

# SUBSURFACE VIEWS

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## “Easy” Targets in Plain Sight Excite Student Research

Over the last 25 years, faculty and students at the United States Military Academy at West Point have been using Ground Penetrating Radar (GPR) to locate and characterize archeological features on the campus. The most enticing of these targets is a cannon battery complex, buried in place in the 1930s which is now a grass field used for marching parades. The hunt for those buried cannons over the decades allowed students to learn geophysics and do independent research projects, but never resulted in conclusive evidence to locate the cannons or the battery complex. In a surprising twist, recent attempts to gather more widespread GPR data are leading to a new methodology that may allow characterization of glacial geomorphology as well. The key seems to be in visualization of large-scale depth slices.

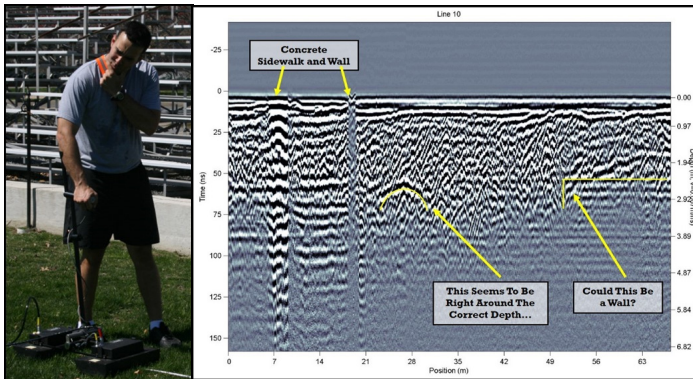
Early attempts to locate the cannons, in the mid-1990s, used a pulseEKKO® 1000 GPR and both 110 MHz and 225 MHz center frequency antennas. GPR surveys were collected with a very coarse line spacing, 5 to 10 meters apart. Later, aerial photos from the 1920s, predating the burial of the cannons, allowed georeferencing their likely locations. The cannon locations were thought to be directly underneath two sets of permanently mounted metal bleachers built on gravel pads.

The pulseEKKO® 1000 could not fit underneath to collect data and, even if it could, it was thought that the data would not be usable because the metal bleachers would cause severe interference.

A big break came with newer GPR data collection capabilities, quicker and more user-friendly data processing, and the ability to create depth slices from grids of GPR data. In 2008, still using the pulseEKKO® 1000 system, Cadets Katelin Grant and Anton Faustmann collected a grid of data (Figure 1). Early attempts at depth slicing used the EKKO\_Mapper software to process the small, 5-by-5-meter square grid with lines spaced 1 meter apart, but the results were inconclusive and, again, very localized over the probable target location.

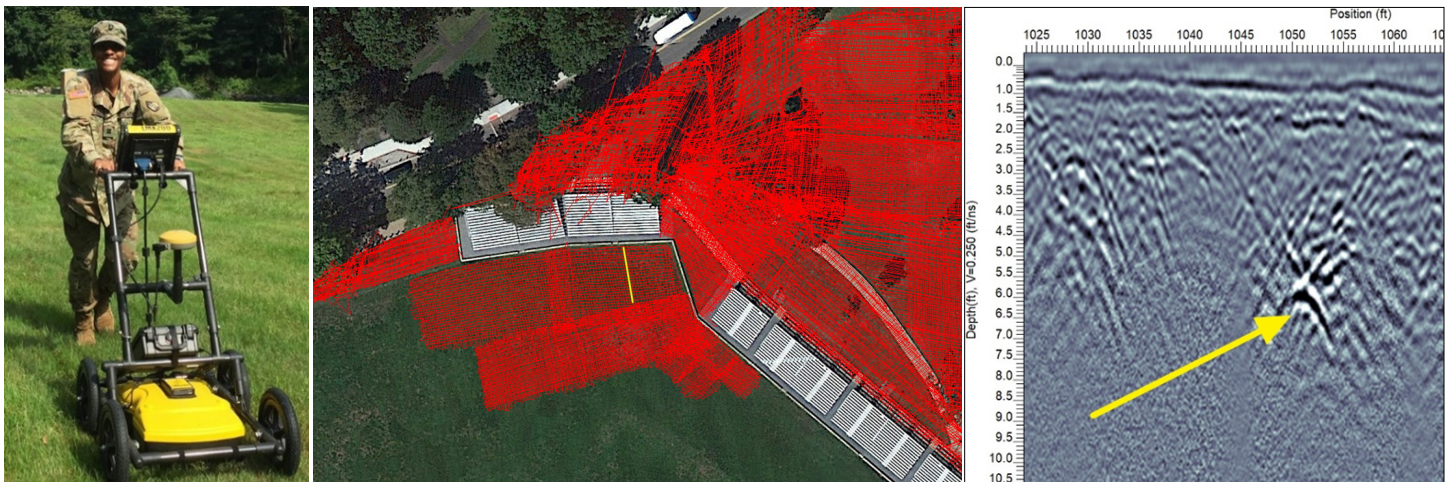
In hindsight, one of the primary limitations might have been the bias in designing the GPR surveys to target what was thought to be the exact location of the cannons. The aerial photos and historic maps of the area provided a high confidence level, leading to small, localized surveys directly over the “known” location of the cannon.

