. Reith and K. Armstrong, http://www.lowcarbonfutures.org/assets/media/clcf_ccu_report_21_july_final_sm.pdf.pdf

CO_2 sequestration

Mercedese Maroto-Valer

University of Nottingham

Carbon capture and storage (CCS) technologies have the potential to reduce overall mitigation costs and maintain the use of fossil fuels as an energy source in the short-term, whilst future non-fossil based fuel energy systems are developed and implemented. CCS is a process consisting of the separation of CO2 from industrial and energy-related sources, its transport to a geological formation and long term isolation from the atmosphere. This paper reviews key areas of CO2 sequestration in geological formations, including physical and chemical trapping mechanisms, storage capacity and costs. In addition, CO2 sequestration above-ground by mineralisation will also be discussed.

Industry, clustering and CO_2 transport

Professor Dermot J Roddy

Newcastle University

Looking beyond the power generation sector, there is growing interest in the potential for using a Carbon Capture & Storage (CCS) approach to decarbonise energy-intensive industry. The fact that such industries are often co-located in clusters close to power stations opens up the possibility of developing multi-user CO_2 pipeline networks for collection and transportation. This presentation examines the practical issues associated with retrofitting CCS to industrial facilities, explores the technical and legal issues associated with building a CO_2 network based on experience around the world with CO_2 pipeline projects, and considers the issue of costs. It also reviews the current state of knowledge on design of pipelines for CO_2 transportation. The issues involved in sizing a CO_2 network which can evolve to meet future needs are considered before concluding with a case study from North East England as an example of what is possible in an area of high CO_2 emissions.

Static CO_2 storage capacity estimation

Sam Holloway

BGS

So-called static CO_2 storage capacity estimation methods use simple volumetric calculations to estimate reservoir pore volume, and storage efficiency factors and/or pressure limits to produce CO_2 storage resource estimates. In essence, a reservoir formation is first divided into those parts that satisfy the basic requirements for CO_2 storage - including that they are sealed, at sufficient depth and meet various cut-offs such as a minimum permeability – and those parts that do not. The parts that are technically suitable and accessible are then divided into storage assessment units. These are characterised in terms of e.g. their reservoir properties, depth, temperature, pressure and boundary conditions. Simple calculations are then made to estimate the CO2 storage resource present in their pore space. The presentation will describe a methodology for producing such estimates, their likely accuracy, their relevance to policy makers and the critical role of storage efficiency factors. It will also touch on a possible way forward for policy-relevant storage capacity estimation that would allow global capacities to be estimated and compared.

Acknowledgement: The author thanks the Energy Technologies Institute, who commissioned and funded much of this work as part of the UK Storage Appraisal Project, and also all the project participants for their support and contributions.

Estimating Dynamic CO_2 Capacity of UKCS Deep Saline Aquifers

Eugene Balbinski

RPS Energy

The collaborative UK Storage Appraisal Project (UKSAP) has recently made systematic CO_2 storage estimates of both ‘static’ and ‘dynamic’ capacity in offshore UK saline aquifers and hydrocarbon fields. This presentation explains what is meant by dynamic storage capacity in this context and how such estimates can be made for saline aquifers. It presents the UKSAP classification of saline aquifers into different storage types, focussing on those classified as ‘open’.

The particular issues arising for ‘open’ aquifers regarding storage definition and estimation and the relevant EU guidelines are discussed. A set of assumptions taking account of these considerations which facilitates estimates of dynamic storage capacity from simplified models is presented. It is explained how numerical simulation of single injector simplified models can be used to estimate dynamic capacity for large open aquifers requiring multiple injectors. In making these estimates it was convenient to divide the simplified open aquifer models into three storage regimes. It is explained how these storage regimes are used in the UKSAP CarbonStore database to make estimates of dynamic storage capacity for UK offshore open saline aquifers.

Acknowledgement: The author thanks the Energy Technologies Institute, who commissioned and funded this work as part of the UK Storage Appraisal Project, and also all the project participants for their support and contributions.

The impact of geological structure on CO2 storage in the Bunter Sandstone, UK

Kate Thatcher, Amy Clarke, Jon Gluyas, Simon Mathias, Richard Davies

Durham University

The Triassic Bunter Sandstone of the UK's Southern North Sea is a high quality reservoir with large volumes in depleted gas reservoirs and brine formations that could be used for CO_2 storage. We are interested in how two scales of geological structure affect CO_2 storage. At the formation scale, production and pressure data, along with a 3D structural model have been used to assess compartmentalisation within the target reservoirs. This has implications for containment and the volume of CO_2 that can be stored in a predicted location. At the sub-km scale, numerical models of CO_2 injection into a stochastically generated fluvial channel network have been used to study pressure build-up in a brine formation. We investigate the influence of the channel network on the spread of the CO_2 plume and on injection well pressure. These detailed studies illustrate the type of site characterisation that is necessary to assess storage volume, rates of injection and longer term stability of the storage site.

