The influence of water pollution on the slowed weathering rates and accelerated biomass productions observed in two Portuguese granitoid areas

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Quantitative geochemical mole-balance studies were first applied by Garrels and Mackenzie (1967) in the study of a pristine area (Sierra Nevada, USA); using the so-called 'balance-sheet' method, they could envisage which natural processes were responsible for the composition of springs and groundwater in their area. More recently, other mole-balance models were developed to address problems such as the influence on mineral weathering rates caused by the growth of biomass (Taylor and Velbel, 1991) or to analyse the chemical evolution of water along a flow path caused by the mixing of different water types plus the reaction with solid phases (Parkhurst, 1997). In the present paper, we present a summary of the most important conclusions of two studies, carried out in two Portuguese granitoid areas (Pacheco and Van der Weijden, 1996; Pacheco *et al.*, submitted), which, among other things, analysed the influence of soil, saprolite and ground water pollution on the intensity of mineral weathering (plagioclase and biotite) and on the rates pine growth in those areas. In these two studies, a different mole-balance algorithm was applied, the so-coined Silica-Bicarbonate (SiB) algorithm, which is able to separate the contributions to water chemistry associated with natural sources from those associated with anthropogenic and other pollution sources.

The type and abundance of secondary minerals present in the soils derived from a certain rock type depend primarily on the environmental parameters climate and topography, as early recognized by Tardy *et al.* (1973), on the local drainage conditions, and on the mineralogy and chemistry of that rock type; in the case of a granite under temperate climatic conditions, the most important weathering reactants are plagioclase (major) and biotite (minor), and the most common associated secondary products are vermiculite (low rainfall/stagnant drainage conditions), halloysite (moderate to high rainfall/favourable drainage conditions) and gibbsite (very high rainfall/excellent drainage conditions). But the formation of a certain weathering product may also be influenced by factors such as pollution, as pointed out by Pacheco and Van der Weijden (1996) in a study of the Fundão granitoid plutonite (central Portugal); they suggested that, under stagnant leaching conditions and raised levels of soil/saprolite water contamination caused by the application of manure and fertilizers on farmland, vermiculite could result from the weathering of biotite, instead of halloysite the most stable product under the local rainfall conditions. The influence of soil and saprolite water pollution on the intensity of mineral weathering was later corroborated by Pacheco *et al.* (submitted) in a study of the Chaves-Vila Pouca area (northern Portugal), a granitoid and forested area located along a large-scale Hercynian fault; in this case, it was noticed that two water types linked to the weathering of the same plagioclase type (andesine-An_{40}) could be associated to the formation of mixtures with 50% gibbsite plus 50% halloysite, when the water type was less polluted, and to mixtures with 30% less gibbsite when the water type was definitely contaminated.

In pristine forested areas, the rates of biomass production and of elemental uptake depend on factors such as climate, morphology, soil fertility, tree species, and stand maturity; for instance, regarding tree species, the response of elemental uptake to the demand of biomass production is different when considering coniferous or deciduous species (coniferous species appear to meet all of their annual requirement of nutrients via the uptake process, while deciduous species meet only about 70% of their needs throughout that process, the rest being provided by translocation of nutrients from older tissue). Besides, most of the annual uptake of elements is provided by recycling from decay of previous year's litter and only a small part is removed from the mineral compartment through weathering.

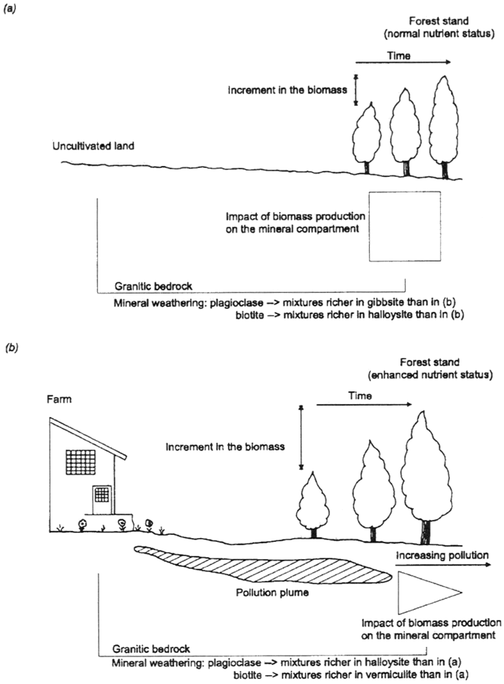

FIG. 1. Schematic representation of the impact of soil, saprolite and ground water pollution on the intensity of mineral weathering and on the rates of biomass production.

The impact of biomass production on the mineral compartment can be investigated by mole-balance models by applying them twice, with and without the inclusion of a botanical uptake term in the calculations. Following up this strategy in the study of a pristine area, Taylor and Velbel (1991) concluded that the weathering rates calculated without accounting for botanical factors are usually minimum estimates which can be a factor of four less than the estimates obtained when those factors are incorporated into the mole-balance model; the differences between these estimates vary considerably among minerals, being slight for plagioclase and much greater for nutrient-rich minerals such as micas. In inhabited areas the relation between biomass production and mineral weathering may be different as noticed by Pacheco *et al.* (submitted); in these areas, especially where the mixing of farmland and forest characterizes the local land use, the entrance of plumes of contaminated groundwater into forest ecosystems by subsurface outflow from adjacent farmyards may provide plenty of nutrients to the biomass, resulting in a slowed consumption of the mineral compartment. In their study, Pacheco *et al.* (submitted) first pointed out that there is indeed a relation between the calculated biomass productions and the ratios between the farm and forest densities; the biomass productions are high when both farms and forests are present and low when only forest land appears. And then, by applying the SiB algorithm with and without accounting for botanical factors, they showed that the impact of biomass on the mineral compartment decreases as the available nutrients provided by pollution increase, becoming nil at a certain stage, presumably where these nutrients plus those associated with recycling and translocation are enough to sustain the biomass. Beyond that stage, pollution may cause a retardation of mineral decomposition, especially of biotite, where the leaching conditions increase the residence time of contaminated water in contact with saprolite material.

The ideas discussed in the previous paragraphs are schematically represented in Fig. 1. In situation (a), an uncultivated area with an adjacent forested area is represented. In this case, given the lower cation concentrations in the soil and saprolite water and due to the normal nutrient status under the forest stand, the plagioclase and biotite weathering are intense (soils richer in halloysite plus gibbsite), the increment in the forest biomass within a certain period of time is low, and the impact of elemental uptake on the mineral compartment is high (represented by the large square). On the other hand, on situation (b), where a farm is situated in the vicinity of a forest allotment, the raised cation concentrations in groundwater as well as the enhanced nutrient status at the forest soil, produce less intensive weathering on plagioclase and biotite (soils richer in vermiculite plus halloysite), higher rates of biomass production, and reduced 'botanical impact' on the mineral compartment (the triangle indicating lower and lower impacts for higher and higher levels of groundwater contamination).

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