MARCH 2014 9th Newsletter

MUSTANG NEWS

A MUltiple Space and Time scale Approach for the quaNtification of deep saline formations for CO_2 storaGe

ABOUT MUSTANG

MUSTANG aims at developing guidelines, methods and tools for the characterization of deep saline aquifers for long term CO_2 storage, based on a solid scientific understanding of the underlying critical processes.

Field investigation technologies specifically suited to CO_2 storage will be improved and developed. These are destined to improve the determination of the relevant physical and chemical properties of the site, and enabling short response times in the detection and monitoring of CO_2 plumes in the reservoir and overburden during both the injection and containment phases. An improved understanding of the relevant processes of CO_2 spreading is aimed at by means of theoretical investigations, laboratory experiments, natural analogue studies as well as dedicated CO_2 injection tests, a deep injection of supercritical CO_2 to take place at the Heletz site (Israel) and a shallow injection of gaseous CO_2 that has taken place at the Maguelone site (France).

MUSTANG is funded by the EU FP7 and coordinated by Uppsala University. The consortium is comprised of 19 institutions. A number of organisations are affiliated through the Scientific, Industrial and regulatory Advisory Board (SIRAB).

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MUSTANG HIGHLIGHTS 2014

- The 9th consortium meeting was held in Haifa, Israel, on September 30th - October 1st, 2013 and a one-day 10th consortium meeting was held in Barcelona, Spain February 19th, 2014, with focus on the completion and summarizing of the project results.
- A training course on CO_2 storage in saline aquifers was held in Göttingen, Germany on October 10th to 11th, 2013. This was the third MUSTANG Training course and participants, mainly PhD students and Post Docs, attended from different countries. The course was organized jointly with two other EU-projects, TRUST and PANACEA. Proceedings, including links to the presentations, are to be found at http://www.co2mustang.eu/Third-Training-Course.aspx
- Project progress has been presented in various contexts, such as Global CCUS Summit, in Beijing, China, October 22nd – 23rd, 2013.
- Work on the MUSTANG book is in an intensive stage and planned to be completed by May, 2014.
- The main work of the project has been focusing on the planning and execution of the field activities at the Heletz CO_2 injection site, where intensive work is and will be carried out to the end of the project. Laboratory analyses of the cores have also been continued, showing interesting results of rock behavior when in contact with CO_2 and/or CO_2 and brine. Modeling work has continued, in particular in terms of modeling the CO_2 behavior at other MUSTANG test sites and summarizing the MUSTANG modeling findings.

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WORK AT HELETZ CO_2 INJECTION SITE PROGRESSES TOWARDS CO_2 INJECTION (BENSABAT, J.; NIEMI, A.)

New Project deliverables are available at

http://www.co2mustang.eu/MustangDeliverables.aspx

Completion of the drilling of the injection and monitoring wells:

- The drilling operations were completed in the winter of 2012 and at the end of these operations we perforated the injection well. The monitoring well was left as an open borehole in the lower section (from the depth of 1200 m to the depth of 1640 m). In both wells cores were taken from both the caprock and the target layer and are analyzed by many partners of the consortium (UEDIN, CNRS, UGOE UU and LIAG) and by the University of Stanford.
- Upon reaching the target depths, a number of logs were conducted in the wells. These logs were interpreted by partners GII and CNRS. The reservoir layers with good properties were identified and this information was used for the selection of the perforation intervals.
- One of the very early conclusions from the core analysis was that the rock of target reservoir (a poorly cemented sandstone) is unstable and the borehole could not be left open. Accordingly, we proceeded with the procurement of a 7" carbon -steel casing, its installation in the well and the cementation with Portland cement. This work was carried out by Partner Lapidoth. At the end of the cementation a cement bond log was carried out and the well was perforated.
- In May 2013 we started the hydrogeological characterization activities. After a short period of testing it was, however, observed that most of the pumping was carried from the wellbore storage, that the reservoir is not producing and the well is clogged.
- Well Stimulation: Once it was clear that the wells were clogged, efforts were initiated to outline a work-plan for the stimulation. Service companies and experts were contacted and after evaluating the financial capabilities it was decided to re-perforate the injection well and to conduct a series of swab suctions. These activities took place in November 2013. Following the re-perforation of the injection well, we were able to produce water with a fast recovery rate. Injection of water was possible at a rate of ~6 barrels/minute for a pressure of 1250 psi. This is equivalent to an injection rate of ~60 m^3/hour for a pressure of 85 bars. These values already indicated signs of good hydraulic properties. The monitoring well was stimulated only by means of swab suctions. In the injection test we were able to sustain a rate of 4 barrels / minute for a pressure of 400 psi or an injection rate of ~35 m^3/hour for a pressure of ~7 bar.
- After the well stimulation activities the pump test activities were resumed in December 2013. The pump test was carried for more than 10 hours, using two pumping rates (5.5 m^3/hr and 2.9 m^3/hr). Pressure was recorded by means of a sensor placed above the pump. The pump test was analyzed using the SPT software developed at EWRE and it was found out that the hydraulic properties are far better than the ones assumed during the planning phases of the experiment and even somewhat better than indicated from the laboratory samples. The actual values of the permeability are of ~740 md for

