Hypocentre location and spatial distribution of microseisms: A mountain case

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Outline

- **Motivation and Turtle Mtn. background**
- **Seismic array and data processing**
- **Microseism distribution & geologic significance**
- **Conclusions & Acknowledgements**

Permanent monitoring

- Mountain case to test oilfield-related technology
- Develop event detection algorithms (also for hydro-fracing, production-induced seismicity)
- Develop hypocentre location codes and procedures
- Check with real data
- Interpret geologic case

Data and data processing

- Data: Old Turtle Mountain seismic array

  six-station (FRANK and FARM) data (Nov.,1986 - Jun.,1996)
  three-station (FRANK array) data (Nov.,1986 - Dec.,1988)

- Velocity model: homogeneous, Vp = 4.7km/s, Vp/Vs=1.73

- Program: HYPOMH

- Phases: P, S

Hypocentre location concept

(HYPOMH – Matsuura & Hirata, Tokyo Univ.)

- Provide velocity model
- Give initial hypocentre location and origin time
- P & S ray trace to calculate traveltimes from hypocentre to stations
- Bayesian then least-squares minimization of traveltime residuals to estimate source location

Seismic monitoring efforts: Turtle Mtn.

- Earth Sciences Division of Alberta Environment

  Weichert and Horner,1981

  Jun.-Sept.,1981

  One single monitoring station

- Sciences Division of Alberta Environment

  Bingham, 1996

  Nov.,1986 – Jun., 1996 Low-frequency vertical geophones

  Six-station monitoring array on the eastern flank of Turtle Mountain

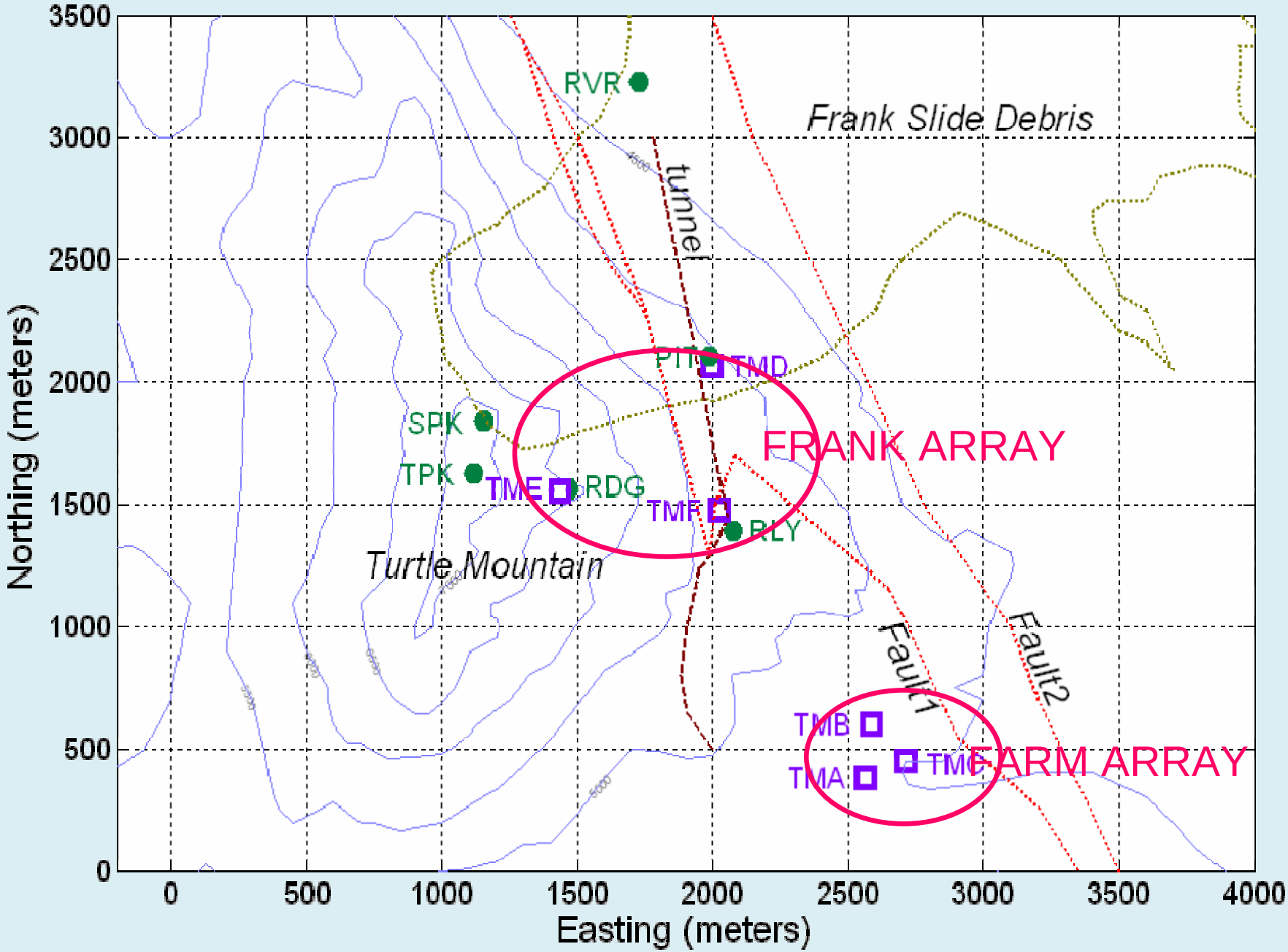
  Univ. of Calgary Applied Seismic Group

