A Microseismic Survey of the Northern Colorado Front Range

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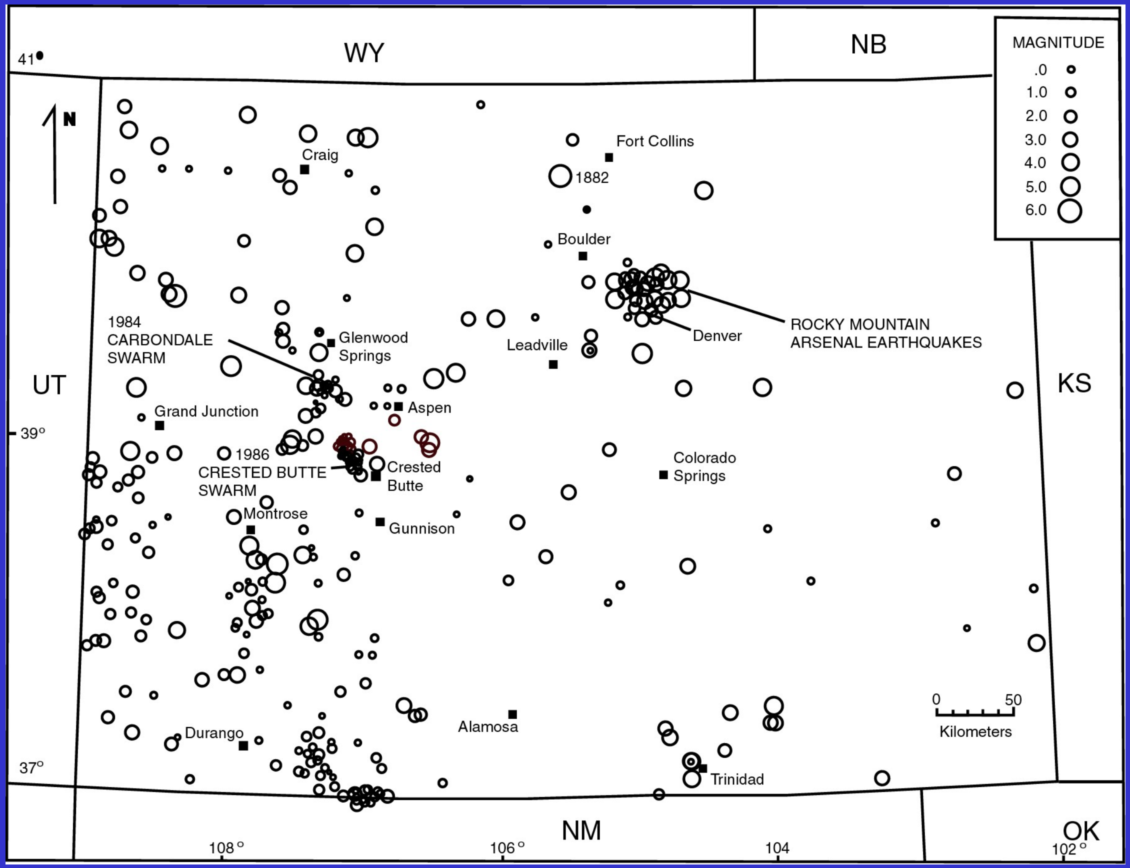
Introduction

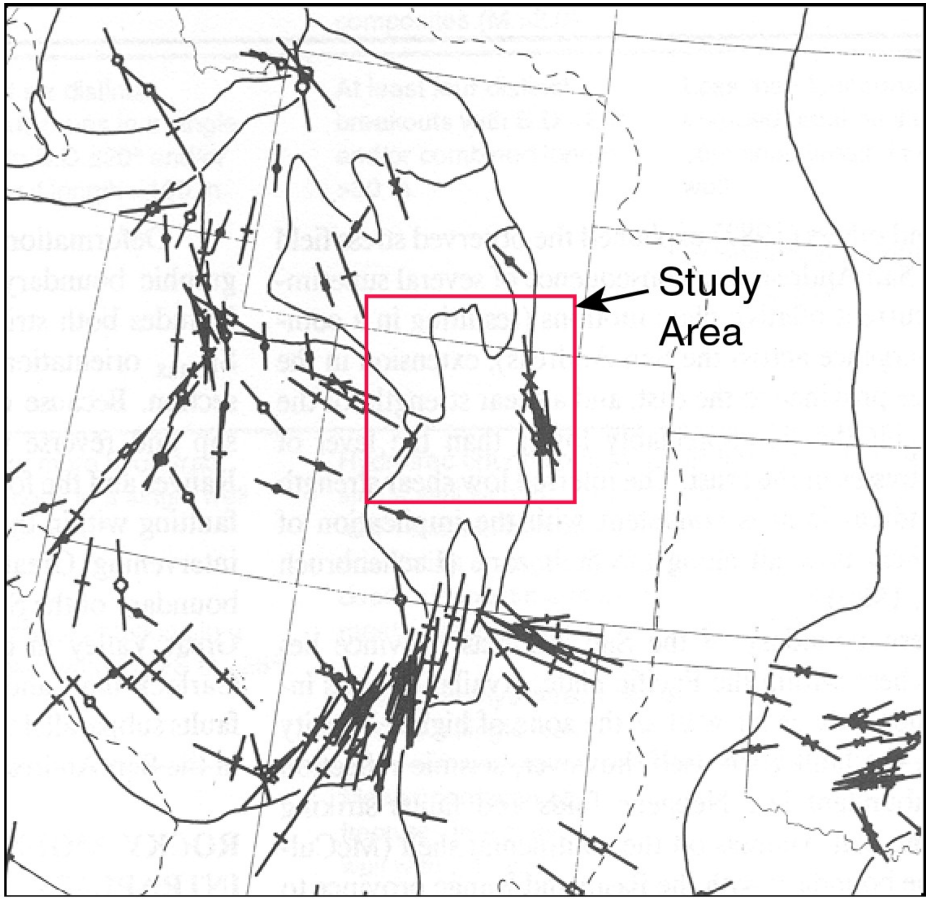
- I deployed multiple seismic stations to monitor microearthquake activity in the northern Front Range.
- Purpose: to more accurately depict the amount of microseismicity and the associated seismic hazard.
- Possibility of erroneous determination of seismic hazard in the past

