



Geology, Hydrocarbon Potential Reservoirs and Age dating of the Ordovician Sequence Stages Ghadames and Murzuq Sedimentary Basins West Libya

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ABSTRACT

The Ordovician strata are mainly clastic, with palynological stage units identified in the Ghadames and Murzuq basins (F. Belhaj, 1996). Correlations are complicated by barren sections, inconsistent electric log markers, lateral lithological variations, facies changes, limited well control, and shallow penetration depths. Major unconformities correspond to the Sardinian and Taconian orogenic events, part of the broader Caledonian orogeny. The base of the Ordovician section is poorly defined in large areas of these regions, but Ordovician units are widespread. The sediments are categorized by a well-defined upper boundary unconformity, with the basal unconformity only partially known from a few wells and outcrops. Internal contact relationships among rock units are unclear, and while biostratigraphic analyses have identified several stages, their full extent is uncertain due to low palynomorph occurrence. Ordovician sandstones have excellent reservoir properties and significant hydrocarbon accumulations, with Tan ezzuft Shales acting as the primary hydrocarbon system.

The clastic fill of the Ghadames and Murzuq Basins is complex due to varied depositional environments and their origins as erosional remnants of a thicker Paleozoic continental margin along Gondwana. Both basins have undergone significant erosion and sediment reworking, influenced by multiple tectonic events. Key formations along the Murzuq Basin's flanks include Tihemboka, Tibesti, Gargaf, and Atshan Sadale. They contain a substantial Paleozoic sedimentary succession of marine and transitional sediments overlying a Proterozoic to Precambrian basement, along with Mesozoic deposits. The Paleozoic sedimentation rate was low, with maximum infill exceeding 12,000 feet. The sedimentary records reveal multiple structural developments, with some faults showing north-south variations. The Paleozoic infill consists of six stages, representing five lithostratigraphic formations from the Cambro-Ordovician period: Hasawnah, Achabiyat, Hawaz, Melaz Suqran, Mamuniat, and Bir Tlacin, with some rock units absent in both basins.

Keywords: Hydrocarbon Potential Reservoirs, Age dating, Ordovician Sequence stages, Murzuq and Ghadames Sedimentary Basins, Libya.

1. Introduction

The objective of this paper is to inclusively review the geology of both the Ghadames and Murzuq basins with emphasis on the Ordovician Sequence. The exploration work generally has been slow and most of the wells drilled in the region did not penetrate the total sequence of Ordovician.

The Ghadames and Murzuq Basins are major North African Paleozoic Basins. Almost equal portions of the Ghadames basin are present in both Libya and Algeria also small portion is located in southern Tunisia. The Ghadames Basin in Libya is bounded by the Qarqaf Arch (Jabel Hassauna) in the South, the Jabal Nafusah uplift in the North and the Sirt Basin and Dor El-Gussa Sub-Basin at the East. Murzuq basin is bounded by the Qarqaf Arch (Jabel Hassauna) in the North and Nager in the south.

Many authors and researchers have investigated the Ordovician Sequence Stages of the Ghadames and Murzuq Sedimentary Basins, as well as their adjacent regions, involving several prominent figures in the field [1, 2, 3, 25, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32 and 33]

A significant number of authors and researchers have conducted extensive investigations into the Ordovician Sequence Stages of the Ghadames and Murzuq Sedimentary Basins, along with the surrounding regions. Their studies often encompass various geological aspects, such as stratigraphy, paleoenvironments, and sedimentology. Many prominent figures in the field have contributed to this body of research, providing valuable insights into the geological history and depositional processes that shaped these basins during the Ordovician period. Their collaborative efforts have not only enhanced our understanding of these sedimentary systems but also

established important correlations with other geological formations in adjacent areas.

