GEOPHYSICAL INVESTIGATION AND MONITORING OF ACTIVE LAYER AND PERMAFROST CONDITIONS:

Current and potential applications of geophysical surveys and logging

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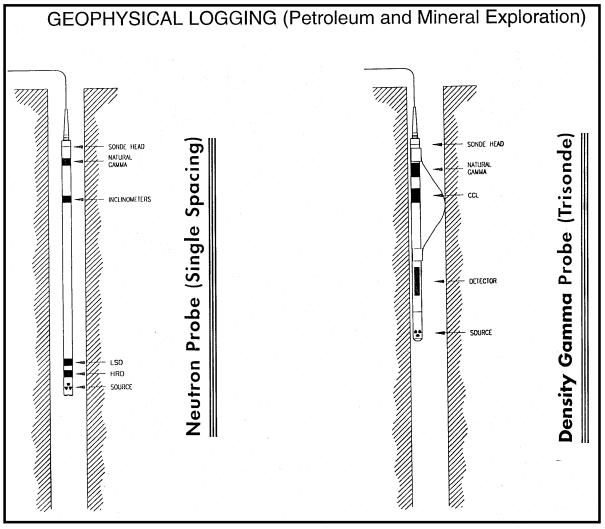
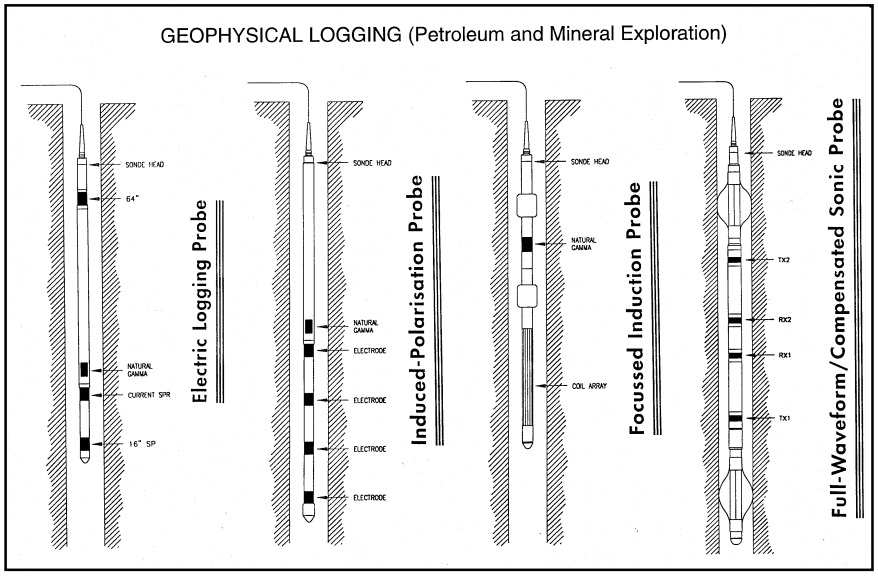
GEOPHYSICAL LOGGING

a) Open holes (fluid – drilling mud)
b) Closed holes (plastic casing)
c) Permanent installation (thermistor cable, TDR, conductivity probe, ...)
d) Petroleum and mineral exploration
e) Acoustic televiewer
f) Electromagnetic tomography (Ground Penetrating Radar)
g) Cone penetration test (penetration-rate controlled)

(point resistance, creep behaviour, temperature, in situ electrical resistivity, seismic wave propagation, friction, pore pressure, ...)





