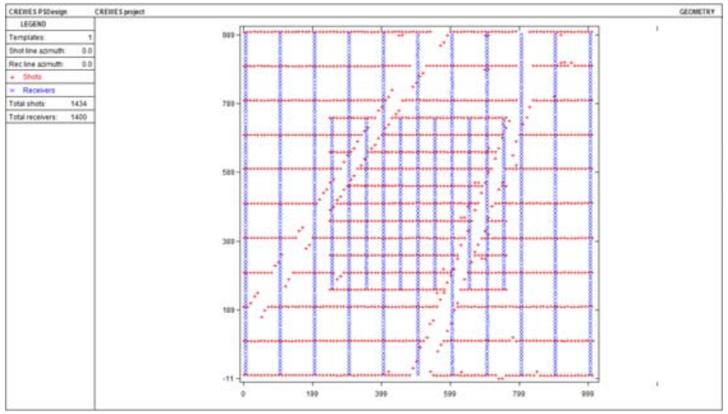
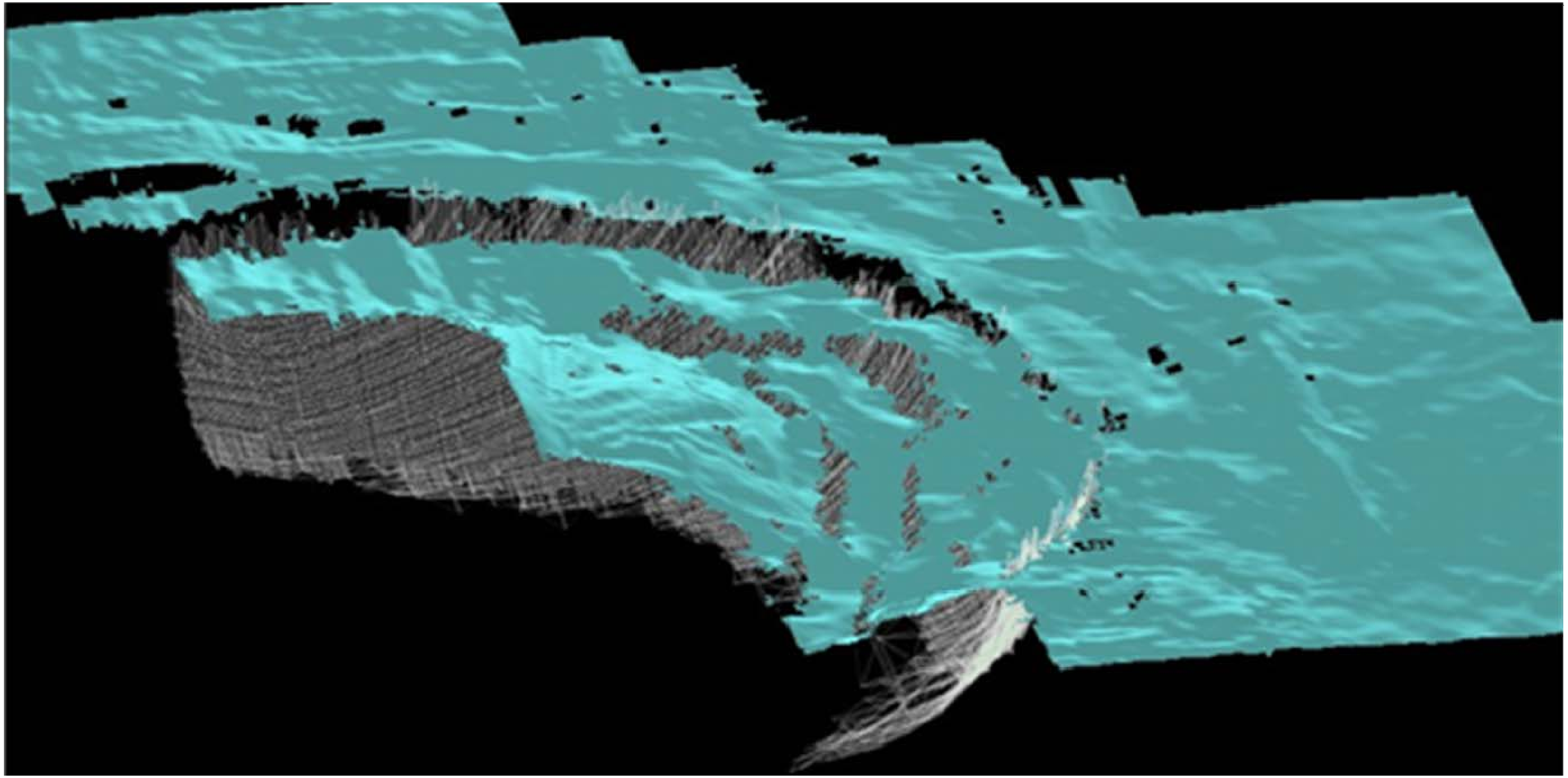
New approaches to seismic monitoring at the Brooks Field Research Station

