Microseismic Technology to Monitor Fault Reactivation

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Abstract

Reservoir pressure variations associated with oil production and EOR processes have geomechanical impact and may result in potential fault reactivation. To avoid, it is important to investigate pressure levels associated with the production processes which can cause such effects. To evaluate if alternate water and CO2 injection in a sandstone reservoir from a mature onshore field in Northeast Brazil could result in potential fault reactivation, a stimulation operation was proposed. It was specially designed to extend the reservoir pressure beyond the project's levels to monitor any possible induced microseismicity that could be interpreted as fault activation.

Introduction

Miranga is a mature field located on the central portion of the Reconcavo Basin in Northeastern Brazil(Figure 1).
The shallow section consists of Marfim, Pojuca and São Sebastião formations, and is structurally bounded by a set of faults that deform the structure off the axial form, creating a tortoise shell shaped structure with blocks in its central portion. The reservoir rocks are sandstones deposited in a fluvial lacustrine environment during the Early Cretaceous.

To improve the recovery factor, the field's asset team decided to inject CO2 at high pressure in the Catu sandstone reservoirs.

The EOR would additionally serve as an evaluation of technologies that could contribute to key development projects in the pre-salt fields offshore in the Santos Basin. The carbon dioxide produced in the future pre-salt fields will be re-injected into the reservoirs to increase their recovery.

One concern for the Miranga project was the potential of triggering a fault activation during injection, which could represent a risk for the reservoir and environment.

Petrobras needed technologies capable of monitoring and evaluating fault activation.

Since the project start, a considerable amount of data was collected to avoid any fault activation associated with the CO2 injection, including lab analysis, image logs, pressure measurements, breakouts, extended leak-off tests and minifracs. The objective was to estimate in-situ pressures and the vertical and horizontal stresses for geomechanical modeling.

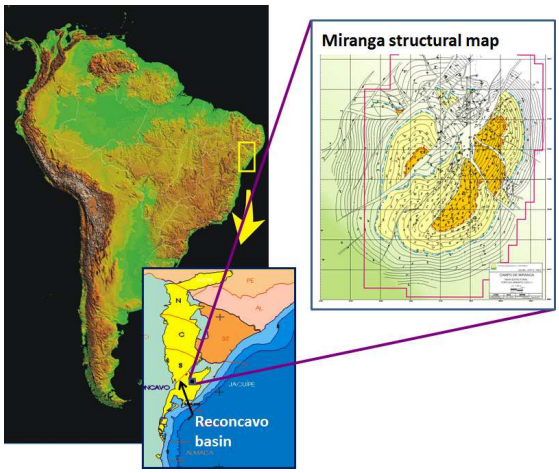

Figure 1: Localization of Miranga field

Pre-job Activities:

In order to simulate the impact of a future CO2 injection, Petrobras and Schlumberger planned to monitor a water injection test near a fault. The microseimic monitoring project involved deploying three-component geophone accelerometers (GAC's) in two nearby wells to evaluate how the fault would behave during the stimulation process. Experience from other parts of the world demonstrated that the microseismic technology is effective in differentiating hydraulic fracturing from fault activation or movement.

The fault activation indicators sought included: the event location, the P/Sh ratio, the frequency-magnitude relationship of the generated microseismic events (b-values) and source mechanism inversion attributes.

The long term plan for the Miranga field is to inject CO2 below the formation breakdown pressure (250 Kgf/cm2), so two water injection tests at 20 bpm with duration of 40

minutes each is planned to mimic the long term CO2 injection.

Modeling

A pre-job microseismic survey design was performed in order to mimic the event magnitudes with a 3D finite difference viscoelastic code to simulate moment tensor sources and generate detailed microseismic three-component synthetics (Figure 2).

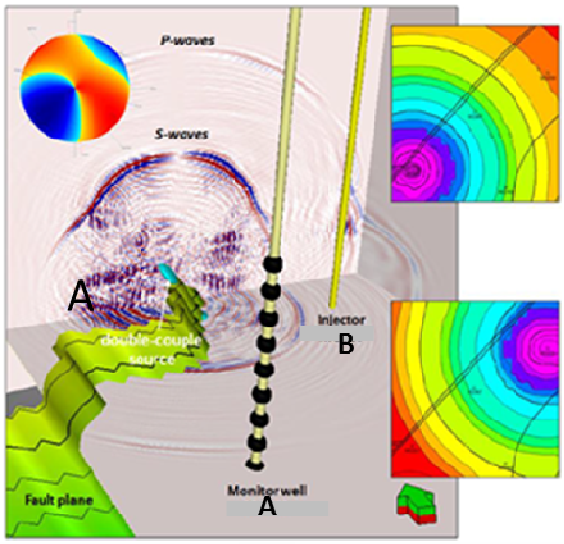

Figure 2. Miranga microseismic survey modeling included 3D finite differences synthetics and event magnitude modeling.

This work assisted in the candidate well selection, provided the minimum event magnitude detection, and gave the expected accuracy for microseismic event location (~20m). All wells selected during the design phase were located in the same fault block with the injector to monitor well distance at about 420 m (Figure 3).

