# Structural aquifer mapping using transient electromagnetic methods

**Esben Auken, Anders V. Christiansen And Kurt I. Sørensen**

HydroGeophysics Group
Department of Earth Sciences, University of Aarhus,
www.hgg.au.dk

# Outline

¿ How does the transient method work?

¿ Strengths and limitations

¿ Transient systems

¿ Structural/lithological mapping – a survey

¿ Concluding remarks

# Basics Physics of TEM

## How does it work?

A stationary current flows in the transmitter loop

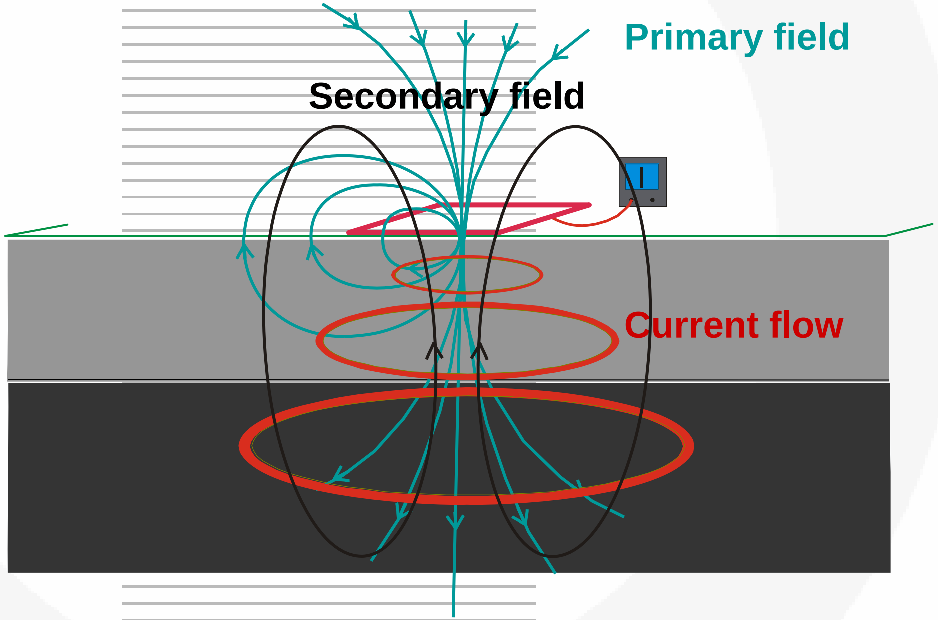
-which sets up a primary magnetic field

The current is shut off abruptly

-which induces currents in the subsurface.

This generates a secondary magnetic field

-which is measured in the receiver coil at the surface



# Basics Physics of TEM

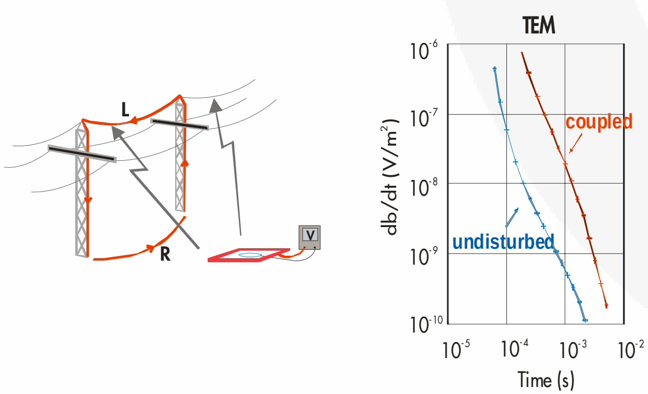
- **The magnitude of the Earth response - dependent on the subsurface resistivity**
- **Noise**
  - power distribution grid
  - distant thunderstorms
- **Largest penetration depth**
  - background noise level
  - magnetic transmitter moment
- **Near surface resolution**
  - timing and instrument accuracy
  - accurate modeling of system response

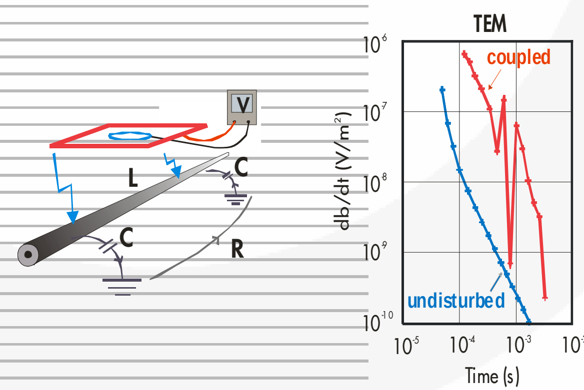
# Outline

- How does the transient method work?
- **Strengths and limitations**
- **Transient systems**
- Structural/lithological mapping – a survey
- Concluding Remarks

# TEM Method – Strengths and Limitations

- \+ High production rate
- \+ Sensitive to low resistivity sediments - clay or salt water interfaces
- \+ Large depth of penetration
- \+ Limited sensitivity to non 1-D conditions
- \- Conceptually advanced
- \- Sensitive to coupling to power lines, buried cables, fences etc.
- \- Only 1-D inversion is available at present state



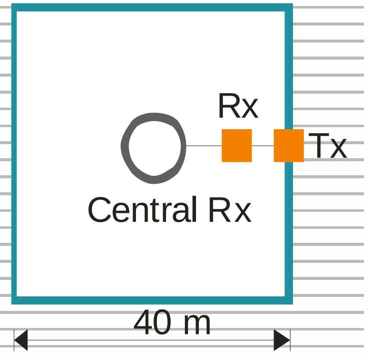



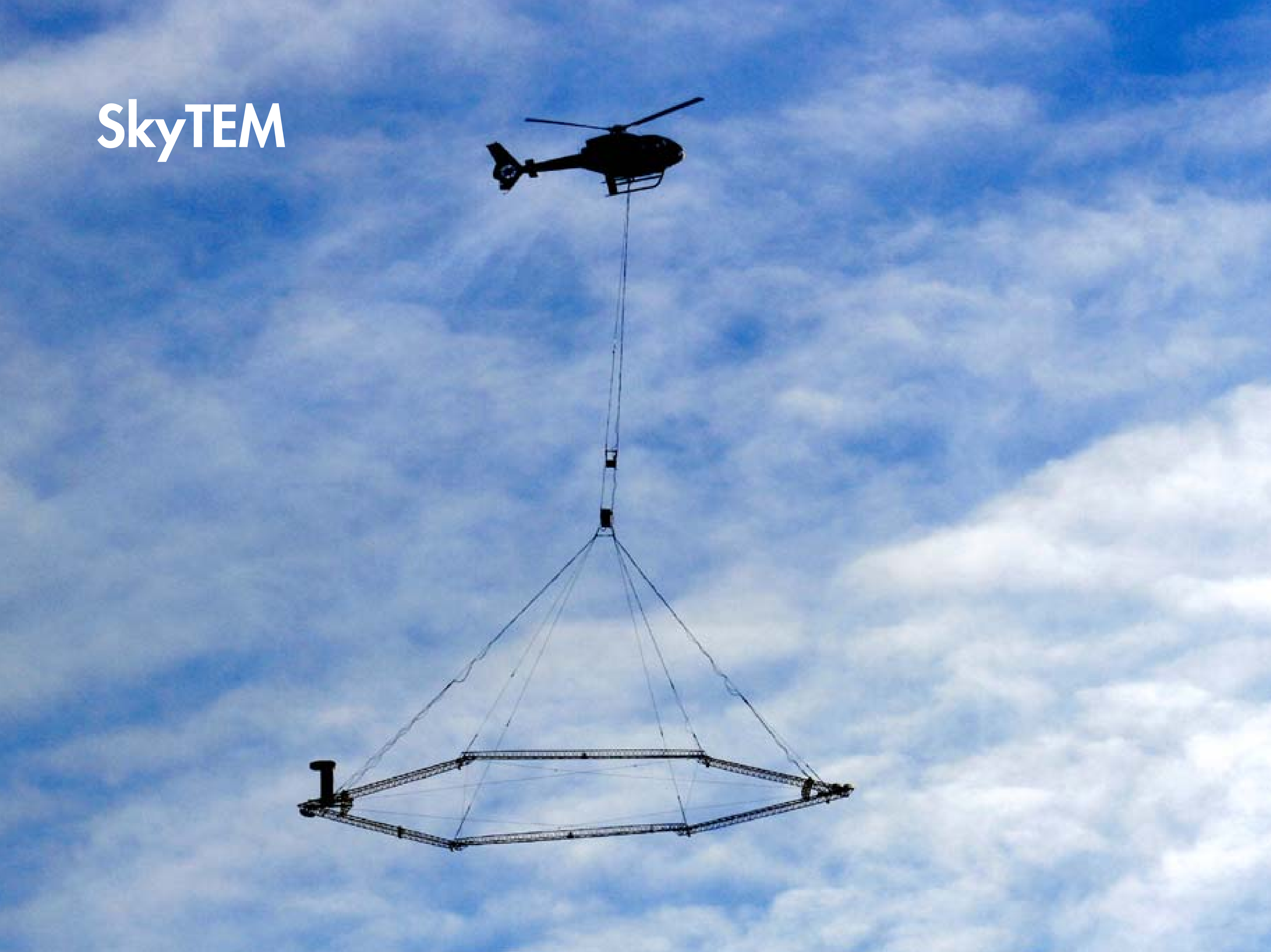
# Ground-based Versus Airborne Systems

| Ground-based | Airborne |
|---|---|
| - Low daily production | + High daily production |
| - Requires ground access | + No ground access |
| + Cost effective in small areas | + Cost effective in large areas |
| + Early time measurements - most systems | - Early times measurements - only some systems |
| - Small transmitter moment | + Large transmitter moment |
| - Single site measurements | + Continuous measurements |
| - Couplings difficult to recognize | + Easy to cull couplings |

