[AV]Fracture Imaging Pilot Designed to Compare Various Microseismic Monitoring Techniques*

Didier Drapeau[1], Francis Cerda[1], Laszlo Maurel[2], Pablo Ferguson[2], Raul Sanchez[2], Christophe Maisons[3], Emmanuel Auger[3], Regis Agut[2], and Philippe Matheron[2]

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[1]DGEP/SCR/RD/PJ, TOTAL SA, Pau Cedex, France (didier-hubert.drapeau@total.com)
[2]Total Austral, Buenos Aires, Argentina
[3]Magnitude, Sainte Tulle, France

Abstract

"Hydraulic Fracturing is an economic necessity for low permeability reservoirs. The production potential is evaluated as a function of fracture penetration and conductivity". Highly conductive flow paths generated by fracturing some distance away from the wellbore needs to be imaged. Fracture mapping is considered as one of the key challenges for tight gas reservoir development.

Microseismic monitoring is known as a technique able to provide fracture imaging. Indeed, changes in pressure and stress induced in the formation by the hydraulic fracturing process cause small slippages to occur along preexisting fractures. These shear failures generate P- and S-waves, which can be recorded at seismic receivers.

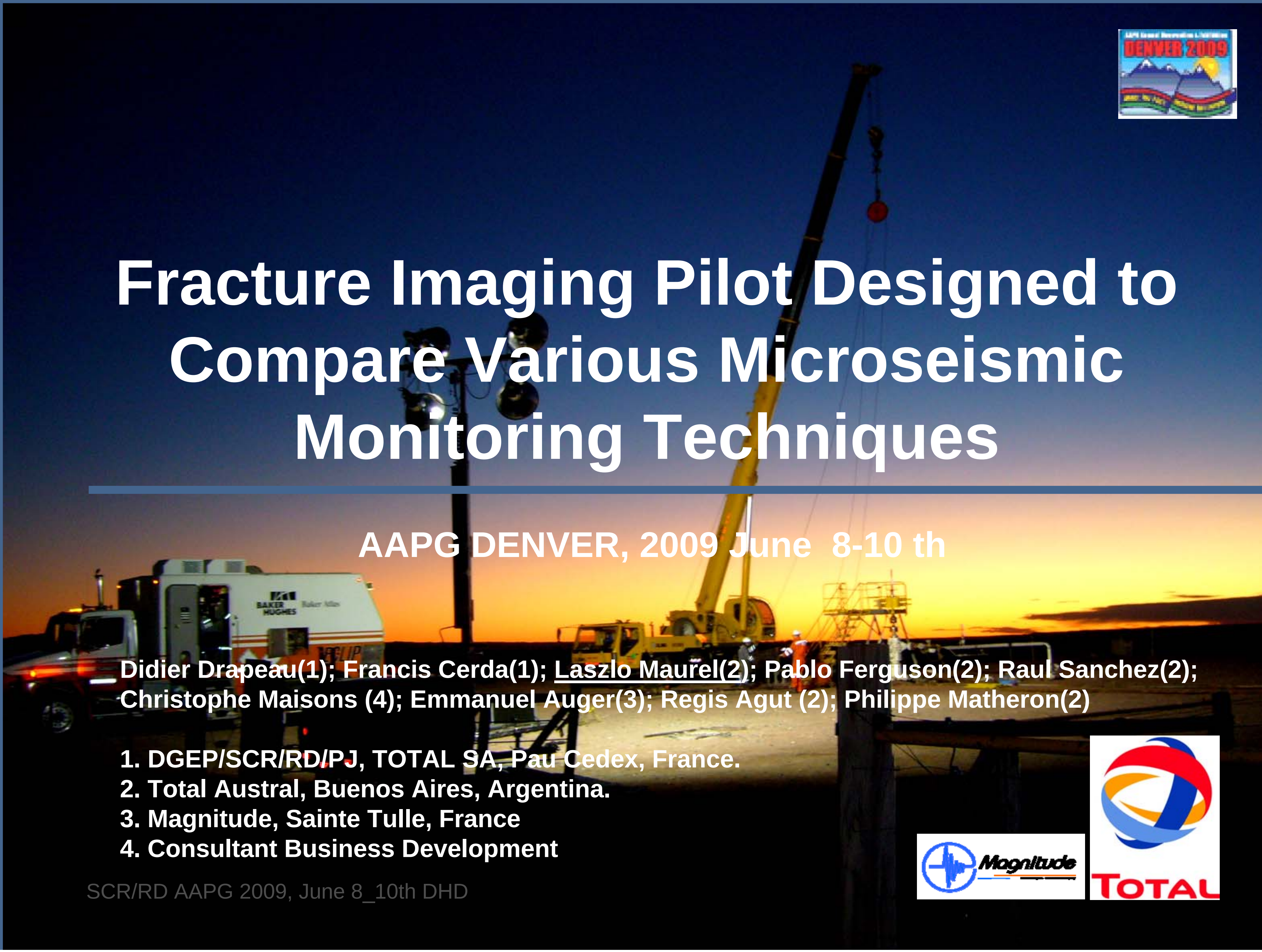
Microseismic amplitudes are small; therefore, the common technique is to run sensitive downhole tools in an offset well at small recording distances. However, availability of existing wells and the small well spacing is often a strong limiting factor to the application of this technique. Alternative solutions exist but results are as yet unclear.

For this reason, TOTAL has completed in 2008 a unique pilot experiment on the Aguada Pichana Field (Neuquen Basin, Argentina) to develop, test, and validate alternative microseismic designs which can be applied to hydraulic fracture mapping for tight gas reservoir developments.

The pilot program includes microseismic monitoring from the treatment well (wire-line design), from the observation well (as reference), from dedicated shallow wells, and from dense surface networks. The pilot results are going to be compared for various stages of fracs with and without proppant.

The two pilot objectives are to validate an alternative fracture imaging technique and to evaluate the potential benefits of various fracturing programs.

This article on this unique pilot will present (1) the challenge and the objectives, (2) the monitoring networks tested, (3) the program and the frac stages performed, and (4) the results



Fracture Imaging Pilot Designed to Compare Various Microseismic Monitoring Techniques

AAPG DENVER, 2009 June 8-10 th

Didier Drapeau(1); Francis Cerda(1); Laszlo Maurel(2); Pablo Ferguson(2); Raul Sanchez(2); Christophe Maisons (4); Emmanuel Auger(3); Regis Agut (2); Philippe Matheron(2)

1. **DGEP/SCR/RD/PJ, TOTAL SA, Pau Cedex, France.**
2. **Total Austral, Buenos Aires, Argentina.**
3. **Magnitude, Sainte Tulle, France**
4. **Consultant Business Development**

