GPR Technology Vol 7, No. 28, October 2011

Subsurface Views

Sensors & Software Inc.

From our customers' files

Ice shelf GPR surveys

Ice shelves are thick (> 20 m) floating masses of ice attached to land. In the Canadian Arctic these features exist along the northern coast of Ellesmere Island, but have been losing mass since the early 20th century. At present, information about ice shelves and how they have changed is mainly restricted to areal extent with limited knowledge of ice thickness.

In the spring of 2008, the Milne Ice Shelf was traversed with pulseEKKO PRO GPR systems with 50 and 250 MHz antenna frequencies during the Canadian Ranger's Op Nunalivut Patrol. Both systems yielded good results, even in temperatures below -30^{0} C, and were able to penetrate the entire depth (>94 m) of the thickest known parts of the ice shelf. On a subsequent survey in 2009, the smaller 250 MHz system was used exclusively.

System Set-up

The pulseEKKO PRO was mounted in sleds and towed behind a snowmobile at approximately 20 km/hr (Figure 1). Positioning was provided by an external NX-01 Star GPS receiver connected to the Digital Video Logger (DVL) which inserted a unique position into every GPR trace. The higher frequency (250 MHz) shielded bi-static transducers were custom-fitted into a plastic sled that sat directly on top of the snow surface.

(continued on page 3)

Next generation of IceMap goes wireless:

IceMap - Integrated GPR

One of the very first applications for GPR in the 1950's and 60's was measuring the thickness of glaciers and Antarctic ice sheets (see accompanying story). Measuring ice thickness is one of the best applications for GPR because the electrical properties of ice allow the GPR signal to easily travel to great depths before being absorbed.

As oil and gas exploration moved north into the Arctic in the 1970's, another ice thickness application emerged: monitoring the ice thickness on winter ice roads used to transport equipment and people into remote areas for resource exploration.

(continued on page 2)

In this issue

IceMap - Integrated GPR

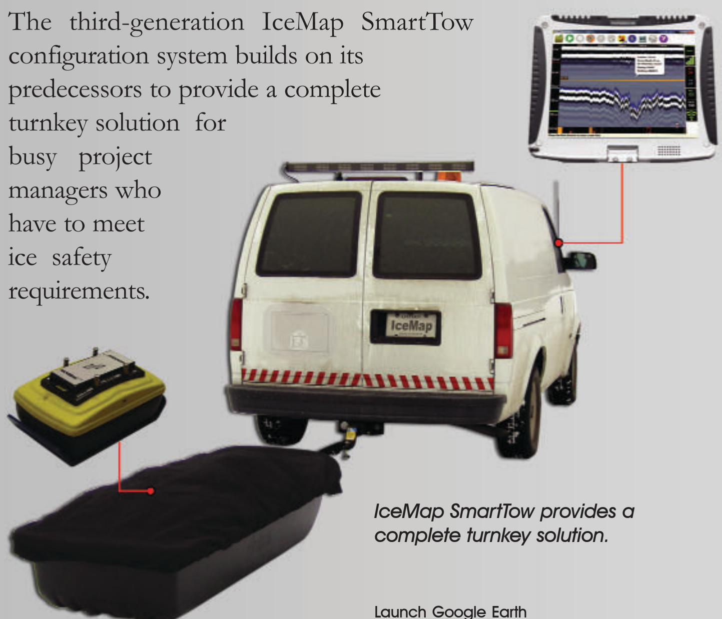
(continued from page 1)

Sensors & Software's principals have been involved in the evolution of this application since the 1970's. In the early days, it took a truck full of equipment, batteries and extremely-knowledgeable operators to produce ice thickness cross-sections on burnt paper records.

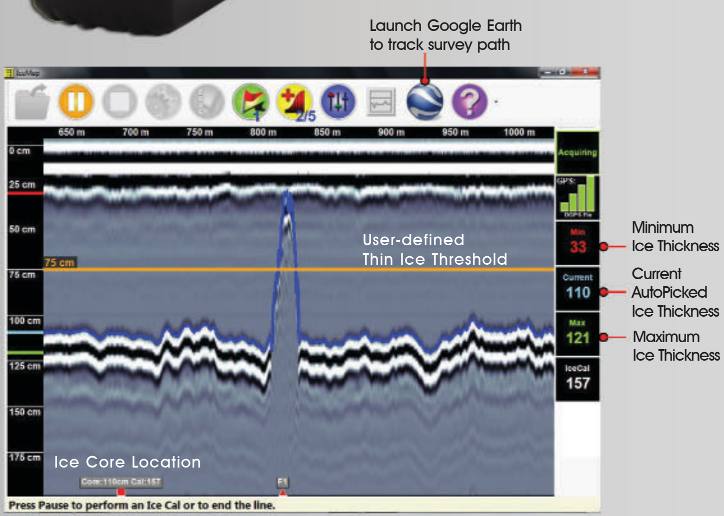
By 2001, when a Noggin GPR system was first used for this application, the days of ice profiling with a compact, low power-consuming, easy-to-use GPR system recording digital data had begun.

