THE KINETICS OF QUARTZ DISSOLUTION AND PRECIPITATION

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Silica precipitation in geothermal power plants and in reservoir formations is considered to be a potential problem area in the successful development of geothermal power from liquid dominated resources. In order to gain insight into the significance of this problem and to estimate the rates of precipitation of silica under varying conditions, a literature review and evaluation was made.

Data on the kinetics of quartz dissolution and precipitation in water was fitted to an expression derived from absolute rate theory, assuming that the mechanism could be represented by the equation:

$$SiO_2 + 2H_2O = Si(OH)_4$$

k'_f and k'_b, the specific forward and back rate constants were obtained for various sets of literature data at temperatures ranging from 25°C to 625°C, primarily along the saturation curve for water. The rate constants were plotted as log k'_f or log k'_b against 1/T (K^{-1}) and a linear fit obtained. Log k'_f is found to vary between -9.67 (s^{-1}) at 25°C and -0.07 at 350°C, and log k'_b between -6.19 and +1.83 for the same temperature range.

Although there is sufficient literature data to observe trends in quartz dissolution and precipitation in water, the data are too variable in quality to estimate precipitation rates accurately. Kinetic data on other silica polymorphs or in other solutions is quite inadequate to draw any significant conclusions.

DISCLAIMER

Figures 1, 2, 3.

Absolute rate theory to describe kinetics of silica solubility in the aqueous phase.
(See S. Glasstone, K. J. Laidler and H. Eyring, Theory of Rate Processes, McGraw Hill Book Co., New York, 1941).
A = surface area, σ = surface site density. For other symbols, see reference.

$$SiO_2 + 2\,H_2O \underset{k_b}{\overset{k_f}{\rightleftarrows}} C^* \underset{k_b}{\overset{k_f}{\leftrightarrows}} Si(OH)_4$$

$$K^*_f = \frac{[C^*]}{[SiO_2]\,[H_2O]^2} \quad ; \quad K^*_b = \frac{[C^*]}{[Si(OH)_4]}$$

Figure 1

$$
\begin{aligned}
\frac{dn_f}{dt} &= \frac{\kappa\, k\, T}{h}\,[C^*]\,A\sigma \\
&= \boxed{\frac{\kappa\, k\, T}{h}\,K^*_f}\;[SiO_2]\,[H_2O]^2\,A\sigma \\
&= k'_f\,[SiO_2]\,[H_2O]^2\,A\sigma
\end{aligned}
$$

Figure 2

$$
\frac{dn_f - dn_b}{dt} = k'_f\,A\sigma\,[SiO_2]\,[H_2O]^2 - k'_b\,A\sigma\,[Si(OH)_4]
$$

$$
\frac{n}{m} = \frac{n_o}{m}\,e^{\frac{-A\sigma\, k'_b\, t}{m}} + \frac{k'_f}{k'_b}\left(1 - e^{\frac{-A\sigma\, k'_b\, t}{m}}\right)
$$

