

# **Evaluating aquifer flow conditions using heat as an in-well tracer**

**Steve Sellwood, UW – Madison Department of Geoscience**

**Jean Bahr, UW – Madison Department of Geoscience**

**Dave Hart, Wisconsin Geological and Natural History Survey**



**Wisconsin Geological &  
Natural History Survey**

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**Funding provided by:**

- **University of Wisconsin Water Resources Institute**

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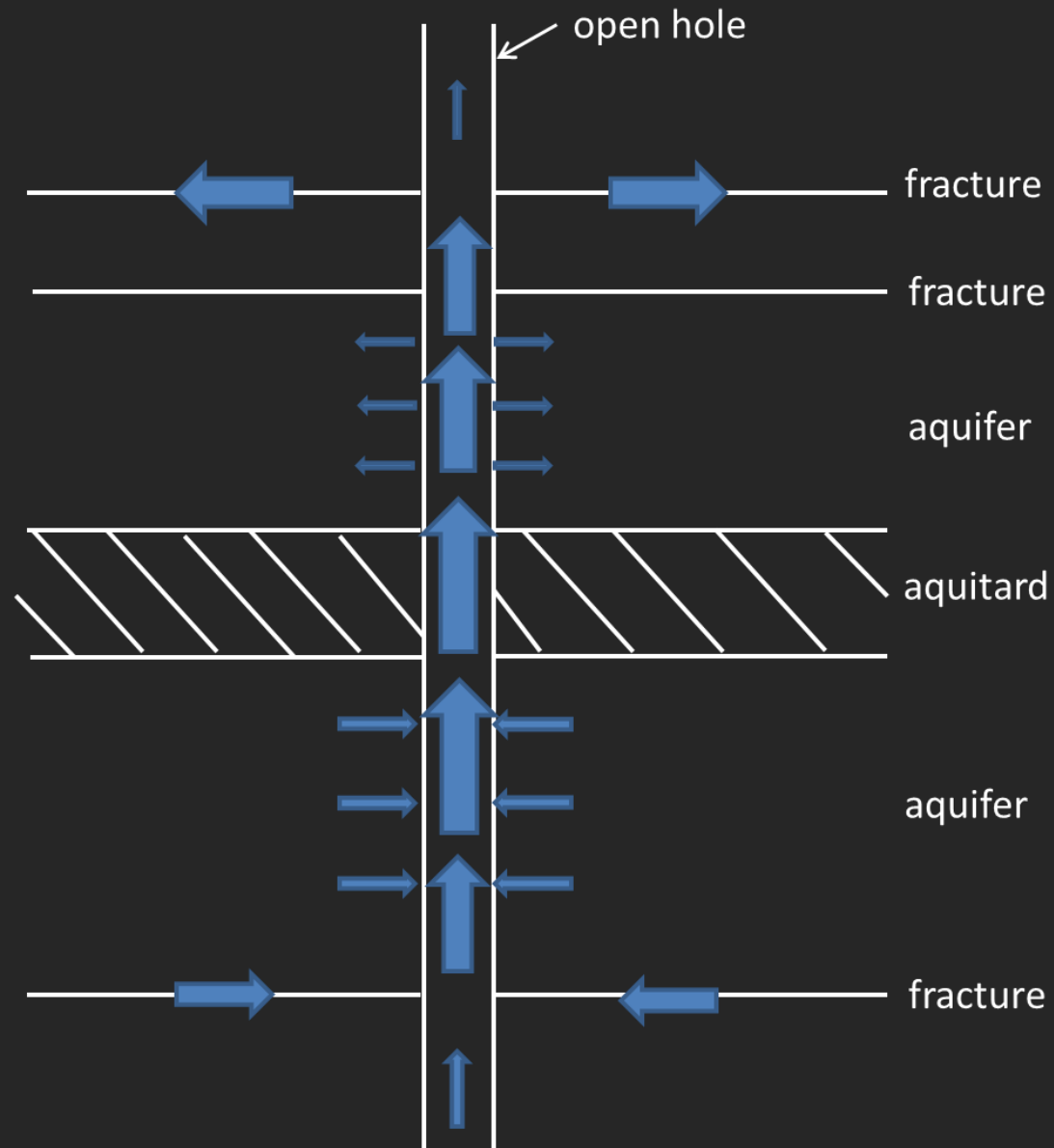
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- **University of Wisconsin Water Resources Institute**
- **Geological Society of America Student Research Grant**



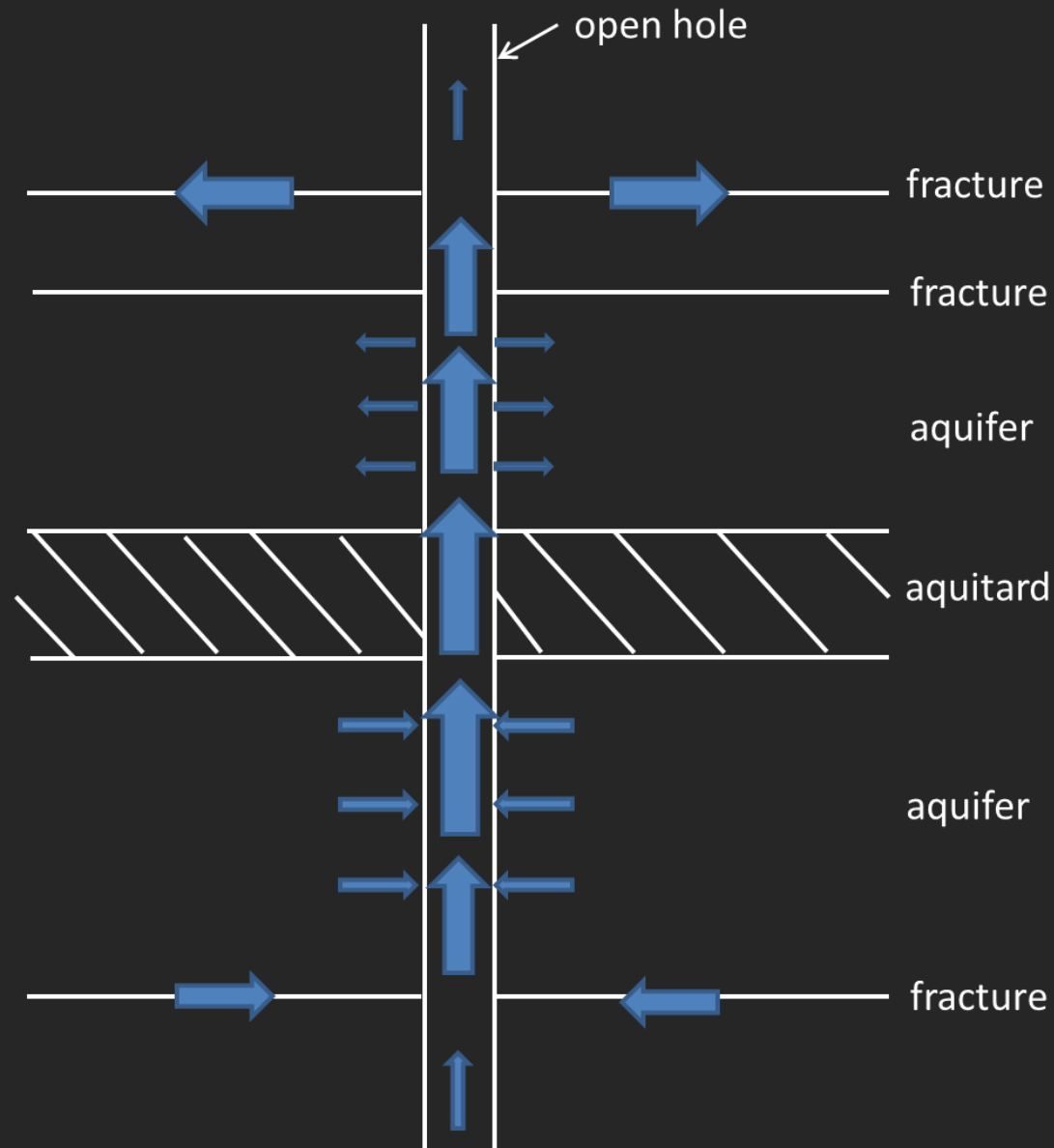
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# What can borehole flow tell us?



