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Geochemical and Isotopical Analyzes of Groundwater in a Karst System : The case study of Fez-Meknes Basin (Morocco)

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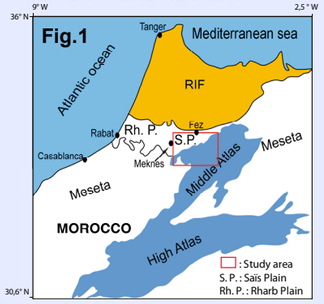
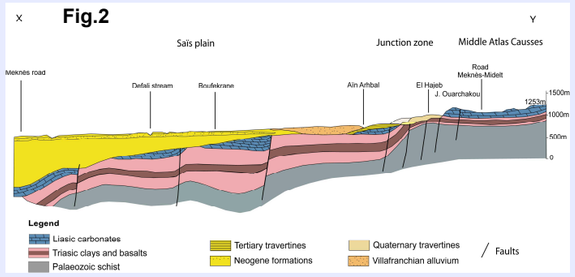
INTRODUCTION : The karst Middle Atlas Causses reservoir mainly composed of Liasic dolomitic limestone, overlying Triassic clays, evaporates and basalts, is the main drinking water supply in Fez-Meknès region (Saïs Basin). Because of the increase population, the number of drilling for irrigation of agricultural land and some longer drought periods in recent years, the issue of sustainable groundwater management arises. Recent analyzes have shown a decline in its chemical quality and punctually some turbidity problems. In order to enhance understanding of this hydrosystem and the interactions between the different main springs of Liasic and Triassic origin, and their connections to the major spring (Bittit), an integrated hydrochemical study was conducted coupled to isotopic analyzes of delta O-18, delta-D and Radon-222. Four surveys were performed in fall and spring seasons (2009-2011).

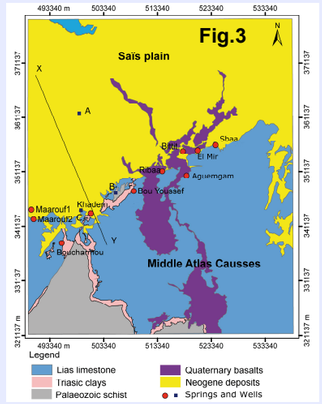
GEOLOGICAL SETTING



Geographical localisation of our study area (red rectangle) between the Saïs Basin and Middle Atlas Causse.

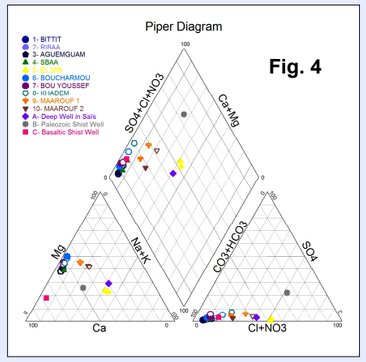


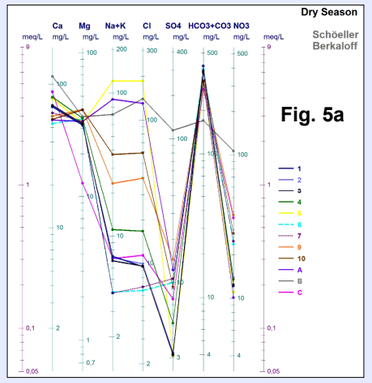
Geological Section (XY - Fig. 3) of the south rifain groove according to the geological map of El Hajeb 1/100000 (Chamayou et al., 1975)



Geographical map of springs and wells at the foot of the Causses (Qarqori, 2015)

HYDROCHEMISTRY : Major elements





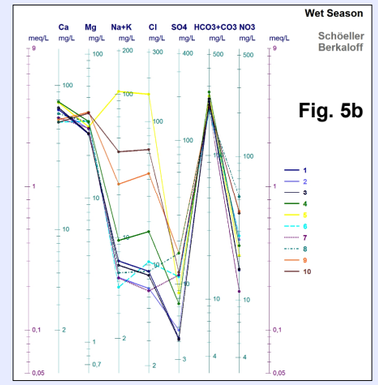
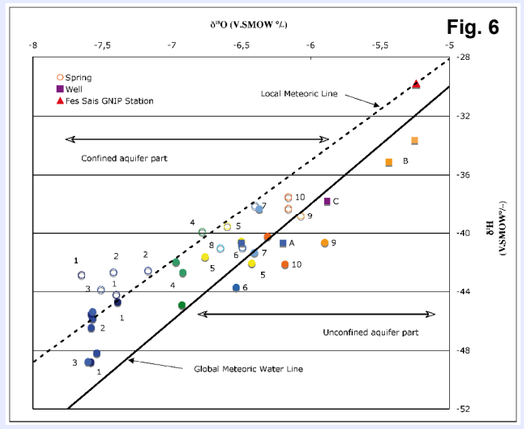


