S4 Mobile Laboratories

Technical Packet, Subterra Grey

Version 2025

Contents

S4 Mobile Laboratories is an Ohio-based company that develops innovative mobile soil laboratories allowing non-scientists to map and analyze spatial concentrations of chemicals underground. We provide training on our equipment and technical support for our customers. S4 Mobile Laboratories is not a service provider.

This technical packet describes the current version of the **Subterra Grey**, a field-ready device used in the search for human burials in the shallow subsurface (< 1 m) with forensic, police, military, and related applications. This packet describes the underlying technology, equipment, and software, and provides general guidelines for use of the Subterra Grey.

1. Statement of the problem

The problem addressed in this packet is the difficulty of locating clandestine human burials using traditional prospection techniques. In recent reviews of geological and geophysical forensic methods, a wide range of technologies are noted as regularly employed by law enforcement specialists, forensic anthropologists, and military officials to find clandestine human burials and forensics objects: metal detectors, magnetic surveys, electromagnetic conductivity and resistivity surveys, ground penetrating radar surveys (GPR), auguring, cadaver dogs, and gravity and seismic fluctuation monitoring (Narreddy 2024; Raji et al. 2023).

Geophysical prospection techniques are widely used to determine the location, size, orientation, and depth of disturbed soils and buried features which may represent clandestine burials. These geophysical techniques identify specific locations of interest but cannot confirm the presence of a human cadaver without additional analysis. In the case of the geophysical survey technique most commonly used in the search for clandestine burials, GPR measures the time taken for electromagnetic energy induced into the ground to be reflected back from an interface between buried horizons or features. These reflected signals may be interpreted as burials, but GPR alone does not discriminate between human burials and many other subsurface features. It does not record the presence of bones, tissues, or decay product residues within the mapped horizons or features. Interpretation of GPR data is complex and requires expert analysis. Once located via geophysical survey, a possible clandestine burial must either be excavated or soil cores must be collected and sent for laboratory analysis to confirm the presence of a human body or decay products.

Cadaver dogs are a method primarily used by police, the FBI, and the military in the search for clandestine human burials and remains. Dogs have sensitive olfactory systems and are trained to detect the odors of thirty volatile organic compounds (VOC) produced during the human decay process (Lopa 2021: 18-21, with references, also see Section 4.2 below for details on the chemistry of human decay). Dogs indicate the location where odor is most intense, which may not be exactly where the physical remains are located. The success of using cadaver dogs is dependent upon a wide array of variables, e.g., breed, trainer and training method, age of burial, soil and environmental conditions, depth of burial, deliberate, attempts to disguise the burial. Locations of burials may be misidentified by cadaver dogs because of underground water flows or air currents at the time of survey. Lopa (2021) reported a range of 40-100% success claimed for cadaver dogs by their handlers, although other forensic investigators claim that the ability of cadaver dogs to find burials is much lower.

Studies measuring the efficiency of these various prospection methods as applied to clandestine human burials often note a common problem of false positives (e.g., Berezowski et al. 2021). When possible, we recommend that a suite of prospection techniques be employed within an investigation area and can provide corroborating positive results. This multiple technique approach represents current best practices in the search for clandestine burials.

2. A solution: *in situ* shallow subsurface spectroscopy

Our solution to the problems of pinpointing the exact location of clandestine burial and confirming the presence of human remains is the Subterra Grey, a mobile geochemical laboratory built by S4 Mobile Laboratories. The Subterra Grey employs a minimally invasive probe system and near-infrared (NIR) spectroscopy to identify the presence of human decomposition products in the shallow subsurface. The Subterra Grey employs onboard spectrometers and software to detect fatty acid compounds resulting from the decay of human remains. In addition, a penetrometer built into the Subterra Grey probe detects the presence of less compact soil associated with a refilled grave excavation. Both kinds of results are provided in the field in real time.

Adipocere, a waxy substance that forms as part of human cadaver decay, can survive in buried soils for decades or much longer, dependent upon soil type, moisture content, temperature, and other factors (Schoenen and Schoenen, 2013). Significantly, the fatty acid salts in adipocere are detectable using spectroscopy in the NIR spectrum at specific wavelengths that form a chemical ‘target’ for identifying the presence of a cadaver. Soil chemistry is mapped immediately adjacent to the probe with a vertical maximum probe depth of 90 cm, depending on ground and environmental conditions.

