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Investigation and Evaluation of Reservoir Quality of the Upper Cretaceous Rocks (Belqa Group) in North Jordan (NW Irbid)

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Abstract

Upper Cretaceous rocks are widespread in Jordan, covering uncomfortably the rocks of the Lower Cretaceous (Kurnub Sandstone). These rocks consist mainly of limestone, marls, chalk, biogenic chert and phosphate of primarily marine origin. Age determination of these rocks was based on the abundance of macro and microfossil content. Man researchers subdivided the Upper Cretaceous succession. The classification of Powell (1989) is considered in this study, particularly for the Belqa Group, which is of Coniacian to Maastrichtian in age. This investigation will focus on the geology of Wadi Es Sir, Umm Ghudran; Amman silicified limestone, and Al Hisa phosphorite formations, that belong to Ajlun and Belqa Groups respectively. Moreover, sedimentary structures, lithological characteristics Microfacies types and fossil content were evaluated. Using the lithostratigraphy and the fossil content of those formations, 6 Microfacies types were identified. Evaluation of the cross-section, the tectonic processes and the prepared rose diagrams indicate that the study area was affected by compressional as well as by tensional forces. Two major tends of fracturing can be identified in the rose diagrams. The measured physical properties show that the porosity is variable and ranges between 30% and 48%. The bulk density has values between 1.8 and 2.2 g/cm^3. The different obtained results point out that the studied rocks represent good reservoir.

Keywords

Investigation, Belqa Group, Cretaceous, Amman Silicified limestone, Umm Ghudran

1. Introduction

Location of the Study Area

The Study Area is located Northwest of Irbid city. It covers about 10 km^2, and is situated between 323,433 and 32,3415 North and 354,651 & 354,915 East (**Figure 1**).

Upper Cretaceous carbonate rocks crop throughout most of Jordan overlying sediments of the lower Cretaceous Kurnub Sandstone Group. They are generally composed of limestone, marls, chalk, biogenic chert and phosphate of mainly marine origin.

The age determination of these rocks is based on the abundance of the macro and microfossil content [1] [2].

There are different Lithostratigraphy subdivisions. The subdivisions of [1] are currently considered in this study, particularly Ajlun Group (Cenomanian-Turonian in age), and the lower part of the Belqa Group (Coniacian-Maastrichtian). This

