Variable depth to bedrock under mountain streams influences channel temperature, dewatering, and concurrent stream water gains and losses

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Mountain headwater streams provide unique ecological habitats that are influenced by underlying geologic structure, including bedrock depth, a characteristic that is often ill-defined. We evaluated the importance of low-permeability bedrock depth for summer stream temperature and channel dewatering patterns using horizontal-to-vertical spectral ratio (HVSR) seismic methods along 8 headwater streams in Shenandoah National Park (Virginia USA). HVSR data collected from 2015-2020 were complimented by spatially continuous surveys of stream channel dewatering during baseflow conditions (128.5 total km of stream length), multiyear stream temperature data from 64 locations, and repeated paired discharge observations using the salt dilution method. Median bedrock depth ranged 1.5 to 3.4 m, with half of the 8 stream corridors showing and average depth < 2 m. Measured bedrock depths were not well represented by existing large-scale geologic datasets or readily predicted based on topography. Two subwatersheds showed a general downstream deepening of the bedrock contact but others showed shallow bedrock throughout or had discrete, deeper bedrock zones (e.g. >20 m depth). The stream with the deepest average underlying bedrock contact supported the coldest summer temperatures, displayed a characteristic thermal signature of deeper groundwater influence, and did not dry during baseflow conditions. Patchy channel dewatering was observed at baseflow throughout the study area, as exemplified by the image below that shows a stream disconnected by a localized deposit of alluvium. Bedrock depth variability along the channel was associated with dewatering observed within some streams, though our results also indicate the importance of the shallow groundwater reservoir in maintaining streamflow and influencing paired streamflow gain and loss patterns. Our study demonstrates the importance of shallow, low-permeability bedrock contacts on stream-groundwater exchange, impacting channel habitat and connectivity within headwater stream networks.