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In this issue

GPR detects Pleistocene "Ghost Tracks"

In a recently published research article[1], T. M. Urban et al. document the use of ground penetrating radar (GPR) to successfully detect footprints in White Sands National Monument, New Mexico, USA. These are no ordinary footprints however, but so called "ghost tracks" from the Pleistocene Epoch. These Ice Age footprints were made by mammoths, giant sloths, and humans more than 11,000 years ago. Unlike fresh footprints on a beach, which appear in negative relief, these footprints were filled-in with new sediment over the years making them flush with the ground surface or, in some cases, just beneath a layer of sand. This means that the prints are often not visible, but they may become temporarily visible under certain moisture conditions, only to disappear again when those conditions change – hence the colloquial term used for them, "ghost tracks". The good news is that these footprints, although not visible to the human eye, can be found with geophysical methods, including GPR, allowing the researchers to locate and study them at any time. Additionally, because excavating the footprints is time-consuming and destructive, large numbers of footprints can be quickly documented with GPR while leaving them intact.

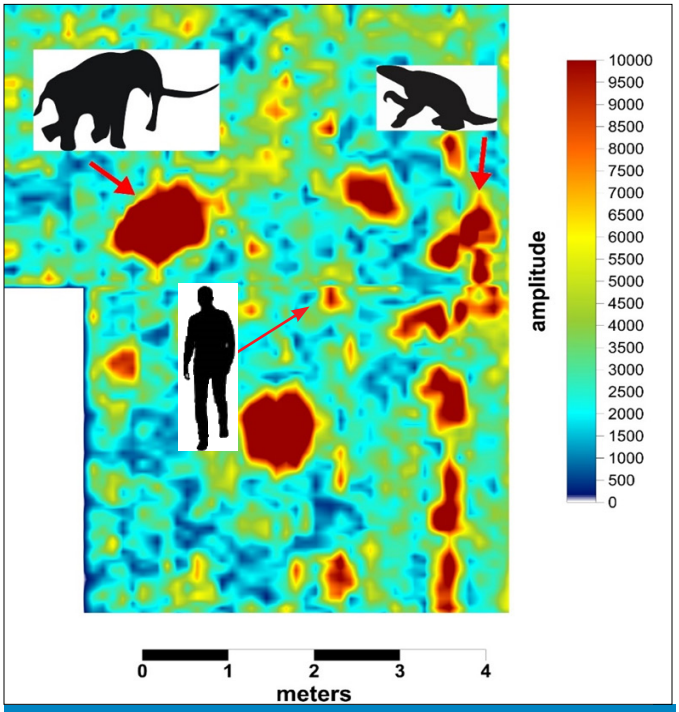

Figure 1: Depth slice map from 2 to 4 ns shows mammoth, giant sloth and human footprints detected with a NOGGIN® GPR system using a center frequency of 250 MHz.

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The team's study describes their attempt at imaging footprints using a NOGGIN® 250 MHz SmartTow™ system, which was a success (Figure 1). Since this initial work, however, the researchers have collected several other GPR data sets using NOGGIN® and pulseEKKO® GPR systems with 250, 500 and 1000 MHz center frequency antennas (Figure 2), which will be described in future research articles.

Figure 2: Collecting GPR data at White Sands National Park with a NOGGIN® 250 SmartTow™ system (left) and a pulseEKKO® 500 SmartTow™ system (right). A foam pad was used to protect the footprints while the work was conducted.

It was found that mammoth footprints result in substantial compression of sediment that shows up especially well in 3D representations of the GPR data (Figure 3); not surprising since these would have been the largest land animal around at that time. Foam mats were used to cover the ground surface to protect the delicate prints from damage. Close grid-line spacing was required to detect the much smaller human footprints. GPR data processing included routine procedures such as Dewow, gain, background subtraction, migration, and envelope, as described in the original paper[1].

