Low Cost Seismic Monitoring Strategies

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Outline

- Mining Seismology Background
- Monitoring Objectives
  - Documentation
  - Ground vibration measurements
  - Rockburst risk management
- Monitoring Strategies
  - **Regional stations**
  - **Single station**
  - **Temporary deployments**
  - Mine/district networks
  - In-mine microseismic networks
- Open-source software

Background

Background

Bursts and bumps

- Understanding and managing bursts is the main focus of mining seismology
- Seismic monitoring in mines dates back to the early 1900s (South Africa and Germany)
- Bursting continues to be a significant problem for many mines

Lucky Friday burst, 1990's

Solvay Collapse, 1994

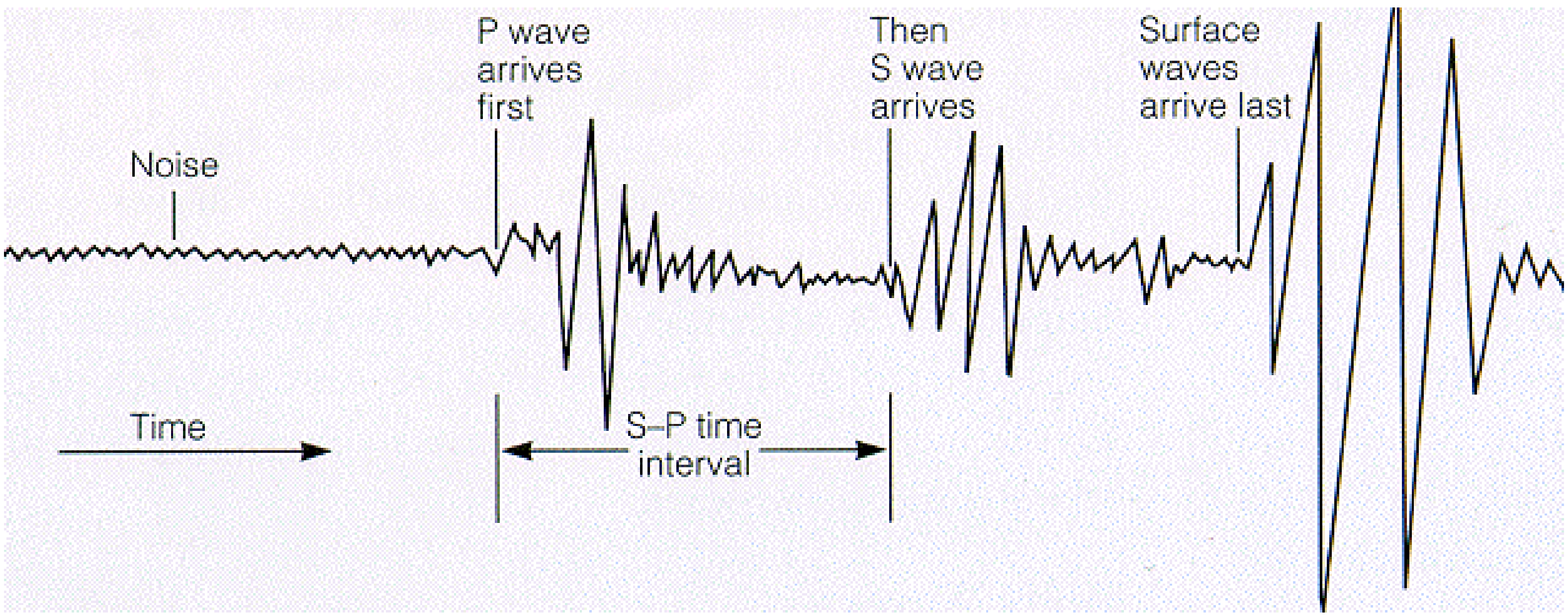
Background
Mining seismology

Goal: Understand the Earth and its response to extraction

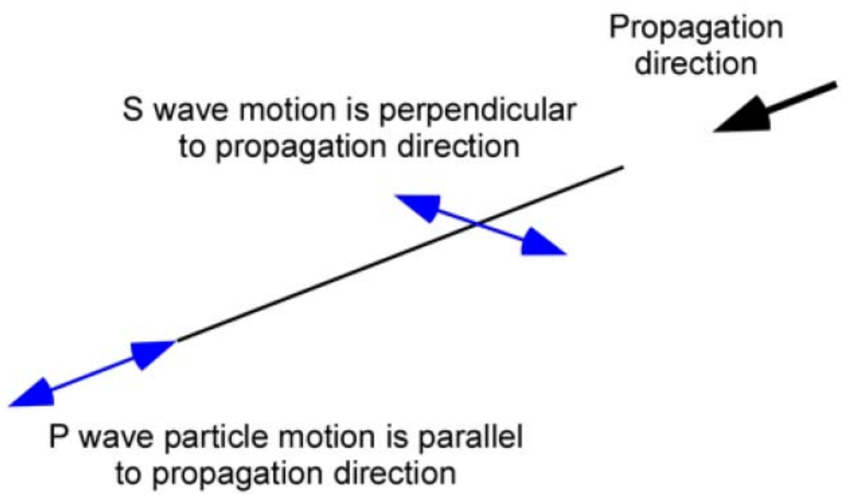
- Active
  - Put energy into the system
- Passive
  - Listen to the systems' emitted energy

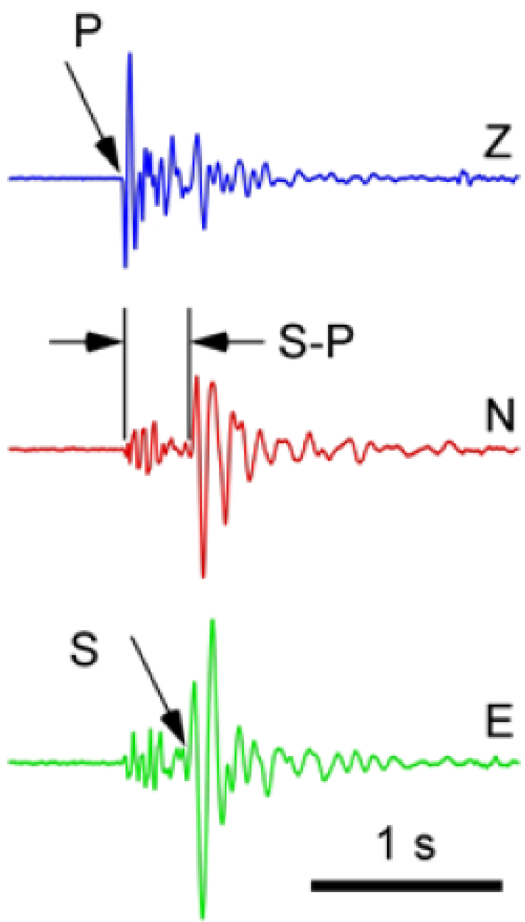
Background
Seismic events

- Seismic events: sudden, displacements which radiate energy (mechanical waves)



Background
Seismic phases





Monitoring Objectives
Event catalogs

A seismic catalog consists of:

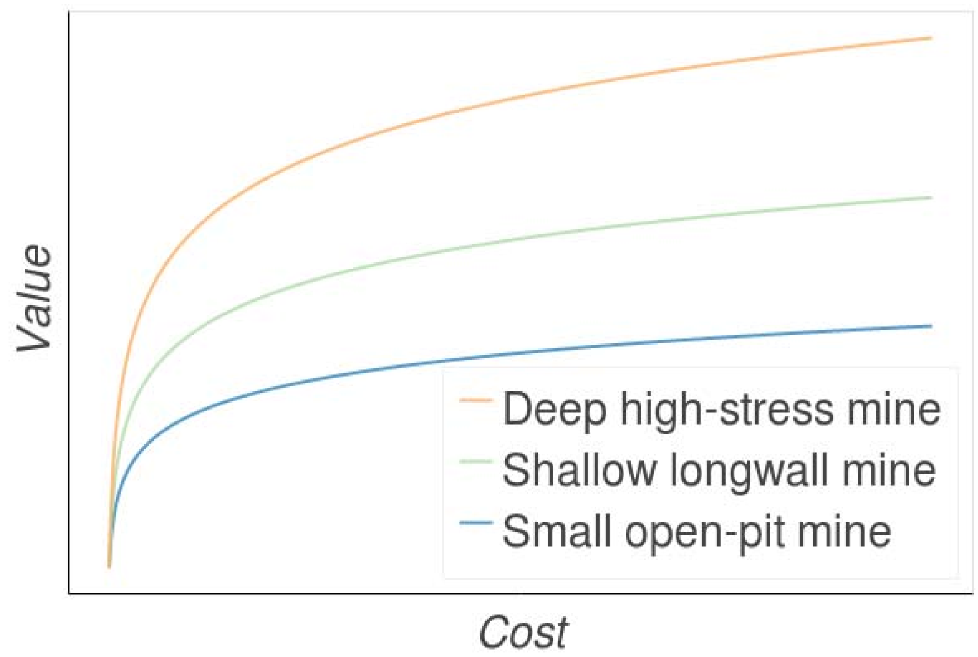
- Origin time
- Location
- Magnitude
- Other source parameters

event_name	latitude	longitude	depth	magnitude
2016-07-30T00-16-13	47.48400	-115.78317	-0.02	0.38
2016-07-30T00-51-18	47.50017	-115.80083	3.62	-0.13
2016-07-30T11-08-12	47.48300	-115.78633	-0.32	-0.16
2016-07-30T18-48-21	47.48250	-115.78633	0.56	-0.37

