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GSI3D 2011

Software manual and methodolgy

Geological Modelling Systems Team

Open Report OR/11/020

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Front cover

Splash screen for the GSI3D 2011 version

Bibliographical reference

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GSI3D 2011

Software manual and methodolgy

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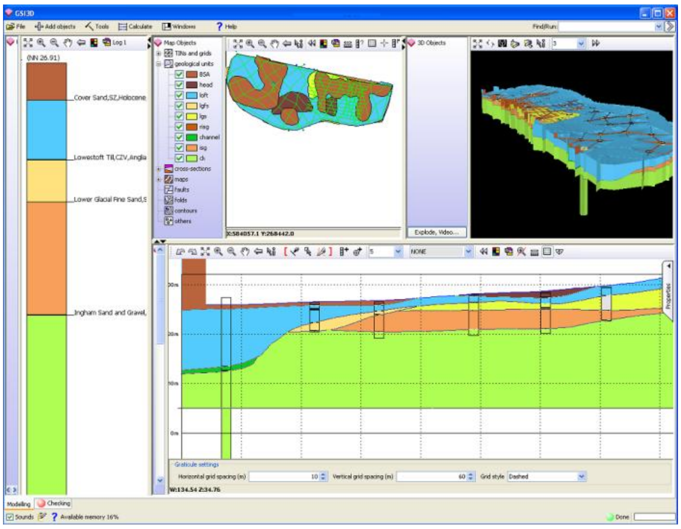

Keyworth, Nottingham British Geological Survey 2011

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Acknowledgements

The Geological Surveying and Investigation in 3 Dimensions (GSI3D™) software tool and methodology has been developed by Dr. Hans-Georg Sobisch (INSIGHT GmbH) over the last 18 years. Initially development was in collaboration with Drs. Carsten Hinze and Heinrich Mengeling of the NLfB (Niedersaechsisches Landesamt fuer Bodenforschung - Soil and Geological Survey of Lower Saxony) based in Hannover (Hinze, Sobisch and Voss, 1999; Sobisch 2000). BGS acted as a test bed for the accelerated development of the tool and methodology from 2002 and from 2006 to 2010 BGS and Hans-Georg Sobisch worked on the extension of GSI3D to deal with complex bedrock geology. Many people have used the software and contributed to the development over the past 10 years and it is credit to those users (and their patience) that GSI3D has developed into the useful and usable tool it is now.

Since April 2010 the GSI3D methodology and software is on release through the GSI3D Research Consortium www.gsi3d.org.uk.

1. GSI3D Philosophy and Workflow

„Nur einfache Lösungen sind gute Lösungen"

Only simple solutions are good solutions

(Hans-Georg Sobisch, 2001)

'The familiarity which geologists and geophysicists have with this methodology [working with cross-sections] suggests it as a sensible, user-friendly approach to working with a truly three-dimensional modelling system.'

(Dabek, et al. 1989)

The 3D investigation and characterisation of the Earth's sub-surface is the prime objective of any geological investigation or survey. Until recently the outputs of such surveys have been mainly 2-dimensional analogue and then digital geological maps (polygons without height information) and in some cases supported by contoured surfaces of key layers or boundaries. These maps cannot depict key detail on the sub-surface distribution of many of the units present in the stratigraphic sequence.

GIS systems have progressed matters by enabling topologically correct ordering of geological units that can be expressed as a complete stack of distributions or coverages displayed as surfaces but still without full attribution of the z parameter in terms of 3D geometry.

With advances in computing power and technology and the availability of increasingly precise and sophisticated Digital Terrain Models (DTM) it is now possible to envisage a new survey concept and a totally new output: - **the 3D geological framework model** (Kessler & Mathers 2004; Kessler et al. 2009). This can also be considered as a 3D geological map, or, as the geological map extended into the third dimension.

Today there are many sophisticated geological modelling packages available to build 3D models and many targeted at the petroleum and mining sector are very complex requiring expert modellers and are costly to licence. GSI3D differs in being a software tool and methodology designed by geologists for their colleagues, and as such it is intuitive and easy to use and has gained widespread acceptance. GSI3D enables the construction of 3D models In order to meet the objectives of many geological investigations and follows the approach that the creation of a model must rest in the hands of the geologists who knows the ground. Only their specialized tacit knowledge of the geological processes and evolution of a landscape can ensure the integrity of a 3D geological framework model.

The success of the GSI3D methodology and software is based on the fact that it utilizes albeit digitally, exactly the same data and methods that geologists have been using for two centuries in order to make geological maps: data types commonly include

1. Boreholes classified lithologically and interpreted stratigraphically
2. Geological outcrop data (linework and measurements)
3. Topographic maps and latterly Digital Terrain Models (DTMs)
4. Cross-sections
5. Contoured maps of buried surfaces
6. Geophysical data
7. Geochemical and geotechnical measurements
8. Hydrogeological data

The true difference to conventional surveying practice is the increased speed/efficiency at which all data can be visualized and analysed in relation to all other information enabling new insights into the geometries and arrangement of the deposits.

The use of intersecting user-defined cross-sections has been proved to be a solid and possibly the only tool to model the often complex geological situations in the shallow geosphere (Mathers & Zalasiewicz, 1985, Dabek et al. 1989, Sobisch 2000, Kessler & Mathers 2004).

In addition as part of the 3D modelling exercise the scientist is forced to continuously revise the integrity of the local stratigraphy. The entire ‘stacking order’ (4-D topology) of all deposits in a study area are captured in a Generalized Vertical Sequence (GVS).

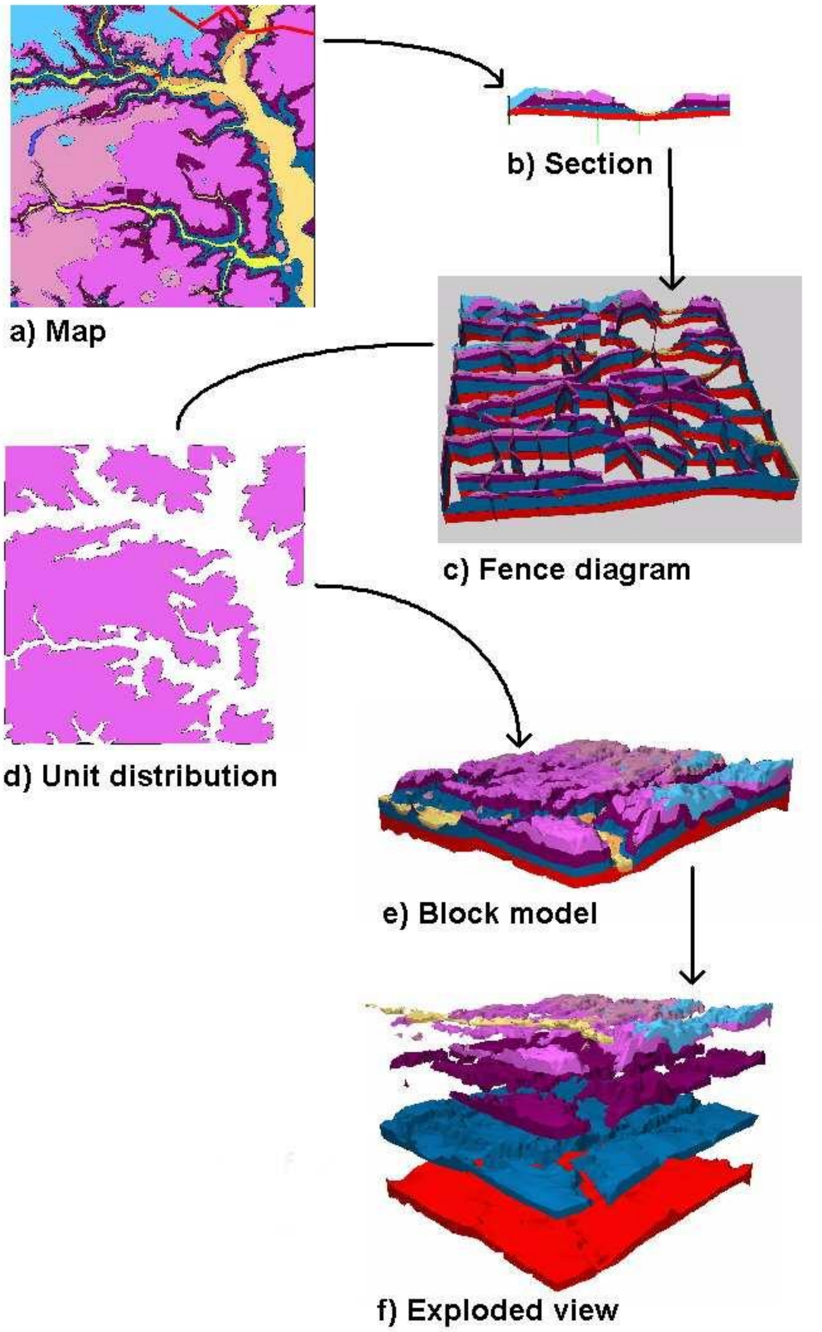
Using GSI3D, once the geoscientist has:

a) defined the local stratigraphy
b) completed the correlation of all units in cross-sections
c) created all the boundaries of each geological units at surface and at depth (outcrop and subcrop)

The 3D model of the area is completed by computation. In this process the form of all the geological units in the model are calculated as closed triangulated, topologically ordered objects (a.k.a. shells, volumes).

Using GSI3D the geologist can query the computed model to produce new thematic maps, uncovered maps, domain maps, thickness plots, volume calculations, borehole prognoses and virtual sections and slices according to specific applied requirements (see Section 5).

The GSI3D methodology aims to maintain a dynamic model of the near surface as part of the strategic surveying and continuous data revision process carried out by geologists. When new data or knowledge is obtained the geologist can review the new data (say boreholes), then, as needed, iterate the sections, unit distributions or even introduce new units into the stratigraphy. The ultimate aim is not to store fixed outputs (such as traditional maps, GIS layers or grids) but to maintain and continually upgrade an integrated dynamic geological model.

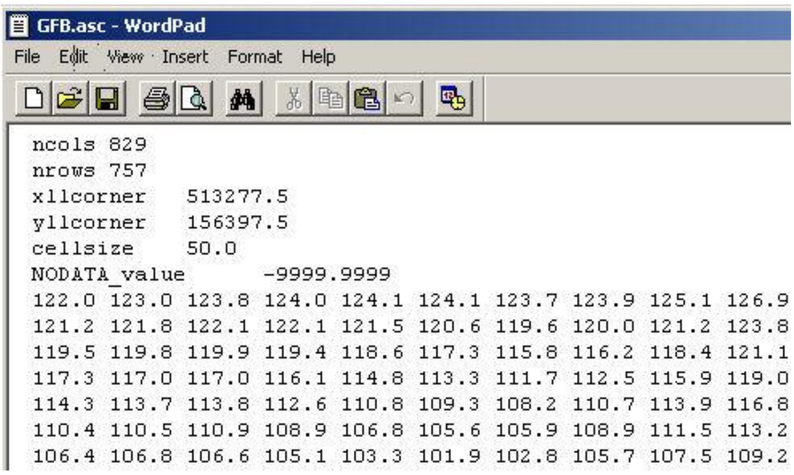

a) Map
b) Section
c) Fence diagram
d) Unit distribution
e) Block model
f) Exploded view

2. Assembling the main file types

A small sample dataset is available on www.gsi3d.org.uk/downloads.html

2.1 Model capping surface (DTM, DEM)

Existing surfaces and elevation models can be loaded into GSI3D as non-proprietary **ASCII grid files (*.asc)** in the following file format:




```
ncols 829
nrows 757
xllcorner    513277.5
yllcorner    156397.5
cellsize     50.0
NODATA_value       -9999.9999
122.0 123.0 123.8 124.0 124.1 124.1 123.7 123.9 125.1 126.9
121.2 121.8 122.1 122.1 121.5 120.6 119.6 120.0 121.2 123.8
119.5 119.8 119.9 119.4 118.6 117.3 115.8 116.2 118.4 121.1
117.3 117.0 117.0 116.1 114.8 113.3 111.7 112.5 115.9 119.0
114.3 113.7 113.8 112.6 110.8 109.3 108.2 110.7 113.9 116.8
110.4 110.5 110.9 108.9 106.8 105.6 105.9 108.9 111.5 113.2
106.4 106.8 106.6 105.1 103.3 101.9 102.8 105.7 107.5 109.2
```

The data is spatially referenced to the lower left corner (xll,yll) of the grid. Its extent is then governed by the number of columns/rows and the cell size in metres.

For reference see: http://en.wikipedia.org/wiki/ESRI_grid

Any other required surfaces such as the base Quaternary, watertable, or an unconformity can be imported in this same format and viewed in 2D or 3D. These surfaces can also be selected to cap the calculation of the model so themed outputs can be generated with the geology truncated along surfaces other than the ground surface.

2.2 GVS

The Geological Vertical Sequence - **GVS file** is a **tab separated ASCII text file; (*.gvs)** and forms the backbone of the GSI3D project. It is produced by the modeller using a text editor and evolves throughout the project to finally contain all units in their correct and unique super-positional order (stratigraphy). The order defines the 'model stack' that is calculated to make the 3D geological framework model. Geological stratigraphies can be extended to encompass a chronology of man-made deposit as needed.

An exception to the ordered stack is lenses enclosed within single units which are added on to the bottom of the list in the format below.

The table below shows the essential elements of the GVS file, please note that the Header name “name” and “id” are obligatory, whereas the other header names can be chosen freely. Published models will carry the header information as a series of attributes, therefore it is wise to pick meaningful names for the columns and where possible use understandable names rather than proprietary codes for use in the fields.

name	id	Stratigraphy	Lithology	Genesis	Free text
Alv	10	ALV	CZ	Fluv	Overbank...
Lgfg	20	LGFG	SV	glac_fluv	Sheet sands...
Loft	30	LOFT	CSZV	Glac	Lodgement till…
Sand_lens_t	-150	SAND_L	S	glac_fluv	Intra till lense (top)
Sand_lens_b	150	SAND_L	S	glac_fluv	Intra till lense (base)

name — the model code provides the link to the correlation lines and must be unique. The order from top to bottom MUST be the stratigraphic order of the entire model area. (except for lenses, see Section 2.3)

id — The ID column is used internally to differentiate between “normal” layers/units and lenses. In the future it may also be used to link databases directly to the GVS.

The LINK_ID must be an integer number between -65000 and +65000 with no decimals with increasing numerical value down the table

Stratigraphy… — This column, and any subsequent columns, is used to provide the link to the legend file entry. The legend entries are case sensitive and must match exactly the entries in the legend file (see example below). There can be multiple columns in order to attribute the model by different parameters, for example Chronostrat, Lithology, Genesis, Porosity.

NOTE: The GVS file must not contain any special characters such as ‘ “& $

Regional_v6+header.gvs

	name	id	Stratigraphy	Strat_text	Lithology	Lith_notes	Gen_code	Genesis	Age	Colour
2	dtm	0	DTM	Any dtm						
3	mgr	1	MGR	Made Ground						
4	wgr	2	WGR	Worked Ground						
5	wmgr	3	WMGR	Infilled Ground						
6	bsa	5	BSA	Blown sand	S		Aeol	Aeolian	Holocene	brown
7	alvtop	6	ALV							
8	stobco	7	STOB	Shoreface and beach upper						
9	peat	10	PEAT	Peat	P		Pal	Paludal	Holocene	black
10	alv	20	ALV	Freshwater Alluvium	CZ		Flv	Fluvial overbank	Holocene	grey
11	itdu	30	ITDU	Intertidal Deposits u	CZ		Int	Intertidal flats	Holocene	grey
12	tfd	30	ITDU	Intertidal Deposits u	CZ		Int	Intertidal flats	Holocene	grey
13	stob	35	STOB	Shoreface and bea	VS		Lit	Littoral beach and	Holocene	brown
14	sabd	35	STOB	Shoreface and bea	VS		Lit	Littoral beach and	Holocene	brown
15	peat1	40	PEAT	Peat	P		Pal	Paludal	Holocene	black
16	alv1	50	ALV	Freshwater Alluvium	CZ		Flv	Fluvial overbank	Holocene	grey
17	itdu1	60	ITDU	Intertidal Deposits u	CZ		Int	Intertidal flats	Holocene	grey
18	stob1	35	STOB	Shoreface and bea	VS		Lit	Littoral beach and	Holocene	brown
19	lde	65	LDE	Lake deposits	CZ			Lacustrine	Pleistocene Ipswic	grey
20	head	70	HEAD	Head	CZSV	very variable	Mam	Mass Movement	Pleistocene post A	brown
21	brk	75	BRK	Stutton Formation						
22	rtdu	80	RTDU	River terrace Depo	SV	local lenses	Flv	Fluvial mainly bra	Pleistocene post A	yellow brown
23	lde1	90	LDE	Lake Deposits	CZ	finely lamina	Lac	Lacustrine	Pleistocene post A	grey
24	gstc	100	GSTC	Glacial Silt and Clay	CZ	finely lamina	Glac	Lacustrine glacia	Anglian	grey
25	gsg	120	GSG	Glacial Sand and G	SV	locally claye	Gflv	Fluvial glacial	Anglian	brown
26	gstc1t	170	LOFT	Lowestoft Till	CZSVLB		Glal	Glacial	Anglian	grey-black
27	gstc1	130	GSTC	Glacial Silt and Clay	CZ	finely lamina	Glac	Lacustrine glacia	Anglian	grey

Example of an extended GVS being assembled in EXCEL

2.3 The Legend file

This is a **tab separated ASCII text file (*.gleg)** used to assign colours and textures to the map polygons, borehole logs, sections, and geological units and can be edited in Wordpad or EXCEL. The legend file contains one line per legend entry. The file structure is outlined below; note that the first row in the table below is for **explanation only** – legend files **should not contain any header information.**

LEG_ID	Description	Red	Green	Blue	Transparency	Texture link
ALV	Sandy, clayey …	55	66	77	255	TEXTURES\gravel.jpg

LEG_ID — This column contains the codes corresponding to the entries in the GVS files (Stratigraphy, Lithology, Genesis, Porosity etc.) and the codes used in borehole log classifications

Description — Free text description of the unit

Red — Red value (0-255)

Green — Green value (0-255)

Blue — Blue value (0-255)

Transparency — Pre-set transparency (0-255) (0 = transparent; 255 = full colour)

Texture link This field contains the file path to the image that will be used for texturing. If a relative file path is specified then the path will be relative to the folder in which GSI3D is installed. This is to provide support for standard texture libraries. For non-standard texture images absolute file paths are required.

Note: Both the GVS and the Legend file can be created and edited within GSI3D using the GVS and Legend editor described in Section 4.1. At time of writing the editor is in BETA release and cannot handle lenses. If a project does contain lenses the GVS and Legend file should be edited outside GSI3D in Wordpad, Excel or similar.

NOTE: GSI3D 2011 only supports Red Green Blue (RGB) values for legend colours. If users have existing legends in CMYK or other colour space please contact the GSI3D Helpdesk for advice.

NOTE: Users with old projects and texture libraries should contact the GSI3D Helpdesk for advice if any difficulties arise in migrating projects from older versions of GSI3D.

2.4 Borehole Data

Two **tab separated ASCII text files** are required, an index or location file **(*bid)** and a downhole log file **(*.blg)**.

The ***.bid** file is the borehole index file, containing a unique ID, x, and y coordinates to define borehole location, and the start (collar) height of the borehole (z parameter) relative to the project datum.

The borehole index file (*.bid) needs to be prepared with the following structure:

Unique Borehole ID	Easting	Northing	Start Height
SE64SW23.	123456	123456	11.22

All boreholes MUST contain a number in the start height column. (-99999 if not known). GSI3D displays borehole logs according to their own start height, although the user has the option to 'hang' all sticks on the DTM if that is preferred or considered more reliable. This option should be used with care, taking into account the relative confidence in the borehole datum's compared to the DTM. If confidence in the borehole data is high, use the start height. If not, and the confidence in the DTM is relatively high, consider hanging the borehole sticks from the DTM.

The ***.blg** file is the downhole log file, with information **on the depth (z) in metres to the base** of each of the identified units starting from the start height. The log must be 'complete' from the surface downwards and not intermittent, intervals of core loss and uncertainty should be coded as absent data not left blank.

The borehole log file (*.blg) needs to be prepared with the following structure:

Unique Borehole ID	Depth to base of Unit from start height (in metres)	Lithostrat Code	Lithology Code	Other codes	More codes
SE64SW23.	1.23	ALV	CZ	ABC	DEF
SE64SW23.	4.56	LGFG	SV	ABC	DEF
SE64SW23.	7.89	LOFT	CSZV	ABC	DEF

NOTE: The *bid and *blg files must NOT contain any header information

The choice of boreholes should be largely independent of any pre-conceived geological model. Whilst the project remit may require that boreholes offering a certain type of information are included, care should be taken to ensure that an objective approach is used when including or excluding primary data.

The borehole stratigraphical classification can be revised as an iterative process during the development of the sections and the geological model. The level of refinement of the coding is largely driven by the intended resolution of the model. Coding of distinct lithologies within members and formations is also recommended to permit subsequent analysis of facies patterns.

2.5 Geological Linework

Polygons and lines can be loaded into GSI3D as **standard ESRI shape files (*.shp)** and will be displayed in the map window. Polygons can then be used to create 'envelopes' (Section 4.5.2).

Note: GSI3D does not support 3D shape files.

Multiple shape files may be needed in order to complete a modelling project, these might include layers such as:

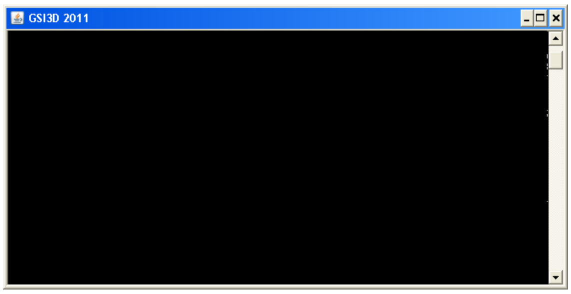
- Man-made deposits and features
- Mass-movement
- Surface geology
- Superficial deposits
- Bedrock geology
- Linear Features (e.g. faults)

3 The User Interface

3.1 General layout

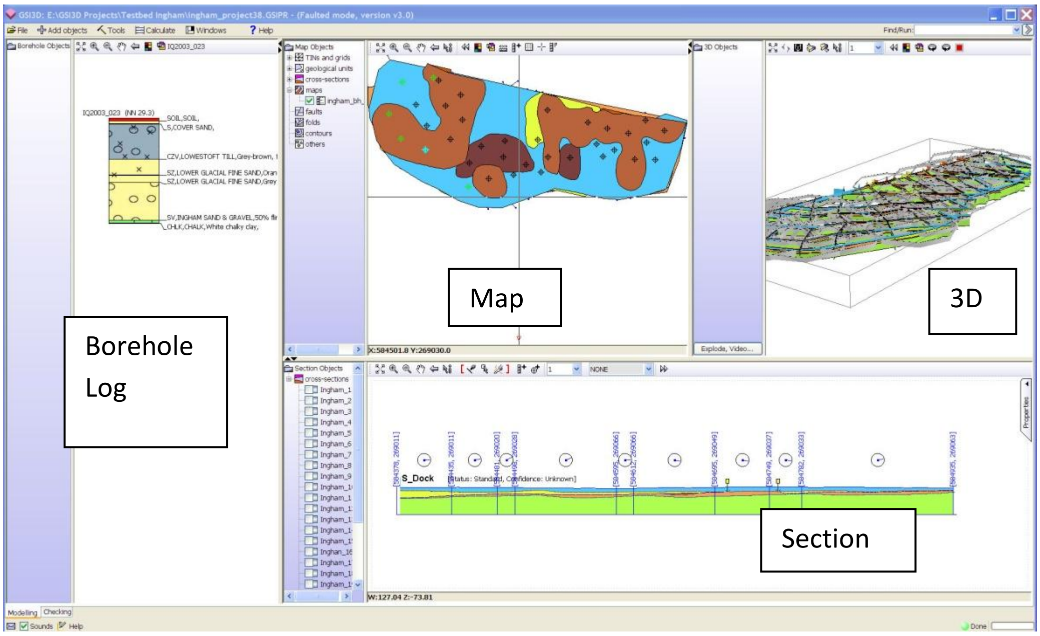
Start the GSI3D software from the desktop shortcut or via Start > Programs.

The MS DOS console window and splash screen with version number are displayed briefly:



NOTE: Closing the MS DOS console window will automatically shut down the programme and any unsaved data will be lost!

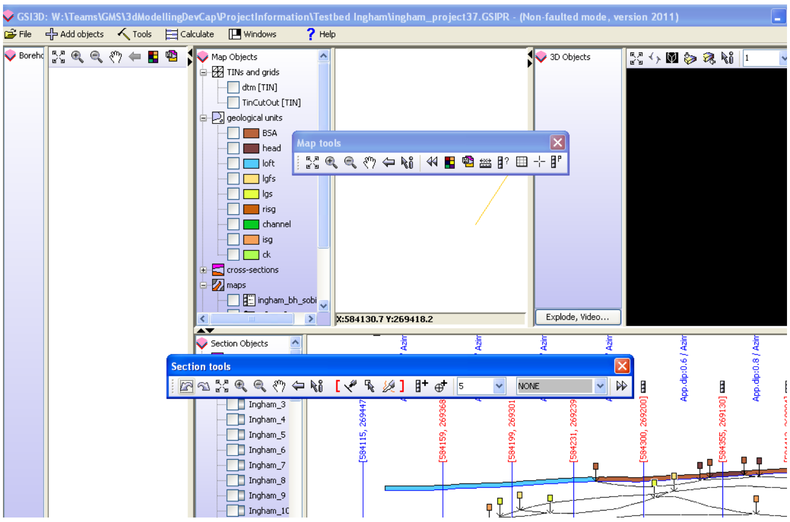
Then the main screen is displayed with its default arrangement of windows. The user can arrange the windows manually or split them up (see Section 3.2.5) During usual modelling sessions the windows are arranged as shown below. On exit the current set-up of windows will be stored for the start of the next session.



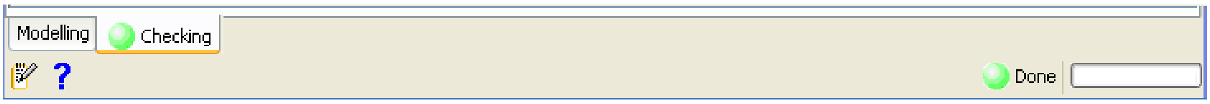
The basic layout is composed of four individual windows, the borehole viewer left, the map window top centre, the 3D window top right and the section window below. Arrows on the margins of the windows allow each to be maximized or minimized, whilst clicking on the edges allow dragging of the windows to any preferred size depending on the type of work being undertaken. Similarly the left hand Table of Contents (ToC) margin present within each window can also be enlarged or reduced in width within its own window.

A series of commonly used predefined layouts of the windows can be accessed using the ***Windows > Perspectives*** pull down menu on the top toolbar (see Section 3.2.5) or by using Keystroke ***F3***. By using the split-dock window toggle function from at ***Windows > Split/dock*** (or Keystroke ***F11***) all the windows can be split and maximised and minimised individually, and docked together again to return to the standard layout.

All toolbars can be made to float by dragging the left hand side of the toolbar to anywhere in the software window. Pressing the 'X' on the top right of the toolbar re-docks the toolbar in its original place. The image below shows floating toolbars.



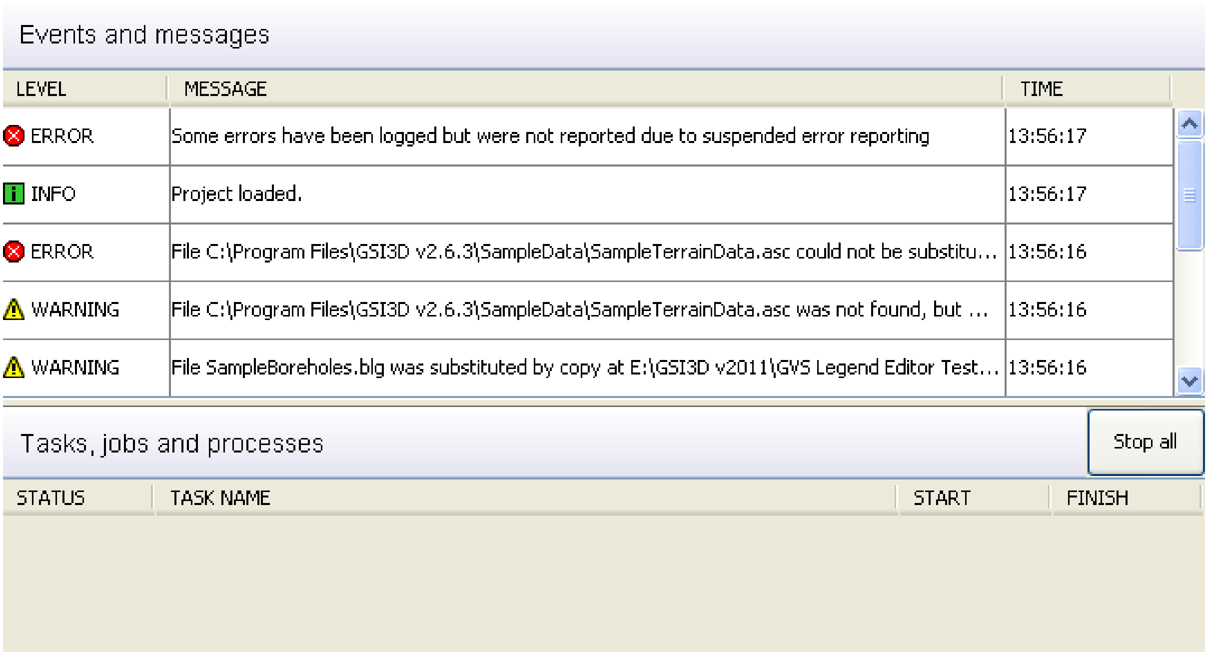
3.1.1 Bottom Toolbar



Located on the bottom toolbar are tabs to allow work to occur in modelling mode (normal default working) and Checking mode. The latter opens a window with two panels.

Events and messages is a log of events (shown below), each with a description, severity and time stamp. This list is not maintained between sessions, the software begins a new log when it is started up. Critical errors which have stopped an operation from happening or which have caused part of the software to crash will usually be alerted to the user via a specific message pop-up as well as being logged to the console. The green checking button in the bottom right of the main GSI3D window will turn red if there are un-read errors in the list.

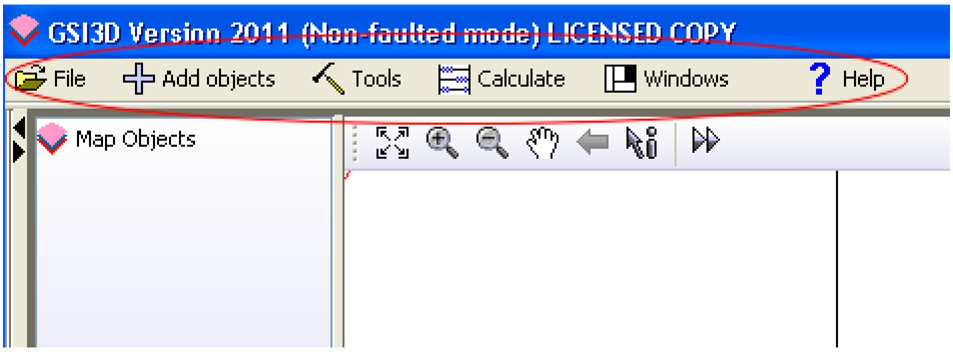
Tasks, jobs and processes is not active in GSI3D v2011 and can be ignored.



Other options on the bottom toolbar include an option to open a blank notepad to record metadata or observations that are then saved along with the project, and a Help option that contains a link within the software to supporting user documentation. At the far right is a progress bar.

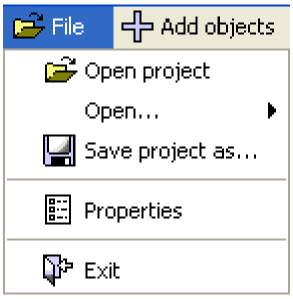
3.2 Pull down menus etc.

The top toolbar of the main GSI3D window contains six pull down menu options as follows :



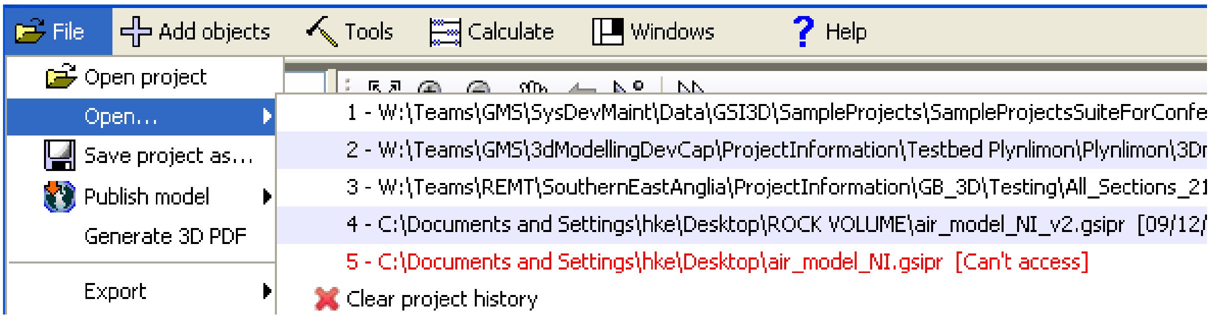
3.2.1 File

The File menu contains the following options:



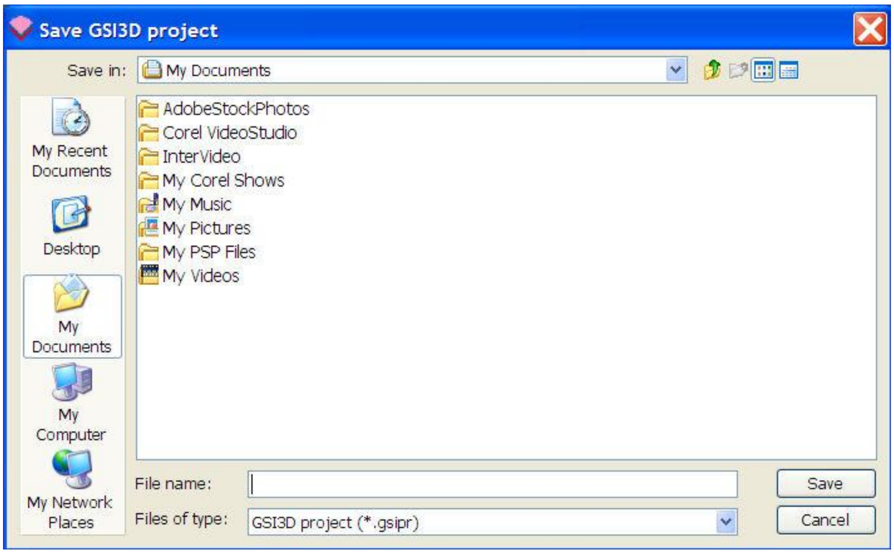
Clicking the ***Open Project*** option opens a browser box to navigate and select the *.gsipr project file required. GSI3D only allows one project to be open in a single software session at any one time, although by opening the software multiple times more projects can be loaded for inspection. Only one version is editable at any one time.

The additional option ***Open...*** when expanded presents a link to open any of the most recently used modelling project (see below) to continue working.



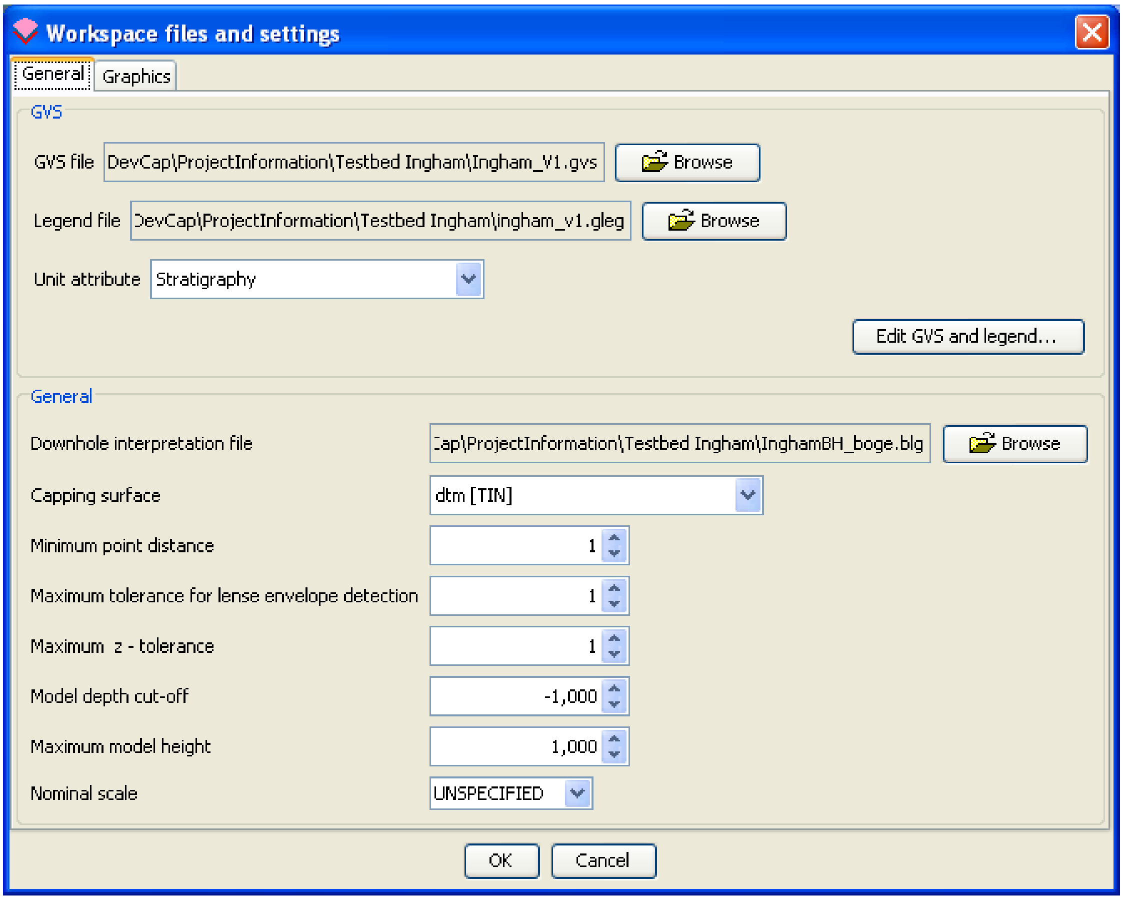
After one project has been opened the loading options become inactive. To load a different project the user must re-start GSI3D.

Selecting ***Save Project as...*** enables the current project be saved as a project workspace *.gsipr. Use the standard explorer dialog box (shown below) to navigate to a preferred folder location, name the file and Save.



This ***Properties*** option displays the dialog box used to define the properties and links of the workspace that are being used in a session. This functionality and the dialog box are described fully at Section 4.1.

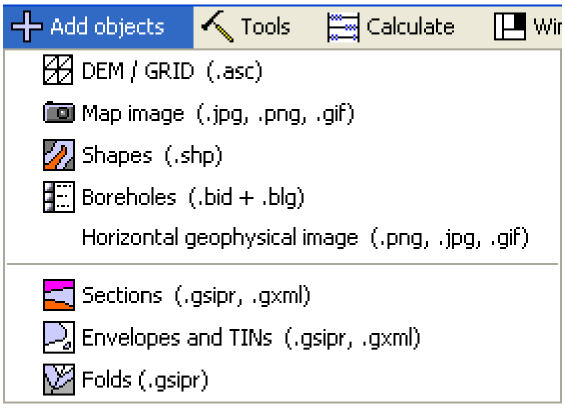
Under the General tab the dialog contains a GVS and a General section. In the GVS section the user can select and edit the GVS and Legends, as well as set the overall attribute for the GSI3D project. Also the *.blg borehole is located and the overall capping surface (usually the DTM) is selected.



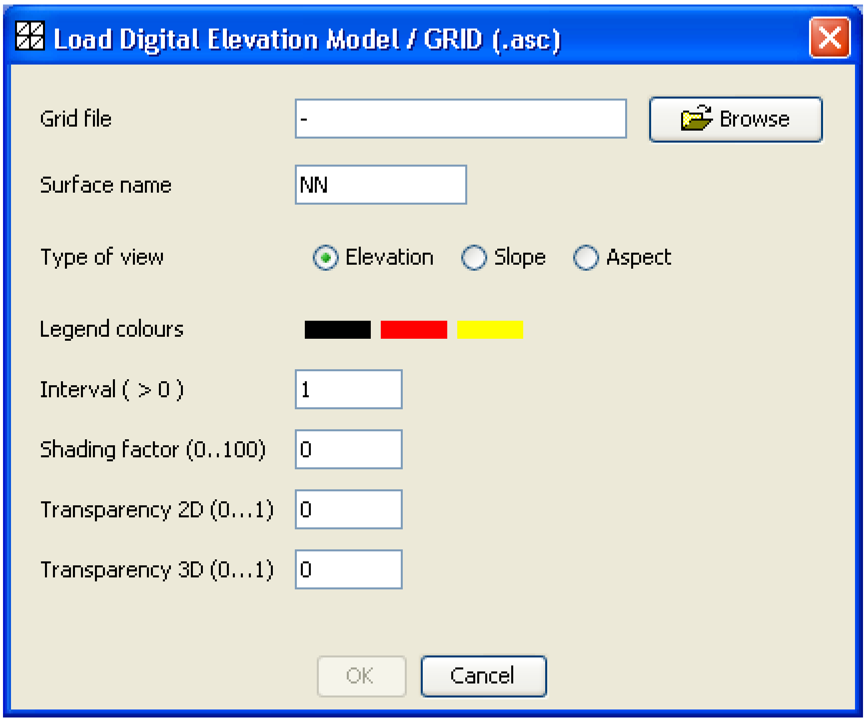
The ***Exit*** button closes the application. The user will get the dialog box below offering one chance to cancel this operation after that any previously unsaved data is lost. Clicking on the close icon on the GSI3D layout window has the same effect.

3.2.2 Add Objects

This is the main menu for loading data from prepared files and/or other projects into a GSI3D project.



Clicking on the ***DEM / GRID (*.asc)*** option produces the loading and properties box shown below.



Click ***Browse*** button at the top-right to navigate through the file structure to the particular DEM you wish to load. Once located select and open the .asc file and load into the file box and the file name is inserted into the ***Surface name*** box. The name can be altered here.

The remaining properties enable various methods of adjusting and enhancing the display of the DEM including colour ramps, shading, aspect and transparency and can be experimented with to produce the desired effect.

Finally click ***OK*** to load the DEM that should then appear in the map window. Large grid files may take a few seconds to load. Extremely large grids may cause GSI3D to crash due to a lack of memory. If this happens you will need to reduce the resolution or the extent of the grid data.

NOTE: DTMs etc loaded through this function are used for visualisation and reference only. The DTM or "Model Capping Surface" used as section profiles and for the model calculation must be created as a TIN (triangle mesh) from this grid (or other data) as described below in Section 4.1.1. A Grid can be converted into a TIN object via *right-click > Convert to TIN.*

NOTE: Please see the Glossary at Section 7 for the definition of the DTM, DEM and DSM as used in the software and this manual.

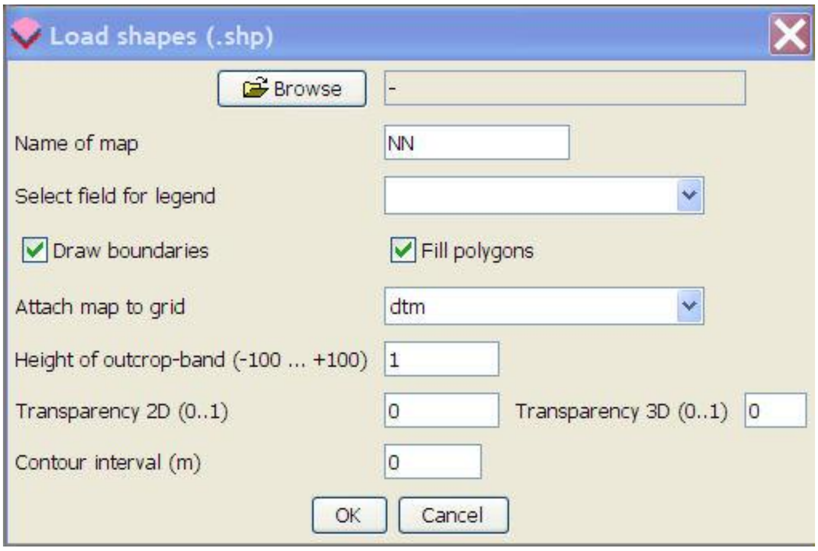
Selecting ***Map Image (*.jpg, *.png, *.gif)*** produces the properties box shown below. Click the ***Browse*** button at the top-right to navigate through the file structure to the particular digital map file you wish to load (supports JPEG, PNG and GIF images). Once located select and open the image file to load into the ***Image*** field. The file name may be assigned or changed here if needed using the ***Name*** field.

Check the ***Convert to grayscale*** box if appropriate and adjust the ***Transparency*** setting to suit. The default is 0 i.e. solid colour/opaque, a setting of 0.5 is recommended if a degree of transparency is required.

Click ***OK*** and the image will load from the file into the map window and added to the ***maps*** folder in the map window object tree.

NOTE: The file must be accompanied by a geo-registration file (world file) (e.g. *.jpw/*jpgw for JPEG images).

Selecting ***Shapes (*.shp)*** produces the dialog box below.



Click the ***Browse*** button to navigate through the file structure to the particular shapefile (*.shp)e you wish to load. Once located select and open the *.shp file; this is loaded into the file box and the file name is inserted into the ***Name of map*** box. The file name may be changed for display purposes here if needed.

The ***Select field for legend*** box displays the attributes of that particular shape file such as LEX for Stratigraphic Lexicon entry and ROCK for lithology in the case of BGS DiGMapGB shapes.

Check the ***Draw boundaries*** and ***Fill polygons*** options to show the coloured polygons in the map window.

In the ***Attach map to grid*** box all the DEMs that are loaded are listed, it is important to highlight and select the correct DEM that corresponds to the geographical location of the .shp file (e.g. surface geological map with DTM and bedrock map with rockhead – base Quaternary). This enables the user to visualise the crop lines in the section view. This is an elementary function in GSI3D because it allows the integration of 3D subsurface data with the surveyed geological linework (2D).

NOTE: a DTM covering a larger area than the individual .shp file can be used, and several .shp files can be loaded to tile the area of a large DTM. GSI3D however becomes confused if you try to load multiple .shp files (e.g. map tiles) and then register them to more than one DTM (e.g. corresponding DTM tiles). It is thus advisable to have DTMs available for the complete project area as well as tiled DTMs if modelling is proceeding on a sheet-by-sheet basis. In this way individual sheets can be modelled and deposited in corporate data stores whilst bespoke project areas and regional compilations can also be viewed as a whole in the GSI3D map window.

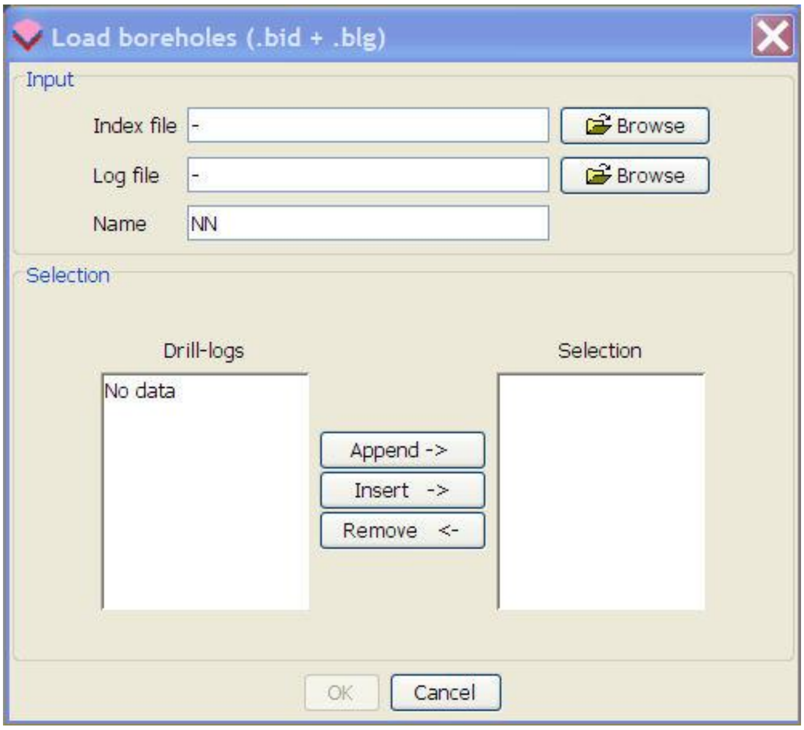
In the ***Height of outcrop-band*** field the user can set the vertical height in metres for the display of the polygon theme (usually the geological unit at outcrop) along the DTM profile on the line of section. This facility aids the drawing of sections by producing bands of colour along the DTM surface trace using the same colour scheme as defined by the Legend file. Inserting a positive value colours up a band above the DTM profile, a negative height value colours up the band below the DTM profile.

Adjust ***Transparency*** to suit from 0 to 1. Default is 0 i.e. solid colour, we recommend a setting of 0.5 if a degree of transparency is required.

Click ***OK*** and the coloured map polygons will be loaded and display in the map window. If the shapefile is large this may take a few moments.

Note: GSI3D does not support 3D shape files

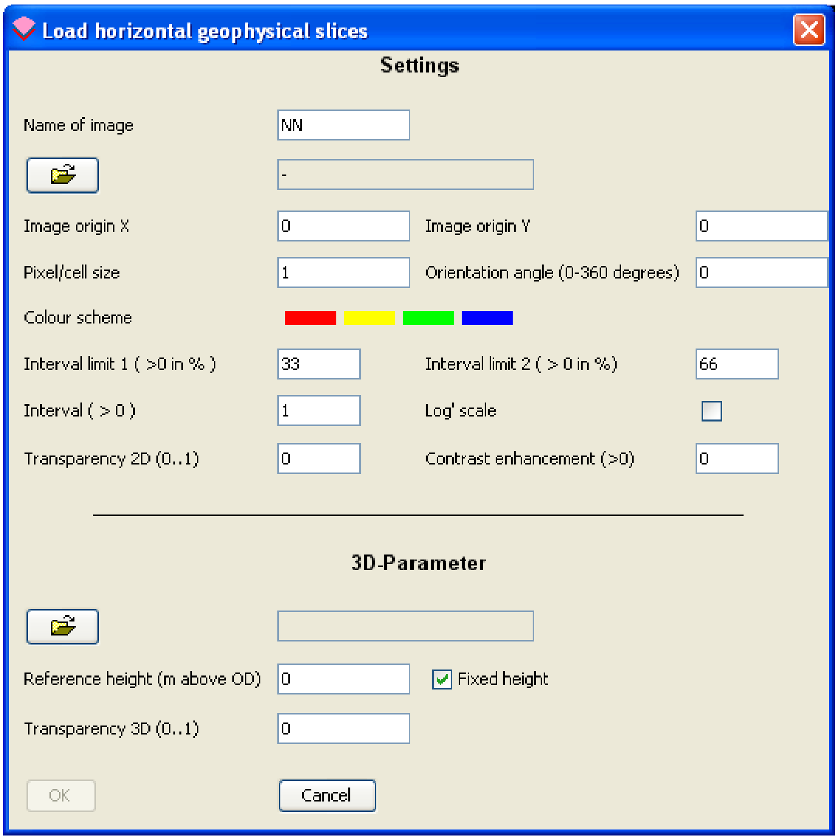
The **Boreholes (*.bid / *.blg)** option produces the borehole loading screen shown below:



Click the two separate ***Browse*** buttons to navigate through the file structure to the two borehole files needed. The upper file locator requires the *.bid index file listing the unique borehole number, coordinates and start height. This file is the master table and is automatically listed in the ***Name of Object*** box, all the boreholes in this table are also automatically listed in the ***Drill-logs*** field with a note of the total number of records above. The lower file selector requires a *.blg downhole log file giving properties such as stratigraphy, lithology, texture etc. together with depths to the base of each unit from the start height of the borehole.

The selected boreholes display their unique identifier in the **Drill-logs** box. Highlighting one and pressing Ctrl-A selects them all, otherwise select those required. A range of entries can be selected by holding down the Shift key, and a collection of entries can be selected by holding down the Ctrl key. Editing of the borehole list is made possible through the **Append, Insert** and **Delete** buttons. Once the required boreholes are all listed in the **Selection**, click ***OK*** and they will be loaded into the workspace. Boreholes are plotted in the map window, those with simple location details only colour red whilst those with downhole coded units (i.e. suitable for modelling) are coloured black or green depending on their total depth, this cut off can be adjusted by right clicking on the borehole file in the ***maps*** folder in the map window object tree and selecting **Properties** and entering the desired cut-off value.

Horizontal geophysical image enables a geo-registered image to be loaded at a defined elevation (z) value or alternatively draped on a surface.



In order to display geophysical horizontal slices as maps and in 3D, the slices have to be geocoded, by defining the lower left corner and the pixel or cell size (m/Pixel) of the slice.

Click the ***Browse*** button to navigate through the file structure to the slice you want to geocode. This can either be a picture or a grid file (*.gif, *.jpg, *.rst, *.asc or *.grd). Type in the coordinates for the lower left corner ***Image origin X*** and **Image origin Y,** as well as the ***Pixel/ cell size*** in m/Pixel. If necessary, you can change the angle of the slice in counter-clockwise orientation from the North-South direction, by filling in the setting box ***Orientation Angle (0-360°)***. If a *.rst, *.asc or *.grd file is loaded you can define the **Colour scheme** (in the usual way of changing colour settings), ***Interval (lower) limit* 1 (>0 in %), *Interval (upper) limit* 2 (>0 in %), *Interval* (>0)**, the ***Contrast enhancement*** *(>0)* and check the **Log scale** box if appropriate. For both, pictures and grids you can now or at any point later in the working session choose the ***Transparency 2D*** settings. Default is 0 a solid colour, we recommend a setting of 0.5 if a degree of transparency is required.

