Working with truly 3-dimensional data types – 3D polylines and multipatches

Overview:

In this exercise, we will briefly introduce the way that ArcGIS Pro can be used to visualise, query, and analyse truly 3-dimensional data. We will explore some multi-patch geological data for the city of Nottingham in the UK, and take a brief look at some of the ways in which 3-dimensional data can be processed. Note that this practical is intended only to provide a brief introduction to the visualisation and processing of 3-dimensional data in ArcGIS and is not a comprehensive tutorial on its functionality in this area.

Download the Data for the Exercise:

Go to the British Geological Survey's web site and download the 'Lithoframe250 Nottingham-Melton multipatch format' data here, after agreeing to the licence conditions: http://www.bgs.ac.uk/downloads/start.cfm?id=1855 . Multi-patches are one of several 3-dimensional formats used by ESRI: https://desktop.arcgis.com/en/arcmap/latest/extensions/3d-analyst/multipatches.htm. Typically, they consist of triangles defined by nodes with x, y, and z coordinates, though sometimes other basic shapes are used. The triangles can form open surfaces or closed volumes. Lithoframes are British Geological Survey's 3-dimensional means of presenting geological data. For ESRI software, BGS generally use unclosed multipatch features. The above link contains a set of multi-patch data for geological formations underlying the Nottingham area of the UK, as well as Ordnance Survey data – a Digital Elevation Model and some raster backdrop imagery of the surface features. Unzip these data to a suitable folder location.

We have created two further map layers for use with this exercise:

- **Planned_bhole**: A 3D polyline, depicting the depth of a proposed borehole within the study area
- **Fencediag**: a 2D polyline, which we will use to generate a cross-sectional graph of the underlying geology later in this exercise.

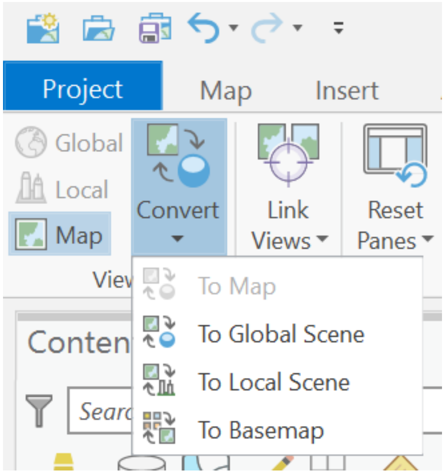
Visualising Multipatch Data:

Let us begin by viewing these data within ArcGIS Pro: open up the 'Notts-Melton250k.lyr' file to display all of the data that you have just downloaded. The **Notts-Melton250k_OS_Miniscale.tf** layer provides a coarse spatial resolution raster tiff of the surface features in this study area, whilst the **Notts-Melton250k_OS_250k.tif** layer (see the open data folder) provides a 1:250,000 scale raster representation of surface features in this area. **OSDTM** is a digital elevation model for the study area. Begin by turning on and off the visibility of these three layers, to familiarise yourself with the study area. Load up the **fencediag** and **planned_bhole** layers too.

Next, so that we can explore the underlying geological map layers, right-click on each of these three layers in turn in the left-hand table of contents and select **remove**. If you right-click on any one of the geology layers that remain in the left-hand table of contents window and select *attribute table*, you will see that each consists of a single feature and that its type is listed as *multipatch* in the second attribute field **shape** (other fields are simply feature unique ID numbers, Red-Green-Blue colour combinations for display, and the name of the strata to be displayed). If you right-click on **planned_bhole** in the left-hand table of contents and look at its table of attributes, under the *shape* field, you should see that it is listed as 'polyline ZM', meaning that the polyline has 'z' coordinates describing the height of vertices and is therefore 3-dimensional. Do the same for **fencediag** and you will see that in its table of attributes, the *shape* is listed as a regular *polyline*, without any mention of Z coordinates.

