SEG | WORKSHOP

Next Generation Geophysical Land & Shallow Water Acquisition Technologies

28 - 30 September 2026 | Abu Dhabi, UAE



To bury or not to bury

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STRYDE

Outline

- Coupling
  - Theory
  - What characterizes poor coupling
  - Gravity coupling
  - Seabed example
- Tilt
- Noise
  - Wind
  - Anthropogenic
- Operational aspects
  - Deployment
  - Acquisition and pick-up
  - Vibroseis operations

Coupling: Theory

Reference papers from Hoover and O'Brien (1980) and from Krohn (1984) showed that the geophone plant can be approximated by a damped oscillatory coupling: high resonance frequency and high damping are beneficial

Factors impacting the coupling quality are the contact between ground and sensor, sensor mass and consolidation of the ground

The reference paper from Krohn (1984) and the follow-up experiment from Fleure et al. (2017) both conclude than burying the sensor is best

For well deployed sensor, the perturbation can be just a few %. This can increase to dBs for poor planting

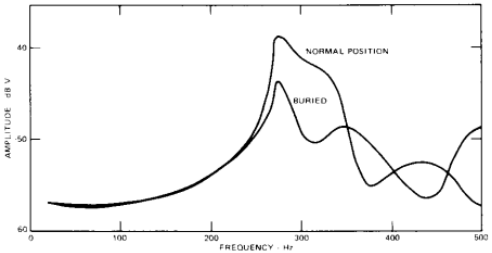
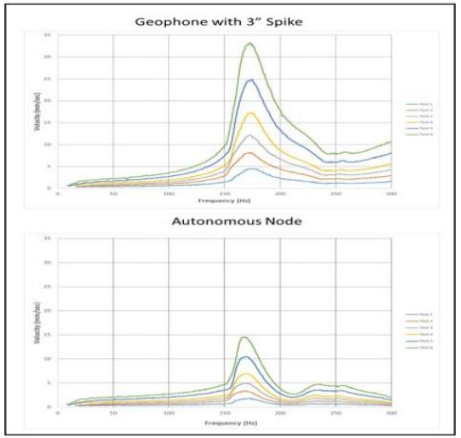


FIG. 11. Amplitudes for a buried vertical geophone and for one in its normal position in sand.

Christine E. Krohn, Geophone ground coupling, GEOPHYSICS. VOL. 49. NO. 6 (JUNE 1984): P. 722-731.

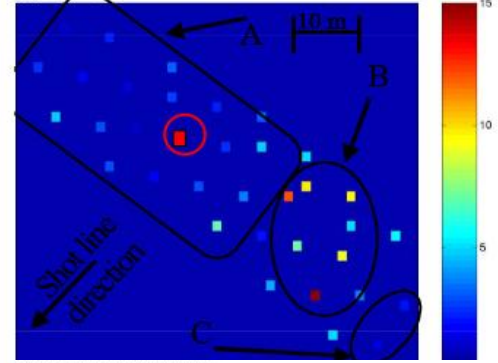


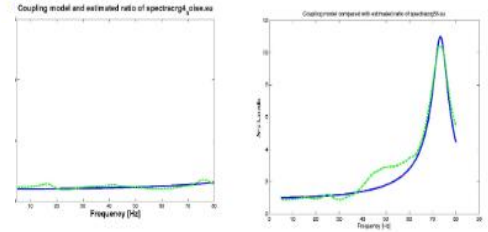
Tom Fleure*, William Halvorson, Rick Miller, Receiver ground coupling revisited; a laboratory experiment to investigate the effects of an autonomous nodal recording system, SEG International Exposition and 87th Annual Meeting, 2017

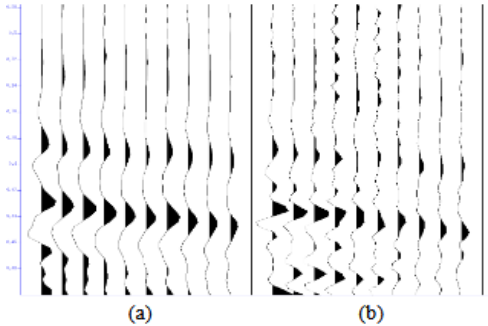
Poor coupling example

- From a paper looking at a method to correct for the coupling variations they observed (SLB Dhahran Research)

- Resonance peak at 70 Hz seen on poorly coupled sensor
- Signal present, with added high frequencies and phase variations on the first arrivals