ACOUSTIC TELEVIEWER

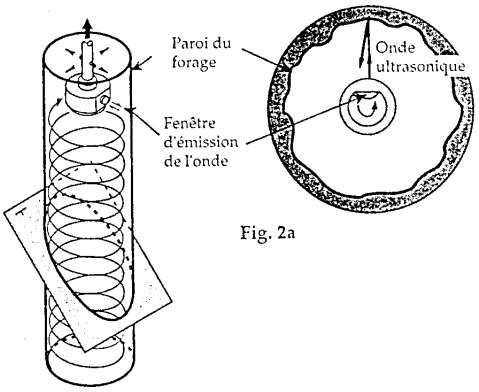


Fig. 2a

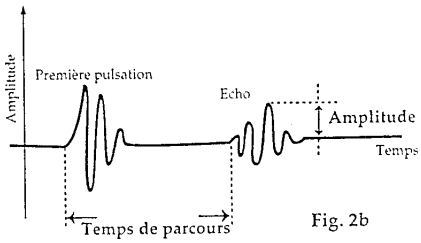
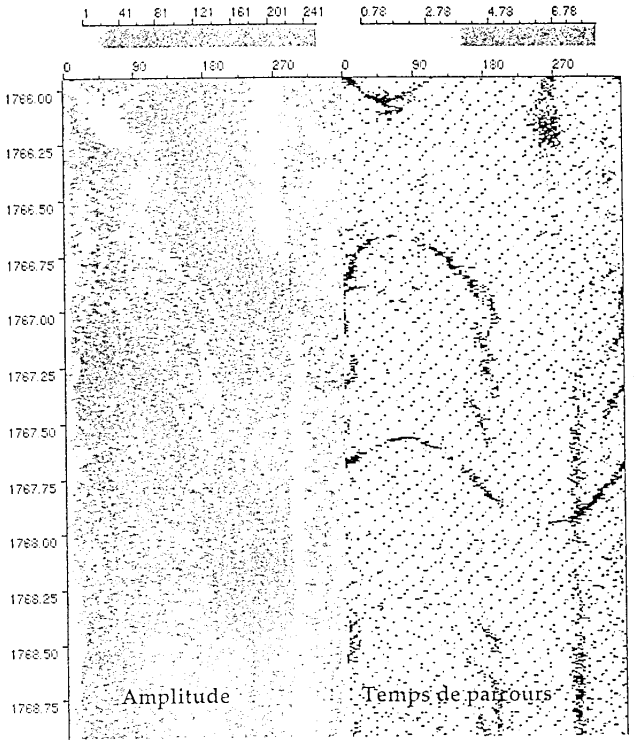
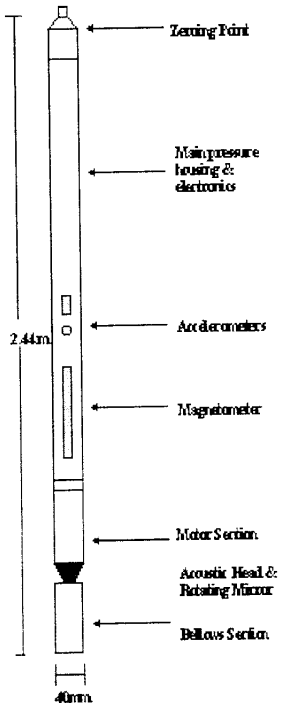


Fig. 2b





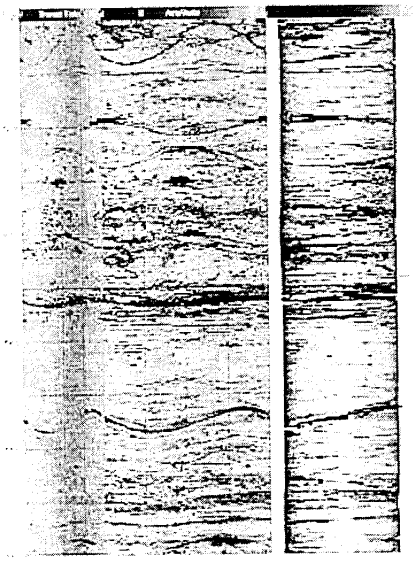


Figure 2: Typical acoustic image showing from left to right: depth, travel time, amplitude and a 3D image of the borehole.

