From the air to the atomic level of a ditch

Integrating geophysical & geochemical methods at the prehistoric cropmark site at Forteviot (Perthshire, Scotland)

Cuenca-Garcia,C., Jones, R.E., Hall, A.J. & Poller, T.

Department of Archaeology, University of Glasgow, G12 8QQ, Scotland
carmen@cuencagarcia.com

The detection of archaeological features through routine geophysical survey can be variable, depending on local geological and soil conditions. However, the influence of these factors has rarely been explained satisfactorily. Geophysical and geochemical methods are rarely integrated in the study of a single site, even though they provide potentially complementary data. This poster shows the results of a comparative analysis exploring the integration of soil geochemical analyses and routine geophysical surveys to investigate a Prehistoric ditched enclosure at the prehistoric ceremonial site at Forteviot, Scotland. The results not only enhanced the interpretation of the targeted feature surveyed, but begin to develop a better understanding of how the setting of a site may affect geophysical and geochemical datasets.

NATURAL ENVIRONMENT RESEARCH COUNCIL
University of Glasgow
SERF

The Problem

1. The Site

Cropmarks identified by aerial photography at Forteviot **revealed an early prehistoric ceremonial landscape and an early medieval cemetery**. The site is one of the most important Pictish Royal Centres of Scotland.
It is located in southern Perthshire and overlies sedimentary bedrock (Old Red Sandstone), glacio-fluvial superficial deposits and well-drained agricultural brown soils. Since 2006, the SERF project has been exploring the factors involved in the creation of such a significant centre of ceremony at Forteviot. A key objective was to characterise the cropmark complex by targeted geophysical surveys and archaeological excavations.

2. Previous Geophysics

Prior to excavation by SERF, **initial gradiometer and earth resistance surveys** were carried out. The **results were disappointing** by comparison with the aerial photographs in that they yielded little beyond confirming some cropmarks. The gradiometer data, (1m and 0.5m line spacing, zigzag mode), was characterised by very faint and negative responses indicating the ditches. The performance of the earth resistance survey (1m x1m sampling interval) was similarly rather poor. The problem, therefore, is **what reasons lie behind the poor results of the geophysical surveys? Would other routine prospecting techniques provide better results?**

Methods

3. An Integrated Approach

The multi-technique geophysical survey and soil sampling aimed **to detect the ditched enclosure** and characterise the soil physical and chemical properties of the ditch deposits, topsoil and subsoil.

Multi-technique Geophysical Survey — The surveys were conducted prior to and after the plough soil was stripped to assess the effect of the topsoil on the results.

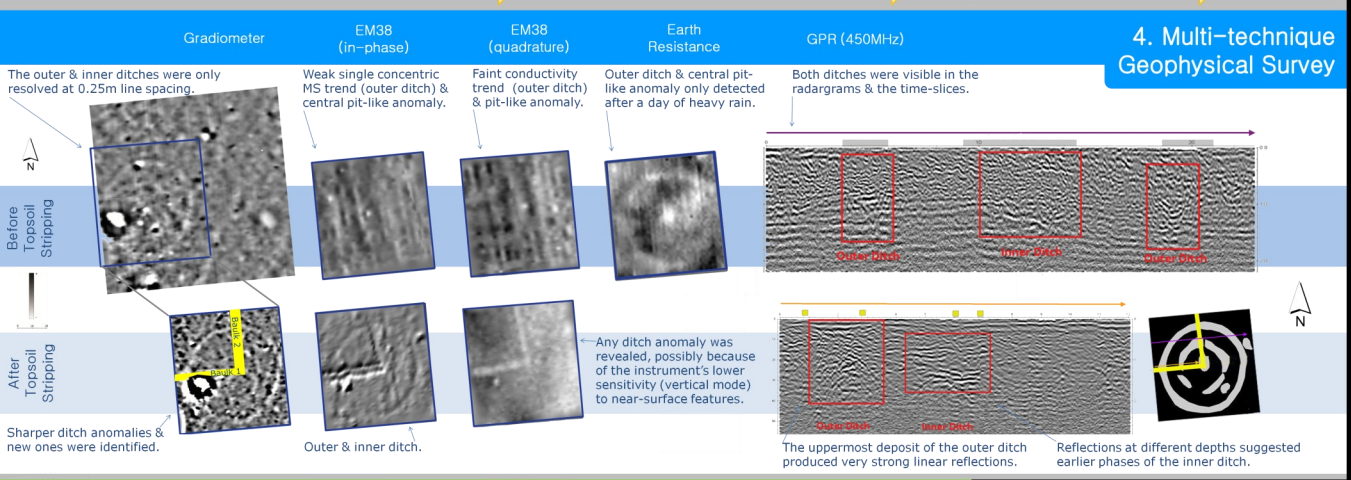
Sequential Soil Sampling — Topsoil (before & after stripping) and exposed ditch sections.

Geo-chemical Analyses — Magnetic Susceptibility (MS), LOI, pH, EC, Phosphate, pXRF, ICP-OES.