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- Identify permeable features
- Identify aquitards
- Determine flow direction (up or down)
- Understand implications for contaminant transport



# **Research goals:**

- **Use heat as an in-well tracer to measure borehole flow**
- **Use borehole flow data to characterize aquifer flow conditions**

# In-well heat tracer tests:

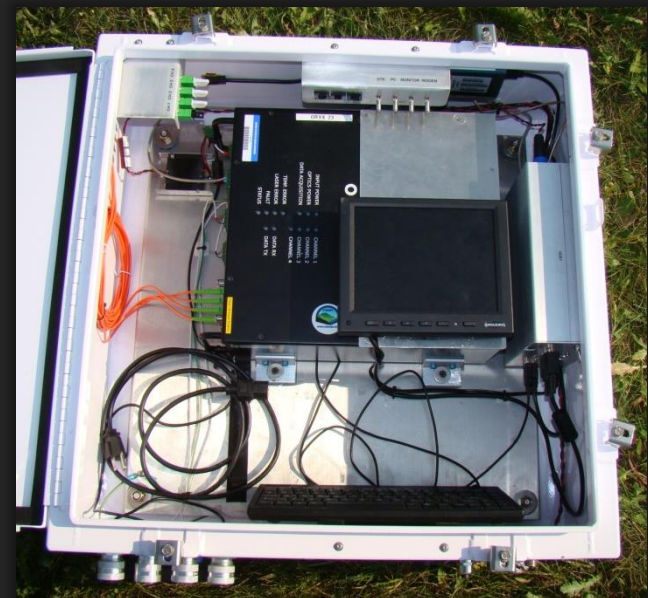
- Induce heat pulses at discrete depths using downhole heater



Peter Sobol, UW – Madison

# In-well heat tracer tests:

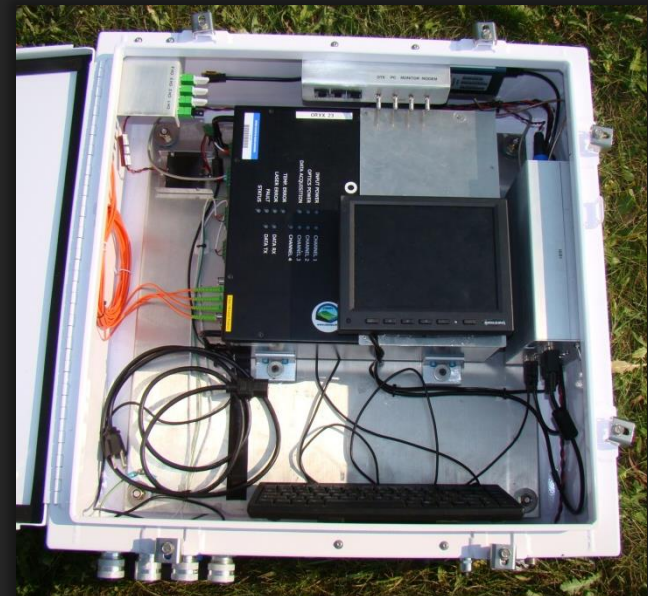
- Induce heat pulses at discrete depths using downhole heater
- Monitor temperatures in the well with fiber optic Distributed Temperature Sensing system (DTS)

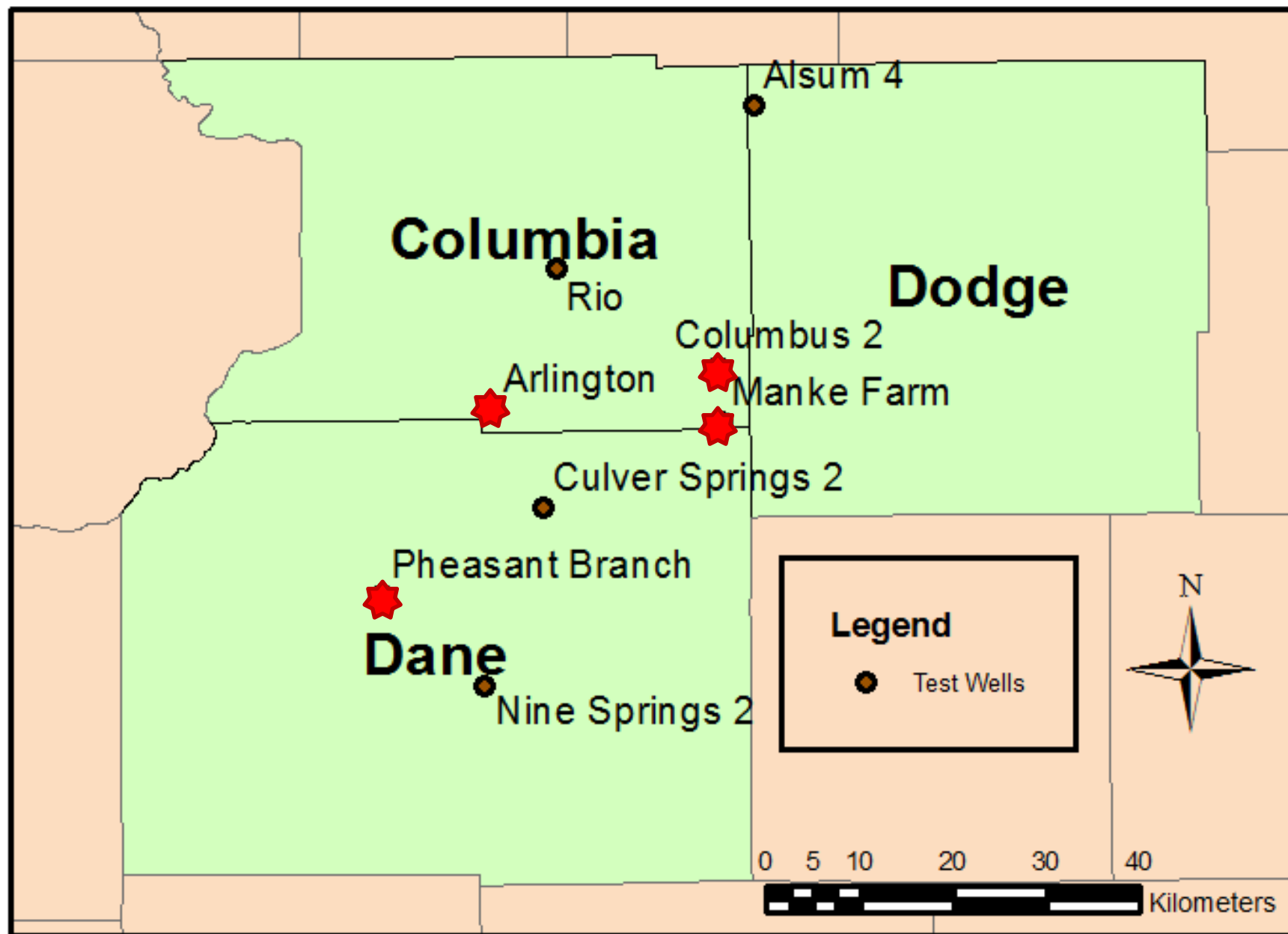


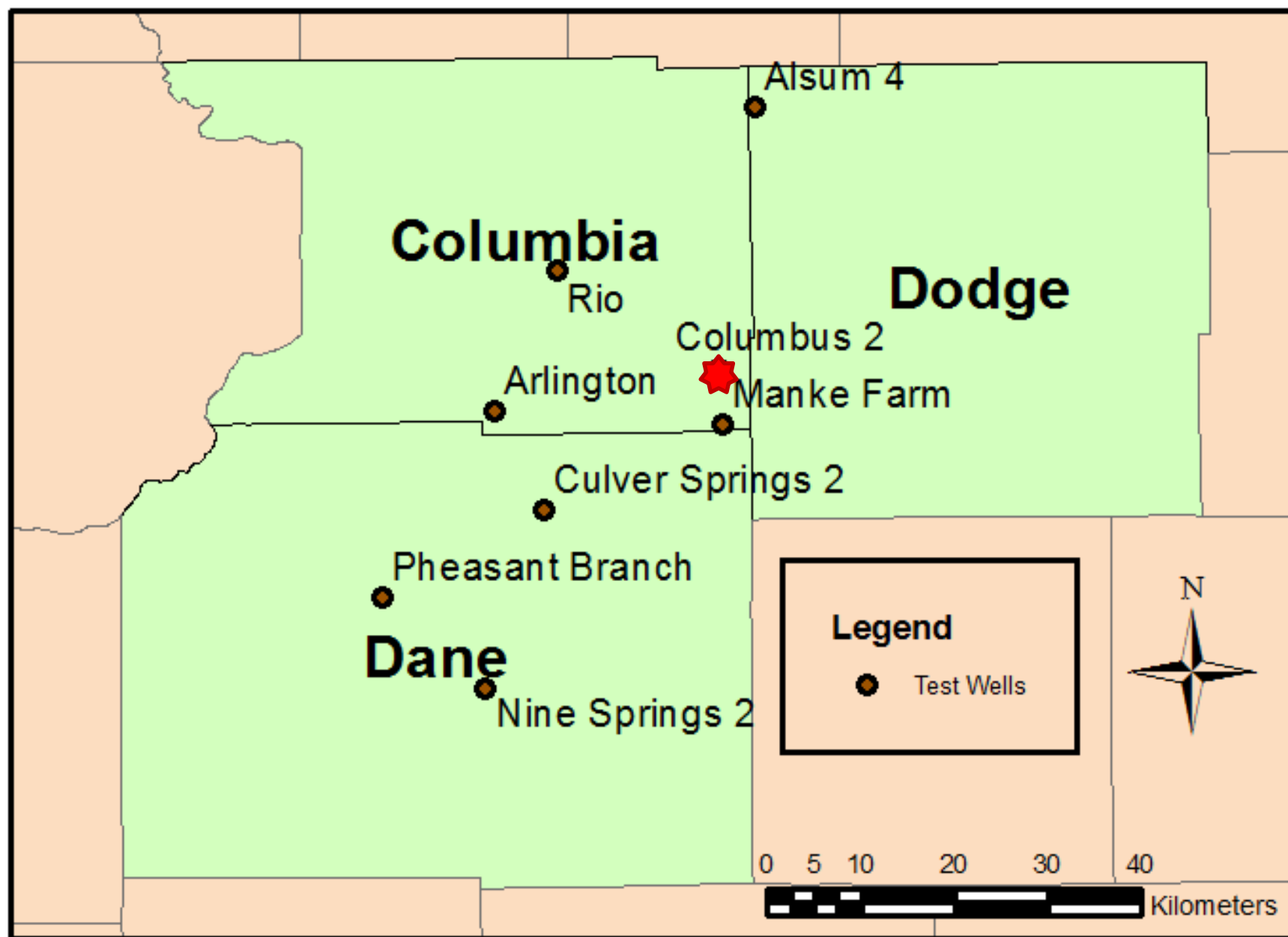


# In-well heat tracer tests:

- Induce heat pulses at discrete depths using downhole heater
- Monitor temperatures in the well with fiber optic Distributed Temperature Sensing system (DTS)
- Use heat movement to determine flow direction, calculate flow velocities

