Structurally controlled geothermal systems in southeastern British Columbia

Theron Finley

Martyn Unsworth, Stephen Johnston, Jonathan Banks

Dept. of Earth & Atmospheric Science, University of Alberta

UNIVERSITY OF ALBERTA FUTURE ENERGY SYSTEMS

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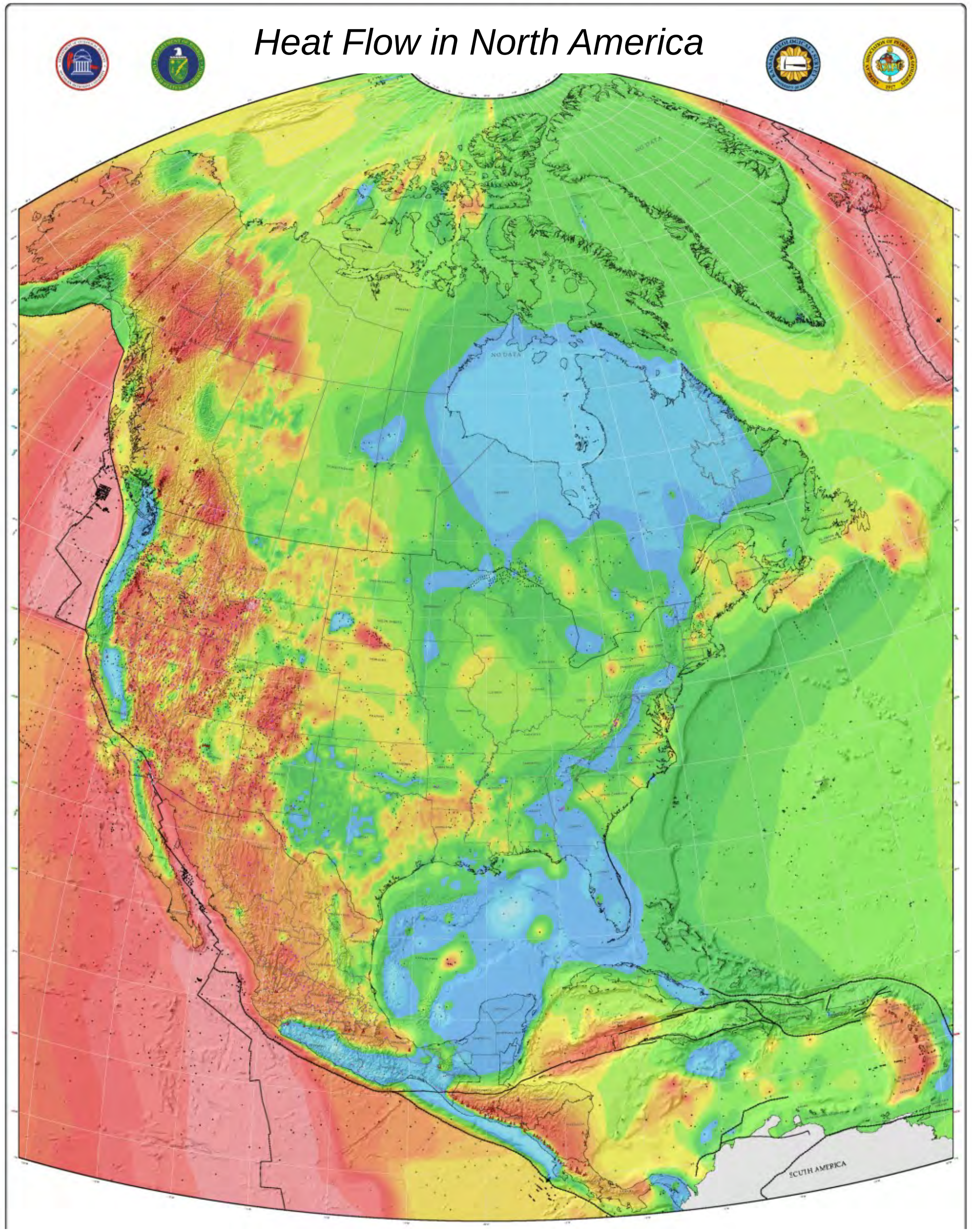
Fault plane with slickenlines plunging ~40°

Geothermal energy in Canada

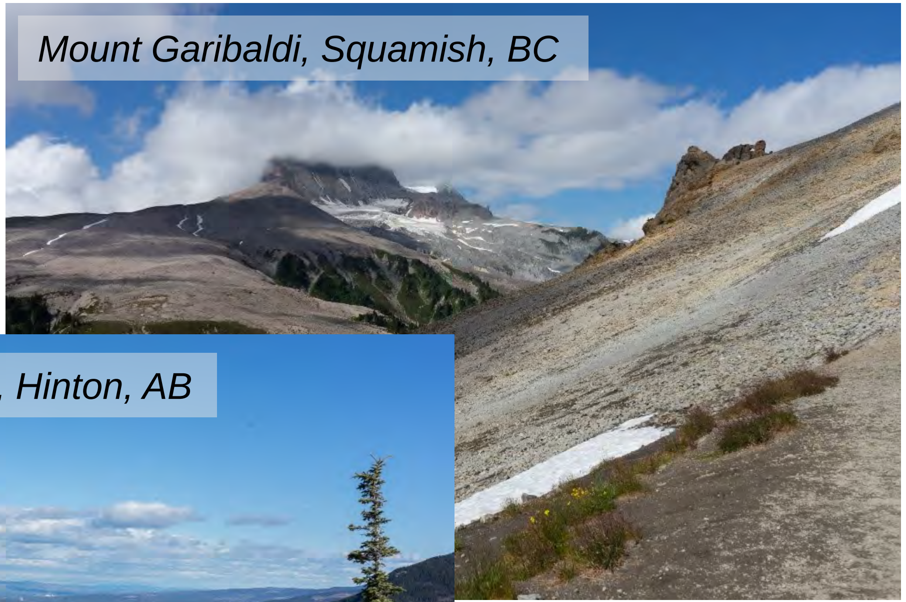
- Currently no existing geothermal plants, but there is a recent surge of exploration and research activity.
- Western Canada is prospective due to elevated heat flow, steep geothermal gradients, etc.
    - Similar values to western US – 100mW/m^2
- Why no geothermal in Canada?
    - Socioeconomic and regulatory factors.
    - Geological uncertainty is a big risk; drilling wells is expensive.
- Need to employ geological, geophysical, and geochemical methods to predict, find, and characterize geothermal resources in Canada.

