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Geomorphological Changes in River Courses as an Indicator of the Presence of Hydrocarbonate Structures in Southern Iraq, Morphotectonic-Geophysical Study

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Abstract. In southern Iraq, many rivers have been subjected to changes, meander, and migration, in their courses, is changing temporally and spatially. The current study focused on analysing the causes of the meanders of many river courses and which they relate to the structural and oil fields in Basrah Governorate. Many sites were selected, the locations of the Tigris River (three sites) and Euphrates River north of Basrah, as well as the site of the Qarmat Ali river meander in the center of the city. In this study, the technique of Sub Bottom Profiler (SBP) is used to perform cross-sections and to identify the characteristics of river bottoms, and Transverse River Profiles (TRPs) index is applied to the cross-sections of the river bottoms for quantitative analysis to identify the main causes of these meanders. The results of the current study revealed that most of the changes and meanders of these rivers are influenced by neotectonics activity, therefore most of these meanders are associated with the presence of oil field structures. As the meander of Tigris river is affected by the Majnoon field structure and the meander of Euphrates river north of the city is affected by the Rumaila field structure (west of Qurna), the meander of the Qarmat Ali river influenced by Nahar Ben Umar field structure, so the application of this study has given active results about the meanders of these river courses which consider as an effective indicator of the presence of oil geological structures, so it can be applied in other locations.

INTRODUCTION

The river courses in southern Iraq, such as Shatt Al-Arab, Tigris and Euphrates rivers during the pre-and post-Christmas centuries, were not as they are currently in an aspect of the geological and geomorphological setting, this case has been documented by many theories, geological facts and archaeological discoveries it was noted that the current major rivers change their courses in some areas naturally or abnormally (human impact) [1-3]. In southern Iraq, many rivers that have been subjected to changes, meander and migration in their courses are changing temporally and spatially, the geographers and the interests in sedimentation have attributed the change in these courses to the role played by the ground surface and sedimentary and morphological factors in the area [4][5]. On the other hand, geologists attributed the changes in the courses of ancient rivers to influence the region by neotectonic activity, which played a prominent role in the presence of most of the oil geological structures in the region [2][6][7].

The migration and discontinuity of river channels during this time are the significant mechanism that changes the geomorphology of the river streams. The river channels which consider sensitive to any variations caused by tectonic effects where it is closely associated with active structures (Holbrook and Schumm, 1999) [8], which in turn are responsible for changes in morphology, hydrological characteristics and fluvial processes of a river channel (Vikrant and Sinha, 2005)[9]. In southern Iraq, the large sediment thickness causes the effect of this activation to be unclear and the impact of this tectonic activity cannot be outlined using only one technique, therefore, the integration of data that can be obtained from many techniques such as the field technique of Sub Bottom Profiler (SBP) and the quantitative analysis of geomorphic indices are more important for more detailed information about the impact of this

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activation, especially if these techniques are applied in the river channels [8]. The current study focused on analysing the causes of the meanders of many river streams and the extent to which they relate to the structural and oil fields in Basrah Governorate using SBP is used to perform cross-sections and to identify the characterises of river bottoms, and Transverse River Profiles (TRPs) index is applied to the cross sections of the river bottoms for quantitative analysis to identify the main causes of these meanders. In the past, these types of studies have not been conducted on rivers in this area, but it has been applied on the Shatt Al-Arab stream to determine the extent to which the region is affected by the neotectonics activation factor [8].

THE STUDY AREA

The study area is located in Basrah Governorate, many sites were selected, the locations of the Tigris River (three sites) and locations of Euphrates River (one site) north of Basrah (See Fig.1).

