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Geophysical and geochemical definition of a rural medieval churchyard at Furulund, Hedmark, Norway

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Background

In Norway, ca. 2000 churches are believed to have been in existence in the Middle Ages. Of these, 647 are still in use, and a further 614 sites are attested in historical sources, but now abandoned. This leaves a considerable number attested only via hints in toponymical and folkloric sources (Brendalsmo and Eriksson 2015). Although automatically protected by the Norwegian Cultural Heritage Act, their inexact locations render them inadequately maintained and threatened by continual natural processes, agricultural activities or acts of destruction.

Given the large number of potential sites, their mapping by way of intrusive methods is deemed costly thus unfeasible. An urgent need exists to develop alternative approaches so that these sites can be protected.

Small, rural, abandoned medieval church sites tend to lead a fairly anonymous existence. However, in 2014 the Norwegian Directorate for Cultural Heritage (NO: *Riksantikvaren*), and Hedmark County Council received alarming information regarding the church site at Furulund north of the town of Kongsvinger (Fig. 1). Human skeletal remains began surfacing as a result of ploughing, prompting concern that the graveyard was rapidly being decimated. The Directorate sought advice from the Norwegian Institute for Cultural Heritage Research (NIKU) on how to map the site using non-intrusive methods. Two methods were proposed and ultimately employed; preliminary geochemical sampling and analysis using portable Xray fluorescence (pXRF) followed by highresolution groundpenetrating radar (GPR) surveys.

Figure 1: The abandoned medieval church site of Furulund is situated along the River Glomma, between the town of Kongsvinger and the village of Kirkenær in Hedmark County. Map source: The Norwegian Mapping Authority, 2016.

Portable XRF has been successfully applied to a variety of archaeological settlement and industrial sites (Hayes 2013, Gauss *et al.* 2013) but has never before seen use to delimit a mortuary site. Geochemistry was chosen on the assumption that the systematic mapping of certain elements across the church site would yield relatively enhanced values that would map differential land use and the presence of ploughed up burials, and thus delimit the cemetery. Portable XRF was used as it is flexible, rapid, cost effective and the instrumental resolution sufficient for the purpose.

The use of geophysical methods to detect and map graves, clandestine or otherwise, has a long and well-established history, and a considerable body of literature exists on the subject (e.g. Vaughan 1986, Bevan 1991, Davenport 2001, Cheetham 2005, Jones 2008). Due to its comparatively high spatial resolution and its capability to resolve relatively small targets whilst simultaneously providing depth information, GPR is generally considered the most suitable solution for mapping inhumation burials in graveyards and cemeteries (Conyers 2006, Jones 2008, Moffat 2015). Alternative geophysical methods have also seen some success, particularly when combined with other techniques (e.g. Davenport 2001, Nobes 1999, Linford 2004, Dalan *et al.* 2010).

Method

The probable graveyard area was estimated to be within a 50 x 50m area, encompassing both the area the farmer had set aside as the church location and the area where bones were found ploughed to the surface. To keep costs minimal, transects were used for geochemical sampling to delimit the graveyard. Five transects were established with a sample spacing of 5 m. In total, 61 samples were taken over the graveyard, with additional background samples taken in an area outside the graveyard (Fig. 3). Samples were taken with a push auger used to the base of the plough soil and the sample extracted.

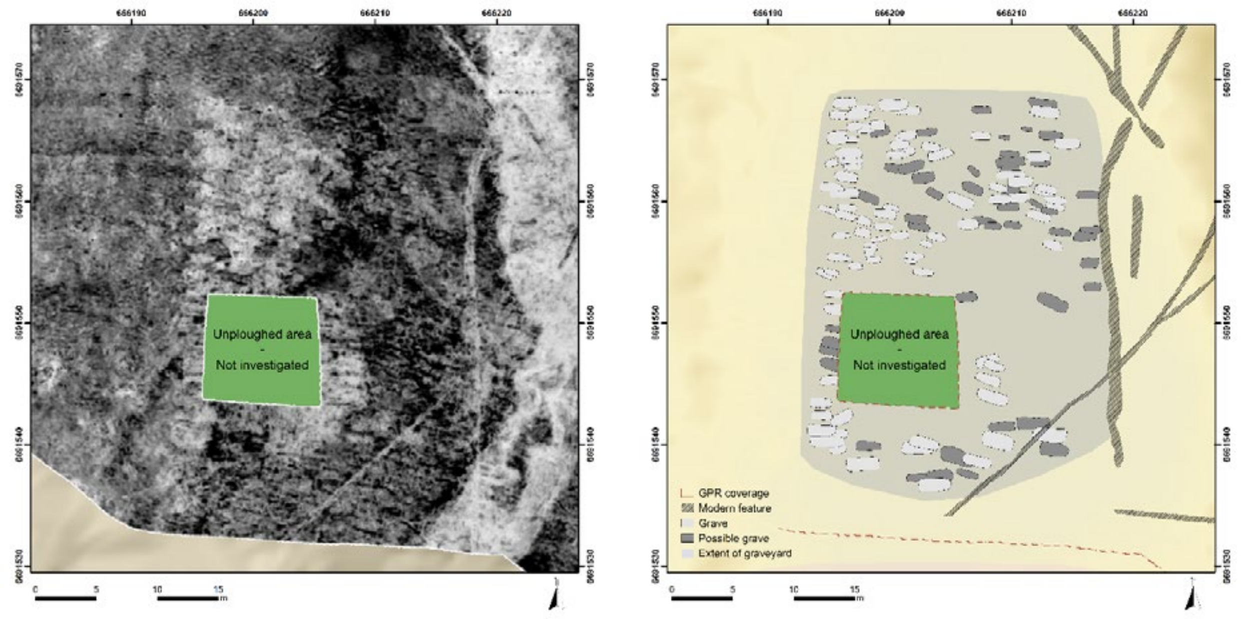

Figure 2: Left: GPR depth slice and, right: interpretation of the graveyard area. Map source: Norwegian mapping Authority 2016.

