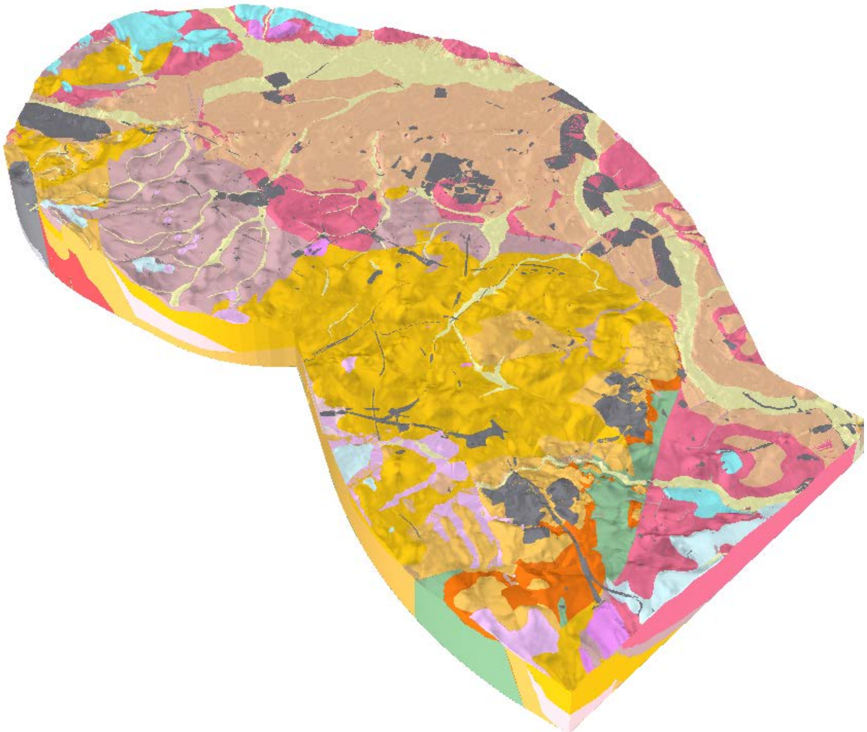
GSI3D model metadata report for HS2 Area 8 (Drayton Bassett to Rugeley)

GEOLOGY AND REGIONAL GEOPHYSICS

Open Report OR/15/074



BRITISH GEOLOGICAL SURVEY

GEOLOGY AND REGIONAL GEOPHYSICS PROGRAMME

OPEN REPORT OR/15/074

GSI3D model metadata report for HS2 Area 8 (Drayton Bassett to Rugeley)

K Ambrose

Edits by A M Barron, H Burke & H V Gow

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Map

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Summary

This report describes the 3D geological model of HS2 (High Speed 2 rail link) Area 8 (Drayton Basset to Rugeley), created by Keith Ambrose with support from Steve Thorpe. The model was created as part of a set of nine geological models that cover the proposed HS2 rail route from the end of the HS2 London model to Birmingham and the West Coast Main Line near Lichfield. The models were funded from the NERC/BGS Science Budget to promote BGS modelling and geological interpretation services to this important infrastructure project and to test methodologies and procedures for creating geological models by multiple compilers.

The report describes the model construction and purpose, with spatial limits and scale, sources of information, data processing, workflow, decisions, assumptions, rules and limitations, together with images of the model.

1 Modelled Volume, Purpose and Scale

The model purpose was to model the bedrock, superficial and artificial ground following the proposed High Speed Rail link between London and Birmingham (HS2). The model area covers a 25km section of the route from Drayton Bassett in the south to Rugeley in Staffordshire in the north with a 5 km buffer (Figure 1). This is one of an initial group of nine models along the proposed route. Area 7 to the south was modelled by Keith Ambrose; the area to the north has not yet been modelled. The model is suitable for use at scales between 1:100 000 and 1:10 000 to a depth of 30 m below Ordnance Datum (OD).

The geology of the area is described in Powell *et al.*, (2000), Barrow *et al.*, (1919) (northern part) and Bridge *et al.*, (1998) (south east corner). The bedrock geology of this section of the route comprises Carboniferous and Triassic age strata, which are overlain by superficial deposits of glacigenic and fluvial origin. Artificial deposits, such as gravel pits and embankments are also modelled. Prior to the modelling work an assessment of the quality and availability of digital geological linework and existing 3D models of the whole HS2 route between London and Birmingham was undertaken (Barron et al., 2012). As a consequence of this review, most of the geological mapping of this sector was deemed to be adequate, dating from a recent revision undertaken in the 2000s to geological sheet 154 (Lichfield). This 3D model is based on geological linework from existing 1:10 000 and 1:50 000 scale DiGMapGB data, with new data added for the Lichfield sheet mapping. The northern most part of Area 8 is on geological sheet 140 (Burton upon Trent), which dates from the late 1940s. Modifications have been made in the northernmost part of the model, with new bedrock and superficial linework added, mainly in relation to the artificial deposits. However, some errors were also noted in the recently mapped areas.

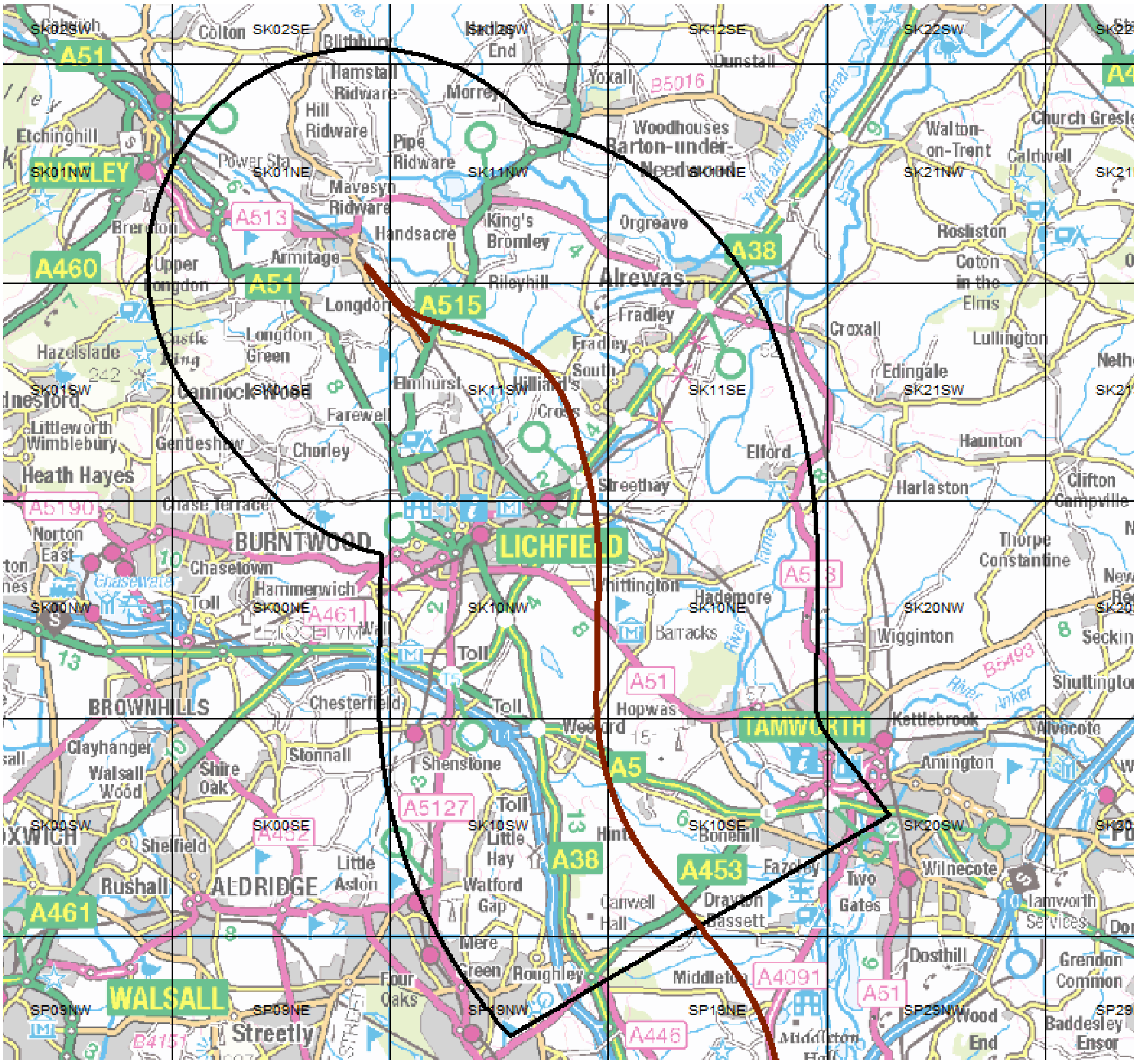

Figure 1. Location of the Area 8 model (outlined in black), proposed route (red line) and National Grid 1:10 000 map sheet areas (grey)