The lower part of the properties box is restricted for the definition of the ***3D-Parameter*** of the horizontal slice, either connecting the elevation of the slice in relation to the DTM or other surface or giving an absolute height above or below datum as a sheet. In order to link the slice to the DTM or any other surface use the file locator icon to navigate through the file structure to the appropriate file and define the relative distance of the horizontal geophysical slice to the surface in the ***Reference height*** (m above or below) settings box. The ***Fixed height*** box in the same line turns off automatically in this case. In cases where the slice was taken with an absolute height related to OD, define this elevation in the ***Reference height (m above or below 0D)*** box. These absolute settings can be modified any time during the working session. If necessary choose the ***Transparency 3D*** properties. Default is 0 a solid colour, we recommend a setting of 0.5 if a degree of transparency is required.

Click ***OK*** and the horizontal slice appears as a map in the ToC file tree of the map window.

The geo-registered and displayed horizontal geophysical slices can be stored in the saved *.gsipr project file.

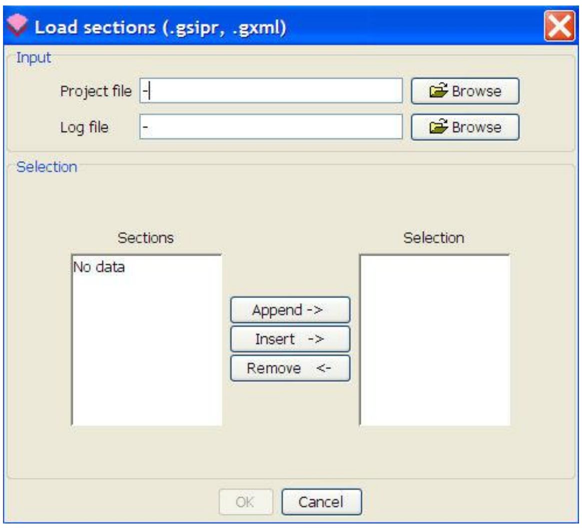
NOTE: The coordinate setting properties can only be changed <u>before</u> the first visualization of the slice, not during the first or any other working session.

NOTE: The project *.gsipr file only stores a link to the geophysical picture or grid, referring to the location of the respective picture or grid while geocoding. Changing the location of the picture or grid into another folder will result in loss of the data for the picture or grid. But if these files are in the same directory as the *.gsipr project file the system automatically checks this directory and chooses the indicated picture. This enables the transfer of the complete folder (*.gsipr and slices) into a different directory environment.

The following three options enable the direct import of objects from existing GSI3D *.gsipr or old-style *gxml files. These options are only used when merging work from different projects.

Load Sections (*.gxml, *.gsipr)

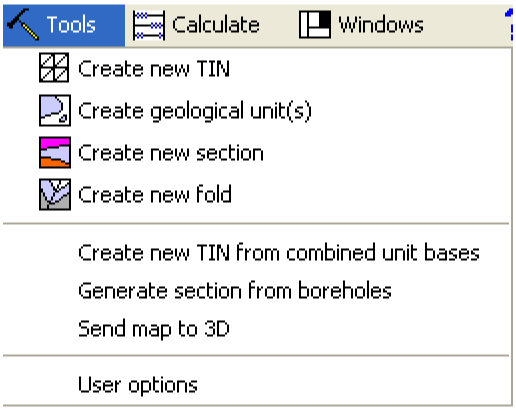
Selecting this option produces the dialog box below in which clicking the folder buttons requires navigation to and selection of the desired *.gsipr and *.blg files (downhole borehole interpretation file) for the sections. If no boreholes are present in the sections simply selecting any *.blg file will suffice. The sections available are listed in the bottom right box and can be Appended, Inserted or Deleted into the selection box on the left. Once data is selected the ***OK*** button at bottom left becomes bold and clicking on it loads the selected items.



The **Load Envelopes or TINs (of geological units)** and **Folds** options operate in exactly the same way.

3.2.3 Tools

This menu contains a selection of tools and functions used in the modelling process.



Selecting the **Create new TIN** option produces a dialog box to name the TIN.

Multiple Tins can be created and are stored in the *.gsipr file. The one to be used for calculation (the Model Capping Surface) is defined and stored in the Workspace properties settings (see Section 3.2.1).

Creating a new TIN object produces an empty object under the ***TINs and grids*** folder in the map window object tree. The TIN data is created by the procedure described below in Section 4.1.1.

Selecting **Create geological unit(s)** displays the colour coded GVS as a listing and enables selection of the units required to be created within the ***geological units*** folder within the map window ToC. These units are simply placeholder entries for the units and are subsequently populated with their distributions (envelopes) and calculated TINs during the modelling process.

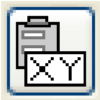
Create new section opens a dialog box requesting the input of a name for the section object. The name must be unique, duplicates will be rejected by GSI3D. Be systematic in labelling sections making use of the sheet on which they occur and their direction and sequential number where possible e.g. TM14_NS2 is the second north-south aligned section on the TM14 25K tile. Once selected this section appears at the bottom of the list of sections in the ToC of the section window and is ticked as the active section enabling construction to commence. This function is also used to specify the alignment of synthetic sections, once the model is calculated as described in Section 5.

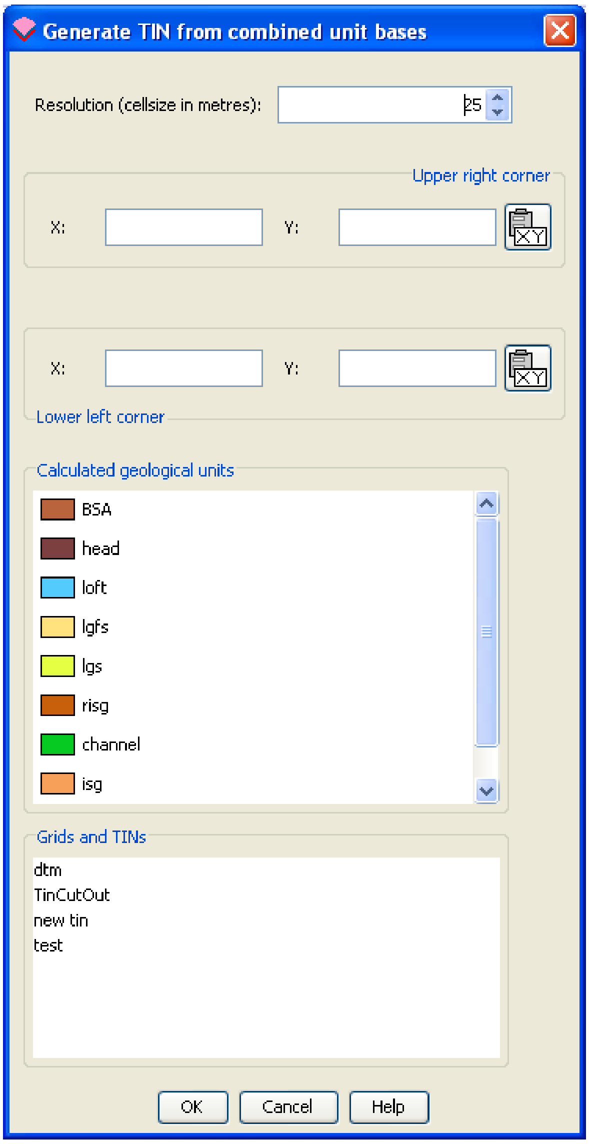
NOTE: Always open all existing sections and geological units prior to creating new ones so that all the sections and envelopes will appear in the saved *.gsipr file at the end of the session. GSI3D only stores what is loaded at the time saving is executed and doesn't automatically append data from previous sessions.

Create new fold similarly produce dialog boxes asking the user to name the object and then placing it as an entry in the appropriate folder in the ToC.

Create TIN from combined unit bases allows the user to create a new TIN object by combining the bases of previously calculated units.

The image below shows the dialog box where users first define the desired cell size and enter the upper right and lower left corners for the surface, this can be done by entering numbers or by placing the red cursor triangle at the right place in the map window (using the info tool) and then hitting the button to transfer the Eastings and Northings.

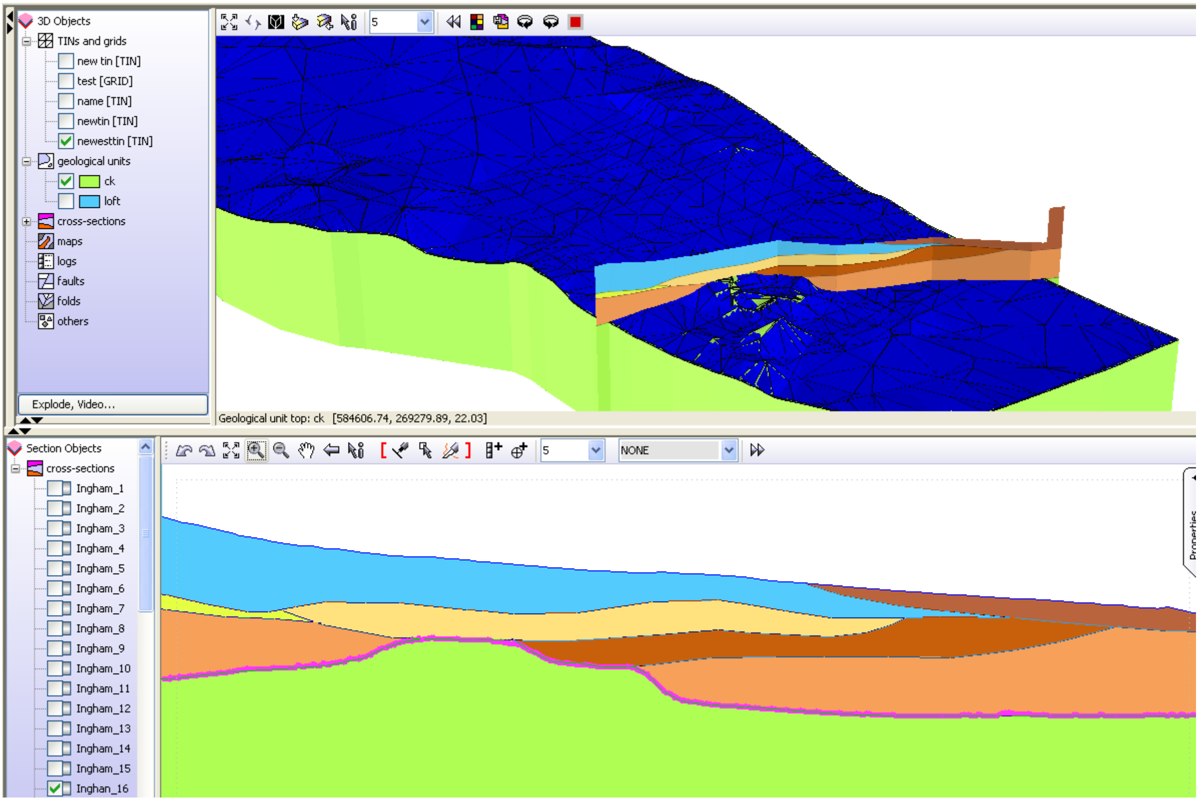




Under ***calculated geological units*** the user can choose which units to merge. If the DTM needs to be part of the desired surface (e.g. where a rockhead surface equals the DTM) this needs to be selected as well from the TINs and Grids folder.

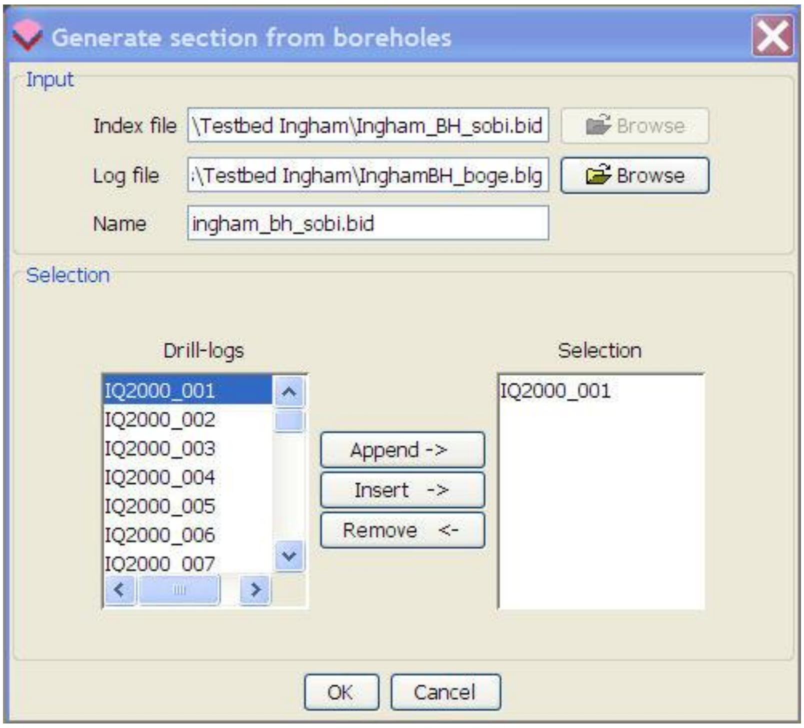
After pressing ok the user has to specify a name for the TIN and following that it appears in the TIN ToC. The TIN can be exported as an ascii grid should this be desired.

The image below shows a rockhead surface (calculated by combining all Quaternary units) in the 3D window (where it overlies the green Chalk bedrock unit) and in section view (as the pink line)



The **Generate section from boreholes** option opens the borehole-loading screen explained above in Section 3.2.2. Selecting borehole locations from a borehole index file (*.bid) automatically generates a section from the specified string of boreholes.

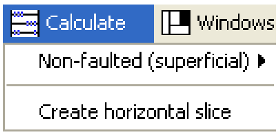
NOTE: The points will be connected to a section as listed in the Selection list on the right, so the user must add the borehole string in the correct order.



Send map to 3D produces a dialog box with a file selector to identify a grid to attach the selected map to. The map is specified in the ***Name of 3D map*** box. Alternatively a fixed reference height can be applied to the map by checking this option and entering the required elevation, transparency settings are also included.

User Options contains some user specific settings.

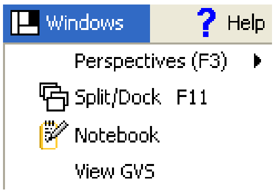
3.2.4 Calculate



The Calculate menu contains 2 options to start the calculation of a geological model and is described in Section 5.

Create horizontal slice allows the user to define a horizontal plane to create a synthetic section (map) after the model has been calculated. The new map is consequently listed under the map folder in the table of contents and can be viewed in the 3D window or be exported as a shape file via ***right-click > export***.

3.2.5 Windows



Perspectives (F3)

Layout perspectives adjust the layout of the different windows to preset locations in order to facilitate the accomplishment of a particular task. They are designed to reduce the labour involved in setting up the user interface when you are switching between different modelling tasks. In previous versions this would have required the user to drag all of the window dividers to their desired positions.

There are five built in layout perspectives to choose from:

You can also quickly cycle between the different available perspectives by pressing the **F3** key on the keyboard.

Map and Section

This layout minimizes all except the map and section windows. The section window is made smaller in relation to the map window owing to the usually linear nature of section graphics, allowing the map to occupy the majority of the screen real estate. This perspective is designed to facilitate the initial building of lines of section from the map data.

Map

This layout minimizes all except the map window. This allows you to work on interrogating and build objects in the map. For example, you may wish to use this mode to build geological units from surface linework.

Map and Borehole

This layout minimizes all except the map and borehole windows. The borehole window is made smaller in relation to the map window owing to the usually vertical nature of the borehole graphics, allowing the map to occupy the majority of the screen real estate. This perspective is designed to facilitate interrogation of the borehole data represented on the map.

3D

This layout minimizes all except the 3D window. This allows you to investigate the model objects in 3Dimensions more easily.

Standard

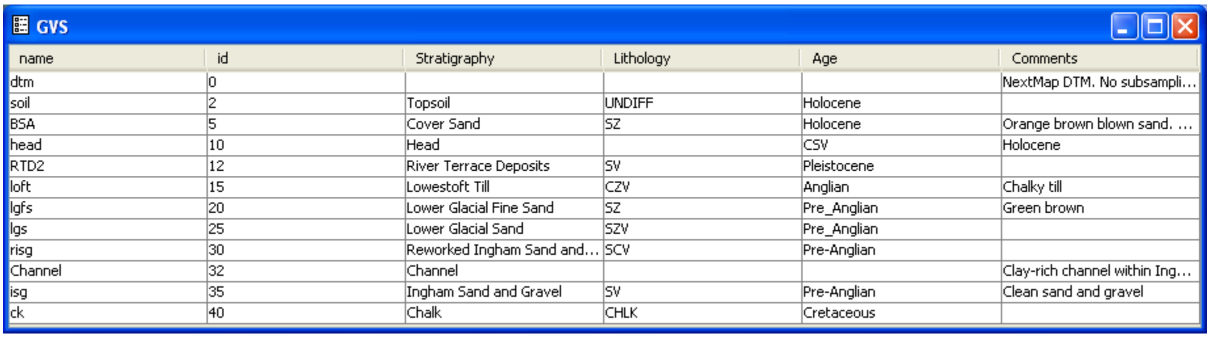
This opens all windows (borehole, map, section and 3D) to reasonable default sizes, allowing you to inspect and work on the model in any way you wish.

Split /Dock F11

This function enables the component windows to be separated and reassembled into the default layout. Once split the windows are available for resizing, minimizing etc as desired to achieve a perspective of choice for a particular task or session. If a window is closed accidentally the interface should be re-docked, and then split again to regain the lost window.

View GVS

Selecting this option brings up a display of the GVS table in a separate window to give a quick overview of the loaded GVS. The GVS can be edited using the GVS-Legend editor from the workspace dialog box (see section 4.1.1) or outside GSI3D using notepad or wordpad.



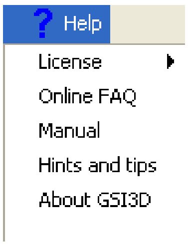
name	id	Stratigraphy	Lithology	Age	Comments
dtm	0				NextMap DTM. No subsampli...
soil	2	Topsoil	UNDIFF	Holocene	
BSA	5	Cover Sand	SZ	Holocene	Orange brown blown sand. ...
head	10	Head		CSV	Holocene
RTD2	12	River Terrace Deposits	SV	Pleistocene	
loft	15	Lowestoft Till	CZV	Anglian	Chalky till
lgfs	20	Lower Glacial Fine Sand	SZ	Pre_Anglian	Green brown
lgs	25	Lower Glacial Sand	SZV	Pre_Anglian	
risg	30	Reworked Ingham Sand and...	SCV	Pre-Anglian	
Channel	32	Channel			Clay-rich channel within Ing...
isg	35	Ingham Sand and Gravel	SV	Pre-Anglian	Clean sand and gravel
ck	40	Chalk	CHLK	Cretaceous	

Notebook

This opens a window to record notes during a modelling session, these are saved within the project workspace and can be used to keep a trail of notes.

3.2.6 Help

The help pull down menu (shown below) contains the following options

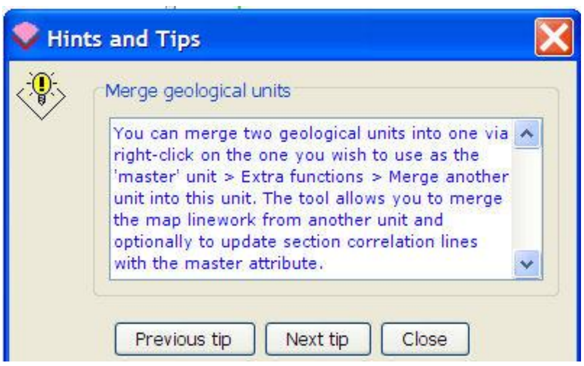


License contains various options for digital licensing of GSI3D. The exact options may vary from version-to-version. Please refer to the licensing documentation on the GSI3D website for up-to-date information on how to manage licenses within GSI3D - www.gsi3d.org.uk - or contact the Helpdesk.

Online FAQ contains a link to frequently updated FAQ consortium web pages. This function may not work on all computers, depending on your internet settings. The URL for the FAQ is http://www.gsi3d.org.uk/faq.html.

Manual contains a link to the user documentation. This function does not work on all computers, depending on your settings. The latest manual is always available from the GSI3D Consortium website – www.gsi3d.org.uk.

Hints and Tips contains a series of hints and tips of new features and workarounds.



About GSI3D gives information about version number, copyright and the development team

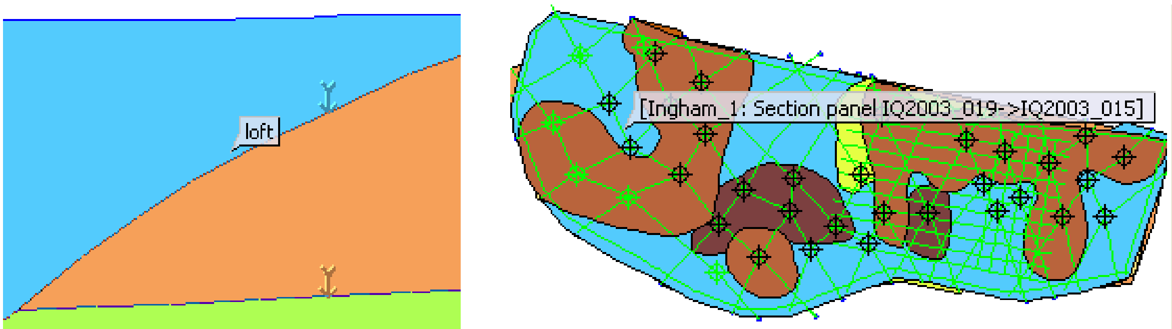
NOTE: When publishing output from GSI3D the software should be referred to as GSI3D ™

3.2.7 Floating tooltips

Floating tooltips are available for objects in the Map and Section windows. Hovering with the cursor on objects in these windows allows you to quickly identify objects without using the info tool.

Tooltips can be activated temporarily in any navigation mode by holding down the ***Shift*** key and then hovering the mouse cursor over the line or object that you wish to identify.

Tooltips can be activated permanently in both windows by pressing the ***F7*** key. Pressing the key a second time will switch them back off again. When in permanent tooltip mode, tooltips will be rendered as you hover the mouse over lines or objects you wish to identify. It is not advisable to use permanent tooltip mode in a map or section window that contains a lot of data because you may find that performance is reduced or you may experience graphics flicker as you move across objects.



Tooltip in section and map window identifying unit name of correlation line and section name.

Note that the tooltip is semi-transparent, allowing you to see the linework behind it even when the tooptip is visible.

3.2.8 Window folder options

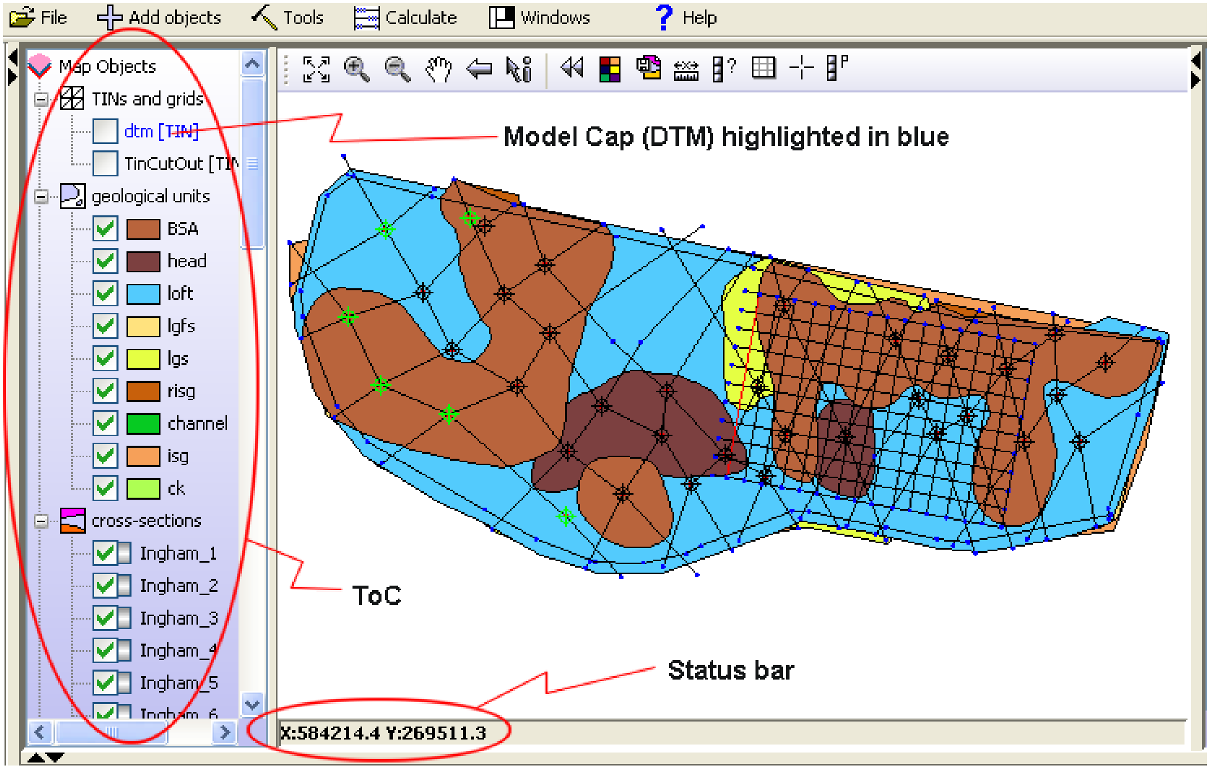
The folders present in each of the four dynamically linked GSI3D windows are tabulated below

	Map	**Section**	**3D**	**Borehole**
Grids -TINs	∗		∗	
Geological Units	∗		∗	
Cross sections	∗	∗	∗	

Maps	*		*	
Drill logs			*	*
Faults	*		*	
Folds	*		*	
Contours	*			

3.3 Map window

An example map window is shown below, in common with the other windows it has a main screen with a Table of Contents (ToC) at left, the icon toolbar at the top and the x, y coordinate display for the cross hair position in the status bar at the bottom of the window. Other query information also displays in the status bar when the info tool is selected from the toolbar. The border between the main screen and the ToC can be resized to suit by hovering on the border until the double arrow is displayed and then dragging by holding down the left mouse button, release button to stop.

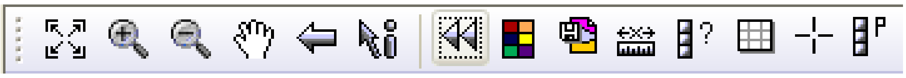


3.3.1 Toolbar

The standard toolbar contains the following icons:

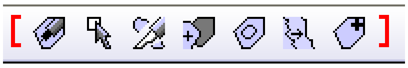
1 2 3 4 5 6 7

Once expanded additional icons are available (8-14)



8 9 10 11 12 13 14

and with a geological unit editable the polygon tools editing icons are added (15-21)



15 16 17 18 19 20 21

1. Zoom to full extent

Click fits the whole object to the extent of the map window

2. Zoom In

Click on, then click in window and hold down whilst dragging mouse to construct a marquee around the area to zoom in to, release on completion. The mouse wheel can also be used to zoom in and out.

3. Zoom Out

Click on, click in window, and repeat to incrementally reduce the magnification. This tool cannot draw a box to zoom out to a specified area. The mouse wheel can also be used to zoom in and out.

4. Pan

Click, then click in window and hold, drag to new position and release, drag and drop.

5. Back to previous view

Click, displays previous views, useful in scale changes, (**NOTE: not an undo button**).

6**. Info tool**

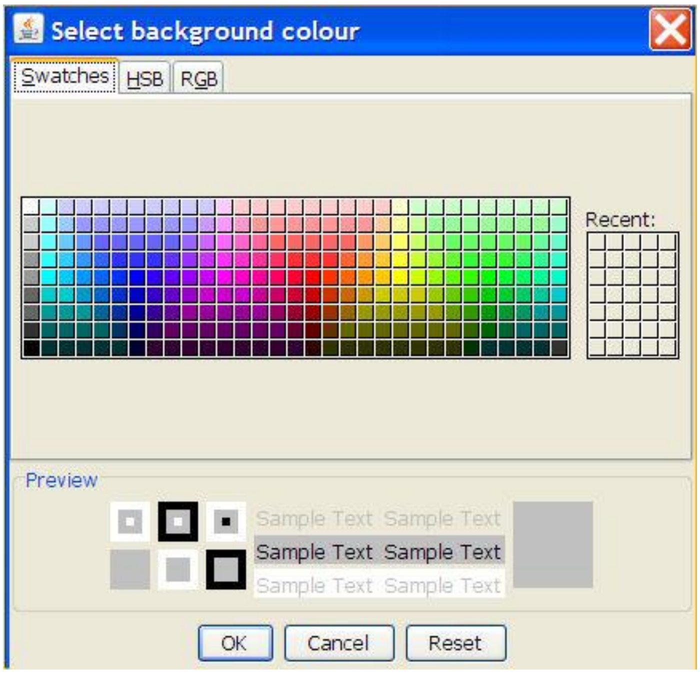
Click to activate and then click on objects (sections, faults, polygons) within the window to display their identity on the bottom bar. See also Tooltips at Section 2.1 above.

7. Extra tools flyout button

Click to display extra tools 8-14.

8. Select background colour

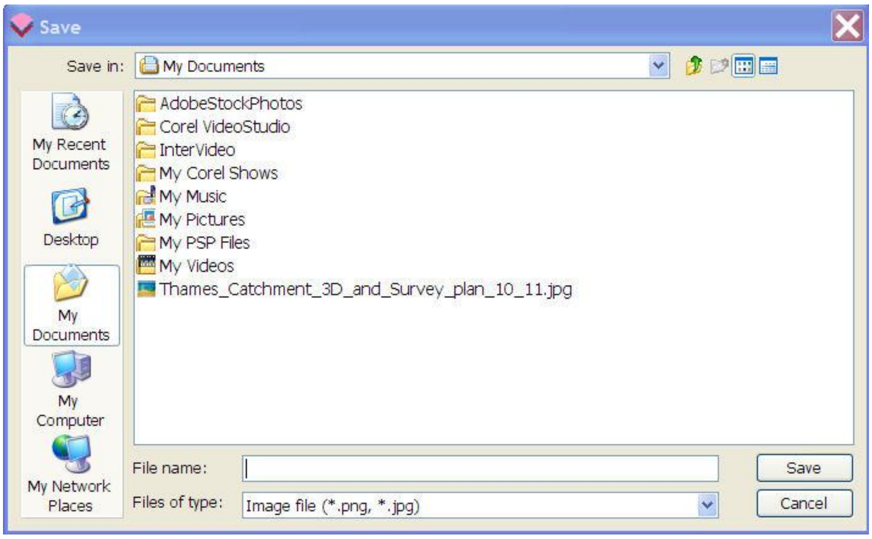
Click brings up the dialog box below to select a suitable background colour in 3 different ways:



The Swatches tab shows 270 colour tiles, the HSB (Hue, Saturation, Brightness) and RGB (Red, Green, Blue) tabs allows selection by interactive slider bars.

9. Save map window as image

Saves the contents of the map window as a geo-registered *.jpeg or *.png image. The default is to save a png file, by typing the file name with the *.jpg extension a jpeg is saved.



When saving a registration file is generated automatically (*.jpgw/jgw or *.pngw), enabling the import of the map to GIS systems.

10. Measuring tool

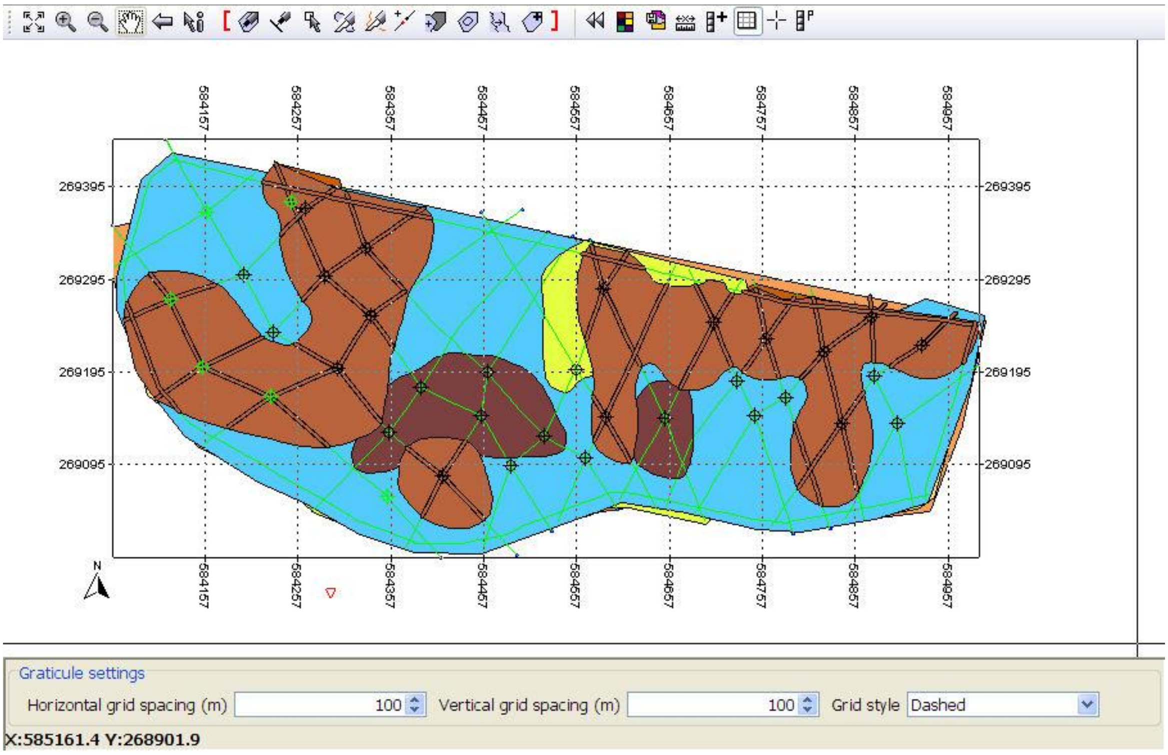
Enables a line to be drawn in the map window and the total length is displayed in the status bar on the right hand side, double click to complete the operation.

11. Synthetic log

This button is only relevant once geological units (volumes) have been calculated (see Section 2.1) and enables the creation of synthetic logs displayed in the borehole viewer. After activating the button, clicks anywhere within the modelled area are displayed in the map window as a log in order to instantly display a predicted geological sequence at that point in the borehole viewer.

12. Graticule

Click to display graticule.



The map graticule is a rectangular grid overlay, calibrated in metres. It is used to help the modeller decide on the positions of map objects and can also be used in graphical outputs. The graticule is operated by a toggle button in the map window toolbar. Clicking the button once will toggle the graticule on, clicking it again will toggle the graticule off. The graticule can also be toggled using the keyboard shortcut ***Ctrl + H***.

When the graticule is toggled on a new set of controls appears at the base of the map window which allow the user to specify the settings for the graticule. These options allow the graticule spacing to be set and also the line style. The grid spacing can be set differently for the vertical and horizontal lines.

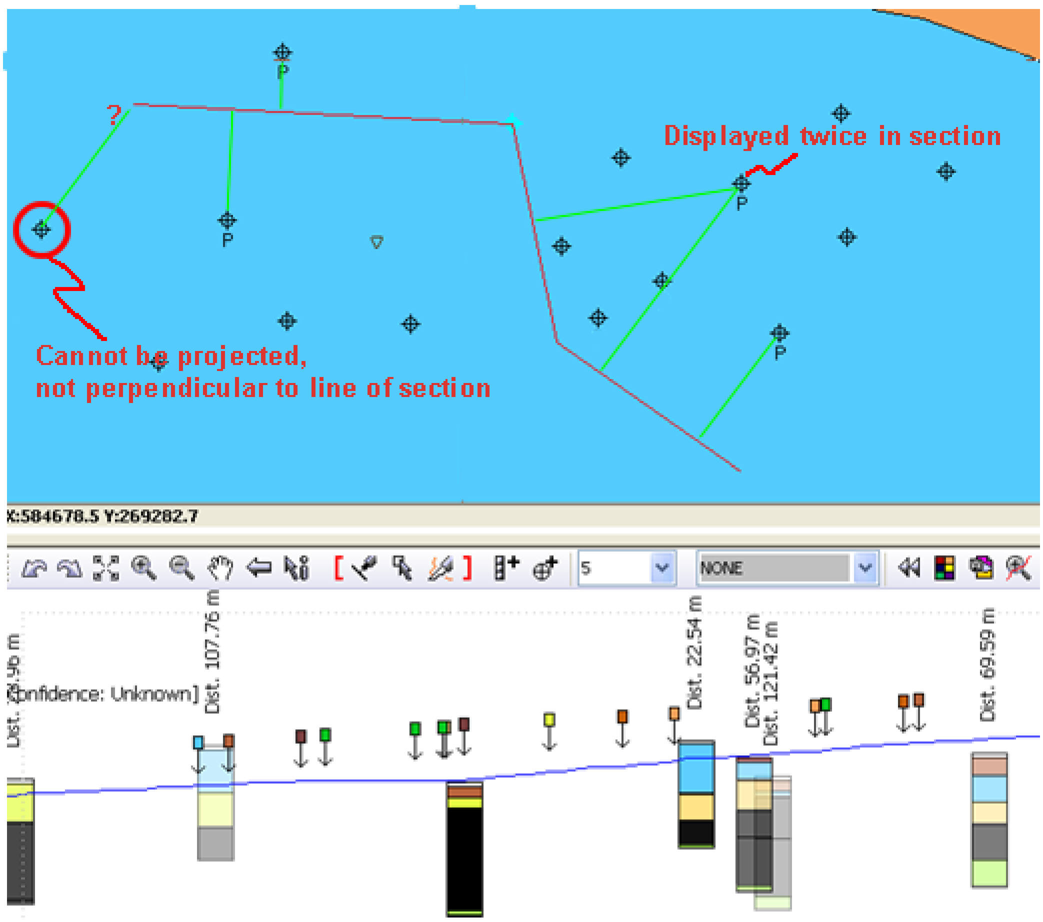
13. Show/Hide cross hairs

Toggles the map window cross-hairs on and off.

14. Select borehole to project

This function allows selected boreholes to be projected graphically (not added) to the active section for reference purposes. This enables the use of close-by borehole information without affecting the line of the section. Click the button to activate the tool, and then pick boreholes in the map window to project them into the currently active section. Projected boreholes can be cleared out of a section via ***right-click > Remove projected boreholes*** on an individual section object in the section window ToC.

The image below shows projected boreholes which are of varied transparency in proportion to their distance away from the line of section. They are labelled in section with their offset distance normal to the section and in map view with a label 'P'. Only boreholes where a line can be drawn from the borehole position perpendicular (at 90 degrees) to the line of section can be projected onto that section. Boreholes that lie between two section limbs will be projected into both positons in the section and displayed twice int he section picture:



Polygon and line tools (15-21)

The polygon and line construction and editing tools within red brackets are only displayed when a geological unit is in editable mode.

15. Construct Polygon

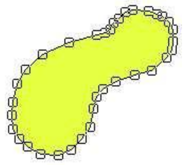
Enables the construction of a new polygon during envelope building,

Click to activate, click at start position, and then click to add nodes to make shape double click to complete and close the polygon.

16. Node editor

Mainly used in editing polygon shapes or dragging nodes to overlap adjacent polygons to enable combination.

Click to activate, right click to select any polygon, displays all existing nodes. Enables addition of nodes to line by clicking on it and removing nodes by double clicking on them.



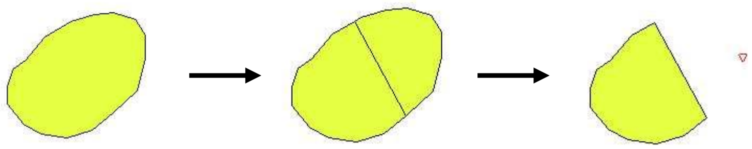
17. Split Polygon

Very useful for chopping away chunks of a polygon during the construction of envelopes.

Click to activate, click at point outside polygon to start a line for splitting, then drag to beyond other side of polygon and double click to produce a line crossing the polygon splitting it in two.

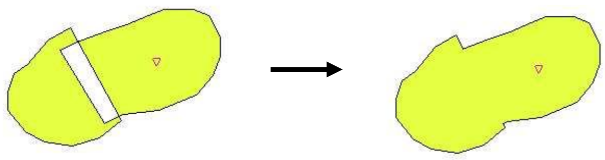
Then use polygon info tool (see below), click on it to activate it, then right click on any segment of line in the half of the polygon you wish to be deleted, and select delete polygon from pull down menu, finally confirm your decision.

NOTE: When splitting a polygon the initial and final clicks that define the cut line must be within the same polygon. A cut line cannot be produced by starting the cut line in one polygon traversing a second to terminate in a third polygon i.e. A-B-A works A-B-C does not.



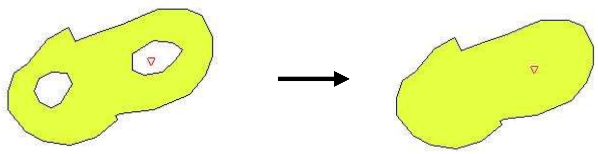
18. Combine overlapping polygons

Click, automatically combines any polygons in the editable layer that overlap each other. Useful for the drawing of envelopes that include surface outcrops and subcrops.



19. Combine adjacent polygons and fill holes

Click, automatically merges all selected polygons with common (mutual) boundaries and incorporates (deletes) all polygons totally enclosed within those selected polygons i.e. fills islands-holes. Useful for combining polygons of all overlying units in the construction of envelopes of partly or largely concealed strata. It is important to select all polygons to be combined to form the envelope first then click this button, any holes in the distribution should then be cut out (deleted) using the Info (select) and then Select Polygon functions in the normal way.



20. Clean polygons

Click, the tool automatically cleans up coinciding nodes from two separate polygons along mutual boundaries. It also cleans polygons according to the Minimum node spacing defined in the workspace properties (see Section 4.1)

21. Insert selected polygon

After selecting a polygon using the Info tool the polygon can be incorporated into the envelope (layer data) by clicking on this button. The info tool leaves a red triangle in the map view to help you visualise which polygon has been selected. When importing intricate polygons the Minimal Point distance must be set to 0 in order to avoid slivers of *no data* (see Section 3.7).

3.3.2 Map window properties

Mouse wheel zooming

The map window can be zoomed in and out using the mouse wheel. Scroll the wheel forwards to zoom in and backwards to zoom out.

Mouse clicks

Use the left mouse click in conjunction with the Info tool (icon 6 above) to query objects such as boreholes, DiGMapGB polygons, section lines, faults and grids displayed in the map window. The query information is displayed at the bottom left corner of the map window. See also floating tooltips Section 3.2.7.

NOTE: Every mouse click in ‘info’ mode leaves behind a small red triangle that indicates the location of the previous query.

Right click anywhere within the map window produces the following options:

Insert comment

Produces a dialog box to type in free text to add a note at the selected location (red triangle). Comments can be displayed as balloon symbols by ticking on the show comments box in the window properties settings box

Window properties

Produces a settings box comprising a series of options to display (by ticking) or hide certain properties within the map window.

Show cross-section

Right click on a section line gives the option to display this section in the section window. Sections must be visible in the map window for this function to operate – the query will not look for hidden sections.

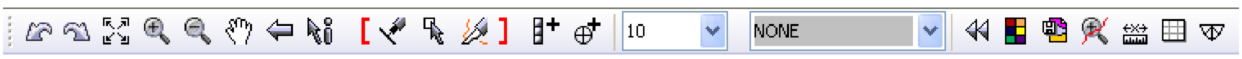
Insert borehole or knick point

First select a borehole by clicking on it using info mode, then right click on part of the active section line (the section that is currently displayed in the section window is known as the active section and its map linework is red) gives the option to insert the last-selected borehole log into that line segment or alternatively add an additional coordinate point specified immediately before clicking on the line.

3.4 Section window

3.4.1 Toolbar

Once expanded the toolbar contains the following icons from left to right,



1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22

1. Undo

Undo the last edit. Note that the undo-redo is not active for 100% of all possible actions. General actions such as digitizing, editing etc are supported, but some more complex actions may not be undoable.

2. Redo

Undo the last edit. Note that the undo-redo is not active for 100% of all possible actions. General actions such as digitizing, editing etc are supported, but some more complex actions may not be undoable.

3. Zoom to full extent

Fits the whole object to the dimensions of the section window.

4. Zoom In

Click on to activate, then click in window and hold down whilst dragging mouse to construct marquee around area to zoom in to, release on completion.

5. Zoom Out

Click on, click in window, and repeat to incrementally reduce the magnification.

NOTE: if the mouse has a wheel, this can also be used for zooming in and out.

6. PAN

Click to activate, then click in window and hold button down, drag to new position and release.

7. Back to previous view

Displays previous view (zoom and pan), **not** an undo button.

8. Info tool

Click to activate info mode, then position mouse cursor on the object or location you wish to interrogate, the x and z coordinates automatically display and scroll in the status bar, if a correlation line is clicked on its identity is displayed instead.

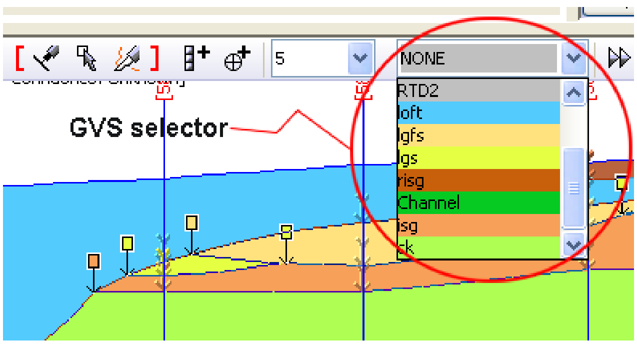
Line tools

In red brackets (9-11)

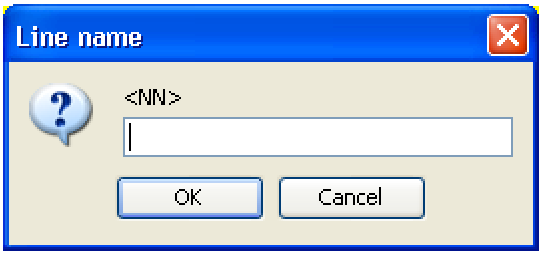
9. Draw line

Click on the icon to activate drawing (digitizing) mode. In the section window, left-click once at each desired node location to construct the new line. Double click to complete the line.

When digitizing in section it is best to use the GVS selector to pick a unit name before digitizing. This automatically attributes each digitized line with the selected GVS attribute and saves a lot of time naming the lines individually:



If NONE is selected in the GVS selector (or there is no GVS loaded) a prompt will appear for the name of the digitized line when the line is completed via a double-click:



10. Edit line

Click on the icon to activate. Click on the line you wish to edit to make it active, the nodes are displayed as grey boxes.

Edit the nodes as follows:

- To reposition: click and hold the node, drag and release at new position.
- To insert a new node: click on the line where a new node is required.
- To delete a node: double click on the node you wish to delete.

NOTE: The last 3 nodes of a correlation line cannot be deleted. Use right click to delete line!

11. Split line

Click on the icon to activate: Draw a line of two nodes crossing the correlation line at right angles where you wish the split performed. Double click when placing the second node to terminate the cutting line. Select the node display (Edit line icon, 12 above) to check the split has been performed. Each segment retains its original attribution.

NOTE: The last 2 nodes of a correlation line cannot be split as this would leave a solitary node which does not constitute a line.

12. Add borehole to section

For use in adding borehole positions to the end of sections (added to the right-hand end of the section in the section window). With the desired borehole selected in the map window using the Info tool (and displayed in the borehole viewer to validate its worth) simply click on the icon to add the currently selected borehole to the section under construction (active section).

13. Add point to section

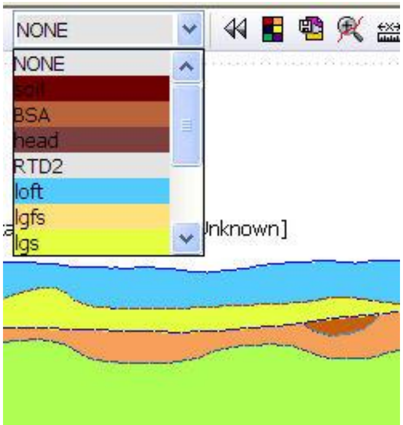
For use in adding knick-points whilst constructing sections, with the desired coordinate location selected in the map window using the Info tool, simply click on the icon to add the location to the section under construction (added to the right-hand end of the section in the section window).

14. Set vertical exaggeration

This field enables the setting of vertical exaggeration, simply select a value from the pull-down list. To specify a value that is not in the defaul list, type the desired value into the field and hit enter. The new value will be added to the list.

15. GVS selector

This produces a pull-down list of the GVS entries. You can use this to digitize correlation lines of a particular unit one after the other and have them be attributed with the current selection in that list automatically. Simply select the unit you want to draw and start creating linework. They will be attributed and coloured up by that unit. To stop using this function, select “NONE” from the top of the list. Note that the pull-down list displays the relevant colour for each unit for ease of identification.



16. Extra tools flyout button

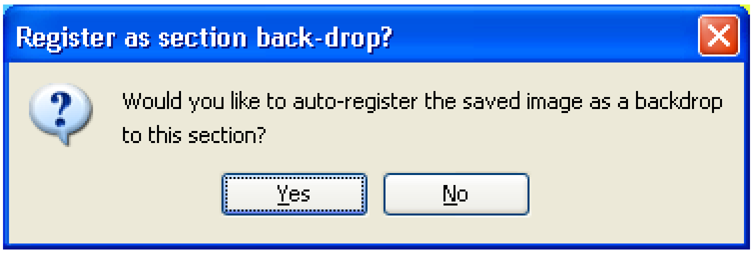
Click to display extra tools 15-22.

17. Select background colour

Brings up a standard colour palette from which to choose a background colour for the section window (as described above for Map window Section 3.3.1.).

18. Save section window as image

Saves a synthetic or a correlated section as *.png or *.jpg, png is the default setting .jpg needs to be added to the file name if JPEG is required. No geo-registration file will be produced unlike the map window. Only the visible part of active section will be exported, best results are achieved when the section window is expanded as much as possible. The result is the equivalent to a screenshot. When the image is saved there is an option to register the image into the section as a section raster.



19. Fit section view to view in map window

This function enables the user to zoom in the map window to exactly the same segment of a section that is currently displayed in the map window thus coupling the two scales

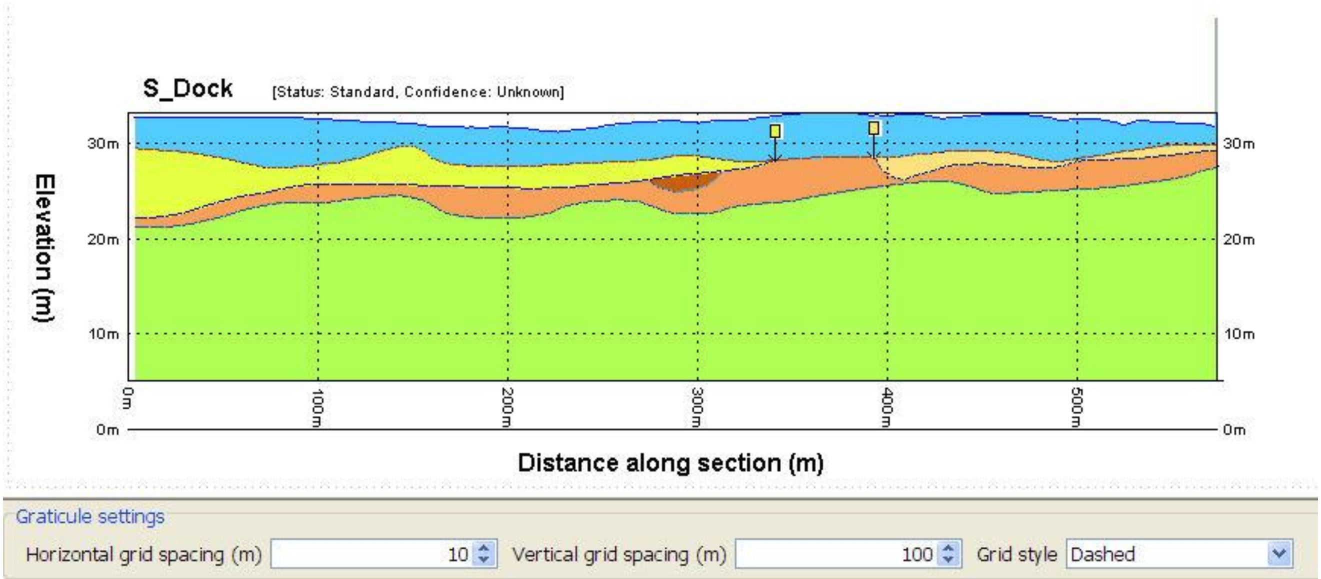
20. Measuring tool

Draw a line within the section window, its length will be displayed in the status bar at extreme right, double click to finish.

21. Graticule

The section graticule is a rectangular grid overlay, calibrated in metres. It is used to help the modeller decide on the positions of correlation lines and can also be used in graphical outputs. The graticule is operated by a toggle button in the section window toolbar. Clicking the button once will toggle the graticule on, clicking it again will toggle the graticule off. The graticule can also be toggled using the keyboard shortcut ***Ctrl + G***.

