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Using gamma probes to improve in situ diffusion experiments in the Callovian-Oxfordian argillaceous rock

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The Callovian-Oxfordian argillaceous rock is currently studied by Andra, the French radioactive waste management agency, as potential host-rock formation for radioactive waste. Since 2004, several radionuclide diffusion experiments have been performed *in situ* at 490 m depth in the Meuse/Haute Marne Underground Research Laboratory [1]. In these experiments, dissolved radionuclides were injected in vertical boreholes. The radionuclide content decreased in the boreholes due to diffusion towards the rock. This decrease was followed through water sample analyses. At the end of the experiment, overcoring the boreholes made it possible to map the radionuclide content into the rock cores. These experiments helped investigating diffusion over 1-2 years and a few centimeters migration distances.

Longer experimental duration and migration distances are necessary to better constrain undisturbed rock diffusion properties, both parallel and perpendicular to bedding planes. This was made possible thanks to the development of specific gamma probes [2, 3]. These probes allow monitoring in real time the evolution of radionuclide distribution in the rock volume (~0.1 m^3) surrounding them. Two tests have recently been implemented. The first one is dedicated to dissolved ^{22}Na diffusion from a horizontal borehole surrounded by 4 gamma probes. The probes are located 35 cm far from the injection borehole, both vertically and horizontally to evaluate diffusion anisotropy. These probes also measure the rock natural radiation. This background signal is mainly due to the presence of ^{40}K and its value is constant. Therefore, it can be subtracted from the measured value in presence of injected ^{22}Na. On the other hand, this background signal can be used to calibrate the probes. The second test follows the potential mobility of U from solid UO_2 with another type of gamma probe – measuring lower radiation energy [3]. Both tests should last 8 to 10 years.

This technology may be useful to monitor *in situ* gamma emitter migration in other geological contexts.

[1] Delay et al. (2014), *Geological Society, London, Special Publications* 400, 7-32.

[2] Lin (2017), *PhD thesis*, Lyon University.

[3] Lin et al. (2019), *Nuclear Instruments and Methods in Physics Research Section A* 938, 14-19.