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Post-Eocene kinematics of faults that host potential geothermal systems in southeastern British Columbia

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Summary

A concentration of thermal springs with outlet temperatures ranging from 20-80˚C occurs in southeastern British Columbia (Woodsworth and Woodsworth, 2014), and is an attractive target for geothermal energy exploration. There is no active or Quaternary volcanism in the immediate vicinity (within 100s of km), and yet the crustal heat flow in this region is relatively high (~80-100 mW/m^2; Davis and Lewis, 1984; Majorowicz and Grasby, 2010). The thermal springs in this region occur in association with several major fault zones, which may permit deep circulation of fluid through fractured reservoirs (Grasby and Hutcheon, 2001). Here, we present new data from structural mapping of these fault zones (Columbia River fault, Slocan Lake fault, Purcell Trench fault, Southern Rocky Mountain Trench fault, and Redwall fault). Our datasets of fault plane and slickenline orientations suggest a recent, post-Eocene phase of dextral strike-slip faulting not previously identified by regional mapping. The NNE-SSW stress field required for these kinematics is similar to the present-day stress field derived from crustal earthquake focal mechanisms. Future geothermal exploration efforts in this area should focus on fault segments oriented favourably for slip and dilation within this stress field.

Theory / Method / Workflow

Hydrothermal systems (i.e. thermal springs) in the Canadian Cordillera are spatially associated with major fault zones (Grasby and Hutcheon, 2001). In other fault-hosted geothermal systems (e.g., Great Basin, Rhine Graben), hydrothermal circulation has been shown to correspond to zones of enhanced permeability caused by high fracture density, localized extension, and/or active slip and dilation (Faulds et al., 2011; Meixner et al., 2016). Thus, the current stress state of the crust and resulting fault kinematics can predict which fault segments are most permeable; faults oriented parallel or oblique to S_{Hmax} (maximum horizontal compression) are more likely to be permeable than those oriented at a high angle to S_{Hmax}. Furthermore, there is a positive relationship between strain rate and fault permeability – seismic activity has been shown to maintain fault permeability via episodic refracturing of minerals precipitating within the fault zone (Curewitz and Karson, 1997).

Our new structural data includes hundreds of orientation measurements of fault planes and slickenlines at roadside outcrops and on shorelines of lakes in fault-occupied valleys. Most fault exposures are assumed to be subsidiary splay faults of the main fault zones, which are often covered by lakes or thick glacial overburden. Care was taken to avoid mistaking Riedel shears for the more diagnostic mineral growths on the lee side of fault plane asperities. Where possible, cross-cutting relationships were documented in order to constrain the relative timing of deformation. Measurements were used to define coherent structural domains and plotted on equal-area stereoplots using Orient software (Vollmer, 2019). Beach ball plots were generated from the average kinematics of each set of structural measurements and compared to the focal mechanisms and stress orientations of earthquakes in the study area (Rogers et al., 1980; Ristau et al., 2007).

Results, Observations, Conclusions

Our regional-scale investigation of the structural settings of hydrothermal systems in southeastern BC has revealed a consistent pattern of dextral kinematics on brittle sub-vertical fault planes coincident with the surface traces of faults previously mapped as Eocene and Jura-Cretaceous in age; brittle dextral kinematic indicators are a common feature at exposures of the Southern Rocky Mountain Trench, Columbia River, Slocan Lake, and Purcell Trench faults. The timing of this transpressional deformation is likely post-Eocene based on the cross-cutting relationships we observed in Eocene-aged rocks and the brittle nature of the kinematic indicators (i.e., slickenlines rather than mylonites). The NNE-SSW stress field required for these kinematics (Figure 1) is consistent with the focal mechanisms of several crustal earthquakes that have occurred in the region (Rogers et al., 1980; Ristau et al., 2007), suggesting that transpressional strain has persisted from the Eocene to recent. Faults oriented at 30-45° to S_{Hmax} are most likely to slip, thereby maintaining fault permeability. Likewise, fractures oriented parallel to S_{Hmax} are most likely to dilate and allow for fluid flow. Future geothermal exploration efforts in southeastern British Columbia should focus on fault segments oriented favourably with respect to the stress field.

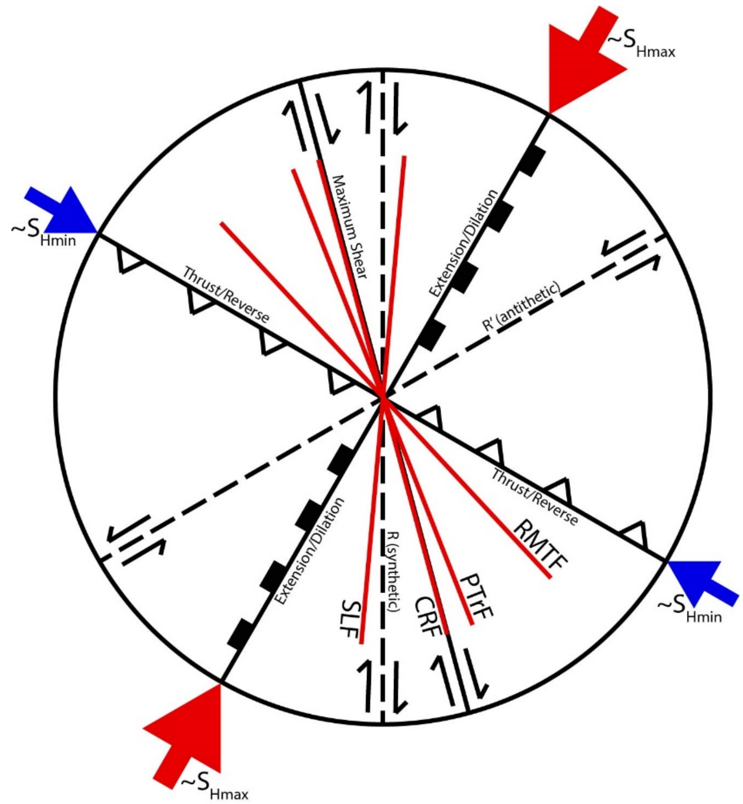

Figure 1. Strain ellipse for approximate S_{Hmax} orientation in southeastern BC (Ristau et al., 2007), and corresponding predicted modes of brittle deformation on faults and fractures. Average orientations of the Rocky Mountain Trench Fault (RMTF), Purcell Trench Fault (PTrF), Columbia River Fault (CRF), and Slocan Lake Fault (SLF), are shown for reference.

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