# [EA]Geology of West Karun Oil Fields Shared Between Iran and Iraq*

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## Abstract

Iran-Iraq boundary has 23 oil fields on both sides of the border. These fields contain more than 30 billion barrels of oil reserves with production capacity of more than 5 million barrels of oil per day. This presentation illustrates the geology and reservoir extensions of oil fields located in Khuzestan Province, SW Iran, west of the Karun River, and crossing over into southern Iraqi Provinces of Basrah and Misan. The shared supergiant complex of Azedgan-Yadavaran-Majnoon contains more than 20 billion barrels of oil reserves. These joint fields are considered green and none of these fields have been developed to full capacity. Late Oligocene-Early Miocene Asmari Formation is an important reservoir in in these fields and it is part of the Asmari-Gasharan-Khadzumi Petroleum System which provides massive oil reserves-production in Iran, Iraq, and other Gulf countries. The Asmari Formation consists of about 400 m of cyclic platform limestone, dolostone, sandstone, and shale. The Formation is equivalent to the Euphrates, Ibrahim, Tarjil, and Palani Formations in Iraq and to Dammam and Burgan Formations in Saudi Arabia and Kuwait. Reservoirs of Bangestan Group include the thick Sarvak Limestone Reservoir (300 m to 1000 m thick) of Cenomanian-Turonian age and the Illam Reservoir (50 m to 200 m thick) of Turonian-Campanian age. These two reservoirs form a single reservoir in most of the Dezful Embayment in SW Iran and are capped by Gurpi/Pabdeh marls. Sarvak Formation is the lateral age-equivalent of the Mauddud, Rumaila, and Mishrif Reservoirs in Iraq. The Ilam Formation consists of fine-grained argillaceous limestones with interbedded shales, deposited under shallow to deep open-marine conditions. Diagenetic processes have reduced its reservoir quality, while extensive fracturing enhances reservoir properties. The Albian Kazhdumi Formation consists of 300-500 m of dark bituminous shale, is the main source horizon in SW Iran. Kazhdumi TOC average is 6 %, classifying Kazhdumi as one of the richest source rocks in Iran. The Lower Cretaceous Fahliyan Formation is a major reservoir West of Karun River into the border with Iraq. This formation is equivalent to the lower Ratawi - Minagish Formation, which is a significant hydrocarbon reservoir in Iraq, Kuwait, and Saudi Arabia. Fahliyan is part of the Khami Group, which attains thickness of more than 1500 meters in the subsurface of the Dezful Embayment, consists of limestone deposited in a shallow carbonate shelf environment. Fahliyan is sealed by Gadvan compact clastics and sourced from Garau - Jurassic Formations.

## 1 - Introduction

Zagros Geological Complex (ZGC) in west Iran encompasses Dezful Embayment (DE) or Depression, which contains tremendous oil resources in SW Iran. This (DE) of (ZGC) represents the majority of Iran's onshore oil reserves and production. The Complex is a convergence plate boundary between the Arabian Plate and Eurasian-Iranian Plate, which runs in a SE-NW trend from the Arabian Sea/Hurmoz Strait in SE Iran to Taurus Mountains and thrust belt on the Iraq-Turkish Border. The Deformation Zone created by the plate collision is about 300 km wide and 2000 km long. The collision of the Arabian Plate and Iranian Plate took place in the Miocene and led to the closing of Neo-Tethys Ocean. DE contains 12 km of Infra-Cambrian-Pliocene sediment with prominent giant oil fields such as Ahwaz, Marun, Gachsaran, Mansuri, Agha Jari, Bibi Hakimeh, and Rag-e Safid. The Iranian part of the Zagros Basin has more than 300 anticlines, mostly filled with oil.

Iran-Iraq boundary runs for 1500 kilometers, with 23 oil fields located on both sides of the border. This paper will focus on shared fields located in SW Iran, west of the Karun River in the Iranian Province of Khuzestan and the Iraqi Governorates of Basrah and Misan. These fields will be named herein after as WKF or West of Karun River Oil Fields.

WKF comprises massive producing complex with more than 50 billion barrels of oil reserves and production capacity of more than 5 million barrels of oil per day. Among the shared fields from the Iranian side include Darquan, Susangerd, Jufier, Yaran, and the super-giant fields of Azadegan and Yadavaran. From the Iraqi side, the shared oil fields are located mainly in Basrah Province (Majnoon Field) and Misan Province (Faqqi, Amara, Halfaya, Huwaiza, and Noor). The supergiant complex of Azedgan-Yadavaran-Majnoon contains more than 30 billion barrels of oil reserves.

