



Petroleum Occurrence Probability along Sinjar Anticline/ NW of Iraq

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Abstract

Petroleum system analysis of Sinjar anticline (which is located in the NW of Iraq) is presented. Previous geophysical data (gravity, magnetic and seismic interpretation controlled by boreholes) revealed presence sedimentary basin as a graben south of Sinjar anticline during Paleozoic and Mesozoic times, as a source for generation of petroleum, migrates to Sinjar anticline as a typical reservoir rocks, forming a perfect petroleum system presumed during Mesozoic and Cenozoic times. The presence of oil sites in the extension of Sinjar uplift inside Syria suggests the presence of oil in this anticline since the largest part of it is inside Iraq.

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Introduction

If undiscovered oil accumulations exist in any region, chances of success in logical exploration depend largely upon the extent to which the basic facts of stratigraphy and structure are known and upon the quality of interpretations which are placed upon these facts[1]. The anticline is one of the most desirable and preferred places for the presence of oil, as it forms traps for oil and natural gas. And the evidence for this is that 80% of the world's oil was found in anticline traps. The presence of oil or gas or both, is associated with the presence of rocks suitable as a reservoir,

such as limestone rocks available in the Sinjar anticline. So we will give an idea about the location of study area and the geological setting with discussion about hydrocarbon occurrence in the following sections.

Location of study area:

Sinjar anticline is located to the Northwest of Mosul, northern Iraq, and is approximately 1400 meters high. It is approximately 145km. from Mosul. It is strategic, mountainous, rugged area, adjacent to the Syrian border, see figure 1.

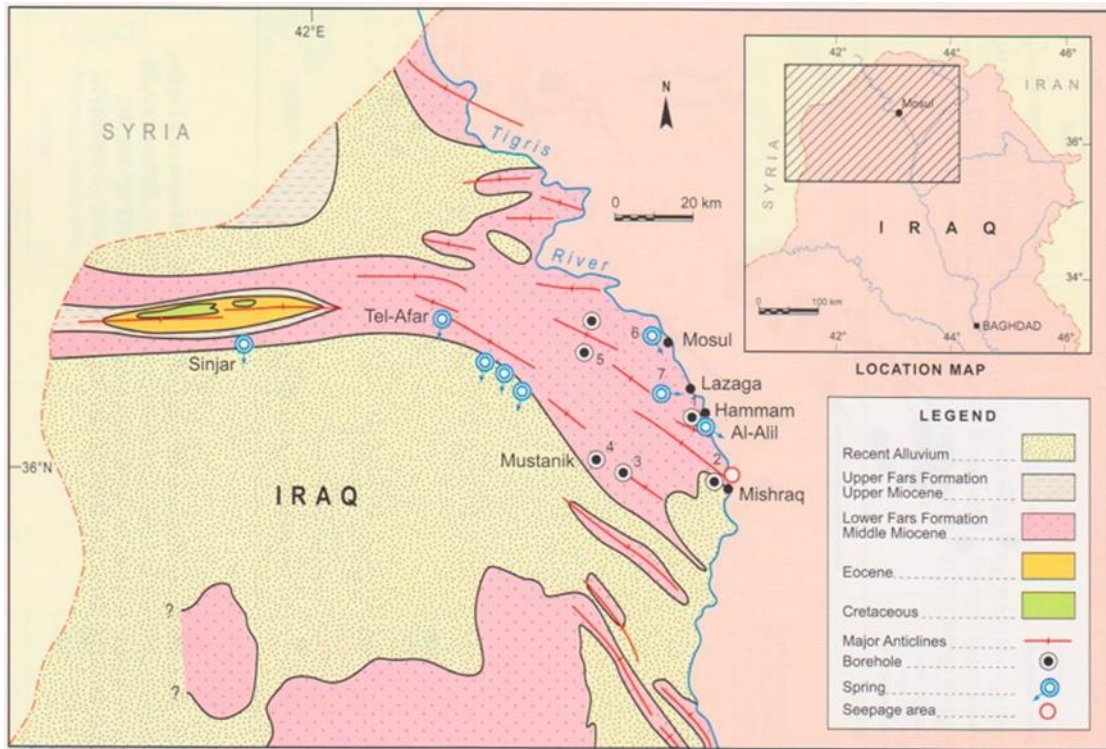


Fig.1 Location map of Sinjar anticline[2]

The Sinjar anticline is a double plunging with almost E – W trend. It is asymmetrical with steeper northern limb (45 – 80)° and gentler southern limb (15 – 25)°, its length is about 80 km, whereas the width ranges between (9.25 – 12. 5) km. The oldest exposed rocks belong to the Shiranish

Formation, whereas the youngest rocks belong to the Fatha Formation, see fig. 2.

2. Stratigraphy:

The exposed rocks in the studied area range in age from the Late Cretaceous, represented by the Sinjar Formation up to Late Miocene, represented by the Injana Formation [2], see table 1.

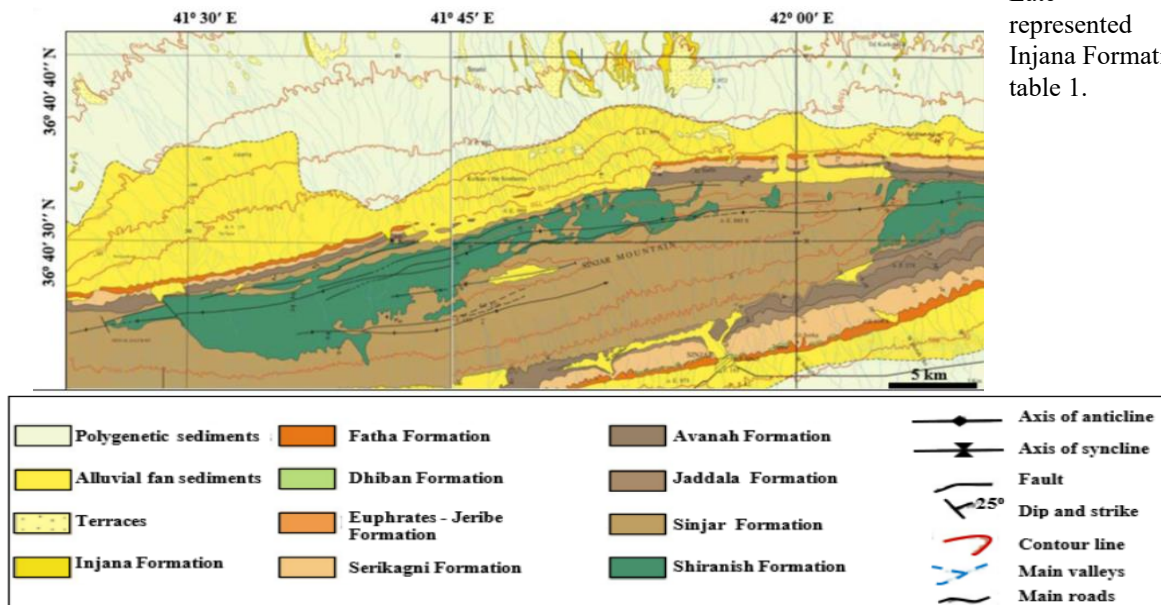


Fig.2 Geological map of Sinjar anticline [2].