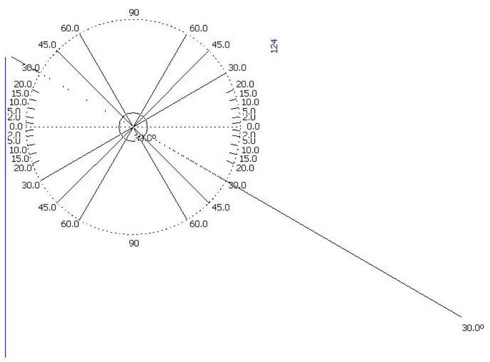
When the graticule is toggled on a new set of controls appears at the base of the section window which allow the user to specify the settings for the graticule. These options allow the graticule spacing to be set and also the line style. The grid spacing can be set differently for the vertical and horizontal lines.



22. Clinometer

A clinometer tool is available in the section window to assist in the drawing of correlation lines. When selected the clinometer will appear when you digitize a line.

Click on the clinometer icon to activate this tool for line construction, and then select the draw line tool (above) with the placement of the first node the clinometer appears centered on the node to aid the positioning of successive nodes. The clinometer migrates to centre on the last node of the string as line drawing progresses.



Initially it will display a default set of angles. These can be altered by going into the section properties ***r-click > Properties*** and clicking on the ***Clino settings*** button in the properties dialog (described below in Section 3.4.2).

Alternatively an angle label can be displayed next to the mouse cursor when digitizing, which may be easier to use than the full clinometer. Normally this is active by default, and it can be toggled on and off via ***Tools > User options > Section (tab) > Display angle label when drawing line***.

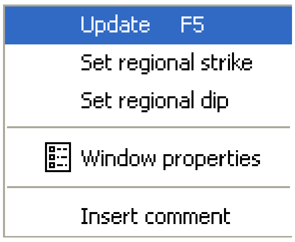
3.4.2 Section window properties

Use the left mouse click with the Info tool highlighted to query objects such as boreholes, correlation lines, and cross-points. The query information is displayed at the bottom left corner of the section window. Alternatively you can hold down Ctrl and hover over a line, crop arrow and cross-hair to display a tooltip with the attribute.

Right click on a borehole or a knickpoint position (this option must first be selected in the section properties box to display) gives the extra option to delete it.

Right clicking on a cross-points arrow gives the additional option to show crossing section i.e. switch to the intersecting section the point queried is then highlighted on the intersecting section with a red cross.

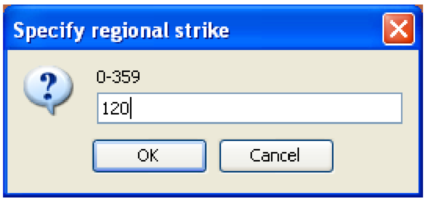
Right click anywhere within the section window produces the following standard menu

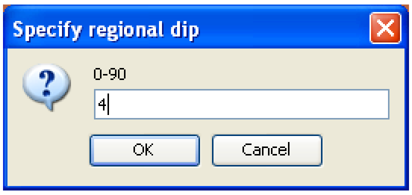


Update

Refreshes the section window

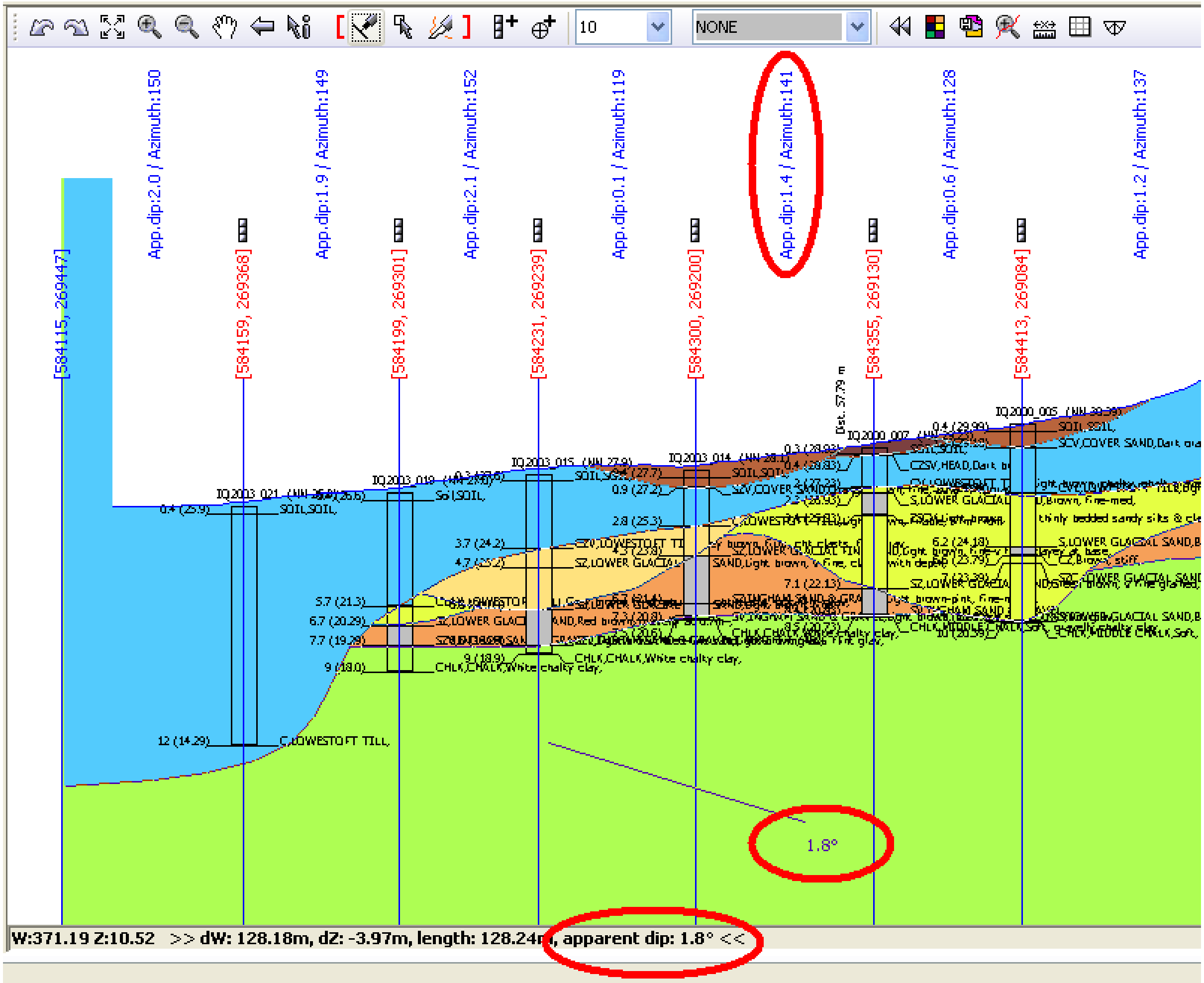
Set Regional strike and dip





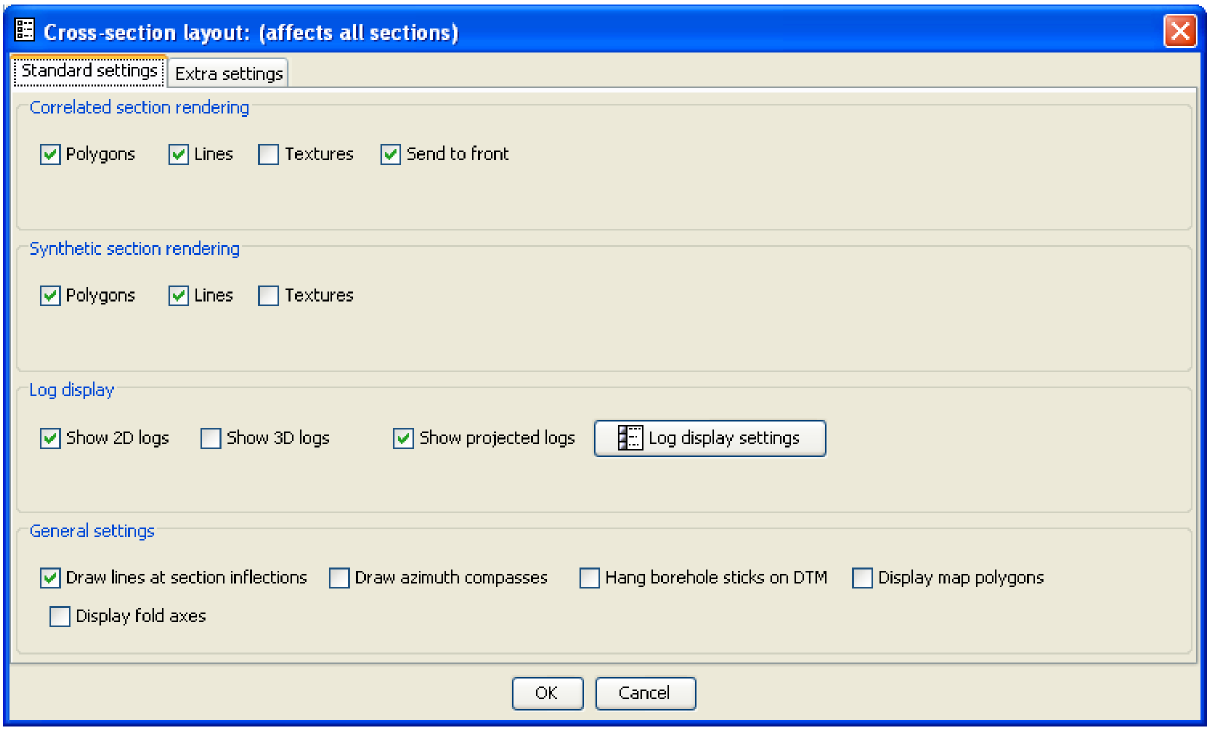
Once values have been set for regional dip and strike the option to show lines at log positions will also display the strike of each limb of the section and the apparent dip that would be present in that limb if the units at that point were striking and dipping according to the user-defined regional values. Note that both strike and dip must be set to enable this. The benefit of this is that it allows the modeller to see how far from the regional trend their own correlation lines are within the section panels and hence gives an opportunity to review in light of this information. Additionally the apparent dip is displayed whilst drawing a correlation line. The image below shows how dip and strike information can be displayed during the modelling process.

NOTE: to display the Apparent Dip and Azimuth for each section limb the display must be enabled in the section properties window (see below)



Active section properties

This option is available via right-click on the section window and is also available from a right click on any section in the ToC > Properties and will affect the individual section only. To make settings on all sections, use ***right-click > Properties (all sections)*** on the sections folder in the section window ToC.

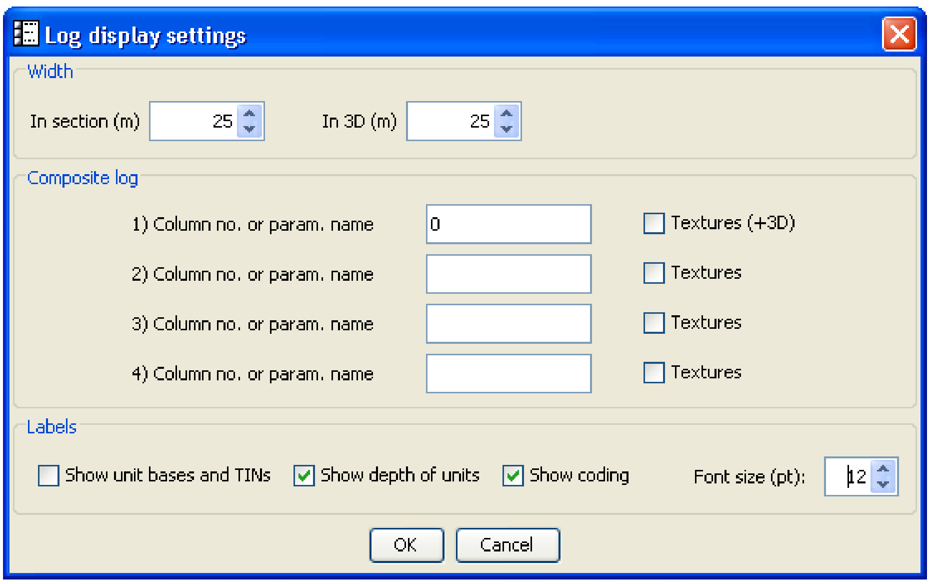


Under the **Standard settings** tab:

Correlated section rendering contains boxes to show (checked) or hide (unchecked) polygons, lines, textures and send to front. This affects the display of digitised correlation lines.

Synthetic section rendering contains show/hide boxes for polygons, lines and textures. Synthetic sections are those displayed after a model has been calculated (see Section 5).

Log display contains show-hide boxes for borehole logs in 2D and 3D plus the ***Log display settings*** box for the logs shown below. It also contains the option to switch on/off the display of projected logs.



Width

In section sets the thickness of the borehole stick in the section window in metres (scaled relative to the section). The default is 25m.

In 3D sets the thickness of borehole columns/sticks in the 3D window.

Composite Log

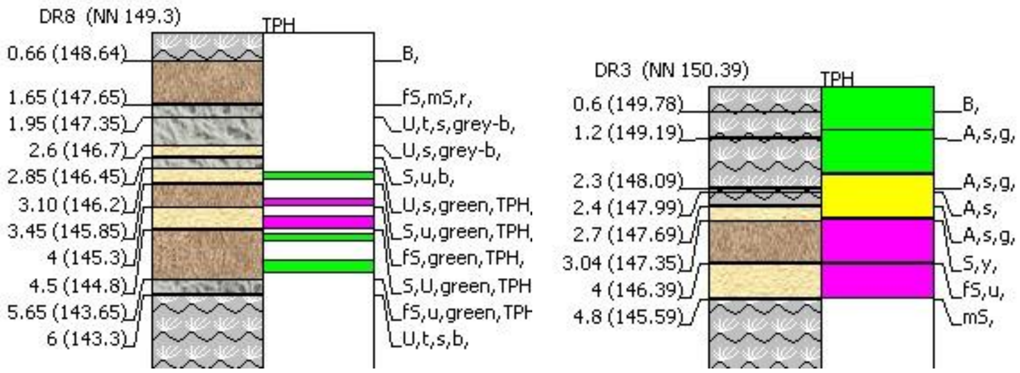
Up to 4 borehole sticks can be displayed in a ***composite log***, the numbered ***column number or parameter-name*** boxes are filled by entering the selected columns (0,1,2 3… from left to right) in the downhole *.blg file or parameters from a point data source, here the header value has to be entered.

Tick the ***Textures*** box alongside each field to display representative textures instead of colours.

Labels

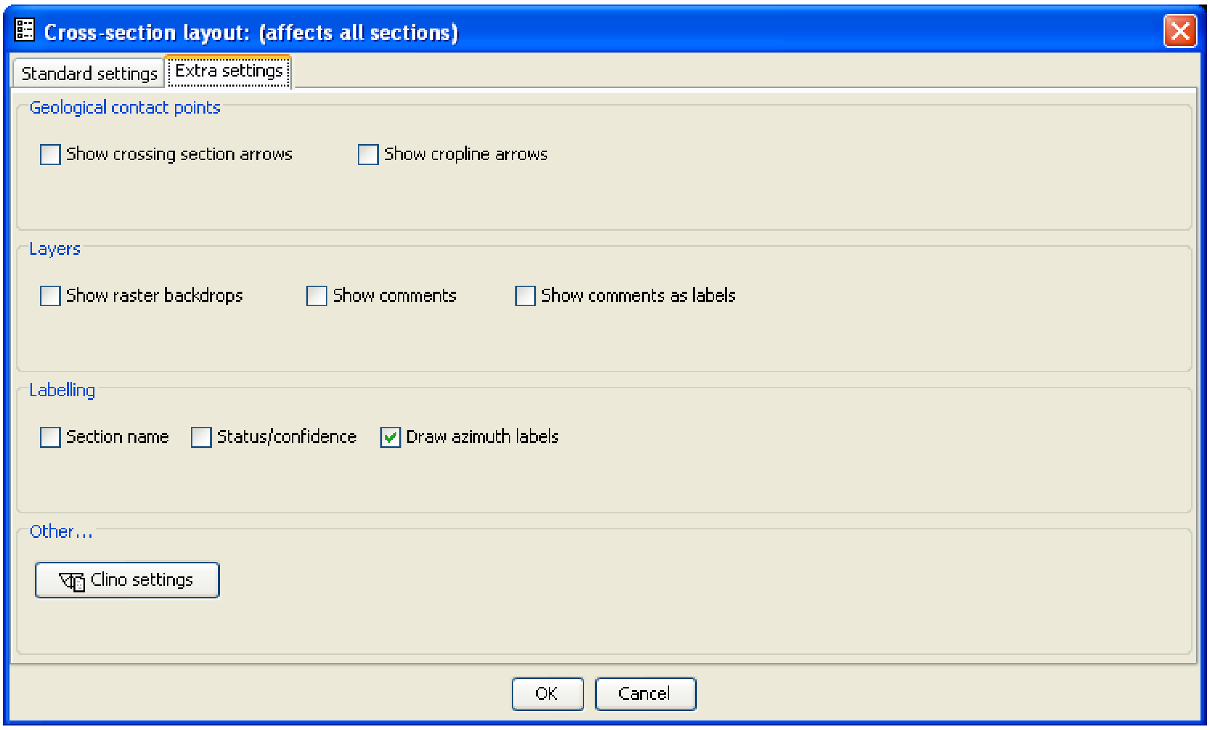
Includes toggles to show or hide the depth of units and the unit coding in the borehole logs. The option to show unit bases and TINs can be used to display the elevation of a calculated geological unit base or an arbitrary workspace TIN in the log picture. This could be used to show a water table surface in the log, for example.

The user can change the appearance of the text on section windows in the font size input field. The image below shows composite logs with textures, point parameter data and labels.



General settings contains boxes to show/hide drill log-knickpoint positions, draw azimuth compasses, hang all borehole sticks on the selected dtm, display map polygons along the profile surface, display fold axes.

The ***Extra settings*** tab contains show/hide boxes as follows



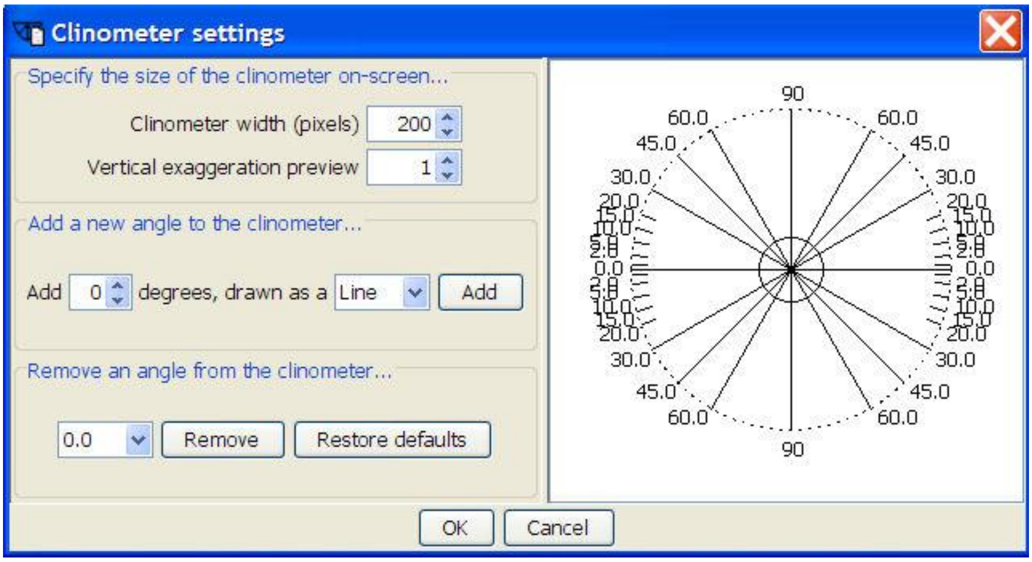
Geological contact points, crossing section arrows and cropline arrows

Layers, display raster backdrops, comments and comment labels

Labelling, section name, status/confidence, azimuth labels and fold labels

Other: Clino settings

Click on the clino settings button to open the Clinometer settings window (below)



Use the dialog to adjust the appearance of the clinometer to suit. Note that the clinometer tool is activated using the clinometer on the icon toolbar (see above) and only displays in line drawing mode.

Specify the size of the clinometer on-screen

The options in this first panel allow you to set the physical size of the clinometer on screen in pixels up to a maximum of 400 pixels. As you change this setting you will see a preview of how big the clinometer will actually appear on screen. It also allows you to preview what the clinometer will look like at a vertical exaggeration (note that setting the vertical exaggeration in this dialog has no effect on the section, it is purely for previewing within the dialog itself).

Add a new angle to the clinometer

Use the settings on this panel to add more angles to the clinometer display. You can also specify whether the angle you wish to add will be drawn as a full line or just a tick line. Click Add to see how the new angle will appear in the preview pane of the dialog. If an angle already exists in the clinometer settings and you wish to change the line style then use the add function to do this also by adding the angle a second time with the preferred line style; this will re-draw the angle in the way you chose.

Remove an angle from the clinometer

Use these options to remove individual angles from the clinometer display. First select the angle you wish to remove from the pull-down list and then click remove. Note also the “Restore defaults” button which allows you to go back to the system settings for the clinometer.

The settings you specify for the clinometer in the section window will apply only to that section, meaning you can calibrate the clinometer differently for each section in your model. Note that these settings are lost when you close the program

Insert comment

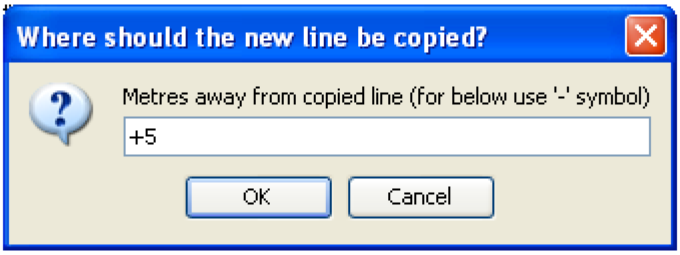
Produces a free text box to annotate the section with comments, these are placed at the location last selected using a left mouse click in the section window and are saved into the project file when the workspace is saved via ***File > Save as...***

Right-click on a correlation line produces the extra three functions below:

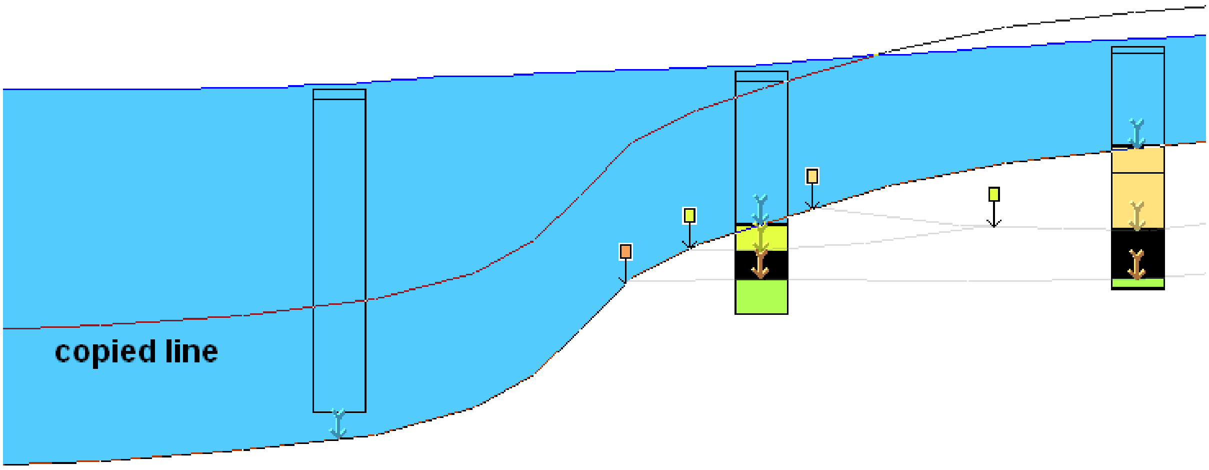
Copy line
Densify line
Smooth line

Copy line

A correlation line can be copied within a section by doing *r-click > Copy line* in the section window. Before the line is copied the user is prompted to specify how far away (in metres) the new line should be created from the line being copied. To place the new line below the existing line the user should specify a negative value in the prompt. The example here shows what the user would enter to copy the line plus 5 metres above the line being copied. If a GVS unit is selected the copied line will inherit that attribute, if none is selected the line will be attributed with NN



NOTE: This tool is fine for areas of parallel or open folding but must be used with care in areas where cylindrical or tight folding is suspected and where competency differences exist within the sequence leading to different responses and shaped units within the folded sequences (e.g. stratigraphic thickening, accommodation structures).

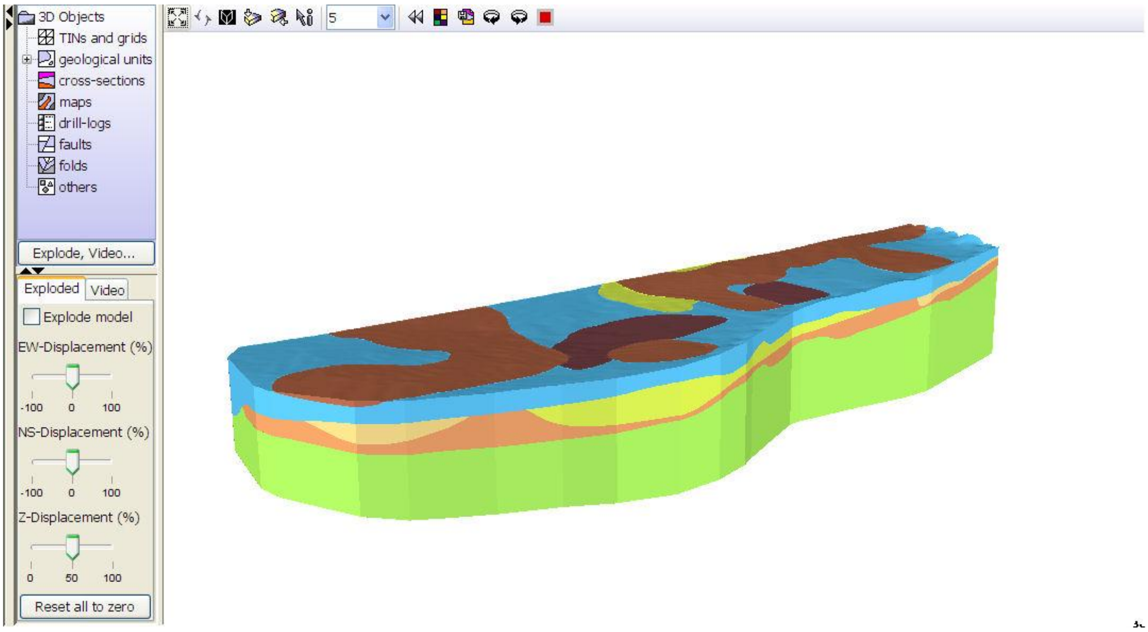


Densify line is used to add nodes to a correlation line for detail see Section 4.4.5

Smooth line is used to add nodes and smooth a correlation line for detail see Section 4.4.5

3.5 3D Window

An example screenshot of the 3D window is shown below illustrating a calculated model of discontinuous superficial deposits resting on chalk bedrock (in green).



Navigation

Navigating in the 3D window is mainly carried out using mouse control although some basic functions are still included in the toolbar:

- Holding the left mouse button down and moving the mouse around rotates the model in all directions.
- Holding the right (or middle) mouse button down and dragging down the page zooms in, dragging the cursor up the page zoom out again.
- Holding down both left and right mouse buttons enables repositioning and centering of the model.

3.5.1 Toolbar and tabs

When expanded the toolbar contains the following icons from left to right

1 2 3 4 5 6 7 8 9 10 11 12 13

1 .Zoom to full extent

Click, fits the whole object (fence diagram, surface, envelope, grid 'model') to the dimensions of the 3D window.

2. Refresh window

Refreshes the 3D graphics.

3. Show or hide the frame

Toggles the frame on and off.

4. Plan view

Adjusts the 3D view to a vertical view, i.e. the model is viewed from above in plan view.

5. Side View

This instantly adjusts the model to a side horizontal view.

6. Info tool

Click the tool to activate then left click on objects such as geological unit panels within sections, and unit surfaces in 3D window these are then highlighted by changing colour (to bright yellow) and their identity is displayed in the status bar.

7**. Set vertical exaggeration**

This field enables the setting of vertical exaggeration, simply select a value from the pull-down list. To specify a value that is not in the defaul list, type the desired value into the field and hit enter. The new value will be added to the list.

8. Icon expansion-contraction arrow

Toggle to expand and contract the toolbar.

9. Select background colour

Click brings up a standard palette to select background colour.

10. Save 3D window as image

NOTE: File extensions must be entered in the File name dialog box.

11. Rotate right

Click, starts the model spinning incrementally to the right, anticlockwise about a vertical axis preserving any tilt (inclination) present at the start. Once spinning the icon changes to a stop sign that when clicked halts the spin.

12. Rotate left

Click, starts the model spinning incrementally to the left, clockwise about a vertical axis preserving any tilt (inclination) present at the start. Once spinning the icon changes to a stop sign that when clicked halts the spin**. NOTE: rotation speed will depend on model size!**

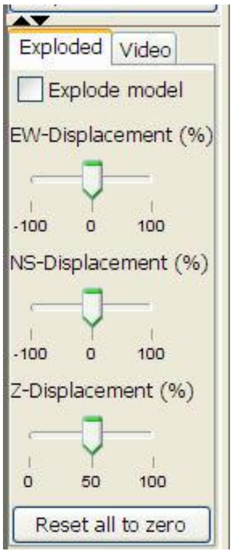
13. Render on/off

Toggle button that switches off the 3D window to save memory and back on again.

Explode, Video tab

The Table of Contents border also contains a screen which can be expanded or minimised using arrows as for the main windows. This screen contains two selectable tabs at its header **Explode** and **Video** (shown below).

Explode

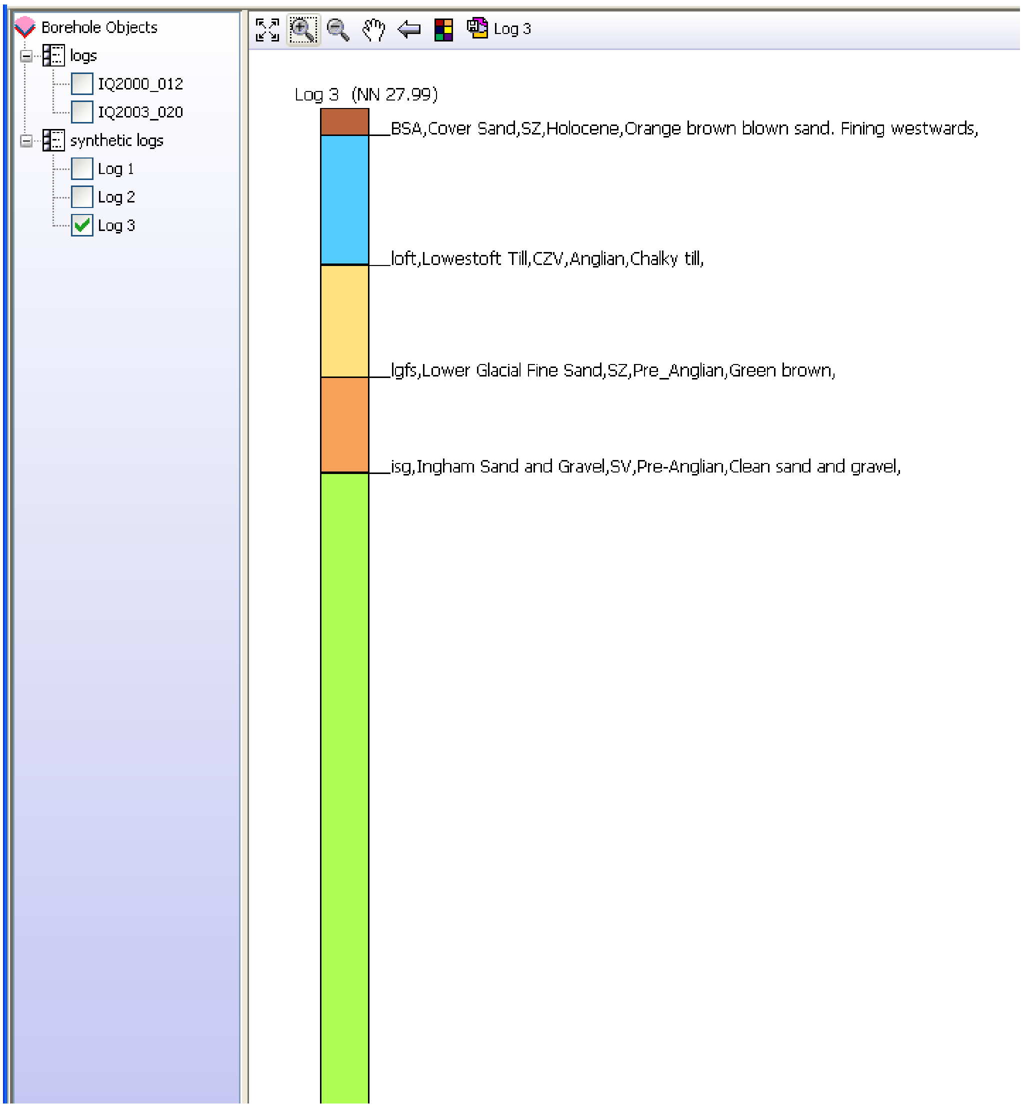


Checking the ***Explode Model*** box separates all the geological units in the model according to the GVS order with the topmost units displayed highest. Use the slider bars to change the exploded view in the x, y and z dimensions.

3.6 Borehole log window

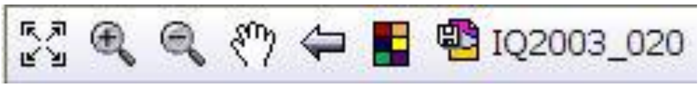
A typical borehole viewer screen is shown below. Boreholes are selected in the map window and display as logs in the Borehole Viewer. When logs are first sent across they require resizing and the properties setting to obtain a reasonable image. This log contains full annotation of the units. Once several boreholes have been selected switching between them is achieved in the Table of Contents of this window by checking the required borehole.

In the table of contents real boreholes are listed under **logs** and synthetic boreholes under **synthetic logs**



3.6.1 Toolbar

The toolbar contains the following icons from left to right.



1 2 3 4 5 6 7 8

1. Zoom to full extent

Click, fits the whole object (annotated log) to the dimensions of the section window.

2. Zoom In

Click on, then click in window and hold down whilst dragging mouse to construct marquee around area to zoom in to, release on completion.

3. Zoom out

Incremental zoom out.

4. Pan

Click, then click in window and hold, drag to new position and release, drag and drop.

5. Back to previous view

Click, displays previous view.

6. Select background colour

Click brings up a standard palette to select background colour.

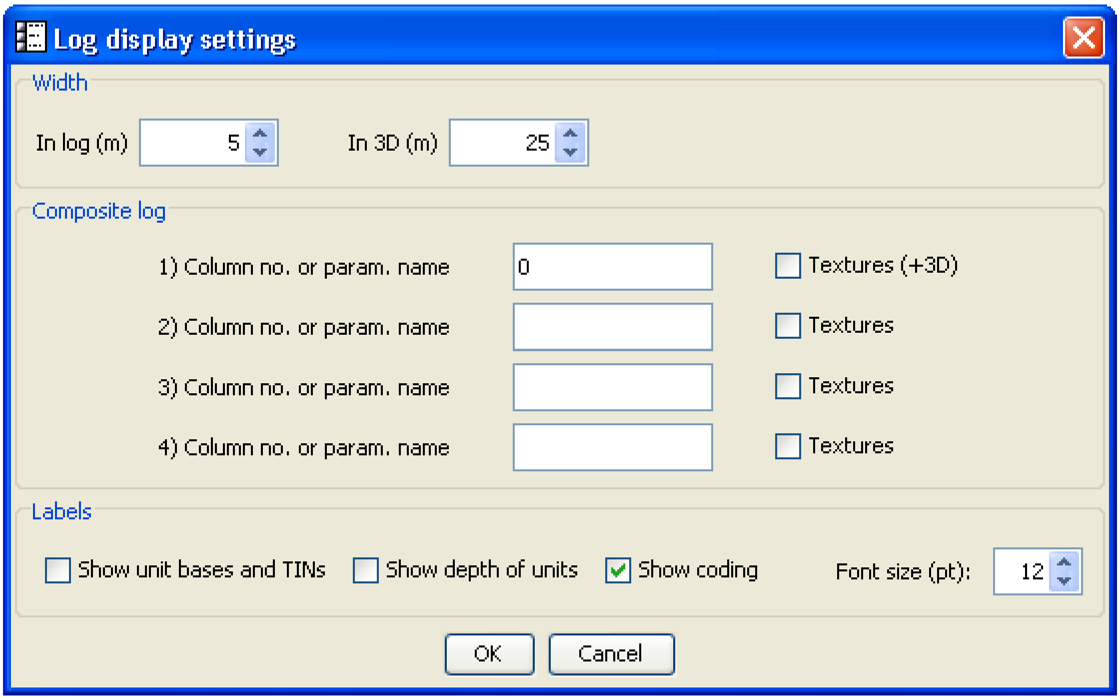
7. Save window as an image

8. **Borehole number,** refers to the displayed log.

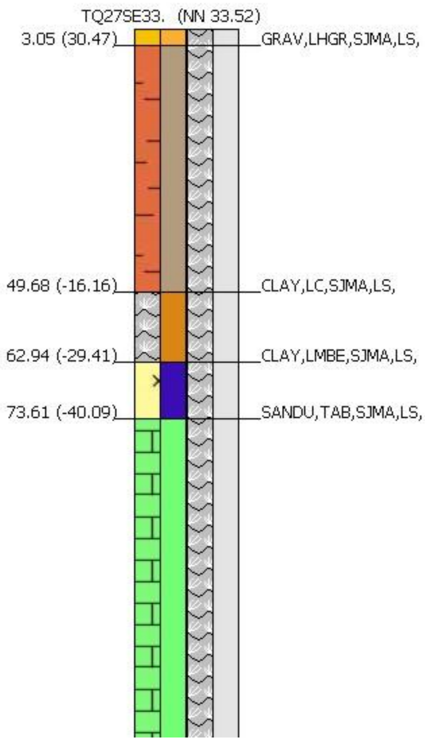
NOTE: When the first log is displayed in each session it is necessary to scale the borehole log appropriately using zoom to full extent and the properties settings.

3.6.2 Borehole log window properties

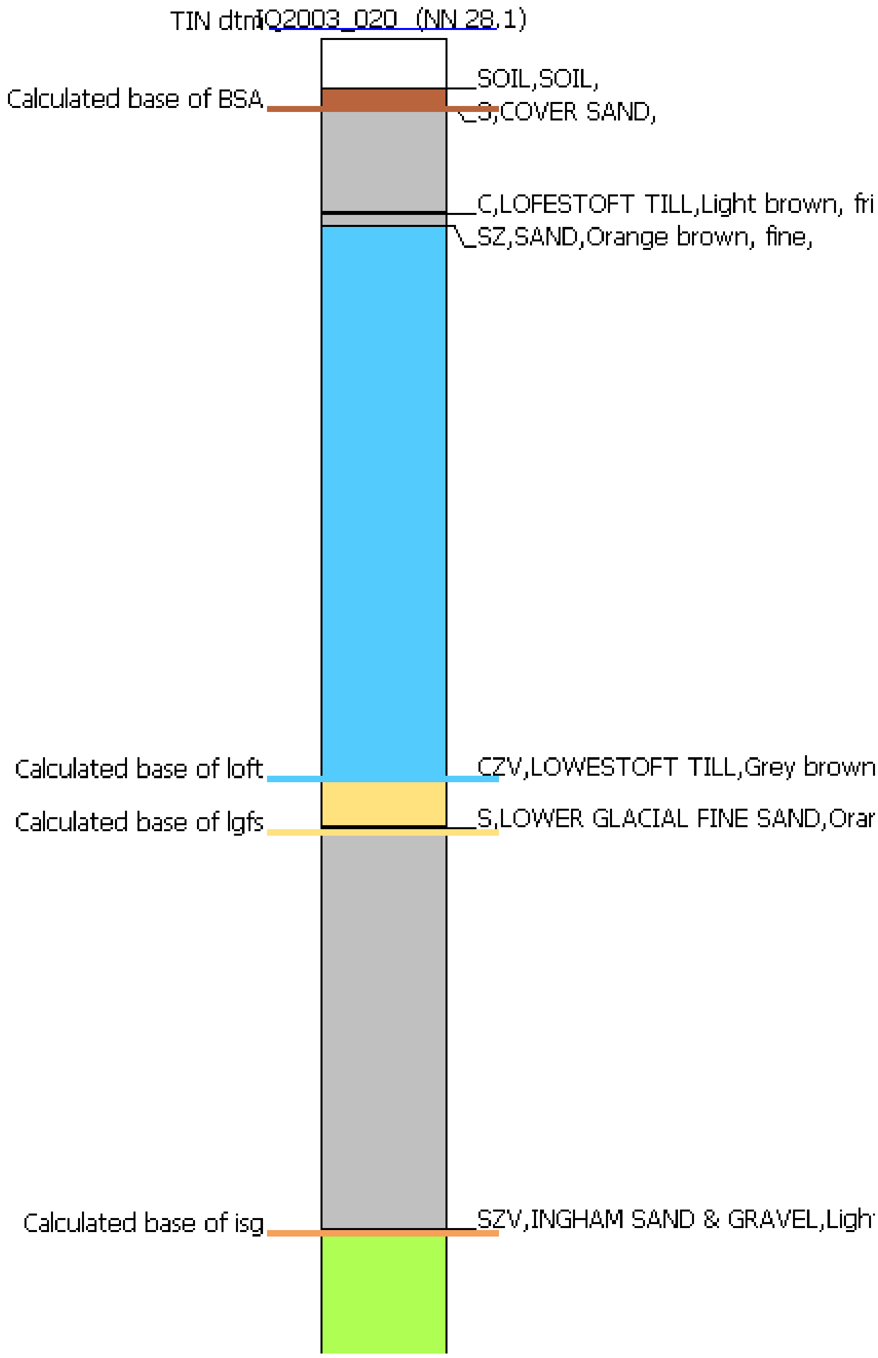
Right click anywhere within the borehole window gives the option to set the properties of the borehole sticks. The ***Log display settings*** dialog box (shown below) is the same as the one used for the section window Section 3.4.2 and is explained in detail there.



An example of a fully annotated multiple stick borehole is shown below



Switching on the show calculated unit bases and TINs allows geological unit bases and other surfaces to be displayed in the borehole log (both real and synthetic). This is useful for spot checking the model as well as displaying surfaces such as watertables against boreholes. An example of this display is shown below.



4.Working with projects and objects

4.1 Building and Saving a project

A GSI3D project is comprised of data and links to data that represent the model. A project always has a core project file which has a ***.gsipr** file extension. The GSIPR file contains all of the primary data for the model including geological unit envelopes/lines and the section correlation linework. It may also hold other supporting data such as a model capping surface and other triangulated surfaces.

The GSIPR file also holds links to supporting data. Usually this includes at least a link to the stratigraphy file (GVS) and the legend file (GLEG). Additionally there may be links to vector information (GIS shapefiles), georegistered raster maps and borehole maps.

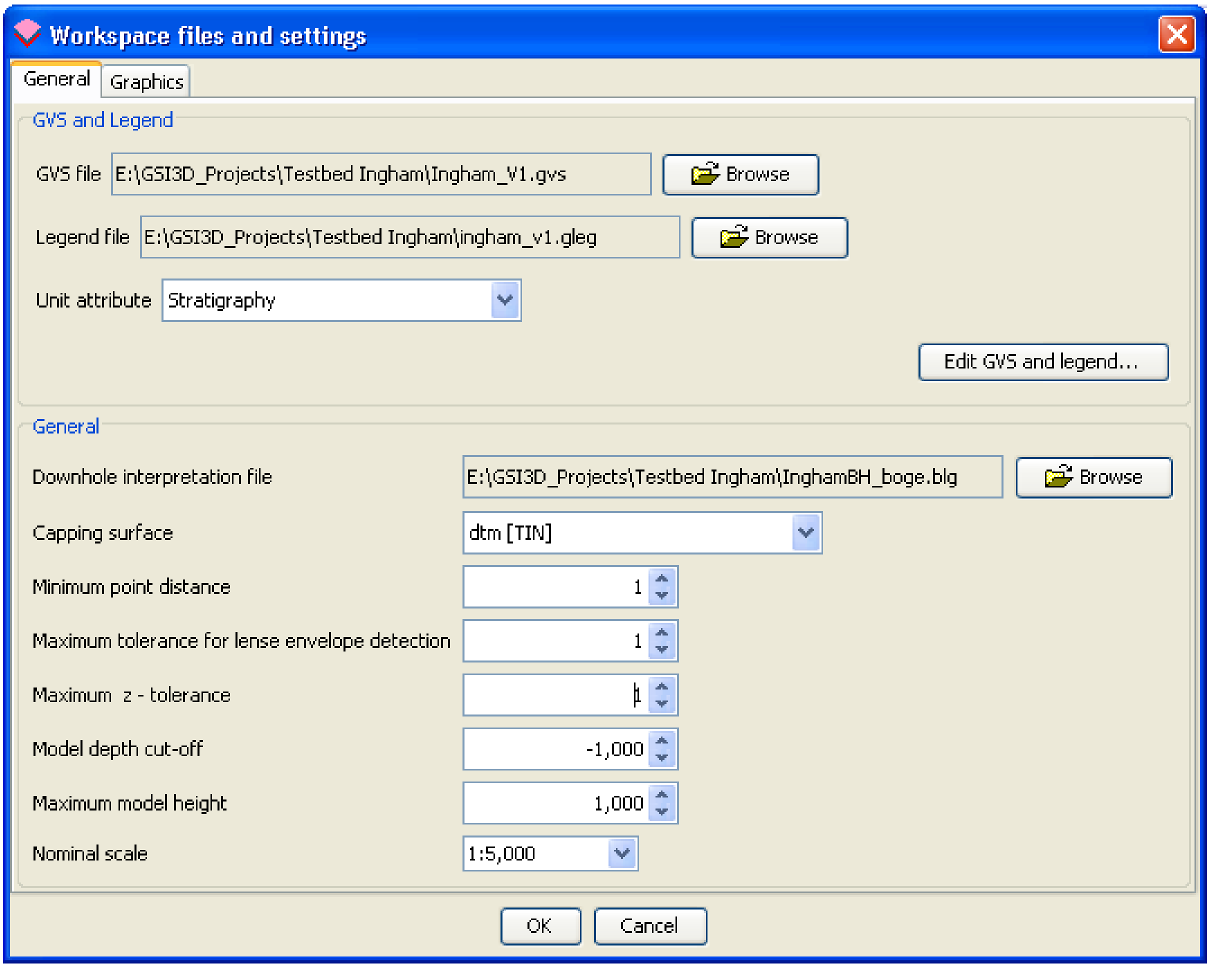
The *.gsipr file is XML based. The file format is not based on a standard schema and should be treated as proprietary as the exact syntax of the XML is subject to change without notice between versions of the software. Therefore, if you intend to build tools outside of GSI3D which will rely on the file structure you should take advice from the GSI3D Helpdesk on the potential risks.

Note whilst loading any already established *.gsipr file the whole screen will grey-out to prevent further operation.

To establish a project from scratch or to change the parameters of an existing project, the Properties dialog box is used (from the edit pull down menu)

Under the **General** tab the **Workspace files and settings** dialog box enables the user to:

1. Browse and select the location of the **GVS file** (*.gvs)
2. Browse and select the location of the **Legend file** (*.gleg)
3. Browse and select the location of the **Downhole Interpretation File** (*.blg)
4. Select the **Capping surface** to be used for model calculation from a pull down menu of available surfaces within the project (the DTM must be created under Grids and TINs first, see sections 4.2-4.3 below)
5. **Minimum Point Distance** sets the minimum spacing distance (in metres) between nodes used for calculation (in x,y) below this threshold points will be discarded
6. **Max tolerance for lense envelope detection** sets the maximum tolerance (in metres) for the difference between a lense correlation and the lense envelope (in x,y)
7. **Maximum z-tolerance** sets the distance (in z) below which points will be discarded
8. **Model depth cut-off** (will only be operational in future bedrock releases)
9. **Maximum model height** (will only be operational in future bedrock releases)
10. **Unit attribute** sets the overall GVS attribute (column header) for the project on start up.
11. **Nominal scale** enables the user to assign a nominal scale to the project, this is stored as a tag in the project workspace only and does not affect the calculation.



All settings and files can be changed and re-saved during a session.

4.1.1 Using the GVS-Legend Editor

The GVS and legend files can be created manually using spreadsheet software such as Excel or a simple text editor such as Wordpad or Notepad. However, GSI3D v2011 also contains a BETA release of a new GVS and legend creation and editing tool which enables the creation and editing of these files interactively from within the software.

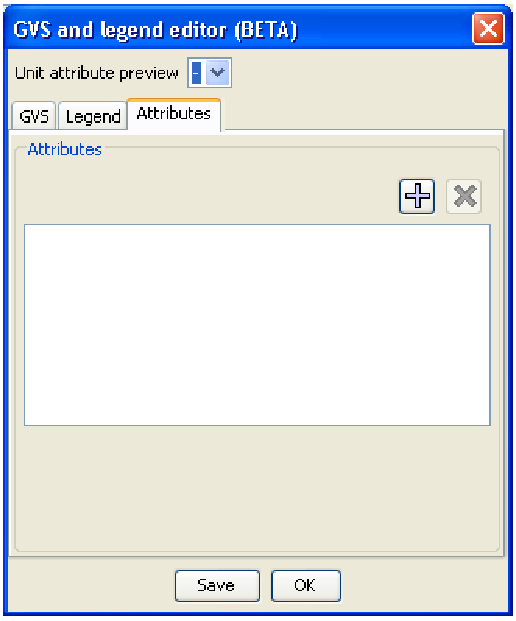
The editor can be used to modify existing GVS and legend files, and it can also be used to create new GVS and legend files from scratch.

NOTE: At the current time the GVS-Legend editor has no support for lenses. Therefore, if lenses are being modelled, do not use the GVS-Legend editor. The new editor is provided as BETA functionality and it is very important that you keep backup copies of existing GVS and legend files before attempting to modify them in the GVS-Legend editor in case of any problems.

Creating a new GVS and Legend

Open the workspace properties dialog via ***File > Properties***. Select a location for the new GVS and Legend files using the file browse buttons against the fields ***GVS file*** and ***Legend file***, respectively.

Click ***Edit GVS and legend...*** to open the GVS-Legend editor. The dialog will appear as below:

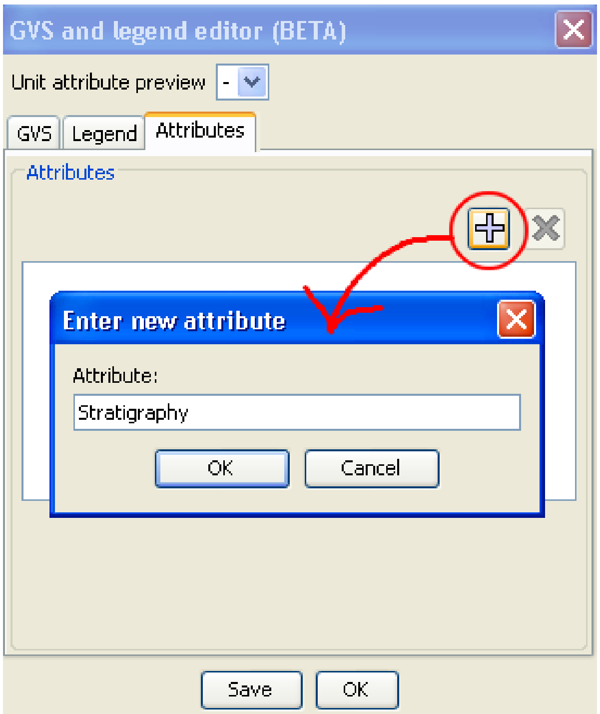


There are three tabs in the GVS-Legend editor dialog. When creating a new GVS and legend from scratch the ***Attributes*** tab will be selected by default when the dialog opens.

Step 1: Create attributes

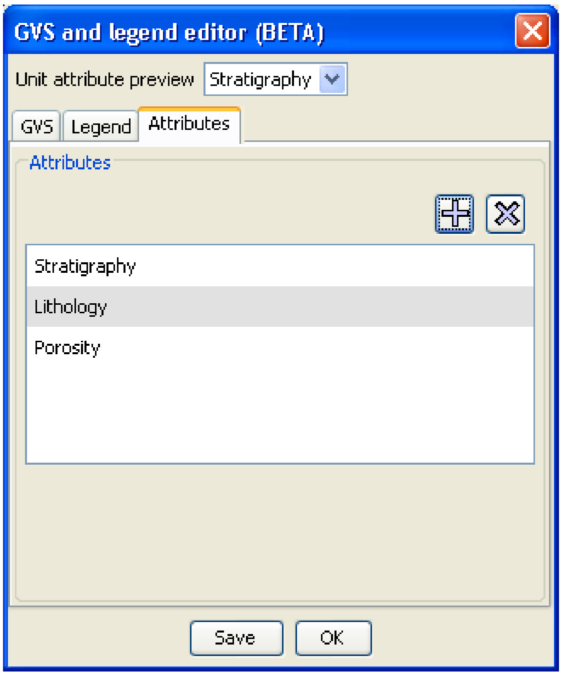
The GVS and legend cannot exist without attributes, so at least one attribute must be created to begin with. Attributes are the lookup values which GSI3D will use to decide how to draw geological units and other objects in the various windows. Typical attributes include Lithology, Stratigraphy, Chronostratighaphy, Porosity etc.

Click the add icon to create a new attribute and enter a name such as “Stratigraphy”.



The new attribute will be added to the attribute listing. Note also that the attribute appears in the ***Unit attribute preview*** selection box at the top of the dialog.