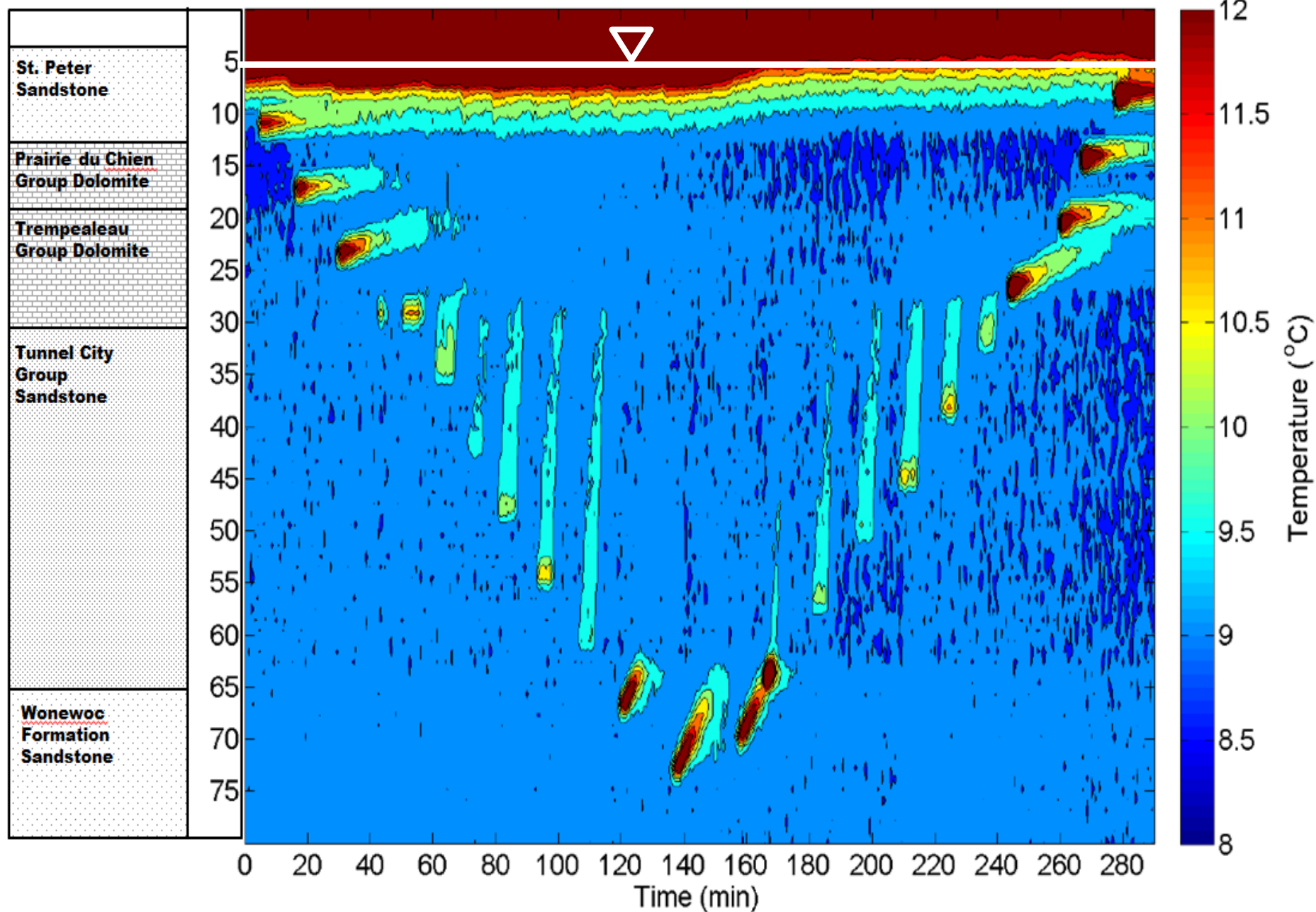






Depth (m)

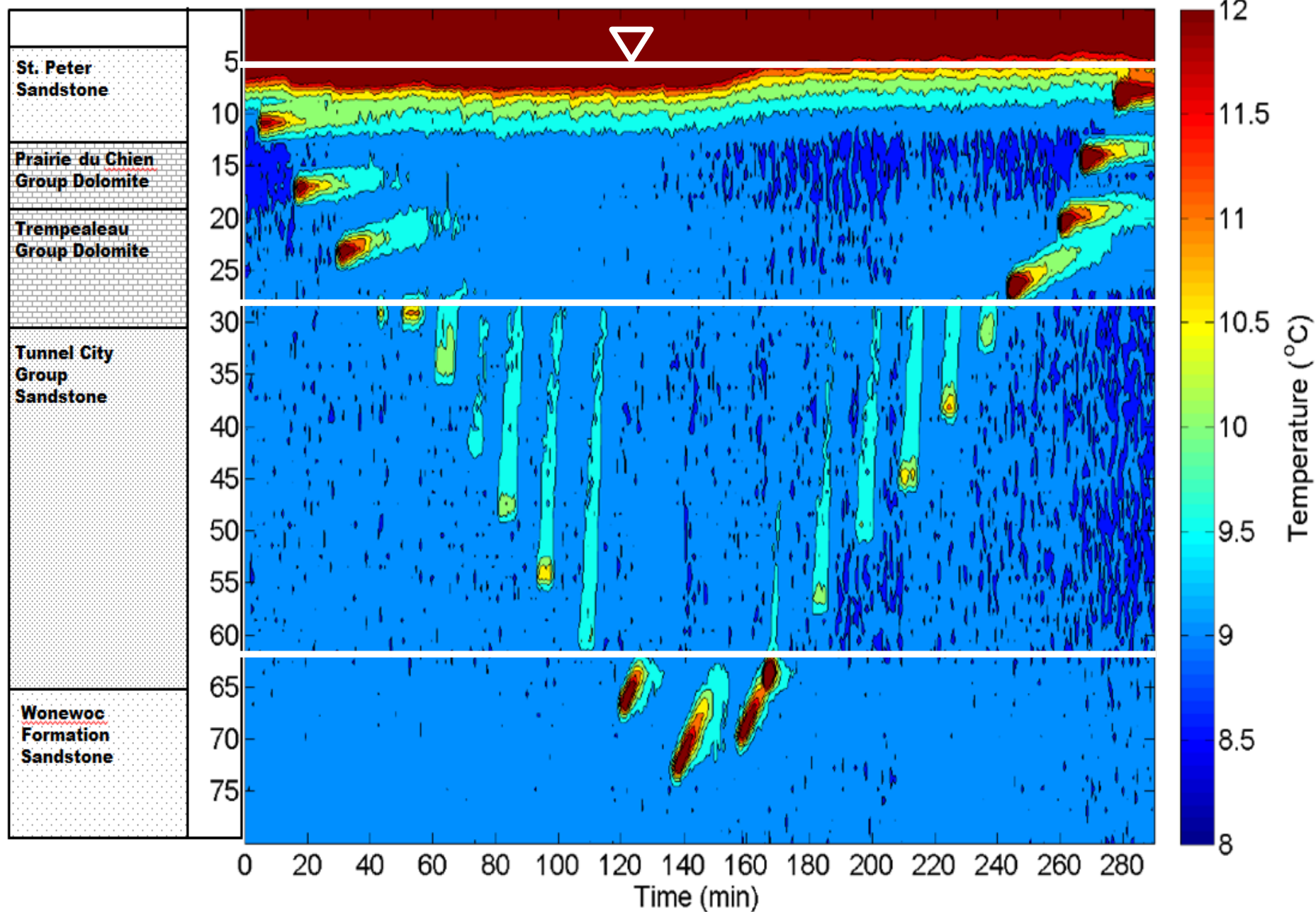
# Columbus Borehole DTS Tracer Test Data



