Lacq CO_2 Pilot

An integrated CO2 oxycombustion capture, transportation and storage project

Frontiers in geosciences – IPGP CCS seminar

Case studies sessions

March 19th, 2008

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TOTAL

- INTRODUCTION
- METHODOLOGY OF GEOLOGICAL STORAGE ASSESMENT
- LACQ CASE STUDY (ROUSSE SITE)

TOTAL

1. INTRODUCTION

INTRODUCTION
Objectifs des études d'évaluation du stockage

- **Evaluer la capacité et la performance du stockage**
  - Evaluer le volume stockable et ses incertitudes (prouvé, probable, possible)
    - Caractériser le piège (réservoir/couverture), son volume poreux, le faciès, la minéralogie, le fluide en place etc.
    - Modéliser le comportement, la migration et le devenir du fluide injecté et stocké en réservoir à court terme et à moyen terme.
- **Evaluer l'intégrité du site**
  - Modéliser
    - le site : réservoir et l'interface réservoir/couverture
    - le complexe : pile sédimentaire et puits
  - Identifier et quantifier les modes de défaillances
  - Déterminer la pression max admissible au fond => la pression max en tête
    - Modéliser le puits (thermo, perte de charges) pour P, T au fond en fonction P, T surface
    - Modéliser le couple réservoir/couverture (géoméca, contraintes, P etc.)
  - Déterminer des scénarii de fuite
- **Etablir le dispositif et le plan de monitoring** en fonction des coûts/intérêt et faisabilité

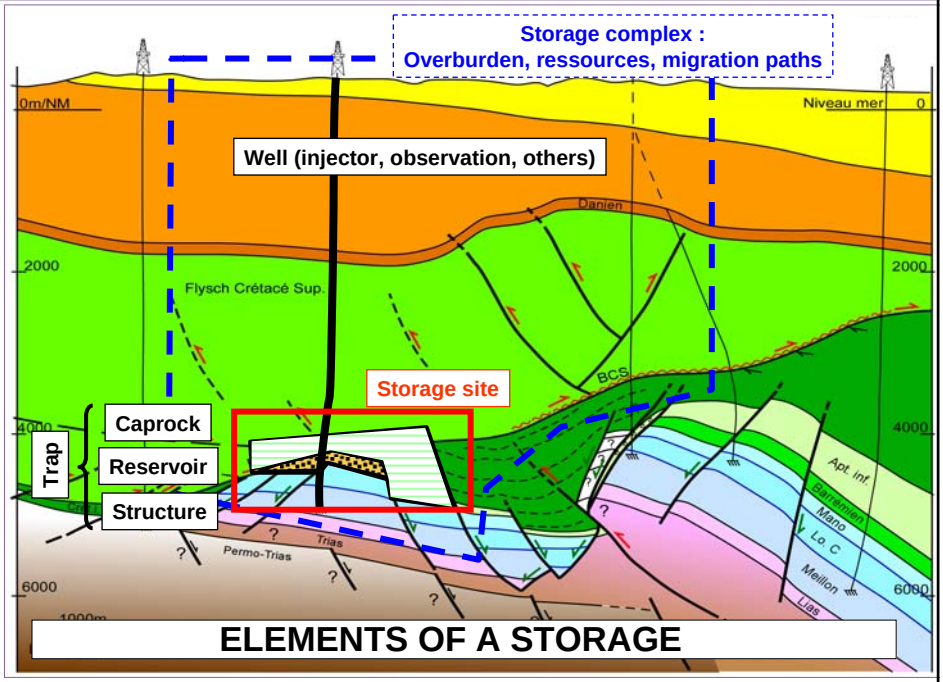
2. METHODOLOGY OF GEOLOGICAL STORAGE ASSESMENT

Elements of a storage

General workflow of an assesment study

Integrity study

TOTAL



ELEMENTS OF A STORAGE

TOTAL

WORKFLOW OF STORAGE EVALUATION STUDIES

Objectives

- Storage performance (Volume, Pmax)
- Storage integrity

taking account of uncertainties…

General workflow

1. Site and complex characterization
2. Injection (and reservoir) modeling
3. Performance and risk assessment
4. Monitoring plan

TOTAL

Integrity assessment study

- To evaluate the integrity of the storage :
  - Short term : during the production and injection period,
  - Long term: from the end of the injection and for a 1,000 to 5,000 year period
- Ultimate goals :
  - To evaluate the maximum reservoir acceptable pressure ;
    - Caprock loss of integrity threshold
    - Possible modes of failure
      - Hydraulic and thermal fracturing of caprock
      - Activation and opening of fractures and faults
      - Reduction of the capillary barrier efficiency
  - To establish qualitative and quantitative model of the scenarii of leakage out of the reservoir upward through caprock, fractures, faults and existing or new wells
  - To define a plan for monitoring the integrity of the storage

