Detection of Structural Control on Formation Water Quality, in Hemrin Oilfield, northern Iraq, Using Lineament Analysis and Hydrochemical Data

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Abstract
Formation water analyses of Tertiary reservoir (Euphrates, Jeribe, and Dhiban formations) in Hemrin oilfield reflect high salinity variation between Albufudhul, Nukhaila, and Allas domes. The present study suggests that this variation resulted by two reasons, (1) percolation of surface waters (rain water) which lead to devastation of oil type, (2) interaction between water and host rocks. Satellite image and DEM were used to detect the lineaments and morphometric analyses, which interpret the structural control on salinity variation. The main direction of lineaments are NE-SW, which prevailing with subsurface vertical faults between Albufudhul and Nukhaila domes that playing with SE limb of Albufudhul dome as conduits for percolation of surface water (rainwater), that lead to dilute the salinity and change the formation water properties from Albufudhul to Nukhaila domes, while the present of vertical fault between Nukhaila and Allas dome considered as semi impermeable according to geometry of domes, so Allas dome considered as semi closed system in comparison with Albufudhul and Nukhaila domes, that lead to increase in salinity and change of formation water properties. Formation water is classified as salinity variety water from medium salinity (TDS of 7430 mg/l), to brine, (TDS of 59118 mg/l), of mixed origin from meteoric water and connate water, of variety of pH value (6.75-8.89) from weak acidic to alkaline. Its type is Na-SO_4-chloride and anions are ordered as rCl > SO_4 > HCO_3, whereas cations ordered as rNa > Ca > Mg. This type of water is associated with open system reservoir, influenced by percolation of surface water and consider as bad zone for preservation of hydrocarbon accumulations especially in Albufudhul and north east limb of Nukhaila domes, while Allas dome considered as closed system reservoir, which is a good zone for preservation of hydrocarbon accumulations.

Keywords: Formation water, Salinity variation, Hemrin oilfield, Structural control, PCI Geomatica, lineaments extraction. Kirkuk, Iraq.

Introduction
Hemrin oilfield is one of the important oilfields in northern Iraq; it consists of three domes (Albufudhul, Nukhaila and Allas) from NW to SE [1]. This field produces the petroleum from main Tertiary reservoirs (Euphrates, Jeribe and Dhiban formations). The formation water produced from these domes reflects high variety and differences in chemical and physical properties from dome to another. This research done by analyzing the structural interpretations of available satellite images of Hemrin structure to detect a possible meteoric water percolation effect on the properties of the formation water. In addition, the hydrochemistry of water was studied to identify water origin and to determine its quality. Formation water is natural water presents in pores and holes of the reservoir rocks before water injection to maintain the reservoir pressure [2]. Formation water can be classified into three groups based on the variations in its source and composition. The three groups generally identified are meteoric water, connate water and mixed water. Meteoric water is the water recently involved in atmospheric circulation and percolated downward. It forms a small part of geological period when compared with the age of surrounding rocks [3]. The presence of carbonate, bicarbonate, and sulphate in formation water suggest that at least some of the water had probably come from the surface [4]. Connate water is the water that trapped in pores of sediments or other rocks during depositions; this water has been out of contact with the atmosphere since its deposition [5]. Most of the formation waters are brines, characterized by an abundance of chloride, and they often have concentration of dissolved solid many times greater than old water. This mean if the dissolved mineral content of the ancient sea was approximated the same as that of present sea, that original water has acquired some additional mineral matter since it entered the rock [4]. Formation water analysis that contain chloride and sulphate, carbonate - bicarbonate are meteoric connate mixed that may occur near the present ground surface or may be found below unconformities [6].

The study area covers Hemrin oilfield with its three domes (Albufudhul, Nukhaila and Allas). It lies within Saladdin governorate boundary, approximately 35 km NE Tikrit city and about 80 km to SW Kirkuk city, within the foothill zone which is part of the unstable shelf of Iraq [7]. Hemrin oilfield is an anticline that extended NW-SE from Al-Fatha gorge where Tigris River passes near its northern plunge to its southern plunge near the region of intersection of Al-Adhaim River with the fold and long more than 70 km and average width between (4-7) km (Fig. 1). The land surface rises gradually from southeast to northwest to a maximum elevation of 505 m above sea level (Fig. 2).

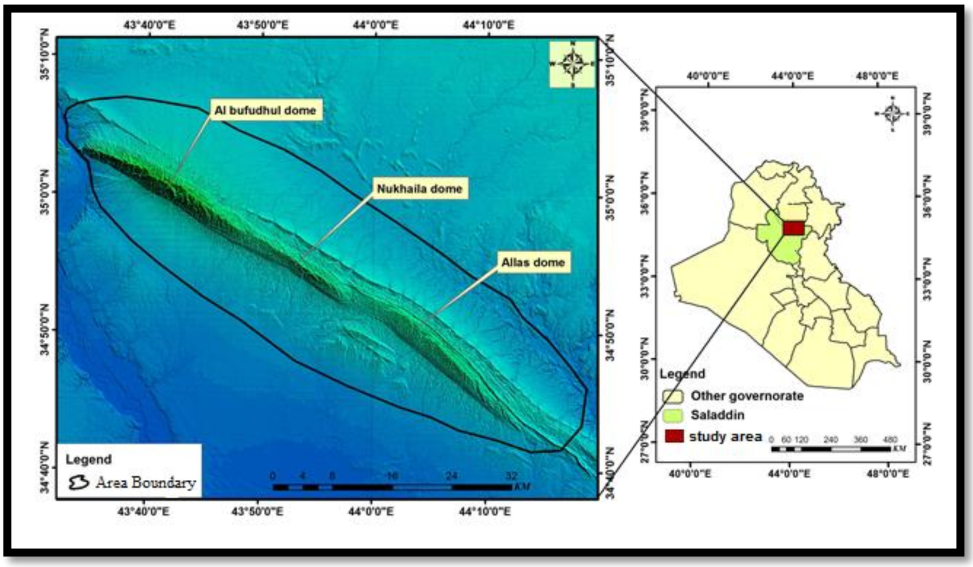

Fig. 1: Location of study area

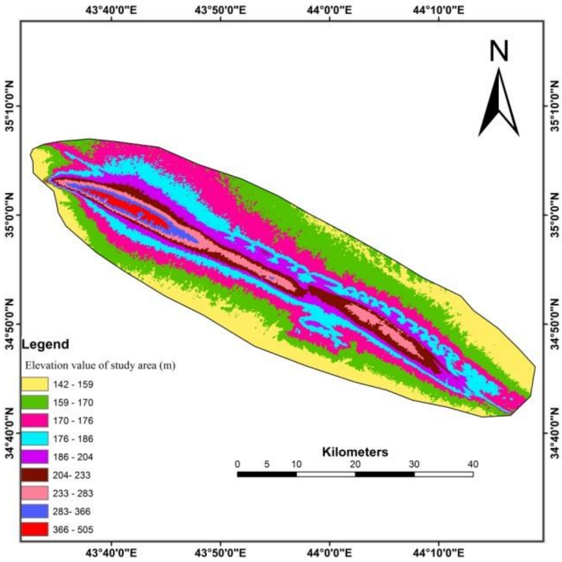

Fig. 2: Elevation map of study area generated from DEM data (resolution 30 m).

