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High Resolution Mega Mapping: A New Approach towards Improved Structural Understanding

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Summary

Merging multiple seismic time interpretations whilst honouring maximum spatial resolution allows the construction of optimised structure maps which combine the advantages of extensive coverage whilst preserving great detail where available. EBN has identified the need for detailed structural information originating from seismic data for both regional prospectivity studies and prospect specific analyses targetting hydrocarbons as well as geothermal energy. Regional scale coverage is needed to better understand fault systems in their broad tectonic context whilst the subtle detail is required to understand observations at field or at well scale, e.g. fault-cut outs and fault juxtapositions.

The aim of the HiRes Mega mapping project is to improve resolution of subsurface structure maps at key horizon levels, to better image existing fields, potential traps and associated fault systems. These grids are also suitable as input for time-depth conversion to obtain HiRes depth maps.

As the HiRes seismic time grids originate from many different surveys and/or processing versions, a fully functional automated Petrel workflow has been developed to efficiently calibrate and merge the different grids, a task which can be rather complex, time consuming and error prone if undertaken manually.

Introduction

The subsurface of the Netherlands represents some of the world's best studied geology. This is not due to extensive outcrop fieldwork but a result of the very active oil and gas industry. A significant amount of subsurface information, in particular well and seismic data, has been acquired over the past decades in the search for oil and gas. A large proportion of this data has been made public, facilitating the study of the Dutch subsurface by many companies and organisations. TNO, the Dutch Geological Survey, produced regional subsurface maps based on this subsurface data, covering effectively the entire country on and offshore (~100.000 km^2). These publicly available grids are generated at a grid resolution of 250x250 meter (Ref. 3,5). Whilst this resolution is perfectly adequate for regional purposes, it is suboptimal for more detailed studies at prospect or field level and can be improved in areas where 3D seismic coverage exists. Around 55% of the Dutch territory is covered by 3D which is typically processed to a horizontal resolution of 25x25 meter (Figure 1a). This means that much more structural detail can potentially be obtained by making use of the full inherent resolution of the seismic. E&P operators generally use higher resolution than 250x250m for mapping prospects and planning wells. However, these higher resolution mapping products are typically limited to (relatively) small areas e.g. at survey scale. In addition, these products are often for inhouse use only, considered confidential and are thus not available publicly for further study.

EBN is a Dutch state company that participates in most oil and gas exploration and production activities in the Netherlands and, more recently, increasingly involved in geothermal ventures. From this perspective EBN has identified the need for detailed structural information originating from seismic data for regional prospectivity studies. In particular geothermal operators, with tight budgets, are often solely reliant relaying on public data for their subsurface evaluations.

