

# Integration between 4D and reservoir fluid flow properties

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When we follow the history of the development of the seismic technique to reveal the unknown subsurface then we note different developments that determined at large the progress of this particular geophysical method. In most cases this progress finds its origin in a technological improvement that triggered the application. In that category, for example, the computer played an important role in acquiring and processing the seismic data. Hand in hand with this progress went the description of the seismic measurement in terms of the underlying principles of acoustic wave propagation. The computer made it possible to mimic the seismic technique and in doing so to understand the sensitivity of the measurement to the heterogeneity of the geological subsurface complexity. More importantly the computer facilitated the processing of actual recorded seismic data by recognising that in order to make an image of the subsurface the journey of the acoustic wave into the Earth has to be replayed in some way or the other with the measurement as input. It was with no doubt Jon Clearbout who, as the first scientist, brought this concept to our attention. He stated that what we have to do is to follow the acoustic wave from its source into the ground to its reflection point back to the recording transducer, the geophone. In order to achieve this goal Jon claimed, you need wave theory to trace the seismic data back in time from the source and the geophone to the interior reflection point and then look at time zero. For it is at just this time instant when the down-going wave from the source and the up-going wave at the receiver meet. The reflection point has been moved, migrated to so to speak, to its true position in the Earth and hence the name of the game: *migration*. Thus it is the causality of the acoustic arrival that makes it possible to convert the 2D-space and 1D-time measurement at the Earth's surface into a 3D image of the subsurface in a process that nowadays is denoted as *depth imaging*. It is clear that you must have a background model to move the data to that particular depth location.

In the nineteen-nineties experiments were carried out where, after some time lapse, the seismic measurement was repeated at the same location with the intention to find out whether the seismic contrast had changed. The latter being triggered for example by the change of reservoir conditions due to the exploration programme. This type of geophysics was coined as *4D seismic* to honour the repetition of the process in time, which is however substantially larger than the actual seismic measurement time. Since the sampling rate in the two time directions is not comparable, it is a bit presumptuous to call the process 4D, *time-lapse seismic* describes the process in a better way.

The sampling rates of the common 3D measurement are chosen such that the 3D *heterogeneity* is sufficiently captured. The repetition interval has to be chosen that the *localised change* of the 3D heterogeneity is sufficiently captured.

In the realm of time-lapse seismic we distinguish three problem areas:

- I. The repetition constraints of the experiment in the 3D configuration. If these conditions are not met we encounter the problem that the time-lapse image is unreliable due to the non-repeatability.
- II. The time-lapse image formation.
- III. The relation of the observed change in the time-lapse image and the corresponding and the corresponding change in the reservoir.

The repeatability issue mentioned under I is important, insofar when this condition is not met the differences in acquisition are mixed with the differences in the reservoir. Again improved technology is coming to our help. For example the Ocean Bottom Technology is developed to guarantee equal receiver conditions at the different time instants. Further the *a-priori* assumed unchanged seismic reflector above the reservoir acts as calibration horizon to synchronise the time-lapse data sets. Still this subject is far from solved and deserves our full attention.

It is clear that the time-lapse image process mentioned under II needs careful consideration. In standard 3D imaging we employ a background model to achieve our goals. Are we using the same background model for the two time instants and consider the difference of the so-obtained images or are we simultaneous imaging the time-lapse data sets to obtain the difference? It is the difference that makes the difference. In this workshop we will address this important issue.

The question raised under III is the most important issue that prompted this workshop. The promises of time-lapse seismic can only be cashed if the change between the sequential seismic measurements can be related directly to a factual change of the reservoir parameters. This does not involve better imaging only, but also a better understanding of the rock-physical parameters that cause the seismic image to change. Up to now the laboratory rock-physical experiments were not all optimistic in the change of the seismic image due to a scaled parameter change. In practice however these changes in the seismic image were much more pronounced. This calls for a better understanding of our models and their scaling behaviour. The aim of this workshop is to evaluate existing and new strategies for monitoring temporal changes in the subsurface by time-lapse seismic and quantifying these changes in terms of dynamic reservoir parameters. Questions that will be addressed are:

- How can we improve repeatability?
- Can we monitor changes in AVO or AVA? Should we infer velocity changes from differences in amplitudes or traveltimes or both?
- How can we benefit from multi-component measurements and how can they be used to evaluate the change in anisotropy?
- What model should we adhere to be able to seismic monitor stress changes?
- Can we distinguish between changes in fluid parameters and stress conditions?
- Can permeability be inferred by monitoring fluid fronts?

With these questions we started our workshop. On the next pages you find the response of our colleagues.