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In this issue

Sensors & Software loves to share customer stories in our newsletter! We find that customer stories are always popular with our newsletter readers. This newsletter contains two articles kindly provided to us from customers. The details and descriptions are those of the authors and Sensors & Software has not made any edits except for typographical errors. If you have a GPR topic of interest to share, please contact us and submit your suggestions.

Noggin® 500 Reveals Details of a Roman Fortress

Written by Andre Gonciar – Bioarch Canada

In 2015, we acquired a Noggin® 500 SmartTow configuration, for archaeological exploration and teaching (Figure 1). Being new to GPR, to learn its capabilities, we conducted an intensive, 6-week GPR survey inside the Roman Fortress Castrum Cumidava in Rasnov, Romania (Figure 2).

Figure 1: Noggin® 500 SmartTow system used for the survey of the Roman site in Transylvania, Romania.

Figure 2: Aerial photo of Castrum Cumidava site showing excavations that are still open. The black structures are confirmed by excavation, while white structures are inferred by extrapolating the results from the excavations.

The presence of a Roman fort was first documented by M.J. Ackner in 1856. The first excavations were carried out in 1939 but were never published. Excavations resumed in 1969 – 1974 but only the 1969 – 1970 results have been properly published. Since 2006, excavations have continued inside the castrum, but, so far, no results have been published beyond summary excavation reports.

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Our survey covered the entire interior surface, except the areas heavily affected by current and past excavations (Figure 2). XY grids of different sizes (to account for topographic imperatives) were set with line spacings of 0.5 m or 1 m. The total area covered by the GPR survey grids was roughly 120 x 160 meters.

