



Tectono-History of the Silurian Sharawra Formation in Northwestern and Central Arabia

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ABSTRACT

The distribution of the Silurian shales of the Qusaiba Formation of Arabia was affected by pre-existing Late Ordovician paleo-highs and the Silurian sandstones of the Sharawra Formation were severely influenced by the syntectonic Acadian movements.

Detailed lithologic correlation and structural analyses of the Sharawra sections indicate that pronounced thinning of the formation eastward is due to tectonic influence rather than depositional. This thinning is attributed to Late-Silurian - Early Devonian tectonic movements. These movements are believed to be synchronous with the Acadian uplift phase of the Caledonian time, which have rejuvenated pre-Silurian paleo-highs and causing severe truncation of thick deposits of the Sharawra Formation prior to the deposition of the Late Silurian-Early Devonian? Tawil Formation.

Two main structural elements that affected the Sharawra Formation in central Arabia are represented by the north-south trending and northerly plunging Hail Arch and to a much lesser the northwest-southeast trending and southerly plunging Qusayba high.

Introduction

The present work aims to study the Early Silurian Sharawra Formation in northwestern and central Arabia to understand its tectonic setting and depositional history (Figure 1).



Fig. 1: Index map showing the location of the studied area in northwestern and central Arabian Peninsula.

The Tabuk and Widyan basins offer excellent outcrops to document the tectonic and depositional history of the Sharawra Formation (Figure 2).



Fig. 2: Distribution of the outcrops of the Lower Paleozoic rocks in northwestern and central Arabian Peninsula.

This paper is based on field investigation and literature review of published work.

The study area extends from Tabuk in the west to Qusayba in the east. The area covers Tabuk, Qalibah, Tayma, Baq'a and Buraydah quadrangles. This paper is based on the author's field work and geological data published by Janjou and others¹ (Tabuk quadrangle), Janjou and others² (Al Qalibah quadrangle), Vaslet and others³ (Tayma quadrangle), Janjou and others⁴ (Jabal Misma quadrangle), Bartlett and others⁵ (Hail quadrangle), Vaslet and others⁶ (Baq'a quadrangle), Manivit and others⁷ (Buraydah quadrangle), and Williams and others⁸ (Jabal Habashi quadrangle).

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Paleozoic rocks are exposed as a great curved belt parallel to the northern margin of the Arabian Shield. These rocks are best exposed in Tabuk and Widyan basins (Figure 2).

The Paleozoic succession is represented by Cambro-Ordovician Saq Formation; Ordovician Qasim Formation; Late Ordovician Zarqa/Sarah formations; Silurian Uqlah, Qusaiba, and Sharawra formations; Devonian Tawil, Jauf, and Jubah formations; Carboniferous-Permian? Shajara Formation, Late Permian Unayzah Formation, and Permian-Triassic Khuff Formation (Figure 3).

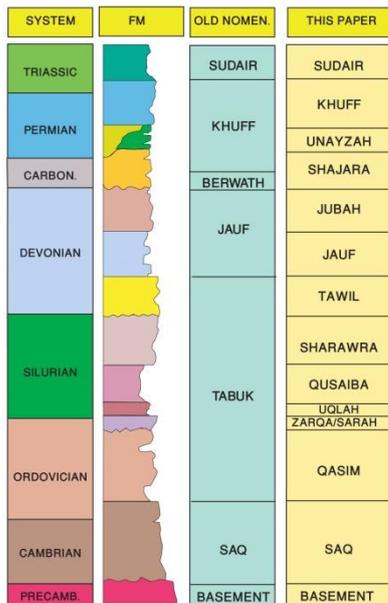


Fig. 3: Old terminology of the Ordovician-Silurian-Devonian succession of the Tabuk Formation (Powers and others, 1966) and Paleozoic lithostratigraphic units and nomenclature followed in this study.

Stratigraphic relationships of outcrop sections of the Sharawra Formation from Tabuk area to Qusayba area were studied to establish the tectonic influences on the Sharawra Formation.

