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GEOPHYSICS TRAINING PACK V1.1

Archaeology Shetland

WHO IS THIS PACK FOR?

This pack is intended for all volunteers assisting with data acquisition during Archaeology Shetland led geophysics surveys.

WHAT IS IN THE PACK?

The pack aims to provide links to existing videos, guidelines and/or manuals explaining how to conduct Gradiometer and Earth Resistance (ER) surveys using a Bartington 601 Dual Gradiometer and a TR Systems Meter, respectively.

WHAT IS EXPECTED OF YOU?

We do not expect you to become experts prior to helping volunteer with us on our survey days. Training will be given on site, and we will be learning through doing while working in small groups. However, we do ask you to come prepared to site. This involves watching the following three videos (links below). They will give a flavour of what the tools look like, how to set them up and run them.

How Resistivity Surveys Reveal Archaeology - YouTube
A Community Group guide to running Geophysics for Archaeology- what we do and how it works
Bartington Grad601 Setup

In addition, please read the following sections SURVEY METHODS which introduce the two geophysical survey methods we are using; PRACTICALITIES which outlines some of the practical working methods and check the KIT LIST as it is especially important to wear non- magnetic clothing and shoes for anyone using the Gradiometer. Links to further reading are supplied for those who want to know more but it is not a pre-requisite.

Figure 1: Earth Resistance survey at Uyea carried out by volunteers at Archaeology Shetland, June 2026 using the TR Systems meter kindly on loan from The Bressay History Group (images S. Jennings).

SURVEY METHODS

There are many different methods of geophysical survey that can be used for archaeological investigations. However, there are two types that have been consistently and routinely used, often together, across Britain and Europe since the 1950's: namely Gradiometry and Earth Resistance also known as Electrical Resistivity. These two archaeological remote sensing methods are available to the group through the loan of a TR Systems Earth Resistance meter from The Bressay History Group and a Bartington Grad601 (dual sensor) gradiometer on loan from Aberdeen University.

HOW DO THEY WORK?

Earth Resistance/Electrical Resistivity:
The TR Systems meter passes an electrical current through the ground and measures resistance across an area between two electrodes set 0.5m apart. This allows a depth of investigation of 0.5-1.0m. Low electrical resistance corresponds to things that conduct electricity well and in an archaeological context usually corresponds to ditches and pits or middens which due to their organic contents can retain moisture. High electrical resistance, where the flow of electricity is impeded is often caused by stone foundations, walls or bedrock. The ground moisture conditions will affect the contrast between archaeological features and the background values, so the results are strongly weather dependent and are also very difficult to repeat. Further information regarding Earth Resistance survey can be found here: https://en.wikipedia.org/wiki/Electrical_resistance_survey/

