

Petroleum System Criteria of the Ordovician Succession, Murzuq Basin, SW Libya

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ABSTRACT

The petroleum systems, which have been active in the six basin in Libya. Scientifically; currently our task to investigate the Petroleum criteria in Murzuq Basin, SW Libya. A single petroleum system was active in the Murzuq Basin, comprising upper and middle Ordovician, reservoirs, which are charge by Silurian source rocks. The dominant feature of the study area is the Qarqaf Uplift, a huge broad anticlinal structure of Caledonian-Hercynian origin with an E-W trending axis[1]. This structure constitutes the northern boundary of the Murzuq Basin, which is filled by Palaeozoic and Mesozoic sediments of marine and continental origin. The Qarqaf Uplift consists essentially of Cambro-Ordovician rocks with occasional minor basement exposures and Tertiary volcanic flows or plugs. The geological succession relevant to eastern and northeastern Jabal al Hasawnah.

The cumulative effects of tectonic movements of Palaeozoic, Mesozoic and Cenozoic ages have produced the present-day structural framework of the Murzuq Basin. The drilling activities cross the Murzuq Basin; shows that there are more than 60 exploratory wells have been drilled in the basin, resulting in the discovery of 15 oil pools with around 4000 MMBL of oil in place. Most wells are located on the structurally highest elements in the basin and deeper portions are untested, largely because of the presence of extensive sand dune 'seas'. Finds to date include nine commercial and six technical discoveries. These are all in Upper Ordovician Mamuniyat sandstone reservoirs, sourced by Lower Silurian Tanezzuft shales. Potential younger traps in the Devonian sandstones. The main trapping mechanism is structural, often reflecting glacially related Palaeo topographical factors, but other subtle trap types may occur, mainly related to stratigraphically truncation and to permeability barriers[5].

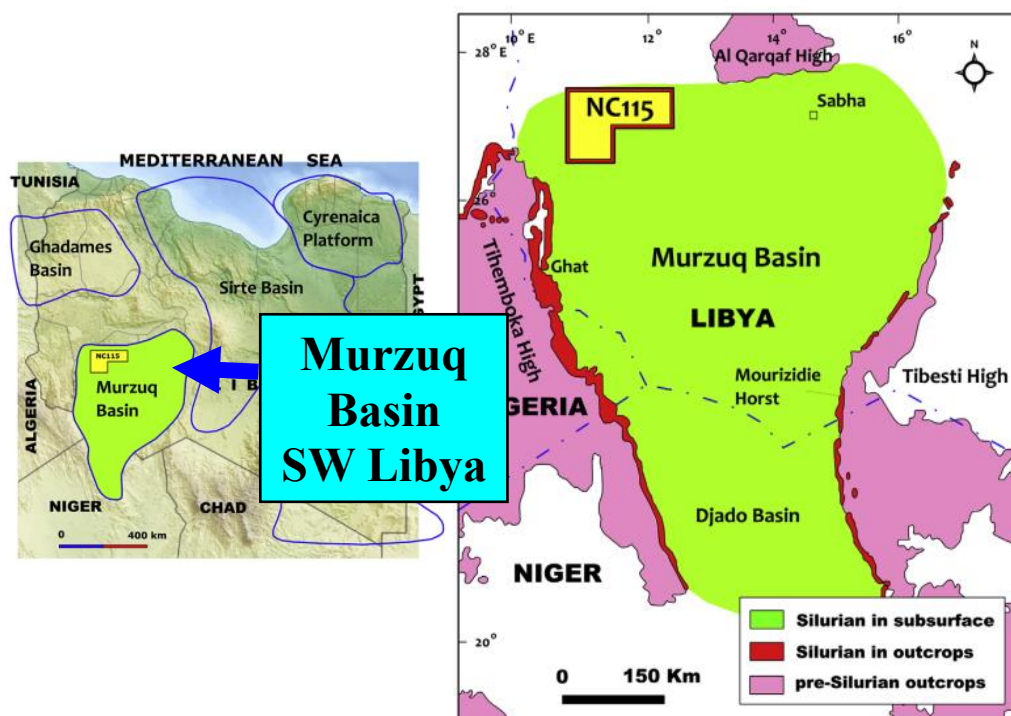


Fig. 1. Location of the study area.

I. INTRODUCTION

The studied area contains a large intracratonic basin (Fig. 1) coveting an area of over 350, 000km²[5]. It is bounded to the north by the Gargaf Uplift, to the west by the Tihemboka Arch and to the east by the Tibesti Uplift. To the south, it extends into Niger and is there known as the Djado Basin. The sedimentary section in the central part of the basin has a thickness of 3500 m, comprised mostly of Palaeozoic and Mesozoic rocks. The oldest Palaeozoic rocks outcrop on the flanks of the basin. Cretaceous sediments form an escarpment in the northern and eastern parts, while the central part is covered by the dunes of the Murzuq Sand Sea. The 62 wildcats drilled in the Murzuq Basin found 11 oil fields, including two giants, with reserves of approximately 2 billion BBL.

The Ordovician Mamuniyat Formation shows an increase of marine influence toward the north. It is dominated by proximal periglacial outwash fans in the south giving way to fluvial-estuarine and shelf deposits in the north. Poor correlatability within the Mamuniyat is a function of the complex stratigraphy likely due to a series of rapid, glacially driven changes in sea level and corresponding drainage incision, followed by inundation, reworking of sediments and backfilling of estuaries[6].

II. LOCATION OF STUDY AREA

The Murzuq Basin, located in southwestern Libya, is one of a number of intracratonic basins located on the Saharan Platform of North Africa (Fig.2)[2].