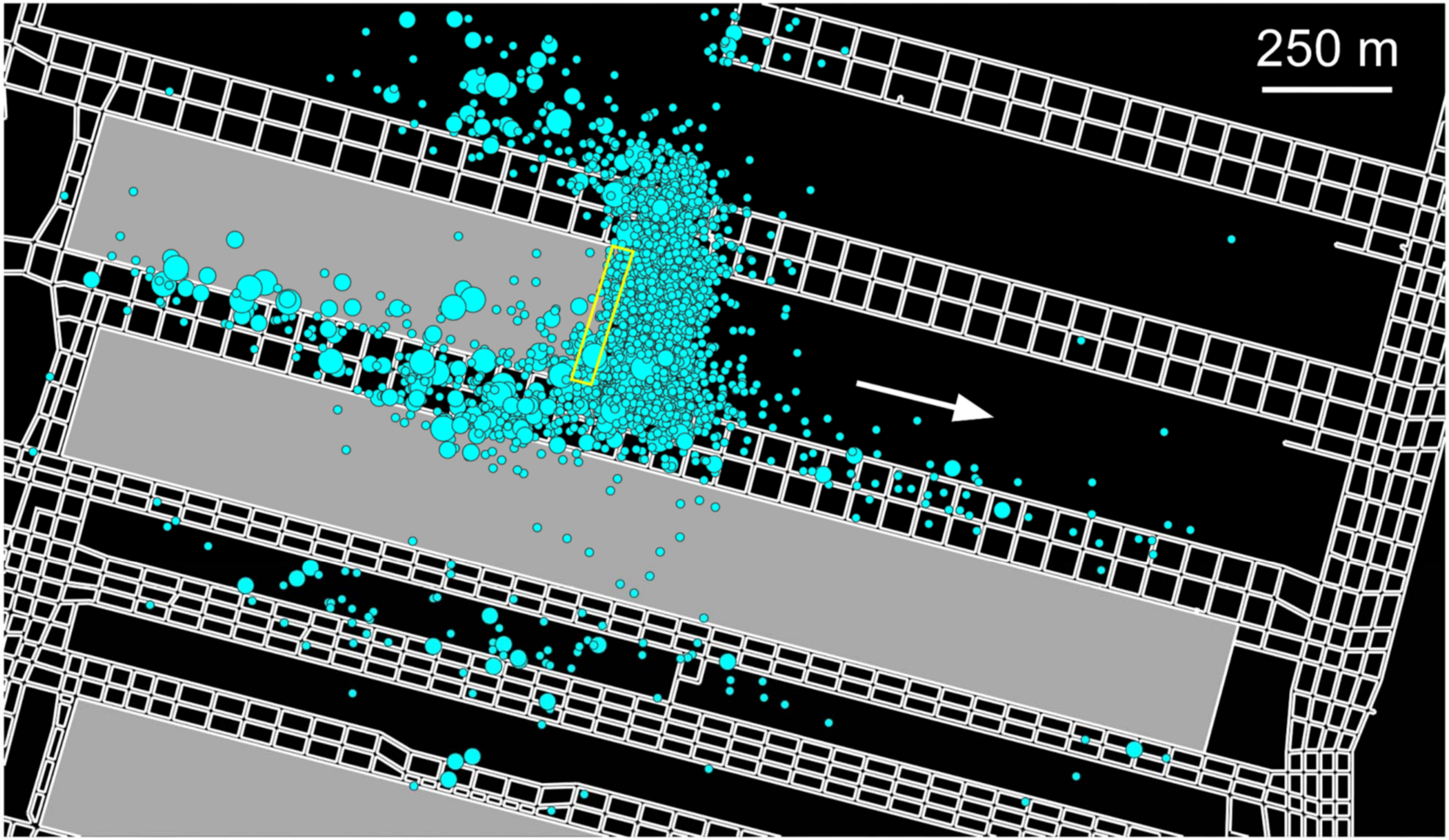
Background
Value of seismic monitoring

The Value of monitoring depends on:

- Mining method
- Geological conditions
- Propensity for bursting
- Amount of seismicity
- Monitoring objectives



Monitoring Objectives CDJA(3



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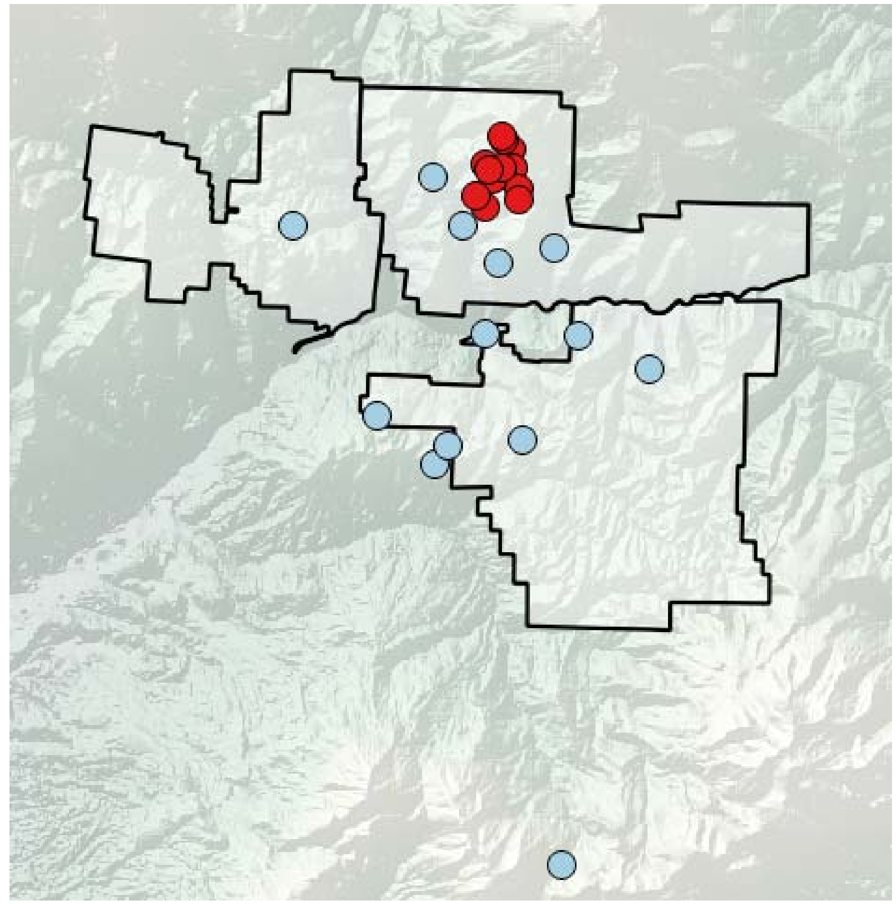
CDJA(3 I need a background picture for this one

