Magnetometer Basics

(source: http://sussexarch.org.uk/geophys/index.html)

This is a very helpful website for the beginner – for all those involved in CLASP's work, it is well worth visiting the website.

(*Note: I copied the introductory comments below from this site for my own education – but I hope they will also be helpful to colleagues – it is an excellent introduction to the subject, plus a tutorial in how to set up the site for taking readings. GH)*

1. Magnetometers

Magnetometers measure the local magnetic field strength. As well as the earth's magnetic field, some archaeological features have a measurable magnetic field. Burning will cause substances to become magnetised, metals such as iron have a strong magnetic field, and even the fill of a ditch will show up because there are magnetic particles in soil, so if you have a deeper depth of soil because of a ditch, you will get more of a magnetic field to measure.

There are three main types of magnetometer, all of which do the same thing, but in a different way.

- The first, the **Proton magnetometer** is actually rather slow compared even to resistivity, so it is little used. It works by inducing a magnetic field which will cause the protons in a hydrocarbon fluid to align, then by measuring how fast the protons snap back once the induced magnetic field is turned off, a measurement of the local field strength can be taken.
- **Alkaline-vapour magnetometers** work in much the same principal, but are much faster, allowing almost continuous readings to be taken. Unfortunately, they are also very expensive putting them out of the reach of most people's budget.
- The third type, which is most commonly used, is the **fluxgate magnetometer**. These consist of a metal core around which is wound a coil of copper wire. The fluxgate magnetometer can also take continuous readings, but is a lot cheaper to produce that the vapour magnetometers. The downside is, unlike the other two types of magnetometer, the fluxgate does not not measure the total field strength, only the portion of it relating to the alignment of the sensor itself. That means that turning the sensor will cause the reading to change. They are also sensitive to changes in temperature, so readings will change of the course of a day.

The way around this is to use a Gradiometer setup. If you have two sensors placed one above the other, then you can take one reading from the other to get what is known as the 'magnetic gradient'. So if you turn the instrument, then both sensors will register the change, effectively cancelling the change out. As one sensor is closer to the ground than the other, it will be affected to a greater extent than the other sensor. Therefore the difference in reading between the two sensors can be taken as a reading for the magnetic influence of the ground beneath the meter, hopefully excluding everything else. The two sensors need to be properly aligned before a survey takes place, and the sensors can be unevenly affected by changes in temperature, so 'drift' measurements need to be taken at a fixed point in the landscape between grids. Because there is no need for contact between the ground and the instrument, a survey can be done by just walking along the ground. This is quicker than resistivity and also allows more readings to be taken with no increase in survey time. Rather than pressing a button to log a reading, modern meters take readings at pre-defined time intervals, so it up to the user to walk at a fixed rate to a set of beeps made by the meter. A bit of practice is needed, as this is not so easy for beginners to do as a resistivity survey. A magnetometer is not affected by groundwater like a resistivity meter, so surveys can be taken throughout the year, but certain magnetic bedrocks will render the machine useless. They are better at picking up ditches than a resistivity meter, but not as good at picking up walls, unless there is a substantial foundation trench or the wall is comprised of a burnt material such as bricks.

The main commercial options in archaeology used are both Fluxgate Gradiometers. The FM256 by Geoscan Research and its predecessors, the FM36 and the FM18, were until recently, used by most people. There is now a cheaper, but still expensive option on the market in the form of the **Grad601 by Bartington** *(Note: CLASP has purchased one of these).* The alignment of the sensors is easier than the Geoscan meters, and there is less drift. The sensors also have a greater vertical spacing, giving a greater contrast in readings. Both meters come in one or two gradiometer options, so you can take two sets of readings at once, thereby increasing the speed of your surveys.

2. Software Available

After you have completed your survey, the data stored in the meter is ready to be transferred to a computer for interpretation. The data is usually downloaded by connecting the instrument to the computer using a cable. The software for interpreting resistivity and magnetometry is broadly the same, as both deal with results as a set of numbers within a grid, though some extra features and filters are helpful for magnetometry. The most basic function of the software is to assign a set of colours to the numbers so the user can visually see the changes in the readings over the survey area. Extra functions known as filters can help to process the data to make certain features easy to see.

There are various pieces of software available for Archaeological Geophysicists. The most common ones for resistivity and magnetometry are listed here. The software for GPR is completely different to the software used for resistivity and magnetometry, having to deal with the waveforms received by the antenna. It is beyond the scope of this page to discuss.

- Geoplot is the oldest commercial software, and for many years was the only option. It is fully featured, but the user interface can be difficult to use, and the dongle system for copy protection can be cantankerous.
- ArcheoSurveyor is a more recent offering to the commercial software market. It is fully featured and more user friendly than Geoplot, but is expensive. Snuffler (Available from this website)
- Snuffler is freeware, and aimed at the amateur geophysicist. I must admit a bias here as I wrote the software. It is freely downloadable and distributable, and whilst it is not as fully featured as the two commercial offerings, it covers most of the basic functions needed for resistivity and magnetometry, and is more user friendly that Geoplot. It is only available from this website.

