Modelling CPT Data

Contents

Goals

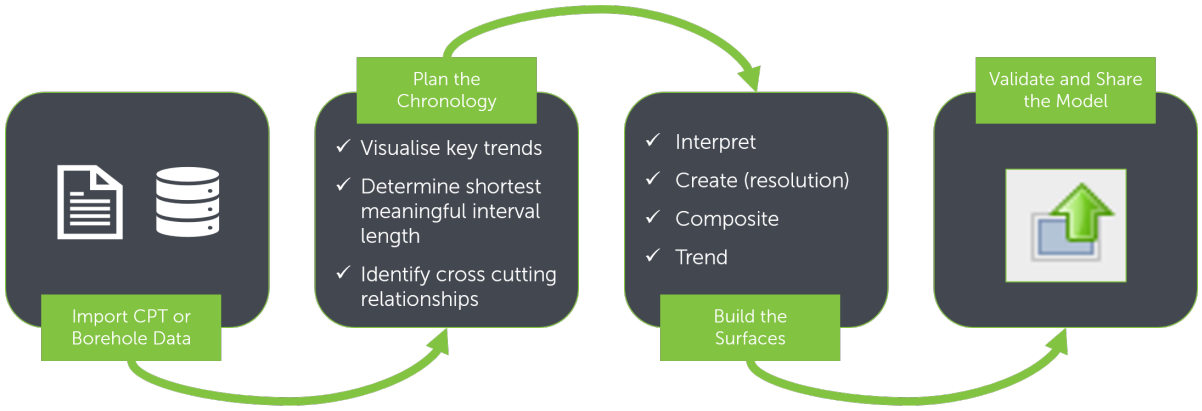
Modelling very laterally extensive lenticular geology from Cone Penetrometer Test (CPT) and borehole data can be challenging given the amount of detail often available vertically in the subsurface data relative to the horizontal spacing of the data. Although borehole data is more commonly known, we are seeing increasing numbers of clients using a more economical, non-invasive alternative, CPT data, to build their geological models.

This How To guide will build upon some fundamental concepts in Leapfrog and step you through a workflow to create a geological model, using relatively widely-spaced, but highly detailed geotechnical data, CPT data, imported as boreholes.

Key Concepts Covered

- Surface Resolution
- Anisotropy (Isotropy)
- Surface Chronology
- Snapping (surfaces to boreholes)
- Intrusion Editing Options, including Compositing and Trends

Workflow Overview



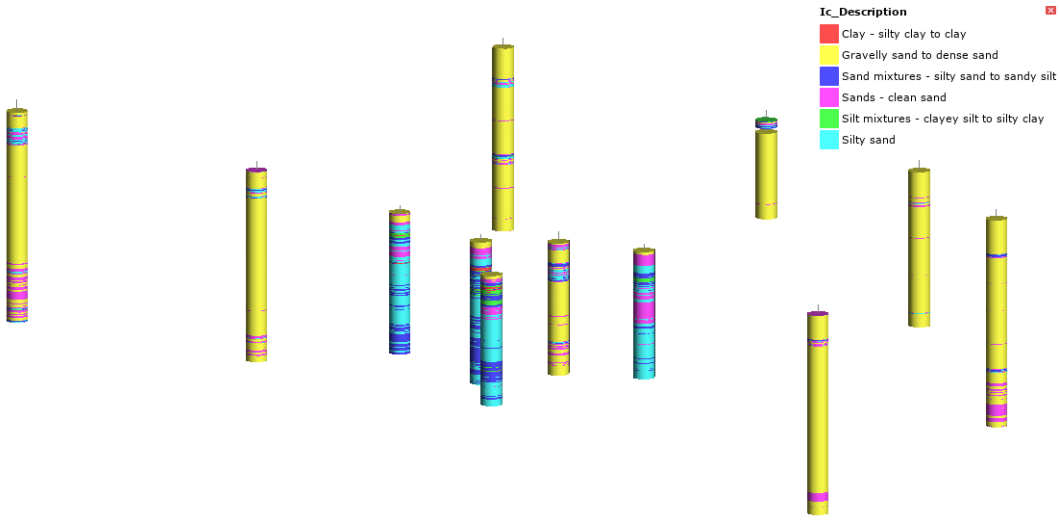
Step 1: Import Your Data

Your CPT data can be imported via the **Boreholes** folder in the tree:

1. Right-click the **Borehole Data** folder, select **Import Boreholes**).

You can import this data from a range of sources, including csv, gINT files, AGS files or ODBC databases.