The joint fields are considered green and none of these fields have been developed to full capacity. On 30 November 2015 (Tehran Summit) Arvandan Oil & Gas Co. has introduced WKF to foreign and domestic investors under the new arrangement known as IPC or Iran Petroleum Contract. The current political conditions, especially after US cancelled the nuclear deal in August 2017 and the subsequent re-instatement of sanctions by US is making full development of these fields uncertain over the short period of time.

## 2 - Geomorphology

The Khuzestan Plains in Iran and the Mesopotamia Plains in Iraq constitutes low wetlands, barely rising a few meters above sea level, and partly covered with marshes. These marshes are fed by the Tigris River in Iraq and the Karkeh River in Iran and are named in Iraq as Huwaizah Marshes and in Iran as Hoor Al Azm Marshes, Figure 1.

The Karun River has its rise in the Baḵtiari Zagros Mountains west of Isfahan and follows a meandering course southward to the Persian Gulf. After bisecting modern Ahvāz, the river continues in a general southerly direction towards its mouth at Shatt al-Arab (Arvand Rud in Persian). There are major oil fields in Hawizah Marshes, primarily under man-made islands north of the city of Basra, Iraq. The fields include the super-giant Majnoon Field, in addition to Huwaiza Field in Misan province and Sindibad Field in Basra.

In Iran, vast areas of Hoor al-Azim have been dried for oil exploration and desiccated due to oil drilling and upstream dam construction (Karkeh Dam). This has caused immense dust storms which reached the city of Ahwaz in Khuzestan.

## 3 - West Karun Shared Oil Fields

WKF are located in the massive producing complex in Khuzestan Province near the Iraqi border. These fields are Azedgan North, Azedgan South, Yaran North, Yaran South, Yadavaran, Darquan, Jufeir, Sepher, Susangerd, Arvand, Sohrab, and Band e Karkeh. They are under control of the Petroleum Engineering and Development Company (PEDEC), Arvandan Oil and Gas Company, subsidiaries of NIOC (National Iranian Oil Company). On 30 November 2015 (Tehran Summit) Arvandan Oil & Gas Co. has introduced six oil fields, i.e. Susangerd, Jufeir, Sepher, Band-e-Karkheh, Arvand, and Sohrab, to foreign and domestic investors under the new Iran Petroleum Contract or IPC.

WKF area west of the Karun River in SW Iran contains 200 development wells, 40 exploration wells and 7000 $km^2$ of 3-D seismic. The Central Production Unit, located in Jufier Field has a treatment capacity of 165,000 b/d. The block contains 64 billion barrels of in-situ reserves with production of about 300,000 b/d (see Figure 2).

The main production is coming from Yadavaran 85,000 b/d, South Azadegan 83, 000 b/d, and North Azedgan 40,000 b/d. Production estimates for these fields in 2015 were projected at 400,000 b/d in 2018, 1,000,000 b/d in 2020 and 1,500,000 b/d in 2023 but never reached due to sanctions and exiting of international oil companies. Iraq on the other side produces about the same level of WKF from the Majnoon Field alone.

## 4 - Petroleum Systems

There are 5 Petroleum Systems in the Iranian Zagros Complex:

1) Aasmari-Gasharan-Kazhdomi (AGK) Petroleum System, which is the most prominent Petroleum System in Iran and also globally.
2) Bangestan-Gurpi- Kazhdomi Petroleum System, which contains Saravak and Ilam reservoirs.
3) The Lower Paleocene-Eocene Pabdeh Petroleum System.
4) The Santonian-Maastrichtian Gurpi Petroleum System.
5) The Neocomian-Aptian Gadvan Petroleum System.

The Kazhdumi and the Pabdeh Formations have the highest potential for hydrocarbon generation and assumed to have charged Asmari and Bangestan reservoirs in the oil fields of SW Iran (see Figure 3). Overall, the 5 petroleum systems in Iran caused an impressive gathering of oil and gas fields that represent some 8 % and 15 % of global oil and gas reserves, respectively. AGK includes the Asmari Reservoir, which has been producing massively for more than hundred years. The reservoir is capped by Gasharan anhydrites and sourced from the Khadzumi Formation.