Geological CO_2 storage – how is CO_2 trapped?

Martin Blunt

Imperial College London

Carbon capture and storage (CCS), where CO_2 is injected into geological formations, has been identified as an important way to reduce CO_2 emissions to the atmosphere. While there are several aquifers worldwide into which CO_2 has been injected, there is still uncertainty in terms of the long-term fate of the CO_2. Simulation studies have proposed capillary trapping – where the CO_2 is stranded as pore-space droplets surrounded by water – as a rapid way to secure safe storage. However, there has been no direct evidence of pore-scale trapping. We have imaged trapped CO_2 clusters that occupy up to 25% of the pore space at representative storage conditions with micro-computed tomography (μ-CT) and measured the distribution of trapped cluster size; this work suggests that capillary trapping could be an effective, safe storage mechanism.

We then discuss implications for field-scale design of storage sites.

CO_2 EOR and Storage in the North Sea: A Developer's Perspective

James Lorsong & Gareth Roberts

2Co Energy Limited, 14 Buckingham Street, London WC2N 6DF
james.lorsong@2coenergy.com

CO_2 storage in conjunction with enhanced oil recovery (EOR) offers inherent advantages in net cost and geological security. Although CO_2 EOR has been considered for North Sea reservoirs for more than 30 years, logistical and economic barriers have hindered deployment. The Don Valley Power Project is designed to provide 4.5 Mt of CO_2 per year, which could create sufficient scale to make EOR an attractive alternative to storage alone. We discuss the current CO_2 EOR practices in North America and potential applications in the UKCS.

Limited sequestration of CO_2 in natural analogue quantified by stepwise C & O stable isotope extraction

N. Heinemann[1], M. Wilkinson[1], A. E. Fallick[2], R. S. Haszeldine[1]

*[1]School of GeoSciences, The University of Edinburgh, The King's Buildings,
West Mains Road, Edinburgh, EH9 3JW*
[2]Scottish Universities Environmental Research Centre, East Kilbride, G75 0QU, Scotland
N.Heinemann@sms.ed.ac.uk

Natural storage analogue studies allow calibration of extrapolated, experimentally-determined, mineral reaction rates during geological storage. The southern North Sea (UK) Fizzy gas accumulation (c. 50% natural CO_2) contains dolomite cement which could be 'normal' diagenetic or sequestered late CO_2 charge. Previous work using an adjacent gas field with low CO_2 content as a standard suggested that 0 – 25 % of the CO_2 in the Fizzy field is currently sequestered.

Stepwise extraction of CO_2 from dolomite from the Fizzy and the Orwell fields yields similar but not identical C & O ratios. While the cores of the dolomites are very similar, the rims of the Fizzy field have more positive □^{13}C ratios, closer to the calculated equilibrium for the present-day CO_2 than those of the Orwell field control. Mass balance suggest that 0 – 10 % of the total CO_2 in the Fizzy field is sequestered at present day, both confirmation of, and an improvement on, the previous estimate.

Evaluating the structural integrity of fault-bound traps for CO_2 storage

Graham Yielding & Peter Bretan

Badley Geoscience Ltd

The successful storage of CO_2 in structural (faulted) traps requires, amongst other things, a thorough evaluation of all the potential factors that may result in leakage from the trap. In a typical fault-bound trap, three key factors need to be considered:

1) *3D geometry* of the reservoir intervals at key faults in the trap in order to determine if the host reservoir is in contact (juxtaposition) with a reservoir on the other side of the fault (possible across-fault leakage), or is in contact with a non-reservoir (~side-seal). Building and verifying a 3D geological model of the trap is a pre-requisite for this step.

2) *Capillary properties of Fault Rock,* generated as a result of fault movement, which can result in the development of a lateral fault seal to the trap even if reservoir juxtaposition is present. Predictive algorithms such as Shale Gouge Ratio can be used to estimate the amount of shale that has been entrained into the fault rock. These fault-seal attributes can be calibrated to derive the potential height of a CO_2 column the fault could support before CO_2 leaks through the fault rock across the fault.

3) *Fault Reactivation* potential in the in-situ stress field, to determine if the fault is strong enough to support the increasing pore pressure generated by CO_2 injection. If a fault is close to failure, dilatant micro-fractures could provide migration pathways which allow buoyant fluids to migrate up the fault and thus escape from the trap. The potential for failure is generally expressed in terms of some measure which indicates the proximity to the rock failure envelope, for example Slip Tendency for sliding on cohesionless faults, or Fracture Stability if the fault rock has some mechanical strength.