The Subterra Grey is best viewed as complementary to other techniques currently in use for locating clandestine human burials. As a probe-based system requiring high sample densities, the Subterra Grey is not appropriate for large area forensic prospection. Rather, traditional approaches such as visual inspection, human remains detection dogs, or geophysical methods should be used to limit target areas within which the Subterra Grey can locate the grave and verify the presence of human remains. The Subterra Grey is a confirmation tool, not a wide-coverage survey tool.

3. Brief history of the company and development of the Subterra Grey

S4 Mobile Laboratories started in 2010 as a university research project with the goal of developing a field probe for recording shallow subsurface remains via soil spectroscopy at archaeological sites. Our initial results demonstrated proof-of-concept at field sites in Kansas in 2012 using a commercial probe-spectrometer system (Veris P4000) originally designed to test nutrient levels for agribusiness clients (Matney et al. 2014). Our specific focus on forensic applications and clandestine human burials, leading to the Subterra Grey, began in 2014. In 2015, laboratory studies systematically examined four different proxy indicators of adipocere in soil using different soil types (Travaly 2016). This work was fundamental to showing that spectroscopy could be used to detect human decay products in the laboratory.

S4 Mobile Laboratories was incorporated in April 2019. A prototype probe system was built and successfully deployed to detect the target spectral peaks in field studies at two forensics research centers: the Institute of Forensic Anthropology and Applied Science (IFAAS) at the University of South Florida in 2019 and the Southeast Texas Applied Forensic Science Facility at Sam Houston State University in 2020 (Lopa 2021). In both studies, decay products from donated human bodies confirmed our results from the laboratory proxy studies **[Figure 1]**.

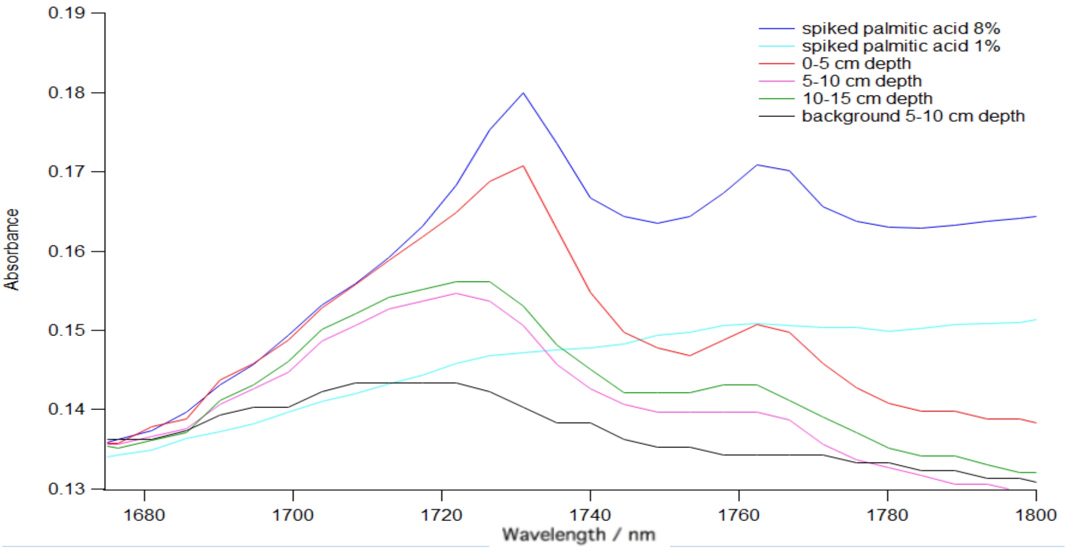

Figure 1. NIR spectra combining the results of: (1) three soil samples from the IFAAS in May 2019. These spectra are the red, green and pink lines. Here there are two primary peaks visible. (2) One spectrum taken as a background sample is shown as a black line. (3) Two soil samples spiked with palmitic acid as a proxy for fatty acid salts. In this plot, we chose to plot concentrations of 8% and 1% palmitic acid. These spectra employed dry soil.

