Security of CO_2 storage in Norway

Carbon dioxide capture and storage (CCS) in deep saline aquifers is implemented full-scale at the Sleipner gas field in Norway. The offshore gas field Sleipner, in the middle of the North Sea, has been injecting 1 million ton CO_2 per year since 1996 without leakage.

Semere Solomon, 21/02-2007

The Sleipner project, operated by the Norwegian oil and gas company Statoil, is a commercial project which involves several different actors, including energy companies, scientific institutes and environmental authorities from Norway, Denmark, the Netherlands, France, UK and the EU. The project started under the auspices of the Saline Aquifer CO_2 Storage (SACS) research and development project. The Sleipner CO_2 injection project is undertaken by Statoil and the operator found that it is easier as well as more economical to separate the CO_2 (4 to 9.5 % in content) from the natural gas and re-inject it instead of paying a CO_2 tax. The removed CO_2 is injected into salt water containing sand layer, called the Utsira formation, which lies 1000 meter below sea bottom (Figure 1). Saline formations (i.e. deep underground porous reservoir rocks saturated with brackish water or brine) can be used for storage of CO_2.

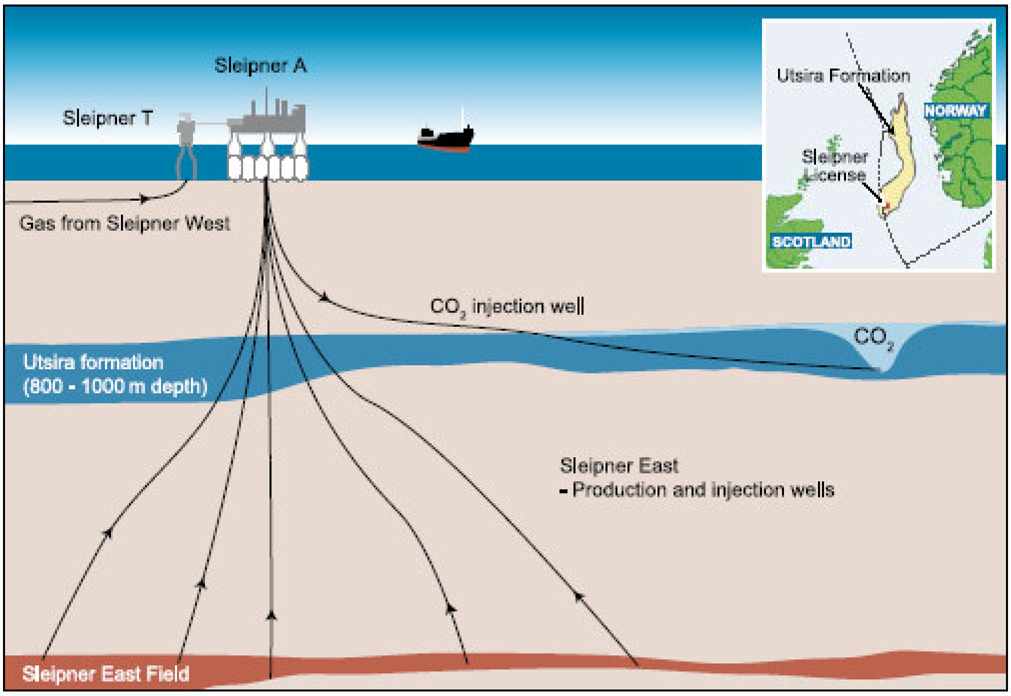

Figure 1: Simplified diagram of the Sleipner CO_2 Storage Project. Inset: location and extent of the Utsira formation [1].

Site characterization

The Sleipner reservoir was mapped and characterised using regional two dimensional (2D) seismic datasets and well data (Figure 2a), while more detailed work was carried out around the injection site using a three dimensional seismic dataset and more closely spaced well data (Figure 2c). The Utsira formation is a highly elongated sand reservoir, extending for more than 400 km from north to south and between 50 and 100 km from east to west, with an area of some 26 100 km^2 (Figure 2b). The distance from the top of the Utsira formation to the surface, generally ranges from 700 to 1000 m. The thickness of the sand layer varies from around 200 m and range up to more than 300 m in certain areas [2]. The Utsira Formation has a good storage quality with respect to porosity, permeability, sealing capacity and storage capacity. It is estimated that below 800 m depth the formation has a pore volume of 9.18 x 10^{11} m^3 with a storage capacity of the entire aquifer 42 Gt (giga ton) CO_2 [3]. This roughly corresponds to 500 – 600 billion cubic meter CO_2, which equals 400 years of CO_2 emissions from fossil fuelled power plants in the EU.