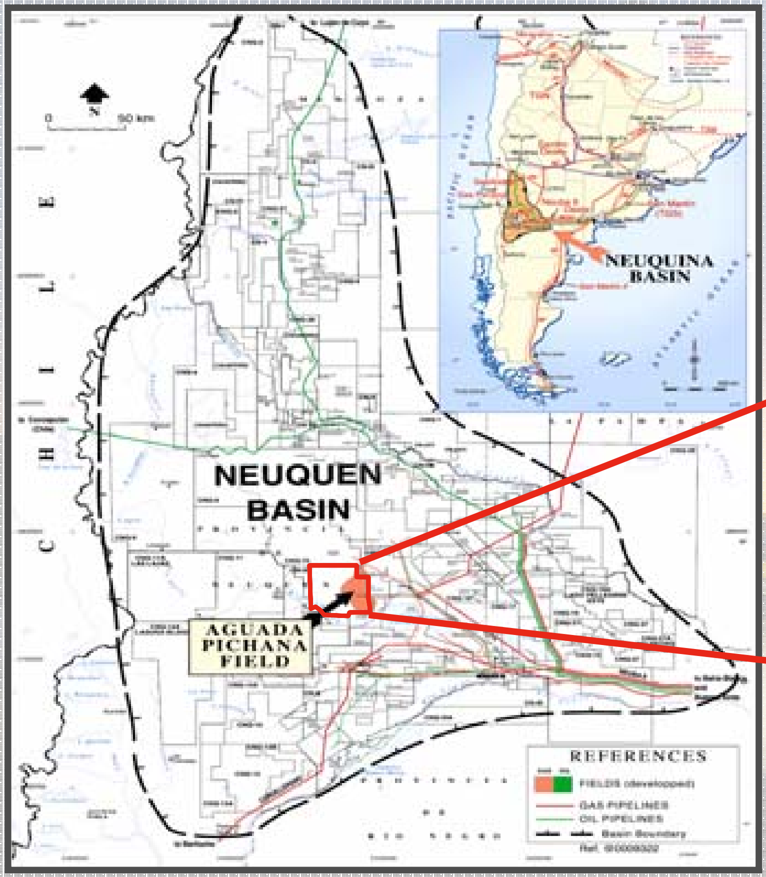
AGENDA

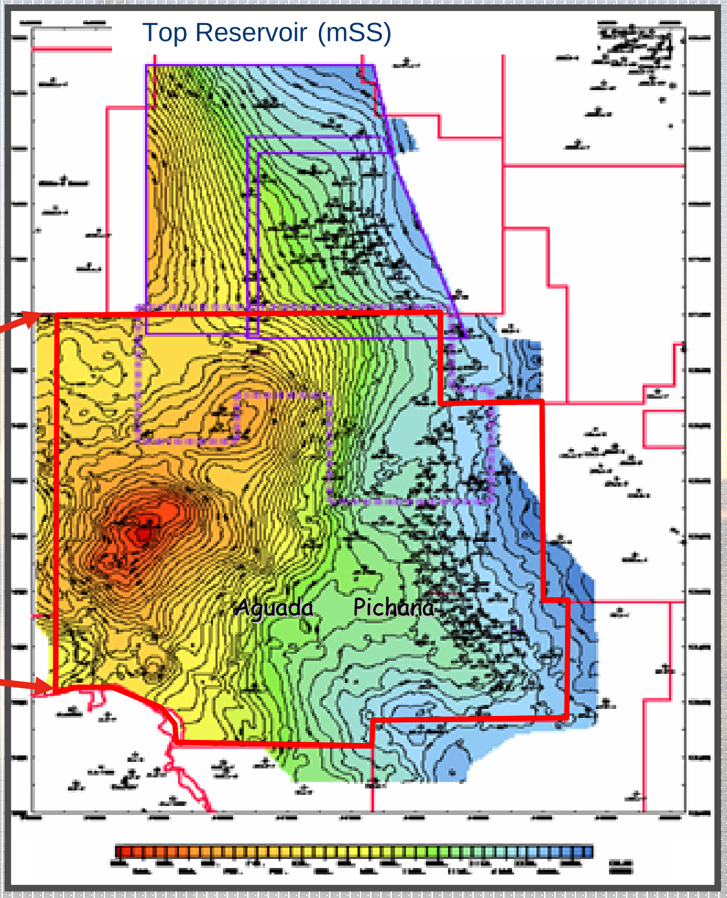
- **Regional Setting**
- **Pilot Objectives & program**
- **Main operational results based on ‘massive’ frac**
  - From observation well : REFERENCE
  - From Surface Network
  - From Near-Surface Network
- **Conclusions**

Regional Setting

Regional Setting (1/2)

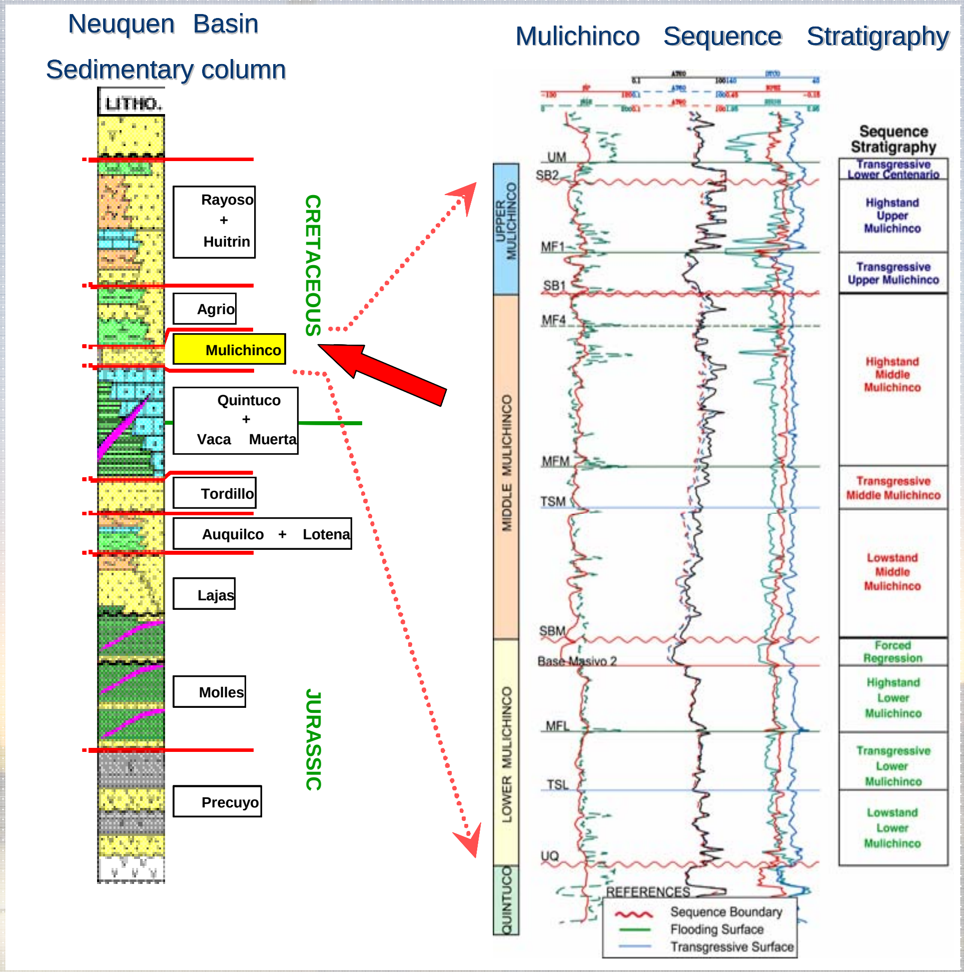
Total Austral has undertaken to develop the southwestern fringe of the Aguada Pichana gas field (Neuquen Basin), which is characterized by lower permeability (0.1 – 1 mD in reservoir conditions)





Regional Setting (2/2)

- Main Reservoir : Mulichinco sandstone
- Moderate size hydraulic fracturing performed up until now on AP Main
- No longer suitable for the new development phase
- « Massive » hydraulic fracturing test programme launched
- to obtain the hydraulic fracturation propagation mode and geometry using the microseismic technique.



