ArcGIS Desktop:
Digital mapmaking

UNIVERSITY OF
OXFORD

Software Used

ESRI ArcGIS Desktop v10.2.1 *Windows 7*

Microsoft Excel

Files Used

ArcGIS exercise files v2.0.zip

Copyright

Acknowledgements

The geographic data files used in the exercises include several from Natural Earth, a public domain map dataset available at 1:10m, 1:50m, and 1:110 million scales. This is found at http://www.naturalearthdata.com/ .

Contents

1 Introduction

1.1. What will you learn?

This course will help you learn to use *ArcGIS Desktop* to create maps for a wide variety of purposes; for example, to incorporate into *Word* documents or *PowerPoint* presentations. It is a three-part course on *Desktop*, covering most of the mapmaking, editing and querying aspects of the software, as well as an introduction to spatial analysis.

In these three sessions we will cover the following topics:

- The user interface and menu structure
- Managing data and outputting maps
- Chloropleth maps
- Editing, geoprocessing and querying map data
- Georeferencing raster images
- Heads-up digitisation
- Introduction to spatial analysis

1.2. What is ArcGIS Desktop?

ArcGIS Desktop is a geographic information system (GIS). GIS is designed to store, query, analyse, process, and visualise geographic data. It is typically used for making maps for illustration and performing spatial analysis to answer research questions. Powerful and relatively complex, *Desktop* is the industry standard for GIS.

ArcGIS Desktop is one product in a range that also includes *ArcGIS Explorer* and *ArcGIS Online* (see below). *Desktop* incorporates several software modules. The two most important ones for the purposes of this course are *ArcMap* and *ArcGIS Administrator*. You should also be aware that there are several 'licensing levels' of *Desktop*, with progressively more functionality -- and higher price tags! These are: *ArcView* (basic package), *ArcEditor* (standard package) and *ArcInfo* (advanced package).

1.3. Where can I get a copy?

ArcGIS Desktop is centrally funded by the university. Any member of the university may purchase a copy for use on personal machines. This is available from the IT Services Online Shop http://www.it.ox.ac.uk/want/shop. Please note that *ArcGIS* is available for Windows only, so Mac users will need a Windows installation, using either Boot Camp or a virtual machine. Furthermore, for Mac users running Windows, we have recently (Jan 2013) become aware of problems installing *ArcGIS* from the disk image provided by the manufacturer, ESRI. Contact maps@bodleian.ox.ac.uk for assistance in working around this.

Another option for accessing the software is to purchase one of the ESRI Press textbooks, e.g. *GIS Tutorial 1: Basic Workbook*. In addition to being very good textbooks, these contain a fully functional 180-day copy of *ArcGIS Desktop*, licenced for educational purposes.

When it is not being used for teaching, the 30-seat Training Room in the Radcliffe Science Library is available for drop-in use. A weekly calendar is posted

on the door. All of the machines in the room have *ArcGIS Desktop* installations. However, you should bring a USB memory device to work from, as there is no persistent storage space on the network for readers and any files you put on the Desktop will be wiped when you log out.

Many departmental computer labs also have *ArcGIS* installed. Because the software is centrally funded, any department is eligible to have it on their machines.

1.4. Other GIS software

Apart from ESRI's *ArcGIS* range, there are two other major GIS packages.

Quantum GIS (QGIS) is the leading open source alternative to *ArcGIS*. It is somewhat less powerful (especially on spatial analysis and page layouts/graphics) and, though popular, is not industry-standard software. Support for it is typical of open source software – perhaps not quite as robust or polished as that of proprietary software. *QGIS* itself is slightly more buggy than *ArcGIS*, although these glitches tend to be confined to more peripheral or advanced parts of the software that receive less attention from developers. The chief advantages of *QGIS* are that it is free, it does not require a licence configuration, it is cross-platform (it will run on *Windows* / *Mac OS* / *Linux*), it is rather simpler and more intuitive than *ArcGIS*, and for *Windows* there is a 'portable' version of it that will run entirely off a USB stick (no admin rights required). The IT Learning Programme will begin offering a termly 9-hour course in *QGIS* beginning in Trinity Term 2015.

Pitney Bowes *MapInfo Professional* is the proprietary alternative to *ArcGIS*. It has traditionally been seen as the 'cheap and cheerful' GIS option. It is no longer available through the university as centrally funded software, as it was superseded by *ArcGIS* in 2011.

Besides *ArcGIS Desktop*, there are also two other mapping applications in ESRI's *ArcGIS* software suite.

ArcGIS Explorer is the 'little brother' of *Desktop*. It is a very rudimentary and highly streamlined GIS that is free to download and easy to use. In *Explorer*, ESRI have attempted to make GIS as accessible as possible to the beginner -- becoming proficient in *Desktop* represents a significant investment of time. For users who need to only make a few very simple, rough-and-ready maps, or to simply display and explore layers of geographic data, *Explorer* may be adequate. However, there are significant limitations to what can be achieved in *Explorer*, and it is not recommended for creating publication-quality images. For users who intend to progress to learning *Desktop, Explorer* is a very easy introduction to the concepts of GIS. Not only do many of the principles used in *Explorer* translate directly into *Desktop*, but much of the terminology and icons are the same.

The other version of ArcGIS is *ArcGIS Online*. This is a cloud-based GIS, where the interface is a web page and all of your map data is stored online in your user password-protected account. In terms of functionality, it is even more limited than *Explorer*.

2 Basic Skills

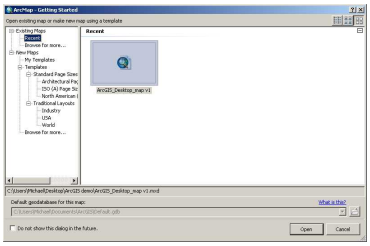
The *ArcMap* user interface may at first be a bit daunting and unfamiliar – huge arrays of buttons and windows that behave in slightly strange ways. However, once you break the interface down into its basic components and understand their behaviour and the underlying logic, it all starts to become clear.

Exercise 1 Explore a map document (.MXD)

- *Start ArcMap*
- *Open an existing map document*
- *Explore ArcMap's user interface*
- *Use the navigation controls*
- *Change a layer's style*
- *Save the map document*
- *Output a map image*

Task 1

Start *ArcMap*



Step 1

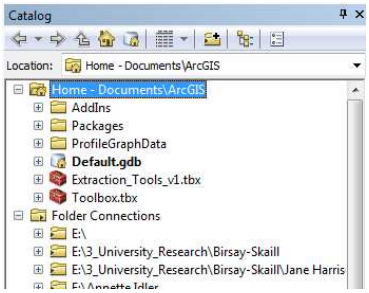
From the Windows Desktop, click **Start | All Programs | ArcGIS | ArcMap10.2.1.** The **ArcMap - Getting Started** window will appear. NB: this may be slightly different on your computer, depending on how *ArcGIS* has been installed.

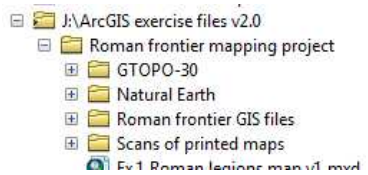
Getting Started will provide shortcuts to opening your most recent map documents (.MXD). This is generally a useful feature, but in this case we will open the MXD from within *ArcMap*. Click **Cancel** and you will enter an empty map document.

The operative word here is 'empty'... *ArcMap* does not contain any geographic data by default – you must provide it!

Task 2

Open an existing map document





Step 1

In the *ArcMap* window, find the Catalog on the right. This is used mainly for finding data and adding it to workspace. It essentially functions like a file browser, but there are two very important differences that are not very intuitive.

The first difference is that you cannot instantly begin browsing through folders in Catalog. **FOLDERS WILL NOT APPEAR IN CATALOG UNTIL YOU 'CONNECT' THEM**. You will do this in the next steps. Once a folder is connected in Catalog, it will stay connected in this and future *ArcMap* sessions, until you actively disconnect it.

The other big difference is not relevant at this particular moment, but worth mentioning anyway: **FOLDERS IN CATALOG WILL NOT AUTOMATICALLY REFRESH THEIR CONTENTS**. If you have an *ArcMap* session running and you are looking at a folder in Catalog, then you minimise *ArcMap* and add some files to that folder through Windows (let's say you download some more data into the folder or create a new *Excel* spreadsheet) your new files will NOT appear in Catalog until you force a 'refresh.' To refresh the Catalog's view of a folder, simply right-click on it and choose **Refresh**.

Step 2

To connect your project folder in Catalog, right-click on 'Folder Connections' and click **Connect to Folder**.

A **Connect to Folder** window will open.

Step 3

In the **Connect to Folder** window, browse to the **ArcGIS exercise files v2.0** folder on your hard drive and single click on it. If you are working on your own, then it is wherever you downloaded the exercise files .ZIP archive.

You MUST have unzipped the exercise files .ZIP archive to proceed with this step. If you cannot find it in the **Connect to Folder** window, then either you have not downloaded it yet or you have not unzipped it. Remember, to unzip a ZIP file you need only to right-click on it in Windows and choose **Extract All**.

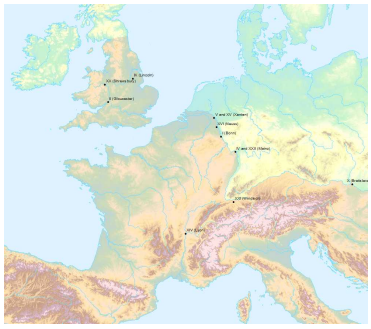
You only really need to connect your top-level project folder. You will be able to access all of the subfolders within it through Catalog.

Click **OK**. The **Connect to Folder** window will close and **ArcGIS exercise files v2.0** will appear in Catalog.

Step 4

Expand the exercise files folder in Catalog by clicking on the '+' symbol next to it.

The exercise files folder contains two project folders. Expand **Roman frontier mapping project**.



Step 5

Open the **Exercise 1.mxd** file by dragging it from Catalog into the large pane in the middle of the *ArcMap* interface.

ArcMap will parse the MXD file, which is really little more than a set of instructions (i.e. the MXD contains no geographic data content itself). One of those instructions will be to open several files on your hard drive, add them to the map as 'layers,' and apply particular styles to them.

There are two other ways you could have opened an existing map document in *ArcGIS* You have already seen the **Getting Started** window. Alternatively, before you even start *ArcMap*, you could browse to the MXD file on your hard drive (i.e. through Windows) and double-click on it. Windows will start *ArcMap* and use it to open the MXD file, by file association.

Task 3

Explore the elements and behaviour of the *ArcMap* user interface

Step 1

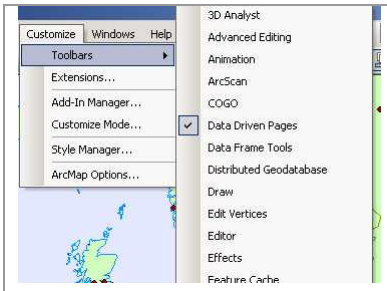
By default, the top row of controls in the *ArcMap* user interface is a traditional Windows-style set of pull-down menus, e.g. **File**, **Edit**, **View**, **Bookmarks**, etc. Pull a few of them down – these should be familiar.

Step 2

Directly below this top row are one or more rows of toolbars. These are 'dockable,' in the sense that they can be displayed either in 'floating' or 'docked' mode. In floating mode, they appear as separate little windows in the workspace. To 'dock' a floating toolbar window, simply drag it up into the area of the other toolbars. To 'undock' a docked toolbar, grab it by the handle (the vertical row of four dots on the left of each toolbar) and drag it down into the map window.

Try undocking one of the toolbars, so that it floats. Then, move and resize the floating toolbar. Finally, re-dock the toolbar up in its previous location.

NB: you can also re-arrange the docked toolbars with respect to each other. Drag them by their handles to their new locations.



Step 3

You can switch the toolbars on and off. Click **Customize | Toolbars**, and you will see a checklist. Each item on the list is a separate toolbar, each of which has several buttons on it. Those toolbars that are ticked in the list are visible in the *ArcMap* window.

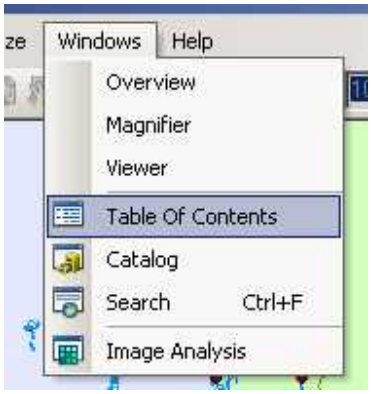
Try switching a few toolbars on and off, and watch them appear and disappear from window. When finished, leave the **Standard** and **Tools** toolbars switched on.

Throughout these exercises, the buttons you need to click will be referenced according to the toolbar they are found on, e.g. **Standard** toolbar, **Tools** toolbar, **Layout** toolbar, etc. If you cannot find the toolbar in question, it may not be switched on. In this case, go to **Customize | Toolbars** and check.

Step 4

Finally, beneath the docked toolbars is a set of one or more windows. The main window in the centre, which is always open, can be switched between Data View (i.e. a map) and Layout View mode.

Try switching between Data View and Layout View by clicking the buttons  at the lower left corner.



Step 5

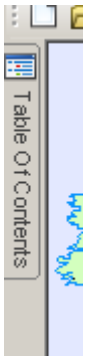
There are additional windows to the left and right of the data/layout window. These may be opened or closed, according to your preferences. To the left is a **Table of Contents** window (hereafter known as TOC), which lists all of the layers that have been added to the map. By default, the TOC lists the layers in their drawing order (i.e. those at the top of the list are drawn on top of the layers further down the list) but it can also organise them in other ways.

If the TOC is open, it can be closed by clicking the **Close** icon  in the upper-right corner. If it is closed, it can be opened again by clicking **Windows | Table of Contents**.

Also, if the TOC is visible, the AutoHide function can be enabled, by clicking the **AutoHide** icon  in the upper-right corner. When this is switched on, the table will automatically minimise itself when not in use, appearing as a tab on the left of the screen. By hovering over or clicking that tab, you can then re-open the table very quickly.

Try closing and opening the TOC and enabling and disabling the AutoHide function.

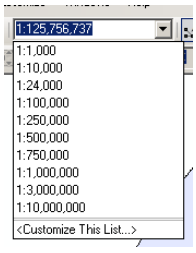
TOC = Table of Contents

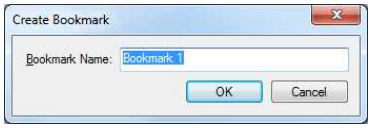


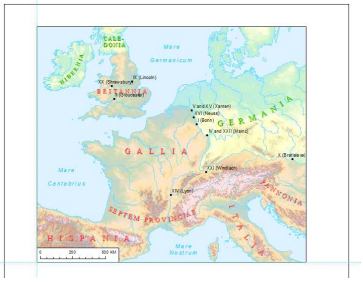
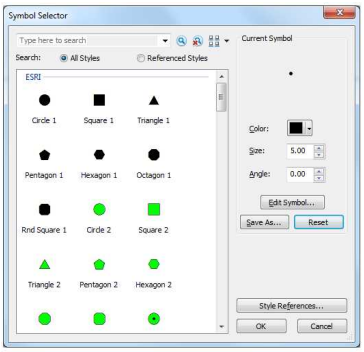
Auto-hide tab

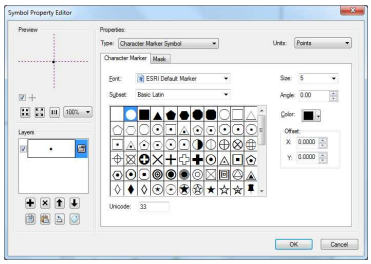
Step 6

The *Catalog* window, to the left of the data/layout window, behaves in the same way as the TOC. Try opening, closing, and autohiding it.

Task 4 Use the zoom controls	Step 1 Click the **Zoom In** button  on the **Tools** toolbar
	Step 2 Define the area of the map to which you would like to zoom in. Using the mouse, drag a rectangle across the area, starting in the upper-left corner and finishing in the lower-right corner. When the mouse button is released, the map will zoom in. NB: If at any time you get 'lost' in the Data View and can't see anything, click the **Zoom to Full Extent** button  in the **Tools** toolbar (see below)
	Step 3 Click the **Zoom Out** button  on the **Tools** toolbar
	Step 4 Drag a fairly large rectangle in the map window to zoom out. The new view will be centred on the rectangle, and the smaller the rectangle, the further out the view will be zoomed.
	Step 5 Experiment with the other zoom controls. The roller button in the centre of your mouse (if you have one) is a zoom in/out control. The **Fixed Zoom In / Out** buttons   on the **Tools** toolbar are also zoom controls. Pressing CTRL – and CTRL + on your keyboard will also produce a fixed zoom in/out
Task 5 Zoom to an exact cartographic scale 	Step 1 Pull down the scale menu in the **Standard** toolbar and select a scale. For this dataset, try **1:10,000,000**. The map will zoom in to that scale
	Step 2 Click inside the text box on the scale menu (as opposed to dragging down the menu) and type a value directly into it. Try **1:15,000,000** or **1:50,000,000**. The map will now zoom to that custom scale. This means that effectively you are not limited to the options in the menu.
Task 6 Zoom to a layer's extent	Step 1 In the TOC, right-click on a layer and go to **Zoom to Layer**. The map viewpoint will change in order to frame that layer. NB: This is a quick and easy way of ensuring that all of the features in e.g. your site distribution layer are visible in the map.

Task 7 Pan the viewpoint	Step 1 Click the **Pan** button  on the **Tools** toolbar.
	Step 2 Drag the mouse across the map window to pan the view in any direction.
	Step 3 Experiment with the other pan controls. You can pan using the scrollbars on the side of the Data View. You can also pan using the arrow keys on your keyboard.
Task 8 Restore views using the **Full Extent**, **Previous Extent**, and **Next Extent** buttons	Step 1 Click the **Full Extent** button  on the **Tools** toolbar. The map will zoom in or out to frame all of the layers currently added to it, regardless of whether their visibility is currently switched on.
	Step 2 Click the **Previous Extent** button  on the **Tools** toolbar. The map will return to the last view created. Click the button several times to progress backwards through the series of views that you have defined.
	Step 3 Click the **Next Extent** button  on the **Tools** toolbar. The map view will now progress forwards through the sequence of views. Keep clicking on it until you reach the full-extent created in Step 1 of this task.
Task 9 Navigate to a predefined viewpoint and scale using a Bookmark 	Step 1 Pull down the **Bookmarks** menu at the top of the window. This is a list of all of the predefined bookmarks in this map document. This MXD has one bookmark: **Northern Frontier 1**. Click on it. The map will zoom to the viewpoint stored in the saved bookmark. NB: The bookmark will define only the geographic area shown in the map and the scale (i.e. zoom). It will not switch layers on/off, change layer styles etc.
	Step 2 Define your own new bookmark. Zoom to an area of interest (e.g. the United Kingdom). Click **Bookmarks | Create**. A **Spatial Bookmark** window will appear. Type **United Kingdom** in the text box. Click **OK**. The **Spatial Bookmark** window will close.
	Step 3 Click the **Zoom to Full Extents** button  in the **Tools** toolbar, in order to change the map view to something else.