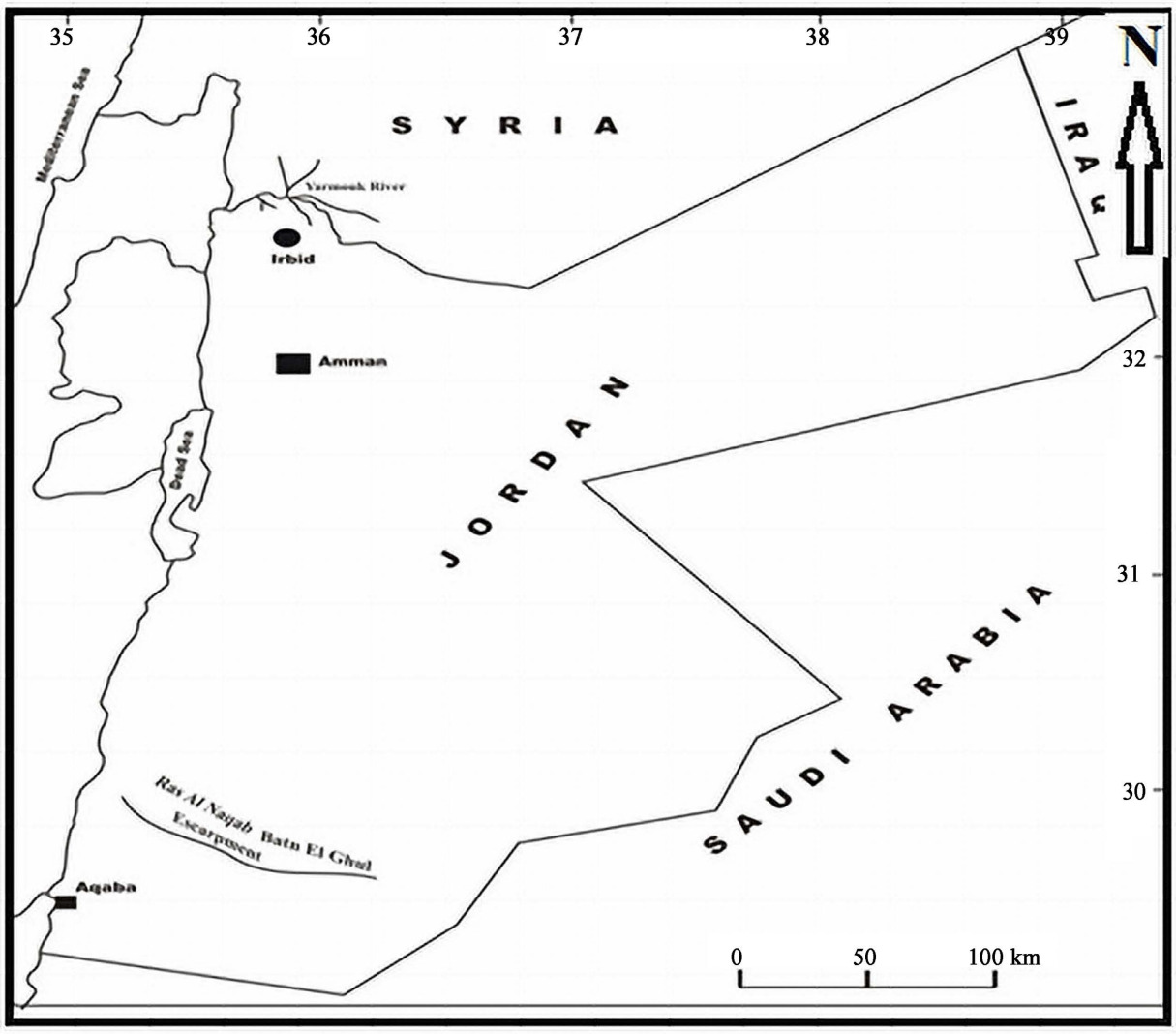

Figure 1. Location map of the study area situated between 323,270 E and 353,560 N.

investigation will focus on the geology of Wadi Es Sir, Umm Ghudran; Amman silicified limestone, and Al Hisa phosphorite formations that belong to Ajlun and Belqa Groups respectively. Microfacies and chemical analysis will be carried out on the carbonate rocks of those formations. In addition to that, the lithological characteristics, sedimentary structures fossil content will be evaluated.

The Late Cretaceous sediments of Wadi Es Sir, Umm Ghudran f Amman silicified Limestone und Al Hisa phosphorite formations in the study area (North West Irbid) were studied by [3]. They reported that during the deposition of Wadi Es Sir Formation, the shelf morphology in northern Jordan was fairly uniform, and the climatic was warm. As the Sea level recessed, lagoons, rudest banks and oyster flats were formed.

With begin of deposition of Umm Ghudran Formation in the Coniacian time, colder and more nutrients-rich conditions prevailed resulting in the deposition of sediments, composed mainly of planktonic organisms. However, Oyster-rich beds at the base of Amman Formation indicate the return of very shallow and coastal conditions during early Campanian time. Nutrient-rich upwelling water of the Tethys Ocean resulted in the deposition of predominantly carbonate sediment rich in organic material [4].

During early diagenesis fecal pellets consisting of phosphatic grains were buried and transformed into chert [3] [5] [6].

On its top, the A7/B2 aquifer is hydraulically separated from the locally productive B4 aquifer by the Muwaqqar aquitard (B3). The transmissivity of the (B2/A7) aquifer ranges from 9 m^2/day to more than 900 m^2/day. The storage coefficient of this aquifer in the confined condition varies from 10^{-3} to 10^{-5}, while the specific capacity varies from less than 0.01 L/s/m to more than 50 L/s/m and the permeability ranges from 0.01 to more than 100 md. [7] [8].

Variable thickness and lithological consistence within the Formation reflect some structural unrest in the north Jordanian shelf during the time of depositions. As the sea recessed toward the top of the Amman Formation, tidal flats were common, erosion prevailed, and phosphatic sand beds of the Al Hisa Formation was deposited. During Late Campanian time open marine conditions were reestablished, and the Muwaqqar Formation began to form predominantly in Maastrichtian time, where the scarcity of the formation of phosphatic grains within the sediments biogenic silica, hampered. By comparison with the Upper Cretaceous oysters of Northwest Europe [9] who recognized two major oyster-facies, a shallow carbonate platform facies form in Cenomanian-Turonian. The platform-carbonate, consist mainly of limestone, marly limestone, marls and dolomites and minor tongues of silicates sediments marking a series of transgression periods during the deposition of the Ajlun Group.

The objective of this study attempted to carry detailed sedimentological investigation on the exposed surface rocks of the Belqa Group northwest of Irbid.

