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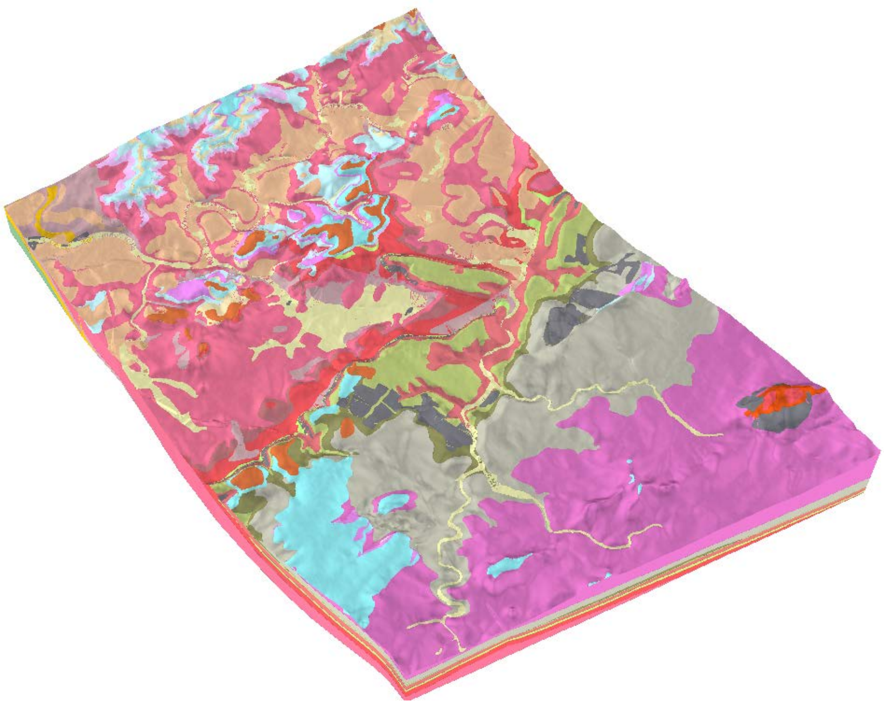
GSI3D model metadata report for HS2 Area 5 (Ladbroke to Cubbington)

Geology and Regional Geophysics

Open Report OR/15/072



BRITISH GEOLOGICAL SURVEY

GEOLOGY AND REGIONAL GEOPHYSICSPROGRAMME

OPEN REPORT OR/15/072

GSI3D model metadata report for HS2 Area 5 (Ladbroke to Cubbington)

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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 5 (Ladbroke to Cubbington), 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 deposits, mass movement deposits and artificially modified ground along the proposed High Speed Rail Link between London and Birmingham. This model covers a 25 km stretch of the proposed route through Warwickshire, between Ladbroke in the south-east and Cubbington in the north-west and to 5 km either side of the route (Figure 1). This is one of an initial group of nine models along the proposed route (Areas 1 to 9), in common with the eight other HS2 models. The bedrock geology of this section of the route comprises Triassic to Lower Jurassic strata, together with superficial deposits of glacigenic and fluvial origin, landslide and artificial deposits. This model is suitable for use at scales between 1:100 000-1:10 000, down to a depth of 30 m below Ornance Datum (OD).

