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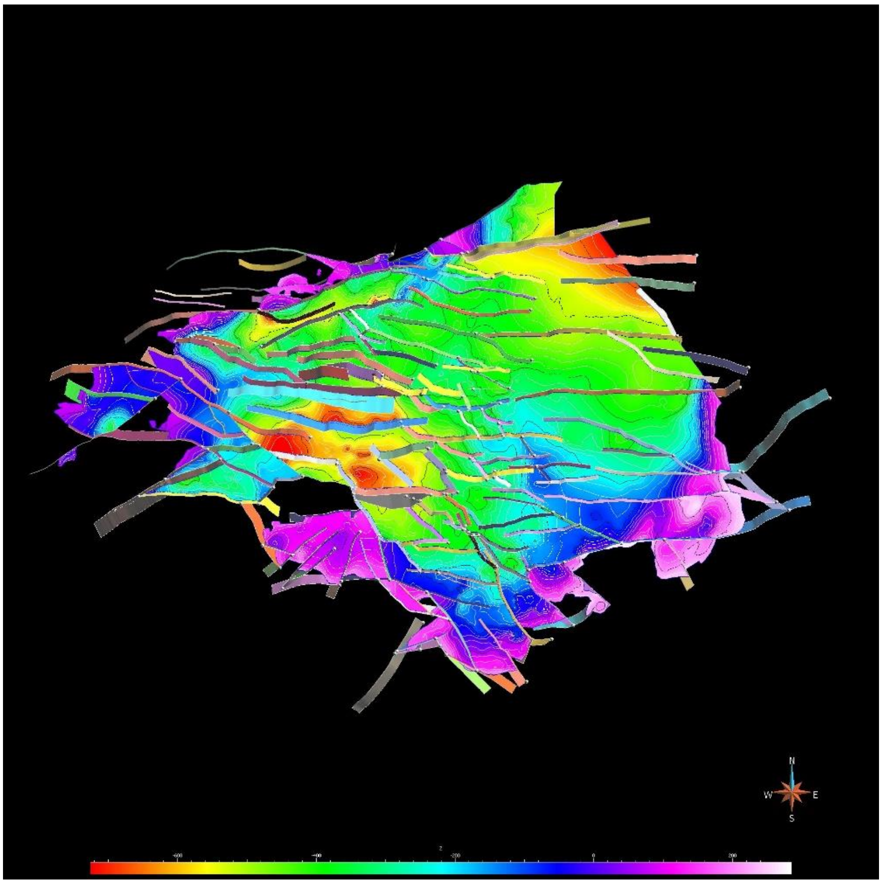
Clyde Catchment GOCAD® bedrock regional model, 2013.

Geology and Landscapes Scotland

Open Report OR/13/036



BRITISH GEOLOGICAL SURVEY
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Clyde Catchment GOCAD® bedrock regional model, 2013.

Mike McCormac

Keywords: Clyde catchment, GOCAD®, 3D modelling, Carboniferous, bedrock

National Grid Reference

SW corner 237000,637000

NE corner 310000,686000

Map

Sheet 23 (E&W),31(E&W). Parts of 22E, 24W,30E and 32W 1:50 000 scale

Front cover

GOCAD® image of regional faulted model of the Hurlet Limestone Horizon

Bibliographical reference

MCCORMAC, M 2013. Clyde Catchment GOCAD® bedrock regional model, 2013. *British Geological Survey Internal Report*, OR/13/036. 19pp.

Keyworth, Nottingham British Geological Survey 2013

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Foreword

This report is a published product of the British Geological Survey (BGS) describing a 3D regional bedrock model of a selection of Carboniferous horizons covering the west-central part of the Midland Valley of Scotland. The report is a revised version of internal report IR/13/014, and is suitable for external use in conjunction with the Clyde Catchment Regional GOCAD® model.

Acknowledgements

This report is a review of modelling work which would not have been possible without the collection, analysis and digital capture of mine plan data by Bill Maclean and the borehole stratigraphical analysis and coding of Anthony A.M. Irving. Scanning and geo-rectification of mine plans was carried out by Murchison House Cartographic and GIS colleagues. Alison Monaghan is thanked for her patience and thoroughness as model editor and QA assessor.

Seumas D. G. Campbell is thanked for his able project management and encouragement.

Contents

Foreword i

Acknowledgements i

Contents ii

Summary iii

1 Modelling project history, purpose and general methodology 1

1.1 General aspects 1

1.2 Model use and limitations 4

1.3 Horizon creation 4

1.3.1 Model concatenation 5

1.3.2 Deep horizon surface creation 6

1.3.3 Regional fault system 8

1.3.4 Final refinements 9

Appendix 1 14

References 15

FIGURES

Figure 1. Extent outlines for the modelled surfaces, superimposed on the 625k scale bedrock geological map. Base Coal Measures horizon in black, Index Limestone horizon in magenta and Hurlet Limestone horizon in yellow, major sill complexes in pink or green. 1

Figure 2. General stratigraphical chart for the modelled area. Modelled horizon names in magenta. 2

Figure 3. Extent of available mine-working elevation data for the Meikle Hill Main coal seam (black dot clusters). 6

Figure 4. Interpolated isopach contours for the interval between the base of the Coal Measures and the Index Limestone Horizon. 7

Figure 5. Interpolated isopach contours for the interval between the base of the Coal Measures and the Hurlet Limestone horizon. 8

Figure 6. GOCAD® screen image of regional modelled fault system and the Base Coal Measures horizon surface. 9

Figure 7. GOCAD® screen image of elevation contoured Glasgow Ell Coal Seam surface 10

Figure 8. GOCAD® screen image of elevation contoured Base Scottish Coal Measures Formation surface 11

Figure 9. GOCAD® screen image of elevation contoured Base Upper Limestone Formation (Index Limestone) surface 12

Figure 10. GOCAD® screen image of elevation contoured Base Lower Limestone Formation (Hurlet Limestone) surface 13

TABLES

Table 1. *Modelled horizons and Lexicon and RCS codes for the intervening intervals* 3

Summary

The main project aims covered in this report were to create a faulted structural bedrock model, using GOCAD® 3D modelling software, for a selection of regionally persistent, mid to late Carboniferous, lithostratigraphical horizons present across the west-central Midland Valley of Scotland. The single regional model was created by concatenation of existing local scale models, extended modelling to depth using interval thickness isopachs and fitting to a revised and extended regional fault model.

