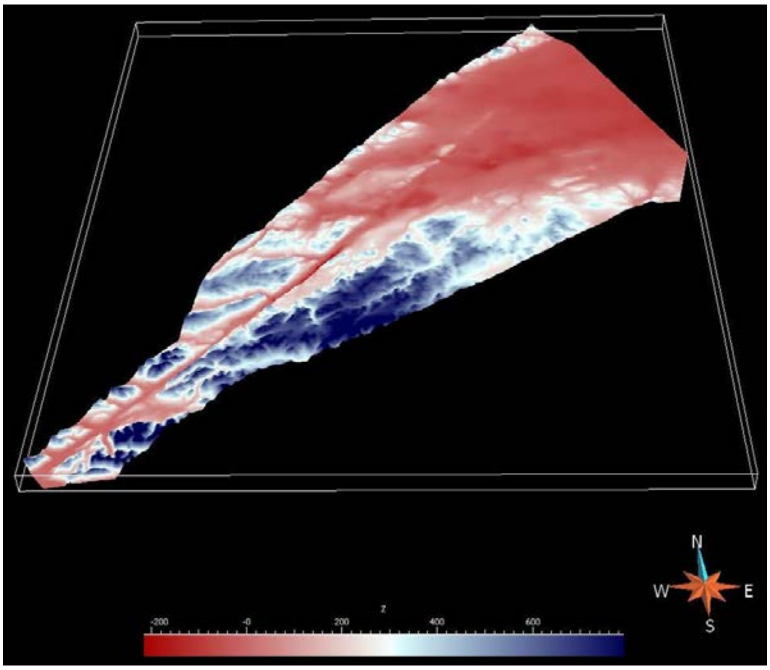
Model metadata report for the Great Glen – Moray Firth merged Rockhead Elevation Model

Geology and Regional Geophysics Scotland

OR/14/060



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1 Modelled volume, purpose and scale

The goal was to derive a merged onshore-offshore Rockhead Elevation Model (RHEM) for the Great Glen – Moray Firth Region (Figure 1), approximately 8622 km^2. The purpose of the model was to: (i) provide a 'capping surface' for the 3D bedrock model of the area; (ii) enable calculation of Quaternary sediment volume and thickness distribution in the area; and (iii) explore combined GSI3D-GOCAD methodologies which could be used to produce this type of model. The resulting RHEM is suitable for interrogation but not fit for use at a higher resolution than 1:250 000.

