University of Wales Trinity Saint David
MA in Cultural Astronomy and Astrology
Archaeoastronomy Module

Fieldwork in Archaeoastronomy Notes

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01/03/2015

1. Introduction

These notes are a work in progress. They are intended to convey the very basics of fieldwork for the Archaeoastronomy module of the MA. They might look like quite a lot of notes, but they are written so you need to read through them only once, and then refer back to particular sections as needed. And remember, we will provide assistance, so please ask.

These notes don't cover all the techniques for all the possible things you'll need to measure or assess for your project. Instead it focuses on the essential elements that you'll need to master whether you've chosen a Medieval church or a Neolithic stone circle for your essay. Techniques particular to your site will be found in previous archaeoastronomical research done to sites similar to the one you've chosen, and that should be part of the literature review for your project. But look at those techniques with a critical eye: how accurate are they? Can you improve them somehow?

Fieldwork in Archaeoastronomy is not set in stone. Be creative, but keep in mind that you want to make measurements as accurate and precise as possible.

2. Required Equipment

For fieldwork in this module you will most definitely need a way of obtaining the latitude of your site(s) and the azimuth and horizon altitude of the direction(s) you want to measure. There are many different ways to do this (see sections below), using different tools. For a complete project we recommend the following. However, it depends on how much detail you need for your particular project.

- GPS unit. The Garmin 12XL, although outdated, is still an amazingly good GPS unit that does averaging and can be found relatively cheap on eBay and other second-hand online stores.
- Compass. Make sure you buy a relatively good one, with a precision of at least half a degree. The Suunto KB14 is an example of a direct-reading one, which which often used by geologists and archaeologists. It can be read to half a degree and estimated to a third of a degree. Apart from direct-reading ones, prismatic compasses are also often used for surveying.
- Clinometer. A clinometer is the easiest way of measuring altitude. If you decide to get one, make sure you get one with a good precision as well. Suunto makes good clinometers and compass/clinometer combos as well.
- Theodolite. If you wish, you might choose to use a theodolite instead of the compass/clinometer for higher precision. The University has theodolites, but availability is an issue: theodoloties are heavy and difficult to transport. This is why we do not require you to use one for this module. However, if you do decide to use one you might want to contact a local engineer or university to see if you can borrow one from them.

- To determine the direction you want to measure to good precision (a very important step, see section 7) you'll most probably need steel tape, cord or string, surveyor's rod(s), tent pegs, etc. depending on the site and technique.
- A notepad, pencil or pen to take notes of your measurements, while on the field. You might also want to use electronic devices such as a mobile phone, tablet, netbook or laptop but keep the weather conditions in mind!
- Clothing and footwear. It is absolutely essential you check weather forecasts and dress appropriately when going to do fieldwork. Do take extra clothes with you in case it gets colder or starts raining when you're involved in your work.

Note: These are just suggestions. Feel free to buy other GPS units, compasses, etc. But make sure you get equipment that does what you want it to do, and that does it to good accuracy.

3. Determining Site Coordinates using a GPS handheld

GPS units are very common these days, specially in cars, mobile phones and laptops. However, most of them are not that precise, and they almost never tell you their accuracy. A handheld GPS unit will always tell you the accuracy of the measurements. The Garmin 12XL, the recommended unit for fieldwork in this module, has an accuracy of nine metres 95% of the time and can go down to 3-4 metres when one uses the averaging function.

A more complete description of how to use the GPS is given in Kim Malville's powerpoint and CM recording. An alternative way of determining latitude in the UK is to use Ordnance Survey map references which can then be converted to latitude and longitude on the OS website (http://www.ordnancesurvey.co.uk/). Other countries will have similar institutions, but you might have to pay for them.

Note: It is strongly advised you practice a bit and familiarize yourself with your GPS unit well in advance of your field-trip. Try it out in your garden or just outside your house. Learn how to use averaging with your unit and wait for the error to come down to acceptable values before taking note of the values.

4. Using a Compass to determine an Azimuth

An azimuth is an angular measurement in the horizontal coordinate system. This is explained in greater detail in the Celestial Mechanics notes but, for all intents and purposes, it means that the azimuth is an angle that is measured along the horizon. Like all measurement systems you need a point of reference, a zero point, and, for azimuths, this is North. The whole horizon, which, if you were in a place with no skyscrapers like a desert or the sea, would form a circle around you that comprises 360 degrees, usually represented as 360º.

So, if you went and measured the azimuth of a hill on the horizon exactly due north you'd get either 0º or 360º, which are equivalent. If the hill was due east then you'd get 90º, due south would give you 180º, and due west 270º. But how does one go about measuring azimuths?