Table-1. Geological Formations of Sinjar Anticline[2]

Formation	Age	Thick. (m)	General description
Injana	Late Miocene	300 – 400	Sandstone interbedded with siltstone and claystone in rhythmic cycles, all rocks are reddish-brown in color
Fatha	Middle Miocene	550 – 630	Green marl interbedded with limestone and gypsum in rhythmic cycles, in the upper cycles, reddish brown claystone occurs.
Jeribe		100 – 125	Well bedded greyish white limestone
Dhiban		5 – 100	Mainly limestone with rare limestone
Serikagni	Early Miocene	65 – 300	Well bedded white limestone with some marl intercalations
Avanah		85	Marly limestone interbedded with marl
Jaddala	Middle Eocene	500 – 550	Marl interbedded with marly limestone
Sinjar	Early Eocene-Late Paleocene	170	Well bedded, white, and very hard limestone
Aaliji		50	Shale and marl
Shiranish	Late Cretaceous	565 (exposed)	Bluish green, papery marl, in the upper part well bedded greyish white limestone in the lower part

Overview about petroleum system of northern Iraq

Most of the known oil accumulations of Northern Iraq probably originated by upward migration from earlier, deeper accumulations which were initially housed in stratigraphic or long-established structural traps. Mapping and studying a petroleum system helps explorationists predict which traps will contain petroleum and which will not. It also helps them focus on that part of a province that will most likely contain accumulations. The Triassic and older formations, down to the Ordovician Khabour

quartzite-shale formation, are known best from the deeply eroded mountain folds of the north eastern borderlands in addition to Akkas -1 and Khleisia-1 wells. A few wells have entered the Triassic in Northern Iraq, and at Jebel Atshan well was continued to explore the Permian Chia Zairi formation. Lately, a deep well at Khleisia-1, north of Anah, has been drilled deep into Ordovician elastics. Triassic sandstones are exposed in the floor of the Ga'ara depression, north of Rutbah[3]. The age-range and areal distribution of

the main post-Triassic rocks are fairly well established for most parts of Iraq including Sinjar area, see figures 4,5,6,7,8,9&10[4].

type. Sets of such maps have been published for northern Iraq [3&4]. Many of the important outstanding stratigraphical and structural problems relating to Iraq may be interpreted as requirements for the improvement of these and similar maps.

If suitable lithofacies units are selected for portrayal, the maps indicate the probable areas of source, and the possible limits of contemporaneous reservoir or carrier formations for the age interval concerned. Also, the approximate locations of major permeability wedges and of other potential stratigraphic trap conditions may be discerned [1].

The initiation and growth of structures which may have provided traps for migrating oil, and the progressive evolution of favored migration

Isopachous and lithofacies maps are perhaps the most informative mode of expressing reconstructions of this

trends and paths, as gradients developed towards potential trap situations within the permeable reservoir units.

In the type of oil migration study for which isopach facies maps may be employed in Iraq at present, the most useful distinction for illustration is between those lithofacies assemblages which are associated with permeable reservoir formations and those associated with impermeable non-reservoir formations. The permeable sandstones may be differentiated from the permeable limestones. Also, the readiest distinction is generally between fine-grained, argillaceous sediments, deposited in an offshore or basinal environment, to which source-rock capabilities may be attributed, and lagoonal or other impermeable formations which are usually not to be regarded as source beds.

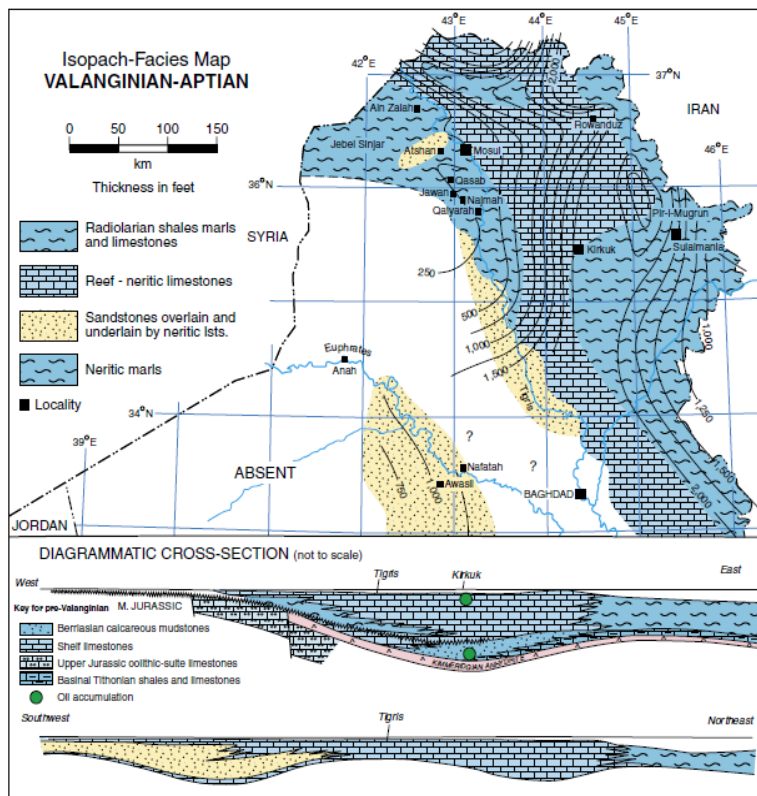


Figure 3: Isopach-facies map of Valanginian rocks, schematic

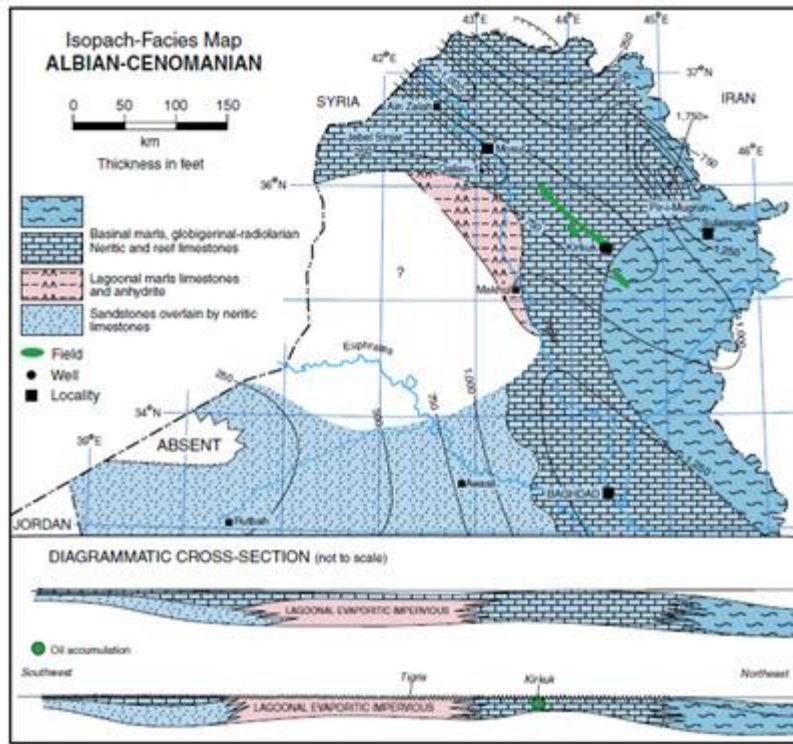


Figure 4 Isopach-facies map of Albian-Cenomanian^[4]