When importing the data, you will need to choose an attribute column (for example, the IC category description table) so you can build a categorical model, otherwise known as a Geological Model.



2. Import a topography surface or generate one directly from your collar points.

If a Topography surface exists in the **Topographies** folder prior to the creation of a geological model, the model will automatically be cut to topography.

For more information, see the Importing Boreholes topic in the online help, or watch the video.

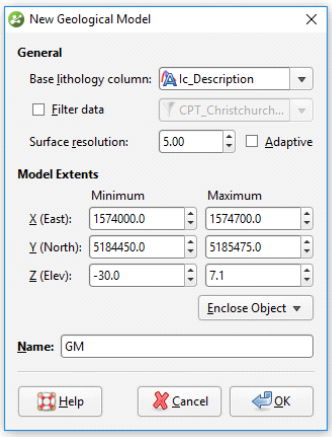
Step 2: Create a New Geological Model

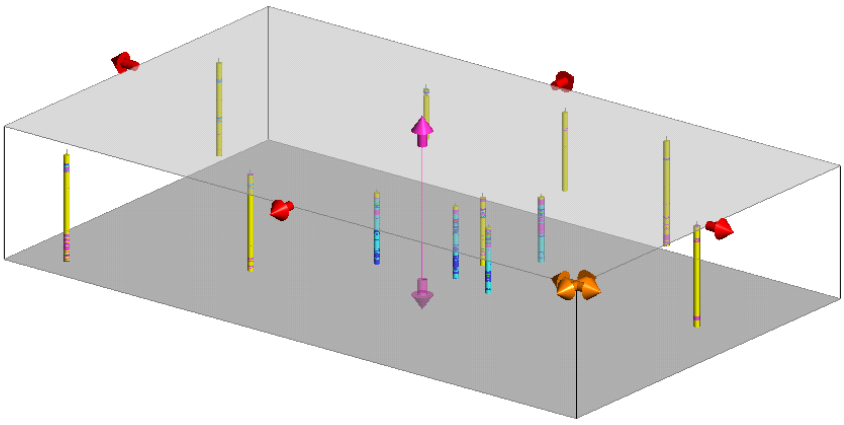
Now you have imported your data, it's time to create a new Geological Model:

1. Right-click **Geological Models** folder, select **New Geological Model**.

2. Choose your borehole data as the **Base lithology column** of your model.

3. Set reasonable **Model Extents** and **Surface resolution**.





4. Once the model is generated, double-click it in the project tree and activate Snapping (set **Snap to Data** to **Drilling Only**).

For more information, see the Geological Models topic in the online help.

Step 3: Plan the Chronology

1. Drag your CPT borehole data into the scene to visualise it.

Look at the intervals, familiarise yourself with the interval lengths and dominant trends, if any. Use your judgement and knowledge to identify the predominant unit, the age relationships* (if possible) between units, and the desired volume connectivity between boreholes for each unit.

* Depending on the interval geometry and degree of interbeddedness (in sedimentary environments), the age relationships may or may not be relevant to the overall construction of the model surfaces.

Ultimately, the priority of the cutting relationships between the surfaces will be the most important factor in generating the final model volumes.

In preparation for modelling, here are a few things to consider:

- Inspect the intervals on a couple of key borehole traces to find the largest interval that you would be prepared to have composited into the neighbouring lithologies. Make a note of how long it is for use later.
- Visualise the trends in the dataset by viewing the boreholes side on. What intervals do you want to see connected between boreholes? Make a note of the distance between the farthest apart intervals you'd like to see connected in your model. Also make a note of the anisotropy you see in the raw data and how exaggerated is it.

Chronology Planning Summary

Visualise the data looking for...	Make note of ...	So that you can...	So that your model has...
Predominant Lithology	The most common lithology across my site, that other lithologies intervals are interbedded with.	Set it as the **Background lithology**	A background lithology to embed other lithologies into and fill any gaps in your model
Short intervals that exist within other lithologies	The length of the largest interval that you would be prepared to have interpreted as a different material	Apply a rule to **Composite** anything shorter into neighbouring lithologies	A degree of simplification while still modelling significant lenses and material changes
Intervals that you would interpret as extending between boreholes	The longest distance between boreholes that you want the model to 'connect'	Apply a **Trend** to connect data points between measured points	A realistic geological interpretation of the CPT data.
Unit distribution within and between boreholes	The downhole unit sequence	Decide on an appropriate **Surface Chronology** priority (cutting) order	The best chance of being built with the right cross cutting relationships

Step 4: Build the Surfaces

For CPT data, using an 'Intrusion' surface is recommended, even when you're not modelling an actual intrusion (geologically speaking). This is where best practice comes in. Intrusion surfaces offer the most flexibility for modelling complex geometries.

