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SEDIMENTOLOGY OF UPPER CRETACEOUS FORMATIONS FROM KURDISTAN REGION, NE−IRAQ

A THESIS

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BY

Zardasht Ahmad Taha
B.Sc. in Geology, Sulaimani University, 2003

Supervision by:

Dr. Kamal Haji Karim

Assistant Professor

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Supervisor Certification

I certify that this thesis has been prepared under my supervision in the Department of Geology of the University of Sulaimani, in fulfillment of the requirement for the degree of M.Sc. in Geology.

Signature:
Name: *Dr. Kamal Haji Karim*
Title: *Assistant professor*
Address: *University of Sulaimani*
College of Science
Department of Geology
Date: / /

The Certification of the Chairman of the Committee of Higher Student. According to the recommendation submitted by the supervision, I nominate this thesis for discussion.

Signature:
Name: *Dr. Kamal Haji Karim*
Title: *Assistant professor*
Address: *University of Sulaimani*
College of Science
Department of Geology
Date: / /

We, the examining committee, her by certify that we have read this thesis and examined the student in its contents and whatever relevant to it and, in our opinion; it is adequate with "   ” standing for the Degree of master of Science in Geology/Sedimentology.

Signature:	**Signature:**
Name:	**Name:**
Title:	**Title:**
Address:	**Address:**
Date: / /	**Date: / /**
(Chairman)	**(Member)**
Signature:	**Signature:**
Name: *Dr. Kamal Haji Karim*	**Name:**
Title: *Assistant professor*	**Title:**
Address: *University of Sulaimani*	**Address:**
Date: / /	**Date: / /**
(Supervisor and Member)	**(Member)**

Approved by the Council of the College of Science

Signature:

Name: *Dr. Parekhan M. Abdul-Rahman*

Title: *Assistant professor*

Date: / /

Dedicated:

To

My Father

My Mother

My Sisters and my Brother

And

To Whom Search for Truth

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Zardasht A. Taha

ABSTRACT

The present study is concerned with sedimentology of the Late Cretaceous outcrops of Dokan limestone, Gulneri Shale, Kometan and Shiranish Formations in the areas that is located between Sulaimanyia and Arbil Governorate at northeastern Iraq. This area includes Dokan, Qamchuqa Gorge and Safeen Mountain. The lithology, stratigraphy and lithofacies of the above formation are studied in addition to inspection of their boundary conditions in the surrounding areas.

Dokan Limestone Formation (Cenomanian) mainly consists of Oligostiginal limestone which is deposited during drowning phase (transition to post drowning phase) of the Arabian Platform by closing of the Iranian Plates front which exerted excessive load on the former plate. It has a local distribution which exists only in Dokan dam site and represents the transitional phase between shallow marine Qamchuqa and deep marine Kometan Formations. Therefore, it is suggested in this study to include this formation in Kometan Formation. The boundaries of Dokan limestone Formation are gradational and contain no conglomerate and paleosol but some short submarine erosion is not excluded. It deposited in the large foredeep basin (with Kometan Formation) and previous small basin that was bounded by unconformity from all sides is not ascertained in this study.

Gulneri Shale Formation (Early Turonian) mainly consists of limestone and marly limestone with no more than 20% laminated shale. The Thin section study showed that the shale is highly deformed which has foliation-like texture in which the planktonic foraminifera's are transformed to elongated grains. Therefore it is most probable that the shale is formed by pressure solution which is representing insoluble residue materials in which the organic materials are accumulated by filtering. This is aided by observing bending of the shale laminae around the spherical limestone bodies. Field study showed that the bodies are formed by pressure and they are not conglomerate as assumed previously. It is deposited, as Dokan Limestone Formation, during drowning of Arabian platform when the platform suffered from submarine reworking of sediment above the fair weather base outside the studied area (possibly at the south of the studied area.) By the wave and current some clay is transported and deposited as marly limestone (as now it is called Gulneri Shale Formation). This formation is deposited in the large foredeep basin (with Kometan Formation) and previous small euxinic basin that bounded by unconformity from all sides is not ascertained in this study. The boundary shows no unconformity except possible submarine erosion or slow rate of deposition for short time.

This formation also occurs only in Dokan dam site and it does not exist in the near by surrounding areas. Therefore we suggest to be combined it with Kometan Formation too.

Kometan Formation (Turonian-Early Campanian) consists of fine grain pelagic globogerinal limestone about 50 -127m thick which contain chert nodules and stylolites in Dokan area. It represents the main deposit of the post drowning phase (almost total submerging) of the Arabian platform which is deepened by closing of Iranian Plate to Arabian platform due to load of accretionary prism that accumulated between the two plates. The area of the distribution of this formation is extended to the southwestern limb of the Safeen anticline (northeast of Arbil City) where which has been previously mentioned that Bekhme Formation is overlying Qamchuqa Formation but now it is clear that former formation not occur and Kometan and Shiranish Formations overlying Qamchuqa Formation. This notifies that the drowning of the Arabian platform was covered Arbil Governorate during Late Cenomanian- Campanian which is attributed to the tectonic subsidence of the studied area. The boundaries of the formation are conformable in most areas, only in Dokan area show slow rate of deposition and little submarine erosion forming a local hiatus. The previous micropebbles, at the contact with the overlying Shiranish Formation are studied in field and in thin section which are interpreted as chert nodules. Where the environment was suitable, during deposition, the Middle Campanian fossils can be found such as in the Dola Root Valley at the west of Sulaimani city. Therefore the age of the formation must be amended to Turonian-Middle Campanian.

Shiranish Formation is about 180 -228m thick and consists of bluish white marl and marly limestone. It represents the sediment of the initial phase of the burial phase of Arabian Platform during Middle Campanian. The crises of burial are attributed high influx of the siliciclastic sediment of Shiranish and Tanjero Formations. The burial of the Arabian platform had begun after continental colliding of Iranian and Arabian continental by which the southern Neo-Tethys is closed totally and the studied area changed to Foreland Basin. According to this, the ophiolite and Radiolarite has uplifted and transformed to source area during Late Campanian. The drowning and burial of the platform was not synchronous (diachronous) which is represents the deepening and siliciclastic burial stepped forward to south and southwest. (The Environment of Shiranish Formation was slightly shallower than that of Kometan Formation because it contains, in the studied area, at least two pelecypod biostrome one of them is located at Dokan area and the other one in Chwarta area.

LIST OF CONTENTS

Subjects **Pages**

Chapter Four: Tectonic Development and Depositional History

List of Figures

List of Tables

CHAPTER ONE

INTRODUCTION

1.1- Preface

The present study is originally proposed and funded, as an M.Sc. thesis, by a Turkish Oil Company (Genel Energy) that works now in the Taq Taq Oil Fields. The study area, as proposed, includes Dokan area, Qamchuqa Gorge and Safeen Mountain where the Late Cretaceous Dokan limestone, Gulneri shale, Kometan, and Shiranish Formations are cropped out. These Formations, according to Buday (1980), are deposited during two cycles, first is the Cenomanian – Early Campanian Cycle, the second is Late Campanian–Maastrichrian Cycle.

The present study is concerned with sedimentology of the above Late Cretaceous formations. According to (Bellen et al., 1959, Buday, 1980, Jassim and Goff, 2006) the lower and upper boundaries of these formations are unconformable. In the recent years, new papers are published which gave opposite ideas as compared to that of above authors. Among the new studies that of Karim and Surdashy (2005), Karim et al., (2007) and Ameen (2008) by which many modifications are suggested for the boundary of Kometan and Qamchuqa Formations. During the field work, many observations are recorded in many localities that assist the abilities for further new modifications.

1.2- Location and Geomorphology

The studied area is located in between Sulaimani and Arbil governorates in northeastern Iraq which is bounded by latitude (35^{0} 53^{-} $16^{=}$ and 36^{0} 32^{-} $41^{=}$) N and longitude (44^{0} 37^{-} $59^{=}$ and 45^{0} 14^{-} $20^{=}$) E. The studied area constitutes a part of Zagros mountain belt, where the high mountain chains are in northwest southeast direction. The area is occupied by many mountains such as Sara, Kosrat, Gally and Safeen. The studied formations are cropping out mostly along the lower side of the above mountains

(Fig.1.1and 1.3). In the same direction and between these mountains there are narrow or wide subsequent (strike) valleys, most of which coincide with synclines, while few of them are developed along the axis of anticlines by erosion of their core. The main erosional valleys are Gali Smaqulley and Sarmord, Khdiran, and Zewe valleys (Fig1.3).Moreover, the mountain chains are dissected by many large or small consequent valleys, the largest one is that in which the Little Zab Rivers flow. The area contains three large plains: Bitueen, Marga, and Piramagroon, which are located to the west, east and south of Dokan Lake.

1.3- Geological Setting

The studied area is located in the Western Zagros Fold-Thrust Belt, directly to the southwest of the main Zagros Suture Zone (Stocklin, 1968; Buday, 1980; Buday and Jassim 1987; Mc Quarrie 2004 and Jassim and Goff, (2006). Structurally, the area is located within the High Folded and Imbricated Zones (Buday, 1980 and Buday and Jassim, 1987) Fig. (1.1). the area mainly consists of high amplitude anticlines, many of which are asymmetrical with the southwestern limb steeper than the northeastern one. The strata suffered from intense deformations due to imposed stress of Iranian Plate. The stresses generated many transverse and thrust faults in the area. Most of the gorges are developed along transversal normal and strike slip faults, such as Qamchuqa, Smaqully, and Sargalu, Ranyia and Tabeen. Due to the stress of Iranian Plate, the northern boundary of the area is characterized by obscured anticlines and synclines. These phenomena is very clear in the Imbricated Zone, especially those that are located in the transition Zone between Qamchuqa and Balambo formations, along the line that connects between Sulaimanyia city and Ranyia town. The main depression in the area is the area below and around Dokan reservoir, which most possibly represent a graben. However, nowadays, apparently, this graben resembles a large syncline in which the dissected by normal faults, anticlines are so modified that appears as plunging anticlines beneath the plain.

In all studied sections of the studied area, the Late Cretaceous formations are underlain by Qamchuqa Formation (Fig. 1.2 and 1.3) and overlain by Tanjero and Kolosh Formations in Sulaimanyia and Arbil Governments, respectively. Kometan, Gulneri and Dokan Formations pinch out toward the northwest of the studied area (to the west of the Dokan Dam) (Fig.1.5 and 1.6). This may attribute in literature (Ex: Buday, 1980) to non-deposition of these formations due to uplift of the Dohuk and some part of Arbil areas.

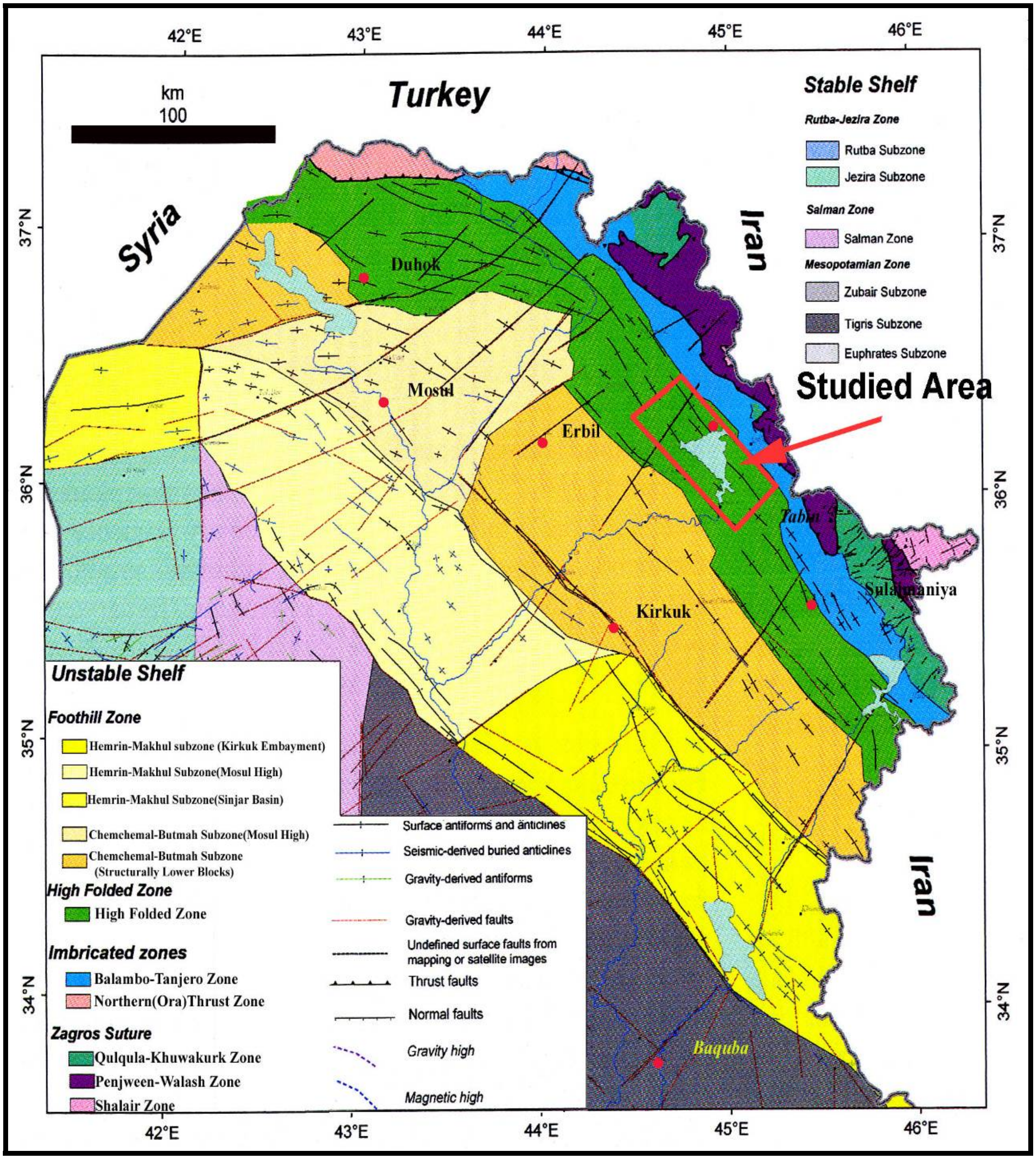

Fig.1.1: Tectonic map of the northern Iraq (Al-Kadhimi *et al*, 1996) on which the studied area is indicated.