The chemical and physical properties of the formation water play an important role in field development and planning, and quantifying reserves as well as calculation of completion costs including casing and surface equipment costs. Formation water analysis helps operators to estimate expenditure such as the costs of water injection. Finally resistivity of formation water that depends on the salinity represent one of important parameters of computer processed interpretation of the logs that used in static and dynamic modeling of the reservoir. Both chemical and physical analyses of the formation water show a very wide salinity variation across Hemrin oilfield. This study will focus on the role of the structural control (e.g. fracture system and fold geometry) on the variations in formation water salinity.

The study aimed to:

1. Analyze the lineament characteristics that have structural origin, and their impact on formation water recharge and salinity variation.
2. Assess the chemical and physical properties of formation water in Hemrin oilfield.
3. Determine the origin of formation water.
4. Determine the factors that control the salinity variation in the formation water in the studied field and describe the relationship with structural background of the field.
5. Separation of domes production according to formation water background.

Geological background

Hemrin north anticline which contains Hemrin oilfield is asymmetrical, doubly plunging anticlines; the southwestern limb is steeper than the northern one. This steepening is well displayed by the outer cycles of evaporatic sequence [8]. The southwestern limb is small and high dip (50°-70°) while the northeastern limb is longer and with low dip (10°-15°) [8]. Hemrin structure consists of three domes from NW to SE (Albufudhul , Nukhaila, Allas). Albufudhul dome is separated from Nukhaila dome by Darb Almilh saddle while Nukhaila dome is separated from Allas dome by Nukhaila saddle [1]. The fractures system here is divided by two types according to the genetic classification of fractures [9] and [10], the two sets are; (ac) which is towards (NE-SW) and parallel to dip of beds and perpendicular on anticline axis, and the set (bc) is (NW-SE) and parallel to the anticline axis. The (ac, bc) sets are perpendicular on bedding plane, and intersection with other planes in vertical angle to form orthogonal fracture system. Shear fractures that form 3 systems conjugate shear fracture. System (hol) acute (a), system (hol) acute (b), system (hko) acute (c).

Stratigraphically, many sedimentary sequences are exposed in the study area, with age ranged from middle Miocene to Recent (Fig. 3). The oil field formations are described, from oldest to youngest as following:

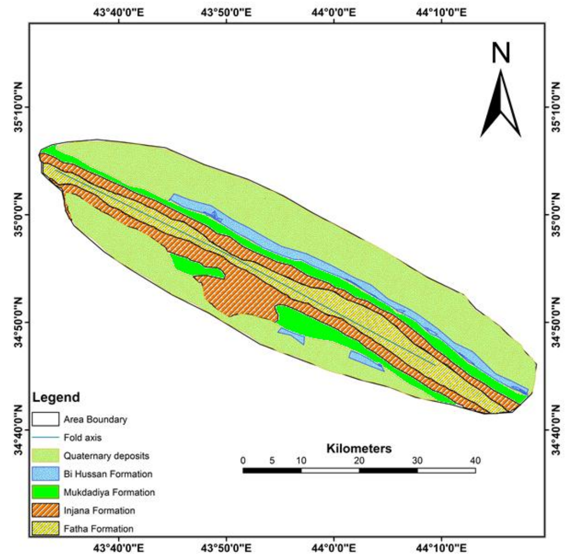

Fig. 3: Geological map of study area (modified from AlNaqib, 1959)

1. Euphrates Formation

It is comprises of 60.5 meter of shelly, chalky, well bedded recrystallized limestone, with intercalation of thin layers of marl and anhydrite. The age of the formation is early Miocene and was deposited in shallow marine environment dominated by reefs and lagoons [11]. In northern Iraq, the formation is interfering the Serikagni and Dhiban formations. It is mainly consists of limestone. The average thickness of Euphrates Formation is between 70-60 m [12] and it represents the main oil reservoir in Hemrin oilfield.

2. Dhiban Formation

It comprises 49 m of white, massive to bedded anhydrites with subordinate grey to buff, dense, occasionally shelly, dolomitic limestone. The age of formation is detected in the middle Burdigalian (early Miocene) and it was deposited under dry conditions resulted by sabkhas and saline environment. Dhiban Formation considered as complementary oil reservoir to Euphrates and Jeribe reservoirs within Hemrin oilfield.

3. Jeribe Formation

It is comprises 64m of grey, porous, slightly marly, occasionally anhydritic and shaly recrystallized limestone. The age of formation is early middle Miocene and its depositional environment was dominated by lagoonal (back reef) and reef environment [11]. This formation considered among source rocks that generating hydrocarbons in Hemrin field (Jassim and Goff, 2006). Jeribe formation may exposed on the surface in the southwest plunge of Albufudhul dome [9].

4. Al-Fatha Formation.

This formation is exposed on the surface; the maximum thickness of Al-Fatha formation reaches to 288 m and occupies the core of Hemrin north anticline. It comprises anhydrite, gypsum and salt, interbedded with limestone and marl. The age of the formation is middle Miocene and its depositional environment was dominated by shallow marine environment (lagoon) [11]. This formation forms the cap rocks for the oil reservoirs in Hemrin oilfield.

5. Injana Formation

The thickness of formation is 132 m in the study area and consists of three members. The transition member, lower claystone member and upper sandstone member. The latter two members are differentiated according to the prevalence of claystone and sandstone respectively [13]. The environment of sedimentation is mostly continental and its age is late Miocene. This formation prevails on both limbs of Hemrin north anticline. The appearance of gravel layer above Injana Formation marks the beginning of Mukdadiya formation.

6. Mukdadiya Formation

The thickness of the formation is 180 m in the study area and is exposed continuously on both limb of Hemrin north anticline. It is composed of medium to coarse sandstone with pebbly sandstone in the lower part [12]. The age of the formation is lower Pliocene and its sedimentary environment represented by a fluvio-lacustrine environment [11].