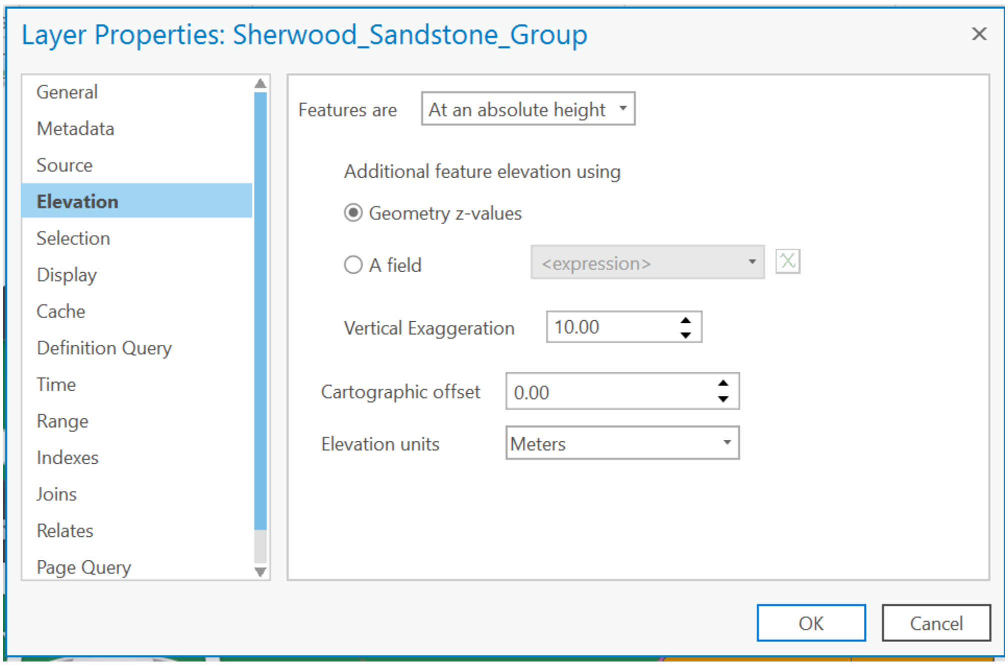
The difficulty in looking at these data in ArcGIS Pro as a map is that whilst the 2-dimensional spatial extents of the various map layers are clear, their 3-dimensional spatial extents are not currently obvious. To see the three-dimensional nature of the data, we need to convert the display from a map to a scene. As the study area (Nottingham) is relatively small, a local scene is preferably to a global one, which would typically be used at international or continental scales.

To conver the map, head for the *View* menu, then choose *Convert…To Local Scene*