The Silurian succession is represented by marine sandstones and shales of the Uqlah Formation, marine shales of the Qusaiba Formation, and deltaic micaceous siltstones and sandstones of the Sharawra Formation (Figures 3 and 4).

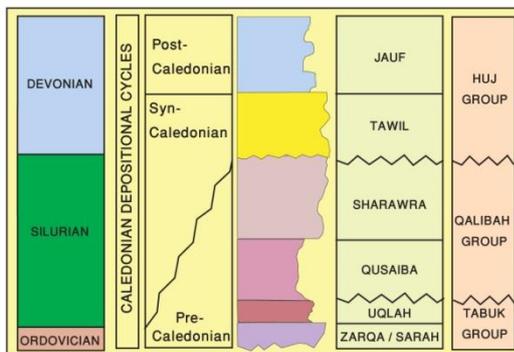


Fig. 4: Generalized subdivision of the Lower Paleozoic succession into mega depositional cycles as a result of the Late Silurian Acadian time –equivalent tectonic movements.

Previous Work:

The eastern part of the study area (Al-Qasim region) was mapped by Burchfiel and Hoover¹⁰ and Pocock and Koop¹¹. The western part (Tabuk region) was mapped by Bramkamp and others¹² (in Roach) (Aramco unpublished report, in Laboun²³). These and other early field works of Aramco geologists were summarized and published by Thralls and Hasson^{13,14}, Steineke and others¹⁵, Powers and others⁹, and Powers¹⁶. Series of geologic investigation maps were published by USGS and Aramco from 1956 to 1963. Paleontologic studies were published by Rickards and Koren¹⁷, El-Khayal^{18,19}, El-Khayal and Romano²⁰, and McClure²¹. Regional geologic works were carried out by Laboun²²⁻³¹, and Vaslet³²⁻³⁵. Detailed geologic mapping was carried out by Bureau de Recherches Geologiques et Minieres (BRGM) geologists. Mahmoud and others³⁶ mapped and discussed regional distribution of the Sharawra Formation in northern and central Arabia.

Definition and Description of the Silurian Rock:

Pocock and Kopp¹¹, were the first to measure and describe Lower Silurian rocks in central Arabia. About 45 meters were measured in a composite of three sections in a steep cliff west of the village of Qusayba, Al-Qasim (Aramco, unpublished report, in Laboun²³).

These rocks were named the "Qusaiba shale" and informally defined by Pocock and Kopp¹¹ as the upper member of the Lower Ordovician-Lower Silurian "middle Uyun Formation" (obsolete) of the "Uyun Group" (obsolete). The middle member is the "Er-Ra'an" and the lower member is "Hanadir".

Silurian rocks were also reported from Tabuk area in the northwest of Arabia, by Bramkamp and others¹². The field work in the Tabuk area was reported by Roach³⁷ (Aramco unpublished report, in Laboun²⁹), Bramkamp and others¹² (in Roach) replaced the term "middle Uyun Formation" (obsolete) of Pocock and Kopp¹¹ in central Arabia by a new term for the Lower Ordovician- Silurian rocks, the "Tabuk Formation" (obsolete) (Figure 3) which included the three members "Sharaura", Er-Ra'an", and "Hanadir" with two intervening unnamed sandstone units.

The term "Tabuk formation" (obsolete) was first appeared in a summary paper of the stratigraphy of Saudi Arabia by Thralls and Hasson^{13,14} for Ordovician and Silurian rocks. Six Paleozoic formations were shown in a table and a cross section published by Thralls and Hasson^{13,14}. Though the formations were not formally defined, a generalized lithology, thickness, and age were shown.

The measured and described section of the Tabuk Formation (obsolete) by Bramkamp and others¹² (in Roach), in Tabuk area was accepted and formally published by Steineke and others¹⁵ as the type section for the Ordovician-Silurian rocks of the formally defined the Tabuk Formation (obsolete). Steineke and others¹⁵ discarded the terms "Sharaura", "Qusaiba", Er-Ra'an", and "Hanadir".

