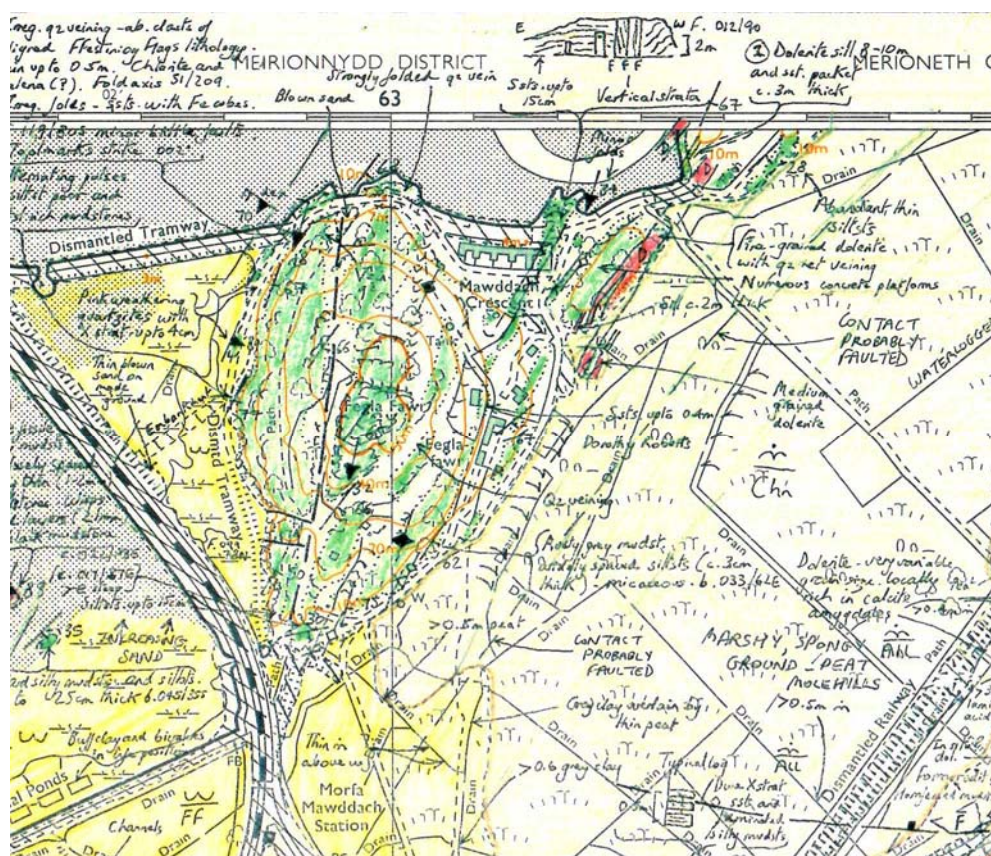


www.geologicalmapping.com
info@geologicalmapping.com

A MAPPING GUIDE 'CAUGHT BETWEEN A ROCK AND A HARD PLACE'

Modern-day geology students are caught in an awkward position, trapped between paper and digital worlds. They receive varying advice; the old school emphasizes traditional tools; compass and altimeter. The field map, or slip', is of primordial importance and has to be 'inked-in' every night. Exposures need to be delimited with a green or dotted line. The end result, the field map, is a thing of beauty, with a strong artistic component (see example below). Invariably, the map with the neatest, smallest, handwritten notes carries off the Mapping Prize. In many cases, you can look at one of these maps and instinctively know that the student 'gets' mapping; their map is totally believable.



More enlightened lecturers now emphasize digital mapping, using GPS and even making the map directly in GIS software. But to go the whole hog, with digital mapping, you need a ruggedized tablet and special, expensive software. Phone-based software (Field Move) is good, particularly for taking numerous structural measurements quickly. But the small screen size is restrictive and it is difficult to draw contacts accurately on the screen. The keyboard makes it difficult to make extensive notes, which means a notebook has to be used. Sketches are impossible.



This guide outlines the way Geological Mapping Ltd makes maps. It is a middle way, between traditional, and fully digital, mapping. It is not intended to contradict or interfere with your own mapping training or the requirements of your University. Neither is it cutting-edge. As software and phone applications evolve, it will become obsolete, in the same way that GPS has more or less extinguished compass and altimeter.

In the world of industry, far from academia, there is always an emphasis on good time management and getting field observations (notes and structural measurements) into a format that can be used in a Geographic Information System (GIS). There is always a deadline. Data collection must therefore be well organized.

The main business of Geological Mapping Ltd is map-making. These maps vary tremendously in scale. From 1:50, for example, maps of glacially smoothed surfaces at Scandinavian gold mines, to 1:50,000, in the case of regional hydrocarbon exploration in South America. But, increasingly, because the maps are digital, they are 'scale-less'. It is possible to zoom in and plot the map at any scale and level of detail you wish.

In my mind, making cross sections and 3D models also constitutes 'mapping'. In many jobs, cross sections are compiled from drill core logging and these contribute to 3D models, of the type you will have seen in hydrocarbon exploration. Important surfaces, such as stratigraphical contacts, gold-bearing veins, or faults, are 'wireframed' and visualized in 3D, playing with viewing directions and lighting to emphasize the geology.