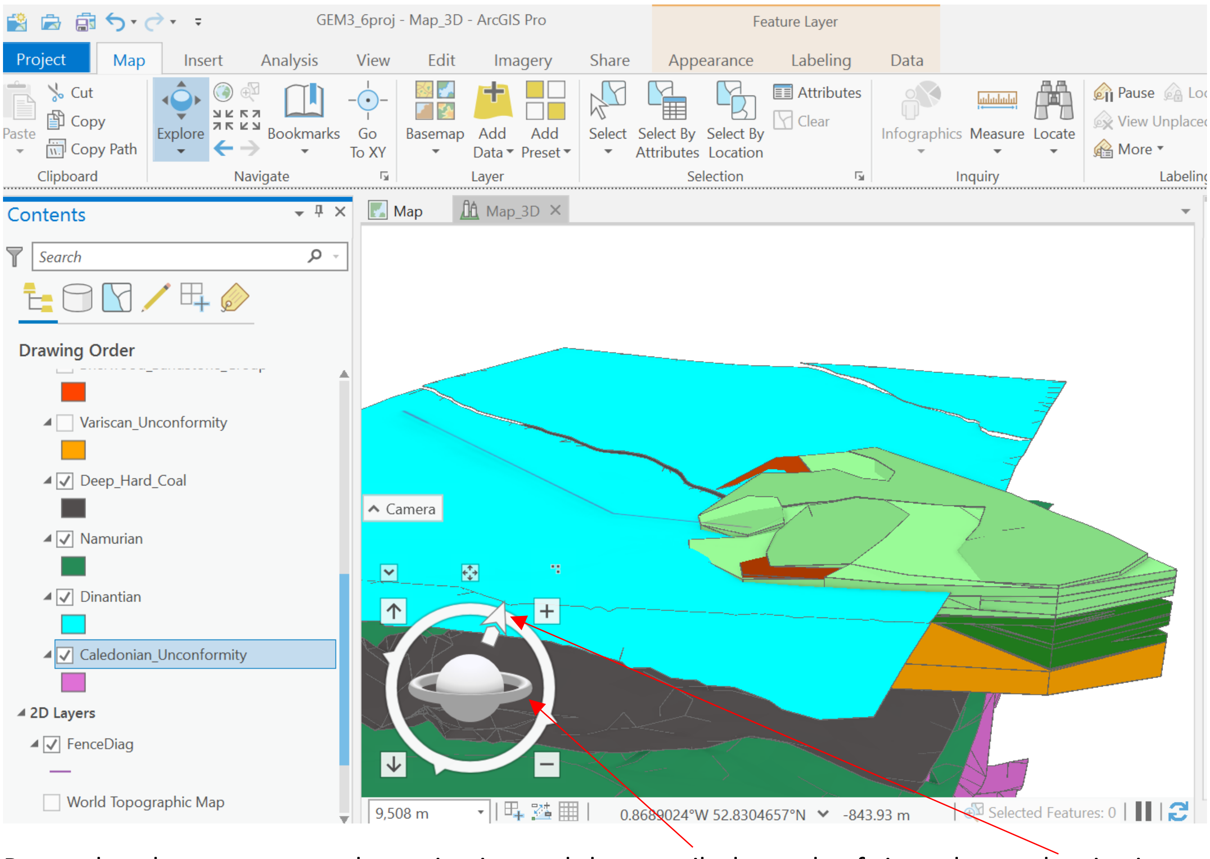


ArcGIS Pro will then automatically sort the data into those layers that are truly 3-dimensional (i.e. with x, y, and z coordinates defining their spatial locations, such as the multi-patch layers) versus those that are 2-dimensional (i.e. with x and y coordinates only). Additionally, ArcGIS Pro will introduce a *ground* layer, which comprises elevation data used for display. By default, ESRI's world elevation base data layer will be sourced from the cloud and used for this purpose.

You may find the geology easier to navigate visually if you exaggerate height differences in layers. This is typically done by a vertical exaggeration factor, a multiplier applied to z coordinates prior to display. To set this, right click on each of the multi-patch geology layers in turn and choose *properties*. Under *elevation,* set the *vertical elevation* to **10** rather than 1, repeating this for all layers:



To see how the geology multi-patch layers overlie one another, you may find it helpful to turn off the visibility of the **ground layer**. You may wish to turn on and off the visibility of some of the multi-patch geology layers too, so you can see their relative vertical positions.



Remember that you can use the navigation tools here to tilt the angle of view, change the viewing direction and zoom in and out.

1. Question

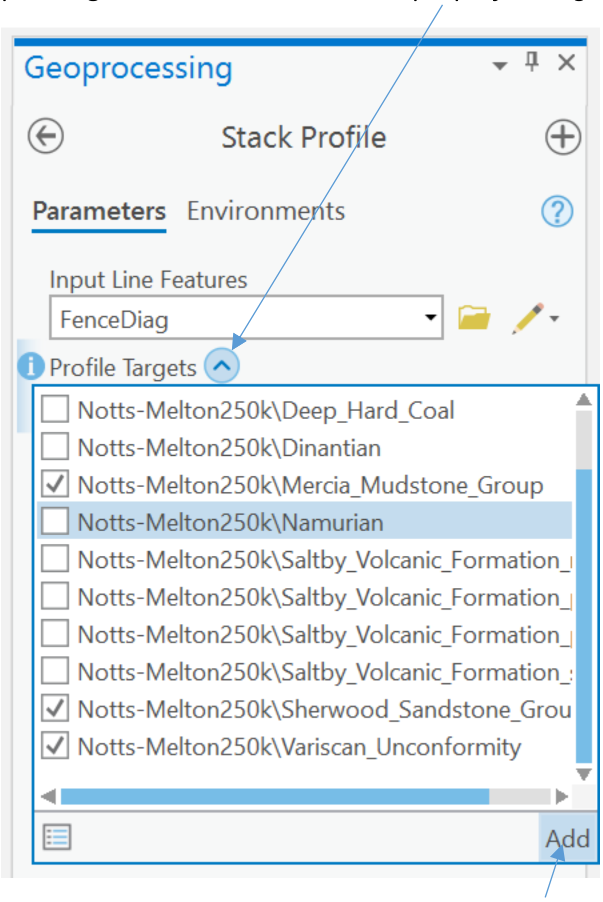
Which layer is the deepest of the various geological layers? (For the answer, see the last page of this handout)

