THE HYDRO – STRUCTURAL INTERRELATIONS IN PART OF AL-RAZZAZAH BASIN, IRAQI WESTERN DESERT

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ABSTRACT

The studied basin is located to the west of Al-Razzazah Lake extending between longitude 42º 00' – 43º 45' E and latitude 32º 00' – 33º 15' N. It is a part of Al-Razzazah hydrogeological basin, including many wadies such as Ghadaf, Ubaiyidh and Slugi. The exposed geological formations in the area range in age from Cretaceous to the Pleistocene with various lithologies. This variation in lithology has remarkable effective impression on the geomorphological units represented by the karst features, shallow depressions and the intermittent wadies. The main aquifers in this basin lie within the Umm Er Radhuma, Dammam and Tayarat formations; which consist of intensively faulted fractured and karstified limestones and dolomites. Groundwater flow is from west and southwest toward east and northeast. Through structural study of the basin, it was found that a relation exists between the direction of the groundwater flow with the direction of the major faults. The Nukhaib Graben is considered as a site of groundwater accumulation, as a recharge area, while the discharge area is located and expresses itself in a series of springs along the Euphrates Fault Zone where the groundwater is shallow and will participate in the recharging of Al-Razzazah Lake. The analysis of the lineaments, delineated from satellite images and aerial photos show that the N40°– 60°E are the prevailed direction in addition to the N20° – 35°W trend. The transverse lineaments (E – W) control the behavior of the groundwater flow and the direction of the main wadies in the basin. According to the structural relation, an attempt was carried out to specify the best locations for exploitations through connecting the lineaments density map with the distribution of the hydraulic conductivity. It is concluded that there are no rules controlling the movement of groundwater through the faulted and karstified carbonate aquifers, and each case should be treated separately.

العلاقات المائية والتركيبية المتبادلة في جزء من حوض الرزازة، الصحراء الغربية العراقية

قيس جاسم سعود و أيسر محمد ألشماع

المستخلص

يقع الحوض المدروس غرب بحيرة الرزازة بين دائرتي عرض 00' 32º – 15' 33º شمالاً وخطي طول 00' 42º – 45' 43º شرقاً، وهو جزء من حوض الرزازة الهيدروجيولوجي ويضم العديد من الوديان أهمها الغدف، الأبيض والسلوكي. تتكشف في الحوض تكوينات من العصر الطباشيري إلى عصر البلايستوسين. تميز المنطقة ظواهر سطحية أهمها الفيضات المتشعبة والخسفات وبقايا التلال والوديان وشبكات التصريف المتكونة بفعل عوامل ألحت الناتجة عن الظروف المناخية المتقلبة.

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تمتد المكامن الجوفية الرئيسية في المنطقة ضمن الصخور الجيرية والدولومايتية لتكوينات الدمام، أم الرضومة والطيارات والتي تتصف بكثافة الصدوع والشقوق وبانتشار ظاهرة الكارست فيها. تجري المياه الجوفية من غرب وجنوب غرب المنطقة باتجاه الشمال والشمال الشرقي نحو بحيرة الرزازة، حيث تعد منطقة النخيب في الجنوب الغربي منطقة تجمع غزير للمياه ألجوفية، وشرقا يعد صدع الفرات حاجزا لسير المياه ألجوفية ومنطقة تصريف طبيعية من خلال انتشار العيون على امتداده.

اظهر التحليل العددي للتراكيب ألخطية من خلال دراسة الصور الجوية والمرئيات ألفضائية إن النسبة الأكبر من التراكيب الخطية تمتد باتجاه شمال 40º - 60º شرق وهي تعكس بالمقابل أعلى نسبة في مجموع أطوال التراكيب الخطية، ثم اتجاه شمال 20º - 35º غرب. تمت محاولة لإيجاد أفضل المواقع للاستثمار من خلال مقارنة خريطة كثافة التراكيب ألخطية مع انتشار التوصيلية الهيدروليكية وتبين بأنه لا توجد قاعدة لحركة المياه ألجوفية في خزانات الصخور الجيرية خلال ألصدوع و التكهفات وان كل حالة يجب أن تدرس لحالها.

INTRODUCTION

Groundwater information is most useful to water resources management that includes the presence of groundwater in designated areas, the depth to groundwater, the quantity and quality of water available for development, recharge sources, the extension of the aquifer and the discharge zones. These information are generally sought by hydrogeologist using conventional methods, whereas, the application of satellite images can be used to estimate some of these requirements.

The analysis and interpretation of the tectonic framework of a basin is considered to be a helpful tool in determining some of these aqueous system characterizations. The distribution and trend of lineaments is part of the study, which deals largely with the depth, flow direction and accumulation of groundwater in the aquifers. In carbonate aquifers, the porosity is highly influenced by the density of fractures, which in turn controls the flow of groundwater and the physical parameters of the aquifer, when fractures effect will reach the surface, the velocity of surface recharge will increase. Therefore, by linking the analysis of lineaments (i.e. direction, length, intersections and depth of penetration) with the hydrogeological setting of the basin will help in determining the interrelation between the groundwater system and the tectonic framework and to find the best sites for water exploitation.

THE STRUCTURAL FRAMEWORK OF THE BASIN

The Al-Razzazah basin is located to the west of Al-Razzazah Lake (Fig.1), mostly within the Stable Shelf. The exposed outcrops range from Late Cretaceous, represented by Tayarat Formation to Quaternary sediments along the lake.

Many faults are present in the area (Fig.2). The east – west trending faults are the oldest deep basement faults (Al-Kadhimi *et al.*, 1996), which are important due to their hydrogeological relations. The northwest – southeast trending faults are also important due to their influence on the flow direction of groundwater. The discharge zone of the basin is represented by springs aligned along the northwest – southeast Euphrates Fault Zone. The north – south and northeast – southwest trending faults are noticed also in the basin, but are less significant.

■ Hydrogeology of the Basin

Groundwater in the study area occurs under both unconfined and semi-confined conditions in highly fractured and karstified limestones of Umm Er Radhuma Formation (Middle – Late Paleocene) and Dammam Formation (Early – Late Eocene). The direction of groundwater flow is from the west and southwest, where the groundwater level is 190 m above sea level, toward the east and northeast, where the water level reaches (20 – 50) m above sea level Consortium,1977) (Fig.3). The groundwater discharges to the surface through a series of springs aligned along the western side of Al-Razzazah Lake. Groundwater recharges mainly from subsurface flow, while the unconfined parts of the aquifers recharges from rainfall, also.

