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Classical observations and stable isotopes for identification the diagenesis of Jeribe formation at Jambour oil Fields-Kurdistan Region-Iraq

Namam M. Salih[a], Ibtisam M. Kamal[b], and Alain Préat[c]

[a]Faculty of science, Petroleum Geosciences Department, Soran University, Soran, Kurdistan Region, Iraq;
[b]Faculty of Engineering, Chemical Engineering Department, Soran University, Soran, Kurdistan Region, Iraq;
[c]Res. Grp. – Biogeochemistry & Modeling of the Earth System, Université Libre de Bruxelles, Brussels, Belgium

ABSTRACT

Jeribe Formation in two subsurface sections were studied using samples from two wells of Jambour oil field, Kirkuk area-northern Iraq to determine its petrographical characteristics, microfacies, depositional environment, and diagenetic signatures based on $\delta^{18}O$ and $\delta^{13}C$ isotope analysis. Three main types of associated microfacies were detected: mudstone, wackestone, and packestone/grainstone. The inspected formation experienced various diagenetic processes. The well-preserved dolomitization and pressure-solution and stylolitic microstructures bring a new insight in form of the paragenetic sequence. The isotopic signature data revealed that the positive covariance of ^{18}O and ^{13}C isotopes is closely associated with infiltration of meteoric water during the mesogenesis.

KEYWORDS

Jeribe formation; Jambour oil field; petrography; microfacies; 18O and 13C isotopes

1. Introduction

The distribution of petrophysical geometry and the isotopic signatures in the carbonate rocks mainly understand the imprint of diagenetic fluids on the carbonate host rocks. Carbonate neritic rocks are commonly characterized by essential heterogeneities in the petrophysical characteristics (Lucia 1999, Moore 2001). These petrophysical heterogeneities are commonly influenced by several diagenetic processes such as: dissolution, cementation, replacement, compaction in different temperature and pressure conditions (Moore 2001). Diagenetic influences preserve as a record of fluid chemistry of different sources that is difficult to prove it only with classical observation. Carbon $\delta^{13}C$ and oxygen $\delta^{18}O$ isotopic analyses can show significant records of fluid conditions and fluid composition (Allan and Matthews 1982; Jenkyns 1995; Weissert et al. 1998) that draw a powerful tool for debriefing gaps dealing to diagenetic conditions in Jeribe Formation.

Significant events related to carbonate diagenesis are often associated with major changes in the oxygen and carbon isotopic composition of host limestone (Morse and Mackenzie 1990; Fisher et al. 2005). The oxygen isotope composition is more susceptible to diagenesis than the carbon isotope composition, which is partly due to the temperature-related fractionation seen in oxygen isotope composition (Morse and Mackenzie 1990), while $\delta^{13}C$ composition is more susceptible to global carbon cycle and co-occurring organic matter (Oehlert and Swart 2014). Ali and his team used $\delta^{18}O/\delta^{16}O$ and $\delta^{13}C/\delta^{12}C$ in the carbonate rocks of the Jeribe Formation in

