Basrah Journal of Scienec C *Vol.23, No. 1,10-20, 2005*

Hydrogeochemistry of Yamama Reservoir Formation Water – West Qurna Oil Field- Southern Iraq

Abdul-Mutalib H. Al-Marsoumi and Abdul-Wahab D. S.*
College of Science- Basrah University
***South Oil company**

Abstract

Six formation water samples were collected from six wells sunk inYamama reservoir formation water in West Qurna oil field. Temperature, pH, and electrical resistivity were directly measured on the spot. Then the collected samples were analysed for Na^{+}, K^{+}, Ca^{+2}, Mg^{+2}, Fe total, H_2S, Cl^{-}, CO_3^{-2}, HCO_3^{-}, SO_4^{-2}, and Total Dissolved Salt (T.D.S). The formation waters under study are characterized by their acidic medium (pH=5.88) and thermal nature (97-115°C) and low resistivity. The hydrochemical study suggests that the Yamama formation waters be of Na-Ca-Chloride type. This type of water reflects the marine origin and subjection to diagenesis processes, further more, the hydrochemical ratios indicate the expected west ward flow of Yamama formation water in West Qurna field, besides, the relative stagnant conditions favorable for hydrocarbon preservation.

هيدروجيوكيميائية مياه تكوين مكمن اليمامة – حقل غرب القرنة- جنوبي العراق

عبد المطلب حسون المرسومي عبدالوهاب داود سلمان*
كلية العلوم- جامعة البصرة
*** شركة نفط الجنوب**

الخلاصة

جمعت ستة نماذج مياه مكمنية من ستة ابار حفرت في مكمن اليمامة في حقل نفط غـرب القرنـة،درجـة الحرارة و الأس الهيدروجيني و المقاومة الكهربائية قيست موقعا ، بعد ذلك نماذج المياه حللت الى المكونـات الآتيـة: Na^{+}, K^{+} , Ca^{+2}, Mg^{+2}, Fe total, H_2S, Cl^{-}, CO^{-2}_3 HCO^{-}_3,$SO\text{-}^2_4$, and Total Dissolved salt

مياه التكوين قيد الدراسة تتميز بوسطها الحامضي (pH=5.88) وطبيعتها الساخنة(97-115°م) و مقاومتها القليلة جدا بسبب المحتوى العالي من الأملاح الذائبة التي أكسبتها ملوحة عاليــة . الدراسة الهيدروجيوكيميائية بينت أن مياه تكوين اليمامة من نوع صوديوم-كالسيوم-كلوريد الذي يدل على الأصل البحري والتعرض للعمليات التحويرية وكما دلت الدوال الهيدروكيميائية والجريان النسبي المتوقع لهذه المياه باتجاه غرب حقل غرب القرنة وكذلك توفر الظروف الملائمة لحفظ الهيدروكاربونات.

