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Contents Of Vol NO 1,2 Year 28th

An Assessment of the Hydrogeology and Hydrochemistry of the main Aquifers in Darnah Region, NE. Libya

Fathi M. Salloum*

ABSTRACT

The aim of this paper is to evaluate the Hydrogeology and hydrochemistry in the main aquifer in Darnah region, the Eocene Apollonia and Darnah formations, which are exposed only in the northwest center, and consists mainly of fossiliferous limestone; perched aquifers from the Tertiary Oligocene (Al Baydah and Al Abraq Formations) and the Miocene Al Faidiyah Formation) in which the limestone are contributing to the water resources in the eastern side, Martubah area. Most of the southern part of the study area is covered by the Neogene rocks of Al Faidiyah Formation. A number of chemical analyses from previous consultant studies in the Darnah region were reviewed and analyzed. In addition, more samples from different localities were collected during June 2006. Some of these samples are from pumped wells and others from natural flowing springs. The newly performed analyses show a reasonable agreement with the previous data whenever cross-checking was possible. The salinity of the main aquifer in the western part of the study area shows a quite regular increasing trend west to east and north to south (Fig. 4 and Fig. 8), the water quality trend is matching closely to the groundwater flow direction. Many trials have been performed to estimate the recharge of aquifers in the area. The

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climate of the study area has been discussed in order to understand the relation and link with estimation of aquifer characteristics in terms of recharge and water balance, these parameters are important for long term water management for Darnah region. Climatic data were identify the environment and further more classify the area in the range of weather humid up to Desertic class. Water resources have been also discussed, discharge measurements of springs were evaluated through the last decades with respect with water wellfields in the upper stream.

Introduction

The context of this paper was a part of the work performed on June 2006 by a group of Scientist from universities of Tripoli and Benghazi within the Environmental assessments base line survey on Block

42-44 Darnah region, led by Professor Mustafa J.Salem.

Darnah is located in the north eastern part of Cyrenaica, Al Jabal Al Akhdar, east Libya. The study area extends from the Mediterranean coast in the north to about 100km in the south. It extends from Wadi AnNagah in the west, to Wadi Al Khalij east of Darnah. The actual size of the area is about 3750km^2 (Fig.1). Darnah city is considered one of the most important and largest centers between the cities of the Eastern region.

Al Jabal al Akhdar is a crescent-shaped ridge attaining a height of more than 850 meters a.m.s.l, in its central part west of Darnah. The northern flank consists of step plateaus which has been formed as a result of a series of faults and beach terraces. These plateaus are more or less parallel to the Mediterranean Sea, the flank of Al Jabal al Akhdar dips gently toward the south direction forming the Cyrenaica Plateau.

Due to the high relief, the wadis in the north are short and deeply cut, reaching the sea after only few kilometers, e.g. Wadi Darnah. While toward the south, wadis get wider and shallower. The landscape in this area gradually becomes lower and forms large, undulated platform, lying at an altitude of 100-200 m. with discontinuous scarps. The general gentle dip of this area was found to be toward the east and to southeast. Two escarpments (upper and lower) is intersected the study area

The groundwater reservoir is made of thick calcareous series of Tertiary main aquifer (Eocene, Darnah Formation). In correspondence with extensive development of marly layers in the Oligocene (Al Baydah, Abraq and Al Faidiyah Formations), perched aquifers occur locally. The groundwater is generally fresh, its quality deteriorates progressively southward and eastward, due to leaching of evaporites in Tertiary rocks. In coastal areas, increasing salinity by sea water intrusion was due to the over pumping of the huge number of the drilled wells in the area. Chemical analyses of previous collected data were checked and reviewed with the most recent which were inventoried, and collected over 23 water points, these are analyzed in the framework of the present study. Recharge mechanism is complex, because deep percolation of rainfall is controlled by several factors.

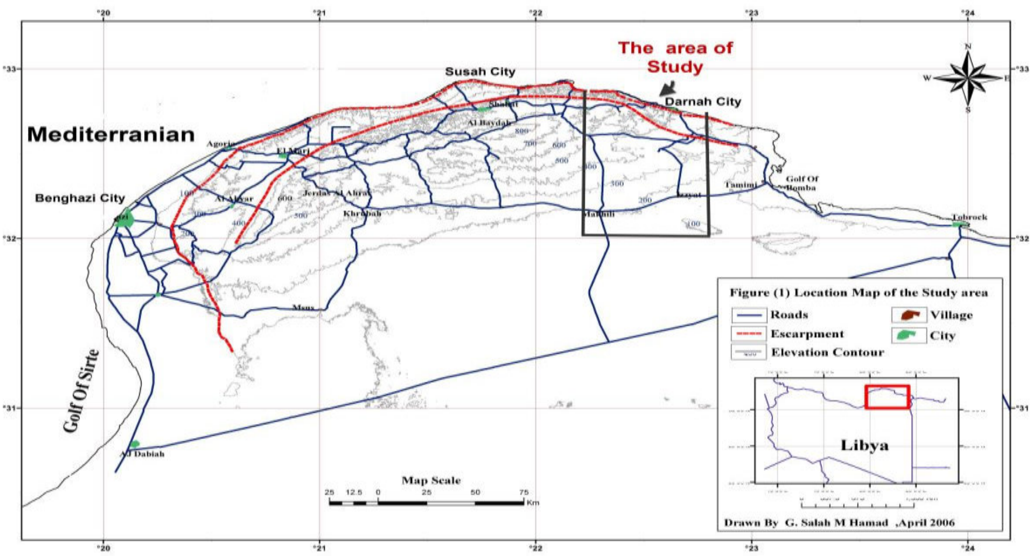

Fig. 1: Topographic map shows the study area (Salloum et al., 2006)

Isotope tools were also used for recharge analysis through water age dating, recharge sampling campaign of groundwater and rainfall had been performed.

Climate

The records of climatic parameters data were taken from the Meteorological Data Center in Tripoli, Darnah Metrological Station and Al Fatayeh Agriculture Project. Other information were collected from Darnah for the years 2004-2006.These later information will be dealt separately. It is important to emphasize here that the reliable data during this survey were only for the areas in the northern parts, namely Darnah and Al Fatayeh. It is expected therefore that some variations between these mentioned sites and the central and southern parts of the area where a semi-desert environment prevail with less rainfall and humidity. The Darnah area has moderate climatic conditions dominant year-around. As the area is located on the Mediterranean Sea from north and northeast on one side and high topography on the other, while it is open to the semi-desert topography from its southern direction.

The mean monthly temperature ranges in the region between 14.9 ^{0}C in winter (January) and 27.3 ^{0}C in summer (August). However, High relative humidity prevail, it ranges between 70% in the winter and 78% in the summer, and the maximum value of the relative humidity was recorded in October.

The rainfall is irregular in Darnah area, the monthly rainfall ranges was found between 0.1 mm. in July and 58.9mm in January. While In Al Fatayeh Agriculture Project east of Darnah, it was 0.1 mm. in July and August, to 88 mm in December. The maximum total monthly rainfall in December 1991 was 323.4 mm. When considering the number of rainy days in the Darnah Area it was recorded at 0.0 in the months of July and August, and 10.4 days in January, as an exception in Darnah area in 1991 the number of rainy days was 24 in December of the said year. The highest annual rainfall in the neighboring areas to Darnah is at the town of Al Gaigab west of Darnah, where the rainfall reaches 350 mm. On the other hand to the south of Darnah in Al Mekhili (west of Al Ezziat village), the annual rainfall is only 40 mm. However, at Martubah (southwest of Al Fatayeh) is only 130 mm/year. It can be conclude that annual rainfall increases west of Darnah. While it decreases southwards from Darnah, where the topography gets lower, away from the coastline, therefore the semi-desert environment prevails.

Data from the year 2004 are partially missing, while complete data from the year 2005 gave a reliable relationship, where the highest Evaporation was recorded in July. According to the temperature, wind, sunshine, and humidity data, Evapotranspiration was found to be 73% as calculated by previous consultants (GEFLI, 1974).

General Geology

Most of Al Jabal Al Akhdar lithostratigraphic units are Tertiary in age, with the exception of small areas of late Cretaceous age. The Eocene (Apollonia and Darnah Formations), Oligocene (Al Baydah and Al Abraq Formations) and Oligo-Miocene (Al Faidiyah Formation), have been recorded. Most of the area of study is covered by Al Faidiyah Formation and Darnah Formation (Fig. 2) .The following is a brief summary of the exposed formations in the study area:

Apollonia Formation (Early to Middle Eocene):-

Only the upper part of this formation is exposed, along the northwest part of the area. It is composed of intercalated of limestone and chalky marl with some chert in places. The maximum thickness reaches 300m in subsurface well (Zert, 1974). This formation is overlain by Darnah Formation with a transitional conformable surface. However, laterally interfingered with Darnah Formation as well.

Darnah Formation (Middle to Late Eocene):-

The Darnah Formation is overlying and sometimes interfingering with Apollonia Formation, it is composed of limestone to dolomitic limestone with large chert nodules at some level. The base of this section is characterized by the massive, hard with common *Nummulites*. The reported thickness at the type section reach 100m (Zert, 1974).

Al Baydah Formation (Early Oligocene):-

It consists of two members, the lower Shahhat Marl Member and the upper Algal Limestone Member. The Shahhat Member consists of yellowish marl and chalky limestone of 20m thick, The Algal Limestone Member consists of skeletal limestone which is very rich in coralline red algae, in the study area around Darnah only the Algal Limestone Member is present, this formation thins out towards the south east. Al Baydah Formations unconformably overlain by Al Abraq Formation.

Al Abraq Formation (Middle Oligocene):-

It consists of calcarenitic to calcilutitic limestone locally becomes dolomitic limestone, dolomites or marls. In the area of study, the uppermost part is characterized by massive, yellowish marly limestone, with common echinoids and bioturbation.

Al Faidiyah Formation (Oligo-Miocene):-

This formation covers most of the area of study. It consists of two units: A basal clay unit usually dark green and glauconitic, which is overlain by the younger fossiliferous limestone unit. This formation rests on the older rocks with an erosional unconformity surface.

Structurally, the entire area of Northeast Libya and AI Jabal al Akhdar in particular including Darnah are tectonically unstable. It is generally considered as a faulted oriented WSW-ENE with slightly curved axis Anticlinorium, including Darnah area, It is thought that the area experienced uplifting since Late Cretaceous time. The uppermost Cretaceous and Paleocene strata may be missing in some areas as a result of the said uplift. While thick Eocene, Oligocene and Neogene sequences were deposited.

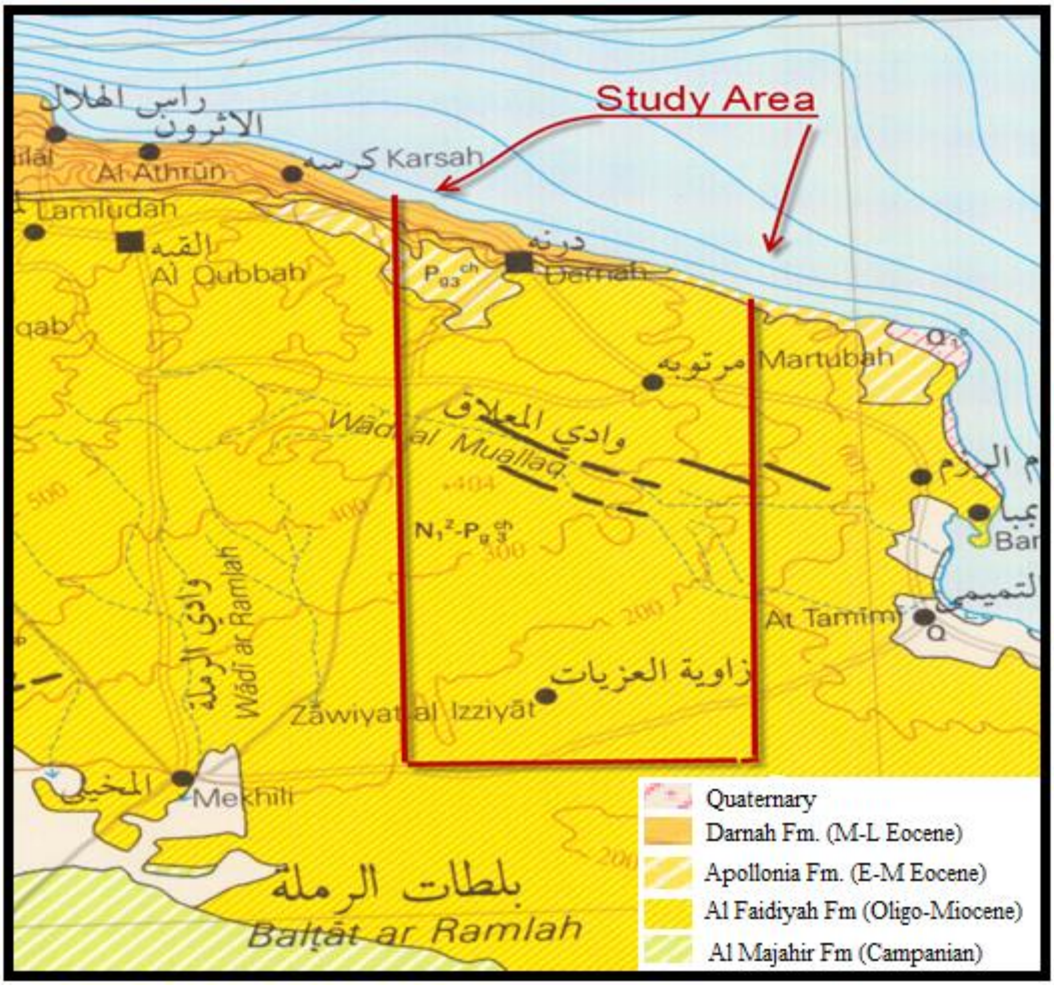

Fig. 2: Geological map of NE Libya Scale 1,000,000, showing the study area, after (IRC, 1985)

In the western part of the study area there are three major fault zones, the coastal belt between Darnah and Ras-Attin, the escarpment line between Martubah and Umm Ar-Razzim and the important lineament of Wadi Al Muallag, most wadis in the study area are controlled by structure framework, The marine erosion which produced the coastal escarpments also followed the main trends of tectonic features. In the south-western and southern parts of the study area extensive jointing indicates that tectonics exists also in these areas as is the case in the north, where several minor fault systems such as NW-SE and NE-SW, (Fig. 3). In the north toward N-NE, in the east toward NE-E, in the middle W-E to SE, in the south wadis are N-S to SE. (Salem and Salloum, 2006).

Geomorphology

Apart from the deepest incisions formed by the main wadis especially in the northern and eastern parts of the area, and the escarpments which flank the coastal strip of the northwestern and eastern part of the region, the rest of the study area is generally flat or gently rolling. Due to this generally flat landform small and linear morphological undulations give good indications and may be important for interpreting regional and local structures. (Salem, and Salloum, 2006).

Two escarpments are prominent in this area. The first one runs along the southern margin of Damah city, while the second one lies further southeast cutting the village of Martubah. Other smaller terraces at different levels were also recorded as being old shoreline (Fig. 3).

The escarpment which runs parallel to the shoreline is the highest in the most westerly part of the area where it exceeds 300m.a.s.l. This escarpment diminishes toward the northeast corner of the area where it reaches the sea-level. The maximum high topography which prevails on the northwestern edge of the study area slopes gradually into the southern area also where it descends to lower than 150 m.a.s.l. in the central and southern parts of the area. These topographic highs and lows are very much coincident with and controlled by structure influence of anticlinal swells and faulting (Salem, and Salloum 2006).

Drainage:-

Northwest part of the Area: The drainage pattern in the northwestern part of the area is characterized by deep and relatively short wadis that run more or less from south-southwest toward north-northeast. Wadi Darnah in particular starts to flow toward the southeast then turns northeast to flow into the sea at Darnah city. In the eastern part of the area, wadis flow from west-southwest toward east northeast into the sea just outside the study area. (Fig. 3).

Two principal wadis runs nearby Martubah area, Wadi Al Khalij and Wadi Al Hemaysah, the total catchment area reaches 550km^2. Wadi Al Khalij Catchment area is 361 km^2 and flows eastward, then deviate north -northeast across the Al Fatayeh plateau for a distance of about 23 km, from the axis of Darnah-Tobruk highway (Fig.3).

Central Parts of the Area: Wadis in the Central Zone, flowing from west to east long stretches of these wadis run E-W and NNW-SSE, being clearly controlled by faulting and fracture systems which strike the same way as can be seen in Wadi Al-Muallag, its catchment area is 778km^2, and it flows over a distance of about 100km from the southern flank of Al Jabal Al Akhdar to eastwards ends at Al Tamimi in the east. Wadi Al Shaggah drains an area of about 500km^2 south of Wadi Al Muallag; it terminates at the western side of the Gulf of Bombah at Al Tamimi town.

Southern Parts of the Area: The area shows a poor climatic pattern. The area is devoid of limestone are supported on top by a hard calcareous crust forming a cap made of caliche deposit. Natural caves as well as dug cisterns are found to collapse in many instances once the supporting thin caliche layer deteriorates from below and becomes weak. Such collapse dolines are common in the area of study. (Salem and Salloum, 2006). Wadi El Ezziat, Catchment area is 2059km², this Wadi contains a number of running parallel long and wide wadis rarely flowing, they drain most of their water just south of Wadi Al Muallag, and they finally disappear further south of Al Ezziat end at very flat areas known as Baltah. Wadi Al Ramlah, catchment area is 931km², this Wadi is the biggest in the southern area in terms of discharge, and however it is flowing outside of the study area (Fig. 3).