1 Modelling project history, purpose and general methodology

1.1 GENERAL ASPECTS

The main project aims were to create a faulted structural bedrock model, using GOCAD® 3D modelling software, for a selection of regionally persistent, mid to late Carboniferous, lithostratigraphical horizons correlated (Browne et al., 1999) across the west-central Midland Valley of Scotland (Figure 1). The horizons selected for regional scale modelling were the Glasgow Ell Coal Seam (Scottish Middle Coal Measures Formation), base Scottish Coal Measures Group, the Index Limestone bed/base Upper Limestone Formation and the Hurlet Limestone bed/base Lower Limestone Formation/base Clackmannan Group (Figure 2 and Table 1).

The regional scale model was created largely by bringing together previously completed local scale modelling work (McCormac, 2009 (IR/09/068), McCormac, 2012 (IR/12/046)) with an earlier part-regional bedrock model of the Western Clyde Catchment area (Monaghan & Pouliquen, 2009 (IR/09/070).

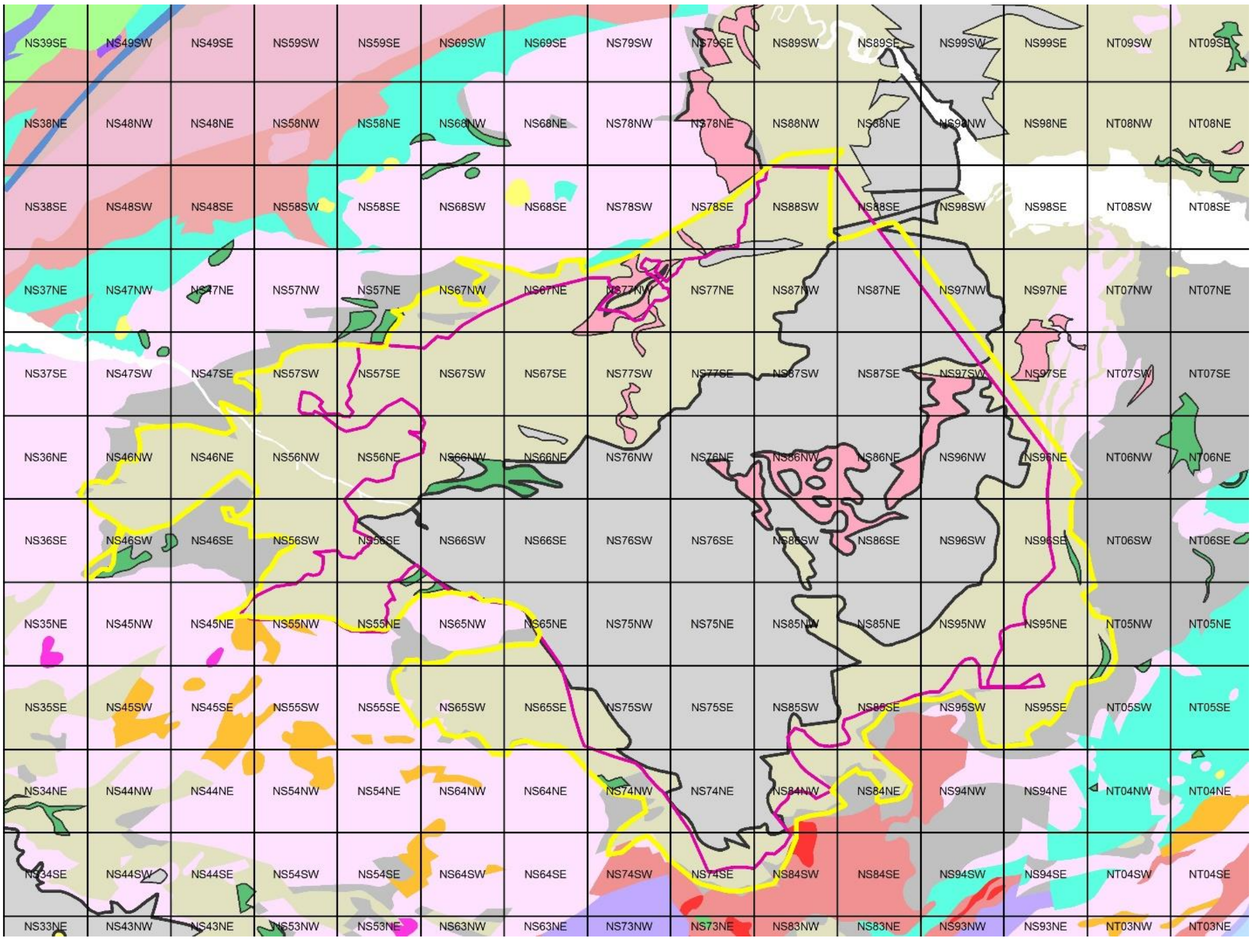

Figure 1. Extent outlines for the modelled surfaces, superimposed on the 625k scale bedrock geological map. Base Coal Measures horizon in black, Index Limestone horizon in magenta and Hurlet Limestone horizon in yellow, major sill complexes in pink or green.

