Sedimentological and Foraminiferal Examinations of Kalash Formation, Sirt Basin-Libya.

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Abstract

Kalash Formation (Upper Cretaceous) has been petrographically and micropaleontologically investigated in the penetrated successions of six drilled wells located in Concessions 11 and 32 of Western Sirt Basin. The dominant lithologies are limestones and argillaceous limestones with minor dolomitic limestone. However, the extent of the dolomitization increases southwards. These carbonates are usually between mudstone-wackestone with less common packstone texture. It reflects low energy depositional environments ranging from basinal (at lower intervals) to relatively shallower slope or basinal margin (at upper intervals) settings. Compaction, dolomitization and dissolution are the dominant recognizable diagenetic processes affecting Kalash carbonates.

The estimated porosity is poor-fair (<5%) of moldic, vuggy and/or intraskeletal types. Porosity is best developed in P1-11 and GG1 -11 as well as the top of the J1-32, although it is absent in wells F1-11, H1 and L1 -32.

The microfossils (smaller benthic and planktic foraminifers) are the dominant bioclastic components herein. The presence of *Globotruncanita stuarti*, *G. stuartiformis*, *Globotruncana aegyptiaca*, *Rosita fornicate*, *Rugoglobigerina rugosa*, *Siphogenerinoides* sp. and *Bolivina incrassata* assign the studied part of Kalash Formation to *Globotruncanita aygyptiaca* Zone of Caron (1989) (Early Maastrichtian) age.

Introduction

A petrographic and paleontological study was carried out to evaluate the Kalash Formation in six selected wells from Concessions 11 and 32 in the western Sirt Basin (Fig.1). Table 1 shows the studied intervals. A total of 750 feet of stratigraphic section, 72 thin sections and 55 paleontological slides have been carefully examined and analyzed for this project. The objectives of this study are:

- Macroscopic examination of well cutting and side wall cores
- Detailed microscopic and macroscopic examination of thin sections and slides
- Assessment of carbonate textures and porosity.
- Assessment of index fossils and age determination of diagenetic history.
- Interpretation of depositional environment.

Table. 1: Studied wells and corresponding intervals.

Well	Interval (ft).	Total Footage
F1-11	6650-6750	100
GG1-11	7400-7500	100
Pl-11	6500-6600	100
Hl-32	7700-7800	100
Jl-32	4800-500O	200
Ll-32	5200-5350	150

