# Monitoring fluid injection using time-lapse analysis: a Rainbow Lake case study

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- Gas and solvent were injected into the Rainbow B pool, a carbonate reservoir, to help extract the remaining oil

## OBJECTIVE

- To determine the locations of the injected gas and solvent using time-lapse analysis

# What is time-lapse analysis?

- 4D seismic - 4$^{th}$ dimension is calendar time
- Refers to repeating a seismic survey after a period of time in an effort to image changes that could have occurred in a reservoir
- Time-lapse analysis is useful:
  - Improve production by finding bypassed oil
  - reservoir changes in between wells can be detected

# Significance of Study

- Not much time-lapse work done on carbonates because the fluid changes are difficult to detect
- BUT, time-lapse analysis of Rainbow B shows that the fluid changes are **bigger** than expected due to the pore geometry

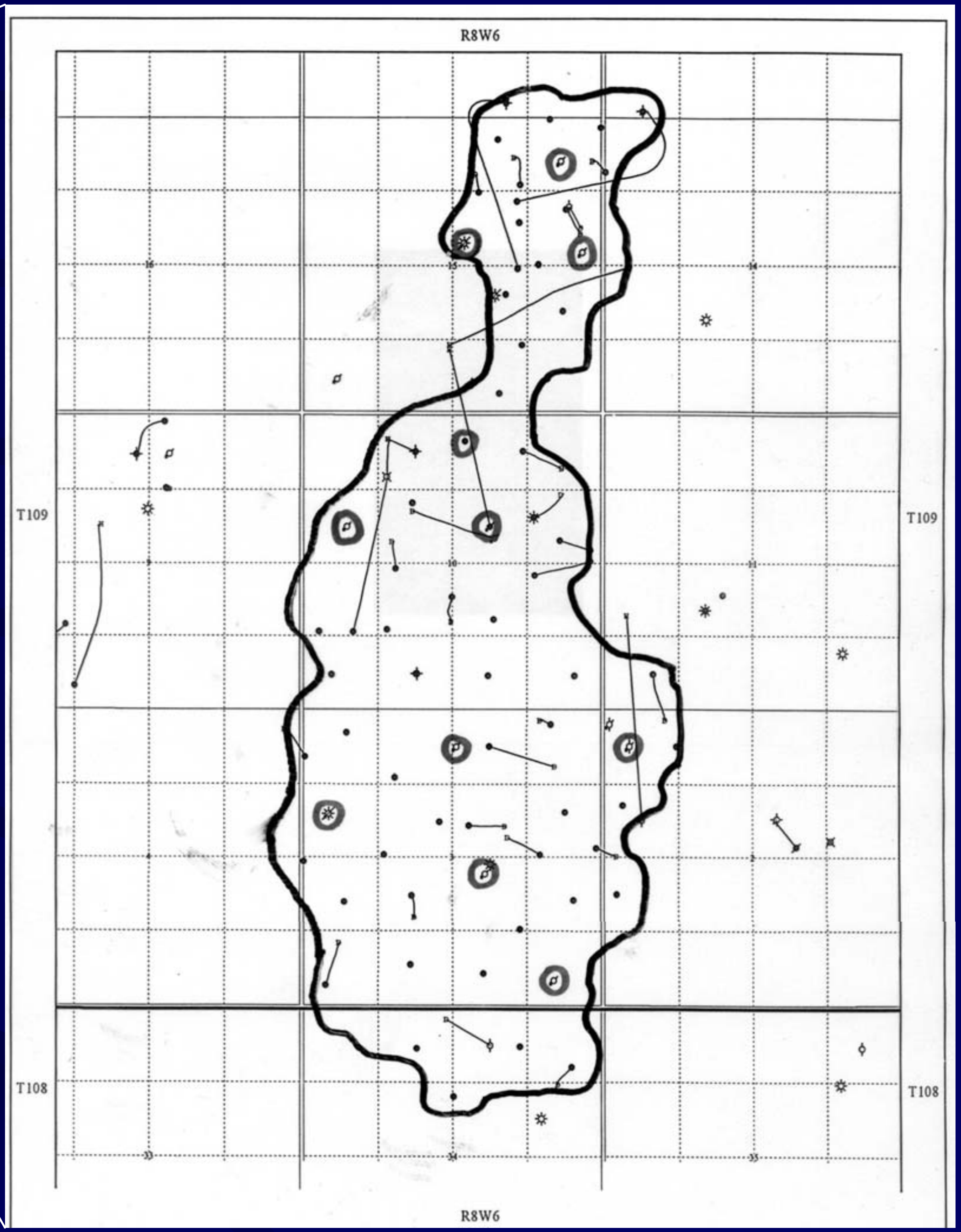
# Main result

- Time-lapse analysis appears to detect the presence of gas and solvent in some, but not all locations

# Outline

1) Background
2) Time-lapse results:
   - Time-delay map
   - Amplitude change map
3) Compare time-lapse results to geology and engineering data

# BACKGROUND

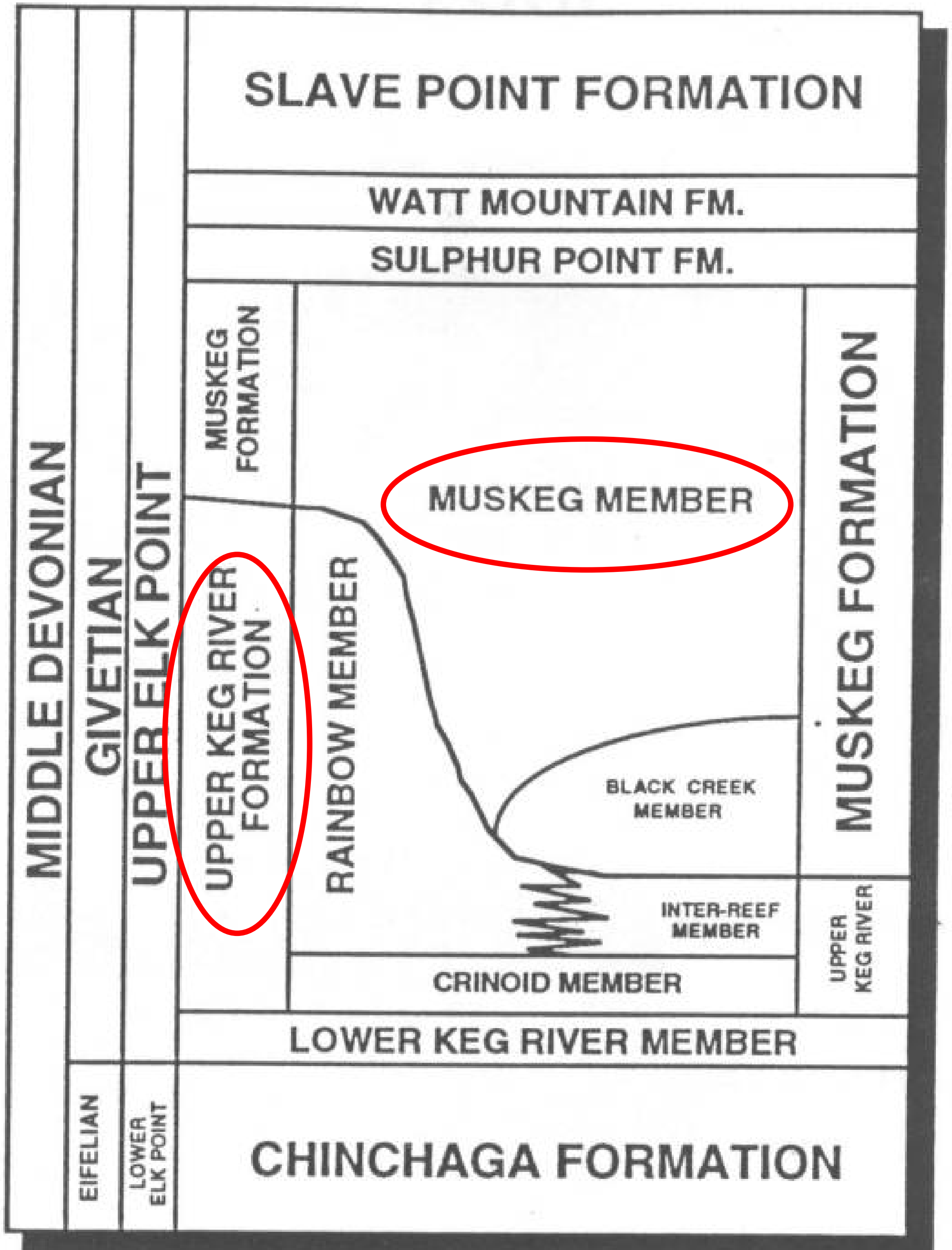




Rainbow B pool:

5.6 km * 2.1 km

Thickness of ~200 m

Depth ~ 1800 m




Reservoir rock: Keg River formation (mostly dolomitic) is producing oil

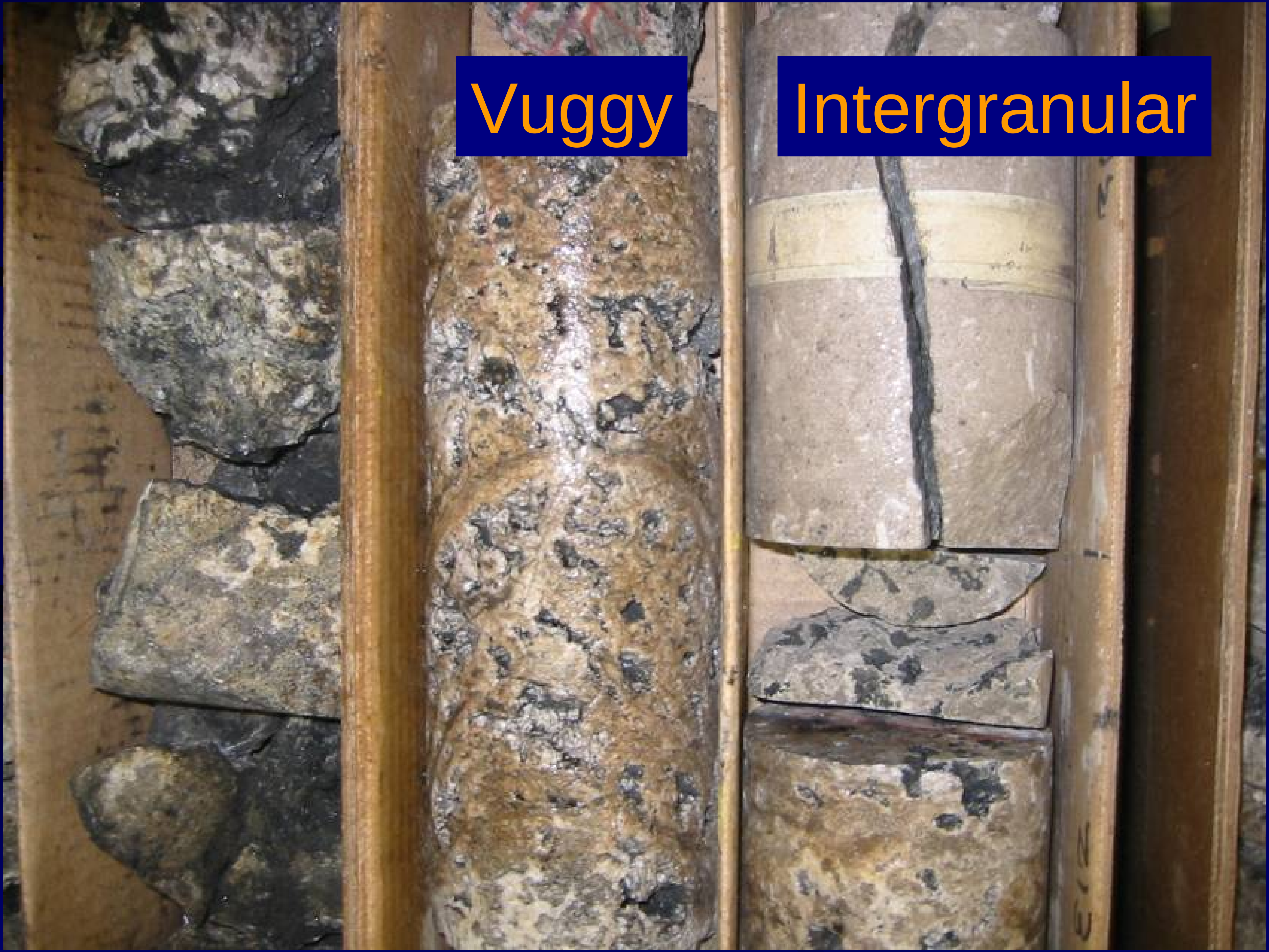
Seal rock: evaporitic Muskeg member

(Laflamme, 1993)

# Pore geometry

- Pore geometry affects the velocity changes
- Fluid substitution in low pore aspect ratio (cracks) rock causes greater velocity change than high pore aspect ratio (round) rock. (Kuster & Toksoz, 1974)
- Rainbow B reef is mostly vuggy and has a low pore aspect ratio.
- The Gassmann equation underpredicts the velocity changes

# Core from well 7-10:  reef mostly dolomitized

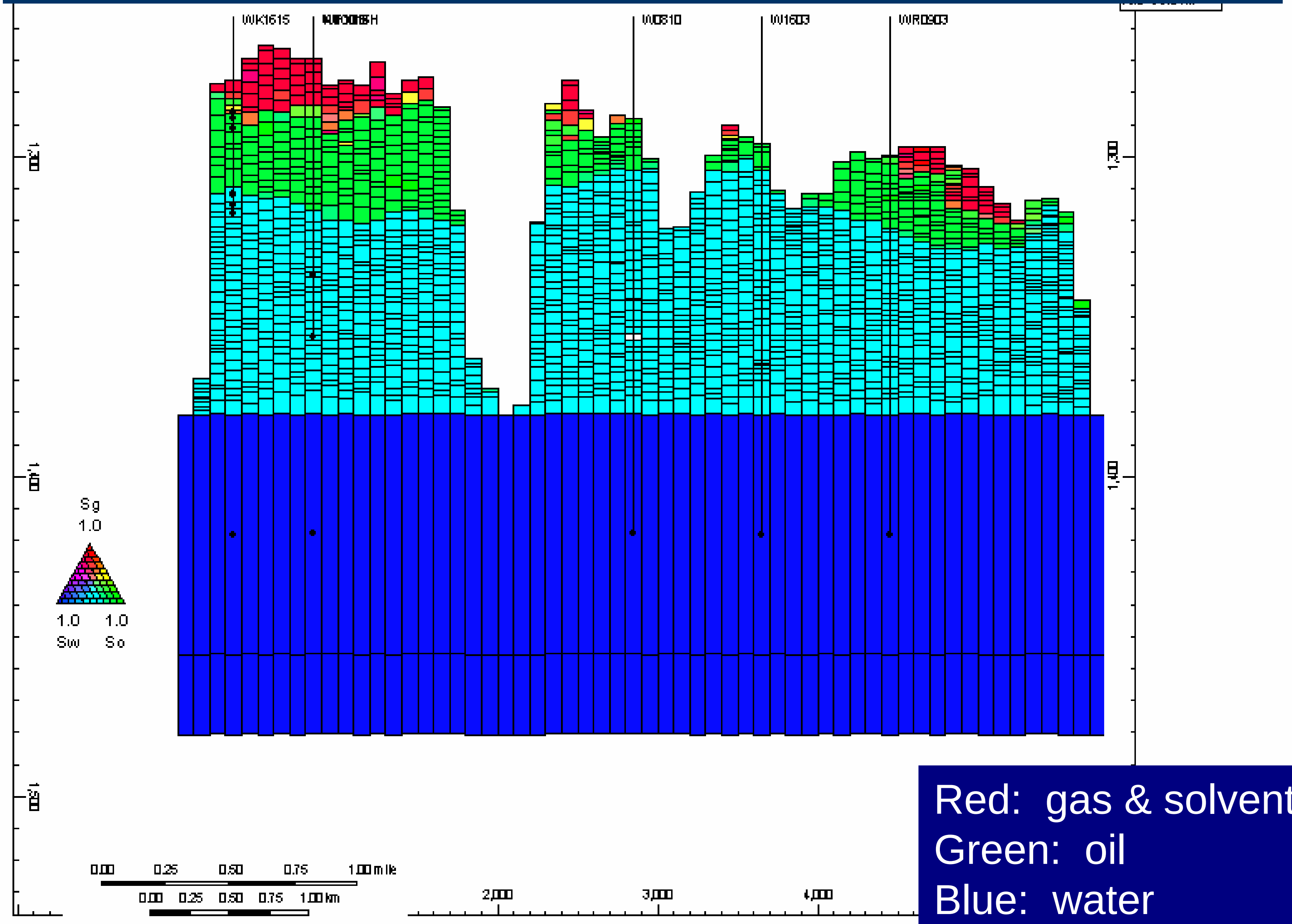


# Rainbow Pool Timeline

- 1965 – pool was discovered and oil produced by natural drives: primary production
- 1968 – pool waterflooded: secondary production
- 1984 – miscible gas and solvent injection: tertiary production

- 1987 – 3D seismic data acquired in area
- 2002 – 3D seismic data acquired again