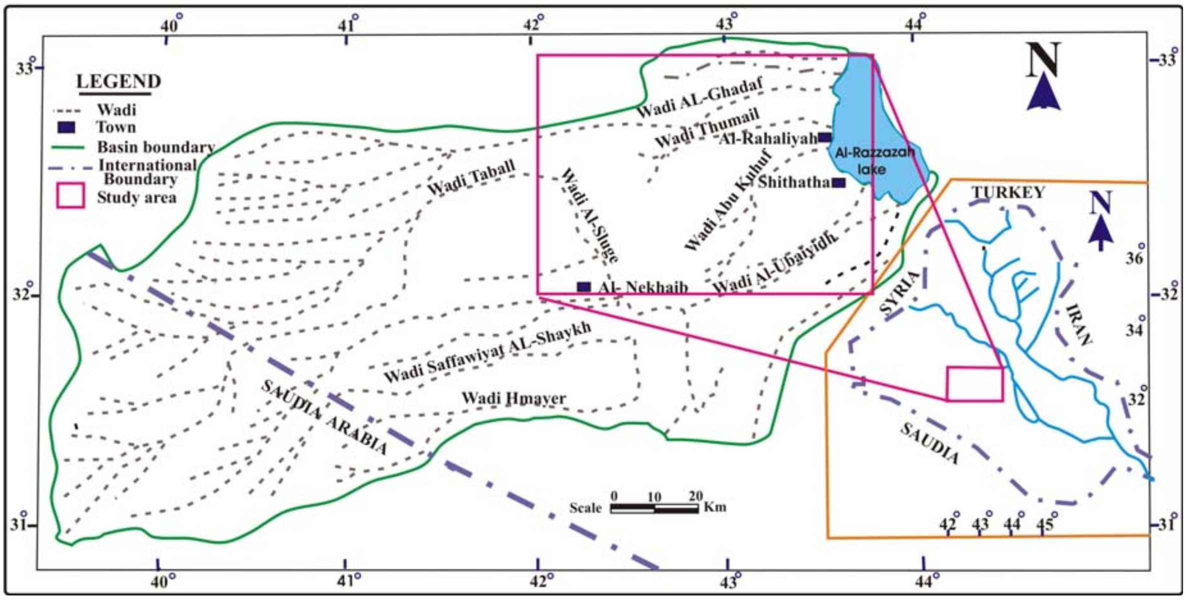

Fig.1: Location map of Al-Razzazah Basin

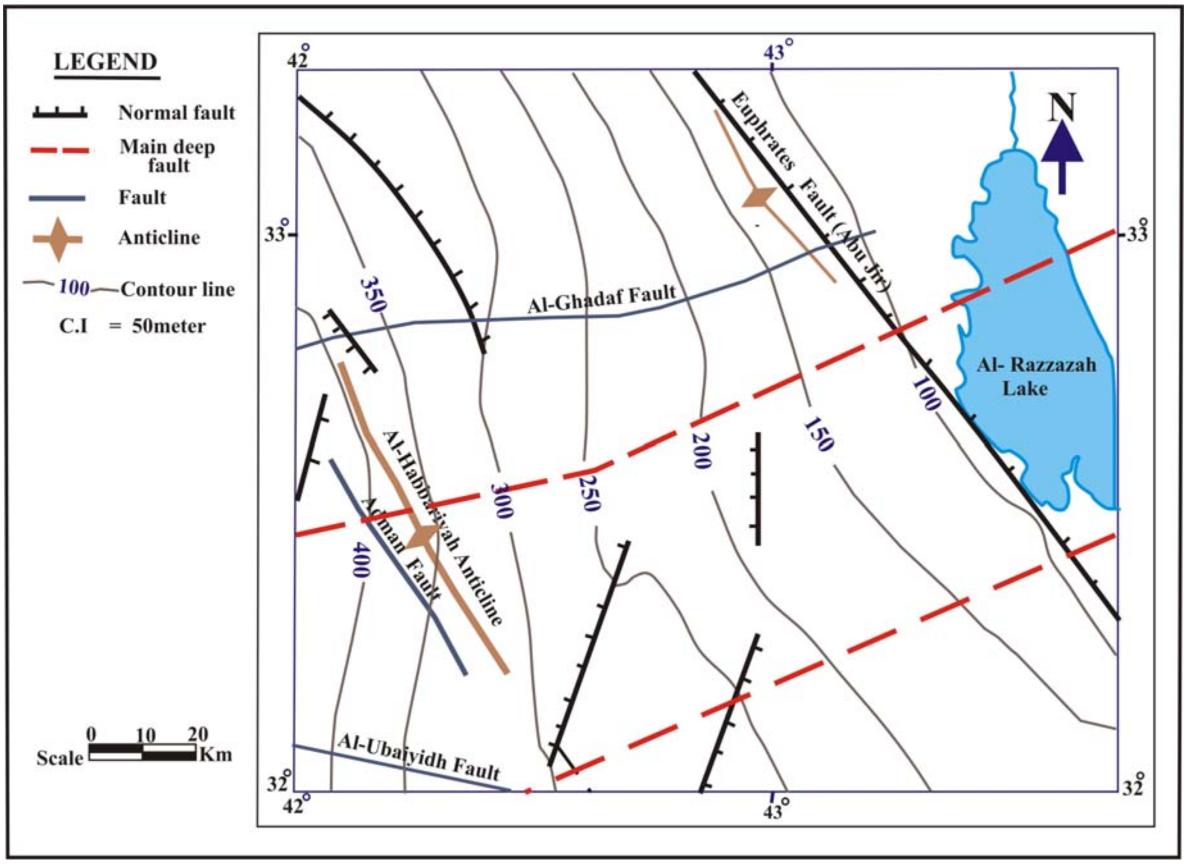

Fig.2: Structural map of the study area
(based on Al-Azzawi, 1988, Al-Kadhimi *et al.*, 1996 and Sissakian, 2000)

