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Hydrogeological and Geophysical study of the Braga Basin Aquifer system, central Tunisia

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Abstract

A synthetic study including hydrogeological, geophysical and hydrochemical approaches has been applied in Braga basin located in central Tunisia, in order to determine the hydrogeological and the geochemical behavior of Braga groundwater. The seismic reflection data provides a good tool for the study of geometry reservoirs and to find the main hydrogeological units characterizing the Upper Cretaceous complex and the Mio-Plio-Quaternary (MPQ) series. So, we could determine a variety of thickness and facies of these multilayer systems with individualized depocenter basins and sub-basins. Indeed, the spatial mapping of some seismic horizons has allowed us to track the position of the roof and wall levels aquifers, characterize their geometric configurations and therefore assign the suitable areas for hydrogeological exploration.

Keywords: Braga region, hydrogeological, hydrochemical, the seismic reflection, central Tunisia.

Introduction

Groundwater is an essential natural resource. Depending upon its usage and consumption, it can be a renewable or a nonrenewable resource. Groundwater is the world's most extracted raw material with a withdrawal rate currently in the estimated range of 982km^3/year. The quality of groundwater is the result of the processes and reaction that act on the water from the moment it squeezes in the atmosphere of the time it is discharged by a well. Therefore, the determination of groundwater quality is important to observe the suitability of water for a particular utilization[1].

Groundwater (GW) is one of the important national resources of drinking water in both urban and rural zones of Sidi Bouzid region (central Tunisia) [2]. Groundwater resources management should be integrated with recognition of the geometry, the hydrodynamics and geochemistry of aquifers. Many authors developed several geochemical and geophysical to be applied in different hydrogeological conditions[2-9].

Many hydrogeological studies were done in this area[10-11], where petroleum exploration wells, hydrogeological wells,seismic lines and Hydro-litho-stratigraphic[12] were of great importance to improve the knowledge and comprehension of the features of deep aquifer systems. This paper examines the groundwater hydrochemical characteristics and geometry of the aquifer[13-14], the final results can be used to plan the future development of the GW resources in Southwestern Sidi Bouzid (Braga basin).

Study Area: The Braga Aquifer is located in the Southwestern part of Sidi Bouzid (central Tunisia) It lies between 9°16'2"and 9°26'5" N latitudes, and 34°65'5" and35°06'3" E longitudes covering an area of 808 km^2

This region is characterized by an arid climate with large temperature and rainfall variations. Annual average rainfall and annual temperature are, respectively, 260 mm and 18.7 ◦C. In addition, the potential evaporation is estimated 2049, 5 mm/year.

The geology of the studied area is investigated by several authors[6,9,12]. The study area is characterized by a complex and complicated geology and compartmentalized by a highly developed network of faults. It has played an important role in structuring the basin and in the hydrodynamic tablecloths housed there [15].

Material and Methods

Water samples were collected in 2014 from38 wells, located in Braga region, for chemical analysis (table-1). PH and electric conductivity were measured in the field using standard handheld calibrated field meters. Water samples were analyzed for their chemical (major ion) composition in the laboratories of the Agricultural office of Sidi Bouzid region.

The hydrogeochemical analysis is obtained from analytical methods. HCO_3^- were determined using a titration with HCl; while So_4^{2-} were analyzed by Chromatography liquid phase. Cl^- and Ca^{2+} were determined respectively using titration with $AgNO_3$ and titration with EDTA titrimetric method. Mg^{2+}, Na^+ and K^+ were analyzed by using an atomic absorption spectrometer. The results are shown in Table 1. The data were processed using computer programs such as ARC GIS 9.3[16-20], DIAGRAMME[21] and SURFER 8.

The hydrogeological section established in (figure-2) using water wells were also used to determine MPQ geometry through channel transit. The structure and geometry of the lower Turonian aquifer (upper Zebbag formation) were determined by interpreting 2D seismic reflection section and wire-line and water wells (figure-3).

The groundwater Piezometric mapping (figure-4) was obtained by Surfer program interpolation using the database of water samples 2014. In order to know his hydrochemical aspect we proceeded by classification methods such as Piper, Schoeller.

