EXPLORATION & PRODUCTION

DGEP/SCR/RD

Results of the Lacq pilot's monitoring
Focus on microseismicity

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TOTAL

CCS pilot, Lacq, France

Introduction

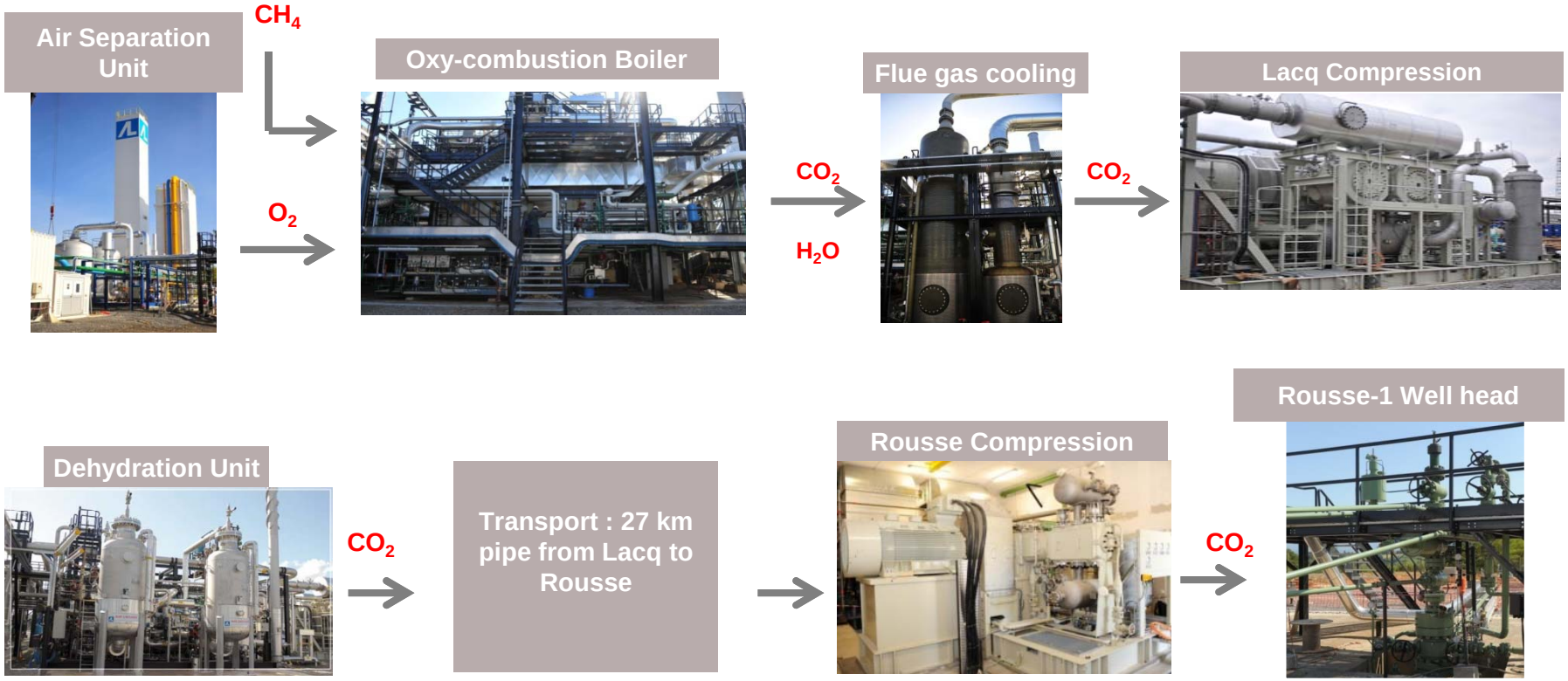
Key areas

- Presentation of the Lacq pilot
- Monitoring program
- Micro-seismic monitoring
- Conclusions
- Questions

