Australian Journal of Basic and Applied Sciences, 4(5): 673-686, 2010
ISSN 1991-8178

Hydrocarbon Source Rock Evaluation of the Super Giant Ahwaz Oil Field, SW Iran

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Abstract: Dezful Embayment in Southwest of Iran is one of the most potential areas for exploration and development of the hydrocarbon reservoirs in the word. This zone includes some super giant oil fields likes Ahwaz, Maroun, Gachsaran, Agha Jari and some other oil fields. Several potential source rock units with different geological ages were deposited in this tectonically developed depression making this area as the most prolific region in the Middle East. The most important source rocks in the Dezful Embayment are the Lower Paleocene-Eocene Pabdeh Formation, the Santonian-Masstrichtian Gurpi Formation, the Albian Kazhdomi Formation and the Neocomian-Aptian Gadvan Formation. The contribution of each source rock to the charge of the Dezful Embayment oil fields was extremely variable. Source rock maturity and potential of these source formations at the Ahwaz oil field in the SW of Iran have been investigated by Rock Eval 6. The petroleum generating potential of these source rocks was evaluated by different parameters including Tmax, TOC, S1, S2, HI, OI, and PI. According to these parameters the Albian Kazhdumi and the Lower Paleocene-Eocenee Pabdeh Formations have the highest potential for hydrocarbon generation and assumed to have charged the Asmari and Bangestan reservoirs in the Ahwaz oil field. The Rock-Eval parameters suggest that the Gadvan and Gurpi Formations are the subordinate source rocks in this area and their contribution to the charge of the reservoirs is negligible.Burial and thermal history modeling was performed to determine timing of hydrocarbon generation in the Pabdeh and Kazhdumi source rock in the Ahwaz oil field. Burial history reconstruction and thermal modeling indicate that beginning of the oil window was dated as 15Ma for the Kazhdumi Formation and 5Ma for the Pabdeh Formation. The beginning of the oil window occurred for the two source rocks when they were buried to a depth of 3500m. The expulsion of oil would have begun 10 Ma ago for the Kazhdomi Formation and 3 Ma for the Pabdeh Formation. The main phase of Zagros folding occurred during the late Miocene and Pliocene. The migration of hydrocarbons from source rocks, was enhanced by the syn-orogenic fracturing of reservoir rocks in the Asmari and Bangestan (Sarvak and Illam) Formations

Key words: Dezful Embayment, Ahwaz oil field, Thermal maturation, Kerogen, Tmax, Basin modeling

INTRODUCTION

The Dezful Embayment is one of the most prolific areas in south of Iran and includes 45 oil fields, often associated with gas caps. Several of them are categorized as super giants as they contain 10 to 50 billions barrels of oil-in-place, i.e. Agha Jari, Ahwaz, Bibi Hakimeh, Gachsaran, Mansuri, Marun and Rag-e Safid. This zone is characterized by intense structural depression and was formed as a result of the Late Cretaceous continental collision between Eurasian (Central Iran) and Persian Plates.

Several potential source rock units with different geological ages were deposited in this tectonically developed depression making this area as the most prolific region in the Middle East (Alsharhan 1989). The accumulation of oil results from a Cretaceous/Tertiary petroleum complex which includes 4 main source rock layers of unequal importance, i.e. the Gadvan (Neocomian Aptian), the Kazhdumi (Albian), the Gurpi (Santonian-Masstrichtian) and the Pabdeh (Eocene). These layers generated 99% of the onshore Iranian oil reserves, trapped into two main reservoirs, the Asmari (Early Miocene) and Bangestan (Cenomanian) limestones which contained 330 billions barrels of original oil in place, corresponding to more than 7% of the current global reserves (Bordenave and Huc, 1995).

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The 250 to 500m thick Asmari Formation is a high-energy limestone rich in large Foraminifera which retains excellent reservoir characteristics over most of the Dezful Embayment. Its reservoir quality is generally enhanced by a prominent system of fractures which occurs near the tops of the high-relief anticlines. In SW Dezful Embayment, the basal part of the Asmari becomes sandy (Ahwaz sandstone Member) which increases its porosity. The Asmari is capped by the thick evaporates of the Gachsaran Formation which forms an effective seal. The Bangestan reservoir includes the thick Sarvak limestone (300m to 1000m thick) of Cenomanian- Turonian age and the thinner Illam Formation (50m to 200m thick) of Santonian age. These two reservoirs form a single reservoir in most of the Dezful Embayment and capped by the thick Gurpi/Pabdeh marls.

Ahwaz oil field (Fig. 1), one of the most important Iranian super Giant oil fields, was discovered in 1956 and now has more than 450 producing wells. This oil field has an anticline structure 72 km long and 6 km wide with NW-SE trending symmetrical anticlinal, located in southwest of Iran and central part of north Dezful region. Its main reservoir is the Asmari Formation and Bangestan Group with the production rate of 1000,000 barrels/day. The recoverable hydrocarbon is estimated as 10 billion barrels of oil and 13. TCF gas (Motiei, 1995).

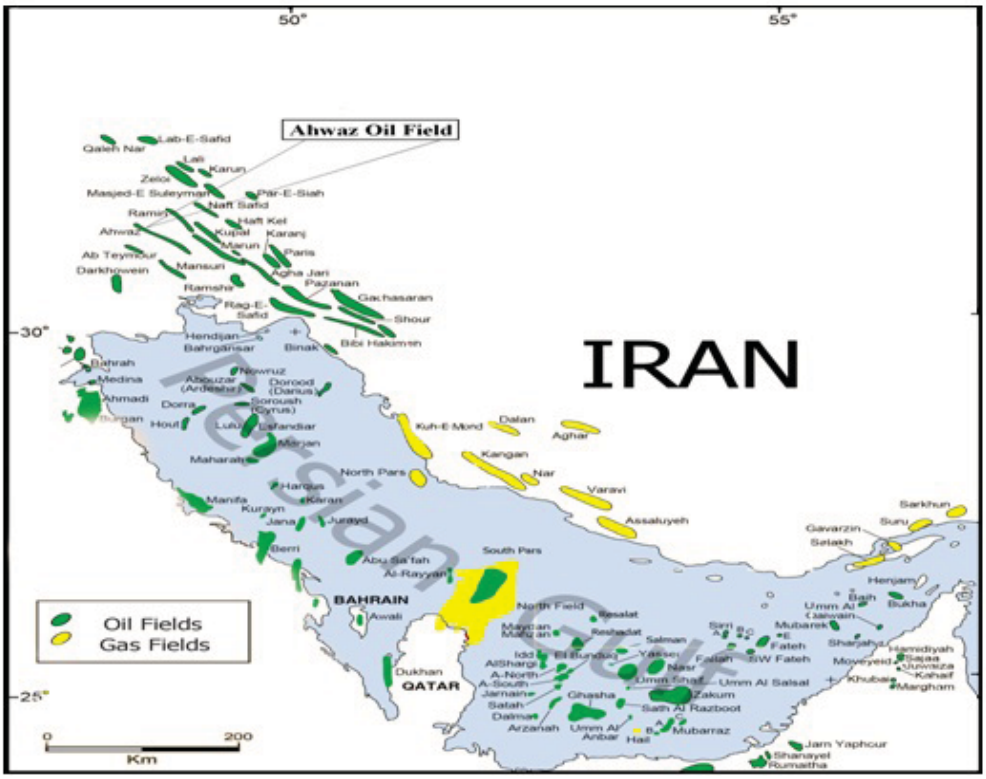

Fig. 1: The location of Ahwaz oil field in the Dezful Embayment, SW of Iran.

