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Long-lived deformation recorded along the Precambrian Thelon and Judge Sissons faults, northeast Thelon Basin, Nunavut

Rebecca C. Hunter[1], Bruno Lafrance[2], Larry M. Heaman[3] and David Thomas

[1]British Columbia Geological Survey

[2]Mineral Exploration Research Centre, Harquail School of Earth Sciences, Goodman School of Mines, Laurentian University

[3]Department of Earth and Atmospheric Sciences, University of Alberta

Summary

The Thelon and Judge Sissons faults of south-central Nunavut are well-preserved, long-lived dextral transcurrent fault zones with complex reactivation and fluid flow histories. Three deformation events characterize these faults beginning with the ca. 1830 Ma to ca. 1760 Ma initial faulting event, followed by a ca. 1760 Ma to ca. 1750 Ma epithermal event, and a ca. 1600 Ma to ca. 1300 Ma late reactivation event(s). The late reactivation event(s) formed irregular, non-cohesive crackle to mosaic breccias and gouges, which became the primary pathways for hydrothermal fluid movement related to uranium mineralization.

Introduction

In this study we describe the formation of internal structures along two well-exposed, Paleoproterozoic faults named the Thelon and Judge Sissons faults, which formed in the hinterland regions of the Taltson-Thelon and Trans-Hudson orogenies. These faults are well-exposed at surface and their 3D geometry is constrained by multiple drill holes. The investigation into the age and tectonic history of the Thelon and Judge Sissons faults provides additional insights into how fractures, veins, and breccias formed and changed through time, eventually creating the conditions that drove and focused hydrothermal fluid flow during reactivation events.

Discussion

Several lines of evidence suggest that the ENE-trending Thelon and Judge Sissons faults initially formed as dextral transcurrent strike-slip faults. First, a large monzogranitic Hudson Intrusive Suite pluton is dextrally offset by up to 14 km along the two faults as shown on geological and airborne magnetic maps. Second, the strike and dip of the steeply-dipping WSW- to WNW-trending quartz veins and NNW- to NNE-trending sinistral fractures in the damage zone of the Judge Sissons fault, are consistent with their formation as extensional veins parallel to the shortening direction and antithetic Riedel (R’) shear fractures, respectively, during dextral strike-slip faulting. Finally, the shallow rake of slickenlines along slip surfaces in the fault core zones, and the asymmetry of slickenline-parallel trailed material and cross-cutting steps, are further indicative of dextral transcurrrent movement. Faulting produced breccias and cataclasites that acted as pathways for the infiltration of fluids, the formation of quartz veins, and pervasive hematization in the damage zone and core zone of the faults (Figs. 1a, b). Continued movement along the faults fractured and fragmented the veins and breccias and resulted in the development of complex, multi-generational, cross-cutting quartz veins and breccias (Fig. 1c). The formation of the faults is bracketed between ca. 1830 Ma, the crystallization age of the monzogranite pluton, and ca. 1760 Ma, the age of Wharton Group magmatism.