In 2021, S4 Mobile Laboratories began longitudinal field testing of decomposition in controlled burial contexts in Leetonia, Ohio, using pig cadavers as proxies for human bodies. This project measures falloff in the detection of burials as chemical concentrations attenuate in the shallow subsurface over time, maps the spread of the fatty acid salts spatially through time, and determines the detection limits of the Subterra Grey empirically. Our study with shallow subsurface spectroscopy complements similar studies testing various geophysical equipment, soil, and geological conditions using both pig carcasses and donated human cadavers (e.g., Pringle et al. 2021; Doro et al. 2022; Molina et al. 2024). Data for the S4 project in Leetonia are still being collected prior to planned publication.

In 2023, S4 Mobile Laboratories began collaborations with the University of Saskatchewan and the University of Alberta at several field sites in Canada where investigators are working with First Nations tribal groups to map the locations of child burials at Indian Residential School sites. The unmarked graves are known to exist, but their number and location are not yet confirmed. These projects are of an extremely sensitive nature to the collaborating First Nations groups and results of the surveys have not been published.

Commercial production of the Subterra Grey started in May 2024 with the initial sale of a fully functional Subterra Grey unit to the University of Alberta.

4. Direct spectroscopic detection of burial remains

4.1 Basic concepts of spectroscopy

Spectroscopy is the study of interaction between matter and light. For present purposes, this interaction involves the absorption or scattering of visible and infrared (IR) light. The data obtained from spectroscopy is presented as a spectrum, a plot of detected light intensity as a function of the wavelength or frequency (color) of the light (Helmenstine 2019). While there are many types of spectroscopy that could be employed for the Subterra Grey, our early fieldwork and research determined that diffuse reflectance spectroscopy (DRS) is the best solution for in situ measurement of soil chemistry related to human decomposition.

In diffuse reflectance spectroscopy (DRS), visible and infrared light is directed to the material of interest, which in this application is grave soil located in situ underground. The light interacts with the soil particles, some of it being absorbed and some being reflected. The result is that some light of each wavelength is diffusely reflected, or scattered, back from the surface of the soil and is collected by the equipment to be analyzed (Bradley 2002). The intensity of this diffusely reflected light, measured as a function of the frequency or wavelength, constitutes a diffuse reflection spectrum and contains information about the chemical content of the soil. The Subterra Grey inserts a probe with a sapphire window and fiber optic system into the ground to measure the DRS spectra of in situ soils immediately adjacent to the probe window. The Subterra measures spectra over the whole visible and near infrared (NIR) fiber optic wavelength range, 400 to 1950 nm.

Organic functional groups, such as those associated with human decomposition products, have characteristic absorption bands in the (mid-infrared) MIR spectral region, with wavelengths 2,500 to 25,000 nm, outside the range of the DRS spectrometers used in the Subterra Grey. These absorption bands are the fundamental bands representing the vibrations of the atoms within the molecules. The fatty residue from human burials contains many methylene ($-CH_2-$) groups, which have CH-stretch absorption bands at 3420 nm and 3500 nm in the MIR region. The NIR spectral region contains overtones and combinations of the fundamental bands. Specifically, the NIR spectra of fatty burial residue contains bands at 1731 and 1764 nm that are the overtones of the methylene CH-stretch fundamental bands that are observed in the MIR region. Although these NIR bands are relatively weaker than the fundamental bands in the MIR, they suffer from less interference from water in the soil and they fall within the wavelength range of easily available fiber optics. Thus, the Subterra Grey was designed to use the bands at 1731 and 1764 nm as the ‘fingerprint’ for the presence of human decomposition products.

4.2 Human cadaver decomposition

Most published decomposition studies recognize four or five stages of decomposition for bodies on the terrestrial surface (Bass 1997; Galloway et al. 1989; Marks et al. 2009; Payne 1965; Reed 1958). Of these, the earliest biochemical process of decomposition is autolysis, or cell death, which leads to tissue necrosis and putrefaction, which is followed by the destruction of the body's organs and soft tissues due to bacterial proliferation and microorganism activity (putrefaction). In the active decomposition stage, abdominal gases release and purge fluids leak from the body orifices. Active decay is followed by advanced decomposition or skeletonization.

The rate at which a cadaver moves from one decomposition stage to another depends upon the local environment, particularly temperature, moisture, and insect access, as well the condition of the cadaver and scavenger access (Haglund 1997; Mann et al. 1990; Reeve, 2009; Sorg et al. 1998; Synstelie, 2009). Rates of decomposition are considerably slower if the cadaver has been buried rather than left on the surface, in part due to reduced access for insects and scavengers (Carter & Tibbett 2008). The decomposition rate of a buried body is faster in loamy and organic soils when compared to clayey and sandy soils (Tumer et al. 2013). For buried cadavers, two of the major environmental variables affecting decomposition rate include moisture availability and soil texture. Dry, sandy soils promote desiccation due to rapid diffusion of gases through the soil, which retards decomposition, while in moist, clayey soils, conditions can become dominated by anaerobic microorganisms, which are not efficient decomposers (Carter & Tibbett 2008).