CONTACT N. M. Salih namam.muhammed@gmail.com Faculty of science, Petroleum Geosciences Department, Soran University, Soran, Kurdistan Region, Iraq
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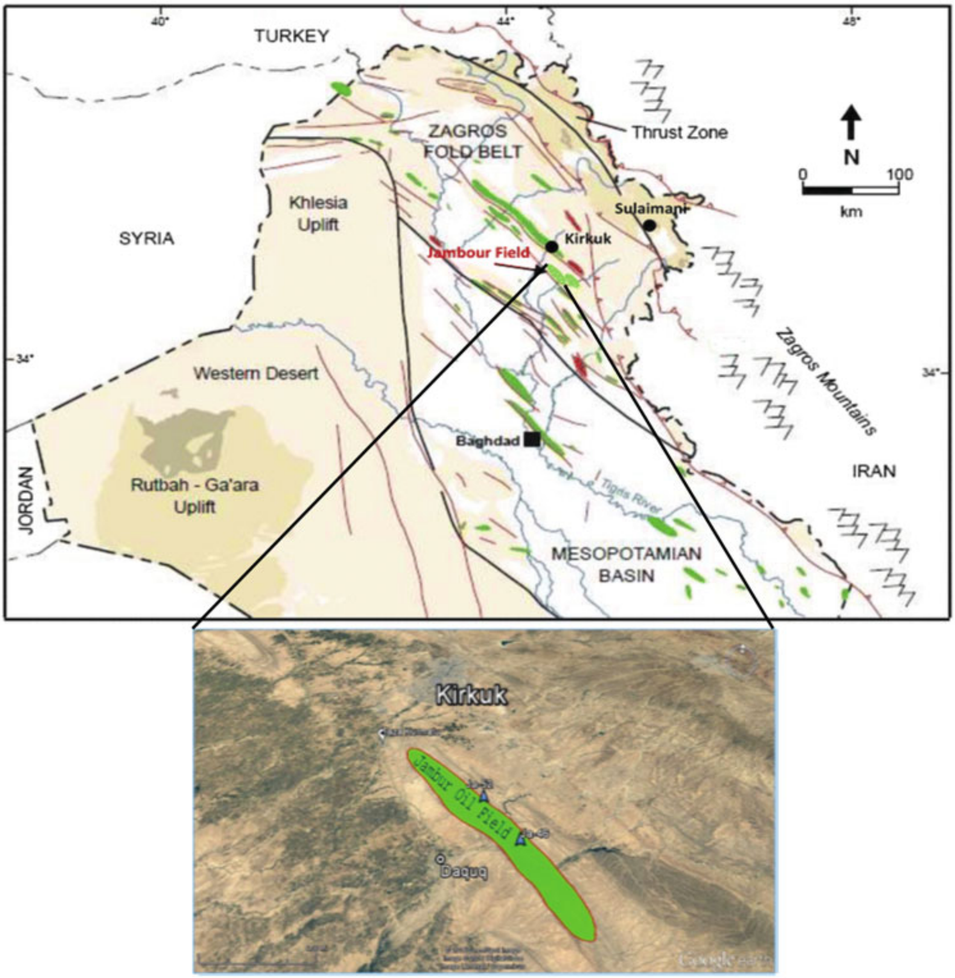

Figure 1. Map illustrating the location of Jambour oil field and both chosen sites.

eastern part of Iraq to define the paleotemperture for Neogene, which proved a cooling period during deposition of Jeribe Formation (Al-Mashaikie, and Ali 2018).

The age of Middle Miocene was identified for the formation based on genus of Orbulina (Buday 1980), the deposition was related to transgressive event (Al-Zaidy 2013). The Middle Miocene Sequence in Iraq was deposited in marine transgression during a phase of strong subsidence that overlapped the margins of the former Oligocene–Early Miocene basin (Jassim and Goff 2006). This sequence overlain by thick evaporites, carbonate, and marls of the Lower Fars Formation in the intra-shelf area (Jassim and Goff 2006). Relatively, uniform features characterize the Jeribe Formation as reported by (Buday 1980, Baban, Abdulla, and Omar 2018). It deposited in lagoons, back-reefs and reefs and sometimes in the offshore environments (Bellen et al. 1959). The formation probably records the evolution of a shallowing upward carbonate ramp sequence (Aqrawi et al. 2010; Al-Dabbas et al. 2012). It located in Jambour Oil Field (Figure 1) around 30 km southeast of Kirkuk city. Tectonically, the field is located in the Folded Zone of the Unstable Shelf (Jassim and Goff 2006).

In the current study, two wells were chosen, both located on the North-East flank of Jambour structure as shown in Figure 1. The investigated wells are Jambur-46 and Jambur-52. The horizontal distance between the two wells is about 7305 meter. The total depth of Jambour-46 is

about 2825 meter, while of Jambur-52 is about 2163 meter. The petrographical observation and stable isotopes data in Jeribe Formation were integrated and compared for the purpose of documentation the influence of diagenetic fluids on carbonate rocks, and to unravel the significant fluctuation of oxygen-carbon isotope composition, in addition to understand the diagenetic and depositional settings of Jeribe Formation in each well.

