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Metadata report for the Craven Basin 1:250 000 resolution geological model

Geology and Landscape Programme

Open Report OR/14/024

BRITISH GEOLOGICAL SURVEY

GEOLOGY AND LANDSCAPE PROGRAMME

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Metadata report for the Craven Basin 1:250 000 resolution geological model

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Summary

This report describes the Craven Basin 1:250 000 model data and workflow. The model is based on the faults and surface contour plots in the map appendix of the following subsurface memoir:

Kirby, G A, Baily, H E, Chadwick, R A, Evans, D A, Holliday, D J, Holloway, S and Hulbert, A G, Pharoah, T C, Smith, N J P, Aitkenhead, N, Birch, B. 2000. The structure and evolution of the Craven Basin and adjacent areas. Subsurface Memoir of the British Geological Survey.

1 Modelled volume, purpose and scale

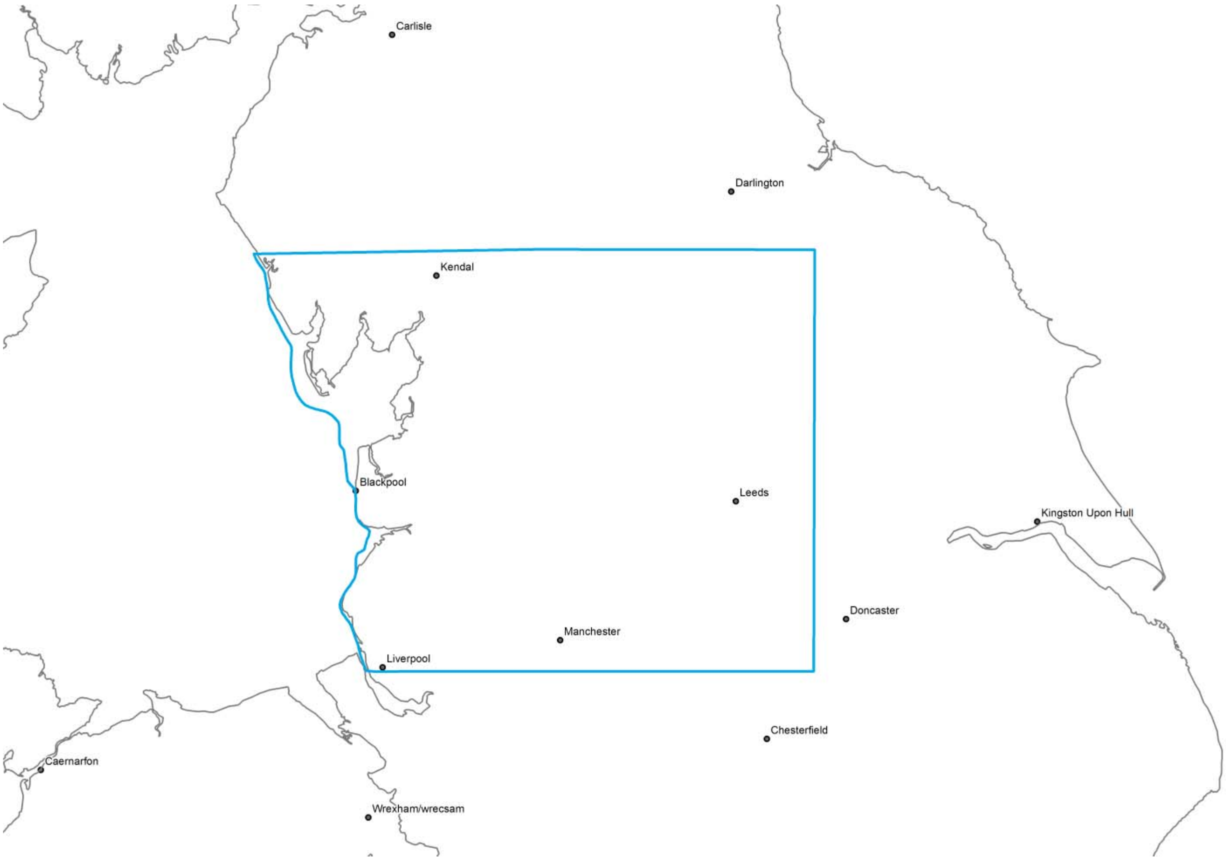

Figure 1 Modelled area (in blue)

This is a faulted GOCAD® regional model extending onshore across Yorkshire, Lancashire and the southern part of Cumbria (Figure 1). The model was constructed from digital data compiled for the Craven Basin Subsurface Memoir (Kirby et al., 2000). The results of the study are contained in the 1:625 000 scale structure contour (Figures 2), preserved thickness and subcrop maps and that accompany the Subsurface Memoir, so the data and model generated is regional to national in scale.