Introduction

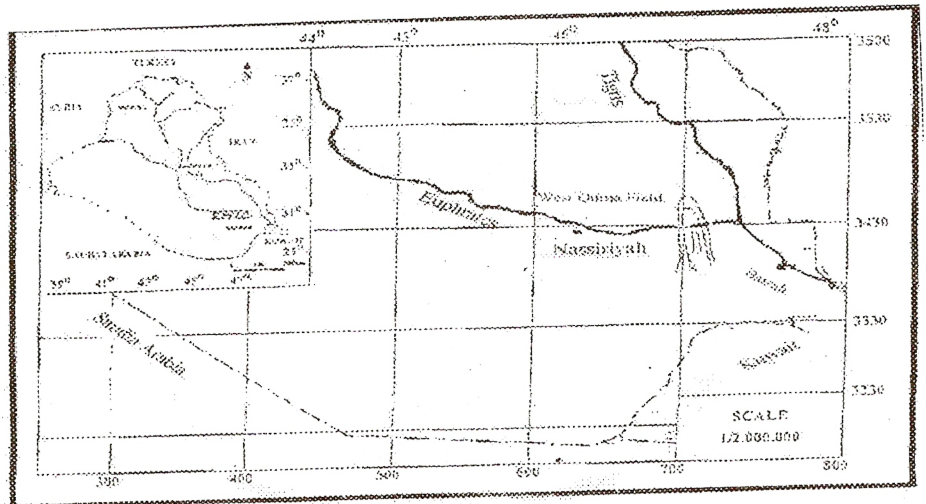
West Qurna field (WQ-field) represents one of the commonest oil fields southern Iraq. This field is located about 70 Km northwest Basrah city (Fig. 1). Previous seismic survey demonstrated that WQ- field is composed of an elongated double plunging asymmetrical anticline trending northwest-southeast. According to the tectonic subdivision, WQ- oil field occurs in Zubair subzone of Mesopotamia zone (Buday and Jassim, 1987). Yamama Formation represents one of the most widely distributed formations in Iraq and neighboring areas, it is also form one of the most important oil production reservoirs, southern Iraq that extents from Late Berriasian-Early Valanginian within the main retrogressive depositional cycle (Berriasian-Aptian) south of Iraq (Buday, 1980). Yamama Formation consists mainly of fragmental limestone with wide lateral lithological variation (Van Bellen, et al., 1959).

Hydrochemical studies give indications concerning origin, diagenesis and probable flow direction of formation water. The water flow plays an important role in accumulation and preservation of hydrocarbon compounds (Bajorski, 1970). Furthermore, Collins (1975) pointed out that the hydrochemical studies of formation water offer a valuable information dealt with hydrocarbon accumulation processes.

The present study is an attempt to delineate the hydrochemical characters and then to trace the probable direction of water flow within Yamama Reservoir of West Qurna oil field.

Methodology

To conduct the present hydrogeochemical study six fresh formation water samples were collected from six oil well sunk through Yamama oil reservoir in WQ- field Fig(1).



Fig(1) Location map.

The physical properties comprises temperature, pH, and electrical resistivity (R) were measured immediately by different techniques using portable tools. Then samples were stored under refrigeration condition. All analyses were accomplished within 3- 4 weeks of sample collection date.

Procedures for water analysis were those recommended by the Water Resources Division of U.S. Geological Survey ;Na^{+}, K^{+} were determined by Galen Kamp 400 flame analyzer , Ca^{+2} and Mg^{+2} were measured by titration using EDTA. Cl^{-} was performed by titration using $AgNO_3$, CO_3^{-2}, and HCO_3^{-} were measured by titration using HCl, while SO_4^{-2} was estimated gravimetrically as barium sulfate by titration with acid.

The precision of chemical analyses was conducted by multiple analysis of water sample, following the method suggested by Rose et al., (1979) and were within the acceptable value at both confidence level of 95% and 63%, and the applied methods are of high analytical accuracy. The correlation coefficient also calculated for the gained raw data.

Results and Discussion

Physical and Chemical Properties

The results of physical properties besides the concentration of the determined major ions of the Yamama formation waters were listed in Table(1).

Hem, (1985) showed that the color of the ground water ranges between pale yellow to dark brown depending upon their organic matter contents. The reservoir waters understudy varies between pale brown to dark brown due to the presence's of hydrocarbon materials .The releasing of dissolved gases (Methane and Ethane) at the ground surface, acquire the reservoir water understudy special odor. According to Hamil and Bell (1986), its believed that the presence of suspended hydrocarbons and the oxidation of dissolved ferrous iron to insoluble ferric hydroxides were responsible for the turbidity of the present formation water.

The formation water under study exhibited high degree of turbidity due to the occurrences of hydrocarbon materials. Moreover, these waters are thermal(97-115°C) and characterized by their acidic medium (pH=5.88). Based on Morad (1998), this result could be attributed to the high contents of HCO_3^- and CO_2 in Yamama reservoir water. On the other hand, the absence 0f CO_3^{-2} ion in the formation water under study supports this conclusion.