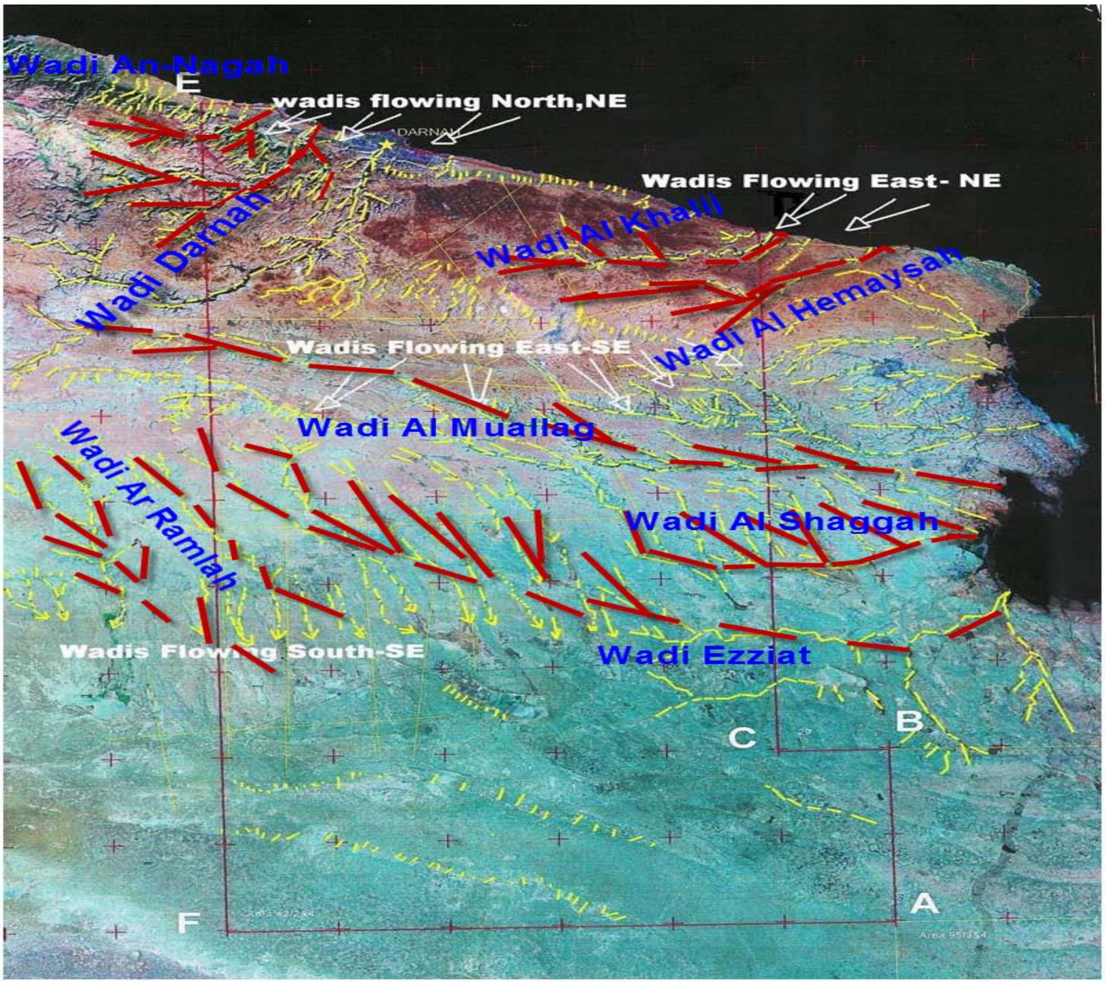

Fig. 3: Satellite image of Darnah region shows major drainage pattern. (Note: The wadis flow are coinciding With structural pattern (after Salem and Salloum, 2006)

Cavernous Phenomena:-

Many types of Karstic features are of erosion action, by solution of near surface rocks, forming caves, potholes, grooves, other Karstic features are sink holes and surface caves on mainly softer rock of Al Faidiyah and Al Abraq formations, the biggest cave in Darnah Region in Wadi Ehtas SE Wadi Darnah tributary is Al Shagaia Cave with multi-levels, connected holes, full of Stalagmites and Stalactites of various sizes.

Hydrogeology

Until recent years, the intense hydrogeological research have been initiated, several studies have been conducted, the most important ones were done by Marchetti (1958), GEFLI (1972), and the Institute for Geological and Geophysical Research (IGGR, 1971). According to the geology, hydrogeological conditions as well as the water resources allocations, the study area fall in the second hydrogeological unit which include Al Gubbah-Darnah and Al Bumbah (Pallas,1979).

Available studies and the results of the deep and shallow drilling suggest that the natural groundwater outlets are confined to the limestone formations of the Eocene, Miocene and Oligocene. Potential Aquifers are located in Darnah and Apollonia formations, from which spring water discharge through the wadi Darnah and Wadi Al Athroun (Ayn Dabbusiah) as well as the wells that have been implemented. Groundwater is also found in Al Baydah and Al Abraq formations, many wells have been drilled in the region and some springs in Wadi Al Nagah and along the mountain slope adjacent to the sea and the mountain slope (GWA, 2005)

The main aquifer, Darnah Formation is composed of Nummulitic limestone, characterized by high permeability and good transmissivity resulting from the nature of the rocks with common cracks and cavities. The free water level in these formations present at different levels and in accordance to the morphological and geological conditions (structural properties and lithology of water bearing rocks). However, water levels deviates steadily toward the east, feeding younger formations, (Fig. 4) where the water level gradient inclination to the east is less than slope of the formations. The thickness of the main aquifer is about 150 meters above the shale and mud intercalated with limestone, this led to the formation of many springs, with variable productivities. (GWA, 2005).

The middle Oligocene aquifer has a limited thickness, Al Baydah Formation is composed of weathered, permeable algal calcarenitic limestone with medium transmissivity, and draws its water from direct recharge of the Quaternary sediments, and where strong hydraulic connection is locally related to the main reservoir in the region by direct contact through the cracks within the impermeable beds. This formation is underlain by the impermeable Shahat Marl Member.

Al Faydiah Formation, where its bottom is lined with clay layers to form water bearing formation, this aquifer draw its water from direct infiltration, there have been locally direct hydraulic contact with the main reservoir in the region (Hydroprojekat, 1971) but the water in this aquifer is considered the primary source to feed aquifers regional level, which are geographically extended on the plateau which is the most rainy areas. The shallow reservoir is the main source of water resources in the region and the ancient underground through many small springs and wells (Fig. 4).

Groundwater Flow:

From the examination of the piezometry map (Fig. 4) the groundwater flow regime in the respective aquifers can be appraised, as well as the possible interrelationship between the different ground water bodies described above. groundwater flow the main aquifer which ensures in the north-western part of the study area is essentially a consequence of the groundwater flow generated in the central parts of Al Jabal Al Akhdar, lying to the west of the study area where water level elevations are the highest. On the other hand, in the southern and eastern parts of the study area groundwater flow is quite difficult since these areas are characterized by very uniform water levels near to sea level elevation, which result from the generally very scattered control points. In fact, in these areas, due to the extremely low or even absent hydraulic gradients, effect groundwater flow in the Main Aquifer: most prominent piezometry feature which dominates the groundwater flow is the west-east oriented mound with water table elevations ranging from about 120 to 200m.a.s.l (Fig. 4).This groundwater mound is maintained by under flowing groundwater, from the parts of the Jabal Al Akhdar lying to the west of the study area. A sharp permeability increase of the aquifer in the south is also testified. The very steep hydraulic gradients, immediately south of the sea coast to the east of Darnah town, indicating a low permeability in the northern direction. This- low permeability zone, however, cannot be viewed as an impervious boundary as it was supposed on some previously prepared piezometric maps (Hydroprojekat, 1971 and GEFLI, 1974), since there are no geologic evidences for such an assumption. Along the lower reaches of Wadi Darnah the steep gradient noted above are attenuated due to the drain effect of the Wadi itself starting at about 10 km inland from the sea coast.

By considering a local increase in permeability over the respective area as evidenced in the GEFLI report, by considering a percolation from the overlying perched Oligocene (Al Abraq) aquifer back into the main aquifer, particularly along the northern part of the piezometric plateau, where the perched aquifer has been identified. The variability, according to different directions of the hydraulic gradients, which generally can be observed since the gradients in the north-south directions considerably steeper than those of northwest-southeast. It is considered that such circumstance indicate the presence of directional transmissibility which is quite common in fractured aquifers.

With regard to the extension of the Oligo-Miocene Al Faidiyah Perched aquifer, water level control points are relatively scares. The groundwater flow apparently originates on the second plateau in the surroundings of Martubah where water levels are in excess of 300m.a.m.s.l., and from here it is directed towards east, south and west consist of low to very low yield springs frequently reduced just to a trickle.

Groundwater flow in the Perched Oligocene (Al Abraq) aquifer can be appraised only in the most north-western part of' the Al Fatayeh Plateau. The zone where groundwater flow originates in this aquifer is not identified due to lack of data, however, it can be supposed as already mentioned that it is diverted from the piezometric mound of the main aquifer where water level elevations exceed 170 m.a.s.l. The high elevation piezometry is maintained along a south-north axis due to the flat structure.

Hydraulic Characteristics (Main Aquifer)

Information on the hydraulic characteristics of the main aquifers are numerous, in particular in the northwestern part of the study area. only in this area the hydraulic characteristics can be appraised in major details, while in the southern and eastern parts, very scattered data on aquifer Transmissibility and specific capacity , they are not sufficient to evaluate in more reliable terms the regional aquifer parameters. Data have been obtained from the pumping tests performed in the numerous completed wells. Where they are only available on the main aquifer. Such as Specific capacity data, reflecting the Transmissibility in the vicinity of the bore hole, together with aquifer and well constants. Transmissibility data determined during long duration pumping tests; Short term storage coefficient data from tests having an observation wells .The specific capacity data, which are numerous (86 values in the northwestern part of the study area). (GEFLI, 1972) reported that, the results of the step drawdown tests showed, the maximum value of specific capacity obtained, was considered for each test, in order to minimize the effect of well loss (CQ2). The maximum value, as normal, has generally been obtained at lowest discharge rates. The low Transmissibility resulting from step-drawdown tests is confirmed also by the analysis of this parameter directly determined in the Martubah wells as reported by GEFLI (1972) from the pumping test data obtained in these wells, both in drawdown and recovery phases, a Transmissibility variation with time is generally an evident indicating partial penetration effect. The storage coefficient is very uncertain since only one pumping test (in Martubah well and related piezometry) furnish relevant data. The storage coefficient from this pumping test is 1.76×10^{-4} which would be characteristic for a confined aquifer. This is in contrast with the assumption that in the area the aquifer is in water table conditions (unconfined). However, it must be pointed out that in thick non homogeneous anisotropic reservoirs, which is the case of the main aquifer.

On the basis of the studies and investigations performed by Franlab (1974), in the southern part and confining areas to the west, a very high Transmissibility (in the order of 10^{-1} to 10^{-2} m^2/sec characterizes this part of the study area, which seems matching with the flat piezometric surface.

The Groundwater levels ranges from 25 to 600 meters in the area of Ras Al-Hilal-Darnah and Martubah-, water is flowing toward the southeast in the direction of the Gulf Al-Bombah (Fig. 4). While Groundwater level was found to be 0 meters towards the east near Ayn Al-Gazela area which are on the sea shore, the ground water flows towards the north in the direction of the Gulf of Bombah. Franlab (1974) have studied the area of Mechili, Ezziat and Kharuba. The groundwater level ranges from 10 to 30m.a.m.s.l. in Mechili area, water flowing towards south-south-east, the water quality is fair (medium quality) ranging from 1700-2500 Micro-mhos/cm represented well fields of Al Ezziat and Buhindi and Al Thuban (Fig. 5). The rest of Southern Jabal

Akhdar area, groundwater level ranges from 10 to 400 meters of water flowing towards the south and south-east, the quality ranging from 1000 to 7000 Micro-mhos / cm.

Springs

Most of the important springs flow out from the area at Wadi Darnah and Al Gubbah (west of Darnah). A number at 19 springs were identified, and measured. Some springs are permanent and produce water with high discharge and good quality. Others are less significant .The springs in the region are mainly flowing from the Karstified beds of the Eocene rocks of Darnah Formation and the underlying Apollonia Formation, the inventoried springs in Darnah region which produce appreciable amounts of water are as follows:- Bu Mansour springs, Ayn Al Blad, Ayn Al Khalij, Ayn At Tanji, Al Mugger , and Ayn Martubah

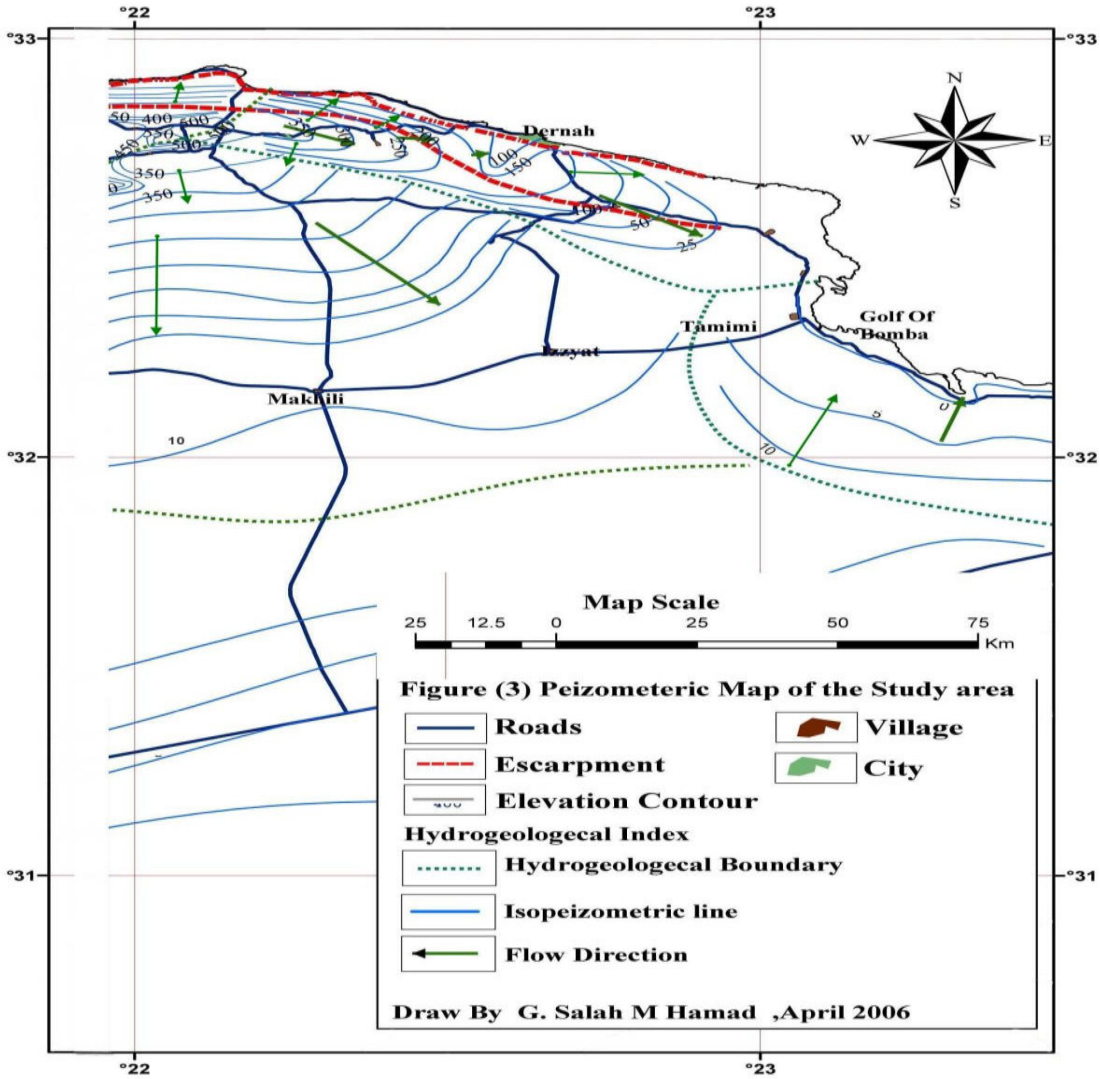

Fig. 4: Piezometric map of the study area (Salloum et al, 2006)

out at the above springs and many others, only Ayn Bu Mansour and Ayn Al Blad are the most producing and dependable permanent sources of water in Darnah, these springs were the subject at many studies by numerous researchers and consultants, the latest was performed under the supervision of the author in 1997 for the purpose of water management in wadi Darnah.

Ayn Al Blad

The spring is located in the western edge of Wadi Darnah about 4.2 km away from Darnah city, its catchment area is about 25 km. Ayn Al Blad is a very important source of water supplying the city of Darnah with potable water .

The Pleistocene Wadi terraces about 15-30m thick play an important role in the process of feeding the spring these sediments are highly permeable with an infiltration rate of 1.2 to $3.4x10^{-4}$ m/s., the spring was measured by several workers. It was found that its discharge was about 65 to 145 l/s in 1977 (Hydroprojekat, 1971), and 67 l/s (Italconsult, 1977), 60 l/s measured by General Water Authority in 1977, and LTCC, 1997. We have measured the spring in June 2006 and found that the discharge is seasonally variable, our value was 30 to 45 liters /second. the reason for lowered of discharge level is similar to that of Ayn Bu Mansour, namely the drilling of water wells upstream had seriously effect on the spring discharge. Water samples from Ayn Al Blad spring was analyzed chemically (Table 2) the salinity is still within the international standards, as its total dissolved solids 565 mg / l.

Bu Mansour Spring

Ayn Bu Mansour is in fact a group of openings on both sides of Wadi Darnah , and most of them flowing out the west side of the wadi , since these openings are at the end been collected in one channel, they may be called with one name. The spring was studied by Gefli 1972, and Italconsult 1978, (Salloum et al 2006).

Ayn Bu Mansour is located about 6 km from the main Dam in Wadi Darnah, this spring is flowing out of highly Karstified thick limestone rocks through the Darnah - Apollonia contact, thick sequence of Travertine sediments were deposited downstream of these springs, this may be due to the presence of barriers and high flow rates in addition to the high Wadi floods during the Pleistocene or Plio-Pleistocene.

The discharge of this spring was measured several times, and was found to be ranging between 195 to 230 liters / second (Gefli, 1972), and about 120l/s. In 1997 the discharge was measured by the author using Price current meter, it was reduced to about 80 l/s. Continuing lowering of spring discharges were noticed, probably due to mainly increased number of drilled water wells in the same aquifer upstream. Some of the newly drilled wells we sampled in June 2006 during the field survey. The measured salinity was 582mg/l, this salinity increases in the direction to the east of Wadi Darnah. Gefli (1974) indicated that the source of water to this spring may be from the west of Darnah (Ayn Marah), they made their hypothesis on pumping operation of the wells in Ayn Mara , which when they are in operation ,the production of the spring was directly affected. Bu Mansour Tunnel is located at an elevation 119-135 m.a.s.l, it is a Man-Made excavated Tunnel for the collection of springs water, it was inventoried by our team only up to 300m long due safety reasons, The discharge of the spring was adopted by (GAW 2005) to 100l/s (8640 m^3/day).Table 1 presents the water resources from wellfields and the main springs in the area around Darnah City which are mainly used for municipal supply , these were used for future planning, there still more efforts should be implemented to evaluate the water resources with respect to the rapid growth of population and the capability of the resources.