During active decay, there are increased levels of soil carbon, nutrients, and pH (Carter et al. 2007; Vass et al. 1992). As a result, the C:N ratio decreases during decomposition. In addition, during active decay, muscle decomposes to form volatile fatty acid (Vass et al. 2002). Vass et al. (2002) also indicate that significant decomposition products include 3-methylindole and the biogenic amines putrescene and cadaverine. At skeletonization, or advanced decay, there is increased concentration of soil nitrogen, potassium, calcium, and magnesium; concentrations of phosphorus, ammonium, sulfate, chloride, and sodium can also remain above basal levels (Vass et al. 1992). Tumer et al. (2013) found increased calcium carbonate ($CaCO_3$) contents in burials with decomposing remains compared with empty control graves. These studies indicate that the soil chemistry of grave soils change significantly enough during active and advanced decomposition.

The formation of adipocere, a fatty, greasy substance, is associated with a retardation of the rate of decomposition (Fiedler et al. 2015). Adipocere occurs when fats in soft tissues are converted into the salts of saturated fatty acids in saponification (Hanganu et al. 2017). Adipocere formation is promoted under the limited oxygen conditions common in moist, clayey soils (Schoenen & Schoenen 2013; Ubelaker & Zarenko 2011). Other environmental factors that have been associated with the formation of adipocere include neutral or moderately alkaline conditions, warm temperatures, and sufficient time (Ubelaker & Zarenko 2011; Widya et al. 2012). Although adipocere formation is not as commonly connected with arid environments, it has been reported when there is an appropriate microenvironment, including a cadaver wrapped in clothing in direct contact with the soil, especially if the conditions promote the retention of moisture inside the cadaver (Byard et al. 2019).

The fatty acids in adipocere degrade slowly, especially under anaerobic conditions (Fiedler et al. 2015; Schoenen & Schoenen 2013), and so can persist in the soil for decades, or even longer. Adipocere from a cadaver on the soil surface can migrate with bodily fluids into the soil located beneath the cadaver (Cassar et al. 2011); high concentrations of fatty acids in soil are usually associated with fluids leaked from a decomposing human body (Ubelaker & Zarenko 2011).

The Subterra Grey directly detects the fatty material in the form of long $–(CH_2)_n–$ molecular chains, with *n* typically in the range 16-18 repeating units. Therefore, the Subterra Grey is able to detect the fatty part of the burial remains at any stage of decomposition from a fresh cadaver to advanced decomposition, so long as the fatty material remains localized in the vicinity of the burial in sufficient concentration to be detected. In a fresh cadaver, the fat content (often 18% - 30% of human body mass) is largely present as triglycerides. As the decomposition progresses, the triglycerides are converted to free fatty acids. In neutral or basic soils, the fatty acids are neutralized to form sodium and potassium fatty acid salts and then transition to insoluble calcium and magnesium salts of fatty acids. Most body fat is present as saturated fat such as myristic acid, palmitic acid, and stearic acid, but there some unsaturated fatty acids, such as oleic acid. As the decomposition proceeds, the unsaturated fatty acids are gradually converted to saturated fatty acids. As noted above, under certain conditions the fatty material might be found concentrated in the soil as the waxy adipocere; in other cases, it may be distributed through the grave soil (Lopa, 2021). In all of these forms, the fatty $–(CH_2)_n–$ molecular chains remain largely intact and are detectable by the Subterra Grey as NIR absorption bands at 1731 and 1764 nm.

5. Direct penetrometer detection of soil compaction

The Subterra Grey probe includes, in addition to the spectrometers, a soil penetrometer that makes a continuous measurement of the insertion force (in pounds) used to push the probe into the shallow subsurface. The Subterra Grey probe has a maximum mechanical insertion force of 500 pounds, although the software is typically set at a lower maximum to avoid damage to the probe during insertion.

