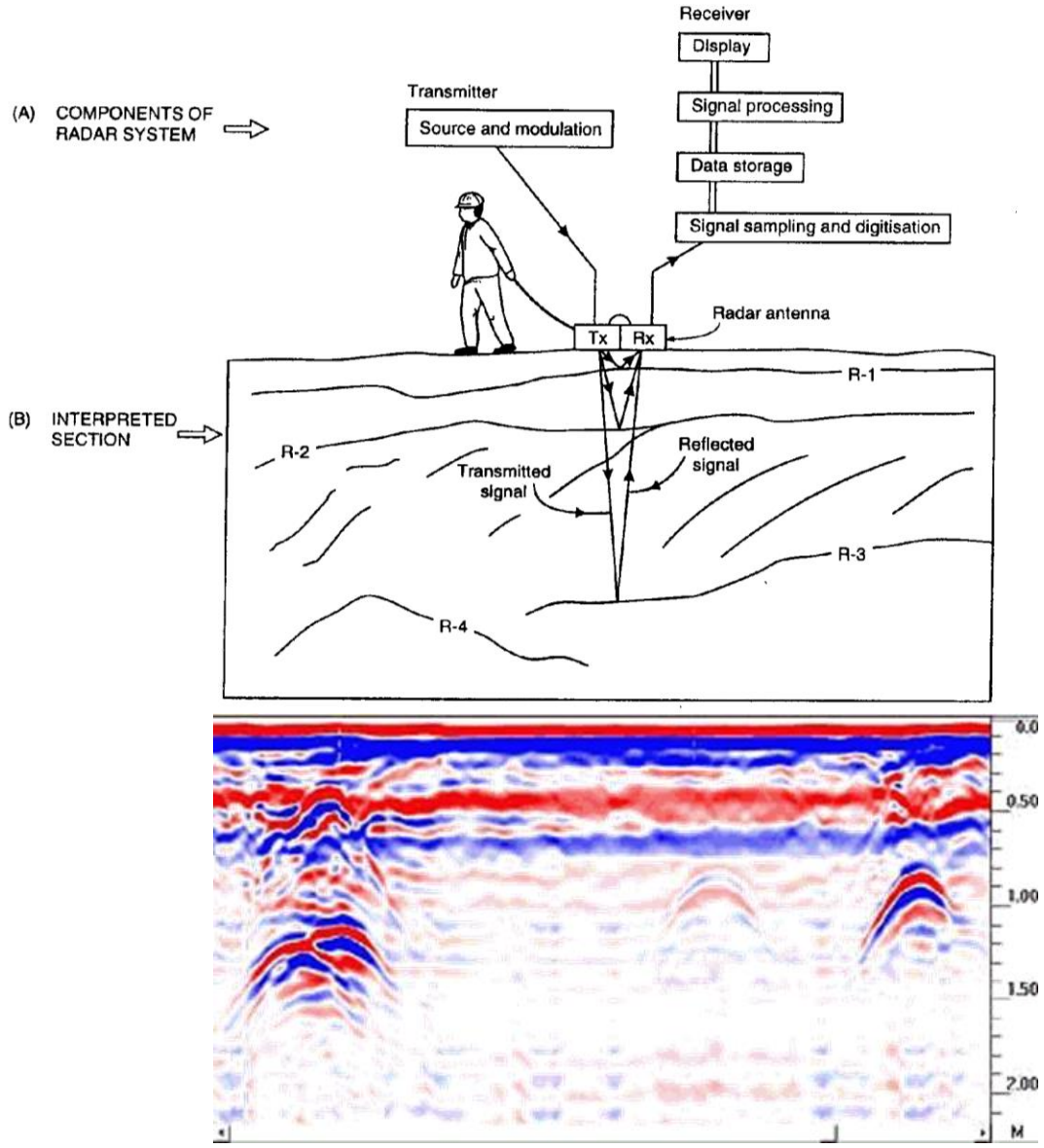
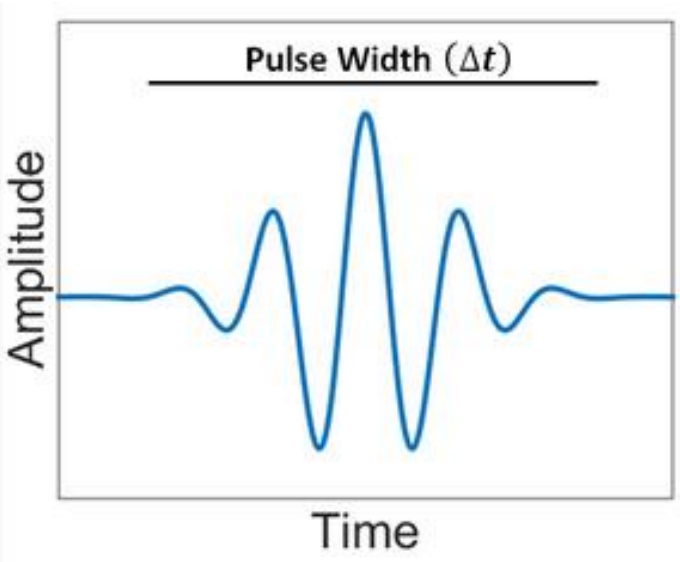
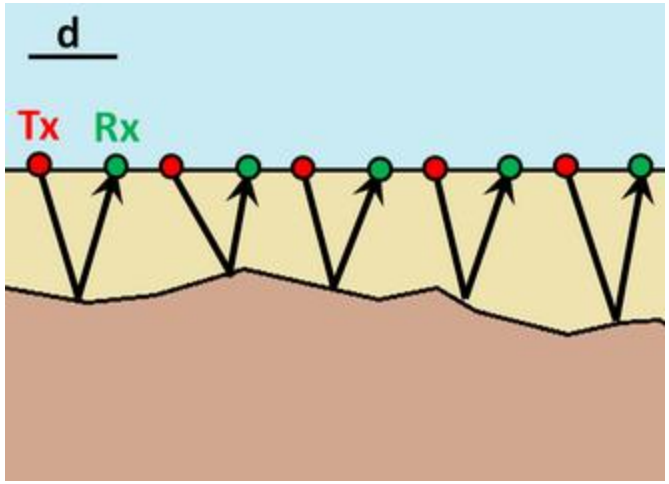
# Ground Penetrating Radar (day 3)



