

INA Plc. exploration and production activities in Syria, successful achievement of hydrocarbon discoveries and developments

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REVIEW

INA-Industry of Oil Plc. (Croatia) has been present in Syria since 1998, working on exploration and development of hydrocarbon fields located in the Hayan Block. Recently, INA Plc. has been preparing the exploration activities in the Aphantia Block as well. All exploration activities are led by INA Branch Office, while development and production (for now exclusively in Hayan Block) is operated by Hayan Petroleum Company, a joint venture between INA and SPC (Syrian Petroleum Company). Since 1998 six commercial discoveries were reported in the Hayan Block, namely Jihar, Al Mahr, Jazal, Palmyra, Mustadira and Mazrur Fields. The largest proven reserves are related to Jihar Field where hydrocarbons were discovered in heterogeneous reservoir sequences, mostly in the fractured Middle Triassic carbonate reservoirs of the Kurrachine Dolomites Formation. Complex reservoir lithology assumed advanced reservoir characterization that included integration of all geologic and engineering data. Such characterization included several or the following models and calculations: (1) estimation OHIP potential scenarios and production foreseeing by dynamical simulations; (2) structural interpretation from 3D seismic data; (3) petrophysical variables estimation based on core analysis, log data and well tests. Moreover, in some reservoirs facies distribution was made using stochastic simulations. Advanced computer modelling of rock fracture geometry had been applied using interpretation of image logs, combined with core data. Two discrete fracture network models were stochastically created, giving fracture's parameters as input for dynamic simulations, also making to predict more production scenarios as base for the next development stage.

Key words: Syria, Hayan Block, Aphantia Block, Triassic reservoirs, Kurrachine Dolomites Formation, hydrocarbons

1. INTRODUCTION IN E&P HISTORY IN HAYAN BLOCK AND ACQUISITIONS IN APHAMIA BLOCK

INA-Industry of Oil Plc. (Croatia) has been active in Syria since 1998, and is currently independently performing exploration activities in the Aphantia Block and developing Hayan Block (Figure 1.1). INA Branch Office in Damascus was opened in 1998 to handle the exploration, while Hayan Petroleum Company, a joint venture between INA Plc. and Syrian Petroleum Company (SPC, now GPC), operates development and production of Hayan Block.

Since 1998 INA made six commercial discoveries in Hayan Block with significant oil, gas and condensate reserves: Jihar, Al Mahr, Jazal, Palmyra, Mustadira and Mazrur fields. Development was technologically divided into two areas: (1) Hayan Block West, with oil, gas and condensate reserves in Jihar, Jazal, Al Mahr and Mazrur Fields; (2) Hayan Block East, with gas and condensate reserves in Palmyra and Mustadira Fields (Figure 1.2).

Oil production started in August 2005 (Jihar-2 well), while gas production in December 2006 (Palmyra-1 and -3 wells). Currently existing production systems allow the average production gas rate of 1.2 MMm³/d (42 MMft³/d) and the oil rate of 1,200 m³/day (7,550 bbl/d).

This will be significantly upgraded by the new gas treatment plant, currently being finalized and scheduled for full capacity operation in 2011, which will increase the production capacity to 1,800 m³/day (11,320 bbl/d) of oil and condensate, 4 MMm³/day (141 MMft³/d) of gas and 350 m³/d (2,200 bbl/d) of LPG.

The Aphantia Block is located NW from the Hayan Block (Figure 1.1). Currently, activities in the Aphantia Block include second extension of Initial Exploration Phase. The first initial exploration phase started in 2004 and lasted for 4 years. The first extension lasted for two more years with 270 km² of 3D seismic and 2 exploration wells. The second extension (2 years) resulted in 1 new exploration well. Exploration results indicated several hydrocarbon shows in wells drilled in the Aphantia Block, i.e. the Salamiah, Jaddua, Mudawara and Beer As Sib localities.