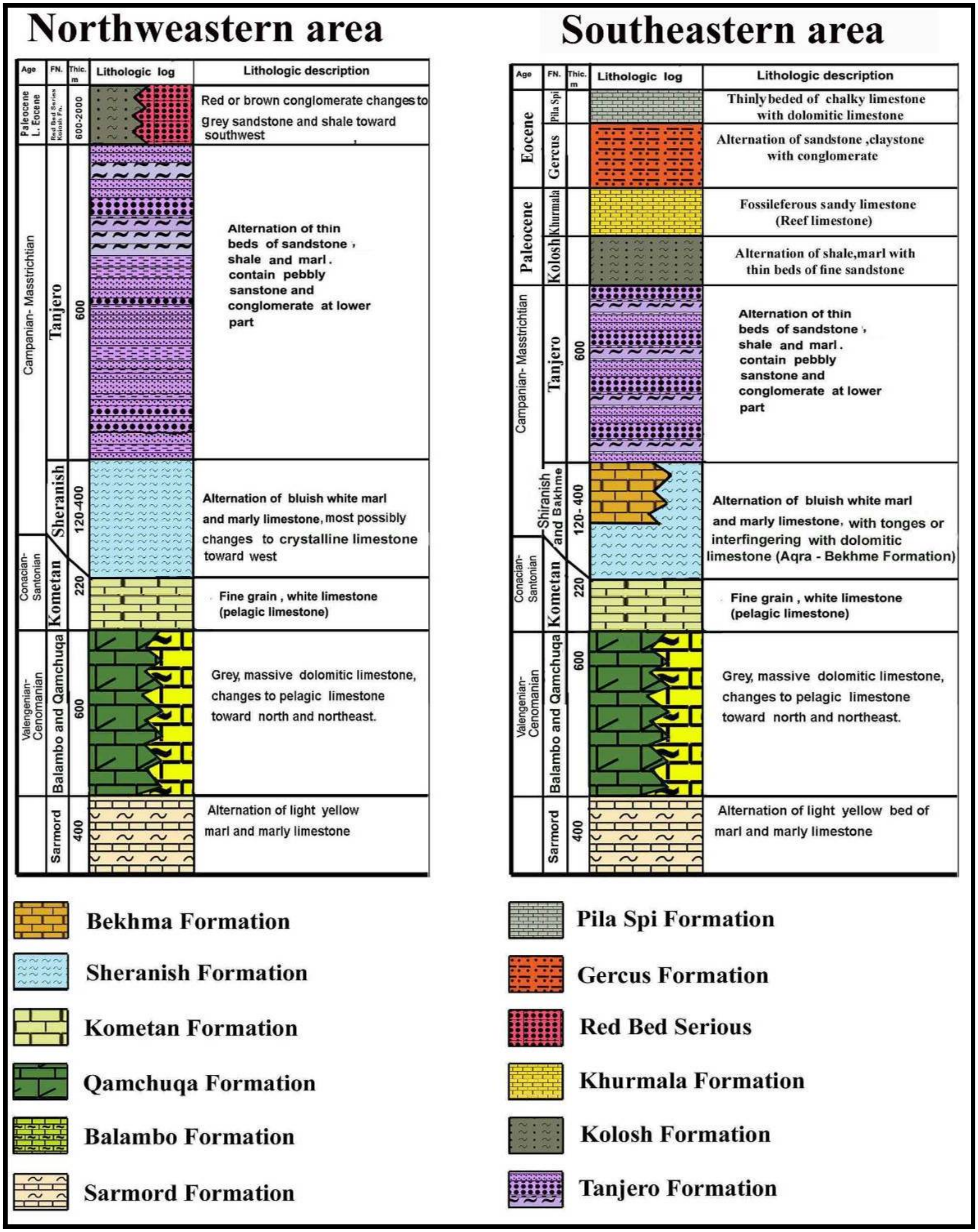

Fig.1.2: General stratigraphic column of the studied area (Ameen, 2008).

1.4- Studied sections

Three sections are chosen and sampled in the Sulaimani and Arbil Governorates, to be studied in details. The selection of these sections is based on the maximum obtainable information (facies change) and degree of the differences between some Formations in Late Cretaceous located at Qamchuqa Gorge, Dokan dam site and Safeen (Fig.1.11) in the assortment, the distribution of the sections is considered so that they include the entire studied area. However, the process of the selection has suffered from three constrains. The first is that, the high thickness of these formations. The second is that the formations are effected by many thrust and reverse faults, especially in the Imbricated Zone, which most possibly have caused repetition of some intervals.

The third is that these formations, in many places, form vertical erosional and fault cliffs, which cannot be sampled and even inspected.

In addition to the four studied sections, the formations are inspected accurately in all available continuous and isolated outcrops. Most of the outcrops, when topography has permitted, are stepped on continuously along the dip and strike to see vertical and lateral facies changes. In opposite to other formations, the facies change is so rapid, in some places, that when stepping on, several different facies could be recognized in a distance of about 5 kms. The sampled sections are:

1.4.1- Upper Dokan Section

Upper Dokan Section at latitude 35° 56' 23" and Longitude 44° 00' 39” and which is located about 3 km to the east of the Dokan dam site near the Tourism village. The section exposed along the lower part of the northwestern limb of Sara anticline (Fig.1.3, 1.4, and 1.9).

1.4.2- Lower Dokan Section

This section is located 500m to the south of the Dokan dam on the right side of the paved road that leads to Koyia and Arbil cities at the intersection of N latitude 35° 56' 57.43" and E longitude 45° 56' 54.38". The glauconite beds are exposed along the road cut and are about 1.5m thick (Fig.1.3, 1.4, 1.7, 1.8, and 1.9).

1.4.3- Qamchuqa Gorge Section

Qamchuqa Gorge section: it is located at 10 km to the west of Surdash village, directly to the northwest of the previous Qamchuqa village (now transferred to near Dokan town). The section is exposed along the left side of outlet of Qamchuqa gorge. It is at Latitude 35˚ 53' 50" and Longitude 45˚ 01' 48".(Fig. 1.3 and 1.5).

1.4.4- Safeen Section

This Section is located Southwestern Shaqlawa Town, and Northwestern of Qalasinja Big Village, at Latitude 36˚22' 24" and longitudinal 44˚18' 25" (Fig. 1.3 and 1.10).

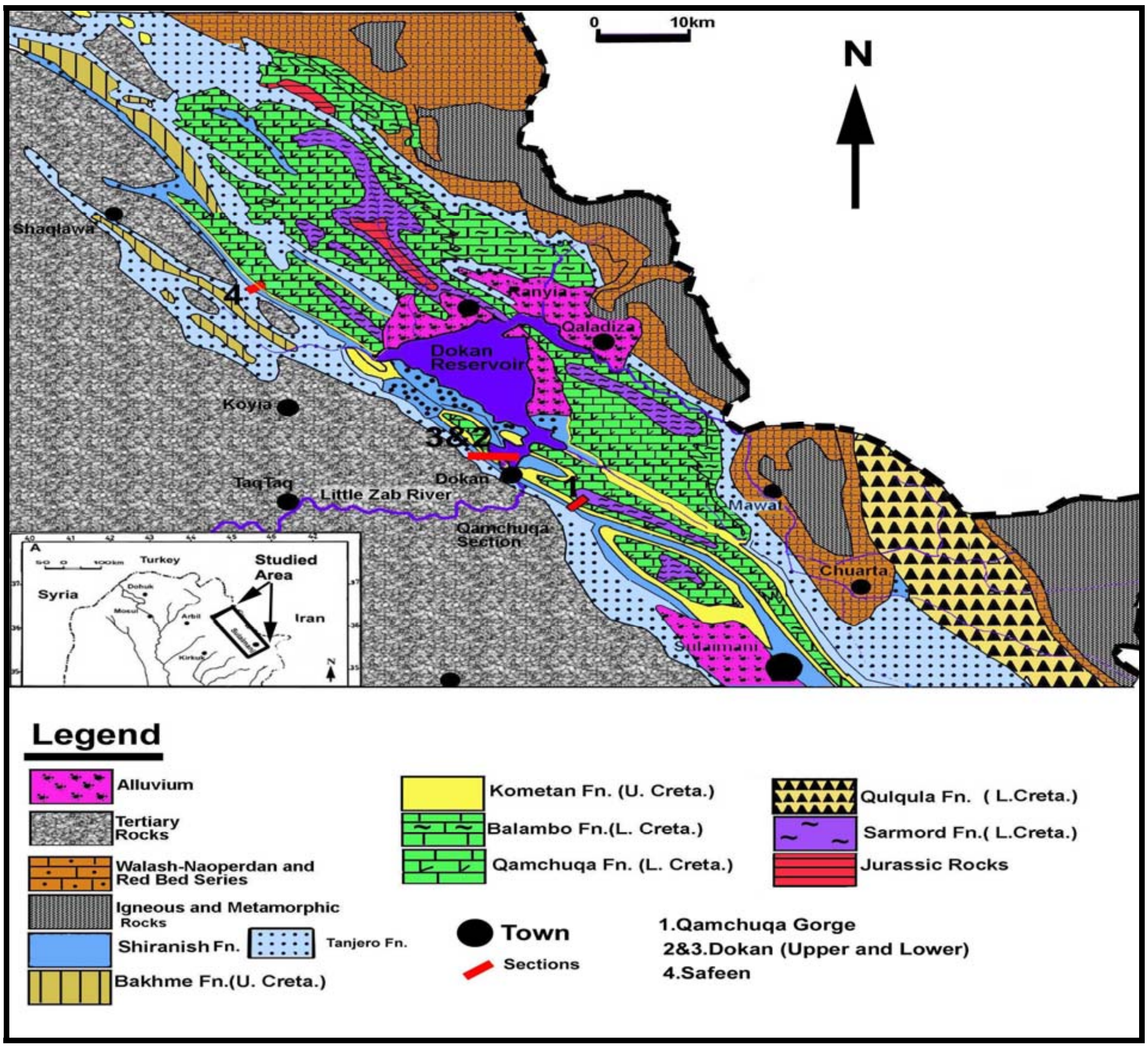

Fig. 1.3: Geological map of the studied area and sections (Modified from Sissakian, 2000).

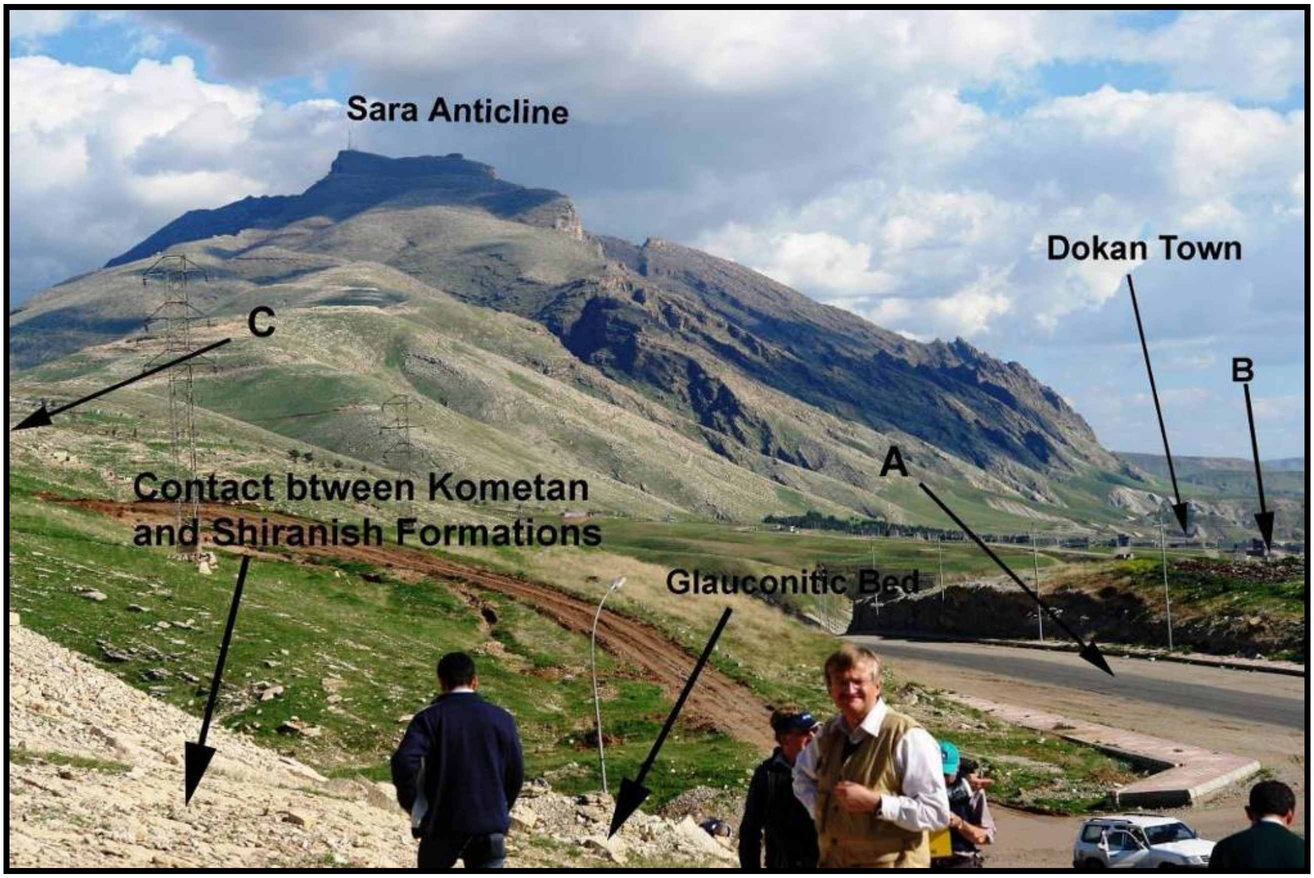

Fig.1. 4: Northwestern Plunge of Sara Anticline: A) Sulaimaniya-Erbil main road, B) Little Zab River, C) Dokan dam site. All smooth light color surfaces are covered by Kometan Formation.

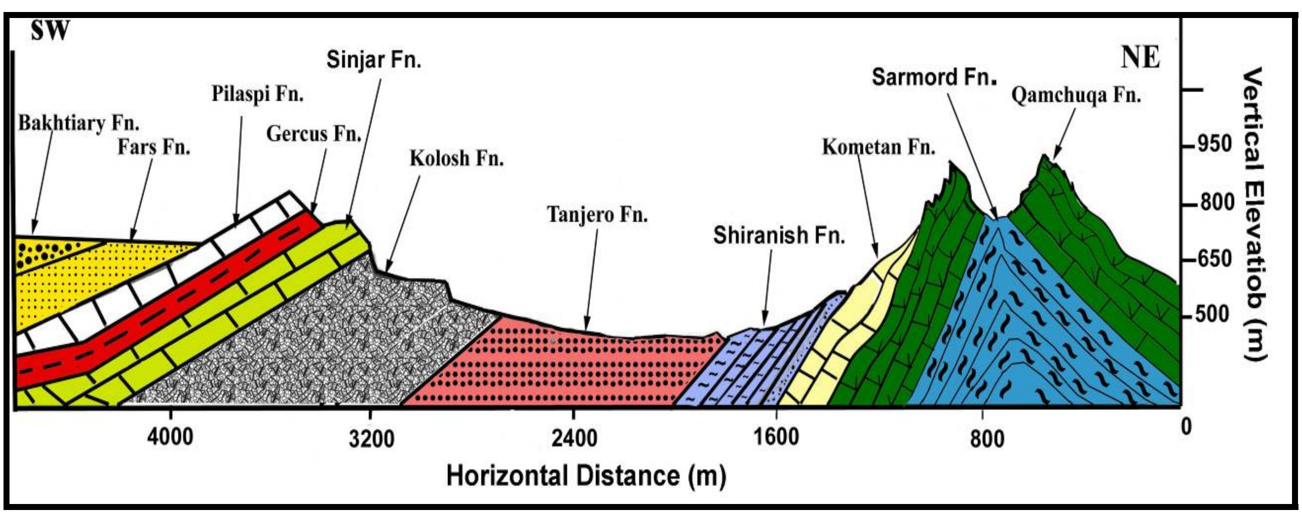

Fig.1.5: Geological cross section of left side of the Qamchuqa Gorge.

Fig.1.6: Lower Dokan section showing the boundary between the studied formations.