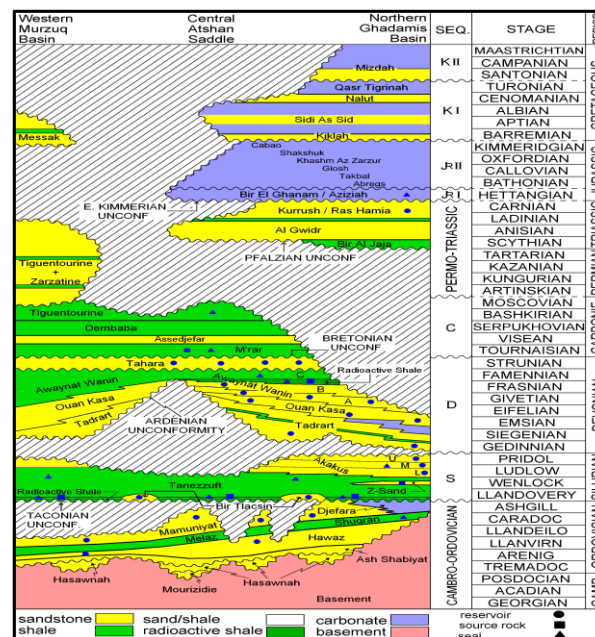


Fig.1. Chrono-stratigraphic Chart of Ghadamis and Murzuq basins in Libya

1.1.Cambrian Sequence

Fig.1. illustrates the formations associated with the Cambrian period, providing a visual representation of the various strata and rock types that emerged during this significant era in the history of the Murzuq and the Ghadames basins.

Mourizidie Formation

[34] first described the Mourizidie formation at the type locality in Mourizdie Horst southwest of the Murzuq Basin outcrop (Fig. 3). The formation consists of arkosic sandstone underlying the Hassaouna formation and overlying the metamorphic basement.

In the Ghadames area the only wells that encountered Cambrian of possibly Mourizdie formation are wells A1-69, A1-66, A1-23, and A1-42. In the central area Ghadames basin in the Kabear area, some wells may encounter Cambrian of possible Mourizidie formation which needs more paleontological age dating to be confirmed.

The Cambrian basement outcrops in the Al Qarqaf Arch and consists of biotite gneiss. This Cambrian basement age dated by K/Ar and found to be ranging from 520 to 554 Ma. Rock samples of the basement have been analyzed from boreholes in Ghadames Basin and outcrop from Al Qarqaf Arch have been radiometrically dated, [35].

[36] Show an age range of 570 to 470 million years. Massa (1988) reported that the basal core of well A1-66 consists of an altered spinel, pyroxene, olivine peridotite. A1-69 well consists of metamorphosed black clays.

In the areas of west Libya, no wells drilled deep enough to allow evaluation of the Mourizidie formation. However, it is expected that this formation is present in both areas of Ghadames and Murzuq basins.

2.Pre-Ordovician Sequence Cambrian Sequence

Cambrian age Sequence has been assigned to strata exposed between outcrops of alleged Precambrian basement exposures and a section of Caradocian to Ashgillian strata in the Al Qarqaf Arch region by [37]. This Cambrian age assignment is tentative. The age of the exposed granite is Cambrian to possibly Early Ordovician, similar to that of the Bin Ghanimah granites in the Tibisti region [38]. The exposed sections are barren of diagnostic fossils and contact relationships with the Ordovician section are not well understood. Therefore, a Cambrian sequence has not been recognized. All Ordovician stages have been palynologically identified whenever possible in the subsurface of both Ghadames and Murzuq basins areas. Correlation is difficult though, due to barren sections, lack of consistent electric log markers, considerable lateral lithological changes, facies variations, sparse well control, insufficient penetration depths and the regional impact of several major unconformities, corresponding to pulses of the Sardinian and Taconian orogenic events, both forming part of the Caledonian

worldwide orogenic event. The base of the Ordovician section is not known over large regions of the study area. [35].

Represented by the Hassaouna Formation which was introduced by Massa and Collomb 1960 after Jabal Hassouna in Gargaf Arch located between Ghadames and Murzuq basins. Generally, the Hassaouna Formation consists of brown to yellowish brown massive to medium to coarse grained highly cross beds silicified sandstone with abundant conglomeratic lenses overlain by an Ordovician sequence of Tremadocian age. [35].

Hassaouna formation is present in both Ghadames and Murzuq basins and encountered in the subsurface and in the outcrop of the Murzuq basin and areas of the southern and central Ghadames basin in wells A1-66, A1-69, A1-10, B1-91, A1-4, and B1-69. F. Belhaj 1996. This formation should be considered as a future exploration target in both sedimentary basins.

3. Ordovician Sequence

Please Refer to Figures 1 and 2.