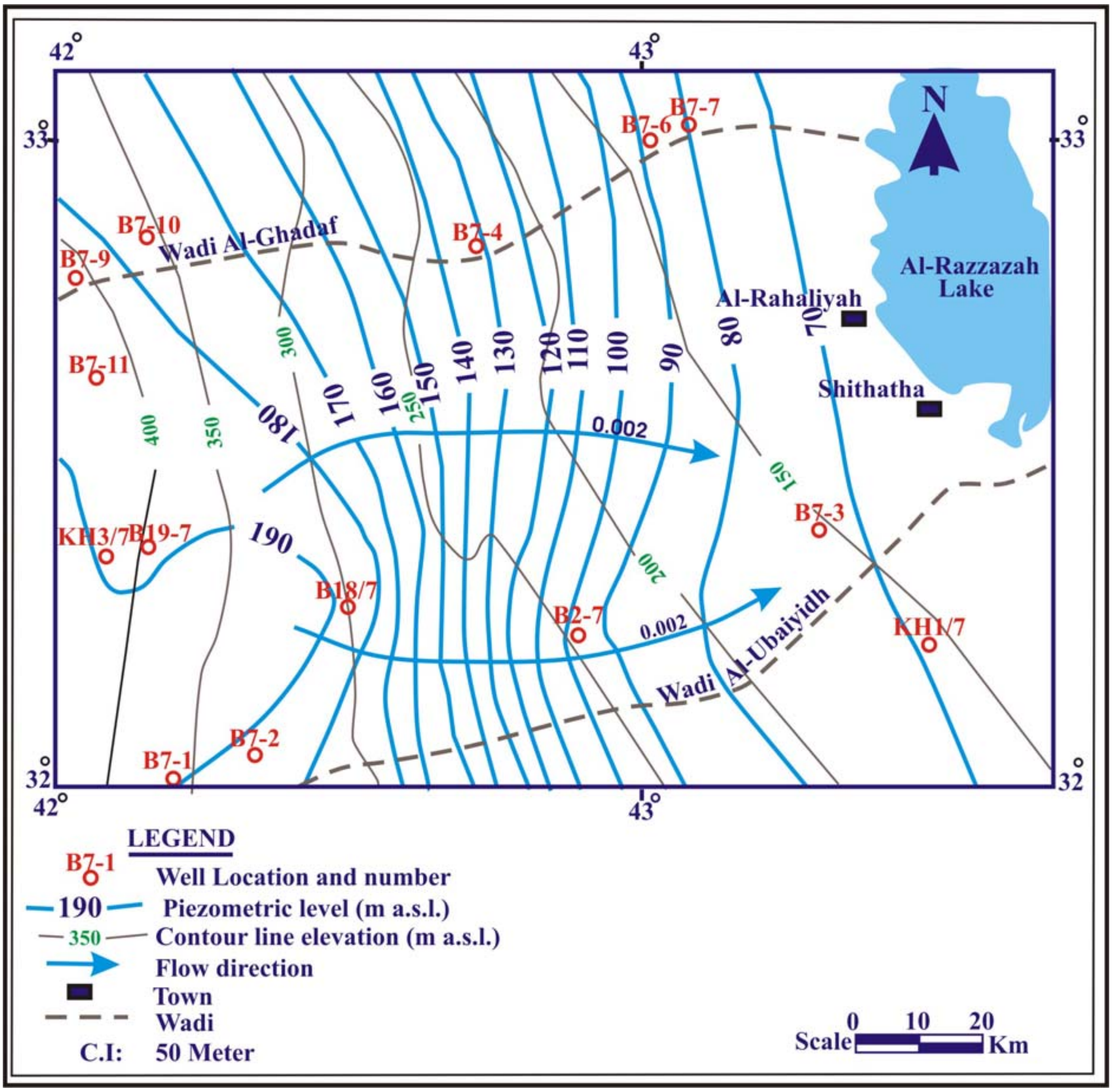

Fig.3: Piezometric map of the study area

■ Frequency Analysis of Lineaments

To understand the relation of fractures to groundwater occurrence, a lineament map is drawn (Fig.4) compiled from several documented references (Consortium, 1977; Al-Amiri, 1979; Al-Azzawi, 1988 and Sissakian, 2000).

A 15 X 15 Km grid is imposed on the lineament map, the trend of lineaments was measured (Fig.5), then grouped into (0 – 10°) sets, and the percentages of each set was calculated, then presented as a frequency rose diagram (Fig.6).

The major lineaments direction is N40° – 60°E, the average is N50°E and total length is 1875 Km in NE direction, whereas the N20° – 35°W, the average is N27°W, with total length of 1287 Km in NW direction, represents the second dominant direction. Most of the northeast directed lineaments extend without interruptions, while the northwest directed lineaments are short intersected segments, except the major Euphrates Fault. This confirms the development of a tectonic reactivation along the NE – SW trending faults (Al-Shamma'a, 1993).

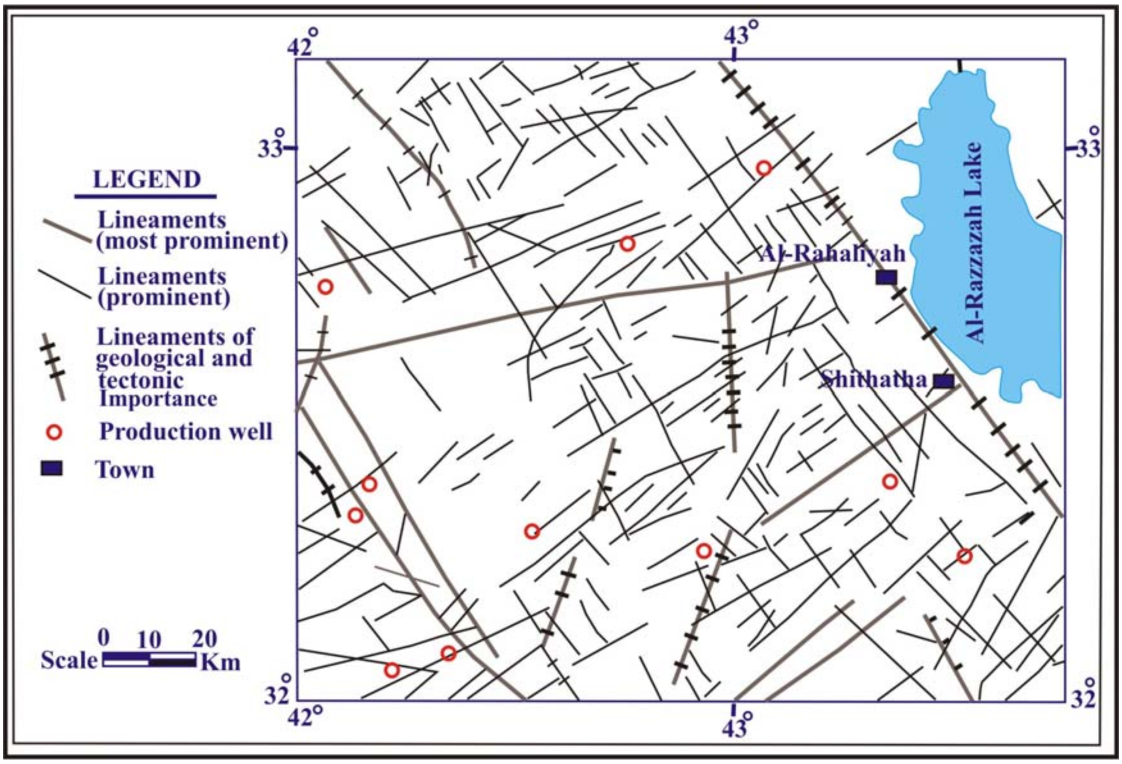

Fig.4: The lineament map of the study area
(based on Consortium, 1977; Al-Amiri, 1979; Al-Azzawi, 1988 and Sissakian, 2000)