The following is a guide to geological mapping, based on the methods of Geological Mapping Ltd. It relies heavily on GPS.



TOOLS OF THE TRADE



Cruiser jacket. This is an important piece of kit (see battered example above). It allows hands-free work, with pockets for everything. The hand lens is attached to the jacket. You can pick up cheaper versions, such as fishing jackets, which do the job, from outdoor shops. If you have everything in the single jacket, it becomes difficult to forget anything! It can just be thrown on in the morning.

GPS. With capability to store at least 500 waypoints. Download cable. I use Garmin GPSmap 62. It comes with simple software (MapSource) for downloading waypoints.

Compass. Silva and Suunto models, with clinometer, are best. Bruntons are over-priced status symbols.

Notebook. I like the soft-backed Deakin Rite-in-Rain mini-notebooks, with 48 pages.

www.deakin.com. Consider a bulk order with colleagues to keep prices down. There are UK suppliers.

Pencils. Two propelling pencils and leads. 0.5 mm.

Scratch pen (essential for determining hardness – a very important tool). Impoverished students can use a large nail.

Pen magnet (igneous and volcanic rocks are frequently distinguished by content of magnetic minerals).

Hand lens. I carry two. X20 Iwamoto and X6 Ruper. The Ruper has a large lens, which means you can place a camera up to it and take super close-up photographs. It takes some practice, but the results are stunning.

Hammer. Estwings terrify me. They are so lightweight that numerous blows are required, causing dangerous flying chips. I recommend a cheaper fibreglass-handled 2lb hammer. Often, a single blow is all that is required. Much safer. See <http://www.ukge.com/>

Camera. A point-and-click is fine, with macro. Practice close-up photographs. Most people take photos too far from the subject. Loop the strap round your wrist as you take photos. Cameras get wrecked when they drop onto rock. Likewise iPhones. Many cameras have GPS capability, which tags your photo with its location. The downside is that having GPS enabled tends to wear down the battery quickly.

Goggles. Buy cheap, wrap-around plastic glasses from B and Q.

Hammer holster. It is crucial to work hands-free. These can be bought cheaply from hardware stores.

Hard hat. Where appropriate. I mostly use a stiff wide brimmed leather hat for non-dangerous situations. It sheds the rain and guards from the sun. It is also good for sitting on, for sketching or lunch.

Map case. I now rarely use one, but it does provide a good place to keep a paper map. The BGS ones are leather and fold open.

Permanent marker pen. A black Sharpie is ideal. For labelling your samples. Mark the samples on two side.

Acid. Invaluable. Dilute HCl.

MAP-MAKING – THE SIX COMMANDMENTS

1. Every geological observation (note, structural measurement, photograph) must have xyz (east, north, elevation) coordinates. This means a GPS waypoint, a Field Move locality or coordinates read from a map. (Elevation may be difficult if reading from the map.)
2. Key geological observations (with the exception of field sketches, which stay in the notebook) must make it into digital format the same day. This may mean stopping fieldwork one hour earlier, to allow time in the evening.
3. Map appropriately for the scale of your final map. Don't get bogged down in detail that will never make it to the final map.
4. Start with the simplest geology. This may be a well exposed fault or dyke in a wave cut platform. You can always go back and fill in gaps or add more detail.
5. Sweeps. Kind your mind organized and consider various 'sweeps' of the locality, each sweep concentrating on a particular feature. Sweep 1, Contacts, Sweep 2, structural measurements, Sweep 3, detailed observations and photos. This approach is time efficient – it also applies to logging drill core.