Using a compass to determine the azimuth of a given direction is quite straight-forward but might depend on the type of compass you have. They usually come with easy instructions but in general you'll have to do the following:

i. Aim the compass towards the direction you want to measure (see section 7 for how to determine and mark this).
ii. Check that the compass is in a flat position. If it isn't the "needle" might be stuck to the top glass, preventing it to move freely. Some compasses have an air bubble inside, like a level, that can alert you to this.
iii. Read the azimuth value from the compass' scale.

Note: It is strongly advised you practice a bit and familiarize yourself with your compass at home well in advance of your field-trip. Try measuring azimuths of particular things in your home and outside your window like a lamppost across the street.

However simple using a compass may be, it bring some serious issues. Compasses do not truly measure azimuth because they use the Magnetic North, instead of the True North, as their reference. This means that adjustments need to be made. The following two sections deal with the most important of these.

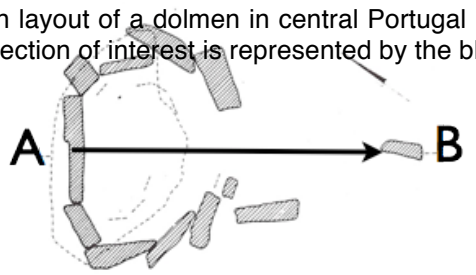
4.1 Local Magnetic Anomalies

Local Magnetic Anomalies are small, local variations of the Earth's magnetic field. These might be due to high levels of ferromagnetic material concentrated in the vicinity, or some other unaccounted for change in the local magnetic field. This means that a compass could be way off when using it to measure azimuth bearings. There is a way to minimize this effect on your measurements, when they are small enough. This way also allows you to notice if local magnetic anomalies are big enough that compass measurements cannot be trusted at all.

It is best practice to do as follows for any measurement, whenever it is possible to do so:

i. Establish the line of orientation first, using surveyor's rods, tape and/or string if need be (more on this in section 7). This is represented by the black arrow in Fig 1, i.e. from A to B;
ii. Measure this line's azimuth with the compass in both directions. Using Fig 1 as an example, measure

Figure 1. Plan layout of a dolmen in central Portugal (orthostats in grey). The direction of interest is represented by the black arrow.



from position A towards B, and also from position B towards A;

iii. Some compasses have a minor scale, in small print, below the one you would be using. This scale has a 180º offset, which means you should use it when reading the azimuth in the contrary direction (from position B in Fig 1), instead of reading it from the major scale.
iv. If your compass has only one scale you'll need to subtract or add 180º from the azimuth measured in the contrary direction opposite to the one you are interested. If the azimuth you're reading is higher than 180º you should subtract 180º from it, whereas if it's lower you should add the same amount to it.

v. Average the two measurements using the following formula, where azA is the azimuth as measured from position A and azB' is the azimuth measured from position B, already corrected as above:

(azA + azB') / 2 , that is, sum the two values and then divide them by two.

This gives you a more precise value for the azimuth. If you see a large difference between the two values azA and azB', then a local magnetic anomaly is severely affecting your compass readings. In such cases it's better not to use the compass at all and consider other methods.

To sum up: while on the field always measure the azimuth of your line of orientation in both directions and then work out the average value as described above.

4.2 Magnetic Declination and True North

Magnetic Declination is the angle between Magnetic North and True North. This is the most important correction you'll have to do to your compass measurements, and you'll always need it.

The value for the magnetic declination varies wildly in space (different locations) as well as in time (different years). They are usually printed on survey or military maps, but they always out of date so don't ever use them. There are theoretical models that can give you estimates of it at any time and any place. The website of the National Geophysical Data Center of the NOAA can quickly calculate it for you, given the latitude and date you did your measurements. The website is located at: http://www.ngdc.noaa.gov/geomag-web/

However, this is only an estimate, and things might be very different when on the field. It is recommended that you try and measure it yourself. This is not always easy and it's a very time consuming exercise, but if you're going to be using your compass for measuring azimuths you need to have a sense of the magnetic declination of your site(s) and you need to state this in your essay.

Among the many possible techniques to measure the magnetic declination we're going to highlight three here:

I. Gnomon

You can use a gnomon to determine the North-South direction (i.e. the direction of the shadow of the gnomon at local noon or, in other words, the direction of the smallest shadow) which can then be extended using string or a cord. This line's orientation can then be measured with a compass. The compass reading will give you the magnetic declination, i.e. the value you should subtract from all other azimuths in order to get correct value).