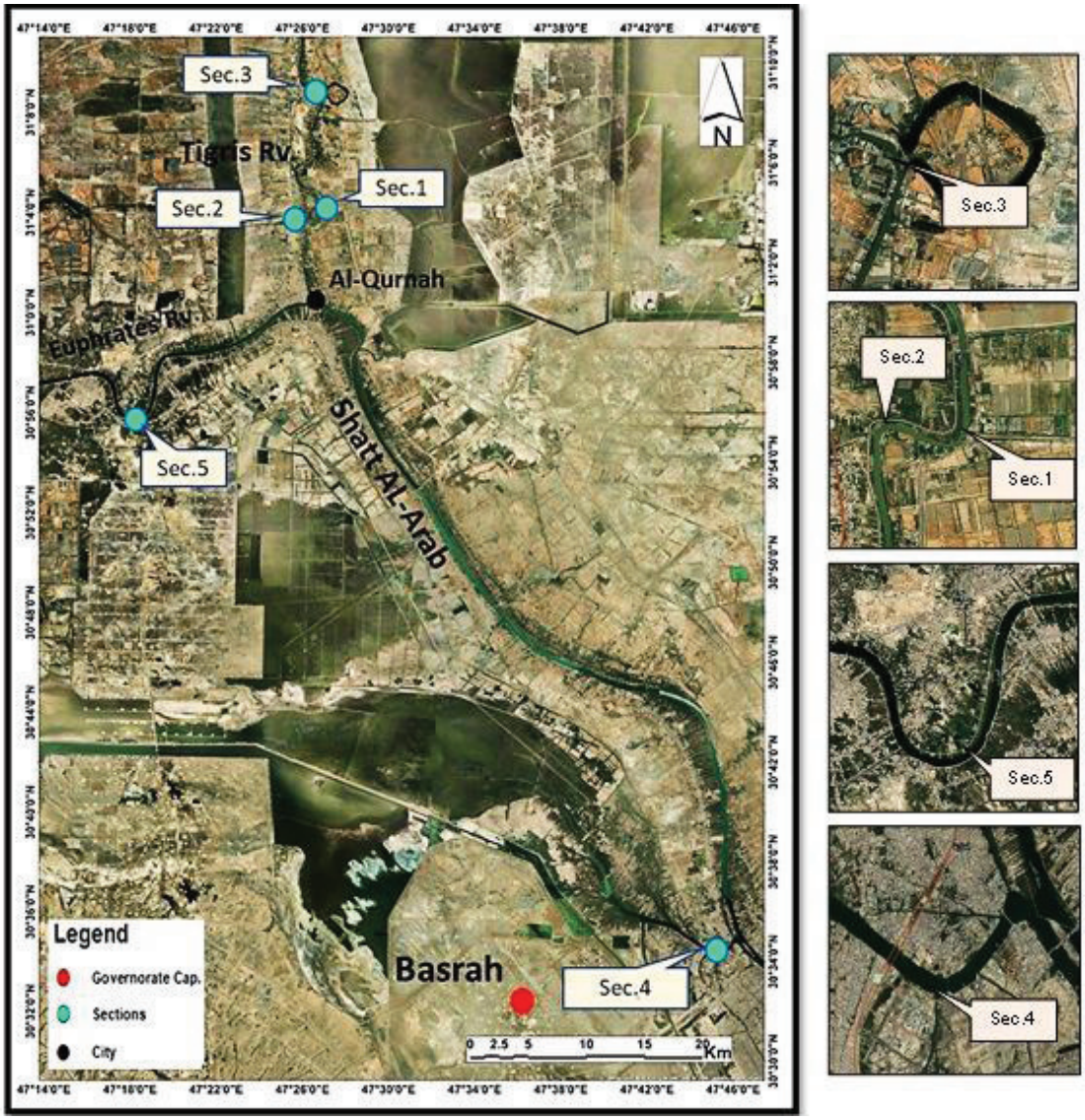

FIGURE 1. Map of the study area is located in Basrah Governorate, shows the selected river meanders, the locations of the Tigris River (three sites), and locations of Euphrates River (one site) north of Basrah. As well as Qarmat Ali River in Basrah city centre

The locations of the Tigris and Euphrates rivers were selected before the connection of the two rivers to form the Shatt Al-Arab River, which in turn flows from the contact area in Qurna city for a distance of 204 km toward the Arabian Gulf, the locations of the Tigris river were selected in this study and in this particular area because there are many meanders in the riverbed, while the choice of Euphrates river because it has a major meander in Medaina city before its contact with the Tigris river north of Basrah. The selection of the location of the Qarmat Ali River is also due to the large meander in the river before its contact with the Shatt Al-Arab course near the Basrah city centre.

Geologically, the study area is located in The Mesopotamian plain, it is a broad flat deltaic complex with shallow brackish water marshes, the study area is located in the Zubair subzone, formed the southernmost of a Mesopotamian zone, which is almost corresponding with the Shatt Al-Arab River, the Mesopotamian zone is covered by Quaternary sediments of marsh and lacustrine sediments deposits as well as fluvial and aeolian deposits from Tigris and Euphrates Rivers.

