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Fractured Reservoir Characterization Incorporating Microseismic Monitoring and Pressure Analysis during Massive Hydraulic Injection

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Abstract

The fractured basement gas reservoir in Yufutsu field was characterized by integrating static fracture information obtained from borehole micrtyo-resistivi images and dynamic information recorded during a massive hydraulic injection operation. Yufutsu gas reservoir is so called “fractured reservoir” seated in Cretaceous granite and Eocene conglomerate formation at around 4 - 5km depth in the Southern Ishikari Plain, central Hokkaido, Japan. One of the most important issues in the development of this reservoir is how to model the fracture system which contributes to the hydrocarbon migration.

A massive hydraulic injection and microseismic monitoring operation was conducted in 2005 with an objective to delineate the spatial distribution of the fractures by stimulating pre-existing fractures. The injection schedule and anticipated areas of the stimulation were thoroughly designed and predicted by using a numerical simulator, which runs on a Discrete Fracture Network (DFN) model. The DFN model was created on the basis of fracture information obtained from borehole images. The injection of more than 5,600m^3 of slick water, without any additives, effectively induced microseismic activities and accordingly improved the injectivity of the well.

A preferential direction of the observed microseismic distribution showed a good consistency with the prediction. However, significant differences in the pressure responses were observed. These mismatches were fed back to modification of the model, which finally showed a reasonable match. Furthermore, a precise analysis of source locations and a focal mechanism analysis were applied to the representative microseismic multiplet events. Those two independent analyses revealed existence of two dominant orientations of the fracture system, which are consistent with the most likely orientations of shear slippages in the current stress condition around the injection well.

Introduction

One of the remarkable characteristics of the fractured reservoir is a wide variation of the well productivity. Many poorly productive wells and few highly productive wells are randomly distributed, which is a typical naturally fractured reservoir[1]. The wide variation in well-production is considered to be attributed to heterogeneity of fracture distribution. Therefore the delineation of spatial distribution of the fracture system contributing to the fluid flow is desired and challenging issue for optimal development of naturally fractured reservoirs.

The Yufutsu oil and gas field is located in the Southern Ishikari Plain, central Hokkaido, in northern Japan. The reservoir, seated at around 4 km depth, is known as a so-called “fractured reservoir”, where oil and gas have accumulated in cracks in the granite and overlying conglomerates.[2] The rock itself has very little porosity and permeability. Space for the storage of gas/oil and paths for these hydrocarbons to move must be provided by various scales of fractures. Local variations in effective stress due to fault compartmentalization also can significantly impact reservoir production.[3]

Despite the extensive studies of the Yufutsu field, knowledge of the fracture network is limited around the boreholes. No reliable data of fractures away from the boreholes was available. The 2-D reflection seismic survey technique still does not have enough resolution to see fractures at 4km depth. This fact makes it difficult to delineate the overall fracture system and create a reliable reservoir model in this field.

To challenge the issue and to gain more knowledge of the fracture system in the Yufutsu field, JAPEX conducted a massive hydraulic injection and microseismic monitoring experiment in May, 2005 by forcusing the potential of microseismic monitoring as a tool for fracture delineation, which has been actively studied in a geothermal industry.[4,5,6] JAPEX succeeded in inducing and recording thousands of microseismic events in the gas saturated reservoir and demonstrated the feasibility of this approach.