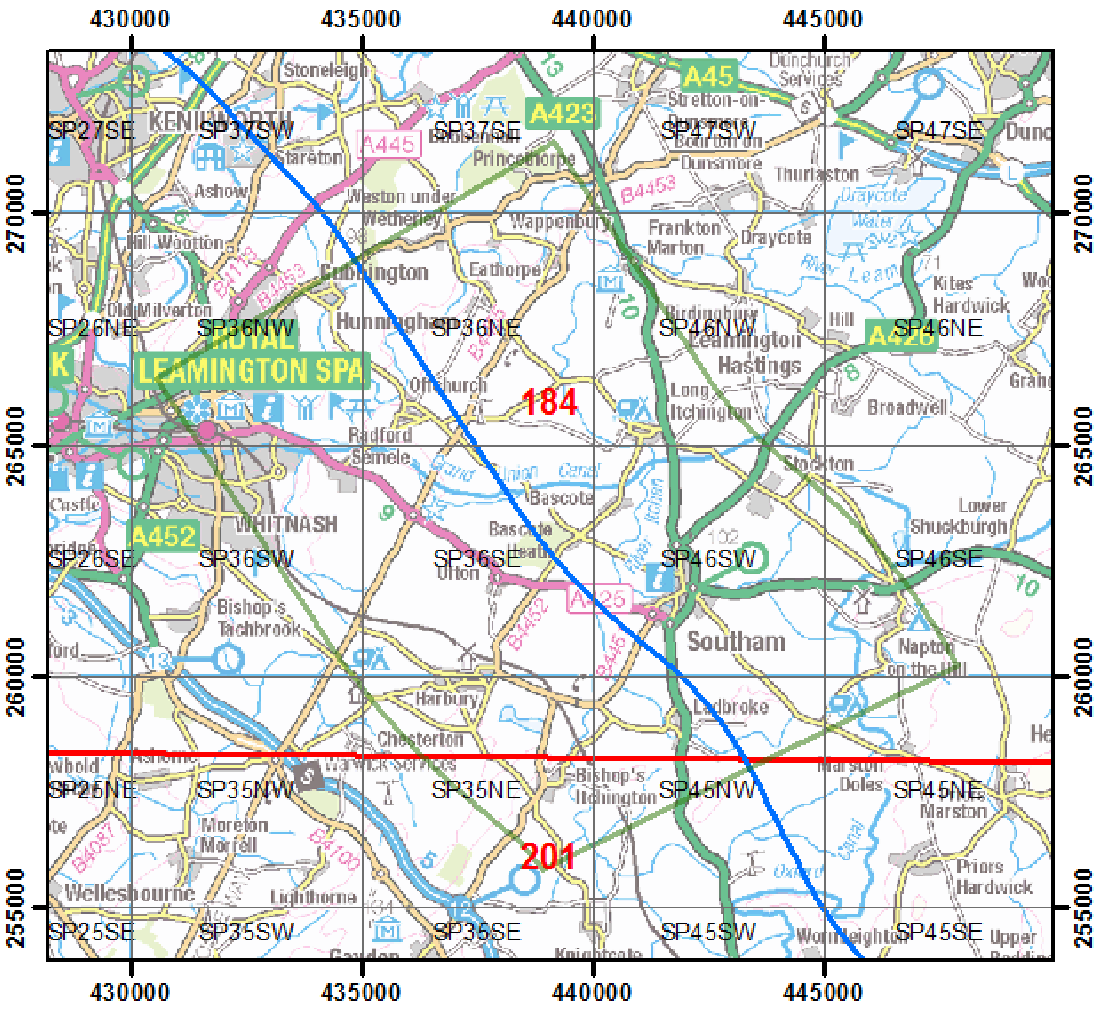

Figure 1. Location of the Area 5 model outlined in green. Proposed HS2 route shown in blue, model area outlined in green. BGS 1:50,000 scale map sheet areas are shown in red, 1:10,000 maps in grey. Contains Ordnance Survey data © Crown Copyright and database rights 2014.

Prior to the modelling work, an assessment of the quality and availability of the 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, the geological mapping of this sector, dating from the 1970s, was deemed to be in need of some revision, requiring some modifications to the geology and linework on the maps. Thus this 3D model is based on geological line work from existing 1:10 000 and 1:50 000 scale DiGMapGB data to which modifications have been made.

2 Modelled Surfaces/Volumes

The modelled bedrock, superficial, artificial and landslip 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 and landslips were 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 List of geological units modelled

LEX-RCS	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	
SLIP-UNKNOWN	LANDSLIP DEPOSITS	Variable composition
PEAT1-P	PEAT	Occurs above alluvium. Variable composition
ALV-XCZSV	ALLUVIUM	Clay, silt, sand and gravel
HEAD-XCZSV	HEAD	Clay, silt, sand and gravel
PEAT-P	PEAT	Occurs below alluvium
RTD1-XSV	RIVER TERRACE DEPOSITS, 1	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
DMG-XSV	DUNSMORE GRAVEL MEMBER	Sand and gravel
TILMP-DMTN	TILL, MID PLEISTOCENE	Some areas of this unit were originally classified as Upper Wolston Clay
GFDMP0-XSV	GLACIOFLUVIAL DEPOSITS, MID PLEISTOCENE	Sand and gravel
GLLMP-XCZ	GLACIOLACUSTRINE DEPOSITS, MID PLEISTOCENE	Very limited outcrop, composed of clay and silt
ODT-DMTN	OADBY MEMBER	Till
WOC1-XCZ	WOLSTON CLAY MEMBER	Occurs above WOSG-XSV – the former Upper Wolston Clay. Composed of clay and silt
WOSG-XSV	WOLSTON SAND AND GRAVEL MEMBER	Now known as the Wigston Sand and Gravel Member
WOC-XCZ	WOLSTON CLAY MEMBER	Occurs below WOSG-XSV; BOSW-XCZ in DiGMap-50
THT-DMTN	THRUSSINGTON MEMBER	Till
BGSG-XSV	BAGINTON SAND AND GRAVEL FORMATION	Sand and gravel
MRB-FLMST	MARLSTONE ROCK FORMATION	Ferruginous limestone
DYS-SIMD	DYRHAM FORMATION	Interbedded siltstone and mudstone
CHAM-MDST	CHARMOUTH MUDSTONE FORMATION	Mudstone
RLS-MDLM	RUGBY LIMESTONE MEMBER	Interbedded mudstone and limestone
SASH-MDST	SALTFORD SHALE MEMBER	Pinches out south-east at depth
LPMB-LMST	LANGPORT MEMBER	Now known as the White Lias Formation
PNG-AROCLS	PENARTH GROUP	Interbedded argillaceous rocks and subordinate limestone
BAN-MDSI	BLUE ANCHOR FORMATION	Full outcrop not originally shown; outcrop missing beneath some areas of landslide deposits
BCMU-MDST	BRANSCOMBE MUDSTONE FORMATION	MMG-MDST in DiGMap-50

AS-SISD	ARDEN SANDSTONE FORMATION	Original mapped outcrop showed some discontinuities but is known to be continuous. Boundary has been adjusted to take this into account with some fieldwork. Composed of siltstone and sandstone. Pinches out south-east at depth
SIM-MDST	SIDMOUTH MUDSTONE FORMATION	MMG-MDST in DiGMap-50
TPSF-MDSA	TARPORLEY SILTSTONE FORMATION	This unit was not originally mapped but has been added with the aid of some fieldwork. Lies within the MMG-MDST outcrop in DiGMap-50. Composed of mudstone and sandstone
BMS-SDST	BROMSGROVE SANDSTONE FORMATION	This unit has been renamed the Helsby Sandstone Formation since model was built
WAWK-MDSS	WARWICKSHIRE GROUP	Warwickshire Group is not subdivided for model owing to uncertainties in some boreholes. Composed of mudstone, siltstone and sandstone

The Upper Carboniferous succession present at depth beneath the Bromsgrove Sandstone in the north-west part of the model could not be subdivided using the borehole data available, and is attributed to the Warwickshire Group, which is the parent of the units with which it is correlated in the Area 6 model to the north-west.

The Bromsgrove Sandstone Formation is part of the Sherwood Sandstone Group. Recent work has renamed this unit as the Helsby Sandstone Formation (Ambrose *et al.* 2014). Units from the Tarporley Siltstone Formation up to the Blue Anchor Formation are all part of the Mercia Mudstone Group. All of these units are Triassic in age.

The Penarth Group is subdivided in the BGS Warwick memoir (Old et al., 1987) into the Westbury Formation, Cotham Member and Langport Member of the Lilstock Formation. The Langport Member (now known as the White Lias Formation) is shown separately in the model but the Westbury Formation and Cotham Member (now Formation) were not distinguished on the 1:50 000-scale map or in the model as they are thin and lithologically similar, and are combined as the Penarth Group.

The Saltford Shale Member and Rugby Limestone Member are part of the Blue Lias Formation. This, together with the Charmouth Mudstone Formation up to the Marlstone Rock Formation are part of the Lias Group. These are all of Jurassic age.

