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SEDIMENTOLOGICAL ANALYSIS OF THE MAIN FACIES' ASSOCIATION OF THE KABAW FORMATION, NW LIBY

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Abstract— **The Early Cretaceous Kabaw Formation exposed in western Jabal Nafusah NW Libya, extends along the escarpment from eastern Jadu to Tunisia, it is unconformably overlies the Shakshuk Formation, and is unconformably overlain by Kiklah Formation, this study dealing with sedimentological analysis of the outcrops of the Formation in western Jabal Nafusah.**

The Kabaw Formation Neocomian (Early Cretaceous) comprises essentially sandstone locally containing thin horizon rich in vertebrate fossils, in this study the vertebrate fauna provides new stratigraphical evidence, they strongly support a Neocomian age for the Kabaw Formation.

The sand grains of the Kabaw Formation show several mechanical patterns similar to those observed on sand grains from the Kiklah and Chameau Mort Formations; this may indicate a mixed continental environment where alluvial and Aeolian conditions alternated.

The Kabaw Formation consists of yellowish-gray, friable, fine to medium grained, cross-bedded sandstones, the sediments consist a silicified wood fragment, fish teeth, turtle shells and crocodile teeth were.Owing to the lack of a detailed study of facies associations and depositional environments for Kabaw formation in the past, so i studied formation detailed study.

After a detailed description of sedimentary rocks for Kabaw Formation in my study area, it description on the basis of variations in the grain size, color, bedding, mineral composition, texture, fossils and sedimentary structures, it has been identified and divided sedimentary rocks for Kabaw Formation to six facies associations, each representing a particular environment of deposition, and discuss the parameters controlling the deposition of this sediment, these were deposited within four main depositional environments: Braided River, Meandering River, Eolian Dune, and lacustrine depositional environments.

The vertical and lateral correlation of facies associations characterized by a progressive change from proximal to deeper depositional setting which are cleaily observed from sand grain size, sedimentary structures and biogenic content.

Detailed petrographic analysis of the Kabaw Formation has revealed the importance of variations in mineral composition, and classify the sandstones and source rocks, and studied sediment to improve our understanding of the diagenetic history and its relationships with depositional, assist at interpretation of the sedimentary facies and depositional environment, examine the local and regional plate-tectonic setting of the Kabaw Formation and the Ghadames Basin.

Keywords— **Kabaw Formation, Sedimentology analysis and petrogriphica study, facies chractreztic, sedimentry structures and depositional environment.**

I. INTRODUCTION

The previous work for Kabaw Formation is exposed in western Jabal Nafusah was first described by (Burollet, 1963), extends along the escarpment from eastern Jadu to Tunisia, it is unconformably overlies the Shakshuk Formation, and is unconformably overlain by Kiklah Formation (Hammuda, 1971).

The Kabaw Formation consists of yellowish-gray friable, fine to medium sandstone, the base expose ferruginous coarse-grained sandstone with scattered granules progressively becomes finer grained with shale and siltstone beds at the top (El Hinnawy and Cheshitev, 1975).

The sandstones commonly display cross bedding sedimentary structures, western ward the formation is 90 m-thick, it is consisting well-cemented cherty, brecciated, dolomitic horizon, varies in thickness alternation of limestone and dolomite beds has been reported from the upper part of the Kabaw Formation near the Tunisian border (Burollet, 1963; Busson, 1967).

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The age of the Kabaw Formation was tentatively designated as early cretaceous (Antonovic, 1977), in a sand quarry at Ganawn Village just below the town of Jadu, the lower part contains abundant vertebrate fossils; the assemblage collected from this locality includes the following (Belhaj, 1996).
A dinosaur vertebra of a spinosaurus (?), sharks' teeth, fish scales and rounded teeth identified as lepidotes sp, crocodile teeth and dermal plates, turtle shell fragments (Charig, 1973).
This Study discusses the main facies charctreztiuc of the Kabaw Formation, using discription outcrup sections and petrographica analysis in the western part of Jabal Nafusah.