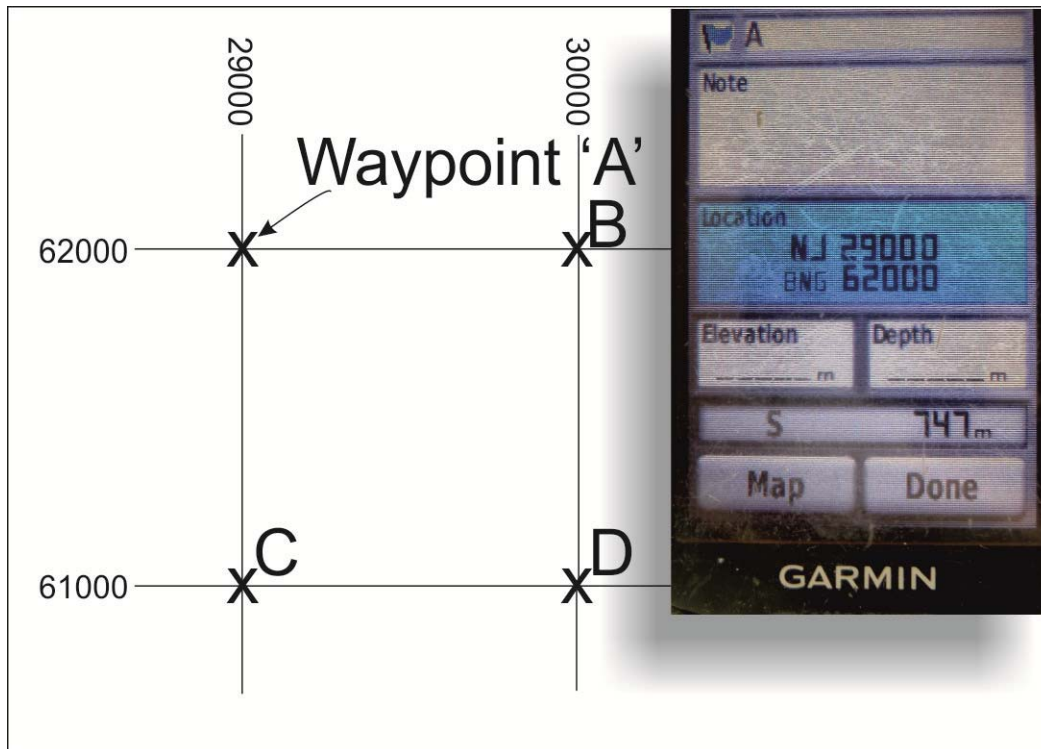


6. If you don't understand the geology of a particular area, don't waste time. Walk away and return later that day, or another, from a different direction. Often, problems solve themselves this way because you have seen more geology.

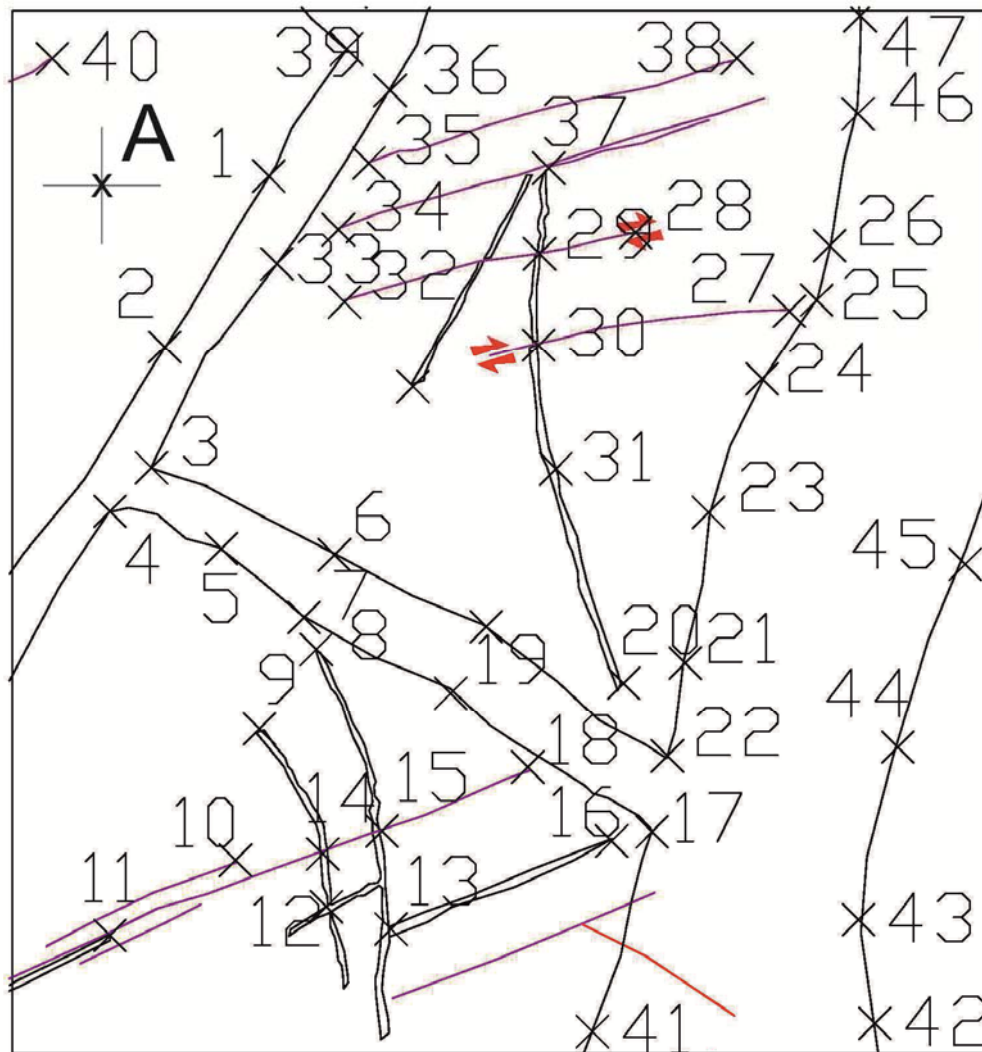
MAP-MAKING – STEP BY STEP

Most of the practical aspects of geological map-making cannot be taught in a book or on paper. Things such as 'feature mapping', which rely on topography, such as dip and scarp slopes; the use of 'float' (rock fragments in soil or from rabbit burrows) to determine what lies beneath; spring lines marking either faults or lithological contacts. These things can only be appreciated in the field. So the following guide concentrates on the organization of field data and recommended steps.