The study area is bounded by Takhadid- Qurna transversal fault in the north site, and Al-Batin fault in the south [9]. The Mesopotamian zone is characterized by the presence of many plunging subsurface structures which represent faults and salt structure [6]. Al-Sakini (1995) mentioned that the Mesopotamian zone movement is caused by deep faults of the basement rocks, and Alpine activity movement which is still effective in present times [10].

METHODOLOGY

In the current study, two techniques have been performed, the field technique of Sub Bottom Profiler (SBP) and a geomorphic index of Transverse River Profiles (TRPs). The SBP is a marine geophysical technique, it is an acoustic exploration technique that is mapping the sub-bottom river or seabed, the SBP section is produced by reflecting an acoustic pulse from the seabed and sub-seabed materials. The pulse is generated by a source towed by the boat; the reflected signal is received by the transducer/transceiver. The reflection of acoustic energy takes place at the boundaries of differing acoustic impedance, the reflection strength depends on the degree of impedance contrast. Technically, a portion of the incident energy reflects from the sediment-water interface, while the rest of the energy will transmit deeper through the substrate (McQuillan, et al., 1984[13]; Davies et al., 1997[14]). The technique of Sub Bottom Profiler is used to perform cross-sections and to identify the characteristics of river bottoms. The SBP fieldwork is carried out using the Strata Box™ device with 10 kHz, which was produced by SyQwest, Inc., USA.

The purpose of using the SBP survey is to identify the bottom characterises of selected sites and to depict how these bottoms are affected by tectonic or structural activity or subsurface uplift, as well as to use SBP sections in TRPs applications. Five cross-sections of the mentioned sites were completed using SBP technique, three cross-sections of the Tigris River with a distance of 60,65, and 60 m for sections (sec.1, sec. 2 and sec. 3) respectively, while the cross section of the Qarmat Ali river (sec.4) was completed with a distance of 245 m, which represents the longest cross-section, while the cross section of the Euphrates River (sec.5) was completed with a distance of 240 m.

The TRPs is one of the geomorphic indices which are suitable for calculating the level of tectonic activity and its characteristic of an area. The TRPs application can be provided important information on both geomorphic features and hydrodynamic factors of drainage basins. The TRPs analysis represents a new method for tectonic activity analysis using many TRP parameters that are quantifiable and comparable [11].

The TRPs analysis includes several initial steps that include making a slight alteration to cross-sections by changing values and making them within range (0-1), which represent the highest and lowest values in the TRPs curve (See Fig. 2). For the interpretation of the river section using Eh or Eh/Ch parameter that used Ch parameter, if Eh parameter value is close to 1 the lateral incision is greater than vertical incision and allow to locate the tributaries, where the values decrease relatively, then it can be interpreted as the vertical incision tends to increase and allow to identify the tectonics factors or lithological contrast. To describe the channel symmetry (Bs), it can be given by Th-0.5, where it is a normalized distance of the Thalweg line from one end of the section, 0.5 is the central TRP on Li/L axis which is the central point of the drainage basin of the section. Bs values would vary from +0.5 to -0.5 and with zero value is indicated perfectly symmetric basin. The (Ln) in Table 1 is the normalized section length derived from the Lp/L max ratio, where Lp is the length of the individual TRP, the valley width at each TRP location. L max is the maximum valley width of the TRPs analysis, while Eh* is the mean Eh value of the TRP. This parameter is important for expressing valley incision for two reasons, first, it is a two-dimensional parameter, and secondly, it incorporates an element of linkage throw (Ln) between all the TRPs of the river basin.

Figure 2. shows Smoothening of TRPs curve and its parameters, above cross sections captured by SBP survey in Sec.3. So, X axis is the ratio of Li/L, where L is the section length; Li is the distance of the individual data point from the channel at one end of the section. While the Y axis is the ratio of $\Delta Hi/\Delta H$, where ΔH is the difference between the

maximum and the minimum elevations of the section, ΔHi is the difference in elevation between the individual data points. M point on H1-H2 line is linked with A point by a straight line that crosses the TRP curve at P point, P point linked with N point on H1-H2 line to define the normalized expression of the average valley-side incision (Eh). Each TRP has two values of Eh; one for the east bank [Eh (R.b.)] and the other for the west bank [Eh (L.b.)].