The model was developed as part of the Regional UK Lithoframe Programme, the aim of which was to convert the structural data interpreted in the subsurface memoirs into 3D models. Other models in this series include the Northumberland and Solway Basin, East Midlands, Cheshire Basin and Weald Basin models. The Craven Basin model provides an understanding of the regional bedrock structure in the North West and Central part of England (particularly for the Carboniferous rocks) and extends from +600 to -7500m OD. The structure of the Lower Palaeozoic and older basement rocks in the region are not considered in this model.

As the Craven Basin was derived from digital data compiled for the Regional Subsurface Memoir series, tasks such as drawing seismic interpretation to well control have already been performed. This document describes the process of creating a GOCAD model from derived digital contour data as shown in the shaded Base Namurian surface in Figure 3.

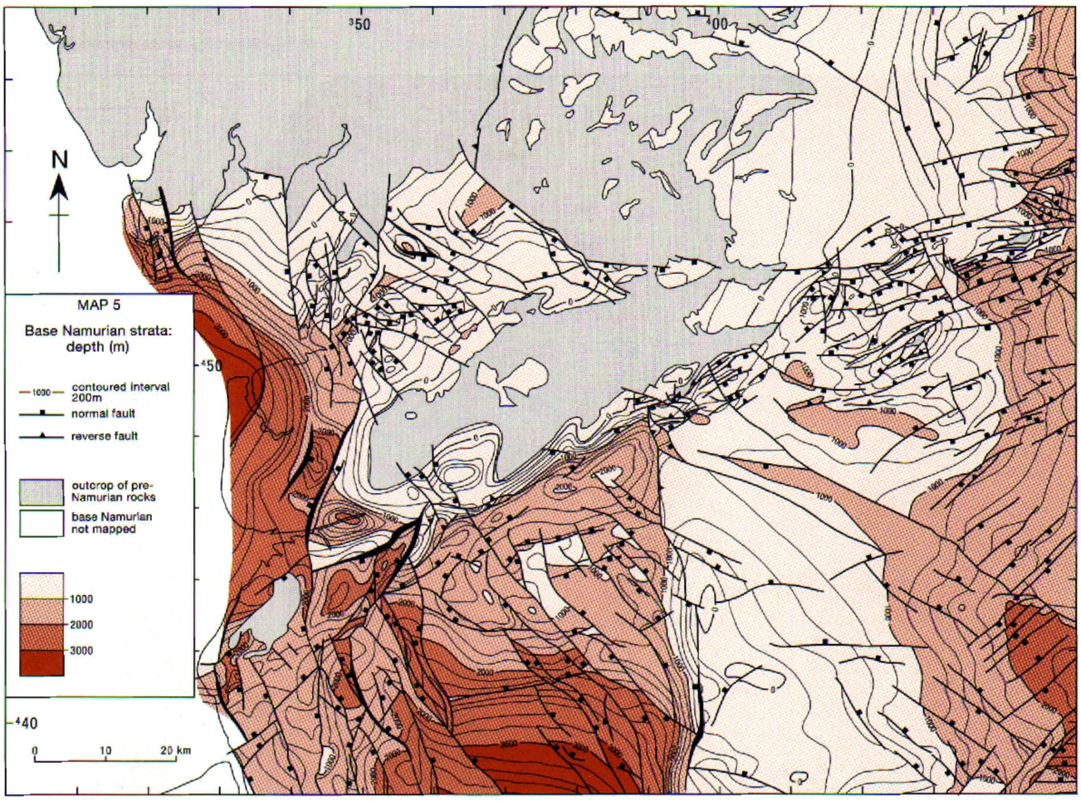

Figure 2 An example structural contour map of the Base Namurian Strata from the Craven Basin Subsurface Memoir