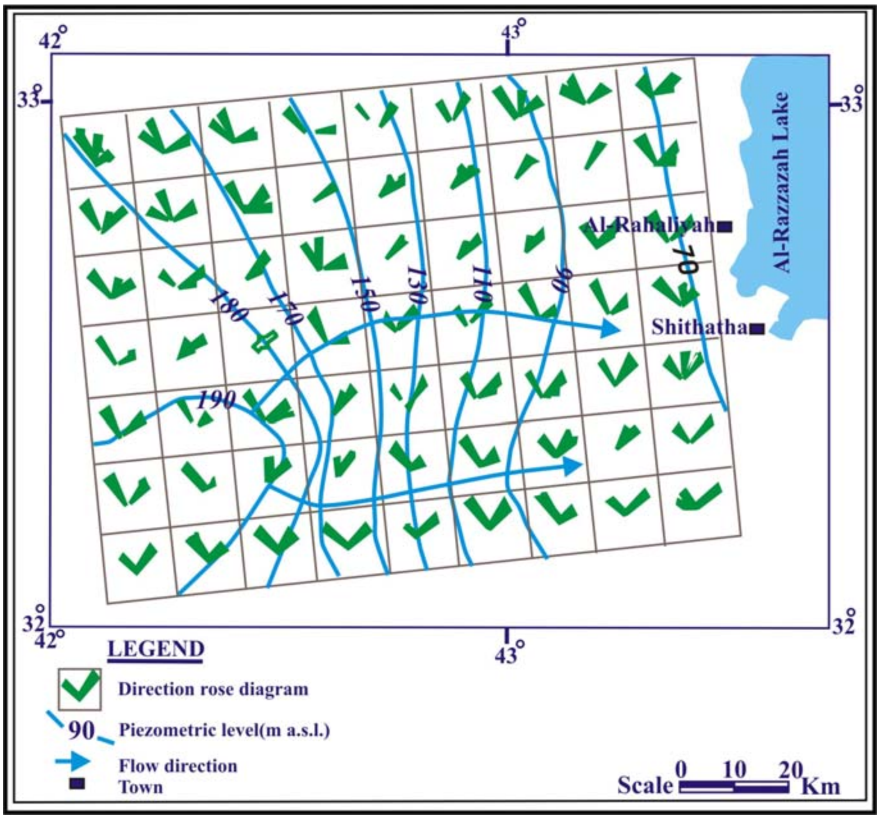

Fig.5: Lineaments frequency distribution within the study area

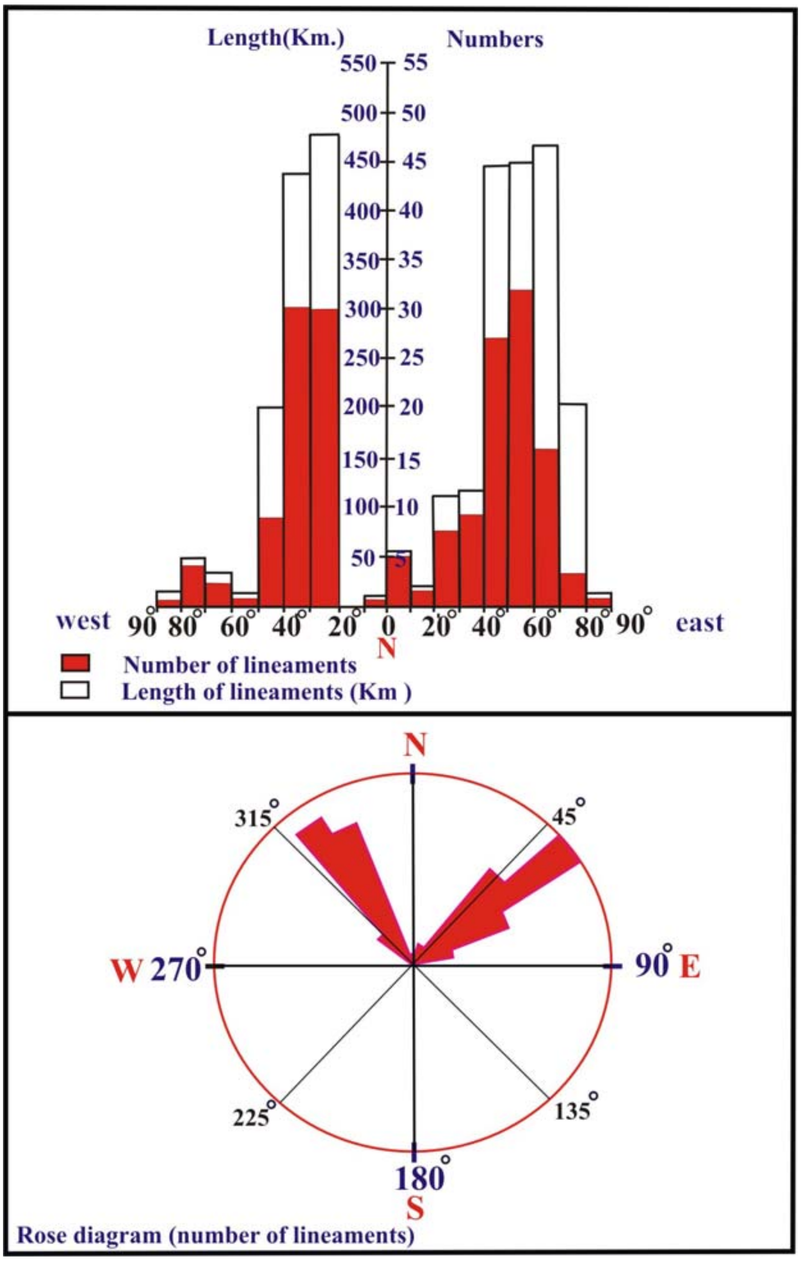

Fig.6: Rose diagram and histogram of length and number analysis of lineaments in study area

The E – NE trending lineaments control the direction of the main valleys in the basin, which is considered an important hydrogeological factor, in addition of acting as boundary conditions that separate Al-Razzazah basin from the neighboring basins.

The NW – SE trending faults, specifically the Euphrates Fault act as a barrier that restrain the groundwater flow and drain it through a series of springs, located along the fault zone. The basin as a whole is disrupted by the effect of deep seated faults, which show clearly the domination of block tectonics in the basin. This movement causes a lifting of blocks and sinking of others, which in turn reflects on the flow of the groundwater.

■ Density of lineaments intersections

A lineaments intersection ratio map is drawn (Fig.7) to illustrate the position of the high intersections ratio, which points to the areas of high yield of groundwater due to the increase in permeability (Rao, 1985).

