



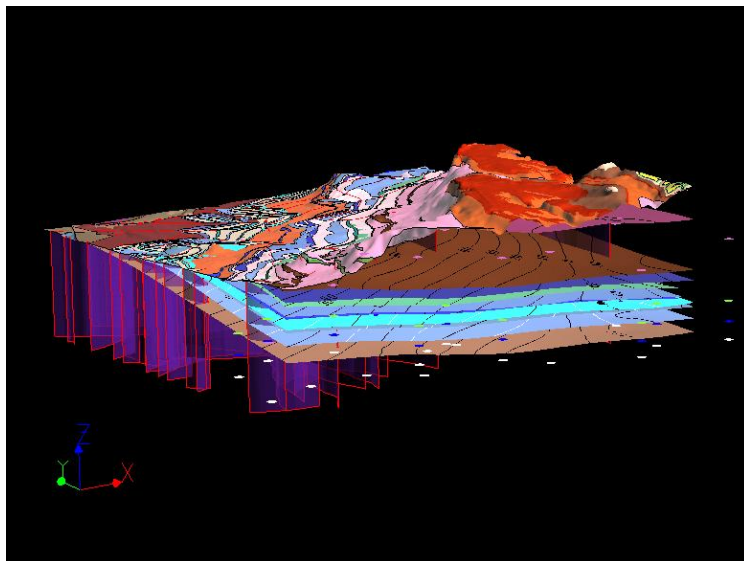
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A guide to the construction of the DGSM Nottingham Melton Lithoframe 50K Colston Bassett Gocad model

DGSM Programme

Internal Report IR/05/072



BRITISH GEOLOGICAL SURVEY

DGSM PROGRAMME

INTERNAL REPORT IR/05/072

A guide to the construction of the DGSM Nottingham Melton Lithoframe 50K Colston Bassett Gocad model

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Front cover

Image of the Colston Bassett Gocad model.

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Summary

This report describes the rationale behind the construction of the Nottingham Melton Lithoframe 50K GOCAD model for the Colston Bassett area. This work was carried out between April 2001-March 2005, as part of the Nottingham Melton DGSM-UK project (E1362S96 Task 06). This model comprises part of the area covered by the Melton 50K geological map sheet (142).

1 Introduction

The purpose of this report is to briefly describe the process carried out to construct the GOCAD model for the Colston Bassett area of the Melton Mowbray (142) geological sheet. This work was carried out between April 2001-March 2005, as part of the DGSM-UK project (E1362S96 Task 06). The purpose of the model was to provide a methodology for modelling at Lithoframe 50K scale. This report assumes that the reader has some knowledge of the main types of modelling software and does not give a detailed guide to the use of such software.

Note: The work was carried out before the Lithoframe concept was firmly established. However, the size of the area modelled (15x20 km) conforms to that now held for a Lithoframe 50K model (suggested tile size of 20 x 20 km) (see S. Mathers & A Monaghan PowerPoint presentation).

Building models within BGS has evolved considerably since the inception of the DGSM. The Nottingham Melton project was carried out at the same time as the DGSM-Framework, whose remit was to specify the standards to construct a DGSM. Hence many of the procedures (e.g. some Best Practice documents) were not in place at the time that some of the procedures described here took place and hence any non-conformance to these procedures probably results from their lack of availability at the time.

2 Project Planning

At the start of the project a Project Plan was devised. At this point the project tasks and deliverables were defined. These are outlined for the Nottingham Melton project in the project final report. Best Practice procedures as defined by the DGSM project were to be followed during the project.

3 General Methodology

3.1 DEFINING THE MODEL AREA

For this model the Colston Bassett area of the Melton Mowbray (142) 50K geological sheet was chosen: The extent of the model is as follows:

Min. Eastings: 460000
Max. Eastings: 480000
Min. Northings: 325000
Max. Northings: 340000

It is recommended that a fringe around the area of at least 1 km is chosen in order to reduce the edge effects associated with surface modelling. Cropping of the model to the true project area will produce a cleaner looking model. This will have resource implications for data capture.