This study is focused on evaluation of petroleum generation potential and thermal history of the Pabdeh, Gurpi, Kazhdomi and Gadvan Formations at the Ahwaz oil field's structure.

Geology And Stratigraphy:

The Dezful Embayment is a depressed area within the Zagros Folded Belt. This embayment represents a foreland basin where subsidence at the foot of the uplifting Mountain Front Fault has resulted in the deposition of thick post-Oligocene sediments, including up to 3000 m of Upper Miocene–Pliocene Agha Jari and Bakhtiyari Formations. In this region, the Miocene evaporites of the Gachsaran Formation horizon which forms a very good seal for the Asmari reservoirs, acted as a major detachment. This thick incompetent unit decoupled the folds above it, which are currently exposed at the surface, from the underlying folds, which host the majority of the hydrocarbons in the Iranian sector of the Zagros (Sepehr, et al 2006). The sediments composing the Dezful Embayment are up to 12000 m thick and, except for the Devonian and Carboniferrous systems; the

section is a nearly continuous, conformable sequence from the Infra-Cambrian to the Pliocene. Sedimentation began with important Infra-Cambrian (Vendian) evaporites, followed by the shallow marine carbonate and clastic deposits of the Lower Paleozoic from the Permian and throughout most of the Mesozoic and up to Lower Miocene; the area was part of a broad, shallow carbonate platform. Subsequently, thick evaporates followed by continental red beds characterize the Mio-Pliocene. Folding accompanied by syntectonic and posttectonic molasses took place in Plio-Pleistocene time.

Stratigraphy of Source Rocks:

Most of source rocks in south of Iran were deposited in tropical or equatorial dominating calcareous environments. The Mesozoic and Cenozoic source rock were deposited in intracratonic depression at the time when anoxic conditions prevailed as a result of water-column stratification, during high stand. These source rocks (Fig.2) contain at least 70% carbonate and are best referred to as argillaceous limestone or as marls. They have excellent source characteristics with TOC values up to 8% and hydrogen Indexes to 550 g HC/kg TOC (Bordenave and Hegre, 2002).

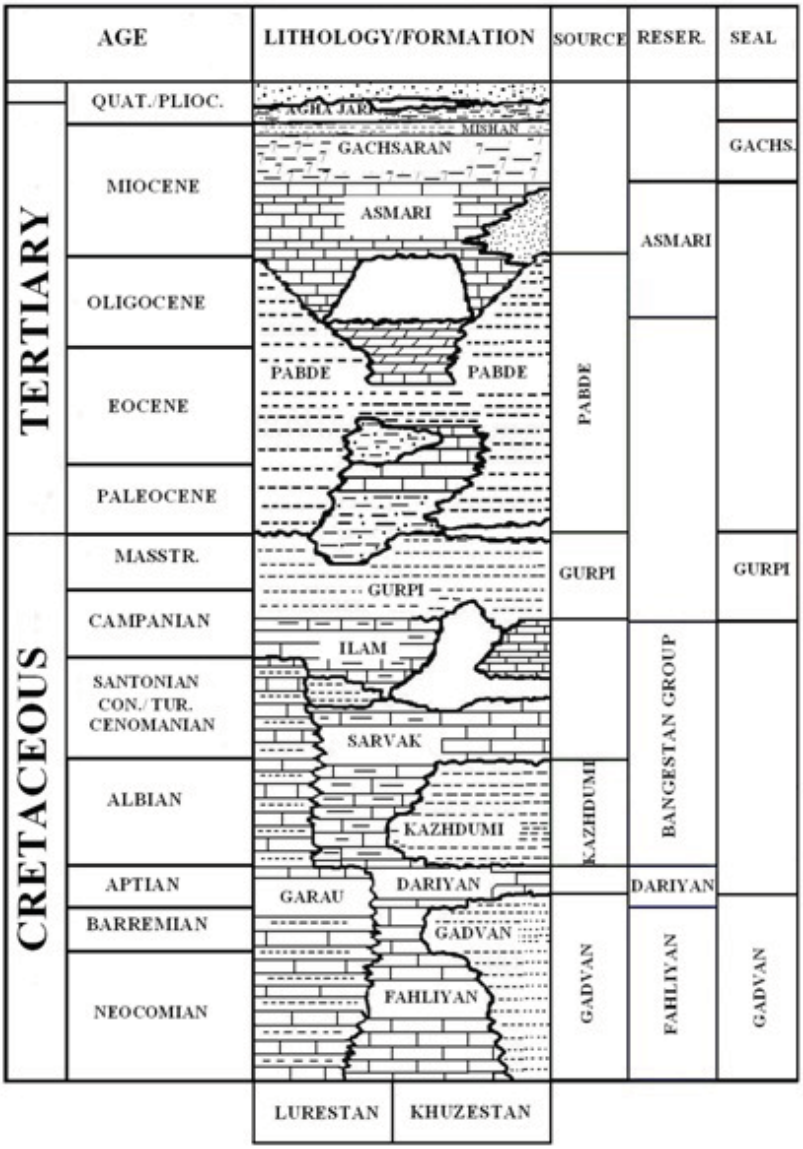

Fig. 2: Schematic stratigraphy and source- reservoir-seal relationship for the Dezful Embayment (Bordenave, 1990).

Pabdeh Formation:

During lower Paleocene-Eocene, a deep open marine sedimentary environment basin elongating NW-SE covers most parts of south of the Iran. 150-250m argillaceous and fine grained dark grey marl sediments of the Eocene Pabdeh Formation were deposited under the euxinic condition, and are rich in planktonic fauna of Globorotalia and Globigerina. The Eocene Pabdeh Formation is a part of thick carbonate successions of Zagros basin, composed of dark -gray marls, shales and carbonates rich in pelagic microfauna. This formation has been interpreted as deep pelagic facies and separates the giant structural traps of underlying Bangestan Group (Cretaceous) from overlying Asmari reservoirs (Oligo-Miocene).

For decades, Pabdeh Fm. was considered a monotonous deep-water shale facies with a limestone unit in it's middle part. Recent studies showed a significant part of this formation consists of limestone beds, deposited in a ramp environment. Alternation of shale and limestone beds of this Fm. in NE Illam province represents a rhythmic behaviour (Khodabakhsh et al 2008). The Paleocene-Eocene foreland setting of Pabdeh Fm. was suitable for development of a distally steepend ramp. In this condition, co-existance of clastic and carbonate sediments occurs. Storm events significantly affected the ramp setting and were able to transport sediments from onshore to a deeper outer ramp where they were deposited as shell-lag deposits. These storm events produced distal tempestite with characteristic sedimentary structures and composition (Mohseni, and Al-Aasm, 2004).

The average TOC values of the Pabdeh Formation is varying from 3% in Fars to 7.5% in the Lurestan, and the organic matter is mostly algal (type II) with HI to 500 (mg HC/ g TOC). However, terrestrial influences (type III) are visible.

