Induced seismicity for geothermal energy production: a new synthesis

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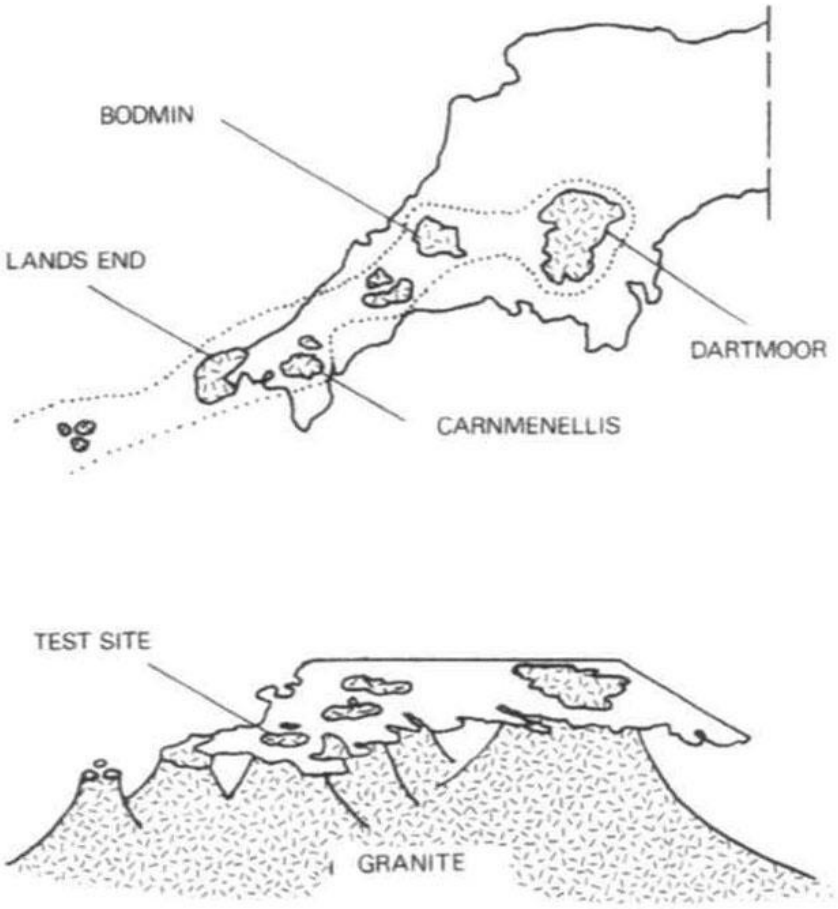
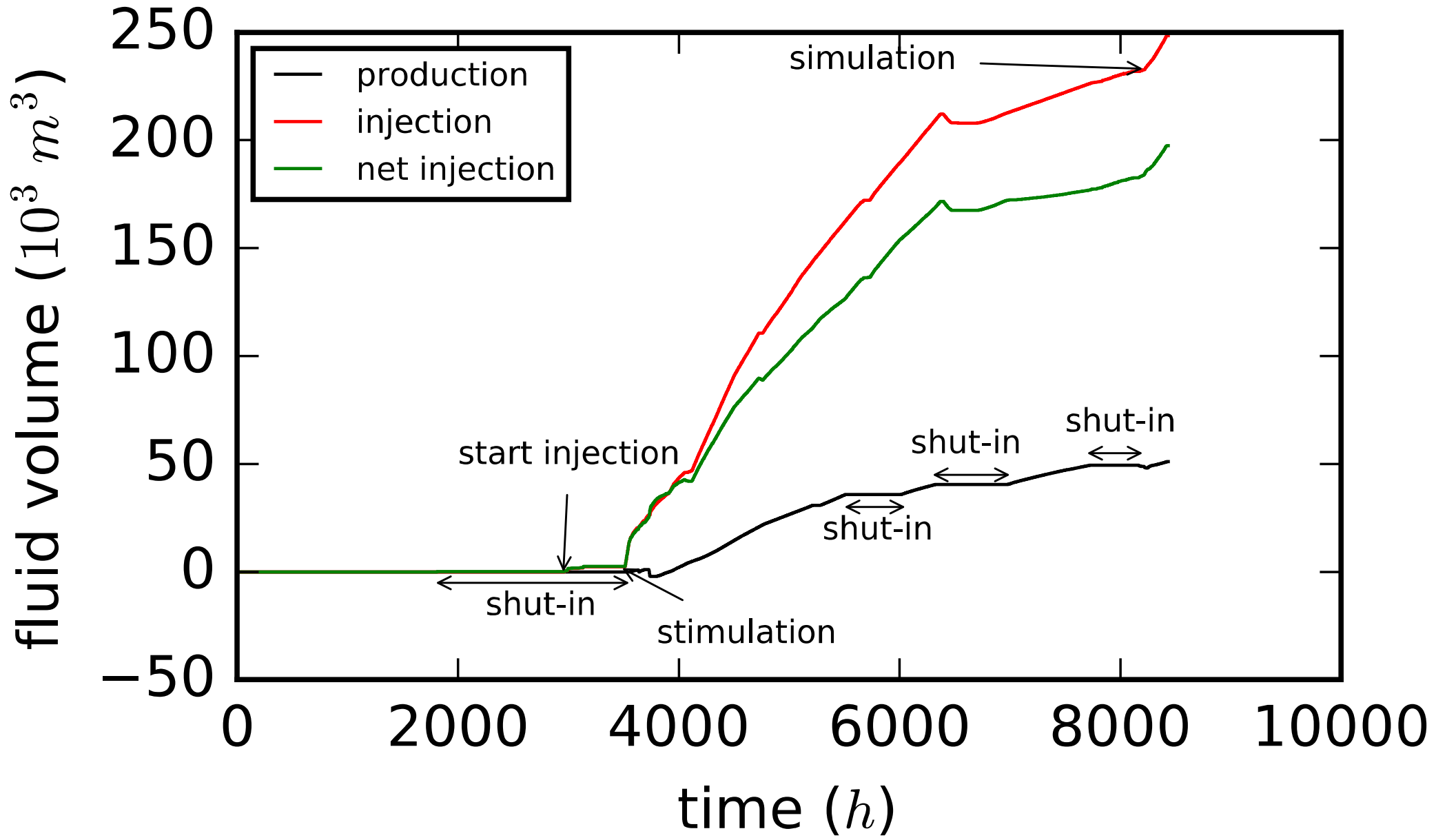
Introduction—Site Location

