



The Silurian Play: Geology and Hydrocarbon Occurrence in the Ghadames-Berkin-Illizi (Algeria, Tunisia, Libya)

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Summary

The Upper Silurian play is one of the largest plays by areal extent in North Africa. It encompasses the Ghadames, Berkin, Illizi Basins from Algeria to the east to Libya to the west.

Different tectonic events influenced the deposition and then the removal of the Silurian beds throughout the area. The present day structural configuration is the results of the effects of movements related to the Pan African orogeny, Taconic, Caledonian, Hercynian and Alpine phases. Each of major phases have had significant direct or indirect influence on the Hydrocarbons habitat

Exploration activities in the three countries resulted in the discovery of at least thirty oil accumulations with totaling 2000 of MMBO (million barrels of oil) in place from this Silurian oil play. Most of wells were drilled in the structurally highest parts of the above-mentioned basins.

We have attempted to shed a light on these different regional geological factors controlling the habitat of hydrocarbons.

Particular emphasis is given to the following aspects:

1. Lithostratigraphic correlations of the Upper Silurian reservoirs throughout the adjoining Algeria, Tunisia and Libya.
2. Regional thickness, facies and their respective reservoir quality characteristics and distribution.
3. Hydrocarbons entrapment.

Introduction

During at least twenty years, exploration activities in the three countries have focused mainly on the Devonian and Triassic plays. The Silurian intervals were not tested despite numerous oil and gas shows.

In the Silurian Akakus, oil zones have been bypassed because of low resistivities observed on the wireline logs (0.6 - 3 ohms) erroneously interpreted as high water saturation intervals. Further detailed petrophysical/mineralogical studies pointed to the presence in the rock matrix of high concentration of conductive minerals such of as the iron oxydes, and siderite that have an effect on the logs resistivity readings.

In Algeria, during the early sixties, the Silurian M, A, B units of the F6 reservoir Lower Akakus has tested oil and gas in southwestern Illizi and Ahara high with many discoveries such as Stah, Mereksene, Askarene, Oahnet, Edeyen and TinFouye.

Recently, this play has been successful in the south Tunisia. In 2002, AGIP discovered the Adam field where oil and gas have been tested from a gross interval of more than 300 meters, at the depth of 3,000 meters from two zones of the Akakus A , B sands respectively flowing at a rate of 259 and 3,500 bopd .

In Libya, the first Upper Silurian oil discovery has been made in the sixties, mainly in the northwestern and in Al Kabir trend where about twenty oil fields and three gas pools have been found. The oil finds are mostly related to the Lower Akakus sandstones which flowed oil at the rates in the range of 500 to 1500 bopd.

Theory and/or Method

We have integrated all previous studies including my geological study on the Silurian for the Libyan NOC (internal report, Echikh, 1984) as well as the oil companies internal reports and public data from the three countries: Algeria, Tunisia and Libya.

For Algeria, published available data are including mainly data on the western flank of the Ghadames - Berkine basin and its southern flank over the Ahara High and Illizi platform.

Discussion

Presently, the Silurian is eroded and/ or non deposited on the north uplifts of the Dahar (Algeria, Tunisia Nafusah (Libya) highs and is absent south on the Qarqaf Uplift in Libya and the Hoggar Shield. Westwards, its extension is limited by the Amguid – El Biod Arch located in Algeria. The eastern boundary is not well defined as it is being overlapped by the edge deposits of the Sirt Basin.

Lithostratigraphy & Lithofacies :

In Libya, the Silurian rocks largely outcrop along the western (Djabal Akakus) and north eastern (Dor Al Gussah) flanks of the Murzuk Basin . In Algeria, it is outcropping along the northern parts of the Hoggar Shield. We will focus on the Lower Akakus and upper part Tanezuft, being the most important Silurian hydrocarbon bearing reservoirs. Several diagenetic process are affecting negatively the Lower Akakus reservoirs quality with clay, carbonate or pyrite ferruginous cements that can reduce porosity and permeability.

Several nomenclatures have been established in the three countries of Algeria, Tunisia and Libya.

In Algeria: The Argiles Principales and Alternances Greso Argileuses, respectively. For the Illizi updip - the Lower Akakus equivalent is: F6 reservoir Units M, A, B. In the Rhourde Nouss area, it is consisting of fine to medium sandstones with shales intercalations. The porosity is in the range of 6 to 17 percent and permeability from 2 to 8 millidarcies.

