Involvement of siderophores in the dissolution of basaltic glasses

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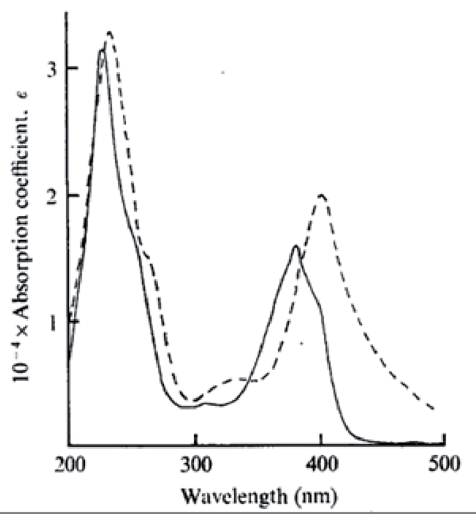
Introduction

Microorganisms such as bacteria or fungi are known to play an important role in mineral weathering processes. Nevertheless their contribution and the mechanisms still remain unclear. In poor iron conditions, many bacterial species can synthesize a substance called siderophore. It may help them to acquire from their environment, the micronutrients they need for their growth.

Pyoverdin, is the green-yellow pH dependent siderophore produced by Pseudomonas species, and can be easily identified with a maximum of absorbance between 365 to 410 nm from pH 3 to 10. It has the ability to form a strong complex with iron(III) ions before being absorbed by the bacteria. However, other ions can also be bound to pyoverdin with lower affinities. Each [pyoverdin-ion] complex formed has generally its own spectrophotometer spectra (variations of intensity or maximum lag) (see Figure) hence the interest of creating a bank of reference spectra.

The basaltic glasses being composed of several metals (e.g. Fe, Al, Si, Na, Ca, Mg), spectral analysis can be a simple way to identify and evaluate the quantity of complexed metal.

Absorption spectra of pyoverdin (____) and the [pyoverdine-Fe^{3+}] complex (- - -)



Source: JM Meyer and MA Abdallah. The fluorescent pigment of Pseudomonas fluorescens: biosynthesis, purification and physicochemical properties. Journal of General Microbiology, 107:319-328, 1978

Experimental procedures

The first step consisted in synthesizing pyoverdin. For this, 10µL of Pseudomonas aeruginosa bacteria strain were firstly grown in a rich medium (LB) containing ($g.L^{-1}$ in distilled water): Triptone, 5; beef extract, 5; NaCl, 5. After 3 days of incubation, 20 µL was transferred into a poor medium (CAA) used to induce the pyoverdin production. It contained $g.L^{-1}$: casamido acids, 5; K_2HPO_4, 1.18; $MgSO_4.7H_2O$, 0.25.

For the complexation experiments, 4 solutions of metals must be prepared using: Al_2O_3, $Ca_3P_2O_8$, MgO and $FePO_4.2H_2O$ at respective elemental concentrations of 75, 250, 60 and 50 $µg.L^{-1}$ (determined with previous ICP results (obtained by immersing basaltic samples in ultra pure water for 5 to 25 days).

Because of the pH variations of pyoverdin and more generally the role of pH r in mineral dissolution, each sample was buffered at a pH of 6.38 using $NaHCO_3$ 1mM. Thus, results would be comparable with the ones obtained later with glass samples weathered in the same conditions.

Results and discussion

Entirely dependent on pyoverdin production, these experiments have not been performed because of the impossibility to obtain the pigment in large quantities, and so remain theoretical for now.

A first production test performed to verify the method has been successfully achieved, validating the experimental procedure. Then at three different times, bacteria were cultured in three tubes containing LB medium and in one of them only the bacteria have developed. The CAA incubations were processed from this tube (with and without the buffer in a second phase) without success whatever the conditions were.

The first trial with the buffer may have led to an osmotic shock causing the death of the cultures, a hypothesis rejected by the second trial. The problem might be directly due to the strain: perhaps the one that developed in the tube is not Pseudomonas aeruginosa, or maybe bacteria were stressed and unable to produce the siderophore.

Conclusion

Simple spectrophotometric experiments can be helpful to understand the mechanisms involved in the dissolution of basaltic glasses. They can indicate the complexed metals by spectral comparison, a first range of concentrations, and even an idea of the speed (and thus of the affinity constant) of the metal uptake by the bacteria. But experiments with bacteria are hardly reproducible, which can be problematic for the validation process of this method and associated results.

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