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Surface properties, solubility and dissolution kinetics of phytoliths, from bamboos of Reunion Island

F. Fraysse [a], O.S. Pokrovsky [a], J. Schott [a], J.D. Meunier [b]

(a) Laboratoire des Mécanismes de Transfert en Géologie (LMTG), UMR 5563 UR 154 CNRS Université Paul-Sabatier IRD, OMP, 14, Av. Edouard Belin, 31400 Toulouse, France
(fraysse@lmtg.obs-mip.fr)
(b) CEREGE, Europôle méditerranéen de l'Arbois, BP80, 13545 Aix-en-Provence, France

Phytoliths, constituted mainly by micrometric opal, exhibit an important control on silicon cycle in superficial continental environments, however, their physico-chemical properties and their reactivity in solution are still poorly known.
The aim of this work is to determine the solubility and dissolution kinetics of bamboo phytoliths from Réunion Island and to characterize their surface properties via electrokinetics measurements and potentiometric titration.

Background

Dissolved silicic acid in soil solutions, trapped by plant roots, precipitate in aerial tissues cells like micrometric opal particles called phytoliths (Fig.1). Then, this phytoliths are released by organic matter degradation in litters and then can be transferred to soils or evacuated by aerial or hydrographic ways. The phytoliths studied have been sampled at the northwest of Reunion Island in the M horizon at a depth of 20cm (Fig.2). Their origin is bamboos.

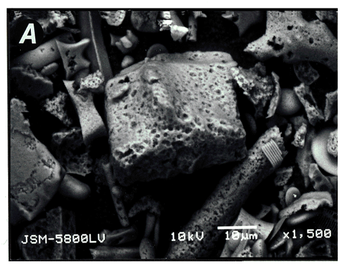


Fig. 1: Phytoliths view by S.E.M. (Meunier J.D., 1999)

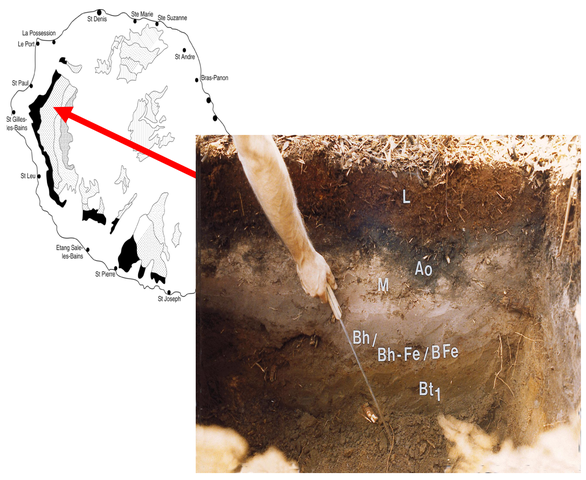
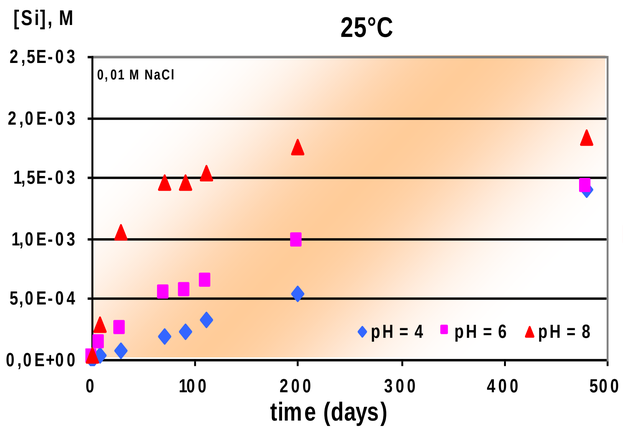
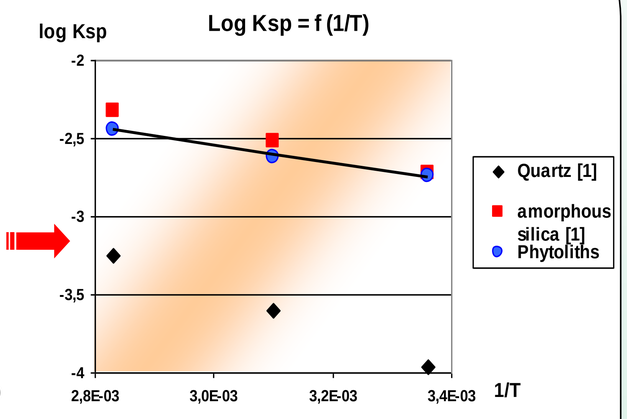