Don Lawton, Malcolm Bertram, Kevin Hall and Kevin Bertram



Exploration – finding and mapping new reservoirs

Eagle Butte impact crater – southern Alberta

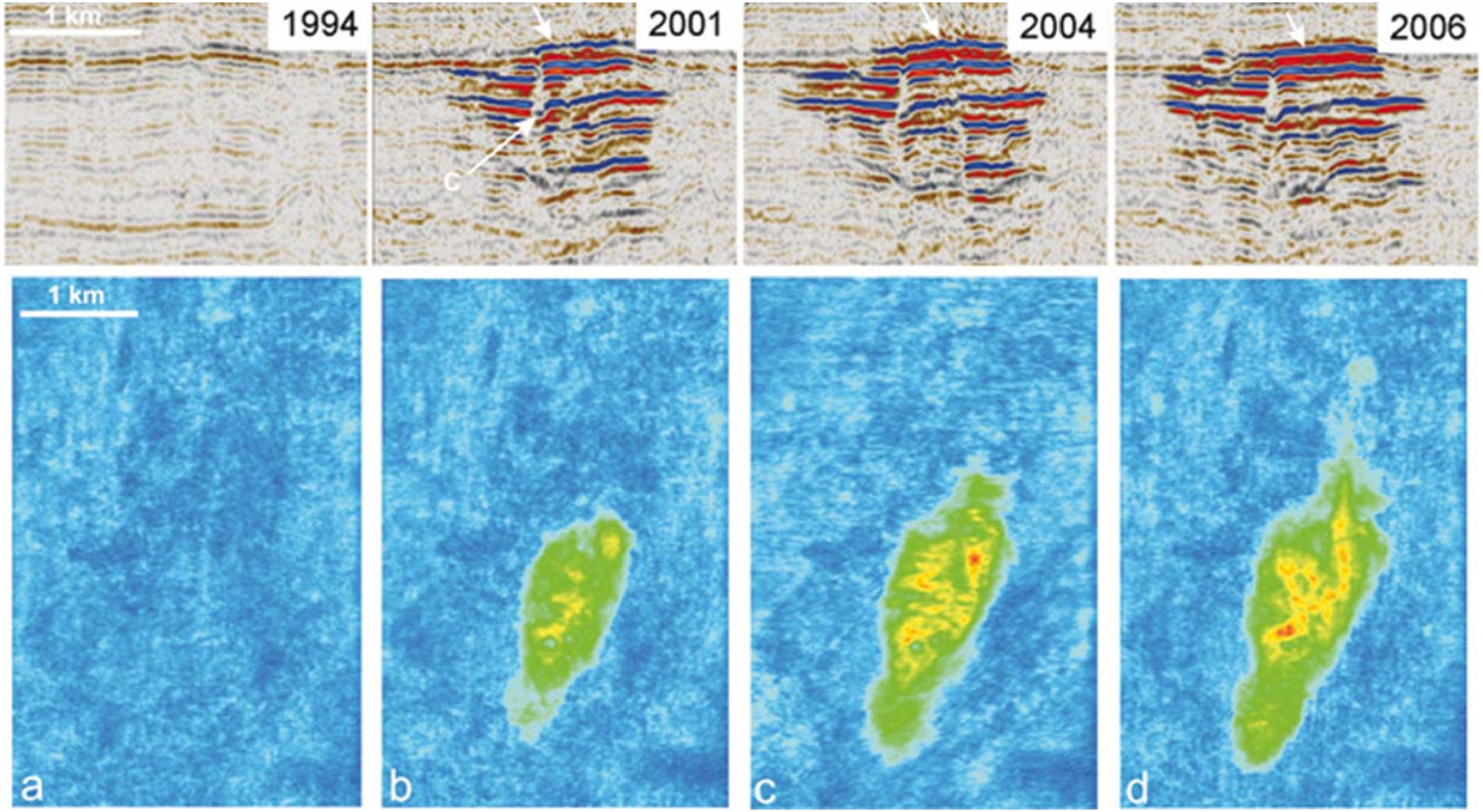


Hanova, 2004

Data courtesy Encana

Monitoring – changes in reservoirs temporally and spatially

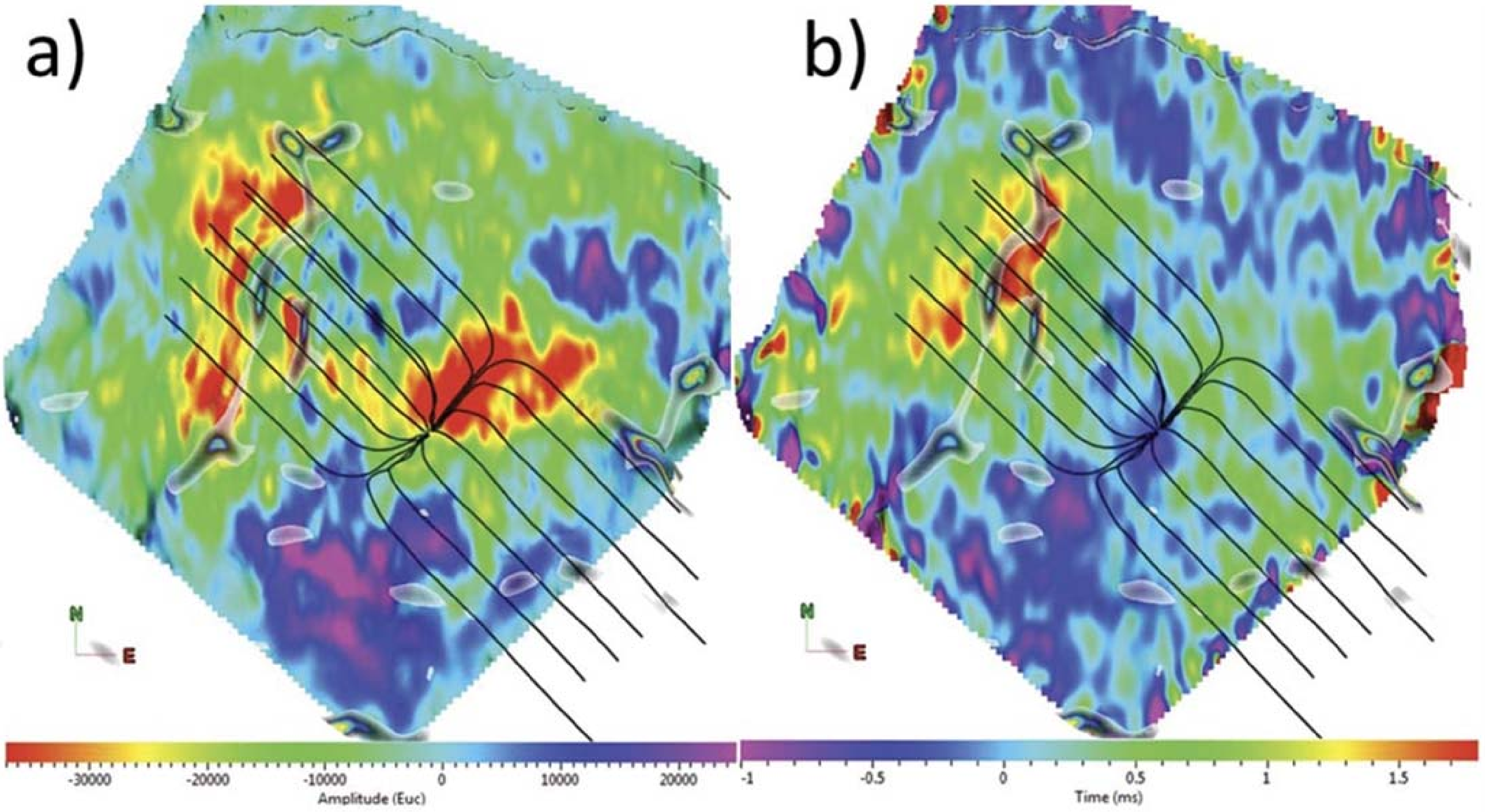
Sleipner



Chadwick et al., 2010

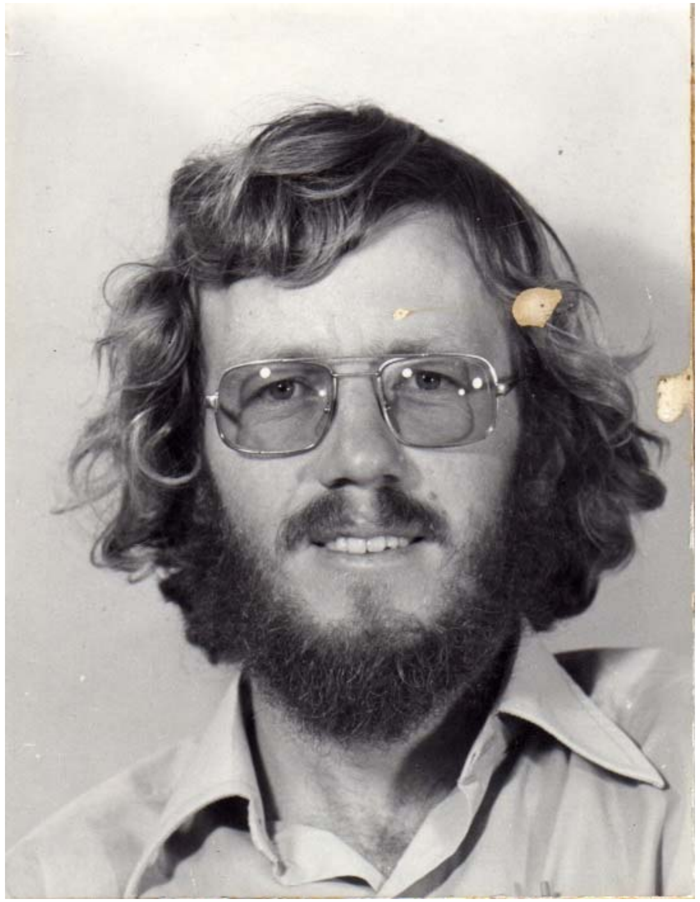
Monitoring – changes in amplitude and travel time

