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

Geology and Regional Geophysics Programme

Open Report OR/14/028

BRITISH GEOLOGICAL SURVEY

GEOLOGY AND REGIONAL GEOPHYSICS PROGRAMME

OPEN REPORT OR/13/049

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

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Summary

This report describes the Weald Basin 1:250 000 model data and workflow. The model is based on the faults and surface contour plots in the following Department of Energy report:

Chadwick, R A, Evans, C.J., Holloway, S and Kirby, G.A., Lamb, R.C., Penn, I.E. and Smith, N.J.P. 1983. The hydrocarbon prospectivity of the Weald and eastern England Channel. Deep Geology Report 83/3 (prepared for the Department of Energy). British Geological Survey.

1 Modelled volume, purpose and scale

Figure 1: Modelled area (in red). Topological Map - Ordnance Survey data © Crown copyright and database right 2014.

This is a faulted GOCAD® regional model extending onshore across Kent, Surrey, Sussex, Hampshire and the Isle of Wight and offshore into the English Channel (Figure 1). The model was constructed from data digitally derived from the Weald Basin Report (Chadwick et al., 1983). The results of the study are contained in structure contour maps of various scales (1:50 000, 1:100 000 and 1:250 000) but it was decided that the 1:250 000 scale maps covering the whole area were the appropriate ones to use for consistency. An example of one of these maps can be seen in Figure 2. An example of the type of surface produced from this data can be seen in Figure 3.

The model was developed as part of the Regional UK Lithoframe Programme, to convert the structural data interpreted in the subsurface memoirs and other subsurface reports into 3D models. The Weald Basin model provides an understanding of the regional bedrock structure for the Mesozoic and later strata.in Northern England (particularly for the Carboniferous rocks) and extends from +300 to -2 600m OD.

As the Weald Basin Model was derived from digital data compiled for an earlier BGS report, 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.

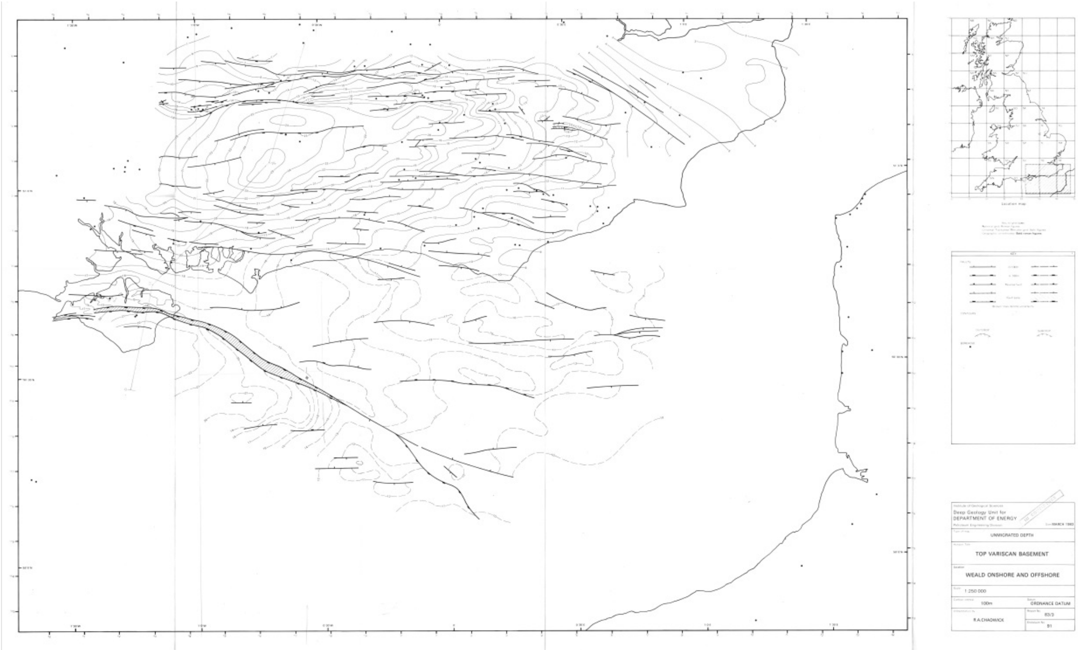

Figure 2: Example structural contour map of the Top of the Variscan Basement from the Weald Report