TOTAL

Integrity assesment study

Workflow developped at an R&D level :

1. Modelling of the short and long term behaviour of the acid gas within the reservoir
2. Geochemical effects on the reservoirs, caprocks and wells completion
3. Potential failure modes of the storage (capillary sealing failure, mechanical failure of caprock, fault and fracture reactivation, loss of well integrity)
4. Scenarii of leakage from reservoir to surface and the associated risks
5. Plan for monitoring

TOTAL

Integrity assesment study. Workflow : Step 1 to 5

Maturity level: Green : operational, Orange : R&D, Red R&D

1. Modelling of the short and long term behaviour of the H2S-CO2 acid gas within the reservoir
   - Short term fate : Reservoir model with adapted thermodynamics for injection period
   - Long term fate of acid gas : Coupled geochemical and flow model
2. Geochemical effects on the reservoirs, caprocks and wells completion
   - Evaluation of reservoir matrix alteration
   - Evaluation of caprock alteration (matrix, faults and fractures)
   - Modelling of well cement alteration
3. Potential failure modes of the storage
   - Capillary sealing failure
   - Mechanical failure of caprock : hydraulic (and thermal) fracturing
   - Loss of well integrity
4. Scenarii of leakage out of the reservoir and the associated risks

   Non routine study.

   Workflow :
   1. Base line study of present leakage through overburden and wells (up to aquifers and surface – biosphere and atmosphere)
   2. (coupled) Flow model of the overburden (reservoir, caprock, faults)
   3. Combined evaluation of leakage through wells and overburden
   4. Risk analysis
5. Plan for monitoring

TOTAL

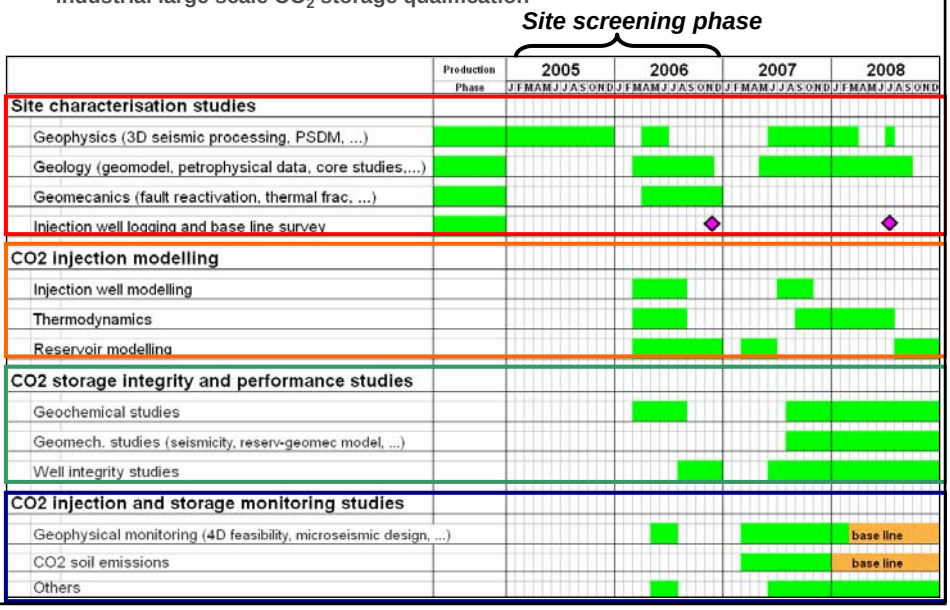
LACQ CASE STUDY (ROUSSE SITE)

11 -

TOTAL

Rousse integrated geosciences studies schedule

- Methodology to be applied for site selection but also to prepare future industrial large scale CO_2 storage qualification



LACQ CASE STUDY (ROUSSE SITE)