In practice, when a grave is excavated and then refilled, the refilled soil is less densely packed than the surrounding undisturbed soil. The insertion force within a grave is substantially reduced (sometimes to a half or a third) relative to the undisturbed soil near it. Typically, when the probe reaches undisturbed soil at the bottom of the grave, the insertion force increases abruptly. The softer soil evidenced by reduced insertion force is often the first sign that a grave may have been found. Confirmation is provided by the spectroscopic detection of human remains as noted above.

6. Current equipment

Figure 2 shows the assembled Subterra Grey unit in the field with its primary components labelled. Figure 3 shows the sample insertion summary plot shown on Subterra Grey screen during field data collection. The spectra on the left-hand side of the screen show the two spectral peaks characteristic of a buried human cadaver. Each plot represents the average of contiguous samples taken over depth intervals of 2.5 cm. Insertion force is indicated in the lower central display panel.

Figure 2. Subterra Grey with labelled parts.

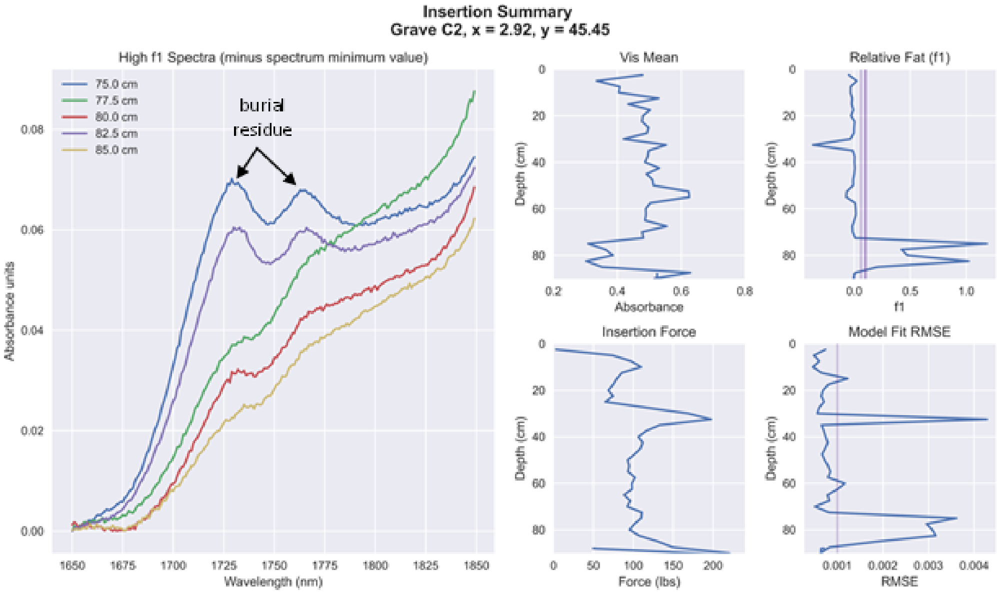

Figure 3. Sample insertion summary plot shown on Subterra Grey screen during field data collection.

7. Current research and development projects for the Subterra Grey

Several potential confounding factors are being addressed during continued refinement of the Subterra Grey. The goal of our empirical approach is to minimize the occurrence of false positive results, optimize sampling strategies and sampling intervals, and better define our limitations of signal detection across varied geological, soil, and environmental conditions.

7.1 Sampling protocols and time needed to complete a survey

The measurement of spectra using the Subterra Grey probes is limited to the soil in direct contact with the probe window. The spectral measurements are taken in a near continuous vertical column, often with 1 cm of vertical separation between data points, while the horizontal distribution of data is discrete. Thus, it is of great importance to consider the sample density taken at a potential grave location to avoid the danger of missing a body by taking too few data points or by creating a sample pattern that leaves large areas unprobed. Both of these conditions would create false negative results. The Subterra Grey does not map the horizontal locations of the samples.

The general rule of thumb is that the spacing of samples (probe insertions) should be smaller than the survey target (i.e., the clandestine burial), thus within the survey area any target burial would be sampled by at least two probe insertions. An anticipated child burial or burial of a partial adult cadaver thus represents a smaller target than a typical adult burial and may require closer spacing of probe insertions. Default sample spacing should be no greater than 0.25 m for expected adult burials and 0.10 m for expected child burials.