## 5 - Gachsaran Seal

The Miocene Gasharan, formerly known as the "Lower Fars Series" in the Zagros geosyncline of SW Iran can be divided into 4 major stratigraphic units with different nomenclatures:

1) Anhydrite-salty facies (Gachsaran Formation).
2) Sandy-silty facies (Razak Formation).
3) Gypsum-anhydrite facies (Namaki Formation).
4) Massive salty facies (Qeshm Formation).

The Gasharan Formation with thickness of 600-1200 meters provides a very efficient regional seal to the Asmari Limestone reservoir.

## 6 - Asmari Reservoir

The Miocene Asmari Formation consists of about 400 m of cyclic platform limestone, dolostone, sandstone, and shale. The Asmari was deposited in a shallow marine environment of the Zagros foreland basin and it is best developed in the Dezful Embayment Zone. The Formation is equivalent to the Euphrates, Ibrahim, Tarjil, and Palani Formations in Iraq and to the Dammam and Burgan Formations in Saudi Arabia and Kuwait, respectively. The Asmari reservoir has very high production rates, although its porosity and matrix permeability are not as high. Primary porosities in the Asmari carbonate reservoirs range from 5-15 %, with permeability range from a few millidarcies to 30 mD. However, extensive fracturing has significantly enhanced the productivity of the reservoir, with well test results indicating effective porosity up to 25 % and permeability of 100 mD. Production rates can be maintained for very long periods because of the great vertical extent of the oil columns. The Asmari reservoir has been producing since 1908 and it produced 530,000 b/d from the Ahwaz Field since 1958 and 400,000 b/d from the Marun Field since 1966. In Khuzestan, the Asmari Formation ranges from 320–488 m in thickness, of which net reservoir ranges from 10 to 280 m. The Asmari is much thinner in the south-eastern Zagros, thickening towards the northwest and is productive at depths between 300 and 3,300 m. Maximum thickness of the Asmari Formation is found in the NE corner of the Dezful Embayment. In the SW part of the Zagros Basin, the Asmari Formation overlies the Pabdeh Formation. The Asmari is capped by the thick evaporates of the Gasharan Formation and sourced by Khadzumi Formation.

## 7 - Ahwaz Sandstone Member

In the SW of Dezful Embayment, Asmari lithology changes into a mixed siliciclastic-carbonate deposit consisting of carbonate beds with several intervals of sandstone, sandy limestone, and shale. This facies provides the Ahwaz Sandstone Member in some oil fields such as the super-giant fields of Ahwaz, Marun, and Mansuri. The distribution of Ahwaz Sandstone along the strike of the Zagros foreland basin is restricted to the southwestern margin of Zagros and can act as an aquifer.

## 8 - Pabdeh Formation

The Eocene Pabdeh Formation is composed of marls, shales, and carbonates, deposited in a ramp environment. Average TOC values of the Pabdeh Formation are varying from 3 % in Fars to 7.5 % in the Lurestan and the organic matter is mostly algal/Type II kerogen.

## 9 - Gurpi Formation

The Santonian-Masstrichtian Gurpi Formation consists of marl and shale with low organic content of 0.5-1.5% and its role as source would be very limited. Shales of the Gurpi Formation provide the major top seal to the Sarvak and Ilam reservoirs in many parts of Iran. However, fracturing limits the seal efficiency of this formation, allowing partial communication between the Bangestan and Asmari reservoirs.

## 10 - Bangestan Group

The group includes the thick Sarvak Limestone Reservoir 300-1000 m of Cenomanian-Turonian age and the Ilam Reservoir 50-200 m of Turonian-Campanian age. These two reservoirs form a single reservoir in most of the Dezful Embayment in SW Iran and are capped by Gurpi/Pabdeh marls.

### 10-1: Ilam Formation

(Turonian-Campanian): consists of fine-grained argillaceous limestones with interbedded shales, deposited under shallow to deep open-marine conditions. Diagenetic processes (including cementation, dolomitization, dissolution, neomorphism, bioturbation, compaction, and silicification) have reduced its reservoir quality, while extensive fracturing enhances reservoir properties. The porosity ranges from 9-20 %, and permeability is generally moderate to low, commonly less than 10 mD. The Ilam is subdivided into Upper Ilam and Lower Ilam (main reservoir). The source rock for Ilam oil is the Jurassic Sargulo Formation.Net reservoir thickness of the Ilam Formation may reach up to 150 m. Ilam oil is heavy, with API of 22 and GOR of 300 scf/stb. Ilam has lighter oil in Susangerd. Upper Ilam is oil-bearing in the Azedgan Field, but it is water-bearing in the fields of Sepher and Jufier. Lower Ilam is oil-bearing in the Sepher and Jufier Fields.