Analysing multi-patch data

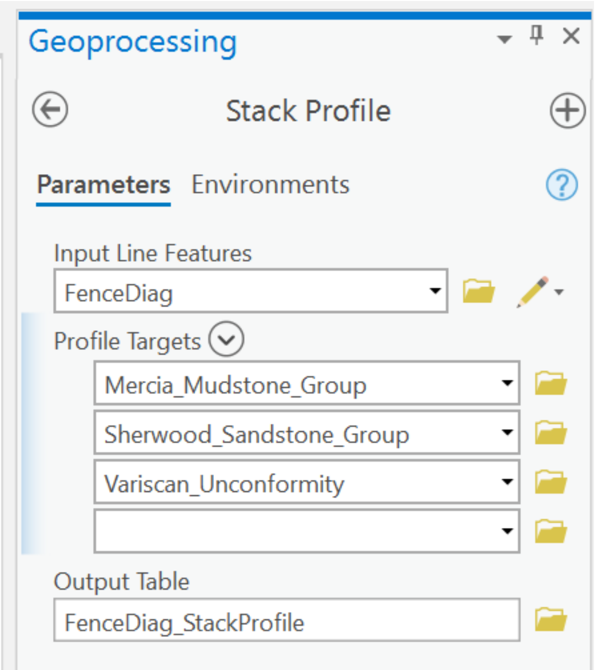
It is possible to analyse three-dimensional data such as 3D polylines and multipatches using geoprocessing tools, just as you would do with 2-dimensional data. To explore these tools, first make sure you activate the 3D Analyst (and preferably Spatial Analyst) extensions via the *project* menu / *licensing* and then the *configure your licencing options* button.

As a first example of this, we will generate a table showing the depth to various geological strata along a transect, defined by the **fencediag** polyline. To do this, head for the *Analysis* menu, then press the *tools* icon on the ribbon to activate the geoprocessing toolbox. Then, search for 'stack', and run the *stack profile* tool.

As *input line features*, choose **fencediag**, and then select some of the geological multipatch layers by pressing the button to select multiple *profile targets:*



After selecting your layers and pressing the *add* button, choose a suitable table name for your output:



ArcGIS will now generate a table with the locations and depths of these three strata along the length of the **fencediag** transect across our study area – you should find this under *standalone tables*. Right-click and choose *open* to take a look at it.

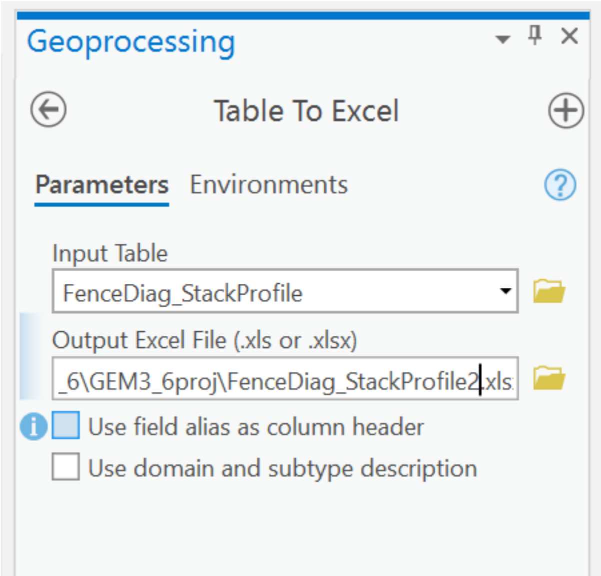
The *First_dist* and *First_Z* fields contain the distances along the **fencediag** transect in metres. The *sec_dist* and *Sec_Z* fields are essentially the same information, whilst *line_id* is the ID of the line in **fencediag** that was used to generate the table (there is only one line with ID zero). *Src_name* indicates the multipatch layer used to derive the height information.