2 Modelled Surfaces/Volumes

The modelled bedrock, superficial and artificial deposits are listed in Table 1 in the relative stratigraphic order used in the model. Brief descriptions of the geological units are given here, but more detail can be found in the BGS Lexicon of Named Rock Units. The level of detail and extent of the natural geology in the model may differ from that shown in other BGS datasets. Artificial ground was modelled according to the corresponding 1:50,000 scale geological maps. Table 1 should be used as the legend for viewing images of the model in this report

Table 1. Geological units modelled in Area 8

LEX-RCS code	Lex_Description	Comments including included units in DiGMapGB-50
WMGR-ARTDP	WORKED AND MADE GROUND	Variable composition
MGR-ARTDP	MADE GROUND	Variable composition
WGR-VOID	WORKED GROUND	
LSGR-UKNOWN	LANDSCAPED GROUND	Variable composition
ALV-XCZSV	ALLUVIUM	Clay, silt, sand and gravel
HEAD-XCZSV	HEAD	Clay, silt, sand and gravel
PEAT-P	PEAT	Peat
RTD1-XSV	RIVER TERRACE DEPOSITS, 1	Sand and gravel. Underlies alluvium very extensively
RTD2-XSV	RIVER TERRACE DEPOSITS, 2	Sand and gravel
RTD3-XSV	RIVER TERRACE DEPOSITS, 3	Sand and gravel
RTD4-XSV	RIVER TERRACE DEPOSITS, 4	Sand and gravel
RTDU-XSV	RIVER TERRACE DEPOSITS, UNDIFFERENTIATED	Sand and gravel
GFDUD-XSV	GLACIOFLUVIAL DEPOSITS, DEVENSIAN	Sand and gravel. Limits of Devensian glacial deposits are uncertain
TILLD-DMTN	TILL, DEVENSIAN	Till. Limits of Devensian glacial deposits are uncertain
TILMP1-DMTN	TILL, MID PLEISTOCENE	Till. Limits of Mid Pleistocene glacial deposits are uncertain
GFDMP-XSV	GLACIOFLUVIAL DEPOSITS, MID PLEISTOCENE	Sand and gravel. Limits of Mid Pleistocene glacial deposits are uncertain
TILMP-DMTN	TILL, MID PLEISTOCENE	Till. Limits of Mid Pleistocene glacial deposits are uncertain
SIM-MDST	SIDMOUTH MUDSTONE FORMATION	Mudstone. MMG-MDST in DiGMap-50.
TPSF-MDSA	TARPORLEY SILTSTONE FORMATION	Mudstone and sandstone. MMG-MDST in DiGMap-50.
BMS-SDST	BROMSGROVE SANDSTONE FORMATION	Sandstone. This unit has been renamed the Helsby Sandstone Formation. Mudstones have been mapped within this unit in the Lichfield area but have not been modelled
WRS-SDST	WILDMOOR SANDSTONE FORMATION	Sandstone. This unit has been renamed the Wilmslow Sandstone Formation
KDM-PESST	KIDDERMINSTER FORMATION	Pebbly sandstone. This unit has been renamed the Chester Formation. Limits may be imprecise where overlain by glaciofluvial gravels
LTWB-SDST	LITTLEWORTH BEDS	Sandstone. Limits imprecise in places owing to inconsistent recording in boreholes.They have not been mapped.
HPBR-BRSS	HOPWAS BRECCIA FORMATION	Breccia and sandstone. Mapped limits and borehole coding may be imprecise because of difficulties in distinguishing from overlying conglomerates of Kidderminster Formation and glaciofluvial gravels
ALY-MDSS	ALVELEY MUDSTONE MEMBER, SALOP FORMATION, WARWICKSHIRE GROUP	Mudstone, siltstone and sandstone. Separately mapped and modelled only in south east corner of Area 8.
HA-MDSS	HALESOWEN FORMATION	Mudstone, siltstone and sandstone. Separately mapped and modelled only in south east corner of Area 8
WAWK-MDSS	WARWICKSHIRE GROUP	Mudstone, siltstone and sandstone. Only subdivided into component formation in the south east corner
PMCM-MDSS	PENNINE MIDDLE COAL MEASURES FORMATION	Mudstone, siltstone and sandstone. Shown as a single unit but includes mapped coals on the surface outcrop in the north west corner of Area 8
PLCM-MDSS	PENNINE LOWER COAL MEASURES FORMATION	Mudstone, siltstone and sandstone. Shown as a single unit; occurs in subsurface only so no mapped coals or sandstones

2.1 BEDROCK GEOLOGY

Figure 2 is a geological map of the bedrock units modelled, showing the current DiGMapGB-50 dataset, which has not yet been updated to show revisions made to the bedrock mapping in the model area. The Hopwas Breccia Formation, Kidderminster Formation, Wildmoor Sandstone Formation and Bromsgrove Sandstone Formation are part of the Sherwood Sandstone Group. Recent work on the Sherwood Sandstone Group has led to the re-naming of units from the Kidderminster Formation upwards respectively as the Chester Formation (mudstones mapped within this unit around Lichfield are thin and have not been modelled), Wilmslow Sandstone Formation and Helsby Sandstone Formation (Ambrose *et al*, 2014).

The Triassic aged units in the model are Tarporley Siltstone and Sidmouth Mudstone formations, which are part of the Mercia Mudstone Group. The Littleworth Beds have been distinguished as a separate unit in boreholes drilled for coal exploration, but have not been mapped and the unit has not been formalised. There is inconsistency in the recording of the unit, with some boreholes not recording it. The logs are mostly from old boreholes, drilled before 1970. Two have geophysical logs but are inconclusive in defining the unit. Although modelled, there is some doubt about the authenticity of this unit and it may be part of the Chester Formation. The Alveley Member (ALY) is part of the Salop Formation of the Warwickshire Group. This group, of Carboniferous age, has not been subdivided into its component formations due to insufficient evidence in many boreholes, with the exception of the south east corner. Pennine Lower and Middle Coal Measures form small outcrops in the north-west and south-east of the model area.

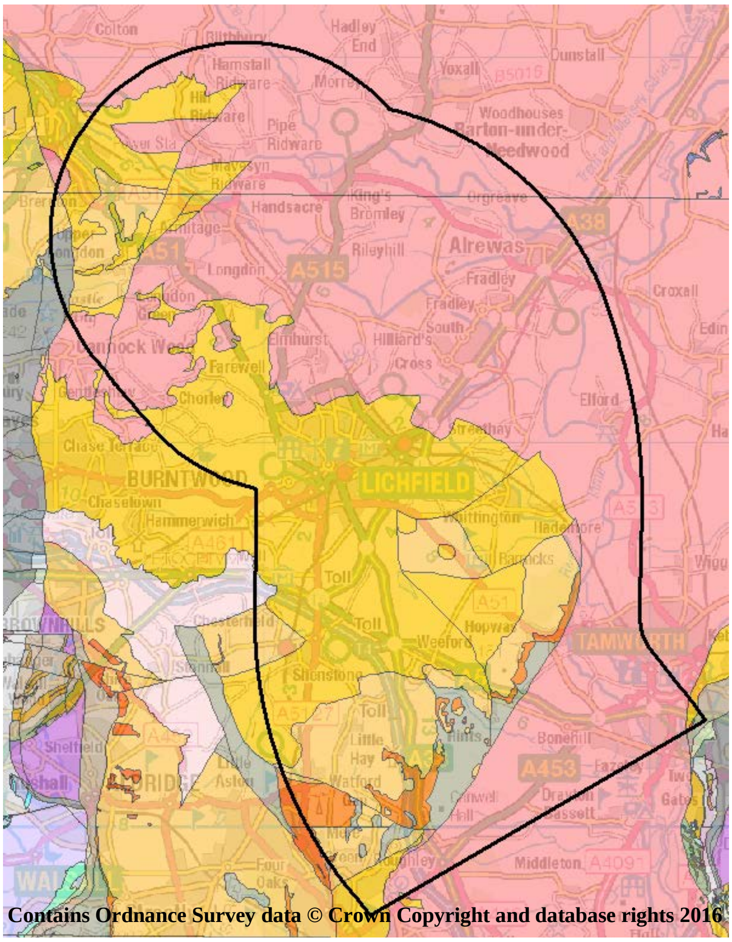

Figure 2. DigMapGB-50 bedrock geology map of the Area 8 model. Key as Table 1

2.2 SUPERFICIAL GEOLOGY

The superficial deposits in the model area comprise patches of till and glacial sand and gravel associated with the last two major glaciations (Figure 3). The oldest of these are Mid Pleistocene aged glacigenic deposits, which occur mainly in the north and south of the model area. Younger Devensian aged glacigenic deposits are mapped in the west of the model area. A wide tract of fluvial deposits runs roughly north-south through the eastern half of the model area. These comprise river terrace gravels and alluvium associated with the River Tame and River Blithe and their tributaries. Head is mapped in valley floors and patches of peat are located in the south-west of the model area. Figure 3 shows the current DiGMapGB-50 superficial geology mapping of the area, which has not yet been updated with the recent revisions made to the geological maps of the area. One major change, for example, is the re-classification of a large area of glacial sand and gravel north of Lichfield to a river terrace gravel.