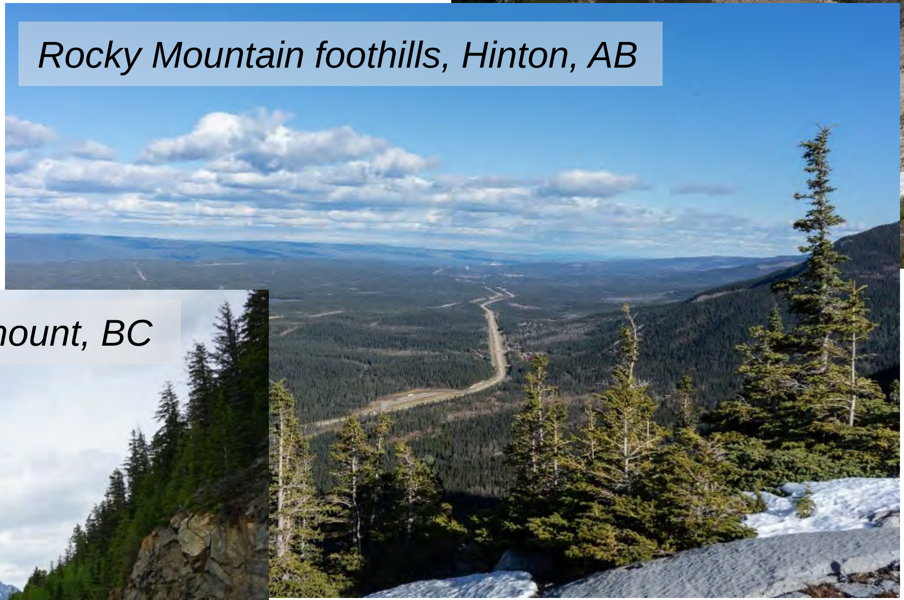


Blackwell and Richards (2004)