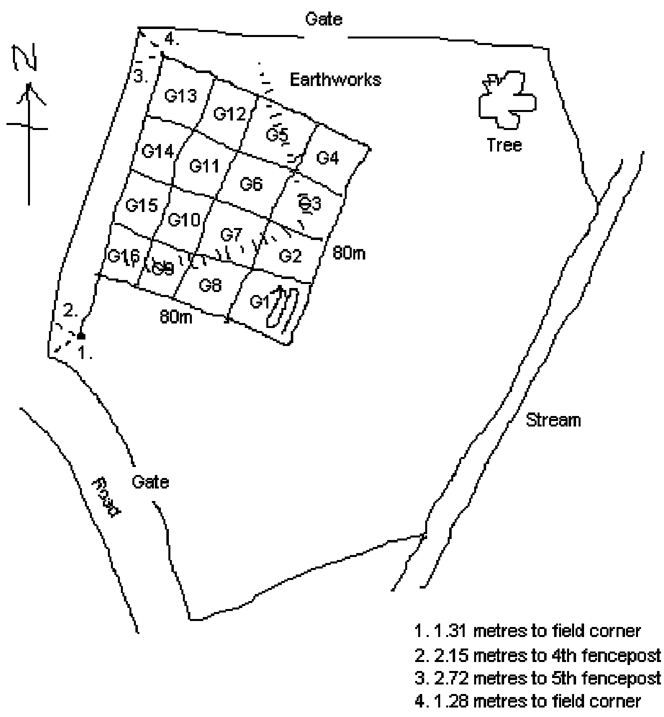
(Note: CLASP has downloaded a copy of Snuffler, and can give a copy to anyone who wants it – contact Fred Kay, Dave Hayward or Gren Hatton).

3. Setting Up A Grid

When taking a reading using a piece of geophysics equipment, you are getting a response from a single point on the landscape. Whilst this is meaningful, in itself it is a useless piece of information. Geophysics surveys work by comparing readings from one area with another, so patterns can be recognised. The best way to do this is to take readings at regular intervals, which can then be displayed on a computer. Whilst it is possible to measure out where every single reading should go for a survey, this would be horribly time consuming, so the best way is to have a set of large squares which are subdivided by a series of marked strings when the survey takes place. The size of the squares that make up the survey area is important. Too small and you spend too long setting up the squares, too big and performing the survey itself becomes a problem. Resistivity meters have a cable, so if the squares are too big then the cable gets stretched. Magnetometers do not suffer from this restriction, so larger grid squares can be used. For resistivity, most people tend to use 20mx20m grids, though for magnetometry, 30mx30m and even 40mx40m grids are not uncommon. The choice is up to you and most hardware and software will cope with a variety of grid sizes.

It is essential that, when you set up a grid for a survey, you can set out the same grid again later on. This is so you know exactly where on your site the new features are and can tell people where they should be excavating. The best way to do this is to set up a baseline.

If you can find two points that can be found again by referencing them to fixed points in the landscape, you can draw a line between them and offset your grids from this line. The fixed points can be anything that is fixed in the landscape and is unlikely to be moved. You need two of these features for each point. If you measure from the point on the end of your baseline to each of the fixed points, you will be able to triangulate back from the two fixed points back to the baseline point using the measurements you have recorded. Whilst it is desirable to have the length of the baseline equal to the length of the survey area, it is not always possible, so you must record how far along the baseline the survey area begins. The baseline itself can be positioned anywhere you wish, but there are certain constraints, such as availability of fixed points to reference from. Generally, you should set up your baseline in such a way that the grid squares will not conflict with the boundaries of the site and cause disruption to the survey.

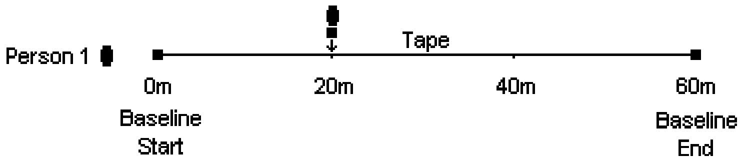


Once you have set up your baseline, the grid squares themselves can be offset from it. There are several methods, described below. Whatever method you use, a quick sketch of the baseline, grids, local features and any relevant measurements should be made for your records, so the grids can be reconstructed as necessary. Notes relevant to the processing of data should also be made, such as the direction of survey within a grid and the order in which the grid squares are surveyed.

3.1 Setting up a grid using tapes

Unless you have a large amount of money, you will be probably setting up your grids using tapes, usually a combination of 30 metre and 50 metre tapes. You will also need a quantity of ranging poles, painted stakes, or bamboo canes topped with colourful tape for visibility. Canes are lighter if you have to carry them to the survey area but harder to see and push into the ground. They can also be somewhat less than straight, which can cause problems described later. Painted stakes about 40cm long, of 40-50mm square section, are a good compromise, and can be seen from a couple of hundred metres or so.

There are two main processes involved in setting up a grid using tapes; the first is sighting and measuring, the second is triangulation.