# Conventional Ground-based 40 x 40 m TEM

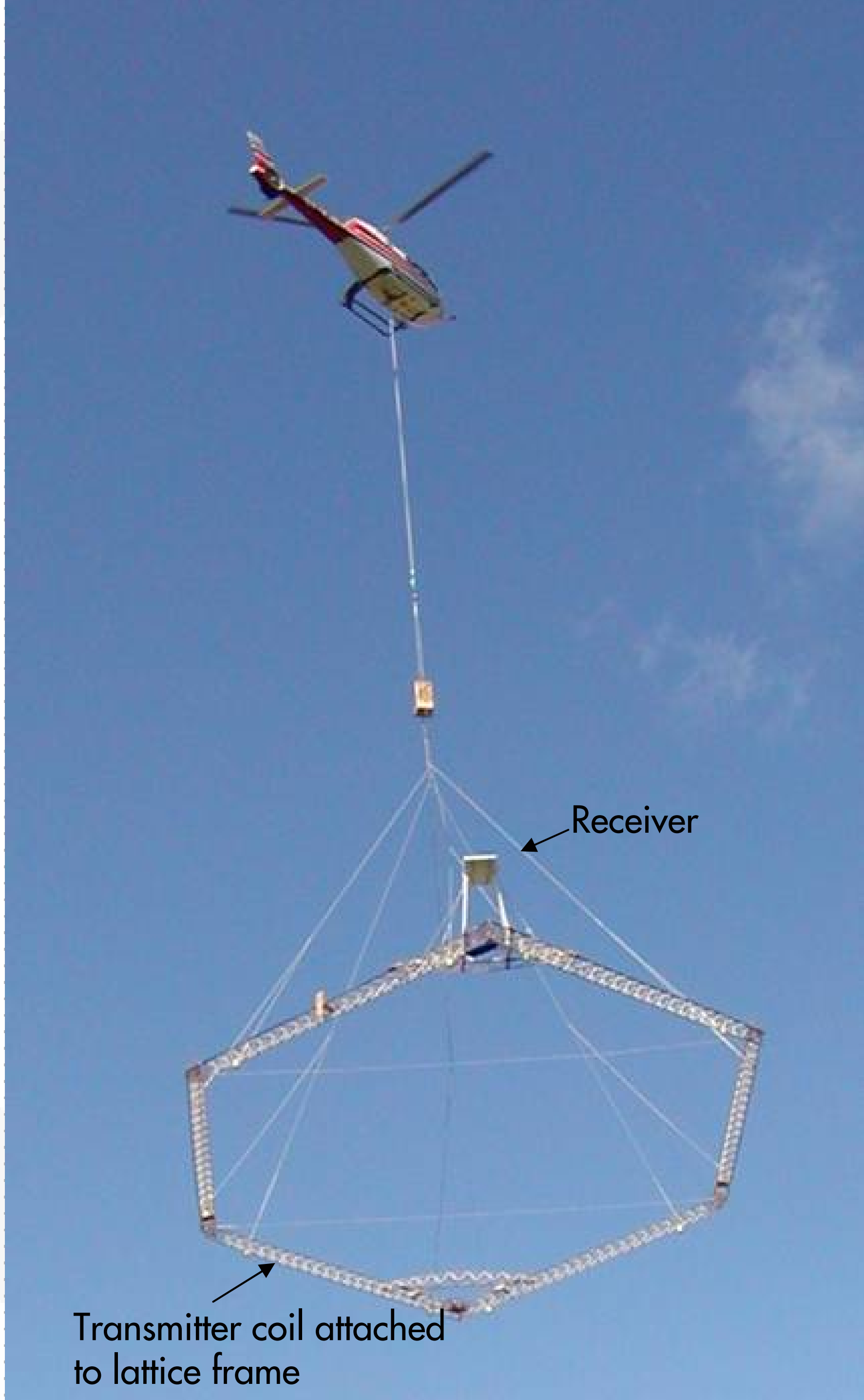
- Magnetic moment: 4800 $Am^2$
- 16 soundings per day – 1 $km^2$
- Sounding distance: 250 m
- Penetration: 100 - 150 m





SkyTEM

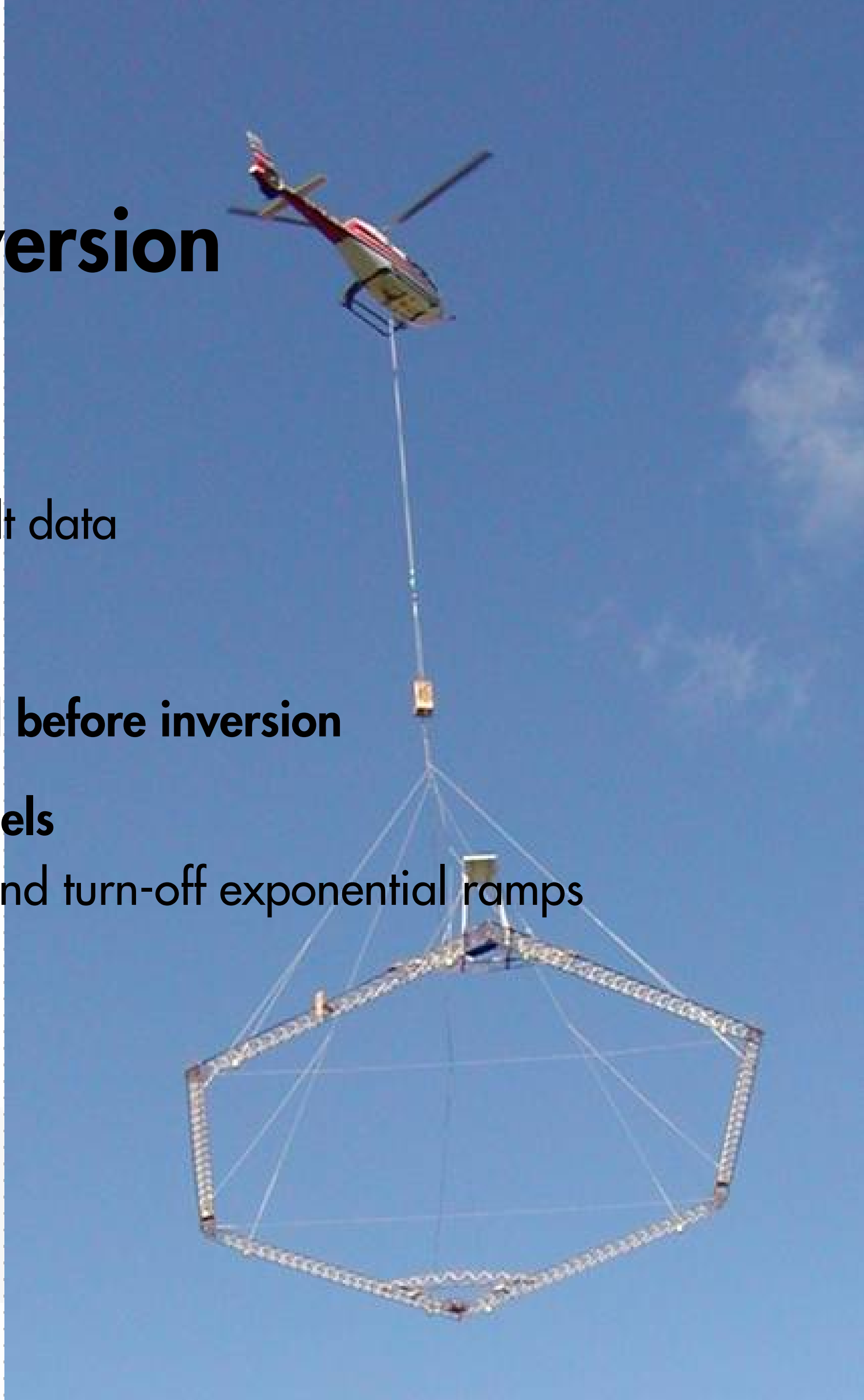
# SkyTEM at a Glance

- **Low moment - near-surface resolution**
  - 12 000 Am2
  - Turn off ~ 5 μs
  - x- and z-component
- **High moment – large penetration**
  - 90 000 Am2
  - Turn off ~ 38 μs
  - z-component
- **First time gate**
  - structural mapping ~16 μs
  - vulnerability mapping ~11 μs
- **Operating altitude ~30 m**
- **Speed up to 70 km/hr**



# Data Processing and Inversion

- **Navigation - altitude and tilt**
  - Altitude - recursive canopy filters
  - Tilt - correction of altitudes and db/dt data
- **No leveling**
- **Noise and coupled db/dt data are culled before inversion**
- **Laterally Constrained Inversion (LCI) models**
  - Low-pass filters, front gate, turn-on and turn-off exponential ramps
  - Altitude as constrained parameter