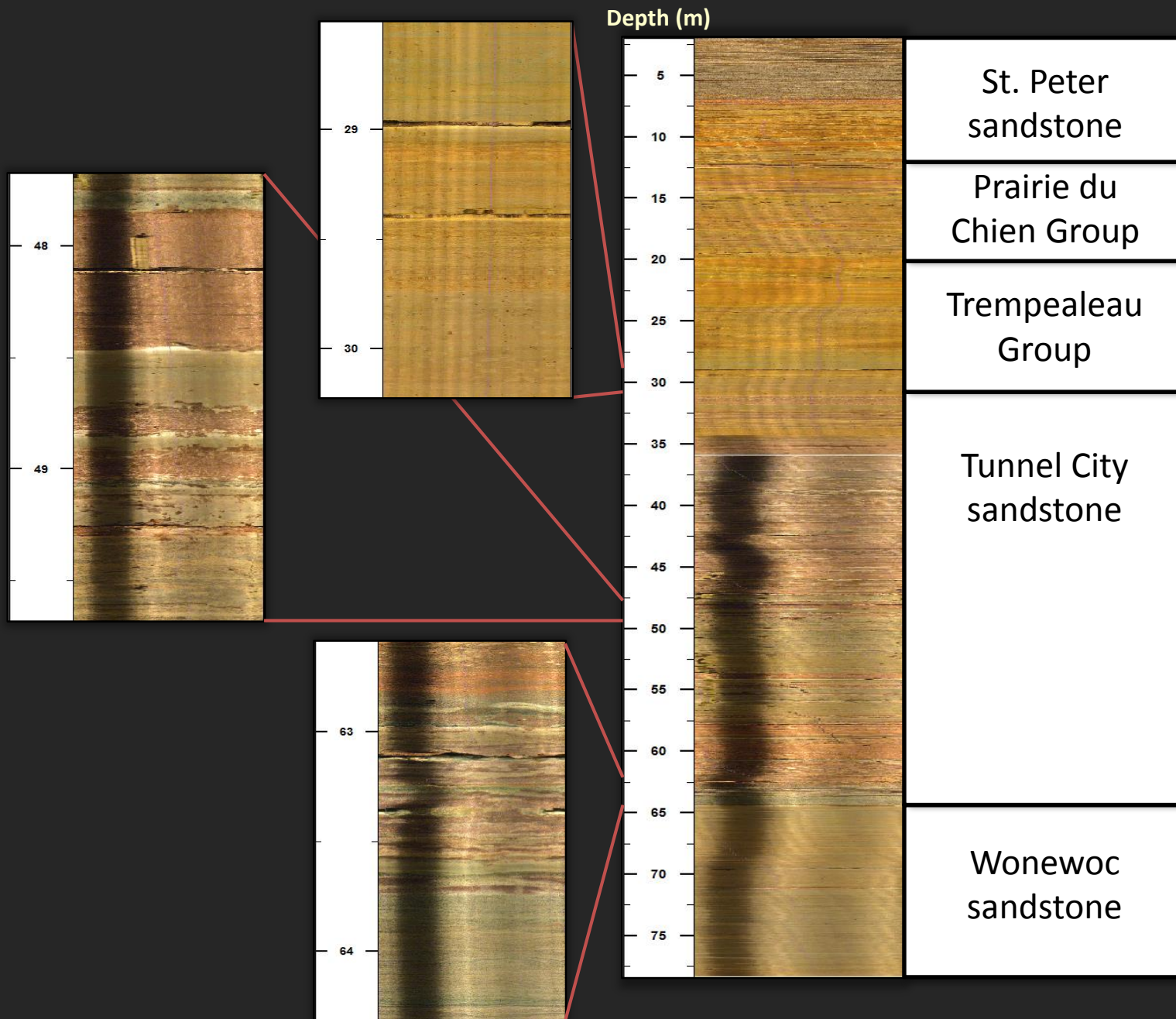


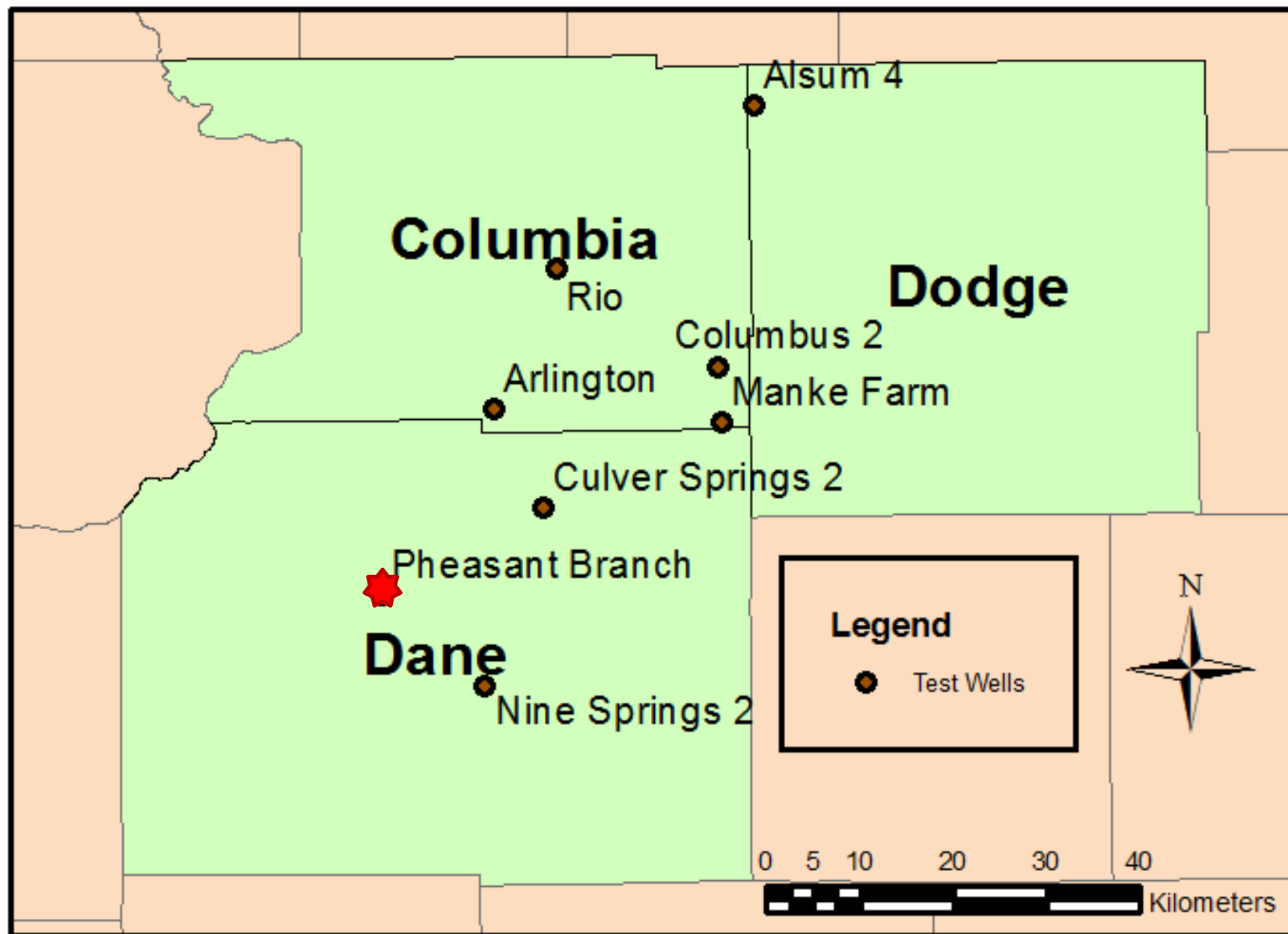
Depth (m)

## Columbus Borehole DTS Tracer Test Data



# Optical Borehole Images of the Columbus borehole







Depth (m)

# Pheasant Branch DTS Tracer Test Data



Tunnel City  
Group  
Sandstone

Wonewoc  
Sandstone

Eau Claire  
Shale

Mt. Simon  
Sandstone

10

20

30

40

50

60

70

80

0

20

40

60

80

100

120

140

160

180

200

220

240

Time (min)