The first step is to create 4 waypoints manually on your GPS. You should label them A, B, C, D. Program them with the east and north coordinates of the topographic grid you are using. For example, see below, which shows a 1 km (1000 metre) grid. The importance of this will become clear later.



Make a sketch of the geology (it helps if exposure is good) in your notebook or on a plain piece of paper. It does not have to be to scale or accurate. Then walk along and mark important geological contacts with GPS waypoints. In particular, mark changes of direction and intersections of features. Note the critical waypoints on your sketch. Waypoints cost nothing, so feel free to take numerous, every few metres if necessary. The GPS keeps a running tally, 1,2,3.....etc. Until it runs out of memory (I only use GPS with > 500 waypoint memory).



The map above has no scale, but let's assume it is about 100 or 200 metres across. Each cross is a numbered GPS waypoint. With practice, you will soon figure out what is the best density of waypoints. You will also find that, on your sketch, you only need to sketch on a few of the crucial waypoints. Your GPS will have a map page, showing the waypoints on the map. You will quickly see your geological map taking shape as you accumulate points. On rare occasions, one of the waypoints may not be 'where it should be'. It may have 'jumped', perhaps because of some quirk of the satellites. Ignore these when it comes to map-making.

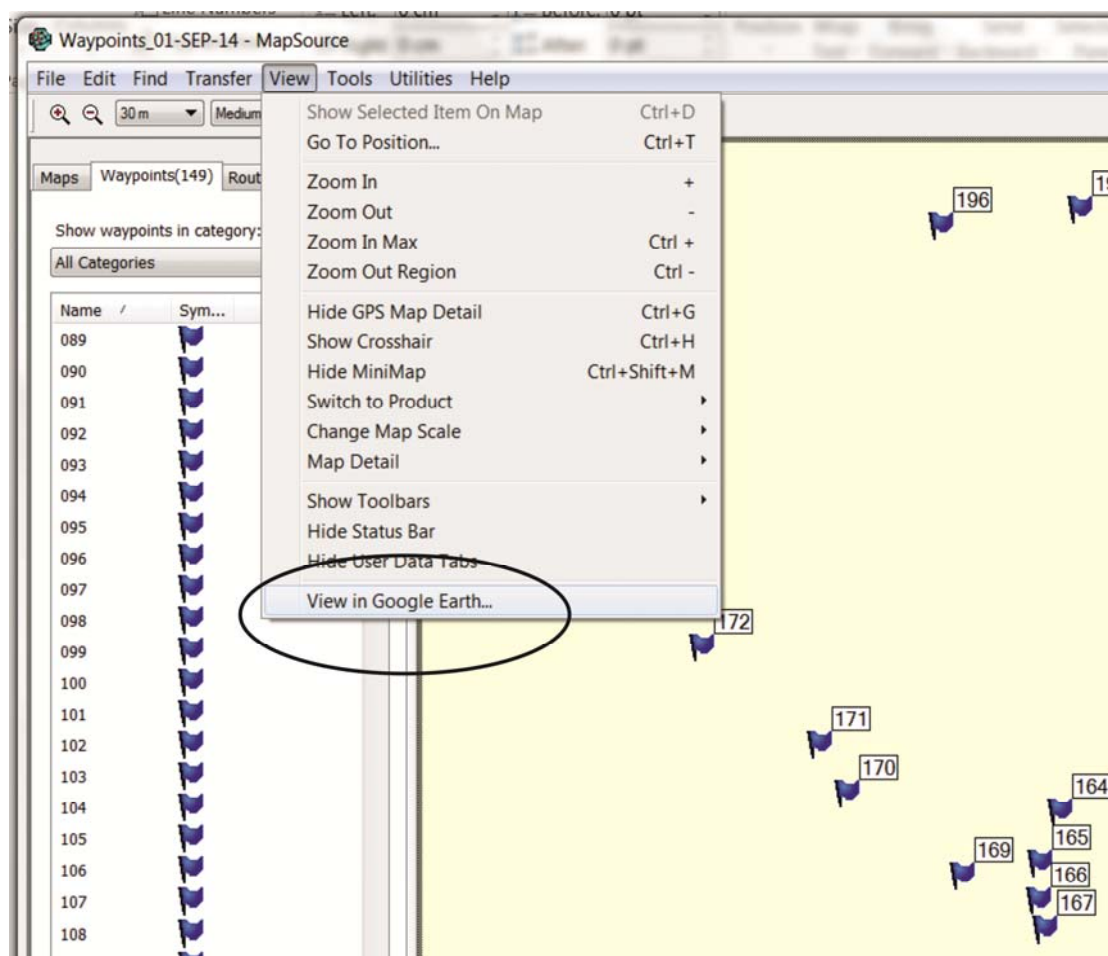
Map-making by GPS is a trial and error process. I recommend you give it a go in your back gardens, or neighbourhood, before going into the field. Follow fences, mark gates and trees. Then import the waypoints into Google Earth. This can be done direct from the GPS software – there is usually an option to 'view waypoints in Google Earth'. This practice will give you a head start and an idea of GPS accuracy (more than enough for the average mapping project).