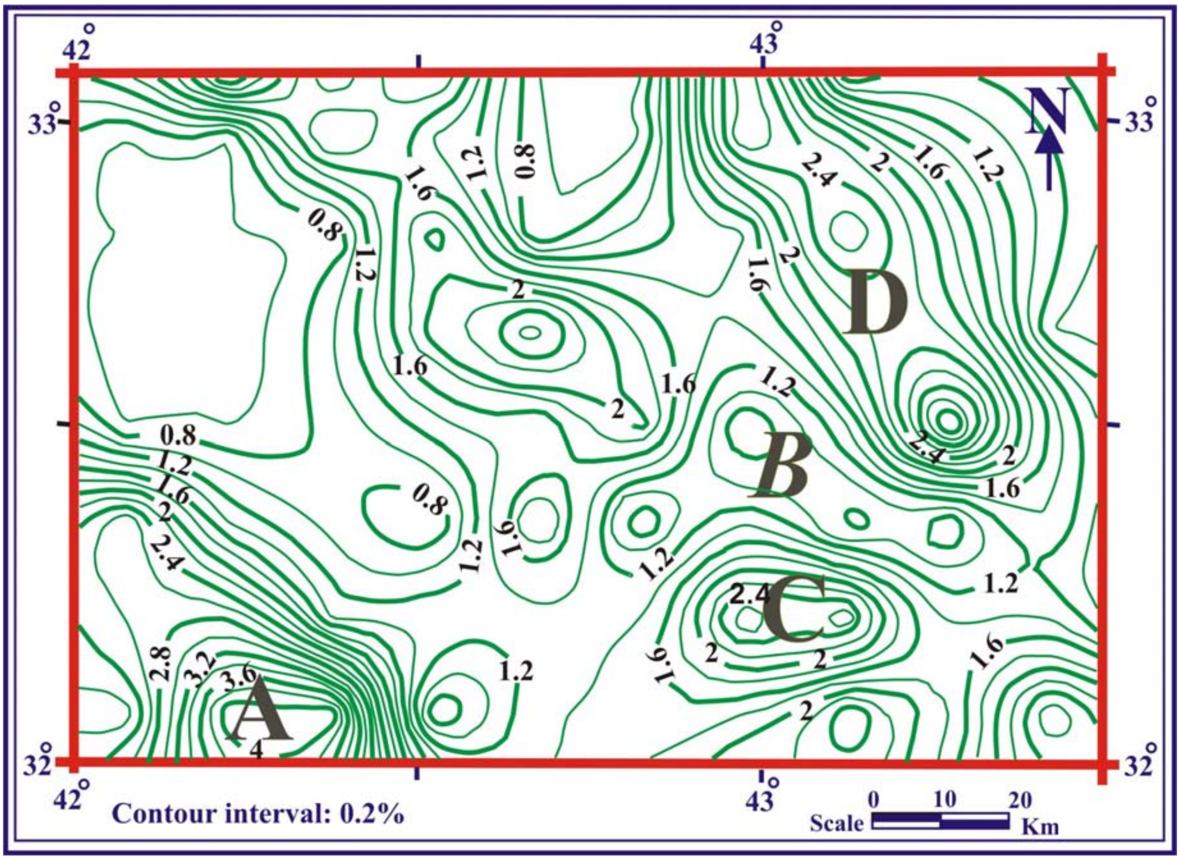

Fig.7: Lineaments intersection ratio map of study area

The 15 X 15 Km grid is used to count the lineaments intersection by overlay the grid network on the lineament map. The contour anomalies represent the most promising zones of groundwater utility (Sondergger, 1970). The determination of the hydrogeological characteristics is achieved through the analysis of the lineaments intersection map linked with the density analysis of lineaments and the study of the litho-structural rock units in addition to the nature of the drainage patterns in the basin (Rao *et al*., 2000).

The anomaly A in Fig. (7) reflects high presence of lineament intersections in the Nukhaib basin, which represents the main recharge area of the studied basin and is controlled by a northwest – southeast trending lineaments. Drilled wells in Nukhaib basin show a high potential yield and high transmissivity factor (4000 m^2/ day) (Table 1). The anomaly B (Fig.7) is another promising zone of both high yield and transmissivity (1000 m^2/day) and is located parallel to the Euphrates Fault Zone. The anomaly C (Fig.7) is located along the major valley in the basin (Wadi Al-Ubaiyidh) and is also characterized by a high yield and transmissivity (4000 m^2/ day), while the anomaly D (Fig.7) points to the effect of the Euphrates Fault Zone along which a series of springs are located. These springs represent the discharge zone of the basin, in addition to the presence of some artesian wells in this part of the basin and also posses a high yield and high transmissivity factor (1500 m^2/ day).

Table.1: Drilled wells information (after Consortium, 1977)

Water point	Location latitude / longitude	Elevation m (a.s.l)	Drilling depth (m)	Water level from surface (m) / Above sea level (m)	Discharge l/ sec / m^3 / day	Pumping time (minute) / Recovery time (minute)	ΔS Maximum drawdown (m)	Transmissivity m^2 / day	Hydraulic conductivity m/ day	Storage coefficient
KH1/7	32º 16' 07''	90.22	629.7	20.55	25.5	860	0.39	15506	172.28	6.37×10^{-4}
	43º 37' 15''			69.67	2203.2	20				
B7-7	32º 59' 11''	101.4	150	15.50	3.46	1440	16.42	27	0.442	□
	43º 08' 10''			85.90	298.94	600				
B7-6	32º 59' 07''	12.3	150	22.09	14.07	2880	18.4	171	1.29	□
	43º 08' 00''			90.13	1215.04	900				
B7-4	32º 53' 03''	170.7	150	36.9	25.55	2880	1.45	2692	79	□
	42º 48' 30''			133.3	2207.52	9				
B7-9	32º 48' 14''	358.92	232	173.74	19.05	2880	0.23	15529	316.91	□
	42º 02' 26''			185.08	1645.9	0.5				
B 7-1	32º 02' 51''	311.8	202	121.75	12.491	750	21.32	120	3.529	□
	42º 13' 48''			190.05	1079.22	510				
B19/7	32º 21' 02''	326.9	268	173.3	25.55	900	0.81	6953	71.97	0.011
	42º 08' 08''			189.69	2207.5	1020				
B18/7	32º 18' 33''	285.36	374	96.31	23.9	1320	1.36	3455	33.22	□
	42º 32'58''			189.05	2064.96	1440				
B2/7	32º 16' 00''	234.19	443.7	139.78	25.55	2880	2.44	3672	41.72	□
	43º 01' 04''			94.22	2207.5	25				
B7-3	32º 33' 26''	95.6	196	32.12	25.55	2880	1.31	1879	37.97	□
	43º 26' 38''			72.48	2207.5	1260				
B7-2	32º 04' 48''	287.86	162	97.95	□	□	□	□	□	□
	42º 21' 52''			130.91	□	□	□	□	□	

■ Geology and Stratigraphic Correlation

The geologic map of the basin (Fig.8) shows the extension of the Quaternary sediments in a strip form at the western part of the basin. These sediments are bounded by the Paleocene rocks, in the west and the Eocene; Pliocene – Pliestocene rocks, in the east that points to the presence of a graben, where subsidence caused the recent sediments to be accumulated relatively to both eastern and western uplifted blocks. Therefore, normal faults that are responsible for the formation of the graben are detected (Faults 1 and 2 in Fig.9). Other NW –SE trending faults (Faults 3 and 4 in Fig.9) show the step faulting effect by placing the Cretaceous rocks next to the Quaternary sediments, at a side and next to the Pliocene rocks, at the other side. The NE – SW trending faults (Faults 5 and 6 in Fig.9), which uplifted the Paleocene rocks to be adjacent to the Pliocene and Eocene rocks are truncated by the transverse fault (Fault 7 in Fig.9) that shifted Wadi Al-Ubaiyidh.