Amplitude **Travel time**



Goodway et al., 2012

Exploration and monitoring



Exploration
(1975)

Monitoring
(2015)

Monitoring applications for hydrocarbon assets

- Enhanced petroleum recovery
- Well and cap rock integrity
- Hydraulic fracturing (shale gas and tight oil)
- Steam chamber containment and conformance
- Fugitive methane emissions
- Secure carbon storage
- Acid gas disposal
- Produced water disposal
- Induced seismicity

Monitoring surveys and technologies

Geophysics

Surface seismic
VSP
Microseismic
Cross-well

Electrical
Electromagnetic
Micro gravity
Density tomography
Magnetics

New Technologies

DAS
DTS
Fibre geochem

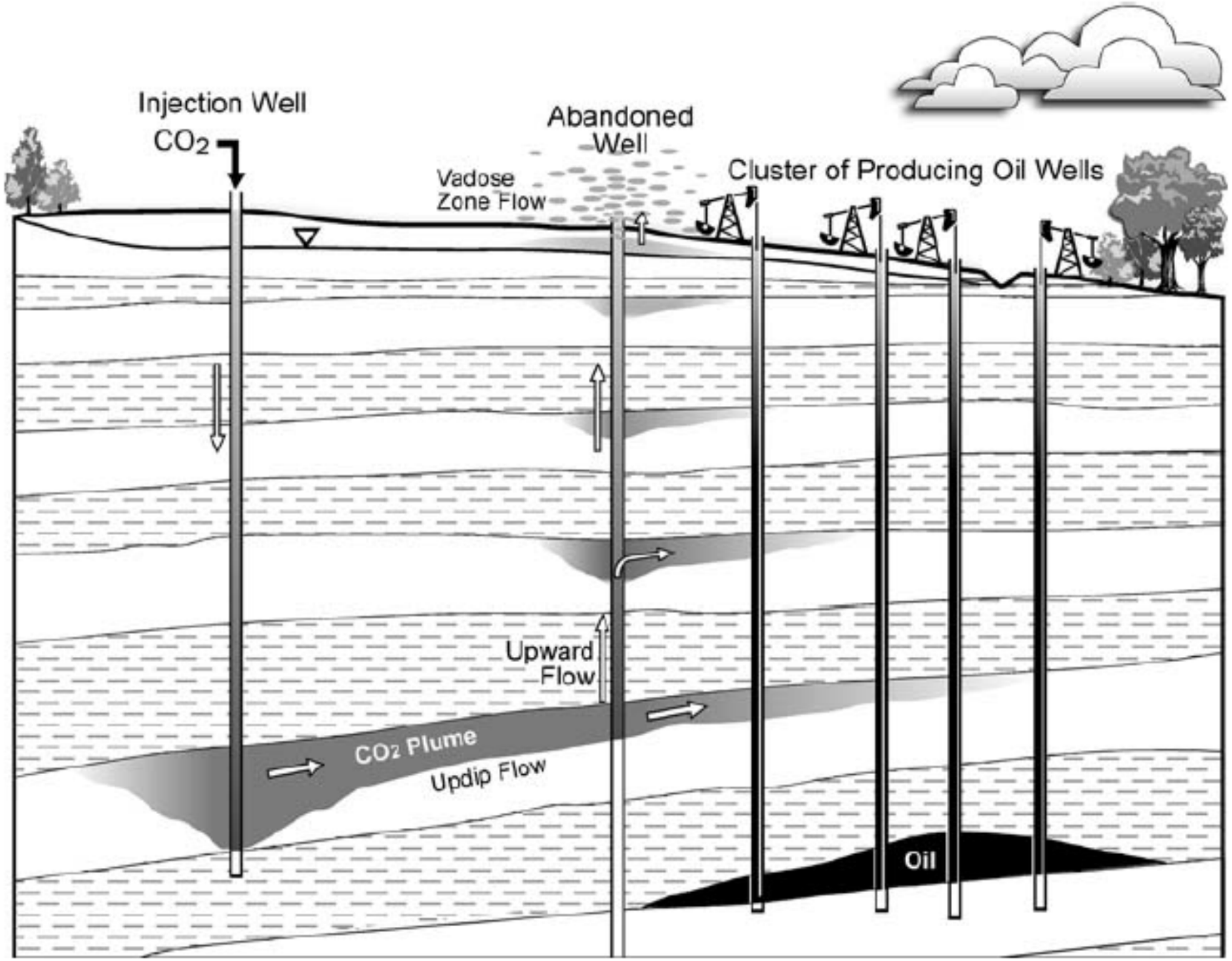
Tilt meters
DGPS
INSar

Nano gravity
Muon density tomography

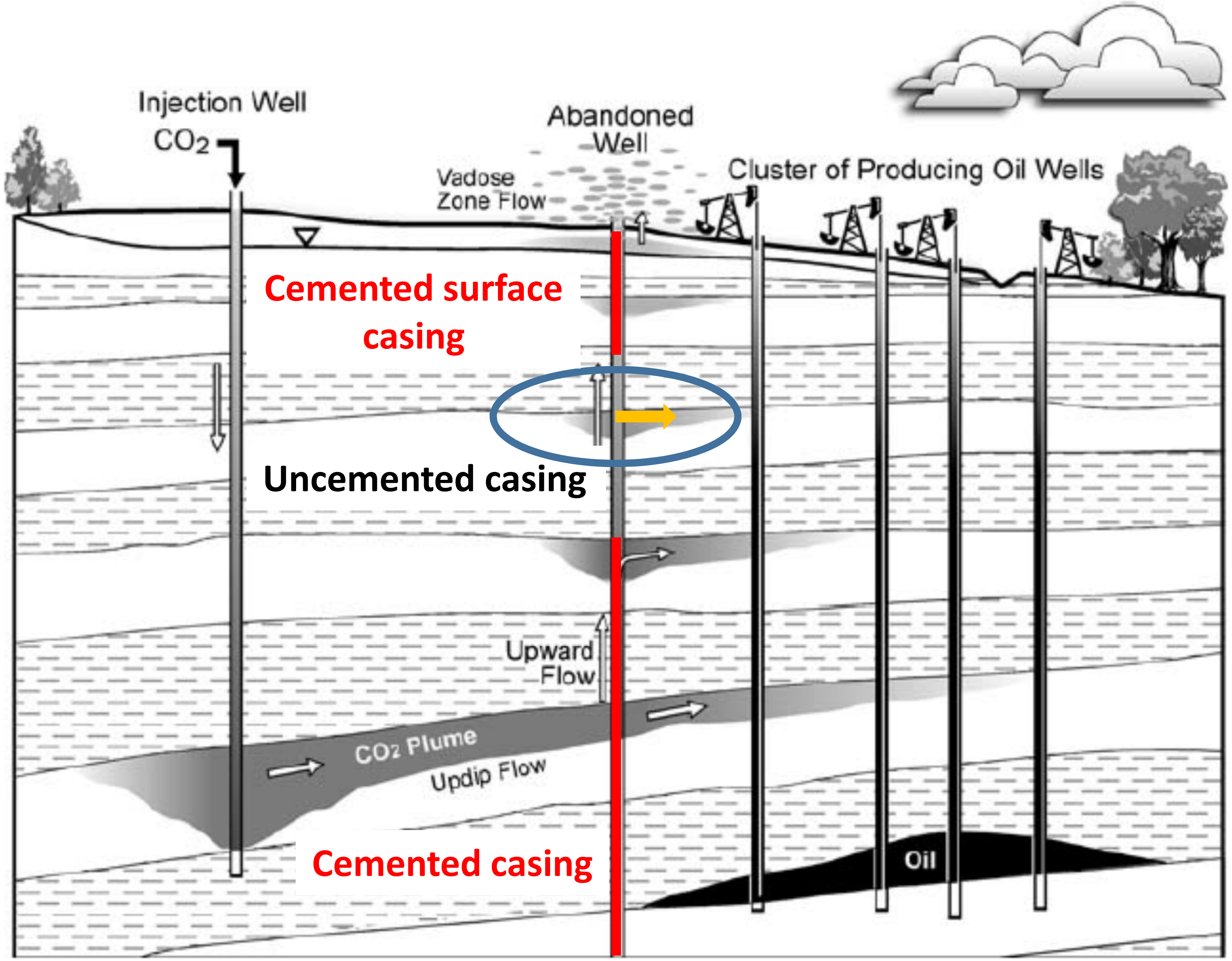
Integration

Rock properties
Geology
