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The Temporal Variation of Quartz Dissolution Rates: Have Quartz Dissolution Rates Changed over Historic Time?

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Over the past 30 years numerous studies characterized the dissolution rates of major rock forming minerals. These data render it possible to determine the extent to which dissolution rates may or may not have changed over historic time. Quartz steady state dissolution rates at pH 4 were obtained from a variety of literature sources. Quartz has been chosen for this analysis because 1) it is pervasive in natural systems, 2) its dissolution mechanism is relatively simple, and 3) a large number of quartz dissolution measurements are available at near to neutral conditions. These dissolution rates are plotted as a function of their publication date in Figure 1 below; all rates depicted on this figure were obtained at far from equilibrium conditions. A striking correlation between publication year and measured steady state rate is apparent. The earliest rate on the figure, published in the 1970's is 10^{-15} mol/cm^2/sec, whereas the most recent rate (Stradth, 2000, in press) is 10^{-18} mol/cm^2/sec, indicating a decrease of three orders of magnitude in less than 30 years! Data published between these studies is closely consistent with this trend. A least squares fit of these data is represented on the figure. This fit has a slope consistent with an annual 0.13 order of magnitude decrease in quartz dissolution rates since the 1970's. The correlation coefficient of this fit (R^2) is 0.802; it is possible that R^2 would be higher if it were possible to make this correlation with the actual date the experiments were performed rather than their publication date. The data and regression curve shown in the figure, therefore, strongly support the possibility that quartz dissolution rates have decreased substantially over historic time. If the decrease with time of quartz dissolution rates has been continuous, this observation can explain a large number of historical events. For example, taking a linear extrapolation of these rates back to biblical times suggests that quartz dissolution rates may have been on the order of 10^{250} mol/cm^2/sec. Such remarkably fast rates may account for the 'disappearance without a trace' of some ancient cities. In addition, terrestrial erosion rates would have been far greater than today. Such effects would need to be accounted for in global cycles, in particular in estimating the role of surface weathering on atmospheric CO_2 content and climate. Nevertheless, any conclusions based on comparisons of literature kinetic rate data, such as those presented above, should be carefully tested by performing a set of consistent rate measurements of quartz as well as the other major rock forming minerals. Clearly, inconsistencies among rates reported in different studies may stem from differences in 1) solid preparation, 2) experimental techniques used to measure rates, 3) surface area measurements, 4) the amount of time waited prior to the investigator declares their experiments to be at steady state, and 5) improvements in analytical techniques. Until the origin of these and other possible inconsistencies among dissolution rates reported in the literature are resolved it will not be possible to precisely determine the extent and consequences of mineral dissolution rate variations over historic time.

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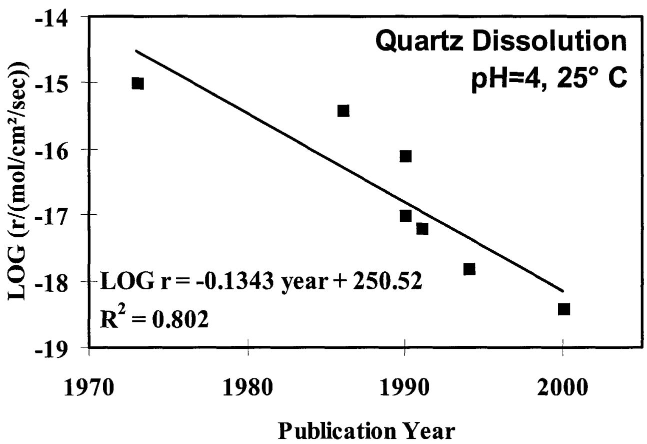

Figure 1: Measured steady state/far from equilibrium quartz dissolution rates as a function of publication date. The symbols in the figure represent data reported by Nickel (1973), Chou and Wollast (1986), Brady and Walther (1990), Blum et al. (1990), Bennett (1991), Dove (1994), and Stradh (2000). The line represents a linear least squares fit of these data (see text).