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Validation of Microseismic Acquisition Geometry

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SUMMARY

this paper presents an analysis of microseismic acquisition strategies for a range of monitoring applications from reservoir characterization to environmental warning systems

Introduction

Microseismic monitoring acquisition options range from borehole (single or multiple) to surface (evenly distributed or patch). As different providers can each currently propose a range of such options the main challenge is to identify the geometry that can provide the data which fits best the monitoring requirements.

With the increase in popularity of the microseismic survey as a solution for monitoring reservoir stimulation, many datasets have been collected over the past few years. The analysis of this large database should provide clear indications of the best practices to follow depending on the monitoring objectives. Nevertheless, the microseismic monitoring methodology is not standardized and a comparison of different datasets – even a comparison of results from different methods for the same dataset – seems to be inconclusive. One way to predict what methodology can work best under a given set of conditions is to simulate numerically a range of acquisition options for a candidate survey; and then validate the methodology by comparing to the results of the actual field deployment.

Method

The goals of a projected microseismic monitoring survey set the thresholds for parameters such as the minimum magnitude detectable and the event location uncertainty to be attained. The selection of the monitoring network is then based on the predictions of the performance of each set of acquisition parameters in the given geological and operational context.

Waveform analysis is first performed when evaluating both surface and borehole deployment. For borehole the information is used to restrict positioning the sensors to locations where a clean signal (easily identifiable phases) can record (Figure 1a). This restriction affects the array geometry and performance. Similarly, for surface deployment the analysis of synthetic waveforms and the associated paths geometry provides information for the network design (e.g. aperture). The comparison of the synthetics with recorded data will confirm the suitability of the initial velocity model and the initial assumptions for the network design (vertical array depth, surface array aperture)

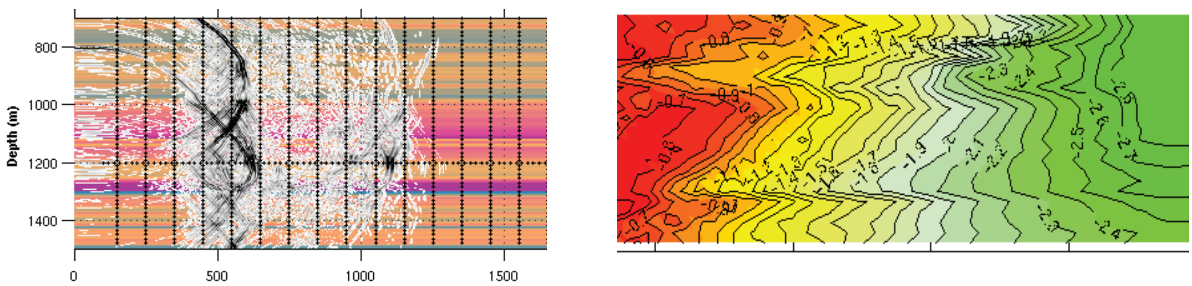

Figure 1 *a) (left) waveform modelling for the analysis of waveform complexity. b) (right) Network sensitivity for n array deployed mid-depth above the target based on the waveform analysis.*

To map the expected distribution of the minimum magnitude event that can be detected and located within the volume of interest the amplitudes modelled and the noise expected are evaluated based on the processing method appropriate for the given geometry. Estimating the noise before the job is a difficult task. Validating these predictions can provide better constraints for predicting the performance of future projects.

Borehole arrays are best suited to record and locate small magnitude events within a short range; the performance is nevertheless uneven and declines rapidly with distance, particularly for one-well configurations (Figure 2a). When it is important to achieve an even performance across the target area a distributed array (surface, shallow) is recommended (Figure 2b). Nevertheless, the minimum event size detectable increases with depth and, depending on geology and operations, this network might have the ability to locate only a few events. Assuming self-similarity holds at the lower end of the scale (and therefore small events should have be triggered if larger magnitude events have been observed), the source parameters of the events located after the acquisition of the dataset should be able to confirm the values and distribution of the minimum magnitude predicted.