Flow in porous media
Flow engineering
Geomechanics
Groundwater
Fugitive emissions
Tracers

Containment risk



Containment risk



After Celia et al., 2004

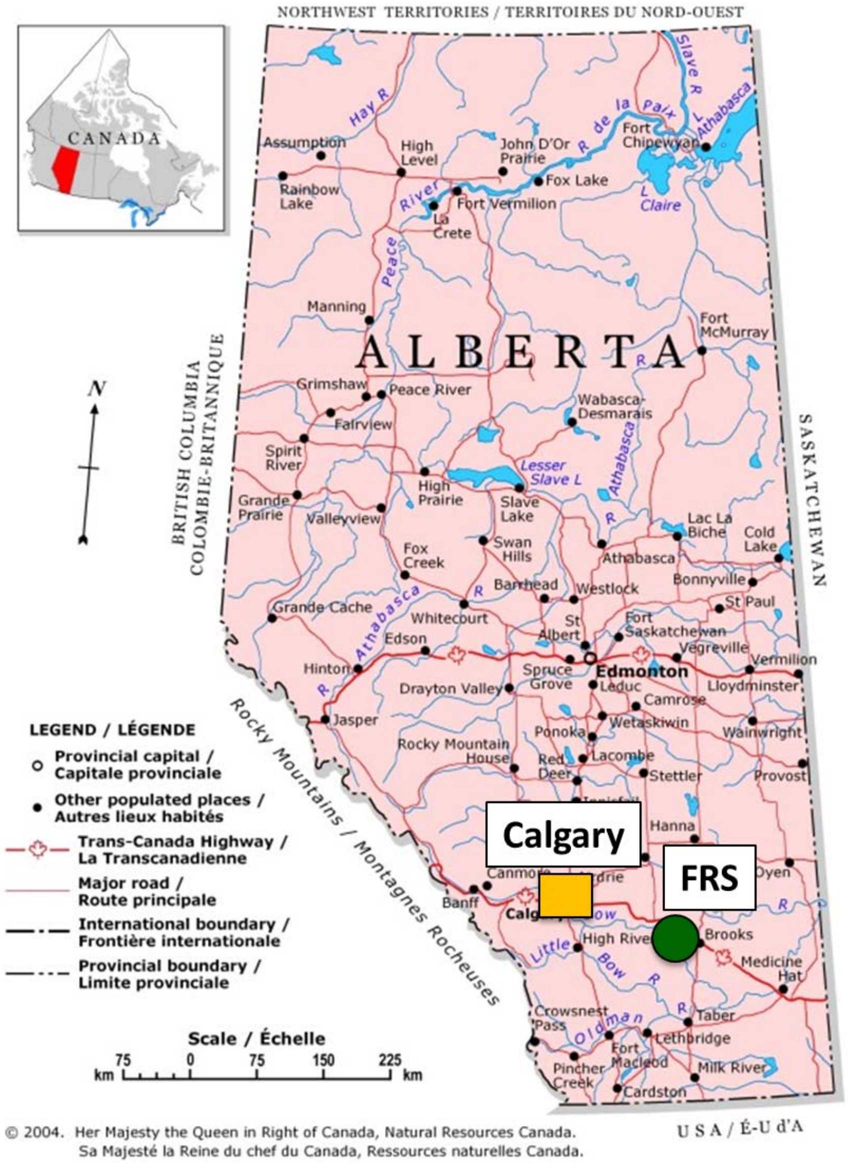
Verification of conformance and containment

- Thin reservoirs (saturation-thickness)
- Resolution, tuning
- High rock matrix K and μ values
- Cap rock integrity - how
- Fluid migration through legacy wells
- Impacts on groundwater
- Pressure vs. gas saturation

Seismic monitoring advances

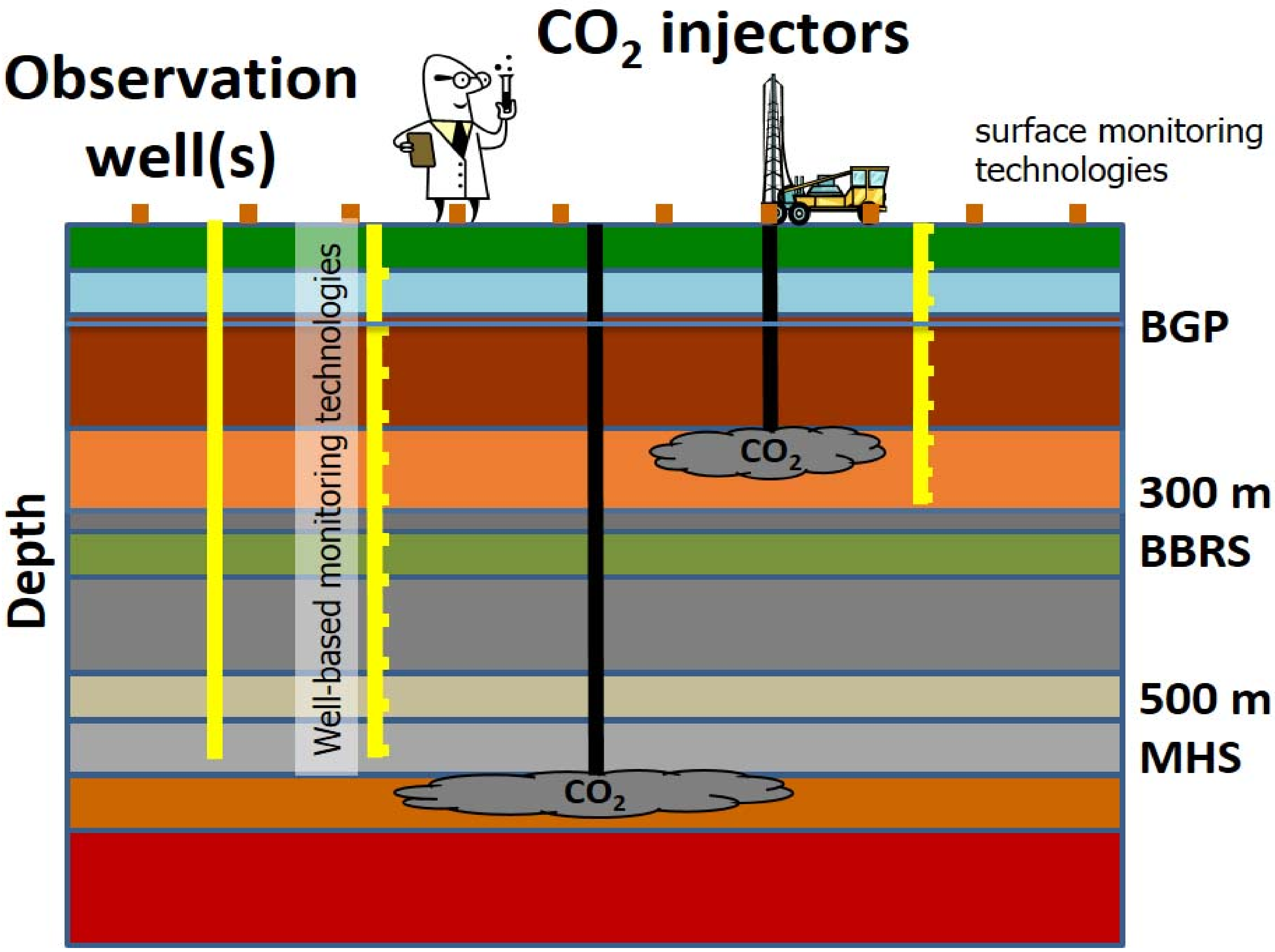
- Multicomponent seismic volumes
- Sensors close to reservoir
- Robust and slim sensors
- Repeatable seismic source
- Continuous seismic recording (passive)
- Continuous seismic recording (active source)
- Rapid response to trigger event
- Temporally unaliased geological processes (high repeat rate)