Note that local noon is not exactly midday, unless you happen to be exactly under your time-zone meridian. You can use planetarium, or astrology, software (Stellarium is freely available: http://www.stellarium.org/) to determine local noon, i.e. the time of the sun's culmination, for your site.

This technique, as described, adds uncertainty when laying out the cord to extend the north-south gnomon shadow. This can be improved upon by using two gnomons at two different points along the 0° magnetic bearing. A more detailed description of this improvement is coming but feel free to come up with your own ideas.

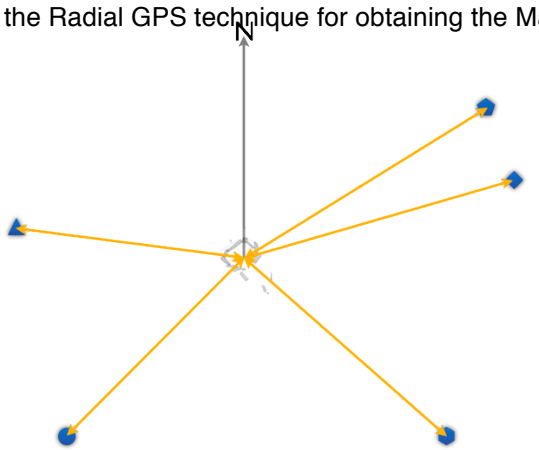
II. Linear GPS

This technique lies somewhere in-between the previous one and the following one. It uses GPS readings and compares them with compass measurements to give you the magnetic declination. A detailed description is coming...

III. Radial GPS

Sometimes the Linear GPS technique cannot be applied as the landscape is too hilly or too inaccessible for you to venture too far. In such cases it might be more convenient to do it locally. The Radial GPS technique

Figure 2. Example of the Radial GPS technique for obtaining the Magnetic Declination.



allows you to do this in the surroundings of your site(s).

i. With the site of interest at the centre choose four or more markers in the local landscape. The more you choose the better, but four to six seems to give good results. Then, still at the site, measure their azimuths with your compass;
ii. Move to each of the markers you've chosen (the blue shapes in Figure 2) and take their GPS coordinates (both latitude and longitude). Measure the azimuth of the site of interest from each of these points as well to correct for local anomalies (as in section 4.1 above);
iii. The GPS coordinates are later converted to azimuth bearings using a spreadsheet. The azimuths obtained with the compass and the ones obtained from the GPS coordinates are compared and their difference (the magnetic declination) is to be averaged over all the markers. This will also give you an error (the standard deviation).

A spreadsheet will be provided to help with the calculations.

Some compasses allow you to adjust the scale to the local magnetic declination, once you've ascertained it. This allows you to take measurements directly. But be absolutely sure you've calculated the right magnetic declination. If you made mistakes it will be more tricky to correct them if you've adjusted your compass than if you didn't.

To sum up: Magnetic Declination is a big problem when using a compass, but there are ways to work around it. Choose what best suits your monument and surrounding landscape and, if you have to, you can also use the online estimators, but you'll always need to explain why you choose to do that in your essay.

5. Measuring Horizon Altitude

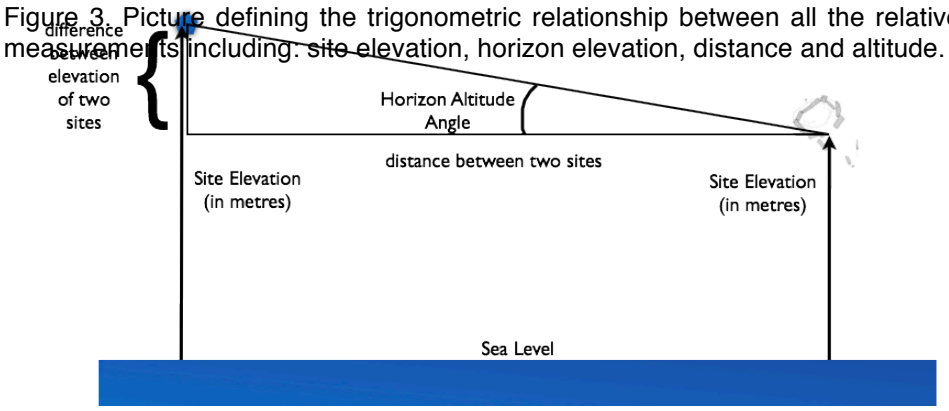
Horizon Altitude (altitude for short) is a measure, in degrees, of the difference in elevation between your site(s) and the distant horizon (see figure 3). It's relevance for astronomy comes from the fact that, as can be seen in the figure XX, whenever the horizon is non flat, an azimuth reading in itself is misleading. In the figure you can see the sun rising and climbing on two different dates. The rightmost one trajectory has the sun rising at an altitude of 0º behind the hill, whereas the top trajectory has the sun rising to the left of that, but, because that side of the horizon has a certain altitude, the sun is only seen rising on top of the hill. Both events then share the same azimuth, but have very different altitudes. Measuring the hill's altitude allows you to distinguish these two events. Depending on your site(s) and project, you might need to measure it along particular orientations or do a complete survey of the horizon.