Handheld GPS accuracy is becoming excellent, often less than 1 or 2 metres (even though the GPS screen may indicate an error of 4 or 5 metres). Hold the GPS up and take the waypoint immediately above the feature of interest; there is no point introducing location errors from the outset.

(At many mines I use the same GPS approach, often with the luxury of a surveyor with very

precise, differential GPS. This system allows millimetre accuracy. I generally spray paint all the important waypoints on the rock surface (not recommended on Mull!) and he will follow and survey each point. In the evening he will give me a printed map of the waypoints; I go back to the field and sketch on quickly the geological contacts, faults etc. A lazy way of mapping, but very time-efficient.)

In the evening, download the GPS waypoints using a cable and MapSource, or whatever software comes with your GPS. Before downloading, make sure, under 'Edit, Preferences', you have set the Position format as 'British National Grid' (or relevant projection formats if you are mapping abroad). MapSource also allows you to view the points directly in Google Earth, which is very useful.



The data will be downloaded from MapSource as a csv or Excel spreadsheet (see below). Or it can be cut and pasted directly into Excel. Some GPS software brings all the data into one cell; use 'Excel, Data, Text to Columns' to split it into columns. These data form the backbone of your field data spreadsheet, and, in turn, of your map and GIS. Importantly, MapSource also allows the data to be exported as dxf files. These drawing files are fundamentally important for map-making and can be imported into most drawing and GIS software.

temp waypoint	East	North	Elevation
1	435618	7403783	442
2	435523	7403705	472
3	435532	7403677	472

4	435537	7403641	478
5	435548	7403632	482

Because your GPS will run out of waypoint memory (some have capacity for 500, others for > 1000 waypoints), as the days go by, you will need to create a new column with a 'Master Locality' number (see below).

Locality	temp waypoint	East	North	Elevation
3484	1	435618	7403783	442
3485	2	435523	7403705	472
3486	3	435532	7403677	472
3487	4	435537	7403641	478
3488	5	435548	7403632	482

If you are using Field Move, then you will be able to download your localities and structural readings as csv files and insert them into the spreadsheet. I find phone-based software too restrictive for notes, because of the fiddly keyboard, so I write notes in my notebook, along with sketches. And those notes must be distilled into digital format the same evening. The sketches cannot be captured – they stay in the notebook. Tablets can handle decent sketches, iPhones cannot.

The final spreadsheet will look something like this (see below). The date is crucial. It allows you to distinguish 'temporary' waypoints and the Master Localities. The notes do not have to be comprehensive, or to capture every detail of the notebook. Of course, sketches will not make it into digital format.

Date	Area	Master Locality	temp waypoint	East	North	Elev	structure type	Dip dir	Dip	Notes
30-Jun-14	Mull west	3484	1	435618	7403783	442	dyke contact	145	23	rhyolite dyke, with flow foliation parallel to
30-Jun-14	Mull west	3485	2	435523	7403705	472	bedding	34	51	thinly bedded siltstones
30-Jun-14	Mull west	3486	3	435532	7403677	472	fault	46	56	major fault, with 0.2 m of gouge
30-Jun-14	Mull west	3487	4	435537	7403641	478	fault			limonite stained fault

Now comes the tricky part. How to make your final map? And this is where modern students are caught in the trap between digital and paper. What is the point of having the fundamental skeleton of the map (waypoints) in digital format if the map is going to be made by hand and coloured-in with crayons?

I don't have all the answers. But Geological Mapping Ltd uses Mapinfo Discover, similar to ArcGIS, to import the spreadsheet, plot structural symbols automatically, and make the final geological map.

What realistic options do students have? Low- or high-tech? If you want to draw your map digitally, and draw symbols digitally, then these are some options:

1. Take a trial subscription for Mapinfo, which is a proper GIS, which can be easily queried. Or install a student version e.g.

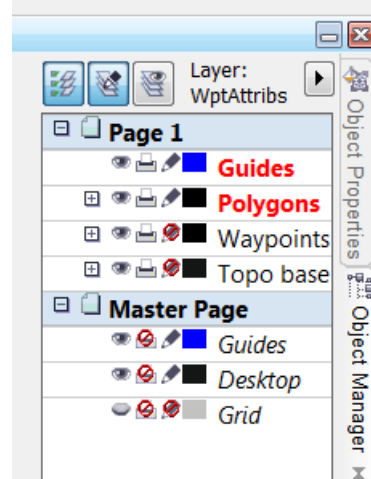
http://store.leeds.ac.uk/browse/extra_info.asp?compid=1&modid=1&catid=221&prodid