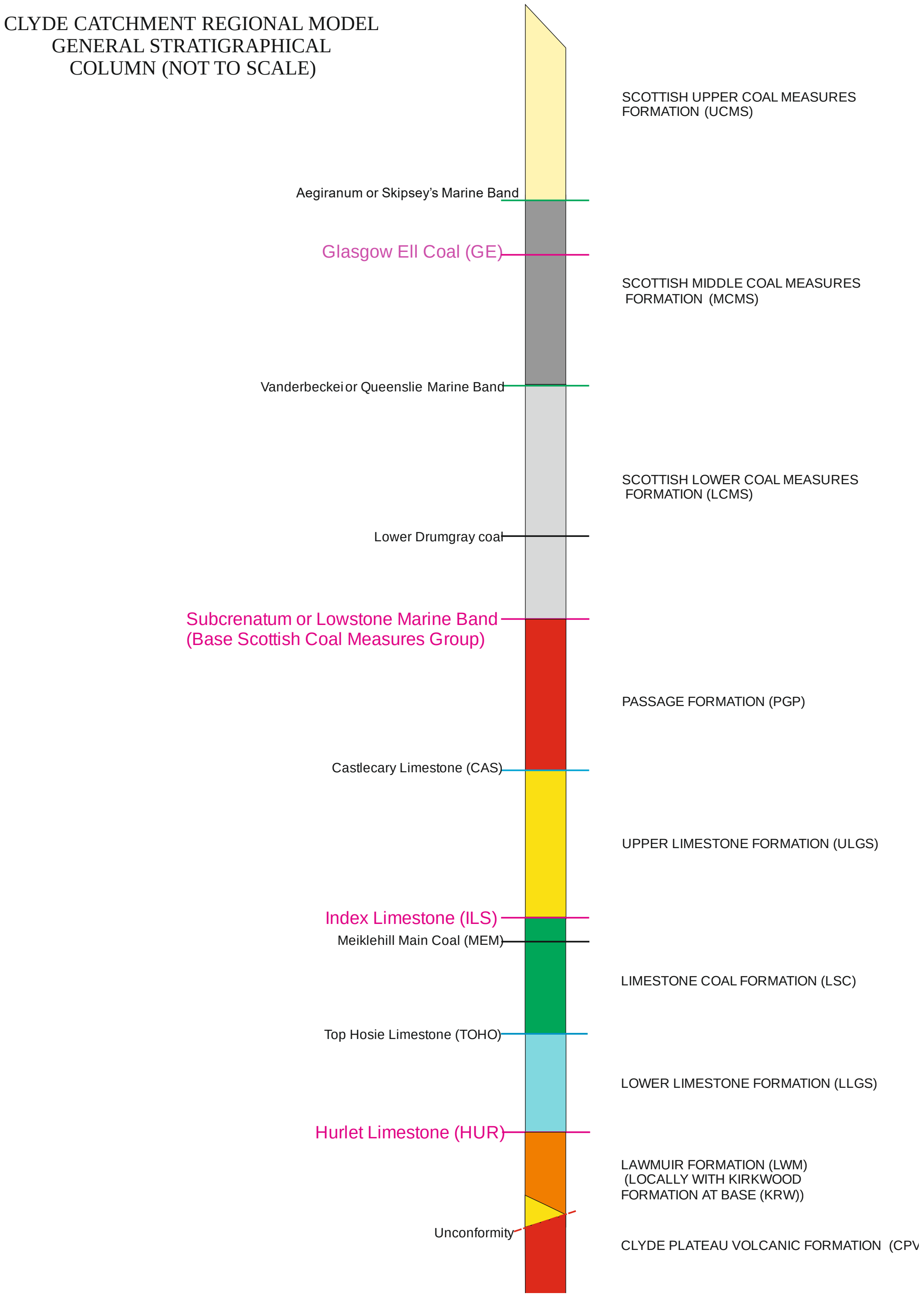

Figure 2. General stratigraphical chart for the modelled area. Modelled horizon names in magenta.

HORIZON	STRATIGRAPHICAL INTERVAL	LEX-ROCK CODE
Rockhead		
	Middle and Upper Coal Measures	MCMS-MEAS & UCMS-MEAS
Glasgow Ell Coal		GE-COAL
	Lower and Middle Coal Measures	LCMS-MEAS & MCMS-MEAS
Base Scottish Coal Measures		CMS-MEAS
	Passage Formation and Upper Limestone Formation	PG-CYCC & ULGS-CYCC
Index Limestone		ILS-LMST
	Limestone Coal Formation and Lower Limestone Formation	LSC-CYCC & LLGS-CYCC
Hurlet Limestone		HUR-LMST

Table 1. ***Modelled horizons and Lexicon and RCS codes for the intervening intervals***

The model was processed in GOCAD® 64bit Version 2009.3, patch 3. The GOCAD® model was prepared using best practice methodologies developed and documented through previous modelling work carried out by the author and other British Geological Survey colleagues in the Midland Valley of Scotland and the UK continental shelf.

As some of the methods used in creating the model described here are not reported in previous work, they are detailed in the appropriate parts of the following text.

The notional scale of use of the model is 1:50 000 scale as that was the largest scale of map linework used for horizon limiting and control crop lines. Where available, 1:10 000 scale digital linework was used. In some cases, this was essential as many coal seam crops used as controls are unrepresented on the smaller scale maps. 1:10 000 scale digital linework was also used to control model parts falling within the area of the current bedrock 1:50 000 scale Sheet 23 East; the map linework across this sheet has seen no recent update and major misfits occur across sheet boundaries with adjoining, more recently compiled, sheets.

The regional model subsumes previously prepared district models for the Western Clyde Catchment area, Bellshill, Motherwell, Cumbernauld, Falkirk, Larkhall, and Carluke. The individual models are described in Monaghan & Pouliquen, 2009 (IR/09/070), McCormac, 2009 (IR/09/068) and McCormac, 2012 (IR/12/046). Components of a confidential site-specific model created for a study of the Ravenscraig redevelopment site were not included in the model.

1.2 MODEL USE AND LIMITATIONS

As a basis for future study or enquiry at a local level, the district horizon models remain the appropriate first choice, even though in some areas the regional model has the benefit of additional interpolated control data. However, the fault system has evolved through all stages of modelling across the Clyde Catchment, and as the fault system integrated with the regional model is the most up to date (at the time of writing), should be used to control further modelling at all scales.

The model is appropriate for use between 1:50,000–1; 250,000 scales. The intention is that the model be used to define regional scale subsurface structure. It is not meant for local or site-specific studies.

The Base Coal Measures horizon is controlled by an often dense borehole network and projected mine plan elevation data, compiled from different coal seams. As such, the structural configuration of the horizon is well controlled in almost all parts of the coalfield. Thickness trends within the Scottish Coal Measures Group are hence relatively well constrained on both the regional and individual fault block scale.

Mine plan elevation data from a single Limestone Coal Formation seam are used to constrain the Clackmannan Group horizons over the northern and western parts of the model. However, in contrast to the Coal Measures, only regional inter-horizon thickness trends may be reliably discerned.

1.3 HORIZON CREATION

The bringing together of previously completed area models is largely a manual process in GOCAD®. However, the completed regional surfaces were processed and fitted to a revised regional fault system using the GOCAD® Structural Modelling Workflow®.

The GOCAD® surfaces for each horizon were created in three distinct stages.

- Initial lateral concatenation, where possible, of the relevant horizon surfaces derived from previously completed Clyde Catchment area bedrock models.

- Creation of horizon surfaces connecting the deeper horizons (Index Limestone and Hurlet Limestone horizons) below the area of the Central Coalfield, using regional isopach maps as control data sources.
- Re-fit of horizon surfaces to the regional fault system and primary control data

1.3.1 Model concatenation

Merging of previously modelled surfaces in GOCAD® is technically straightforward by setting vector link constraints between the adjoining surface borders and running the 'sew borders' and 'merge parts' utilities. However, for a successful outcome, the adjoining surfaces need to be quite well matched in elevation and structural topography. Where this is not the case, usually due to staged acquisition of control data sets (McCormac 2012, paragraph 1.1) and changes in the number and geometry of the crosscutting fault network, comprehensive manual editing is required to achieve smooth continuity between models. In many cases a better result is obtained by merging the horizon point data sets from adjoining models and remodel to a new continuous boundary curve in the GOCAD® Structural Modelling Workflow® as continuous surfaces. There is however, a major time expenditure involved, as the entire fault network has to be regenerated in the Workflow and the subsequent horizon re-fitting process subject to iterative checks and editing.