3.1.1 Standard Stratigraphic Markers

The Standard Stratigraphic Model (SSM) defines the level of detail that is expected in a suite of models for a region, that are designed to be consistent in resolution, depth and applicability. The SSM consists of a series of modelled surfaces that are defined for a given programme or set of projects, taking into account survey area and depth, scale and resolution. The SSMs are defined by identifying the key stratigraphic marker surfaces that provide consistent, widespread and well-defined features at outcrop, in boreholes and from other survey responses. For this project the major stratigraphic surfaces at formation level were chosen, together with some at member level for the Jurassic stratigraphy. These are:

- DTM
- Rockhead
- Top Dyrham Formation (DYS)
- Top Charmouth Mudstone Formation (CHAM)
- Top Brandon Sandstone (BRNS) (part of CHAM)
- Top Beckingham Member (BKHM) (part of Scunthorpe Mudstone Formation - SMD)
- Top Fen Farm Limestone (FFML) (part of Granby Member of SMD)
- Top Barnby Member (BNBM) (part of SMD)
- Top Westbury Formation (WBY) (part of Penarth Group)
- Top Blue Anchor Formation (BAN)
- Top Cropwell Bishop Formation (CBP)
- Top Edwalton Formation (EDW)
- Top Gunthorpe Formation (GUN)
- Top Radcliffe Formation (RDCF)
- Top Sneinton Formation (SNT)
- Top Sherwood Sandstone Group (SSG)
- Top Variscan unconformity
- Base Warwickshire Group
- Top Deep Hard Coal
- Top Dinantian
- Caledonian Unconformity
- Faults

3.2 DATA SELECTION AND PREPARATION

Identification of datasets and digital capture of relevant datasets needs to be done early in the project lifecycle. The data selected to construct models must be described by standard metadata, so that features shown in a model can be tracked back to the data on which it is based. In general, this will mean that the data are held in corporate databases that have been subjected to documented reduction and validation.

3.2.1 Borehole data

A search of the SOBI database revealed over 1400 boreholes in the area, of which over 160 were >200 m in length and 126 of these are >600 m in length. Hence data from 214 high quality boreholes were used to construct the Colston Bassett model. Of these, only a few had any geological data associated with them in the BGS Borehole_Geology (ORACLE®) database prior to this project. Hence there was a requirement to carry out a significant borehole databasing exercise. The following bases were databased using the core log descriptions alone:

- Lias Group
- Penarth Group
- Mercia Mudstone Group
- Sherwood Sandstone Group
- Permian = Variscan unconformity
- Cambriense Marine Band = Base Upper Coal Measures
- Aegiranum Marine Band
- High Hazles Coal
- Top Hard Coal
- Vanderbeckei Marine Band = Base Middle Coal Measures
- Deep Hard Coal

During this project a database of the stratigraphic surfaces listed previously was created in MS Excel and later uploaded into Borehole_Geology. Whilst it is clearly better to input the data directly into Borehole_Geology (using, for example, an Access interface such as the one designed by K Lawrie), on this occasion there were clear reasons for initially inputting the data into Excel. During this project a geologically untrained, 'casual' member of staff (A. Arora) was tasked with the input of data. Apart from the correct recognition of stratigraphy, some of the other factors that data inputters need to be aware of include the need to correct for different datum surfaces (e.g. rotary table, Kelly Bushing, GL), metric versus imperial measurements, underground (mining) boreholes that go up (upbores) rather than down (downbores), underground (mining) boreholes that have both upbore and downbore sections, boreholes that use a mining datum (typically 10,000 ft below OD), the use of old stratigraphy in the written logs – hence the need to 'translate' old stratigraphy into new from the written logs and the need to carry out geophysical log interpretations where boreholes only core short sections of the entire hole. Hence it was considered sensible to collect the data in Excel rather than input directly into Borehole_Geology and run the risk of needing to continually correct the corporate database. The complexity of borehole data entry was new to the casual staff member and it was felt important to maintain control of the data and QC the data prior to uploading. The data was subsequently uploaded into Borehole_Geology using the NSJ interpreter code and the NM content code to identify project and level of coding.

