Journal of Applied Science

Biannual Peer Reviewed Journal Issued by Research and Consultation Center , Sabratha University

Issue (13)
September 2024

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Editorial

We start this pioneering work, which do not seek perfection as much as aiming to provide a scientific window that opens a wide area for all the distinctive pens, both in the University of Sabratha or in other universities and research centers. This emerging scientific journal seeks to be a strong link to publish and disseminate the contributions of researchers and specialists in the fields of applied science from the results of their scientific research, to find their way to every interested reader, to share ideas, and to refine the hidden scientific talent, which is rich in educational institutions. No wonder that science is found only to be disseminated, to be heard, to be understood clearly in every time and place, and to extend the benefits of its applications to all, which is the main role of the University and its scholars and specialists. In this regard, the idea of issuing this scientific journal was the publication of the results of scientific research in the fields of applied science from medicine, engineering and basic sciences, and to be another building block of Sabratha University, which is distinguished among its peers from the old universities.

As the first issue of this journal, which is marked by the Journal of Applied Science, the editorial board considered it to be distinguished in content, format, text and appearance, in a manner worthy of all the level of its distinguished authors and readers.

In conclusion, we would like to thank all those who contributed to bring out this effort to the public. Those who lit a candle in the way of science which is paved by humans since the dawn of creation with their ambitions, sacrifices and struggle in order to reach the truth transmitted by God in the universe. Hence, no other means for the humankind to reach any goals except through research, inquiry, reasoning and comparison.

Editorial Committee

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Journal Address:

Center for Research and Consultations, Sabratha University

Website: **https://jas.sabu.edu.ly/index.php/asjsu**

Email: **jas@sabu.edu.ly**

Local Registration No. (435/2018)

ISSN 💻 2708-7301

ISSN 🕮 2708-7298

Publication instructions

The journal publishes high quality original researches in the fields of Pure Science, Engineering and Medicine. The papers can be submitted in English or Arabic language through the Journal email (jas@sabu.edu.ly) or CD. The article field should be specified and should not exceed 15 pages in single column.

All submitted research manuscripts must follow the following pattern:

- Title, max. 120 characters.
- Author Name, Affiliation and Email
- Abstract, max. 200 words.
- Keywords, max. 5 words.
- Introduction.
- Methodology.
- Results and Discussion.
- Conclusion.
- Acknowledgments (optional).
- References.

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Invitation

The Editorial Committee invites all researchers "Lectures, Students, Engineers at Industrial Fields" to submit their research work to be published in the Journal. The main fields targeted by the Journal are:

- Basic Science.
- Medical Science & Technology.
- Engineering.

Refereeing

The Editorial Committee delivers researches to two specialized referees, in case of different opinions of arbitrators the research will be delivered to a third referee.

Editorial Committee

CONTENTS

ASSESSMENT OF HYDRAULIC PARAMETERS OF THE QUATERNARY AQUIFER USING PUMPING TEST, JIFARAH PLAIN, NORTHWEST LIBYA

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Abstract

Groundwater conditions (GWCs) of an area depend on aquifer hydraulic parameters such as transmissivity (T), storativity (S), hydraulic conductivity (k), and specific capacity (Sc). These parameters play a key role in groundwater flow modeling, well performance, solute and contaminant transport assessment, and the identification of areas for additional hydrologic testing. The present work aims to estimate the hydraulic parameters (T, k, and Sc) of the Quaternary aquifer in the study area and to create an integrated geographical database and map spatial distributions through geographic information systems (GIS) programs. The results indicate that the average value of transmissivity (T) of this aquifer differs from one locality to another, ranging between 6.36 m^2/day and 7150 m^2/day, calculated based on Cooper-Jacob and Theis recovery solutions. The hydraulic conductivity values (k) ranged from 0.04 m/day to 47.66 m/day. The specific capacity (Sc) of wells ranged from 7.29 to 642.86 m^3/d/m. Spatially, transmissivity and hydraulic conductivity values increase in the north and northeast directions, while they gradually decrease in the western and southern parts of the study area. Great variation in the values of the hydraulic parameters is recognized and attributed to the variation in the lithological properties, either laterally or vertically.

Keywords: Jifarah Plain; Quaternary Aquifer; Transmissivity; Hydraulic Conductivity; Pumping Test.

Introduction

Surface and underground freshwater are the most essential of man's requirements for life. They not only serve as vital substances for human existence but also play an important role in advancing growth due to the world economy and civilization. The need for the development of water resources has become more urgent than ever before.

In some arid countries, such as Libya, groundwater is the sole source of water supply. The Jifarah Plain is located in the northwestern part of Libya. Although this plain occupies about 1% of the total land surface area of Libya, it is economically the most important part of the country. About 50% of the population of Libya lives in the Jifarah

Plain, which has the largest population density in the country. The Jifarah Plain covers approximately 60% of the irrigated land, making it the most important human and agricultural resource that provides an economic base for Libya. In the last few years, rapid population growth, extensive development, substantial improvement in the standard of living, and the lack of comprehensive planning efforts have all led to an imbalance between increasing water demand and the existing limited water supply. Securing water resources of appropriate quantity and quality is of prime importance to fit the prospective development programs. Thus, exploring groundwater in the Jifarah Plain with acquired knowledge is considered a vital demand.

For the past few decades, characterizing aquifer systems and identifying groundwater resources have become of prime importance in the field of hydrogeology (Lachaal et al., 2011). Pumping tests are one of the suitable means for computing reliable and representative values of the hydraulic characteristics of aquifers (Kruseman and de Ridder, 1994; Mawlood, 2019). Pumping rate, groundwater flow patterns due to pumping, etc., play an important role in the management and sustainable development of groundwater resources (Zahid et al., 2017). The test is performed by pumping a well at an almost constant pace while measuring water level variations at the same pumped well and a nearby well, if possible (Mawlood and Ismail, 2019).

It is estimated that 10 percent of the world’s food supply is based on unsustainable groundwater pumping (World Bank, 1998). Hence, to develop pragmatic and scientific planning for managing groundwater resources, it is essential to quantify hydrogeological parameters. This requires knowledge of aquifer properties, specifically hydraulic conductivity and transmissivity (Sinha et al., 2008; Sattar et al., 2014).