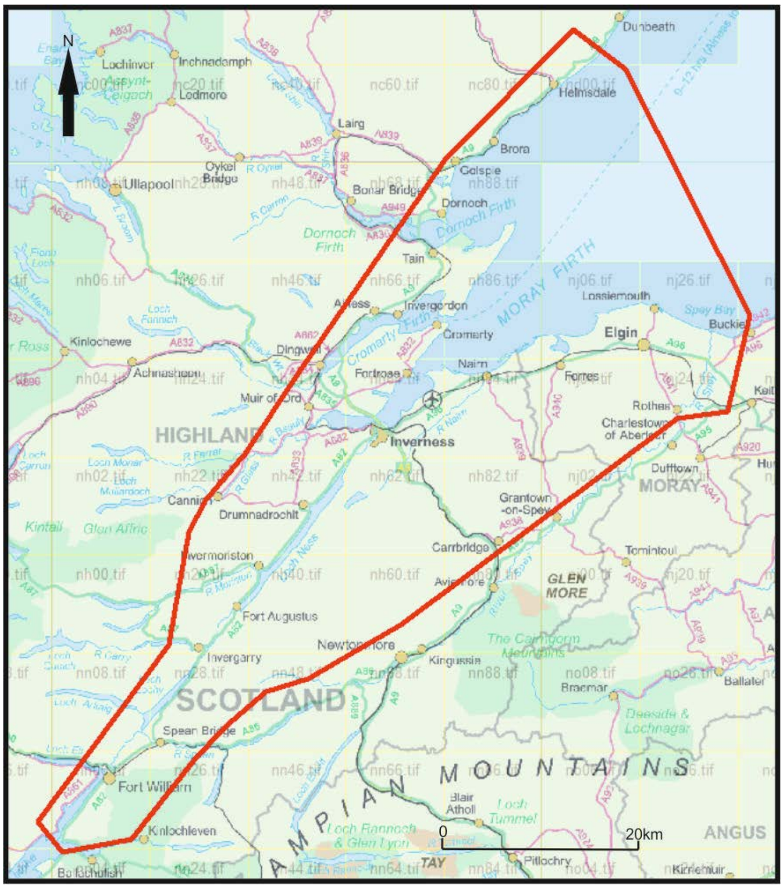

Figure 1: Location of modelled area, outlined in red

2 Modelled surface

The modelled surface comprises a merged onshore-offshore RHEM using a combined GOCAD and GSI3D workflow. In the production of the merged RHEM, surfaces for the base of water, peat and superficial deposits (undifferentiated) were constructed in GSI3D. A merged onshore-offshore digital surface model was also derived in GOCAD from an onshore Digital Terrain Model (DTM) and offshore bathymetric data.

Code	Geological Unit
WATER	Water
PEAT	Peat
QUU	Quaternary deposits undifferentiated
PQU	Pre-Quaternary deposits undifferentiated

Table 1: GVS showing modelled units

3 Model datasets

Data (downhole): 290 borehole logs, located in onshore areas only, were used to guide construction in GSI3D of 33 cross-sections spanning the onshore and offshore areas. (cumulative length = 2167 km; Figure 2).

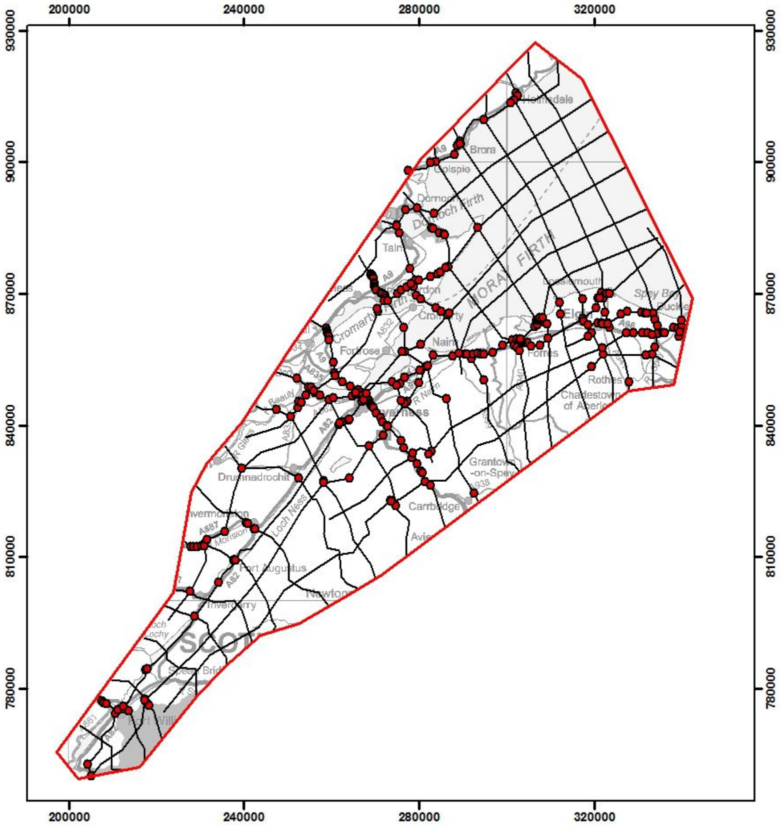

Figure 2: Location of borehole logs and cross-section network used in the model development

Data (maps - onshore): The 1:625 000 superficial geology map (BGS) provided a guide for cross-sections and envelopes drawn in GSI3D.

Data (maps – offshore): Quaternary Sediment thickness contours were taken from the offshore geology maps for Caithness (BGS) and Moray-Buchan (BGS).

Data (Digital Terrain Models (DTMs)): For the onshore area, the Bald Earth DTM was used at a resolution of 1: 250 000. For the offshore area DigBath contours were used to generate a DTM in GOCAD™ (see below). Combining the two resulted in a merged onshore-offshore DTM, used to cap the model.

4 Model development log

Modelling was carried out using the 2009 version of GOCAD™ and the 2011 version of GSI3D.

4.1 STAGE 1: BUILD MERGED ONSHORE-OFFSHORE SURFACE MODEL

The Bald Earth Model was sampled at 250 m resolution, imported to GOCAD™ and clipped to the Area of Interest (AOI) using region editing tools. An outline for the offshore area was created using the 0 m DigBath contour; this enabled the offshore area to be removed from the Bald Earth Model using the region editing tools, leaving an onshore-only triangulated surface.