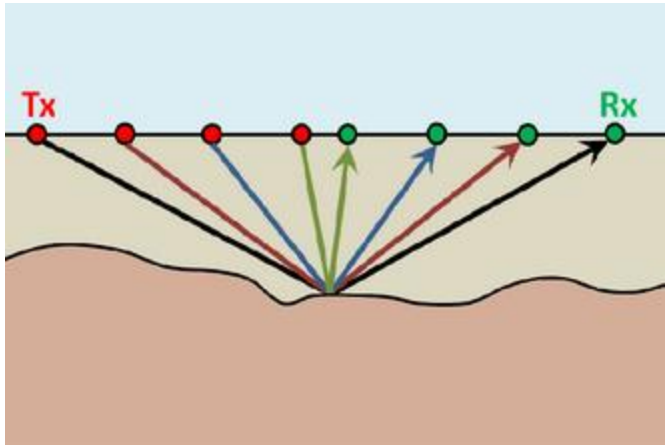



# From Last Time

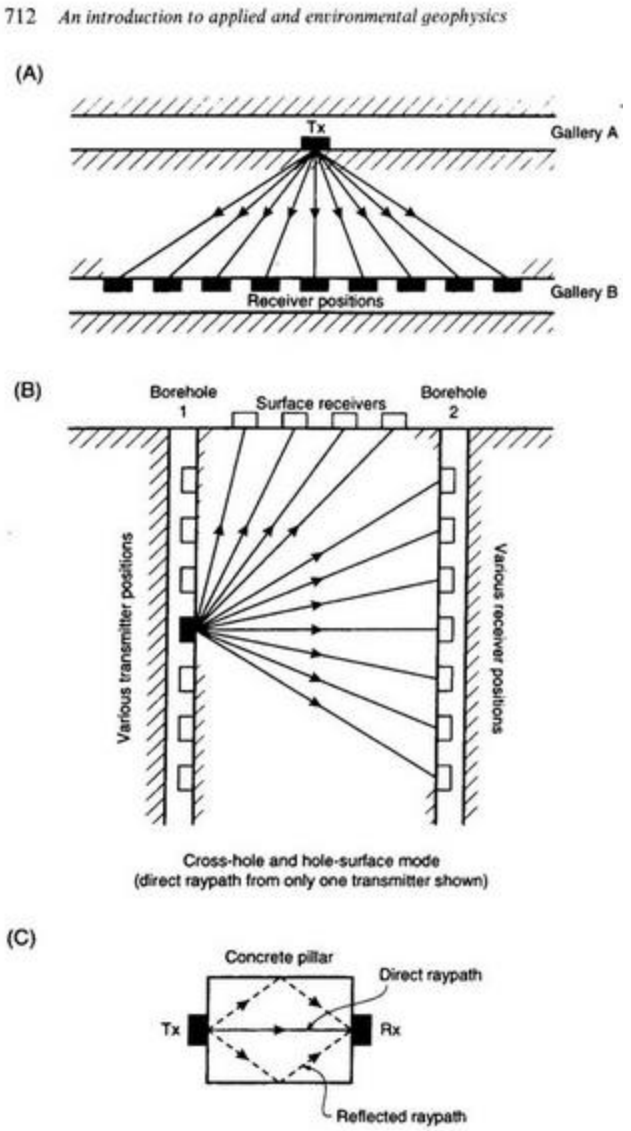
## Common Offset




## Common Midpoint




## Transillumination



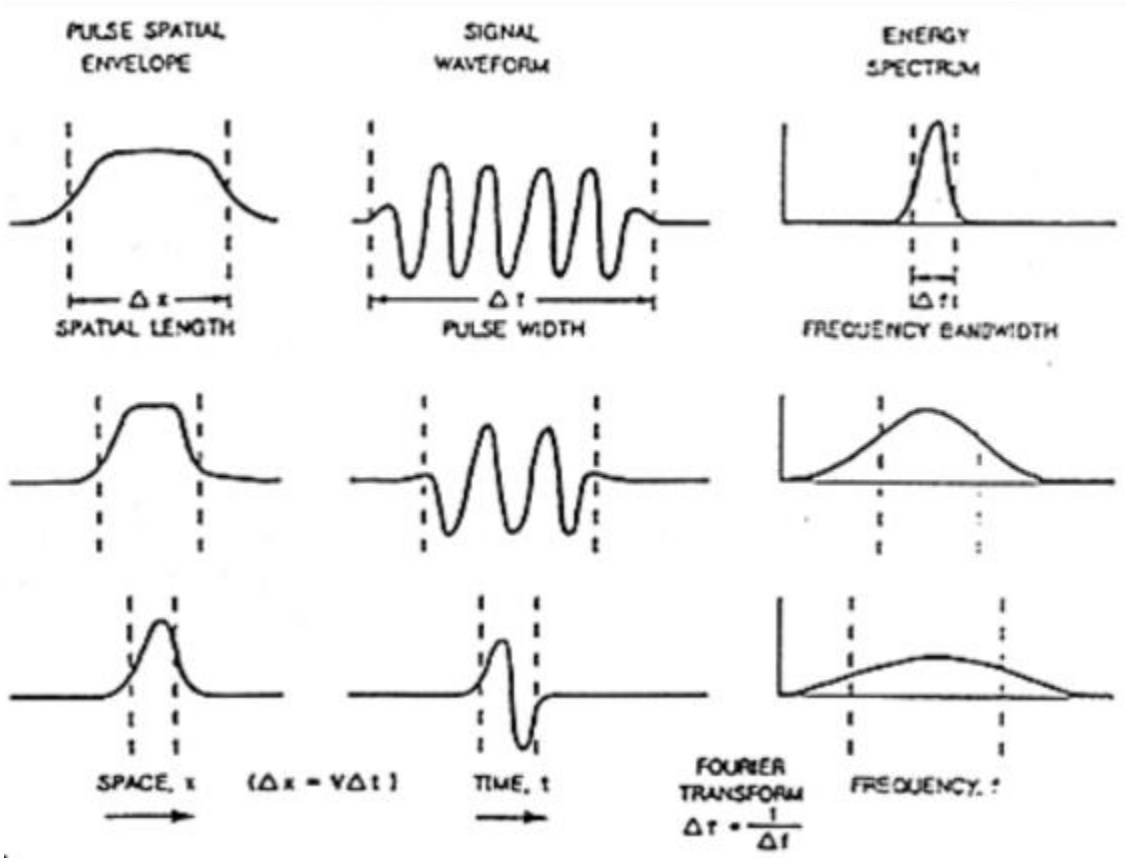
# From Last Time

- Shorter pulses contain a wider range of frequencies
- Shorter pulse overall contain higher frequencies
- Spatial length increases as pulse length increases

$$\lambda = \frac{V}{f_c} = \frac{c}{f_c\sqrt{\varepsilon_r}}$$

$$f_c = \frac{1}{\Delta t}$$

$$\lambda = V\,\Delta t = \frac{c\,\Delta t}{\sqrt{\varepsilon_r}}$$



# From Last Time

- There is a compromise between resolution and probing distance:

Higher frequencies → Better resolution

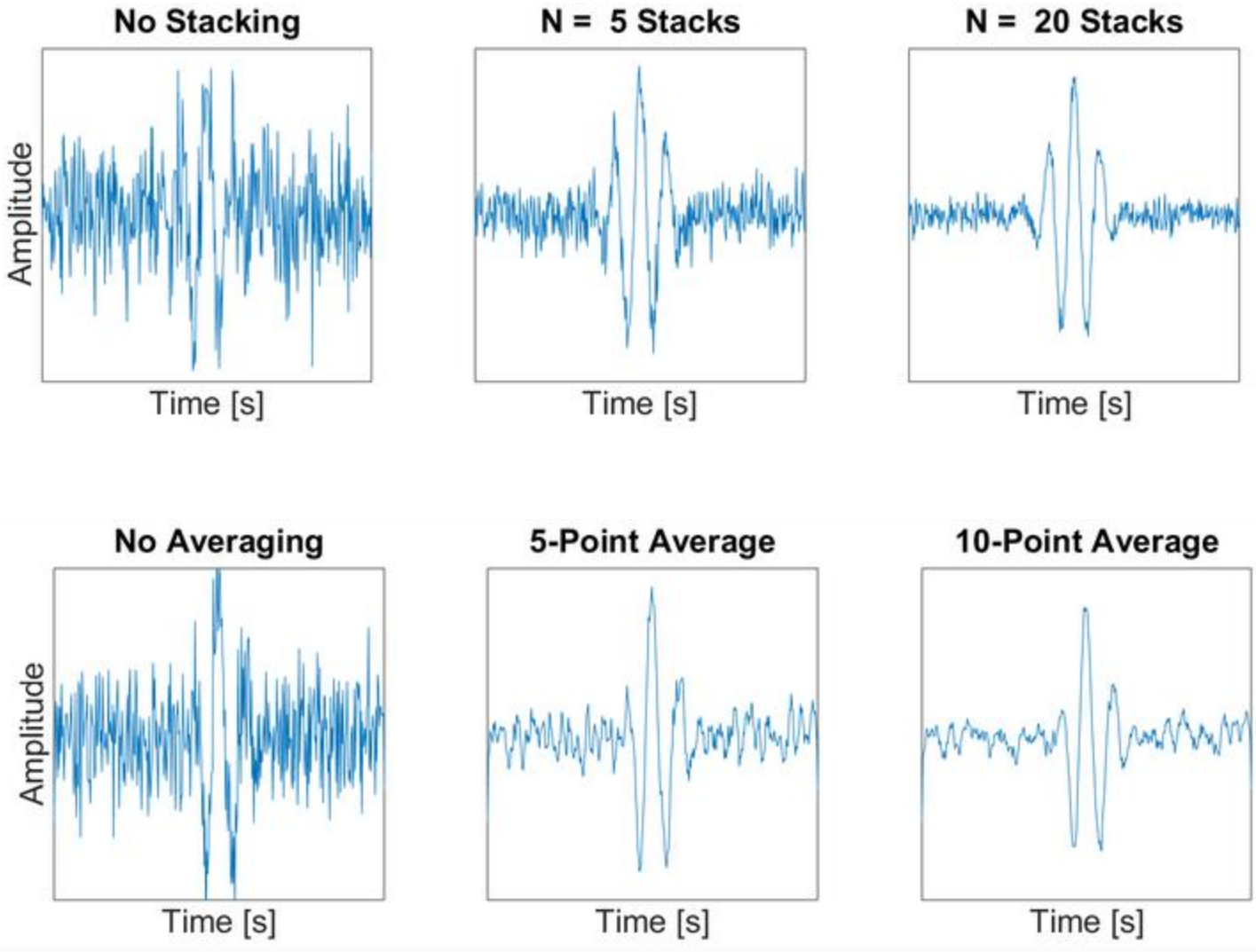
*Layers:* $L > \frac{c}{4 f_c \sqrt{\varepsilon_r}} = \frac{c \Delta t}{4 \sqrt{\varepsilon_r}}$

*Objects:* $L > \sqrt{\frac{V\,d}{2 f_c}}$

Higher frequencies → Lower probing distance

$$D = 3\delta \approx \begin{cases} 1510 \sqrt{\dfrac{1}{\sigma f}} & \text{for } \omega\varepsilon \ll \sigma \\ 0.0159 \dfrac{\sqrt{\varepsilon_r}}{\sigma} & \text{for } \omega\varepsilon \gg \sigma \end{cases}$$