A workflow for evaluating the structural integrity of traps is illustrated using case studies from the North Sea. The first study is from a field in the Southern North Sea where CO_2 rich (50%) gas is trapped in sandstones of the Rotliegend Group. The second case study comes from an integrated 3D study into the proposed CO_2 storage in the Johansen Formation in the Troll field, offshore Norway.

Structural uncertainty: Why it matters to Carbon Storage

G. Johnson, R. Wightman, J. Grocott, and A. Gibbs

Midland Valley, 144 West George Street, Glasgow, G2 2HG.

The successful operation of a carbon storage site requires that the storage complex has demonstrable effective capacity, containment and injectivity. These three requirements cannot be fully appraised without the construction of a 3D geological model of the storage complex to allow, for example, volumetric assessments, potential spill pathways and further dynamic reservoir modelling. To construct a 3D structural framework requires the compilation of various forms of data (e.g. wellbore, seismic, and surface data). However, uncertainty is intrinsic to nearly all forms of geological data (Mann, 1993, Davis, 2002). Uncertainty can be reduced by applying best practice approaches developed in the oil and gas and mining sectors to construct structurally valid 3D geological models. Specifically, establishing valid structural models allows the identification and reduction of type 1 and type 3 uncertainties defined below.

A structurally valid model is one which incorporates the kinematic history of the model to assess the dynamic development of the structure. A complete structural restoration incorporates line length and area balancing techniques, decompaction and reconstruction that establishes the (in)validity of the interpretation. Impacts of an invalid interpretation can be costly in an exploration setting and in a CCS setting can affect all three requirements of a storage complex. Uncertainty can be classified by type, for example, Wellmann et al. (2010) propose three types of specific structural uncertainties: 1) imprecision and measurement error; 2) stochasticity, and; 3) imprecise knowledge. The first type is exemplified by resolution issues in seismic data or the inability to exactly pick a lithological boundary from a well-log. The second type is typified by interpolation errors (and is essentially dependent on data density) and the third type can arise from ‘conceptual uncertainty’. Bond et al. (2007) described the experiential bias introduced in the interpretation of a forward-modelled synthetic seismic section demonstrating type 3 uncertainties. Here, as well as bias based on previous experience of structural styles, the authors showed that when interpreters considered the development of the structure through time, they were much more likely to interpret the ‘real’ structure. Hence, in CO_2 storage projects it is critical to understand the dynamic development of a structure to arrive at a valid interpretation and thus 3D model of the storage complex.

We present data from a case study where a full understanding of the kinematic history of the structure allows greater understanding of the role geology may play in capacity, containment, and injectivity of CO_2 storage projects. We show that the establishment of the structural geological history through restoration and balancing enables greater assessment of containment and capacity whilst it also permits the subsequent development of a structurally grounded ‘fracture recipe’. This recipe contains various proxies for fracture generation based on forward modelled strains of a structure which when realised can be tested for stability in present day stress fields. This information can then be used by reservoir modellers to predict fracture control on CO_2 plume migration and thus impacts fractures have on injectivity of CO_2.

References

Bond, C.E., Gibbs, A.D., Shipton, Z.K., and Jones, S., 2007. What do you think this is? “Conceptual uncertainty” in geoscience interpretation. GSA Today, v.17, n.11, p.4-10.

Davis, C.J., 2002. Statistics and Data Analysis in Geology, 3rd Edition. Wiley, New York, NY.

Mann, J.C., 1993. Uncertainty in geology. Computers in Geology—25 Years of Progress. Oxford University Press, pp. 241–254.

Wellmann, J.F., Horowitz , F.G., Schill, B., Regenauer-Lieb, K., 2010. Towards incorporating uncertainty of structural data in 3D geological inversion. Tectonophysics, v.490, n.3-4, p141-151.

