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Evidence of Hydrological Conditions Influence on Sr Behaviour in Streamwaters. The Strengbach Catchment Case Study (Vosges Mountains, France)

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Strontium and particularly $^{87}Sr/^{86}Sr$ ratios in stream waters have been often used to calculate weathering rates in catchments. Nevertheless, in the literature, discharge variation effects on the geochemical behaviour of Sr have been frequently neglected (Bain et al., 1998). In the present study, we demonstrate that in an homogeneous silicate catchment, hydrological conditions can strongly influence the variation of the Sr isotopic compositions in the drainage waters.

Site description and methods

The Strengbach forested catchment (80 ha area) is located in the eastern part of the Vosges mountains (North-Eastern France). The climate is temperate oceanic mountainous and the mean rainfall amount is about 1400 mm/year. The total runoff reaches 853mm for the 1986-1995 period which corresponds to a mean annual discharge of 21 l/s. The bedrock is a 320 My base-poor leucogranite that has been affected by postintrusive hydrothermal events. The soils are rather deep, sandy and stony and belong to the brown acidic to ochreous podzolic soil series. A small hydromorphic zone, which only represents 2% of the total catchment area, takes up the valley bottom near the outlet. This area can contribute significantly to stream water output particularly during storm events (Idir et al., 1999; Ladouche et al., 2000). ICP-MS and TIMS measurements were performed on surface waters collected regularly within the catchment (rainwater, throughfall, soil solutions, springwater, streamwater and tributaries) in order to determine their respective Sr concentrations and Sr isotopic compositions with respect to hydrological conditions.

Results and discussion

A regular survey of both Sr concentrations and Sr isotopic compositions of the Strengbach streamwater has been performed during a whole hydrological year. During the low water flow period, streamwaters are significantly less concentrated and less radiogenic (Sr = 11.6 ppb and $^{87}Sr/^{86}Sr$=0,7246 as an average, respectively) than during high water flow period (Sr = 13 ppb and $^{87}Sr/^{86}Sr$=0,7252 as an average, respectively). This is contrary to a dilution process by meteoric waters that have comparatively low Sr isotopic ratios and low Sr content (Probst et al., 2000). The Sr isotopic compositions recorded in the surface waters (soil solutions and spring water) of the south-facing slope (the most affected by hydrothermal processes) are less radiogenic than those of the north-facing slope and the saturated area. This indicates that during high water flow periods, waters draining the north-facing slope and the saturated area contribute significantly to stream discharge at the outlet. Furthermore, a detailed study shows that $^{87}Sr/^{86}Sr$ ratios in stream water behave in three different ways according to hydrological conditions. Thus, during the low water flow period (discharge <10 l/s), there is a positive linear relationship between Sr isotopic ratios and the discharge (Figure 1). This particularly reflects the response of the small hydromorphic zone to moderate storm events, whereas, during this period, the stream water is mainly characterized by less radiogenic deep water, which originates from the south-facing slope. On the opposite, flood events which occur in high water flow conditions, are characterized by significantly less radiogenic Sr ratios during rising discharge than during recession stages (senester hysteresis). This would indicate the main contribution of deep waters from the north-facing slope by piston flow process.

Conclusions

These investigations allow to confirm the slight incidence of rainwater on stream water chemistry (Ladouche et al., 2000) and points to the occurrence of isotopically distinct contributive areas in the catchment. The influence of these areas on stream water composition depends on both hydric and hydrological conditions. This study also shows, that even on a single bedrock, the $^{87}Sr/^{86}Sr$ ratios in surface waters can vary in function of flow rate. It is therefore necessary to consider discharge variations if using Sr isotopes for calculation of weathering rates in catchments.

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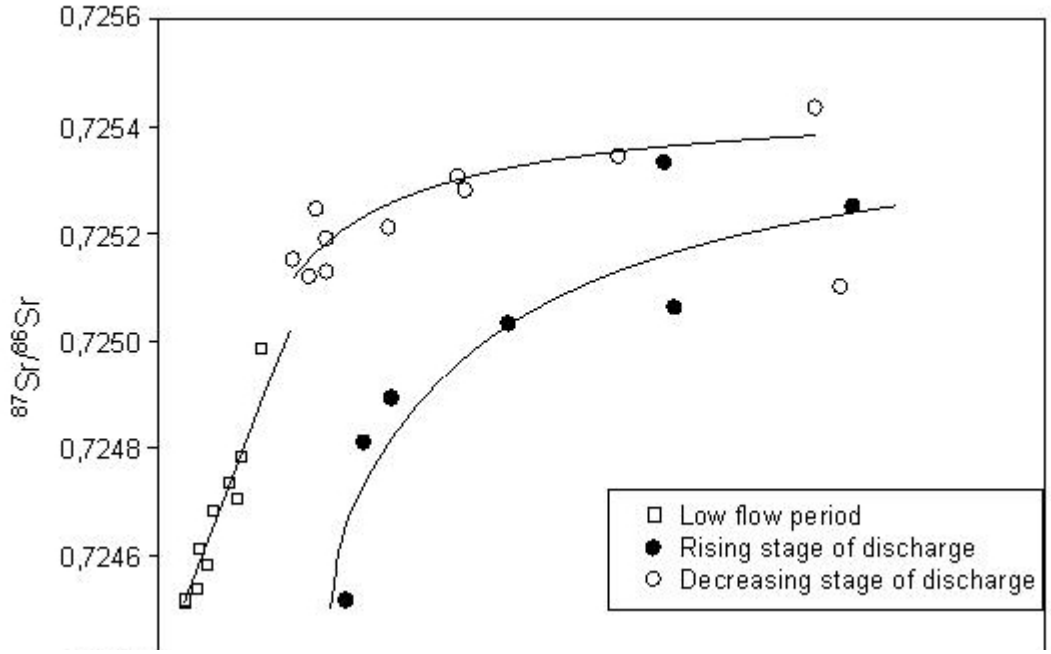

Figure 1: Relationships between discharge and Sr isotopic ratios in the stream showing the influence of hydrological conditions

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