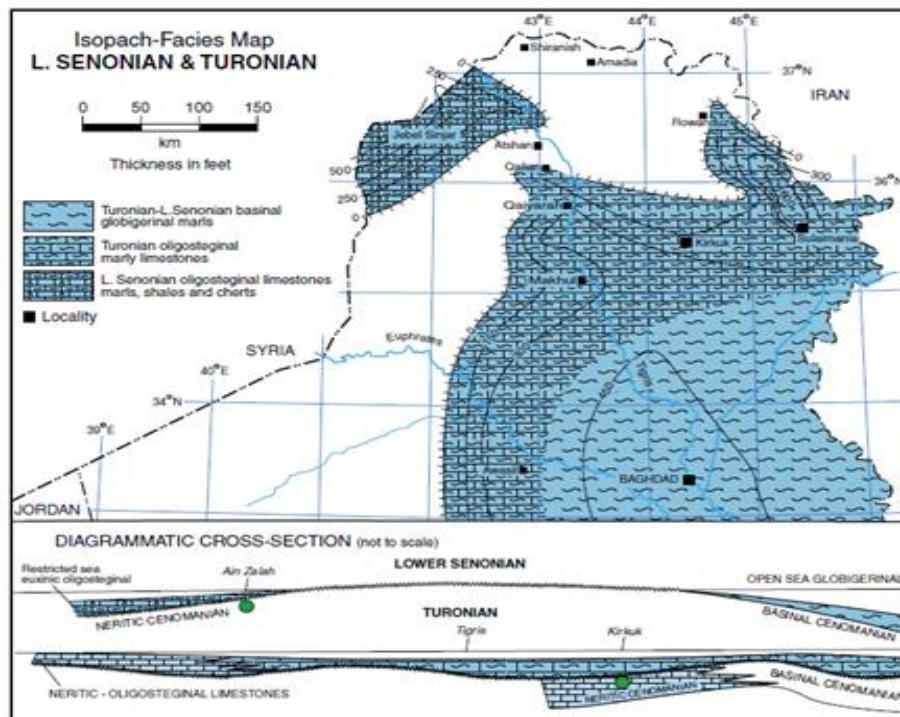


Figure 5 Isopach-facies map of lower Senonian and Turonian rocks^[4]

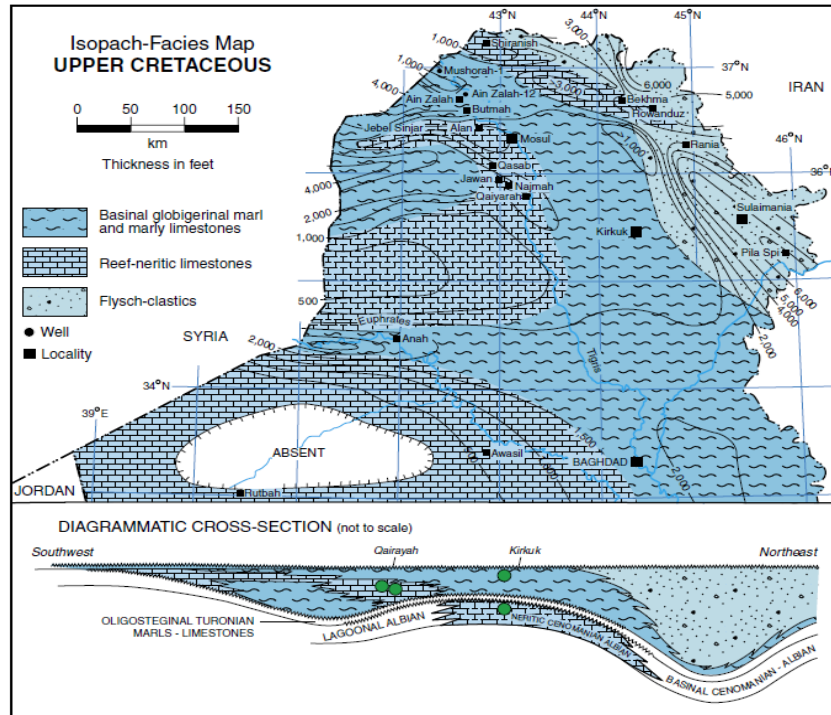


Figure 6 Isopach-facies map of the Upper Cretaceous rocks^[4]

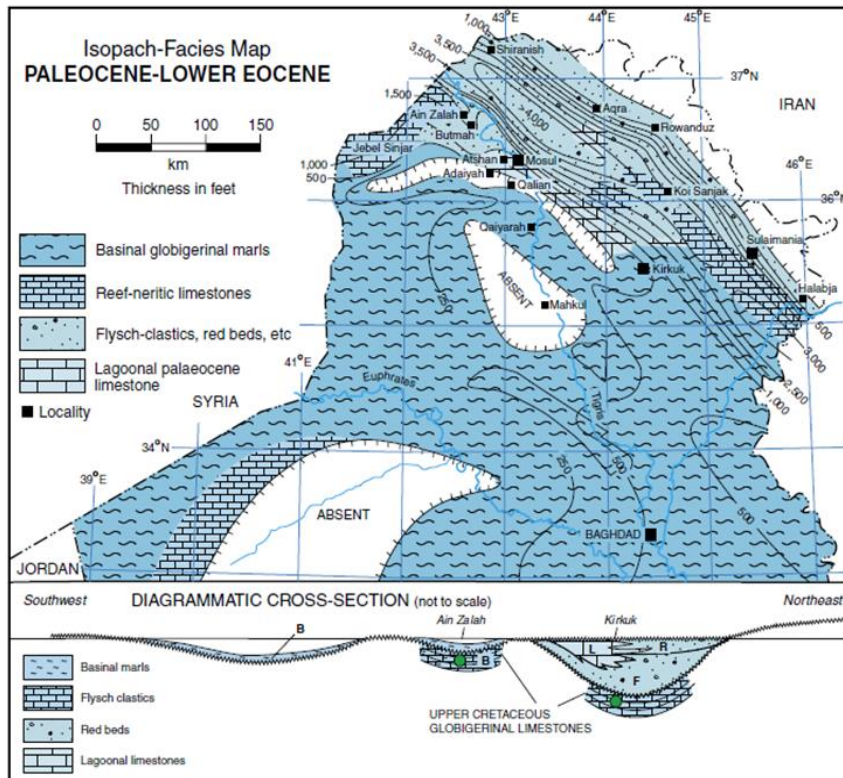


Figure 7 Isopach-facies map of Paleocene-lower Eocene rocks^[4]