Gurpi Formation:

Gurpi formation lies by an erosional disconformity on Illam Formation and turns gradually to the purple shales of the overlying Pabdeh Formation. The Gurpi Formation was dated the Santonian- Masstrichtian based on the presence of foraminifer species *Globotruncana calcarata* and dinocyst species *Odontochitina porifera* in the lowermost parts and foraminifer species *Morozovella velascoensis* in the uppermost parts of the section. In type section, in north of Masjed- E Suleyman city, this Formation consists of gray shale with layers of marl. The Cretaceous / Tertiary boundary (KTB) is located some 57 meters below the Gurpi and Pabdeh contact within the black shales of the Gurpi Formation (Ghasemi-Nejad & Zarei, 2006). In the context of source quality and source richness of the Pabdeh Formation, the Gurpi Formation has a low organic content. The Gurpi marls generally have a low organic content (0.5-1.5%) and its role in the main fields by attention to the distribution and thickness of organic layers would be very limited (Bordenave and Burwood 1990).

Kazhdumi Formation:

The Albian Kazhdumi Formation consists of 300m dark bituminous shale with a dark argillaceous limestone layer in the type section in the Khuzestan mountain front area. In north of the Dezful and northeast of Lurestan, the Kazhdumi Formation changes to carbonate unit, laterally. This Formation is substituted by the Garau Formation in the south and central part of Lurestan Province. In the central part of the Dezful Embayment, the Kazhdumi sequences were deposited in a silled, intrashelf depression with pelagic fauna. During the Albian, the Arabian platform was closed to the equator, according to plate tectonic reconstruction, and under a humid climate as shown by the large amount of fresh water which flowed into the Dezful depression through a system of rivers. This water was nutrient rich, ideal conditions were realized for high plankton productivity in the shallow low-density oxygenated fresh water (Bordenave, 2002). Kazhdumi TOC values vary from 1 to 11% with average values in the 5% range in the center of the depression. The high TOC content, classifying the Kazhdumi as one of the richest source rocks. The Kazhdumi organic matter contains up to 5 to 7% per weight of sulfur, this fact explains the high sulfur content of the oil generated (Bordenave, 2002).

Gadvan Formation:

The Gadvan Formation which is deposited from late Neocomian to Aptian is a part of the progradational Megasequence VI (Alavi, 2004) of deep-marine to shallow-shelf sediments. At the type locality, the formation consists of about 107 m of dark gray, argillaceous, bioclastic limestone interbedded with gray, green, and brownish yellow marl. Laterally, the formation grades into dark shale and argillaceous limestone in the Khuzestan Province. It is located between the tope of Neocomian Fahliyan limestone and base of 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) and ranges in deposition from a shallow –marine to neritic, inner –shelf, low energy environment.

Methodology:

For this study 191 samples (drilled cuttings) were taken from what were considered to be the main candidate source rock unites, including the Pabdeh, Gurpi, Kazhdumi and Gadvan Formations from 11 wells at the Ahwaz oil field.

The collected samples were analyzed using a Rock-Eval 6/STD in order to determine the kerogen type, TOC content and thermal maturity, which are the main parameters for characterizing a hydrocarbon source rock. The Rock-Eval pyrolysis is one of the simplest and fastest methods used for assessing the hydrocarbon generation potential of petroleum source rocks that meet the needs of petroleum prospects (Espitalie et al. 1985). It provides data on organic content of rocks type and maturity of organic matter. Measured parameters include S1 (mg HC/ g Rock), S2 (mg HC/g Rock), S3 (mg CO2 /g Rock), Tmax (°C) and TOC (wt %) (Table1 and 2) used to characterize petroleum potential, types of organic matter, degree of evolution, etc. This method enables us to predict oil and gas windows and estimates the quantity of hydrocarbon generated from a specific source rock. Several additional parameters including HI (Hydrogen Index, (S2/TOC*100)), OI (Oxygen Index, (S3/TOC*100)), and PI (Production Index, S1/ (S1 + S2)) are calculated from these measured values, and are shown in Table1 and 2. Maturity indicators include Tmax, the temperature at which the maximum amount of pyrolytic hydrocarbon (S2) are generated, and Production Index (PI=S1/S1+S2), where S1 the thermally extractable hydrocarbon. Details of the analytical procedure and discussion of Rock-Eval parameters are available in Espitalie et al (1977), Petrs (1986), and Peters and Cassia (1994), Bordenave, (1993).

Burial history profiles were constructed for well No. 67, and the time of oil expulsion was estimated by thermal modelling using Genex programmer developed by IFP. Samples were analyzed by Rock-Eval 6/ST at the Organic Geochemistry Lab of AmirKabir University of Tehran.

RESULT AND DISCUSSION

Results of source rock analysis are given in table 2. The ranges of different parameters values for each Formation are summarized in table1. Histograms showing the geochemical parameters variation for each Formation with mean values and standard deviations (Figs.3). Kerogen type and maturity level can be determined using HI vs. Tmax diagram (Fig. 4,5). As shown in the Fig. 5, most of the Pabdeh Formation samples fall in regions of Immature to early oil generation window but other Formations entered oil generation window.

Pabdeh Formation:

The TOC values of the Pabdeh Formation ranges from 0.83-6.08 wt% with a mean value of 2.67wt%. After considering the approximately 0.75 wt% inert carbon (Fig. 6), it will contain 0.08- 5.33 wt% TOC. This Formation yields HI values of 82-522(mg HC/ g TOC), which is typical for oil-gas prone type II kerogens (Fig.4,5). Most samples have kerogen type II and sometimes a mixture of type II/III is also noticed. A few samples that fall in kerogen type III are considered to be due to carbonate facies effect or weathering (Fig 4). According to Tmax (410-446 ºC) and PI (0.05-0.69) parameters that have a mean value of 427ºC and 0.37, respectively, the Pabdeh Formation thermally is immature or early mature (Fig.5). A plot of Genetic Potential (S1+S2) vs. TOC was established to determine petroleum generating potential (Fig.7). As seen in Fig. 7, there is a good agreement between TOC and Genetic Potential (S1+S2) values with each other. According to the TOC versus S1+S2 diagram, the Pabdeh Formation has very good to excellent potential for oil generation (Fig.7).

Gurpi Formation:

The TOC values of the Gurpi Formation ranges from 0.43 to 3.46 wt% with a mean value of 1.4 wt%. After considering the approximately 0.4 wt % inert carbon (Fig. 6), it will contain 03-3.06 wt% TOC with a mean value of 1.06 wt%. The Gurpi Formation yields HI values of 106 - 462 (mgHC/g Rock) with a mean value of 268 which is typical for mixture of marine and terrestrial organic matters (type II and III) (Fig.4,5). Variation of Tmax (417-449 ºC) and PI (0.15-0.69) show that this Formation has different maturity levels from immature to peak of the oil window (Fig. 5). The TOC,S1+S2 and HI values indicate that the Gurpi Formation has fair to good hydrocarbon generation potential and isn't a fundamental source rock for supplying of reservoirs.