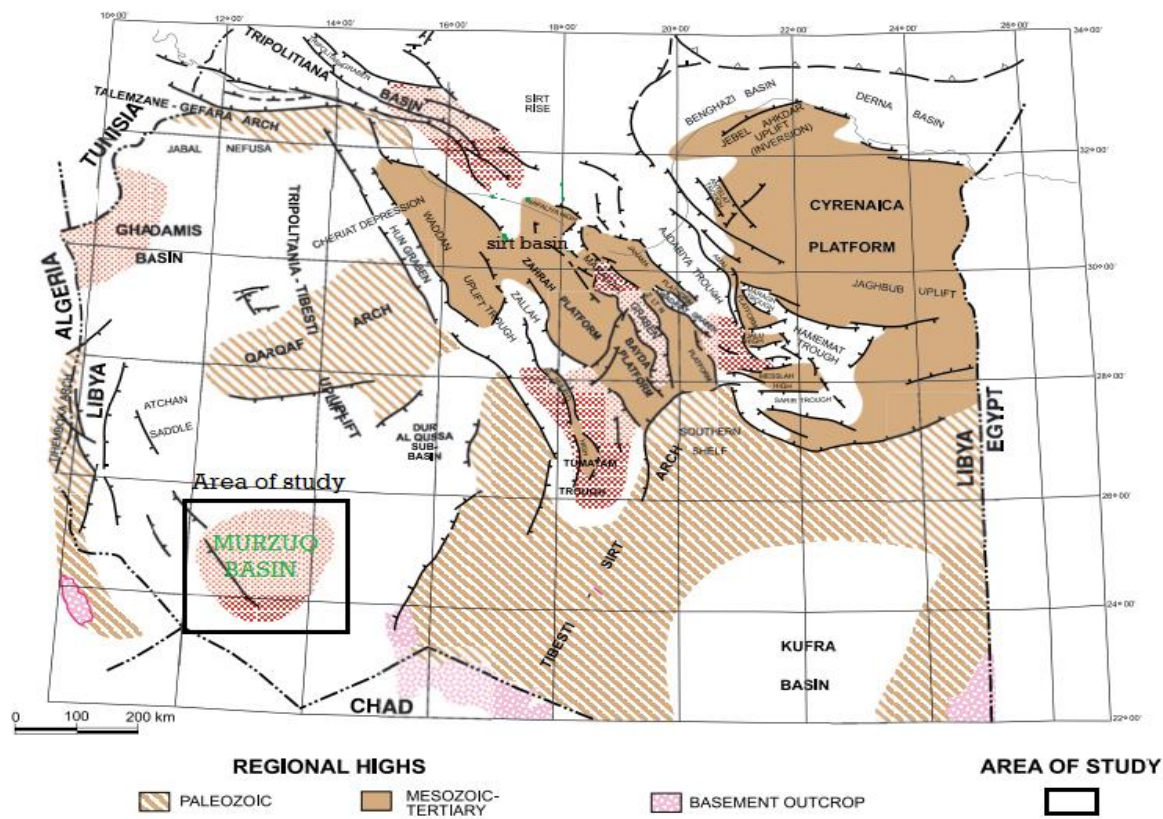


Fig. 2. Location map of the study area.(Rusk, D. C., 2001, Libya: Petroleum potential of the underexplored basin centers—A twenty-first-century challenge)

III. GEOLOGY OF THE STUDY AREA

The Murzuq Basin was influenced by marine environments in the Paleozoic and became a more or less continental basin without marine outlet from the Permian onwards. This continental phase was interrupted only by the marine Maastrichtian transgression, which reached the northeastern margins of the Murzuq Basin. Last remnants of the uppermost Cretaceous sandstone are situated 50 km northeast of Sabha. During the long period of about 65 million years through the Tertiary the continental endorheic Murzuq Basin was formed mainly by deflation rather than by fluvial erosion during humid intervals. These processes carved out the Ridge between the present large sand sea areas. The two separated depressions of the Awbari and Murzuq sand seas have to be much older than the studied remnants of the paleolake levels. The dip and the increasing thickness of the Cretaceous Formation into the center of the basin indicate continuous subsidence of the Murzuq Basin up to the Tertiary. There is however no evidence for Maastrichtian or Paleogene sedimentation in the inner parts of the Murzuq Basin. In contrast, the elevation of the Brak Member limestone decreases towards the center of the basin by 30 m to 50 m. Reasons for this could be imprecise measurements, erosion, changing water level in the paleolake even a small continuation of subsidence.

The relief of the oldest paleolake level in the Murzuq Basin is very similar to the present morphology.

a. Paleozoic

Deposition of mostly continental siliciclastics during the Cambrian and marginally marine to marine siliciclastics during the Ordovician and Silurian continued essentially without interruption from Morocco to the Middle East. Uplift and erosion during the Late Silurian Caledonian orogeny initially defined the limits of the Paleozoic basins of Libya. The east-west-trending Qarqaf arch separated the Murzuq Basin; the north-south-trending Sirt-Tibesti arch separated the Murzuq Basin[2].

b. Mesozoic

A very thick sequence of continental sediments of Triassic to Early Cretaceous age occupies the central part of Murzuq Basin. Along the Murzuq Basin margins and the nearby Qarqaf and Tibesti arches, Paleozoic and basement rocks are exposed.

The dominant feature of the study area is the Gargaf Uplift, a huge broad anticlinal structure of Caledonian-Hercynian origin with an E-W trending axis (Frist and Klitzsch, 1963).