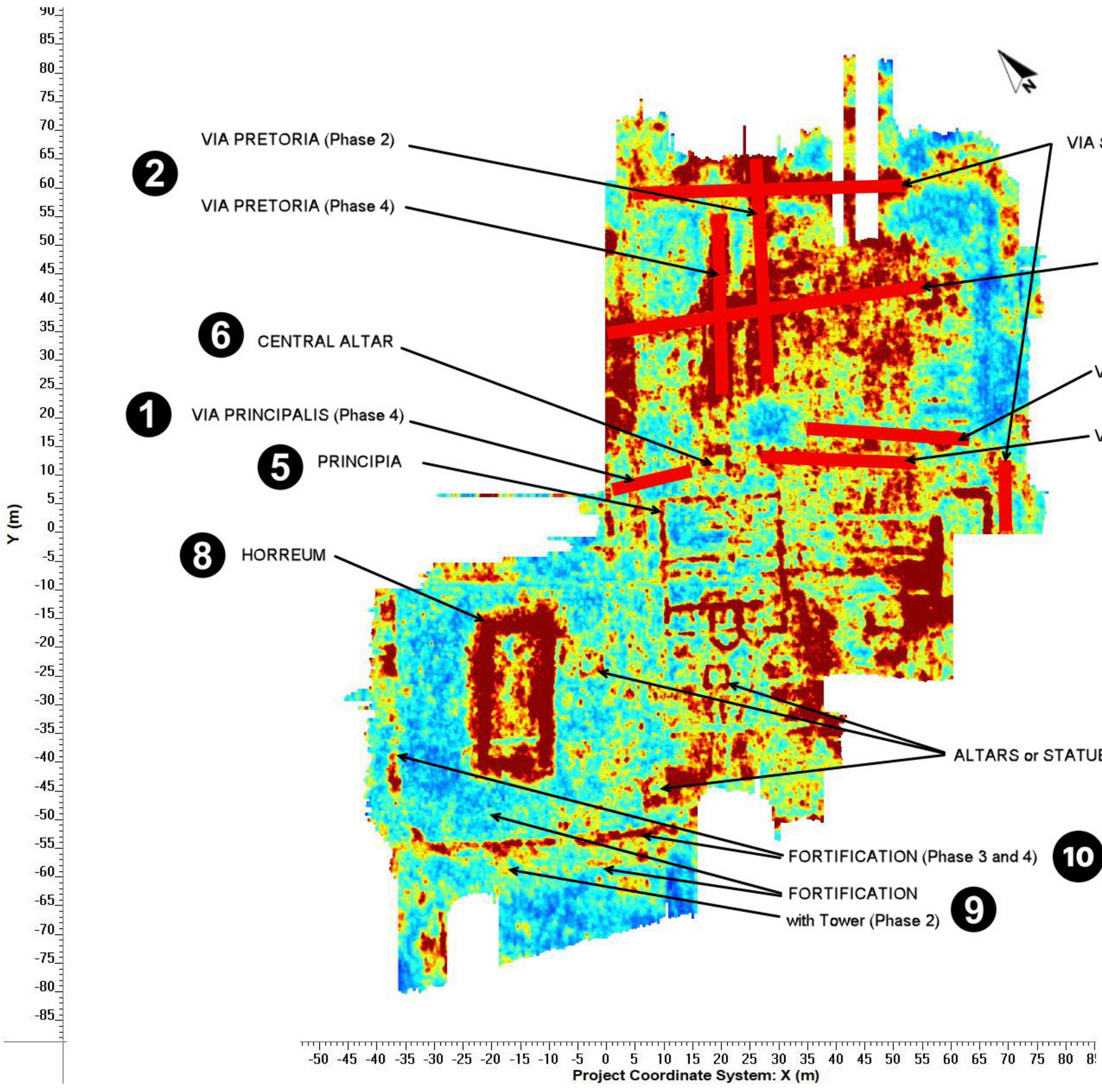

Figure 3: 70 to 80 cm depth slice displayed in EKKO_Project from the Noggin® 500 GPR data showing strong (red) reflections from buried structures. Annotations are the interpretations of the structures revealed by the GPR.

As shown in Figure 3, the results are spectacular!!! We have a full and detailed overview of the layout of the castrum in its last phase. All the important, typical Roman streets have been identified:

1. Via Principalis (**1**), linking the southwest and the northeast gates,
2. Via Praetoria (**2**), perpendicular to the Via Principalis (**1**), going from the central core of the castrum to the main (NW) gate,
3. Via Sagularis (**3**), around the interior of the castrum, along the fortification walls, and
4. Via Quintana (**4**), sub perpendicular to Via Praetoria (**2**), separating the North half of the castrum in two.

Via Principalis (**1**), divides the castrum in two major sectors: the North half is composed of wooden barracks, except for one single stone building in the western quadrant, fully excavated. The large number of GPR reflectors on both sides of the eastern half of Via Quintana (**4**) may suggest the presence of the various castrum shops, such as the smithy (blacksmith).

The South half of the castrum contains all the remaining stone buildings, with the core administrative building, the Principia (**5**), a large (approx. 17 x 20 m), complex structure with multiple rooms and four or five apses (semi-circular structures) on the South side.

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On both sides, there are several adjacent buildings, all the way to the Via Sagularis (**3**), to the North. In front of the Principia (**5**), at the intersection of Via Principalis (**1**) and Via Praetoria (**2**), we have identified the unit's altar (**6**). Behind it, several smaller, square structures of variable size, have been identified, possibly well(s), statue foundations, and/or other altars (**7**). To the West, we have confirmed the presence of a large (approx. 11 x 19 m) rectangular building, most likely a warehouse (horreum, **8**).

The most important aspect of the GPR results is the information regarding the castrum evolution, exposing more of its "quirks". The evidence available now from the archaeological excavations is mostly anecdotal, and tentatively identifies three separate phases. However, the GPR data seem to suggest the presence of four phases.

Phase 1: potentially from 101/2AD to around 117AD – it was made of wood and earthen fortifications, invisible to the GPR due to a combination of very weak signal, destruction, and reconstruction of later phases.

Phase 2: saw the construction of stone fortifications (**9**). However, at the intersection of the earliest iteration visible of Via Pretoria (**2**) and Via Principalis (**1**), the GPR data shows no traces of stone foundations of either the required altar or command structures, which indicates that all interior structures were still made from wood. This phase came to an end most likely with the first Marcomannic War, possibly around 170AD, with the partial or total destruction of the wooden structures.

Phase 3: construction resulted in an overall expansion of the fortified perimeter and the construction of the stone buildings in the South half of the castrum (**10**). The GPR data provides detailed mapping of almost all the stone structures in the camp. It also shows that Via Principalis (**1**) was moved 4 – 5 m to the SW and Via Pretoria (**2**) about 10 m to the West from the previous phase, which also meant that the NE and SW gates were moved, and, since Romans really liked straight roads and orthogonal layouts, by extension, the NW and SE gates were moved as well.