When ice road construction companies and government transportation groups saw the cost-effectiveness of GPR technology to continuously measure ice thickness and quickly delineate problem areas, the methodology for building and monitoring ice roads changed. Since that time we have worked closely with these groups and regulatory parties to improve our products in both ease-of-use and practical outputs.

The third-generation IceMap SmartTow configuration system builds on its predecessors to provide a complete turnkey solution for busy project managers who have to meet ice safety requirements.



IceMap SmartTow provides a complete turnkey solution.



IceMap user-interface features.

IceMap SmartTow features

- **Wireless, Fully-integrated Tow Sled** - The SmartTow configuration provides the GPR sensor, battery, GPS and wireless communications components in a rugged, environmentally-designed IP67 field case; all set in a field-tested tow sled. The IceMap Sled is towed across the ice surface via truck, snowmobile, ATV or by hand. Rapid data acquisition enables the system to be towed at speeds up to 80 km per hour.
- **PC for Data Display and Recording** - A Toughbook PC mounted in the tow vehicle receives the data from the sensor package over a dedicated wireless communications channel. The embedded IceMap software on the Toughbook PC provides a simple user-interface for real-time monitoring of ice thickness both graphically and numerically while surveying. The operator has a view of the ice thickness at all times.
- **Simple Settings** - The only parameters the operator needs to set are data collection speed in km/hr or mph, the depth and the sample interval distance on the surface.
- **Auto-Picking** - Data are processed and the ice bottom reflection automatically picked using a unique algorithm developed by Sensors & Software. The auto-picked bottom of ice is continuously displayed on the data image along with current ice thickness value. The display also shows the maximum and minimum ice thicknesses for the current survey line.
- **Thin Ice Warning** - The operator can set the minimum thickness threshold line to any value so that when the current ice thickness drops below that value, an audible warning sounds and the display flashes in red.
- **Ice Core Calibration** - The IceMap software makes it easy to enter coring results to calibrate the ice velocity and update ice thickness for the most accurate results.
- **GPS** - Integrated GPS for accurate positioning, allowing thin and problem ice areas to be quickly pinpointed.
- **Survey Path** - During data collection, the real-time survey path can be overlayed on Google Earth images or satellite photos.
- **Data Review** - After completing a survey line, the entire line can be quickly reviewed by using the threshold line to reveal all the locations with ice thinner than the current threshold value.
- **IcePicker** - Included with the package is the IcePicker software which allows the user to systematically review and edit ice thickness data. The edited data can be exported in a variety of forms including tabulated results needed for regulatory Health & Safety reports, geo-referenced information for GIS platforms and overlays on Google Earth.

The latest IceMap sets a new standard for this old application. The full-featured SmartTow configuration is essentially ready to go once you are on site. Hook it to your tow vehicle, turn on the power and you are ready to work.

For more information on IceMap contact our Application Specialists.

Ice shelf GPR surveys *(continued from page 1)*

The Milne Ice Shelf's surface topography is characterized by a series of ridges and troughs (some of which have very steep gradients) which parallel the coast and prevailing wind direction. The set-up of the 250 MHz system enabled areas of extreme topography to be traversed, something not possible with the 2 meter long 50 MHz antennas a year earlier.

GPR Data Processing

Post-processing (DEWOW filter and trace differencing) of the data was performed using the EKKO_View Deluxe software. Two-way travel time (ns) was converted to ice depth using a propagation velocity of 0.170 m/ns based on a common midpoint (CMP) survey. Ice thicknesses were determined using a combination of manual and automated selection in the IcePicker software. A DVL gain function was applied to visually enhance the reflection at the ice shelf base at the expense of internal resolution. The large difference in dielectric properties between ice and water made the bottom of the ice shelf clearly identifiable in most traces. Two strong continuous events are clearly visible on most GPR cross-sections. The flat uppermost event corresponded to the air-ice interface while the lower undulating event corresponded to the ice-water interface (Figure 2). Topographic correction for elevation used GPS data, but the correction may not have adjusted for topography due to limited accuracy of a non-differential GPS receiver. Undulations in the post-processed cross-sections appear to reflect the ice shelf's characteristic ridge and trough surface topography, although further study is required to confirm this observation.