The Thrussington Member up to the Dunsmore Gravel Member, of mid Pleistocene age, are all part of the Wolston Glacigenic Formation (McMillan *et al.*, 2011) but only some of the units have been named. The underlying Baginton Sand and Gravel Formation is a pre-Anglian deposit but the remaining glacigenic units were deposited by the Anglian ice advance. Much of the sequence, cropping out in the northern part of Area 5, shows a distinct and unusually well-developed stratigraphy.

The river terrace deposits and alluvium are part of the Warwickshire Avon Valley Formation.

3 Modelled Faults

Faulting is limited in Area 5. Several small faults, most with throws of less than 20 m were modelled, dipping at around 60 degrees for drawing guidance, based on mapped surface faults (Figure 2). These were modelled using the superficial engine as steps in the geological surfaces rather than as a faulted bedrock model where the unit is in contact across the fault. One fault on the western side of Area 5 has a maximum throw in excess of 60 m in the Whitnash area. However, much of its length falls just outside of HS2 model Area 5.

A number of newly mapped faults with downthrows of less than 20 m have been added and existing faults modified in the central part of the area

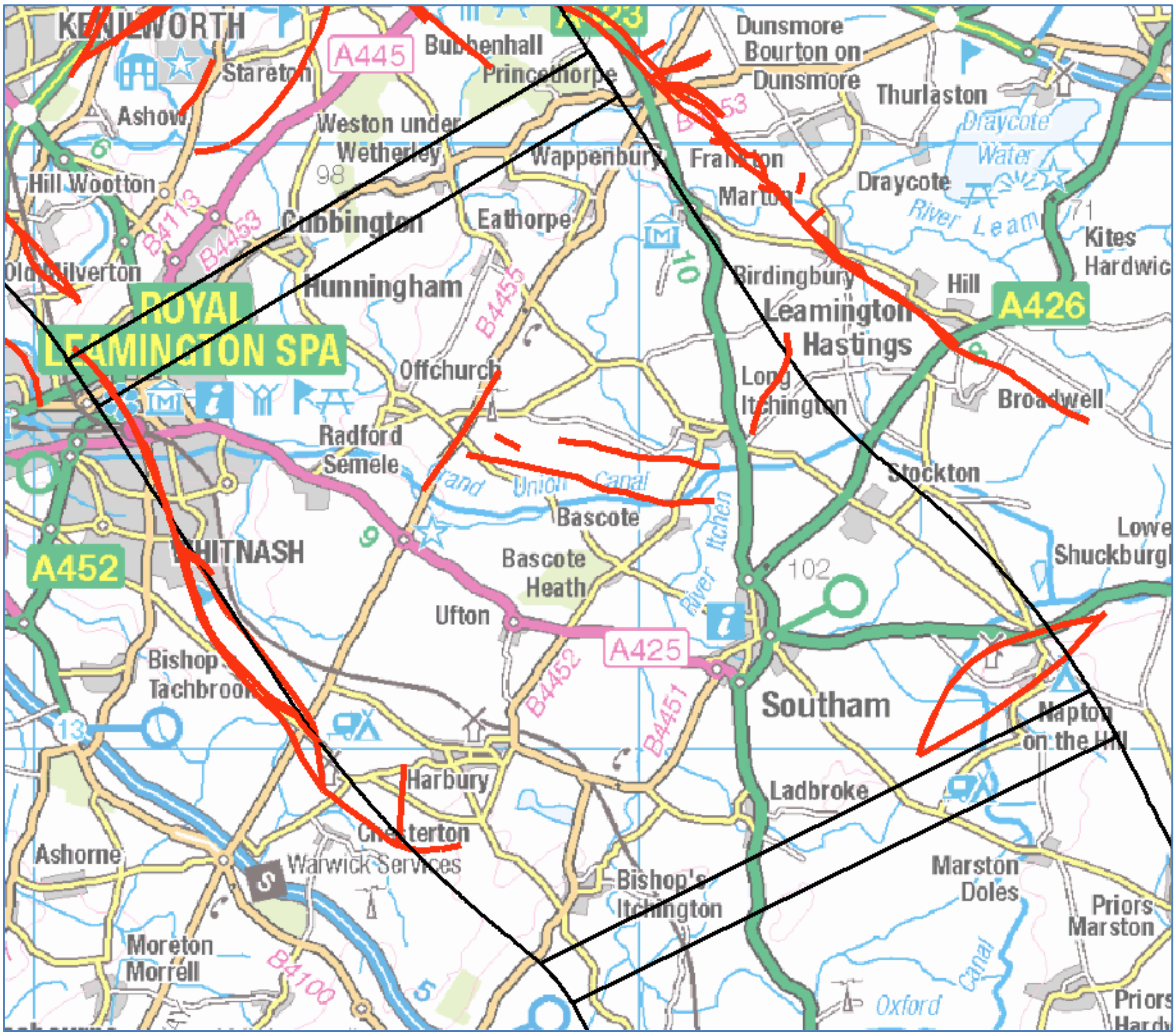

Figure 2. Area 5 geological faults are shown as red lines (12 in total). Contains Ordnance Survey data © Crown Copyright and database rights 2014.

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).

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

A few problems are noted in the central part of Area 5 centred on the outcrops of the Mercia Mudstone Group that includes the mapping of Tarporley Siltstone, Sidmouth Mudstone, Arden Sandstone and Branscombe Mudstone formations. The Arden Sandstone is known to be a continuous bed across much of the country, but in the original mapping it lacked continuity. A limited amount of fieldwork was undertaken to produce a continuous outcrop across the area, backed up by office work. This entailed the addition of several new fault traces and the extension of existing ones. The Sidmouth Mudstone and Branscombe Mudstone formations were not delineated as these units postdate the publication of the map (Howard *et al*., 2008) and subdivision was not possible owing to the discontinuous outcrop of the Arden sandstone. The Tarporley Siltstone Formation was not shown in the original mapping and was mapped based on field and office based work. Two boreholes revealed the presence of superficial deposits in Whitnash that had not been mapped. These were added during the fieldwork. Other amendments were made in the office to areas of artificial deposits in the Southam – Stockton area; some were due to extensions of quarry operations and others had not been mapped during the original survey. Minor amendments have been made to the classification of some of the superficial deposits in the north of the area.