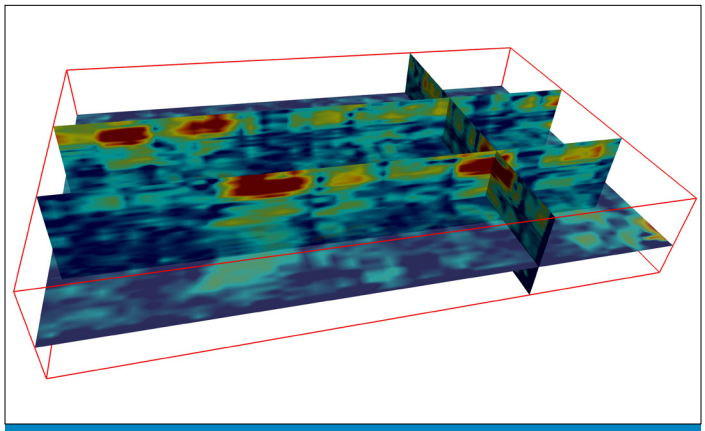

Figure 3: 3D representation of mammoth footprint obtained using a NOGGIN® 250. Mammoths would have been the largest land animals in the area, and their footprints lead to substantial compression of the sediment underneath.

The team, a collaborative, interdisciplinary group including researchers from Cornell University (USA), Bournemouth University (UK), and the U.S. National Park Service, has also previously successfully imaged mammoth footprints with a magnetometer[2], though they highlight some of the advantages of GPR in their new article. In particular, the magnetometer is less sensitive than GPR when it comes to smaller footprints, such as those of humans. The GPR also provides depth information, which is useful when assessing the footprints; especially in cases where two or more track-making events are superimposed, or in cases where sediment compression beneath the footprint is useful to understand, such as with mammoths (Figure 4).

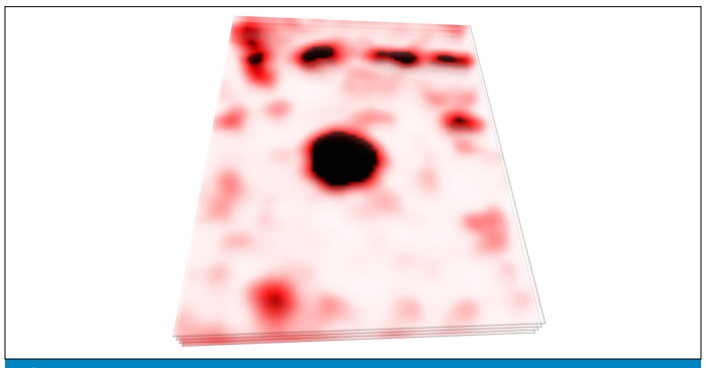

Figure 4: Depth slice of mammoth footprint (center) and giant sloth footprints (top) detected with GPR. Data collected with a 250 MHz center frequency NOGGIN® system.

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This unusual application of GPR has captured significant public attention, with the findings being covered in more than 120 news outlets worldwide. The Ice Age footprints of White Sands had also received widespread press coverage in 2018 when the same team published a study suggesting that footprints showed Pleistocene humans harassing and stalking a giant sloth[3].

Story courtesy of Thomas M Urban from Cornell University.

1. 3-D radar imaging unlocks the untapped behavioral and biomechanical archive of Pleistocene ghost tracks https://rdcu.be/bXKRW
2. Use of magnetometry for detecting and documenting multi-species Pleistocene megafauna tracks at White Sands National Monument, New Mexico, U.S.A - https://doi.org/10.1016/j.quascirev.2018.07.012
3. Footprints preserve terminal Pleistocene hunt? Human-Sloth interactions in North America https://doi.org/10.1126/sciadv.aar7621

New Product: Pavement Density Profiler (PDP)

A Fast & Simple Pavement Uniformity Indicator

"Proper compaction of an asphalt pavement is essential for long-term pavement performance. Studies indicate a 1 percent increase in density can extend the asphalt pavement service life by at least 10 percent."
Federal Highway Administration, U.S. Department of Transportation

There has been extensive research that shows that the life expectancy of asphalt pavement is highly dependent on uniform asphalt compaction. The widely accepted quality control metric for new paving is to drill core samples in the finished road and then, measure their density in the laboratory. The coring process, besides being destructive, typically takes days, and the results from the lab are received long after the pavement has cooled and there is any chance of taking corrective action if problems are found.

