ORIGINAL PAPER

Reservoir properties and seal efficiency in the Zubair Formation in Euphrates Subzone, Southern Iraq

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Abstract The lower cretaceous Zubair Formation in Euphrates Subzone south of Iraq is divided into three members. These members are divided depending on the variation in lithology. The upper and lower members, which consist mainly of shale is known as Upper Zubair Formation and Lower Zubair Formation, respectively. The middle Zubair Formation consists mainly of sandstone. Intra-formation Zubair-shale are primarily seals, as well as source rock. The gained hard and software data are loaded into GeoFrame system. A trial is done to perform the formation evaluation for Zubair Formation on available data for nine wells. The created project contains all the operation of the reservoir properties. The quality of a sealing rock from both upper and lower is determined by the minimum permeability and effective porosity (less than 80 mD and 9 %, respectively). The sealing rock of Zubair Formation is mainly the shale rocks, which is an organic-rich elastic rock that may suppose to be efficient. On the other hand, the reservoir sand facies have good petrophysical properties. The average of effective porosity was 18 %; however, the permeability is at least 250 mD. The geological setting may supports the horizontal migration of oil to the western area along Abo-Jir fault to the stable shelf successions.

Introduction

The Lower Cretaceous Zubair Formation can be considered as an important reservoir in the south of Iraq and some of adjacent countries (Ibrahim 2001) due to good reservoir properties. Zubair Formation is divided in Euphrates Subzone into three units, which are characterized by cyclic mode of deposition as will be mentioned later. It is divided into five or two units elsewhere, wherein this difference in divisions is built up on depositional environment (Idan 2012). Furthermore, the divisions of Zubair Formation in the area of interest were as follows (unpublished reports of OEC and SOC):

– Upper Zubair Formation (UZbfn)
– Middle Zubair Formation (MZbfn)
– Lower Zubair Formation (LZbfn)

The Euphrates subzone lies to the west of the Mesopotamian zone (Fig. 1), with monoclinal tilting to the NE. Euphrates Subzone is represented by relatively small to medium monoclinal folds, separated with wide synclines between them, similar to box-fold shape. These folds are with NE ward gradual oriented fault system (Jassim and Goff 2006).

The primary known reservoir rock in the Zubair Formation are the main sandstone member, in addition, may be in certain places, to the two source-seal members (Ibrahim 2001). Intraformation Zubair shale is the primary seal, which envelops the reservoirs from the same formation (Sharland

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Fig. 1 The tectonical zonation and the area of study representing by target oil fields (Al-Ameri et al. 2011)
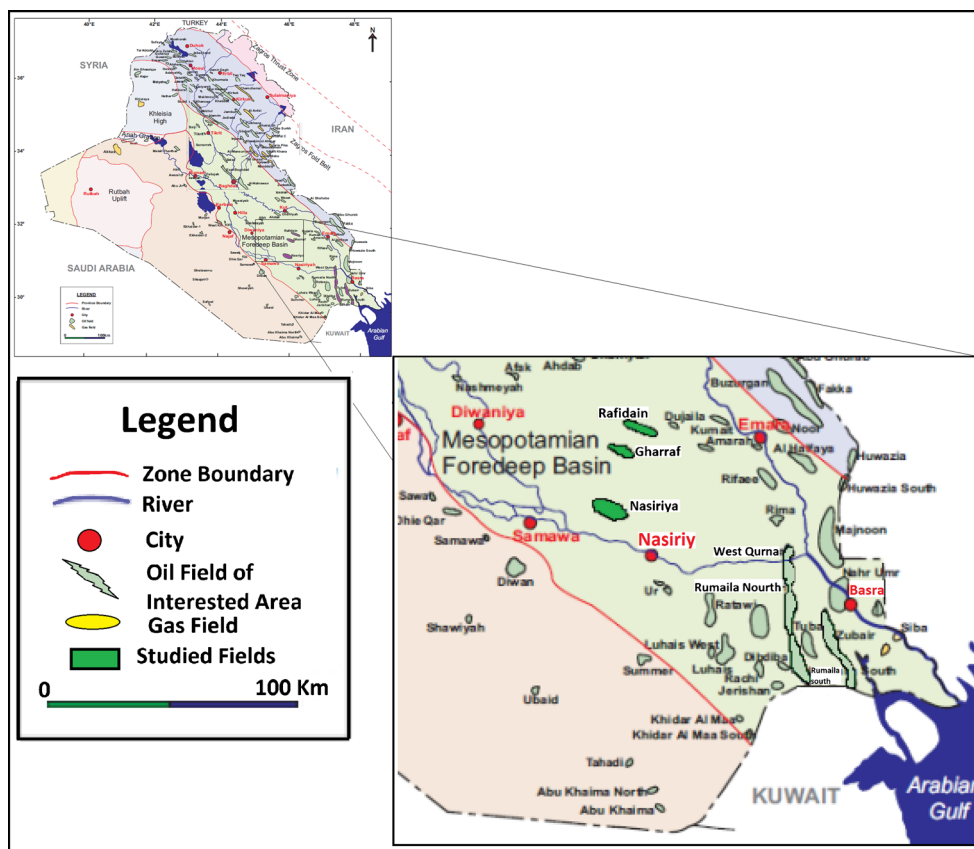
et al. 2001). The Zubair Formation is represented mainly by clastic facies sequences, while limestone is restricted to the upper part of the formation (Aqrawi et al. 2010), which represents a transgressive phase. The shale packages become thinner toward the western area of the study while the coarse clastic packages become thinner toward the eastern area (Jassim and Goff 2006). Such variation in the thicknesses must be due to progradation of the delta sand bodies.