Helal³⁸ amended the formally defined Tabuk Formation (obsolete) by confining it to the Ordovician rocks and introduced and formally defined the term "Sharawra Formation" for the Silurian rocks. Powers and others⁹ included the Devonian Tawil Sandstone as the upper member of the Tabuk Formation (obsolete) and divided the formation as measured and described by Bramkamp and others¹² (in Roach and in Powers and others⁹), into seven lithologic units they retained only the basal unit, Han, "Sharaura adir member and discarded the other units", "Qusaiba", and Er-Ra'an" members.

Sharawra Reinstated:

The term "Sharaura" was introduced by Pocock and Kopp¹¹ for a member in the middle Uyun Formation (obsolete). This member and other members of the formation were discarded by Steineke and others¹⁵ when they formally defined the Tabuk Formation and by Powers and others⁹ and Powers¹⁶ when they redefined this formation.

The term "Sharawra" as spelt and published by Helal³⁸ was used and reinstated as a member of the Tabuk Formation by Laboun^{22,23}. The other members of the Tabuk Formation (obsolete) Ra'an and Qusaiba were used and reinstated by Laboun^{22,23} as well. This practice was accepted and the terms Ra'an, Qusaiba, and Sharawra were used by geologists and appeared on the geologic maps.

Tabuk Formation Discarded:

Since the formal definition of the Tabuk Formation (obsolete) by Steineke and others¹⁵ the formation was used, amended, and redefined formally and informally by many geologists; Layne and Reese³⁹, Bramkamp and others⁴⁰⁻⁴¹, Brown and others⁴², Helal³⁸, Powers and others⁹, McClure⁴³, Clark-Lowes⁴⁴, Laboun^{22,23}, and Lozej⁴⁵. The Tabuk Formation (obsolete) was raised to a group rank "Tabuk Group" by El-Khayal and Romano²⁰ and Janjou and others¹.

The recognition of regional unconformities within the Tabuk Formation (obsolete) by McClure⁴³, Clark-Lowes⁴⁴, Laboun^{22,23}, Vaslet³² and others resulted in revising the lithostratigraphic nomenclature of the Lower Paleozoic where the term "Tabuk Formation" (obsolete) was discarded and new formations were introduced as shown in Figure 3.

New Formations Introduced:

The BRGM geologists substituted the term "Tabuk Formation" by seven formations: the Qasim Formation (Ordovician)⁶, Zarqa Formation (Ordovician)⁶, Sarah Formation (Ordovician- Silurian)⁸, Uqlah Formation (Silurian)¹, Qusaiba Formation (Silurian)², and Sharawra Formation (Silurian)², and Tawil Formation (?Silurian-Devonian)² (Figure 3). The term "Tayyarat Formation" was first appeared in the publication by Le Strat and others⁴⁶ but it was originally proposed by Vaslet and others⁶ to include the Qusaiba and Sharawra members in the Baq'a quadrangle. Since the term "Tayyarat" was already used by Dunnington and others⁴⁷ for a Cretaceous formation in south Iraq, the

term "Tayyarat Formation" was discarded by Mahmoud and others³⁶ and it was replaced by the term "Qalibah Formation".

Tabuk and Qalibah Groups:

The term Tabuk was reintroduced by Janjou and others² as a group "Tabuk Group" to include "all the deposits assigned to the glacial episode that affected the continent of Gondwana during the Late Ordovician". It means that this group includes the Zarqa, Sarah, and Uqlah Formations.

Janjou and others² raised the Qalibah Formation of Mahmoud and others³⁶ to a group status "Qalibah Group" and raised the Qusaiba and Sharawra to formation ranks (Figure 3).

Geologic Setting:

Stratigraphy:

Lower Paleozoic rocks are well exposed in the studied area from Tabuk to Buraydah (Figure 2). The Cambrian to Early Ordovician? Sandstones and siltstones of the Saq Formation (Risha, Sajir, and Hilwan members) rests non-conformably on the Proterozoic rocks of the Arabian Shield. The Ordovician shales and sandstones of the Qasim Formation (Hanadir shale, Kahfah sandstone, Ra'an shale, and Quwarah sandstone members) rests conformably on the Saq Formation. The Late Ordovician to Early Silurian? glacial and peri-glacial sediments are represented by the Zarqa, Sarah (Hawban shale member), and Uqlah formations. These glacial deposits fill in paleo-valleys unconformably incised in the members of Saq and Qasim formations. The Early Silurian shales and sandstones are represented by the Qusaiba and Sharawra formations, respectively. The Sharawra Formation is unconformably overlain by the Late Silurian? to Early Devonian sandstones of the Tawil Formation (Figure 3).