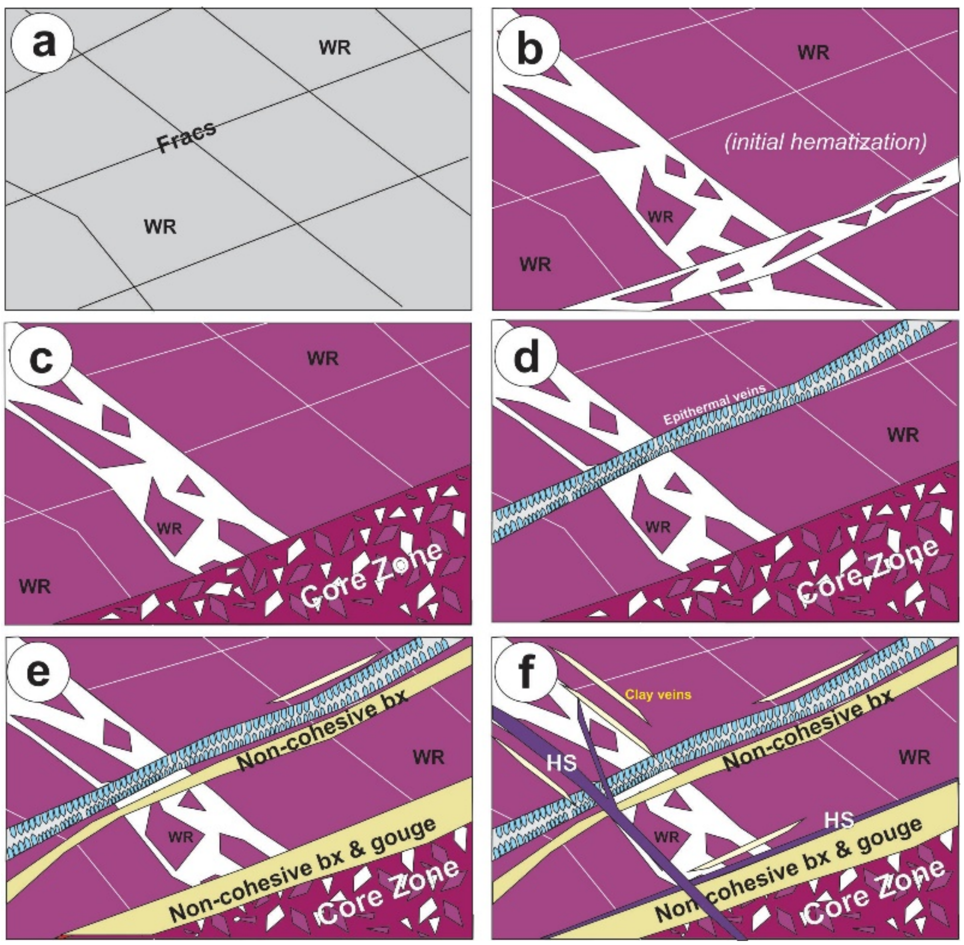

Fig. 1: Paragenetic overview of the different quartz and breccia events related to movement along the Thelon and Judge Sissons faults: (a) initial faulting event - early fracturing and the start of the damage zone; (b) initial faulting event - vein infill of early fractures, early pervasive maroon hematite alteration and subsequent creation of quartz crackle breccias; (c) initial faulting event - ongoing fault movement led to the development of the core zone proto- to mesocataclasites; (d) epithermal event - quartz veining event with comb, crustiform, cockade and bladed textures; (e) late reactivation event - creation non-cohesive fractures, breccia and gouge along the margins of and nearby older fault structures; and (f) late reactivation event - emplacement of specular hematite (HS) and clay veins along and within the fault rocks outside of the main pervasive clay and specular hematite alteration envelope surrounding nearby uranium mineralization.

The upflow of hydrothermal fluids along the two faults resulted in the development of breccias and veins with upper crustal level textures similar to those described for epithermal (epizonal) precious metal deposits (Fig. 1d). For example, the comb-textured veins with zoned euhedral quartz crystals are indicative of open space filling over extended periods of time at the upper crustal levels of epithermal systems or peripheral to those systems (Oliver and Bons, 2001). The repeated changes in the texture and composition of quartz layers in crustiform, banded, and cockade veins are indicative of fluctuations in fluid chemistries and conditions due to cooling, mixing, fluid-rock interactions, boiling, and transient pressure releases (Buchanen, 1981; Fournier, 1985; Dong et al., 1995). Hydrothermal fluid flow along the Thelon and Judge Sissons faults may have been driven by localized magmatic activity. This event is therefore tentatively bracketed between ca. 1760-1750 Ma, the age of bimodal volcanic rocks of the Wharton Group (Peterson et al., 2002; Rainbird et al., 2003; Peterson et al., 2015b) and ca. 1720 Ma, the onset of Thelon Formation deposition (Rainbird et al., 2003; Palmer et al., 2004).

Late, post-Thelon reactivation of the Thelon and Judge Sissons faults created an extensive network of non-cohesive fractures, breccias and gouge (Fig. 1e), which became pathways for hydrothermal fluids. The increased porosity of the wall rock allowed these fluids to create extensive and pervasive alteration halos of clay and specular hematite. Outboard of the main pervasive alteration halos, specular hematite and clay veins are observed and form a subtle outer distal alteration halo (Fig. 1f). The breccias are crossed by slip surfaces with dip-parallel slickenlines suggesting either normal or reverse slip during reactivation of the faults. The formation of fracture-fill gouge along moderate- to shallowly-dipping structural anisotropies is also consistent with normal or reverse reactivation of the faults, and this reactivation would create the required fracture networks and pathways for the flow and circulation of mineralizing fluids.

Conclusions

The Thelon and Judge Sissons faults are long-lived Paleoproterozoic to Mesoproterozoic faults with complex reactivation and hydrothermal histories. The faults initially formed at <1830 Ma as dextral transcurrent faults. They were reactivated at ca. 1760 Ma during the migration of hydrothermal fluids to upper crustal levels and between ca. 1600 Ma and ca. 1300 Ma during the emplacement of uranium mineralization during reverse or normal movement along the faults. The structural history of the Thelon and Judge Sissons faults is similar to that of other large dextral strike-slip faults in the Rae craton (e.g. McDonald and Wager Bay fault zones), which formed in the hinterland of the Taltson-Thelon Orogen to the west and the Trans-Hudson Orogen to the east, respectively. It is also broadly similar to that of the Altyn Tagh and Karakorum faults in Tibet, which formed in the hinterland of the Himalayan Orogen during the collision of India with Eurasia.

Large crustal-scale faults are often the loci of active hot springs produced by the discharge of hydrothermal fluids at surface. Along the Thelon and Judge Sissons faults, breccias and veins with comb, crustiform, cockade and bladed textures, formed due to the discharge of hydrothermal fluids possibly heated at depth by Wharton Group magmas. As with other large crustal-scale faults, the fluids may have reached the surface to form hot springs. Reactivation of the two faults during far-field accretionary events at ca. 1600 Ma and during Laurentia-wide extensional events at ca. 1500 Ma to ca. 1300 Ma channeled the flow of new pulses of hydrothermal fluids resulting in the formation of unconformity-type uranium deposits.

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