One limiting factor in all searches is time. Our experience with the Subterra Grey, in searching well delimited areas where the time required to walk between probe locations and position the equipment is minimal, is that 10 data points can be collected in roughly 40 minutes. This time estimate takes into account detailed note-taking and appropriate spacing of probe insertions. Sample protocols must be designed to minimize the danger of false negatives, while considering realistic time parameters in confirming buried cadavers suspected after GPR, canine, eyewitness accounts, or other methods have limited the search area. Table 1 shows a selection of possible sample protocols and their anticipation time of completion.

Size of survey area	Sample spacing (m)	Sample configuration	**No. of samples**	Estimated time required
1.0 m line	0.25	transect	5	20 minutes
1.0 m x 1.0 m	0.25	grid	25	1 hour, 40 minutes
1.0 m line	0.10	transect	11	44 minutes
1.0 m x 1.0 m	0.10	grid	121	8 hours, 4 minutes
2.0 m line	0.25	transect	9	36 minutes
2.0 m x 2.0 m	0.25	grid	81	5 hours, 24 minutes
2.0 m line	0.10	transect	21	1 hour, 24 minutes
2.0 m x 2.0 m	0.10	grid	441	29 hours, 24 minutes
5.0 m line	0.25	transect	21	1 hour, 24 minutes
5.0 m x 5.0 m	0.25	grid	441	29 hours, 24 minutes

Table 1 Survey area, insertions and estimated time required.

It is possible to decrease the time taken to complete the survey by increasing the distance between samples. The use of single probe insertions taken at random intervals from each other is discouraged as it would increase the possibility of missing the burial altogether.

7.2 False positives

Background levels of fatty acid salts are found in many contexts since they can be a naturally occurring minor component of soil organic matter. As part of our field protocol, we take spectra in transects across a suspected grave excavation, including probe holes in undisturbed ground that serve as controls. These controls define the background level for fatty acid salts and the average insertion force outside of a grave. To date, at the sites in both Canada and the USA, the background levels of fatty acid have always been lower than what can be detected or confidently measured with the Subterra Grey. That is, the detected background results from the noise in our detection and data analysis process. For a fatty acid signal to be considered a ‘hit’ it needs to rise above this noise level.

A second possible false positive is presented in a scenario where a non-human mammal has died and decomposed in the area of interest. The burial of dead mammals in a covered pit is rare (outside of a pet cemetery); while possible, this seems a highly unlikely scenario. We anticipate that the Subterra Grey will be employed in field contexts where there is a reasonable expectation of finding clandestine human burials (e.g., through informant testimony, geophysical or other prospecting technologies, drone photography) and, thus, the chances of a coincidental burial of a non-human mammal is minimal.

7.3 Dispersal of human decay products

The fatty burial remains have low solubility in water and, as such, the movement of human decay products in the soil is limited. When cadavers are left exposed at ground surface, there is very little lateral leaching of decomposition products away from the body. For example, in an experiment at the Australian Facility for Taphonomic Experimental Research (AFTER), Barton et al. (2020) reported a lateral spread of up to 30 cm for human and pig cadavers left exposed on the surface over a 700-day period. In our field studies in Florida and Texas, noted above, we also observed a limited lateral leaching of decomposition for bodies left exposed on the ground surface.

The chemical compounds formed during the decomposition of a human cadaver can be expected to leach downward into porous or low-density soils. The movement of these compounds laterally will be affected by the nature of the burial pit. Disturbed grave soils are less compact, and we anticipate that detectable amounts of fatty acid salts for buried bodies will be limited to the volume of the pit dug to hide the body. A human burial represents a substantial quantity of fatty material which will persist at detectable levels underground unless it is chemically degraded or dispersed over a wide area.

The chemical degradation pathway is an aerobic breakdown fatty residue. Generally, fatty materials will decompose more slowly in an underground burial, and in some cases anaerobic environments fatty acids are well preserved. Dispersion of the remains could occur by the movement of water underground. The fatty material, present either in the acid form, or as the calcium and magnesium fatty acid salts, is insoluble in water and is expected to remain relatively immobile in the soil over long periods of time. However, if the fatty material is present in a third form, as water soluble sodium or potassium salts, then greater dispersal can be expected depending on the extent of water movement underground. The dispersal of the remains will depend on many factors, including the topography, the soil chemistry, and the soil hydrology.

The S4 Mobile Laboratories field study mapping the longitudinal dispersal of decay products from a controlled burial noted earlier will provide empirical data on the Subterra Grey's ability to detect attenuated dispersal of human decay products.

