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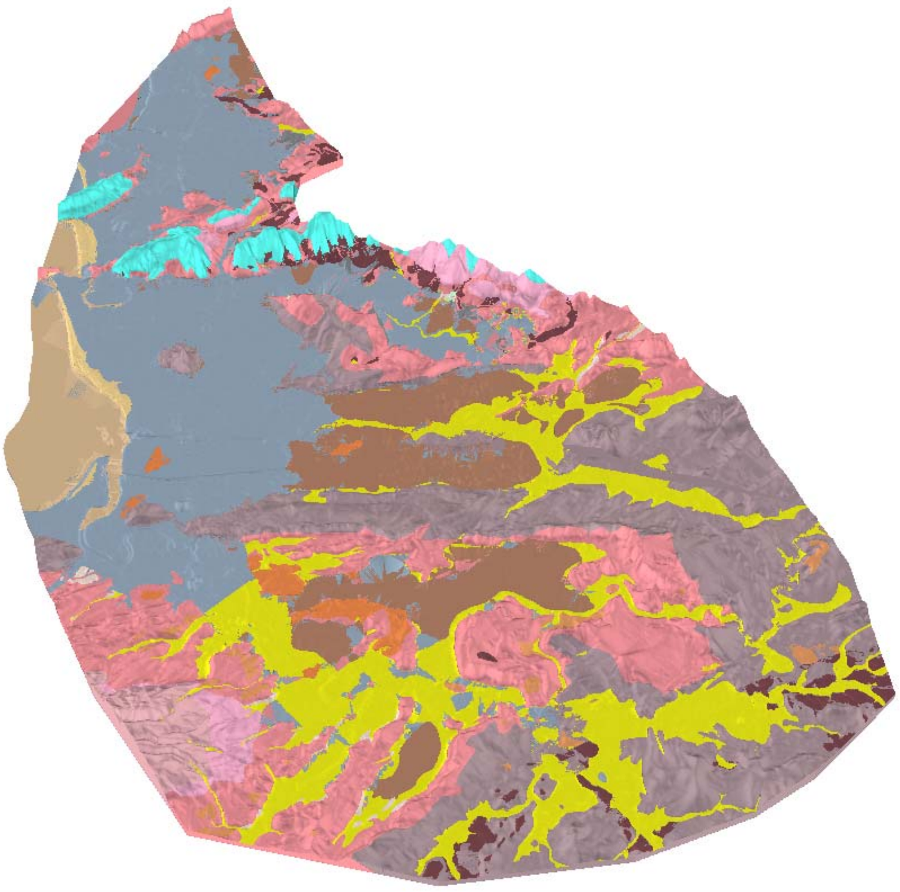
# Model metadata report for the Somerset Levels 3D geological model

Geology and Regional Geophysics Programme

Open Report OR/13/050



BRITISH GEOLOGICAL SURVEY

GEOLOGY AND REGIONAL GEOPHYSICS PROGRAMME

OPEN REPORT OR/13/050

# Model metadata report for the Somerset Levels 3D geological model

H. Gow, C. Cripps, S. Thorpe, C. Horabin & J. R. Lee



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Somerset Levels 3D geological model, looking SW to NE

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# Foreword

This metadata report describes the data and workflow used in a 3D modelling study by the British Geological Survey (BGS) of the Somerset Levels. The model was initially produced as a superficial deposits model under the Landscape Evolution team, part of the Climate Change programme during 2009/2010. The model was revised in 2014 as part of the Geology and Regional Geophysics Programme to provide a basic, low-resolution, geological framework model in response to the flooding crisis in the region. This revised model also includes 1:625k bedrock geology data.

# Acknowledgements

The authors would like to thank Stephen Booth for providing his local knowledge, geological expertise and continued enthusiasm for this project, and Ricky Terrington for providing modelling guidance.

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# Summary

This report summarises the data, information and methodology used in a 3D geological model of the Somerset Levels. The model was constructed using the GSI3D software package and comprises superficial deposits at 1:50,000 scale and lower resolution bedrock units.

# 1 Modelled volume, purpose and scale

The project area encompasses the catchments of the rivers Parrett and Brue and their outflow to the Bristol Channel, as well as other areas of low elevation that collectively form the Somerset Levels (Figure 1,2). The 3D geological model of the Somerset Levels was initially developed in 2009/10 to increase our understanding of the marine, near-coastal and terrestrial response to environmental change during the Late Quaternary. The model has since been revised in 2014 to include all Quaternary deposits and generalised bedrock with a model cut-off depth of -28 m OD. The model can be used to highlight broad areas of environmental vulnerability that can be targeted during subsequent studies.