The Early and Middle Devonian shales, limestones and sandstones are represented by the Jauf Formation (Sha'iba, Qasr, Subbat, Hammamiyat, and Murayr members) and Jubah Formation. These rocks are exposed in a window in the Jawf area in the north (Figure 3).

The Carboniferous Shajara Formation includes the Berwath Formation of Hermer and Owens (1968) which was defined from Well ST-8 that drilled at Wadi Aba Arawath south of Ara'r town, northern Arabia.

The Shajara Formation is best exposed at its type locality at the Wadi Ash-Shajara in the Qusayba depression and in a narrow strip from Niqrat Ablaq and Ash-Shiqqah, north of Buraydah, to Wadi Ar-Rayn in the south. The Shajara Formation rests unconformably on all older units from the Carboniferous to the Precambrian. This Sub-Shajara unconformity represents the influence of the Hercynian tectonic movements.

The Permian rocks are represented by the Unayzah Formation (Shiqqah and Safra members) is best exposed at the base of the Khuff carbonates escarpment. The Late Permian is represented by the Khuff (Huqayl, Duhasan, and Midhnab members, - Triassic: Khartam

member) Formation (Figure 3). The Permo-Carboniferous rocks (Shajara, Unayzah, and Khuff Formations) are exposed in the Widyan Basin, east of the Hail arch.

Acadian Tectonic Movements:

Following the Late Ordovician Taconic movements and glaciation periods, thick Early Silurian shales of the Qusaiba Formation were deposited. During Late Silurian the region went through another series of gentle movements contemporaneous with the Acadian tectonic phase of the Caledonian orogeny (Laboun, in press). The early phase of this movement may have started after the deposition of the Sharawra Formation. This movement reached its maximum phase prior to the deposition of the Tawil Formation. The influence of the Acadian movement is evidenced by severe truncation of the Sharawra, Qusaiba, Uqlah formations and Hawban Member of the Sarah Formation. In the northern part of the Qusayba depression, the Tawil Formation rests unconformably on the Sarah Formation.

The influence of the Acadian and glaciation events were used by Laboun to subdivide the succession into pre-Acadian (Qusaiba and Sharawra formations), syn-Acadian (Tawil Formation), and post-Acadian (Jauf Formation) (Figure 4).

Pre-Acadian Stratigraphy:

The following is a brief review of pre-Acadian lithostratigraphic units:

Qusaiba Formation:

Lithology: marine shale and minor shallow marine siltstone.

Age: Early Silurian

Underlying contact: disconformable with underlying Sarah Formation or has a sharp contact with the marine flooding surface with Uqlah Formation.

Sharawra Formation:

Lithology: shallow marine shale and deltaic sandstone siltstone and minor shale.

Age: Early Silurian

Underlying contact: disconformable with the underlying Qusaiba Formation.

Overlying contact: Unconformable with overlying Tawil Formation.

Tawil Formation:

Lithology: braided fluvial and shallow marine sandstone siltstone.

Age: Early Devonian

Underlying contact: unconformable with various older units; Sharawra, Qusaiba, and Sarah formations.

The Tawil Formation was divided by Janjou and others¹ into four members. The members, from base to top, are; the Samra, Ghumar, Tufayhah, and Juraniyat members.

Structure of Tabuk and Widyan Basins:

Tabuk basin is bounded to the west by the Red Sea escarpment and to the east by the northerly-plunging. The Paleozoic rocks form part of a large homocline

structure trending north-northeast with a dip of about one degree. The basin is interrupted by a system of primary fractures oriented parallel to the axis of the Red Sea and by secondary fractures that strike northeast and north-south. Fayha graben and Tabuk graben are the main structural elements in the Tabuk basin^{1,2,4}.