The Microfacies studies of the carbonate rocks of the Belqa Group were carried out to achieve information about the depositional environment of those

formations. In additions to that lithological characteristics sedimentary structures and their fossil content were evaluated.

Petrophysical evaluation and reservoir quality of Ilam formation (Late Cretaceous), Ahvaz Oil field, dezful bayment, SW Iran [10].

Reservoir Quality of Upper Jurassic Corallian Sandstones, Weald Basin, UK. [11].

The measurement of porosity and bulk density has given that the porosity is with variable values and ranges between 30% and 48%. Higher porosities can be related to the presence of fractures and or to dissolution of some soluble material within these rocks. Obtained bulk densities range between 1.8 and 2.2 g/cm^3. Higher values characterize the low porous rocks.

Both bulk density and porosity values show that the ability to store liquids in the studied formations is described to be medium.

2. Methodology

2.1. Field Work

The geological investigations were focused on collection of data used in:

1) Drawing cross section of the different specified locations in the study area.

2) Describing lithology and sedimentological structures of the outcropping formations in the study area.

3) Collecting of oriente rock samples, throughout the studied columnar section, with consideration on the changing in lithology.

4) The collected samples were used for Microfacies studies.

2.2. Laboratory Work

Preparing of thin sections for Microfacies studies.

1) Study of thin sections.

2) Representation of measured structural elements.

3) Determination of the porosity.

4) Determination of the bulk density.

3. Results and Discussion

The Ajlun Group is probably Cenomanian to Turonian in age (**Figure 2** shows the age of formation in Wadi Al Ghafar site). It consists of alternating beds of indurated marl, marly limestone, dolomitic limestone and dolomite. According to [2], the stratigraphic boundaries of the undifferentiated Na'ur, Fuheis, Hummer, Shuaib and Wadi As Sir Formation of the Ajlun Group, was defined according to changes in lithology in outcrop and boreholes.

The Belqa Group is probably of Upper Cretaceous (Coniacian) to Tertiary (Upper Eocene) in age [12]. According to [2] this group is subdivided into six formations four of which are within the Cretaceous period.

1) Wadi Es Sir Formation crops throughout most of Jordan and represents the topmost formation of Ajlun Group, which is disconformably overlain by the