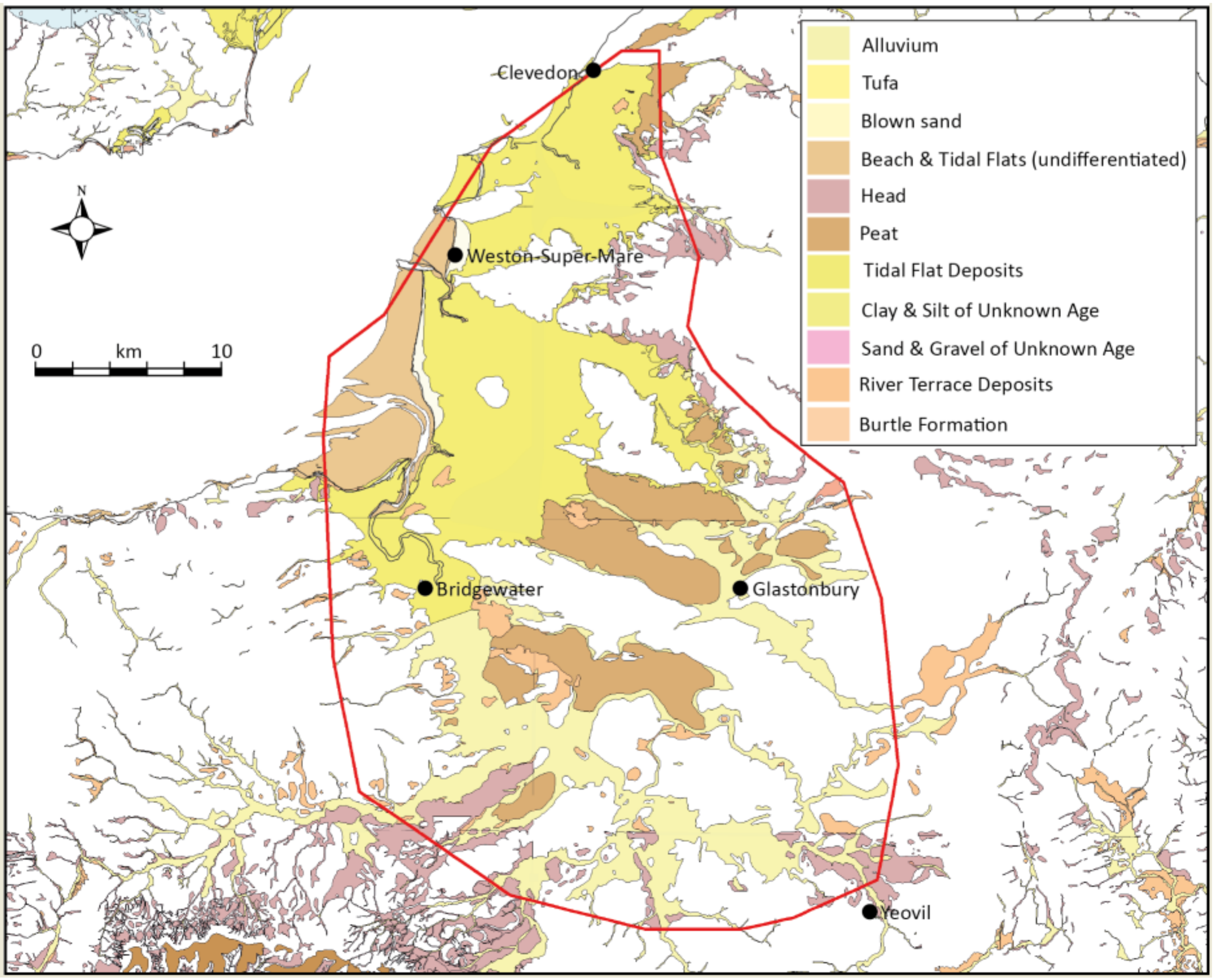


**Figure 1. Project area and 1:50,000 scale superficial geology.**

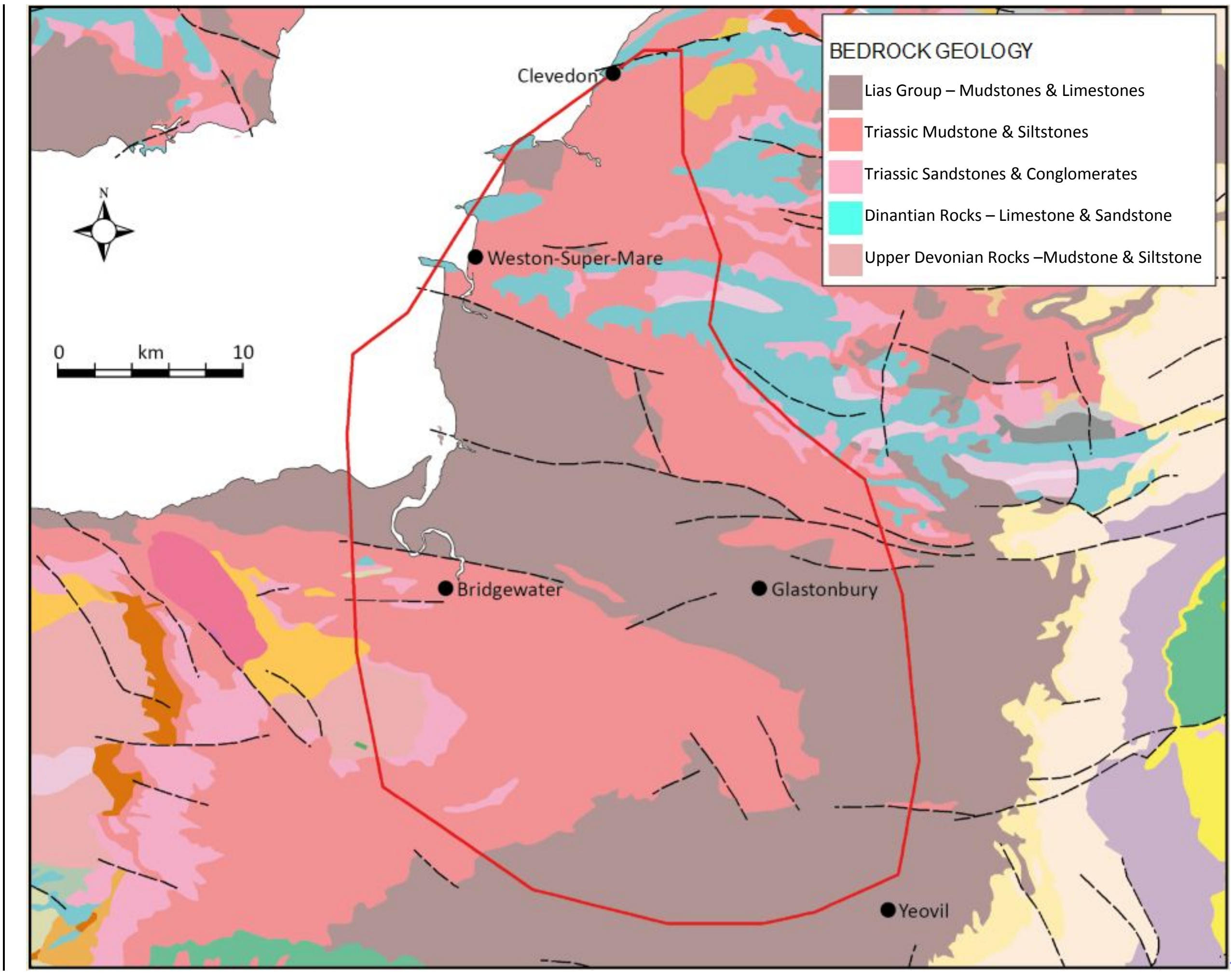


**Figure 2. Project area and 1:625,000 scale bedrock geology. Also shown on the map are known fault systems. These are shown on the map as dashed lines but have not been modelled.**

# 2 Modelled surfaces/volumes

Below is a list of units that have been modelled as volumes in the Somerset Levels model (BGS lexicon codes in brackets, www.bgs.ac.uk/lexicon).

Superficial deposits:

- Alluvium (ALV)
- Tufa (TUFA)
- Blown sand (BSA)
- Beach and Tidal Flats, Undifferentiated (BTFU)
- Peat (PEAT3)
- Head (HEAD)
- Tidal Flat Deposits (TFD2)
- Peat (PEAT2)
- Tidal Flat Deposits (TFD1)
- Peat (PEAT1)

- Sand and Gravel (SGAO)
- River Terrace Deposits, 1 (RTD1)
- River Terrace Deposits, Undifferentiated (RTDU)
- Unknown Drift (UNKND)
- Burtle Formation (BUB)

Bedrock deposits:

- Lias Group (LIAS)
- Triassic Rocks – Mudstones and Siltstones (TRIAS-MDSS)
- Triassic Rocks – Sandstones, Conglomerate (TRIAS-SCON)
- Dinantian (DINA)
- Upper Devonian (UDEV)

These geological units were chosen to best represent the current 1:50,000 scale superficial and 1:625,000 scale bedrock geology in the Somerset Levels basin. For the units TFD1, TFD2, PEAT1, PEAT2, PEAT3 that don't conform to standard BGS lexicon entries, we assigned them an informal unit name and status. These units all belong to the Somerset Levels Formation as defined by McMillan et al. (2011)

In some locations, sand and peat have been modelled as lenses when they could not be correlated into a particular unit, such as sand channels or small areas of peat. These units only occur within the Quaternary (superficial) succession.

# 3 Modelled faults

Due to time constraints no faults were modelled in the bedrock but are known to occur and will need to be included within any upgrade of the model.

# 4 Model datasets

General caveats regarding BGS datasets and interpretations are:

- Geological observations and interpretations are made according to the prevailing understanding of the subject at the time. The quality of such observations and interpretations may be affected by the availability of new data, by subsequent advances in knowledge, improved methods of interpretation, improved databases and modelling software, and better access to sampling locations.
- Raw data may have been transcribed from analogue to digital format, or may have been acquired by means of automated measuring techniques. Although such processes are subjected to quality control to ensure reliability where possible, some raw data may have been processed without human intervention and may in consequence contain undetected errors.
- All bedrock units have been simplified and faults are not included in the model (i.e. modelled as un-faulted objects).

- A flat cut-off base has been applied to the model at -28m OD. This should not be interpreted as the base of any of the geological units, simply a level for the extent of the modelling.
- Some discrepancies with the borehole start heights were noted, and these are attributed to errors in data ingestion but additionally could be a result of anthropogenic changes (peat workings, draining of peat areas) or natural processes of soil compaction/ablation.

## 4.1 Digital Terrain Model (DTM)

The geological model uses a capping surface to define the uppermost limit of the model. This Digital Terrain Model (DTM) is derived from the NextMap 5 m DTM (InterMap Technologies) at a subsampled scale of 50 m. Due to limitations of the DTM (such as the inclusion of trees) the whole dataset has been further refined by removing woodland and is stored corporately as the 'BaldEarth Model' (Figure 3). 'BaldEarth' is a BGS derived dataset produced by combining NextMap data (licensed to BGS) and free Ordnance Survey (OS) Panorama Data. It was generated to cope with deficiencies in the NextMap data associated with forested land.