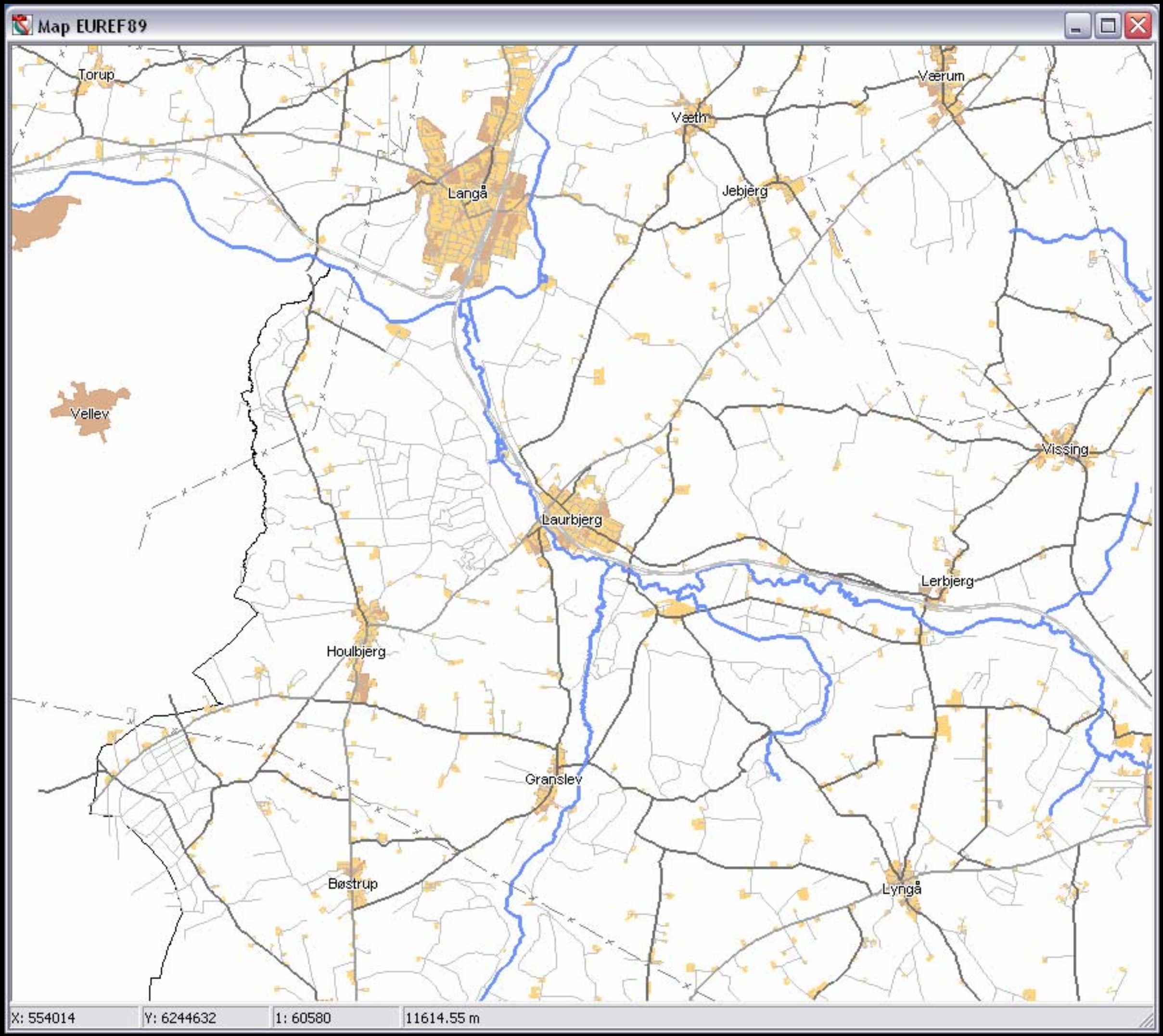
# Outline

- How does the transient method work?
- Strengths and limitations
- Transient systems
- **Structural/lithological mapping – a survey**
- Concluding Remarks

