Modeling and simulation of a deeply penetrating low frequency subsurface radar system

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Background

- Radar subsurface imaging used for geophysical exploration
- Low frequency radar systems (1-5MHz) have been used for km range imaging: Mars, Antarctica
- Adrok Ltd. operates portable compact system (2.5 - 100MHz)
- Used for detecting minerals, oil/gas, water by remote sensing
- Exploration depth limited by absorption losses
- Data stacking increase signal to noise ratio
- How deep can we image through rock with such a system?

Aims

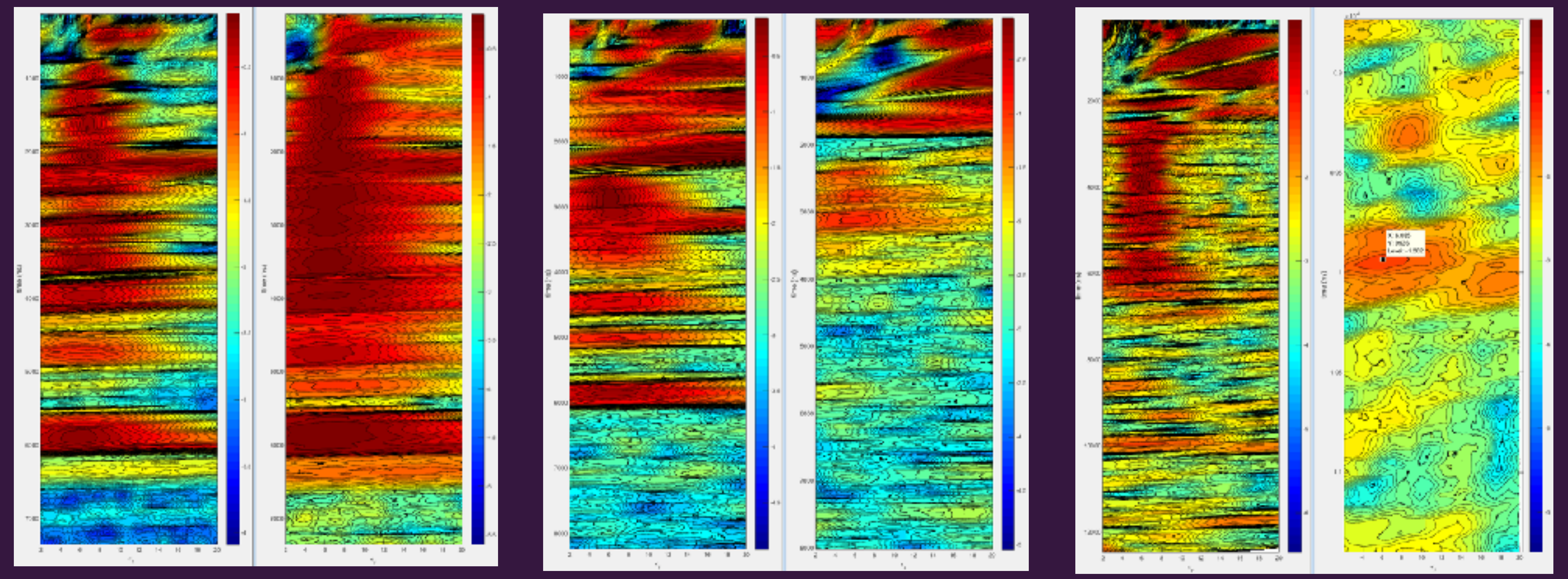
- Model radar system
- Model subsurface structures
- Numerically simulate experiments
- Use result as guide for experimental design and feasibility studies
- Select a specific rock type and target for this study

Methods

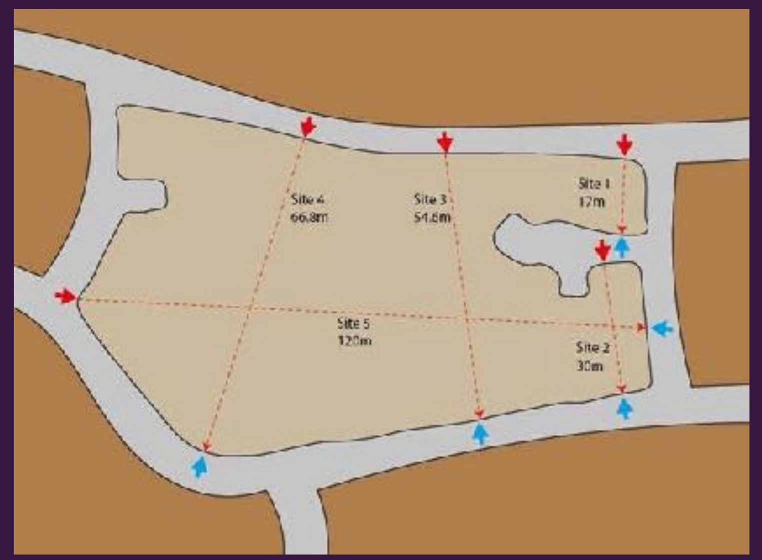
- Measure sensor output, noise level, sensitivity
- Measure physical properties of limestone in-situ
- FDTD/ray tracing numerical simulation (Maxwell in ground)
- Detect reflection time from wet layer
- CMP/WARR scan to build velocity model (semblance velocity spectrum)
- Vary target depth, rock roughness
- Vary stack (500-250,000), scan length (50-200m), line sampling (10-50)
- Test signal processing methods on synthetic data