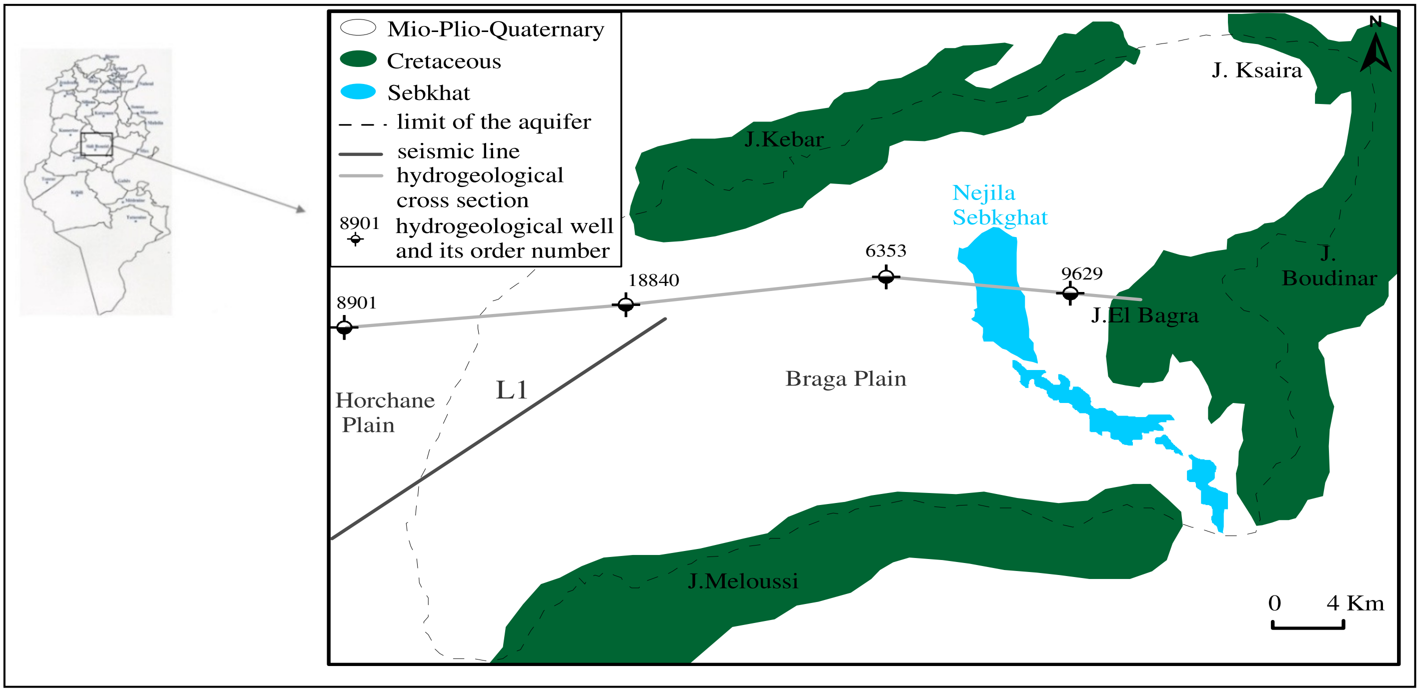

Figure-1
Study area map and use seismic line

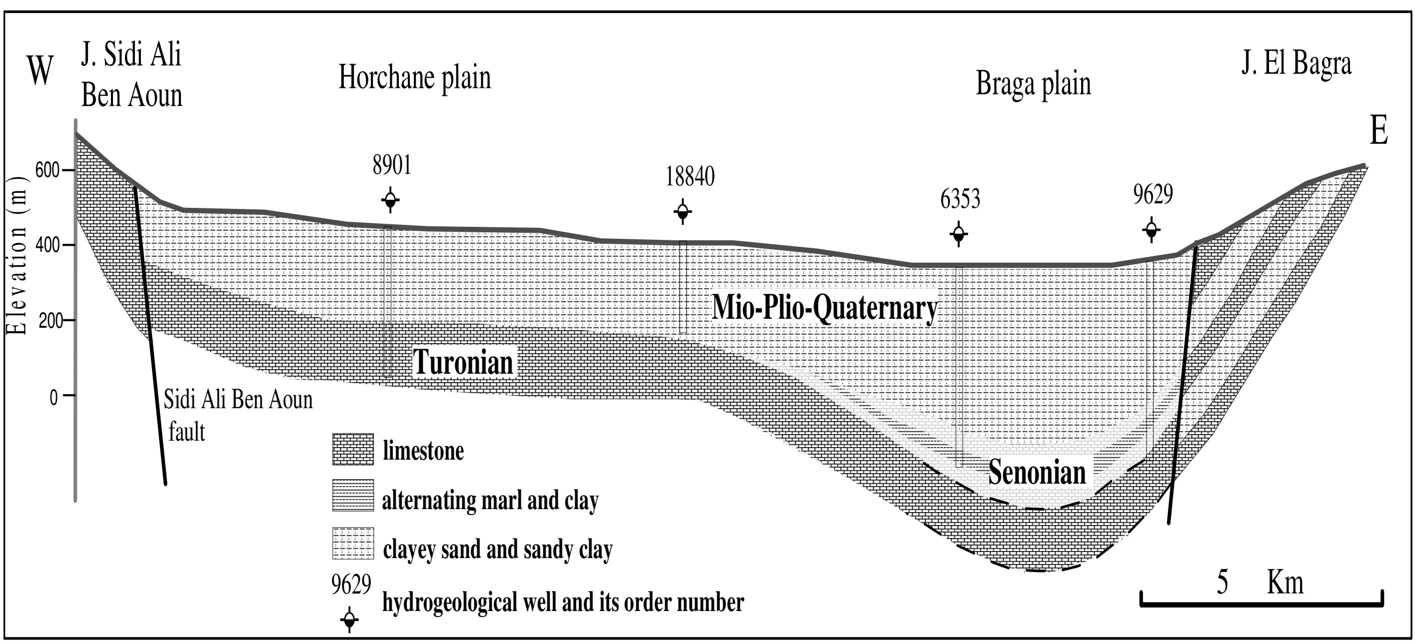

Figure-2
Hydrogeological cross