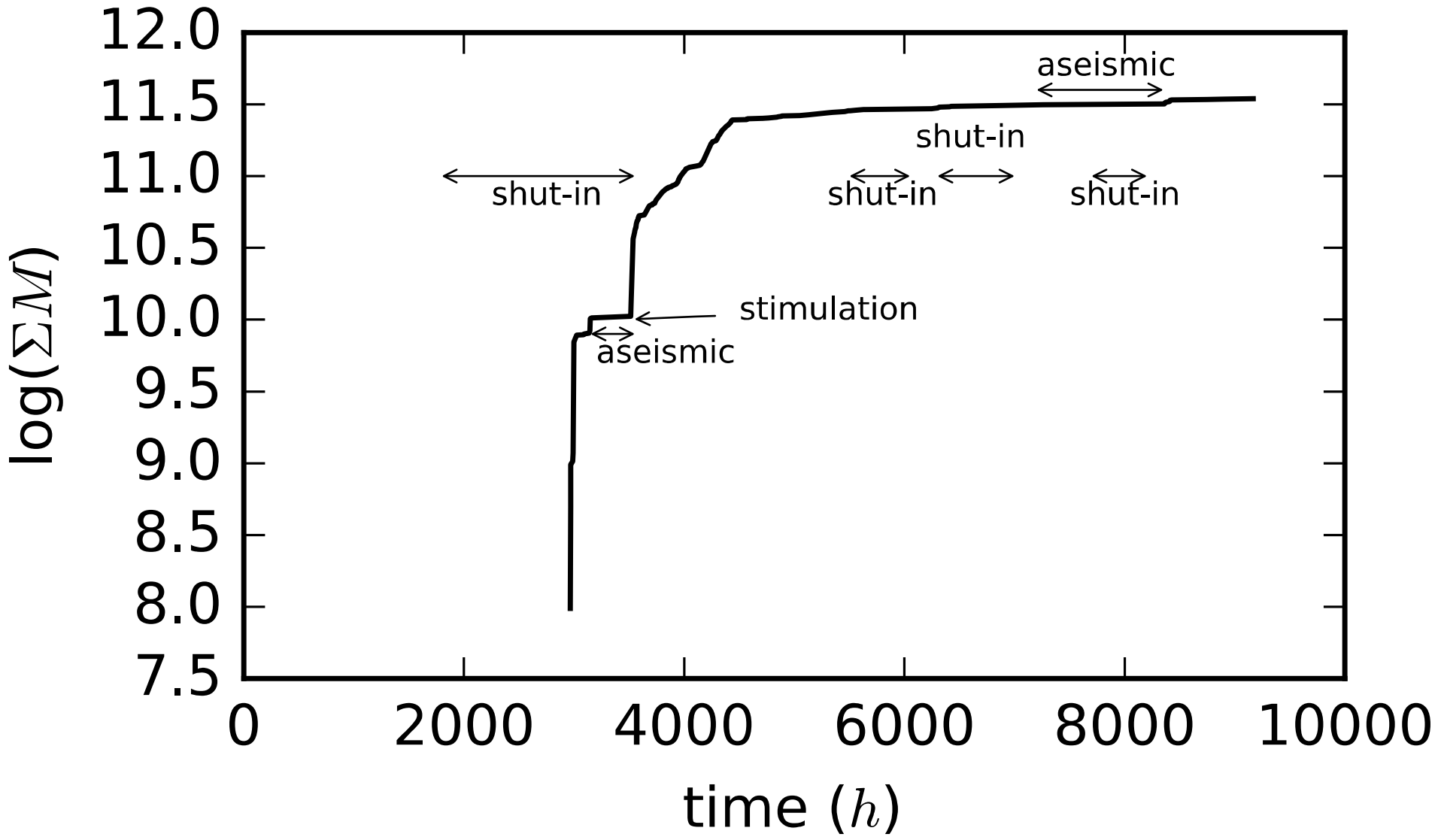
- Rosemanowes Quarry
- Carnnenellis granite—Hercynian period
- Gravity: >10km depth



