V013 POSTSTACK INVERTED SEISMIC DATA USED IN WELL PLANNING ON THE OSEBERG FIELD

Å. SKÅLNES¹, E. ZACHARIASSEN², A. RYSETH¹ and H. FJELLBIRKELAND²

¹ Norsk Hydro Research Centre, 5020 Bergen, Norway

² Norsk Hydro Production

This paper presents a case study where geophysical techniques including post-stack inversion and seismic modeling, are integrated with geological data and knowledge in order to determine an optimal location for a new horizontal production well.

Introduction

The main reservoir units on the Oseberg Field are the Oseberg, Rannoch and Etive Formations (ORE). In addition considerable quantities of hydrocarbons are located within the Tarbert and the Ness Formations. Fluvial channel sandstones within the Ness Formation and the shallow marine sandstones in the Tarbert Formation contain approximately 30 % of the total oil in place. The optimal way of producing these reserves is by dedicated horizontal wells. A well correlation profile from the northern part of the Oseberg Field is given in Fig. 1.

The Tarbert Formation is eroded towards the west and south. The sandstones are of variable reservoir quality and an ORE production well (C-24) showed that the existing geological model overestimated the thickness of the Tarbert Formation towards the west and thus the objective and position of a planned Tarbert production well (C-16A) had to be revised.

Seismic inversion

Conventional seismic interpretation of the Tarbert Formation is very difficult and it was therefore decided to evaluate whether post-stack inverted seismic data could be used to map the extent of the Tarbert reservoir sands.

The inversion method used was recursive trace integration of zero-phase seismic data combined with a background model based on interpolation of low-pass filtered well log impedances. The inverted data were loaded into the seismic interpretation system. It appeared that the presence of a low acoustic impedance event correlated with the geological model of one of the productive Lower Tarbert sands.

However, manual interpretation of the low acoustic impedance event on the interpretation system proved to be difficult, especially at the edges which in fact were the areas of greatest interest. Instead acoustic impedance maps were extracted using the interpretation of the Top Brent horizon as a reference (wherever present Tarbert is the upper part of the Brent group).

Initial evaluation showed that the presence of gas strongly influenced the acoustic impedance and the further analysis was restricted to the area outside the gas cap. Acoustic impedance values extracted at the well positions are cross plotted against the vertical thickness of the Tarbert sand in Fig. 2. The figure shows that there is a very strong negative correlation (-0.90) between extracted acoustic impedance and the sand thickness.

This observation was confirmed by a simple seismic modelling experiment. From the modelled data we observed that if the true acoustic impedance in a thinning layer is constant, the inverted acoustic impedance will vary with the thickness of the layer. The reason for this effect is that the interference pattern between the reflections from the top and bottom of the layer cannot be resolved by the inversion procedure.

Geostatistical estimation

Cokriging is a geostatistical estimation technique that can be used to combine sparsely distributed well information with dense seismic information. The method is conditional, meaning that the estimated data are identical to the measured data at the well locations. Cokriging was used to combine the well information with the inverted acoustic impedance into an areal map of estimated sand thickness.

In the area where the Tarbert producer was planned, the estimated thickness was below 10 m. This map of estimated sand thickness was compared with the thickness map from the geological model made **after** the drilling of Well C-24. The two models were very similar but the important point is that the cokriged estimate was made without using information from Well C-24.

Information from a well drilled after this estimation study (Well C-26) was consistent with the thickness estimated by using cokriging. Based on the information from C-24, C-26 and the thickness map estimated from the inverted seismic, it was decided to change the objective of the C-16A well from a Tarbert producer to a Ness producer.

Ness Formation

A detailed mapping of the fluvial sandstones in the Ness Formation was thus initiated. Sedimentological interpretation of core material shows that the Ness Formation can be divided into two main facies assemblages reflecting deposition within fluvial channel (I) and associated floodplain systems (II). Fluvial channel sandstones form the principal reservoir rock, whereas floodplain deposits comprising mainly mudrocks, thin and impure sandstone layers and coal represent potential barriers to fluid flow.