The present study aims to carry out a hydrogeological investigation in the central part of the Jifarah Plain in northwest Libya to calculate the hydraulic parameters of the Quaternary groundwater aquifer to achieve optimum groundwater use in terms of sustainable water management. Attention was given to determining hydraulic parameters such as transmissivity (T), hydraulic conductivity (k), and specific capacity (Sc) through the analysis of data from pumping tests carried out by the General Water Authority (GWA) and creating an integrated geographical database and map of spatial distributions through geographic information systems (GIS) programs.

Description of the Study Area: The study area (3913 km²) is located in the coastal part of the Jifarah Plain in northwest Libya, between latitudes 32°32'49.5"N and 32°56'57"N, and longitudes 12°29'21.7"E and 13°25'32.5"E (Figure 1). It extends from the Mediterranean Sea in the north to the Ben Ghashir area in the south, and from Tajoura in the east to Surman City in the west. It includes many major cities and towns, the most important being Tripoli, the capital, and Al-Zawiya City.

The climate in the study area is arid to semi-arid and typically Mediterranean, with irregular annual rainfall. The average annual rainfall and evapotranspiration rates are 250 mm and 1535 mm/year, respectively (Alfarrah, 2011). The daily maximum temperature range recorded during the period from June to September is 29–49°C, and the minimum temperature recorded during the period from December to March is 1–15°C (El Baruni, 2000).

Topographically, the terrain rises gradually from sea level along the coast to an elevation of 174 m above mean sea level (MSL) at the southeastern extremity, while the southwestern sector achieves an elevation of approximately 88 m above MSL, as shown in the Digital Elevation Model Figure (1).

The study area is covered by deposits of the Quaternary, represented by the Gargaresh Formation, Jifarah Formation, and sand dunes with silt and gravel deposits, sometimes with limestone deposits, all belonging to the Quaternary period. Additionally, several valley deposits cross the area from south to north. The most important wadi is Wadi Mageneen, which extends to the sea in the north. Furthermore, limestone and dolomitic rocks of the Middle Triassic (Al Aziziyah Formation) are exposed on the surface in the Al Aziziyah area, south of the study area Figure (2).

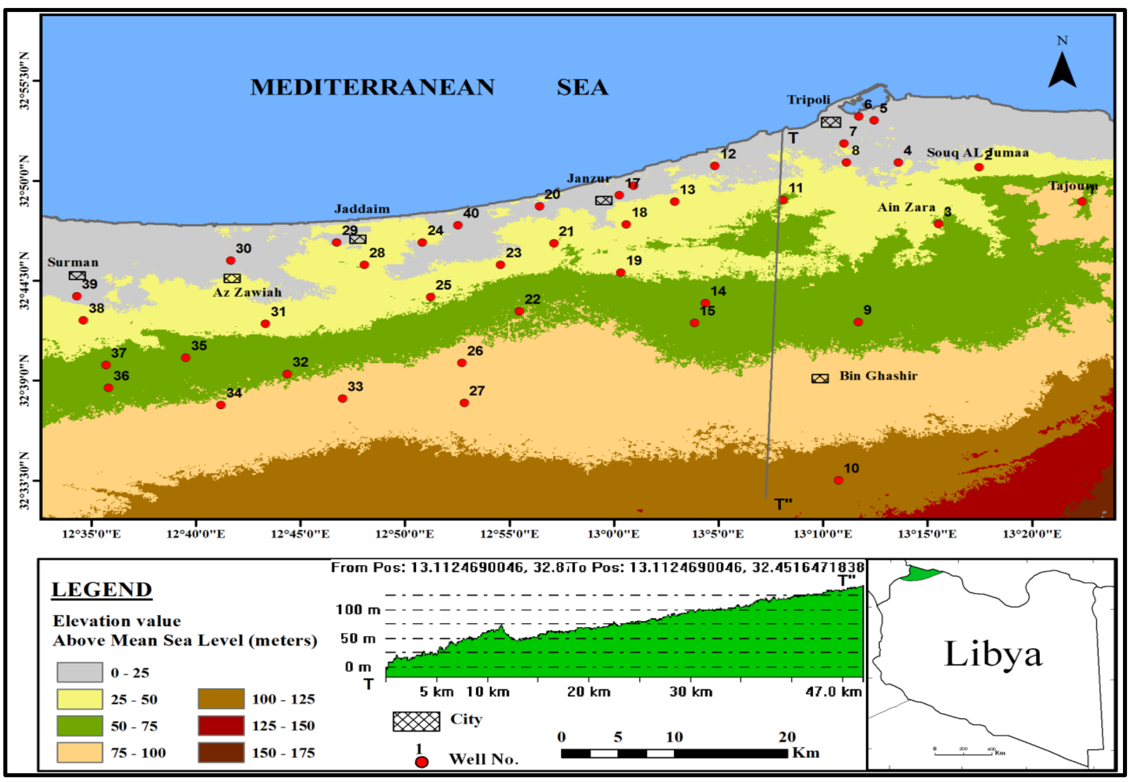

Figure (1): Location Map and Digital Elevation Model (DEM) of the Study Area.

(Based on ASTER DEM with 30m Resolution)

Geological and Hydrogeological Setting

1 Geology

The Jifarah Plain is covered by rocks ranging in age from Triassic to Quaternary. Structurally, the most important structural feature within the plain is the Al Aziziya W-E trending fault that divides the thick Tertiary-Quaternary sequences to the north of it and only thin Quaternary deposits to the south. Parallel to the Al Aziziya fault, a coastal fault occurs further to the north. Possibly, the boundary between the Jabal Naffusah and the plain, expressed as a conspicuous escarpment, has also been predisposed by a fault. Pallas (2006) mentioned that the block faulting and the near-shore environment result in a pronounced change in lithology, both laterally and vertically. Furthermore, the main faulting system of the Jifarah Plain plays an important role in the hydrogeology of the plain by juxtaposing the Upper Cretaceous and Tertiary water-bearing formations with the great Triassic aquifer. Several authors suggest that other faults occur in the plain, mainly with NW-SE strikes, but these do not seem to be hydrogeologically significant (Pallas, 1978; IRC, 1992).