II. AIMS OF THE STUDY

The objectives of this study are to investigate the various sedimentary facies in order to construct the depositional environment and discuss the parameters controlling the deposition of sediment.

III. LOCATION OF THE STUDY AREA

The study area of Kabaw Formation, located in the western part of Jabal Nafusah, northwestern Libya (Fig 1). Study area covered an area from Ryaynah to Wazan village, between the coordinates of:(31° 45' 00" to 32° 05' 00" N and 10° 40' 00" to 12° 21' 00" E). Selected data from six sections are location in table 1.

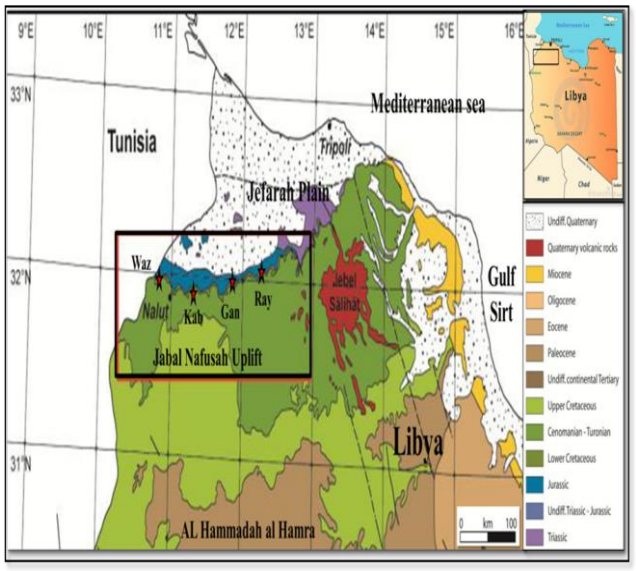

Fig 1. Geological map of NW Libya showing the location of the study area (Black box) Jabal Nafusah Uplift and distribution of the studied sections (Red stars), (modified from Sadalmelik, 2007 and Hassan, 2009).

Table 1. Shows locations of wells in study area.

section	Block	Latitude	Longitude
1	**Ryaynah**	32° 01' 27.9" N	12° 20' 58.7" E
2	**Ganawan**	31° 59' 22.6" N	11° 58' 54.3" E
3	**Kabaw (A)**	31° 55' 04.4" N	11° 19' 30.3" E
4	**Kabaw (B)**	31° 54' 25.4" N	11° 19' 39.9" E
5	**Wazan (A)**	31° 58' 59.5" N	10° 45' 12.8" E
6	**Wazan (B)**	31° 58' 27.3" N	10° 44' 14.0" E

IV. METHODS OF THE STUDY

To achieve the essential purpose, several steps are needed, and these are:

1. Literature review
2. Data base collection.
3. Field work investigations and sampling.
4. Description and interpretation of the outcrop sections which including sedimentological investigation of the facies associations, depositional environment.
5. Laboratory analysis includes microscopic and/or textural and mineralogical description.
6. Petrographic studied which include mineralogy, primary sedimentary texture and post depositional digenetic aspects.
7. Correlation of the studied outcrop sections and facies distribution. Environment and discuss the parameters controlling the deposition of sediment.

V. SEDIMENTOLOGY AND DEPOSITIONAL ENVIRONMENTS

The Kabaw Formation is studied in details from the outcrop sections exposed in the western part of Jabal Nafusah, owing to the lack of a detailed study of facies associations and depositional environments for Kabaw formation in the past, it has been divided into six facies associations, each representing a particular environment of deposition, these were deposited within four main depositional environments: Braided River, Meandering River, Eolian Dune, and Lacustrine depositional environments.
In this paper, we will review the sedimentary analysis of the three main facies present in the studied rock sectors in the study area, which are the first, second and third sedimentary facies Association.

