Evolution of the weathering rate of a labradorite feldspar introduced in acid soils over nine years

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The knowledge of rates of cation release from mineral dissolution due to the weathering in forest soils is necessary to understand the evolution of nutrient availability and water of soil solution quality. It is also an important term to input-output budgets of forest ecosystems in the aim of predicting their sustainability. However, the rates of mineral weathering measured from laboratory experiments are commonly up to one to three orders of magnitude higher than rates determined from fields studied. From soil chronosequence studies, White et al. (1996) calculated that the rate of dissolution for specific minerals as a function of stand age and suggest that it is controled by the evolution of surface reactivity.

The mineral test technique (Sadio, 1982) was selected to measure the effect of contact lenght in soil on the rate of mineral dissolution in soil. A labradorite feldspar type have been selected to put in acid forest soil (3.8< pH soil water < 4.5) in north of France as a test of soil geochemical function because: (1) plagioclase is an abundant mineral in soils and it is generally the main calcium source in acid soil; (2) contrary to phyllosilicate, plagioclase weathering is not related to transformation reaction and to microdivision: dissolution is the main reaction; (3) in acid soils generally limited pools of 'base' cations was known to be reponsible of the forest decline during the past decades. These ecosystems developed on acid soil are the most sensible to intensification of the forest management and to the increase of anthropogenic acid deposition; (4) in addition, the weathering rate is high in these acid soils and the variation of this rate can be observed during a short period.

Material and method

Specimens of labradorite feldspar have been ground. The 100−200 mesh fraction was submitted to magnetic separation to removel Fe-Mg mineral observed as traces in these crystals (ilmenite, chlorite, biotite, pyroxene) and then was washed after ultrasonic treatment in distilled water. This last treatment was repeated three time. The comparison between total analysis of the cystals and punctual analysis obtained by microprobe $(Si_{2.49}Al_{1.49}K_{0.02}Ca_{0.52}Na_{0.45}O_8)$ suggest that the fraction used as test-mineral in soils contain only 0.1% of ilmenite as small inclusions. The calcium
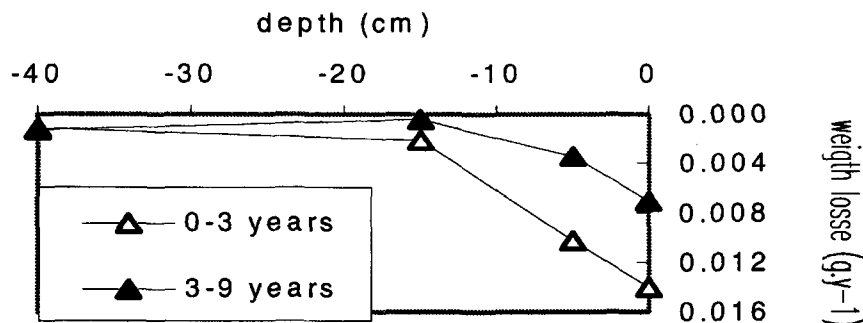

FIG. 1. Weigth losses of labradorite feldspar in Monthermé's soils under spruce during the first three years (0−3 years) and during the six last years (3−6 years) in g.y^{-1} vs depth of soil horizons in cm.
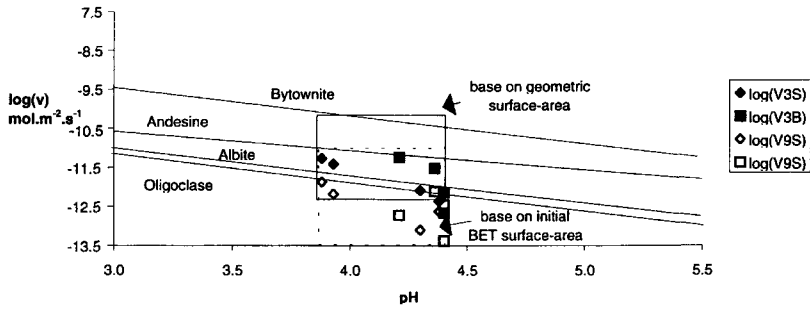
FIG. 2. Dissolution rate of labradorite feldspar (log(v)) in Monthermé's soils under spruce (S) or under beech (B) during the first three years (3) and during the six last years (9) comparated to the dissolution rate of plagioclase obtained in laboratory (from Blum and Stilling, 1995).

content varied between 0.49 and 0.55. Small bags (5 × 10 cm) of 20 mesh polyamid either containing 3 g of 100−200 mesh labradorite and 1 g of 250−400 mesh grund pur quartz crystals were carefully introduced into the main horizons (under forest floor and at the depth of 5, 15 and 40 cm) of ten soils. Four replicates of these bags were inserted from the side of a pit which was then refilled, retaining the original horizons. Two replicates were sampled after 3 years and two after 9 years for all horizons of all soils. The results obtained in a Typic Dystrochept from Monthermé (Ardennes) where the mean annual precipitation is 1100 mm and the mean annual temperature is 8°C will be the most detailed in this presentation. This site was monitored for 7 years in order to separe the impact of forest species in soil function (Nys, 1987). The pH of soil solution was ranged between 3.8 and 4.4.

Recovery of the labradorite from bag after incubation in soils was obtained by sieving and manual removal of roots and quartz. Accuracy of the recovery was controled by optical microscopy and weight control of quartz until the 1g initially introduced in the bags was recovered.

Result and discussion

The results shows that the weight losses of labradorite generally decreased with depth and increased with time. In the deepest horizons of certain profiles, weight losses during the three first years were too low to be measured. In the forest floor layer, weight losses of plagioclase ranged under 1.5% and 1.7% respectively after 3 and 9 years. The rate of weight losses by year generally decrease strongly during the six last years except for the sample in the deepest horizon where the dissolution rate ranged around 0.2% (Fig. 1). The rate during the six last

years represented 10 to 50% of the rate during the three first years.

Constants for dissolution rate constant of labradorite feldspar were calculated from geometric or initial BET surface-area and are respectively of 0.015 and 0.1 ± 0.02 m^2 g^{-1}. After 9 years in soil, the BET surface-area of the plagioclase fraction, which have a weight losse of 0.8%, was about 0.7 m^2 g^{-1}. In upper soil horizons of Monthermé's forest, during the first three years, the dissolution rate based on geometric surface-area ranged between bytownite and andesine rate obtained in laboratory experiments (Fig. 2). The calculation incorporating geometric surface area overestimated this weathering rate. A change of one order of magnitude was obtained between dissolution rate based on geometric or on initial BET surface-area and also between dissolution rate during the three first years and six last years. The same dissolution rate was observed under spruce and beech although the soil-pH under these two species present signifiant difference. The difference of the moisture (+25% under beech if compared to spruce) probably explain this behaviour.

The results of test mineral technique can allow to determine the decrease of the dissolution rate as a function of the change in the surface reactivity of the mineral with time. From fresh surface mineral, the decrease of dissolution rate of labradorite is very strong. Using the initial of final BET surface-area, these rates decreased respectively to one or two orders of magnitude.

A first experimentation in laboratory of dissolution of labradorite felsdpar introduced in soil showed that the element releases (Si, Al, Ca) from labradorite decrease with weigth losse in soil. It is probably due to limit of element diffusion through the silica-rich altered layer.