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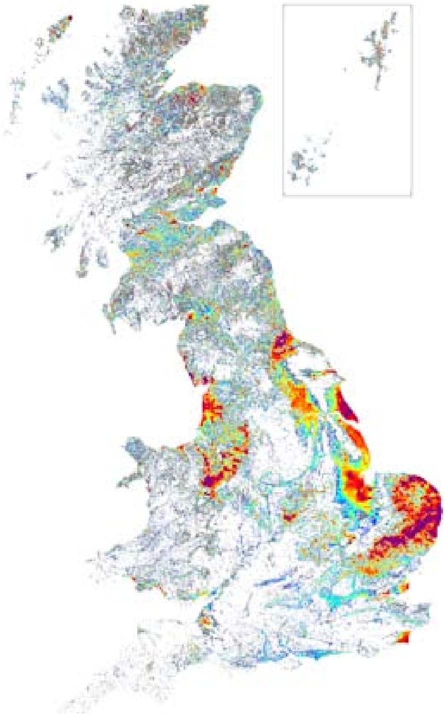
The National Superficial Deposit Thickness Model (SDTM V5): A User Guide

Information Products Programme

Internal Report OR/09/049



BRITISH GEOLOGICAL SURVEY

INFORMATION PRODUCTS PROGRAMME

INTERNAL REPORT OR/09/049

The National Superficial Deposit Thickness Model (SDTM V5): A User Guide

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Contributor/editor

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Quaternary, superficial, drift, thickness, rockhead.

National Grid Reference

SW corner 0,0
Centre point 350000,610000
NE corner 700000,1220000

Map

Sheet 1, 1:50 000 scale, SDTM

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Maps and diagrams in this book use topography based on Ordnance Survey mapping.

Keyworth, Nottingham British Geological Survey 2010

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Foreword

This report is the user-guide to the content and application of the national Superficial Deposits Thickness Model (SDTM) produced by the British Geological Survey (BGS). The model demonstrates the variation in thickness of Quaternary-age superficial deposits across Great Britain.

Contents

1 Summary

The Superficial Deposits Thickness Model (SDTM) is a raster-based dataset designed to demonstrate the variation in thickness of Quaternary-age superficial deposits across Great Britain. Quaternary deposits (all unconsolidated material deposited in the last 2.6 million years) are of particular importance to environmental scientists and consultants concerned with our landscape, environment and habitats. The BGS has been generating national models of the thickness of Quaternary-age deposits since 2001, and this latest version of the model is based upon DiGMapGB-50 Version 5 geological mapping and borehole records registered with BGS before August 2008.

2 What the dataset shows

The dataset shows the modelled variation in thickness of unconsolidated deposits, less than 2.6 million years old. This includes everything that is fluvial, glacial, marine, residual, aeolian or anthropogenic in origin. The thickness of these deposits represents the depth down to top of bedrock, known as 'geological' rockhead. The thickness variation across Great Britain partly reflects how these deposits were laid down and also their preservation since deposition. The distribution of these deposits is not uniform, sometimes they are laid down in thin veneers, sometimes they are laid down as large irregular masses and sometimes they are laid down as infill to deeply incised, narrow valleys. The complexity of the thickness variation is a function of the complex, pre-quaternary terrain hidden by these units and their mode of deposition..

The SDTM comprises three individual datasets of information, two sets describe thickness variation as modelled via two standard geo-mathematical techniques, and a third set details 'proximity' or 'fit' of the data to the original source information (useful for determining confidence or uncertainty in the models). The dataset is supplied in two GIS formats: ESRI® and MapInfo® and is also available in ASCII grid formats. The data takes the form of 'raster' gridded information; it is a geo-registered grid of numerical values.

2.1 DEFINITIONS

The SDTM comprises three individual datasets of information; two datasets describe thickness variation and a third dataset details 'proximity' of the modelled data to the original source information. The three supplied datasets are as follows:

1. The ASTM **A**dvanced **S**uperficial **T**hickness **M**odel is a model of thickness variation **indirectly** derived from archive borehole records and map data.
2. The BSTM **B**asic **S**uperficial **T**hickness **M**odel) is a model of thickness variation from **directly** derived from archive borehole records.
3. The DBUFF (**D**istance **Buff**er) dataset is a calculation of spatial distance to the location of any data point used in the model. This provides the user with an indication as to how far the computer has had to interpolate and extrapolate the data from a measured observation point.

The two thickness-modelling methods use identical input data, but process it in slightly different ways. Both methods rely on identifying, in a borehole or on a map, where there is a point of contact between bedrock (pre-Quaternary) and superficial (Quaternary) deposits. This point of contact is called 'geological rockhead'. On a geological map is it defined as the outer limit of all Quaternary (2.6 million years old or younger) deposits. In a borehole record, it can be slightly harder to define, and a number of 'keywords' are used to identify from borehole logs the point at which rockhead has been reached. In general, geological maps record a minimum thickness of 1m at the limit of the Quaternary deposits (1m represents the minimum thickness that can be portrayed on a map due to the limitations of the map scale and the width of a sharp pencil (a 0.1mm wide pencil line represents an on-ground width of 1m on a typical survey fieldslip). In boreholes, the depth down to the point of rockhead can vary considerably; for vertical and non-deviated boreholes the depth to rockhead equals the 'thickness' of the quaternary deposits. Figure 1 below, outlines the basic data captured from maps and boreholes.