The Ordovician Sequence is represented by Ashebyat, Haouaz, Melez Chogran, Memoniat, and Bir Tlacin Formations.

The stratigraphic chart shown in figure 2, indicates the presence of the Ordovician sequence stages in both areas of Ghadames and Murzuq basins.

4.Ashebyat Formation

Ashebyat Formation has been reported to be present and may change facies into the Haouaz Formation. Little is known about this formation in the Ghadames and Murzuq basins.

5. Haouaz Formation

[39] Considers the Al Qarqaf area a type area for the Haouaz formation. The Haouaz formation is the underlying Melez Chogran formation. The Haouaz formation in the Ghadames and Murzuq basins generally consists of fine-grained, well-bedded, platy,

silty micaceous, green and gray shales, and Skolithes beds were recorded.

The formation is encountered in wells MM1-66, F1-66, C1-49 and G1-66 have been age-dated, (Belhaj, 1996). Their age is ranging from Arenigian to Llandelian. However, wells A1-8, B2-34, A1-23, A1-42, and A1-147, B1-147 and B1-23 wells in both Ghadames and Murzuq areas which encountered Haouaz Formation. The wells MM1-66, F1-66, G1-66 and C1-49 that are age dated and thus can be correlated with the wells drilled within oil fields in both Ghadames and Murzuq basins areas for better understanding of the facies of the Haouaz reservoir.

Gargaf group is undifferentiated which made it difficult to assign any hydrocarbon shows to this formation. If the Haouaz formation is a candidate reservoir in Ghadames and Murzuq area, then the Tanezuft shale is the source rock and the seal of these reservoir group. Well, E1-66 in the Emgayet oil field in the Ghadames basin tested around 200 BOPD, also encountered oil shows in well C1-49 from Gargaf undifferentiated sandstone units.

6. Melez Chogran Formation

[40]. Described this formation as thin interbedded shale intercalated with angular to subangular fine-grained sandstone. Age of the Melez Chograne ranges from Llanvarian to Caradocian. In well A1-1 drilled in the Atshan saddle between the Ghadames and Murzuq basins encountered Caradocian age. This formation is also experienced in a few wells in Ghadames and Murzuq basins with insufficient information to evaluate its potential in both areas.

Generally, Meleze Chogran expected to be present in both areas of Ghadames and Murzuq which is considered as a seal for the lower Ordovician reservoir units. Fig. 2. Subcrop map of the Ordovician stages age dated control

of more than 30 wells analyzed strata, assigned to various stages in Ghadames and Murzuq Basins.

7. Memouniat Formaiton

[39] Introduced the formation. The type section of Memouniat is located in the western area of Al Qarqaf Arch and was studied in detail by [41]. It consists mainly of sandstones in the southern Ghadamis Basin and facies out to siltstones and limestones interbedded with shales and sandstones of the Djefara formation towards the northern area of the Ghadames Basin. The Memouniat sandstone generally transgressive sequence present in the paleohighs and filling the incised valleys influenced by glaciations which have been observed from cores around the

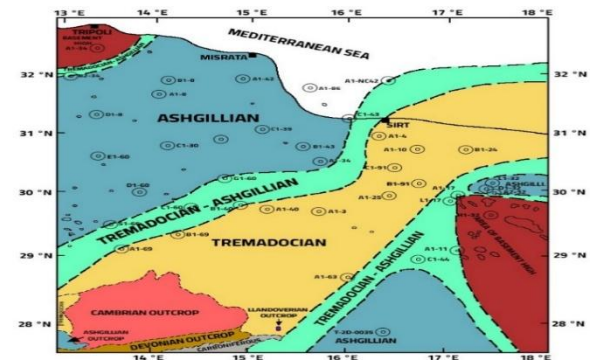


Fig.2. Sub-crop map of the Ordovician stages west Libya Basins. Modified after Belhaj 1996