	Step 4 Click **Bookmarks | United Kingdom**. The map will zoom to the viewpoint stored in the saved bookmark.
	Step 5 Navigate back to the **Northern Frontier 1** bookmark.
Task 10 Toggle between the Data View and Layout View 	Step 1 In the bottom-left corner of the central pane in the *ArcMap* interface, there are two small icons.  The default one (left) is for Data View, which you are in at the moment. This allows you to work in a completely geographical space. Click the icon to the right of Data View. This changes the central pane to Layout View, which is a publishing space. The larger rectangle represents the edges of an A4 sheet of paper, and this is where you will eventually arrange your map and elements such as scale bar, legend, inset maps etc. In this MXD file, much of this work has already been done. You will learn how to do the basics of this in Exercise 3 on layouts.
Task 11 Change styles through the **Symbol Selector** and **Layer Properties** windows 	Step 1 A key concept in GIS is that you can apply whatever visual style you like to geographic data and it is a completely non-destructive process – you will not affect the underlying source data. When you first open a vector or raster file in *ArcMap*, it will have a default style. For vector files (e.g. shapefiles, SHP) you can change the style through the **Symbol Selector** window. There are two ways of accessing this. First, the easy way. Beneath each layer in the TOC, there is a small style swatch. For layers of point objects, it is a single point symbol. For lines, it is a line sample. For polygons, a rectangle with a fill and outline. Double-click directly on one of these style swatches (not on the name of the layer). This is a shortcut to the **Symbol Selector** window.



Step 2

The options you are given in **Symbol Selector** will obviously depend on whether you have chosen a point, line or polygon layer. Here, you get control over the basic characteristics of the style: the pattern, the size/thickness, and the colour(s).

Whatever changes you make in **Symbol Selector** or its sub-windows will NOT be applied to the map until you click **OK**.

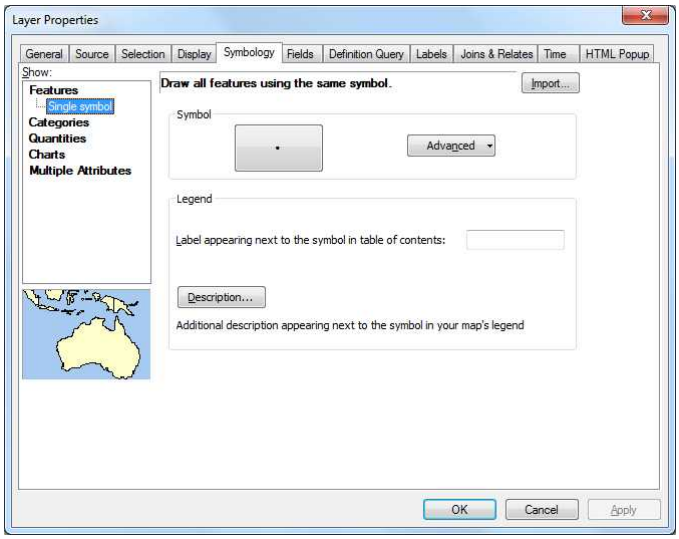
Try it – make a change to the style, then click **OK**.

Remember that nothing you can do in **Symbol Selector** is destructive to the layer's source data. You are merely changing the way that data is displayed in this particular map document.

From **Symbol Selector**, you can launch other windows that will give you finer control over the exact details. For example, you are offered a basic (and very useful) colour palette in **Symbol Selector**, but by clicking **More Colours** you can go into a more sophisticated colour selector that will enable you to e.g. specify exact colour values. Also, in **Symbol Selector** you are given a default set of symbol libraries. However, by clicking **Edit Symbol** you can go to the **Symbol Property Editor**, where you fine-tune the exact appearance of the symbols. Both of these tools are ultimately pretty important – we won't go into them in detail, but they are worth exploring when you have time. They are pretty intuitive. The only thing worth mentioning about them is that **Colour Selector** and **Symbol Property Editor** are both 'sub-windows' of **Symbol Selector** – when you click **OK** in them, you will return to **Symbol Selector**, not go back directly to the map..

Step 3

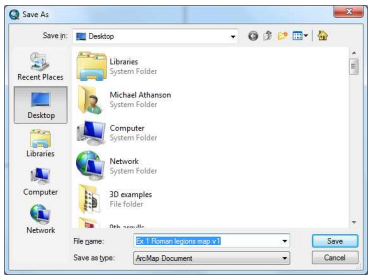
The other way of accessing **Symbol Selector** is more convoluted, but worth knowing about. This time, in the TOC, double-click on the name of a layer rather than the symbol swatch.

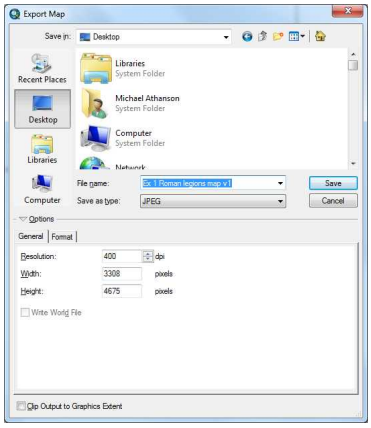


The **Layer Properties** window will appear. This is one of the two most important pop-up windows that appears in *ArcMap*. As the name suggests, this is where you control the properties of individual layers in the map – as opposed to the overall map document as a whole. You will keep coming back to **Layer Properties** again and again for things such as colour-coding, layer translucency, labelling..

There are tabs across the top of **Layer Properties**. On the **Symbology** tab, you will see the full range of symbology schemes offered in *ArcGIS*, The most simple (default) scheme is to apply a single style to all objects in the given layer. This is **Features > Single Symbol**. In this option, you will see a single style swatch. By clicking on that, you will go to **Symbol Selector**. This now behaves in the exact same way as above, EXCEPT it is a sub-window of **Layer Properties** – whatever changes you make will not be applied in the map until you click either **OK** or **Apply** in **Layer Properties**. The only difference is that **OK** will also close the window, whereas **Apply** will not.

When you have finished exploring **Symbol Selector**, return to the map

Task 12 Save the map document under a new name  	Step 1 Just as with any other piece of software, you may wish to periodically save your work, or resume working on this project later. In this case, you would want to save the 'map document' (MXD file), which will enable you to resume this session later. This is distinct from saving the map as an image, which you will do in the next task. To save the document, click **File | Save** (to overwrite the current session) or **File | Save As** to save a new version. As with other software (and especially while you are still learning GIS) it is strongly recommended that you regularly save new versions of your documents, identifying them by appending 'v1,' 'v2' etc on to the end of your filenames. In this task, you are saving the map document as a whole (the MXD) and in the next, you will export an image of the map as a finished product. These are both distinct from 'saving edits' you have made to a particular layer's source data. You will not encounter 'saving edits' until you start making destructive edits to layers in Exercise 10. Note also that, if you were to try to close *ArcMap* while you had unsaved changes to the MXD, you would prompted to either **'save changes'** or not. If you were destructively editing layers (you won't until Exercise 9) you might ALSO then be prompted to **'save edits.'** The important thing to remember is that 'changes' refers to the MXD and 'edits' refers to the layers – these are completely different things!
Task 13 Output an image of the map (TIF) and inspect it	Step 1 As you progress with your mapmaking project you may wish to either save a preview image of the map or the finished product. This is a bit like taking a digital photo of it. It will produce a static image which you can then e.g. use in *PowerPoint* or *Word*, email to someone etc. Click **File | Export Map**. The **Export Map** window will open.



Step 2

In the **Export Map** window, browse to any desired location on your hard drive. The image you are going to export needs a meaningful name -- and version number!

The **Save as Type** menu allows you to choose different image file formats. A few brief notes on format:

If you only want to save a rough draft, esp if you want to keep the file size small so that you can e.g. email it to someone, then JPG is fine. JPG is a compressed file format, specifically a 'lossy' compression method. A side effect of lossy compression is that the image is slightly degraded, and this cannot be reversed. But the benefit is that JPG can make file sizes absolutely tiny.

In most cases, though, TIF is your better option. TIFs can be either uncompressed (in which case the file size is MASSIVE) or they can use 'lossless' compression. TIF compression is 'lossless' because it simply removes redundant colour information from the file. For example, if your image has many pixels that are the exact same colour, it only saves that colour once then says 'same again, same again, same again.' So TIF compression is EXTREMELY efficient for images that use only a few colours (e.g. diagrams and most maps) but not so great for photographs that have many thousands of colours. So TIF is really the best file format for finished map images – especially the master copies.

Set **Save as Type** to TIF.

Step 3

Next, you need to specify the 'resolution' of the output images.

Digital image 'resolution' is often defined in various ways. In this case, there are two (mutually dependent) aspects of it. One is the density of pixels on the page (expressed in 'dots per inch,' or dpi) and the other is the height and width of the image in pixels. Because your map document has a given physical size (in inches or cm) as one of its properties, altering the dpi changes the height/width, and vice versa.

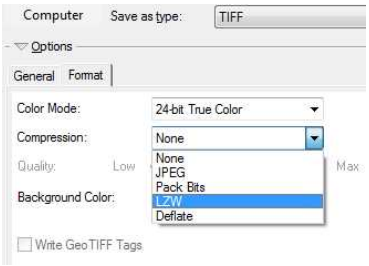
If you need to work to exact pixel heights or widths (for example, to fit onto a web page) then you can specify resolution that way. However, most people will use dpi.

The rules of thumb for dpi are:

For rough drafts, use about 200 – 400 dpi.

For final copies, 400 dpi is the bare minimum. Most publishers look for 600 dpi where possible. Anything much over 600 is overkill. Perhaps as high as about 800 dpi if you would like to be able to enlarge the image 50% or so without pixellating it. But remember: enlarging or shrinking a map image by more than perhaps 30-50% can have very undesirable effects on text and line objects, so it is much better to first find out the required physical print size of the image and work to that spec from the start.

Set **Resolution** to whatever you wish.



Step 4

Because you have chosen the TIF format, you now need to tell *ArcGIS* to use compression. If you forget this step, the TIF will be uncompressed, resulting in an enormous file size!

Under **Options**, go to the **Format** tab. Set Compression to LZW.

If you were using JPG, the options on the **Format** tab would be different. Instead of compression method, you would have a slider where you could control the image quality (i.e. compression level)

Finally, click **Save**. *ArcGIS* will render out an image of your map and save it at the specified location.

Step 5

Minimise *ArcMap* and browse to the location on your computer where you told it to put the image.

Right-click on the image and go to its **Properties**. Check the file size. A compressed TIF should be somewhere in the region of 1 – 10 MB depending on the size and colours, while an uncompressed TIF might easily be 10 – 100 MB!

If you have forgotten to specify LZW compression, then instead of going back into GIS there is another way of doing it in Windows. Open the image in *Paint* (under **Start | Programs | Accessories)** and simply Save it there. *Paint* automatically saves TIFs using LZW.

Click on the image you saved to inspect it. It should show you whatever content was visible in the main pane in *ArcMap* – whether you were in Data View or Layout View at the time.

Congratulations!

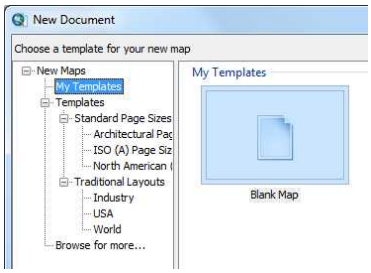
Next, you will learn how to create a new (empty) map document and begin to populate it with layers of data.

Exercise 2 Create a map document

- *Start a new map document*
- *Add layers of data to the map*
- *Manage layers and apply styles*
- *Change the map's projection*
- *Plot a layer of point features from coordinate data*
- *Make some basic adjustments to the map in Layout View*

Task 1

Open a new (empty) map document in *ArcMap*



Step 1

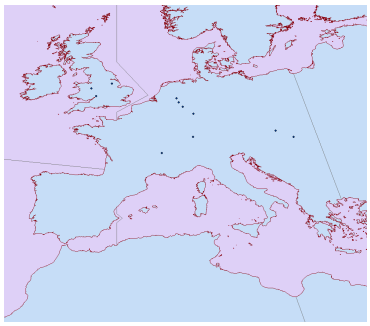
If you are carrying on from the previous exercise and you still have *ArcMap* open, then go to **File | New**. The **New Document** window will open. Click **OK**.

On the other hand, if *ArcMap* is not currently running then start it – either by clicking on a shortcut on the Desktop or by going to **Start | Programs | ArcGIS**. When the **Getting Started** window appears, simply click **Cancel**.

Either way, you will enter an empty map document.

Task 2

Add layers of data to the map using *Catalog*



Step 1

In Catalog, browse to the **Roman frontier mapping project** folder.

Step 2

Drag the following files from Catalog into the Data View:

Natural Earth > **10m_coastline**

Natural Earth > **10m_land**

Natural Earth > **10m_ocean**

Roman frontier GIS > **Roman_legions_67AD_v2**

Step 3

Zoom in on western Europe.

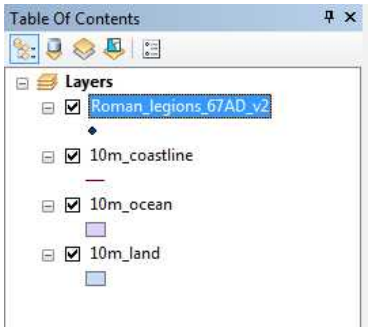
Task 3

Manage layers through the TOC

Step 1

Having added some layers to the map document, use the TOC to remove one. Right-click on a layer in the TOC and go to Remove.

Now add it back, from the Catalog



Step 2

Note that you can (non-destructively) change a layer's name as it appears in the TOC. This is a bit like creating an alias – you are not actually changing the name of the source file.

Why might this be useful? In Exercise 6, when you create colour-coded symbology for a layer, the layer's name will eventually appear in the map's legend. In Exercise 7, when you start making selections of data and promoting them to layers, renaming them will help you keep track of what's what. You can also create groups of layers through the TOC to help you manage them, and name the groups.

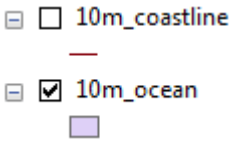
To rename a layer in the TOC, simply click on the name of the layer once to highlight it, then pause, then click again to edit.

Alternatively, you can make the same change through the **General** tab in the **Layer Properties** window (double-click on the layer in the TOC)

Step 3

As you might have guessed by now, the little check box next to each layer in the TOC is a visibility toggle. By default, all layers added to the TOC are visible.

Try switching one off and on again and observe the effect in the map.



Step 4

The layers listed in the TOC can be organised in various schemes, according to the row of icons arrayed along the top of the TOC window. The default is the one on the far left, which is Drawing Order. 

In Drawing Order mode, the layers on the top of the list are drawn 'above' (i.e. superimposed on) the layers further down. This means that layers near the bottom of the drawing order may be partially (or completely) blocked from view by those above.

ArcMap tries to be a bit intelligent here – when you drag a layer into the map from Catalog, it will tend to put point layers near the top of the drawing order, line layers in the middle, and polygon layers and rasters near the bottom.

Of course, you can change the drawing order of layers at any time. Try dragging the **10m_land** layer to the top of the TOC. The polygons in this layer will now block out the legions point layer beneath.

Put the **10m_land** layer back at the bottom of the drawing order.

Task 4

Apply styles to the layers in the map

Step 1

Open the **Symbol Selector** (see Exercise 1Task 10) for each of the layers in the map and set the styles specified below. Note that, when you have the colour palette open, you can see the name of each colour by hovering the cursor over it.

Land:

Fill colour = 'Olivine Yellow'

Outline colour = 'No Colour'

Ocean:

Fill colour = 'Sodalite Blue'

Outline colour = 'No Colour'

Coastline:

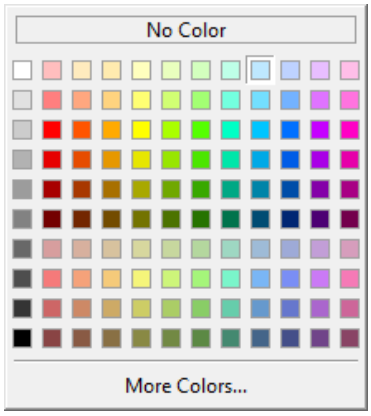
Colour = 'Apatite Blue'

Width = '0.5'

Roman Legions:

Symbol = 'Circle 1'

Size = '4'



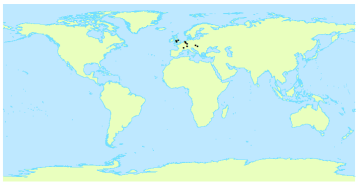
The default colour palette in *ArcGIS* offers a limited set of choices (remember you can go to **More Colours** if you wish) but the palette is organised in a very sensible way. Left-to-right, the colours vary by hue and top-to-bottom they vary by 'value' (or brightness). The top six rows are highly saturated colours, while the bottom four rows are relatively desaturated (muted) equivalents.

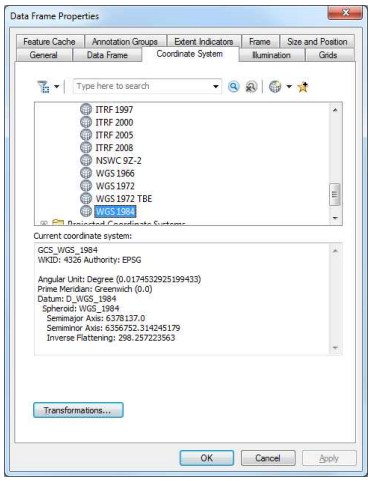
Take some time to experiment a little with colour schemes, esp the fill colours of the ocean and land. Bear in mind a few general principles:

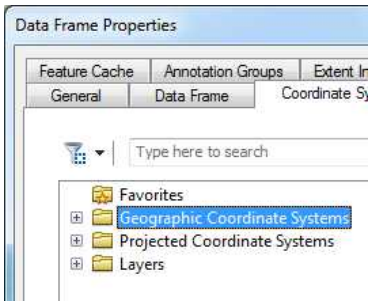
1. You want the overlay of your map (in this case, Roman Legions and any associated labelling) to contrast sharply against the base map. That contrast is usually a 'value contrast,' so a dark overlay on a light base, or vice versa.
2. The base map is really just there for context and to orient the viewer – it shouldn't distract from the overlay. Avoid using vivid colours in the base map and usually avoid sharp colour contrasts between e.g. land and sea.
3. Sea should normally range somewhere between a bright, pale blue and nearly white. Alternatively, it can be a very dark blue. The coastline should normally be just a little darker than the sea – no more than two notches downward on the palette, and within the same hue (column)
4. With landmasses you have a bit more latitude, ranging in hue from green to yellow to almost orange. As with the ocean, stick to high/low values, i.e. top or bottom of the palette.
5. In the base map, the contrast between land and sea colours may be very slight, e.g. very pale blue and green, with a slightly darker coastline.

Task 5

Change the map's projection







Step 1

Zoom out to the map's full extents. Use the tool!

Note that the map is, by default, projected in a latitude/longitude format. This is the native projection of the layers first added to the map document.

Step 2

In the **Table of Contents**, right-click the **Layers** data frame at the top of the table. A pop-up menu will appear. Click **Properties**. A **Data Frame Properties** window will appear.