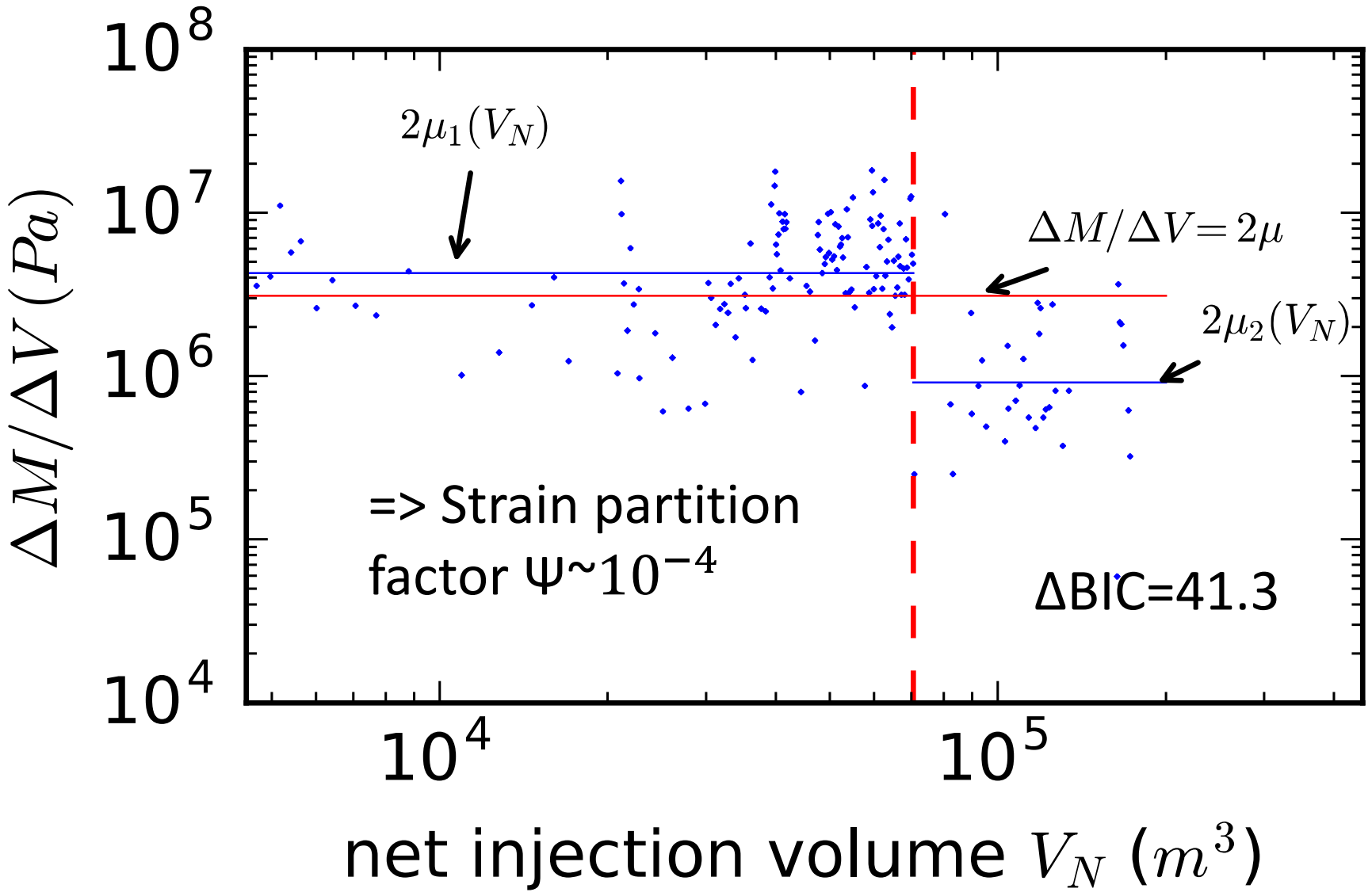
Fluid Injection History – Phase 2A



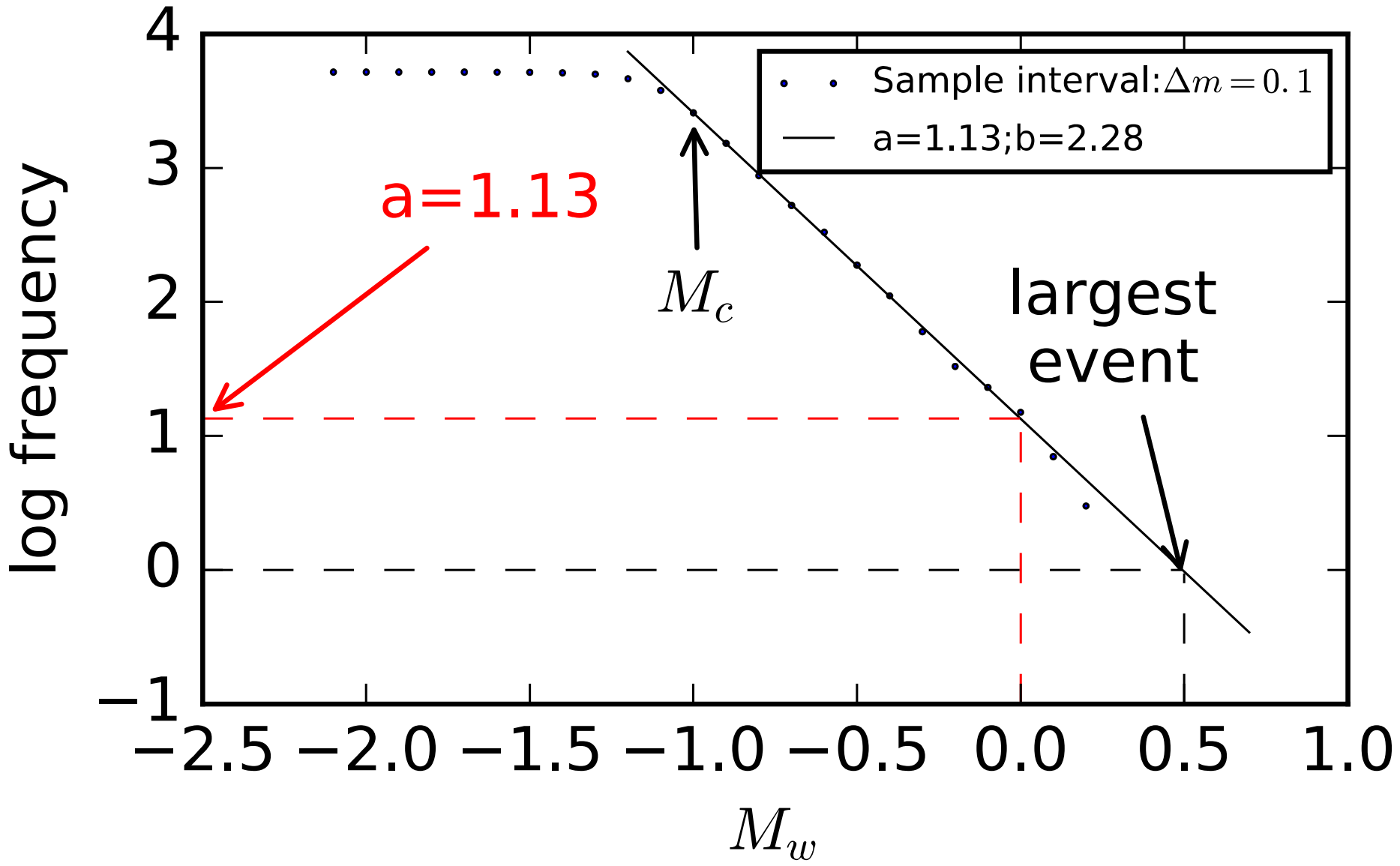
Induced Seismicity – cumulative seismic moment