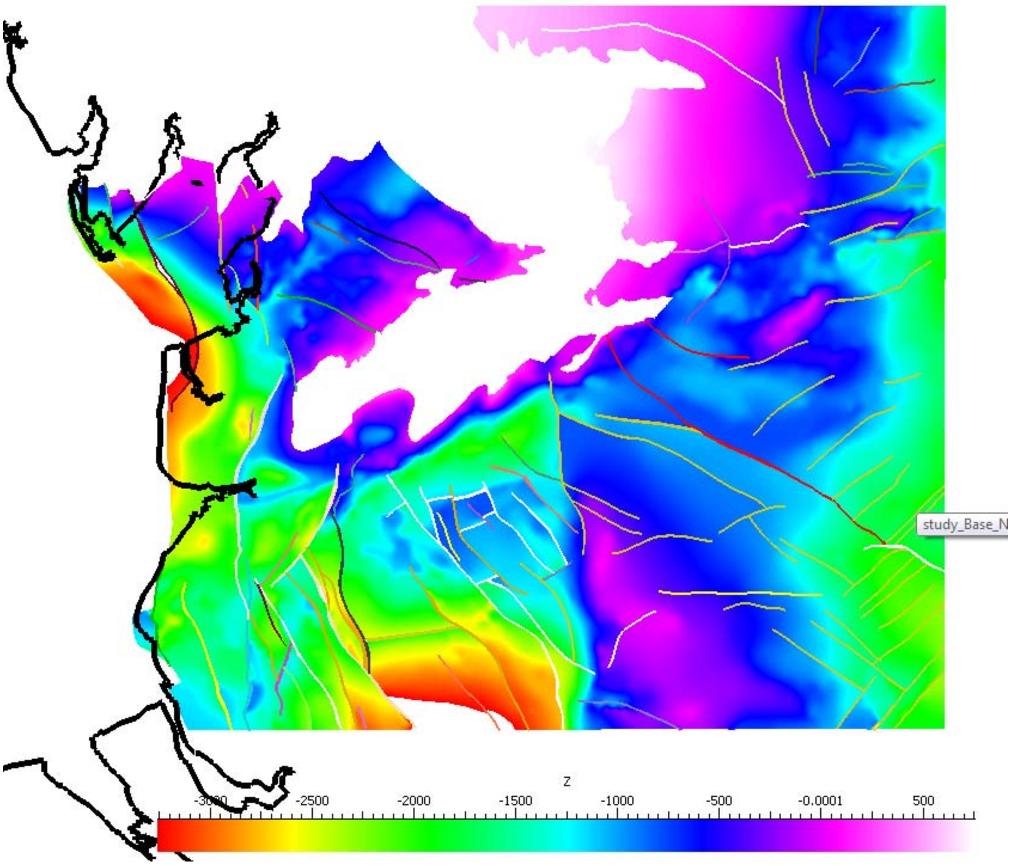

Figure 3 Modelled Base Namurian Surface with the coastline in black (depth range in metres)

2 Modelled surfaces/volumes

The surfaces were generated from the structural depth contour plots. Well control was *not* directly used.

Surfaces modelled are (numbers relate to stratigraphic order):

Rockhead

01 Base Permo-Trias

02 Base Westphalian (Base Coal Measures)

03 Base Namurian (Base Stainmore and Hensingham Groups)

04 Base Chatburn (Parent unit is Bowland High Group, Courceyan Age (CF) — Chadian Age (CI))

05 Top Caledonian Basement/Base Dinantian

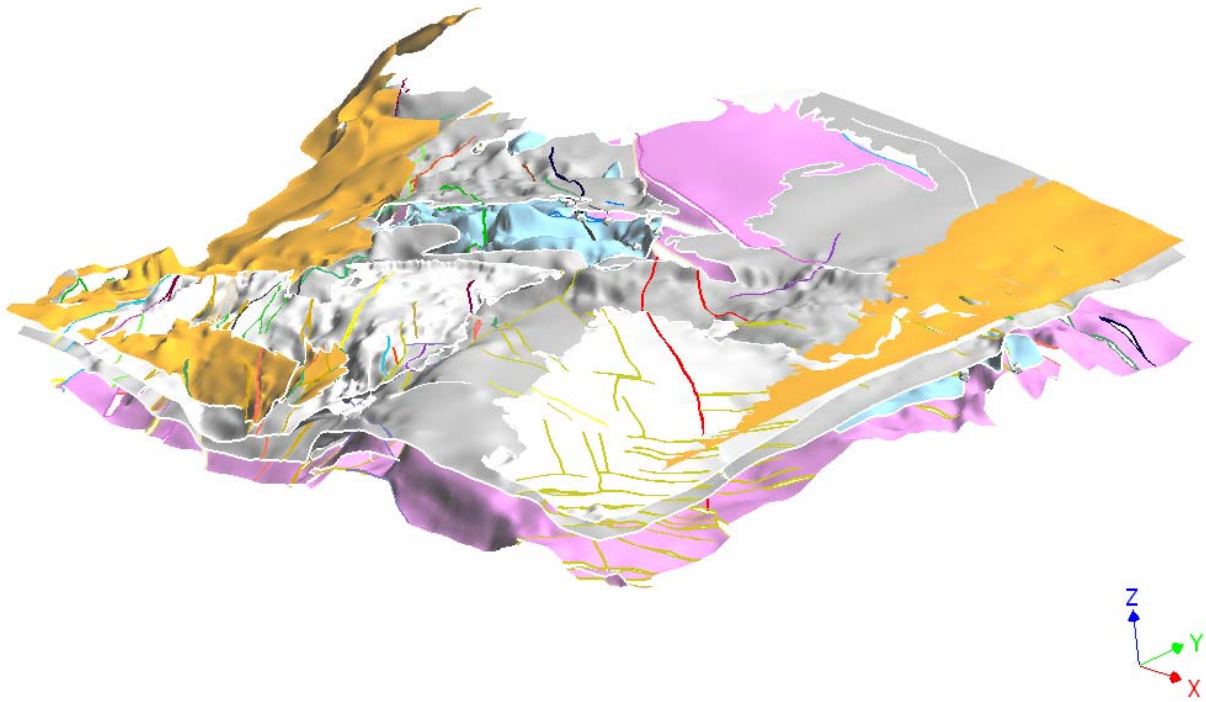

Figure 4 Image of modelled surfaces viewed from the South-East with the Digital Terrain Model outcrop included.