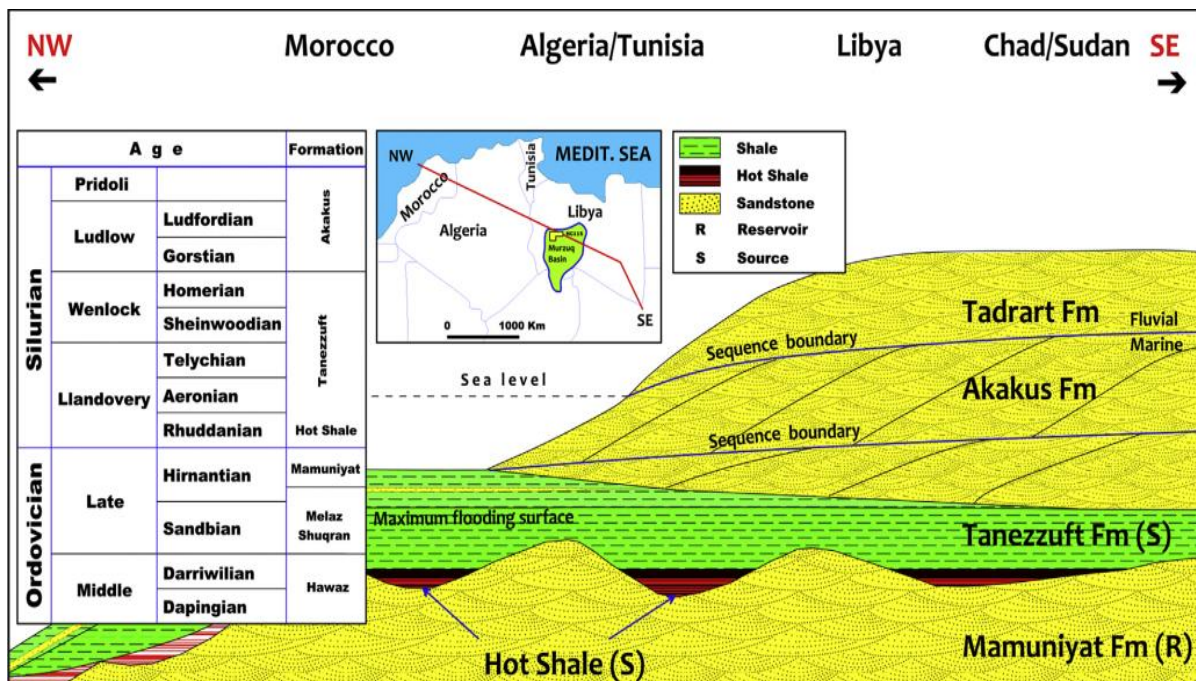


Fig. 3. General depositional model and chronostratigraphic chart for Upper Ordovician to Lower Devonian sediments in North Africa with emphasis on the lowermost Silurian Hot Shales (after Lüning et al., 2000).

This structure constitutes the northern boundary of the Murzuq Basin, which is filled by Palaeozoic and Mesozoic sediments of marine and continental origin. The Gargaf Uplift consists essentially of Cambro-Ordovician rocks with occasional minor basement exposures and Tertiary volcanic flows or plugs. Upper Cretaceous and Paleocene rocks of the Zimam Formation unconformably overlie the northern flank of the Gargaf Uplift. The geological succession relevant to eastern and northeastern Jabal al Hasawnah. The Ghadames Basin is bounded by the Nefusa Arch to the north, the Tihemboka-Gargaf Arches in the south and the Tripoli-Soda Arch to the east. Its internal architecture is dominated by a Hercynian unconformity, which separates a truncated Cambro-Ordovician to Carboniferous succession below from a northward-thickening Mesozoic-early Tertiary wedge above (Figs. 2). The Ordovician Mamuniyat Formation shows an increase of marine influence toward the north. It is dominated by proximal periglacial outwash fans in the south giving way to fluvial-estuarine and shelf deposits in the north. Poor correlatability within the Mamuniyat is a function of the complex stratigraphy likely due to a series of rapid, glacially driven changes in sea level and corresponding drainage incision, followed by inundation, reworking of sediments and backfilling of estuaries.

IV. DATA AND METHODS OF STUDY

1. General

-This underexplored basin-center area covers more than 30,000 km². In all these discoveries, sandstones of the Ordovician Memouniat Formation are the reservoirs. The Ordovician rocks of this area were first described by Massa and Collomb (1960). They are widespread over large portions of the North African craton (Pierobon, 1991). Four formations represent the sequence, namely Ash Shabiyat (Lower Ordovician), Hawaz (Middle Ordovician), Melaz Shuqran and Mamuniyat (Upper Ordovician) (Lüning et al., 2000). We focus here on the Hawaz and Mamuniyat formations, which are important reservoirs (Fig. 3). The Hawaz Formation was first described and named after Jebel Hawaz on the Al Qarqaf High by Massa and Collomb (1960).

In the NC115 Concession, it is overlain by the Ordovician Melaz Shuqran Formation (Fig. 3), where it reaches 150 m in thickness. Its probable mid-Ordovician age is based on palynological evidence (Hallett, 2002).