A best practice has been established by A Kingdon as a result of this databasing activity. A large amount of staff time and effort was expended creating and QCing the digital borehole dataset. Databasing is a crucial and time consuming part of the process of creating a DGSM and it is recommended that geologists carry out this task. Whilst databasing can be viewed simplistically as a data inputting job, it is clear that any models constructed using this data will ultimately depend on the quality of this initial work.

3.2.2 Borehole geophysical log data

Borehole geophysical log data was available to the project and represents an important record of the downhole geology, particularly as most deep boreholes in the area were not fully cored. Hence it was essential to carry out a borehole geophysical log interpretation exercise. Many geophysical logs were already present in the BGS digital well log database, Wellog, however, 19 geophysical logs were present either on tapes requiring specialist reading and loading into Wellog or were present as paper logs requiring digitising. As a result of this acquisition exercise, 49 geophysically logged boreholes were available to the project for this area. All of these were examined and stratigraphic surfaces were entered directly into Borehole_Geology. To provide the detail needed to produce accurate, well constrained surfaces, 45 stratigraphic units were picked and inputted into Borehole_Geology for this area (Table 1).

For any given stratigraphic surface there will always be differences between a geophysical log derived depth and a cored or driller's depth. Normal convention has it that the geophysical log depth takes precedence. Borehole_Geology allows the input of geophysical log derived depths but this results in more than one depth entered per surface leading to confusion amongst users as to how the data was derived and which depth is correct. Currently, the only place to store information regarding whether the data is a geophysical log derived depth or a driller's depth is in the 'Comments' field. Hence it is recommended that a new field be created in Borehole_Geology to accommodate this requirement. Borehole stratigraphic surfaces picked during this exercise were identified in Borehole_Geology by the insertion of "Geophysical log interpretation" in the Comments field.

3.2.3 DTM

During the course of the project various DTM's were available, e.g. CEH, NEXTMap. The NEXTMap DTM undoubtedly gives the best resolution, but manipulating this in GOCAD proved problematical as it constitutes a large points based dataset. Hence a 100 m DTM was used, derived from the 50 m CEH DTM dataset.

As processing power increases it is likely that the handling of larger datasets will become possible, allowing better resolution models. The resolution of the DTM limits the resolution of the final model as elevation (Z) values for point datasets etc are obtained by projection from the DTM. A 100 m DTM is only capable of providing an approximate elevation value at any given point.

Bitmap images of 250K geology and 1:50K topography were draped onto the DTM in GOCAD to allow easy reference to surface location or geology.

3.2.4 DiGMapGB-50

The source of surface mapping data was BGS DiGMapGB-50 1:50 000 scale digital geological map data, now available in ESRI Shapefile format (and also in MapInfo TAB format). For the Colston Bassett model the data were provided (R Armstrong pers. comm.) in XYZ polyline format, in addition to ESRI Shapefiles. The Z value at each X-Y location was calculated from the CEH 50 m grid-cell DTM. This allowed the geological linework to be imported into GOCAD and visualised in its correct 3D location. Because of the requirement (due to hardware/software performance) to use a 100m DTM for this model the Z values were subsequently re-calculated

using the model DTM. As well as the polylines forming the geological polygons the polylines were also supplied as Top Surfaces and faults. These were created by applying spatial and logical queries based on the polygon lexicon coding. The Top Surface polylines were combined with Top Marker depths from the borehole data to produce a combined Top Surface dataset for Surface modelling.