### 10-2: Sarvak Reservoir

The Albian-Turonian Sarvak Formation is the lateral age-equivalent of the Mauddud, Rumaila, and Mishrif Formations in the Iraq and Arabian Plate. It is the second most important reservoir in SW Iran after Asmari. It consists of carbonates deposited on a gently sloping shallow marine environment. The Sarvak is productive in a large number of major oil fields in Iran including Agha Jari, Gachsaran, Marun, Bibi Hakimeh, Mansuri, Ahwaz, Sarvestan and Sirri C, D, and E. Reservoir quality within the Sarvak is controlled by a number of factors including facies, fracturing, and late-stage fracture-controlled diagenesis. Primary matrix porosity is generally low at 4-6 % and permeability is about 1 mD, but porosity is commonly improved by intensive fracturing and increased to 7-14 %. Net reservoir thickness from 5 to more than 250 m. The reservoir is capped by the Gurpi/Pabdeh marl and sourced from the Kadzhumi Formation.

## 11 - Kazhdumi Source

The Albian Kazhdumi Formation consists of 300-500 m of dark bituminous shale and is the main source horizon in SW Iran. Kazhdumi TOC average is 6 %, classifying Kazhdumi as one of the richest source rocks in Iran. Kazhdumi, Asmari, and Bangestan constitute by far the dominant petroleum system of the Dezful Embayment, being responsible for the accumulation of more than 7.3 % of the world reserves in an area of 40,000 km² in the Iranian Zagros Fold Belt. The Kazhdumi origin of the oil of the Dezful Embayment main fields such as Agha Jari, Ahwaz, Bibi Hakimeh, Gachsaran, Mansuri, Marun, and Rag-e Safid was verified from stable isotope oil-to-oil and oil-to-source rock correlation and bio-marker signatures (Bordenave, 2002). During Early Miocene, the Khadzumi was buried to depths of about 3500 meters, reached the oil window, and charged the Arabian trend traps in the western Dezful Embayment. Oil migrated vertically towards the closest anticlines through a system of fractures. Oil expulsion occurred almost everywhere in the Dezful Embayment after the onset of the Zagros folding and charging the Asmari and Bangestan. Expulsion of oil started 10 Ma ago in Early Miocene.

## 12 - Khami Group

The Khami group with thickness of more than 1500 meters in the Dezful Embayment is separated from the Bangestan group by the Kazhdomi shale formation. The group is divided into 5 formations: Surmeh, Hith, Fahliyan, Gadvan, and Dariyan. Surmeh and Hith belong to Late Jurassic, while Fahliyan, Gadvan, and Dariyan belong to Early Cretaceous.

The Khami Group contains several high-pressure reservoirs, with significant light oil of API 36-44 and gas reserves.

### 12-1: Fahliyan Reservoir

The Lower Cretaceous Fahliyan Formation creates major reservoirs in the Abadan plains and the area West of the Karun River into the border with Iraq. This formation is equivalent to the Lower Ratawi-Minagish Formation, which is a significant hydrocarbon reservoir in Iraq, Kuwait, and Saudi Arabia. The Fahliyan was deposited in a shallow carbonate shelf environment. The Fahliyan is sealed by the Gadvan and sourced from the Garau-Jurassic Sargelu Formations. The Fahliyan reservoir is a diagenetic-heterogenous reservoir influenced by diagenetic processes: dissolution and fracturing enhanced reservoir properties while cementation, compaction, and dolomitization reduced reservoir properties. Shakeri and Parham (2013) described 8 units of the Fahliyan Formation with the upper 3 units described as poor-fair reservoir and porosity values of 0.7-7.8 %, the middle unit of good-excellent porosity 15-19 %, the three lower middle units of fair-good porosity 2-14 %, and the lower unit of good-excellent porosity 8-18 %. This lower unit is considered the best reservoir zone of this formation due to dissolution effect.

Testing results of the Fahliyan reservoir (upper and lower) in well Sepher-1 were as follows:

The well tested oil of 3,624 b/d from the U. Fahliyan at depths of 4220-4224 meters, 2,808 b/d oil from the L. Fahliyan at depths of 4457-4466 meters, 2,665 b/d oil from the L. Fahliyan at depths of 4503-4512 meters. In addition, the well tested water at depths of 4561-4577 meters in the L. Fahliyan Formation.