Dedicated Pilot to reach this goal was set up

Pilot Objectives & Program

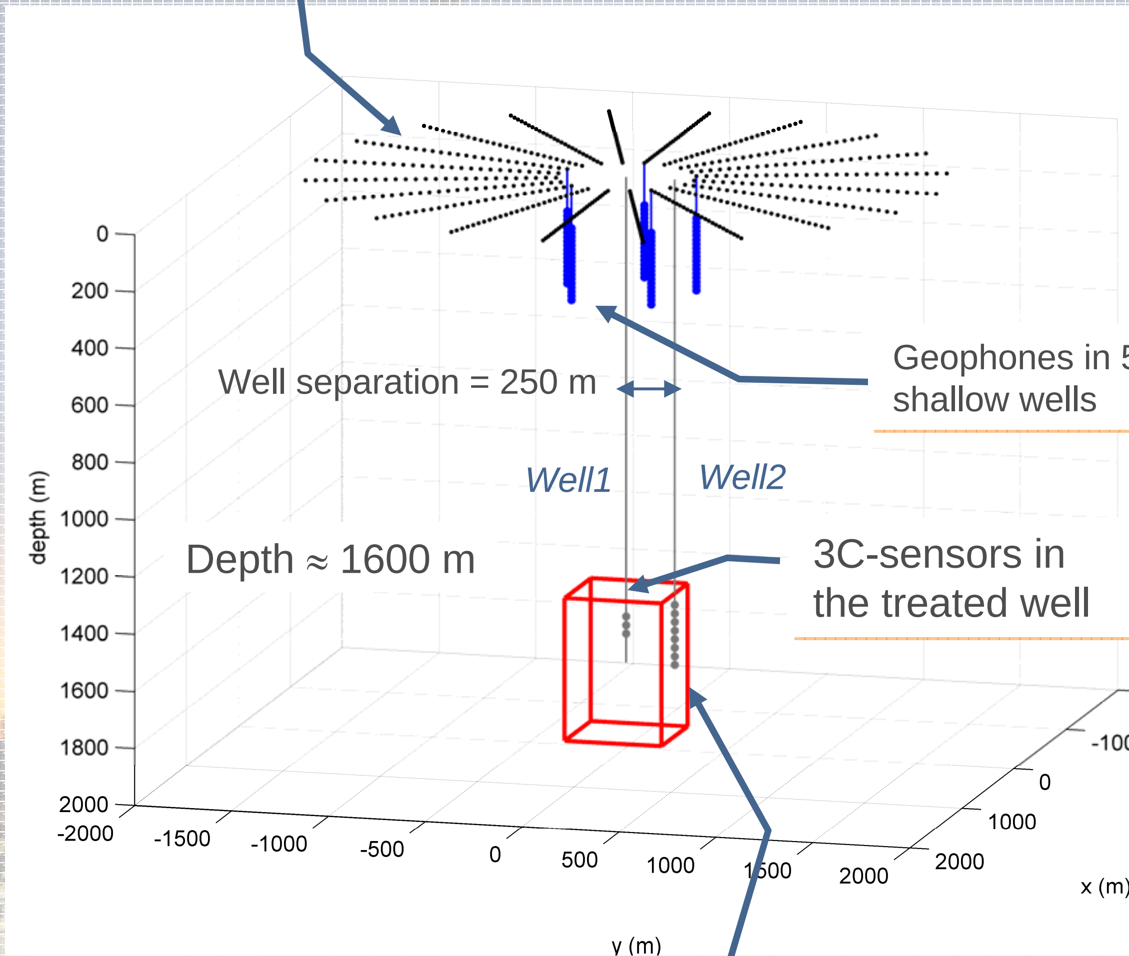
Pilot Objectives & Configurations

- Develop, test and validate alternative μ-seismic techniques
  - avoiding an observation well
  - Minimizing delays and costs of acquisition and processing

- Three alternate configurations tested:
  - Wire line sensor antenna in the treated well (without proppant in well1)
  - Sensor antenna in dedicated shallow wells with "beam forming processing: new application
  - Surface sensor network

- Reference configuration
  - Antenna in dedicated deep observation well

Surface network:20 lines of 26 traces (6 geophones per trace)



Geophones in 5 shallow wells

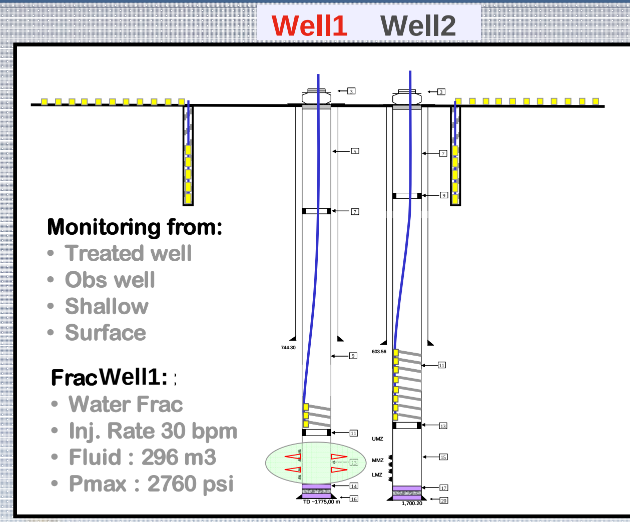
3C-sensors in the treated well

Reference network:
3C-sensors in the observation well

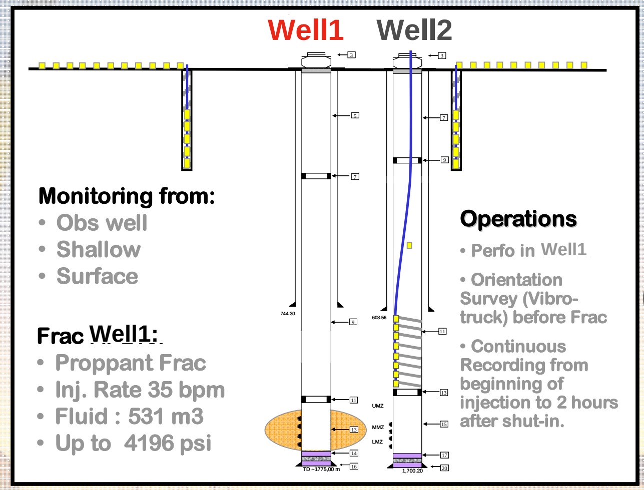
Pilot Program

- The pilot program included:
  - Three stages of frac jobs:
    - with and without proppant in Well1,
    - propped frac in Well2
  - Monitoring
    - in both treated and observation well,
    - in dedicated shallow wells (“near-surface network) and
    - from a surface network