VI. FACIES ASSOCIATION (FA)

Facies Association 1 (FA1) Medium to very coarse sandstone of Saskatchewan type Braided River.

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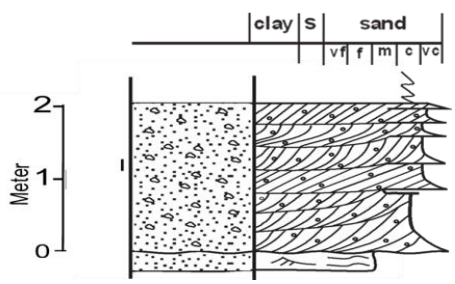
Description: This facies association composed of conglomeratic, medium to very coarse –grained sandstones, grayish yellow to pale yellow colored sometimes mixed with dark brown color, often poorly to moderate sorting, with rounded to subrounded- sub angular grains, display planar cross - bedding, the cross bedding truncated from the top and tangential from the base, which usually shows normal grading with scattered granules, the planar cross bedding grades up into small scale trough cross bedding.

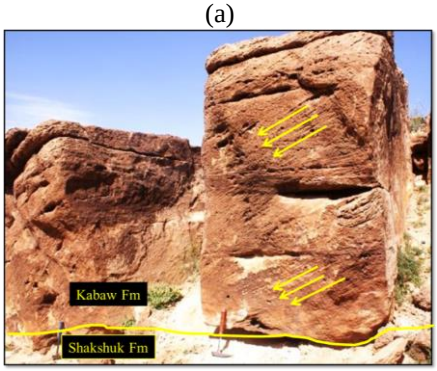
The bed thickness ranges from about 5 to 50 cm. which stacked at sets of 1.5 to 3.5 m-thick, the generally thickness in this facies association ranging between 3.5 to 7 m, the sets separated from each other by thin sheet of clay were showing thinning up stacking patterns (Fig 3), see (Appendix 1) lithology and sedimentary structure legend.

Sometimes the bed tops expose calcareous nodular surfaces (Fig4), Palaeocurrent measurements mostly indicate northwest trend, the sandstones sometimes consist fragments of petrified wood and bones usually associated with rounded pebbles and cobbles of rock fragments, the lowermost bed rests unconformably above the Shakshuk Formation where the top of Shakshuk Formation characterized by presence of brownish clay (hard ground), and this facies is conformably contact overlain by (FA2).

Interpretation: The sandstones of (FA1) were deposited from traction by unidirectional current, planar and trough cross stratification probably lateral migration of channel bed-forms, which are sustained by the thinning up stacking patterns.



(a)



(b)

Fig. 2. (a,b) Medium to very coarse -grained planar and trough cross - bedding sandstone unconformably overlie the Shakshuk Formation, in addition to clarifying my drawing for part (FA1) bedding (Ganawan section).

The pebble and cobbles contents indicate the high energy depositional current, these sandstones suggested to be interpreted braided river environment deposits which are supported by the absence of overbank deposits (Miall, 1996), such rivers probably resemble to Saskatchewan type of (Miall, 1977&1978).

Fig. 3. (Concretion calcite seen at the top surfac e (Ganawn section).

Facies Association 2 (FA2) Fine to Medium Sandstone of Platte type Braided River.

Description: This facies association composed of sandstone with scattered pebbles, the sandstone fine to medium often medium to coarse grained, yellowish- brown to pale yellow yellowish-brown, sometimes light gray colored.

The sandstone poorly to moderately well sorted, with subrounded to subangular grain shapes, granules usually scattered throughout the sediments and concentrated at the base of bedsets.

The sediments regularly display planar cross bedding, occasionally grades into current ripples, irregularly and trough cross bedding, the sedimentary structures often small to medium scale (Fig 4), the sandstone sometimes structureless and well sorted sandstones.