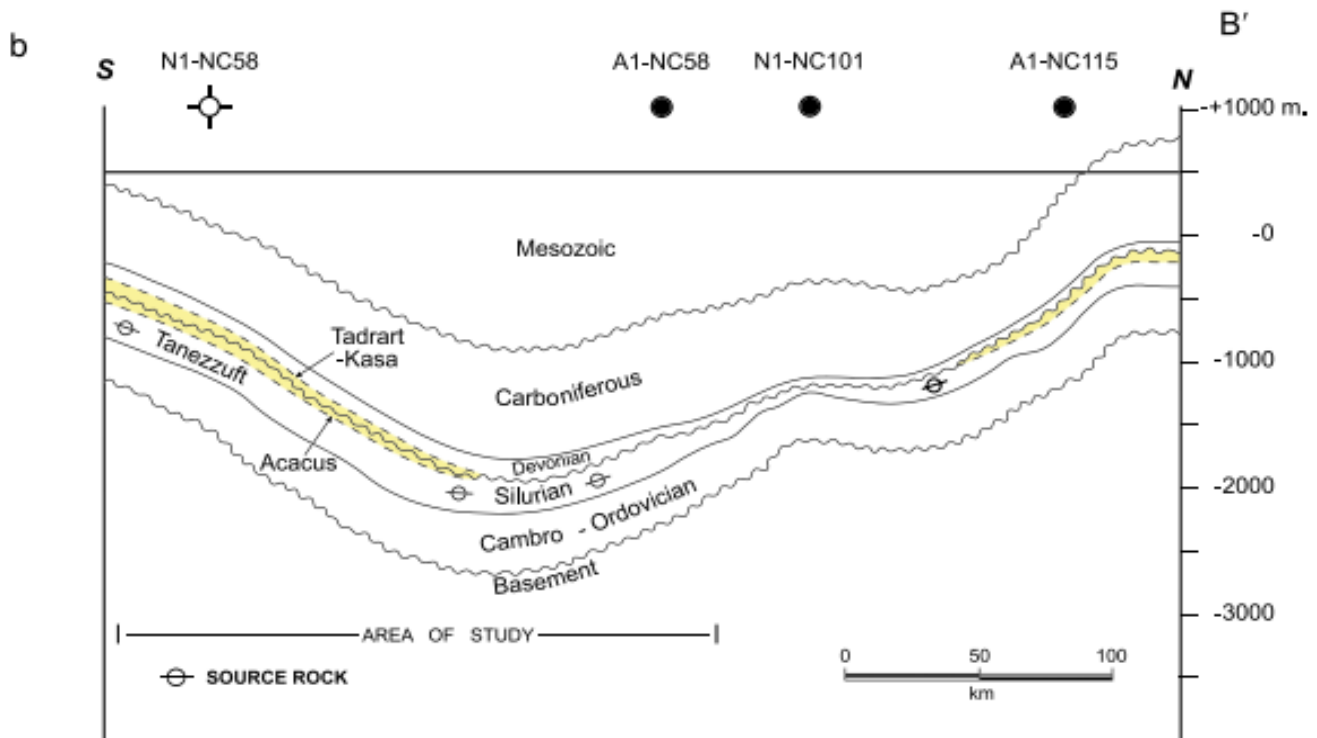


Fig. 4. North-south structural cross section B-B', Murzuq Basin area of study.

The formation consists of fine- to medium-grained quartzitic sandstone that is moderately to well cemented by siliceous material. It is kaolinitic in parts, has poor visual porosity, and contains thin streaks of moderately- to well-compacted, sub-fissile to fissile shale (Hallett, 2002; Ramos et al., 2006). These deposits reflect the onset of the first major Palaeozoic marine transgression in the region (Echikh and Sola, 2000; Ramos et al., 2006; de Gibert et al., 2011). Only four wells have been drilled there (Figure 4), and one well, A1- NC58, is a marginal oil discovery. Within about 50 km to the north are seven small, undeveloped oil-field discoveries, with total reserves of about 150 million bbl, and one major discovery, Elephant (N1-NC174), with estimated reserves of 500 million bbl of oil.

average porosity of the Acacus sandstone is approximately 15%. The Tadrart-Kasa sandstones, undifferentiated, have an estimated net thickness of as much as 200 ft and an average porosity similar to that of the Acacus. This sequence pinches out at the Caledonian surface in the northern part of the area. The depth to the Memouniat ranges from 8000 to 11,500 ft. The Acacus and Tadrart-Kasa are at depths of 6500 to 10,500 ft in the Murzuq Basin center (Figure 7), (Masera Corporation, 1992).

-The Tanezzuft shale provides a reliable seal throughout the area for the Memouniat Formation. Generally, effective shale seals are interbedded with Acacus sandstone beds. In a few places, upper Acacus sandstones are overlain by Tadrart-Kasa sandstones, which could create a combined reservoir, as in the Ghadamis Basin. Uennin shale beds provide adequate seals for the Tadrart-Kasa sequence.