What We Know

Historical seismicity in Colorado from 1870-1992 (After Bott and Wong 1995)

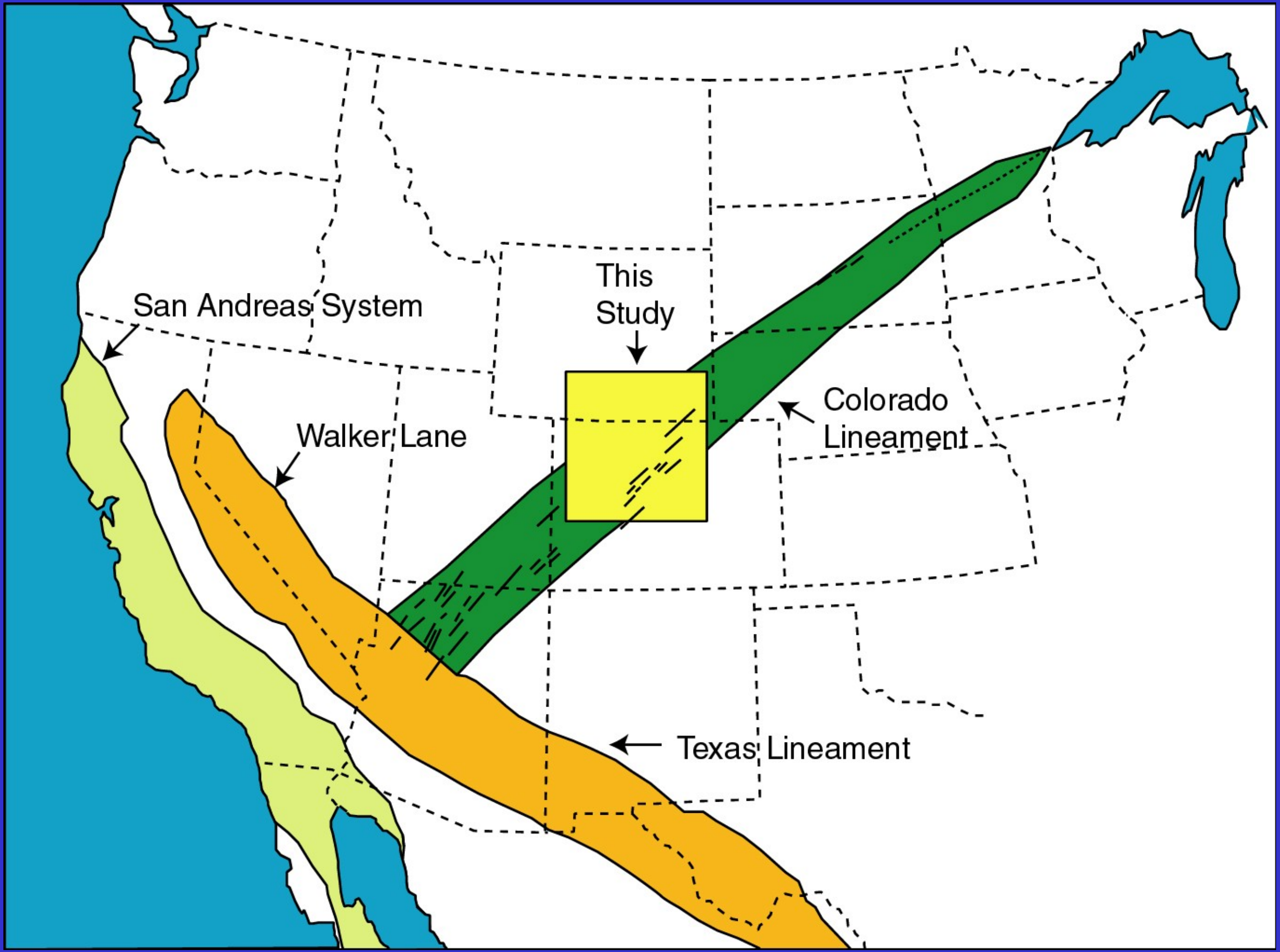


Stress Regime in Colorado (Zoback and Zoback, 1989) and The Study Area



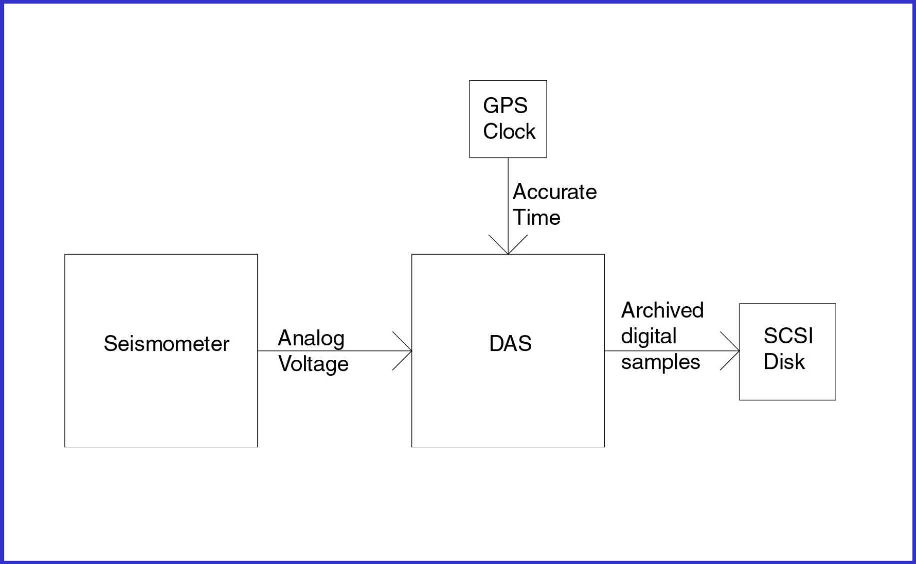
- Maximum horizontal compressive stress axis trending north to northwest
- Colorado seems to be extending perpendicular to this axis, but little data exists for north-central Colorado.

The Colorado Lineament



Background Knowledge

How a Seismic station works



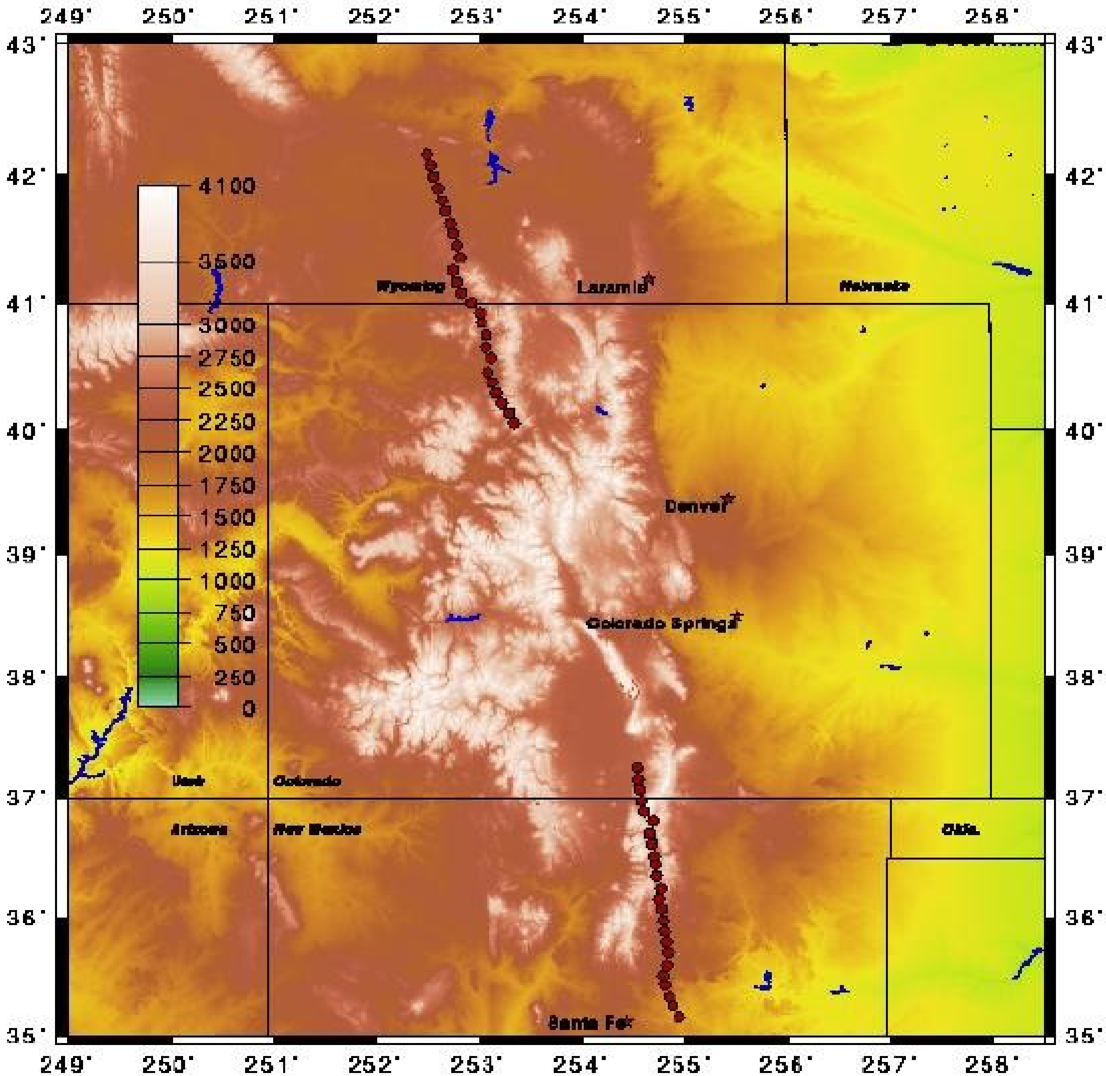
- Seismometer (Sensor): spring-mass/magnet system moving within a coil of wire
- DAS samples voltage stream and digitizes analog samples
- GPS provides clock information
- External SCSI disk archives the digitized data

Short-period and Broadband Seismometers: Differences

- Two types of sensors: broadband and short-period.
  - Broadband sensors
    - Record ground displacement
    - Can record earthquake waves with periods from 0.02 to 110 seconds
    - Records seismic energy from any distance
    - Exceptionally sensitive sensor
  - Short-period sensors
    - Record ground velocity
    - Most effectively records earthquake waves with periods near 0.5 seconds
    - Only records local seismic energy (originating near the sensor)
    - Does not record waves with periods outside of a narrow range