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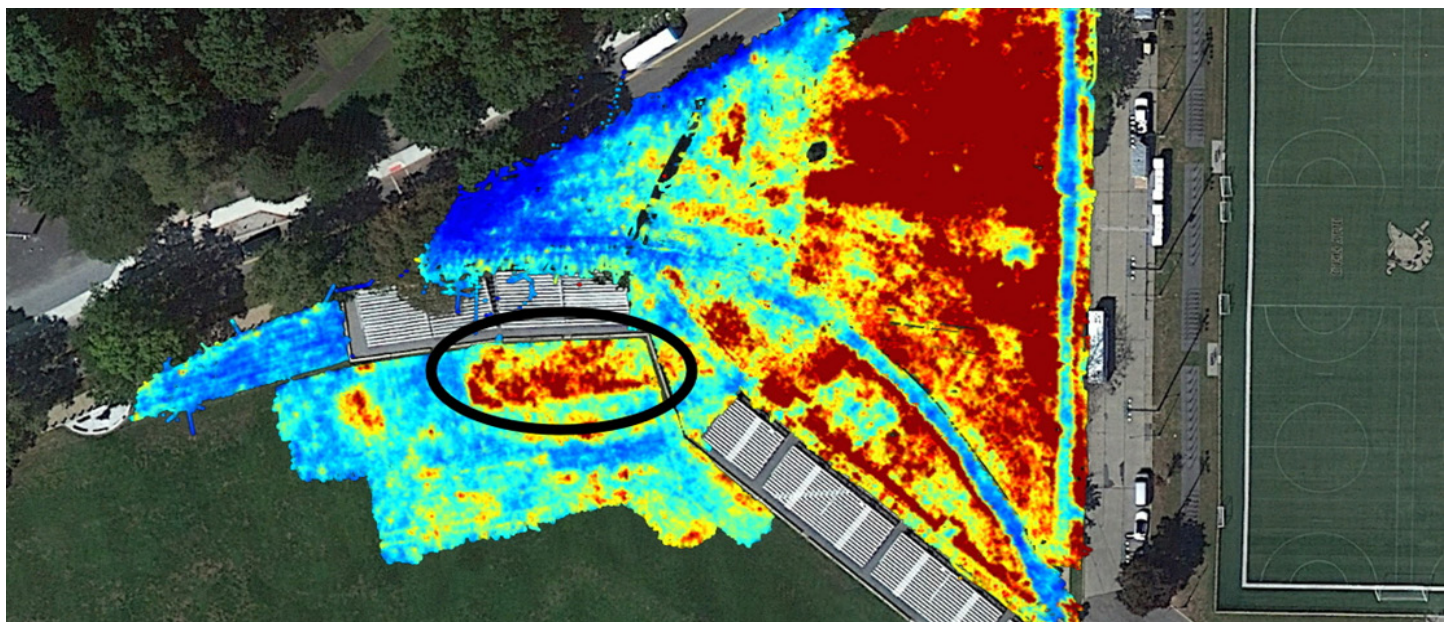


**Figure 1:** Cadet Anton Faustmann collecting 225 MHz center frequency GPR data with the pulseEKKO® 1000 in 2008. One GPR profile from this survey is annotated with rough interpretations from the Cadets.

