**Velocity Model: Southern North Sea Mega Merge Rev 2**

A velocity model was built as it was deemed necessary for this PhD research project and was utilised for this research article.

The velocity model created is the same size as the Southern North Sea Mega Merge Rev 2, a total areal extent of > 26,000 km2. This is a relatively large area to be depth converted with a velocity model, as typically this is done for singular seismic surverys rather than merged volumes . Due to the large extent of the area needing depth conversion, it was decided to keep complexity to a minimum, as this would decrease development and processing time. The end product was suitable for basin-scale depth conversion and hence basin-scale studies. Studies at a smaller scale may be more suited to using a velocity model developed at that scale.

**Data**

The velocity model had three data inputs. These were seismic surfaces (two-way time), well-time-depth relationship data, and well-tops.

Velocity Model Surfaces

The velocity model used six surfaces (Table. 1). Five were generated from the seismic survey, and one (Seabed) was generated from bathymetry data. The Seabed bathymetry data was initially in the depth domain when acquired from EMODNET. Items in the velocity model had to be in the time domain before building, so the Seabed was converted to the time domain before being reconverted back to depth. Fortunately, being the Seabed, this only required water depth velocity to be modelled, a velocity of 1494 m/s was used for water (reference 1). The methodology for creating the seismic surfaces used within this velocity model is in the main article supplied with this suppelmentry material.

A limitation of the velocity modelling software within Petrel is that all surfaces have to cover the same aerial extent throughout the area depth converting, with no gaps present within data. If gaps in the data are present, the software will not model that area. Gaps within the data were common due to; the original extent of deposition was not the same for all surfaces, erosion occurred/unconformities formed, being pierced by salt structures. In order to avoid gaps in the velocity model, the surfaces were extended so that they all had the same ariel footprint; where the surfaces had been extended their depth values were shifted so that they were <.1 m below the above surface. This allowed for all layers to be present with complete coverage of the area being depth converted, but stopped any issues arising from layers being nonexistent.

Well Data, time-depth relationships

The well data used was in the form of time/depth relationship data. Time/depth relationships were generated from seismic well-ties. Seismic well-ties were created in wells with checkshot, density, and sonic logs. Wavelets were generated to create a synthetic seismogram that could be compared with the seismic data; wavelets were created in two separate ways; firstly, a 30Hz ricker wave, this was compared against the seismic data as this was the easiest method to implement. If the ricker wavelet was a poor match against the seismic data, a new wavelet was extracted from that specific well and used. Several algorithms were used for wavelet extraction to find the best fit; the deterministic extended white algorithm was often used. The well-ties were then quality controlled by bulk shifting or, in extreme cases, stretch squeezing to fit the log depth data to the seismic data. This process generated suitable well time/depth relationships that could be used within the velocity model. Over 70 wells were used in this process

Welltops

Well tops were applied using three approaches.

1. Looking at significant lithological/stratigraphic changes in the petrophysical data
2. Using composite well log reports and comparing them to the petrophysical data
3. Well tieing the data using check shots and using key seismic reflections within the seismic data seismic data

Well tops had to be applied for every layer of the velocity model in each well so that residuals could be generated to quality control the generated velocity model.

**Velocity Model process**

The velocity model was built using an iterative process; each time a new model was generated, the residuals were analysed, and the parameters of the model were adjusted accordingly. A number of differently layered models were generated in the initial stages. However, a 6-layer model was found to be most fitting for the velocities observed within the stratigraphy of the Southern Permian Basin. The layers used within the model can be seen in table 1.

Once the correct amount of layers for the model had been chosen, the best velocity equation for each layer was applied. Petrel offers a number of different velocity equations for layers within a velocity model, however, the ones used are the following;

V=Vo=Vint : Seabed

V=Vo+kZ : Cenozoic, Chalk group, Triassic, Zechstein

V=Vo+k(Z-Zo): Jurassic

The velocity modelling used the minimum depth method and optimised for K when calculating the linear velocities of the model. No spatial corrections were applied to wells to modify the velocity model and hence change the residuals to 0, as it created an unrealistic velocity model with bullseye-like anomalies around wells within the velocity model area.