Note the significant fractures at 53.7m and 54.8m

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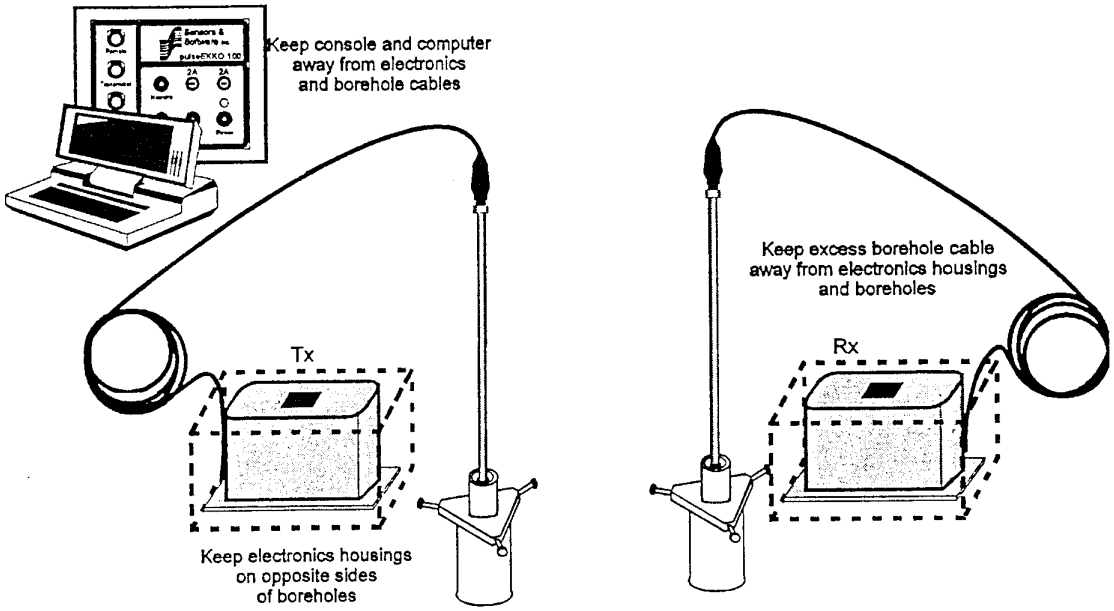
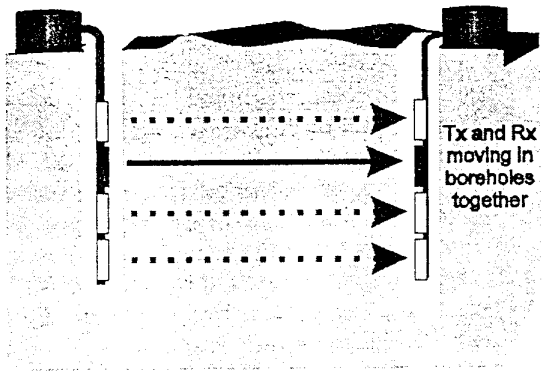
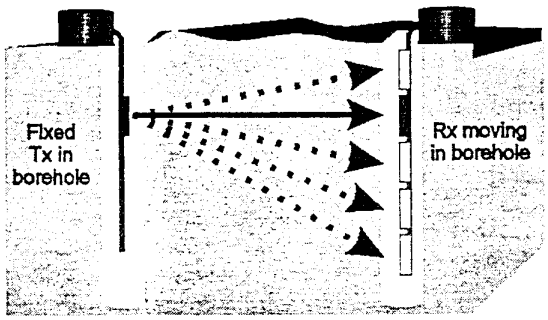
ELECTROMAGNETIC TOMOGRAPHY (GPR)