If you are able to determine the age relationships between units, it is good practice to build the surfaces consistently in chronological order; however, for various reasons, it is frequently difficult to determine the surface chronology. In this case, the interbedded nature of the units precludes us from relying on chronology alone to define our surface generation prioritisation.

First Surface

1. Within your new Geological Model, right-click **Surface Chronology** and select **New Intrusion** > **From Base Lithology**.

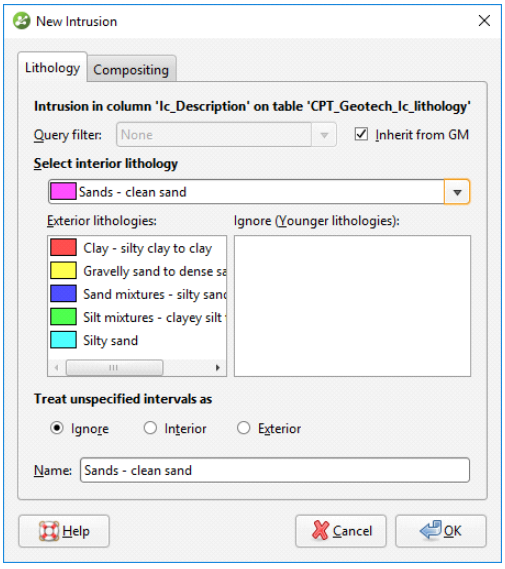
Selecting **From Base Lithology** allows you to select units from the borehole database table you selected when the model was initially created.

2. To begin, use the **Select interior lithology** dropdown to select the unit closest to the top of the holes (typically youngest).

In this case we'll begin with the 'Sands – clean sand' unit.

3. As this is the first surface you're creating, leave the remaining units in the **Exterior lithologies** column.

The **interior lithology** is the category that is being modelled, the **exterior lithologies** are the older categories that it contacts, and the **ignored lithologies** are the younger categories which may contact the interior category but will be modelled as the next surface. This is explained in detail here.



4. View the surface in the scene to see what has been created.

The first pass surface is rarely suitable; we will look at the following options for editing this surface:

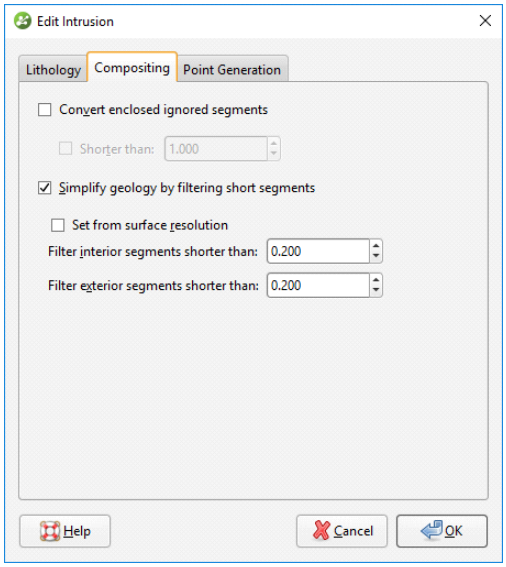
1. Composite - Simplify geology by filtering short intervals
2. Add a trend
3. Adjust the surface resolution

Edit the Surface

1. Composite

1. Expand out the new surface to view the contact points object below.
2. Double-click the contact points object to open it.

3. On the **Compositing** tab, uncheck the default **Set from surface resolution** box and enter the interval length you noted earlier during planning.
4. Shorter intervals will be filtered out. In this case we will filter out both interior and exterior segments shorter than 20 cm (0.2m).



This value can be changed at anytime and the resulting surface will regenerate accordingly. After we look at the other editing options, you may wish to revisit this one.

