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Solute sources and water mixing in a flashy mountainous stream (Pahsimeroi River, U.S. Rocky Mountains): Implications on chemical weathering rate and groundwater–surface water interaction

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ABSTRACT

Identifying solute sources and mixing processes between various water types is challenging in geologically diverse, fractured rock settings, where various minerals contribute to solute loads and mixing between groundwater and surface water can occur at difficult-to-delineate point locations. In such regions, chemical indicators that allow constraining characteristic mineral fingerprints of drainage lithology or aquifer end-members are critical. This study assesses solute sources and water mixing in the Pahsimeroi River, a small stream with highly variable discharge draining two heavily deformed mountain ranges of the U.S. Rocky Mountains. Solute inputs to the main stream were estimated using an end-member mixing model with $^{87}Sr/^{86}Sr$ and Na/Sr ratios as tracers considering that these depict the compositional variability pertaining to the various carbonate and silicate lithologies of the basin. Our results show that the mean solute input from carbonate-dominated terrains decreases from 95.9% in the headwaters to about 36.4% in the lowlands while the corresponding inputs from volcanic and metamorphic sources increase from 3.63% to 51.0% and 0.45% to 12.6%, respectively. Data further indicate highly variable chemical weathering rates with highest values observed in the steeper uplands. Calculated CO_2 consumption rates (mean value: 0.14 Mmol km^{-2} a^{-1}) are lower than the reported continental average (0.21 Mmol km^{-2} a^{-1}) possibly due to lower than average streamflow at the time of sampling and significant input of carbonate solute-enriched baseflow in the downstream sections where the basin shallows and decreases in width. The herein delineated gaining stream segments are consistent with those deduced from downstream seepage runs which suggests that groundwater sustains perennial flow in the agriculturally developed lowlands.

1. Introduction

Assessing the long term reliability of water resources associated with Rocky Mountain streams is important because they comprise sensitive ecosystems and also supply water for hydroelectric power, irrigation and potable usage. Robust information about stream water availability and quality is critical for sustainable management of these resources. In general, the availability of stream water depends upon components the specific watershed's water budget; particularly precipitation, evapotranspiration as well as the degree to which streams are discharging to or are fed by local groundwater (baseflow). Stream water quality and ability to provide potable supply or to support wildlife, in turn, depend upon the watershed geology, climate, and land use regime(s) as well as the degree of mixing between surface and groundwater reservoirs. Climate change and increasing water usage since the early to mid-20's century caused a significant decline in streamflow in watersheds of the western U.S. and the Rocky Mountains in particular (Rood et al., 2005; Luce and Holden, 2009; Luce et al., 2013). Given that continuing decline in future decades is likely, assessments of sustainable limits for water extraction are critical. Such assessments require a detailed understanding of water mixing and solute sources.

Documenting water mixing in streams is challenging given that it can vary seasonally between wet and dry periods, and also spatially depending on local hydrogeologic conditions. For instance, in sedimentary systems where surface runoff as well as diffuse recharge from local groundwater can contribute to streamflow (Winter et al., 1998; Lambs, 2004; Langhoff et al., 2006; Anibas et al., 2011), numerical models relying on extensive climatic and hydrogeological parameters are commonly applied to quantify the contribution of various tributaries and baseflow to streamflow. These methods, however, are subject to uncertainty particularly in crystalline (i.e., fractured) rock settings where mixing can occur at difficult-to-delineate point locations along fractures or fault planes (Winter et al., 1998; Sophocleous, 2002). In