12.5

12

11.5

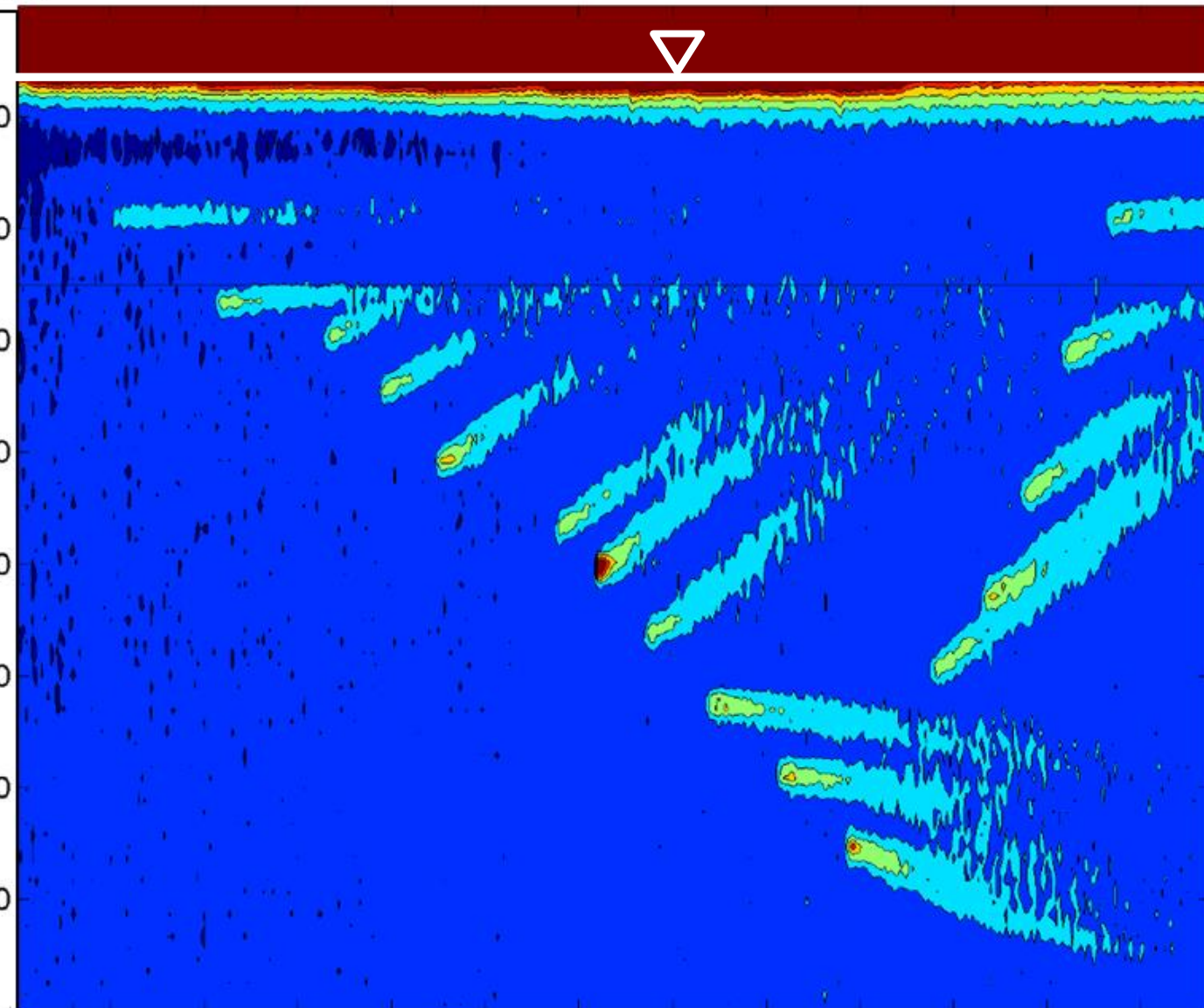
11

10.5

10

9.5

Temperature (°C)





Depth (m)

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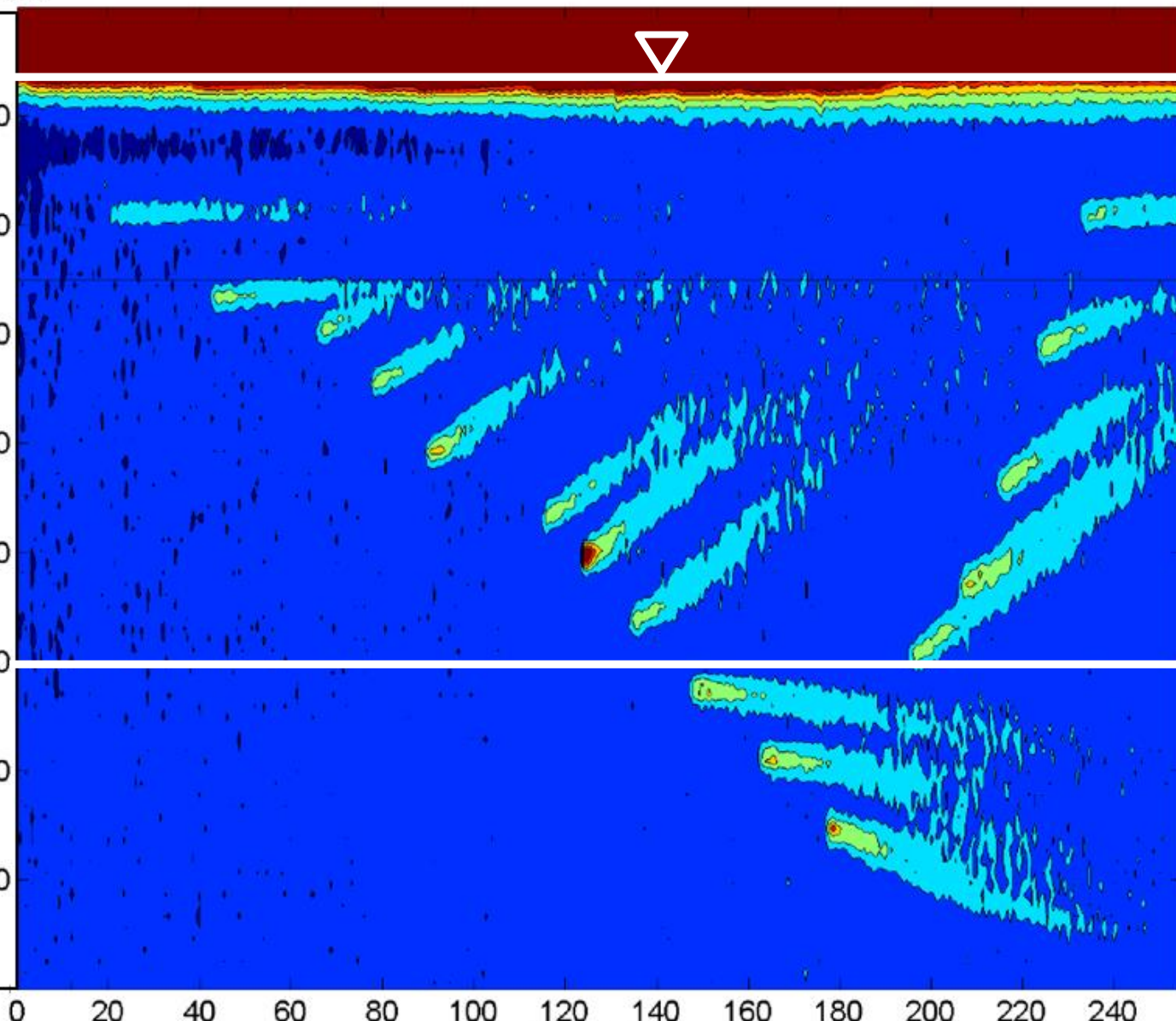
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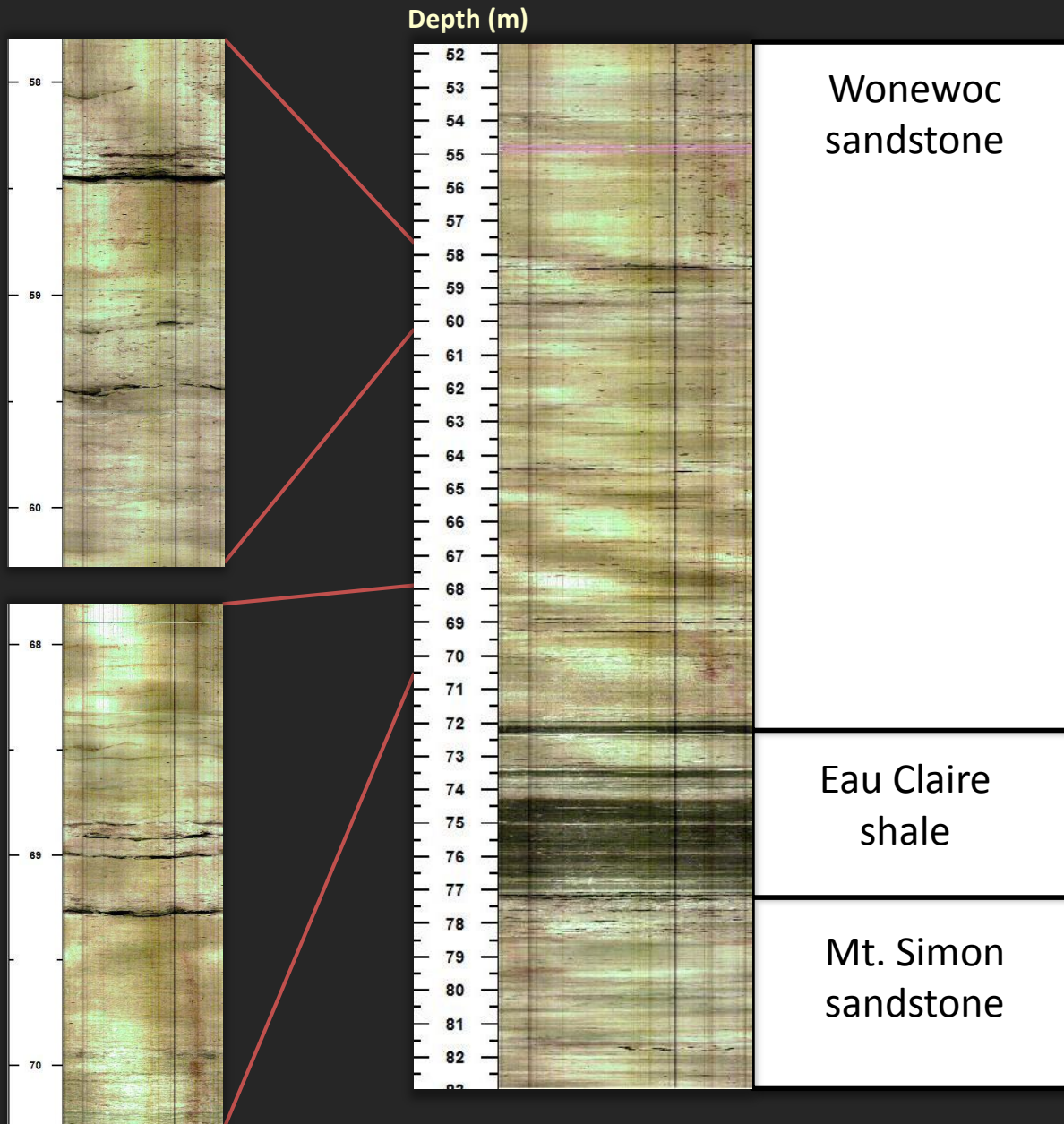
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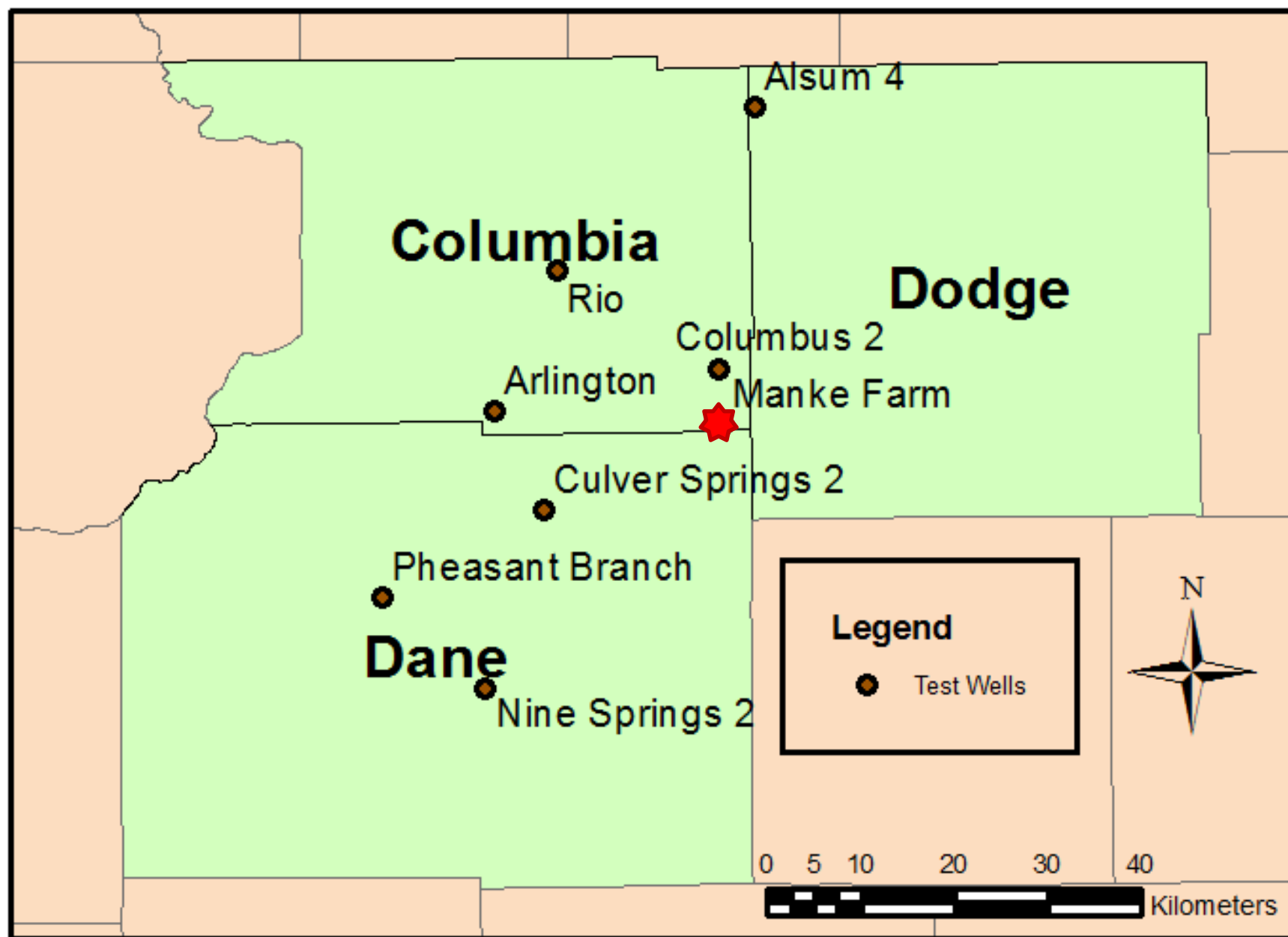
9.5