Chambers, Derrick James Allen (CDC/NIOSH/SMRD), 4/16/2018

Monitoring Objectives
Documentation

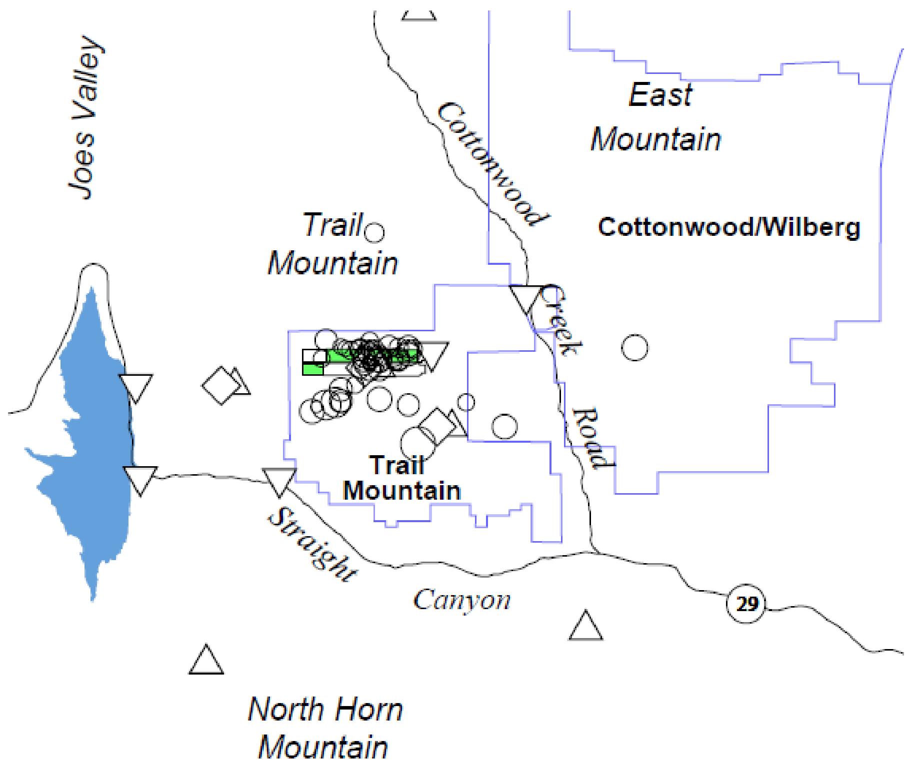
- Discriminate between tectonic and induced sources
- Determine from which mine (in a district) a source originated
- Gather information to help determine when/if more monitoring efforts are justified



Instrumentation and Networks

Measure ground vibration

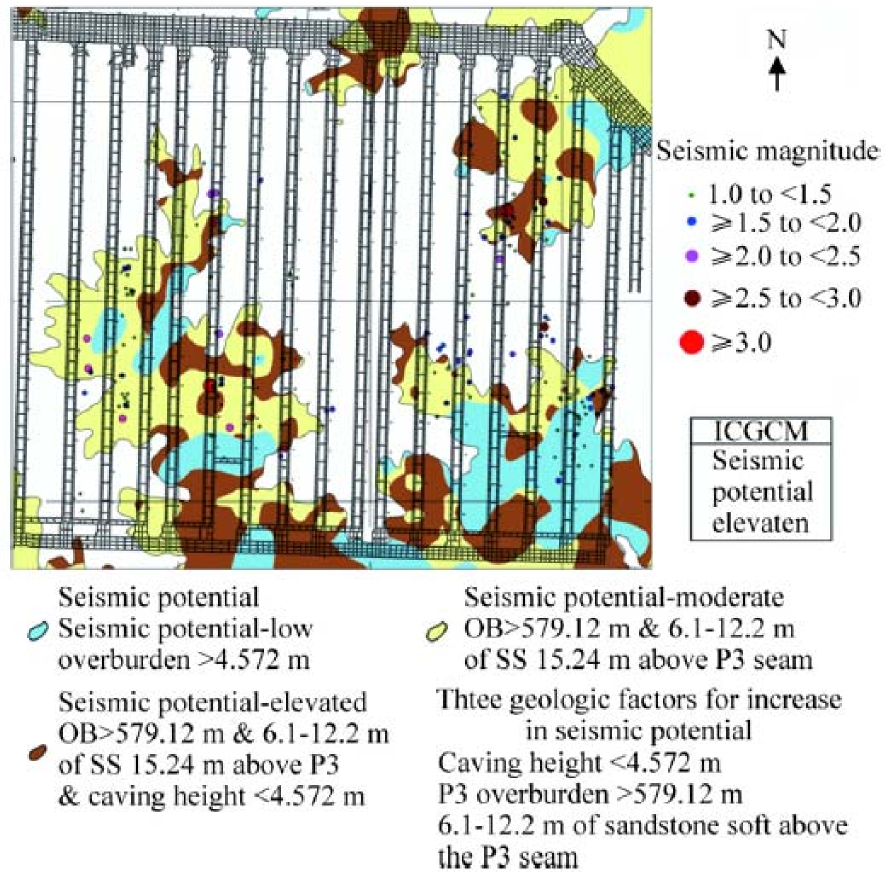
- Ensure ground support system can handle expected dynamic loads
- Determine design parameters for nearby surface structures (eg dumps, mills, offices)
- Enforce ground motion limits for sensitive structures (eg houses, dams, etc.)



Arabasz et al. 2002

Monitoring Objectives
Rockburst risk management

- Rescue response
- Back analysis of significant events
- Seismic hazard assessments (short to long term)
- Evaluation of mine design performance

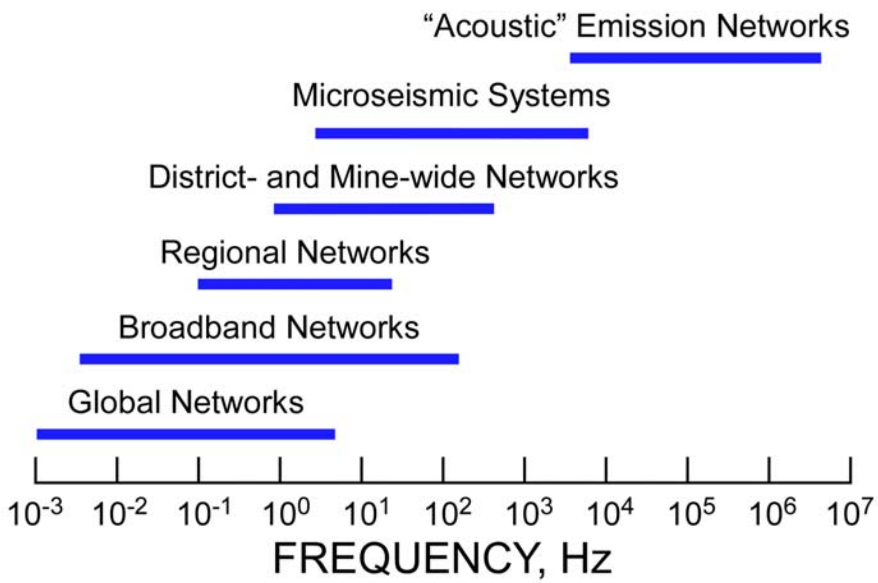


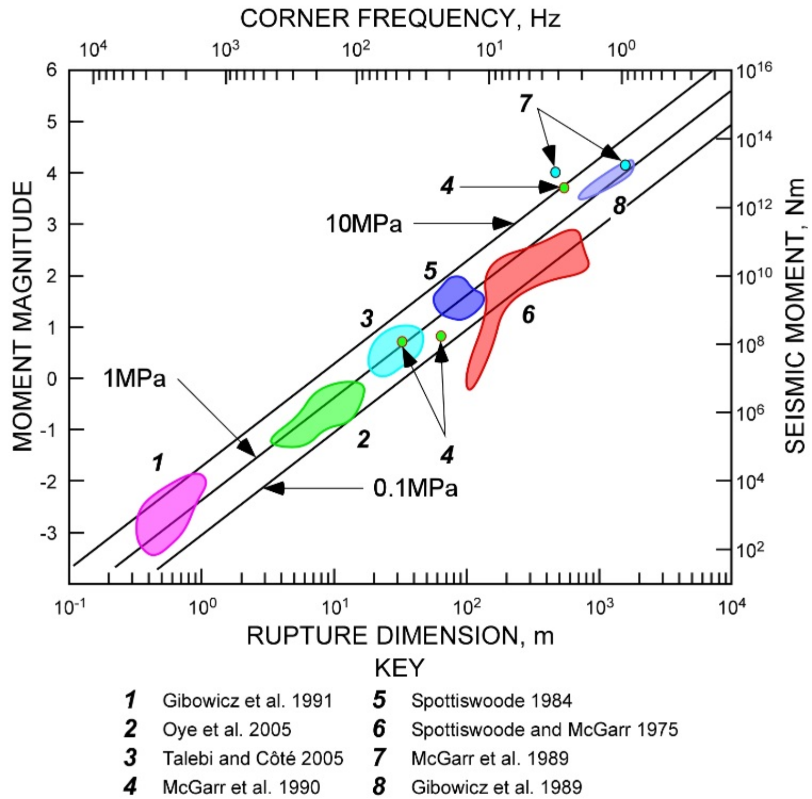
Van dyke et al. 2017

Monitoring Strategies

Monitoring Strategies
Instrumentation considerations

- Cost
- Acceleration, velocity, or displacement
- Frequency range
- Sampling rates
- Deployment duration