Table

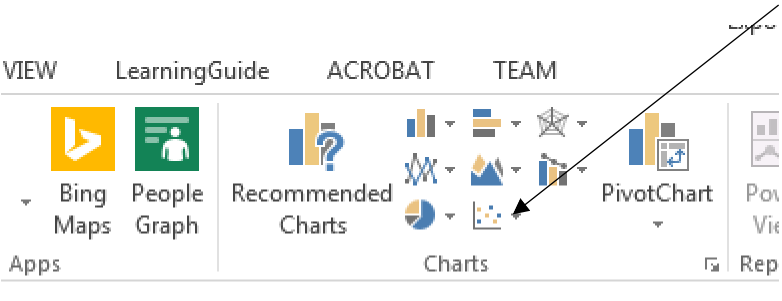
fenceout

Rowid	OBJECTID	FIRST_DIST	FIRST_Z	SEC_DIST	SEC_Z	LINE_ID	SRC_TYPE	SRC_ID	SRC_NAME
178	0	4875.800045	59.890227	4897.487487	60.226647	0	Multipatch	0	Notts_Melton250k_Mercia_Mudstone_Group
179	0	5055.193622	63.197874	5155.806944	63.483532	0	Multipatch	0	Notts_Melton250k_Mercia_Mudstone_Group
180	0	4897.487487	60.226647	5010.404902	62.910204	0	Multipatch	0	Notts_Melton250k_Mercia_Mudstone_Group
181	0	6012.803706	58.626304	6657.932434	52.823521	0	Multipatch	0	Notts_Melton250k_Mercia_Mudstone_Group
182	0	6657.932434	52.823521	6908.821678	48.917832	0	Multipatch	0	Notts_Melton250k_Mercia_Mudstone_Group
183	0	5403.476849	62.521338	5483.59705	62.05983	0	Multipatch	0	Notts_Melton250k_Mercia_Mudstone_Group
184	0	5483.59705	62.05983	5939.69585	59.187533	0	Multipatch	0	Notts_Melton250k_Mercia_Mudstone_Group
185	0	5332.893267	62.981694	5403.476849	62.521338	0	Multipatch	0	Notts_Melton250k_Mercia_Mudstone_Group
186	0	8484.290173	34.011662	8613.529106	32.525354	0	Multipatch	0	Notts_Melton250k_Mercia_Mudstone_Group
187	0	6908.821678	48.917832	8484.290173	34.011662	0	Multipatch	0	Notts_Melton250k_Mercia_Mudstone_Group
188	0	8613.529106	32.525354	8718.702084	31.59812	0	Multipatch	0	Notts_Melton250k_Mercia_Mudstone_Group