Apparent shear modulus v. injected volume

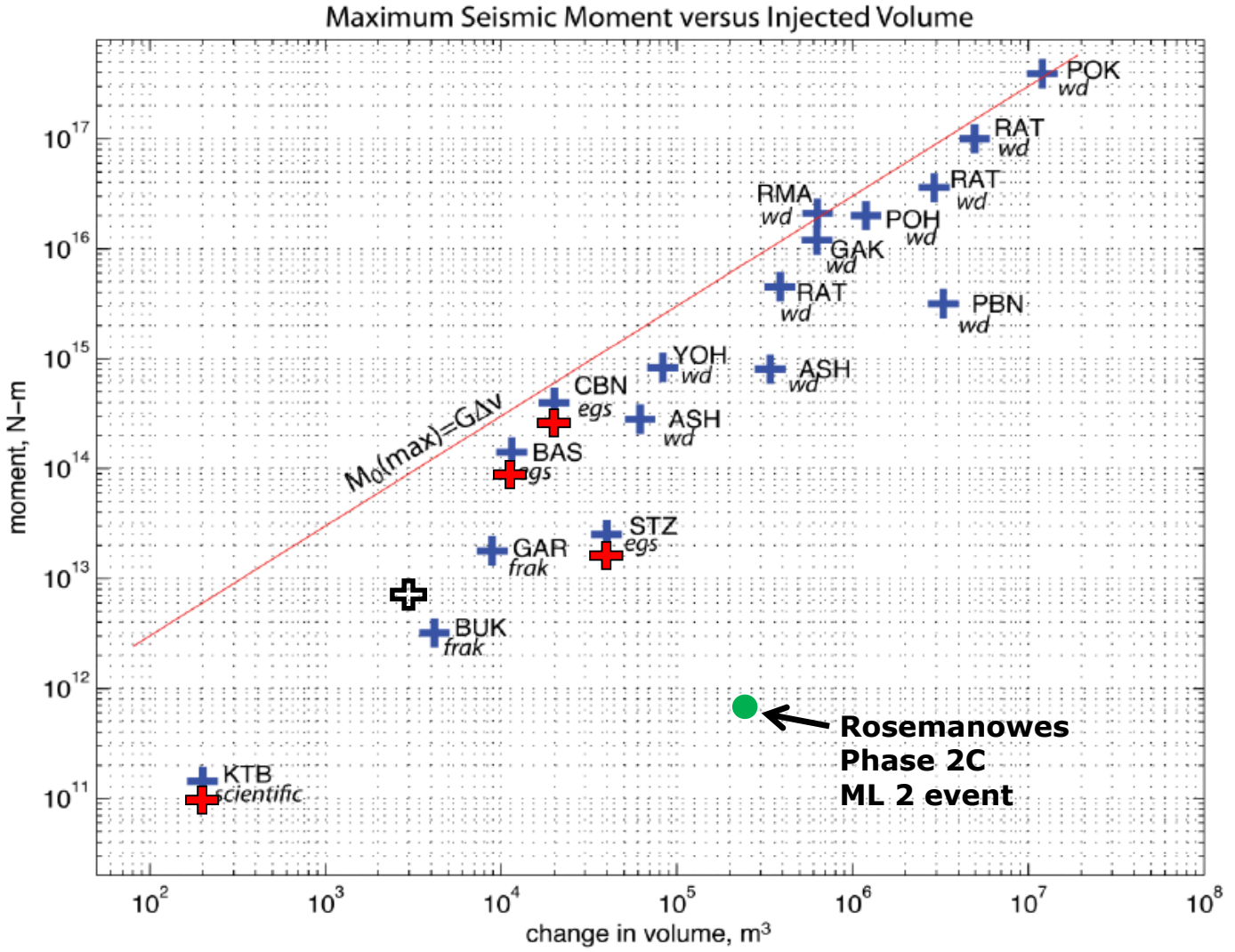


Frequency-magnitude distribution – Phase 2A

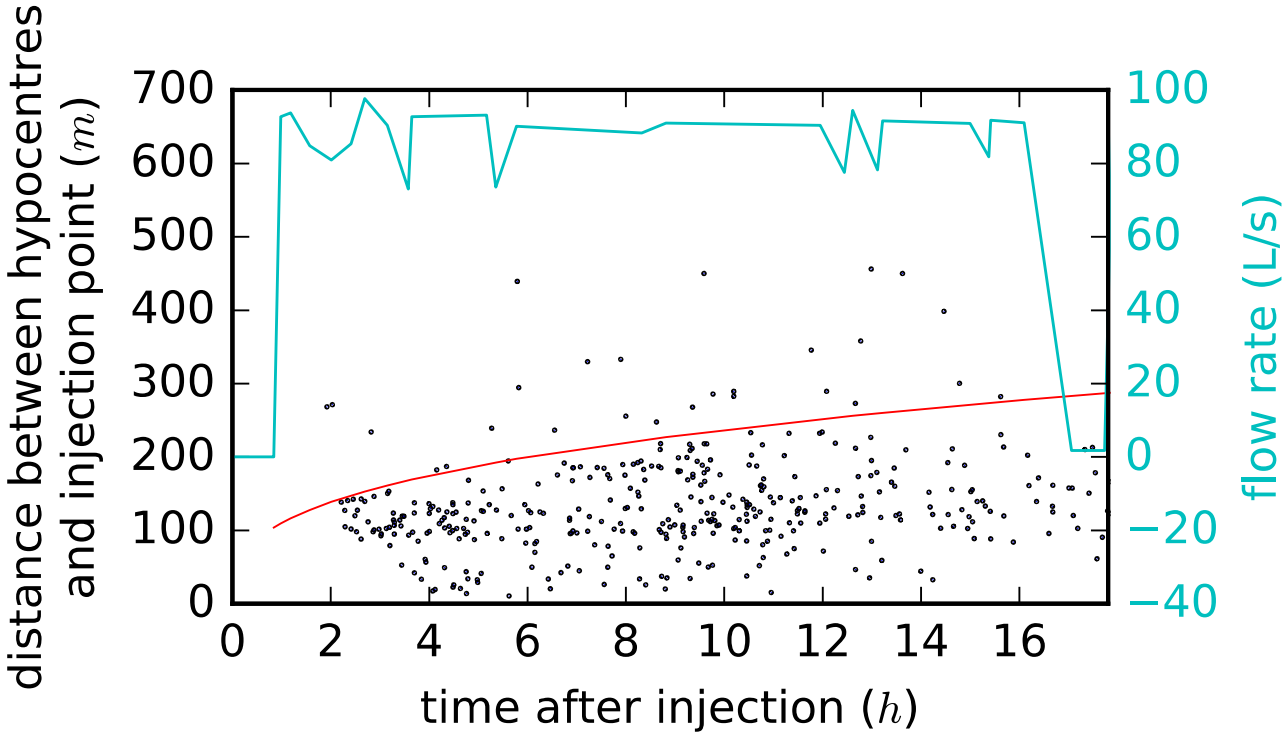