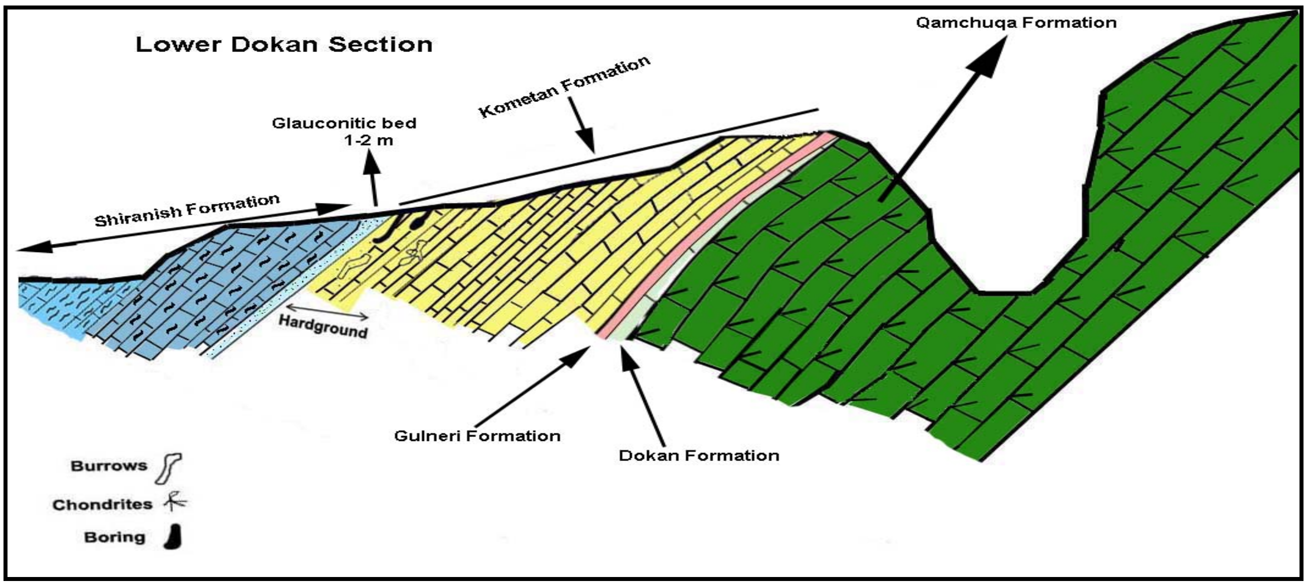

Fig. 1.7: Contact between Kometan and Shiranish Formations in the Dokan sections.

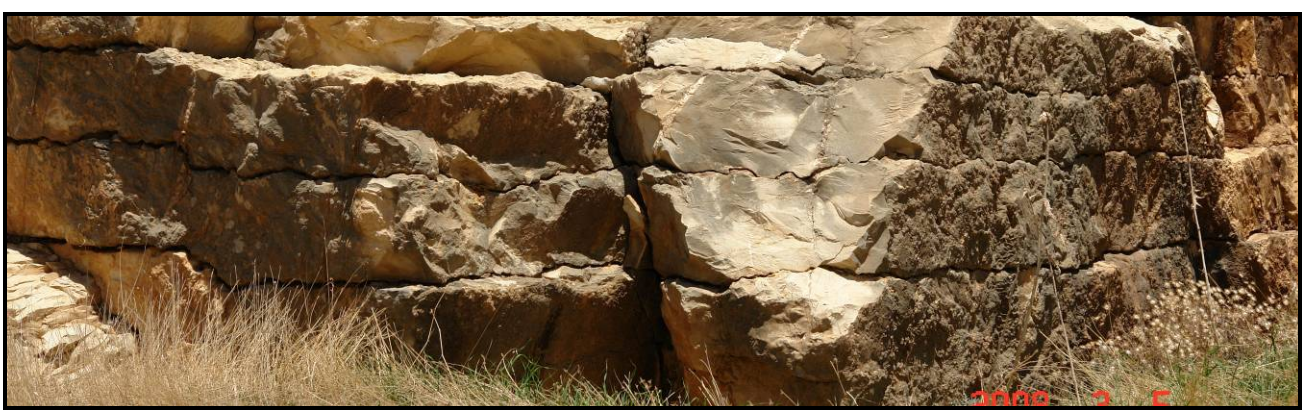

Fig.1.8: Typical bedding thickness of Kometan Formation in Dokan area, the beds are separated by well developed stylolites (coincide with depositional bedding surfaces).

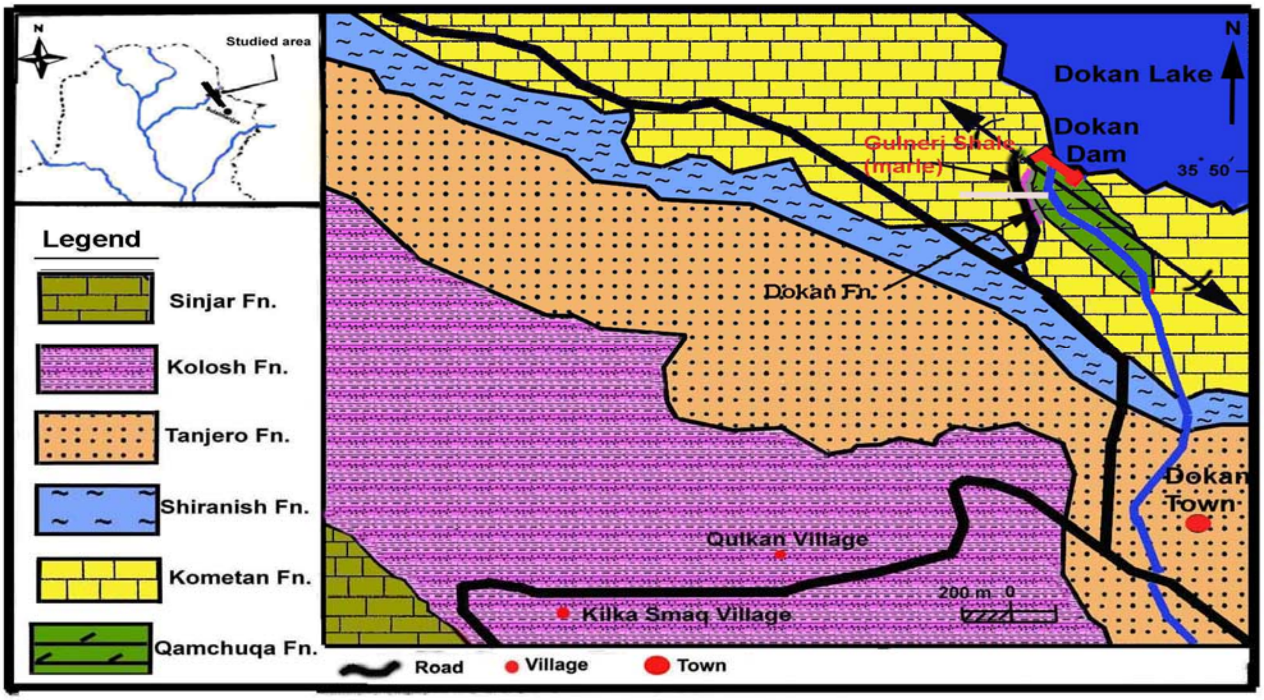

Fig.1.9: Simplified geological map of the studied area lower Dokan and Upper Dokan sections (Modified from Sissakian, 2000).

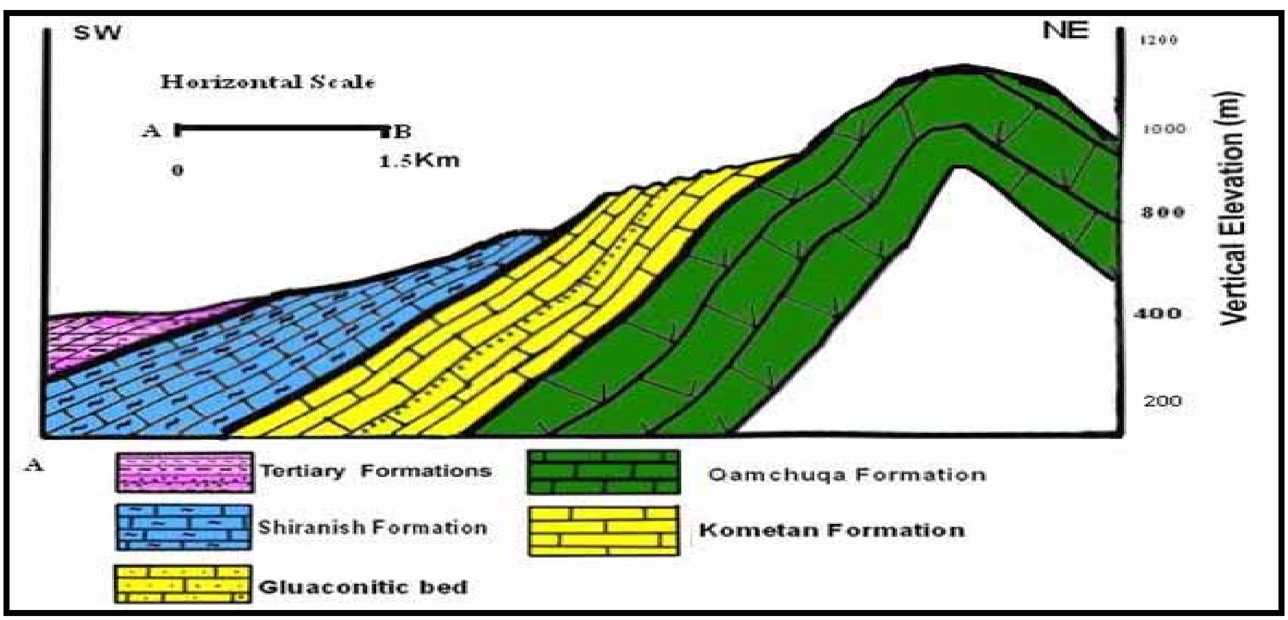

Fig.1.10: Geologic cross section of the southwestern limb of Safeen anticline section where the related section is taken.

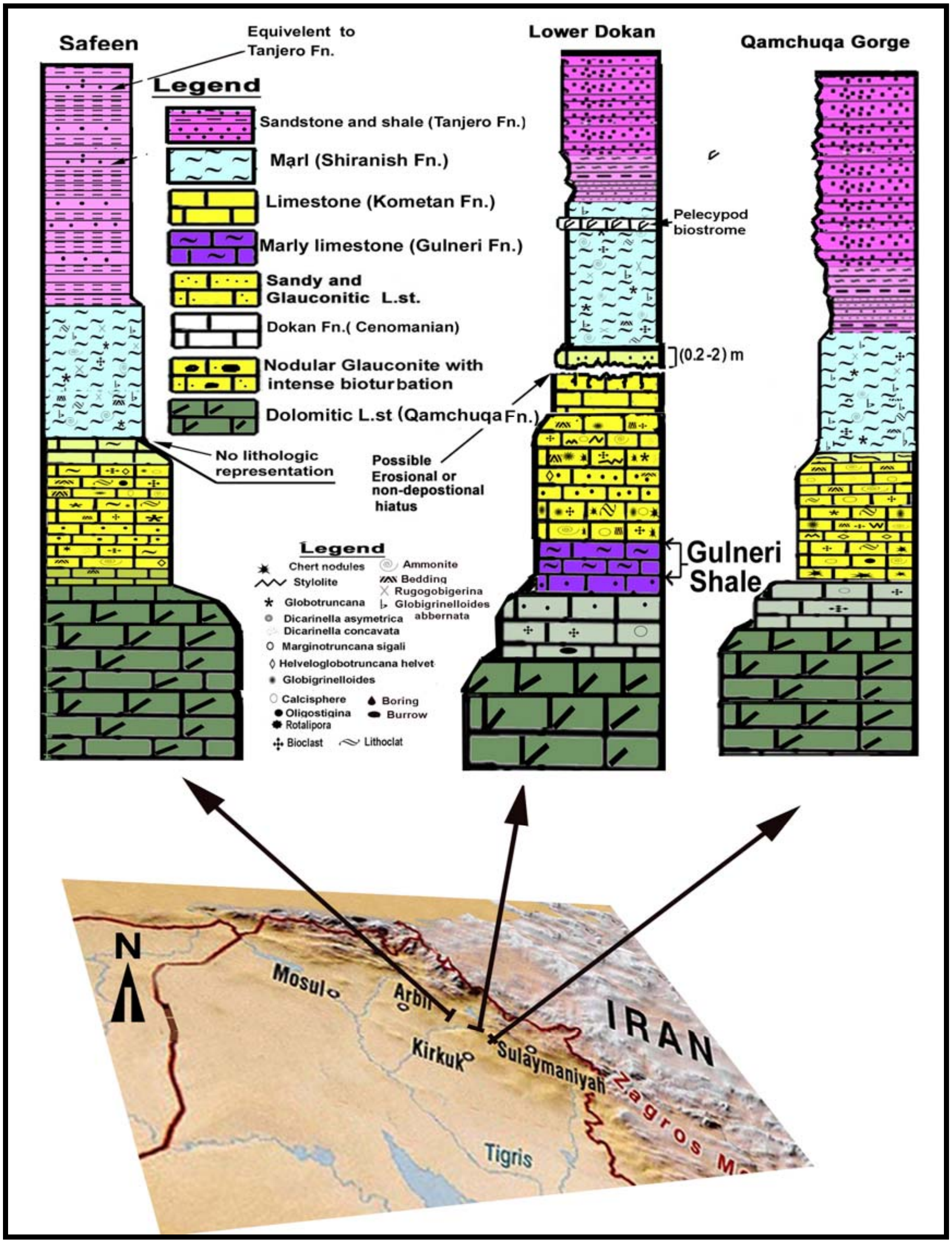

Fig.1.11: Stratigraphic column of the three studied outcrop sections and their location on simplified map of the northern Iraq.

1.5-Aim of the study

The main objective of this work is to study environment, tectonic and boundary conditions of the Cenomanian-Campanian rocks which is represented by Dokan, Gulneri, Kometan and Shiranish Formations through detail sedimentological study of the formations. Other aims of the study are as follow:

1.Description and analyzing of different constituents and lithofacies of the formations in order to establish the depositional environment and basin development to interpret different depositional processes with stratigraphy and sedimentological history of these sediments.

2. To establish the relation between formation with both underlying and overlying formations, in addition to laterally facial changes.

3- Study of the relation of the environment of each formation with tectonic development and depositional history of the Zagros Fold-Thrust belt and compare the results to the previous study.

1.6- Methodology

To achieve the aims of this study, the following works are conducted:

1- Detailed field study of the outcrops to get a general view of the distribution, lithological changes in addition to vertical (stratigraphic) and geographic (lateral) lithofacial changes. Indication of most suitable sections for sampling.

2. Study of about 100 thin sections of the collected samples of all outcrops of area and description of the sections.

3-Thin section study under binocular and polarizer microscopes for differentiation of the constituents and photographing the most useful samples. Some samples are studied under fluorescent microscopes for identifying organic materials.

4-Calculating percentage of the constituents (for identification of facies and rock types) by using point counter. The method of Flugel, (2004, in: Betzer, et al., 2005) is used for point counting in which void with in particles are counted as constituent of the particles. In the slides and samples that contain few allochems the visual estimation by using the charts prepared by Folk et al., (1970) and Tucker (1989).

5- The Samples were digested by dilute HCl from fresh outcrops for identifying insoluble residue.

6- Few samples are prepared for nano-fossils study for age determination in University of Mari Curie, Paris.

1.7- Previous Work

According to Bellen et al., (1959), Shiranish Formation is first defined and described by Henson in 1940. He selected the type section at Shiranish Islam village north eastern of

Zakho. Owen and Nasr, 1958, in Bellen et al., (op. cit.) has described briefly the distribution, age, lithology , fossil content and stratigraphy of the formation in addition to surface distribution at different localities in northern Iraq. Abdel-Kireem, (1983) has studied the paleoecology and bathymetry of the foraminiferal assemblages of the Shiranish Formation in the Dokan region. He assigned it as one of the most widespread units of the Campanian-Maastrichtian transgressive cycle in Iraq. Abawi and Abdel-Kireem, (1982) studied the biostratigraphy of Shiranish formation Sulaimania-Dokan region, northeastern Iraq.