Phase 4: the changes from the third to the fourth (last) phase seem to indicate that the wooden structures inside the castrum, as well as the NW gate, were partially destroyed, possibly during the Germanic Invasions around 250AD. The GPR data shows that Via Principalis (**1**) was not straight any longer, since the gates at both ends were not aligned; the SE segment of the road remains unchanged, but the NW portion, starting from the stone altar (**6**) at the "center" of the castrum rotated at a 15° angle counterclockwise from its initial phase 3 orientation. Furthermore, the last iteration of Via Quintana (**4**) was not perpendicular to Via Pretoria (**2**) but parallel with the South segment of Via Principalis (**1**) indicating a large scale and perhaps complete restructuration of the area containing the wooden buildings, which – sadly – were not visible to the GPR.

In conclusion, the impressive detail of the structures of Castrum Cumidava provided by the Noggin® 500, at that time our newly acquired GPR system, did not disappoint!

Geoforensics - Innovative 3D Modelling GPR Data for Graveyards and Criminal Investigations

Written by T.B. Kelly and Professor G.D. Wach - Dalhousie University

Geoforensics is the application of geological/geophysical techniques to forensic and archaeological investigations. Accurate representations of the subsurface may be needed but cannot be acquired by invasive techniques that may disturb the ground in culturally sensitive areas, or areas involving a criminal investigation. Ground-penetrating radar (GPR) is a proven, non-destructive, and non-invasive geophysical technique used extensively for imaging the subsurface across a wide range of applications. Subsurface reconstructions using GPR have typically been presented as 2D vertical and horizontal cross sections, resulting in a visualization of subsurface objects and their spatial extents. With the development of new software, 3D modelling of GPR data is now emerging as the new standard. Despite these new developments, there remains an inadequate examination and testing of these techniques, especially in deciding if their application is justified and advantageous.

This study applied a GPR grid survey on a churchyard cemetery (Figure 2) to produce and assess 2D- and 3D-modelled reconstructions of the cemetery burial locations (Figures 3-5).

Two of the study objectives were to (1) demonstrate a unique workflow (Figure 1) method to visualize the data in 3D and (2) to provide a better understanding of the subsurface using a 3D model to accurately show the size and shape of buried objects and their spatial relationships.

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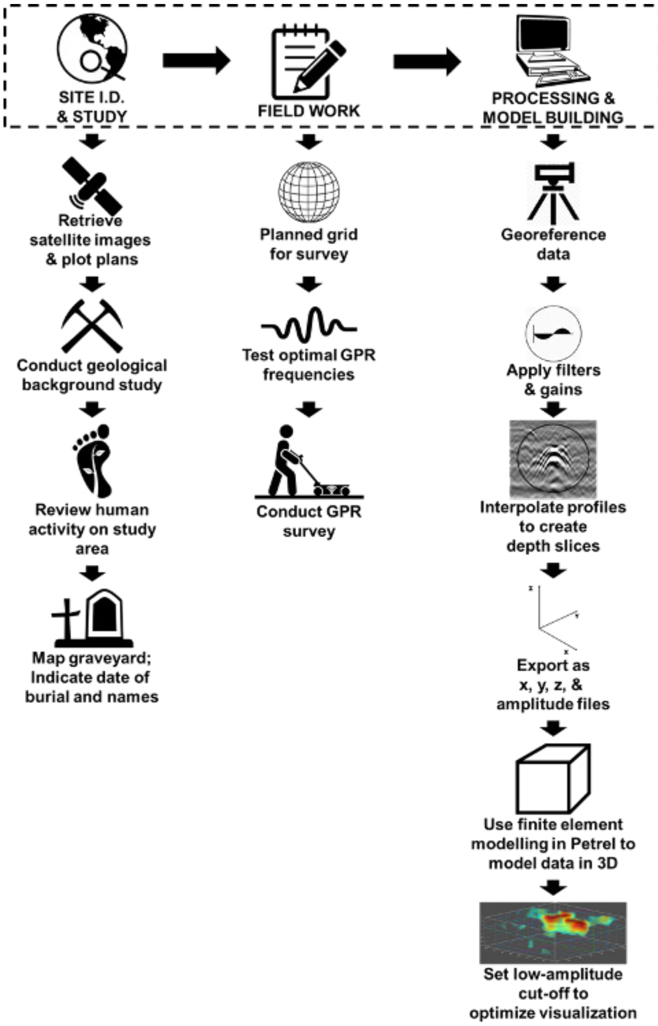

Figure 1: Workflow for site investigation, data collection and data processing.