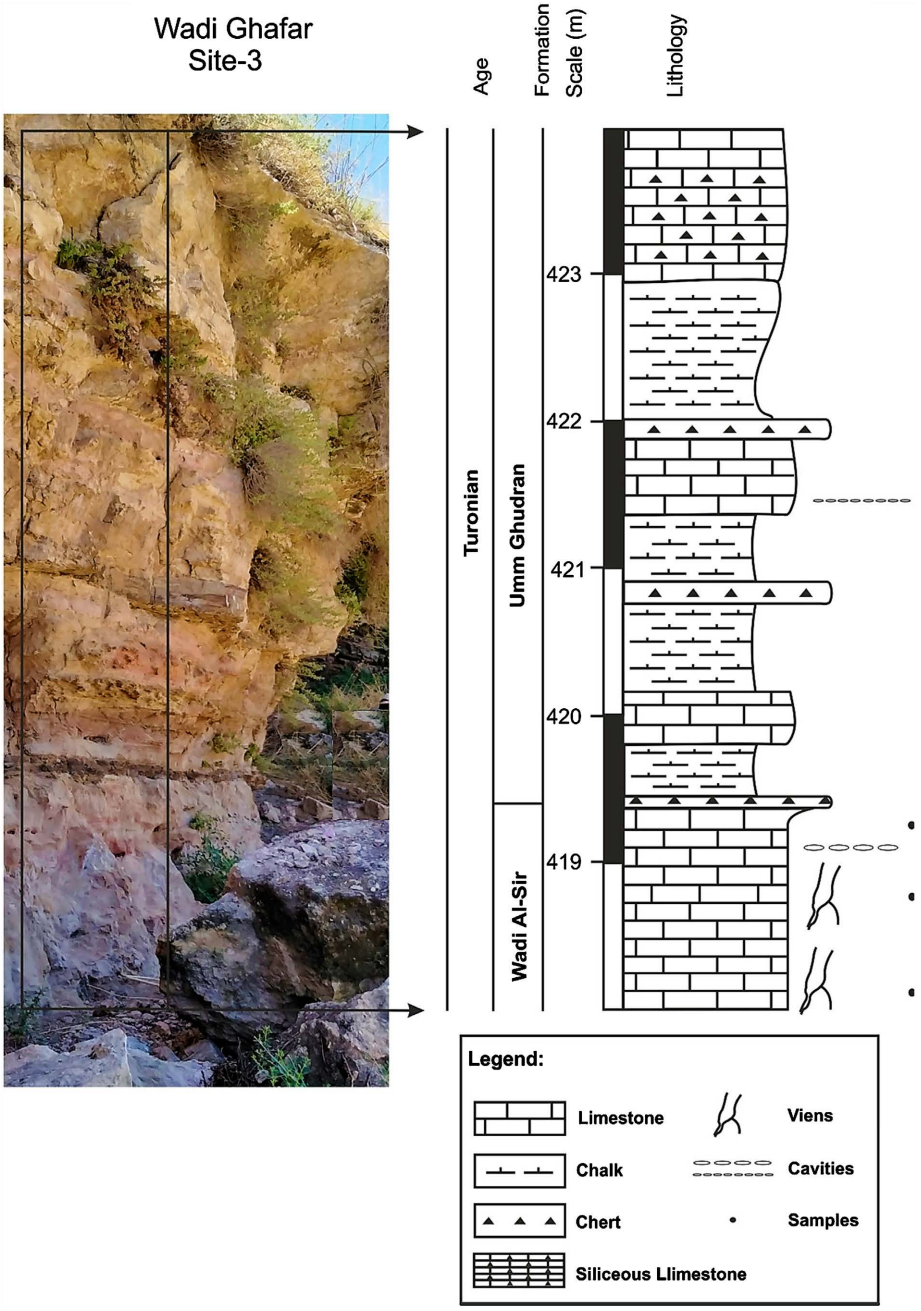

Figure 2. Columnar section of the exposed rocks of the Belqa Group in Wadi Al Ghafar area North West Irbid.

white chalks of the Belqa Group. It is distributed along the Rift escarpment from north to south Jordan [2].

This formation consists of well-bedded massive limestone, dolomitic limestone and dolomites with some nodules of chert. According to its Foraminifera and Ammonites contents, the formation is assigned to Turonian to Coniacian age [13].

2) Um Ghudran Formation

In the study area this formation consists predominately of intercalations of

white, fossiliferous, bioturbated marly chalk, marly limestone and marl with thin layers of chert. The lithology changes from platform sediments to carbonate mud providing a suitable environment for a rich benthic fauna.

3) Amman Silicified Limestone Formation

The Amman Silicified Limestone Formation can be traced from North to South Jordan due to its distinctive lithology its medium to thick-bedded grey, brown or white chert and grey microcrystalline limestone, which are intercalated with thin layers of chalky marl and chalk with medium bedded, locally cross-stratified oyster-coquina grainstone [3].

Amman silicified limestone Formation is distinguished and characterized by the abundance of chert beds, nodules of chert and limestone. Evidence of shallow marine origin of a (Monterey Formation Type) chert-phosphorite-dolomite sequence: Amman Formation (late cretaceous), central Jordan Facies [14]. It is broadly distributed and consists mainly of chert and siliceous sediments, as well as carbonates (limestone, chalk) and phosphorite. According to [15] the total thickness of this formation ranges from 100 - 120 meter consisting of yellow to grey, soft to medium hard to hard, fossiliferous limestone and creamy to yellow marl and chalk beds, which are inter-bedded with medium to thick brown to very dark brown chert layers and phosphorite beds epically at the upper part of this formation.

Variable thicknesses and lithological consistence within the formation reflects some structural unrest in the north Jordanian shelf during the time of deposition.

As the sea recessed toward the top of the Amman Silicified Limestone Formation, tidal flats were common, erosion prevailed, and phosphatic sand bed of Al Hisa formation was deposited. During late Campanian time open marine conditions were reestablished, and the Muwaqqar Formation began to form predominantly in Maastrichtian time, where the scarcity of the formation of phosphatic grains within the sediments biogenic silica, vulnerable. The platform carbonate, consist mainly of limestone, marly limestone marls and dolomite and minor deposits of siliciclastic sediments marking a series of transgression periods during the deposition of Ajlun group & the oyster-coquina grainstone and oyster bioherm facies with thick bed of large scale oyster-coquina grainstone, large scale cross-stratified oyster-banks and large oyster-bioherm up to 30 m thick were formed [3].