Other changes to the mapped linework included revising the attribution of bedrock, artificial and superficial deposits, completing outcrop of Blue Anchor Formation that was missing beneath areas of landslide, revising some boundaries. Also noted were changes on the Warwick 1:50 000 sheet (184, 1984) that did not reflect the original mapping. What was mapped as the Upper Wolston Clay (a glaciolacustrine sequence) appears in the Cubbington and Offchurch- Hunningham areas as Thrussington Till. This is incorrect as it is above the Wolston Sand (now Wigston Sand and Gravel Member) which overlies the Thrussington Till. A decision was made to change this to TILMP-DMTN from Wolston Clay as some of the notes on maps suggested non-chalky till (i.e. not Oadby Till) and this may have been the reason for the change.

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

Borehole records examined included both Keyworth and Wallingford held logs. Closely clustered sets of boreholes were not all coded but the deepest and most representative were included. Any significant local variation in sequence was also recorded by coding. Entries were all made directly into the corporate BGS *Borehole Geology database* (BoGe). However, many of the boreholes were either very shallow and thus did not provide any data on the bedrock geology, or did not contain sufficient information to be coded in any meaningful way. This includes many of the old Chalk borehole records which do not provide sufficient data to subdivide the Chalk into its constituent formations.

After borehole coding was completed, the boreholes were extracted from the BGS *Single Onshore Borehole Index* (SOBI) database using a set of queries. The borehole log file (.BLG) needed to be deduplicated and a borehole filter tool was used to address this. A total of 253 boreholes were coded out of a total of 880 in the model area (Figure 3). The 116 boreholes used in the model and the 35 cross-sections constructed from them are shown in Figure 4.

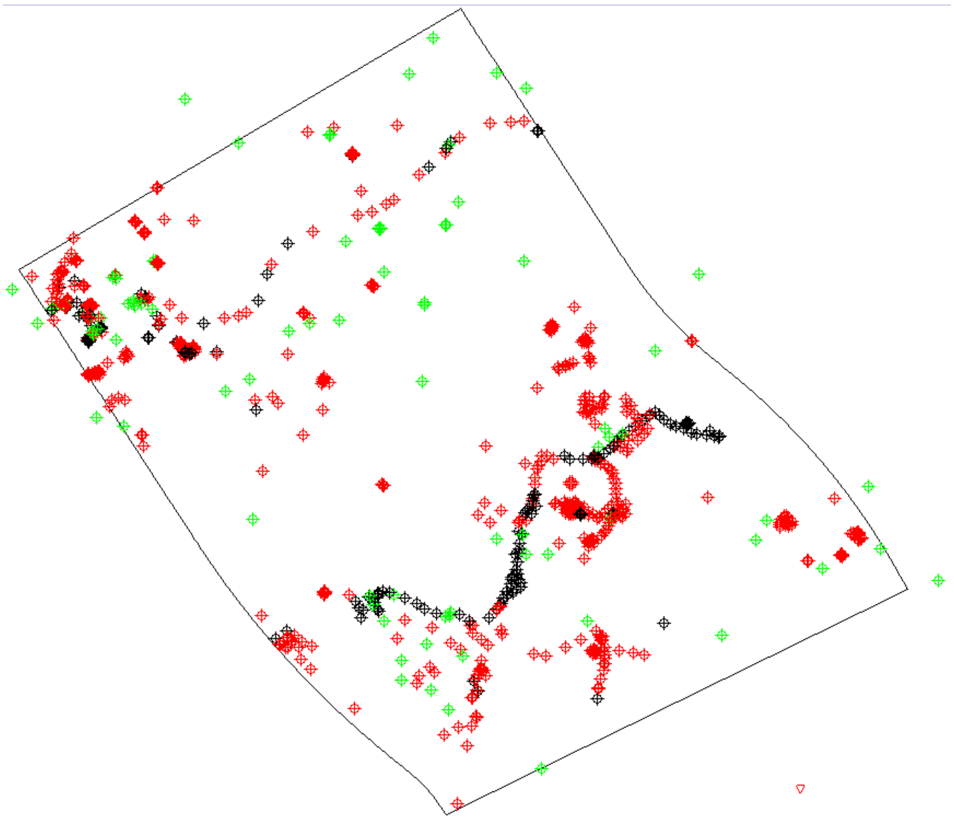

Figure 3 Distribution of all available borehole data in the model area. Boreholes with drilled depths under 10m are shown in black, those over 10m are coloured green. Red boreholes have no downhole information recorded in corporate databases. Model area outlined in black.

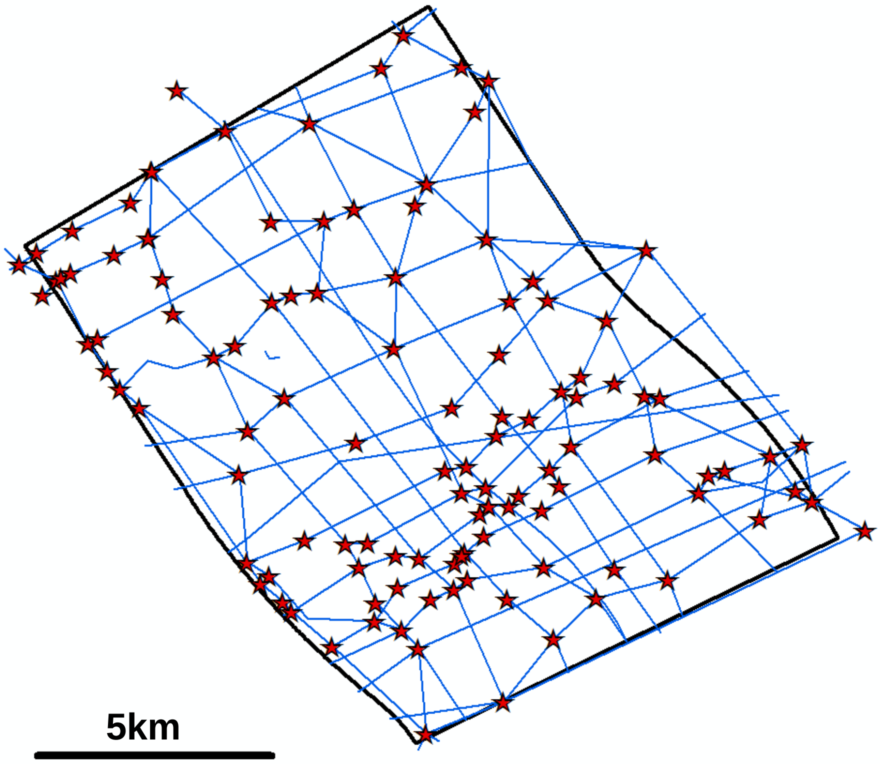

Figure 4. Distribution of boreholes used to constrain the 35 cross-sections in the model. Borehole locations are shown as red stars, cross-sections in blue, model area outlined in black.