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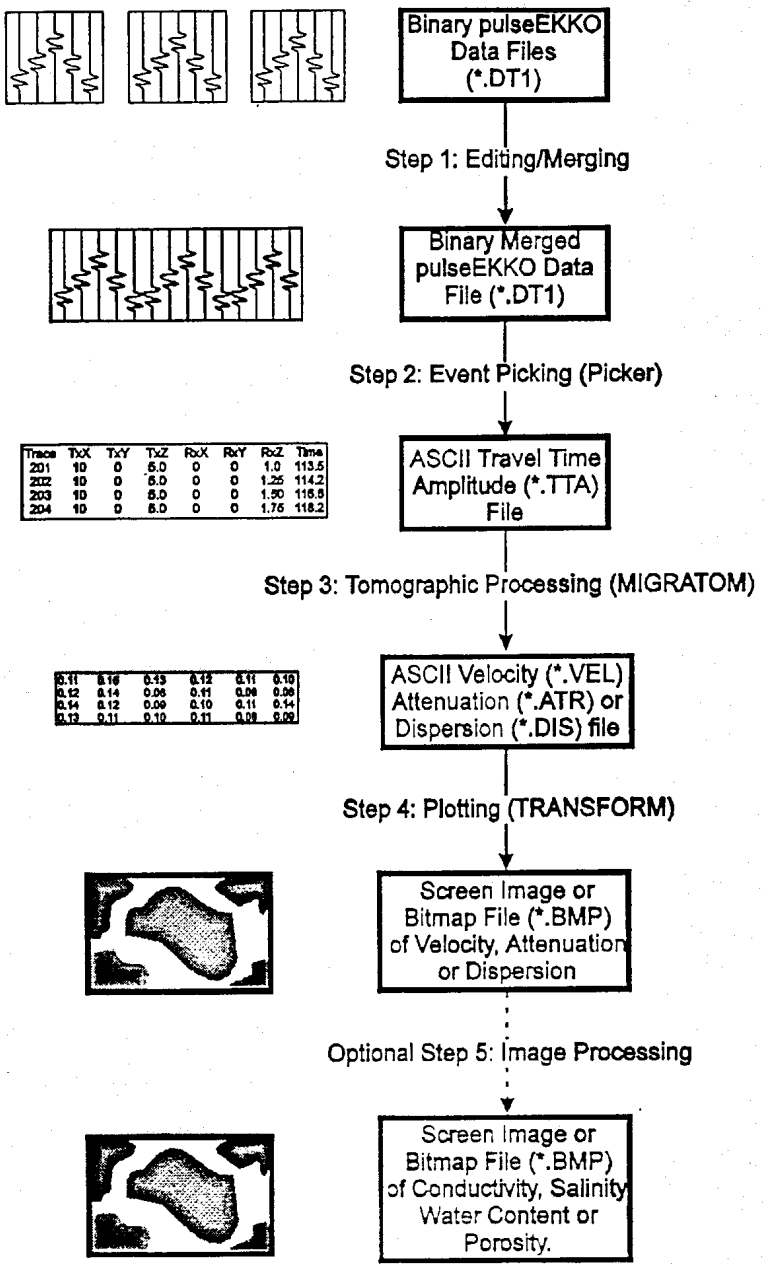
EM TOMO (Sensors & Software Inc. Procedure)



EKKO_IMAGE data flow.