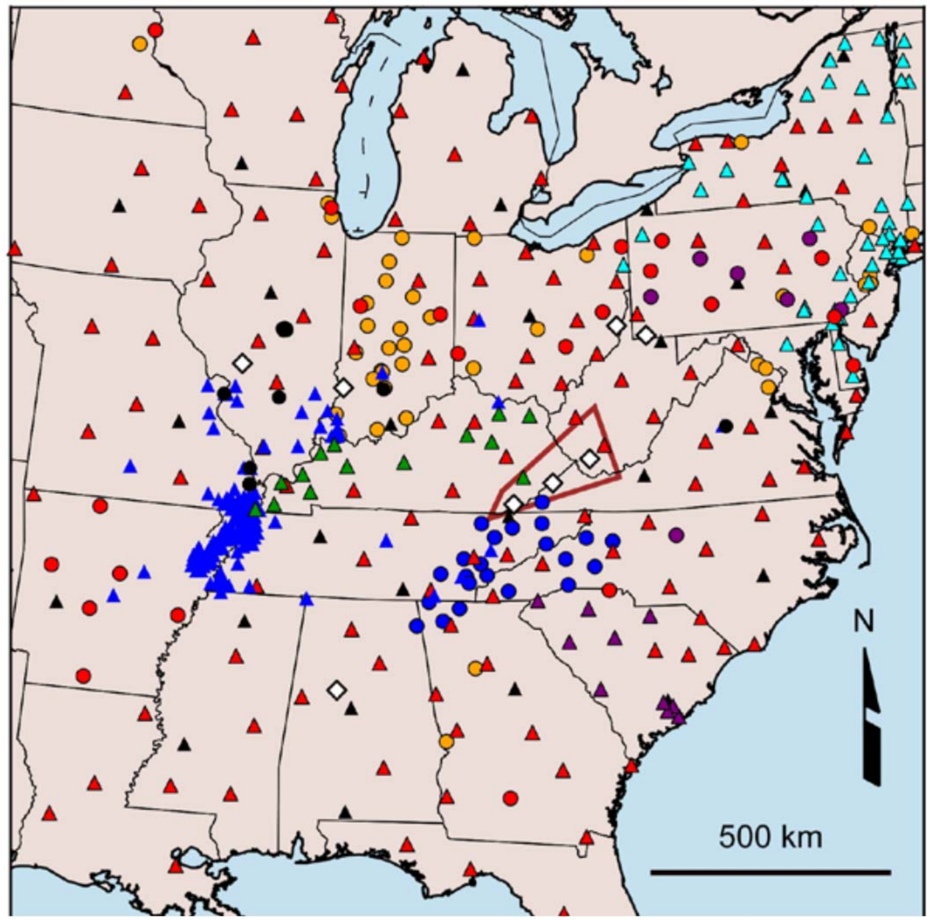




Monitoring Strategies

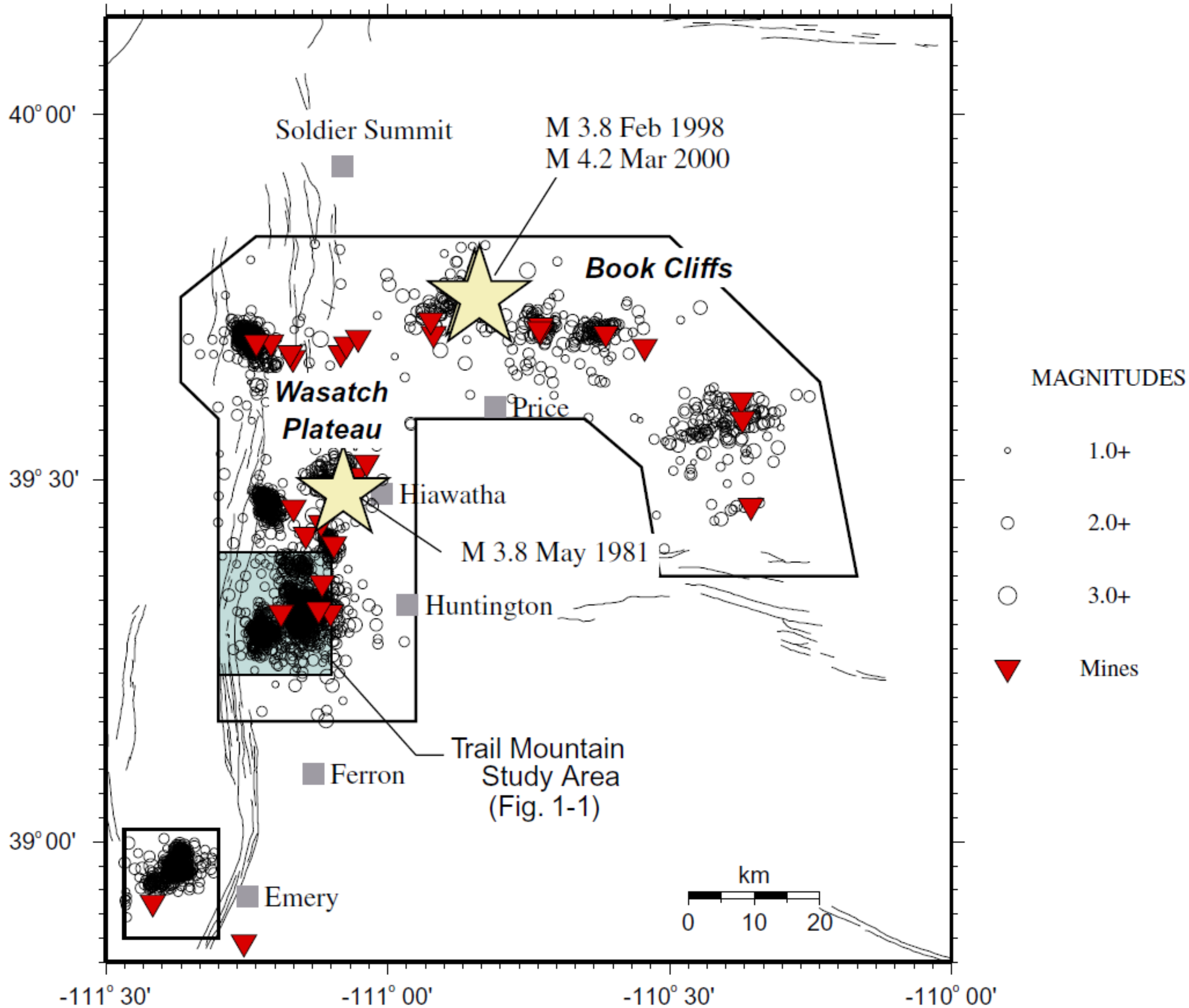
Regional networks

- Typically run by government agencies or universities
- Data are freely available for download through various web-services
- Sensors are typically spaced very far apart, resulting in large location errors
- Many organizations allow mines to “sponsor” new sites for better coverage
- Very low cost (for the mine)