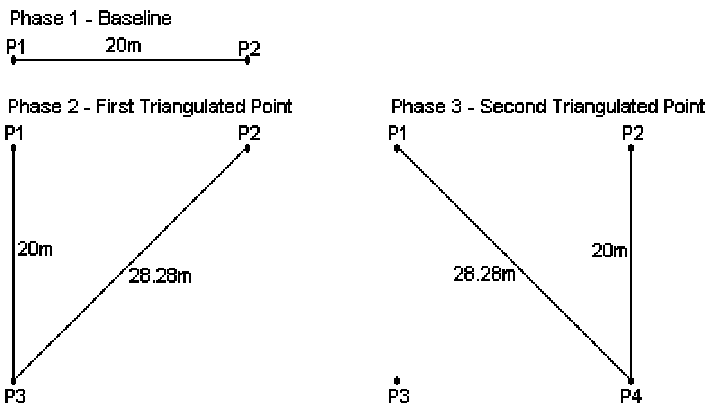


To set up your baseline in the first place, you will need to use sighting and measuring. Assuming you are going to be making your baseline the same length as your survey area, you will need to choose a starting point and then measure using a suitably long tape the distance of your survey to the end point of the baseline. If you are surveying a large area, the baseline should be at least 100-150m. If the baseline is constrained by a factor other than the survey area then you will have to pick the two points and measure to the survey area. Most importantly, your baseline should be straight, and you can do this by sighting in the points using tapes and ranging poles or stakes/canes.

If you have points on your baseline and you want to set up the intervening points, start by placing two ranging poles in the ground at these end points. With a tape running in between these two poles, set up poles at the required distance in between. With one person holding these new poles, another person can stand at one end of the baseline and instruct the first person to move the pole until it is in line with the two poles at the ends of the baseline. Errors can creep in here, usually because the poles are not upright or in the case of bamboo canes, because the canes themselves are not straight.

Once you have set up your baseline, you can now set up the grid squares, and here we need a little bit of maths. If you can remember your maths lessons at school, you may remember that when dealing with right-angled triangles, the square on the hypotenuse is equal to the sum of the squares of the other two sides. Basically, if you want to set up a square from two points you can make two right-angled triangles using tapes to get the other two points. If you don't want to do the maths, all that you have to remember are the diagonals for the three most common squares used in geophysics:

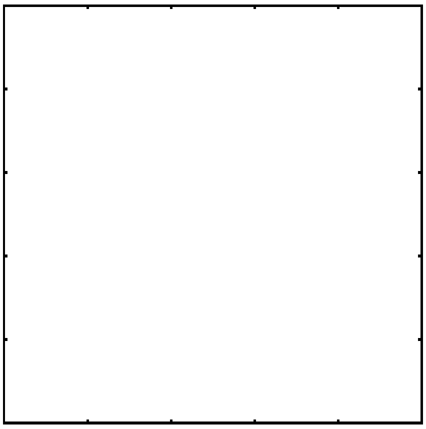
- 10m square: diagonal = 14.14m
- 20m square: diagonal = 28.28m
- 30m square: diagonal = 42.43m
- 40m square: diagonal = 56.57m



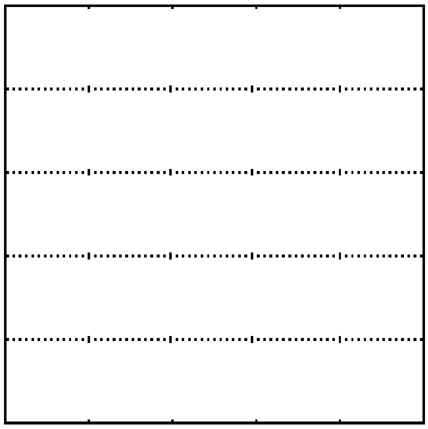
Using two tapes, a square can be set up from a baseline or another two adjacent points in two stages, as shown on right. It should be noted that this method can produce cumulative errors, so when triangulating to a new point, you should always use the oldest adjacent points available to you. When you have set up a point, and if there are other suitable points available, the new point can be checked by looking to see if it is line with two or more already existing points. Errors can be caused by vegetation or other terrain getting in the way, or by the slope of a hill. Whilst this method is useful for small surveys, larger surveys need something that has smaller cumulative errors.

If you are surveying a very large area, a quicker and more accurate way to set up a grid is using a combination of the sighting method used for the baseline and the triangulation method shown above. Say you have a 100m tape and want to set up an area 100m square containing 25 grid squares of 20x20m each for surveying. Additionally to your 100m tape, you will need a 30m tape. First of all, set out a baseline of 100m using the sighting method. At the ends of this baseline, use triangulation to set up two points offset 20m from the baseline. With these two additional points, you can now use sighting again to set up the two sides of your 100x100m survey area.

Phase 1 - Set out the baseline and triangulate two points offset 20m from the ends



Phase 2 - Sight in the two sides of the survey area and check the final side is 100m



Phase 3 Run the tape between points on the sides of the survey area and sight in the intervening points

When you have these two lines, you can check they are correct by measuring between the ends to make sure the last side is also 100m. The first time I was shown this I thought it would be very inaccurate, but the error on the last side was only 7cm over 100m, which is perfectly acceptable. Finally, you can set up all of the points within the survey area by running the 100m tape between all points on both sides and sighting them in between the two ends.