The Glasgow Ell Coal Seam and Base Scottish Coal Measures Group regional horizon was created entirely from existing models which extend across the whole area of interest. However, the Index Limestone and Hurlet Limestone horizons were previously only modelled in areas where they exist at relatively shallow levels, mainly around the periphery of the Central Coalfield (Figure 1). Primary control data in these areas consist of boreholes and mine plan elevation data for workings in the Meiklehill Main Coal. These coal workings are taken as primary control on the Index Limestone horizon (on average, 66 metres below the horizon), but are available only over a limited area (Figure 3). Elsewhere, secondary control data are applied, comprising map crop-lines of significant limestone beds and marine bands within the immediately overlying strata.

The Top Hosie Limestone horizon is also modelled in parts of the region but the coverage was insufficient to warrant creation of an additional regional surface.

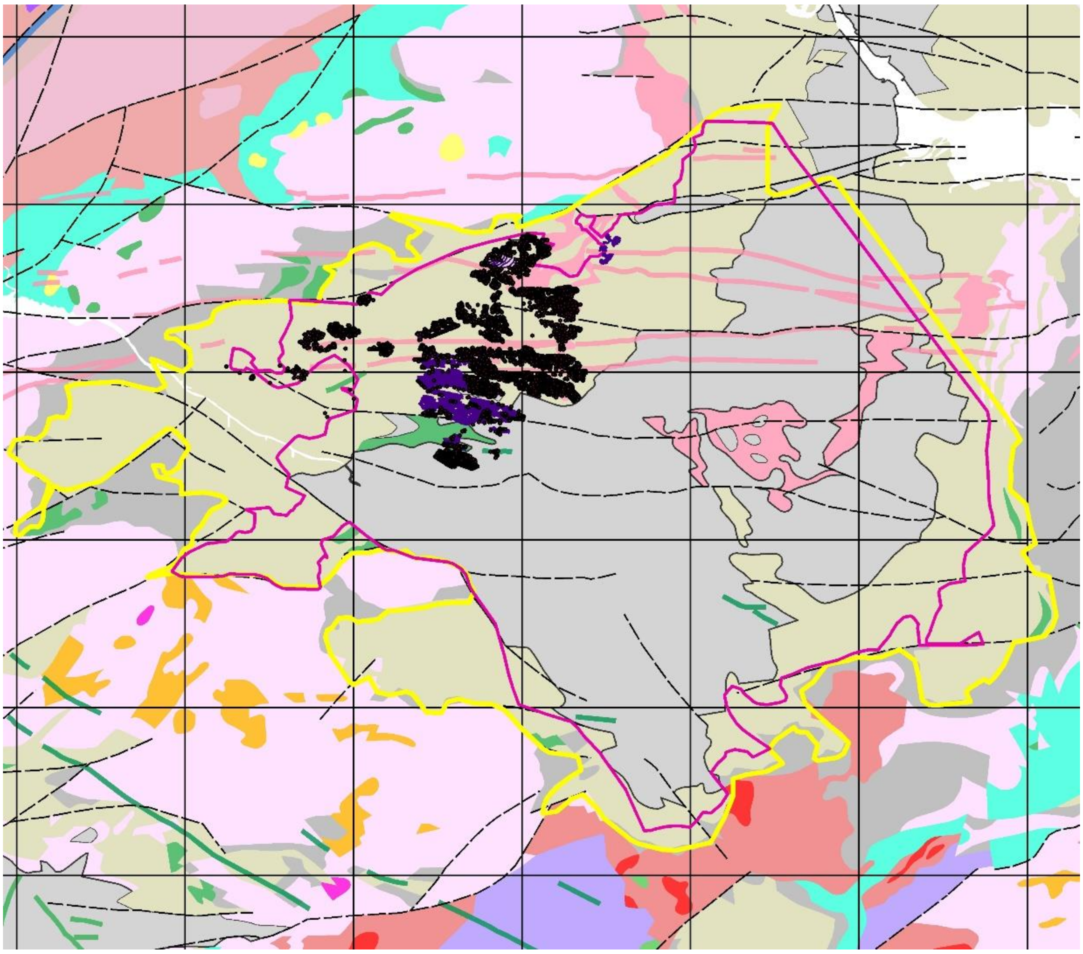

Figure 3. Extent of available mine-working elevation data for the Meikle Hill Main coal seam (black dot clusters).

1.3.2 Deep horizon surface creation

To complete the horizon coverage at depth below the Coal Measures, a set of isopach maps were created for the interval between the base of the Coal Measures and the relevant horizon. The base Coal Measures horizon is used as a datum level as it is regionally the most closely controlled surface, with extensive mine-plan elevation and borehole intercept data sets. The isopachs were generated by interpolation in ArcGIS of thickness values recorded in boreholes and 1:10 000 scale bedrock geology GVS columns on maps located around the periphery of the coalfield (Figures 4 and 5). This gave a more realistic depth control on the ILS and HUR surfaces within the basin than an assumed constant thickness value, used in most previous modelling, though local thickness variation against syn-depositionally active faults remain unrepresented in the model.

The data were imported to GOCAD® as contoured interval thickness shapefiles. GOCAD® surfaces, with the thickness value as a property, were created for the two horizons from the data, using the standard GOCAD® Structural Modelling Workflow® procedure. The base Coal Measures horizon surface was converted to a grid of elevation control points which were then incremented by the corresponding thickness property value, transferred vertically from the isopach surface.

The adjusted data grids were then merged with the corresponding horizon point-sets from the peripheral modelled areas and the deep borehole intercepts within the basin (Appendix 1). The 50k scale horizon map limit-lines were cut or spliced, as appropriate, to create a single closed boundary curve for the full extent of the modelled regional surfaces (Figure 1).

The combined control point data sets and outline curves were run through the GOCAD® Structural Modelling Workflow® to produce a continuous un-faulted horizon surface. The regional fault plane surfaces (section 1.2.3) were then loaded to the GOCAD® Structural Modelling Workflow® and the surfaces fitted using both automated and manual editing tools.