Continue adding attributes as desired. Shown below is a simple attribute listing containing Stratigraphy, Lithology and Porosity:

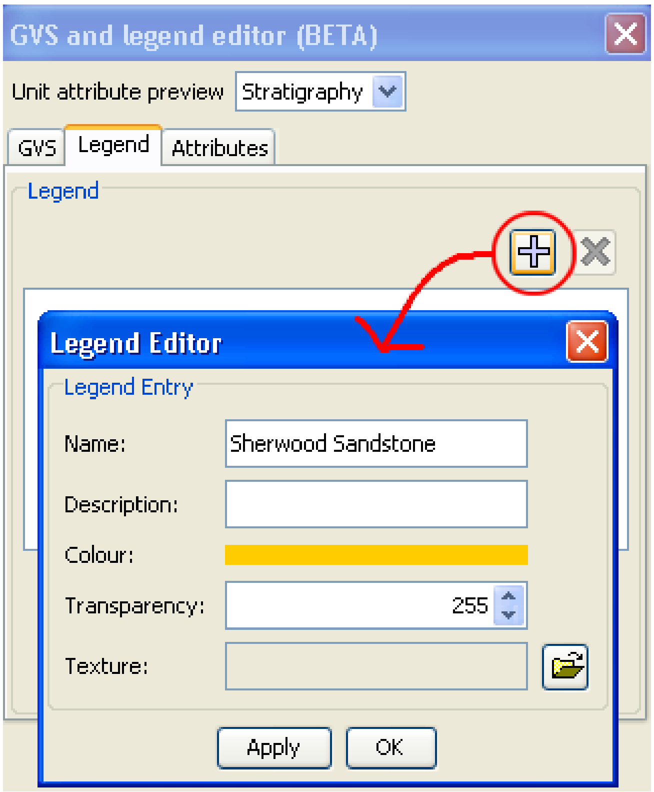


Step 2: Create Legend entries

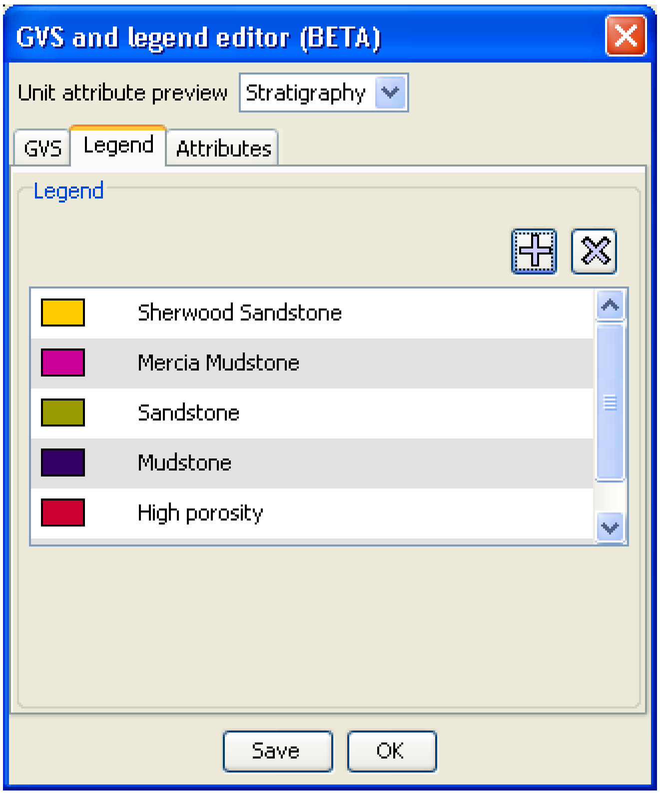
As soon as at least one attribute is added to the attribute listing the legend can be constructed. It is possible to construct the GVS before the legend, but if legend values are available the construction and setup of the GVS will be easier.

The values entered in the legend are independent of the GVS. The legend will contain a list of all possible legend lookup values for all attribute values including Lithology, Stratigraphy etc.

Click on the legend tab and click the add icon to create a new legend entry. The legend entry dialog will be displayed. Enter a name for the legend entry and optionally a description, and then choose a colour and optionally a colour transparency and texture image. When all values are set, click Apply > OK. The new legend entry will be added to the legend listing.



Continue adding new legend entries until all desired values are in the listing. Note that the legend listing can be in any order so the values can be added in any sequence (unlike the GVS listing which is constructed in stratigraphical order). Shown below is an example legend with some lookup values that could be used to colour by the attributes Stratigraphy, Lithology and Porosity:



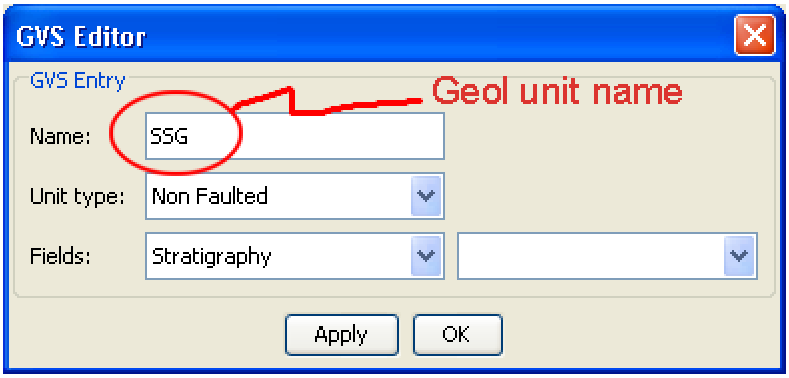
Step 3: Create GVS entries

Once some attribution and legend information is entered the GVS can be constructed. Select the GVS tab and note the 4 buttons that are available:

1) Moves the selected GVS entry one position up the listing
2) Moves the selected GVS entry one position down the listing
3) Creates a new GVS entry
4) Deletes the selected GVS entry

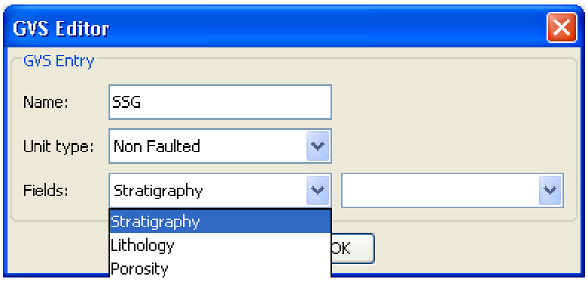
The additional tools 1 and 2 are required for sorting the GVS listing because the entries in this listing are required to be in stratigraphical order, with the top-most or youngest stratigraphic unit at the top of the list.

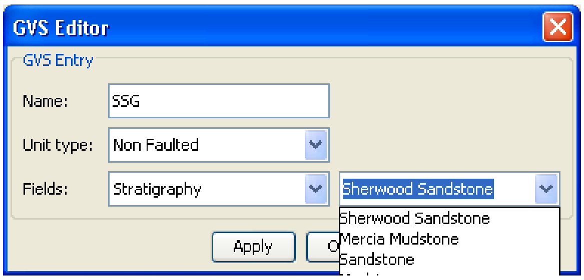
First, click the add icon to display a blank GVS entry dialog. First enter a name for the GVS entry. This name will be the master code that is used throughout GSI3D for the geological unit, for example it will be the name used on section correlation lines for this unit. The name can be a real name, or a coded value (for example ***Sherwood Sandstone Group*** could be coded as ***SSG*** for convenience).



NOTE: The field labelled *Unit type* is currently not used in GSI3D v2011. It contains only one value and can be ignored.

The next step is to choose legend lookup values for each available unit attribute. The two selection boxes on the bottom row of the GVS entry dialog allow the attribution to be selected. The box on the left contains a list of all the entries in the Attributes tab; the box on the right contains a list of all the entries in the Legend tab. First choose an attribute on the left, and then select a legend lookup value from the list on the right.

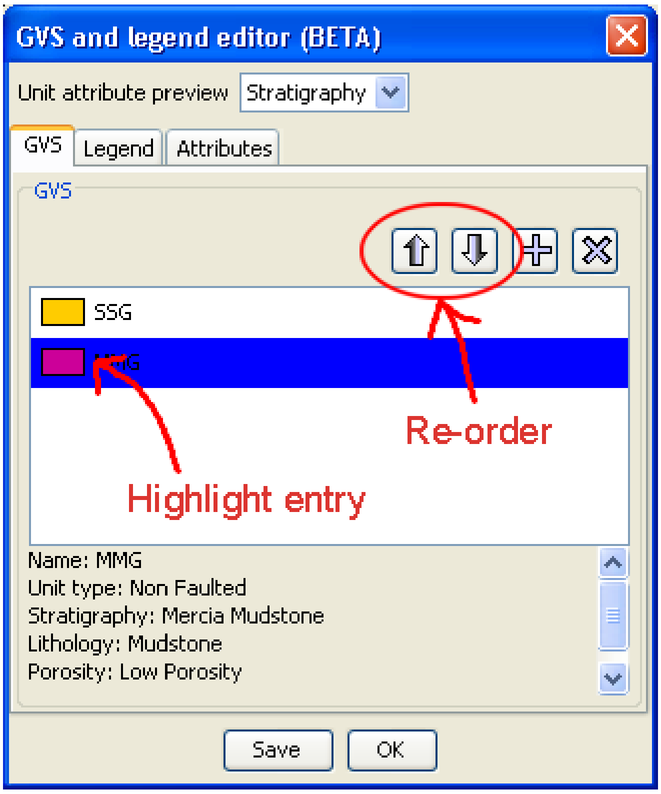




NOTE: Each time an attribute-legend pair is set, click Apply to apply the selection.

When all values have been set, click OK. The new GVS entry will be displayed in the GVS entry listing. Repeat the whole process once for each GVS entry that is required.

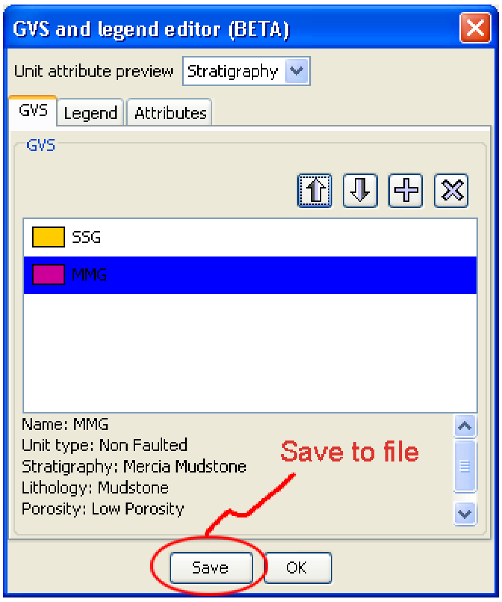
The GVS listing can be constructed in any order initially, but to be usable in a model **the list must be ordered stratigraphically** using the up and down buttons in the toolbar of the GVS tab. To move a GVS entry, click on it once to highlight in the listing, and then click the up or down button to move it through the list.



Note that clicking once on a GVS entry to highlight it will also display a summary of the entries attributes in the lower area of the GVS tab.

Step 4: Saving the files

When working in the GVS-Legend editor all of the objects and edits are held in the working session only. To reflect any creation or edits back to the selected GVS and GLEG files press Save in the GVS-Legend editor dialog. Always make sure you keep backups of GVS and GLEG files in case of any problems with the file save function.



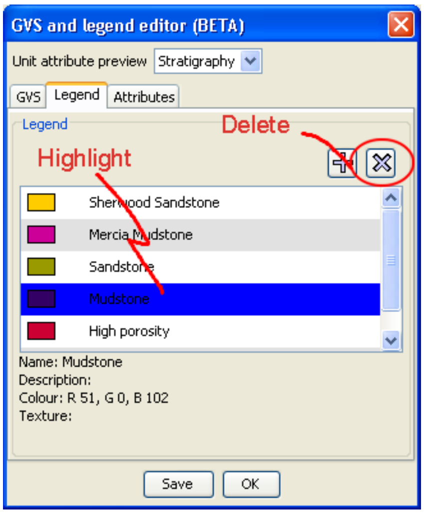
Editing an existing GVS and legend

The GVS-Legend editor can be used to modify an existing GVS and legend. If the GVS and legend are part of a GSI3D project they will be automatically loaded when the project GSIPR file is loaded; otherwise simply start GSI3D and select the relevant GVS and GLEG files manually in the ***File > Properties*** dialog to begin editing.

NOTE: The GVS-Legend editor has no support for lenses. If a project or GVS contains lenses do not use the GSV-Editor. Instead, modify the files manually in Excel, Wordpad, Notepad or similar. Always take backups of important GVS and GLEG files when working to mitigate any risk of file corruption.

With the GVS and legend files loaded in the workspace, click on ***Edit GVS and legend..*** to open the GVS-Legend editor dialog. This will display the entries for the GVS, legend and attributes for the currently loaded GVS and legend.

To delete entries from any tab, single click on the desired entry to highlight and click the delete icon:



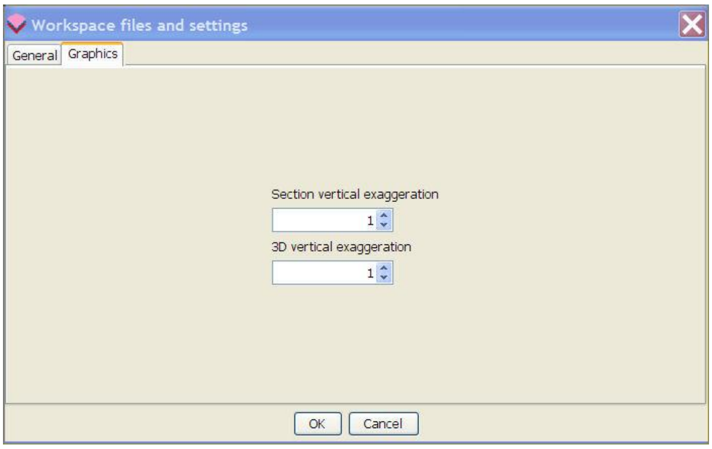
To edit a GVS or legend entry, simply double click on its entry in the appropriate listing (attributes cannot be edited once create). This will open the appropriate edit dialog. For details of how to use the GVS and legend edit dialogs, refer to the above section on creating new GVS and legend entries.

NOTE: GVS names cannot be edited once created. This is because there is currently no mechanism to cascade the change through a project (e.g. to rename correlation linework with a new value).

Any changes made in the GVS-Editor dialog will be reflected in the GSI3D workspace immediately when the ***OK*** button is clicked, but will be lost when the program is closed down. To save any changes into the GVS and GLEG files make sure to press ***Save***.

NOTE: Saving the GSI3D project via File > Save as... will not save any changes to the GVS and legend. The Save function in the GVS-Editor dialog is currently independent of the GSIPR save function.

The **Graphics** tab contains options for setting the vertical exaggeration for sections and 3D display. These settings are not applied immediately, but will be stored in the project file and used as the default when the project is next loaded.



4.1.2 Model capping surfaces

Every GSI3D project should have at minimum one model capping surface. The model capping surface provides a cap to the model in a range of important situations. For example, in order to build a section a capping surface is required to prevent the section geometry (and hence the graphics) from flooding upwards into the 'sky'. A model capping surface is also vital when calculating geological unit bases and volumes because the surface constrains the calculation of these objects. In many situations, GSI3D is programmed not to allow you to perform certain operations unless a capping surface is specified in the project.

In a superficial geology model, the capping surface will usually be a DTM (Digital Terrain Model) whereas in a bedrock model the capping surface might alternatively be a rockhead (top bedrock) surface or an unconformity.

To specify a capping surface you must first import a suitable one into your project workspace. Surfaces can be imported as a GRID or as a TIN via the Add objects pull down menu Section 3.2. 2. Once imported these objects will appear in the map window ToC under Grids or TINs. GSI3D uses

TINs to calculate models, therefore an imported GRID object must be converted to a TIN object this is done via a right-click on the object and selecting ***Convert to TIN***.

Once you have a usable TIN object in your map window ToC you must specify it as the model cap via ***File > Properties*** and then select the desired capping object from the ***Capping surface*** pull-down list. Note that this list only contains available TIN objects.

NOTE: Capping surfaces are usually the largest data objects in a GSI3D project. The *.gsipr file will become much larger when you add a TIN surface to it and save the project. Always ensure that the capping surface is at an appropriate resolution for the scale of the modelling work. Very high resolution DTMs for example will make the project file extremely large and will reduce the calculation performance considerably. If the surfaces are exceptionally large GSI3D could run out of memory and crash.

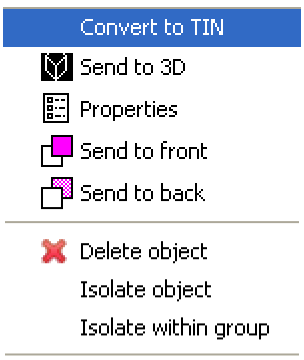
4.2 GRIDs

When obtaining GRID data for use inside GSI3D it is important to make sure that you obtain an ASCII version of the data. ASCII format is in plain text. The ESRI binary version of this format (the proprietary binary ESRI grid, which is the usual format when working inside an ESRI environment) cannot be loaded into GSI3D. If you have a binary format file you will need to convert it to ASCII via an ESRI tool such as ArcToolbox.

Once you have obtained an ASCII format GRID file you can import it into the map window object tree via ***Add objects > DEM/GRID***.

Grids are used in GSI3D for visualisation, display in cross-sections and as DTM capping layers, however these need to be converted to TINs to perform model calculation as described above at Section 4.1.1. The grids are held in the ***TINs and Grids*** folder in the map window. The individual objects are identified in the ToC as either TINs or grids, right clicking on the objects produces differing pull down menus as explained below. Additionally right clicking the overall folder offers the option to **Create new TIN** in addition to the standard self-explanatory options listed below.

Right clicking on an individual grid produces the following menu:

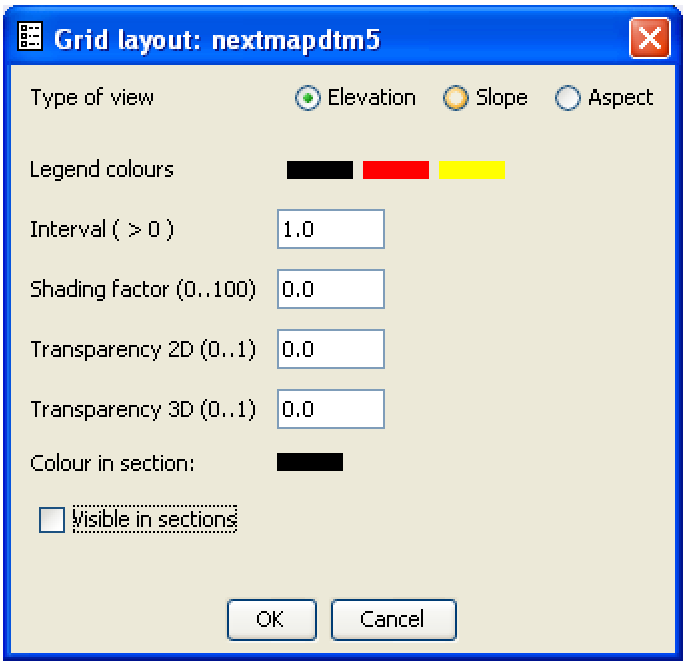


Convert to TIN is used to convert a GRID to a TIN for use in model calculation and is described above at Section 4.1.1

Export raster enables saving of ascii grids as surfer grids, and vice versa

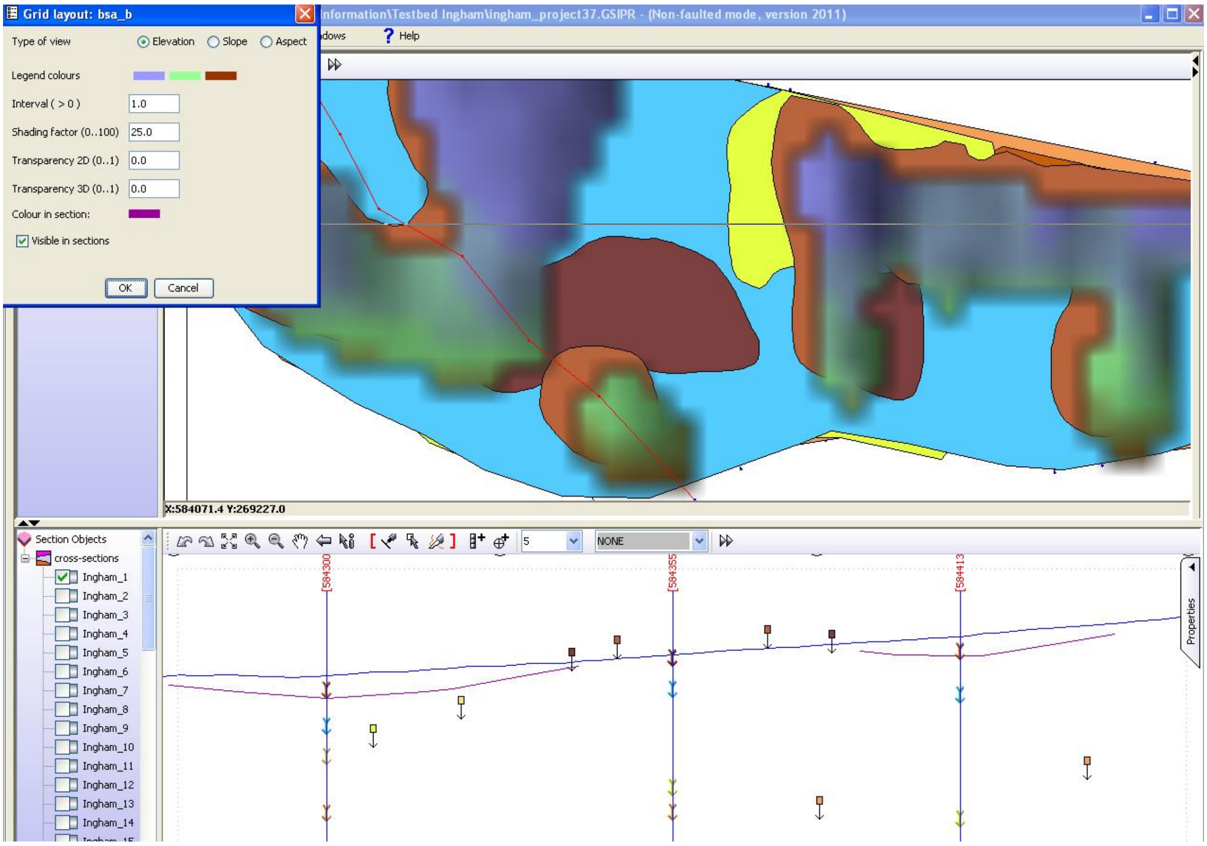
Send to 3D view sends an individual surface grid to the 3D viewer

Properties calls up the property box shown below which is identical to that for fold axial planes and TIN objects (Section 4.3)



The display settings can be specified for the map, section and 3D windows, switching on visible in sections enables the display of the grid in the section view.

A grid can be made visible in section, the **Colour** of the line can be specified and the **visible** switch needs to be ticked. The image below shows a Grid displayed as a shaded relief map and as a purple line in section



Send to front self explanatory

Send to back ditto

Delete object ditto

Isolate object ditto

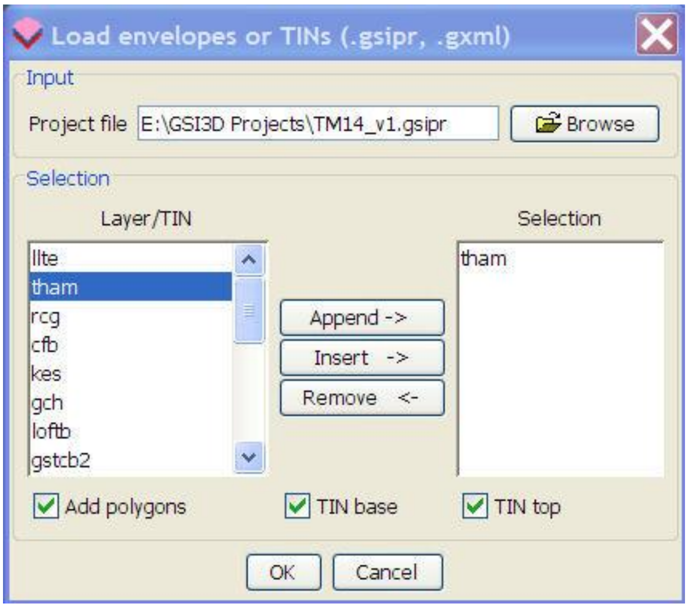
Isolate within group ditto

4.3 TINs

A TIN is a Triangulated Irregular Network. It is used inside GSI3D to represent a surface; In GSI3D, TIN objects are stored inside the *.gsipr project file. TINs can be imported in several ways

Importing from another GSI3D project

You can import a TIN object from an existing GSI3D project file (*.gsipr) via **Add objects > Envelopes and TINs**. You should see the following dialog.



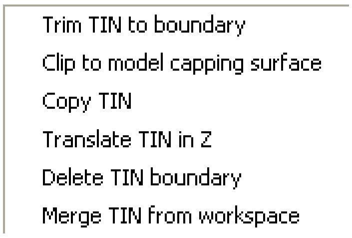
Use the browse button to select the *.gsipr file containing the TIN needed. When this loads you will see a list of all available TINs in the list on the left. Highlight the desired entry (or highlight multiple entries using Shift or Ctrl key) and click on ***Append*** to copy them to the selection list on the right. Choose the desired options using the checkboxes at the bottom of the dialog box and click ***OK*** (for a simple TIN import you will usually only need the ***TIN base*** option to be checked).

Importing from GOCAD

If you have a GOCAD surface (TSurf format .TS file) you can import this into GSI3D as a TIN. Firstly you must create a new blank TIN object to hold the GOCAD data. Select ***Tools > Create new TIN*** and specify a name for the new object when prompted. The new blank TIN object will be added to the map window ToC. Find the new blank TIN object in the ToC and choose right-click to give ***Import and Export > Import Gocad TIN.*** In the dialog that appears, browse for and open the .TS GOCAD surface file that you wish to load into the TIN object. After a few moments the data will be loaded into the GSI3D TIN object. When you save the GSI3D project this data will be stored in GSI3D TIN format inside the project *.gsipr file.

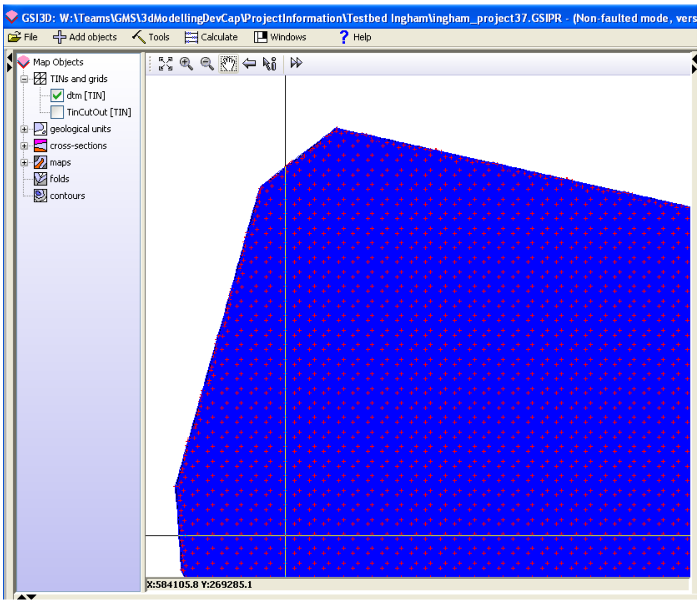
Right clicking on an individual TIN will produce this menu

Create, edit and merge contains functions as follows



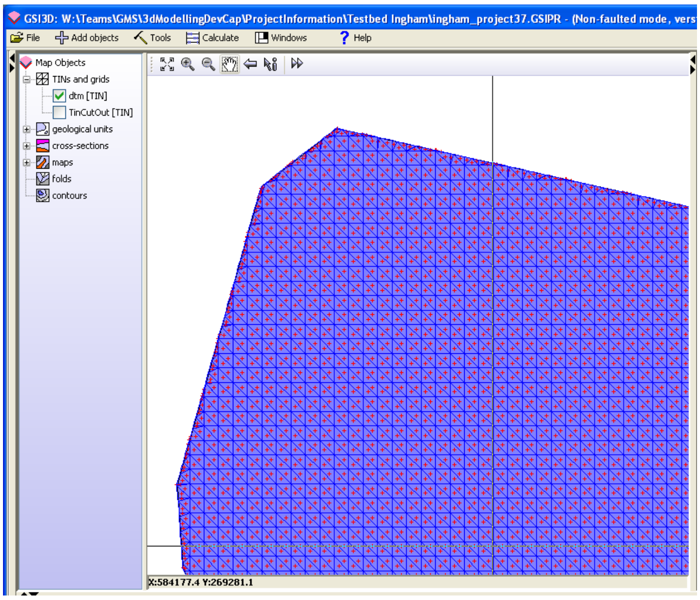
Trim TIN to boundary

As imported the TIN and its corresponding envelope (coverage) initially equates to the full extent of the loaded dataset.

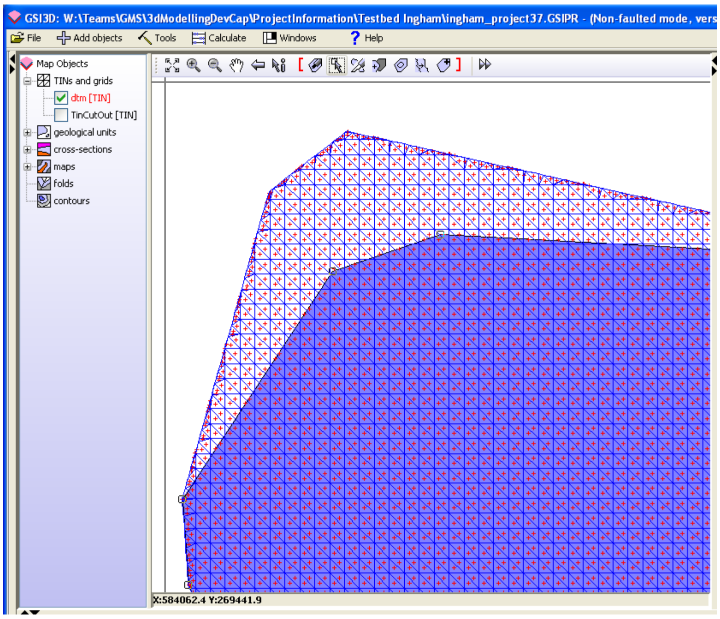


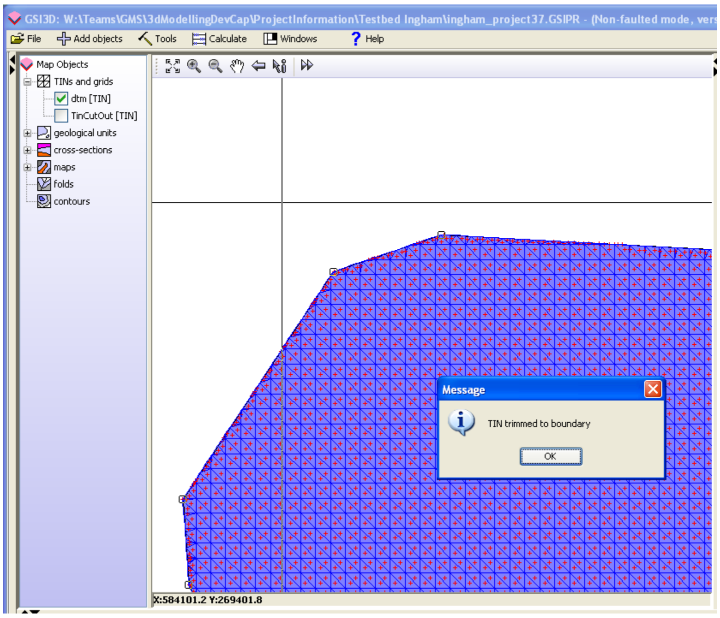
These settings can be adjusted using the property box for the individual TIN.

The next picture below shows properties adjusted to display the semi-transparent envelope and the triangulated surface whose extents coincide. The envelope can be made editable, ***right click > switch on edit***, and then the envelope may be revised to a bespoke area or shape for calculation by dragging and inserting nodes to shape, (second picture below) this can include holes and islands in the same way as the envelope for any geological unit.



Once the envelope is satisfactory ***switch off edit*** and then select from the ***extra functions*** select the ***Trim TIN*** option. The TIN is then trimmed to the extent of the envelope as in the third picture below. Alternatively the default envelope can be deleted and a new bespoke one created using the polygon construction tools.





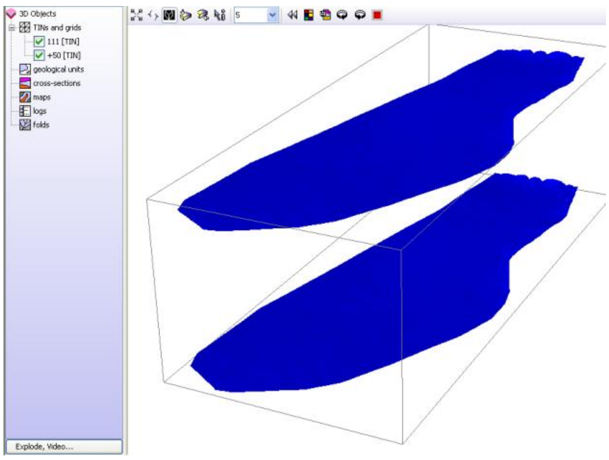
When the project is saved it is stored in the *.gsipr as the clipped Tin and envelope and so is available instantly for further calculation (provided it is the selected DTM coverage in the Workspace properties).

NOTE: This is an essential tool for clipping a DTM to a required area for calculating the model. It also can be used to clip GoCad TINs and export them.

Clip to model capping surface enables any TIN to be truncated (cut) by the model capping surface (DTM) selected in the workspace. Any points that lie above the capping surface will be reset using the value of the capping surface TIN at that location.

Copy TIN greatest a copy of the selected TIN and after giving it a new name appears in the table of contents.

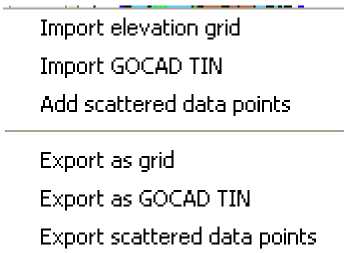
Translate TIN in Z enables to take a copy of a TIN and transpose it in z elevation, by entering a positive or negative number. The image below shows the original and 50m transposed copy in the 3D window



Delete TIN boundary deletes the boundary polygon of the selected TIN object.

Merge TIN from workspace allows the merging of 2 TIN objects that are open in the active session.

Import and Export



Import elevation grid

Selecting this option allows the user to convert an ascii grid into a TIN object. In this process the raster is automatically triangulated and so can be used in model calculation and also it can be stored and clipped as part of a model file.

Import GOCAD TIN

This function allows the direct import of GoCad Tsurf TINs into a GSI3D project When saving the project the imported surface(s) it will be saved as part of the model *.gsipr file.

Add scattered data points

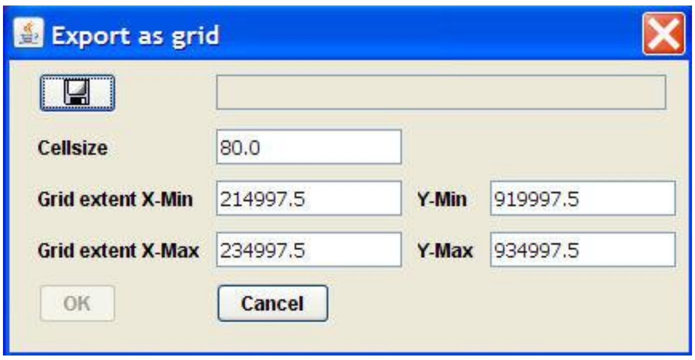
This function allows extra data points such as contour datasets of to create a TIN object. The data points are imported as tab-separated xyz ascii data in *.dat format.,

NOTE: this file does not contain a header which is shown below for explanation only.

X	Y	Z
620227	245907	21.36207

Export as grid (*.asc)

This function enables the export of the TIN object as an ASCII grid.



This standard save box requires the user to define the cell size and extent of the grid, the default value the cell size is model dependant and the extent is the whole project area.

The following two options enable interchange of surfaces with the GoCad modelling package

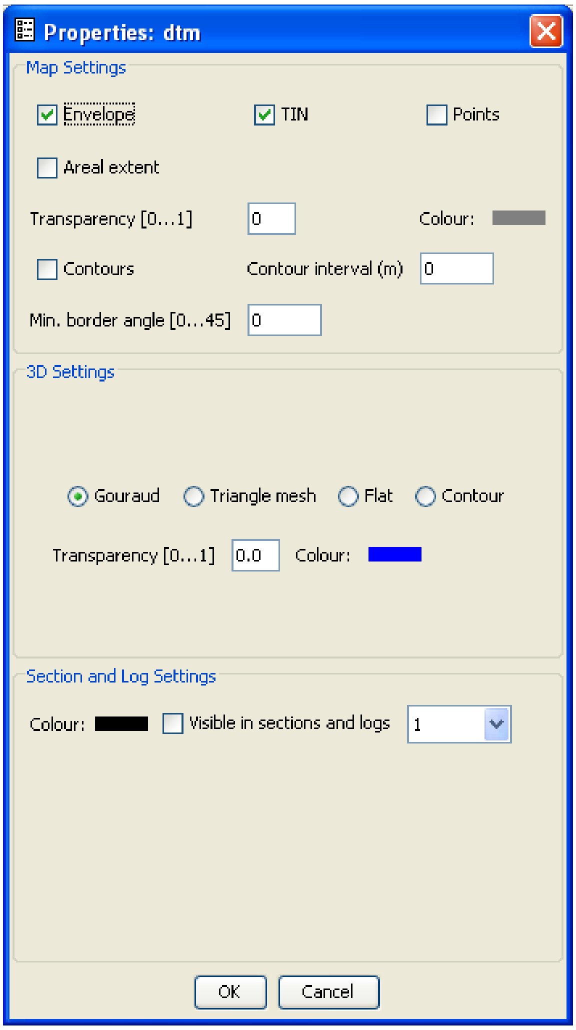
Export as GoCad TIN

This function will export the TIN into GoCad tsurf format. The resulting TIN is an exact copy of the GSI3D TIN .

Export scattered data points exports all points of the selected TIN into tab separated *.dat format (format see above)

Send to 3D sends an individual surface TIN to the 3D window

Properties calls up the tin property box shown below



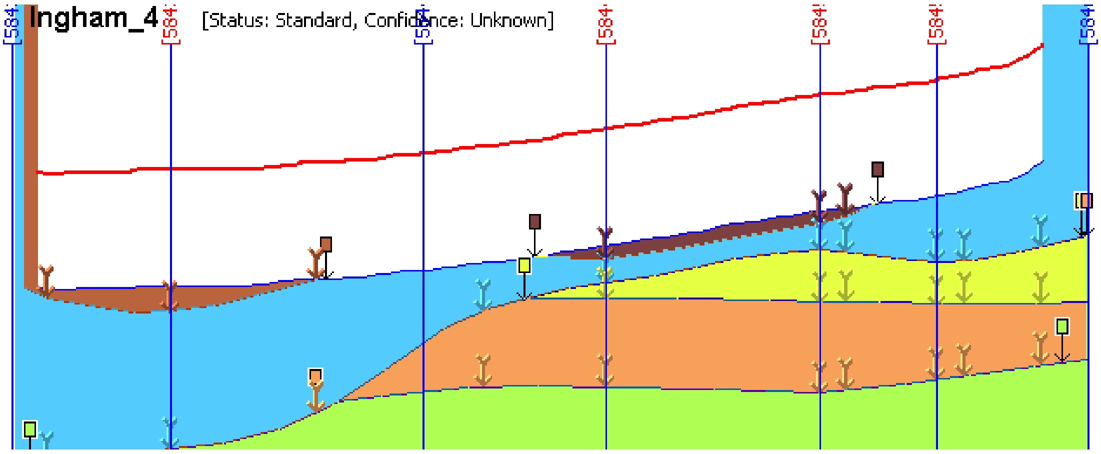
The display settings of the TIN can be specified for the map, section and 3D windows

In the **Map Settings** the TIN can be displayed as an **Envelope** (coverage) as the **TIN** , as **points** or as the **areal extent** as a blue line

In the **3D Settings** are options for **Gouraud, triangle mesh, flat and contour** plus a dialog box to specify **Contour Interval Transparency** and select **Colour** via a palette.

The **Section Settings** enable the TIN to be displayed in the section window by switching the option on. The **Colour** of the TIN to can be specified, and the thickness of the line can be specified in metres.

NOTE: the TIN that is set as the Model capping surface is always displayed in blue

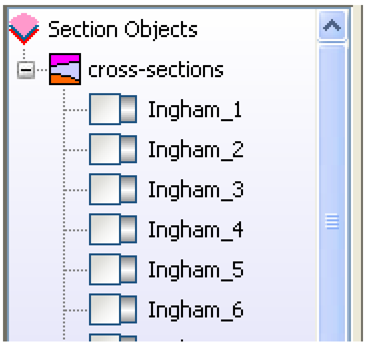


This image shows the capping surface (DTM in blue) and a 5m transposed TIN in red with the line thickened to 3m

Send to front	self explanatory
Send to back	**ditto**
Switch on edit	makes the object editable
Delete object	ditto
Isolate object	ditto
Isolate within group	ditto

4.4 Sections

4.4.1 Section tools and properties

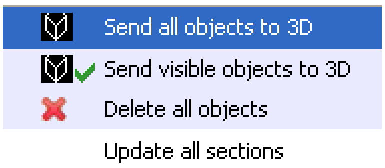


The sections loaded from the *.gsipr file are by default displayed in the map and the section window. Double click on the folder expands to lists all the loaded sections

The section lines are specified in the map window (see section construction below at Sections 4.4 2 and 4.4.3 whilst the actual section construction and editing occurs in the section window. In the section window only one section can be shown (by ticking box) at once.

The tools and properties for working with sections **are only available from the section window** and are as follows.

Right click on the cross-section folder in the section window ToC gives a menu as follows



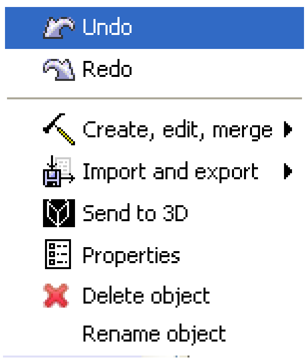
Send all objects to 3D Click this option to load all the sections into the 3D window.

Send visible objects to 3D loads the active (ticked) section into the 3D window

Delete all objects: self explanatory

Update all sections: self explanatory

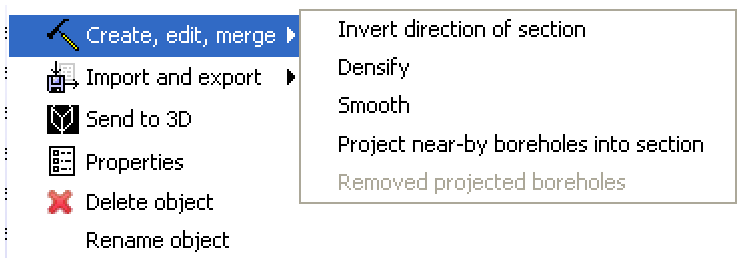
With the cross-section folder expanded **right clicking on the individual sections** gives



Undo self explanatory

Redo self explanatory

Expanding the **Create, edit merge** option displays the following sub-menu



Invert direction of section

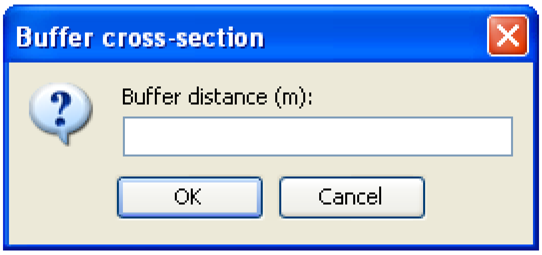
Reverses the section in the display and will be saved in this changed orientation unless switched back.

TIP: Additional positions (boreholes or points) can only be added to the end (right-hand end) of a section. So you can invert a section to add points beyond the start point of a previously digitized section. The section can then be inverted a second time to enable correlation to be completed (if preferred) in the original orientation.

Densify adds nodes to all correlation lines in the relevant section (see Section 4.4.5)

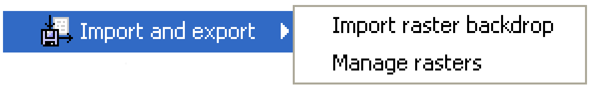
Smooth line smoothes and adds nodes to all correlation lines (see Section 4.4.5)

Project near-by boreholes into section allows the user to set a buffer (see below) around the section and project boreholes on to it.



Remove projected boreholes removes all projected boreholes from the section

Import and Export option expands to the following sub-menu:

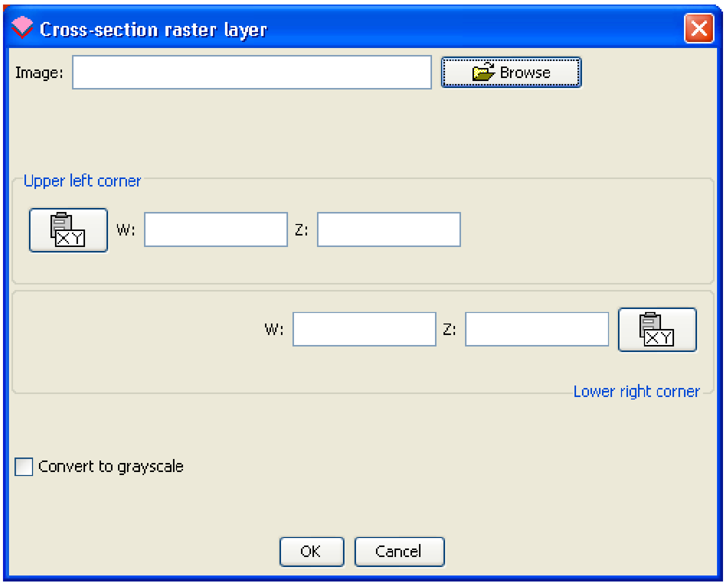


These options enable the import and management of rasters (images) in section. Rasters imported into a section are treated as a graphical backdrop, allowing linework to be digitised over the top of the image. Examples of such imports include scanned field notes, photographs of cliff sections and depth-converted seismic images (note that GSI3D has no depth-conversion functionality for seismic data or images, and this process should be carried out using specialist software). Support is provided for the standard image formats JPG, PNG and GIF.

NOTE: section raster support has changed in v2011. If importing existing section images from a v2.6.3 project (which we're previously visible only in 3D along straight sections), please contact the GSI3D Helpdesk for advice on how to migrate.

Rasters can be imported into existing sections, or a new section can be created for the raster. Either way, a section object must be present before importing the images.

Import raster backdrop displays the following dialog which provides for the import of a new raster image into the section:



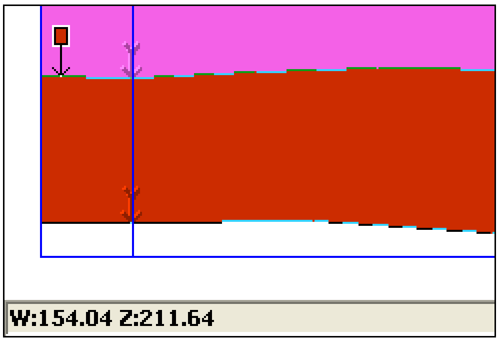
Step 1: Select image file

Select the image file using the ***Browse*** button.

Step 2: Geo-register the image in the section

Next provide the geo-registration information for the image. This will tell GSI3D how to scale and stretch the image within the section window. The section raster images are registered in the plane of the section in the coordinate space [W,Z], where W is the distance along the section (in metres) from the first 'borehole' position (i.e. the far left of the section), and Z is the true elevation (relative to OD/sea-level). The raster image is registered using the upper-left and lower-right corners.

The [W,Z] values can be read off the section window status bar and entered manually. The W and Z are displayed in the status bar as the mouse cursor is moved around the section window:



Alternatively, the [W,Z] position of a given point in the section can be pasted into the fields using the paste buttons against each pair of input fields. To do this, select info mode in the section window and click the desired location in the section. Then bring the raster import dialog back into focus and click the paste button against the input field pair that corresponds with the clicked-on position (i.e. upper-left OR lower-right). Next, go back to the section window and click the second corner potision , and perform the same paste operation in the raster dialog for the other corner of the image.

NOTE: the geo-registration can handle sections that are not straight on the map, so raster images can be added to sections with kink-points.

Step3: Convert to grayscale (optional)

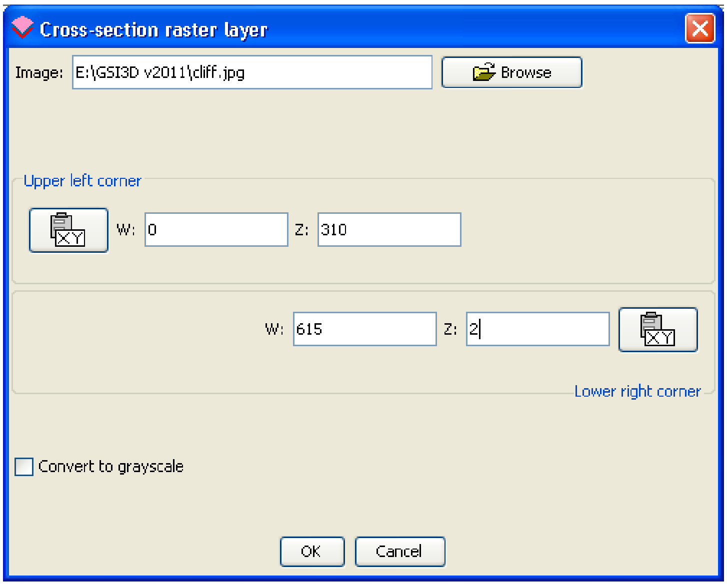
If desired, check the box ***Convert to grayscale*** to change the image from full colour to grayscale. This may be useful for certain types of image and is provided only for convenience. Note that the image file itself will **not** be modified by this setting.

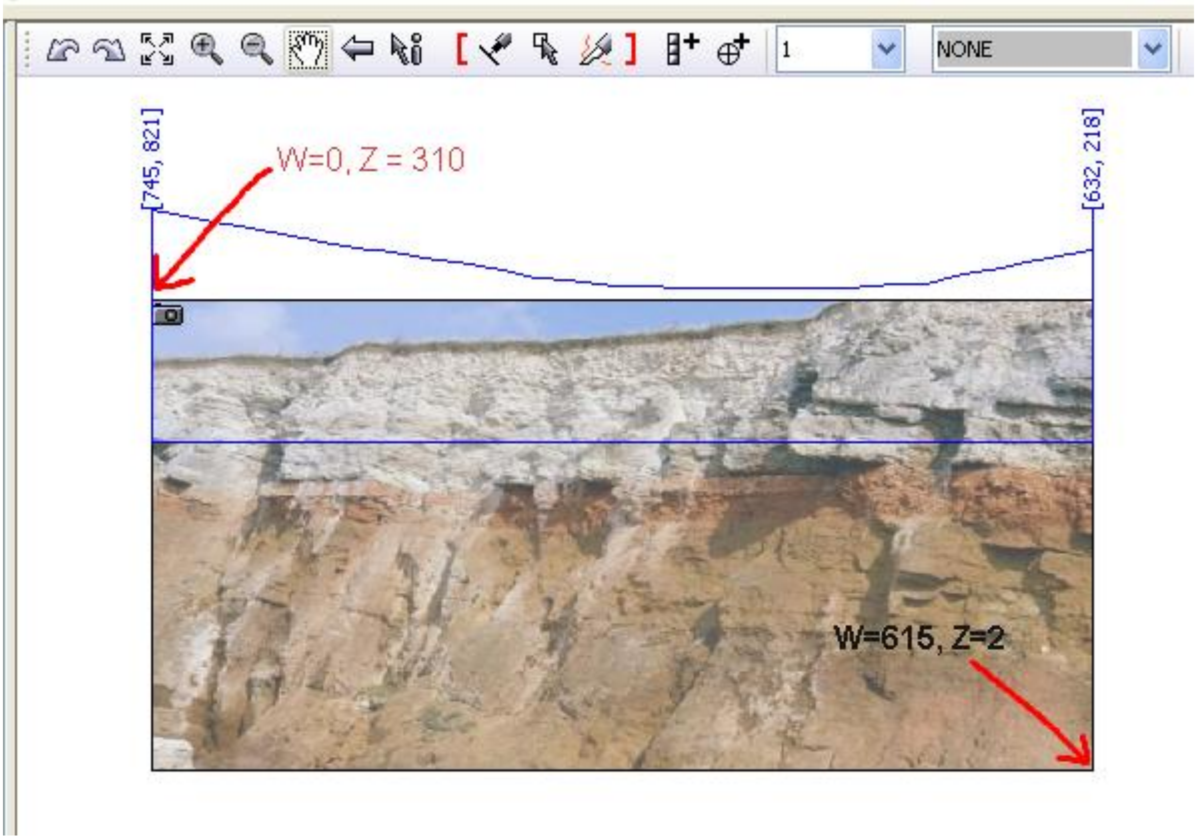
Step 4: OK

Click OK to import the image into the section. To see the image in the section it might be necessary to refresh/update the section window using the ***F5*** key, or ***right-click > update*** in the section window.

Example import – below is an example of importing a cliff section photograph. The image is registered between upper-left of [0, 310] and lower-right of [615,2].

NOTE: any rasters imports made during a working session will be saved into the project file (GSIPR file) when the project is saved.