4) Al Hisa phosphorite

The Late Campanian to probably early Maastrichtian Al Hisa Phosphorite formation consist mainly of Phosphorite beds with intercalations of marl, chalky marl, limestone, chert and oyster-coquina layers and can be easily distinguished from the underlying Amman Silicified Limestone Formation, which is generally composed of hard, massive chert and silicified limestone beds. The Phosphorite formation occurs in the Upper Cretaceous-Maastrichtian rocks [16]. Burdon, Handbook of the geology of Jordan to accompany and explain the three sheets of

the 1:250,000 Geological Map East of the Rift by [17]. The upward gradually disappearance of chert and phosphate beds, mark the start of Muwaqqar Formation. The Al Hisa Phosphorite Formation in north Jordan was deposited in a very shallow marine environment with strong agitation, primarily shallow intertidal and subtidal fluctuation zone. New Insights for Understanding the Structural Deformation Style of the Strike-Slip Regime along the Wadi Shueib and Amman-Hallabat Structures in Jordan Based on Remote Sensing Data Analysis [18].

4. Results of the Structural Measurements

Rectangular and 60˚/120˚ system is the most common in the three sites caused by tension and shear forces respectively. **Figure 3** shows the Columnar section of the exposed rocks of the Belqa Group in the study area Northwest Irbid. Three rose diagrams were obtained from 120 measurements from each site as it is shown in **Figures 4-6**. These figures show that there are two major trends of fractures in the area. **Figure 7** is diagram showing the main joints trends in Wadi al Ghafar (NNE-SSW) site.

Reservoirs of the Balqa Group

Um Ghudran, Amman Silicified limestone Formations and Al Hisa phosphorite are the main formations exposed in the study area. However, these formations are not saturated with fluids in the study area, but they are overlying Wadi Es Sir Formation, which is considered to be the main aquifer in north Jordan. Um Ghudran and Amman Silicified limestone Formations are highly fractured, brecciaed, and contain dissolution cavities which made them prospective for groundwater recharge.

5. Conclusions

The thickness of Amman Formation in north Jordan increases in thickness toward N and NW of Jordan.

- Microfacies studies carried out on the gathered samples from the outcrops of the Amman Silicified Limestone Formation exposed in the study area resulted in the recognition of six Microfacies types:
  - Bioclastic-Foraminiferal-Packestone.
  - Echinodermal-Bioclastic-Peloidal Wackestones to Packestone.
  - Ostracodal-Echinodermal-Bioclastic phosphatized-floatstone.
  - Bioclastic-Gastropod-foraminiferal-floatstone.
  - Foraminiferal-Gastropod-Peloidal-Skeletal Phosphatized Rudstone.
  - Brecciaed nodular chert showing chert matrix.

The Microfacies of the Amman Silicified Limestone Formation are formed generally in shallow marine environment indicating more open marine conditions or in open platforms, bays and open lagoons. The presence of peloides, infraclasses, foraminifera, gastropods and Ostacoda supports this suggestion.

