Geophysics Field Camp
“A Hands-online Experience”
The Seismic Method

Courtesy of ExxonMobil

Mitchum et al., 1977b

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Hammer seismic survey near Hockley, Texas
2. Source – Vibe/dynamite/whacker/hammer
Compressional ("P") Wave

Identical to sound wave – particle motion is parallel to propagation direction.
Shear ("S") Wave

Particle motion is **perpendicular** to propagation direction.

Animation courtesy Larry Braile, Purdue University
What instruments do we use?

- Motion in → the output depends on the transducer
  - Velocity of the proof mass (geophones)
  - Displacement of the proof mass (MEMS)
Seismic Refraction

Note: $V_{p1} < V_{p2}$

Determine depth to rock layer, $z_R$
Installing 3C station on Turtle Mtn.
Wiring
3C seismic station
An example of a seismogram recorded
Suppose that a subsurface microseismic event (perhaps a hydraulic fracture, thermal heave, production-related break, or tectonic release) occurs, at some time $t_0$, a distance $d$ away from a 3C receiver. Further imagine that the earth is simple in this case with homogeneous P- and S-wave velocities ($V_p$ and $V_s$).

The P-wave radiated from the microseismic source will arrive at the receiver at a time $T_p = t_0 + d/V_p$. The S-wave will arrive at a time $T_s = t_0 + d/V_s$.

We usually don’t know the origin time of the event $t_0$, but we can subtract the P and S arrival times so that we don’t have to know it to find a distance:

$T_s - T_p = \text{distance} \times (1/V_s - 1/V_p)$

$\text{distance} = (T_s - T_p)/(1/V_s - 1/V_p)$
Hypocenter location
The following seismograms, recorded at a downhole 3C geophone in the Cold Lake Alberta thermal, bitumen recovery site, indicate that a microseismic event has occurred. From the seismograms, about how far away from the geophone was the event? Note that velocities are approximately: $V_p = 2000\text{m/s}$ and $V_s = 700\text{m/s}$. Recall that $T_s - T_p = \text{distance} \times (1/V_s - 1/V_p)$.
Source-receiver distance from P and S traveltime difference

- $T_s = 0.35\text{s}; T_p = 0.27\text{s}$

  \[
  \text{distance} = \frac{0.08\text{s}}{(1/700\text{m/s} - 1/2000\text{m/s})} = 86\text{m}
  \]

So, now we know how far away the source is, but in what direction (azimuth) and at what depth?
Now let’s estimate the direction of the arrival to get the location of the source. Assume that we know the depth (D) and orientation (Z = vertical, X = north, Y = east) of the 3C downhole geophone.

Microseismic event location
Direction and location

3C receiver

d = 86m

θ
Smartphones have three orthogonal accelerometers (motion sensors). They can sense motion and orientation in 3 directions.
VibSensor User Guide

VibSensor makes collecting, analyzing, and exporting high quality accelerometer data easy. Read on to learn about the four main functions of the app, followed by a discussion of getting the best data from your device.

Visualizing

Mobile devices contain an accelerometer that measures along each of the main axes of the device. By convention, the axes are labeled as follows.

![Diagram of phone axes]

- **X**
- **Y**
- **Z**

### Runs

<table>
<thead>
<tr>
<th>Data</th>
<th>Edit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acq: 28 Jul 2020 (11:57 am)</td>
<td>Length: 0 min 5 sec</td>
</tr>
<tr>
<td>Points: 558</td>
<td>Gaps: none</td>
</tr>
<tr>
<td>Data rate: 97.6 Hz</td>
<td>Units: m/s²</td>
</tr>
<tr>
<td>Peak raw: X (1.14) Y (2.17) Z (LIMIT)</td>
<td></td>
</tr>
<tr>
<td>ISD: X (0.19) Y (0.31) Z (2.4)</td>
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<td>Resonances:</td>
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<td>rms vibration: X (0.23) Y (0.38) Z (2.9)</td>
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</tbody>
</table>

### Power Spectrum

![Power spectrum graph]

- **X**
- **Y**
- **Z**

scale: 1 X
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![Diagram of accelerometer axes]

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### Data

- **time (s)**
  - 1.0
  - 2.0
  - 3.0
  - 4.0

- **accel (m/s^2)**
  - 5.0
  - 0.0
  - -5.0
  - -10.0

### Power Spectrum

- **linear**
  - 10.0

- **log**
  - 10^0

- **scale:** 1 X

### Vibration

- **X**
- **Y**
- **Z**
- **linear**
- **log**
- **scale:** 1 X
Seismology smartphone exercise

- Download 3C app
- Check direction of 3C component motions
- Look at frequencies of various vibrations
  - Passive monitoring indoor and outdoors
- Try walkaway source — store recorded amplitudes
- Compare smartphone response to Raspberry shake response for a known nearby source
Activity - Seismology & vibration monitoring

- Understand measurement of vibrations and seismic waves
- Gain experience in using a major type of instrument and its data
- How we can use these waves to infer geologic & engineering information
Raspberry Shake Seismometers – various sensors (vertical and horizontal geophones, pressure)

- One vertical geophone
  - a pressure gauge (infrasound)
  - Two horizontal components
  - 3C accelerometer
- System
  - Power
  - Signa processing
  - Communication
Broad-band Seismograph Networks
Geophysics Field Camp

A “hands-online” experience

Questions, comments, or queries?