Total dissolved salts (TDS) are considered as standard qualitative evaluating parameter for water quality. The results of chemical analysis revealed that the examined formation water in the studied wells showed very high content of TDS (average = 152267ppm). These waters were classified as excessive saline water according to Richard (1954) cited in El-Ghandour et al.,(1983). Moreover, there is an eastward decreasing of water TDS content in the WQ-field, which could relate to the mixing with injection water.

The electrical resistivity (R) variations are important for interpretation of water saturation, which in turn affect the estimation of total amount oil contained in the field (Smalley et al., 1995 in Salman, 2003). The present waters samples exhibit very low R value (0.0415-0.0989 ohm), which attributed to the high TDS value (Table, 1).

Major cations and anions measured in this study were listed in Table (1). A compilation of water analysis from six water samples shows that Na, Ca, Mg, Cl and SO_4 form over 90% of the TDS. The high TDS value together with the low resistivity clarify the brine nature of the analyzed water. It's worth mentioning here that the potassium concentration in the present formation waters is nil, therefore, its not discussed in this work.

Sodium is the dominant cation in sea water because of its high mobility in hydrosphere (Mason and Moore, 1982; Faure, 1998). The average concentration of this element in common oil field water is 40000 ppm. In general the concentration of sodium in formation waters depends on the lithology of the reservoir, duration of trapping, depth of reservoir, and the cation exchange reaction (Collins, 1975; Hem, 1985) .The concentrations of sodium in Yamama formation waters is higher than that of sea water (table, 2), this fact illustrates the connate origin, the prolong period of water trapping in addition to the high rate of ionic substitution.

The average concentration of calcium in the Yamama reservoir water is 13724 ppm, which occurs within the common range of calcium concentration in oil field waters as reported by Collins (1975). Moreover, Salman (2003) depicts that there is a close correlation between Ca and the salinity of Yamama formation water. The direct correlation coefficient between Ca vs. TDS($r=0.87$) proved that most of the available Ca were derived from dissolution of carbonate minerals which form the bulk of Yamama Formation.

Generally, the solubility of magnesium carbonate is grater than that of calcium carbonate and the precipitation of dolomite from solution is extremely low (Faure, 1998). Mineralogically, Yamama Formation consists essentially of calcite with subordinate dolomite (Al-Mohamed, 2002), this fact explain the low concentration of the magnesium in the water samples understudy in comparison with calcium. Dolomite appear to contribute Ca and Mg to Yamama formation water as proved by the positive correlation between those two elements(r=0.59). The concentration of Mg varies from well to another (table, 1) which probably related to the various degree of dolomite solubility. The Mg were sympathetically correlated with TDS and Ca (r=0.87), reflects that the concentration of Mg rises with the salinity.

The solubility of iron in water depends upon the pH and the oxidation-reduction conditions (Mason and Moore, 1982), the analysed water samples show low Fe contents (table,1)which implies either the low clay mineral contents in Yamama Formation or the deposition of dissolved iron as pyrite under the prevailed reducing conditions.

The formation water under consideration reveals low concentration of HCO_3 (Av.=634ppm) besides the absence of CO_3 as a result of H^+ acquisition by most of CO_3 to form HCO_3 when the pH of formation water below 8.2 (Davies and Dewiest, 1966).

Most oil field waters are brines characterized by an abundance of chloride (Levorson, 1967). The measured chloride in the water samples understudy (Av.=104524ppm) is higher than that of sea water (18980ppm) as reported by Mason and Moore (1982), such result may indicates that the original water has acquired some additional mineral matter since entered Yamama sediments.

The concentration of SO_4 in the analysed sampled ranges between 29 and 2100 ppm with an average value of 872 ppm, the high value of SO^{-2}_4 is expected since most oil field water are characterized by their enrichment with this anions (Collins, 1975). Based on Levorson, (1967), the concentration of SO^{-2}_4 in oilfield water is highly controlled by the activity of Sulfate Reducing Bacteria (SRB). The low value of SO^{-2}_4
In comparison with sea water is attributed to the dissociation of this anion with depth and activity of SRB. On the other hand, Al-Yasiri (2000) found a

close relationship between the isolated SRB and SO^{-2}_4contents in the formation water of upper sandstone member of Zubair Formation.