7. Bai Hussan Formation

Bai Hussan formation has coarser grain size than Mukdadiya formation and is younger in age. Bai Hussan formation consists of two members: the conglomerate member (conglomerate with lenticular beds of sandstone) and the claystone member (silty to sandy, calcareous claystone) with thickness of the formation is 137m [13]. Bai Hussan formation was deposited in a fluvio- lacustrine environment. The formation is overlain by terrace gravels and/or alluvial deposits and sometimes covered by fine grain sediments of Quaternary age [11]. The role of Injana, Mukdadiya, and Bai Hussan formations contrast on the influence on percolation of water properties through prepare dissolved salt through washing processes and transport downward to formation water.

Materials and Methods

Satellite images of the area are of the main data used in this study, they are used for the extraction of lineaments. Considering spatial resolution of the available satellite images and the extension of the study area, Landsat 8 image is selected for this study. This image has a resolution of 30 m, which can easily detects the lineaments. The Landsat 8 has eleven bands sensitive to different wavelengths Table (1). In the present study six bands used for extract lineaments, these bands detect visible (2, 3, 4), near infrared "NIR" (5), short wave infrared "SWIR 1, 2" (6,7), while other bands may not be suitable to detect the lineaments. The Landsat 8-band-5 image is selected for automated lineaments extraction because it is has a high reflection for soil and low reflection for water in comparison with other bands (Fig. 4). Digital Elevation Model (DEM) of the Shuttle Radar Topography Mission (Fig. 5) used for morphometric analysis and to create an elevation map of the study area.

Table 1: Specifications of Landsat 8 bands and wave length

	Bands	Wavelength (micrometers)	Resolution (meters)
Landsat and Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS)	Band 1 - Coastal aerosol	0.43 - 0.45	30
	Band 2 – Blue	0.45 - 0.51	30
	Band 3 – Green	0.53 - 0.59	30
	Band 4 – Red	0.64 - 0.67	30
	Band 5 - Near Infrared (NIR)	0.85 - 0.88	30
	Band 6 - SWIR 1	1.57 - 1.65	30
	Band 7 - SWIR 2	2.11 - 2.29	30
	Band 8 – Panchromatic	0.50 - 0.68	15
	Band 9 – Cirrus	1.36 - 1.38	30
	Band 10 -Thermal Infrared (TIRS) 1	10.60 - 11.19	100 * (30)
	Band 11 -Thermal Infrared (TIRS) 2	11.50 - 12.51	100 * (30)

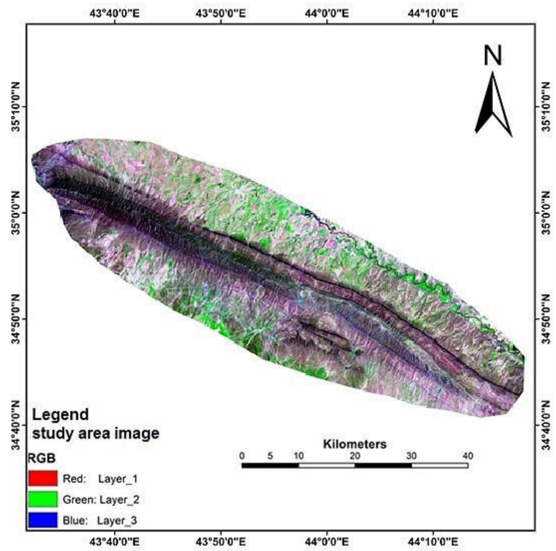

Fig. 4: Satellite image of studied area (extracted from land sat 8)

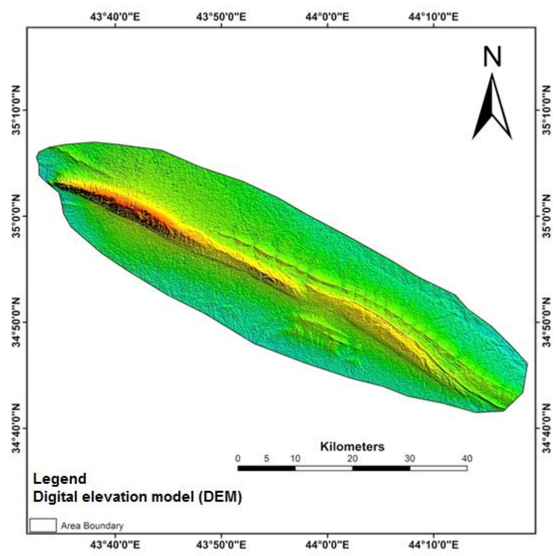

Fig. 5: Digital Elevation Model (DEM) of the studied area

The lineaments are extracted using PCI Geomatica software which consists of edge detection, thresholding and curve extraction steps [14]. These steps were carried out over satellite images under the default parameters of the software Table (2).

Table2: Parameter Entry Screen of Automatic Extraction Process

Name	Description	Values
RADI	Radius of filter in pixels	10
GTHR	Threshold for edge gradient	20
LTHR	Threshold for curve length	20
FTHR	Threshold for line fitting error	3
ATHR	Threshold for angular difference	15
DTHR	Threshold for linking distance	20

Formation water from Tertiary strata in three domes (Albufudhul, Nukhaila and Allas) were analyzed for the physical and chemical parameters, pH, TDS, major cations (Ca^{+2}, Mg^{+2}, Na^{+}) and anions (SO_4^{-2}, Cl^{-}, HCO_3^{-}). Sulin, 1946 classification used to describe the origin and quality of formation water.

Result and Discussion

Lineaments are topographic linear discontinuities in direct connection with the faults and the composite fractures, and they are associated with geomorphological features or a various tectonic structures such as faults, fractures, folds axes and lithological contacts and presumably reflect subsurface phenomena [15]. The subsurface effect is valid if the origin of the lineament is controlled by geological structures such as faults and fractures (drainage divides) or human effects (roads, field boundaries) can also exist in the region [15]. The results of automatic lineament extractions in the study area are shown in (Fig. 6). 3034 structural related lineaments have been recognized within the study area between 0°-180°. Lineaments range in length from 0.06 to 7.53 km with a mean length of 0.677 km. This lineaments pattern is interpreted to reflect the pattern of fractures. The total number of lineaments with lengths and directions are given in Table (3). Density map (Fig. 7) shows contrast lineaments in limbs and core of Hemrin north anticline.