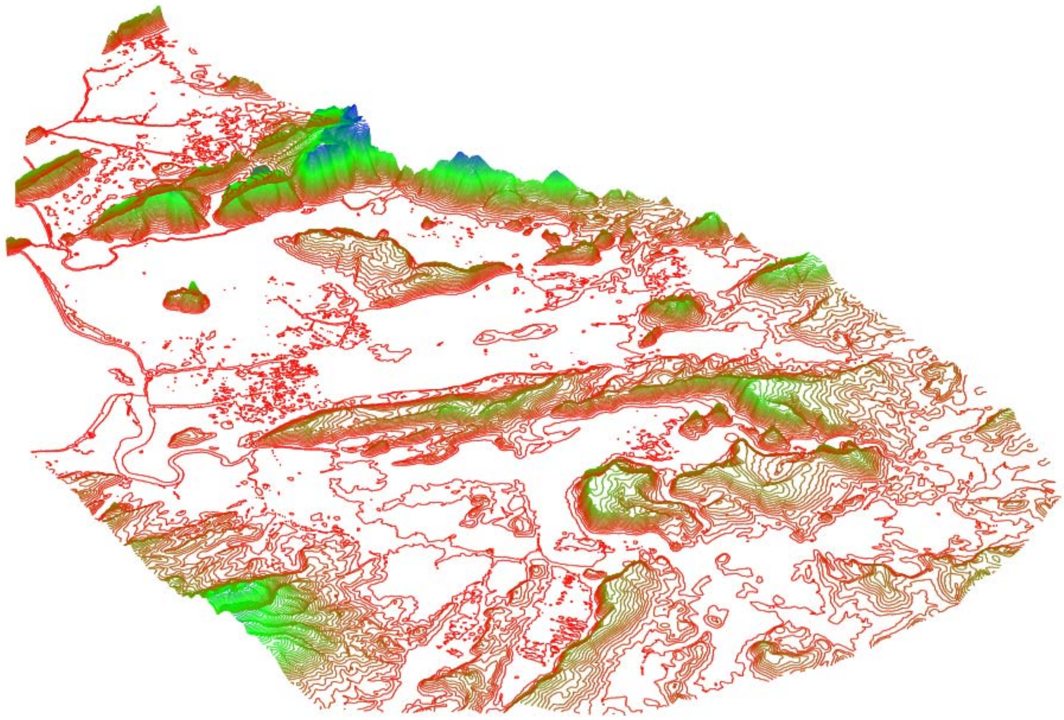

**Figure 3. BGS BaldEarth DTM shown as 5m contour intervals (x10 vertical exaggeration).**

## 4.2 Borehole Data

Borehole records held by BGS are stored and administered within a corporate database called the Single Onshore Borehole Index (SOBI) and this includes basic information such as borehole location, surface elevation and date of drilling. Interpretative and factual geological information obtained from these boreholes (i.e. drill depth, geological sub-division), is held within a separate but parallel database called Borehole Geology (BOGE) (Figure 4).

Within BOGE, a project index file was generated containing the borehole records used within the Somerset Levels model (Figure 5). As per the project coding guidelines, four boreholes per 10 $km^2$ were selected to be interpreted. These boreholes were then attributed according to their lithology using the Unlithified Deposits Coding Scheme (Cooper et al., 2006) creating a series of downhole logs. These logs were then input into the geological modelling software and form the basis of the geological interpretation (Section 4.4). Other projects may have interpreted boreholes from the study area but these have not been included in this model.

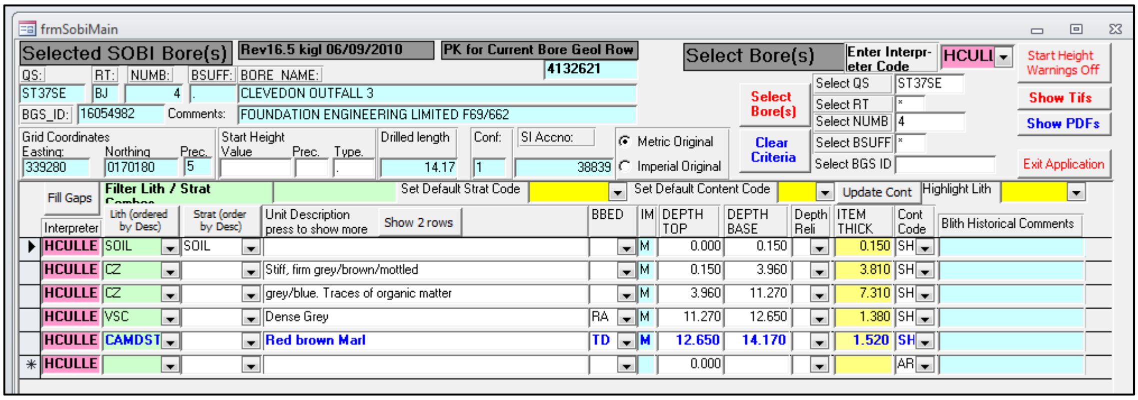


**Figure 4. Borehole Geology Database.**

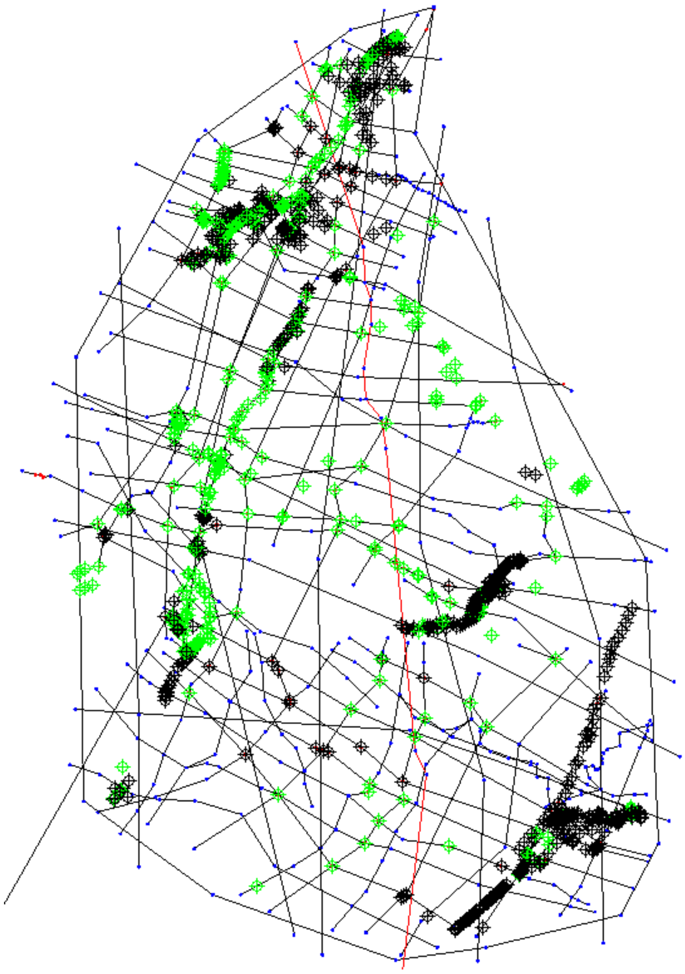

**Figure 5. Boreholes and cross-section locations. Boreholes drilled to a length of 10m or less are shown as black points, those deeper than 10m are green points.**

## 4.3 Map Data

- BGS 1:50,000 superficial DiGMap GB was used for outcrop and geological unit formation (Version 2.18, released 22/05/2008).