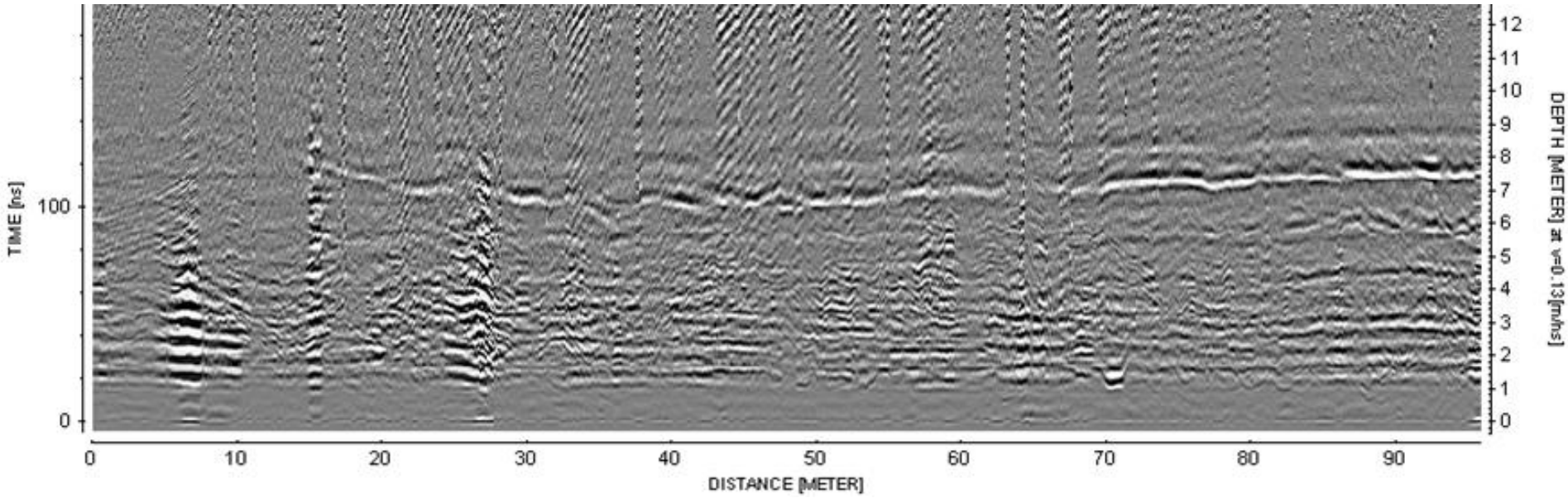
# From Last Time



# Today's Topics

- Interpretation and some examples

# Example: Potash Mine



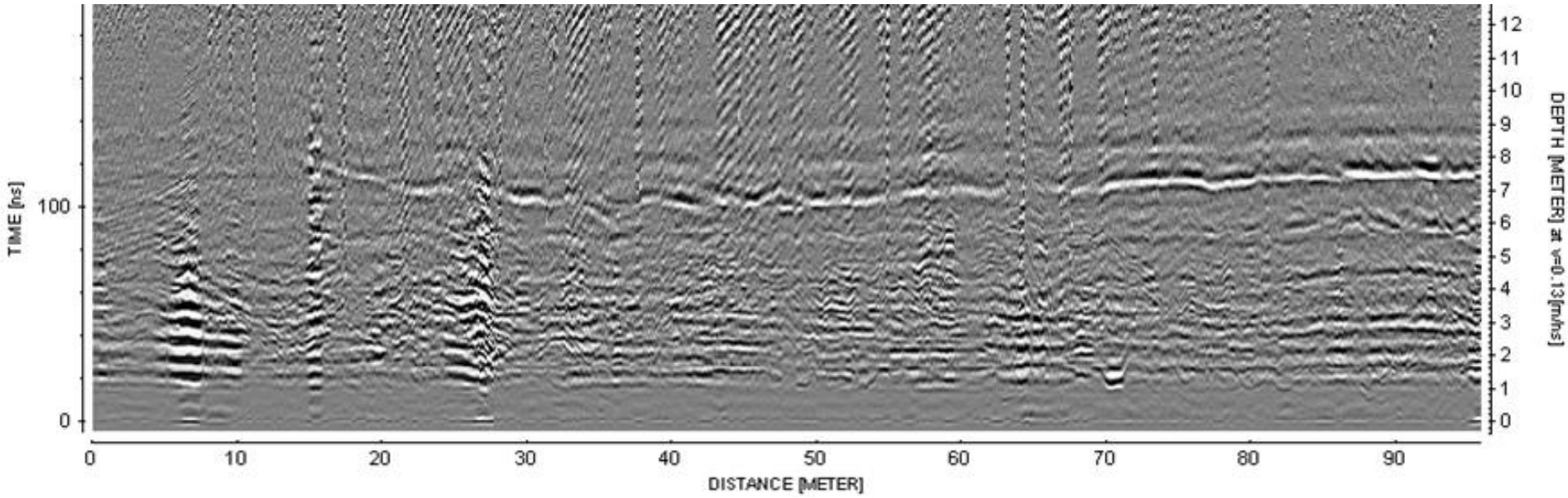

- Water was leaking into the potash mine

→ Reducing structural integrity of mine shafts

→ Want to know where water is and its source

→ Water infiltration produces a strong reflector

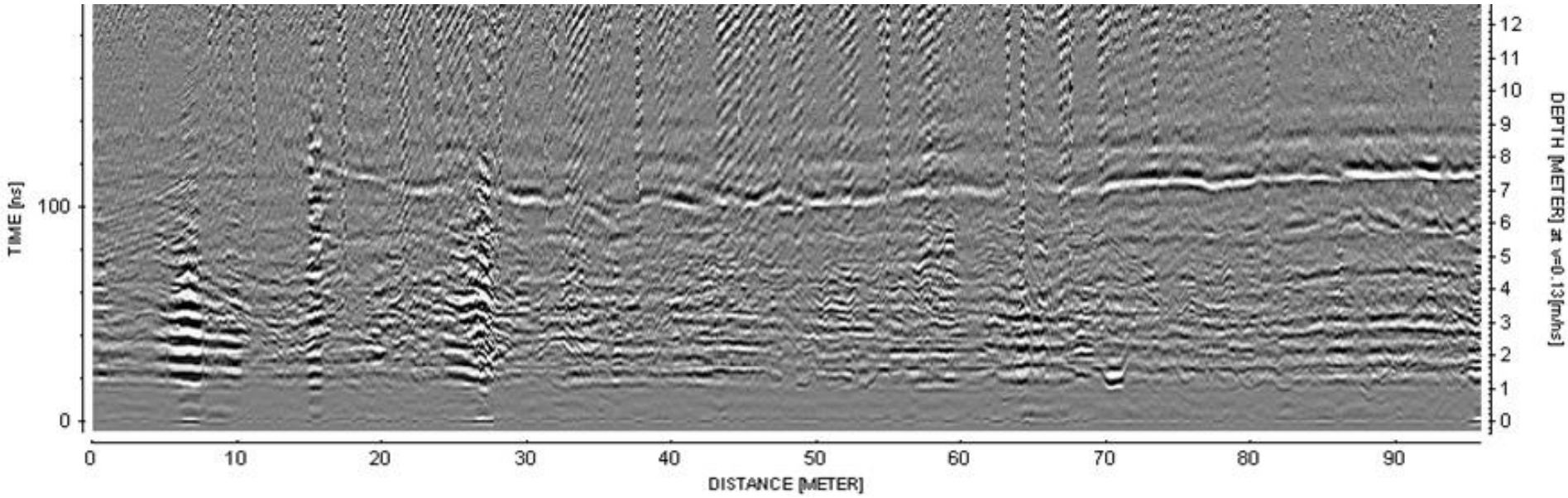
# Example: Potash Mine




- Zero offset survey performed.
- Arrival time to depth conversion performed

**Q:** Without a direct ground wave measurement or hyperbola to obtain propagation speed, how could they do conversion?

# Example: Potash Mine

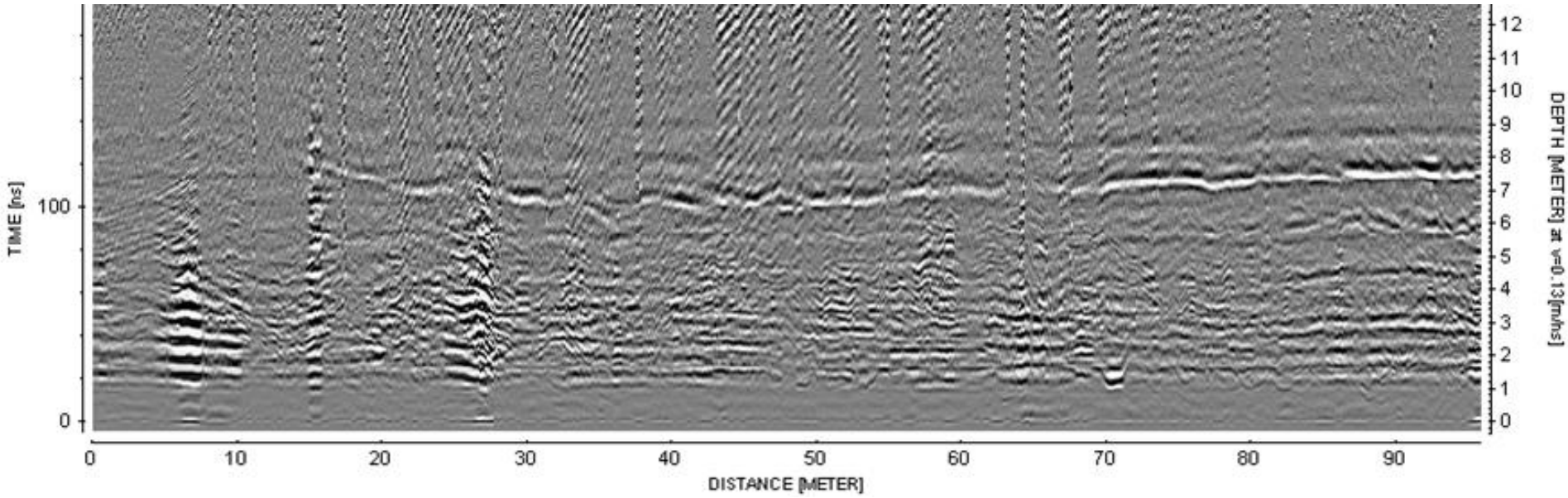



