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SUBSURFACE VIEWS

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IceMap in Iceland

Iceland is the island of fire and ice in the North Atlantic Ocean. The island is volcanically active (remember the eruption of the Eyjafjallajökull volcano in April 2010 that disrupted air traffic across the Atlantic and Europe for many days?) but glaciers also cover about 11% of the country.

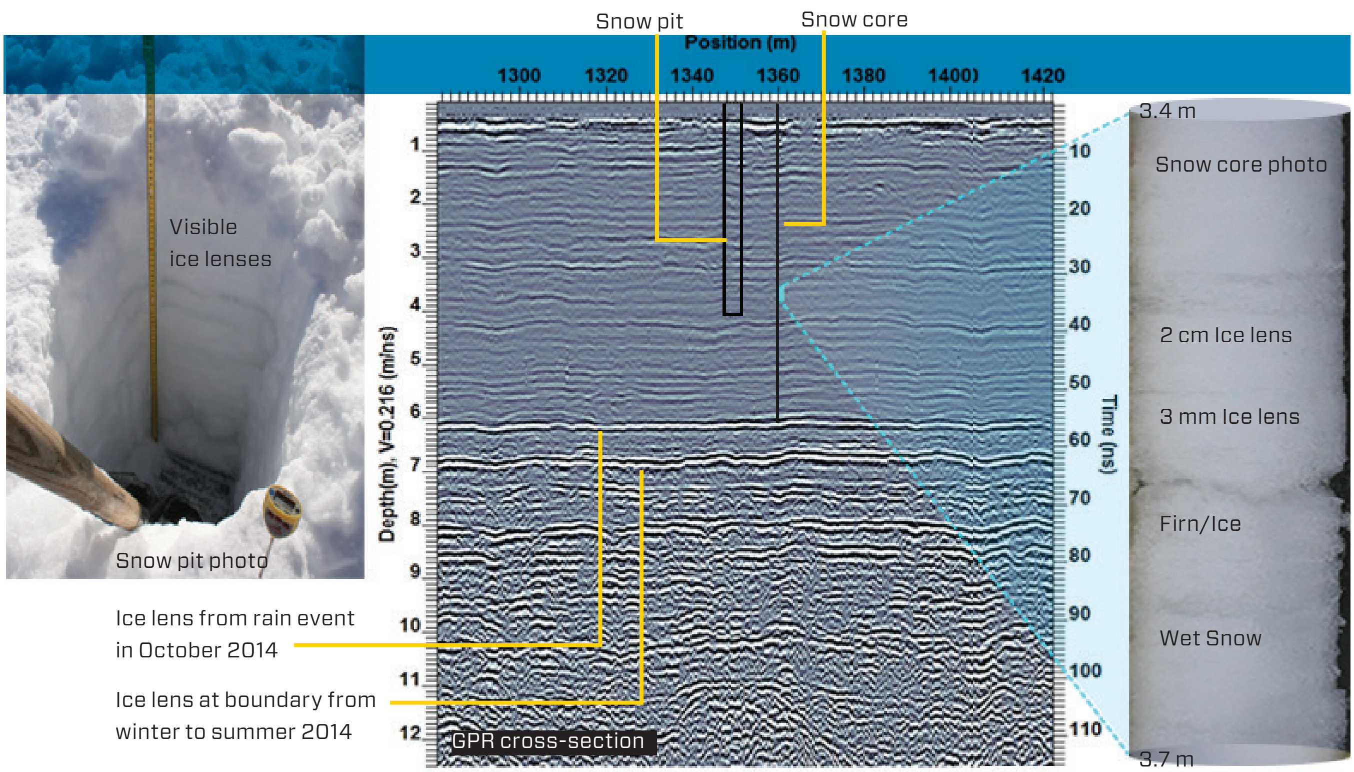
Iceland generates 99% of its energy from renewable sources: hydroelectric and geothermal. Landsvirkjun (The National Power Company) is one of the largest producers of renewable energy in Europe and its total electricity generation in 2011 was 12,485 Gigawatt-hours. Landsvirkjun operates 14 hydroelectric power stations all over Iceland in five separate catchment areas. Glaciers play a critical role in hydroelectric power production in Iceland.

Over 70% of energy is produced with hydroelectric power generated by glacier and snow melt fed rivers. The melt water from snow and glaciers is stored in reservoirs and diversions during the summer (see Map on page 2) and utilized over the winter, when inflow is low. Knowing the amount of snow accumulated in the catchments by late winter is vital for spring inflow estimates for reservoirs. Calculating melt water volumes ahead of time allows for adjustments to be made to the annual power plan if needed. This ensures Iceland's power requirements are met without interruption.