Site characterization

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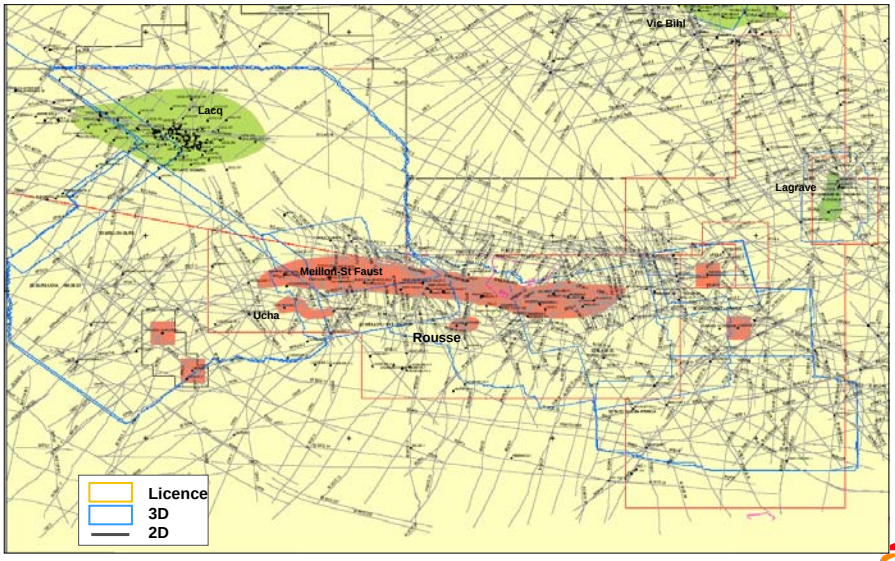
Site characterization
Seismic and well regional data base



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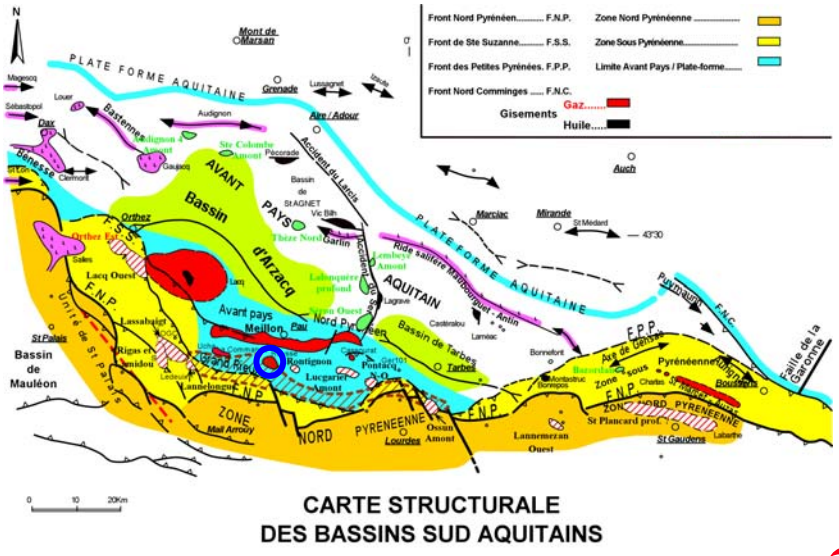
Site characterization : geological framework