2. Add a Trend

1. In the project tree, double-click the surface and click on the **Trend** tab.
2. Apply the anisotropy from your planning observations. The scale of the ellipsoid should be based on the distance you noted between intervals during the planning stage.
3. In this case we will use a simple horizontal plane, with Ellipsoid Ratios set to 40x40x1. The 'cones' have now become 'pancakes', and several new lenses have been created.
4. Modify the plane and the ellipsoid ratios until you're satisfied with the connectivity of units between boreholes.

There are no 'right' or 'wrong' ellipsoid ratio values, as long as the resulting surface is in line with your interpretation, your selected trend orientation and ellipsoid ratio values are appropriate.

3. Adjust the Surface Resolution

If you have edited the compositing and the trend, and you're still not achieving desirable results, reduce the resolution of the surface to make it more flexible. Remember: the smaller the triangles comprising the surface, the more detailed the surface can be, but the processing time will increase.

Surface Review

Review the updated surface in the scene, does it fit the CPT data as you would like? Go back and experiment with the settings above to arrive at something you are happier with. As you build up more surfaces, don't be concerned about the surface overlaps, these overlaps will be resolved when the surfaces are activated in the Surface Chronology and the volumes are generated.

Remaining Surfaces

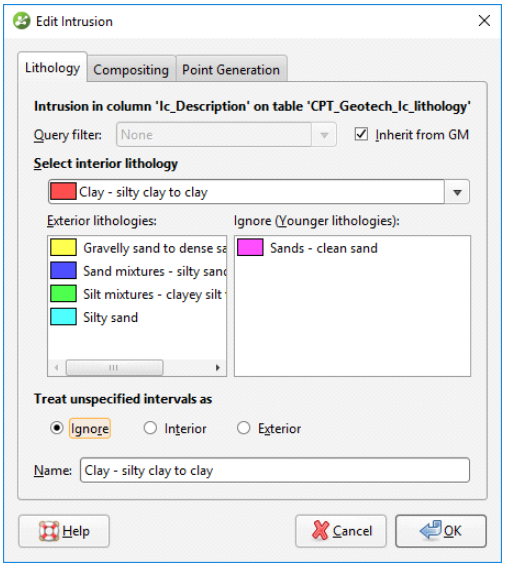
The remaining surfaces could be built in a few different sequences without significant impact on the final volumes. The strategy utilised in this guide is to first model the smaller, more isolated units, followed by the

more prevalent units. The remaining 4 surfaces will be built in the following order: 'Clay', 'Silt mixtures', 'Sand mixtures', and lastly 'Silty sand'. The remaining unit, 'Gravelly sand to dense sand', does not require it's own surface to be built, as it will be defined as the Background lithology once all the other unit volumes have been created.

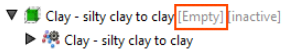
Clay Surface

1. Build the 'Clay – silty clay to clay' surface as a new **Intrusion**.
2. This time, move the unit we just built (Sands) into the **Ignore (Younger lithologies)** column.

> It is very important when building surfaces not to duplicate contact points, and we've already honoured the contact points between the 'Sands – clean sand' unit and all other units.

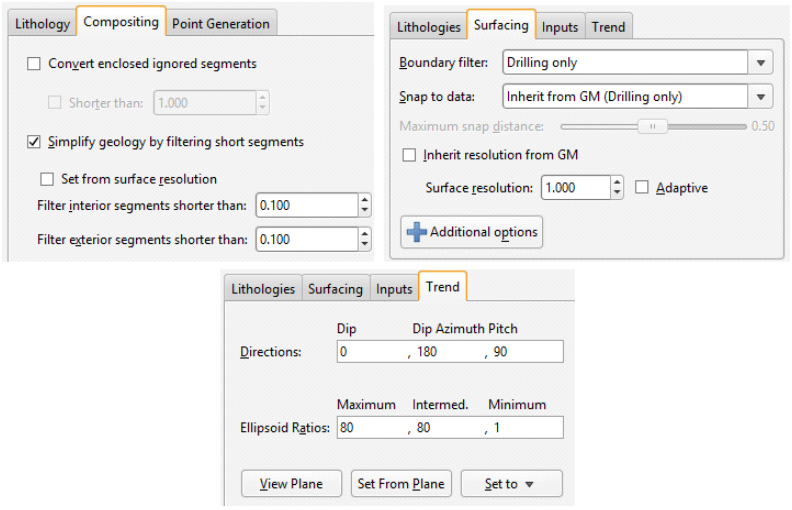


In this case, the first pass surface we attempted to create is actually empty. This is likely due to a combination of factors: resolution, lack of relevant trend, automatic liberal compositing rules.