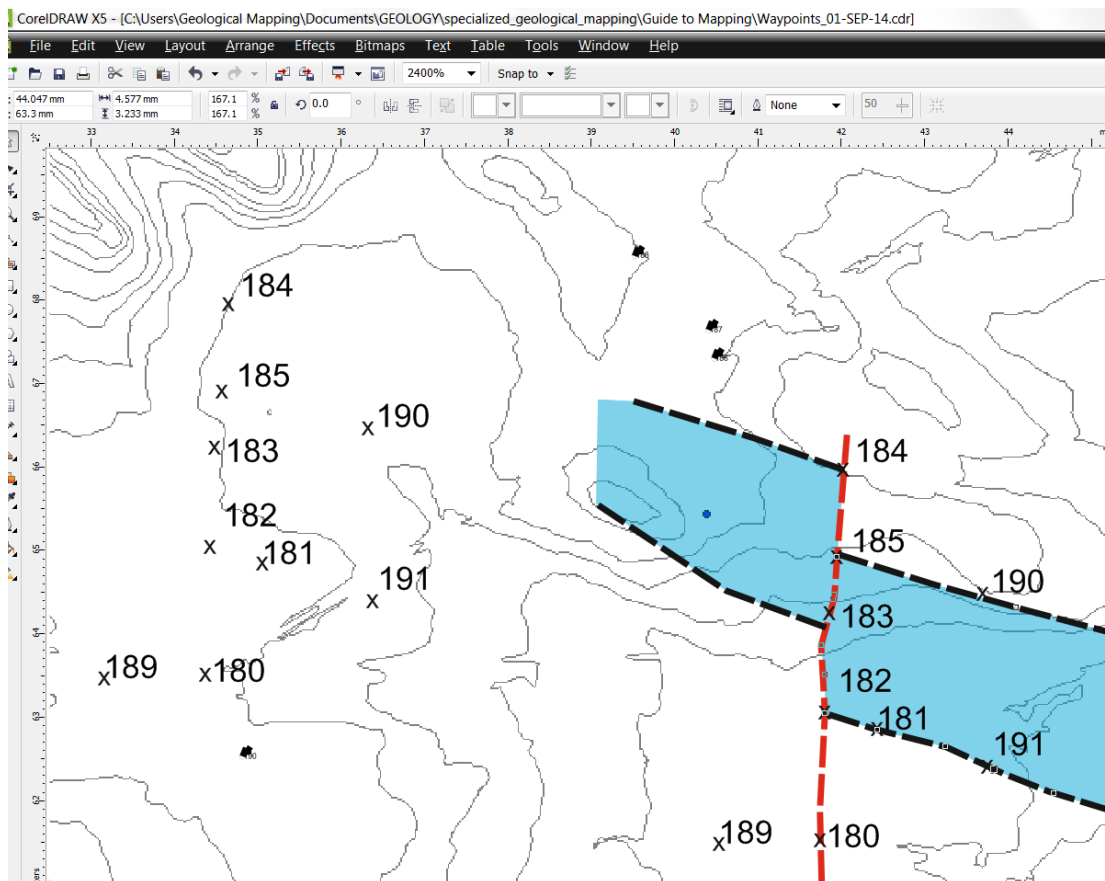
- =1466. Discover is a plug-in with more geological features, such as structural symbol-plotting and section-making. The downside is that the learning curve is enormous.
2. Use Coreldraw, a simple drawing program, which is paid for.
 3. Adobe Illustrator, a simple drawing program, which is available cheaply on monthly subscription.
http://www.adobe.com/uk/creativecloud/buy/students.html?sdid=KKTXM&skwcid=AL!3085!3!52397132418!b!!g!!illustrator%20academic&ef_id=VS08HQAABXehemD1:20150423102100:s
 4. Use Autocad Map 3D. Student versions are available. This is not a true GIS, but is good for producing a final product. You can draw lines, coloured polygons (areas of fill) <http://www.autodesk.com/education/free-software/autocad>. The learning curve is steep.
 5. Use Field Move Clino software, which can export structural measurements, localities and contacts as csv (opened with Excel) or kmz (Google Earth) files.
 6. Spheristat. This is an excellent, cheap software and is discussed below.

The problem with all of these packages is that there is a steep learning curve. Corel and Adobe are perhaps the simplest and most intuitive. Let's talk through Coreldraw.

Open a new blank Coreldraw document. Then import your base topographic map, normally as a scanned paper map. Scan it before you go into the field, so it is not grubby. Scan it carefully, so there is as little distortion as possible. Lock the layer which contains the topographic map. Create a new layer and then import your waypoint dxf files (which you created in your GPS software, MapSource using File, Save As and selecting dxf on the dropdown file menu). Crucially, the pre-programmed A,B,C,D waypoints allow you to 'fit' all the other waypoints to the underlying topographic base map, which will have a printed grid (at 1 km intervals, if it is a 1:10,000 scale base map). With Coreldraw you select all the waypoints and, holding the CTRL key, use the corner sizing arrows to stretch them to the correct scale. Once they are correctly positioned, lock the layer.



Create a new layer (e.g. Polygons) and start making your map in it. The screenshot above shows layers with the scanned topographic base, GPS waypoints, and polygons. The screenshot below shows the partially made geological map (with contacts drawn using the field sketch in your notebook). The colour polygons (the areas with colour) can be made slightly transparent ('Window, Docker, Lens') so that the topographic base behind is visible.