The studied water-bearing rocks range in age from Miocene to Recent times. Figure (2) shows the geological map for the investigated part of the plain, and Figure (3) shows the hydrogeological cross-section in the study area. The important rock units in the study area are:

Tertiary Rocks: The studied Tertiary rocks in the northern-central part of the Jifarah Plain are represented by the Miocene rocks and the Pliocene deposits.

a. **Miocene Rocks:** These are represented in the northern and central parts of the Jifarah Plain. These rocks are covered by Quaternary rock units and are not, however, exposed on the surface except in limited areas in the eastern part of the Jifarah Plain. The Miocene rocks in some places consist of a clayey series at the base overlain by a more calcareous series that forms what is known as the Early Miocene rocks. In other places, the Early Miocene rocks consist mainly of sandstones interbedded with shale and mudstone. These are overlain by clayey series, which change vertically to limestone and sandstone layers of the Middle Miocene. They also change laterally to gray marl interbedded with shale and gray limestone deposits. The Late Miocene-Quaternary boundary is not distinct; however, it is usually characterized by successive layers of claystone and sandstone.

b. **Pliocene Deposits:** Represented by the Al Assah Formation, this unit overlies the Miocene rocks and is overlain by the Jifarah Formation. The Al Assah Formation is composed mainly of evaporite rocks in the form of gypsum with shelly sand and clayey sand, and sand with gravel in the upper part.

Quaternary Rocks: The total recorded thickness of the Quaternary rock units is about 600 m along the coast of the Jifarah Plain (El–Baruni, 2000). The Quaternary rocks cover most of the studied area and are classified into two lithostratigraphic groups as follows:

a. **Pleistocene Deposits:** These are represented by two formations. The Jifarah Formation consists of fine materials (silt and sand), occasionally with gravel and caliche bands. It covers extensive parts of the Jifarah Plain. The Gargaresh Formation makes steep cliffs along the shore, stretching from Tajura in the east to the Tunisian border in the west. This formation is made of calcarenite including shell fragments and minor sandy grains, occasionally intruded with silty material. The Gargaresh Formation extends from the shoreline up to 3 to 6 km southward.

b. **Holocene Deposits:** These deposits cover most of the surface-mapped area, usually reaching thicknesses of several meters. They consist of various types, including recent wadi deposits, which are composed of loose gravels and loam with thicknesses varying from 0.5 to 2 meters. Beach sands form a narrow strip along the coast and are composed of shell fragments with a small proportion of silica sands. Eolian deposits, represented by sand dunes and sheets, cover large areas of the Jifarah Plain and patches along the coastal strip. The height of these dunes ranges from 5 to 20 meters above the plain, and they are primarily made of fine to medium-grained silica sand, with coastal dunes containing shell fragments and small amounts of silica sands. Fluvial-eolian deposits are found on the plateau surface, consisting of silt, clay, and fine sands with occasional caliche bands. Sebkha sediments are observed along the coastal areas, occupying relatively low-lying topographic regions and separated from the sea-by-sea cliffs. Some sebkhas experience occasional incursions of seawater, while others may have subsurface connections to seawater. These areas are often marked by the presence of scattered sand islands.

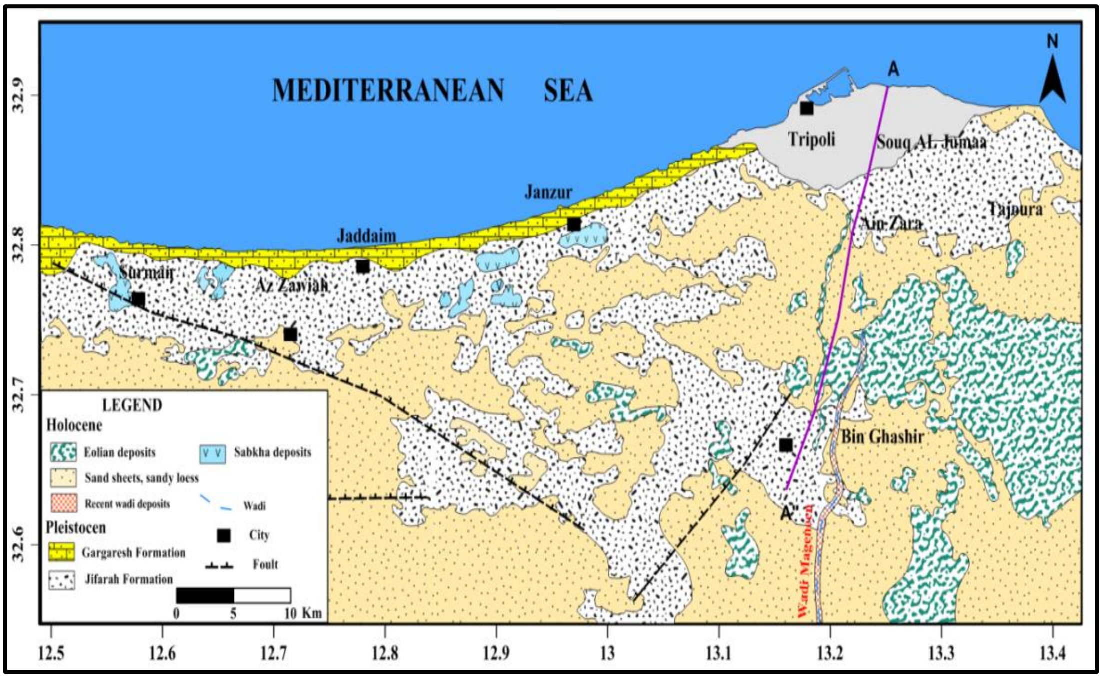

Figure (2): General Geological Map of the Study Area (Industrial Research Centre, 1975).