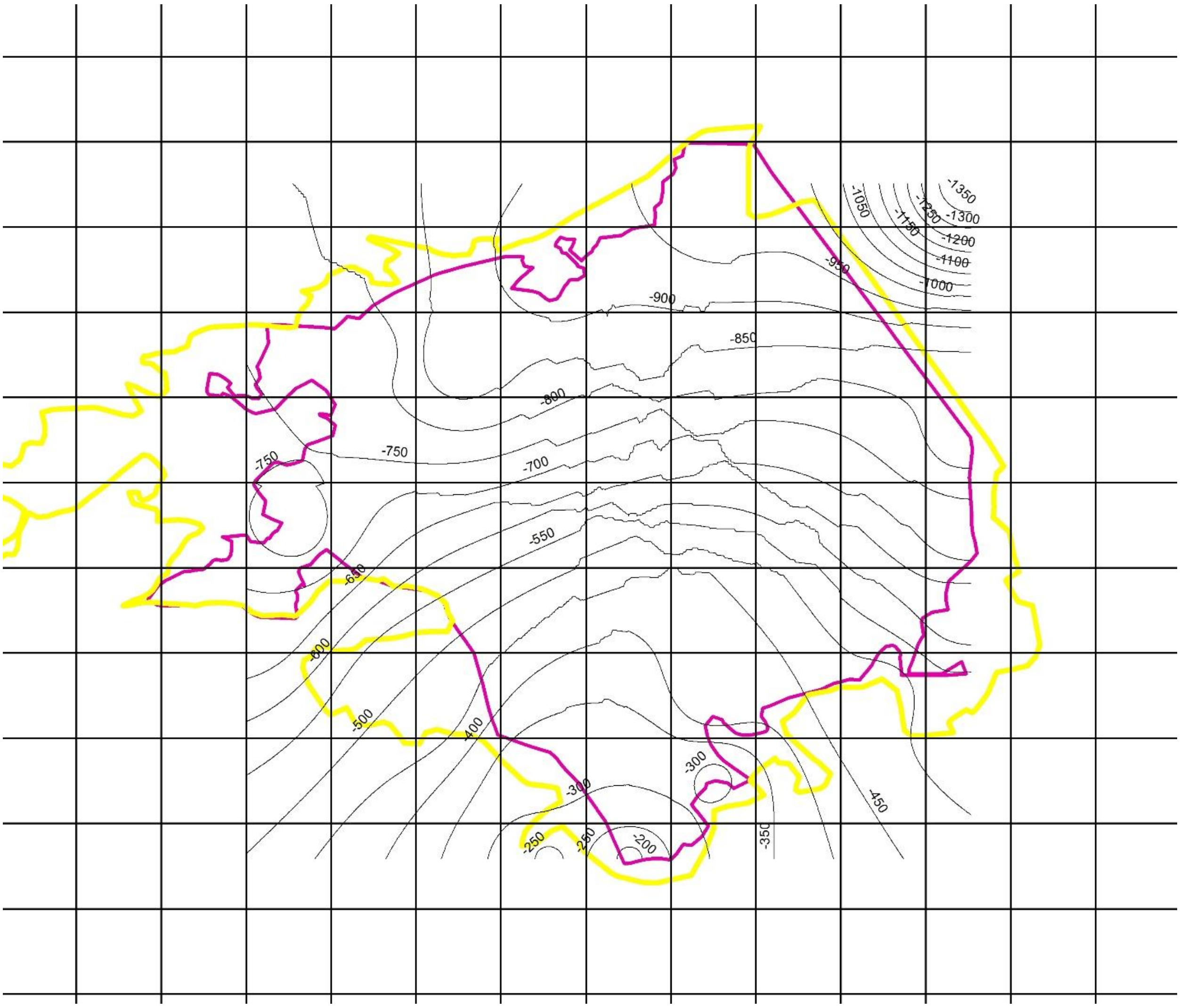

Figure 4. Interpolated isopach contours for the interval between the base of the Coal Measures and the Index Limestone Horizon.