3.2.5 Other datasets

The [rockhead model](#) as produced by R Lawley et al. was used. Mine plan data was available for the Cotgrave Colliery for the Blackshale, Deep Hard and Deep Soft seams. The Blackshale and Deep Hard data were used by Huw Sheppard to construct surfaces in Surfer, and imported into the model as Zmap grid files. Although a seismic interpretation exercise was carried out for the Lithoframe 250K Nottingham Melton model (See Jones et al. 2005), this was not used for this model as it was felt that sufficient, well-constrained stratigraphic detail was available from the boreholes in this area, whereas the seismically derived grids were of lower resolution.

4 Modelling

The area of the combined Colston Bassett Lithoframe 50K model covers approximately 300 sq km and was constructed in Earth Decision Science GOCAD Software, Version 2.0.8 (Figure 1). The model incorporates all the DiGMap outcrop linework at 50K, DiGMap fault linework at 50K and all databased boreholes. Thirteen surfaces have been modelled for the Colston Bassett area, primarily using a combination of DiGMap linework and borehole data. A further 6 surfaces have been added, from the Nottingham-Melton model, to show the deeper, regional structure. The deepest horizon modelled solely for the Colston Bassett area was the Top Sneinton Formation. This reaches a depth of some 330 m below sea level (450 m below topography), in the south-western corner of the area.

The major faults, identified during the seismic interpretation phase, were correlated with faults mapped at the surface on the Nottingham and Melton 1:50 000 scale map sheets.

If using the model within GOCAD it is recommended that it is not viewed with a vertical resolution greater than x5.

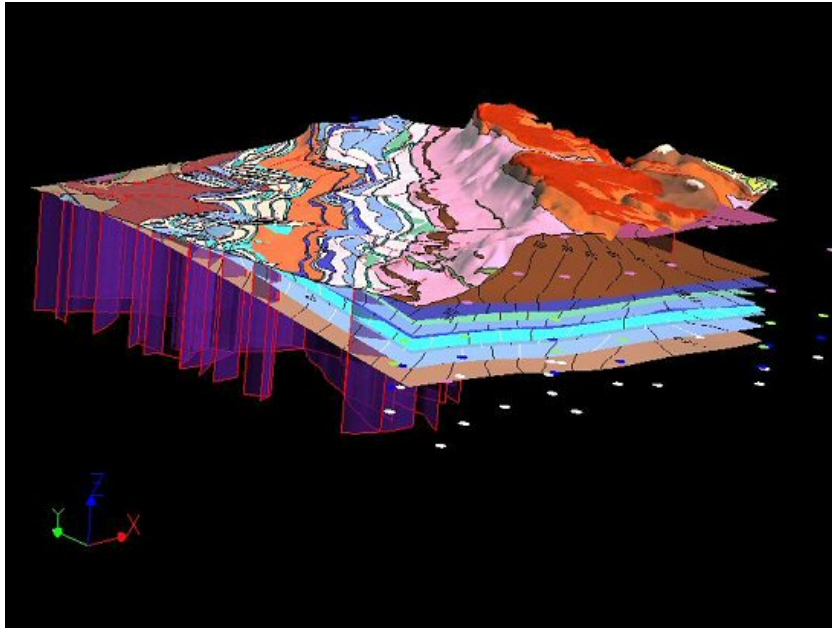


Figure 1. GOCAD model of the Colston Bassett area

4.1 SURFACE MODELLING

The expectation of building the model was to produce surfaces as the primary output. GOCAD produces surfaces by triangulation; these can then be modified (interpolated) by the Discrete Smooth Interpolation (DSI) method, which is an iterative method. The goal of the DSI method is to create a smooth result. The purpose of this stage was to create continuous surfaces representing the main SSMs; these are listed previously. All modelled surfaces except the DTM and Rockhead were constructed by combining all the Digmap outcrop linework at 50K and all databased boreholes. The basic procedure followed is outlined below:

- The CEH DTM data was extracted from the ORACLE database and imported into GOCAD as XYZ points. A GOCAD DSI surface was fitted to the XYZ data
- The DiGMap jpeg (bitmap) of 250K geology and Ordnance Survey 50K topography were prepared and draped onto the DTM topography
- The rockhead surface was created from a combination of 1 km grid rockhead supplied by Bruce Napier and the CEH DTM. In places the rockhead lies above the DTM. Where this was the case the DTM surface was used.
- The borehole data was extracted from Borehole_Geology using an *SQL* query. Subsequent to this project an intranet application has been built to provide this information via the DGSM Data Portal and it is recommended to use this application. There were many boreholes that lacked start heights and, as GOCAD requires OD based z values, the extracted dataset needed editing before it could be of use for modelling.
- The DiGMap 50K linework was imported as curves and z values derived from the 100 DTM.
- The borehole data for a particular horizon was extracted and converted to XYZ points in GOCAD

- The surfaces were then generated, by fitting a triangulated plane to the borehole points and DiGMap outcrop linework data using the DSI. The DSI was run to interpolate geometry with boreholes acting as *control nodes*. In some cases Thickness constraints were applied, using adjacent (above/below) surfaces for control. The surfaces were cut using the DiGMap 50K croplines so that the horizon surface appears as per the DiGMap linework.
- Subsurface extents of units were derived from boreholes and/or project area.
- In places the generated surfaces overlapped or broke through the DTM, giving the appearance that the geology occurs above the DTM. This is a function of: the distribution of controlling datapoints; the surface relief geometry, especially where very flat; and the resolution of the DTM. This was corrected, as far as possible, using the GOCAD function *Remove Crossovers*, but some minor crossovers still exist
- In cases of simple ‘layer-cake’ geology such as in this model the construction of horizon surfaces is relatively straightforward.
- The DTM was used to limit the uppermost position of the stratigraphic units.
- Although the density of borehole data over the project area is very good, compared to the country as a whole, the sub-surface constraint is still very much inferior to the surface outcrop. This results in a very ‘imbalanced’ model which is tightly constrained by mapping at the surface but only loosely constrained, by scattered boreholes, at depth. This makes many parts of the surface highly dependent on single points and in particular to single-point errors. Because of the often large distances between nearest points there is often no indication as to the cause of the differences in surface elevations. A difference of tens of metres could be attributed to a fault or a slight change in dip, or a combination of the two.

4.2 FAULT MODELLING

In the GOCAD model it was desirable to model the interpreted fault surfaces as independent entities, for instance so that the surfaces can be projected to ground surface. The source data for the fault modelling were the DiGMap surface faults at 50K.

Within the Colston Bassett area the smaller surface mapped faults which have no sub-surface control were modelled by projecting vertically as planes using the GOCAD Fault Construction Wizard. These fault planes can be used to cut the surfaces at depth, or just used for visualisation purposes. To produce acceptable performance the DiGMap fault traces were degraded by removal of redundant points. This was done prior to importing to GOCAD. Fault lines at the surface therefore have points at irregular intervals – straight faults have widely spaced points, angular fault lines have many more points