  Stewart et. al., 2004

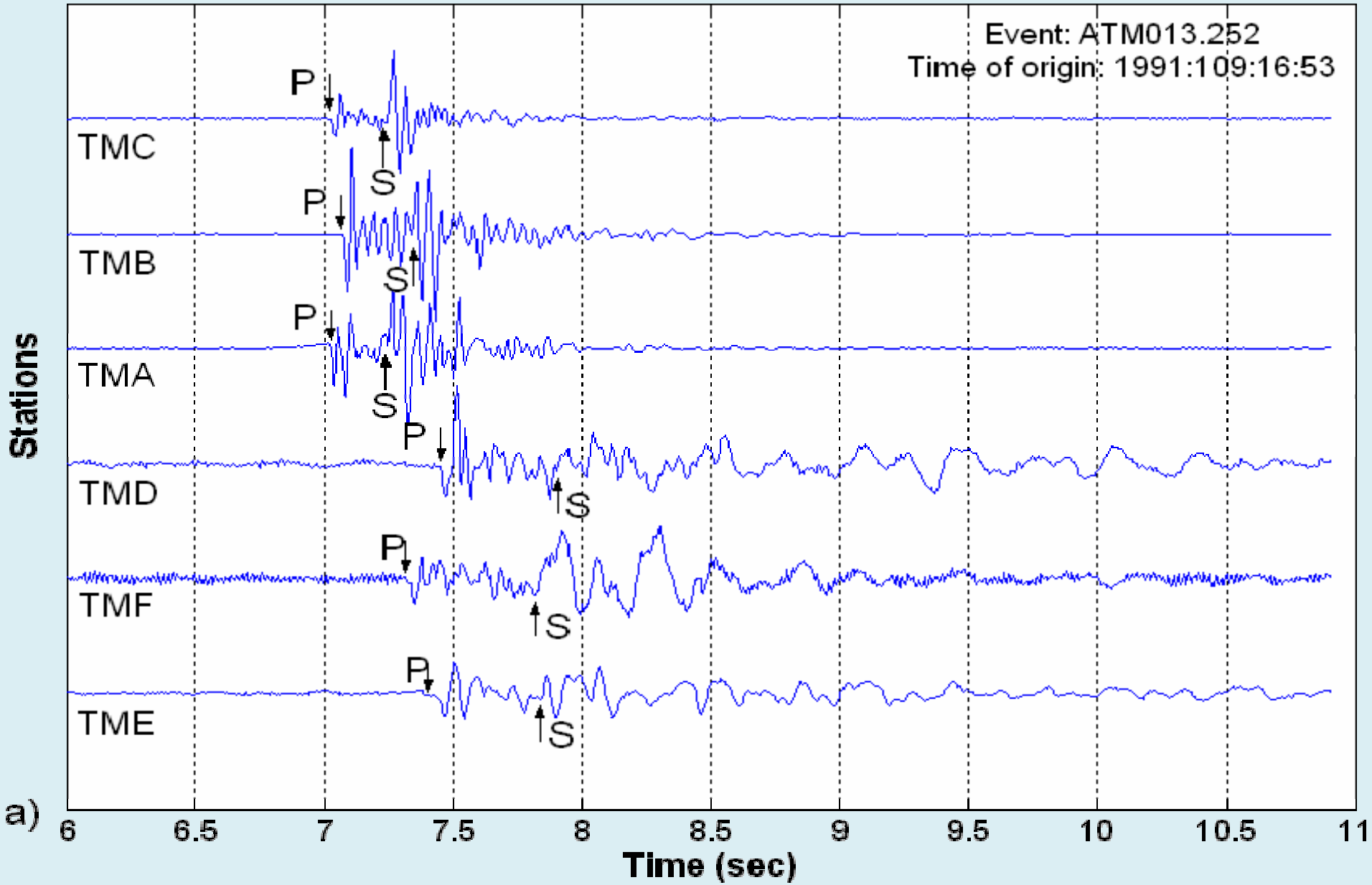
  From 2004 High-frequency 3C arrays

  Six-station monitoring array on the summit and eastern slope of Turtle Mountain