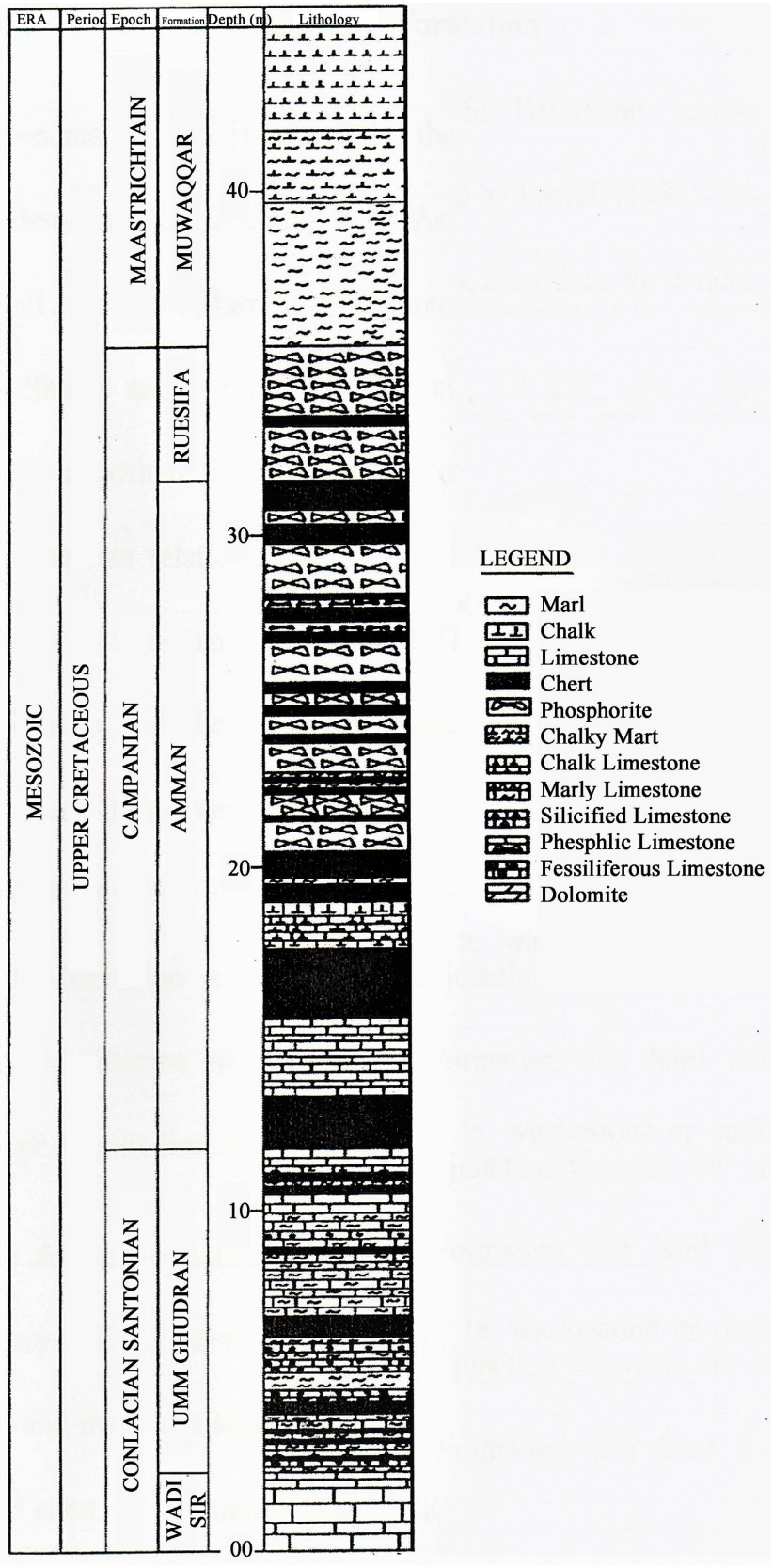

Figure 3. Columnar section of the exposed rocks of the Belqa Group in the study area Northwest Irbid.