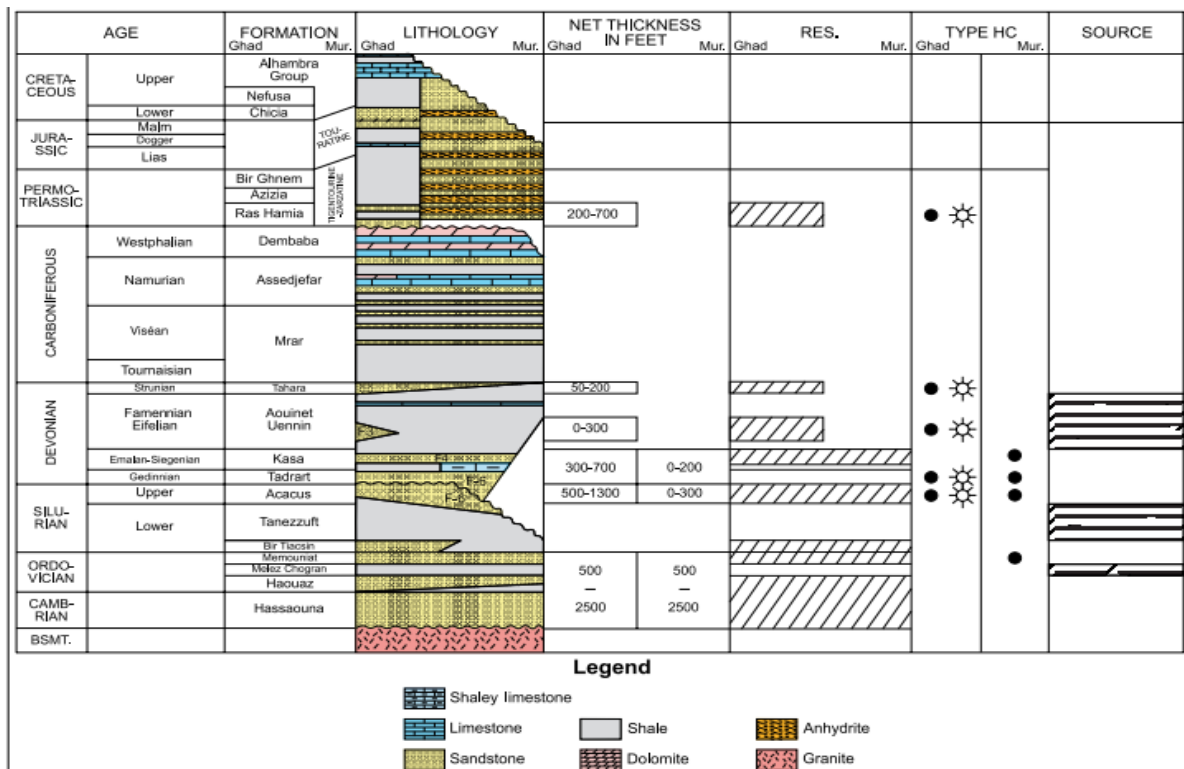


Fig. 5. Generalized stratigraphic chart of Murzuq Basin, showing source and potential reservoir intervals.

2. Reservoirs.

-Main potential reservoirs for the area include the Acacus and the Lower Devonian TadrartKasa sandstones (Figure 5), as well as the main pay in the basin, the Memouniat Formation. The net sandstone thickness of the Memouniat Formation ranges from approximately 500 to 2500 ft and has an average porosity of 10–14%. The Acacus net sandstone thickness is from 0 (at the north edge of the study area, where it is truncated) to 300 ft (Figure 6) . The

3. Source rock, timing, and migration.

The Tanezzuft shale is the only effective oil source of importance in the Murzuq Basin (Hamyouni, 1991). It is possible, however, that very minor amounts of early oil were expelled from Devonian Uennin organic-rich shale in the basin center (Meister et al., 1984). Permotriassic sediments in eastern Murzuq Basin comprise mainly fine-grained sandstone and mudstone[3].

North-South Line Through G1-NC115 to M11-NC115

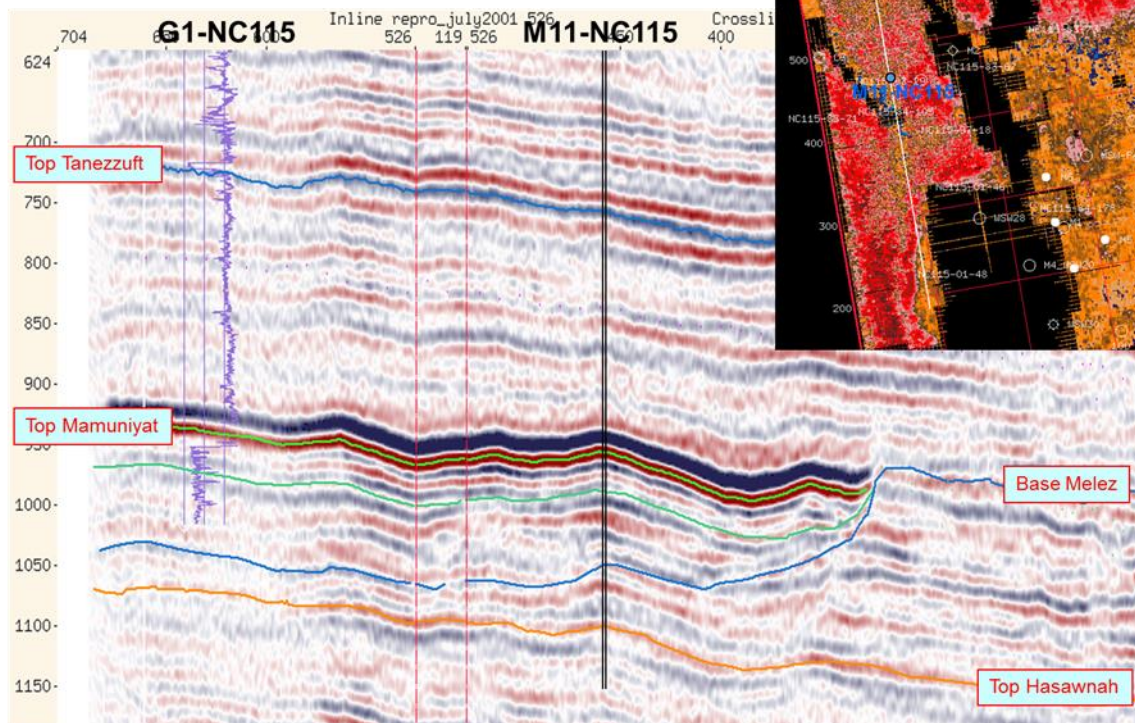


Fig. 6. Seismic map of the Acacus Formation, Murzuq Basin.