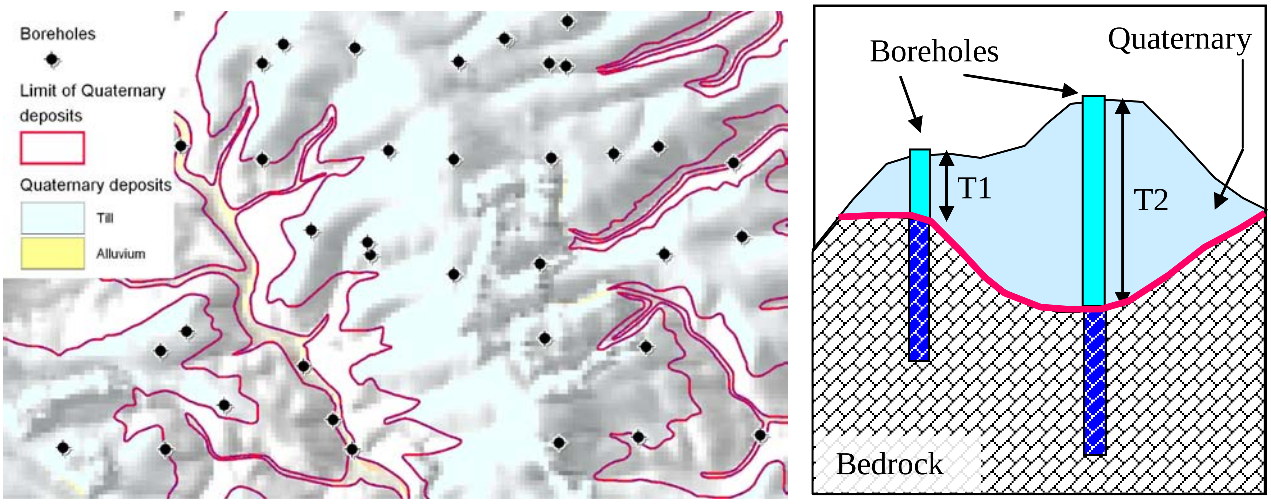


Figure 1. A typical geological map, modified to show location of boreholes and the limit of the Quaternary deposits known as rockhead (red line), and a schematic cross section through quaternary deposits and bedrock, showing how thickness of the Quaternary deposits can vary (T1 and T2). Note also the buried rockhead (red line) extending under the Quaternary unit.

The direct model (BSTM) simply involves a ‘best fit’ interpolation between the known borehole thicknesses, without extrapolating the data beyond the margin of the quaternary deposits (the limit of the quaternary deposits representing a line of 1m minimum thickness). Using the direct thickness model the output data looks like the example shown in figure 2.

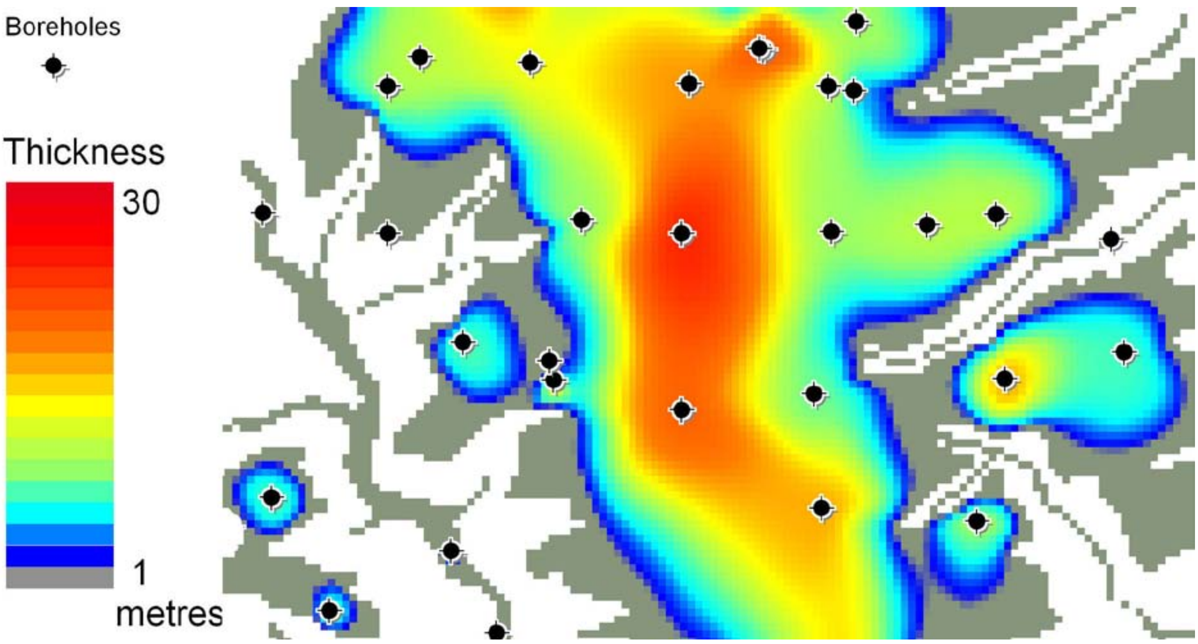


Figure 2 Map extract from the BSTM version, showing direct modelling of thickness from borehole-to-borehole, within the known areas of Quaternary deposits.