The table below summarises the general stratigraphy of the Craven Basin 3D geological model:

SUMMARY OF STRATIGRAPHY, AND GEOLOGICAL AND TECTONIC EVENTS

QUATERNARY		Holocene Pleistocene		Glacial and postglacial deposits	0–100 m	Mainly erosion
NEOGENE		Pliocene Miocene				Regional uplift, tilting and erosion, basin inversion early Miocene (Alpine Collision)
PALAEOGENE		Oligocene Eocene Paleocene				Regional uplift, tilting and erosion. Dyke injection ?Basin inversion (?Pyrenean Collision)
CRETACEOUS		Upper				Regional subsidence
		Lower				Extensional basin formation with periodic footwall uplift and erosion—details unknown
JURASSIC		Upper Middle				
		Lower	Lias Group	Mudstone and limestone	120 m	
TRIASSIC		Upper	Penarth Group	Siltstone, mudstone and sandstone	15 m	Regional subsidence
		Middle	Mercia Mudstone Group	Mudstone, siltstone and halite	300 m	
		Lower	Sherwood Sandstone Group	Sandstone, minor siltstone and mudstone	500 m	Extensional faulting
PERMIAN		Upper	Cumbrian Coast Group (W) 'Zechstein' (E)	Siltstone, sandstone, mudstone, gypsum and anhydrite, dolomitic limestone	<200 m	Regional subsidence
		Lower	Appleby Group (W) Yellow Sands (E)	Sandstone and conglomerate	<400 m	Extensional faulting and basin formation
CARBONIFEROUS	Silesian	Stephanian				Basin inversion, regional uplift and erosion; intrusion of Whin Sill, Pennine mineralisation (VARISCAN OROGENY)
		Westphalian	Coal Measures	Siltstone, sandstone and mudstone, red above, grey with coals below	800–1600 m	Mainly regional subsidence with minor extensional faulting; periodic localised minor basin inversion
		Namurian	Stainmore and Hensingham groups	Sandstone, siltstone, mudstone, limestone and thin coals	50–1000 m	
	Dinantian	Viséan	Liddesdale and Alston groups	Limestone, mudstone, siltstone, sandstone and thin coals	100–900 m	
			Upper Border Group	Siltstone, mudstone, sandstone, limestone and thin coals	0–800m	
			Middle Border, Fell Sandstone and Orton groups	Sandstone, siltstone, mudstone and limestone	0–800 m	Major period of extensional faulting and basin formation; widespread volcanism in early part, sporadic and local thereafter
			Lower Border and Cementstone groups	Limestone, mudstone, siltstone, sandstone and anhydrite	0–4500 m	
		Tournaisian	Birrenswark, Kelso, Cockermouth lavas	Basaltic lavas	0–50 m	
			Upper Old Red Sandstone	Sandstone, siltstone, mudstone and conglomerate	0–200 m	?Minor extensional faulting
DEVONIAN		Upper Middle				Acadian deformation, uplift and erosion
		Lower	Cheviot Lavas and Lower Old Red Sandstone	Andesitic volcanic rocks, conglomerate and sandstone (Cheviot Block only)	0–?1000 m	Intrusion of Cheviot, Weardale, Shap and Skiddaw granites etc. / Continued subduction
SILURIAN			'Basement Rocks'	Shale, greywacke, limestone, lavas and pyroclastic rocks, commonly cleaved		Other Lake District intrusions / Collision between Laurentia and E. Avalonia
ORDOVICIAN						Subduction and ocean closure (CALEDONIAN OROGENY)

Figure 5 Summary of the stratigraphy, geological and tectonic events for the Craven Basin and adjacent areas

3 Modelled faults

All of the faults used in the construction of the model were sourced from the Craven Basin Subsurface Memoir (Kirby et al., 2000). These were digitised per surface as ESRI polyline shapefiles as part of the Regional UK Lithoframe programme. As the model was regional in scale, an initial filtering of the faults was applied to ensure that only those that had significant throw/displacement (>100 m) were used for the surface construction.

To do this, vertical faults were selected that had a length of greater than 10 000 m, as it is recognised that the greater the length of the fault (in 2D space) the greater the throw/displacement (Young-Seog and Sanderson, 2005). By selecting faults over 10 000 m, the majority of the faults with throws of greater than 100 m would be selected for use in the modelling phase. These fault polyline shapefiles were imported and grouped by the surface in which they displaced.

All of the 'non-vertical' faults classified in the original Craven Basin EarthVision project were selected as there were relatively few of these, and these were interpreted as having a significant heave in the original model.

The total distribution of faults modelled can be seen in Figure 6.