Other methods of measuring pavement density include electrical capacitance (PQI) and nuclear density gauges. The use of nuclear density gauges is complicated due to the safety, security and transportation regulations required for the handling of radioactive source materials. Many jurisdictions do not accept or use nuclear gauges. Like coring, these methods only sample a small area of the pavement, typically 100 cm^2. The challenge is knowing if enough samples have been taken to ensure adequate sampling of the large road surface area. Point sampling leaves gaps in the measurements and increases the risk that there may be areas in the road that fall outside the compaction quality requirements which could lead to premature road failure.

The new Pavement Density Profiler (PDP) addresses the need to acquire density measurements over a large area of pavement quickly. Data is collected in a non-destructive and non-contacting manner and displayed in real-time during the paving process to quickly assess the uniformity of the paving job.

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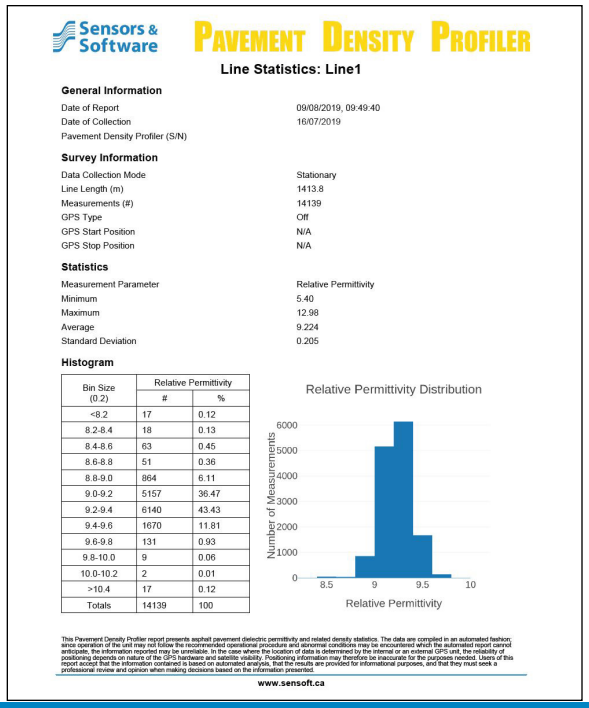
The PDP measures the variability of the asphalt pavement and can collect data in point (Figure 1), profile (Figure 2) and area mapping (Figure 3) modes of operation, providing more complete density measurements than destructive coring. Areas of high and low density can then be targeted for further investigation.



Sensors & Software

PAVEMENT DENSITY PROFILER

Line Statistics: Line1

General Information

Date of Report	09/08/2019, 09:49:40
Date of Collection	16/07/2019
Pavement Density Profiler (S/N)	

Survey Information

Data Collection Mode	Stationary
Line Length (m)	1413.8
Measurements (#)	14139
GPS Type	Off
GPS Start Position	N/A
GPS Stop Position	N/A

Statistics

Measurement Parameter	Relative Permittivity
Minimum	5.40
Maximum	12.98
Average	9.224
Standard Deviation	0.205

Histogram

Bin Size (0.2)	Relative Permittivity	
	#	%
<8.2	17	0.12
8.2-8.4	18	0.13
8.4-8.6	63	0.45
8.6-8.8	51	0.36
8.8-9.0	864	6.11
9.0-9.2	5157	36.47
9.2-9.4	6140	43.43
9.4-9.6	1670	11.81
9.6-9.8	131	0.93
9.8-10.0	9	0.06
10.0-10.2	2	0.01
>10.4	17	0.12
Totals	14139	100