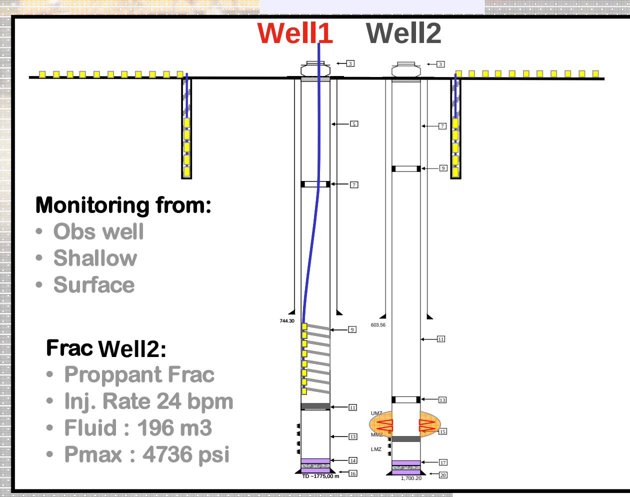
- Deliverables:
  - 4D mapping of hydraulic fracture (azimuth, length, height, growth)
  - Recommendations for the more accurate deployment option



FRAC 1



FRAC 2 (massive)



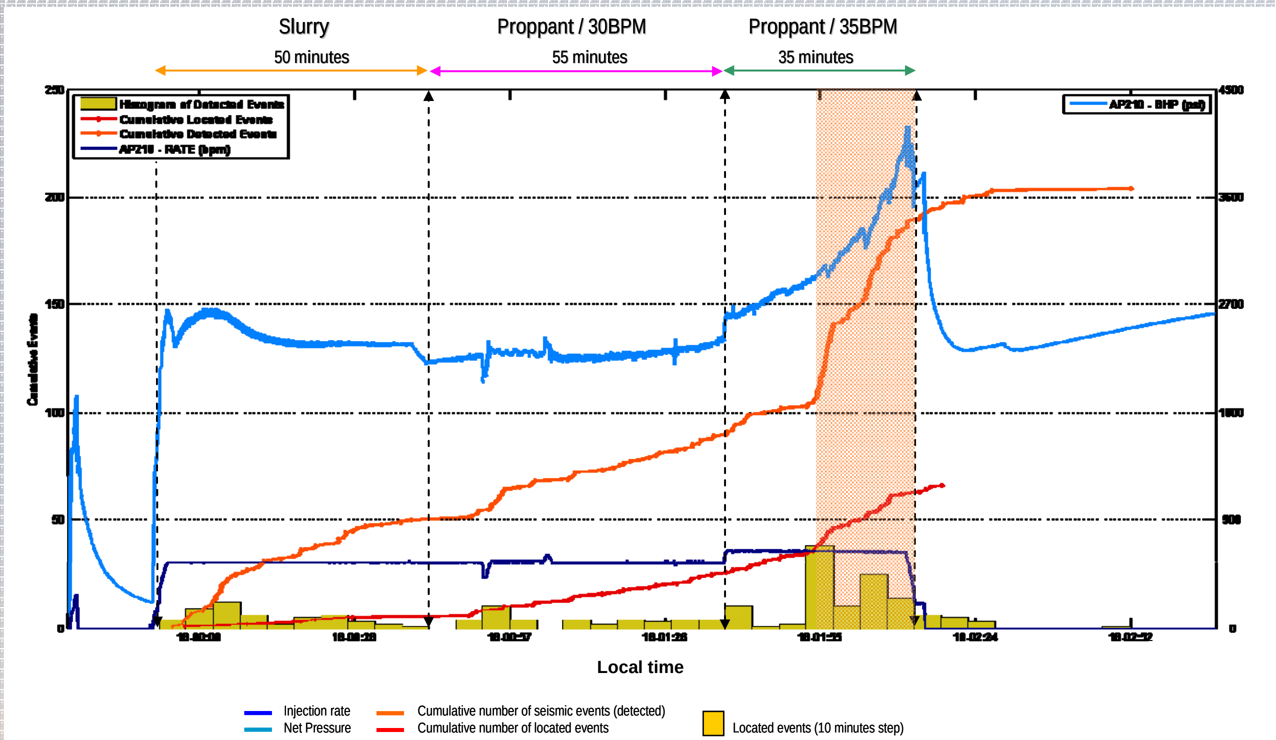
FRAC 3

Main Operational Results based on 'Massive' Frac

Key points for the interpretation

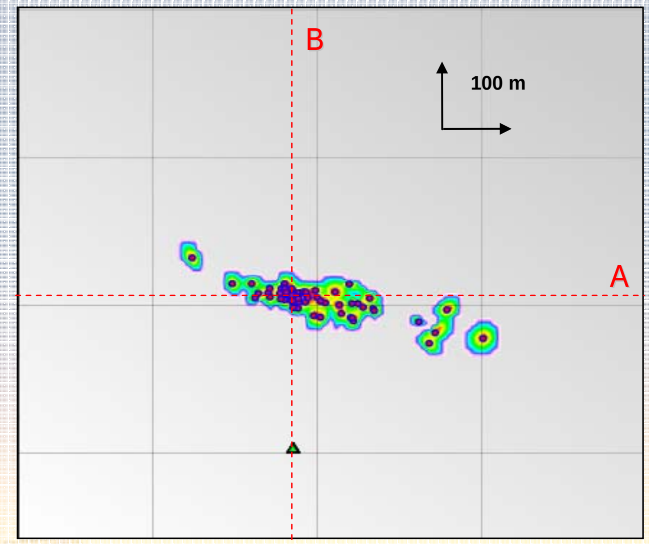
- Seismicity of expected magnitude:
  - -2.8 to -1.9 for frac 2,
  - -2.8 to -2.3 for frac 3 (US Rockies “standard” of -3 to -2)
- Wide majority of the detected and located microseismic events during the injection phase : very few or no events during the fall-off.
- Moderate number of recorded seismic events (max of 200 during frac 2, standard processing), may be in relation with the intensity of frac jobs (comparison frac 2 / frac 3)