Material and methods

A basic understanding of the reservoir properties was obtained from the analysis of the well logs (Table 1), DST tests, cutting samples, and shows, as well as plugs analyses record. These collected data are exported and loaded into GeoFrame system (Fig. 2). The aim of the present paper is to perform the formation evaluation for Zubair Formation in the study area in order to understand the following points:

- Identify hydrocarbon bearing reservoirs
- Identify average reservoir properties (volume of shale, porosity, permeability, and water saturation)

Log interpretation sequence

In order to perform formation evaluation for the studied intervals depending on available data from wells AAm_1, AAm_3, AAm_5, Ga_1, Ga_2, Ga_3, and Ns_1, Ns_2, and Ns_3 (Table 1), log interpretation and integration with other data types has been done (core analysis, DST, and composite log data), but the display is restricted on AAm_3, Ga_2, and Ns_3 for facility as follow:

- Job preparation: This is the first stage which should be made before using the computer or any software; this stage include looking for different kinds of electronic form data including wire line logs, core description, well test, mud log, and/or any kind of human-obtained geological data. Qualitative interpretation using composite log is one of the important steps of this stage; this step can help in the next work, which may help with the following:

1. Determination of sand, shale, and bad hole intervals when logging tool get stuck somewhere in the bore hole during logging operation.
2. Determination of porosity permeability and the approximate thickness to each unit.

Table 1 The availability of hard and soft data

|	Field name	Well name	X coord.	Y coord.	No. of samples	Logs availability
Euphrates Subzone	Rafidain	AAm_1	614800	3533800	67	Complete
		AAm_3	613650	3532700	69	Complete
		AAm_5	611100	3536500	69	Complete
	Gharraf	Ga_1	602200	3514516	74	Complete
		Ga_2	593300	3517300	74	Complete
		Ga_3	597200	3517500	72	Complete
	Nassiriah	Ns_1	596300	3465650		Complete
		Ns_2	591900	3467950	84	Complete
		Ns_3	598800	3466850	84	Complete

3. Calculation of the average porosity of each reservoir unit.
4. Estimation of (Rw) using different methods.
5. Determination of the approximate (Sw) in hydrocarbon zones.

- Compute true vertical depth (TVD) and TVDSS: TVD usually from the rotary table Kelly bushing (rtkb), and it is equal to the measure depth (MD). TVDSS is the true vertical depth sub-sea.
- Pre-computation (pre-calculation): The resulting curve of pre-calc are used as input data (or curves sometimes) for the next stage. The data are likely the formation temperature, calibrated Rw, and Rmf to formation temperature mud cake, thickness, and borehole problems.
- Environment correction: It is the adjustment that must be made to log measurement to bring them back to the standard conditions for which the tools are characterized, as well as different measurements requiring different

corrections (Hejooj 2009). Normally, environmental correction is run after the data are loaded and before interpretation take place. For the case under study, environmental corrections are done for the available logs to the three wells in respect to borehole size and mud weight.