The beds thickness of this facies association occasionally ranging between 0.1 to 5.5 m, the generally thickness in this facies association ranging between 5.5 to 12 m, palaeocurrent measurements show flow unidirectional paleoflow toward the northwest.

This facies association described from the lower part of the Kabaw formation (from Ryaynah section to Wazan (A) sections only) (Fig 5. A&B), the conformably contact boundary between (FA2) and (FA3) at (Ryaynah-Ganawan-Kabaw (A) sections), also conformably contact between (FA2) and (FA4) at (Wazan (A) section).

Interpretation: This facies association interpreted as deposition by a braided river, the river experiences annual flooding, braiding develops at intermediate and low discharge, (Smith, 1971), coarse grained bedforms and pebbly lags indicate a high-energy bed-load system (Miall, 1985), although some fining-upward sequences can be identified.

Planar cross-bedded sandstone facies and (Rust's, 1978), sometimes change to low energy indicate interbedded current

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ripples lamination sandstone low - angle cross- stratified sandstone facies, small to medium-scale bedforms producing planer cross bedding in modern sandy braided rivers include both linguoid and straight-crested transverse bars (Smith, 1971, 1972), low angle cross-beds may represent deposition under high energy conditions, this high energy fluctuating processes that transport course- grained unsorted sediment is typical of braided stream depositional environment (Collinson, 1986).

Fig. 4. (A pebble scattered at the base of planar and trough cross- bedded sets and a finer in grain size to medium-grained sandstone is sometimes evident, finning upward (Ganawan section)

Planar cross-stratification dominates, with scattered ripple cross-strata; trough-shaped cross strata from mega ripples are scarce, probably because these forms are destroyed by slowly falling water levels over the bars, (Miall, 1977) such characters may attribute to Platte-type model to shallow river or those without topographic differentiation (Miall, 1978).

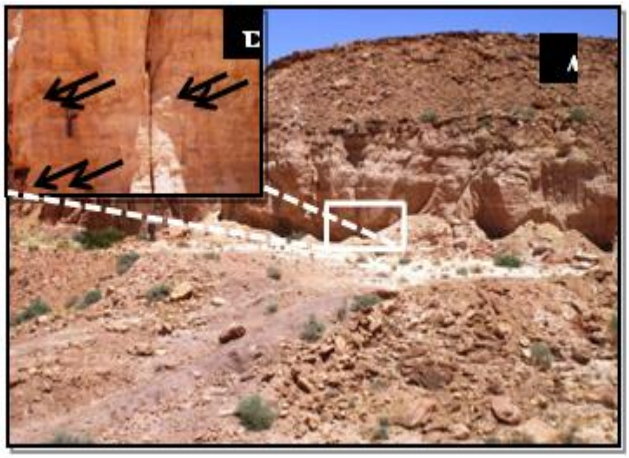

Fig. 5. **(**A) General view FA2 (Kabaw (A) section), (B) Close view sandstone unidirectional, medium scale Co-sets planer cross bedded (Kabaw (A) section).

Facies Association 3 (FA3) Fine to Medium grained, small Planar to Trough cross-bedded sandstone of Meandering River.

Description: This facies association composed of pale yellow, brown, light-brown colored sandstones, fine to medium - grained, moderately to well- sorted display medium-scale low angle planar cross bedding amalgamated with trough cross- stratifications, the beds often terminated upward by current ripples and /or horizontal laminated beds (Fig 6).

The beds stacking within medium co-sets, usually exhibit fining upward in grain size and thinning up bedded, the cross bedding generally in unidirectional orientation with partly bidirectional trends. Some plant fragments recorded in some localities, these beds decreasing in thickness laterally due to erosion.

The thickness of this facies association ranging from 2 to 4 m, this facies association regularly alternated with the (FA4) of varicolored mudstones. The conformably contact boundary between (FA3) and (FA4) at (Wazan (A) and (B) sections), also conformably contact between (FA3) and (FA6) at all sections in study area.