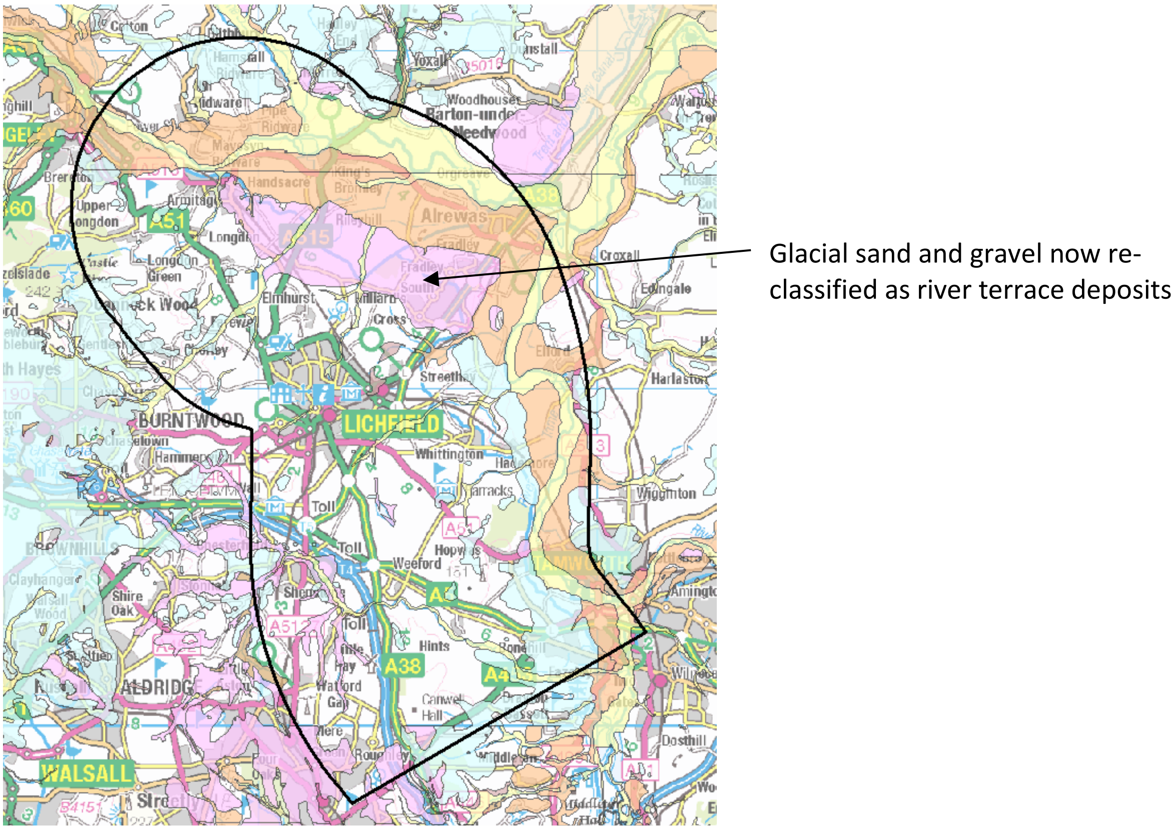

Figure 3. DigMapGB-50 superficial geology map of the Area 8 model. Key as Table 1

2.3 ARTIFICIAL DEPOSITS

Artificial deposits are mapped and modelled throughout the area. These are subdivided into four categories: *made ground* is used for areas where the land surface has been artificially raised, such as road and railway embankments; *worked ground* is used for areas where the land surface has been lowered, such as quarries and road cuttings; *landscaped ground* is areas where engineered cut and fill has occurred, such as industrial estates; and *worked and made ground* is used for backfilled pits and quarries.

Very little artificial ground was mapped in the Area 8 model area before the corresponding 1:10 000 scale map sheets were revised. Figure 4 shows the newly mapped/modelled artificial ground within the Area 8 model area, which is not yet incorporated into the DiGMap-GB datasets.

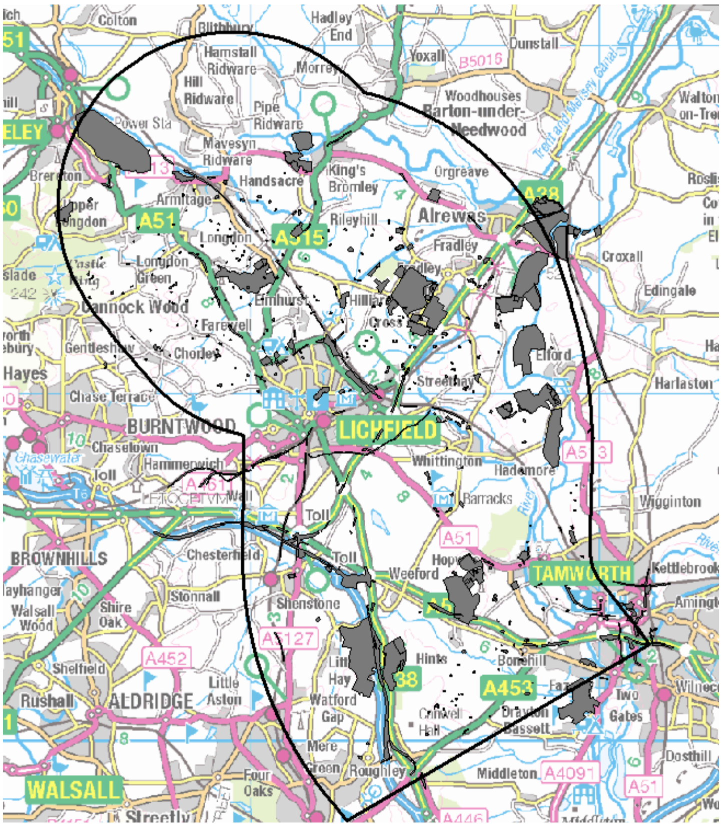

Figure 4 Distribution of modelled artificial ground in Area 8

3 Modelled Faults

A number of normal geological faults are mapped within the model area. Figure 5 shows the current mapped faults in the DiGMapGB-50 dataset and Figure 6 shows the revised fault network represented in the Area 8 model. Four of these faults are major structures: the *Birmingham Fault* runs NNE-SSW across the area and the north-south trending *Western Boundary Fault* of the Warwickshire Coalfield just clips the south eastern corner of the area and continues south into Area 7. These faults form a graben that links the Needwood Basin to the north with the Knowle Basin to the south. These sedimentary basins and the graben were active during the Triassic, resulting in synsedimentary movement during the Permian and Triassic and a much thicker (c. 1000 m) sequence of these deposits within the graben. Carboniferous aged Warwickshire Group rocks that crop out on the upthrow side of this fault are absent in the floor of the graben. Carboniferous rocks reappear in the extreme west of Area 8 on the upthrow side of the north-south trending *Great Barr Fault*, which forms the eastern boundary to the South Staffordshire Coalfield. A number of other faults, mainly showing a N-S to NE-SW orientation, occur within Area 8 together with a number showing a general E-W trend. These faults show variable downthrows and some significant structures with throws of up to 100 m. The *Hints Fault* trends NE-SW across the model area and downthrows the rocks to the east by an estimated 200 m in the southern part of the model area, diminishing northwards. This fault was extended north-east following a recent re-survey of 1:10 000 scale map sheets in the area.

Faults are modelled using the GSI3D superficial engine as steps in the geological surfaces rather than as a faulted bedrock model where the unit is in contact across the fault.