Structural framework

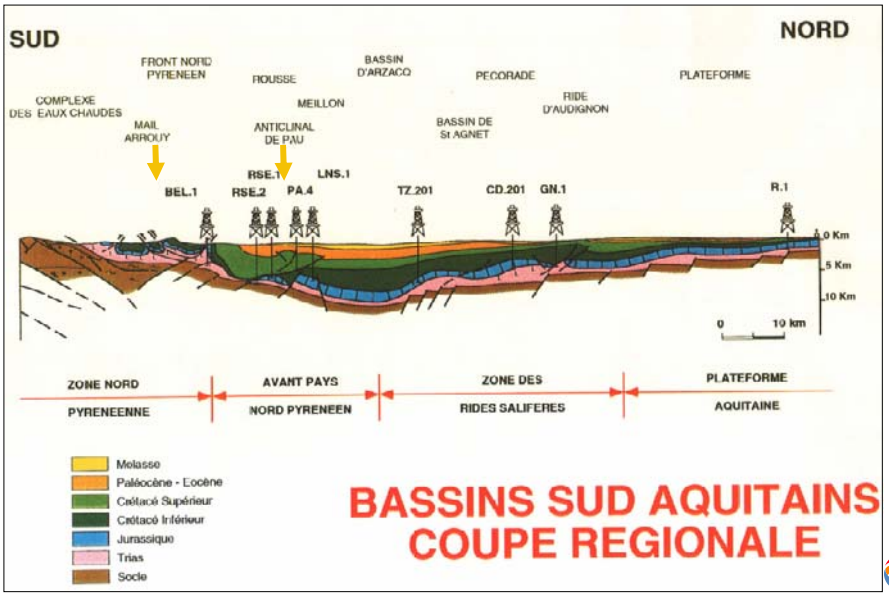


CARTE STRUCTURALE
DES BASSINS SUD AQUITAINS

TOTAL

Site characterization : geological framework

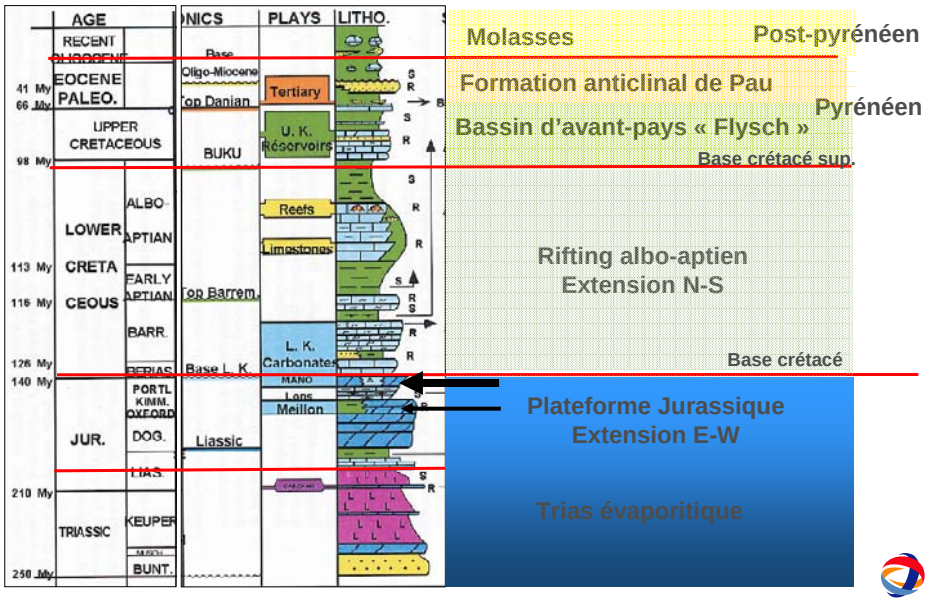
N-S regional geological cross section



BASSINS SUD AQUITAINS
COUPE REGIONALE

TOTAL

Site characterization : geological framework
Stratigraphic column



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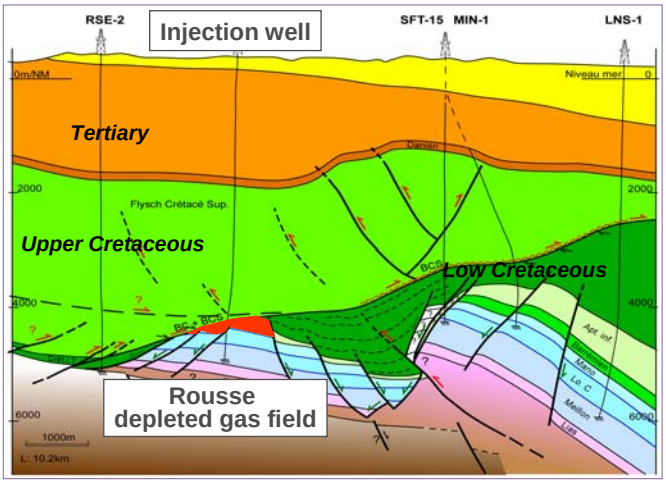
CO_2 injection into Rousse depleted gas reservoir



Jurassic fractured dolomitic reservoir *(in red)*

Thick cap rock *(in green and orange)*

Depth # 4500m/MSL

Temp. # 150°C

Initial P = 485 barg

Current P # 30 barg

Initial CO_2 = 4,6%

No aquifer

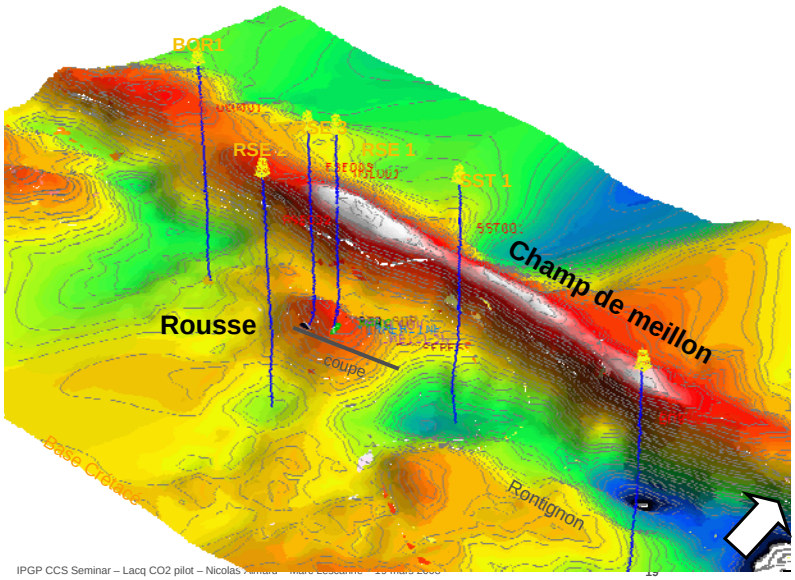
Existing unique well RSE-1 producing since 1972

