Chemical-hydrodynamic control of arsenic mobility at a river confluence

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River confluences are natural reactors where key process controlling the fate of contaminants at different scales occur. A better understanding of the interactions between biogeochemical reactions and the hydrodynamics of a river confluence may lead to innovative strategies for contaminant risk evaluation and management.

The Lluta river is a precious water resource for Arica y Parinacota in northern Chile, an extremely arid region. Although the construction of a dam is being planned to increase water availability, the likely accumulation of arsenic-rich iron oxyhydroxides in the dam sediments has prompted careful analysis from environmental authorities and the local scientific community. The main source of As-rich fine particles is the confluence between two rivers in the Chilean Altiplano, the Caracarani and the Azufre river, thus making it a perfect natural laboratory to study interactions between biogeochemical reactions and hydrodynamics.

We performed field and laboratory studies to characterize the chemistry and hydrodynamics at this confluence. After mixing of the Caracarani (pH=8; Fe, As<0.1 mg/L, low turbidity, Q~150L/s) and the Azufre river (pH=2, Fe=80 mg/L, As=2 mg/L, low turbidity, Q=50 L/s), a highly variable spatial distribution of pH and turbidity was found within the first 300m downstream of the confluence. Characteristic light-brown fine particulate material was found in stagnant areas with varying As concentrations up to 600 mg As/kg sediment for low flows. We reproduced the mixing of these waters at different velocities using jar-test type of experiments. Although the production of fine oxyhydroxides was also observed, the concentration of arsenic in the flocculated material (particles >0,45 um) was remarkably lower (<50 mgAs/kg of sediment) compared to the natural flocs. Furthermore, we found that the mixing velocity is a critical parameter determining the As sequestration potential by te oxyhydroxides.

Acoustic Doppler velocimetry at the confluence showed spatially variable turbulence intensities at the streamwise and across-stream directions, producing heterogenous distribution of particulate material on the river bed. Fresh flocs are thus exposed to varying chemical environments and hydrodynamic turbulent stresses determining arsenic sorption, floc formation, and floc strength. At larger time and spatial scales, flow characteristics during flood and drought seasons are likely to determine the formation/mobilization of arsenic repositories within the watershed.

Project funded by Conicyt, Fondecyt 1100943.

From peak metamorphism to orogenic collapse: insights into the exhumation history of the Clearwater metamorphic core complex

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Abstract

Metamorphic core complexes are ubiquitous features in orogenic belts around the world and offer exceptional opportunities to investigate the rheological and thermal characteristics of the middle crust during orogenesis. The Clearwater metamorphic core complex in northern Idaho, U.S.A. exposes some of the deepest rocks in the Cordilleran orogen and records a complicated polymetamorphic history starting in the Paleoproterozoic, with the youngest high-grade metamorphism resulting from late Cretaceous Sevier crustal thickening.[1, 2, 3] Categorization of the Clearwater complex as a core complex has recently been confirmed based on structural data, thermobarometric data, and $^{40}Ar/^{39}Ar$ cooling ages, all of which suggest rapid Eocene exhumation of regionally metamorphosed mid- and lower-crustal rocks within the complex.[1, 3] Despite these data, the structural and thermal evolution of the Clearwater complex during Eocene exhumation remains cryptic.

The Clearwater complex is comprised of two lithologically and structurally distinct zones: an internal zone comprised of basement schist, gneiss, and anorthosite, and an external zone with both Archean to Paleoproterozoic basement and metapelitic rocks of the overlying Mesoproterozoic Belt Supergroup.[1, 4] These zones are bound by conjugate sets of E- and W-verging normal faults. The geological significance of these faults is unclear. This paper integrates new $^{40}Ar/^{39}Ar$ muscovite and biotite cooling ages along an E-W transect across the Clearwater complex with respect to major extensional structures, 1:24,000-scale mapping, microstructural analysis, and metamorphic phase equilibria modelling in order to constrain the structural and thermal evolution of the Clearwater complex from maximum crustal thickness to Eocene gravitational collapse of the Sevier orogenic belt.

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