3.2 Survey Lines

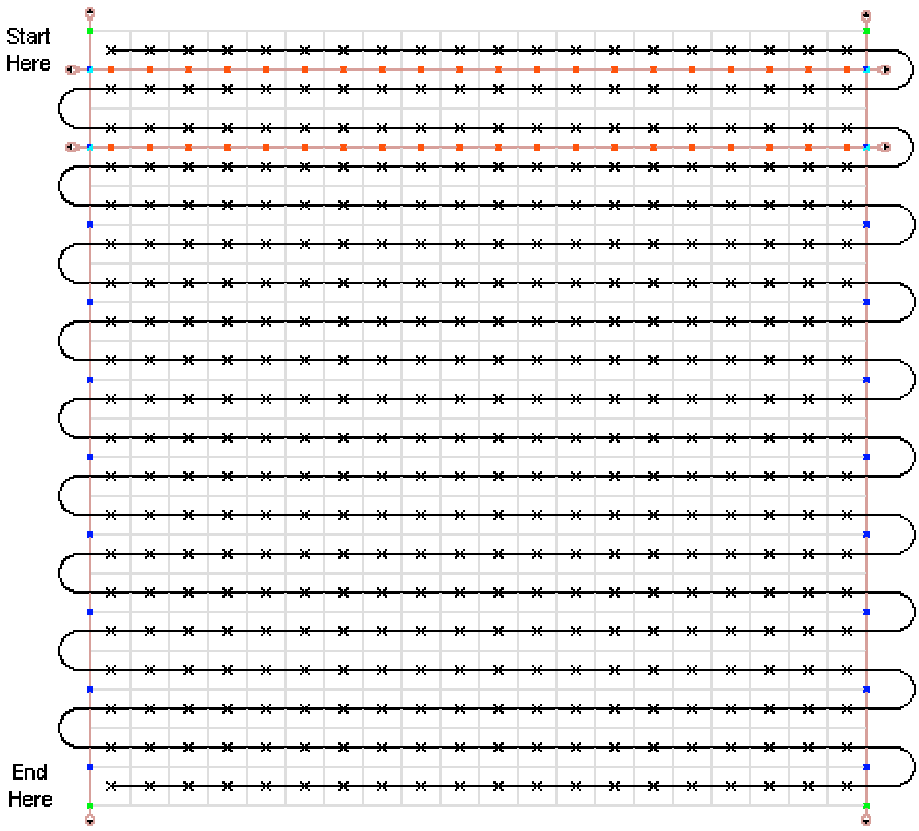
Now we get down to what happens inside one of our grid squares. The object is to take readings at a regular interval, usually every metre for resistance. The best way to accomplish this is to have a set of strings marked up with paint, which we can set out within the grid square and use to tell us where to take the readings. Tapes are not really suitable as you keep having to look for the point you want, which slows you down. There are various ways to mark and use your strings, the first one is used for resistivity. You will need a minimum of three of these marked strings, though four is better, for reasons that will be explained later. This example assumes a grid size of 20m, which is standard for resistance surveys.

The first two strings go between the corners of the grid square, on opposite sides. Different colours are needed here to mark up the strings. Firstly, you will need a mark near either end of the strings, 20m apart, to show where the string should be placed on the corners of the grid square. Secondly, a series of marks in a different colour to show where the second set of strings should be placed. You will need one of these marks 1m in from each of the original end marks, then every 2m.

The second set of strings are placed between the marks on the original two strings on either side of the grid. Firstly, as before, you will need marks of one colour 20m apart, which will be placed on the marks on the original strings. Secondly, a set of marks in another colour to show you where to take a reading with your equipment. If you are taking a reading every metre, then these marks start 0.5m in and then every 1m after that.

This will give you a set of strings that will show you where to take your readings. You do not however take a reading on the string itself, you take the reading next to the string, up one side of the string and back down the other. By doing this, we can take two lines worth of readings without moving the string, which saves time. Having two strings going across the grid means the equipment operator can start on the next string whilst the first string is being moved to a new position. Loops at the ends of the strings, past the points marking the 20 metres allow you to use pegs to fix the strings on the ground. Plastic (or wooden) pegs are best as they won't interfere with magnetometer equipment.

The second set of strings I will talk about here are for magnetometry. With magnetometry, you are not placing probes in the ground at a certain point, but you are walking to a set pace using a set of beeps from the machine, which you should time to match point marked on your lines. The lines between the corners of the grids will stay the same as for resistivity. The beeps will match points along the line at every metre, but these will not start half a metre out like with resistivity. The first beep will be at the start of the line, with subsequent beeps every metre after that, so the lines should be marked accordingly. The sensor column is held half a metre from the line as you walk



along it, so that the readings are taken in the centre of the 1m squares. Magnetometry is also usually done using 30 or 40m grids, rather than the 20m used for resistivity.