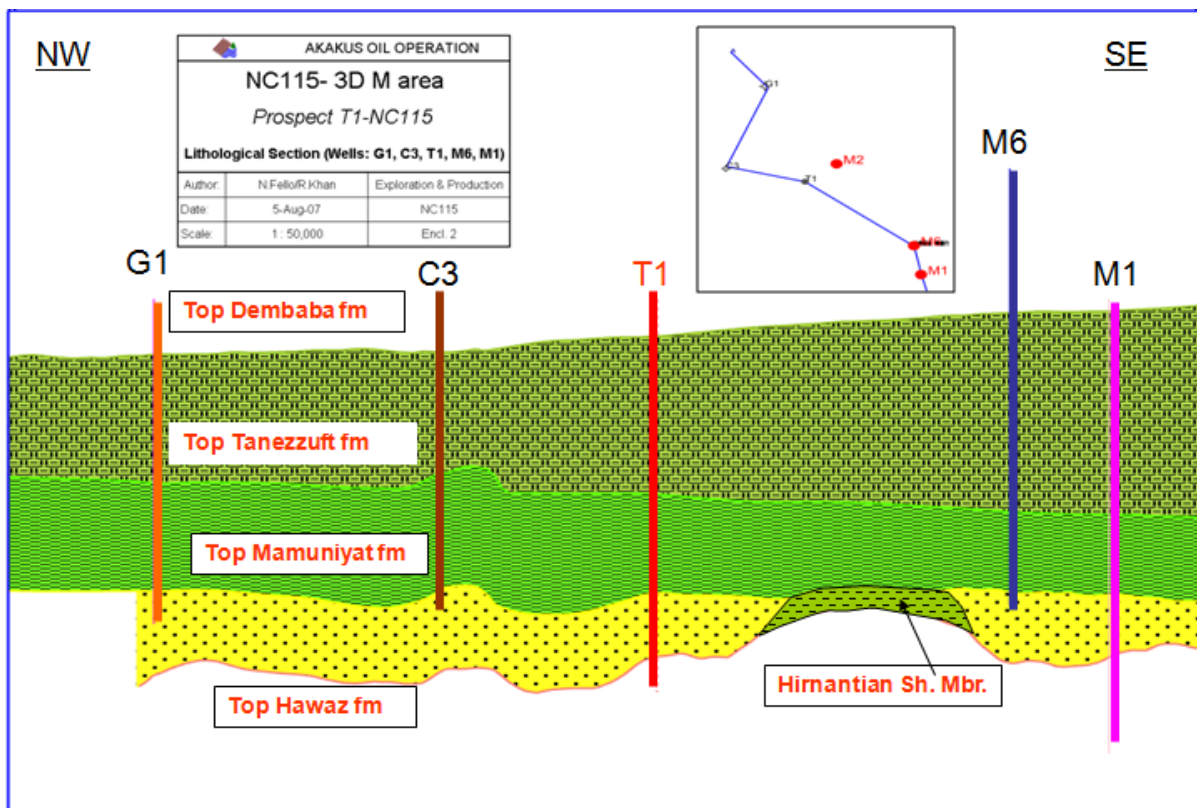


Fig. 7. Lithological NC115-3D M area- Akakus oil Operations (2007).

The Tanezzuft shale is 400–1600 ft thick in the study area. The average TOC is 1.8%. The peak oil-expulsion window is approximately 6500–9000 ft. Therefore, because the depth to the base Tanezzuft is from 7000 to 11,500 ft in the study area, the Tanezzuft is in peak-oil to wet-gas generation stages. Vertical, updip, and fault pathways provided easy, short-distance pathways for migration of oil to the adjacent reservoirs. Migration apparently took place from the Early Jurassic to the Early Cretaceous, after the establishment of most, if not all, of the traps in the study area.

3. Traps.

Structural trap types are basically the same as those in the Ghadamis Basin center. The expected trap types are low-relief, simple, and faulted anticlines; drape anticlines over paleotopographic relief or faulted structures. Unconformity truncation of the Acacus and onlap pinch-out of the Tadrart-Kasa, in association with dip or fault closure, are also potential traps in the area.

The Murzuq Basin (Fezzan) is one of several intracratonic North African basins that has a predominantly marine Palaeozoic clastic infill, although with recurrent continental influence. The maximum depth to Precambrian basement reaches about 3500 m in the basin depocentre. The Palaeozoic succession is unconformably overlain by up to 1500 m of mainly Mesozoic continental deposits. Present-day tectonic elements delimiting the basin are the Tibesti-Haruj, the Tihemboka and the Gargaf uplifts on the eastern, western and northern flanks respectively, while to the south the basin narrows and terminates in the Djado sub-basin of northern Niger.

The general age of the whole succession has been established by earlier regional studies of the Murzuq Basin; Repsol and other license partners have refined these datings on the basis of several geological studies (Aziz, 1992; Herzog, 1997a, b), recently confirmed by palynological analyses. This work has resulted in some correlational changes: most notably strata previously believed to belong to the Silurian Akakus Formation have now been assigned to the Basal Devonian sandstone. Mesozoic units have also been redefined and parts of what were earlier thought of as representing the lower Quaternary succession are now assigned to the Taouratine Formation. The main reservoir rock is provided by the Mamuniyat Formation, with overlying Tanezzuft Formation shale giving the cap rock. The main reservoir sandstones represent shoreface deposits with good reservoir quality. The secondary target is provided by the sandstones of the Hawaz Formation, which are important where the Mamuniyat Formation is thin or

even totally absent; Hawaz sandstones are shallow marine deposits with fair reservoir quality. The third target is provided by the Basal Devonian sandstone, which may have an attractive potential in the central part of the license area, with fair reservoir quality. The Tanezzuft Formation shale is considered to be the main source rock; present geochemical data indicate that the Lower Tanezzuft 'Hot Shale' interval represents the main source unit with huge amounts of generated hydrocarbons. terns have been extensively interpreted by the use of FMI logs. The Mamuniyat Formation is the principal reservoir in the upper Ordovician succession of the Murzuq Basin. It has hitherto been assumed to have a ubiquitous occurrence beneath the base Silurian subcrop. Previous depositional models for the Mamuniyat Formation describe outwash alluvial fans at the southern margins of the basin passing into a northwesterly trending braided fluvial system. The Mamuniyat sandstones generally contain 80 to 97% quartz, 2 to 4% lithic fragments (quartzites and cherts), 2 to 3% micaceous minerals (sericite, muscovite and chlorite) and 1 to 5% opaque minerals, including pyrite. Silica and sometimes mixed silica and kaolinitic cements are common.