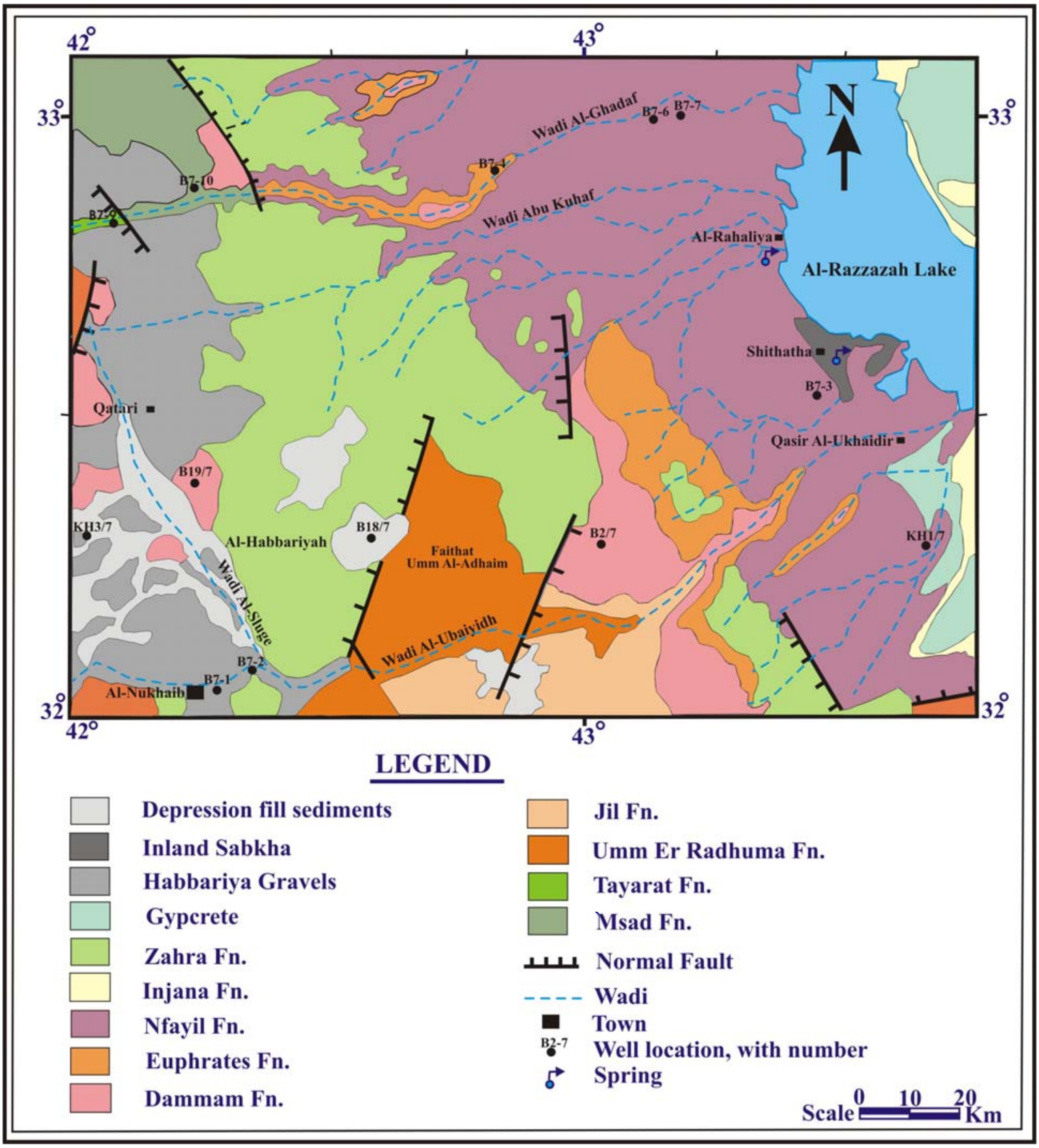

Fig.8: Geologic map of the studied area
(modified from Sissakian, 2000)

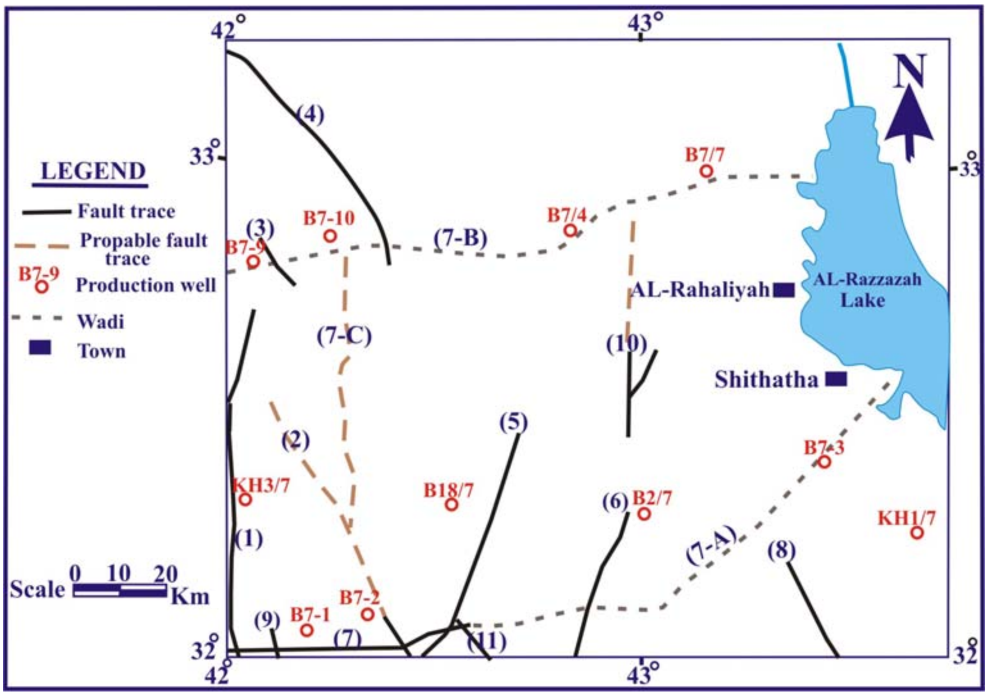

Fig.9: Faults interpreted from the geologic map of study area

Three stratigraphic correlation sections between wells (Fig.10) were drawn, along E – W (Fig.11), N – S (Fig.12) and NW – SE (Fig.13) (Consortium, 1977). These sections illustrate the movement along the faults and show a regional slope toward Al-Razzazah Lake, in addition to the formerly mentioned effect of faults on the continuity of the formations.