Geothermal resource types in western Canada

- Volcanic
- Sedimentary
- Fault-hosted

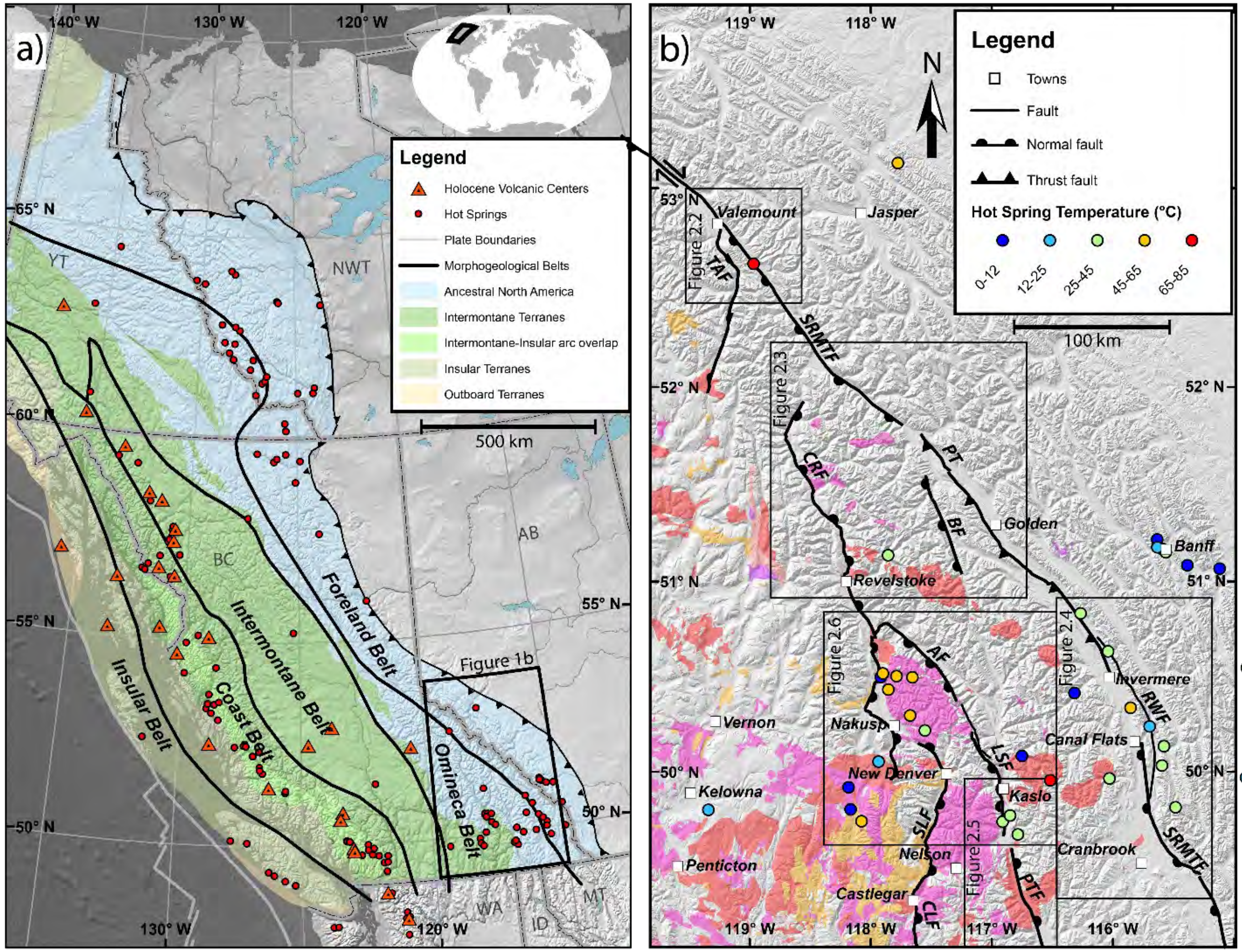

Mount Garibaldi, Squamish, BC


Rocky Mountain foothills, Hinton, AB


Rocky Mountain Trench fault, Valemount, BC

Structurally-controlled geothermal resources in Southeastern BC

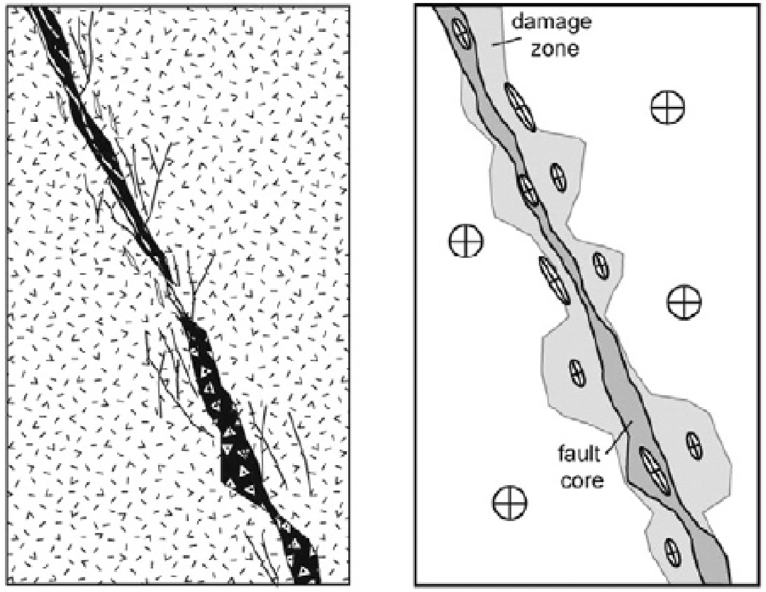
- Southeast BC has high heat flow, numerous hot springs.
- No active volcanism, but plutons have been shown to have high radioactive heat generation.
- Grasby & Hutcheon (2001) speculated that several major faults control the location of hydrothermal systems.

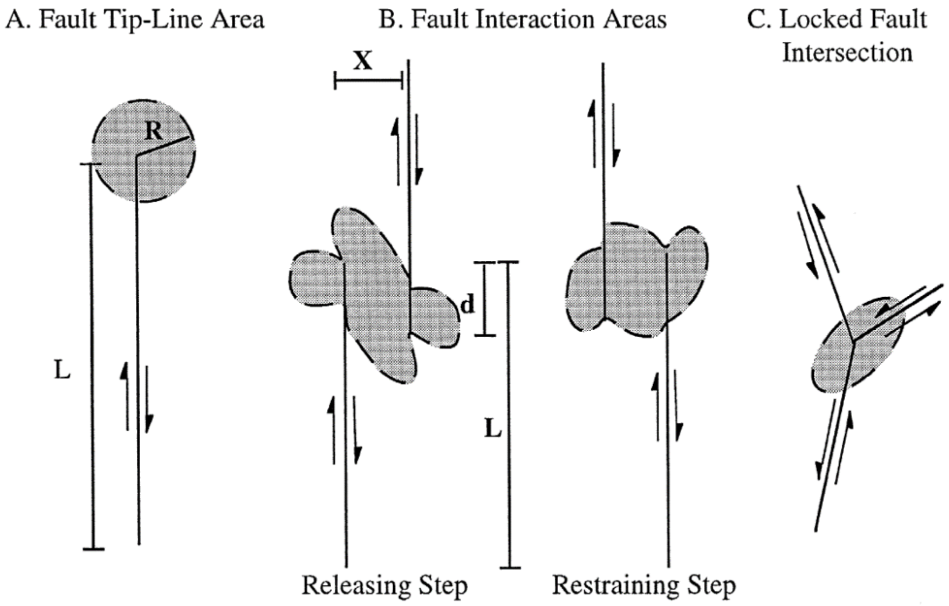


Fault-zone hydrogeology

- Faults often very permeable along the fault plane, and impermeable across.
- Play a significant role in directing groundwater flow.
- Factors that may influence the permeability of faults include:
    - **Age** – Active faults maintain permeability.
    - **Kinematics** – fluids flow in the direction of medium stress.
    - **Stress orientation** – faults oriented for slip or dilation are more permeable.
- Some structural settings are more favourable for hydrothermal upwelling.

Permeability structure of fault zone (Bense et al. 2013)





Favourable structural settings (Curewitz and Karson, 1997)

Structural Fieldwork

- Focused on major fault zones:
  - Columbia River fault
  - Slocan Lake fault
  - Purcell Trench fault
  - Southern Rocky Mountain Trench fault