section for the Braga region. (Gassara, 1980 modified)

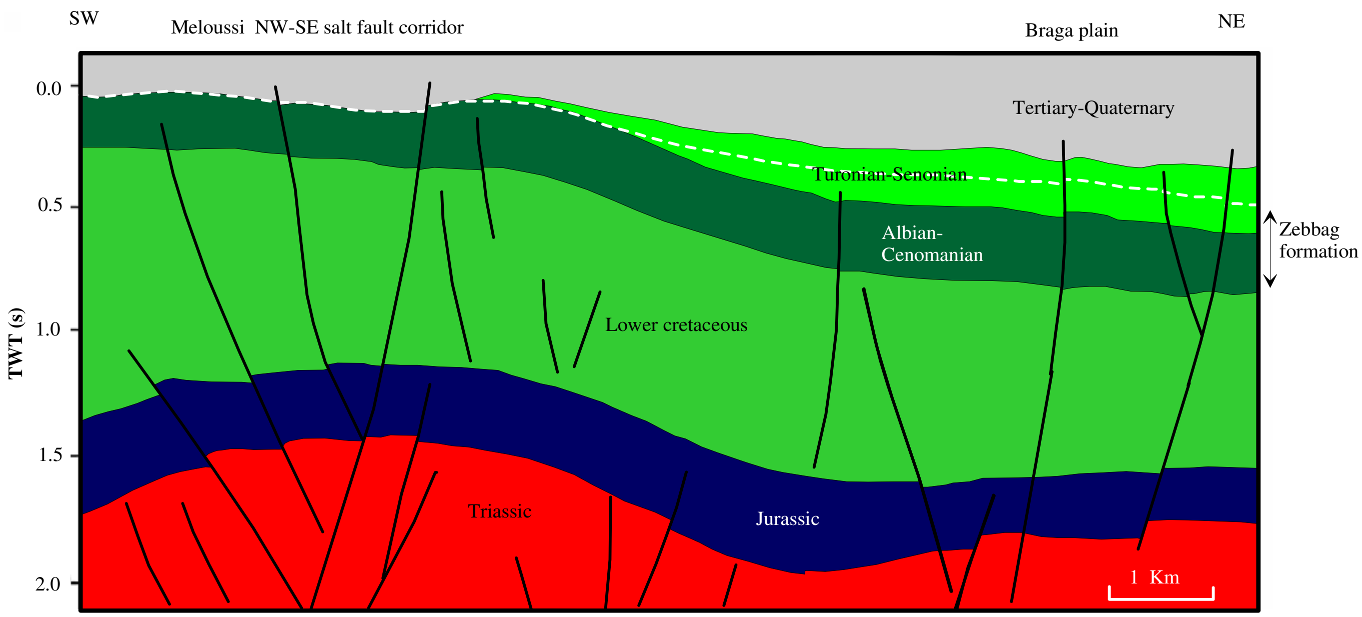

Figure-3
Interpretation of seismic section crossing (Zouaghi, 2005)