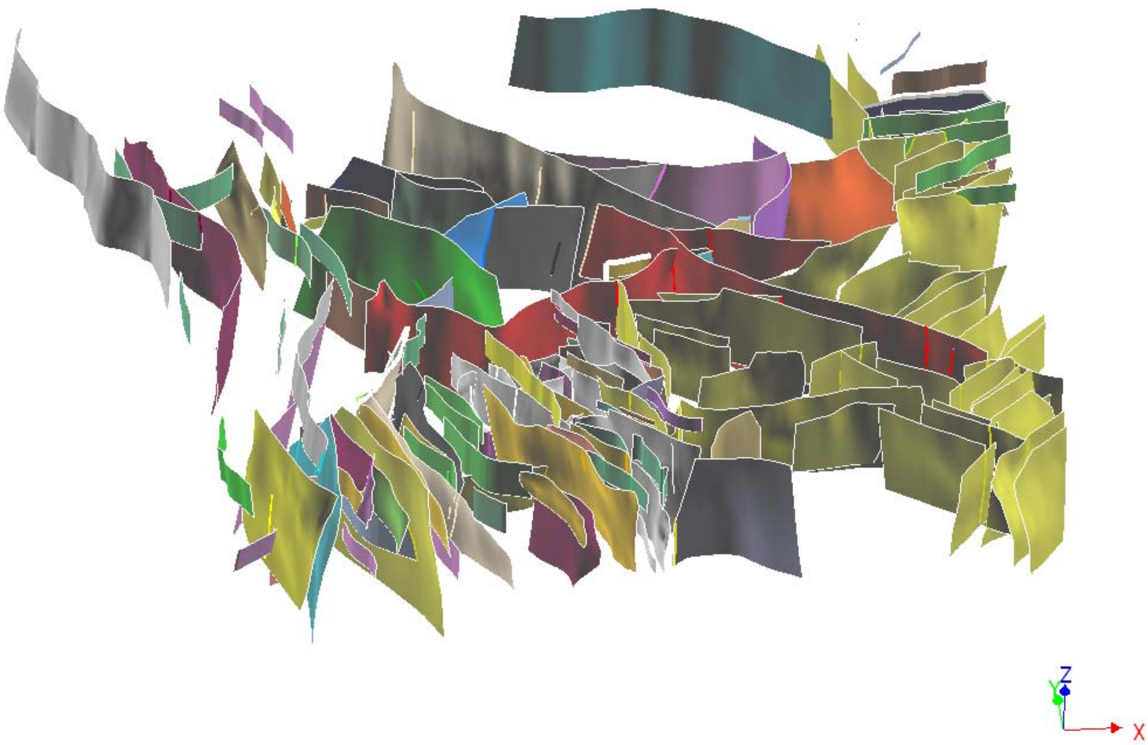

Figure 6 Distribution of the modelled faults for the Craven Basin Model

Two types of faults were produced using the Structural Modelling Workflow in GOCAD®. Some of the faults were produced using the fault sticks method and the rest used the Fault Centre Line method. For both types of faults generated, the Structural Modelling Workflow in GOCAD® was used to develop the contacts between the faults.

The fault traces digitised in ArcGIS have no Z-Value (elevation) associated with them, being in effect lines on a map. Therefore it was necessary to attribute them with an elevation for use in the 3D model construction. The method used was to construct an unfaulted surface model for each horizon and then drape the fault traces relating to each horizon on its surface. This gives an approximate fault elevation per model horizon.

The Z-attributed fault traces were then displayed together in 3D, and given a colour relating to the horizon it is associated with. These fault traces were then visually inspected to find their related fault trace at different levels which indicates a coherent structure cutting several horizons. When such a spatial correlation was observed, a new object was constructed from several different GOCAD curve objects that make up the structure. The Fault Sticks section (3.1) describes this workflow.

When a significant fault was observed that is unique to a single horizon, or whose relationship to fault intersections on horizons lying above and/or below is unclear, then the fault was modelled as locally vertical. The Fault Centre Line section (3.2) describes this workflow.

3.1 FAULT STICKS

1. Each surface was calculated using the contours digitised from the Craven Basin memoir to give a raw unfaulted surface.
2. The fault traces generated were draped onto their respective surface. For example, the Permo-Trias fault dataset was draped onto the Permian-Triassic raw surface. This was repeated for each of the fault datasets per horizon.
3. Faults were grouped by their fault location. For example, each of the fault traces for the F1016 fault was grouped into one curve object in GOCAD® (Figure 7).
4. The grouped fault traces were allocated a *Fault Stick* data type in GOCAD® and put through the Structural Modelling Workflow for generating a fault surface. Manual editing of the fault surface was sometimes necessary to smooth out any spikes or anomalous data.