Figure 5 Current Area 8 mapped faults shown in DigMapGB-50 (red)

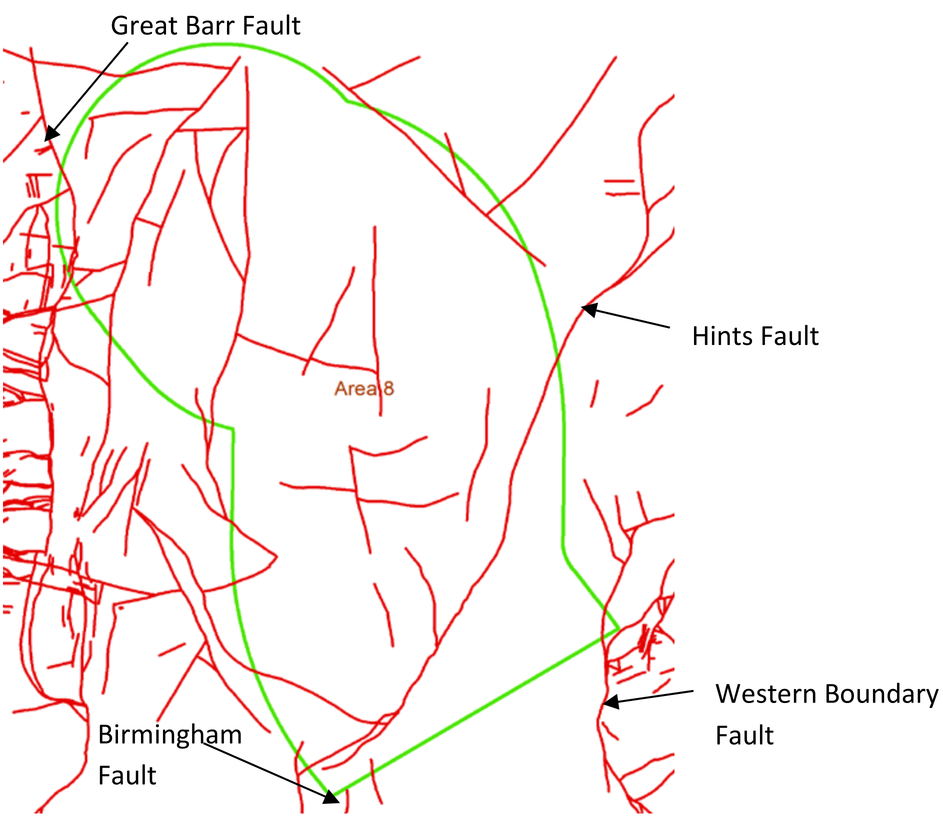

Figure 6. Revised Area 8 faults modelled (red), model area outlined in green

4 Model Workflow

The standard GSI3D modelling workflow was followed for this project. GSI3D software utilises a range of data such as boreholes, digital terrain models (DTM) and geological linework to enable the geologist to construct a series of interlocking cross-sections. Borehole data is represented in GSI3D by two proprietary files: a borehole identification file (.bid), that contains 'index'-level information including location and start-heights; a borehole log file (.blg), that contains the borehole interpretation. Constructing cross-sections is intuitive and flexible, combining borehole and outcrop data with the geologist's experience to refine the interpretation.

Using both the information from the cross-sections and the distribution of each unit a calculation algorithm creates the triangulated surfaces for the top and base of each unit. In order to control the relative vertical ordering of the calculation, a generalised vertical section file (.gvs) is established. A proprietary legend file (.gleg) is created to control symbolisation of the cross-section and model. The modeller can view all the units in 3D and iteratively return to the cross-section to make amendments or add further cross-sections to refine the model. This process is a standard methodology within BGS for modelling Quaternary and simple bedrock horizons and is fully documented in Kessler *et al* (2009).

In Areas 6, 7 and 8, to aid the calculation of bedrock units in faulted areas, scattered data points were created for the geological units that intersect the base of the model. This was then manipulated in GSI3D so that it could be applied to the respective geological units. This process aided the calculation of the geological units to the basal model limit.

5 Model Datasets

5.1 GVS AND GLEG FILES

The generalised vertical section (.gvs) and geological legend (.gleg) files were assembled using Notepad or Excel and iterated as the model expanded and new units were encountered. The GVS was based on DiGMapGB-50 data by identifying all those geological units that are within a 5km area of the HS2 route. However some units occur only in subcrop, so additional units in the GVS had to be appended as modelling progressed. The GLEG files were created using the standard BGS colours from DigMap-50. Overall GVS and GLEG files were created for the whole HS2 route, rather than for each individual model area. Thus the units used in this model are only a subset of those available in the overall HS2 GVS file.

5.2 GEOLOGICAL LINEWORK

The model is covered by 1:50 000 scale geological map sheets 140 (Burton upon Trent) and 154 (Lichfield). A number of problems were noted with the existing mapping of these sheets, which necessitated a partial re-survey of the corresponding 1:10 000 scale standards for the model area. The amended 1:10 000 scale linework is used in the HS2 Area 8 geological model, but is not currently approved for inclusion into corporate datasets. In areas where the mapping has not been revised the model uses published 1:50 000 scale DiGMap geology linework. The revised 1:10 000 scale geological map sheets are shown in Figure 7.

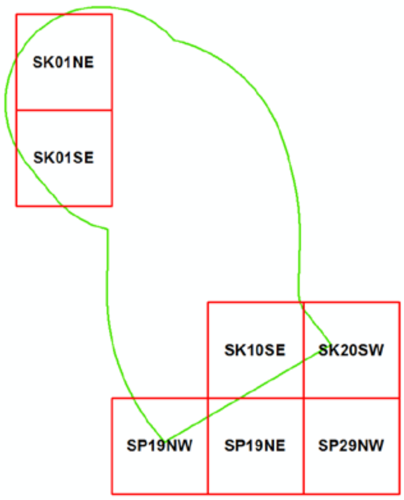

Figure 7 Plot of 1:10 000 scale map sheets that were revised (outlined in red) and used in the model. The currently unpublished linework on these maps is used in the model.

5.3 DIGITAL TERRAIN MODEL

The terrain model used in this model was the BGS Bald Earth 20 m DTM obtained from the BaldEarth model and trimmed to the project area (5 km buffer of the route shapefile). A NextMap DTM was also included, but not used for modelling.

5.4 BOREHOLE DATA

A review of borehole records in the BGS *Single Onshore Borehole Index* (SOBI) in the model area was carried out and those that held sufficient geological information were selected for coding in the BGS *Borehole Geology* database (BoGe). After borehole coding was completed, the boreholes were extracted from the BGS *Single Onshore Borehole Index* (SOBI) database for use in the 3D modelling software using a set of queries. The borehole log file (.blg) needed to be deduplicated and a borehole filter tool was used to address this. Some boreholes were coded using geophysical gamma ray logs. A plot of borehole data used in the model and the cross-sections constructed from them are shown in Figure 8.

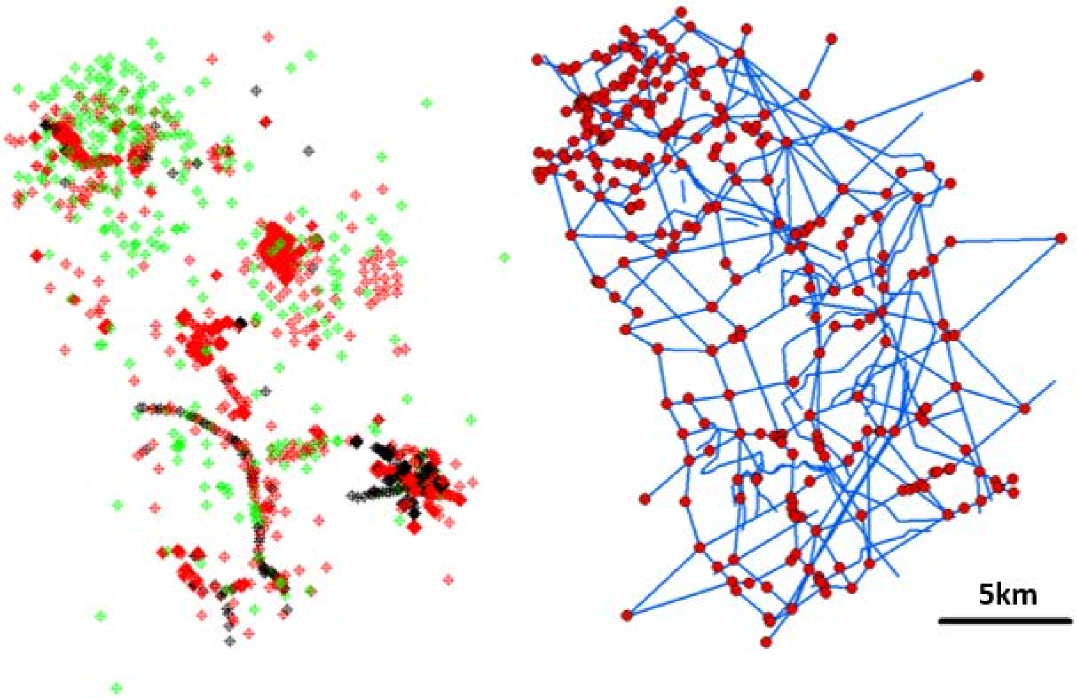

Figure 8. Left: plot of available borehole data in the model area, colour coded according to drilled depth. Black boreholes are under 10 m and green boreholes are 10 m and over. Red boreholes are not coded. Right: plot of the 287 boreholes used in the 72 cross-sections constructed to constrain the model

Some records in the list contained entries that were used to 'fill-in' units that were missing, for example TPSF Tarporley Siltstone Formation, Littleworth Beds. A set of priorities were applied to borehole records that were coded by more than one project. The records at the top of this list have a higher priority and the filter tool keeps these records and discards other matching records. This left a total of 884 boreholes coded out of a total borehole count of 2578.

