Hydrothermal Circulation and Thermal Springs in the Middle Atlas–Saïss Basin (Morocco): Implications for Geothermal Energy

Fatima-Ezzahrae Lahrach [1*], Lalla Amina Ouzzaouit [1], Nour Eddine Berkat [2],

Loubna Ait Jana [1], Abdelmounim Qarbous [3],

Mohammed Boumehdi [2], Larbi Boudad [1]

[1]Department of Geology, Faculty of Sciences, Mohammed V University, Rabat, Morocco
[2]National Office of Hydrocarbons and Mines, Rabat, Morocco
[3]Department of Geology, Regional Centre for Education and Training Professions, Rabat, Morocco
** Corresponding author: E-mail address: fatimaezzahrae_lahrach3@um5.ac.ma*

ABSTRACT

Morocco hosts several geothermal manifestations associated with deep hydrogeological circulation and tectonic activity. The Middle Atlas and the adjacent Saïss Basin constitute one of the main hydrogeothermal regions of the country, where numerous thermal springs emerge along major tectonic structures. However, research on hydrothermal alteration and its relationship with geothermal potential in Morocco remains limited. This study analyzes the spatial distribution of thermal springs and hydrothermal alteration indicators in order to better understand hydrothermal circulation within the Middle Atlas–Saïss hydrogeological system. The methodology is based on the integration of geological and structural analysis with the mapping of hydrothermal alteration zones derived from remote sensing data, complemented by field observations. The results highlight the Imouzzer Marmoucha area, where the hottest thermal spring of the Middle Atlas (Skhounate Marmoucha) emerges, associated with active hydrothermal circulation and the presence of calcite veins cutting Jurassic limestones. The distribution of thermal springs shows a strong relationship with tectonic structures, which control deep groundwater circulation. Groundwater flows, mainly oriented toward the north and northwest, re-emerge at the base of the Tabular Middle Atlas along NW–SE oriented fractures before discharging into the Saïss Basin, which represents the main hydrogeological discharge zone. To better constrain the functioning of this hydrothermal system and the geometry of the geothermal reservoir, hydrogeochemical and geophysical investigations are recommended. The integration of these multidisciplinary approaches will contribute to a more accurate assessment of the geothermal potential of the Middle Atlas and the Saïss Basin, paving the way for their sustainable energy development.

Keywords: Hydrothermal circulation; Groundwater flow; Thermal springs; Geothermal energy; Middle Atlas-Saïss Basin.