- BGS 1:625,000 bedrock DiGMap GB was used for outcrop and geological unit formation (Version 5.17, released 11/02/2008).
- BGS 1:50,000 Glastonbury 296 Bedrock and Superficial geological map (British Geological Survey, 1973)
- BGS 1:50,000 Wells 280 Bedrock and Superficial geological map (British Geological Survey, 1984)
- BGS 1:50,000 Bristol 264 Bedrock and Superficial geological map (British Geological Survey, 2004)
- OS OpenData 1:50,000 map data was used as the base topographical map.

## 4.4 Generalised Vertical Section (GVS) and Geological Legend (GLEG)

GSI3D modelling software uses two files to describe the stratigraphical order and colours of the units contained in the model. These are the Generalised Vertical Section (GVS) file which contains the name and stratigraphical relationships for every geological unit in the model together with its lithology (defined by the BGS Rock Classification Scheme) and a description field (Table 1).Table 1. GVS used in Somerset Levels 3D model. Thick black line represents the superficial to bedrock boundary.

| Model Name | LEX | RCS | Full Name | Age | Description |
|---|---|---|---|---|---|
| alv | ALV | CZSV | Alluvium | Quaternary (Holocene) | Fluvial Silty clay, but can contain layers of silt, sand, peat and basal gravel |
| tufa | TUFA | CATUFA | Tufa | Quaternary | Calcareous deposits at or near springs and seepages |
| bsa | BSA | S | Blown Sand | Quaternary | Sand dunes |
| btfu | BTFU | CZS | Beach and Tidal Flat Deposits (Undifferentiated) | Quaternary | Composite of 'Beach deposits': Shingle, sand, silt and clay. Beach deposits may be in the form of dunes, sheets or banks, and 'Tidal Flat Deposits': commonly silt and clay with sand and gravel layers; possible peat layers; from the tidal zone |
| peat3 | PEAT_3 | P | Peat ‘3’, ‘upper peat’ | Quaternary | Informal unit of Somerset Levels Formation. Accumulation of wet, dark brown, partially decomposed vegetation. |
| head4 | HEAD_4 | CZSV | Head ‘4’ | Quaternary | Head - Colluvium/hillwash (probably post 5000 years BP) |
| tfd2 | TFD_2 | CZSV | Tidal Flat Deposits ‘2’, ‘upper estuarine clay’ | Quaternary (Holocene) | Informal unit of Somerset Levels Formation. Normally a consolidated soft silty clay, with layers |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | of sand, gravel and peat. Characteristically low relief; from the tidal zone. |
| peat2 | PEAT_2 | P | Peat '2', 'middle peat' | Quaternary | Informal unit of Somerset Levels Formation. See description of peat_3 |
| tfd1 | TFD1 | CZSV | Tidal Flat Deposits 1, 'lower estuarine clay' | Quaternary (Holocene) | Informal unit of Somerset Levels Formation. See description of tfd_2 |
| peat1 | PEAT_1 | P | Peat '1', 'lower peat' | Quaternary | Informal unit of Somerset Levels Formation. See description of peat_3 |
| sgao | SGAO | VS | Sand And Gravel Of Uncertain Age And Origin | Quaternary | probably Devensian - OIS2 or OIS4 in age |
| rtd1 | RTD1 | SV | River Terrace Deposits, 1 | Quaternary | Sand and gravel, locally with lenses of silt, clay or peat |
| rtdu | RTDU | VS | River Terrace Deposits (undifferentiated) | Quaternary | Sand and gravel, locally with lenses of silt, clay or peat |
| unknd | UNKND | CZSV | Unknown Drift (superficial deposits) | Quaternary | Silty clays of unknown age and origin |
| bub | BUB | SV | Burtle Formation | Quaternary (Pleistocene) | Marine sands and gravels with shells - Ipswichian OIS5e in age |
| Lias | LI | MSLS | Lias Group | Jurassic | Lias Group. Mudstone, siltstone, limestone and sandstone |
| trias-mdss | TRIA | MDSS | Triassic rocks - mudstone, siltstone and sandstone | Triassic | Mercia Mudstone and Penarth groups, undifferentiated. Mudstone, siltstone and sandstone. |
| trias-scon | TRIA | SCON | Triassic rocks - sandstone and conglomerate | Triassic | Mainly Sherwood Sandstone Group. Sandstone and conglomerate. |
| dina | DINA | LSSA | Dinantian rocks undifferentiated | Carboniferous | Avon and Pembroke Limestone groups, undifferentiated. Limestone with subordinate sandstone and argillaceous rocks. |
| udev | UDEV | MDSS | Upper Devonian rocks | Devonian | Upper Devonian rocks. Mudstone, siltstone and sandstone. |
| sand_lens_top | CHAN | S | Top of channel lens | Quaternary | Top of sand lens found within the tidal flat deposits. |
| peat_lens_top2 | PEAT | P | Top of peat lens | Quaternary | Top of peat lens found within the tidal flat deposits. |

| | | | | | |
|---|---|---|---|---|---|
| peat_lens_top1 | PEAT | P | Top of peat lens | Quaternary | Top of peat lens found within the tidal flat deposits. |

The Geological Legend (GLEG) contains information to provide colour to the model. The software uses a simple Red-Green-Blue reference system, so in Table 2 columns 3, 4 & 5 refer to the Red, Green and Blue values and the final column refers to the transparency value for every unit in the model.