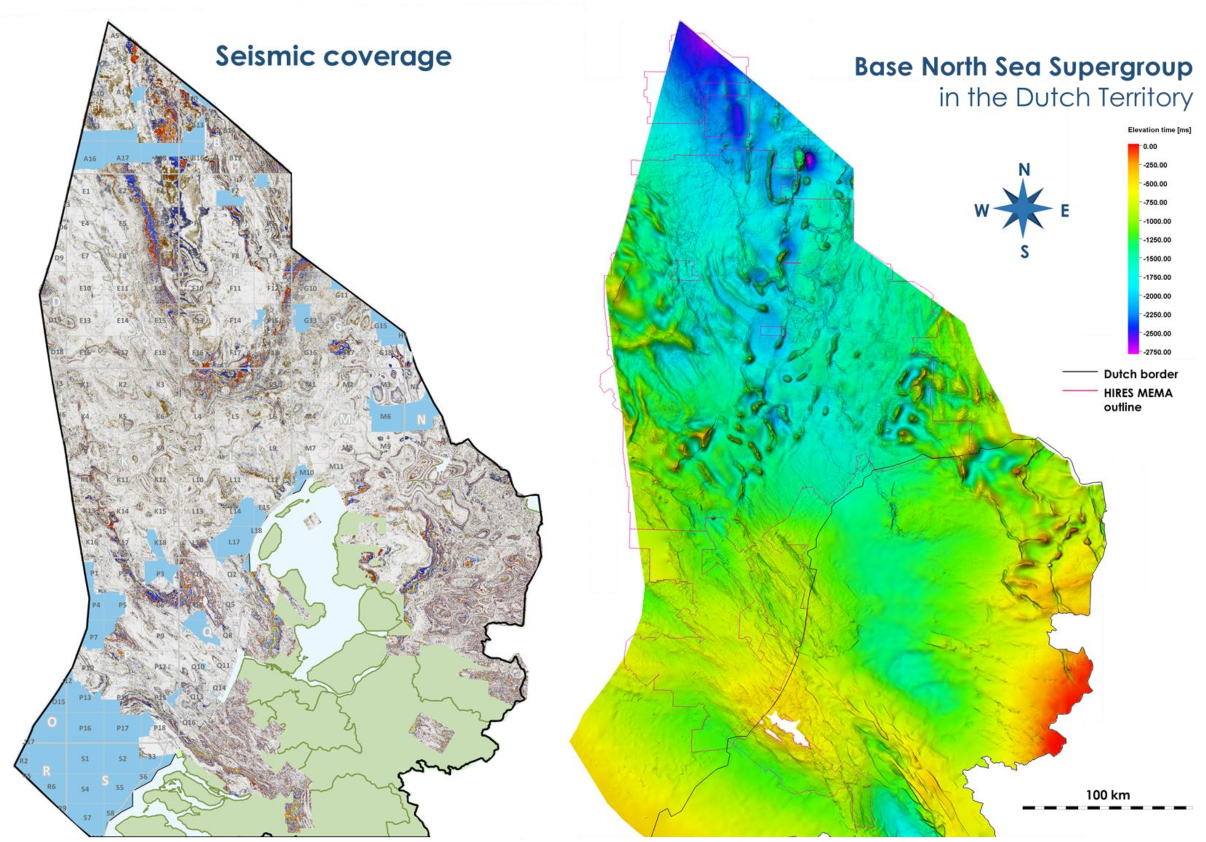

Figure 1 *a (left) 3D seismic coverage in the Netherlands covers around 55% of the total area, b (right) example of a merge of high resolution horizon data at 25x25m resolution and regional horizon data from TNO at 250x250m resolution.*

To ensure access to optimal structural data, EBN initiated a large scale in-house seismic mapping project, the HiRes Mega Mapping project, where, when available, the highest spatial resolution data is used (Ref 1,2). For areas without 3D seismic coverage, the maps rely on existing (low) resolution horizon data as published by TNO. For unravelling structural styles, the resulting maps combine the best of two worlds: the large country-wide coverage as offered by the TNO mapping replaced with High Resolution mapping where available (Figure 1b). Whilst EBN has access to almost all data, the HiRes Mega Mapping products planned for sharing are based on non-confidential data only. The high quality structural maps from EBN's HiRes Mega Mapping project allows drilling operators to better de-risk their targets and plan their wells more safely and more effectively. The intent is that high resolution horizon maps will also eventually contain fault related structural elements to further improve detail and accuracy.

Method

The following workflow is being used in order to create the HiRes Mega maps for representative horizons:

1) ***Identification of key horizons for the HiRes Mega Mapping project.***

The project aim is to improve resolution of subsurface structure maps in depth at key subsurface stratigraphic interfaces so as to better image existing fields, potential traps and associated fault systems (Figure 2). In addition, the time horizons should not only be representative of the key subsurface stratigraphic interfaces but should also allow the building of effective velocity models for time-depth conversion. Shallow horizons that exhibit good quality seismic response which allow the use of auto-tracking technology can be mapped efficiently whilst preserving a high level of structural detail. Deeper and more structurally complex horizons, typically with a less well defined seismic response, demand more manual interpretation methods, taking significantly more time, effort and interpretation skill. Based on these considerations the following reflectors where selected:

Full Name	Short Name	Age
Base Upper North Sea Group	B_NU	5,33 Ma (Tertiary)
Base North Sea Group	B_NLNM	56,8 Ma (Tertiary)
Base Chalk Group	B_CK	99 Ma (Upper Cretaceous)
Base Rijnland/Vlieland Group	B_KN	140 Ma (Lower Cretaceous)
Base Schieland Group	B_S	156 Ma (Upper Jurassic)
Base Altena Group	B_AT	203 Ma (Lower Jurassic)
Base Upper Germanic Triassic Group	B_RN	243 Ma (Upper Triassic)
Base Lower Germanic Triassic Group	B_RB	251 Ma (Lower Triassic)
Base Zechstein	B_ZE	258 Ma (Permian)

