Introduction

Being a mature basin, the UK Central North Sea area has benefited from the acquisition over time of extensive 3D seismic coverage, both on a speculative and proprietary basis. Major seismic contractors have undertaken the task of joining and merging the 3D seismic datasets of various vintages in order to provide basin-scale contiguous 3D seismic. Maersk Oil UK has acquired data covering most of the Central North Sea over a 15,000 km^2 area. Even though such a huge data set brings real advantages in facilitating exploration and new venture efforts, extracting the information and utilising it in a timely manner is challenging.

In this work, the interpretation was carried out by applying a novel approach, which generates a 3D geological model directly from the seismic. The main objective of the study was to deliver a new horizon framework covering the entire volume in the shortest time frame. Moreover this work aimed to test the feasibility of the method on very large dataset and verify the existing manual interpretations of key horizons. The outputs from this study were used for different applications in exploration such as shallow hazard assessment, identification of potential prospects and regional basin modelling.

Relative Geologic Time Model

The method consists of a computer aided, two-step workflow to build a relative geologic time model (RGTM) (Pauget et al, 2009) directly from the seismic. A model is first computed using the minimization of a cost function which depends on the distance and the similarity of the mini-traces between seismic points. This process automatically tracks every horizon within the seismic volume to constrain a grid and a relative geological time is computed for every point. The seismic interpreter then checks relationships between horizons to refine the links between the nodes inside the grid until an optimum solution is obtained. Such approach has been already tested on various case studies (Gupta et al, 2008; Lemaire et al, 2010; Schmidt et al 2010; Lacaze et al 2011).

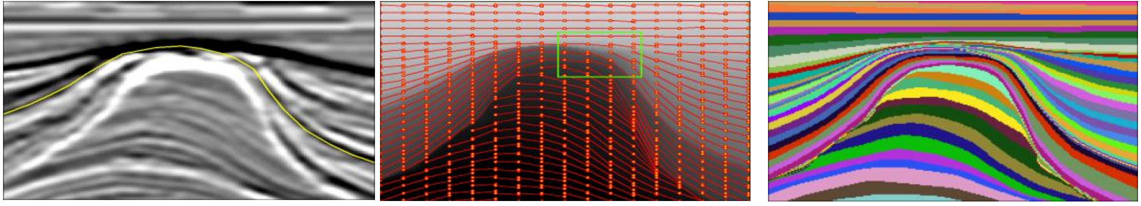


Figure 1– Method for the Relative Geologic Time Mode (Pauget et al, 2009). (Left) Synthetic seismic section showing a salt dome. (Middle) Geomodel grid, a realisation of the connection between the nodes is based on seismic correlation. (Right) Based on the relationships between the nodes, a continuous geological model is computed.

With a large data set, it becomes difficult for the interpreter to extract a geomodel from the entire volume in a single step. The seismic volume is therefore divided into sub-areas, having common overlapping boundaries and each sub-area is interpreted independently. Merging the sub-areas is carried out by synchronising the relative geological positions between the different grids. Such a process can be applied at a large scale and helps to solve some ambiguities more easily.

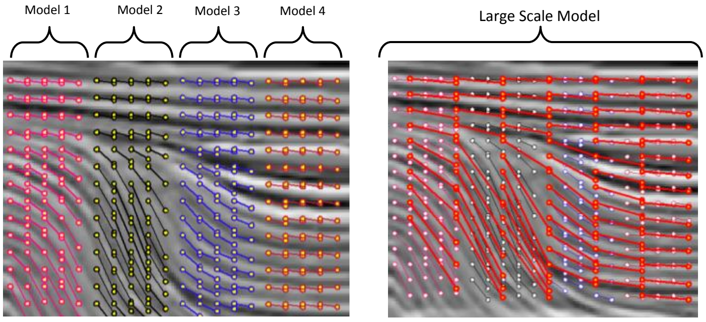
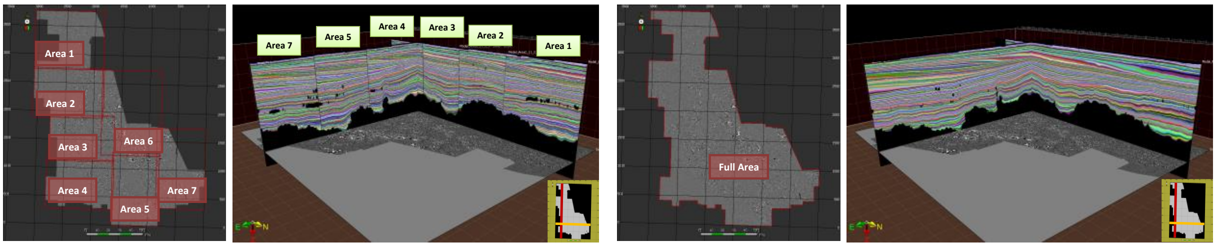


Figure 2– Large-scale modelling. (Left) Sub-areas were a grid is created. (Right) Merging of the model is realised by synchronising the sub-grids.