In the laboratory, samples were dried, crushed and homogenised prior to analysis using a Niton/Thermo Scientific XLt3 GOLDD+ portable XRF in mining mode. Standard reference materials were used for empirical calibration. Samples were analysed in cups with a 6µm polypropylene film, with the instrument in a field stand. The analytical time was 300 seconds between all filters, the longer duration necessary for lighter element detection (Z=<22) as helium purge was not available. The calibrated values for the selected elements were imported into the geographical information system *ESRI ArcGIS 10.2.2*. Using the *Geostatistical Analyst* extension, interpolated and gridded surfaces representing trends in the values were generated using ordinary kriging, which were then combined with other data sources for further analysis.

The GPR survey followed several weeks of cold (c. 0-12°C), but unusually dry (0-0.2mm) weather. A total of 1.8 hectares was surveyed using a motorized 16-channel, 400MHz *MALÅ Imaging Radar Array* (MIRA) from *MALÅ Geoscience*. Antenna spacing was set to 10.5 cm and the measurements time-triggered at a rate of 50Hz.

Once collected, the data were processed using the *ApRadar* software, developed by *ZAMG Archeo-Prospections®/LBI ArchPro*, where trace interpolation, time-zero corrections, band-pass frequency filtering, spike removal, de-wow filters, average-trace-removal, amplitude-gain corrections, amplitude balancing and Hilbert transformations were applied. Time-to-depth conversion was set to a velocity of 10 cm/ns for the upper parts of the dataset, down to 10 ns, decreasing to 8 cm/ns at 20 ns and beyond. The conversion was based on hyperbola fitting carried out in *Sandmeier Scientific ReflexW*. The data were then resampled to a resolution of 8 x 8 cm, and subsequently interpolated into a 3D data block from which georeferenced depth slices were generated. In order to visualise, analyse and interpret the data, the depthslices, in the form of grey-scale TIFF images, were then imported into *ArcGIS*, where they were combined with other data sources, visualised and interpreted.

Results

The GPR survey identified a cluster of features, which is interpreted as graves belonging to the former church site. These features are largely E-W orientated, rectangular to sub-rectangular in plan and containing homogeneous, absorbing backfills. As a group, they are clearly defined against the natural subsoil, which has strongly reflecting properties. A total of 130 individual graves have been identified, 84 of which have been classified as “certain”, the remaining 46 classified as “possible”. Those features that can be positively and clearly identified as graves, measure between 80 – 250 cm in length, and 35 – 80 cm in width. Combined, the graves form a distinct clustering with a relatively clear outline and delineation (Fig. 2).

The data from elements commonly associated with human activity were visually compared to the GPR interpretations. Of these, Fe (iron), Ca (calcium), P (phosphorous), and Cu (copper) were clearly spatially associated with the graveyard. Ca was enhanced only where bones were visible on the ploughed surface, whereas Fe was connected to soil processes and the enhanced organic inputs. P was less defined, but enhanced by the cemetery.

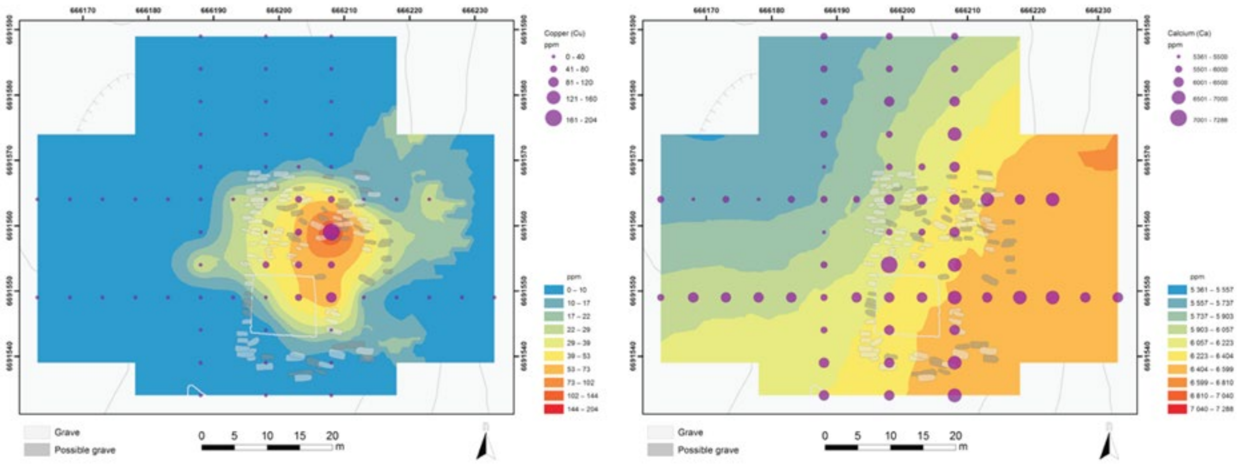

Figure 3: Ordinary kriging of elemental data for Cu (left) and Ca (right), with the GPR interpretations. All values in parts per million (ppm). Map source: Norwegian Mapping Authority, 2016.

Surprisingly, the enhancement of Cu was concentrated in the area with the graveyard where graves are less abundant, and the concentration of Cu is tentatively interpreted as the church location (Fig. 3).

Conclusion

The church and associated graveyard were efficiently located and defined with the combination of non-destructive prospection methods, allowing for their future protection from further damage. There is great potential for the combined approach to define and thus protect the many other modest medieval rural graveyards in Norway, many of which are equally under threat from modern land use.

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