Th VM01

High Quality Regional Velocity Modelling For Depth Conversion

I. Meisingset (FIRSTGEO), J. Hubred* (First Geo), D. Krasova (First Geo)

Summary

Regional high quality 3D velocity models have been constructed for the purpuse of depth conversion, using world leading mature technology which has been developed, and used, over a period of almost 30 years. The models, which are in daily use in many oil companies, will be presented in open session for the first time.

Introduction

The oil and gas industry needs velocity models of high quality for regional exploration. Over the last three decades there has been a growing acceptance, and demand for, regional 3D velocity models made from seismic processing velocities. Three of the largest models of this type that have been built are presented. The first model, built from 491 2D and 3D seismic surveys and 198 wells, covers the Norwegian Barents Sea up to Svalbard. The second model, built from 1158 2D and 3D seismic surveys and 3631 wells, covers Mid Norway and the Norwegian, UK, Danish, German and Dutch sectors of the North Sea down to 52 degrees north. The third model, built from 470 2D and 3D seismic surveys and 696 wells, covers the entire Australian North-West Shelf. In terms of data contents and regional extent these are some of the largest high quality 3D velocity models that have been constructed. The modelling principles that make this possible are reviewed.

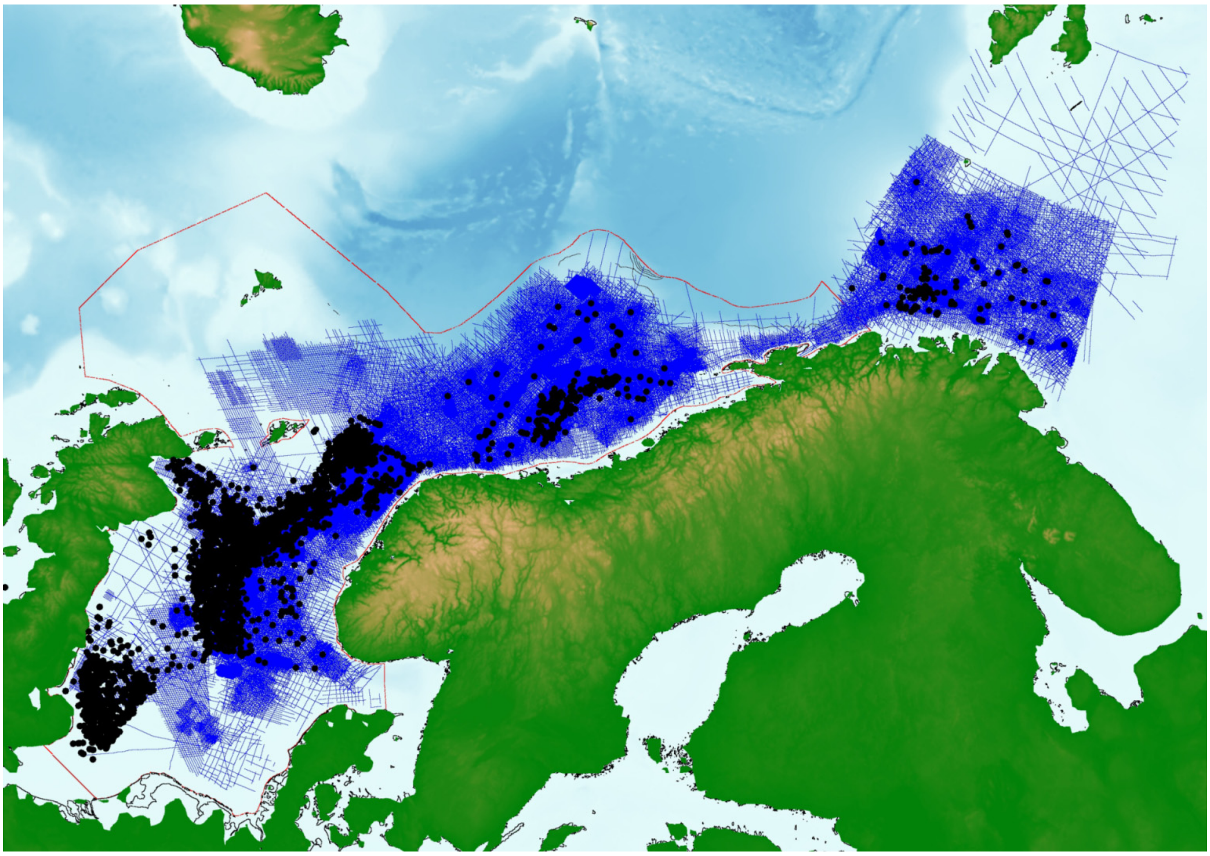

Figure 1 *Data base for the Barents Sea and Mid Norway + North Sea velocity models.*

Modelling principles

The preferred type of seismic processing velocity to use as input for velocity modelling is the unsmoothed and uninterpolated velocity which makes the gathers flat. In the past, this would be a manually picked stacking velocity from NMO analysis. At present, it may be an output from RMO after pre-stack time migration, or it may come from a depth imaging work flow.

