Introduction to the Geological Record
Week 6 Practical: Introduction to Digital Topographic data

During this practical, you will learn how to import topographic data into a software in order to perform a basic topographic analysis. The software that you will use is called ArcGIS and it includes a series of packages. You will use ArcMap and ArcScene.

The analysis will be performed in the area around the Lake District (that you will visit during your field trip). The Digital Elevation Model (DEM) of the area is from SRTM. It is a ~23-m resolution DEM, which means that each pixel is approximately 23 meter wide. The DEM is available on Learn.

During this practical, you will be dealing with a few large files. I strongly recommend that you work on the hard drive of the computer, in the folder "Workspace" on C:

DO NOT FORGET TO COPY WHAT YOU HAVE CREATED IN THIS FOLDER AND PASTE IT ONTO YOUR HOME DRIVE OR A USB STICK BEFORE LOGGING OFF (all your work will otherwise be deleted when you log off). You will need ~50 Mb of space.

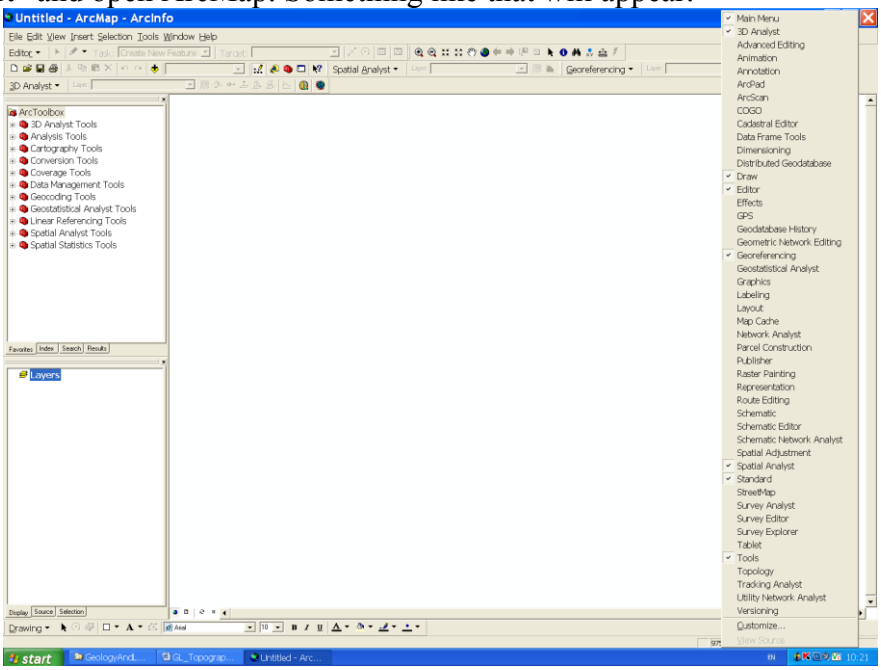
I. Downloading the topographic data

I have put on Learn a zip file containing the DEM of the area and a picture of the geological map of the area. Download the zip file, place it in a folder (e.g., create a "practical6" folder in "C:/Workspace") and unzip the file. IMPORTANT: place all the files from the zip file and all the files that you will create in a UNIQUE folder that you will not move. You cannot overwrite files created with ArcMap: once you have created a file, you cannot create another file with the same name. If you want to move or delete files, do it through the **ArcCatalog** (see below).

Also, make sure that the path to your directories (e.g. C:/Workspace/Practical6) contains no names with spaces. Spaces confuse ArcGIS and the computer may not find your files if you have spaces in the folder names. "MyFolder" is ok, "My_Folder" is ok, "My Folder" is not.

II. Opening ArcMap + basic information

Go to "Start" and open ArcMap. Something like that will appear:



On the left of the ArcMap window, two windows should be open: the "Table of Contents" (ToC) window and the Toolbox window. If the ToC window is not open, go to Windows → Table of content. If the Toolbox window is not open, click on the red toolbox button at the top. The toolbox window is where you will find most of the tools that you will use.

If something doesn't work in ArcMap, make sure that:

(1) you have enough space on your disk (if your disk is full, ArcMap will not tell you, it will just stop working!)

(2) <u>the commands that you are willing to use are activated: go to "Customize" → "Extensions" → tick the boxes that you need (in your case, "3D analyst", "geostatistical analyst" and "spatial analyst" are the ones that you will use).</u>

Before starting, make sure that all the toolbars that you will need are displayed. Right-click anywhere in the toolbar at the top: a menu will appear, as shown on the previous figure. Make sure that the following toolbars are selected:

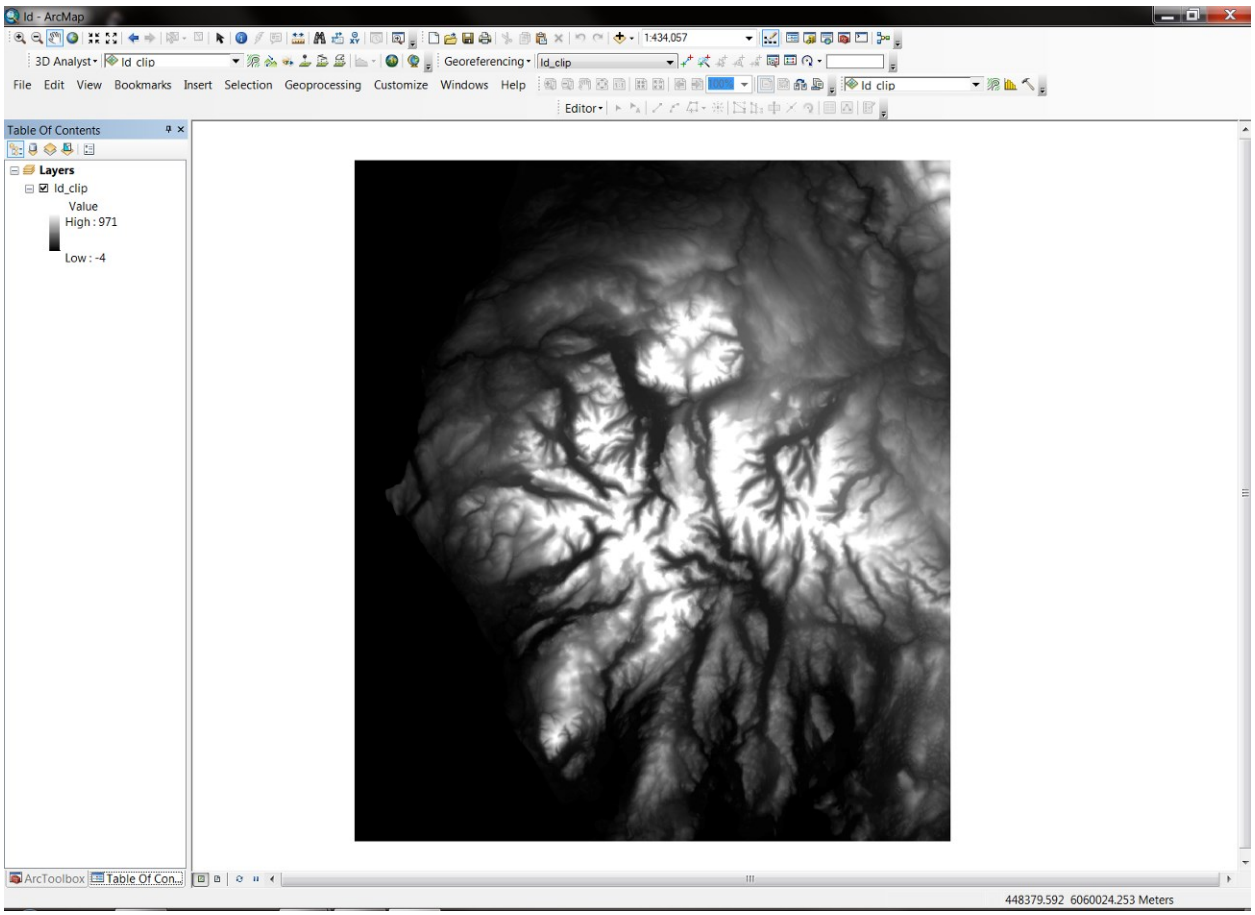
3D Analyst – Editor – Georeferencing – Layout – Spatial Analyst – Standard – Tools.