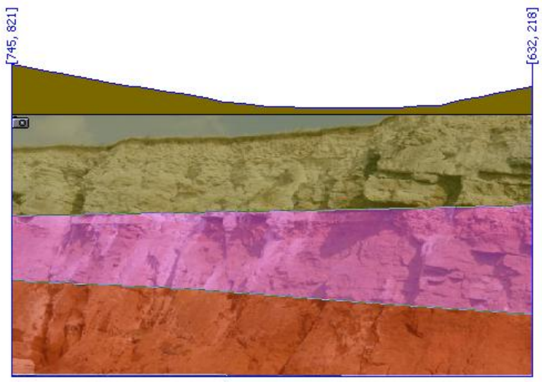




Hunstanton Cliff image © Copyright NERC.

For more images and full terms and conditions visit GeoScenic: http://geoscenic.bgs.ac.uk

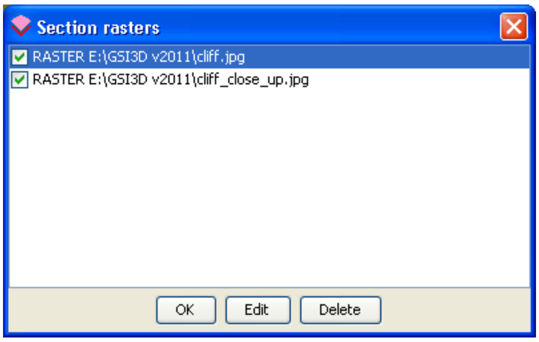
The raster image can now be digitised over:

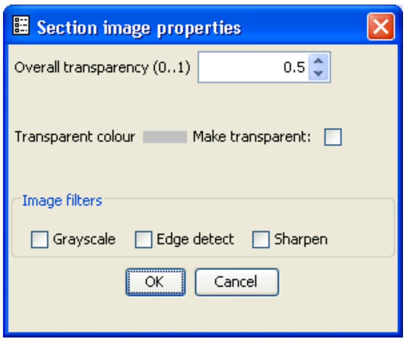


Any number of raster images can be imported into a single section. **NOTE: importing several raster images and/or importing raster images that have large file zies can adversely impact the performance of the graphics in GSI3D, depending on the image files.**

Manage rasters provides options for managing individual raster images within a section. A list of all rasters in the section is displayed. Use the checkboxes to the left of each entry to show and hide individual raster images in the section. The changes will take effect when the OK button is clicked.

To delete an entry, click to highlight it in the listing and then click ***Delete***. To edit an entry, click to highlight it, and then click the ***Edit*** button.





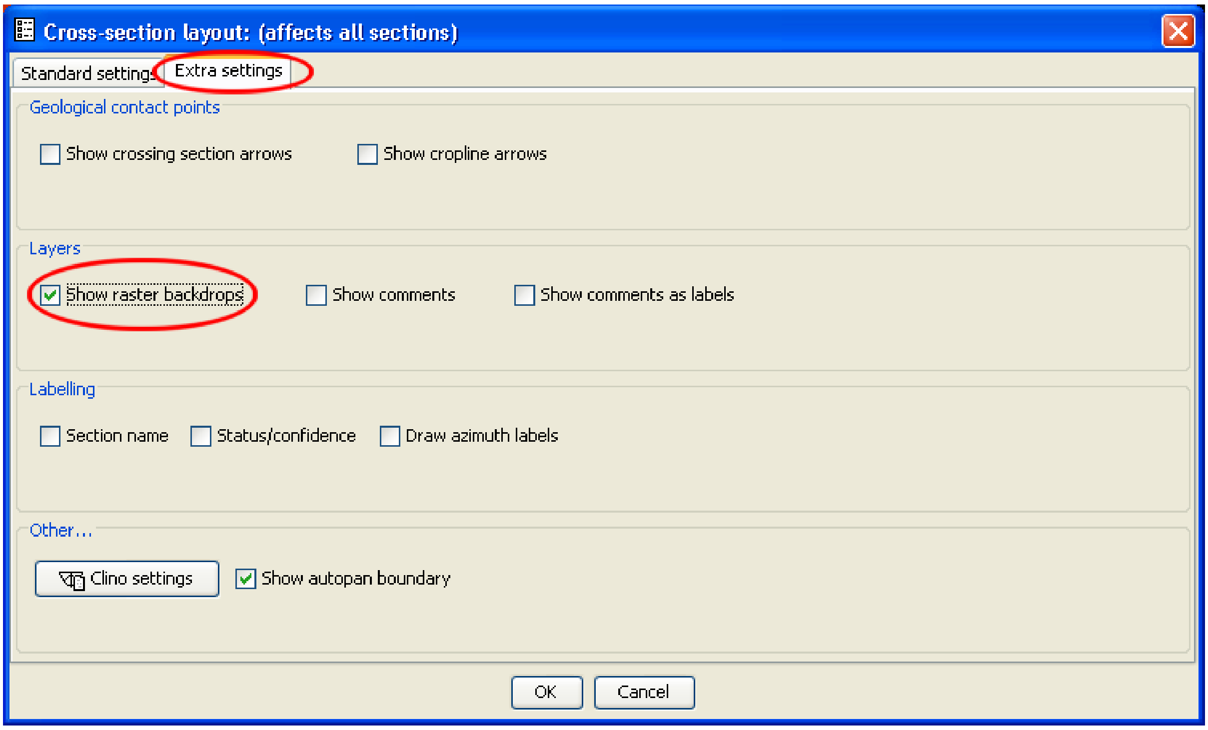
The ***Edit*** button opens the properties for the section image. Edits can be made in this dialog to adjust the transparency of the image and some other filters and settings can be applied.

Overall transparency adjusts the transparency of the entire image (0 is opaque, 1 is fully transparent).

Transparent colour allows the selection of a single colour to make transparent in the image. This option is useful for removing white backgrounds on images, for example, because making the white background transparent makes the section graphics clearer. To use this option, pick a colour, and then use the checkbox to apply the transparency.

Image filters provides some rudimentary filtering capability on the image, such as grayscaling and edge detection. **NOTE: depending on the image file these filters may not apply correctly in all cases, and are provided as a convenience only. Advanced image processing should be carried out using specialist software.**

All raster images within a section can be hidden via the properties dialog for the section object (and also the section window via right-click, which affects all sections), using the checkbox ***Show raster backdrops***.



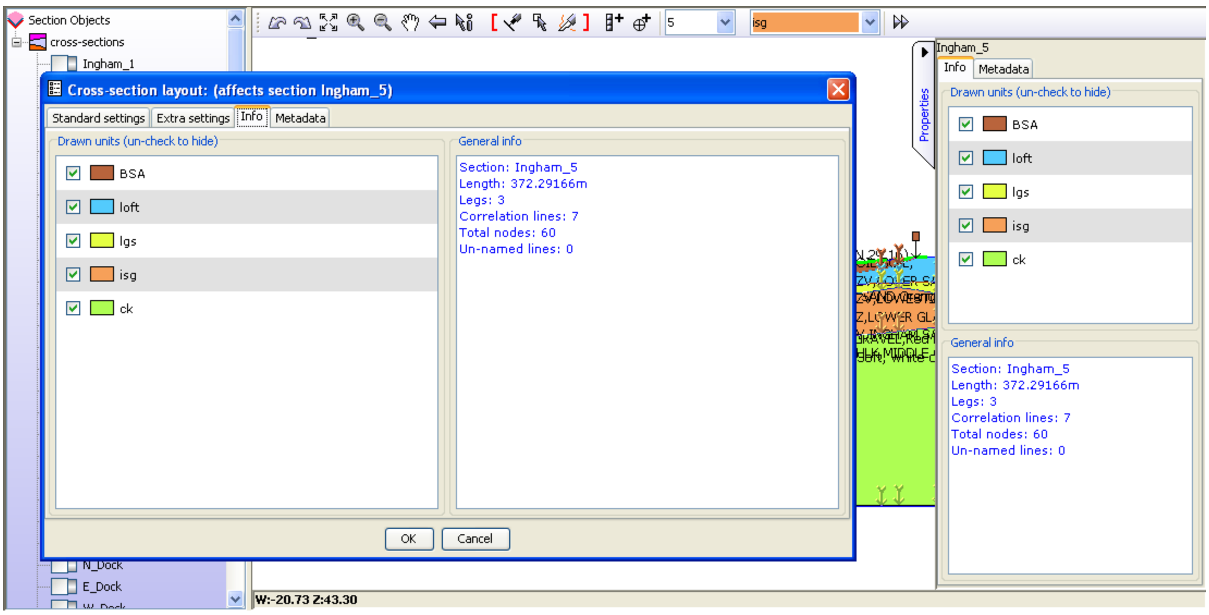
Send to 3D Self explanatory

Properties

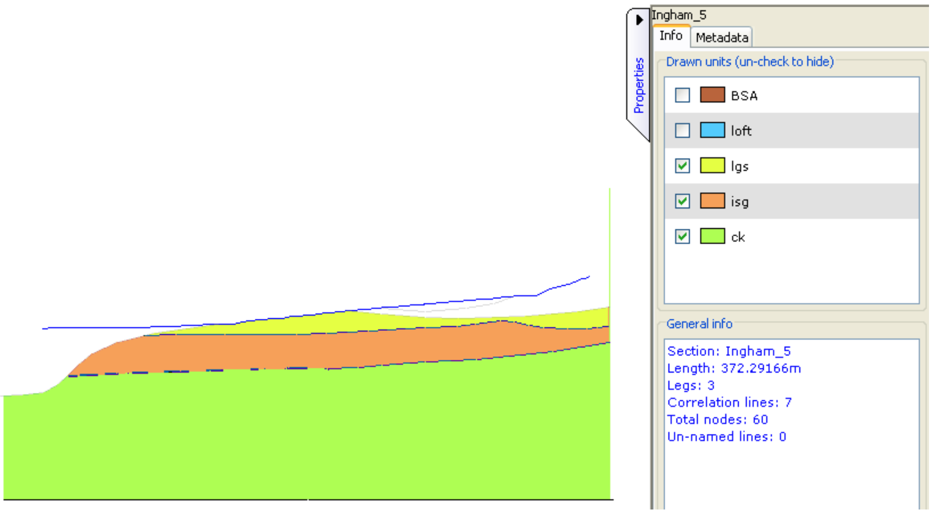
Click on Properties to reach the cross-section layout window described in Section 3.4.2 and gives the option to set the properties for the relevant section only.

In addition the setting for an individual section contain ***Info*** and ***Metadata*** tabs

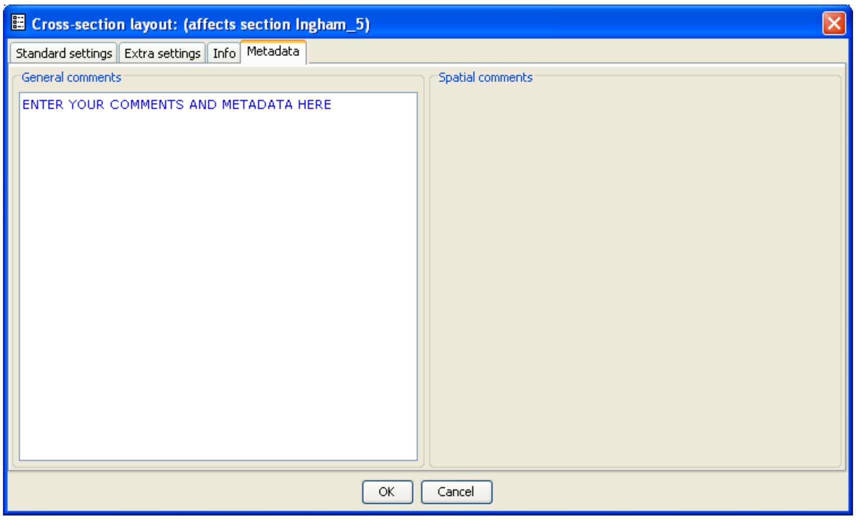
The ***Info*** tab produces a display listing the units present within the section and details of its overall dimensions (see below), the information is also displayed in the tab on the right hand side of the section window.



Both windows give the user the option to switch individual geological units in the section on and off, see example below, where units BSA and loft have been switched off



the ***Metadata*** tab produces a free text box for comments, these will be stored in the project file as xml tagged text.



Delete Object self explanatory
NOTE: Remember if a section is deleted from the table of contents in this way and then a new version of the *.gsipr file is saved the deleted section will not exist in the new *.gsipr file.

Rename Object produces a dialog box to rename the section

4.4.2 Simple Section construction

This example section is constructed from the following datasets, *.gvs, *.gleg, *asc. (grid dtm), *.shp (surface geology polygons), *.bid (borehole index) and *.blg (downhole classification).

The screen grabs are produced with the polygons and lines for correlated sections switched on, also the synthetic lines, 2D logs and map polygons all other settings switched off . Log display settings have all labels switched off. Under extra setting tab show crossing section arrows is switched off initially (screen grabs A-D) then turned on to assist correlating the deepest unit. In normal section construction all crossing section intercepts (if any) would normally be displayed from the start.

Initial simple section construction and correlation of an area might use the following steps. This example is for unfaulted artificial, Quaternary and layer- cake bedrock geology with digital geological mapping (*.shp) and coded boreholes available.

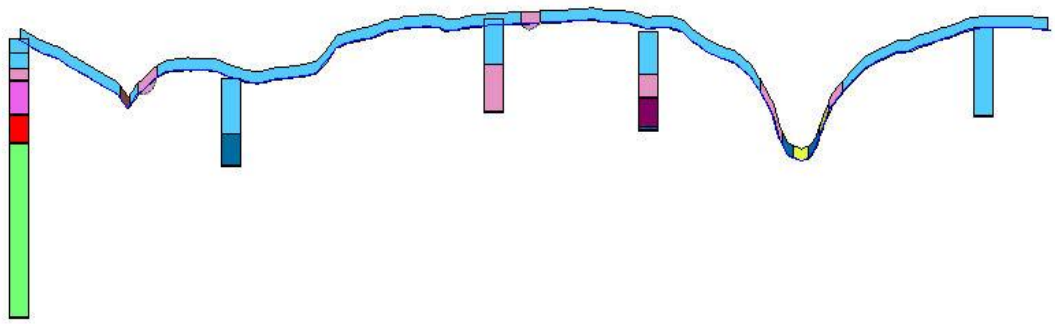
1. From the **File** pull down menu select **Properties** and load the *.gvs and *.gleg files and specify the *.blg file that will be used. Using the **Add Objects** pull down menu load the DEM (*.asc), and also Create TIN using the DTM. Then load geology shapes files (*.shp) and ensure it is attached to the correct DTM, then add boreholes (*.bid and *.blg). Arrange the windows to display map and section windows and borehole windows. Save the workspace.
2. Select **Create new section** from the **Tools** pull down menu and give it an appropriate sequential name e.g. TM14_NS1 in the dialog box. This name will automatically appear ticked (editable) in the ToC of the map and section window.
3. Looking at the data decide a rough alignment for your first section and begin to use the **Info** tool in the map window to examine the logs of any boreholes close to the intended line of section. (Display logs in Borehole window see Section 3.6)
4. Using the **Info** tool Start your section either by selecting a borehole or if none is suitable selecting a start point by clicking in the map window (red triangle marks the spot)
5. Click on either the **add borehole** or **add point** icon (whichever refers) on the section window toolbar.
6. Pan along your intended line of section and select your next borehole or point on it and add noting the section window refreshes, then continue to add points, and/or boreholes until the section is complete.
   NOTE: as the section line is constructed it is highlighted as active (in red) and grows across the map window. Sometimes you need to Update or Zoom to full extent to refresh the section display
7. Use the **Show full extent** icon in the section window to examine the string of coloured boreholes sticks and points and the trace of the DTM produced (see A below) check it looks OK, adjust properties (see above for example settings) by right clicking in the window and selecting **Properties** and also the Vertical Exaggeration by typing in or selecting an appropriate value in the toolbar.
8. If a surface geology Shapes *.shp file is loaded (as here) tick the **Display map polygons** box in the cross-section layout box to show a coloured layer of the relevant geological map along the DTM (check you attached on the shape file to the dtm on loading, you can adjust the ribbon thickness if necessary. This should produce a section analogous to B below

   NOTE: It is possible to display multiple map bands across the DTM but a surface geology map (often combined superficial and bedrock) should ideally be used as this is the geology at the DTM .

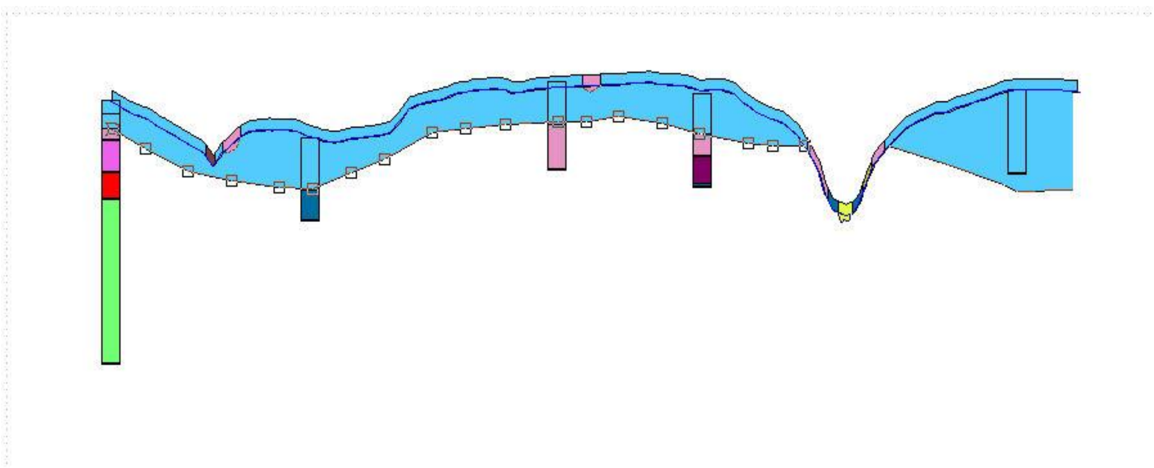
9. Using the surface geology, boreholes and your understanding of the area start to draw correlation lines using the **Draw line** tool in the section window toolbar

first along the base of the **youngest** unit in the section (see C below) Select this unit from the **GVS** pull down menu so that the correlation line is automatically labelled. The unit should colour instantly as far as the dtm or in the case of lower units the base of the overlying unit. Any errors in colouring up indicate vertical stacking of units that do not agree with the stratigraphy (*.gvs) file. If the polygons do not colour first check that they are ticked on in the Section layout properties box. Use the **Zoom in** tool where needed and produce precise lines with regularly spaced nodes giving geologically sensible shapes to the units. Start with **the youngest** and work down the GVS sequence (its like exhuming progressively older palaeosurfaces, erosional contacts and unconformities).

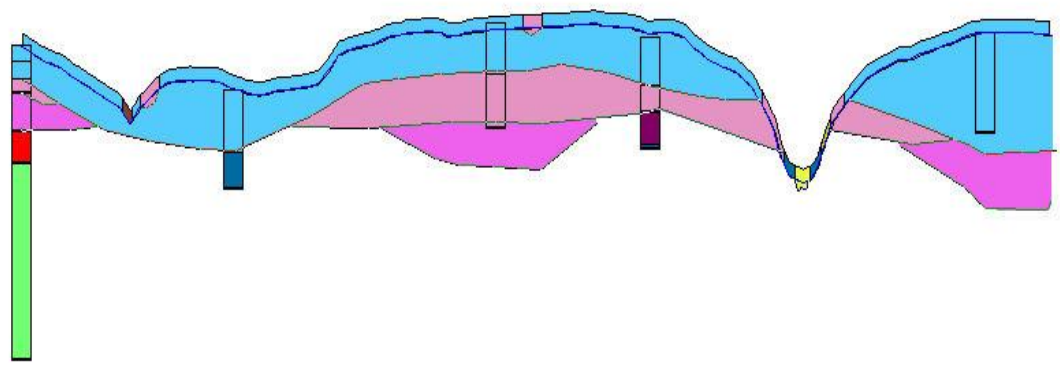
10. The **Rename line** option (right click on the line with the Info tool selected) can be used to rectify any wrong attribution using the correct gvs code for the unit base. Proceed to work down the section drawing lower and lower bases. At depth are they are likely to extend uninterrupted across the whole section. Check all units colour up correctly as you go (see C and D below).
11. When you are happy with the section select **File** > **Save project** label the file e.g.TM14_v1.gsipr This saves your first section in case of a crash as you continue to work.
12. Again select Tools > **Create new section***,* label it and then construct a second section in the same way and save the project again as a new version. as e.g. TM14_v2.gsipr.
13. Start to cross the area with regularly spaced sections in two orthogonal directions. Once some sections cross switch on the **Show Crossing section arrows** box form the **Extra Settings** tab of the **cross-section layout** and refresh to display the positions of contacts in intersecting lines (see E below).
14. Whilst correlating snap fit the lines to the intersections. This is achieved once the line is drawn, by selecting the **Display nodes** icon, then left clicking on the line to show the node string and dragging a node (click and holding down left button) to the approximate crossing arrow position, a dialog should appears asking you if you wish to snap the two lines. The software only allows lines with the same attribution to be snapped avoiding erroneous correlations. If the dialog doesn't appear this may be the cause. Alternatively adjust the crossing section to fit the active one if the evidence suggests it is a better solution. It is easy to swap between the intersecting lines by highlighting the **Info** tool and right click on the crossing arrow base and select the top option to **show the crossing section**. A red triangle appears at the selected point from the first section.
15. Bespoke project areas may require a different orientation and frequency of section lines depending on the envisaged output. Save the work frequently and keep all the sections you have drawn loaded in the section window table of contents, any disasters can be immediately selected and deleted from this table before saving allowing their sequential numbers to be reassigned.



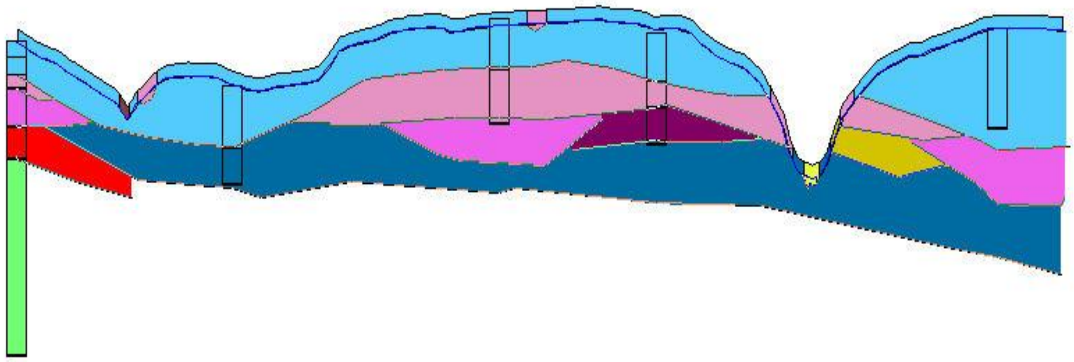
A: DTM, borehole sticks coloured and outcrop-band coloured TM14NE_WE1



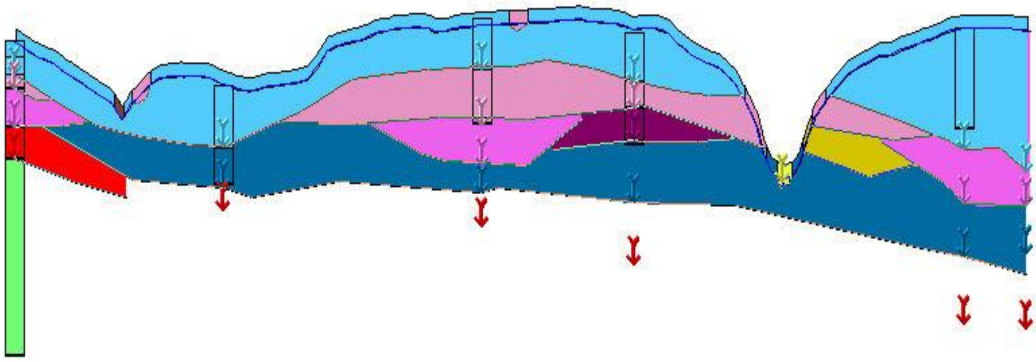
B: Base of till showing nodes



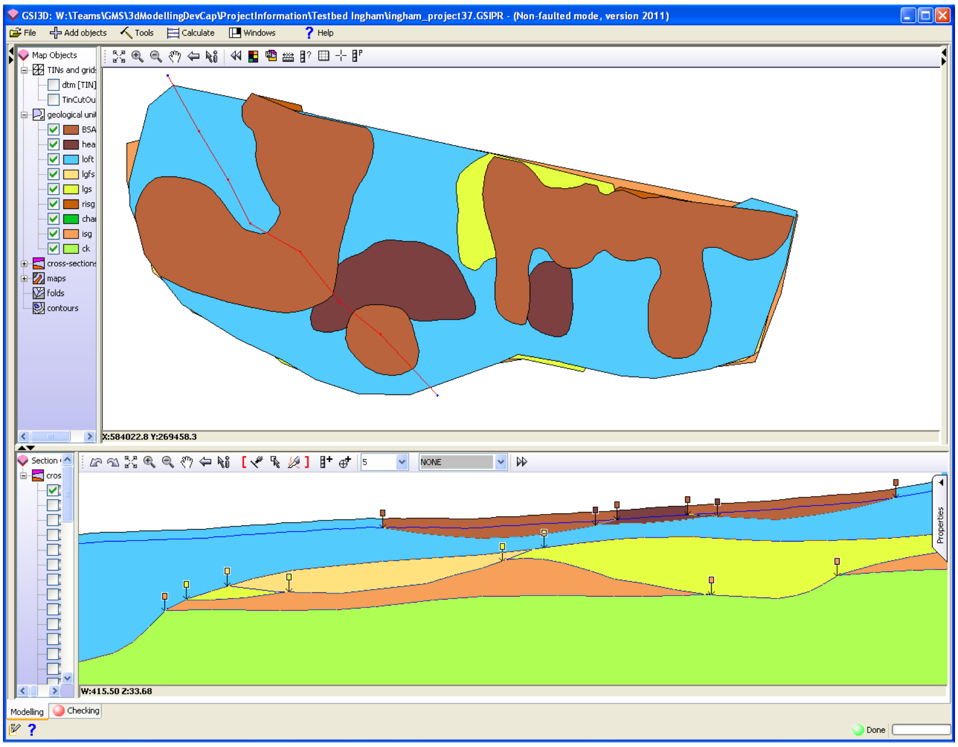
C: All Superficial geological units correlated



D: Most bedrock units correlated



E: Levels of base LLTE inserted as arrows from crossing sections



The image above shows a completed section snapped to outcrop and subcrops.

NOTE: for subcrops to become available the subcrop has to be completed in the geological unit. When a project starts off with the geological map band and crop ticks will only be available at the DTM. Ideally cross-sections and unit distributions (envelopes) should therefore be worked on iteratively.

4.4.4 Fence diagrams and types of sections

The Fence Diagram

A full fence diagram is usually composed of sections of various types (listed below). Where possible one set of major sections should aim to intersect structures and valleys close to right angles and the orthogonal set should be aligned at 90 degrees to the first set , but in detail still take account of surface topography and sub-surface structure.

NOTE: It is not essential to draw all sections in a particular orientation first, in many case drawing widely spaced sections in two orientations normal to each other first and then filling in with intervening sections is better especially in bedrock modelling where the overall structure can be defined at an early stage of fence diagram construction.

Helper sections

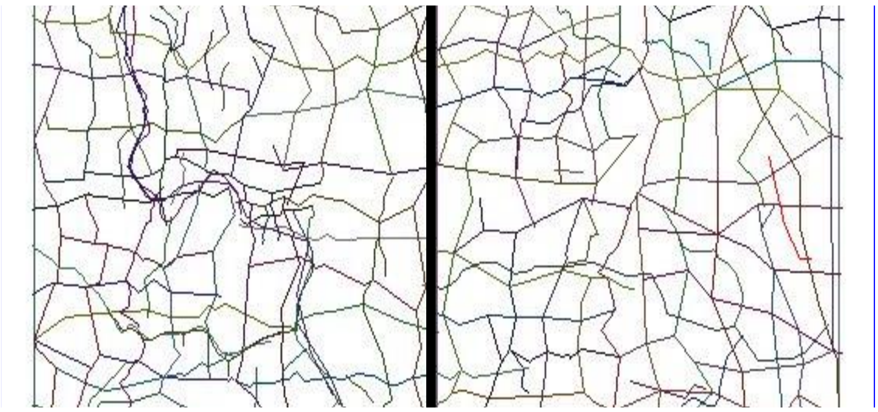
In addition to the main fence or grid of sections additional short helper sections may be required to model linear deposits, such as alluvial tracts, and isolated outcrops such as outliers in a dissected landscape. These sections are to provide sufficient information on the base of the deposits to enable satisfactory triangulation of its shape. Helper sections along linear tracts are best run along the axis of the deposits so that triangulation from side to side of the deposit producing a flat basal surface cannot occur. Any small patches of deposits without cross sections will end up being calculated as a very thin layer on the dtm, in certain cases e.g. thin blanketing head deposits this can represent a satisfactory solution enabling the distribution of the deposit to be seen. In the case of helper sections it is only necessary to correlate the units requiring “help” plus any that overlie them.

Docker sections

Docker sections are produced along the limits of the project area, these may be either follow grid lines or be digitized to follow more irregular boundaries such as watersheds or city limits. They are produced in the normal way. It is important though that all sections meeting the docker sections are extended slightly beyond them so their intersection points (cross-ticks) can help construct the docker section.

The main function of docker sections is to ensure a perfect fit between adjacent modelled tiles or areas (by sharing the common docker section). Docker sections are often revised when modelling proceeds to adjacent areas and further data is examined, in such cases the revised section is then returned to the original tile and intersections are adjusted to it.

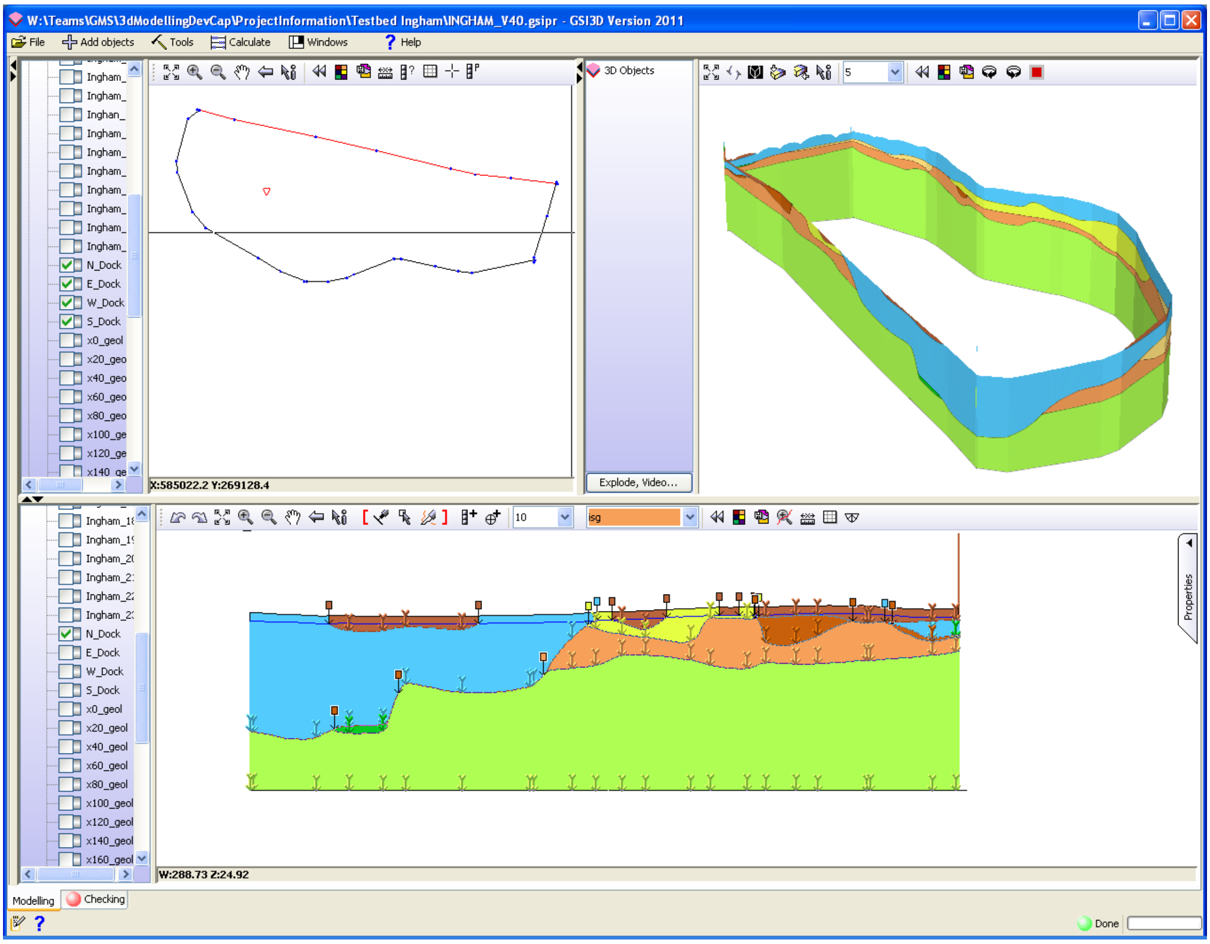
To allow proper construction of docking sections it is necessary to work with a DTM slightly larger than the project area, this buffering ensures a complete DTM trace is available for the construction of the section along the project edge.



TM14 Central Docking Section TM24

The convention of labelling docking and helper sections so that their purpose can be identified is recommended, e.g. TM24_Dock_W. The section carries the same name in the two adjacent model tiles.

The image below shows 4 Docking sections surrounding a non-rectangular project, in map, 2D and 3D window.



Digitizing sections from rasters

Sections can also be produced by digitizing over georeferenced vertical sections that can be displayed in the section window as rasters. These might for example include sketches of exposures, depth converted seismic profiles, geophysical sections or pre-existing published sections. Raster management is described in section 4.4.1.

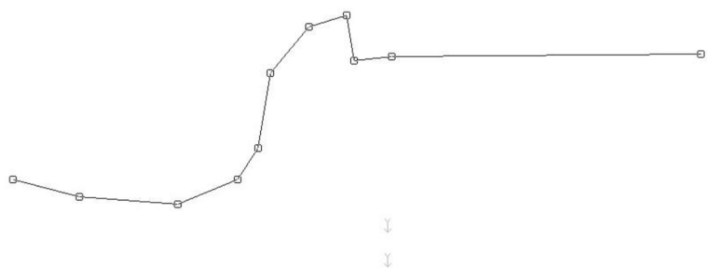
4.4.5 Section checking, editing and snapping tools

NOTE: The following functions update all lines in the selected section.

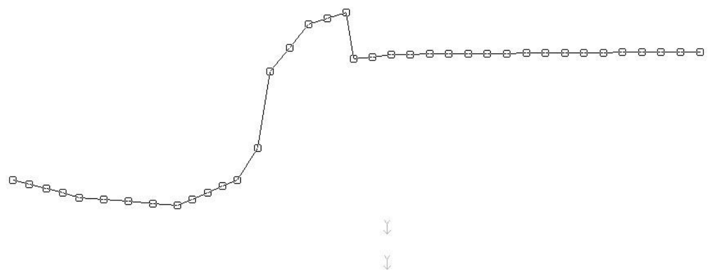
Densify line displays an entry screen to type in the maximum distance (in the 'W' dimension – i.e. along section from left to right) in metres between two adjacent nodes that is permitted along correlation lines, where this distance is exceeded an equally spaced node(s) are inserted to populate the line.

Smooth line displays an entry screen to type in the distance in metres (in the x dimension) between two adjacent nodes that is permitted along correlation lines, this function however not only populates the line but changes the shape of the line to a smoother shape.

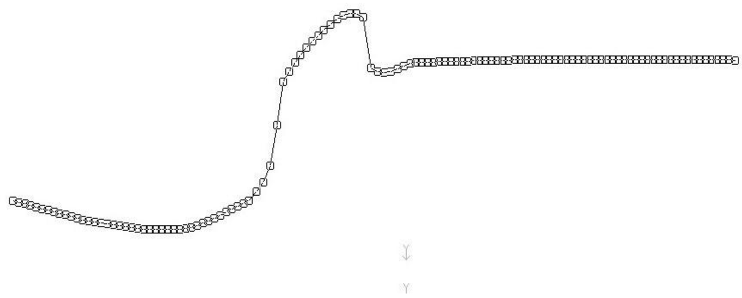
Line before population or smoothing



Line populated (nodes every x metres in x dimension), line shape remains

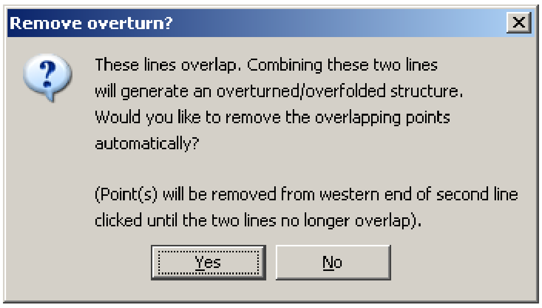


Line smoothed (nodes every y metres in x dimension) line shape smoother

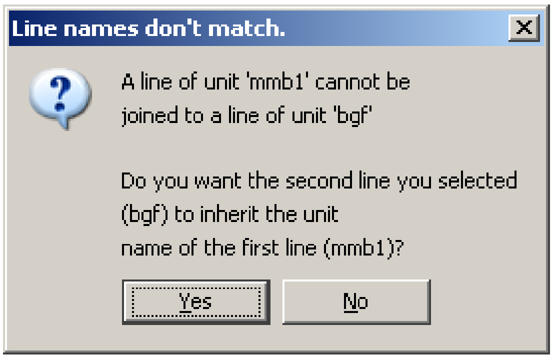


Join correlation lines

To join two correlation lines, with the Info tool in the section window active hold down Ctrl on the keyboard and click on the two lines one after the other. If the lines are of the same attribute and their end-points do not overlap then a dialog appears and the join will be performed. If the lines overlap the user is prompted thus:



Clicking “No” will perform a naïve join and will result in an overturned fold in the correlation line. If the user attempts to join two lines with different attributes then the join can still proceed but the user must respond to the following prompt:



Clicking “No” will abort the join operation. Clicking “Yes” will re-attribute the second line to that of the first and then perform the join. The result of a successful join operation will be shown immediately in the section window.

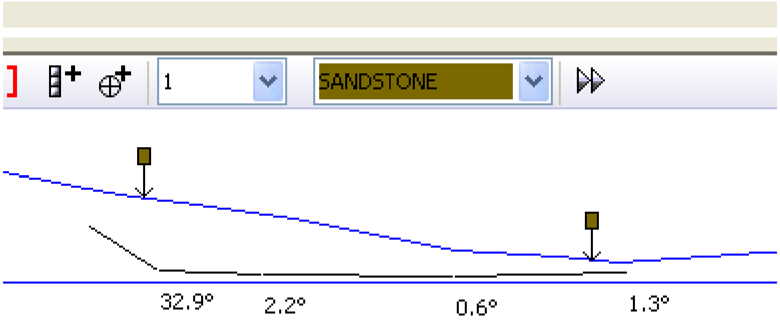
Snapping correlation lines to map linework

It is desirable, that the correlation line digitizing is as accurate as possible with-respect-to the map linework. Correlation lines can be ‘snapped’ to map linework positions where the unit name attributes match. Locations in the section where a piece of map linework crosses over are shown by **crop arrows** with small rectangular boxes displaying the colour of the map line unit:

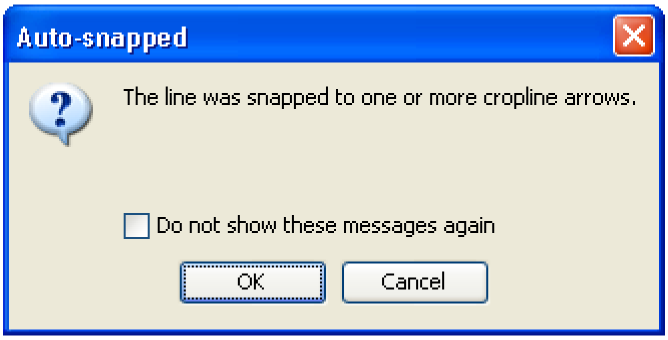
Hovering over these arrows whilst holding down the Shift key will display a tooltip describing the type of map linework that is crossing over.

These arrows are calculated by finding the intersection between the line of the section on the map and the piece of map linework (i.e. the boundary of a unit envelope). Their elevation in the section (Z-position) is calculated on-the-fly by using the model cap (DTM) and the GVS to find where the arrow should sit relative to any existing correlation lines in the section. By default, the arrows will rest on the model capping surface (DTM), and hence represent locations where the correlation line outcrops at the ground surface. If a correlation line of a unit that is stratigraphically higher up is present at that location the arrow will automatically drop down to rest on the other unit's correlation line. This represents a position of subcrop of the unit represented by the arrow against the base of another overlying unit.

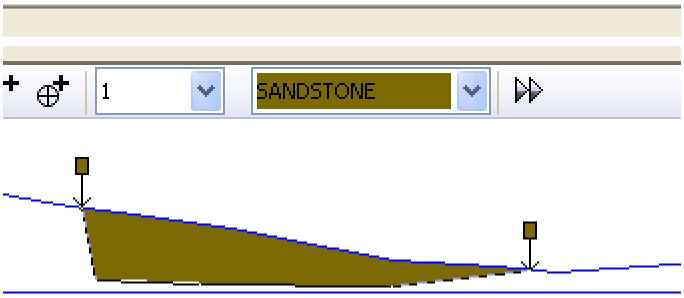
When a correlation line is drawn in section, GSI3D will automatically attempt to snap the line to the crop arrows. In the below example, an outcrop of Sandstone exists between the two arrows. BY drawing the line roughly as below:



GSI3D tries to snap the ends of the line automatically to the arrows upon the double-click to end line. The following confirm dialog is shown, together with an option to hide such messages:



And the line is auto-snapped:

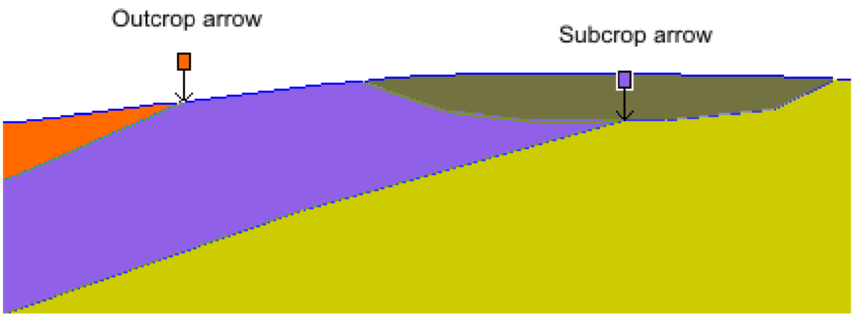


This helps to improve the accuracy of correlation in section by encouraging the interpretation to match the map linework.

NOTE: To prevent auto-snap, hold down the Ctrl key whilst digitizing.

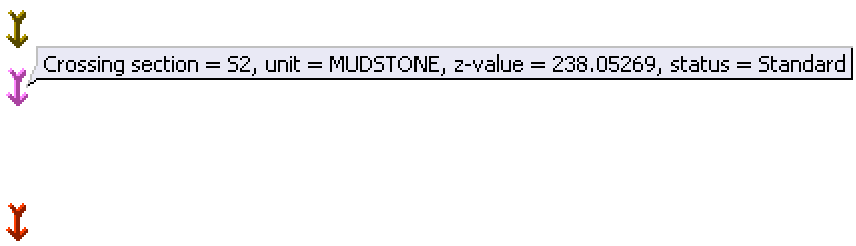
Existing linework can be snapped retrospectively by using the node edit tool in the section window. To snap an existing correlation line to an outcrop or subcrop arrow, use the line edit tool and hold down the Ctrl key on the keyboard whilst dragging the correlation line node towards the base of the arrow. If the geological unit attribution of the map arrow and the correlation line match then the line node will snap to the arrow.

The ideal situation is to have all correlation lines snapped to their outcrop and/or subcrop locations in section.



Snapping correlation lines to other sections

It is desirable, that the correlation line digitizing is as accurate as possible with-respect-to the correlations digitized in other sections that intersect with the current section (known as ‘crossing sections’). Correlation lines can be ‘snapped’ to crossing section positions where the unit name attributes of the correlation line match. Locations in the section where a correlation line from another section intersects with the current section are shown by **crossing section arrows** which display in the colour of the intersecting correlation line’s unit attribute. The attribution of the crossing section arrow can be interrogated by holding down the Shift key in info mode, and hovering over the arrow. Arrows usually appear as a vertical stack signifying where multiple correlation lines from one section intersect with the current section:

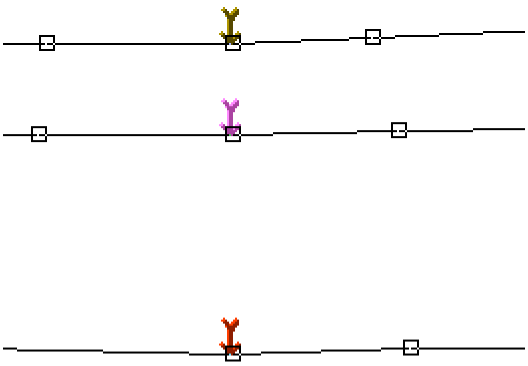


When digitizing, GSI3D tries to snap nodes of the line automatically to the crossing section arrows upon the double-click to end line. GSI3D will do this by inserting a new node at the location of the crossing section arrow. The following confirm dialog is shown, together with an option to hide such messages:

NOTE: To prevent auto-snap, hold down the Ctrl key whilst digitizing.

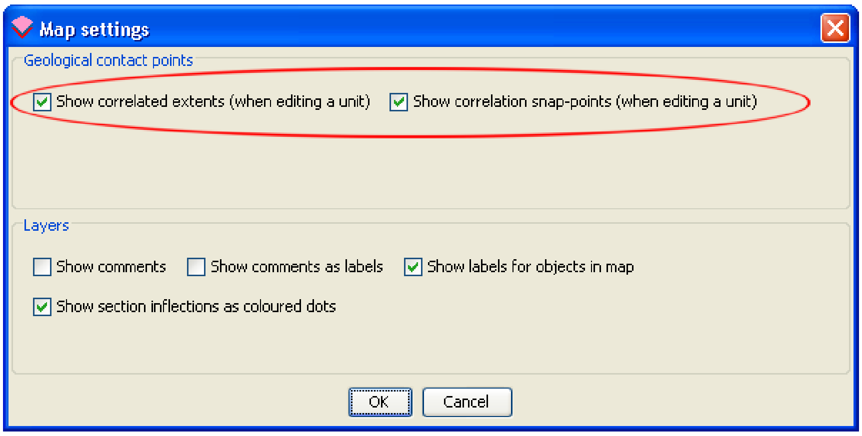
Existing linework can be snapped retrospectively by using the node edit tool in the section window. To snap an existing correlation line to a crossing section arrow, use the line edit tool and hold down the Ctrl key on the keyboard whilst dragging the correlation line node towards the base of the arrow. If the geological unit attribution of the crossing section arrow and the correlation line match then the line node will snap to the arrow.

The ideal situation is to have all correlation lines snapped to their corresponding crossing section arrows.

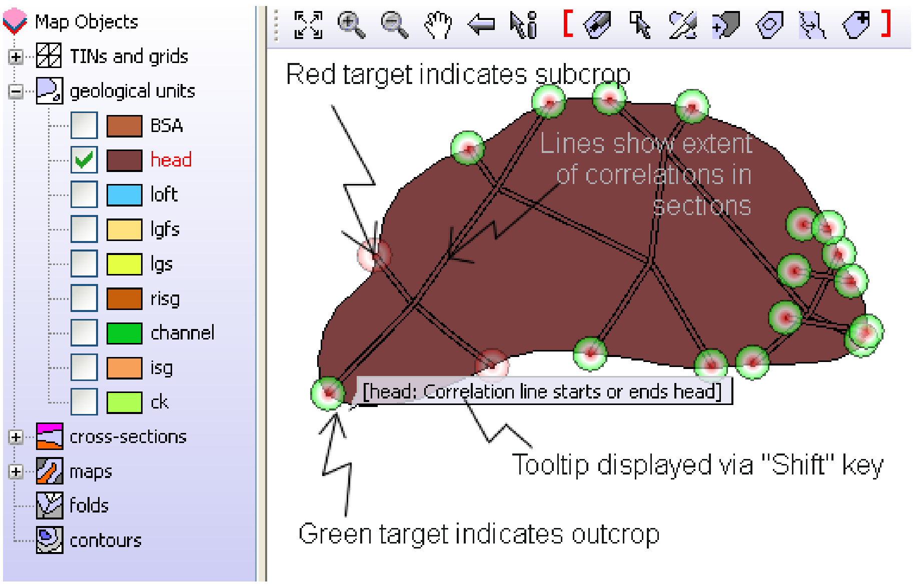


Snapping map linework to sections

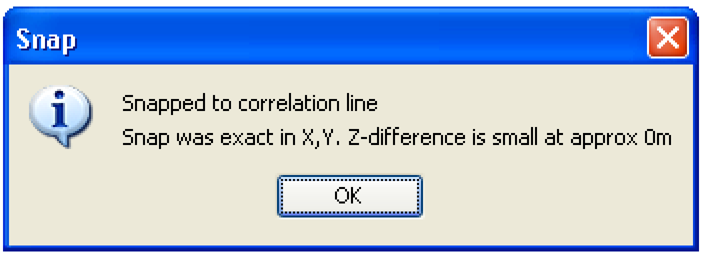
As well as being able to snap correlation lines in the section to the cropline arrows it is also possible to snap the map linework to the correlated extent in the map window. This function is not active by default because the calculation of these positions can impede graphics performance. To activate the functions, right-click in the map window and choose Window Properties. In the properties dialog that appears, make sure that the options for "***Geological contact points***" are checked on and click ***OK***:



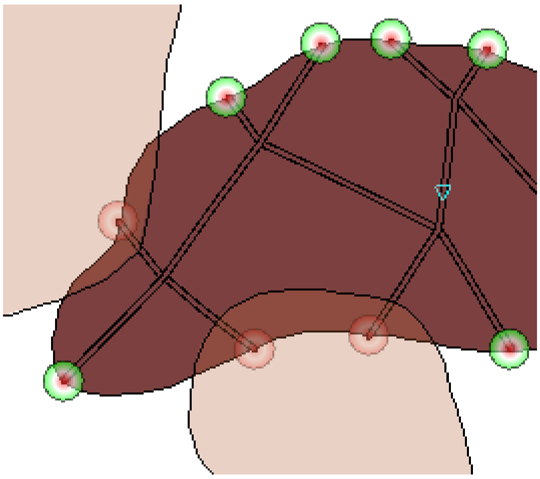
Make a geological unit editable via ***Right-click > Switch on edit*** in the ToC. The map will now show the correlated extent of that unit as a series of thick lines; these lines show where the unit has been correlated in the sections. Also, the end-points of the correlations lines will be shown as “target” circles.



The map linework (envelope boundary) can be snapped to these target circles. To do this, use the node edit tool in the map window toolbar to select an envelope boundary. Next, choose the node that will be snapped to the target circle. Hold down the ***Ctrl*** key on the keyboard and drag the node towards the target. When the node is close to the target the snap will occur. A confirmation will be shown:



There are two types of target circles; outcrop and subcrop. Green target circles indicate positions where the end of the correlation line in the section is at (or very close to) the ground surface or model capping layer (DTM). Hence the green targets represent outcrop positions. Red target circles indicate positions where the end of the correlation line in the section is beneath the surface. Hence the red target circles represent subcrop positions. The picture below shows a geological unit resting partially on top of the one being edited. Note how the target circles are red where the overlying unit sits on top of the unit being edited (the overlying unit is shown with 50% transparency so that the unit below is visible)



4.5Geological units

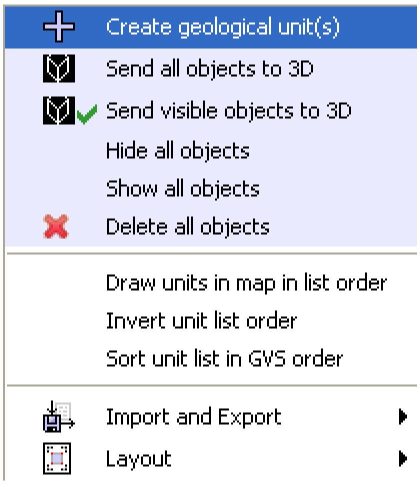
This folder, present only in the map and 3D windows, contains the individual geological units, for ease of working these are usually ordered in accordance with the gvs.

The units contain **shapes** or coverages defining the extent (presence-absence) of the unit in plan view. Their coverage may be composed of outcrop and/or subcrop.

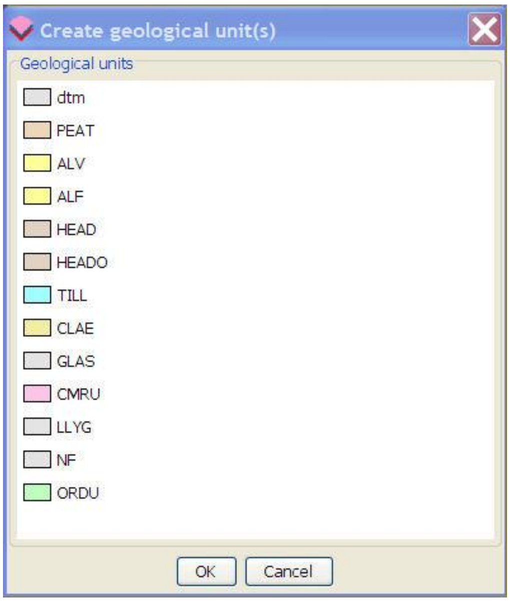
After calculation the triangulated top/base and volumes are contained within the individual unit entries in the ToC of the map window.