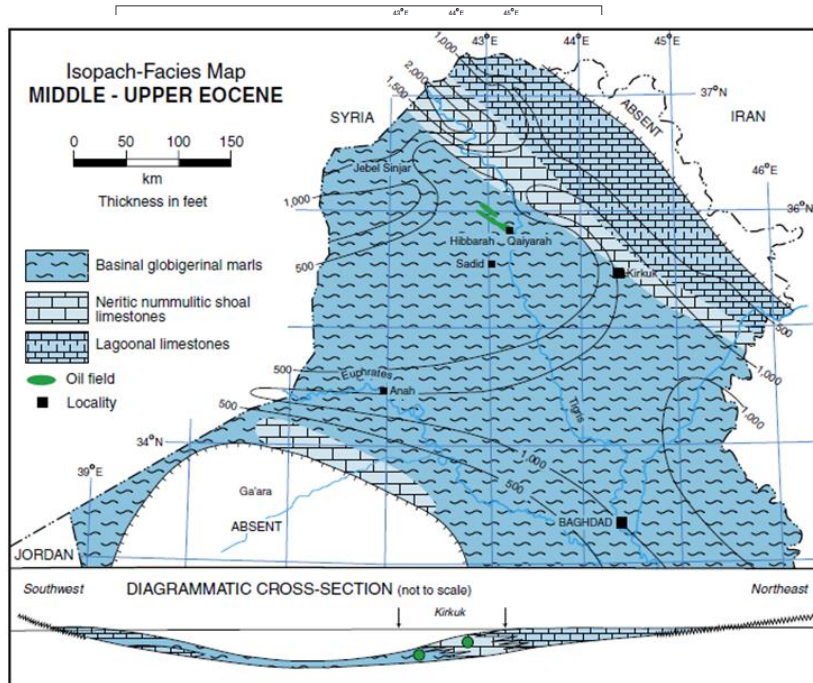


Figure 8 Isopach-facies map of middle and upper Eocene rocks[4]

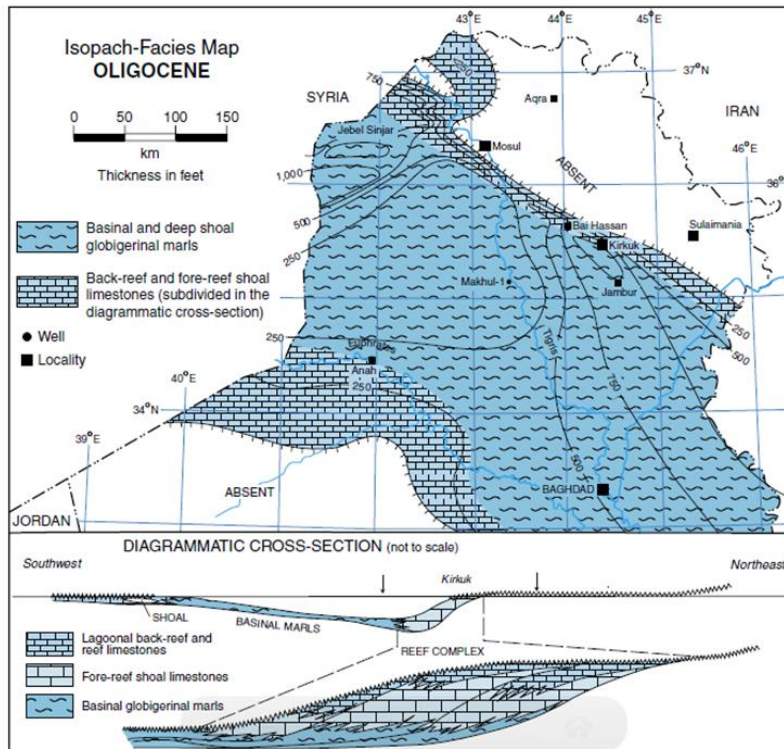


Figure 9 Isopach-facies map of Oligocene rocks, schematic^[4]

Identification of possible reservoir-carrier formations and cap-rock or seal units in any section presents little fundamental difficulty. There appear to be several oil accumulations in anticlinal crests in Iraq which, by their presence, have preserved the original porosity of the reservoir rock in their own immediate surrounds, whereas, in the synclines and pitches, cementation and like processes have entirely sealed the aquifer. In Iraq the fundamentally important case of conversion of impermeable seal-type units to readily penetrable reservoir units is that provided

by fracturing. Two fields in north Iraq (Ain Zalah and Butmah) draw most of their present production from fractures in fine-grained, water-permeated globigerinal limestones of Upper Cretaceous age, and there are similar possibilities for production (not yet quantitatively assessed) from similar limestone. The Tertiary "Main limestone oil of Kirkuk also owes much of its ease of production to extensive fracturing within the porous, permeable reservoir, see figures 11,12 and 13^[3].

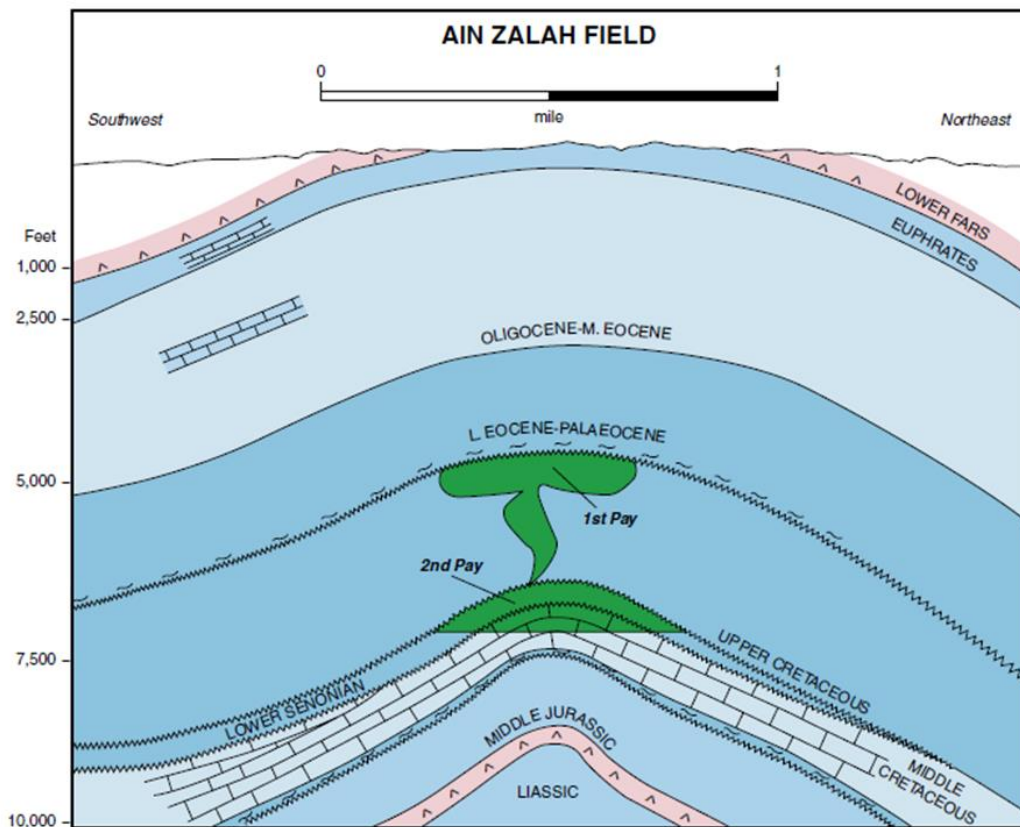


Figure 10: Cross section of Ain Zalah oil field, showing generalized stratigraphy and structure^[4]