Table 3: Number and length of lineaments in study area

Interval	Number of lineaments	Number %	Length (km)	Length %
0°-010°	255	8.4	159	7.73
010°-020°	248	8.17	171	8.32
020-030	303	9.98	213	10.36
030°-040°	326	10.74	218	10.6
040°-050°	285	9.39	195	9.48
050°-060°	198	6.52	127	6.18
060°-070°	165	5.43	112	5.45
070°-080°	125	4.11	70	3.4
080°-090°	60	1.97	45	2.18
090°-100°	130	4.28	70	3.4
100°-110°	114	3.75	60	2.9
110°-120°	165	5.43	127	6.18
120°-130°	165	5.43	141	6.86
130°-140°	150	4.94	117	5.6
140°-150°	95	3.13	60	2.9
150°-160°	60	1.97	45	2.18
160°-170°	60	1.97	45	2.18
170°-180°	130	4.28	80	3.89
Total	3034	99.89	2055	99.79

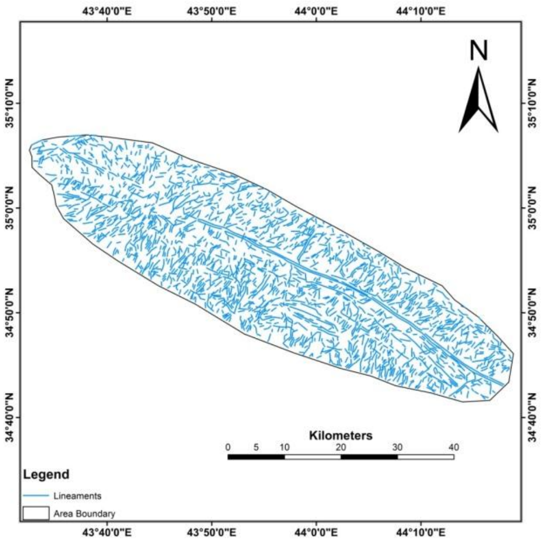

Fig. 6: Automatically extracted lineaments in the study area.

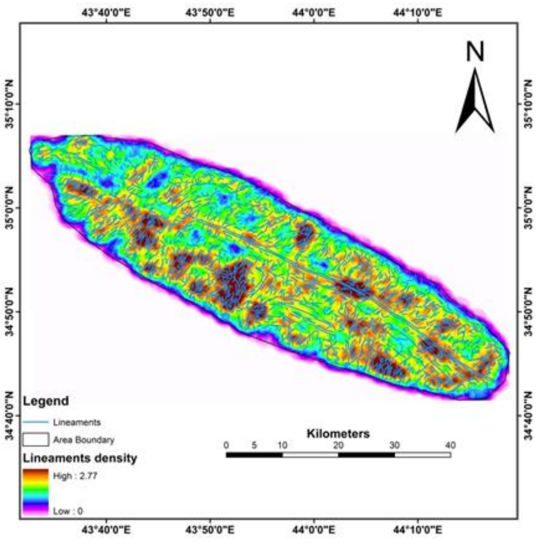

Fig. 7: Density map of study area.

Lineaments are classified into two types according to the classification of El-Etr (1974), which is based on the lengths of the lineaments; the lineaments with length less than 2 km are represented by blue color, while the lineaments with length more than 2km are represented by red color (Fig. 8). There are 2995 lineaments with lengths less than 2km which represent 98.72 % of the total lineaments, while only 39 lineaments with lengths more than 2 km, which represent 1.28 % of the total lineaments.

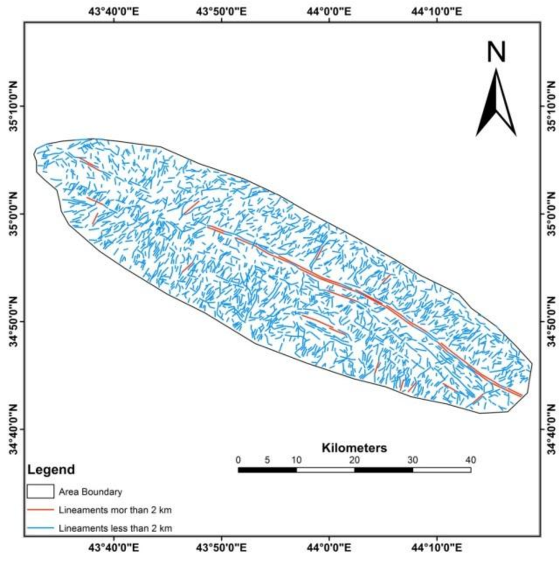

Fig. 8: Classification of Lineaments in the study area.

The orientation of the lineaments were calculated using Rockworks® V.15 software to create a "rose diagram" and identify the main prevailing orientation of the lineaments and then the effective tectonic forces in the study area. The study area is divided into three domes which represent one part, for correlations purpose (Fig. 9). The frequencies and lengths of the lineaments are instated on the rose diagram. The frequencies of three domes reflect the main trend of lineaments is highly concentrated in NE-SW direction and the secondary trends are NW-SE, which increase in Allas dome. The main trend is influence in the general direction of drainage in the east and west Hemrin anticline, which reflects the extension fracture for set (ac, bc) in studied area, while the second direction is parallel to the strike of anticline axis and resulted from the compression forces on the anticline and reflect shear fracture. The different lengths of three domes are due to different intensity of folding which is the highest in Albufudhul dome and is lowest in Alls dome, and due to surface area which reflects increased lengths of lineaments in Allas dome.

Analysis of the hydrogeological drainage network features is important, because they and their density are controlled fundamentally by the underlying lithology and structural background [16]. Morphometric analysis shows that the prevailing dendritic type of drainage patterns in the study area (Fig. 10), which is an indication for intensive structural control on drainage lines. The denser the drainage network is the less recharge rate, while less drainage density is high percolation that recharge into ground water [17]. The drainage density map of study area (Fig. 11) shows that both limbs of Albufudhul and Nukhaila domes are regions of percolation into subsurface, while Allas dome considered as a region of surface runoff.

The results of physical hydrochemical properties of formation water in Hemrin oilfield are listed in Table (4). The studied formation water shows different water quality, ranging from weakly acidic to alkaline from dome to another (pH=6.75-8.89) (Fig. 12). This could be a result of the percolation of surface water and high concentration of HCO_3^{2-}. According to TDS analysis the formation water can be classified as moderately saline (brackish) to highly saline water (brine) (TDS= 7430-59118). This value increase towards Allas dome (Fig. 13). This variation is a result of the percolation of surface water into the reservoir that led to dilute the salinity in Albufudhul and Nukhaila domes. Allas dome considered as semi impermeable for percolation of surface water bas a result of the fold geometry.