CaMI Field Research Station



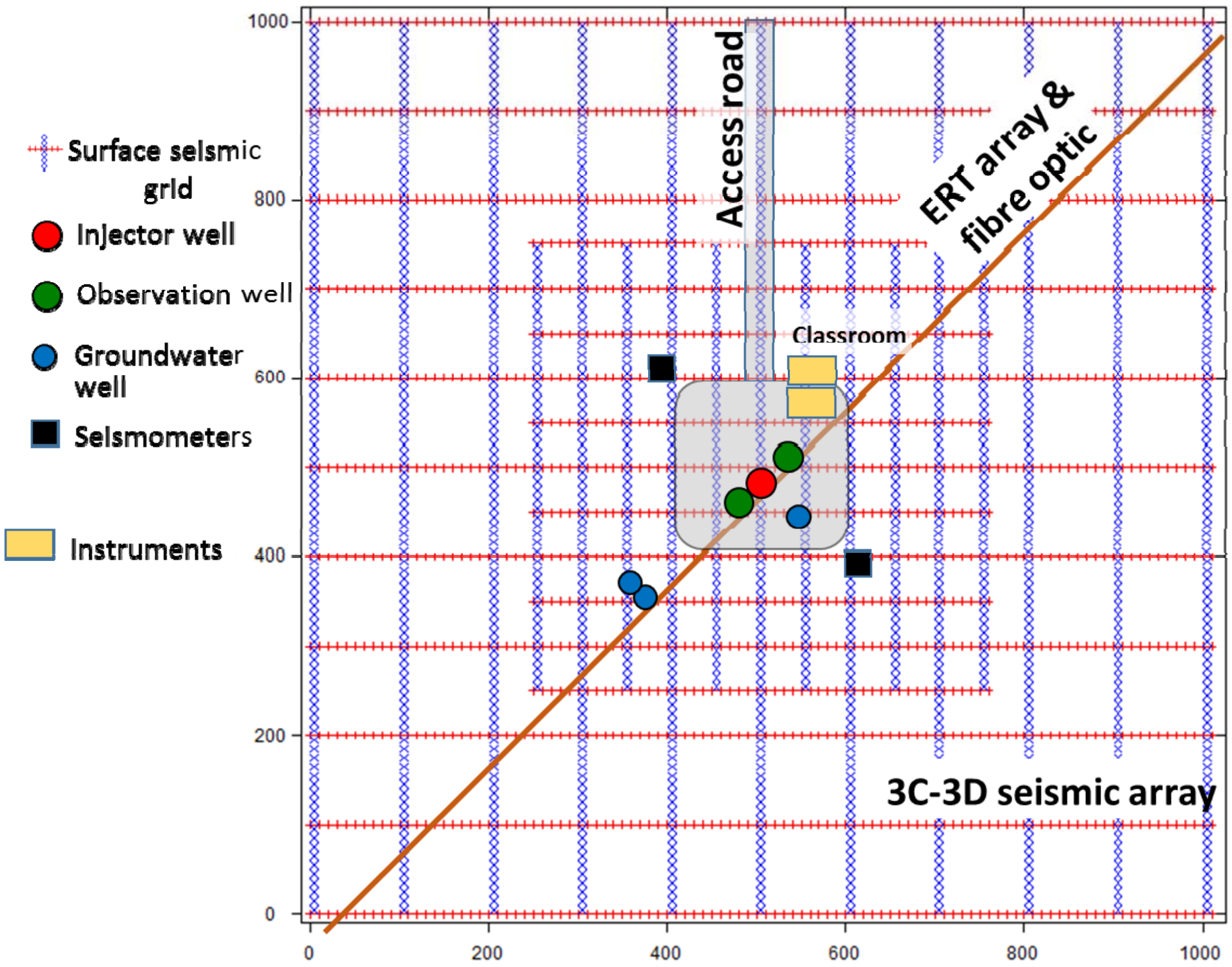
Land leased from Cenovus Energy

CaMI Field Research Station



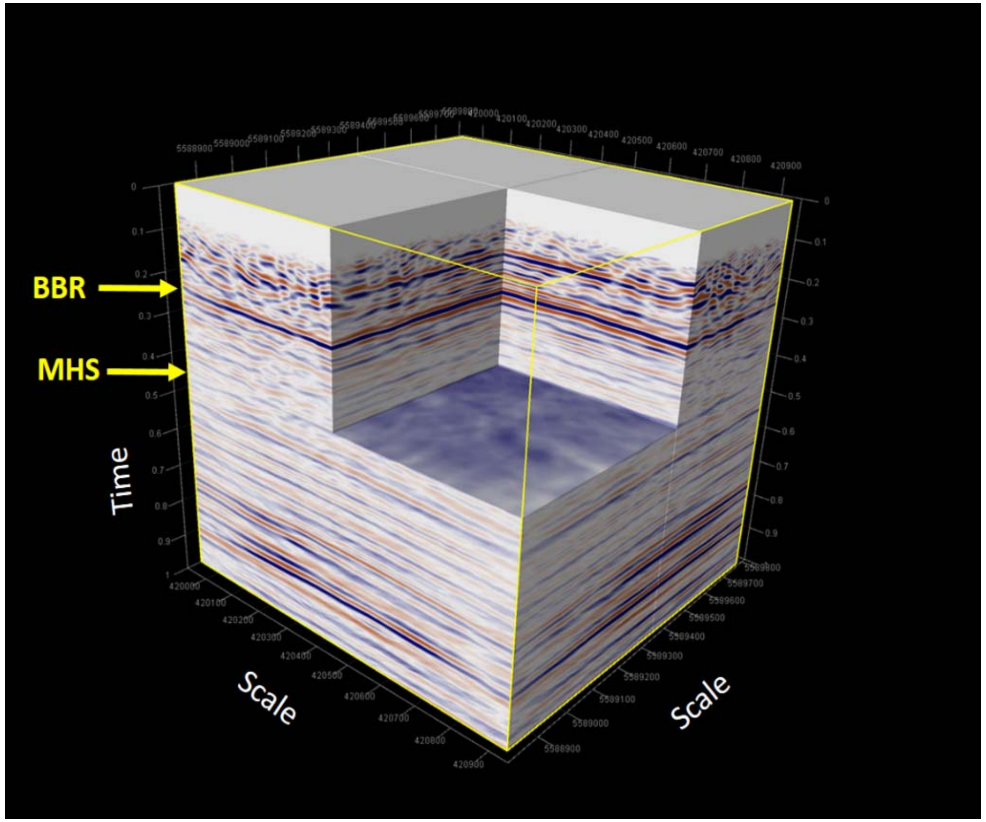
- BGP : Base of Groundwater Protection
- BBRS : Basal Belly River Sandstone
- MHS : Medicine Hat Sandstone