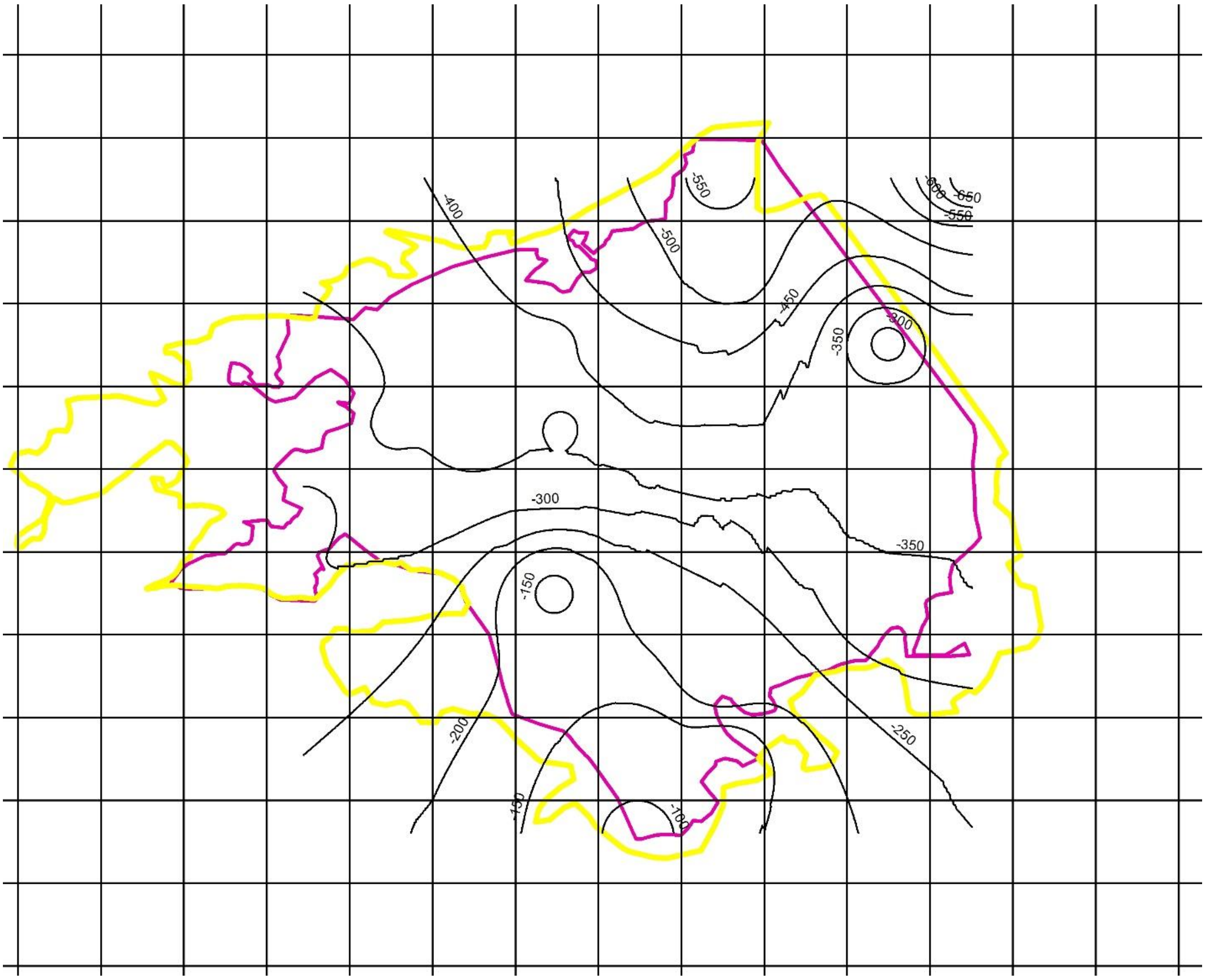

Figure 5. Interpolated isopach contours for the interval between the base of the Coal Measures and the Hurlet Limestone horizon.

1.3.3 Regional fault system

The modelled fault system (Figure 6) was assembled from fault sets created for previous GOCAD® modelling work. The existing fault names were changed to a sequential number and intersections checked for a good fit, otherwise the individual fault planes were left unchanged. A few additional faults were added, mainly to control the peripheral parts of the model and to accommodate structural complexity resolved by recently acquired mine plan elevation data.

The processes of fault selection and geometrical construction are detailed in the modelling reports for the previous area models (Monaghan & Pouliquen, 2009 (IR/09/070), McCormac, 2012 (IR/12/046))

Figure 6. GOCAD® screen image of regional modelled fault system and the Base Coal Measures horizon surface.

1.3.4 Final refinements

The regional primary control data sets, especially borehole intercepts, were re-inspected to check for aberrant entries and the surfaces re-interpolated to honour the data. Where primary control data are sparse or non-existent, outcrop linework of less significant, but locally mapped, coal seams or other lithostratigraphical horizons were captured and used as additional secondary controls.

Elevation data derived from interpreted regional seismic profiles (Hooper 2003 and subsequent BGS interpretation) were inspected with a view to refining some of the deep structure of the basin model. However, the very poor event resolution and the lack of horizon-to-borehole ties and correlation to the modelled fault system, rendered the data unusable.

The areal fit of surface limits to mapped crop-lines were inspected and manually adjusted where necessary. Horizons within small peripheral outliers, previously excluded on grounds of size or location, were modelled and appended to the main model. Elevation crossovers between horizons with the rockhead surface were also corrected, but as this process could upset the areal fit, an iterative refinement process was required.

As the fault network had evolved during the circa 5-year lifetime of the Clyde Catchment bedrock modelling project, some substantial misfits between horizons and faults had developed in parts of the model. Manual surface editing was employed to correct most of these problems, but manually generated interpretational data were introduced to otherwise uncontrolled model parts to maintain the correct sense and size of throw along some faults.

GOCAD® screen-capture images of the three final horizon surfaces (faults removed for clarity) are illustrated below (Figures 7, 8, 9 and 10)

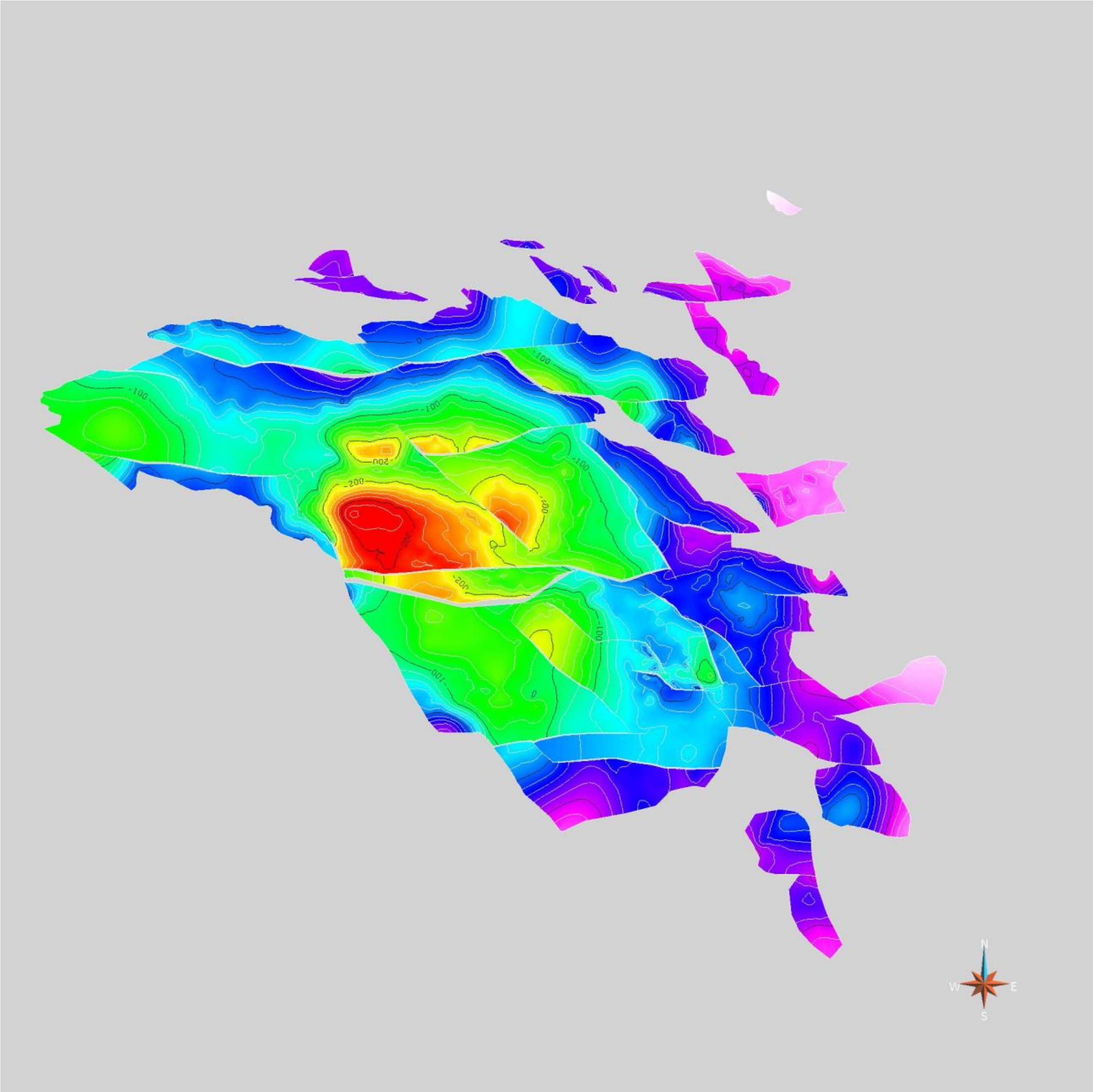

Figure 7. GOCAD® screen image of elevation contoured Glasgow Ell Coal Seam surface