You are now ready to use ArcMap. Don't forget to save your ArcMap file from time to time.

III. Basic Operations with ArcMap

<u>Note: If you want to move, copy, rename or delete files, do it through the ArcCatalog:</u> 

To begin with, you will load the DEM of the Lake District: click the button "add data" (the plus on the yellow square) and move to the folder where you have placed the DEM. If the folder doesn't appear in the selection, you will have to "connect to the folder" using the button with the folder symbol with the little "+". Select "ld_clip" ("ld" is for Lake District) and click on "Add". Your window will look like that:



The “Table of Contents” window shows the different layers displayed. At the top of this window are buttons that allow you to show the layers by drawing order (the most useful), by source or by visibility. When layers are shown by drawing order, you can hide them, move them up or down (= towards the foreground or background), or change their properties (for example the colour scheme) by clicking on their name. CAUTION, right-click and double-left-click do different things!

If you right-click on one of the layers in the layer window, you have the option of removing it. When you remove something from ArcMap, the file itself is not deleted: you can import it again if you want.

You can zoom in and out and navigate in the landscape, using the mouse or the magnifier/hand/globe tools in the toolbar at the top. The globe will fit the zoom to display all the layers in the window. If you right-click on one of the layers in the layer window, you have the option of “zooming to layer”: this can be useful if you have lost your image by navigating too far away from it.

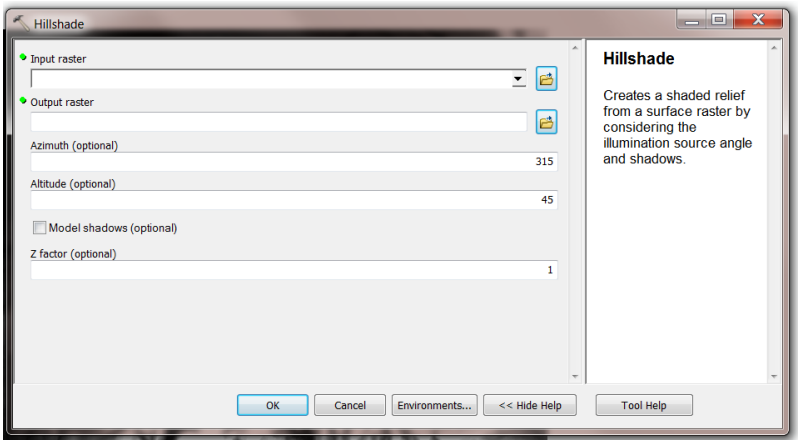
IV. Basic topographic analysis operations.

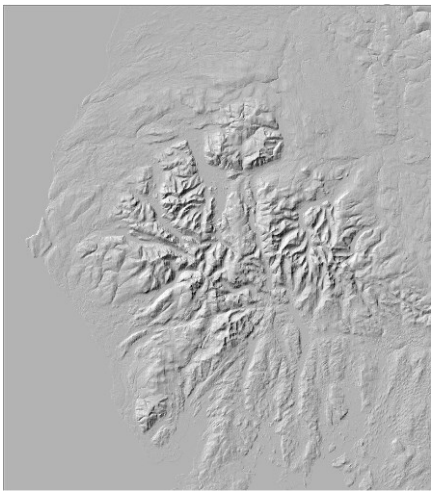
IMPORTANT: ***you can be lost very quickly, submerged by the number of files that you will create. I suggest that for each file name, you use a prefix that refers to the area that you are studying (or the exercise number) and a suffix that refers to the type of data. Example: you can use the prefix “ld” for the Lake District exercise. “ld_hillshd” will be the hillshade file of the area, “ld_slope” will be the slope file, etc.***

1) Producing a shaded relief map of the area

Shaded relief can enhance some of the topographic features in the landscape. To generate such a map, go to the Toolbox window → Spatial Analyst tools → Surface → Hillshade. This will open a window (see right):

→ select the DEM from the dropdown list as the “input raster” and click on the “open folder” icon to the right of “output raster”; navigate to your destination folder, give a name to the hillshade file (e.g. “ld_hillshd”) and click on “Save” then click on “OK”. You should obtain something like that (see below): can you spot hills, valleys and ridges?

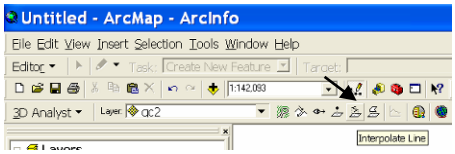




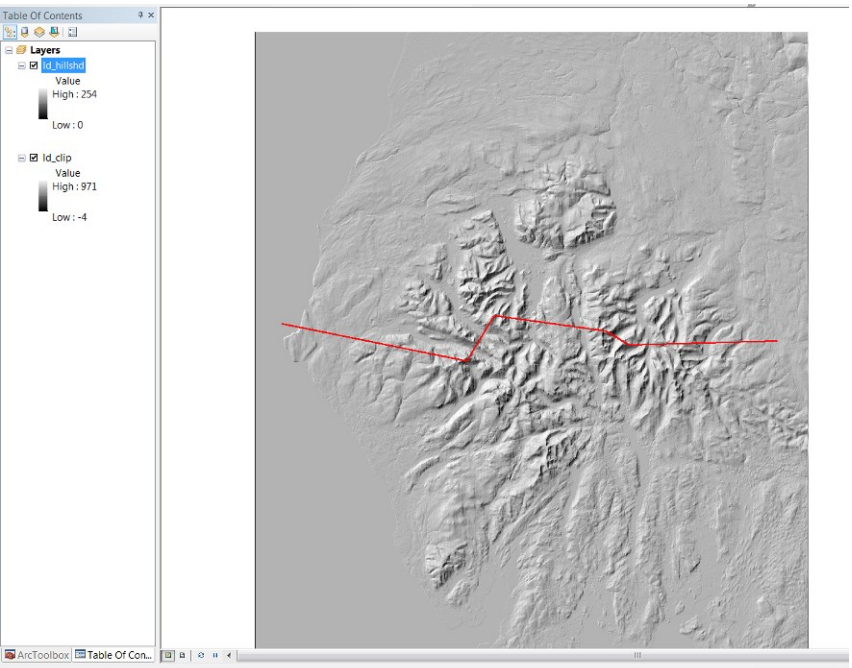
2) Extracting topographic profiles

You may want to know how much relief there is in an area. Topographic profiles can allow you to easily visualise the relief along a line of transect, for example from a ridge line to another, across a valley or along a given path. Let's try to image the relief along a line going across the whole Lake District massif from the coast to the eastern side of the massif. We will try to cut through a couple of the prominent valleys in the area.