# Northern Europe

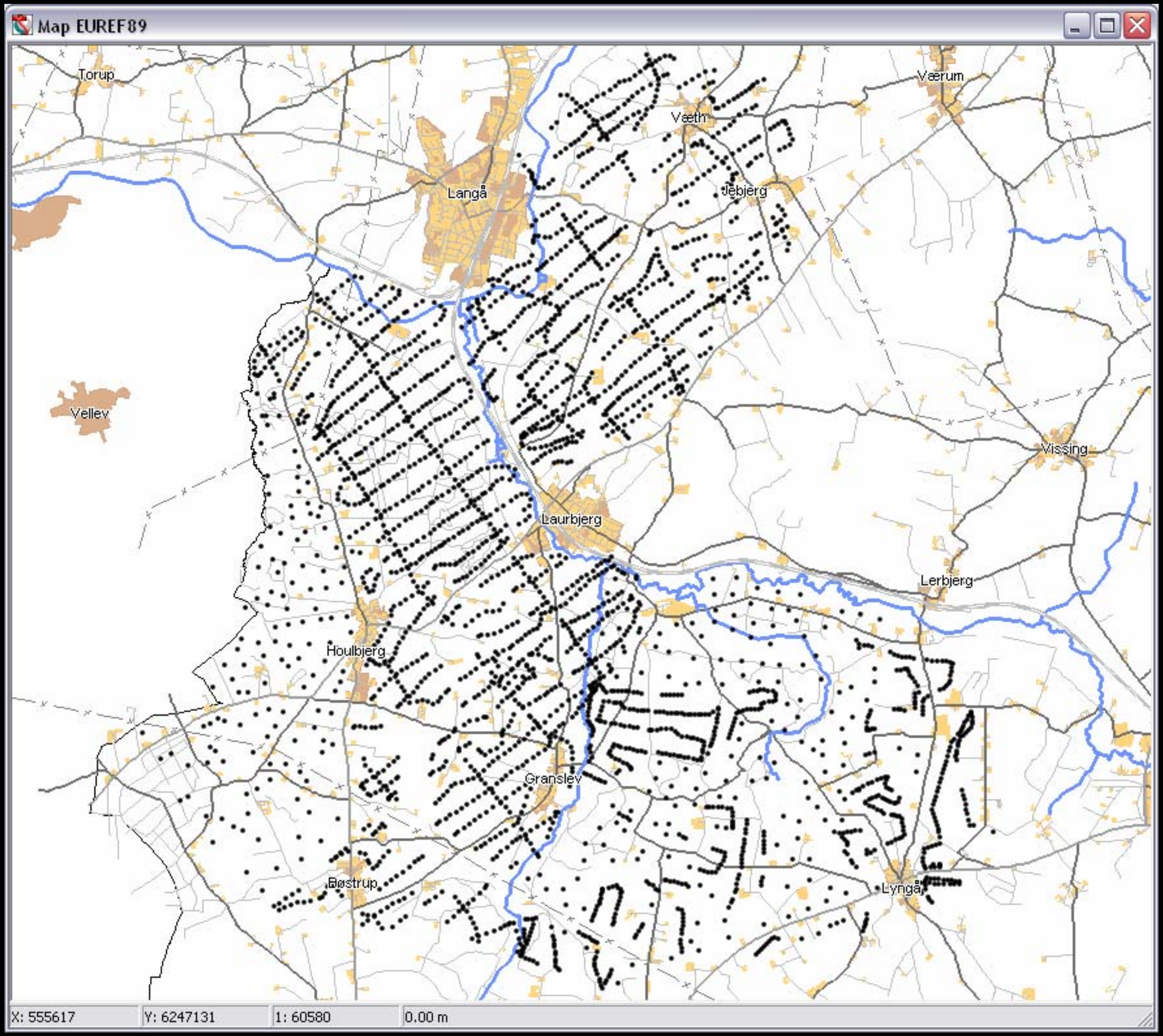
- Investigation area is approx 100 km²

# The survey area

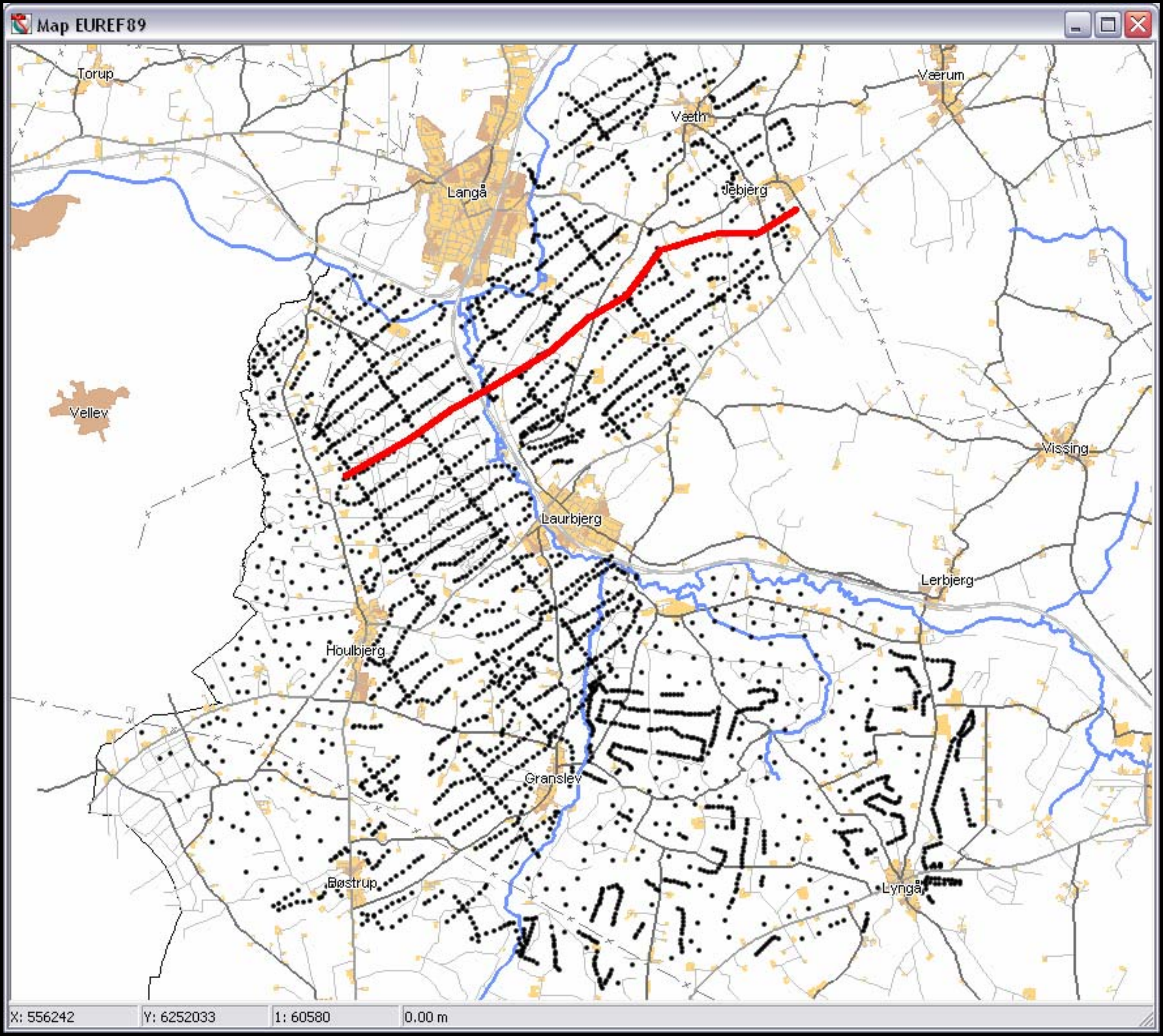



12 x 12 km²

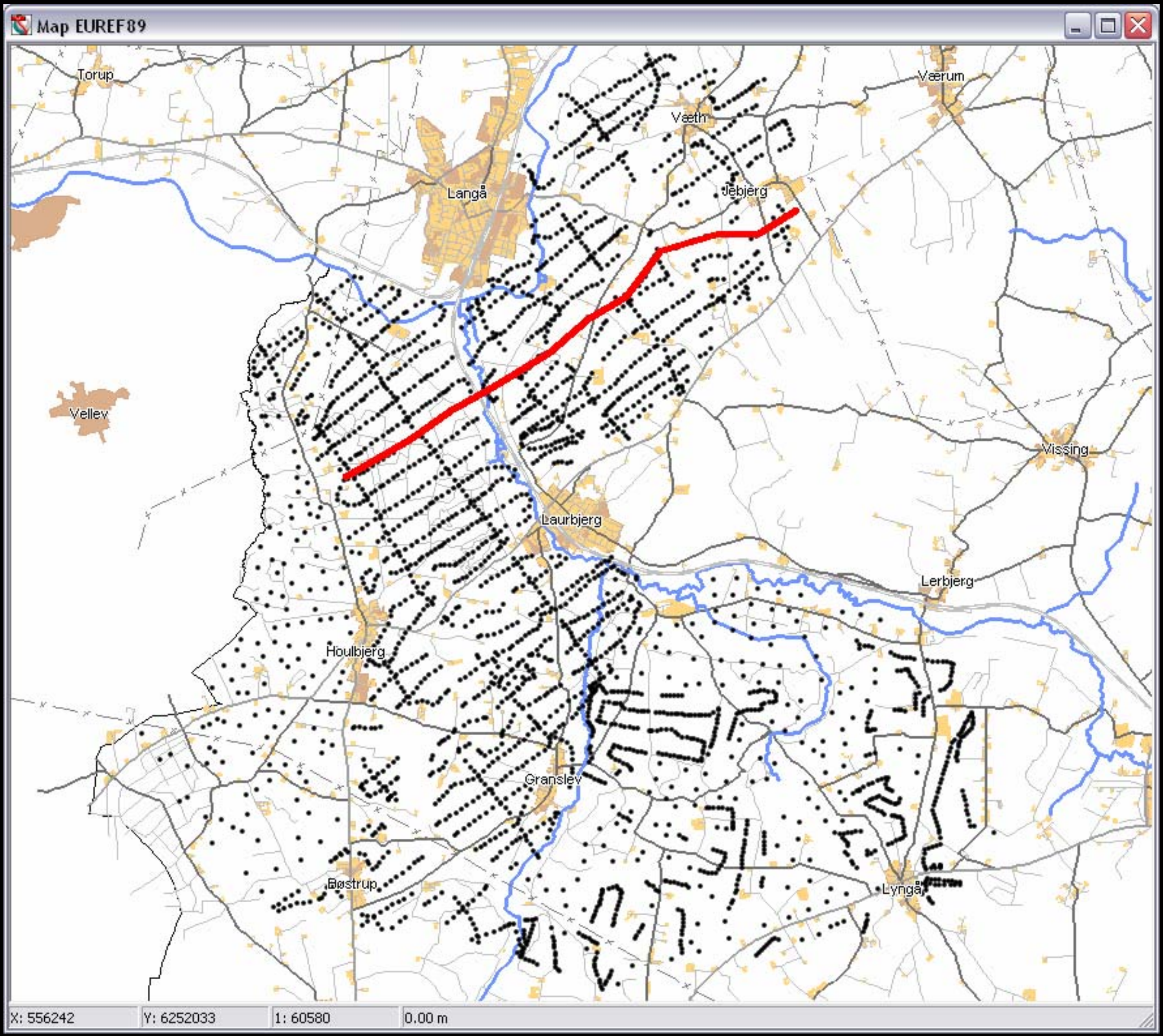
# Flight Lines – Sounding Points



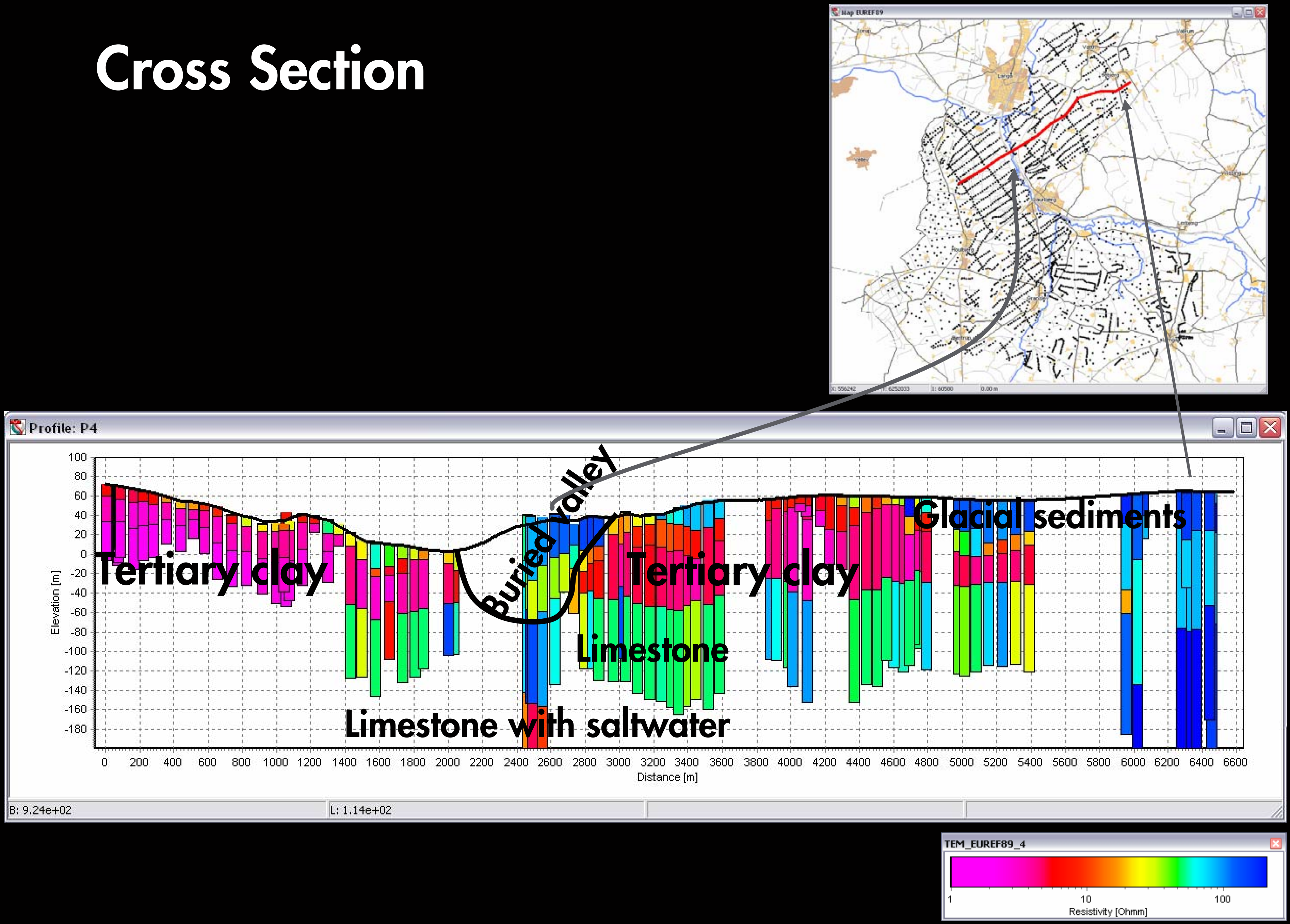
# Location of Cross Section



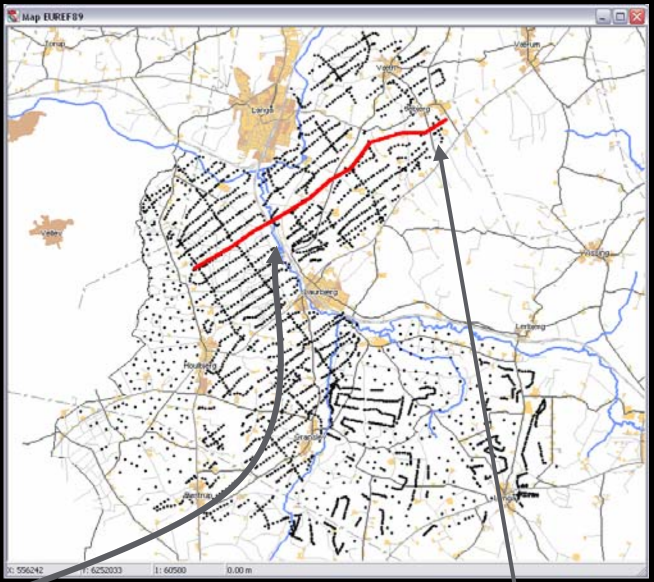
# Cross Section

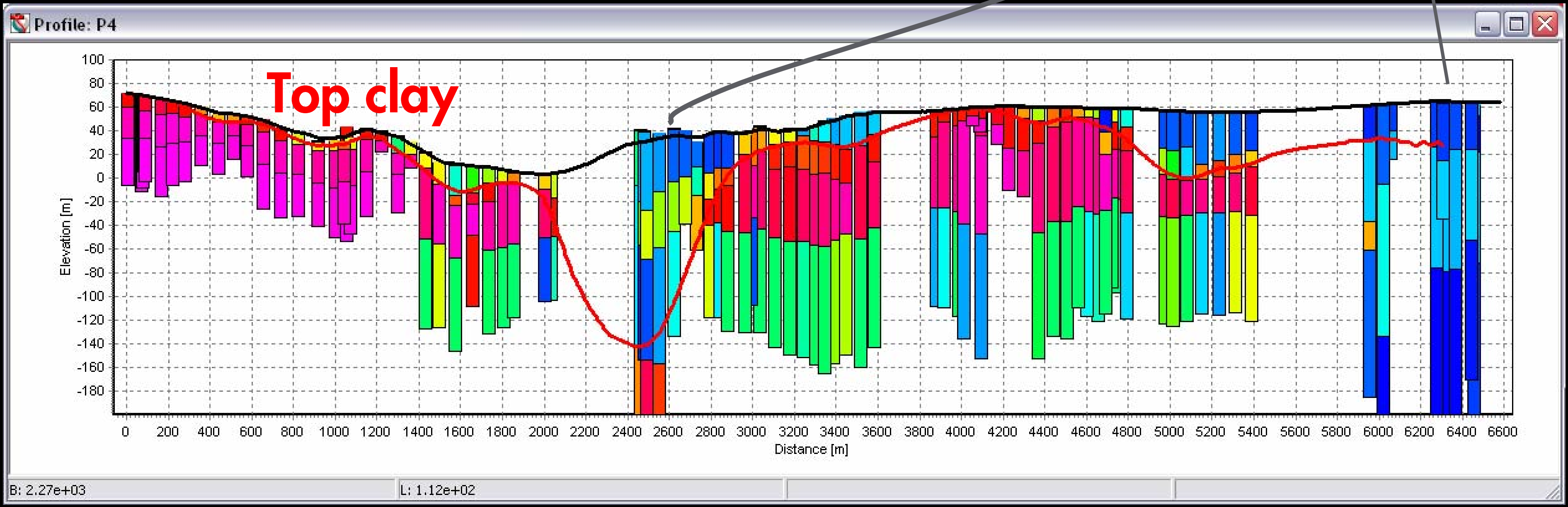