**A:** Potash in an **anhydrite mineral**.

From known physical properties, **V ~ 0.13 m/ns**

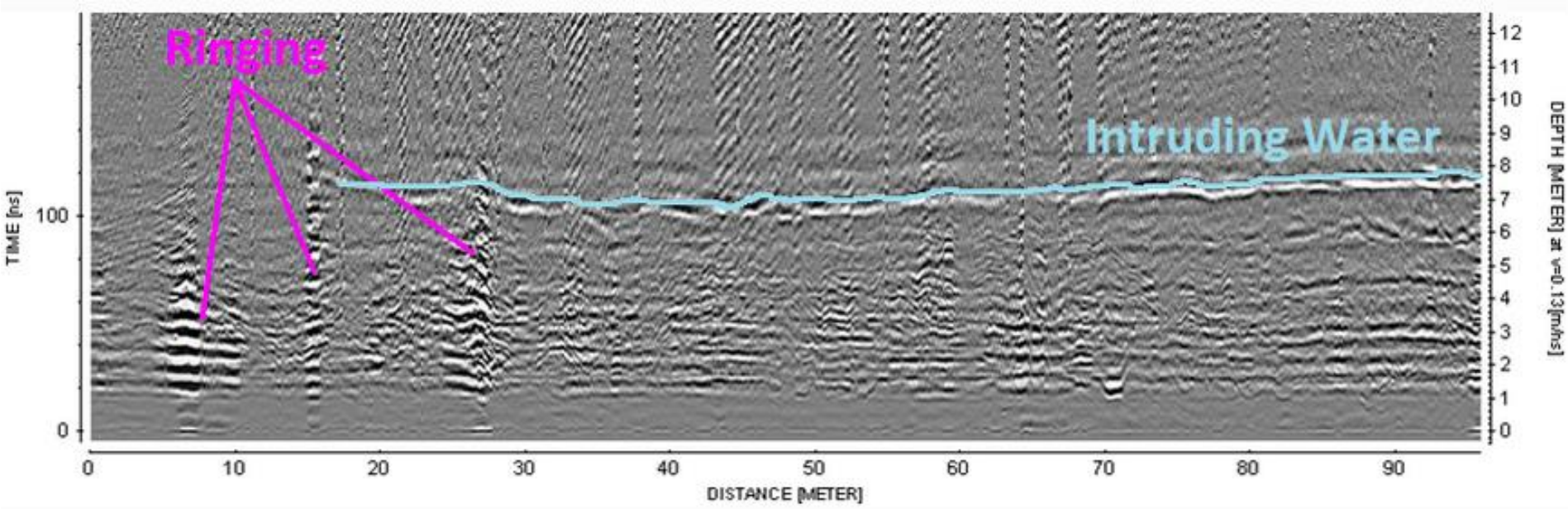
**da = Vt/2**

# Example: Potash Mine




**Q:** What kinds of features do you see in the data?

# Example: Potash Mine




- Strong reflector from intruding water (7 - 8 m from shaft)
- Water is delineated and seems to be coming from the right
- Ringing from mine infrastructure

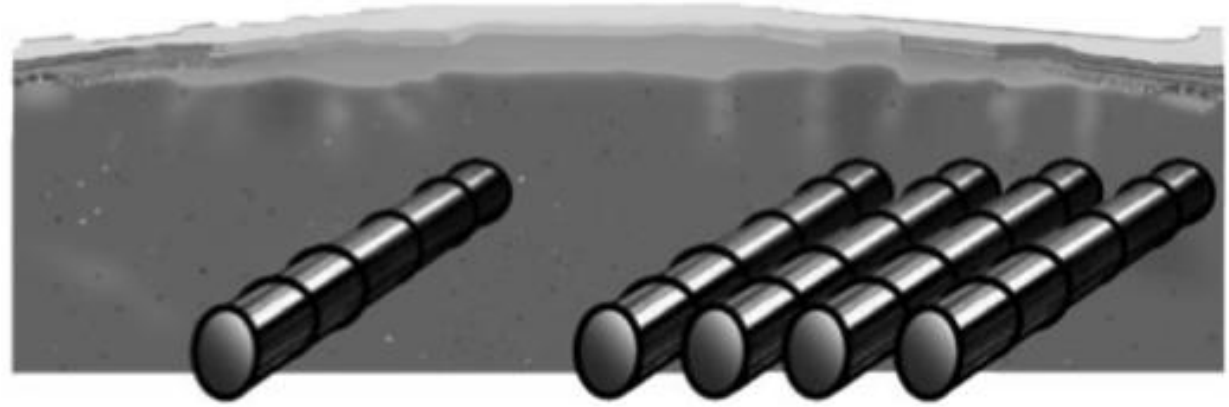
# Example: Underground Storage Tanks

- Want to locate a set of underground storage tanks.