Interpretation: The sediments characterized by trough and planar cross bedded, thinning up stacking patterns and finning upward in grain size of sediments, typically compared with the point bar of meandering river system (Jackson, 1978).

The horizontal lamination may represent upper-flow-regime flatbed condition forms only a small portion of the facies, the ripple cross-strata may represent low energy conditions near the top of the bar (Allen, 1963), the finning-upward in grain size probably attributed to lateral accretion of meandering point bars transported as bed-load.

This facies association observed from western part of the study area (Ganawan section), which interpreted as meandering river stream depositional environment.

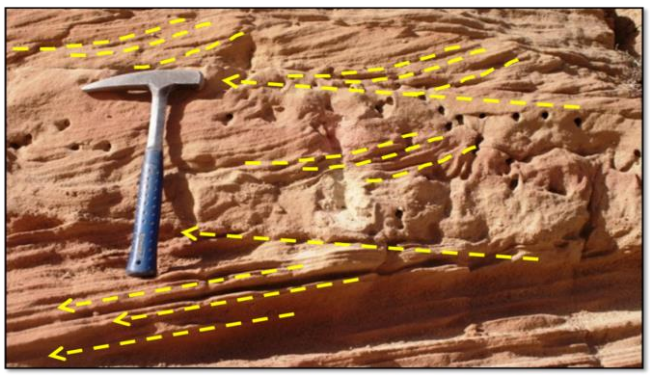

Fig. 6. Medium- scale sets planar and trough cross bedded sandstone (Ganawan section).

Main Boundary Surface and Correlation of the Study Sections

Six sections were described and logged sediment logically including of palaeocurrent measurement data and ichnological observations were correlated together. As a clear basal contact often, interpreted to provide detailed examples of lateral and vertical facies interaction, hand specimens also collected and analyzed petrographically following detailed facies analysis.

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Main Boundary Surface (S).

Two main boundary surface **(S)** in Kabaw Formation of the study sections (Fig 7), **(S1)** This surface occurs at the boundary unconformably surface, between base Kabaw Formation (FA1-FA3&FA4) and top Shakshuk Formation, (**S2**). This surface between top Kabaw Formation (FA6& FA5) and base Kiklah Formation, this boundary explains erosion unconformably surface (Fig 8).

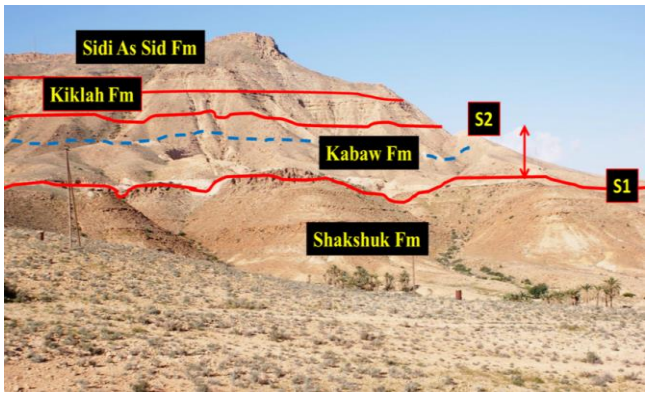

Fig. 7. General view for Kabaw Formation and main bounding surfaces (S1&S2) (Ganawan section).

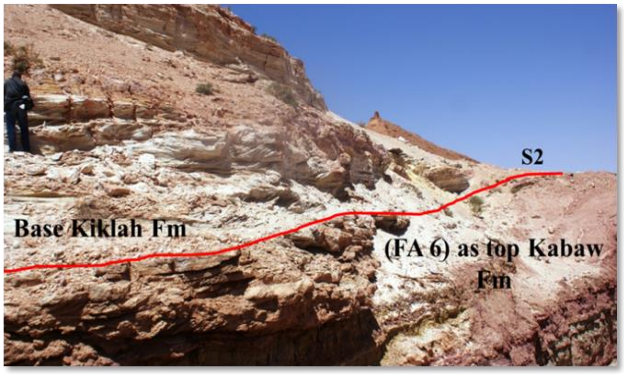

Fig. 8. Boundary unconformably surface (S2) between (FA6) as top Kabaw Formation and base Kiklah formation (Wazan (A) section).