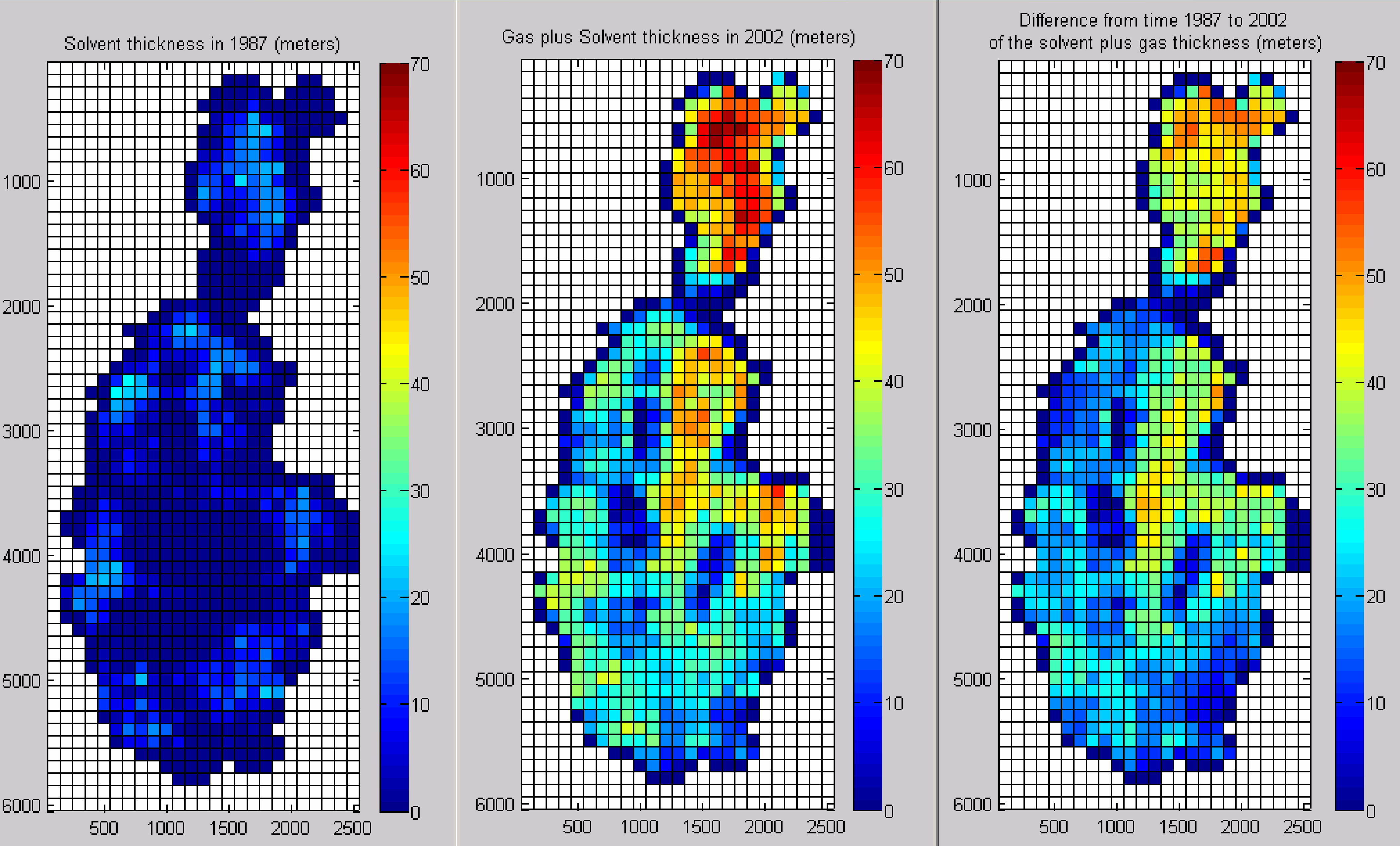
# Fluid contacts from 1987 to 2002




Red: gas & solvent
Green: oil
Blue: water

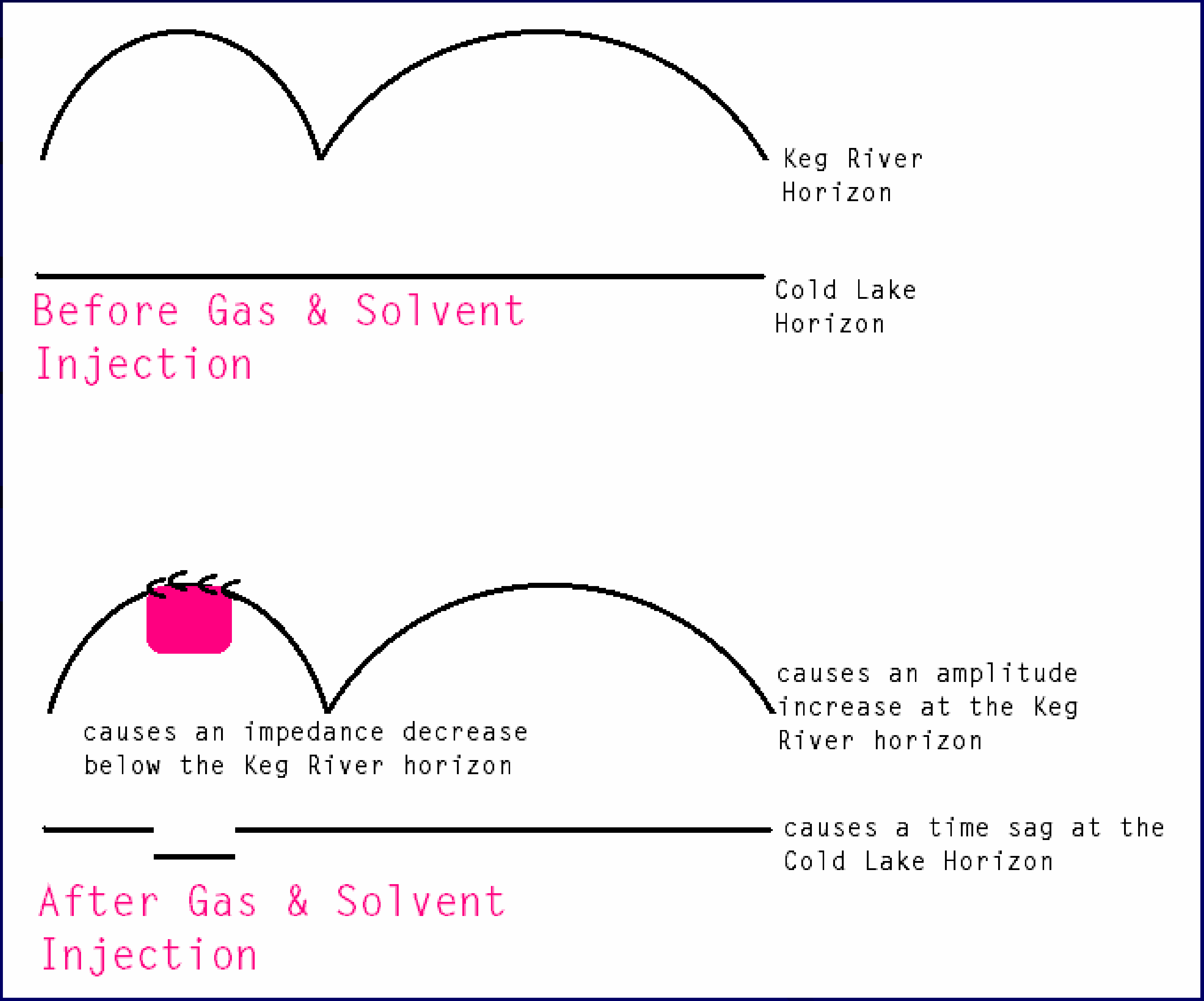
# Gas Plus Solvent Thickness (m)