Table 1. Available water resources for Municipal and Agriculture uses (estimates of the year 1998), (GWA, 2002)

Source	Capacity m^3/day	Capacity Mm^3/yr.
Shaihah Well field	7,776.00	2,838,240.00
Desalination Plant- Mengar Rabeh	7,776.00	2,838,240.00
Water Desalination – Bu-Msafer	2,592.00	946,080.00
Ayn Al Bald (Spring)	2,592.00	946,080.00
Bu Mansur Tunnel and springs	8,640.00	3,153,600.00
Sewage Plant resources water resources	9,504.00	3,468,960.00
Al Hishah Well field instead of Al Maggar wells	10,368.00	3,784,320.00
Al Dahar Al Hamar well field	8,640.00	3,153,600.00
Total	57,888,00	21,129,120.00

Water Quality of the study Area

A number of chemical analyses data of the groundwater in the Eocene aquifers (Darnah and Apollonia), and the Oligo-Miocene Aquifers (Al Faidiyah and Al Abraq) are available from previous studies, for Darnah region including the southern part, these data (Table 2) were checked and reviewed in comparison with our recent data. Over 35 water points were inventoried, complete analyses to a number of 23 water samples (Table 2) were conducted in the framework of the present study (Fig. 5). During the Field survey, water quality was tested in the field from water wells, springs and cisterns, the type of collected data were, site location (geographic with coordinates),well depth, well number (if any), and any other available information. The field measurement data was mainly Electrical Conductivity (EC), pH, and Temperature, (Table 2).

The water samples were analyzed in Benghazi (The Scientific Center for Research and Development-Chemical and Bacteriologic analyses), reliability of data was checked by the Laboratory of

Man-Made River Authority in Benghazi. The analysis includes calcium, magnesium, sodium, potassium, bicarbonate, carbonate, sulphate, total dissolved solids (TDS), total alkalinity and total hardness (Table 2)

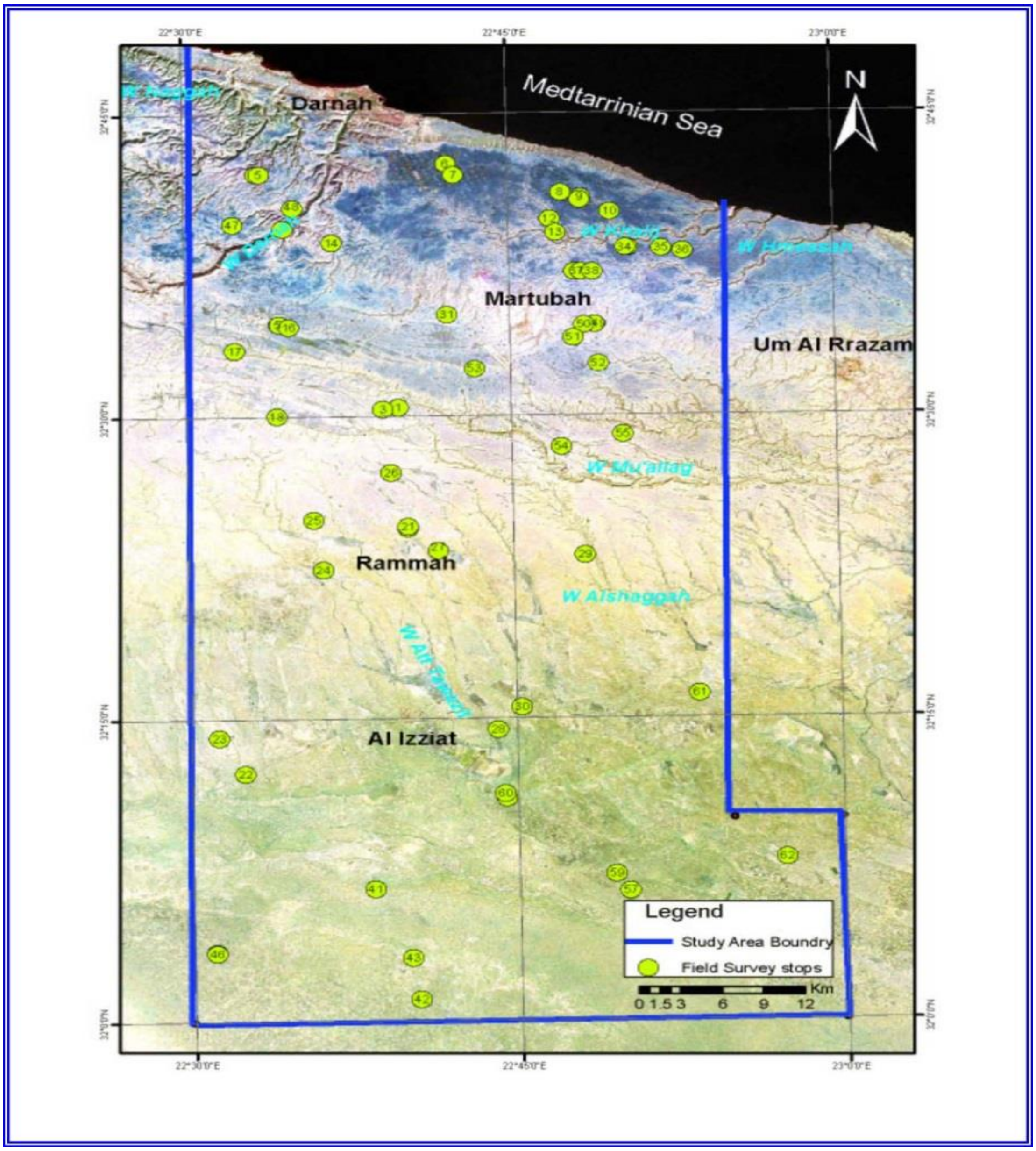

Fig. 5: Satellite image shows water sampling locations in Darnah Region.

Field Measurement and Physical Parameters

Water Temperature Measurement:

The overall water temperature of the study is ranging from a minimum of 21 ^{o}C to a maximum of 27.1 ^{o}C, depending on the different exposure of the water, from contact springs, they have lower temperature than water from drilled wells, water traveled through deeper fractures in the Karsts shows higher temperature. The pH values for study area ranges from 6.4 to 8.4 with an overall average of 7.82. The pH value shows a difference between the mean (7.82 mg/l) and median (7.9 mg/l), which is very small (0.08) statistically indicating approximately normal distribution.

Electrical Conductivity (EC) and Total Dissolved Solid (TDS):

The electrical conductivity values of water in the study area ranges from 5696 to 730 micro-Siemens per cm (µs). The conductivity measurement is an excellent indication of total dissolved solids in water (Hem, 1985). The total material in solution may be quantified by conductivity (EC) and total dissolved solids (TDS), the actual relation between them is dependent upon the individual ionic composition / organic content and silica content for each water. Most natural waters have a ratio of between 0.55 and 0.7 (TDS/EC). The concentration of total solid in the study area ranges from 405.9 to 3132.8 (mg/l). Both TDS and EC is considered high in the study area, the reason for that is the week recharge to aquifers, and the dissolution of the Karstic limestone.

Total Alkalinity:

The total alkalinity show a difference between the mean values (225.82 mg/l) and median (228 mg/l), which is very small. Statistically indicating approximately normal distribution concentrations. The hardness of water in the study area ranges from 236 mg/l as $CaCO_3$ to a maximum of 1200 mg/l as $CaCO_3$ with an overall average of 236 mg/l as $CaCO_3$. It is classified as a very hard water.

Presentation of results chemical analyses

The software package, Groundwater for windows, Rock Works and GWW (UN 1995) has been used to plot the water chemistry of the study area (Table 2) the data can be expressed in milligrams per liter (mg/l) for many proposes, the data may also displayed in graphical form. Two graphs have been used from the package named Piper diagram (Fig. 6) and Stiff pattern (Fig. 7) the results of these graphs showed useful information regarding determination of the classification and type of water.

Piper or Trilinear diagram

The major ionic species in most natural waters are (Na^+, K^+, Ca^{2+}, Mg^{2+}, CL-, CO_3, HCO_3, and SO_4) Trilinear diagram can show the percentage composite ion of their ions by grouping Na and K together the major Cations can be displayed on one Trilinear diagram likewise if CO_3 and HCO_3 – are grouped there also there of the major anions (Piper 1944).

Table 2, Chemical analyses of water samples from the Darnah region (Salem and Salloum, 2006)

ID	Loction Name	N	E	ELEV m	Temp	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	HCO_3 mg/l	CO_3 mg/l	SO_4 mg/l	Cl mg/l	TDS mg/l	Total hardness. as $CaCO_3$ mg/l	Total Alkalinity $CaCO_3$	EC mic-sim/ cm	pH	TDS Calculated	Calculated EC
1	W- 5	32 39.119	22 41.498	251	25.6	78.3	71	260	7	200	0.1	109	487	1139	488	205	2160	7.6	1212	2299
10	Fatyeh-1	32 41.966	22 42.506	242	27.1	65.4	59.4	229	7	216	0.1	121	378	1001	408	221	1820	7.9	1076	1956
11	W-431/2	32 41.052	22 47.499	217	25	57.1	51.8	275	13.9	172	0.1	99	445	1066	356	177	1960	7.9	1114	2048
12	W7/206	32 36.691	22 25.603	441	21.3	37.9	34.4	122	7	196	0.1	61	152	542	236	201	852	8.4	610	960
13	W_8/206	32 39.701	22 37.981	292	26.2	58.4	53	229	41.9	229	0.1	84	370	975	464	234	1620	8.24	1065	1770
15	KT-J3	32 39.474	22 54.998	3	24.6	102	92	230	21	260	0.1	230	514	1430	638	265	2600	7.8	1449	2635
16	H.48	32 45.056	22 36.757	267	25.1	76.2	69.2	189	11	260	0.1	67	480	799.7	475	265	1454	7.5	1153	2095
19	W.1_Ardam	32 34.575	22 34.314	359	21.8	66.2	60.1	81	6	223	0.1	54	177	405.9	413	228	738	6.4	667	1213
2	Martuba Spring	32 24.202	22 48.493	258	21.5	50	45	221	13.9	176	0.15	94	390	942	312	181	1720	8	990	1808
21	W-2-2106	32 44.378	22 35.683	265	24	76	69.2	80	4	260	0.1	38	163	437	475	265	795	7.8	690	1256
25	S-1	32 23.540	22 41.835	239	25.5	112	1001	230	10	223	0.1	480	355	1183.1	700	223	2151	7.1	2411	4384
26	AYN-BLAD	32 42.702	22 37.176	62	22.5	49	45.1	78	50	236	0.1	29	184	465	310	241	847	7.43	671	1223
28	W-4	32 42.334	22 40.513	250	27.1	70.4	63.8	147	70	236	0.1	38	369	588	438	241	1069	7.4	994	1808
3	Ayn Bu Mansure	32 41.952	22 36.626	108	21.2	48.8	44.3	92	13.9	200	0.1	34	214	582	304	205	969	8	647	1077
30	S-5432	32 40.854	22 48.382	217	25.5	72.2	65.5	230	13	223	0.1	135	461	828	450	228	1507	7.7	1200	2184
31	W-3	32 40.539	22 35.072		21.6	47.3	42.9	78	40	223	0.1	35	199	437	295	228	796	7.8	665	1212
0	Aldram Well					44.3	40.2	107	20.9	216	0.1	45	172	560	276	221	970	8.3	646	1118
5	Martuba /2 A.30	32 34.578	22 45.607	279	23	54.5	49.5	191	13.9	172	0.1	82	351	865	340	177	1660	8.1	914	1754
6	WS.206	32 45.822	22 33.619	267	22.5	50.7	46	92	13.9	251	0.1	59	158.2	572	316	256	989	8.1	671	1160
7	Tunnel_S-1	32 40.111	22 36.668	103	22.4	46.2	41.9	115	7	241	0.1	53	156	577	288	246	941	8	660	1077
8	Ayn_Al_Muggar	32 37.377	22 31.232	274	21	57.7	52.4	244	13.9	113	0.1	89	476	1024.2	360	118	1840	8.2	1046	1879
29	Meteorology	32 24.080	22 34.847	26	26	192.5	174.7	920	44	347	0.1163	240	1986	3132.8	1200	352	5696	8.28	3765	
9	Az.c.w	32 13.635	22 35.334	190	26.7	93.7	85	260	7	200	0.1	304	413	1288	584	205	2260	8.3	1363	2391
	Max					192.50	1001.0	920.0	70.0	347.0	0.15	480.0	1986.0	3132.8	1200	352.0	5696.0	8.40	3765.00	4383.63
	Min					37.9	34.4	78	4	113	0.1	29	152	405.9	236	118	738	6.4	610.4	959.52
	Mean					69.86	102.50	204.35	19.57	220.57	0.10	112.17	393.49	906.07	440.26	225.35	1626.70	7.84	1116.55	1786.66
	Median					58.40	53.00	191.00	13.90	223	0.10	82.00	369	828.00	408	228.00	1507.00	7.90	994.30	1788.93
	SD					32.80	197.94	171.12	17.33	44.08	0.01	107.56	370.44	569.95	204.00	44.08	1047.64	0.46	702.29	763.53
	% CV					46.95	193.12	83.74	88.51	19.99	10.51	95.89	94.14	62.90	46.34	19.56	64.40	5.85	62.90	42.73
	n					23	23	23	23	23	23	23	23	23	23	23	23	23	23	22.00

The major cations and anions has been plotted in the Trilinear diagram (Fig. 6), which indicates that there is a progressive change towards the western end of the study area, this is possible due to the mixing of water when travelling within the aquifer it represents a water type “Sodium chloride water”.

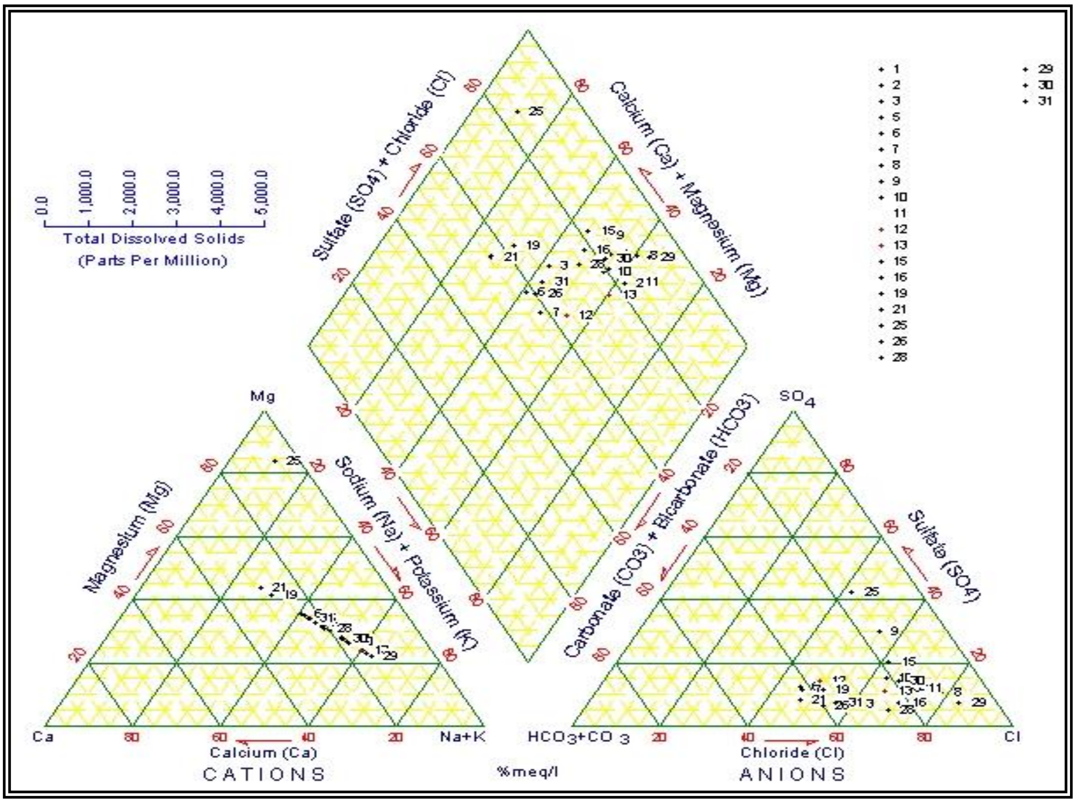

Fig. 6: Piper (Trilinear) Diagram presents the analysed water samples in the study area

Stiff diagram:

A second type of graphical presentation of chemical analyses is the Stiff pattern by (stiff, 1951) Data from the study area have been plotted in (Fig. 7) a polygonal shape is created from four parallel horizontal axes extending on either side of a vertical zero axes. Stiff Pattern is useful in making a rapid visual comparison between water from different sources. The larger the area of the polygonal shape, the greater the concentrations of various ions. The diagram has shown one type water which is NaCl except for three locations, two of them are (W.1-Ardam and W-2-2106) showed MgCl and one location showed SO_4-Cl. The reason for that is the ion exchange between Na and Mg as result of the dissolution of dolomite, the 3rd is SO_4 that is due to the dissolution of the gypsum.

The following is the type of water resulted from Stiff Pattern, reference (location Map Fig3. and Table 2)

- **Water samples of Sodium Chloride type are :-**

  W5, S5432, Khlij-3, W8206, H48, W432/2, Izz.cw, Fatayeh, Ayn Mugger, Martubah 2/A30, Martubah Spring, Ayn Bu Mansour, and W4.

- **Water Samples of Sodium Bicarbonate type are** :-

  W3, ws206, Tunnel S1, W7206, W1 Ardam, W2-2106, and Ayn Blad

- **Water Samples of Magnesium Sulfate** :-

  Only one sample is S1, in the area of Rammah north of Al Ezziat. Since all data of water samples in (Table 2) were represented and interpreted through three Stiff Diagrams. The result is showing in (Fig. 7).

Dissolution – precipitation:

The computer program called MINTEQA2 was used to calculate the thermodynamic properties of the ionic components of the water samples. The program calculate the saturation indices (SI) of all possible minerals by listing the percentage distribution of components among dissolved and absorbed species.

The recorded data in Table 2 show the saturation indices of water as calculated by MINTEQA2 program (Brown and Allison, 1987), for the selected minerals (Anhydrite, Aragonite, Calcite, dolomite and Gypsum). Further the concentration of carbonate was very low, and ranged from 0.1 to 0.15 mg/l. The concentration of bicarbonate was high, it ranges from 113 to 347 mg/l. It is clear that the main process in water quality is the mixing of water with in the aquifer and dissolution of carbonate minerals as the water moves in Karstified limestone.

Geochemical aspects

The groundwater chemistry as shown in Table 2, has been examined from both the total salinity and the ionic composition of dissolved solids Point of view. Naturally, the attention was focused on the main Eocene aquifer. The total salinity in the main aquifer in the western part of the study area shows a quite regular increasing trend from west to east and from north to south as shown in water quality map (Fig. 8) and (Table 2), in terms of electric conductivity. This increasing trend is particularly evident in the northwestern zone, where the control points are dense. Salinity ranges here from about 500 mg/1 to 2000 mg/1. The salinity values along the sea coast, in view of the extreme variability due to local conditions, should be disregarded when examining the regional picture, extreme result which has been discarded was such our sample from the Meteorological Station near the coast at the eastern side of Darnah city, where the ground water exploited mainly from the shallow quaternary aquifer, and the well was drilled to 80m, and water was discharged from 20m below sea level, water in this level is already considered saline.

