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Radon constrains the transit time of springs water at the border between tabular Middle Atlas and the Sais Basin (Morocco)

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The tabular Middle Atlas (TMA) is an important fractured karstic reservoir in northern Morocco constituted by Liassic limestones and dolomites with a nearly sub-horizontal attitude, overlying basalts, shales and evaporates of Triassic age, as well as Paleozoic anchi-metamorphic schists. The zone is characterised by relative abundant rainfall (700 mm/y) and the absence of a surface watershed, which lead to an important groundwater reservoir hosted in the karstic (k-) aquifer. TMA is bordered to the North by extensive graben-like, normal, northward, fault-systems, which burden the Karstic formations under Plio-quaternary sediments at the Sais Basin border. At this limit, several important springs of high water-quality occur at the northernmost outcropping Lias limestone, which is overlaid in some areas by quaternary travertines. Two of these springs in particular, Bittit and Ribaa springs, provide almost drinking water for the town of Meknes (0.7 Million inhabitants), for local population and agriculture. These springs experienced a significant drop in water flow-rate in the last decades. Although the main origin of this water is certainly the k-aquifer, the drop in water-table raises several questions regarding the modality of water transport (influence of fractured and karstic systems in particular) and the possible participations of other groundwater reservoirs, which may deteriorate the high water-quality. A recent study has been carried out to shed some light on these questions, by using geochemical methods (K, Mg, Na, Ca, Fe, Mn, Ba, Sr, As, Sb, Hg, HCO3, SO4, NO3, Cl, Br, delta18-O, deltaD, Rn, EC, O2, pH, Eh, Temp). Constraints on the groundwater flow-path have been obtained by using a radon- hydrochemical- isotopic characterisation of spring waters. Here we report the results of the first geochemical sample collection (November 09).

Several springs in the TMA yield Mg-Ca HCO3 rich water equilibrated with limestone and dolomite, having a very similar Rn activity of 3000 Bq/m3, unrelated to spring altitude. Similar radon activity is also found in a deep well in the Lias-confined aquifer of the Sais Basin and is hence considered to be the steady state activity in k-aquifer. Other springs situated at lower altitude yield more mineralised water (EC = 1200 uS/cm), richer in Na, K, Cl and Rn (15000 Bq/m3). These waters partially interacted with a non-karstic aquifer, most probably the deeper underlying Paleozoic schists (p-aquifer), as suggested by hydro chemical similarity with a water sample collected from a well in these shists. Since such water springs-out of Liassic carbonates, the measured Rn activity probably differs from the equilibrium activity achieved in the underlying p-aquifer, depending on the transit time from p-aquifer and the radon half-life (3.8 days). Furthermore, three other springs have hydrochemical characteristics intermediate between p- and k-aquifers, suggesting that a binary mixing of these waters occurred, either in the k- or in the p- aquifer. In principle, if the groundwater mixing occurred in k-aquifer, unsupported Rn activity would be lower than the activity expected from the binary mixing because of the time elapsed since the mixing occurred. The data show on the contrary that the mixed water has Rn activity higher than the expected activity calculated from the mixing. This suggests that groundwater mixing occurred in the p-aquifer. The excess of radon relatively to the expected activity calculated after the mixing, is interpreted to result from Rn radioactive ingrowth during the residence time in the p-aquifer, followed by radon decay occurred during uplift from p-aquifer to the spring in the Liassic carbonates. With this simple model, the measured Rn excess constraints the total time elapsed since the beginning of interaction with the p-aquifer on a time scale of 2 weeks. Remote sensed imaging of the area evidences that these “mixed” springs lies on important tectonic alignments, which suggest that fractures system could play a role in the fast upwelling of groundwater.