**Table 2. GLEG used in Somerset Levels 3D model.**

| | | | | | |
|---|---|---|---|---|---|
| ALV | DESCRIPTION | 255 | 255 | 0 | 255 |
| TUFA | DESCRIPTION | 204 | 255 | 204 | 255 |
| BSA | DESCRIPTION | 255 | 221 | 138 | 255 |
| HEAD | DESCRIPTION | 124 | 64 | 64 | 255 |
| PEAT | DESCRIPTION | 188 | 130 | 92 | 255 |
| TFD | DESCRIPTION | 153 | 176 | 190 | 255 |
| SGAO | DESCRIPTION | 255 | 201 | 255 | 255 |
| RTDU | DESCRIPTION | 246 | 160 | 89 | 255 |
| UNKND | DESCRIPTION | 130 | 136 | 132 | 255 |
| BUB | DESCRIPTION | 255 | 139 | 61 | 255 |
| LI | DESCRIPTION | 176 | 148 | 148 | 255 |
| TRIAS-MDSS | DESCRIPTION | 255 | 148 | 148 | 255 |
| TRIAS-SCON | DESCRIPTION | 255 | 176 | 201 | 255 |
| DINA | DESCRIPTION | 84 | 255 | 237 | 255 |
| UDEV | DESCRIPTION | 237 | 176 | 176 | 255 |
| CHAN | DESCRIPTION | 255 | 249 | 158 | 255 |

### 4.5 Rockhead Elevation Model (RHEM)

Where insufficient borehole data was available, the BGS Rockhead Elevation Model (version 2009) was used as a guide to determine the depth of the superficial deposits. This data has since been superseded but for continuity with the previous modelling, the 2009 version was used.

# 5 Model development log

During the course of the modelling, each modeller kept a running log of the development, changes and decisions made for their designated modelling areas (Figure 6). These records are kept as part of the model storage and metadata (QA) process and can be accessed as needed.

17/02/10

Group_v4_12.gsipr

Checked SH_EW_hcullen_11, Checked SH_EW_hcullen_12, Checked SH_EW_hcullen_13, Checked SH_NS_hcullen_01, Checked SH_NS_hcullen_02, Checked SH_NS_hcullen_03, Checked SH_NS_caip_1, Checked SH_NS_caip_2, Checked SH_NS_caip_3, Checked SH_NS_caip_4
Group_v4_13.gsipr

18/02/10

Checked SH_EW_caip_01, Checked SH_EW_caip_02, Checked SH_EW_caip_03, Checked SH_EW_caip_04, Checked SH_EW_caip_05, Checked SH_WE_cgh_1, Checked SH_NS_cgh_1
Group_v4_14.gsipr

19/02/10

Checked SH_NS_cgh_2, Checked SH_WE_cgh_2, Checked SH_WE_cgh_3, Checked SH_NS_cgh_4, Checked SH_NS_cgh_3
Group_v4_14.gsipr

12/3/10
Group_v4_19.gsipr

**Figure 6. Example of a development log.**

# 6 Model workflow

GSI3D geological modelling software uses a series of files to setup the working project file. These are:

- Geological Vertical Section (GVS) – a file which contains the stratigraphical order of the geological units
- Geological Legend (GLEG) – a file describing the colours for the geological units
- Borehole ID (BID) – a file containing the location and start height of each borehole
- Borehole Log (BLG) – a file containing the geological information found within the borehole and its depths
- DTM – capping surface to the model
- Rockhead Elevation model
- Map data

The standard GSI3D workflow (Kessler and Mathers, 2004; Kessler et al., 2009) allows the modeller to create cross-sections across the project area by connecting boreholes and correlating the baselines for each of the geological units. Once a series of cross-sections have been created a distribution for the outcrop and subcrop for each unit can be described. 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. The modeller can then 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 whole process is a standard methodology for creating superficial geological models and is documented in the following publications (Kessler & Mathers, 2004; Kessler *et al* 2009).

Two exceptions to the standard methodology have been employed to enable a better model to be produced. Firstly, alluvium can be a very thin and discontinuous unit and this can cause problems with the model calculation. To improve the quality of model calculation, a depth of 2m has been applied to the DTM and exported as a grid of points. This grid has been trimmed by the alluvium surface distribution polygon (which was further buffered by 2m around its outline) and where any cross-section correlation has been drawn, a buffer distance of 100m has been applied to the section. The resulting grid has been used to form the base to the unit. The second exception relates to the model calculation of bedrock units and uses a similar gridding technique. Due to the nature of the geology (some units extend to depths greater than the base of the model) an arbitrary base has to be drawn to create a neat model base. This has been drawn at -28m OD. For each of the bedrock units the distribution envelope has been taken and applied to a -28m grid to create a flat surface for each unit. This surface has then been loaded into the model and the calculation takes into account the base surface together with the correlation points along all sections.