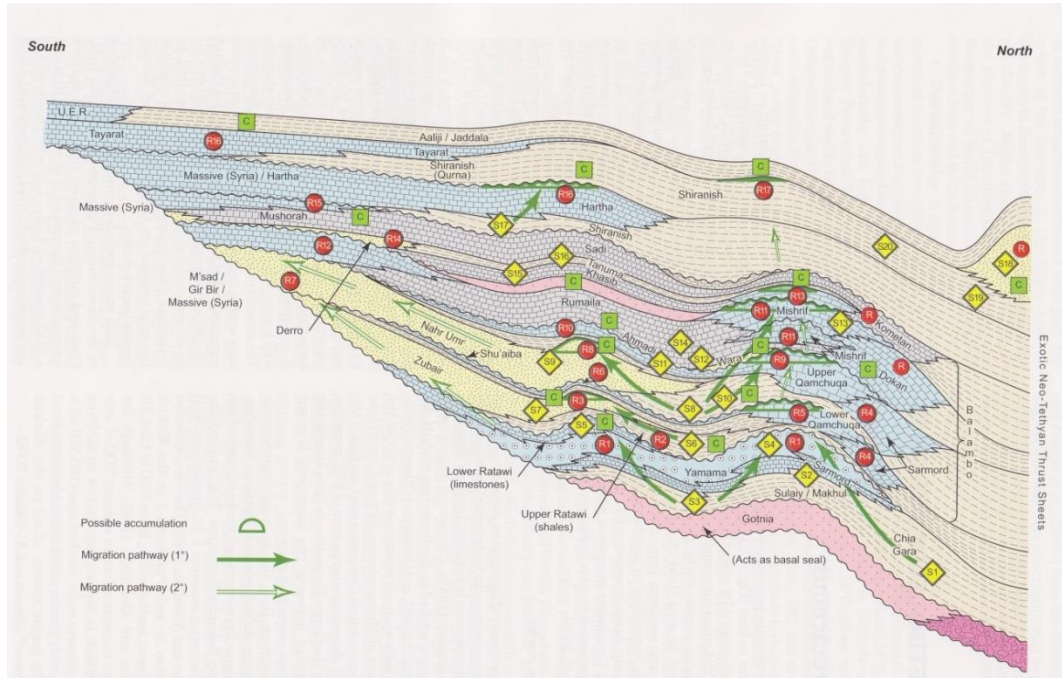


Fig.11 Schematic cross section through the Cretaceous system in Iraq showing the spatial distribution of source, reservoir and seal units. The most important source rocks are probably are in supersequences I (S1 and S2) and II (S10). Very limited data has been published on Cretaceous source rocks in Iraq^[3].

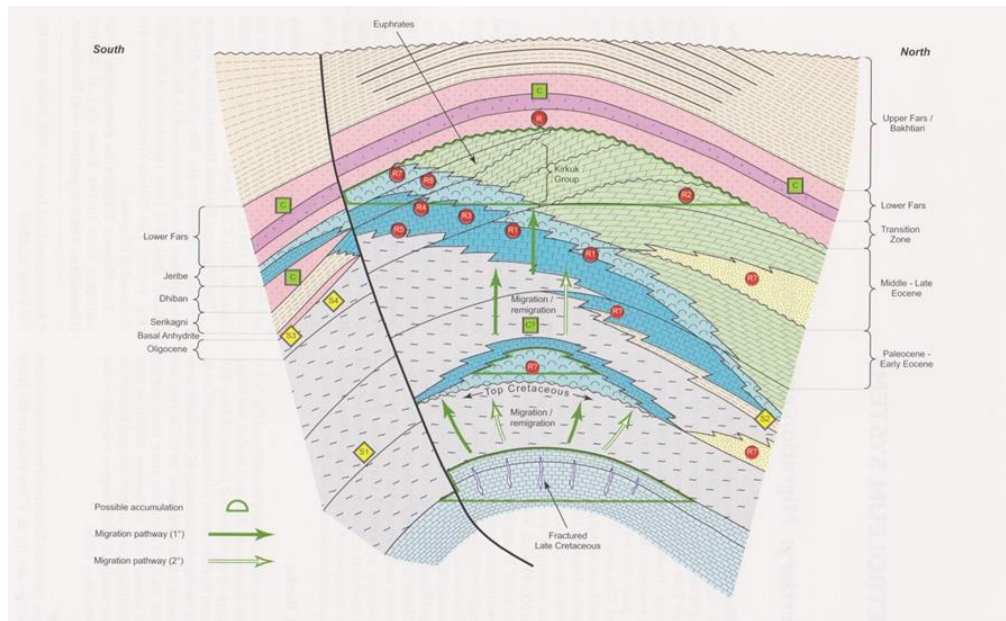


Fig.12 Schematic cross section showing the main reservoirs and seals in Cenozoic plays in Iraq. Most production comes from late Neogene anticlines with a top seal provided by the Lower Fars formation. The most productive reservoir intervals have well developed matrix porosity and are highly fractured^[3]

Again, the time of incidence of fracturing is rather critical. A tight limestone or shale unit may serve through a long period to contain oil in an underlying reservoir, until fracturing is occasioned by folding or other events. After fracturing, oil may be lost by vertical upwards migration to a higher reservoir, or to escape at surface, and, after passage of the oil, the fracture-voids may be resealed by mineralization. This should occur in situations which involve favorable migration trends towards the known fields if the developmental history is fully considered. They should have produced oil prolifically. Five or six formations of Jurassic and Cretaceous age, which fulfill all the requirements mentioned. Other units may have functioned as relatively unimportant source beds feeding small accumulations which perhaps remain to be discovered, or adding their small quotas to the main accumulations which stem from the main source rocks. There are two modes of approach to the important problem of determining a direct relationship between the oil accumulations and the source beds from which they derive. The most direct and satisfactory approach is through detailed and exhaustive geochemical investigation of the reservoir oils and of solvent extracts of organic materials from the supposed parent source-beds (or better still, from all possible source rocks in the region). The second and indirect approach is through the consideration of regional development histories, as portrayable in isopach-summation and facies maps.