Caprock and fault integrity: insights from experiments on Bunter and Rotliegend topseals

Anne Pluymakers, Jon Samuelson, Suzanne Hangx[1] and Chris Spiers

HPT Laboratory, Faculty of Geosciences, Utrecht University, The Netherlands
[1]Now at: Shell Global Solutions International

For safe storage of CO_2 it is important to maintain topseal integrity and to avoid reactivation of, and subsequent leakage through, fault zones. We have conducted triaxial strength tests, as well as simulated fault shearing and healing tests, on caprocks from a) the Zechstein anhydrite overlying the Rotliegend reservoir sequence, and b) the Röt /Solling claystones overlying the Bunter reservoirs. Triaxial tests indicate that CO_2 has no significant influence on the failure strength of Zechstein anhydrite under in-situ conditions. Fault healing experiments indicate that compaction and healing/sealing of wet anhydrite fault gouge is rapid and involves solution transfer processes. The influence of CO_2 on fault healing and reactivation in anhydrite are currently being analyzed. Direct-shear tests on Röt/Solling claystones indicate that neither the frictional strength nor slip stability of reservoir fault zones will be affected by CO_2 in the short-term. Measurements of the influence of long term mineralogical changes are ongoing.

Estimating injectivity for saline aquifers – The UKSAP method

Simon Mathias (Durham University), Grahame Smith (Senergy Global), Eugene Balbinski (RPS Group), Jeff Masters (RPS Group)

There has been much effort focused on estimating volumetric CO2 storage capacity in saline aquifers over large regional areas in many different countries. But such estimates are of limited value if not attached to some form of associated economic cost. A major geologically dependent factor in this respect is the number of injection wells needed to utilize the storage capacity within a practical amount of time. This paper presents and discusses the various methods used to estimate number of injection wells needed for to utilize the hundreds of saline aquifer units contained within the recently completed, Energy Technology Institute funded, UK Storage Appraisal Project (UKSAP). The paper covers a range of issues including: maximum pressure stipulation, injection pressure estimation and how to deal with open and closed aquifers. Finally the paper presents relevant regional scale findings from UKSAP concerning utilization of saline aquifers in the North Sea and their economic implications.

Monitoring

Bernd Wiese

Potsdam

The injection of CO_2 into the subsurface at the Ketzin test site, Brandenburg (Germany), is monitored simultaneously by distributed temperature sensing (DTS) and two pressure sensors located at the wellhead and in 550 m depth. The data is used to recalculate a continuous pressure profile along the entire length of the injection well. The data allow calculate the thermodynamic properties of the CO_2 inside the injection well as well as potential phase transitions during the injection process. Due to compression a heat flux establishes between injection well and subsurface. Two methods are applied to determine the heat flux: a: direct calculation based on the thermodynamic state b) Local temperature differences of the DTS data occur due to different distance of the DTS cable to the heat source. The magnitude of these differences is proportional to the heat flux.

Monitoring subsurface CO_2 emplacement and security of storage using muon tomography

Vitaly A. Kudryavtsev[1], Neil J. C. Spooner[1], Jon Gluyas[2], Cora Fung[1], Max Coleman[3]

[1]*Department of Physics and Astronomy, University of Sheffield, Sheffield, S3 7RH, UK*
[2]*Department of Earth Sciences, Centre for Research into Earth Energy Systems, Durham University, Durham, DH1 3LE, UK*
[3]*Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA*

The monitoring of carbon storage sites during CO_2 emplacement and subsequent storage (to detect for possible leakage) is a major challenge. The methods available today, particularly those which can be applied to offshore sites are episodic and expensive. An elegant solution may be provided by cosmic-ray muon tomography, muons being the subatomic unstable particles produced from oxygen and nitrogen atoms, in the upper atmosphere in collision of protons and heavy nuclei accelerated in remnants of supernova explosions. Muon tomography has already been used to seek archaeological and geological features. We developed a model to test if this approach would work for monitoring CO_2 storage and show that muon detection is a viable method. Our results indicate that we could detect as little as 0.4% change in the mean reservoir density at about 1 km depth (equivalent to 7% of pore volume). Hence, cosmic ray muon detection could monitor migration of injected CO_2 continuously and inexpensively relative to seismic monitoring and help rapid introduction of this essential technology.

The framework for storage risks and risk assessment in geological storage

Bill Senior

Senior CCS Solutions Ltd
bill@senior-ccs.co.uk

Ensuring that geological storage is safe and secure is a key objective for all stakeholders including the public, regulators and industry. This is an essential to gain public acceptance for storage. The European CCS Directive was developed on the basis that the regulatory framework for geological storage should be based on environmentally safe storage and integrated risk assessment for CO_2 leakage. Minimising leakage risks and robust assessments of storage security are also necessary to enable industry investment in storage that is a requisite for future deployment.

The CO_2 Storage Life Cycle Risk Management Framework to be used in Europe is described a European Commission Guidance Document. This emphasises that risk management should be an ongoing and iterative approach throughout the project lifecycle that addresses the risks relating to containment and potential leakage. Risk management is intended to identify, mitigate and manage identified risks and uncertainties at each stage of a storage project. It is site specific and must be integrated with site characterisation, modelling, monitoring and corrective measures. A three step approach is suggested; i) risk identification and assessment incorporating hazard characterisation, exposure and effects assessments, ii) risk ranking and ii) risk management measures.