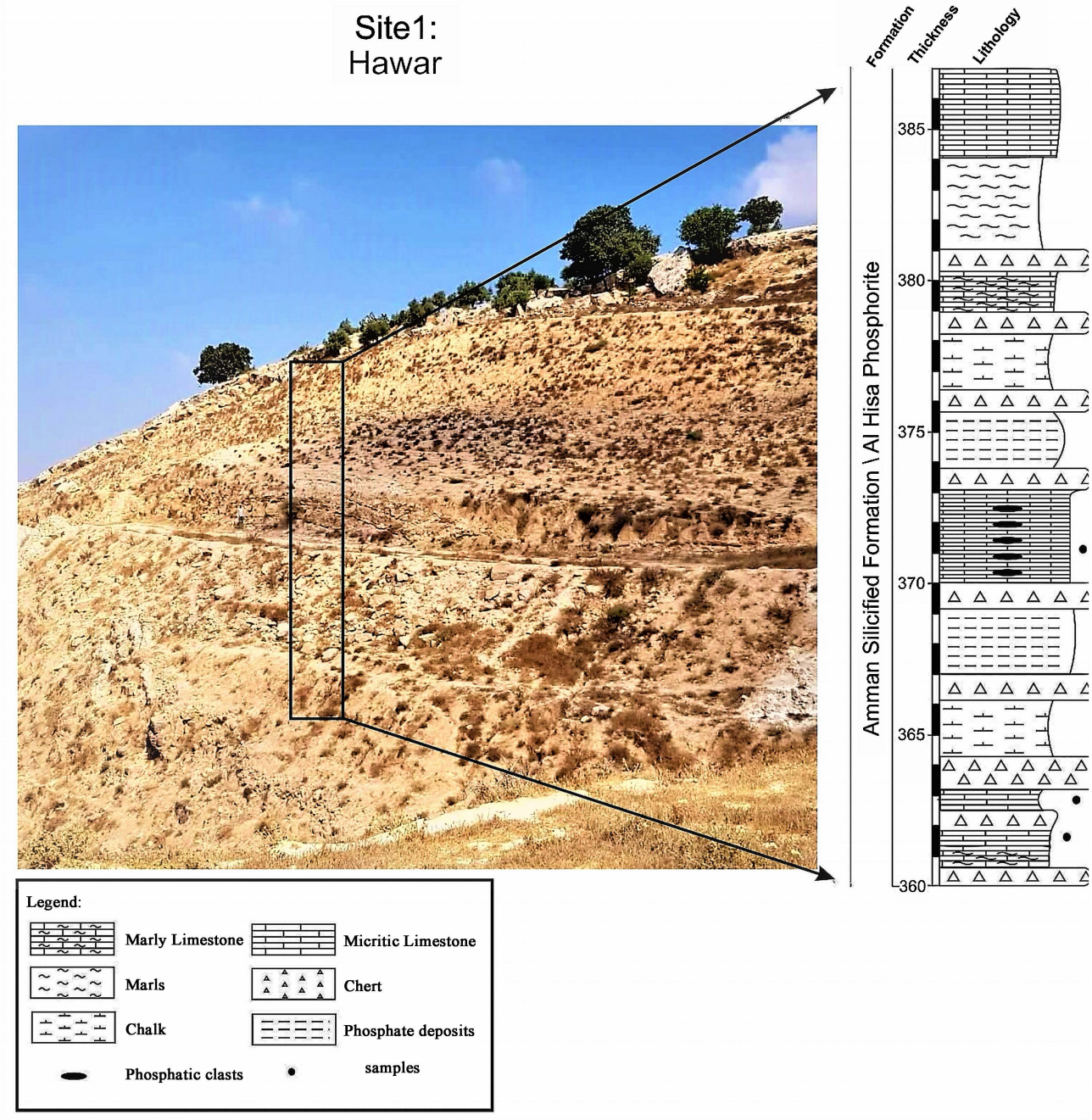

Figure 4. Columnar sections of the exposed Belqa Group in Wadi Al Ghafar area Northwest Irbid.

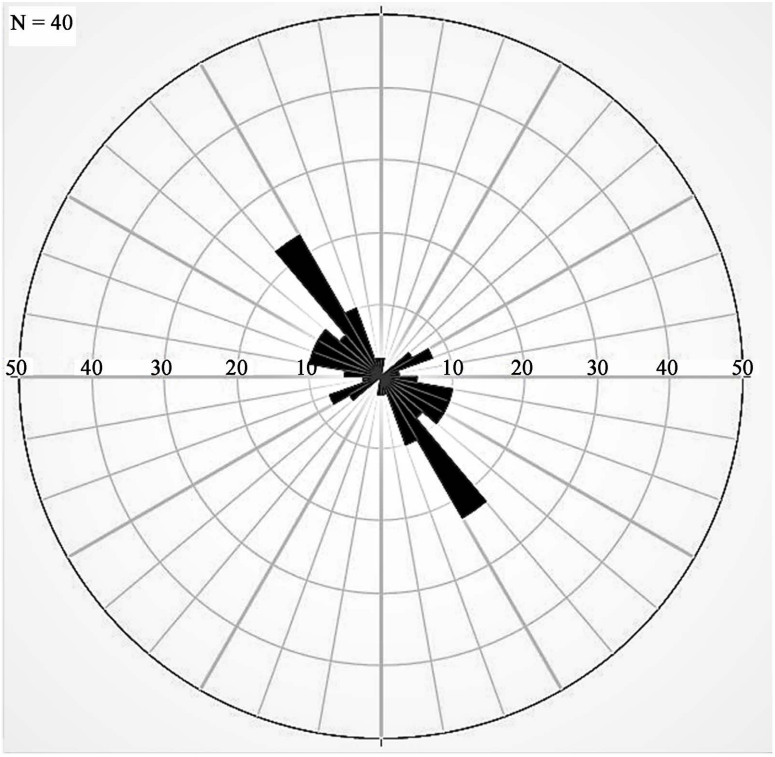

Figure 5. Rose diagram showing the main joints trends in Wadi al Ghafar (site 1 (ENE-WSW)).