The in-direct model (ASTM) uses the same borehole thicknesses and quaternary map limits, but rather than interpolating 'thickness', each data point is compared with a digital terrain model (DTM) and the elevation of the point of rockhead above sea-level is calculated. The rockhead ‘elevations’ from the boreholes and map margin are then interpolated across the entire map area to create a rockhead elevation model. This model is then subtracted from the DTM to derive a thickness model. An example if this indirect model of thickness is shown in figure 3.

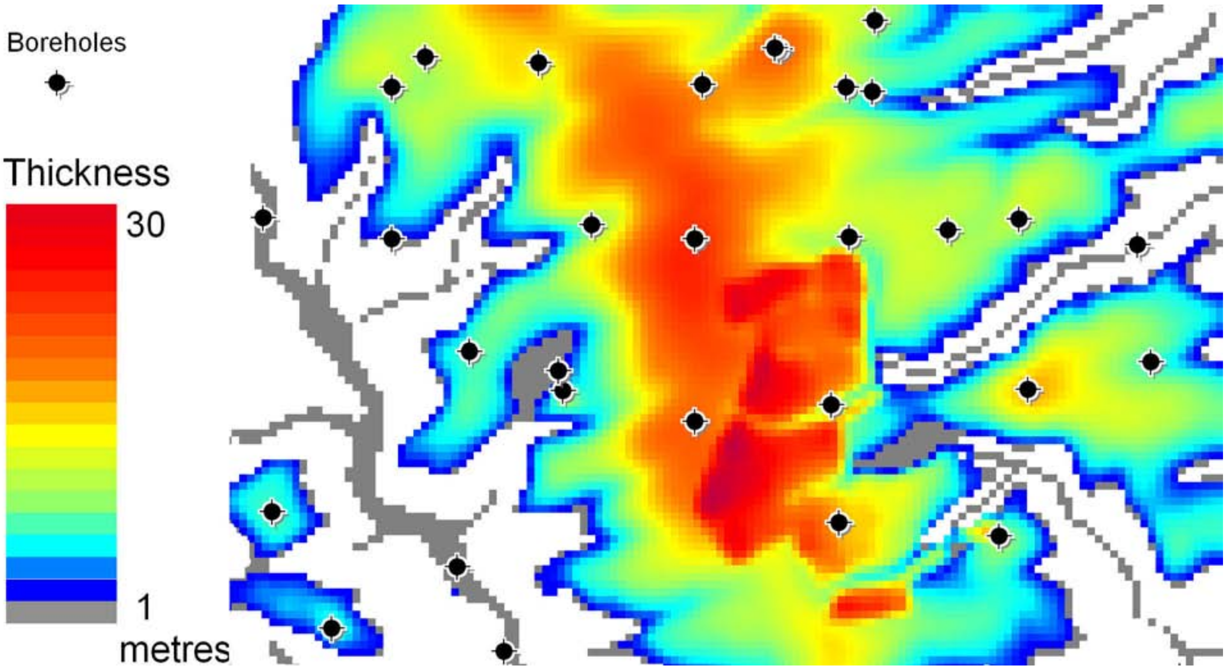


Figure 3. Map extract from the ASTM version, showing indirect modelling of thickness via rockhead and modern topography extrapolation, within the known areas of Quaternary deposits.

The data fit model (DBUFF) uses only the location of the boreholes and the quaternary map margin. This model displays how far any particular point on the map is from a 'source' of thickness information (note, this model does NOT show quaternary thickness, only how far any point in the model is from a known data source). The closer a location is to a known datapoint, the more accurate the model results are for that location, so users can interrogate this dataset to determine how accurate the BSTM and ASTM models are for their areas of interest. The output of distance-to-data model is shown in figure 4.