- Rw determination: Formation water resistivity has been determined for the studied zones by comparing with the uses of south oil company, which is equivalent to 0.0195 at 3,000 m MD (Turkey, per. Com., 2010).
- Make a decision between clean or shale sand reservoirs: The first decision is whether to classify the reservoir as clean, which satisfies the assumption of Archie (Asquith 1990). This assumption is based on the formation that contains saline water and is free of conduction clay minerals, so there is no contribution to conduction other than the electrochemically free formation water in the pore space or as a shaly reservoir, which does not satisfy the Archie assumption (ibid).

According to above mentioned points and consideration of the depositional environments of Zubair Formation which characterized by shale–sand intercalation, the studied zones should be evaluated using the dual-water system equation which is one of non-Archie effective porosity model compatible to the Zubair Formation reservoir (cf. Hejooj 2009).

- Reservoir Zonation: The primary requirements of the zonation scheme are that the reservoir zones have to be correlatable in a stratigraphic sense. Geological zonation of reservoirs is taken to be equivalent to petro-physical segregation of lithological units, that reservoir zonation is based on lithostratigraphy only; however, this will not always be the case. Figure 3 are stratigraphic correlation cross sections, which illustrate the correlation between Ns_3, Ga_2, and AAm_3. As shown, the western parts of the formation (Nassiriah oil field) is cleaner from the eastern part (Rafidain oil field), while Gharraf oil field (in the middle distance) is in between in respect of reservoirs mud content. After that, this determination has been
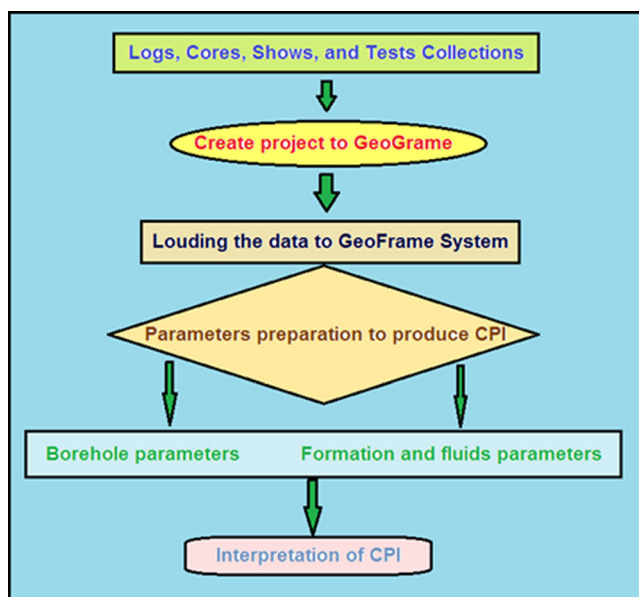
Fig. 2 Flow chart showing the steps of GeoFrame system work