Several discontinuous events were apparent in the upper ~15 m of many GPR cross-sections. These discontinuous events likely correspond to internal reflecting horizons caused by the alternation between firn and ice lenses, and were most often present in the 250 MHz data owing to that system's higher resolution.

Results and Conclusions

Mean ice thickness for the Milne Ice Shelf was ~55 ±1.9 m with a standard deviation of 22 m and a maximum thickness of 94.1 m. Considerable spatial variability was observed across the ice shelf. Maximum ice thicknesses were observed in proximity to a tributary glacier. This location of maximum thickness is the same as that identified in a 1981 RES study which provides corroborating results. The authors found that the higher frequency system (250 MHz) struck an excellent balance between resolution and penetration depth. Further, the ease of maneuverability of the smaller, shielded transducers allowed them to access areas of extreme topography via snowmobile. When considering the advantages of the higher frequency GPR system it is important to note that the ice imaged here was cold and relatively free of debris and other inclusions that are often present in temperate glacier ice. Further, the strong dielectric discontinuity (ice-water interface) made the base of the ice shelf easily identifiable.

Figure 1: *The pulseEKKO PRO was mounted in sleds and towed behind a snowmobile at approximately 20 km/hr.*

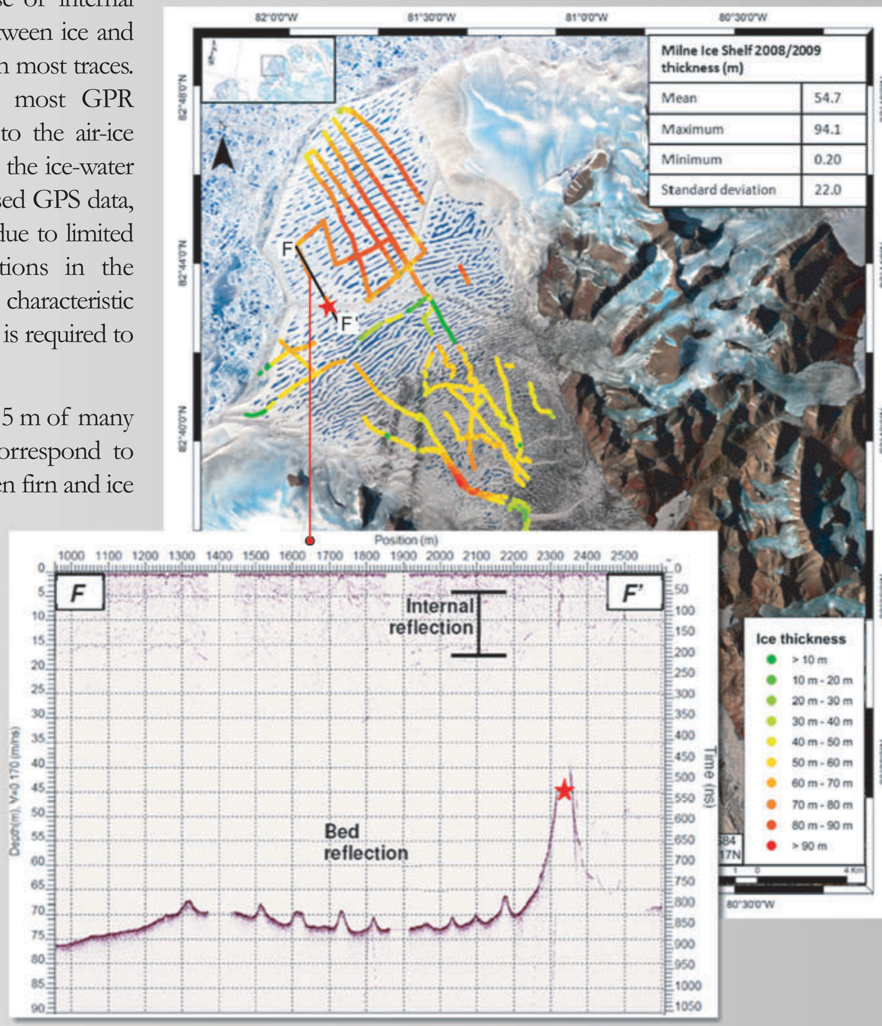


Figure 2: *Aerial photo of the coast of Ellesmere Island and the Milne Ice Shelf with ice thicknesses superimposed in variable colors. The location of the GPR survey line, F - F', is indicated as a black line; the cross-section view of the line shows the strong reflection from the bottom of the ice shelf with the red star indicating a crack.*

Story and pictures courtesy of Colleen Mortimer and Luke Copland, University of Ottawa.