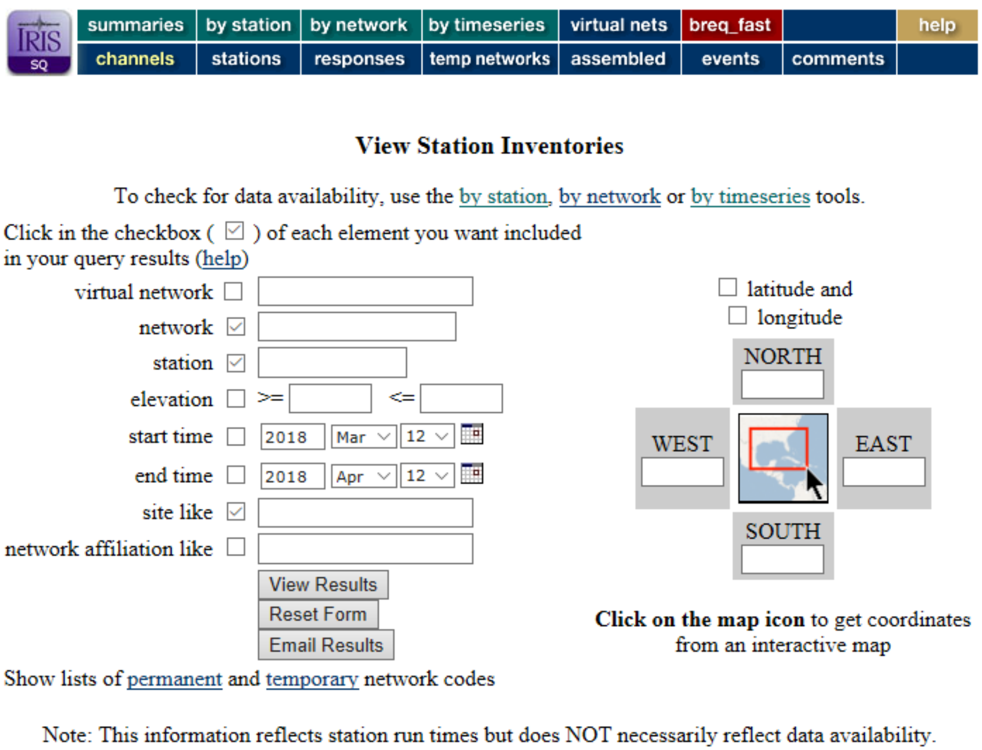
Monitoring Strategies

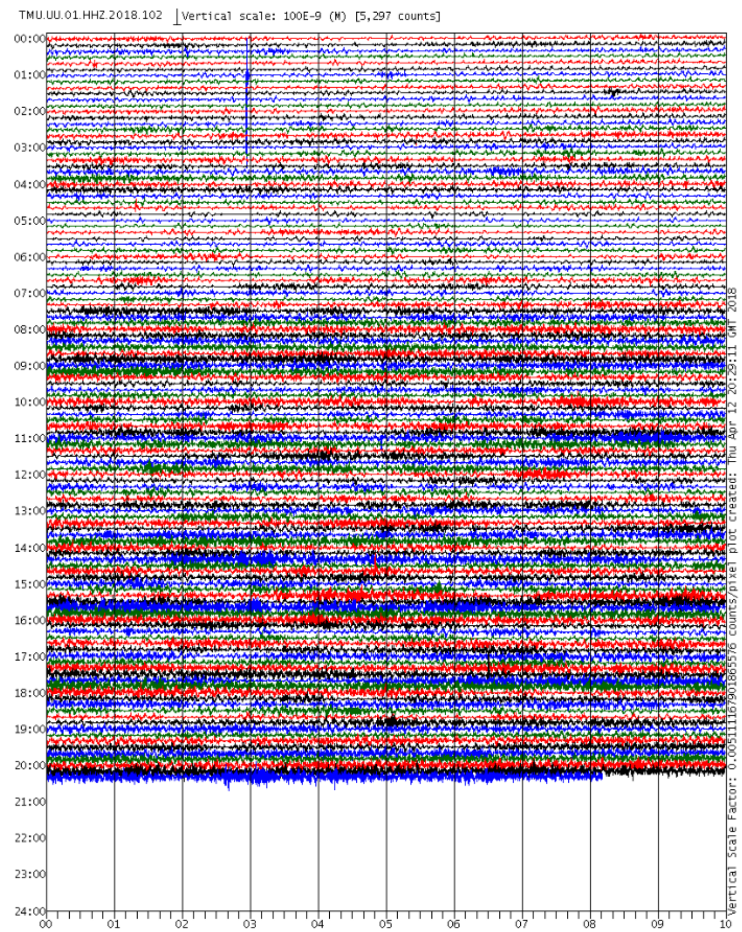
Regional networks



Arabasz et al. 2002

Monitoring Strategies
Regional networks



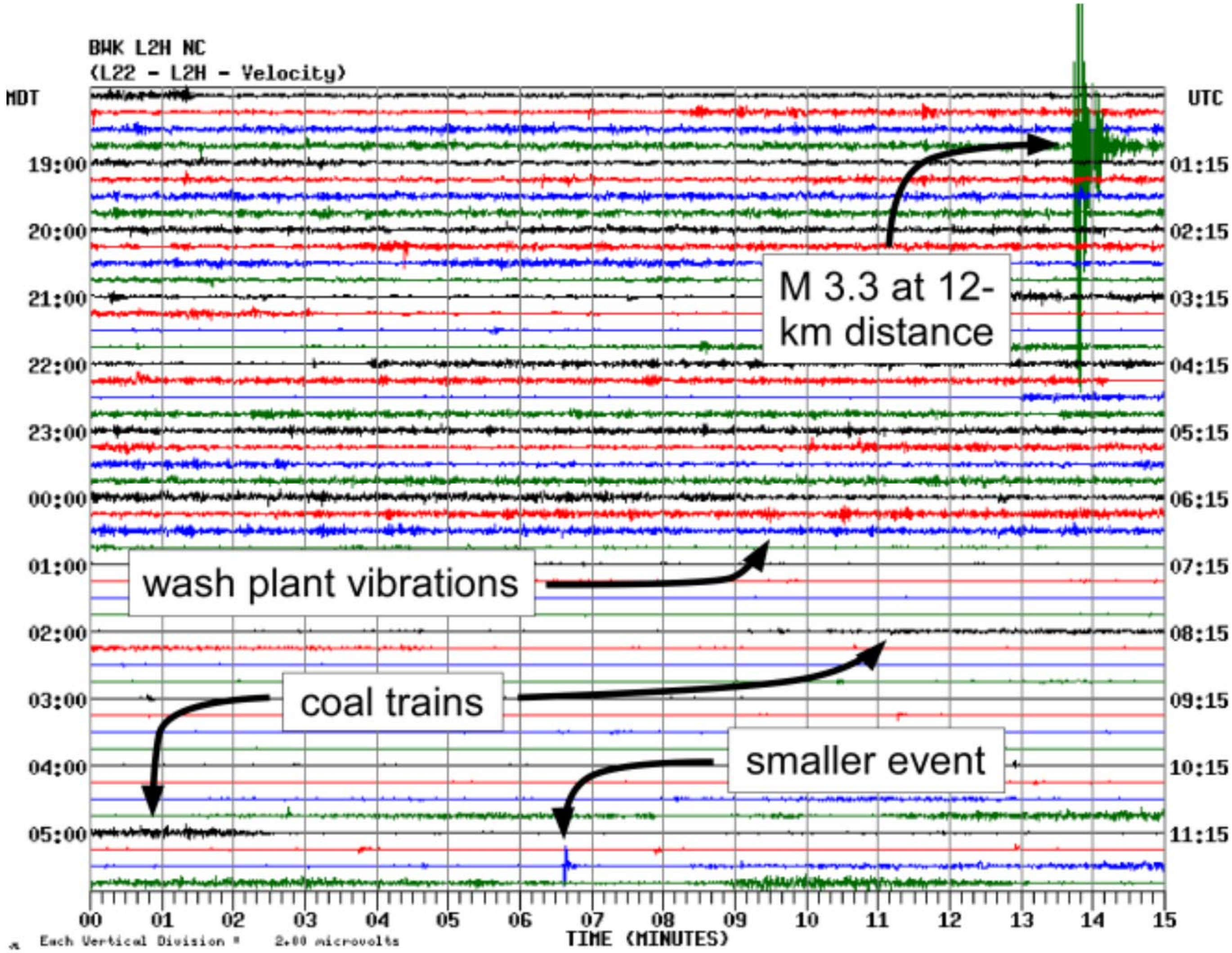


Monitoring Strategies
Single station deployments

- A single three component stations can:
  - Record event count
  - Estimate rough locations
  - Calculate magnitudes
- Can be placed in the mine or office
- Many off-the-shelf options available
- Low cost