In Tunisia: The Akakus Formation has been described as alternating dark, silty, micaceous shales and fine to very fine grained. It is divided into Tanezuft and Acacus A, B, C Units. Aissaoui and Alt (2004) indicates that porosities are within the range of 10 to 20 percent and permeabilities between 40 to 150 millidarcies.

In Libya, the Silurian sequence was subdivided lithologically into two formations: The Tanezuft and Acacus (Lower, Middle and Upper Units). Akakus sands exhibit usually good petrophysical properties in the southern productive areas (Echikh, 1998) of the Ghadames Basin. The average porosity calculated from the logs is between 20 to 25 percent. Deterioration of reservoir quality occurs toward the northwest part of the basin: Lower porosities between 8 to 20 percent and maximum permeabilities do not exceed 10 millidarcies. The Silurian reservoirs show sandier facies (above 60 percent of sand) and improved petrophysical properties on the southern flank of the basin (Libya, Algeria. Reservoir quality (less 30 percent of sand) deteriorate towards the northwestern parts where open marine shale prone environment predominates (Echikh, 1984) The Lower Akakus thickness values are ranging between 700 and 1200 ft.

Structural traps : Most of the discovered hydrocarbons accumulations are found in structural traps that have

some stratigraphic components for some of the pools. As previously discussed the complex structural history of the region has produced a wide variety of structural traps of different ages.

Many structures have grown successively throughout geological time, from Silurian to Carboniferous (Hercynian phase) and Cretaceous (Austrian phase) and Eocene (Alpine phase) movements. The structure sizes and hydrocarbon productivity are directly related to the tectonic phase types. Generally, the structure size is ranging between 5 to 18 Km² in the Al Hamra high area and between 5 to 9 Km² in the Al Kabir high area. It does not exceed 2 to 7 Km² in the northwestern areas.

The major local traps initially of Hercynian age were restructured later by the Austrian compressional movements and produced high amplitude (100 to 200 meters) faulted features observed over the El Biod Arch, such as Rourde Nouss and Brides oil and gas field. Other features were formed during the pre-hercynian phase (Illizi basin and Al Kabir trend) and are characterized by medium to low relief of 30 to 60 meters amplitude and 10 to 15 km² of size. Dry holes analysis (Echikh, 1984,1987,1998) indicate that the most productive traps are related to the oldest structures formed before the hercynian phases. This is explained by the fact that the first phase of hydrocarbon generation from the Silurian source rocks occurred during the late Carboniferous era.

Tectonic erosional effects, structuration and trap efficiency

Each of major phases has had significant direct or indirect influence on the Hydrocarbons habitat. Some of the main influences are as follow:

Caledonian movements -

In late Silurian time, the western and southern flanks of the studied areas were uplifted and partially eroded. Subsequently, this caused the Silurian sandstones being placed in direct contact with lower Devonian. As a result the Silurian reservoirs often lack seals in some fields.

In late Lower Devonian (Emsian) the Ahara high was uplifted and was partially to completely eroded and covered by the Frasnian radioactive shales.

Hercynian movements

Hercynian tectonic movements were significant in placing Paleozoic source rocks and reservoirs in direct contact over large areas within the Mesozoic section. The Hercynian phase has limited the extension of the Silurian and Devonian source rocks through erosion. Perhaps against Triassic volcanics present over the Dahar High.

Hydrocarbon charging and preservation

The Akakus reservoir charging is still controversial. In Libya, (Eni -Agip, 2000 ; Boote, 1998, Dardour, 2004, Hallet, 2002) AGIP suggests hydrocarbon charging from the deep Silurian Tanezuft shales through the vertical faulting. Other authors (Dieckman and al) are indicating that new source rocks was identified with the Silurian Argilo-Greseux (equivalent Akakus) as an additional contribution besides the Silurian Tanezuft. In Algeria, the preservation of hydrocarbons in regionally tilted low relief traps and fault controlled anticlines can be disrupted by secondary fault reactivation. Additionally, the uplift of the southern flank of this basin during the Late Cretaceous led to the infiltration of fresh water into the PZ and Trias- Jurassic reservoirs, flushing the hydrocarbons trapped in those structures.

Conclusions

Hydrocarbons richness vary widely across the Berkine - Ghadames Basin, depending on several key geological controls. The most important factors controlling the habitat in the Silurian petroleum system are: reservoirs quality, tectonic erosional phases, structuration ,traps efficiency ,hydrocarbon charging , communication, preservation and hydrodynamic conditions.

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