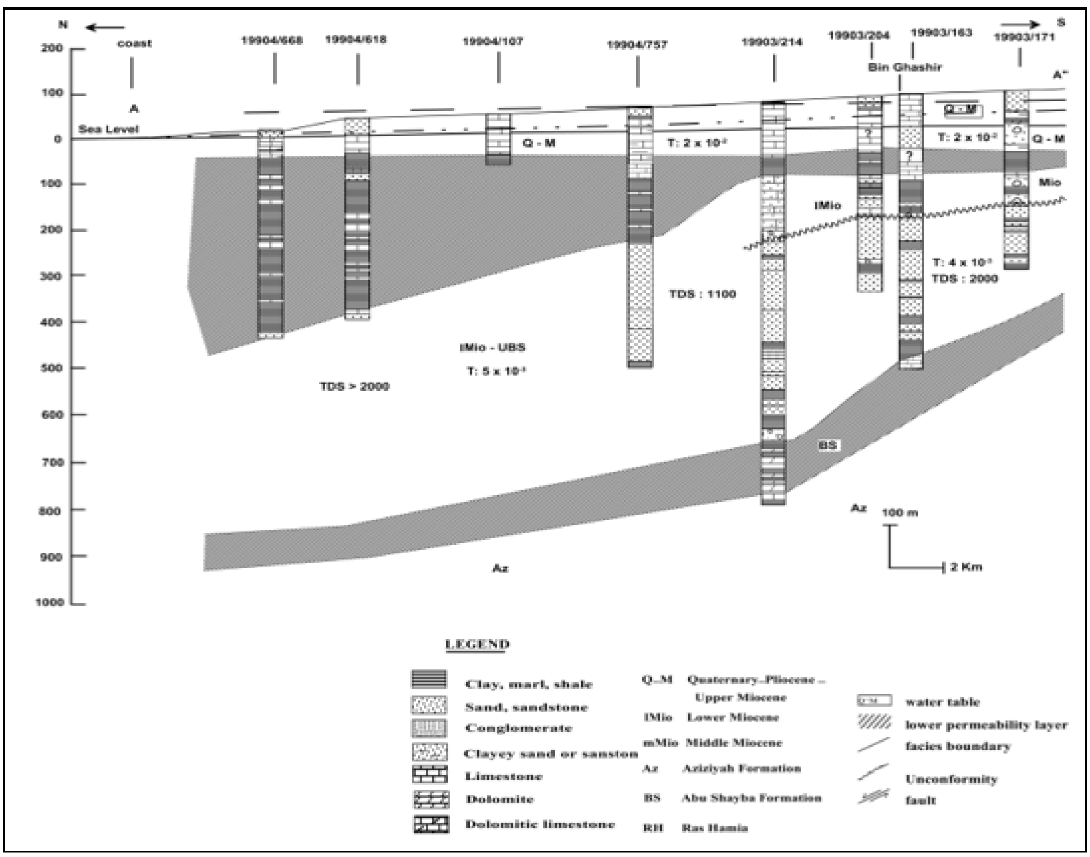

Figure (3): Hydrogeological Cross Section D Through the Jifarah Plain (Kruseman and Floegel, 1978).

2 Hydrogeology

The aquifers containing significant amounts of water in the Jifarah Plain have been classified by Krummenacher (1982), as shown in Table (1).

The unconfined Quaternary-Pliocene-upper Miocene aquifer, referred to as the Quaternary aquifer, represents the main water-bearing aquifer in the Jifarah Plain. It is located to the north of the Al Aziziya fault and constitutes the main source of irrigation and domestic water supply in the region. The aquifer has approximately the same extent as the Miocene transgression and is separated from the lower aquifers by thin Middle Miocene clays. It contains good quality water in the central and eastern parts. In central Jifarah, the lithology of the upper aquifer varies widely and includes limestone, gravel, marl, clay, sand, and sandstone. Between Sabratah and Bir al Ghanam, the lower part of the upper aquifer consists of gypsiferous limestone and gypsiferous sandstone. The groundwater in the Quaternary aquifer occurs under free water table conditions, where it is overlain by permeable surficial deposits and separated from the lower Miocene aquifers by an impermeable clay layer of Middle Miocene age. The bottom of the Quaternary aquifer generally lies between 30 and 200 m below the land surface, and its water table ranges between 20 and 60 m. The depths of wells utilized in this aquifer range from 30 to 180 m. The saturated thickness of the formation varies from 10 to 90 m. Most wells tapping this aquifer yield productivity levels of about 20–80 m^3/hr in the northern and eastern parts of the plain, decreasing to productivity levels of about 10–50 m^3/hr in the southern and western regions. Most of the recharge for this aquifer comes from rainfall that infiltrates into the aquifer. According to Pencol (1978) and Krummenacher (1982), the estimated recharge is between 5–15% of the annual rainfall. Other sources of recharge include irrigation losses, water supply network losses, surface water recharge, and lateral recharge from subsurface flow towards the north. Possible recharge may occur through upward leakage from older aquifers in some localities.

Table (1): Classification of Aquifers in Jifarah Plain (Kremenchug, 1982).

Group	Predomintal	Comment
Miocene-Quaternary	Sands, sanstone and sandy limestone	The main aquifer of Jifarah Plain; unconfined
Oligo-Miocene	Calcareous sandstones	Significant confined aquifer in the north of Jifarah Plain
Cretaceous	sandstone and limestone	the main aquifers of this group are the Sidi as Sid limestone which is unconfined aquifer
Jurassic	Detrital limestones and sandstones	Significant source of water at the foot of Jabal Naffusah

Triassic	Limestone and sandstones	The main aquifers of this group are the Aziziyah limestone and the Abu Shaybahsandstone and clay; important source of water in Central Jifarah

Materials and Methods

1 The materials used in this study were:

- Several previous studies and reports about the geology and hydrogeology of the Jifarah Plain were collected.
- Geological map for NW-Libya by the Industrial Research Centre in Libya (1975), Tripoli, Libya.
- SRTM images of the study area (N32E012 and N32E013) from the Shuttle Radar Topography Mission, with details down to 30 m lengths (available at https://dwtkns.com/srtm30m/).
- ArcGIS software program (v. 10.3) was used to extract the Digital Elevation Model (DEM) of the study area.
- Mathematical programs (Excel 2010 and ArcGIS 10.3) were used to analyze data and information obtained from pumping tests, as well as for contouring maps demonstrating the hydrogeological properties of the groundwater aquifer.
- Hydraulic parameters of the Q-M aquifer were studied based on pumping test data from 40 wells carried out by ***the General Water Authority*** (GWA).

The data used for this work were obtained from the General Water Authority (GWA). All pumping wells utilized for the tests were monitoring wells drilled by the GWA and tested immediately after drilling to measure well performance; no production wells were used. The pumping test techniques consisted of three sequential stages: the Step-Drawdown Test, conducted in three stages with different pumping rates lasting from 3 to 6 hours for each stage; the Constant Rate Test, performed over a 24-hour duration; and the Recovery Test, conducted following the constant rate test. Discharge rates during these tests ranged between 6 m^3/hr and 79 m^3/hr for both single- and multi-stage tests. During and after the tests, data were collected and analyzed to determine hydraulic parameters, including transmissivity (T), hydraulic conductivity (K), and specific capacity (SC). A single-hole pumping test was employed for all 40 wells due to the absence of observation wells (piezometers). The data generated from these tests were used to estimate the transmissivity (T) of the aquifer. Pumping test data were plotted as time-drawdown curves on semi-logarithmic paper using Microsoft Excel, assuming that water withdrawn from the aquifer was derived entirely from storage and discharged instantaneously with the decline in head Figure (4). However, the storage coefficient (storativity, S) could not be calculated due to the lack of observation wells.