Well work over planned mid 2008

TOTAL

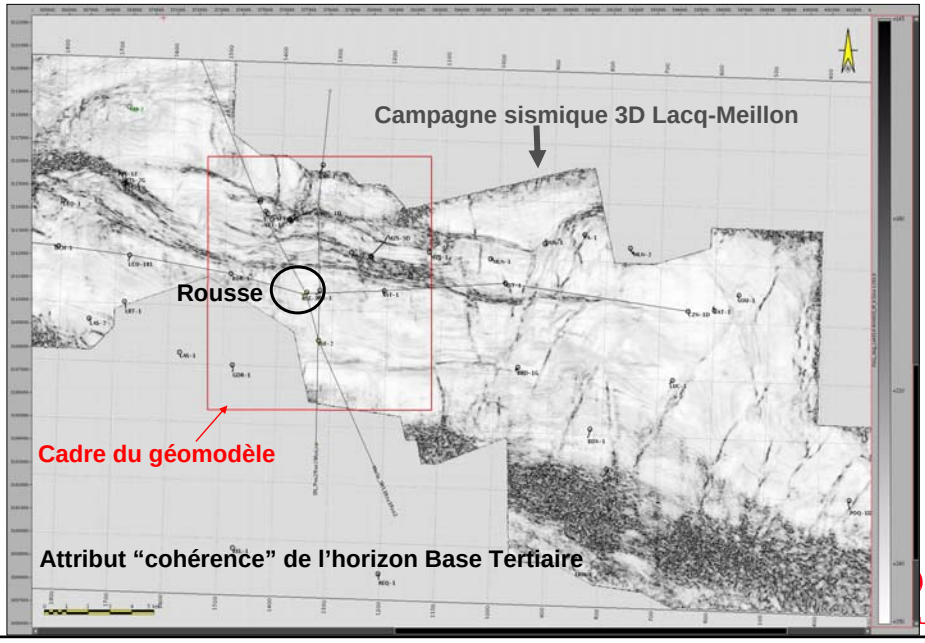
Site characterization : structural mapping