The main risks fall in two broad categories: local safety and environmental risks and global effects resulting from release of CO_2 back to the atmosphere, negating the intended purpose of storage. The main pathways and mechanisms for leakage out of any storage site are well understood in general terms and can be evaluated for any site. The main geological leakage pathways relate to possible failures of caprocks, faults, fractures or trapping. Manmade pathways are primarily wells, both abandoned wells and operational injection wells, including the risk of CO_2 blowouts. Site specific risk assessment will depend on site geology, storage option type, injection plans, pressure evolution, trapping processes, plume development, immobilisation of CO_2, as well as the site location and setting.

Outstanding issues with storage risk assessment will be reviewed. A major challenge is the need for better characterisation, quantification and prediction of the probability of leakage, potential flux rates, duration and amount of leakage for all leakage mechanisms. Improved understanding of the dynamic controls and variation of leakage risks through time, dispersion models and marine impacts is also needed. Another requirement is for better integration between technical assessments and commercial and regulatory aspects, for example relating to transfer of liability and financial security.

CO_2 Management at ExxonMobil's LaBarge Field, Wyoming, USA

Jim Herbertson

ExxonMobil

Description

Production of natural gas containing high concentrations of CO_2 began from the LaBarge field in 1986. Since start-up, ExxonMobil has successfully implemented a wide range of technologies and approaches to effectively manage the substantial volumes of carbon dioxide (CO_2) associated with production. Many of the technologies and approaches used for managing CO_2 at LaBarge are direct examples of technologies and approaches being proposed for carbon capture and storage (CCS).

Application and Results

The Shute Creek gas plant, which processes the LaBarge field production, handles the lowest hydrocarbon content natural gas commercially produced in the world. The gas composition entering Shute Creek is 65% CO_2, 21% methane, 7% nitrogen, 5% hydrogen sulfide and 0.6% helium. The Shute Creek gas plant separates CO_2, methane, and helium for sale and removes hydrogen sulfide for disposal.

Most of the CO_2 captured at Shute Creek is ultimately used for enhanced oil recovery (EOR). EOR is consistently cited as one of the most viable early opportunities for large scale implementation of CCS. ExxonMobil's LaBarge operation is the largest demonstration of this approach to CCS in the world today. Currently, ExxonMobil provides 7 million tons per year of CO_2 for EOR.

A concentrated sour gas stream of 2/3 hydrogen sulfide and 1/3 CO_2 is injected down structure into the same reservoir from which it was produced, safely disposing of the hydrogen sulfide along with approximately 400,000 tons per year of CO_2. Other technologies and approaches that have reduced CO_2 emissions include the ExxonMobil patented low BTU fuel co-generation system that reduces CO_2 emissions by about 50% when compared to emissions from purchased power.

Significance

Cumulatively, through the application of these technologies, ExxonMobil is capturing and managing over 75% of the CO_2 produced from the LaBarge field.

Additionally, new technologies are being demonstrated or developed that can provide additional reductions in emissions, either at this site of others with similarly challenged production streams. Construction has started on a demonstration plant to commercialize the ExxonMobil invented Controlled Freeze Zone (CFZ) gas treatment technology. CFZ allows separation of CO_2 and other gas contaminants from a gas stream without the use of solvents or absorbents. Successful commercial demonstration of CFZ would enable the development of increasingly sour gas resources around the world by substantially reducing gas treatment costs and integrate easily with geo-sequestration of sour gas components and EOR.

Experience Gained

ExxonMobil has led the greenfield development of a viable CO2 market based on EOR and industrial uses since the start of production at the LaBarge field in 1986.

Operations at the Shute Creek Treating Facility have demonstrated the safety and viability of commercial scale CO2 capture – CO2 avoided equivalent to emissions from a ±650 MW coal fired power plant.

Over 75% of the produced CO2 is controlled.

A new CO_2 separation technology for produced gas, Controlled Freeze Zone (CFZ™) is currently under commercial scale testing.

Carbon capture and storage in the Cambrian and Ordovician strata of the Illinois Basin, USA

Hannes E. Leetaru[1], and Robert J. Finley [1]

[1]*Illinois State Geological Survey, 615 E. Peabody Dr, Champaign, IL 61820, USA*

The Cambro-Ordovician strata form the most important carbon sink available for the sequestration of CO_2 in the heavily industrialized Midwest of the United States. The three most significant sequestration reservoirs are the Cambrian Mt. Simon Sandstone, Cambrian carbonate intervals in the Knox Group, and the Ordovician St. Peter Sandstone.