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 5). These records are kept as part of the model storage and metadata (QA) process and can be accessed as needed.

> Artificial deposits added 13/6/14. Problems noted with current and former quarries in the Southam-Stockton area. Southam Quarry artificial deposits extended to cover recent extension to quarry. Areas of worked/infilled ground added in Stockton area that were not shown on 1:50K map
>
> Superficial added 13/06-01/07/14
>
> Additional cross sections added to help with calculation
>
> Superficial and artificial deposits successfully calculated

Figure 5. Example of model development log text

7 Model Assumptions, Geological Rules Used etc.

Where alluvium and first order river terrace deposits (RTD1-XSV) are adjacent to each other, RTD1-XSV has been extended beneath the alluvium. This is demonstrated in map view and in cross-section *HS2_Area5_SW-NE_Section2_KA* (Figure 6). Similarly, head deposits are also extended beneath alluvium where the two units meet.

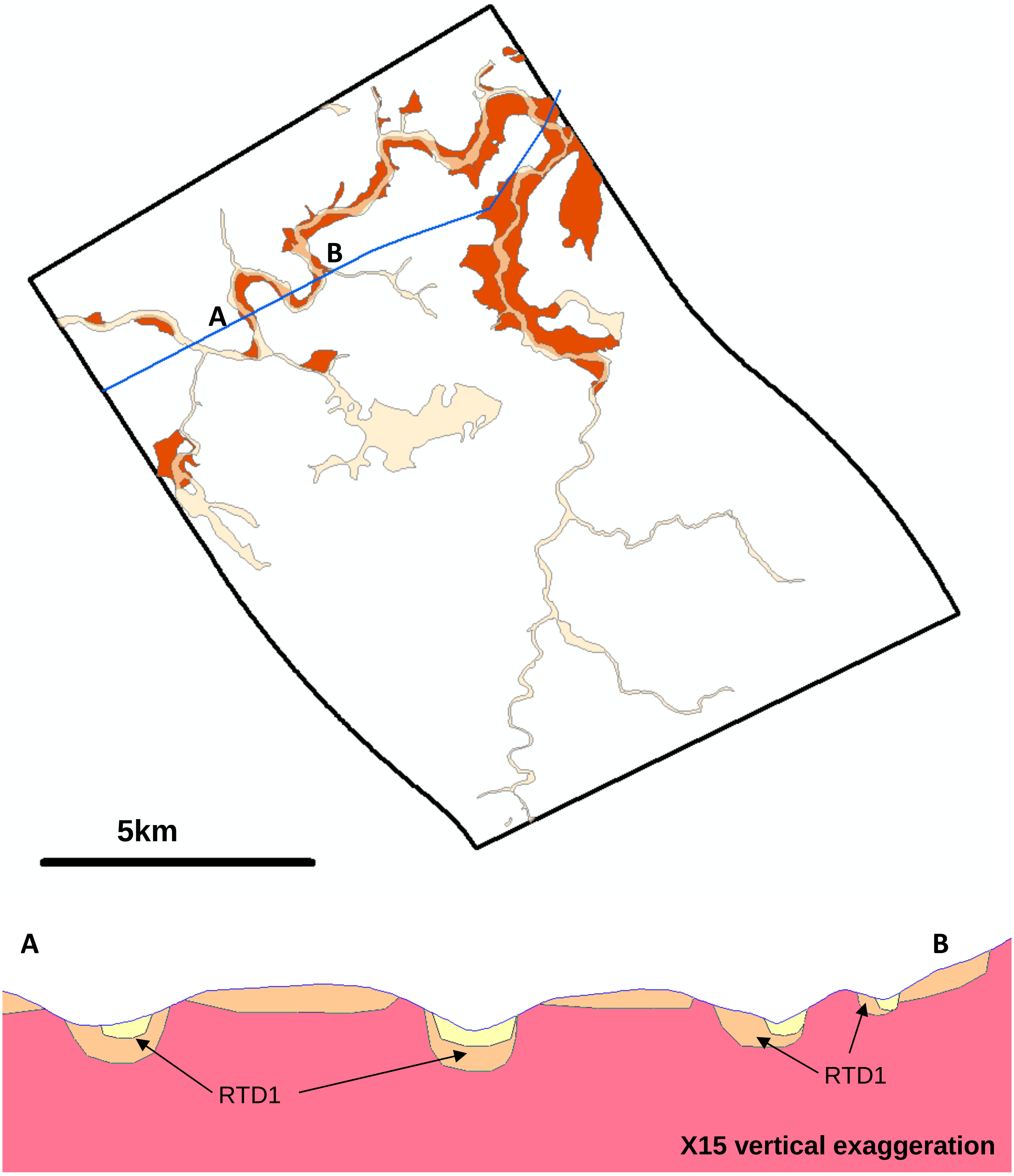

Figure 6. Extension of river terrace deposit RTD1- XSV beneath alluvium. Alluvium is pale yellow, with a transparency in the map view to show the underlying RTD1-XSV (orange). Cross-section *HS2_Area5_SW-NE_Section2_KA* is shown as a blue line. Alluvium is pale yellow in the cross-section and RTD1-XSV is pale orange.

The complexity of the sequence of glacigenic superficial deposits in the northern part of Area 5 means that although each of the units are generally inferred to extend beneath the overlying unit, there is local pinching/feathering out or overlapping of units such that they may also underlie units higher in the sequence. Their relative stratigraphic order is as shown in Table 1.