2. Methodology

The samples were collected from drilled cores at Jambur field. 55 samples have been taken from two oil wells; Jambur-46 at (1518.5–1586.5 m) depth, and Jambur-52 at (1890–1949.5 m) depth. Thin sections were prepared in Northern Oil Company-Kirkuk. 38 thin sections belong to Jambur-46, and 19 to Jambur-52 oil wells have been prepared and examined under optical microscope. A detailed lithology, petrographic, microfacies and $\delta^{18}O$–$\delta^{13}C$ isotopes analytical study were carried out based on Tucker procedure (Tucker 1996). Carbonate powders of 16 samples were reacted with 100% phosphoric acid at 70 °C using a Gasbench II connected to a Thermo Fisher Delta V Plus mass spectrometer. All values are reported in per mil relative to V-PDB (Vienna PeeDee Belemnite). Reproducibility and accuracy was monitored by replicate analysis of laboratory standards calibrated by assigning $\delta^{13}C$ values of $+1.95‰$ to NBS19 and $-46.6‰$ to LSVEC and $\delta^{18}O$ values of $-2.20‰$ to NBS19 and $-23.2‰$ to NBS18. Reproducibility for $\delta13C$ and $\delta18O$ was ±0.0x and ±0.0 y (standard deviation $= 1$) respectively.

3. Results and discussion

3.1. Lithology

A previous study demonstrated that the Jeribe Formation lithology consists of recrystallized and massive limestones in beds of 1-2 m thickness in Jebel Sinjar (Bellen et al. 1959). The authors pointed out that at the base of the formation conglomeratic beds occur. The lithology of Jambur-46 oil well at two depth ranges revealed dolomitic limestone were inspected at two depth range: (i) 1515.5 m to 1540 m, the observations show that the lithology consists of white to buff, partly brown, moderately hard fine crystalline, in places anhydritic, vuggy, caveraneous, fossiliferous, with blocky calcite cements, (ii) from 1540 m to 1586.5 m, the observations obtained revealed that the lithology consists of brown, slightly to moderately hard limestone, the latter display a fine crystalline, vuggy, caveraneous texture associated to anhydrite interbedded with blocky calcite. Regarding Jambour-52, the succession consists of slightly hard, marly limestone, partly dolomitized, sometimes fairly porous, microfractured contain irregular pyrite markings locally interbedded with white, hard calcite (Figure 2).

3.2. Petrography

The petrographic study of carbonates in Jeribe formation is carried out throughout (55) thin sections. The petrography highlights that the carbonates consist mainly of groundmass and binding grains, they are considered as an important constituent index for finding out the depositional environments and textural types (Tucker 1981). The depth of the inspected wells was 58 m and 71 m for Jambour-52 and Jambour-46, respectively. The study recognized three main microfacies types (Figure 4a–f).