Step 3

In the Data **Frame Properties** window, click the **Coordinate Systems** tab (if it is not already selected)

Step 4

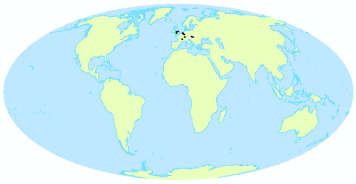
Under **Select a Coordinate System**, there is a file tree containing roughly 100 predefined 'coordinate systems' (i.e. map projections) that you can use to re-project the data in the map. Browse to: **Projected Coordinate Systems > World > Mercator (world)**.

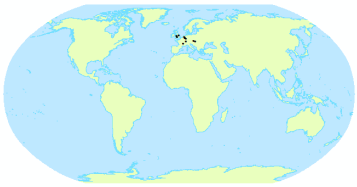
Step 5

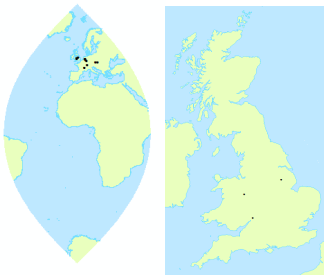
Click **OK**. The **Data Frame Properties** window will close, and the map will be re-projected using the Mercator projection. Study the map and the distortions it contains. The Mercator projection (also known as a 'conformal' projection') is generally useful for navigation, because straight lines drawn on the projection produce accurate compass bearings. However, while it preserves directions, it distorts distances, and it greatly distorts polar areas.

Task 6

Experiment with different projections







Step 1

Change the map projection to: **Projected Coordinate Systems > World > Mollweide (world)** (see Task 5 above) This is an 'equal-area' projection, which preserves the areas while distorting directions and distances. In that sense, it is the opposite of the Mercator projection.

NB: If you get an error message while changing the projection, for the purposes of this exercise, you can ignore it.

Try:

Projected Coordinate Systems > World > Robinson (world)

This strikes a good balance between the conformal and equal-area projections you just saw. This is a pretty good compromise if you need to map the whole world. In general, though, if you are mapping a smaller part of the world, a regional projection will be better.

Projected Coordinate Systems > National Grids > Europe > British National Grid

This is a projection based on a Cartesian grid that covers the UK and is optimised for representing the British Isles. Zoom in on the UK, and you will see that it is displayed in its familiar shape and orientation. However, as you get further away, the areas and directions become progressively more distorted.

What you really need for a European mapping project is a continental projection.

Projected Coordinate Systems > Continental > Europe > ED 1950 SPBA LCC

This is one of many projections that have been optimised for Europe as a whole. It attempts to preserve both shapes and relative sizes, to equal degrees.

Task 7

Inspect the **Roman_Legions_67AD_v2** *Excel* spreadsheet

Step 1

Minimise *ArcMap*.

Step 2

In Windows, browse to the exercise files folder and open the *Excel* spreadsheet **Roman_Legions_67AD_v2**.

Step 3

Note that the spreadsheet contains a variety of geographic data, including placenames and their respective latitude/longitude coordinates.

	A	B	C	D	E	F
1	Modern_name	Modern_country	Legion_qty	Legion_name	Latitude	Longitude
2	Gloucester	UK	1	II	51.864245	-2.238156
3	Lincoln	UK	1	IX	53.230688	-0.540579
4	Shrewsbury	UK	1	XX	52.707303	-2.755327
5	Xanten	Germany	2	V and XV	51.657108	6.44865
6	Neuss	Germany	1	XVI	51.204197	6.687951
7	Bonn	Germany	1	I	50.73743	7.098207
8	Mainz	Germany	2	IV and XXII	49.992862	8.247253
9	Windisch	Switzerland	1	XXI	47.4779	8.21669
10	Bratislava	Slovakia	1	X	48.145892	17.107137
11	Budapest	Hungary	1	XIII	47.497912	19.040235
12	Lyon	France	1	XIV	45.764043	4.835659

This table is properly formatted for GIS import:

1. This is a table of data, as opposed to e.g. a matrix. Each row in the sheet represents a single 'record' of data and will correspond to a single point object when plotted.
2. There is only one table on this worksheet. Separate tables should be put on separate worksheets.
3. Each different 'field' of data has its own column in the sheet, i.e. placename is separate from country rather than combined with it
4. The very first row in the sheet is column headers
5. The data content begins at the second row and there are no empty or 'skipped' rows until the end
6. The latitude/longitude is given in a 'decimal degrees' format (see Exercise 4 on geocoding) rather than 'degrees-minutes-seconds'
7. The data is otherwise 'tidy'

- There are no comments among the data
- In categorical fields, the terms used are exactly consistent
- In numerical fields, empty records or cases of 'no data' are given a single NULL value (in this case, -999) to distinguish them from actual '0' values.

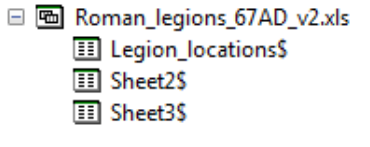
So this is ready to plot in GIS. However, if you receive coordinate data, note that you MUST know which geographic coordinate system it is expressed in.

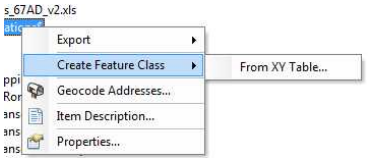
Latitude/longitude is easy to recognise because latitude is always between -90 and 90, while longitude is -180 to 180. If the numbers are much greater than 180 (in some cases up to six or seven digits) then they are normally a 'projected' (i.e. flat earth) coordinate system based on metres rather than degrees. But there are many hundreds of these projected coordinate systems all over the world. You will need to find out which one it is before you can plot the points – if you don't know what your coordinates mean, neither will *ArcGIS*!

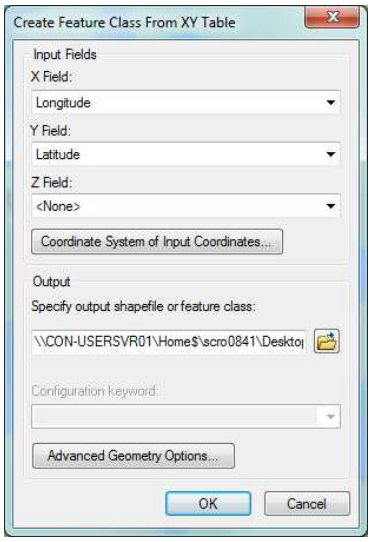
Close the *Excel* spreadsheet.

Task 8

Plot the **Roman_Legions_67AD_v2** data as a layer of point features







Step 1

In *ArcMap*, browse to the **Roman_Legions_67AD_v2** spreadsheet in Catalog.

Click on the '+' symbol to expand the view of the spreadsheet. You will see a list of the individual worksheets in the document. You can create points from any of these sheets, but only one at a time

Step 2

Right-click on the 'Legion Locations' worksheet in the document and go to **Create Feature Class > From XY Table**. The **Create Feature Class from XY Table** window will open.

Step 3

In the **Create Feature Class from XY Table** window , set the following

X field = Longitude

Y field = Latitude

Step 4

One of the most common mistakes in creating points is to forget to specify the coordinate system. If you forget to do this, your points will most often end up in a completely incorrect part of the world!

Click **Coordinate System of Input Coordinates**. The **Spatial Reference Properties** window will open.

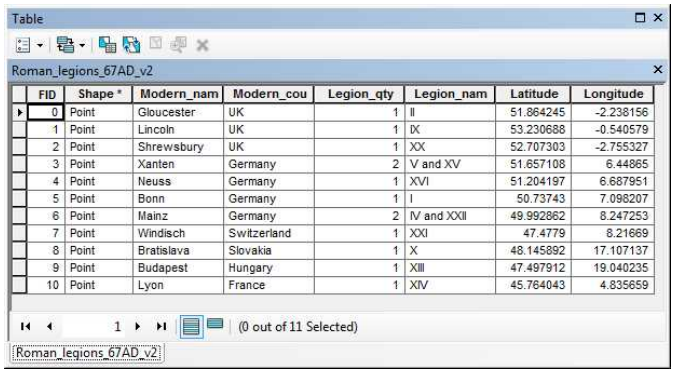
Step 5

In the **Spatial Reference Properties** window, choose the appropriate coordinate system.

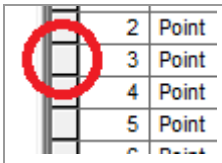
The first choice is between 'Geographic' and 'Projected.'

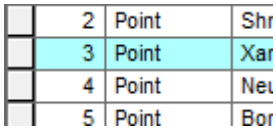
Geographic systems are all different versions of Latitude/Longitude (there are many national standards for it and a few international standards). Projected systems are all 'flat earth' grids optimised for different parts of the world.

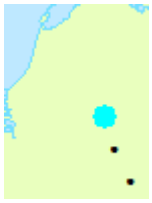
In this case, browse to **Geographic > World > WGS-1984,** then click **OK**. The **Spatial Reference Properties** window will close, taking you back to **Create Feature Class from XY Table**.

	Step 6 In the **Create Feature Class from XY Table** window, specify the **Output** location on your hard drive. This is where *ArcMap* will put the shapefile you are about to create. In this case, put the file in the exercise files folder and give it an appropriate name and version number, e.g. **Roman_Legions_67AD_v1**. Click **OK**. The **Create Feature Class from XY Table** window will close, the shapefile of points will be created in the given location. Processes in *ArcMap* that result in creating new shapefiles will usually add them automatically into the map. However, this particular process does not.
	Step 7 Add the **Roman_Legions_67AD_v1** points shapefile into the map by dragging it from the Catalog.
Task 9 Inspect the attribute table of the **Roman_Legions_67AD_v1** layer and create labels	Step 1 In the TOC, right-click on the Roman_Legions_67AD_v1 layer and go to **Open Attribute Table**. The **Attribute Table** window will open.  Just like **Layer Properties**, the attribute table is one part of the *ArcMap* interface that you will come back to again and again as you work. Note that all of the attributes have been imported correctly from *Excel*. You will not be able to edit any of the contents of the table at this stage, because that would be a destructive edit to the source data. To do so, you would need to start an 'editing session,' which you will do in Exercise 9.

FID	Shape *	Modern_nam	Modern_cou	Legion_qty	Legion_nam	Latitude	Longitude
0	Point	Gloucester	UK	1	II	51.864245	-2.238156
1	Point	Lincoln	UK	1	IX	53.230688	-0.540579
2	Point	Shrewsbury	UK	1	XX	52.707303	-2.755327
3	Point	Xanten	Germany	2	V and XV	51.657108	6.44865
4	Point	Neuss	Germany	1	XVI	51.204197	6.687951
5	Point	Bonn	Germany	1	I	50.73743	7.098207
6	Point	Mainz	Germany	2	IV and XXII	49.992862	8.247253
7	Point	Windisch	Switzerland	1	XXI	47.4779	8.21669
8	Point	Bratislava	Slovakia	1	X	48.145892	17.107137
9	Point	Budapest	Hungary	1	XIII	47.497912	19.040235
10	Point	Lyon	France	1	XIV	45.764043	4.835659







Step 2

In the **Attribute Table**, on the far left of each record there is a square grey box. This is a selection handle. If you click it, you will select that record and it will be highlighted cyan – not only in the table but in the map as well.

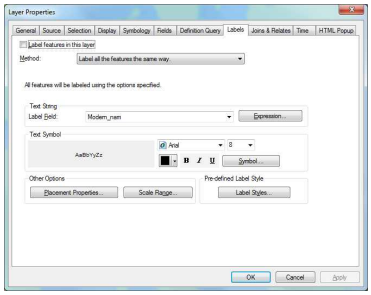
Try it.

Choosing items individually through the attribute table is one way of creating a selection of data, although not a terribly useful one.. You will learn more about creating selections in Exercise 7.

Step 3

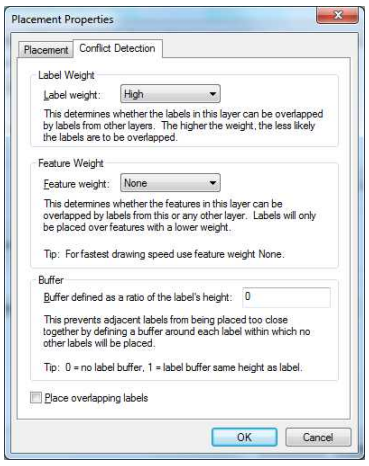
In the next task you will create labels for your new points, based on one of the columns in the **Attribute Table**. As you can see, the obvious one to go for is 'Modern Name.'

Close the **Attribute Table**.



Step 4

Open the **Layer Properties** window of the **Roman_Legions_67AD_v1** layer (see Exercise 1Task 11 if you forget how) and go to the **Labels** tab.



Step 5

On the Labels tab, set the following:

Label features in this layer = enabled

Text Field = Modern_Name

Text Symbol Size = 9

You can of course change the label colour. Labels for overlays (relatively important) should be black or dark. Labelling for less important features (e.g. in the base map) might well be mid-tones that only slightly contrast against their background..

The only other thing you need to change at this stage is the rules used for positioning the labels. Click **Placement Properties**. The **Placement Properties** window will open.

Step 6

By default, *ArcMap* will not draw labels that overlap each other in the map – it will only draw one or the other. The result of this is that, if you have points clustered near to each other, not all of them may be labelled.

This is generally undesirable, but fortunately you can change it here.

In the **Placement Properties** window, enable the **Place overlapping labels** option box.

As you might guess, it will force *ArcMap* to draw all labels no matter how many are overlapping. This will allow you to at least see all such conflicts. At first, you will not be able to do anything to resolve them. You cannot reposition labels individually without first converting them to annotation (see Exercise 3).

Click OK. The **Placement Properties** window will close.

Step 7

In the **Layer Properties** window, click OK. The window will close, and your labelling will be applied in the map.

Note that, if you now zoom in and out on the map, the labels will automatically be redrawn at each new scale in order to maintain a consistent print size.

Step 8

If desired, save your MXD and export an image of your map.

Having acquired some basic skills in working with map documents and layers of geographic data, you will now move on to the later stages of map production. Here you will work with the map as a layout of graphical elements.

Exercise 3 Basic map layout

- *The essentials of working in Layout View*
- *Create labels for a layer from a column (field) in its attribute table*
- *Edit labels individually*
- *Create 'cosmetic' labels using the Draw tools*
- *Create a scale bar and box – group them*
- *Align scale bar using guidelines*

Task 1

Open the **Exercise 3.mxd** document in Layout View

Step 1

Open **Exercise_3.mxd**. This is similar to the map document from Exercise 1, except it is missing the labels and scalebar. You will add them in this exercise.

Step 2

Change to Layout View (see Exercise 1Task 10)

Step 3

Open the Layout and Draw toolbars if they are not already open (see Exercise 1Task 3Step 3)

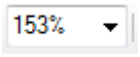
You will not always need the Draw toolbar when working in Layout View (you will in this exercise) but you will almost always need the Layout tools.

The navigation controls you used in Exercise 1 to move around the map should be thought of as **geographic** controls. Zoom in/out changes the cartographic scale of the map and Pan moves the area shown in the map.

The Layout toolbar contains another set of navigation controls for moving around the Layout space. The zoom and pan icons have a 'page' symbol on them.

The Layout navigation controls are obviously active only when you are in Layout View. The geographic navigation controls, however, are available in both Data and Layout View. This implies that, when you are in Layout View, you can use either set, i.e. use geographic zoom to tweak the map's viewpoint, and layout zoom to closely examine part of your document.

Having two sets of navigation controls in Layout View is useful, but it presents the risk that you will accidentally e.g. zoom the map geographically when you actually meant to zoom in on the layout – easily done, but very annoying if you have spent a long time fine-tuning the map's exact view. If you catch this mistake soon enough, you can simply use the geographic **Previous Extent** tool to step back. The better solution is to have created a Spatial Bookmark (see Exercise 1Task 8 and 9) ahead of time, so that you can always restore the map's extents later if necessary.

	Step 4 Practice using all of the Layout navigation controls: **Zoom in /out** and **Pan**  **Zoom Whole Page**  **Percent scale** (at 100%, what you see on screen is your physical print size)  **Go Back/Forward to Extent**  When you have finished, use **Zoom Whole Page**  to restore the view.

Task 2

Create labels from a field (column) in the attribute table of the **Roman_Legions_67AD_v2** layer.

Step 1

Create labels from the 'Modern_name' field of the **Roman_Legions_67AD_v2** layer (see Exercise 2Task 9Step 4)

Try making the labels medium to dark grey rather than black. Site labels (which often need to be small to fit them all in) should be a sans-serif font such as Arial, for legibility. At least 8-pt, not often larger than 11-pt.

When you first create a set of labels from a layer's attributes, that label set is 'linked' back to the source data. There are two aspects of this link. The first is that, if you were to edit the layer's attribute table, and labels generated from that table would correspondingly be updated. The second is that, while the labels are still linked back to the attribute table, you CANNOT manipulate individual labels – you can only make changes to the entire set, through **Layer Properties**.

It is pretty rare that your label set will be perfect when you first generate it. There are almost always at least a few positioning problems: labels overlapping each other, labels running off the edge of the map, or those simply needing a nudge in one direction or another. To make any of these piecemeal adjustments, you will need to convert the labels to an 'annotation layer.' You will do this in the next task.

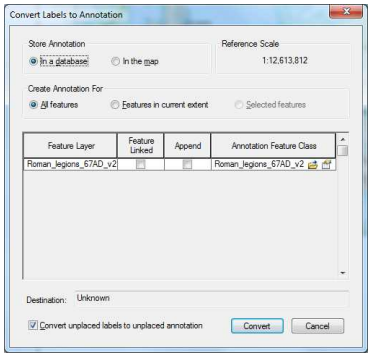
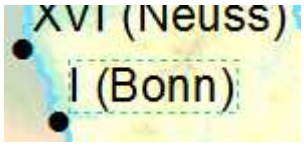
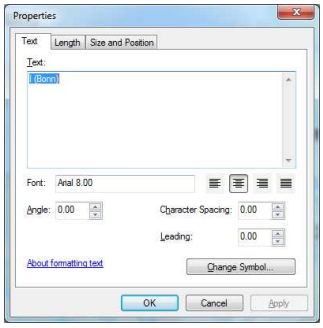
The conversion to annotation effectively severs the link to the source data – once you do it, you cannot go back!

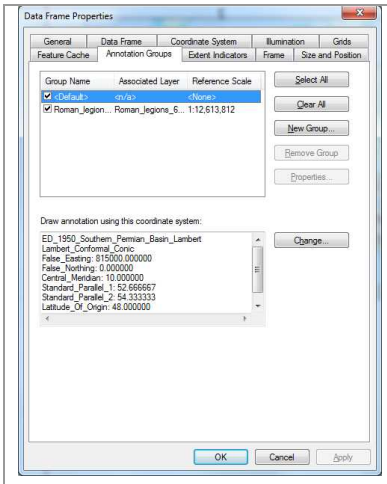
Once the labels are 'annotation,' you will be able to edit them individually. However, at that stage you will no longer be able to easily change the style of the entire group, e.g. font, size, colour etc.