Temperature (°C)



# Optical Borehole Images of the Pheasant Branch borehole

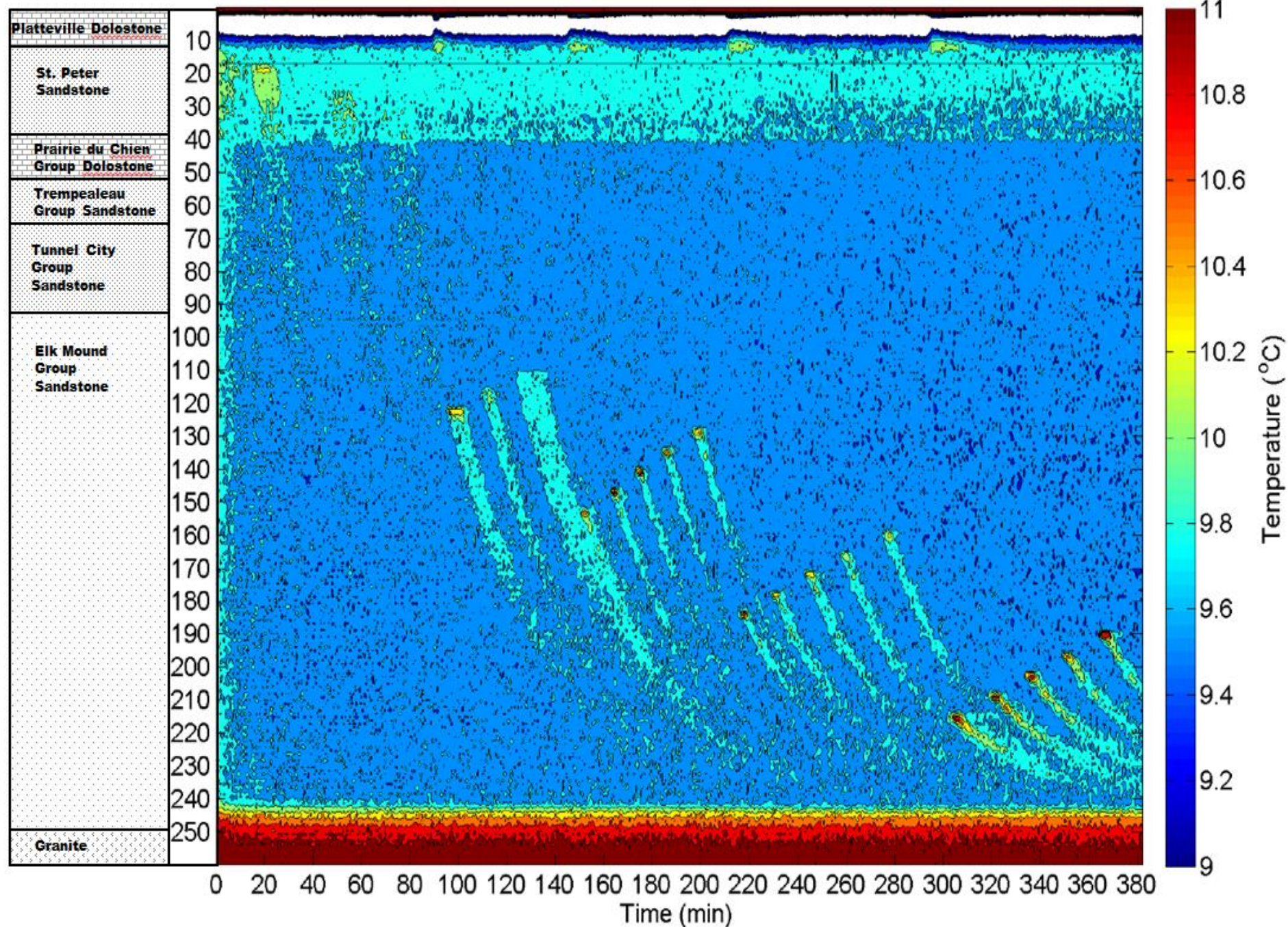






Depth (m)