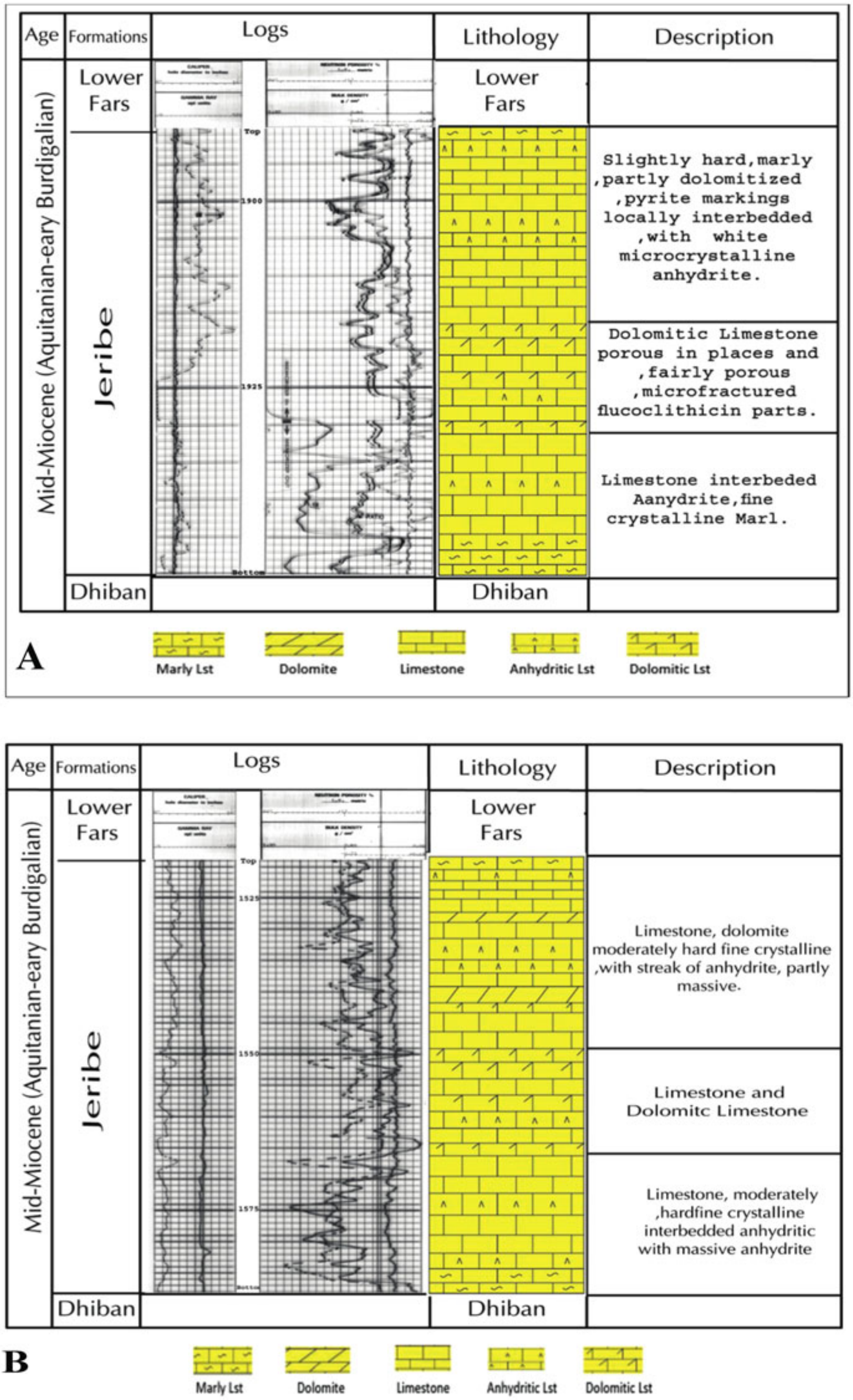

Figure 2. Stratigraphic column section of Jeribe Formation at the well-46 (A) and 52 (B).

3.2.1. Lime mudstone microfacies

This facies consists mainly of micrite which is slightly affected by recrystallization processes. It contains of gastropods, pelecypods, benthonic and planktonic foraminifers such as miliolids and

Borelis. Quantitavely, it composes of more than 40% of the limestone units and it occupies about 30% of the total thickness of the formation. This facies is common in the upper parts of the Jeribe Formation (Figure 4b).

3.2.2. Lime wackestone microfacies

The grains of this facies usually consists of skeletal and non-skeletal grains. The skeletal grain includes: miliolids, Borelis, gastropods, rotalids, green algae, dentdritina. This facies composes of more than %50 of the whole formation's thickness. The grains of wackestone range between 10 and 15 percent in a micritic matrix. The facies commonly contains pellets. It is a characteristic of shallow, open-marine environments (Figure 3a,d). The facies divided into two subtypes, the first with abundant miliolids with bivalves, gastropods and green algae mainly in the most lower and some middle parts of the formation, the second with rotalids in which their chambers are well identified.

3.2.3. Lime Packstone-Grainstone microfacies

The facies composed of both skeletal and non-skeletal grains, with miliolids, Borelis, peneroplids, gastropods, green algae, dendritina (Figure 3d). The facies characterized by predominant fossils and skeletal components (%50–60) that dominate the framework of the rocks, and leaving up to 10% of minor micrite between grain-supported limestones. The dominance of grains over micrite refers to high agitation level. This microfacies is common in the lower part of the formation, it is interpreted to indicate shoals and subtidal zones. The microfacies consists of two subtypes: lime benthic-rotallid packstone-grainstone, and lime alveolinides bioclastic packstone, displaying a strong diagenesis on the bioclasts despite the ghosts and external parts of their shapes that still can be recognized (Figure 3a).