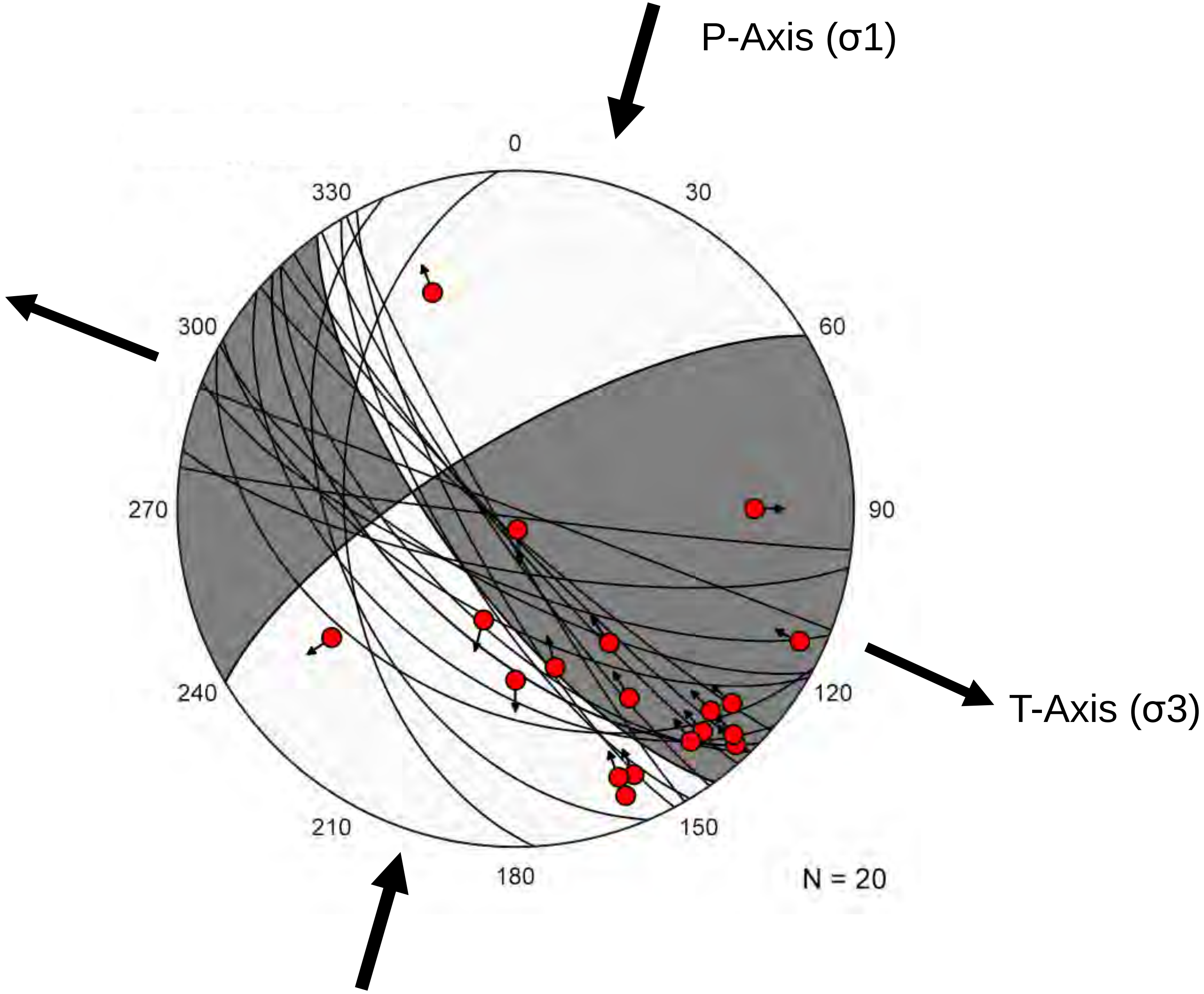
- Specifically looked for kinematic indicators (e.g., slickenlines) and age constraints (e.g., cross-cutting).

- Road cuts and lakeshores in fault zones were most useful.