# 7 Model assumptions and geological rules

- For the purposes of geological modelling tidal flat deposits have been delineated into two units (*tfd2* and *tfd1*) which are separated by peat. In reality, the tidal flat deposits form part of a continuum and little stratigraphic sub-division is evident. These units are mapped as TFD on BGS 1:50,000 scale DiGMapGB datasets.
- It is believed that the modern alluvium is too extensive to be attributable to the action of river deposition alone. In particular, there looks to be a straight, arbitrary line drawn delimiting the alluvium with other deposits; this can be seen just south of Bridgwater. This suggests that there is some discrepancy in the meaning of the term ‘alluvium’. It is thought that alluvium was used a blanket term for all fine grained siliciclastic deposits at surface in this area, particularly in the higher reaches of the basin, even if it was thought that the ‘alluvium’ had a marine origin of deposition. However, for the purposes of this model, we have kept to the original mapping of the alluvium.
- The unit *unknd* (Unknown Drift) is mapped as ‘Higher Estuarine Alluvium’ on the published Wells 1:50,000 geological map, and it is mapped as TFD1 on BGS 1:50,000 scale DiGMapGB dataset. As the code TFD1 was already in use and to distinguish it from other TFD units, it was decided to assign the unit a map code that did not imply a mode of origin. Green (1965) proposes an estuarine environment of deposition, and that the units post-date the Head deposits, and pre-date the TFD deposits. The units in the model and GVS adhere to this hierarchy.
- Outside of borehole control, there is poor lateral heterogeneity due to the nature of the superficial deposits. This means that which means that most of the model is constructed using conceptual knowledge, and it is likely that there is more complexity to the superficial deposits than has been modelled.

- Due to the discontinuous nature of the peat deposits within the tidal flat sediments, *tfd1* and *tfd2* were reconstructed through all cross-sections that contain superficial deposits beneath a depth of c.0 m OD. This coincides broadly with the base of *peat2* which is interpreted as a former land-surface. Where this peat was not encountered, the base of *tfd2* was constructed around 0m OD with some variance on a section-to-section basis (+/-3m). All underlying tidal flat units are correlated as *tfd1*. In certain areas, such as the smaller valleys, the relationship between *tfd2* and *tfd1* was rationalised as the same rules could not be applied. In these areas the tidal flats were either removed or reduced to *tfd2*.
- Further to the above point, the nature of the peat has led to a number of possible models being proposed as to the number and extent of the peat deposits. In some areas it is unclear whether a peat at surface will continue laterally underneath the tidal flat deposits, or become a separate unit below the tidal flat deposits. During modelling, both ideas were put forward and the current position as modelled is the one believed to be correct. With further study (greater borehole interrogation, more cross-sections, GIS study of the bases of all peat layers) this may prove to be incorrect.
- The depths of superficial deposits within the basin were taken from the borehole data where possible. Where insufficient evidence exists, the rockhead elevation model surface (RHEM 2009) was used as a guide.

# 8 Model limitations

- This model is a rapid-response, low-resolution model aimed at providing a basic geological framework for the region and should not be used for detailed analysis of the surface or sub-surface. As such, the built model only reflects the generalised complexity and geometry of the superficial and bedrock geology of the area.
- The GSI3D modelling software relies on a generalised vertical section (GVS) to define the sequence of units. The sporadic distribution and interdigitation of peats within the tidal flat deposits meant that this stratigraphical sequencing would not function with the limitations of the GVS. Because of this the tidal flat deposits had to be sub-divided to allow the peat units to be correlated.
- Since modelling commenced in 2009, additional boreholes, improved elevation data and relevant literature have been identified although not incorporated into this revised model. Adding this data to the model would greatly improve its resolution and quality. Due to time constraints it has not been possible to implement this into the 2014 revision. In the future this should be a priority should a higher resolution model be required.
- Due to the shallow and thin nature of the superficial deposits in this area, the calculation of the model could be improved by constructing further cross sections.