The digenetic process is more clearly observed at the samples of Jambour-46 than the samples of Jambour-52. The skeletal and non-skeletal grains are not clearly observed in the former well and considerably altered the original composition of limestone. Fracturing, dissolution, and replacement seemed the most abundant diagenetic features occurred in both wells. These fractures were filled by calcite cements, also the dolomitizing fluid dissolved the former limestone was replaced by dolomite crystals (Figure 3a, c, e, f).

3.3. $\delta^{18}O$ and $\delta^{13}C$ isotopes signatures

The results of $\delta^{13}C$ and $\delta^{18}O$ isotopic analyses of the carbonate sections are plotted in Figures 5 and 6 and listed in Table 1. A total of 16 samples were analyzed from both wells.

In Jambour-46 section, the mapped oxygen isotopic distributions vary across the section from +1.70 ‰ VPDB to +2.53‰ VPDB, the mean value is +1.46‰ VPDB, while the $\delta\ ^{13}C$ isotopic distributions vary from −0.16 ‰ VPDB to +2.10‰ VPDB, the mean value is +1.70 ‰ VPDB. Regarding Jambour-52 section, the $\delta\ ^{18}O$ values vary from +0.20‰ VPDB to +2.92‰ VPDB, the mean value is +1.61‰ VPDB, while the $\delta^{13}C$ values vary from +0.56 ‰ VPDB to +1.73 ‰ VPDB, the mean value is +1.14 ‰ VPDB. The results confirmed that low carbon isotope values in the most lower part of both well sites (at depth 2040, 1560, 1943, 1948 m) were detected followed by significant increase of carbon isotope composition as shown in (Figure 4).

The synchronism of the new data estimated in the current work and other data from the literature confirm that the low values in oxygen and carbon isotopes are due to a diagenetic influences (Shackleton and Kennett 1975; Woodruff, Savin, and Douglas 1981; Miller and Fairbanks 1985; Miller, Wright, and Brower 1989). The fluctuation in carbon values is probably due to gain and loss of organic material (Keke et al. 2016; Xu, Ramanathan, and Washington 2016).