An outline was defined for the offshore area using the 0 m Digbath contour and a digitised line following the eastern margin of the AOI. Bathymetric contours (from Digbath) were imported as curves to GOCAD™. The outline and curves were then used to interpolate an offshore surface, using GOCAD™'s structural modelling workflow.

The onshore-only triangulated surface was merged with the offshore surface (Figure 3). This was achieved by creating a new surface from the offshore and onshore surfaces. This new surface was then used to generate pointset data. The pointset data were combined with the AOI boundary (densified to 250 m) to interpolate a new merged surface, using the structural modelling workflow.

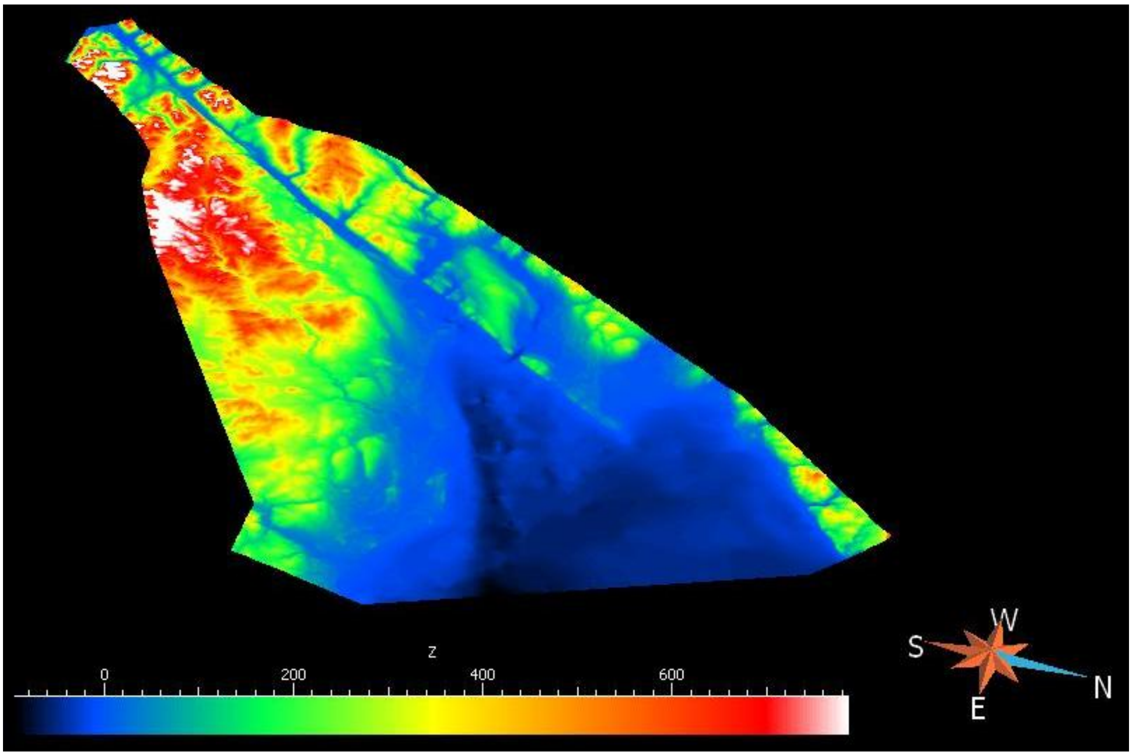

Figure 3: Merged onshore-offshore DSM built in GOCAD™

4.2 STAGE 2: COMPILING AN OFFSHORE QUATERNARY SEDIMENT THICKNESS MODEL

Quaternary thickness contours were digitised in ARCGIS™, using georeferenced offshore geology maps for Caithness and Moray-Buchan (Figure 4). These contours were attributed for thickness and brought into GOCAD™ as curves. A script was applied to the curves, which subtracted the thickness value from the surface model (created in STAGE 1), to generate rockhead surface contours. These were used to interpolate an initial offshore rockhead surface using the structural modelling workflow.