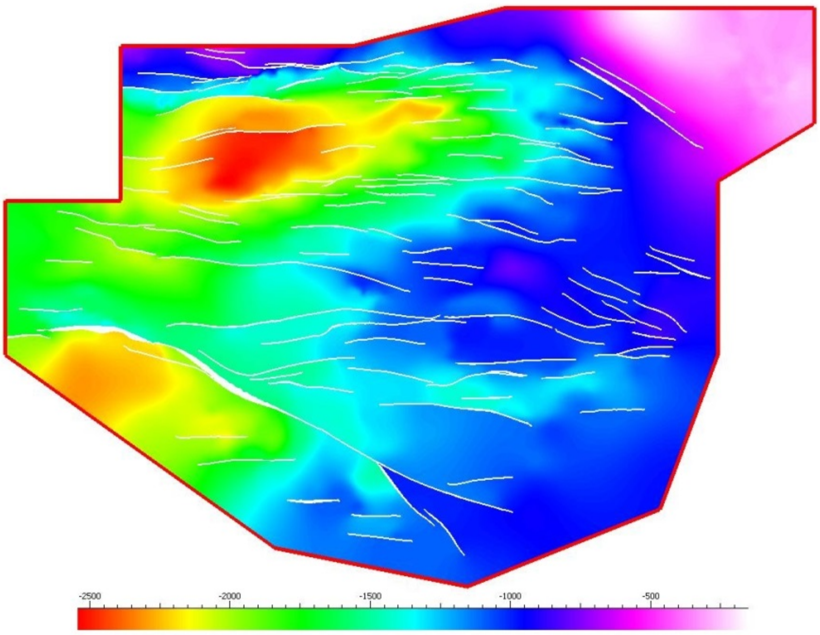

Figure 3: Modelled Top of the Variscan Basement surface (depth range in metres)

2 Modelled surfaces/volumes

The surfaces were generated from the structural depth contour plots (Chadwick et al., 1983). Well control was *not* directly used.

Surfaces modelled (Figure 4) are (numbers relate to stratigraphic order):