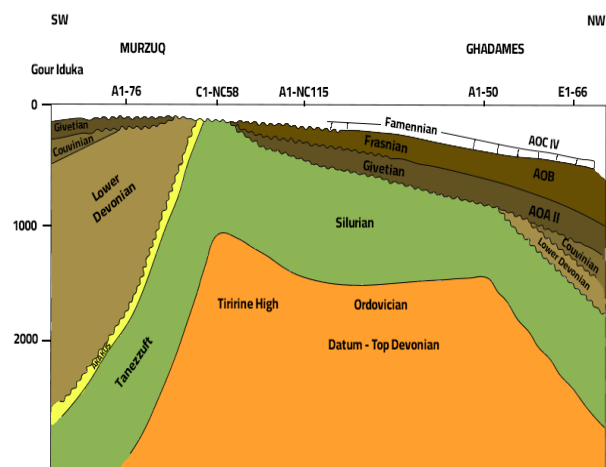


Fig.3. Cross Section Tiririne High of Murzuq Sedimentary Basin South West A1-76 to E1-66 North East

Qarqaf Arch areas and Atshan saddle. It is encountered in many wells in the northern and southern areas of Ghadamis and Murzuq basins. The thickness of the Memouniat formation ranges from 50 feet in wells A1-40 to Maximum of 500 feet in C1-49 and 800 feet in well A1-70, [12] unpublished report. The upper unit of the Memouniat formation is composed of quartzitic sandstones, occasionally, tan, cryptocrystalline, dolomitic in part as a good marker in the Ghadames basin area. The lower units are mainly composed of shales and siltstones. [41] considered the Memouniat Formation as a glacial marine cycle. Some workers include Iyadher and the overlying Tannezuft formation together as one formation.

Memouniat formation is considered the main reservoir producer in both the Ghadames and Murzuq basins. Memouniat formation is a reservoir producer in southern areas of the Ghadames basin and in Murzuq basin considered the main producer.

8. Bir Tlacin Formation

Bir Tlacin is facies of Memouniat and Iyadher formations. The occurrence of these sediments is local and believed to be formed from the erosional reworked sediments and material deposited in the rimmes of the paleohighs caused by the Taconian events in both Murzuq and Ghadames Basins.

Bir Tlacin sediments are possibly present associated with the paleohighs present in both areas. The sandstone facies of this formation should be considered as one of the major reservoirs in both areas.

9. Ordovician sedimentary sequence paleontologically age dated

The Cambrian stages are mostly not represented or either the units were barren or not penetrated by wells drilled in the region.

9.1. Tremadocian Stage

Tremadocian strata age units are present in both the Ghadames and Murzuq basins (Fig. 2). Extensive

palynological analyses including around 60 wells were recognized by several important palynological markers:

1. *Acanthodiacrodium* aff. *Scytotomillei*.
2. *Vukanis-phaera Africana*.
3. *Virgatasporites radii*.
4. *Saharidia Downier*.
5. *Acanthodiacrodium angustum*.

Also, rare reworked Cambrian acritarchs such as *Celtiberium geminum* and *Cristallinium cambriences*. Strata with a Tremadocian age have been assigned to the lower portion of the Haouaz Formation (Robertson Group plc UK, 1992).

Tremadocian sediments in Wells A1-10, A1-3, A1-40 and A1-4 (Figure 2) consists mainly of quartz sandstone, silty mudstone argillaceous and siltstone which include erosional weathered igneous and metamorphic rocks in the area near Al Qarqaf Arch of inner to outer neritic environment. The deposition during Tremadocian time, and acritarch content, was a fully marine, moderate, to high-energy environment near the Al Qarqaf Arch as suggested by lithology.

Tremadocian strata have been penetrated at shallow depth in the NE quadrant of the study area. There, an unnamed major positive regional structure straddles the boundary between the Sirt and Ghadames basins transitional evidenced by the configuration of structure contours on the top of the Tremadocian section. Tremadocian strata have not been reached at sufficient depth. The regional uplifts, cored by basement rock, are located in both the NW and SE corners of the study area. These uplifts have been intermittently active and high, during both the Paleozoic and Mesozoic eras. Due to the lack of diagnostic fossils, paleontological analyses show undifferentiated Tremadocian to Ashgillian stages (Figure 2).

9.2. Arenigian Stage

The Arenigian age strata included based on two only palynological markers:

1. *Anomatoplasidium tappaniae*.

2. *Eupoikilofusa cf. ergatoides*.