Local extension of units occurring beneath River Terrace Deposits as follows:

THT-DMTN extends under RTD2-XSV

THT-DMTN, WOL-XCZ extend under RTD3-XSV

THT-DMTN, WOSG-XSV, DMG-XSV extend under RTD4-XSV

In some of the deep boreholes the Tarporley Siltstone Formation is not distinguished. It is known to be present everywhere at the base of the Mercia Mudstone Group and has been constructed through the model with only an approximate thickness in places.

The geology of the area is described in Old *et al.*, (1987). On the map, the Westbury Formation and Cotham Member (now the Cotham Formation) have been combined into one unit, the Penarth Group. They are similar lithologically, have narrow outcrops and are retained combined in the model. The Langport Member (now renamed the White Lias Formation) is also part of the Penarth Group, but although thin (c. 2 m), is a distinctive marker bed that locally has a significant outcrop area.

The Upper Carboniferous Warwickshire Group is within the modelled depth only in the northern part of the area. It cannot be divided even to formation level in the model although locally, individual formations and members of the Salop Formation have been recognised in boreholes.

8 Model Limitations

8.1 MODEL SPECIFIC LIMITATIONS

The glacigenic stratigraphy is complex but generally in a layered sequence. Some areas of superficial deposits have been amended or changed, notably the Thrussington Till that has been renamed TILMP in parts of the model area, e.g. around Offchurch and in the Offchurch-Hunningham area.

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. The Whitnash Fault, at the western edge of the model, is not authentically represented in the model.

Two units are thin - WLI, and AS. These, and those thinning laterally beneath others or the DTM, required node densification (automatically, to 100 m-spacing, or manually) to avoid thin-skin effects in 3D. Not all these effects are fixed.

The Saltford Shale Member and Arden Sandstone Formation die out in the southern part of the area but the limits indicated are approximate because of the lack of borehole data. The Bromsgrove Sandstone, Tarporley Siltstone and Sidmouth Mudstone formations are present across all of Area 5 but south-eastwards extend below the modelled depth of -30 m AOD.

The Arden Sandstone Formation was previously mapped as a discontinuous unit. More recent work (Warrington *et al.*, 1980; Howard *et.al.*, 2008) has shown that is a continuous unit across much of the UK. Fieldwork was undertaken to correct this.

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). It has been added with limited fieldwork and, in places, has been run through the model with only an approximate thickness in places.

Figure 4 shows all boreholes available in Area 5, with those over 10 m deep coloured green. Figure 4 shows the boreholes chosen as potentially useful for constraining the model. Cross-sections are also shown, indicating where this subsurface data may constrain the model. This gives the model user some idea where the model is most and least 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

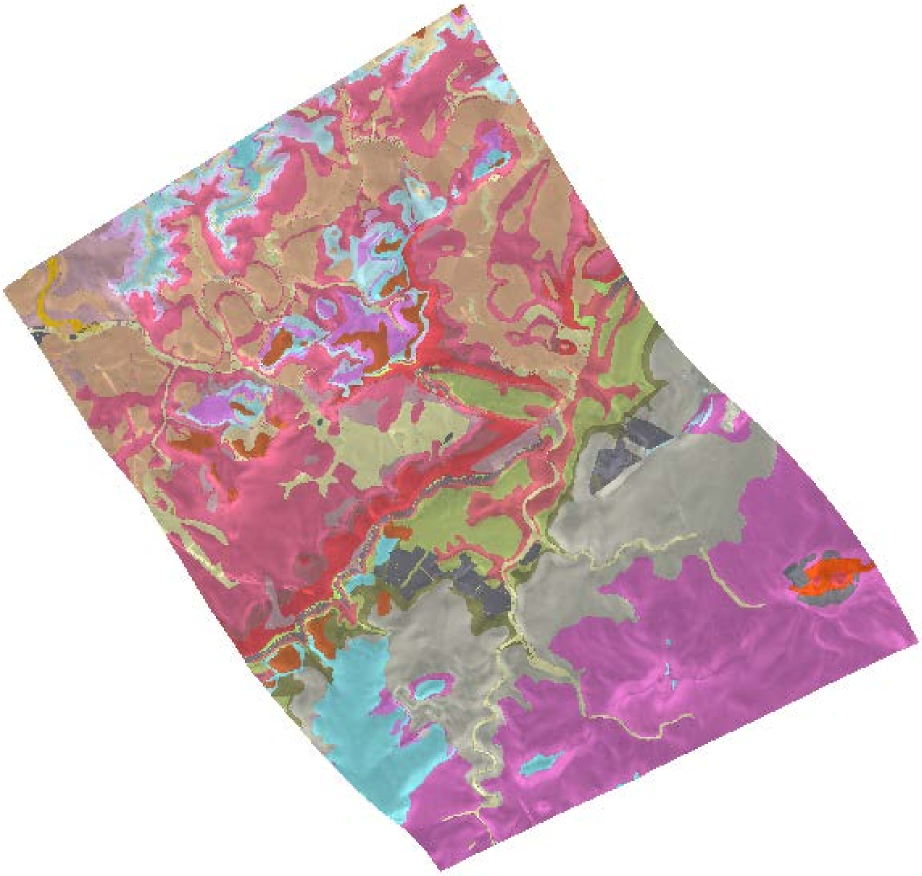

Figure 7. 3D plan view of calculated volumes of all units. Key to geology as per Table 1.