4.5.1 Geological units tools and properties

A right click on the overall geological units folder gives the following options



Create geological unit(s)



This option produces the list of geological units contained in the GVS that have not yet been created in the project. The required unit(s) is/are selected and clicking OK opens an empty object with the unit name(s) in the folder.

The following options are self-explanatory

Send all objects to 3D

Send visible objects to 3D (i.e. all sections currently switched on)

Hide all objects

Show all objects

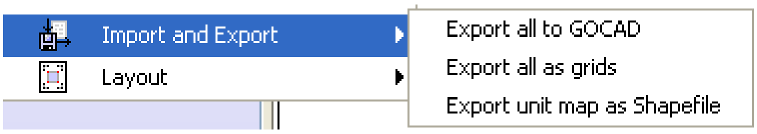
Delete all objects

Draw units in map in list order orders the geological units in the map view as they are listed in the ToC (which might not be the right order in the GVS, see below)

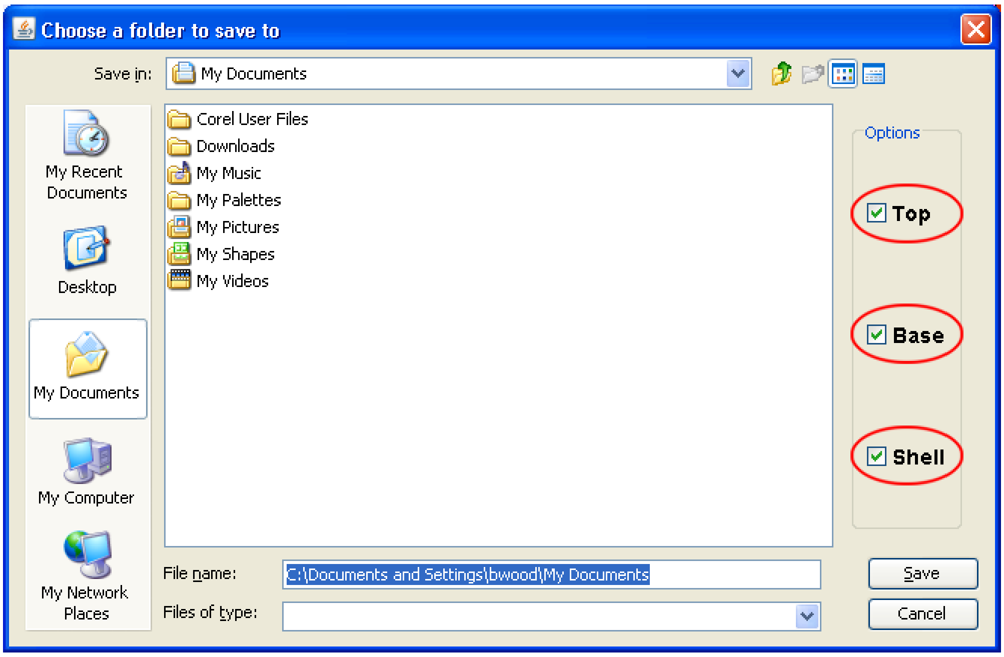
Invert list reverts the order in the ToC, but not in the map, **Draw units in map in list** order must be used to re-order the map view.

Sort unit list in GVS order orders the ToC list in GVS order – again the map view will not changed unless **Draw units in map in list** order is used.

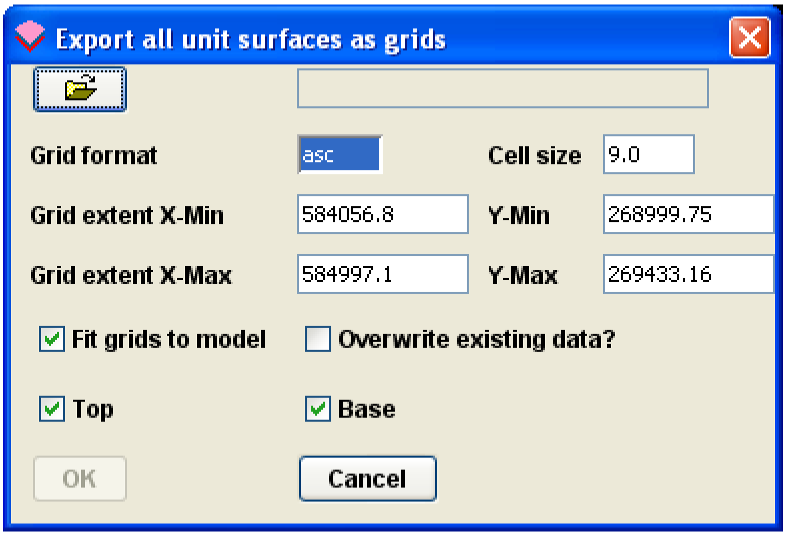
Import and Export expands to the following sub-menu



Export all to GOCAD exports all geological untis into Gocad *.ts format. The dialog box below show the default setting which will export the top, base and unit shell, removing ticks allows for example only shells to be exported.



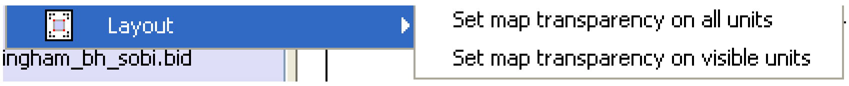
The **Export all as grids** option brings up the standard windows save box enabling the user to save the top, base and thickness (unitname_b for base, unitname_t for top and unitname_th for its thickness), of all the modelled units as individual ASCII or surfer grids. This is carried out as a batch job for all the units in the stack. The cell size can be selected and the grid extent is set to the total area of the model, but this can also be changed to export a bspoke area of the model. Clicking on the folder icon on the top left brings up the standard Windows save dialog, here a folder needs to be selected for the export**.**



Export unit map as shapefile exports the <u>map window content</u> as an attributed shape file **(***shp).

NOTE: This option does not export the full coverages of all units but deliberately creates a single shape file of the current map view. To obtain full coverage of a geological unit as a shape file the unit can be isolated and the exported. Alternatively the ESRI toolbox (see section 6) can be used to batch convert all coverages.

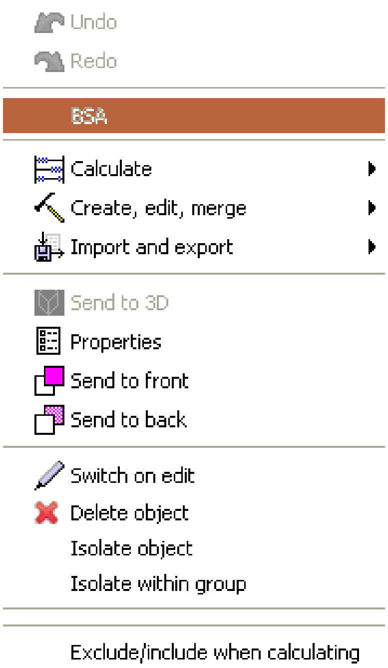
Layout contains



Set map transparency on all units Self Explanatory

Set map transparency on visible units Self Explanatory

Right click on the individual geological units produces the following menu.

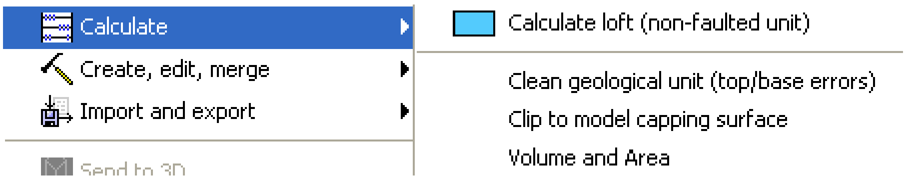


Undo Self-explanatory

Redo Self-explanatory

Unit ID displays the gvs code for unit (inactive)

Expanding the **calculate** option gives the following sub-menu



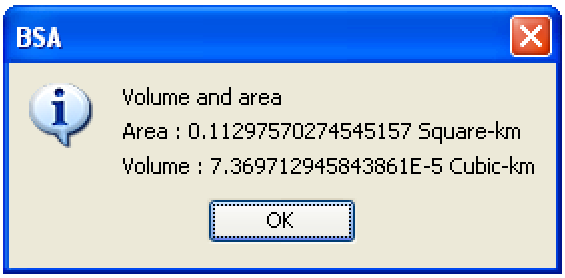
Calculate unit (non-faulted unit) calculates this individual unit in isolation from the rest of the stack – this allows for a quick look at the emerging unit.

NOTE: the unit top will not be correct if it is overlain by other geological units, as these will not be considered in the calculation.

Clean geological unit (top/base errors) cleans any areas of the unit's calculated top and base where the two surfaces overlap, cross-cut or coincide. Depending on the model this may only make a very small difference to the end result, but in some cases may provide a cleaner calculated result. The normal calculation routine ignores this step by default.

Clip to model capping surface will do the same as **Calculate unit (non-faulted unit)** but trim any triangles that go above the capping surface see Section 5

Volume and Area displays the volume and area of the calculated unit (in sq and cu metres)



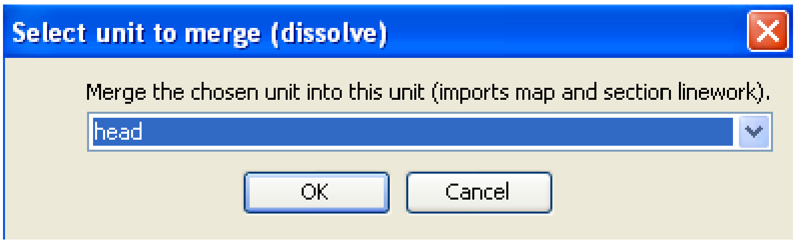
Create edit, merge and paste tools contains functions to:

Paste shapes

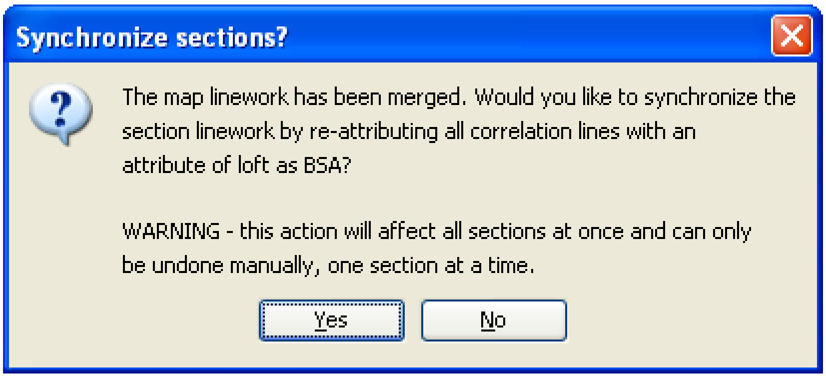
This function pastes polygons copied from the geological shape file into the receiving editable unit after copying from objects in the map folder (see below)

Merge (dissolve) another unit into this unit can be used to merge (dissolve) other geological units in the project into the active unit using the selection dialog shown below.

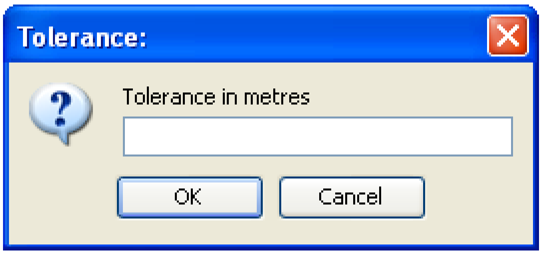
NOTE: This function should be used with care as it cannot be un-done



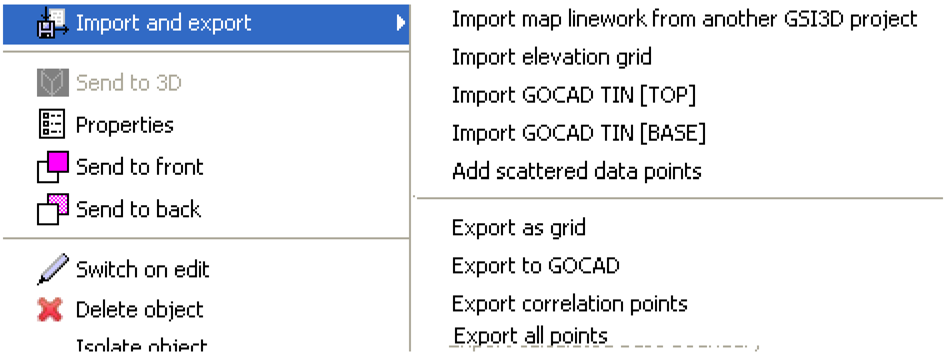
After a successful merge the user gets prompted to also re-attribute all correlation lines from the merged unit, see screen below. Again, this should be carried out with care.



Simplify unit map linework simplifies the map linework using the Douglas-Peucker algorithm and a user-specified distance tolerance. All vertices in the simplified linework will be within this distance of the original line.
http://en.wikipedia.org/wiki/Ramer%E2%80%93Douglas%E2%80%93Peucker_algorithm



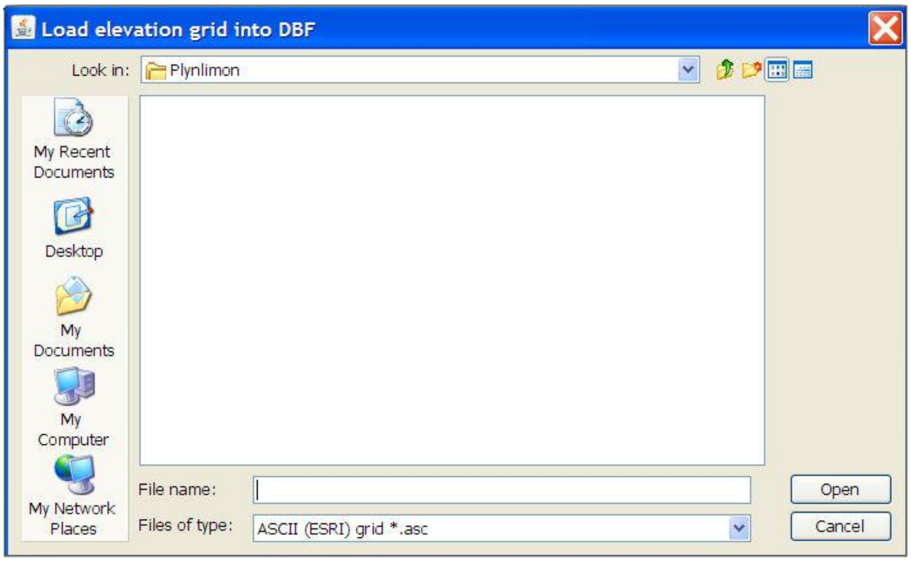
Import and Export expands to



Import linework from another GSI3D project allows the import of envelopes from legacy projects directly into this geological unit.

Import Elevation grid

Selecting this option allows the user to import an existing ascii grid into a geological unit using the following standard loading box.

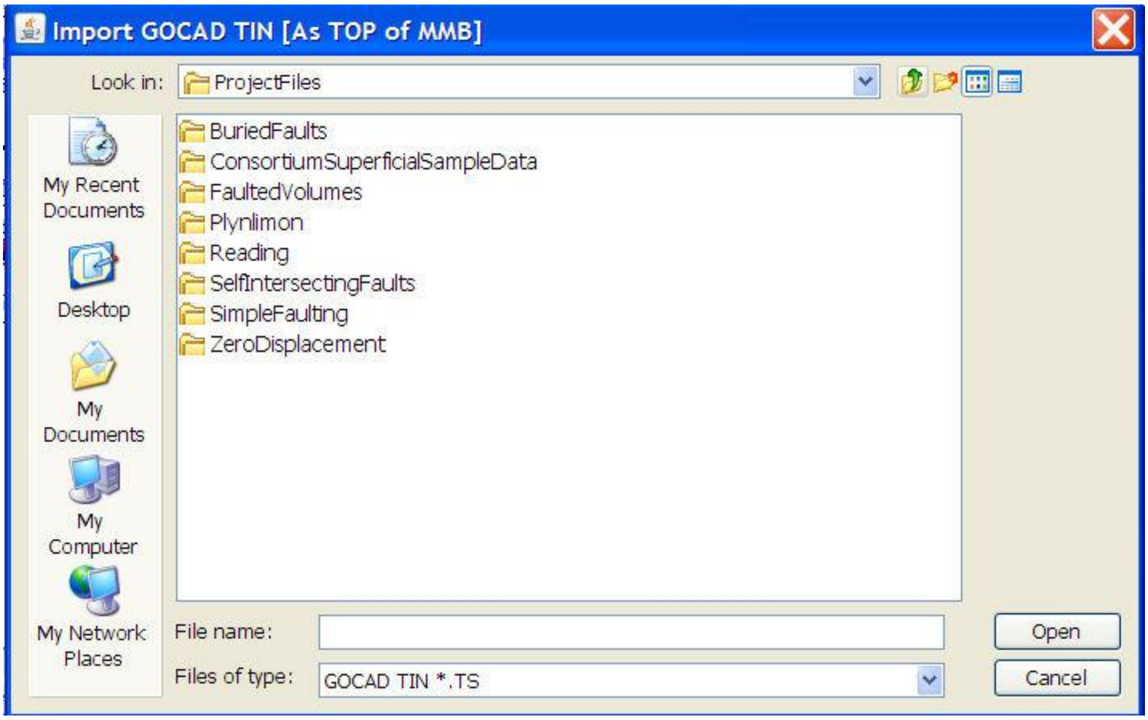


In this process the raster is automatically triangulated and so can be used in model calculation

NOTE: When saving the project the imported surface(s) it will be saved as part of the model *.gsipr file.

Import GOCAD TIN (TOP) & (BASE)

This function allows the direct import of GoCad Tsurf TINs into a geological unit for calculation.
NOTE: When saving the project the imported surface(s) it will be saved as part of the model *.gsipr file.



Add scattered data points

This function allows extra data points such as points along contour lines or scattered helper points where data is sparse to support the conceptualised geometry of the unit. Selecting the option produces a standard loading box.

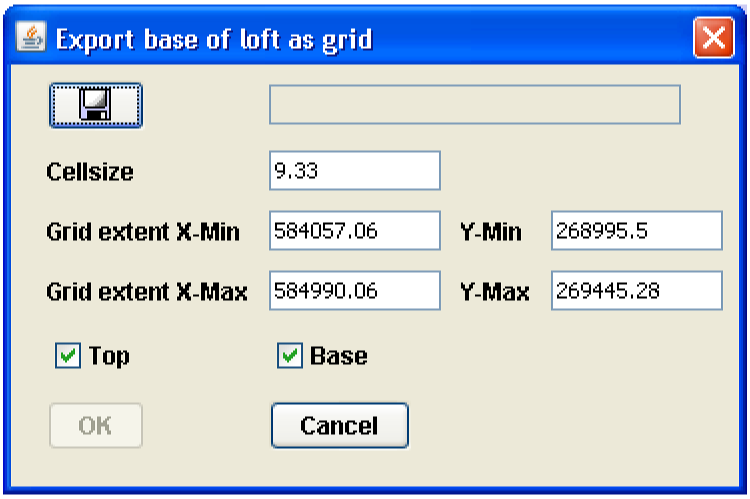
The data points are imported as tab-separated xyz ascii data in *.dat format., <u>note this file does not contain a header</u> which is shown below for explanation only. The unit must already contain an envelope.

Point name	X	Y	Z
A1	620227	245907	21.36207

NOTE: When saving the project the imported data points will not be saved as part of the model *.gsipr file.

Export as grid (*.asc)

This function enables the export of the base and/or top of an individual geological unit as an ASCII grid. Use the Top/Base check boxes to choose which aspects to export.

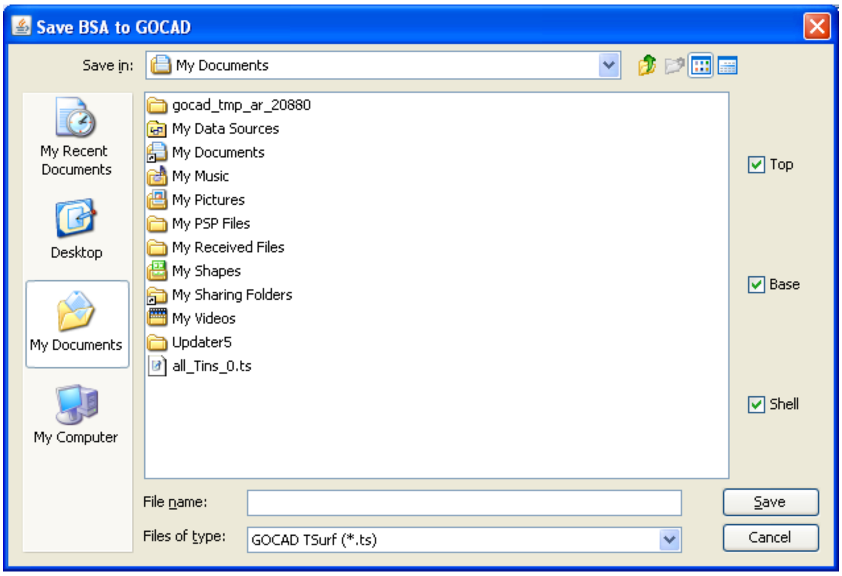


This standard save box requires the user to define the cell size and extent of the grid, the default value the cell size is model dependant and the extent is the whole project area.

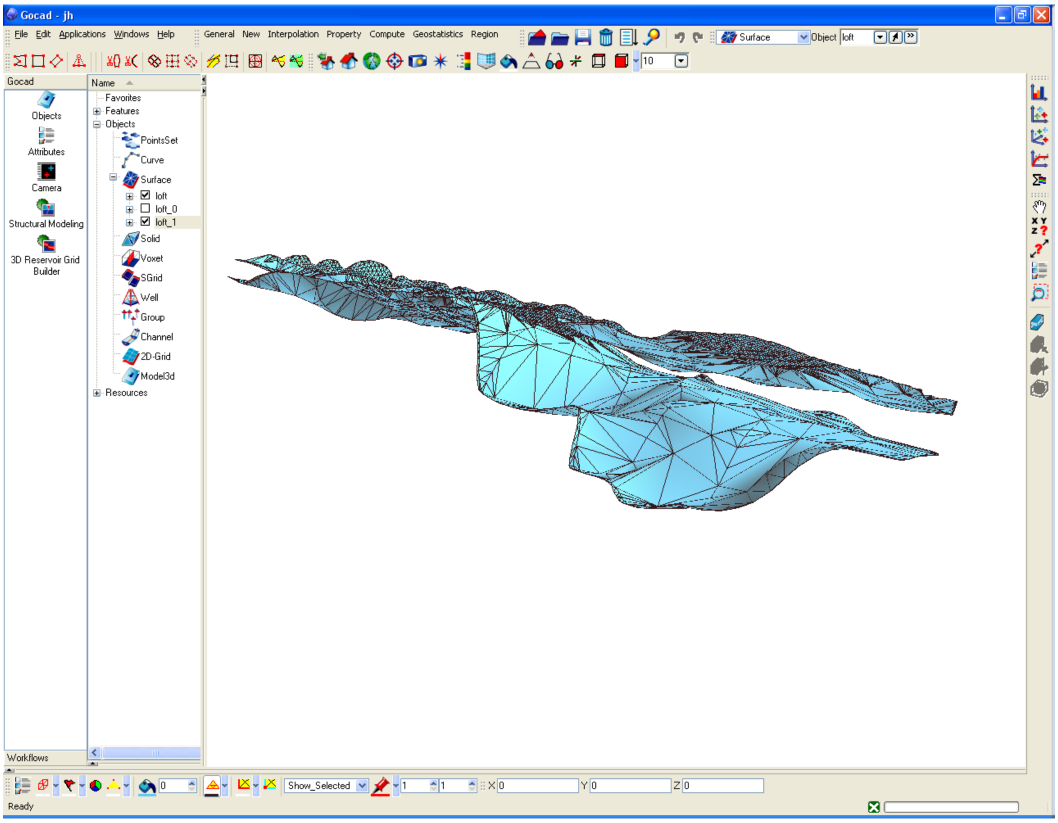
The following two options enable interchange of surfaces with the GoCad modelling package

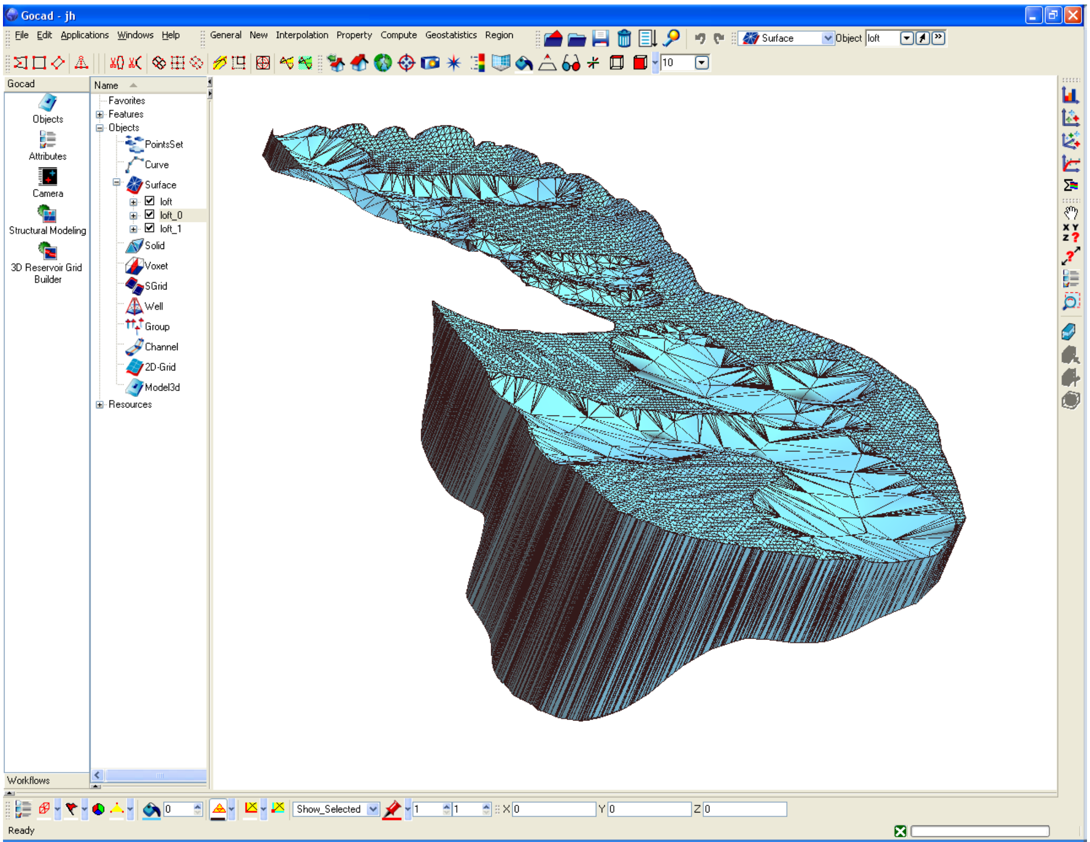
Export to GOCAD

This function will export the geological unit into proprietary GoCad format. The created TINs will be an exact copy of the GSI3D TIN .



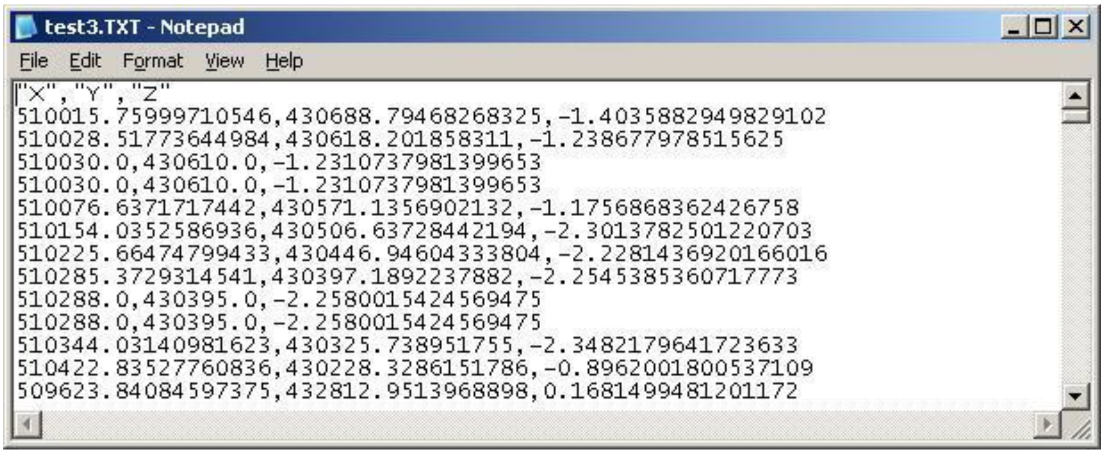
The default option is to export the base, to and shell of the geological unit. The image below shows a GSI3D modelled unit in Gocad (top and base as well as the entire watertight shell)


Gocad - jh
File Edit Applications Windows Help
General New Interpolation Property Compute Geostatistics Region
Surface
Object loft
Gocad
Objects
Attributes
Camera
Structural Modeling
3D Reservoir Grid Builder
Name
Favorites
Features
Objects
PointsSet
Curve
Surface
loft
loft_0
loft_1
Solid
Voxet
SGrid
Well
Group
Channel
2D-Grid
Model3d
Resources
Workflows
Show_Selected
Ready


Gocad - jh
File Edit Applications Windows Help
General New Interpolation Property Compute Geostatistics Region
Surface
Object loft
Gocad
Objects
Attributes
Camera
Structural Modeling
3D Reservoir Grid Builder
Name
Favorites
Features
Objects
PointsSet
Curve
Surface
loft
loft_0
loft_1
Solid
Voxet
SGrid
Well
Group
Channel
2D-Grid
Model3d
Resources
Workflows
Show_Selected
Ready

Export Correlation points

This function exports all the correlation points (excludes envelope derived x,y,z) from the sections as comma-separated x,y,z values in ascii format (see below) to a named file *.txt

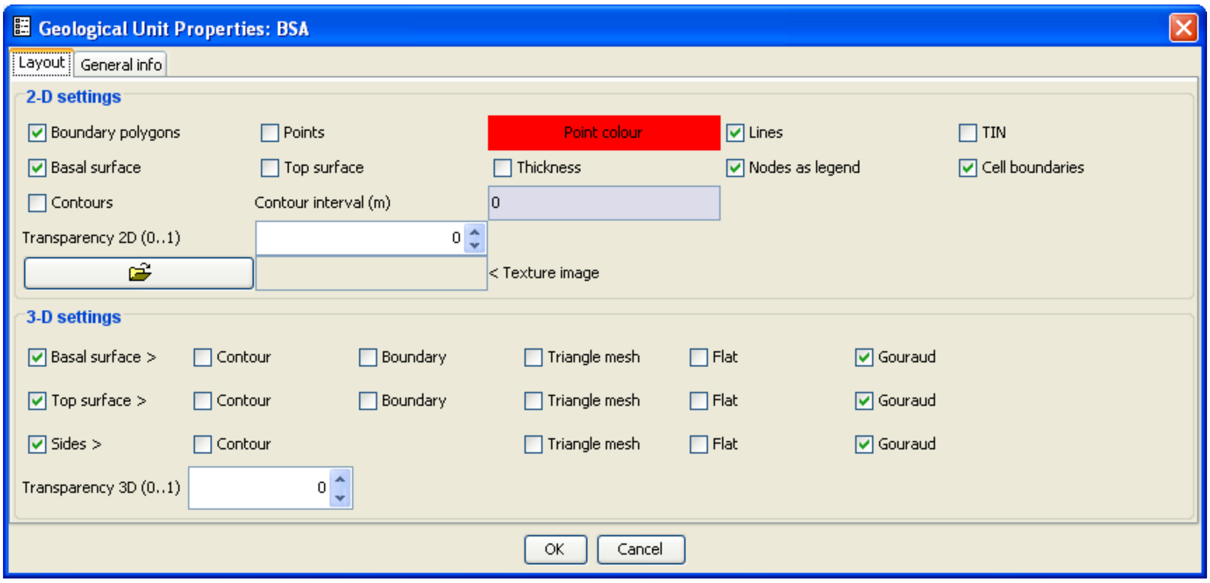


This function exports all points (envelopes and correlation nodes) as comma-separated x,y,z values in ascii format to a named file *.dat

Export all points exports all base points of the geological units (includes correlation and envelope) into the same format as above.

Send to 3D sends an individual geological unit to the 3D viewer

Properties as shown below



Layout tab

The display settings of the TIN can be specified for the map, section and 3D windows

In the **2D Settings** the TIN can be displayed as an Envelope (coverage) as the TIN , as points or as the areal extent. Transparency can be set and a texture image can be loaded

In the **3D Settings** are options for Gouraud, triangle mesh, flat and contour plus a dialog box to specify Transparency on the tops, bases and walls of the geological unit.

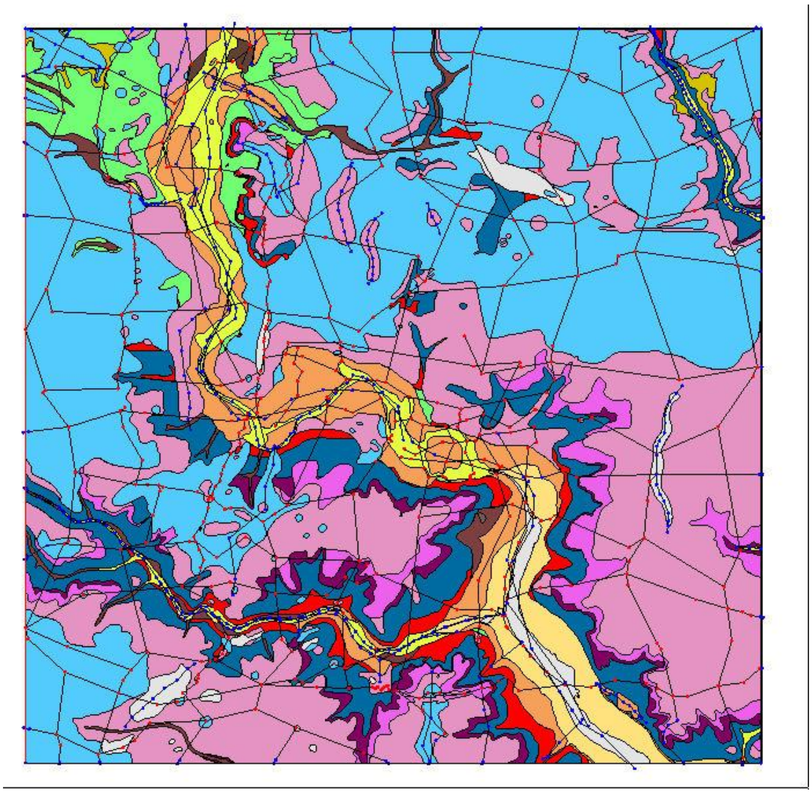
Send to front	self-explanatory
Send to back	self-explanatory
Switch on edit	makes the object editable
Delete object	self-explanatory
Isolate object	self-explanatory
Isolate within group	self-explanatory

Exclude/Include when calculating when calculating can be used to exclude a unit (for example made ground or all Quaternary deposits) from the calculation

General Info tab gives a very basic summary of the number of lines for the geological unit in the map, and the number of nodes digitised in section for the unit.

4.5.2 Constructing and working with Envelopes

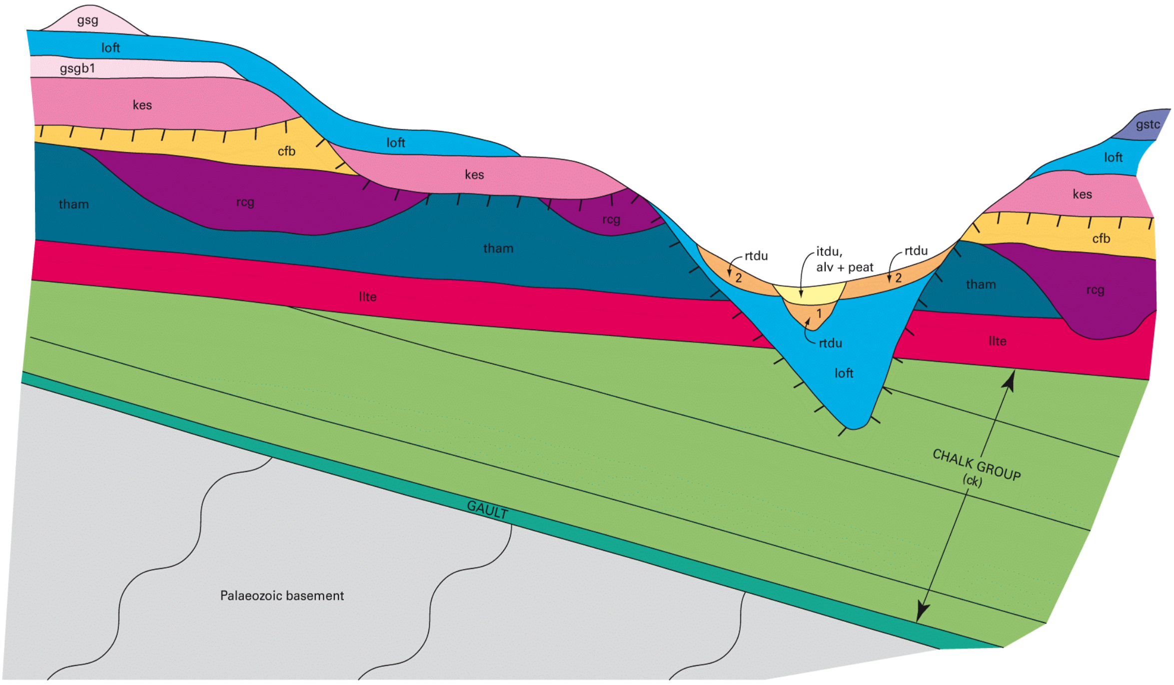
There is often no unique or correct way to construct an envelope but some general guidance is provided here using data from the TM14 mapsheet around Ipswich in southeast England..



Geological map of TM14 Ipswich showing surface geology (10 x 10 km)

Stratigraphy of TM14 – 24 (Ipswich area)

Colour	Name	Label
	Peat	peat
	Alluvium	alv
	Intertidal Deposits	itdu
	River Terrace Deposits	rtdu
	Glacial Silt and Clay	gstc
	Glacial Sand and Gravel	gsg
	Lowestoft Till	loft
	Glacial Sand and Gravel	gsg**bl**
	Kesgrave Sand and Gravel	kes
	Chillesford Sand	cfb
	Red Crag	rcg
	Thames Group (London Clay)	tham
	Lambeth Group and Thanet Sand	llte
	Chalk	ck



Data loaded, *.gvs, *.gleg, dtm (*.asc) geological map shapefiles (*.shp) for surface and top bedrock.

Screen grabs are of the map window or parts thereof.

NOTE: In these examples some of the units are superficial others are unfaulted bedrock

Here examples are given for drawing 6 envelopes from TM14 the alluvium, river terrace deposits envelopes can be largely drawn from the surface geological linework, the Kesgrave sands and gravels requires a combination of surface outcrop information and data from sections and boreholes on its concealed limits, the Red Crag envelope is drawn simply from the bedrock geological linework which was produced from the sections and the Lower London Tertiaries envelope involves combining a stack of bedrock units. The Glacial Channel deposits envelope is drawn entirely from the correlations along the sections as it is completely buried and only recorded in deep boreholes. Together these examples illustrate the use of the various envelope drawing tool functions and the types of envelope likely to be encountered in superficial and simple bedrock geology.

NOTE: Where envelopes continue to the margins of project areas they must be drawn to extend beyond the limits of the area to be calculated as defined by the interactive TIN coverage.

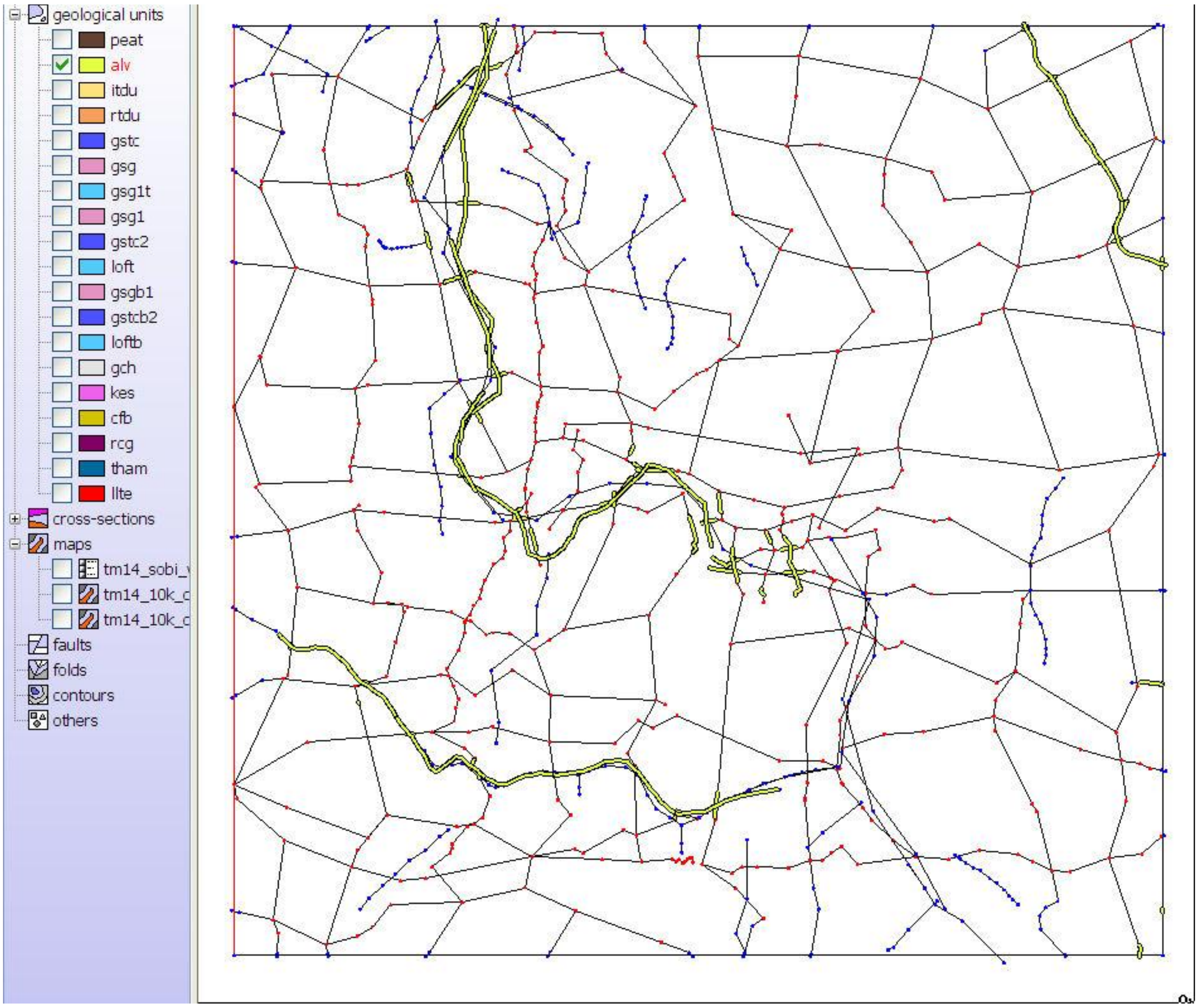
Procedure

First select **Tools** > **Create geological unit(s)** and select the six units required identified by their correct codes, this places entries into the ToC of the map window for each. Expand geological units folder to confirm their presence

1. Alluvium Envelope

Being the youngest deposit the alluvium envelope is simply constructed by

1. Right click on the alluvium entry and **switch on edit**, the unit name changes to red and the4 extent of the unit in sections is displayed as a colour coded band along the sections



2. **Either** using the **Info** tool to select each polygon of alluvium from the surface geology shape file and individually insert them into the envelope using the **insert selected polygon** tool. When complete switch the geology map off and on to check all strips of alluvium have been added into the layer **Or** right click on the surface geology map and select show **Open shape table,** resize the table as needed to view the first few columns clearly, click on the attribute column displayed by the map (right click map and check under properties if unsure) and the rows order alphabetically, then highlight all the rows with the appropriate alluvium code and minimise the table, return to right click on the surface geology map and select **copy shapes** then right click on the editable alluvium unit **(**destination) **>Extra Functions>Create, edit, merge and paste tools** and select **paste shapes** to insert the polygons into the Alluvium unit.

NOTE: if the selected polygon is a multipart shape file in Arc all the other parts of this unit will be copied as well. If this is not desirable, the multipart needs to be dissolved in Arc. The individual parts can be viewed in the below shp table.

tm14_10k_comb_superficial_geology_polygons shape data

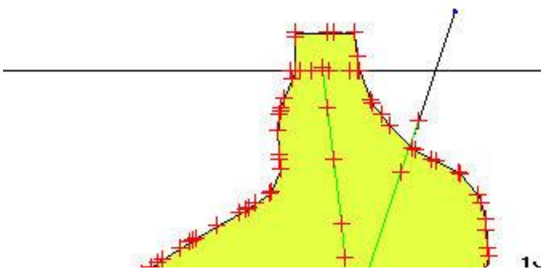
LEX_ROCK	LEX	LEX_D	R...	...	R...	R...	R...	B...	
ALV-SICL	ALV	ALLUVIUM	SICL	SI...	SICL	CL...	NO...		
ALV-SICL	ALV	ALLUVIUM	SICL	SI...	SICL	CL...	NO...		
ALV-SICL	ALV	ALLUVIUM	SICL	SI...	SICL	CL...	NO...		
ALV-SICL	ALV	ALLUVIUM	SICL	SI...	SICL	CL...	NO...		
ALV-SICL	ALV	ALLUVIUM	SICL	SI...	SICL	CL...	NO...		
CFB-SAND	CFB	CHILLESF...	SA...	SA...	SA...	SA...	ME...	Not...	N
CFB-SAND	CFB	CHILLESF...	SA...	SA...	SA...	SA...	ME...	Not...	N
CFB-SAND	CFB	CHILLESF...	SA...	SA...	SA...	SA...	ME...	Not...	N
CFB-SAND	CFB	CHILLESF...	SA...	SA...	SA...	SA...	ME...	Not...	N
CFB-SAND	CFB	CHILLESF...	SA...	SA...	SA...	SA...	ME...	Not...	N
CFB-SAND	CFB	CHILLESF...	SA...	SA...	SA...	SA...	ME...	Not...	N
CUCK-CHLK	CUCK	CULVER C...	CHLK	CH...	CHLK	CH...	FO...	Not...	N
CUCK-CHLK	CUCK	CULVER C...	CHLK	CH...	CHLK	CH...	FO...	Not...	N
CUCK-CHLK	CUCK	CULVER C...	CHLK	CH...	CHLK	CH...	FO...	Not...	N
CUCK-CHLK	CUCK	CULVER C...	CHLK	CH...	CHLK	CH...	FO...	Not...	N
CUCK-CHLK	CUCK	CULVER C...	CHLK	CH...	CHLK	CH...	FO...	Not...	N
CUCK-CHLK	CUCK	CULVER C...	CHLK	CH...	CHLK	CH...	FO...	Not...	N
CUCK-CHLK	CUCK	CULVER C...	CHLK	CH...	CHLK	CH...	FO...	Not...	N

3. Return to the attribute table and select all entries in the table (Ctrl + A) to return to the surface geology map display , switch off the surface geology map to inspect the alluvium polygons.

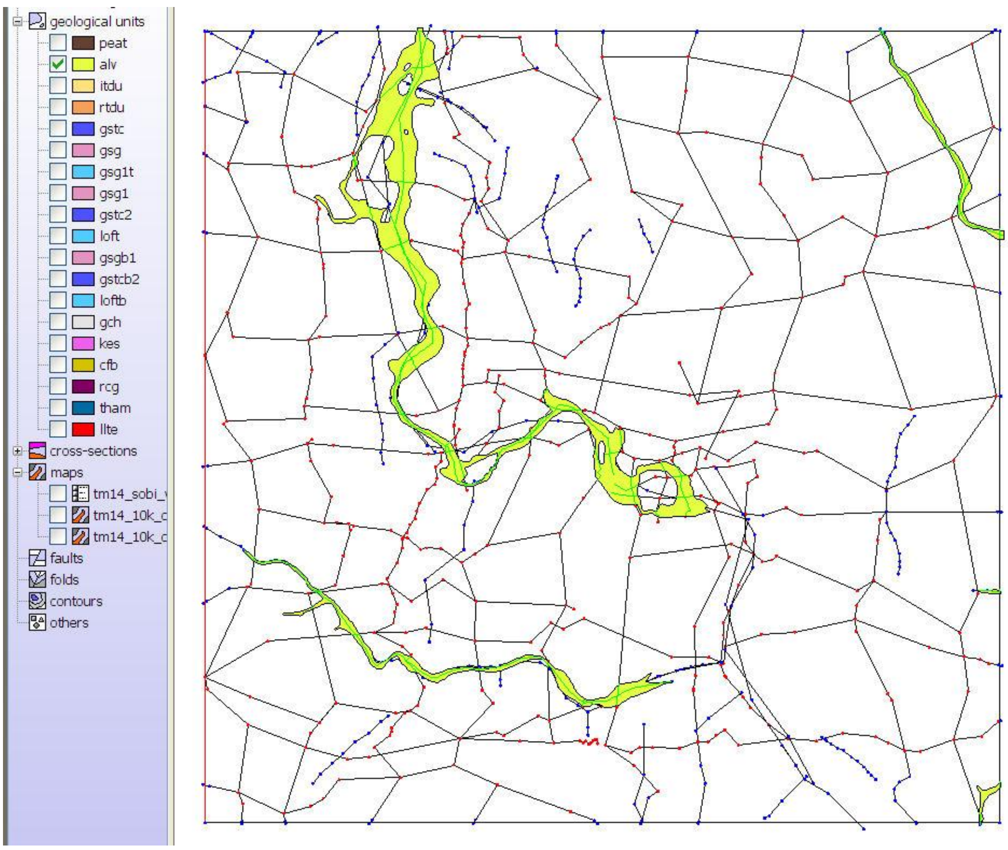
4. **Switch off** edit and right click on the unit>**Extra Functions**>**Calculate**>**Calculate unit as non-faulted unit,** the display should refresh with the extent of the unit along sections now showing in green. Right click on the unit again>**Properties** and in the dialog box tick on and select a colour for **points** within the **2D settings**. Update, the nodes for the base of the unit available for calculation are now displayed.

5. Ensure that the bases of the unit in sections correspond precisely with the selected polygons.

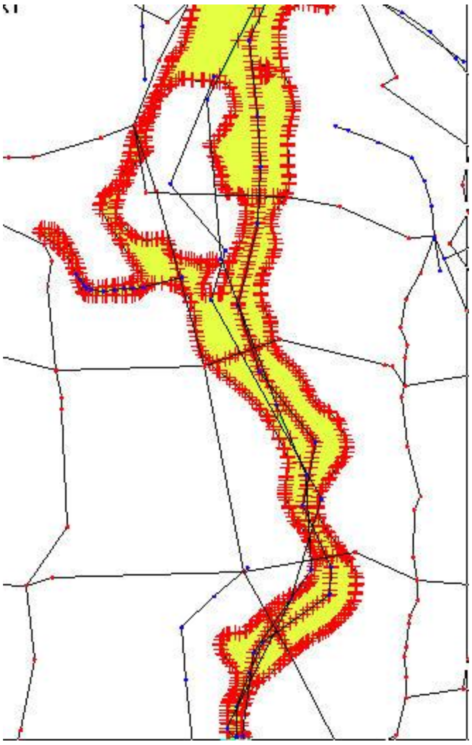
6. Stretch the envelope (polygons) at mapsheet margins to just beyond boundaries, **Switch off edit**



7. Save the workspace



Completed Alluvium envelope of TM14



Detail of the Alluvium envelope showing lines of continuous correlation (green line) along sections and nodes(green crosses) along sections and boundaries.

2. River Terrace Deposits Envelope

These occur flanking the alluvium, peat and intertidal deposits and almost everywhere beneath them. We will assume that laterally they pinch out to coincide with the edge of these overlying deposits where no fringing river terrace exists. The low terrace fringing the alluvial tract and the deposits beneath the alluvial tract (lowest terrace) are not subdivided in this illustration.

Procedure

1. Right click on the river terrace deposits entry and **switch on edit**, the unit name changes to red and the extent of the unit in sections is displayed as a colour coded band along the sections

2. **Either** using the **Info** tool to select each polygon of river terrace, alluvium, peat and intertidal deposits from the surface geology shape file and individually insert them into the envelope using the **insert selected polygon** tool. When complete switch the geology map off and on to check all strips of river terrace have been added into the layer **Or** right click on the surface geology map and select show **Open shape table,** resize the table as needed to view the first few columns clearly, click on the attribute column displayed by the map (right click map and check under properties if unsure) and the rows order alphabetically, then highlight all the rows with the appropriate, alluvium, peat, intertidal deposits and river terrace code and minimise the table, return to right click on the surface geology map and select **copy shapes** then right click on the editable river terrace unit **(**destination) **>Extra Functions>Create, edit, merge and paste tools** and select **paste shapes** to insert the polygons into the river terrace unit.

3. Return to the attribute table and select all entries in the table (Ctrl + A) to return to the surface geology map display , switch off the surface geology map to inspect the river terrace polygons.