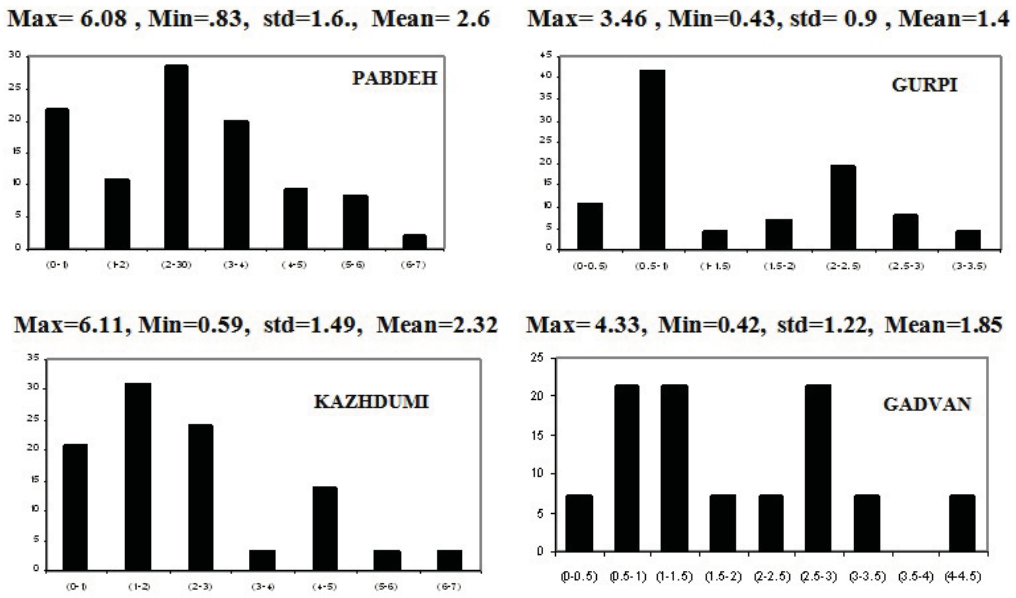

Fig. 3: TOC histograms for the studied Formations with mean and standard deviation values.

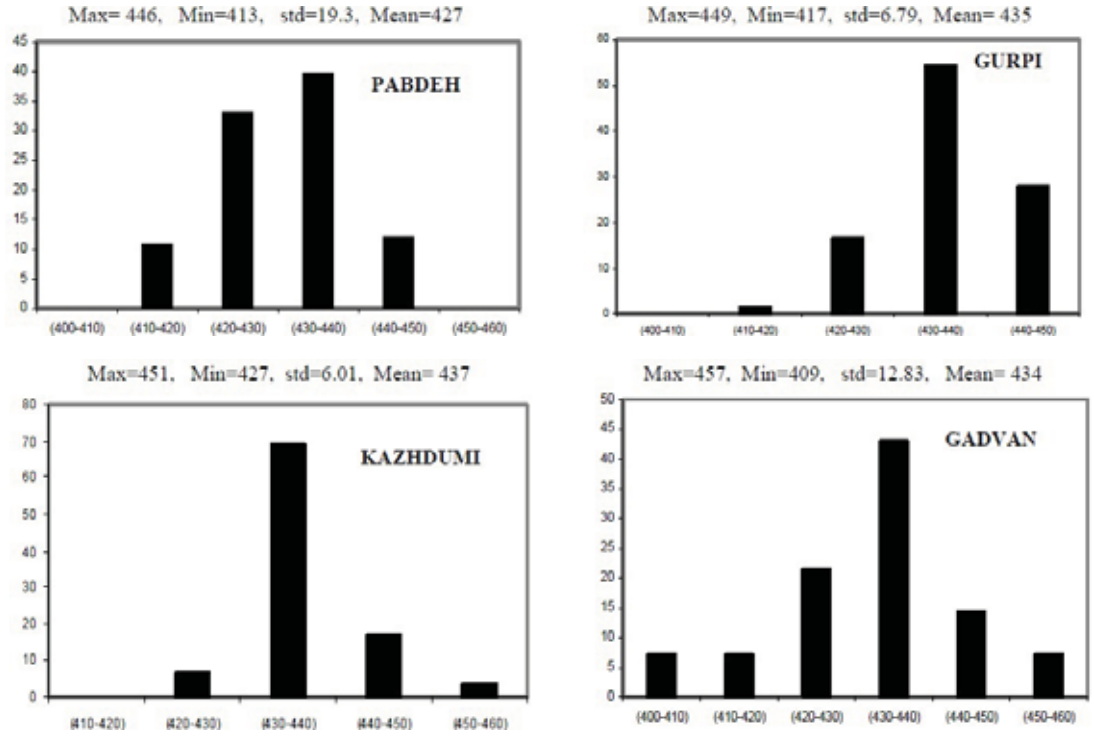

Fig. 4: Tmax histograms for the studied Formations with mean and standard deviation values.

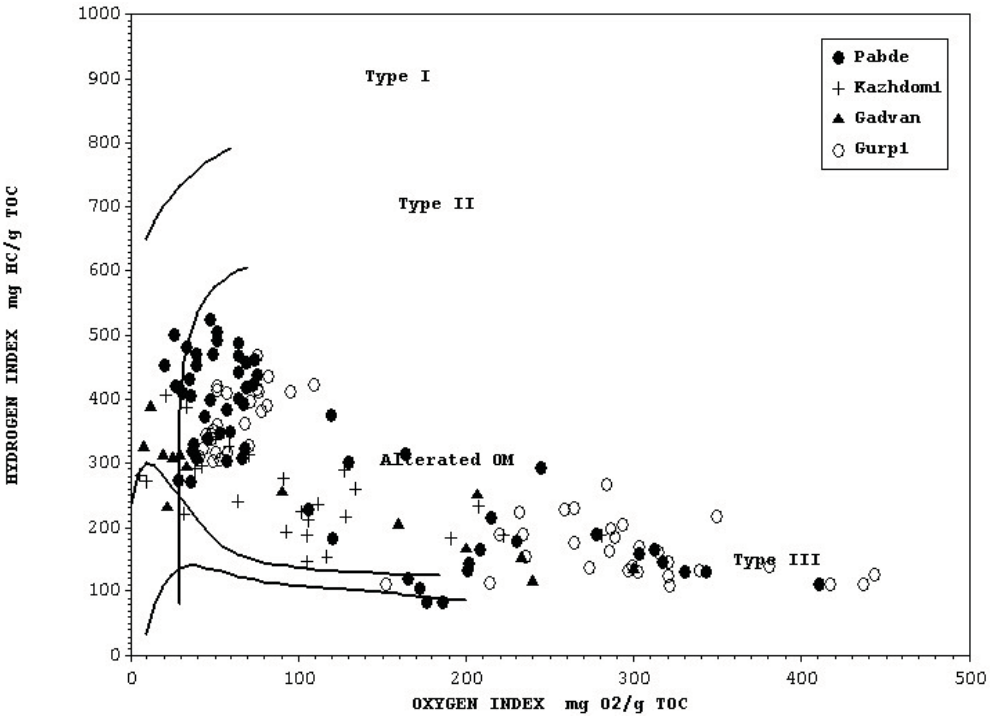

Fig. 5: VanKrevlen diagram, showing Rock-Eval Hydrogen Index vs. Oxygen index for the studied samples. The increasing in OI is related to the carbonate facies