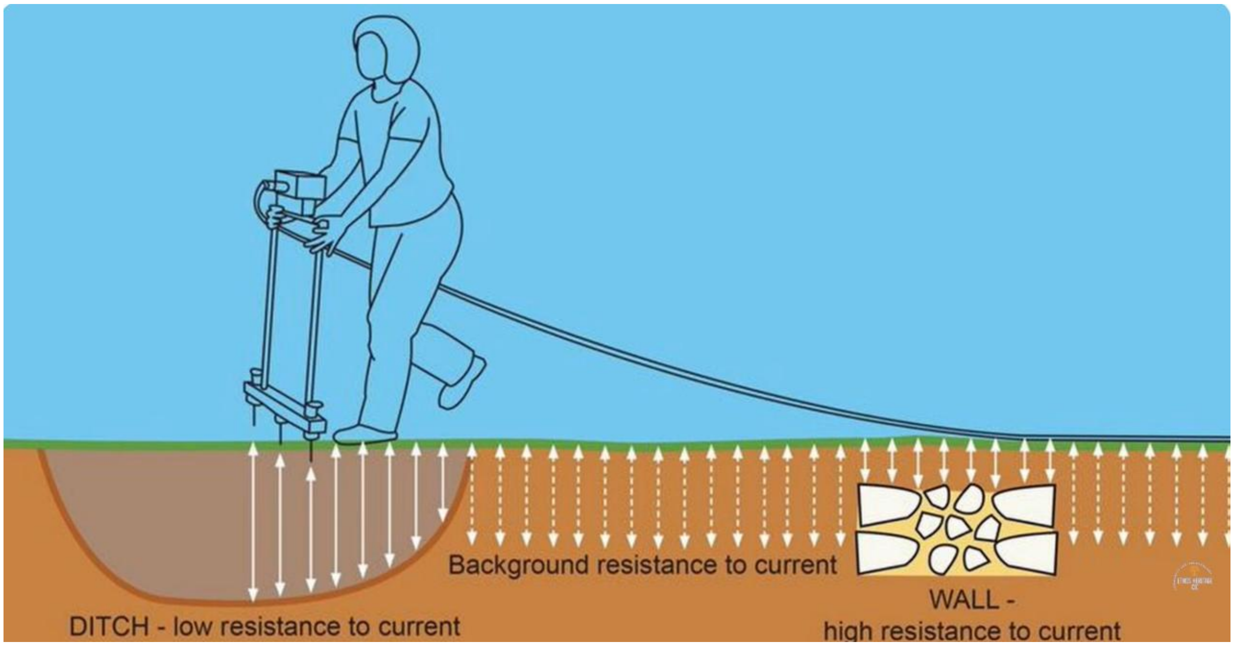

Figure 2: Screenshot from video 'How resistivity Surveys Reveal Archaeology' posted by Ethos Heritage CIC. Available at https://www.youtube.com/watch?v=XR9b5oufy6I [accessed 11/08/2026]

Gradiometry:
The Bartington Grad601 (dual sensor) is a fluxgate gradiometer (Figure 3). While a magnetometer measures magnetic field at one sensor location, a gradiometer measures the difference between two or more magnetic measurements using two sensors in each tube at different heights. This highlights near-surface archaeological targets while suppressing deep bedrock anomalies (SCARF 2012). The gradiometer survey technique relies on the contrast between the magnetic properties of human-made/archaeological features and the natural subsoil and bedrock. The Grad601 dual sensor allows data to be collected from two traverses at the same time thereby halving the acquisition time.

Figure 3: Gradiometer survey being carried out at St Ninian's Isle, with traverses between the orange flags.

The strength (high (~100nT) to low (0-3nT)) and the sign (+ve or -ve) of the magnetic anomaly along with its shape on the mapped survey results can be used to interpret possible causes such as kilns, hearths, walls, ditches and pits or isolated ferrous objects (Figure 4).

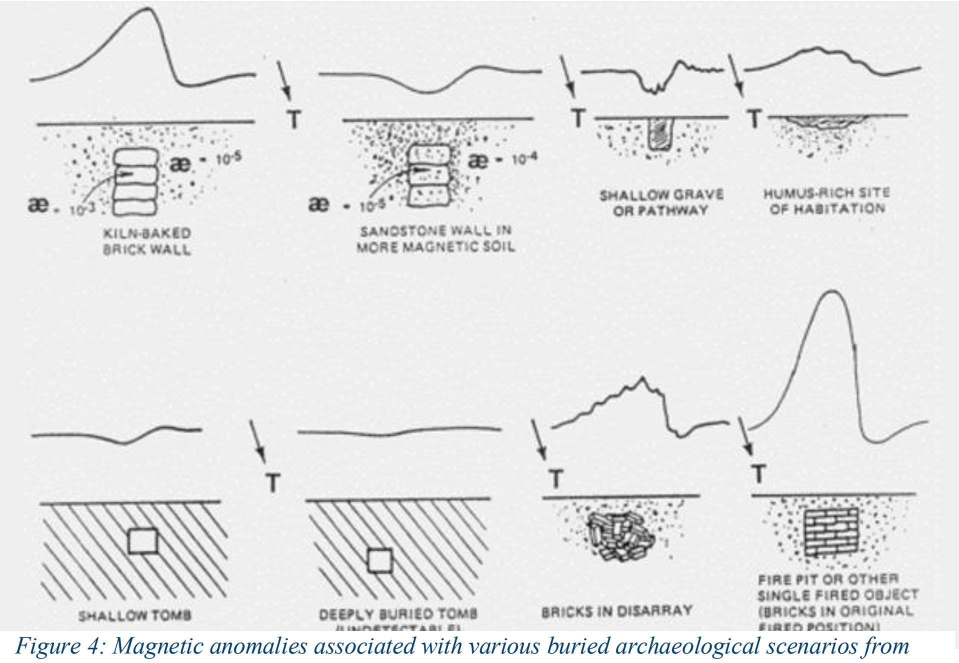

Figure 4: Magnetic anomalies associated with various buried archaeological scenarios from https://www.gemsys.ca/archaeological-applications/discovering-mankinds-past-secrets/ [accessed 11/08/2026].

Additional guidelines, product overview, manuals and case studies can be found at the Bartington website available at : https://www.bartington.com/products/grad601/ .

SURVEY METHODS (CONT.)

There are a number of ways that magnetic enhancement is related to human activity: -

High (~100nT)

- Thermoremanent Magnetisation which results when clay and stones containing iron oxides such as magnetite are heated above their Curie point (approx. 580°C). After cooling, they retain a strong permanent magnetic signature aligned with the Earth's magnetic field at that time. Thermoremanent Magnetisation is associated with hearths, kilns and furnaces. This produces a strong dipolar/bipolar magnetic response ~100nT.
- Small ferrous objects will produce a strong bipolar response of ~100NT.