CCS pilot, Lacq, France

Pilot Objective and Capture description in Lacq

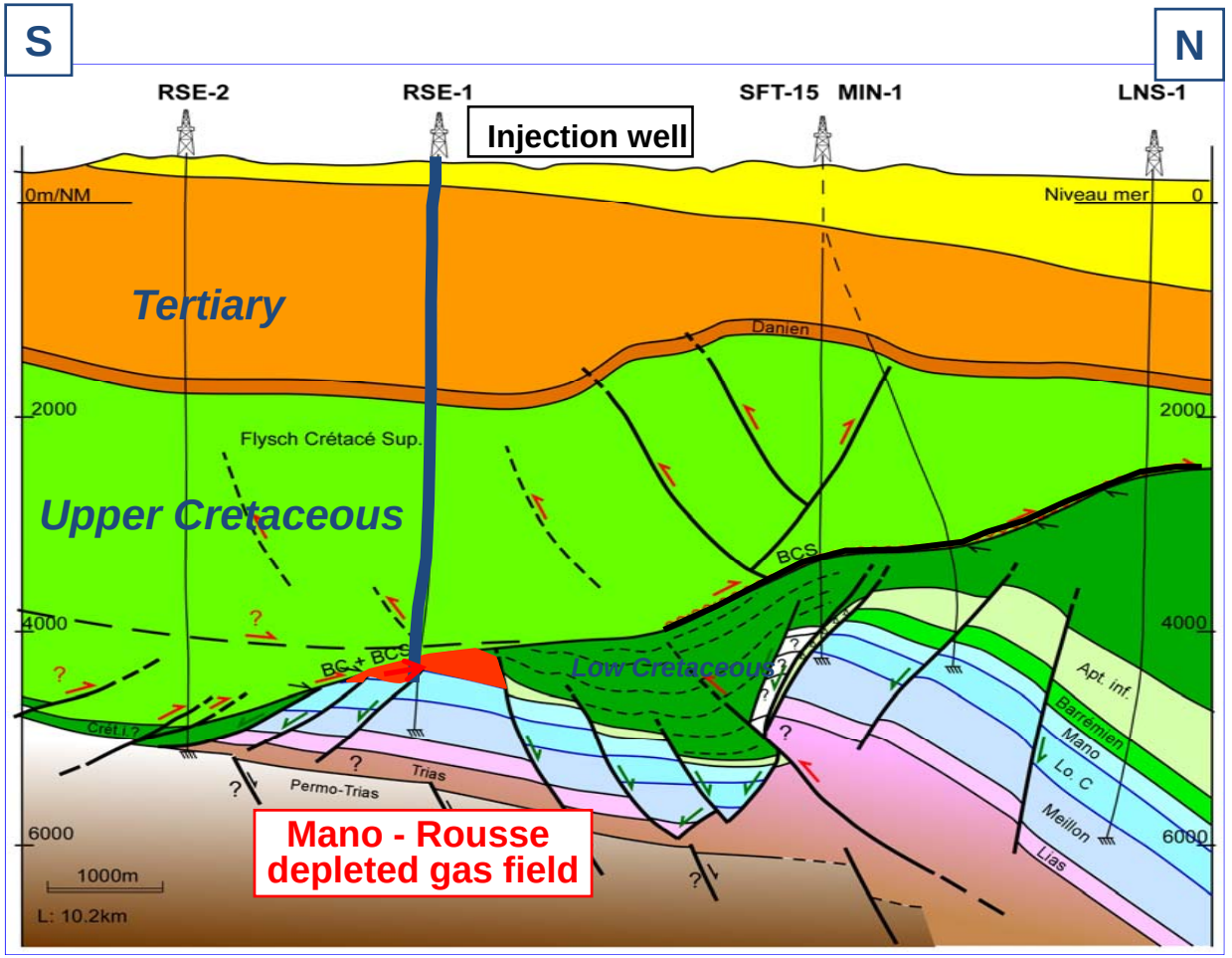
- Demonstrate technical feasibility of an integrated onshore CCS scheme
- Reduced scale (1/10th) – 30MW oxycombustion boiler
- Two sites



CCS pilot, Lacq, France

CO_2 storage into Rousse

- Depleted gas reservoir producing from 1972 to 2006
  - ✓ Depth = 4500m,
  - ✓ Temperature = 150°C,
  - ✓ Initial Pressure = 485 bar
- Fractured dolomitic reservoir
- No aquifer support
- A tightly sealed cap rock
- Maxi injection : 100 ktonnes, pressure@endinjection:100 bar



Geological cross – section (S – N)