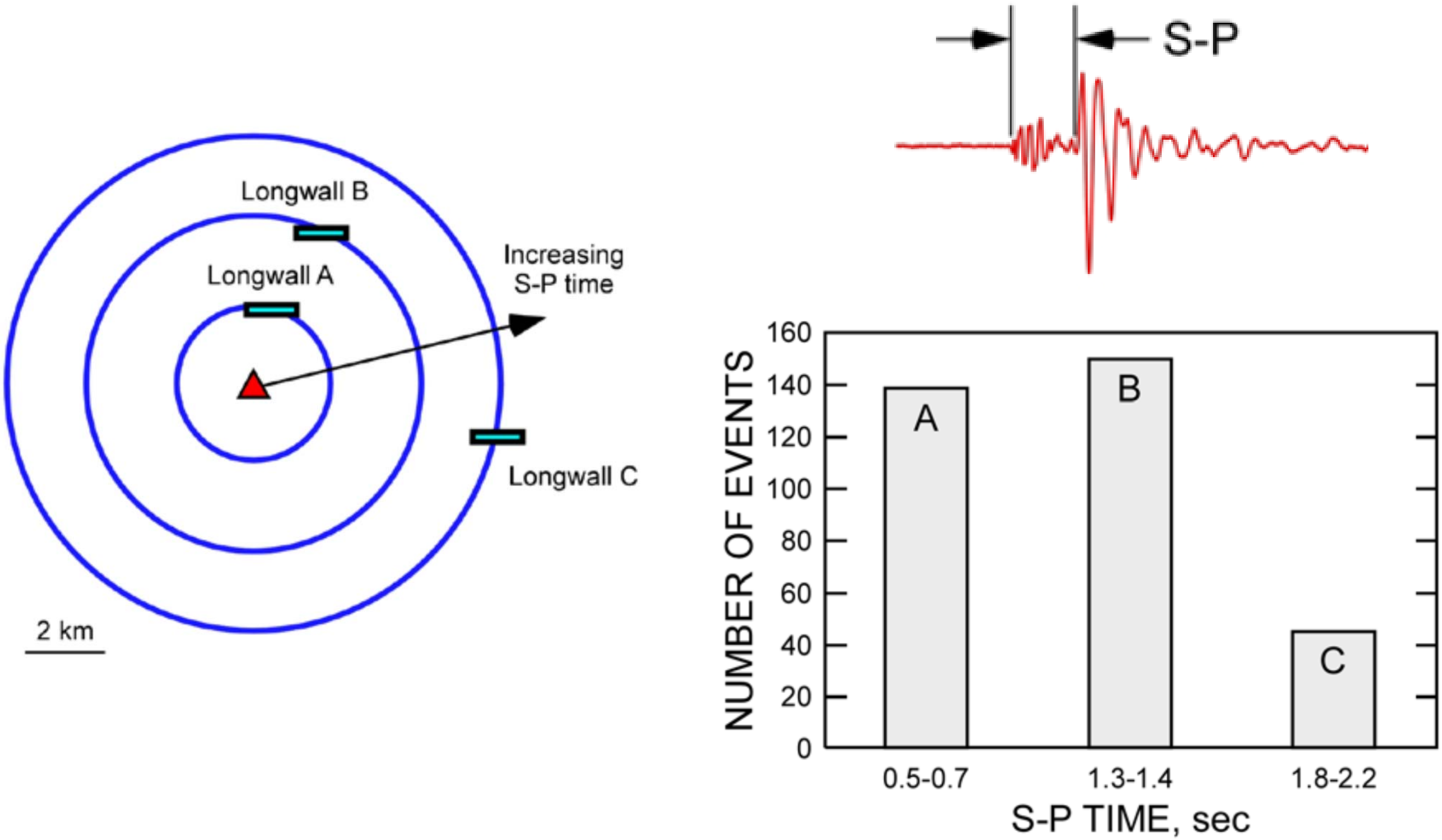
Raspberry Shake

Monitoring Strategies
Single station deployments



Monitoring Strategies

Single station deployments

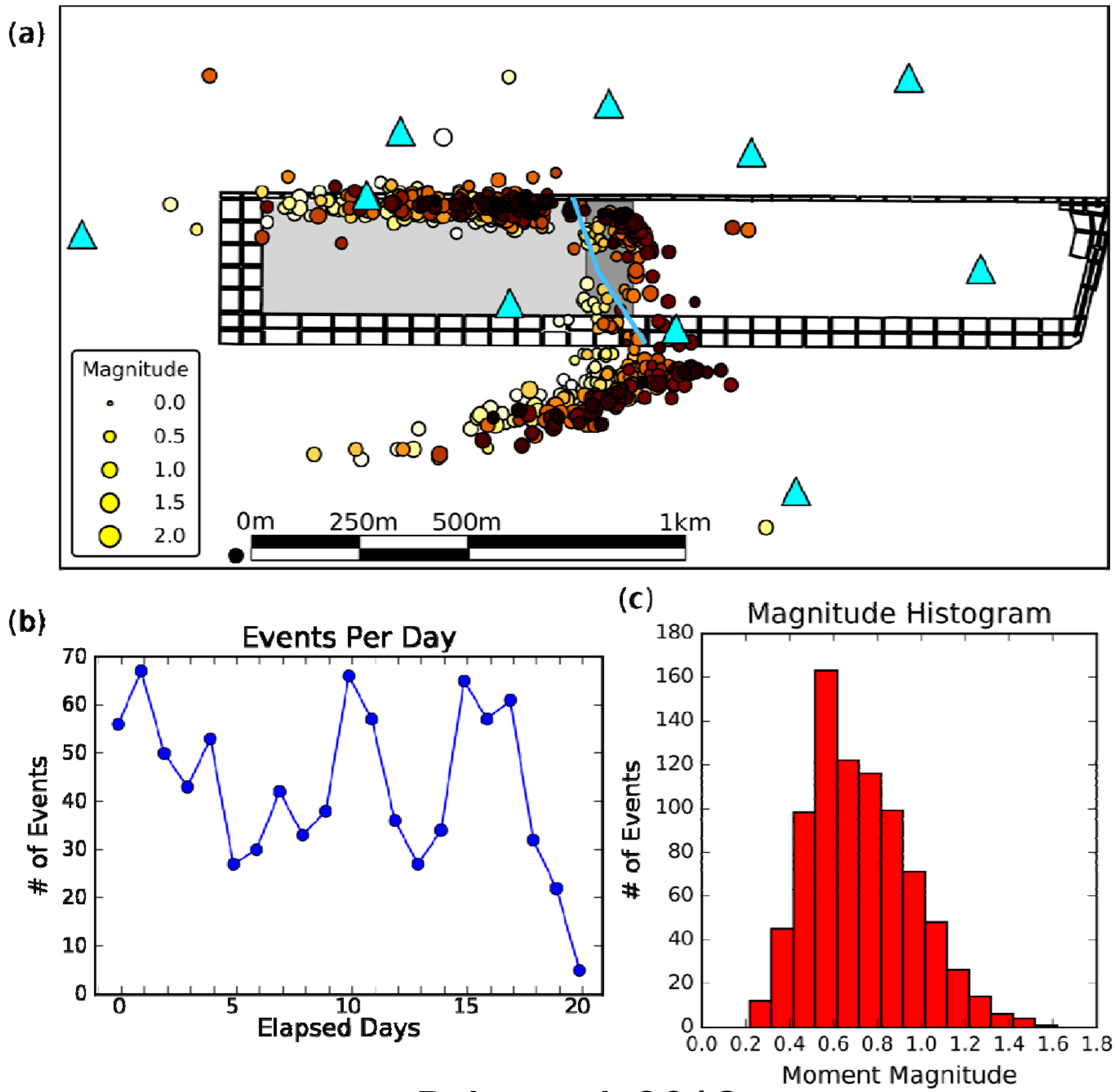


Monitoring Strategies
Temporary deployments

- Can be used to survey/document seismicity with little commitment
- Flexible deployments
- Real-time data is difficult
- Low cost