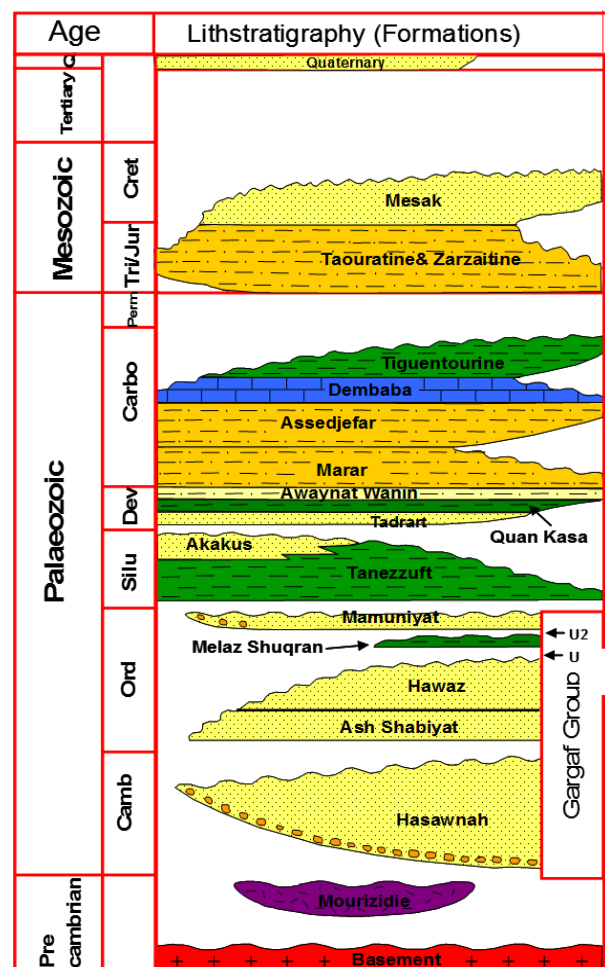


Fig.8. Lithostratigraphy formation.

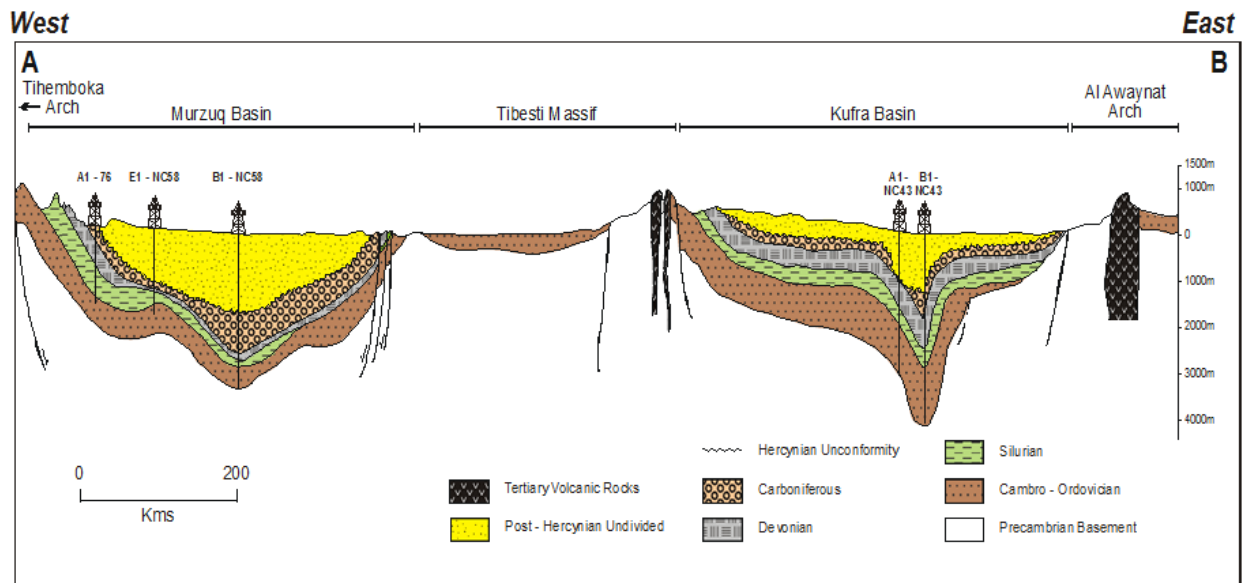


Fig. 9. Cross section of southern Libya through the Kufra and Murzuq basins. Fello *et al.*, (2006)