On the other hand, light oil of 44 API was recorded/tested in the Fahliyan Formation of the Arvand oil field near the border with Iraq. In the Susangerd oil field, the Fahiliyah Reservoir (discovered 2009) contains light oil recoverable reserves of 870 million barrels. Jufiar Field has been producing from the Fahliyan for 4-5 years, with an average rate of 1500 b/d. the Yadavaran oil field produces light oil from the Fahliyah reservoir with API 40. The supergiant S.Azadegan produces from several reservoirs including the Fahliyan, Sarvak, Khadzumi, and Gadvan.

### 12-2: Gadvan Formation

The late Neocomian-Aptian Gadvan is a thin sandstone reservoir that produces light oil in the Jufier oil field. It is hard to be detected by seismic as these sands are thin and may take the form of lenses rather than continuous layers. It is equivalent to the Zubair Formation in Iraq. The Gadvan Formation is deposited in deep-marine to shallow-shelf environment, located between the Fahliyan Limestone and the Dariyan Formation. Lateral facies changes occur; the formation in the Khuzestan province consists of dark shale and argillaceous limestone, whereas in the Lurestan province, the limestone passes to dark and black argillaceous limestone of the Garau Formation (Nocomian-Coniacian). Gadvan oil is mostly light but can be heavy in Jufier and Sepher Fields and heavy-medium in Arvand and Darquan Fields.

## 13 - Major Oil Fields on Both Sides of the Aisle

Azedgan and Yaran oil fields in Iran and Majnoon oil field in Iraq can form a single supergiant oil store to be the largest in the world. Moving a bit southward from this complex, there is another supergiant store, Yadavaran Field in Iran, and its extension in Iraq of Block-9. Azedgan and Yadavaran fields alone are expected to boost Iran’s oil production capacity by 1,000, 000 b/d once fully developed. Yaran oil field in Iran is estimated to contain 2 billion barrels of in-situ crude oil in its reserves, with major portion of the field located in Iraq. Iran was planning to start pumping crude oil from the South Yaran oil field in 2017 at an initial rate of 10,000 b/d.

Yadavaran oil field contains oil in place reserves of 12 billion barrels, of which 3.2 billion barrels are recoverable. The field currently produces 85,000 b/d and will reach 350,000 b/d when fully developed. Cumulative production so far surpassed 60 million barrels from the Fahliyan and Sarvak reservoirs of the Yadavaran Oil Field.

Azadegan oil field (North and South) was once described as Iran’s biggest oil discovery in decades and is believed to have in-place oil reserves of 33 billion barrels, including 6 billion barrels recoverable. South Azadegan Field was discovered in 1999 and put on-stream in 2008. The field produces 50,000 b/d and has been projected to produce 600,000 b/d in Phase 3 development. North Azedgan Field is largely located in a lagoon area, which forced PEDEC to modify drilling methods in order to protect the lagoon environment. Water depths in some areas can reach 5 meters, and so cluster drilling were carried out in the field. Oil production from this field started in April 2016, with production stands at 50,000 b/d and gas production of 39 mmscfd. With the full implementation of the early production plan, the output of North Azadegan will reach 110,000 b/d.

Huwaizah Field in the Hawaizah marshes is located near Iran's border north of Basra and extending to 63 kilometers to the east of Misan Governorate, Iraq. The first well was drilled at the Howaiza Field at the end of the 1970s, but the development was halted because of the Iran-Iraq war in 1980-1988. Geological studies and preliminary forecasts indicate reserves of more than 1 billion barrels of oil in the field, of which

220 million barrels recoverable. Mishrif carbonates, Nahr Umr sands (Middle Cretaceous), Shuaiba carbonates, and Zubair sands (Lower Cretaceous) form the pay zones. Huwaiza Field first pay zone consists of Upper Cretaceous, which tested 4,000 b/d of gas rich oil in 1976. The pressure at the Upper Cretaceous reservoir was so high that the rig used in the discovery was destroyed. The field is projected to produce 20,000-30,000 b/d after the completion of the Development Plan, which was projected to start in 2017.

The supergiant Majnoon oil field in Iraq was discovered in 1976 by Braspetro through drilling of well Majnoon-1 to a total depth of 3535 meters in the Ratawi/Fahliyah Formation. One of the wells in the field has penetrated 14 oil zones, and that as why the field was named Majnoon, which is Arabic for Crazy (see Table 1). The field is located 60 km northwest of Basrah, a city on the border with Iran, extending northerly toward the Misan Governorate under Huwaizah marshlands. Recent calculations by the Iraqi Oil Ministry has put Majnoon's reserves to be 38 billion barrels of oil in place. The field was awarded to Shell and partners in 2009, the production started in 2014, reached 215,000 b/d in 2016 and currently produces 250,000 b/d. The field can have production capacity of 1-2 million b/d when fully developed.