Technical Papers & Notes

1. **Assessing the potential to detect oil spills in and under snow using airborne ground-penetrating radar** - SEG: Geophysics; Vol. 75; No. 2; Pg. G1-G12; 2010
   By: John H. Bradford, David F. Dickins, Per Johan Brandvik **ref 432**

2. **Semblance response to a ground-penetrating radar wavelet and resulting errors in velocity analysis** - EAGE: Near Surface Geophysics; Vol. 8, No. 3, pg. 235-246; 2010
   By: Adam D. Booth, Roger Clark, Tavi Murray **ref 433**

Upcoming GPR courses & workshops

One Day Noggin® Short Course
November 7, 2011
January 9, 2011

Our Noggin® short courses are offered throughout the year to anyone interested in learning more about GPR and subsurface imaging.

One Day Conquest™ Short Course
November 8, 2011
January 10, 2011

Our Conquest™ courses are offered to anyone interested in learning more about our concrete imaging instrument.

Imaging Concrete with GPR workshops
- November 15, 2011 - New York, NY
- December 6, 2011 - Mississauga, ON

See us at ...

AGU
San Francisco, CA
December 5 - 9, 2011
www.agu.org/meetings/

World of Concrete 2012
Las Vegas, NV
January 24 - 27, 2012
www.worldofconcrete.com

CGA 2012
Las Vegas, NV
March 6 - 8, 2012
www.commongroundalliance.com/

Ask-the-Expert

What's involved in GPR topographic compensation processing?

GPR cross-sections are most readily used when they are geometrically similar to the actual subsurface.

In GPR cross-sections, time is used interchangeably with depth; further, depth and elevation are interchangeable when the ground surface is flat. GPR cross-sections using a zero time datum appear distorted when topographic variations occur.

Figures 1a and 1b illustrate the concepts.

Both signal amplitude and travel time are impacted by topographic changes; a variety of computer processing manipulations are used to re-construct reasonable facsimiles of the subsurface.

The most widespread topographic compensation uses simple time shifts to compensate for slowly varying topography as depicted in Figure 1c.

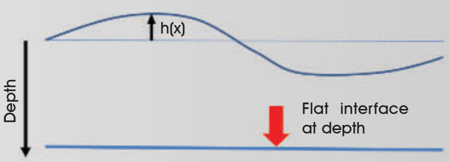


Figure 1a: Undulating surface over a flat reflector.

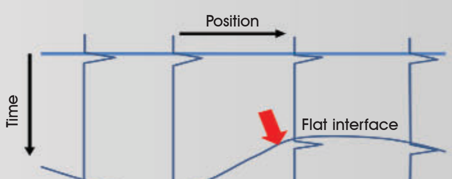


Figure 1b: Resulting GPR cross-section as a "flat" surface and undulating reflector

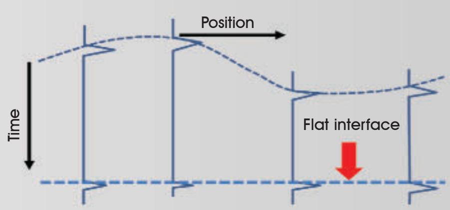


Figure 1c: Use of a topographically determined time shift to "correct" the cross-section.

Each GPR trace is shifted in time by the amount $\Delta t = \frac{-2h(x)}{v}$ where h(x) is elevation at position x, and v is velocity.

In Figure 2a, a strong "flat" water table reflector under a sloping surface results in a water table that slopes up to surface. After applying a static time shift topographic compensation the more representative cross section in Figure 2b is obtained.

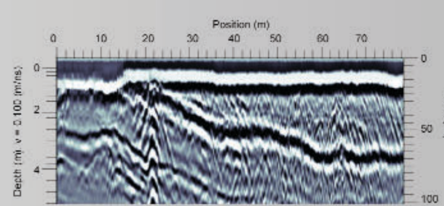


Figure 2a: GPR cross-section observed over a "flat" water table with a varying surface topography.

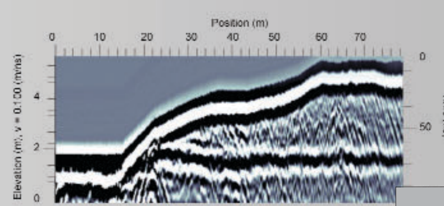


Figure 2b: GPR cross-section after applying a time shift topographic compensation.

More sophisticated methods are possible; concepts and references are in the Technical Note #469 (see www.sensoft.ca/topo-correction).