[Figure XX]

To measure it the simplest tool is the clinometer. Much like a compass, you just point it in the right direction and take note of the number it gives you. Clinometers use only gravity to work, so there's no need for any adjustments. They can be used to measure any altitude, not just horizon altitude, and so have a broader application within Archaeoastronomy (see section 8).

You might be interested in more precision than the 0.5º or so most clinometers give you. A theodolite can do that, or you can use your GPS or maps to get it, but this might not always be feasible, as it depends heavily on how far the horizon lies. If you're using maps to determine the horizon altitude you need to find the horizon first, which might lie kilometres into the distance and thus require you to get completely different maps. The same problem is posed by using the GPS as, in this case, you'd have to physically move to a

Figure 3. Picture defining the trigonometric relationship between all the relative measurements including: site elevation, horizon elevation, distance and altitude.



location on the horizon and take some GPS readings.

If you do decide to use your GPS the only thing you'll need is to get the site coordinates (both latitude and longitude) and elevation, then go to the place in the horizon (a hill, mountain or another site) and repeat the same procedure. The altitude can then be obtained using basic trigonometry and the figure 3 above. A spreadsheet that does this for you will be available. If you're using maps, you'll only need the difference in elevation and the distance between the two sites for your calculation.

The above are easiest to use if you are measuring along a particular orientation, for instance along a corridor. However, you might want to survey the whole horizon searching for, for e.g. foresights to the stones belonging to a stone circle or just looking for potential calendar markers. In such cases you should take a panoramic photo of the horizon. You can do this by taking several pictures of the horizon in several directions and then using software to collate them together. Most digital camera or photo printer software these days can do this for you. You'll also need to measure the azimuth and altitude of a few markers on the horizon so that later you can extrapolate the rest.

6. Using a Theodolite

There are many reasons why you might want to use a theodolite for your measurements: you might not be able to use a compass on your site(s) due to magnetic anomalies, you might not be able to directly estimate the magnetic declination, or you might be interested in a higher level of precision (see section 7).

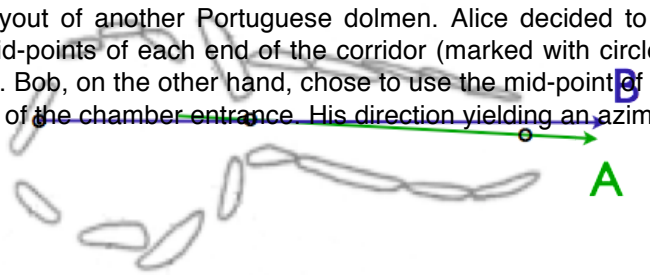
A theodolite will easily give you measurements with minute-of-arc precision, but they are quite heavy to take into the field, and require set-up and a careful procedure which takes some time. Ruggles (1999, pp.164-71) gives an in-depth description of the procedure to use a theodolite for archaeoastronomical fieldwork purposes and we refer you there for more information.

7. Choosing your Markers

Using your compass and clinometer, or a theodolite, to measure an orientation is not enough. You need to determine the orientation you want to measure to good precision. Most of the times, this is trickier than everything else.

Consider the figure below. If Alice decides to use the corridor to determine her orientation she might choose to mark the midpoints of both ends of the corridor (marked by circles in the figure). Alice would be measuring along the green line, A. Bob, on the other hand, might choose to use one of Alice's markers, the mid-point of the chamber entrance, and a new one: the mid-point of the main orthostat, which means he'll be measuring along the blue line, B. As the picture illustrates there is a considerable angular difference between the two lines, which, in this case, would amount to a 2.9º difference in the measured azimuths. A difference that

Figure 4. Plan layout of another Portuguese dolmen. Alice decided to measure the line marked by the mid-points of each end of the corridor (marked with circles), measuring an azimuth of 176.9º. Bob, on the other hand, chose to use the mid-point of the main orthostat and the mid-point of the chamber entrance. His direction yielding an azimuth of 179.8º.



would be obtained even if the directions were measured to high precision using a theodolite!