Seismic moment budget

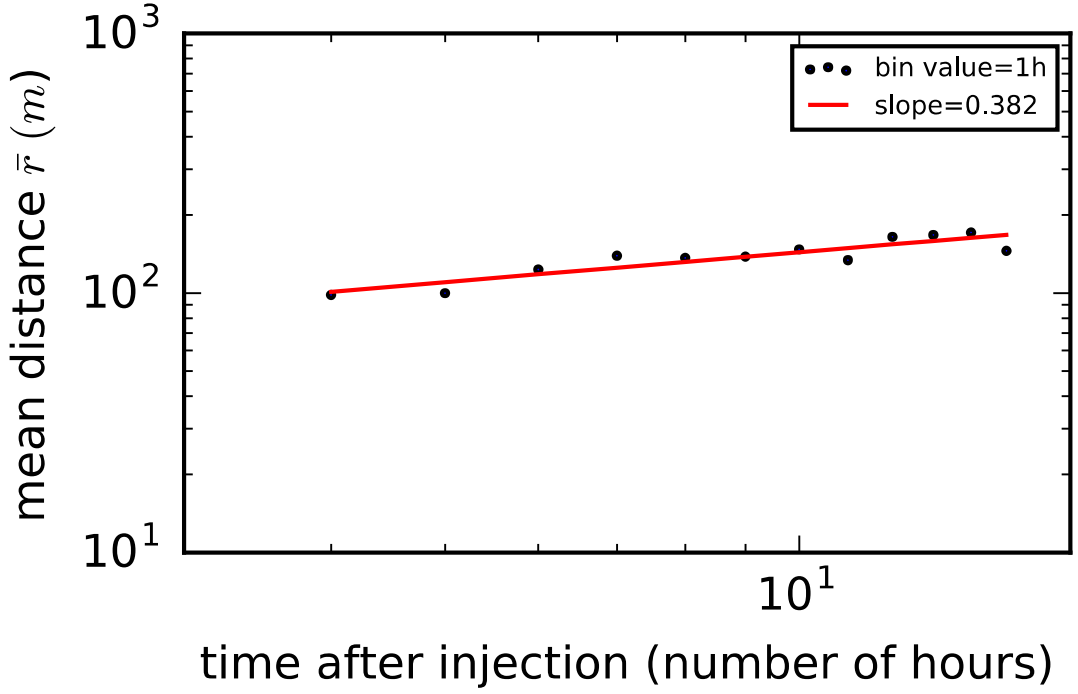
Adapted from McGarr 2013



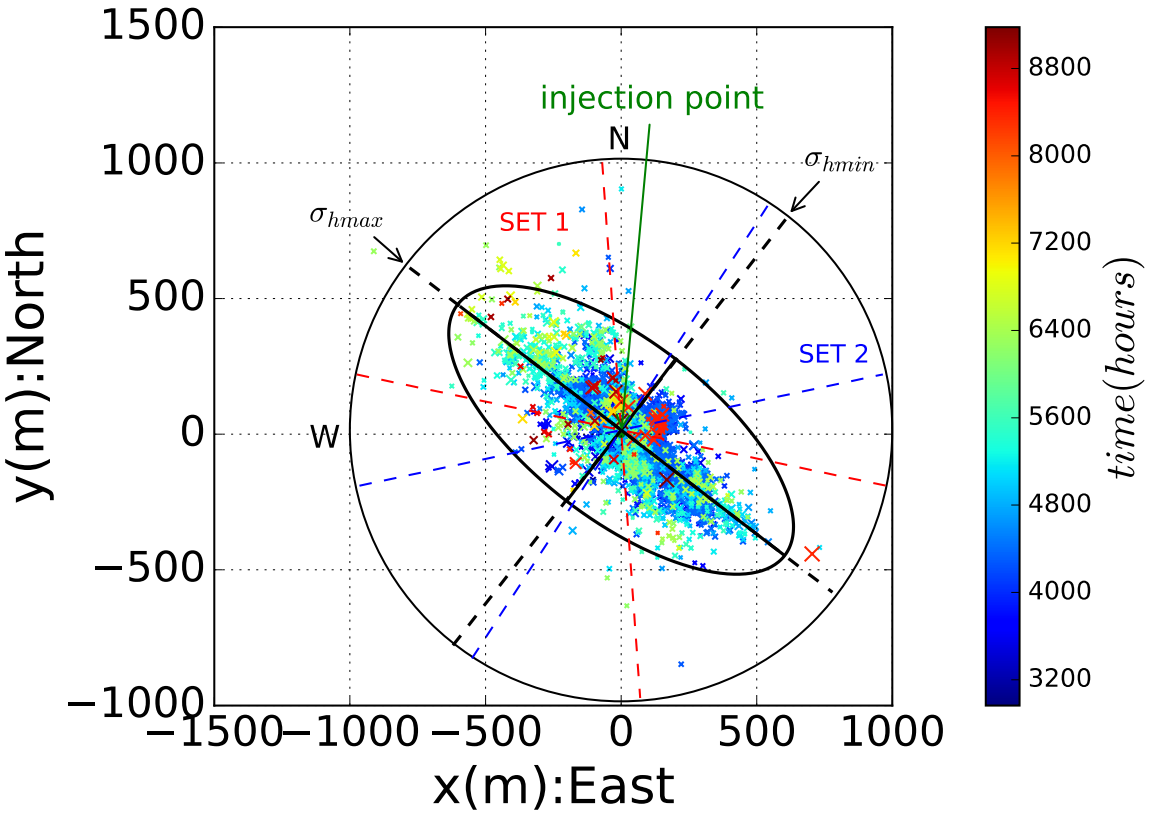
Seismicity Cloud Diffusion? $R \sim t^H$