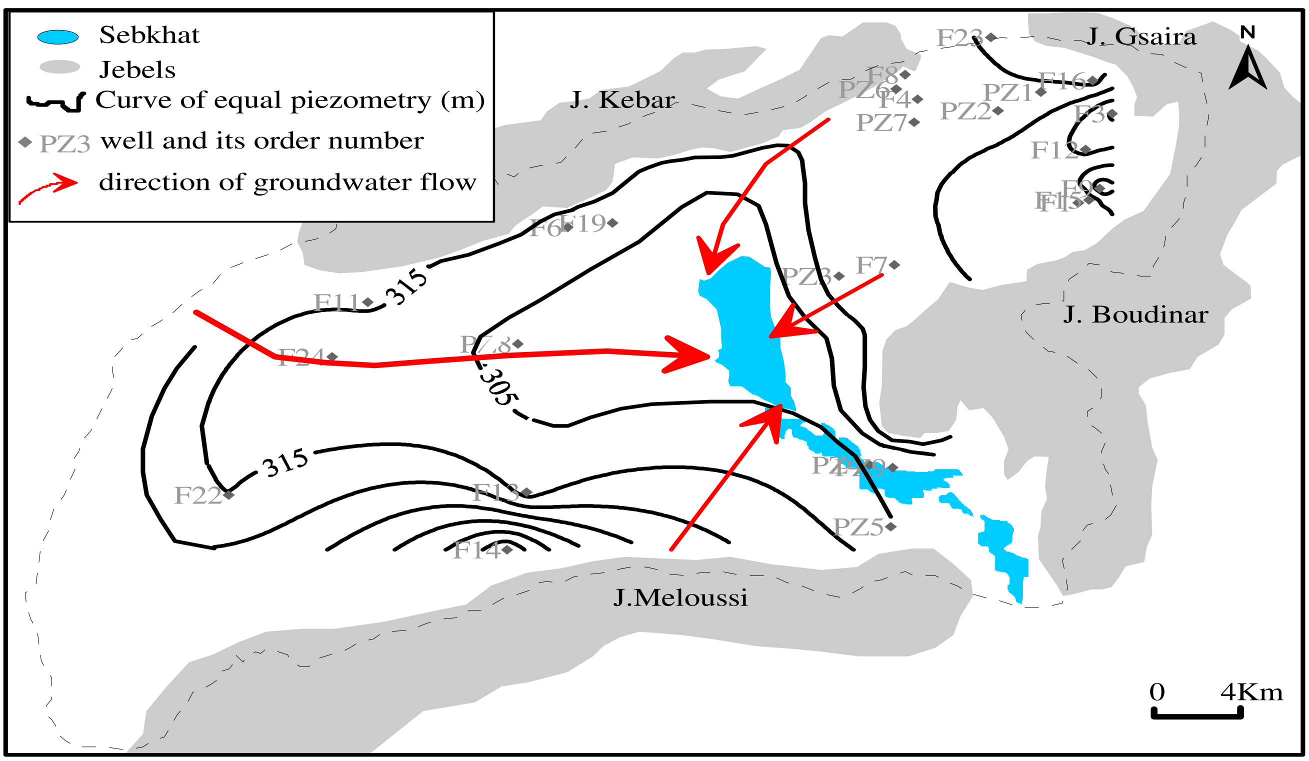

Figure-4
Piezometric map of Braga complex aquifer (2014)

Results and Discussion

Water Quality Analysis: Groundwater hydro-chemical analysis data of samples for Braga are represented in table-1. The pH values slightly above neutrality (between 7.29 and 8.09), electrical conductivity vary between 0.6 and 6.63 µS/cm and salinities (TDS) between 0.8 and 7.72 g/l (table- 1).