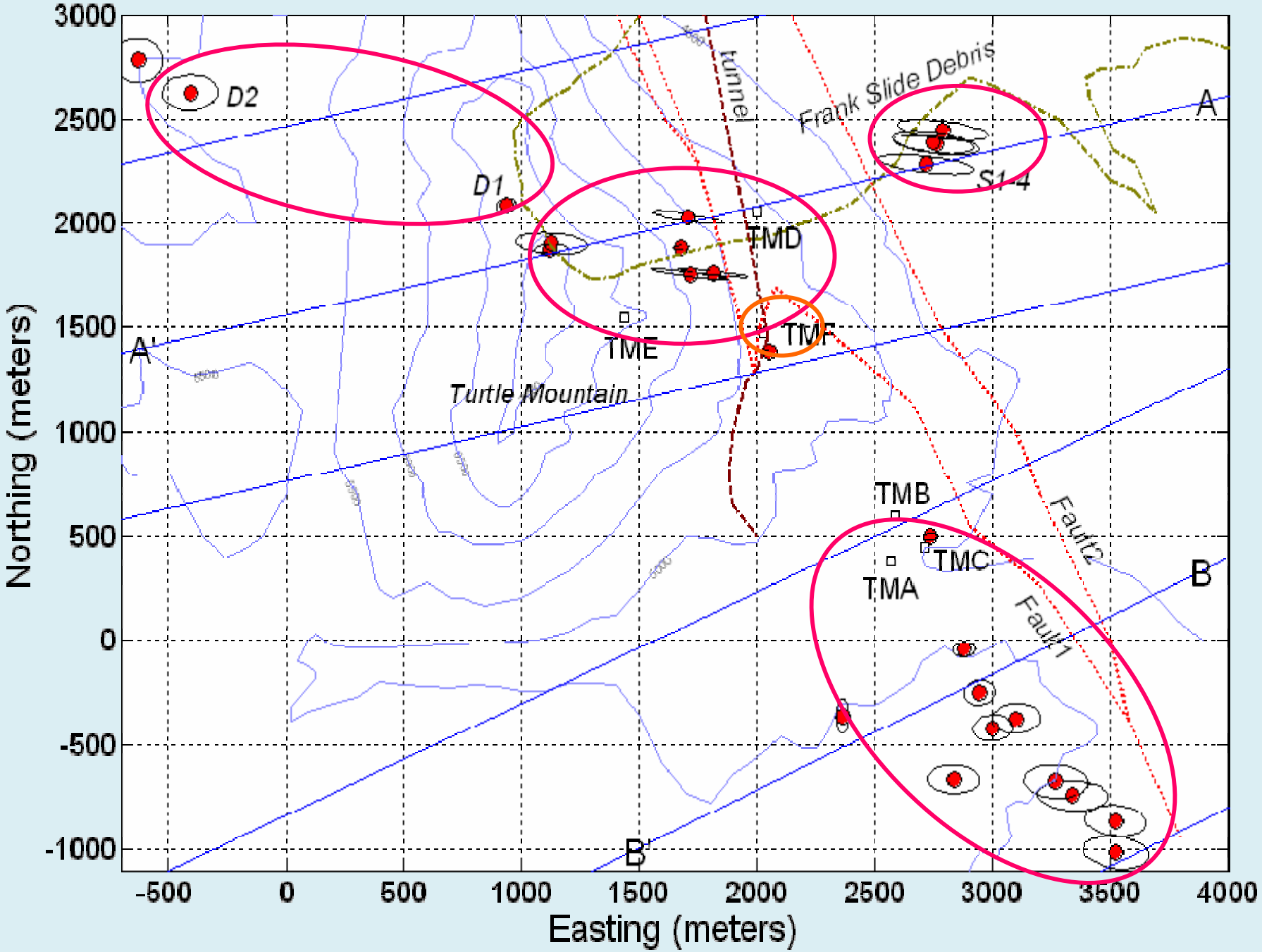
Old and New Turtle Mnt. Seismic Arrays



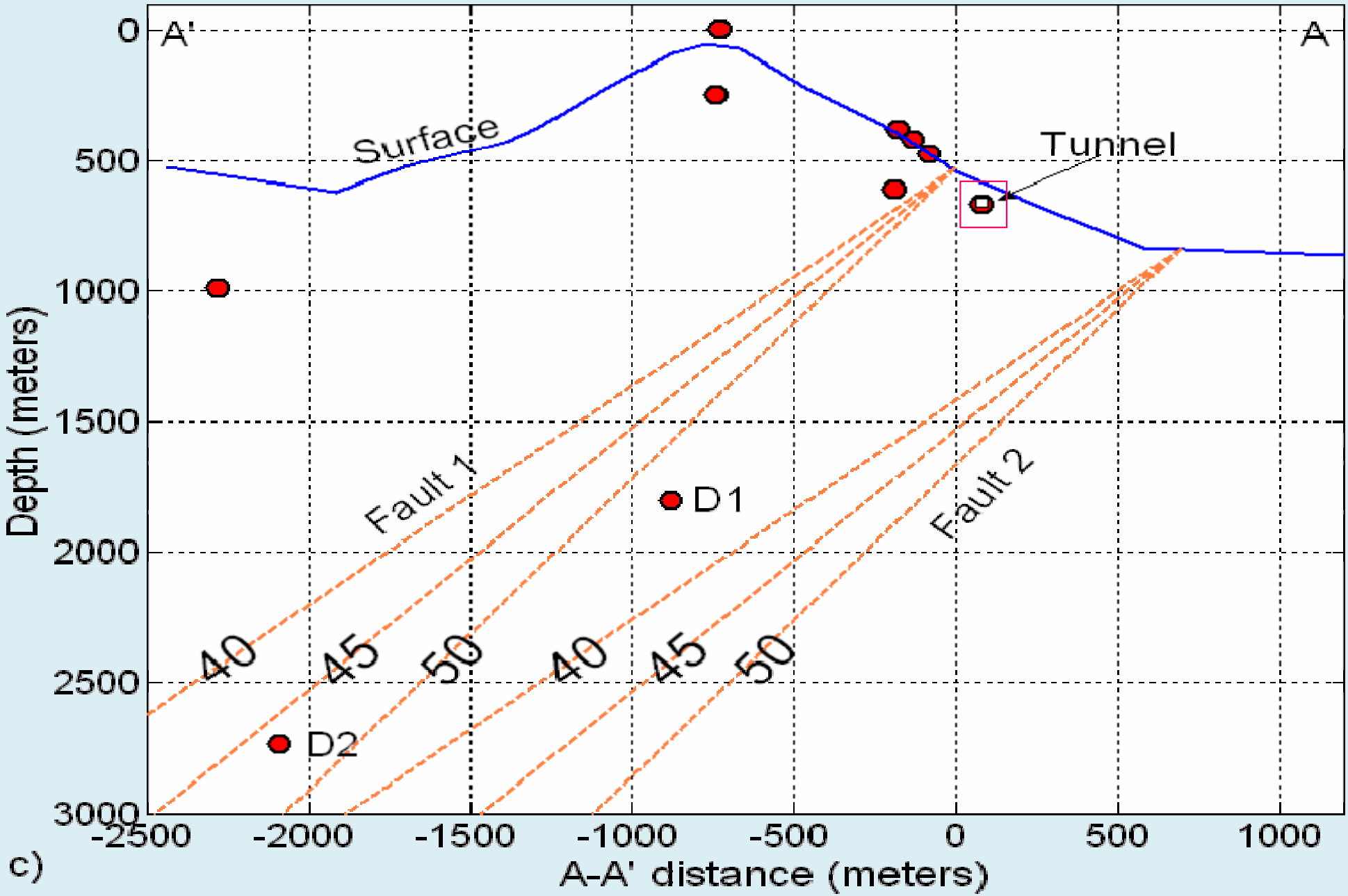