After a model was built, the residuals were analysed to see which wells had the highest residual value. These wells were then quality controlled by plotting the time/depth relationship data and removing areas where the interval velocities could be considered too high or low for that layer. The velocity model was then regenerated, and the residual of the well quality controlled investigated; if the residual was a lower value (better) and within parameters, it was left, and no further quality controlling was done to it. However, if the residuals were still high after several quality control attempts, it was removed from the model.

**Residuals**

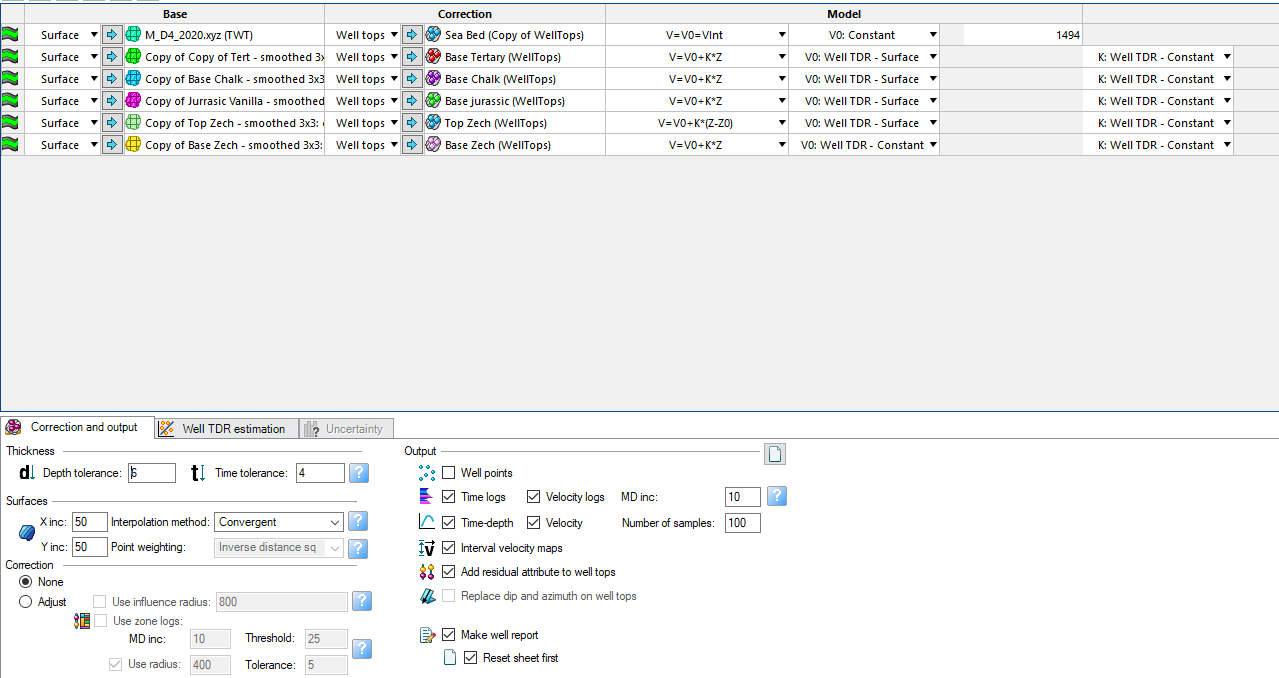
An acceptable level for residuals at the top and base Zechstein was 5%. The deeper a layer is, the less sensitive the residual becomes to how many meters out it is in sync the generate surface is to the well top within the well. This makes getting the Zechstein within that 5% boundary easier than shallowly buried layers. For example, we had great problems with the Seabed residuals commonly being out >10%, this as the sea bed is shallow in the Southern North Sea <100 m, so a 30m depth being out 3m would lead to a 10% residual, due to the these being relatively small values and not affecting the top and base Zechstein they were largely ignored.

See Final\_vel\_mod\_res.PDF (Supplimentrary materials) for a residual table from the final velocity model.

**Final Product**

The final velocity model was fit to purpose for converting any data synthesised using the Southern North Sea Mega Merge Rev 2 from the time domain to the depth domain

V = Layer velcoity, Vo = Vint =, K = , Z = , Zo =



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| --- | --- |
| Surface | Velocity Model Layer |
| Sea Bed | 1 |
| Base Tertiary | 2 |
| Base Chalk | 3 |
| Base Jurassic | 4 |
| Top Zechstein | 5 |
| Base Zechstein | 6 |