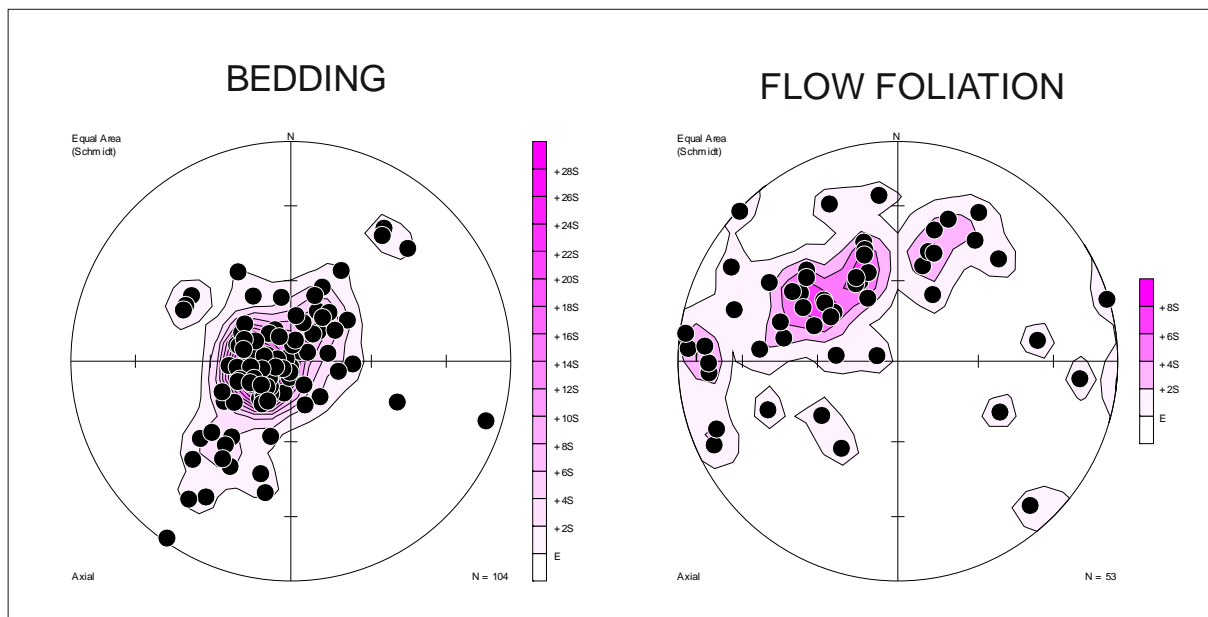


The remainder of the map, the legend, for example, can be drawn simply in Coreldraw, holding down the CTRL key whilst copying items, to keep the map neat and square.

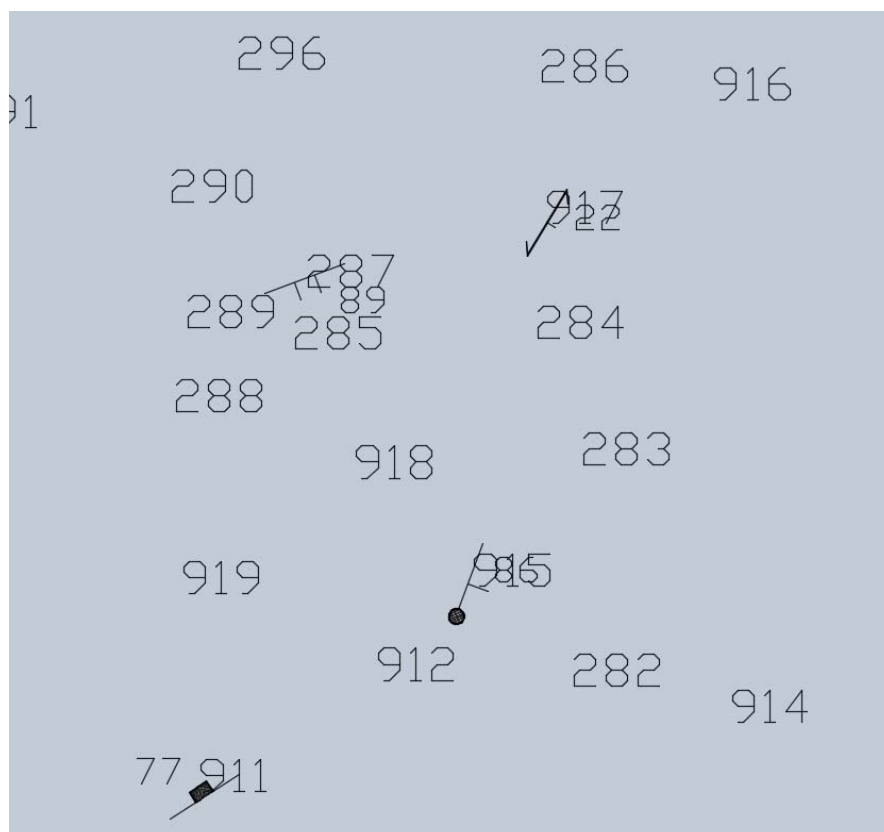
STRUCTURAL SYMBOLS

These present another obstacle. How to represent them on the final map? Hand-drawing every symbol will take forever.