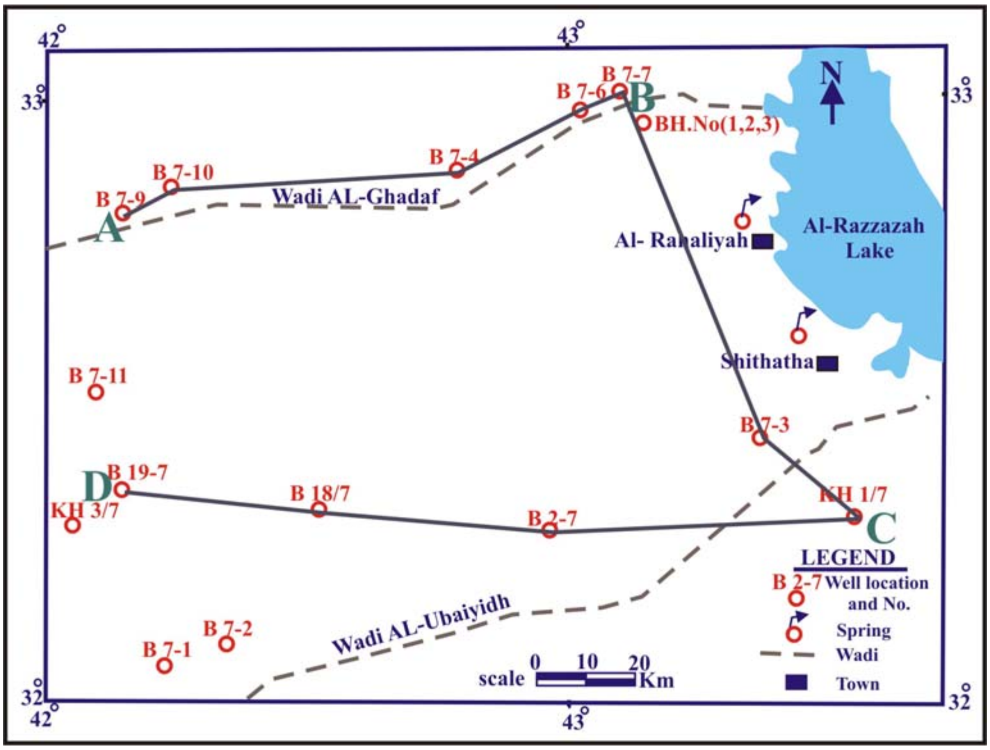

Fig.10: Location of the stratigraphic cross sections

■ Fractures and Groundwater

Open fractures extend several kilometers in the basin and act as groundwater conduits for groundwater movement. The piezometric map (Fig.3) shows that the groundwater generally flows north eastward coinciding with N50°– 65°E fractures in the southeastern and central parts of the basin.

Well yield data of the Al-Razzazah basin is examined to explore the relation between the yield of wells with areas of high fractures density (Locations A, B, C and D, in Fig.7). Drilling in a high density fracture zone increases the chance of encountering multiple fractures and thereby obtaining a high well yield. The wells in the study area with yields greater than 25 L/ sec are within the trend of high fracture density zones, especially those along and near the discharge zone of the basin, where the effect of the Euphrates Fault Zone caused the rise of groundwater level and drain as springs. In spite of that, we cannot generalize that every well located within a fault zone should possess high yield. The major faults that truncate the flow direction will shift the flow path in a direction far from the prevailed fractures direction.

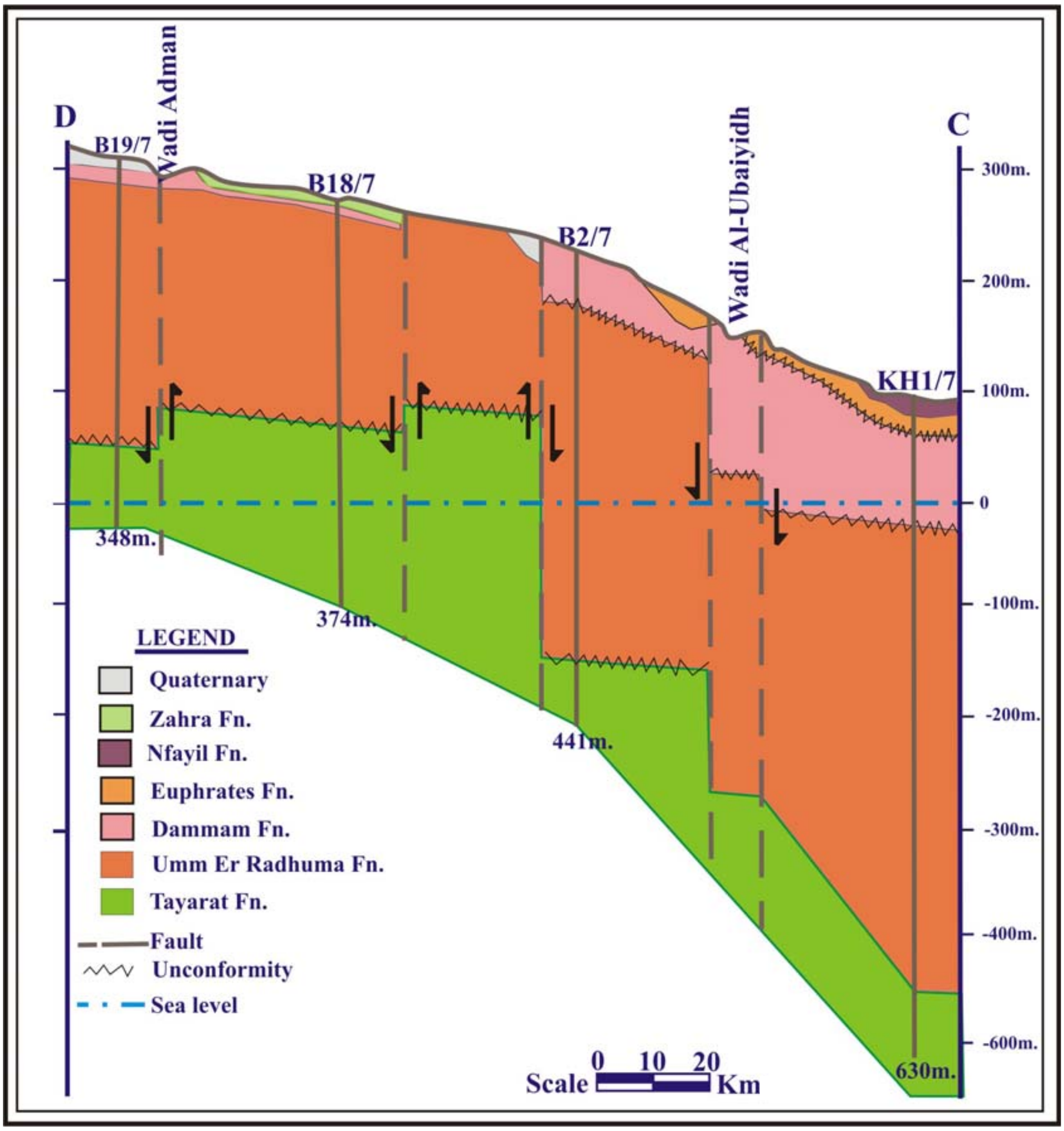

Fig.11: East – West cross section (modified from Consortium, 1977)