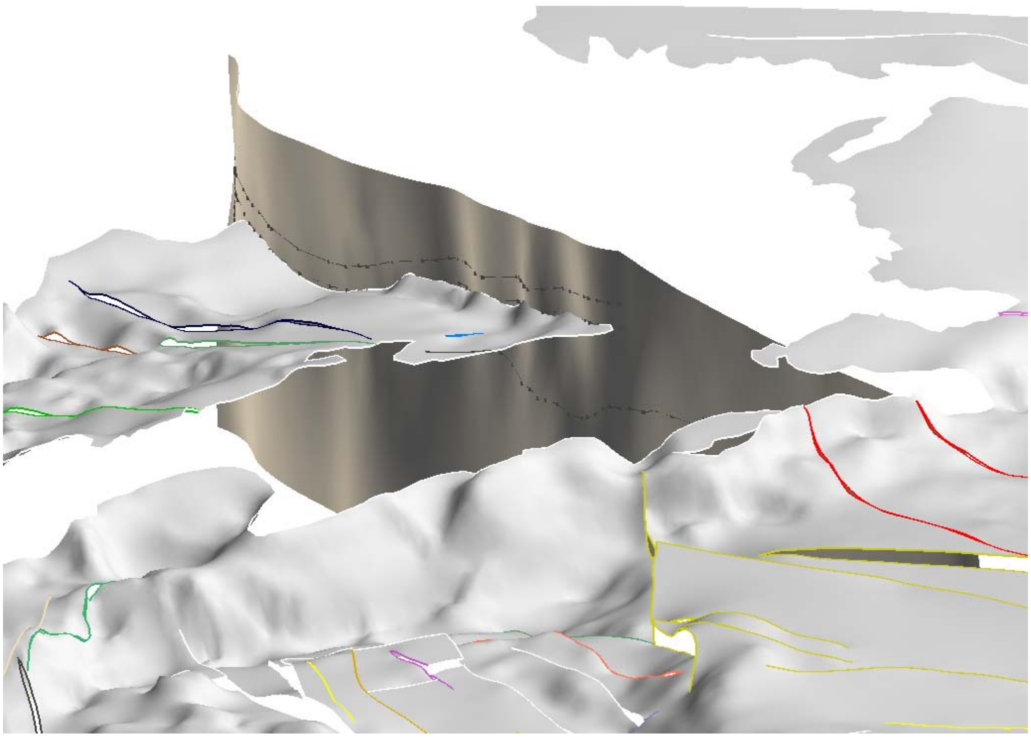

Figure 7 Left image shows the unfaulted Permian-Triassic surface (in grey) with the faults sticks (in black) of a fault from the Craven Basin dataset. The right image shows the faults sticks with the constructed fault from the draped fault sticks.

3.2 FAULT CENTER LINES

If the fault trace only occurred on a single surface, the *fault centre line* data type was used in GOCAD® Structural Modelling workflow. The *fault centre line* allows the user to specify the elevations of the top and the base of the fault and the dip angle. The fault generated is a simple extrusion of the fault centre line.

4 Model datasets

DTM

Used as a reference dataset. The DTM source was NextMap at a 250 m cell/mesh size resolution.

Rockhead Elevation Model

BGS RHEM onshore was used, on which the entire outcrop for each of the surfaces generated in the project was draped. The resolution of the RHEM was 500 m cell size.

Borehole data

Boreholes used to construct the modelled surfaces are listed in the Northumberland-Solway basin subsurface memoir (Kirby et al., 2000). The surfaces described in this report are based on structural contour data from the memoir.

Map data

The map data were generated directly from the Subsurface Memoir (Kirby et al., 2000) and cross-referenced with DigMap GB 1:250 000.

Mine plan data

No mine plan data were used.

Seismic data

Seismic data were interpreted and used in the generation of the contour data in the Subsurface Memoir (Kirby et al., 2000).

Geophysical data

Please see details in the Subsurface Memoir (Kirby et al., 2000)

4.1 GOCAD® OBJECTS

The following objects relate to the project specific data types within the GOCAD® project file. Each of the horizon datasets will have a pre-cursor number to identify its stratigraphic position and a CRVN addition to identify it's origin from the Craven Basin model:

01 – Base Permo-Trias_CRVN

02 – Base Westphalian_CRVN

03 – Base Namurian_CRVN

04 – Base Chatburn_CRVN

05 – Base Dinantian_CRVN

4.1.1 Pointset – GOCAD® project

- Contains all of the structural contours as points
  (e.g. 02_Base_Westphalian_Structural_Contour_Points_CRVN_vs)

4.1.2 Group - GOCAD® project

Group names in GOCAD® project on the left, description on the right.