Obs. Well: Chronograms & Location Maps

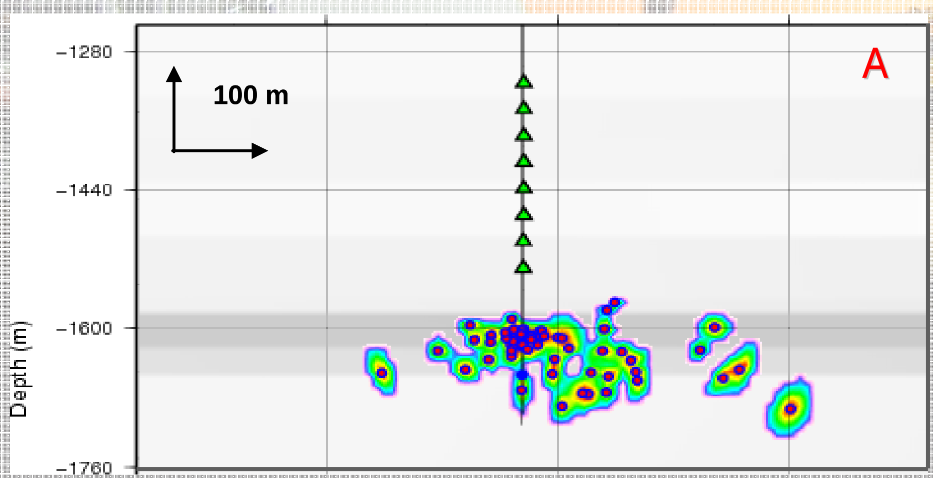


Frac#2 Seismicity

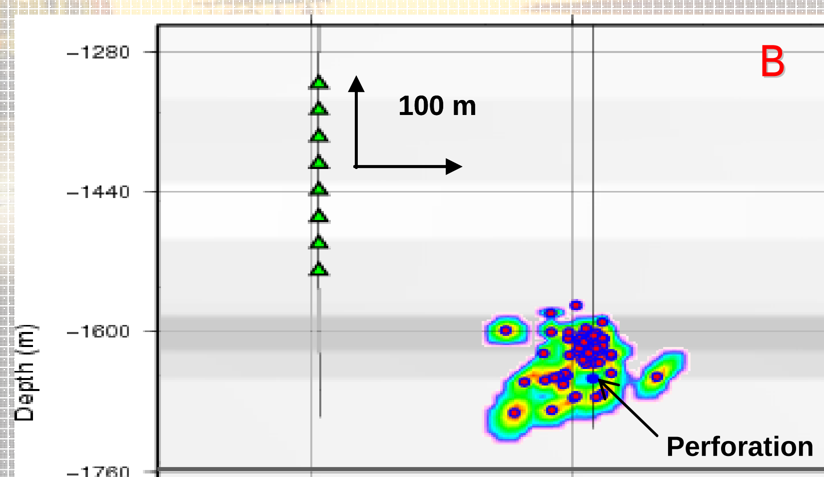
- Location Threshold -2.8
- Max Magnitude -1.9
- AP/AS from 0.1 to 1



Epicenter Map



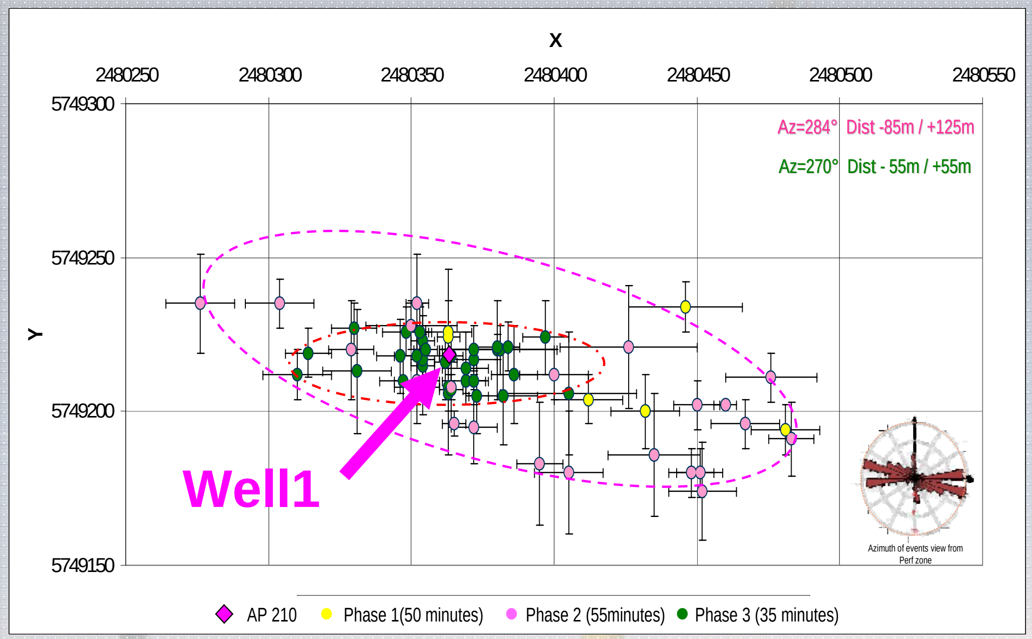
Cross Section (Easting)



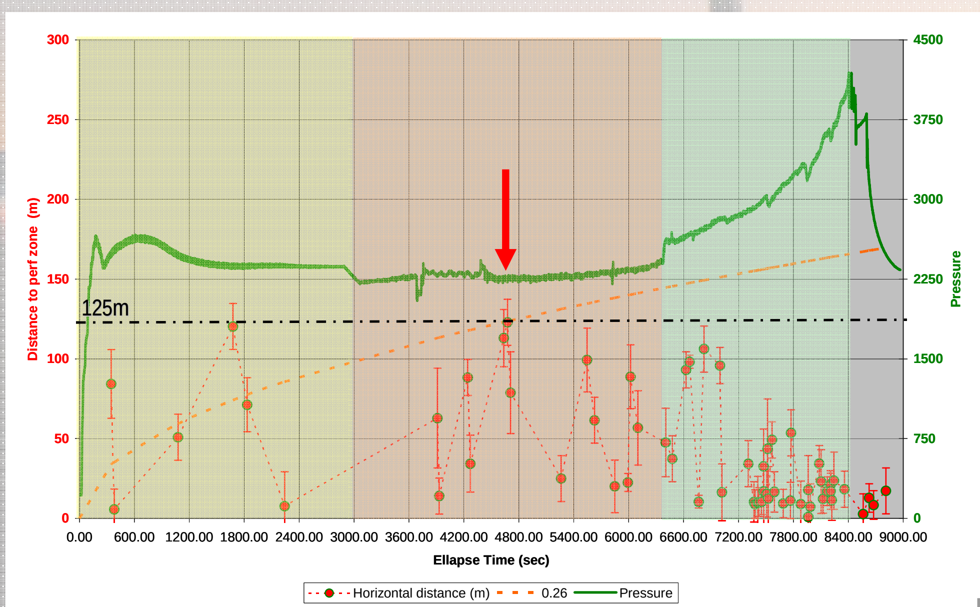
Cross Section (Northing)