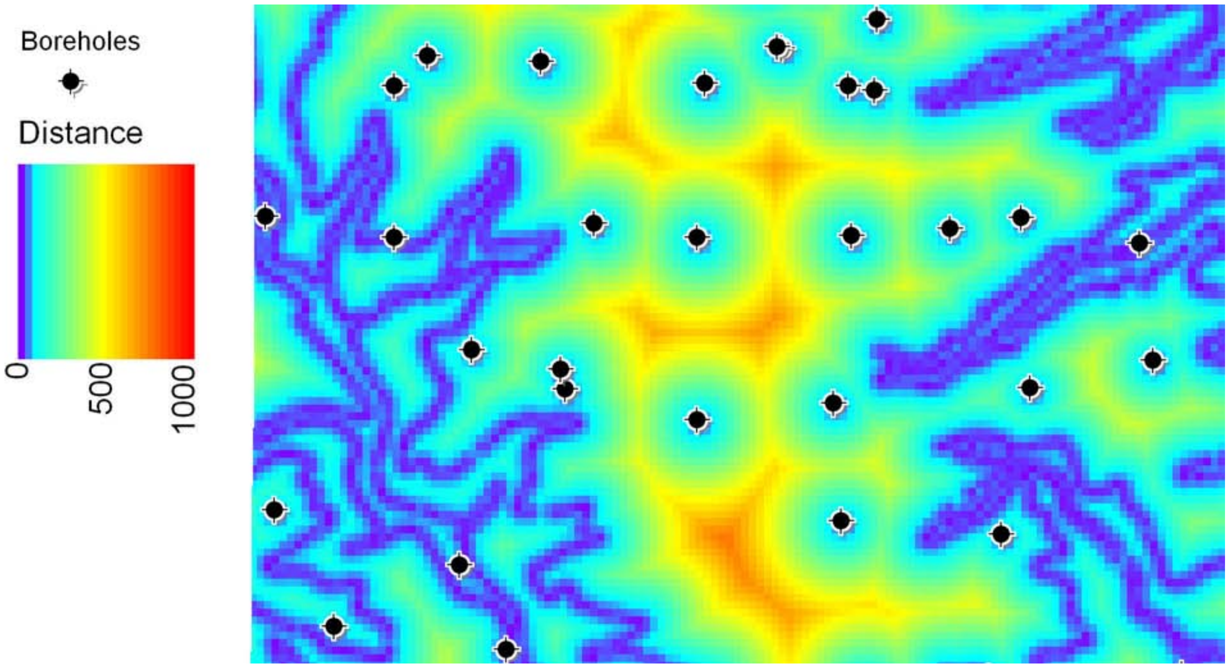


Figure 4. Distance to data grid, showing how far (in metres) any cell in the model is from either a borehole or mapped limit of Quaternary deposits.

So which thickness model do I use?

Either thickness model can be used; both are derived from identical data and merely show the information in slightly different ways. The main difference between the models is the use of the digital terrain data in the ASTM model to provide an ‘overprint’ of the current land surface; this gives the ASTM model a more 'natural' and 'geological' appearance. However, using the DTM in this way can introduce artefacts into the model, especially where borehole data is sparse, and so some care and judgement should be exercised when using the ASTM model in areas of few boreholes (see section 5.2) .

The BSTM model is more 'simplistic' in its appearance and effectively only shows thickness variation within the borehole dataset. The model is prone to having a 'spotty', bullseye dominated appearance, and although less aesthetically pleasing than the ASTM result, the bullseyes provide important information, helping to identify spurious data and also buried channels, eskers and other geological features. The downside to a borehole-only data model is that areas with too few boreholes cannot be modelled very well and in these areas (mostly rural or remote) we can only show a 'minimum of thickness' of superficial cover (1.0m). A discussion about the limitations of the models is provided in section 5.

As a general rule, users who are seeking information about proven depths (ie 'is there a borehole near my location that has proved rockhead and if so at what depth?') should use the BSTM data set in conjunction with the DBUFF information to determine the proximity of known thickness data and values. Users seeking more generic information (i.e. "what ranges of thickness could I expect in the 1- 2 kilometres around my location"), can use the ASTM (or the BSTM) version to look at the range of values the models provide, as well as using the DBUFF data to assess the uncertainty of those values.

In conclusion, both models show the same data albeit in different ways and with slightly different results. It is therefore advisable to use both models and determine which gives a result most appropriate to your need. Further details of how the ASTM and BSTM models are derived, and any assumptions made of the data are given in sections 2.4 - 5 below.

2.2 DATA DESCRIPTION

The data is supplied in proprietary ESRI and MapInfo grid formats, but can also be supplied in several ASCII grid formats. Within most GIS systems the data can be imported, opened and displayed as a colour image, with each colour representing a value of thickness at any given location on the map. A widely used colour scheme has been applied that shows graduated colours from dark blues to bright reds as the value of thickness increases. Most GI systems will also allow the user to interrogate the grid to measure the modelled thickness at any location. Across Great Britain, Quaternary deposit thickness varies from 1m to 160m but is typically in the range 1m to 20m. Areas shown in the model to have a NULL value (often displayed as white or transparent in GIS) are where no Quaternary-aged deposits exist (where pre-Quaternary bedrock is present at surface). All values of thickness and distance in the model are expressed in metres.

2.3 WHO WOULD BENEFIT FROM THE DATASET?

This dataset is for users who are seeking information about the depth to bedrock/thickness of Quaternary deposits across Great Britain. The transition between Quaternary and Bedrock units is is known as 'geological rockhead' and is an import surface for geologists, civil engineers, hydrogeologists and environmental scientists because it is where most physical and chemical properties of the deposits dramatically change. Strength, lithology, conductivity, porosity, permeability are most strongly affected by this transition surface, so an understanding of how deep it lies beneath ordnance datum is vital . Whilst the data is provided as a raster dataset, most GIS tools will allow the user to contour and further analyse the data to create vector outputs and a range of buried-terrain parameters. How was the dataset created

The Superficial thickness models have been created by interpolating values derived from borehole and map information. The workflow used to create the information is given in figure 5. and is summarized thus:

2.4 DATA SOURCES

There are three primary sources of data used in the model: boreholes, geological map data and a digital terrain model (topography).

Borehole data has been derived solely from BGS Single Onshore Borehole Index (SOBI) holdings.

