Electrical Resistivity Tomography (ERT) as an essential tool to investigate sites in discontinuous permafrost

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What is Electrical Resistivity Tomography (ERT)?

• ERT is a geophysical technique in which DC electrical current is injected into the ground between one pair of electrodes and the voltage is measured between another pair.

• A line (array) of electrodes is used and an instrument called a terrameter acts as a switch box and a measuring device, sending energy to different sets of electrodes through a set sequence.
Principle of ERT and permafrost

- The electrical resistance of water in the ground is very low.
- The electrical resistance of ice in the ground is up to several orders of magnitude higher.
CURRENT APPLIED

VOLTAGE MEASURED

ACTIVE LAYER
(LOW RESISTIVITY)

PERMAFROST
(HIGH RESISTIVITY)

CURRENT PATH
• The ABEM Terrameter LS that we use shows the results of the survey as a coloured section as it takes place.
• When the survey is finished, the measurements stored in the terrameter can be offloaded with a USB key.
Is ERT new?

- Not really.
- But the instrumentation and software needed has become much more user-friendly.
- It’s time to treat ERT as an essential and cost-efficient tool for discontinuous permafrost investigations in the Territories.
How do you undertake an ERT survey?

- Choose the spot on your site where you want the deepest measurement – that’s the mid-point.
- Move the terrameter and its car battery source to the mid-point and lay out the cables away on both sides.
- Push an electrode into the ground at each contact on the cable and join the cable connections to the electrodes using jumper cables.
- Select the set-up on the terrameter and start the survey.
• The depth of penetration of the ERT depends on the type and length of the electrode array.
• We use the Wenner array which gives a penetration depths of about:
  – 12 m for an 80 m array
  – 25 m for a 160 m array
  – 60 m for a 400 m array.
• The greater the depth, the less the horizontal and vertical resolution.
• Space is needed for the survey. 400 m is really long and it’s not always possible to lay it out at a given site.
What are the advantages of ERT?

- Adds a second dimension to frozen ground conditions to a single borehole measurement.
- It’s possible to create a 3D image using parallel survey lines.
- Non-invasive technique: no disturbance and all equipment removed.
- It’s possible to do a survey beneath a raised building and even across water.
- A single person can set up and undertake a typical survey in half a day but several surveys per day can be undertaken with more man-power. Equipment can be carried in roughly 4 person-loads.
- Inexpensive to undertake an ERT survey once equipment purchased (costs about $30-50K).
- ERT surveying is easier to learn and easier to interpret than GPR.
Reproducibility and change through time
MP341 (near Fort St. John, northern BC)

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Note: resistivity values shown in model blocks (not contours)
Disturbance impacts at Burwash Landing and Destruction Bay

**Destruction Bay:**
- Firesmart area with deeper active layer but permafrost intact

**Burwash Landing:**
- Firebreak with talik (unfrozen zone) to 8 m

**Copper Joe subdivision:**
- Effect of 1999 fire – talik to 7 m
Disturbance impacts, Dawson

West Dawson: undisturbed (60 m permafrost)

Dawson School field: 5-6 m deep talik over permafrost

Klondike Valley: cleared section with 5 m talik
What are the limitations of ERT?

• ERT simply gives you measurements of electrical resistivity. You have to provide the interpretation.
• Like all geophysical techniques, you need some ground-truthing (e.g. frost probing, boreholes (preferably with temperature measurements)).
• The contrast is great between colder or coarse-grained frozen and unfrozen ground, but the resistivity of fine-grained permafrost containing significant unfrozen moisture at a temperature just less than 0°C may exhibit a lesser contrast.
• Massive bedrock without water will not show any contrast between frozen and unfrozen conditions.
• Saline permafrost may have low resistivities which could be incorrectly interpreted as unfrozen ground if there is no other information.
Challenging sites require ground-truthing

Bedrock site
Mt. McIntyre
near Whitehorse

Proposed wind generator site, Burwash Landing
Conclusions

• ERT surveys proved invaluable for the hazards mapping project in the Yukon.
• The surveys were able to evaluate conditions to much greater depths than the boreholes which were drilled using a light rig.
• The 2-D sections revealed the lateral changes in permafrost conditions, the presence of taliks and the depth of the base permafrost.
• Where it is suspected that ground freezing conditions vary at a site, a single borehole backed up by ERT surveys could be an economical survey method.
• ERT surveys can also be undertaken beneath buildings providing access is possible.
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