Kometan Formation is first described by (Dunnington, 1953 in Bellen et al., 1959); who selected the type section which is located at 400 meter to the west of Kometan village in Naudasht valley at the foot hill of Qandil mountain about 20 km to the north of Ranyia town in the Imbricated Zone. It is exposed in Thrust; High and Low Folded Zones with recording in the Mesopotamian zone also (Dunnington, 1958, Buday, 1980, Buday and Jassim, 1987). Sediments of Kometan Formation were deposited in different environments ranging from shallow shelf, restricted oligosteginal facies to open marine globigerina facies (Jassim and Goff, 2006).

Karim et al (2001) had studied the contact between Kometan and Shiranish Formations (Late Cretaceous) in the view of paleoecology and sedimentology from Dokan area in which many stratigraphic features that are indicating hardground are found which are represented by glauconite-filled boring and omission surface (Fig.1.12). They indicated, under the effect of previous studies, unconformable contact between the two formations. But Karim et al (2008) amended the contact to conformable one between Kometan and Shiranish Formation in Dokan, Chuarta and Qandil areas and established a conceptual model to show the tectonic and paleogeographic setting of the contact during Early Campanian.

Four Biostratigraphic foraminifera zones: *Globotruncana renzi-Glt. sigali* Zone, *Glt.concavata* Zone, *Glt. fornicata* Zone, and *Glt. fornicata-Glt.elevata-Glt.stuartiformis* Assemblage Zone have been distinguished. According to these Zones Kometan Formation, aged the late Turonian-Early Campanian in Northern Iraq (Al-Jassim, Al-Sheikhly and Al-Tememmy, 1989). Five new species of benthonic Foraminfera, *Spiroplectammina sayyabi, S. rectangularis, Gaudryinella kometanesis, G. triquadratus and Osangularia abnormis* have been described; they are from the Upper Turonian-Lower Campanian Kometan Formation of Northern Iraq (Al-Jassm, Al-Sheikhly and Al-Tememmy, 1989).

Gulneri Formation was first described by Lancaster Jones in 1957 from the site of Dokan dam in the high folded zone, where it consist of about 2 meter of black, bituminous, finely laminated, calcareous, shale with some glauconitic and cellophane in the lower part (Bellen et al., 1959). Abawi and Hammond, 1997 studied the foraminifera biostratigraphy of the Gulneri Formation in Kirkuk area and assigned it to Late Turonian age.

The Gulneri Formation is separated by unconformities with both the underlying Dokan and the overlying Kometan Formations (Bellen, 1959, Buday, 1980, Jassim and Buday, 2006, Rund *et al,* 2006). Dokan limestone Formation was first described by Lancaster Jones in 1957 in Bellen et al., 1959. The type located is on the site of Dokan Dam.

Abawi, et al., (2006) studied the foraminifer biostratigraphy of the Gulneri Formation in Dokan area and assigned it to Early Turonian age. Safeen Anticline one of the long and high mountains in the area and stratigraphically, ten geological Formations are exposed in this anticline, these Formation range in age from late Cretaceous (Bekhme, and Shiranish Formation) to Paleogene (Kolosh, Khurmala and Gercus Formations), the lower contact of the Shiranish Formation with the underlying Bekhme Formation is conformable in the field. However, occasionally glauconite occurs at the lower contact in some localities marking an unconformity surface (Al-Amire, 2005). Al-Khafaf, 2005 studied foraminifera biozonation of Kometan Formation (Upper Cretaceous) in Dokan–Endezah area Northeastern Iraq, he suggest (Middle Turonian-Early Campanian) age for the Kometan Formation

The expected age for Gulneri Formation in Dokan area is Cenomanian –Turonian age, and it depends mainly on the two species of Pollen grains (*Ephedripites ambonoides and Ephedripites zaklinskaie*). By studding of the Dinoflagellates, Spores and Pollen), it seems that Dokan Formation is of Late Albian–Cenomanian age in the studied area (Sarraj, 2007).

Ameen and Karim (2008) studied the equivalent lithologies of Dokan, Gulneri and Kometan Formation in the Bekhme Gorge, Gail Zanta and Perse Anticline. They concluded that the lithologies, in the gorge, do not include conglomerate (unconformity), in contrast to previous studies. They farther discussed the evidences of the conformable nature of the contact between Qamchuqa and Bekhme Formations.

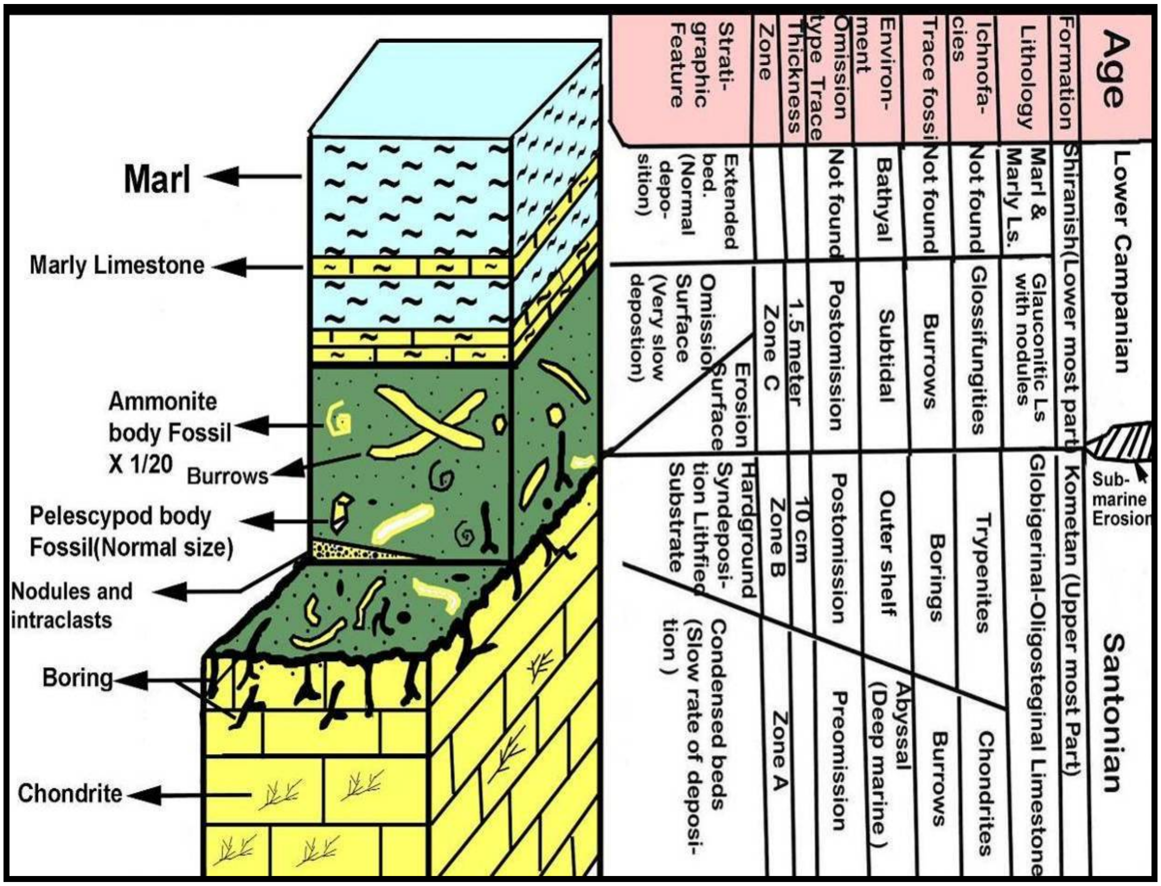

Fig.1.12: Stratigraphic column of boundary between Kometan and Shiranish Formations of Dokan area (Slightly modified from Karim *et al.,* 2001).

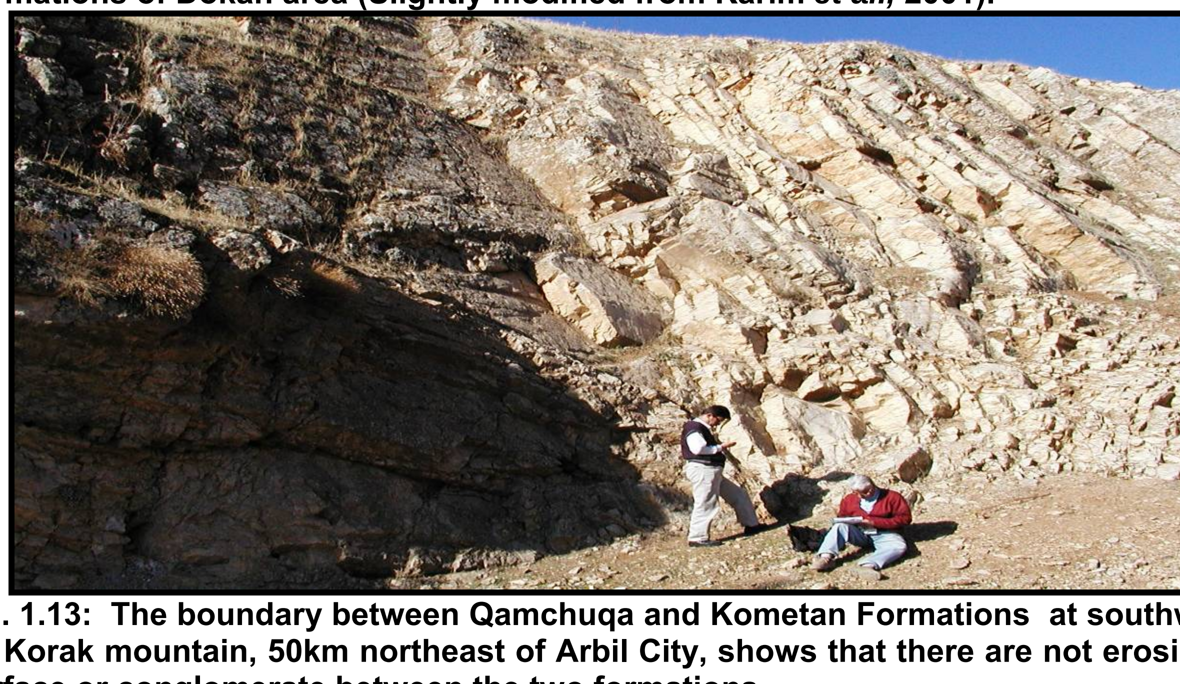

Fig. 1.13: The boundary between Qamchuqa and Kometan Formations at southwest of Korak mountain, 50km northeast of Arbil City, shows that there are not erosional surface or conglomerate between the two formations.

CHAPTER TWO

LITHOLOGY AND STRATIGRAPHY

2.1-Preface

This chapter deals with the detailed study of stratigraphy and lithology of the formations that are included in the study. The formations such as Dokan, Gulneri, Kometan and Shiranish Formations are mainly consisted of pelagic and hemipelagite limestones. According to Westphal and Munnecke (2003), the distribution of carbonate deposits is dependent on paleoenvironmental conditions such as temperature, salinity, and nutrient levels. These factors can be inferred easily in the fossiliferous successions but for the present formation which contain lesser fossils the establishment of the environment is difficult. The fossils are all planktonic (with few benthonic) foraminifras and little signs of currents and waves can be seen.

The study tries to survey and study all accessible outcrops. Four sections are selected as representation of the studied area which are so selective that give the most suitable and new data for the study. The field and thin sections studies are used to subdivide and correlate the rocks of the sections.

The vertical (time) and lateral (geographic) relationships between the formations themselves in one side and with underlying and overlying formations are deciphered by extensive field and laboratory studies. These relations as the boundary condition are extremely necessary for tectonic, environmental and paleogeographic modeling. The study of the contacts let the geologist to put the formation and neighboring units either in a one basin or in several basins by applying Walther Law as cited in Blatt *et al.,* (1980).This is also useful for tectonic consideration of the formation it's depositional basin during Late Cretaceous. The formations consist of white to grey well bedded limestone at the base and change to silicilclastic at the top.

2.2- Dokan Limestone Formation

According to (Bellen et al., 1959) first described by Lancaster Jones in 1957. They cited that the type locality is on the site of Dokan Dam in the High Folded Zone N-NW of Sulaimaniya NE Iraq. It is composed of four meters of light grey or white; white-weathering oligostigenal limestone, locally rubbly, with glauconitic coatings of constituents pebble-like masses. The lower contact of Dokan Formation with the Upper Qamchuqa Formation (or sometimes with Jawan Formation) is unconformable (Bellen, et al., 1959 and Buday, 1980, Fig.2.1). The presence of *Rotalipora cushmani* in Dokan Formation indicated the age of Late Cenomanian age (Al-Shdidi et al., 1995) which is equivalent to Rumaila Formation in middle and southern Iraq. Al-Juboury et al., (2006) mentioned that the Cemomanian age of the Dokan Formation in the northeast Iraq.

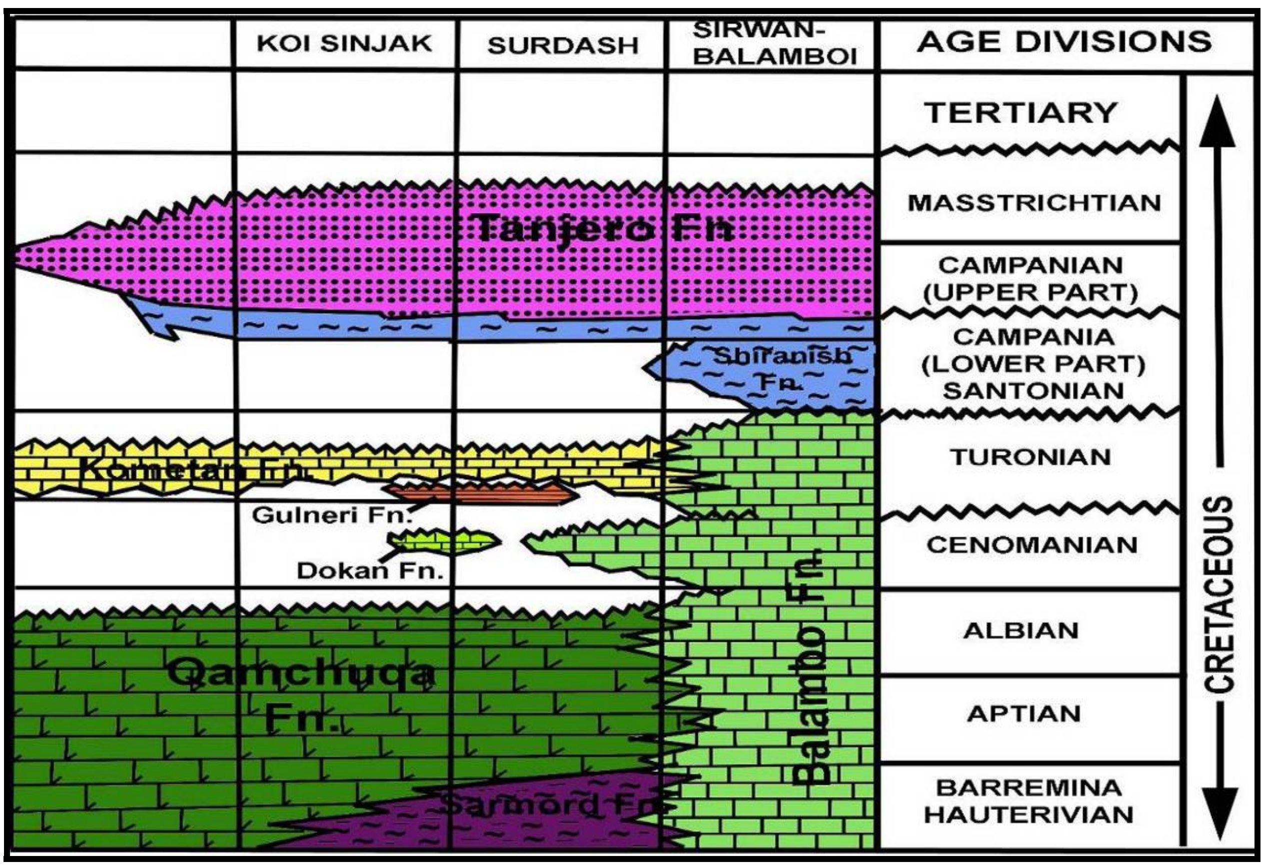

Fig.2.1: Time expanded stratigraphic column of the Late Cretaceous (Bellen, *et al.,* 1959) showing that both Dokan and Gulneri Formations are bounded by unconformably from all sides.