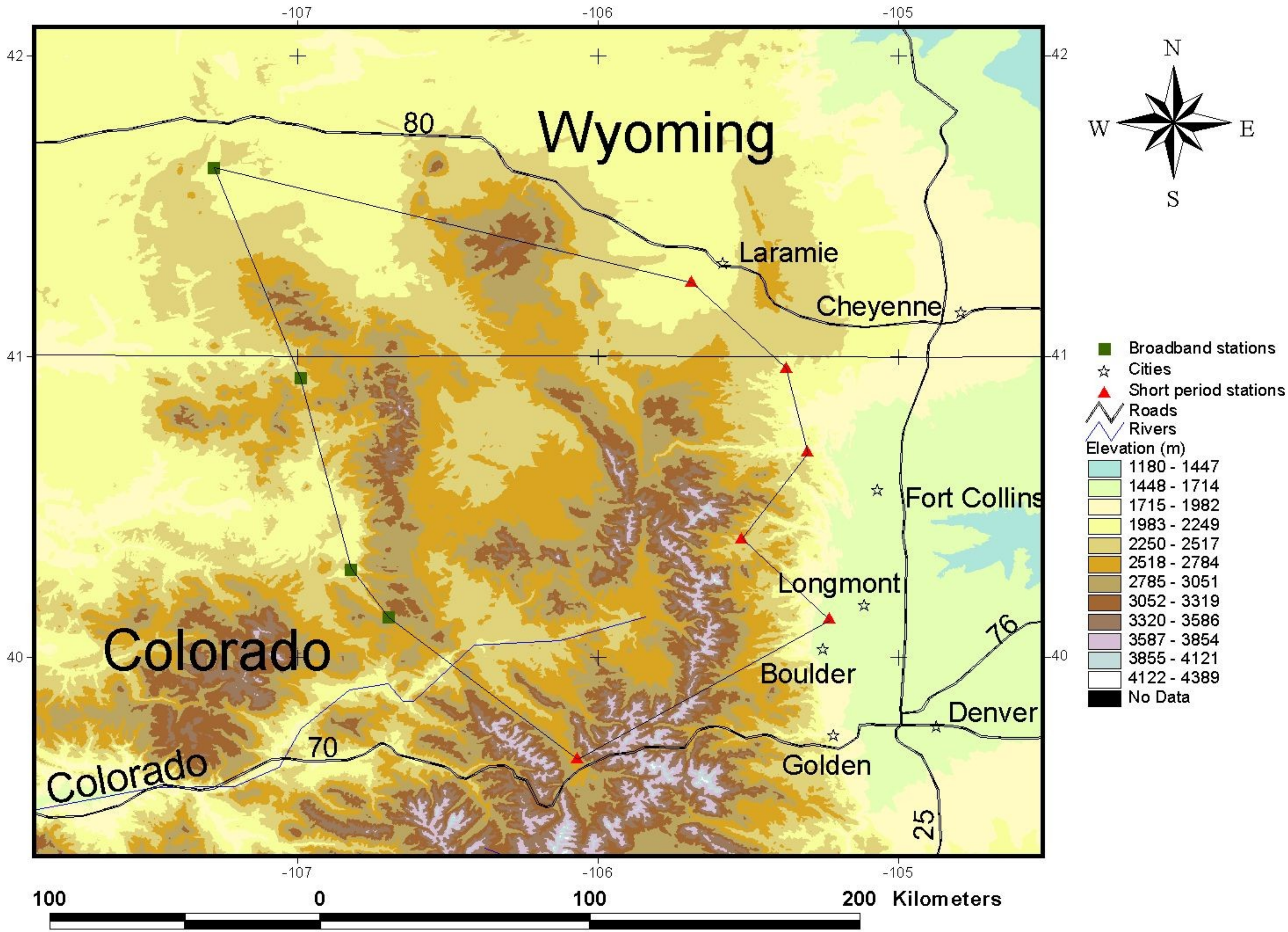
Deployment

CDROM Deployment (June 5th - 12th, 1999)



Constructing a Vault and Situating the Sensor

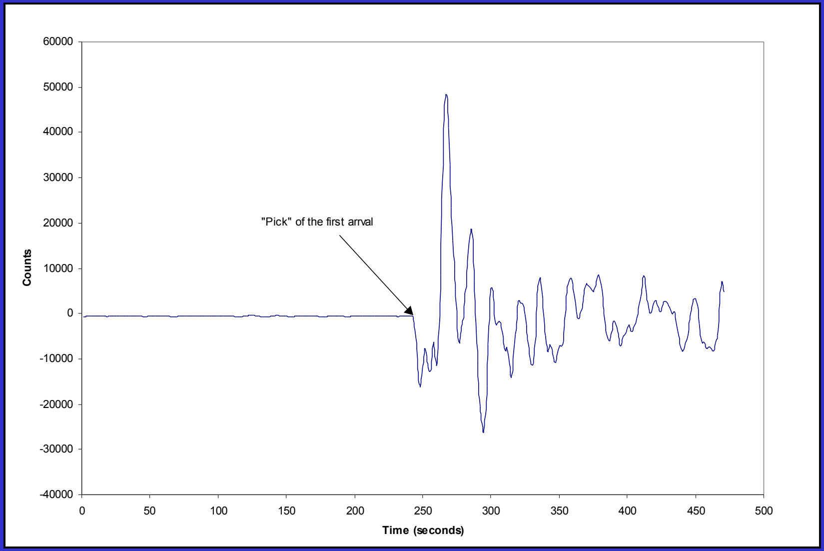
L-22 Deployment (Short-period seismometers; June 14th – 17th, 1999)