Seismogram recorded by six stations



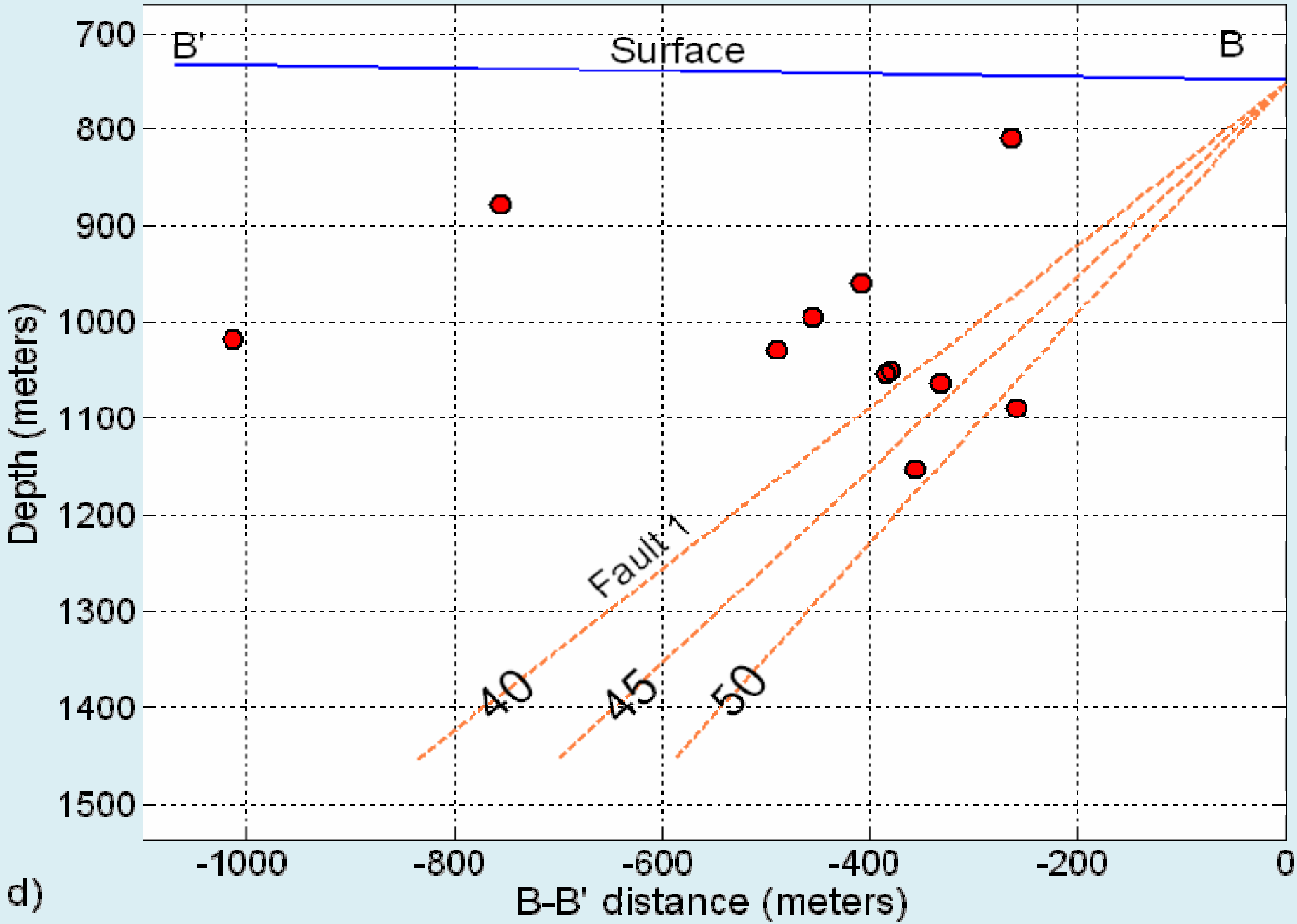
Events Located by both sub arrays



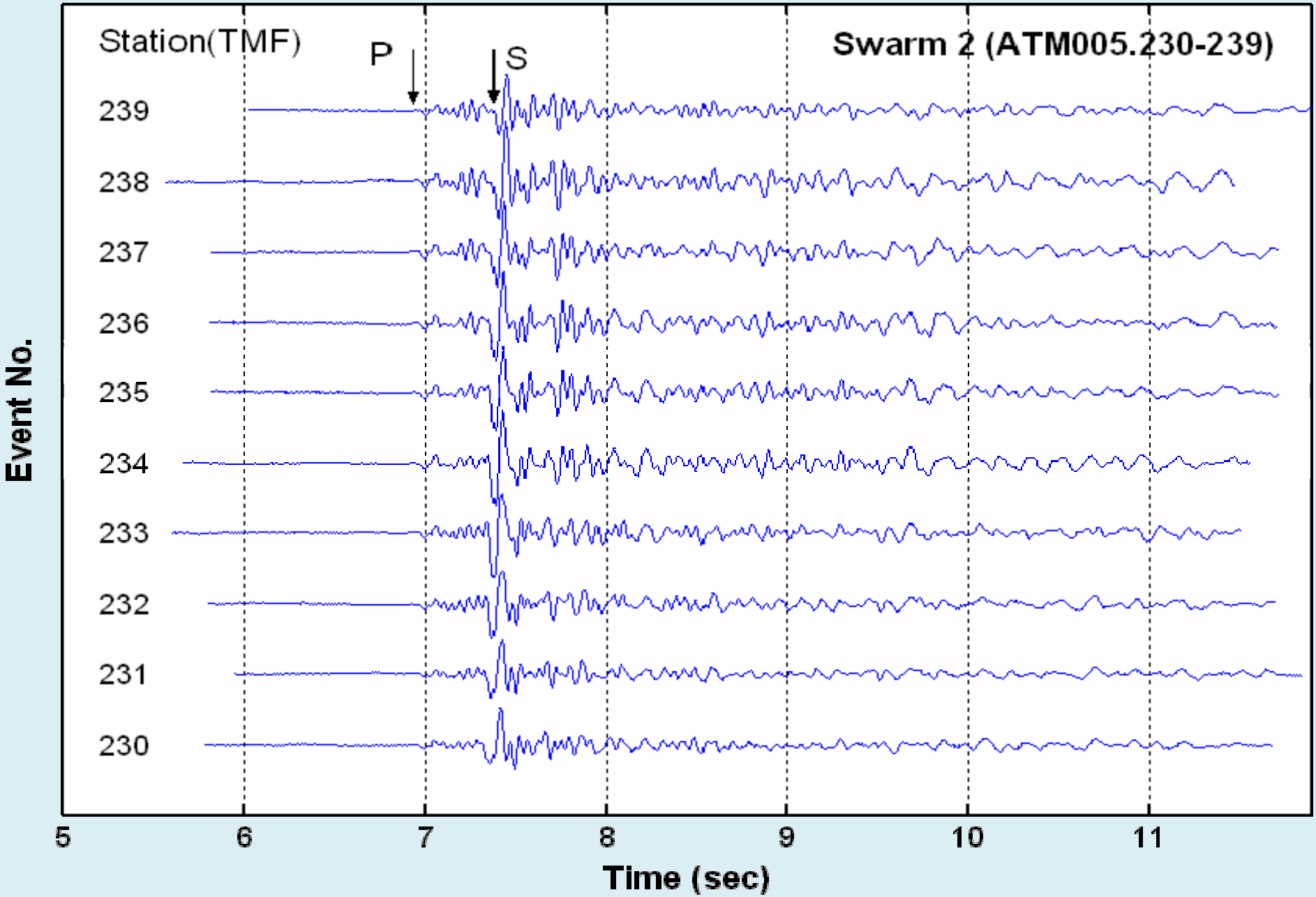
Cross section of A-A’