The Icelandic highlands are in a maritime climate resulting in a complex snowpack structure with high variability in spatial snow distribution. For the past 25 years Landsvirkjun has annually surveyed glaciers for mass balance using conventional methods such as digging snow pits but has now added surveying of snow-on-land to the monitoring program.

In spring 2015, an IceMap system was used to provide continuous snow thickness data from the catchments both on and off glaciers, improving on the conventional "point" ***continued on page 2***

Sensors & Software

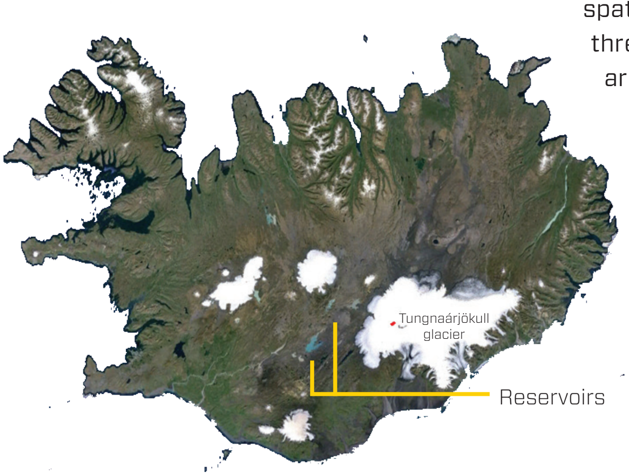


IceMap makes a large difference in accurately estimating water volumes for hydroelectric power generation.

continued from page 1 measurements and adding to the knowledge of snowpack extent and winter snow accumulation.

The IceMap system consists of a Noggin 500 GPR and an integrated GPS housed in an environmentally-sealed box strapped on a toboggan and towed by snowmobile. Data is sent wirelessly to a rugged laptop positioned near the snowmobile operator to allow real-time monitoring of the data.

In total, 65 cross-sections were surveyed on land to assess snow thickness and spatial distribution in the three main catchment areas. Periodically, snow pits were dug to validate the GPR data, calibrate for depth and for gathering data for snow-water equivalence calculations.



After a successful snow-on-land campaign, the program was expanded for assessment of snow accumulation on glaciers for comparison with conventional methods. The image above shows a GPR section on Tungnaárjökull glacier and the snow pit and ice core for the same location.

The GPR reflectors are used like tree rings to identify the boundaries and layers such as the extent of the previous summer's melt, the current winter's snow accumulation and significant rain and melt events. Layer thicknesses can be traced for many kilometers.

IceMap enables acquisition of much higher spatial resolution water content data resulting in more informed decisions regarding operation of the hydroelectric system. Snow distribution on land in Iceland can be very uneven within small areas so the data provided by IceMap makes a large difference in accurately estimating water volumes for hydroelectric power generation.

Story courtesy of Andri Gunnarsson, Landsvirkjun

Late Bronze Age Urban Settlement in Cyprus

Noggin 250 discoveries

We are delighted to present a brief summary of some exciting work by Thomas Urban, Kevin Fisher, Katherine Kearns, Jeff Leon, and Sturt Manning; Cornell University and University of British Columbia.

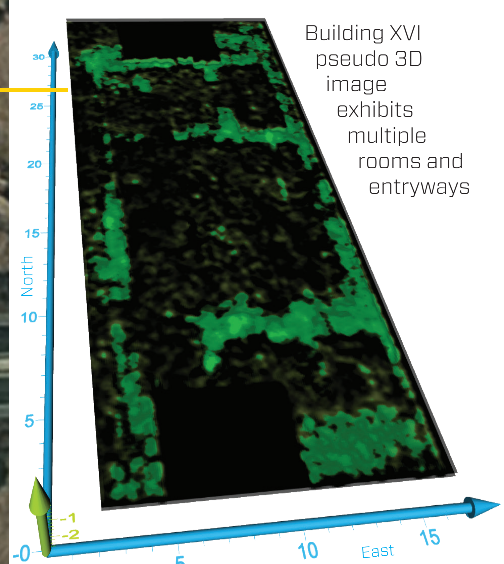
The Mediterranean Island, Cyprus, experienced many changes throughout the Bronze Age, with increased social, political and economic complexity emerging in the Late Bronze Age (1650–1100 BC). Settlements on the island became increasingly urban in composition and international in scope. These settlements created and defined a new Late Cypriot society. Kalavasos-Ayios Dhimitrios (K-AD) is among these sites, and therefore critical to understanding this transformation. Using a Noggin 250 ground penetrating radar (GPR) system, we located and mapped unseen architecture at K-AD.