These seismic processing velocities will be proportional to well velocities when we have hyperbolic moveout, which is when the overburden layers within reach of a gather are nearly flat and have nearly constant velocities. Areas with hyperbolic moveout have small lateral velocity variations. Areas with non-hyperbolic moveout have large and rapid variations. Low pass horizontal frequency filtering can be used to separate out and reject the non-hyperbolic velocities, leaving a (mainly) hyperbolic seismic processing velocity data set where the similarity to well velocities has been greatly improved. This is the main geostatistical filtering principle used in the regional velocity models presented.

Seismic processing velocities from the same acquisition and processing (the same survey) are internally consistent, but there are differences from survey to survey. These differences originate in part with the seismic acquisition and in part with the processing, and they normally do not disappear if two different acquisitions are merged and processed together. In the regional models presented, this difference has been compensated by survey to survey balancing. Velocity fields from merged 3D surveys, which often are internally inconsistent, have been split and balanced. The balancing process makes the collection of seismic processing velocities regionally consistent.

The key to high quality in a velocity model lies in data coverage. The database needs to be as large as possible, and velocity modelling needs to automatically process overlapping data in a way that honours the best (most consistent) data sets and rejects outliers. Interpolation should be avoided as much as possible, but may be necessary in certain areas, like the northern Barents Sea, where the available data base is limited.

After filtering and balancing of the seismic processing velocities it is gridded into a 3D model, and then compared to wells. The next step is to model delta anisotropy. In the velocity models presented, a scaling factor SCF = well velocity / seismic processing velocity has been used as proxy for delta. SCF is calculated from wells, and applied below seabed (water is isotropic to seismic wave propagation). After application of SCF and 3D well tie the resulting average velocity model will match the wells to within model resolution.

The resolution of the final regional velocity models is limited mainly by the ability of seismic processing velocities to image geological velocity (the vertically measured well velocity). In the horizontal direction the resolution is limited by the hyperbolic moveout requirement. Geological velocity changes over shorter distances than a seismic cable length (for instance a channel with cemented sandstone fill) will result in non-hyperbolic anomalies which need to be rejected. The geological velocity from such features cannot be recovered. In the vertical direction there is no such edge effect when entering into a high or low velocity layer, there the limitation is in how densely velocities have been picked in seismic processing. Internal oil company studies in Norway show that conventional processing velocities are able to resolve a limestone layer down to a vertical thickness of between 150 and 200 ms TWT, depending on seismic frequency. When making a regional velocity model from conventional seismic processing velocities, this is what to expect. Some types of high resolution seismic velocity analysis can give much higher resolution, where such data are present the resolution can be higher. Extensive tests have been made with regards to what kind of grid spacing is necessary to carry the useful information from seismic processing velocities in a 3D model. Normally 3km by 3km laterally and 100ms TWT vertically is enough. Grid refinement to higher resolution may be needed in order to properly represent the included well data. The models presented for the Barents Sea and Mid Norway / North Sea were gridded with this resolution, and refined to 1km by 1km laterally to honour wells better. The Australia North West Shelf model was gridded with 2km by 2km and 50ms TWT vertically and not refined. The reason for the 50ms vertical resolution there was to obtain a more accurate position for the base of a Tertiary limestone sequence.

Using a 3D velocity model for depth conversion

The 3D velocity model can be considered to consist of two components. The vertical component is the increase in velocity against time, which mainly happens as a consequence of increased compaction. The lateral component is due to thickness and lithofacies variations within the overburden. When depth converting, the vertical component will create an average velocity map with the same shape as the time map, with “velocity faults” where there are time faults. Additional information about details in the velocity field is captured from the time map, through the relationship between time and velocity in the vertical component. The lateral component will warp the map slightly, so that velocity contours do not follow time contours exactly. When there are no dramatic velocity discontinuities in the subsurface (such as salt), a 3D velocity model of the dimensions used here will be able to give an accurate depth conversion of a faulted terrain.