Fig. 3 Major oil pays of the lower Cretaceous Zubair Formation of Nassiriah province, South of Iraq. In depth successions with logs lithology and SP
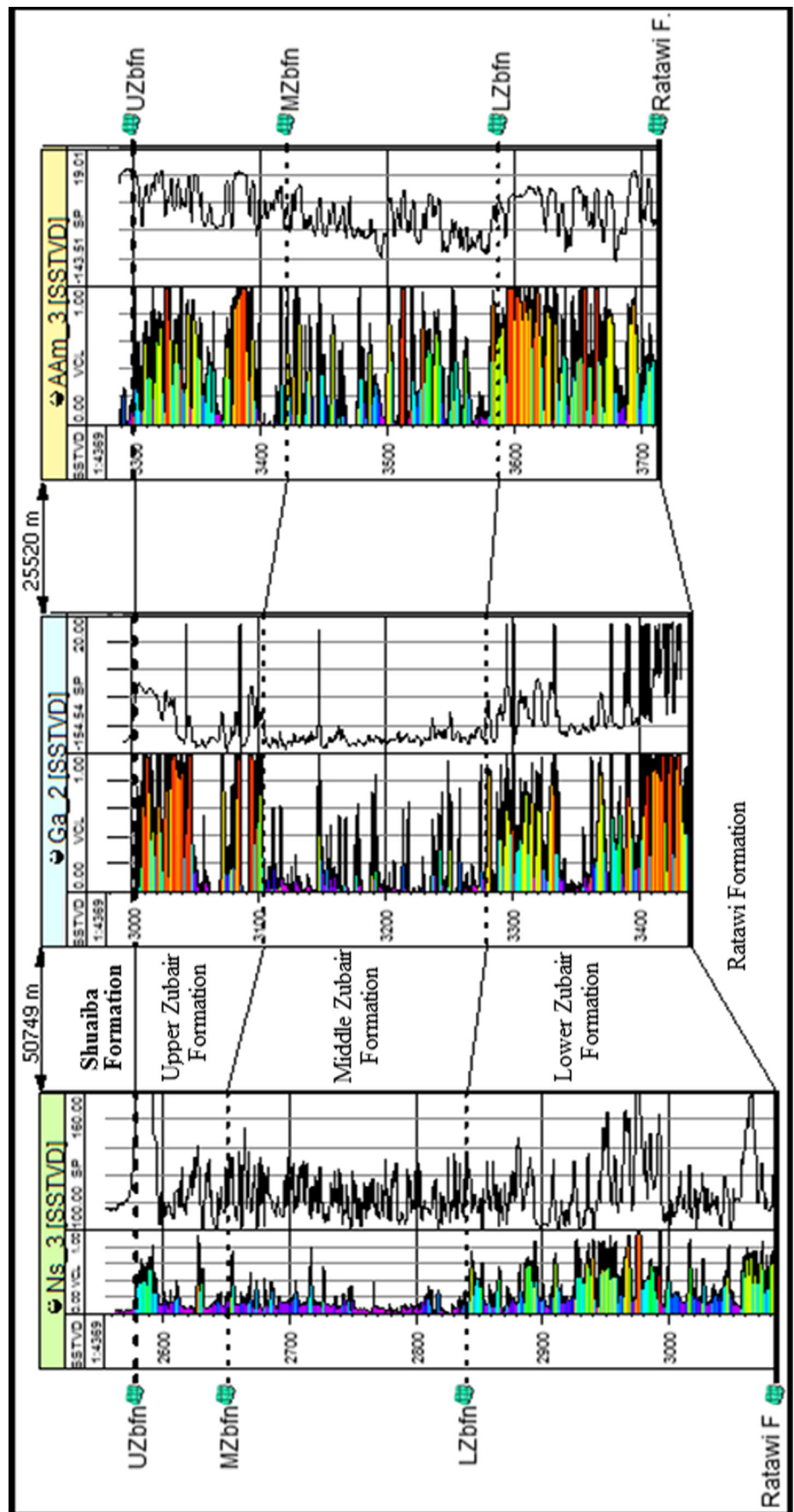
confirmed when final interpretation is reached as will be explained in the next section.

- Volume of shale (VSh) determination: Tow radioactive elements, potassium (K), and thorium (Th) tend to concentrate in shale. In contrast, shale-free sandstone (generally named as clean zones) contains very little K and Th because the chemical environment that prevails during their deposition is not favorable for the accumulation of radioactive minerals (Setyowiyoto and Samsuri 2008). However, clean sandstone (i.e., low shale content) may also produce a high gamma ray response if it contains K feldspars, micas, glauconite, or uranium-rich water. In the current study, the program evaluated the shale content depending on shale effect in log response. The used logs are mainly GR and density-neutron logs, but also shale content calculations depending on SP logs are estimated Fig. 4. Finally, VSh curves are calculated depending on corrected GR. Computing shale volume from GR depended on the GeoFrame equation processer.

- Porosity estimation: Total and effective porosities have been determined using two different methods: they are neutron-density logs and sonic log methods. In general, there is good matching between the two porosity values, one from the N-D log comparing with the porosity from the routine core analysis. The sonic porosity ranges from 18 to 30 % in the Euphrates Subzone as shown in the Fig. 4. While detailed porosity values were less than 9 % in the shale members but more than 18 % in the middle sand member.

- Permeability calculation: It was calculated in the program processer software using Timur equation as shown in Fig. 4. It cannot fail to say there is a good match between the estimated and core analysis permeability. The permeability ranges from 100 to 1,000 mD in the Euphrates subzones. In specific, the tow shale members have approximately 80 mD, while in the sand member, permeability is 250 mD at least. The three previous sections are

illustrated in the Figs. 3 and 4. The figures showed that the upper and lower parts of Zubair Formation have highly decreased in porosity and permeability and in opposite, increase in the shale content. These results may support and realize the indication of the Zubair petroleum system. This fact may be not continuous and is broken somewhere within the Mesopotamian basin.