Fault plane with slickenlines plunging ~40°

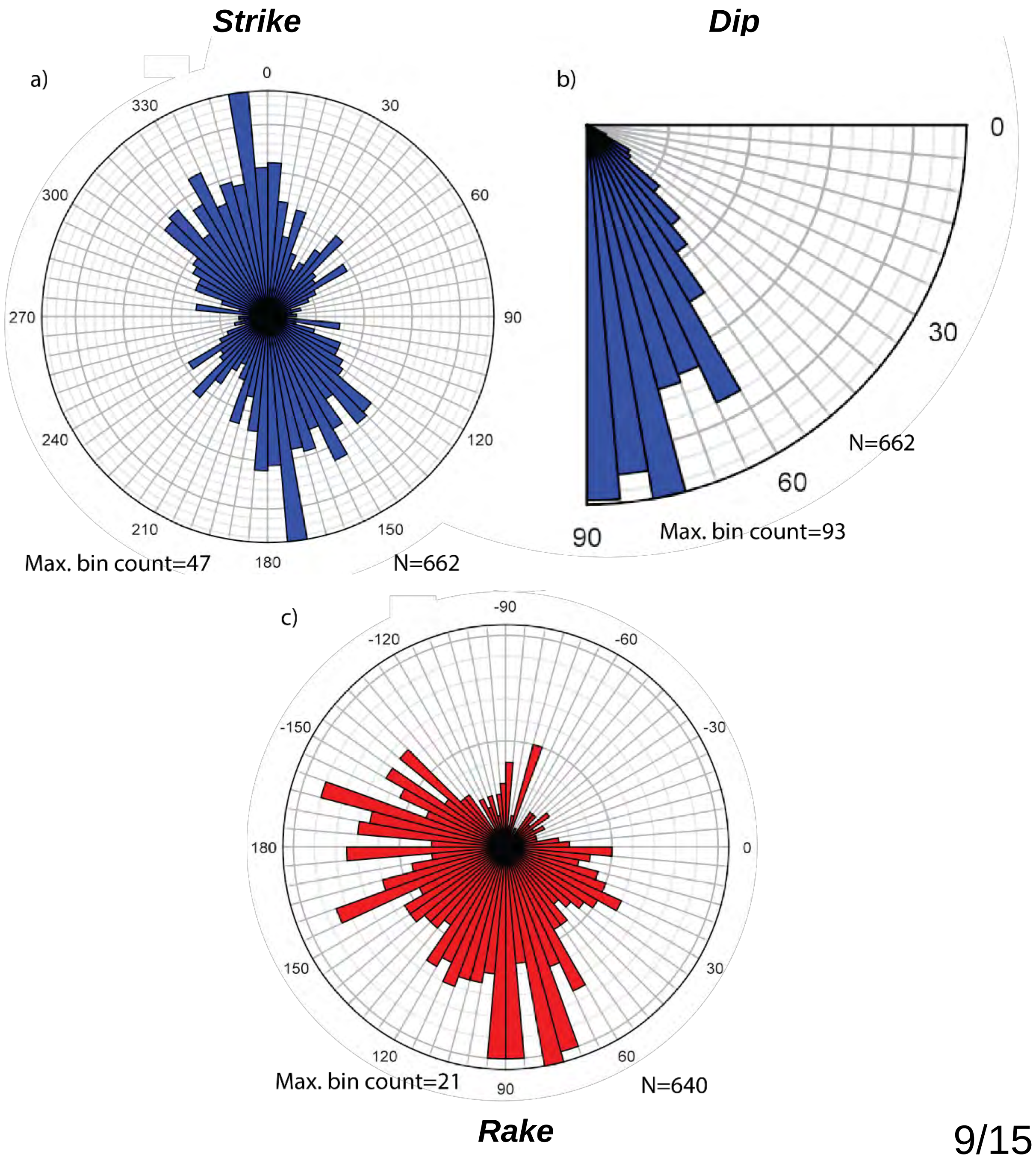
Dextral slickenlines

Beach balls



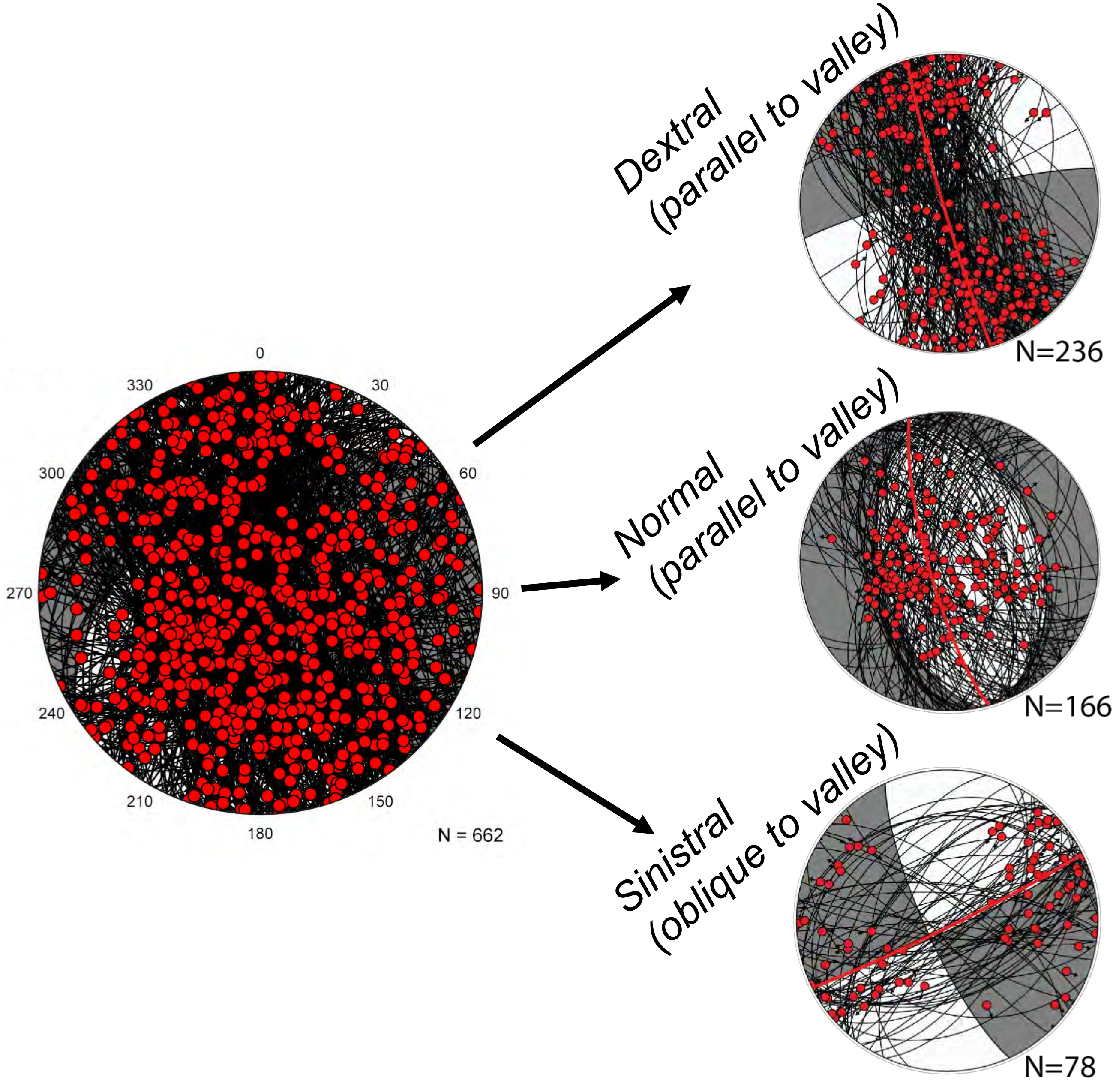
Kinematic Analysis I

- Collected 662 kinematic indicators
    - Majority on faults striking NNW-SSE and dipping >60°
    - Two populations: normal and dextral



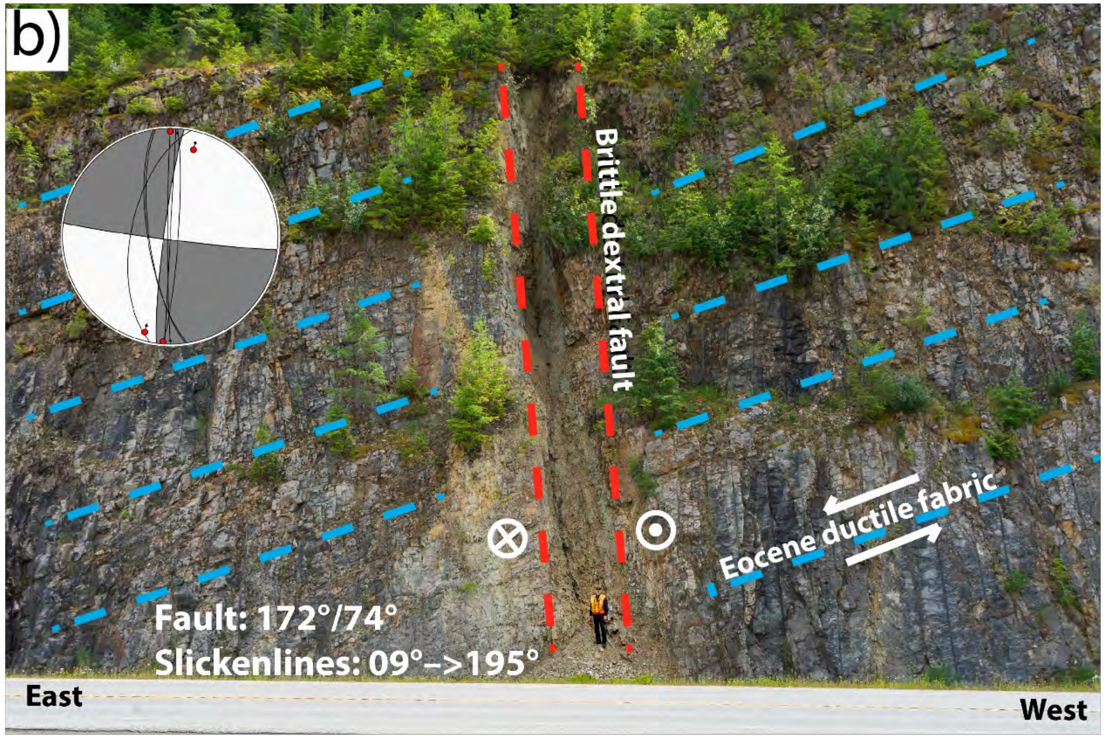
Kinematic Analysis II

- Separated faults oriented at low angles (parallel) to valleys from those at high angles (oblique).
- Filtered into sets with similar kinematics.
- Dextral faults are largest population of valley-parallel, followed by normal faults.
- Notable population of sinistral faults at high angle to valleys.