Also, when you convert labels to annotation, you are assigning them the map's current scale as a 'reference scale.' This means that, if you were to later zoom the map in/out, the labels would correspondingly get larger or smaller! It is possible to later change an annotation layer's reference scale, but this is not generally a good practice, because you may then need to refine each label's exact positioning. It is better to avoid changing scale once you have started working with annotation.

So labelling (and esp converting to annotation layer) is about the LAST stage of your mapmaking workflow:

1. Add all of your layers of data to the map and assign styles
2. Decide on the map's extent (you will need to know the height/width of the finished product!) which will determine the map's cartographic scale
3. Create a spatial bookmark at the map's extent so that you can restore it if necessary
4. Generate your labels from the attribute table, deciding on the style that will apply to the entire label set
5. Convert labels to annotation and make any individual edits or repositioning needed

	Step 2 Make any final changes to the style of your labels.
Task 3 Convert the labels to an annotation layer and edit them individually	Step 1 Define a spatial bookmark for your map extents, so that you can restore the view later if necessary
	Step 2 Right-click on the **Roman_Legions_67AD_v2** layer and go to **Convert Labels to Annotation**. The **Convert Labels to Annotation** window will open.
	Step 3 In the **Convert Labels to Annotation** window, set **Store Annotation** to **In the Map.** The annotation layer will be stored in the MXD file. If not all of your labels are currently visible in the map but you would like to keep them, then check the **Convert Unplaced Labels to Unplaced Annotation** box. On the other hand, if you are certain that you want only the labels you can currently see, then by unchecking the box you can tell *ArcGIS* to ignore everything else. If in doubt, keep the box checked. Click **OK**. The **Convert Labels to Annotation** window will close and your labels will be converted.
   	Step 4 In Layout View, edit some of the individual annotation objects you have created. The only tricky part of this actually selecting the labels you wish to edit. In Layout View, if you single-click on the box containing the map (the 'data frame') you will highlight it in a single dashed line. This is for moving the data frame around on the page, resizing it etc. You will do this later in the exercise. Instead, you want to double-click on the data frame. The data frame will be highlighted in **an extra-thick hachure pattern**, indicating that you can now select annotation objects **within** the map. Once the data frame is highlighted this way, single-click on any of the labels. The label will be highlighted in a dashed line. To move the label, now simply drag it. To edit the label's content or style, double-click on it. A **Properties** window will open – make your changes to the label's content or style through the window, then click **OK**. It is possible to highlight more than one label this way, and change styles for several at once. You can rotate labels through **Properties**. You can also copy and paste labels (if one is missing) and delete them. IF YOU CANNOT GET A LABEL HIGHLIGHTED, IT MEANS THE DATA FRAME HAS NOT BEEN SELECTED PROPERLY (see above)



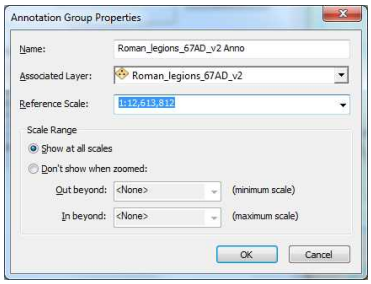
Step 5

Check the reference scale of your new annotation layer.

In the TOC, find the data frame. This is the layered icon  at the top of the table. Think of it as a 'container' for your layers, in the sense that it has a set of global parameter that apply to the entire map.

The data frame corresponds to the map object in the Layout View. It is possible to have more than one data frame in the same Layout (i.e. the same MXD file) which is how you would e.g. add a smaller 'detail' or 'locator' map as an inset to your main map.

Right-click on the data frame and go to **Properties**. The **Data Frame Properties** window will open.



Step 6

In the **Data Frame Properties** window, on the **Annotation Groups** tab you will see the annotation layer you have just created.

One of the properties of your annotation layer is its **Reference Scale**. If you have specified e.g. 8-pt font size, then this is the map scale at which your labels will be 8-pt. Zoom in and they will become bigger!

As mentioned earlier, if you are in the position of having to zoom your map in/out AFTER having converted to annotation, you will need to set the annotation layer's refence scale to the current (new) scale. Here in the data frame is where you would do it – highlight the layer you need to re-scale, then click **Properties**. In the **Properties** window, set **Reference Scale** to **<Use Current Scale>**, then click OK, then OK to return to the map. Your annotation objects should now be rescaled – that was easy enough, but (depending on how drastic the change was) you may need to now reposition some or all of your labels, as the re-scaling may have shifted them.

Click OK to close the **Data Frame Properties** window.

Task 4

Create 'cosmetic' labels using the Draw tools

Step 1

The workflow of the previous two tasks (generating labels from an attribute > applying style > converting to annotation > individual edits) is a little convoluted, but it has two important advantages:

1. For large numbers of features (e.g. site layers) it is the quickest way of generating a lot of labels
2. The outcome of the workflow (an annotation layer) is geographically referenced. If you needed to pan the map, the labels would move **with** the data, i.e. stay in their correct places

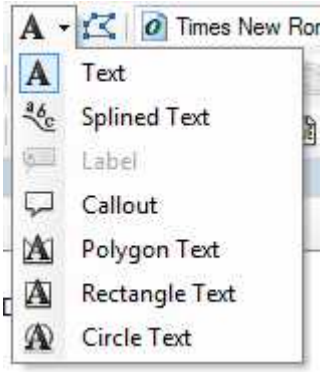
So the above workflow is generally recommended for labelling large numbers of features that can be labelled in horizontal (or at most, rotated) text.

In some cases, though, annotation is less effective for labelling. Or you may simply need a shortcut way of adding some text to the map. In this case, use the Draw toolbar to add a text object.

This is particularly useful for

1. Labelling rivers, which usually need curved rather than rotated text
2. Labelling large polygons (oceans, countries etc) that may extend some distance off the map, because the 'placed annotation' label will often end up outside of your map
3. Labelling features when you do not have any suitable fields in the attribute table to generate them (not a great practice, but it's a shortcut)

The disadvantage of the Draw tools is that the text objects they create are layout objects rather than geographic features. If you need to pan the map, the layout text will NOT move with the data.

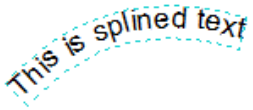


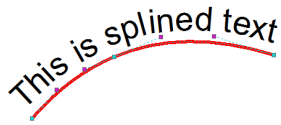
On the Draw toolbar, pull down the **New Text** menu.

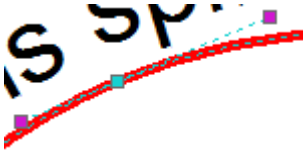
You can add **Text** (horizontal/rotated) or **Splined Text** (i.e. curved)

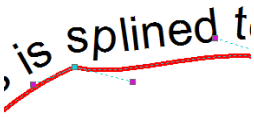
Click on the **Text** tool, then simply click anywhere in your map that you wish to add a label, and begin typing.

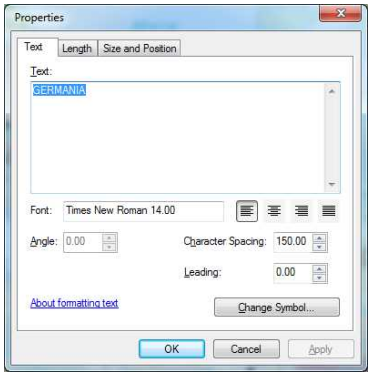
The text you create this way can later be edited much like annotation text.











Step 2

On the Draw toolbar, select the **Spline Text** tool.

In this case, you need to first draw the curve that the text will follow. A few bits of advice:

1. Make the curve simple where possible: one point at the start, one in the middle to define curvature, and one at the end
2. Make the curve just a little longer than the area you want the text to occupy
3. For rivers, you may need a more complex curve. But keep it simple and just add points where there is a major change in direction.

When you have the **Spline Text** tool selected, click once in the map to start drawing your curve, and once at each subsequent point along the curve. Double-click on the final point, to finish the curve.

Step 3

Once the curve is finished, there will be a curved text object with 'Text' as the content.

Double-click on this using the **Select Elements** tool and you will open its **Properties** window. You can change the text here, and make many of the other changes as above (except you cannot rotate spline text). Click OK to close **Properties**.

Step 4

When you have highlighted an item of curved text, you can also edit the curve using the **Edit Vertices** tool. When you are in vertex editing mode, the light blue handles on the curve are the control points you defined, and the purple handles are their tangents. Have a play with them to see how they behave, if you wish. Click on any other tool icon to exit vertex-editing mode.

Step 5

Now use the Draw tools to create some text to label territories (e.g. Gaul, Germania, Britannia) and oceans and seas in the map. Choose whatever styles you like.

Labels for water bodies generally in a shade of blue just a little darker than the oceans/lakes themselves, and use italics. Labels for territories can be anything, but generally choose something subtle or muted to de-emphasise labelling in your base map, if it is less important than the overlay.

Generally, text for oceans and territories should be fainter (but larger in font size) than the site labels. Use all CAPS, if you wish.

Note also that, where possible, you should use character spacing to 'stretch' the label text horizontally to give a sense of proportion. Large oceans and territories might use spacing of 150 – 400. Smaller states, rivers, lakes etc more like 30 – 100.

Step 6

Practice labelling as much as you can – creating labels, editing them, and applying different styles.

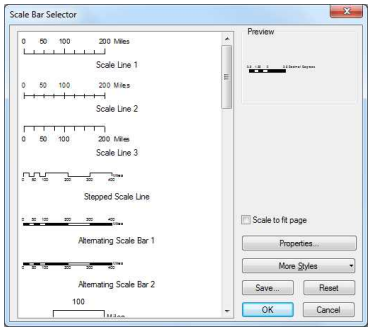
Labelling is one of the most fiddly and time-consuming parts of mapmaking, but it is very important. Labels that are well placed and clearly legible make all the difference to the finished product.

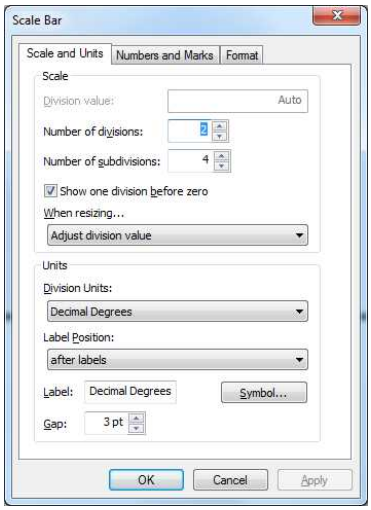
If you need to label a LOT of features in your map or your sites are very densely concentrated, then you may have a difficult labelling job. A few approaches to this:

1. Make more than one map – easy enough, once you have set up the first map
2. Make a second (detail) map of the most concentrated areas, and inset this into the corner of the main map (you will need to create a new data frame in order to do this)
3. Spread your labels out and use leader lines to connect them back to their corresponding features
4. Use letters or numbers to label features – obviously you then have to include a key!

Task 5

Create a scale bar inside a box and group them together





Step 1

Create a scale bar.

Click on **Insert | Scale Bar**. The **Scale Bar Selector** window will appear.

Step 2

On the left of the **Scale Bar Selector** window there is a menu of scale bar templates. The first few templates are fairly standard, while some further down are more elaborate.

Highlight one of the templates, then click **Properties**. The **Scale Bar** window will appear.

Step 3

In the **Scale Bar** window you can specify the style and properties of the scale bar before you create it. Don't dwell too much on this, though, because you can always change these settings later once the object is created (simply by double-clicking on the scale bar object in the Layout View). Most of the map components listed on the **Insert** menu behave this same way.

Set the scale bar properties as follows:

On the **Numbers and Marks** tab:

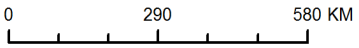
Numbers > Frequency = Divisions

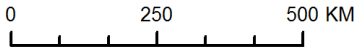
On the **Scale and Units** tab:

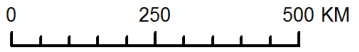
Units > Division Units = Kilometers

Unit > Label = KM

Click **OK** then **OK**. Your scale bar will be created in the layout.





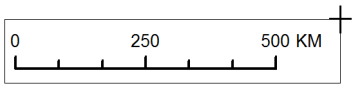


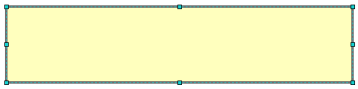
Step 4

Your scale bar can be edited as much as you like. You could double-click on it to go back into its **Properties**. If you single-click on it, you could move it around the layout or re-size it. It is linked to the data frame (map) view, so if you make the scale bar longer or shorter, the numbers on it will correspondingly change. On the other hand, if you zoom in the map in or out, the scale bar will also be re-drawn automatically.

Generally, you want to have decided the final extents of the map (hence, the map scale) before you get to the stage of adding the scale bar. This is because you usually want the scale bar length to be a nice round number (10, 50, 100, 150, 200 etc) and if you subsequently zoom in/out, it will change.

Lengthen or shorten the scale bar to a nice round number, or it will look a bit silly. Then look at the number of subdivisions (tick marks) on the bar. Does the nice round number divide evenly into those subdivisions? For example, if you have a 200-km scale bar, you would normally want either two subdivisions (100-km each) or four (50-km each) or eight (25-km each) etc. Three would not make any sense, because each would represent 66.66 km. This sounds like a fine point, but anyone who actually consults the scale bar might well notice it. You can change the number of subdivisions in the **Properties** window, on the **Scale and Units** tab.





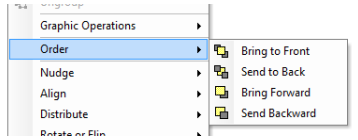
Step 5

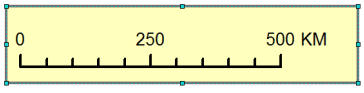
Draw a box around the scale bar.

On the Draw toolbar, select the **Rectangle** tool.

Simply click in one corner of the scale bar and drag a box to the diagonally opposite corner, being sure to leave a little bit of a margin between the box and the bar.

Your box will appear, by default as a yellow polygon. For the moment, it is on the top of the layout's drawing order, so it is blocking out the scale bar below.

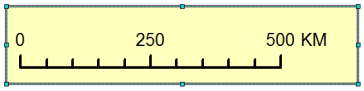


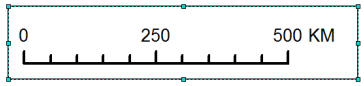


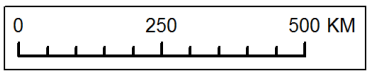
Step 6

Push the box down one level in the drawing order. Right-click on it and go to **Order > Send Backward**. This will send it 'back' one level, so it will be between the scale bar and the map.

If the box disappears completely at this stage, it is probably because you accidentally selected **Send to Back** and it is now at the very bottom of the drawing order (behind the map) and therefore may be hidden from view. In this case, just click CTRL+Z to undo.







Step 7

The scale bar should now appear to be 'inside' the box, but chances are that the box is not quite the right size, and you certainly don't want the yellow fill style..

Adjust the size of the box. First, zoom in on the box using the Layout Zoom In tool (NOT the geographic zoom tool!) so that you can get a close-up view.

Next, single-click on the box so that you can re-size and reposition it around the scale bar.

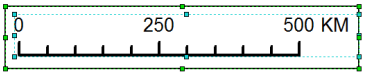
Finally, double-click on the box to open its **Properties**. Set the following:

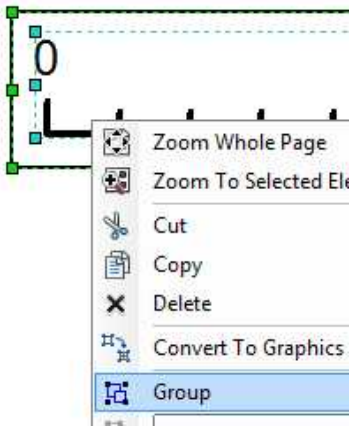
Fill colour = white

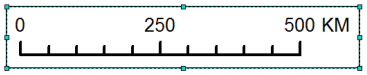
Outline colour = black

Outline width = 0.5

Click OK to close **Properties**.







Step 8

Finally, group the scale bar and box together.

Single-click on one, then hold down SHIFT and single-click on the other. Make sure that you have both selected, then right-click and go to **Group**.

If you are zoomed in on the layout, click the layout **Zoom Whole Page** icon to restore the view to the whole document.

The two components will now be a 'group' that can only be selected, moved, scaled as a whole. To get back to the component level, you would need to Ungroup them.

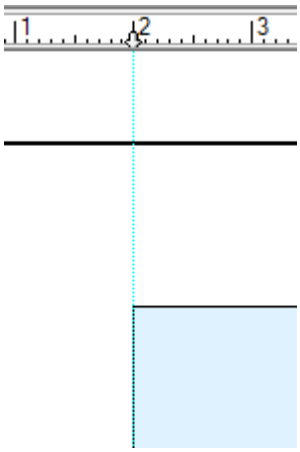
A layout with many components (scale bar, legends, title block, inset map etc) may have several groups and sub-groups (groups are hierarchical). So, to edit a fine detail of e.g. an item on a legend, you may need to 'ungroup' several levels down, make your change, and then re-group things to restore the structure..

Generally this is the way layouts are put together: add individual components from the Insert menu, align and style them, and then group them together into larger and larger pieces. In the example here you will simply put the scale bar in the corner of the map.

Instead of going to the trouble of drawing a rectangle around the scale bar as a separate object, you could have simply used the Frame tab of the scale bar's properties to create a border. That would have been rather quicker, and possibly more precise, but ultimately a bit more limited – if you wanted to make the box slightly larger to put other things in it next to the scale bar (citation, north arrow etc) then using a Frame would have made it difficult to do that. On the other hand, you may prefer to work that way.

Task 6

Align the scalebar group in the lower left or right corner of the map (data frame) using guidelines



Step 1

Now that you have the scale bar and box grouped together, let's say that you want to put the scale bar group exactly in the lower left or right corner of the map (data frame).

You might try to do this by zooming in on the layout as far as you can and trying to align them by eye, but this would be folly – they would never quite line up.

Alternatively, if you prefer using layout 'coordinates' you could do this alignment entirely by using the **Size and Position** tabs in the **Properties** of the data frame (map) and scale bar group. You would set their Position X,Y to the same location. That's not bad, and would actually be worth trying once you get into more complex layouts. But that's a bit abstract if you are inclined to working visually with graphics.

The third approach is to use a 'snapping' behaviour to get the map and scale bar group aligned on each other. It is possible to set up snapping to an arbitrary grid in the layout (this is in **ArcMap Options** if you are interested) but what is simpler and more intuitive is to simply create a vertical and a horizontal guideline and snap them into the intersection.

Note the horizontal ruler extending along the top of the Layout View. This is (be default) graduated in cm.

To set up a vertical guideline, click somewhere along the ruler. A vertical cyan line will be created through the layout. Using the handle at the top, you can now drag this left or right (depending on which corner of the map you want to use) but stay on the page.

Step 2

Map components will (by default) snap to guidelines when they get close enough to them.