01 Base Tertiary

02 Base Lower Greensand

03 Top Corallian

04 Top Cornbrash

05 Top Penarth Group

06 Top Variscan Basement

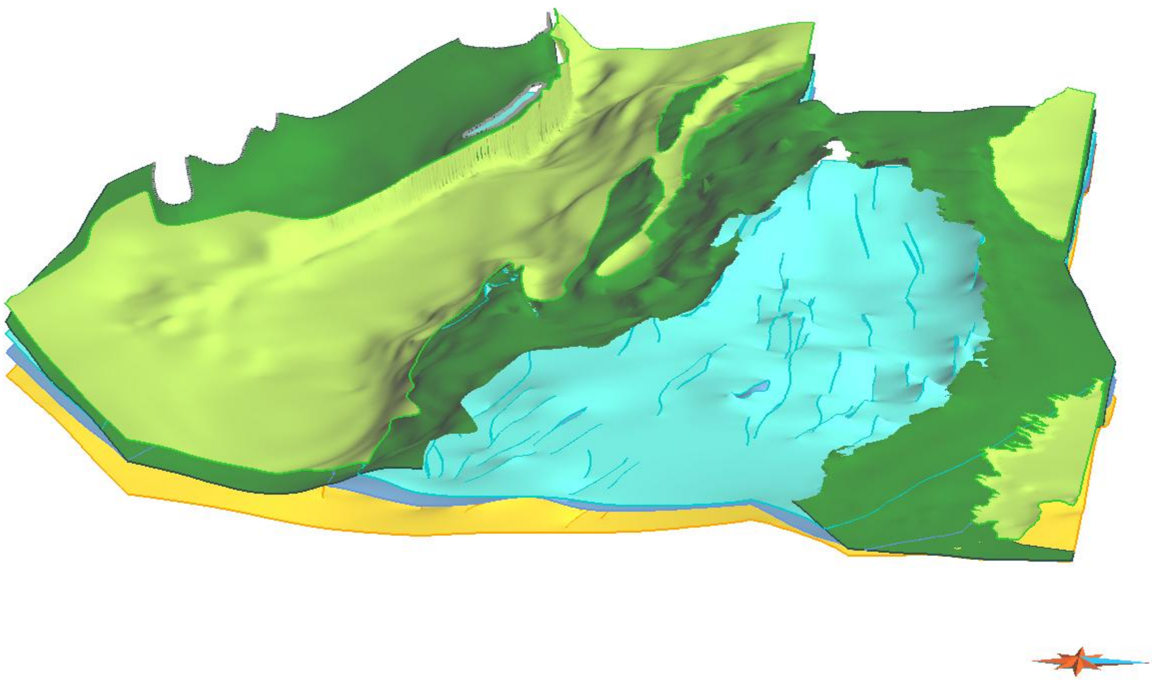

Figure 4: Image of modelled surfaces viewed from the West.

The figure below summarises the general stratigraphy of the Weald from Chadwick *et al* (1983):

CHRONOSTRATIGRAPHIC			LITHOSTRATIGRAPHIC		
JURASSIC		Callovian	Cornbrash	Upper Cornbrash	
JURASSIC	MIDDLE	Bathonian	Cornbrash	Lower Cornbrash	
JURASSIC	MIDDLE	Bathonian	Forest Marble		
JURASSIC	MIDDLE	Bathonian	'Great Oolite' limestone or Great Oolite'; 'Great Oolite' / Frome Clay		
JURASSIC	MIDDLE	Bathonian	Fuller's Earth	Upper Fuller's Earth Fuller's Earth Rock Lower Fuller's Earth	
JURASSIC	MIDDLE	Bajocian (Aalenian)	Inferior Oolite	Upper Inferior Oolite Middle Inferior Oolite Lower Inferior Oolite	
JURASSIC	LOWER	Toarcian	Upper Lias	Upper Lias Sands (Bridport Sands / Yeovil Sands) Upper Lias Clays Junction Bed	
JURASSIC	LOWER	Pliensbachian	Middle Lias	(Marlstone Rock Bed)	
JURASSIC	LOWER	Pliensbachian / Sinemurian / Hettangian	Lower Lias	Green Ammonite Beds Belemnite Marls Black Ven Marls Shales with Beef Blue Lias	
TRIASSIC			Penarth Group (Rhaetic)	Lilstock Formation Westbury Formation	Langport Member Cotham Member
TRIASSIC			Mercia Mudstone Group	Blue Anchor Formation Variegated Marl Upper Red Marl Anhydrite Siltstone Saliferous Marls (Equivalent) 'Lower Red Marl Waterstones Formation (Equivalent)	Grey Marl Tea Green Marls
TRIASSIC			Sherwood Sandstone Group	'Bunter' Sandstone 'Bunter' Pebble Beds	
PERMIAN			?Absent		
CARBONIFEROUS	UPPER	Westphalian D	Upper Coal Measures	'Upper Sandstone Division'	
CARBONIFEROUS	UPPER	Westphalian C / B	Middle Coal Measures	(Lower Tilmanstone M.B.) (Ripple M.B.) 'Lower Shale Division'	
CARBONIFEROUS	UPPER	Westphalian A	Lower Coal Measures	'Lower Shale Division'	
CARBONIFEROUS		Namurian absent	Absent		
CARBONIFEROUS	LOWER	Brigantian (not proven) Asbian (not proven) Holkerian Arundian Chadian (not proven) Ivorian Hastarian	Carboniferous Limestone		
DEVONIAN		Famennian Frasnian Givetian	Marine Devonian		
DEVONIAN		Stages not proven	?Old Red Sandstone		
SILURIAN		Stages not proven Wenlock Llandovery			
ORDOVICIAN		Caradoc Arenig			
CAMBRIAN		Tremadoc (?present)			

Table 3.1a Chronostratigraphic position of principal lithostratigraphic units

Figure 5: Summary of the stratigraphy, geological and tectonic events for the Weald Basin

3 Modelled faults

All of the faults used in the construction of the model were sourced from the Weald Report (Chadwick et al., 1983). These were digitised per surface as ESRI polyline shapefiles as part of the Regional UK Lithoframe programme. As the model was regional in nature, an initial filtering of the faults was applied to ensure that only those that had significant throw/displacement (generally >100 m) were used for the surface construction.