-107
-106
-105
42
41
40
80
Wyoming
Laramie
Cheyenne
Fort Collins
Longmont
Boulder
Denver
Golden
Colorado
70
Colorado
76
25
N
W
E
S
Broadband stations
Cities
Short period stations
Roads
Rivers
Elevation (m)
1180 - 1447
1448 - 1714
1715 - 1982
1983 - 2249
2250 - 2517
2518 - 2784
2785 - 3051
3052 - 3319
3320 - 3586
3587 - 3854
3855 - 4121
4122 - 4389
No Data
100
0
100
200 Kilometers

Processing

Processing Digital Seismograms

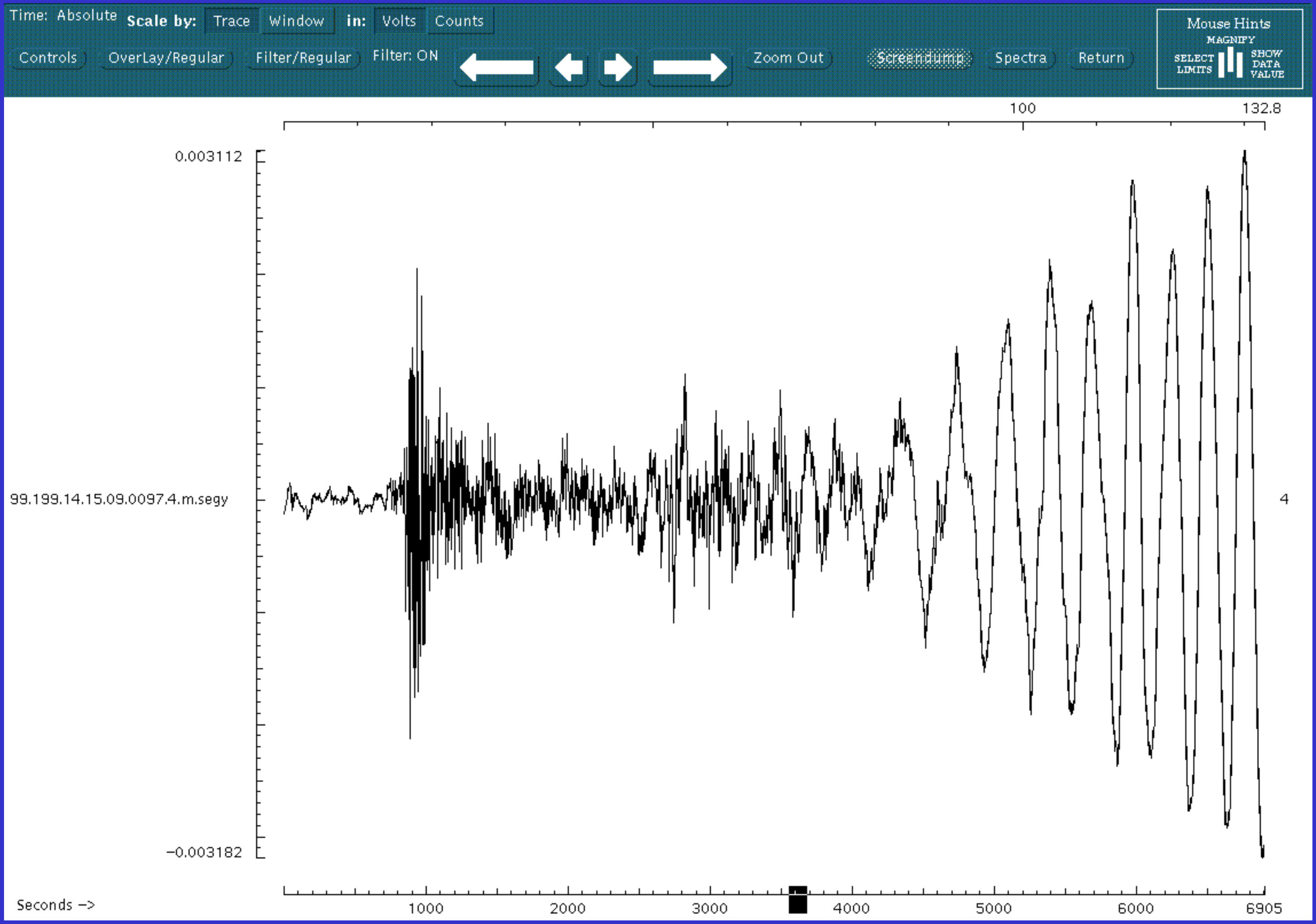


P-Wave velocity (km/s)	Depth to top of layer (km)
5.70	0.0
6.00	8.3
6.70	27.0
7.90	49.0