2. GEOLOGICAL SETTINGS OF THE HAYAN BLOCK

Hayan Block belongs to the tectonic province of the northern Arabian platform in Syria. The large part of the central Syria, including Hayan and Aphantia Blocks, is a part of Palmyrides mountain range, which is intracontinental transpressive mountain fold belt (ref.7)

expressed as zone of uplifted topography and maximal altitude of 1385 m. This range extends from the Dead Sea Fault Zone to the Euphrates Graben, and is 400 km long and 100 km wide. That is divided on the north and south parts by the Jihar Fault extending also in the Al Dawn Depression (e.g. refs.7,8). Main tectonic events, according to the summary⁷, can be outlined in approximate periods (in Ma) as:

- a) Early Cambrian to Early Silurian (560-420 Ma) extension and rifting, thermal subsidence and sea level regression;
- b) Early Silurian to Early Carboniferous (420-360 Ma) mild compression uplift and erosion;
- c) Early Carboniferous to Late Permian (360-245 Ma) renewed extension and subsidence;
- d) Early Triassic to Early Cretaceous (245-135 Ma) extension, subsidence and rifting along major faults (Palmyrides through);
- e) Early and beginning of Late Cretaceous (Hauterivian to Cenomanian; 135-94 Ma) renewed extension and subsidence in interior fractured basins along Palmyride, Sinjar and Euphrates Troughs, including Aptian and Albian transgression;
- f) Late Cretaceous to Late Palaeogene (end of Oligocene; 94-23 Ma) compressional phase, continuous subsidence in Palmyride, Sinjar and Euphrates troughs;
- g) Miocene to recent (23-0 Ma) continental collision between Arabia and Eurasia, inversion of Palmyrides and Euphrates Troughs.

The detailed evolution of Palmyride or Northern Arabian Platform in Syria can be found by refs.^{1,2}, and about evolution of the Eastern Mediterranean by ref.⁶. Triassic sequences (Figure 2.1) are very important parts of hydrocarbon systems (as source, reservoir and isolator rocks) in entire Syria, what is, e.g. well documented by ref.⁴.

Generally, several dominant lithofacies from Palaeozoic to Cenozoic as well as main stratigraphic intervals including source, reservoir and isolator rocks can be recognized (e.g. ref.³). The rocks through these large chronostratigraphic intervals are mostly represented by carbonates, marlstones, claystones and sandstones (Figure 2.1). The first three lithologies are mostly source and isolator rocks, while carbonates can be highly fractures