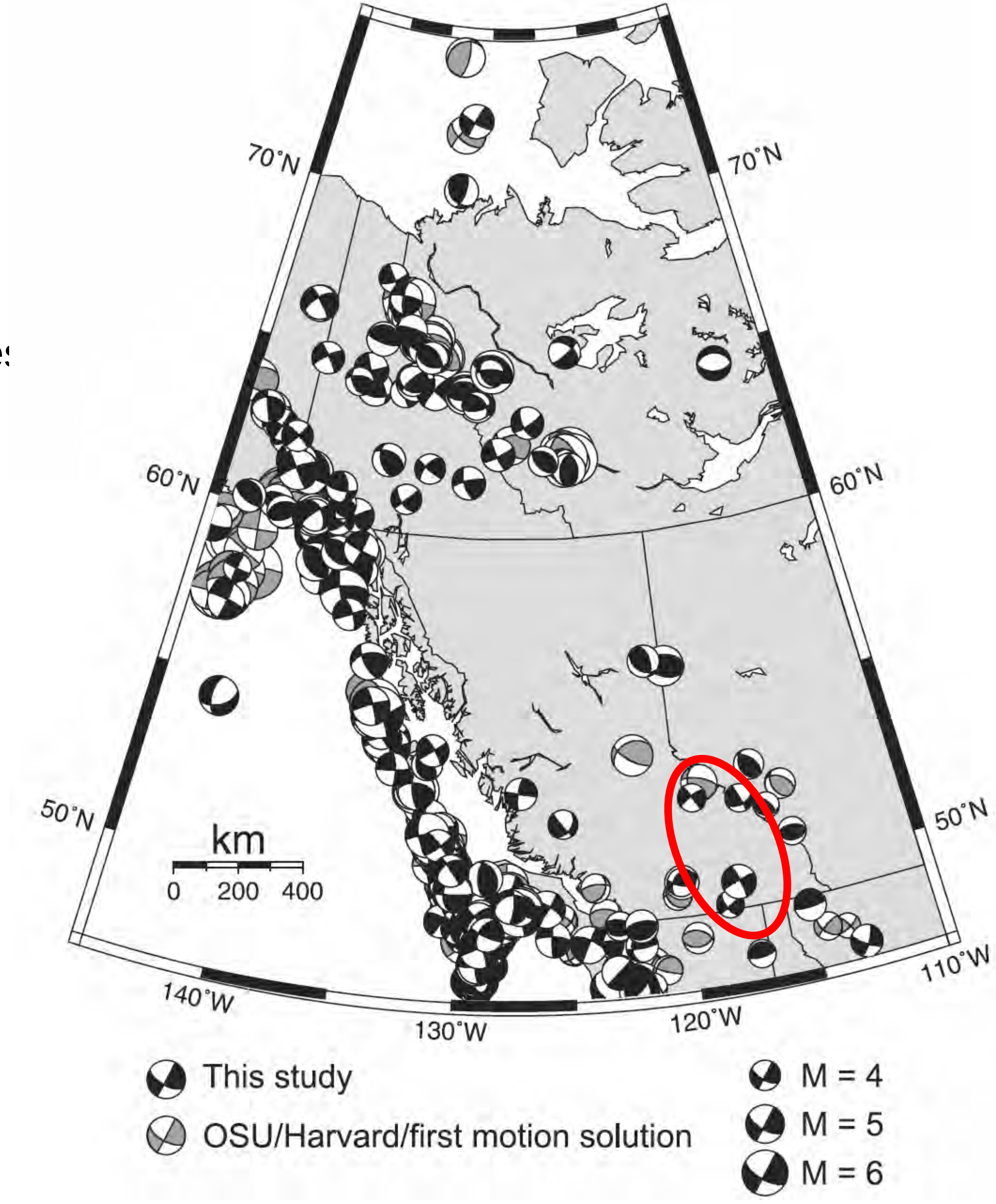


Fault Age and Stress State

- There are more dextral faults than normal faults.
- Cross-cutting relations suggest post-Eocene age.
- Fault beachballs and earthquake focal mechanisms are aligned – sugges dextral faulting is ongoing.