The correlation panel presented in Fig.1 illustrates the vertical and lateral distribution of reservoir and non-reservoir lithologies in the Ness Formation in the central area of the Alpha structure. In Lower Ness (Fig. 1), coal beds and abundant floodplain deposits dominate the succession, and reservoir sandstones are usually encased within non-reservoir rocks. However, thick fluvial channel deposits are seen in the southern part of the correlated profile, and represent possible drilling targets. Upper Ness (Fig. 1) comprises a main unit of dominantly fluvial sandstone and mudrocks, with less coal, although a laterally persistent coal-bearing interval is usually seen at the top of the formation. As in Lower Ness, reservoir sandstones are present in the southern part of the profile, and pinch out to the north. Accordingly, the area around wells C26 and 30/6-13 is identified as a possible target area for a producer in the Ness Formation.

Integration of detailed sedimentological and biostratigraphic data, using the entire well data base (approx. 90 wells) have served as a basis for establishing a high resolution stratigraphic zonation of the Ness reservoir. Tentative deterministic sandstone distribution maps are constructed for each stratigraphic zone on the basis of lateral lithology variation between the studied wells. These sandstone distribution maps have been correlated with the information from the inverted acoustic impedance in order to optimize the definition of areas with high probability of containing reservoir sandstone bodies in the Upper Ness interval.

The fluvial channel sandstone bodies in the Ness Formation show a large variability of measured vertical thickness. Maximum values recorded from the present data base reach up to about 26 m, but sandstone bodies in the thickness range from 2 m to about 8 m are most common. This means that mapping of individual sandstone bodies in the Ness Formation based on seismic data is not possible, except for unusually thick bodies. However, vertical stacking of the individual sandbodies leads to an average sand thickness of about 9 m.

Seismic modelling experiments show that this is close to but within, the limit of the resolution present in the seismic data. These modelling experiments have further shown that thin coal layers inbedded with shale may give similar seismic response as channel sandstones. This is a severe problem when mapping sandstone bodies in the coal-bearing Lower Ness interval, but must also be taken into consideration for the Upper Ness interval.

As a guide during interpretation of the post-stack inverted data, the geological models (isochores) of both Upper and Lower Ness were depth-to-time converted and imported to the seismic interpretation system. Acoustic impedance maps within the assumed Upper Ness Formation were produced and compared with the channel thicknesses observed at the existing wells.

In Fig. 3., a cross plot between the acoustic impedance extracted 8 msec below the Base Tarbert and the total Upper Ness channel sandstone thickness, is shown. For channel sandstone thicknesses above 5-10 m there is a clear relation between the inverted acoustic impedance and the total channel sandstone thickness. However, for channel sandstones with a thickness below 7.5 m hardly any correlation can be observed. The overall estimated correlation coefficient is -0.5.

Due to the large variations in acoustic impedance values for the thinner (< 10 m) channel systems, the problem of identifying areas with high probability of channels did not appear suitable for statistical or geostatistical techniques. The approach chosen instead was to extract acoustic impedance maps from several levels within the Upper Ness interval, identify areas with low acoustic impedance and analyse the vertical sections (inlines and crosslines) in these areas. Extrapolation of observed channel systems away from existing wells was also attempted.

The C-16 well was planned to penetrate several possible sandbodies at different levels in the Ness Formation according to the generated sandstone distribution maps and acoustic impedance data. Results from the drilling showed that the well encountered several sandstone-rich zones within the Ness Formation and that these zones correlate very well with low acoustic impedance zones that was observed on the inverted seismic data. The well is currently producing very well from two of the penetrated sandbodies.

Fig.1: Well correlation profile from the northern part of the Oseberg Field

Fig. 2: Acoustic impedance versus thickness of Tarbert sand layer

Fig. 3: Acoustic impedance versus total Upper Ness channel sandstone thickness