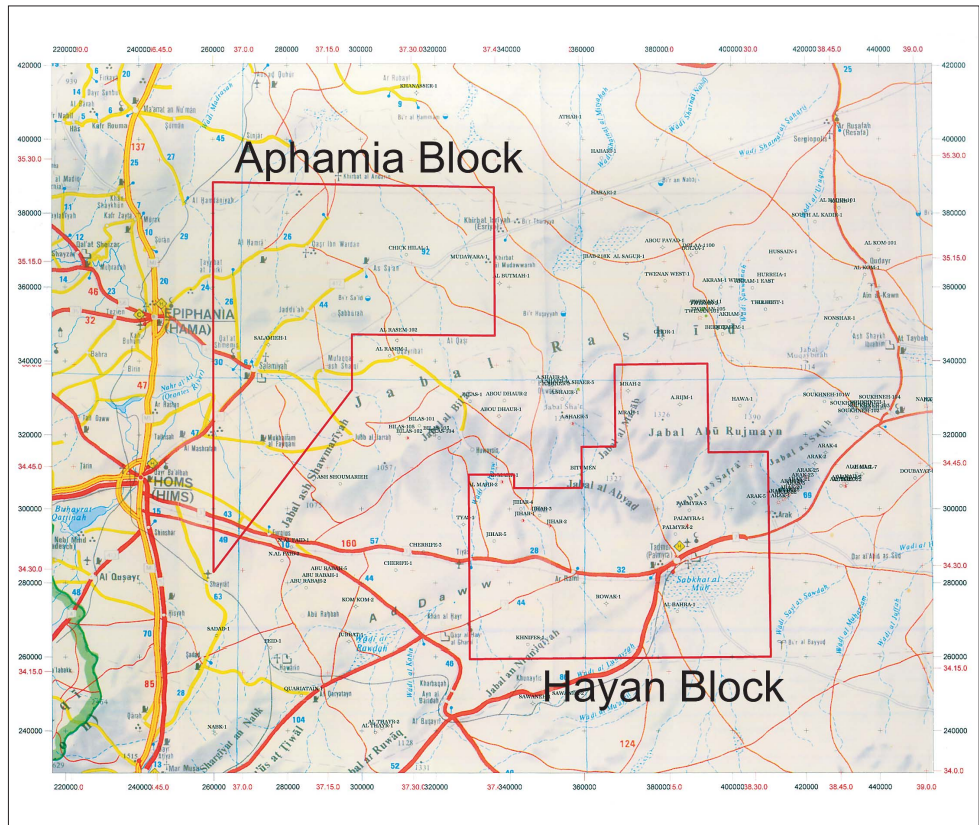


Fig. 1.1. Schematic map of Hayan Block (development area) and Aphamia Block (exploration area)

Sl. 1.1. Shematska karta koja prikazuje blok Hayan (kao razradno) te blok Aphamia (kao istraživačko područje)

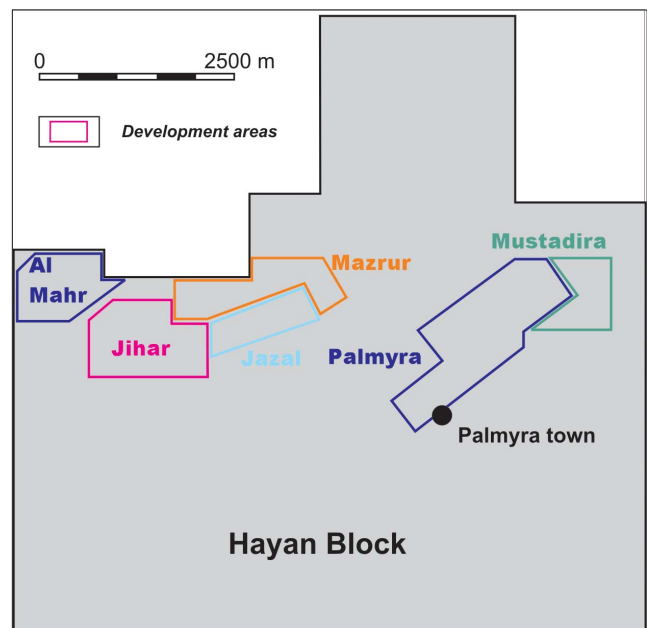


Fig. 1.2. Schematic map of development areas (discovered fields) in the Hayan Block

Sl. 1.2. Shematska karta razradnih područja (otkrivenih polja) unutar bloka Hayan