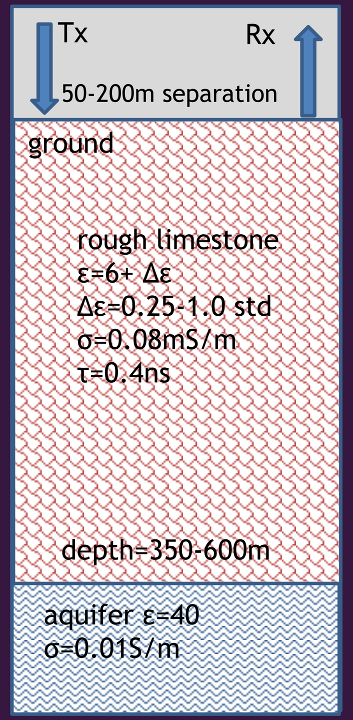
Results

- Stack of 500 traces finds water at 350 +/- 5m assuming velocity known with correlation analysis
- Velocity estimated with same order of accuracy with 100m 20 point WARR line
- Increasing WARR line to 200m improves, but more than 20 samples does not
- Estimation considerably improved by de-enveloping with Hilbert transform
- Small fluctuation in ε (0.25 std) helpful through backscatter
- If rock is too rough (std 1.0) multiples interfere and estimation fails
- Increasing stacking and depth, keeping layer just detectable, gives maximum exploration depth of 600m using stack of 250,000 which is a 1 day acquisition with current equipment



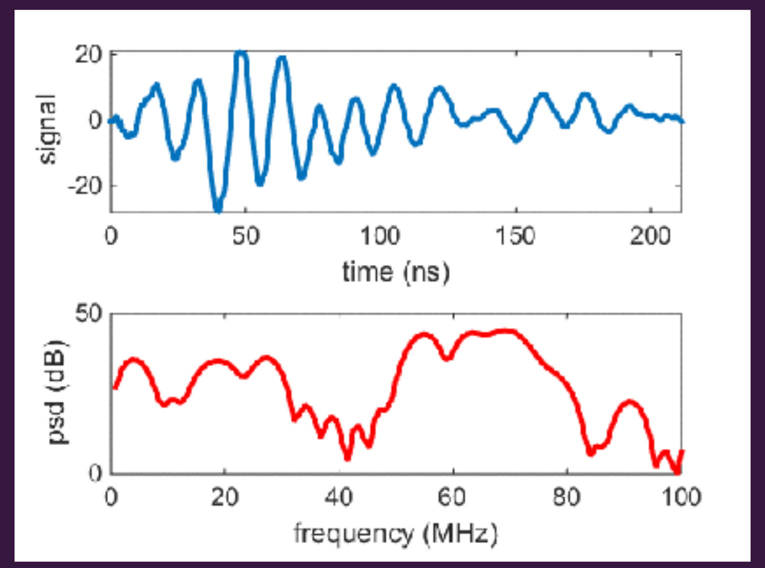
Velocity spectra. **Left:** de-enveloped versus normal. **Mid:** increased roughness to 0.5 and 1.0. **Right:** spectrum with target at 600m and zoom.

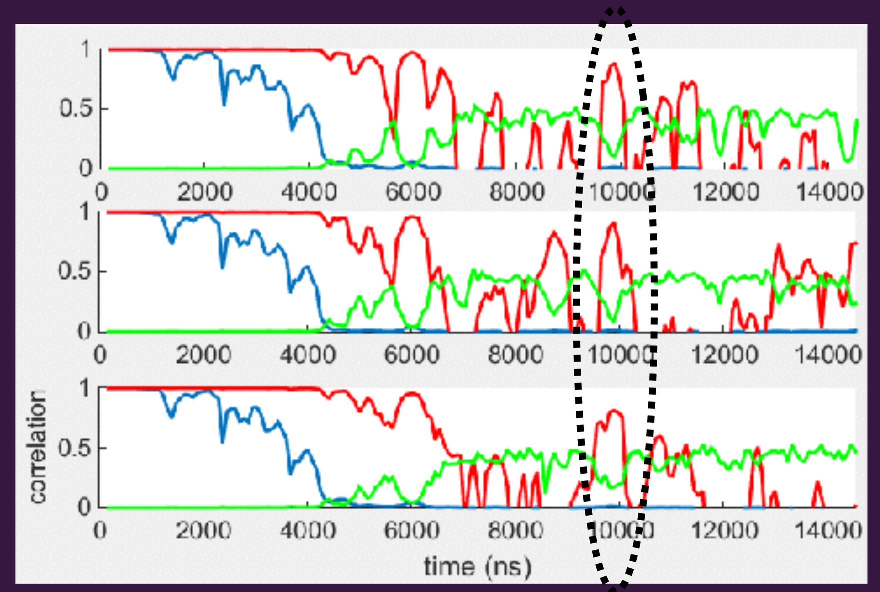




Left: radar pulse was sent through limestone to measure frequency dependent attenuation rate to which model parameters were fitted

Right: synthetic ground model used for modeling and simulation





Left: emitted pulse and power spectrum. **Right:** reflection detection at 600m (peaks in red curve). Repeated three times with independent noise.

Conclusion

Results indicate that with the modeled equipment a water layer (or other reflector) can be detected quickly at a depth of 350m through limestone by detecting the arrival time of the reflection using a correlation analysis of a scan and a phase based velocity spectrum analysis of a WARR scan over a 100m line sampled at 5m intervals. Small irregularities in dielectric of about 0.25 in the limestone are beneficial for the interpretation but if these fluctuation become very large multiples interfere with dielectric (velocity) estimation. Under the constraint of a one day survey and limitations on the data acquisition rate, maximum exploration depth was estimated at 600m. Results from this specific scenario may be applicable to exploration in other highly resistive earth based materials such as granite, igneous rocks, certain types of coal, and permafrost.

Contact Information

adrokgroup.com

References

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