2 Methodology for Determining Hydraulic Properties of Aquifers

Hydraulically, groundwater movement depends primarily on the parameters of the aquifer through which the water flows. Hydraulic parameters play a vital role in evaluating well yields, determining recharge rates to the aquifer, and developing optimum groundwater management schemes. Pumping and recovery tests are the most widely used methods for determining aquifer parameters and properties. Numerous methods are available for analyzing and interpreting the results of pumping and recovery test data, depending on the field conditions.

The main hydraulic parameters considered in the study of the Quaternary aquifer are:

I. Transmissivity (T): Transmissivity is the rate at which water passes through a unit width of a saturated thickness of an aquifer under a unit hydraulic gradient. Th**e** hydraulic conductivity refers to the volume of water (Q) that will move in a unit of time under a unit hydraulic gradient through a unit area.

The following two methods of data analysis were applied:

a. Jacob Method:

Jacob's Time-Drawdown Method is appropriate only for the portion of the test in which equilibrium conditions are reached or when a complete cone of depression has developed. A time-drawdown graph is prepared on semi-logarithmic paper, with drawdown plotted on the vertical axis (arithmetic scale) and time on the horizontal axis (logarithmic scale). Jacob's correction is applied for drawdown if s2/2H>0.003s^2/2H > 0.003s2/2H>0.003 m for the water table aquifer (Raghunath, 1987). According to Jacob (1946), transmissivity can be calculated using the following equation:

$$T = \frac{0.183Q}{\Delta S}$$

Where: T = Transmissivity in m^2/day.

Q = well discharge, m^3/day.

ΔS = slope of line in meters per log cycle (m).

b. Recovery Method:

The calculated values of transmissivity obtained from the recovery method can provide an additional estimate of aquifer transmissivity, which may be more accurate than the initial estimate. In some cases, uncontrolled variations in the pumping rate during the pumping test can affect the drawdown measurements. However, such variations do not influence the recovery rate. According to the Theis recovery method, the following equation is applied to calculate transmissivity:

II. Hydraulic Conductivity (K): Hydraulic conductivity is a quantitative measurement of permeability, representing the ease with which water can pass through a unit thickness of an aquifer. Hydraulic conductivity (K) and transmissivity (T) are related by the following expression:

$$\mathbf{T = Kb.}\ \text{Thus,}\ \mathbf{K = T/b}$$

Where: b = saturated thickness of the aquifer m.

The average thickness in the studied aquifer amounts about 150 m Abo Shaala, (2007).

III. Specific Capacity (Sc): Specific capacity is the discharge rate per unit drawdown. Mathematically, specific capacity (Sc) is expressed as:

$$\mathbf{SC = Q/s}$$

Where: Q = the discharge rate in m^3/d. s = drawdown in m

The productivity of a well is often expressed in terms of its specific capacity (Freeze and Cherry, 1979).

Results and Discussion

Both the Theis and Cooper-Jacob methods were appropriately applied to estimate the aquifer hydraulic parameters in the study area. Table (2) summarizes the details of the wells considered for the hydraulic properties assessment, while Table (3) presents the calculated values of transmissivity, hydraulic conductivity, and specific capacity of the investigated aquifer. From this table, it can be observed that transmissivity values range from 6.36 m^2/day at well no. 9 to 7,150 m^2/day at well no. 40, with an average of 895 m^2/day. The transmissivity contour map Figure (5) shows an increase in transmissivity values toward the north and northeast directions of the study area. This increase in transmissivity aligns with groundwater flow, which generally moves in the same direction, resulting in higher groundwater discharge from wells penetrating the studied aquifer. According to the classification of aquifer potentiality proposed by Gheorge (1979), which is based on transmissivity values Table (4), the estimated transmissivity values of the Quaternary aquifer in the study area indicate that the aquifer can be categorized into three distinct zones Figure (5):

- Zone 1: Highly Potential: Transmissivity values range between 640 and 7,150 m^2/day. Approximately 37.5% of the studied wells fall into this category.
- Zone 2: Moderately Potential: Transmissivity values range between 85 and 413 m^2/day. Most studied wells (about 55%) are located in this zone.

- Zone 3: Low Potential: Transmissivity values range between 6.36 and 40 m²/day. Only 7.5% of the studied wells are located in this zone.

The calculated hydraulic conductivity of the aquifer ranges between 0.04 m/day at well No. 9 and 47.66 m/day at well No. 40 Table (3). The hydraulic conductivity contour map Figure (6) shows that the highest values of this parameter are recorded in the northern part of the study area. The calculated specific capacity of wells ranges from 7.29 to 642.86 m³/d/m, with a mean of 113.55 m³/d/m Table (3). It is worth noting that the variation in transmissivity, hydraulic conductivity, and specific capacity values is mainly attributed to lateral facies changes.

Some previous attempts have been made to estimate the hydraulic properties of the Quaternary aquifer in the Jifarah Plain using different methods of pumping tests. Among them, Kruseman and Floegel (1978) stated that the transmissivity along the Jifarah Plain coast varies between 2×10−32 \times 10^{-3}2×10−3 and 1×10−21 \times 10^{-2}1×10−2 m²/s, and further inland between 2×10−22 \times 10^{-2}2×10−2 and 1×10−11 \times 10^{-1}1×10−1 m²/s. The storage coefficient is between 6% and 20%. Krummenacher (1982) estimated the transmissivity to be about 100–8000 m²/day and the storage capacity of this aquifer to range from 6% to 9%.

El Baruni (2000) reported that the transmissivity is in the order of 1.2×10−31.2 \times 10^{-3}1.2×10−3 to 1.0×10−11.0 \times 10^{-1}1.0×10−1 m²/s, with a storage coefficient between 6% and 10%. Abo Shaala (2007) estimated the transmissivity values of the aquifer in the central part of the Jifarah Plain to range between 10 and 1642 m²/day. Al Farrah (2011) deduced an average transmissivity value of 5.94×10−45.94 \times 10^{-4}5.94×10−4 m²/s for central Jifarah, with the highest values recorded in the eastern part of central Jifarah. Gejam (2018) noted that the transmissivity of the Miocene-Quaternary unconfined aquifer ranges between 100–8000 m²/day, with the storage capacity ranging from 4% to 10%.