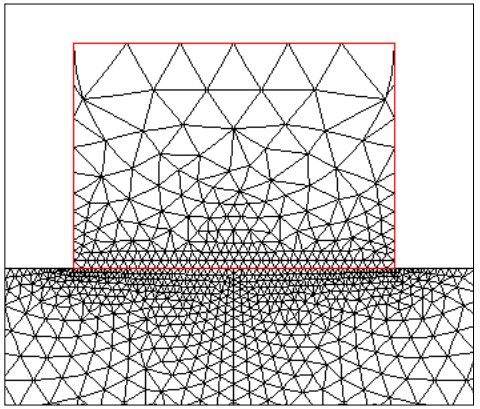




Claudio Bagaini* and César Barajas-Olalde, Schlumberger Dhahran Carbonate Research, Assessment and compensation of inconsistent coupling conditions in point-receiver land seismic data, SEG Int'l Exposition and 74th Annual Meeting Denver, Colorado, 2004

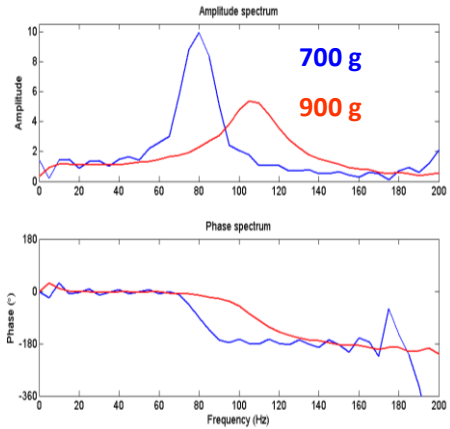
Gravity coupling

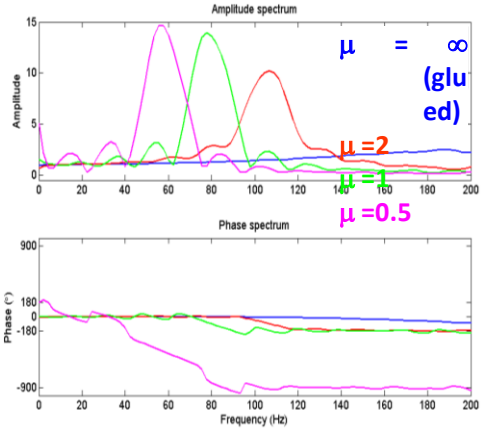
- Gravity coupling: relies on friction at surface
- Can work in some cases for vertical coupling
- Surface can be less consolidated
- Any obstruction can make the housing unstable



Horizontal coupling resonance in main seismic band, even with full contact surface

- Mitigated by increased weight





weight friction coefficient

Gravity coupling: seabed

- Gravity coupling because planting and burial are impractical (preferred for permanent installations)
- We need to correct for vertical coupling quality: the hydrophone is used as a reference for PZ calibration
- PZ Matching operators typically show large frequency dependency for amplitude and phase
  - Demonstrating non-optimal Z coupling
- Large Shear waves noise leakage on vertical can be caused by unstable sensor package (rocking motion)

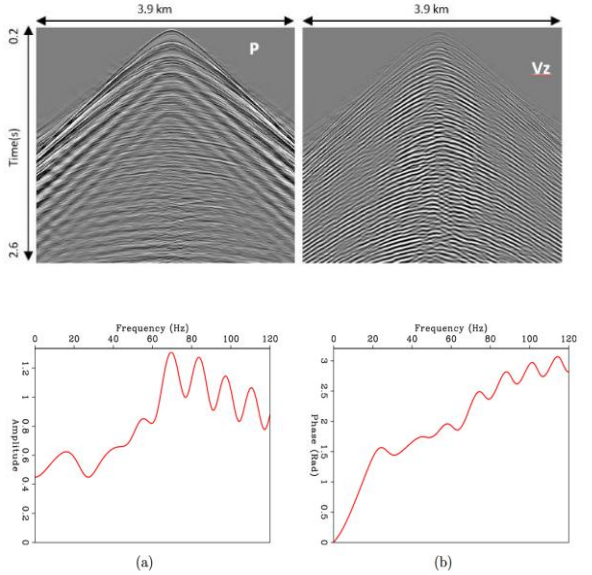


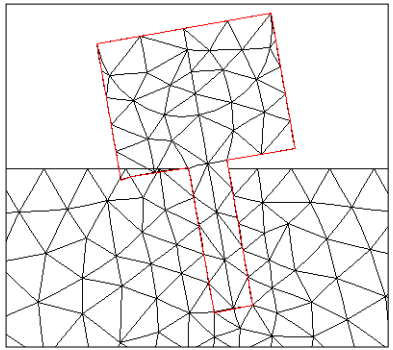
Figure 5: Frequency response of the calibration filter with 41 coefficients obtained from the long-offset refracted waves. (a) Amplitude spectra of the filter. (b) Phase spectra of the filter. [ER]

