



## **Geophysical constraints on the groundwater circulation and its renewal at the main Bittit spring, supplying Meknes and its region (Sais Basin): Characterization & conceptual model.**

Gineth Saracco, Mohamed Rouai, Konstantinos Chalikakis, Abdelilah Dekayir, Helene Miche, Adriano Mayer, Khaoula Qarqori, Brahim Abderahim, Christophe Emblanch

### **► To cite this version:**

Gineth Saracco, Mohamed Rouai, Konstantinos Chalikakis, Abdelilah Dekayir, Helene Miche, et al.. Geophysical constraints on the groundwater circulation and its renewal at the main Bittit spring, supplying Meknes and its region (Sais Basin): Characterization & conceptual model.. 2nd Annual Meeting MedGU, Nov 2022, Marrakech, Morocco. pp.1-6. hal-03831266

**HAL Id: hal-03831266**

**<https://hal.science/hal-03831266>**

Submitted on 26 Oct 2022

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

## **Geophysical constraints on the groundwater circulation and its renewal at the main Bittit spring, supplying Meknes and its region (Sais Basin): Characterization & conceptual model.**

Gineth Saracco<sup>1</sup>, Mohamed Rouai<sup>2</sup>, Konstantinos Chalikakis, Abdelilah Dekayir<sup>2</sup>  
Helene Miche<sup>1</sup>, Adriano Mayer<sup>3</sup>, Khaoula Qarqori<sup>2</sup>, Brahim Abderrahim<sup>2</sup> and  
Christophe Emblanch

<sup>1</sup> CNRS-UMR7330, AMU, CdF, INRAE, IRD, OSU Pytheas, Europole de l'Arbois,  
13545 Aix-en-Provence, cedex 4, France

<sup>2</sup> University Moulay Ismail, Meknes 50000, Morocco

<sup>3</sup> EMMAH, UAPV, 84000 Avignon, France  
corresponding-author-ginet@cerege.fr

### **Abstract.**

Previous hydrochemical and isotopic studies of the tabular Middle-Atlas karst showed that the Sais basin is mainly fed at its northern border by the carbonated Causses of the fractured Lias, in particular by El Hajeb cause to the east and the Guigo cause west (Miche et al, 2018).

In a context of over-exploitation of the water karst system accentuated by the current climatic variations, with recurrent droughts and sparse strong thunderstorms, the karstic spring of Bittit, main water source of Meknes and its region, is strongly solicited. Since we have obtained a conceptual model using hydrochemical and isotopic data, Bittit is mainly involved by the cause of El Hajeb (1500m) and partially by the cause of Imouzzet (1340m). It is necessary to localize the depth of mixing zones and the direction of preferential flows around Bittit spring, for a better understanding of aquifers renewal.

The coupling of electromagnetic sounding (EM34) and electrical resistivity tomography (ERT) show a tightening of conductivity zones according to the SE-NW direction. It means preferential flows at depth quasi-perpendicularly to the causes, contrary to what was supposed. This was confirmed by depth estimates of potential sources (drainage area in the porous structure) by using electrical multi-scale wavelet tomography of spontaneous potential (SP) around Bittit. A global conceptual model based on hydrochemical, isotopic and geophysical data is proposed.

**Keywords:** Electromagnetic mapping, Electrical resistivity tomography, Multi-Scale Wavelet Tomography of Spontaneous Potential, Conceptual model.

## **1 Introduction**

The rapid growth of the population in the Fez Meknes region and the increasing aridity of the climate observed in recent years have been accompanied by an increase in

the number of boreholes needed for a more diversified and intensive agricultural development. In this context, knowledge of the modes of circulation and seasonal variations of groundwater resources become a major challenge for the control of possible desertification or soil depletion, and to ensure a sustainable water supply of sufficient quality for the surrounding villages and towns.

The deep aquifer of the Saïs basin, fed by the causses of the Middle Atlas, becomes crucial for understanding the renewal of water in the cities of Meknes and Fez (more than 2.4 million inhabitants). The causses with an area of 1500km<sup>2</sup> constitute a plateau formed essentially of limestone and Liassic dolomites, playing a hydrological role and an important reservoir. The discharge of the aquifer takes place essentially at the level of a complex system of sources located in its northern border [6]. The Lias is located under a thick Tertiary marly series (about 1000m) in the plain of Fez. The extension of the Lias under the Saïs basin constitutes an important confined aquifer (10% of Morocco's water resources, according to the IAEA [4]). It is a reservoir compartmentalized by large faults, forming discontinuous or even absent blocks in places [3],[7-8]. Its structure remains poorly defined in the absence of detailed seismic exploration. We focused in this study on the Ribaa-Bittit complex, and more particularly at the main source Bittit supplying Meknes and its region (Fig.1).