In the 3D analyst toolbar, make sure that the layer selected is the DEM layer (that is, the one that contains the elevation data, not the hillshade one) and click on the "interpolate line" button:

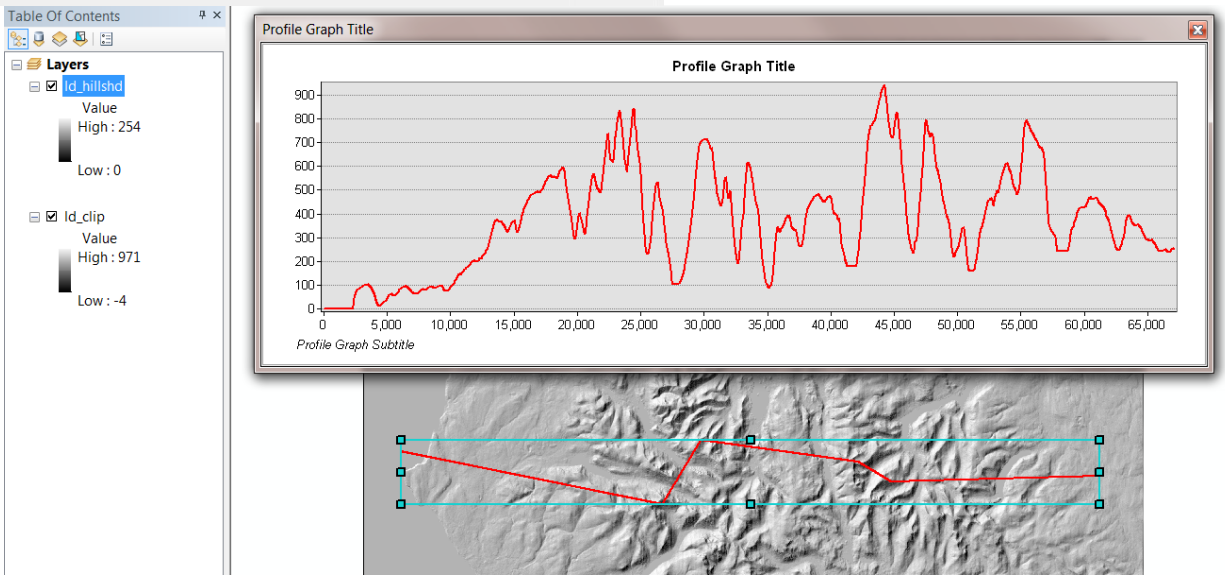


Then, trace the line along which you would like your profile to be traced (see example below). Double-click when you are finished.



You can delete the line if you are not happy with it (just press the "delete" key – if the line is not selected, click on the black arrow button in the toolbar at the top and select the line).

When you are happy with your line, click on the "Create profile graph" button (2nd button to the right of the "interpolate line button): your topographic profile will appear. Elevation is in meters in this case. Note: the left tip of the profile corresponds to the point where your line begins (it is West if you have traced your line from W to E, it is East if you have traced it from E to W).

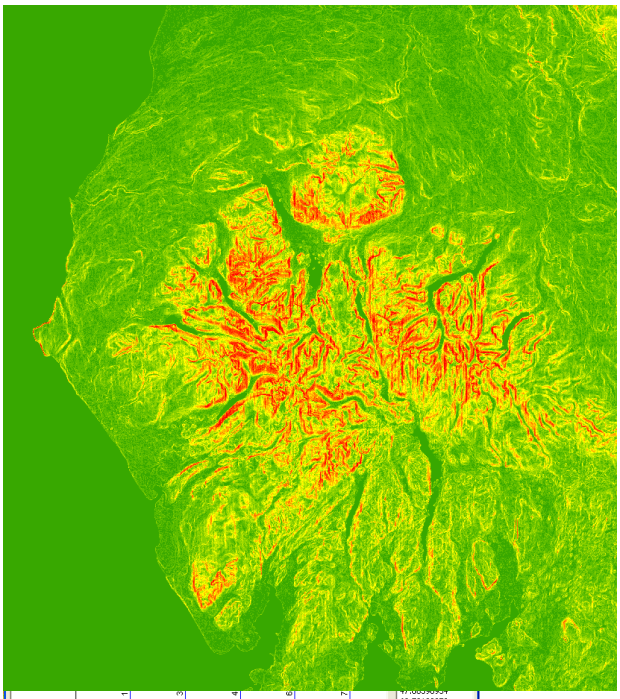


If you right-click on the graph, you can "copy as graphic" and paste it in power point or Word for example. You can also "export" it as Picture or Data (see the different tabs in the window that appears). In "Data", you can choose the text format and open the file with Excel

(in this case, you will have two columns, one with the distance and the other with the elevation). In “Advanced properties”, you can change the title, axis labels, etc.

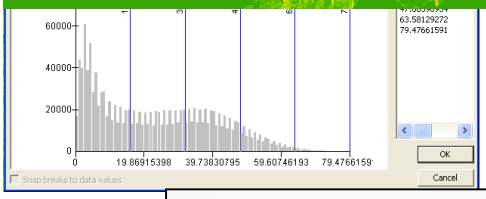
3) Performing a slope analysis

Slope is probably one of the most useful pieces of information that can be used to assess how geology affects topography. The steepness of the slope is usually (but not always!) correlated to the resistance of the rocks exposed. To obtain a slope map of the area, go to the Toolbox window → Spatial Analyst tools → Surface → Slope. This will open a window: proceed as for “hillshade” (described above). Give your output file an informative name (e.g. “ld_slope”). You should obtain something like that (see below):



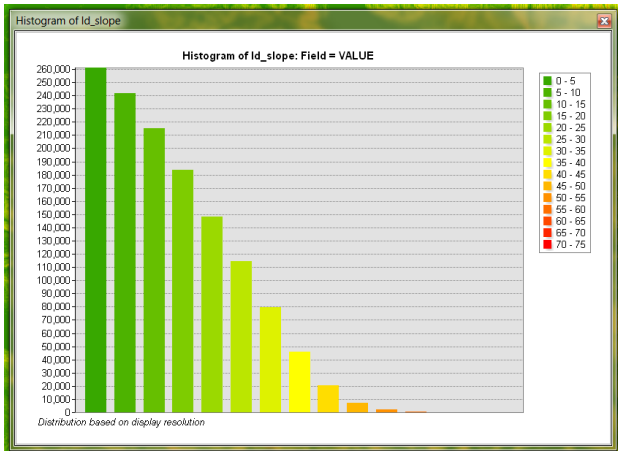
Green represents low slopes, red are steep slopes.

To rearrange the size and boundaries of the bins, double-click on the slope layer in the “Table of Content” window (e.g. “ld_slope”). A window will appear: click on the “Symbology” tab (see figure below). In this window, click on the “Classify” button: a new window will appear (see figure below left). In the “Method” scroll down menu, select “defined intervals” and specify the “interval size” (in degrees). Here, you could choose 5 degrees. Then click OK (twice).