## 14 - Other Iranian Oil Fields West of the Karun River

The area west of the Karun River contains other oil fields, although not the size of Azedgan and Yadavaran but still significant in terms of reserves and production capacity. The main four fields are Jufier, Sepher, Susangerd, and Darquan oil fields. These fields are still green, some are in the exploration stage, others not developed or not fully developed.

Jufier oil field was discovered in 1976 by Deminex, and located in Khuzestan Province, 50 km west of Ahvaz, 30 km east of supergiant Azadegan oil field, and near Ab Tymor oil field. The field is close to the West Karun Processing Unit. The field has 6 wells including 4 producers. Wells Juf-1 and 2 has reached TD of 4300 meters in Cretaceous reservoirs. In 2010, new wells were drilled and discovered 4 reservoirs of Ilam with API 18-23, Sarvak with API 20, Gadvan with API 23, and Fahliyan with API 34. Oil in place reserves were estimated at 2 billion barrels, including 230 million barrels recoverable. In September 2010, the field produced 100,000 barrels from 4 wells, or 3500 b/d. In 2017, the field produced 1300 b/d. Cumulative production from the field reached about 3 million barrels in 2017.

Sepher oil field was discovered in 2011 and it is adjacent to the Jufier Field. Oil in place reserves were estimated at 2 billion barrels, with 300 million barrels recoverable. The field produces oil from Ilam reservoir 22-23 API, Gadvan 34-38 API, and Fahliyan reservoir 38 API. DST testing of Fahliyan at 4500-4600 m on well Sepher-1 produced oil at rates of 1000-7000 b/d according to chock size and period of testing. The well experienced a high-pressure zone of more than 10,000 psi in the Fahliyan Formation. Since Jufier and Sepher are close to each other, development plan outlines include drilling 8 vertical wells in Sepher Fahliyan and 24 horizontal wells in Jufair Ilam to reach plateau production rate of about 40,000 b/d.

Susangerd oil field was discovered in 1967 but started production in 1990. Production in 2017 was about 5000 b/d from 2 producing wells out of total 5 wells in the field. This production was sent via pipeline to the West Karun processing facility. Oil production is coming from 4 reservoirs of Asmari 16 API, Ilam 22 API, Sarvak 20 API, and Fahliyan API 38 with oil of high sulfur content of 4 %. Asmari has been encountered at 2380 meters in well Susangerd #1 and it is considered mid to heavy at 19 API. Estimated reserves reported by the NIOC as Stock Tank Oil in Place, is 6996 million barrels, including 2 billion barrels recoverable. The Fahiliyah Reservoir (discovered 2009) contains oil

recoverable reserves of 870 million barrels. This reservoir is sealed by the Gadvan Formation and sourced from the underlying Khazdumi Formation. Well Susangerd #3 was drilled to a total depth of 5,000 meters to evaluate multiple reservoirs within the Jurassic and Cretaceous horizons.

Darquan oil field was discovered in 1964, and located close to the supergiant Yadavaran Field, not far from Iraqi fields of Siba, Sindibad, Nahr Umar, and Zubair. The field contains 2.85 billion barrels of oil reserves in Cretaceous and Jurassic formations at depths of 4000-4700 meters. In 2002-2003, Well Darquan-4 test flowed 20,000 b/d, while Darquan-5 test flowed 10,000 b/d. In early 2006, production was 55,000 b/d and reached to 100,000 b/d on 13 January 2008. The field reached cumulative produced oil of about 200 million barrels since 1999. ENI signed Development Contract 2009 Phase III worth US $1.5 billion to produce 260,000 b/d by 2017 but pulled out from Iran in 2011 due to sanctions.

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Figure 1. General location of Hawaizah Marshes/Hoor al-Azim in Iraq-Iran border.