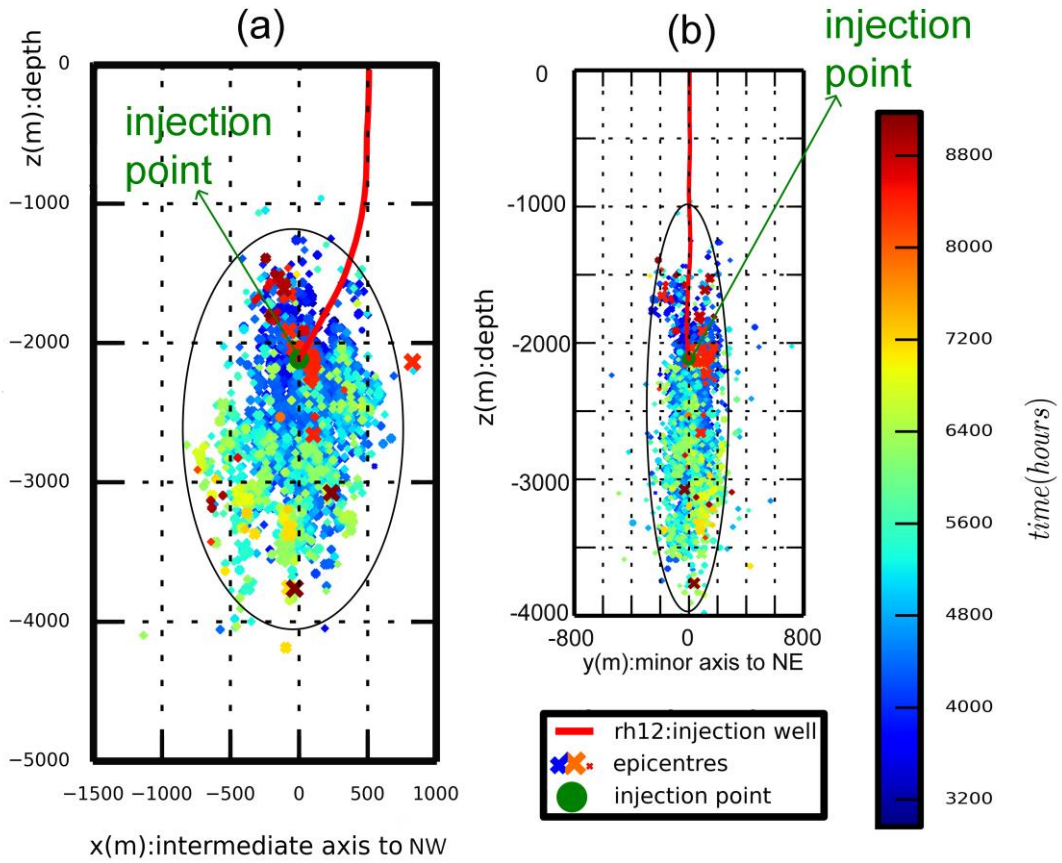


H~0.38 (c.f. H~0.1 for earthquake-earthquake triggering, Huc & Main, 2003)

