CO₂ GEOLOGICAL STORAGE IN FRANCE (PARIS BASIN) IN DEPLETED RESERVOIRS & AQUIFERS

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PICOREF is a R&D programme dedicated to the storage of CO2 in permeable reservoirs. It is supported by the French Ministry of Industry, in the framework of RTPG Funds (Réseau de Technologies Pétrolières et Gazieres: “Network of technologies for petroleum and gas industry”), and by a consortium of French companies, research institutions and academic laboratories. The project is headed by IFP (Institut Français du Pétrole: French institute of petroleum).

PICOREF (Plégeage du CO2 dans les Réservoirs géologiques, En France: “CO2 trapping in geological reservoirs, in France”) has two main objectives:

- Identify injection sites in France and define pilot operations from a selection of geological reservoir targets that can be considered as adapted to CO2 storage.
- Elaborate and test a methodological work-flow chart able to address, as quickly and precisely as possible, a site evaluation for a CO2 storage project.

In PICOREF research project setting, Gaz de France and the consortiumship are evaluating two types of potential CO2 geological storage: a depleted hydrocarbon field and deep saline aquifers, from the Saint Martin de Bossenay structure case study (South-East of Paris Basin). The main objective is to define a methodological approach that can be applied to an analogue case at industrial scale. The approach includes a series of needs, tools, or questions, that are addressed:

- Baseline characterization (regional and structural geology, reservoir and caprock features, temperature and pressure, fluids, etc).
- Description of the storage operation / concept in terms of time phases (pre-injection operations, injection with eventually additional recovery of hydrocarbons, monitoring during injection, long-term verification, etc).
- Reservoir and geochemical modelling techniques and parameter values available to predict the storage behaviour along the successive time phases.
- Monitoring and verification techniques adapted to the specific site features.
**CONTEXT**

The status of France is rather unique concerning its energy management. A major part of the electricity is of nuclear origin (76.6 to 78.1 % in the years 2000s), so that CO$_2$ emissions per inhabitant averages ca. 1.75 t$_C$.yr$^{-1}$ (ca. 3 t$_C$.yr$^{-1}$ for OECD countries). France's CO$_2$ reduction commitment within the Kyoto protocol is thus quantitatively modest, and the effort may be limited to the stabilization of emissions at the present-day level. Nevertheless, a true concern of French public authorities with respect to climate change has progressively emerged. The need to decrease by 4 or 5 times by the year 2050 the level of national greenhouse gases (GHG) emissions is now clearly outlined at the government level as an overall objective, which includes worldwide environmental awareness, and national industrial competitiveness as well. Accordingly, technological challenges to reduce GHG emissions, including CO$_2$ capture and storage (CCS), already are, and will be considered as high-priority national R&D issues (Brosse, 2005).

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**PICOREF PROJECT**

The Paris Basin appeared as a big potential in terms of CO$_2$ capture and storage when considering both the amount of CO$_2$ produced and the availability of depleted fields and deep saline aquifers. These two types of potential sites for CO$_2$ storage are under investigation:

A quick screening of the French depleted hydrocarbon fields in terms of CO$_2$ capacity done in a prior RTPG project (2004) highlighted a set of oil-field structures as potential sites for a pilot project with appropriate features (burial depth, temperature, pressure, fluids, reservoir lithology). In the SE part of Paris, several candidates are available. Most of the oil fields are located either in the limestone unit of the Dogger formation or in sand-rich units of the Keuper formation. In 2005, we investigated the feasibility of CO$_2$ re-injection and storage in a depleted oil field with reservoir engineering, well characterization and monitoring perspectives. The Saint Martin de Bossonay oil field, produced at present time by the french drilling company SMP, has been selected for simulation of CO$_2$ storage.

Two aquifers seem to be potential candidates for CO$_2$ storage, the Dogger Formation and the Keuper Formation. In 2005, we focused on the SE part of the Paris Basin where subsurface is the best known. First, because petroleum exploration has been active in this basin for more than thirty years and secondly, because subsurface has been also investigated for geothermal resources. Lastly, industrial sources of pure CO$_2$ are present in the region, which could reduce the capture cost during the pilot operation.

Furthermore, the project is drawing up a “site documentation” which shall identify all the requested parameters (existing French regulations, risk assessment, authorizations…) for a CO$_2$ storage site in collaboration with the French Administration.