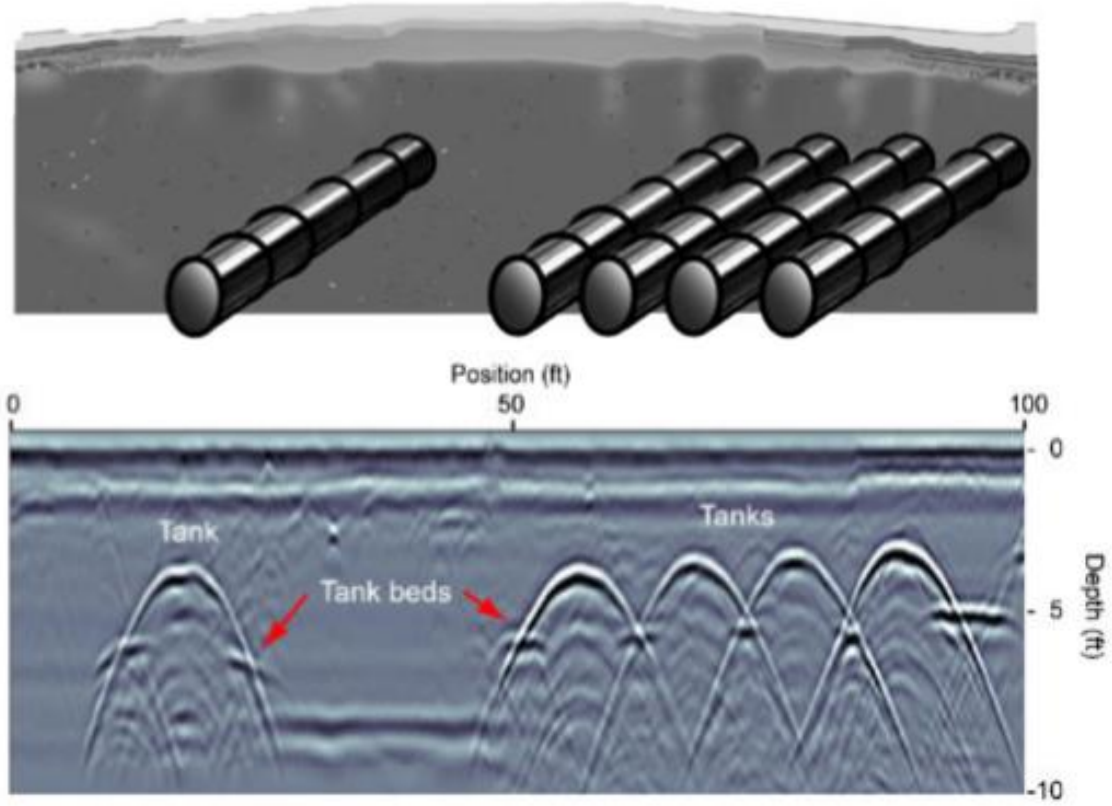
  **Q:** What direction would you orient your survey lines? Why?

  **Q:** What features do you expect in your radargram?

**Diagram of problem**



# Example: Underground Storage Tanks




**Q:** If tanks too big to be point reflectors, can you still obtain layer velocity? How?

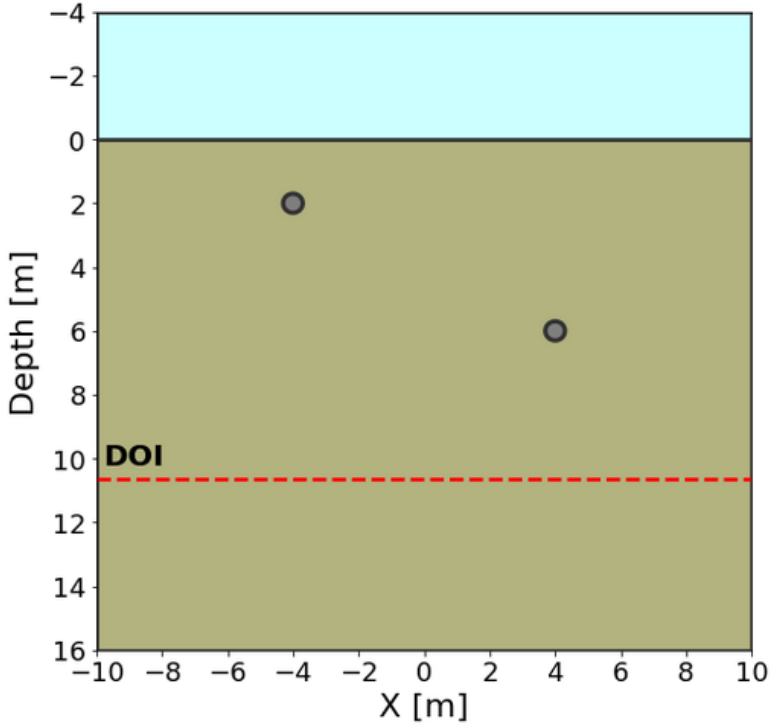
**Q:** How can you figure out the horizontal location and depth to each tank? (assume you know the velocity)