Application on the UK Central North Sea Dataset

This multi-scale approach was applied on a large seismic data set covering the Central North Sea area. The volume itself results from a time pre-stack merge of different seismic surveys acquired over time by a major seismic contractor. The total area of this dataset covers 15,000 km^2. In order to process the full volume with the same resolution, it was decided to decimate the volume to a bin size of 100mx100m and to limit the time window from 0 to 5500 ms. Due to remaining multiples and the rapidly deteriorating quality of the signal below the Base Cretaceous Unconformity (BCU), the interpretation was limited to a zone going from the seabed to the BCU. No initial information, either existing horizons or well markers, was used as input to the process.

The full volume was divided into 7 overlapping sub-areas, of some 2,000 to 2,500 km^2 each (Figure 3.a). Of the eight week project, one week was spent independently on each sub-area to create a relative geologic time volume, and the last week was focussed on the merging of the sub-models into a single volume covering the entire area (Figure 3.b). From this, a new class of attributes is derived in conjunction with regional horizons with which to map the available seismic attributes.



(a) (b)

Figure 3–Large Scale Relative Geologic Time Model. (a) Total volume of 15,000 km^2 is divided into 7 overlapping sub-areas of around 2,000 km^2 each, processed independently. (b) The merging of all the sub-areas provides a regional model covering the entire survey from which any horizon slice can be derived.

Shallow Hazard Assessment

In the context of a pre-drill Shallow Hazard assessment, horizon slices rather than time slices provide a better contrast between shallow anomalies and geological features. As shown in Figure 4, the shallow horizons derived from the model show clear channels, information which could be helpful in initial well planning and site survey design.

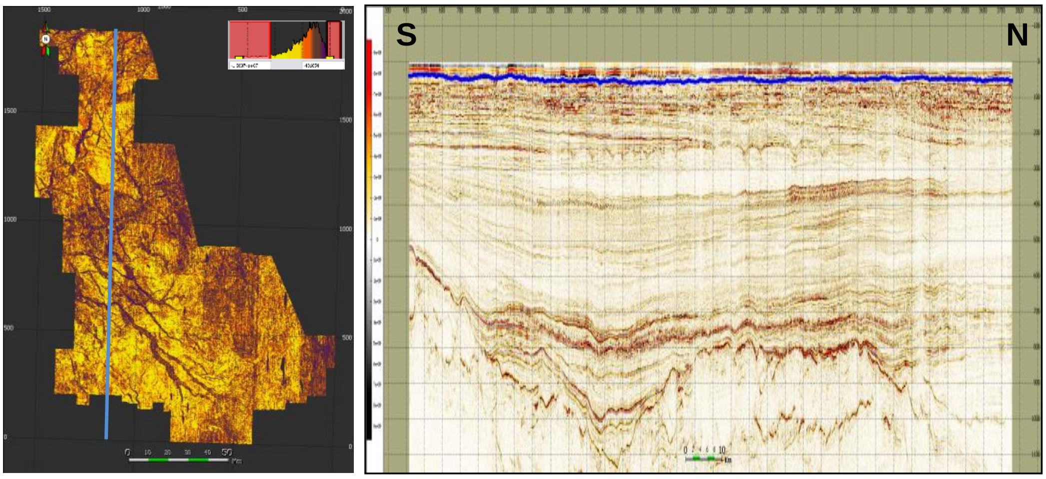


Figure 4–Large scale shallow horizon slice showing clear channels.

Enhancement of Mass Debris Flows

The seismic envelope extracted along a horizon close to the Early Paleocene Top Maureen Formation, reveals features interpreted as mass debris flows of marl and limestone coming from paleo-highs to the North West and flowing towards the paleo-lows of the central basin over a distance of approximately 100 km (Figure 5). The image shows bright amplitude contrasts useful in delineating and understanding the spatial extension of the geological body on a regional scale.

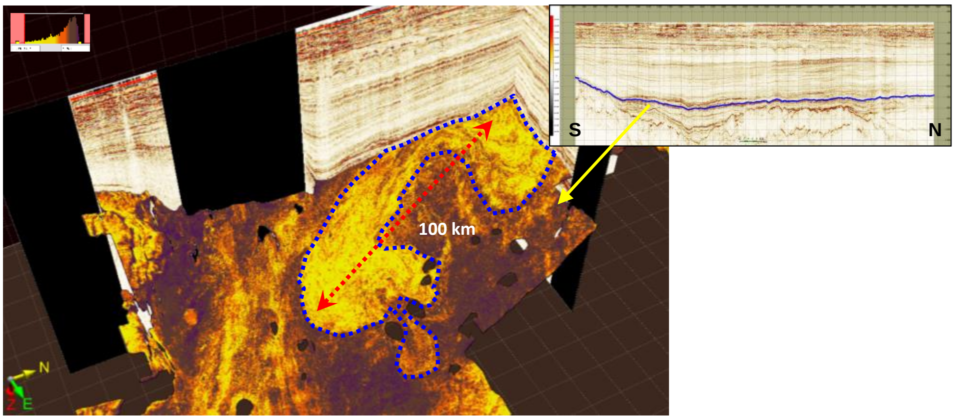


Figure 5 – Seismic envelope mapped on a horizon, close to the top Maureen formation. This horizon reveals a mass debris flow.