Table 1 *Key Horizons in the Dutch Subsurface for HiResMeMa project*

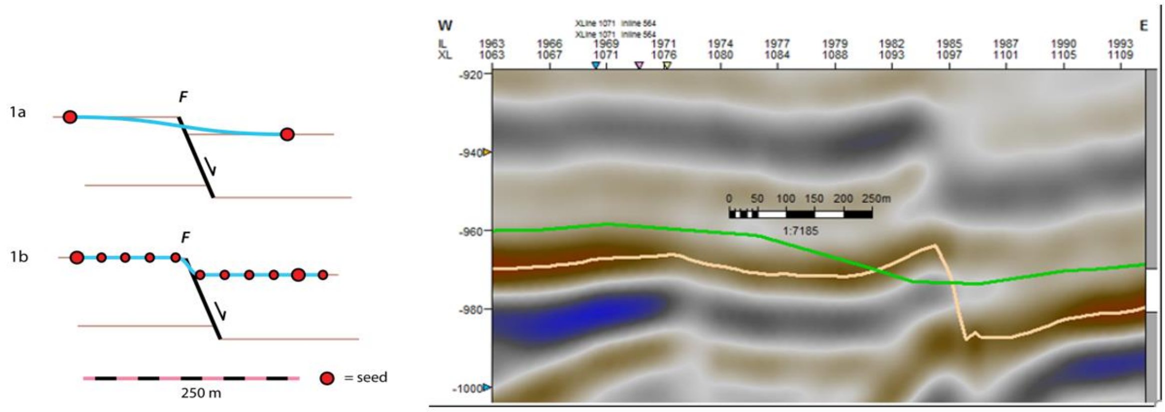

Figure 2 *left) Schematic of fault sampling with (1a) 250 m horizontal resolution and (1b) 25m resolution, right) Seismically defined fault with full resolution event tracking in yellow and low resolution mapping in green (based on 2D seismic).*

2) Inventory of available seismic data and interpretation grids

Given its state participation role in Dutch E&P activities, EBN is entitled to virtually all of the seismic data acquired in the Netherlands, the majority of which is available on workstations spread across multiple projects. This step involves QC of the seismic data and interpretations, transfer to a single master project, validating seismic to well ties, correcting any identified data issues and adding any missing horizon interpretations. In addition, an audit trail is maintained keeping track of which 3D volumes or projects the interpretation grids are originating from. Whilst some 3D data cubes are available in the depth domain, it has been decided to limit the interpretations for this project to time volumes only. By using this approach, all data can be merged in the time domain and at a later stage, time-depth conversion can be undertaken using a high-resolution regional velocity model.

3) Selecting the relevant grids for the subsequent merge process.

For several areas, multiple seismic 3D surveys have been acquired or multiple versions of processing are available. Generally the most recent (re-)processing of the seismic volumes demonstrate the best imaging and hence are best suited for interpretation and subsequent merging. In some cases, polygons are created which delineate sub-areas of interpretation data that are "preferred" in terms of quality.

4) Adjusting and merging grids

As the grids originate from different surveys and/or processing versions, bulk-shifts may be required for optimal merging. At this stage, a Petrel workflow script automatically derives and applies a single time-shift factor for each survey horizon to create alignment with a selected reference survey horizon, thus reducing the severity of possible merge artefacts. To date, the regional horizons of TNO are selected as reference to which all the HiRes input grids are bulk-shifted. As a last step, the different input grids are regridded to a common grid resolution of 25x25m. Special attention was given to the different coordinate systems that are in use in the Netherlands: Amersfoort/RD New for onshore data, ED50-UTM31 for offshore data. Because of these differences and due to computational constraints, it was decided to build separate HiRes Mega maps for on- and offshore as an intermediate step. The final merge of on- and offshore which requires a coordinate transformation was subsequently carried out. The workflow for merging the different grids can be complex and time consuming if undertaking manually. Hence a fully functional automated Petrel workflow has been developed (Figure 3).

