Geological Modeling of the Senonian Aquifer in the Oued Guir Watershed (Southeast Morocco)

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Abstract. The Oued Guir watershed in southeast Morocco stretches widely from the High Atlas in the north to the Hamadas in the south. This basin is characterized by an arid climate strongly influenced by continental conditions. The Lower Guir has become a focal point for the development of modern agriculture following the launch of the Green Morocco Plan. This has led to increased overexploitation of groundwater, specifically the shallow Senonian aquifer. The objective of this study is to model the geological formations of the Senonian aquifer using the Geological Modeling System and GIS software, based on drillings and wells data to understand better the distribution of geological formations and hydraulic characteristics of this aquifer. The obtained geological model shows lateral and vertical variations of the facies and thickness of the Senonian formations. The facies change between clays, silts, and sands, while the thickness exceeds 650 meters. From a hydrodynamic point of view, the transmissivity of this aquifer varies between 0.11×10^{-4} and 7.2×10^{-4} m²/s, with an average of 3.65×10^{-4} m²/s. These characteristics play a crucial role as aquifers in the basin that ensure water resources of the Boudnib area.

Keywords: Guir watershed, Geological Modeling System, GIS, Senonian, Aquifer, Morocco.

1. Introduction

Drills and wells provide essential information for modeling the distribution of deeper geological formations [4]. The Cretaceous deposits are crucial in the groundwater reservoirs of the Lower Guir watershed [6]. Being the most economically potential area with modern agriculture in the Draa-Tafilalet region, the area has significant economic importance [7].

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The focus of this study is to model the Cretaceous aquifer formed by limestone, marl, gypsiferous marl, and red sandstone [3-5]. The latter house three sub-aquifers (Fig. 1): Infra-Cenomanian, Turonian, and Senonian aquifers, which can store significant amounts of groundwater currently exploited for irrigating traditional oases and, notably, modern agricultural extensions [2-10]. Our objective is to characterize the Senonian aquifer using the Geological Modeling based on the GMS software. This allows us to understand the Senonian deposits' distribution and this aquifer's hydrodynamic characteristics.

2. Study area

The Oued Guir watershed, one of the southeastern basins of Morocco, has a total surface area of about 4231 km2. Geographically, it encompasses three provinces, partially covering the province of Figuig to the east and a large part of the provinces of Errachidia and Midelt to the north (Fig. 1).

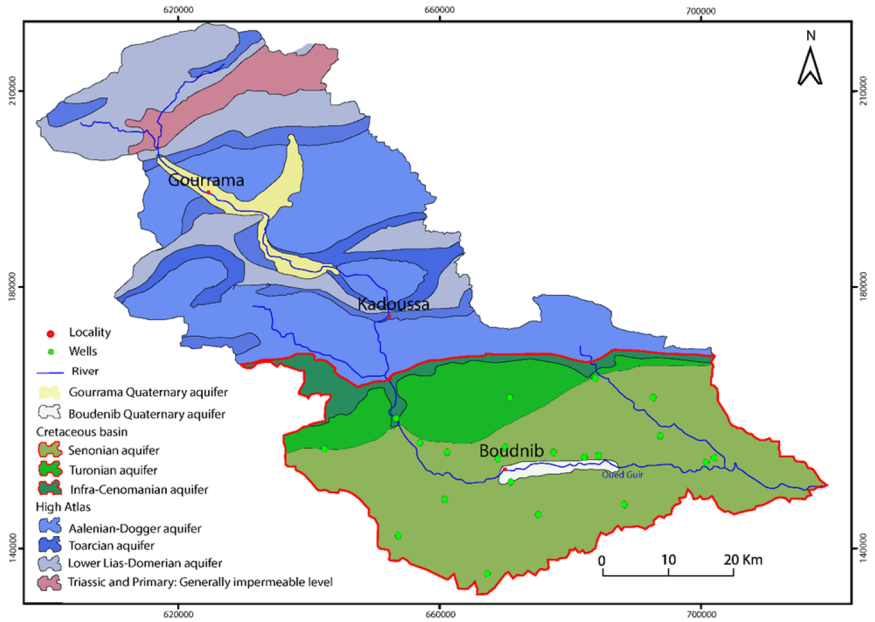

Fig. 1: Spatial distribution of the main aquifers in the Oued Guir watershed.

