

# "Laboratory studies of induced seismicity and earthquake scaling"

Paul Young, Professor of Geophysics, University of Toronto.

Acknowledgements and THANKS to M.H.B (Farzine) Nasseri, Laszlo Lombos (Ergotech), my research group and colleagues (past and present), research partners and sponsors including UofT, Ergotech, MTS, ASC, Itasca, CFI, OIT, MRI, NSERC, MMT.

**Induced MicroSeismicity and Scaling** 

Km & 100s Hz

UNIVERSITY OF



2

SW NE 14 09 1999



UNIVERSITY OF



After Goodfellow and Young – GRL 2014



Benson PM, Viciguerra S, Meredith PG and Young RP (2008), Laboratory Simulation of Volcano Seismicity, Science, Vol 322.



## Engineering Application: Hydraulic Fracturing



Goodfellow SD, Nasseri MHB, Maxwell S and Young RP, Hydraulic Fracture Energy Budgets: Insights from the laboratory, GRL 2015



## Engineering Application: Hydraulic Fracturing



Goodfellow SD, Nasseri MHB, Maxwell S and Young RP, Hydraulic Fracture Energy Budgets: Insights from the laboratory, GRL 2015

6



### Rock Fracture Dynamics Facility (RFDF)





#### True-Triaxial Geophysical Imaging Cell and Polyaxial Testing Machine



•Polyaxial servo-controlled loading system; 6800 kN axial, 3400 kN lateral

- •Polyaxial (true triaxial) and triaxial geophysical imaging cells
- •Temp. up to 200 °C

•Full waveform continuous Acoustic Emission (18 sensor 3D array sampled at 10MHz – up to 8hrs)

- •3D velocity measurement system (including 6P and 12S axial sensors)
- •Pore pressure control and 3D permeability along independently controlled axes



# True-Triaxial Testing (TTT): Geophysical Imaging Cell

One of the few *True Triaxial Rock Deformation Facilities with Integral Geophysical Imaging* for laboratory experiments and modelling of rock fracture:

- 3D geophysical measurements provide data to validate models
- 3D directional permeability measurements
- Coupled hydraulic, stress, and thermal conditions
- Laboratory simulation of the engineered subsurface environment of the Earth





# Transducers for Velocity and AE in TTT





# TTT Acoustic Emission





# TTT Source Characterization of AE







#### Micro-CT and Thin Section Analysis

Ghaffari, H.O. Nasseri, M.H.B. & Young, R.P. (2014), Nature Scientific Reports

Nasseri, et al. (2014), IJRMMS

1.0 cm



σ

 $\sigma_3$ 



### AE Location and Failure Planes

 $\sigma_3$ =10,  $\sigma_2$ =50,  $\sigma_1$ =550 MPa









#### Permeability Prediction, Statistical Approach

σ<sub>3</sub>=10, σ<sub>2</sub>=50 MPa





### Thank you