One method of filtering was to select faults that had a length of greater than 10 000 m (a value arrived at by experimentation), 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, many of the faults with throws of greater than 100 m are selected for use in the modelling phase.

For shorter faults, finding those that had significant displacement and were worthy of inclusion in the model was a case of manual inspection. This was achieved by taking all of the faults that had a length shorter than 10 000 m, and examining the contour values across and within a buffered distance (usually either 250 or 500 m) in order to estimate the change in elevation across the fault. From the results of this, faults that were less than 10 000 m in length but were found to have a throw greater than 100 m were selected for use in the project.

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

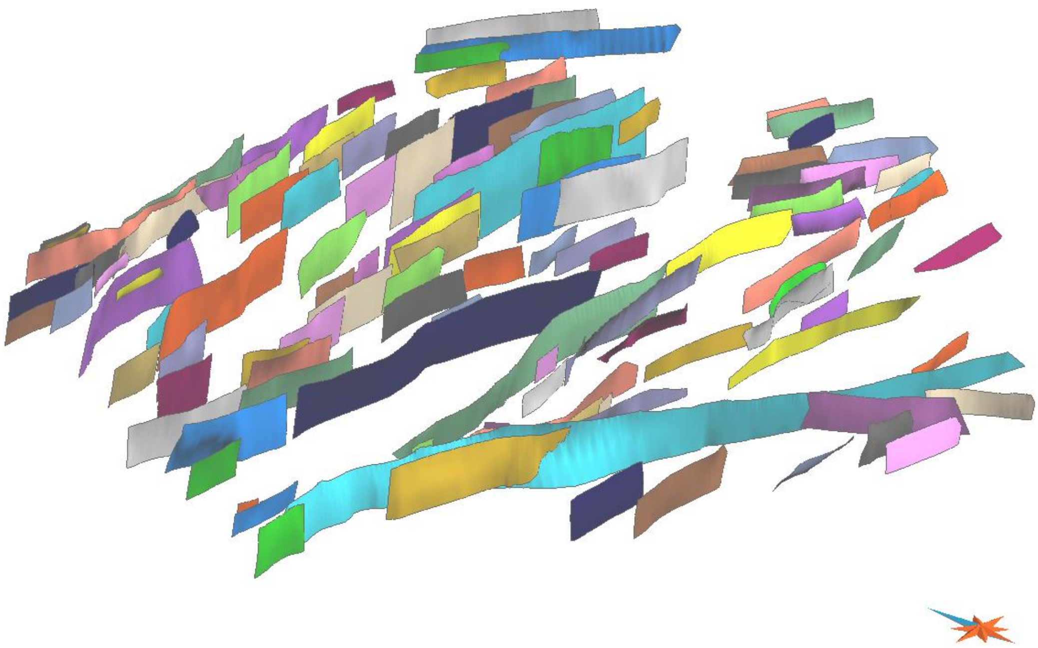

Figure 6: Distribution of the modelled faults for the Weald Basin Model

Two types of faults were produced using the Structural Modelling Workflow in GOCAD®. Some of the faults were produced using the fault sticks method (whereby fault cuts at individual surfaces were combined to produce a fault surface) and the rest used the Fault Centre Line method (a single fault line at a particular level, with a fault dip and direction applied). For both types of faults generated, fault contacts were modelled where individual faults were crossed or truncated by other faults in the model

3.1 FAULT STICKS

1. Each surface was calculated using the digitised contours to give a raw unfaulted surface.
2. The fault traces generated were draped onto their respective surface.
3. Faults were grouped by their fault location – meaning each draped fault trace that corresponded with an individual fault was extracted to a new fault curve object - further filtering could be undertaken at this point, as not all draped fault cuts were necessarily required to produce an aesthetically pleasing fault object (Figure 6).
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.