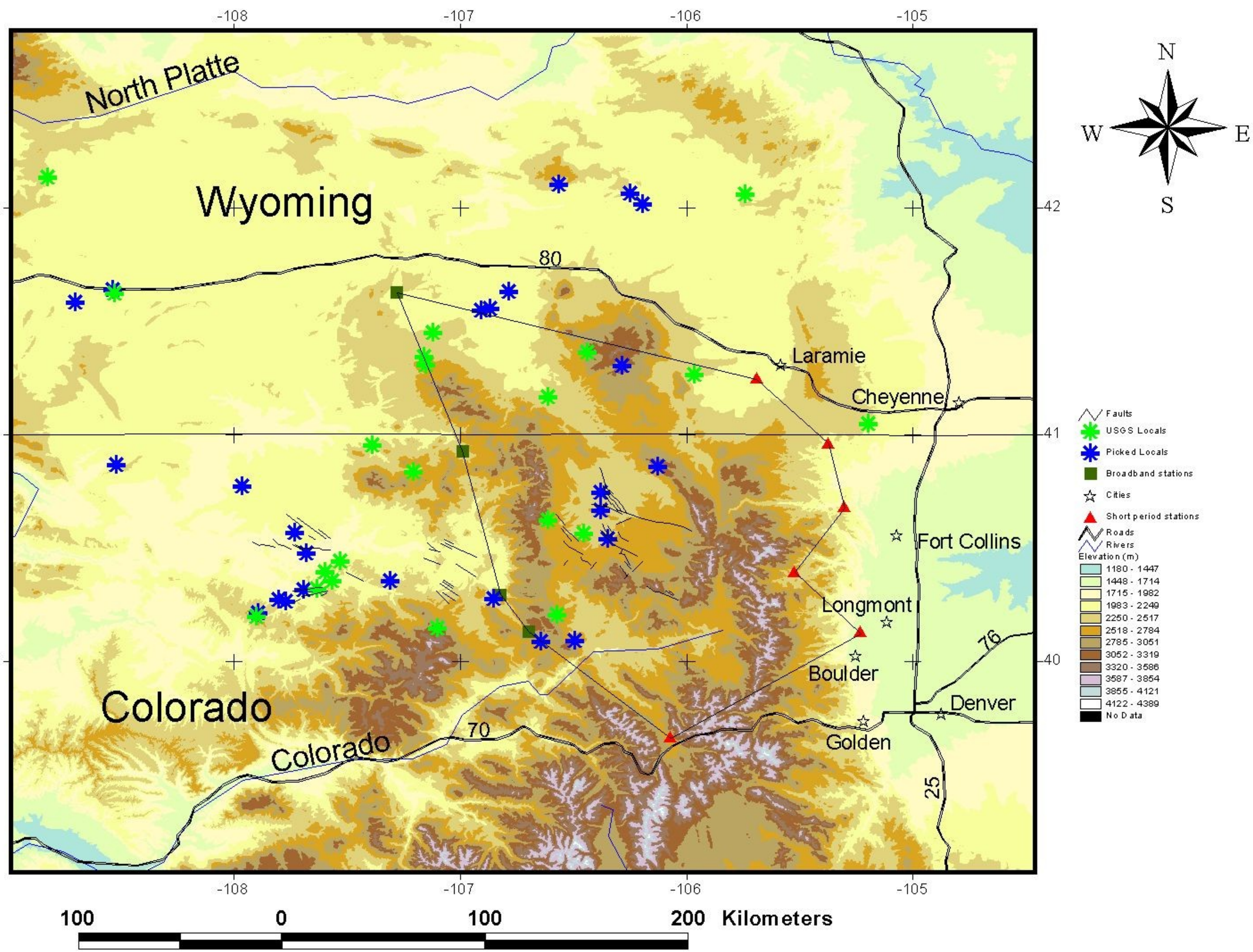
Crustal velocity model appropriate to west/central Colorado. After Bott (1991)

- Convert "raw" DAS data to SEG-Y or mSEED format
- Search 34 days (~24,000 files or 8 Gb) of continuous data using *pql* for any impulsiveness across all or most stations.
- Rank "events" by quality of seismograms
- "Pick" the first arrival of the event
- Locate the highest quality events with HYPOINVERSE using P-wave arrival times from each station, S-wave arrivals from one station if possible, and the appropriate crustal model