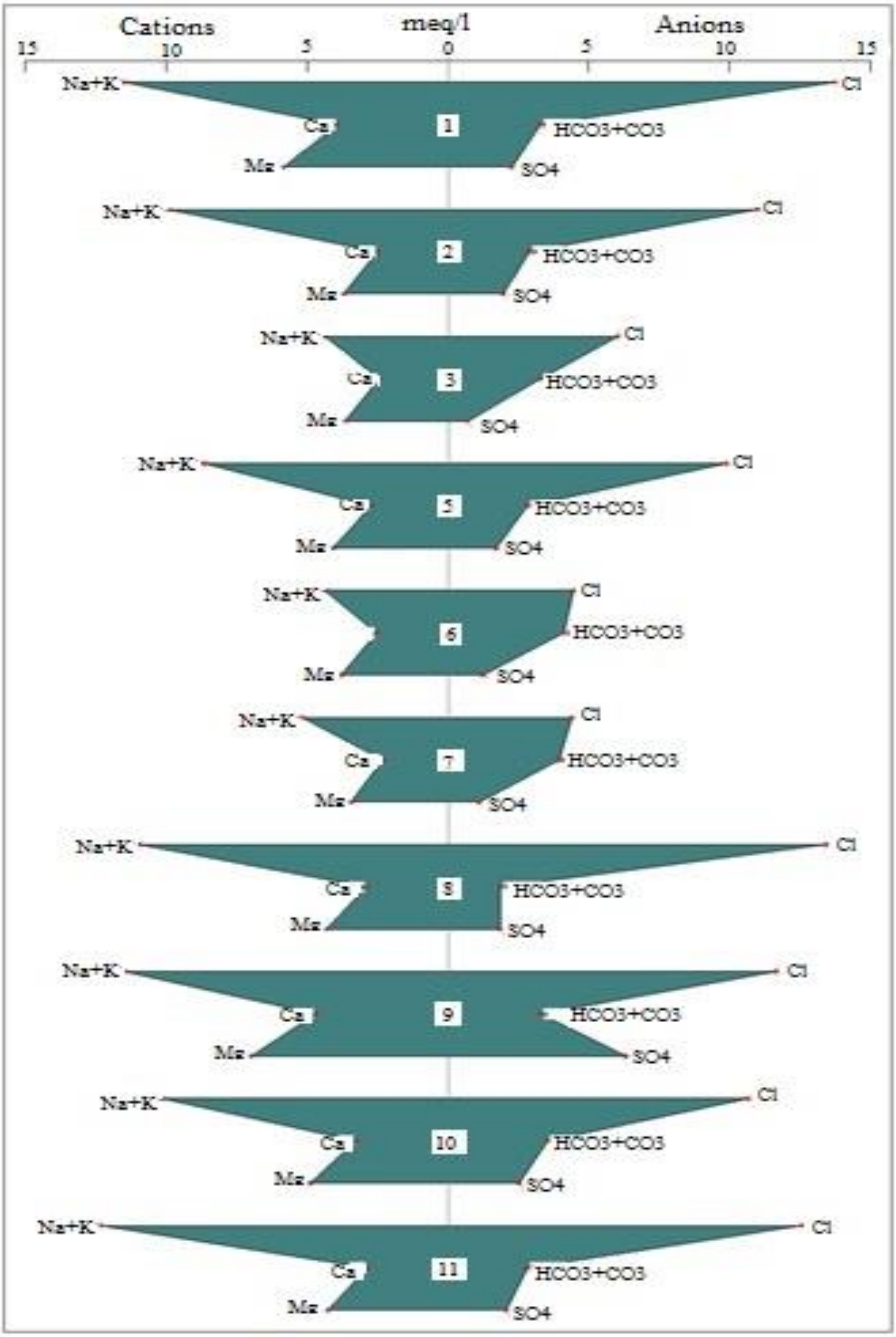

Fig. 7: Stiff diagram (For samples no. see Table 2)

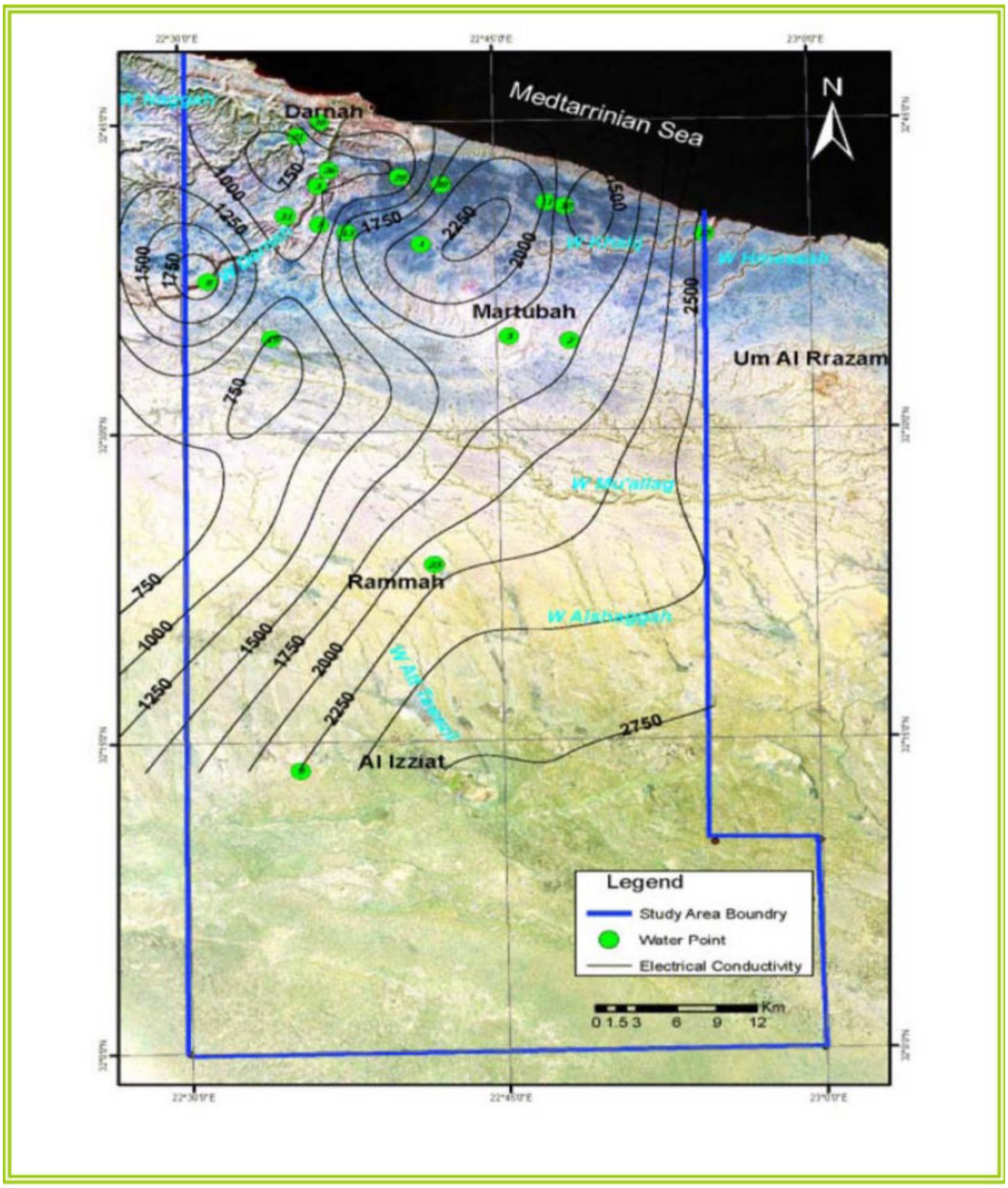

Fig. 8: Variation in Electrical Conductivity map, Darnah Region (Salem and Salloum, 2006)

To the south of the study area, as it can be deduced from the very few information available, groundwater salinity for a considerable distance is averaging around 1500 mg/l. Only further south, near Al Ezziat Village, there is a rapid increase in total salinity in the directions of both, south and eastward of the study area (Fig. 8). Due to lack of water points available in the area, only one sample was collected from the Camp well of Al Ezziat, It is however, believed that this single value is not sufficient, and may be considered not representative to the huge area (south of the study area). From our results, In the eastern and southern parts of the study area, salinity in the main aquifer is generally high, and no regular trend of salinity variations can be recognized, however previous data, Franlab (1974) and Italconsult (1978), gave indications of very high salinity values, over 4000mg/l of ground water salinity was observed in wells from Al Kharuba to Al Tamimi in the east. with the exception of the spring water samples in the Wadi Darnah area, and Al Hishah (South west of Darnah), have the lowest salinity, water sample were mostly taken from drilled wells which penetrate for a considerable thickness of the Eocene aquifer. With the present information available, the matter of salinity variation with depth, the relationship is generally straight in the area east and south of the study area. Salinity increase is essentially due to the increase of chloride content, as shown in (Table 2), while sulphate salinity is only occasionally of relevant amount, the values from the samples of Al Rammah and Al Ezziat are examples.

low salinity values is encountered along the Escarpment, in the area west of Darnah ,while values from Al Fatayeh - Martubah line, of low salinities cannot be regarded as representative, since they refer to thin fresh water bodies floating on the underlying saline water in the Eocene Aquifer. The accumulation of fresh water can be considered due to local recharge from floods and/or rain water, through the locally Karstified, Al Faidiyah and Al Abraq Formations. The composition of the dissolved solids is quite variable. In view of the very variable total salinity, the matter of ionic composition has been examined with the aid of milliequivalents percentages of the seven main ions (Ca, Mg, Na, K, $HC0_3$, $S0_4$, and Cl)

Utilization Aspect

The results of water analyses were examined also from the utilization point of view. As far as potable use is concerned, the waters below the total salinity of 1500 mg/l, which is considered by W.H.O (1984). The maximum permissible salinity, are suitable for this purpose. The groundwater in the south even with this total salinity value occasionally show a sulphate content in excess, of the maximum permissible limit of 400 mg/l. This may cause problems, in particular if the relatively high Mg content is also considered. $N0_3$ is usually present in groundwater. However, the amount rarely exceeds the 45 mg/l limit, considered by W.H.O. as a concentration potentially hazardous for infants. The high salinity waters encountered in the eastern part of the study area are interpreted as waters having a very long residence time in subsurface formations. This supposed long residence time is in accordance with the fairly flat piezometry and the probably poor recharge, due to relatively low rainfall surplus.

<u>Considerations on Recharge</u>

Several methods have been used to calculate the recharge in order to evaluate water balance, accordingly; evapotranspiration was calculated using Oliver, Blaney-Kriddle, Turc, Penman, Hassan and Thornthwaite in comparison with piche method. Since all these methods have advantages and disadvantages. However, Penmann (1948) found that his method is the most accurate and suitable for water balance calculations, which takes in consideration all climatic variability affecting rainfall. (Bukcheim, 1986). Had used penman's method, and found that the losses increase between March and November, this stimulate the soil to replenish and compensate moisture. Accordingly, the groundwater will be recharged by the rainfall during December which was found to be about 2% of the total annual rainfall in winter season, its maximum value reach in January about 8.9%.

Considering and comparing other locations of Libya with similar rainfall conditions, such as, Benghazi Plain, Al Jifarah Plain. Rainfall surplus values have been estimated for 18 stations for a number of years and these values were plotted against the respective values of annual rainfall (Fig.9), the scattered points on the graph indicate that the relationship between the two factors is quite irregular but there appears to be a general trend of rainfall surplus increasing with increase in the amount total rainfall. An annual rainfall of less than 175mm is likely to produce nil or very little surplus (Raju, 1980). So similar condition might exist in the Darnah region. However, trials been performed using another tool as the Isotope techniques for recharge analysis through water age dating. (Italconsult, 1978), had performed a sampling campaign of groundwater during 1977 for Tritium (^{3}H), Deuterium (^{2}H) and Oxygen (^{18}O). Eleven most representative groundwater samples were collected from Perched and the main aquifer at Darnah area. It can be concluded that Tritium was found in samples in Wadi Darnah, indicating recent water in the main aquifer, flood occurrence of Wadi Darnah was quite frequent, more recent water tend to accumulate in the upper part of the aquifer. The areas east of Wadi Darnah and Wadi Al Muallag show no Tritium content, indicating no contribution from rain water or local flood to the aquifer. The Tritium content from flood water can be expected only in quite narrow strip along Wadi Darnah. The results show that the Tritium concentrations varied from 0.2 to 6 TU. From the higher ^{3}H values, it has been estimated that the proportion of modern water since 1963 could represent about 5 to 10% of the sampled water, the basis of this assumption has been the tritium concentration of 100 TU for the cumulative rainwater sample for the period 1963 to1977. ^{3}H content below 1 TU in groundwater was considered as an indication of negligible content of modern water content. As the annual rainfall in the region varied from 79 to 277 mm, 5 to 10% recharge yields 4 to 27.7 mm to be the average value of groundwater recharge in Wadi Darnah.

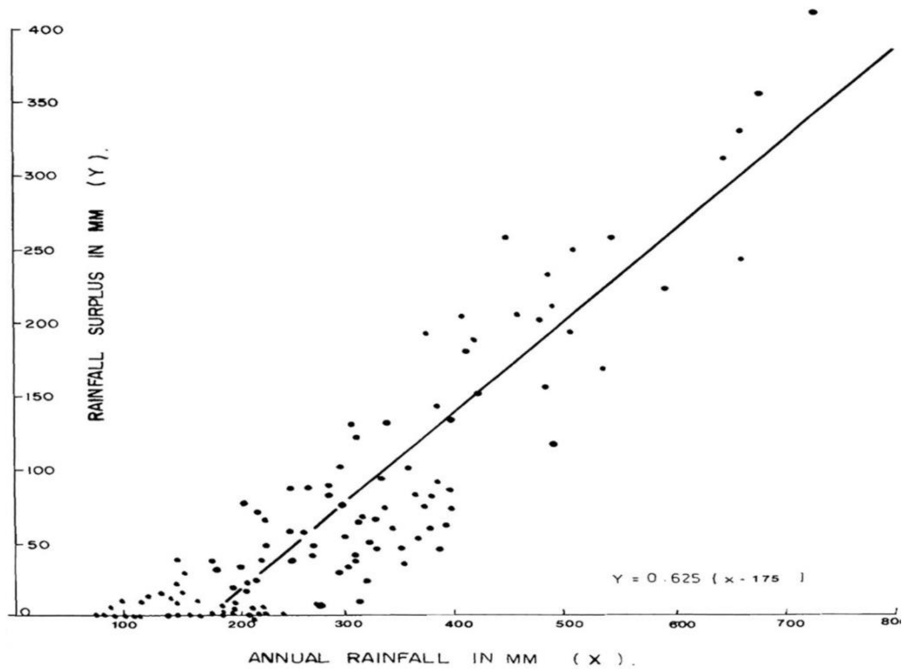

Fig. 9: Relationship of annual rainfall and rainfall surplus (Raju, 1980)

Bahadur et al., (1980) have summarized recharge evaluations which were recorded in NE Libya as a reference (Table 3) .The results indicated that changes in hydrogeological situations, variability in precipitation and scanty knowledge about soil moisture in the unsaturated zone make it difficult to evaluate recharge to the groundwater. However, there have been some empirical approaches to estimate the recharge from climatic parameters in the region tabulated below.

Table 3: Average annual groundwater recharge in north Cyrenaica (Bahadur et al., 1980)

Source	Studied area	Recharge (mm/year)
GEFLI(1972)	Eastern region	19.9 – 49
Jaroslav Cerni (1973-74)	Goat Al Sultan	40 - 122
Franlab (1976)	Southern Al Jabal Al Akhdar	3.7 - 10.6
Italconsult (1977)	Bombah- Tobruk	4.0 – 27.7
Pallas (1978)	Eastern region	1 – 93
NCB (1979)	Benghazi region	38.6
Hydrogeo 1985	Al Baydah – Bayiadah	Un-measurable

However, the Hydrogeo (1992) have found that age value indicates the occurrence of modern water in the upper part of the main Eocene aquifer and that the whole groundwater system is active and recharged under the present climatic condition. An evaluation of the recharge is however, not possible with the isotopic data available, and above all because of the complex nature and the hydrogeological characteristics of the aquifer.

Conclusion:

Darnah region is characterized by moderate climatic conditions dominant year-around. Where the weather conditions are quite stable from year to year as the changes from one year to other is quite small. The region's climate has been classified as Semi-arid. As the area is located on the Mediterranean Sea from north and northeast on one side and high topography on the other, while it is open to the semi-desert topography from its southern direction.

Groundwater is confined to the limestone formations of the Eocene, Oligocene and Miocene ages, and aquifers are located underground Darnah main formation and Apollonia, including the flow of water through the springs of the Valley and the wadi Darnah and Al Athrun (Ayn Dabbusiah).

The groundwater level is shallow in Mechili area, water flowing towards south - south-east, the water quality is fair (medium quality), ranging from 1700 to 2500 Micro- mhos / cm .near the wellfields of Ezziat,

Buhindi and Al Thuban.

The rest of Southern Jabal Akhdar area, groundwater level ranges in depth water flowing towards the south and south-east, the quality ranging from 1000 to 7000 Micro-mhos / cm the shallow reservoirs represent Quaternary formations which is composed of beach rocks and sediments of streams and wadis deltas .Wadi Darnah is considered to be the most important shallow reservoirs, which were until recently the main source of permanent water in the region.

Groundwater flow is quite difficult since these areas are characterized by very uniform water levels near to sea level elevation, which result from the generally very scattered control points

The difference concentration of ions of water can be explained by mixing effect and mainly by the dissolution of the karst limestone as the groundwater moves within the aquifer. Water is classified as very hard

The main hydro-chemical processes in the study area is dissolution of Karst limestone, which involves ion exchange and dissolution of carbonate minerals especially gypsum and dolomite. Water quality (calcium bicarbonate to mixed bicarbonate chlorine) high rang exist from north-western region, to the north and in the east Martubah to Al Bombah, it get more saline towards the south. The water samples collected for hydro chemical analysis were sufficient for a detailed evaluation, and was reasonable, and geographically distributed within the study area. The newly performed analyses show a reasonable agreement with the previous data whenever cross-checking was possible, the water quality trend is matching closely to the groundwater flow direction.