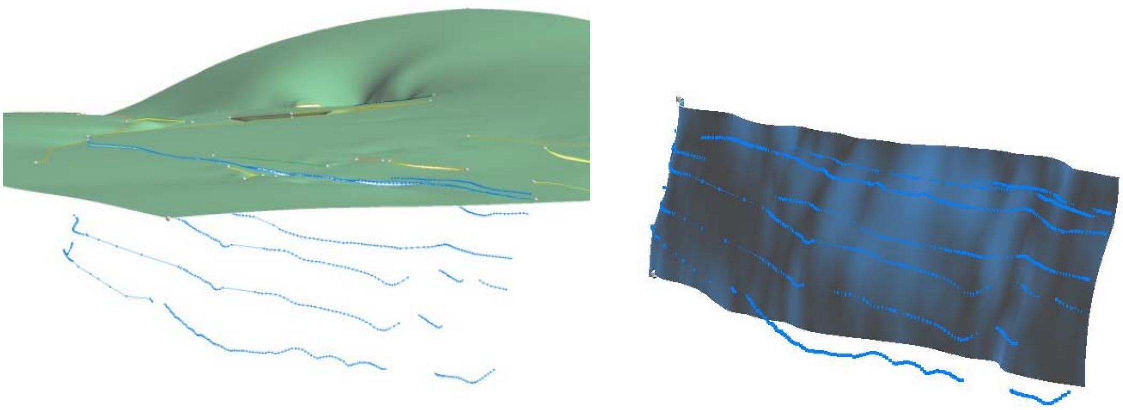

Figure 7: Example from the Northumberland-Solway Model (Terrington and Thorpe, 2013) showing the construction of a fault surface (the Closehouse-Lunedale fault) from fault sticks (right image in blue) and the interaction of the fault with the Permo-Trias surface prior to faulting (in green).

3.2 FAULT CENTER LINES

If the fault trace only occurred on a single surface, or the fault heave over several surfaces was insignificant, 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. This fault type is often used where faults displace the outcrop (or subcrop).

3.3 FAULT CONTACT MODELLING

After fault construction, fault intersections need to be modelled and constraints built. This is normally done within the modelling workflow using the "Fault Contact Modelling" dialogue. This works well with relatively simple fault networks and was used in this case as there were not many intersecting faults. For more complex networks or where individual faults may not always have the same vertical extents, manual construction of fault contacts and constraints produces a better model. To do this, we use the "cut by surfaces" method with the "build constraints" option selected. This fills the fault contact table in the same way that the workflow method does.

4 Model datasets

Digital Terrain Model (DTM)

Used as a reference dataset. The DTM source was NextMap at a 200 m cell size resolution. A surface was then created from extracted points. Optimisation was performed to produce more triangles in areas of more detail.

Borehole data

Boreholes used to construct the modelled surfaces are listed in the Weald Report (Chadwick et al., 1983). No extra boreholes were used and the surfaces described in this report are based on structural contour data from the report.

Map data

The map data were generated directly from the Weald Report (Chadwick et al., 1983) 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 Weald Report (Chadwick et al., 1983).

Geophysical data

Please see Chadwick *et al* (1983)

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 it using the schema:

01 – Base Tertiary

02 – Base Lower Greensand

03 – Top Corallian

04 – Top Cornbrash

05 – Top Penarth Group

06 – Top Variscan Basement

4.1.1 Pointset – GOCAD® project

- Contains all of the structural contours, derived from the modelled surfaces, as points (e.g. 01_Weald_Base_Tertiary_Structural_Contour_Points_vs)

4.1.2 Group - GOCAD® project

- EastMidlands_faults - contains all of the fault surfaces generated through the Structural Modelling workflow (e.g. weald_WLDF_001_ts).
- EastMidlands_Raw_faults - contains the “grouped” fault data used for fault surface creation.
- EastMidlands_Raw_Data – contains the contour and crop data used for surface modelling, borehole data points, and the “pre-grouped” fault cut data used for fault modelling