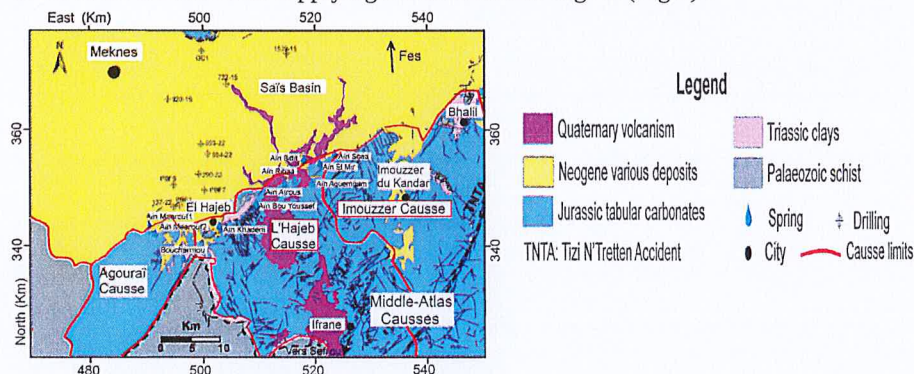


Fig. 1 Simplified geological map of Meknes-Fez area, with El Hajeb and Imouzzzer causses .

Between 2004-2011, the flow rate varied from 1600 l/s to 2000 l/s depending on rainfall [1-2]. Groundwater circulations are conditioned by networks of fractures, the latter frequently playing the role of drains [6-7].

## 2 Geophysical studies.

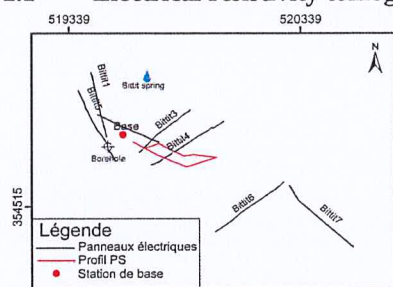
The objective is to obtain a better understanding of the structure and functioning of the Liassic aquifer, on a finer scale, around its main outlet, the source of Bittit.

Three geophysical measurement methods were chosen for their complementarity. Electrical resistivity tomography (ERT), electromagnetic sounding (EM34) and multi-scale wavelet tomography (MSWT) from electrical spontaneous potential measurements (PS). Their complementarity is based on the exploitation of the different physical phenomena that specific sensors record. The electrical resistivity method is more

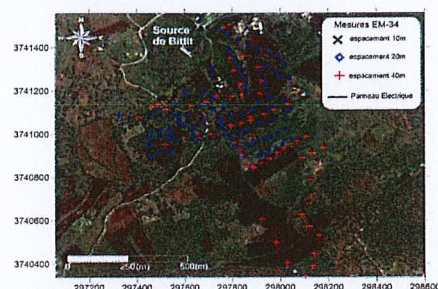


sensitive to characterize electrically resistant formations and the electromagnetic method, electrically conductive structures or formations (via the phenomenon of induction). These two types of method thus provide additional information on the geological structure, while the electrical PS measurements generated by the flow displacement in the porous structure will make it possible to better locate the potential sources linked to the dynamics of underground water circulations ([9], [5]).