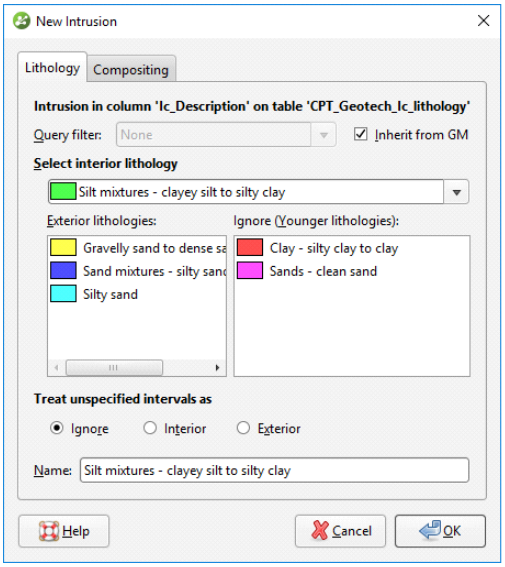
3. Adjust the trend, filtering lengths and resolution to generate a meaningful 'Clays' surface.

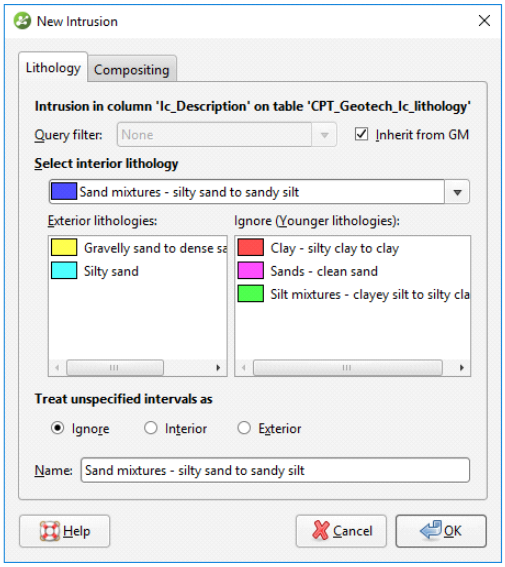
> No one parameter will result in a surface being created, all 3 must be modified appropriately to generate a meaningful surface.



Silt Mixtures & Sand Mixtures Surfaces

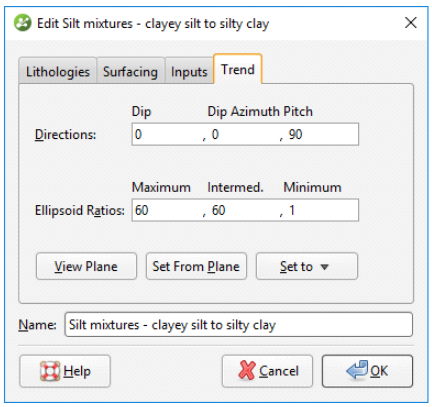
1. Build the 'Silty mixutres - clayey silt to silty clay' and 'Sand mixutres - silty sand to sandy silt' surfaces as new **Intrusions**.

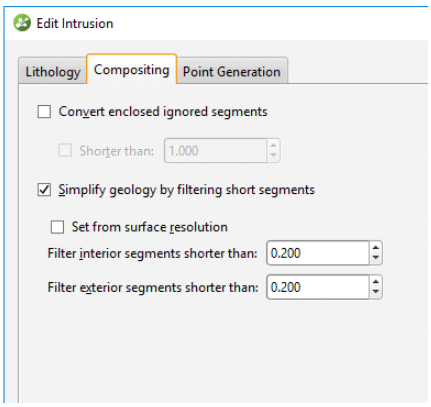


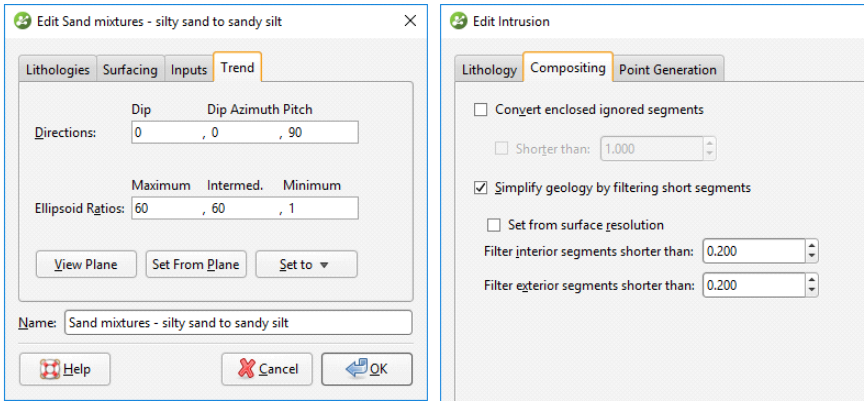


The resulting 'Silty mixtures' surface is also empty, like the original clay surface was.