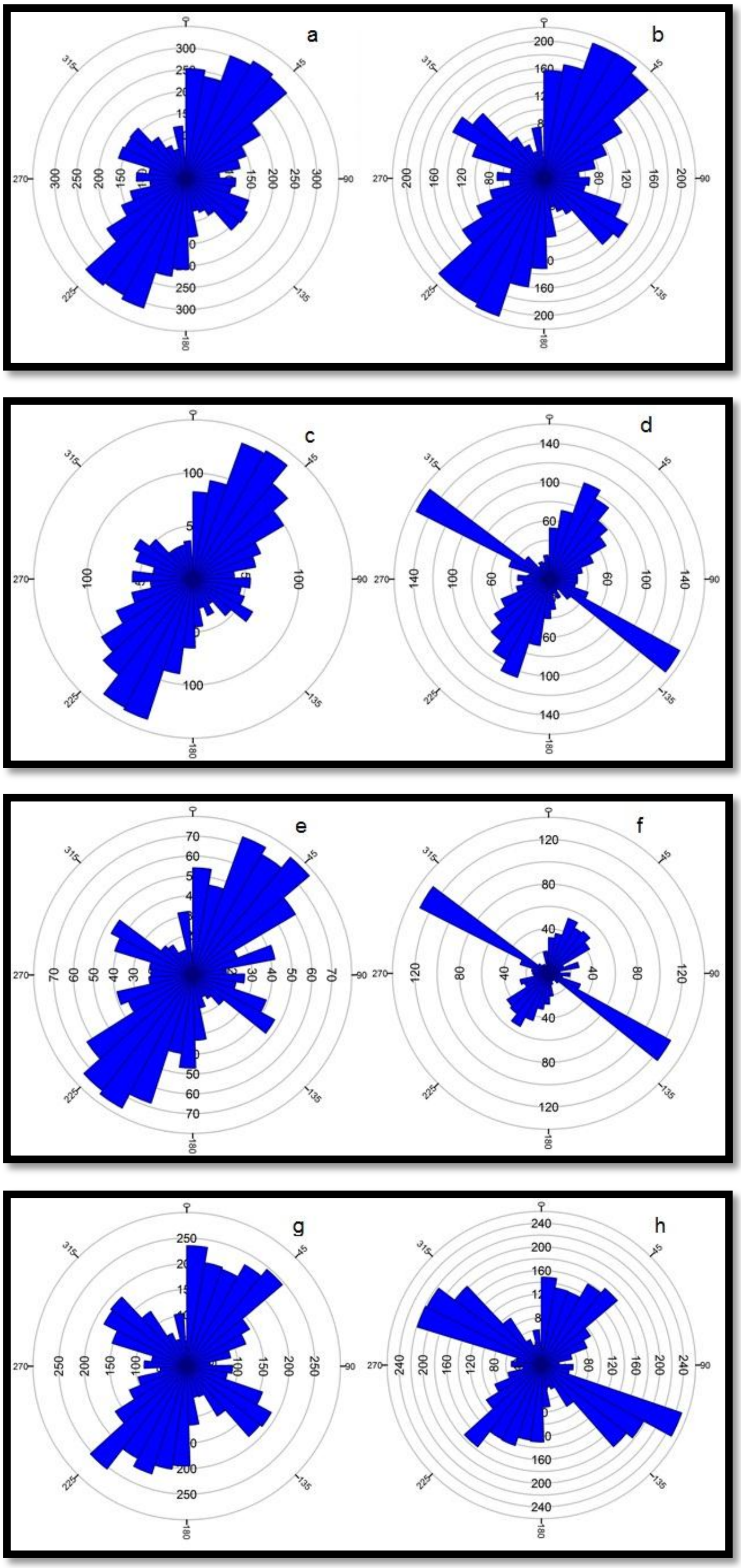

Fig. 9: Shows rose diagram analyses for the detected lineaments in Hemrin structure (a) Lineaments frequency of three domes (b) Lineaments length analysis results of the three domes (c) Lineaments frequency of Albufudhul dome (d) Lineaments length analysis results of Albufudhul dome (e) Lineaments frequency of Nukhaila dome (f) Lineaments length of Nukhaila dome (g) f Lineaments requency of Allas dome (h) Lineaments length analysis results of Allas dome.

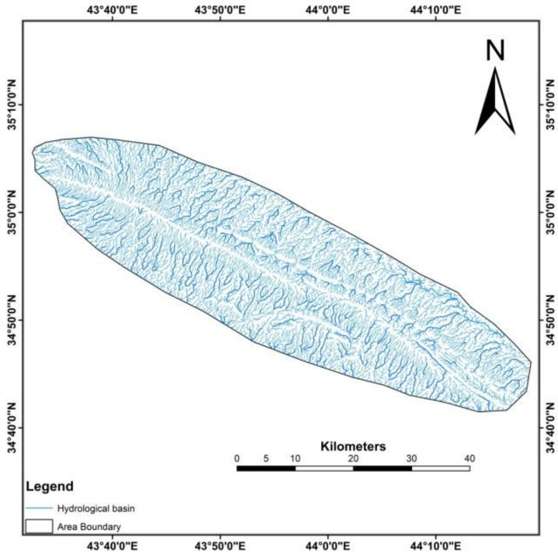

Fig. 10: Drainage network map of study area.