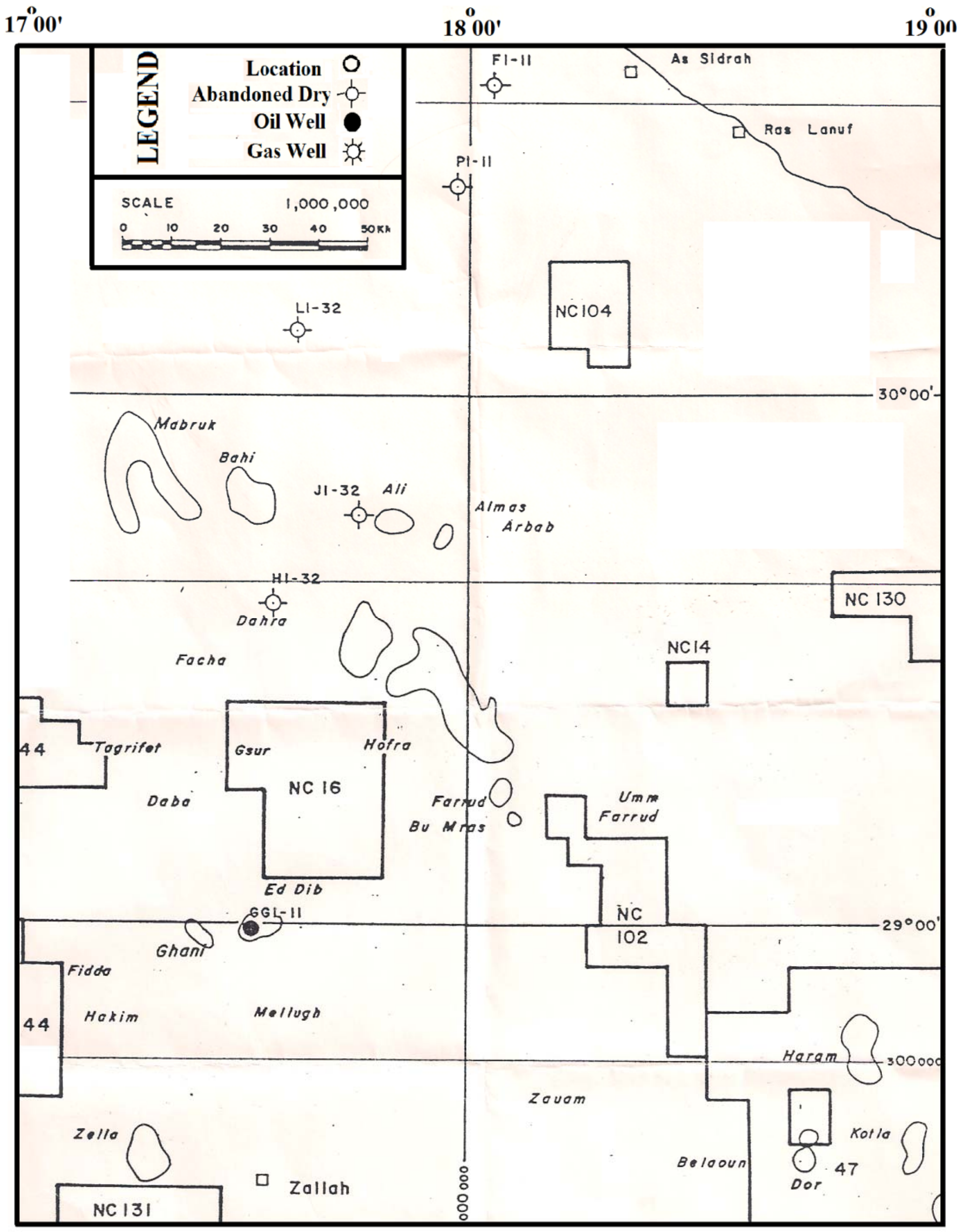

Fig. 1: Location map shows the studied wells F1-11, P1-11, GG1-11, J1-32, L1-32 and H1-32 in Sirt Basin, Libya.

Stratigraphy and lithology

The Kalash Formation underlies the Paleocene Hagfa Shale or Lower Sabil Formation and overlies the Sirte Shale. The dominant 1ithologies of the Kalash Formation in the study area are limestone and argillaceous limestone with some calcareous shale interbeds. Dolomitic limestone is a subordinate lithology.

The carbonates of the Kalash Formation are not always entirely pure limestone. Some partially dolomitized limestone, calcitic dolostone and dolostone can be identified, and these became more significant towards the south of the study area. The calcitic portion of mixed calcite/dolomite lithologies is either undolomitized matrix or calcite cement.

Three distinctive lithologic trends can be identified in the study area:

1. Increase in dolomite toward the south
2. Increase in calcite toward the north
3. Increase in silica toward the south.

Textures and microfacies

Distinctive carbonate textures and microfacies were recognized in Kalash carbonates in the study area according to the depositional texture of Dunham (1962). The most common texture is open marine wackestone. Mudstone and packstone are rare, but best represented in the Concession 32 wells and well P1-11 (see Plates I and II).

Ideally, the Kalash carbonates in the studied intervals are deepening upward, transgressive sequences. Relatively deeper carbonate facies are distinguished by the relative abundance of fine carbonate mud, the darker color and a characteristic deep water fauna. In contrast, the slightly shallower facies can be recognized as more lightly colored, coarse grained textures with a partially dolomitized matrix and a mixed benthic-planktic fauna.