If Alice and Bob were using a particular feature of the distant horizon, for e.g. a hilltop, as foresight, i.e. if they were measuring the orientation of this hilltop from the site, this would be less of a problem, but

sometimes, it might not be possible to discern any foresight in the landscape or you might want to measure other orientations. In such cases you should come up with your own back and foresights, like Alice and Bob did, using a combination of tape, string, surveyor's rods or anything else that might help. There is no one answer to all possibilities.

Once you've decided on what to measure you should lay out markers that will serve as back and foresight (the circles in Fig 4). These can be anything from little flags to surveyor's rods that you can stick in the ground, or even just a stretched piece of string or cloth. Just make sure you set two or more points, or a straight line that you can then point at using your compass and clinometer or theodolite. Make sure you explain what and why you chose these points as markers on your essay.

To sum up: Get a plan layout of your monument(s) and, whenever possible, visit it/them before taking the measurements. Work out the lines along which you're going to be measuring and whether you need extra equipment like surveyor's rods, tape, flags, string, poles, etc. Also decide whether you want, or need, high precision in your measurements or if a compass/clinometer will do the work. Do this well in advance to have enough time to buy and test the equipment beforehand.

8. Beyond "Horizon Astronomy"

The rise and set of celestial bodies (see Celestial Mechanics notes on "Horizon Astronomy") might be over-emphasized in Archaeoastronomy but non-horizon features might also be encoded into archaeological or historic sites, for e.g. in a stone circle, the culmination of a celestial body might "touch" the tip of a particular stone as seen from the circle's centre, or a luminary might be seen to rise or set following the slope of a hill or stone as if rolling along it.

The possibilities are endless but, if you suspect such features are present, you need only apply the same techniques discussed above: measure the azimuth(s) and altitude(s) of the places you think the sun, moon, planet or star would be. In the examples given in the previous paragraph, you'd have to measure the azimuth and altitude of the tip of the stone as seen from the circle's centre and, for the second case, again measure both azimuth and altitude of the hill slope, maybe both at the top and bottom. You will later be able to figure out if it's possible for any celestial body to do what you suspect it might do (see Celestial Mechanics for Archaeoastronomy notes).

9. Orientations vs Alignments

To prevent a few of the seven sins of Archaeoastronomy one should learn to distinguish between orientation and alignment. Orientations are merely directions: any two points will always give an orientation, whether these be two stones or two trees. Alignments imply intent. Two stones might be oriented towards sunrise on a specific day, but was this intentional? There's a considerably broad region of the horizon in which anything that is pointing towards it might be said to be oriented towards sunrise, but it could be aligned with something else: moonrise, a particular star, a sacred hill on the horizon, or not be aligned at all.

Orientations are measured on the field, and might need to be worked out or corrected after the fieldwork is conducted. These orientations can later be compared with theoretical values for the positions of celestial objects and test for alignments. These theoretical values stem from the highly numerate field of Celestial Mechanics for which there is a separate set of Notes.

Comparing measured data (the orientations) with theoretical data is a tricky thing as one can be quick to jump into conclusions (for e.g. read on Thom paradigm in Ruggles 1999). In fact over-interpretation has been a big problem in the history of Archaeoastronomy (see bibliography in the module's handbook) so be careful. Always strive to substantiate your claims with historical, archaeological, ethnographic and/or other archaeoastronomical literature.

10. Frequently Asked Questions

This section presents some of the questions that might have popped up while reading these notes or while on the field. This section will be constantly updated with answers and more questions.

a. How do I find True North?
b. Should I use a compass and clinometer or just a theodolite?

Depends on the site and the amount of precision you want to claim. For example, if you are measuring the orientation of a Medieval Cathedral, or the Giza pyramids, you might want to use a theodolite to get minute-of-arc precision, but if you are working on pre-historic sites, with rough stones and badly preserved overall, the biggest source of error will be due to the choice of markers (section 7) and this will always overshadow the accuracy of the instrument of measurement. In such cases a compass is sufficient, given that local magnetic anomalies and magnetic declination are appropriately dealt with.

c. Since the theodolite is more precise shouldn't I just use one and ditch the compass?

Not necessarily. See the answer to question b, and section 7 for details of when the theodolite's accuracy doesn't translate into orientation accuracy.

d. Do I really need to determine the Magnetic Declination for each site?
e. I've taken all the field measurements I want and have corrected for True North. What do I do now?
f. Can I use software like Google Earth to get my azimuth readings?
g. Can I use software like Google Earth to get my horizon altitude readings?
h. How do I find the centre of a stone circle?