Table (1) Major cation and anion besides some physical properties results of Yamama Reservoir formation water in West Qurna oil field.

Wellno. / Component	1	2	3	4	5	6
T.D.S. ppm	254150	127750	175241	152360	122300	81805
CO^{-2}_3 ppm	Nil	Nil	Nil	Nil	Nil	Nil
HCO^-_3 ppm	244	549	402	244	539	1830
Cl^- ppm	191700	85200	119493	102950	79875	47925
SO^{-2}_4 ppm	29	550	550	200	1800	2100
Ca^{+2} ppm	37200	9220	14400	10800	6400	4320
Mg^{+2} ppm	2916	1458	1458	1069	1215	558
Fe total ppm	3	32.5	Nil	Nil	3	Nil
Na^+ ppm	76003	42078	58084	52443	42993	26720
H_2S ppm	33.5	Nil	119	Nil	Nil	n.a
pH	4.42	6.8	4.53	6.5	6.33	6.9
Temp.° C	115	109	105	105	101	97

n.a= not analysed

West East

Table(2):The average chemical composition of sea water, and the formation water of Yamama reservoir and other common oil fields in ppm.

Water type / Component	Sea water ++	Oklahoma +	Texas +	Los Anglos +	Present Study
Ca	400	9100	21680	20000	13724
Mg	1272	4232	2638	523	1446
Na	10556	54395	42803	48737	49720
K	380	n.a	166	1040	Nil
Cl	18980	106216	111860	80336	104524
HCO_3	140	450	330	n.a	634
SO_4	2649	768	130	n.a	872

++ After Mason and Moore, 1982

\+ After Collins, 1975

n.a not analysed

Hydrochemical ratios

rNa/rCl For WQ field ranges between o.611 and o.860 with an average value of 0.768. According to Ivanov et al., (1968) , it is apparent that the formation water understudy is of marine origin .Table(3) shows there an increase in rNa/rCl ratio in the west ward direction of WQ field which in turn demonstrates probable formation water flow in the same direction Owing to Bojarski (1970) the obtained rNa/rCl value reflects relative stagnant conditions, which favorable for hydrocarbon preservation.

rCl/rMg in Yamama reservoir waters ranges between 19.81 and 32.55 with an average value of 25.588, this ratio varies randomly through out the studied wells,Table(3), which elucidate different degree of Mg enrichments within the formation water under consideration.

Alekin,(1953) in Jamil, (1978) pointed out that rCa/rMg decreases with increases of formation water salinity and depth, the reverse case were obtained in the present study which probably related to the ionic replacement of Ca in sediment by Na in formation water .

Table (3)The hydrochemical ratios of Yamama Reservoir formation water.

Well No.	rNa/rCl	rCl/rMg	rCa/rMg
1	0.768	32.55	6.061
2	0.762	19.81	3.745
3	0.839	22.22	3.16
4	0.86	29.03	4.645
5	0.611	22.22	7.65
6	0.75	27.70	5.94

Conclusions

From the results of Yamama formation waters the following conclusions were drawn;

1- The pale brown to dark brown color of formation water is related to the presence of suspended organic matter, while the oxidation of ferrous iron to insoluble ferric hydroxide were responsible for the turbidity of the present formation water.

2- The acidic medium of the present formation water is due to high contents of CO_2 and H_2S gases.

3- The high TDS content is responsible for low R value and the Hypersaline Yamama formation water.

4- The formation water is of Na-Ca-Chloride type, which suggest the marine origin and the subjection to various degrees of diagenesis.

5- The concentration of selected cations and anions is controlled by ; the amount of TDS, oxidation-reduction conditions, long period of trapping, cation exchange capacity, and the activity of SRB.

6- Hydrochemical ratios (rNa/rCl, rCl/rMg, and rCa/rMg) indicates the probable west ward direction of water flow, various degree of Mg enrichment, and favorable conditions for hydrocarbon accumulation.

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