Nearly a decade later, in 2017, the hunt for the cannon picked up again using the LMX200™ GPR and the SliceView-Lines module of the EKKO\_Project™ software. With the ability to collect GPR data quickly in a “random-walk” pattern and to easily georeference the data for visualization as depth slices, a new strategy for locating the cannon was developed. Instead of looking for a single cannon directly above the suspected location, it was decided to survey a much larger area, which could reveal the entire footprint of the coastal artillery complex. Cadets Matthew Panner, Yasheika Beckaroo, Nick Dabbelt, and Randy Forstiere each surveyed different areas (Figure 2) and patched the data together to begin revealing evidence of the buried cannon complex (Figure 3).



**Figure 2:** Left - Cadet Yasheika Beckaroo collecting GPR with the LMX200™ in 2019. Middle- Map of the individual GPR surveys collected in the area and patched together. Right - GPR cross-section with a strong hyperbola where the cannon complex is suspected to be. This GPR profile is indicated with a yellow line on middle map



**Figure 3:** The 4.5-foot depth slice superimposed on Google Earth reveals the interpreted location of the cannon complex (black oval).

Using GPR as both a research and teaching tool, a Geography Methods class then used the LMX200™ GPR to collect a patchwork of small grids. As more grids of data are collected over the larger area, the depth slices are starting to reveal broader features under the centuries-old landscaping that are characteristic of glacial geomorphology. For example, the cannon battery was built in a natural depression known as a kettle lake, created by glaciers at the end of the last ice age.

Cadets and faculty hope to continue collecting GPR data over the entire 16-acre area, to finally identify and characterize the archeology and geomorphology hidden in plain sight.

*Story courtesy of LTC Mindy Kimball of the US Military Academy at West Point*

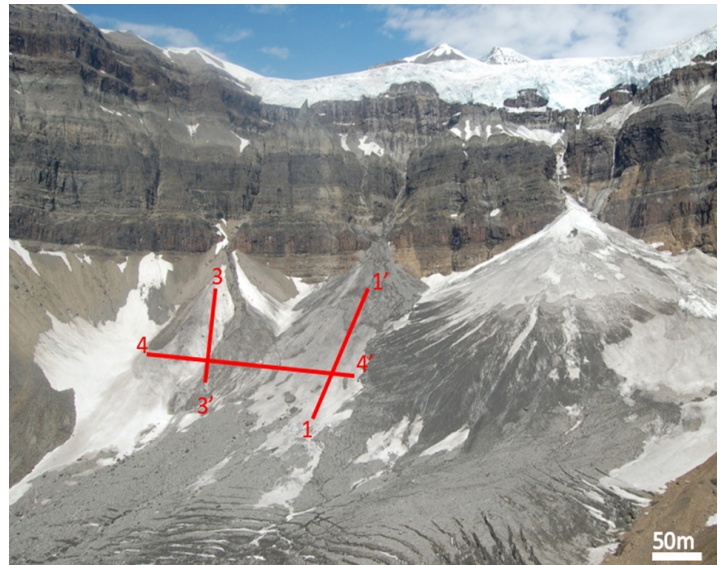
## GPR Imaging of Icy Debris Fans

Researchers from Bucknell University in Lewisburg, Pennsylvania used ground penetrating radar (GPR) to non-invasively investigate the subsurface characteristics of icy debris fans. We would like to share some of their work. Although fans in Alaska and New Zealand were studied during their research, this article focusses on the work done on the McCarthy Glacier, Alaska, USA.

Icy debris fans are found at the head or along the side of valley glaciers where high-level ice caps are detached from valley glaciers (Figures 1 and 2). These unstable, rapidly changing landforms have recently been described as deglaciation features on Earth, however, the subsurface characteristics remain unknown and the processes that lead to their formation are poorly understood.