Each deepening upward sequence is initiated as a pelagic, basinal deposit and ends as a relatively shallower, basin margin or slope deposit (Horowitz, Potter. 1971).

Mudstone

Lime mudstones are not especially abundant in the study area. These are mud rich sediments which contain less than 10% carbonate grains. The rare mudstones of the Kalash carbonate were deposited in basin to basin margin setting. Most mudstones have rare disseminated pyrite, organics and microstylolites (Plate II B). These mudstones also have rare fractures which are probably the result of overloading and early compactional forces. Generally, it was difficult to differentiate basinal and slope mudstones because available samples were cuttings.

Mudstones have the poorest developed pore system. In the study area, porosity is characteristically moldic after skeletal grains which are especially susceptible to dissolution. Because mudstone has very few skeletals, they necessarily lack significant moldic pore space.

Wackestone

Wackestones are the volumetrically most important texture. Diversity and relative abundance of the fauna differentiate relatively shallower basin margin/slope wackestones from relatively deeper basinal wackestones. In general, the fauna of the slope/basin margin deposits will be a diverse admixture of shallower and deeper forms. Especially conspicuous shallow water organisms include benthic foraminfera, echinoderms and bryozoans. Diagnostic basin organisms include planktic foraminifera and fine skeletal debris (Plate I A-D).

Another criterion to distinguish basin margin/slope deposits from the basin wackestones is the type of matrix. Neomorphic microspar and dolomicrospar replacement of the matrix are both indications of shallower deposition. These fabrics contrast with the characteristic basinal deposits which have a micrite matrix.

Most porosity in the study area is best developed in the wackestones. These secondary pores are generally skeletal molds after planktic foraminifera. Dolomitized wackestones, invariably slope deposits, have the best developed pore networks, although this facies is not well represented in the study area. Porosity is generally lacking in wackestones (Plate II A) except in the GG1-11 well where there is poorly developed vuggy, moldic and intra-skeletal porosity.

Packstones

Muddy, grain-supported packstones are most commonly slope deposits and rarely basinal facies. Most packstones are rich in planktic foraminifers and rarely peloids.

Subordinate carbonate grains include echinoderms, benthic foraminifers, bivalve molluscs, ostracodes and algae. Pyrite is an accessory constituent (Plate II C).
Porosity is generally absent, except in the well Pl-11 sequence where vuggy, moldic and intraskeletal pore types were poor to fair.

Clotted Textures

Clotted textures are rare and are found only in well Jl-32. Clotted textures generally contain miliolids, rotalids, peloids and traces of glauconite. The matrix is often dolomitized. Clotted textures are probably sediments of upslope or shelf margin which have been eroded, transported seaward and deposited in the deeper slope/basin margin environment.

Micropaleontology contents

Twenty-seven species of foraminifers (6 planktic and 21 benthic) have been identified from the studied intervals Table. 2. The planktic species are identified using Postuma, (1971) and Horowitz, and Potter, (1971). All indicate Late Cretaceous age with few Paleocene taxa from well J1-32. Two benthic foraminifers (*Siphogenerinoides* sp. and *Bolivina incrassata*) are very diagnostic for the Late Cretaceous.

Porosity

Porosity in the studied Kalash Formation is poor to absent. Classification of porosity according to Choquette, and Pray, (1970) is followed in this study. Generally Porosity is mainly primary and existed between the micritic grains of the matrix in the mudstone rocks. Nevertheless, it was reduced to essentially zero by compaction and dewatering of the liquid rich sediments. Intraskeletal pores, generally the chambers of planktic foraminifers were cemented by numerous cements. The secondary porosity is evidenced as molds, vugs, fractures and intercrystalline voids. Nevertheless, many of these were also occluded by cements or are volumetrically insignificant. It must be stressed that dolomitization has not created any significant pore space in the studied intervals. In fact, dolomite cement reduces porosity.