Now, the slopes are colour-coded to represents the intervals 0-5, 5-10, 10-15, etc. degrees. You can now analyse the distribution of slopes in the landscapes. You can also do some statistics on this distribution: in the Spatial analyst toolbar, use the scroll down menu to make your slope file appear in the “Layer” box, then click on the histogram button (see below).

A histogram with the distribution of slopes in the studied landscape will appear, with the number of pixels per bin on the y-axis (see to the right). As with the topographic profile (see section IV.2), you can right-click on the diagram to copy (and paste) the figure or to export the picture or data (e.g. in text format; in this case you will have two columns: bin values and number of pixels with a given slope per bin).



You can analyse such distributions: is the distribution unimodal? Bimodal? What is the range of slopes in the studied area? What are the slopes with the greater frequency? What does it mean for this landscape? Feel free to discuss with the demonstrators.

V. Georeferencing images on the DEM

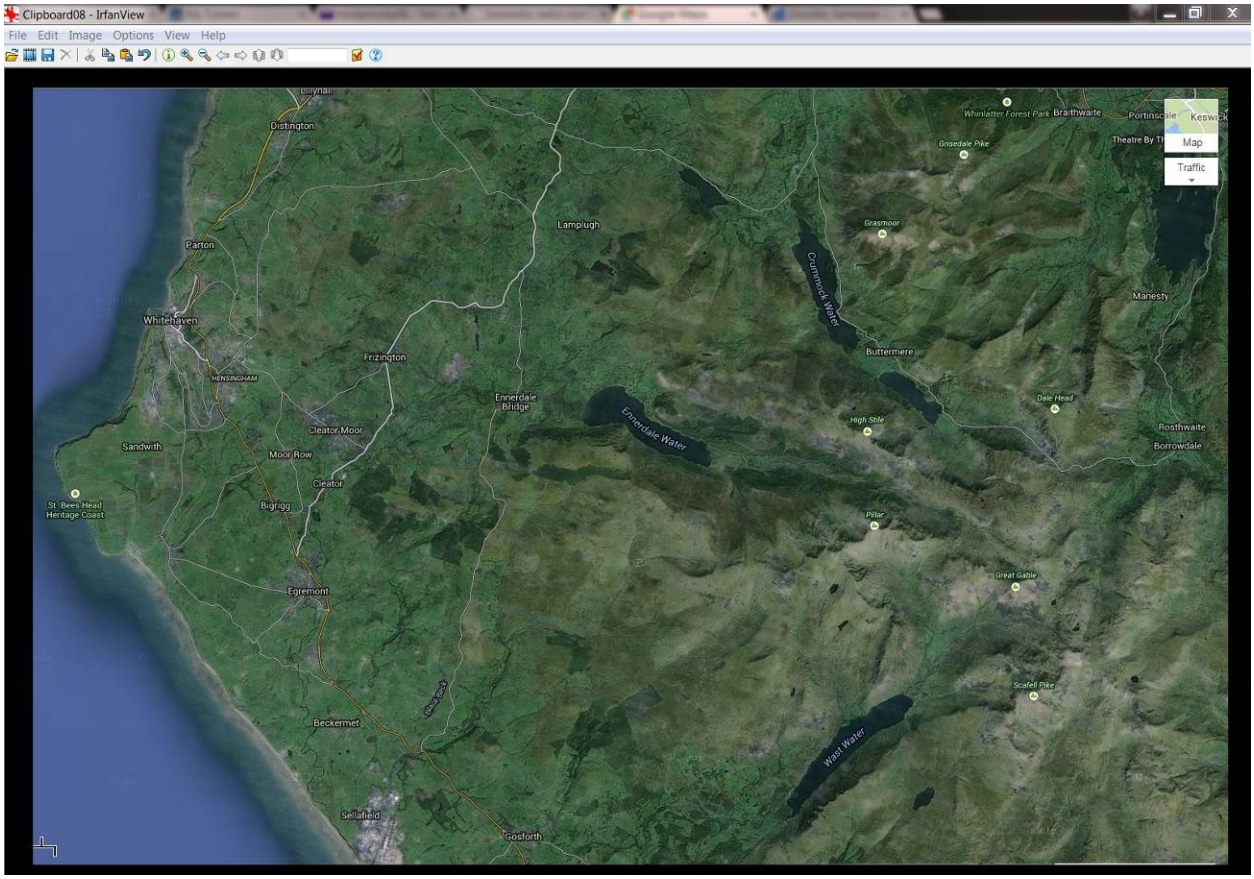
The information displayed in ArcMap so far is derived from the DEM so it allows you to visualise mostly relief and geomorphology. However, you may want to investigate how the morphology relates to other properties of the landscape: vegetation, human activity, geology… In this section, you will learn how to take such information from other sources and superimpose it on the topographic information in ArcMap. We will pick two sorts of images:

- Satellite images from Google Map,
- Geological map (in the zip file on Learn).

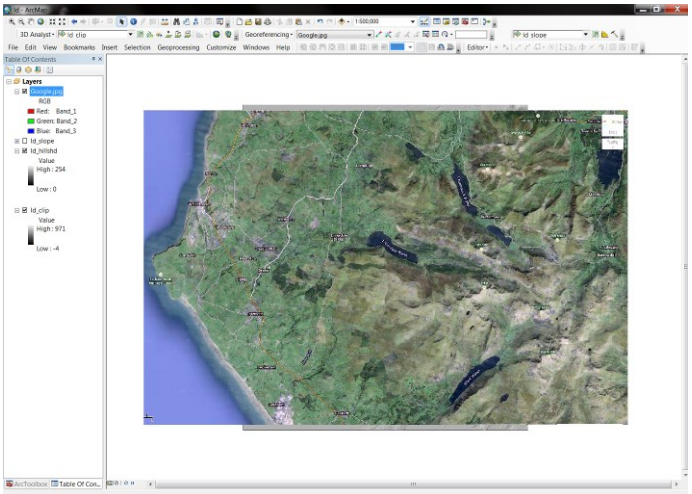
We will need to georeference the images to make sure that they are superimposed (nearly) perfectly on top of the topography. To proceed, we will use tie points which are remarkable points that are easily recognisable on both the DEM and the image that we want to georeference (e.g., summits, tributary junctions, coastal features).

Let's start with Google Map:

- move to the zone of interest with Google Map and take a screen shot (using the "Print Screen" key).
- Open IrfanView (or another visualisation software if you have another preference) and paste the screen shot.
- Select the area of interest with the mouse and crop it (Edit → crop selection). Save the image as a JPEG (I call mine "Google.jpg"). In the example below, I have decided to focus on the western part of the Lake District including the coast. You can take a screen shot of a wider area if you want, or a screen shot of a very small area that you are interested in particular, or more than one screen shot (you can create a mosaic of images by repeating the procedure below for each image).