This basin belongs to the Eastern High Atlas and is bounded by the Marginal Folds and High Plateaus to the north, the Saharan domain to the south, and the Central High Atlas to the west. From a geological point of view, Hercynian and Alpine tectonics have influenced the formation of the basin's plateaus. The l Cretaceous formations begin with the alternations of marls, clays, silts, limestones, and gypsum of Infra-Cenomanian, overlain by the Cenomanian-Turonian limestone bed [3-9]. The Senonian outcrops south and north of Boudnib, is made of sandstones, siltstones, clays, and local gypsum [3]. The Tertiary sandstones, conglomerates, and clay-siltstones and the Plio-Quaternary silts, sands, and alluvial deposits in the central part and south of Boudnib [1] overlie the latter.

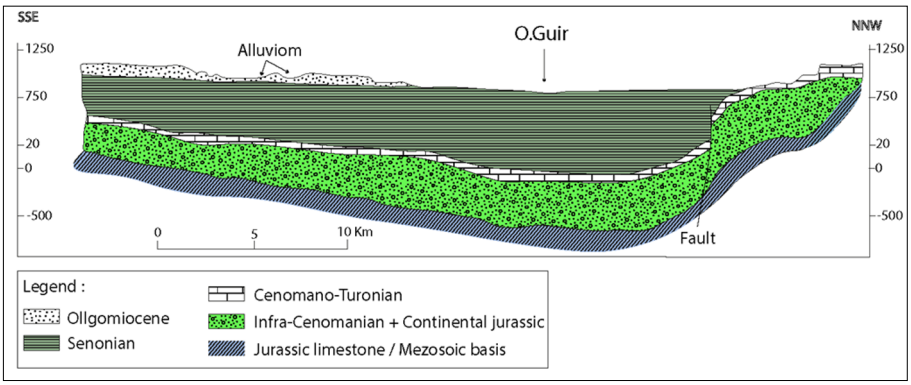

Fig. 2: Synthetic geological section of the Boudnib region.
Source: Campanie Africaine de Géophysique, Prospection géophysique par méthode électrique dans le bassin d'Errachidia-Boudnib. Rapport de synthèse, 1988.

3. Methodology

The methodology for this study involved several key steps. The first step is collecting data from the literature (i.e., published works and reports) and the technical sheets from IRE wells and drills provided by the Guir-Ziz-Rheris Hydraulic Basin Agency. Once gathered, the collected data is meticulously processed using GIS software, which creates accurate and informative thematic maps (i.e., depth, thickness, permeability, resistivity …). The Groundwater Modeling System (GMS) was utilized for geological modeling, providing a detailed and reliable representation of the underground Senonian formations. This approach facilitated a structured analysis and yielded relevant results for understanding the hydrological dynamics of the region [8].

4. Results and discussion

Drills and wells data collected on the Senonian formations of the Lower Guir watershed indicate a rich lithological and stratigraphic diversity. The latter are studied in distinct geological deep-sections distributed along the Boudnib area (Fig. 1). Correlations of sections allow visualizing the thickness variations and spatial lithological distribution over the study area. Indeed, cross-sections of various directions of the elaborated geological model reveal a notable increase in aquifer thickness from east to west; however, gradual decrease is observed towards the basin's northern and southern borders (Figs. 3 and 4). The wells data indicate a complex and heterogeneous aquifer composed of various detrital sediments, including clays, stilts, and sands. In the light of the obtained results, the Senonian continental deposits show a crucial role as aquifer reservoirs permitting a good conservation and circulation of the groundwater coming from the High Atlas Mountains in the north.

Geological modeling reveals important lateral and horizontal variations in terms of facies and thicknesses varying from 250 meters in the southward to 650 meters in the middle. This can be explained by the heterogeneity of the basin during the deposition of these formations as well as the post-depositional tectonic events during the geodynamic evolution of the area. Transmissivity values, obtained, are varying between 0.11×10^{-4} and 7.2×10^{-4} m^2/s, with

an average of 3.65 × 10-⁴ m²/s due to the granulometry of each facies. This underlines the vital importance of this aquifer for the sustainable management of the basin's water resources.