## 2.1 Electrical resistivity tomography (ERT) in the Bittit area.

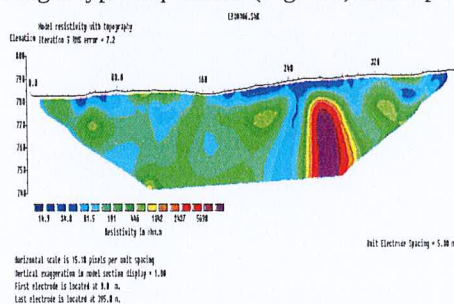


**Fig.2** Position of electrical panels ERT (black) and SP profiles (red)

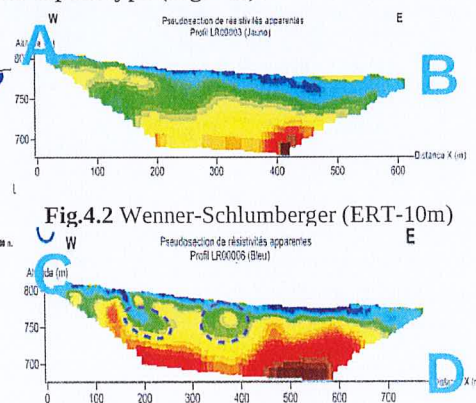


**Fig.3** Position of electromagnetic panels (EM34: x 10m, o 20m, + 40m sampling)

Early electrical resistivity tomography studies in the Ain Bittit region (Fig.2) down to depths of 60m (5m sampling steps along profiles ranging from 300m to 475m) have shown the existence of highly conductive zones contained in geological structures in channels or pockets around 15-30m deep (Fig. 4.1). In order to obtain information on the geological structure down to the first 100 meters of depth, additional campaigns were conducted with 10m sampling on 620m long profiles, with a Wenner-Schlumberger type acquisition (Fig. 4.2) and dipole-dipole type (Fig. 4.3).



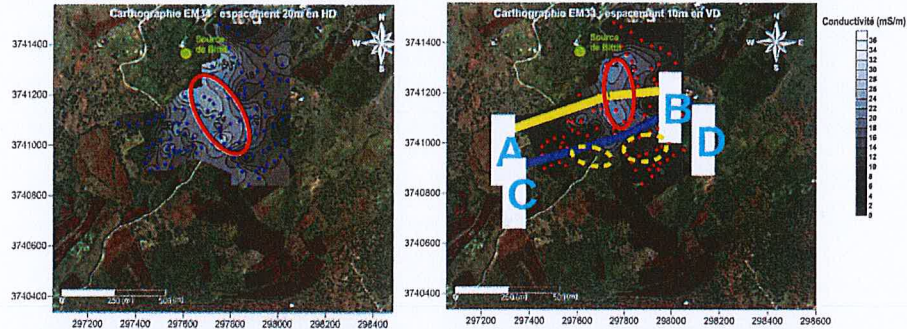
**Fig. 4.1** Highlighting of a draining fault (ERT profile 4, confer Fig.2)



**Fig.4.3** Dipole-Dipole (ERT-10m)

- **A-B profile:** Highlighting of a porous zone where water can preferentially flow
- **C-D profile:** Two flow areas (@750m) are highlighted perpendicular to the Causses (black dotted lines)

## 2.2 Electromagnetic sounding (EM34): Conductivity mapping of Bittit area



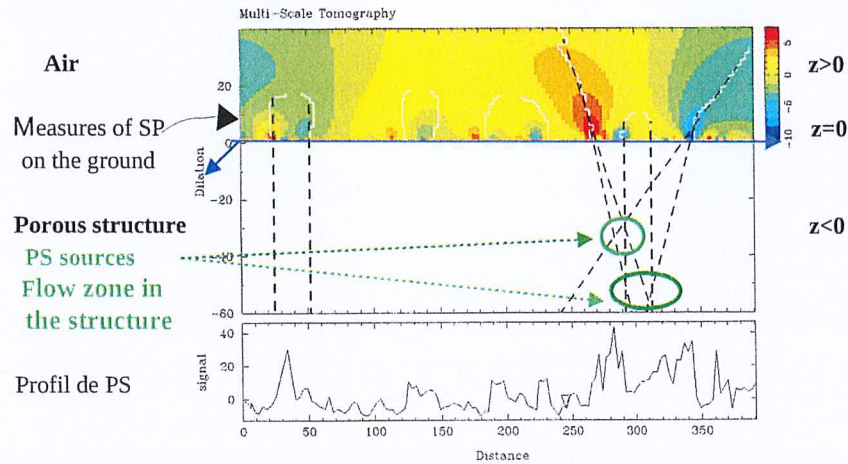
**Fig. 5.a** Conductivity-Horizontal dipole

**Fig. 5.b** Conductivity-Vertical dipole

**Fig. 5 a,b:** Cross-checking of electrical conductivity results (EM34) with electrical resistivity tomography (ERT) for profiles A-B, C-D.