Seal efficiency

Rocks that are seals have pore throats that are too small and poorly connected to allow passage of adjoining hydrocarbons (Downey 1994). A typical rock-sealing surface does not behave like impermeable plastic sheet but more like a fine mesh screen. There are micro and macro-sealing properties. The former is depending on the buoyancy pressure, while the later is depending on the lithology, thickness, ductility, and uniformity.

Zubair Formation, as shown in Figs. 3 and 4, have a good amount of shale volume in the upper part, which indicates good seal properties, especially the thickness of the upper and the lower Zubair Formation (over than 100 m) satisfy in this area. On the other hand, these organic-rich clastic rocks have the best properties to be seal rock in respect to lithology, ductility, and uniformity. On the above, the upper Zubair Formation is satisfying the assumption of the seal efficiency when taking into account the low permeability values.

Reservoir modeling

In order to complete the view of the reservoir extension, the model has been done in same project. The model depends on all the parameters of the input logs and output factors of the GeoFrame. In addition, the GeoFrame took into account each
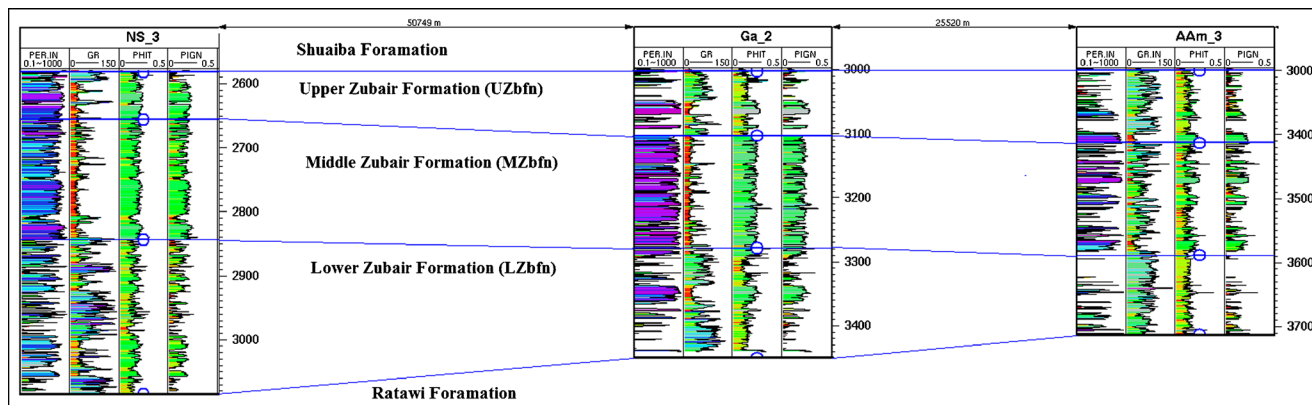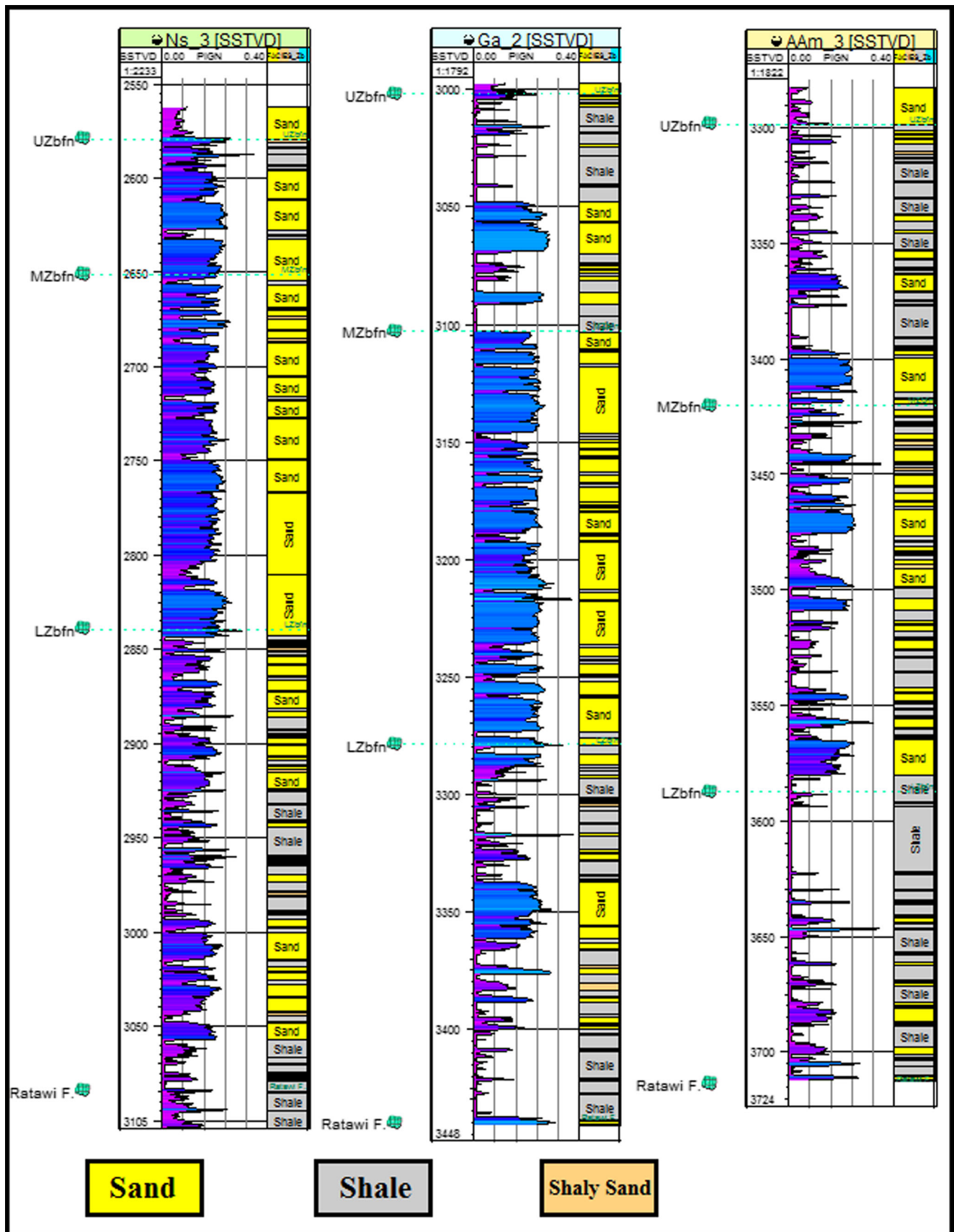