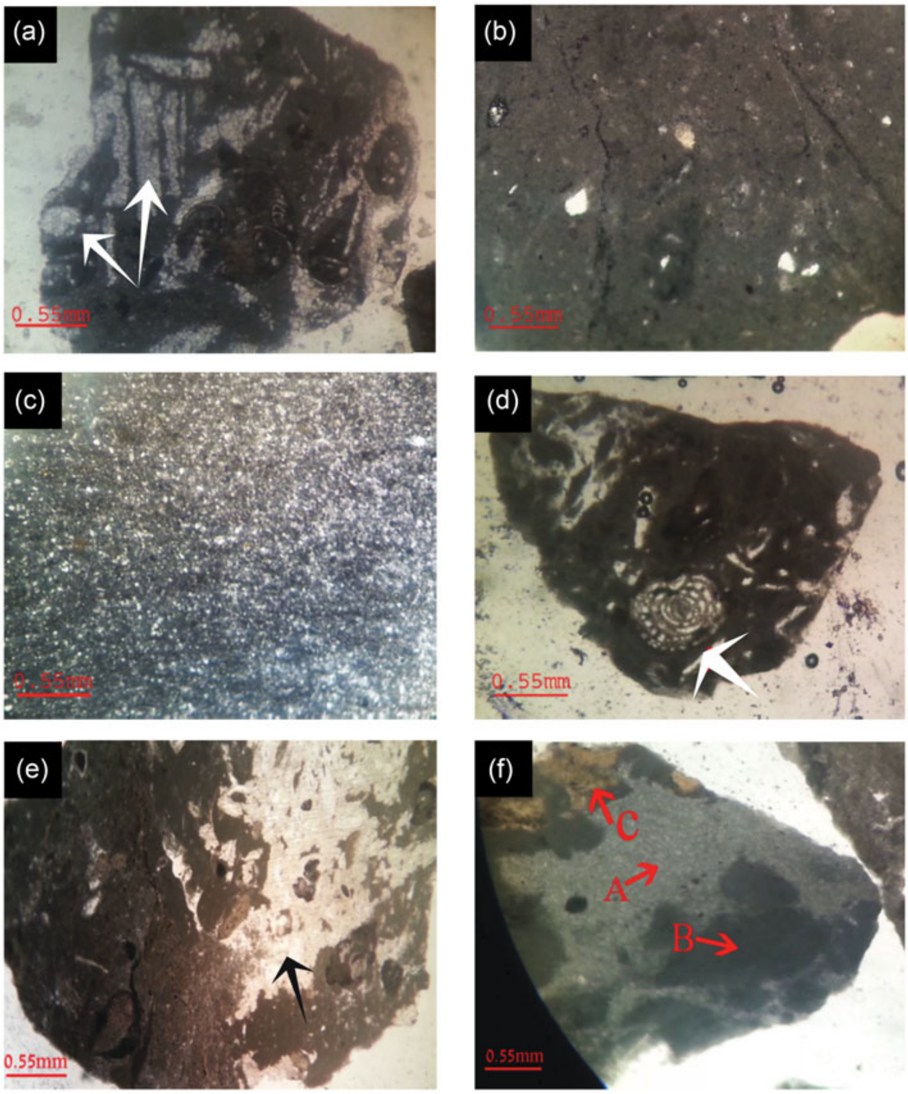

Figure 3. Plane light (a, b, c, d) photomicrographs of Jeribe Formation samples. (a) Replacement process showing the host limestone replaced by rhombohedral dolomite (see white arrows), depth 1540 m, Ja-46. (b) Stylolite feature filled by Pyrite, act as a channel to infiltrate fluids easier than in the compact grain-sized facies, depth 1972 m, Ja-46. (c) Neomorphic process, dolomitic crystals replaced the former micrite, depth1976 m, Ja-46. (d) Lime wackestone microfacies, the white arrow showing the Borelis melo, depth 1542 m, Ja-46. (e) Lime mudstone microfacies, calcite cement filling the large void space (arrow), constituted one cleavage, depth 1897 m, Ja-52. (f) Lime wackestone microfacies, the common diagenesis process is dolomitization replaced the former host limestone (arrows), depth 1935 m, Ja-52.

The results of the seven samples from host limestone are in agreement with oxygen isotopic composition of Miocene limestone values (δ^{18}O: up to +2.92‰ VPDB and δ^{13}C: up +2.92‰ VPDB). Also, they are in line with marine isotopic signatures samples from Eastern Atlantic ocean carbonates (Miller, Wright, and Brower 1989; Zachos et al. 2001).

The negative values of δ^{13}C and δ^{18}O for Jambour-46 section may be attributed to changes of chemical composition of fluids after the deposition of the host limestone, also to relative changes in sea level and to local environmental conditions (Colombié, Lécuyer, and Strasser 2011; Yan, Sun, and Liu 2012).

Table 1. Carbon- and oxygen-isotope ratios (‰ VPDB) from Jeribe Formation (Jr.52 = well No.52; Jr.46 = well No.46)

Sample	Depth (m)	δ ^{18}O	δ ^{13}C	Sample	Depth (m)	δ ^{18}O	δ ^{13}C
Jr.52-1	1890	0.90	0.88	Jr-46-1	1515.5	1.87	0.22
Jr.52-2	1896	1.42	1.73	Jr-46-2	1528	1.25	2.10
Jr.52-3	1900	0.20	1.08	Jr-46-3	1540	1.47	1.73
Jr.52-4	1905	1.82	1.69	Jr-46-4	1550	2.24	1.83
Jr.52-5	1915	0.68	1.40	Jr-46-5	1560	1.30	−0.16
Jr.52-6	1928	2.30	1.19	Jr-46-6	1571	2.53	0.66
Jr.52-7	1943	2.92	0.56	Jr-46-7	1580	2.33	1.57
Jr.52-8	1948	2.66	0.61	Sr-46-8	1586.5	−1.70	0.61

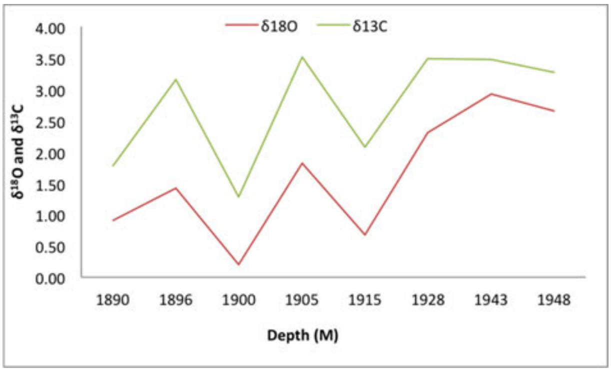

Figure 4. δ ^{18}O versus δ ^{13}C plot (Jr.52).