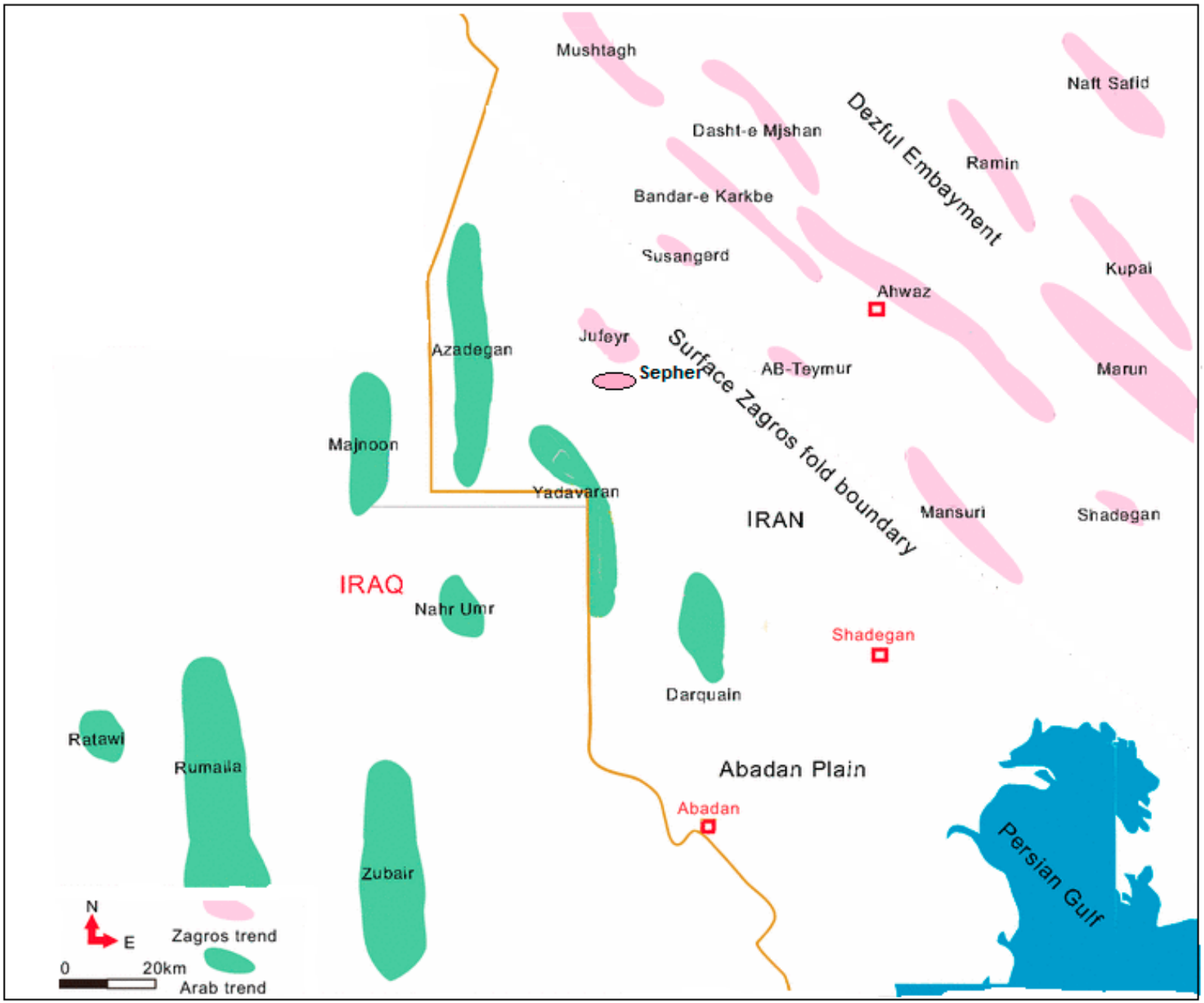


Figure 2. Location of oil fields west of Karun River in Iran and into border with Iraq.