## 1987 | 2002 | Difference

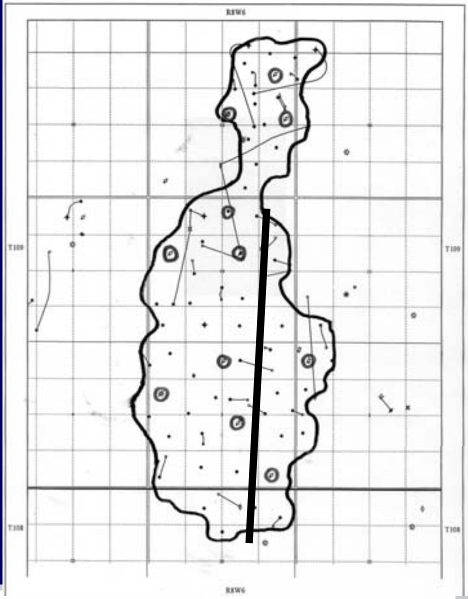


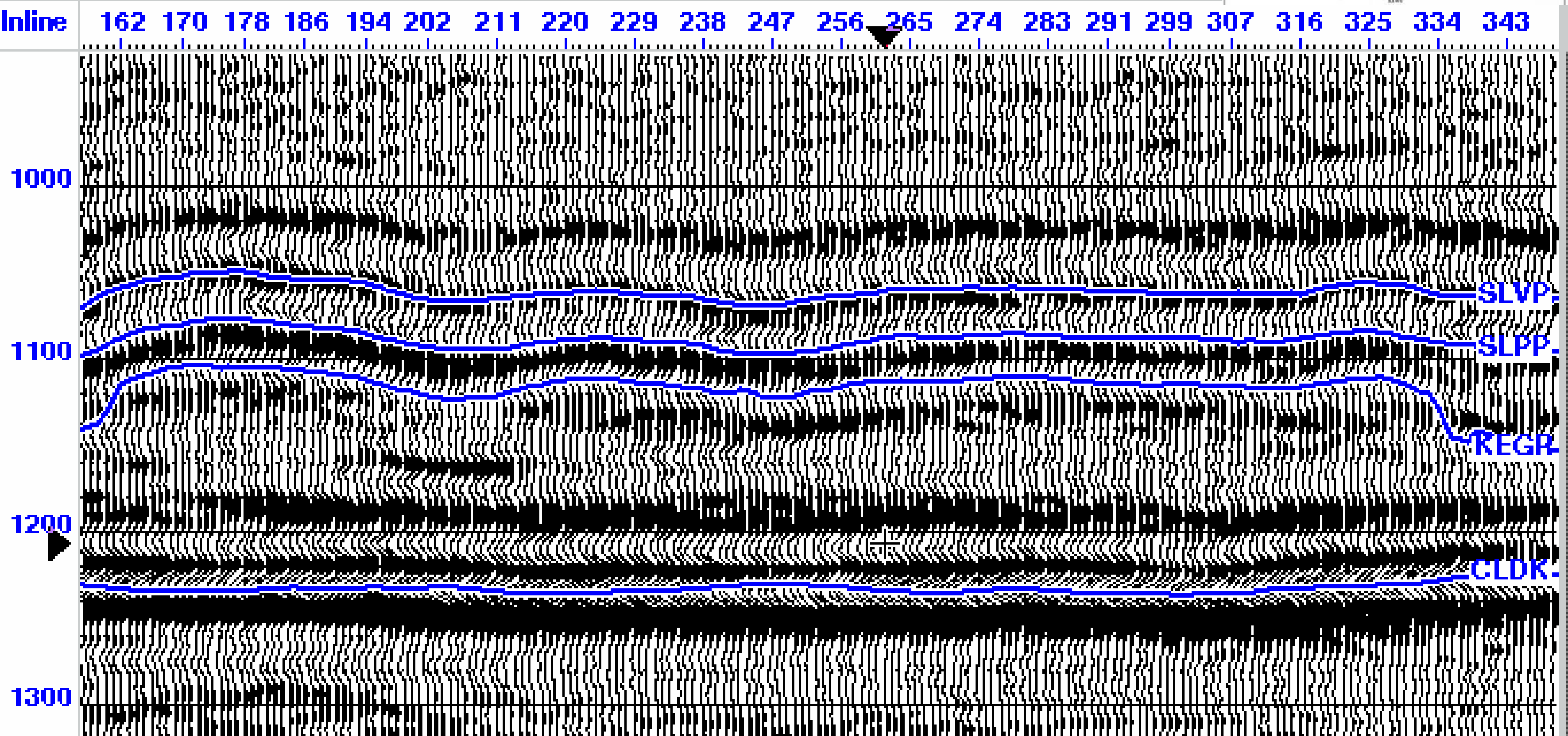
# TIME-LAPSE RESULTS

# Seismic changes expected from the injection of gas and solvent

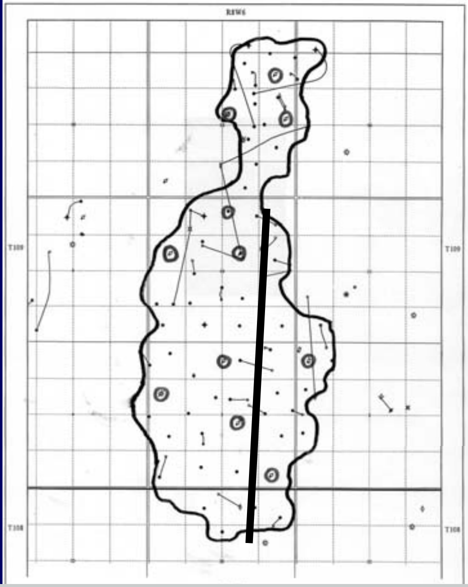


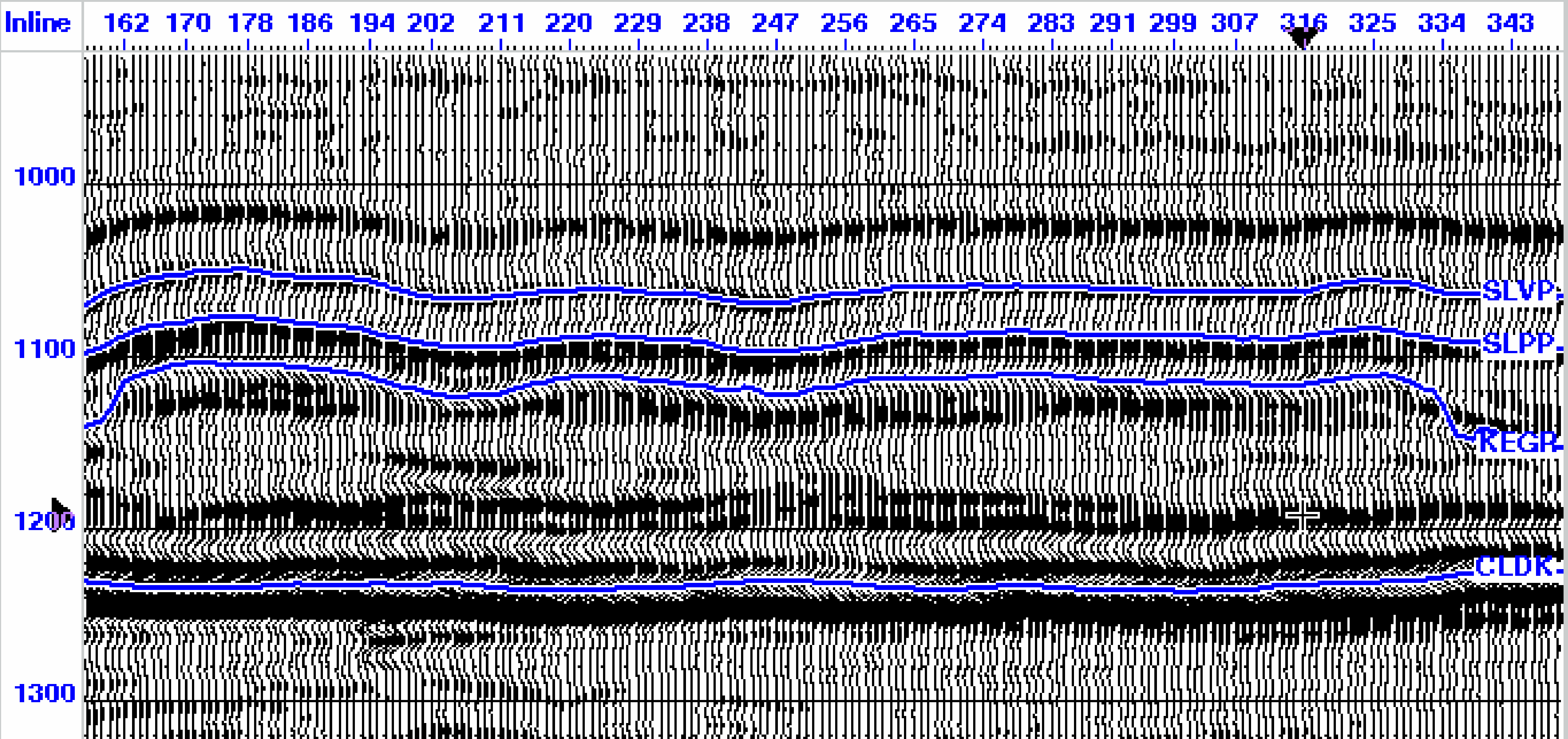
# 1987 seismic data (Base)
# Crossline 130



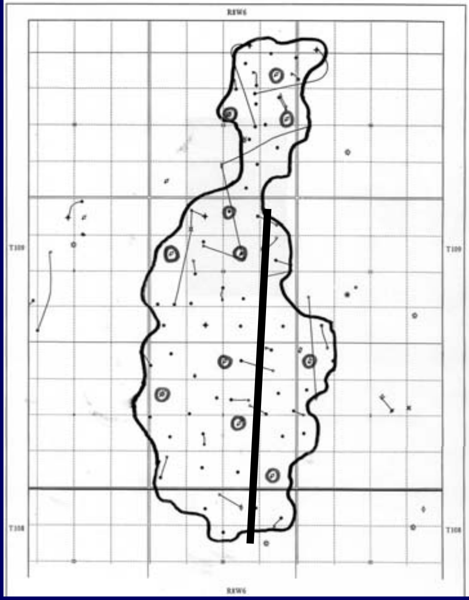


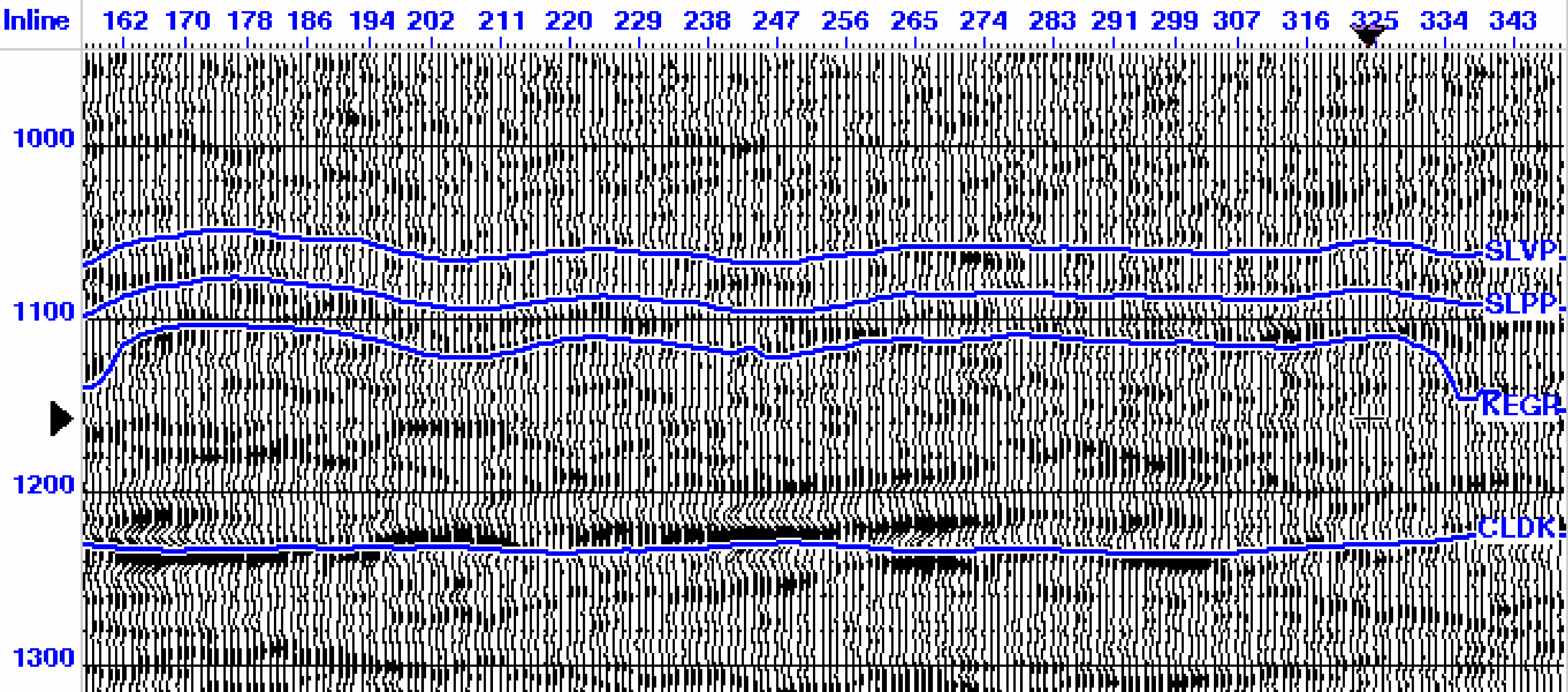
# 2002 seismic data (Monitor) higher frequency content