Several methods have been used to calculate the recharge, almost all methods have advantages and disadvantages, however, from experience, Penman method is the most accurate and suitable for water balance calculations, which takes in consideration all climatic variability affecting rainfall, there still more efforts should be implemented to evaluate the water resources in the area with respect to the rapid growth of population and the capability of the resources. No long monitoring records in any groundwater and hydrological studies been performed, this leads to question reliability of data use in some aspects which deals with water resources management and Planning.

Acknowledgment

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تقييم الهيدروجيولوجيا والهيدروكيمياء في طبقات المياه الجوفية لعصر الايوسين في منطقة درنة

فتحي محمد سلوم*

الملخص

الهدف من هذه الورقة هو تقييم الهيدروجيولوجيا والهيدروكيمياء في خزان المياه الجوفية الرئيسي في منطقة درنة ، بتكوينات الايوسين (ابولونيا ودرنة) وهذه التكوينات تتكشف اساسا في وسط الشمال الغربي ، وتتكون من الحجر الجيري و الحجر الجيري الاحفورية . الوحدات الصخرية للخزان المعلق المعروف بخزان البيضاء و الابرق (تكوينات الاوليجوسين و المايوسين) ، التي تطفوا فوق خزانات المياه الجوفية الرئيسية تساهم جزئيا في توفير الموارد المائية بشرق المنطقة بمرتوبة ويغطي طبقات النيوجين (تكوين الفايدية) غالبية الجزء الجنوبي من منطقة الدراسة .

هناك عدد كبير من التحاليل الكيميائية من الدراسات الاستشارية السابق في منطقة درنة تم استعراضها و تحليلها .

بالإضافة فقد تم جمع مزيد من العينات من مناطق مختلفة خلال فترة الدراسة الحقية بشهر يونيو 2006 ، بعض هذه العينات تم تجميعها من الابار التي يتم ضخها او من بعض العيون التي تتدفق طبيعيا و خاصة بوسط وادي درنة ، تم دراسة هذه التحاليل الكيميائية ومضاهاتها ، حيث تبين اتفاق نتائج هذه العينات مع نتائج بيانات سابقة . درجة ملوحة المياه الجوفية بالخزان الرئيسي في الجزء الغربي من منطقة الدراسة اظهرت زيادة طبيعية في الاتجاه من الغرب الى الشرق ومن الشمال الى الجنوب ، كما تم مضاهاة نوعية المياه مع اتجاهات سريان المياه الجوفية . وقد اجريت العديد من التجارب لتقدير تغذية طبقات المياه الجوفية في المنطقة . تم البحث احصائيا بمناخ منطقة الدراسة من اجل فهم التعرف على المناخ و البيئة وكذلك تصنيف نطاق الطقس العلاقة الارتباط مع تقدير خصائص طبقات المياه الجوفية هناك محاولات و استعمال طرق مختلفة لتقدير مدى استجابة الخزانات للتغذية و اعادة الشحن و التوازن المائي ، هذه المعايير مهمة لإدارة موارد المياه على المدى الطويل لمنطقة درنة ، تمت مناقشة الموارد المائية ، وتقييم تصريف مياه العيون او الينابيع خلال العقود الماضية في المجرى العلوي لوادي درنة .

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Plasma Electromagnetic Diagnostics On Tokamak Systems

(Part I)

A.S. Alhasi & .A. Mohamed*

Abstract

In this work, we try to bridge the gaps between electromagnetic theory and the experimental work. In this study, the magnetic field ($\vec{B}$), the plasma current (I), the Ohmic power (P) and finally the plasma electron temperature (T_e) are covered. To simplify the approach, we adhere to plasmas, with circular cross-section. Thus we use the geometry of the torus, where (φ) is in the toroidal direction and (θ) is in the poloidal direction.

INTRODUCTION

Great deal of research has been carried out in plasma physics during the past few decades. Comparable to any other subdiscipline of physics, the field of plasma includes a very substantial body of knowledge covering a wide variety of branches, ranging from the most theoretical to the most practical. In plasma, major quantities confrontation between theory and experiment is possible. This confrontation places strong demands upon theory to do calculations in realistic configuration. But it also requires that the properties of plasmas be measured experimentally as accurately as possible. For this reason much of the effort in experimental plasma physics is devoted to devising,

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developing and proving techniques for diagnosing the properties of plasma-well known as plasma diagnostics [2,6].

The prospect of generating economically significant amounts of power from controlled thermonuclear fusion is the driving major force behind the research on plasma. The overall objective of plasma diagnostic is to deduce information about the state of the plasma from practical observation of physical processes and their effects. The high temperatures sought for fusion frequently eliminate the possibility of internal diagnosing by material probes [5,7].

The aim of this work is to smooth the way for researchers and engineers in this field by casting the theoretical physical laws into a simple quantitive mathematical formulas. To this end the coordinate system is that of toroidal geometry, which is suitable to most promising fusion reactors mainly tokomaks. A simple torus shown in figure (1) depicts the toroidal geometry of a tokomak reactor. Here, the toroidal axis (vertical by convention) is encircled by the magnetic axes. It is a single toroidal field line that generally locates the peak of the plasma current and plasma density profiles. The magnetic axis also identified with the toroidal direction parameter (φ). Similarly closed poloidal curves encircling the magnetic axis, indicate the local poloidal direction (θ). To carry the measurement two coils (loops) are used [12,7].

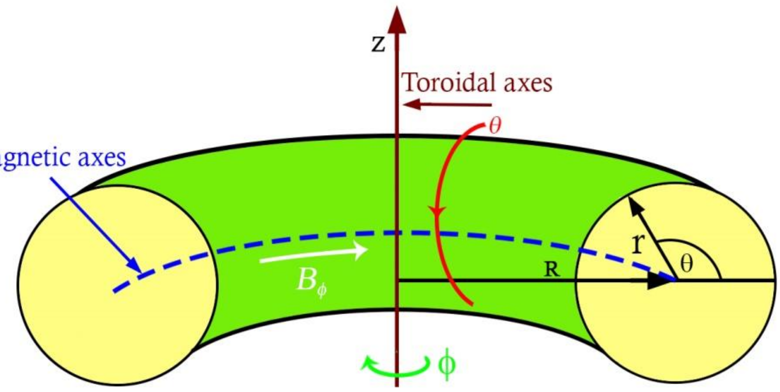

Figure (1): Primitive toroidal coordinates

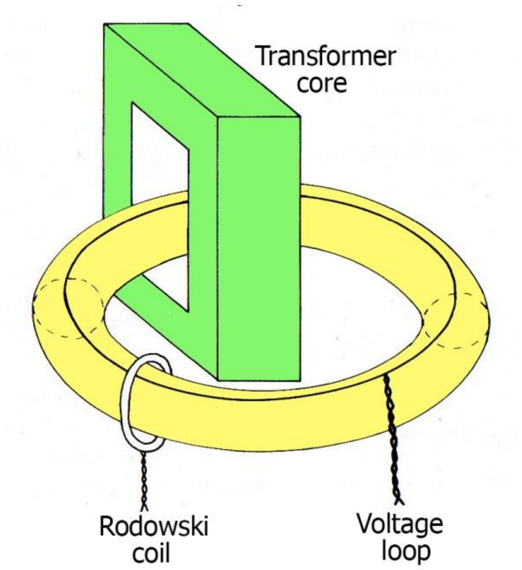

Figure (2): Rogowski coil loop that encircle the magnetic axis. A loop voltage that encircles the toroidal axis as shown in figure (1).

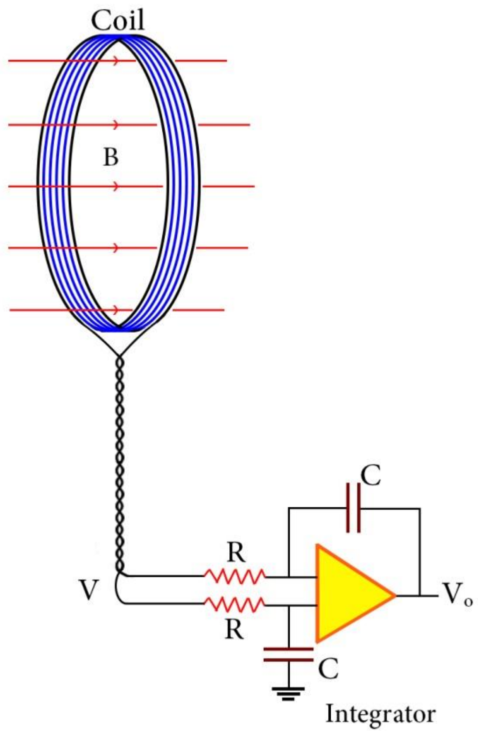

Figure 3: Typical magnetic coil and integrated circuit.

THEORY AND DERIVATIONS

1-Magnetic field Measurement:

We start from the differential form of Maxwell's equation (Faraday's law)

$$\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t} \tag{1}$$

Integrating both sides of equation (1) over the surface(S) with the differential area vector $d\vec{a} = \hat{n} da$ where $\hat{n}$ is the unit vector normal to the surface (S), we get

$$\int_{s} (\vec{\nabla} \times \vec{E}) \cdot d\vec{a} = -\int_{s} \frac{\partial \vec{B}}{\partial t} \cdot d\vec{a} \tag{2}$$

Using Stokes theorem we change the surface integral on the left side of equation (2) to a line integral to obtain ([1,8]):

$$\int_{line} \vec{E} \cdot d\vec{l} = -\int_{s} \frac{\partial \vec{B}}{\partial t} \cdot d\vec{a} \tag{3}$$

Here, $d\vec{l}$ is a segment of length vector along the perimeter of the surface area.

The simplest way to measure the magnetic field in the vicinity of a point in space is to use the so called magnetic coil as shown in figure (2). We assume the magnetic field in the pinch as uniform with cylindrical cross-section. A coil with cross-sectional area (A) and (N) number of turns with an integrator and/or oscilloscope (with some non trivial impedance) senses the voltage cross the coil ends. If the coil is good conductor or if the impedance of the electronics is large (∞) the electric field $(\vec{E}_{in})$ inside the coil itself is zero and the left side of equation (3) can be written as:

$$\int_{coil} \vec{E}_{in} \cdot d\vec{l} + \int_{end} \vec{E} \cdot d\vec{l} = -\int \frac{\partial \vec{B}}{\partial t} \cdot d\vec{a} \tag{4}$$

Since the electric field inside the coil is zero, thus equation (4) reduces to:

$$\int_{end} \vec{E} \cdot d\vec{l} = -\int \frac{\partial \vec{B}}{\partial t} \cdot d\vec{a} \tag{5}$$

The magnetic flux (ϕm) is related to the magnetic field ($B\varphi$) in the φ-direction and the electric field ($E\theta$) in the θ – direction is related to the emf ($V\theta$) cross the coil ends respectively [3,10]:

$$\phi_m = \int_s \vec{B}_\varphi da \tag{6}$$

$$V_\theta = \int_{end} \vec{E}_\theta dl \tag{7}$$

If the magnetic field is uniform in space and varying in time, we can relate the emf (Vθ) to the magnetic field flux (ϕm) in the z-direction. Thus:

$$V_\theta = -\frac{d\phi_m}{dt} \tag{8}$$

Using equations (5), (6), (7) and (8) we get:

$$V_\theta = -\frac{d}{dt}\left(\int_s B_\varphi \, da\right) = -\frac{\partial B_\varphi}{\partial t}\int_s \, da \tag{9}$$

If we have a loop with an area A and N number of turns, equation (9) reduces to:

$$\mathrm{V_0} = |\mathrm{V_\theta}| = \left|-\frac{\mathrm{NAdB_\varphi}}{\mathrm{dt}}\right| \tag{10}$$

Using an analog integrating circuit with resistance(R) and capacitance (C) , we obtain the time constant τ = R C. Therefore, equation (10) becomes:

$$\mathrm{V_0} = \frac{\mathrm{NAB_\varphi}}{\tau} = \frac{\mathrm{NAB_\varphi}}{\mathrm{RC}} \tag{11}$$

Since the quantity (RC/NA) is known and V0 is measured:

$$B_{\varphi} = \left(\frac{RC}{NA}\right) V_0 \qquad (12)$$

The above calculation gives the component of $\vec{B}$ normal to the plane of the coil. If $d\overline{B}/dt$ is non-uniform then it is the mean value over the surface that we measure. The surface integral strictly spans the space between the leads to the coil as well. The leads are usually twisted to make this contribution negligible, [8,4].

The most general case is when we allow a current to flow in the measuring coil. This will change the magnetic field Bφ in its vicinity and thereby changes the measured voltage by induction. The magnetic coil with total resistance Rc is connected to an integrated circuit whose resistance is Re. If the inductance (L) of the coil, the resistance of the measurement electronics Re and the resistance of the coil Rc are included in equation (10) we will have the general form as:

$$\frac{L}{R_e}\frac{dV_{\theta}}{dt} + \left(1 + \frac{R_c}{R_e}\right) V_{\theta} = NA\frac{dB_{\varphi}}{dt} \qquad (13)$$

Here, L is defined as the self- inductance of magnetic coil.

2- Current measurement in the cross-sectional area of the torus:

The so called Rogowski coil is used to measure the total plasma current (I) flowing through the cross-section. This solenoid coil with ends brought around together to form a torus is illustrated in figure (4). If this coil has uniform cross-sectional area (*A*) with constant turns (*n*) per unit length (provided the magnetic field varies little over one turn spacing that is if $\vec{\nabla} B/B << n$) implies that $1/l << n$, where l is the length of the torus. Thus, we can work out the flux linkage per turn as [7,6]:

$$\Phi_i = \int_s B_\varphi \, da \tag{14}$$

where i =1, 2…We can sum this over all turns to get the total flux linkage as

$$\phi = n \int_s da \int_l B_\varphi \, dl \tag{15}$$

The last integral in equation (15) is just Ampere's law

$$\int_l B_\varphi dl = \mu_0 I \tag{16}$$

where I is the total current enclosed by the loop (l) as shown in figure (4). The area of cross-section of the coil is $A = \int_s da$, thus the total flux linkage is

$$\phi = nA\mu I \tag{17}$$

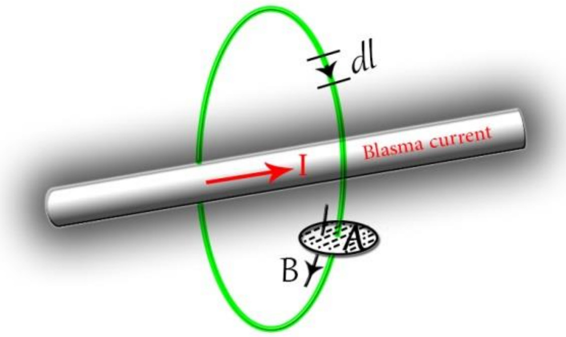

Figure 4: Equivalent geometry of the integral form of flux through a Rodowski coil.

Here n is number of turns of the coil and μ is the magnetic permeability of the medium in the solenoid. Hence the voltage out of the loop may be measured as

$$V = -\frac{d\phi}{dt} = nA\mu\frac{dI}{dt} \tag{18}$$

Which is usually integrated electronically to give a signal proportional to I. This provides a direct measurement of the total current through the centre of the plasma cross-section.

3- Ohmic Power and Conductivity Measurement:

Assuming that the plasma current to be constant during the time of plasma confinement inside the fusion experiment reactor (tokomak), the plasma resistance (R_P) is defined as [12, 8]:

$$R_p = \frac{V_\varphi}{I_\varphi} \tag{19}$$

where V_φ and I_φ are the loop voltage, and the plasma current along the toroidal φ-axis of the reactor torus respectively. The plasma resistance is important because it determines the Ohmic heating input to the plasma and also because it may be used to estimate the electron temperature. However, before moving on to these matters we must consider the more general situation in which the currents are not constant and the inductance makes a significant contribution [9].

Starting from the Poynting vector as applied to a volume bounded by a surface (S) outside the plasma on which the measuring voltage loop lies, see figure (1), we can write:

$$-\int_{s}\frac{\vec{E}\times\vec{B}}{\mu_0}\cdot\hat{n}da=\int_{v}(\vec{E}\cdot\vec{J})dv+\frac{1}{2}\int_{v}\left(\frac{1}{\mu_0}\frac{\partial B^2}{\partial t}+\varepsilon_o\frac{\partial E^2}{\partial t}\right)dv \qquad (20)$$

Here $\vec{J}$ and $\hat{n}da$ are the current density vector and the outward pointing surface element bounding the volume element dv respectively [6].

The first term on the right hand side is the total Ohmic heat dissipated within the volume. The second term is the rate of change of the stored electromagnetic energy within the plasma.

However, the left hand side is known as the Poynting flux or the rate of input of electromagnetic energy from the external circuits. The factor $\frac{1}{2}\varepsilon_0$is proportional to $\frac{1}{2\mu_0}\mu_0\varepsilon_0=\frac{1}{2\mu_0}\frac{1}{c^2}<<1$. Therefore, according to [12,6] the energy density of the electric field can be dropped from the second term of equation (20). In geometrical description of the torus cross-section, equation (20) can be written as:

$$-\int_{s}\left(\vec{E}\times\frac{\vec{B}}{\mu_0}\right)\cdot d\vec{a}$$

$$=\int_{v}(\vec{E}\cdot\vec{J})dv+\frac{1}{2}\mu_0\int_{v}\left(\frac{\partial B_{\varphi}^{2}}{\partial t}+\frac{\partial B_{\theta}^{2}}{\partial t}\right) \qquad (21)$$

The input in the left hand side can be written as:

$$-\int_{s}\left(\vec{E}\times\frac{\vec{B}}{\mu_0}\right)\cdot d\vec{a}=V_{\varphi}I_{\varphi}+V_{\theta}I_{\theta} \qquad (21)$$

where $(V_{\varphi},I_{\varphi})$ are the loop voltage and the current around the torus major axis respectively and (V_{θ},I_{θ}) are the loop voltage and the current around the torus minor axis of the torus respectively. Using equation (21) and equation (22) the Ohmic power (P) can be obtained:

$$P=\int_{v}(\vec{E}\cdot\vec{J})dv=V_{\varphi}I_{\varphi}+V_{\theta}I_{\theta}$$

$$-\frac{1}{2}\mu_0\int_{v}\left(\frac{\partial B_{\varphi}^{2}}{\partial t}+\frac{\partial B_{\theta}^{2}}{\partial t}\right)dv \qquad (23)$$

The last two integrals can be put in the following forms:

$$\frac{1}{2\mu_0}\int_{v}\left(\frac{\partial B_{\varphi}^{2}}{\partial t}\right)dv=\frac{1}{2}\frac{\partial\left(L_{\varphi}I_{\varphi}^{2}\right)}{\partial t} \qquad (24-a)$$

$$\frac{1}{2\mu_0}\int_v \left(\frac{\partial B_\theta^2}{\partial t}\right) dv = \frac{1}{2}\frac{\partial\left(L_\theta I_\theta^2\right)}{\partial t} \qquad (24-b)$$

These are the energy inductances in the (φ) and (θ) directions of the cross-section of the torus respectively. The inductances can be defined as:

$$L_\varphi = \frac{1}{\mu_0 I_\varphi^2}\int_v B_\varphi^2\, dv \qquad (25-a)$$

$$L_\theta = \frac{1}{\mu_0 I_\theta^2}\int_v B_\theta^2\, dv \qquad (25-b)$$

Substituting the above noted terms in equation (23) we obtain the Ohmic power (P):

$$P = V_\varphi I_\varphi + V_\theta I_\theta - \frac{1}{2}\frac{\partial\left(L_\varphi I_\varphi^2 + L_\theta I_\theta^2\right)}{\partial t} \qquad (23)$$

The first term on the right hand side represents the resistance contribution of the plasma if it is steady. The second term on the right hand side represents the inductance contribution of the plasma if it is time varying.