This Pavement Density Profiler report presents asphalt pavement dielectric permittivity and related density statistics. The data are compiled in an automated fashion; since operation of the unit may not follow the recommended operational procedure and abnormal conditions may be encountered which the automated report cannot anticipate, the information reported may be unreliable. In the case where the location of data is determined by the internal or an external GPS unit, the reliability of positioning depends on nature of the GPS hardware and satellite visibility. Positioning information may therefore be inaccurate for the purposes needed. Users of this report accept that the information contained is based on automated analysis, that the results are provided for informational purposes, and that they must seek a professional review and opinion when making decisions based on the information presented.

www.sensoft.ca

Figure 1: PDP point measurement PDF report. The PDP samples a point on the asphalt pavement thousands of times in 30 to 60 seconds and generates statistics and a histogram of the results.

The PDP works by transmitting a radio wave signal towards the ground surface and detecting the reflected wave, measuring the dielectric permittivity of the asphalt pavement. This information can be converted to density or air void content values for real-time, in-field results.

The complete PDP system is housed in a single battery-powered unit that connects wirelessly to a tablet for viewing and control of the system. This simplifies training, field setup and operation and ensures consistent field results.

There are many powerful and innovative features in the PDP, including:

- Setup & Survey in minutes
- Factory calibration - no need for complicated or tedious in-field calibration
- Quick, in-field validation process to ensure system performance before work begins
- Automated reports in PDF format
- Data export in CSV (spreadsheet) format

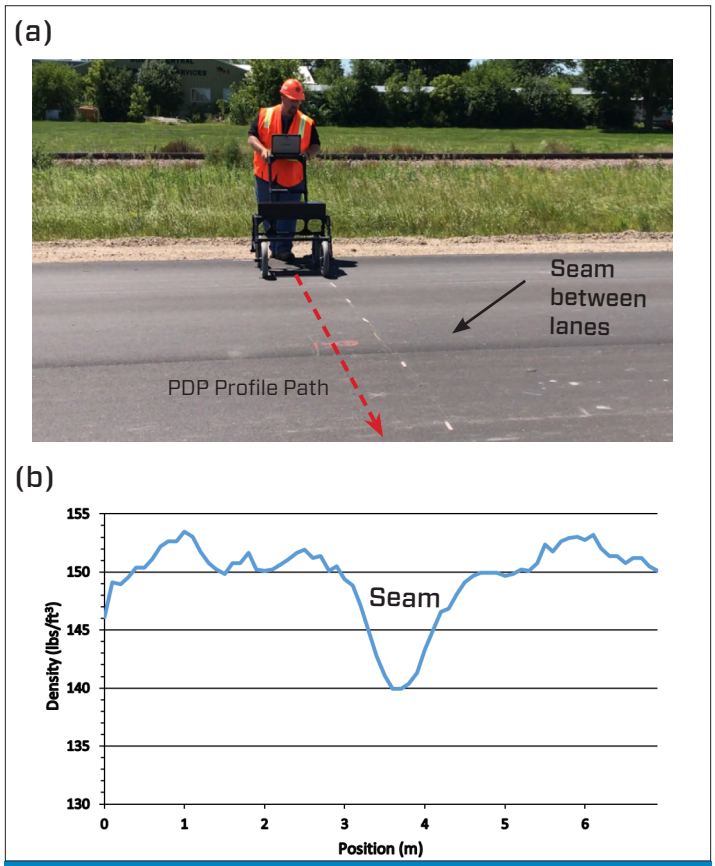


Figure 2: (a) PDP profile data collected every 0.1 meters across two lanes. The profile plot (b) shows that the density of the seam is low compared to that of the 2 lanes.

