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Critical Zone Exploration in the Tropics: Clues from small experimental watersheds in South Cameroon and South India
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Understanding the relative controls of forcing factors on the silicate chemical weathering rates and the associated atmospheric CO2 consumption is usually assessed through investigations based on small to medium granito-gneissic watersheds from 1 to100 km2 located in different climatic and tectonic settings. In addition to climate, the importance of the thickness and nature of the blanket of loose and transportable weathered material, namely regolith, which overlies the intact bedrocks, was also recently invoked, especially in tropical environment. We have conducted an integrated approach of the Critical Zone in two pristine forested small watersheds located in Cameroon and India. Both watersheds have developed on granito-gneissic bedrocks of stable Precambrian shields. Our approach is directed at (i) understanding the bio-geochemical, hydro-geological and hydrological processes and (ii) assessing the long-term and contemporary chemical weathering rates.
The Nsimi watershed, South Cameroon, has been the first to be monitored since 1994. It belongs to the Nyong River basin and has a humid tropical climate. It is characterized by a deep mature lateritic mantle and mean annual rainfall of 1600 mm. The second watershed, under investigation since 2003, is located at Mule Hole, South India. It belongs to the sub-humid zone of the climatic gradient of the Kabini River basin in the rain shadow of the Western Ghâts. It is characterized by an immature thick regolith and mean annual rainfall of 1100 mm.
In both watersheds, the water balance was calculated from on time-series of hydrological and climatic data and then modelled for lean/normal/high rainfall years. The contemporary chemical weathering rates were established by coupling the water balance with geochemical time-series in groundwater, stream water and rainfall. The degree of weathering and the thickness of the regolith were achieved by combining investigations of geophysics (electrical resistivity logging and tomography), mineralogy, and bulk chemical analyses. This allowed us to assess the long-term chemical weathering mass balance at the watershed scale.
In the Nsimi watershed, the contemporary chemical weathering rate, even though low (2.8 mm/kyr), predominates over the mechanical weathering rate (1.9 mm/kyr). Compared to the Rio Icacos watershed, the most studied tropical site, the chemical weathering fluxes of silica and sodium in the stream are 16 and 40 times lower, respectively. This is not only related to the protective role of the regolith, thick in both cases, but also to differences in the hydrological functioning. The carbon transfer occurs primarily in an organic form and essentially as colloids

produced by the slow biodegradation of the swamp organic matter. These organic colloids contribute significantly to the mobilization and transfer of Fe, Al, Zr, Ti and Th in the uppermost first meter of the swamp regolith.

In the Mule Hole watershed, the contemporary mechanical weathering rate (25 mm/kyr), predominates over the chemical weathering rate estimated for both stream (0.3 mm/kyr) and groundwater (3.0 mm/kyr). This difference is due to the disconnection of groundwater and stream during the monitored period of time. The contemporary denudation rate is then 28 mm/kyr, twice the one integrated over the last 100 kyr estimated with 10Be with the streambed sand. The immature, relatively thick regolith has a great potential to produce alkalinity by chemical weathering. Depending on the runoff and therefore climate variability with a more humid gradient (i. e. intensification of the monsoon), the production of alkalinity would increase and consequently increase the atmospheric CO2 consumption.

This study has important signification in terms of quantification of the amount of weathered material at small watershed scale and hence of the assessment of the impact of silicate chemical weathering on atmospheric CO2 consumption. The hydrological functioning may then constitute a critical parameter for carbon cycle modelling. This study also stresses the need to have accurate monitoring at the watershed scale in a context of changing climate and to maintain such observatories for decades.

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