**Figure 1:** Icy debris fans were imaged using a pulseEKKO® GPR system with antennas with a center frequency of 100 MHz.



**Figure 2:** Ice debris fans associated with the McCarthy Glacier in Alaska. The numbered red lines indicate the approximate locations of the GPR lines shown in Figures 3, 4 and 5.

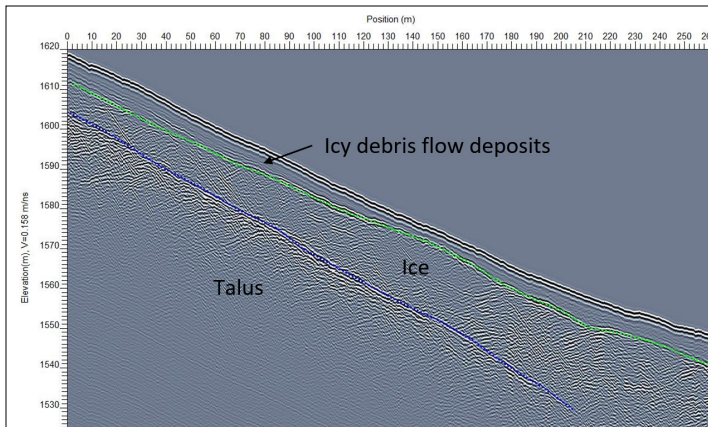
The surface processes building these features have been observed to include ice avalanches, rockfalls, icy debris flows, and slushflows, which results in composition including snow, ice, and lithic (rock) deposits for icy debris fans. Recent deposits on icy debris fans are hundreds of meters long, tens of meters wide, and meters thick. Periods of intense ice melting or significant rockfall produce concentrations of significant rock deposits.

To better understand the structure of icy fans and the processes that create them, we used a pulseEKKO® system with 100 and 200 MHz center frequency bi-static, unshielded antennas to collect the GPR data. The time sampling rate depended on the frequency of the antenna; 100 MHz data were sampled every 0.8 ns, while 200 MHz data were sampled every 0.4 ns. All GPR data were collected with 16 stacks per trace (see accompanying article for more information about stacking) and a time window of 3000 ns.

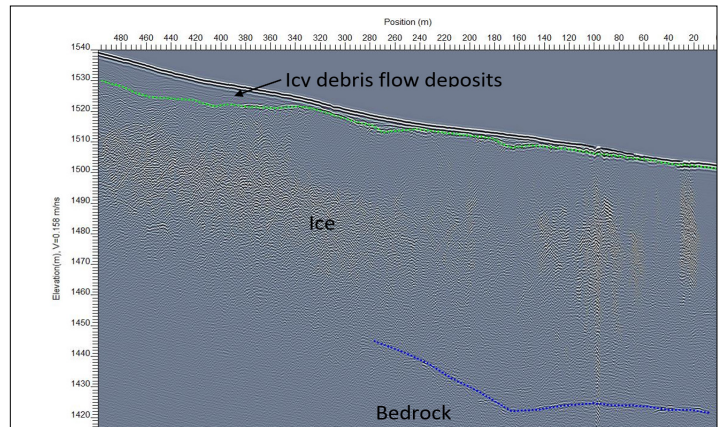
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GPR profiles (Figure 2) were used to determine the subsurface geometry of the fans and common mid-point (CMP) and wide-angle reflection/refraction (WARR) soundings were used to measure the GPR signal velocity in the subsurface. Using the CMP Analysis routine in the EKKO\_Project™ software, these measurements provided an average velocity of 0.16 m/ns, which is a typical velocity for ice. The CMP/WARR soundings indicated little velocity variation from surface material to depths up to 53 m within the icy debris fans. For more information about CMPs, see <https://www.senssoft.ca/blog/cmp-survey-using-the-dvl-500p/>