Correlation of the Study Sections

The Kabaw Formation is divided into six facies associations, the vertical and lateral succession of facies associations characterized by a progressive change from proximal to deeper depositional setting which are clearly observed and identified from sand grain size, sedimentary

The lateral correlation of recognized facies associations and studies sections revealed four main depositional environments these are: braided river, meandering river, eolian dune, and lacustrine depositional environments (Fig 9).

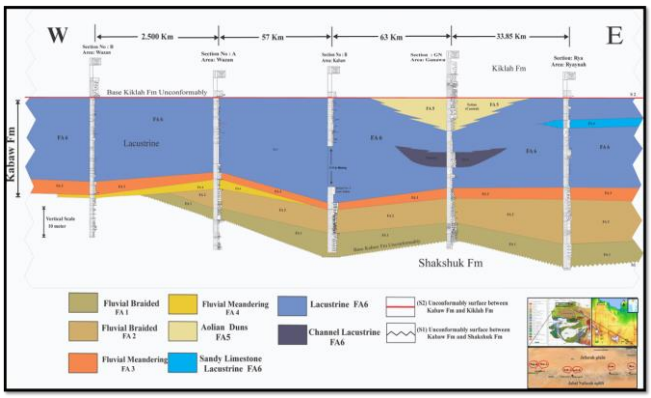

Fig. 9. Measured sections-oriented W-E lithological correlation panel along strike of the northern margin of Jabal Nafusah in Kabaw Formation section showing four deposited environments..

Braided River deposits

This braided river deposits characterized by basal conglomerates sandstones, the sandstone within this association shows internal structures such as cross-lamination and planar and trough cross-stratification sandstone, stacked as repeated cycles of (FA1& FA2), these stacking patterns range in thickness from 1.5 to 5.5 m.

The generally thickness in this facies association ranging between 3.5 to 12 m, which increase in thickness eastward, beds exposed in four measured sections from (Ryaynah section) in the east to (Wazan(A) section) in the west, expose unconformity contact between Kabaw Formation (FA1) and Shakshuk Formation, the upper boundary between braided river (FA2) and meandering river (FA3).

(FA1) Lateral and vertical thickness variations found from (Ryaynah section) in the east to section (Wazan (A) section) in the west, maximum vertical thickness in (Ryaynah section) about 7 m, decreasing thickness to the west in (Ganawan section) about 5.5 m, and increasing thickness to (Kabaw (A) section) more than 5.5 m, is minimum thickness this facies associations in(Wazan (A) section) about 3.5 m, and this facies associations absent at (Wazan (B) section) in the west.

(FA2) The lateral and vertical thickness variations in this facies associations found from (Ryaynah section) in the east to (Wazan (A) section) in the west also, maximum vertical thickness in (Ryaynah section) about 12 m, decreasing thickness to the west in other sections ranging about 5.5 to 7 m in the west.

Meandering River deposits

This Meandering River deposits of Kabaw Formation characterized by sandstone within this association show internal structures such as small planar and trough cross - stratified sandstone, with mudstone varicolored, often terminated upward by current ripples, stacked as repeated cycles of (FA3&FA4), generally poor drainage, slow rates of accumulation, these stacking patterns range in thickness from

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1 to 4 m, beds exposed in all sections from (Ryaynah section) in the east to (Wazan(B) section) in the west, expose lower boundary (FA4) at(Wazan (B) section) is unconformably contact between Kabaw Formation and Shakshuk Formation, and expose upper boundary is sharp surface between fluvial meandering river deposits (FA3) and lacustrine deposited.
(FA3) The lateral and vertical thickness variations in this facies associations found all sections from (Ryaynah section) in the east to (Wazan (B) section) in the west, generally vertical thickness in this facies association ranging between 2 to 4 m, increasing thickness in the east and decreasing thickness to the west area.