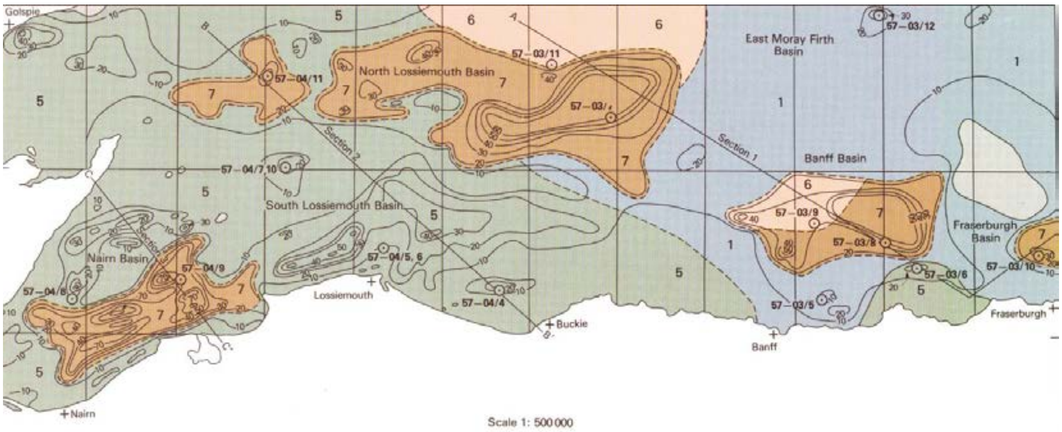

Figure 4: Offshore Quaternary sediment thickness contours from the Moray-Buchan offshore geology map. These contours were digitised and imported into GOCAD™ to be incorporated in the model building

4.3 STAGE 3: BUILDING CROSS-SECTION IN GSI3D

A GSI3D project was set up to build initial bases for peat (PEAT), Undifferentiated Quaternary and Holocene deposits (QUU) and water (WATER,i.e. Loch Ness). A total of 33 cross-sections were constructed, constrained by 290 borehole logs. The base of the 'WATER' unit is an approximation, which was crudely guided by Ordnance Survey 1:50 000 loch bathymetry contours. The offshore rockhead surface model, developed in stage 2, was imported to provide a guide for the QUU-base in offshore areas.

Modelled units were generated for WATER, PEAT, and QUU in GSI3D (Figure 5). Tops and bases for these units were interrogated in GOCAD™ to check their quality. Large parts of the generated surfaces onshore were found to be unrealistic (Figure 6). This is a result of attempting to model thin units over a large area with extremely variable relief (-100 m to 1000 m OD). In order to eliminate triangulation directly through topographic highs (e.g. mountains), an extremely dense network of cross-section would be needed covering all the major topographic obstacles. Increasing the density of cross-sections by the necessary extent was not practical over the scale of the model area (8662 km^2 area). For this reason, data were imported to GOCAD™ in order to build improved surfaces with which to constrain the merged offshore-onshore RHEM.

The findings from this stage of the analysis indicate that there is a limit to the relief and area that superficial deposit modelling in GSI3D should be applied. In areas of high relief, especially where superficial deposits are relatively thin, and in models covering large areas where dense section distributions are impractical, the triangulation process in GSI3D does not adequately describe the form of superficial deposit surfaces.