The correlation between the results obtained by previous researchers and the present work reflects the following observations:

- A significant variation in the values of the hydraulic parameters is recognized, which can be attributed to the lateral and vertical variation in the lithological properties of the water-bearing formations and the degree of accuracy of the methods used for analysis.
- The estimated values reflect a reasonable ability of the aquifer to transmit, store, and yield groundwater, as well as the lateral changes in aquifer conditions.

Table (2): Hydrogeological Data of the Studied Wells.

Well No.	*Well name*	*Longitude*	*Latitude*	*Ground elevation (m)*	*Total depth of drilling (m)*	*Water level (m) (a.m.s.l.)**
1	T/1/0737/0/87	13°22'23.34"E	32°48'50.75"N	78	86	58.41
2	T/1/0179/0/81	13°17'28.73"E	32°50'45.33"N	35	85	23.48
3	T/1/0712/0/90	13°15'31.44"E	32°47'37.03"N	55	50	19.96
4	T/1/0704/0/90	13°13'37.28"E	32°50'59.97"N	20	50	37.7
5	T/1/0097/0/93	13°12'27.72"E	32°53'20.21"N	13	51	10.3
6	T/1/0713/0/90	13°11'43.21"E	32°53'32.56"N	11	50	22.11
7	T/1/0700/0/90	13°11'0.22"E	32°52'2.33"N	16	48	15.35
8	T/1/0711/0/90	13°11'7.82"E	32°51'1.08"N	21	56	26.95
9	T/1/0839/0/92	13°11'41.55"E	32°42'13.96"N	64	157	94.8
10	T/1/0483/0/86	13°10'44.96"E	32°33'30.40"N	114	171	77.53
11	T/1/0397/0/87	13° 8'5.79"E	32°48'56.65"N	47	130	45.94
12	T/1/0634/0/90	13° 4'50.17"E	32°50'48.95"N	21	50	18.8
13	T/1/0152/0/87	13° 2'54.46"E	32°48'51.90"N	41	96	34.88
14	T/1/0620/0/90	13° 4'22.45"E	32°43'15.61"N	58	160	87.76
15	T/1/0746/0/89	13° 3'51.22"E	32°42'10.19"N	63	153	73.51
16	T/1/0907/0/92	13° 0'55.18"E	32°50'22.55"N	4	98	21.43
17	T/1/0548/0/91	13° 0'16.37"E	32°49'12.13"N	17	87	32.17
18	T/1/0403/0/89	13° 0'35.80"E	32°47'36.67"N	26	183	45.3
19	T/1/0033/0/89	13° 0'20.14"E	32°44'57.33"N	46	150	37.16
20	T/1/0018/0/2000	12°56'26.51"E	32°48'35.94"N	9	105	23.45
21	T/1/0803/0/91	12°57'7.77"E	32°46'33.25"N	41	118	44.33
22	T/1/0278/0/95	12°55'29.21"E	32°42'49.24"N	73	132	63.66
23	T/1/0486/0/2000	12°54'35.70"E	32°45'22.56"N	33	140	51.55
24	T/1/0442/0/92	12°50'51.08"E	32°46'36.67"N	28	96	32.1
25	T/1/0005/0/76	12°51'14.25"E	32°43'35.53"N	45	156	25.72
26	T/1/0442/0/92	12°52'44.25"E	32°39'59.28"N	87	84	19.6
27	T/1/0454/0/92	12°52'51.23"E	32°37'46.29"N	85	232	87.65
28	T/1/0891/0/95	12°48'3.82"E	32°45'22.34"N	38	115	59.18
29	T/1/0510/0/87	12°46'45.16"E	32°46'35.62"N	14	103	35.5
30	T/1/0133/0/76	12°41'40.40"E	32°45'36.88"N	21	100	-8.18
31	T/1/0629/0/89	12°43'20.63"E	32°42'7.37"N	42	161	25.37
32	T/1/0391/0/76	12°44'22.91"E	32°39'21.30"N	70	75	16
33	T/1/0078/0/94	12°47'1.73"E	32°38'1.35"N	87	23.3	77.54
34	T/1/0373/0/76	12°41'12.59"E	32°37'38.82"N	79	75	25.58
35	T/1/0631/0/76	12°39'31.82"E	32°40'16.02"N	60	77	24.46
36	T/1/0362/0/76	12°35'50.13"E	32°38'36.88"N	68	77	25.15
37	T/1/0354/0/76	12°35'42.77"E	32°39'51.21"N	57	83	24
38	T/1/0095/0/94	12°34'38.15"E	32°42'18.67"N	30	130	35.22
39	T/1/0094/0/94	12°34'18.68"E	32°43'39.45"N	13	132	34.31
40	T/1/0443/0/92	12°51'55.06"E	32°47'32.96"N	13	95	19.6