Depositional Model
According to the sedimentological and stratigraphical of the Early Cretaceous, Kabaw Formation sediment can be divided into six facies associations, characteristics each representing a particular environment of deposition, these were deposited within four main depositional environments: Braided River, Meandering River, Eolian Dune, and Lacustrine depositional environment.
A proposed depositional model explaining the depositional setting is illustrated in (Fig 10).

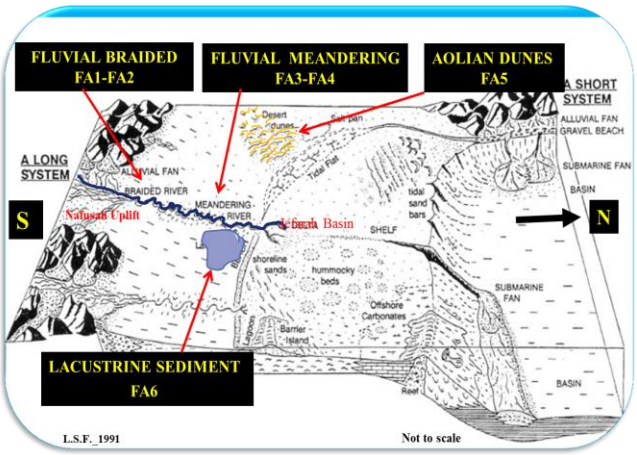

Fig. 10. Depositional environment model of Kabaw Formation.

VII. CONCLUSIONS

This conclusion summarizes the research presented in chapters one, two, and three, it represents the results of Kabaw Formation study, which includes data collected from the field observation and petrographic thin section of different intervals and localities. The Kabaw Formation exposed in western Jabal Nafusah extends along the escarpment from eastern Jadu to Tunisia northwest Libya. The main results of the studied Kabaw Formation are as following:

- The Kabaw Formation consists of clastic dominated sediment deposited in continental depositional setting, including sparse of fresh water carbonate sediments often reflect progressive lower energy upward of the stacking patterns.
- The Kabaw Formation provides an important insight into the palaeoecological evolution of the North African margin during the early cretaceous.

Previous interpretations have considered the Kabaw Formation to have been deposited generally, under fluvial conditions, new additional interpretations where achieved includes eolian and biogenic evidence of fresh water lacustrine (fresh water Ostracoda) environments.

- Six facies' associations (FA) recognized from Kabaw Formation, each represents a particular environment of deposition, these were deposited within four main depositional environments: braided river, meandering river, eolian dune, and lacustrine depositional.
- In this paper, we will review the sedimentary analysis of the three main facies present in the studied rock sectors in the study area, which are the first, second and third sedimentary facies Association.

(FA1) Medium to very coarse sandstone of Saskatchewan type Braided River; (FA2) Fine to Medium Sandstone of Platte type Braided River; (FA3) Fine to medium grained, small planar to trough cross - bedded sandstone of meandering river.

VIII. RECOMMENDATIONS FOR FUTURE WORK

Suggest additional works to be done in future:

- More detailed study in the frame of sequence stratigraphic in order to improve the regional sequence stratigraphy and correlation for the entire Mesozoic, particularly during Early Cretaceous time.
- Improved understanding of climatic controls fluvial infetuencing depositional processes.
- Correlation for Kabaw Formation with subsurface for Ghadames basin and Jefarah plain.
- More detailed of sedimentary petrography, including digenetic minerals, porosities, major constituents to understand reservoir properties in details.
- Establish a detailed correlated of Kabaw Formation and Kiklah Formation in Ghadames Basin with Messak Formation in Murzuq Basin, also correlation with the Nubian Formation in Sirt Basin and AL Kufrah basin.

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