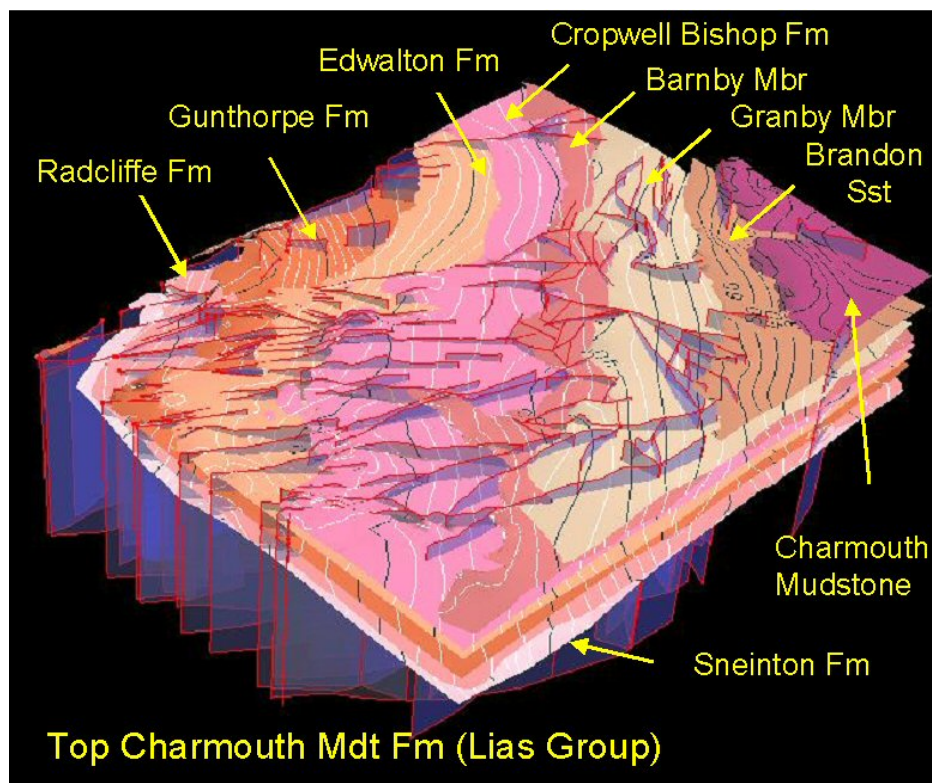


Figure 2. Faults in the Colston Bassett Gocad model.

4.3 INTEGRATION OF OTHER DATASETS

Extra coal surfaces were modelled in Surfer that were required to be imported into the model. To import Surfer files into GOCAD, firstly they need to be converted from the surfer grid format to Arc-compatible ascii format using a 'grid convert' utility, which is freeware from Geospatial Designs. This creates Zmap grids that can be readily imported into GOCAD using 'File-Import Objects-Landmark-Zmap-Ascii Grid as a 2D grid' command. A BGS report has been written by Huw Sheppard describing this procedure (see IR/05/057).

5 Model validation, metadata and archiving

The model was examined in detail by K Ambrose (KAM). A number of comments related to the overall presentation of the model e.g. such as the use of a scale bar, the use of a GVS summary log, the need for a transparent topographic layer with grid lines to enable a proper positional check of the data. Other comments included:

- Labelling of surfaces needs to be more obvious. *Response:* Agreed

- Surfaces should be ‘cut’ by the faults. *Response:* Cutting the model surfaces (horizons) using faults frequently results in highly erratic surfaces, because of lack of sub-surface constraint. Rectifying these is an extremely time consuming exercise.
- Top BAN – some spurious high data points outside area of modelled surface, in the south. Surface looks a bit odd at x50 particularly some of the outliers which appear to be too low and the surface bends over and dips the wrong way in 3 places. *Response:* This model should not be viewed at x50 vertical resolution !
- Top BNBM – surface flattens off at surface in places. At x50, some rogue well points just outside surface model area to the south. Generally a good and smooth surface. Crop looks a bit irregular at base and top at x50. *Response:* see above.
- A number of surfaces come through the DTM layer and lie on top of it, as follows: BAN, FFML, BRNS, CHAM, DYS, CBP, SNT, RDC, *GUN, EDW, CBP*. The areas concerned are almost exclusively adjacent to the outcrops. *Response:* As referred to earlier, the 100 m DTM gives only an approximate elevation so that the error can be several metres. In many cases the modelled Tops will only lie a few metres beneath the ground surface, far less than the error in the DTM. The low dips and relatively flat topography (over much of the model) result in surfaces which should lie a few metres below the ground surface lying just over the DTM. GOCAD includes a facility to ‘*Remove Cross Overs*’. This has been used extensively, along with ‘*Set Thickness Constraints*’ to correct many instances of ‘crossover’ but it is often achieved by re-modelling the surface unrealistically so some ‘crossover’ have been left in the model.
- Top RDCF is much smoother with a few minor highs and lows at x50. The thickness of the formation is too large in places. *Response:* This model should not be viewed at x50 vertical resolution. Viewing at this resolution will identify minor discrepancies in the modelling of the surface
- Top CBP - Good surface, even at x50; faults indicate some of highs/lows; slightly spurious data point in SE corner causing surface to rise up. *Response:* This is an artefact of the gridding process, which could be removed by the manual editing of nodes or insertion of ‘phantom’ points to control the gridding.
- The following surfaces should also be added to this model: crop Marlstone Rock Formation, top Nottingham Castle Sandstone, top Permian so that all of the Mesozoic is modelled. *Response:* Top Nottingham Castle Sandstone has been added to the model. Project time constraints meant that not all surfaces could be modelled. The crop Marlstone Rock Formation is represented by the Top DYS surface.
- Top DYS – not sure what this is supposed to represent as all of it appears on the model as highly irregular areas mainly within the DyS subcrop but locally overlapping with the outcrop. *Response:* Agreed. This has been corrected. This is the Top DYS surface, which also corresponds with the base Marlstone Rock Formation. In places the top DYS is not present which makes constraining the gridding of the surface difficult. However, it is now believed to be a reasonable representation of the surface.
- Some of the faults extend above the topo layer. The faults are simplified and are not in the correct position in a number of places, being displaced from the formation boundaries they control. *Response:* The faults still project above the DTM in places and need trimming to intersect but not project through the DTM. The faults were extracted from DiGMap and should be spatially correct.
- A number of the crop layers show errors in the mapped lines with highly irregular boundaries when viewed at x50. The main culprits are FOSTON, BECKINGHAM, GRANBY, BNB, BNT, CTM, BAN, CBP, SNT, RDC. *Response:* The crop lines were extracted from DiGMap so are spatially correct. The problem with the ‘highly irregular

boundaries' is probably a function of viewing the surfaces at x50 vertical resolution, which is not recommended. A number of these crop lines are not represented in the final model.

As a result of these comments a number of aspects of the models were dealt with before acceptance. These include elimination of all overlapping surfaces and obvious rogue data points. Following correction of the model it was again reviewed by KAM and approved. It was then accepted and approved by the Project leader. The relevant Metadata was submitted to the Metadata manager and files were uploaded into the GSF and GLOS.

References

Most of the references listed below are held in the Library of the British Geological Survey at Keyworth, Nottingham. Copies of the references may be purchased from the Library subject to the current copyright legislation.

JONES, N.S., NORTON, G.E. & C.P. ROYLES. 2005. A guide to the construction of the DGSM Nottingham Melton Lithoframe 250K Gocad model. British Geological Survey Internal Report IR/05/071.