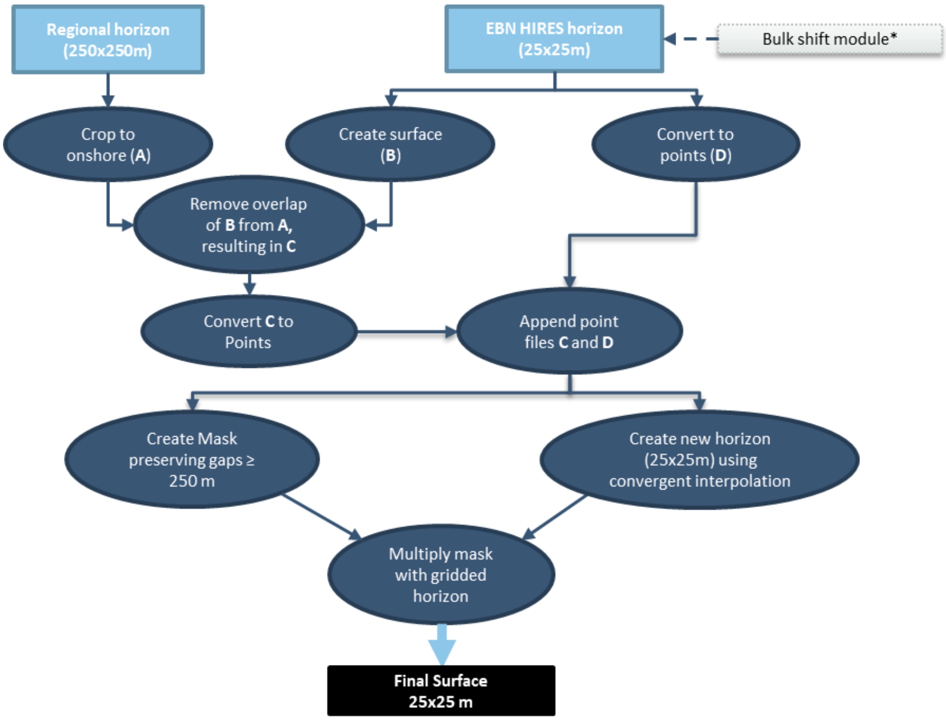

Figure 3 *Schematic overview of the detailed mapping workflow of merging HIRES interpretation with regional interpretations. The process is fully automated using macros.*

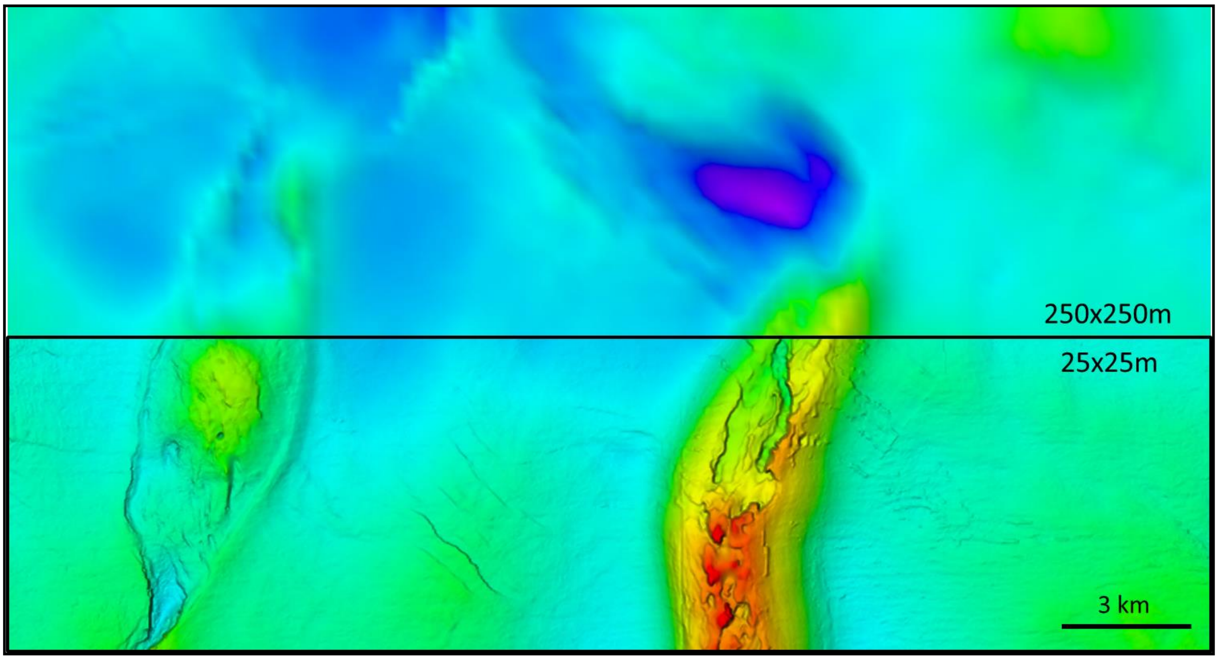

Figure 4 *Comparison between regional interpretation at 250x250m scale (above) and high resolution interpretation at 25x25m scale (below). Note the difference in structural detail.*

Conclusions

Merging seismic time interpretations whilst honoring maximum resolution allows the creation of high resolution regional scale structural maps which combine the advantages of wide coverage with great detail. Regional scale coverage is needed to better understand fault systems in their broad tectonic context whilst the subtle detail is required to understand observations at field scale or at well scale, e.g. prospect volumetric and risk assessment, fault-cut outs and fault juxtapositions. The high resolution grids are also suitable for horizon attribute mapping (Ref. 4), high precision time-depth conversion and geological timing of the subsequent fault movements leading to paleo-tectonic reconstructions. Also seismic hazards analysis benefits from better structural knowledge.
A particular application is improved understanding of which lineaments constitute flow barriers (sealing faults). In hydrocarbon fields this understanding can help to define new infill drilling targets leading to better recovery factors. In geothermal projects doublet placement requires the absence of flow barriers (faults) in between injector and producer.

References

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