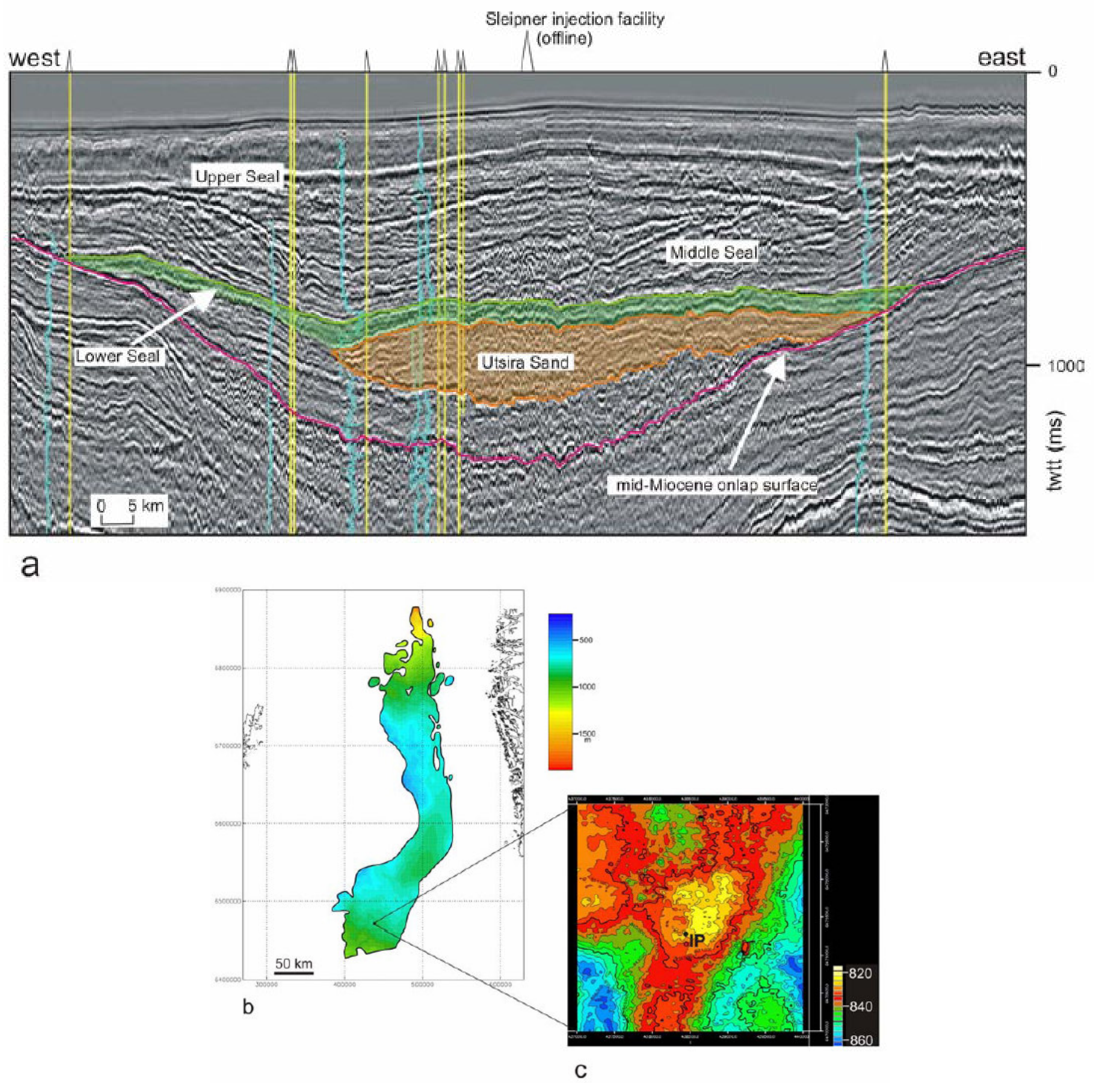

Figure 2: a) Typical 2D seismic reflection profile across the Utsira reservoir b) Regional depth map of the top of the Utsira Sand, based on 2D seismic surveys and incorporating 3D data around Sleipner injection point. c) Detailed depth map of the top of the Utsira Sand around Sleipner injection point (IP), based on 3D seismic data, source [2].

Storage security

The study of the Sleipner area demonstrates the geological security of CCS in deep saline aquifers [2] and [4]. Available geological information shows absence of major tectonic events (disturbance of the rocks by geological structures such as faults) after the deposition or creation of the Utsira formation. This implies that the geological environment is tectonically stable and a site suitable for CO_2 storage. Microseismic (shaking and vibration at the surface of the earth resulting from underground movement due to CO_2 injection) studies suggest that the injection of CO_2 in sands of the Utsira Formation can not trigger or cause any measurable

The Bellona Foundation
P.O. Box 2141 Grünerløkka, 0505 OSLO, NORWAY
Phone: 23 23 46 00 Fax: 22 38 38 62
E-mail: bellona@bellona.no, URL: http://www.bellona.no

movements of the ground. This further builds confidence in the geological security of CO_2 storage at Sleipner [4]. Moreover, evidence from ten years experience of CO_2 storage shows no leakages [2]. The site is well characterized and the CO_2 injection process was monitored using both time-lapse (measurements taken at different time intervals) seismic and gravity methods which provided insights into the geometrical distribution of the injected CO_2 and verified safe injection (Figure 3). The injected CO_2 will potentially be trapped by geochemical processes. Solubulity trapping has the effect of eliminating the buoyant forces that drive CO_2 upwards, and through time it can lead to mineral trapping, which is the most permanent and secure form of geological storage [5].