The evaluation of these formations was accomplished using wireline logs, core data, pressure data, and seismic data from the USDOE-funded Illinois Basin Decatur-Project being conducted by the Midwest Geological Sequestration Consortium (MGSC) in Macon County, Illinois. All three reservoirs have significant potential. The Knox reservoir is composed of interconnected solution cavities that make CO_2 plume prediction difficult. The St. Peter is a potential reservoir, but at 52 m (170 feet) thick has less storage capacity than the Mt. Simon. The Mt. Simon is over 487 m (1600 feet thick) at Decatur and has porosities ranging up to 30 percent and permeabilities of over a Darcy. The basal Mt. Simon contains the best reservoir facies and was deposited in a braided river – alluvial fan system. The middle section of the Mt. Simon has permeabilities of less than 1 mD and was deposited in a marine depositional environment. Reservoir flow simulation suggests that this middle section is a baffle that impedes the flow of CO_2 into the upper Mt. Simon. The porous upper Mt. Simon was deposited in a nearshore tidally influenced environment.

By fall 2011the MGSC should be injecting 1000 tonnes per day of CO_2 into the basal Mt. Simon at 2133 m (7000 feet) for a three year period to test the sequestration potential of this formation. Planned subsurface monitoring of the CO_2 plume include a verification well 305 m (1000 feet) from the injection well with continuous monitoring of pressures and sampling of formation waters from multiple intervals within the Mt. Simon, a permanent geophone well for 4D VSP acquisition and a 4D surface seismic program. Reservoir simulation and the subsurface monitoring are to be used to help manage the areal extent of the plume by using these data to recommend changes in the injection interval through time. At least two other Illinois CCS projects with planned injection rates of over 3000 tonnes per day are also in development and should begin injection into the Mt. Simon in the next couple of years.

Learning by doing: CCS in Australia

Peter J Cook

CO2CRC and the University of Melbourne, Australia

Australia has a number of proposals for large scale development of CCS under consideration and one major CO_2 storage project under construction as part of the Gorgon LNG project which will commence CO_2 injection in 2014-2015.

However, Australia's first and its only operational storage project at the present time is the CO2CRC Otway Project, where 66,000 tonnes of CO_2 have been injected into sanstones at depths ranging from 2000-1500m. The project has served as an outstanding example of international collaborative research. The cost of the project to date is of the order of $60 million
Initially in 2008, CO_2 injection was into a depleted gas field and this provided a range of important science outcomes in terms of monitoring, CO_2 migration and storage efficiency. It was valuable for the operational experience of CCS that it provided, including successfully working with the local community. More recently, in 2011, the Centre has been undertaking a series of highly innovative field experiments, with the aim of determining residual saturation of CO_2 in a heterogeneous aquifer system, followed by work to determine minimum detection levels for CO_2 using 3D seismic.

The work of the CO2CRC Otway Project has been very influential in the development of an onshore CCS regulatory regime and in providing first hand experience of CCS to the EPA. It has also been an extraordinarily valuable resource for informing politicians, decision makers and the public at large about CCS and for demonstrating the technical feasibility of geological storage.

Injectivity and storage update on the DOE-NETL Central Appalachia Southwest Virgina coal seam injection project for SECARB Partnership

Steven M Carpenter

Advanced Resources International, 1282 Secretariat Court, Batavia, OH 45103
scarpenter@adv-res.com 513-460-0360

The US Department of Energy – National Engineering Laboratory (DOE-NETL) has funded the Southern States Energy Board (SSEB) who manages the CCS projects for the Southeastern Carbon Sequestration Partnership (SECARB) as one of the seven Regional Carbon Sequestration Partnerships. The Partnerships are charged with pursuing technical and marketable applications for carbon capture and storage. These partnerships have revealed application successes and constructability realities that must be addressed in order for this technology to become marketable, scalable and more importantly, used by industry.

An overview will be presented and specific details of the Virginia Coal Seam Carbon Sequestration project will be shared. The Virginia project uses Enhanced Coalbed Methane as an offset to the project to increase fuel production and to take advantage of existing infrastructure for the sequestration. Specifically, the regional storage impact, site injection and conclusions and plans for Phase III large scale site injection will be discussed.