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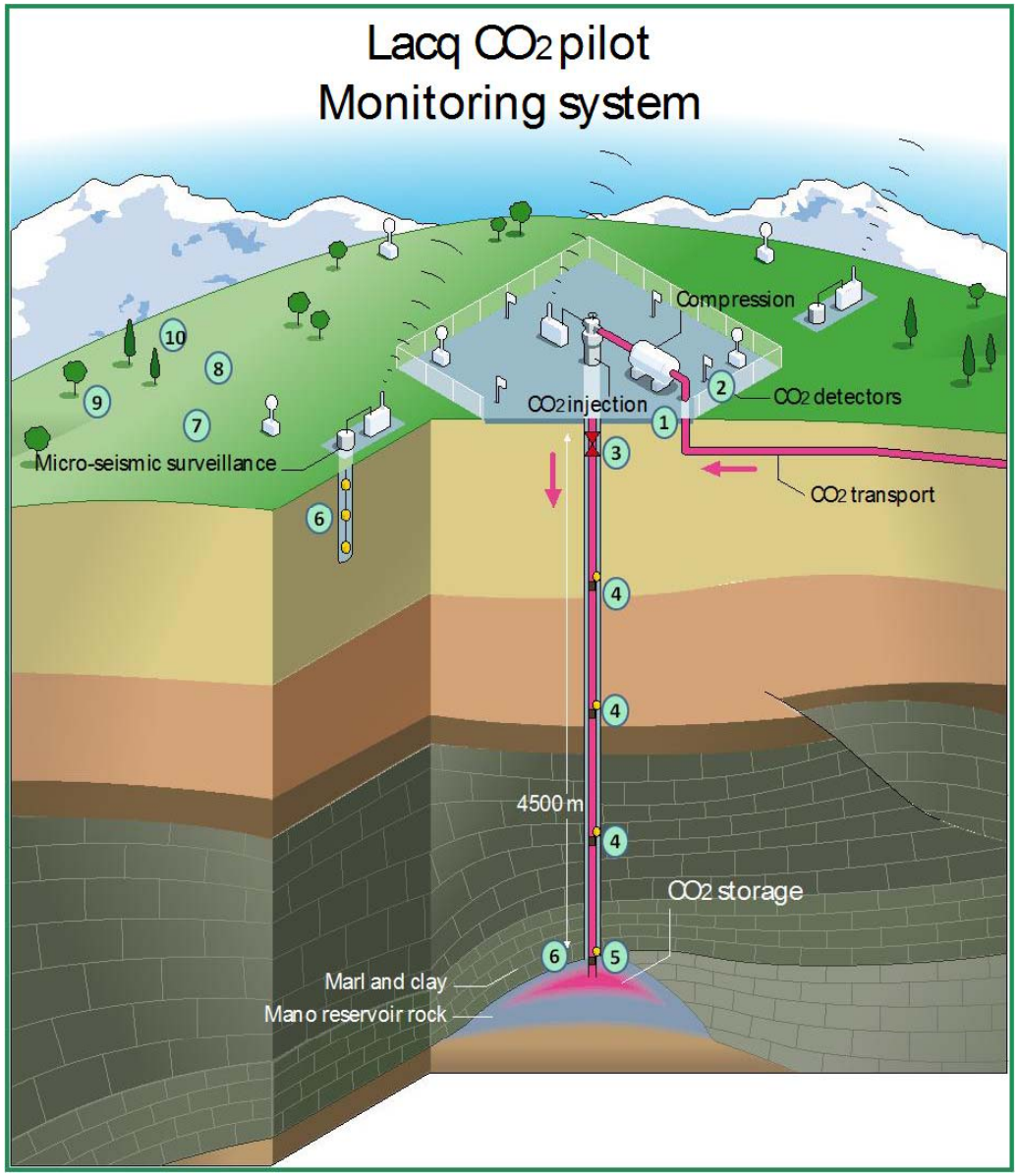
Rousse storage monitoring program



Objectives

- Confirm that CO_2 remains confined in reservoir, to check site integrity
- Check that CO_2 behavior as expected
- Get info to calibrate tools and acquire R&D data
- Follow well integrity and well performance

3 periods

- Pre-injection (baseline ante 2010)
- Pilot: Injection + 3 years observation
- Post pilot: to be defined

Micro-seismicity monitoring

Objectives, feasibility, design

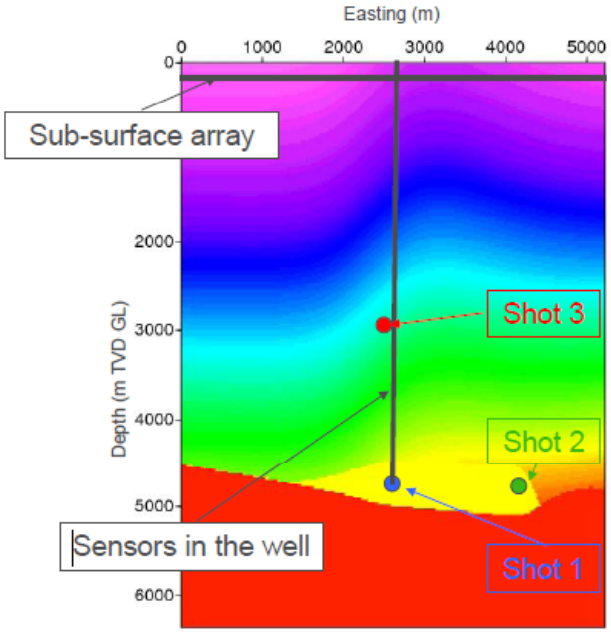
- Objectives :
  - ✓ Confirm that gas remains confined in reservoir
  - ✓ Monitor the reservoir and cap-rock integrity
  - ✓ Get R&D data