Field monitoring layout at the Field Research Station

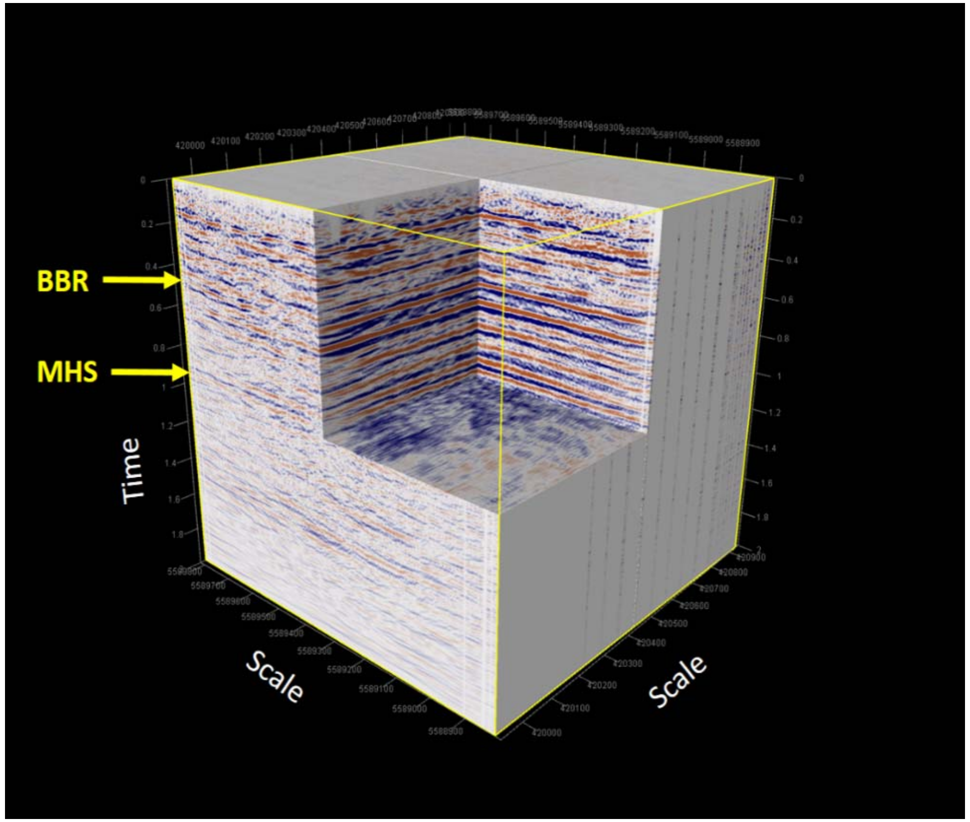


CaMI.FRS multicomponent seismic volumes

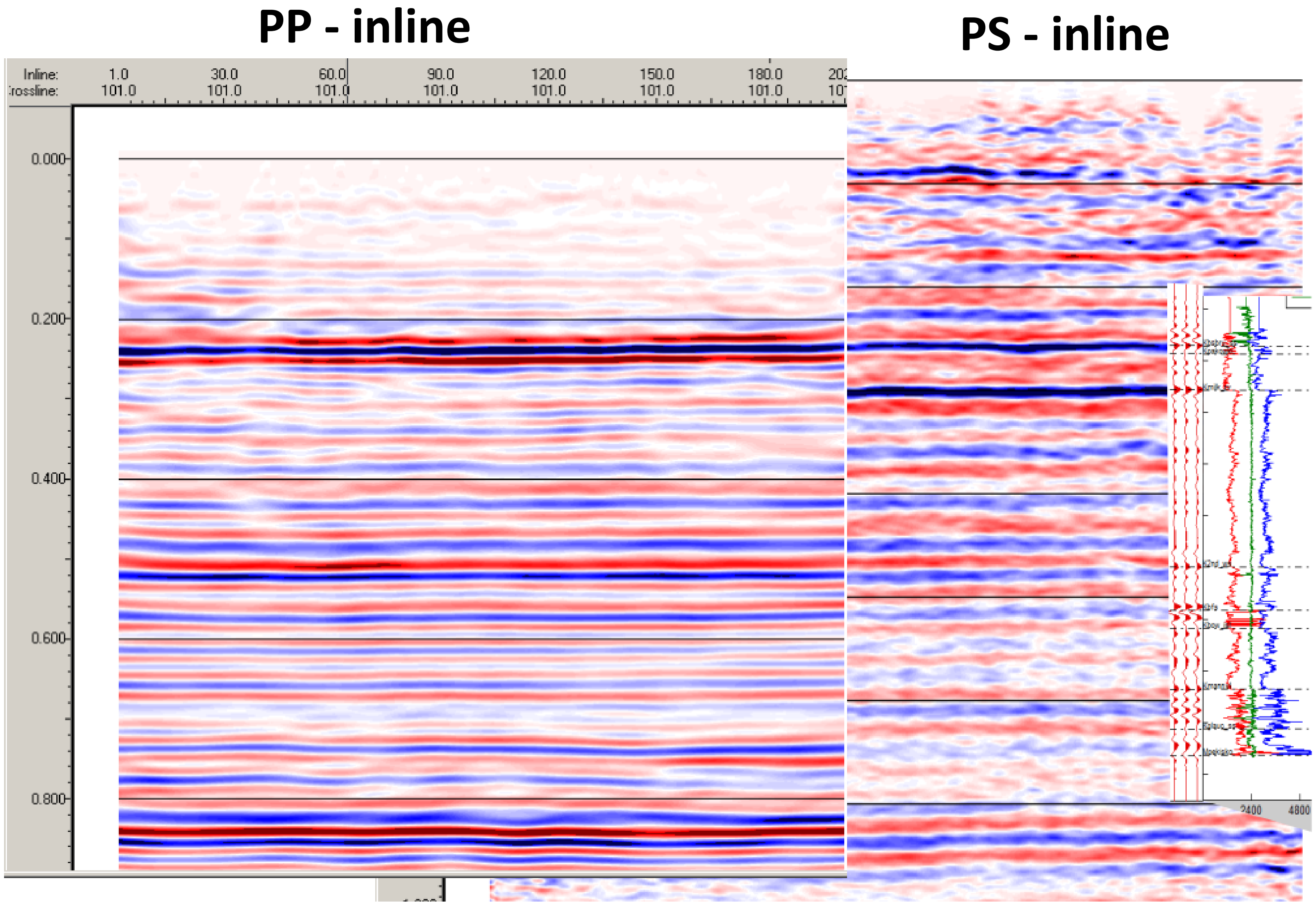
PP



PS



CaMI.FRS PP-PS correlation



Helen Isaac

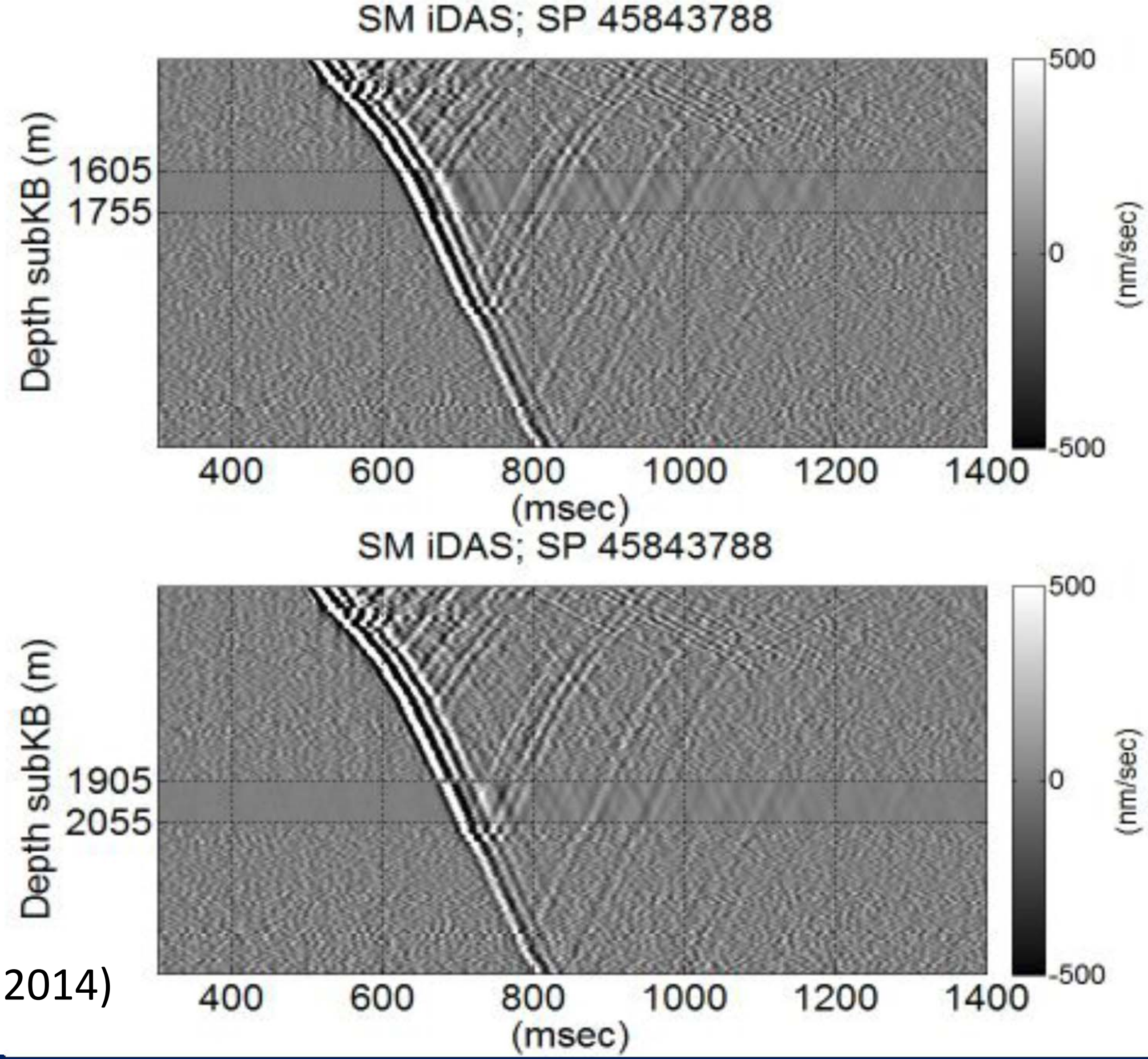
