Subsurface fracture network mapping using seismic data

Mu Luo[1]; Isao Takahashi[2]; Mamoru Takanashi[3]; Yoshihiko Umezawa[4]

[1] Geology Dept., JGI; [2] INPEX; [3] JOGMEC; [4] ZADCO

Subsurface fracture network mapping using seismic data

Mu Luo (1), Isao Takahashi (2), Mamoru Takanashi (2) Yoshihiko Umezawa (3)
(1) JOGMEC (currently at JGI., Inc.), (2) JOGMEC, (3) Japan Oil Development Company (currently at Zakum Development Company)

The ability to accurately determine subsurface fracture networks is critical since such networks can control fluid flow thus can have a major impact on many engineering aspects. Here we present a case study of mapping a possible fracture network using wide-azimuthal Ocean Bottom Cable (OBC) seismic data recorded over a Middle East offshore producing field. Our results demonstrate the potential for obtaining detailed fracture information through seismic studies, and how such information can be used for enhanced oil and gas productions. A brief discussion is also given to our latest research on this topic.

The presence of vertical fractures and/or aligned porous grains alters rock's physical properties. In such rocks, seismic waves will sense various degrees of stiffness and compliance of the rocks thus cause observable seismic azimuthal anisotropy: a direction-dependent phenomenon of preferred wave propagation.
There is an established understanding that reservoir complexity could be diagnosed through seismic anisotropy studies. Thus for enhanced oil and gas production, there is an increasing need to image subsurface fracture systems through the study of seismic data. One of the technical challenges remaining is to maximally exploit seismic attribute sensitivities to improve the mapping of the spatial distribution of subsurface fractures. This requires the true signal characteristics of recorded data being maintained.

In this case study, using three pre-defined reflectors, we mapped a possible fracture network of a test area within a field in two steps: (1) construction of multi-azimuthal attribute maps and (2) description of the fracture network through orientation and ratio of seismic anisotropy by directly measuring long and short axes of ellipses of all the maps built in the first step. Arrival-times and amplitudes of pre-stack data were processed and analyzed using two analysis scales which allows a better understanding of attribute sensitivity and offers detailed information of the fracture system of the test area. Our results confirm a feasible methodology of mapping the fracture systems through simple visual inspection.

This case study suggests the presence of a field fracture network and/or aligned porous grains groups in which fractures trend mostly NW-SE/NE-SW with a wrenching appearance, which can be tied to the known geological conditions but could not otherwise be disclosed from core samples or large-scale faults. Also, water breakthrough observed in the field is possibility caused by fractures in which fluid-flow of a target layer could be either NW-SE or NE-SW, depending on the locations of injection and production wells and the major faults, as well as the conductivity of the fracture network. Flow behavior could be further complicated as fracture swarms intercept main faults and heterogeneity. Nevertheless, knowledge of small-scale fracture network obtained from seismic data, incorporating with large-scale faults, could provide a better solution to predict fluid flows as demonstrated in this study.

This study provides a promising approach in mapping reservoir anisotropy (or fractures) that could give rise to highly-permeable networks. Our current research is focusing onto the development of an integrated processing/analyzing technique in which improved fracture network mapping and subsurface imaging are expected to be achieved through recovering the true seismic characteristics for target reservoirs by reducing overburden effects.