Forensic Science International 253 (2015) 119–124

Contents lists available at ScienceDirect

Forensic Science International

journal homepage: www.elsevier.com/locate/forsciint

The utility of ground-penetrating radar and its time-dependence in the discovery of clandestine burials

Dominic Salsarola [a], Pasquale Poppa [b], Alberto Amadasi [b,*], Debora Mazzarelli [b], Daniele Gibelli [b], Emma Zanotti [b], Davide Porta [b], Cristina Cattaneo [b]

[a] *Società Lombarda di Archeologia (SLA), Italy*

[b] *LABANOF, Laboratorio di Antropologia ed Odontologia Forense, Istituto di Medicina Legale e delle Assicurazioni–V. Mangiagalli 37–Università degli Studi di Milano, Italy*

ARTICLE INFO

Article history:
Received 10 February 2015
Received in revised form 22 April 2015
Accepted 4 June 2015
Available online 14 June 2015

Keywords:
Forensic anthropology
Ground-penetrating radar
Decomposition
Soil
Clandestine burials

ABSTRACT

In the field of forensic investigation burial is a relatively common method of hiding a corpse. The location of clandestine graves is, however, a particularly difficult task in which multiple forensic disciplines such as anthropology, botany or archaeology can provide valuable assistance. The use of GPR (ground-penetrating radar) has recently been introduced as a method in the detection of these graves, but what is the true potential of this tool in an operative search scenario?

In this study a total of 11 pig carcasses were buried in two wooded areas, each presenting a similar soil composition. The animals were subsequently exhumed at regular intervals, ranging from 2 to 111 weeks, using systematic GPR analysis of the burial sites and archaeological recovery of the subjects that were then autopsied. GPR proved to be useful in recognizing anomalies at the chosen depths of burial and appeared to be dependent on the state of decay of the samples, producing only slight anomalous readings in the presence of skeletal remains: at 92 weeks from burial the difference in signal was weak and at 111 weeks GPR survey offered no helpful information as to burial location. The experiment, in this particular context, determined the technique as being successful in the presence of recent burials, highlighting the need for a multidisciplinary approach in the operative search for buried human remains.

1. Introduction

The clandestine burial of a corpse is an increasingly discussed topic in the broader subject of forensic investigation. The search for a clandestine grave ideally calls for the deployment of an inter disciplinary forensic search team. The methods typically employed all have their origins in traditional fields of application including remote sensing (vertical and oblique aerial photography, thermal and false colour imagery), geophysics (both active and passive), specialised search dogs, archaeological evaluation (surface surveying and archaeological landscape analysis), archaeology and botany. In recent years the evolution of search techniques and forensic geophysical investigation has led to a wider use of geophysics in general and in particular of ground-penetrating radar (GPR). This geophysical approach is a non-invasive technique that uses electromagnetic pulses (EMP) which, through the propagation, reflection and refraction of an electromagnetic signal, can reproduce software-generated 3D images based on data previously gathered in the field. The method relies upon electromagnetic radiation in the microwave band (UHF/VHF frequencies) of the radio spectrum which is transmitted from a primary antenna and travels through the ground reflecting off buried interfaces and structures at various depths until all of its energy has dissipated. The returning signals are subsequently detected by a receiving antenna generally housed within the same instrument on the surface of the search area.

GPR is frequently used in a number of fields, both civil and military; in civil engineering for example, it is used for the 3D detection of underground industrial features such as tubes, cabling and structures, or for the evaluation of the condition of reinforced concretes. It has been increasingly employed since the beginning of the 1990's in archaeological contexts, particularly in evaluation campaigns. In the military field GPR is generally deployed during mine clearing operations in the presence of minimal metal mines or non-metallic mines.

In recent years GPR has become one of the geophysical tools available to forensic teams in the search for buried human remains,

* Corresponding author.
E-mail address: alberto.amadasi@unimi.it (A. Amadasi).

http://dx.doi.org/10.1016/j.forsciint.2015.06.006
0379-0738/

and though being a discipline that is still in its youth, various studies have highlighted the importance of this growing field of application. The first available literature concerning the implementation of GPR in the search for buried bodies was published following experiments performed in cemeteries where it provided help in detecting most of the existing burials [1–4]. After these promising initial results, GPR was tested in the field, but no precise information is available concerning the number of cases in which the technique was actually applied or their outcome. The results of later studies showed that one of the main aspects limiting the application of the method was related to the specific features detected by the system. Different authors have pointed out that several variables contribute to the detection of anomalies in the signal recorded by the instrument: the presence of a corpse, soil modifications induced by excavation, the presence of fabrics or synthetic materials used to clothe, wrap or further conceal victims, and so on [5]. An anomaly may refer to the interruption of underlying stratigraphical sequences, differing geological matrices and the probable alteration in compaction and/or humidity between the backfill of a grave and surrounding undisturbed deposits. In short, the geological make-up of a backfill, its state of aeration or humidity and its state of compaction would appear to be of great importance, as highlighted by several studies focusing on the influence of different geological characteristics in the detection of interred large mammals such as pigs [6,7]. These studies have led to an initial standardisation of data acquired by the system under different conditions. GPR proved to obtain better results at greater depths in the case of sandy/dry soils without the interference of rocks, bushes or trees, whereas soils rich in rocks and stones frequently caused false positive readings. Difficulties increased in clayey and/or wet soils rich in organic inclusions. In sandy dry soils the signal loses much less energy and can therefore propagate to greater depths as opposed to the amount of energy that is absorbed by denser terrains. The amount of humidity contained within the soil also contributes to the absorption of the electromagnetic signal, limiting the transmission of EM energy and therefore hindering or impeding the identification of targets at even relatively shallow depths [5].