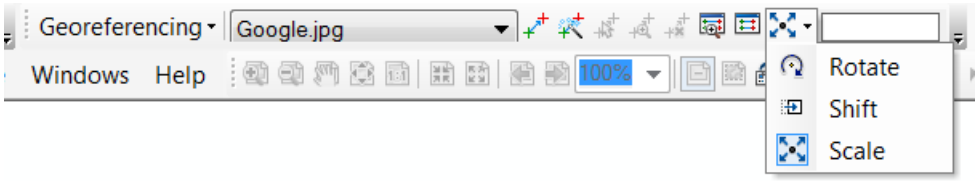
- In ArcMap, use the Add Data button and select the JPG file (don't double-click or it will just show the different layers that compose the JPG file). Click "add". You will get a message warning you that the data you are importing is missing spatial references, which is fine because we are going to georeference it now.
- Make sure the Georeferencing toolbar is displayed (see below left). In the Georeferencing toolbar, use the scroll down menu to have the jpg file appearing in the "layer" box. Then, click on the Georeferencing button → Fit to display. The image will appear in the middle of your window.



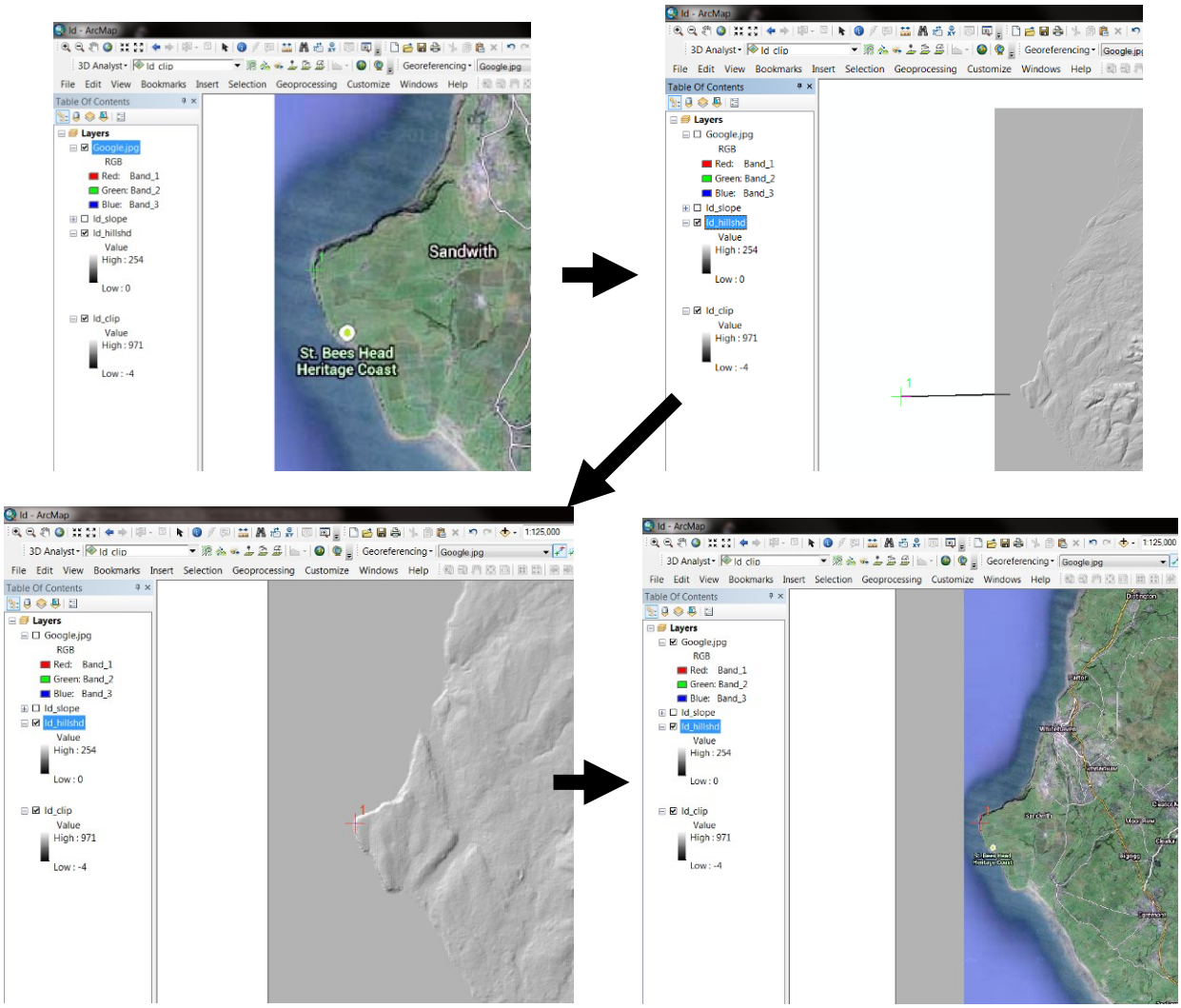
- The main tool you will be using is the "Add control point" tool, that is, the button with the green and red crosses in the Georeferencing toolbar.

IMPORTANT: make sure that the active layer in the toolbar (drop down box to the right of "Georeferencing") is still the JPG image that you are working on. Click on the button , then click on one of the

noticeable points on the JPG image (e.g. features along the coast, key summits, cliffs or valleys, lake edges) and click on the corresponding point on the DEM. Note that you can hide the JPG image in the middle of the operation, which greatly facilitates the operation. The image will be translated/rotated/distorted to make the location fit. Note: translation / rotation / distortion can be performed manually using the button at the right end of the Georeferencing toolbar (see below, try "scale" for example).

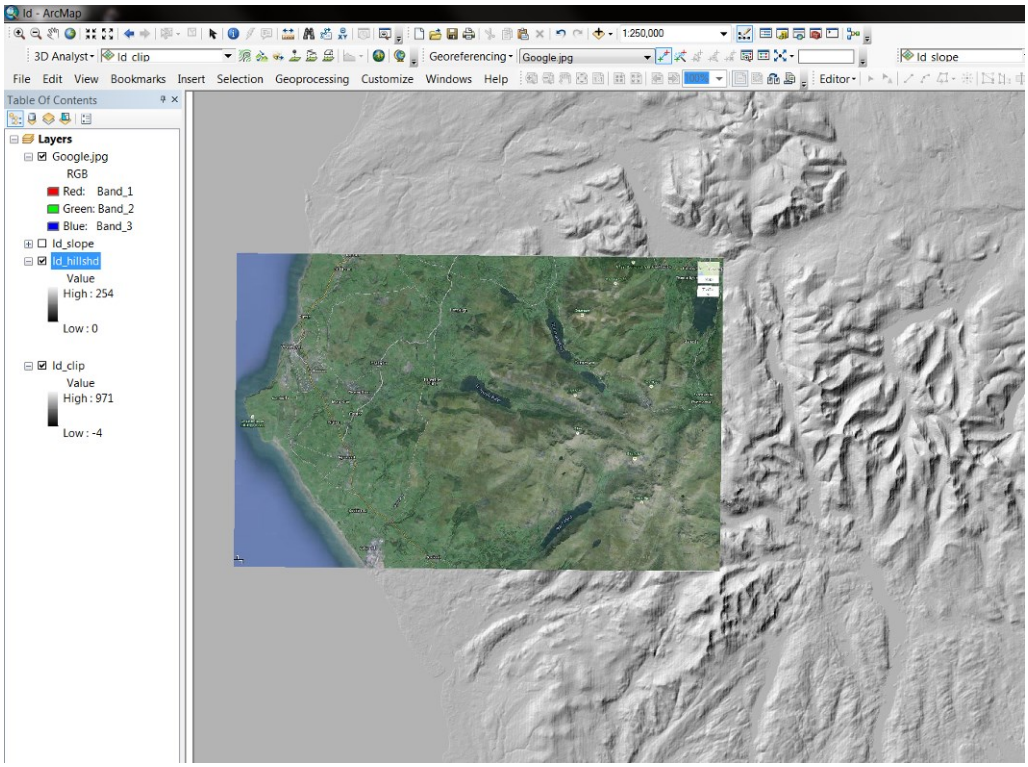


In the example below, I select the Westernmost point on the coast (on St Bees Head) (1), hide the Google image by ticking it off in the Table of Contents window (2), click on the same point on the shaded relief from the DEM (3) and show the Google image again by ticking it on in the layer window (4). The image has been translated to have the two locations fit exactly.