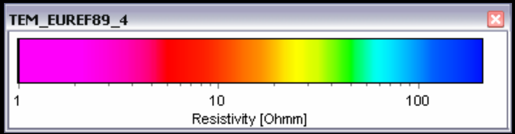
# Cross Section



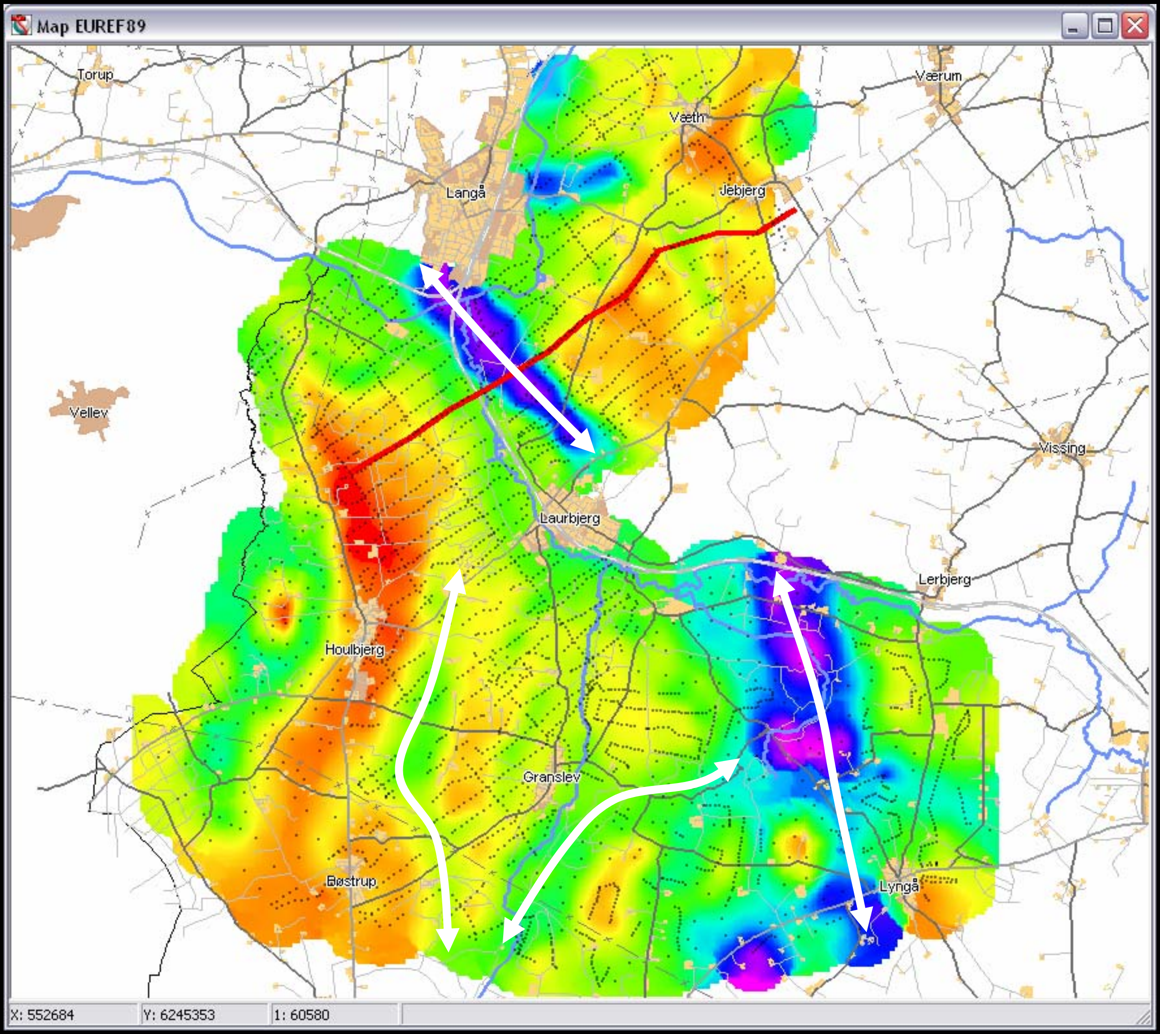
# Cross Section – Top Clay

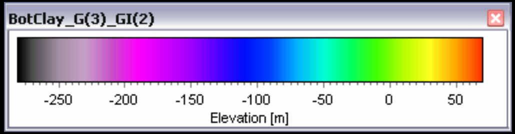


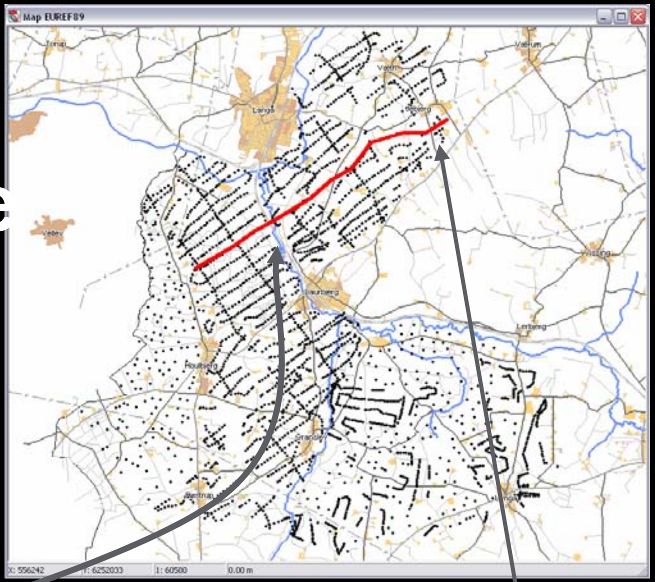



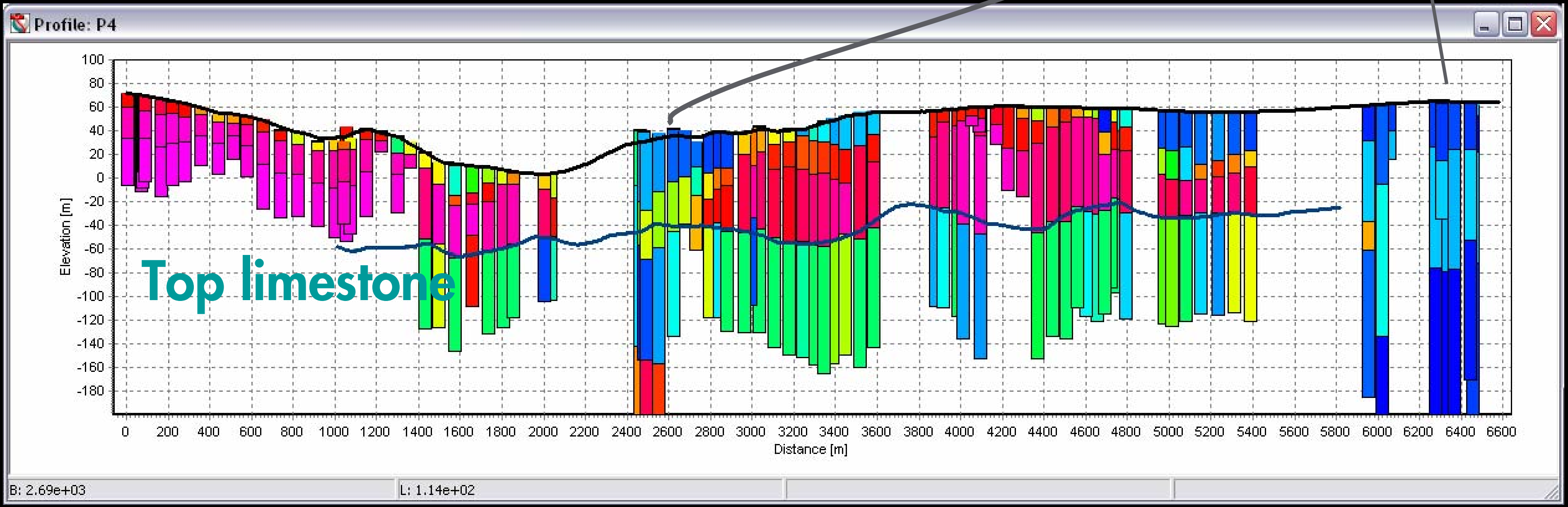
# Top Clay

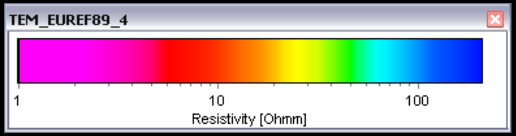

Map EUREF89
Torup
Værum
Væth
Langå
Jebjerg
Vellev
Vissing
Laurbjerg
Lerbjerg
Houlbjerg
Granslev
Bøstrup
Lyngå
X: 552684
Y: 6245353
1: 60580