Basin Modelling

Large-scale basin modelling studies rely on overburden horizons to provide the appropriate and accurate burial history. In the Central North Sea however, usually only a very limited numbers of shallow horizons are available for this particular purpose, (Mid-Miocene Unconformity and Top Paleocene). These represent the main velocity breaks and therefore are also required during depth conversion. In this study, an analysis of the geological variations in depositional sequences, based on the “thickness cube” attribute, was used to select additional horizons that would help more accurately predict burial history, and consequently migration pathways, hydrocarbon generation and pressure profiles. The “thickness cube” is a vertical derivative of the RGTM (Figure 6.a); it reveals the instantaneous variations of the geology for each seismic voxel. This attribute is sensitive to the convergence and divergence of the geological horizons and clearly shows stratigraphic discontinuities characterized by a maximum of thinning (Figure 6.b).

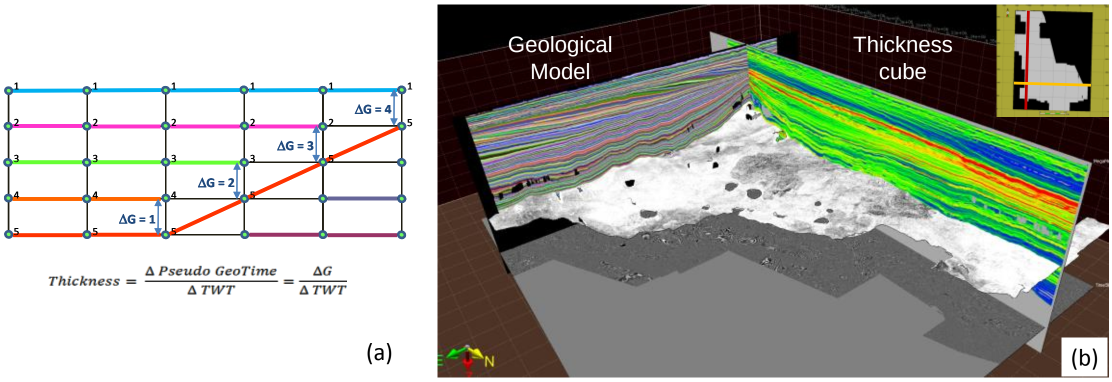


Figure 6 – (a) Thickness attribute corresponds to the vertical derivative of the geological model for each seismic point. (b) Applied to the UK North Sea dataset, it reveals stratigraphic thinning and discontinuities.

In the context of the North Sea, five additional over-burden horizons corresponding to major stratigraphic discontinuities were detected by the maximum of thinning (Figure 7.a). The horizons were identified and reported in the regional stratigraphic column (Knox & Halloway, 1992) as shown on Figure 7.b. Due to the scarce well information in the shallow interval, the main challenge here consists in properly associating each horizon with the correct corresponding stratigraphic age.

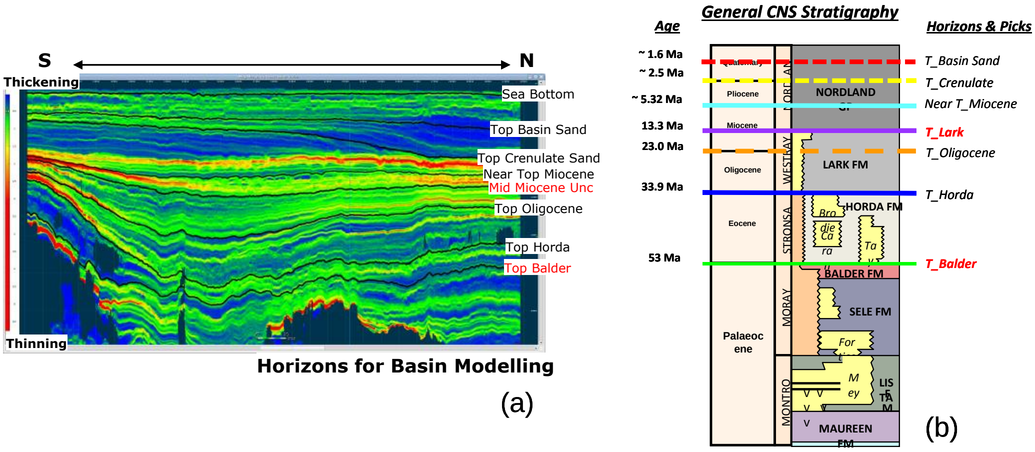


Figure 7 – Large-scale basin modeling studies. (a) In addition to the two available horizons, top Lark and top Balder, five horizons were created based on the maximum of thinning of the thickness attribute. (b) These horizons were properly identified according to the regional stratigraphic column.

Conclusions

The geomodel approach is an efficient method to quickly leverage information contained in large-scale seismic data. Applied to the North Sea dataset, covering 15,000 km^2, this workflow was delivered in 8 weeks. Outputs from the study were used for different applications such as shallow hazard assessment; horizon slicing along seismic attributes; delineation of geological features and basin modelling. From a regional standpoint, such a method offers multiple applications and provides the framework for further more in-depth and focused interpretation work.

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