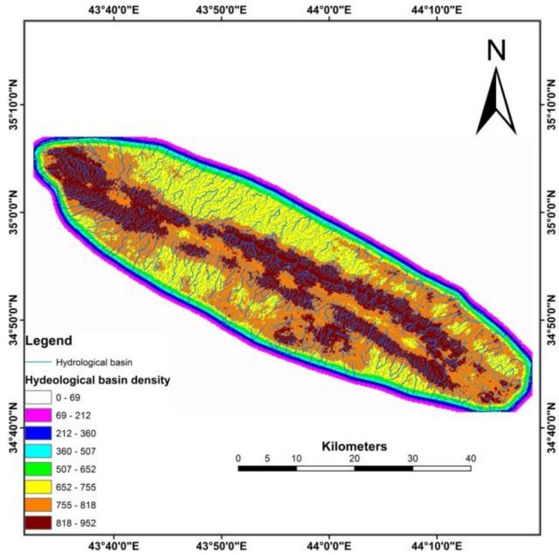

Fig. 11: Drainage density map of study area

Table 4: Physical and chemical properties of formation water in Hemrin oilfield

Dome	Formation	pH	TDS	Ca^{2+}	Mg^{2+}	Na^{+}	HCO_3^{-}	SO_4^{2-}	Cl^{-}
Albufudhul	Jeribe/Dhib	8.83	10832	720	169	2765	623	2771	3621
Nukhaila	Jeribe	8.5	9214	320	48	2541	700	2340	2485
Nukhaila	Jeribe	8.62	9175	320	97	2400	851	2121	2485
Nukhaila	Jeribe	8.81	8030	280	73	2404	588	2147	2485
Nukhaila	Euphrates	6.88	8022	340	278	1945	1793	906	2698
Nukhaila	Euphrates	6.95	8460	560	133	2117	1623	973	2982
Nukhaila	Euphrates	7.76	8219	520	169	1991	1440	1188	2769
Nukhaila	Jeribe	7.36	7430	340	278	1489	2928	342	1775
Nukhaila	Jeribe	8.29	18009	600	109	5582	529	5168	5858
Nukhaila	Jeribe	8.09	24202	1000	194	7274	651	4375	9940
Nukhaila	Jeribe	6.93	25125	880	218	7825	431	4542	10650
Nukhaila	Euphrates	7.55	11878	420	206	3156	2440	1676	3550
Nukhaila	Euphrates	6.91	12130	480	133	3316	2771	1606	3550
Nukhaila	Euphrates	7.3	13562	420	230	3405	2623	1667	3905
Nukhaila	Jeribe	8.89	24957	660	48	8070	488	6208	8875
Nukhaila	Jeribe	8.67	31687	800	194	10239	651	6236	12780
Nukhaila	Jeribe	8.55	35431	900	303	11608	478	5574	15975
Nukhaila	Euphrates	7.2	14960	440	230	4335	1342	2263	5680
Nukhaila	Euphrates	6.92	12148	400	315	3284	1830	1125	4793
Nukhaila	Euphrates	7.5	13555	560	242	3640	2174	1935	4615
Nukhaila	Euphrates	7.68	12959	600	363	3045	1539	2245	4260
Nukhaila	Euphrates	7.35	12631	660	303	3040	1596	2579	3905
Nukhaila	Euphrates	7.36	12455	640	330	2998	1769	2413	3905
Nukhaila	Jeribe	7.5	19552	1060	327	5282	1115	4365	7100
Allas	Euphrates	7	36161	920	605	11443	3318	1789	17786
Allas	Euphrates	7.13	37235	900	660	11669	2879	1858	18460
Allas	Euphrates	8.47	23729	800	48	7175	981	6209	7455
Allas	Euphrates	8.21	27013	1360	726	7123	610	6092	10650
Allas	Dhib/Euphr	8.88	24572	840	157	7421	488	4038	10118
Allas	Dhib/Euphr	8.54	49627	1437	957	15655	1891	3325	25915
Allas	Dhib/Euphr	8.59	45490	1120	533	15110	915	2926	24140
Allas	Euphrates	8.67	35019	1040	133	11291	732	6779	14200
Allas	Euphrates	8.04	56572	1840	678	18071	1408	5251	28400
Allas	Euphrates	8.26	59118	1680	775	19104	1342	5292	29998
Allas	Euphrates	6.75	49172	880	775	16765	2318	1731	25560
Min		6.75	7430	280	48	1489	431	342	1775
Max		8.89	59118	1840	957	19104	3318	6779	29998

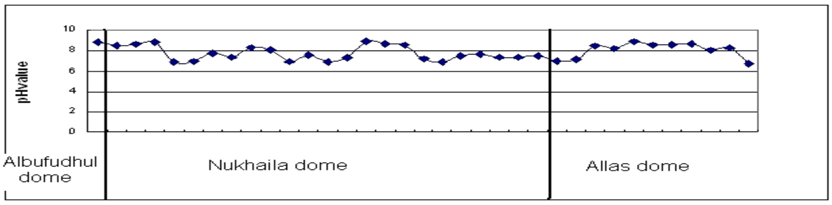

Fig. 12: (pH) value variation in Hemrin oilfield

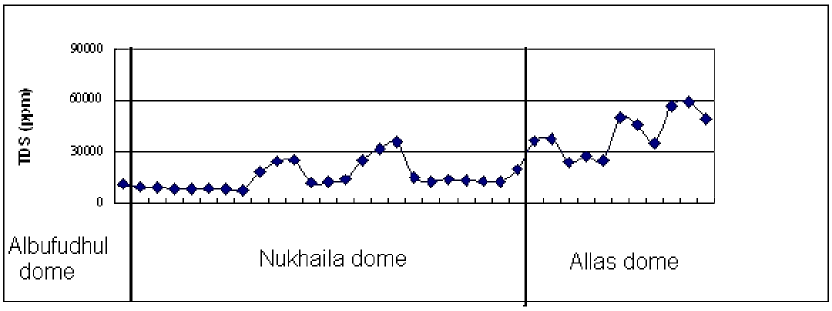

Fig. 13: Salinity variation in Hemrin oilfield

Major cations and anions including (Na^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, HCO_3^{2-}) were analyzed in the present study. Sodium is one of the most abundant ion in formation water, because it's high solubility in water and hard precipitation. The concentration of sodium in sea water reaches about 10550 ppm [18] and more than 40000 ppm in the water of some exampled oilfields in the world [2]. The concentration of sodium in studied oilfield is 1489 to 19104 ppm. It is less than of sea water (10556 ppm), due to mixing with surface water. The concentration of calcium in Hemrin oilfield is ranged from 280 to 1840 ppm, which does not occur within common range of calcium concentration in formation water as reported by [2]. This is due to dilution caused by intruder surface water.

Magnesium is the abundant alkaline earth group metal, makes up about 2.1% weight of the earth crust [2]. The concentration of Mg in Hemrin oilfield ranged from 48 to 957 ppm. The concentration of Mg^{2+} in the Hemrin oilfield is less than Ca^{2+} and Na^+ ions; this is due to the low solubility of dolomite.

Chloride is the dominant ion having highest concentration in Hemrin oilfield ranged from 1775 to 29998 ppm. This high concentration of chloride is due to the ease solubility and difficult adsorption on clay minerals. The concentration of chloride in Hemrin field is less than that of sea water (18980 ppm) [18]. This indicates that water origin is mixture of connate water with metioric water. The concentration of sulfates in the area understudy is ranged from 342 to 6779 ppm. The present of sulfate with sodium and magnesium ions impacts directly the emergence and activity of sulfate reducing bacteria, which causes oxidation of oils and convert them to heavy crudes [2]. The concentration of SO_4^{2-} under study is higher than the sea water (900 ppm), such result is an indicator on washing from the upper layers and transporting downward to formation water. The concentration of bicarbonate in Hemrin oilfield is ranges between 431 to 3318 ppm. This high concentration of SO_4^{2-} and HCO_3^{2-} in Hemrin oilfield resulted from the washing of upper layer which consists of the anhydrite, gypsum and carbonate units of Fatha Formation, which exposed in the core of the anticline.

The result of Formation water analysis in Hemrin oilfield shows gradually increasing in the concentration of the chemical and physical properties from Albufudhul dome to Allas dome (Fig. 14). This variation is due to structural control on percolation of surface water, that lead to dilute the salinity and change the formation water composition through fracture system and fold geometry. There is a very good relationship between the percolation of the surface water and fracture system represented by the lineaments in the studied area. The fractures intersections within the studied area are prevailing in two directions. The main direction is the NE-SW that perpendicular on fold axis, while the secondary direction is the NW-SE that increasing in Allas dome (Fig. 9). The main direction is prevailing with subsurface vertical faults between three domes. The vertical fault near Nukhaila dome and SW limb of Albufudhul dome is control the salinity variation and formation water properties, through playing as conduits for percolation of the surface water. This lead to dilute the salinity and change the formation water properties from Albufudhul to Nukhaila domes. The vertical fault between Nukhaila and Allas domes considered as semi impermeable for percolation of the surface water according to dome geometry. Because this fault, Allas dome considered as semi closed system on Albufudhul and Nukhaila domes which lead to increase the salinity and dissolved material of formation water (Fig. 15).