In the field, only at Dokan dam site and in fresh road that cut Dokan Formations can be identified. All attempts for recording in surrounding places such as Piramagroon, Sara, Daban, Qarasard, Kosrat and Safeen Anticlines are failed. Even, at the distance of a few hundred meters at the south and north of the dam site the formation can not be identified.

2.3- Nature of Contacts Dokan Formation with Qamchuqa Formation

As shown from above Cretaceous expanded stratigraphic column of Bellen et al., (1959), the contact of Dokan Formation are unconformable from all sides. This means that it is deposited in an isolated basin. From the column which appears that the contacts with Qamchuqa and Gulneri Shale formations are unconformable (Fig. 2.1).

But field study showed that no sign of major interruption in sedimentation which are shown by the above authors are occurred. This doesn't mean that there is no possible some marine erosion across the contact. This is because, in many cases shallow marine contain more or less current and wave erosion. In the contact neither conglomerate nor Karstification or paleosol are found. Even the color and stratification between the two formations show no too much differences as both consist of grey lithology and thick beds but that of Qamchuqa Formation are thicker (Fig.2.3).

It seems that the contact is conformable which is represented by transitional zone which shows gradual change of massive grey dolostone to thick beds of grey oligostiginal limestones. This is aided by citation of Sarraj (2007) who mentioned that Dokan Formation is about 20 meter thick. This increase in thickness from 4m to 20m is normal in the formations that have conformable contact due to the absence of very clear contrasts between the formations. The contact is indicated optionally according to personal estimation.

Evidence of conformability is the absence of missing age across the boundary as the Dokan formation is Late Cenomanian while Qamchuqa Formation is Cenomanian Buday (1980). Aqrawi (2008) has assigned the carbonate of Dokan Formation as the deposit of sub-basinal environment. This is very important for the present ideas which put the formation as transition between Qamchuqa (platform carbonate) and Kometan Formation (basinal carbonate). This is because the transition between Platform and basinal is the subbasinal environment. This is reflected by bedding and type of planktonic forams.

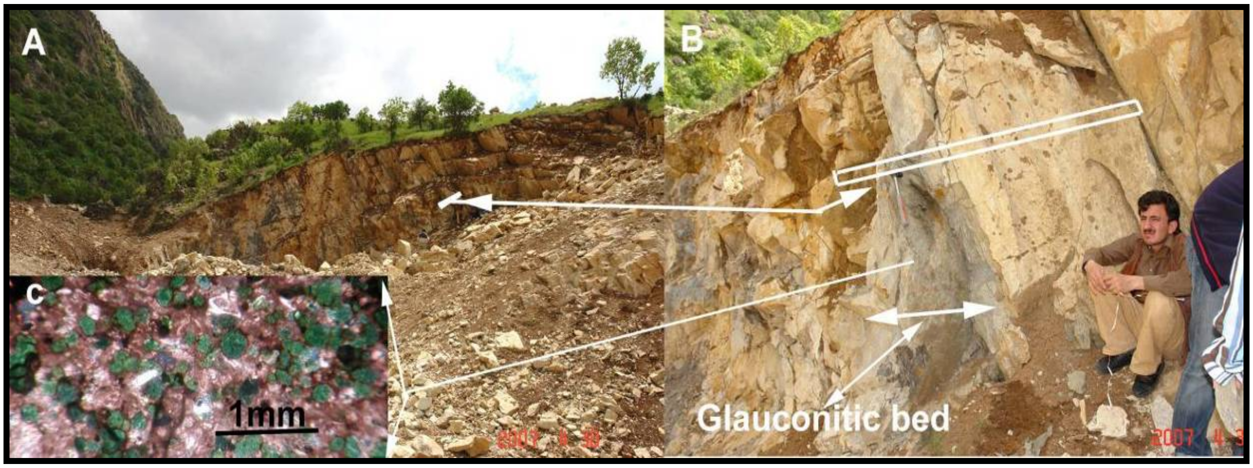

Fig.2.2: A and B: Big Qalay Senje section showing the occurrence of the glauconitic limestone bed at the lower part of Kometan Formation. C: Thin section photo of the bed.

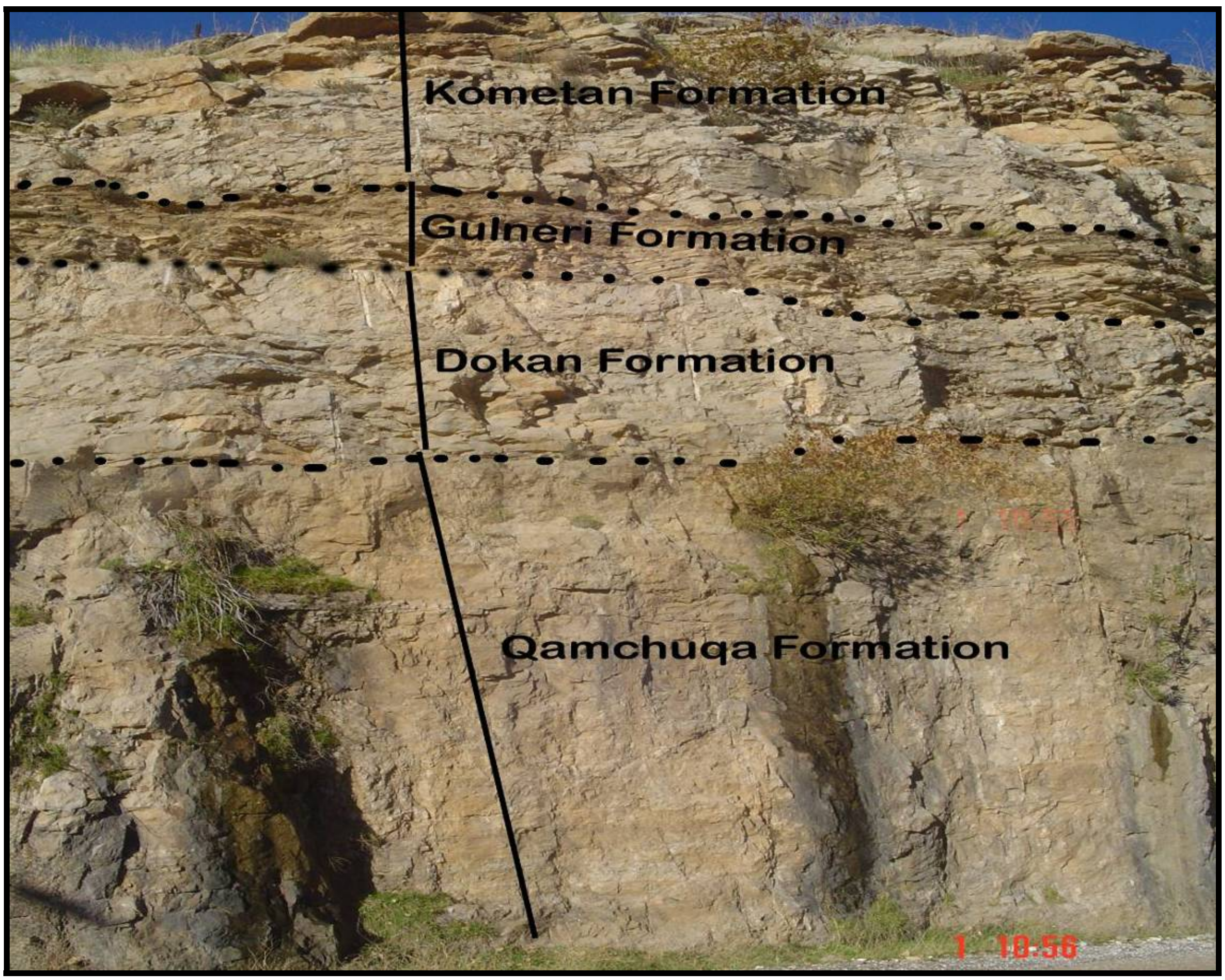

Fig.2.3: Road cut cliff about 15m high, directly to the south of Dokan Dam showing the studied formations.

2.4-The Gulneri Shale Formation

This formation was first described by Lancaster Jones in 1957 from the site of Dokan Dam in the High Folded Zone, where it consists of about 2m of black, bituminous, finely laminated, calcareous shale with some glauconite and cellophane in the lower part. The age of the formation is Early Turonian (Bellen et al., 1959). They also cited that in some reports of Dokan Dam it is mentioned as Shiranish Shale.

The high bitumen content and dwarfed fossils indicate that the formation was deposited in a euxinic environment (Jassim and Goff, 2006). The formation is separated by unconformities with both the underlying Dokan and the overlying Kometan Formations (Buday, 1980). According to Abawi et al., (2006) eight planktonic and six benthonic foraminiferal species were recorded from the type section of Gulneri Formation at the site of Dokan Dam, Dokan area indicates an Early Turonian age as seen in (Fig.2.16). the distribution of the formation is almost unknown. It is cropping out around the type area and was struck in the borehole Kirkuk 116 on the Avanah dome.

Fossils were found relatively rich. The assemblage are composed of *Rotalipora* cf. *apenninca, Globotruncana* Helvetica, minute *Globigerinide, Gumbellinids*, fish detritus, small *bicarinate Globotruncana,* etc., Bellen et al., 1959. P.122. According to the evaluation of the fossils the age of the formation is Early Turonian (Buday, 1980).

The Late Cretaceous subsurface sections in the Kirkuk well No.117 and Jambur well No. 13) has been studied micropaleontologically by Abawi and Hammoudi (1997). They included Gulneri Formation in the Lower part of the *Marginotruncana sigali* Zone of Late Turonain age and Kometan Formation in the upper part of the *Marginotruncana sigali*, the *Dicarinella* primitive, the *Dicarinella concavata*, the Rosita formicate and the *Globotruncaita elevate* Zones which range in age from Late Turonian to early Campanian a local unconformity separates the two formations from each other (Fig. 2.14 and 2.16).

Out the dam site, the formation disappear and change to thin bedded limestone or marly limestone such as Tabeen Gorge and both side of Qarasard anticline at northeast and east of the dam respectively (Fig.2.3 and 2.6). During fieldwork, the contacts of the formation with both underlying and overlying formations are accurately inspected.

2.5- Nature of Gulneri contracts

Bellen, et al., (1959) mentioned that unconformable contact with Dokan Formation at the dam site was represented by the occurrence of micro-conglomerate. According to

Buday (1980), locally around Dokan area and in I.P.C. Well No.116, a thin and bituminous shale unit of Early Turonian age is bounded at the top and bottom by erosional unconformities. This shale intervenes between the Kometan and the Cenomanian oligostegina limestone unit. The Cenomanian oligosteginal unit is defined as the Dokan limestone and the thin Turonian shale recognized in the nomenclature as the Gulneri shale. He added that they were perhaps preserving from Early Turonian erosion only in slight depressions in the erosion surface, which terminates the Qamchuqa Formation.

In this study, the unconformable boundary is not ascertained, as neither conglomerate or Karstification and paleosol are found when the type section and surrounding areas are inspected. This formation contains, in one place of dam site, boulders and gravels-like limestone masses. These masses have hummocky smooth surface and bounded by highly deformed dark color shale–like materials (Fig. 2.4). The masses have low sphericity and roundness which are not associated with terrigenous or intraformational sand-sized lithoclast or bioclasts. Therefore, these masses are most possibly assigned previously as conglomerate by Bellen (1959) and Buday (1980). But in our estimate they are nothing except ball and pillow-like structure which formed by pressure. The origins of these structures are discussed in detail by Karim (2004) which found in competent and incompetent beds. Read (1985, p.15 and Einsele, 2000, p.143) mentioned that the nodular shaly limestone is formed on the carbonate platform during drowning. This is applicable for Gulneri Shale Formation because as discussed later, it represent the sediment of drowning phase which meaning deepening not uplifting and erosion as interpreted by Bellen *et al.,*(1959) and Buday(1980).

These masses to have prerequisites of conglomerate must be associated with terrigenous or intraformational sand and bioclastic grains. The recent age determination does not refer to gaps in sedimentations as Al-Shdidi et al., (1995) indicated Late Cenomanian age of Dokan Formation while the age of Gulneri Formation is Early Turonian as recorded by Abawi et al., (2006). The recording of deepwater planktonic foraminifera, by later author, emphasizes the absence of unconformity. The slightly sharp contacts of Upper and Lower contact is observed in only one locality (Fig.2.3) in the other localities around Dokan dam site, the contact is gradational. According to these facts, the boundary of the Gulneri Shale Formation has not suffered from uplift and subaerial erosion. This study tend not to refuse the submarine erosion which most possibly occurred during drowning of the Qamchuqa and Dokan Formation which later discussed in detail in the section (4.9).

It is possible that the slight sharp contact with both underlying and overlying formations is argued as unconformable by some ones. If it is true it make unsolvable problem because many formations contain several beds or packages of beds that bounded by sharp contact. These formations are such as Lower Fars, Upper Fars, Kolosh, Khurmala and Tanjero Formations. The sharp contact may be generated by short duration of tsunami, hurricane, typhoon, storm and submarine current.

Tucker (1991, p.129) mentioned that many gradational beds boundaries, may become sharp especially when limestone passing up into mud rocks. He added that in many limestone platforms, the bedding plane is not primary depositional surfaces but they have been produced by pressure solution during burial. These are may be true for the boundary of the Gulneri Formation and boundary between Dokan and Qamchuqa Formations.

Fig.2.4: Close up photos of the Gulneri Formation shows boulder and gravel-like masses of limestone. These masses are associated with marl but not contain sand size and bioclasts grains.