This project PICOREF will continue in 2006-2007 within the French National Research Agency (ANR).
CO₂ STORAGE IN DEPLETED FIELD: SAINT MARTIN DE BOSSENAY CASE STUDY

In PICOREF research project setting, Gaz de France is more particularly evaluating the potential CO₂ geological storage in depleted hydrocarbon field, from the Saint Martin de Bossenay structure case study. The main objective is to define a methodological approach that can be applied to an analogue case at industrial scale. The approach covers a series of needs, tools, or questions, that are addressed:

- Baseline characterization (regional and structural geology, reservoir and caprock features, temperature and pressure, fluids, etc).
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Saint Martin de Bossenay is located in the South-East of Paris Basin, 120 kilometers in the South-East of Paris. The oil field, discovered by Shell, and produced at present time by the french drilling company SMP, has produced 1.5 millions cubic meters of oil. The field is hosted by limestones of the Dogger formation and is trapped by an anticline structure, close to the Saint Martin de Bossenay regional fault. The structural play is imaged at the basin scale, on composite seismic lines reprocessed by BRGM (figure 1).

The four reservoir units (A, B, C & D) are in grainstones of Lower Callovian “Dalle Nacrée Formation” (A & B) and in dolomitised mudstones of Bathonian “Comblanchien Formation” (C & D). The thickness of each reservoir is around 10 meters in average, the permeability between 1 and 100 mD and the porosity between 5 and 15%.

THE DOGGER RESERVOIR AT SAINT MARTIN DE BOSSENAY

In the A & B units, the reservoir properties are mainly controlled by sedimentological parameters. The grainstones of the “Dalle Nacrée Formation” present clearly oblique stratifications, interpreted as intertidal sigmoidal megaripples, deposited in coastal environment (Figure 2). This interpretation is based on analogue outcrop sedimentological studies, in a Burgundian quarry, exploited for “Comblanchien
Formation” limestone (Plombière-les-Dijon). This model implies that reservoir bodies are elongated in the sense of paleo currents, and that their extension is controlled by the paleo coastal line morphology.

**Figure 2:** core in “Dalle Nacrée Formation”, and analogue outcrop (Plombière-les-Dijon) showing intertidal sigmoidal megripples

In the C & D units, the reservoir properties are controlled by the complex diagenesis of “Comblanchien Formation”. The porosity and permeability depend on dolomitisation and de-dolomitisation successive events (see figures 3 to 6).

**Figure 3:** Macro sample from well SMB 18 (Saint-Martin de Bossenay). This sample is situated at the top of the “Comblanchien Formation”. Dark brown color suggests strong dolomitization, and black areas are probably open burrows filled with residual hydrocarbons. Sample is around 7 cm long.

**Figure 4:** Same sample as previous image, in the dark part (field of view is ~ 2 mm large). Picture taken from a thin section analysed in cathodoluminescence. Medium brown rounded areas are mostly fine ooids and peloids, bright orange zones are micritic calcite or micritic cement. Dark areas are large dolomite crystals developed in pore spaces, some of which show typical rhomboedral shape and fine luminescent stripes. Non-luminescence like the one in dolomite here is most often interpreted as resulting from a high Fe/Mn ratio. Blue zones are intergranular porosity (around 15-20 %), forming a probably well connected network.

Dolomitization finally remains limited and most of the rock still is oolitic calcite limestone. Dolomite has here no or little influence on porosity.
Figure 5: Macro sample of a 3 m thick poorly recovered interval from well SMB 201, in the upper half of the “Comblanchien Formation”. The rock is light brown with numerous vugs.

Figure 6: Same sample in thin section. The rock is a massive dolostone with vuggy porosity. The rhomboedral shape of dolomite crystals can only be seen on pore edges. Some of these crystals show curved edges, which are typical of the so-called saddle or « baroque » dolomite, usually interpreted as high temperature and deep burial dolomite. In most of the rock volume, the crystals form a thight mosaic, with dirty looking cores due to a high concentration of inclusions.

The connectivity of the porous network appears here much more dubious as in the sample from well SMB 18.

SEM analysis conducted on dolomite crystals showed a near stoichiometric Mg/Ca ratio, fairly constant over the studied interval. At first sight, stable isotope composition of the oxygen of dolomite samples is in good agreement with a high temperature and burial origin.
CONCLUSION

For the time being, the geological model is updated, taking into account in particular the complex diagenetic story of Comblanchien Formation. The next steps, in 2006-2007 within the frame of French National Research Agency GEOCARBONE project will focus on reservoir model update and CO₂ geological storage numerical simulation, and size a possible future injection pilot in south-east Paris Basin.

ACKNOWLEDGMENTS

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