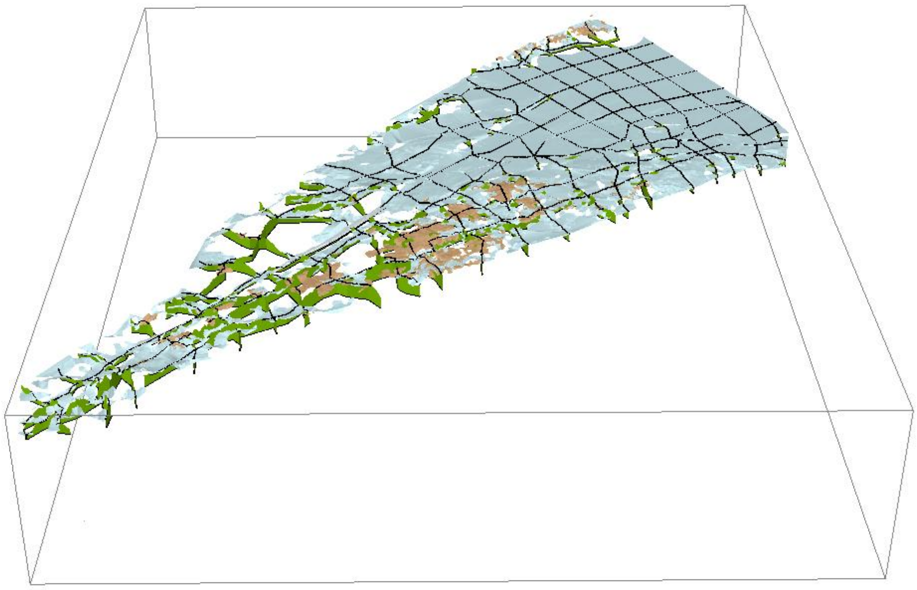

Figure 5: Model surfaces developed in GSI3D

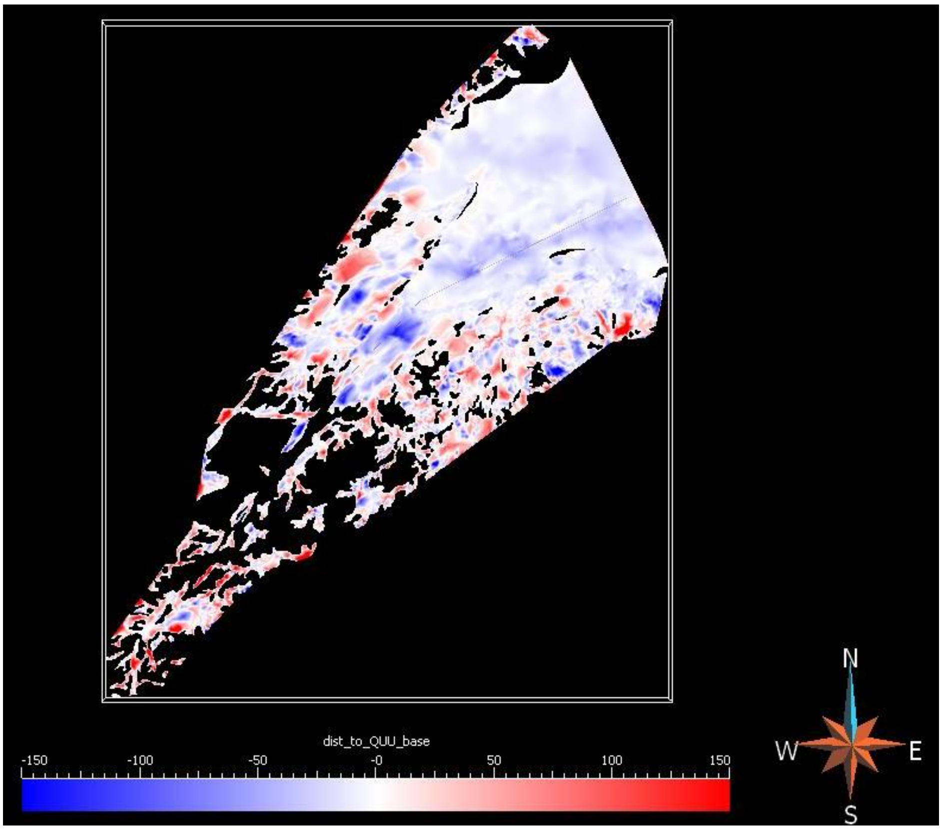

Figure 6: Problems with the direct triangulation model. Areas in red indicate where the modelled QUU base lies above the QUU top – impossible in reality. Such problems are difficult to avoid in high relief areas using direct triangulations.

STAGE 4: MERGED RHEM INTERPOLATION IN GOCAD™.

In GOCAD™, pointset data were generated from the original GSI3D-derived QUU-base. These were used to re-interpolate a surface (margin points were attributed as 'control nodes' while cross-section points were attributed 'control points'). A DSI interpolation was run (x 10 iterations) to build an initial surface; a denser grid of triangulation points was generated through repetitive use of the 'split triangles' and 'beautify triangles' functions (note - these don't affect actual z values). This resulted in a surface better suited to manipulation in order to eliminate known errors.

The first process was to 'remove cross-overs' (i.e. make sure QUU-base is below QUU_top). The QUU_base was 'pushed down', so that the minimum QUU thickness was 0.5 m. A difference (diff) property was created to test the superficial thickness values now required by the surface. In a number of places difference still exceeded 100 m, so the surface was modified to ensure that difference could not exceed 80 m – the maximum suggested by the input datasets. This was carried out by applying a script to the QUU_base surface:

```
if (diff <-80){Zmod = (Z-diff)-80;} else {Zmod = Z;}
```

Zmod is a modified elevation value which would subsequently be adopted by the surface. An edge effect is produced in the resulting Zmod values, which is removed by:

```
if (Zmod > 1000){Zmod = Z;} else {Zmod = Zmod;}
```

The Zmod value is then adopted by the surface using:

```
Z = Zmod;
```

The result is a QUU_base that: is constrained by the input data; does not cross over the land surface; and does not imply sediment thicknesses above those observed in input datasets. Essentially, this is the most 'realistic' QUU_base surface.