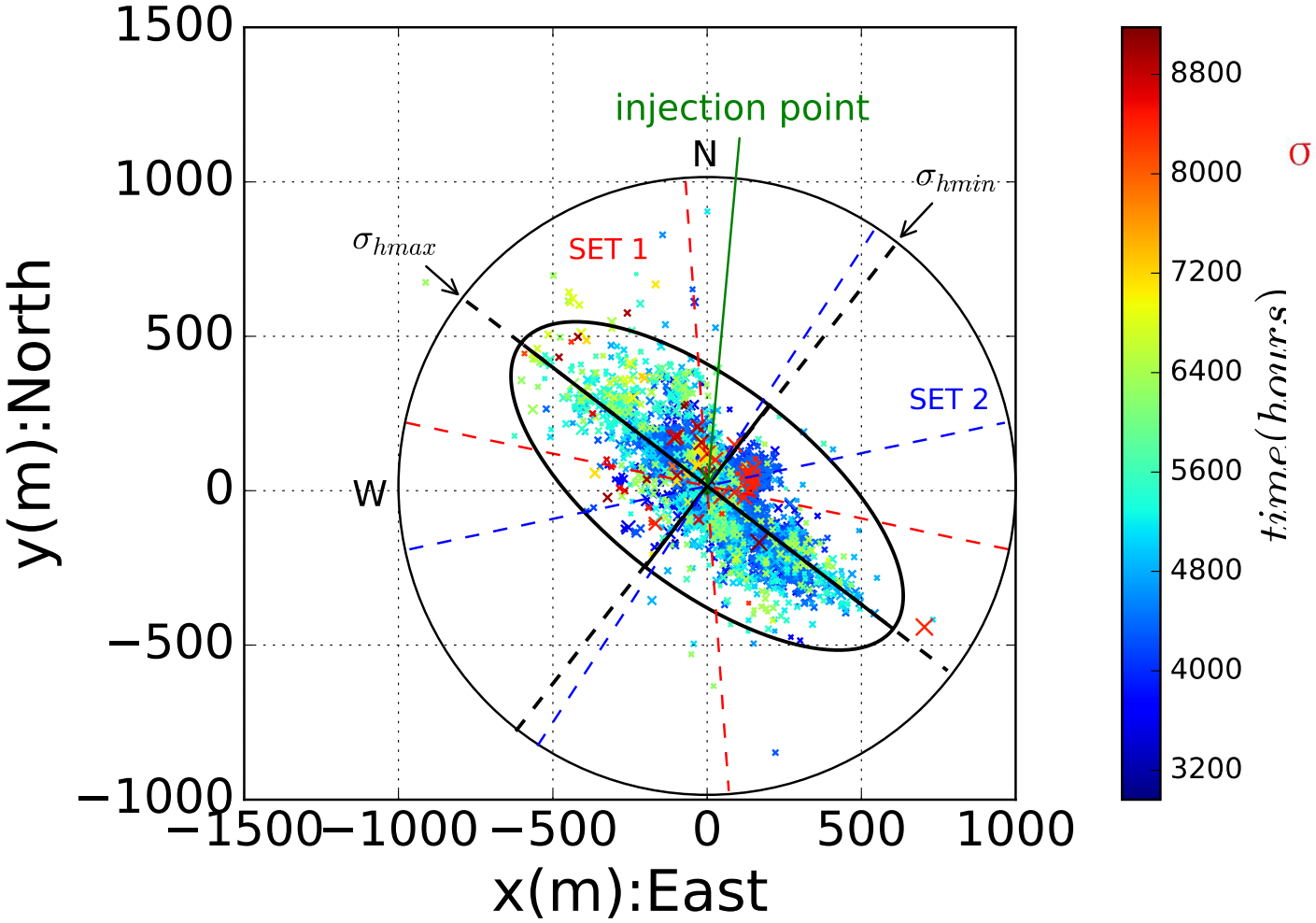


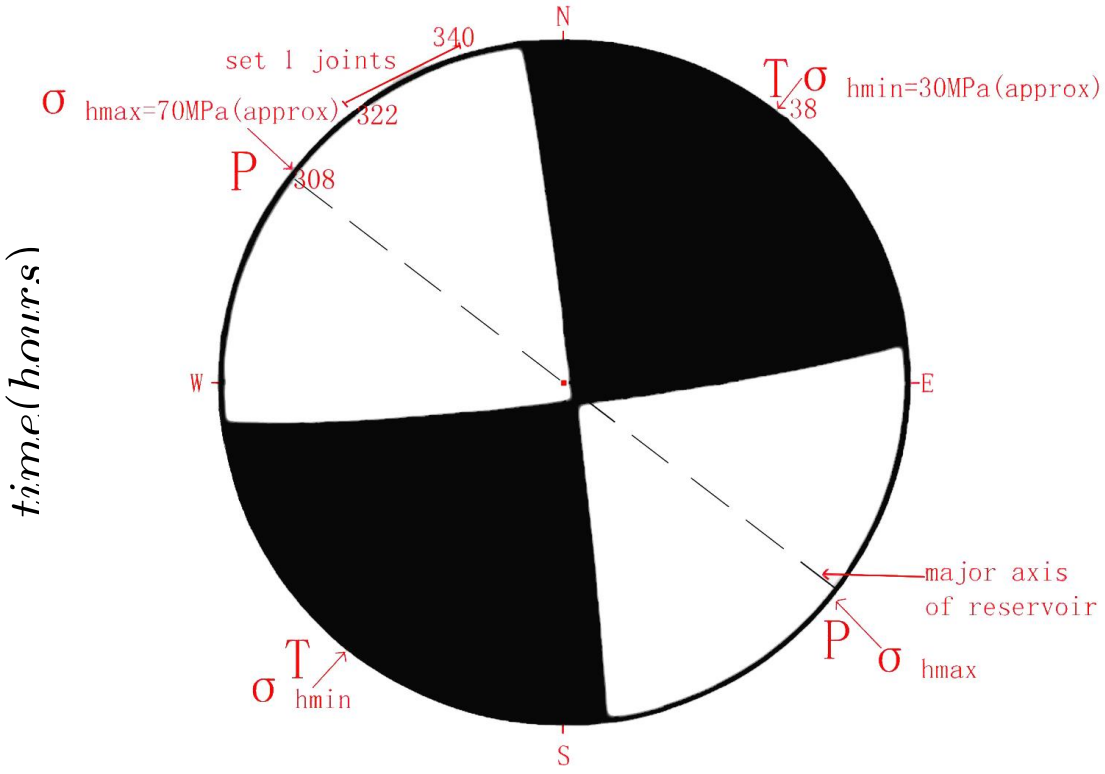
Seismicity cloud alignment, stress anisotropy, and pre-existing fracture orientation