Also phitino- zones and acritarchs diversity are present throughout the interval analyzed. Strata assigned to this stage are creatable correspondent to the lower and middle portion of the Haouaz Formation. Well A1-8, A1-8, and B2-34 (Fig. 2). Generally this interval of Arenigian stagen generally consists of sandy conglomerate with abundant quartz pebbles, coarse to conglomeratic and mudstone which suggests high-energy environment represents inner neritic environment of deposition. The marine palynomorphs and a mixed arenaceous/argillaceous lithology indicate a fully marine inner neritic environment of deposition. This strata analysis from wells only penetrated in the northern corner of the Ghadames basin area (Fig. 2). The geographic distribution of this strata in the Ghadames basin seems to be affected by two palaeo-highs; one in the north-central part and the other in Murzuq basin region. (Fig. 1).

9.3.Llanvirnian Stage

Llanvirnian strata are present in both Ghadames and Murzuq sedimentary basins which have been identified by the palynological markers:

1. *Dicrodian rodium normale*.
2. *Striatotheca quieta*, *Velatachitina* sp.
3. *Conockitina symmetrica*.
4. *Multiplicisphaeridium rayii*.

Llanvirnian has been encountered in well A1-42 (Fig. 2), of interbedded sandstone and silty mudstone representing inner to outer neritic environment in wells A1-42, B2-34, and A1-8. An inner neritic environment (Fig. 2). Llanvirnian age strata represent or equivalents to the Lower Melez Chogran Formation in western Libya of both Ghadames and Murzuq sedimentary basins.

9.4.Llandelilian Stage

Llandelilian strata have been identified by the paleontological:

1. *Stelliferidium stiertulum*.
2. *Frankea sartbenardenese*.
3. *Gonionsphaeridium*.

Llandelilian strata consist of non-calcareous mudstone and fine to angular sandstone, deposited in a fully marine inner neritic environment. The strata is equivalent to this in the Melez Chogran Formation [42]. During Llandelilian time, the Ghadames and Murzuq sedimentary basins possibly tilted SE, and a gentle uplift formed in the area of well A1-42, where Llandelilian strata are absent (Fig. 2).

9.5.Caradocian Stage

Caradocian strata occur widespread throughout the study area. The age of this interval is based on the palynological marker of only *Orthosphaeridium ternatum*.

Caradocian strata consist mainly of sandstone and silty mudstone from a fully marine, outer neritic environment of deposition, with minor indications of terrestrial influxes in well A1-43. Strata with a Caradocian age are thought to be equivalent to the Melez Chogran Formation [42]. The reduced thickness of this interval suggests that it has been truncated by erosion. In places, a condensed section might be present. Caradocian strata have not been identified in well A1-42 in the NE portion of Ghadames basin area (Fig.1). This might suggest a sea-level change or local pre-Caradocian uplift.

10. Summary and Recommendations

The Ordovician sedimentary sequence is complicated due to the following:

The most complicated sedimentary sequence is the Ordovician in all sedimentary basins in North Africa to study and correlate faces because of its direct contact with basement heat where the original internal sedimentary structures altered, changed, and replaced as an indicator of a primary environment of deposition metamorphosed.

The number of tectonic events caused extensive rapped erosion, nondeposition and redeposition of short distance lateral and vertical extent reflects the complicated facies which is made it difficult to correlate different depositional units.

Ghadames and Murzuq region being positioned in the South Pole during Cambro-Ordovician time of glacier events influenced the nature of in situ deposition and abrupt local facies made it difficult to study the distribution of this important facies.

Farther age dating analysis and Cheo stratigraphic selected sections study with closer distance between key wells for all the most preserved complete Paleozoic sequences.

These strata have been grouped into the Ordovician sequence with a well-defined upper bounding unconformity but, the extent of the basal unconformity is known only from a few wells and from outcrops in the Al Qarqaf Arch region. The sequence is predominantly clastic.

Internal contact relationships between rock units are unclear. Biostratigraphy analyses, mainly palynological, although identifying the presence of many stages, did not reveal the full extent of those stages due to the low frequency of palynomorph occurrence. Ordovician sandstones have excellent reservoir characteristics and contain giant hydrocarbon accumulations in the Murzuq Basin, where the Tanezzuft Shales form both the sealing and petroleum source systems. A similar setting prevails in the study area.

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