All boreholes within SOBI **over** 5m in length have been assessed and where possible some indication of superficial deposit thickness has been digitally captured. This requires a degree of interpretation of the borehole records, seeking out keywords and information that identifies if or where geological rockhead is encountered in the borehole. Data cleansing has excluded bores of the following types:

- Boreholes less than 5m in total length
- Inclined boreholes
- Subsurface bores or boreholes associated with quarrying and temporary sections.
- Bores with unreadable or ‘vague’ analogue records

- Bores with ambiguous location details
- Bores deemed to have an inaccurate/spurious interpretation of superficial content
- Bores starting ('spudding') within bedrock (as defined by spatial reference to DigMapGB)

The remaining 770,000 boreholes have been subjected to a series of statistical tests to determine general thickness trends (minimum, maximum, mean, mode, standard deviation etc). Data falling outside expected ranges has been submitted for checking and correction or discarded. The borehole data has then been compiled into a vector point file, in preparation for modelling.

Geological map data has been derived solely from the DiGMapGB-50 version 5 dataset. This data is a 1:50,000 scale digital geological map of Great Britain. All Quaternary-age polygons and Artificial-deposit polygons in the dataset have been compiled so that areas of natural superficial deposits and anthropogenic deposits are collated into a single layer of data. Internal boundaries within this layer have been dissolved and basic edge matching and data cleansing performed; creating a single polygon showing the extent of Quaternary deposits across Great Britain. This dataset has then been rasterised to form a baseline 1 metre minimum-thickness model, and has also been converted into a vector point file, in preparation for modelling.

Digital terrain data has been solely derived from the Intermap® NextMap©DTM product. This is a radar-derived raster grid of terrain elevation. The grid has a 50m by 50m cell size and is a down-sampled version of the original 5m by 5m NextMap© product. All the borehole data and map data are back-interpolated against this DTM to assess elevations of borehole locations and points of rockhead contact, relative to sea-level.

2.5 GRIDDING PARAMETERS:

The models are created from the vector point files by using Vertical Mapper® and MapInfo® GIS to 'interpolate' between the data points. Previous work indicated that a Natural Neighbour algorithm provides a robust and easy to use method of interpolation. Natural Neighbourhood interpolation uses area weighting of the Voronoi neighbourhood of each data point, incorporating the 'influence' of any surrounding data points immediately adjacent to it.

The grids are generated with a cell spacing of 50m by 50m, and data is aggregated by a 25m radius (i.e. points located less than half a cell spacing from their neighbours are averaged).

Grids are smoothed (Hermitian smoothing) with local minima and maxima honoured but extrapolation beyond these values prevented.

Grids are nulled where DiGMapGB-50 indicates no superficial material to be present.

Grids are overprinted with a minimum value so that areas where no bore data is present, but drift is known to occur, are given a minimum 1.0m thickness.

Gridding of data is iterative. Initially only boreholes proving the whole superficial thickness are processed; boreholes that terminate within the deposits are subsequently added where interpolation indicates they will affect the model (this provides a ‘minimum thickness model and is useful in areas of low borehole density

2.6 MODEL CHECKING AND PUBLICATION

The models are checked statistically, and geologically. Statistical checking of the data identifies areas where the model does not honour the original source information. Any part of the model that deviates by more than 2m thickness from the original borehole data is re-checked to determine the cause. If the deviation is caused by spurious data it is rejected and the model recalculated. Any area where the rate of change of thickness is notably large, is also rechecked for erroneous modelling problems. Geological checking of the data occurs in two stages: An initial geological check is made when the model is first created; this check is performed by geologists familiar with the Quaternary deposits of Great Britain, and is a visual inspection of the model, analysing anomalous features such as bulls eyes (prominent areas of thickened or thinned deposits) to determine if they reflect the variation of thickness the geologist would 'expect' to see at that location. Secondary checking by a geologist is used to assess whether any corrections of the data have improved the model or caused further issues. The secondary checking process can be repeated several times in areas where data error or Quaternary complexity require it, until the modellers and geologists agree that the data has been processed and checked sufficiently to make a 'fit for purpose model..

Finally, model publication requires conversion of the grids for use in ESRI® and Mapinfo® systems and creation of the DBUFF dataset. The DBUFF dataset is created using the Mapinfo® Vertical Mapper© algorithm for 'grid buffering'. The vector point files used to create the ASTM and BSTM models are processed through the grid buffering tool to create a new model showing shortest distance any point in the model is from the nearest vector point. The basic premise behind this model is that the ASTM and BSTM models are most accurate where they are closest to the data points used to create them.