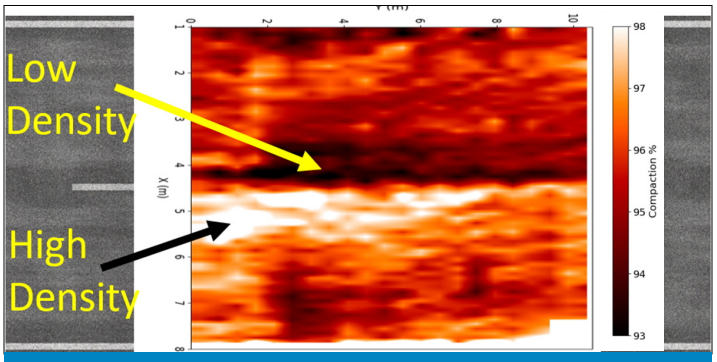


Figure 3: PDP 2D Area plot (plan map view). Ten PDP profiles were collected 1 meter apart across two lanes. The density map image shows the variation in density, including high and low densities around the seam between lanes.

The PDP lowers costs by reducing the need for expensive cores and optimizing the coring locations to anomalous areas. Further, pavement compaction procedures can be adjusted on an ongoing basis by eliminating the delay between paving, coring and the lab measurements. The PDP brings a new level of functionality and efficiency to measure pavement properties. For more information, contact us.

TIPS: Determining pipe diameter from GPR data

While most utility locators simply want to know where a pipe is located, there are times when more detailed information is required. One example is knowing the diameter of a buried pipe.

To estimate pipe diameter, three important conditions must exist:

1. The pipe must be non-metallic – since the GPR wave will not penetrate metal, it will never see the reflection from the bottom of the pipe.

2. You must get a reflection from the top and bottom of pipe (Figure 1) – even if a pipe is non-metallic, it doesn't necessarily mean you will get a reflection from the bottom. Reasons for this include the pipe diameter being too small (so the travel time within the pipe is too fast) or the reflection being too weak to be detected by the GPR receiver.

   To confirm that the 2 hyperbolas are from the top and bottom of the same pipe, look for two things:

   (a) the two hyperbolas (from top and bottom) should be exactly located one on top of the other (Figure 2).

   (b) the bottom hyperbola has the opposite polarity of the top hyperbola. In Figure 2, the hyperbola reflection from the top of pipe is caused by the GPR wave travelling from soil to water, resulting in bands that are black-white-black. The reflection from the bottom of pipe is caused by the GPR wave going from water to soil, so the bands are the opposite polarity: white-black-white. This has to do with the reflection coefficient, moving from a lower to higher dielectric constant in the first case, and then, vice-versa.

3. The contents of the pipe are known – most typically, it would be empty (air or gas) or water-filled.

Once you satisfy all the criteria above, we can calculate the estimated diameter. Let's start with our familiar depth-time equation:

$$\text{Depth} = \text{Velocity} \times \left(\frac{\text{Time}}{2}\right)$$

Since we are only concerned about what happens inside the pipe, the above equation can be re-labelled to read:

$$\text{Diameter} = \text{Velocity} \times \left(\frac{\Delta T}{2}\right)$$

where ΔT is the change in time, measured between the top and bottom of the pipe (Figure 1)

Velocity is that of the GPR wave travelling in the material inside the pipe

Figure 2 shows a zoomed image of a water pipe, where the top and bottom of pipe are clearly seen.

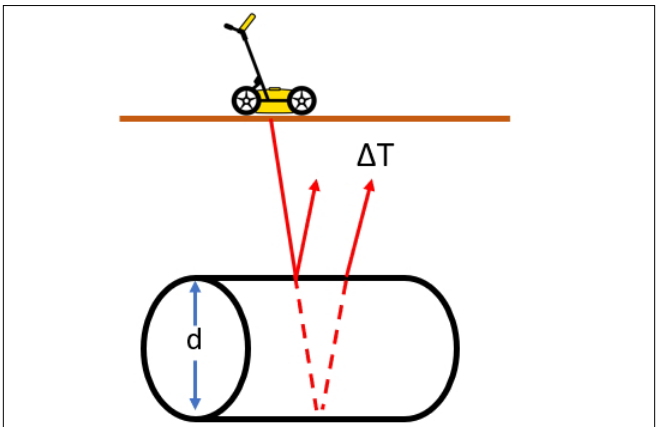


Figure 1: Schematic representation of the change in time, ΔT, measured between the top and bottom reflections from the pipe with diameter, d.