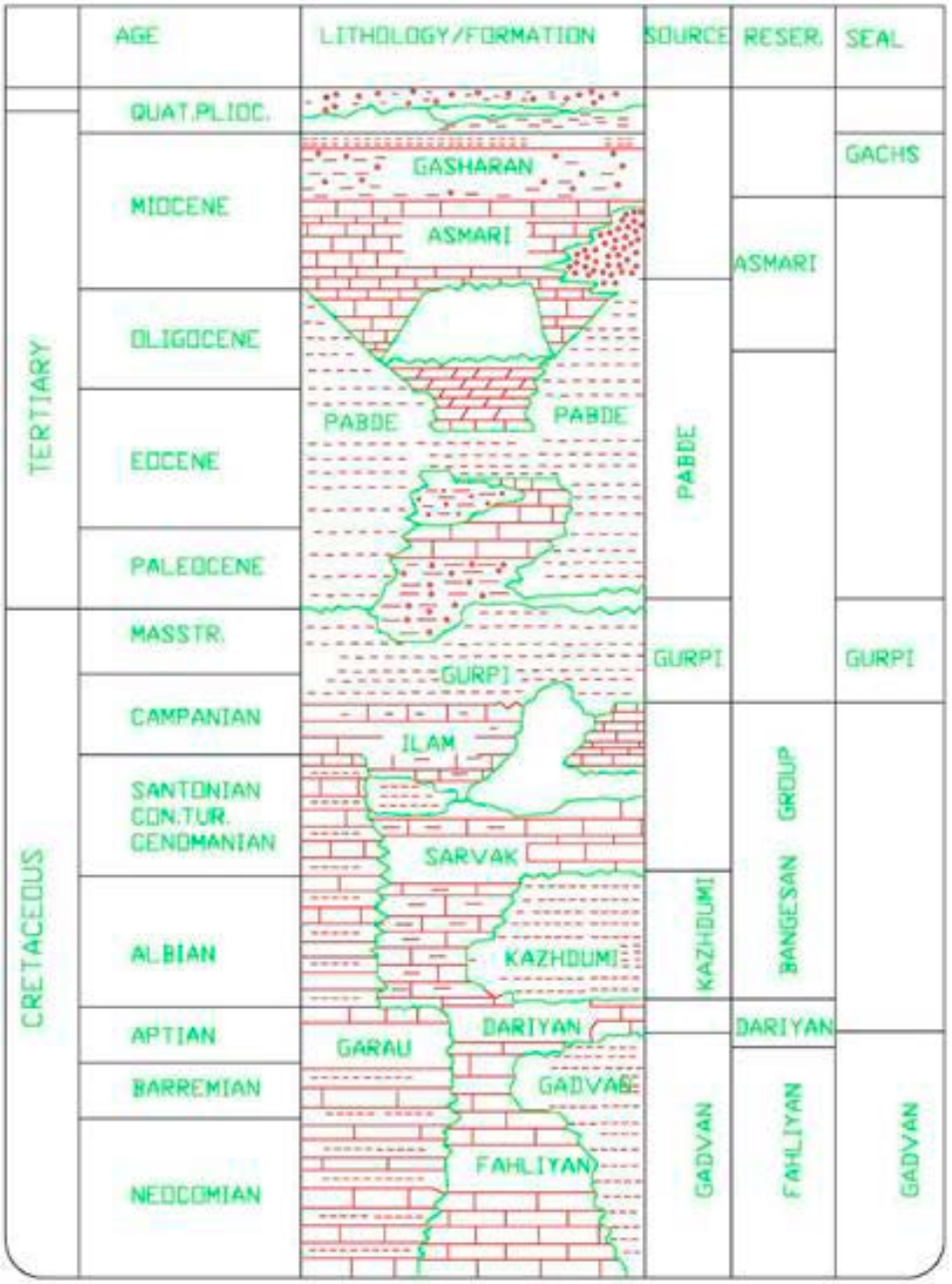


Figure 3. Petroleum systems in Cretaceous-Tertiary sequence of SW Iran.

| WELL MAJNOON-3- IRAQ | | |
|---|---|---|
| FORMATION- **IRAQ** | TOP (m)-**IRAQ** | FORMATION- **IRAN** |
| ALLUVIUE/HAMMAR | 8 | BAKHIATRI |
| U.FARS/DIBDIBBA | 27 | |
| L.FARS | 1025 | AGHA JARI |
| GHAR | 1320 | |
| DAMMAM- MIOCENE | 1427 | ASMARI |
| UMM AL RADHUMA | 1636 | |
| AaLiji | 1952 | PABDEH |
| SHIRANISH | 2087 | GURPI |
| HARTHA | 2226 | |
| SADI | 2362 | |
| TANUMA | 2470 | ILAM |
| KHASIB | 2511 | |
| MISHRIF | 2567 | SARVAK |
| RUMAILA | 2811 | |
| AHMADI | 2824 | |
| MAUDDUD | 2994 | SARVAK/ KHADZUMI |
| NHAR UMER | 3169 | KHADZUMI |
| SHAUIBA | 3354 | DARIYAN |
| ZUBAIR | 3500 | GADVAN |
| RATAWI- L.CRETACEOUS | 3792 | FAHLIYAN |
| YAMAMA | 3853 | |
| SULAIY | 4227 | |

Table 1. Stratigraphic correlation in Cretaceous-Tertiary sequence of SW Iran and Southern Iraq as depicted from well Majnoon-3 in Iraq.