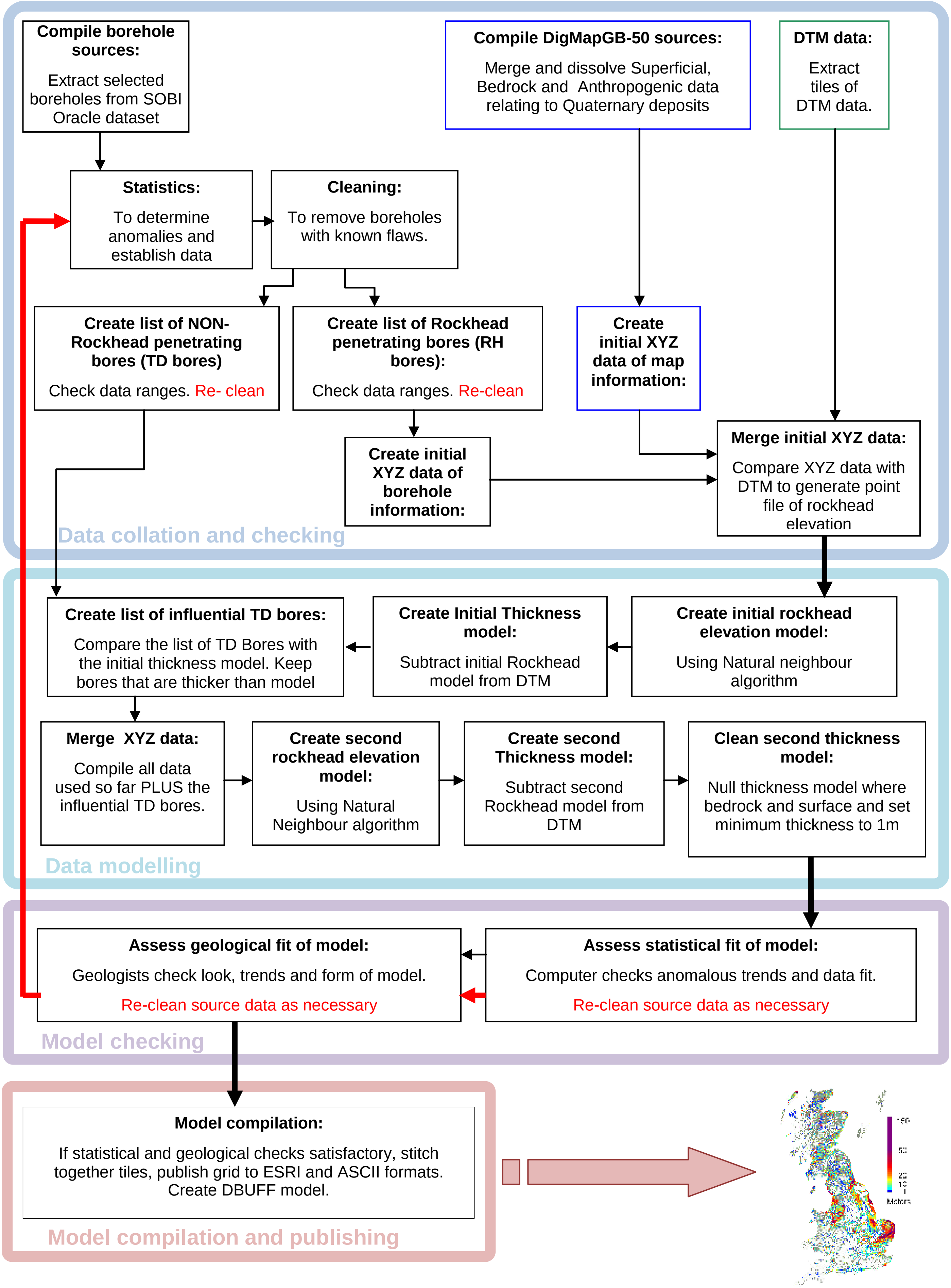
3 Technical information

The data is supplied in proprietary ESRI® and MapInfo® formats, but other formats, including ASCII grid formats, can be supplied on request. The grid comprises 50m cells (50m in x and y directions) but this data can be down-sampled to larger grid sizes if needed (most GIS systems can down-sample grid data), We do **not** recommend **decreasing** cell sizes to less than 50m as this adds no additional accuracy to the model. All the values of thickness and distance in the model are expressed in metres, and the model is normally supplied with a British National Grid projection.

Most GI systems will import /open and display the data as a colour image, with each colour representing a value of thickness at any given location on the map. Most systems will also allow the user to 'interrogate' the grid to measure the modelled thickness/distance at any location. Across Great Britain, Quaternary deposit thickness varies from 1m to 160m but is typically in the range 1m to 20m. Areas shown in the model to have a NULL value (often displayed as white or transparent in GIS) are where no Quaternary-aged deposits exist (i.e. where pre-Quaternary bedrock is present at surface). All values of thickness and distance in the model are expressed in metres.

The original data used to make the grid comprises the digital geological map of Great Britain DiGMapGB-50 and the NextMap® DTM (50m cell resolution). DiGMapGB-50 is a 1:50,000 scale data set and so we do not recommend using the grids at scales larger than this (i.e. the data is **not** designed to be used at 1:10,000 or 1:25,000 scales. *Users requiring this level of detail should contact BGS for advice about creating higher resolution models from our source datasets.*

Figure 5. A summarised modelling workflow.



4 Data history

In line with BGS naming conventions relating to the use of the DiGMapGB data product, this model is known as the Superficial Deposits Thickness Model –V5, and its component files are titled: ASTM_V5, BSTM_V5 and DBUFF_V5. The 'V5' suffix refers to the version of the DiGmapGB-50 data that the model is based on (version 5).

Since 2001 there have been three previous published versions of the SDTM as follows:

1. SDTMv1
2. SDTMv2
3. SDTMv2.1

We do not publish information relating to how the dataset changes from version to version. This is because on average 25,000 new boreholes are added to our borehole collections every year and our geological maps are continuously updated, making tracking of every data change in a mathematical model like the SDTM unviable. We do however, monitor overall changes between versions in order to help identify data trends and unusual data features. The SDTM aims to include the best available data at time of compilation. As we gather new and additional data it is sometimes necessary to discard older information, and thus we expect the datasets and the subsequently re-gridded models to evolve and change through time.