POSTER ABSTRACTS

Preliminary evaluation of offshore transport & storage of CO_2

Steven M. Carpenter

Advanced Resources International, 1282 Secretariat Court, Batavia, OH 45103
scarpenter@adv-res.com 513-460-0360

The DOE-NETL has funded the Southern States Energy Board (SSEB) who have teamed with IOGCC (and others) to prepare a report that will have as its primary objective to conduct studies to evaluate the potential for geological storage of CO2 utilizing existing offshore oil and natural gas fields in the Gulf of Mexico nearing the end of productive life, and in areas that have not been subject to oil and natural gas production (other than GOM). These offshore geologic settings, along with wells and infrastructure (where it exists), may be suitable for CO2 sequestration with the adaptation of technical, regulatory, and business modifications. Inherent within this objective is the consideration of:

(1) resource mapping of CO2 storage potential and infrastructure in SECARB's offshore areas under Federal jurisdiction in the Gulf of Mexico;
(2) resource mapping of CO2 storage potential and infrastructure in the SECARB region offshore areas under state jurisdiction, and
(3) the current legal and regulatory structures and opportunities in applicable jurisdictions.

The final report will be completed and submitted to DOE-NETL prior to the conference and this will be the first public opportunity to discuss the findings and recommendations of the technical committee.

Prospects for aquifer CO_2 storage in the Bunter Sandstone domes, UK Southern North Sea

J D O Williams, S A Hannis, G A Williams, S Holloway

BGS

The Bunter Sandstone Formation in the UK Southern North Sea is folded into a series of periclines with very large pore volumes. Typically these are overlain by many hundreds of meters of fine-grained cap rocks. Some periclines reservoir natural gas (though few are full to spill point) but many are water-bearing. The greatest risks to the CO_2 storage prospectivity of the periclines are that reservoir quality is variable and many of the cap rock successions that overlie the periclines are partially or fully transected by faults. This presentation will describe (a) the petrographical and reservoir property variation in the Bunter Sandstone and (b) consider what can be learnt about the CO_2 storage prospects of the water-bearing Bunter periclines from the seismically resolvable faults in the cap rocks overlying some of the Bunter gas fields.

CO_2 Storage Potential in Reservoir- aquifer of Daqing Oil Field， Northeast China

Rongshu Zeng Shu Wang

Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing， China

This article made an approximate evaluation of the CO_2 storage potential in the reservoir-aquifer of Daqing Oilfield. The reservoir-aquifer is defined as the aquifer which located in the oil and gas reservoirs in Daqing Oilfield. 24 suitable reservoir-aquifers for CO_2 storage were chosen after geological and engineering analyses. The evaluation method of CO_2 storage potential in saline aquifers is used to calculate the potential in reservoir-aquifers because of the similarity of the two kinds of aquifers. The relative elements include the volume, irreducible water saturation of the reservoir and the CO_2 solubility in formation water. Area factor and thickness factor are used to determine the effective volume for CO_2 storage. In conclusion, the total CO_2 storage potential of the reservoir-aquifer in Daqing Oilfield is about $4\times10^9 \sim 9\times10^9$t. The reservoir-aquifer could be considered as a good CO_2 storage site.

A case study on CO_2 EOR and storage potential in Shengli Oil Field, Jiyang Depression, China

Shu Wang Rongshu Zeng

Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing China

A combined CO_2 storage potential evaluation method was suggested by the authors, based on literatures analyzed and summarized. The method included geological analysis, engineering assessment and potential evaluation sections. By this method a case study of CO_2 storage and EOR potential in maturing fields of Shengli Oil Field, Jiyang Depression, East China was investigated. 41 reservoirs in 183 candidate reservoirs were chosen to be CO_2 storage reservoir, among which 18 reservoirs were suggested during CO_2 EOR (also). Through evaluation, the total incremental oil production of chosen reservoirs is 21.05×10^6t; the total CO_2 storage potential is 136.99×10^6t. The result analysis shows that incremental oil recovery factor for single reservoir ranges for 8% to 20%. And the geological reserve (OOIP) has approximate quadratic polynomial relation with CO_2 storage potential. Such results indicate that Shengli oilfield is suitable for CO_2 EOR and CO_2 storage.

Burlington House
Fire Safety Information

If you hear the Alarm

Alarm Bells are situated throughout the building and will ring continuously for an evacuation. Do not stop to collect your personal belongings.

Leave the building via the nearest and safest exit or the exit that you are advised to by the Fire Marshall on that floor.

Fire Exits from the Geological Society Conference Rooms

Lower Library:
Exit via main reception onto Piccadilly, or via staff entrance onto the courtyard.

Lecture Theatre
Exit at front of theatre (by screen) onto Courtyard or via side door out to Piccadilly entrance or via the doors that link to the Lower Library and to the staff entrance.

Main Piccadilly Entrance
Straight out door and walk around to the Courtyard.

Close the doors when leaving a room. **DO NOT SWITCH OFF THE LIGHTS**.