- 01_Base_Permian_Triassic_Faults_Traces_pl – Fault traces (Z attributed from the Base Permian-Triassic surface)
- 02_Base_Westphalian_Fault_Traces_pl - Fault traces (Z attributed from the Base Westphalian surface)
- 03_Base_Namurian_Fault_Traces_pl - Fault traces (Z attributed from the Base Namurian surface)
- 04_Base_Chatburn_Fault_Traces_pl - Fault traces (Z attributed from the Base Chatburn surface)
- 05_Base_Dinantian_Fault_Traces_pl - Fault traces (Z attributed from the Base Dinantian surface)
- 3DFaults – All faults grouped
- Fault_Centerlines_pl – Fault traces associated with a single horizon
- Fault_Outlines_Borders_pl – Outline border of faults
- Fault_Point_Sets_vs – Point cloud of fault geometries
- Fault_Traces_Joins_pl – Two or more fault traces correlating spatially between horizons
- Faults_Structural_Modeller_ts – Faults with no CRVNF identifier but outputted from the structural modelling workflow as a fault surface
- OLD_Duplicate_Faults_ts – Duplicate faults
- Old_Surfaces_ts – Old or component surfaces
- Outlier_Inlier_Outcrop_Curves_pl – Outcrop polygons of the model horizons
- Structural_Contour_Point_Parts_vs – Structural contour point parts.

4.1.3 Surface - GOCAD® project

- Contains those surface horizons that have been clipped to the combined outcrop and subcrop for that horizon (02_Base_Westphalian_Combined_CRVN_ts)
- Contains all of the fault surfaces generated through the Structural Modelling workflow with the CRVN indicating it is from the Craven Basin Model, the F identifying it as a fault object and the number relating to a unique identifier (e.g. CRVNF_2019_ts)

5 Software Used and Model workflow

5.1 SOFTWARE USED

- GOCAD® version 2.1.6 and GOCAD® v2009
- ArcGIS 9.3
- MS Excel

5.2 MODEL WORKFLOW

The following workflow was used to generate the Northumberland-Solway Basin Model:

1. Compiled all raw data into a GIS
2. Imported all fault traces, outcrop data and structural contours for each horizon into GOCAD® version 2009 onwards.
3. Additional data added included the GB RHEM and the NextMap DTM surfaces (See Model Datasets Section 4)
4. A raw surface (uncut by faults at this stage) for each horizon was modelled using a combination of the structural contours and outcrop which had elevation values applied from the RHEM surface data.
5. Every fault trace was draped onto its corresponding surface using the 'Transfer Property by Vertical Projection' tool and then following the methodology established in Sections 3.1 and 3.2, the fault plane was constructed.
6. Once all of the faults had been constructed, branch contacts were established between the faults using the Structural Modelling workflow.

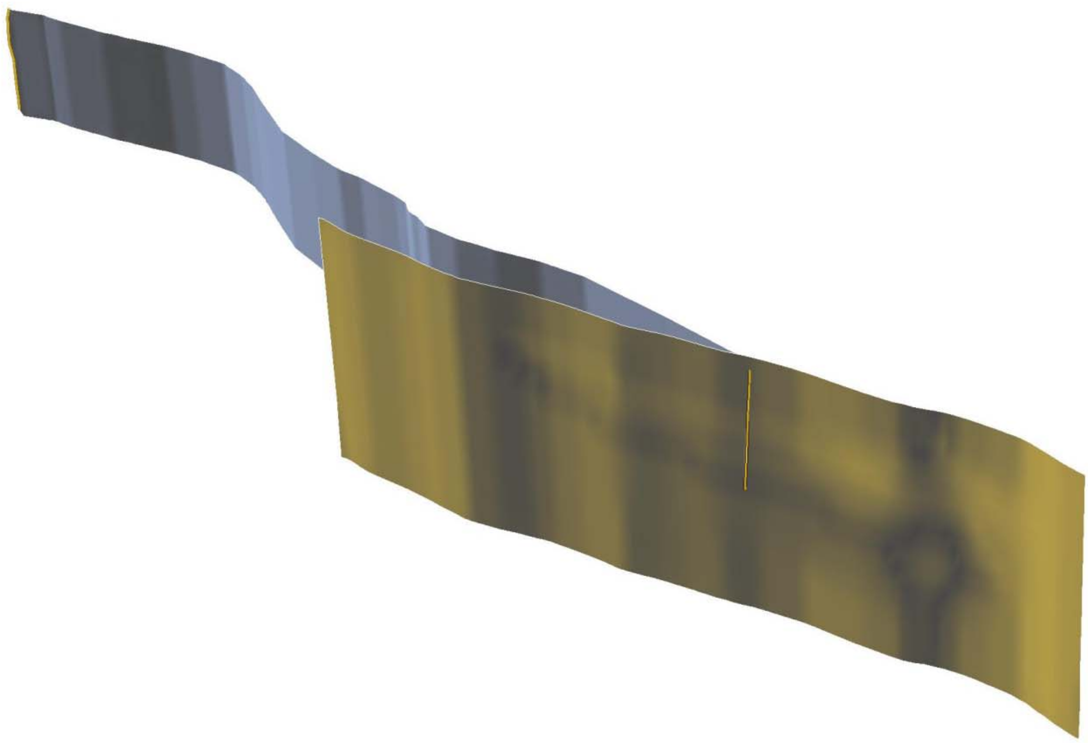

Figure 8 An example fault contact between two faults.