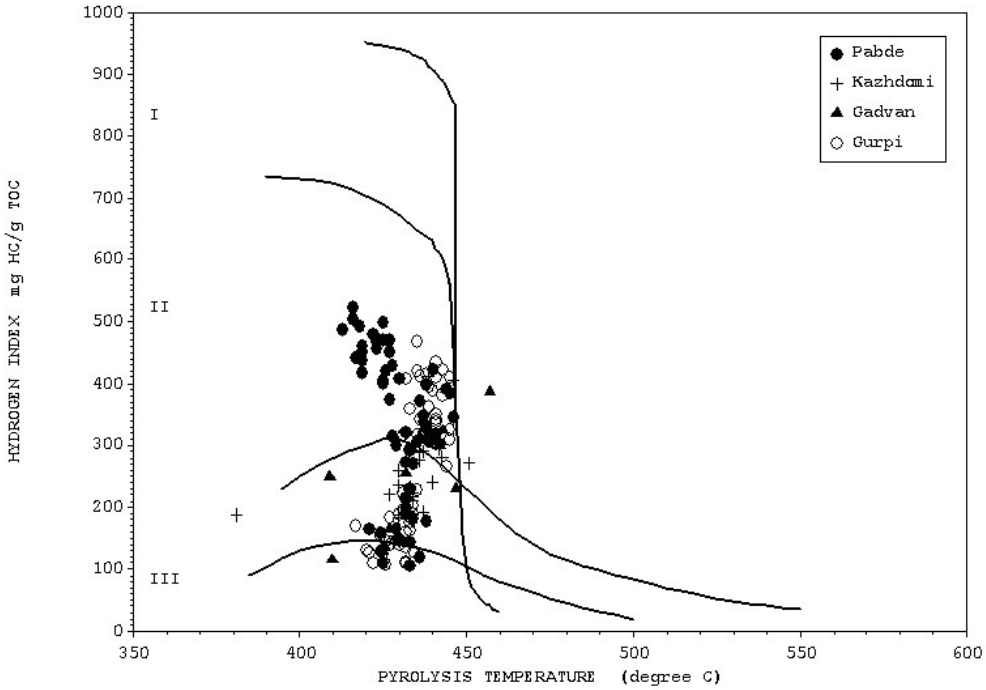

Fig. 6: Tmax vs. HI diagram, showing the maturity levels of the sampled units.

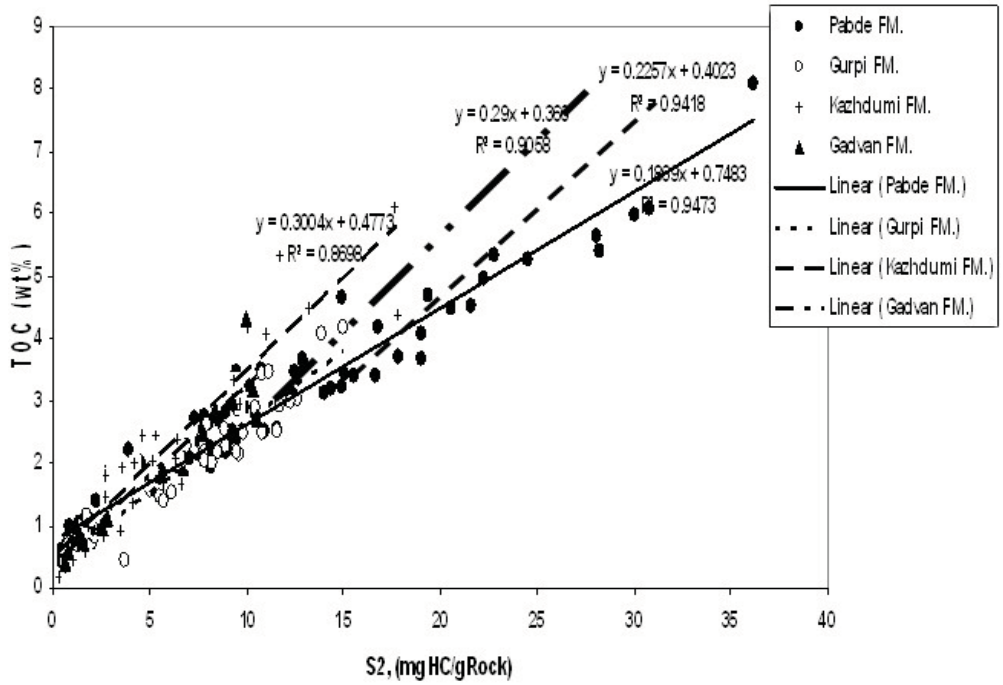

Fig. 7: Rock-Eval pyrolysis S2 vs. TOC showing inert carbon content of the studied Formations [After Conford, 1994, Dahl, 2004].

Kazhdumi Formation:

The TOC values of the Kazhdumi Formation ranges from 0.59 to 6.11 wt% % with a mean value of 2.32wt%. After considering the approximately 0.48 wt% inert carbon (Fig.6) it will contain 0.11 to 5.63 wt% TOC with a mean value of 1.84 wt%. This Formation contains type II/III kerogens and most likely comprises type II kerogen and yields HI values of 146 to 407(mg HC/g Rock) that explains the Kazhdumi Formation subjected to an anoxic condition in time of deposition of argillaceous sediments (Fig. 5). According to Tmax (427-451ºC) and PI (0.19-0.76) parameters that have a mean value of 437ºC and 0.45, respectively, this Formation is thermally mature and reached to the oil window (Fig.5). According to TOC versus S1+S2 diagram and HI value this interval has a good to excellent source rock potential for oil and gas generation in this area.

Gadvan Formation:

The TOC content of the Gadvan Formation ranges from 0.42 to 4.33 wt%. This Formation contains 0.37 wt% inert carbons (Fig. 6), and then the TOC_{Live} varies between 0.05-3.96 wt% with a mean value of 1.48 wt %. This Formation comprises mixing of type II/III oil and gas-prone kerogen with HI values ranging from 115 to 385 with mean of 244(mg HC/ g TOC Rock) (Fig.5). According to Tmax (409-457 ºC) and PI (0.4-0.76) parameters that have a mean value of 433 ºC and 0.59, respectively, this Formation reached to peak of the oil window and is thermally mature. The TOC, $S1+S_2$ and HI values indicate that this Formation has a poor to good source rock potential for gas generation (Fig.7).

Burial History Reconstruction:

Burial history is a method for assessment of source rock maturation. Maturity of source rock is controlled by different parameters, like burial history and thermal gradient. In fact, maturation is slowly thermodynamic changes of kerogen to hydrocarbon that causes migration of hydrocarbon to higher porosity reservoir rocks. Time and temperature, which depend on the rate of subsidence and sedimentation, have an important role in maturation of organic matters and burial history.

At this study, Genex software is used for the constructed the burial history profiles. Input data for this program were lithology, depth, kerogen type, geothermal gradient and heat flow.

A burial history profile for well no.67, which terminated at a total depth of 4913 m in the lower Cretaceous Fahliyan Formation, is presented in Fig 8 and 9.