Table-1
Physic-Chemical properties of water samples for the Braga aquifer

N° well	pH	TDS	EC	Ca	Mg	Na	K	Hco$_3$	Cl	So$_4$	No$_3$
1	7,46	4,11	4,29	14	20,8	16,7	0,71	2	34	13	1,3
2	7,41	3,88	3,77	13,2	18,4	14,6	2,25	2,8	28	12	1,27
3	7,43	3,81	3,56	14,8	14,8	13,7	0,49	3,6	24	8,8	1,24
4	7,45	2,81	2,58	10,4	12,4	9,6	0,38	3,6	20	6,3	1,22
5	7,76	2,68	2,61	8,8	12	9,7	0,36	2,8	20	9,6	1,016
6	7,34	5,98	5,57	20	25,2	17,6	0,32	3,2	48	14,7	1,564
7	7,38	6,58	6,02	20,8	28,4	19,7	0,31	2,8	52	13,3	2,241
8	8,09	3,22	3,39	3,6	17,6	16,8	0,26	4,4	20	13,6	1,119
9	7,61	4,04	4,04	5,2	17,6	19,7	0,25	4,8	20	18,4	1,935
10	7,67	4,042	4,18	8	22	17,6	0,24	4	30	21,3	1,29
11	7,79	6,95	6,59	14,4	36,8	20	0,27	4,4	56	7,1	0,822
12	7,42	3,63	3,59	10	19,2	16,1	0,178	2,8	28	21,8	0,451
13	7,62	3,31	3,06	10,4	17,6	13,1	0,21	3,2	18	14,2	0,548
14	7,51	3,13	2,83	9,6	18,8	11,7	0,2	2,8	16	13,8	0,693
15	7,43	2,94	2,76	9,6	15,6	11,3	0,2	2,8	18	12,8	0,645
16	7,57	2,74	2,62	5,2	17,6	10,7	0,15	2,8	18	9,5	0,645
17	7,37	6,65	5,78	12	42,8	16,8	0,14	4	40	21,7	1,88
18	7,61	0,8	0,6	3,2	6,4	4,4	0,2	4,4	4	1,8	0,629
19	7,45	1,91	1,57	4	11,2	4,9	0,24	3,2	14	1,5	1,032
20	7,63	1,31	1,24	3,2	8,8	5,2	0,27	3,6	6	7,3	0,87
21	7,89	5,93	5,73	11,6	29,6	19,5	0,15	3,6	40	20	1,22
22	7,36	5,56	4,92	13,2	28,4	15,8	0,13	3,2	36	24,1	1,3
23	7,68	2,64	2,75	7,2	11,6	13,4	0,1	4	18	16,1	1,29
24	7,42	3,95	4,14	4,8	18,4	18,4	0,09	4	26	15	1,822
26	7,42	4,46	4,12	6,8	27,2	14,6	0,099	3,6	26	15,3	1,048
27	7,66	2,73	2,57	4,8	18,8	10,4	0,11	2,8	18	9,4	0,548
28	7,49	2,44	2,48	6	16	9,9	0,12	3,2	16	9,2	0,516
29	7,86	3,33	2,94	6,4	18	10,1	0,11	3,2	18	9,6	0,903
30	7,54	4,24	3,84	8	28	10,8	0,129	3,2	26	14,9	0,693
31	7,81	2,14	2,56	7,6	16,4	9,1	0,11	3,2	16	9,5	0,903
32	7,84	3,72	3,64	8	21,2	10,6	0,11	3,6	24	16,9	0,882
33	7,32	5,77	5,7	12	30,8	16,1	0,16	3,2	40	28	0,919
34	8,07	2,45	2,28	4,8	15,6	7,3	0,11	3,6	16	8,7	1,467
35	7,48	3,44	3,01	6,4	22	5,9	0,119	3,2	18	14,2	0,564
36	7,69	3,36	3,12	9,2	17,6	6,1	0,13	3,2	18	19	0,41
37	7,49	3,75	3,54	9,2	20,8	6,8	0,2	2,8	20	13,9	0,353
38	7,94	6,9	6	27,6	29,6	9,4	0,31	3,6	38	35	1,016
39	7,29	7,72	6,63	21,2	39,6	9,8	0,18	3,2	46	31	0,596

The representatives of the chemical results in a Piper diagram [21] are shown in figure-5, they usually reveal chemical facies of magnesium sulphate and calcium-chlorinated types. Indeed, analysis of the chart shows that all water withdrawn from the aquifer MPQ is characterized by a chloride-mixed facies rich in magnesium and calcium.

