Title: The Mountain is fractured and permeable: bedrock hydrology of the Laramie Range and mountain front areas

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Abstract:
With funding from NSF EPSCoR and Wyoming Water Development Commission, we've established 3 long-term bedrock monitoring sites centered at the Laramie Range and its mountain front recharge areas in southeastern Wyoming. This research infrastructure includes: (1) 3 saprolite (weathered granite) wells and 9 fractured granite bedrock wells at *Blair Wallis* in Laramie Range; (2) 6 stream gauges, 11 riparian wells, and 7 bedrock wells completed in and downstream from outcrop of the Casper Aquifer at *Belvoir Ranch*, Denver Basin, which drains the eastern slope of the Range; (3) 1 snow sensor and 2 multilevel wells completed in basement granite, Fountain Conglomerate, and two Casper Aquifer intervals at *Government Gulch*, Laramie Basin, which drains the western slope of the Range. At all three sites, water level and temperature are being monitored. At Blair Wallis, single- and cross-hole hydraulic tests have been carried out. Based on the characterization and monitoring data collected in the past 3 years, results are summarized for each site:

(1) *Blair Wallis*: bedrock water level responds annually to spring snowmelts but not significantly to summer/fall rainfalls; bedrock permeability is derived from open fractures and approaches those of "medium sand"; at 3 bedrock wells, permeability diminishes with depth and becomes insignificant at ~50 m *bgs*, interpreted by us as the granite's weathering front; sustained pumping at one bedrock well drained Blair Creek, a perennial creek flowing next to the well field, suggesting bedrock-supplied baseflow; streamflow in Blair Creek is thus composed of snowmelt runoff, rainfall runoff, and groundwater baseflow; between 6~19% of precipitation over the Laramie Range is estimated to infiltrate, thus bedrock groundwater is a significant component of the mountain water budget.

(2) *Belvoir Ranch*: streamflow, riparian, and bedrock (Casper Aquifer) water levels all respond to the same snowmelt runoffs from the Laramie Range; streamflow and riparian water levels also respond to rainfalls in summer/fall, which is not observed in the bedrock; magnitude of water level response in bedrock is controlled by distance to outcrop and proximity to permeable faults.

(3) *Government Gulch*: Casper Aquifer is not only receiving recharge from above via infiltration, it also receives 'sub-charge' from the underlying Fountain Conglomerate, likely driven by the higher hydraulic head of the Laramie Range. At this site, basin-fill aquifers (Casper, Fountain) appear hydraulically de-coupled from the basement granite over a 3-month monitoring period in Spring, 2018.

For the duration of monitoring at the 3 sites, snowmelt infiltration appears to dominate *bedrock* recharge, while the effect of rainfall infiltration is negligible. This is likely due to high evapotranspiration and low soil moisture content in the unsaturated zone during the summer/fall dry seasons.

Selected findings of this research are reported in: (* student co-author)

Shuangpo Ren*, Andrew Parsekian, Ye Zhang, Brad Carr (2018) Hydraulic conductivity calibration of logging NMR in a granite aquifer, Laramie Range, Wyoming, Groundwater, in press, doi: 10.1111/gwat.12798.

Shuangpo Ren*, Samuel Gragg*, Ye Zhang, Brad Carr (2018) Borehole characterization of hydraulic properties and groundwater flow in a crystalline fractured aquifer of a headwater mountain watershed, Laramie Range, Wyoming, Journal of Hydrology, Vol. 403, p. 66-82.