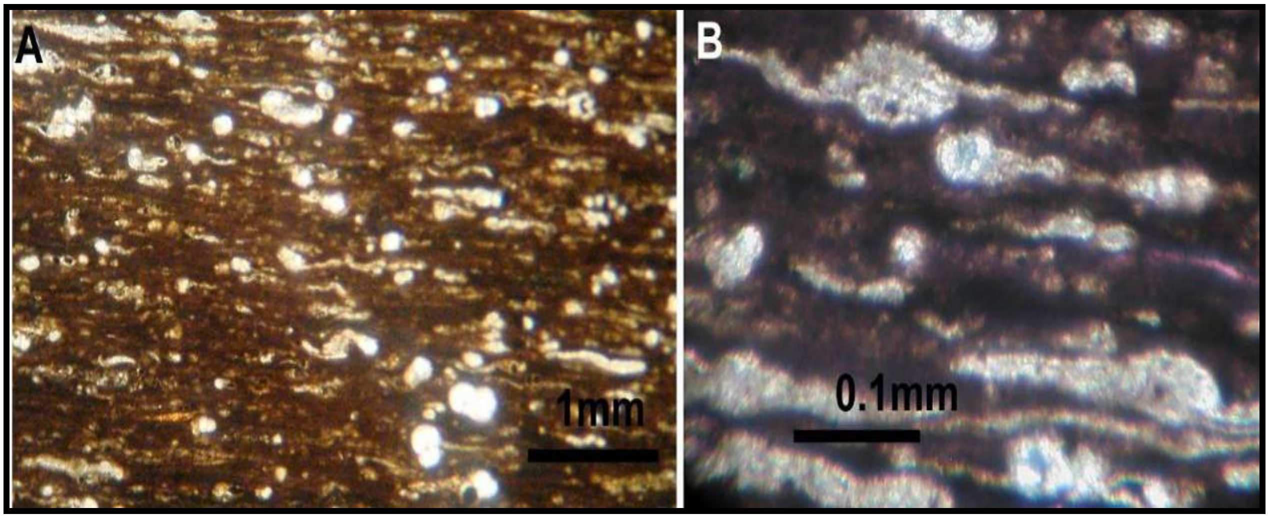

Fig.2.5: Two thin section photos showing intense effect pressure on the marly limestone by which the planktonic forams are flattened and arranged it parallels to bedding plane.

2.6- Kometan Formation

Late Cretaceous Kometan Formation is extensively exposed along both limbs and plunge areas of some major anticlines of northeastern Iraq, such as: Piramagroon, Sara, Daban, Azmir and Goizha, Kosrat, Anticlines. According to Buday (1980), this formation was first described by Dunnington, 1953 at Kometan village near Endezah at the contact between the Imbricated and High Folded Zones. It consist of 50 to 127m white weathering, light gray thin to thick-bedded limestone. Karim (2004) attributed the formation to the transgressive system tract of Late Cretaceous.

Thin section study under polarizing microscopes shows fine grain texture with many planktonic forams, including mainly Oligosteginal and *Globigerina species*. In the areas a around Dokan Dam site where the northwestern plunge of Sara Anticline is dissected by Little Zab River the formation contains spectacular large size and high frequent chert nodules occur with large–scale stylolite in the Kometan Formation(Figs.2.9 and 2.23).

The most important record of the present study is finding the occurrence of about 45m of white bedded fine grain limestone succession around Safeen anticline, especially at the northeast of Qalai Sinje village (Fig.2.10). The forams content showed that these beds belong to both Dokan and Kometan formations (A. M. Khafoor: personal communication) has studied the thin section of succession and proved, by biozonation, that both formations at this locality where previously not observed by Bellen (1958), Buday (1980), Sissakian and Youkhana (1984), Al-Qaradaghy(1989), in contrast they mentioned occurrence of Bekhme in this area.

Omar (2006) has included the succession in Shiranish Formation. It is worth to mention that Kometan Formation in this area, in general, has the same color, bedding thickness and lithology of Kometan Formation in type locality and Dokan area (Fig.2.10). The importance of this finding is that the Kometan is overlying the massive dolostone beds that are previously called “Bekhme Formation” by the above mentioned authors. Therefore, the previously mentioned Bekhme does not exist around Safeen anticline.

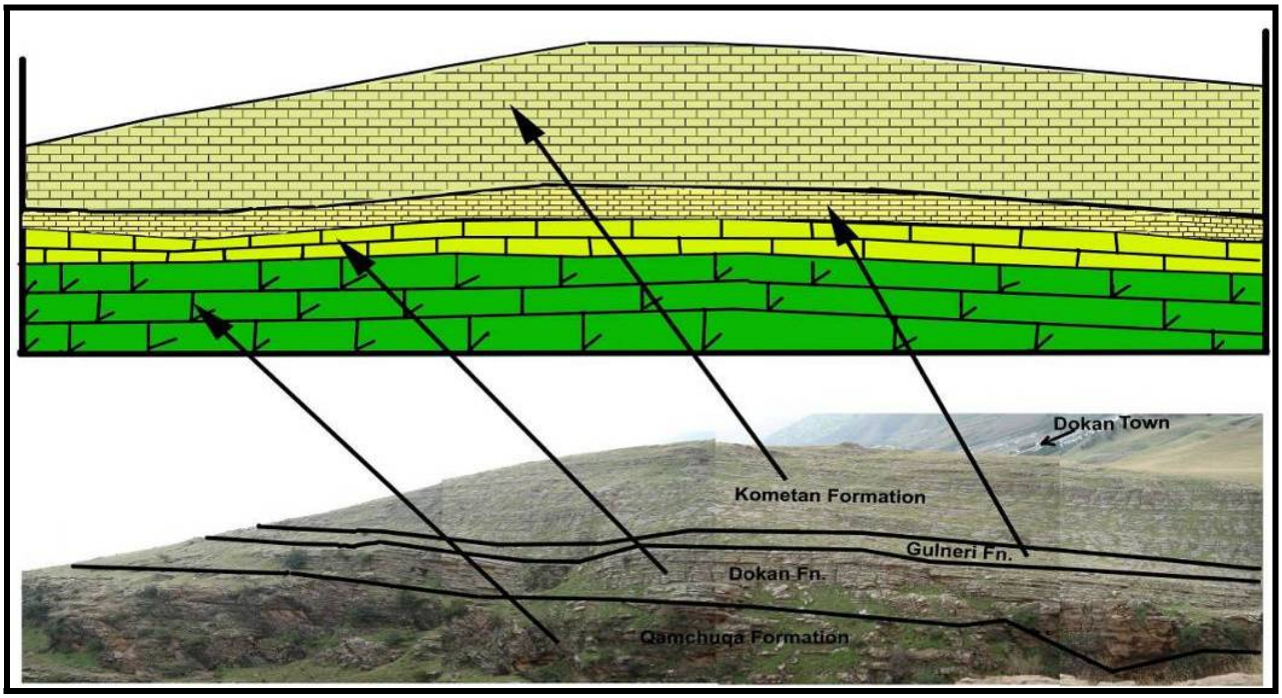

Fig.2.6: The Dokan and Gulneri Formations are laterally disappear in the surrounding of their type section, but their equivalent yet can be found in the Buko Zawa Gorge, three kms northwest Dokan Dam site.

2.7- Nature of the Kometan boundaries

The lower and upper contacts of the Kometan Formation are unconformable (Dunnington, 1953 in Bellen et al, 1959, Buday, 1980). At the types area, the first author mentioned that the upper contact is unconformable but without angular discordance. He further added that faunal and intense glauconite deposition; indicate depositional hiatus and probable erosion. In this contact, in addition to glauconite and faunal break he found polygenetic micropebbles. As mentioned in the later section, the upper boundary of Gulneri Shale Formation, with Kometan Formation, is conformable in most places while one of the localities show more or less sharp contact across, which marl or marly limestone changes to limestone.

Karim et al., (2002), in their study of the trace fossils in the contacts of the two formations, mentioned unconformable contact of the boundary. Later Karim et al. (2008) amended the Kometan with Shiranish Formation into conformable one. They studied the contact at seven different sections in Sulaimanyia area. They did not find conglomerate and subaerial erosional surface as cited before by Bellen et al (1959) and Buday (1980). Therefore, they inferred that the contact is conformable except in two sections (Upper and Lower Dokan) where there are little submarine erosion or slow rate of deposition that are represented by glauconite and rip-up clasts of intraformational origin (Fig.2.7). In the present study, this contact has been re-studied in the field and lab to record further evidences about the contact as come below.

During fieldwork around Safeen anticline (northeast of Arbil city), a glauconite bed, about 20cm thick, is found near the middle of Kometan Formation. While it's upper contact with Shiranish Formation contain no glauconite or erosional surface. This proves further that the glauconite is not necessary to be exist in the boundary of the Kometan Formation but it can occur everywhere when the environment is suitable for generation of glauconite. This is observed also inside Shiranish Formation by Karim et al (2008), whom found at 8km north of Sulaimanyia city glauconite beds inside the formation not at the boundary with Kometan Formation. In this study a bed (1m thick) of glauconitic limestone is found in Chaq Chaq valley inside Shiranish Formation about 15m above the contact with Kometan Formation (Fig.2.15). In literature, Vail, et al (1977), Loutit et al (1988), Haq, (1991) Emery and Myers (1996) glauconite is deposited during maximum flooding (deepening) and the top of glauconite layer is called "maximum flooding surface". They cited that this layer is formed by slow rate of sedimentation which makes condensed section. Therefore, the unconformity, such as that indicated by Bellen et al (1959) is not ascertained in the present study.

Another evidence for absence of polygenetic micropebbles (which mean terrestrial origin) is the occurrence of pebble-like green chert nodule in side glauconitic limestone at Dokan dam site which has the following properties. First, the nodules have thin green coating (or brown in case of oxidation) formed by glauconitzation which are similar, in shape and distribution to those that discussed in detail by Al-Barzinjy (2008) in Kometan

Formation in Dokan area. This author attributed their origin to diagenetic process by replacement of carbonate by silica during burial under high lithostatic pressure.

In the present study and in accordance to the ideas of Al-Barzinjy (op. cit) many transitional grains are found that partially changed to silica which initially they have internal white color while during increase of the silica and progress of chertification, the color gradually change to dark color. Other evidence is that Karim et al. (2001) found hardground directly below the claimed conglomerate in Dokan section 2km south of the dame site. This contact is associated boring, burrows and glauconite development. As mentioned by Einsele (2000), Schlager (1998) hardground is developed during drowning in deepwater.

Another point that shows diagenetic origin is that the claimed “micropebbles” show no sign of current and wave accumulation, roundness, grading and orientation of axes (Fig.2.7). In some case they show a vertical arrangement of the clamed “micropebbles” on the bedding plain which is hydraulically the most unstable condition for grain resting on bedding plain (Fig.2.8). These grains are very similar to chert nodules that are very abundant in Dokan area and discussed by Al-Barzinjy (2008). They claimed that micropebbles mostly flattened and in some cases they have digitations and branching (Fig.2.8). Another evidence which has been founded newly of two sections, in Dolla Root valley, 4km northwest of Sulaimani city, in which the contact between Shiranish Formation and Kometan Formations are clearly gradational without erosional surface, paleosol, conglomerate and glauconite (Fig.2.11). In this locality, a sample from the contact is selected and sends to Mari Cure University, France for Nano-fossils age determination. According to Dr. Carla Muller (Mari Curie Nanofossils expert the samples has the age of Middle Campanian. This is regarded as the first record of the sediment this age in the Northeastern Iraq paleontologically. This is important because it further prove the conformable contact between Shiranish Formation and Kometan Formation that indicated by Karim *et al* (2008) sedimentologically.

The above discussion for the interpretation of gradational contact is supported by the study of Al-Khafaf (2005) who has studied the biostratigraphy of Kometan Formation in Sulaimanyia area in two sections, including Lower Dokan section of the present study. He concluded that the age of Kometan Formation is Middle Turonian−Early Campanian. He also recorded the *Globotruncana ventricosa* index fossil of Middle Campanian that overlying *Glotrancanita elevata* Zone (Lower Campanian) inside Shiranish Formation. In his two biozonation charts no gap can be seen from Turonian to Middle Campanian (Figs. 2.12 and 2.13).

Al–Jassim *et al.* (1989) have conducted biozonation of Kirkuk Well No. 166 and Qarachuq Well No.1. They record neither unconformity nor gaps in sedimentation from Turonian to Middle Campanian (Fig.2.14). Before these two latter study, the age of Kometan Formation was indicated as Turonian−Santonian by Buday (1980, p.174). Ameen (2008) mentioned that the contact between Kometan and Qamchuqa Formations are a transition zone in Qamchuqa Gorge.

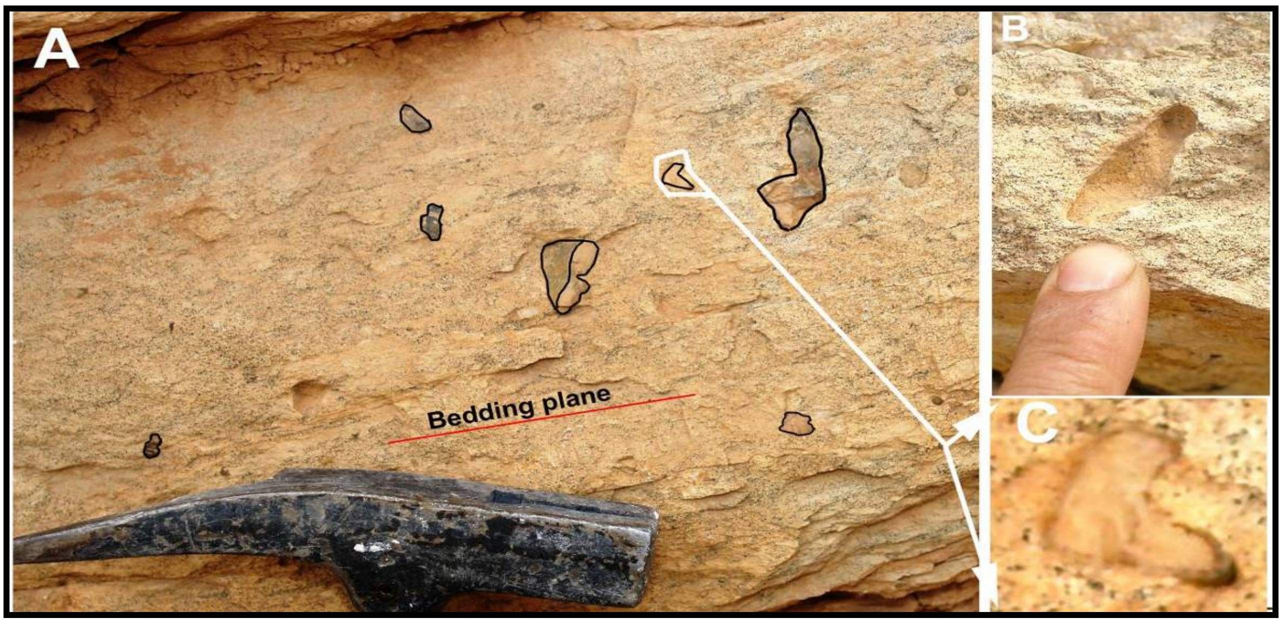

Fig. 2.7: Three photos of the nodules (previous micropebbles of Bellen et al, 1959) in the glauconitic limestone at the contact between Kometan and Shiranish Formation. Most of the nodules are elongate and erected perpendicularly to the bedding plane proving that they are not depositional (see the next figure for compression with chert nodules in Kometan Formation).