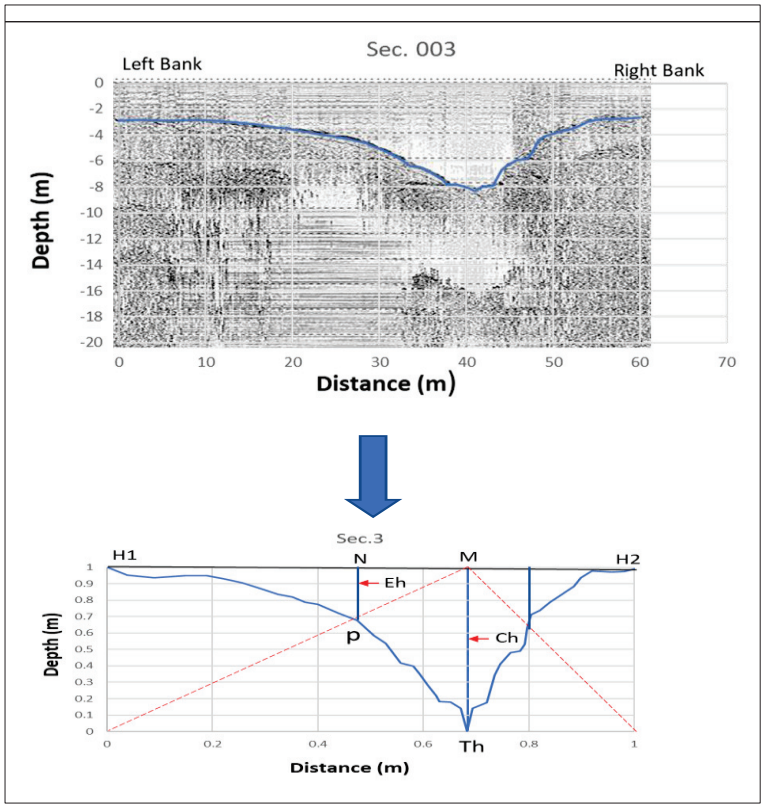

FIGURE 2. Smoothening of TRPs curve and its parameters

TABLE 1. The computed parameters of the TRPs of the river meanders in the selected sites.

Section	Eh (Rb)	Eh (Lb)	Eh (Rb) /Ch	Eh (Lb) /Ch	Eh*	Lp (m)	Lmax	Ln= Lp/Lmax	Ln*Eh	Th	Bs= Th-0.5	
Sec 1	0.56	0.35	0.67	0.42	0.54	61	243	0.25	013	0.57	0.07	High
Sec 2	0.35	045	0.35	0.45	0.4	64	243	0.26	0.14	0.46	-0.04	High tectonic
Sec 3	0.31	0.23	0.31	0.23	0.27	60	243	0.24	0.06	0.69	0.19	Low tectonic
Sec 4	0.4	0.55	0.43	0.59	0.51	243	243	1	0.51	0.28	-0.22	Highest tectonic
Sec 5	0.48	0.45	0.53	0.5	0.51	177	243	0.73	0.37	0.32	-0.18	Higher tectonic

RESULTS AND DISCUSSION

The main objective of SBP surveys is to identify the bottom properties of selected sites as well as to obtain cross-sections of bottoms for use in TRPs applications. The SBP cross-sections (see Fig. 3) revealed that the bottom deposits of most of the selected sites are characterized by fine deposits, mostly made up of mud deposits, it is a dominant attribute of the river bottoms of southern Iraq, as they are located within the sedimentary plain of the Mesopotamian

Basin. The fine nature of the bottom deposits is reflected in the SBP signal's ability to penetrate the depths of more than 20 m. Also, these deposits affected the resolution, as observed from the multiple reflections in most SBP sections, the multiple reflection phenomenon which caused by fine deposits is made to disperse the sound signal from the source, is recorded not at the current study sites, but in the sites of the rivers and lagoons in southern Iraq [12], the multiple reflections appeared clearly and strongly in sections 4 and 5, due to the lack of the current flow and its inability to transport the sediments to areas further away, therefore, the fine sediments will accumulate at nearest sites.