3.3 Making the magnetometer survey

3.3.1 Equipment

The fluxgate gradiometer is the type of magnetometer used in most archaeological surveys. The older proton precession magnetometers are too slow to be useful, and the alkaline vapour magnetometers are too expensive. Fluxgate magnetometers are fast and (relatively) cheap. A fluxgate sensor consists of wire wound around a metal ring. Passing a current through the wire will give different results based on the strength, and direction of the magnetic field. Because the sensors are directional, in fact they can be used to make an electronic compass, they are used in what is known as a gradiometer setup. This involves two sensors, one some distance vertically above the other. The top sensor is less affected by what is under the grounds, so it can be used to cancel out the effects of the Earth's magnetic field. This requires the two sensors to be perfectly aligned, which is the downside compared to sensors that measure the total field strength, like alkaline vapour magnetometers. The magnetic field is measured in nano-Teslas (nT), and archaeological features can be very weak magnetically, often a fraction of a nano-Tesla.

3.3.2 Conditions

Unlike resistivity, magnetometry is not affected by the level of ground water, so surveys can be performed all year round and get consistant results. If the conditions under foot make walking with a steady and unimpeded gait a problem, the results can be affected. By how much is dependent on how well the machine is balanced. Whilst you may be only interested in the archaeology, modern metal can have a negative effect on the results. Metal pipes, fences, bits of broken farm machinery, land drains and rubbish dumped on the survey area will all show up much stronger than any archaeology hidden below.

The underlying geology itself will play a big part in the results that you see. Magnetometers are good at picking up ditches and other cuts in the underlying geology, but some geologies, such as chalk or clay, will not show these cuts unless they are to some extent filled with occupation debris. Other geologies, such as sandstone, give a much better response to magnetometry.

Most importantly, the operator of the device should we wearing no metal. That means, no metal buttons, zips, watches, glasses or belts. Particular attention should be paid to the footwear, which may have metal pins in the heel. Items of clothing can be checked by setting the device to scan mode, and moving them closer to one of the sensors, seeing if the reading changes. The presence of metal is only a problem when taking readings with the machine, or when balancing it at the 'Zero point' (described below).

3.3.3 Equipment Setup

Because of the directional sensitivity to the Earth's magnetic field, fluxgate gradiometers need to be balanced, so that both sensors in the gradiometer column provide an equal response to the ambient field, whichever direction they are facing, otherwise you could get a different reading at the same spot simply by turning slightly. This balancing should result in a background reading of zero nT. This state is achieved by finding a magnetically quiet spot in the survey area, to use as a 'Zero point'. It is important that this spot is quiet magnetically, as the device will not be able to be balanced correctly if there is a significant magnetic signal in the ground in addition to the Earth's magnetic field. Such a spot is found by wandering around with the device in scanning mode and finding a spot where the reading doesn't change significantly over a small area.

Once such a spot is found, the device can be balanced. This involved using a compass to set up non-magnetic pegs at the four cardinal points, and going through the balancing process used by the individual machine. This process differs by manufacturer, and will be described fully in the manual. Older machines will have a manual balancing process that involves turning knobs to adjust the orientation. This can be difficult, and the resulting setup is not usually very stable, as knocking the machine can have an affect on the balance. More modern machines have fixed sensors, and balance electronically, which is a lot simpler and a lot more stable.

Once the machine is balanced, the zero point should be left in place until the survey is done, as rebalancing the machine during the survey is often needed. Rebalancing may be needed due to the machine being knocked, thermal drift, where the temperature of the sensor changes and gives a different reading, or because the survey is being conducted over several days. It is worthwhile keeping an eye on the readings whilst surveying, which should hover around zero nT. If you survey a line where the readings hover around 1 or 2 nT, for example, then return to the zero point at the end of the grid, and rebalance it.

3.3.4 The survey itself

Whilst it is possible to take individual readings manually with a magnetometer, for a survey of any size, that would be quite slow. Generally, the method of collection involves the machine taking readings at a constant rate over time. For these readings to be correctly assigned their proper place in the survey results, the machine needs to know where it is. For any given line in a survey grid, the process works like this. Firstly, before the survey is started, the machine is told how big the survey grids are. Both how many lines, and how long the lines are. Whilst resistivity grids tend to be 20x20m in size, magnetometry grids tend to be 30x30m or 40x40m, as you don't have to worry about the twin probe cable.

Once the machine is set up to know how big the grids should be, the survey can begin. A button is pressed to start a line, and the machine will start taking readings. It will also beep at a constant rate. Once when the line starts after the button is pressed, and again for each metre along the line you are travelling, until it gets to the expected end of the line give the line size it was told. The operator’s job is to match the beeps to the real distance travelled along the ground, usually by following metre marks on an adjacent string laid across the grid. Once a line is finished, the next line is started, usually in a zig-zag pattern rather than starting at the beginning of the line again, until the grid is finished. Whilst the machine will only beep once per metre, that is not when it is taking its readings, the beeps are purely for your benefit.

Magnetometers can take several readings per metre, with four being pretty standard, though this is usually adjustable, so in between each been it will be taking a number of readings. For most surveys, the lines are 1m apart. You need to remember to take readings in the middle of the line, so for 1m spaced lines, the sensor column should be half a metre (horizontally) from the string as it travels along it.