Data collection and processing was achieved using a Sensors & Software pulseEKKO™ PRO SmartCart GPR system and EKKO_Project™ software, respectively. The 3D modelling component was accomplished using Schlumberger's Petrel™ E & P software platform, which is customized to the petroleum industry.

Study Area

The study area is a church cemetery located in Nova Scotia, Canada, approximately 44 km northwest of the capital of Halifax. The survey area consisted of the 30 by 40 meter (1,200 m^2) southern section of the cemetery and resulted in a total of 40 separate radargrams (total distance of profiles was 1,352.5 m); 25 oriented north-south and 15 oriented east-west (Figure 2). Line spacing was approximately 1 m and was adjusted to avoid headstone locations and other surficial features. The 200 MHz center frequency antennae with a separation of 0.5 m were used for all lines.

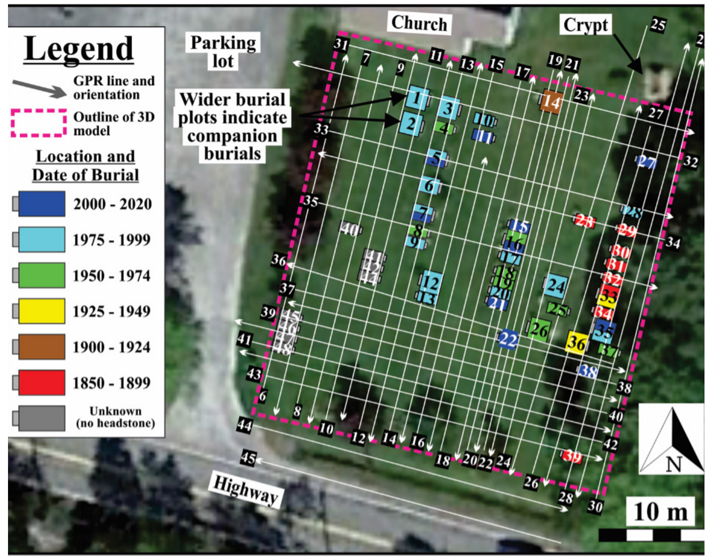

Figure 2: The study area, indicating grave site location/age, GPR line location/number and outline of the model (dashed line).

Model Building and Results

The processed radargrams were exported from EKKO_ Project™ into Petrel™ and interpolated to generate 40 2D depth slices of the subsurface, one every 0.1 m to a total depth of 4 m. The interpolation method in Petrel™ involved importing the 2D depth slices and interpolating data to create a solid 3D volume. This is common for displaying and understanding the 3D shape and spatial relationship of buried objects. In GPR literature, 3D models are displayed in one or a combination of four different ways (Figure 3).

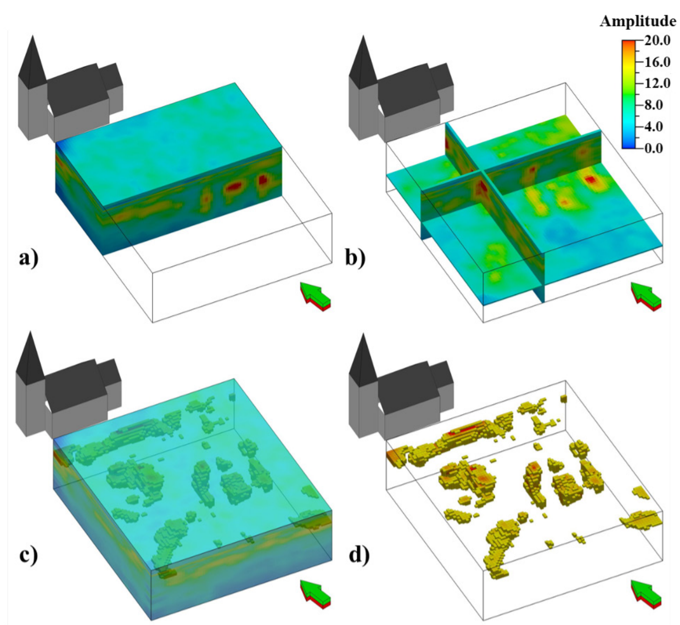

Figure 3: Various ways 3D models are typically displayed (a) Sectioning in a single plane causes difficulties with interpreting the shape and spatial relationship of objects. (b) Sectioning in x, y, and z planes provides a partial interpretation of the shape and spatial relationship of objects. A partial transparency filter (c) and a complete transparency filter (d) can make depth relationships of objects difficult.