Meillon-Rousse Base Upper Cretaceous depth map

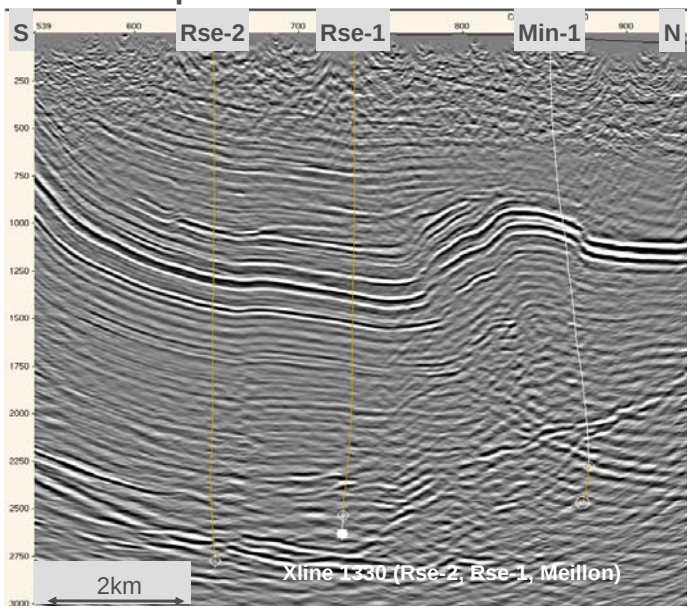


Site characterization : structural mapping

Seismic interpretation



Site characterization : structural mapping
Seismic interpretation



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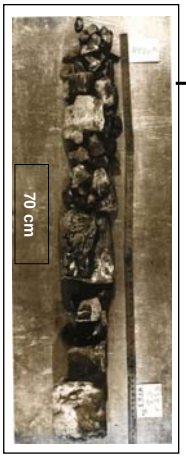
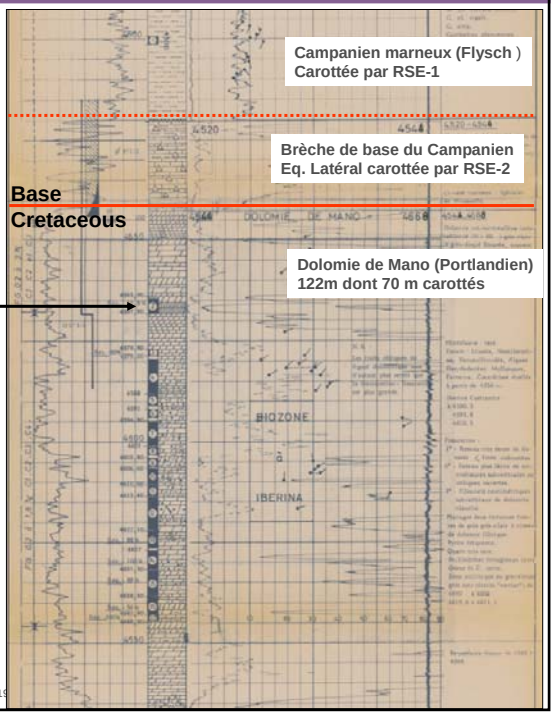
ROUSSE-1 (RSE-1)
Final geological log



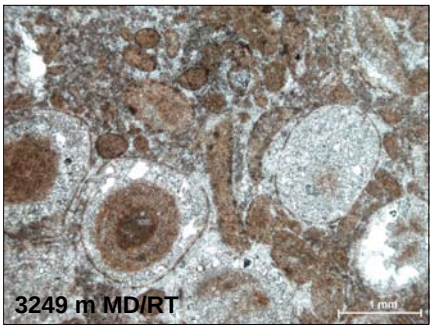


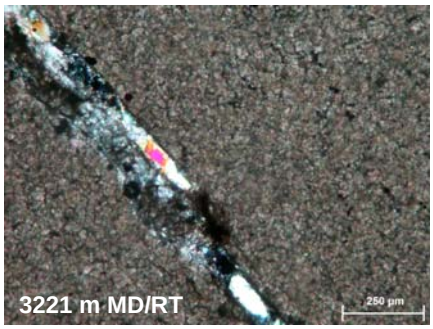
Site characterization : Reservoir characterization

“Dolomie de Mano” : a fractured reservoir

Site characterization : Reservoir characterization

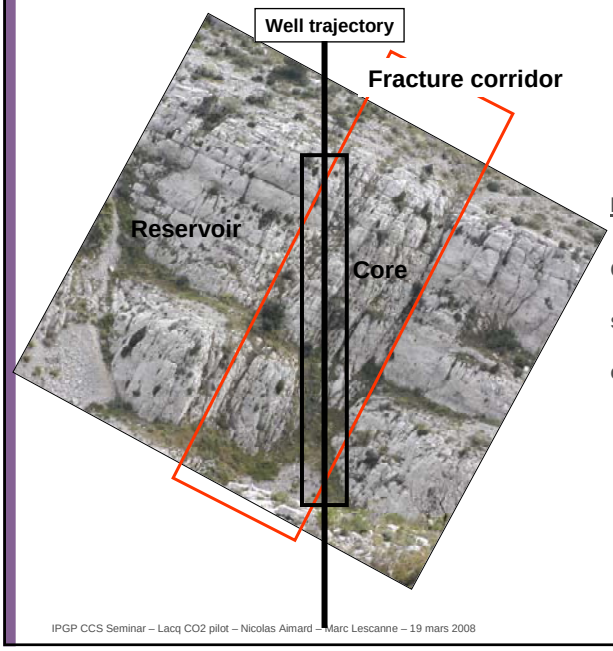
Mano reservoir characterization





- Faciès de barre et d’arrière-barre oolothique.
- Le modèle de dépôt n’est pas responsable du contrôle des propriétés pétrophysiques.
- La fracturation et les circulations hydrothermales associées contrôlent les propriétés pétrophysiques du réservoir

Site characterization : Reservoir characterization
Fractured reservoir characterization