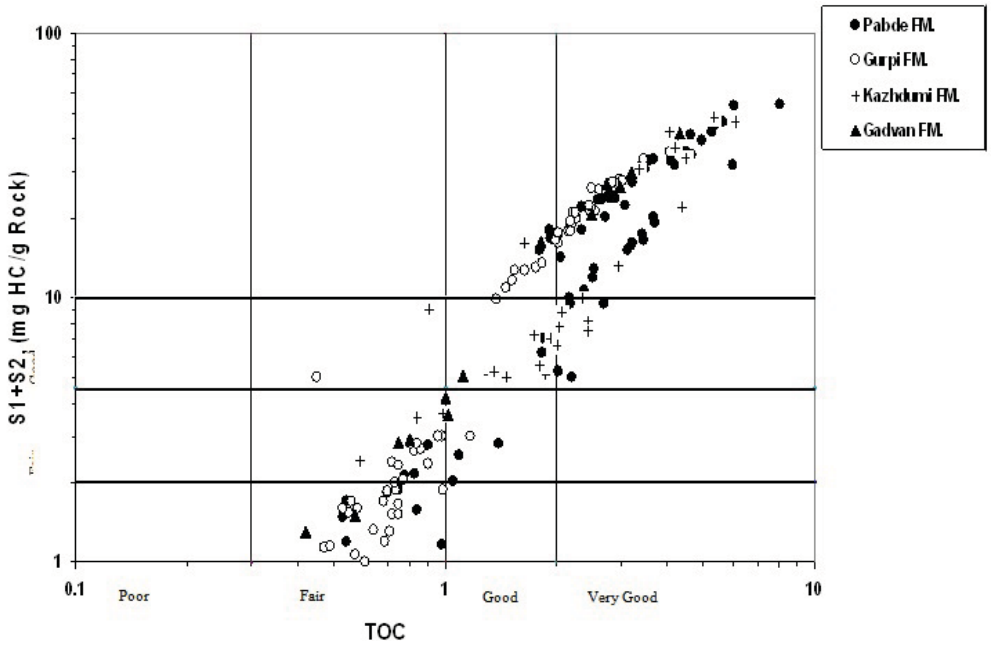

Fig. 8: TOC versus S1+S2 (total hydrocarbon generating potential of rock) showing the petroleum generating potential of the studied source rocks

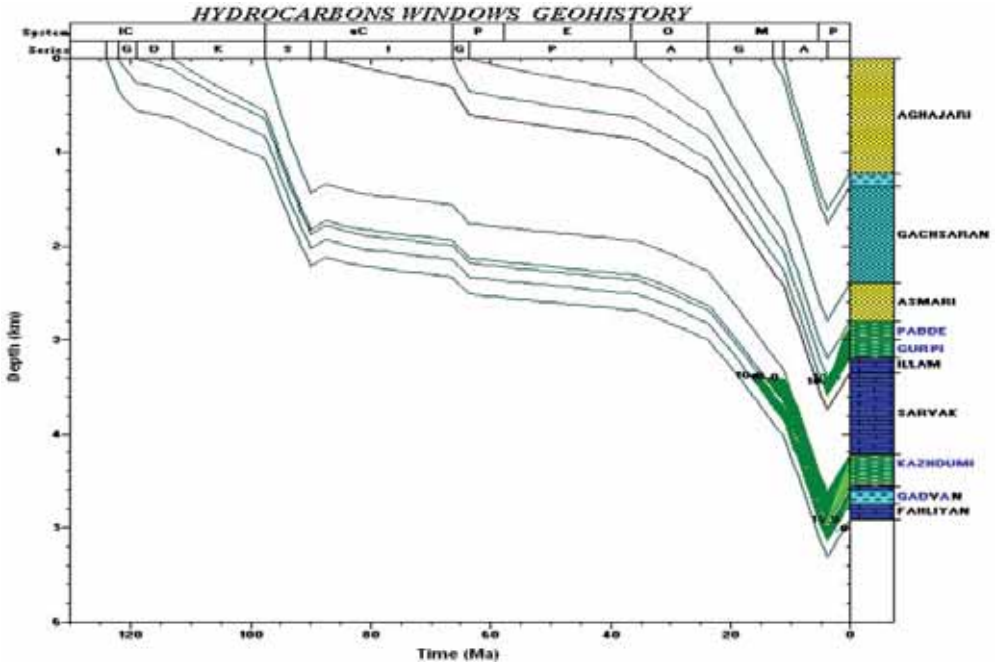

Fig. 9: Burial history profile and oil window of the Neocomian to Quaternary beds at well 67, showing the maturation history of the source rocks.

The stratigraphic column at well 67 can be summarized as follows (Fig.2). At the top is the Upper Miocene Agha Jari Formation which is exposed in the core of the anticline, and comprises some 1222m of siltstone and marl. The underling Mishan Formation (Middle Miocene) consists of 142m of marl and

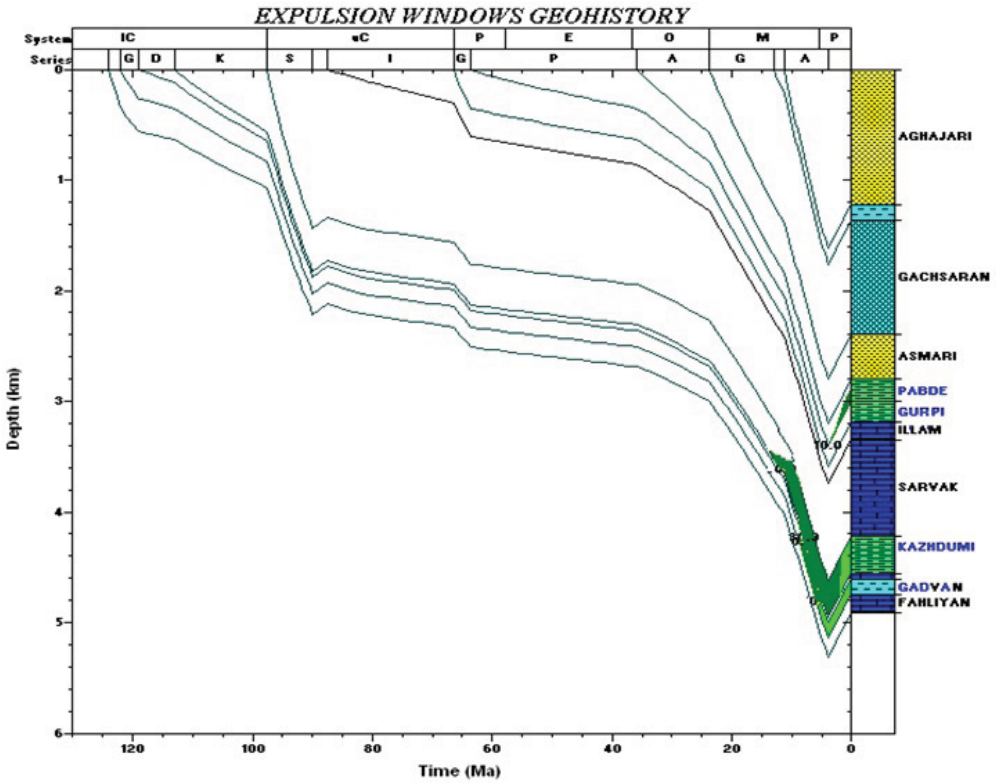

Fig. 10: Burial history profile and expulsion window of the Neocomian to Quaternary beds at well 67.

Table 1: Summary of Rock_Eval data from drilling cuttings.

Formation	Kerogen	Tmax	OI	TOC	HI	PI	S1	S2
Pabdeh	II/III	446-413	20-398	0.83- 6.08	82-522	0.05-0.69	0.15-26.31	0.49-36.17
Gurpi	II/III	449-417	41-427	0.43-3.46	106- 462	0.15-0.69	0.11-25.46	0.47-15.01
Kazhdumi	II/III	451-427	6-284	0.59-6.11	146-407	0.19-0.76	0.2-36.58	0.3-17.78
Gadvan	II/III	457-409	8-295	0.42-4.33	115-385	0.4-0.76	0.69-31.95	0.62-10.5

argillaceous carbonate. Beneath the Mishan Farmation, the Gachsaran Formation (Lower Miocene) comprises 855m of white anhydrite and grey marl. The underlying Asmari Formation (Oligocene_lower Miocone) comprises 407m of sandstone and grey limestones. The Asmari Formation is the main oil reservoir in the Ahwaz oil field. The underlying Pabdeh Farmation of Paleocene_Eocene age (196m) consists of argillaceous and fine grained dark grey marls. Gurpi (191m) Farmation (Upper Cretaceous) is composed of argillaceous limestones with intercalations of marls.