Moderate (1-10nT)

- Human activity can concentrate organic matter and microscopic iron particles, especially in midden material. The disposal of this midden material as infill in pits and ditches, as soil enhancement or dispersed around high frequently area of human activity produces a weak to moderate positive magnetic anomaly of 1-10nT.
- The natural concentration of iron-bearing minerals in topsoil is generally increased relative to the parent bedrock due to weathering and bacterial processes. If this topsoil is moved and used to infill pits or ditches it produces a magnetically higher signal than the feature it infills. This results in a weak to moderate positive magnetic anomaly of 1-10nT.

Negative Anomalies

- A negative or reversed magnetic response relative to the surrounding area can also be produced by human activity. This happens when a ditch or pit is backfilled with a material such as sand, limestone or chalk which has a lower magnetic response when compared to the surrounding material. Similarly empty cavities (tombs or caves) can also show up as weak or negative anomalies.

In all cases, overhead powerlines, buried pipes, fences and other modern ferrous objects will create large magnetic anomalies which can swamp the survey results.

Further reading regarding the use of Geophysics in Archaeology can be found at:

1. EAC_Guidelines_2_Geophysics available at: https://www.archprospection.org/wp-content/uploads/files/EAC_Guidelines_2_Geophysics.pdf/
2. Historic England Terrestrial remote-sensing available at: https://historicengland.org.uk/research/methods/terrestrial-remote-sensing/geophysical-techniques/
3. Geophysical Survey at SCARF (The Scottish Archaeological Research Framework) available at: https://scarf.scot/thematic/scarf-science-panel-report/5-detecting-and-imaging-heritage-assets/5-3-geophysical-survey/

IMPORTANCE OF BEDROCK AND SUPERFICIAL/DRIFT

Gradiometer surveys have been a staple of geophysics surveys in England, especially where many of the archaeological sites consist of banks, ditches, pits and post holes or hearths and kilns. Gradiometer survey has also been successfully applied across large areas of Orkney where the bedrock consists of Devonian Old Red Sandstone which generally has low magnetic properties. In Shetland gradiometer survey has not fared so well as much of the bedrock is significantly more ancient and has been metamorphosed and/or intruded which can result in a higher or a more variable magnetic signature which overshadows any archaeological signature.

The findings from numerous successful gradiometer surveys carried out in Orkney indicate that archaeological pits and ditches are often detected between -3 and 3nT. A detailed geophysical survey carried out at Tingwall as part of The Assembly Project in 2010 found the extremes of their data ranged from -2496.0 to 2391.8nT with a standard deviation of 55.0nT. This strong response resulted from outcropping metamorphic and igneous bedrock and Fe-rich soils which dominated the survey results (Coolens and Mehler 2010). Gradiometer and Resistivity surveys in the Devonian Old red sandstone of Shetland are currently very limited in number and/or are unpublished; notable examples where geophysics was successful are Jarlshof and Old Scatness.

The ER survey is less affected by the underlying bedrock geology unless it intrudes significantly into the interval being investigated or outcrops at surface. However, the overlying superficial or drift geology and soil type can impact the results of both gradiometer and ER survey. Interactive maps of the bedrock geology and superficial drift can be found at the British Geological Society viewer available at : https://geologyviewer.bgs.ac.uk/?_ga=2.253026380.494715349.1786452586-966819957.1786452586/

In Shetland the drift geology is predominantly till, peat or dune sands. The till, also known previously as 'boulder clay', is a group of sedimentary glacial deposits formed by the action of ice and meltwater during glacial and inter-glacial periods in the Quaternary. The till can contain pebbles or boulders brought from outside the area being surveyed which could affect the survey results. If the archaeological remains are buried by sand dunes or thick peat growth such that they are below the range of depth of investigation of the tools being used, they will not be detected.

PRACTICALITIES

This outlines a rough guide to some of what needs to be done to set up the survey and gives a generalised order of events so that you know what type of tasks to expect. This is not carved in stone or exhaustive and will be adapted according to the survey as well as fitting with the conditions on the day.

- Survey grids (usually20mx20m each) need to be marked out prior to surveying.
- We will use non-magnetic equipment such as bamboo canes, plastic markers, plastic cables and baseline measuring tapes.
- Traverse lines every two meters are required for the ER survey but are also helpful for gradiometry.
- Three corner points will be recorded as GPS values and their position relative to stable landscape markers noted i.e. distance and orientation to the corner of a wall.
- Geophysics survey acquisition can be carried out by a lone individual, but the process runs much smoother and more effectively if there is a team of 3 for the gradiometer and 2 or 3 for the ER.
- For the gradiometer survey, one person will take the readings with the tool while the two helpers act as guides, marking the correct position for the traverse to be walked. The team can swap around after each grid, but the person walking with the gradiometer must **not** have anything magnetic on their person, shoes or clothing. Footwear must also **not** affect the gradiometer and will be tested prior to survey.
- For the ER survey, one person will operate the TR meter taking readings every metre along the traverse lines. The TR meter has a long (50m) cable which connects it to the remote probes. It is helpful to have someone assist with this cable while the data acquisition takes place.