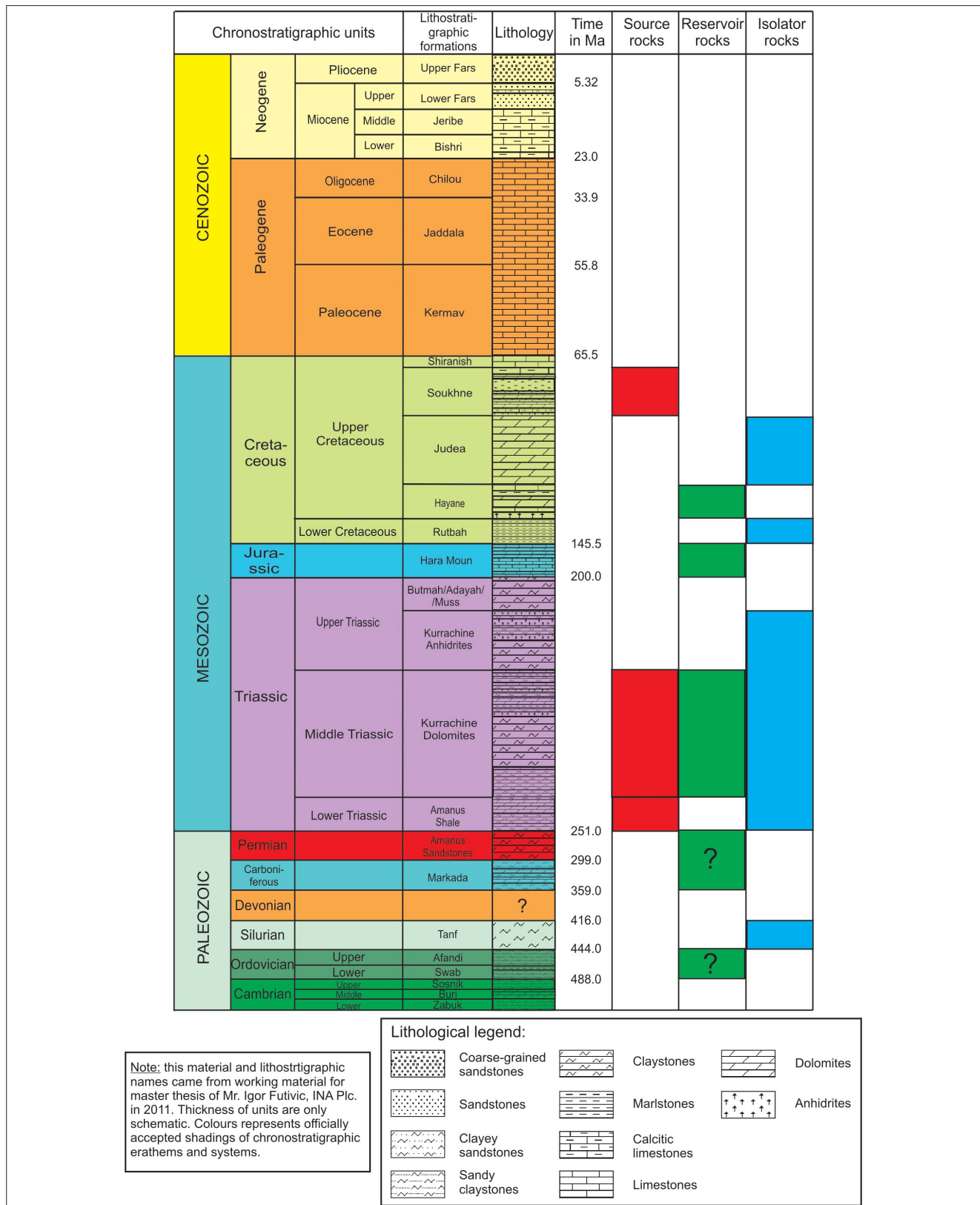


Fig. 2.1. Schematic stratigraphy and main lithological categories of petroleum system in the Hayan Block (units, ages and colours approx. according ref.5)

Sl. 2.1. Shematski stratigrafski prikaz te glavne litološke kategorije naftnoplinskih sustava u bloku Hayan (jedinice, starosti i boje su približno dane prema lit.5)

and play role of reservoir rocks with secondary porosity. Sandstones are sometimes clean or in transitional facies and represents reservoir rocks. It also can be analyzed through lithostratigraphy described in ref.⁷, regarding formations that build hydrocarbon systems (Figure 2.1) in the Hayan Block.

2.1. Palaeozoic formations of hydrocarbon systems

The oldest Afandi Formation (Ordovician) is assumed to be potentially reservoir rocks and it generally consists of siltstones and sandstones with shale intercalations. The next Tanf Formation (Silurian) is considered as isolator (seal) rocks for older reservoirs. It is formed from shales, partly silty and claystones, partly calcareous. The Carboniferous Markada Formation is supposed to be a regional reservoir rocks sequence, including heterogeneous lithology of sandstones, shales and limestones or dolomites in alterations. Sandstones are proven hydrocarbon reservoirs in several Syrian fields such as Arak, Soukhne, Al Hail, Najeeb and Doubayat. The youngest is Amanus Sandstones Formation which is also regionally correlated in Syria, and consists of sandstones, siltstones and sometime shales. It can be considered as reservoir rocks if is developed in sandstone lithofacies.

