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Constraining Reservoir Uncertainty With Frequent 4D Seismic Data at Valhall Field

H.S. Lane, SPE, BP America; R.M. Kjelstadli, SPE, and O.I. Barkved, BP Norge A/S; D.T. Johnson, SPE, BP America; O.J. Askim, BP Norge A/S; and J.-P. Van Gestel, BP Netherlands

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Abstract

Permanent ocean-bottom seismic cables were installed in 2003 at Valhall Field, offshore Norway, as part of a Life of Field Seismic (LoFS) program. Six seismic surveys have been acquired from the permanent system through 2005, in addition to two historical towed-streamer surveys acquired in 1992 and 2002. The various 3D seismic data sets generally show strong time-lapse or 4D effects resulting from primary production.

In a previous paper we described a workflow used to integrate 4D seismic data with conventional well data in a Top-Down Reservoir Modeling (TDRM) computer-assisted history match of a portion of the Valhall field.¹ Two seismic attributes were used to help constrain the reservoir model – a two-way time shift from the surface-tow surveys and a sum of negative amplitude difference between two of the LoFS surveys. These two seismic attributes seemed to provide independent spatial information about the reservoir that was not contained in the conventional well measurements. History matching was also conducted on the conventional well data alone, without the 4D constraints. The results indicated that when run in prediction mode, the history matches that included the additional 4D seismic constraints provided a narrower uncertainty range on the resulting forecasts than did the models that only honored the well data.

In this paper, we examine some additional issues associated with the potential use of multiple time-lapse seismic attributes from the LoFS program in our ongoing quest to further constrain the reservoir history match. We focus in particular on the considerations for choosing an appropriate set of “target” seismic attribute maps for the LoFS history matching effort, which deals with time-lapse intervals that are much smaller than those associated with typical 4D surveys.

Introduction

The main “Tor” reservoir at Valhall is a high-porosity chalk formation that has produced over 500 MMstb since 1982 under primary depletion conditions. Compaction of the soft chalk is a key drive mechanism that has resulted in high intrinsic reservoir energy but has also led to seabed and platform subsidence. The compaction associated with primary production has also had a significant effect on the 4D seismic signature. A waterflood program has recently begun which will extend the field production plateau and also have a significant impact on the 4D observations. Additional background material on Valhall can be found in Refs 1-4.

A conventional 3D marine surface-tow seismic survey was acquired at Valhall during 2002 and matched to a 1992 surface-tow survey, capturing 10 years of production history.² Figure 1 shows a map of the time shift (TS), or time-lapse change in two-way travel time through the reservoir, extracted from the surface-tow surveys. The strong depletion/compaction response seen in this map is the result of increasing bulk density and acoustic velocities in the reservoir with time. The ellipse toward the bottom of the map indicates the region of the field that was the focus of our previous history matching effort¹ and will continue to serve as the focus for our current discussions. Figure 1 also shows the TS map for the focus region after upscaling from the underlying 25m seismic grid to our coarser 100m reservoir simulation grid. It is at this scale that we compare the observed 4D signal (map) to an analogous synthetic 4D map generated from the reservoir simulation model during the history matching process. Additional elastic rock property modeling is required to produce the synthetic seismic attribute map from the simulation outputs (see Ref. 1 for further details).

During the summer of 2003, a permanent seismic array was installed over Valhall allowing for frequent acquisition of time-lapse LoFS surveys.⁴ Table 1 lists the approximate timing associated with the six seismic surveys acquired with the permanent system through the end of 2005. The individual LoFS surveys have been acquired over a period from three to seven weeks. However, because our reservoir simulation uses monthly average well rates that are updated on the first of every month, we have tied the midpoint of each LoFS survey to a single point in time that corresponds to one of these monthly updates.