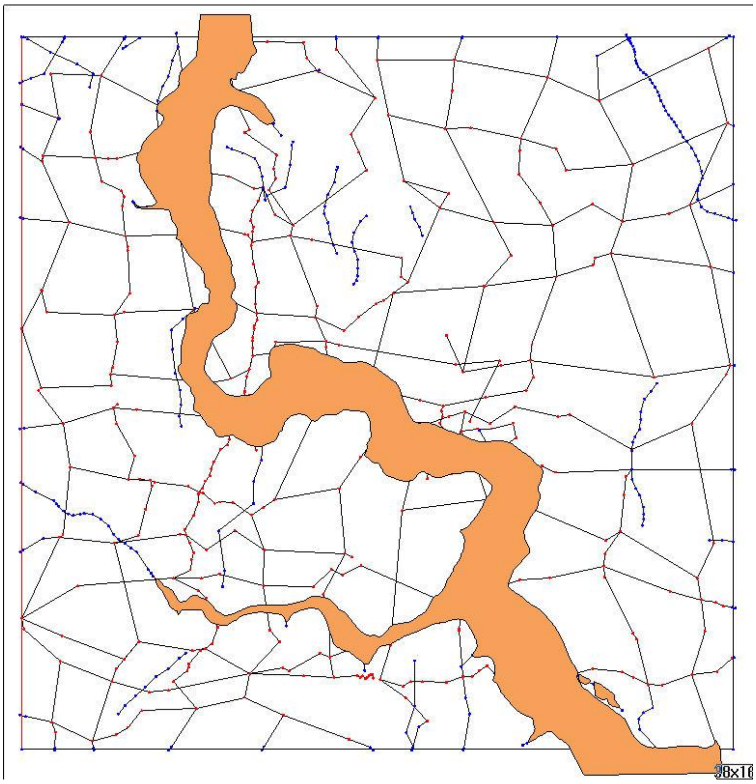
4. Click on the **Fill islands/holes** icon and allow time to refresh, the polygons where in contact or should fuse to make an envelope corresponding to all the alluvial deposits along the valleys.

5. **Switch off** edit and right click on the unit>**Extra Functions**>**Calculate**>**Calculate unit as non-faulted unit,** the display should refresh with the extent of the unit along sections now showing in green. Right click on the unit again>**Properties** and in the dialog box tick on and select a colour for **points** within the **2D settings**. Update, the nodes for the base of the unit available for calculation are now displayed.

6. Within the area of the selected envelopes there should be no breaks in the green correlation line along any of the sections. If there are, then at these points river terrace deposits are thought to be absent and if such cases are found then **Switch on edit** and use the polygon drawing tool to draw the absent areas, these are then cuts it out from the envelope leaving a hole within the polygon
   Note the river terrace deposits are assumed to be present throughout unless otherwise proven.

7. Stretch the envelope (polygons) at mapsheet margins to just beyond boundaries, **Switch off edit**

8. Save the workspace



Completed River Terrace Deposits envelope

3. Kesgrave Sands and Gravels Envelope

The drawing of the Kesgrave Sands and Gravels envelope is more complicated and there are several ways to approach it. The approach described below starts by selecting just the surface outcrop polygons and extends them outwards and merges them as needed to produce the envelope.

1. Right click on the Kesgrave Sands and Gravels entry and **switch on edit**, the unit name changes to red and the extent of the unit in sections is displayed as a colour coded band along the sections

2. **Either** using the **Info** tool to select each polygon of Kesgrave Sands and Gravels from the surface geology shape file and individually insert them into the envelope using the **insert selected polygon** tool. When complete switch the geology map off and on to check all crops of Kesgrave Sands and Gravels have been added into the layer **Or** right click on the surface geology map and select show **Open shape table**, resize the table as needed to view the first few columns clearly, click on the attribute column displayed by the map (right click map and check under properties if unsure) and the rows order alphabetically, then highlight all the rows with the appropriate Kesgrave Sands and Gravels code and minimise the table, return to right click on the surface geology map and select **copy shapes** then right click on the editable Kesgrave Sands and Gravels unit (destination) >**Extra Functions>Create, edit,**

merge and paste tools and select **paste shapes** to insert the polygons into the Kesgrave Sands and Gravels unit.

3. Return to the attribute table and select all entries in the table (Ctrl + A) to return to the surface geology map display , switch off the surface geology map to inspect the Kesgrave Sands and Gravels polygons.

4. Start to extend the surface outcrop polygons by chopping off using the **split polygon** function large chunks encompassed by the top of the unit i.e. areas where younger strata generally overlie the Kesgrave Sands and Gravels. Extend the simplified polygon produced by using the **polygon cutting** tool (which can be used to cut away areas of absence as well as presence) to conform to the extent of the unit at depth as shown as a colour band along the sections.

5. Where two of these expanding polygons meet drag one over the other to create an obvious overlap and then use the **combine polygons** tool to unify them.

6. Compare the emerging pattern with the geological map, and identify any areas where totally buried subcrops are present, insert these into the layer using the **draw polygon** tool to encompass colour band areas along the sections and query any nearby boreholes not on sections to help refine the shape.

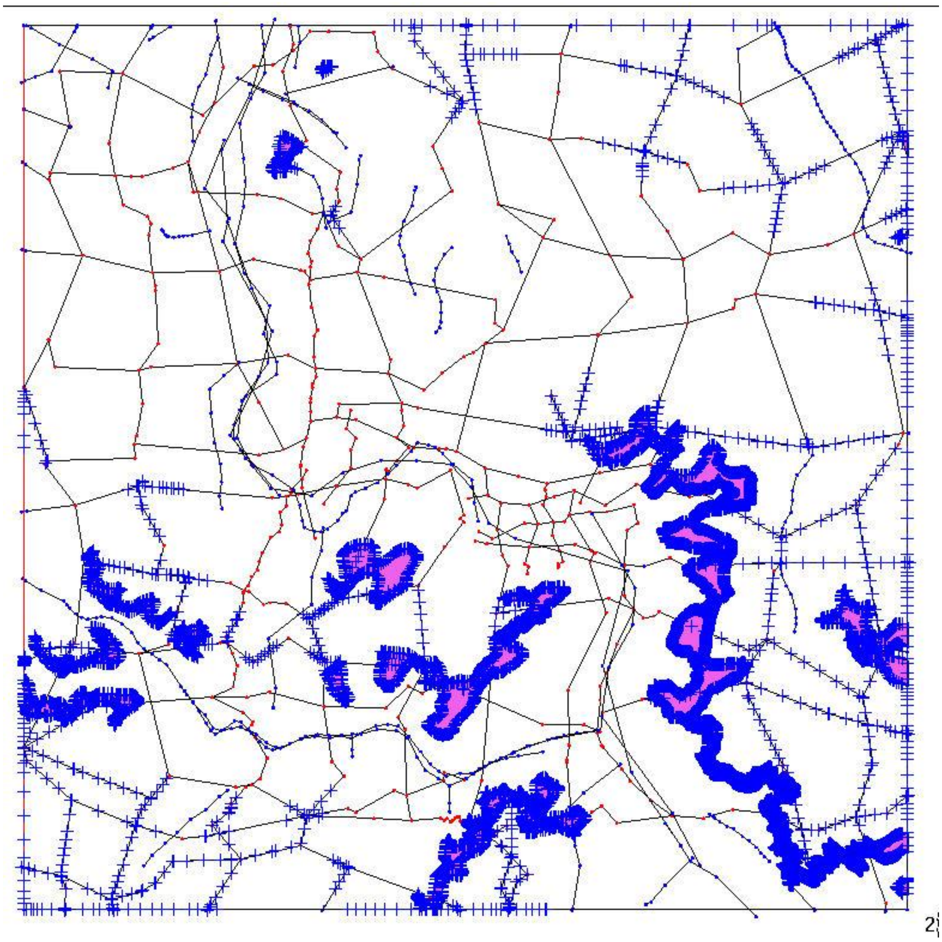
7. Identify any holes within the main polygons where the Kesgrave Sands and Gravels are cut through by younger deposits, this is done by examining the continuity of the correlation colour band along the sections where identified also examine any nearby boreholes not incorporated in sections to help refine the shape. Again use the **draw polygon** tool to cut away the deposit

8. **Switch off edit** and right click on the **unit>Extra Functions>Calculate>Calculate unit as non-faulted unit**, the display should refresh with the extent of the unit along sections now showing in green. Right click on the unit again>**Properties** and in the dialog box tick on and select a colour for **points** within the **2D settings**. Update, the nodes for the base of the unit available for calculation are now displayed.

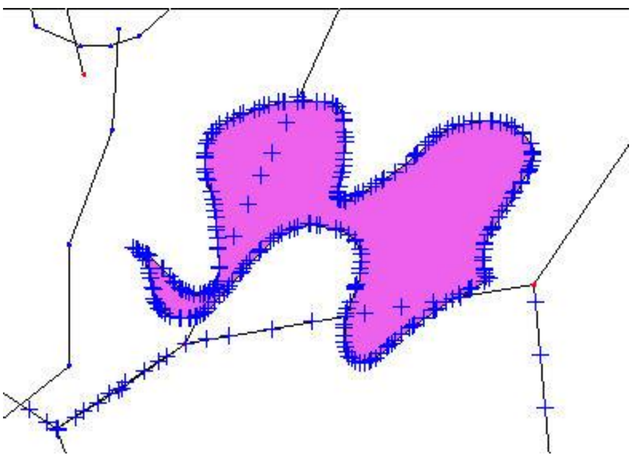
9. Ensure that the bases of the unit in sections correspond precisely with the selected and constructed polygons. To make changes **Switch on edit**

10. Stretch the envelope (polygons) at mapsheet margins to just beyond boundaries

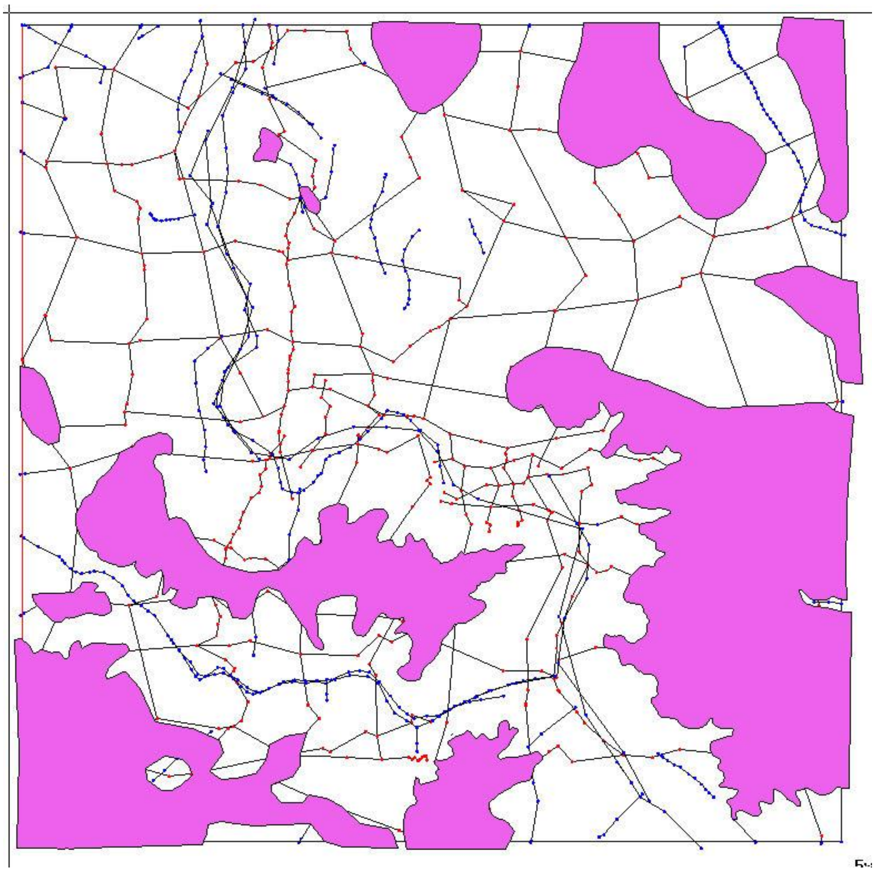
11. Save the workspace



Outcrop of the Kesgrave Sands and Gravels and nodes shown as crosses along sections showing extent of subcrops



Detail of above



Completed envelope for the Kesgrave Sands and Gravels

4. Red Crag Envelope

The Red Crag is a bedrock unit, its envelope is best constructed using the bedrock geology map polygons rather than the surface geology version. It is overlain in parts of the area by the Chillesford Sand the uppermost bedrock unit shown in mustard colour on the bedrock geology map.

1. Right click on the Red Crag entry and **switch on edit**, the unit name changes to red and the extent of the unit in sections is displayed as a colour coded band along the sections
2. **Either** using the **Info** tool to select each polygon of Red Crag and Chillesford Sand from the bedrock geology shape file and individually insert them into the envelope using the **insert selected polygon** tool. When complete switch the geology map off and on to check all the crops of Red Crag have been added into the layer **Or** right click on the bedrock geology map and select show **Open shape table**, resize the table as needed to view the first few columns clearly, click on the attribute column displayed by the map (right click map and check under properties if unsure) and the rows order alphabetically, then highlight all the rows with the appropriate Red Crag code and minimise the table, return to right click on the surface geology map and select **copy shapes** then right click on the editable Red Crag unit (destination) >**Extra Functions>Create, edit, merge and paste tools** and select **paste shapes** to insert the polygons into the Red crag unit.

3. Return to the attribute table and select all entries in the table (Ctrl + A) to return to the surface geology map display , switch off the surface geology map to inspect the Red Crag polygons.

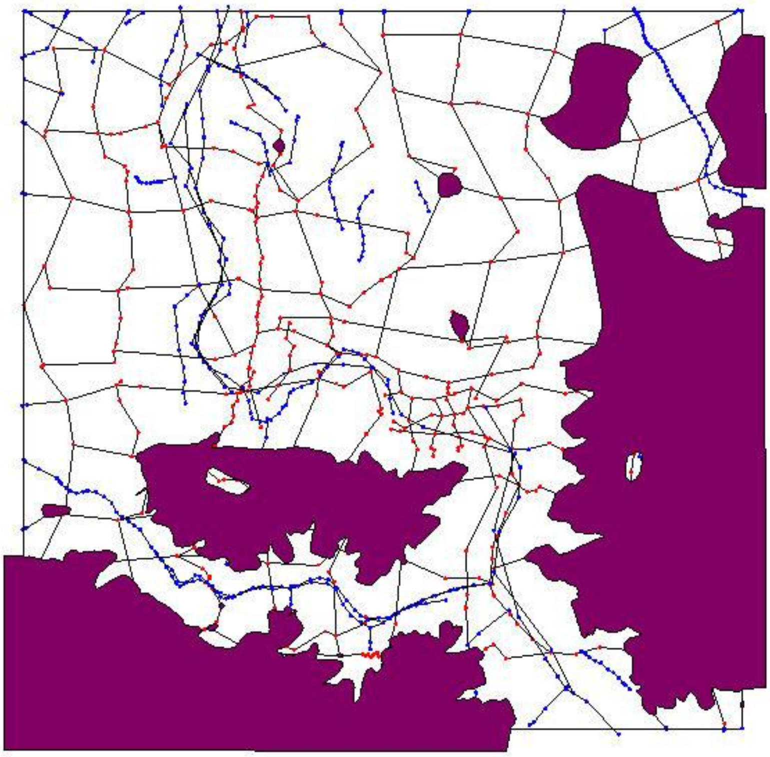
4. Hit the **fill island/holes** button to merge the crops of the Red Crag and Chillesford Sand where they are in contact.

5. **Switch off edit** and right click on the **unit>Extra Functions>Calculate>Calculate unit as non-faulted unit**, the display should refresh with the extent of the unit along sections now showing in green. Right click on the unit again>**Properties** and in the dialog box tick on and select a colour for **points** within the **2D settings**. Update, the nodes for the base of the unit available for calculation are now displayed**. Switch on edit**

6. Update the map window and use the crosses and green correlation lines on the sections and boreholes if any to decide whether the Red Crag extends beneath all the Chillesford Sand crops. Revise polygons as necessary.

7. Stretch envelopes at mapsheet margins to just beyond boundaries

8. **Switch off edit** and save workspace



Red Crag envelope

5. Lower London Tertiaries Envelope

The Lower London Tertiaries bedrock envelope (Lambeth Group and Thanet Sand Formation undifferentiated) is again relatively straightforward , where it is present it always rests on the Chalk and is not cut through in this area by any younger bedrock units.

1. Right click on the Lower London Tertiaries entry and **switch on edit**, the unit name changes to red and the extent of the unit in sections is displayed as a colour coded band along the sections

2. **Either** using the **Info** tool to select each polygon of Lower London Tertiaries and the overlying London Clay, Red Crag and Chillesford Sand from the bedrock geology shape file and individually insert them into the envelope using the **insert selected polygon** tool. When complete switch the geology map off and on to check all the crops of have been added into the layer **Or** right click on the bedrock geology map and select show **Open shape table**, resize the table as needed to view the first few columns clearly, click on the attribute column displayed by the map (right click map and check under properties if unsure) and the rows order alphabetically, then highlight all the rows with the appropriate Lower London Tertiaries and the overlying London Clay, Red Crag and Chillesford Sand codes and minimise the table, return to right click on the surface geology map and select **copy shapes** then right click on the editable Lower London Tertiaries unit (destination) >**Extra Functions>Create, edit, merge and paste tools** and select **paste shapes** to insert the polygons into the Lower London Tertiaries unit.

3. Return to the attribute table and select all entries in the table (Ctrl + A) to return to the surface geology map display , switch off the surface geology map to inspect the Lower London Tertiaries polygons.

4. Hit the **fill island/holes** button to merge the crops of the Lower London Tertiaries , London Clay Red Crag and Chillesford Sand where they are in contact.

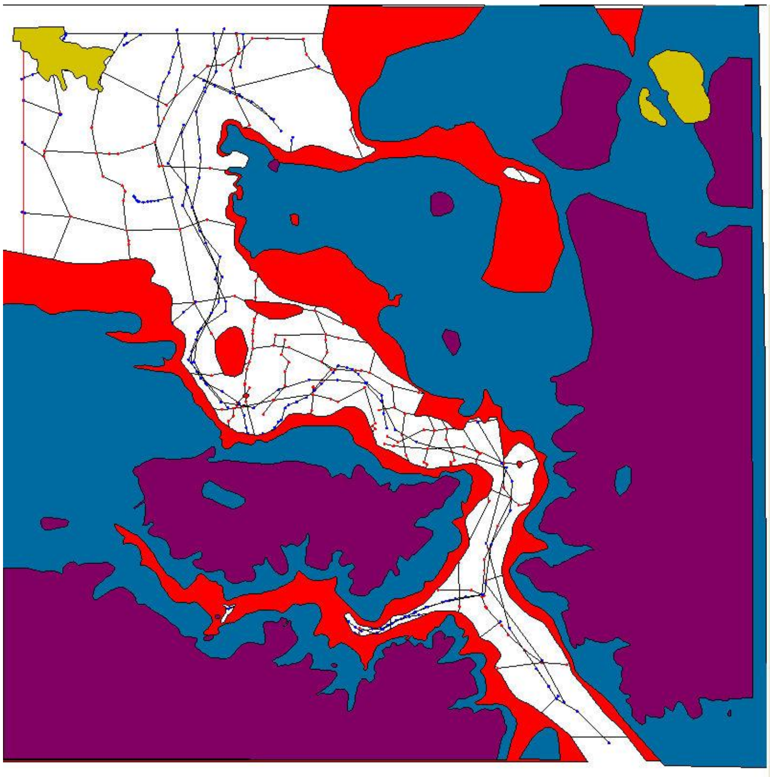
5. **Switch off edit** and right click on the **unit>Extra Functions>Calculate>Calculate unit as non-faulted unit**, the display should refresh with the extent of the unit along sections now showing in green. Right click on the unit again>**Properties** and in the dialog box tick on and select a colour for **points** within the **2D settings**. Update, the nodes for the base of the unit available for calculation are now displayed. **Switch on Edit**

6. Use the crosses and green correlation lines on the sections and boreholes, if any, to decide whether the Lower London Tertiaries extends beneath all the London Clay, Red Crag and Chillesford Sand crops. Revise polygons as necessary.

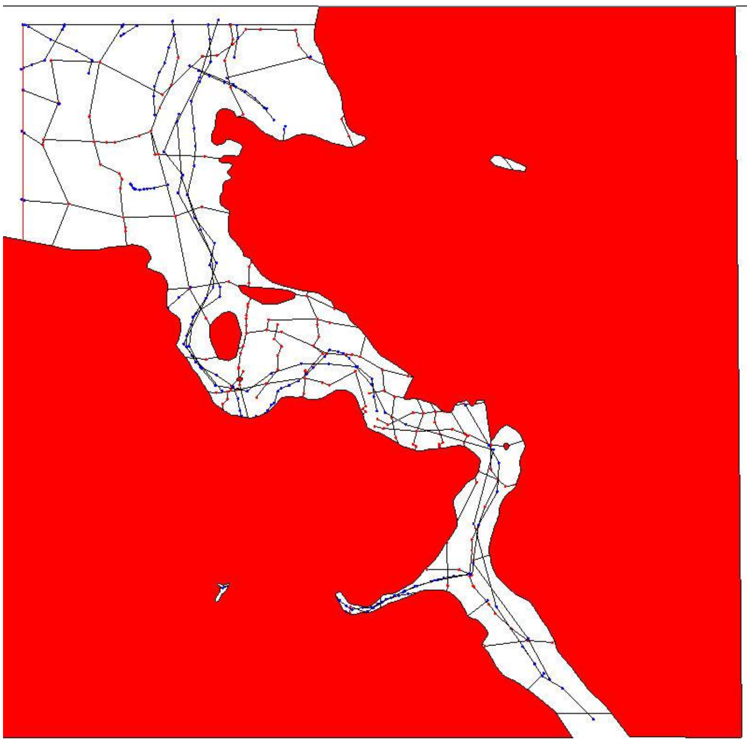
7. Identify any windows where quarries or superficial deposits have cut through the Lower London Tertiaries into Chalk by examining the bedrock map closely and also spotting breaks in the green line continuity of the deposits along sections crossing the major polygons, there are 5 in all. If polygons are mapped **select polygons** to produce holes, otherwise use the **draw polygon** tool to produce the holes.

8. Stretch envelopes at mapsheet margins to just beyond boundaries

9. **Switch off edit** and save workspace



Bedrock geology of TM14 mustard colour Chillesford Sands, purple Red Crag, blue London Clay red Lower London Tertiaries and white Chalk. Produced by stacking envelopes in their correct stratigraphic order.



Lower London Tertiaries envelope

6. Glacial Channel deposits Envelope

Glacial Channel deposits up to 50m thick occur infilling deeply incised tunnel-valleys in the Ipswich area. Some but not all of these features lie below the floors of the major present day valleys such as the Gipping-Orwell system.

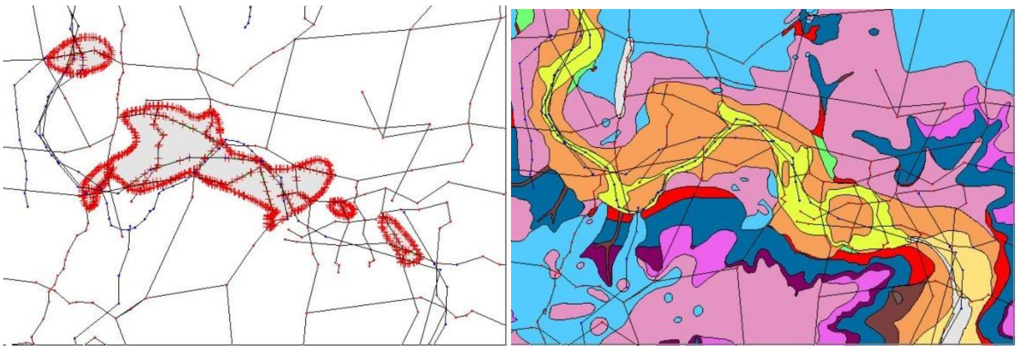
The deposits are known only from boreholes and they do not crop out at surface, construction of an envelope for these deposits is thus achieved by displaying the correlation nodes along the sections in the map window. In this case it was useful to draw additional short helper sections in varied orientations to include all boreholes encountering the deposits in order to define tightly the extent of these buried deposits. The surface geology of central Ipswich is shown below left The extent of the deposits is indicated below right as a continuous purple line along the lines of section with each node shown as a cross. Even with closely spaced sections several possible ways of joining up the segments of purple lines-crosses. In this case the alignment of the present valley and the expected direction of ice-flow were taken into account in drawing the form of the final envelope.

1. Right click on the glacial channel deposits entry and **switch on edit**, the unit name changes to red and the extent of the unit in sections is displayed as a colour coded band along the sections.

2. Using the **draw polygon** tool construct polygons to envelope the extent of the deposits proved in the sections (all available boreholes were used to produce the sections)

3. Stretch the envelope (polygons) at mapsheet margins to just beyond boundaries if needed, **Switch off edit**

4. Save the workspace



Some 19 units are represented in the stacked model for TM14 of which six have been presented here as examples of varied styles of envelope construction. The main types are:

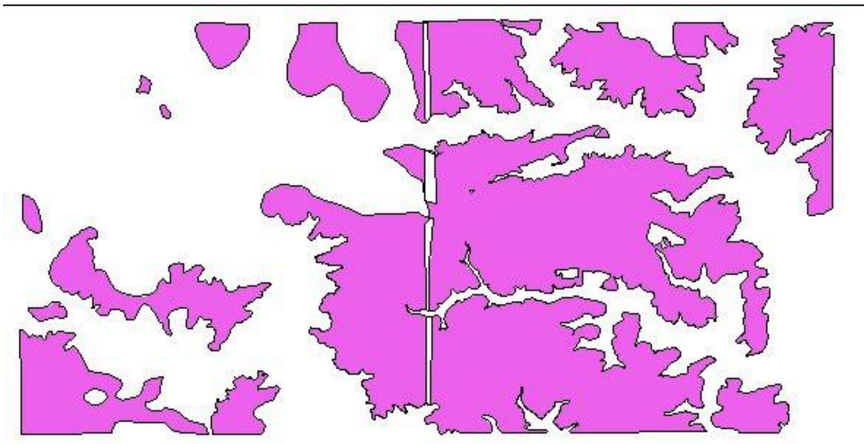
- Totally exposed units i.e. outcrop = envelope   (young unit not overlain) e.g. the Alluvium example above.

- Units with outcrop and subcrop exemplified by the Kesgrave Sand and Gravel envelope i.e. envelope = outcrop + subcrop

- Concealed units such as the Glacial Channel deposits i.e. envelope = subcrop

Merging envelopes

By loading two adjacent projects into the same project (and saving as a new*.gsipr project file) the overlapping envelopes which are stretched just beyond tile limits in construction they can then be merged into continuous envelopes using the envelope editing tools.



Merging two geological units into a single entity

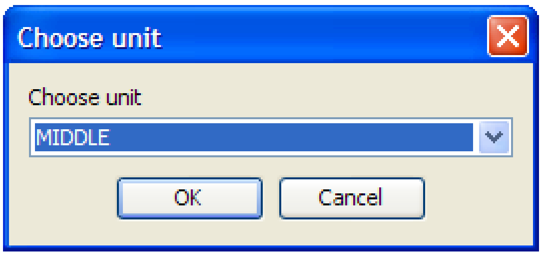
It is possible to merge one geological unit into another. This might be useful if bringing two sets of work together where the same unit has been attributed differently by two workers, or where, during the course of modelling, a decision is made to merge two units into one for geological reasons or for reasons of generalization. For example, if two river terraces have been modelled and on further inspection are found to be parts of the same unit.

NOTE: it is always advisable to backup or save the project immediately before a merge operation as a backup to avoid unnecessary un-picking if the result is not what was desired.

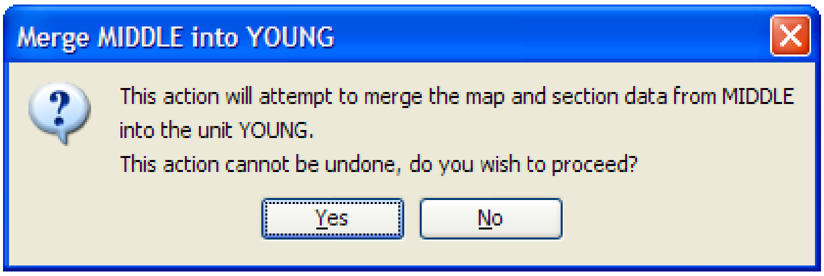
The merge function has two phases, the second of which is optional.

1. Take a copy of the map linework into the 'master' unit
2. Optionally synchronize all section correlation lines with the change by re-attributing lines

First choose which of the two geological units will be the ‘master’ unit. This is the unit which has the attribution and name that you wish to keep. To merge the two units, R-click on the unit selected as the host or 'master' unit and select **Extra functions > Create, edit, merge and paste tools > Merge (dissolve) one unit into this unit.** You will be presented with a list of all the other geological units in the project workspace.



From the list, select the unit to merge into the 'master' unit, and click OK. Then when prompted confirm the merge because some aspects of the merge are potentially profound and cannot be undone simply.



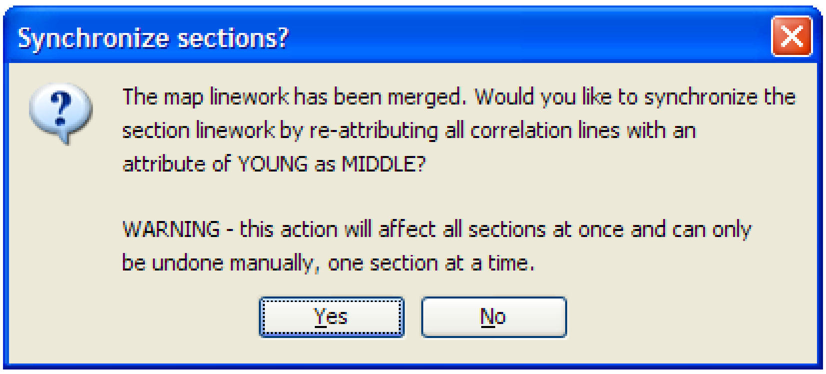
Phase I - Copy map linework

The first phase will take a copy of any map linework found (i.e. envelopes) and paste into the master unit. Note that this copy of the linework is now fully independent of the other unit's linework and following the merge it is possible to delete the other unit from the project (GSI3D will not do this automatically, it will leave the other unit in the workspace complete with its original map linework). Also note that GSI3D will not check for duplicate lines, so if present it is necessary to remove them manually in the usual way. When linework has been pasted in, the following confirmation occurs.

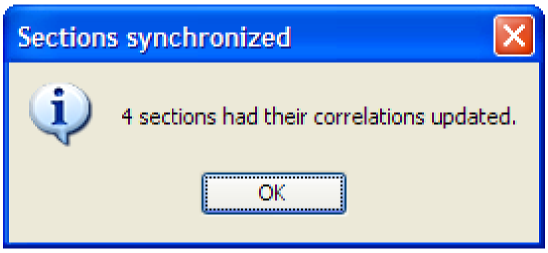
Phase II - Synchronize all sections

The second phase is optional. It allows synchronization all of the sections in the project with the change to the master geological unit. This action will rename all correlation lines attributed as the 'mergee' unit to match the attribution of the master unit. GSI3D will again produce a confirmation dialog (below). Note that this operation ***is*** undoable, but ***only*** on a section-by-section basis, so think carefully before undertaking this operation as the undo process will be extremely laborious when the project contains many sections.

Note: It is always best to take a backup of the project before attempting such operations in case the end result is not desirable.



Choosing to synchronize the sections will carry out this task and then report how many sections were affected by the renaming.



Once the merge is complete hit F5 to refresh the section and the map to see the effects of the changes. At this stage carry out some checks to confirm that you achieved the expected result have been achieved before proceeding with modelling.

4.6 Boreholes

Much of the work involved with boreholes takes place outside the GSI3D software and involves the assembling of borehole index (*.bid) and downhole (*blg) tab-separated files using a text editor. Data held in other tables or spreadsheets can be readily imported and edited into the required formats shown in Section 2.4. Consistency of coding and the establishment of codes for lithology, stratigraphy etc. is all an integral part of building a GSI3D model.

Within the project the borehole locations are displayed in the map window and these can be colour coded into those that have downhole logs and those that don't, also a depth interval can be specified to discriminate between shallow and deeper boreholes.

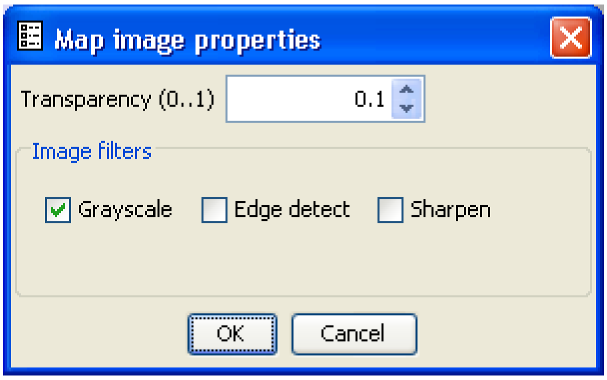
The boreholes when selected in the Map window are displayed in the borehole log window with labels for the coding and depths. Up to 4 separate parameters can be displayed for a single log drawing on the columns in the *.gvs file. Both colours and textures can be displayed. The boreholes can be incorporated into sections with the same display options as in the borehole log window and also sent to the 3D window for visualisation alongside other datasets. Whilst borehole information is very desirable in modelling it is not a prerequisite and many satisfactory models have been constructed without any boreholes.

Once a model has been calculated synthetic boreholes can be 'drilled' through the model by identifying the location in the map window, and selecting the synthetic borehole icon from the map window toolbar (Section 3.3.1) the results are displayed in the borehole log window.

4.7 Maps

Maps imported as raster images (commonly as *.jpg, *.png and *.gif) are held in the maps folder in the ToC of the map window. They can also be sent to the 3D window as flat objects or draped onto surfaces such as a dtm. The maps require correct georegistration into a metric grid format contained in an accompanying worldfile e.g. *.jpgw file. Maps used commonly include topographic maps for locational control, geological maps to be used as a guide for section construction (e.g. thickness, contours, extent plots). Also classified as map objects are plan view images such as colour-ramped dtms , aerial photographs, satellite imagery, horizontal geophysical scans and borehole-datapoint locations.

After right-click on a map image object the below dialog box allows for setting of transparency, grayscale and other filters.



Tip: Using the Save Map as image function (see Section 3.3.1) a map can be created of the current view and directly re-loaded into the map window

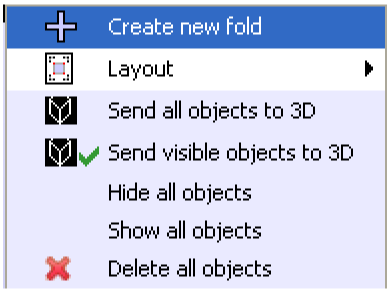
NOTE: Raster images commonly produce very large files and these can adversely impact on the performance of GSI3D. Degraded or sub sampled images should be used where possible. A maximum size of 10Mb is recommended.

4.8Folds

Fold axes can be inserted into GSI3D sections as a guide for drawing, they are however not used in calculation. They are drawn in the Map window, displayed in sections and can be sent to the 3D view for visualisation.

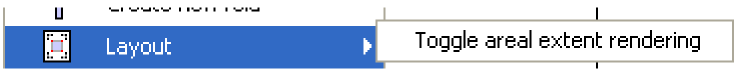
4.8.1 Fold tools and properties

Right click on the folds folder in the ToC gives the following options



Create new fold

Layout expands to a toggle to display or switch off the areal extent of the fold axial planes



Plus the following self-explanatory items, **Send all objects to 3D, Send visible objects to 3D, Hide all objects, Show all objects** and **Delete all objects.**

Right click on an individual fold in the ToC gives

Model fold axial plane See below Section 4.9.2

Extra Functions contains options to export the fold axial plane , **Export as grid (.asc), Export as GeoObject TIN** and **Export TIN as GOCAD TS.**

Send to 3D Self Explanatory

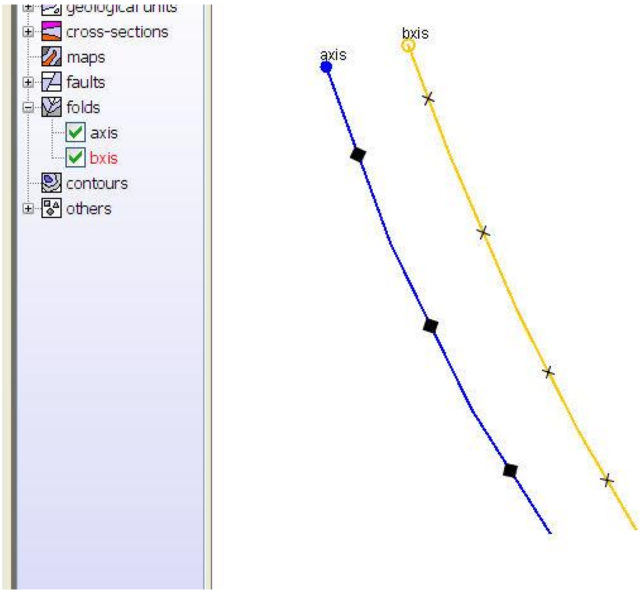
Properties Exactly as for faults (Section 4.8.1) and TINs (Section 4.3)

And the self explanatory options to Send to front, **Send to back, Switch off/on edit** (toggle) **Delete object, Rename object, Isolate object, Isolate within group**

4.8.2 Digitising and Shaping fold axes

Digitising fold axial traces

1. Right-click on the folds folder icon in the Table of Contents of the Map Window and select **Create new fold** from the drop down menu
2. Give the fold a unique identification e.g. "axis" in the dialog box, the fold is then added to the folder
3. Right click on the individual fold name and select **switch on edit** from the drop down menu, the fold name becomes highlighted in blue to indicate it is the active editable object
4. Select the **draw line** icon from the toolbar and left click at one end of the fold axis to place a node and then place nodes along the mapped fold axis at regular intervals finishing the line with a double click, the axis then colours blue and is labelled at its origin
5. Select the **edit nodes** icon to perform adjustments to the node string if required, click on the line to display the nodes then drag nodes using left click and hold (drag and drop). A single click along the line inserts an extra node and double clicking deletes a node.
6. When satisfied with the digitized fold axis right click on the fold name in the Table of Contents and select **switch off edit** from the drop down menu. Save the workspace
7. Repeat the procedure for the next fold and so on.



Antiform (editable) and synform axial traces in the map window

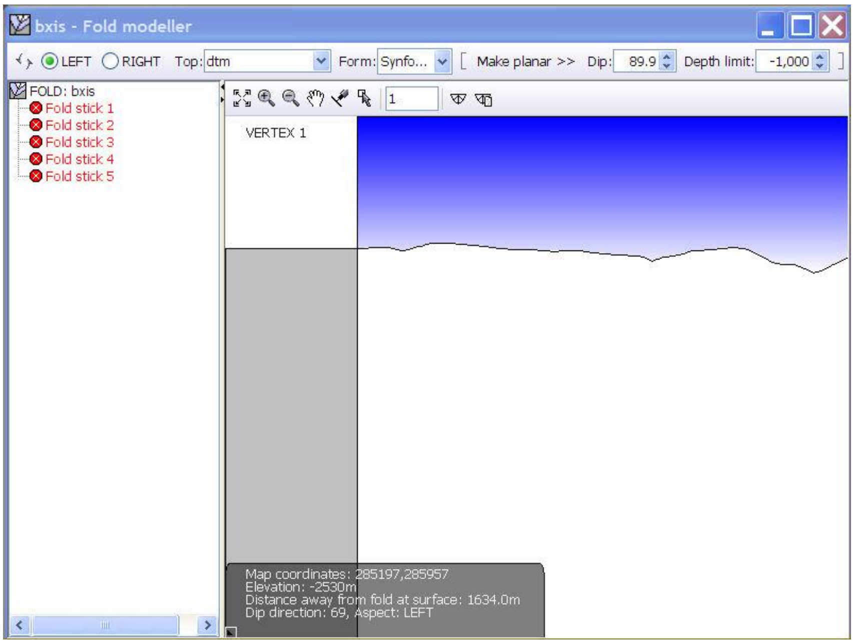
Shaping the fold axial plane

Once a fold or a network of folds, have been digitized there are two methods of defining the shape

Planar fold axial planes

Right click on the fold name (check edit switched off) select **Model fold plane**. This produces a dialog box as shown below. There is an option in the header bar to identify the fold as an antiform or a synform using the drop down list.

The fold axes are by default synforms with crosses indicating converging dips on the trace, whereas the antiform has diamonds indicating diverging dips. The option exists to make the fold axial plane planar at a specified dip or shape it by digitizing in the fold modeller window



The name of the fold is displayed in the header bar and the vertices (nodes) along the trace are listed in red with cross symbols in the Table of Contents. Only the settings in the header bar are used for planar faults enabling the geologist to specify the direction the axial plane dips, **left** or **righ**t w.r.t. digitization direction ,the **Top** capping surface is selected from a drop down list the **Dip** angle of the plane is specified (0-89.9 degrees, but not vertical) , and the **Depth limit** of the fold in metres. Pressing the **Make planar** propagates the settings along all of the trace, the node (stick) labels turn black and the fold plane is constructed.

Right click on the folds folder and select **Layout** and **toggle areal extent rendering** of fold planes to on and check the plane(s) dips in the desired direction, if not return to the digitizing window and switch between left and right

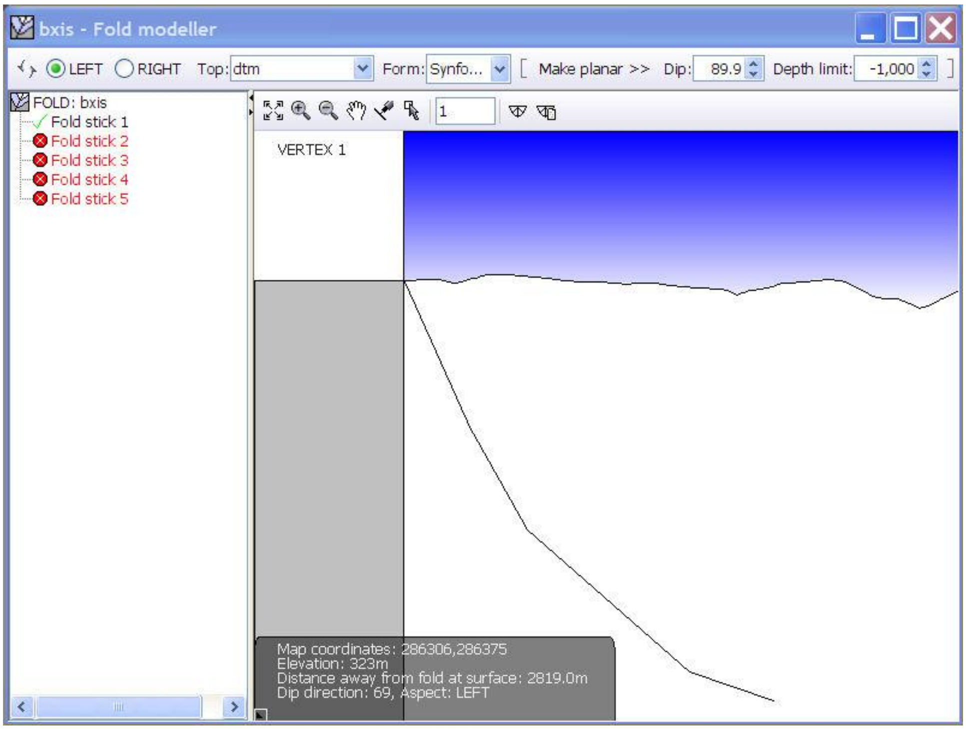
Non-planar fold axes

Here the geologist draws the shape the axialplane at selected points (nodes) along the length of the trace. This should be used also for a fold axis composed of more than one planar element.

Right click on the fold name, select **Model fold plane**. Again the Fold Plane Digitizing box opens. The name of the fold is displayed in the header bar and the vertices (nodes) along the trace are listed in red with cross symbols in the Table of Contents. The left hand pane is for drawing the fold plane.

On loading the digitizer defaults to the first vertex (node) of the trace switching is by double click with the editable vertex then highlighted in brown. The pane displays a cross point from which the dtm (or other capping surface) runs normally to the left of the digitizing direction. If the fold plane dips to the right switch over the pane by clicking the **right** button. The blue upper quadrant represents sky above the dtm (black line) and the grey opposing quadrant is the ground on the other side of the vertical as the direction of dip.

The shape of the fold plane is digitized in the lower right quadrant, the origin point is already detected, select the **draw line** icon and draw the plane using a singleclick to place a node and a double click to terminate the plane at depth. Once drawn and completed nodes can be dragged and dropped, additional nodes can be added (double click along existing line) and deleted (treble click on node). On completion the Vertex name in the Table of Contents turns black accompanied by a green tick.



The fold plane can then be shaped along its' length in the digitized direction at each vertex (node) along the trace if required. Where little information exists the shape can be propagated from one node to others by right clicking on the parent node, select **Propagate** this brings up a dialog enabling propogation to a specified number of nodes forwards or backwards along the trace, producing clones, with the added option to propagate the shape to all other nodes. Other options include **Reset, Show in window** and **Convert to clone**

In the toolbar familiar icons allow, zoom to maximum extent, magnify, zoom out, pan, draw line, edit nodes, and set vertical exaggeration. In addition a floating clinometer icon is available (click on the icon and then drag as required) and this can be adjusted using the final clino settings icon. The window operates at a default vertical exaggeration of 1.

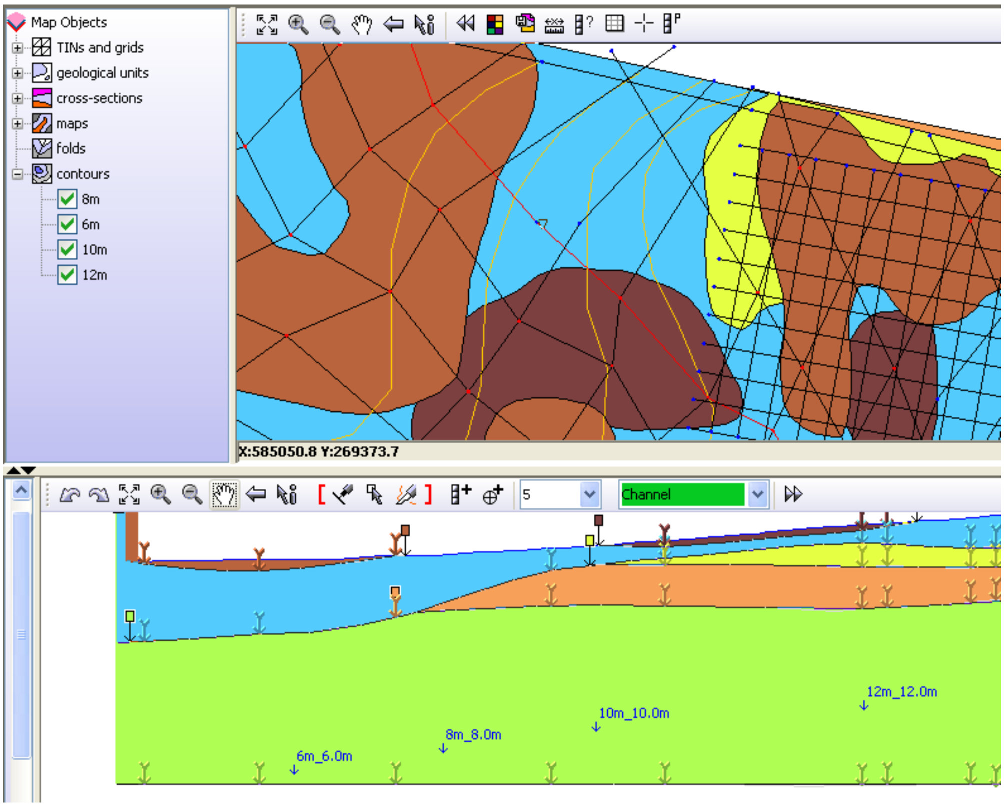
As the fold plane is constructed it is displayed in the map window as a green strip extending from the axial trace is shown if the **areal extent rendering** is switched on (r click of **folds** folder> **Layout** >), and the individual nodes on the trace and plane are also displayed. This is a useful check to ensure that the fold plane has been constructed with the correct dip direction.

Once completed the folds display in any sections drawn across them.

4.9 Contours

By right clicking on the contours folder it is possible to create a hand drawn contour, name it and give it an elevation in the property settings. The contours can then be displayed in cross-sections as ticks to aid correlations (to show in sections, use right-click> Update in the section window). Contours cannot be imported from a contour dataset and cannot be displayed in the 3D window.

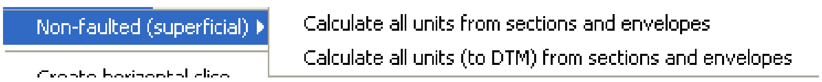
The image below shows 4 hand digitised contours and their display in section.



5. Calculating and delivering models

NOTE: Before any calculation switch off editing on all objects!

The calculate pull down menu is shown below and expands to two options



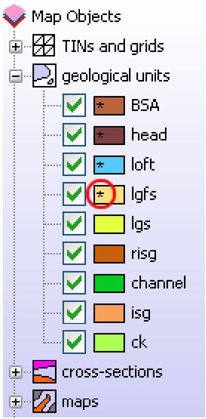
Calculate all units from sections and envelopes

This function starts the standard calculation of all geological objects as Triangulated Irregular Networks (TINs). This process calculates all tops, bases from loaded sections and envelopes. Walls are calculated where the unit extends to the edge of the calculated area as specified by the DTM.

NOTE: It is not always desirable to use the same TIN for the model construction (model capping surface) and the model calculation (calculation TIN). For calculation to proceed cleanly a second copy of the capping surface TIN can be created and then trimmed back to fit within the correlated area of the model (i.e. trimmed back to be within the area covered by sections). This is done by editing the calculation TIN and drawing a polygon for the boundary, and then trimming the TIN data back to that polygon boundary.

During model calculation the progress bar on the bottom right of the screen shows progress.

Also, the legend box alongside each unit in the map window ToC will display an asterisk "*" after it has been calculated. This acts as a visual guide to calculation progress, and the asterisks will be removed after the calculation run. Units are calculated from the top of the GVS to the bottom in order.



Once the calculation is complete, a dialog appears to confirm the process has finished. Press ok to return to the project.

Model calculation can take from a few seconds to several tens of minutes, and the following factors will affect the time required to calculate the entire model:

- Scale and resolution of the model capping TIN (DTM).
- Number of geological units modelled.
- Complexity (node density and line polygon count) of unit envelopes.
- Complexity (node density within and number of sections) of sections.

NOTE: In GSI3D v2011 the model calculation runs as a separate process. This means that the graphical interface of GSI3D will remain responsive, even during very long model calculation runs.

This may be useful, but the user should be aware that making edits to linework during a calculation could have unpredictable results and should be avoided.

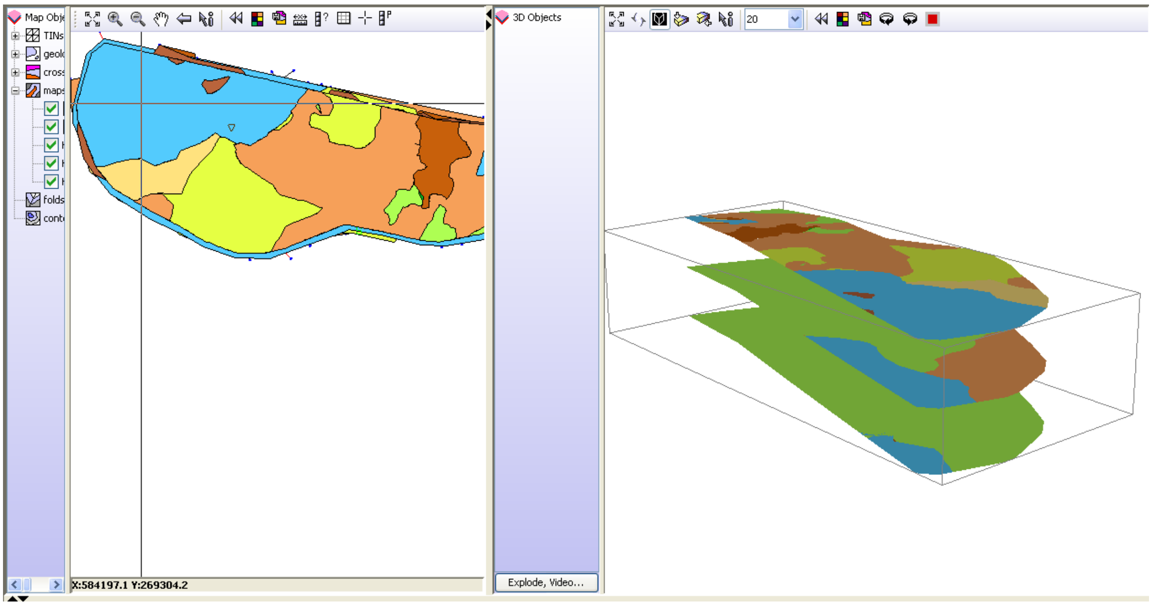
The calculated TINs are added to the geological units in the ToC and can be displayed in the Map Window by changing their Properties or in the 3D Window by right click and send to 3D view. Full details on how to display calculated geological objects are in Section 5

The **Calculate all units (to DTM) from sections and envelopes** function allows the calculation to be trimmed by the dtm. This will remove all triangulations above the DTM and produce a cleaner model, but the calculation will take longer to complete.

NOTE: where these errors occur (e.g. triangles penetrate the DTM) the geological unit will be removed and not pushed beneath the DTM

Create horizontal slice enables the user to cut a precalculated superficial model at a specified elevation and produce a map which can be exported as a shape filed and viewed in 2D and 3D.

The image below shows a synthetic horizontal section in the map window and a series of slices in 3D.

