# Long term weathering rates of twelve mineral fractions isolated from a granodiorite derived soil

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It has been established that laboratory determined weathering rates are several orders of magnitude greater than rates derived from field studies at the catchment or basin scale. These differences are considered to be related to pretreatment (crushing) of mineral specimens in laboratory studies which may result in differences in surface reactivity as well as increased lattice strain. The objectives of this study are to determine the dissolution rates of various mineral fractions separated from an arid zone soil and to compare these rates to reported values for specimen minerals and to weathering rates determined from field studies.

A sample of Pachappa soil, (fine sandy loam mixed, thermic, Mollic Haploxeralf) derived from weathering of granodiorite of the southern California batholith, was collected from a site in Riverside, California. The soil was air dried, lightly crushed with a rubber stopper to break up soil aggregates and sieved. The $0-100$ μm fraction was saturated with 1 M NaCl, followed by deionized (DI) water washing and sedimentation to obtain a $10-100$ μm fraction. This size fraction was boiled in 1 M sodium acetate for 8 hours to remove any possible traces of carbonates (Jackson, 1969) followed by washing with DI water and boiled in 20% $H_2O_2$ at pH 5 to remove organic matter (Kunze and Dixon, 1986), followed by washing with DI water. After further sedimentation the $10-100$ μm fraction was partitioned using magnetic and density separations to isolate various mineral fractions. The experimental procedure follows that described earlier for a plagioclase-quartz fraction (Suarez and Wood, 1995). The materials were washed with benzene and acetone, then dried, then rinsed in DI water and dried. Samples were digested (Jackson, 1974) for elemental analysis. Short term experiments were conducted by adding various quantities of each mineral fraction (0.45 to 1.5 g) to obtain 3.0 $m^2$ surface area in each polyethylene bottle. We added 0.03 L of filtered DI water to each bottle (eight replicates). The bottles were stored in the dark at $24.4 \pm 0.1°C$ and hand-shaken daily.

The solids from each of the replicates were collected and used for the long-term weathering studies. Samples were washed several times with DI water to approximate the initial starting conditions. Next, 7 mL of solution was sampled every 2 to 3 weeks, and the same amount of DI water was added back to replenish the 30 mL volume. All samples were analysed for Ca, Mg, Na, K and Si after filtration. Release rates were calculated by subtracting the initial mass of the element present from the mass present at the next sampling time.

## Results

The XRD analysis of the different fractions indicated the presence of the following minerals: quartz, alkali feldspar, plagioclase, chlorite, hornblende, muscovite and biotite. XRD and elemental analysis established that good separation was achieved between quartz-feldspar, mica and hornblende fractions. Surface roughness factors, calculated from the estimated geometric surface area and the measured B.E.T. surface area, ranged from 34 for the feldspar -quartz fraction to as large as 126 for the muscovite fraction. These values are comparable to those determined by Anbeek (1993) on much larger material ($200-800$μm), suggesting that this factor is still appreciable for silt-sized material.

After the first few samplings, pH values were in the range $5-6$. The Si data, shown in Fig. 1 for the first 40 days of reaction time shows characteristic parabolic release rates observed by others. There was no grinding, harsh pretreatment or sonication, thus we consider that these data provide evidence that parabolic kinetics are not just an artifact of sample preparation. Silica release data, show that after the initial 40 day reaction the chlorite-biotite, very low quartz and feldspar fraction had the highest dissolution rate of $0.15 \times 10^{-12}$ mol $m^{-2}$ $s^{-1}$ and muscovite the slowest release rate, $0.06 \times 10^{-12}$ mol $m^{-2}$ $s^{-1}$. The appearance of an approach to constant rates after 40 days is illusory. After a total reaction time of 8.5 years (only 6.3 y shown in Fig. 1), the Si
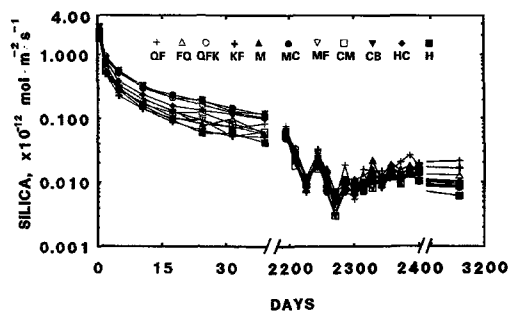
FIG. 1. Silica concentration as a function of time for weathering of mineral fractions Symbols Q,F,K,M, C, and H represent quartz, feldspar(plagioclase, muscovite, biotite, chlorite, and hornblende).

release rates decreased further, ranging from 0.006 to $0.02 \times 10^{-12}$ mol m$^{-2}$ s$^{-1}$. The somewhat higher rates shown immediately after washing in deionized water are likely due to desorption of Si from the mineral surfaces. There is no assurance that 'steady state' rates have been achieved, nonetheless the change in reaction rate is at least quite low (factor of 2 after 3 years. When the concentration data are expressed as a function of mass (mol L$^{-1}$ g$^{-1}$) rather than on a surface area basis (mol L$^{-1}$ m$^{-2}$), the rates show less variation. Surface areas/mass values were 2–3 fold greater for the mica and chlorite-hornblende fractions as compared to quartz-feldspar fractions. Based on laboratory studies with and without various pretreatment, we conclude that the low reaction rates were not the result of surface coatings (secondary minerals and organic matter).

Parabolic release kinetics were also observed for the cations Ca, Mg, Na, K. The Mg concentration after 40 days varied by a factor of 3.5. Again, as with Si, the differences among fractions are less when the data are expressed on a per gram basis. compositions. Sodium and Ca were the predominant cations released from the feldspar fractions, consistent with the feldspar composition (data not shown). Of these 4 fractions, KF contained the largest amount of K-feldspar and also released the largest amount of K. Comparison of our rates to those in previous feldspar weathering studies indicate that these rates are slower than earlier published rates and comparable to published field rates. Previous laboratory rates are based almost exclusively on experiments using ground specimen minerals. Our release rates are about two orders of magnitude lower than most studies and more than an order of magnitude lower than the data of Anbeek (1993). The field rates need to be corrected by the surface roughness factor, $\lambda$, since they report geometric surface areas rather than B.E.T. measurements. Assuming a $\lambda$ of 10, the field values bracket those determined in the present study.

The observation that all minerals fractions weathered at approximately the same rate, when rates are expressed in terms of surface area, is in marked contrast to field observations, where biotite, muscovite and hornblende weather rapidly as compared to feldspars. These data can only be partially explained by the large differences in surface roughness, ranging from 126 for muscovite to 34 for feldspar for our samples. We conclude that our 8.5 y laboratory data are in general agreement with the data from field studies, within the uncertainties of both experimental measurements and field estimates of appropriate surface area.

## References

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