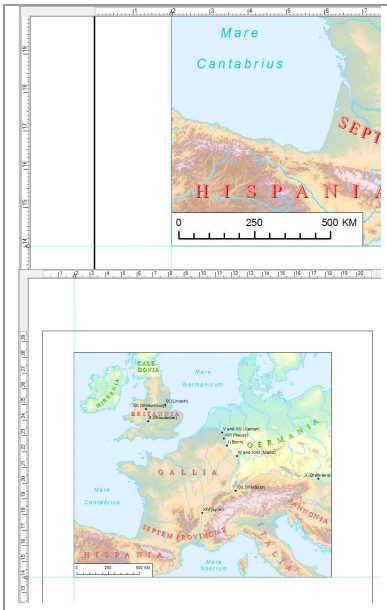
Try it – drag the map left or right, and when its edge approaches the line, the data frame will snap into position.

Step 3

Create a horizontal guideline, somewhere near the bottom of the layout.

Step 4

Drag the map again, putting the lower left (or right) corner at the intersection of the two guidelines.

	Step 5 Now do the same to the scale bar group. Both will have the same corners aligned at the same point -- the guideline intersection. Guidelines are incredibly useful for working in layouts, but they can become annoying if you have many of them and they are causing unintentional snaps when you are moving components around.. If this happens and you don't want to delete your guidelines or move them out of the way, you can temporarily deactivate them – right-click in Layout View and go to **ArcMap Options > Layout View** and disable them **under Snap Elements To**.
Task 7 Output your map	Step 1 Export an image of your map (see Exercise 1Task 13)

You now have a reasonably complete set of skills for making simple maps from existing datasets.

You will quickly come to realise, however, that you often need to create or edit GIS data to be able to produce the map you need. The 'overlay' of the map is usually something that you will need to create, often from your own data. The base map may be something you can acquire (or adapt) from an 'off the shelf' source. If not, you may need to create that as well.

The next set of exercises will cover core skills in doing this.

3 Intermediate Skills

One of the simplest and most common applications for GIS is to simply 'put dots on a map.' This is relatively straightforward, but there are a few shortcuts and potential pitfalls along the way.

If you have a list of placenames you wish to plot on a map, the first thing you will need to do is to 'geocode' them -- get their geographic coordinates. In cases where your placenames are obscure, ambiguous or otherwise problematic, you will be best of geocoding them 'manually,' one by one. For straightforward cases of geocoding, however, there are automated tools that may save you several hours.

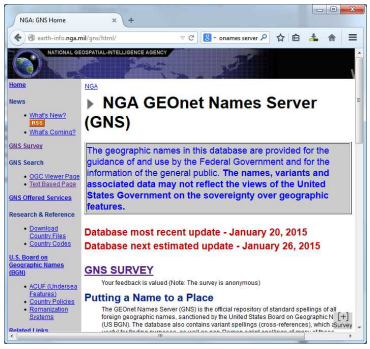
In the following exercise, you will do both.

Exercise 4 Geocode your site records

- *Geocode a single placename*
- *Perform batch geocoding*
- *Identify features in your map*

Task 1

Geocode a single placename



Step 1

In this task, you will 'geocode' (lookup geographic coordinates for) a single placename.

There are many websites out there that publish geographic coordinates for placenames, i.e. online gazetteers. Two of the more extensive and useful ones are Wikipedia and the GEONet Names Server (GNS) of the US National Geospatial Intelligence Agency (NGA).

Wikipedia is good because the coordinates are embedded in articles about the places, so you can confirm that you are getting the correct place. On the other hand, GNS is good because it offers alternative spellings of the same placename.

Open an Internet browser, go to Wikipedia and search for 'Rome.'

Step 2

Virtually any article in Wikipedia about a subject that can reasonably be assigned a point location (from the scale of individual buildings to small countries/provinces) will include a latitude/longitude. These 'Coordinates' are normally located in the upper-right corner of the article. Sometimes it is in the text box on the right of the article.

At the moment, there is no standard format for expressing lat/long in Wikipedia. It is sometimes given in a 'degrees-minutes' format, e.g.

41°54' N 12°30' E

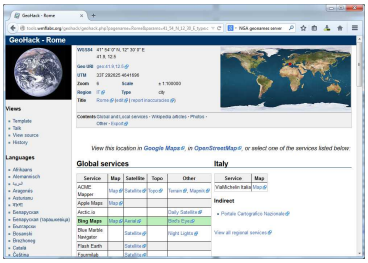
or, if very precise, in 'degrees-minutes-seconds' (DMS)

41°54'12" N 12°30'49" E

This is the traditional way of expressing angular coordinates (i.e. 60 arc-minutes in a degree and 60 arc-seconds in an arc-minute) but unfortunately it is not useful for GIS – you need a single numerical value for latitude and a single value for longitude. Also, 'north/south' and 'east/west' don't mean anything to GIS – you must represent these using positive and negative numbers.

In this case, you need to convert these lat/longs into a 'decimal degrees' (DD) format. This is easy enough to do in Excel, but Wikipedia comes to the rescue.

Double-click on the coordinates given in Wikipedia article on Rome (not on the word 'Coordinates,' but the numbers themselves.) You will go to the GeoHack website, where those coordinates will be turned into all sorts of useful things.



Step 3

The GeoHacks website is not really a 'site' so much as a service delivered through a web page.

The most important thing, for the purposes of this exercise, is that your lat/long will be converted into a decimal format, at the top of the page under 'WGS84'

In this case, the decimal form is 41.9, 12.5. This is what you would want to collate in your spreadsheet of site records. Be sure to keep any negative symbols.

While you are here, have a look further down the page. GeoHacks has also generated links to that given geographic location in 20-some very useful online mapping applications, geolocated photo collections, other Wikipedia articles.. Handy!

If you were going to use these coordinates, you would now cut and paste them into e.g. *Excel*.

Note that, if you are going to paste the coordinate pair directly into a spreadsheet, you MUST split latitude and longitude up into separate columns before importing into GIS. You can either do this by hand or, if you paste '41.9, 12.5' into a single cell, you can use **Text to Columns** to automatically split them at the comma character – you will do this in the next task.

Task 2

'Batch geocode' a list of placenames and tabulate the results in *Excel*

Step 1

You will now use an online geocoding tool to automate lookups for an entire list of placenames.

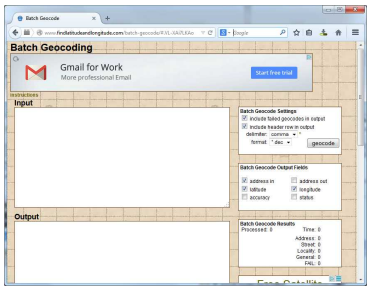
First, open the text document **Roman_garrisons_v1.txt**. This is a list of the placenames you will use.

Placenames can be in any format and they can be as specific as you like: countries, provinces, towns, villages, street addresses, postcodes will all produce results.

Note that we have (with one exception) avoided using commas in this list. This is because the results of the geocoding will be in a 'comma-separated values' (CSV) format, and we don't want commas in our data content – things will get a little mixed up. The comma included in the list will illustrate what happens.

Step 2

Copy your list of placenames to the clipboard (highlight all of them, then CTRL+C)



Step 3

Open an Internet browser and do a search for 'batch geocode.'

The results will include several different web-based geocoding tools. A good one is a website called findlatitudeandlongitude.com. You specifically want the batch geocoding page (there are other tools on the site). The full URL you are looking for is:

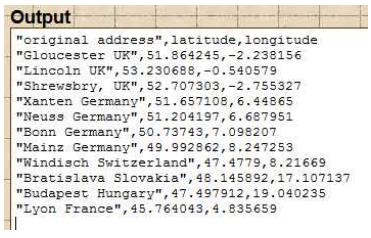
http://www.findlatitudeandlongitude.com/batch-geocode/

Step 4

On the batch geocoding page, paste (CTRL+V) your list of placenames into the 'Input' box.

Step 5

Check your options in the boxes on the right side of the page. For example, if you want an estimated accuracy figure (just an arbitrary scale), tick the box.



Step 6

Click the **Geocode** button.

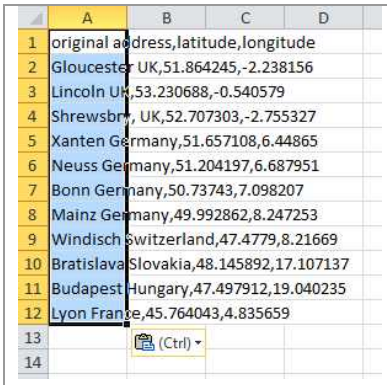
The website will parse your list of placenames, passing each line of text to the Google search engine. It then extracts the latitude and longitude of the first Google search result and reports the outcome in the 'Output' box.

Wait for the geocoding process to finish.

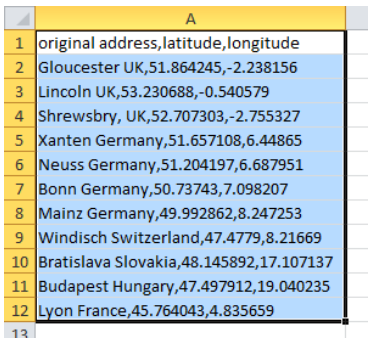
Note that the first line of the results are column headers and the content begins at the second line. Note also that everything is 'comma-separated.'

Step 7

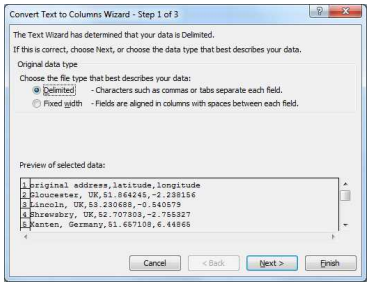
Copy the content of the 'Output' box to the clipboard (highlight all, then CTRL+C)

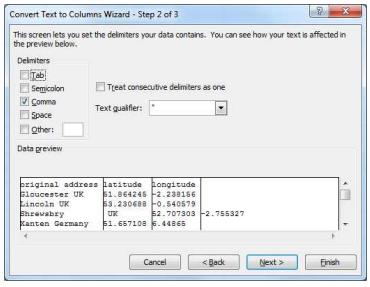


	A	B	C	D
1	original address,latitude,longitude			
2	Gloucester UK,51.864245,-2.238156			
3	Lincoln UK,53.230688,-0.540579			
4	Shrewsbry, UK,52.707303,-2.755327			
5	Xanten Germany,51.657108,6.44865			
6	Neuss Germany,51.204197,6.687951			
7	Bonn Germany,50.73743,7.098207			
8	Mainz Germany,49.992862,8.247253			
9	Windisch Switzerland,47.4779,8.21669			
10	Bratislava Slovakia,48.145892,17.107137			
11	Budapest Hungary,47.497912,19.040235			
12	Lyon France,45.764043,4.835659			
13				
14				



	A
1	original address,latitude,longitude
2	Gloucester UK,51.864245,-2.238156
3	Lincoln UK,53.230688,-0.540579
4	Shrewsbry, UK,52.707303,-2.755327
5	Xanten Germany,51.657108,6.44865
6	Neuss Germany,51.204197,6.687951
7	Bonn Germany,50.73743,7.098207
8	Mainz Germany,49.992862,8.247253
9	Windisch Switzerland,47.4779,8.21669
10	Bratislava Slovakia,48.145892,17.107137
11	Budapest Hungary,47.497912,19.040235
12	Lyon France,45.764043,4.835659
13	





	A	B	C	D
1	original address	latitude	longitude	
2	Gloucester UK	51.86425	-2.23816	
3	Lincoln UK	53.23069	-0.54058	
4	Shrewsbry	UK	52.7073	-2.75533
5	Xanten Germany	51.65711	6.44865	
6	Neuss Germany	51.2042	6.687951	
7	Bonn Germany	50.73743	7.098207	
8	Mainz Germany	49.99286	8.247253	

	A	B	C
1	original address	latitude	longitude
2	Gloucester UK	51.86425	-2.23816
3	Lincoln UK	53.23069	-0.54058
4	Shrewsbry	52.7073	-2.75533
5	Xanten Germany	51.65711	6.44865
6	Neuss Germany	51.2042	6.687951
7	Bonn Germany	50.73743	7.098207
8	Mainz Germany	49.99286	8.247253

Step 8

Open an empty *Excel* spreadsheet and paste (CTRL+V) the content into the far left column.

Note that all of the content has been pasted into a single column. You may need to widen the first (A) column in order to see this. Of course, this format is no good for *ArcGIS*..

Fortunately, there is a very easy way of inserting column breaks at the comma characters.

Step 9

Highlight the entire column where you pasted the data, by clicking on the column header (e.g. A, B C etc)

On the **Data** tab, click **Text to Columns**. The **Convert Text to Columns Wizard** window will open.

Step 10

In the **Convert Text to Columns Wizard** window, ensure that Delimited is selected. You want to break the text into columns at each occurrence of the delimiting character (the commas), rather than at fixed intervals.

Click **Next**.

Step 11

On Page 2 of the Wizard, under Delimiters, tick the box next to Comma. Then click **Finish**.

The Wizard will close, and *Excel* will break up your data into columns as required.

However, note that the one original comma we included in the source data has caused a problem here – *Excel* obviously can't distinguish between our comma and the ones inserted by the geocoder, and has inserted an unintended column break in that record.

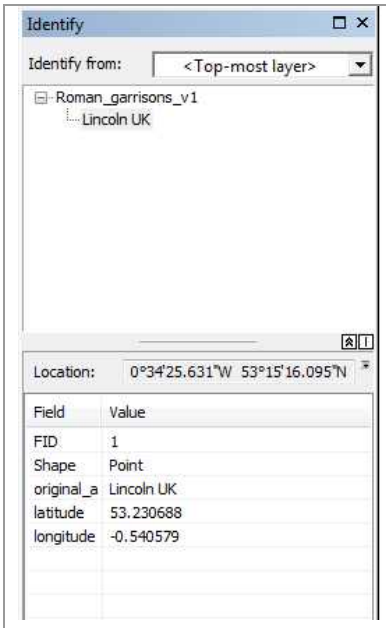
To get around this, you could have told the geocoder (in Options) to use a different delimiting character. 'Tab' or 'pipe' characters were possibilities. In that case, you would just need to tell *Excel* what your chosen delimiter(s) are.

The best advice is to simply plan ahead when you are collating your original list – anticipate problems and make smart use of delimiting characters in order to minimise the amount of 'cleanup' necessary

In this case, to fix the problem, simply drag the lat/longs into their correct place.

If you wanted to add further fields (columns) of data onto your placename records (attributes, statistics etc) now would be the time to do it. In the next task, you will plot these as a layer of points.

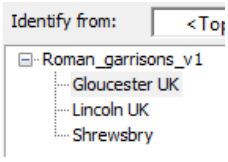
	Step 12 Save this as **Roman_garrisons_v1.XLS** in your exercise files folder. Close *Excel*.
Task 3 Plot your points as a layer in *ArcGIS*	Step 1 Open the **Exercise_4.mxd** document in *ArcMap*.
	Step 2 Create a point layer from the **Roman_garrisons_v1.XLS** spreadsheet (see Exercise 2Task 8). Name the shapefile **Roman_garrisons_v1** Add it to the map.
Task 4 Identify features in your map using the **Identify** tool	Step 1 Once your layer of points has been added to the map, you may want to do a quick check to ensure that your data has been plotted correctly and that there are no obvious 'outliers' in incorrect locations. One way of doing this is to right-click on the new layer in the TOC and go to **Zoom to Layer**. The full spatial extent of the layer's data will be framed in the map view, ensuring that all features in the layer are visible. Try it, and check that all of your sites have been plotted in vaguely plausible locations..
	Step 2 Let's suppose that one of your dots in particular has ended up in a 'dubious' location .. You could identify that dot by generating labels (see Exercise 3Task 2) or isolating it using a selection tool (see Exercise 7). Another approach would be to use the **Identify** tool, on the Tools toolbar. Select this tool.
	Step 3 Click on a point object in your map. The feature you queried will momentarily be highlighted green in the map, then the **Identify** window will open.



Step 4

The **Identify** window presents the row (record) from the attribute table corresponding to the object you clicked on. The attributes are presented as a table.

If you clicked on a cluster of points, there may be several sets of results in the **Identify** window. In this case, there will be a short list in the top of the window, which you can browse through..



Using the **Identify** tool, you may see an obvious error in e.g. data entry or geocoding. To fix it, the best practice would be to go back into *Excel*, make the correction there, then re-create the point layer in *ArcGIS*.

If you had incorrect coordinates for a point, correcting them through the attribute table in *ArcGIS* would not do anything – once the shapefile has been created, the point object's location is no longer 'linked' to it. Equally, while you could 'manually' drag the point to its correct location in the map (you would need to start an editing session) that would not be a good practice in data management.

Exercise 5 Download vector and raster data

- *Visit the Natural Earth website*
- *Download vector and raster layer(s) of your choice*
- *Extract the ZIP files*
- *Open the downloaded files in ArcGIS*

Task 1

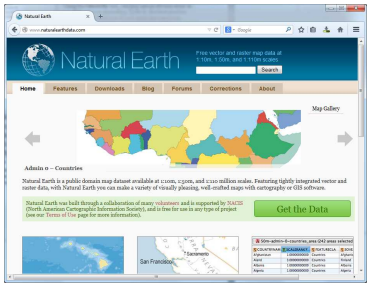
Visit the Natural Earth website and download some vector and raster data

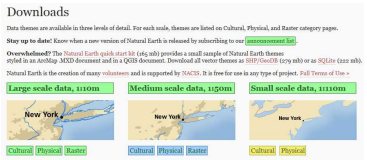
Step 1

There is a huge number and variety of online sources offering GIS data for download. Some are commercial, while others are in the public domain.

One of the most useful freely available products for general purpose base maps is Natural Earth. This includes both physical and cultural layers and is provided at three scales (1:110 million, 1:50 million, and 1:10 million) making it suitable for national mapping roughly down to the level of medium-sized countries, i.e. Italy mapped at A4 size is roughly 1:10 million.

Go to www.naturalearthdata.com and have a look





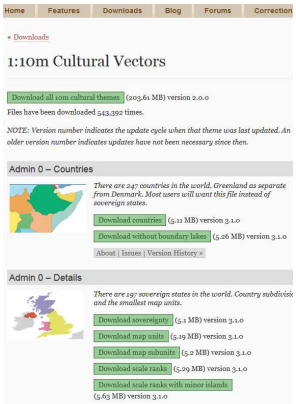
Step 2

On the home page, either click **Get the Data** or go to the Downloads tab.

The downloads are organised first by scale, then by coverage type. 'Cultural' and 'Physical' are both vector layers (i.e. shapefiles) while the 'Raster' images are mainly representations of elevation and bathymetry.

The 1:10 million data is spatially the most detailed. However, do note that it is possible for vector data to be TOO detailed for a given map. For example, if you are mapping the whole of Europe at half-A4 size and you use a 1:10 million vector product, some areas of your coastline will appear 'thicker' than others. In places where the coastline weaves back and forth (e.g. Scandinavia) all of that detail will be concentrated in a small space. Straighter areas of coastline would appear 'thinner.' In that case, you might be better off with a lower-scale data product, e.g. the 1:50 million. Alternatively, the more sophisticated approach would be to run a Simplify process on the 1:10 million data to make it more suitable for mapping at e.g. 1:30 million – in doing so, you would need to be very careful not to introduce topological inconsistencies in the data.

Have a look around at what's offered here.



Step 3

On the Cultural and Physical pages, the download link at the top of the page is for the entire set of layers, or you can download each layer individually.