Fig. 4 : Water Geochemistry of springs and wells and characterization of three water groups : Springs: 1- Bittit; 2- Ribaa; 3- Aguemguam; 4- Sbaa; 5- El Mir; 6- Boucharmou; 7- Bou Youssef; 8- Khadem; 9- Maarouf 1; 10- Maarouf 2.
Full (open) symbols represent dry (wet) seasons. Wells: A- Deep well in Saïs Plain; B- Paleozoic schist well; C- Basaltic schist well

Fig. 5a and 5b : Seasonality expressed by Shoeller-Berkalov diagrams of cations and anions present in springs and wells. Dry season (October-November) in 5a. Wet season (March-April) in 5b. They are referenced as in Figure 4.
Figures 4 and 5a, 5b are using « Diagrammes » Software V. 5.9, LHA, EMMAH, UAPV Avignon, Fr.

•Third groups of groundwaters (**Fig. 4; Fig. 5a and 5 b**):
-Group 1 with liasic origin in the southern sector near the Causses (Bittit, Ribaa, Aguemguam, Boucharmou, Bou Youssef and Khadem);
-Group 2 with triassic origin in the northern sector (Sbaa 2, El Mir, Maarouf 1, Maarouf 2 and A (Deep Well in Saïs))
-Group 3 for the two open wells samples B and C (Paleozoic Schist well and Basaltic Schist well) with a low ratio Mg/Ca, an increase of sulfates and a few Na^+ with a similar Cl^- compared to group 2.
-Seasonality is expressed by bicarbonates and sulfates : bicarbonates decrease after the rainfall season while sulfates increase. This means a higher proportion of groundwater having interacted with gypsum near the Triassic aquitard after the rainfall season.

HYDROCHEMISTRY : Isotopical analysis and interpretation



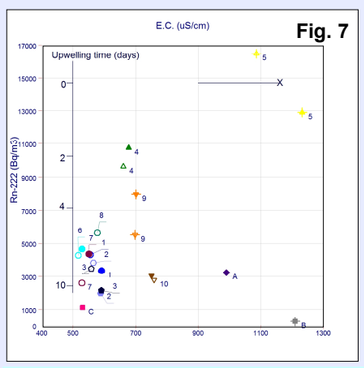


Fig. 6: Seasonality and geographical origin of springs and wells from stable isotopes (delta-O18, delta-D) with respect to the Global Meteoric Water Line (Rozanski et al, 1993) and the Local Meteoric Line (El Ouali et al., 2014). A confined aquifer is characterized in Eastern Sector (Lhajeb Causse) and an unconfined aquifer in Western Sector (Guigo Causse). Full symbols represent dry season and open symbols, wet season.

Fig. 7: Conductivity of water versus Radon-222 activity and transit time of water from the triassic aquitard to the Liasic aquifer. Springs and wells are referenced as in Figure 4.

- Two aquifers co-exist according to their geographical origin (**Fig. 6**) : 1) A confined aquifer in the North-East sector around Bittit (L'Hajeb Causse) with a less enriched isotopic composition;
  2) An aquifer with a high evaporation in the South-West sector (Guigo Causse).
- A seasonal effect is observed : Deuterium excess ($d_{excess} = \delta D - 8\delta^{18}O$) higher after the raining season (open symbols). Larger kinetic effect in the vapor source for the winter recharge.
- Three major recharge zones are estimated.
- Upwelling time based on Radon-222 (T=3.85 days) (**Fig. 7**) : Secular equilibrium reached with the Liasic aquifer for an activity of 3500 Bq/m3. Areas of rapid exchange. Upwelling time from the Triassic aquifer to surface less than two weeks.

General Conclusion : The waters renewal is only conducted by major rainfalls ($^3H \approx 5 \pm 0.3$). Three major recharge zones of different altitudes (*1400m, 1200m, plain*) have been found and two main mixing zones at the limits of Saïs Basin.

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