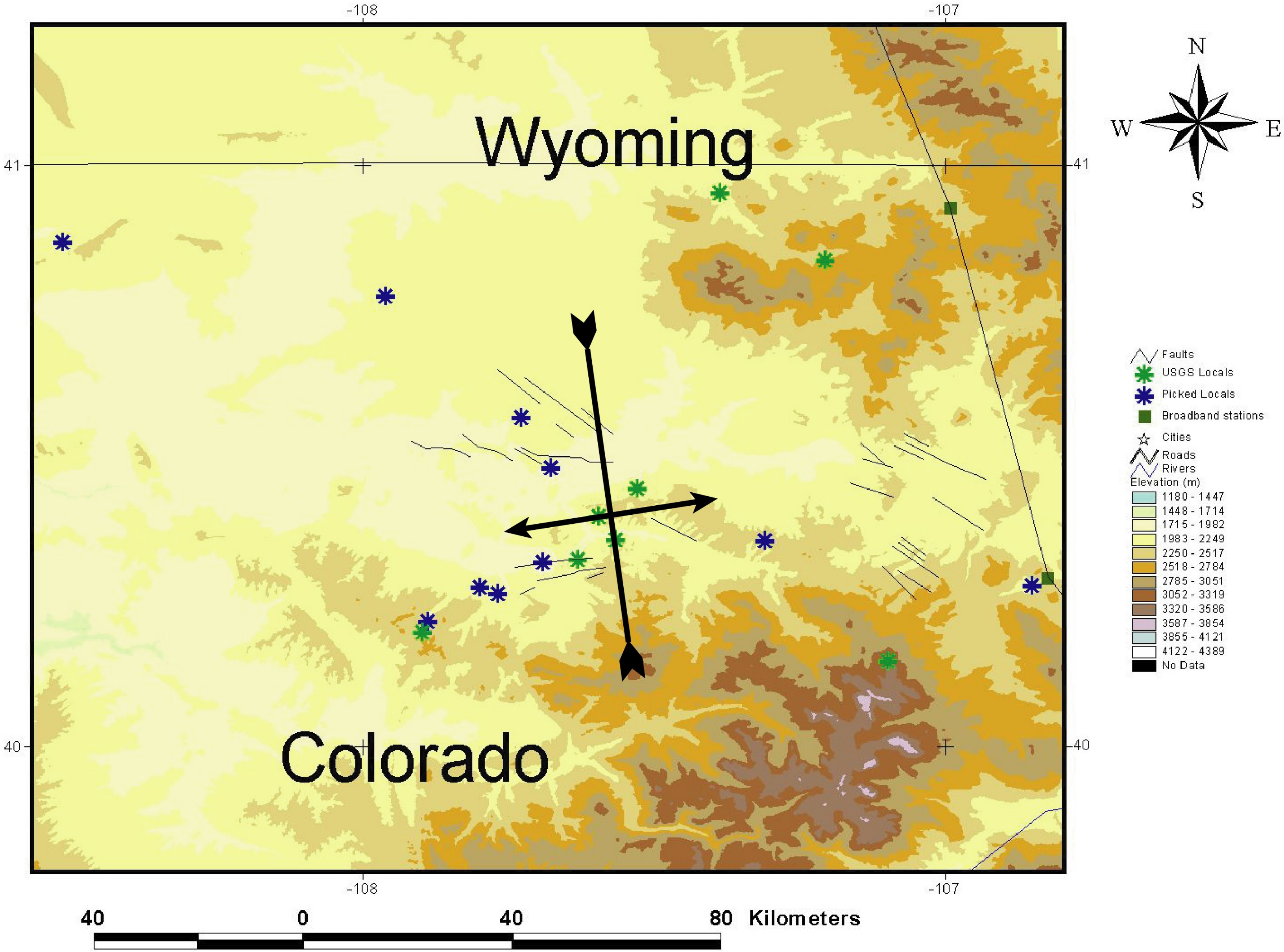
Sample Seismic Recording



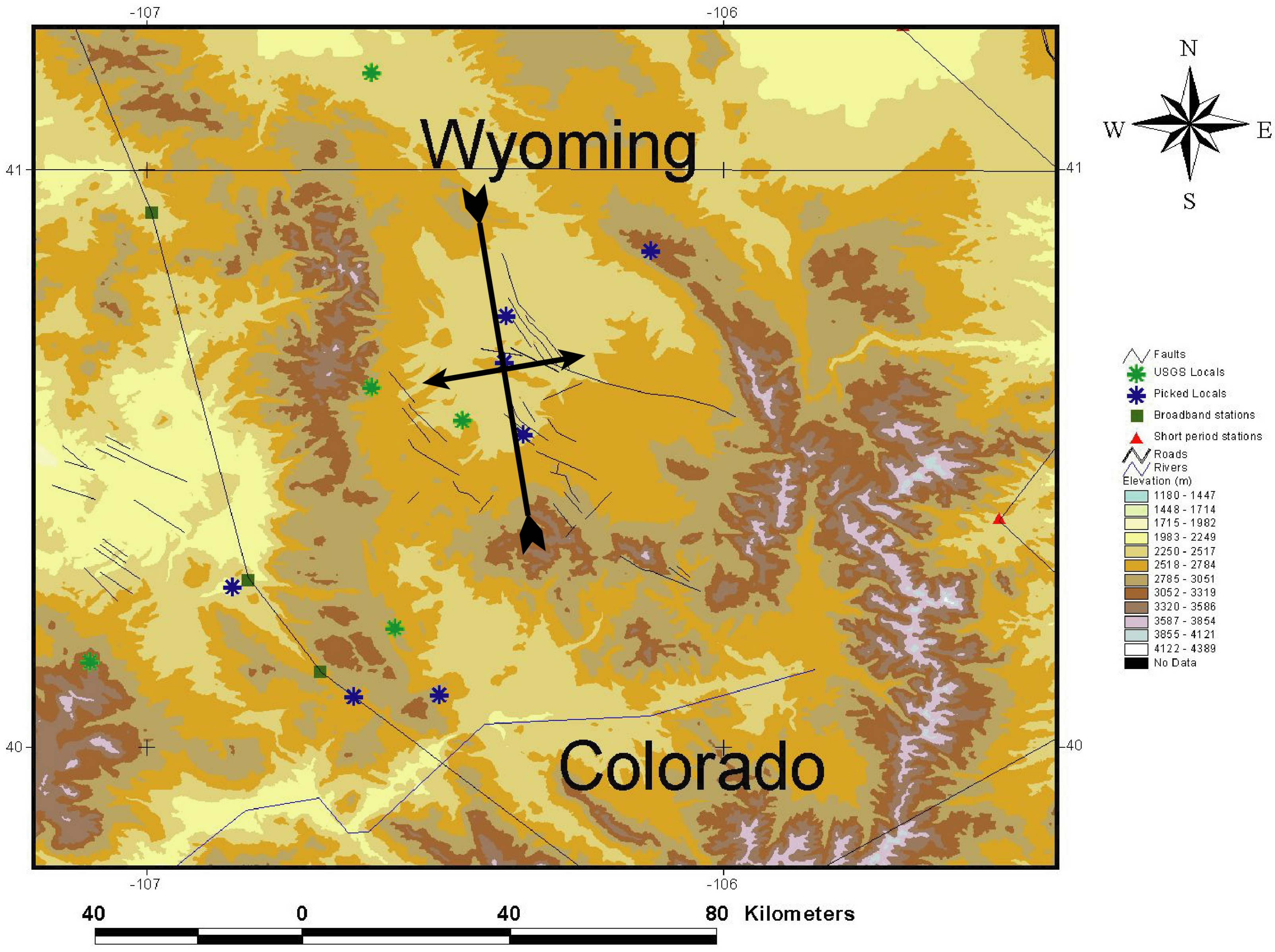
Results



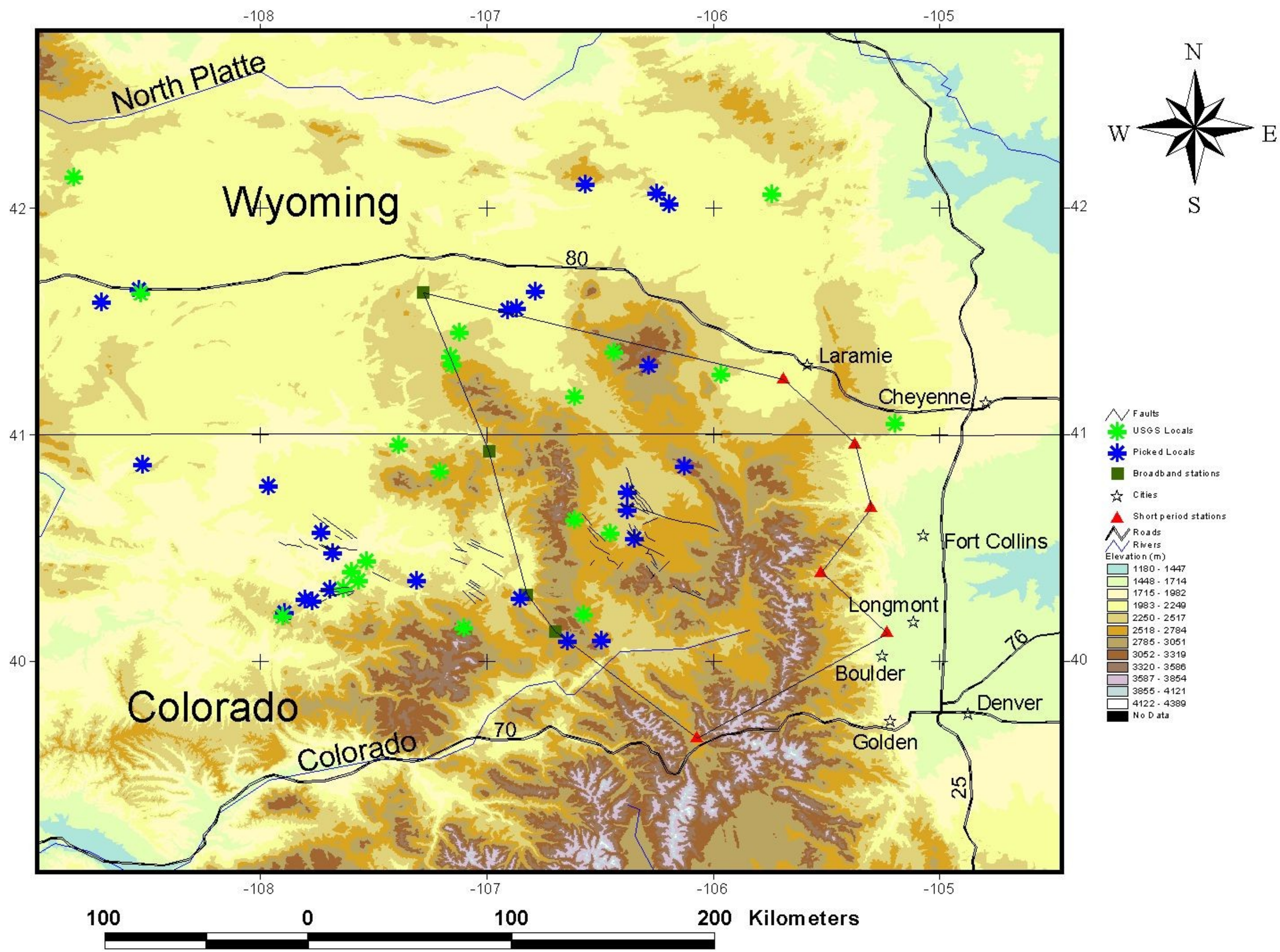
All locations were derived by Godchaux using HYPOINVERSE. The "USGS" locals were also located by the USGS, but Godchaux had tighter control on these locations (a closely spaced array with more stations)



Earthquakes located with faults from Tweto (1979). Maximum and minimum compressive stress axes for Denver area are plotted from Zoback and Zoback (1980)



Earthquakes located with faults from Tweto (1979). Maximum and minimum compressive stress axes are plotted from Zoback and Zoback (1989).



Two events are coincident and lie near Interstate highway 80. Highway construction blasting as the cause of these events is being investigated.

Conclusions

- Earthquake locations
  - All earthquakes were located by Godchaux.
  - Events which were located by both the USGS and Godchaux generally plot far away from one another. Reasons include:
    - Number of stations in array
    - Distance apart of stations in an array
- Linear Trends of Earthquakes
  - These trends plot on known faults or in known fault zones.
  - Conjugate pattern suggests that Zoback and Zoback (1989) stress determinations for slightly east of the northern Front Range are viable for this study area also. These patterns also suggest correlation with the Colorado Lineament.

Conclusions (cont.)

- Magnitude estimates
  - A maximum magnitude calculated by the USGS for an event located by both Godchaux and the USGS was 3.5 (M_L).
  - Over twenty events were located by both, hence magnitude calculations by Godchaux will be verified against the USGS calculations.
  - Subsequently, magnitude calculations will be done on the remaining local events.

What is left to be done?

- Calculating duration magnitudes (M_{dur}) on all events
- Creating a B-value plot (magnitude v. earthquake occurrence), to determine a recurrence interval for large earthquakes in the area