Figure 1. Injection well instrumentation by Class VI Solutions and SageRider underway at Heletz in January 2014.

the horizontal permeability and ~150 md for the vertical one. The depth of the static water table was much deeper than expected, being 200 m. In the course of March to early April we are conducting the FFEC (Flowing fluid electrical conductivity) log, which aims at allowing the characterization of the vertical variability of the hydraulic conductivity.

- The injection kit: After receiving a number of proposals (NATEX of Vienna, CO2CRC of Australia and Trimeric of USA) it was decided to select TRIMERIC for the design and the supervision of the manufacturing of the injection kit. Design criteria included, semi-automated injection system, injection rates of up to 4 tons per hour, well head pressure of up to 80 bars and temperature of 35 °C. Safety of the system was of key importance as well as controllability of the conditions along the system from the CO_2 tank to the wellhead. The manufacturing of the injection kit is completed and after a number functionality tests the kit will be shipped to the site by the end of March 2014.
- The instrumentation of the injection well started on January 26th and successfully completed in a week. The testing indicated that all the systems worked properly (pressure and temperature sensors, DTS, packer, wellhead). Installed technologies included: pressure and temperature sensors at two vertical levels within the injection chamber delimited by the bottom plug of the well the packer; optical fire for DTS and for acoustic sensing, a port for air-lift pumping, a port for injection of CO_2 to mix with water (in order to saturate the water with CO_2), a U-tube for down-hole fluid sampling.
- The instrumentation of the monitoring well will be carried out in April 2014. Installed technologies will include: pressure and temperature sensors, optical fiber for DTS and acoustic sensing, a U-tube for fluid sampling, a port for air-lift pumping and a packer for sealing the target layer from the borehole.
- The site is being prepared for the experiments, including a generator for power supply, a control room with chemical analysis facilities (Mass spectrometer), gas supply for the heat exchanger. All these operations are being finalized towards the first injection of CO_2 in May 2014.

The development of the experimental site at Heletz has undergone major progress in many fields:

- ***Completion of the drilling of the injection and monitoring wells;***
- ***Logging of the wells***
- ***Casing and cementation of the monitoring well;***
- ***Stimulation of the wells.***
- ***Hydrogeological characterization;***
- ***Design, planning and manufacturing of the injection kit***
- ***Design, planning and completion of the injection well***
- ***Design, planning and completion of the monitoring well***
- ***Various logistic operations on site***

Figure 2. Injection kit at Heletz site (2014).

CO_2-RICH BRINE INJECTION THROUGH HELETZ SITE SANDSTONE SAMPLES: ROLE OF THE FLOW RATE INJECTION ON CHEMICAL AND HYDRODYNAMICAL PROPERTIES

(LUQUOT, L.; GOUZE, P; CARRERA, J.)

Flow-through laboratory experiments of CO_2-rich brine were realized to evaluate the chemical processes occurring in the Heletz site. The Heletz sandstone rock is poorly consolidated and has a high porosity (around 23%) and connectivity. Consequently, it was impossible to core the rock into small core rock sample of 9 mm diameter and 18 mm length. We decided to reproduce artificial core rock samples using stainless steel core folder of external sizes 9 x 18 mm and internal size of 7 x 14 mm. We placed in both side one sintered stainless steel sample of 7 mm diameter and 2 mm long and we pressed the Heletz sandstone grains rock sample into the stainless steel folder and sintered discs. The mineralogy, mineral grains sizes and porosity of natural Heletz rock sample were reproduced to mimic the chemical and structural properties of Heletz reservoir. We performed five flow-through experiments at *in situ* storage conditions (T = 60 °C, P = 15 MPa, P_{CO2} = 1.8 MPa). The flow rates injection were 0.05 and 0.30 mL/min. Two different brine solutions were used, both representative of the Heletz reservoir native water. The first one was a synthetic brine of the Heletz reservoir (closed to seawater). The second one was the first one equilibrated with gypsum.