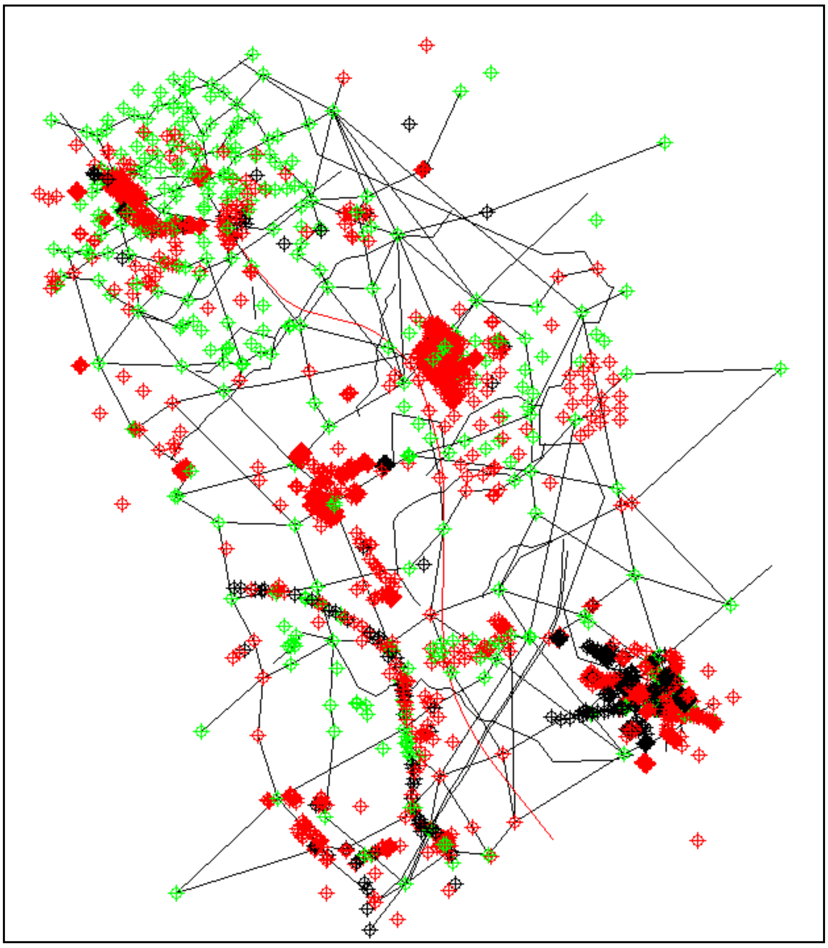

Figure 9. Plot of all boreholes in Area 8. Boreholes over 10 m deep are coloured green, under 10m in black, boreholes in red are not coded. Route cross-section shown in red

5.5 OTHER DATASETS

- Some borehole logs were interpreted from gamma ray logs
- Sixteen cross-sections from the pre-existing Needwood Basin model were used to constrain the geological units modelled.

6 Model Development Log

During the course of the modelling, the modeller kept a running log of the development, changes and decisions made for their designated modelling areas (Figure 10). These records are kept as part of the model storage and metadata (QA) process and can be accessed as needed.

File saved as V2_20.GSIPR

Progress for Area 8

No metadata recorded by KA up to 3rd June 2013.

Project started 18/4/13. 13 approx. east-west and 5 approx. north south cross sections drawn. Followed by drawing of polygons for all main groups, snapping crossing sections to polygons then snapping all points in cross sections.

Figure 10. Example of model development text

7 Model Assumptions, Geological Rules Used etc.

First order river terrace deposits (RTD1-XSV) are modelled beneath alluvium where the two units are adjacent to each other. Figure 11 shows the distribution of these units, with a transparency applied to alluvium (pale yellow) to show the extent of RTD1-XSV (orange) modelled underneath.

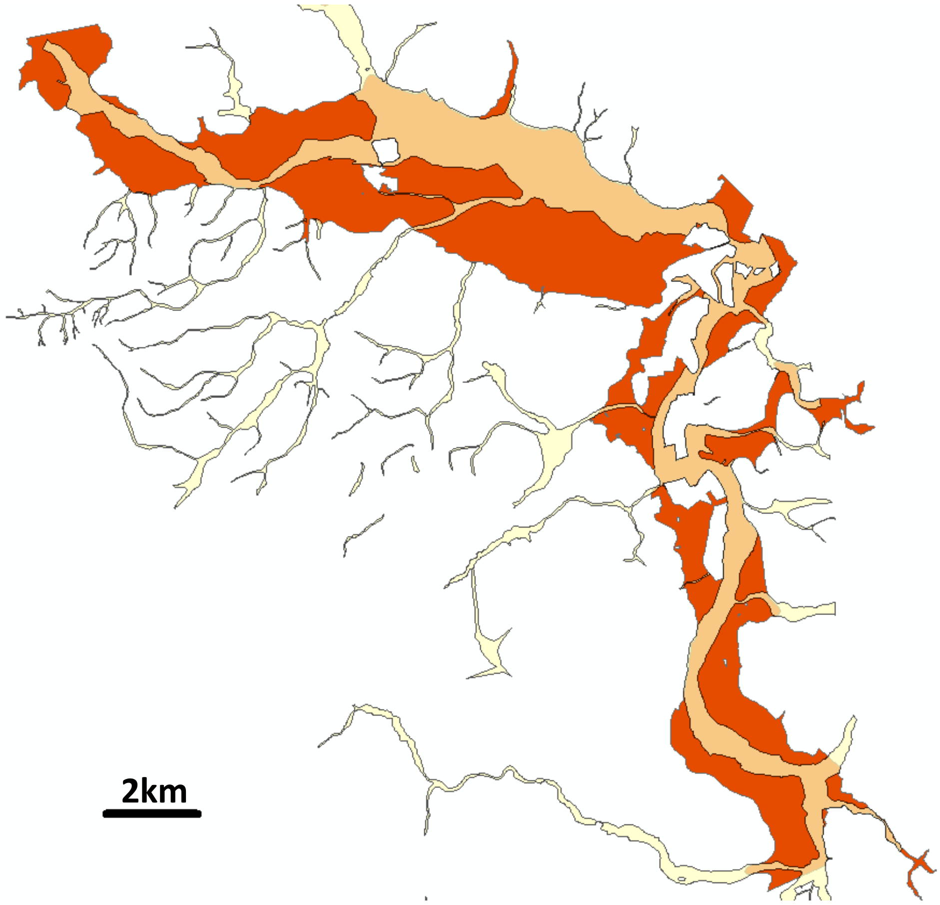

Figure 11. The modelled distribution of first order river terrace deposits (RTD1-XSV) coloured orange beneath alluvium (pale yellow)

Similarly, the extents of older glacigenic units are extended beneath younger Quaternary units. For example, Mid-Pliestocene glaciofluvial deposits (GFDMP-XSV) is extended beneath alluvium and second order river terrace deposits (RTD2-XSV).

In the glacial sediments an arbitrary line was used to determine the western limit of Anglian aged (Mid Pleistocene) superficial deposits, with all those to the west of northing 414 modelled as Devensian age. This necessitated the re-attribution of some of the superficial geology polygons.

An arbitrary decision made to define western limit of Anglian age (MP) superficial deposits, with all those west of around northing 414 attributed as Devensian age and modelled accordingly.

In some bedrock units the mapped subdivisions have been combined into single geological units. For example, all mapped units in the Keresley Member (KRS) are modelled as KRS-ARSC and all mapped subdivisions in the Whitacre Member have been combined into WIT-MDSD in the model.

8 Model Limitations

8.1 MODEL SPECIFIC LIMITATIONS

Although faults were drawn and modelled dipping at around 60° for drawing guidance, all correlated lines are stepped across, either to join into the same unit in the footwall, or if absent there, to join the edge of the polygon at the surface Figure 12 shows the representation of faults in cross-section *HS2_Area8_NS_approx_route*, which runs north-south through the middle of the model area.