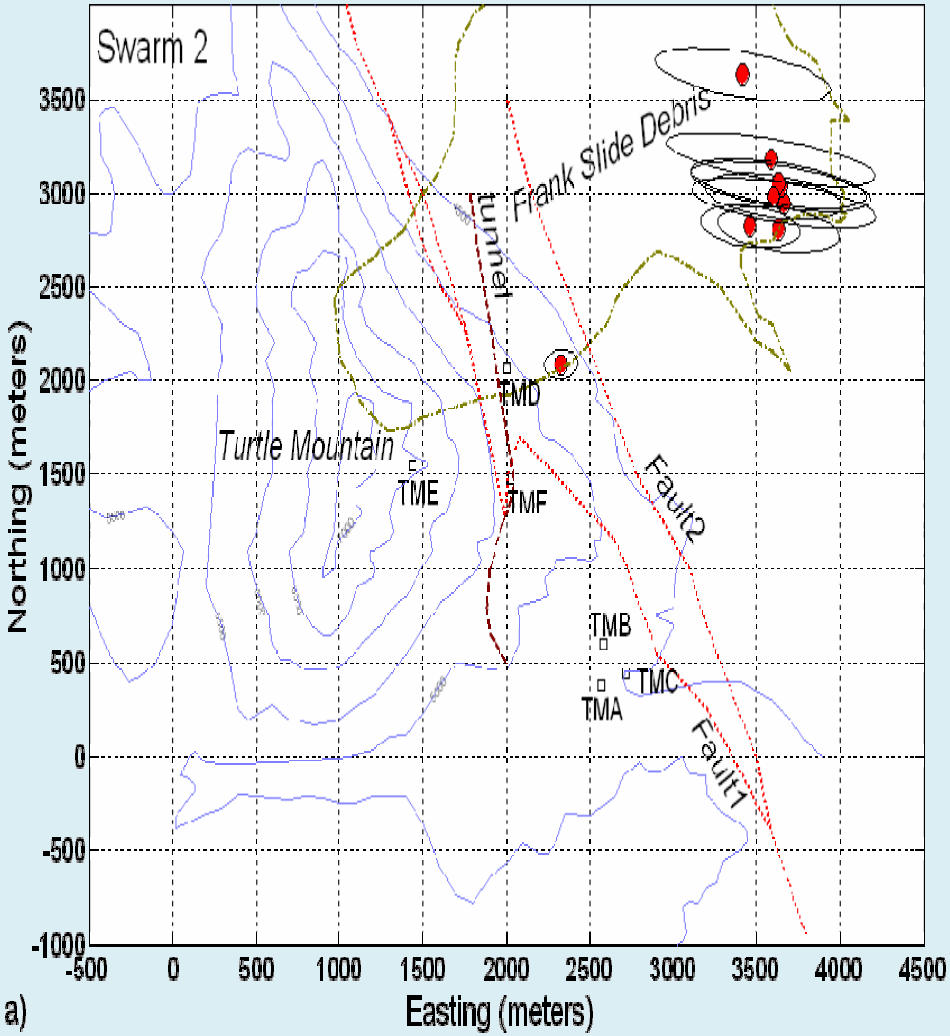
Cross section of B-B’