5 Limitations

There are several factors to consider when using the SDTM. It is a mathematical model based on three data sources. As such it is subject to a number of practical limitations and sources of error as follows:

- Data content
- Data density
- Data artefacts
- Limitations of scale
- Limitations of interpolation and errors of methodology

5.1 DATA DENSITY

All mathematical models are highly dependant upon sufficient data being present to produce a viable output. The SDTM is subject to one primary data density issue: Borehole density. The SDTM contains data from c.770000 boreholes, however, these data are clustered in urban centres and along major transport routes. As a result, rural parts of the model are subject to low borehole data density and interpolation in these areas is calculated over longer distances. To determine if data density is low the DBUFF dataset can provide an indication of distance to the nearest known data point.

5.2 DATA ARTEFACTS

Mathematical models derived from interpolations of terrain-based dataset such as a digital terrain model are sensitive to data artefacts. Two significant types of artefact are present within the ASTM dataset: Tree-stand-clutter and through-hill-modelling (as described below).

5.2.1 Tree-stand clutter

The digital terrain model used in the SDTM is derived from the Intermap® NextMap© DTM. This data set is airborne-radar derived and for much of the UK represents the ground surface. However, large stands of forestry can create a 'false' ground surface signal by fooling tehradar into thinking the top of the tress is actually the ground surface. Thus the DTM is subject to localised areas of 'tree-stand clutter', whereby the elevation of the ground is falsely registered as greater than true ground level. As a result, the ASTM model has localised areas where Quaternary thickness is falsely reported as greater than it really is. An example of this is shown in figure 6.

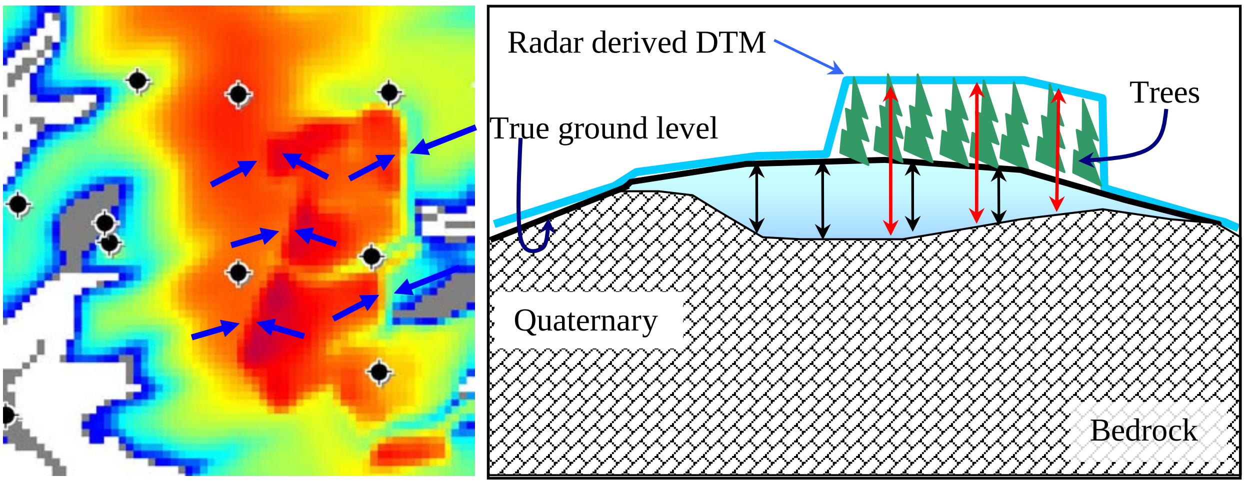


Figure 6. The map extract above shows areas highlighted with blue arrows, where the model shows sudden increase in thickness. The schematic cross section demonstrates that these areas are where the Radar DTM (blue line) deviates over trees, no longer 'tracking' the ground surface (black line). As a result, the model appears to show increased Quaternary thickness (red arrows) instead of the true thickness (black arrows).

5.2.2 Through hill modelling

Through-hill modelling is an artefact caused partly by the nature of the geological deposits, the interpolation method, and the resolution of all the datasets. It is only found in the ASTM dataset, and is a result of the computer compiling an over-simplified model in areas of high relief (mountainous) terrain; areas of relatively thin, but blanketing deposits, such as peat, can completely 'mantle' areas of high relief, causing the computer to extrapolate data **through** the terrain, rather than **over** it, giving the impression that hills or other raised features are constituted wholly from Quaternary materials rather than being bedrock covered by a thin skin of Quaternary material,. As a result, the thickness model is skewed towards unrealistically high values. A schematic diagram showing the causes of this effect is given in figure 7.

Note that these artefacts affect **only** the ASTM version of the model. The BSTM version is dominated by borehole data rather than terrain data, so users should consider switching to using the BSTM model if they suspect their area of interest is affected by terrain issues.