4.1.3 Surface - GOCAD® project

- Contains those surface horizons that have been clipped to the combined outcrop and subcrop for that horizon (01_Weald_Base_Tertiary_ts)
- Other datasets include the DTM derived from the CEH DTM at 200m resolution

5 Model development log

W:\Teams\UKGF\RegionalLithoframe\Data\Weald\gocad

RL_Weald_v0	Construction of initial horizon surfaces for fault stick Z values. Construction of fault objects prior to fault surface modelling.
RL_Weald_v1	Construction of fault surfaces. Surfaces checked prior to fault contact modelling so that faults should intersect correctly.
RL_Weald_v2	Fault contacts created Data edited to remove points from wrong side of faults
RL_Weald_v3	Horizon/Fault contacts created
RL_Weald_v4	Horizon/Fault contacts refined Top Penarth Group surface created from isopach
RL_Weald_v5	Surfaces fitted to borehole points Surfaces fitted to crop
RL_Weald_v6	Horizon cross-overs removed Final Model

6 Software Used and Model workflow

6.1 SOFTWARE USED

- GOCAD® version 2.5.2 and GOCAD® v2009
- ArcGIS 9.3
- MS Excel

6.2 MODEL WORKFLOW

The following workflow was used to generate the Weald Basin Model:

1. Compiled all raw data into a GIS: W:\Teams\UKGF\RegionalLithoframe\Data\Weald\weald.mxd
2. Imported all fault traces, outcrop data and structural contours for each horizon into GOCAD®.
3. Additional data added included the CEH DTM data points (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 DTM 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.

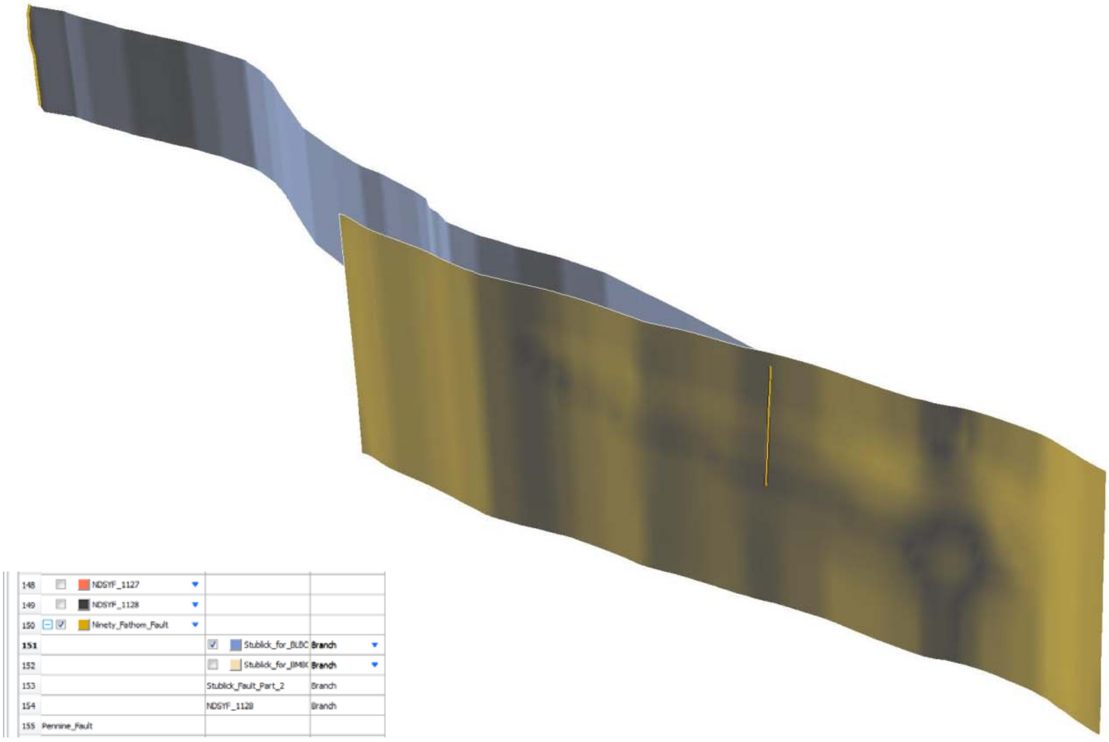

Figure 8: Example fault contact from the Northumberland-Solway Model between the Ninety Fathom fault (Main) and the Stublick fault (branch) from Terrington *et al* (2013)

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®
9. Surfaces were then fitted to crop using the 'Border on curve' surface constraint.
10. Any surface intersections were then removed using the 'Remove crossovers' dialogue.