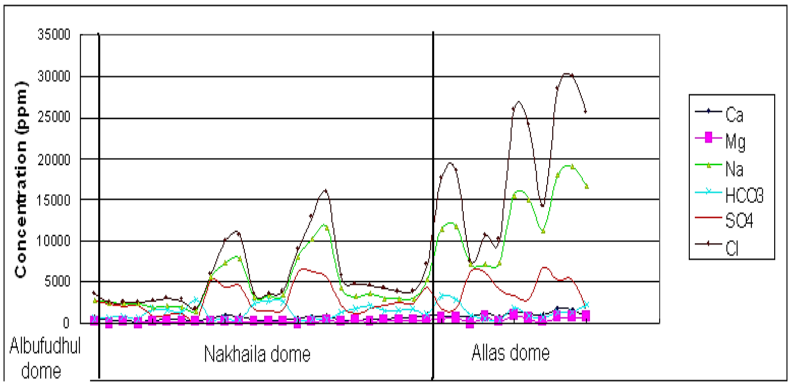

Fig. 14: Chemical properties variation in Hemrin oilfield

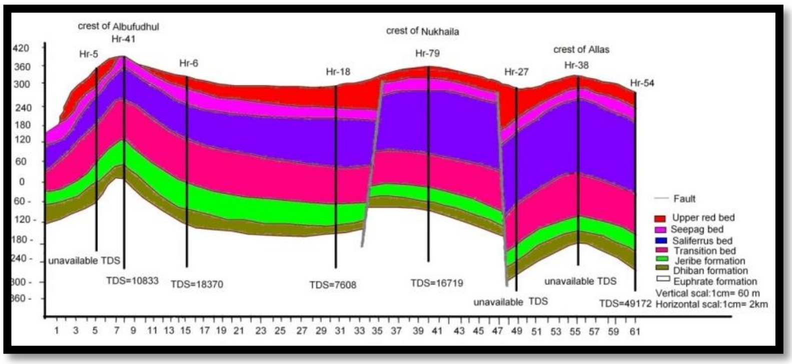

Fig. 15: Longitudal geological cross section along Hemrin oilfield

Origin of formation water:

The origin of formation water in Hemrin oilfield was determined based on hydrochemical ratio rNa/rCl that ranged from 0.931 to 1.57, with an average value 1.19. According to Sulin, 1946, it seems to be that the formation water in Hemrin oilfield is mixed water between meteoric water and connate water Table (5). The hydrochemical ratios rNa/rCl and rCa/rMg decreased with increasing salinity, while the rCl/rMg increased with the increasing salinity [19]. The hydrochemical ratio rNa/rCl and rCa/rMg shows an increase toward NW Hemrin oilfield, while rCl/rMg shows an increase towards SE Hemrin oilfield. Table (5) shows the following predominant feature: (1) prevailing SO_4-Na water type that reflect the following (a) effect of anhydrite and gypsum units of Fatha formation that represent the source of ($SO_4^{=}$), (b) effect of saliferous bed composed mainly of salt bed (NaCl) that may represent the high percent of Na.(2) Meteoric origin for Nukhaila dome, while Allas dome shows high percentage of marine origin.

Table 5: Hydrochemical ratio of Formation water in Hemrin oilfield

Dome	Formation	rCl/rMg	rCa/rMg	rNa/rCl	rCl-rNa/rMg	rNa-rCl/rSo4	Water origin	Water type
Albufudhul	Jeribe/Dhib	7.34	2.78	1.17	-1. 3	0.314	Meteoric	SO_4 – Na
Nukhaila	Jeribe	17.7	4.04	1.57	-10.23	0.829	Meteoric	SO_4 – Na
Nukhaila	Jeribe	8.78	2	1.48	-4.29	0.629	Meteoric	SO_4 – Na
Nukhaila	Jeribe	11.68	2.32	1.49	-5.74	0.771	Meteoric	SO_4 – Na
Nukhaila	Euphrates	3.32	0.74	1.11	-0.37	0.450	Meteoric	SO_4 – Na
Nukhaila	Euphrates	7.68	2.55	1.09	-0.72	0.393	Meteoric	SO_4 – Na
Nukhaila	Euphrates	5.61	1.86	1.108	-0.61	0.343	Meteoric	SO_4 – Na
Nukhaila	Jeribe	2.18	0.74	1.293	-0.64	2.06	Meteoric	HCO_3 – Na
Nukhaila	Jeribe	18.42	3.33	1.469	-8.64	0.720	Meteoric	SO_4 – Na
Nukhaila	Jeribe	17.56	3.12	1.128	-2.25	0.395	Meteoric	SO_4 – Na
Nukhaila	Jeribe	16.75	2.44	1.132	-2.22	0.422	Meteoric	SO_4 – Na
Nukhaila	Euphrates	5.9	1.23	1.37	-2.19	1.064	Meteoric	HCO_3 – Na
Nukhaila	Euphrates	9.15	2.18	1.44	-4.03	1.318	Meteoric	HCO_3 – Na
Nukhaila	Euphrates	5.29	1.1	1.344	-2.006	1.093	Meteoric	HCO_3 – Na
Nukhaila	Jeribe	63.38	8.33	1.402	-25.49	0.779	Meteoric	SO_4 – Na
Nukhaila	Jeribe	22.58	2.5	1.235	-5.31	0.653	Meteoric	SO_4 – Na
Nukhaila	Jeribe	18.08	1.8	1.12	-2.17	0.467	Meteoric	SO_4 – Na
Nukhaila	Euphrates	8.46	1.16	1.17	-1.49	0.601	Meteoric	SO_4 – Na
Nukhaila	Euphrates	5.21	0.77	1.056	-0.29	0.326	Meteoric	SO_4 – Na
Nukhaila	Euphrates	6.53	1.4	1.229	-1.501	0.741	Meteoric	SO_4 – Na
Nukhaila	Euphrates	4.02	1	1.102	-0.41	0.262	Meteoric	SO_4 – Na
Nukhaila	Euphrates	4.42	1.32	1.2	-0.88	0.411	Meteoric	SO_4 – Na
Nukhaila	Euphrates	4.05	1.17	1.18	-0.74	0.404	Meteoric	SO_4 – Na
Nukhaila	Jeribe	7.44	1.96	1.147	-1.09	0.324	Meteoric	SO_4 – Na
Allas	Euphrates	10.08	0.92	0.992	0.079	- 0.106	Marin	Cl – Mg
Allas	Euphrates	9.6	0.82	0.974	0.24	- 0.340	Marin	Cl – Mg
Allas	Euphrates	53.24	10.10	1.48	-25.77	0.787	Meteoric	SO_4 – Na
Allas	Euphrates	5.03	1.13	1.03	-0.15	0.074	Meteoric	SO_4 – Na
Allas	Dhib/Euphr	22.10	3.24	1.13	-2.89	0.444	Meteoric	SO_4 – Na
Allas	Dhib/Euphr	9.28	0.91	0.931	0.63	- 0.723	Marin	Cl – Mg
Allas	Dhib/Euphr	15.53	1.27	0.965	0.54	- 0.389	Marin	Cl – Mg
Allas	Euphrates	36.61	4.74	1.22	-8.27	0.641	Meteoric	SO_4 – Na
Allas	Euphrates	14.36	1.64	0.981	0.27	- 0.137	Marin	Cl – Mg
Allas	Euphrates	13.27	1.31	0.982	0.23	- 0.138	Marin	Cl – Mg
Allas	Euphrates	11.31	0.68	1.011	-0.12	0.228	Meteoric	SO_4 – Na