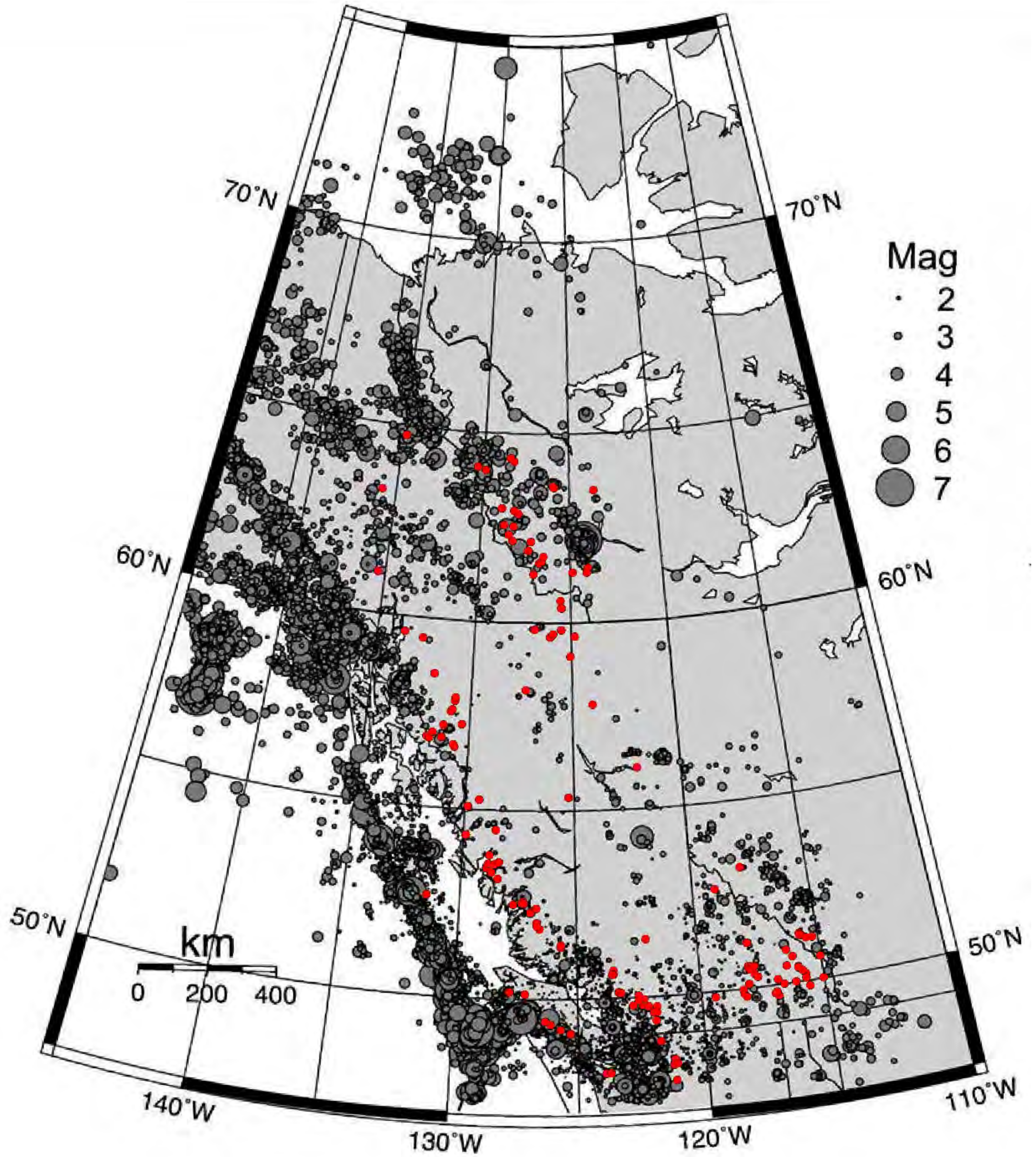
EQ focal mechanisms in SE BC (Ristau et al. 2007)



Thermal spring localization: regional controls

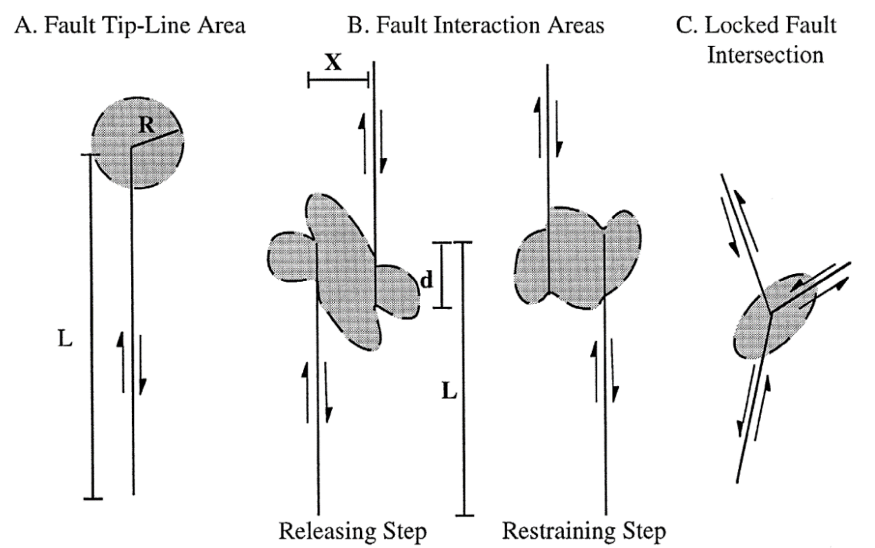
- Regionally, the clusters of thermal springs correspond to clusters of seismicity in western Canada.
- Seismicity is likely important in maintaining fault permeability.

EQ epicentres and thermal springs (after Ristau et al. 2007)

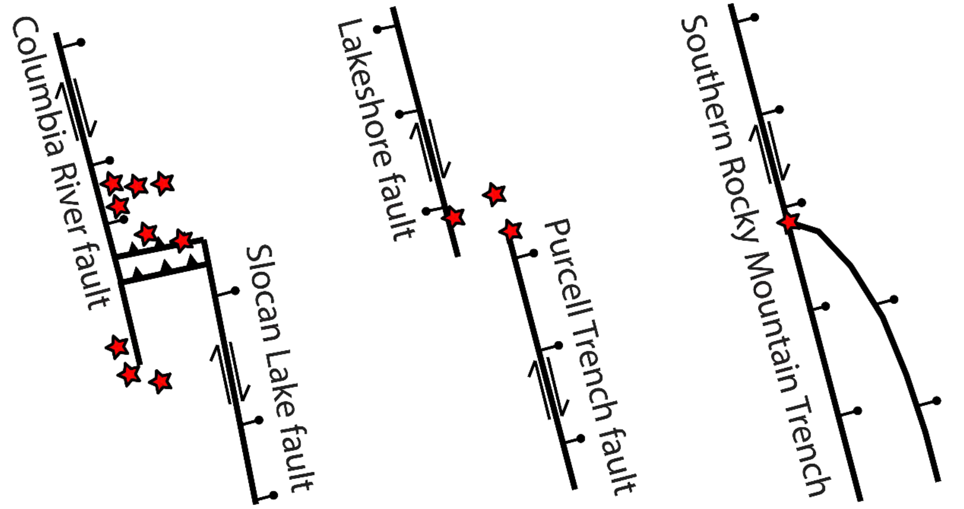


Thermal spring localization: local controls

- Dextral kinematics help understand spring locations along faults.
- Curewitz and Karson (1997) showed that in actively deforming regions, fault permeability is higher at strain-concentration zones.
- Springs in SE BC occur at fault tips, restraining steps, and fault intersections.