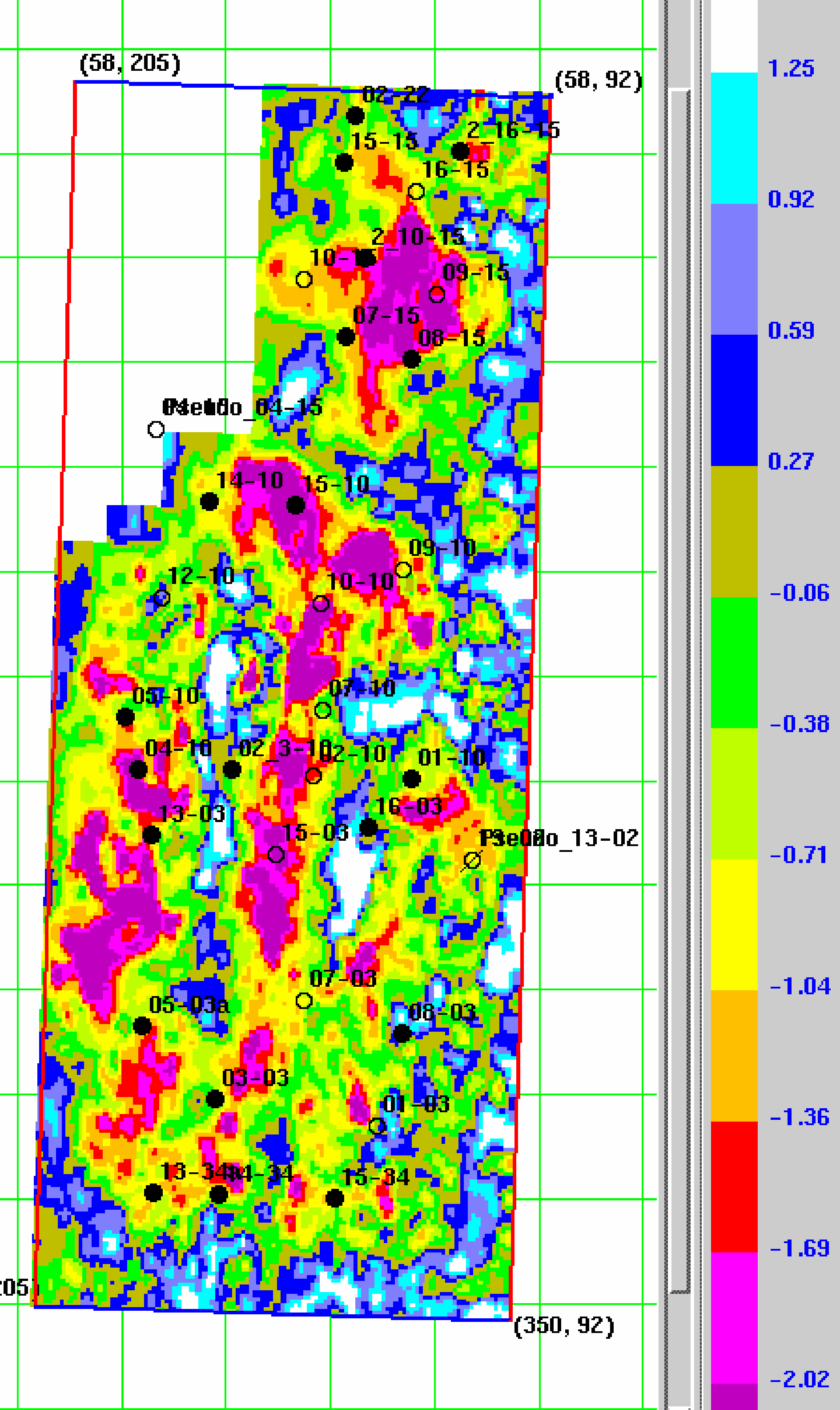


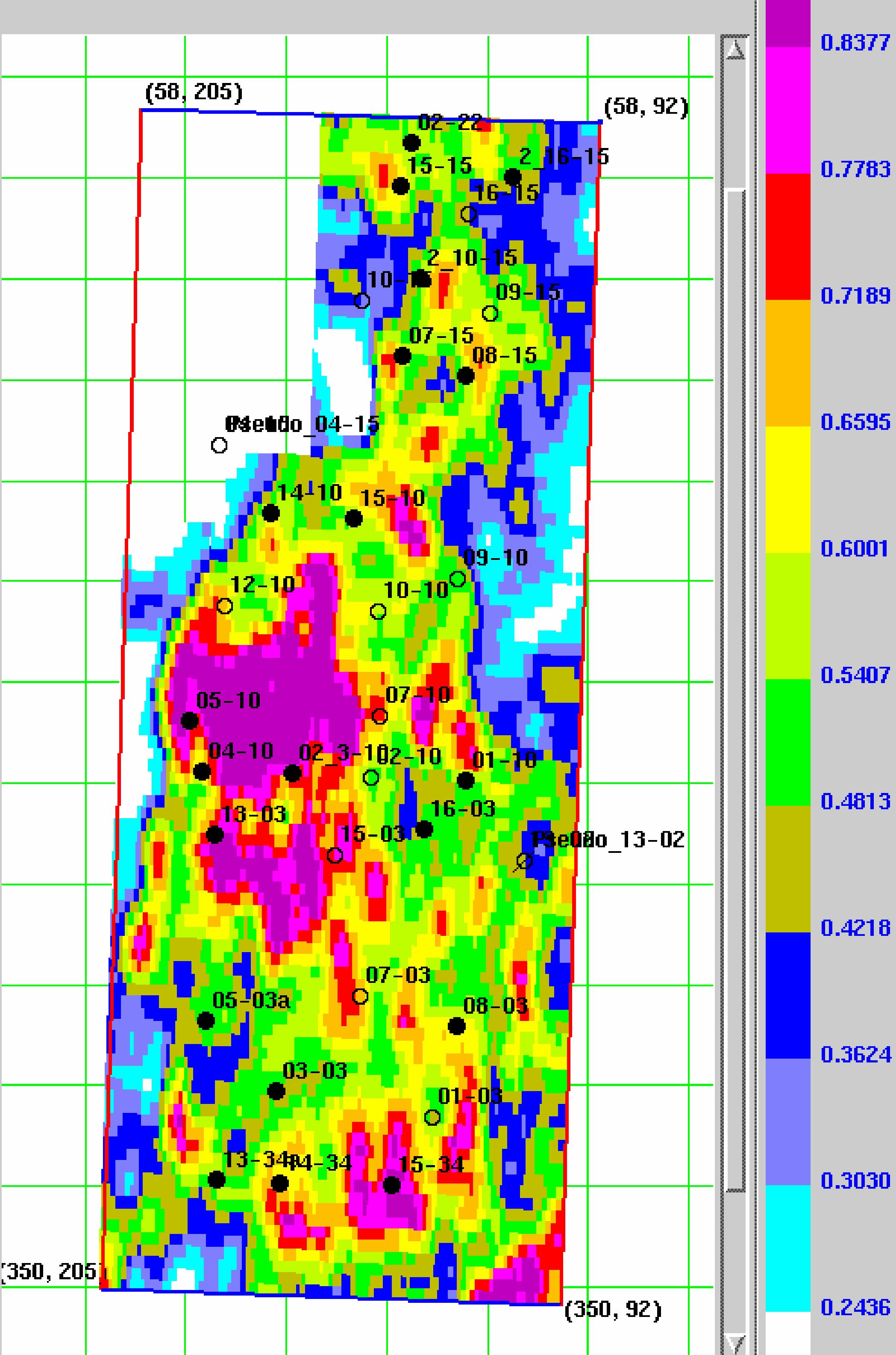
# Difference between the 1987 and the 2002 survey





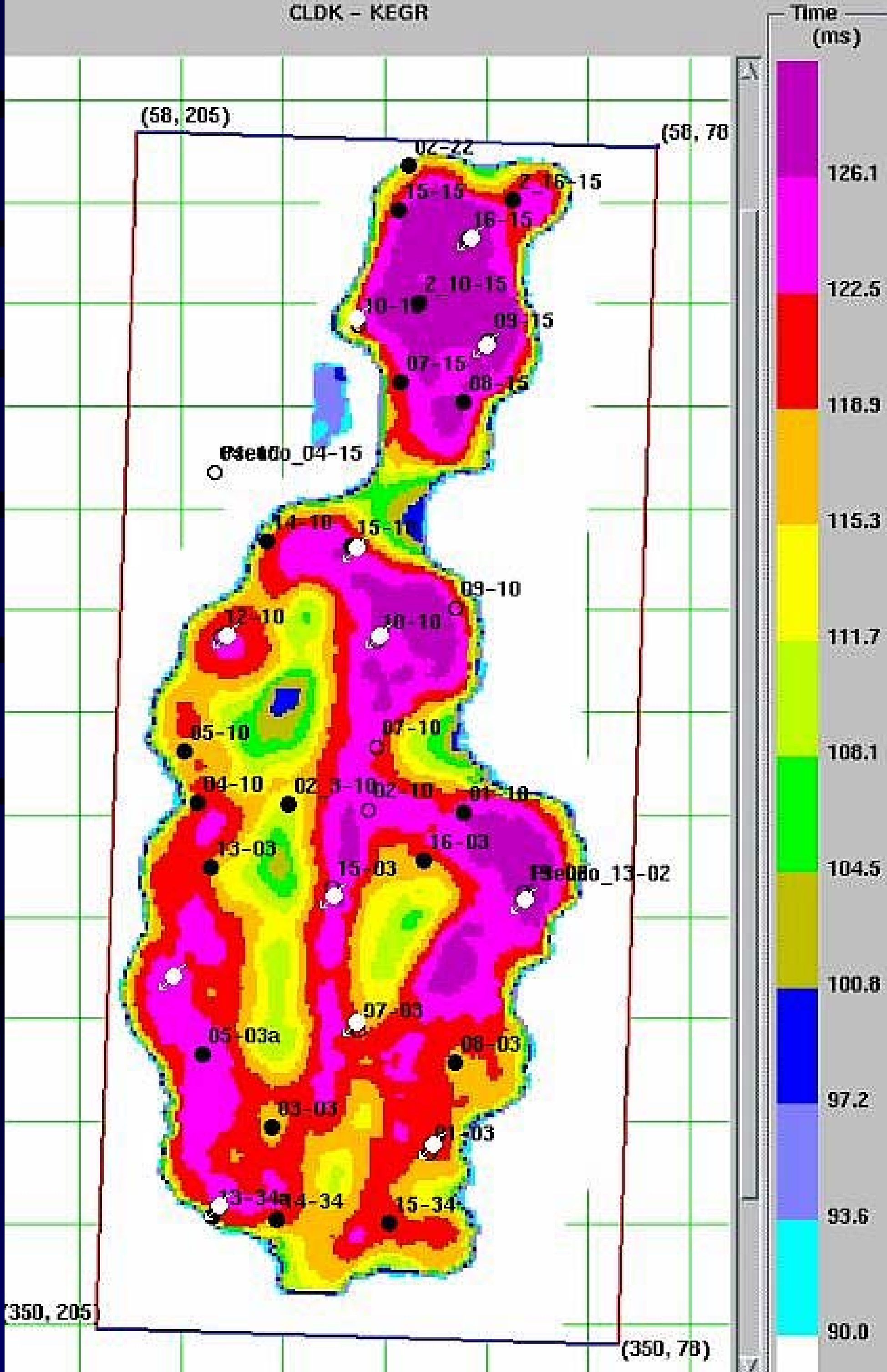
# Time-delay map (ms)