The geochemical methods, involving solvent extraction, chromatographic fractionation, ultra-violet and infra-red spectroscopy, trace metal analysis, isotopic estimations, and a variety of other specialized investigations, may be expected to provide definite answers, eventually, to some

questions. Such methods have been applied with some success in a few regions where there are wide chemical differences between oils in different reservoirs of different ages. The problem in the Middle East may differ in that here most of the oil accumulations are seemingly very similar in fundamental chemical character, regardless of location, nature and age of reservoir. Suitable geochemical techniques no doubt exist, or can be developed, which will "fingerprint" the various oils adequately to enable differentiation of those which stem from different sources. The problem of determining the importance of the role played by vertical migration may be partially solved by application of geochemical techniques, as a part of the larger enquiry attempting to relate oil occurrences to particular source-bed formations. The problem is related also to those involved in interpretation of fracture histories, and of the structural history of the region.

In considering gradient maps as guides to the envisagement of oil migration routes, it is customary to suppose that the oil tends to move directly up the dip, as illustrated in Figure 14-A^[1].

Even though isopach facies maps play no part in the considerations, the philosophy behind selection of structures for exploratory drilling involves some such envisagement. In the setting of Figure 3-A, the large, high and marked structures A and B would be preferred to the lower and flatter structural prospect represented by C. Obviously, in certain circumstances, the easiest path for movement of migrating fluids may run oblique to rather than normal to the isopaches or structure contours, and accumulation may occur in locations which appear to be unfavorably situated relative to others which attract no oil.

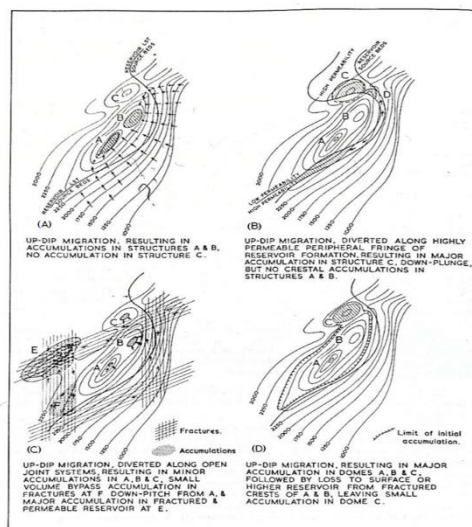


Fig.13: Guides to the envisagement of oil migration routes^[1].

Figure 14-B illustrates diversion through a highly permeable reef-type frontal fringe of the reservoir formation. The conducting fringe lies adjacent to the rock-unit boundary between the neritic limestone reservoir unit (which has low overall permeability) and the offshore source-type sediments from which migrating oil is deemed to originate. Cross-dip migration of this type may have occurred in some parts of northern Iraq within the upper part of the Middle Cretaceous Qamchuqa limestone reservoir.

Figure 14-C illustrates diversion of migrating oil streams through a joint or fracture system which to some extent polarized the reservoir formation. Fracture networks of this type are important in permitting the production of oil from the limestone reservoirs of Iraq and Iran (5). They may be presumed to have played an important part in permitting and directing accumulation, unless they originated, late in history, as a consequence of late-Tertiary folding. There is need for research into the time of origin, nature, areal and stratigraphical distribution, orientation pattern and mineralization and rejuvenation histories of fractures, especially in the limestone reservoirs. Ideally, such research should be conducted both at outcrop, where guiding principles may be established, and on well cores, where the applicability of principles can be checked and evaluated. Detailed knowledge of fracture distribution would find other extremely useful applications in oil field development, in interpretation of production events, and in regional tectonic synthesis. Figure 14-D exemplifies a type of diversion of accumulated oil which is believed to have been of fundamental importance in controlling location of major accumulations in north Iraq and in south western Iran [6]. It is supposed that the major accumulation that is now housed in the Tertiary limestone reservoir of Kirkuk for example has escaped upwards into its present accommodation, from the underlying Qamchuqa limestone differentiated during the late-Tertiary (mainly Pliocene) Alpine orogeny(6). The Qamchuqa is seen as the initial

Conclusions and Discussion

Hydrocarbon probable reserves within Paleozoic succession

Hydrocarbon probable reserves within Paleozoic succession It has been accepted that any rock unit of appreciable thickness which was deposited in a more or less euxinic environment may be suspected of having generated and liberated oil. These potential source beds range from stinking, black, bitumen-saturated shales and limestones to rocks which are now finely recrystallized, off-white, lithographic limestones. Potential source beds are widespread and occur at many horizons in the sedimentary sequence of Northern Iraq. The Lower Silurian marine hot shale in addition to black shale of Ordovician Khabour mian evaporites) extend over most of the western part of Iraq[9].Although, Almashhadani[10] had referred that Sinjar block was high during Paleozoic times, See fig.17,

reservoir for a very large accumulation, resulting from Middle-Lower Cretaceous source beds which lie to the east of Kirkuk. The early accumulation may have been in place by the end of Upper Cretaceous time. The evidence for this postulated history of the Kirkuk oil has been discussed elsewhere (7)¹. Meantime, the Ain Zalah field of northern Iraq provides a convenient proof to vertical migration can and does occur in the region. Oil drawn from fractures in the "First Pay" (Shiranish formation, Upper Cretaceous), is replaced continuously by upwards leak of oil from the porous dolomitized "Second Pay" reservoir (Qamchuqa limestone). The two "Pays" are separated by about 2,000 feet of intrinsically impermeable marly limestones and marls, see figures 11,12 and 13 above. In Arabia, the dominant fields are in reservoirs of Jurassic age, the Kuwait and southern Iraq reservoirs are mainly Cretaceous in age, and the fields of north eastern Iraq and of south western Iran produce from Eocene-Oligocene, Oligocene- Miocene, and Miocene reservoirs. Yet in northern Iraq, which shares Oligo-Miocene production with Iran, the oldest producing reservoir in the basin is also found (Triassic limestone reservoir of the Butmah field) and producible Jurassic oil may yet be discovered in quantity. For the Lower Mesozoic, the findings in the Triassic limestone of the Butmah field, north west of Mosul, are promising, but experience elsewhere in north Iraq suggests that any accumulations which may exist in the Triassic may be small even by world standards. Also, the Triassic oil in Butmah may well be of Palaeozoic source. An elaborate analysis of the tectonic construction of the Middle East in general, including Northern Iraq, has been made by Henson (8)., who stresses the important role played by pre-Miocene vertical movements in the "unfolded area" and in the "folded zone." Henson considers that folding due to late-Tertiary compression was superimposed on and molded against an earlier, deep-seated, block-faulted framework, inherited from the pre-Miocene history of the region.

Formation are believed to be the main Paleozoic source rocks [8], see fig.15. Aqrabi referred that the total organic carbon content (TOC) of 0.9 to 5% in Ordovician shales and between 0.96 to 16.62% in Silurian shale made them as a good source rock. Additional potential source rocks could be the Upper Devonian and Lower Carboniferous Ora shale Formation in addition to the lower shaly beds of the Upper Permian Chia Zairi Formation. So the main target reservoirs within Paleozoic rocks are of Ordovician, Silurian and Permian ages (see fig. 16). While two main regional cap rocks (Lower Silurian shales and Permian) but as seen from this figure the existence of Khleisia block as a graben make it a good sedimentary basin as source rock.