The plasma current (I_φ) can be found from the magnetic flux (ϕ_m) measurement:

$$V_\varphi = -\frac{d\phi_m}{dt} = NA\mu_0\frac{dI_\varphi}{dt} \qquad (27)$$

The voltage $\left(V_\varphi\right)$ can be measured as:

$$V_\varphi = NA_p\frac{dB_\varphi}{dt} = N\pi a^2\frac{dB_\varphi}{dt} \qquad (28)$$

where A_p is the area of the plasma cross section, which approximately equal πa^2 with (a) defined as the minor radius of the torus cross-section. The voltage V_φ can be measured by the linear loop voltage [3,5]. The current (I_φ) can be written as:

$$I_\varphi = 2\pi r \frac{B_\varphi}{\mu_0} = 2\pi a \frac{B_\varphi}{\mu_0} \quad (29)$$

The plasma radius is approximately equal to ($r \sim a$). Therefore if the plasma is steady the inductance contribution is irrelevant. Thus the Ohmic power can be estimated:

$$P = (V_\theta I_\theta + V_\varphi I_\varphi) + small\ inductive\ term \quad (30)$$

Substituting equations (28) and (29) into equation (20), we obtain

$$P = V_\varphi I_\varphi + \left(N\pi a^2 \frac{dB_\varphi}{dt}\right)\left(2\pi a \frac{B_\varphi}{\mu_0}\right)$$

$$= V_\varphi I_\varphi + \left(N\pi^2 a^3 \frac{1}{\mu_0}\right)\left(\frac{dB_\varphi^2}{dt}\right) \quad (31)$$

All terms on the right hand side of the above equation can be measured experimentally.

Using Ohm's law $\vec{E} = \vec{J}/\sigma$ on the left hand side of the above equation, the plasma conductivity can be estimated if the anisotropy of the conductivity (σ) is ignored, thus:

$$P = \int_v \vec{E} \cdot \vec{J} dv = \frac{1}{\sigma}\int_v \vec{J} \cdot \vec{J} dv = \frac{1}{\langle\sigma\rangle}\left(\frac{I_\varphi}{\pi a^2}\right)^2 (2\pi l)(\pi a^2)$$

$$= \frac{1}{\langle\sigma\rangle}\frac{2l}{a^2} I_\varphi^2 \quad (32)$$

where $\langle\sigma\rangle$ is the average conductivity, l and πa^2 are the length and the area of the torus section respectively. We use equations (31) and (32) to obtain:

$$\langle\sigma\rangle\frac{\pi a^2}{2\pi l}=\frac{I_\varphi^2}{P}=\frac{I_\varphi^2}{V_\varphi I_\varphi+\frac{N\pi^2a^3}{\mu_0}\frac{dB_\varphi^2}{dt}} \qquad (33)$$

If B_φ is steady, then we can estimate $\langle\sigma\rangle$ to be:

$$\langle\sigma\rangle\frac{2\pi l}{\pi a^2}=\frac{I_\varphi^2}{V_\varphi I_\varphi}=\frac{2l}{a^2}\frac{I_\varphi}{V_\varphi} \qquad (34)$$

4-ElectronTemperature Measurement:

We can make an estimate of the electron temperature if we use the so-called Spitzer conductivity for $\langle\sigma\rangle$ usually used for fully ionized plasmas [1,11] which is given by:

$$\langle\sigma\rangle=1.9\times10^4\frac{T_e^{3/2}}{Z_\sigma\ln\Lambda}\ \Omega^{-1}\mathrm{m}^{-1} \qquad (35)$$

Here T_e is the electron temperature in (eV), Z_σ is the resistance anomaly determined by the ion charge, and $\ln\Lambda$ is the Coulomb logarithm. Using equations (34) and (35) we get:

$$T_e^{3/2}=\frac{2l}{a^2}\frac{Z_\sigma\ln\Lambda}{1.9\times10^4}\left(\frac{I_\varphi}{V_\varphi}\right) \qquad (36)$$

where $Z_\sigma = Z = 1$ for hydrogen plasmas.

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الطرق الكهرومغناطيسية لتشخيص الحالة الرابعة من المادة (البلازما) في منظومة المفاعلات الاندماجية (توكماك)

ملخص

هذه الورقة هي محاولة لتقليص وتقريب المسافة بين ما توصّلت إليه النظريات الكهرومغناطيسية والتجارب المصاحبة لها في مجال الاندماج والمفاعلات الاندماجية. في هذا البحث، المجال المغناطيسي $(\vec{B})$، التيار الكهربي (I) البلازما، طاقة التسخين (T_e) المؤدية للاندماج، وأخيرا درجة حرارة الإلكترونات في هذا الوسط قد تم التعامل معها. ولتبسيط عملية الوصول لهذه النتائج اعتمدنا أن يمون مقطع البلازما دائريا مع الحفاظ على الشكل الهندسي للمفاعل بزواياه المحورية المعروفة (φ, θ).

Effect of Growth Retardant ALARR on Some Anatomical and Chemical Changes in local Cultivar of Chrysanthemum morifolium

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A Barras – Ali**

ABSTRACT

The growth retardant ALAR was applied at different concentrations to study its effects on some anatomical and chemical Changes in growing stem cuttings of local cultivar of Chrysanthemum morifolium in terms of leaf area, leaf thickness and chlorophyll content in additions to measuring the ability of stem cuttings to resist drought conditions. The results showed that treated leaves were normal in shape but, a reduction in the leaves area have been achieved associated with darker green colour (high amount of chlorophyll Content) with respect to the ALAR concentrations applied. Treated plants showed some resistance to dry conditions.

Key words: ALAR; Chrysanthemum; Chlorophyll content; Leaf diameter; Leaf thickness; Drought tolerance.

INTRODUCTION

Many researches clearly reported that growth retardants posses the ability to convert the shape of many plant species (Basra, 1994; Barras, 2002). Growth retardant ALAR was highly effective ones, especially in a wide rang of ornamental plants. It improved rooting of Carnation and Poinsettia cutting (Read & Hoysler, 1971),

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treated plants were less likely to wilt and recovered more quickly from stress

(EL- Meleigy et al., 1999), reduced plant height of pot chrysanthemum (EL-Sheibany. et al., 2007), growth and yield of nerium (Nerium oleander L) (Ananth & Kumar, 2012), dried flower and plant hight of calendula (Calendula officinalis L.) (Hashemabadi, 2012), reduced apical dominance to tendency of shoot to grow without breaking (EL-Keltawi, et al., 1996). ALAR treated leaves were thicker in texture with Euphoibia pulcherrima and Chrysanthemum (Crittendon, 1966). Its effect was studied in fruit and vegetable plants like, delicious cultivar of apples, mature beans leaves of Amo-1618 treated expanded 4.7% and were 20% thicker (Crittendon, 1966). A little works have been explained the actual mode of action chemicals. Basra, 1994 and Bsrras-Ali, 2002 reported that ALAR is attributed to the formation of 1-1 dimethyl hydrazine on vivo, this hydrazine strongly inhibited tryptamine oxidation in pea epicotyls homogenates. However, the aim of this study was performed to determine the effect of growth retardant ALAR on some anatomical and chemical changes in terms of leaf area, leaf thickness, chlorophyll content and drought tolerance in a local cultivar of Chrysanthemum morifolium.

EXPERIMENTAL

Stem cutting of local cultivar of Chrysanthemum morifolium

L. Asteraceae family supplied from a local arboretum in

Benghazi were planted in 12 cm pots in Al-Fateh center for gifted students. The growth retardant ALAR was prepared at four (Concentrations 0, 1250, 2500, and 5000 ppm). Method of ALAR application, and all other procedures applied described in

(EL-Sheibany et al., 2007). The size of the leaves

have been measured using a planimeter, to calculate the area of

the leaf blade, after that, measuring of leaf thickness was carried out in the fourth and eighth week from last ALAR treatment, this approach performed by using microtechnique procedures using a rotary microtome in wax embedding samples as described by

(Crittendon, 1996). For determination of chlorophyll content

in the leaves spectrophotometer was used according to the procedures described by (Crittendon, 1966). After When all

measurements finished (after 8th week), drought tolerance

measurement was applied, the samples were taken at four

stages of wilting, with the elapse of time between each stage.

Both treated and control plants were selected at the same time as they appeared to dry out (10 days without irrigation) at the same

rate. The plants were selected on a visual basis as follows:

Stage1) slight wilting all plants expected to recover after rewatering

Stage2) moderate wilting, most plants expected to recover.

Stage3) sever wilting, approximately half the plants expected to

recover. Stage4) very sever wilting, most plants not expected to recover. During the whole experiment the temperature and the humidity were under control. Statistical analysis has been done as described in (El-Sheibany et al., 2007).

RESULT AND DISCUSSION

The foliage of ALAR treated plants was consistently much darker green (high amount of chlorophyll content). The most colourfull leaves were achieved in the plants that received 5000 ppm of ALAR after eight weeks (Table 1). The reduction in leaf area was also

Table 1

Analysis	ALAR conc. (ppm)			
	0	**1250**	**2500**	**5000**
Leaf thickness (µ)	322 a	354 b	373 c	434 d
Palisade cells length (µ)	98 a	118 b	156 c	173 d
Number of upper epidermal cells per 400 micron	4.0 a	5.0 a	7.0 b	8.0 b
Total chlorophyll	3597 a	3620 a	3703 b	4067 c

Effect of applying retardant ALAR on chrysanthemum leaves dimensions, anatomical and chemical changes.

Means followed by the same letter, within rows, aren't significantly different at 0.05 level

of significance according to Duncan multiple rang tests

affected by concentration of ALAR. It has been notced that The area was inversely proportion to ALAR concentration applied (r = -0.95). However, these effects were time and concentration dependent manner (fig. 1). Barras- Ali, 2002 reporeted that the darker colour was directly related to the action of growth retardant and not to mineral nutrition. It has been noticed that the reduction of Leave area observed in treated plants caused some change in leaf structure. Photomicrograph of leaf cross section showed that ALAR treated leaves sample were significantly thicker than those of untreated ones. Moreover, it has been found that there were some

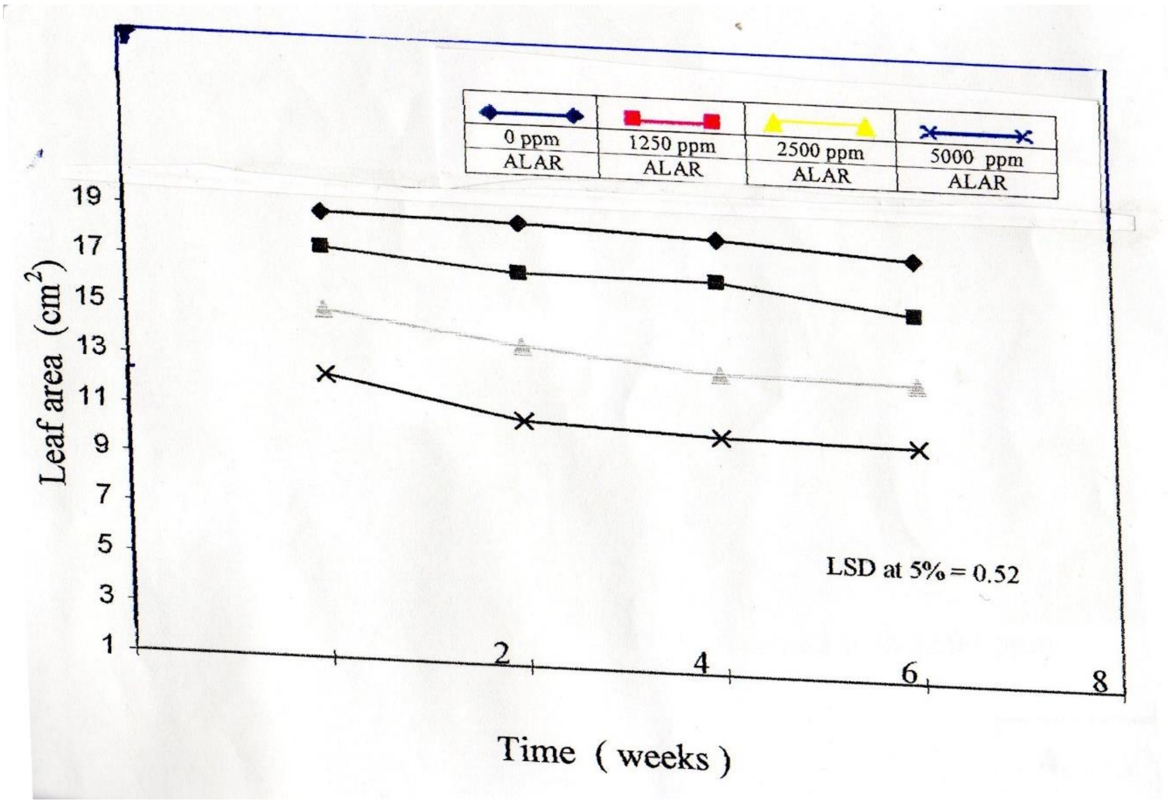

Fig. 1. Effect of retardant ALAR on leaf area.

differences in the number of upper epidermal palisade and lower epidermal cells per unit length of the leaf stem between all treated and untreated leaves (Table.1), which initiated a significant in leaf area between them. Again, these reductions caused by compression of palisade cell, which leads to increases of the number of cells per unit area (fig. 2), for that, the increase in colour was influenced by the increase of green cells per unit area. However, this result agree

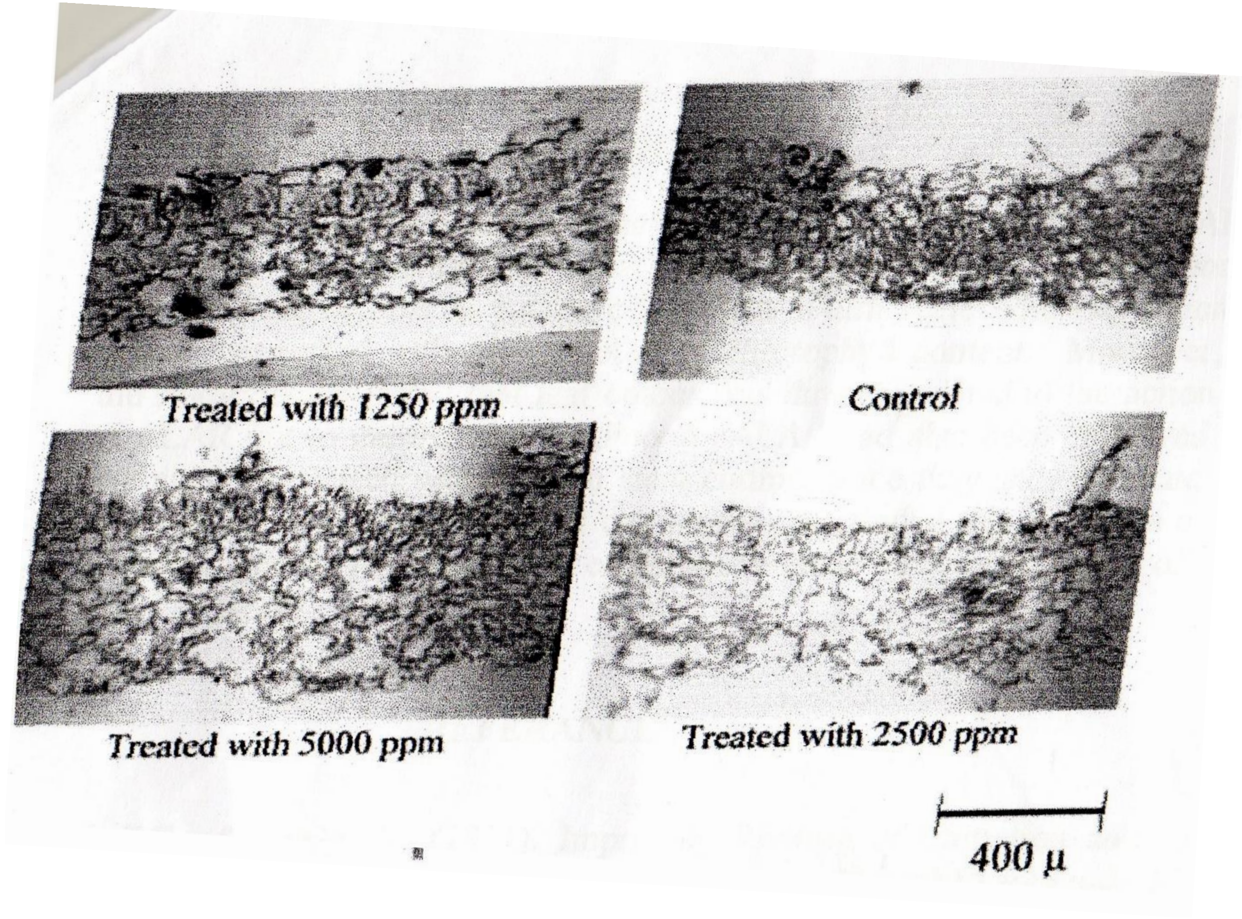

Fig. 2. Effect the retardant ALAR on the leaf section as seen in cross sections by using photomicrograph technique.

with (Hand, *et al*., 1996; Crittendon, 1966), also agree with (*Ananth et al*., 2012) how reported that Alar may act as growth retardant and thereby inhited biochemical processes resulting in less spreading of plants. It was noticed that all plants received high concentration of ALAR (5000 and 2500 ppm) have been recovered from wilting while two third of control plants died. Science all the plants received the same dose from mineral nutrition so; this reflectes the ability of ALAR treated plants to withstand drought condition. Barras-Ali, 2002 reported that aplity of ALAR treated plant to withstand drought condition may due to that ALAR treated plants have a more branched root system, providing firmer anchorage, bitter nutrient and moisture extracting capacity, also El Meleigy, *et al*., 1999 mentioned that, applying growth substance on stressed plant alleviate the adverse effect of drought stress by increasing carbohydrates content, amino acids and fatty acids. Conversely, (Martin & Lopushinsky, 1966) said that ALAR treatment didn't appear to have a consistent effect on the magnitude of deficit developed by plants subjected to drought or delay onset of wilting.