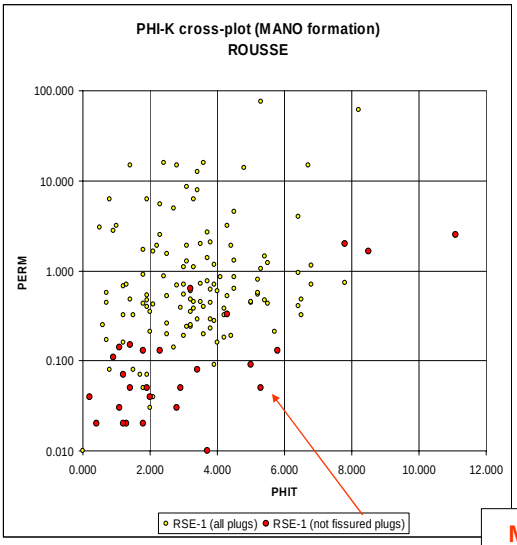


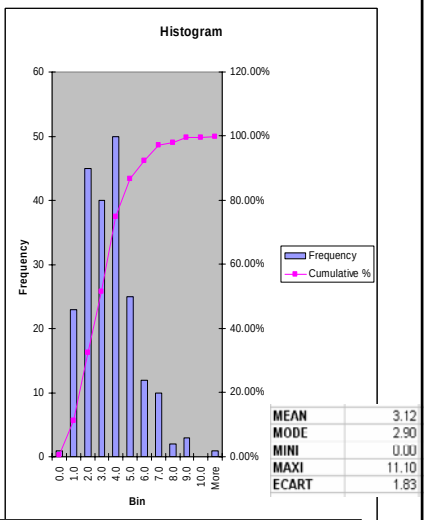
Hypo :

Concentrated fractures in specific and localized corridors.

=> Conductive hyperdrains ?

Site characterization : Reservoir characterization
Mano reservoir characterization





Matrix permeability <= 1 mD

Porosity average : 3%

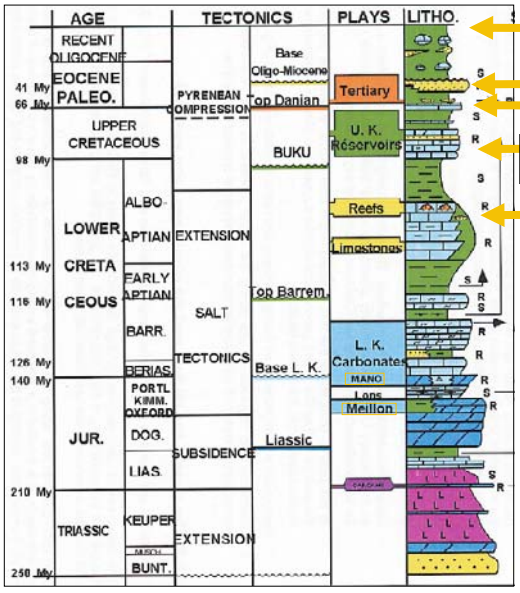
Site characterization : Reservoir characterization

Mineralogy

- **9 minéraux identifiés**
  - Dolomite, Calcite, Quartz, Apatite, Pyrite, Anatase, Chlorite, Muscovite, Smectite
  - Pas d'anhydrite observée
- **optimisation des fractions volumiques**
  - 93.6% de Dolomites en moyenne (84%-98%)
  - 2.5% de Quartz (1.4% - 4.5%)
  - 1.7% de Smectite (0.4%-3.3%)
- **optimisation de la formule chimique**
  - Dolomite légèrement plus riche en Magnésium
  - Chlorite avec 40-60 en Magnésium-Fer: $Mg_4Fe_6Al_5Si_3O_{20}(OH)_{16}$
  - Muscovite: $K_{1.7}Al_{3.4}Fe_{0.3}Mg_{0.3}Si_{6.5}Al_{1.5}O_{20}(OH)_4$
  - Smectite: $Na_{0.5}K_{0.1}Al_{3.3}Fe_{0.2}Mg_{0.5}Si_7AlO_{20}(OH)_4$