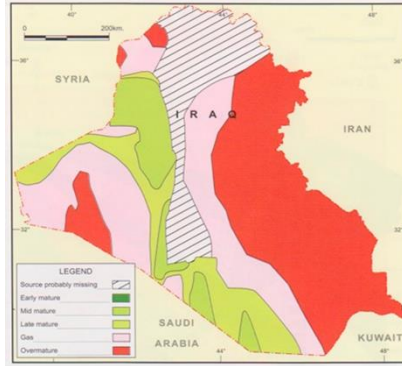


Fig.14 Maturity map of the basal Silurian source rock in Iraq^[3]

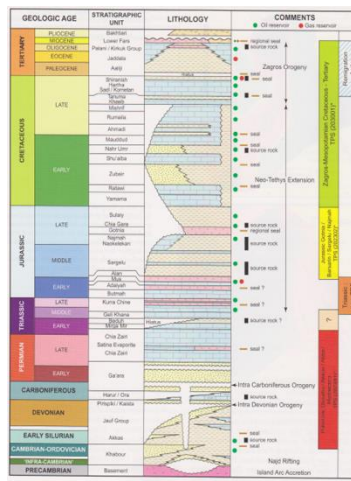


Fig.15 The stratigraphic distribution of source rock, reservoir and seals in Iraq^[3]

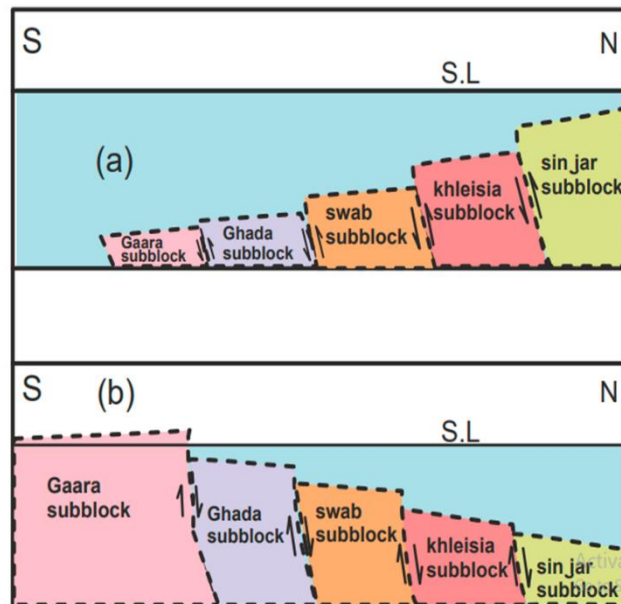


Fig.16 Schematic structural cross sections illustrating the block movements deduced from isopach maps (a) During Paleozoic (b) During Mesozoic^[10].

Hydrocarbon probable reserves within Mesozoic and Cenozoic succession

The Cretaceous stratigraphy of Iraq is thus characterized by the development of abundant source, reservoir and seal facies. Regional subsidence and pulses of tectonic deformation led to the early formation and preservation of structural traps containing Cretaceous reservoirs that predated the generation of oil from upper Tithonian and Cretaceous source rocks. According to Almashhadani ^[10] study there is a big Mesozoic (Jurassic and Cretaceous) sedimentary basin about 2000 m thickness within a graben in Sinjar and south of Sinjar. He called it Sinjar and south Sinjar basins, as shown in fig. (18). Most of the known oil accumulations of Northern Iraq probably originated by upward migration from earlier, deeper accumulations which were initially housed in stratigraphic or long-established structural traps, and which are now largely depleted. Development of the region favored lateral migration from different basinal areas of Upper Jurassic and Lower-Middle Cretaceous time into different areas of primary accumulation (4). Due to Dunnington[11] the huge Kirkuk accumulation, now housed in Eocene-Oligocene limestones, ascended from a precedent accumulation in porous Middle-Lower Cretaceous limestones, which drew its oil from globigerinal-radiolarian shales and limestones of the contemporaneous basin, a short distance east of the present field limits, see figure 13 above. The sulfurous, non-commercial crudes of Miocene and Upper Cretaceous reservoirs in the Qaiyarah area are thought to stem from basinal radiolarian Upper Jurassic sediments, which lie down dip, a few tens of miles east of these fields. Upper Cretaceous oils of Ain Zalah and Butmah drained upward from primary accumulations in Middle Cretaceous limestones, which were filled from basinal sediments of Lower Cretaceous age situated in a localized trough a few miles northeast of these structures. The huge Kirkuk accumulation, now housed in Eocene-Oligocene limestones, ascended from a precedent accumulation in porous Middle-Lower Cretaceous limestones, which drew its oil from globigerinal-radiolarian shales and limestones of the contemporaneous basin, a short distance east of the present field limits.

Eocene-Oligocene globigerinal sediments, considered by some the obvious source material for Kirkuk oil, seemingly provided little or no part of the present accumulation. The reservoir formation may have been filled from these

sources. The oil fields of the Qaiyarah area occur in the anticlinal traps of the Qaiyarah, Najmah, Jawan, and Qasab structures. There are two productive reservoirs, the upper one comprising the porous, neritic lagoonal Euphrates limestone, of lower Miocene age, and the lower one being neritic limestones of Upper Cretaceous (upper Campanian-lower Maastrichtian age). The upper reservoir is more consistently porous and permeable than the lower, which shows marked variation in quality from dome to dome. The Ain Zalah field, situated northwest of Mosul, is in a simple anticline, 12 miles long and 3 miles wide, which exposes Lower Fars limestones and anhydrites. Production is drawn from two "pays", see figure 11 above. The upper or "First Pay" yields oil from fractures in unpermeated globigerinal limestones of Upper Cretaceous age. The "Second Pay" reservoir is of porous and fractured Middle Cretaceous limestones and dolomites, abetted by fractures in overlying lower Senonian-lower Campanian cherts, shales, and oligosteginal limestones. The two "pays" are separated by about 2,000 ft (609.6 m) of barren, marly, globigerinal limestones similar to those in which the "First Pay" is developed. So the probability of forming oil accumulations within Cretaceous rocks in South Sinjar basin and later on immigration of it to the Sinjar anticline north of this basin is expected. Brew et.al study of Abd el Aziz- Sinjar uplift in Syria supports the probability of presence of multiple reservoirs in Cenozoic and Mesozoic carbonates within Sinjar anticline see figures 19 and 20.

from this study we recommend to run a seismic survey around Sinjar anticline and then we recommend to drill two deep wells on Sinjar anticline one in the north limb and another in the south limb after seismic interpretation to explore the probable petroleum reservoirs expected in this study. We believe that this area is regarded as one of the important and promising areas in containing hydrocarbon (oil & gas). This area didn't have a good attention in the past and still, but if the exploration completed with seismic surveys and drilling this area might show big promising surprises, reinforce that presence of many oil and gas fields along Sinjar uplift in Syria.