Depositional environment

The Kalash carbonates in the study area represent open marine sediments deposited in a basin margin/slope to basin setting. These environments are gradational. The latter is the deeper end member of the depositional spectrum and the former is shallower. Precise discrimination between basin margin/slope and basin is difficult because these environments are extremely similar. Nevertheless, distinctive attributes of these environments can be recognized by macroscopic examination of cuttings and petrographic examination of thin sections. The salient characteristics are listed below.
The following features are associated with the basinal deposits of the Kalash Formation.

Table 2: Shows the distribution of the recorded foraminifers from the studied wells. * refers to Paleocene taxa. (+ present and - absent)

Taxa \ Well	F1-11	P1-11	L1-32	J1-32	H1-32	GG1-32
Globotruncana stuarti	-	+	+	-	-	+
Globotruncana stuartiformis	+	-	-	-	+	-
Globotruncana fornicata	+	-	-	+	+	-
Globotruncana* cf. *aegyptiaca	+	-	+	-	+	-
Rugoglobigerina rugosa.	-	-	-	-	+	-
Heterohelix sp.	+	+	+	+	+	+
Bolivina incrassata	-	+	+	-	-	-
Cibicides libycus	+	-	+	-	+	-
Stensioina convexa	+	-	+	-	-	-
Bulimenella sp.	+	-	-	-	-	+
Lenticulina sp.	+	-	+	+	-	-
Osangularia sp.	+	-	+	-	-	-
Marginolinopsis sp.	+	-	-	-	-	-
Gyroidinoides sp.	+	-	+	-	-	-
Spiroplectammina sp.	+	-	-	+	-	-
Neoflabellina* aff. *buticula	+	-	-	-	-	-
Chilostomella sp.	+	-	-	-	-	-
Siphogenerinoides sp.	+	-	+	+	-	-
Stilostomella sp.	+	-	-	-	-	-
Anomalina sp.	+	-	+	-	-	-
Textularia sp.	+	-	-	+	+	-
Heterolepa sp.	+		+	-	-	-
Haplophragmoides sp.	-	-	+	-	-	-
Gaudryina sp.	-	-	+	-	-	-
****Rotalia # 48***	-	-	-	+	-	-
****Operculina patalensis***	-	-	-	+	-	-
Marginolina sp.	-	-	-	-	-	+

1. Micritic matrix.
2. Abundance of fractures and stylolites.
3. Pelagic fauna consisting primarily of planktic foraminifers with their debris.
4. Presence of quartz silt.
5. Absence of glauconite.
6. Replacement of skeletals by pyrite and silica.
7. Shale partings and clay content.
8. Dark color (grey and dark grey) foraminifers.

No single feature is conclusively diagnostic of basinal deposits. Similarly, all basinal deposits in the study area do not exhibit the above characteristics. The recognition of

basinal sediments is based upon subjective criteria which include the above, but also must take into account stratigraphic position and associated facies.
Slope/basin margin are adjacent to and gradational with their slightly deeper, basinal equivalent Wilson, (1975). Recognition of slope/basin margin facies is constrained by the same factors mentioned above. A set of diagnostic characteristics has been assembled, these include:
1. Alteration of the micrite matrix to microspar
2. Fewer or no stylolites and fractures
3. More diverse fauna including planktic foraminifers, rotaliids, miliolids, ostracodes, echinoderms, bivalves, algae and bryozoans
4. Presence of glauconite
5. Partial replacement of matrix, skeletals and intraskeletals by silica
6. Fewer or no shale partings, decreased clay content
7. Light color: white and light grey
Shelf or platform deposits are absent in the study area, although much material in the basin margin/slope sediments are probably derived from the nearby platform of shelf. These faunal components were transported and re-deposited in these environments.