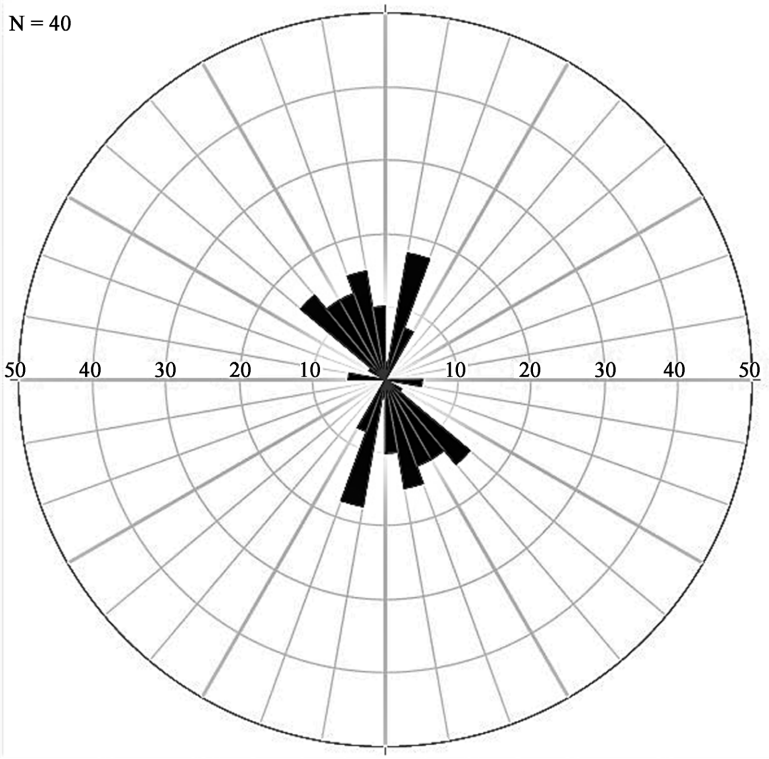

Figure 6. Rose diagram showing the main joints trends in Wadi al Ghafar (NNE-SSW) site 2.

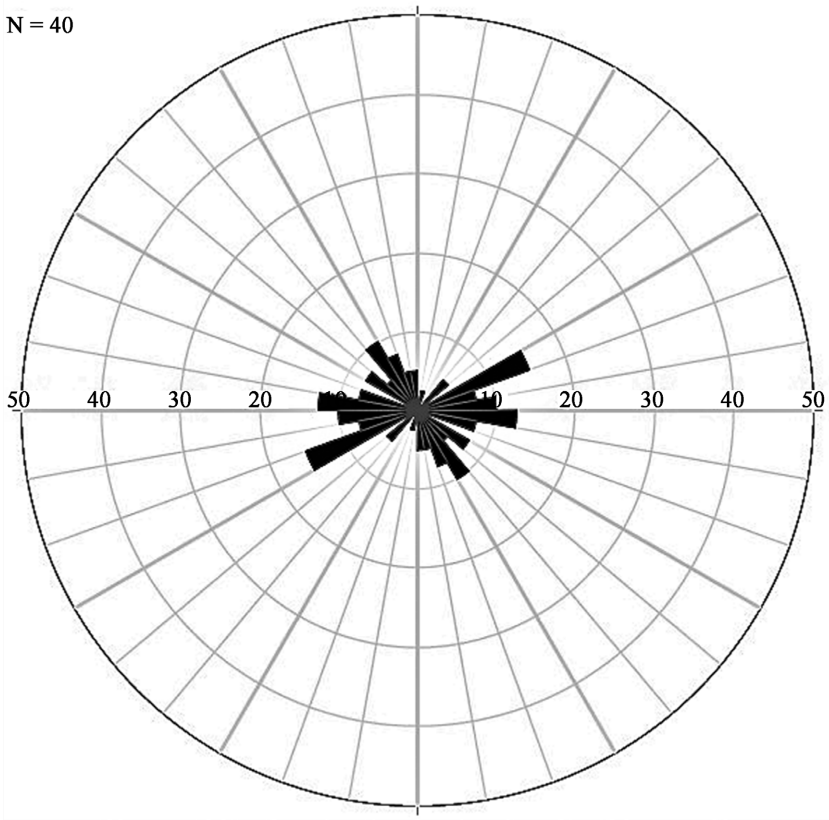

Figure 7. Rose diagram showing the main joints trends in Wadi al Ghafar (NNE-SSW) site 3.

- Amman Silicified Limestone Formation is characterized by high porosity (mainly secondary porosity) and permeability values due to fracturing, leaching and diagenetic processes.
- The evaluation of the Rose diagram indicates two major prevailing joint sets trending approximately (NNW-SSE, ENE-WSW). Other minor sets occur and might reflect local variation in tectonic setting.
- Compression and tension stresses occur in the study area resulting from Folding, Faulting (normal and reverse), fracturing and horst and grabens.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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