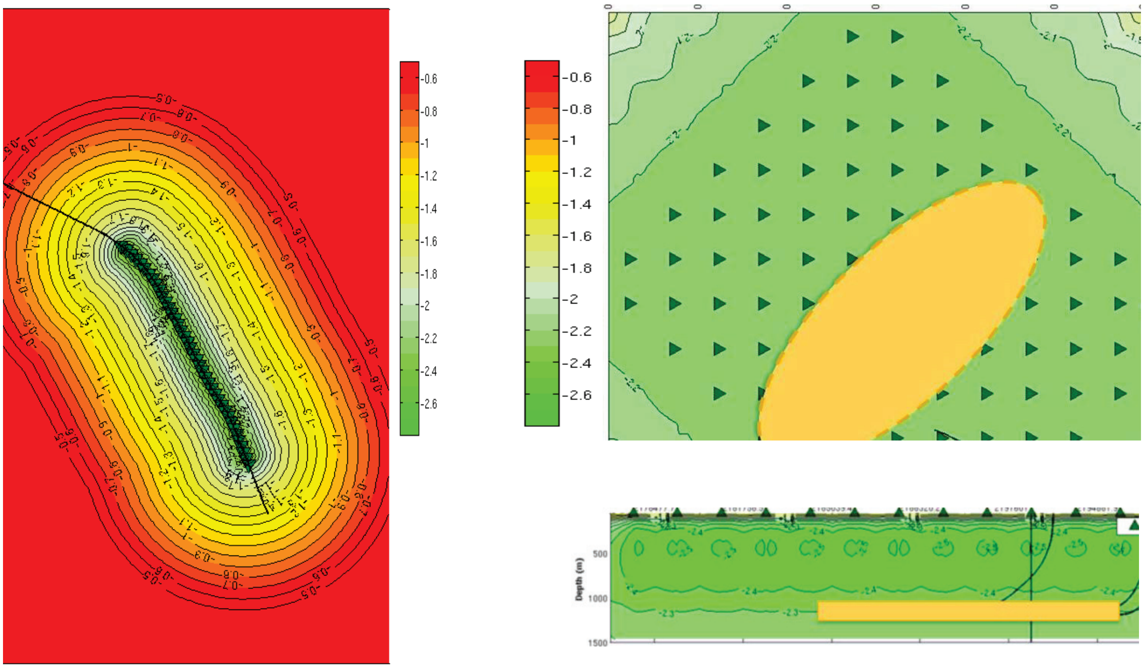

Figure 2 *Comparison of the distribution of minimum magnitude detectable with a borehole and a surface array. a) (left) horizontal cross-section through the target area including the horizontal monitoring well; low magnitude events can be detected in the vicinity of the observation well but the coverage is uneven. b) (right) same parameter mapped in a horizontal and in a vertical cross-section through the target zone: even coverage but decreased magnitude with depth.*

The datasets we tested so far show a good agreement in the range of magnitudes predicted and calculated from recorded data. A good test for the methodology used to calculate recorded event magnitudes can be done sometimes on known events of predictable magnitudes. An accurate prediction of the minimum magnitude threshold can be important of it will give some indications regarding the number of events that could be recorded with a particular network configuration for a given target. In hydraulic stimulation monitoring the magnitudes reported are in general low which means that in order to record a significant number of events this magnitude threshold needs to be very small – below -2.2- -2.4.

Conclusions

A choice of a monitoring network options from the wide range available should be made by comparing the predicted performance with characteristics desired for each particular project. Since the methodology for processing microseismic data is not standardized it is difficult to compare results from different surveys. A comparison of the predicted performance and the results of the microseismic data processing should establish confidence for the methodology. Since only one of the options modelled can in general be tested against the data acquired in the field the validation of different designs requires different datasets.