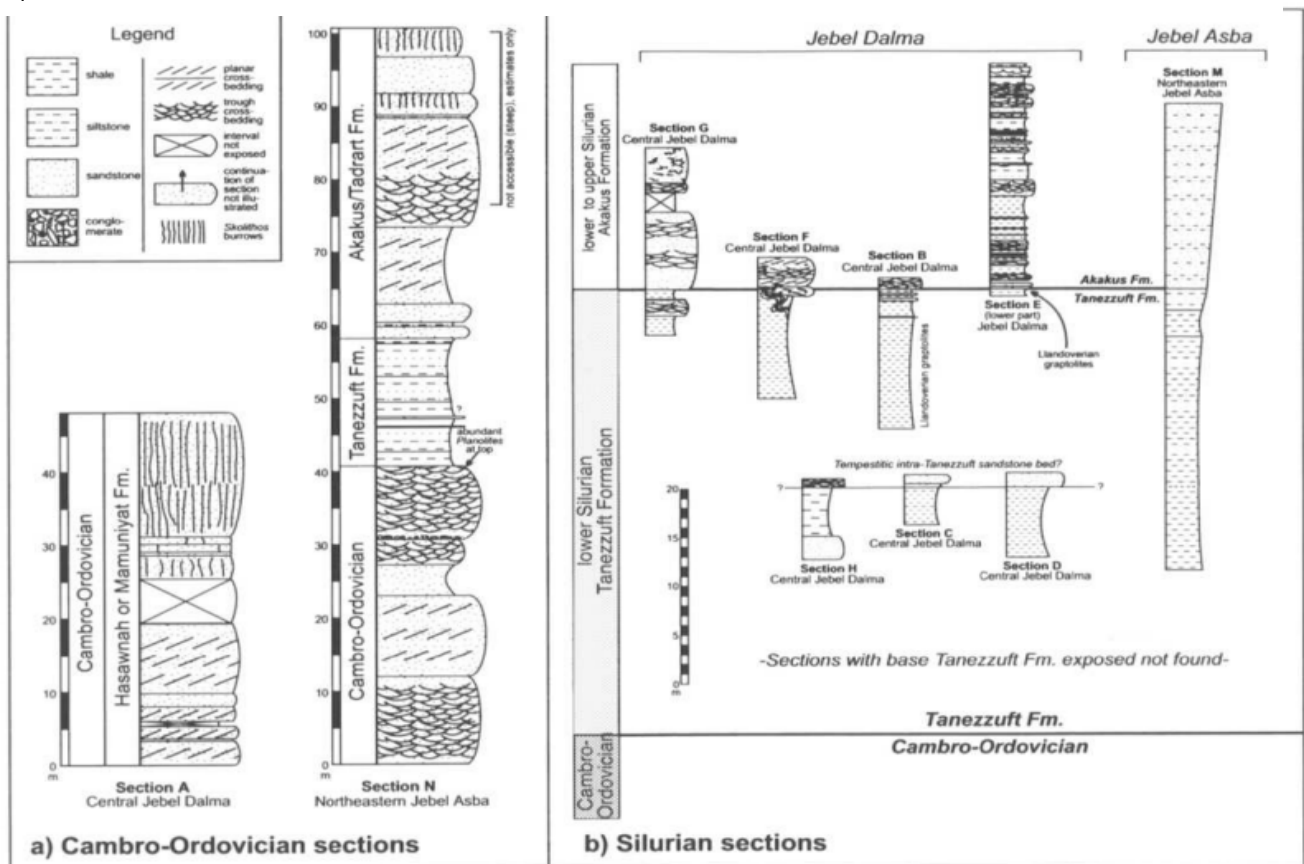


Fig. 10. Cambro-Ordovician and Silurian stratigraphic field sections logged in Jebel Dalmia and Jebel Asba in March/April 1998.

In this study the Cambro-Ordovician succession was studied in sections A (Jebel Dalma) and N (Jebel Asba) (Figs. 9, 10). The unit is composed mainly of fine to medium, partly coarse, sandstones with intercalations of a few conglomeratic beds. Typical sedimentary structures observed in the Cambro-Ordovician strata include wave and current ripples, gravel lenses, conglomeratic lag deposits, load casts and shale intraclasts. Similar features were described by Smart (1998) from the base of the late Ordovician Mamuniyat Formation in the Murzuq Basin of SW Libya and by Ghienne and Deynoux (1998) from Mauritania. Driggs (1993) found a considerable palaeorelief which markedly influenced the lateral thickness distribution of overlying Silurian shales above similar, mainly fluvially filled late Ordovician channels in Algeria (width 2-8 km, depth 100-200 m)[4].

In section A (Fig. 10), metre-scale planar cross-bedding dominates the lower part and may represent a braided delta plain facies. The upper part of section A is dominated by medium-grained sandstones intensely bioturbated. a high-energy nearshore facies is assumed for the Cambro-Ordovician piperock in Jebel Dalma. A similar *Skolithos* dominated succession was described by Vos (1981) from the Ordovician Hawaz Formation in the Gargaf Arch and also occurs in Cambro-Ordovician sandstones near Ghat (both Murzuq Basin, SW Libya) [4].

V. CONCLUSION

- The Murzuq Basin should be subdivided into two main areas in terms of hydrocarbon exploration potential.
- The Murzuq-Djado Trough is an exclusively Palaeozoic structural element filled with strata of Cambrian to Carboniferous age, including several hundred metres of lower Silurian shale that locally provide an excellent to fair source rock potential.
- Sedimentation in the Murzuq basin slowed and stopped during the early Cretaceous, after the deposition of thick sequences of purely continental strata.
- Until now the main reservoir rock has been fluvio-glacial sandstone of late Ordovician age, which provides the reservoir in several oil fields.
- Younger sandstones, such as sand sequences within the Devonian, however, can also have fair to good reservoir quality with cap rock sequences within the Devonian strata or at the base of the Carboniferous.
- The northeastern part of the Murzuq Basin underwent a different structural history until

the mid- or late Carboniferous and was only incorporated in the present day Murzuq Basin when the Variscan collision formed the Jebel Gargaf as a major structural element. Regionally, the Mamuniyat sandstones seem to be present throughout the whole Murzuq Basin, except for eastern areas where data from outcrops (eastern Gargaf, Dur Al Gussah) and a few wells indicate its absence. Most wells in concession NC115 have penetrated the whole Ordovician section down to the Hawaz Formation. Wells in concessions NC58 and NC101 reached only the uppermost part of the Mamuniyat Formation, so that its total development there is not known. In Concession NC115, this formation is characterised by rapid thickness variations ranging between 50 and 150 m. Regional log correlations and core macroscopic observations of the Mamuniyat Formation indicate the presence of four main lithofacies in the Murzuq Basin. The most common lithofacies is a silica-cemented fine grained, hard, often quartzitic sandstone with vertical to subvertical fractures

- Potential structural hydrocarbon traps are provided mainly by convergent elements, generated during Late Ordovician, Late Silurian/Early Devonian, Late Paleozoic, and Early Tertiary compressional episodes.
- Cambrian and Mesozoic extensional episodes may have provided locally closed structures. Additionally, local intrusion by mafic sills has arched Paleozoic reservoirs into structure that may be prospective traps.
- The Ordovician Mamuniyat Formation shows an increase of marine influence toward the north.

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BIOGRAPHIES



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