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A combination of Figure 3b and d provided the best render of the 3D model. Using a transparency filter to remove the low amplitude reflection signal component, the high amplitude reflections remain, which are displayed as the 3D blocks. The high amplitude reds and yellows suggest buried objects and show the shape and size accurately. Combining both the 2D radargrams and the 3D model, it is possible to reach an intuitive understanding of the subsurface.

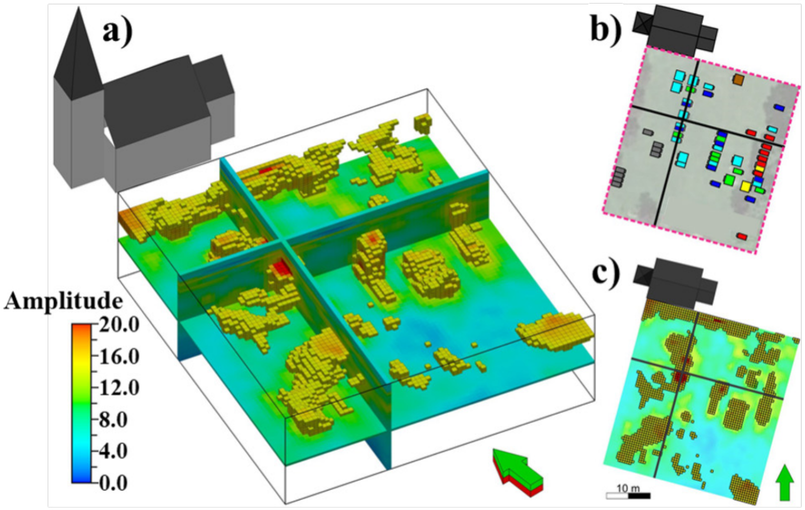

Figure 4: A render of the model. a) The 3D display techniques from Figure 2b and d gave the best visualization of the shape and size of the subsurface objects. The 2D cross-sections and depth slice increase the understanding of the spatial relationships between objects. b) Plan view of the cross-sections relative to the location of the burial sites. c) Plan view showing several high amplitude reflections in the southwest part of the model, which are likely unmarked burials.

For example, GPR Line 35 crosses burials 8, 16, 17, and 32 (Figure 2). Figure 5 shows the radargram for Line 35: unprocessed (top), gained (middle) and the cross-section that is part of the 3D model (bottom). The unprocessed radargram indicates faint hyperbolic reflectors that dissipate below 3 m. The gained radargram reveals more clearer and abundant hyperbolic reflectors and suggests three regions of interest: (1) at 10 m, (2) at 17 – 20 m, and (3) at 28 – 30 m along the radargram. A cross-section through the 3D model shows the three zones more intensely. The high amplitude area at position 9 – 12 m corresponds to burial 8. The high amplitude area from 17 – 21 m corresponds to burials 16 and 17. The moderate amplitude zone between 27 – 30 m corresponds with burial 32.

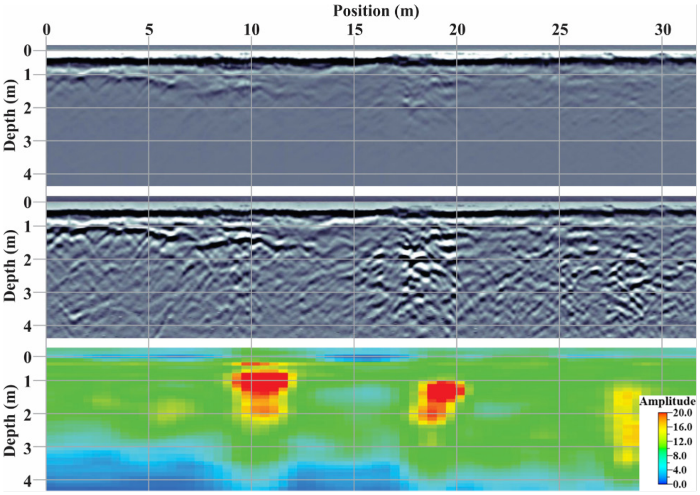

Figure 5: The west to east trending GPR line 35. (Top) The unprocessed radargram showing faint hyperbolic reflectors. (Middle) The gained radargram showing clearer and more abundant hyperbolas. (Bottom) A cross-section through the 3D model showing three zones of high amplitude, interpreted as burials.