2006 - Feasibility study *Performances needed for R&D pilot*

Shot 1 : micro events due to injection – very low magnitude (R&D interest)

Shot 2 : events on border of reservoir

Shot 3 : in caprock (leakage pathways)



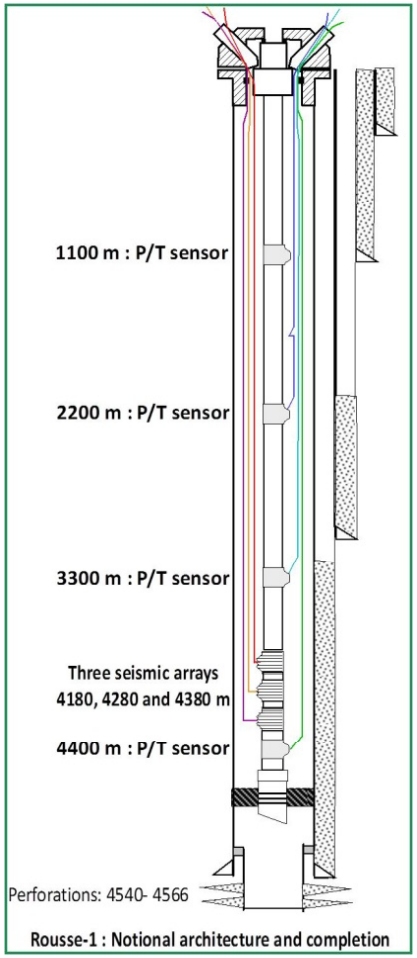
Magnitude	faille (en m)	Déplacement (en mm)
-3	0.31	0.015
-2	1	0.05
-1	3.1	0.15
0	10	0.50
1	31.6	1.58
2	100	5.00
3	316.2	15.81
4	1000	50.0