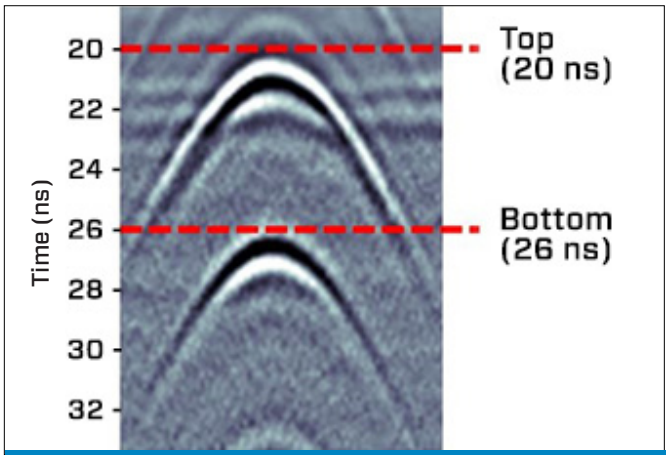


Figure 2: Reflection from top and bottom of a water-filled plastic pipe.

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First, we need to determine the value for ΔT. From the image above, we can see that the time difference between the hyperbola from the top of the pipe and the hyperbola from the bottom of the pipe is 6 ns.

Next, we need to know the velocity that GPR waves travel in the material inside the pipe. We knew that this pipe was water-filled, so the GPR velocity in water is 0.033 m/ns. Plugging these values into the equation yields:

$$\text{Diameter} = 0.033 \text{ m/ns} \times \left(\frac{6 \text{ ns}}{2}\right)$$

$$\text{Diameter} = 0.099 \text{ m}$$

$$\text{Diameter} \approx 10 \text{ cm or } 4''$$

Water-filled, non-metallic pipes are easier to estimate their diameter since water slows down GPR waves, making the bottom hyperbola (originating from the bottom of the pipe) clearly distinguishable from the top hyperbola. With empty (air-filled) pipes or pipes with a very small diameter, the bottom reflection occurs too close in time to the top hyperbolic reflection, thereby making it impossible to distinguish the two.

Remember that this calculation, while handy at times, is only an estimate and requires prior knowledge of pipe contents. It also assumes that the pipe is completely full of that material, which is not always the case. Ground truthing would be the only way to get an exact diameter of the pipe and GPR should only be used to get a size estimate. If you need to be 100% certain of the pipe diameter, you will need to daylight it.

Upcoming Courses

Subsurface Utility Locating with GPR course (NULCA-accredited)

March 2, 2020, Mississauga, ON, Canada

May 4, 2020 Mississauga, ON, Canada

Concrete Scanning with GPR course

March 3, 2020, Mississauga, ON, Canada

May 5, 2020, Mississauga, ON, Canada

3-Day GPR course

June 2-4, 2020, Mississauga, ON, Canada

October 7-9, 2020, Höhr-Grenzhausen, Germany

Upcoming Events

Canadian Concrete Expo - January 22-23, 2020, Mississauga, ON, Canada

(WOC) World of Concrete - February 4-7, 2020, Las Vegas, NV, USA

(GPEC) General Police Equipment Exhibition & Conference - February 18-20, 2020, Frankfurt, Germany

CONEXPO - March 10-14, 2020, Las Vegas, NV, USA

DGG 2020 - March 23-26, 2020, Munich, Germany

(CGA) Excavation Safety 811 - March 24-26, 2020, Palm Springs, CA, USA

(SAGEEP) Environmental and Engineering Geophysical Society - March 29-April 2, 2020, Denver, CO, USA

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