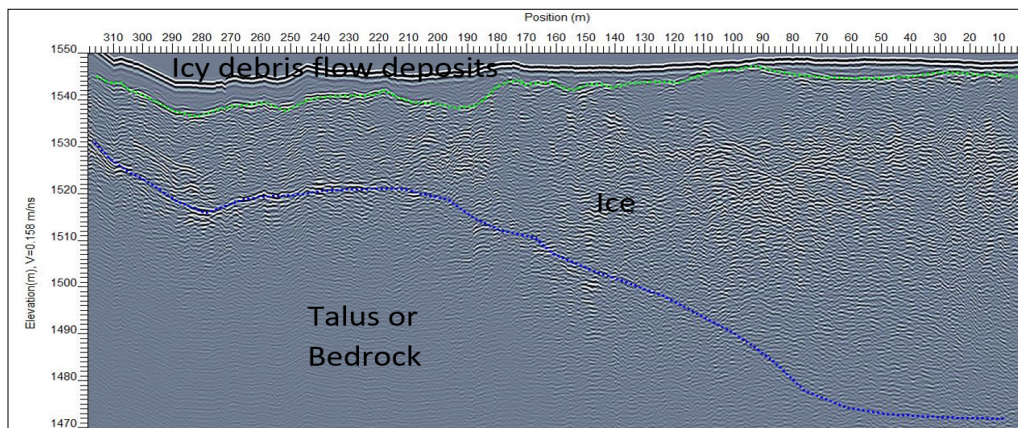
The GPR profiles (Figures 3 to 5) indicate that there is a significant difference in observed GPR signal characteristics above and below the prominent reflector (green boundary); the primary difference is the amount of diffraction patterns in each layer. The shallowest material is layered, with few diffractions, while the material below the green reflector shows significantly more diffractions. These are interpreted as brittle failure planes associated with cracks and crevasses in ice so, we interpret this boundary as the separation between icy debris fan material with high porosity above and ice below.



**Figure 3:** Line 3 plotted with a topographic correction applied. It shows two strong GPR reflectors, the shallower one (green line) interpreted as the interface from the icy debris flow material and the ice and the deeper one (blue line) as the top of the talus (loose rock) under the ice.



**Figure 4:** Line 1 is a downslope line parallel to Line 3 in Figure 3 but a couple of hundred meters to the right. It shows two strong GPR reflectors, the shallow green one interpreted as the interface from the icy debris flow materials and the ice and the deeper blue one, the top of bedrock under the ice.



**Figure 5:** Line 4 generally runs along an elevation contour line and crosses Lines 1 and 3. It shows a significant thickening of the ice where the bedrock/talus reflector gets deeper.

There is a deeper, strong interface (blue boundary) that is interpreted to be the bedrock or possibly older glacial ice in Line 1 (Figure 4). However, for Line 3 (Figure 3) we interpret this to be talus (loose, piled rock), as can be seen in the photo in Figure 2.

Some of the conclusions from this research are:

- GPR reflections from within the icy debris fan appear to be associated with rock-rich interfaces. These interfaces may be produced by melting ice concentrating the rocky materials or rockfall events.
- GPR was useful to image the base of large icy debris deposits.
- Internal GPR reflections become less coherent with depth, may be offset by faulting, and may indicate a rotation.
- The range of GPR signal velocities measured is consistent with ice-rich material with varying amounts of liquid water.

While many reflectors and reflector characteristics still need to be ground truthed in ongoing research, GPR has provided the first images into the structure of icy debris fans.

Find more information about this research here:

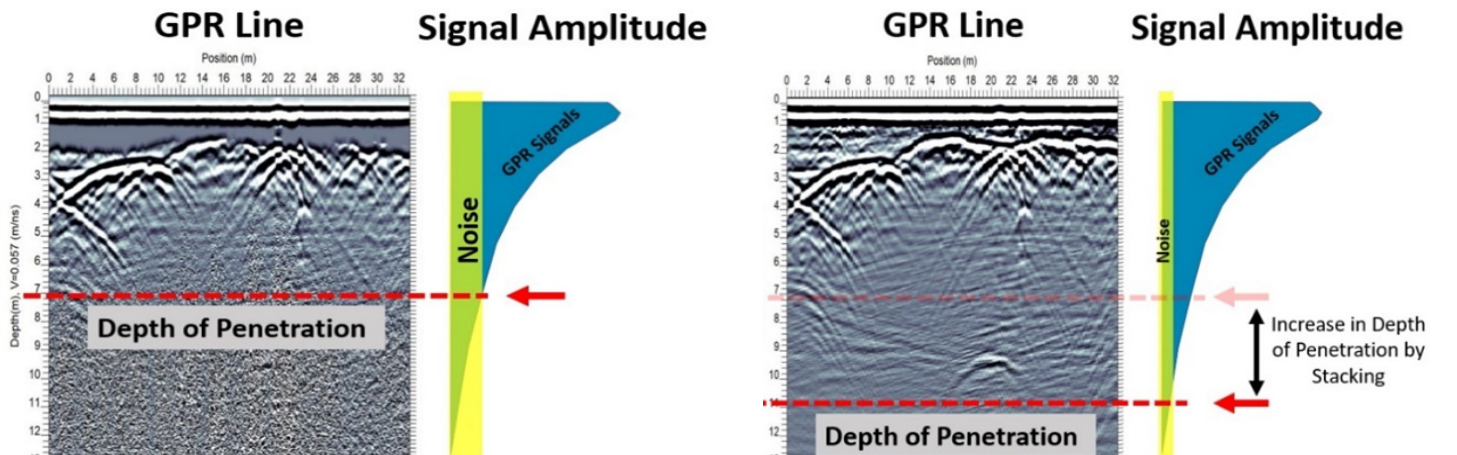
[https://digitalcommons.bucknell.edu/fac\\_journ/1475/](https://digitalcommons.bucknell.edu/fac_journ/1475/)

<https://pubs.geoscienceworld.org/gsa/geosphere/article/531476/geomorphology-of-icy-debris-fans-delivery-of-ice>

Data and story courtesy of Dr. Robert W. Jacob, Bucknell University

## TIPS: Noise, Stacking and DynaQ®

One of the factors that limits the depth of GPR signal penetration into the ground is random background noise from other radio frequency emitters, such as radio and TV stations, cell-phone towers and radio communications in the survey area. The “Depth of Penetration” for GPR is defined as the depth at which the ground materials attenuate the GPR signals down to the same level as the background noise floor, at which point they can no longer be differentiated from the noise (Figure 1, left). This means that, if the random noise floor can be lowered, more of the deeper GPR signals hidden in the noise can be detected (Figure 1, right).



**Figure 1:** Left – the “Depth of Penetration” is the depth where the GPR signals attenuate down to the background noise floor. Right – Stacking GPR traces increases the depth of Penetration by lowering the noise floor so that deeper, weaker GPR signals are detectable.

The noise floor can be reduced by stacking the GPR data traces. In other words, at each collection point on the ground, multiple GPR traces are collected. Those traces are then averaged, and the averaged trace is saved. The averaged trace has less noise, increasing the signal-to-noise ratio and thus, increases the depth of penetration (Figure 2).

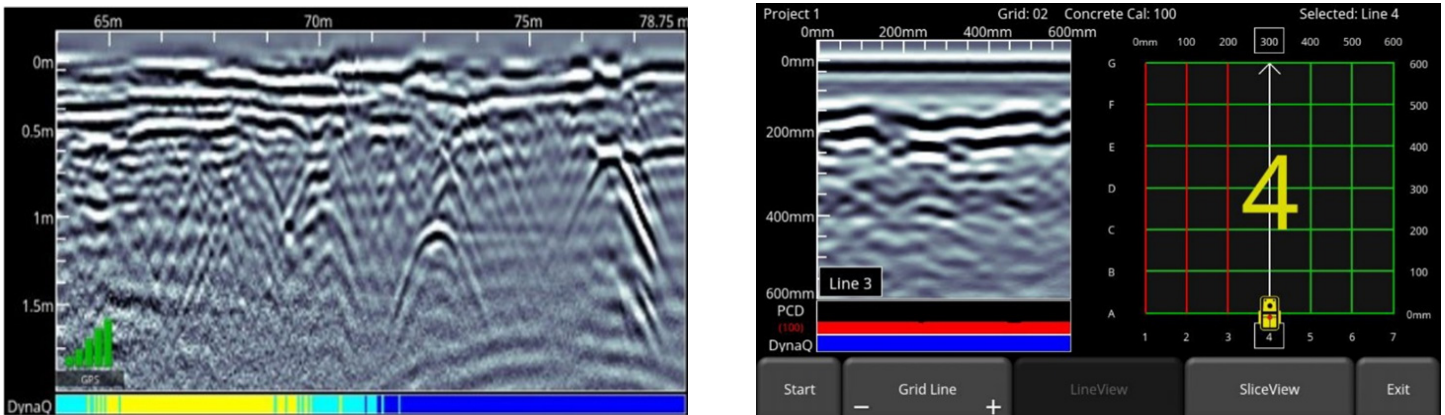
Since the early 1980s, Sensors & Software GPR systems have had the capability of stacking data traces up to 2048 times; the operator set the number of stacks desired and moved the antennas after the GPR trace was stacked, averaged and saved.