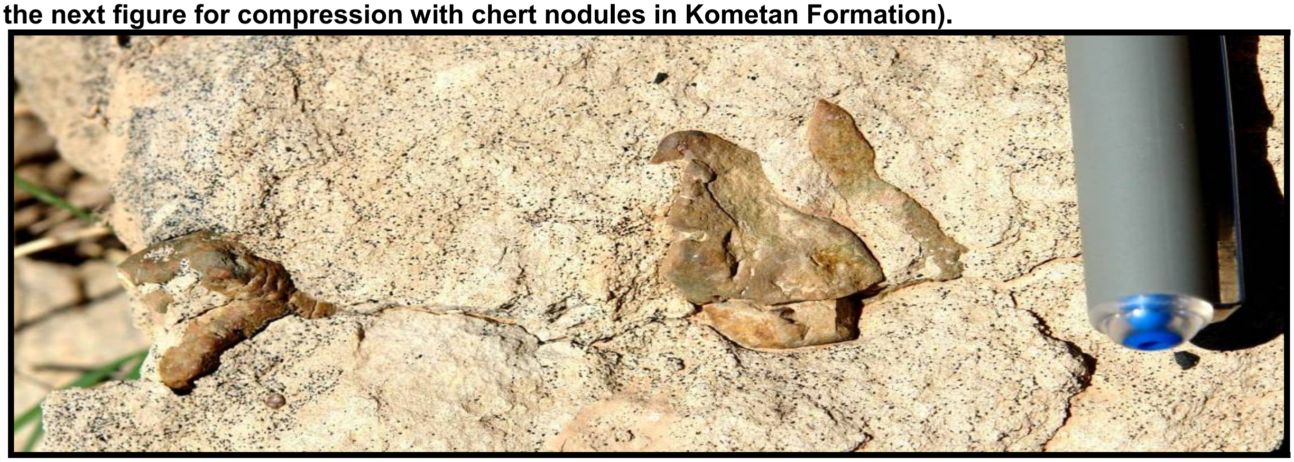

Fig.2.8: A photos of the flattened nodules (previous micropebbles of Bellen *et al,* 1959) in the glauconitic limestone at the contact between Kometan and Shiranish Formation.

Fig.2.9: A and B: Chert nodules in the Kometan Formation, most of the nodules are elongate and erected perpendicularly to the bedding plane proving that they are not depositional which can be compared with the previous figure.

Fig.2.10: Contact between Kometan and Shiranish Formation in the Safeen section no glauconitic contact or erosional surfaces (A, B, and C) square area is representing the contact, glauconitic beds in lower part of the Kometan Formation .

Fig. 2.11: Two photos of the flattened and elongate nodules (previous micropebbles of Bellen *et al,* 1959) which sporadically spread in the glauconitic limestone and coated with lamina of green color material (glauconite) at the contact between Kometan and Shiranish Formations.

Age			Planktonic foraminiferal Zones	Datum Markers
Upper Cretaceous	Early Campanian		*Globotruncanita eleveta*	⊥ *Globotruncana ventricosa*
Upper Cretaceous	Santonian		*Dicarinella asymetrica*	T *Dicarinella asymetrica* ⊥ *Dicarinella asymetrica*
Upper Cretaceous	Santonian / Coniacian		*Dicarinella concavata*	⊥ *Dicarinella concavata*
Upper Cretaceous	Coniacian		*Dicarinella primitiva*	⊥ *Dicarinella primitiva*
Upper Cretaceous	Turonion	Late	*Marginotruncana sigali*	T *Helvetoglobotruncana helvetica*
Upper Cretaceous	Turonion	Middle	*Helvetoglobotruncana helvetica*	⊥ *Helvetoglobotruncana helvetica*

⊥ First Occurrence T Last Occurrence

Fig.2.12: Index fossils for Kometan Formation from Middle Turonian to Early Campanian in Sulaimanyia Governorate (Al-Khafaf, 2005).

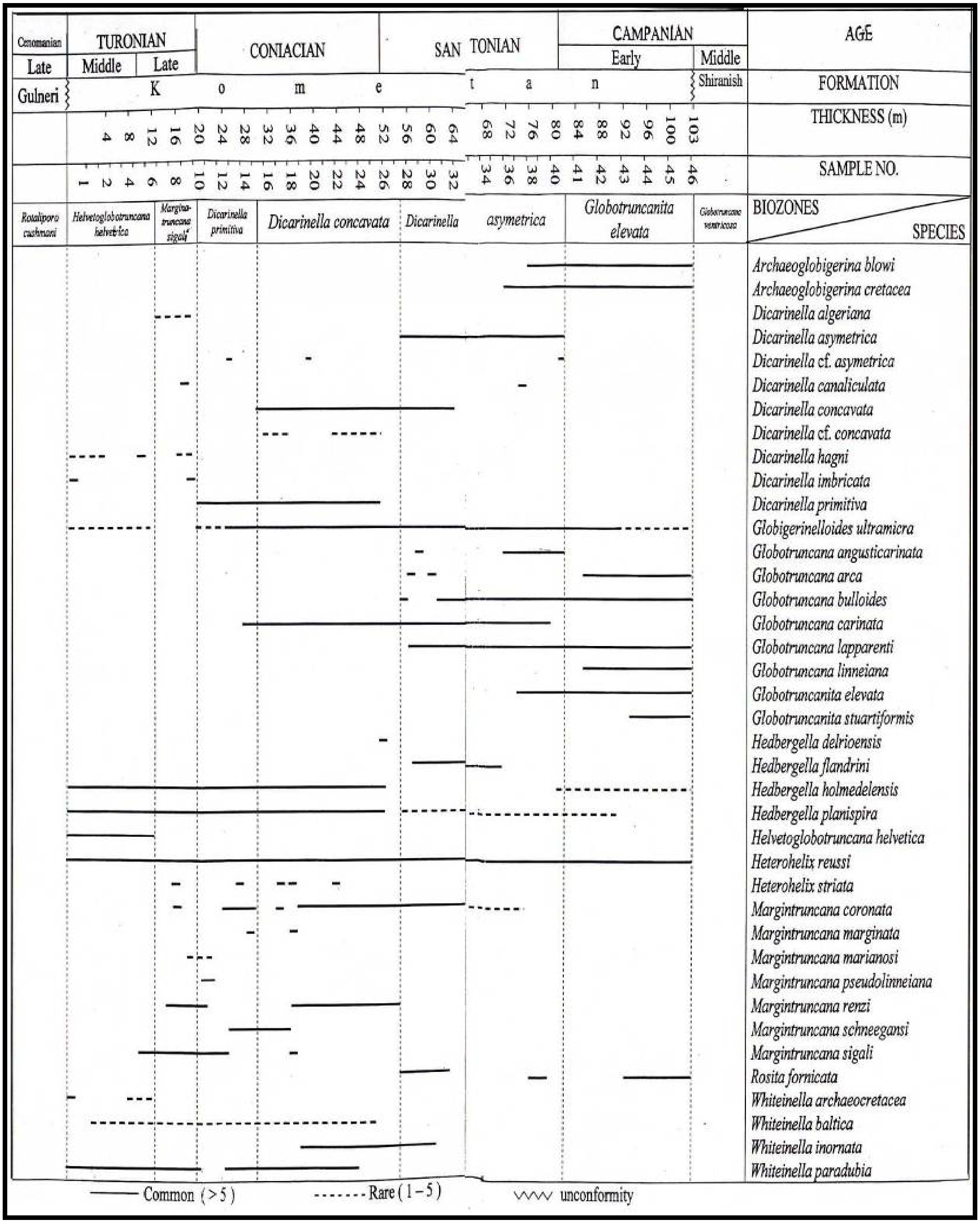

Fig.2.13: Biozonation chart of Lower Dokan section by Al-Khafa (2005) which shows continuation of sedimentation from Turonian until Middle Campanian across the boundary between Kometan and Shiranish formations.

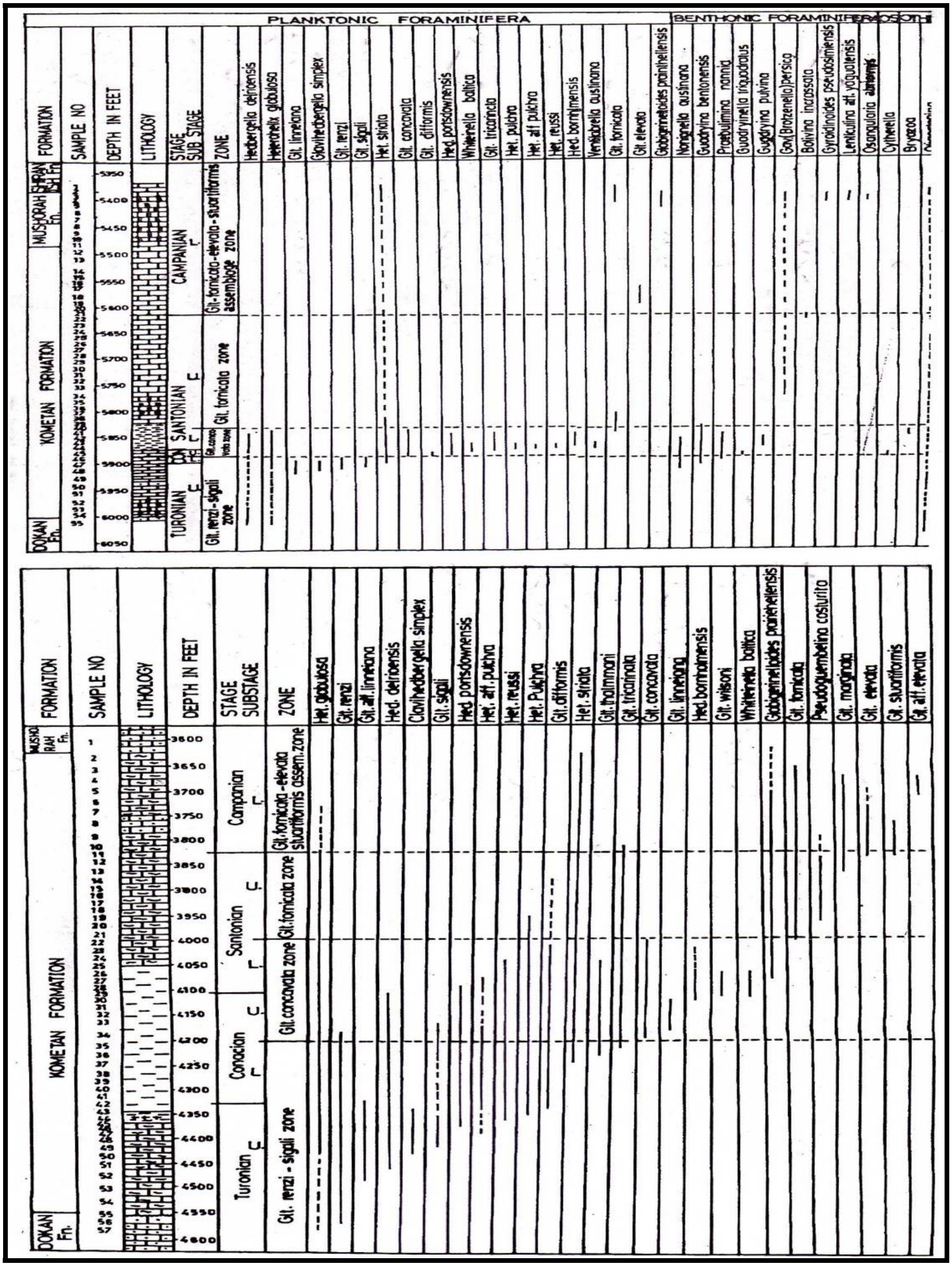

Fig.2.14: Two biozonation charts of Kirkuk Well No. 166 (upper) and Qarachuq Well No.1 (Al–Jassim *et al.* (1989). They recorded neither unconformity nor gaps in sedimentation during Turonian till Middle Campanian.

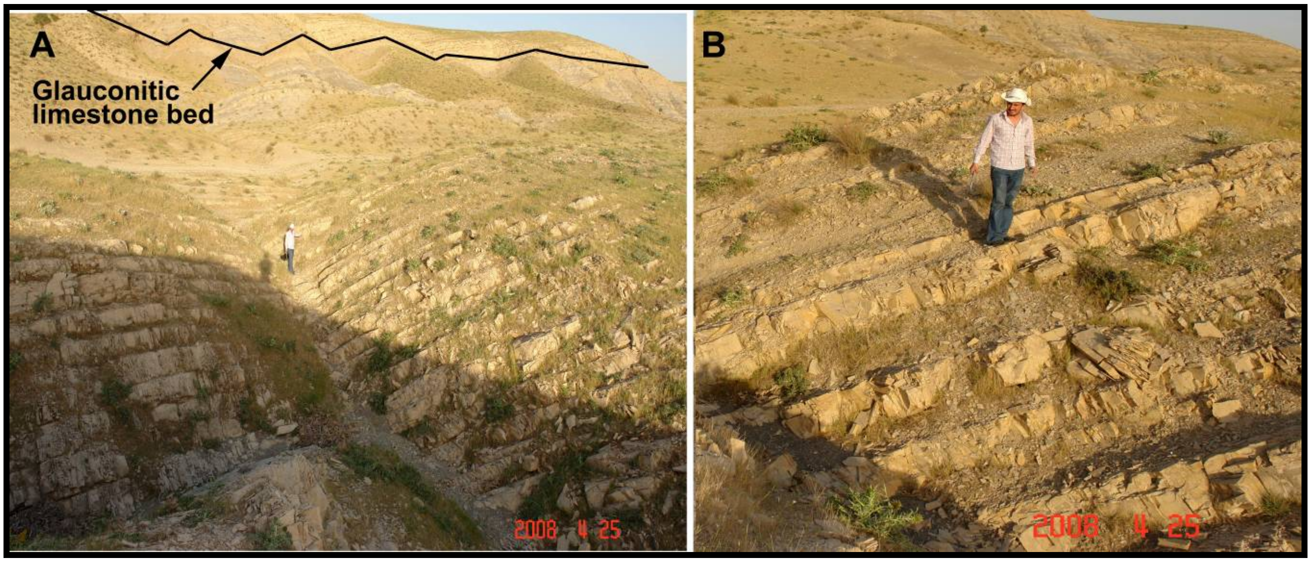

Fig.2.15: A) Contact between Kometan Formation and Shiranish Formation at Dolla Root Valley 4km to the northwest of Sulaimani City and 2km to the south Fayal valley which show clear conformable contact and the glauconitic limestone bed is located inside the latter formation. B) Close up photo of the gradational contact, the white and grey beds are Kometan and Shiranish Formation respectively.

2.8- Age of the Kometan Formation

The Late Turonian-Early Campanian sediments (Kometan Formation) in North Iraq and (Khasib/Tanuma/Sadi) Formations in Southern and central Iraq, overlain conformably by the Late Campanian-Maastrichtian sediments (Shiranish Formation) and these sediments cover the whole Iraq territory (Kaddouri, 2001). Hart and Chatton (1961) revised and re-examined the subsurface and surface sections. They indicated the age of the formation as Late Turonian–Early Campanian.

According to Al-Jassim, et al (1989), the age of the Kometan Formation is Late Turonian–Early Campanian in the northern Iraq depended on the biostratigraphic foraminiferal zones, such as four biozones. First: *Globotruncana renzi–Globotruncana sigali* Zone, second: *Globotruncana concavata* Zone, third: *Globotruncana fornicate* Zone, fourth: *Globotruncana fornicate, Globotruncana elevate, Globotruncana stuartiformis* Assemblage Zone (Fig.2.14). Al-Khafaf, (2005) studied the planktonic Foraminifera biostratigraphy of Kometan Formation from northeastern Iraq in Dokan-Endezah area. He recognizes foraminifera zone and he suggests a Middle Turonian–Early Campanian age for the Kometan Formation Fig. (2.12). According to Hammoudi, and Abawi, (2006), the age of

Kometan Formation is Upper Turonian – Lower Campanian depending upon assemblages of the planktonic foraminifera and benthonic foraminifera (Table 2.1).

Table (2.1) Biozones of the Kometan Formation Hammoudi, and Abawi (2006).