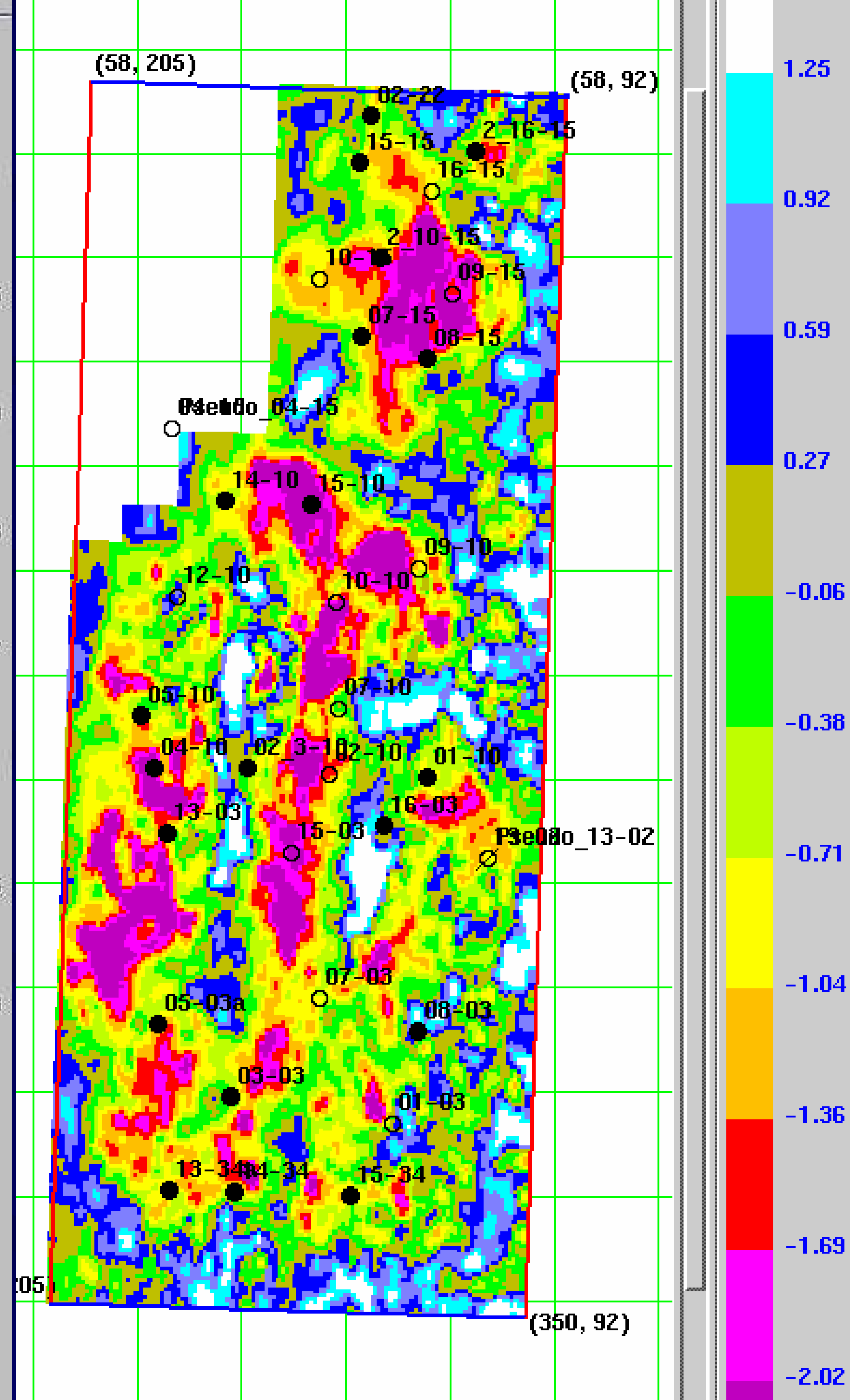



# Difference RMS amplitude map from 1987 to 2002

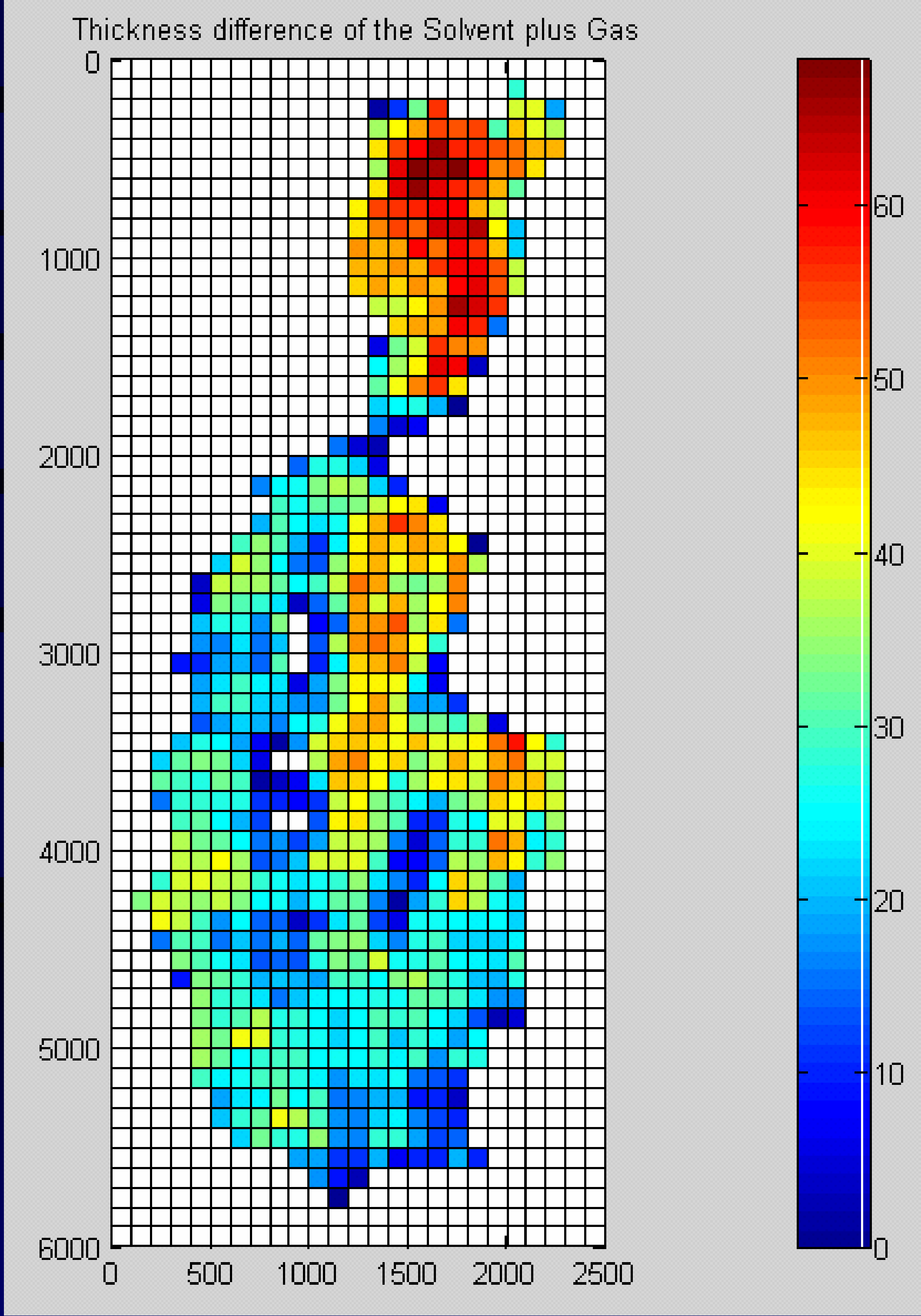
# COMPARE SEISMIC TIME-DELAY MAPS WITH OTHER MAPS