It would be nice, if in the course of a grid, no obstacles were ever encountered, but in the real world, there are things like trees and funny shaped partial grids. Readings can be stopped at any time along the length of a line. You can enter dummy readings, just like with resistivity. You can fill the rest of the line with dummy readings if you have come to a fence, or you can enter a few to get past a tree, and then resume the survey. When entering just a few readings and resuming the survey of a line, you should remember how many readings per metre the machine is set to record. For example, if the machine is recording 4 readings per metre and you want to move on 3 metres to get past a tree, you need to enter 12 dummy readings.

4. Producing An Archaeological Geophysics Report

So you have finished the survey and downloaded the data to your computer, what do you do with it now? After you have a nice image, how do you interpret and present it? How is the report and your data to be stored for future use?

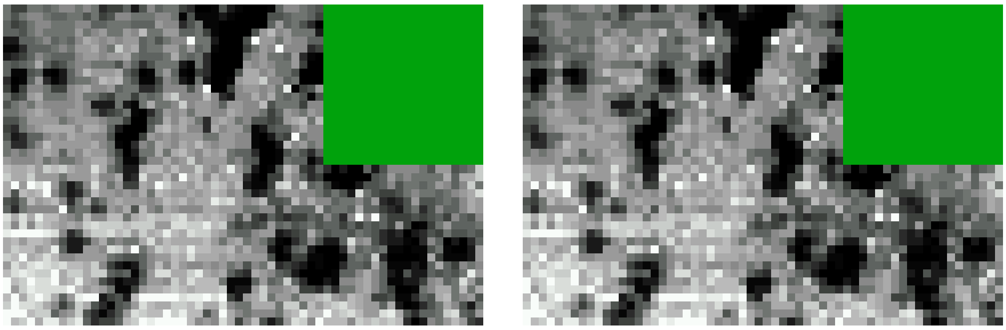
4.1 Processing The Data

Assume that you have downloaded your data into the software you are using the instructions applicable to that software. Also assume that you have taken the individual grids and applied the layout of those grids in the software to produce a composite image. Now comes the fun part, applying the various filters to produce a nice image and interpreting the results, assuming the software you are using comes with these filters.

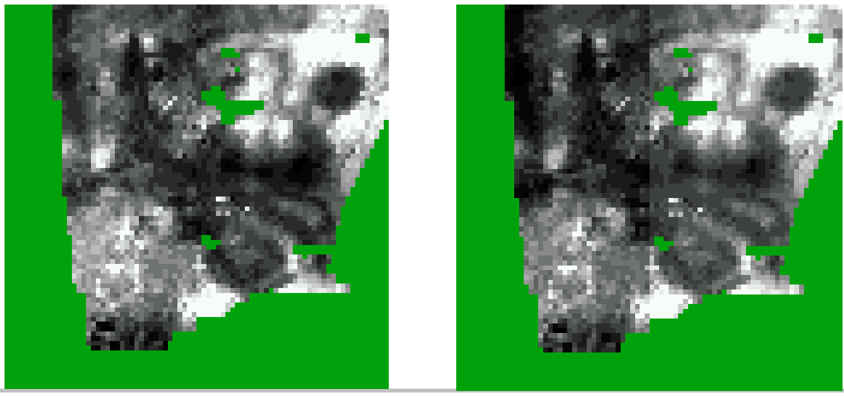
4.2 General filters

Now you have a basic image, you need to look at it to see what filters will help. I will cover here the most basic filters that you will use most. Your software may have other filters that may be of limited use, but you will need to consult the documentation that comes with your software for those. Not all filters are useful in all situations, and filters should be used in a certain order for the best results.

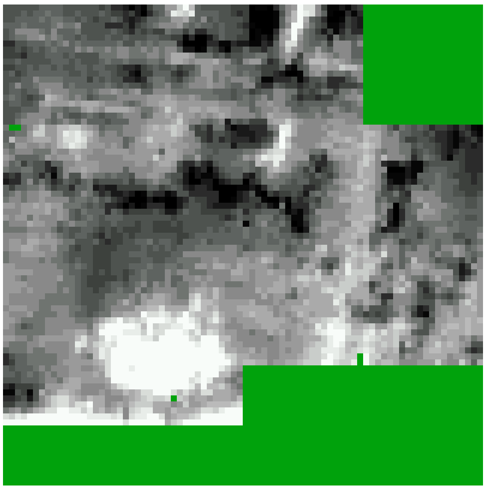
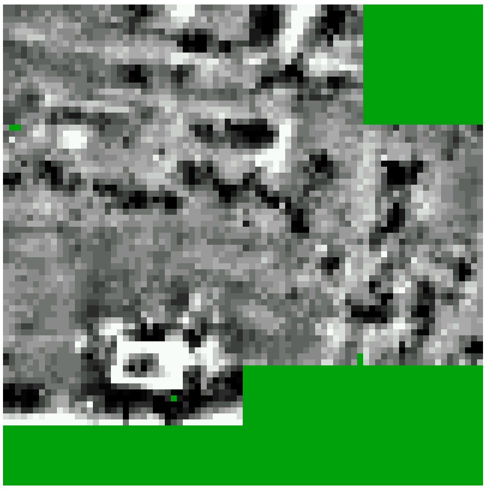
Most images will have some 'noise' that does not relate to the features you are trying to identify. In resistivity, you may have hit a stone and recorded a very high resistance reading. In magnetometry, there may have been a part off a tractor buried in the field causing a magnetic spike. By noise, we specifically mean a single high or low spike within an area of otherwise average readings. Whatever the reason for this noise, it can skew the results of other filters because of the extreme readings involved. So before you apply any other filters, it is worth using the Despike filter to remove these.