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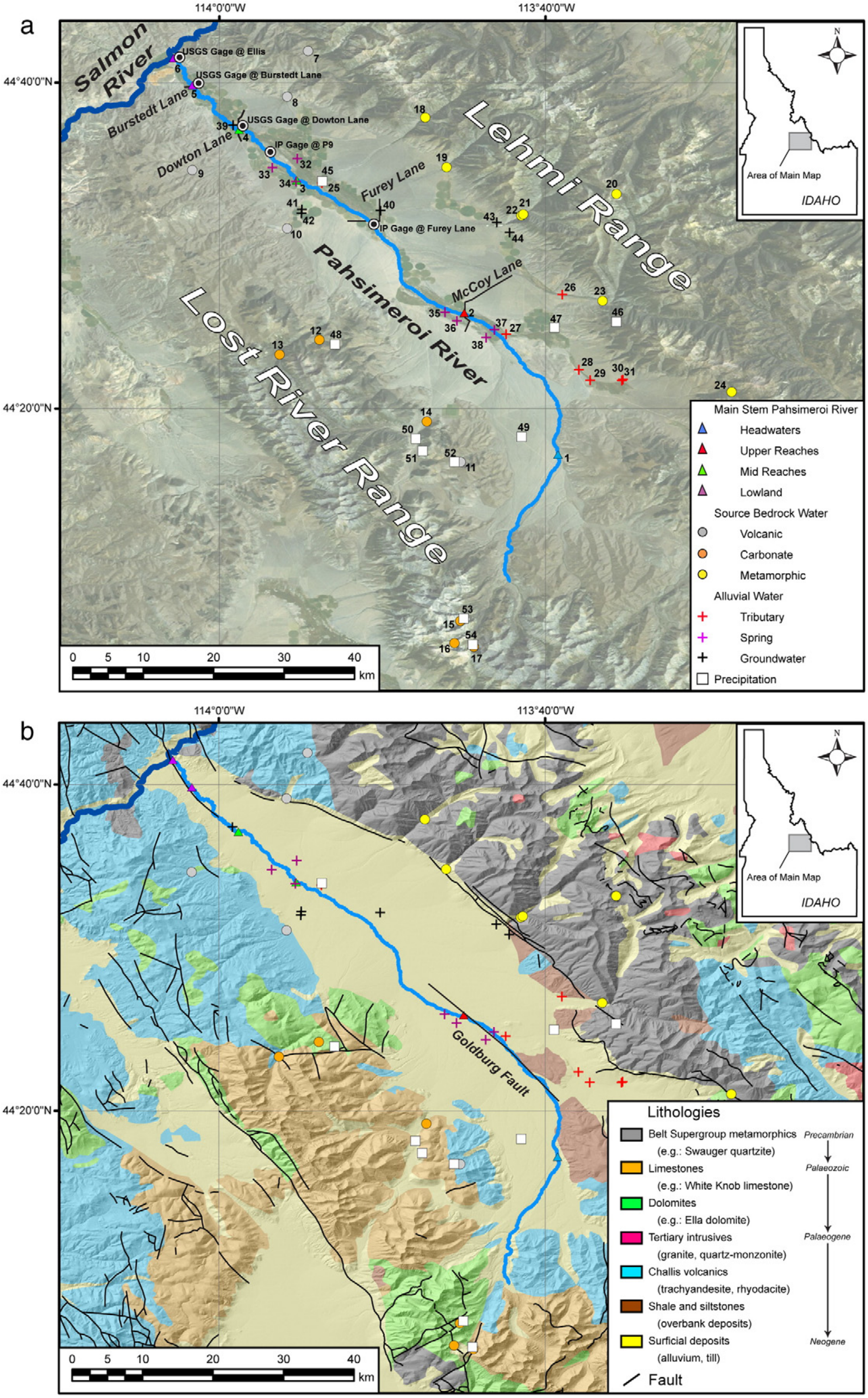
a
114°0'0"W
113°40'0"W
44°40'0"N
44°20'0"N
Salmon River
Burstedt Lane
Dowton Lane
Furey Lane
McCoy Lane
USGS Gage @ Ellis
USGS Gage @ Burstedt Lane
USGS Gage @ Dowton Lane
IP Gage @ P9
IP Gage @ Furey Lane
Lehmi Range
Pahsimeroi River
Lost River Range
Area of Main Map
IDAHO
N
Main Stem Pahsimeroi River
Headwaters
Upper Reaches
Mid Reaches
Lowland
Source Bedrock Water
Volcanic
Carbonate
Metamorphic
Alluvial Water
Tributary
Spring
Groundwater
Precipitation
0 5 10 20 30 40
km
b
114°0'0"W
113°40'0"W
44°40'0"N
44°20'0"N
Goldburg Fault
Area of Main Map
IDAHO
N
Lithologies
Belt Supergroup metamorphics
(e.g.: Swauger quartzite)
Limestones
(e.g.: White Knob limestone)
Dolomites
(e.g.: Ella dolomite)
Tertiary intrusives
(granite, quartz-monzonite)
Challis volcanics
(trachyandesite, rhyodacite)
Shale and siltstones
(overbank deposits)
Surficial deposits
(alluvium, till)
Fault
Precambrian
Palaeozoic
Palaeogene
Neogene
0 5 10 20 30 40
km