- Repeat the operation for a few points. You will need to do that for at least three points which will ideally be relatively far away from each other, ideally forming a wide open triangle (this increases the precision of the operation; if the three points are aligned, it doesn't constrain the transformation very well). Four points is best.

- **If you do something wrong (e.g., click when you shouldn't have done), two options: (1) click on the "Georeferencing" button → Reset transformation → all the tie points will disappear and you will have to restart again. Alternatively: (2) click on the "link table" button to the right of the Georeferencing toolbar ( ): an editable table with all the tie points will appear: you can select a tie point and remove it (e.g., the last point in the table that you have got wrong).**
- After having done this operation for a few points (features along the coast, key summits, cliffs or valleys, lake edges), the image should fit well on top of the DEM (if it doesn't, something must have gone wrong – ask a demonstrator). To stop the "add control point" tool, just click on the "select elements" button (the black arrow in the toolbar:).



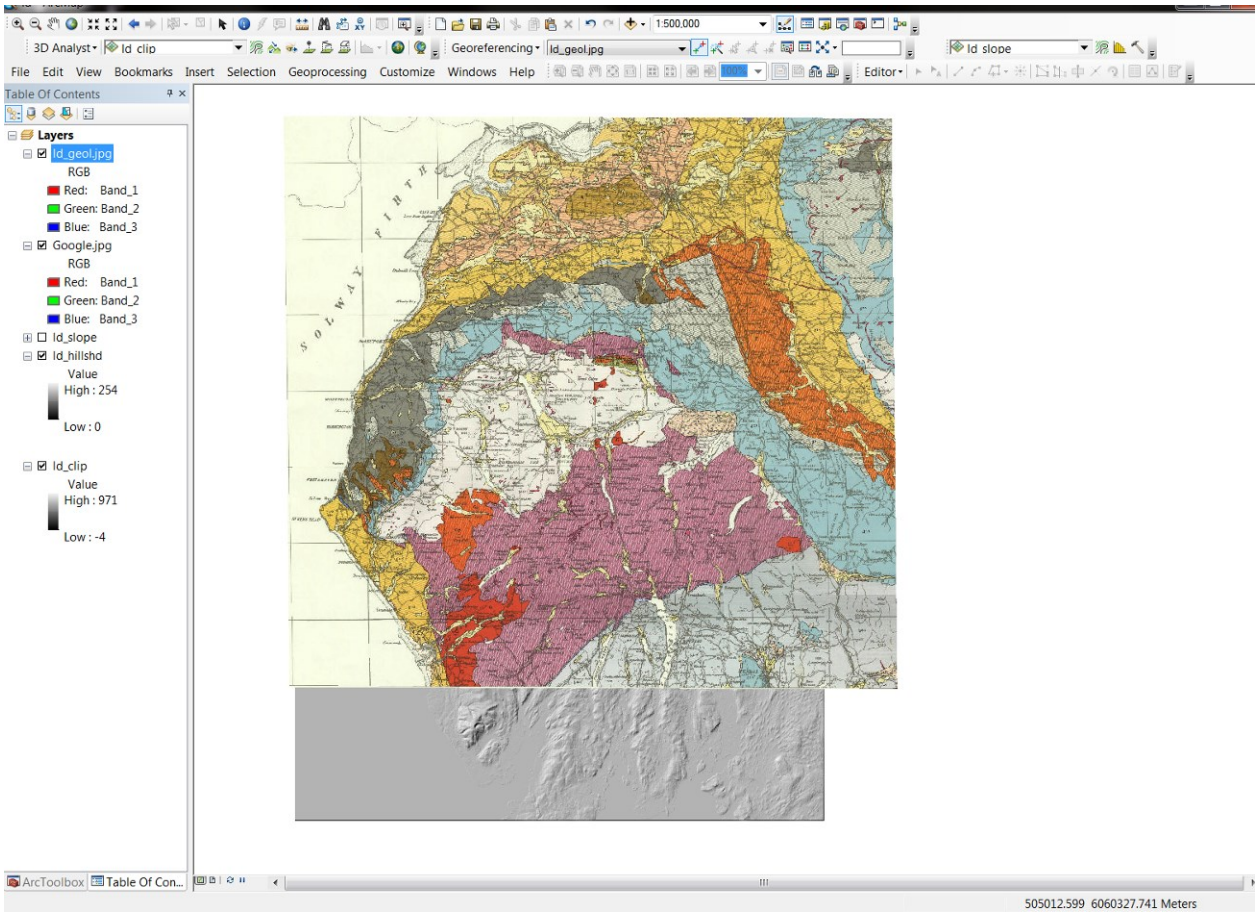
- If you are happy with the result, click on the Georeferencing button → Update Georeferencing. The crosses disappear and your image is given new spatial references. DO NOT FORGET THIS STEP or all your work with the georeferencing will be lost! If you remove the image from your ArcMap window and import it again, it will appear in exactly the same place.

Now, let's do the same with the Geological map ("ld_geol" file on learn).

- In ArcMap, use the Add Data button and select the JPG file (don't double-click or it will just show the different layers that compose the JPG file). Click "add". You will get a message warning you that the data you are importing is missing spatial references, which is fine because we are going to georeference it now.
- IMPORTANT: In the drop down box to the right of "Georeferencing", use the scroll down menu to select the jpg file as the active layer. Then, click on the Georeferencing button → Fit to display. The image will appear in the middle of your window.
- Click on the button then click on one of the noticeable points on the JPG image (e.g. key summits, cliffs or valleys, lake edges) and click on the corresponding point on the DEM. Note that you can hide the JPG image in the middle of the operation, which greatly