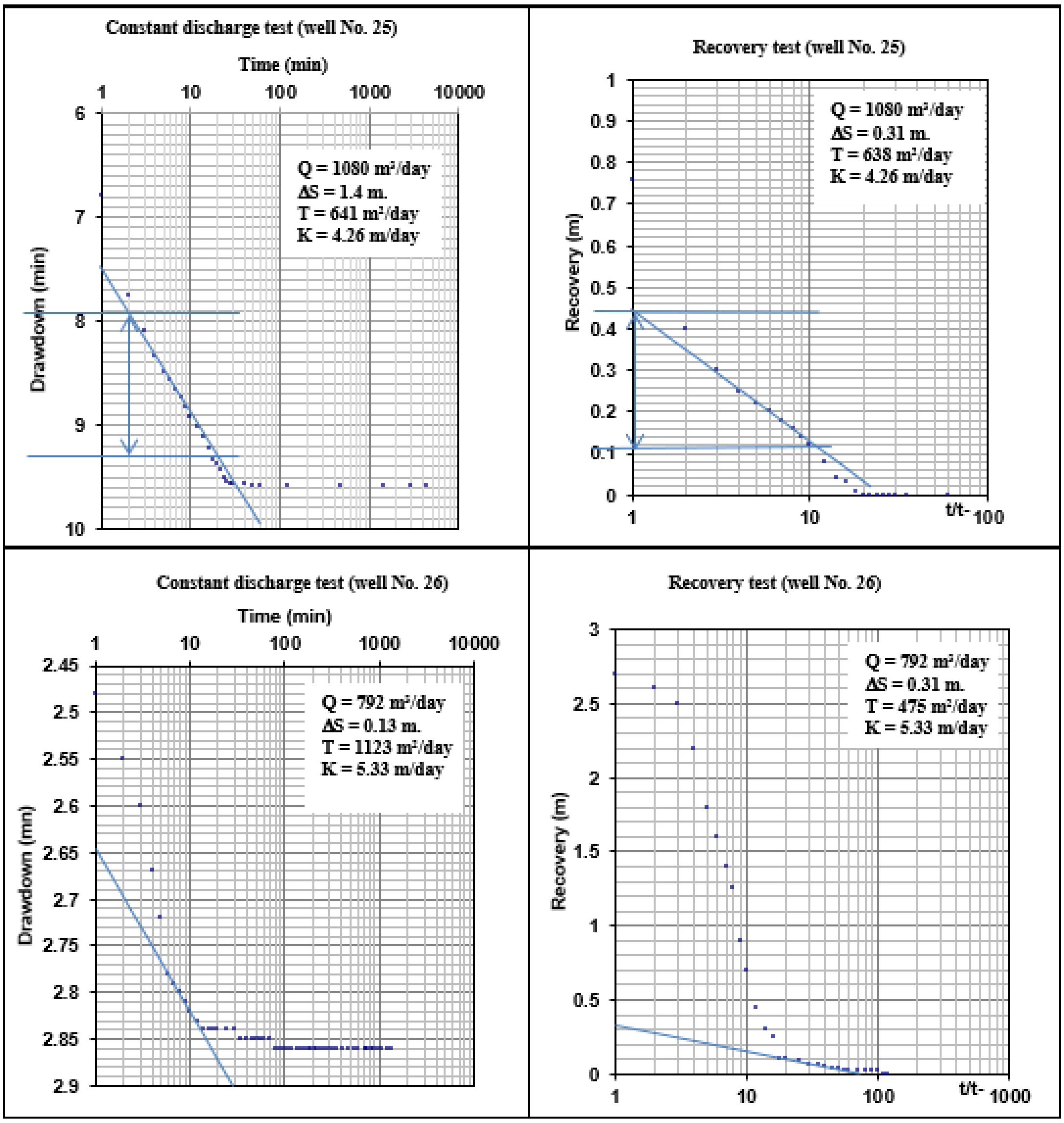

Figure (4): Pumping Test (Cooper-Jacob and Recovery Solution) Results of Wells (25 and 26).

Table 3: Calculated Values of Transmissivity, Hydraulic Conductivity and Specific Capacity of the Investigated Aquifer.

Well No.	Discharge (m^3/h)	Drawdown (m)	Transmissivity (m^2/day)		Average of transmissivity	Potentiality classification	Hydraulic Conductivity (m/day)	Specific Capacity m3/d/m
			Jacob	Theis Recovery				
1	6	9.94	54	26	40	Low	0.27	14.49
2	60	2.24	2359	4743	3551	High	23.67	642.86
3	35	3.88	968	1382	1175	High	7.83	216.49
4	8.3	6.60	182	28	105	Moderate	0.7	30.18

5	36	8.55	264	1581	922	High	6.15	101.05
6	37.7	3.27	1642	335	988	High	6.59	276.7
7	36	24.28	518	290	404	Moderate	2.69	35.58
8	31	8.25	156	21	88	Moderate	0.59	90.18
9	10.08	24.90	6.51	6.22	6.36	Low	0.04	9.72
10	20.13	30.18	111	111	111	Moderate	0.74	16.01
11	79	5.37	864	1668	1266	High	8.44	353.07
12	32	4.42	1080	1166	1123	High	7.49	173.76
13	56	6.14	374	319	347	Moderate	2.31	218.89
14	23.43	11.12	137	105	121	Moderate	0.81	50.57
15	25	34.36	259	103	181	Moderate	1.21	17.46
16	10	2.19	864	9540	5202	High	34.68	37.73
17	27	3.04	3801	1317	2559	High	17.06	213.16
18	28.03	31.68	492	70	281	Moderate	1.87	21.23
19	25	20.24	60	109	85	Moderate	0.56	29.64
20	37.7	7.79	630	1036	833	High	5.55	116.15
21	30	10.17	224	95	160	Moderate	1.06	70.8
22	30	25.50	50	14	32	Low	0.21	28.24
23	31.68	42.52	1468	1402	1435	High	9.57	17.88
24	30.1	5.62	1382	1555	1469	High	9.79	128.54
25	56	13.85	641	638	640	High	4.26	77.98
26	33	2.86	1123	475	799	High	5.33	276.92
27	34.4	10.59	88	100	94	Moderate	0.63	77.96
28	56	13.85	2937	1123	2030	High	13.53	62.38
29	45.51	6.27	263	235	249	Moderate	1.66	174.2
30	35	13.93	118	156	137	Moderate	0.91	60.3
31	21	13.93	122	114	118	Moderate	0.79	36.18
32	40	16.00	196	388	292	Moderate	1.95	60
33	43.2	19.76	132	180	156	Moderate	1.04	42.51
34	30	14.36	134	233	183	Moderate	1.22	50.14
35	12.69	12.15	139	686	413	Moderate	2.75	25.07
36	6	19.74	311	201	256	Moderate	1.71	7.29
37	15	14.00	253	506	380	Moderate	2.53	25.71
38	46.5	8.03	406	129	268	Moderate	1.78	138.98
39	52	12.93	181	121	151	Moderate	1.01	96.52
40	33	2.86	475	13824	7150	High	47.66	276.92

Table (4): Aquifer Potentiality Classification (Gheorge 1979).