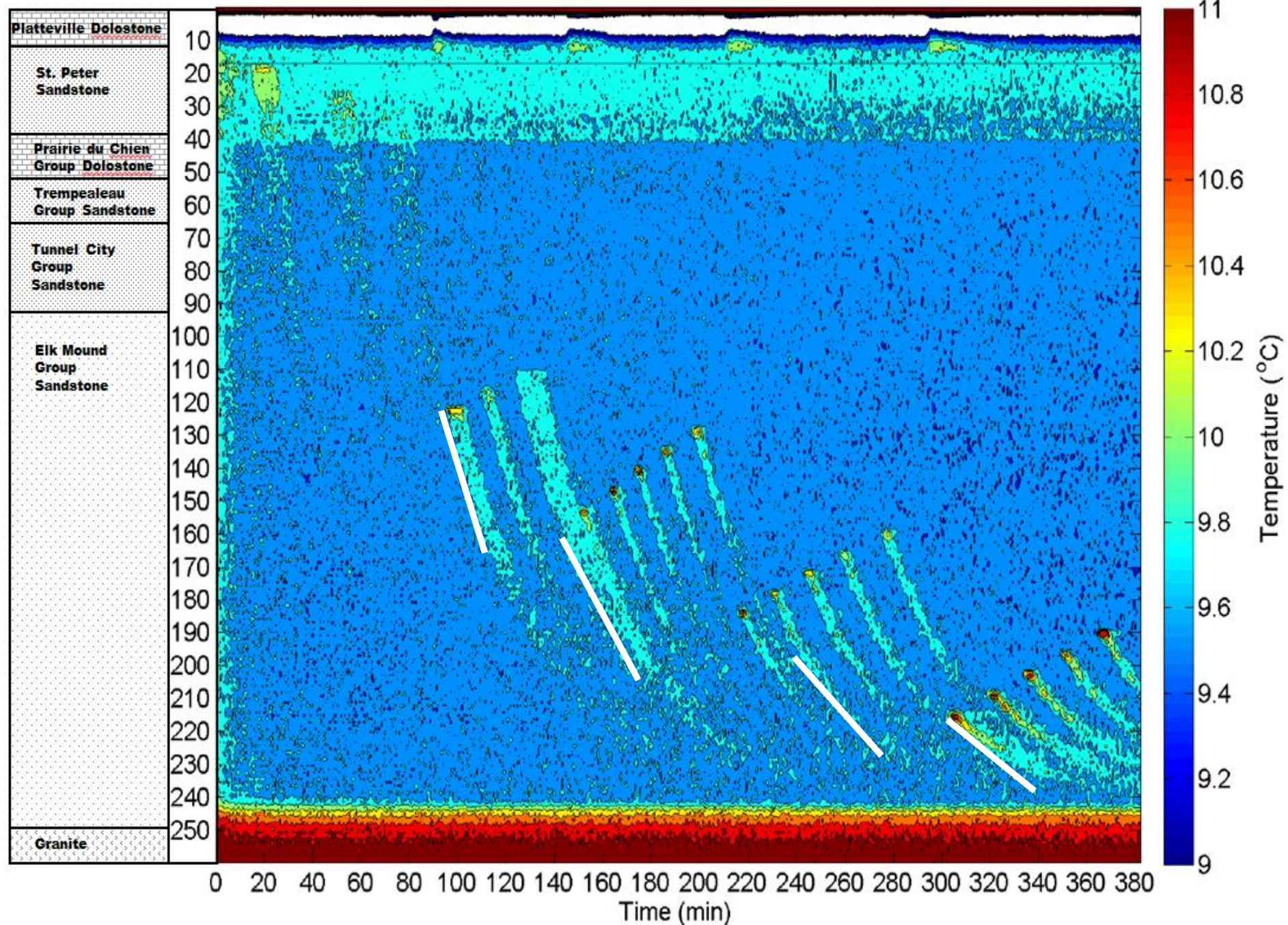
Manke DTS Tracer Test Data

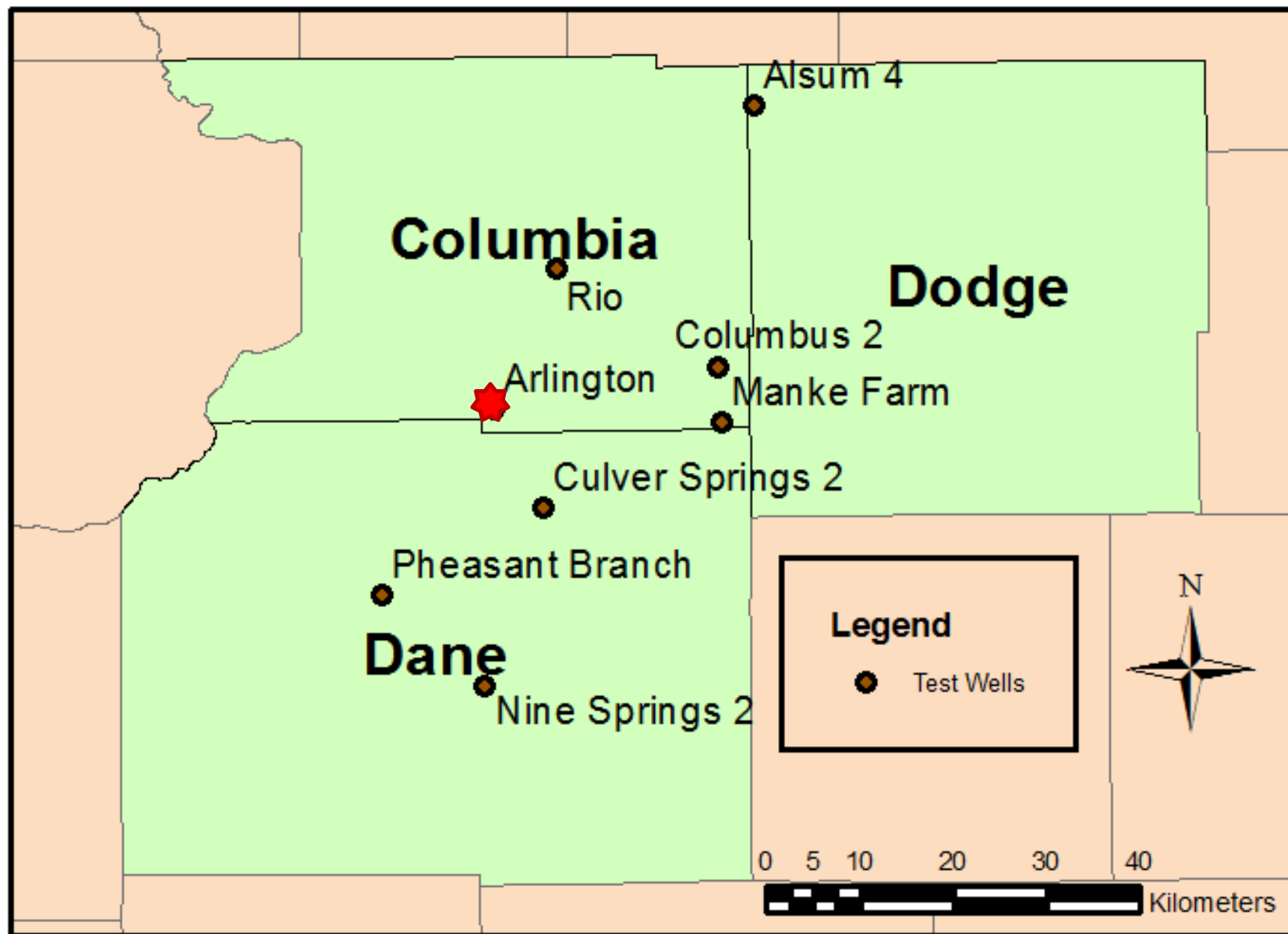




Depth (m)