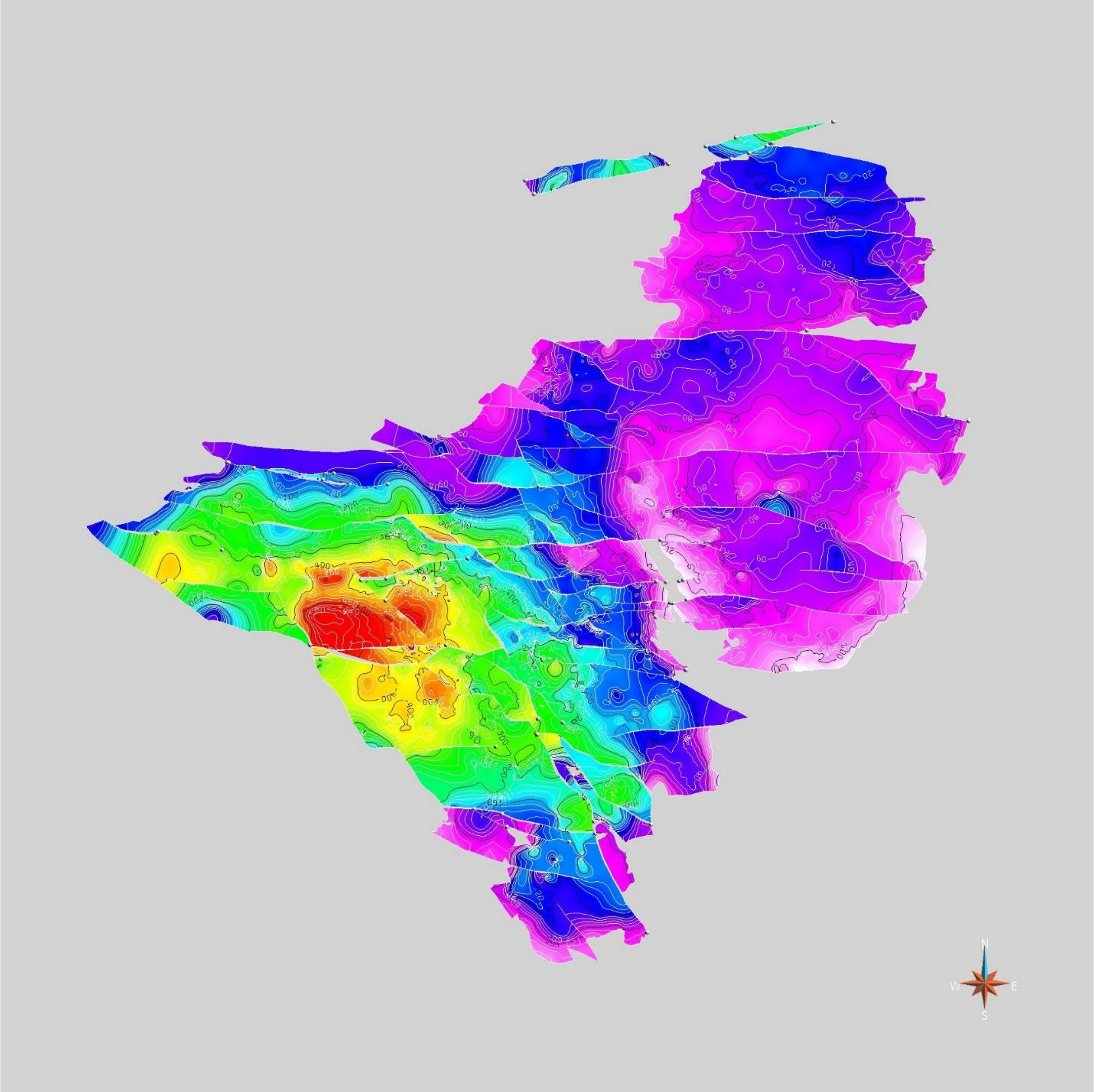

Figure 8. GOCAD® screen image of elevation contoured Base Scottish Coal Measures Group surface