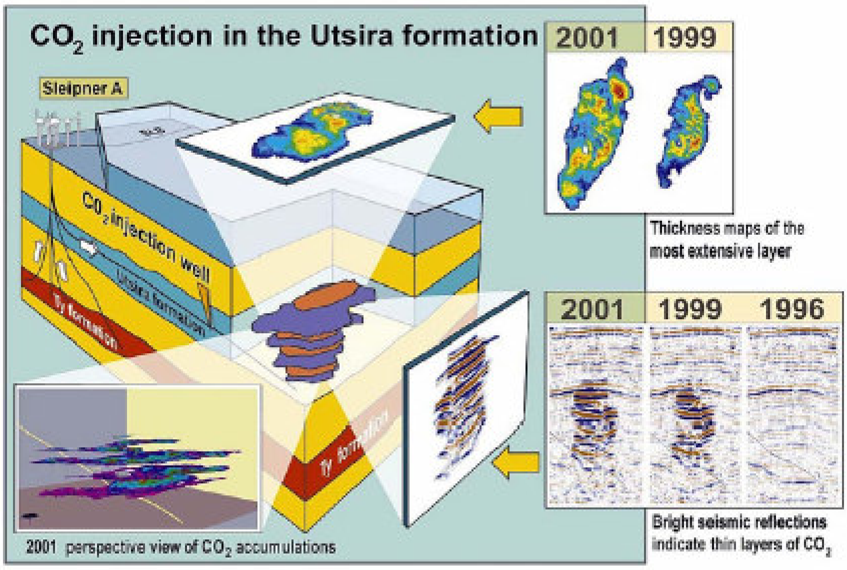

Figure 3: Repeat seismic surveys and position of injected CO_2 [6].

References:

[1] IPCC, 2005: IPCC Special Report on Carbon Dioxide Capture and Storage. Prepared by Working Group III of the Intergovernmental Panel on Climate Change [Metz, B., O. Davidson, H. C. de Coninck, M. Loos, and L. A. Meyer (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 442 pp.

[2] Best Practice manual, 2004: S. Holloway, A. Chadwick, E. Lindeberg, I. Czernichowski-Lauriol and R. Arts (eds.), Saline Aquifer CO_2 Storage Project (SACS), 53 pp.

[3] Bøe, R., C. Magnus, P.T. Osmundsen and B.I. Rindstad, 2002: CO_2 point sources and subsurface storage capacities for CO_2 in aquifers in Norway. Norsk Geologiske Undersøkelse, Trondheim, Norway, NGU Report 2002.010, 132 pp.

[4] Solomon, S. 2006. Carbon Dioxide Storage: Geological Security and Environmental Issues – Case Study on the Sleipner Gas Field in Norway. http://www.bellona.no/artikler/notat_solomon

[5] See Bellona Fact Sheet on CO_2-storage at http://www.bellona.org/factsheets/1191921304.33

[6] Torp, T.A, Gale J. 2004. Demonstrating storage of CO2 in geological reservoirs: The Sleipner and SACS Projects. *Energy*, 29:1361-1369.

The Bellona Foundation
P.O. Box 2141 Grünerløkka, 0505 OSLO, NORWAY
Phone: 23 23 46 00 Fax: 22 38 38 62
E-mail: bellona@bellona.no, URL: http://www.bellona.no

Further readings

[7] Chadwick, R.A., R. Arts and O. Eiken, 2005: 4D seismic quantification of a growing CO_2 plume at Sleipner, North Sea. In: A.G. Dore and B. Vining (eds.), Petroleum Geology: North West Europe and Global Perspectives - Proceedings of the 6th Petroleum Geology Conference. Petroleum Geology Conferences Ltd. Published by the Geological Society, London, 15pp (in press).

[8] Chadwick, A., Noy, D., Lindeberg, E., Arts, R., Eiken, O., Williams, G., 2006: Calibrating reservoir performance with time-lapse seismic monitoring and flow simulations of the Sleipner CO_2 plume. 8th Greenhouse Gas Control Technologies conference (GHGT-8), Trondheim, June 2006.

[9] Fabriol, H., 2001. Feasibility study of microseismic monitoring (Task 5.8). BRGM Commissioned Report BRGM/RP-51293-FR (Confidential).

[10] Holloway S, Chadwick RA, Kirby GA, Pearce JM, Gregersen U, Johannessen PN, Kristensen L, Zweigel P, Lothe A, Arts R, 2002. Final Report of SACS 1 Project. Saline Aquifer CO_2 Storage: A Demonstration Project at the Sleipner Field. Technical report, The SACS Project. http://www.iku.sintef.no/projects/IK23430000/index.html.

[11] Zweigel, P. & Lindeberg, E. 2000: 4D seismikk løser gåten. *GEO 6 - 2000*, 16-18.

The Bellona Foundation
P.O. Box 2141 Grünerløkka, 0505 OSLO, NORWAY
Phone: 23 23 46 00 Fax: 22 38 38 62
E-mail: bellona@bellona.no, URL: http://www.bellona.no