Paleozoic rocks in the Widyan basin to the east of the Hail Arch form a homocline structure that strikes N50W and dipping about 1-2 degrees to the northeast in the Baq'a quadrangle⁶. It strikes also N35W in Jabal Habashi and Buraydah quadrangles and dipping about 1 degree to the northeast^{7,8}.

Sharawra Formation:

Tabuk Basin:

The Silurian succession exposed in the Tabuk basin is represented by Uqlah, Qusaiba, Sharawra, and the lower part of the Tawil formations. This succession in the Tabuk and Qalibah quadrangles were studied and mapped by Janjou and others^{1,2}.

Measured sections of the Sharawra Formation by Janjou and others^{1,2} are the following; at its reference section in Tabuk quadrangle, between Jabal Mukayhil and Tal Az Zufayyir (base lat. 28 14 47 N, long 37 15 55 E, top lat. 28 24 42 N, long. 37 16 42 E) and at its type section at Al Qalibah quadrangle, Ad Dahkiyah area (base lat. 28 02 18 N, long. 37 59 26 E, top lat. 28 11 51 N, long. 38 00 E. Vaslet and others⁶ measured a section at Baq'a quadrangle near Khashm Tayyarat (lat.27 44 35 N, long. 42 41 11 E). The present author measured the Sharawra Formation at Qusayba escarpment in the Buraydah quadrangle. These measured sections were used in this study (Figure 5).

The Sharawra Formation rests disconformably on the Qusaiba Formation. The upper contact with overlying Tawil Formation is marked by an erosion surface. The formation was subdivided by Janjou and others¹ into four members. The members from base to top are: the Jarish, Khanafriyah, Nayyal, and Zubliyat members. The age of the Sharawra Formation was considered to be Llandoveryian to Wenlockian (Early to Late Silurian)¹.

Sharawra Thickness Changes:

The Sharawra Formation, in the Tabuk and Widyan Basins is disconformably overlain by the Tawil Formation. It is mainly composed of micaceous siltstone, claystone, and fine-grained sandstone.

The Sharawra Formation in Tabuk quadrangle shows a pronounced reduction in thickness eastward (Figure 5), as described in the following:

A-Tabuk basin:

The Sharawra Formation is 510 meters thick in its reference section between Tal Az Zufayyir and Jibal Al Midafi (base at lat. 28 28 00 N, long. 37 16 42 E, top at lat. 28 51 18 N, long. 37 06 12 E) in the Tabuk quadrangle. It is 422 meters thick in the Zubliyat area (base at lat 28 31 18 N., long 37 56 18 E.) in the Qalibah quadrangle (Figure 5).

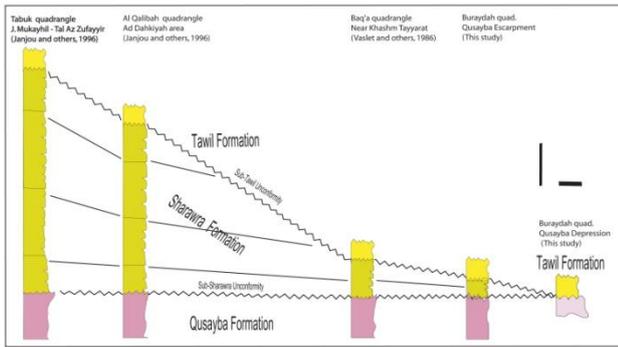


Fig. 5: Stratigraphic cross section of the Sharawra Formation from Tabuk area to Qusayba depression showing the influence of the sub-Tawil unconformity in western and central Arabia. Top of the Qusaiba shale is used as a datum for the section.

B- Nafud basin:

Eastward, the Sharawra Formation in the An Nafud, and Jubbah quadrangles is covered by eolian sands and it is missing on the Hail quadrangle (Hail arch) (Figure 2).