Site characterization : Water Ressources inventory

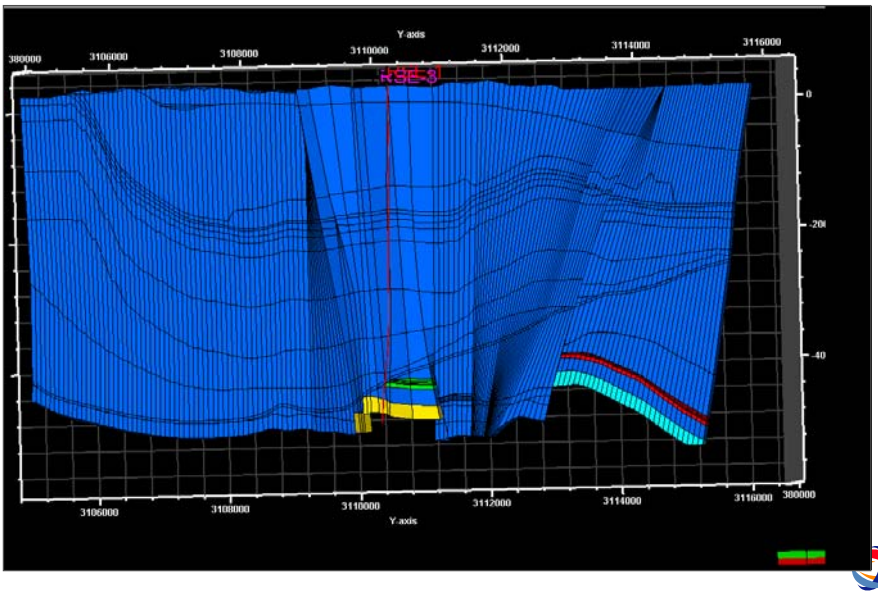
Regional aquifers



- •Nappe alluviale
- •Sables infra-molassiques et grès à nummulites
- •Eocène moyen - inférieur (base de l'Yprésien)
- •Dano-Paléocène (Calc de Lasseube)
- •Sénonien (Flysh Maestr – Campanien)
- •Base du Crétacé Supérieur (Soumoulou et Mazères)
- Aptien Supérieur (Calc. de Clèdes)

Présent à proximité de Rousse
Absent à proximité de Rousse

Site characterization : geo-modeling



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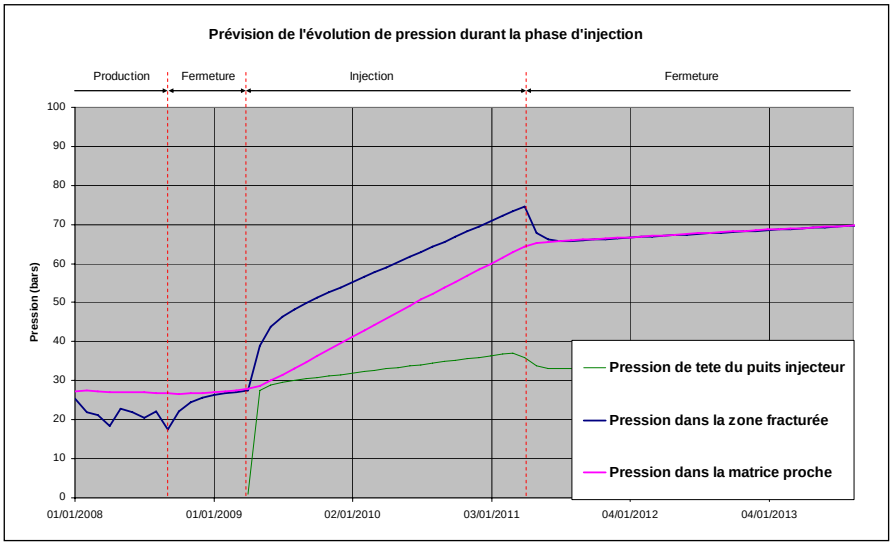
LACQ CASE STUDY (ROUSSE SITE)

Injection modeling

TOTAL

Injection modelling



TOTAL

LACQ CASE STUDY (ROUSSE SITE)

Performance and Risk Assessment

TOTAL

Integrity assesment study

Workflow developped at an R&D level :

1. Modelling of the short and long term behaviour of the acid gas within the reservoir
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5. Plan for monitoring

Geochemical modelling Workflow

Objectif

Evaluer les conséquences chimiques de l'injection de CO_2 dans Rousse

- Impact minéralogique
- Devenir à long terme du CO_2 et temps caractéristiques de l'équilibrage du système
- Localisation des effets dans le réservoir

Démarche

1. Acquisition de données expérimentales
2. Etablissement d'une minéralogie quantitative
3. Equilibrage thermodynamique des minéraux
   - Etat initial
   - Etat basse pression après extraction du gaz naturel
   - Injection de CO_2
4. Modélisation dans le temps et l'espace des réactions chimiques
   - Paramètres cinétiques
   - Géométrie et débits
   - Modélisation couplée transport - chimie

LACQ CASE STUDY (ROUSSE SITE)

Monitoring plan

Monitoring plan

- **Phase d'injection**
  - Comptage du gaz injecté en surface
  - Composition du gaz injecté
  - P et T fond de puits et P réservoir.
  - Suivi microsismique de l'injection (réservoir, couverture)
  - Détection migration de gaz en surface
- **Phase post injection**
  - P et T fond de puits et P réservoir.
  - Suivi microsismique de l'injection (réservoir, couverture)
  - Détection migration de gaz en surface