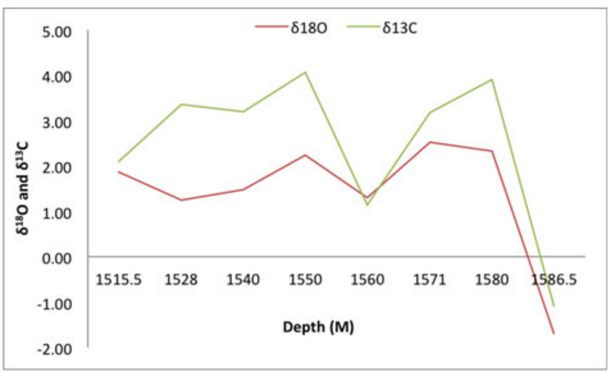

Figure 5. δ ^{18}O versus δ ^{13}C plot (Jr.46).

The results of the other nine samples revealed that the samples exhibit significantly lowered oxygen isotope values as low as −1.70‰ VPDB, while the rest seven samples show a decrease in carbon isotope toward lower values as low as −0.16 ‰ VPDB (Figure 5). The oxygen isotope composition in the basal part of Jeribe Formation at depth 1586.5 m decreases by ∼ −1‰ VPDB immediately below the lime mudstone microfacies altered diagenetically. The magnitude of oxygen isotopic value is varying at different depths in both wells. The lower oxygen isotopic values (Figures 4 and 5) could be attributed to the influences of diagenetic fluids infiltrated within the porosities of the host limestone (Hudson 1977; Price et al. 2008). The fluid-rock interaction during diagenesis mostly result in the lowering of δ^{18}O values, in contrast the diagenetic composition of these samples could be insignificantly alter the δ ^{13}C values of the rock (Hudson 1977; Dickson and Coleman 1980). Geometrically, the stylolittic fractures predate the formation of

blocky calcite and rhombohedral dolomites, hence, Jeribe succession experience a late diagenesis during burial alteration (i.e. mesogenesis).

As a consequence the lower isotopic carbon values are probably linked to organic matter (Madhavaraju, Yong, and Gonzàlez-Leon 2013) and those of oxygen values to the meteoric water line (Allan and Matthews 1982; Fisher et al. 2005; Peter and Amanda 2018). In the current study, since the decreasing values in carbon isotope composition is consistent with lowering values of oxygen isotope, therefore the positive covariance is mainly refers to meteoric water infiltration into the host limestone of Jeribe Formation during burial diagenesis.

4. Conclusion

The petrographic study of the host limestones collected from Jambour oil field of Jeribe Formation core samples (Jr.46 and Jr.52) reflects three main types of microfacies: lime mudstone, lime wackestone, and lime packstone/grainstone. The investigation shows a blocky calcite and rhombohedral dolomite cements, and these cements are products of diagenetic fluids, which were observed remarkably in the samples of Jr.46 compared to those of Jr.52. Since stylolite feature formed prior to these cements that filled by calcite and dolomite, the situation proves that carbonate rocks of Jeribe Formation were subjected to deep burial diagenesis settings. On another hand, the carbonates of Jeribe samples are significantly depleted in $\delta^{18}O$ values compared to the carbonates precipitated in equilibrium with contemporaneous seawater, while the $\delta\ ^{13}C$ values were less influenced by diagenetic processes. However, it was observed that in some samples the carbon isotope recorded low values which indicates the existence of organic matter. The petrographic pattern and the shifted of oxygen-carbon values toward lower values suggest the infiltration of meteoric water in the Jeribe Formation that has significantly altered their pristine values.

ORCID

Namam M. Salih http://orcid.org/0000-0002-5691-5205

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