BotClay_G(3)_GI(2)
-250
-200
-150
-100
-50
0
50
Elevation [m]

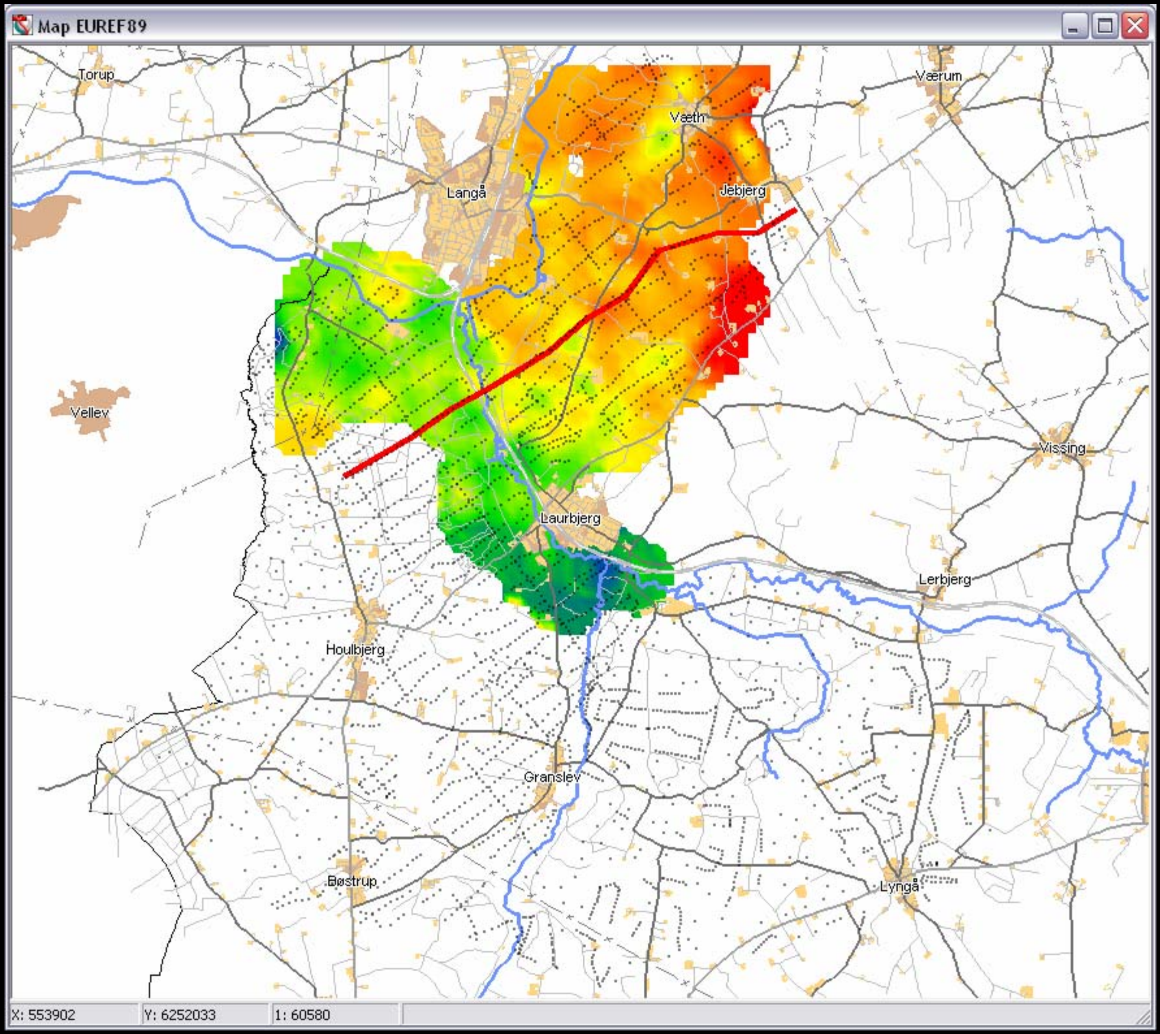
# Cross Section – Top Limestone

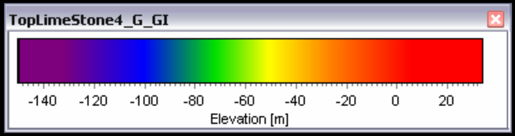


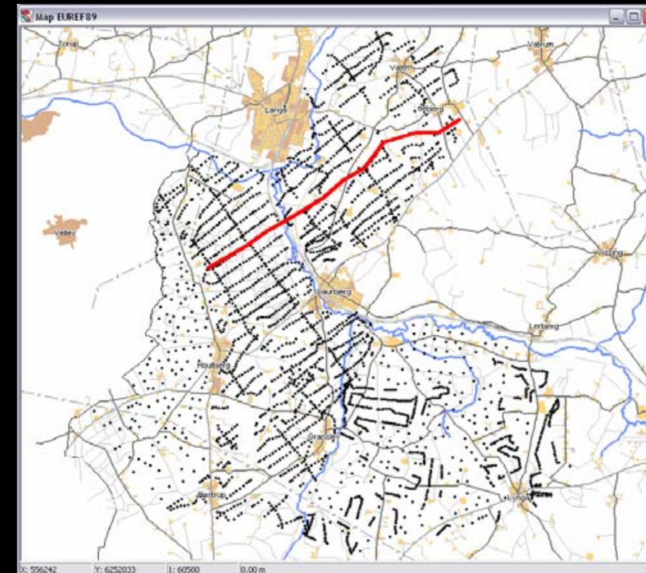



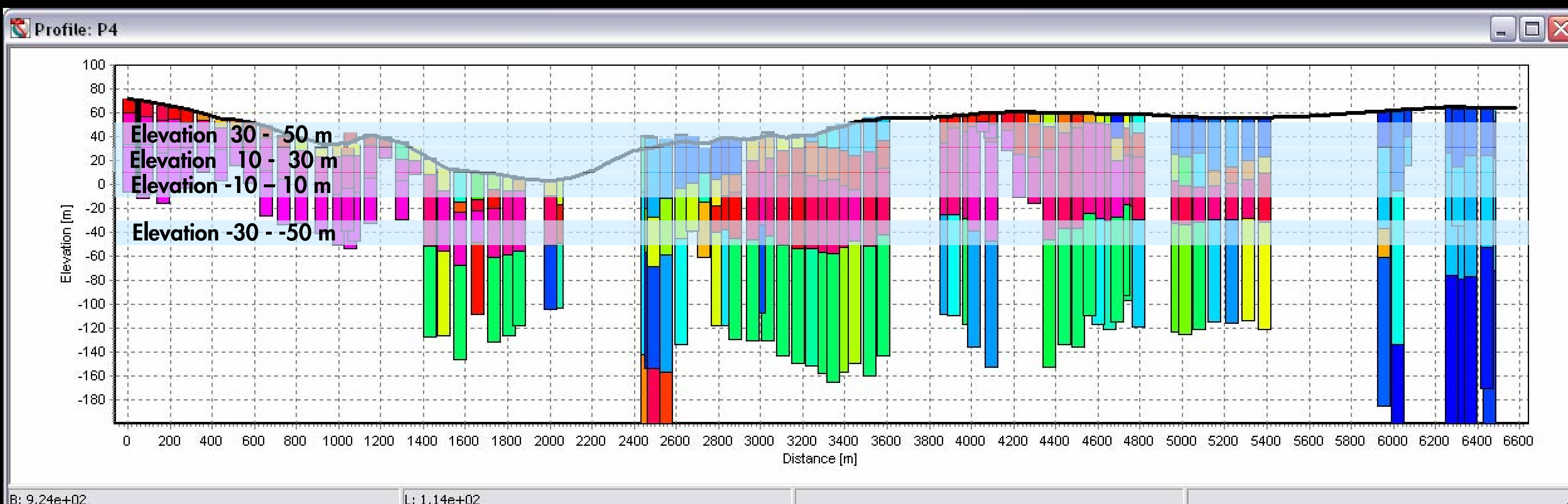
# Top Limestone

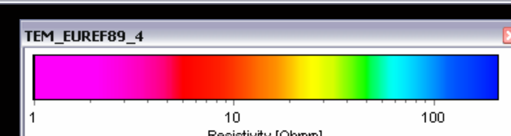


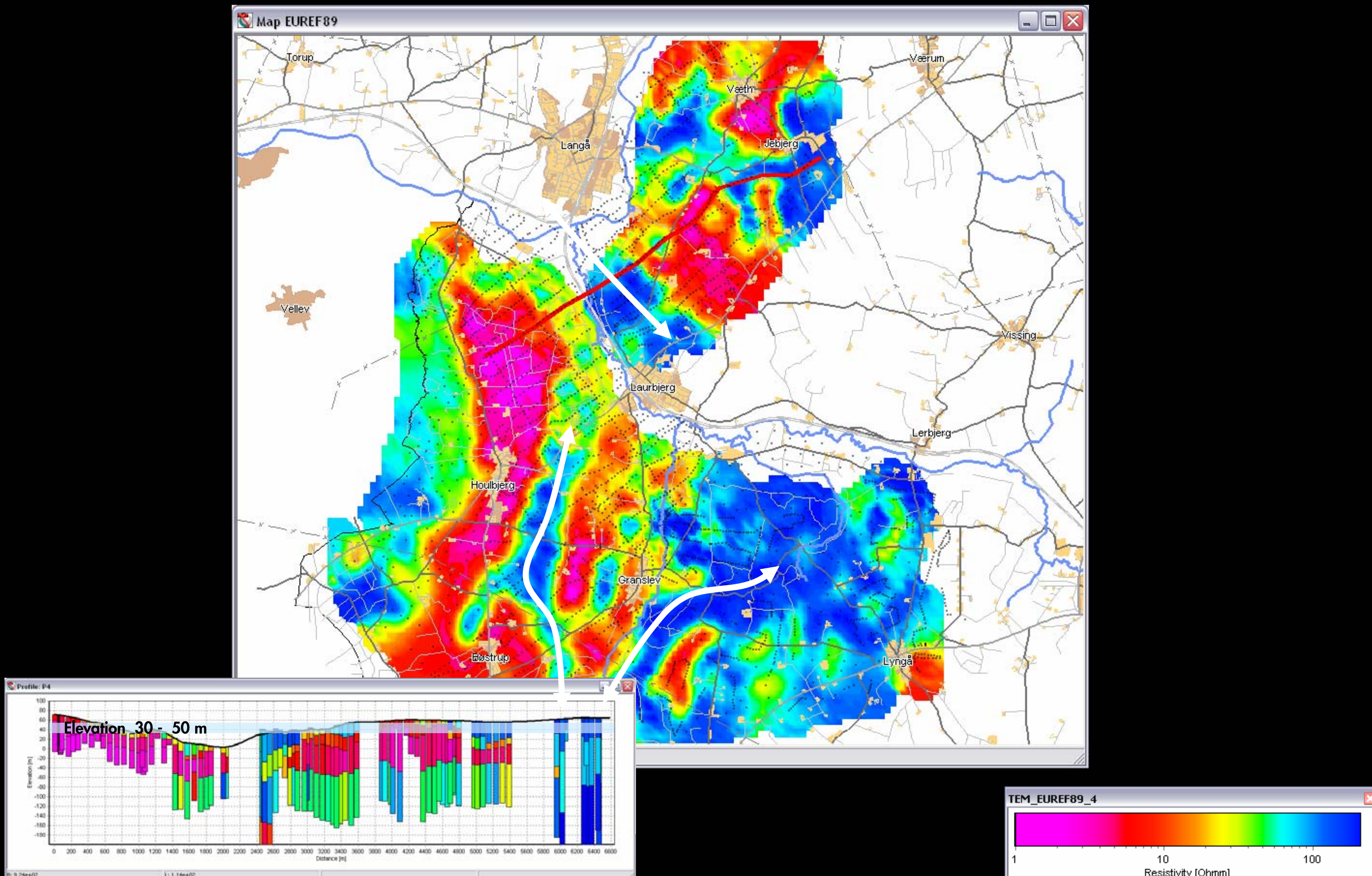
# Average Resistivity



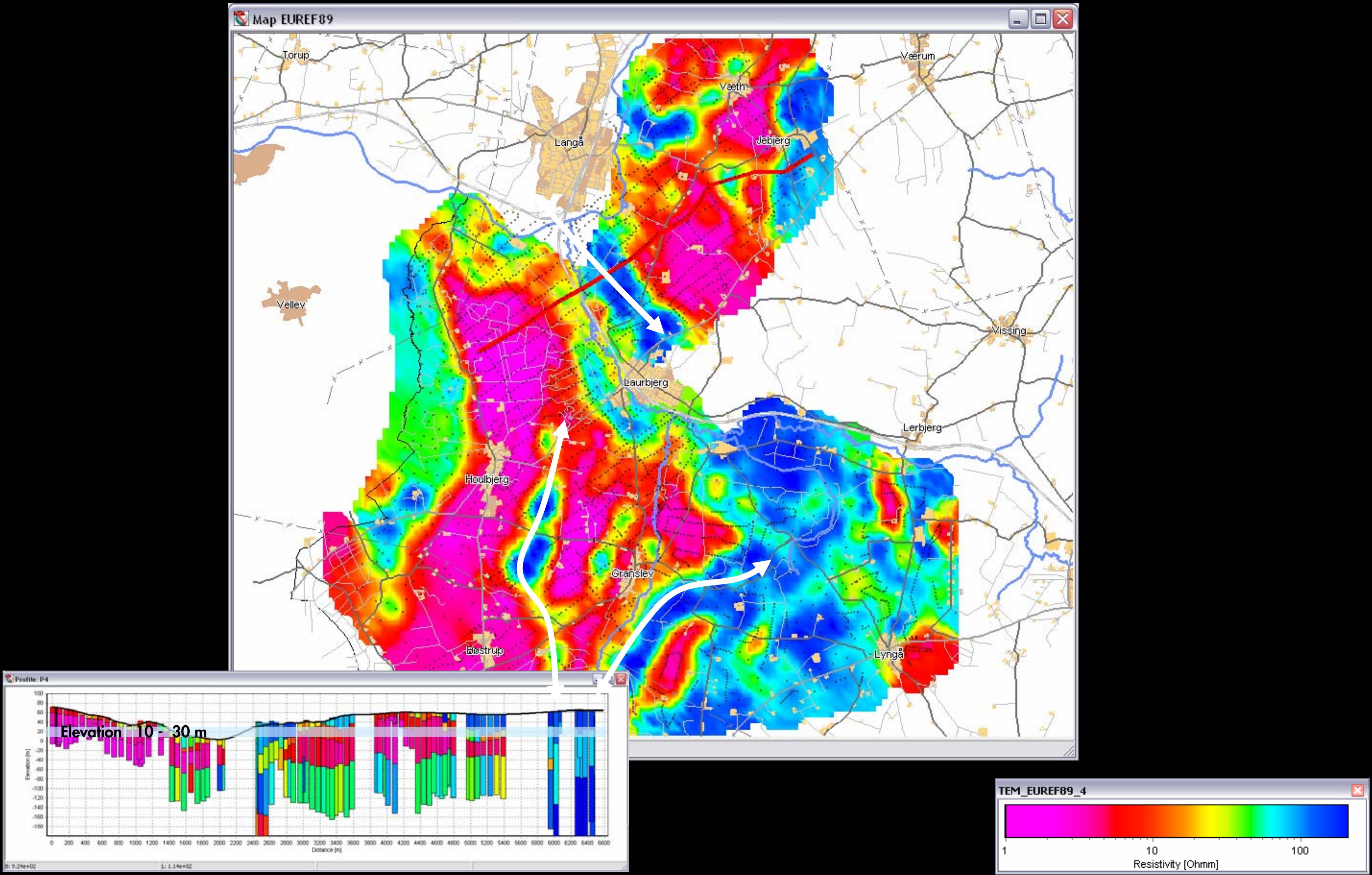