Fig. 4 Show the correlation of the reservoirs, as well as source-seal units in the Euphrates Subzone in terms of lithology, resistivity (converted to permeability), and SP (converted to porosity)

Fig. 5 The first process that divide the each formation 0.25 m in term of volume of shale, which the shale ≥40 % of shale content, sand ≤30 % of shale content, and shaly sand=30–40 % of shale content. *UZbfn* Upper Zubair Formation, *MZbfn* Middle Zubair Formation, *LZbfn* Lower Zubair Formation

Fig. 6 Show the distribution of sand, shale contents in the area of interest. **a** 2D view of the upper surface of the Zubair Formation. **b** 3D view to the whole formation
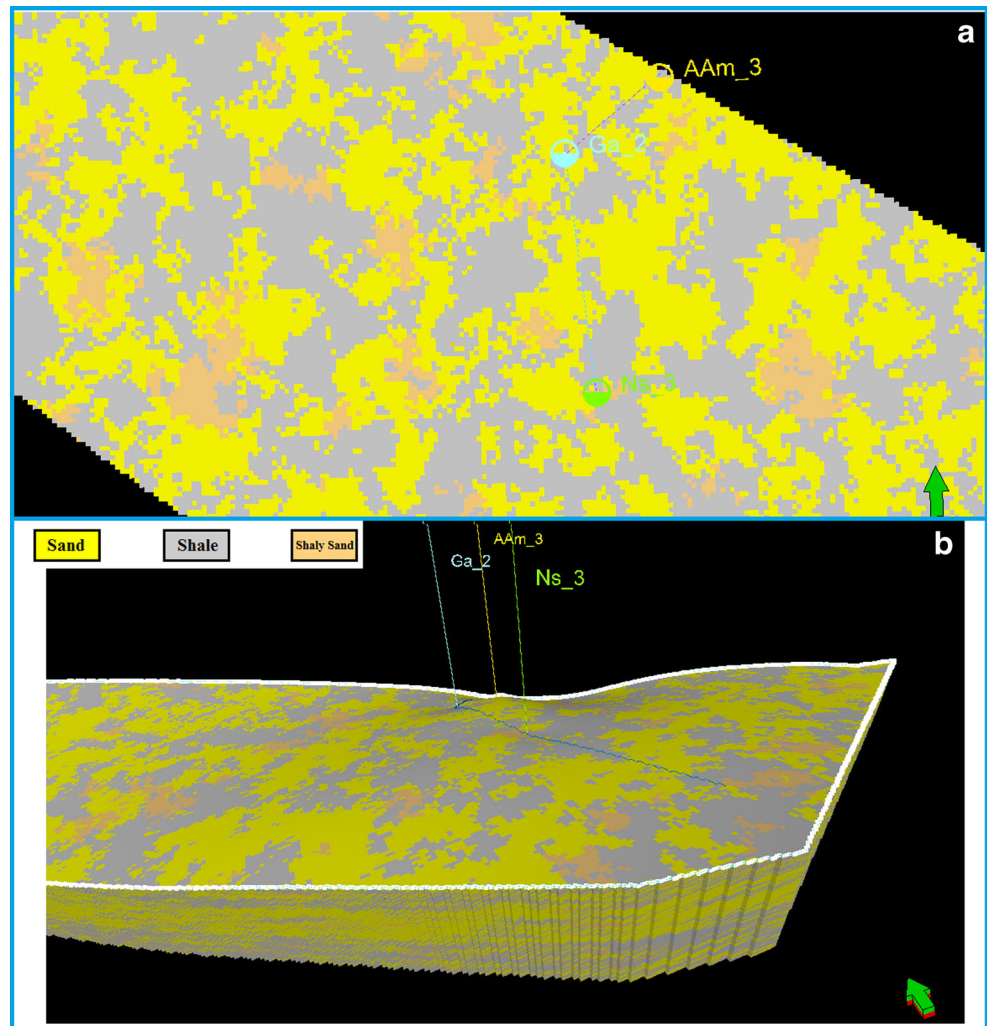
0.25 m horizontally and vertically (Fig. 5). The model produced 20 probability and the geologist choose 1 depending on his geologic sense. The model will distribute the shale content along the area of study (Fig. 6). Finally, a cross-section is done

Fig. 7 Final model of Zubair Formation in Euphrates Subzone, showing the real depth variations and distance between wells and the proposal migration pathway of oil within the same formation. The reservoir-sealing intervals is explained. *UZbfn* Upper Zubair Formation, *MZbfn* Middle Zubair Formation, *LZbfn* Lower Zubair Formation
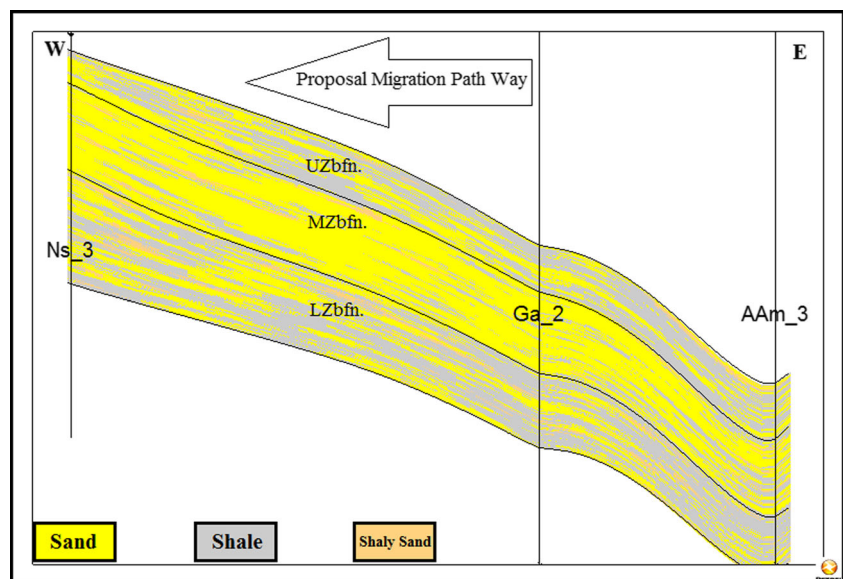
to show the reservoir, as well as the sealing rock (Fig. 7). In addition, this cross-section may indicate the horizontal migration pathway, which might be to the northwest of the area of study. This direction is, finally, ended in Abo-Jir fault zone to the west of Nassiriah and Samawa provinces. Abo-Jir fault is a candidate to be the major conduit that controls the oil migration to the west of Iraq. So, this paper recommends exploring the west part of Iraq in the stable shelf.

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