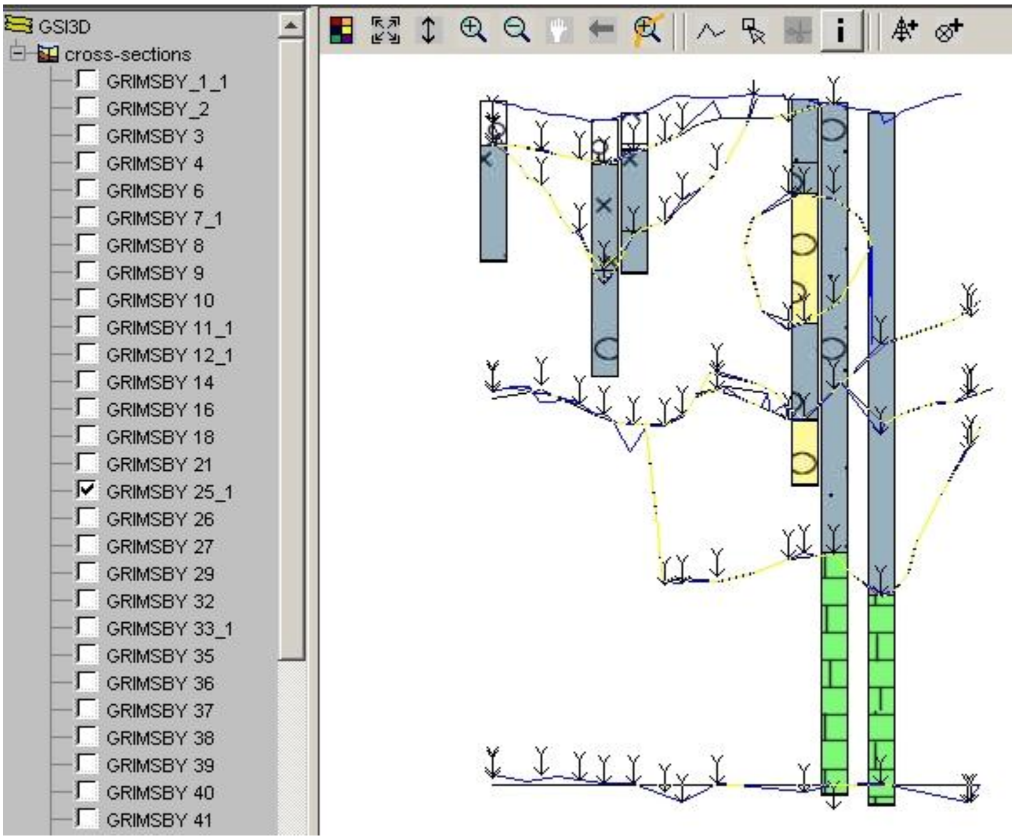


5.1 Checking, analysing, visualising and exporting models.

As with any process of building a model there is the need for continual checking, cross checking, editing and validation of the data and the model using all the tools and functions described. This is an iterative process and continues until the confidence in the model produced is high enough for it to be deposited in the appropriate geological data store(s) or published.

All the following analytical and visualisation functions are useful for validating calculated models.

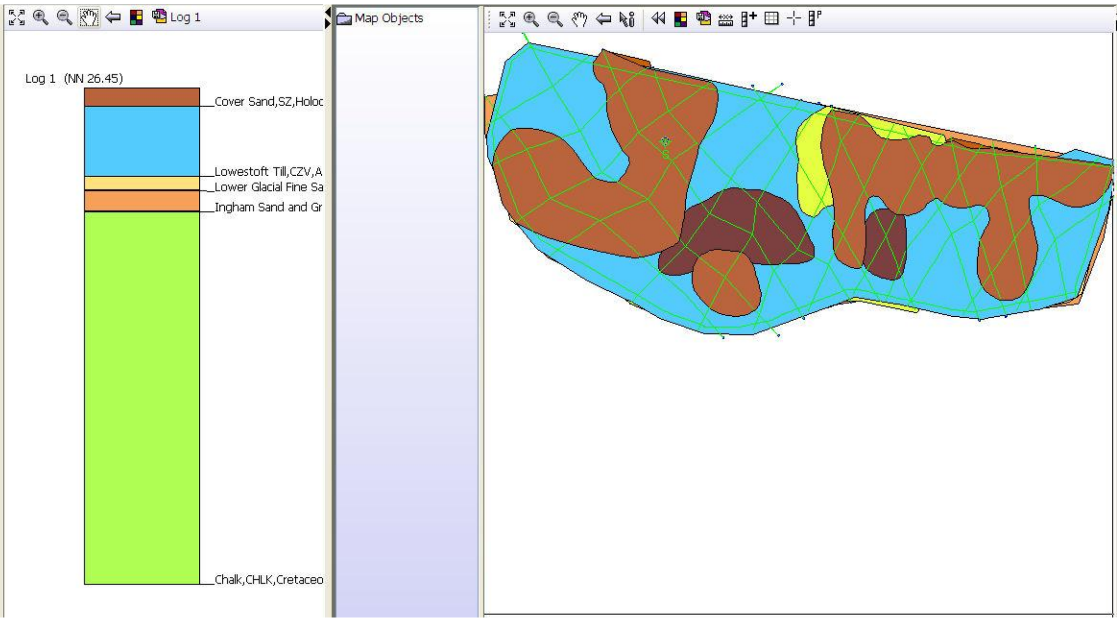
For a detailed check of the calculated model it is recommended that each constructed section is displayed with its correlation lines together with those of the calculated model (see picture below). This is best done with the polygons switched off, as this shows any mismatches very well. Correlation lines can then be iterated and using the update function the revised lines can be viewed instantly and more nodes can be added to the correlation line if necessary.



Model checking – where the lines appear yellow there is an exact match between correlation line (black) and model line (blue)

Synthetic boreholes

As described in section XXX after calculation the model can be inspected using the synthetic log button. All synthetic logs are displayed and listed in the borehole window.

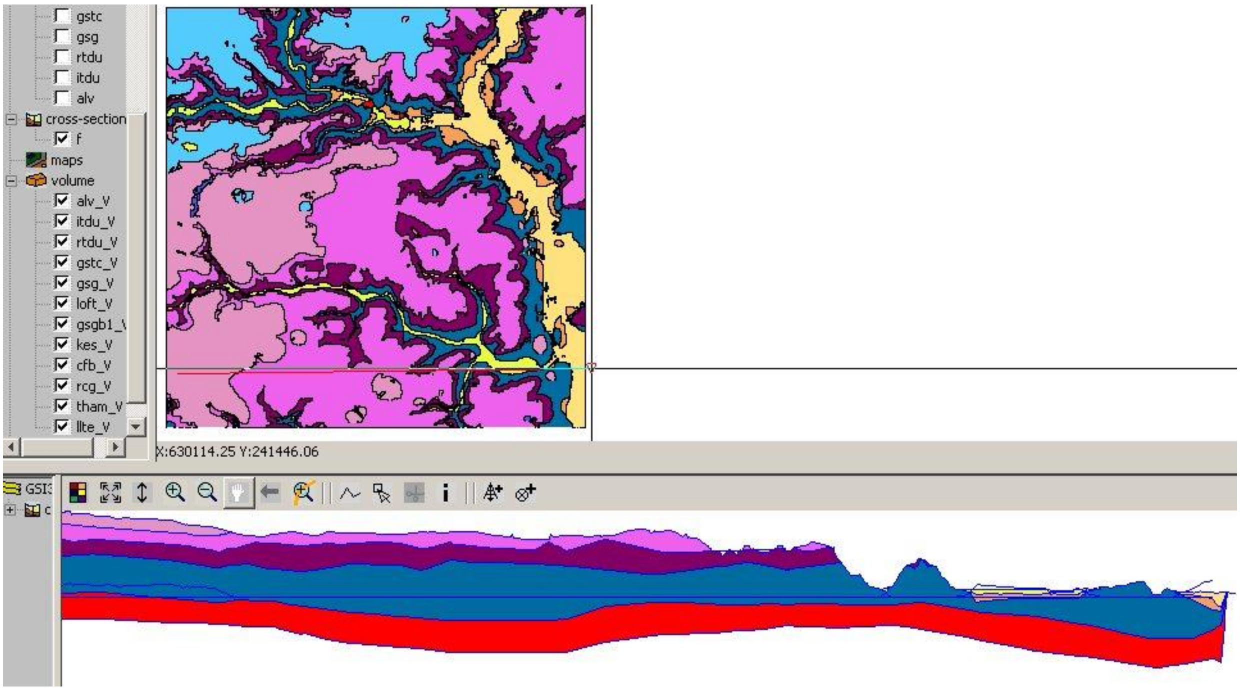


Synthetic sections

One of the best insights into the integrity of the produced model is to draw synthetic sections through it this can be along or across geological and geomorphological structures

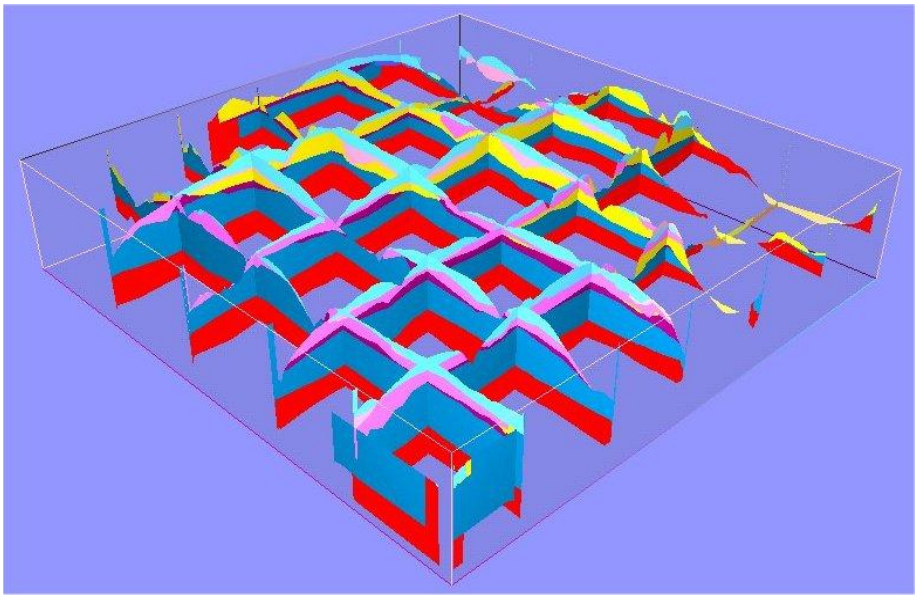
To create synthetic sections:

1. Load the project and calculate
2. Go to *Tools: create new section.* Name the section then use the info tool to place the cursor on the map and use add point to section in the section window. Repeat this until you have the completed cross-section.
3. Set the properties in the section window (right click) and tick on synthetic lines, polygons and textures to display the section.
4. Set the appropriate vertical exaggeration



A particular use of this functionality is to predict ground conditions along pre-determined routes such as flood embankments, tunnels and pipelines, or to help to evaluate the merits of several proposed routes.

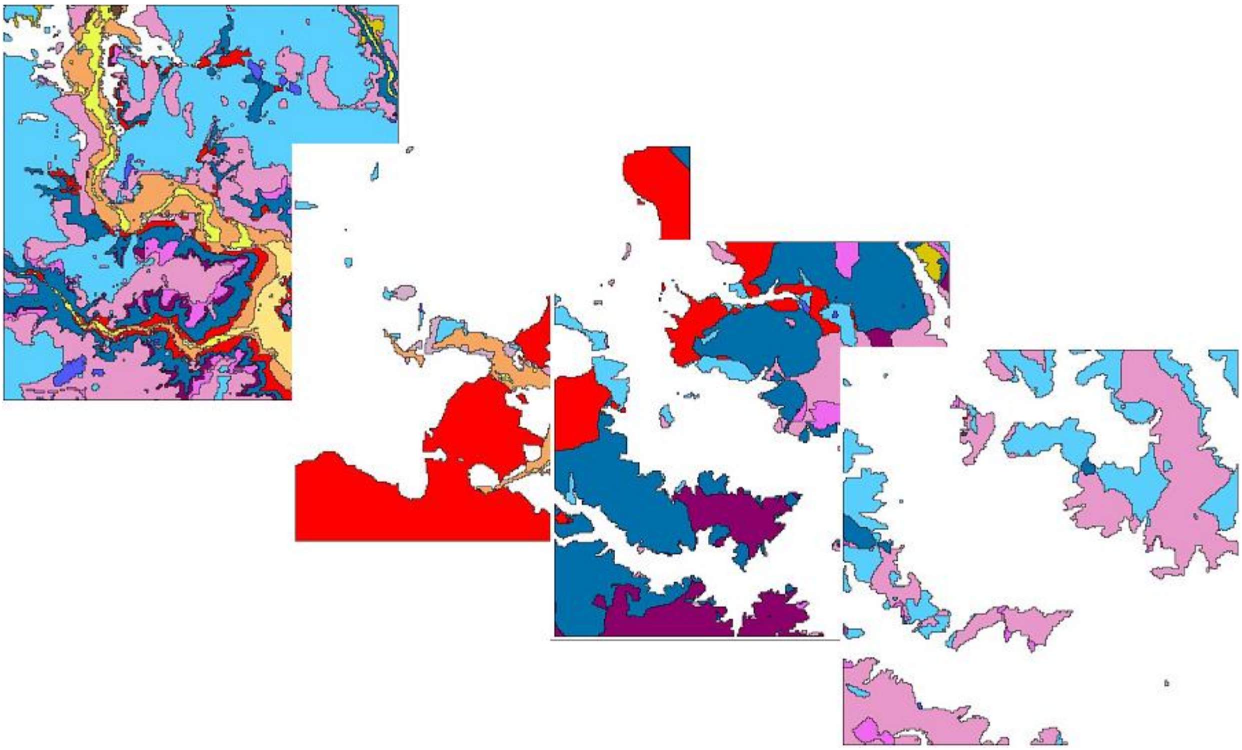
Combining multiple sections in the 3D window leads to the creation of fence diagrams such as the one below, based on a regular 2 kilometre spacing.



Synthetic fence diagram for TL83, viewed from the south-east, note these are calculated not drawn sections.

Synthetic slices

A particularly useful way of testing and presenting your model is to generate horizontal slices at various elevations as illustrated below. The procedure is select calculate horizontal slice from the calculate pull down menu and specify the elevation in metres relative to datum (e.g. 50, 10,-10) in the dialog. After calculation the slice appears as a map object in the map window labelled according to its height.



From top left to bottom right, solid model for TM14 and horizontal slices at OD, +20 and +40 metres white areas in the slices are cut through air (above ground level).

The model can at present only be sliced automatically along planar surfaces, but in the future this will be possible along irregular and or tilted surfaces such as a reduced DTM, a watertable or a planned excavation.

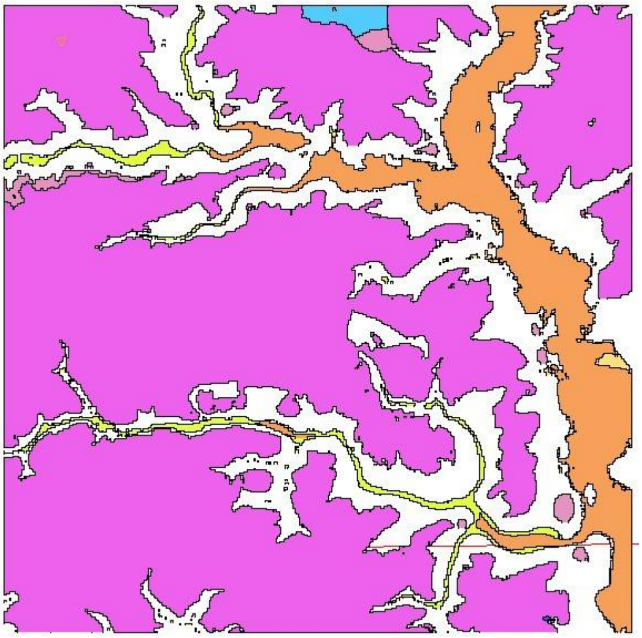
TIP: By loading any surface instead of the DTM (having changed the top entry in the GVS file to fit the file name) and loading all sections, envelopes and gvs, a geological model can be calculated at that particular surface.

Sub- and Supercrop maps

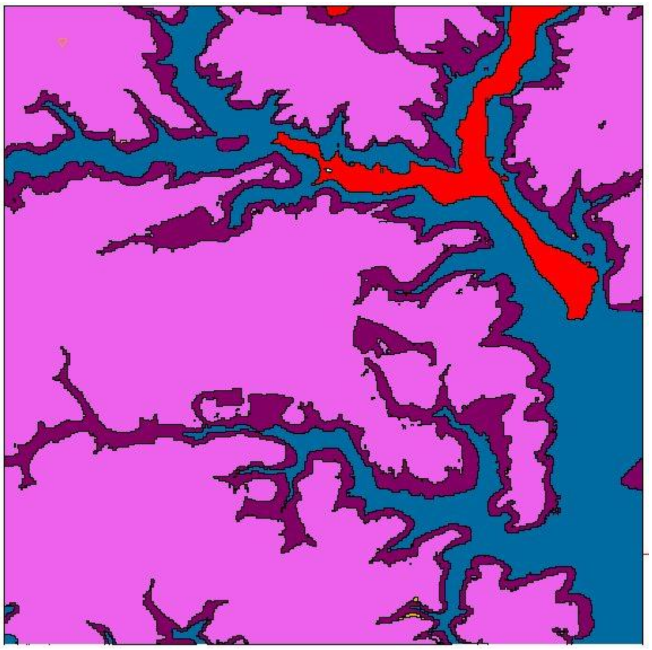
These maps show the arrangement of geological strata resting below or above any defined geological horizon most commonly unconformities such as base of Quaternary, top of Chalk and top of Palaeozoic basement. In GSI3D it is possible to instantly produce these plots for any surface (top and base) defined in the GVS. These maps are generated by looking at the sequence in ascending or descending order (see Section XX) and switching on or off the units you which to be represented in the ToC of the Map Window

.

Below are two examples taken from the Ipswich area.



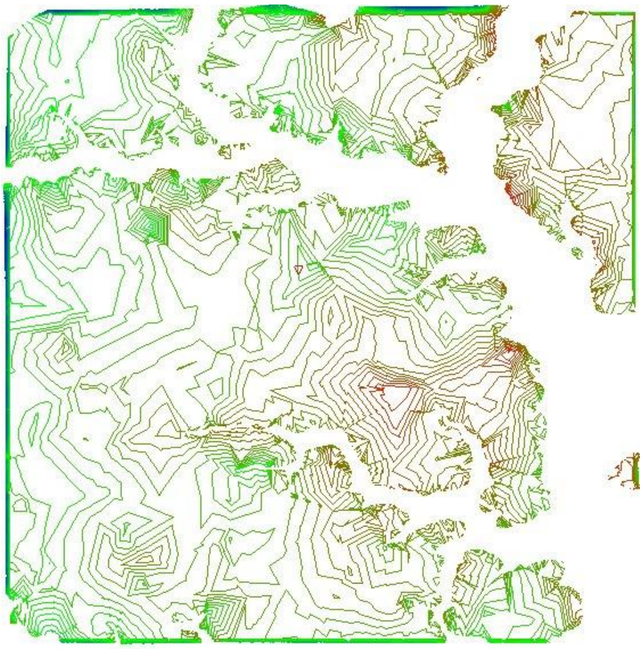
Supercrop map on the top of the bedrock for TM24 (areas in white show “air” e.g. bedrock at outcrop)



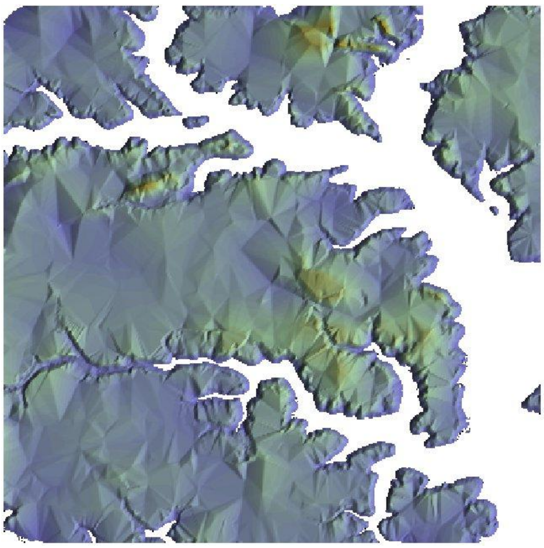
Subcrop map on the base of Anglian and younger deposits.

Contoured surfaces and thicknesses

It is possible to analyse every geological unit by displaying the elevation of its top and base and thickness as a shaded relief map or with contour lines at user specified intervals.

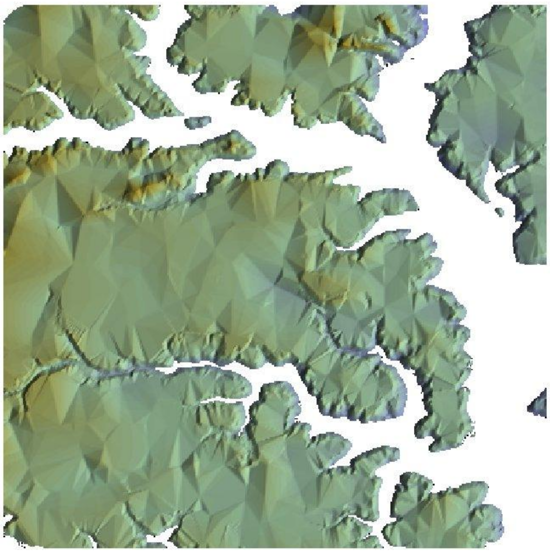


Contours on the base of the Red Crag Formation for TM24: Colour ramp red for low elevations to green for high elevations, interval 1m.



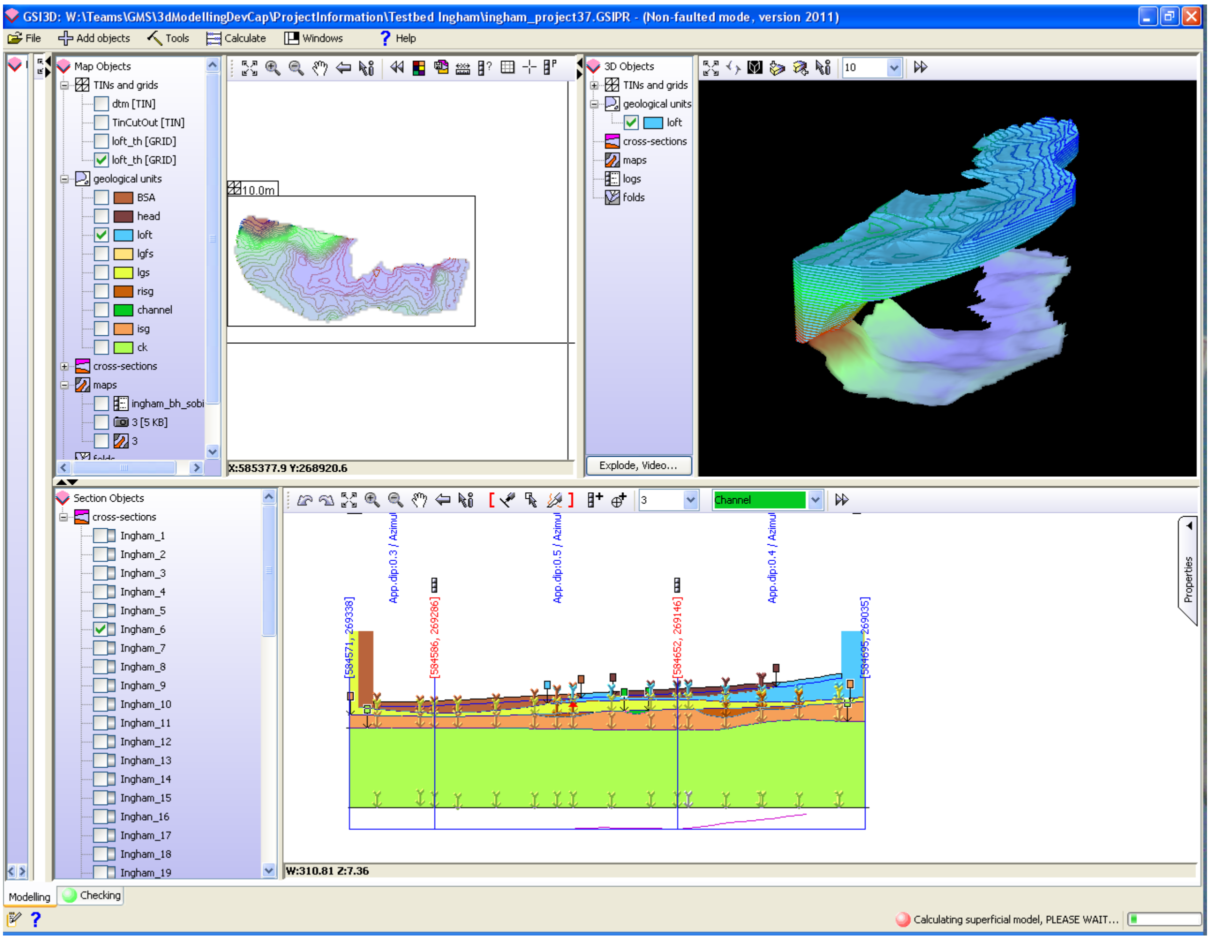
Shaded relief map of the top of the Red Crag Formation for TM24: Colour ramp from brown for high elevations through green to blue for low elevations.

Shaded relief maps can also be produced for the thickness of individual layers or combined packets of strata. Several examples are given below



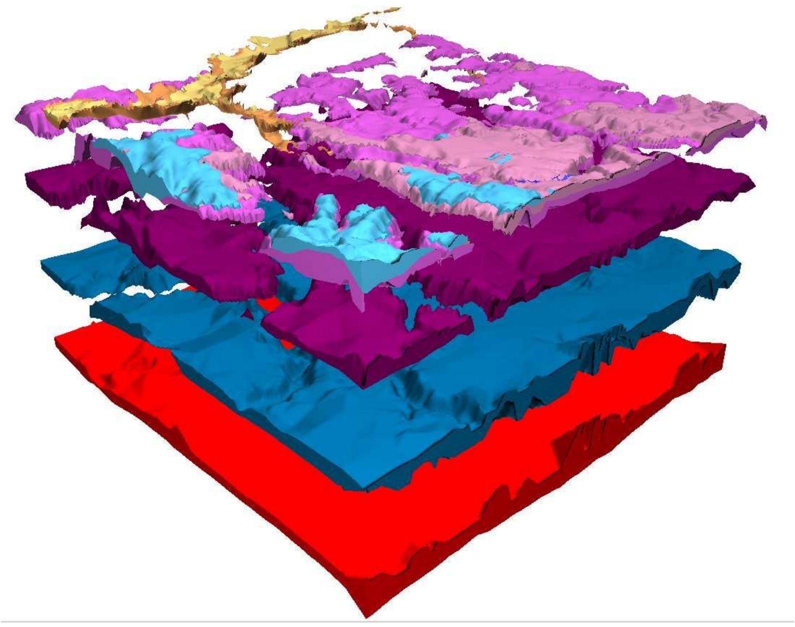
Relief shaded map of the thickness of the Red Crag Formation for TM24: Colour ramp from brown for thickest deposits through green to blue for thin deposits. Notice the feather edge to the deposits on valley sides depicted by the blue rim.

The below image shows a thickness grid in map view, a crossection view of the thickness (purple line) and a comparison between the thickness grid and the actual till body in 3D

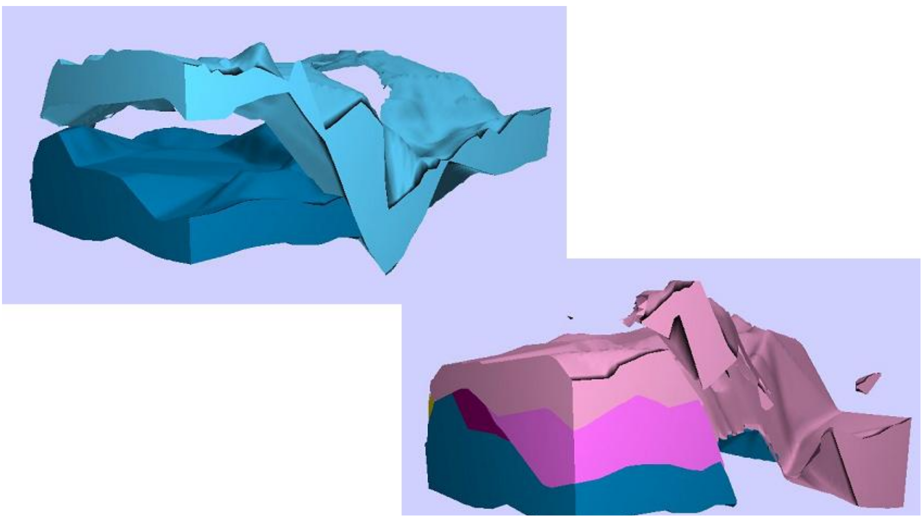


Exploded views

The most impressive tool of all for displaying the model is the ability to explode the layers in the stack by transposing their z values up or down to achieve separation, this procedure is described above in Section 3.4.2. Using this function to alter the positions of layers and switching them on and off geological time can be recreated by sequentially welding the units back together in their ascending stratigraphical order gradually recreating the block model.



Exploded block model of TM24 down to the Chalk viewed from the northwest.

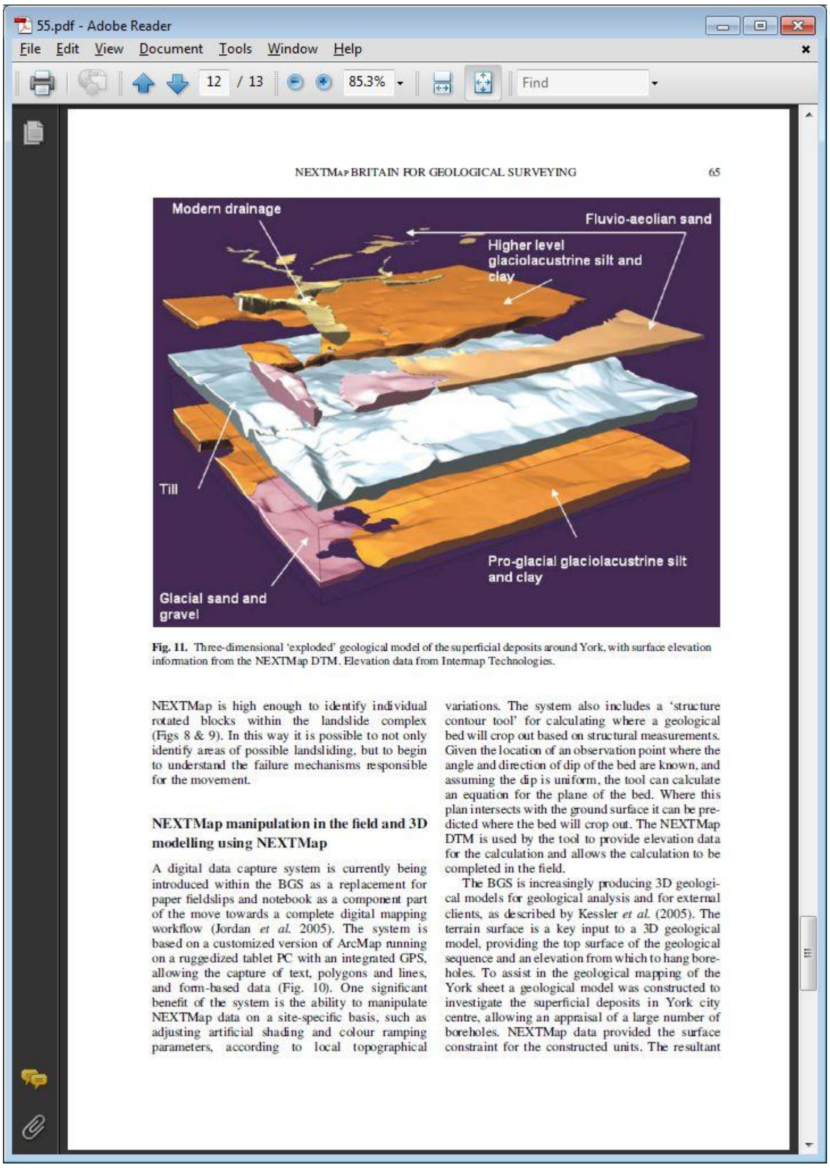


By switching off certain layers in the ToC of the 3D window the geometry of individual or selected units can be examined as shown above.

Model delivery

Models are only useful if they are fit for purpose and are delivered in ways that suit the needs and skills of the end users. GSI3D directly supports a range of standard outputs that enable you to publish your modelling in several different ways. Many more outputs such as 3D shape files, real time fly throughs can be generated and visualised using 3rd party software by converting or directly importing the project xml (*.gsipr). Outputs from GSI3D modelling can include:

Images (map, cross section and 3D) to produce diagrams for reports, an example blow



NEXTMAP BRITAIN FOR GEOLOGICAL SURVEYING 65

Fig. 11. Three-dimensional 'exploded' geological model of the superficial deposits around York, with surface elevation information from the NEXTMap DTM. Elevation data from Intermap Technologies.

NEXTMap is high enough to identify individual rotated blocks within the landslide complex (Figs 8 & 9). In this way it is possible to not only identify areas of possible landsliding, but to begin to understand the failure mechanisms responsible for the movement.

NEXTMap manipulation in the field and 3D modelling using NEXTMap

A digital data capture system is currently being introduced within the BGS as a replacement for paper fieldslips and notebook as a component part of the move towards a complete digital mapping workflow (Jordan *et al.* 2005). The system is based on a customized version of ArcMap running on a ruggedized tablet PC with an integrated GPS, allowing the capture of text, polygons and lines, and form-based data (Fig. 10). One significant benefit of the system is the ability to manipulate NEXTMap data on a site-specific basis, such as adjusting artificial shading and colour ramping parameters, according to local topographical variations. The system also includes a 'structure contour tool' for calculating where a geological bed will crop out based on structural measurements. Given the location of an observation point where the angle and direction of dip of the bed are known, and assuming the dip is uniform, the tool can calculate an equation for the plane of the bed. Where this plan intersects with the ground surface it can be predicted where the bed will crop out. The NEXTMap DTM is used by the tool to provide elevation data for the calculation and allows the calculation to be completed in the field.

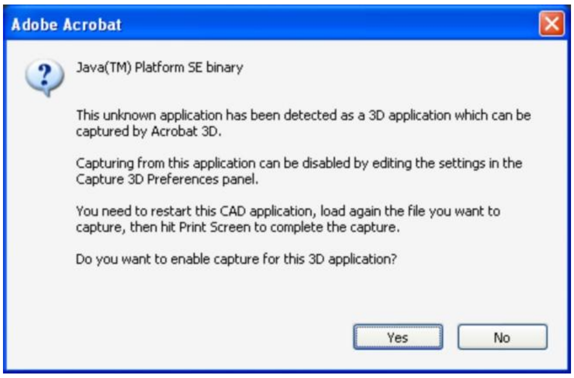
The BGS is increasingly producing 3D geological models for geological analysis and for external clients, as described by Kessler *et al.* (2005). The terrain surface is a key input to a 3D geological model, providing the top surface of the geological sequence and an elevation from which to hang boreholes. To assist in the geological mapping of the York sheet a geological model was constructed to investigate the superficial deposits in York city centre, allowing an appraisal of a large number of boreholes. NEXTMap data provided the surface constraint for the constructed units. The resultant

Videos captures of the 3D window (described in Section 3.5.1)

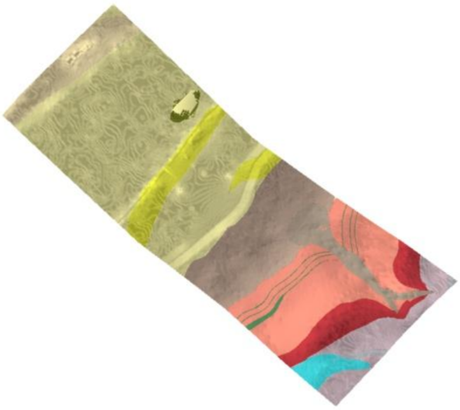
3D PDFs

In order to create a 3DPDF from GSI3D 2011Adobe Acrobat Pro Extended needs to be installed on the computer,. Then follow the workflow below.

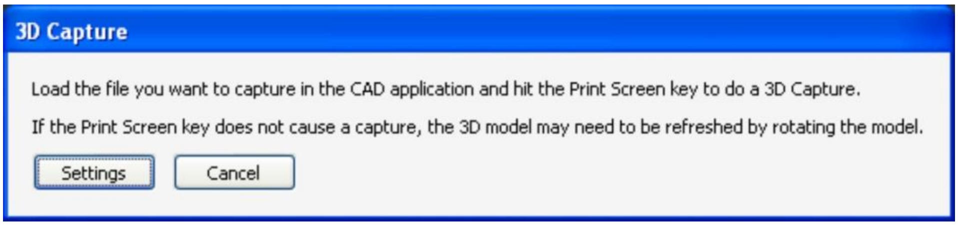
1. Open GSI3D Project. Decide what you what to make a 3D PDF of (Cross-Sections, Calculated model, surfaces)
2. Open Adobe Acrobat 9 Pro Extended
3. In Adobe Acrobat go to File – Create 3D PDF – From 3D Capture
4. A dialog box will open (Fig.1) Click on *Yes* as this will enable to use GSI3D for 3D PDF capture.



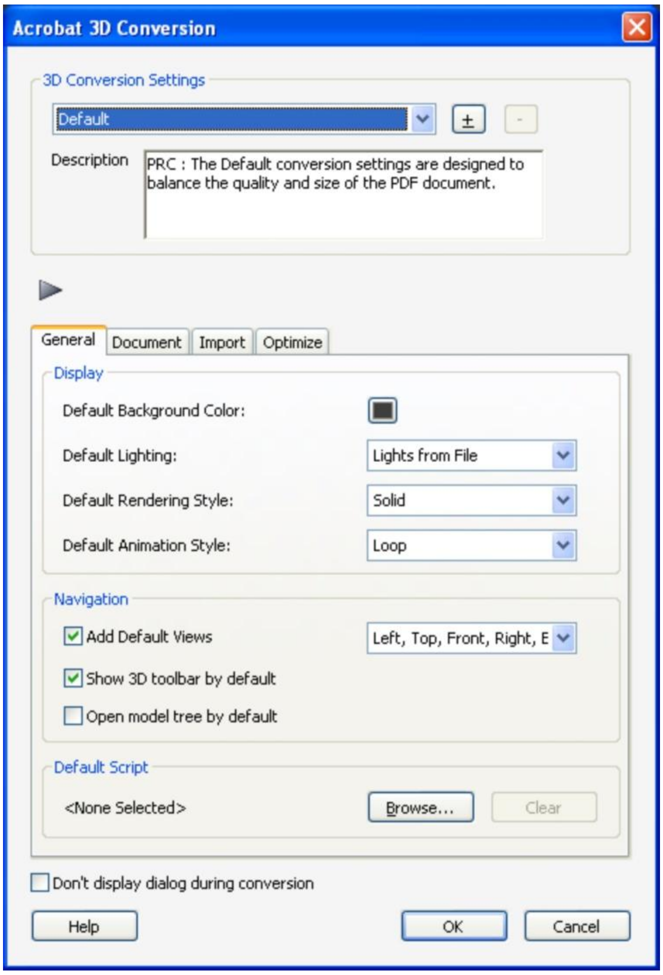
5. Close down the GSI3D and re-open with your preferred 3D objects (Note - this only has to be done once as Adobe Acrobat will recognise the GSI3D software in the future)
6. Send objects to GSI3D 3D Window and put the object in the 3D window into **Plan View** (Fig.2)



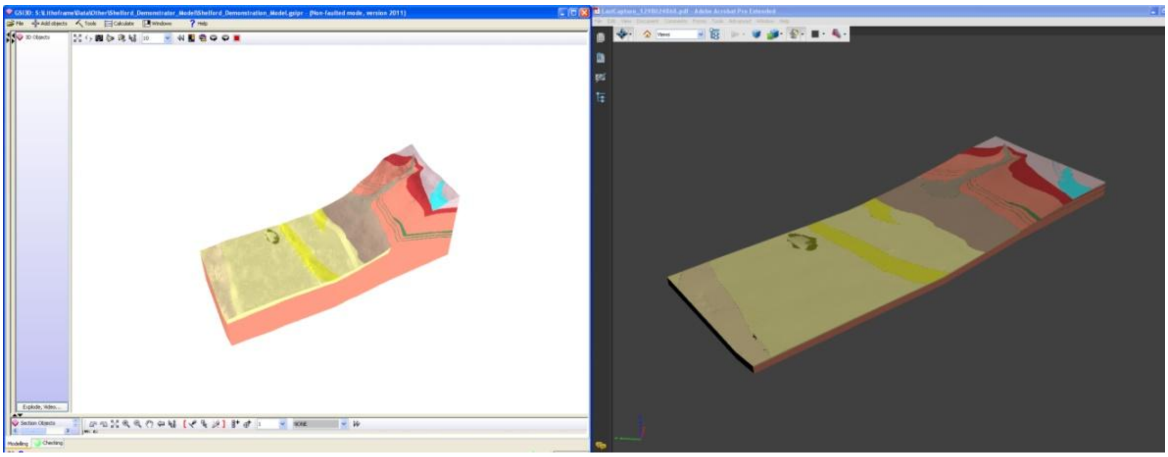
7. You can change the settings using the following dialog box in Adobe Acrobat (Fig.3) – accept defaults for first attempt



8. Press the Print Screen key on your keyboard – this will make the 3D Window flash in GSI3D and bring up the following dialog box in Adobe Acrobat (Fig. 4)

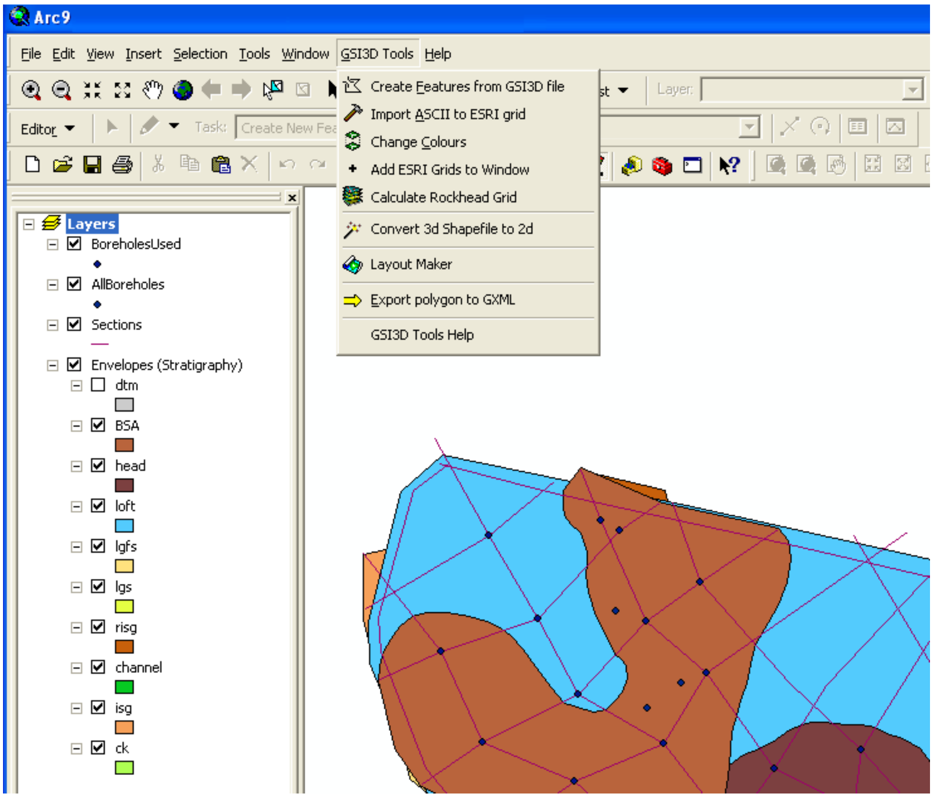


9. In the 3D Conversion settings in Adobe Acrobat 3D – change the default settings to **U3D ECMA Standard Ed 3**. This will allow you to edit the 3D PDF using the *3D Reviewer (allows you to re-name objects and pre-set views etc...)*. Accept the other defaults.
10. The GSI3D 3D object will be captured as a 3D PDF (Fig.5). Please note that the vertical exaggeration of the 3D PDF will revert back to '1'.

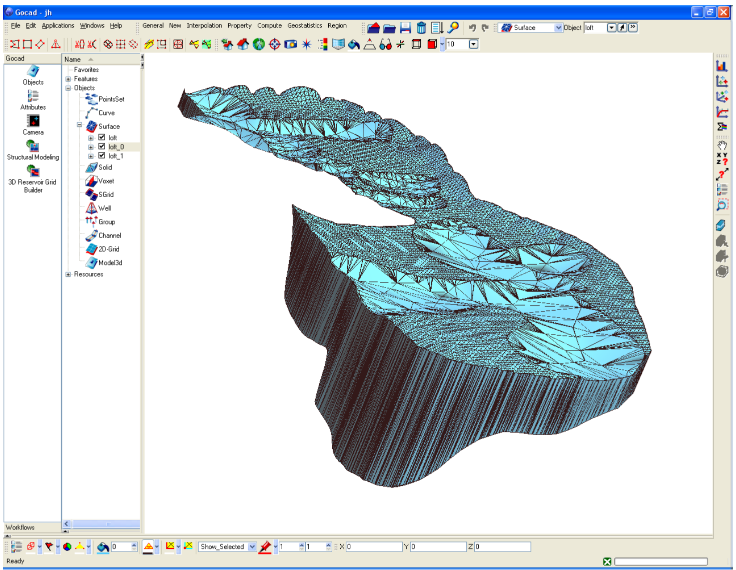


Exports to other geoscience and environmental modelling packages such as ESRI and Gocad (e.g. GRID or triangle mesh data files)

On the GSI3D Research Consortium website a number of tools are available to convert GSI3D project data into ESRI format: http://www.gsi3d.org/additionalDownloads.html. Below is an image of a converted project in ARCMap 9showing the tools available.



GSI3D supports seamless export to Gocad for onwards modelling (see image below), for exports to other software products, please contact the GSI3D Helpdesk.



7. Glossary

ASCII	American Standard Code for Information Interchange
Base	The lower boundary of a particular geological unit GSI3D deals exclusively with the base of geological units in drawing cross-sections
DEM	Digital Elevation Model. Collective term for DTMs and DSMs
DTM	Digital Terrain Model – Model of surface of the solid Earth (generally the boundary between geosphere and atmosphere or hydrosphere). This is traditionally derived from OS contours and spot heights and should therefore exclude all buildings, trees, hedges, crops, animals etc. Sometimes also referred to as 'bald earth' models
DSM	Digital Surface Models are elevation models that include height information from surface objects, such as trees and buildings, as well as from the terrain itself. Examples include unfiltered LIDAR, NEXTMap and photogrammetry produced elevation models
Envelope	Defined here as the extent of a geological deposit in plan view (2D): forming a distribution map of the particular unit, a presence – absence map.
GeoSciML	Geoscience Mark-up Language
GSI3D	Geological Surveying and Investigation in 3D
GML	Geoscience Mark-up language
GOCAD	Geoscience modelling package developed by a French-led consortium
Grid	A rectangular grid attributed with elevation or thickness values of a particular geological unit. GSI3D exports grids as 'ASCII grids' (*.asc) or SURFER grids (*.grd)
GSI3D TIN	Proprietary TIN export from GSI3D in VRML format 1997
GSIPR	The GSI3D mark-up schema and file extension for project files since Version 2.5.
GXML	The GSI3D mark-up schema and file extension for project and TIN files up to version 2
Java	The software programming language in which GSI3D is written. GSI3D runs within a Java process called the Java Runtime Environment, which is installed as part of the GSI3D setup.
Map	A map is the polygonal representation of geological units or domains projected to a plane perpendicular to the earth's surface.

Objects	Geological units in a model stack comprising top, base and walls (a.k.a Volumes).
OD	Ordnance Datum, reference base level used in the UK
Outcrop	The area where a geological unit is intersected by the earth's surface (DTM).
Project File	A *.gsipr file generated in GSI3D containing constructed sections and envelopes prior to model calculation
RCS	Rock Classification Scheme (in 4 volumes) describing and defining all 'Rock types' occurring in BGS datasets . These have been codified into an ORACLE table and are published on the www.
Rockhead	Loose term referring to the surface at the top of the bedrock, where Superficial Deposits are present it corresponds to their base.
Section	Defined here as a vertical x, z plane
Shells	The outer bounding surface or skin of a 3D object or volume
Slice	Defined here for a horizontal x, y plane
Start Height	Term used in SOBI for the level at the top of a borehole, usually equates with the height of the surface (DTM) but not always. Equivalent to the collar height.
Subcrop	The distribution of a buried/concealed geological unit beneath younger deposits.
Subsurface Viewer	An independent software produced by INSIGHT GmbH used to package finished models for sale to customers. The viewer enables basic slicing and dicing analysis of the model which is encrypted within the software. The model cannot be altered or import additional data, the software is not available in a stand-alone form at present.
Supercrop	The distribution of geological units above an older deposit or on a plane of unconformity.
Superficial Deposits	Term used to describe the Quaternary, generally unconsolidated, geological deposits. Sometimes also called drift
Surface	Base or top of a geological unit exported as grid or TIN
ToC	Table of Contents, the left hand marginal panel of the four dynamically linked GSI3D windows
TIN	Triangular Irregular Network. GSI3D exports TINs in Indexed Triangle Mesh format (VRML97)

Unit	A geological unit is a particular geological deposit that has been identified and mapped out during a GSI3D project. A unit is defined by a surface on its base and an envelope of its lateral extent.
Volumes	Geological units in a calculated model stack comprising top, base and walls (a.k.a Objects).
XML	Extended Mark-up language.
XMML	Extended Mining and Exploration Mark-up language

8. Bibliography

A full bibliography of GSI3D related outputs can be found at http://en.wikipedia.org/wiki/GSI3D

Refernces cited in this manual include

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9. Appendix

Keyboard shortcuts

A number of keyboard shortcuts and keyboard modifiers allow you to access functionality more conveniently then via complex menu options. Here is a list of the keyboard shortcuts found in GSI3D that are designed to make modelling tasks easier, quicker or more accurate.

<u>**F-Keys**</u>

F1 - Help

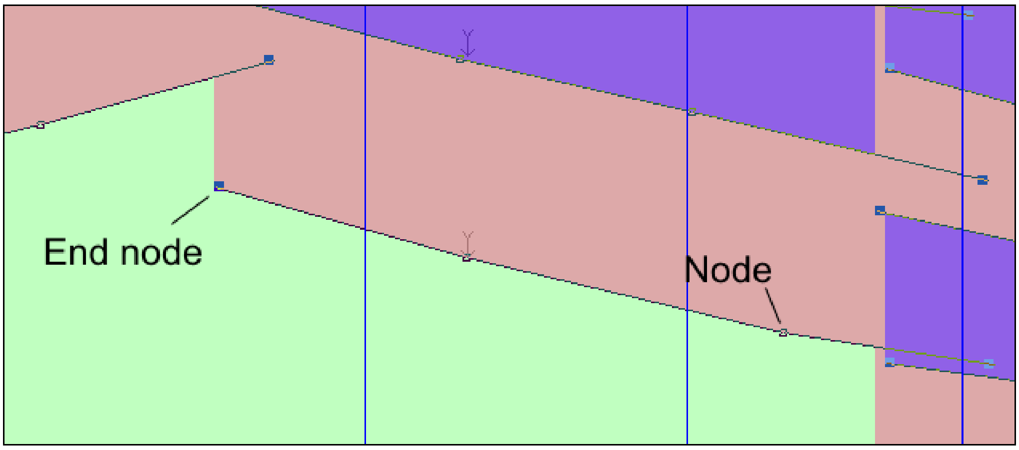
Opens the online help or user manual, depending on the version of the software.

F3 – Layout perspectives

Cycles through the available window layout perspectives. Layout perspectives alter the size and position of the windows in the UI to make particular tasks easier. They save you having to arrange the screen yourself by manually dragging window dividers. Press repeatedly to see all of the available perspectives.

F4 – Correlation line nodes

Toggles the display of correlation line nodes in a section. When active the digitized nodes of all correlation lines will be drawn as a small rectangle. End nodes are filled with blue. This is very useful for checking sections.

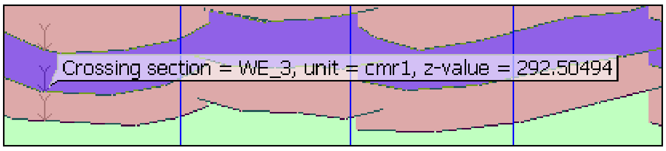


F5 – Refresh/Update

Performs the same function as R-Click > Update in the section window to force a complete refresh of the graphics.

F7 – Tooltips

Toggles tooltips on and off. Press once to activate tooltips, press again to de-activate them. Tooltips appear in the section and map windows when the mouse is hovered over an identifiable object. In the section window you can identify unit names on correlation lines and information about crossing sections. When the tooltips are switched off you can also enable them temporarily by holding down the Shift key whilst hovering the mouse cursor over linework or objects. Note that tooltips may cause graphics to flicker where there is lots of data or complex linework.



F11 – Undock/Dock windows

Undocks and re-docks the UI windows. When undocking, all of the windows and the menu bar are separated out into individual windows. When docking the windows again the standard layout perspective is applied. The same functionality can also be accessed via Windows > Split/Dock.

Other keys

Esc – Cancel operation

The function of the Esc (Escape) key varies depending upon the context. When digitizing linework in sections it will delete the current line you are working on.

Ctrl+G – Section graticule

Toggles the section graticule on and off.

Ctrl+H – Map graticule

Toggles the map graticule on and off.

Ctrl+K – Toggle clinometer

Toggles clinometer on and off in the section window.

Shift – Mouse modifier

In the section and map windows, holding down the shift key whilst moving the mouse cursor will activate tooltips. If you move the mouse over a suitable object (e.g. a correlation line or a crossing section down-arrow) you will see a tooptip describing that object. This is similar to some of the functionality of the info tool but without having to switch navigation modes.

Ctrl – Mouse modifier

In the section window, holding down Ctrl then clicking two lines will attempt to join those lines into a single object.