CONCULSSION

This study clearly showed that the effect of growth retardant ALAR appeared in reducing leaf area, increased stem leaf thickness, and increased the number of palsied cells which in turn achieved darker green colour correlated with high amount of chlorophyll content. Moreover, the study demonstrated that leaf colour was directly related to the action of ALAR not to the mineral conditions. ALAR had also been improved rooting system of chrysanthemum stem cutting, since they showed some resistance to dry conditions, so it can also be concluded that ALAR is a systematic growth retardant as its effect was noticed on a various parts of the plants.

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The Uses of Exposed Raw Materials in Construction: A Stratigraphical and Geochemical Outcome of Zallah Sheet

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Abstract

The Zallah Sheet (NH 33 – 16) area is studied by the Industrial Research Center, and it has a large industrial significance. Throughout the detailed study conducted on the chemical analysis of the sedimentary rocks, the main use of these rocks in construction and building materials includes all of the dimension blocks, natural aggregates, crushing aggregates, concretes, and paving road-stones. However, the manufacture of refractory bricks and Portland cement where the main components of available limestone and clay raw materials. A recalculation for the chemical analyses has been used to determine the limestone and clay percentages for manufacturing Portland cement. The raw materials mentioned above are existing in the following formations (from oldest to youngest); Rawaghah Member of the Bishimah Formation (Ypresian), Al Jir Formation (Lutetian), Thmed al Qusur Member of the Wadi Thamat Formation (Priabonian) and Qarat Jahannam Member of Maradah Formation (Aquitanian - Burdigalian).

Introduction

The study area comprises sedimentary rocks and the construction industry has the basic need for rocks and minerals and if society continues to ask for higher standards of housing, roads and infrastructure development, then the demands for constructional raw materials will continue to

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increase. The primary function of the raw materials in Zallah area is in construction and building stones. Demand for aggregates, concrete, road embankments, bridges and building are essential requirement and important.

Location of the Study Area

The study area located nearly in the central part of Libya between Latitudes 28° 0' N and 29° 00' N; Longitudes 16° 30' E 18° 00' E. with an area 16250 km^2 (Figure 1).

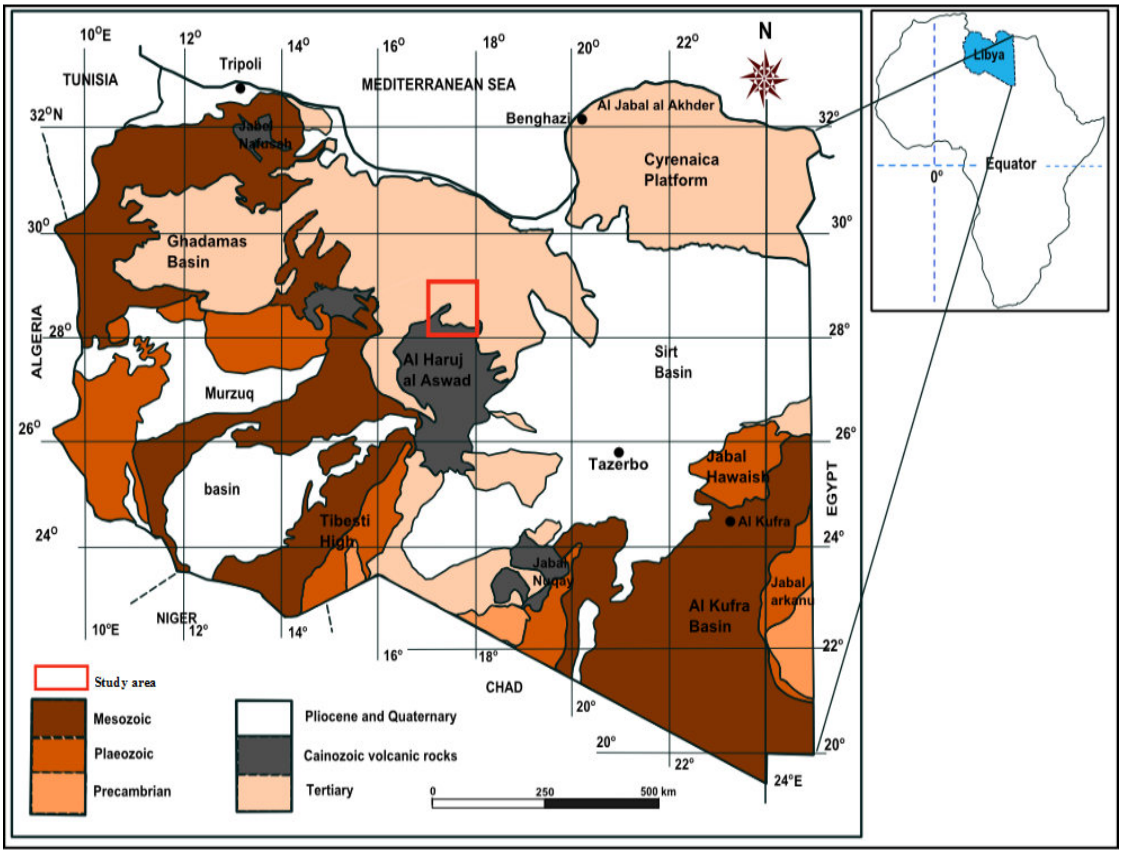

Figure (1) Map of Libya showing different sedimentary basins and the location map of the study area (i.e. Zallah sheet NH 33 – 16).

(Modified after Rusk, 2001 and Ramos, et al., 2006).

Stratigraphy of the Study Area (Zallah)

The reviewed Zallah exposed sections consists largely of four superposed formations from bottom to top: Rawaghah Member of Bishimah Formation (Ypresian), Al Jir Formation (Lutetian), Thmed al Qusur Member of Wadi Thamat Formation (Priabonian) and Qarat Jahannam Member of Maradah Formation (Aquitanian-Burdigalian). Lithostratigraphic chart of the sedimentary formations is shown in Figure 2, (Vesely, 1985).

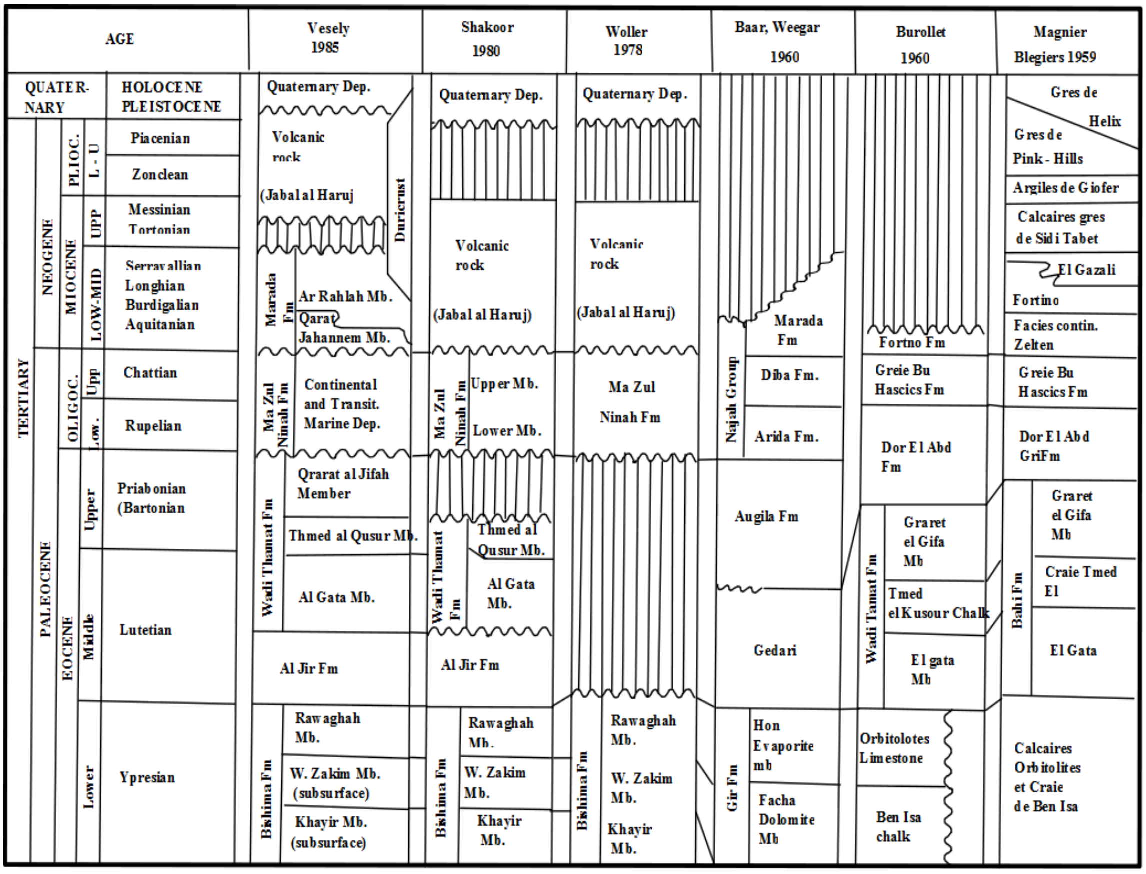

Figure (2) Nomenclature chart of the sedimentary formations in the study area (Vesely, 1985)

Wadi Thamat Formation

This formation introduced by Desio (1935) and lately subdivided into three members, the lower Al Gata, the middle Thamed al Qusur and the upper Qrarat El Geifa members by Vesely (1985). These members are separated from each other by conformable surface. The lower boundary is conformable with Al Jir Formation but unconformable with the overlying Oligocene Continental and transitional marine deposits as exposed at Dur Bu Zanad in Zallah area or Qarat Jahannam Member of Maradah Formation in places.

Al Gata Member

This member is cropped out in the northeastern part (Qarat Ar Raqubah), as well as in the southeastern part and large portion of the west half of the area, with a maximum thickness of 100 m. Lithologically, it consists of marlstone and claystone with thin gypsum intercalations. The marlstone which usually preserved in the lower part of the section is dolomitic in most cases (Figure 3).

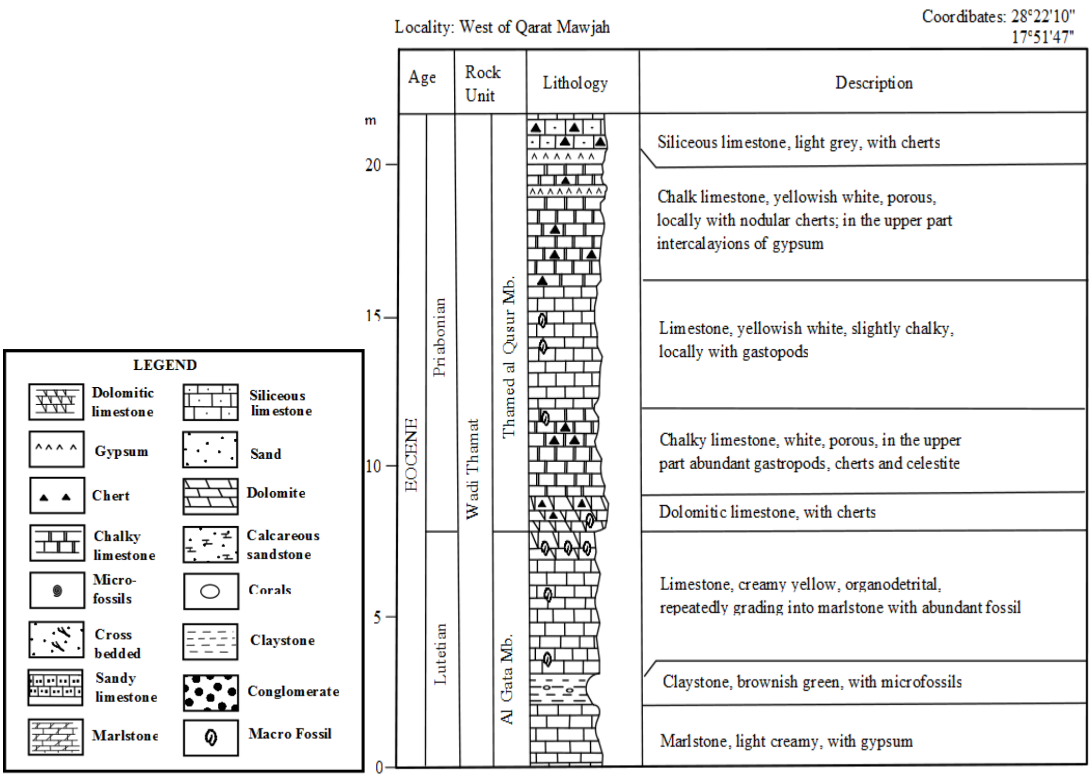

Figure (3) Columnar section of the Wadi Thamat Formation (after Vesely, 1985).

The claystone facies is greenish gray in color with the diagnostic microfossil namely *Dictyoconoides cooki*, which is indicating Lutetian age, whereas, the gypsum intercalation is usually wide and saccharoidal texture Vesely (1985).

Thamed al Qusur Member

It is exposed in the north-northwest and eastern part of the area with a total thickness reaches 40 m. Lithologically, it consists of limestone, chalky with chert nodules in part, and becoming dolomitic in the lowermost part (Figure 3). The bioclasts are predominated by Molluscks and green algae, with foraminifers, ostracodes and corals. The age of this member is Priabonian, as indicated by the presence of the coral *Plocophyllia bartai*, as well as and its stratigraphic position.

Qrarat El Jifah Member

It is exposed in the eastern and northern part of the map with intermitted small patches in the south, with a total thickness reaches 150m. Lithologically, it is dominated by carbonate sequence of limestone and dolomite in part glauconitic and sandy or argillaceous, locally cross bedded with benthonic foraminifera and ostracoda. The macrofossils are mainly of Mollusks and echinoids. However, few vertebrate remains are also present. Based on the stratigraphical position and the correlation with Wadi Bu ash Shaykh sheet this member is dated Late Miocene.

Bishimah Formation

The formation was introduced by Jordi and Lonfat (1963) as two units, Khtar Marl and Rouaga chalk. Vesely (1985) divided this formation into three members, Khayari, Wadi Zakim and Rowaghah members. Only Rowaghah Member is exposed in the western part of Zallah sheet Vesely (1985). The maximum thickness of this formation reaches 30 m. Lithologically, it consists of dolomite, dolomitic limestone with rare argillaceous limestone (Figure 4). This carbonate section locally interrupted with siliceous lenticular cherts. The bioclasts are mostly recrystallized or leached, making the identification impossible task. Hence, based on the stratigraphical position and the correlation with the neighbor Al Washkah sheet the Ypresian age is given to this member.

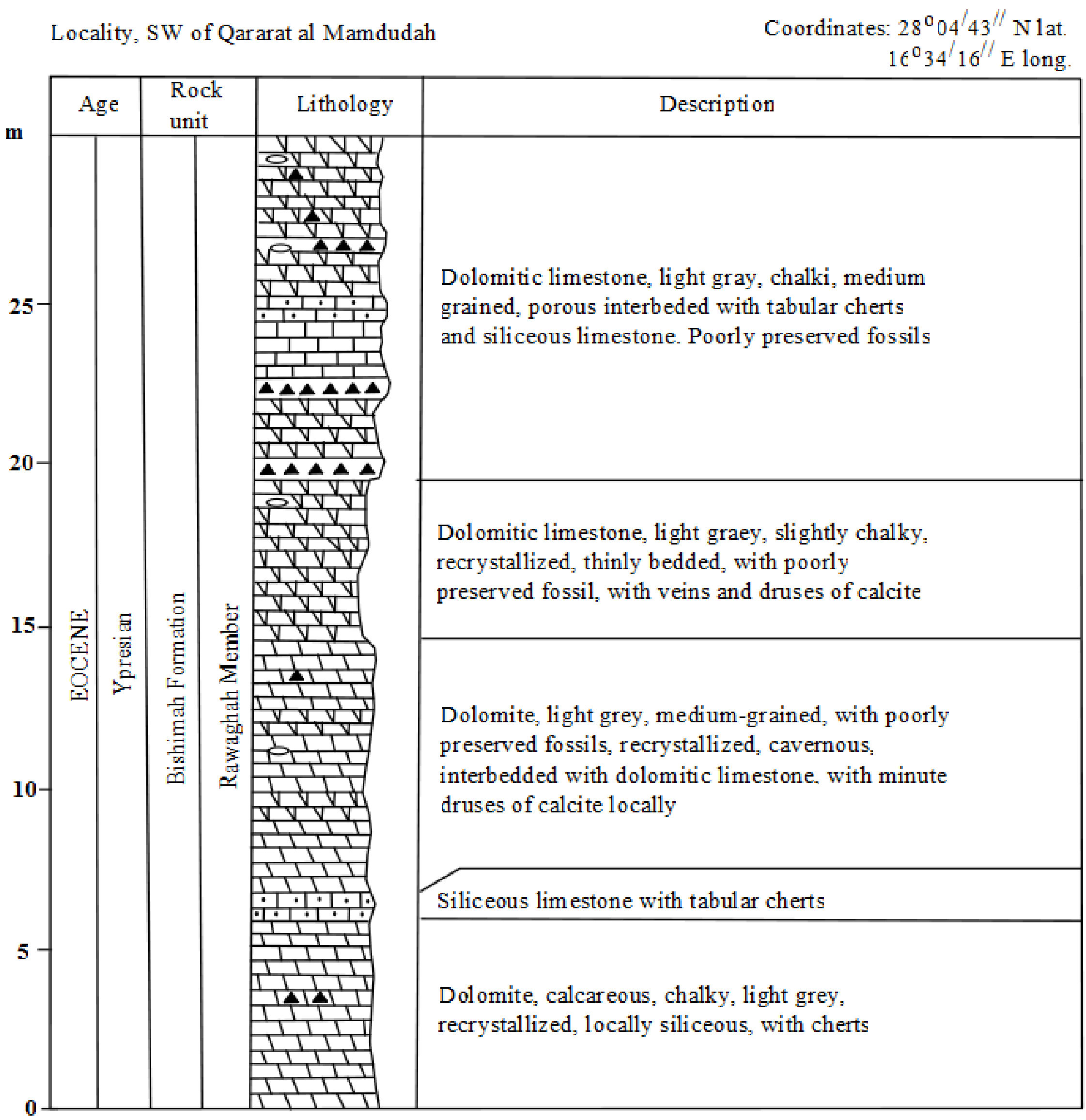

Figure (4) Columnar section of the Bishimah Formation (after Vesely, 1985).