7. The faults were then used to cut the raw surface horizons using the 'Horizon-Fault Contact Modelling' in the Structural Modelling workflow.
8. Fault contacts and surface horizons were either edited using the Structural Modelling workflow parameters or manually using the tools available in GOCAD®

6 Model limitations

The modelled surfaces were directly constructed from the structural contours from the Craven Subsurface Memoir and were not fixed against any boreholes.

Some crossovers may exist between the surfaces. Some of these are directly the result of contours overlapping in vertical space. These have not been resolved either in the Subsurface Memoir or the model itself.

7 Model image

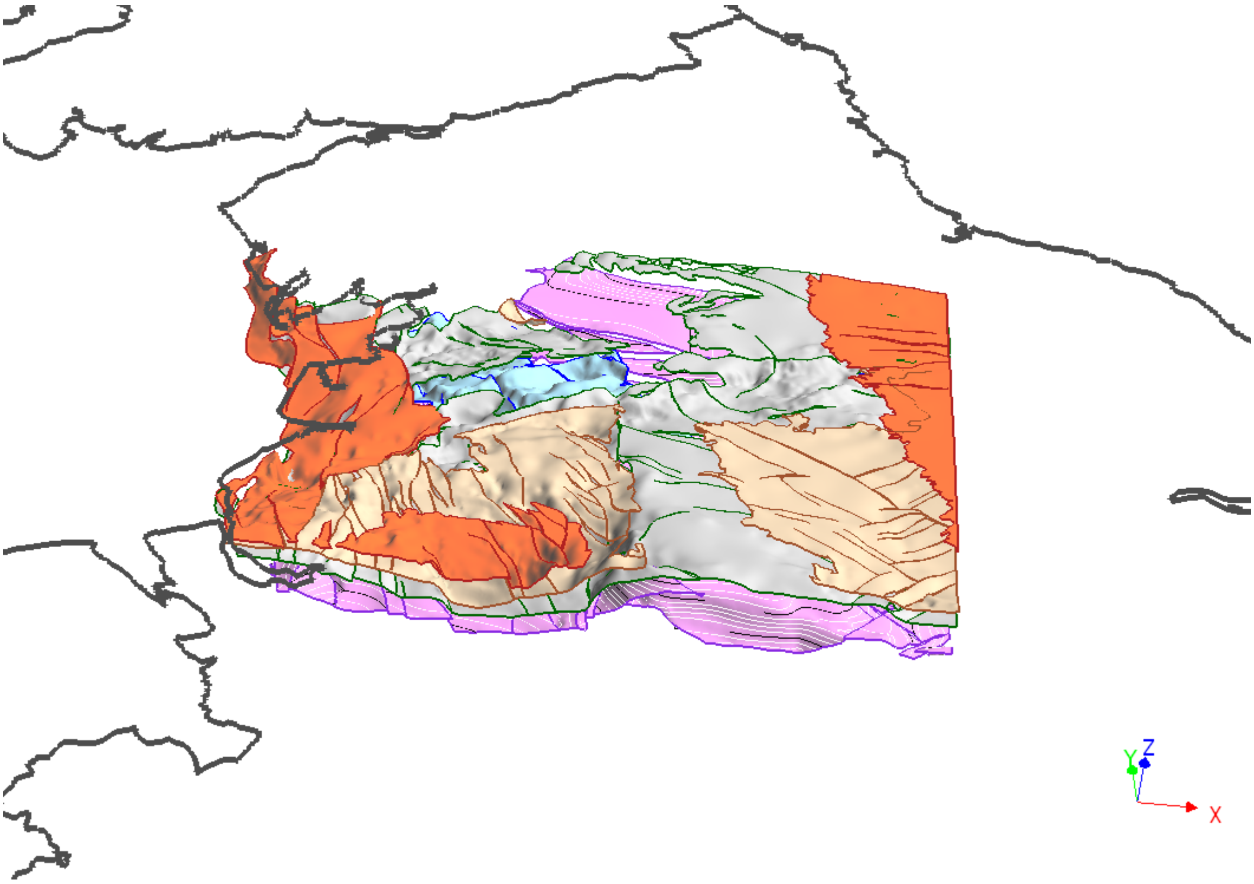

Figure 9 View of the final fault cut surfaces with the UK coastline viewed from the South

8 References

KIRBY, G A, BAILY, H E, CHADWICK, R A, EVANS, D A, HOLLIDAY, D J, HOLLOWAY, S, HULBERT, A G, PHAROAH, T C, SMITH, N J P, AITKENHEAD, N, and BIRCH, B. 2000. The Structure and Evolution of the Craven Basin and adjacent areas. *Subsurface Memoir of the British Geological Survey*.

YOUNG-SEOG, K, and SANDERSON, D J. 2005. The relationship between displacement and length of faults: a review. *Earth Sciecne Reviews*, Vol. 68, 317-334.