Mapinfo Discover, and most other specialist geological packages, are capable of plotting structural symbols on a map. But Geological Mapping Ltd uses a powerful stereogram and map symbol software called Spheristat. The field data sheet, with a little tidying up, can be imported into Spheristat and produces stereograms (see example below).



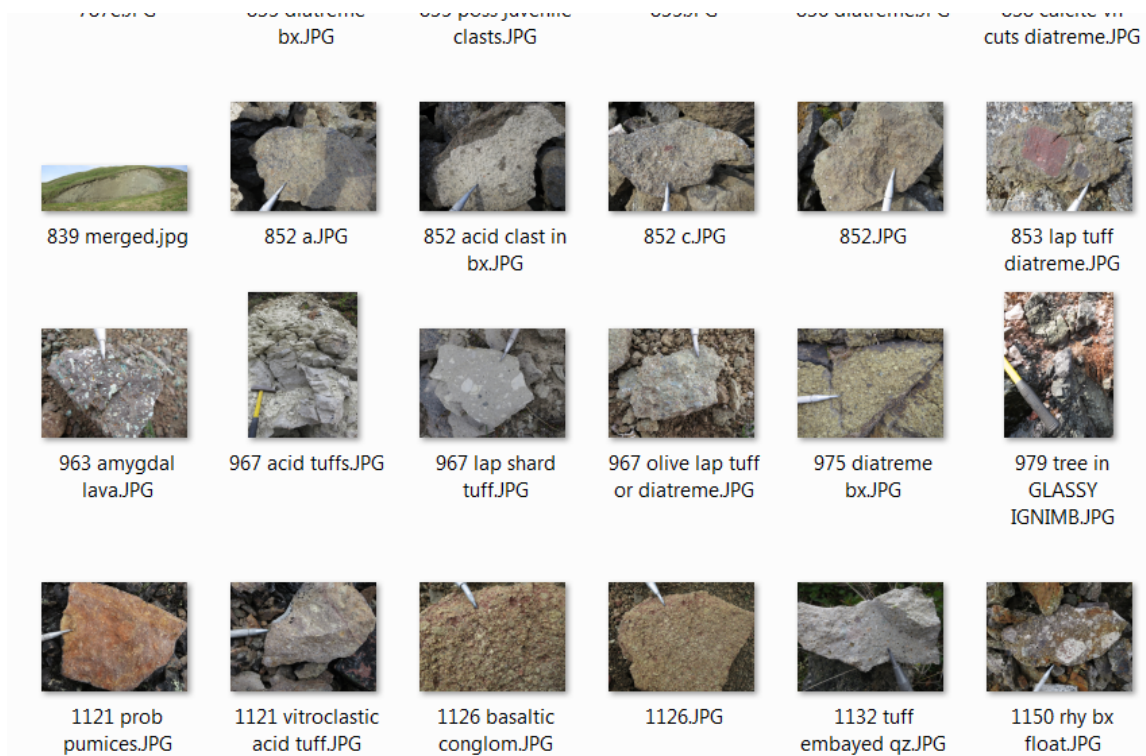
More importantly, Spheristat also produces a dxf map of structural symbols and all GPS waypoints. This dxf can be imported into Coreldraw or Adobe Illustrator. It can form the skeleton of your final map. The example below shows numbered field localities (GPS waypoints) and structural symbols. Where text is superimposed, the offending structural symbols can be shifted slightly in the drawing software to clarify the final map. The pre-programmed GPS waypoints (A,B,C,D) come in handy at this point, allowing the dxf to be stretched and fitted onto the background topography.



PHOTOGRAPHS

Photographs are worth a thousand words, videos even more. I can take hundreds of photos in a single day. I use my digital camera (or iPhone for panoramas – much easier than using stitching software). I always take my field photograph, then immediately photograph the locality number in my notebook or on the GPS screen. It takes a couple of seconds and effectively forms a catalogue of all the photos.

Every evening, in Windows Explorer, I change the filename to the Master Locality Number and a brief geological description (e.g. '23 coarse dolerite.jpg'). The photos of the notebook/GPS then get deleted. This sounds time-consuming, but is a hugely important process and worth its weight in gold when you come to compile your report and final map. The field photos need to be well categorised, or else they become cumbersome and difficult to sort. A screen grab of a typical project photo folder is shown below.



SERVICES

We understand the difficulties that students face if they are not trained in a GIS system. We offer a service which takes your raw field data spreadsheet and produces a dxf 'skeleton' of a map that you can import into Corel/Autocad or other drawing software. This map has:

- 1) all your field localities,
- 2) a kilometre grid that allows you to 'fit' it to your scanned topography, and
- 3) all your structural symbols (see figure on Page 11).

This is provided as a single .dxf file and the service costs £30. Also included in that price are 3 stereograms for the principal structures that you have measured (for example, bedding, schistosity and faults). You decide which structures you want plotted. Contact us for further details and specifications of exactly how the spreadsheet should be submitted and exactly what we provide.