2.2. Mesozoic formations of hydrocarbon systems

Mesozoic stratigraphic sequence includes the major of lithostratigraphic units described as source, reservoir or isolator rocks (Figure 2.1). The oldest is the Amanus Shales Formation (Lower Triassic), with domination of claystones and shales, including just a few carbonate and sandstone intercalations. The next one is Kurrachine Dolomites Formation (Middle Triassic) important as source, reservoir and isolator rocks. It consists mainly from different type of carbonates, evaporates and shales. The reservoirs of this formation in the Palmyra region are mostly saturated with gas. Due to significant hydrocarbon accumulations, formation is divided in three reservoir zones, which can be considered as an informal unit in rang of member. They are named (from the oldest) D2 (Anisian), D1 (Anisian) and C2 (Ladinian). Each of them can be further divided in "subzones". Kurrachine Anhydrite Formation (Middle Triassic) is considered as isolator rocks, representing salts, anhydrites, claystones, dolomites and limestones. Salt is not regionally deposited (or migrated), because in the southern part it is very thin or missing.

In Jurassic, the Hara Moun Formation is considered as interval with reservoir rocks, which is generally composed of carbonate rocks, limestones and dolomites. The several exposed Jurassic surfaces were subdued to karstification. The Rutbah Formation (Lower Cretaceous) includes isolator rocks sequences, although large part is represented with sandstones, but intercalated or overlaid with siltstones, claystones, dolomites or sandy marlstones. The next Hayane Formation (Early/Late Cretaceous) is mostly represented by dolomites, but on the south-west of the Palmyride the marlitic dolomites with horizons of gypsum or anhydrites dominate. The Judea

Formation represents sequence of mostly isolator rocks, i.e. of marlstones, dolomites and limestones. The last one is the Soukhne Formation (Upper Cretaceous) described as sequence of source rocks. It is composed of different limestones and dolomites, marlstones, claystones, but also cherts and sandy and conglomeratic beds.

3. RESERVOIRS, DEVELOPMENT AND PRODUCTION IN THE HAYAN BLOCK

The first discovery of hydrocarbon reservoirs INA made in April 2002, announced it for the Jihar structure. In the same year, it was followed with two other structures – Palmyra and Al Mahr. The very first oil production in Syria started from the Jihar Field (from the Jihar-2 well) on August 25th 2005, as part of the early production phase. About one year later, the gas production started from the Palmyra Field on December 13th 2006 (from Palmyra-1 and 3 wells), and the Jazal Field had been discovered. In the 2007, Mustadira and Mazrur Fields were discovered, production started from Jazal Field. In the February 2008, production started from Mustadira and in the 2009 from the Mazrur Field.

Today the significant surface equipment had been set in the entire Hayan Block. Most of it is located in the area of the Jihar Field, where there are:

- Oil station Jihar developed in the project stage no. 1,
- Export pipeline system Jihar,
- 10 kV OHL to the Jihar Field,
- Oil and gas station Jihar developed in the project stage no. 2,
- Gas treatment plant Jihar from the project stage no. 3,
- Water disposal system Jihar.

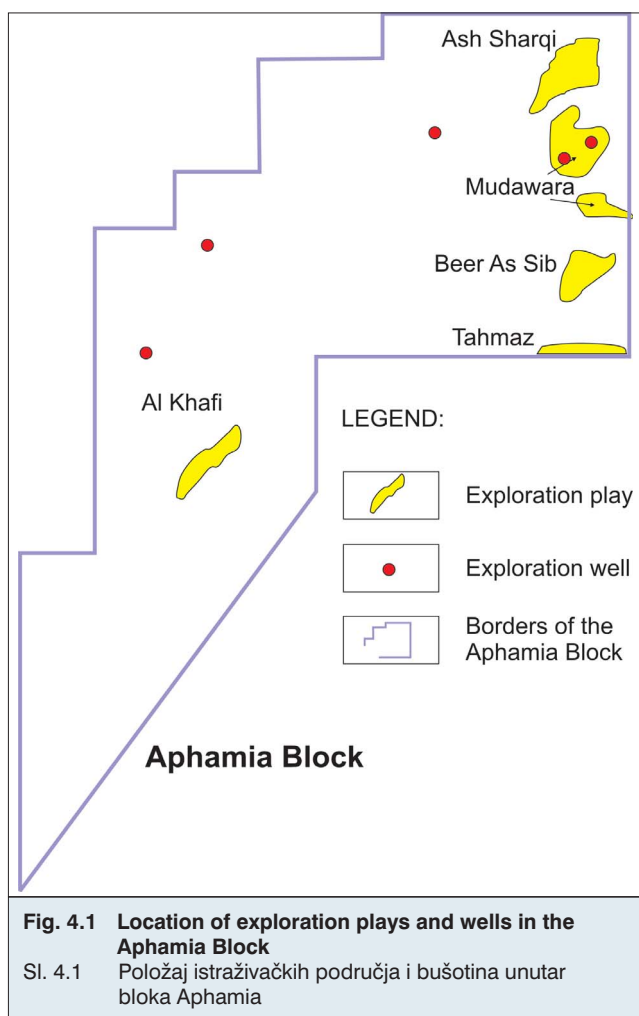
All other, smaller, fields have some sort of distribution system or other equipment for hydrocarbon transportation to main oil and gas stations located at the Jihar Field. Those are:

- Gathering line from the Jazal to the Jihar Field,
- Flow line from Mazrur-1 well to the Jazal Field,
- Flow lines from Palmyra-1 and 3 wells to gas collecting point Palmyra,
- Gas pipeline from the Palmyra to the Arak Field,
- Flow line from Mustadira-1 to gas collecting point Mustadira,
- Gas pipeline to Palmyra gas transportation system.

4. GEOLOGICAL SETTING IN THE APHAMIA BLOCK

The Aphia Block is part of hydrocarbon area in Syria that could be described as "medium explored". Numerous oil, gas and gas/condensate fields were discovered in the area southeast of the Aphia Block (Fig. 4.1), like in the Hayan Block (Figure 1.2).

Source rocks had been determined from well samples. They chronostratigraphically and lithostratigraphically belong to:



- Lower Triassic series, i.e. Amanus Formation (thickness 50-150 m),
- Middle Triassic series (Lower Kurrachine Dolomites Formation, about 400 m),
- Upper Cretaceous series (Soukhne Formation, 100-250 m).

It can be assumed that "hot" shale of Silurian can locally represent source rocks in wider area of the Aphantia Block, but there are still unknown migration pathways for these rocks.

Reservoirs rocks are part of:

- Triassic system (Kurrachine Dolomites Formation, but only with fracture system)
- Jurassic system, i.e. Moun Formation. There is proven saturation with both oil and gas in the Aphantia Block.
- Cretaceous system (Hayan Formation), where are discover oil reservoirs in this exploration block.

Also, the older Permian (Amanus Sand Formation) and Ordovician sandstones are generally considered as the potential reservoir rocks, mostly depending on migration pathways. Seal (or isolator) rocks are generally argillaceous carbonates, marls or shales which overlay reser-

voir sequences of all ages. Fractured reservoirs in the Kurrachine Dolomites Formation can be also covered with anhydrite and salt.

5. CONCLUSIONS

INA produced significant quantities of hydrocarbons from six hydrocarbon fields located in the Hayan Block in the central Syria. Up to now, those are the most important foreign hydrocarbon reserves of company. This production started in 2005 and still has increasing production line, thanks to continuous discovering of the new fields and successful development of the existing reservoirs. Large production initiated building of large surface systems and equipment for transport and collection of oil, condensate and especially gas as well as connection to the adjacent, large Syrian Arak Field, located on the SE.

The further activities will develop in two ways. The first one is maintaining of the present production level through developing of existing fields. The next one includes exploration of potential prospects and plays. This exploration phase can go two ways:

- The first way is exploration of locations in the Hayan Block with plays where the relatively high probability of success for new hydrocarbon discoveries is predicted. There are three such stratigraphical plays. The first is Silurian and Ordovician play (probably in the Tanf and Afandi Formations) located on Palmyra structure. The second one is Carboniferous play (sandstones in the Markada Sandstone Formation) outlined N and NW from Mustadira structure and S from the Palmyra structure. The third is Triassic, estimated NE from Mazzur structure and W from Jihar structure (Kurrachine Dolomites Formation).
- The second way is the entire the Aphantia Block, where INA currently explores. There are hydrocarbon shows in wells from several localities. So, in the Salamiah locality oil and gas shows were observed, in the Jaddua oil, in the Mudawara oil, gas and condensate and in the Beer As Sib oil and gas. Due to geographical vicinity of the Aphantia and Hayan Blocks, the described plays in the Aphantia Block mostly have similar lithology with reservoir units proven in the Hayan Block.

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