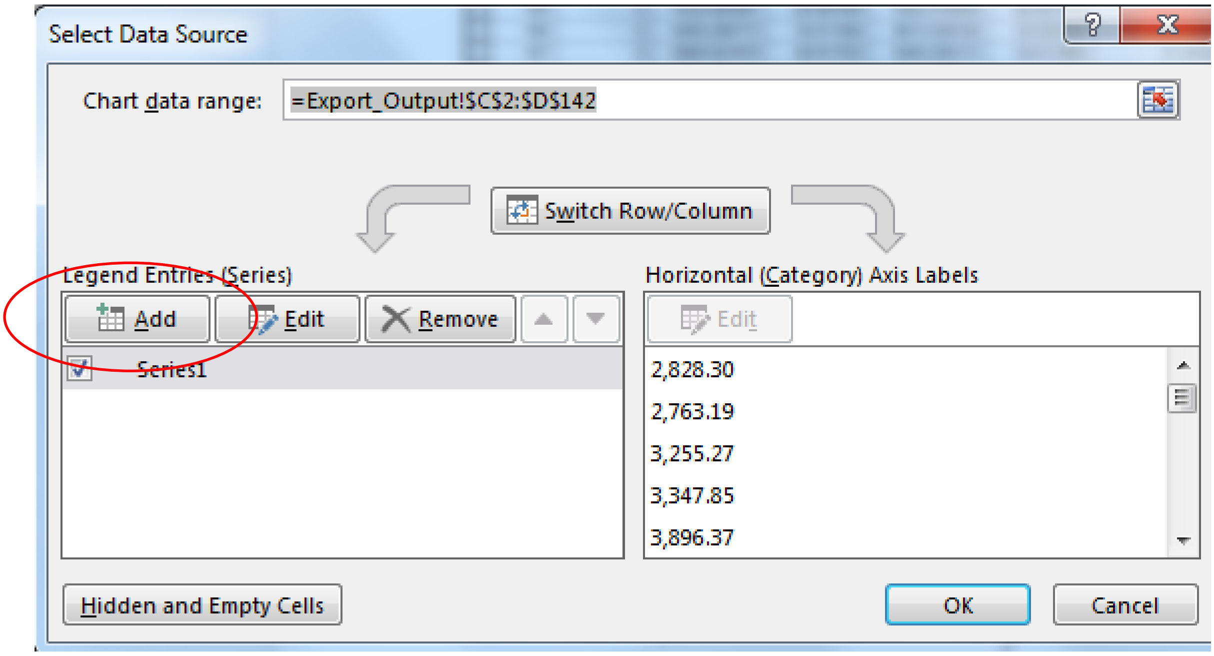
Although ArcGIS can make a graph of these data, it is probably easier to do so in Excel. To export this table to excel, head back to the geoprocessing panel, and this time, search for ‘excel’, then run the *table to excel* tool to create an Excel format version of this table:



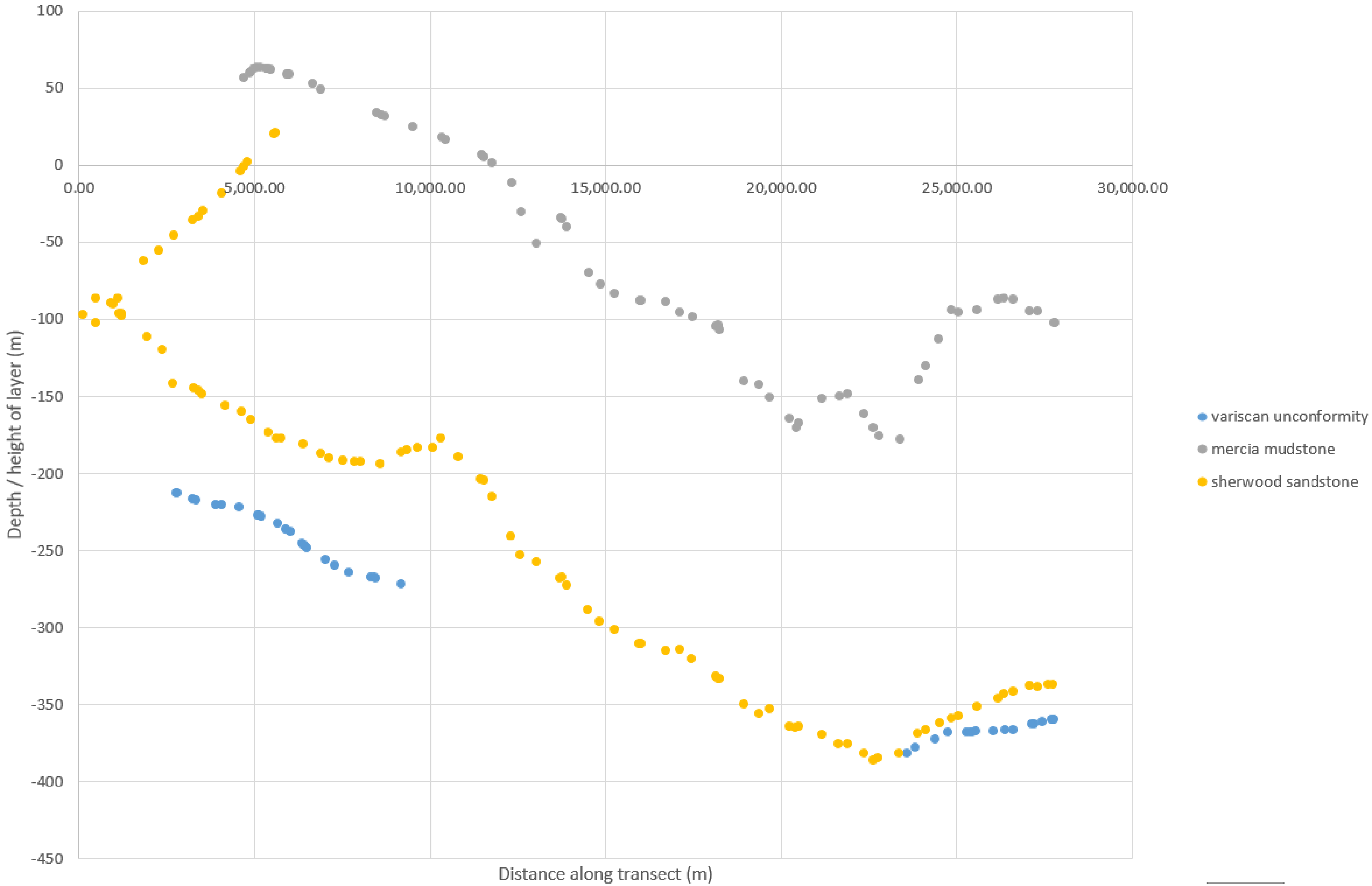
You should now be able to open up and view your data in Excel. If you mark up the data under the 'first_dist' and 'First_z' fields for the Variscan Unconformity rows (the first 140 or so) and then choose *insert* from the menus, you should be able to create a scatterplot of these data:



Right-click on the chart that is created and choose *select data* and then *add.* You can then add further points to this graphic by marking up relevant cells in your spreadsheet to depict the sandstone and mudstone distances and depths in different colours:

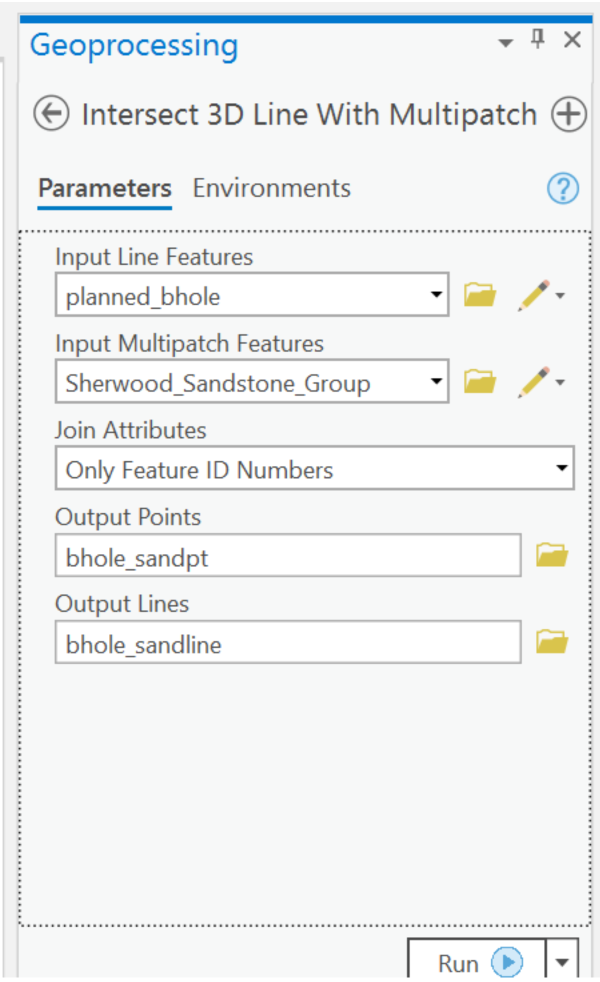


With a little more work in Excel (e.g. choosing *edit* on the above screen and using this to edit the names of each series, and also labelling axes), you should be able to generate output that looks similar to that on the following page:


100
50
0
-50
-100
-150
-200
-250
-300
-350
-400
-450
0.00
5,000.00
10,000.00
15,000.00
20,000.00
25,000.00
30,000.00
Depth / height of layer (m)
Distance along transect (m)
variscan unconformity
mercia mudstone
sherwood sandstone

This is very similar to the idea of a fence diagram. Should you wish to create a fence diagram, you can also do this via the *fence diagram* tool within the geoprocessing toolbox (search for 'fence'), but this tool creates a fence diagram from one or more elevation layers, held as rasters or DEMs. The output is a vertical multi-patch layer – the fence diagram.

Finally, we will briefly look at another example of one of the 3-dimensional analysis operations in ArcGIS Pro – identifying the strata that intersect with our proposed borehole. To do this, head for the geoprocessing panel once more and search the tools for '3d line'. You should be able to find and run the *intersect 3D line with multipatch* tool. As the input, choose the **planned_bhole** layer (basically a vertical line depicting the proposed shaft for a borehole), then choose the multipatch layer for the Sherwood sandstone group as the *input multipatch features*. Optionally, ArcGIS Pro will create a 3D point indicating the location of the point where the borehole line and sandstone multipatch intersect. Specify names for the *output lines* and *output points,* then run the tool:



Within the table of attributes of this output layer, a *dist_3d* field will be used to store the distance along the line at which the two intersect. Similarly, the output line file will be split at the point where the borehole 3D line intersects with this surface. The lines will have the same *dist_3d* field, but also a *length_3d* field too. Choose an appropriate name and location for both the *output points* and *output lines* created.

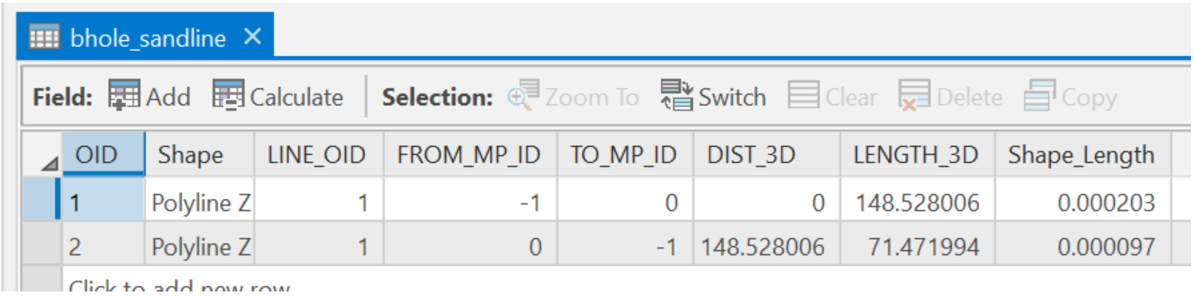
After running the tool, take a look at the attributes of the point and line file that you have created.

2. Question: At what depth would the proposed borehole enter the Sherwood sandstone (intersect with the multipatch of this name)? Answer is provided on the following page.

Answers:

1. Caledonian unconformity

2. 148.5 metres – as should be apparent from the attributes of either the point or line file that you created.



bhole_sandline

Field: Add Calculate Selection: Zoom To Switch Clear Delete Copy

OID	Shape	LINE_OID	FROM_MP_ID	TO_MP_ID	DIST_3D	LENGTH_3D	Shape_Length
1	Polyline Z	1	-1	0	0	148.528006	0.000203
2	Polyline Z	1	0	-1	148.528006	71.471994	0.000097