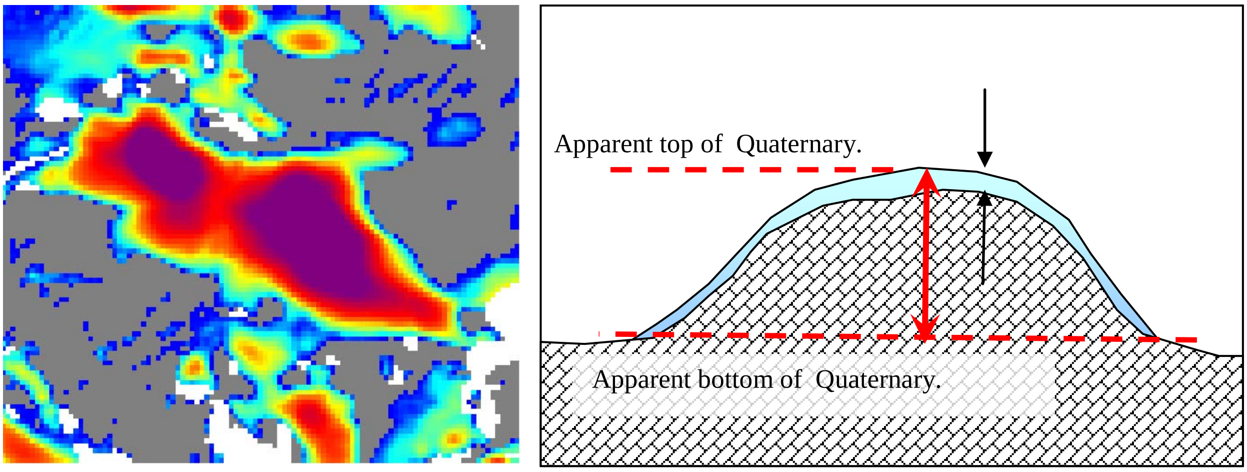


Figure 7. The map above shows an area of apparent increased thickness (red and purple). However, there are no borehole data in this area to 'prove this thickness'; the schematic cross section demonstrates that this apparent thickness (red arrow) is an artefact due to the computer mathematically modelling the Quaternary deposits as a thick mass forming the entire bulk of the hill from base to summit, rather than as the 'thin blanket' draped over it (black arrows).

5.3 LIMITS OF SCALE.

All maps, whether surveyed or modelled are subject to limits of scale. The SDTM utilises 1:50,000 scale geological data and a DTM with a cell resolution of 50m. Users should consider the scale of data they need for their work carefully. The SDTM will not resolve thickness variations and geological complexities at scales larger than 1:50,000 (i.e. at say, 1:10,000) nor will the data resolve variations of less than 50m cell size. For such high resolution modelling users are requested to contact the BGS to discuss their needs. Down-sampling the data to smaller scales (1:250,000) or larger cell sizes (i.e. 100m) can be performed on most GI systems.

5.4 LIMITATIONS OF INTERPOLATION METHODOLOGY AND POTENTIAL ERRORS

Mathematical models can be affected by the methodology used to perform the interpolation, and by general data cleanliness. The interpolation method used to make the SDTM is based upon a Natural Neighbour Algorithm. This method assesses each data point with respect to its immediate 'neighbours. In doing so it establishes a voronoi spatial network over which to interpolate. The method has been chosen as it is fast and widely available in GI systems. The method limits overshooting of data (extrapolating too far above or below the minimum and maximum data values) and is well known as a good interpolation method for honouring the input dataset. It also works very well with clustered data, and given the expected complexity of the buried rockhead surface is a surprisingly simple technique to apply for good results. Throughout the modelling process, care is taken to check the model against its input sources to ensure that any deviation form the original data can be explained by a data issue or a geological complexity beyond the limit of the model scale. Additionally, the method employs a degree of smoothing and averaging of the data to fit the model. This carries the penalty of not honouring data perfectly, but allows for a visually pleasing model, with clear and consistent graduations between thickness values. It is recommended that user familiarise themselves with the included DBUFF dataset as this offers a simple method of assessing interpolation accuracy for the ASTM and BSTM models. Each pixel in the DBUFF dataset shows the shortest distance to the nearest data point used in the thickness mode. It can therefore be used to show how far the computer has interpolated between data points in order to create the values shown in the ASTM/BSTM models. As a general rule, the shorter the distance of interpolation, the better the models are.

Throughout the modelling process care is taken to track and exclude erroneous data as much as possible. In a model containing 13 million data points some erroneous data is inevitable, checking procedures for all the borehole data and map data are established not only for the model, but also for the source databases. Each new version of the model provides checking and elimination options for the data and all excluded information is retained digitally to enable tracking of the model development.

BGS takes every care to ensure that data and model errors are kept to an absolute minimum.

6 Contact information

For all data and licensing enquiries please contact:

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Glossary

Quaternary A geological time period covering the last 2.6 million years.

Superficial deposits Geological deposits that cover the UK that are Quaternary in age or man-made.

Bedrock Rocks and deposits that are older tham Quaternary in age.

Rockhead The point of contact between Bedrock and Quaternary units. The 'ground level', before the quaternary deposits were laid down.

Interpolation A mathematical technique to estimate a trend in data between known points.

Voronoi Used in mathematics, a Voronoi diagram, also called a Voronoi decomposition, named after Georgy Voronoi, is a special method of dividing up data determined by the location of the data points. A Voronoi area defines the space around a data point that is closest to it. (ie Voronoi areas define the closest data point for interpolation purposes)

Hermitian smoothing Used in mathematics, Hermitian smoothing is a technique of analysing a square matrix of values (such as a raster grid) and applying a filter to modify values that do not fit a measurable trend within the data. The effect is to 'smooth' out extraneous values without unduly altering the values so that trending is lost.