The pedological characteristics and the hydrogeology of a subsurface, however, are not the only variables that affect the manner of propagation of EM pulses. The first experimental studies confirmed that other factors may have led to the modification of the GPR signal, some of which at present, have not been fully comprehended. This may explain the decreasing interest in the technology reported after the first optimistic studies were published in the 1990s. Different authors pointed out the unreliability of using GPR for the detection of clandestine burials [2,8] due to the recording of both false positive and false negative results during experiments, this represents a worrying setback for the technique. Such negative conclusions have progressively led to a pessimistic outlook regarding the method's capability of pinpointing buried remains. Further studies, however, have been carried out: Doolittle et al. highlighted the point that the state of decomposition of a corpse may also influence the generation of GPR anomalies [9], the study showed that the detectability of a buried corpse varies with its taphonomic trajectory. When complete skeletisation is reached the body apparently becomes indistinguishable from surrounding undisturbed sediments [10]. The same indication is provided by Bevan et al. who observed limited detectability of skeletonized bodies buried in wooden coffins that had been damaged by the pressure of the overlying backfills of graves [1].

Regarding the relationship between decomposition and the detectability of burials through GPR, relevant information has been gained through experimental studies performed on pig carcasses. In 2006 Schultz et al. noted a modification in GPR responses during studies involving buried pigs weighing between 51.71 and 69.85 kg in Alaucha County, Florida [11]. Six animals were buried in a superficial sandy layer whilst another six were buried between the same sandy substrata and a deeper clayey deposit. Results showed that the subjects placed in the superficial layer were easily detectable, even when skeletonized, whereas the latter half dozen targets highlighted the fact that the greater depth corresponded to decreased detectability. This was probably due to the increased compactness and different matrix of the soil, which led to electromagnetic homogeneity in the deeper contexts. In the more superficial burials the state of decomposition of the bodies was the main factor affecting the detectability of the graves. The same authors performed a similar experiment with small sized pigs in 2008: results revealed that only in the last two months of the experiment, samples buried in the superficial layer had decreased in detectability having reached total skeletization, whereas samples buried at a greater depth proved less detectable from the early stages of the study.

In recent years, however, interest in the use of this technique has been growing, mainly due to the fact that its efficacy has been demonstrated in the archaeological field. This only partially refers to archaeological burials. The available literature clearly argues that geophysics in general is rarely conclusive in the detection of ancient depositions that are unstructured and lacking in grave furniture [13–16].

To our knowledge previous experimental studies of the use of GPR for the detection of clandestine graves have demonstrated that in addition to the dimensions of a corpse, decomposition appears to play an important role. It is therefore clear that in order to distinguish the effects of each variable regarding the reliability of results obtained using GPR, definition can, to a certain extent, be reached through observation and interpretation of the interactions that take place between the dynamic process of decomposition and subterranean environmental factors. Up until now, however, only a limited amount of information has been made available on the topic due to the fact that previous literature referring to operative contexts mainly concerns single or limited case studies and the few publications dealing with experimental studies are usually related to geographical and sedimentary contexts in non-European environments.

The present study field-tested the advantages that GPR can bring to operative forensic investigations that involve the search for clandestine graves in a woodland scenario in Northern Italy. The main purpose of the experiment was to evaluate the efficacy of the technique through tests that refer to two different burial environments in which pig carcasses were monitored at fixed chronological intervals over a total period of thirty months. The predetermined exhumation of the carcasses was carried out with the aim of assessing the reliability of the method and its ability to determine the exact 3D location of the targets over the established duration of the experiment.

2. Materials and methods

2.1. The test area

The test was carried out with the excavation of a total of ten mock graves and involved the burial of 11 pig carcasses, interred contemporarily and exhumed separately at regular intervals over a period of thirty months. The study was set up in two separate plots in the Ticino Regional Park in northern Italy (45°23′ N 8°50′ E) at a height of 95 m ASL. Both areas were composed of coarse fluvial sediments presenting a lithology of mainly crystalline rock covered by poorly developed and highly permeable, loose topsoil. The soil's pH measured 4.5–5.5 on the surface, rising to 5.6–6.6 at the depth of 50 cm. The two almost adjacent areas were selected with a