Kalavasos-Ayios Dhimitrios

K-AD is well positioned as a likely hub for both communication and trade. Surface finds and excavated architecture suggest that the settlement may have covered more than 11ha. Excavations from 1979–1998 (see image below) exposed parts of an urban centre of the Late Cypriot II period (c. 1450–1200 BC). Despite this work, the structuring of wider urban space at K-AD remains unclear. GPR has allowed an expedited search to address unanswered questions at K-AD in an ongoing joint effort with Cornell University and University of British Columbia.

Ground penetrating radar investigation

A previous GPR survey at K-AD found buried structures south of Building X. Additional areas to the west of the Building X complex are the focus of the work described here. A grid survey (with a 0.25 m line spacing) covering a 40m x 60m field to the immediate west of the excavated north-eastern area and a 40m x 60m reconnaissance survey (0.5 m line spacing) of a terrace further west detected many previously unknown features. Perhaps most striking, a large new 12m x 25m structure designated Building XVI (see below the GPR depth slice and the 3D pseudo image) was revealed to the west of the previous excavation area. Evidence of multiple subterranean chamber tombs was also evident in several areas investigated with the Noggin GPR . ***continued on page 4***



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Discussion

The GPR survey at K-AD revealed many significant features and provided high resolution mapping of previously unknown aspects of the site's urban fabric.

The delineation of Building XVI in particular, substantially expands our knowledge of the north-eastern area of the site. The location of a number of potential tombs offers the possibility of improving our understanding of mortuary practice during this transformative period. By placing the architecture found in previous excavations into a broader urban context with the use of GPR, we can move toward a better understanding of Late Bronze Age urban centres such as K-AD, and more generally, the process of urbanisation on the island.

Ask The Expert

If I collect GPR data on a slope, how do I find the exact position of a utility?

Figure 1

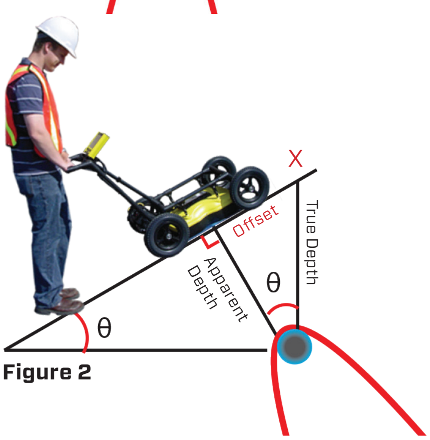

Figure 2

A GPR traversing over objects like utility pipes and cables produce a hyperbolic time versus position response. The apex (top) of the hyperbola indicates the location where the GPR is closest to the utility. When the surface is horizontal, the shortest path for the GPR signals to a buried object occurs when the GPR is vertically above the object (Figure 1). The utility is pinpointed by backing the GPR system up along the survey line until the screen position indicator is on top of the hyperbolic response and marking that position on the surface. Digging a vertical hole at that position will uncover the utility. The map coordinates of that position when entered into a GIS database or a CAD drawing will show the utility in the correct location on a plan map.

Angle in degrees	Apparent Depth (ft)	Offset (ft)	True Depth (ft)
0	1	0.00	1.00
0	2	0.00	2.00
0	3	0.00	3.00
0	4	0.00	4.00
15	1	0.27	1.04
15	2	0.54	2.07
15	3	0.80	3.11
15	4	1.07	4.14
30	1	0.58	1.15
30	2	1.15	2.31
30	3	1.73	3.46
30	4	2.31	4.62
45	1	1.00	1.41
45	2	2.00	2.83
45	3	3.00	4.24
45	4	4.00	5.66

When the surface is sloping, the apex of the hyperbola, the shortest path to the utility, is not vertical, but perpendicular to the slope surface. The position found by backing up the GPR to place the indicator over the top of the hyperbola is NOT the 'correct' location of the target; in other words, a vertical hole dug to uncover the target could miss the target if the slope is severe.

The correct location for a vertical hole would be at the point X, shown in Figure 2. The point X is upslope from the location the GPR backup arrow would indicate. Mathematically, the offset distance up the slope is expressed in terms of the GPR apparent depth and slope angle, θ as:

Offset = tan(θ) * Apparent Depth

The table shows the offset values for several slope angles and utility depths. The table also shows the true vertical depth of the utility; calculated by:

True Depth = Apparent Depth /cos (θ)

The most difficult part of this calculation is measuring the slope angle. Humans tend to over-estimate the angle of slopes, especially after climbing it. A 45 degree angle is very steep and most people would be unable to climb a slope with this angle, let alone conduct a GPR survey on it. Notice in the table that the offset distances from low angle slopes are small enough to be ignored in many cases.

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