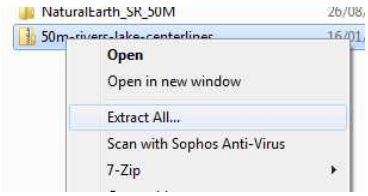
One thing worth noting is that political territories are available both as polygons and polylines (i.e. 'boundaries') Polygons are more useful for e.g. colour-coded mapping, while boundaries (as lines) are generally better for mapping international boundaries. This is because, in the polygon version, two neighbouring countries will effectively be two contiguous polygons – this means that the border will in fact be two overlapping outlines, along the shared border. The problem with that is, if you want to show that border as a dashed line, you will have TWO dashed lines overlapping each other, resulting in a jumbled pattern. In the line version, each border is represented by only ONE object, so that dashed or dotted patterns can be used.

On your own machine, it is probably worth downloading all of the Natural Earth data – most of it will be useful sooner or later.

For the purposes of this exercise, just download one or two layers. Save them to the Natural Earth folder in your exercise files.

Task 2

Extract the downloaded ZIP files



Step 1

Like most GIS datasets, Natural Earth is downloaded as ZIP archives. You must first extract these before you can use them in *ArcGIS*.

To unzip a ZIP file, right-click on it and go to **Extract All**, then click **Extract**.

Each Natural Earth layer will be unpacked into a separate folder.

Task 3

Open the downloaded data in *ArcMap*.

Step 1

If you had *ArcGIS* running in the background this whole time that you were downloading, remember that CATALOG DOES NOT AUTIMATICALLY REFRESH. In this case, your newly downloaded files will not appear.

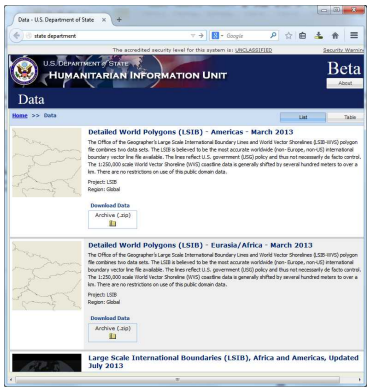
To refresh the view, right- click on your exercise files folder in Catalog and go to **Refresh**. Your files should now appear where you extracted them.

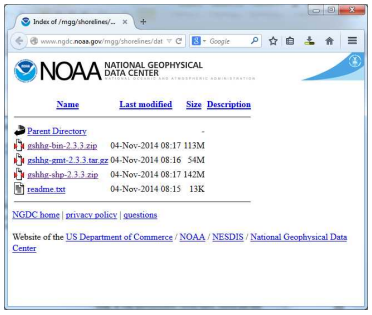
Step 2

Open your downloaded Natural Earth files and have a look. If you downloaded vector data, check out the attribute tables.

Task 4

If you have time..





Step 1

The 1:10 million data from Natural Earth is just about the most detailed general-purpose base map data there is in the public domain.

If you are looking for a base map that is more detailed (larger scale) then you have a few options:

1. The US State Department offers a global landmass/coastline layer and an international boundaries layer, at two scales https://hiu.state.gov/data/data.aspx . The LSIB products are about 1:1 million and the 'Simplified' products are 1:3 million.
2. The US National Geophysical Data Centre offers a global coastline dataset at 1:250,000 scale. http://www.ngdc.noaa.gov/mgg/shorelines/data/gshhg/latest/ and download the latest shapefile (shp) version, named something like **gshhg-shp-2.3.3.zip**. While this is just a coastline layer, coastline objects could be converted into polygons for landmasses
3. Stream in a third-party WMS map image into the background of your map document. This is easy to do, but you cannot manipulate the WMS image – it's 'take it or leave it.'
4. Download OpenStreetMap data (often very detailed) and extract what you want from it – OSM is not quite as neatly prepackaged as Natural Earth. Find it at the Trimble Data Marketplace
5. Stream in WMS high-resolution satellite imagery and digitise map features from it (you will learn how to digitise features in Exercise 9).
6. Licence larger scale data from a commercial source or e.g. national mapping agency in your study area

Have a look at 1 and 2, if you are interested and have the time.

Step 2

There are a vast number of websites that provide GIS data for download.

An Internet search for 'geology map Africa' will return only images of maps (not too useful for GIS). However, a search for 'geology Africa **GIS data download'** will produce much more useful results..

If you have time, have a look for GIS data products relevant to you and see what you can find.

Exercise 6 Join your tabular data onto existing vector objects and create symbology

- *Open an Excel table in ArcGIS*
- *Perform an attribute-based join*
- *Create a 'chloropleth' (colour-coded) symbology for the joined data*
- *Export an attribute table to Excel*

Task 1

Inspect the table in *Excel*

	A	B	C
1	Prov Name	Inscriptions	Earliest
2	Achaea	3	A
3	Aegyptus	-999	
4	Aemilia	7	A
5	Africa Proconsularis	-999	
6	Alpes Cottiae	2	A
7	Alpes Maritimae	0	
8	Alpes Poeninae	1	B
9	Apulia et Calabria	1	B
10	Aquitanica I	3	C.1

Step 1

Open the **Province_stats_v1.XLS** spreadsheet in *Excel*. This is the data you will use to generate a colour-coded map in this exercise. First, you will need to 'join' it onto the polygon shapefile of provinces.

The data is geographically referenced by province – we have been careful here to use the exact same names that are used in our shapefile, because the names must match **exactly** or the join will fail for that record. For illustration, the name of 'Libya Inferior' has been changed, so that you can see what happens.

There are then two fields of data: 'Inscriptions' (numerical) and 'Earliest' (categorical).

Note that it is generally not a good practice to leave cells in a numerical column blank. In *ArcGIS*, a numerical field cannot be blank -- when this spreadsheet is imported into *ArcGIS*, any blank cells will be reassigned as '0.' This may become problematic, because a positive record of '0' is often different to having no available data. To get around this problem, most numerical datasets will have a defined 'NULL' value that represents an absence of data. This is usually a negative number (in this case -999) esp in cases where negative values are not possible in the data itself. Records with NULL values can then be isolated or ignored in subsequent processing.

Note that this does not apply to categorical fields such as 'Earliest.' *ArcGIS* will recognise this as a text field, and blanks are allowed in text. However, the thing to remember in categorical fields is that your terms MUST be exactly consistent. Even if the spelling is identical but there is a space character after the term, that will be counted as a separate category..

Note also that the data is on the first worksheet, called Inscriptions. You will need to know which sheet your data is on when you bring it into *ArcGIS*.

Step 2

Close *Excel*.

Task 2

Open the table in *ArcGIS* and inspect it

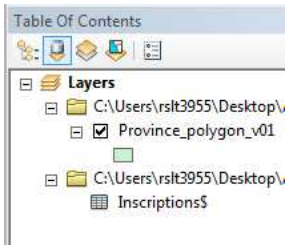
Step 1

Open the **Exercise_6.mxd** file in *ArcGIS*.

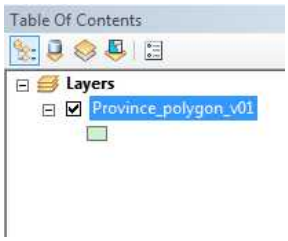
Step 2

In Catalog, browse to the **Province_stats_v1.XLS** spreadsheet and expand it (+ symbol)

List by source mode:



List by drawing order:



Step 3

Drag the Inscriptions worksheet into the map.

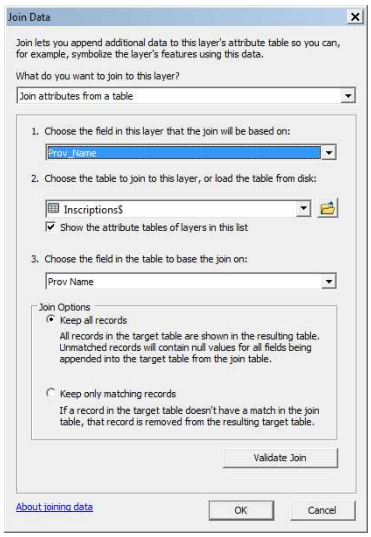
Nothing in the Data/Layout view will change, but there will be two changes in the TOC. The first (obvious) is that the Inscriptions table will be added as a 'table' layer. The second, less evident, is that the TOC will change from **List by Drawing Order** mode to **List by Source** mode.

Source mode is not generally the most useful way of looking at the TOC. You can restore it simply by clicking on the **Drawing Order** icon. 

Note that the Inscriptions table will disappear, as it does not contain any geometry.

Task 3

Perform an attribute-based join



Step 1

Think of an attribute based join as a directional process, i.e. transferring data **from** a table **to** a shapefile.

To create the join, in the TOC, right-click on the layer that is receiving the data (in this case, Province_polygon_v01) and go to **Joins and Relates | Join**.

The **Join Data** window will open.

Step 2

In the **Join Data** window, you will first need to choose between an attribute join and a spatial join.

An attribute join is for joining one table (in this case, an imported spreadsheet) onto another (in this case, the attribute table of an existing shapefile) by performing a matching exercise between a designated column in each sheet.

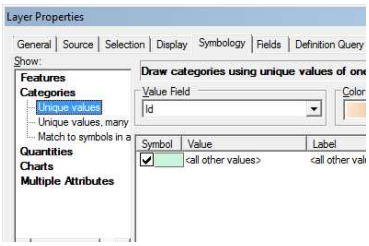
In a spatial join, you are also transferring data from one layer to another, but it works in a very different way. For example, if you have a point layer and a polygon layer that overlap spatially, you could use a spatial join to transfer the attributes of each polygon onto all of the points that fall within it.

You will not do an exercise on spatial joins in this course, as they are not quite as broadly applicable as attribute joins. But it is certainly worth knowing that they exist, because they can be very powerful for solving specific problems.

Pull down the **What do you want to join to this layer** menu and choose **Join attributes from a table**.

	Step 3 You now need to identify the columns that the two tables have in common. Set the following: 1. Choose the field in this layer that the join will be based on = Prov_name 2. Choose the table to join to this layer, or load the table from disk = Inscriptions$ 3. Choose the field in the table to base the join on = Prov Name
	Step 4 There are two **Join Options**. The explanations given are fairly clear. You can either keep all records in the provinces shapefile regardless of whether they appear in your *Excel* spreadsheet, or you can keep only the provinces that have a match in your table. Note that this is NOT in any way destructive, and the join can be undone at any time. In the majority of cases, you will want the first option, because you usually want to be aware of failures to match data – they can sometimes represent errors rather than absences of data. In this case, choose **Keep all records**.
	Step 5 Click **OK**. *ArcGIS* will parse both tables and, where the specified fields match, it will 'transfer' the data from your table to the provinces shapefile.
 n_v01 Id | Prov_Name | Prov Name | Inscriptions 0 Achaea Achaea 3 0 Aegyptus Aegyptus -999 0 Aemilia Aemilia 7 0 Africa Proconsularis Africa Proconsularis -999 0 Alpes Cottiae Alpes Cottiae 2 0 Alpes Maritimae Alpes Maritimae 0 0 Alpes Poeninae Alpes Poeninae 1 0 Apulia et Calabria Apulia et Calabria 1 0 Aquitanica I Aquitanica I 3 0 Aquitanica II Aquitanica II 5 0 Arabia Arabia -999 0 Armenia I Armenia I -999 0 Armenia II Armenia II -999 0 Asia Asia 1 0 Augustamnica Augustamnica 3 0 Baetica Baetica 2 0 Baleares Baleares -999 0 Belgica I Belgica I 8 0 Belgica II Belgica II 5	Step 6 Check the results of the join by opening the attribute table of Province_polygon_v01. The joined attributes will be added onto the right of the table. The second column labelled Prov_Name is the beginning of the joined data. What you are looking at is not actually a unified copy of the source data – you are simply looking at the two (separate) files as if they were one. You could export an independent copy of the joined data – you will do this at the end of the exercise. For the moment, though, this join would be saved only in the map document (MXD). Close the attribute table.
Task 4 Create a categorical	Step 1 Open **Layer Properties** for Province_polygon_v01.

‘chloropleth’ symbology for the joined data



Step 2

On the **Symbology** tab, you will see options for creating ‘chloropleth’ (colour-coded) symbology.

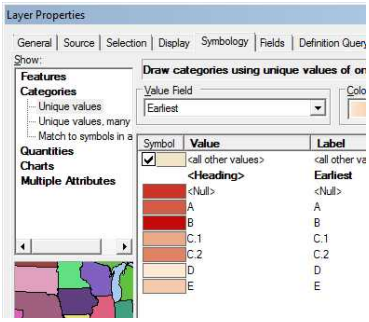
In the menu at the left of the tab, you can choose between **Categories** (i.e. qualitative data, such as our ‘Earliest’ field) and **Quantities** (numerical data, such as ‘Inscriptions’).

To start with, choose **Categories > Unique values**. It is the simplest of the three categorical schemes.

Step 3

In **Categories > Unique values**, pull down the **Value Field** menu and choose the categorical field you wish to use for the colour-coding. In this case, choose the **Earliest** field.

Initially, nothing will happen.



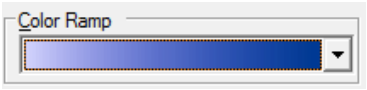
Step 4

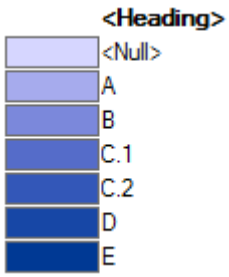
Click **Add All Values**.

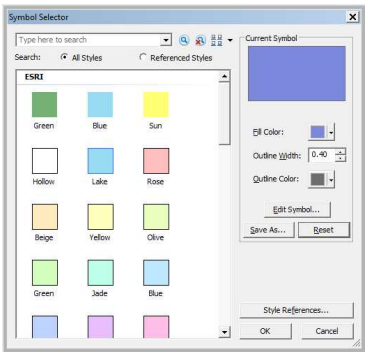
As you might guess, *ArcGIS* will parse the attribute table and collate all of the different values that occur in the chosen field, Earliest. If you see **<Null>** as a value, these are records where *ArcGIS* failed to find a match in your imported *Excel* spreadsheet.

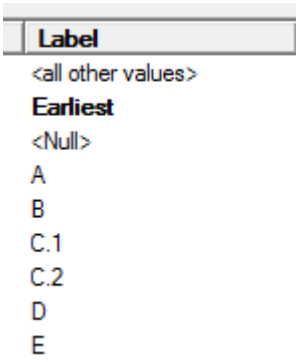
There will also be a Count field, indicating the number of occurrences of each value in your data. Usually this would be useful information, but unfortunately in this case there is a problem with these numbers. The way that Province_polygon_v01 has been formatted as a shapefile means that archipelagic provinces (e.g. Balaeres) are actually represented using four different vector objects, representing the four major islands. This means that Balaeres has four corresponding records in the attribute table, so is counted as 4 occurrences in the Count column here. Landlocked provinces, on the other hand, are only counted once.. This is only one aspect of a wider issue in representing e.g. archipelagic territories in spatial data. To get around it, GIS offers the option of creating ‘multipatch’ or ‘multipoint’ shapefile, in which you can have a s single record of attribute data represented spatially by multiple polygons (or multiple points). In that case, the Count field would have been an accurate count of provinces (rather than polygons). Many geographic datasets use multipatch / multipoint formats for this very reason – but it has not been used here.

Single-hue ramp









Step 5

Pull down the **Colour Ramp** menu and you will see a library of default colour palettes that you can apply to categorical schemes. Some of these offer discrete sets of colours, while others are continuous gradients, i.e. to create a sense of logical progression in the scheme.

Try a few different colour ramps and note the effects.

If the data (Earliest) were completely unrelated categories, then a discrete colour scheme would make sense. However, let's say that these categories represent a chronological sequence of periods A to E. In that case, a continuous single-hue ramp might actually be more informative, e.g. the later periods end up darker.

Step 6

Now that you have seen how to change the colour scheme as a whole, try changing the colours applied to one specific value in the scheme.

Double-click on the style swatch for Value 'A' and you will be open a **Symbol Selector** window (see Exercise 2Task 4). Here you can arbitrarily change the entire polygon style (not only the fill colour, but the pattern, outline etc) applied to those cases. Very handy for emphasising (or de-emphasising) specific subsets of your data.

Double-click on the swatch for the <Null> Value and assign its **Fill Colour** either light grey or No Colour. Obviously you don't want these to appear the same way as data.

Step 7

Periods 'A, B, C, etc' may not be the way you want this data to be labelled in the map's legend – although short codes may actually be better than lengthy terms for storing your categorical data, because they are easier to keep consistent. You can change how these items will appear in the legend by editing the Label column. Think of Label as an 'alias' that is more meaningful to the reader, while Value is the actual data value to which it is being applied..

You will not actually create a legend at this stage. To do it, you would need to first be in Layout view, then find it on the **Insert** menu.

Step 8

As with the other tabs on Layer Properties, the changes you make will not actually be applied until you click either **OK** or **Apply**. If you are repeatedly tweaking colours, **Apply** is a convenient way of previewing the changes in your map without closing and re-opening and the window.

Try it.

Task 5

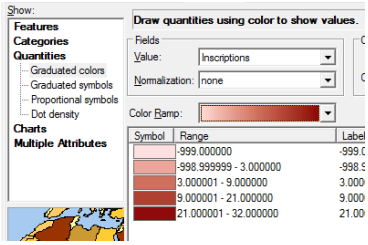
Create a numerical 'chloropleth' symbology for the joined data

Step 1

This time, you will create a symbology for the 'Inscriptions' field, which is numerical data.

Open **Layer Properties** and go to **Symbology tab > Quantitites > Graduated Colours**.

Setting this up is slightly more complicated than a categorical scheme, because here you will be dealing with **ranges** of values rather than discrete values.



Step 2

Pull down the **Fields > Value** menu and choose **Inscriptions**.

ArcGIS will again parse the entire table and generate a default colour scheme for the values of **Inscriptions**.

The default scheme has five 'ranges' (brackets of values), with a colour for each.

Step 3

Pull down the **Colour Ramp** menu. Note that, unlike categorical schemes, only continuous colour gradients are offered for numerical schemes.

Some ramps are made up of many hues, some are 3-hue ramps, and some are 1-hue ramps.

Many hues: these are great in cases where you have a very large range of values to cover and you want to show as much differentiation as you can; however, it can be difficult to 'read' the relative values of e.g. a red polygon compared to a blue one compared to a green one.

3-hue ramps: very good for numerical data with positive and negative values, because you can set the middle hue at '0' and have one hue for positive and the other for negative. So, very good for 'net change' data

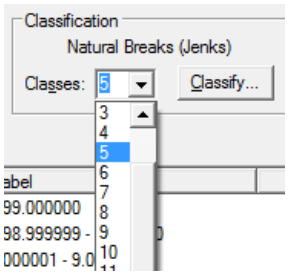
1-hue ramps: these are the most intuitive for numerical data with a single dimension, e.g. all positive values. But the human eye can only reliably distinguish perhaps 5 – 8 shades of the same hue, so you will not be able to differentiate as many parts of the overall value range

Finally, it is worth noting that you can customise colour ramps by right-clicking on them and going to **Properties**.