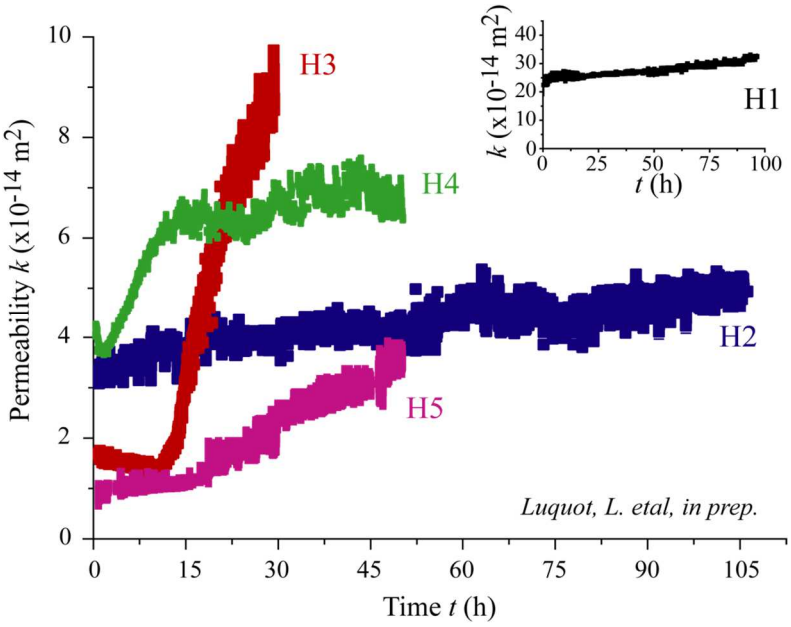

Figure 3. Flow rate injection on chemical and hydrodynamic properties.

The results show an increase in permeability and porosity for all the percolation experiment whatever the flow rate and the brine solution. This is explained by the dissolution of calcite, dolomite and feldspar. We observed that the permeability increase is higher and faster for high flow rate injection than for low flow rate.

MUSTANG – PANACEA – TRUST
TRAINING COURSE ON GEOLOGICAL STORAGE OF CO2
GÖTTINGEN UNIVERSITY, GÖTTINGEN, GERMANY

(OCTOBER, 2013)

This training course presented an overview of the current status of CCS operations and research, with the objective of providing the participants with a basic understanding of the scientific and technical issues that need to be address for the successful injection of CO_2 into saline formations. The course focused on the technical and scientific considerations for CO_2 injection, the exploration of critical process in laboratory studies and by field techniques, as well as the related numerical modeling. The training course was intended for students and professionals that wish to gain a greater understanding of current research findings in the CCS field. Days 1 and 2 focus on general topics, while Days 3 and 4 provides a short introductory training course to parallel CO_2 simulation capabilities of the PFLOTRAN software.

The course was jointly organized by three ongoing EU FP7 Research and Development projects working on the topic (MUSTANG, PANACEA and CO_2TRUST).

Lectures during the first two days of the training course covered the following topics:

- Overviews of the current status of CCS projects and the main challenges
- Information needed and data assembly for characterization of storage sites
- Field techniques for site characterization
- Field techniques for monitoring
- Laboratory experiments of critical properties and processes
- Processes taking place during CO_2 injection and storage, their conceptual and numerical modeling

The last two days were devoted to training on the use of the PFLOTRAN software. The training will be delivered by the developers of this software.

PFLOTRAN is an open source parallel, multiphase, multicomponent and multiscale code for the modelling of subsurface processes. It has the capabilities to model CO_2 storage problems, including thermal, chemical and mechanical effects.

The main goal of this course was to give you the essential understanding and tools to start applying the software to your models. Participants were guided from the software installation to the first simulation cases on a number of hands-on problems.

Figure 4. Participants of the Third MUSTANG Training Course (October 2013, Gottingen)

Proceedings of the 3rd training course are available **HERE**

ANNOUNCEMENT OF NEXT EVENTS

- Final Consortium meeting and last training course in Uppsala Sweden on 26th to 27th May 2014
- Next EGU meeting in Vienna, 27th April to 2nd May 2014

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The sole responsibility for the content of this newsletter lies with the authors.

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IN MEMORY OF PROFESSOR ANDREW CLIFFE

Andrew Cliffe, a brilliant scientist and most importantly a great colleague and friend passed away on Jan 5th, 2014, all too prematurely at the age of 60. We shall keep in our memories his friendship, his kindness and his tremendous professional skills. Farewell to a friend.

Andrew was Professor of Computational and Applied Mathematics at the School of Mathematical Sciences, University of Nottingham. His research concerned developing, analyzing and applying computational techniques for problems ranging from fundamental science to industrial applications. He was also interested in how to represent and quantify uncertainty using numerical methods. Applications of this work included assessing the safety of potential underground repositories for radioactive wastes and understanding the spread of carbon dioxide in deep saline aquifers in the context of Carbon Capture and Storage schemes.

We, his colleagues and friends in the Mustang project that had the privilege of working with Andrew, send our deepest condolences to his family at this difficult time.

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