Summary and conclusions
This report is based on the study of 750 feet of stratigraphic section, 72 thin sections and 55 paleontological slides. All the samples represent the Kalash Formation and are from wells Fl, GG1, P1 in Concession 11 and H1, Jl, L1 in Concession 32.
The dominant lithologies in the study area are limestone and argillaceous limestone. Dolomitic limestone is less important.
Generally, the extent of dolomitization decreases northward in the study area. Mud-supported wackestone is the most common carbonate textures. Mudstone and packstone are rare.
The carbonate sediments of the Kalash Formation were deposited in marine environments ranging from basin to relatively shallower slope or basin margin. Low to moderately low energy deposition prevailed throughout this quiet water setting. High energy deposits are entirely lacking.
The Kalash carbonates in each well were deposited as deepening upward sequences. The equivalent section becomes progressively shallower in a southerly direction, grading from basin to slope.
Compaction, dolomitization and dissolution are the most important diagenetic phenomena affecting the Kalash carbonates. Poor to fair porosity is developed only in wells Pl-11, GG1-11 and Jl-32. Most porosity in the Kalash Formation of wells P1-11, GGl-11 and Jl-32 was created by dissolution of unstable carbonate grains in the mud-supported fabrics, creating skeletal molds. The molds were further enlarged by dissolution to create irregular vugs. Dissolution or leaching occurred in the shallow subsurface where the rocks were exposed to meteoric (fresh water) phreatic fluids.
The micropaleontological analysis of the faunal assemblage indicates relatively shallower neritic conditions prevailed in wells Fl-11, Jl-32, Ll-32, Hl-32. The Kalash Formation in wells GGl-11 and Pl-11 has a neritic fauna.
According to the presence of *Globotruncana* aff. *stuarti*, *Globotruncana* sp., *Heterohelix* sp. and *Siphogenerinoides* sp., a Late Cretaceous age (Maastrichtian) is assigned to wells PI, GG1-11, and Ll-32. Meanwhile, the presence of *Globotruncana* cf. *fornicate, Globotruncana* cf. *stuartiformis. Globotruncana* cf. *tricarinata, Globotruncana* sp., *Rugoglobigerina rogusa*, *Heterohelix* sp., and *Siphogenerinoides* sp., indicates a Late Cretaceous age (Maastrichtian- ?Campanian) for wells Hl-32, Jl-32, and Fl-11.