Fairfield Nodal Zland 3C

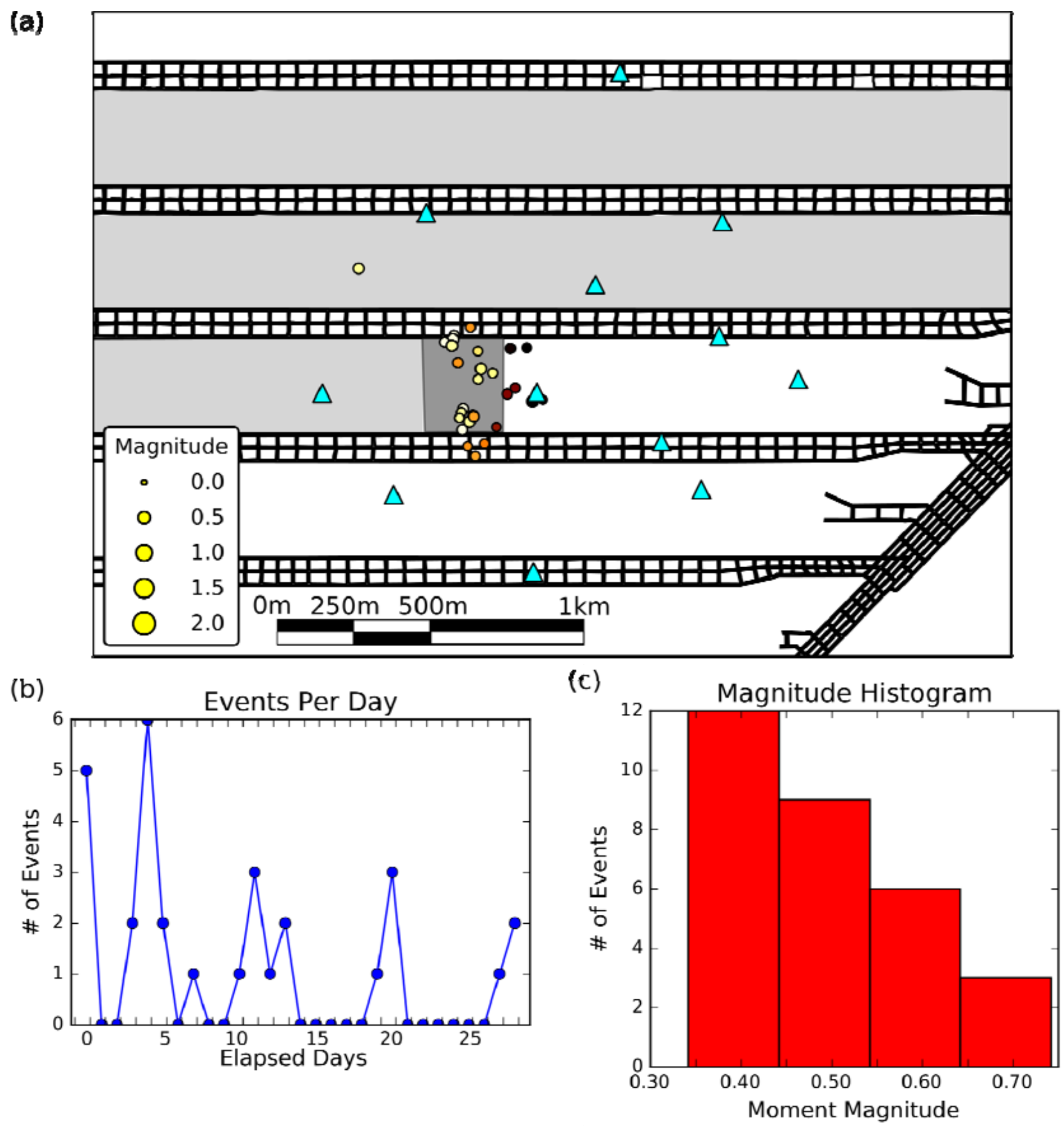
Monitoring Strategies
Temporary deployments



Boltz et al. 2018

Monitoring Strategies

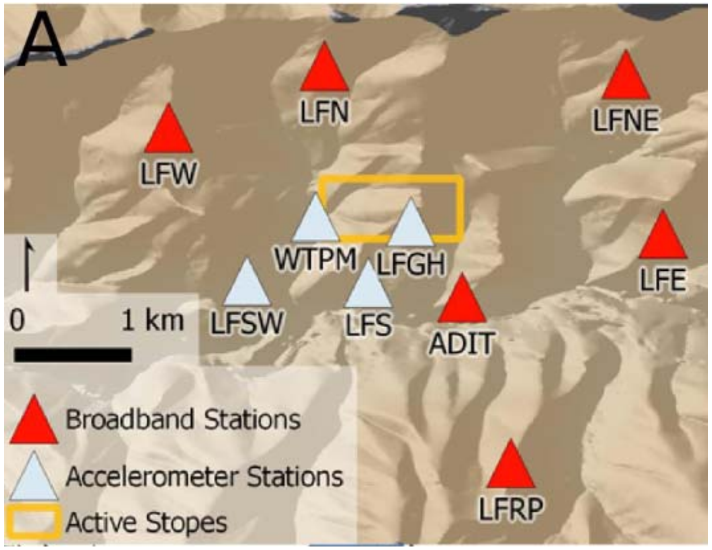
Temporary deployments

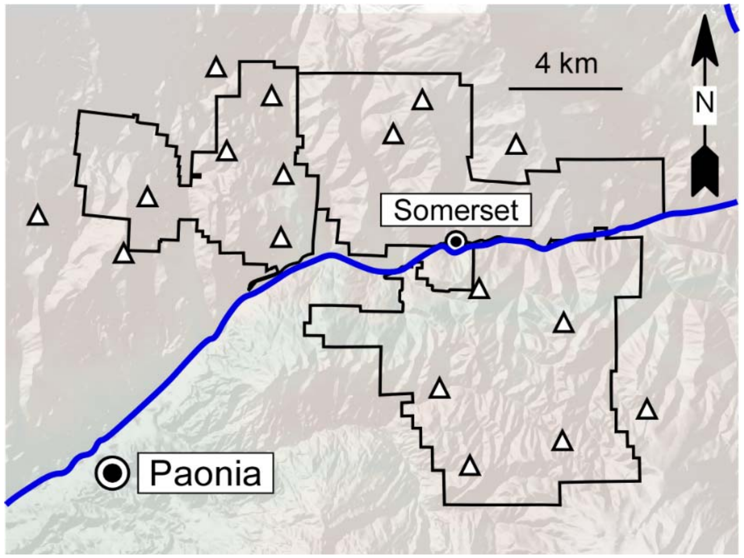


Boltz et al. 2018

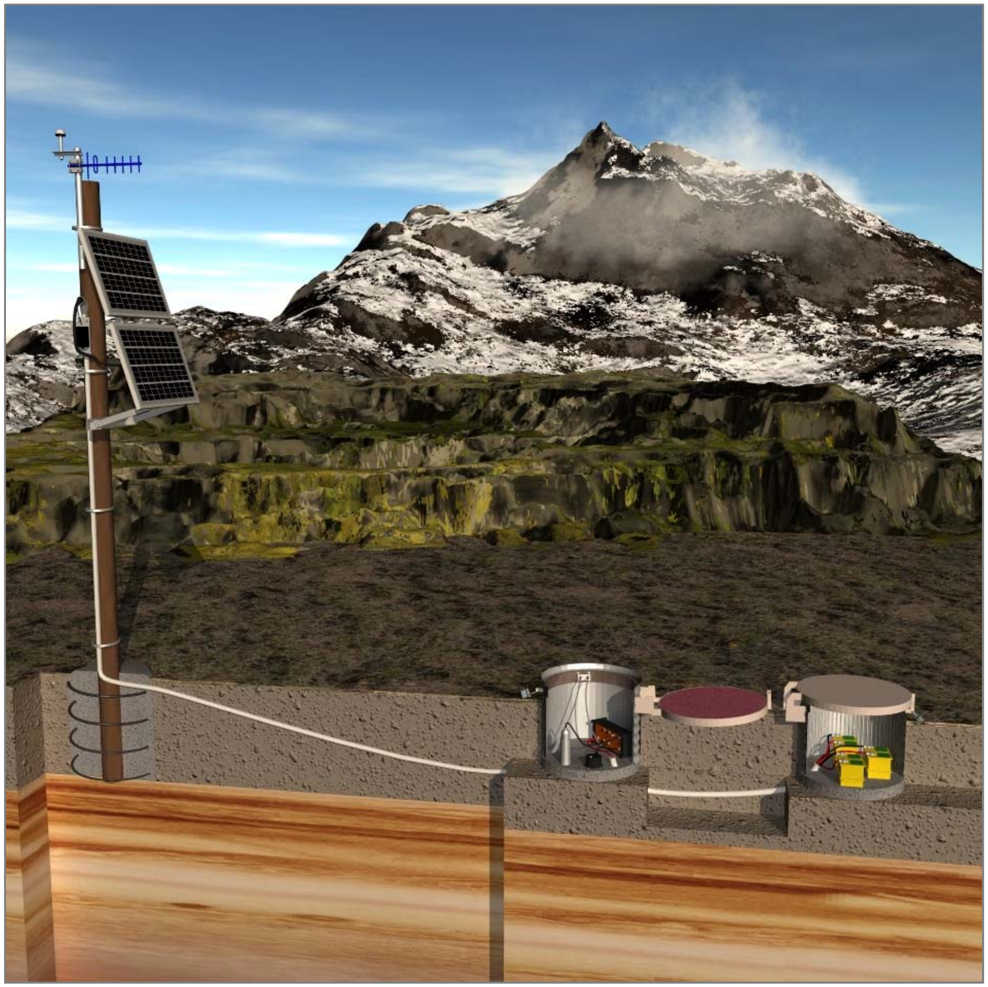
Monitoring Strategies
Mine/district wide networks