Observation Well: global geometry

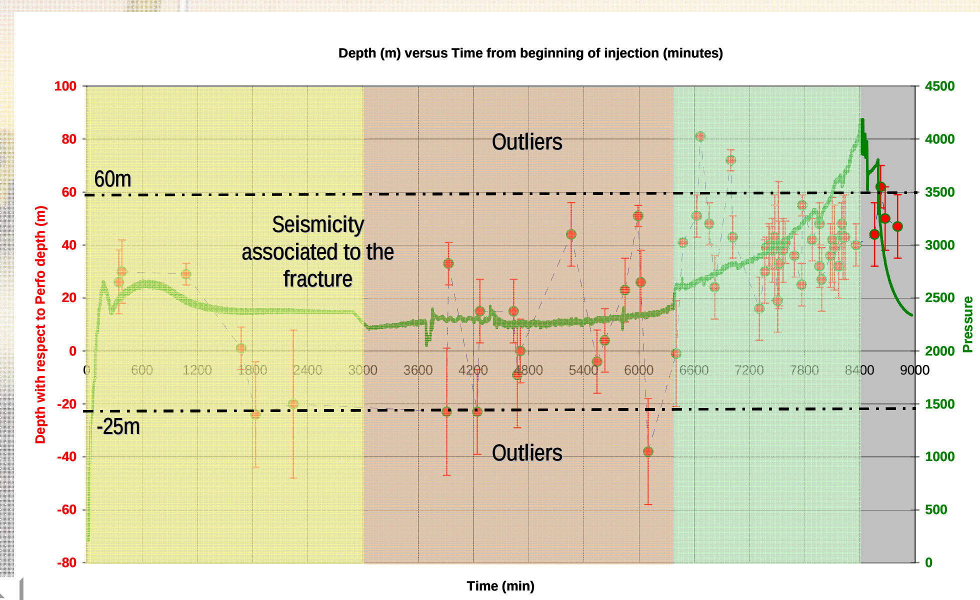
Fracture orientation
NE 275° +/- 10°



Fracture half length = maximum 125 m

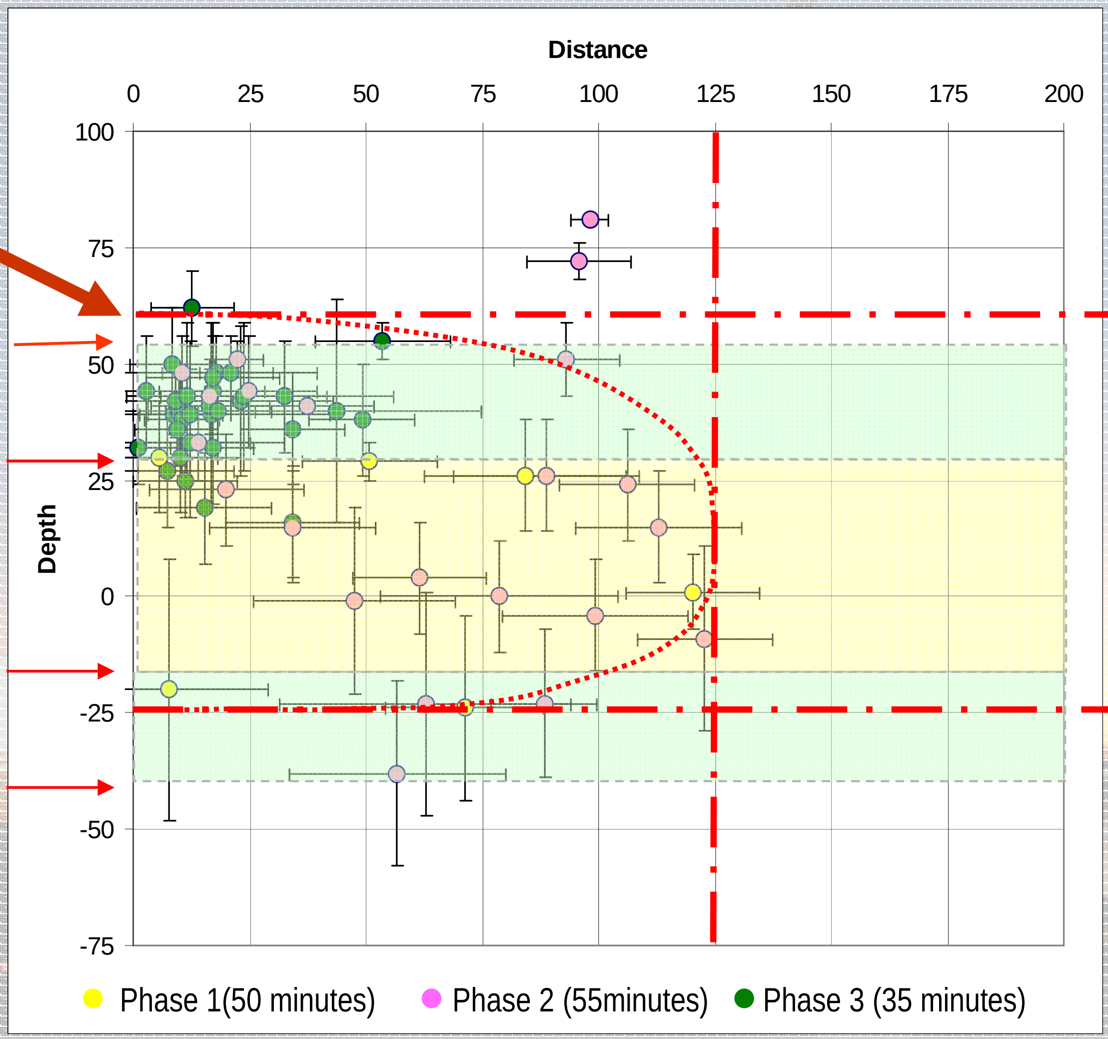


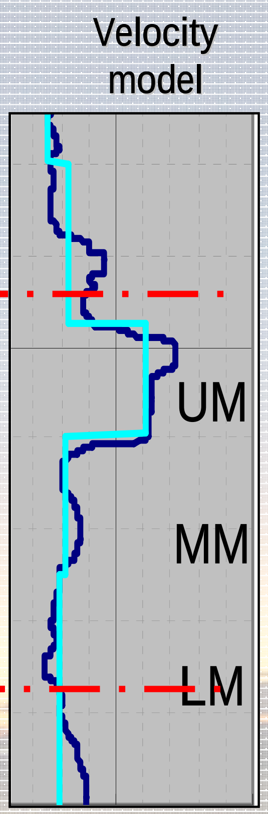
Fracture height about +60m to -25m



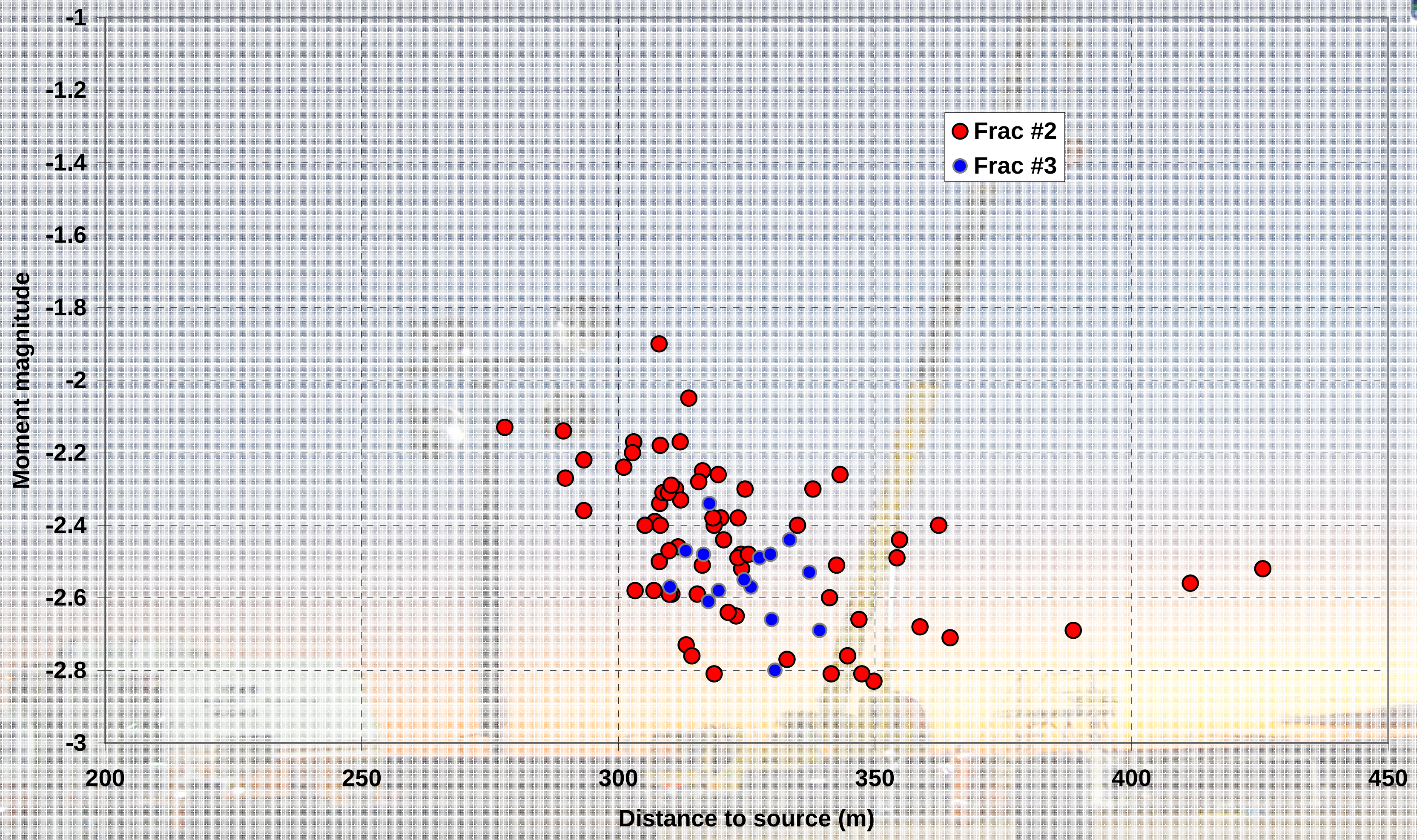
Observation Well: Depth distribution

High seismicity in Upper Mulichinco, at the end of frac job





Maximum distance from Observation to treated well (Aguada Pichana setting)

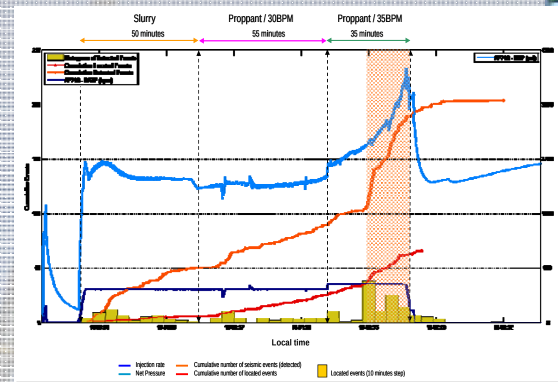


- Maximum distance between microseismic events and geophones ~ 425 m

  (Max offset 340 m for dZ around 270 m)

- Improvement by increasing the number of levels and by applying beam forming technique
- Processing can be applied remotely and in near real time