The underlying Illam Farmation (Santonian) is composed of 153m of light grey limestone, dolomites and recrystallized limestones. The Cenomonian Sarvak Formation (878m) is composed of highly fractured neritic limestones, with interbedded marls. The Bangestan reservoir includes the Sarvak and Illam Formation. The Albian Kazhdumi Farmation consists of 333 m of grey to light brown marls and argillaceous limestones deposited in anoxic environment. The Aptian Dariyan Formation (50m) is mainly composed of porous and dolomitic limestones. The underlying Gadvan Farmation (Neocomian-Aptian), 138m thick, is composed of dark, grey limestone and grey to brown marls. It rests on the Fahliyan Farmation (Neocomian) which comprises light grey limestons(170m).

Burial history reconstruction for the well No.67 suggests that subsidence in the study area remained moderate for some 100Ma from Lower Cretaceous Fahliyan (120 Ma) to the Mid. Miocene Asmari deposition (20 Ma). During this long period, the average apparent subsidence rate varied little, around 20m/Ma. During the deposition of the Gachsaran and the Agha Jari Formation, subsidence increased dramatically between 20 and 3Ma, averaging as much as 350m/Ma. In consequence, oil generation has just occurred very recently.

Table 2: Hydrocarbon source rock evaluation parameters for Rock-Eval pyrolysis data.

Formation	Well No	S1	S2	S1+S2	PI	Tmax	TOC	HI	OI
Pabdeh	101	0.81	0.66	1.47	0.55	424	0.53	125	336
		0.49	1.08	1.57	0.31	425	0.84	129	199
		1.11	8.95	10.06	0.11	419	2.17	412	69
		1.22	9.45	10.67	0.11	425	2.38	397	64
		1.35	5.66	4.01	0.19	428	1.84	308	161
	67	0.3	0.87	1.17	0.26	429	0.98	89	187
		1.12	14.02	15.12	0.07	424	3.13	448	71
		0.93	8.6	9.53	0.1	430	2.7	319	113
		0.45	1.68	2.13	0.21	434	0.78	215	283
	220	0.17	0.5	0.67	0.25	319	0.61	82	185
		0.71	4.53	5.24	0.14	433	2.02	224	105
		1.07	3.93	5	0.21	434	2.2	179	119
		1.71	30.03	31.74	0.05	416	5.99	501	51
		1.59	15.02	16.61	0.1	417	3.44	437	64
		1.34	14.39	15.73	0.09	423	3.2	450	69
		1.4	8.05	9.45	0.15	427	2.19	368	118
		0.89	1.26	2.15	0.41	424	0.83	152	293
	265	0.15	0.81	0.96	0.15	436	0.7	116	163
		0.17	0.71	0.88	0.19	433	0.67	106	173
		0.84	16.65	17.49	0.05	418	3.41	488	51
		1.29	19.03	20.32	0.06	416	3.67	519	47
		1.22	11.58	12.8	0.1	419	2.54	456	74
		1.15	14.93	16.08	0.07	423	3.22	464	64
	273	21.1	9.45	30.55	0.69	432	3.47	272	29
		13	7.31	20.31	0.64	434	2.72	269	36
		8.29	6.79	15.08	0.55	445	1.8	377	57
		7.21	7.01	14.21	0.51	437	2.06	340	58
		9.91	12.38	22.29	0.44	425	3.08	402	36
		15.29	19.4	34.69	0.44	426	4.67	415	27
		15.08	16.79	31.87	0.47	430	4.17	403	30
		10.39	7.57	17.96	0.58	438	2.34	324	37
		15.35	8.07	23.42	0.66	439	2.65	305	39
		15.38	8.9	24.28	0.63	441	2.82	316	37
	296	0.63	1.92	2.55	0.25	438	1.09	176	229
		0.56	2.26	2.82	0.2	421	1.4	161	204
	296	1.49	17.83	19.32	0.08	413	3.69	483	64
		1	10.94	11.94	0.08	419	2.52	434	76
		0.76	5.42	6.18	0.12	429	1.83	296	130
	360	26.31	14.89	41.2	0.64	432	4.64	321	69
		22.21	10.7	32.91	0.67	435	3.51	305	67
		17.12	22.24	39.36	0.43	427	4.96	448	39
		14.02	19.05	33.07	0.42	427	4.08	467	49
		15.88	7.78	23.66	0.67	442	2.59	300	57
		13.02	9.04	22.06	0.59	444	2.35	385	67
	364	16.24	7.83	24.07	0.67	439	2.76	284	64
		17.24	9.48	26.72	0.65	431	2.87	330	80
		14.85	10.48	25.33	0.59	430	2.79	376	59
		17.11	10.2	27.31	0.63	439	3.22	317	87
		20.65	12.91	33.56	0.62	434	3.68	351	80
		22.46	30.82	53.28	0.42	429	6.08	507	32
		18.09	28.19	46.28	0.39	426	5.4	522	38
		15.08	20.56	35.46	0.42	429	4.5	457	32
		16.48	15.54	32.02	0.51	431	3.41	456	41
		19.44	12.49	31.93	0.61	442	3.48	359	49
		20.27	12.96	33.23	0.61	442	3.56	364	49
		12.14	8.14	20.28	0.6	441	2.23	365	67
	365	12.59	21.58	34.17	0.37	422	4.53	476	33
		17.72	24.56	42.28	0.42	425	5.26	467	39
		14	9.89	23.89	0.59	446	2.88	343	53
	385	12.94	9.24	22.18	0.58	436	2.5	370	44
		17.56	36.17	53.73	0.33	419	8.07	448	20
		18.39	28.1	46.49	0.4	425	5.65	497	27
		22.03	22.76	44.79	0.49	428	5.34	426	35
		9.23	7.99	17.22	0.54	438	2.02	396	48
		11.61	6.44	18.05	0.64	437	1.92	335	45
		8.56	8.12	16.68	0.51	440	1.94	419	73