- Multiple permanent stations above/around the mining areas
- Can include underground stations
- Real time data
- Minimal interruptions
- Medium cost



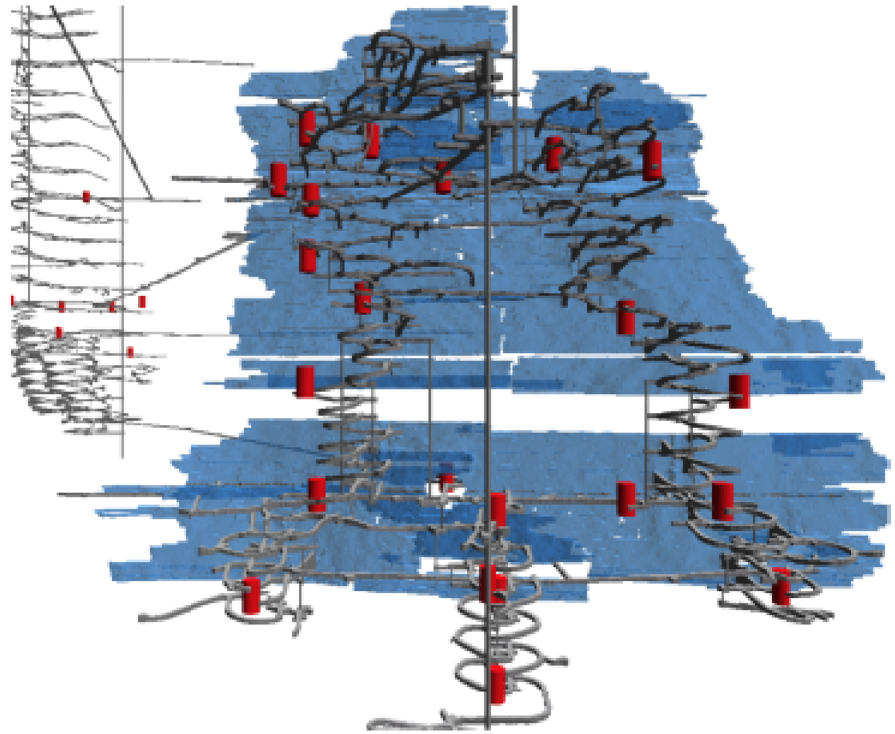


Monitoring Strategies
Mine/district wide networks



Monitoring Strategies
In-mine microseismic networks

- Produces the highest quality data
- Often needed for rockburst management
- Station placement limited by workings or drilling
- Can be “too close” to large events
- Highest cost



Open-Source Software

Obspy – Process/visualize/download data

Seiscomp3 – Data acquisition and processing

Earthworm – Data acquisition and processing

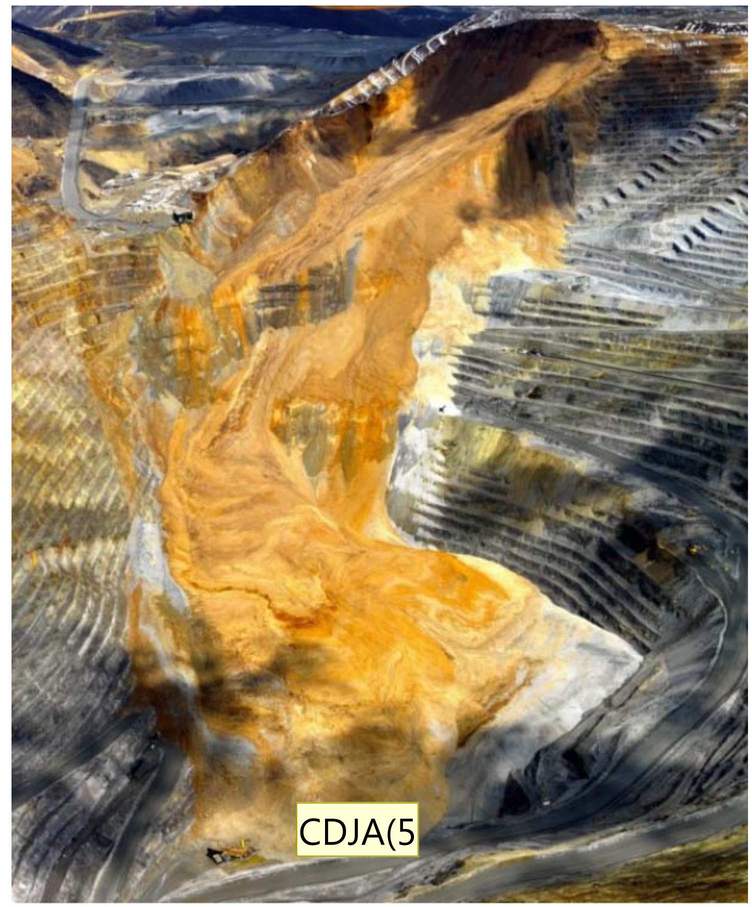
SWARM – Real-time seismic data display

Open-Source Software
Downloading regional data

Getting station data

The following code block shows how you can query and download avaliable station data from IRIS, which stores most public seismic data collected in the US.

In [1]:
```
# import needed modules
import obspy
from obspy.clients.fdsn import Client

# define spatial extents variables
latitude = 40.53829 # use Bingham Canyon mine as an example
longitude = -112.149506
distance = .15  # distance in degrees from point (about 1 degree / 111 km )

# initialize a connection with the IRIS datacenter
client = Client('IRIS')

# define duration for which the stations should have been operational
starttime = obspy.UTCDateTime('2013-04-01')
endtime = obspy.UTCDateTime('2013-05-01')

# get data
inventory = client.get_stations(latitude=latitude, longitude=longitude,
                                maxradius=distance, starttime=starttime,
                                endtime=endtime, level='channel')

# a list of stations
stations = inventory.get_contents()['stations']

# print number of stations found
```



https://github.com/niosh-mining/chambers/mine_design_2018

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CDJA(5 Chambers, Derrick James Allen (CDC/NIOSH/SMRD), 4/16/2018

References

Research

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Swanson, P., Boltz, M. S., & Chambers, D. (2016). Seismic monitoring strategies for deep longwall coal mines. Accessible online at https://www.cdc.gov/niosh/mining/UserFiles/works/pdfs/mcmsw.pdf.

Van Dyke, M. A., Su, W. H., & Wickline, J. (2017). Evaluation of seismic potential in a longwall mine with massive sandstone roof under deep overburden. *International Journal of Mining Science and Technology*.

References

Hardware

Raspberry shake: https://raspberryshake.org/

PSN (single station option): http://psn.quake.net/

Zland portable geophones: http://fairfieldnodal.com/equipment/zland

Software

Obspy: https://github.com/obspy/obspy/wiki

Earthworm: http://www.earthwormcentral.org/

Seiscomp3: http://www.seiscomp3.org/

SWARM: https://volcanoes.usgs.gov/software/swarm/download.php

Thank you

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