C- Widyan Basin:

Baq'a-Buraydah Quadrangle:

The Sharawra Formation is exposed in the Baq'a and Buraydah quadrangles to the east of the Hail arch. The Sharawra Formation is 89 meters thick near Khashm Tayyarat at lat. 27 44 35 N, long. 42 41 11 E, in the Baq'a quadrangle and 42 meters thick at Qusayba escarpment at lat. 26 51 08 N, long. 43 34 48 E in the Buraydah quadrangle (Figure 5).

Baq'a-Qusaiba Paleo-high:

The Sharawra Formation shows a pronounced thinning in the Baq'a-Qusayba area. It is entirely missing in the northern part of the Qusayba depression where the Early Devonian Tawil Formation rests unconformably on the Late Ordovician Sarah Formation (Figure 6).

At the present time the Hail arch separates the well exposed Silurian successions in the Tabuk basin, to the west, from the reduced of King Saud University Widyan basin, to the east. So it is considered that the Baq'a-Qusayba area is a Late Ordovician paleo-high (Figure 7).

On the Hail arch the Saq Formation is non-conformably overlies Precambrian Basement. The Saq was unconformably overlain by discontinuous paleo-valley deposits of the glacial Zarqa/Sarah Formations.

Results and Conclusions:

- 1- The Sharawra Formation shows a pronounced reduction in thickness eastward from Tabuk to Qusayba.
- 2- The Sharawra, Qusaiba, Uqlah formations and the Hawban Member of the Sarah Formation are missing in the northern part of the Qusayba depression.
- 3- The Devonian Tawil Formation rests unconformably on the Late Ordovician Sarah Formation at the Qusayba depression.
- 4- This truncation is probably caused by the Acadian uplift phase of the Caledonian time-equivalent movements.
- 5- These movements took place during Late Silurian-Early Devonian and successively eroded the Sharawra Formation and older units.

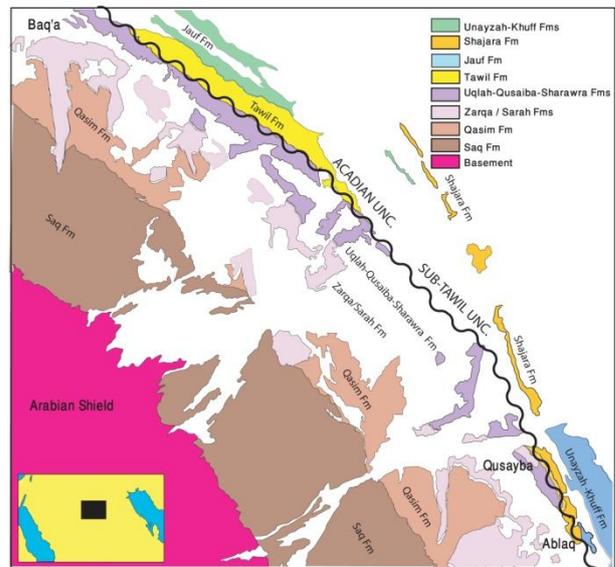


Fig. 6: Detailed geologic map from Baq'a area to Qusayba depression shows the influence of the Acadian tectonic movements (sub-Tawil unconformity) prior to the deposition of the Early Devonian Tawil Formation.

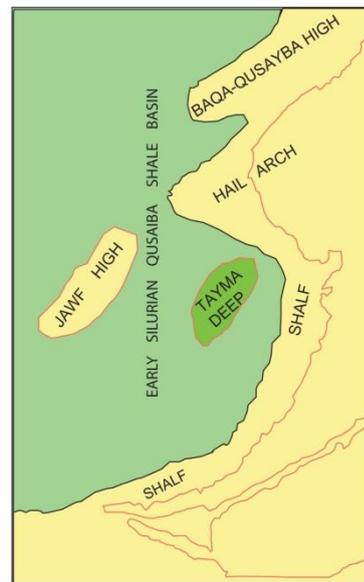


Fig. 7: Generalized distribution of the pre-Silurian, Late Ordovician paleo-highs. Note the Jawf, Hail, and Baq'a-Qusaiba highs.

6- The Early Devonian Tawil Formation rests unconformably on the Late Ordovician Sarah Formation in the Qusayba depression.

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