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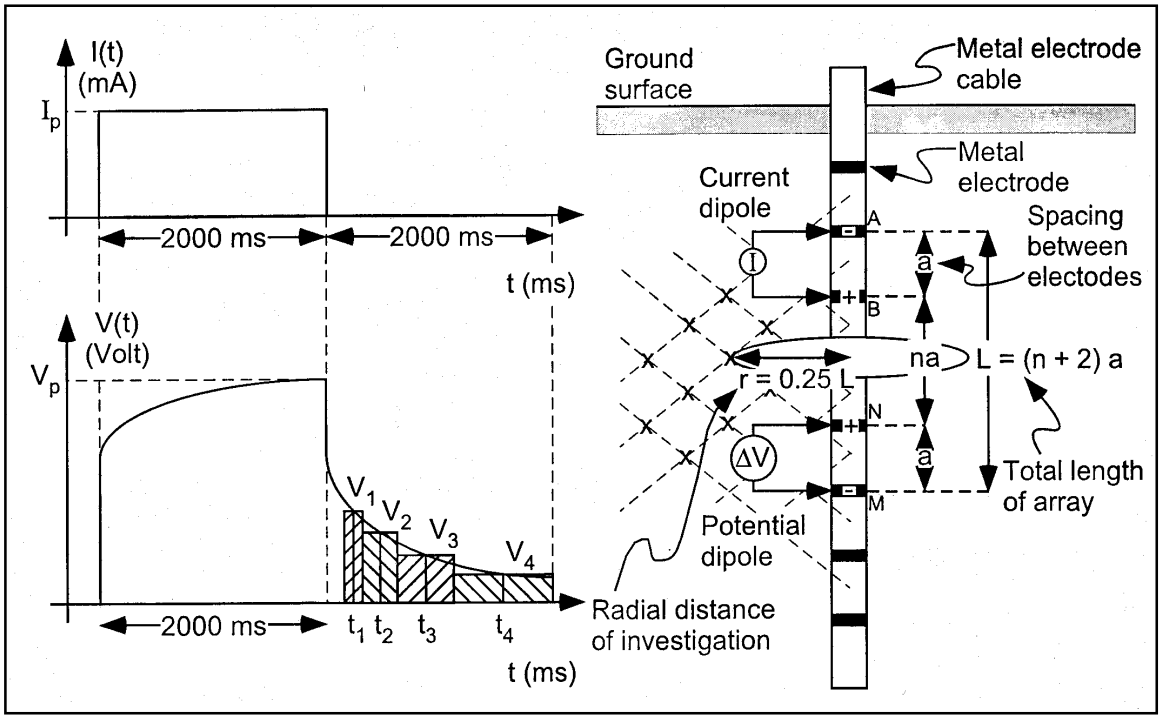
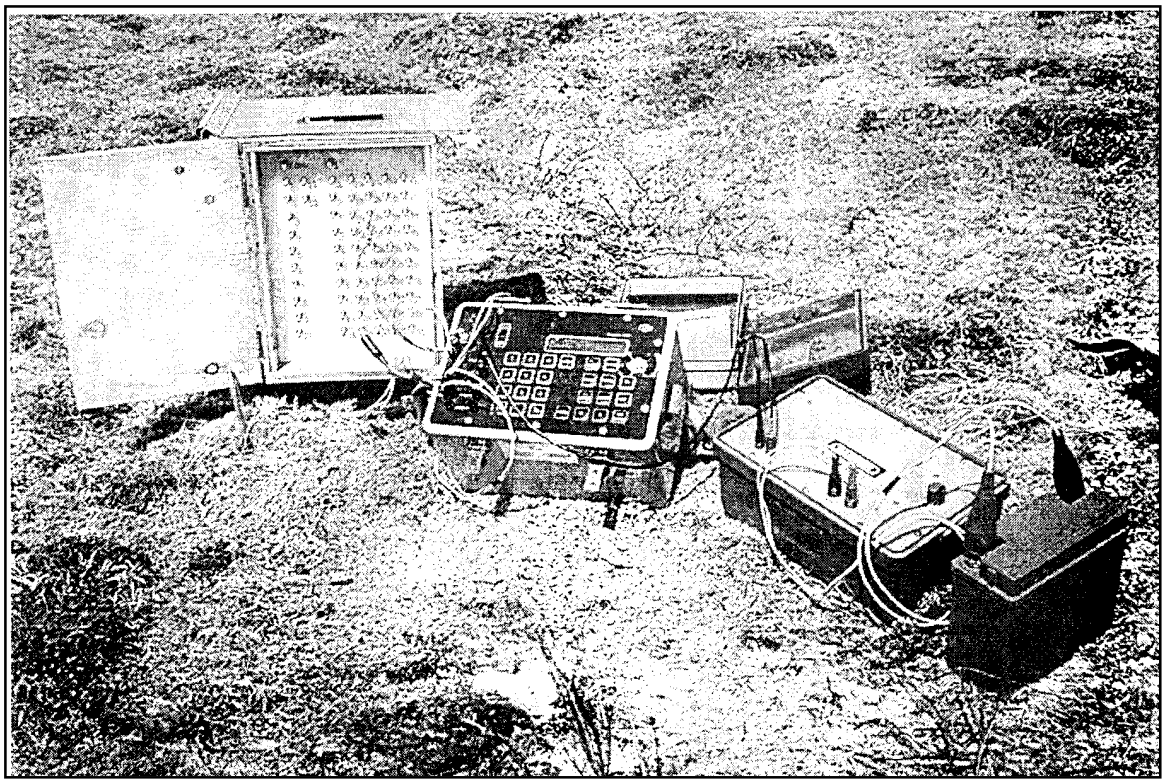
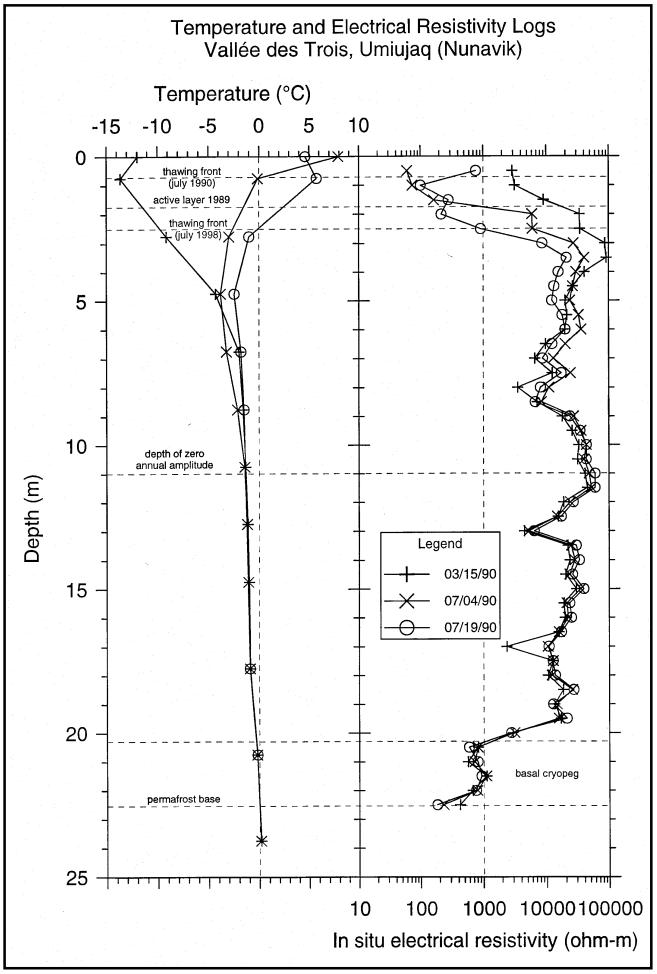

