

DIETRICH Fabienne (2017) : Calcium dynamics in a silicate watershed under semi-arid conditions: Insights from pedogenic carbonate nodules (Far North Cameroon)

Abstract

Ca is closely related to the long-term carbon (C) cycle through global silicate weathering, and both elements are ultimately sequestered in the ocean. However, Ca and C are not systematically directly transferred into the ocean and can be transiently stored on continents as pedogenic carbonate. In Far North Cameroon, significant accumulations of pedogenic carbonate nodules, associated with Vertisol relics and inherited from the African Humid Period (AHP, from 14.8 to 5.5 ka BP), have been observed in a silicate watershed. Their occurrence was unexpected as these carbonate nodules represented large amounts of Ca within Ca-poor silicate settings. Therefore, this study aimed at improving our understanding of the origin of pedogenic carbonate nodules and at better defining their role within the coupled Ca and C biogeochemical cycles. The problem was tackled by providing new clues upon i) the Ca sources of the carbonate nodules, ii) the processes involved in the transfer of Ca from sources to carbonate nodules, iii) and by testing the U-Th dating method on carbonate nodules in such a geosystem.

Sr isotopes have demonstrated that the Ca sources of the carbonate nodules are the plagioclases from the local bedrock and the Saharan dust, with a small contribution of the biotite. The proportions of Ca found in the carbonate nodules and originating from the Saharan dust never exceed 50% and are a function of dust abundance in the soil parental material. We concluded that Ca is mainly supplied by in situ weathering of the local bedrock, whereas many studies dealing with the Ca origin of secondary carbonates report a dominance of atmospheric inputs. The only two studies having reported a dominance of an in situ weathering in Ca origin are concerning carbonate nodules associated with Vertisols, as it is the case in Far North Cameroon. Therefore, it is suggested that the nature of the Ca sources (i.e. in situ weathering and atmospheric inputs) could be function of the type of pedogenesis and edaphic conditions. By using the geochemical compositions of the different sedimentary deposits composing the landscape and the carbonate nodules, as well as by crossing these results with the paleoenvironmental evolution of the landscape proposed by a concomitant thesis, it was possible to highlight three main processes involved in the Ca transfer from local sources to carbonate nodules: 1) hydrolysis of the plagioclases and Saharan dust within the soil parent material; 2) release of Ca in the soil solution; due to the specific edaphic conditions of Vertisols, as well as to the wetter climate during the AHP, Ca was mainly stored in the vegetation, in soil organic matter, and associated to 2:1 clays; 3) finally the precipitation of carbonate nodules resulted from an onset of drier conditions. Changes in mass calculations between carbonate nodules and soil parent material demonstrated that four volumes of parent material are needed to produce the amount of carbonate nodules trapped in one volume of the present-day Vertisol relics. Consequently, Ca was strongly accumulated in carbonate nodules and was therefore not transferred into rivers. As quantification of CO₂ consumption by silicate weathering is based on river geochemistry, carbonate nodules can have a potential impact on this quantification, and therefore on the C cycle assessment. Moreover, carbonate nodules are not limited to Far North Cameroon and have been reported all along the Sudano-Sahelian belt on soil maps. Their occurrence has also been noted in numerous locations around the World, such as India, Texas (USA), or Russia. The attempt to date carbonate nodules of Far North Cameroon using the U-Th method, by means of density separation to isolate calcite, has not been fully successful, due to the high and multiple detrital contents of the carbonate nodules. Therefore, the U-Th dating method is not trivial in such peculiar settings and not ready yet to be used as a routine. One of the main outcomes of this PhD thesis is that carbonate nodules can act as a transient and long-term Ca trapping compartment. This results from the peculiar edaphic conditions provided by Vertisols and changes in climatic conditions, building this way a “geochemical cascade”.