Assemble in the Courtyard in front of the Royal Academy, outside the Royal Astronomical Society.

Please do not re-enter the building except when you are advised that it is safe to do so by the Fire Brigade.

First Aid

All accidents should be reported to Reception and First Aid assistance will be provided if necessary.

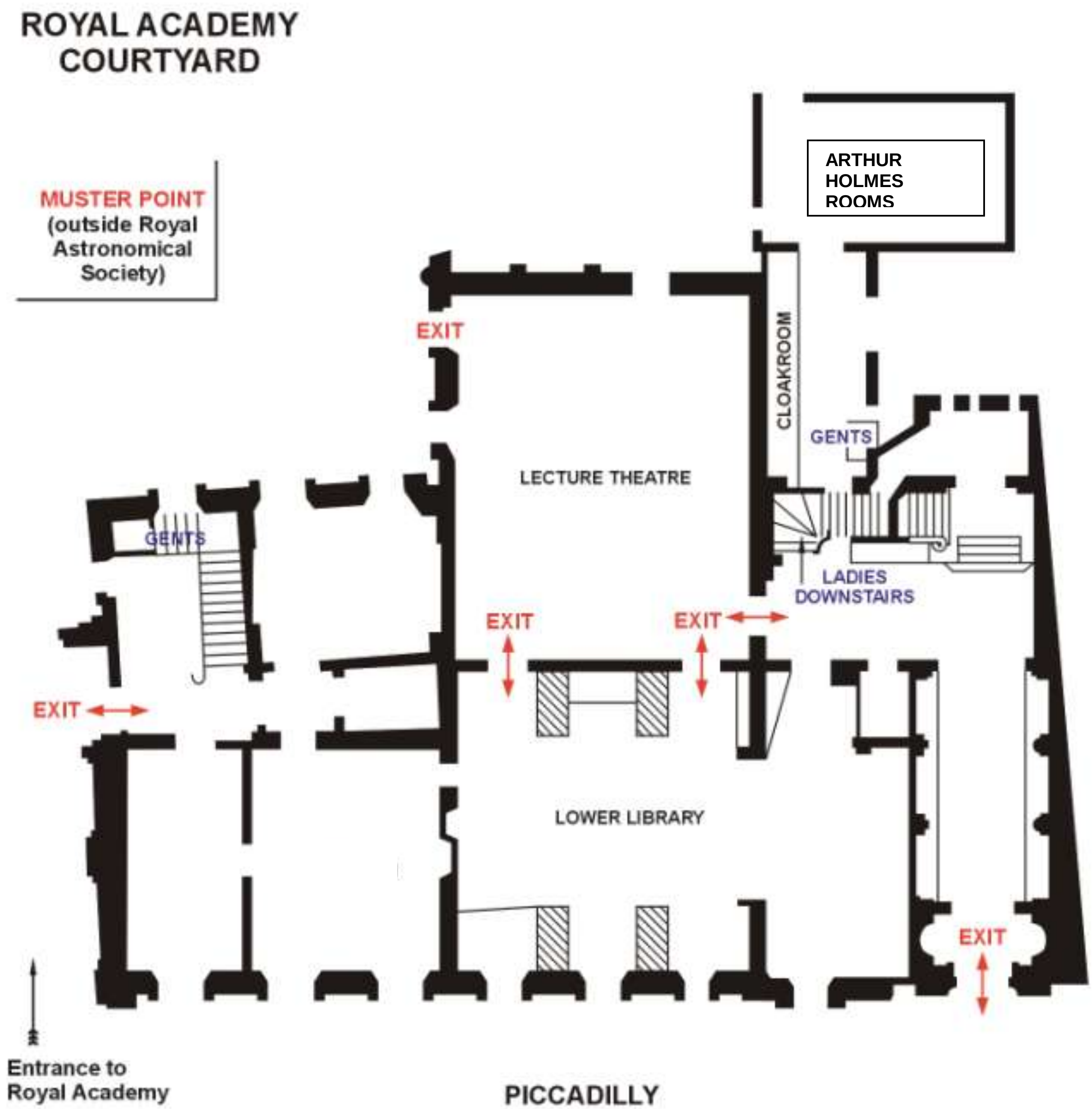
Facilities

The ladies toilets are situated in the basement at the bottom of the staircase outside the Lecture Theatre.

The Gents toilets are situated on the ground floor in the corridor leading to the Arthur Holmes Room.

The cloakroom is located along the corridor to the Arthur Holmes Room.

Ground Floor Plan of the Geological Society, Burlington House, Piccadilly



NOTES

NOTES

NOTES