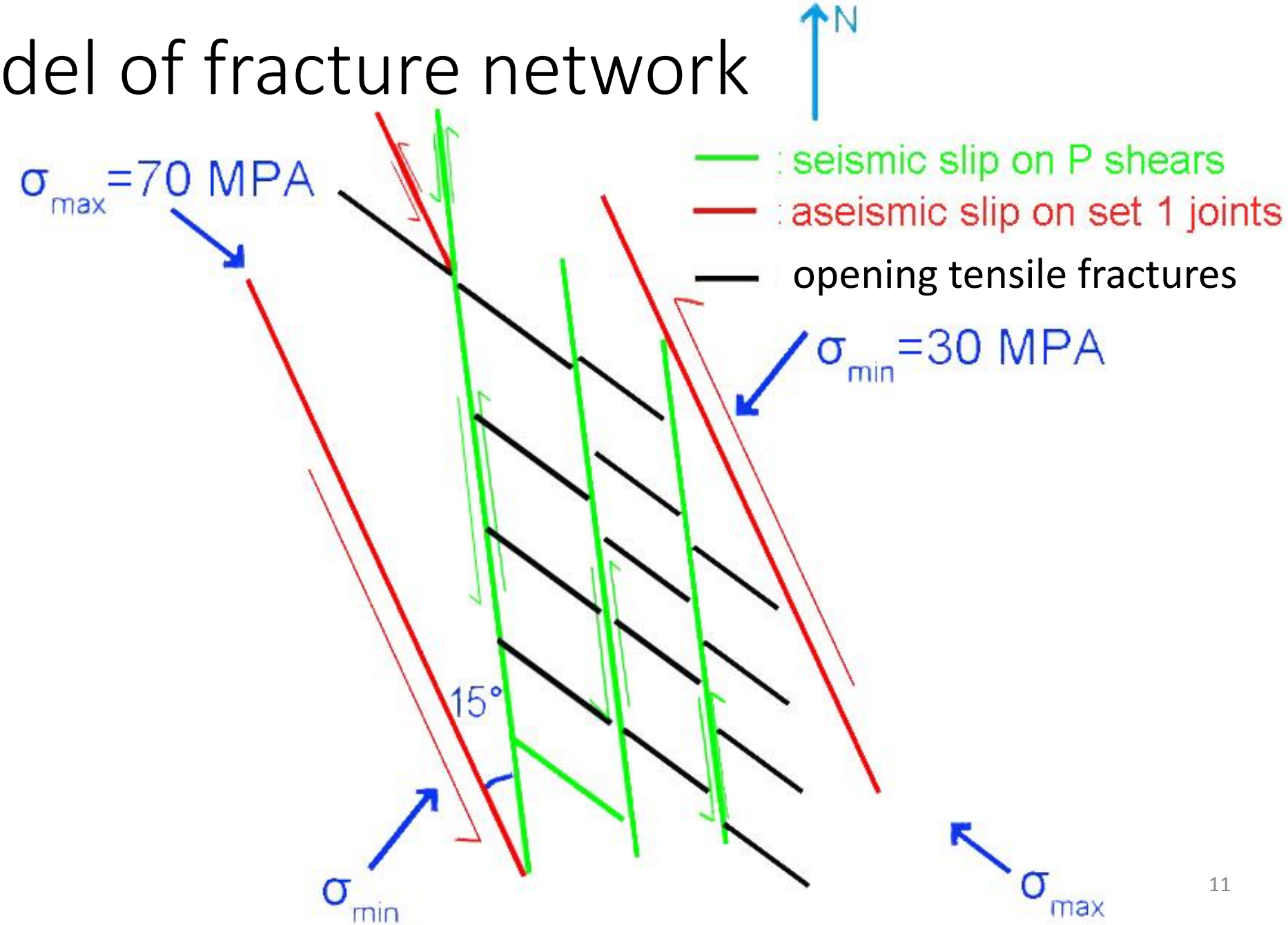
Composite Focal Mechanism



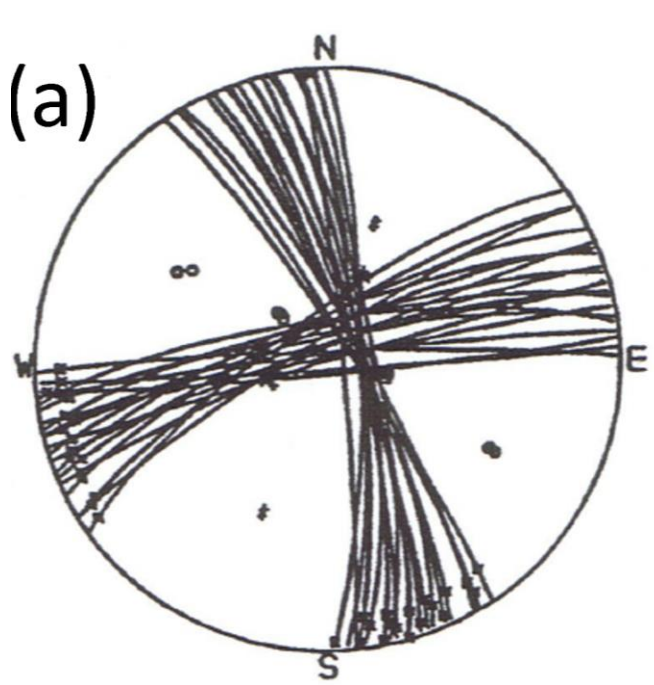


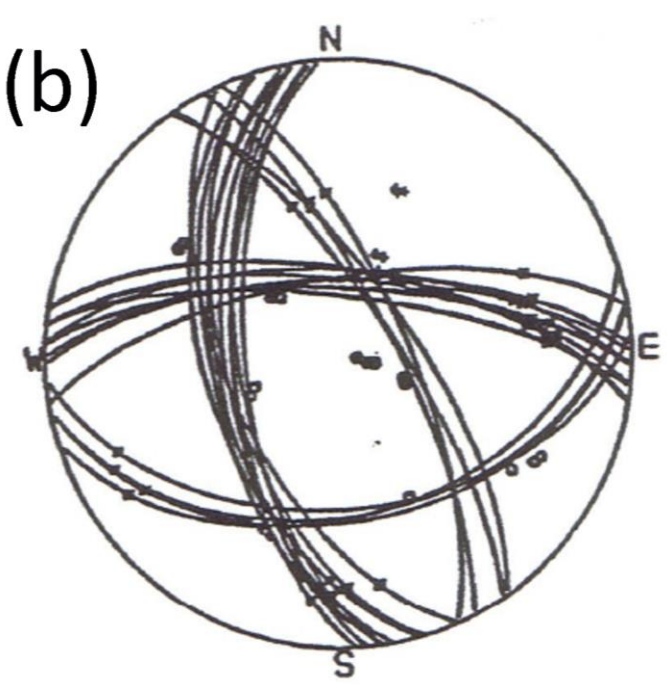
Dominated by small events

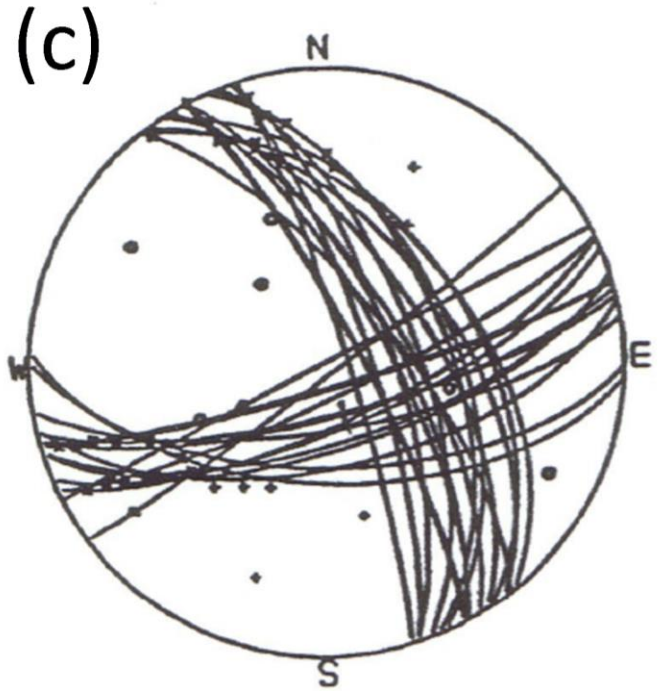
Possible model of fracture network

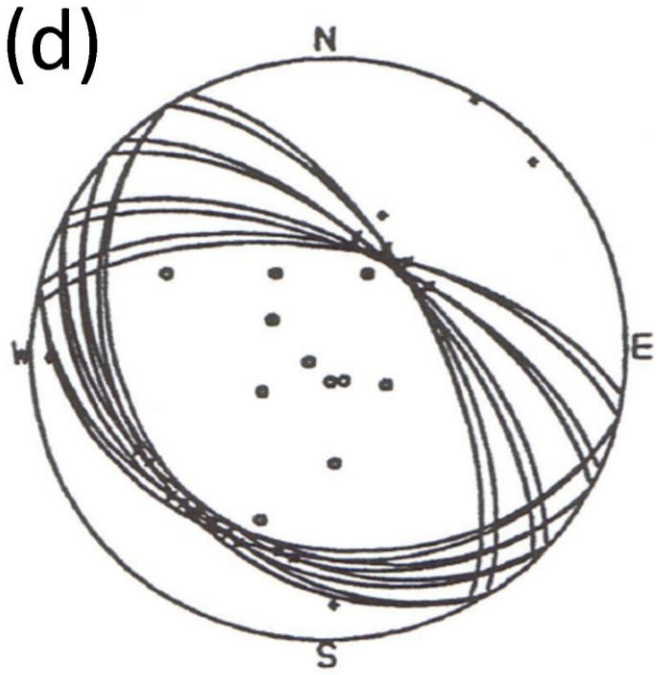


Variability of compatible focal mechanisms for individual events - scaling with size









Larger events have a greater normal component on NW/SE striking faults

Conclusion

- The reservoir is highly compliant – only a tiny fraction (0.01%) of the total available strain is released seismically
- The strain partition coefficient reduces with ongoing injection
- The induced seismicity cloud evolution is best described by ‘non-Fickian’ diffusion with an exponent of ~0.38
- The most likely cause is permeability anisotropy, closely aligned with the present-day stress field
- The composite focal mechanism implies reactivation of local pre-existing fractures in shear at high angle, possibly in turn due to aseismic slip on more optimally-oriented faults