Acquisition

The three wells were prepared by a workover rig so that the microseismic operation could be conducted. Schlumberger provided onsite operations with pumping services in communication with the two wireline acquisition units, and with the personnel who would provide data processing and interpretation services on location. A sonic tool was run on wireline in the injector well prior to the microseismic acquisition to acquire data to enhance the velocity model. A 12 level triaxial GAC tool with 30 m spacing was deployed in Well A with a similar 15 level tool with 15 m spacing being deployed in monitor well C. The microseismic data was recorded continuously, being accessible remotely via a web based viewing program and processed in real time at the well site with results supervised by Petrobras (Figure 4).

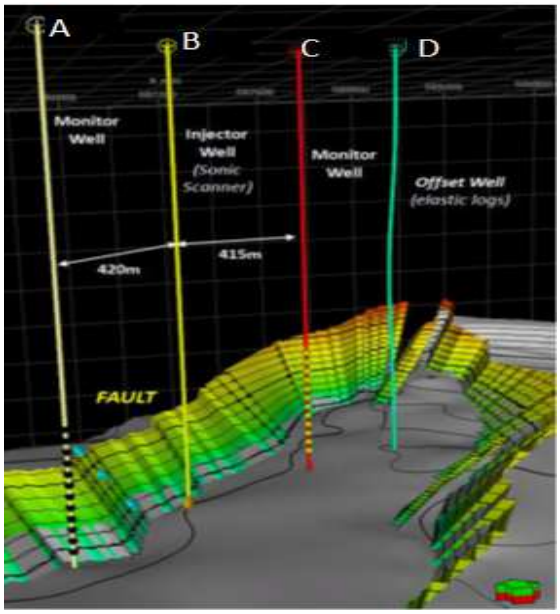

Figure 3. Detail of fault under investigation, the injector and two monitor wells and well D where the elastic log was acquired to improve the velocity model.

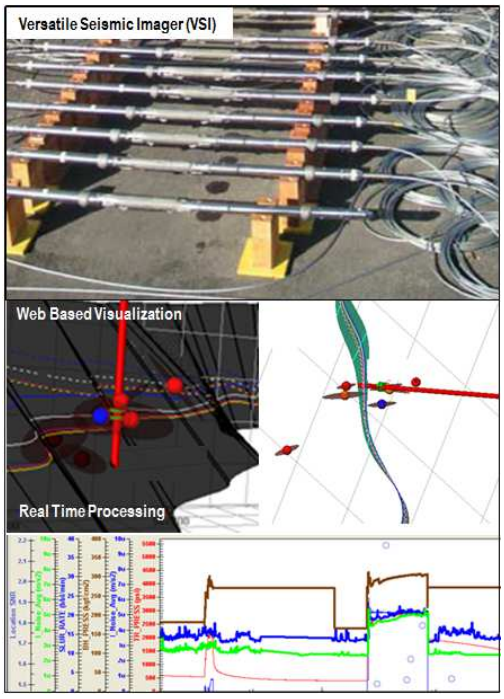

Figure 4: Geophone tools with triaxial accelerometers deployed in two monitoring wells, and examples of some real-time microseismic data processing displays.

Results

Few microseismic events were observed due to the low water injection rate (20 bpm). The events were relatively low in amplitude, and the smallest event magnitude detected was in agreement with the pre-job modeling. No events of magnitude greater than -1.5 were detected in the fault, suggesting that the water injection did not induce significant microseismic deformation on the fault (Figure 5). Together with additional geomechanical data, this gave confidence that the injection planned near the faults will not activate them during the EOR operation.

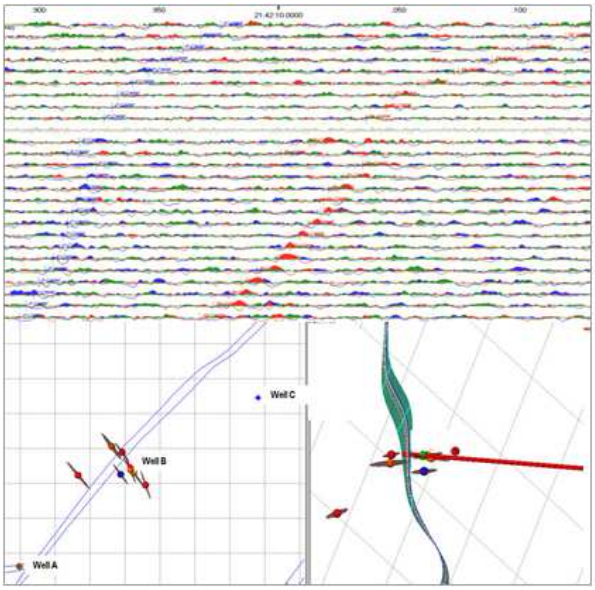

Figure 5. Field results showing waveforms with P and Sh events and a map view with the events mapped with their uncertainty ellipsoids.

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References

Maxwell et all,. A Practical Guide to Interpreting Microseismic Measurements. SPE, 2011.