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Biogenic and non-biogenic Si pools in terrestrial ecosystems: results from a novel analysis method

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Silicon (Si) is a chemical element frequently associated with highly abundant silicate minerals in the Earth crust. Over millions of years, the interaction of such minerals with the atmosphere and hydrosphere produces a myriad of processed compounds, and the mineral weathering consumes CO_2 during the process. The weathering of minerals also triggers the export of dissolved Si (DSi) to coastal waters and the ocean. Here, DSi is deposited in diatom frustules, in an amorphous biogenic form (BSi). Diatoms account for 50% of the primary production and are crucial for the export of carbon into the deep sea. In recent years, it was acknowledged that terrestrial systems filter the Si transition from the terrestrial mineral to the marine and coastal biological pool, by the incorporation of DSi into plants. In this process, DSi is taken up by roots together with other nutrients and precipitates in plant cells in amorphous structures named phytoliths. After dead, plant tissues become mixed in the top soil, where BSi is available for dissolution and will control the DSi availability in short time scales. Additionally, Si originated from soil forming processes can also significantly interfere with the global cycle.

The Si cycle in terrestrial ecosystems is a key factor to coastal ecology, plant ecology, biogeochemistry and agro-sciences, but the high variability of different biogenic and non-biogenic Si pools remains as an obstacle to obtain accurate measurements. The traditional methods, developed to isolate diatoms in ocean sediments, only account for simple mineral corrections. In this dissertation we have adapted a novel continuous analysis method (during alkaline extraction) that uses Si-Al ratios and reactivity to differ biogenic from non-biogenic fractions. The method was originally used in marine sediments, but we have developed it to be applicable in a wide range of terrestrial, aquatic and coastal ecosystems. We first focused on soils under strong human impact in temperate (European) zones, since cultivation influences the Si cycle with multiple consequences for the environment. Results showed that the intensity of the human pressure in the agricultural systems defines the level of BSi depletion, but parent material and weathering degree can also provide the soil with other reactive non BSi fractions.

Secondly we analysed the influence of non-BSi pools of volcanic origin in soils and sediments subjected to volcanic activity. Results showed that a separation method is fundamental in these systems with volcanic shards and strongly weathered products, both of which are also significantly prone to dissolution in the common alkaline sequential extractions.

We conclude that the application of a method that discriminates between Si fractions is mandatory to correctly understand the Si dynamics in terrestrial ecosystems. Although time-consuming and subjected to some limitations, the continuous analysis can be used for this purpose. Future challenges remain however for identifying fractions that cannot be differentiated on either reactivity or Si-Al ratio and for correlating the reactivity of fractions extracted in alkaline environments with the availability in situ.