2. Adjust the trend, filtering lengths and resolution to generate a meaningful surfaces.





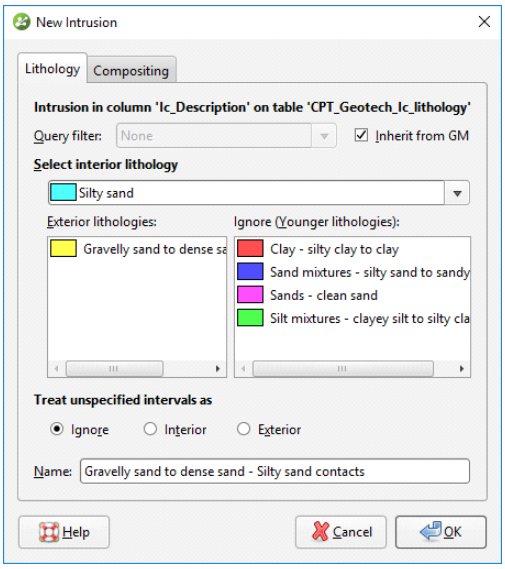


Silty Sand - Gravelly Sand Surface

The last surface we will create will define both the 'Silty sand' and the 'Gravelly sand' volumes.

1. Build the 'Silty sand' surface as a new **Intrusion**.

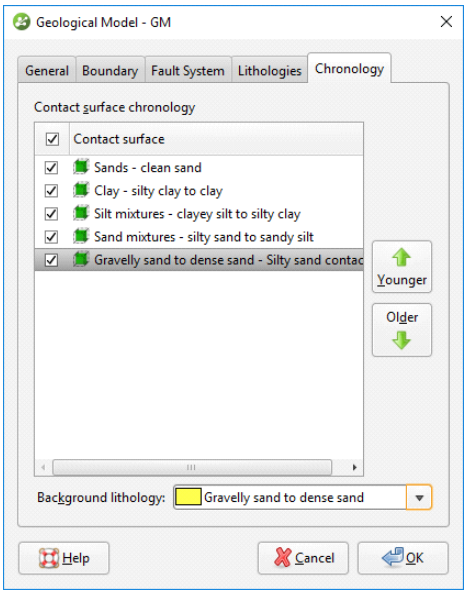
This time only the 'Gravelly sand' unit will be remaining in the **Exterior lithologies** column, thus this one surface defines the separation between these last 2 units.



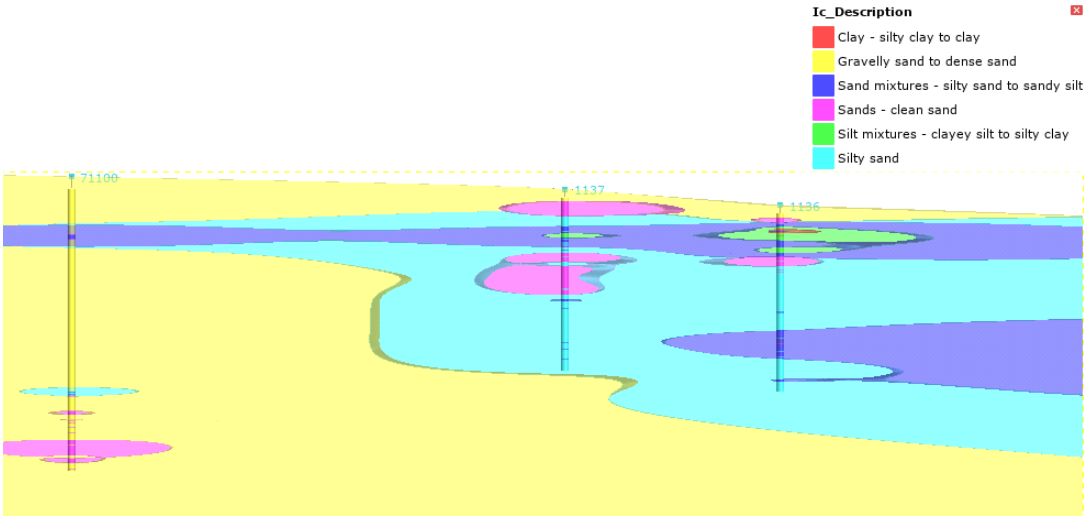
2. Add an appropriate trend.