Figure 3

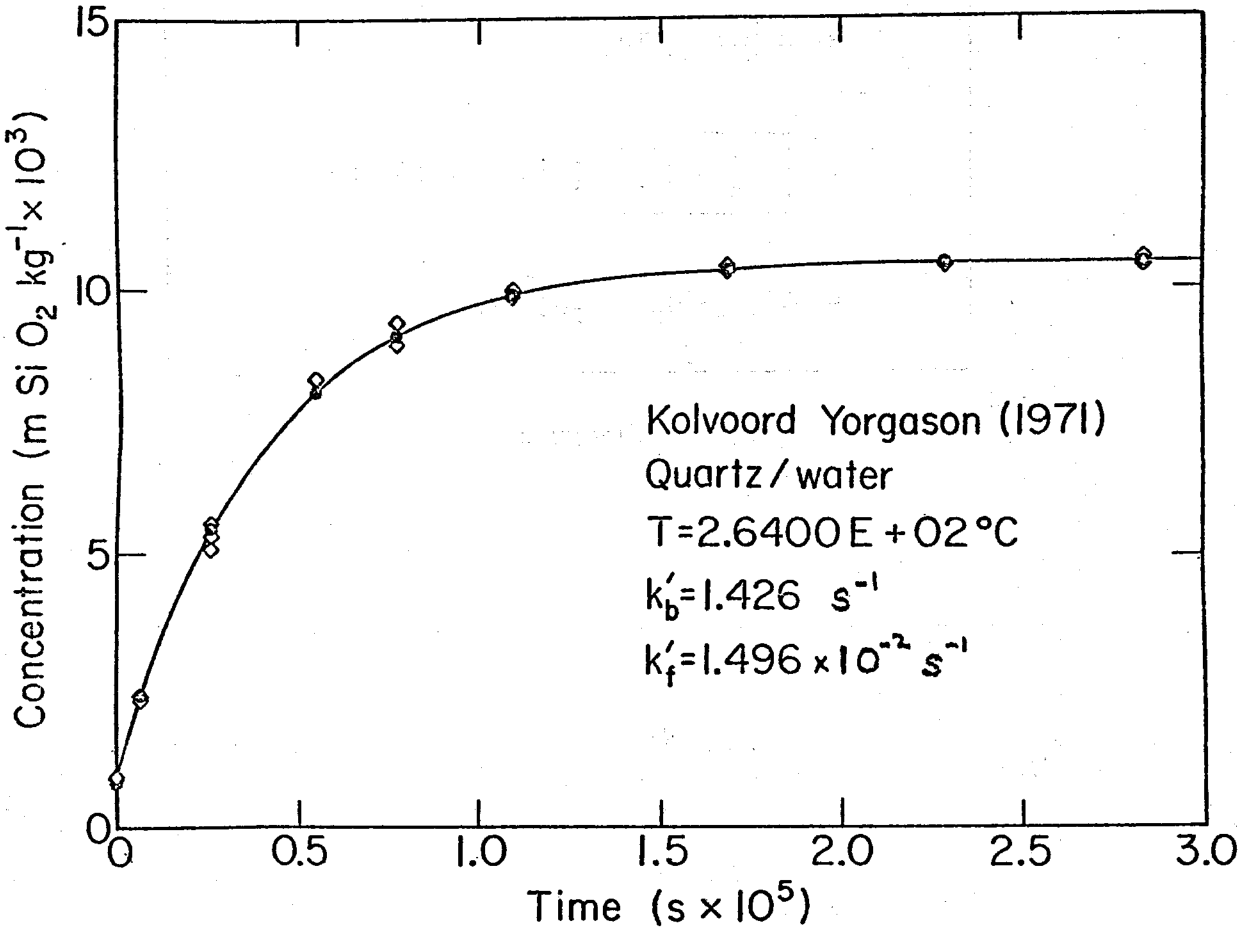

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Figure 4. The dissolution of quartz in water at 264°C. The data are by Kolvoord and Yorgason (Kennecott Exploration, Inc., Salt Lake City). The solid line represents the best fit to the data using equation in Figure 3.