I(t)
(mA)
I_p
2000 ms
2000 ms
t (ms)
V(t)
(Volt)
V_p
V_1 V_2 V_3 V_4
2000 ms
t_1 t_2 t_3 t_4
t (ms)
Ground surface
Metal electrode cable
Metal electrode
Current dipole
A
B
I
a
Spacing between electodes
na
L = (n + 2) a
r = 0.25 L
N
ΔV
a
M
Total length of array
Potential dipole
Radial distance of investigation




Temperature and Electrical Resistivity Logs
Vallée des Trois, Umiujaq (Nunavik)
Temperature (°C)
-15 -10 -5 0 5 10
0
5
10
15
20
25
Depth (m)
thawing front (july 1990)
active layer 1989
thawing front (july 1998)
depth of zero annual amplitude
permafrost base
basal cryopeg
Legend
03/15/90
07/04/90
07/19/90
10 100 1000 10000 100000
In situ electrical resistivity (ohm-m)

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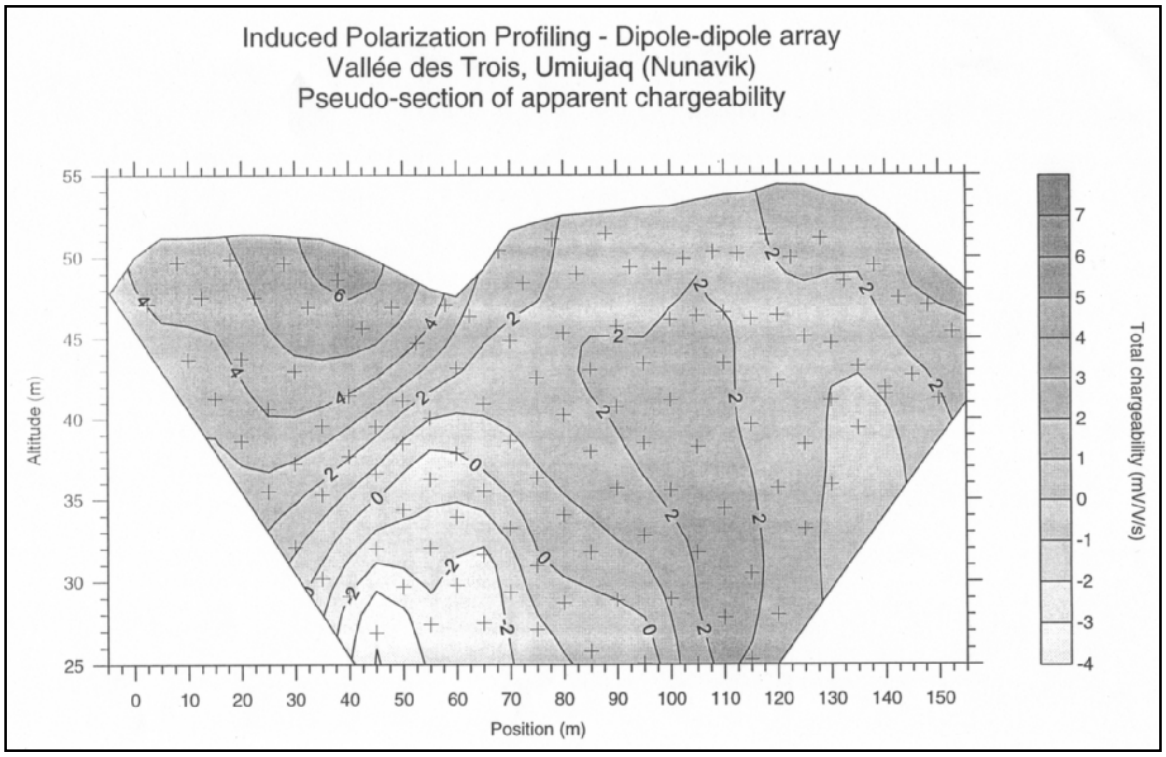
GEOPHYSICAL SURVEYS (SHALLOW GEOPHYSICS)