The Schoeller[21] plots of figure-6 indicate that all of Horchane groundwater has generally revealed the presence of two water families mixed chlorinated and the other chlorinated sodium-rich in magnesium and calcium[22]. Magnesium originates clay intercalations in the stratified layers that make up the aquifer, while the calcium comes from the waters of the borders of the outcrop (Kebar, Majoura- Meloussi and the N-S axis).

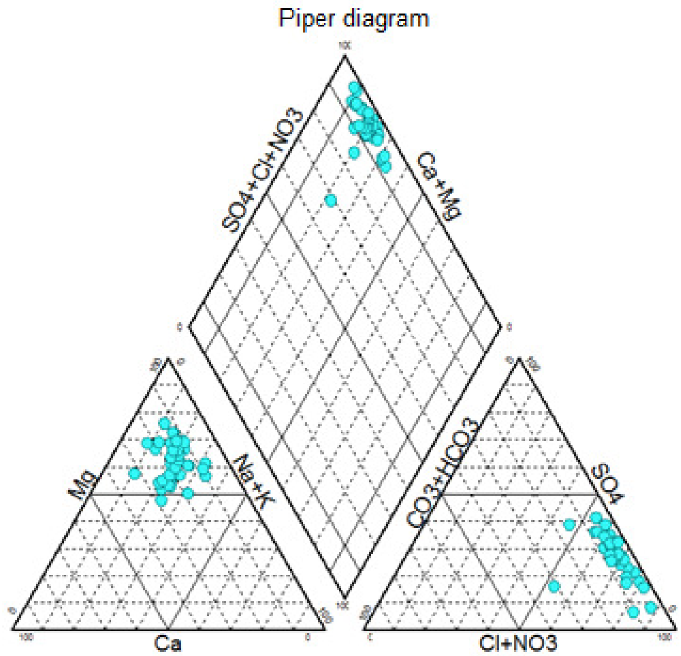

Figure-5
Piper diagram for the water samples of the studied area

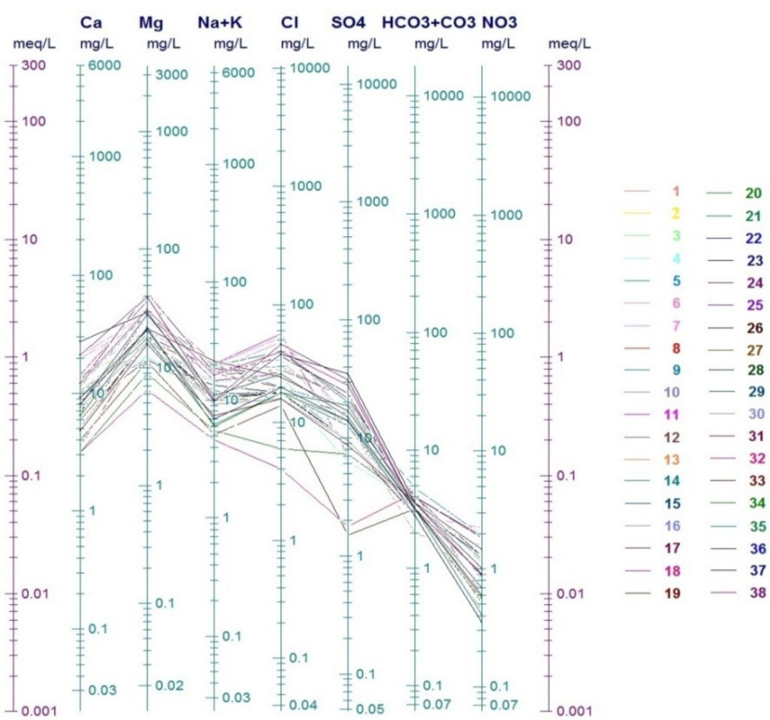

Figure-6
The Schoeller-Berkaloff plots of ground waters taken from the samples of the studied area

Hydrodynamic study: From the new Piezometric[23] maps developed in November 2014 Braga complex groundwater is illustrated in figure-4, groundwater head is ranged between 298 m and 374 m.