Next for resistivity, after the Despike, you should now be looking at the edges of the individual grid squares. If the point where one grid finishes and another starts shows a distinct difference in the readings between the two squares, this needs correcting. In resistivity, this is usually caused by the fixed probes being moved. Your software will have a tool to match these grids so one seamlessly flows into the other. In Geoplot it is called 'Zero Mean Grid', in Snuffler it is called 'Edge Correction'.

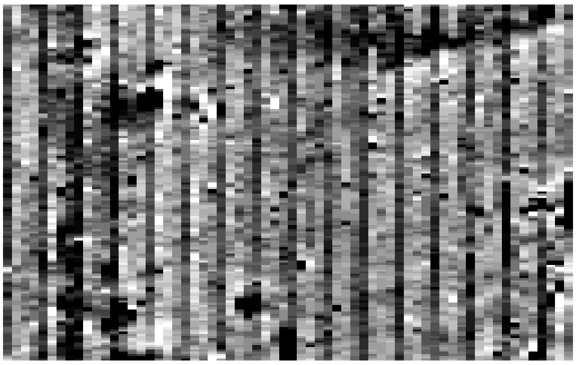
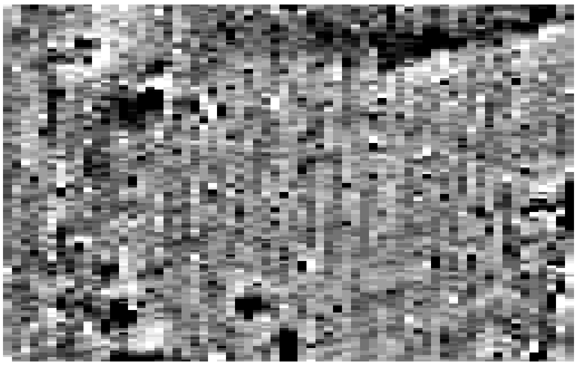


Continuing with resistivity, you should now have an image which is free of artifacts caused by the survey process. You may be able to see some features, but there are ways of making them clearer. The local geology may play a significant role in your image. If these are small features such as solution hollows or cracks in the bedrock, i.e. high frequency features, then you are stuck with these as the features you are looking for are also high frequency. If on the other hand, you have a slow change in the depth of the topsoil across the site, causing a slow but visually significant change in the readings, then there is a filter called a 'high pass filter', or 'Remove Geology' in Snuffler which can help. This filter removes these slow changes and flattens out the site, making the 'high frequency' archaeological features easier to see. You are usually asked to supply a sample size. The filter works by taking an average of the readings around each reading to calculate a background. If you take a large number of readings for the average, then the background will change less and there will be less flattening of the image. If you take a small number of readings, the background will change more and you may start to loose the features you are looking for. You should try several sample sizes to get the right one.

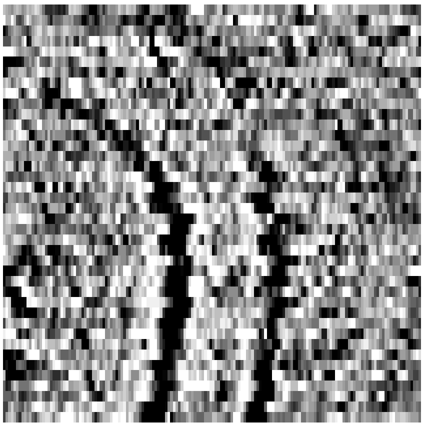



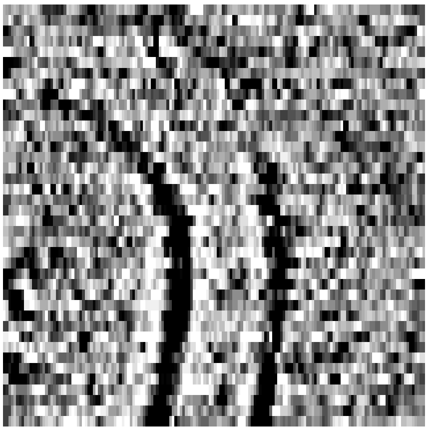
4.3 Filters specific to magnetometry

Moving on to filters specific to magnetometry. The setup of fluxgate gradiometers, and their directional nature, will produce a striped effect across your surveys. This can be removed with a 'de-stripe' feature. Particularly strong signals may cause this filter to leave, or even produce stripes in places. De-striping per sensor/direction may help here, which takes a wider average rather than just dealing with each line one at a time.