Potentiality of the aquifer	Transmissivity (m2/day)
High	> 500
Moderate	50 – 500
Low	5 – 50

Very Low	0.5 – 5
Negligible	< 0.5

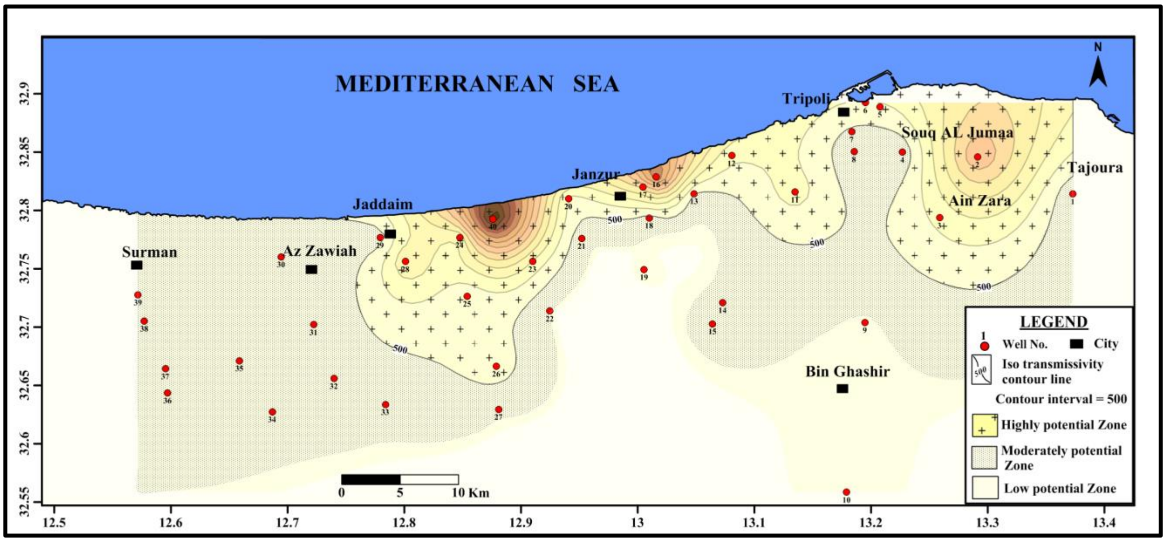

Figure (5): Showing Both a Transmissivity Contour Map and Potentiality Zones of the Quaternary Aquifer in the Study Area.

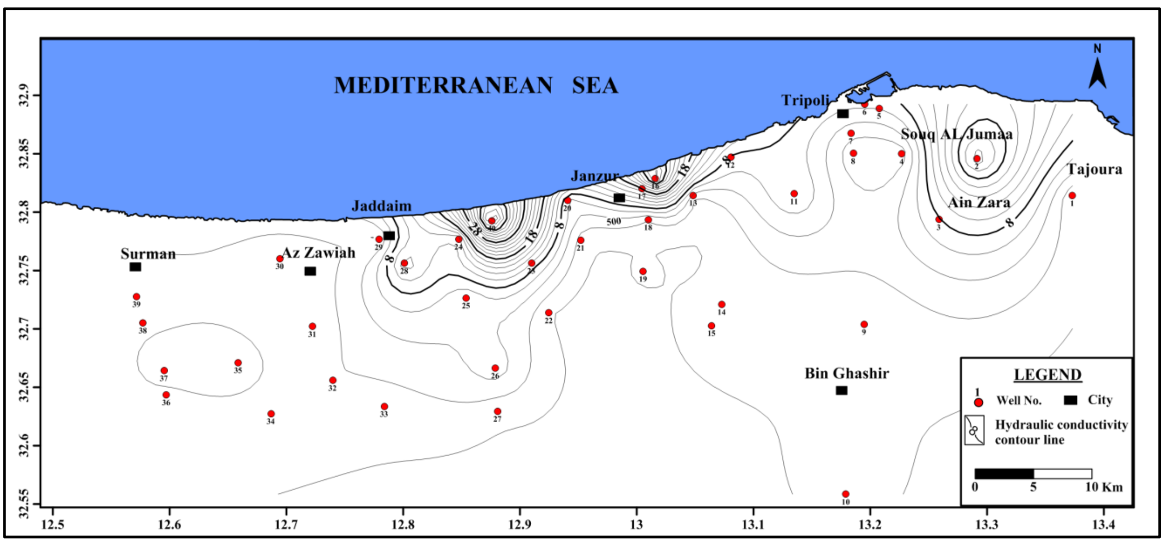

Figure (6): Hydraulic Conductivity Contour Map of the Quaternary Aquifer in the Study Area.

Conclusion

The study area is located along the coast of the central Jifarah Plain in NW Libya. It is characterized by Mediterranean to semi-arid climatic conditions, with hot and dry summers and cold, rainy winters. The terrain is nearly flat, rising gradually from sea level in the north to over 170 meters above sea level in the south. The Miocene-Quaternary unconfined aquifer represents one of the main water-bearing formations in the Jifarah Plain. It is composed primarily of sandstone and sandy limestone, with interbedded limestone, clay, silt, and marl. This aquifer is separated from the lower Miocene aquifer by Middle Miocene clays. The bottom of the Quaternary aquifer typically lies between 30 and 200 m below the land surface, while its water table ranges from 20 to 60 m. The depths of the wells utilized in this aquifer range between 30 and 180 m, with the saturated thickness of the formation varying from 10 to 90 m. Most of the wells tapping this aquifer have productivities of approximately 20–80 m^3/hr in the northern and eastern parts of the plain, decreasing to 10–50 m^3/hr in the southern and western areas.

The calculated transmissivity parameter of the Quaternary aquifer ranges between 6.36 and 7,150 m^2/day, with an average of 895 m^2/day. According to Gheorge's (1979) classification, most groundwater wells (55%) lie in the moderately potential zone, while 37.5% of the studied wells are highly potential. The low potential zone is less pronounced, accounting for about 7.5% of the studied wells. The potentiality of the aquifer increases towards the north. The calculated hydraulic conductivity of the aquifer ranges between 0.04 and 47.66 m/day, while the specific capacity (Sc) of the studied wells ranges from 7.29 to 642.86 m^3/d/m.

Spatially, transmissivity and hydraulic conductivity values increase in the northern and northeastern parts of the study area, while they gradually decrease in the western and southern parts.

Great variation in the values of the hydraulic parameters is recognized, which can be attributed to the lateral and vertical variation in the lithological properties of the water-bearing formations.

Acknowledgement: *My deep gratitude to Dr. Lutfia M. TaebGrabel, Geology Department, Faculty of Science, El-Zawia University, for her useful discussion and critical reading and revising of the paper.*

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