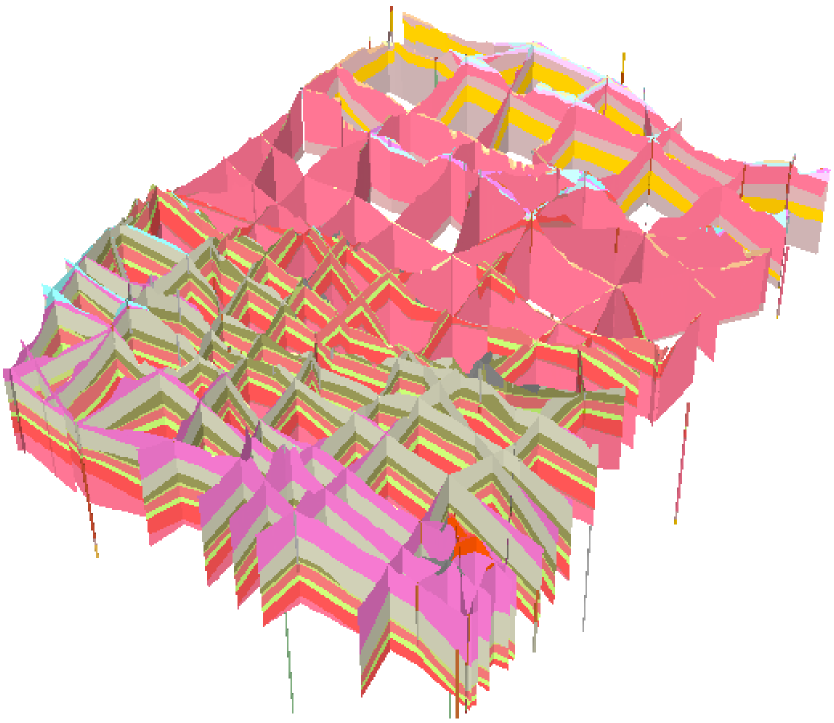

Figure 8. 3D oblique view of all Area 5 cross sections from the south east. Vertical exaggeration x15. Key to geology as per Table 1.

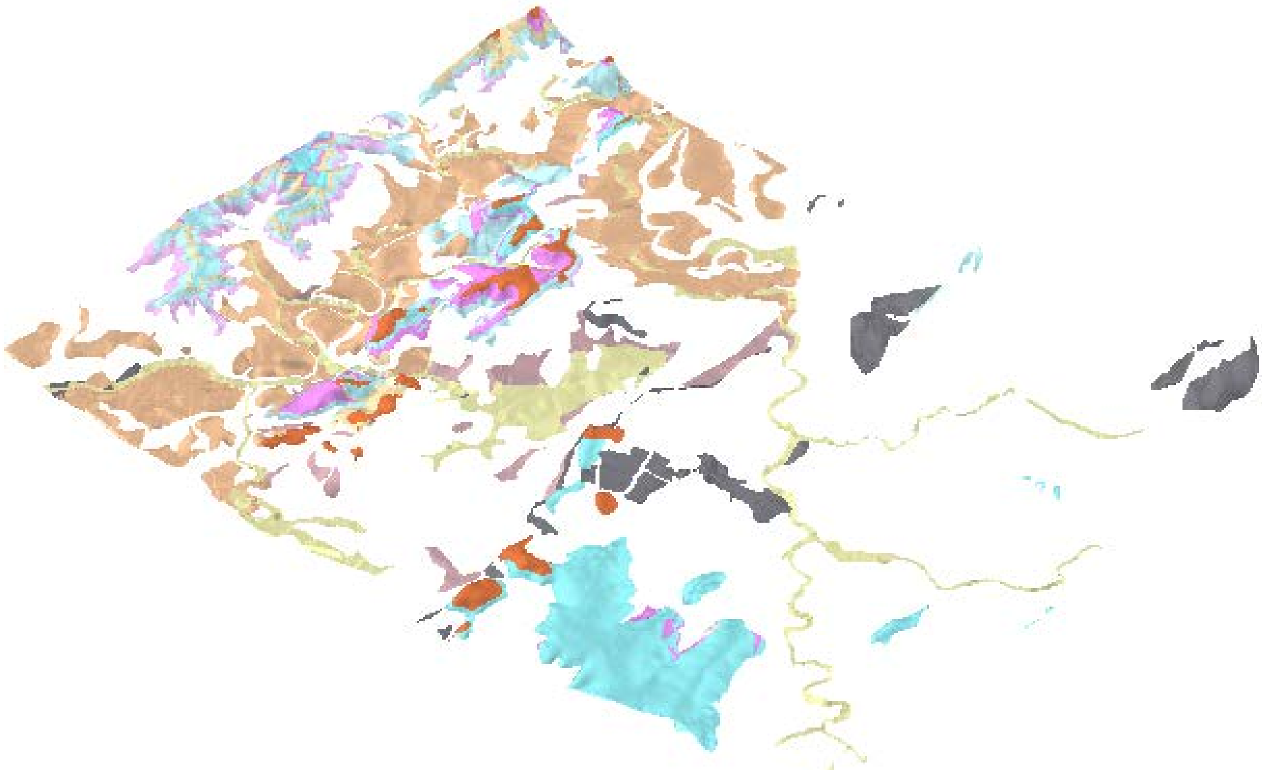

Figure 9. Oblique 3D 'exploded' view of all superficial and artificial deposits in Area 5 from the south. Vertical exaggeration X15. Key to geology as per Table 1.

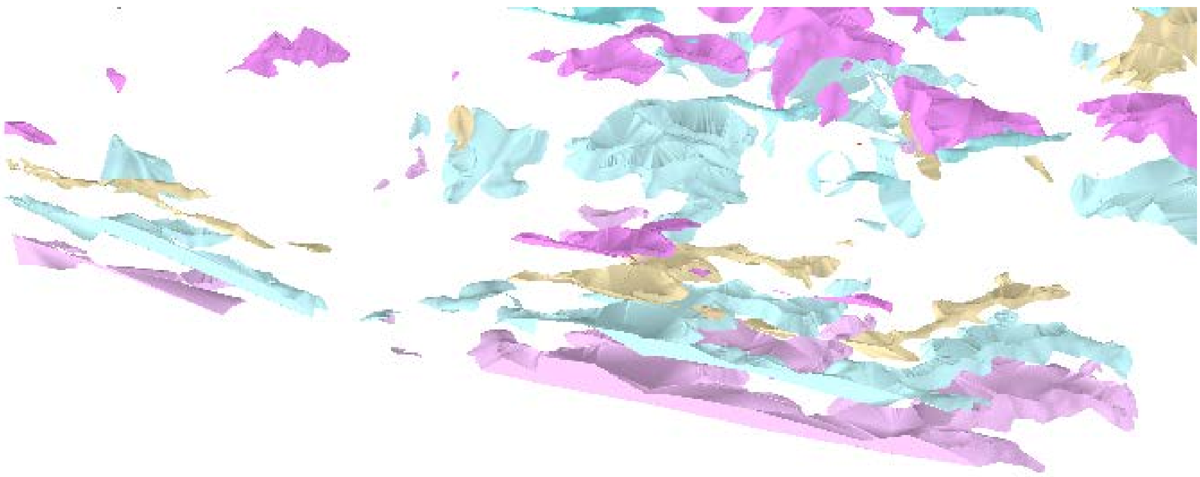

Figure 10. Oblique 'exploded' 3D view of the glacigenic sequence in the north of Area 5, viewed from the north west. Vertical exaggeration x15. Key to geology as per Table 1.