Choose a single-hue scheme, e.g. light to dark red.

Step 4

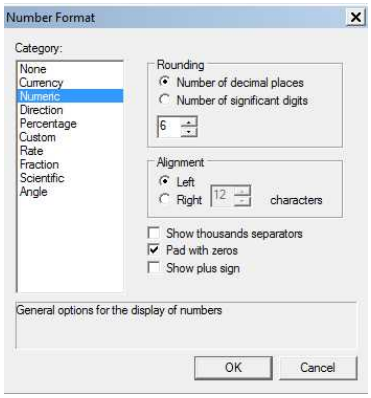
As with categorical maps, having chosen a colour ramp for the entire set of ranges, you can now arbitrarily control the style applied to any given range. Double-click on a swatch to try it.



Step 5

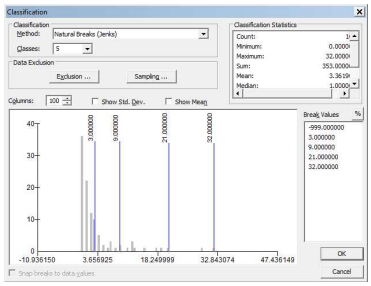
Under **Classification > Classes**, there is a pull-down menu where you can change the number of classes (ranges) in your colour scheme. Try changing it to 8 classes – remember that, with a single hue ramp, there is no point in having many more than about 8 shades.

The colour ramp will be re-applied, so you will lose any piecemeal changes you may have made to individual style swatches in the previous step.



Step 6

Note that, even though your numerical data are all integers (whole numbers) the colour scheme will by default give you five figures to five decimal places. While this doesn't really matter for the 'Range' column, the 'Label' column shows how these ranges will appear in the legend. To get rid of the decimal places, double-click on the word 'Label' and go to **Format Labels**, and make your changes there.

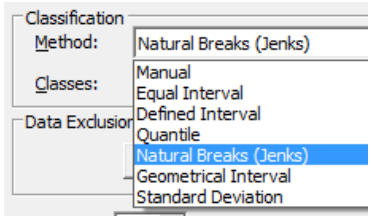


Step 7

Finally, it is possible to alter the ranges of values themselves – odds are that they will not quite be what you are looking for.

The simple way is to simply double-click directly on items in the Ranges column. The number you will be editing here is the **upper** limit of the range.

The more sophisticated way is to click the **Classify** button, which will open the **Classification** window.

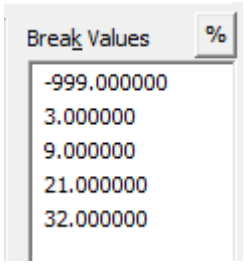


Step 8

The **Classification** window allows you to fine-tune the ranges in your numerical colour scheme.

Under **Method**, you can specify any one of several formal classification methods. If you arbitrarily start changing the ranges, though, this will automatically change over to 'Manual.'

The main panel in the window is a histogram of your data. The horizontal axis is your data values (from -999 to 32) and the vertical axis is the number of records you have with that value. You can zoom in and re-center the histogram by right-clicking within it. The histogram is useful for seeing how your ranges (vertical blue lines) relate to the distribution of your data (grey bars)



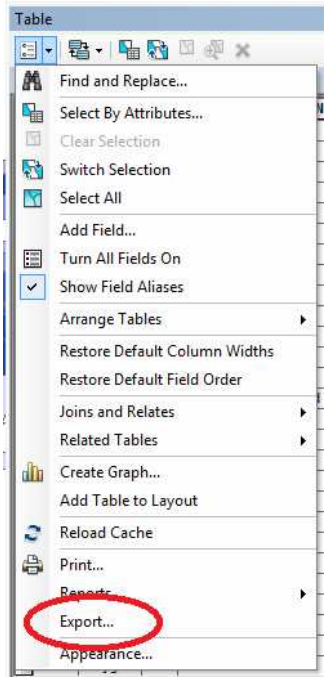
You can manipulate the ranges (blue lines) in the histogram either graphically, simply by dragging them left/right, or explicitly, by editing the **Break Values** table to the right (which can be toggled between percentages and absolute values).

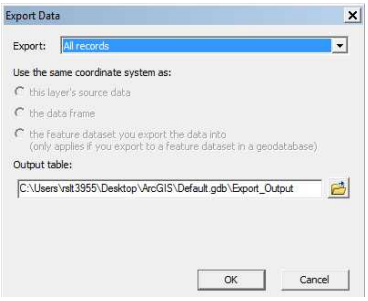
If you are interested in customising your colour scheme at this level, then have a play. The zoom/center controls in the histogram are a little fiddly and take some getting used to, but worth to the effort.

When you're finished, click **OK** to return to the **Layer Properties**, then **OK** to return to the map

Task 6

Export an attribute table to *Excel*





Step 1

As you may have gathered from this exercise, to join your data onto an existing layer of features, you MUST have a column of values that is exactly the same in both, i.e. a key field.

The easiest way to ensure that the columns match is to find (or create) the GIS layer that you will join onto BEFORE you begin collating data in Excel. If you export the attribute table of that layer to GIS, you can then isolate the field you want to use for the join and simply add your own columns of data on to the table. Then, when you bring this back into GIS, you will be guaranteed a 100% match.

To do this, open the attribute table of **provinces_polygon_v1**.

Step 2

Pull down the attribute table menu (upper left corner of the window) and go to **Export**. The **Export Data** window will open.

Step 3

In the **Export Data** window, choose:

Export: All records (as opposed to a selection)

Then click on the folder icon under **Output Table**. The **Saving Data** window will open.

Step 4

In the **Saving Data** window, browse to a location in the exercise files folder and name this table 'Province_attribute_export.' Change the file type to Text File. Click **Save** to close the **Saving Data** window, then **OK** to export the table.

Step 5

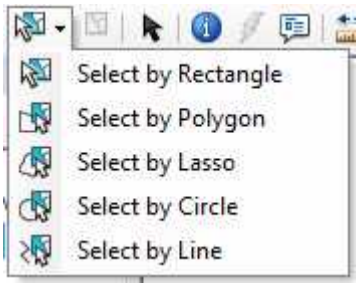
Open **Province_attribute_export.txt** in *Excel*. It is comma-separated values (CSV). In *Excel*, you can break this up into its proper tabular format using **Data | Text to Columns** (see Exercise 4Task 2Step 9)

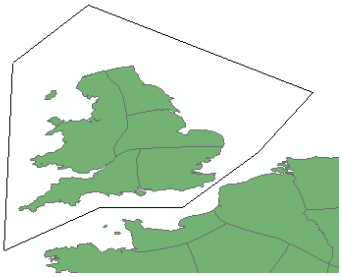
Exercise 7 Select vector objects and extract subsets of layers

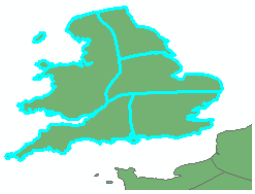
- *Select objects graphically using tools*
- *Select objects by their attributes*
- *View a selection in the attribute table*
- *Promote a selection to a layer and rename it*
- *Export a selection as a shapefile*

Task 1

Select objects graphically using tools







Step 1

Open the **Exercise_7.mxd** document.

This merely contains the provinces_polygon_v1 layer with the data joined on from Exercise 6.

Step 2

On the Tools toolbar, you will see a pull-down menu of graphical selection tools. The default tool is **Select by Rectangle**.

This functions as both a 'point-and-click' tool for selecting single features, and as a 'marquee select' tool, where you can drag a rectangular area and select all the features that intersect it or are contained within it.

Try selecting a few provinces using **Select By Rectangle**.

Note that selected features are highlighted cyan

Step 3

Deselect the features, either by going to **Selection | Clear Selected Features**, or by simply clicking on the **Clear Selected Features** icon on the Tools toolbar.

Step 4

Try the other graphical selection tools. **Select By Polygon** is quite useful, in cases where your area of interest is not rectangular.

Select by polygon works as most vector drawing tools do: click once to begin drawing your polygon, then once at each new vertex, then double-click on the last vertex to finish the drawing.

Any feature that is intersected/contained by your polygon will be selected.

Step 5

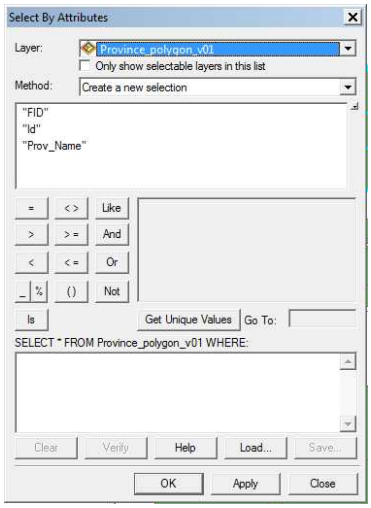
As usual, you can add to the existing selection by holding down the SHIFT key and clicking on more features.

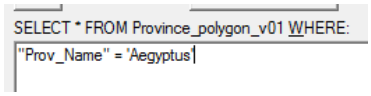
Try it. When you are finished, clear the selection.

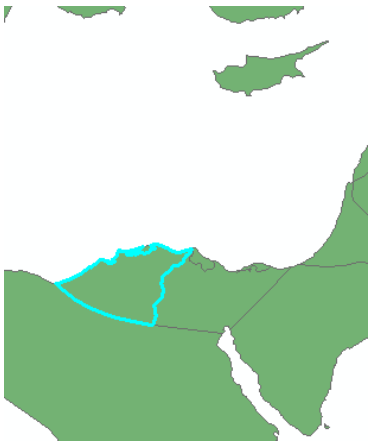
Selecting features graphically works well in cases where the features you wish to select are spatially contiguous. However, they are often **not** contiguous – sometimes your features of interest are defined by their attributes rather than a geographic area. In this case, you will be best off creating an attribute-based selection query

Task 2

Select objects by their attributes







Step 1

Click **Selection | Select by Attributes**. The **Select by Attributes** window will open.

Step 2

In the **Select by Attributes** window, you will write a selection query for the provinces in terms of their attributes.

Step 3

In the **Select by Attributes** window, pull down the Layer menu and choose the layer from which you want to extract a selection. In this case, Province_polygon_v01.

At the bottom of the window there is a text box labelled **SELECT * FROM …**

This is where you will write an SQL query defining your selection criteria in terms of the fields (columns) of the attribute table. Any records that pass these criteria will enter the selection – those that fail will be ignored.

You could type the expression in directly, but it is usually quicker / easier to use the shortcuts provided.

Let's say that you merely want to select the polygon for Aegyptus.

The upper text box contains a list of the fields in the attribute table. In this case, double-click on 'Prov_Name' in the upper text box, and note that it is added to the SQL expression in the lower box.

Now click the button for the '=' operator and note that it will be added.

Click **Get Unique Values**. This behaves as it did in Exercise 6Task 4Step 4. Once the list of values is populated, you can click on any value and it will be added to the SQL expression. In this case, click 'Aegyptus.' Your final expression should be:

"Prov_Name" = 'Aegyptus'

Click OK. The province Aegyptus will be selected in the map and highlighted.

You may have noticed the Boolean AND, OR operators. You can indeed build complex queries (including parentheses etc). Note, however, that the syntax is a little counterintuitive. If you wanted to select Aegyptus AND Achaea, for example, you would need the expression:

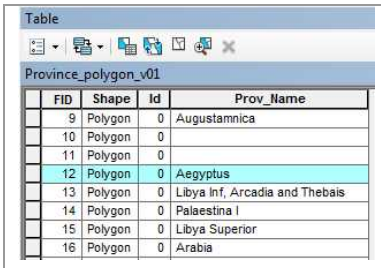
"Prov_Name" = 'Aegyptus' **AND "Prov_Name" = 'Achaea'**

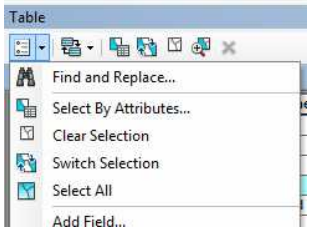
Task 3

View a selection in the attribute table

Step 1

While Aegyptus is still selected, open the province layer's attribute table. Note that the corresponding record is also highlighted.



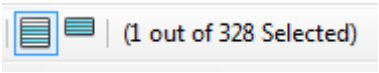


Step 2

Pull down the menu of the attribute table (upper left corner) and note that it is possible to invert (switch) the selection. This would effectively select everything BUT Aegyptus. If you wanted to exclude only a few records from your selection, this would be an easy way to do it, i.e. select the items you want to exclude, then switch the selection. Of course, you could also do this in your initial SQL query by simply by using the NOT operator, e.g. NOT "Prov_Name" = 'Aegyptus'

Step 3

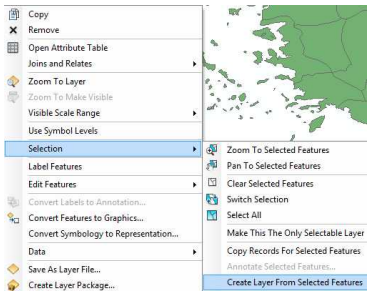
You can also filter the attribute table to display only the selected (highlighted) records. You can toggle back and forth between displaying all records and only selected records, using the icons at the bottom of the window.

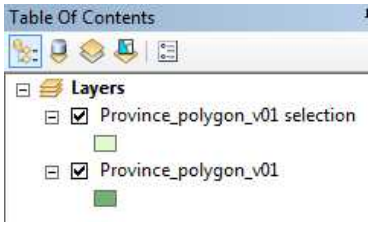


Close the attribute table.

Task 4

Promote a selection to a layer in the TOC and rename it





Step 1

While Aegyptus is still selected, right click on the layer it was selected from in the TOC (Province_polygon_v01) and go to **Selection | Create Layer from Selected Features**

Note that a new layer will be added to the TOC. The word 'selection' will be added to the end of the filename.

This selection layer is **not** an independent copy of the source data, but you can process it on its own. For example, you could apply a new style to it, feed that layer into an analysis or process, generate labels for it, etc. However, it does not 'exist' anywhere outside of the map document. The query that defines the selection is stored in the MXD, but the data content is extracted directly from the original source.

Step 2

Try switching off 'Province_polygon_v01' and notice that the selection layer is unaffected.

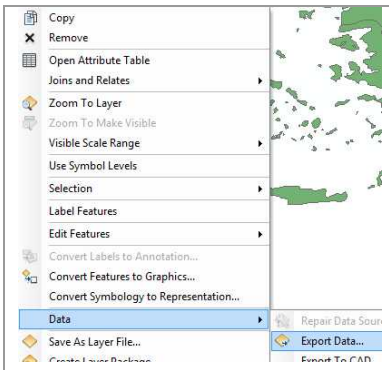
Task 5

Export a selection as a shapefile

Step 1

If you wish to create a copy of the selection so that it exists independently of the source data,right-click on the selection layer in the TOC and go to Data Export Data.

The **Export Data** window will appear.



Step 2

In the **Export Data** window, specify the output destination by clicking on 

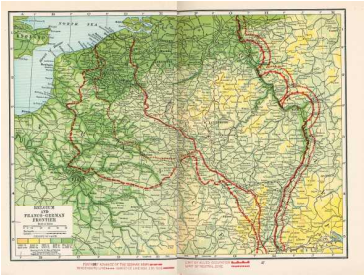
In the **Saving Data** window, browse to a location in your project folder. Set **Save as Type** to Shapefile.

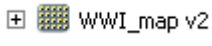
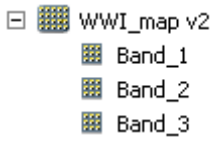
Click **Save**, then **OK**.

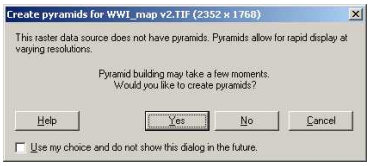
The **Export Data** window will close, the export will be completed, and the results will be added to the map.

Exercise 8 Georeference a raster image

- *Examine the raster image to be georeferenced*
- *Prepare the map for georeferencing*
- *Open the raster and position it approximately in its correct place*
- *Add control points for the raster*
- *Experiment with different types of polynomial raster transformation*

Task 1 Examine raster image to be georeferenced	Step 1 Minimise the *ArcMap* window and browse to the location on your hard drive where the exercise files are stored.
	Step 2 Double-click the **WWI_map_v2.tif** file. It will open in a picture viewer, e.g. *Windows Photo Gallery*. This is a map of the Western Front of the First World War, comprised of a physical/cultural base map of the area around Belgium and northeastern France, and an overlay. Note a few things about the map. There is a geographic grid marked on it – lines of latitude and longitude. This, of course, is very convenient for georeferencing, as it provides many clear points in the image (gridline intersections) whose geographic location is known exactly. Note also, however, that the lines of longitude (vertical lines) curve inwards towards the top of the map. This is due to the map projection used. Accurately georeferencing this image will require many more than three points. Finally, note that there is a vertical seam running down the middle of the image. This map was originally spread across two pages and, when it was scanned, there was a gap down the middle. The gap has been eliminated in a graphics processor, using a simple 'cut and paste' operation.
	Step 3 Close the picture viewer and return to *ArcMap*.
Task 2 Prepare a new map	Step 1 Start a new map document

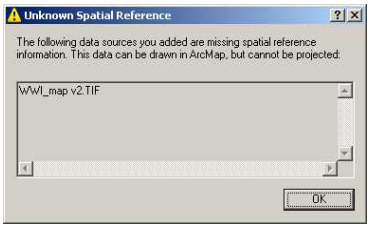
document	Step 2 Add to the map document a vector layer with the coordinate system in which you have the locations of the known points in the raster. In this exercise, you will use the intersections of latitude/longitude gridlines, so choose a layer that uses the WGS 1984 coordinate system. Any of the Natural Earth files will suffice, because they are all based on WGS 1984. In this case, add the layer **ne_50m_admin_0_countries**. Part of the reason for doing this is that adding a vector file with a given coordinate system will define the coordinate system used in the new map document's data frame. Every vector file in GIS has a native coordinate system, which is the coordinate system used to store its data content. The data frame (the icon at the top of the **Table on Contents**) has properties that apply to all of the layers in the current map document, and it too has a coordinate system. In sense, the frame's coordinate system overrides (if necessary) the coordinate systems of any layers within it. If the data frame's coordinate system were not defined by doing this, you would have to define it by going into the frame's **Properties** window. The other reason for adding the **ne_50m_admin_0_countries** layer is, of course, that it will give you a basis for judging the accuracy of your georeferencing.
Task 3 Add the raster to the map document, and prepare the workspace for georeferencing	Step 1 Add the **WWI_map_v2.tif** raster image to the map, using either the **Add Data** button or the **Catalog**. Note that the raster image is represented by the gridded symbol  However, if you expand this, you can see the various bands used to make up the image (in this case, corresponding to the three colour channels: red, green, and blue)  Greyscale images will usually have only one band, while full-colour images have three (normally RGB). However, it is possible for some raster datasets to have more than three bands. This is often the case with remote sensing datasets that include, for example, infrared data. In this case, just add the top node, **WWI_map_v2**



Step 2

A dialog box will probably appear, prompting you to create pyramids for the raster image. This will occur only the first time that you add the raster to a map. Pyramids are essentially low-resolution surrogates of the raster that will allow **ArcMap** to display it much more quickly at certain zoom levels. The raster used in this exercise is relatively low resolution already, so it is not so much an issue. However, many geographic rasters are enormous and, in such cases, pyramids do help a lot.