Stacks	Traces Collected	Trace Saved
1		
2		
4		
8		

**Figure 2:** Stacking traces multiple times and saving the average trace lowers the amount of noise (shown as red signal) in the average trace. The more you stack GPR traces, the lower the noise, the better the GPR signal and the deeper the depth of penetration.

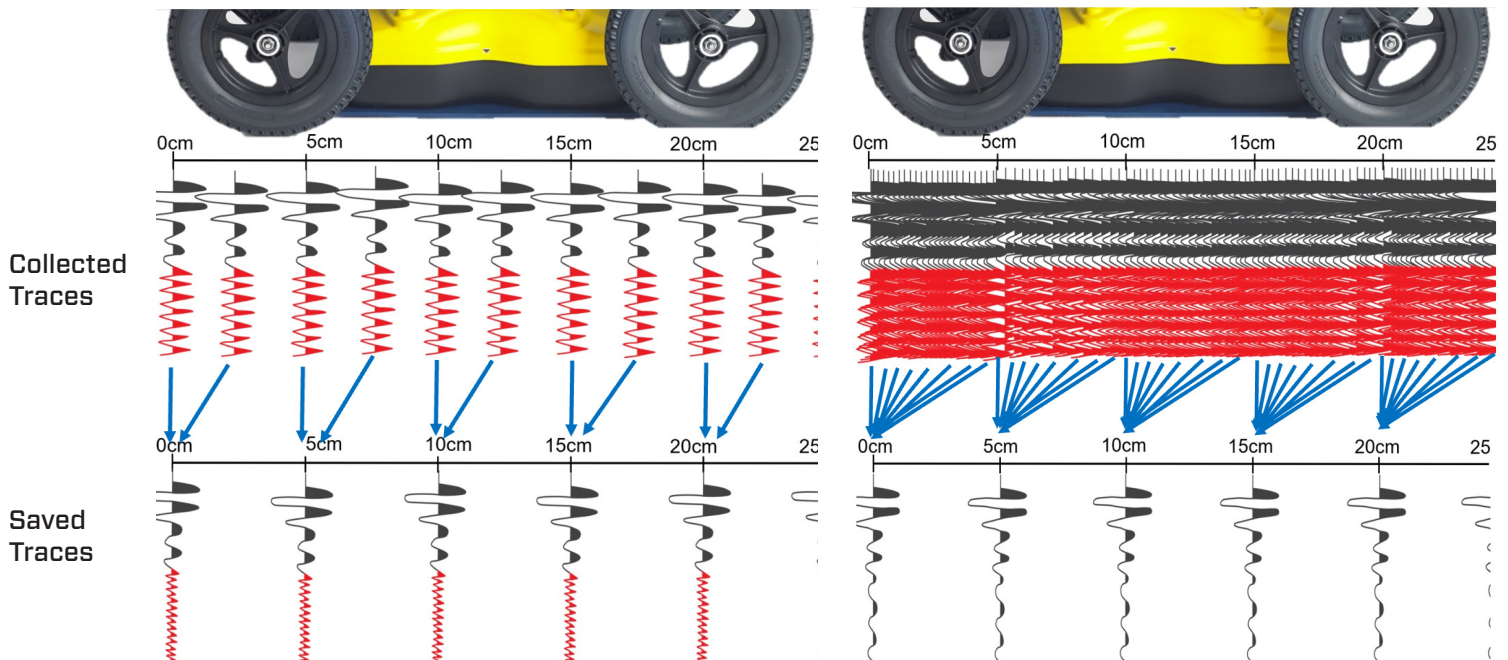
The challenge for users in those days was to optimize the number of stacks to the speed the GPR system was moving. Too few stacks decreased the possibility of achieving a greater depth of penetration and too many stacks decreased survey speed, forcing the user to determine the optimal stacking interval. Following our motto of turning complex to simple, in 2005 we introduced Dynamic Quality technology, or DynaQ®, to eliminate the requirement for customers to self-select the number of stacks by determining optimal stacking dynamically and automatically.