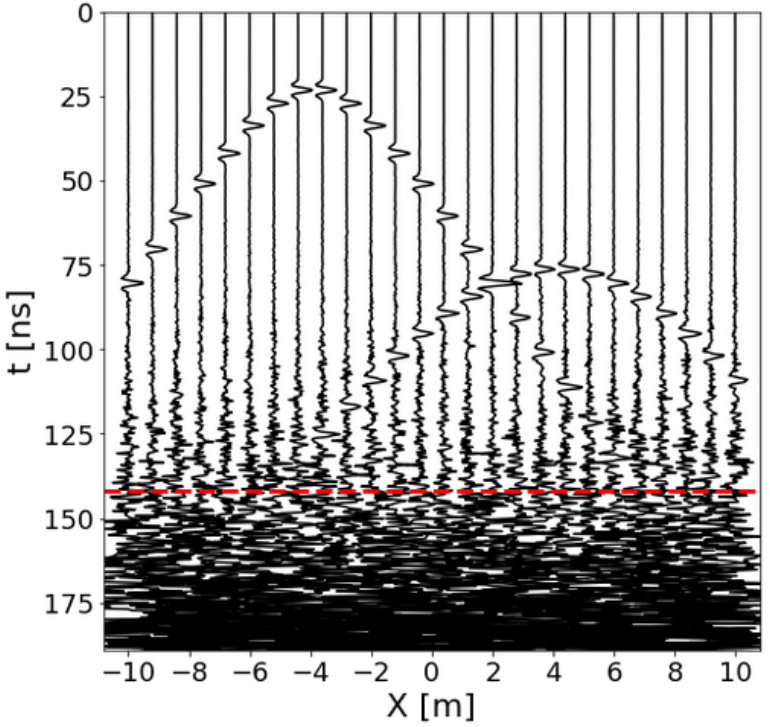
**Q:** Why aren't signatures from tank beds entirely visible?

# Example: GPR App Problem

| | |
|---|---|
| $\sigma$ [mS/m] | 3.00 |
| $\epsilon_r$ | 4 |
| $f_c$ [MHz] | 250 |
| $x_1$ [m] | -4.00 |
| $d_1$ [m] | 2.00 |
| $R_1$ [m] | 0.30 |
| $x_2$ [m] | 4.00 |
| $d_2$ [m] | 6.00 |
| $R_2$ [m] | 0.30 |

- **Zero offset survey**
- **Two buried reflectors**
- **Wave regime!!!**



# Example: GPR App Problem

- **Q1: From the radargram, use the slope to determine the propagation velocity.**

- **Q2: From the preset parameters, compute the probing distance (or DOI) using the quasi-static AND wave regime approximation. Compare to the DOI in the app. What regime are we in?**

- **Q3: Determine the relative permittivity of the host media from the medium velocity you computed. Does it match the value set in the app?**

# Example: GPR App Problem

- **Q1: From the radargram, use the slope to determine the propagation velocity.**

$$m = \frac{(190\ ns - 0\ ns)}{(11\ m - (-4\ m))} = 12.7\ ns/m \quad \Rightarrow \quad V = \frac{2}{m} = 0.157\ m/ns$$

$$V_{true} = \frac{c}{\sqrt{\varepsilon_r}} = 0.15\ m/ns$$

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$$DOI\ (quasi) = 3 \times 503 \times \sqrt{\frac{1}{\sigma f_c}}$$

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- **Q3: Determine the relative permittivity of the host media from the medium velocity you computed. Does it match the value set in the app?**

$$V = \frac{2}{m} = 0.157\ m/ns \quad \Rightarrow \quad \varepsilon_r = \left(\frac{c}{V}\right)^2 = 3.6$$

# Example: GPR App Problem

- **Q4: What is the horizontal resolution of the survey at a depth of 4m? Adjust the location of the reflectors to confirm this with the app.**

- **Q5: How could we improve the survey resolution? What drawback might this have?**

- **Q6: If we increases the radius of one of the reflectors, what happens to its signature?**

# Example: GPR App Problem

- **Q4: What is the horizontal resolution of the survey at a depth of 4m? Adjust the location of the reflectors to confirm this with the app.**

$$L = \sqrt{\frac{Vd}{2f_c}}$$

- **Q5: How could we improve the survey resolution? What drawback might this have?**

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# Example: GPR App Problem

- **Q4: What is the horizontal resolution of the survey at a depth of 4m? Adjust the location of the reflectors to confirm this with the app.**

$$L = \sqrt{\frac{Vd}{2f_c}} = 1.1\ m$$

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Increase frequency → Reduces probing distance

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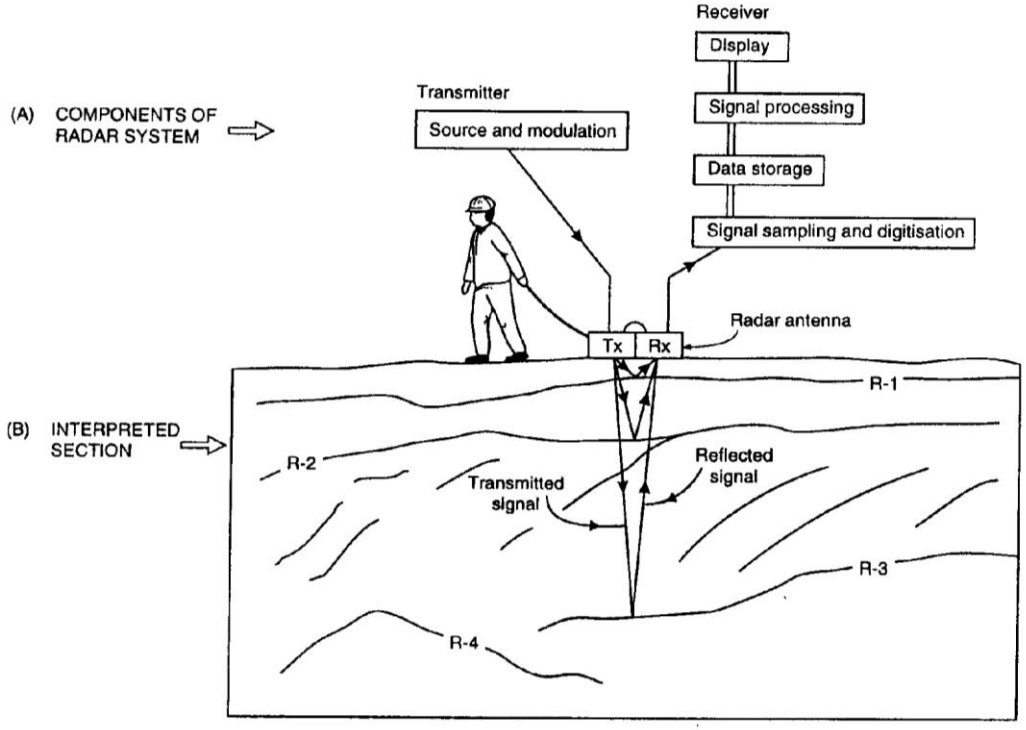
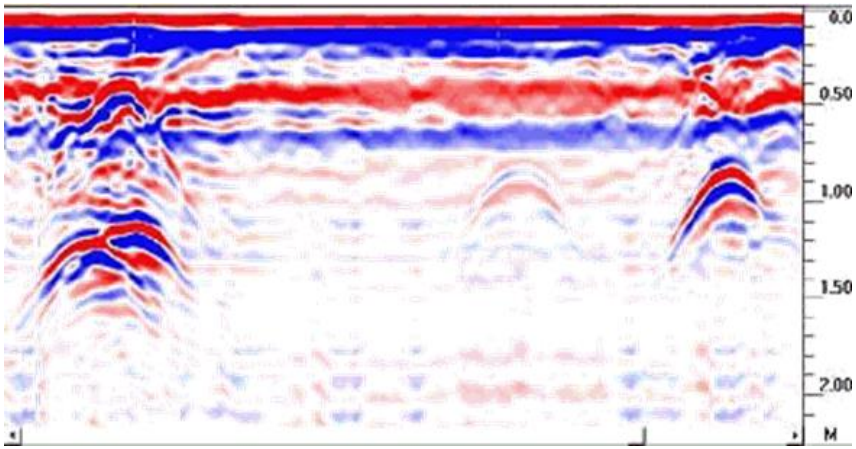
- **Q6: If we increases the radius of one of the reflectors, what happens to its signature?**