Conclusions

The results of this study demonstrated the ability to (1) accurately map a cemetery, distinguishing burial sites from one another, (2) identify otherwise unknown burial sites and (3) create an overall more intuitive, easily manipulatable, 3D model to optimize visualization, a key requirement to help with GPR data interpretation. We expect our findings to be of value to geoforensic and archaeological studies, and criminal investigations.

Reference: A novel approach to 3D modelling ground-penetrating radar (GPR) data – A case study of a cemetery and applications for criminal investigation; T.B. Kelly, M.N. Angel, D.E. O'Connor, C.C. Huff, L.E. Morris, G.D. Wach - Forensic Science International 325 (2021). https://doi.org/10.1016/j.forsciint.2021.110882.

Concrete Scanning Course on SensoftU - Coming in August!

SensoftU, launched one year ago, is an innovative, online learning platform for advancing GPR education. We are proud to add another course to SensoftU: **Concrete Scanning with GPR**.

This course focuses on the use of GPR for scanning concrete. Like the other courses on SensoftU, it features user interactions to improve learning and retention of key concepts (Figure 1). While still providing the necessary theory and operational information, this course emphasizes data examples to illustrate the various situations that concrete scanners can encounter in the field (post-tension cables, pan decking, beams etc.). Upon completing the course and obtaining a passing grade, the user can print a certificate of completion.