Borehole sensors

3C geophone

DAS

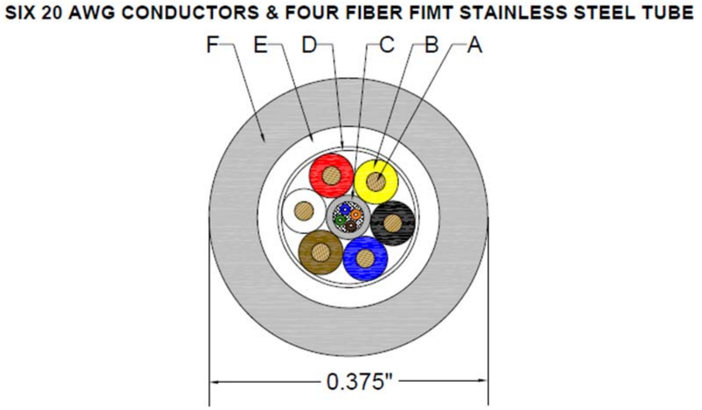
Tom Daley
Barry Freifeld
LBNL

DAS versus geophones



(after Daley, 2014)

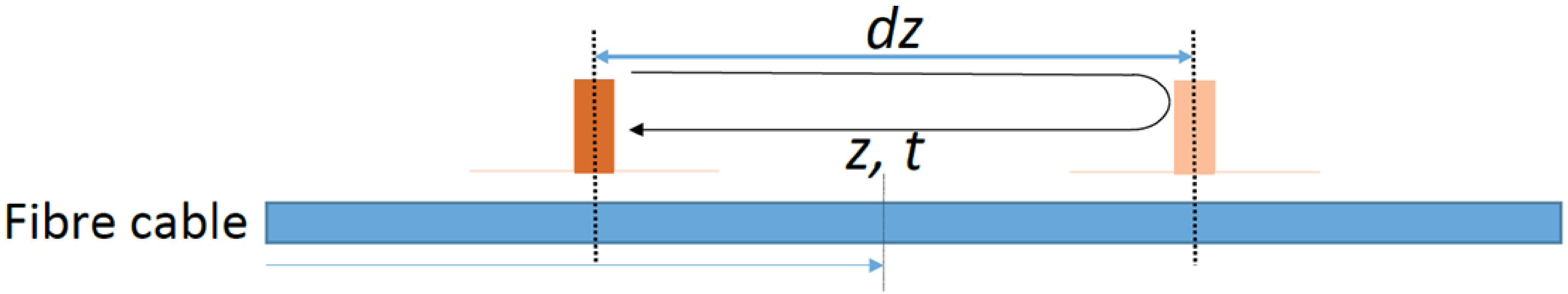
Combined DTS, Heater, DAS
Hybrid copper/fiber-optic cable