No longer a hyperbola, slope trick works, early observed signals.

# Concluding Thoughts: GPR in a Nutshell

- Electromagnetic Method
- Exploits contrasts in **dielectric permittivity** and **conductivity**
- Sends a **pulse** of radiowaves into the ground
- Signals reflect, refract and transmit at interfaces
- Measured signals represented using radargrams



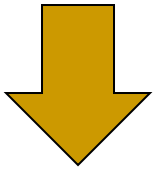
# Concluding Thoughts: When to use GPR

- Generally near-surface applications (10s metres or less)
- Images the interfaces which define subsurface structures
- Examples:

  - Geotechnical problems (rock fractures, slope stability …)
  - Find buried infrastructure (pipes, wires, storage tanks …)
  - Near surface soil properties and structures
  - Forensics
  - Archaeology

# Concluding Thoughts: Planning a Survey

- What do I know about the local physical properties?
- How deep do I need to image?
- What are the dimensions and separations of structures I want to image?



Allows you to pick optimum **grid spacing** and **operating frequency**

# Concluding Thoughts: Optimum Frequency

- **Resolution:**

Layers

$$L > \frac{c}{4f_c\sqrt{\varepsilon_r}} = \frac{c\Delta t}{4\sqrt{\varepsilon_r}}$$

Objects

$$L > \sqrt{\frac{V\,d}{2f_c}}$$

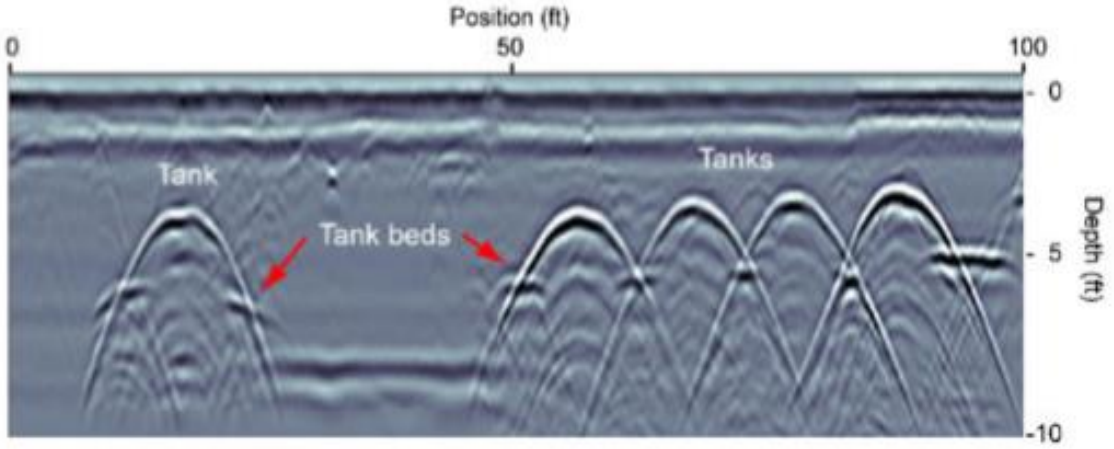
- **Probing Distance:**

$$D = 3\delta \approx \begin{cases} 1510\sqrt{\dfrac{1}{\sigma f}} & \text{for } \omega\varepsilon \ll \sigma \\ 0.0159\dfrac{\sqrt{\varepsilon_r}}{\sigma} & \text{for } \omega\varepsilon \gg \sigma \end{cases}$$

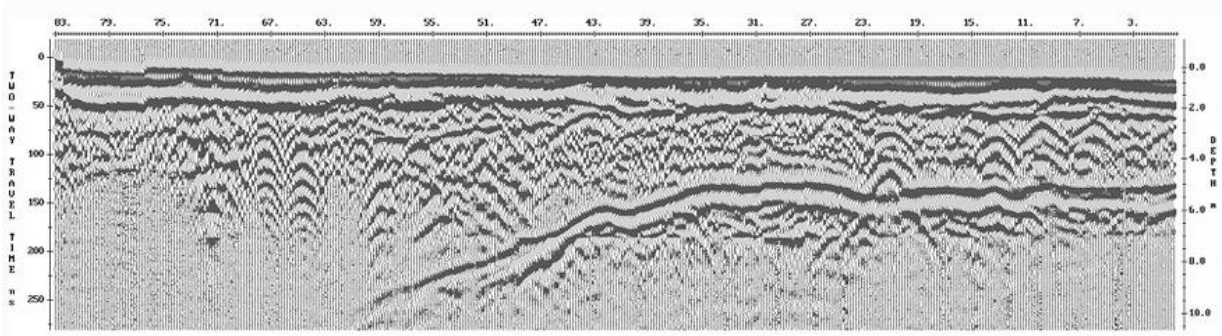
- **Choice in operating frequency is a compromise between resolution and probing distance!!!!**

# Concluding Thoughts: What to Look For

**Hyperbolas**




**Linear Features**



Geometry can give us layer velocities, location of objects and depths of interfaces.

# Questions About GPR?

# Unit Activities

- **Labs (GPR)**
  - Monday, October 21st
  - Tuesday, October 22nd
- **TBL:**
  - Friday, October 18th
- **Quiz:**
  - Wednesday, October 23rd