a) Investigation and monitoring (manual and automatic)
b) Electrical resistivity and induced polarization sounding, traverse and profiling
c) Induction survey
d) Ground penetrating radar
e) Potential field (gravity and magnetism)
f) Seismic method?



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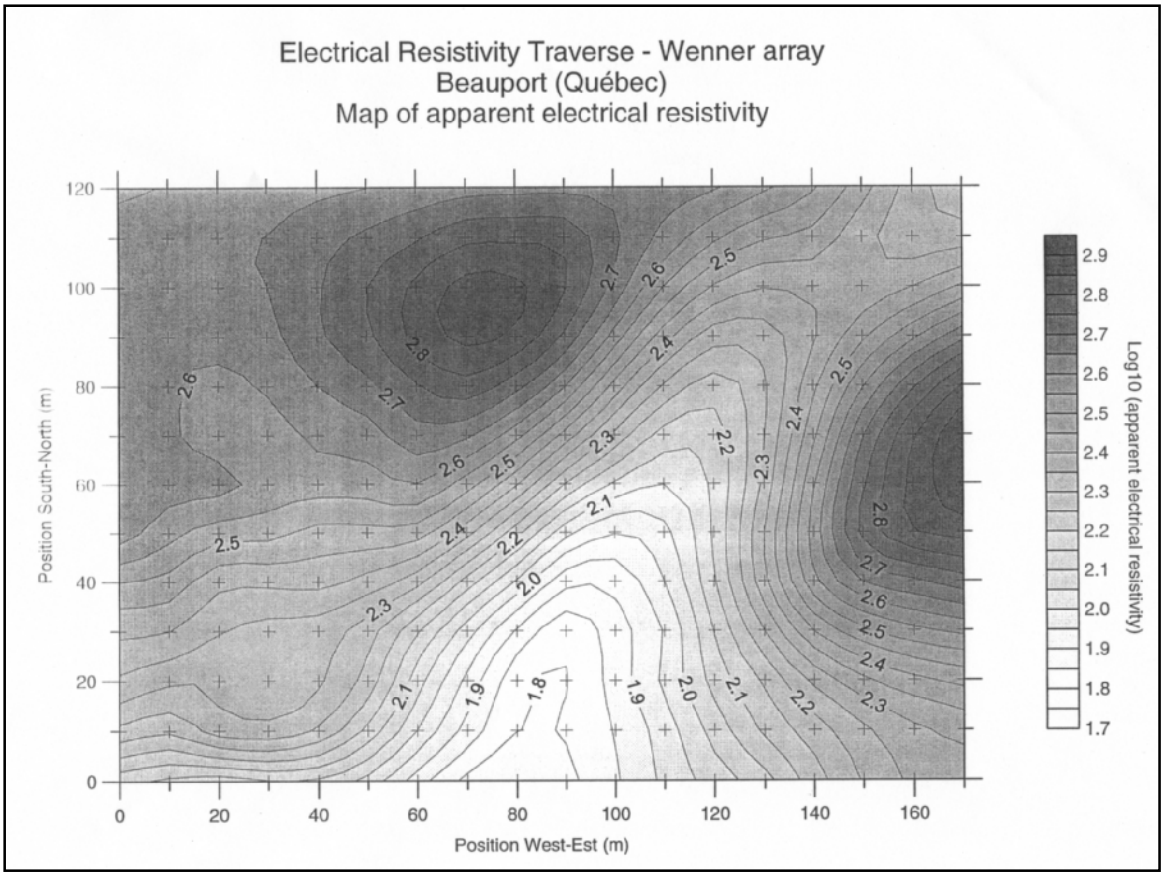
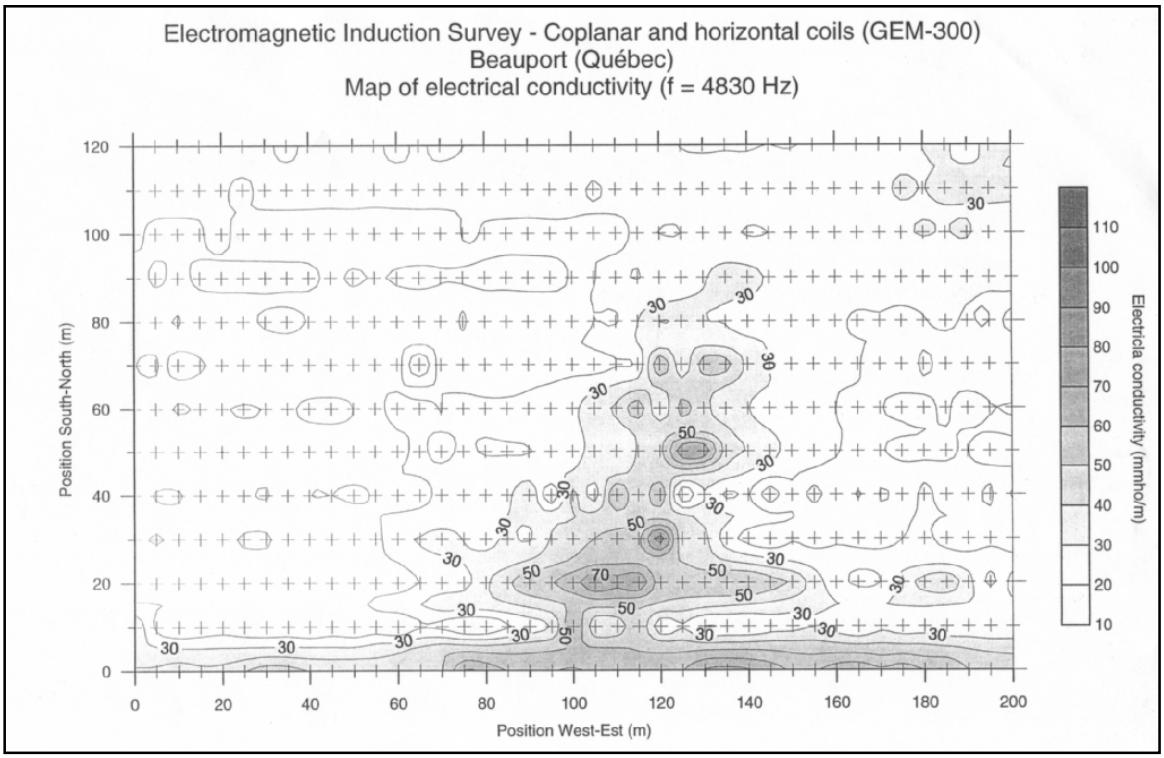