The conductive zone (circled in red) tightens along the North-South (N-S) axis with respect to the dipoles (vertical and horizontal). This confirms a preferential drainage in depth perpendicular to the Causses, and not in the direction of the basin contrary to what was supposed.

## 2.3 Multi-Scale Wavelet Tomography of electrical SP



**Fig 6:** Estimation of the depth of drainage zones in the porous structure by electrical multi-scale tomography from measures of spontaneous potential (SP) near Bittit spring (red profile Fig.2)

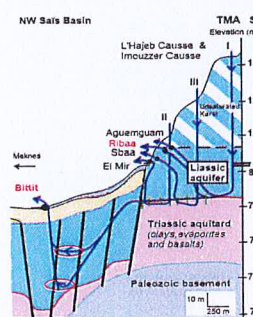
The depths estimated from the Multi-Scale Wavelet tomography ([5],[9]) are of the same order of magnitude as those obtained by electromagnetic soundings and conductivity measurements (EM34). The depth estimation is done thanks to the properties of dilation of the potential field [9]). The depth plays the role of the scale parameter in the sense of the wavelet theory and locates all zones of flows or water exchanges.



### 3 Interpretations & Conclusions

These works allowed us to highlight porous structures or draining faults. The coupling of ERT data to electromagnetic data (EM34) with 3 depths of investigation (10m, 20m, 40m) and two modes (vertical and horizontal dipole) were used in order to study and point out the lateral and vertical change in electrical conductivity on a finer scale around the source of Bittit and towards the Causses. We demonstrated that lateral and vertical variations in electrical conductivity changed with depth along the N-S axis (Fig.4) and that a preferential flow took place perpendicular to the Causses. This work continued with the coupling of measurements of spontaneous potential SP in order to estimate its depth thanks to Multi-Scale Tomography (Fig. 6). Previous hydrochemical studies allowed us to establish a first conceptual model of water circulations at the Causse/Basin transition [6]. A version including geophysics results is given Fig.7.

Variations in electrical resistivity as well as conductivity are directly related to the lateral and vertical change of geological formations. The influence of the climate is difficult to control given the lack of data in previous years on the whole of the basin and the Causses. However, the influence of human activity plays a more active role than that of seasonal variations in the Ribaa-Bittit complex.



**Fig.7** Geophysical contributions to the conceptual model in [6] with groundwater circulations of Imouzzer and El Hajeb causses.

### References

1. Agence du Bassin Hydraulique du Sebou-Fes: Reports 2008-2011, 2015-2016.
2. Amraoui F., Razack M., Bouchaou L., Comportement d'une source karstique soumise à une sécheresse prolongée: la source de Bittit (Maroc), C.R. Geosc., 336, 1099-1109 (2004)
3. Bouloul M., M. Rouai, El Maataoui, Application de la méthode électrique dans la mise en évidence des failles et des contacts anormaux. Notes & Mémoires du Service Géologique du Maroc, 452, 217 (2003).
4. IAEA- Atlas of isotope hydrology, Morocco, Sebou bassin, Vienna, pp. 19-124 (2010).
5. Mauri G., Williams-Jones G. & Saracco G., MWTmat - Matlab application of Multi-scale Wavelet Tomography on potential fields, Comput. & Geosc., 37(11), 1825-1835 (2011).
6. Miche H., Saracco G., Mayer A., Qarqori K., Rouai M., Dekayir A., Chalidakis K., Emblanch C., Hydrochemical constraints between the karst Middle-Atlas-Causses and the Sais basin: Implication of groundwater circulations, Hydrogeol. J., 26(1), 71-87, (2018).
7. Qarqori K., Rouai M., Moreau F., Saracco G., Dauteuil O., Hermitte D., Bouloul M., Le Carlier de Veslu C., Geoelectrical tomography investigating and modeling of fractures network around Bittit spring (Middle Atlas, Morocco), Int. J. Geophysics, no 489634 (2016)
8. Rouai M., Application of fractal geometry to 2D fracture networks in the Middle Atlas aquifer (Morocco), 9th Agile Int. Conf. on G.I.S., 20-22/04, Hungary, 339-344 (2006).
9. Saracco G., Labazuy P., Moreau F., Localization of self-potential sources in volcano-electric effect with Complex Continuous Wavelet Transform & electrical tomography methods for an active volcano, Geophysics Res. Lett., 31(12), June, L12610, 5pages (2004).