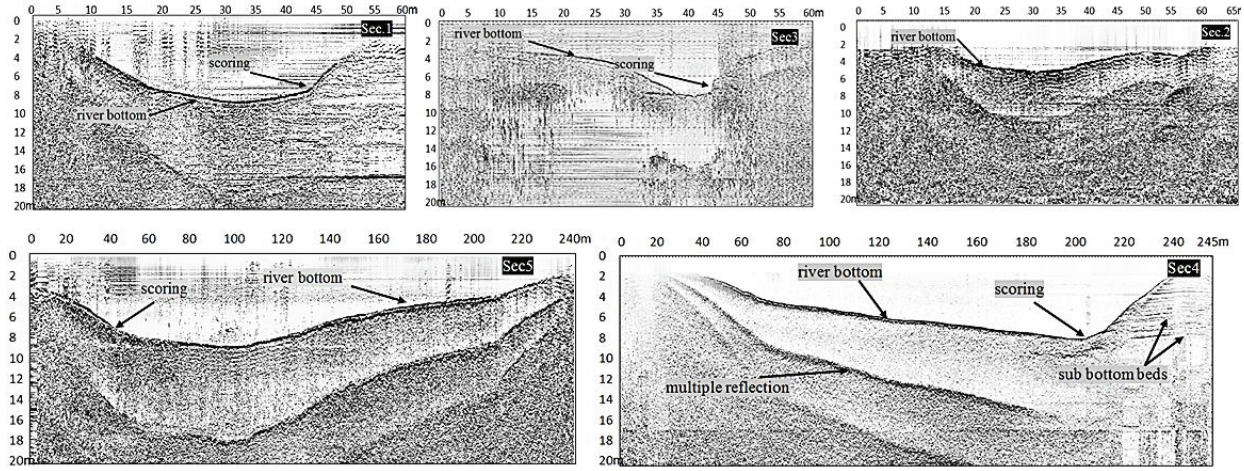

FIGURE 3. The SBP cross-sections show that the bottom deposits of most of the selected sites are characterized by fine deposits, mostly made up of mud deposits, these deposits affected the resolution, as observed from the multiple reflections in most SBP sections

The distinctive features of the sub-bottom have not been identified, which can refer to the evidence of tectonic or structural effects such as uplifts and faulting, but this does not mean that these effects do not exist, this evidence of the presence of tectonic activity may have disappeared or been affected close to the surface due to the presence of fine deposits of the bottoms and even the presence of flood deposits near the banks of the chosen rivers as well as may have disappeared due to human activity. In addition, the selected sites are located within the Mesopotamian Basin, which has a sedimentary cover thickness of up to 12 km above the base rocks. Many studies based on geophysical investigations and remote sensing applications are conducted on land indicate that the region is affected by neotectonics activity, although there is no substantial surface evidence of this activation, evidence of this activation has been inferred in some river sites in many studies because the river streams are more responsive to this activation [3][13][14]. Although the SBP section of current study sites does not confirm the presence of tectonic activity, this does not mean that they are not utilized, the sections were used in TRPs applications to analyse the reasons for recurrent meanders in these sites.

The results of the TRPs analysis (see Table 1) revealed that the area and the selected river courses in the current study are affected by tectonic activity, so the sec. 4 in Qarmat Ali is considered to be the most affected by a tectonic activity because it has the highest value of Ln*Eh and the lowest value of Bs, sec. 5 is followed sec. 4 by in terms of tectonic effect, and this seems clear that the two mentioned sections have the largest meanders compared to the other sections. For sec. 1 in the Tigris River, the results also showed that it was affected by tectonic activity, but by less than a sect. 2 nearby of it, while sec. 3 (in the Tigris River also) had the lowest tectonic effect.

The integration of the SBP and TRPs results confirmed that the meanders of the streams of the rivers in the selected sites are affected by tectonic activity (except site 3) and here it is necessary to know which of the geological structural resulting from the activation processes have affected the change of the courses of these rivers, from figures 1 and 4 in sections 1 and 2 in Tigris River, it is clear beyond doubt that these sites are influenced by the geological structure of the Majnoon oil field which is located in the east of these sites, which extends lengthily from the north to the south and parallel to the Tigris River and the movement of the Tigris River to the west at the two mentioned sites is due to the existence of this structure. As for the meander of the Tigris River in sec. 3, which recorded the lowest value of

tectonic effect, the meander has resulted from morphosediment effect, which can be confirmed by the form of the arc lake which cut from the river. Despite sections 1 and 2 are affected by the geological structure of the Majnoon oil field, this effect is considered to be less than sections 4 and 5, due to the fact that this structure does not cross the river in these sections but passes alongside them and changes the river course westward.

With regard to sec. 5 of Euphrates River, which has the largest meander compared to the other sections, indicates the impact of this site by the geological structure of the Rumaila oil field, which is considered one of the largest oil fields in southern Iraq and cuts Euphrates river (extending from west to east) laterally before its contact with Tigris River, but with regard to secti.4 on River Qarmat Ali, which has the highest tectonic effect compared to the other sections, the figure indicates that this site is affected by the geological structure of the Nahr Ben Omar Oil field, Al-Mayahi, Al-Kubaisi and Hussein indicated that this structure affected the course of the Shatt Al-Arab and diverted its course eastward [3][14].