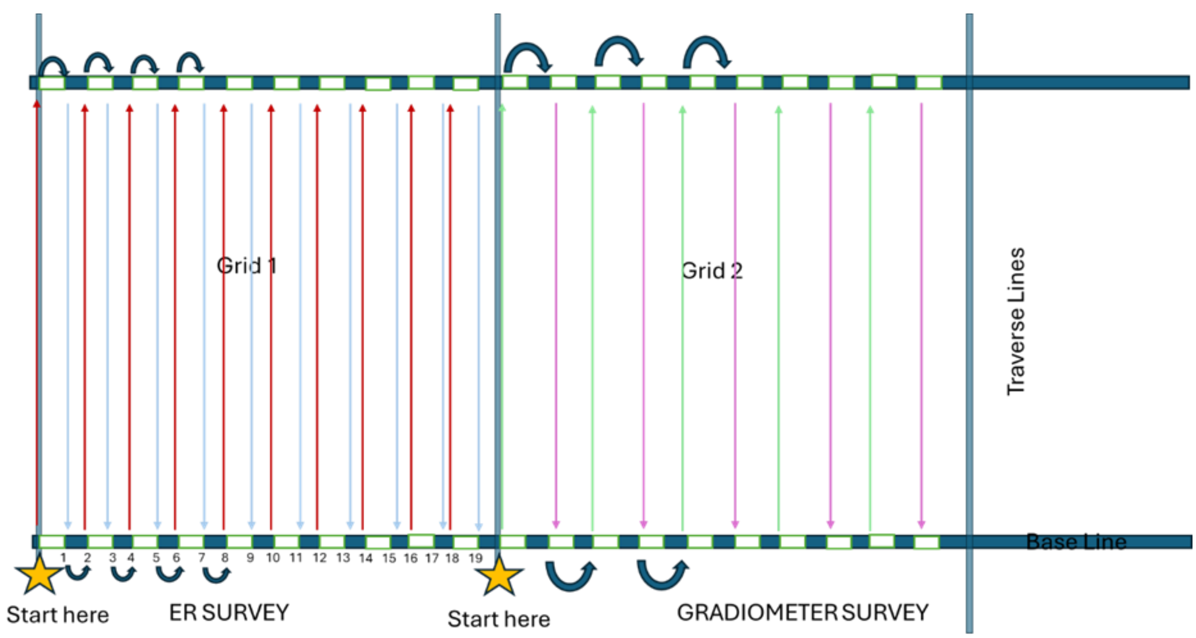

Figure 5: Zig-zag configuration for ER and gradiometer surveys.

PRACTICALITIES (CONT.)

- For both the Gradiometer and ER surveys, the traverses are carried out in a zig-zag fashion. This reduces the amount of walking, but it is essential that the data recording software is told that this is the configuration. The diagram in Figure 5 looks complicated but it's actually pretty simple. The traverse direction is selected based on a cardinal orientation and optimized to be perpendicular to the proposed anticipated subsurface feature(s). The resistivity probes are 50cm apart and should straddle the zero-traverse line. At the end of the first traverse, the operator will move along 1m and return to the baseline recording as they go. Continue until 20 traverses are complete. For the Gradiometer the zig zag approach is the same. However, the dual set up means that two traverses are recorded at the same time, 1m apart. The starting point remains the same as with the ER. Once a traverse is completed, the operator must move over by 2m each time and return to the baseline recording as they walk.
- The Gradiometer survey can be completed in less than half the time of the ER, so it is suggested to run the gradiometer survey first in each grid. The ER survey can start after the gradiometer has traversed half of the grid and is a safe distance magnetically away from the ER tool.
- The ER data can be downloaded directly from the TR systems meter to free software called snuffler while the gradiometer data can be downloaded and imported to Geoplot for cleaning, processing and display.
  More information regarding snuffler can be accessed at:
  http://www.sussexarch.org.uk/geophys/snuffler.html

KIT LIST

No specific kit is required by volunteers as all equipment will be supplied by the organisers. However, it can be useful to bring a mobile phone with a GPS and compass app or a regular compass.

The main requirement for volunteers operating the Gradiometer tool is to wear clothing and shoes that will have no impact on the signal picked up by the tool. Please check that you have **NO** metal or magnetic fasteners, clips or buttons. This includes having items in pockets such as coins, pens or mobile phones. All ferrous jewellery must also be removed. This does not apply to volunteers who are helping with the Gradiometer survey but are not operating the tool as their impact can be mitigated by stepping away by a few metres when the operator and tool approaches.