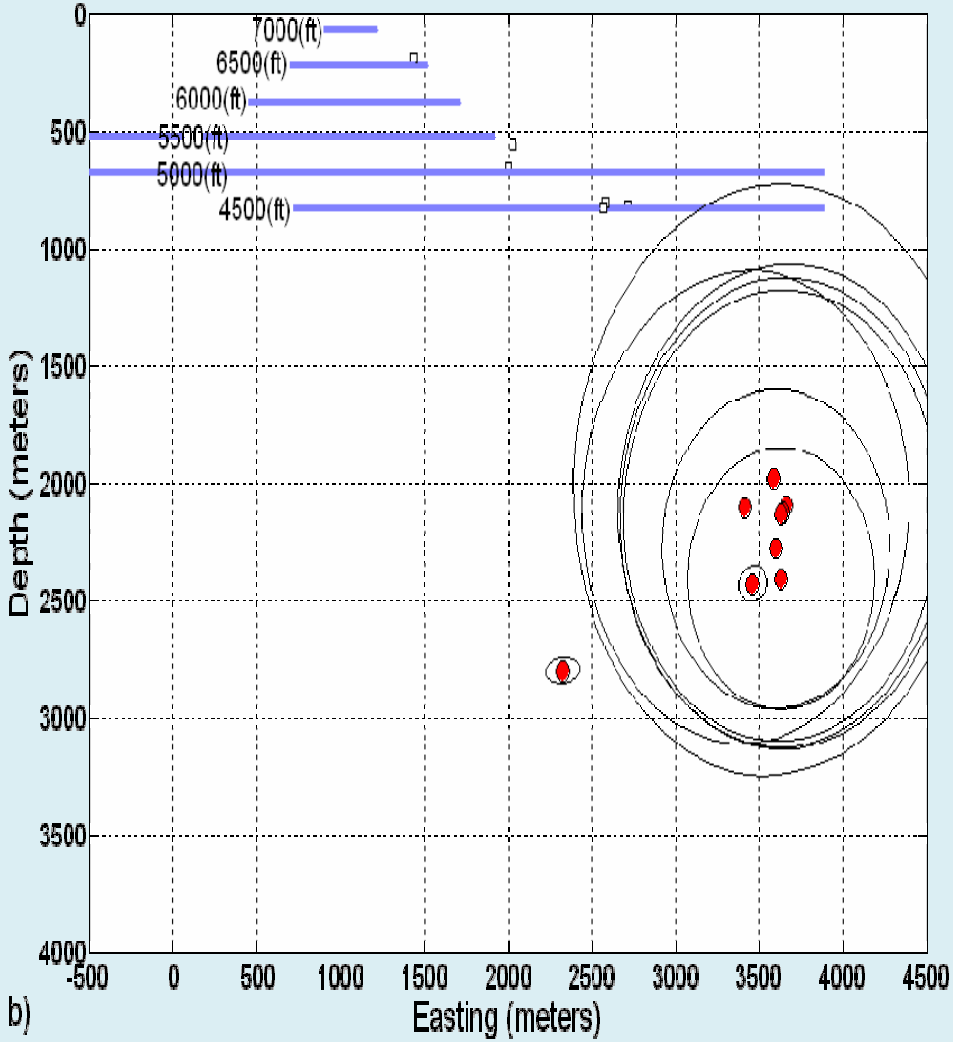


Seismograms of Swarm 2 recorded by TMF

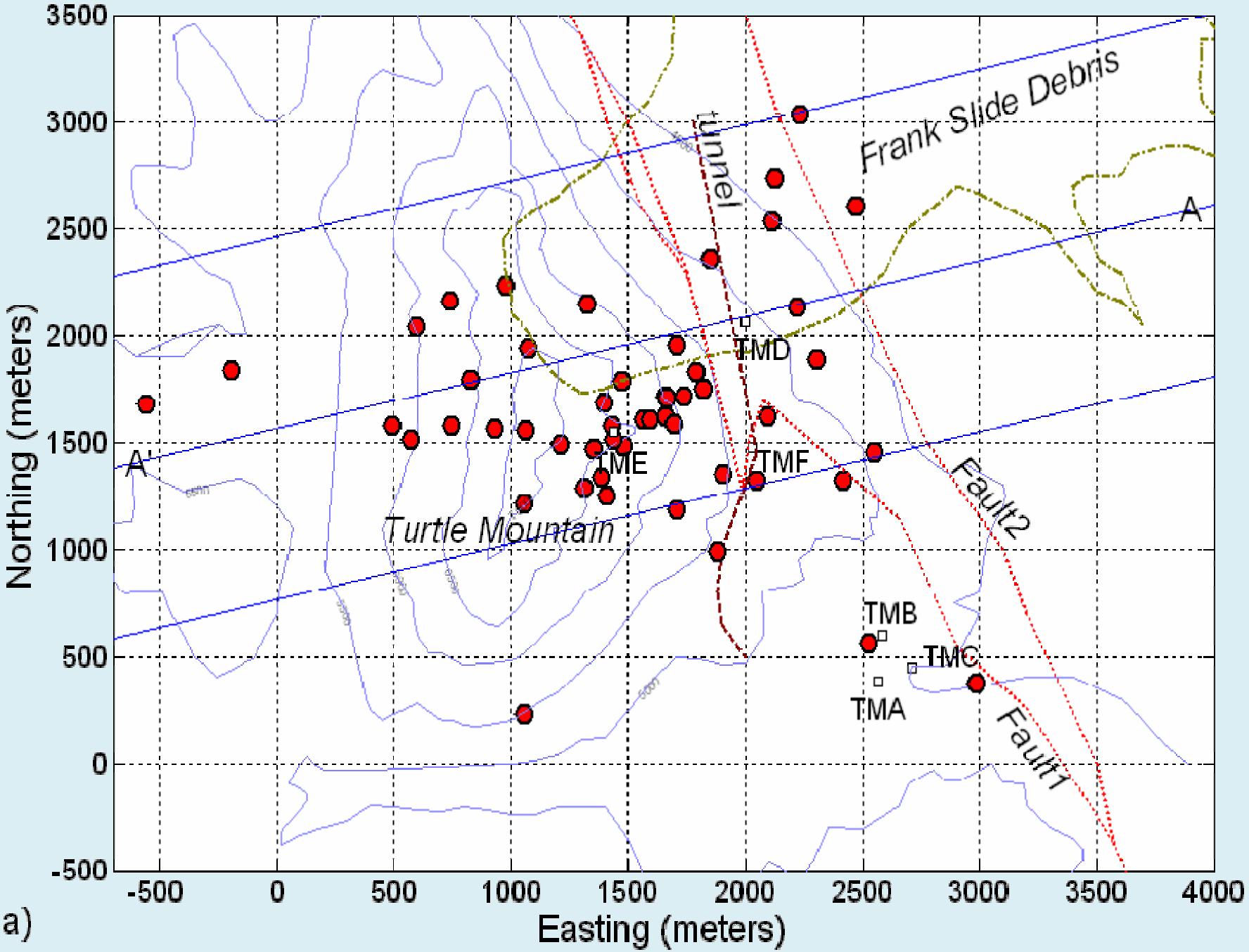


Location and error ellipses of Swarm 2