Fig.2: Study area (Meunier J.D., 1999)

Solubility





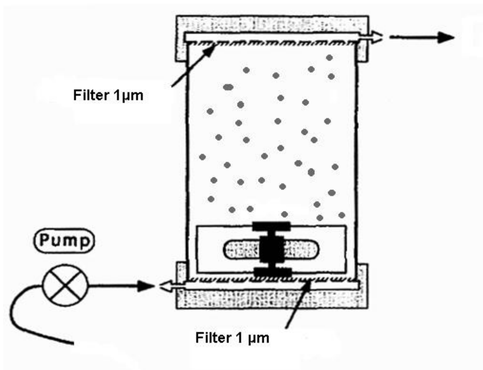
At pH (25°C) = 8, $[SiO_{2\,(aq)}]_{mesured} = [H_4SiO_4^{\circ}{}_{(aq)}]$

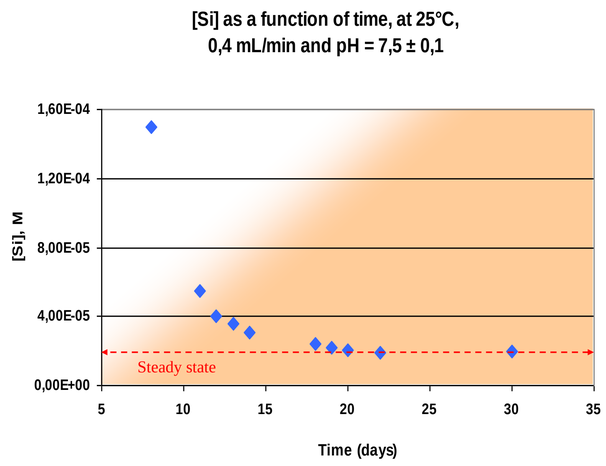
- For phytoliths, $\Delta Hr^{25\text{-}80} = 10.85$ kJ/mole
- For amorphous silica, $\Delta Hr^{25\text{-}80} = 14.44$ kJ/mole
- For quartz, $\Delta Hr^{25\text{-}80} = 25.63$ kJ/mole

T (°C)	C_{SiO2} mmol/L	log K_{sp} phytoliths
25	1,83	-2,74
50	2,38	-2,62
80	3,6	-2,44

Dissolution kinetics

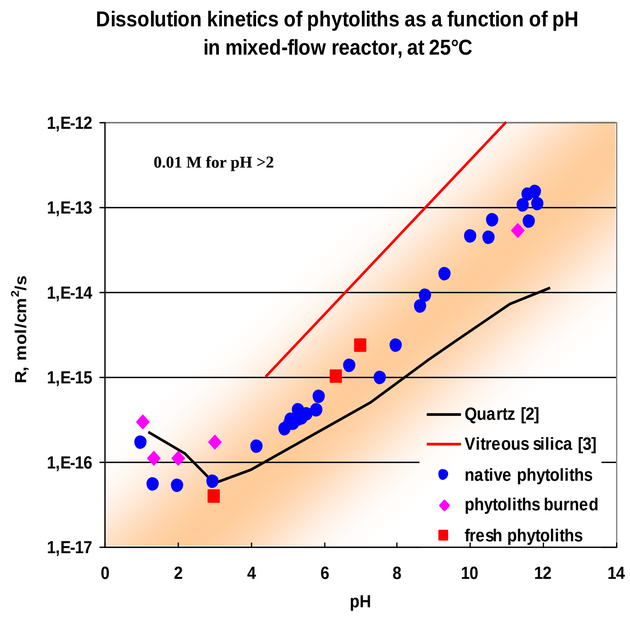
Dissolution kinetics have been made in « mixed flow » reactors.