TOTAL

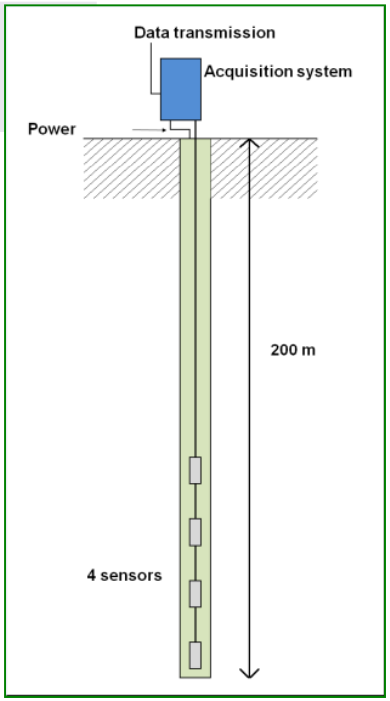
Micro-seismicity monitoring

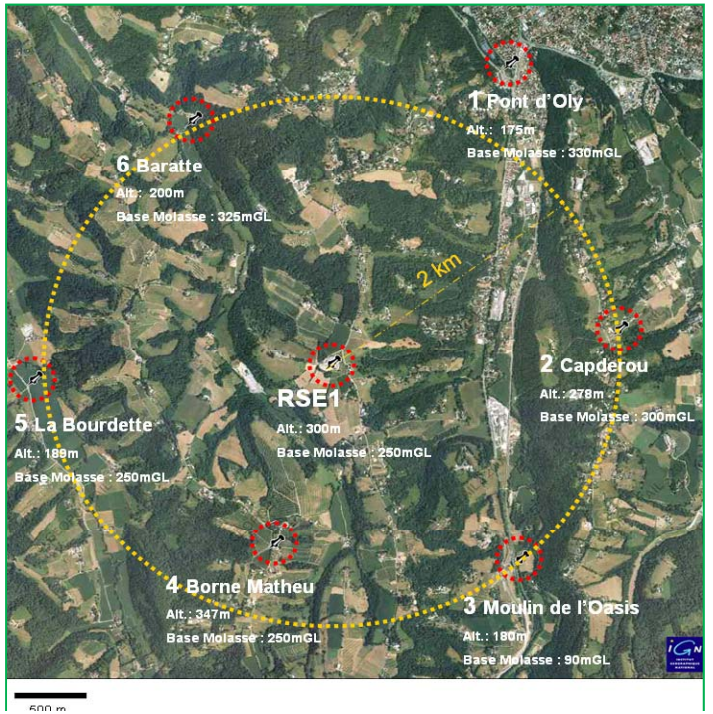
Network description

- Network is composed of
  - One deep array in injection well - Injection completion inside well
  - Seven subsurface arrays in shallow wells
  - One surface seismometer



Rousse-1 : Notional architecture and completion



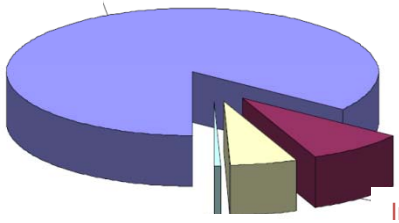


Micro-seismicity monitoring

Subsurface network and baseline in 2009

- Information recorded continuously by Magnitude
- Each subsurface array linked to a surface station, standalone
- During baseline, only subsurface network
- Near seismic events localization determined (velocity model 5 * 5 km provided)

Surface noises



Interference

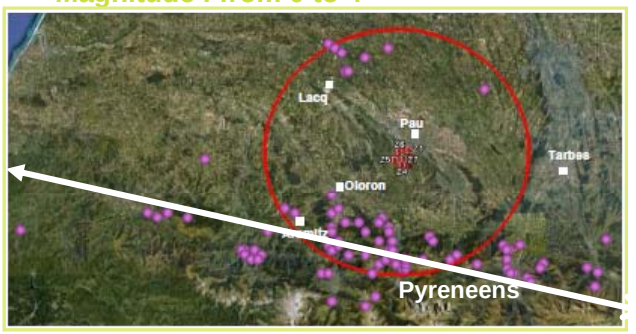
Very near seismic events : 2

Near seismic events : 18

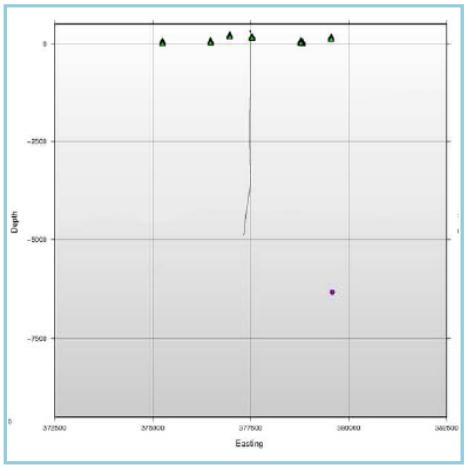
Far seismic event : 103

Far seismic event : 103
Related to Pyrenees seismic activities

Magnitude : from 0 to 4



Very near seismic events
Magnitude : 0.5



Near seismic events : 18
Quarry blasts
Magnitude : from 0.9 to 1.5

Micro-seismicity monitoring

Data during injection in 2010 and 2011

- January 10 to July 10 : non continuous injection
- August 10 to December 10 : continuous
- January to March 11 : no injection
- Since April 2011: 100 ton/day

- Velocity model : very detailed
  - ✓ 7 layers with velocity law
  - ✓ Evolution of the ratio Vp/Vs
  - ✓ Calibration and orientation of the deep array in June 11

In 2010, with subsurface network
Very near seismic event : 6

Magnitude : -1.1 to -0.2

Since April 2011, micro-seismic events detected by the deep seismic array in the injection well

Magnitude : -3.1 to -1.4

TOTAL

Micro seismicity monitoring

Performances of the network, Alarms thresholds

- Very good performance of whole network

Detection sensitivity map

-3 : near the injection wellbore

-2 : near the shallow wells

- French administration asked for alarms thresholds

Official alarms thresholds

According to magnitude and number of events, alarm procedure is activated

- For seismic events with magnitude above 2, in the circle given by the subsurface network
- For magnitude above -1, if there is evidence of propagation in space and in time of seismic events external to the reservoir

TOTAL

Micro seismicity monitoring

Conclusions

- Rousse seismic network performances as initially defined
- Very interesting data acquired for R&D with deep array
- Few micro-seismic events related to reservoir
- Seismic monitoring adapted for this R&D project

Thank you for your attention.

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