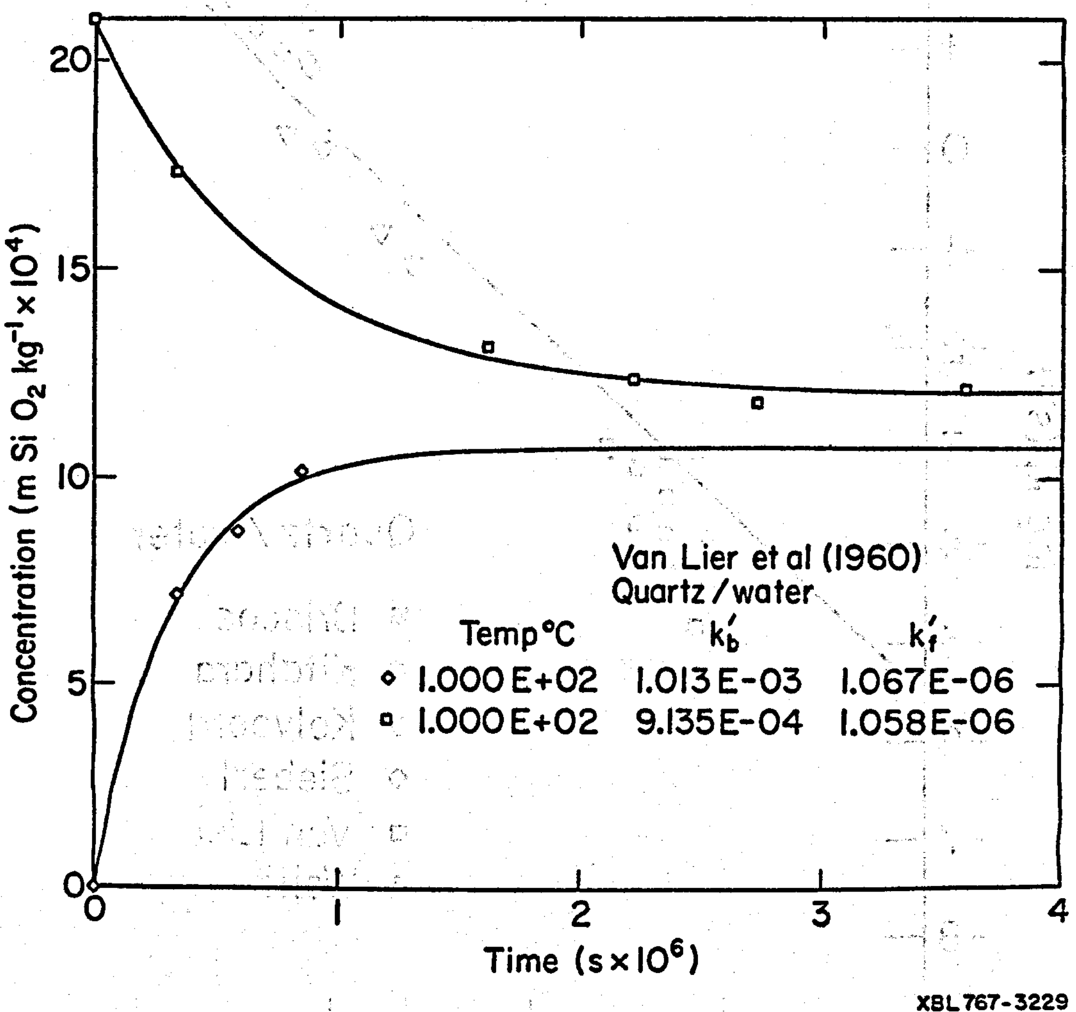

Figure 5. The dissolution and precipitation of quartz in water at 100°C. The data is by Van Lier et al. (J. Phys. Chem. <u>64</u> p. 1675 (1960)). The solid lines represent best fits to the data using equation in Figure 3.