Electrical Resistivity Traverse - Wenner array
Beauport (Québec)
Map of apparent electrical resistivity
Position South-North (m)
Position West-Est (m)
Log10 (apparent electrical resistivity)


Electromagnetic Induction Survey - Coplanar and horizontal coils (GEM-300)
Beauport (Québec)
Map of electrical conductivity (f = 4830 Hz)
Position South-North (m)
Position West-Est (m)
Electricla conductivity (mmho/m)

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MONITORING OF PERMAFROST CONDITIONS

1) Temperature

- Key parameter
- Easiest parameter to measure
- Controls the evolution of other properties
- Modelling training

  Adjustment of model parameters (thermal conductivity, specific heat and thermal diffusivity) as a function of the cryostratigraphy of permafrost over a known period before the prediction over a unknown period

– Can we get the big picture on the evolution of permafrost conditions only by temperature monitoring? The answer depends on our goals.

2) Physical, Geotechnical And Geophysical Parameters

- modelling perspective:
  - i) thermal diffusivity as a function of:
    - T, w, w_{uf} and cryostructure
  - ii) cryostratigraphy of permafrost (another key parameter)
    - Variation of w, w_{uf} and cryostructure with depth
- engineer perspective
  - i) creep behaviour (foundation and slope stability) as a function of:
    - T, w, w_{uf} and cryostructure (cryostratigraphy)
  - ii) dynamic behaviour (earthquake loading, power plant loading)

– geophysics perspective
  - i) broad interest that can provide useful information (data acquisition and reduction, and interpretation are critical steps)
  - ii) integrated approach

- native people perspective
  - open question