Step 5: Generate and Validate the Volumes

1. Double-click **Surface Chronology** to re-order and activate the surfaces to generate volumes.



2. View the **Output Volumes** to ensure the defined cutting relationships were appropriate, if not, re-order the surfaces.

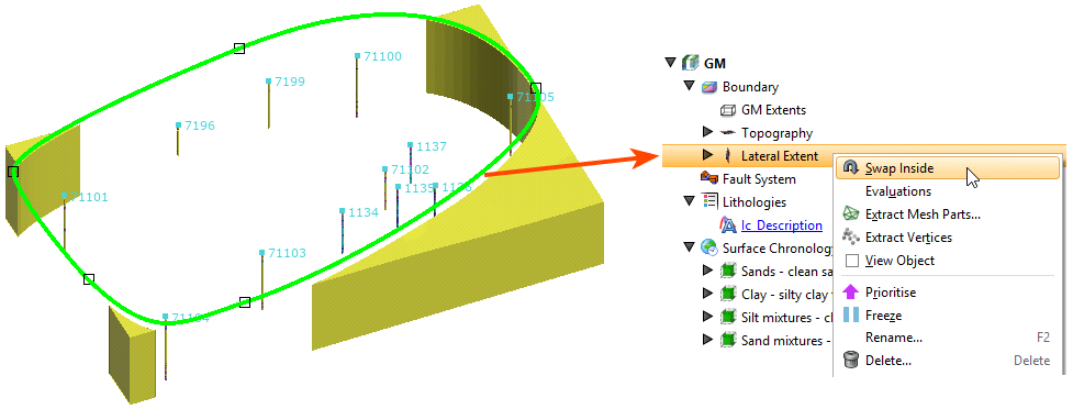


For more information, see the Surface Chronology topic in the online help.

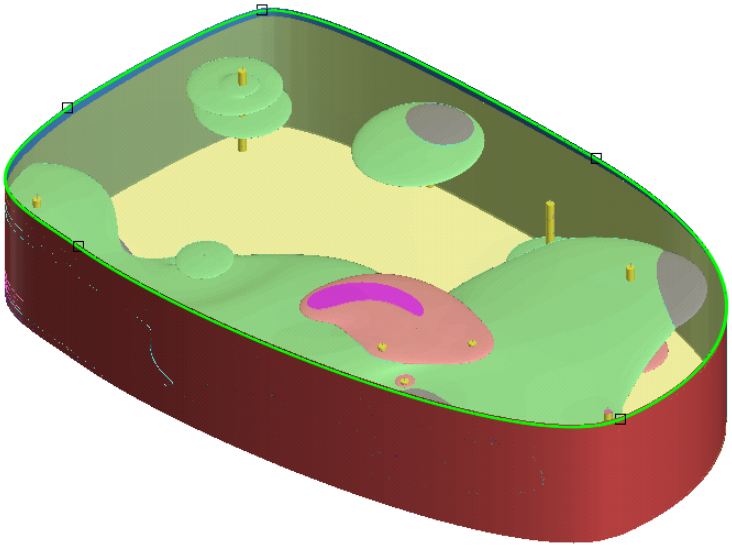
Step 6: Apply a Boundary

If necessary, you can apply a custom boundary to your model, based on the distribution of your input data. Apply a boundary around the model input data by creating a lateral extent.

If your resulting model is the inverse of what you expect, right-click the **Lateral Extent** and select **Swap Inside**.



The model is now within the specified boundary.



For more information, see the Model Boundary Editing topic in the online help.

Step 7: Share Your Model

Now that your model is complete it's time to share it! Sharing your models is easy, whether it's for peer or supervisor review or sharing with a client or stakeholder. There are a number of options available for sharing your model:

- Exporting your model
- Sharing with View
- Sharing with Leapfrog Viewer
- Creating a movie
- Collaborating with Central