4D seismic surveying

Seismic surveying can be limited to two dimensions: length and width, three dimensions: length, width and height, and four dimensions: length, width, height, and time. The last one is called: 4D seismic surveying or time-lapse surveying. The objective is to determine the changes occurring in the reservoir as a result of hydrocarbon production or injection of water or gas into the reservoir by comparing the repeated datasets. This understanding has consequences as increasing the recovery factor of a reservoir final processing product is a time-lapse difference dataset (data from survey 1 is subtracted from data from survey 2). The difference should be close to zero, except where reservoir changes have occurred.

4D seismic surveying involves the following stages: planning acquisition, processing, and interpretation of repeated seismic surveys over a producing hydrocarbon field.
1-Aquisition:-

Seismic data acquisition involves applying a seismic energy source, such as vibroseis truck or shot-hole dynamite at discrete surface location. The resulting energy is reflected back from interfaces where rock properties change. By recording this reflected energy at an array of geophones placed in the ground surface, the results can be processed to produce an image of underground geological structures and a range of attributes that can be used to infer the physical rock properties.

2-4D planning and design:-

The planning process of a 4D survey is more involved than planning a regular exploration 3D survey: Pre-survey evaluation and design studies are critical in
determining 4D survey acquisition, processing, and inversion parameters.

Successful 4D studies aim to increase production and cost savings through better planning of production and injection wells and increased understanding of reservoir characteristics. The following figure shows the work flow in detailed planning.

![Diagram showing work flow for 4D survey planning and design](image)

3-Processing:-

*Obtaining high-resolution data for 4D time-lapse processing :-*
The key to the technical success of 4D seismic applications lies in the repeatability and resolution of the seismic data. If the processed seismic datasets are not identical then the 4D signal can become masked by, or confused with, 4D noise. Time-lapse seismic processing is used to maximize the repeatability of the datasets, while attaining sufficient temporal and spatial resolution to detect the expected subsurface variations. These variations are normally changes in acoustic impedance, but may be an AVO effect, a time shift, or any other aspect of the seismic data. Combinations of responses can also occur.

4-Analysis and Interpretation:-

With an understanding of the fluid production, injection, and geometry in geomechanically active reservoirs such as compaction drive reservoirs, we can detect travel time changes not just in the reservoir, but also in the overburden. In these reservoirs, production causes subsurface deformations and changes in seismic velocity. These changes in the overburden can be monitored and interpreted using time-lapse seismic data. Saturation and pressure changes in a reservoir may be determined from AVO inversion methods; in particular, simultaneous inversion is providing additional quantitative information about reservoir conditions.

Rock physics models using well log and core measurements are brought together to forward model and convert time-lapse seismic measurements into
quantitative production-related changes in reservoir saturation and pressure.

**Time-lapse seismic surveying's experiments**

*Experiments:*-

Many time-lapse seismic experiments have been done offshore, where the wells are few and very apart. Other experiments have taken place in unusual or expensive production scenarios, such as: CO2 flooding and Steam flooding operations in heavy oil.

**Time-lapse 4D gravitation:**-

Field-wide gravity monitoring offers a unique possibility to directly measure changes in mass as they take place in a producing reservoir. These measurements are useful for the movements of gas/fluid contacts, optimizing production and estimating in-place reserves. Four time-lapse gravity surveys have been acquired over the Troll field in a pioneering attempt to image and monitor the rise of the liquid contact during gas production. On the Sleipner field two surveys show the average change in density when CO2 is injected in water-filled sandstone. These surveys represent the first offshore application of gravimetric reservoir monitoring in the world, and new surveys are being planned as production continues. Similar projects have recently been started over onshore gas fields.
References


3- http://www.cgg.com

4- http://petrowiki.org/Seismic_time-lapse_reservoir_monitoring