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Overburden Characterisation Using Passive Seismic Monitoring

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SUMMARY

The passive monitoring of microseismic events can provide a cheap and effective means for monitoring spatial and temporal variations in reservoir properties. These microearthquakes will occur naturally due to regional tectonic stresses, but can be also induced through exploitation activities such as hydraulic stimulation, enhanced petroleum recovery and fluid extraction. Such monitoring offers insights into the dynamic state of stress in a reservoir - invaluable information for developing effective strategies for drilling, injection and production programs.

Although microseismic monitoring has been used to study geothermal fields since the 1970s, the oil industry has only recently started to realise its potential. Whilst 10 years ago microseismic monitoring was relatively uncommon in oil fields, it is now fairly commonplace in monitoring the hydraulic stimulation of fractures, for example. The processing of such data is quite different from approaches used in conventional reflection seismology. In fact, the techniques used are more akin to those used in conventional earthquake seismology.

The use of microseismic data can be divided into two broad categories: the study of the source itself, and imaging the surrounding medium. Sudden stress release on faults and fractures will generate elastic waves that will propagate into the surrounding medium. The first step in any microseismicity study is to locate these events as accurately as possible. Their locations and how they migrate in time can be used to image fault planes, infer fault re-activation, and monitor the propagation of perturbations to the stress field. This can be important in detecting compartmentalization in reservoirs, assessing cap-rock integrity and monitoring injection fronts. Directional variations in the pattern of energy release at the source can be used to determine the orientation and magnitude of the stress field and can be used to further assess the orientation and motion of fault planes.

Given sufficient source and receiver coverage, microseismic data can be processed using imaging tools such as tomography and velocity analysis. As both P-wave and S-wave signals are generated and recorded (see example in Figure 1) there is much potential to determine lithological and fluid properties from P- and S-wave velocities and their ratios. Furthermore, such data are ideally suited to study seismic anisotropy. Unlike conventional reflection seismology, raypaths are not generally vertical and hence directional variations in velocity are more easily assessed. Perhaps the most unambiguous indicator of anisotropy is shear-wave splitting. Measurements of this can be used to assess fracture properties, which are sensitive to spatial and temporal variations in the stress field. Finally, microseismic data are generally rich in frequency content and there is much potential to look at frequency-dependent wave phenomena. For example, they can be used to estimate effective Q. It has also been shown that frequency-dependent shear-wave splitting is sensitive to crack size, aspect ratio, and fluid properties.

In this talk, I will illustrate some of the potential uses of microseismic data in reservoir decision making, showing examples from a range of microseismicity studies. The intent is to illustrate the broad range of applications of passive seismic monitoring and highlight the rich potential such datasets have in reservoir management.