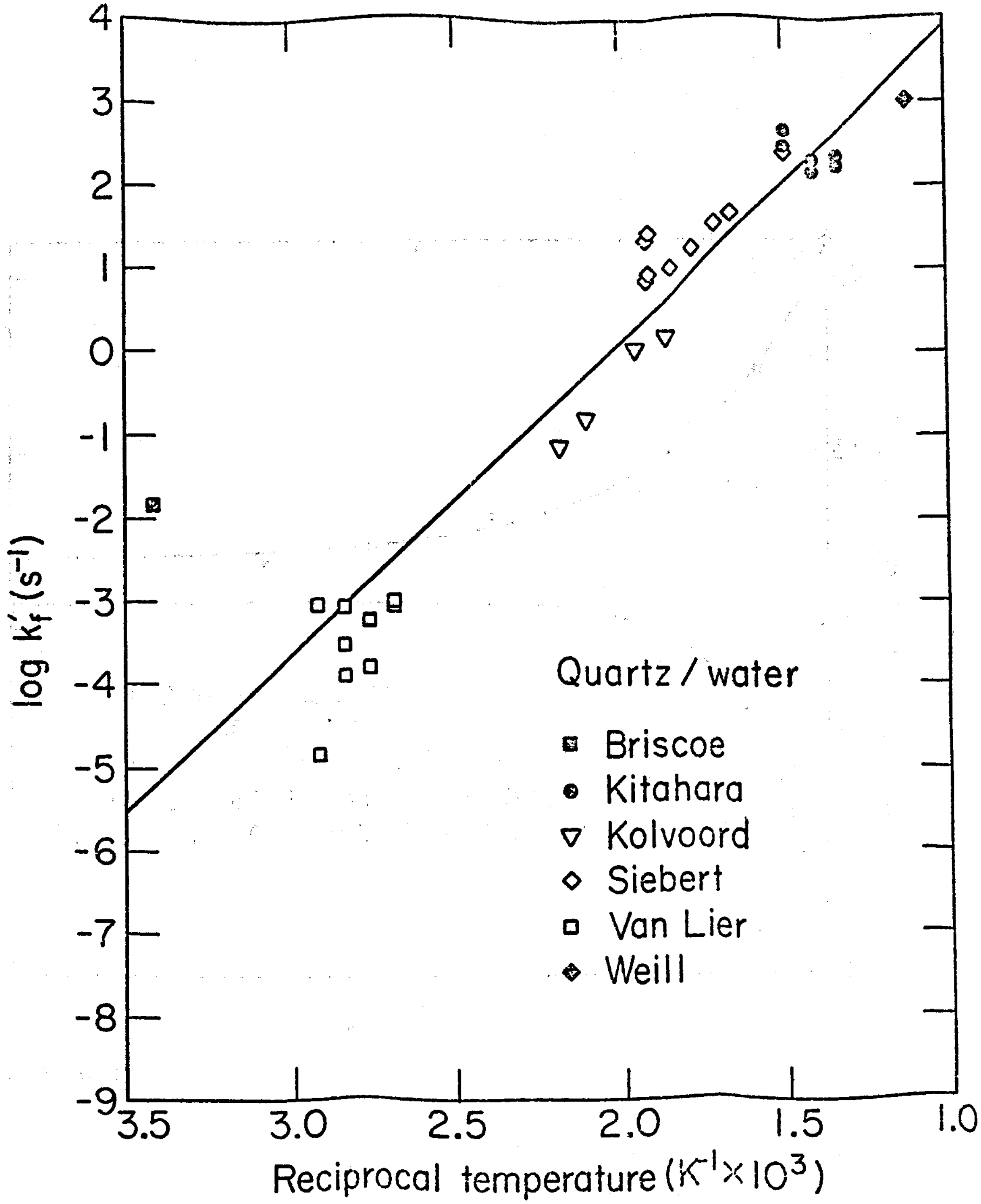

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Figure 6. The specific forward rate constants, k'_f, for the dissolution of quartz in water plotted against the reciprocal of the absolute temperature. Values of k'_f are calculated from literature data.

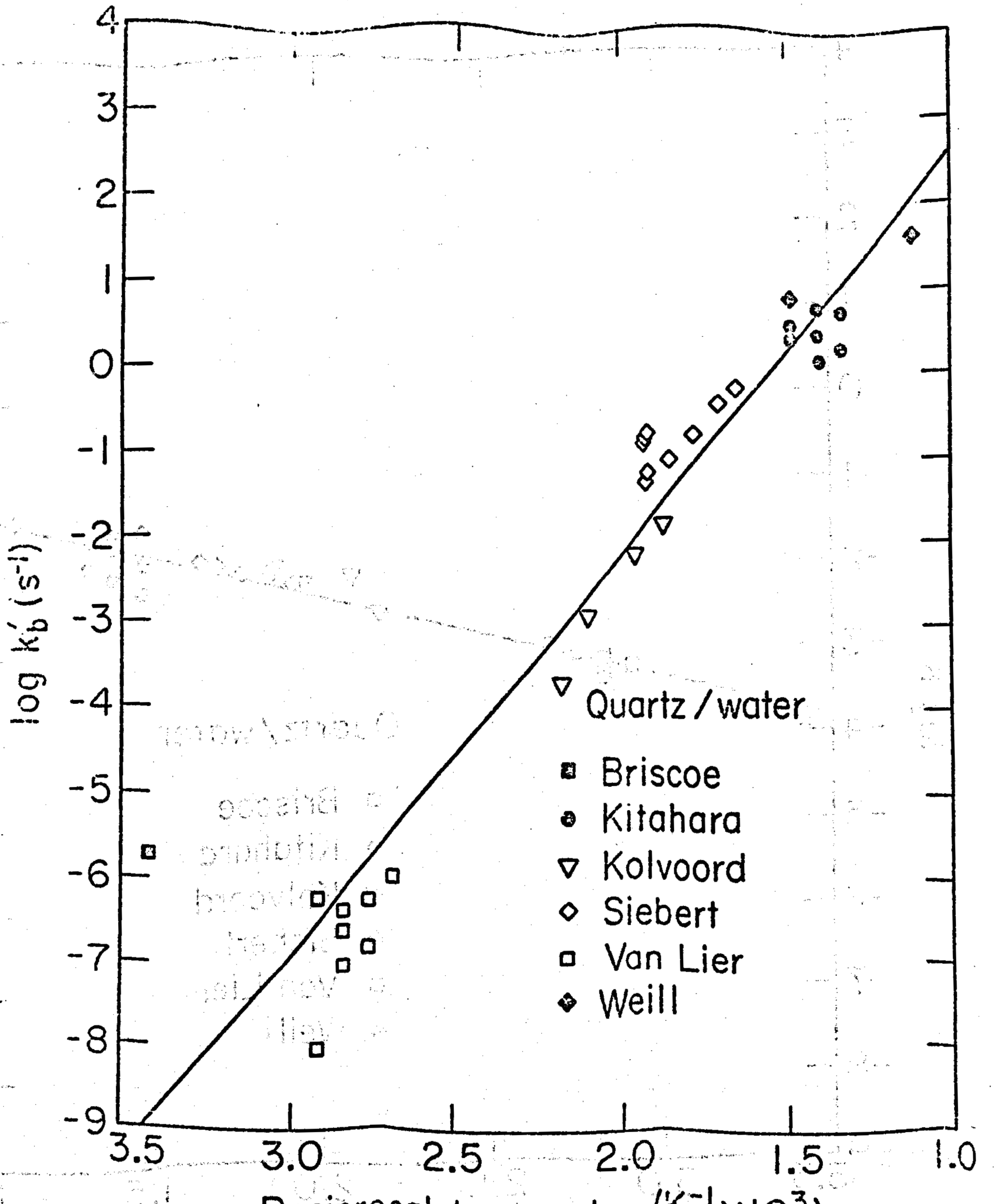

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Figure 7. The specific back rate constant, k'_b, for the dissolution of quartz in water, plotted against the reciprocal of the absolute temperature. Values of k'_b are calculated from literature data.