Observation well Results (standard method)

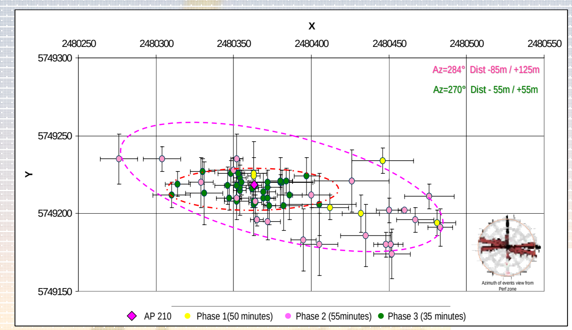


Microseismic events:

✓ Magnitude range of [-2.8, -1.9] for located events

✓ 204 microseismic events detected, of which 67 located

✓ These numbers could be dramatically increased using alternative picking methods (from 67 to more than 580 located events).



Frac geometry:

✓ Azimuth 284°NE in reservoir

✓ Frac Extension: Asymmetry Growth, at least

125 m Eastward and 85 m Westward

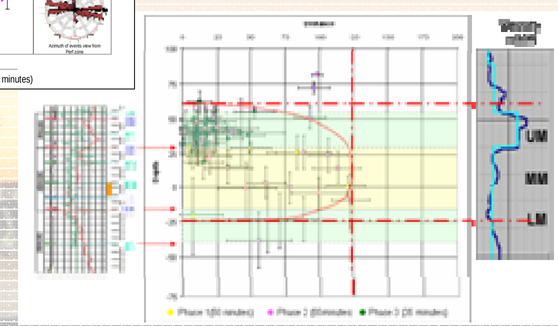
✓ Frac Height +60 m -25 m from perf zone

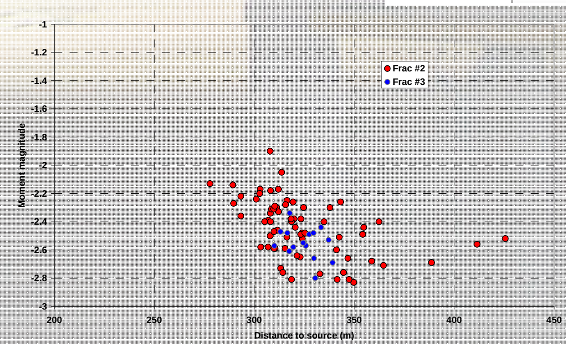
✓ High seismicity in Upper Mulichinco

✓ Consistency with frac simulations

✓ Destabilized zone extends up to 225 m

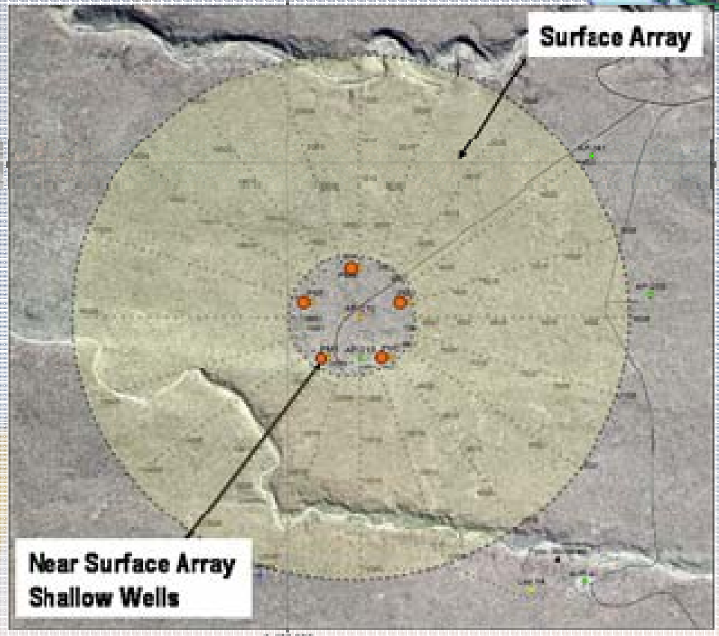
✓ Maximal distance for observation well: 350 m