Table 2: Continue

Gurpi	10	0.98	0.62	1.6	0.61	422	0.58	107	426
		1.26	1.74	3	0.42	424	1.17	149	230
		1.19	1.81	3	0.4	430	0.98	185	230
	203	0.35	0.72	1.07	0.32	429	0.57	126	347
		0.25	1.27	1.52	0.16	431	0.75	169	305
		0.8	1.51	2.31	0.35	432	0.75	201	279
		0.75	2.07	2.82	0.27	434	0.84	246	225
	220	0.86	0.99	1.85	0.46	426	0.7	141	311
		0.66	1	1.66	0.4	430	0.75	133	292
		1.19	1.61	2.8	0.42	434	0.81	199	288
		0.92	1.44	2.36	0.39	433	0.9	160	281
	265	0.29	0.54	0.83	0.35	425	0.44	123	316
		0.4	0.74	1.14	0.35	432	0.47	157	311
		0.44	1.25	1.69	0.26	433	0.56	223	257
		0.41	1.18	1.59	0.26	435	0.53	223	253
	273	7.74	4.99	12.73	0.61	445	1.55	322	70
		7.23	5.51	12.74	0.57	441	1.64	336	45
		7.52	5.53	13.05	0.58	435	1.76	314	57
		14.09	6.91	21	0.67	445	2.26	306	41
		14.6	7.77	22.37	0.65	437	2.45	317	43
	296	0.55	0.76	1.31	0.42	426	0.71	107	318
		0.49	2.13	2.62	0.19	444	0.83	257	275
		0.41	0.9	1.31	0.32	425	0.71	127	325
		0.32	0.54	0.86	0.37	434	0.43	126	298
		0.14	0.76	0.9	0.16	432	0.69	110	209
		0.11	0.6	0.71	0.15	432	0.56	107	150
		0.44	1.25	1.69	0.26	434	0.68	184	216
	360	4.13	5.72	9.85	0.42	443	1.38	414	107
		9.27	8.53	17.8	0.52	439	2.19	389	71
		14.91	12.63	27.54	0.54	435	3.03	417	51
		17.66	9.55	27.21	0.65	441	2.85	335	48
	360	9.34	8.23	17.57	0.53	436	2.02	407	51
		11.71	7.78	19.49	0.6	433	2.18	357	51
	364	15.83	10.47	26.3	0.6	437	2.87	365	67
		10.52	10.77	21.29	0.49	445	2.47	436	71
		22.35	11.13	33.48	0.67	441	3.46	322	54
		9.4	9.45	18.85	0.5	449	2.19	432	62
		11.09	8.9	19.99	0.55	446	2.28	390	63
		1.29	3.72	5.01	0.26	441	0.45	827	193
	365	5.56	6.1	11.66	0.48	441	1.52	401	94
		8.29	7.78	16.07	0.52	440	2.03	383	81
	385	10.48	11.54	22.02	0.48	435	2.5	462	75
		9.56	9.42	18.98	0.5	441	2.2	428	82
		21.86	13.86	35.72	0.61	436	4.06	341	48
		25.46	15.01	40.47	0.63	439	4.17	360	69
		15.89	12.24	28.13	0.56	438	2.98	411	76
		15.18	11.74	27.02	0.56	432	2.91	403	57
		19.59	10.81	30.4	0.64	431	3.44	314	51
Kazhdumi	101	5.55	3.47	9.02	0.61	444	0.91	381	33
		21.28	9.36	30.64	0.69	443	3.34	280	6
		28.68	17.63	46.31	0.62	437	6.11	289	38
		20.89	13.18	34.07	0.61	442	4.49	294	42
		26.93	10	36.93	0.73	440	4.18	239	65
		36.58	11.68	48.26	0.76	427	5.34	219	32
		31.25	11.02	42.27	0.74	451	4.06	271	10
		9.62	6.59	16.21	0.59	446	1.65	399	22
	203	0.74	1.68	2.42	0.31	433	0.59	285	227
		1.19	4.09	5.28	0.23	438	1.36	301	121
		0.84	2.66	3.5	0.24	435	0.84	317	131
		2.47	6.36	8.83	0.28	439	2.07	307	70
		4.2	17.78	21.98	0.19	439	4.37	407	32
		3.61	6.44	10.05	0.36	436	2.37	272	90
		2.87	5.31	8.18	0.35	434	2.43	219	100
		2.62	5.16	7.78	0.34	430	2.04	253	131
		2.16	2.98	5.14	0.42	433	1.32	226	203
		2.46	4.19	6.65	0.37	434	1.97	213	127
		2.28	4.91	7.19	0.32	436	1.74	282	126
		1.81	1.84	3.65	0.5	430	0.99	186	280
		2.37	2.74		0.46	431	1.88	146	105

Table 2: Continue

	67	2.24	2.74	5.98	0.45	381	1.46	188	222
		2.85	2.71	5.56	0.51	429	1.8	151	117
		3.45	3.55	7	0.49	433	1.93	184	105
		2.43	4.18	6.61	0.37	434	2.01	208	106
		2.92	4.59	7.51	0.39	437	2.43	189	92
		3.6	9.6	13.2	0.27	438	2.95	325	59
Gadvan	101	16.43	10.5	26.93	0.61	457	2.73	385	13
		19.54	10.29	29.83	0.66	443	3.2	322	8
		16.98	9.29	26.27	0.65	436	2.98	312	20
		15.87	8.34	24.21	0.66	434	2.85	293	34
		10.79	5.56	16.35	0.66	438	1.82	305	26
		31.95	9.96	41.91	0.76	447	4.33	230	22
		12.98	7.71	20.69	0.63	438	2.49	310	30
	67	1.61	1.29	2.9	0.56	427	0.8	161	198
		2.33	2.76	5.09	0.46	409	1.12	246	204
		1.67	2.52	4.19	0.4	432	1	252	90
		0.69	0.62	1.31	0.52	429	0.42	148	231
		1.34	1.51	2.85	0.47	432	0.75	201	157
		0.75	0.75	1.5	0.5	426	0.57	132	295
		2.42	1.17	3.59	0.67	410	1.02	115	240

In this Oil field the Pabdeh Formation is partly immature to early mature, whereas the Kazhdumi Formation is within the oil window. Burial history reconstruction and thermal modelling indicate the beginning of the oil window was dated as 15Ma for the Kazhdumi Formation and 5Ma for the Pabdeh Formation. The beginning of the oil windows occurred for the two source rocks when they were buried to a depth 3500m.The expulsion of oil would have begun 10 Ma ago for the Kazhdumi Formation and 3 Ma for the Pabdeh Formation (Figs.9, 10).The main phase of Zagros folding occurred during the late Miocene and Pliocene. The migration of hydrocarbons from source rocks (the Kazhdumi and Pabdeh Formations)was enhanced by the syn-orogenic fracturing of reservoir rocks in the Asmari and Bangestan (Sarvak and Illam) Formations

Conclusion:

Source rock evaluation studies have identified the Pabdeh (Eocenee-Oligocene) and the Kazhdumi (Albian) Formations as the main effective source rocks in the Ahwaz oil field, and the Gadvan and Gurpi Formations as the subordinate source rocks and their contribution to the charge of the reservoirs is negligible. Based on pyrolysis Tmax and PI the Pabdeh Formation is immature or early mature in the study area and the Kazhdumi Formation is thermally mature and reached to peak of oil window.

Burial history reconstruction and thermal modeling indicate the beginning of the oil window was dated as 15Ma for the Kazhdumi Formation and 5Ma for the Pabdeh Formation. The beginning of the oil windows occurred for the two source rocks when they were buried to a depth 3500m. The expulsion of oil would have begun 10 Ma ago for the Kazhdomi Formation and 3 Ma for the Pabdeh Formation. The main phase of Zagros folding occurred during the late Miocene and Pliocene. The migration of hydrocarbons from source rocks (the Kazhdumi and Pabdeh Formations) was enhanced by the syn-orogenic fracturing of reservoir rocks in the Asmari and Bangestan (Sarvak and Illam) Formations.

AKNOWLEDGMENT

The authors are grateful for financial support by national Iranian south Oil Company (NISOC), particularly research & development and Geology departments. We also appreciate MS. Peirow for editing this manuscript.

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