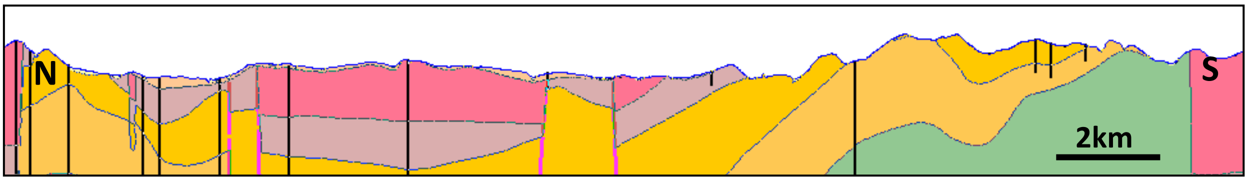

Figure 12 Cross-section *HS2_Area8_NS_approx_route* with faults modelled as steps in the affected geological unit bases. Vertical exaggeration x20.

Figure 8 shows all boreholes available in Area 8, with those with drilled depths of 10 m and over coloured in green. Figure 8 also shows the boreholes used in the cross sections with the lines of section shown to indicate where this subsurface data constrains the model. This gives the model user some idea where the model is most and least certain.

The arbitrary limits of the Devensian and Anglian (Mid Pleistocene) glaciations may mean that some of the superficial polygons have been wrongly attributed. However, until there is a definitive method for distinguishing between the glacial deposits of these ages, this will remain uncertain.

There are some uncertainties as to the precise extent of some of the geological units, notably the Wildmore Sandstone Formation, Hopwas Breccia Formation and Littleworth Beds. The Wildmoor Sandstone Formation is largely fault controlled but the limits are in places uncertain. The Littleworth Beds have not been mapped and are not recognised in all boreholes that should prove them. Thus there is some uncertainty as to their precise lateral extent. The Hopwas Breccia Formation has also not been interpreted in all boreholes that may prove it. As it is a breccia sitting on a conglomerate (the Kidderminster Formation), this is the main reason for its failure to be recognised everywhere.

Some of the deep boreholes have not distinguished the Tarporley Siltstone Formation. It is known to be present everywhere at the base of the Mercia Mudstone Group (Warrington *et al.*,1980) and been extensively mapped on the Lichfield sheet. It has been run through the model at depth with only an approximate thickness in places. This produces a mismatch with the modelled units in Area 7, which at the boundary of the two areas is modelled as Mercia Mudstone Group without being split into formations.

The Warwickshire Group is only depicted in the model at the group level. Although divisible into formations and members, this has not proved possible in all of the boreholes. Outcrops on or close to the model area all indicate the Enville or Alveley Members of the Salop Formation. Because of the similarities between the various members and formations, all comprising dominantly red mudstones and sandstones in varying proportions, their widespread correlation cannot be certain.

8.2 GENERAL MODELLING LIMITATIONS

- Geological interpretations are made according to the prevailing understanding of the geology at the time. The quality of such interpretations may be affected by the availability of new data, by subsequent advances in geological knowledge, improved methods of interpretation, improved databases and modelling software, and better access to sampling locations. Therefore, geological modelling is an empirical approach.

- It is important to note that this 3D geological model represents an individual interpretation of a subset of the available data; other interpretations may be valid. The full complexity of the geology may not be represented by the model due to the spatial distribution of the data at the time of model construction and other limitations including those set out elsewhere in this report.

- Best endeavours (detailed quality checking procedures) are employed to minimise data entry errors but given the diversity and volume of data used, it is anticipated that occasional erroneous entries will still be present (e.g. boreholes locations, elevations etc.) Any raw data considered when building geological models may have been transcribed from analogue to digital format. Such processes are subjected to quality control to ensure reliability; however undetected errors may exist. Borehole locations are obtained from borehole records or site plans.

- Borehole start heights are obtained from the original records, Ordnance Survey mapping or a digital terrain model. Where borehole start heights look unreasonable, they are checked and amended if necessary in the index file. In some cases, the borehole start height may be different from the ground surface, if for example, the ground surface has been raised or lowered since the borehole was drilled, or if the borehole was not originally drilled at the ground surface.

- Borehole coding (including observations and interpretations) was captured in a corporate database before the commencement of modelling and any lithostratigraphic interpretations may have been re-interpreted in the context of other evidence during cross-section drawing and modelling, resulting in occasional mismatches between BGS databases and modelled interpretations.

- Digital elevation models (DEMs) are sourced externally by BGS and are used to cap geological models. DEMs may have been processed to remove surface features including vegetation and buildings. However, some surface features or artefacts may remain, particularly those associated with hillside forests. The digital terrain model may be sub-sampled to reduce its resolution and file size; therefore, some topographical detail may be lost.

- Geological units of any formal rank may be modelled. Lithostratigraphical (sedimentary/metasedimentary) units are typically modelled at Group, Formation or Member level, but Supergroup, Subgroup or Bed may be used. Where appropriate, generic (e.g. alluvium – ALV), composite (e.g. West Walton Formation and Ampthill Clay Formation, undifferentiated – WWAC) or exceptionally informal units may also be used in the model, for example where no equivalent is shown on the surface geological map. Formal lithodemic igneous units may be named Intrusions or Dykes or may take the name of their parent (Pluton or Swarm/Centre or Cluster/Subsuite/Suite), or if mixed units Complex may be used. Highly deformed terranes may use a combined scheme with additional rank terms. Artificially Modified Ground units (e.g.

Made Ground (undivided) – MGR, Landscaped Ground (undivided) – LSGR) are currently regarded as informal.

- The geological map linework in the model files may be modified during the modelling process to remove detail or modify the interpretation where new data is available. Hence, in some cases, faults or geological units that are shown in the BGS approved digital geological map data (DiGMapGB) may not appear in the geological model or vice versa. Modelled units may be coloured differently to the equivalent units in the published geological maps.

9 Model QA

In order for a geological model to be approved for publication or delivery to a client a series of QA checks is carried out. This includes visual examination of the modelled cross-sections to ensure that they match each other at cross-section intersections and fit the borehole and geological map data used. The model calculation is checked to ensure that all units calculate to their full extent within the area of interest and the modelled geological surfaces are checked for artefacts such as spikes and thickness anomalies. The naming convention of the modelled geological units is checked to ensure that recognised entries in the BGS Lexicon of Named Rock Units (http://www.bgs.ac.uk/lexicon/home.html) and the BGS Rock Classification Scheme (http://www.bgs.ac.uk/bgsrcs/) are used as far as possible.

Any issues found in the QA checking process are recorded and addressed before delivery/publication of the model.

10 Model Images

Figures 13 through to 19 show the calculated model, cross-sections and focus on geological units of Permian-Triassic and Carboniferous age. The key to these images is as per Table 1.

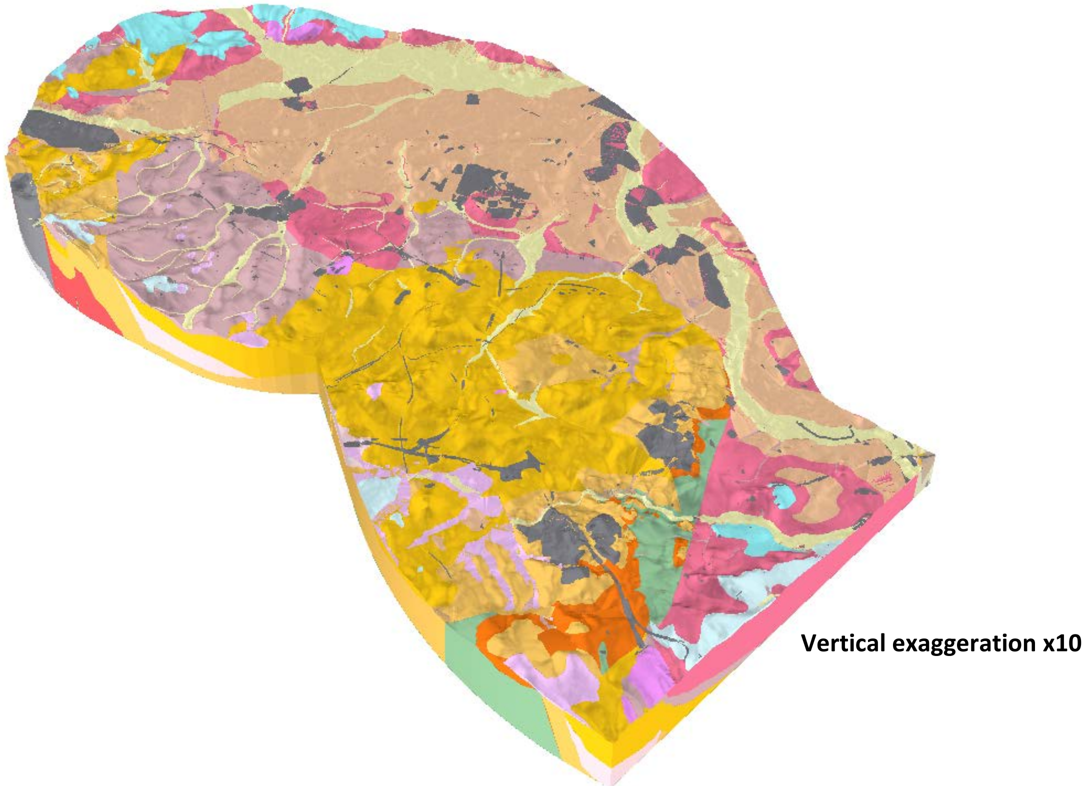

Figure 13 3D view of the calculated model with all units shown, looking from the south