Ettore Biondi and Stewart A. Levin, Application of the up-down separation using PZ calibration filter based on critically refracted waves, SEP report 155, 2014

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Tilt sensitivity



Effect of tilt on sensors

- Some spec degradation (mainly THD) on geophone: well below 1% error
- Accelerometers not affected

Effect of tilt on signal (10 degree tilt)

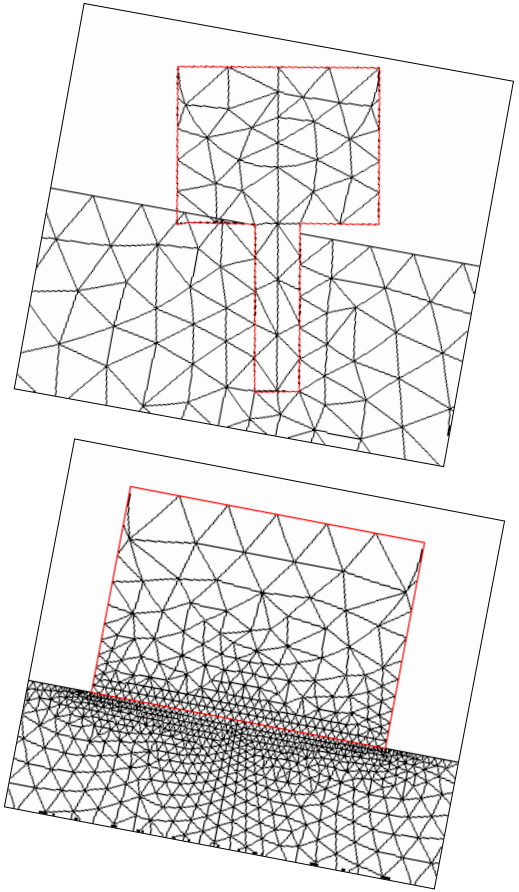
- Slight attenuation of vertical P-wave amplitude: 1.5%
- **Large leakage of vertically propagating S-wave: 17% of amplitude – for all sensors**

All 1C sensors are tilt sensitive

- Only solution: 3C sensor + rotation or vertical plant

Tilt: likelihood and consequences

- A sensor housing on the ground surface is more likely to be tilted
- Tilt will degrade the stability of the sensor housing
- With poor coupling or unstable sensor housing, shear leakage will be amplified by coupling resonance or sensor housing rocking



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Noise: wind

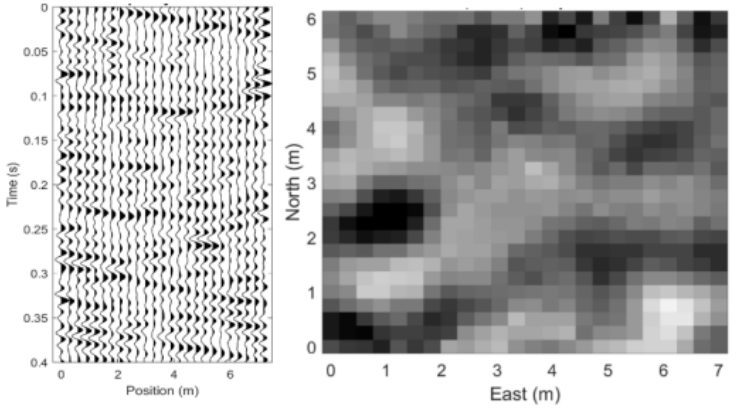
More critical for point receiver nodes vs arrays

Origin 1:

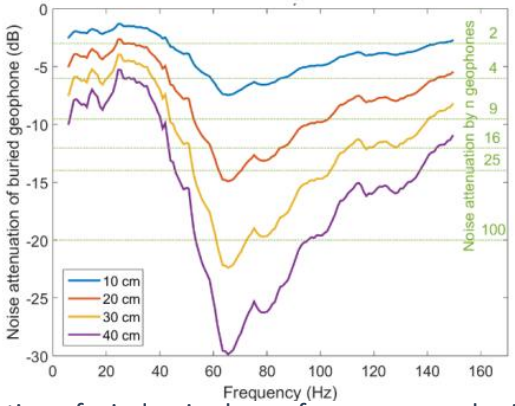
- Direct hit: air or particles moving the sensor housing
  - Shape can help limit
  - Burying avoids it altogether

Origin 2:

- Local surface waves generated by the wind, propagating in the near surface
  - Large attenuation with depth
  - No attenuation for any sensor at the surface



Wind noise recorded on a 30 cm grid:
It becomes coherent!