Surface and Near Surface networks

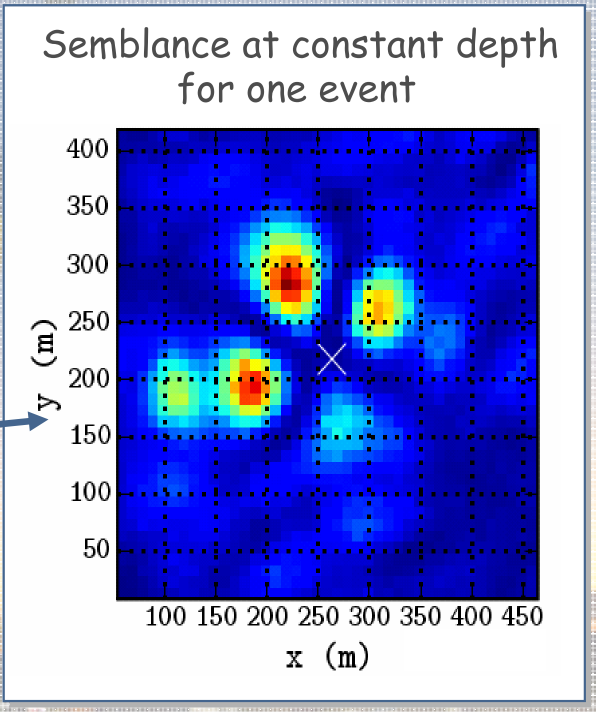
- Both networks effective since being able to detect AND locate:
  - The perforation shot (explosive event) with a S/N ratio of 1:20
  - The "bridge plug" anchoring shot ("simulacra") in well2 (frac 3) which has a magnitude of ~ -2 equivalent to that of microseismic events



- High noise level in surface geophones and near the shallow wells :
  - Only 40% of the sensors on each line efficient for processing
  - red curve indicates the variations in noise level along the line with a retained threshold of 0.002 mV.

Surface network main results

- 67 events with magnitudes down to -2.5 detected (must be improved).
- Beam forming processing
  - allows to increase the detected and located microseismic events
  - BUT unsatisfactory level of uncertainty in locating the events: the focal mechanism should be taken into account in the processing
  - "weighted barycentre" technique provides a better map of the fracture, but only in the x-y plane
- Processing capability requirements could be a limiting factor for use in "near real time".

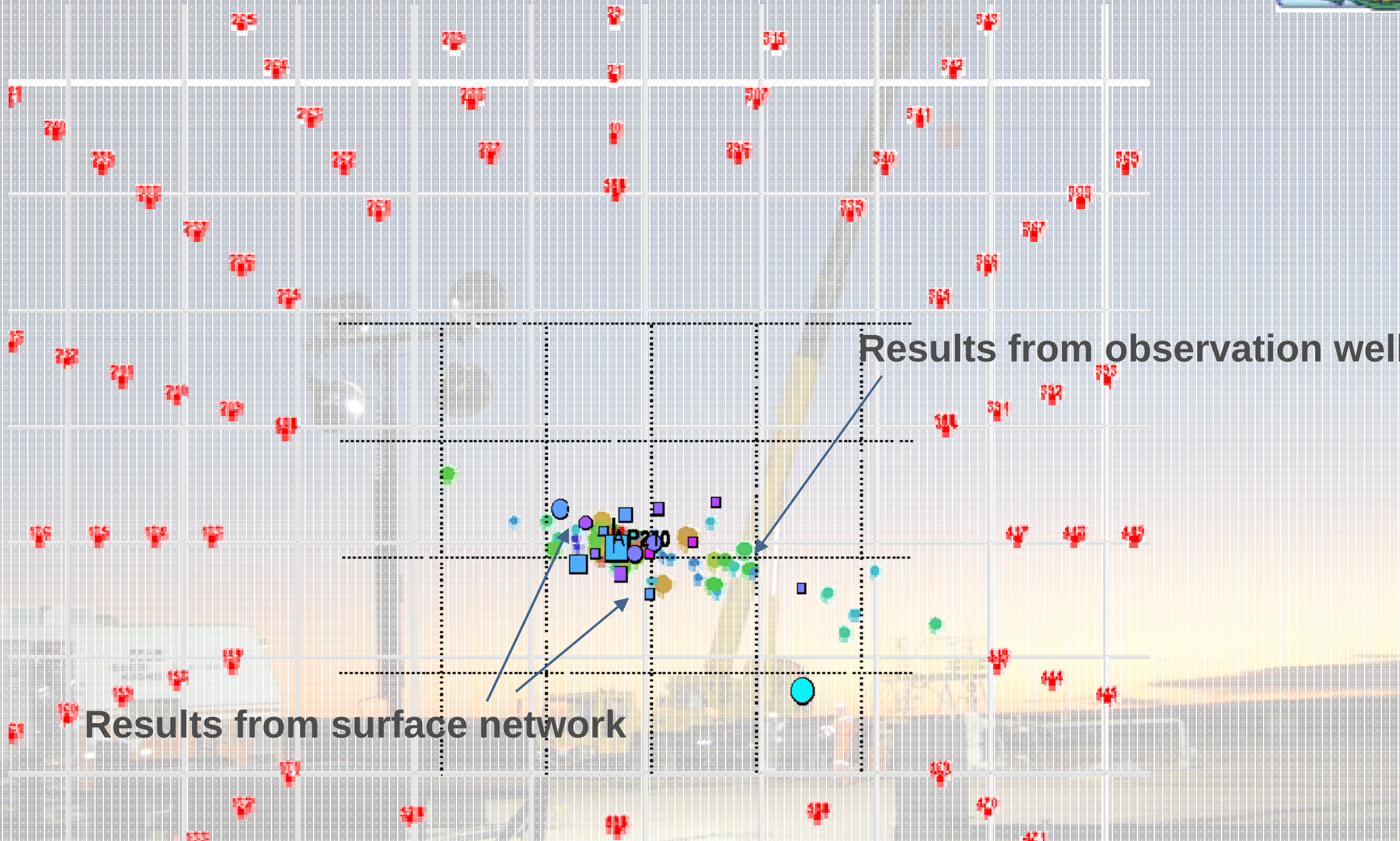


Intermediate imaging step

up to 4 responses for 1 microseismic event

typical of the signature of a strike-slip fault mechanism

Surface Net. – Location with standard approach



Weighted barycenter provides a better image but still an unsatisfactory resolution

- **Artifact not solved**
- **Sensitivity not improved**
- **Source mechanism issue hidden**

Near Surface Network (shallow wells)

Network is effective since it was able to detect AND to locate:

- The perforation shot (explosive event) with a S/N ratio of 1:20
- The bridge plug anchoring shot at the same level as the microseismic events

… but no usable results during frac jobs!

Possible explanation:

radiation pattern of the focal mechanism

Conclusions

Conclusions (1/2)

- Overall operational success especially for the more integrated operations involving many contractors.
- A unique data set to compare various approaches
- Disappointment concerning 2 networks:

-Monitoring in the treated well

- Possible only if no proppant used
- Can detect events during fall-off only

-Shallow wells

- Not conclusive
- More work on lay-out design: emergence angle & multi-component recordings!

Conclusions (2/2)

- **Fruitful results for the remaining two networks:**

- Monitoring in an observation well

- Good results; however, the well should be located within 350m from the treated well
- Further processing possible to increase the number of located events

- Surface network

- Best alternative to the observation well
- More work needed on reliability of detected events; S/N; accuracy of location
- Need to take the focal mechanism into account in the beam-forming process
- Processing capability requirements for use in “near real time”

THANK YOU

FOR YOUR ATTENTION

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