7 Model limitations

The modelled surfaces were directly constructed from the structural contours from the Weald Report and then warped to fit borehole data points (not using the Structural modelling workflow).

The Top Penarth Group surface was constructed from isopach values. Values were gridded in Arc GIS and then added to the Top Variscan Basement surface to produce depth values. The depth values were then exported and used in the modelling process as normal.

The Isle of Wight monocline is presumed to be unfaulted for Cretaceous and younger rocks. More recent studies have shown this not to be the case (Evans et al., 2011)

As part of the modelling process, crossovers may occur between the surfaces. Some of these are directly the result of contours overlapping in vertical space. These have been resolved wherever possible but still may exist in some places.

8 Model image

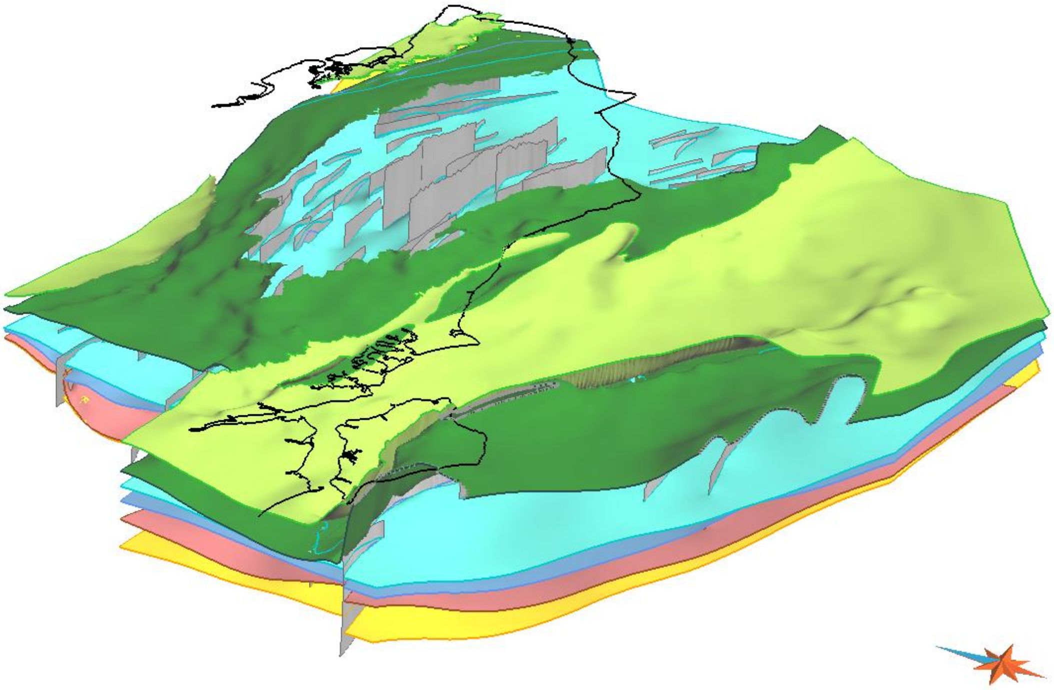

Figure 9 View of the final fault cut surfaces with the UK coastline viewed from the South-West

9 References

CHADWICK, R A, EVANS, C J, HOLLOWAY, S, KIRBY, G A, LAMB, R C, PENN, I E, and SMITH, N J P. 1983. Hydrocarbon prospectivity of the Weald and Eastern English Channel. *Institute of Geological Sciences (BGS)*, DP/83/3.

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