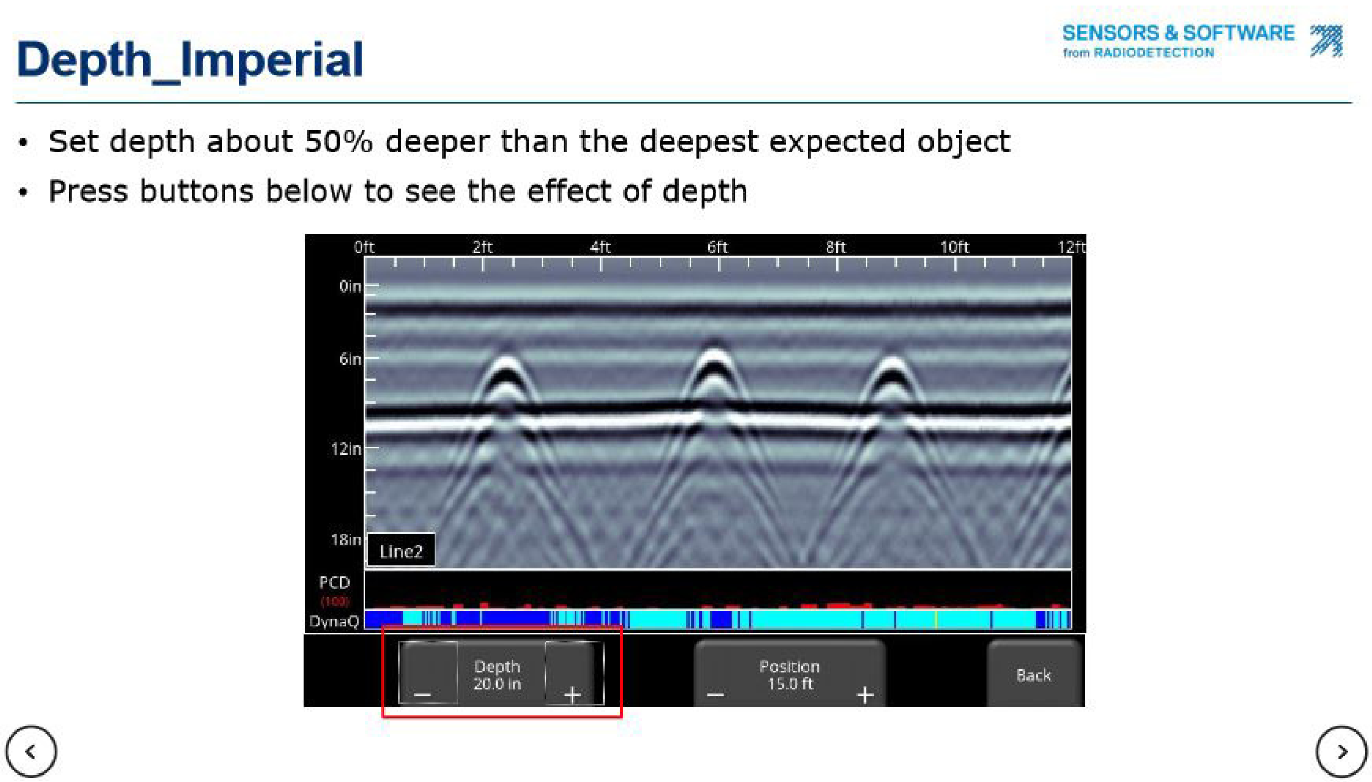

Figure 1: Screen capture from the new Conquest course on SensoftU, showing how to increase or decrease the Depth setting to display more or less data on the Conquest system.

SensoftU was created to augment our existing training offerings, giving our customers additional options for learning. Hundreds of people have logged into www.SensoftU.com to further their GPR knowledge in a convenient and cost-effective way. The feedback has been very positive: "Videos and animations clearly show the concepts being taught", as one user described what they liked about SensoftU. Another user commented that "in a very short time, a full learning package was provided". As to why they took courses on SensoftU, "not having to travel" and "progress at my own pace", topped the list of reasons.

There are 3 other structured courses on SensoftU: Utility Locating with GPR, IceMap and Rescue Radar. These courses were developed following years of experience teaching people about the use of GPR for a variety of applications. All these courses aim to recreate the experience of live, in-person courses, using videos and interactions. It has the added advantage of allowing users to progress at their own pace, and at their schedule.

There is high demand for training on concrete scanning, and this new Concrete Scanning with GPR course will provide a convenient, on-demand training option for the industry. **This new course will be launched in August and is available for purchase on SensoftU. Once launched, every Conquest® 100 system sale will include two free SensoftU courses.**

Whether you are training new employees, providing a refresher course for existing employees or taking a course to meet continuing education requirements, SensoftU is ready and waiting. To register for a course, visit www.SensoftU.com. For group rates and academic discounts, please contact Sensors & Software.

Upcoming Events

ICUEE - The Utility Expo - September 28-30, 2021, Louisville, Kentucky, USA

Covering more than 30 acres, The Utility Expo is the largest event for utility professionals and construction contractors seeking the latest industry technologies, innovations, and trends.

Radiodetection, Schonstedt and Sensors & Software will be exhibiting our products at The Utility Expo.

Come visit us at booth #E1032
Register to attend

CGA Conference & Expo 2021 - October 12-15, 2021, Orlando, Florida, USA

The 2021 CGA Conference & Expo is the premier event for damage prevention stakeholders to assemble to share knowledge, data and technology.

Radiodetection, Schonstedt and Sensors & Software will be exhibiting our products at CGA.

Come visit us at booth #101
Register to attend

Upcoming Courses & Webinars

Webinar - Using GPR for locating Unmarked Graves - August 11th 2021

Attend this free webinar to learn more about using Ground Penetrating Radar (GPR) for locating unmarked graves. Using a combination of GPR theory, instrument setup, survey techniques and data examples, this webinar will provide the community at large (GPR operators, those hiring the service, government) a better understanding of the application and methodology involved for locating unmarked graves.

Register now for this webinar

Virtual Course - GSA 2021 - Ground Penetrating Radar - September 17th 2021, 7am – 2pm

This online course covers a bit of everything about Ground Penetrating Radar (GPR). The agenda includes GPR theory, instrumentation, survey design, data analysis and reporting with EKKO_Project software and GPR data interpretation. To learn more about this course, click here.

Register now with GSA to attend Course 507 - Ground Penetrating Radar

Virtual Course - GPR: Principles & Practice - October 20-21, 2021, online 9am to 1pm EST (UTC -5) (both days)

Attend this online, live instructor led GPR course. Using slides, videos and interactions, participants will learn all aspects of GPR from theory and instrumentation to survey techniques and data interpretation.

Click here to learn more about the course and Register.

On-Demand Training

Pre-recorded webinars and EKKO_Project tutorial webinars are at: www.sensoft.ca/georadar/webinars
Interactive courses are available via our online learning platform: www.SensoftU.com

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