# 9 Model images

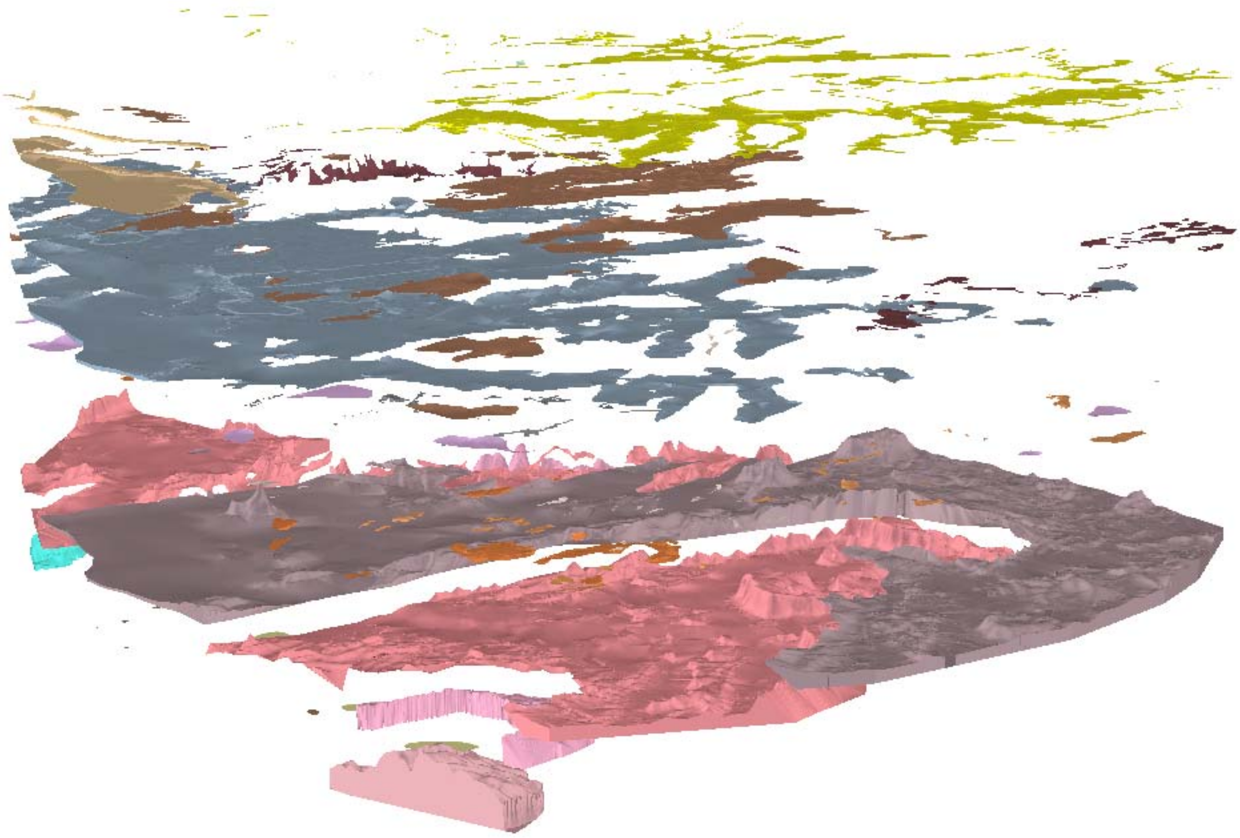

**Figure 7. Exploded view showing the individual units of the Somerset Levels 3D model looking from SW to NE. The main units being Triassic rocks (pink), Lias Group (grey/brown) through to the superficial deposits of Tidal Flats (blue), Peats (brown) and Alluvium (yellow) (x10 vertical exaggeration).**

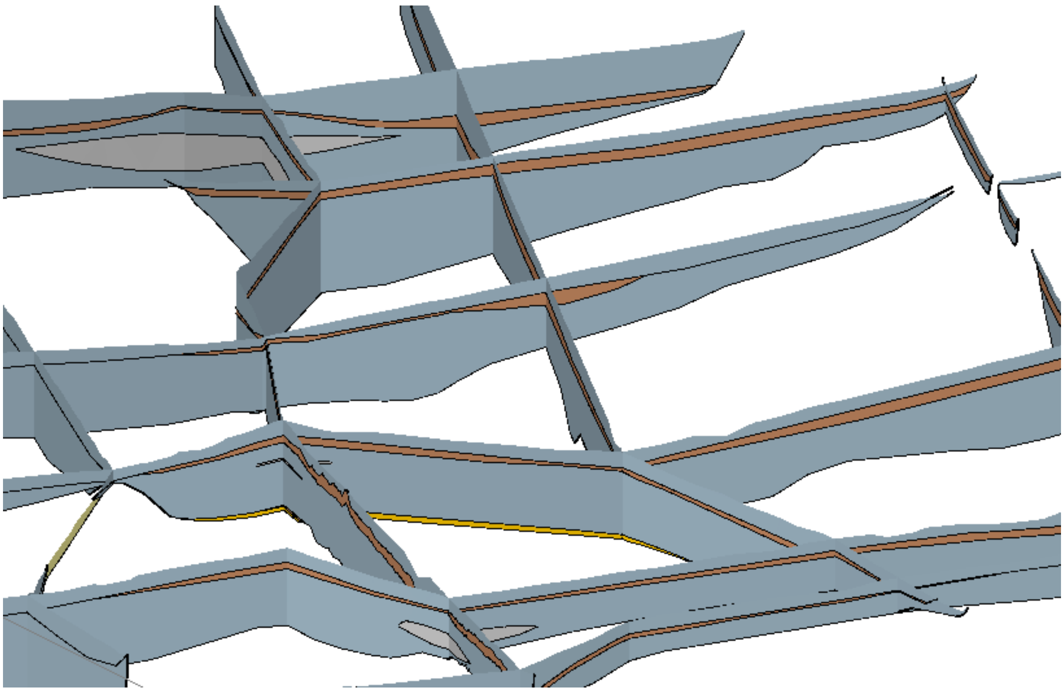

**Figure 8. Correlated cross-sections in 3D showing tfd1 and tfd2 (blue) separated by peat2 (brown) (x20 vertical exaggeration).**

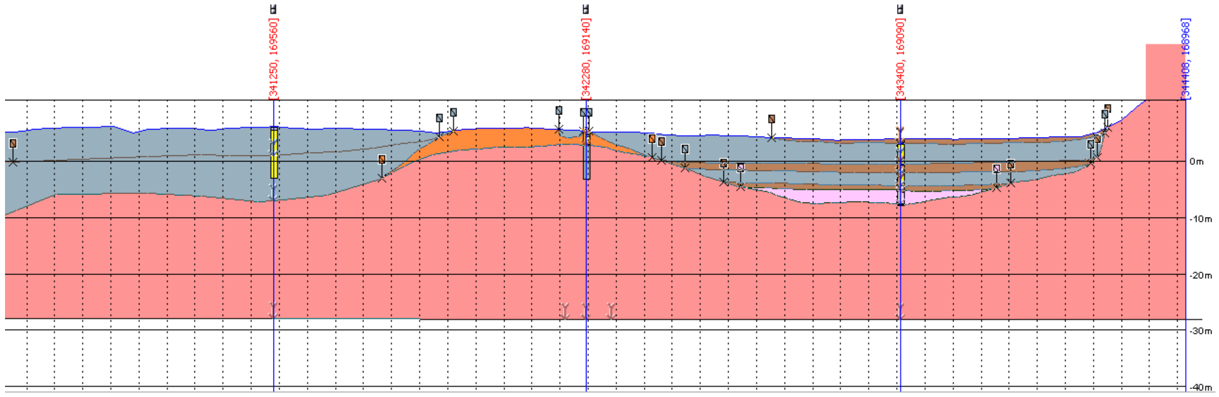


**Figure 9. Example of an east to west section across the basin showing the multiple layers of peat (brown) and tidal flat deposits (grey) beneath the Somerset Levels (x20 vertical exaggeration).**

# 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](http://geolib.bgs.ac.uk).

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