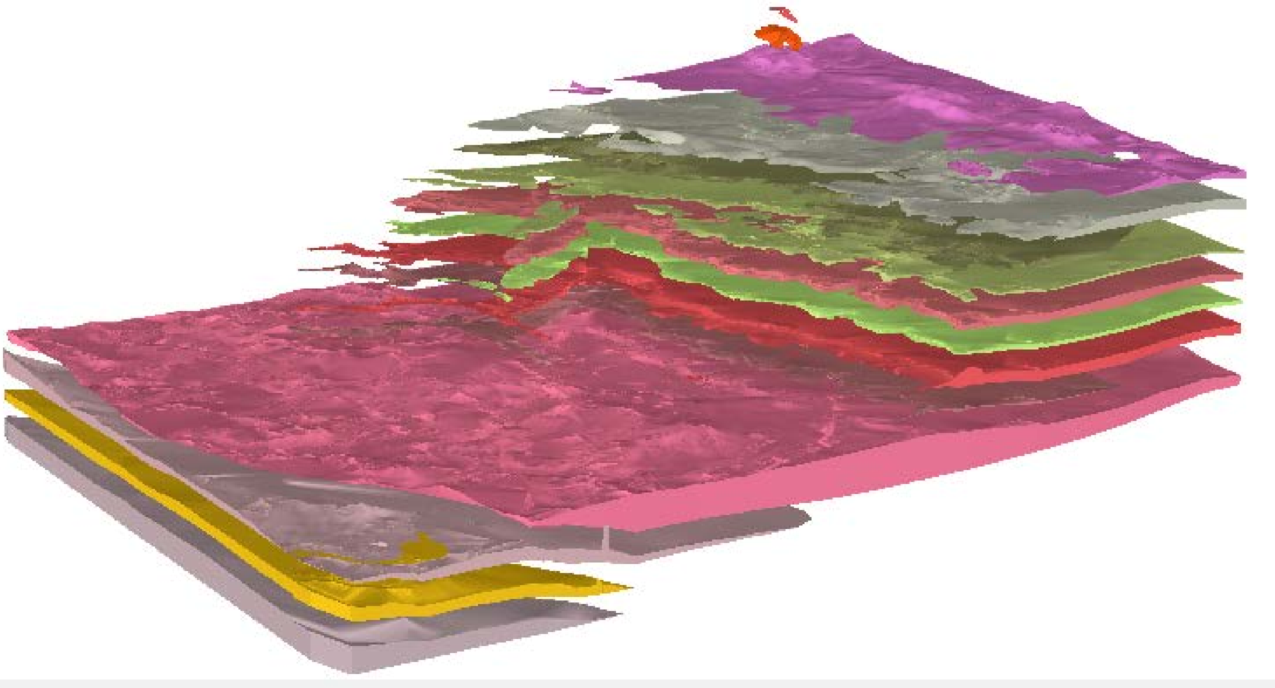

Figure 11. 3D oblique 'exploded' view of all bedrock volumes, from west. Vertical exaggeration x5. Key to geology as per Table 1.

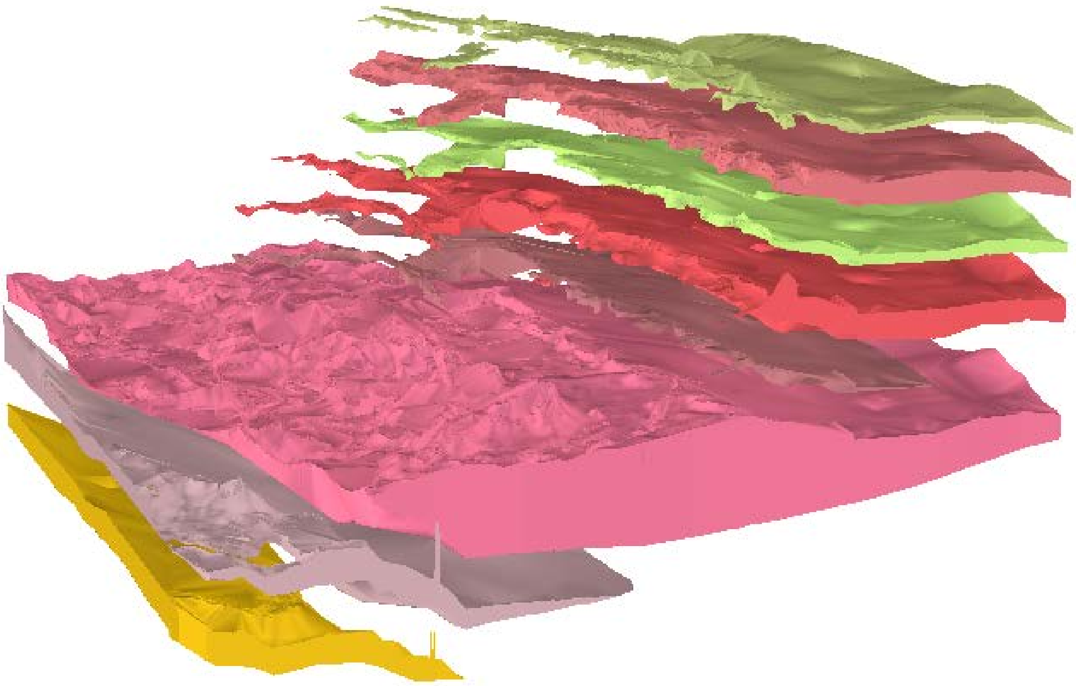

Figure 12. 3D oblique exploded view of the Triassic formations volumes, from the north-west, exaggeration X15. Key to geology as per Table 1.

Figure 13. 3D oblique exploded view of Lias Group formations volumes, from the north west, exaggeration X15. Key to geology as per Table 1.

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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