GROUP	CODE	FORMATION	CODE	MEMBER	CODE	BED/OTHER	CODE
Lias Group	LI	Whitby Mudstone Formation	WHM				
Lias Group	LI	Marlstone Rock Formation	MRB				
Lias Group	LI	Dyrham Formation	DYS				
Lias Group	LI	Charmouth Mudstone Formation	CHAM				
Lias Group	LI	Charmouth Mudstone Formation	CHAM			Jericho Gryphaea Bed	JG
Lias Group	LI	Charmouth Mudstone Formation	CHAM			Loveden Gryphaea Bed	LG
Lias Group	LI	Charmouth Mudstone Formation	CHAM			Brandon Sandstone	BRNS
Lias Group	LI	Charmouth Mudstone Formation	CHAM			Glebe Farm Bed	GLBF
Lias Group	LI	Scunthorpe Mudstone Formation	SMD	Foston Member	FSTL	Stragglethorpe Grange Limestone	SGGL
Lias Group	LI	Scunthorpe Mudstone Formation	SMD	Foston Member	FSTL	Highfield Farm Limestone	HFFL
Lias Group	LI	Scunthorpe Mudstone Formation	SMD	Foston Member	FSTL	Mill Lane Limestone	MLLL
Lias Group	LI	Scunthorpe Mudstone Formation	SMD	Foston Member	FSTL	Littlegate Limestone	LTGL
Lias Group	LI	Scunthorpe Mudstone Formation	SMD	Foston Member	FSTL	Fenton Limestone	FNTL
Lias Group	LI	Scunthorpe Mudstone Formation	SMD	Foston Member	FSTL	Lodge Farm Limestone	LGFL
Lias Group	LI	Scunthorpe Mudstone Formation	SMD	Foston Member	FSTL	Stubton Limestone	STBL
Lias Group	LI	Scunthorpe Mudstone Formation	SMD	Beckingham Member	BKHM	Lincoln Hill Limestone	LCHL
Lias Group	LI	Scunthorpe Mudstone Formation	SMD	Beckingham Member	BKHM	Dry Doddington Nodule Ned	DDDN
Lias Group	LI	Scunthorpe Mudstone Formation	SMD	Beckingham Member	BKHM		
Lias Group	LI	Scunthorpe Mudstone Formation	SMD	Granby Member	GRBL	Fen Farm Limestone	FFML
Lias Group	LI	Scunthorpe Mudstone Formation	SMD	Granby Member	GRBL	Blackmires Limestone	BKML
Lias Group	LI	Scunthorpe Mudstone Formation	SMD	Granby Member	GRBL	Claypole Limestone	CLPL
Lias Group	LI	Scunthorpe Mudstone Formation	SMD	Granby Member	GRBL	Cross Lane Limestone	CSLL
Lias Group	LI	Scunthorpe Mudstone Formation	SMD	Granby Member	GRBL	Holm Farm Limestone	HMFL
Lias Group	LI	Scunthorpe Mudstone Formation	SMD	Barnby Member	BNBM		
Lias Group	LI	Scunthorpe Mudstone Formation	SMD	Barnstone Member	BNT		
Penarth Group	PNG	Lilstock Formation	LTK	Langport Member	LPMB		
Penarth Group	PNG	Lilstock Formation	LTK	Cotham Member	CTM		
Penarth Group	PNG	Westbury Formation	WBY				
Mercia Mudstone	MMG	Blue Anchor Formation	BAN				
Mercia Mudstone	MMG	Cropwell Bishop Formation	CBP			Newark Gypsum	NEWG
Mercia Mudstone	MMG	Cropwell Bishop Formation	CBP			Tutbury Gypsum	TUT
Mercia Mudstone	MMG	Edwalton Formation	EDW				
Mercia Mudstone	MMG	Edwalton Formation	EDW	Hollygate Sandstone Mbr	HLY		
Mercia Mudstone	MMG	Edwalton Formation	EDW	Cotgrave Sandstone Mbr	COT		
Mercia Mudstone	MMG	Gunthorpe Formation	GUN				
Mercia Mudstone	MMG	Radcliffe Formation	RDCF				
Mercia Mudstone	MMG	Sneinton Formation	SNT				
Sherwood Sandstone	SSG	Nottingham Castle Sandstone Fm	NTC				
Sherwood Sandstone	SSG	Lenton Sandstone Formation	LNS				
Permian undiff.	PUND	Roxby Formation	ROX				
Permian undiff.	PUND	Brotherton Formation	BTH				
Permian undiff.	PUND	Edlington Formation	EDF				
Permian undiff.	PUND	Cadeby Formation	CDF				
Permian undiff.	PUND	Marl Slate Formation	MLSL				
Permian undiff.	PUND	Permian Basal Breccia	PBB				

Table 1. List of stratigraphic surfaces (in bold) picked from geophysical logs and inputted into Borehole_Geology.