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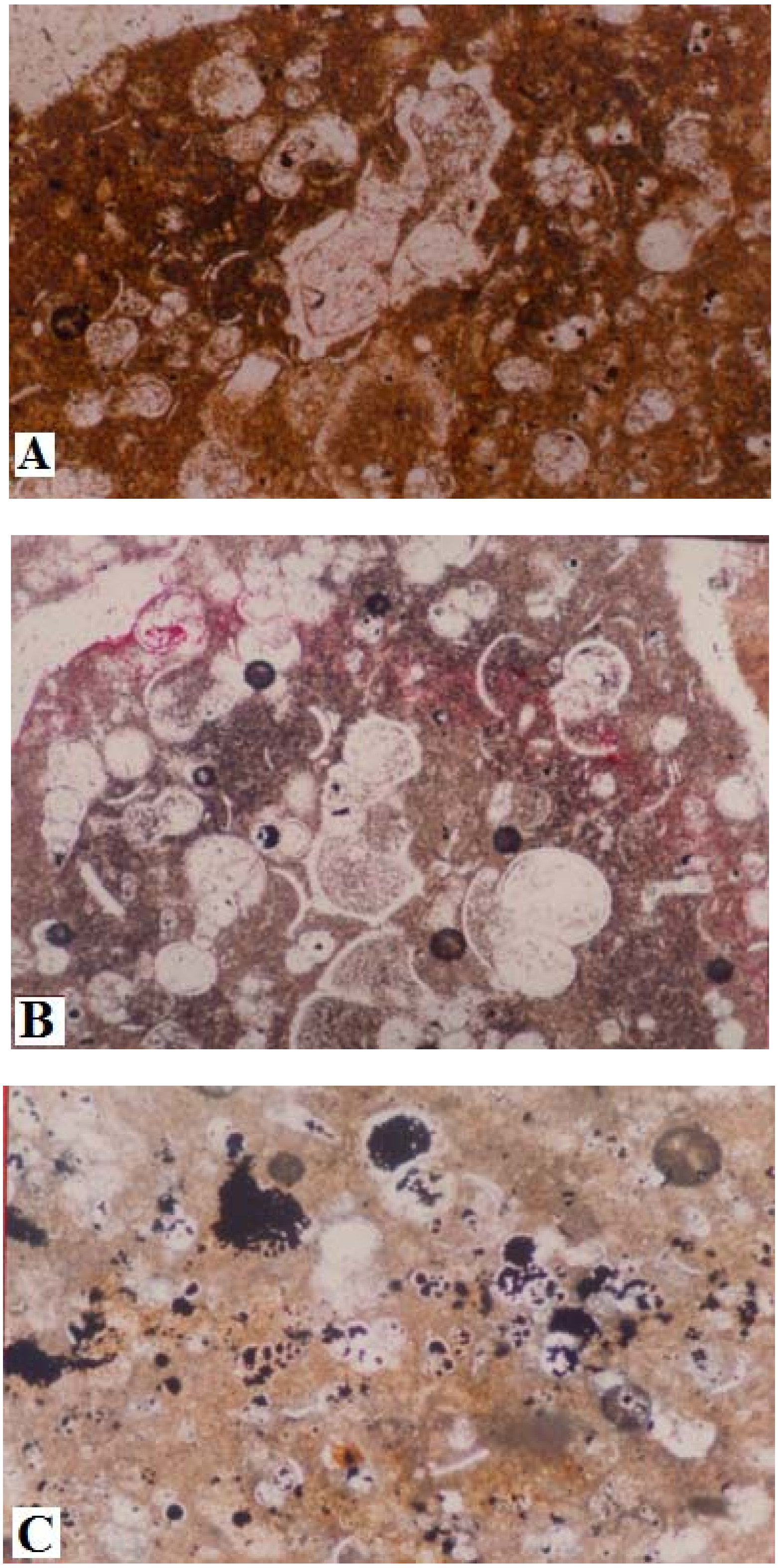
EXPLANATION OF PLATE I

A: Shows planktic foraminiferal – fine skeletal wackestone with *Globotruncana* cf. *fornicata* and numerous whole and fragmented globigeriniids. It contains dense lime mud matrix and pyrite frameboids within the chambers. Well F1-11: 6650-6660', PPL, X35.

B: Shows Planktic foraminiferal wackestone. Common globigeriniids, heteroheliciids and their debris. (Note: *Heterohelix* sp. and *Globotruncana* aff. *tricarinata*). H1-32: 7740-7770'. PPL, X45.

C: Shows wackestone with numerous planktic globigeriniid and heteroheliciids, some tests contain or are filled with pyrite, and with micritic matrix. These intraskeletal spaces are good microenvironments for the formation of pyrite. Well H1-32:7740-7770'. PPL, X45.

PLATE I



EXPLANATION OF PLATE II

A: Shows fine skeletal-planktic foraminiferal wackestone with scattered globigeriniids and single echinoderm spine. Pyritic, blocky calcite spar cements fill the foraminiferal chambers. Well H1-32: 7710-7740'. PPL, X55. Alizarin Red-S stains the thin section

B: Shows lime mudstone. The matrix is microcrystalline carbonate mud or micrite. It contains detrital quartz silt, pyrite and dolomicrospar. Well J1-32; 4980-4990'. PPL, X55. Alizarin Red-S stains the thin section.

C: Shows planktic foraminiferal packstone is a limestone. Common globigeriniids. Micritic matric and microspar. Equant calcite and rare equant dolomite cements, pyritic. Intraskeletal porosity is rare. Well P1-11: 6600'. PPL, X55. Alizarin Red-S stains the lower half of the sample.

PLATE II