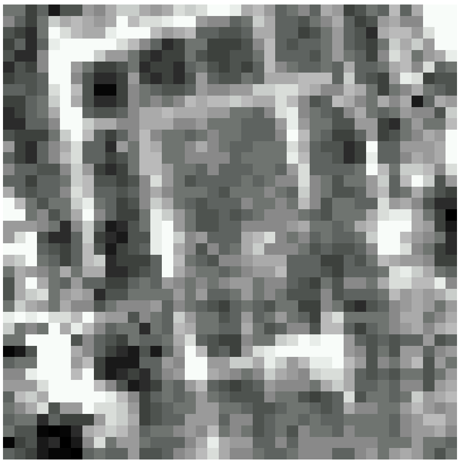



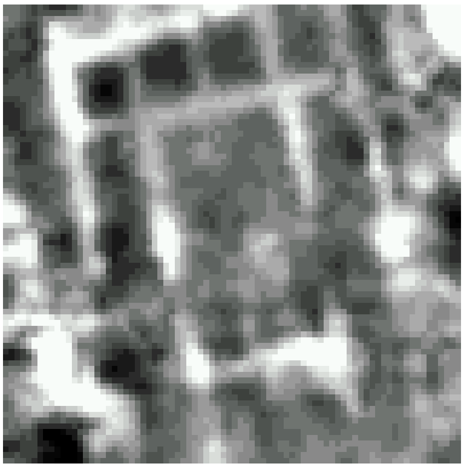
The next useful magnetometry filter is de-stagger. The machine operator may consistently misjudge the position on the grid by a small margin, or walking on a slope might make it difficult to walk at a steady pace. The result can be a staggered effect on linear features. The de-stagger filter can correct this type of error.





The last feature to be used, for both resistivity and magnetometry, <u>and it must always be the last</u>, is the interpolation filter. Interpolation will increase the number of readings and guess what is in between, thereby smoothing out the image and making it easier on the eye. Whilst it doesn't provide any more literal information in the image, it takes advantage of the way the eye and brain work in processing information to help you see the features instead of concentrating on the differences between individual readings.





Now that you have a nice image, you can try and work out what archaeological features are visible. They may not be obvious straight away, prolonged consideration of the image may be needed, especially if the area covered is quite large. Comparison with an aerial photograph is useful as the two can provide complementary information.

The process is best done by viewing the image on a screen rather than a sheet of paper as the colour reproduction is usually better on a screen. Also, get many people to look at the image, as other people can often spot things that you miss. Other than that, recognising features is not something you can explain on a web page, you just have to get experience by looking at many images to be able to distinguish between the archaeology and your local geology.

5. The report

The final report can be summed up in a list of guidelines for information that should be included. If you are just doing a quick survey on a day to satisfy curiosity, and the results are nothing spectacular, then doing a full report is not worthwhile. A large survey or one with good results deserves a full report.

You should have recorded various pieces of information such as the dates of the survey, the location, survey area, the specification of your machine, the weather, the local geology and land use. This information should be given along with a note on any effect it had on your survey. The reason for doing the survey in the first place is also important, with a description of known features or other information that has caused this survey to take place, such as field walking or aerial photographs.

A diagram to show the grid layout and measurements relative to known features or landmarks is helpful. It will allow someone to return to the site and mark out the features you have found for excavation. Then of course the images you have produces using your geophysics software, with appropriate text, north arrow and and scales. The final diagram is an interpretation of the results, showing the survey grids with a diagram of the features found. If the period of the features are known, then they can be marked in different colours. Different colours should also be chosen for high and low resistance features. If colour is unavailable, then different types of shading can be used.

Finally, a text discussion of the results and their meaning along with acknowledgements and bibliographical references. Getting someone to proof read it is helpful.

6. The Archive

A report is no good if there is no-one to read it. First of all, you have to make sure your report reaches the right people. Apart from all the people who have helped you out, there may well be several organisations who need a copy of your report.

Firstly, a copy should be sent to the Historic Environment Record, which is held by the County Archaeologist. If you don't already know who this is, then you can contact the County Council to find out. If you have had to get Scheduled Monument Consent, then English Heritage will need a copy as part of that consent. Your local library may well be interested in a copy, as well as the libraries of any local or county archaeological societies. You will of course have received permission from the landowner to do your survey, so do send them a copy as well.

A digital archive is also desirable – both of the report, and also the raw data from which you have produced your results. The raw data is best stored in the XYZ format, which is a standard text file that records the data along with its position. Your geophysics software should be able to produce this for you. Other information is best stored in Open File Formats, by that, I mean file formats which are not exclusively owned by one company and for which the details of the format are available for anyone to use. As far as image files are concerned, PNG files are best, both because it is an Open File Format, and also because it is not a lossy format, i.e. the compression in the file will not change the image. Any decent paint program should be able to convert your images to the PNG format for you.

Documents are best stored in PDF format, MS Word is nice but proprietary and changeable. HTML is open but you can't control the page breaks. If you can't afford Adobe Acrobat to convert your documents to PDF, you can get them converted on-line. After you have your digital archive ready, burn it to a CD and give copies to whoever you think needs it.