Indeed, except for the SE of the basin, the general flow is always converging towards the salty depression which plays the role of the main outlet table. In the western half of the basin, the flow is East-West direction NW-SE. At its eastern half, it is generally NE-SW. Recharge areas of the aquifer are located mainly in the Piedmont rents of borders reliefs especially Jebels Chebar, Meloussi, Bagra and Boudinar.

Hydro-litho-stratigraphy and Geometry of aquifer: The geological cross section presented in figure-2, located in figure-1indicates the presence of Mio-Pliocene-Quaternary formed by detrital deposits (sands alternations of clays, clayey sands and sandy clays). These deposits, whose thickness can exceed 500m in the eastern part of the basin and can't at the center of the basin (Horchane region), based on a more or less thick layer of limestone attributed to higher Zebbag.

The geometric characterization of the reservoir levels in the basin is determined through Hydro-stratigraphic sections[15] and some seismic profiles[6]L1. These profiles show that three levels of groundwater reservoirs are recognized in this basin figure-3. i. The first level of aquifer is the upper Albian dolomites (Lower Zebbag formation). ii. The second level lodges in lower Turonian limestone (upper Zebbag formation). iii. Clays and marls with limestone intercalations of the Senonian. iv. Clayey sands of the MPQ (Saouaf and Segui formations).

Seismic line1 (figure-3) shows the basin structure that houses Braga exploited aquifer levels from the Turonian to MPQ. The high background Meloussi is a limit for the hydrogeological aquifer complex. This limit is mobilized by the arch halokinetic of Cenomanian Turonian age associated with lower slip fault Meloussi[6], which explains the beveling deep aquifers (Turonian Senonian) to the SW.

Braga basin is a NE-SW direction syncline limited by the N-S axis to the east, the structure of Chebar north and the outcrop Meloussi south. However, the opening compared to Horchane West Basin marks the continuity of the aquifer complex from the Turonian to the MPQ. This multilayer aquifer hollows in the center of Braga basin which is verified by the convergence of underground flow direction directly below Sabkhat Njila.

Conclusion

The hydrochemical approach classifies the hydrochemical facies, identifies the origin of the mineralization and determines the spatial distribution of the salinity. Indeed, the waters are generally of magnesium sulphate and calcium-chlorinated types.

In addition, the interpretation of the obtained results leads to the differentiation of several conductors and resistance levels. The analysis of hydro- Hydro-stratigraphic and seismic sections has identified some resistance levels likely to be of potential aquifers that are: The shallow groundwater staying in sandy series MPQ and semi agents deep aquifers in the Upper Cretaceous carbonates of the upper and lower formations Zebbag. The deep aquifers are found in sandstone sandy terms of Cretaceous age.

References

1. Kumar M.S. and Rajkumar T.J., Groundwater Quality Assessment in Lower Tamirabharani River Basin Tamil Nadu, India, *Int. Res.J. Earth Sci*., **2(10),** 8-15, **(2014)**
2. Aydi W., Saidi S., Chalbaoui M., Chaibi S and Hamed Ben Dhia., Evaluation of the Groundwater Vulnerability to Pollution Using an Intrinsic and a Specific Method in a GIS Environment: Application to the Plain of Sidi Bouzid (Central Tunisia), *Arab J Sci Eng*., **38 (7),** 1815-1831 **(2012)**
3. Gasmi M., Contribution of geophysics to the recognition and management of natural resources, Application inTunisia, Doct. Thesis, Sfax University, Tunisia, 471 **(2002)**
4. Chalbaoui M. And Ben Dhia H, Main characteristics of the reservoirs in the south-west of Tunisia, *C.R. Geos*., **336(13),** 1191-1198, **(2004)**
5. Chalbaoui M., First approach to the study of deep watershed Southwest Tunisian, *C. R. Géos*., **337(16),** 1484-1491, **(2005)**
6. Zouaghi T., Bédir M. and Inoubli M.H., Deep structure of deposits of the Albian-Maastrichtian in central Tunisia: a new limit of the archipelago of Kasserine and geodynamic implications, *C. R. Geoscience.,* **337***, 685-693* **(2005)**
7. Lachaal F., Bédir M., Tarhouni J., Gacha Ben. A. and Leduc C., Characterizing a complex aquifer system using geophysics, hydrodynamics and geochemistry: A new distribution of Miocene aquifers in the Zéramdine and Mahdia–Jébéniana blocks (east-central Tunisia), *Journal of African Earth Sciences*., **60(4),** 222–236, **(2011)**
8. Gabtni H., Alyahyaoui S., Jallouli C., Hasni W. and Mickus K.L., Gravity and seismic reflection imaging of a deep aquifer in an arid region: Case history from the Jeffara basin, southeastern Tunisia, *Journal of African Earth Sciences*., **66(67),** 85-97, **(2012)**
9. Chaibi S., Aydi W. and Chalbaoui M., Hydrogeological Study of the Aquifer System in Central Tunisia: New System Structuring of Horchane Aquifers, *Jour. Water Res. and Prot*., **5(5),** 502-510, **(2013)**