Click **Yes**.

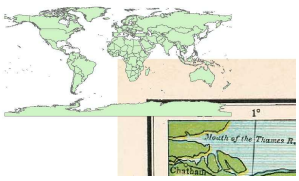


Step 3

When a raster that has never before been georeferenced is added to a map document, an error message may be generated saying '**Unknown spatial reference**.' This simply means that it cannot find any georeferencing file for this raster.

Click **OK**.

The raster will be added to the map, but probably not anywhere near the right place.



Step 4

Open the **Georeferencing** toolbar in the workspace (**Customize | Toolbars | Georeferencing**)

Step 5

Ensure that the raster image is below the **ne_50m_admin_0_countries** layer in the drawing order. If it is not, in the **Table of Contents**, switch to the drawing order mode  and re-order them as shown.

Step 6

Re-style the **ne_50m_admin_0_countries** layer -- open its **Properties** window, go to the **Symbology** tab and open the **Symbol Selector** window. Make the fill transparent (Fill colour = No Colour) and the outline colour e.g. bright red or purple. The purpose of doing this is so that you will later be able to see how closely the coastline of the georeferenced raster matches that of your vector data. Click **OK**, etc to close **Properties**.

Task 4

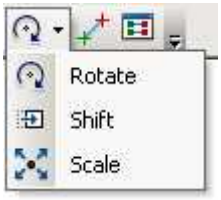
Move the raster to roughly its correct location using the tools on the **Geoferencing** toolbar.

Step 1

Zoom in on the approximate area of the map where the raster will go once it is georeferenced. In this case, it is Belgium and northeastern France.

Step 2

On the **Georeferencing** toolbar, pull down the **Layer** menu and click the raster layer you want to georeference in order to select it. Because it is the only raster you have added to the document, **WWI_map_v2** will be at the top of the list anyway. However, this menu is where you would select a different raster for e.g. later editing its georeferencing.



Use the Strait of Dover as a rough guide

Step 3

On the **Georeferencing** toolbar, pull down the **Georeferencing** menu and click **Fit to Display**. The raster will be moved and scaled to fit it within the current map view. This is the first way of getting the raster in roughly the right place in the map.

Step 4

On the **Georeferencing** toolbar, pull down the **Tools** menu  . This is a set of three tools that you can use to roughly position the raster in geographic space: rotate, shift and scale. You will not need Rotate, because your map is already north-oriented.

Use the tools to shift and scale the raster to roughly fit into the correct space on the map, in relation to the (red) **ne_50m_admin_0_countries** layer. When you have a tool selected, click and drag inside the map window to use it.

Use the Strait of Dover as a guide for how much to shift/scale the image.

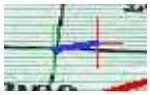
The positioning really does not need to be perfect that this stage! This process is just to reduce the amount of panning you need to do to add the first 2 control points.

Step 5

Once you have finished roughly positioning the raster, to stop using the positioning tools, click the **Pan** tool  in the **Tools** toolbar

Task 5

Add control points to the image



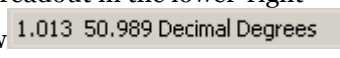
Link (blue line) between control point in raster and correct location in map document

Step 1

On the **Geoferencing** toolbar, click the **Add Control Points**  tool. The cursor will turn into a crosshairs when it is inside the map window.

Step 2

To add a control point, single-click on a known point in the raster image. In this case, start with the gridline intersection at the northwestern corner of the image, located at (1 , 51). Zoom in a little to get the intersection accurately. Then, move the cursor to the correct point in the map document.

There are two ways of finding the correct point in the map document. If you have a layer of vector objects corresponding to your known points (e.g. road intersections, point objects, corners of buildings, etc) then you can go straight there. If you know only the coordinates of your known point, then move the cursor to it using the coordinate readout in the lower-right corner of the map window 

. In this case, navigate to (1, 51).

When you have arrived at the correct location in the map document, single-click on it.

The raster will shift in the map document to place the control point at the location you just specified.

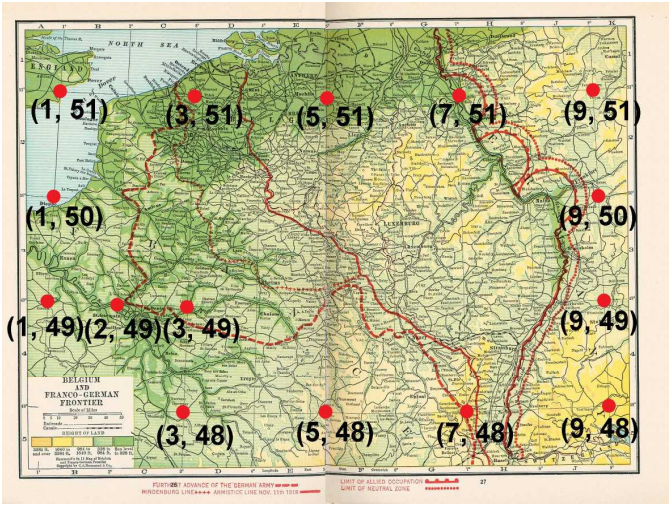
Step 3

The **Add Control Point** tool will still be active. Add another control point, this time at the gridline intersection at the northeast corner of the image (9, 51). When you have added this control point, note that the raster will again shift/scale/rotate to reflect the added point. As you might have guessed by this stage, the georeferencing is updated 'live,' as you add points.

After you have added the first two control points, you shouldn't need to pan the map too far to find your subsequent coordinate locations.

Step 4

Continue adding control points, approximately as shown in the figure below.

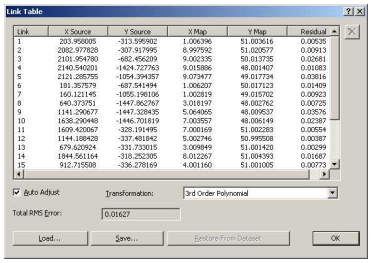


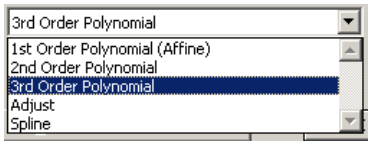
Put points at all four intersections along the eastern and western edges (or as close as you can get) and two or three each along the northern and southern edges. The reason why so many points are needed is that transforming (rectifying) this image will require a complex operation. In effect, the lines of longitude have to be straightened out to make them parallel.

As you add the points, you may get a warning message saying '**The control points are collinear ...**' For the purposes of this exercise, ignore all such warnings.

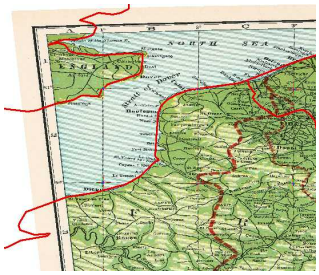
The number of points required for rectification depends on the type of transformation that will be performed. A first-order (a.k.a. 'affine') transformation requires only three, but this is limited to shifting, scaling, rotating, and skewing the image. A second-order polynomial transformation requires six points. A third-order polynomial (the most complex) requires a minimum of ten points.

In this case, accurately converting this image from its current projection (in which the meridians are curved) to fit a Cartesian projection requires much more than an affine transformation. A second-order transformation would give decent results, but why not add ten or more points to see the results of the third-order process?

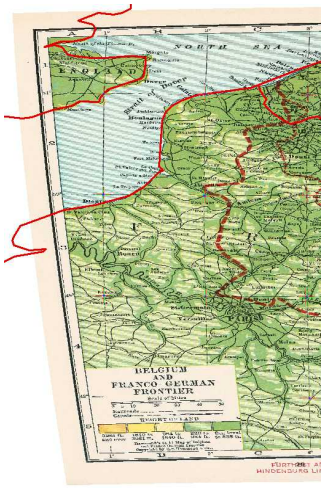




Affine results – not great



2nd Order results – better



3rd Order results – the best!

Step 5

Zoom out to where you can see the whole raster in the map window.

Step 6

On the **Georeferencing** toolbar, click the **View Links** button. A **Link Table** will appear, listing your control point 'links.'

This is where you can get more precise with your georeferencing. Each of the rows in the table represents a control point that you have just added. Because you have been using gridline intersections as control points (and the gridlines are placed at nice round numbers on each axis) the data in the **X Map** and **Y Map** columns should also be round numbers. They probably aren't, at this stage. However, you can double-click on any of the numbers in these columns and type then in explicitly.

Step 7

In the **Link Table** window, double-click each of your entries in the **X Map** and **Y Map** columns and round them to the nearest whole number. In effect, what you are doing is 'snapping' your map control points to the values of the gridline intersections. Don't worry about the **X Source** and **Y Source** columns – those are locations in the raster space, which shouldn't be exact.

NB: You can also delete individual control points from here.

Step 8

When you are done rounding the control point values, pull down the **Transformation** menu. You should be offered several types of transformation, depending on the number of control points you have added. The default (affine) transformation will not do the job in this case. Click on **2nd Order Polynomial** and watch what happens to the raster. It should now be more-or-less rectified to the data frame's coordinate system, which in this case means that the lines of longitude in the raster should be parallel, and the edges of the image should flare outwards to the north.

Try the **3rd Order Polynomial** and see the results. Note that the curvature of the edges of the image is even more complex / less regular. If you zoom in, you will see that the correlation between the coastline in the raster image and that in the **ne_50m_admin_0_countries** layer is even closer.

Click OK. The **Link Table** window will close.

Step 9

Examine the raster's positioning in relation to the **ne_50m_admin_0_countries** layer. If you are not happy with the georeferencing and transformation of the raster, add some more control points and go back into the **Link Table** to continue editing. The more points you add (accurately), the better your results will be.

	Step 10 When you are happy with the results, on the **Georeferencing** toolbar, click **Georeferencing | Update Georeferencing**. This will in effect save the control points you have just added, by updating the world file (.tfw) that has been created.
	Step 11 Add the **ne_50m_populated_places** layer to confirm that the georeferencing is correct. Several of the cities in this layer should match those in the underlying raster.

Once you have added a raster file to a map document, you may want to extract (i.e. 'digitise') certain features from the image as vector objects. This is essentially the digital equivalent of creating a tracing. You might want to do this for any number of reasons: to visually isolate the feature in question; to create a clearer version of the data (if the raster's image quality is poor); to perform some calculation or editing on the extracted feature.

The basic process in *ArcGIS* is that you must create a new shapefile for the digitised features, start an editing session, perform your drawing operations, and then save the results. *ArcMap*'s **Editor** toolbar has a complete set of vector drawing tools, with useful behaviour options, such as vertex snapping.

The technique of digitising features using mouse clicks is sometimes known as 'heads up' digitisation. An alternative approach, favoured by many people who do large volumes of digitising, is to use a digital tablet and stylus.

Exercise 9 Create and edit layers of vector objects

- *Create an empty polygon vector layer*
- *Create features in the layer by 'heads-up' digitising a raster*
- *Edit the features you have created*
- *Save your edits*

Task 1

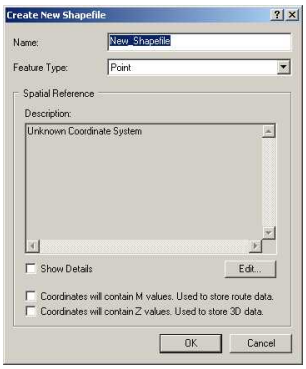
Open a new map document

Step 1

If you do not have the map document from Exercise 8 still open, then start a new map document and add the (now georeferenced) **WWI_map_v2.tif** raster image to the map. If you have not yet completed Exercise 8, then add the **WWI_map_v3.tif** raster image to the map – this is one that has already been georeferenced for you.

Task 2

Create an empty polygon vector layer for the features you will digitise



Step 1

In the **Catalog**, browse to the location on your hard drive where the exercise files are stored, right-click on the folder, and click **New | Shapefile**. A **Create New Shapefile** window will appear.

Step 2

In the **Name** field, type **German Army Furthest Advance**.

Step 3

Pull down the **Feature Type** menu and select **Polygon**.

Step 4

Click **Edit**, then **Select**, then choose the native coordinate system for the new shapefile. In this case, choose **Geographic Coordinate Systems | World | WGS 1984.prj**. Then click **Add** then **Apply**, then **OK**.

Step 5

In the **Create New Shapefile** window, click **OK**. The window will close, and a new polygon shapefile layer will be added to the **Table of Contents**.

Task 3

Start an editing session for

Step 1

Add the **Editor** toolbar to the workspace (**Customize | Toolbars | Editor**).

the newly created shapefile

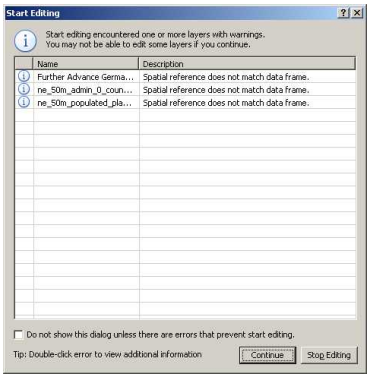
Step 2

Set the coordinate system of the data frame to WGS 1984, if it is not already set. Do this by right-clicking in the data frame in the **Table of Contents** and going to **Properties | Coordinate System** and selecting **Predefined | Geographic Coordinate Systems | World | WGS 1984.prj**. Then click **OK**.

The reason for doing this is that the file you are editing and the data frame must have the same spatial reference.

Step 3

In the **Table of Contents**, click the **German Army Furthest Advance** layer to select it as the layer to be edited.



Step 4

Zoom out to frame the entire **WWI_map** raster layer in the map window.

Step 5

On the **Editor** toolbar, click **Editor | Start Editing**. This will start an editing session.

A warning message may appear saying that you cannot edit certain layers. If so, click **Continue**, then make sure that the data frame's coordinate system is set to WGS 1984 (see above).

A **Create Features** panel will be added to the workspace, to the right of the map.

Make sure that the **German Army Furthest Advance** layer in the **Create Features** panel is highlighted (dark blue)

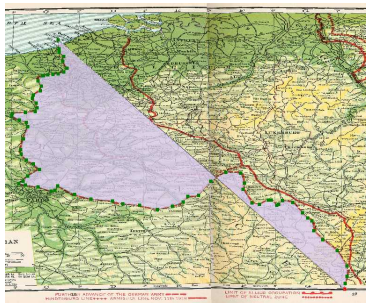
All of the tools on the **Editor** toolbar should now be active 

Step 6

Close the **Create Features** panel by clicking the **Close** icon in the upper right corner.

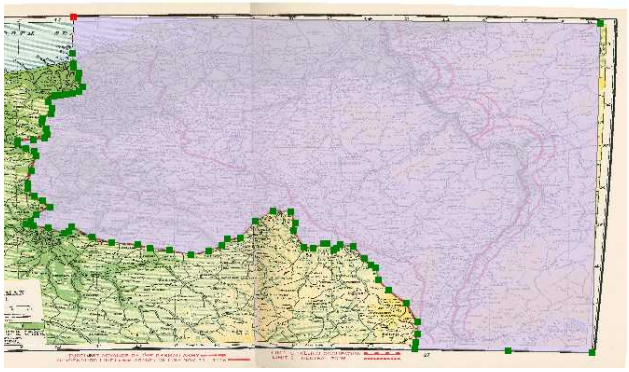
Step 7

On the **Editor** toolbar, click **Editor | Snapping | Snapping toolbar**. The **Snapping** toolbar will appear.

	Step 8 On the **Snapping** toolbar, click **Snapping** and disable the **Use Snapping** option. Snapping, as you might guess, is a behaviour of digitising tools. When the cursor approaches a selectable vector object (a point, or a vertex in a line or polygon), and gets within a certain distance of it, it will automatically 'snap' to it. This is extremely useful if you want any part of your digitised features to line up or join exactly with existing vector features. However, in this case, you are digitising entirely from a raster image, which has no features to snap to. The snapping behaviour would only be an inconvenience, because the digitising tools would only be snapping inadvertently to any polygons that happened to be nearby.
Task 4 Create features in the polygon layer by 'heads-up digitising' a feature in the raster image  	Step 1 On the Editor toolbar click the Straight Segment  tool. The cursor will change to a crosshairs when inside in the map window.
	Step 2 Start digitising the dashed line in the raster image that demarcates the furthest advance of the German Army. Begin at the northern end, somewhat offshore. Single-click once to add the first vertex. Single-click again to add subsequent vertices further down the line. There is no real harm in adding redundant vertices, but try being economical by putting them in only where there is a significant change in direction of the line you are tracing. Note that you can continue to use the keyboard arrows and mouse wheel to pan and zoom the map during the drawing operation. DO NOT double-click while you are still adding vertices, or you will finish the polygon feature! If you put a vertex in the wrong place, don't worry about it. Keep going – you will be able to move/delete vertices after the drawing operation is complete. When you get to the southern end of the dashed line, the results should look something like this. However, don't double-click yet! 

Step 3

Add three more vertices: one roughly at the southeastern corner of the raster, one roughly at the northeastern corner, and one just to the north of the point where you started drawing.



This is simply to ensure that you end up with a well-formed polygon at the end. When you get to the last vertex, double-click. The drawing operation will be completed, the new polygon will be added to the shapefile, and it will be highlighted.

Task 5

Experiment with moving and deleting polygons

Step 1

On the **Editor** toolbar, click the **Edit**  tool.

Step 2

Click on the newly created polygon and drag it to a new location in the map.

Step 3

Press CTRL+Z to undo the move operation.

Step 4

With the **Edit** tool still selected, click again inside the new polygon.

Step 5

Press the DELETE key to delete it.

Step 6

Press CTRL+Z to undo the delete operation.

Task 6

Move vertices in polygon features

Step 1

With the **Edit** tool still selected, double-click inside the new polygon. The **Edit Vertices** menu will appear. Also, 'grab handles' (small green squares) will appear on each vertex you created.

Step 2

Drag one of the handles to move the corresponding vertex to a new location. Note that the vertex handles will move when you drag them, but the polygon outline may not immediately update to reflect the change.

	Step 3 Single click anywhere in the map window to apply the change.
Task 7 Add vertices to polygon features	Step 1 Using the **Edit** tool, double-click inside the polygon. The **Edit Vertices** toolbar will appear.
	Step 2 On the **Edit Vertices** toolbar, click the **Add Vertex**  tool.
	Step 3 Click on the polygon outline, between any two vertices. A new vertex will be added at the specified location.
	Step 4 Drag the newly created vertex to a new location.
	Step 5 Single click anywhere in the map window to apply the change.Press CTRL+Z to undo it, if desired.
Task 8 Delete vertices from polygon features	Step 1 Using the **Edit** tool, double-click inside the polygon. The **Edit Vertices** toolbar will appear.
	Step 2 On the **Edit Vertices** toolbar, click the **Delete Vertex**  tool.
	Step 3 Click on any of the vertex grab handles. That vertex will be deleted.
	Step 4 Single click anywhere in the map window to apply the change. Press CTRL+Z to undo it, if desired.
	Step 5 Leave this map document open for the next exercise, if you are continuing.