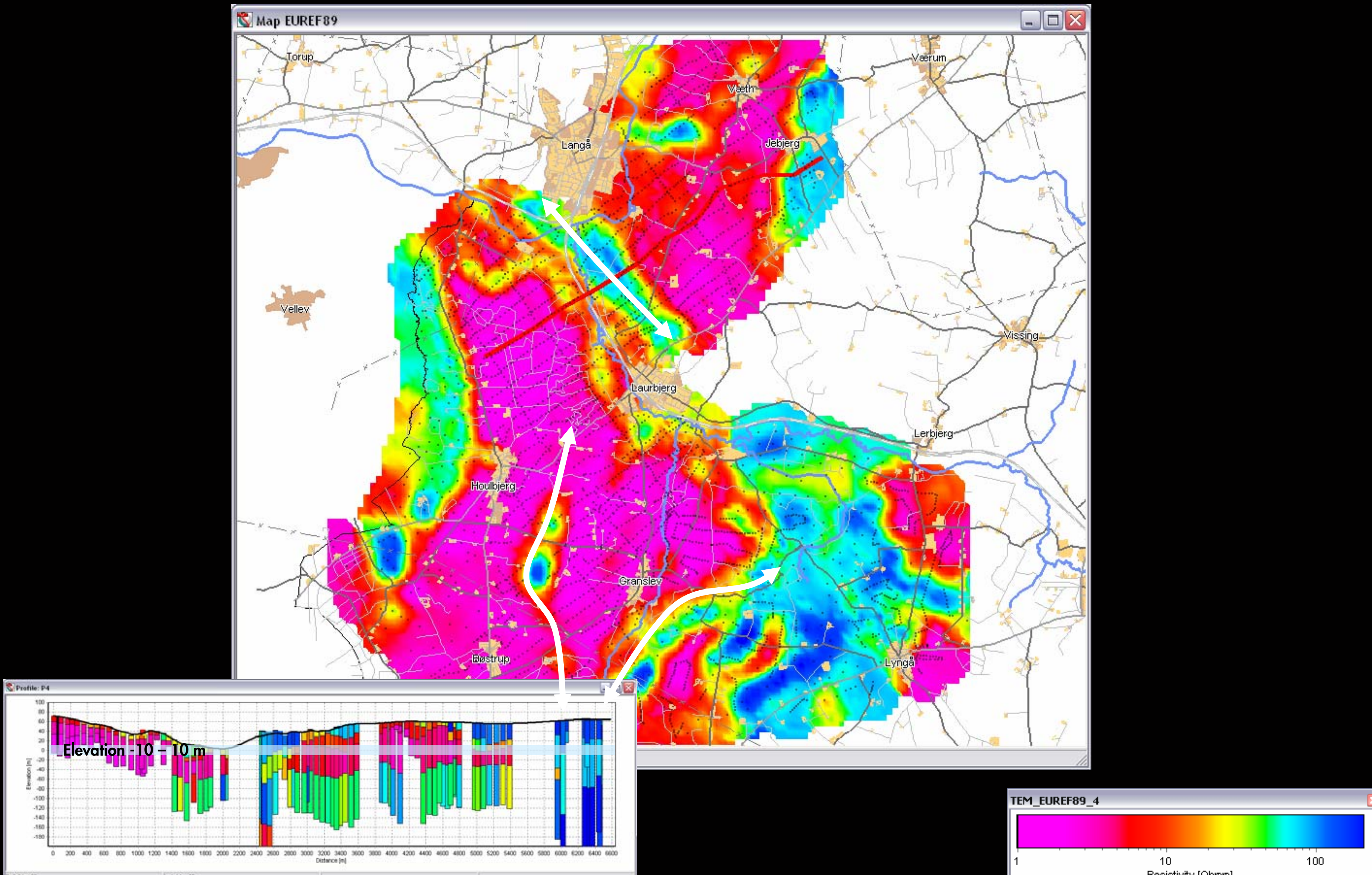
# Average Resistivity 30 – 50 m



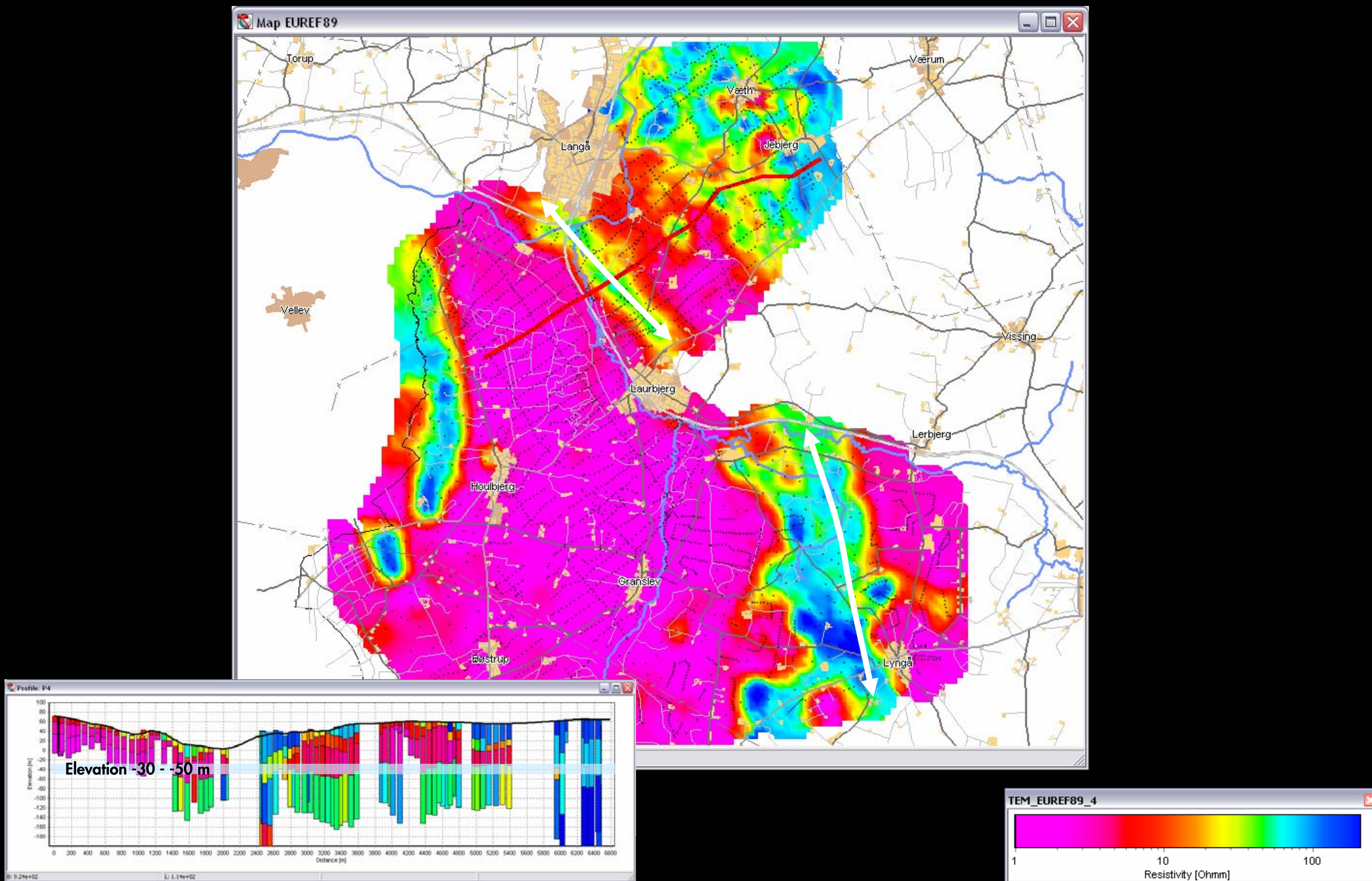
# Average Resistivity 10 – 30 m



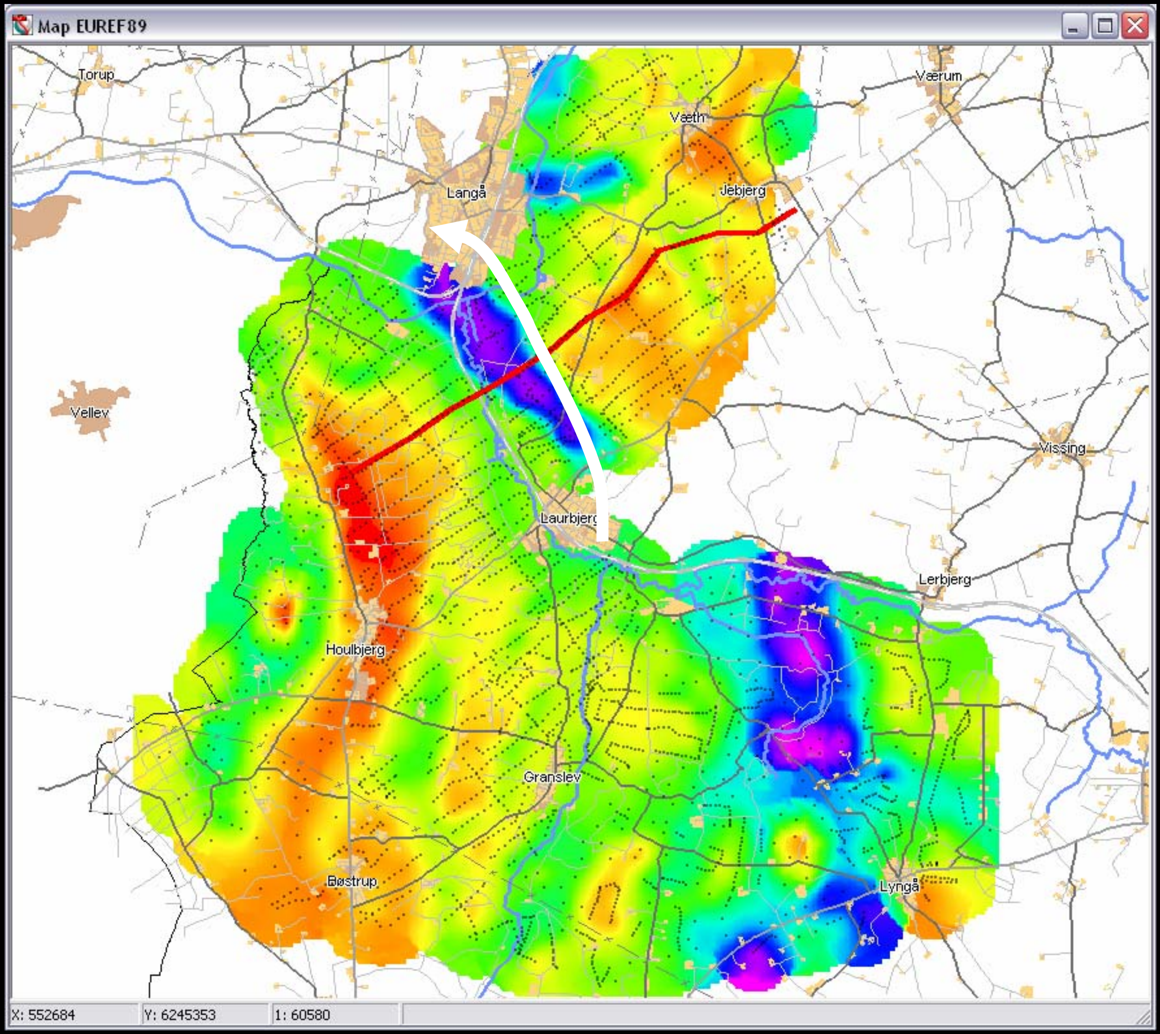
# Average Resistivity -10 – 10 m

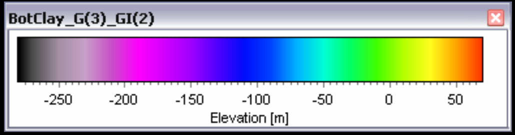


# Average Resistivity -50 – -30 m



# 3D View – Flight Path



# 3D View of the Buried Valley

# Concluding Remarks

- The transient method is in steady development and is one of the strongest tools for hydrogeophysical investigations
- New airborne systems gives data of the same quality as obtained on the ground
- New processing and inversion algorithms are developed for accurate modeling of the TEM systems – gives greatly improved geological models

# 3D View – Mapping the Surface of the Clay