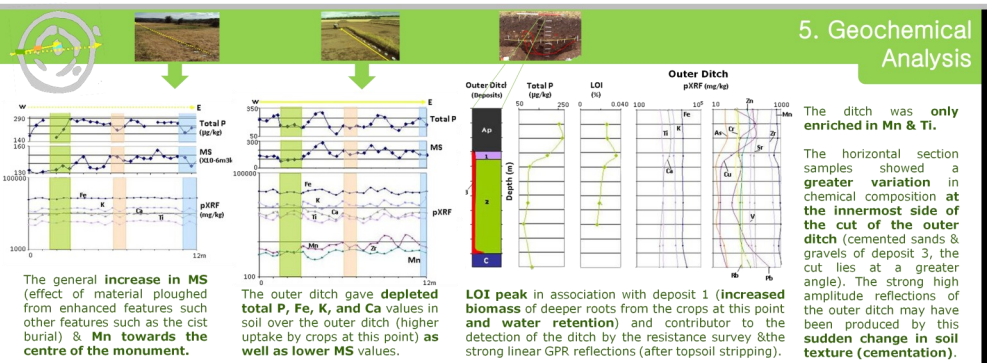
Data Correlation & Analysis

Results

4. Multi-technique Geophysical Survey



5. Geochemical Analysis



The general **increase in MS** (effect of material ploughed from enhanced features such other features such as the cist burial) & **Mn towards the centre of the monument.**

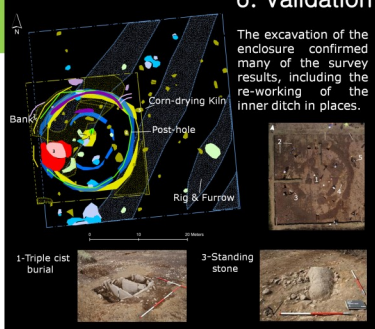
The outer ditch gave **depleted total P, Fe, K, and Ca** values in soil over the outer ditch (higher uptake by crops at this point) **as well as lower MS** values.

LOI peak in association with deposit 1 (**increased biomass** of deeper roots from the crops at this point **and water retention**) and contributor to the detection of the ditch by the resistance survey &the strong linear GPR reflections (after topsoil stripping).

The ditch was **only enriched in Mn & Ti.**

The horizontal section samples showed a **greater variation** in chemical composition **at the innermost side of the cut of the outer ditch** (cemented sands & gravels of deposit 3, the cut lies at a greater angle). The strong high amplitude reflections of the outer ditch may have been produced by this **sudden change in soil texture (cementation).**

6. Validation



The excavation of the enclosure confirmed many of the survey results, including the re-working of the inner ditch in places.

Conclusions

Beyond 'poor gradiometer results'

The topsoil contained magnetic stony material derived from intense ploughing of the underlying glacial parent material. This resulted in 'noisy' datasets that obscured the contrast between the ditch deposits and surrounding soil.

There was no MS enhancement or enrichment of common anthropogenic trace elements in the ditch deposits, which partially explains the characteristic negative magnetic response instead of the more usual positive response. The ditches at Forteviot were associated with a ritual site and so their deposits were not subjected to continuous anthropogenic input as at settlement sites.

The ditches show slight depletions of major elements (e.g. Fe), as well as an enrichment in Mn and Ti. This is due to mineralogical changes in oxides inside the ditch caused by various processes (e.g. land management and redox reactions). These effects lead to the relatively low MS values of the ditch deposits compared to the higher MS of the topsoil and the even higher MS of the subsoil (hence negative contrast).

Reducing the traverse spacing to 0.25m greatly improve resolving the targeted enclosure.

Poor performance of the earth resistance survey?

The high percolation rate of the sandy top/subsoil at Forteviot & general dry conditions hampered several attempts of conducting resistance surveys during this investigation and previous surveys. Some soil saturation conditions were necessary to successfully complete the survey.

Key elements contributing to the contrast detected by the resistance survey were the top high organic matter content deposit (1) of the outer ditch as well as its less truncated character and greater depth of this ditch and the triple cist burial (in comparison to the inner ditch).

The resistance anomalies detected were very informative & greatly complemented the gradiometer results.

Alternatives to survey at Forteviot

The GPR survey produced the most informative results as it gave depth estimation, high resolution mapping, and an approximate truncation level of the ditches. The correlation of these results and the soil physical and chemical analysis provided key information relating to the character of the ditch deposits.

The EM38 instrument attached to the GPS provided the most rapid survey. The quadrature component in vertical dipole of the EM38 instrument demonstrates its potential in identifying archaeological features expected at c. 0.5–1 m, such as at Forteviot, since the noise created by the plough layer was outside the maximum sensitivity range of the instrument. Therefore, this technique may be the best first option to use in extensive and exploratory surveys at sites such as Forteviot

Other findings

Repetition of the geophysical surveys after stripping the topsoil in preparation for excavation allowed detection of further features. This approach can be used to increase the effectiveness of archaeological excavation by showing potential targets that were not exposed on the stripped surface.

A general MS & Mn enhancement of topsoil samples indicating the presence of the enclosure was a useful outcome of the geochemical survey.

Combined pXRF/MS soil measurements may be useful for site assessment prior to surveys & in-situ anomaly interpretation.