The current study concluded that all meanders of the river streams in the selected sites (except site 3) are due to the impact of these sites by neotectonics activity, which resulted in the forming of most of the geological oil structures in southern Iraq, the effect of the river streams by subsurface structures and oil structures may not be limited to the change of current river streams, where Al-Sakini, indicated that the presence of these structures caused a discontinuity in the old river courses such as the old Euphrates river that was flowed in the west side of Basrah city, which has completely changed course to the east to connect with Tigris river and consisting of Shatt Al-Arab River. It influenced by the geological oil structures of Al-Zubair and Tuba oil fields, The meanders of the courses of Tigris and Euphrates rivers and their influence by the subsurface structures is not limited to southern Iraq, the author showed that these rivers have been subjected to a change in their courses in many locations in central Iraq [2].

Therefore, we can conclude that the current study revealed the importance of completing SBP and TRPs surveys at river courses meandering sites because it gives a good indication of the presence of oil geological structures in those sites, so the study recommends the completion of such these surveys in other locations that may give an encouraging indication of the presence of oil geological structures, and It may give a good indication of influence the region by neotectonics activation and it's affecting on the river courses through the sub-surface faults, which have been referred to in many studies [15-17] (See Fig. 5). These sites include the meanders of the Shatt Al-Arab River course south of Basrah city and the meander of the Khor Al Zubair channel course eastward in the southwestern part of Iraq, north of Khor Abdullah as shown in Fig. 5.

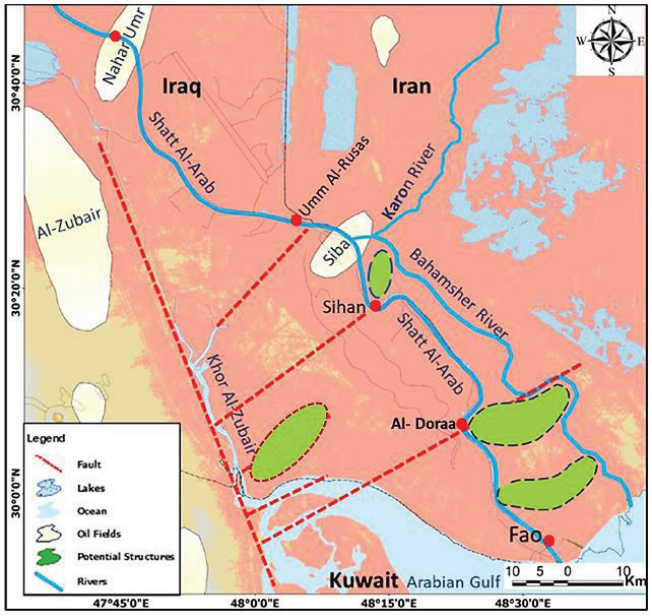

FIGURE 4. The fault systems result from the tectonic effect of southern Iraq

Figure 4 shows the fault systems result from the tectonic effect of southern Iraq, which was derived from the study [17]. The green-marked shapes represent the encouraged proposed sites to the presence of subsurface structures, which

can be detected by conducting future surveys by SBP and TRPs techniques for adjacent river courses meandering sites.

CONCLUSIONS

In the present study, integration of SBP survey and TRPs analysis have been used in many meanders river courses to detect the reasons of these meanders and which are influenced by subsurface structural, the most important conclusions of the current study included:

- The SBP section, no distinctive features have been identified, which can refer to the evidence of tectonic or structural effects, but this does not mean that these effects do not occur, these effects may have disappeared or been affected close to the surface due to the presence of fine deposits of the bottoms of the chosen rivers as well as may have disappeared due to the sedimentary cover thickness of up to 12 km above the base rocks. Although SBP clips did not yield confirmed results on tectonic effect, they were important as cross-sections that showed the morphological form of bottoms which are important in TRPs applications for tectonic effect explanations.
- The integration of SBP survey and TRPs analysis revealed that most of the changes and meanders of these rivers are influenced by neotectonics activity (except site 3 in Tigris River), and these meanders are associated with the presence of oil field structures in Basrah Governorate.
- The study revealed that application of integration of SBP survey and TRPs have given actionable results about the meanders of these river courses which consider as an effective indicator of the presence of oil geological structures, so it can be applied in other locations such as Shatt Al-Arab and Khor Al-Zubair meanders southern Basrah Governorate.

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