Everhard Muyzert, “Attenuation of wind noise by surface arrays and seismic nodes”, 83rd EAGE Annual Conference & Exhibition, Jun 2022, Volume 2022, p.1 – 5

Noise: anthropogenic noise

- Vehicles, crew activity, industrial

E. Kragh et al (2014) made a test to quantify the noise level created by the vibrator fleet:

- It is often the main source of noise

Propagation modes for these noises:

- Through the air
- As surface waves

Both get attenuated when you bury the sensors, especially at high frequency

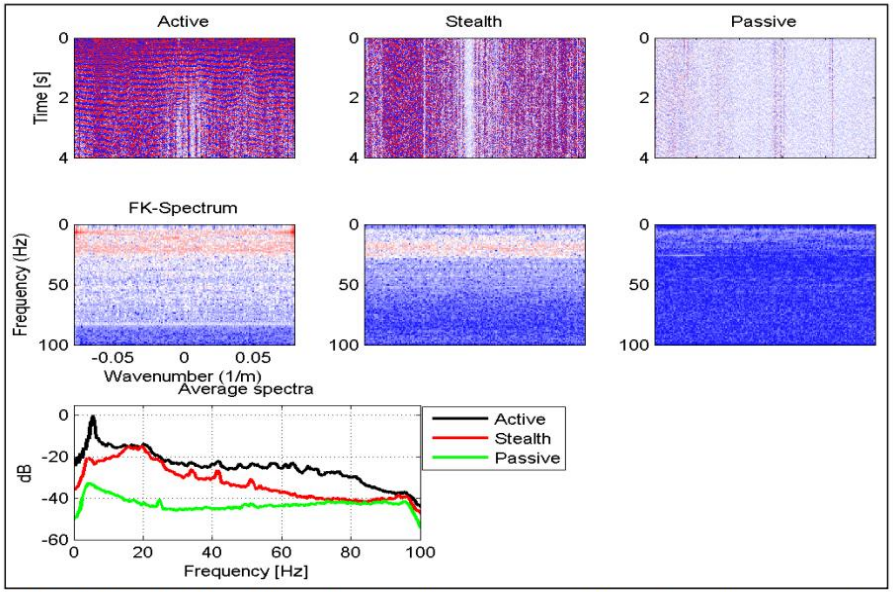


Figure 1. *Active, Stealth and Passive brute stacks (no processing). F-K spectra and average spectra.*

E. Kragh*, M. Daly & J. Quigley, Quantifying Noise in a Land Seismic Image - Stealth Acquisition Experiment, 76th EAGE Conference 2014 Tu ELI1 04

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Operations: deployment

Terrain Deployment Time	RI	Seconds
Flat desert	8.33m	11
Flat desert	12.5m	13
Rocky desert with offsets	7.5m	15
Flat hard gravel	25m	16
Dunes	25m	25

Traditional, on foot

- Walking at 4.5 km/h is 1.25 m/s: 10 seconds for 12.5 m
- Planting time only a small share of total time

From vehicle, automated

- Traveling between points still takes significant time
- Even if you do not need bury, you need to identify location and prepare the ground. Can be automated, so can burial

Very large efficiency improvement from geophone arrays to nodes

Additional impact of dropping burial is much smaller





Operations: during acquisition and pick-up

- Technical downtime, loss and damages: advantage buried
  - Non-buried nodes are much more likely to be disturbed by animal or people
  - They also can be moved or damaged by vehicles



- Pick-up speed: similar
  - Buried node position has been recorded with cm accuracy, they are easy to find guided by a tablet; and they are much less likely to have moved

Operations: Vibroseis



Operations: Vibroseis

The spread seen from a vibrator: total freedom of operation



Operations: Vibroseis

The spread seen from a vibrator: total freedom of operation

Vibrators can drive anywhere above buried nodes, can even sweep on top

Any shooting method is possible and can be implemented very efficiently

Conclusion

BURY if you can

- Your data quality will be as good as your planting. If not buried:
  - More incoherent noise
  - Compromised signal bandwidth, especially at high frequencies
  - Coupling is a major source of distortion of seismic data
  - No sensor can correct for it

- Minor cost at deployment
- Large efficiency gain during acquisition



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