To build the RHEM, the QUU_base surface needed to be merged with the onshore-offshore surface model (STAGE 1), in areas where there is no Quaternary cover, and also with the water base surface to incorporate simplified Loch Ness bathymetry. The water base surface was imported from GSI3D to GOCAD™. Nodes were increased, using the split and beautify triangles functions. A region was created for areas where the water base overlapped with QUU_base. This was subtracted and a new surface: 'water_base_NEW' was created. A region was created within the onshore-offshore surface model for areas where there is no Quaternary cover. The part of this region that overlapped with water_base_NEW was deleted. A new surface, 'merge_all_less_QUU_less_water' was then created from the remaining region. Pointset data were then generated from all of the following surfaces: water_base_New; merge_all_less_Quu_less_water; QUU_base. Using the structural modelling workflow, these points were then used to build a complete, merged RHEM surface for the AOI (Figure 7).

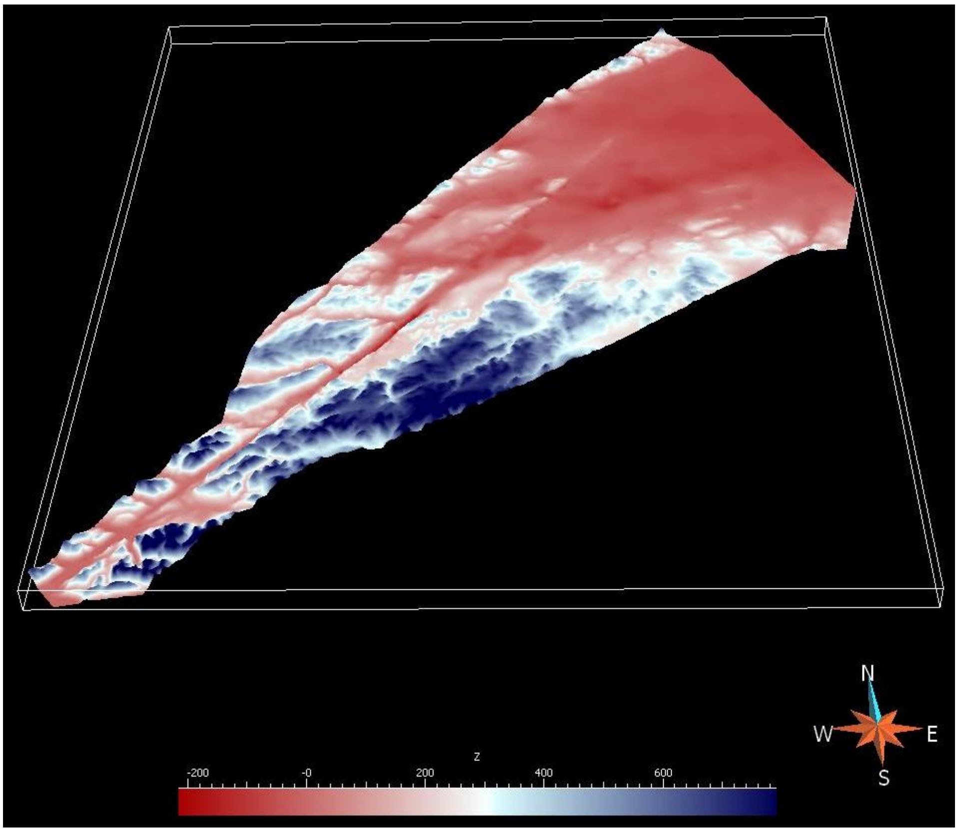

Figure 7: Final onshore-offshore Rockhead Elevation model.

5 Model assumptions

As with all geological models that use borehole information, the model assumes that the interpretation in the original logs is correct, and that the depths and start elevations were accurately recorded. The spatial extent of superficial deposits in the model is based on information in the 1:625 000 scale Superficial Geology map.

6 Model limitations

Using GSI3D solely for this model would not work due to the large project area, high relief, and the limited thickness of the superficial (QUU) deposits.

The model has been highly simplified and developed mainly to establish rockhead.

References

British Geological Survey holds most of the references listed below, and copies may be obtained via the library service subject to copyright legislation (contact libuser@bgs.ac.uk for details). The library catalogue is available at: http://geolib.bgs.ac.uk.

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