Components

- A: 6 x 20 AWG 7/28 Tin Coated Copper; O.D.: 0.96 mm (0.037") Nominal
- B: Colored T-01 (FEP); O.D.: 1.73 mm (0.068") Nominal;
- C: 316L FIMT containing gel and 2 x 50/125 & 2 x SM HT Acrylate Coated Fibers; O.D.; 1.8 mm
- D: PTFE Tape (0.003" Thickness) Wrap over Cabled Core
- E: White P-06; O.D.: 7.75 mm (0.305") Nominal
- F: 316L Stainless Steel Tube; Wall Thickness: 0.89 mm (0.035"); O.D.: 9.53 mm (0.375") Nominal

Optical fibre developments



fibre elongation at location z and time t, u(z,t), is measured over a reference distance dz

time difference (t, t + dt) of elongation spatial difference (dz)

$$\left[u\left(z+\frac{dz}{2},t+dt\right)-u\left(z-\frac{dz}{2},t+dt\right)\right]-\left[u\left(z+\frac{dz}{2},t\right)-u\left(z-\frac{dz}{2},t\right)\right]$$

Courtesy Tom Daley
LBNL

Optical fibre developments

Standard single mode fibre

Helical wound fibre

Barry Freifeld
LBNL

Australian Otway Project images courtesy of LBNL, Curtin University and the CO2CRC

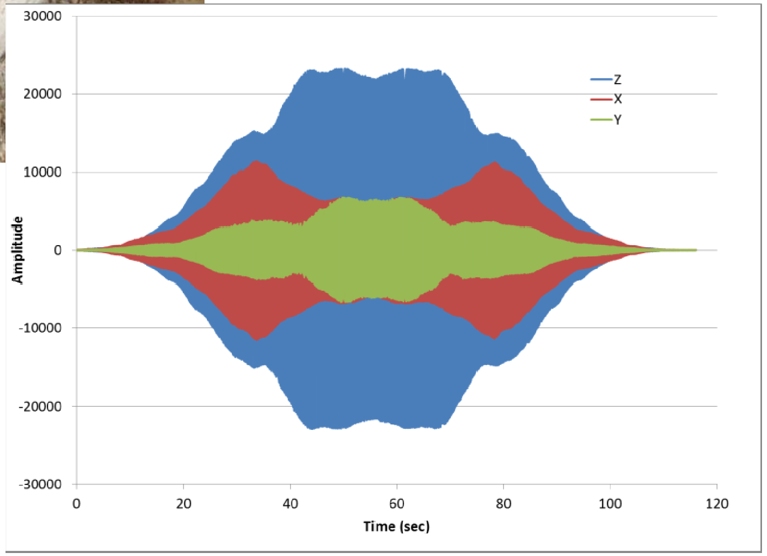
ACROSS continuous seismic source

Courtesy
Mamoru Takanashi
JOGMEC

LBNL continuous source: 0 – 80 Hz

10 T-force rotary source sitting on a 1 m x 2 m x 2 m deep foundation

$$F = Mr\omega^2$$

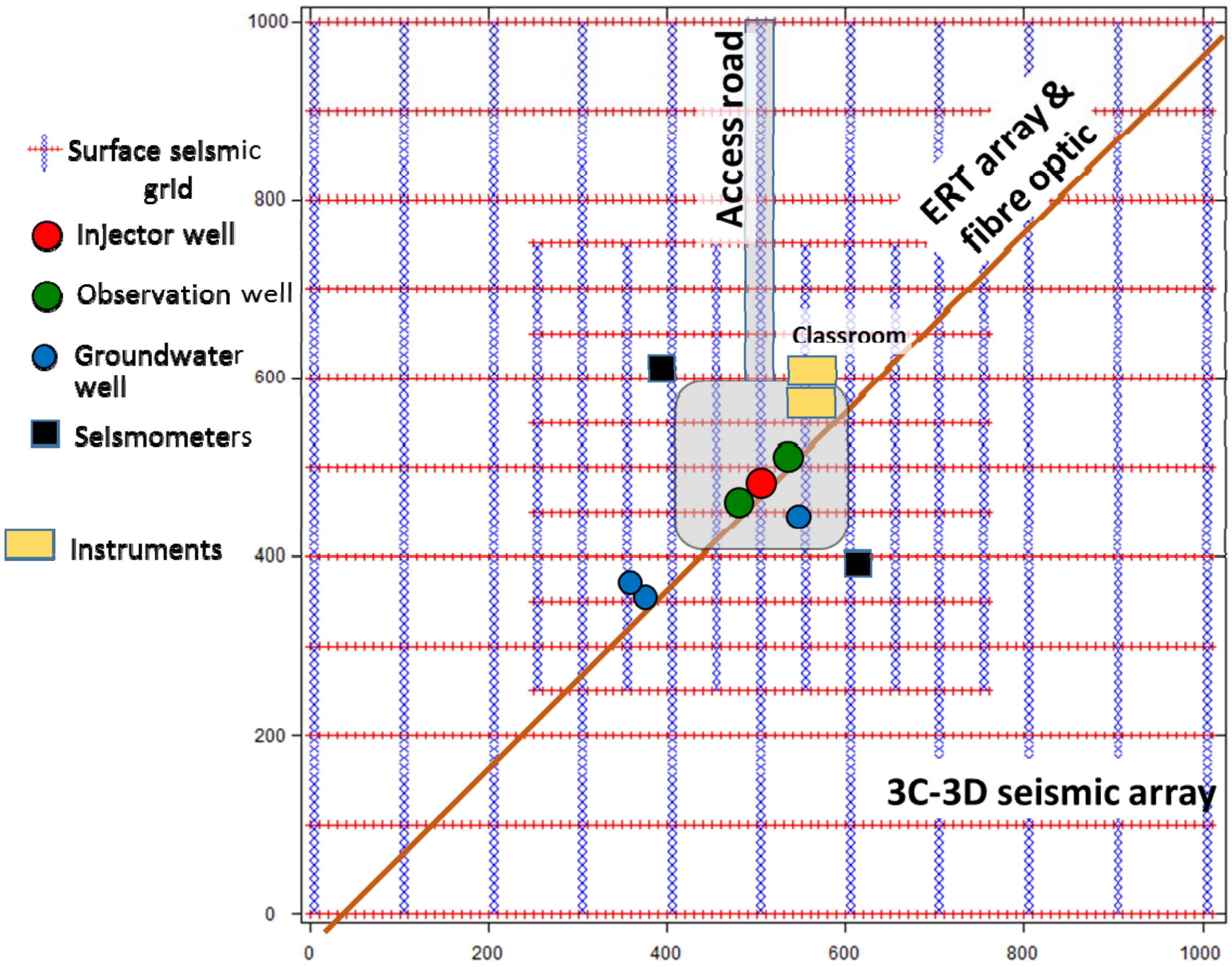


Reference geophone amplitude during a 0-80 Hz sweep, 1 minute up, 1 minute down

Barry Freifeld
LBNL

Australian Otway Project images courtesy of LBNL, Curtin University and the CO2CRC

Field monitoring layout at the Field Research Station



Conclusions

- We need a multiphysics approach to invert for more then velocity and density (or moduli).
- We need snapshots often enough to monitor all of the changes in the reservoir and cap rock
- Ideally we would like semi-continuous acquisition, which will require permanent sources and receivers for active-source methods
- We need permanent, robust, small sensors that preserve integrity of the geology
- How do we deal with ‘big data’?
- Our plan is to evaluate these approaches at the FRS

Acknowledgements

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