Most of you know DynaQ® as the colored scroll bar under your GPR data image that tracks along as you collect GPR data (Figure 3), but that simple colored scroll bar has some powerful technology behind it that reduces random noise, increases data quality and increases the depth of penetration.



**Figure 3:** The DynaQ® bar, seen on all Sensors & Software GPR products with an odometer wheel, scrolls out under the GPR image as the GPR line is collected. The color is an indication of the number of stacks.

With DynaQ®, the GPR system stacks continuously until the odometer indicates that the system has moved one step size and the system needs to start collecting a new trace. At slower speeds the system stacks more times between odometer triggers than at higher speeds, but it always collects the maximum number of stacks possible (Figure 4).



**Figure 4:** With DynaQ®, traces are collected continuously over the Step Size distance (5 cm for the Noggin 250 shown). When the GPR system moves fast (left), fewer traces are collected in each step size (2 traces in this example). The traces in each step size are averaged (stacked) and the average trace saved. When the GPR system moves slower (right), more traces can be collected and averaged. The traces with higher numbers of stacks produce saved traces with less noise (red signal). Both examples show a relatively low number of stacks. Sensors & Software GPR systems can collect up to 2048 or even 65,536 stacks, numbers that are difficult to depict in simple illustrations.

Therefore, if you are struggling to see deep enough, remember that one simple strategy is to slow down and let DynaQ® do its work; stack the data trace more times, decrease the noise floor and increase the depth of penetration.

DynaQ® is standard for all our GPR systems that use odometers – pulseEKKO®, NOGGIN®, CONQUEST®, FINDAR® and LMX®.

With the introduction of the NOGGIN® Ultra 100 capable of stacking up to 65,536 times, we have further enhanced the DynaQ® functionality to take advantage of this additional stacking. New DynaQ® colors – purple, light green, and dark green – represent stacks beyond 511, 2049 and 8192, respectively, giving you visibility into when you are hitting Ultra stacking levels.

DynaQ® is one of the many unique features of Sensors & Software products that help you to achieve the best data quality without needing to worry about complex settings during data collection.

## Upcoming Courses

### Subsurface Utility Locating with GPR course (NULCA-accredited)

[July 6, 2020](#), Mississauga, ON, Canada

[September 14, 2020](#), Mississauga, ON, Canada

### Concrete Scanning with GPR course

[July 7, 2020](#), Mississauga, ON, Canada

[September 15, 2020](#), Mississauga, ON, Canada

### 3-Day GPR course

[September 1-3, 2020](#), Mississauga, ON, Canada

[October 7-9, 2020](#), Höhr-Grenzhausen, Germany



## COVID-19 Update

We know that COVID-19 is top of mind for everyone globally. We want to assure our customers, suppliers, and partners that we are monitoring the situation closely and are taking every precaution to protect our employees and customers, while still maintaining the high level of service that you expect from us.

At this time, we remain open, we are able to process and ship orders, and support you with your GPR sales, support, rental, and repair needs but we have reduced our in-office staff.

Please call ahead before visiting any of our offices, and refrain from visiting our offices if you are not feeling well in any way, if you have traveled outside of the country within the past 14 days, or if you have interacted with someone who has been diagnosed with COVID-19.

We are following guidance from the Public Health Agencies and we will continue to update you should anything change. Should you have any concerns do not hesitate to contact us.

Thank you for your business, and for placing your trust in Sensors & Software.

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