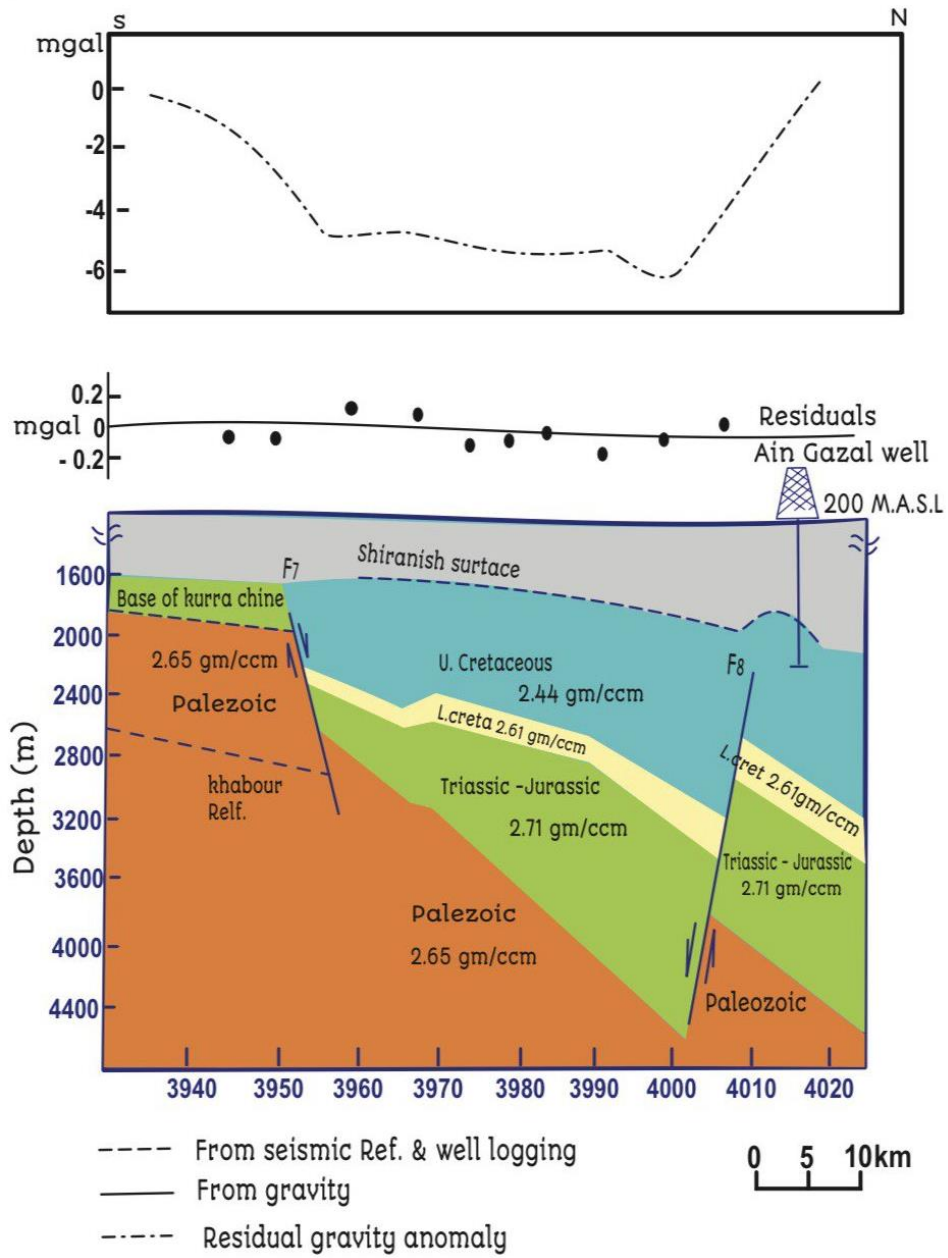


Fig.18 Observed and calculated gravity effect of Sinjar South Cretaceous basin (depo-center) ^[10].

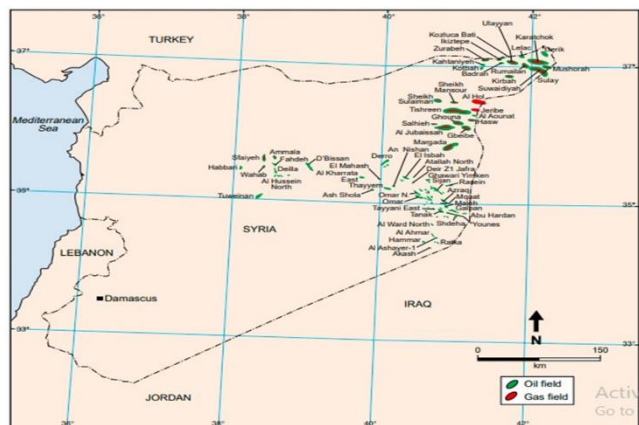


Fig.19 Oil and gas fields of Syria^[11]

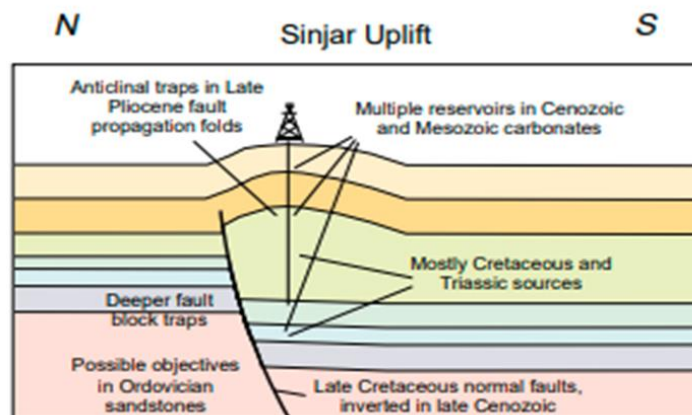


Fig.20 Schematic cross section of trapping configuration in Abd el Aziz- Sinjar oil field of Syria^[11].

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الخلاصة

يُقدّم تحليل للنظام البترولي لطية سنجار (الواقعة شمال غرب العراق). كشفت البيانات الجيوفيزيائية السابقة (التي تُفسّر باستخدام الآبار الجوفية، والتحليلات الجاذبية والمغناطيسية والزلزالية) عن وجود حوض رسوبي كخندق جنوب طية سنجار خلال العصرين الباليوزوي والميسوزوي، كمصدرٍ لتوليد البترول، ينتقل إلى طية سنجار كصخور خزان نموذجية، مُشكِّلاً نظاماً بترولياً مثالياً يُفترض وجوده خلال العصرين الباليوزوي والسينوزوي. يُشير وجود مواقع نفطية في امتداد مرتفع سنجار داخل سوريا إلى وجود النفط في هذه الطية، حيث يقع الجزء الأكبر منها داخل العراق.