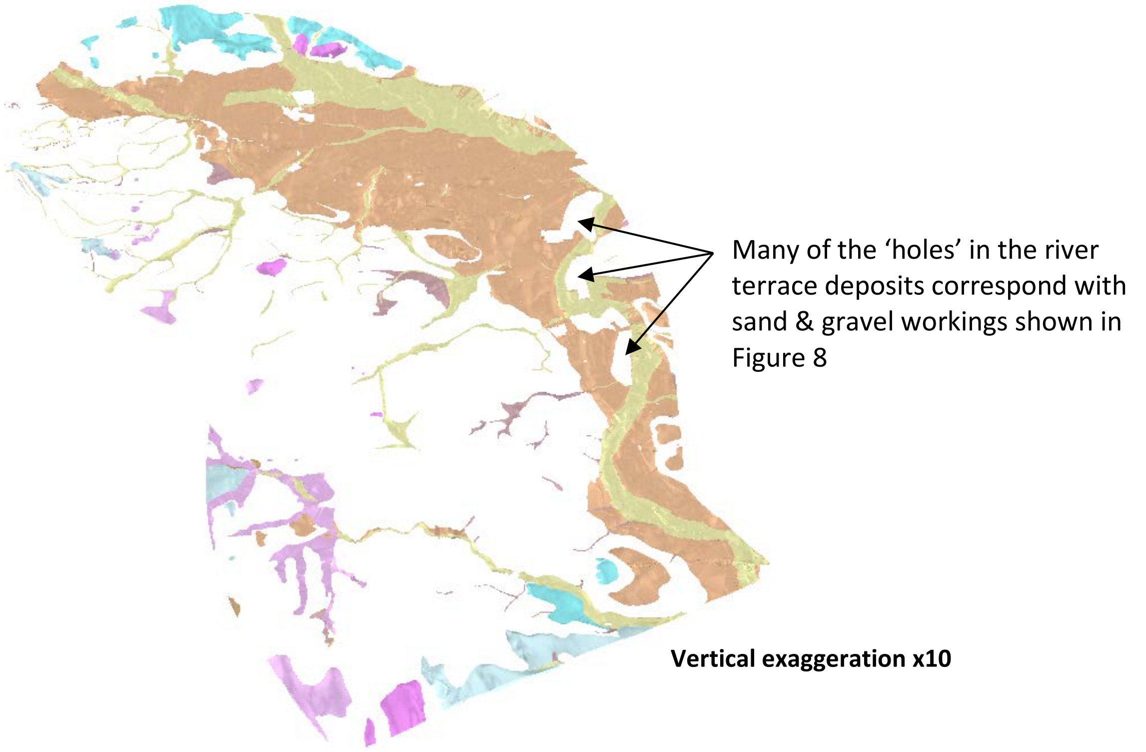

Figure 14 3D view of all superficial deposits in the model looking from the south. These are predominantly alluvium (yellow) and river terrace deposits (peach)

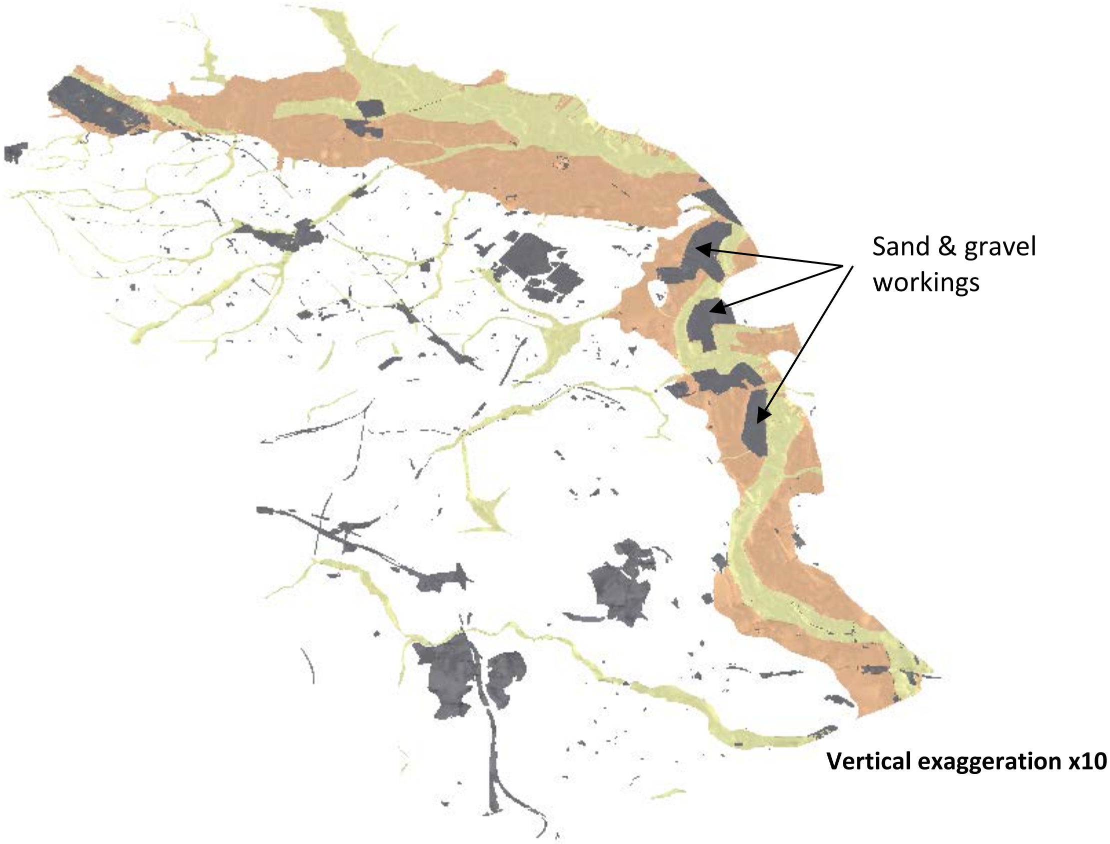

Figure 15 3D view of all Artificial Deposits in Area 8 (grey) shown with Alluvium (yellow) and RTD 1, looking from the south