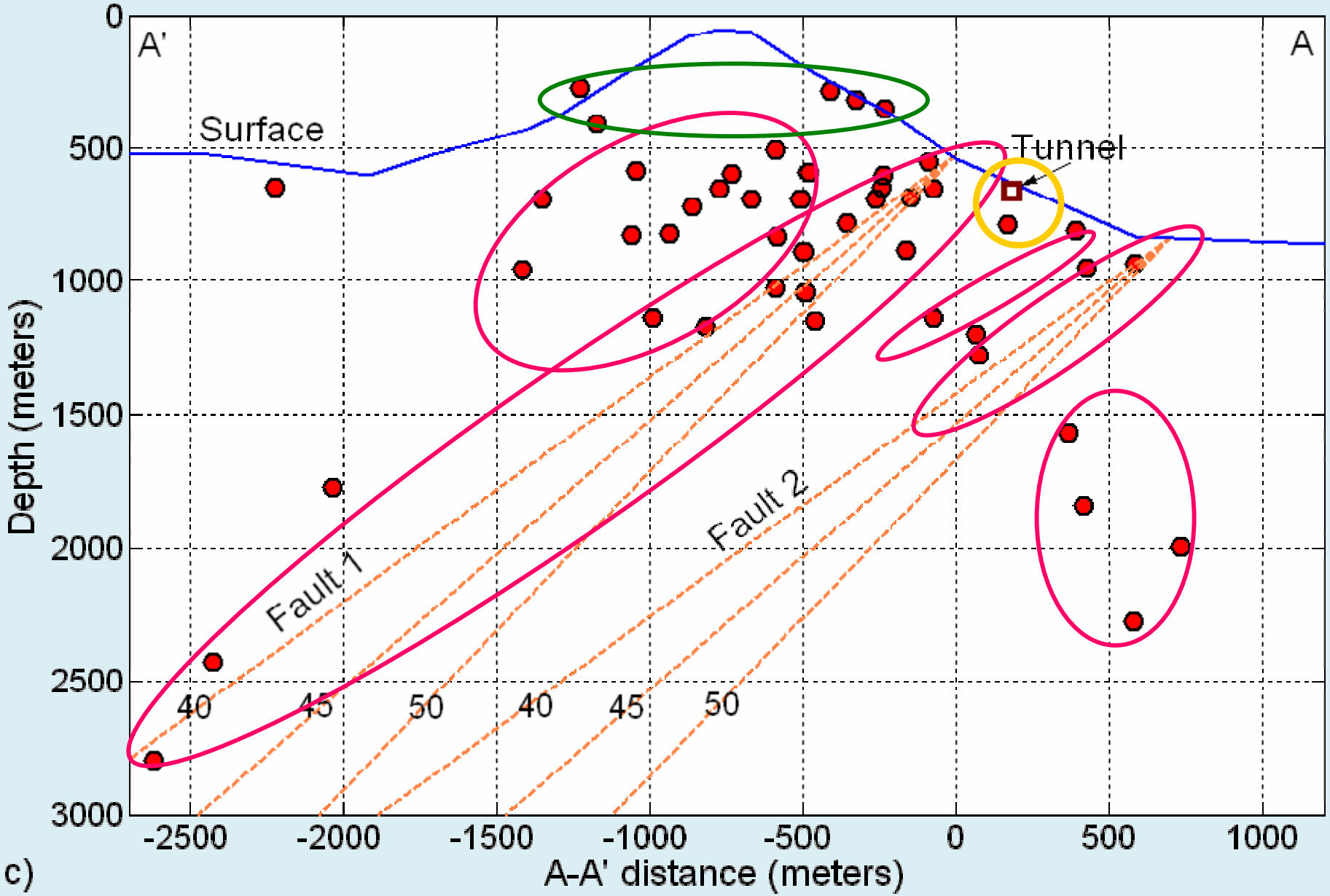




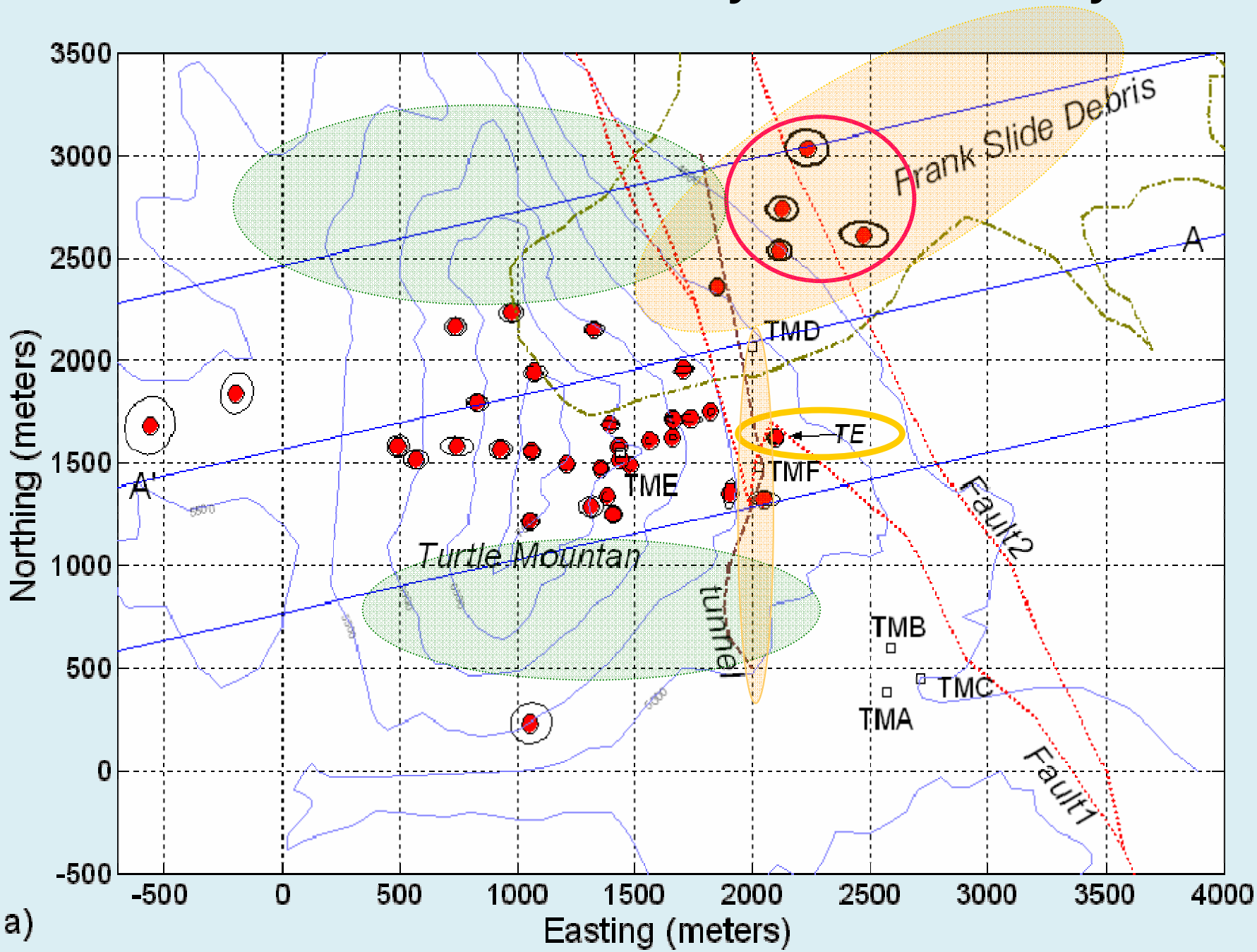
Events located by FRANK array



Cross section of A-A’