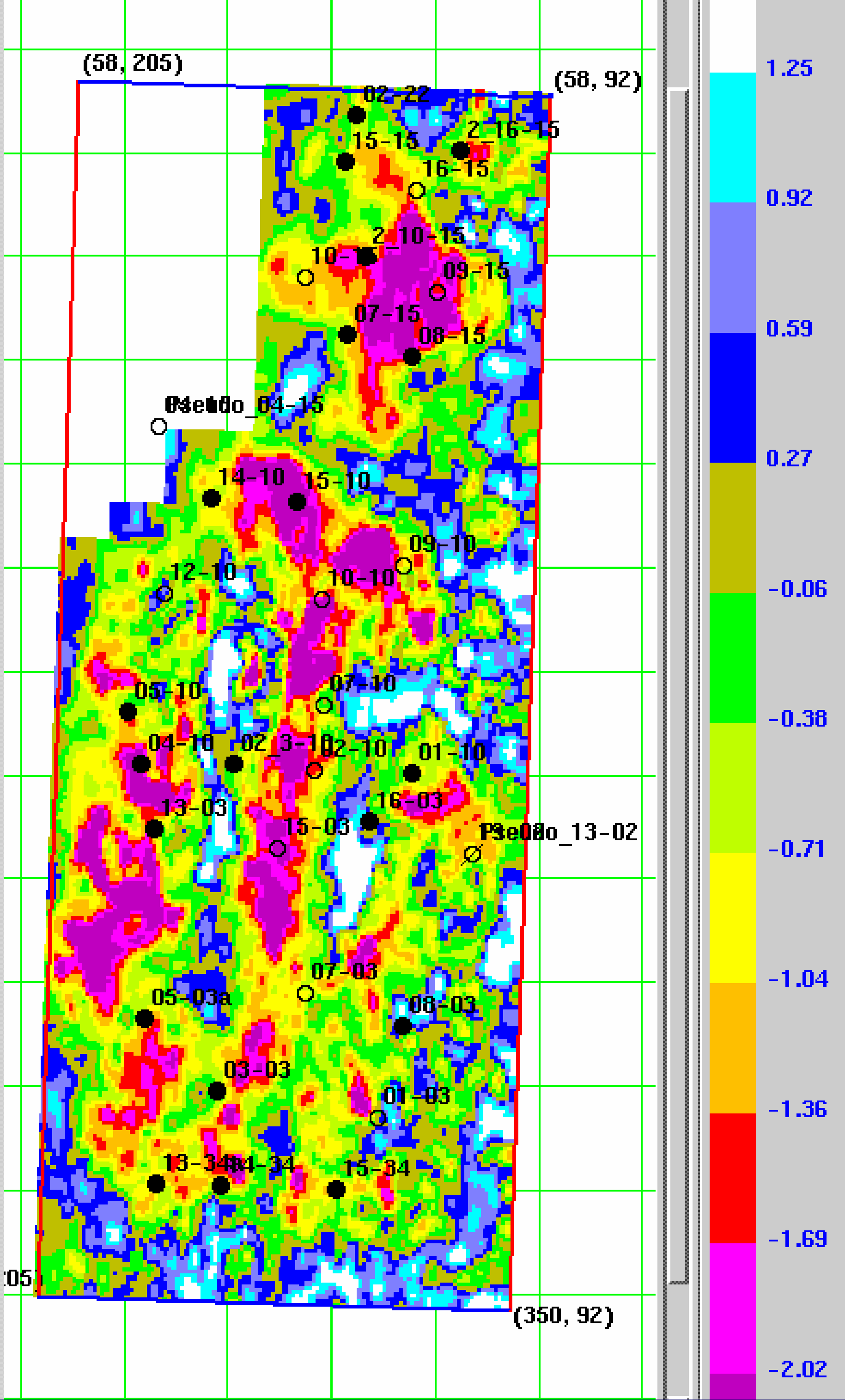

Isochron map (Keg River to Cold Lake)



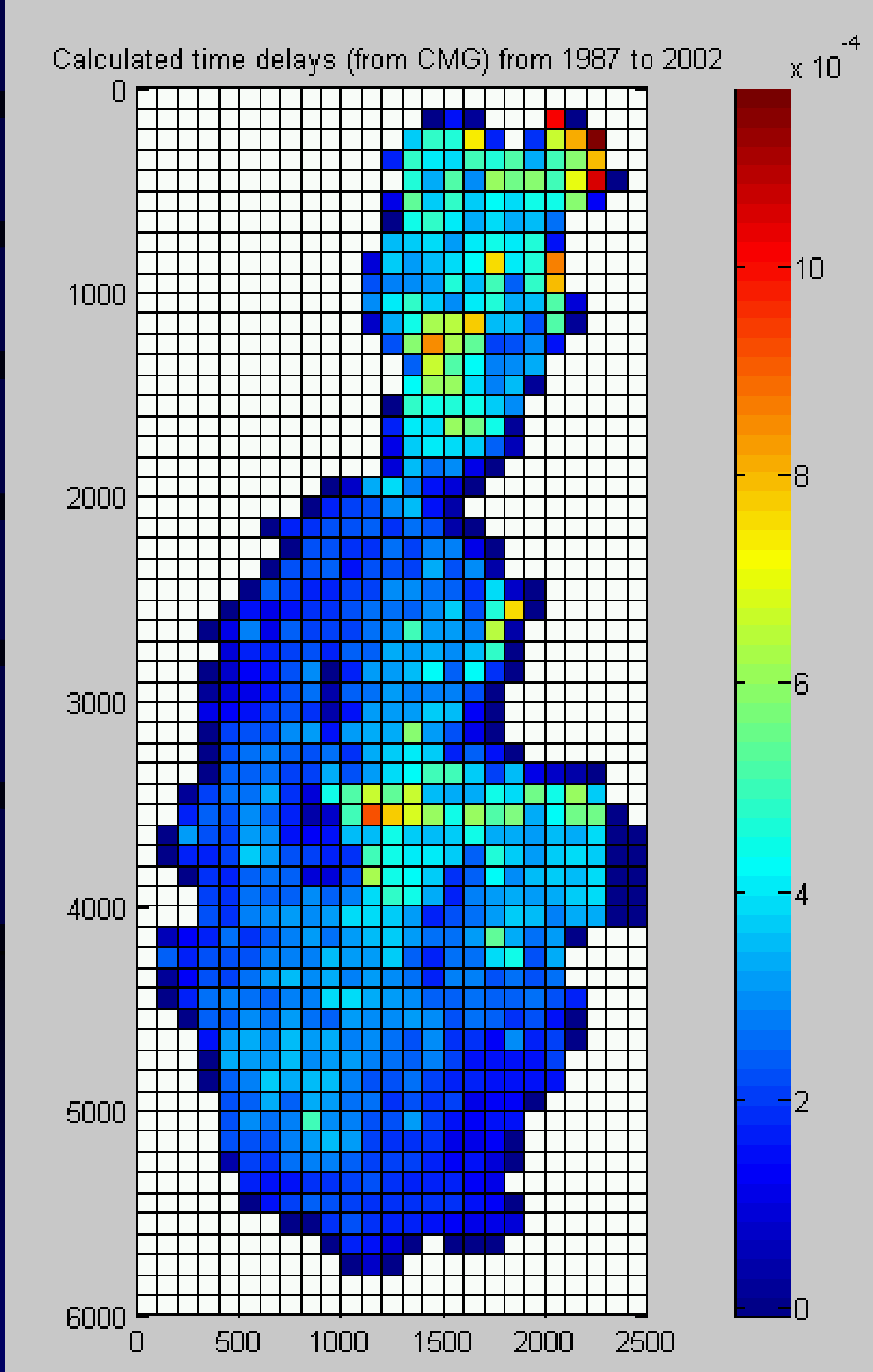

Time-delay map (ms)