10. Chekhma H., Stratigraphic, sedimentological and tectonic Study of Bir El Hafey-Sidi Ali Ben Aoun area (central Tunisia), Thesis, University of Tunis II, 261, **(1996)**

11. Chekhma H. and Ben .Ayed N., Geodynamic evolution of the Cretaceous basins related to the activity of NS faults (Bir El Hafey-Sidi Ali Ben Aoun region, Central Tunisia), *National Office of Mines*., 12 **(1998)**

12. Gassara A., Contribution to the hydrogeological study basin Horchane-Braga, Doct, Thesis, *Pierre and Marie Curie University*., France, 80, **(1980)**

13. Tanfous Amri D., Bédir M., Soussi M., H. Azaiz, L. Zitouni, M. Inoubli and K.B. Boubaker, Halokinesis early Jurassic rifting associated with the Atlas in central Tunisia. (Region Majoura-El Hafay), *Comptes Rendus Géoscience.,* **337(7),** 703-711, **(2005)**

14. Chaibi S., Structural, hydrogeological and hydrochemical characterization of Sidi Ali Ben Aoun - Sidi Bouzid aquifers, Doct, Thesis, *Univ of SfaxTunisia*., 191, (**2014**)

15. Azaïez H., Tanfouz D., Gabtni H., Bédir M and Soussi M., Integrated geophysical study of the triassic salt bodies geometry and evolution in central Tunisia, *Comptes Rendus Géoscience*., **340(1),** 10-19, **(2008)**

16. Baker Thomas R. and Case Steven B., Let GIS be your guide, The Science Teacher, **67(7),** 24-26, http://kangis.org/ learning/publications/ science_teacher/ print/tst 0010_24. Pdf, **(2000)**

17. Longley Paul A., The academic success of GIS in geography: Problems and prospects, *Journal of Geographical Systems.,* **2(1),** 37–42 **(2000)**

18. Saraf A.K., Gupta R.P., Jain R.K. and Srivastava N.K., GIS based processing and interpretation of ground water quality data, Proceedings of Regional workshop on Environmental Aspects of Ground water Development, 17-19, Kurukshetra, India, **(1994)**

19. Himanshu S.K., FISCA, Garg N., Rautela S., Anuja K.M. and Tiwari M., Remote Sensing and GIS Applications in Determination of Geomorphological Parameters and Design Flood for a Himalyan River Basin, India, *Int. Res.J. Earth Sci.,* **1(3),** 11-15, **(2013)**

20. Singh Bijender and Singh Joginder., Land Use / Land Cover Change of Delhi: A Study using Remote Sensing and GIS Techniques, *Int. Res.J. Earth Sci.,* **2(1),** 15-20, **(2014)**

21. Simler R., DIAGRAMMES: Hydrochemistry multilanguage free distribution software, Version 4. Hydrogeology Laboratory of Avignon **(2007)**

22. Golekar R.B., Baride M.V. and Patil S.N., Geomedical health hazard due to groundwater quality from Anjani – Jhiri River Basin, Northern Maharashtra, India, *Int. Res.J. Earth Sci.,* **2(1),** 1-14, **(2014)**

23. Antony Ravindran and Ramanujam N., Experimental Design and Continuous monitoring of Costal Hydraulic study of Beach ground water table at Vellappatti Shoreline, Thoouthukudi District, Tamilnadu, India, *Int. Res.J. Earth Sci.,* **1(1),** 2-10, **(2013)**