Conclusion

From the present study of structural control on salinity variation and origin of formation water in Hemrin oilfield, the following can be suggested:

1. The classification of lineaments shows prevailing short lineaments (less than 2 km) which reflect fracture (joints) within surface sedimentary cover; as well as it shows the influence of basement fault on the study area, from high frequency of lineaments.
2. The frequency and length rose diagrams of the lineaments in the study area showed two major systems of fractures, the first system occur in NE-SW direction. The second system of fractures in NW-SE directions, the lineaments interpreted on satellite images represent surface traces of deep fractures probably on the basement rocks. The analysis of the frequency and length rose diagram of the lineaments showed that the NE-SW direction is the primary direction in the study area which is the same direction of the drainage pattern while the second system NW-SE is the same direction of the strike of Hemrin anticline.
3. Lineaments intensity are prevailing with drainage pattern, so form conduits for percolation of the surface water in Albufudhul and Nukhaila domes, while in Allas dome, this lineaments play on increased the surface runoff, and form badland geomorphological feature.
4. The morphometric analysis indicates that the prevailing drainage system is the dendritic type which is an indicator for high structural and lithological control on drainage lines. The low drainage density play a role in percolation of surface water in Albufudhul and Nukhaila domes, while high drainage density in Allas dome increases the surface runoff.
5. The formation water has different pH (6.75 - 8.89). This range has a positive and negative role on petrophysical specifications of the reservoir (porosity and permeability). Thus any changing in the pH value towards the alkaline state creates problems leading to poor oil production, because alkaline water precipitates the dissolved carbonates in the pores and interstitial spaces reducing the porosity and permeability. While formation water is classified as salinity variety water from medium salinity has TDS of 7430 mg/l, to brine has TDS of 59118 mg/l.

6. The formation water in Hemrin field belongs to Na-SO_4-chlorid type, which suggests mixed origin between meteoric water and connate water.
7. Salinity variation and changes of formation water composition were resulted from percolation of surface water and interaction between water and host rocks, that controlled by structure of the three domes through fractures system and fold geometry. The vertical fault near Nukhaila dome and SW limb of Albufudhul dome has control factor on the salinity variation and formation water properties, through playing as conduits for percolation of the surface water that lead to dilute salinity and change the formation water properties from Albufudhul to Nukhaila domes.
8. The vertical fault between Nukhaila and Allas domes considered as semi impermeable for percolation of the surface water according to dome geometry, so Allas dome consider as semi closed system on Albufudhul and Nukhaila domes that lead to increase in salinity and dissolved material of formation water properties.

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التحري عن السيطرة التركيبية على نوعية المياه المكمنية في حقل حمرين النفطي ، شمال العراق ، باستخدام تحليل الظواهر الخطية والبيانات الهيدروكيميائية

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الملخص

عكست تحاليل المياه المكمنية للمكمن الثلاثي (تكاوين الفرات, جريبي, ذبان) تباين شاسع في الملوحة في حقل حمرين النفطي بين قبتي البوفضول, النخيلة, وقبة علاس. اقترحت الدراسة الحالية ان هناك سببين رئيسيين لهذا التغاير(1) اقتحام المياه السطحية التي تؤدي الى تدمير نوعية النفوط (2) التفاعل بين المياه والصخور المضيفة. استخدمت المرئية الفضائية ونموذج الارتفاع الرقمي لتحديد التراكيب الخطية والتحليل المورفومتري التي تعبر عن السيطرة التركيبية على تغاير الملوحة. الاتجاه الرئيسي للتراكيب الخطية يكون شمال شرق–جنوب غرب, الذي يكون سائد مع الفالق العمودي التحت سطحي الموجود بين قبتي البوفضول والنخيلة, حيث يلعب هذا الفالق مع الجناح الجنوب الغربي لقبة البوفضول كقنوات لتغلغل المياه السطحية (مياه الامطار) التي تؤدي الى تخفيف الملوحة وتغير تركيب المياه المكمنية من البوفضول الى النخيلة, بينما وجود فالق عمودي بين قبتي النخيلة وعلاس يكون غير نفاذ للمياه السطحية لذلك تعتبر قبة علاس نظام مغلق عن قبتي البوفضول والنخيلة, والذي يؤدي الى زيادة الملوحة. صنفت المياه المكمنية كمياه متغيرة الملوحة من المتوسطة تحتوي 7430ملغم/لتر من الاملاح الصلبة الذائبة الكلية الى شديدة الملوحة تحتوي 59118 ملغم/ لتر من الاملاح الصلبة الذائبة الكلية, مختلطة الاصل بين المياه البحرية والمياه الجوية ذات دالة متغيرة من الحامضية الضعيفة 6.75 الى قاعدية 8.89. نوع المياه هو صوديوم – كبريتات– كلورايد, اذ ترتب الايونات السالبة كما يلي كلور> كبريتات> كربونات, وتترتب الايونات الموجبة كما يلي صوديوم > كالسيوم > مغنيسيوم. هذا النوع من المياه يكون متعلق مع نظام مكمني مفتوح متأثر بتغلغل المياه السطحية حيث يعتبر نطاق سيء لحفظ الهيدروكاربون خصوصا في قبة البوفضول والطرف الشمالي الشرقي لقبة النخيلة, بينما تعتبر قبة علاس نظام مكمني مغلق لذلك تكون نطاق جيد لحفظ تجمعات الهايدروكاربون.