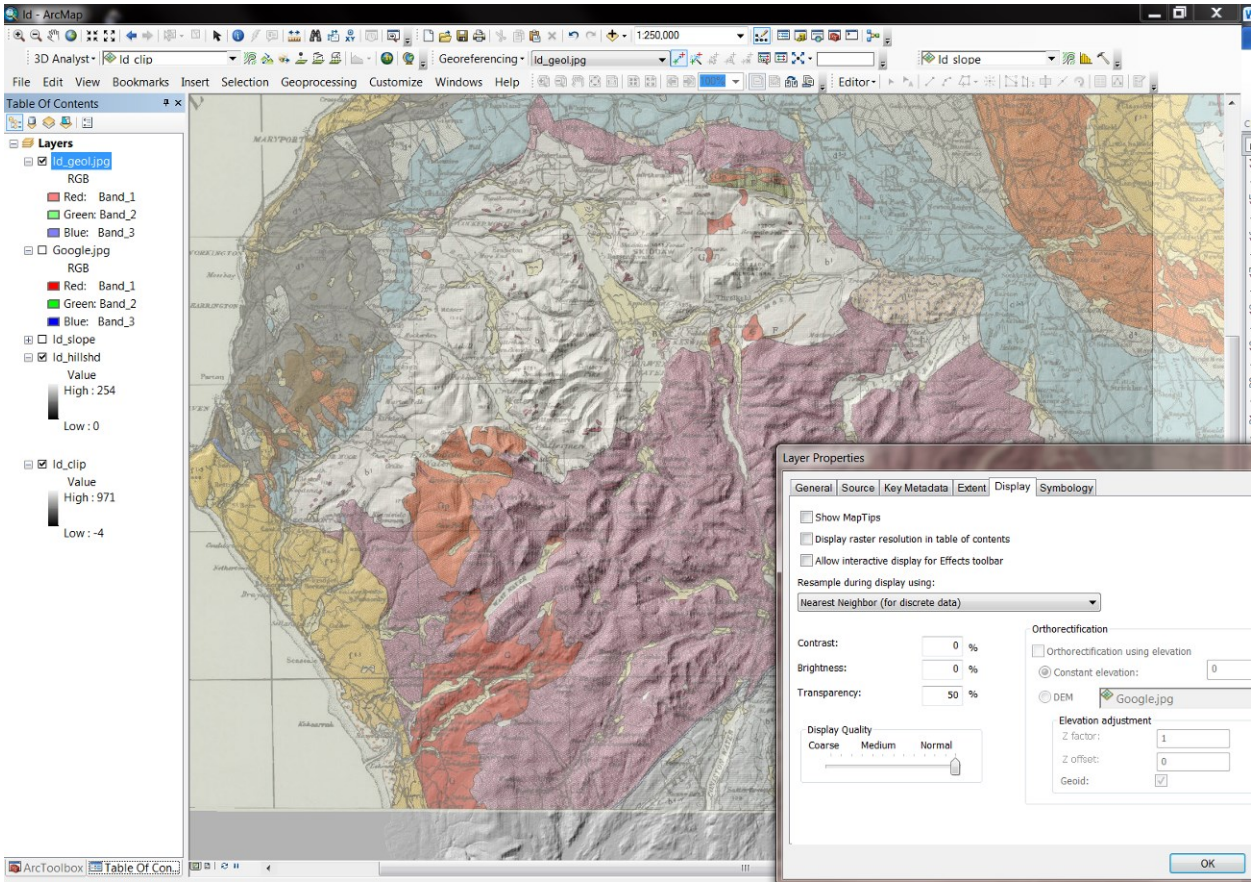
facilitates the operation. The image will be translated/rotated/distorted to make the location fit.

- Repeat the operation for a few points.
- After having done this operation for a few points (key summits, cliffs or valleys, lake edges), the image should fit well on top of the DEM (if it doesn't something must have gone wrong – ask a demonstrator).



- If you want to remove one or more points, click on the "link table" button to the right of the Georeferencing toolbar ( ) : an editable table with all the tie points will appear: you can select a tie point and remove it if you think that you have made a mistake.
- If you are happy with the result, click on the Georeferencing button → Update Georeferencing. The crosses disappear and your image is given new spatial references. Again, DO NOT FORGET THIS STEP or all your work with the georeferencing will be lost! If you remove the image from your ArcMap window and import it again, it will appear in exactly the same place.

Now, you can superimpose the maps and investigate how geology affects the morphology of the landscape. What are the highest summits made of (the caption of the geological map is copied at the end of this handout)? To help you, you can make the geology transparent: in the Table of Content window in ArcMap, double-click on the geological map. A "layer properties" window will appear. Click on the "Display" tab: here you can set the transparency to 50 % for example, which will give the following result:



VI. Visualizing the landscape in 3D using ArcScene

ArcScene has been designed for visualisation purpose. Basically: you can import any of the layers that you have created so far and import them in ArcScene to see them in 3D.To open ArcScene, click the button in the toolbar. A new window will open, looking very similar to ArcMap. As with ArcMap, don't forget to save your ArcScene project from time to time.

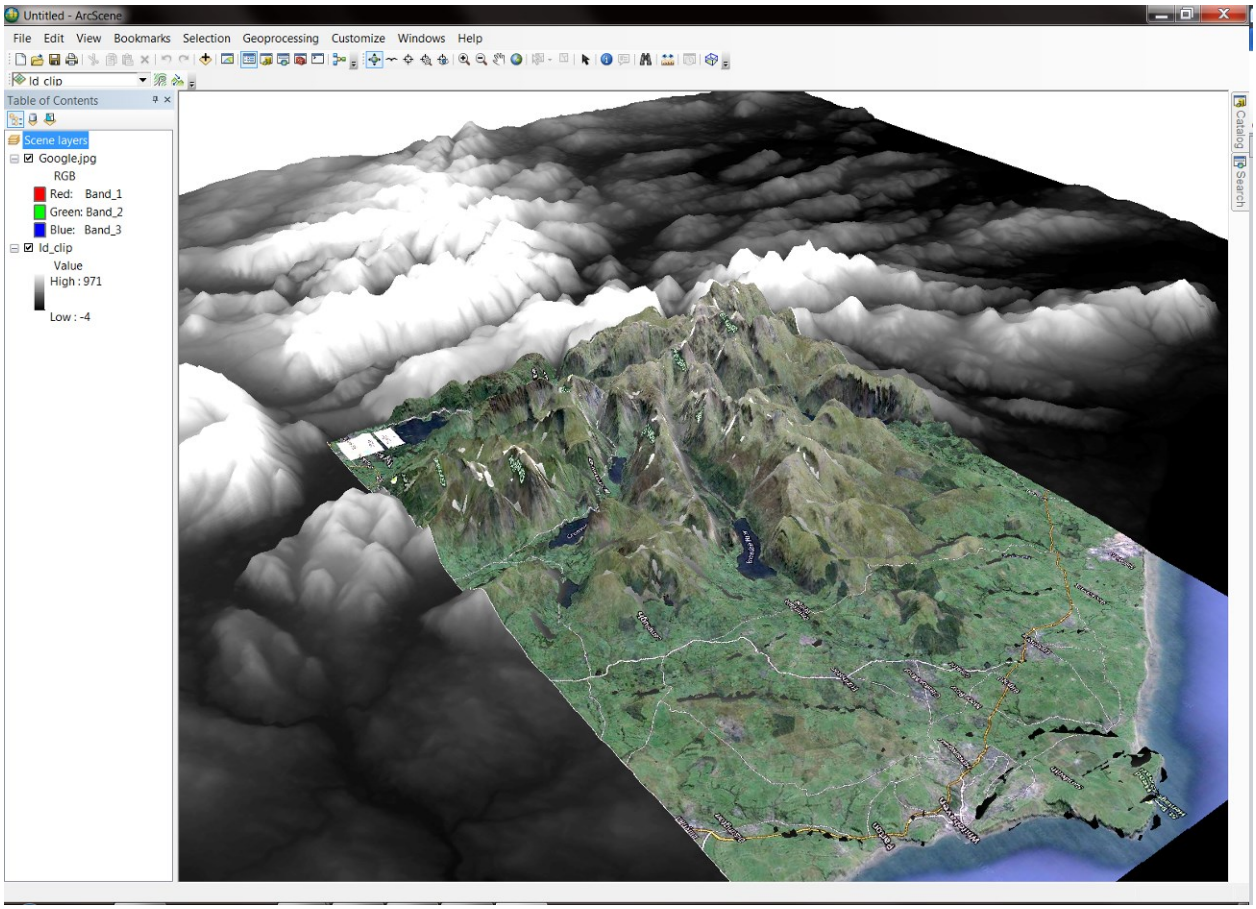
Use the "Add Data" button to import your DEM data ("ld_clip"). Double-click on "ld_clip" in the "Table of Contents" window and go to the "Base Heights" tab in the dialog box that appears. In there, tick "Floating on a custom surface" (your "ld_clip" layer should appear in the box). Note: there is a vertical exaggeration parameter ("Factor to convert layer elevation values to scene units"); 1 is no vertical exaggeration; if you were in the Grand Canyon, you would not really need it but here you can use values of 4 or 5! Click OK. You can now see your landscape in 3D.

