数台のアクロス震源と疎な地震計配置を仮定した深度200m、2kmに位置する石油／ガス貯留層のタイムラプスシミュレーション

Time-lapse imaging simulations using a few ACROSS seismic sources and sparse receiver spacing for oil/gas reservoirs

*笠原 順三[1,2]、羽佐田 葉子[3]
*Junzo Kasahara[1,2], Yoko Hasada[3]

1.静岡大学理学部地球科学科 東京海洋大学、2.東京海洋大学、3.大和探査技術(株)
1.University of Shizuoka, Faculty of Earth Sciences, 2.Tokyo University of Marine Science and Technology, 3.Daiwa Exploration and Consulting Co. Ltd

1. Introduction

Recently unconventional oil and gas productions such as heavy oil, shale oil and gas, and oil below sub-basalt have increased. EOR technology is applied to the unconventional oil/gas field production and the time-lapse monitoring is essential for this technology. Although demands of the time-lapse approach for the EOR are increased, the recent circumstance of oil price requires the reduction of geophysical exploration costs. In ordinary seismic surveys, receiver and source spacing of 25 m are commonly used to obtain smaller bin sizes. Including the recent requirements in view in costs, we tried to prove the effectiveness of our time-lapse method considering cost reduction. In contrast to the conventional seismic exploration, we carried out two time-lapse imaging simulations for the deeper and shallower cases assuming a few seismic source and coarse geophone spacing.

2. Two time lapse simulations

The reservoir depths were assumed to be 2 km and 200 m. We calculated wave fields excited by vertical force by using the 3D finite difference method. By using the synthesized waveform data at selected receivers before and after the changes in physical properties of the presumed reservoirs, we calculated residual waveforms. We conducted 2D or 3D Kirchhoff migration using the residual waveforms to image the temporal-change.

2.1. Reservoir at 2 km

Assumed reservoir was 500 m in both horizontal dimensions, 20 m in thickness at 2 km depth. We examined linear receiver arrays with 5 m and 100 m spacing in simulation of 2D imaging. In 3D imaging, we used only one ACROSS seismic source and a geophone array with 200 m grid.

2.2. Shallow reservoir at 200 m

The next case was a very shallow heavy oil reservoir. We assumed a small reservoir of 20 m in both horizontal dimensions, 10 m in thickness at 200 m depth. We tested two array patterns with 106 and 25 geophones and one or two ACROSS sources.

3. Result

2 km depth case

The results show effective image retrieval even when using only one seismic source and a 200 m-spaced geophone grid array. In cases of linear array, we were unable to identify any significant differences between 5 m and 100 m spacing cases, which dramatically reduces the total installation costs of the monitoring system.

200 m depth case

Even when the source was 800 m apart from the target reservoir, the tiny target with 20 m-long x 20 m-wide x 10 m-thick was effectively imaged. In the case of by 106 and 25 receivers, we did not recognize significant changes. We also recognized that the simulation using two sources gave better image retrieval than using single source, and retrieved images could be controlled by receivers just above the target.

4. Discussion and conclusions

Although we conducted several simulations assuming V_P, V_S, density structure and their changes in the models, the actual production fields varied significantly from the model results. If we use actual structural datasets, the simulation might be more plausible and precise. The reservoir depth, noise conditions, locations of injection and production wells and properties of near surface layers, should be considered.

In this study, we confirmed the effectiveness by examining the results of simulations conducted with two heavy oil models at shallow and deep depths. We effectively imaged the model reservoirs for 200 m and 2 km depths. Using one ACROSS seismic source and geophones with 100-200 m spacing can produce a reliable reservoir image even for a reservoir of several tens of meters in size. The results obtained by simulations in two cases suggest high potential of our method in time-lapse application to heavy oil, permanent reservoir monitoring, and CCS.

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