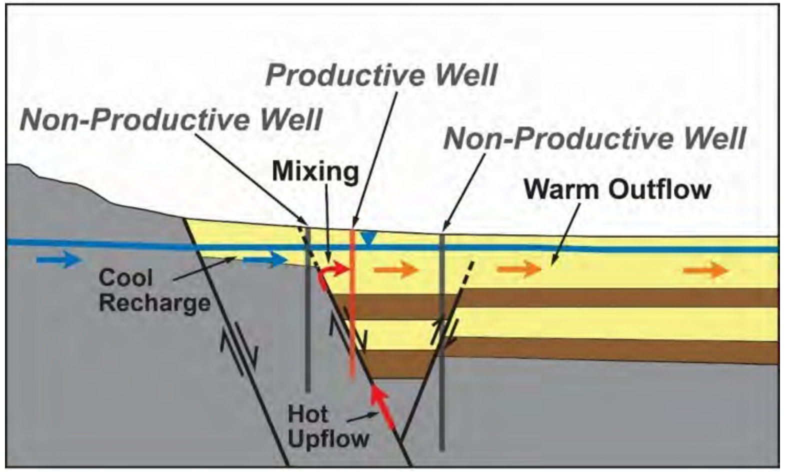
Curewitz and Karson (1997)



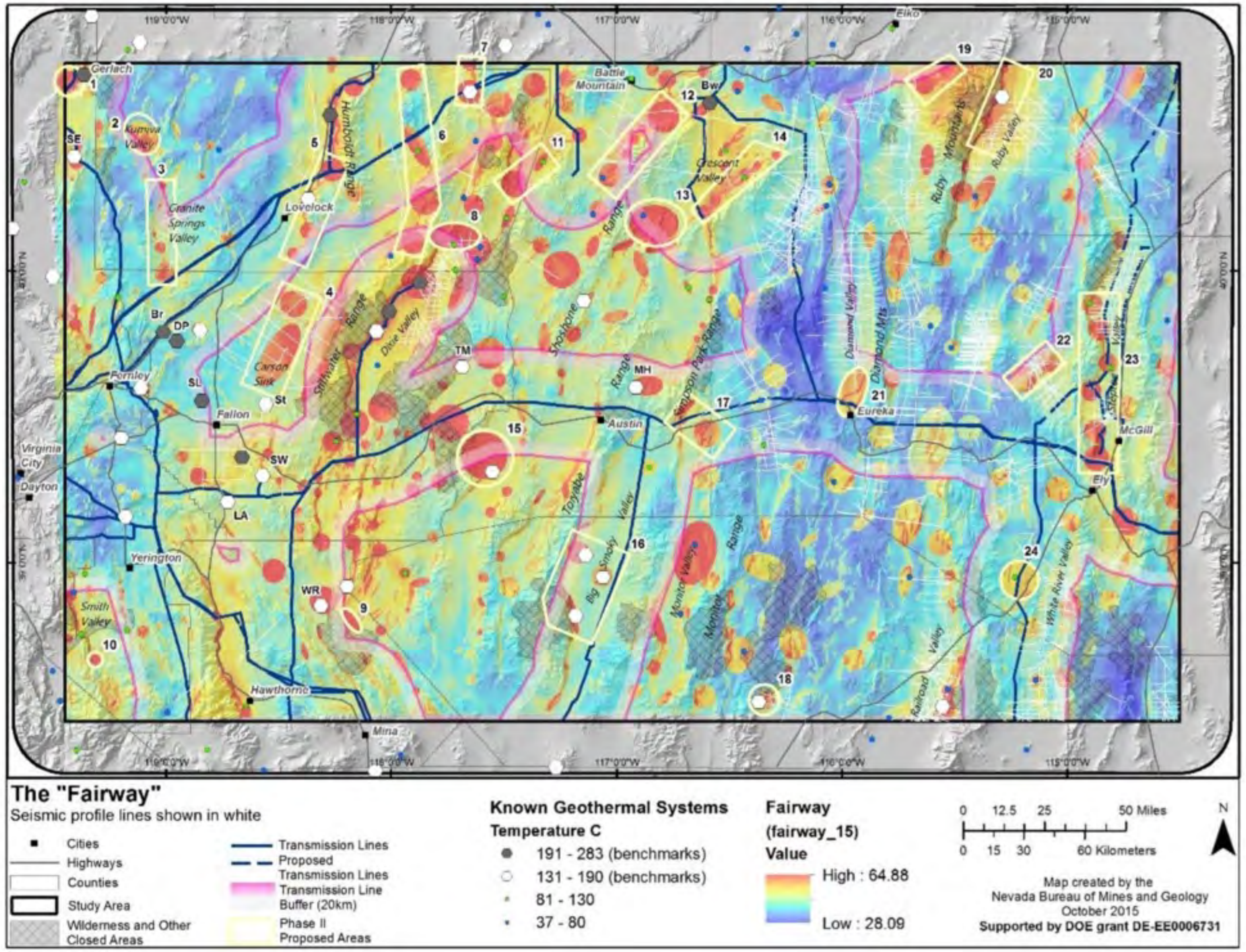
Structural settings of thermal springs in southeastern BC

Predictive mapping of blind geothermal systems

- Blind geothermal systems have no surface expression.
- Structural geology may be used to predict the location of blind geothermal systems.



A blind geothermal system (Richards and Blackwell, 2002)



Play-fairway analysis incorporating favourable structural settings for geothermal upwellings (Faulds et al., 2016)

Conclusions

- The major fault zones in southeaster BC show evidence of dextral slip.
- This phase of kinematics is related to the current stress field and active seismicity.
- On a regional scale, hydrothermal systems are associated with seismicity
- Locally, springs occur near fault tips, step-overs, and intersections.
- This insight may help predictively map blind geothermal systems

Southern Rocky Mtn. Trench near Valemount, BC