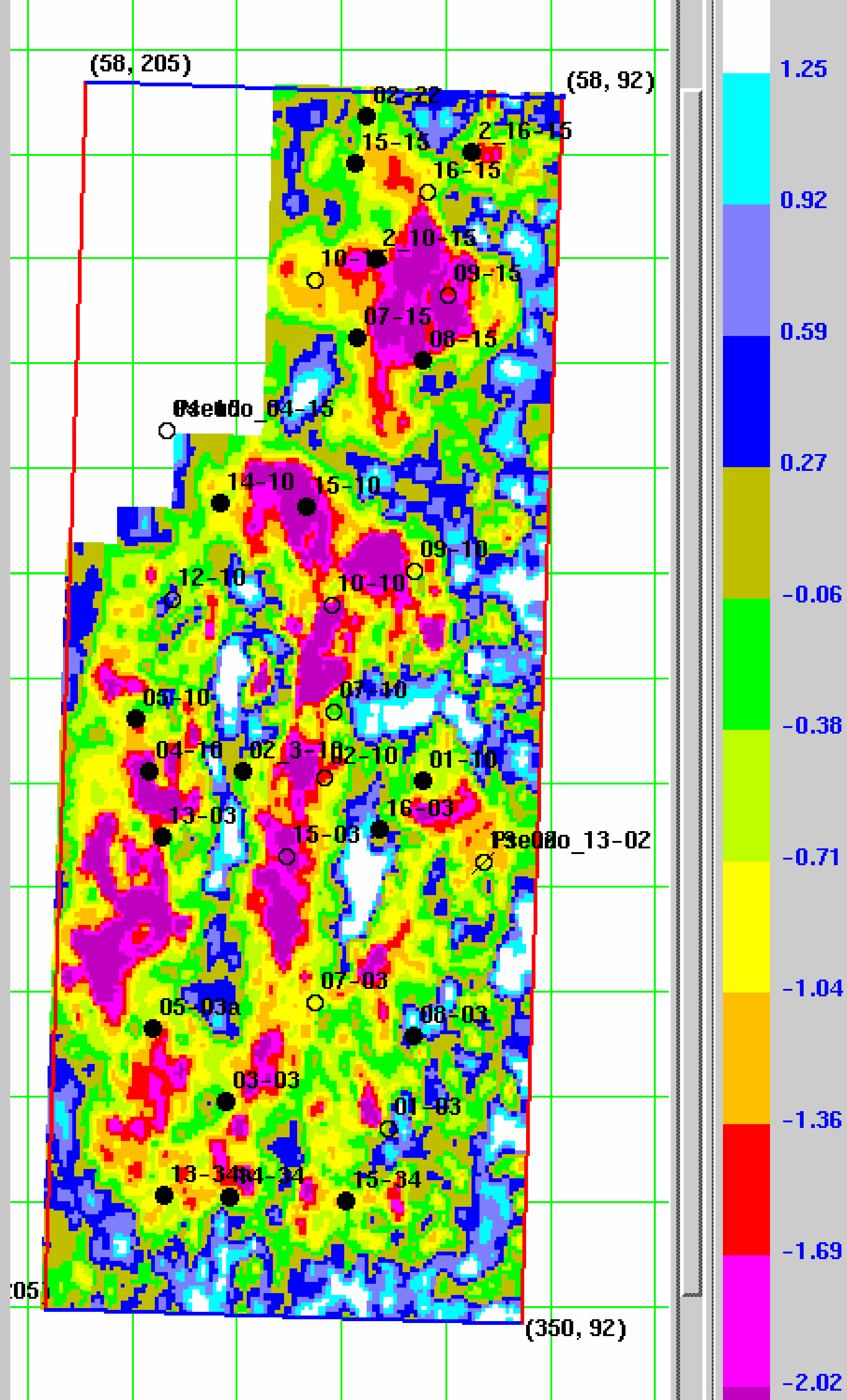



Fluid thickness difference (m)



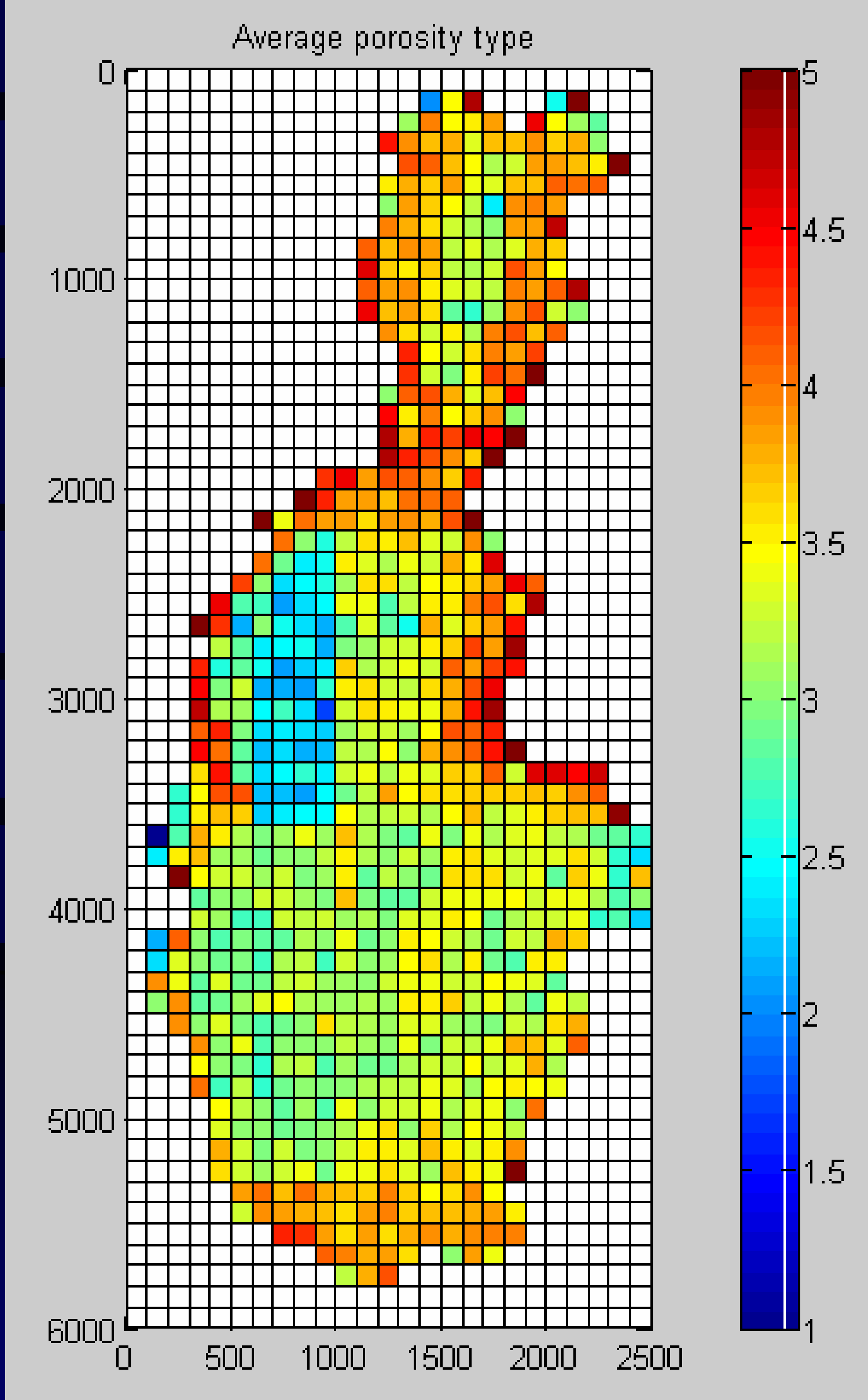

Time-delay map (ms)



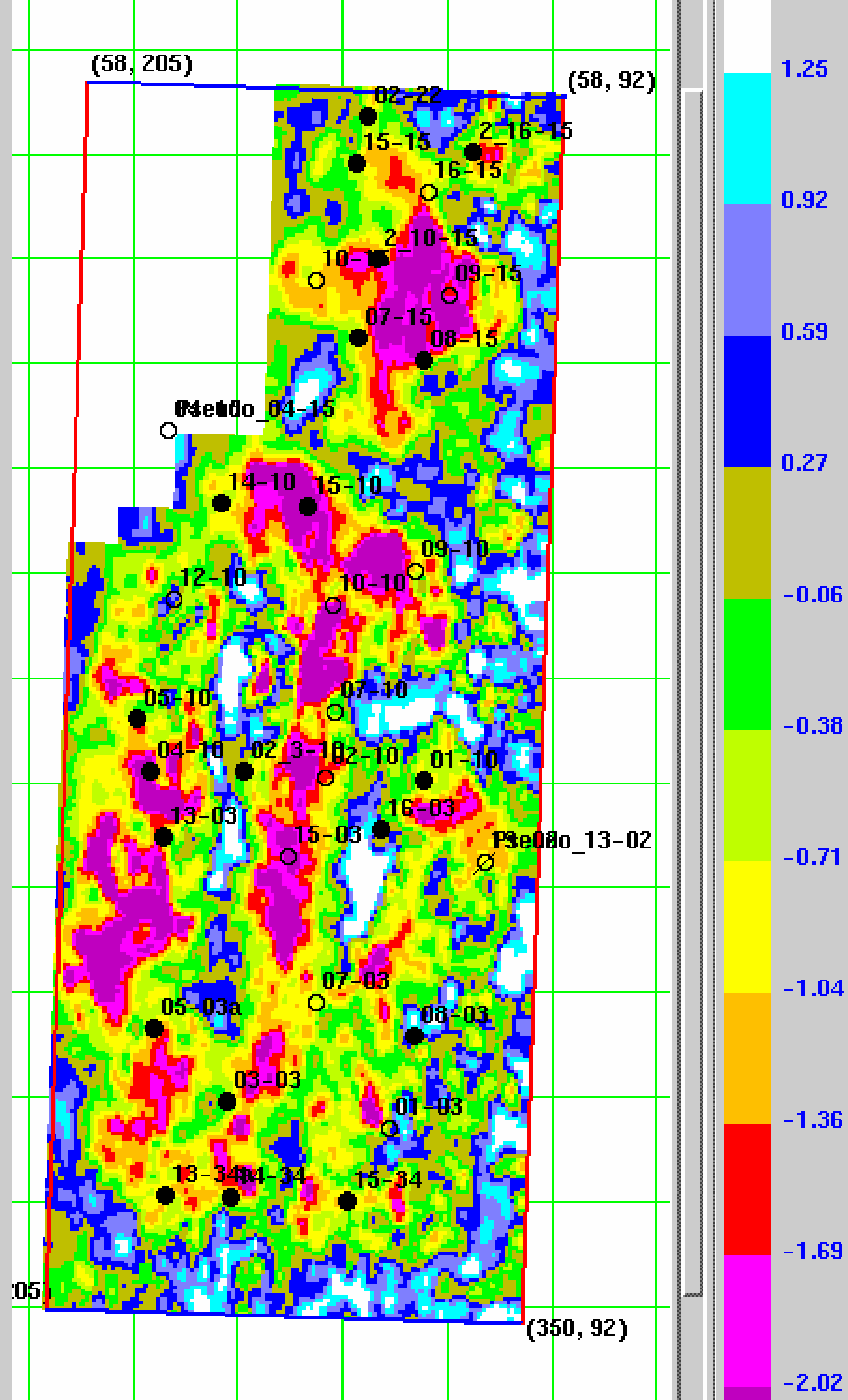




Gassmann calculated time-delay map (s)

Time-delay map (ms)




Porosity type map




Time-delay map (ms)

# Conclusions

1. Time-lapse analysis detected the injected fluids in some, but not all locations.
2. Time-delay results are most useful
3. Vuggy areas show more response than intergranular areas
4. Amplitude change and impedance change results were not useful
5. Gassmann equation underpredicts the velocity change

# Acknowledgements


- Husky Energy for the data
  - Larry Mewhort has helped me tremendously in supplying data and suggestions
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