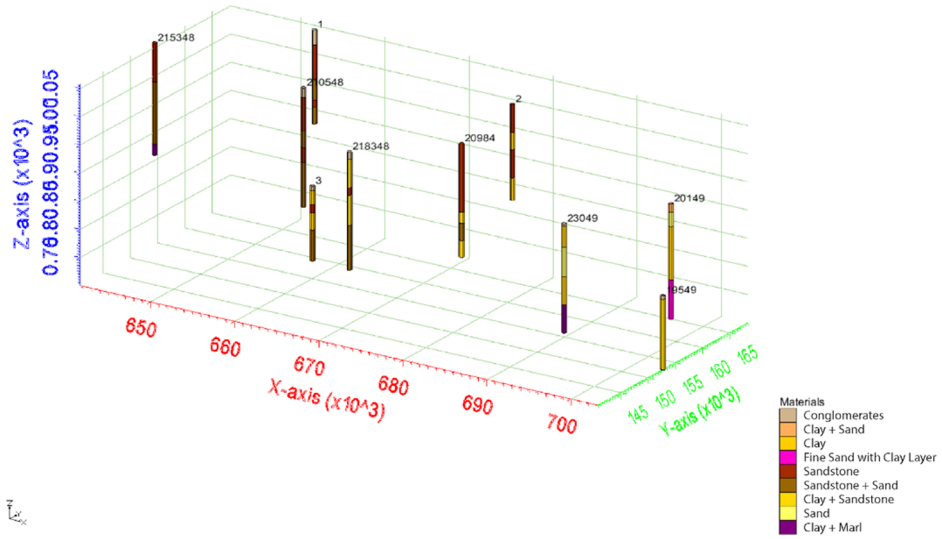

Fig. 1: Distribution of drilling data sheets used.

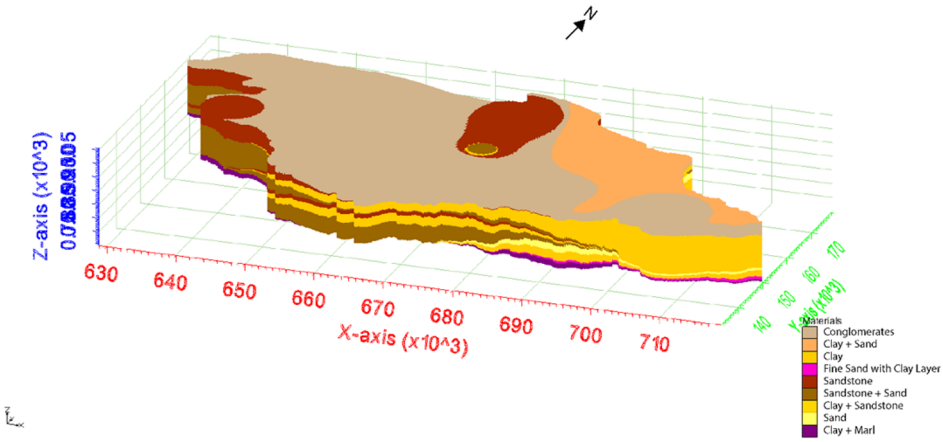

Fig. 2: 3D presentation of the Senonian geological formations of the Oued Guir watershed.

The groundwater reserves in the Cretaceous and shallow aquifers of the lower Oued Guir basin circulate primarily through various lithological and hydrodynamic formations. These reserves are crucial for providing drinking water, irrigation, and other domestic uses, including mining activities. These aquifer formations generally have moderate transmissivity. It's important to note that the region faces significant water shortages due to reduced precipitation and snow, compounded by the over-exploitation of strategic groundwater resources (e.g., modern farms, illicit wells, unauthorized drilling).

5. Conclusion

Geological modeling and correlating logs are essential tools for better delineating the aquifer in the Senonian formations. These techniques enable a precise understanding of the geological structure of the underlying sedimentary layers and help identify areas where

groundwater can circulate easily. This understanding is crucial for professionals to plan the sustainable extraction of this vital resource while minimizing environmental impacts. We must continue using these advanced methods to enhance our understanding of aquifers in regions heavily impacted by climate change. Improved aquifer understanding will ensure resource sustainability and water security in the area, even though the area has seen several measures such as the Kadoussa dam and a groundwater contract, the situation remains very alarming. Therefore, It is recommended that climate change's impacts on water resources in this highly stressed area be better understood. It is also crucial to develop sustainable oasis agriculture adapted to the region's climatic and hydrological context and drastically limit new agricultural extensions.

Funding
No funds, grants, or other support was received.

Author Contribution
All authors contributed to the study's conception and design. Badre Messaoudi, Kabiri Lahcen, and Mohamed El Ouali, who wrote the first draft of the manuscript, performed material preparation, data collection, and analysis. Ismail Ait Lahssaine and Abdelhakim Kadiri made significant contributions to the article's conceptualization, data acquisition, and interpretation. Badre Essafraoui provided comments on previous versions of the manuscript. All authors read and approved the final manuscript.

Ethics approval and consent to participate
Not applicable.

Consent for publication
All the authors have agreed to publish this article.

Competing interests
The authors declare that they have no competing interests

Acknowledgment
The authors gratefully acknowledge this support from the staff of the Guir-Ziz-Rheris Hydraulic Basin Agency.

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