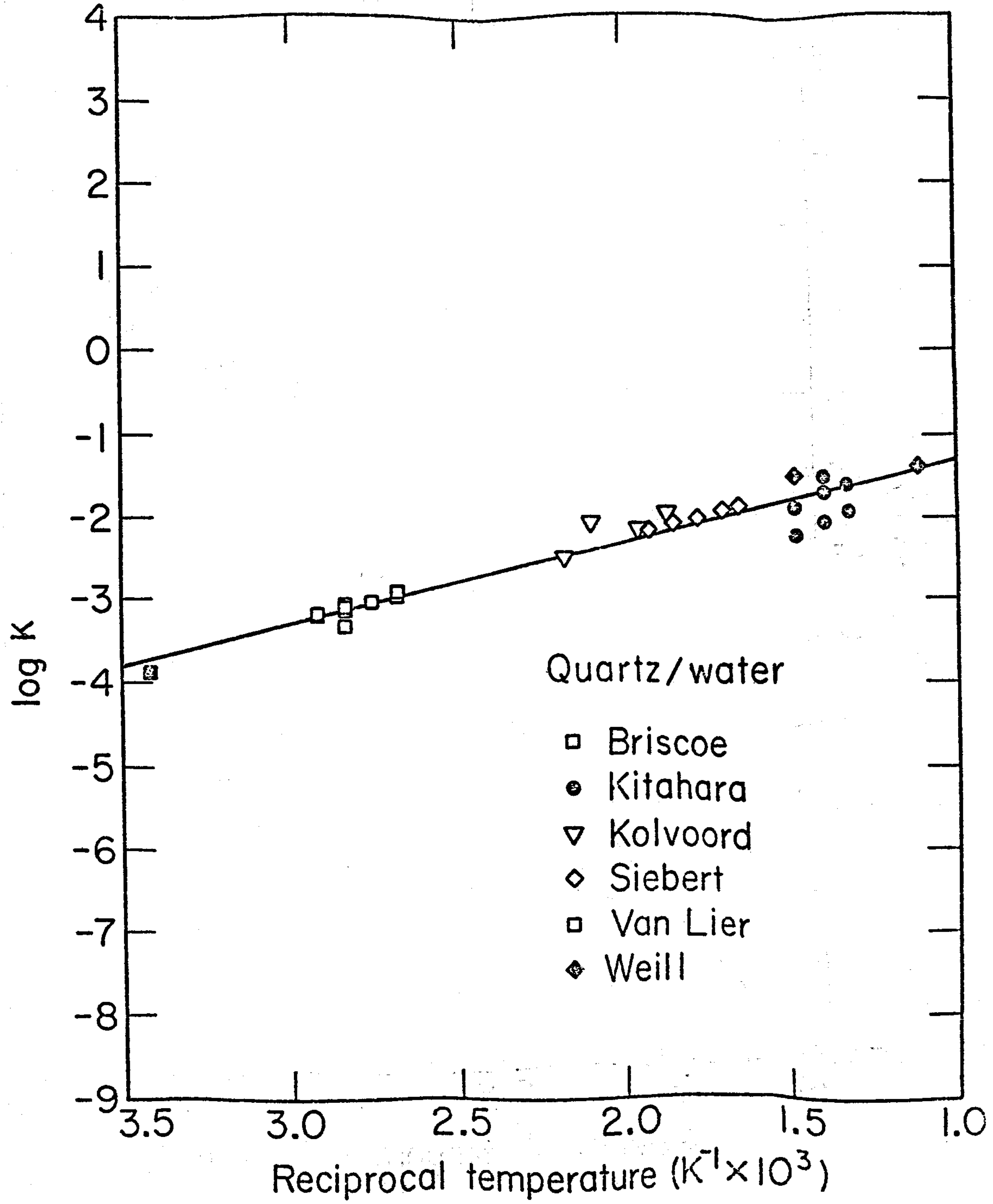

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Figure 8. The equilibrium constant, K, for the dissolution of quartz in water, plotted against the reciprocal of the absolute temperature. Values of K are computed from literature data.