Feel free to explore the different buttons at the top. The "fly" button is a bit tricky (and very funny too): use the mouse to turn left/right and go up/down, left-click to accelerate, right-click to slow down. To stop, either press the "Esc" key or right-click until your flight stops. You can then select another tool by clicking on another button. If you want to go back to the original view, click on the globe button.

When you have played enough, you can add more data, for example the Google Map image: use the "Add Data" button to import "Google.jpg". Then, double-click on it in the "Table of Contents" window, go to the "Base Heights" tab and tick "Floating on a custom surface", using the DEM layer as the source for the heights ("ld_clip"). Apply the same vertical exaggeration factor than you did before. Click on OK. The result will not be amazing

because, depending on the angle of view, “ld_clip” will be above the Google image in some places and below it in some others. You can hide “ld_clip” or use the rendering options:

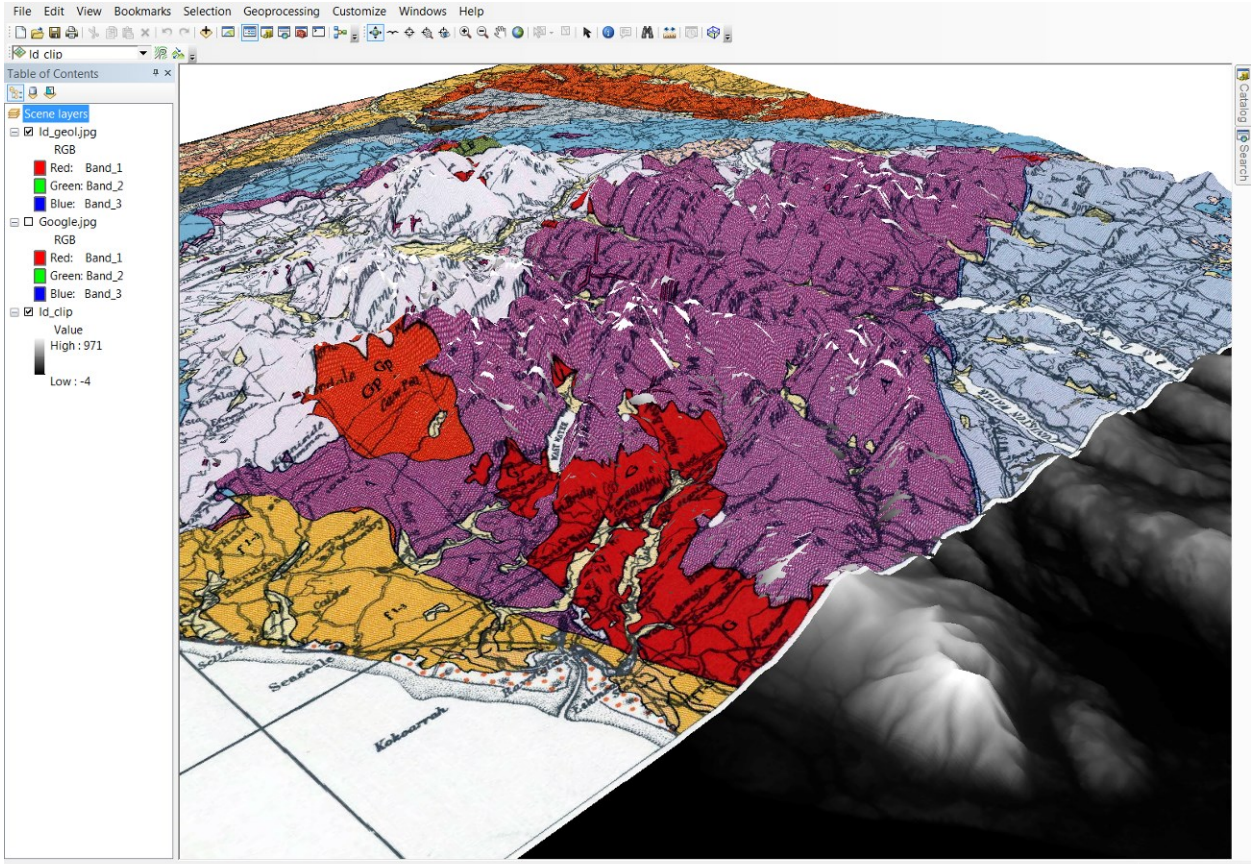
- double-click on the layer in the “Table of Contents” window,
- in the “Rendering” tab, you can select the “drawing priority” (in the “effects” box). If you give a priority of 1 to the Google image and a priority of 10 to the DEM, then the Google image will be drawn on top of the DEM. If the image still disappears in places, you can use the “layer offset” option at the bottom of the “Base Heights” tab to make sure that the image is displayed above the DEM (you can put 10 meters for example: the points from “Google.jpg” will be systematically displayed 10 m above the DEM).
- click OK. This is what you obtain:



Yes, it’s like Google Earth! The advantage is that you can now add the information that you have been extracting using ArcMap. You can add the slope map or the geological map. Just repeat the procedure:

- use the “Add data” button and add your layer,
- double-click on the layer in the “Table of Contents” window,
- in the “Base Heights” tab, select “Floating on a custom surface”, using the DEM layer as the source for the heights (“ld_clip”).
- in the “Rendering” tab, adjust the “drawing priority” (in the “effects” box) so that the most important information is displayed on top. Note: you can also enhance the quality of the images in the “optimize” box at the bottom (so that images look less pixelated).
- click OK.

This is what it looks like if you add the geological map:



So, is the shape of the landscape reflects the underlying geology? Explore the landscape and try to determine whether some of the geological features could have been picked by looking at the landscape. If some observations contradict your intuition (e.g., would you expect granite surrounded by slate to stick out in the landscape or the opposite?), then try to think about the processes that have shaped this landscape over the last tens of thousands of years… Feel free to discuss with the demonstrators.

M. Attal, February 2015