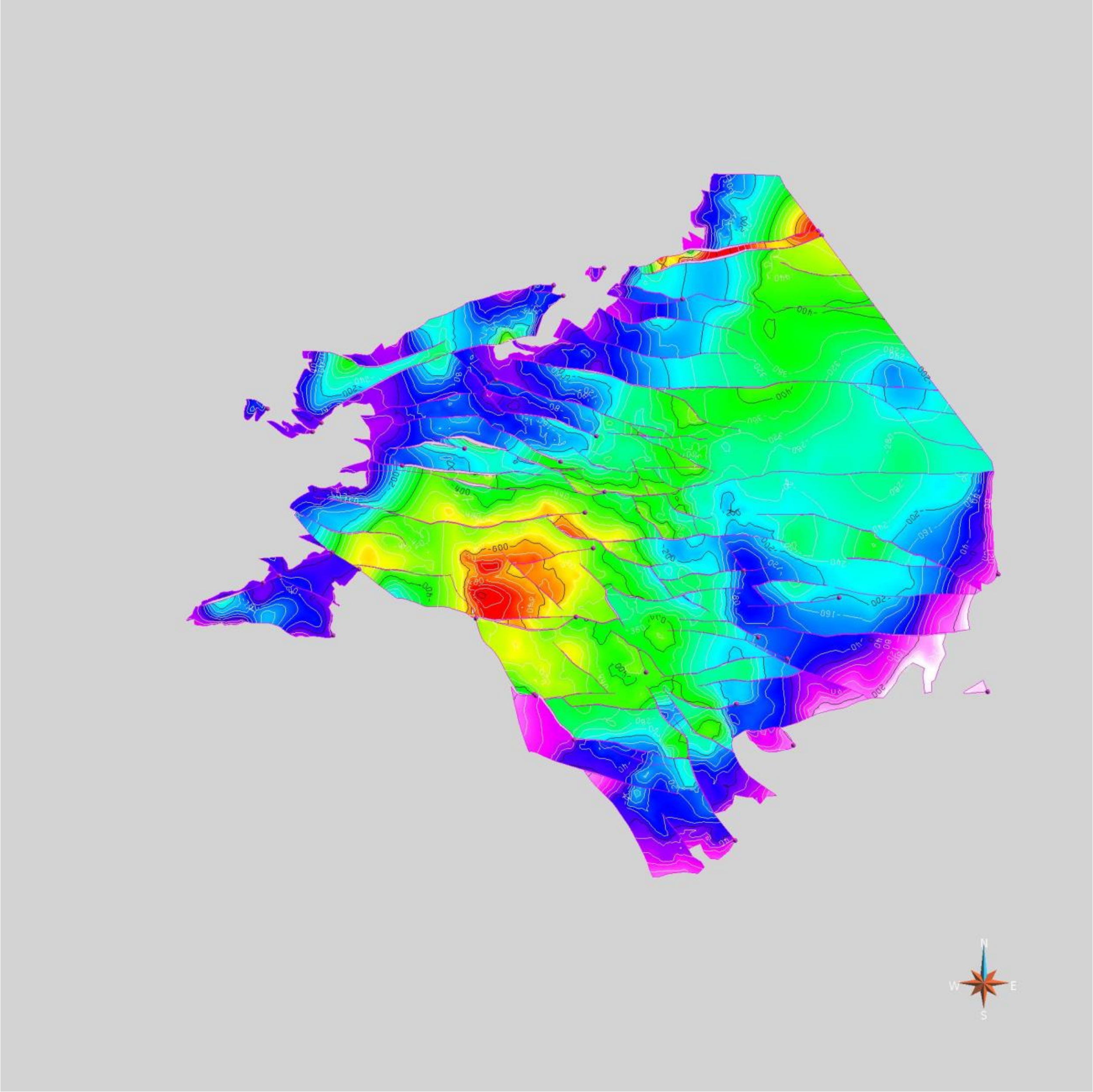

Figure 9. GOCAD® screen image of elevation contoured Base Upper Limestone Formation (Index Limestone) surface

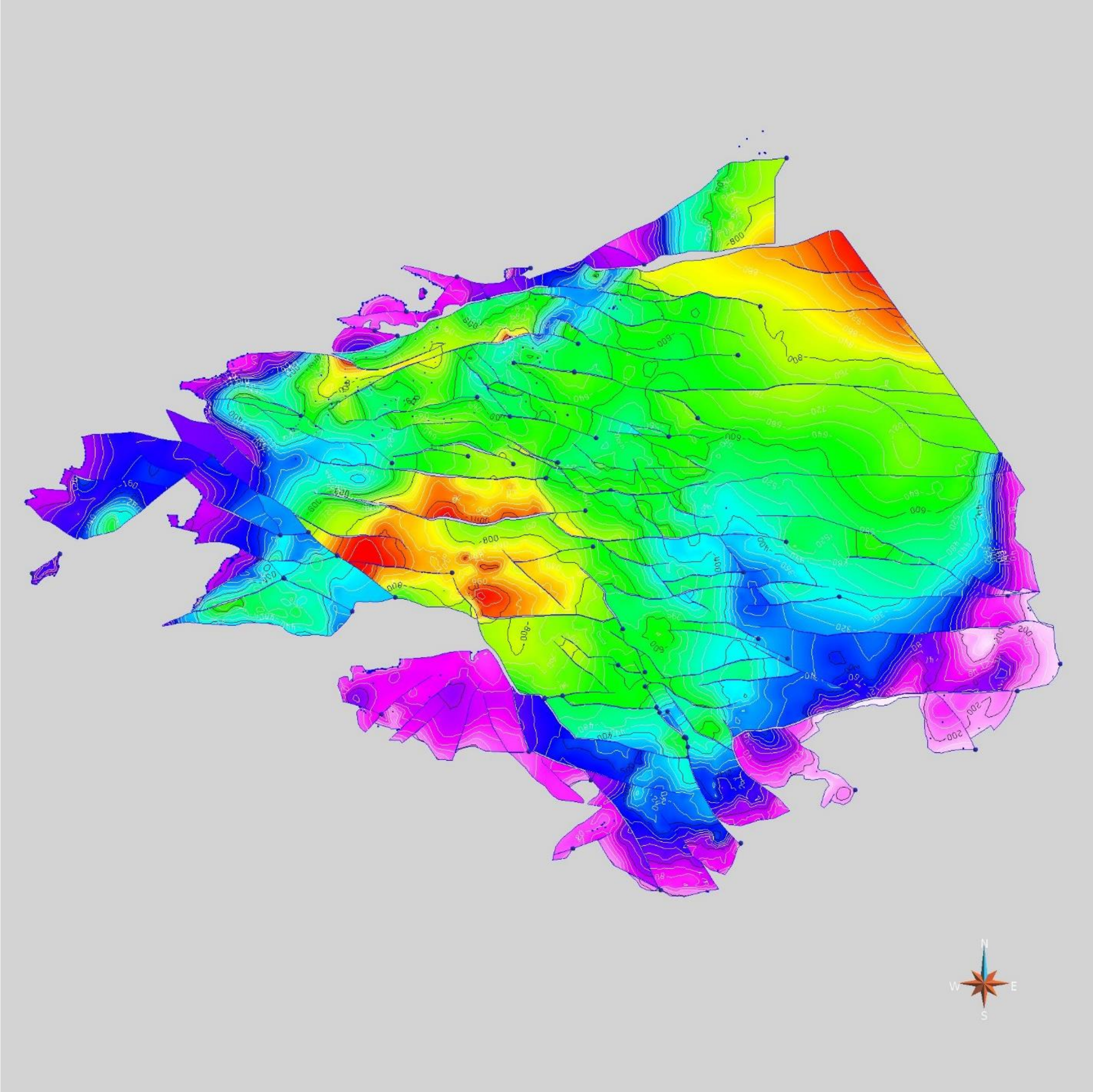

Figure 10. GOCAD® screen image of elevation contoured Base Lower Limestone Formation (Hurlet Limestone) surface

Appendix 1

Listing of stratigraphically significant deep boreholes in the model area. Total drilled depth in metres below ground level.

NS65SE14 Earnockmain No1. TD 386 m

NS75NW68 Clyde Bridge. TD 605 m

NS76SE145 Thankerton. TD 485 m

NS85SE6 Bentyhillocks No1. TD 466 m

NS86SW89 Salsburgh No1A. TD 1300 m

NS86SW92 Muirhouse 1. TD 457 m

NS86SW330 Craighead 1. TD 914 m

NS87SW 22 Rashiehill. TD 1176 m

NS95NE81 Wilsontown Deep. TD 312 m

NS95NE80 Hardwood Mine No. 6. TD 259 m

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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