Al Jir Formation

It was introduced by Burollet (1960) as Gir Gypsum. Later Mijalkovic in 1977 named it as Al Jir Formation. In Zallah area, it cropped out in western part as dolomite-evaporate facies (i.e. chalky dolomitic limestone to limestone interbedded with chalky limestone and evaporites) with thickness up to 60 m southeast of Wadi as Shurfa (Figure 5). However, in the northeastern corner of the area this formation becomes limestone facies with thickness ranges from 50 to 70m. The presence of the larger foraminifera Dictyoconoides cooki and Orbitolites complanatus indicates Lutetian age.

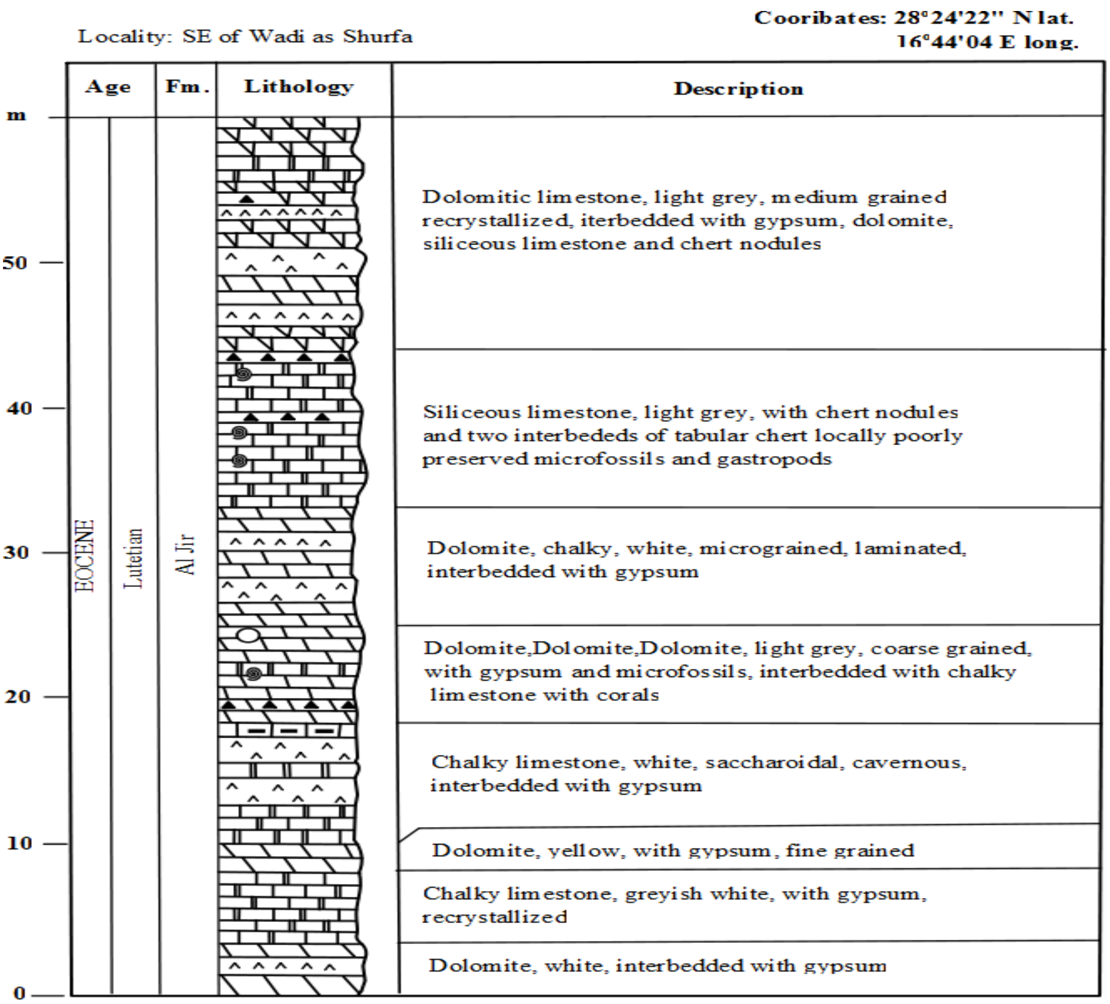

Figure (5) Columnar section of the Al Jir Formation (after Vesely, 1985).

Maradah Formation

This formation introduced by Desio (1935). Later in 1985, Mastera divided this formation into two members; Qarat Jahannam Member which is widely exposed along Zallah trough in Zallah area. Lithologically, it is dominated by siliciclastic deposits with cross bedded sandstone at some horizons interbedded with sandy limestone or dolomite (Figure 6). Based on the presence of the foraminifera *Borelis melo*

Aquitanian-Burdigalian age is given. This member is conformably overlain by Ar Rahlah Member which is only exposed in the north central edge of Zallah sheet as small patches. This Member is dominated by carbonate deposits (i.e. dolomitic limestone and sandy limestone). Due to the lack of any datable fossils except *Borelis melo*, Ar Rahlah Member is dated on the stratigraphic basis and by correlation with the neighbor sheets where datable fossils are present and Aquitanian-Serravallian age is given.

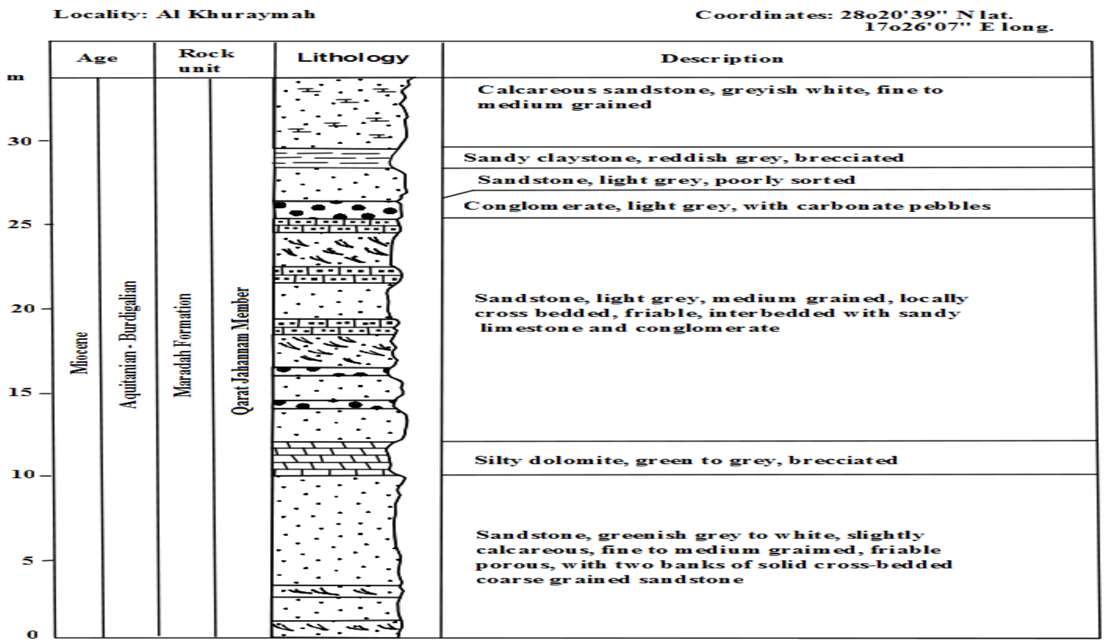

Figure (6) Columnar section of Qarat Jahannam Member of the Maradah Formation (after Vesely, (1985).

Geochemical Data Evaluation

Chemical analyses (Table 1) of some samples in the study area (Zallah sheet) where the chemical data are plotted in ternary system and shows various qualities of rocks and classified as medium purity limestones such as Al Jir Formation to impure limestones (Harries, 1979), as noted in Thamed al Qusur in Wadi Thamat Formation and Qarat Jahannam

Member in Maradah Formation. In addition the Zallah area contains dolomitic limestones (< 50 % $MgCO_3$) in some places especially in Al Jir Formation, and sandstones with intercalated clay. The resulting of the chemical analyses is illustrated in the ternary plots (Figures 7 and 8).

Table (1): Shows typical composition (wt. %) for the raw materials in Zallah area (Note: Sample localities see figure 9)

sample#	SiO_2	CaO	Al_2O_3	SiO_2%	CaO%	Al_2O_3%	$CaCO_3$	MgO	$MgCO_3$
1	4.47	33.84	2.43	10.97	83.06	5.96	60.39	14.76	30.88
2	18.37	21.36	3.17	42.82	49.79	7.39	38.12	16.3	34.10
3	0.68	32.77	0.08	2.03	97.73	0.24	58.48	19.08	39.92
4	2.11	52.34	0.55	3.84	95.16	1.00	93.41	0.99	2.07
5	1.82	30.44	1.23	5.43	90.89	3.67	54.32	18.98	39.71
6	2.6	38.68	0.47	6.23	92.65	1.13	69.03	12.19	25.50
7	19.07	20.84	3.48	43.95	48.03	8.02	37.19	13.14	27.49
8	12.44	26.32	2	30.52	64.57	4.91	46.97	15.37	32.15
9	54.03	1.01	17.39	74.60	1.39	24.01	1.80	3.72	7.78
10	16.91	25.36	0.82	39.24	58.85	1.90	45.26	13.49	28.22
11	96.45	0.29	0.85	98.83	0.30	0.87	0.52	0.05	0.10
12	94.66	1.01	0.55	98.38	1.05	0.57	1.80	0.23	0.48
13	2.2	30.17	0.99	6.59	90.44	2.97	53.84	18.08	37.82
14	1.35	32.77	0.34	3.92	95.10	0.99	58.48	16.66	34.85

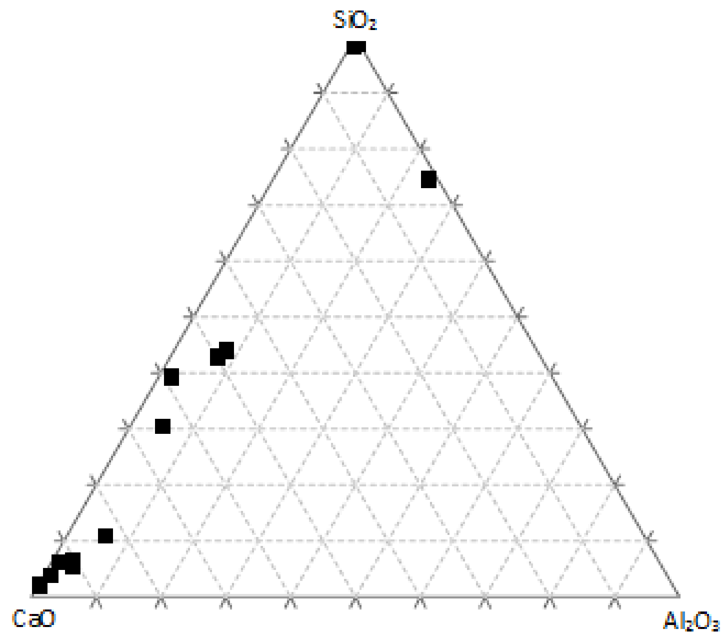

Figure (7) SiO_2-CaO-Al_2O_3 Ternary plot showing the interbedded of limestone and sandstone rocks in Zallah area.

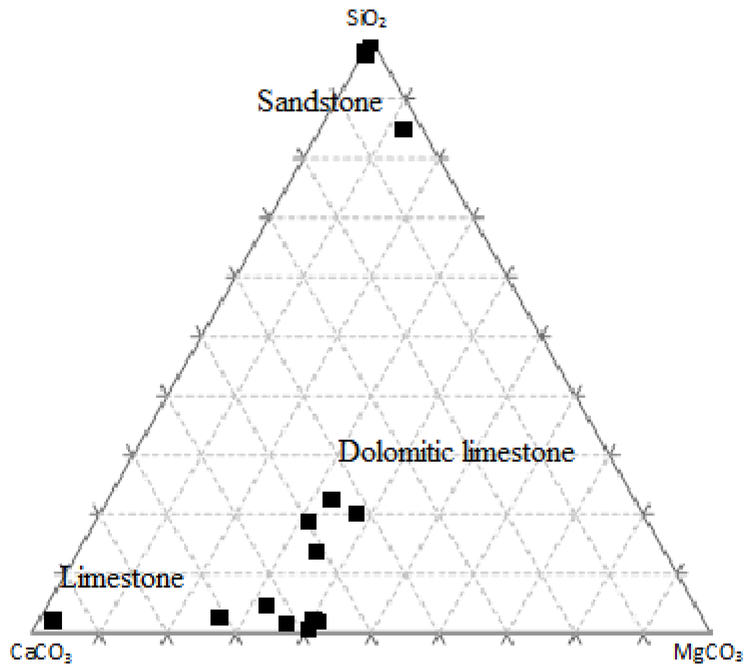

Figure (8) SiO_2-$CaCO_3$-$MgCO_3$ Ternary plot of the different carbonate rock types in Zallah area

Industrial raw Materials and Uses

The most prevalent raw materials available in the study area are limestones and dolomitic limestones, sandstones, clay, gypsum and anhydrite, celestite, iron and natural quaternary deposits (gravels and loose sands). These raw materials can be fully utilized for an extremely wide variety of construction purposes. Plastic clays (commonly montmorillonitic clays) where found in Al Gata and Qrarat al Jifah members. Clays could be used if mixed with lime and sands in manufacturing of bricks and other structural clay products such as tiles, hollow blocks and sewer pipes. Carbonate rocks are suitable for production of cement, crushed aggregates, concrete, as well as dimension stones if considered will occupies important places in the construction of prestigious buildings. Durable mortar also could be made by mixing siliceous lime and clay, also are widely used in road constructions. This study relied primarily on data collection from a geological map sheets located in Sirte – Jufra region (including Zellah Sheet). The authors have been interpreted the chemical analyses available in selected horizons within the concerned study area and assembled to learn the basic components of the rocks and minerals, those of important economic feasibility are taken into consideration. These data have been taken in a simple task to form a map illustrating the available important natural resources of minerals and raw materials in the study area (Figure 9).

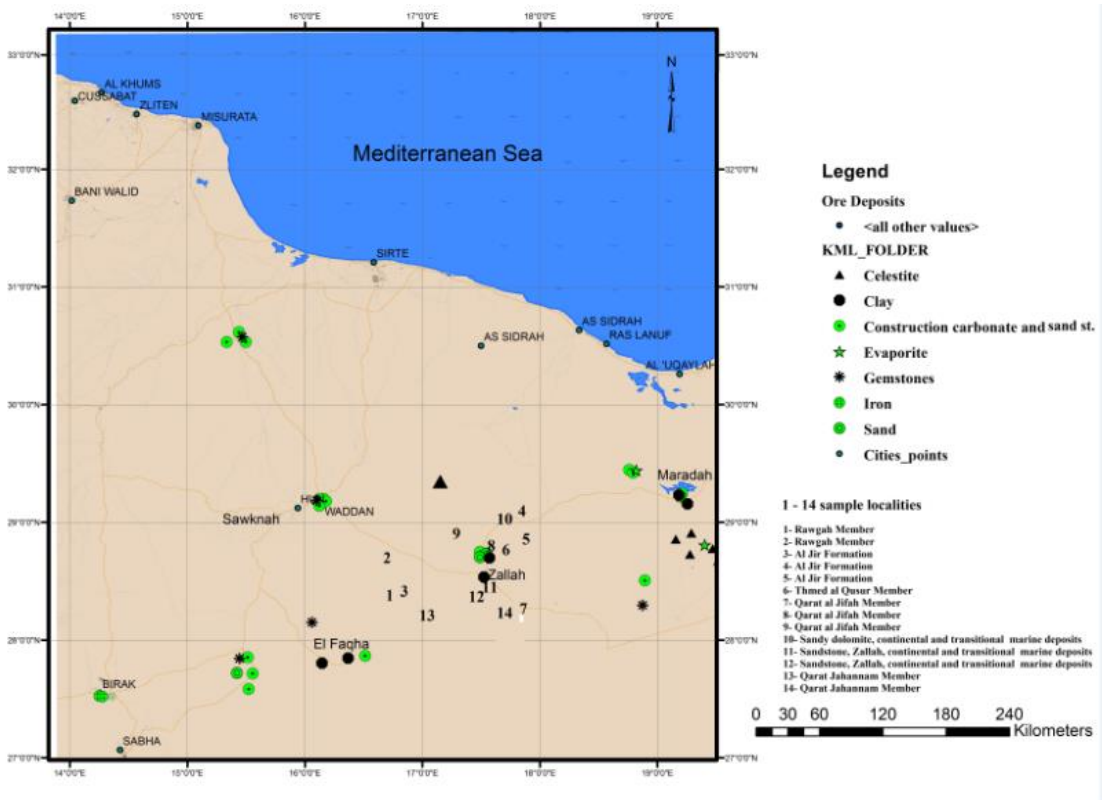

Figure (9) An economical map showing the most important natural resources of the minerals and raw materials available in the Sirte - Jufra area

Conclusions

This study is based on the assemblages of the geological formations and the chemical analysis data in the study area of Zallah sheet. The Geological formations of the Zallah sheet are containing sedimentary and igneous rocks. These rocks are of great importance in construction uses; aggregates (crushing and natural), dimension stones, hollow bricks, cement industry, road construction, wall decoration, tiles and glass industry.

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استخدامات المواد الخام الاولية في البناء: حصيلة دراسة طبقية وجيوكيميائية تفصيلية للوحة زلة

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محمد سالم اشتيوي الفيتوري
احمد محمد مفتاح*

الخلاصة

تعتبر المنطقة المخرطة من قبل مركز البحوث الصناعية ذات أهمية صناعية كبيرة. ومن خلال تقييم الدراسة التفصيلية التي اجريت علي التحاليل الكيميائية للصخور الرسوبية والمتواجدة بمنطقة الدراسة .

أفادت الدراسة ان الاستخدام الرئيسي لهذه الصخور يكمن في استثمار مواد البناء المتمثلة في قوالب البناء، الحصي الطبيعي والصناعي المستخدم في كل من الخرسانة ورصف الطرق، وكذلك الطفلة التي يمكن الاستفادة منها في صناعة الطوب الحراري. بالإضافة لإمكانية استخدام كل من الحجر الجيري والطفلة كمواد خام رئيسية في صناعة الاسمنت، وهذا من خلال التحليل الرقمي للنتائج الكيميائية المتوفرة سابقا. تتواجد المواد الاولية المذكورة أعلاه في التكوينات الجيولوجية التالية من الأقدم الي الأحدث: عضو رواغة بتكوين البشمة (بريسيان)، تكوين الجير (لوتيتيان السفلي)، عضو ثمد القصور (بريبونيان) بتكوين وادي ثامت، وعضو قارة جهنم (اكويتنيان – بورديقاليان) بتكوين مرادة.

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