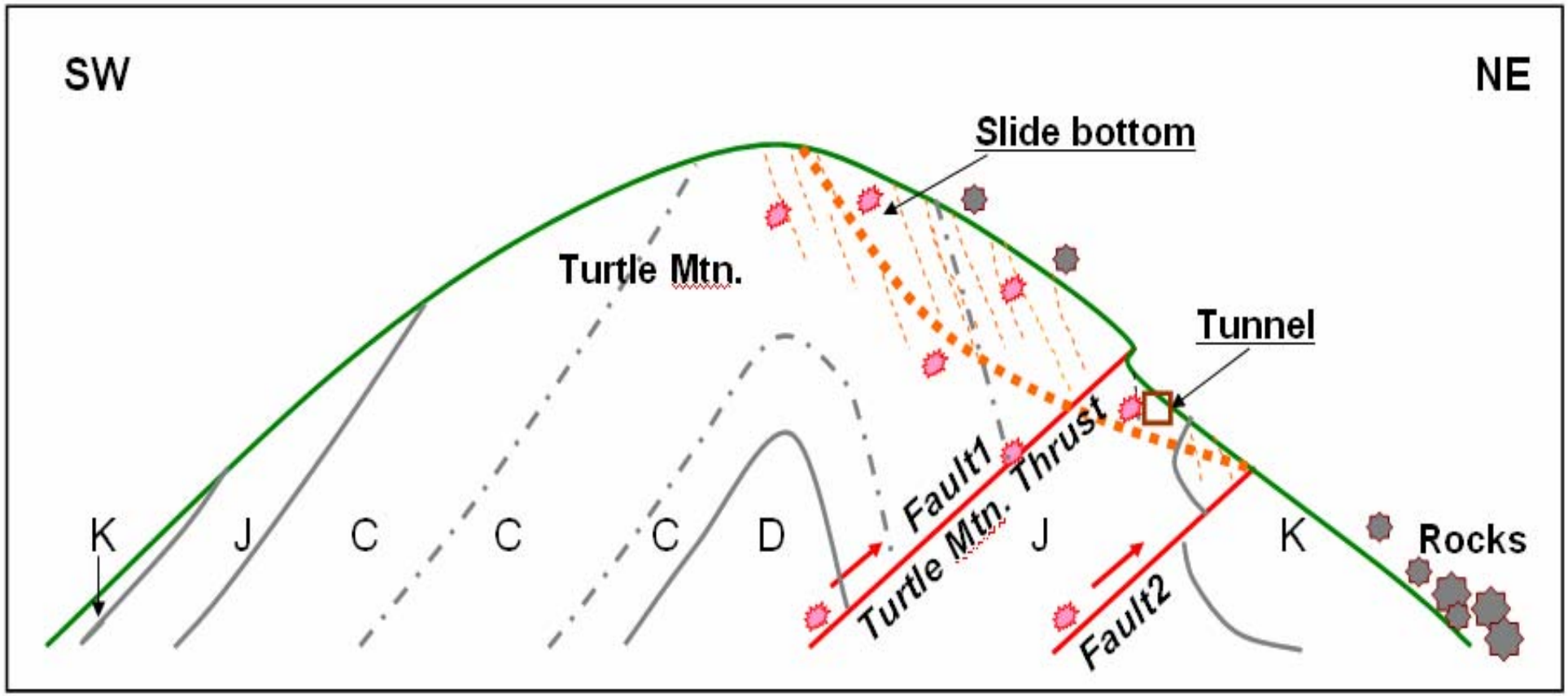


Well-located events by FRANK array

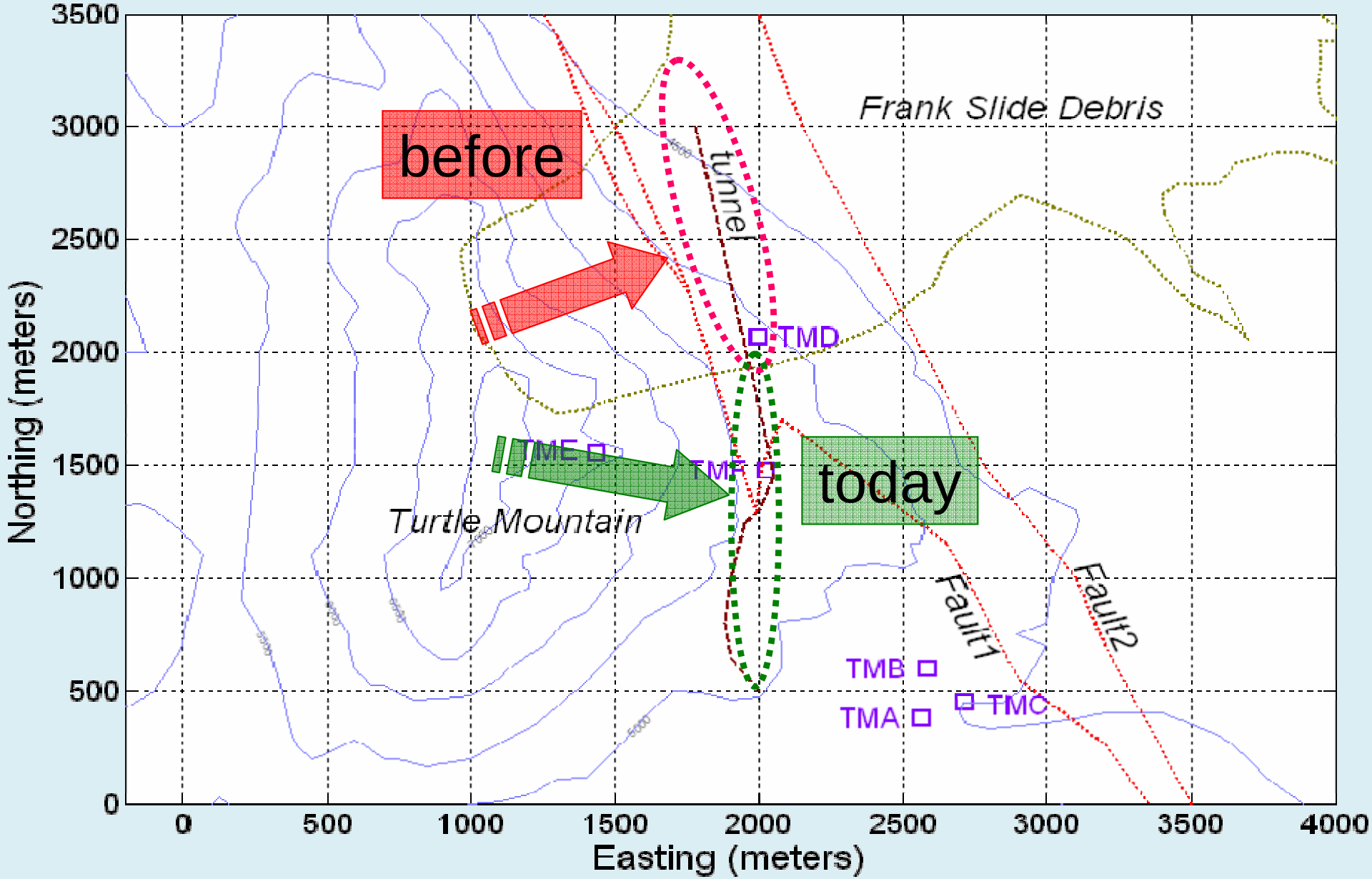


a)

Schematic mechanism of microseisms at Turtle Mtn.



Overlying loads of mine tunnel



Conclusions

- Many events detected (1986-1996) and located
- Local thrust faults appear to be active!
- Microseisms located along fault planes & in the hanging walls.
- Microseisms also related to surface fractures observed on the eastern slope and peak
- Only two events coincide with the later (South) mine tunnel

Conclusions

- Few events are detected on the lower slopes
- No shallow events (< 1.0 km below surface) occurred in the Frank Slide scarp and debris
- Microseimic swarms below boundaries of the Frank Slide at a depth of 1-1.5 km
- Mountain instability may be more related to thrust faulting than mine collapse

Future work

- Remaining data recorded by the earlier array
- Magnitude & source analysis
- New high-resolution seismic data to better localize hypocenters
- Determine the cause of the seismic swarms
- Has the microseismicity changed? Stay tuned!

Acknowledgements

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