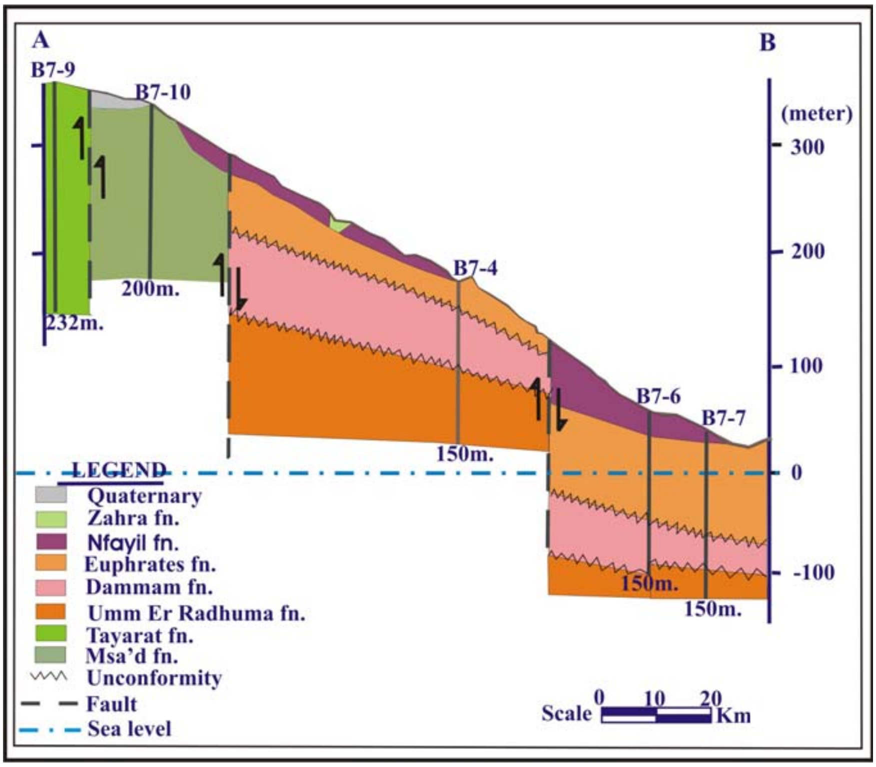

Fig.12: Northeast – Southwest cross section (modified from Consortium, 1977)

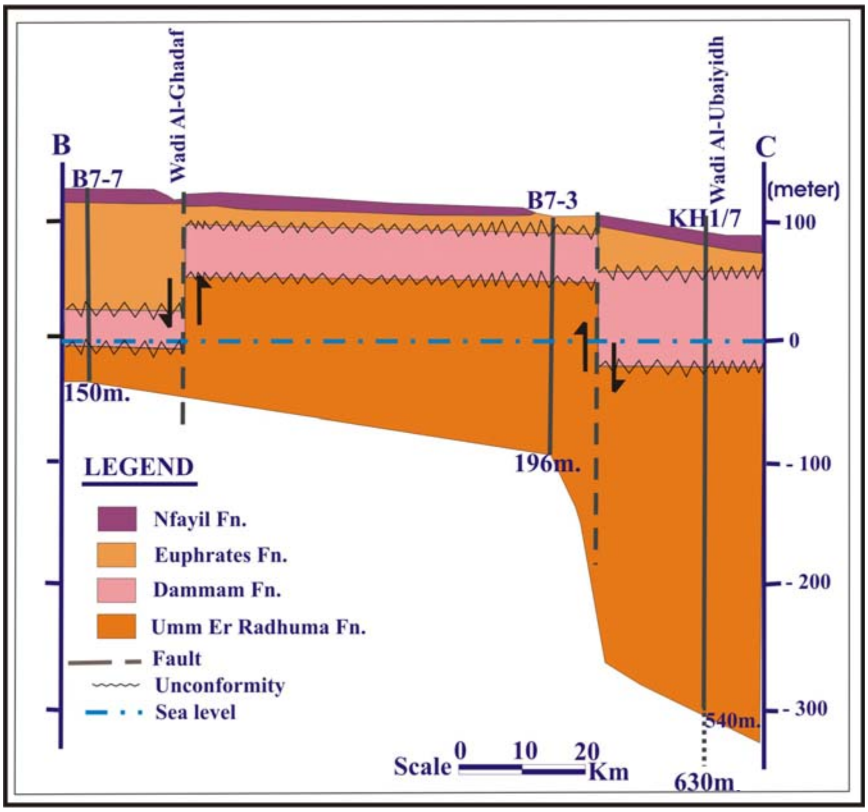

Fig.13: Northwest – Southeast cross section (modified from Consortium, 1977)

CONCLUSIONS

- The interrelation between the underground channels and the intersections with faults, in carbonate dominated areas, make the attempt of finding a relation between the groundwater flow and lineaments trend a matter of estimation.
- Each case is distinguished by its hydraulic characteristics and facial changes of the aquifer in the site, in addition to fault trends and the relative movement along its plane, and well's geotechnical specification.
- The karst features, which are widely spread within the carbonate rocks of the aquifer, highly affect the flow direction of groundwater and make the prediction of groundwater movements, very difficult.
- The study indicates that the high density fracture areas mostly have the best groundwater potential.
- In karst areas, the relation between direction of groundwater flow and faults directions is hard to be estimated.

REFERENCES

Al-Amiri, H., 1979. Structural lineament map of Iraq, prepared from Landsat satellite images, GEOSURV, int. rep. no. 1409.

Al-Azzawi, Th., 1988. The tectonic study of West Euphrates River area by using satellite images and geological information, Unpub. M.Sc. Thesis, Univ. of Baghdad, 108pp.

Al-Kadhimi, J., Sissakian,V.K., Fatah, A. and Deikran, D. B., 1996. Tectonic Map of Iraq, scale 1:1 000 000, 2nd edit. GEOSURV, Baghdad, Iraq.

Al-Shamma'a, A., 1993. Hydrogeologic and tectonic study of the southern part of the Western Desert, the area between Qasra and Shbicha, Unpub. Ph.D. Thesis, Univ. of Baghdad, 200pp.

Consortuim-Yugoslavia, 1977. Water development projects, Western Desert Block No.7, Hydrogeological explorations and Hydrotechnical works, Climatology and Hydrology, Final Report, Vol.1, Republic of Iraq, Directorate of Western Desert Development Projects, (Unpub.).

Koudmani, M., and Al-Ali, M. 2006. Application of remote sensing to hydrology and hydrogeology in Syria, Symposium of the Third International Conference on the Water Resources in the Mediterranean Basin, Tripoli, Lebanon.

Rao, R.S., 1985. A remote sensing based study for quantitative groundwater potential evaluation of a typical hard rock area from southern India, 4th Conference on Remote Sensing for Exploration Geology, Env. Res. Inst. of Michigan.

Rao,Y., Reddy, T. and Nayudu, P., 2000. Groundwater targeting in a hard-rock terrain using fracture-pattern modeling, Niva River basin, Andhra Pradesh, India, Hydrogeology Journal, Vol.8, p. 494 – 502.

Sissakian, V.K., 2000. Geological map of Iraq, 3rd edit. , scale 1: 1 000 000; GEOSURV, Baghdad, Iraq.

Sondergger, J.L., 1970. Water resources assessment, in Reeves R.G. (Ed.), Manual of Remote Sensing, Amer. Soci. Of Photogram., Fall Church, Va., Chap.19, Vol.12, p. 1479 – 1545.