Manke DTS Tracer Test Data

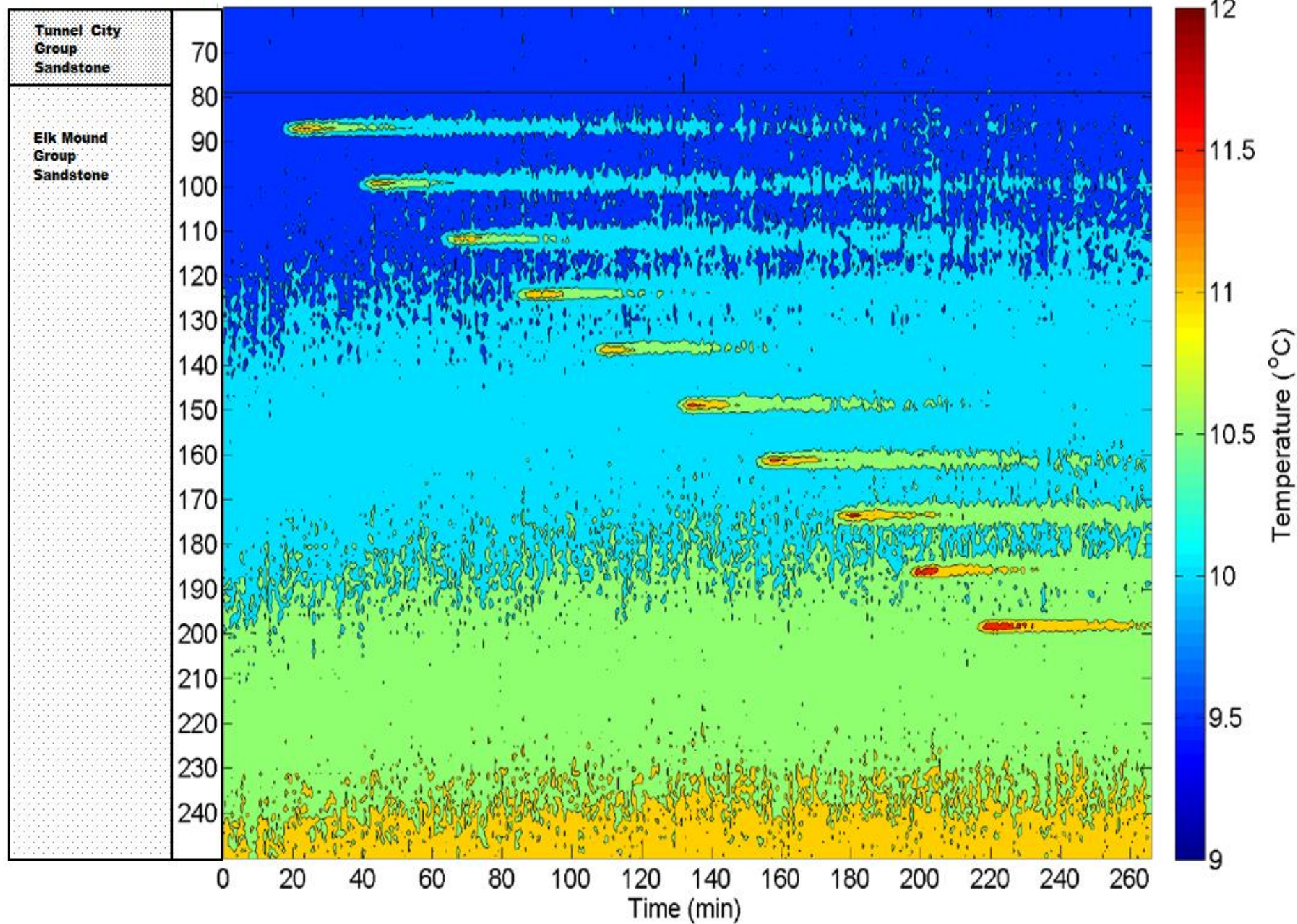




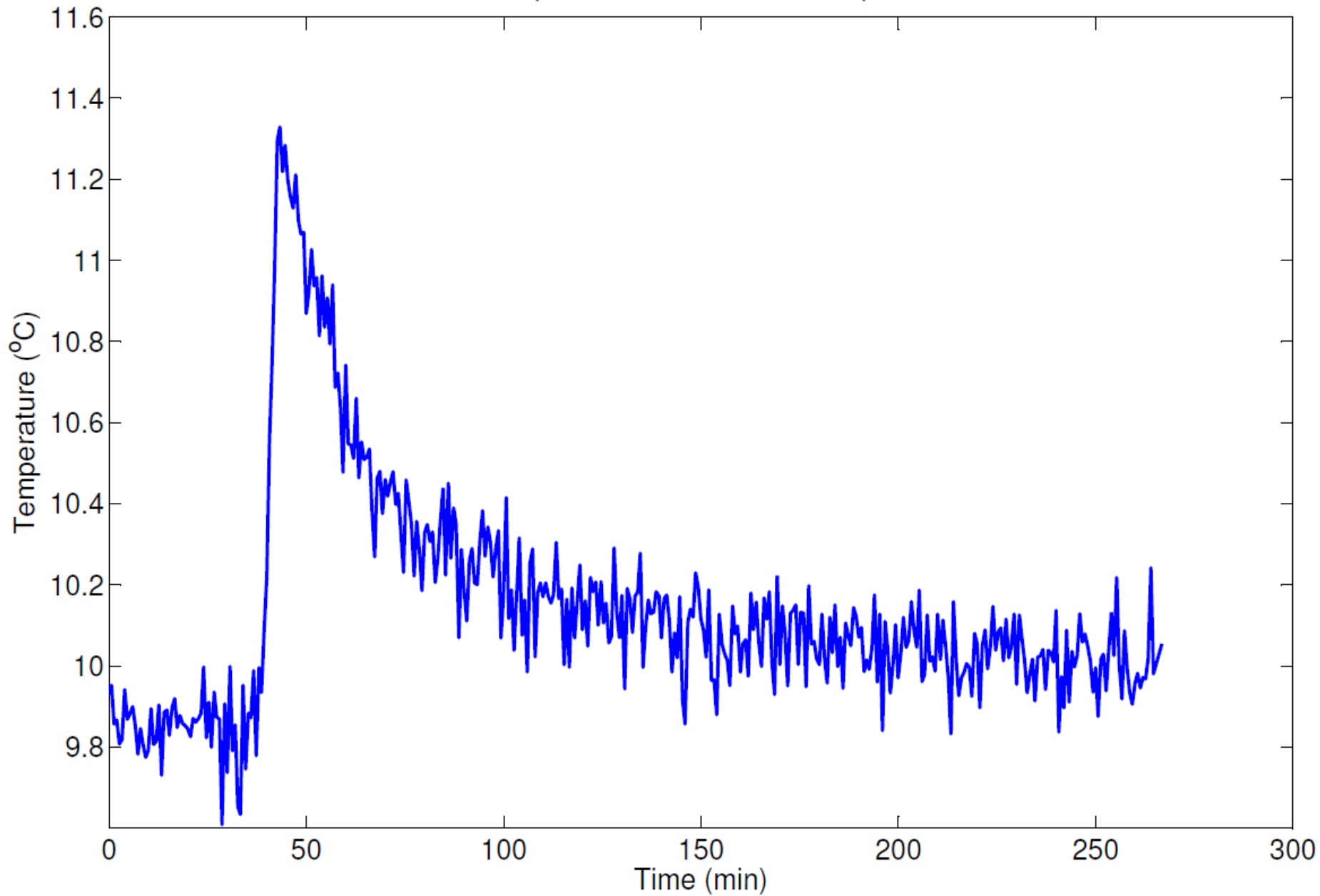


Depth (m)

## Arlington DTS Tracer Test Data



Plot of temperature versus time at depth of 99 m





# Summary and Conclusions

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- Results for no vertical flow may be informative with respect to aquifer flow velocity and/or thermal conductivity
- **Heat tracers are an effective tool for borehole flow characterization**







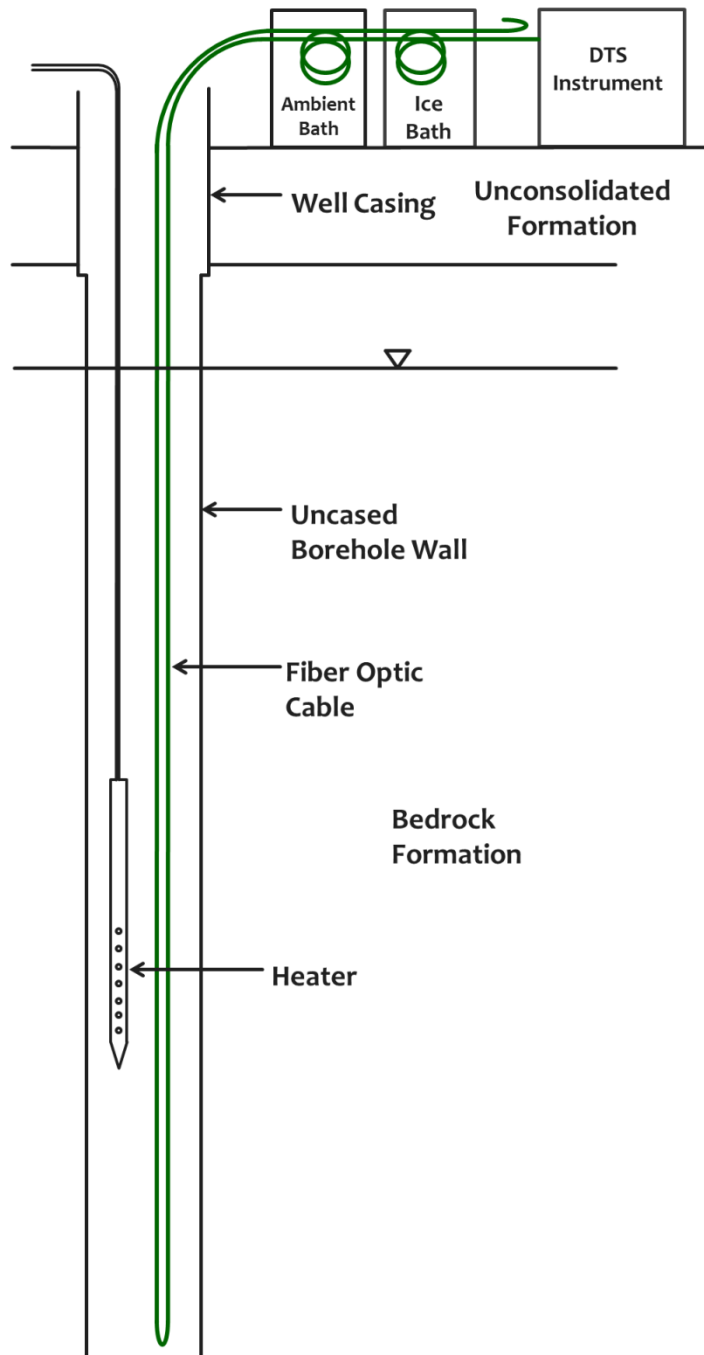












# Experiment Design

- A temperature is recorded for every meter of cable
- Temperatures are re-measured every 40 seconds