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Plumbing system at the brittle-ductile transition of a shear zone - insights from the Bitterroot detachment, MT, USA

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The relationships between fluid-rock interactions, changes in the chemical composition of the rocks and deformation processes in shear zones remain largely unclear, yet they are of importance to a better understanding of heat and mass transfer processes and also to economic geology. Mineralization associated to fluid flow through shear zones permits to identify the fluid pathways and to quantify the amounts and types of fluids within the plumbing system during the activity of the shear zone. This contribution demonstrates that mineralized veins and faults, interpreted in the context of a structural, geologic study can identify the plumbing system within a detachment zone at the brittle-ductile transition.

The study is based on quartzo-feldspathic rocks of the Bitterroot detachment, which experienced extension during the Eocene in the eastern part of the Idaho batholith (MT). High-resolution sampling ($\sim$5 m) of the granodioritic mylonite in the Sweathouse quarry indicates that the stable hydrogen isotope ratios of synkinematic muscovite grains are consistent with a meteoric fluid source (-130 per mil). Small variations of the Qz-Ms oxygen isotope fractionations indicate similar temperatures (about 400°C) along the sampled section. Oxygen and hydrogen isotope measurements of minerals and their included fluids are in progress to complement the existing data on the detachment zone rocks. Field observations suggest different types and hence generations of veins and faults, in terms their strike and dip orientations, and their mineralogy. A detailed microtectonic study revealed that ductile fabrics as well as brittle structural makers (tension gashes, veins and faults) formed within the same tectonic framework. However relative chronologies could be identified when comparing deformation pattern with related mineral growth. Chlorite in isolated centimeter-scale tension gashes, epidote in interconnected meter-scale tension gashes, decameter-scale epidote and quartz veins associated to high-angle brittle faults, as well as pure quartz, and oxide-rich quartz veins, can be distinguished.

The stable isotope compositions of these mineral assemblages and their included fluid inclusions are interpreted in the context of the structural relationships of the minerals and veins, in order to furnish a complete dataset for mapping a brittle-ductile plumbing system in 4 dimensions, at a decameter outcrop scale. The 4D model extracted from the Sweathouse outcrop has been investigated at a kilometer scale further towards the south (Lost Horse canyon), but along the same shear-zone, which will help to improve our understanding of a fluid-assisted migration of the detachment zone through time.

Keywords : Shear zone, brittle-ductile transition, fluid-rock interaction, plumbing system, stable isotopes, structural geology, Bitterroot detachment.