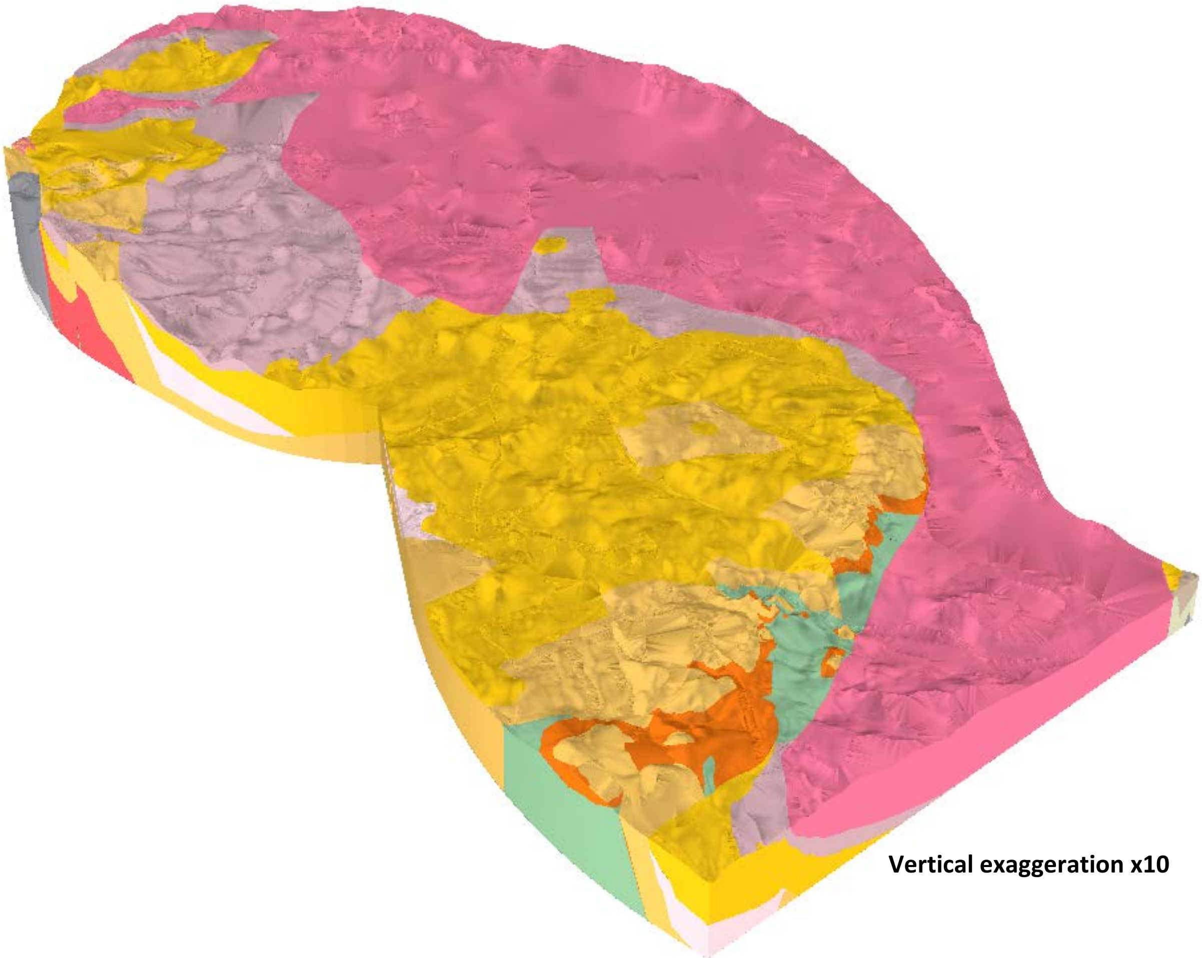

Figure 16 3D 'rockhead' view with the superficial deposits removed to show all modelled bedrock units from the south

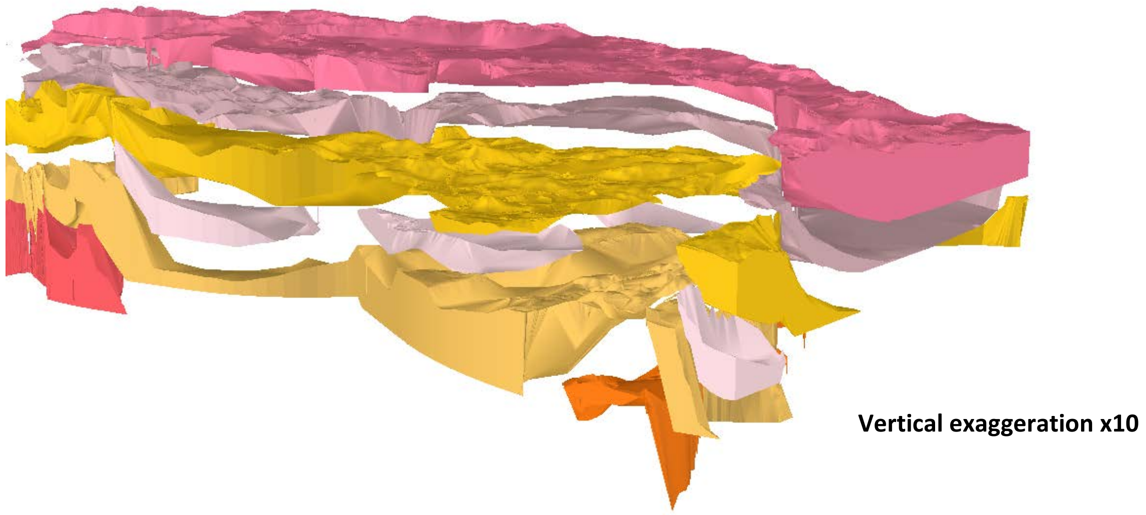

Figure 17 3D 'exploded' view of the Permo-Triassic formations from the south west

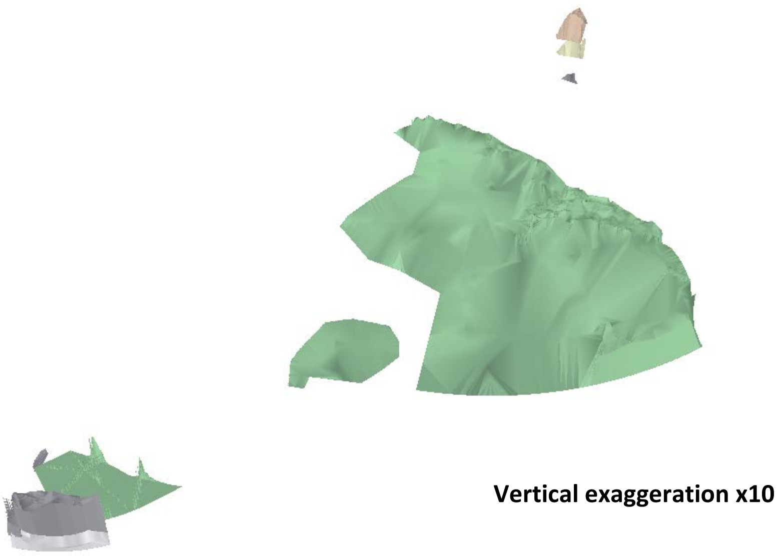

Figure 18 3D 'exploded' view of the Carboniferous formations of Area 8, viewed from the north.

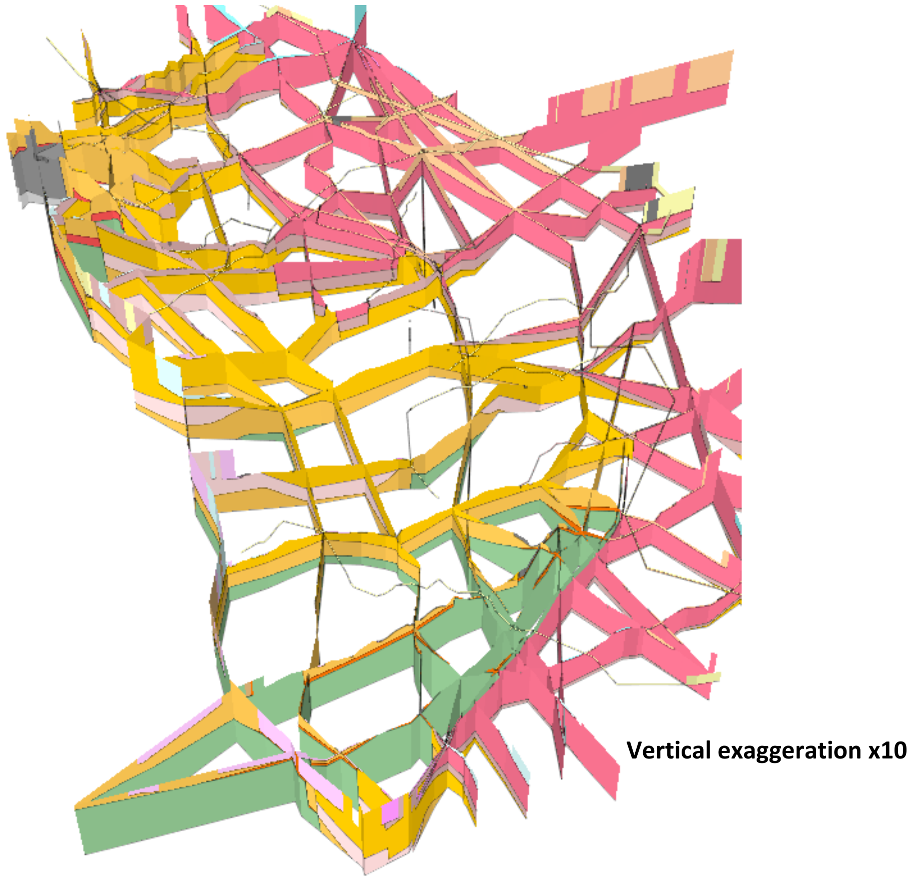

Figure 19 3D 'fence diagram' view of all Area 8 cross sections, looking from the south

11 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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