Rate of dissolution R, mole/cm²/s:

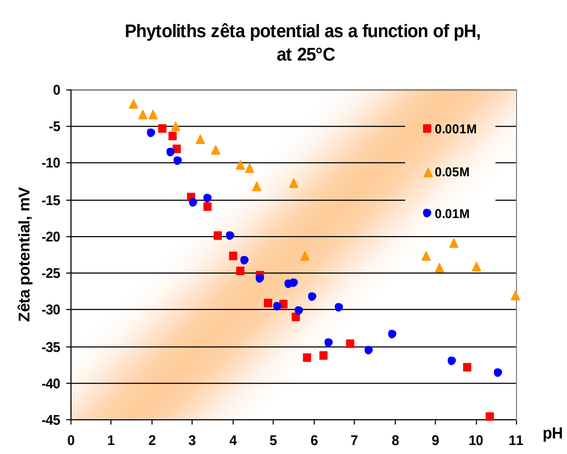
$$R = ((C_{out} - C_{in}) * Q) / (M * S)$$

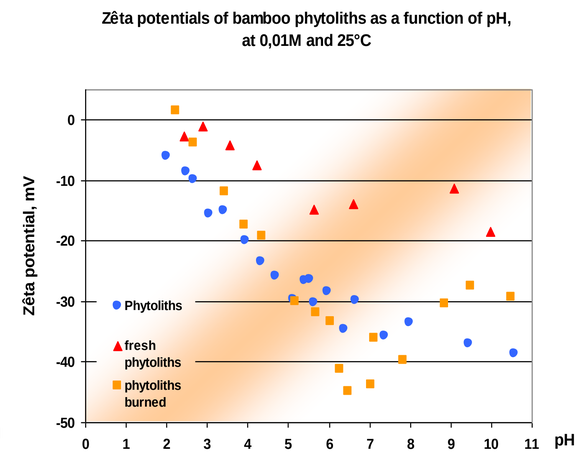


At $4 \leq pH \leq 10$, $R = k_p * a_{OH}^{0.33}$

$R \sim k_{Si} [>SiO^-]^{2.0}$

Zêta potential Measurements



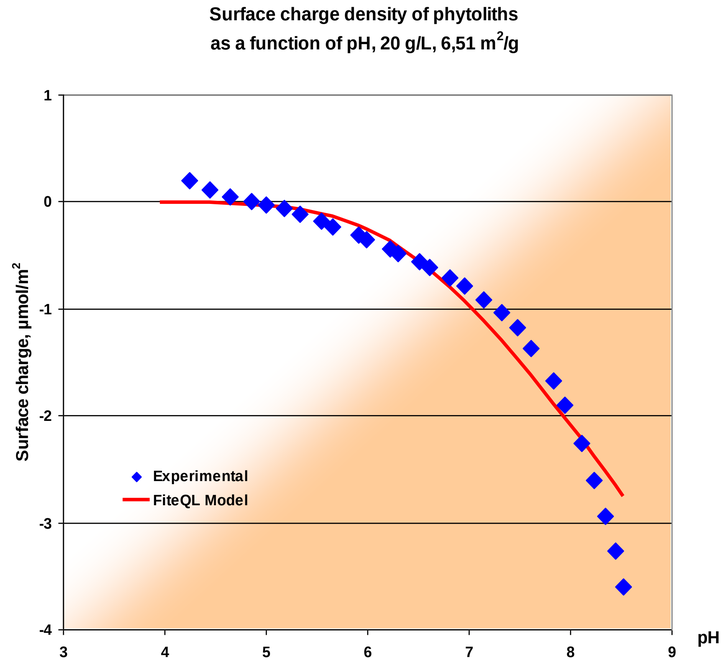


$pH_{IEP} = 1.15 \pm 0.1$

At pH_{IEP}, $[>SiO^-] = [>SiOH_2^+]$

Potentiometric titration

Acid-base properties of phytoliths have been determined by potentiometric titration at 25°C in 0.01M NaCl:



Conclusion

While the solubility of phytoliths is ~ 20 times higher than that of quartz, their reactivity at 25°C are similar. It follows from the results of this study that phytoliths dissolution rate exhibits a minimum at pH ~ 3. This can explain their good preservation in the acidic soil horizons of Réunion Island. Phytoliths can represent a real reservoir of biogenic silica in acid soils like those in Reunion island and consequently must be taken into account to study the global cycle of silicon.

[1]: Rimstidt and Barnes (1980) [2]: Dove and Elston (1992) [3]: Wirth and Gieskes (1979)