7.4 Maximum age of burials detectable

Related to the question of dispersal, is the question of how old of a burial can be found by the Subterra Grey. The Subterra Grey was originally conceived to detect human remains which are several thousand years in age. No testing has been done as of yet with burials of this age but it is feasible that they are detectable. Because of the complexities noted in Section 7.3, the lifetime of detectable remains in a given location will be hard to predict. In our experience, detectable levels of human decay produced in underground burials may persist for more than a century. At the Woodlawn Cemetery in Saskatoon, Canada, the Subterra Grey detected human remains more than a century after burial, and at residential school sites in Canada, buried remains have been found that likely date from the mid-twentieth century. In Akron, Ohio, the abandoned cemetery of the Summit County Infirmary showed the spectral peaks associated with buried cadavers dating from the mid-nineteenth to the early 20th century (graves were unmarked and cannot be dated more precisely).

Importantly, in both the Woodlawn Cemetery and the Summit County Infirmary Cemetery, the soil within the refilled graves, particularly soil deeper than about 30 cm below the surface, remained softer and more easily penetrated than the overlying soil, detectable by the Subterra Grey's penetrometer.

7.5 Limits of detection

The determination of our limits of detection are being established empirically through laboratory and field testing. Previous work has shown that the area under a spectral peak is a function of the concentration of the chemical in the soil. Travaly (2016) showed that four proxies studied via ATR MIR spectroscopy were detectable, and there was variation in the limits of detectability depending on soil conditions. Specifically, the limits of laboratory detection were calcium pyrophosphate (4.0%), leucine (0.4%), palmitic acid (1.0% - 0.01%), and oleic acid (0.1% - 0.01%). From a pig burial, we took soil cores for laboratory testing and found trace levels of oleic and palmitic acid. One sample from the pig burial had visible traces of adipocere; fatty acid peaks in the adipocere for palmitic and oleic acid were indicative of 1.0% - 4.0% concentrations in our controlled test. Berezowski et al. (2023) found domesticated pigs to be a suitable proxy for human cadavers in geophysical surveys with no differences noted in the detected geophysical responses. However, Connor et al. (2018) noted that the rate of pig decomposition (at least in semiarid environments) is not comparable to human decomposition and DeBruyn et al. (2021) found that human and pig decomposition processes impact soil biogeochemistry differently and suggest caution in using pigs as proxies for human decomposition processes in terms of their geochemistry.

8. Current Subterra Grey technical specifications

- Height of assembled unit: 63 in (1.6 m)
- Weight of assembled unit: 61 kg (134 lbs)
- Interface: Microsoft surface tablet, USB-C
- Power source: two onboard 36 V 13 Ah lithium-ion batteries
- Typical battery life: 12 hours
- Maximum probe depth: 90 cm (35.4 in)
- Average time for probe to reach maximum depth: 90 sec
- Probe design: all-fiberoptic probe, sapphire window, steel shaft (50-4536 rev 7)
- Spectrometer 1 VIS/NIR: StellarNet Blue Wave VIS-NIR spectrometer, 400 – 1100 nm
- Spectrometer 2 NIR: Spectral Engines NIRONE Sensor S infrared spectrometer, 1550 – 1950 nm
- Vertical sample interval (spectra and force measurements): adjustable 1, 2.5, or 5 cm or programmable depth sampling pattern.
- Calibration blanks: 2. Spectralon calibration blank, Ocean Insight, two included
- Load cell for continuous force measurement: Loadstar RAS1
- Mechanical maximum insertion force: 277 kg (500 lbs)
- Software-limited maximum insertion force: set by user, recommended 136 kg (300 lbs)
- Operating temperature range: 0ºC to 35ºC (32ºF to 95ºF)
- Storage temperature range: -20ºC to 45ºC (-4ºF to 113ºF)
- Weather limitations: operates in light rain or snow; limit is 2.5 mm (0.1 inches) of rain/hour. The Subterra Grey is not waterproof.
- Onboard location: Geode GPS/GNSS interface is available (UTM zones in North America only); unit not provided
- Available onboard plots of insertion data: Absorbance, SNV Spectra, Contours by Depth, Force by Depth, Insertion Summary [Figure 3 below], NIR Insertion Summary, Modeled Parameters, Raw Spectrum
- Export data file formats: h5, csv

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