Age		Planktonic Foraminifera Zones	
Upper Cretaceous	upper Turonian-lower Campanian	1.*Marginotruncana sigali* 2.*Dicarinella primitive* 3.*Dicardiniella concavata* 4.*Contusotruncana fornicate* 5.*Globotruncanita elevate* 6.*Globotruncana stuartiformi*s	Partial range Zone Partial range Zone Partial range Zone Assemblage Zone Partial range Zone Partial range Zone

2.9- Shiranish Formation

According to Bellen et al., (1959), the formation was described for the first time by Henson in (1940) in unpublished report near Shiranish village, about 20 km. northwest of Zakho Town, northern Iraq. According to same authors, it consists of 228 m of bluish white marl and marly limestone (hemipelagite) which underlain and overlain conformably by Kometan and Tanjero Formations respectively, and cropping out in the northeast Iraq near the border with Iran. According to Jassim and Goff (2006), it deposited in the offshore of the Late Cretaceous Sea. It is consisting of two lithologic parts, the upper is dominated by blue Globigerinal marlstone, and the lower is characterized by alteration of marly limestone and marl. Shiranish Formation represents the basinal facies of the Late Campanian–Maastrichitan sedimentary cycle of north and northeastern Iraq.

According to Abdel-Kireem (1983) lithologically, Shiranish Formation in Dokan region can be subdivided into two member on the basis of the field observations and megascopic and microfacies studies, Lower Marl member and Upper shale member (Figs. 2.17, 2.19 and 2.20). He added that, planktonic foraminifera are abundant and diverse within the lower Shiranish member. Benthonic Foraminifera, however, they are very rare or absent and oceanographic conditions (such as anoxic condition) are thought to have precluded diverse and abundant benthonic taxa.

Al-Qayim (1992) divided the formation in the type locality into three lithologic parts. The middle part is about 20m thick and consists of rhythmic alternation of marly limestone and marlstone. The marly limestone layers are characterized by 2[nd] order rythemic alternation of limestone beds of calcarenite type and limy marlstone of (calcilutite) type. The calcarenite beds show gradual fining upwards onto the laminated marlstone. He added that, the vertical variation of these sediments is imposed on the intensity and uniformity of Teichichnus burrows which distinctively bioturbated these sediments. Both features suggest disruption of the quiet-water depositional environment of the Shiranish formation by storm deposits derived from locally derived shoals.

2.10- Age of the Shiranish Formation

Al-Dolamee (1988) has studied the Shiranish Formation in Sinjar area, mentioned that the age of this Formation Upper Campanian–Middle Maastrichitan depending on the benthonic foraminiferal analysis. He also added that it is deposited in bathyal environment and (depth 500-1500m) has been determined for the Formation in Sinjar area, with influence of turbidity currents. Abdel-Kireem (1983), studied Shiranish Formation in the Sulaimania-Dokan region paleoecological and bathymetry of the foraminifera assemblages decided it age of Shiranish Formation Late Campanian–Middle Maastrichtian (Fig.2.17).

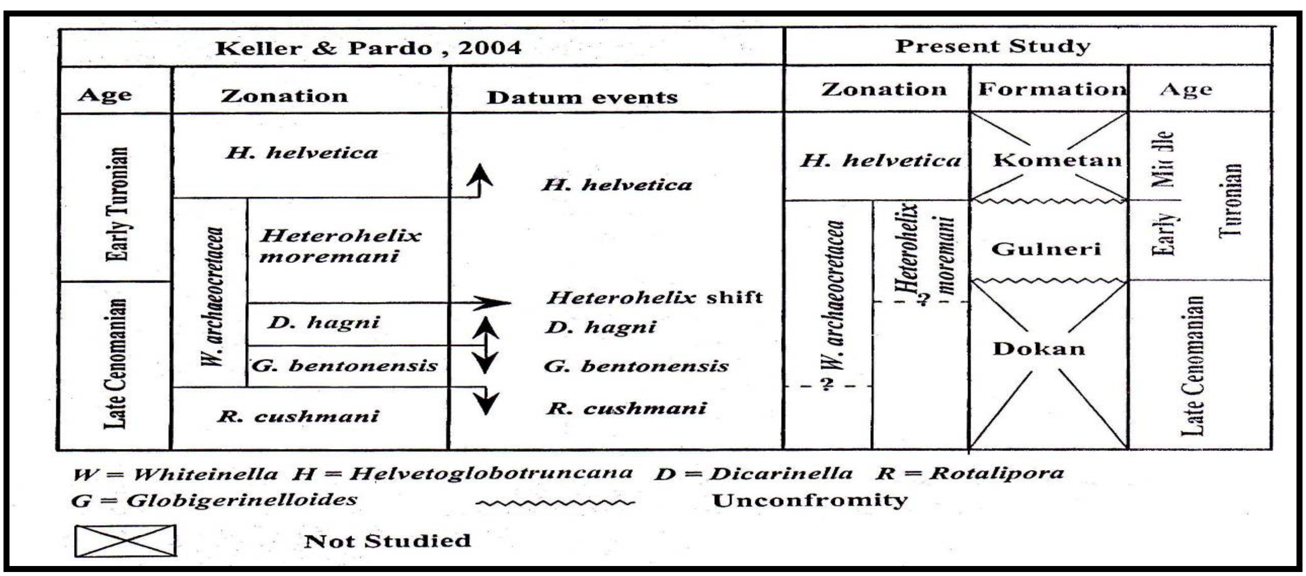

Fig.2.16: Correlation of the present Zonal scheme with that of Keller and Pardo, (2004) and Abawi *et al* (2006).

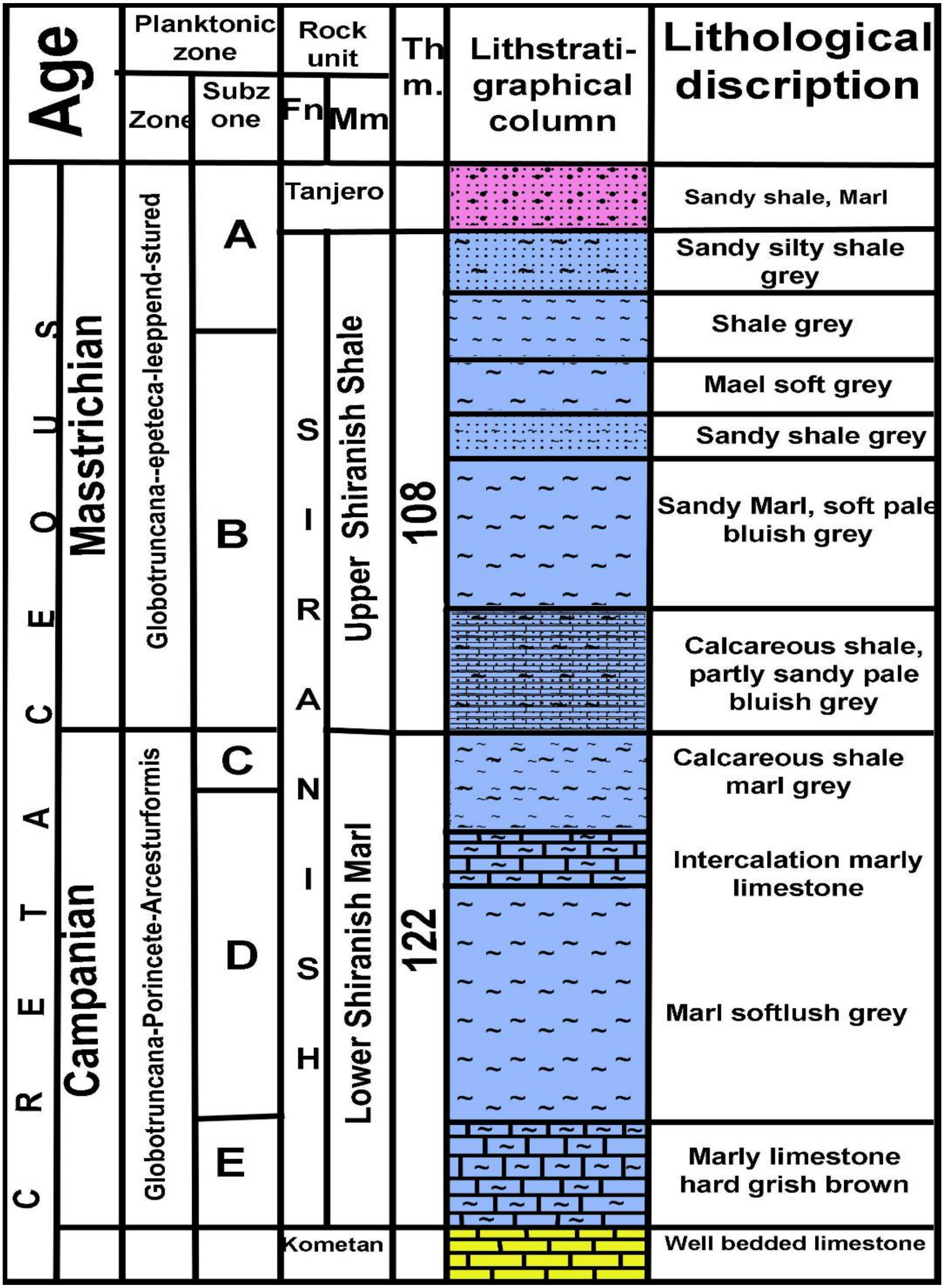

Fig.2.17 Stratigraphical column of Shiranish Formation (Modified after Abdel- Kireem 1983)

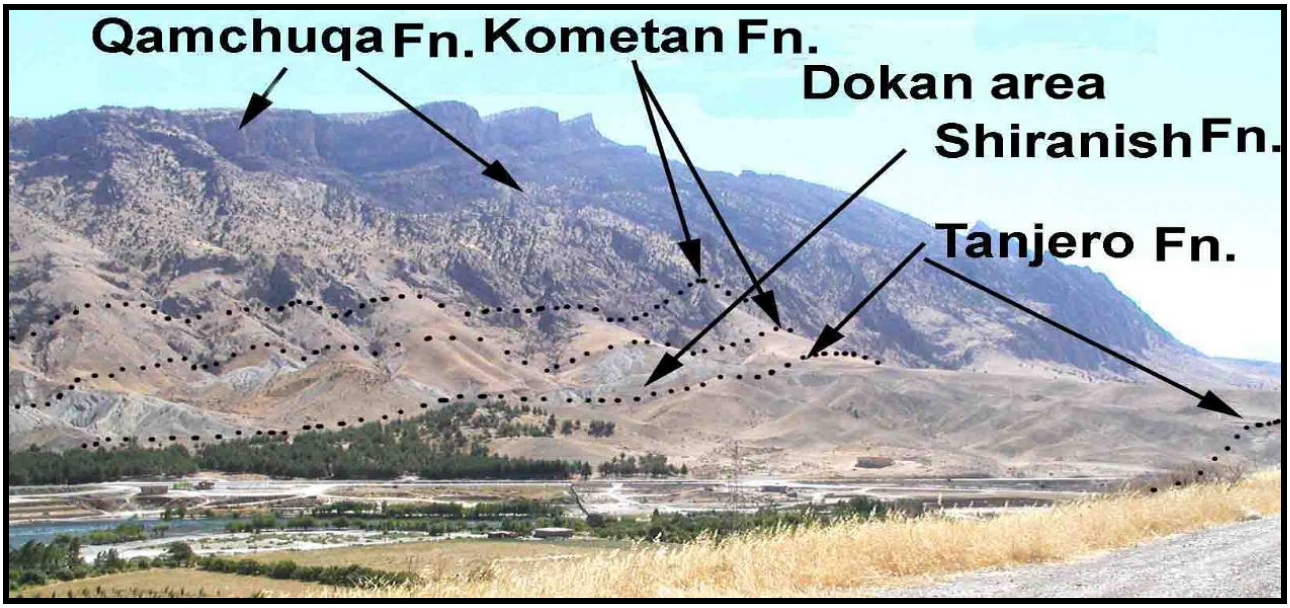

Fig.2.18: Photographic picture shows Dokan region; geologically consist of Qamc-huqa, Kometan, Shiranish, and Tanjero Formations.

2.11-Studied Sections

2.11.1- Safeen section (Qarasinj Big):

This section located about 9km to the Southwest of Shaqlawa in High Folded Zone of Safeen Mountain, in this section Kometan Formation overlain and underlain by Shiranish and Qamchuqa Formation respectively with unconformable contact, In spite of these ideas, the field study by present authors showed that the contact is gradational which consist of alternation of marl and limestone beds (Fig. 2.24). The contact is more or less similar to Dokan sections. Lithologically, Shiranish Formation consist of two units in this studied region the lower consist of marly limestone, which it is white to light grey in color, the upper unit contains blue and bluish grey marls and shales, which have been locally fragmented in to chipsets, pencil structures and the rocks are soft to fairly hard hence the upper unit is more weathered than the lower unite. Al-Rawi (1981) and Hanna (1993) mentioned that upper contact of the formation is gradational with Kolosh Formation. The lower contact of the formation with the underlying Bekhme Formation is conformable in the field. However, occasionally glauconite occurs at the lower contact in some locality marking an unconformity surface (Omer, 2005).

2.11.2- Qamchuqa Gorge Section

This section is located at 6 km to the west of Surdash village, directly to the northwest of the previous Qamchuqa village (now transferred to near Dokan town) (Fig. 1.3). The section is exposed along the left side of outlet of Qamchuqa gorge. At this gorge the contact is sharp and contains neither glauconite nor burrowing or sign of erosion, Dokan and Gulneri Formations is not ascertained in this section (Figs.2.19 and 2.21). The lithology changes suddenly from white fine grain limestone (Kometan Formation) to bluish white marl of Shiranish Formation (Fig .2.22).

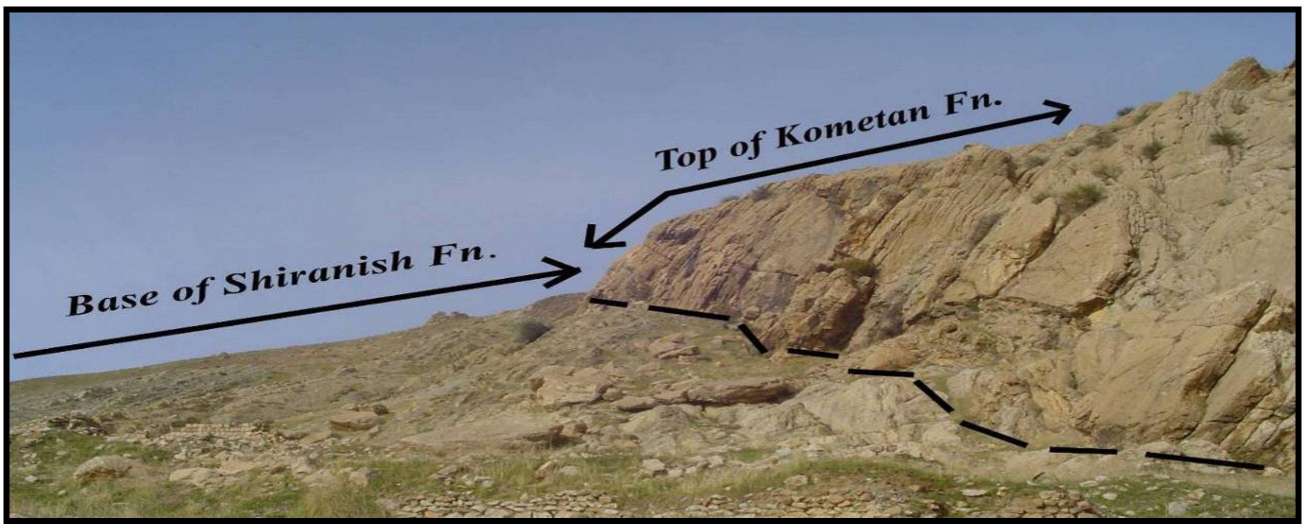

Fig. 2.19: Contact between Kometan and Shiranish Formations of Qamchuqa Gorge sections. GPS reading of location area: E: $45^{\circ}00.825'$ N: $35^{\circ}53.353'$.

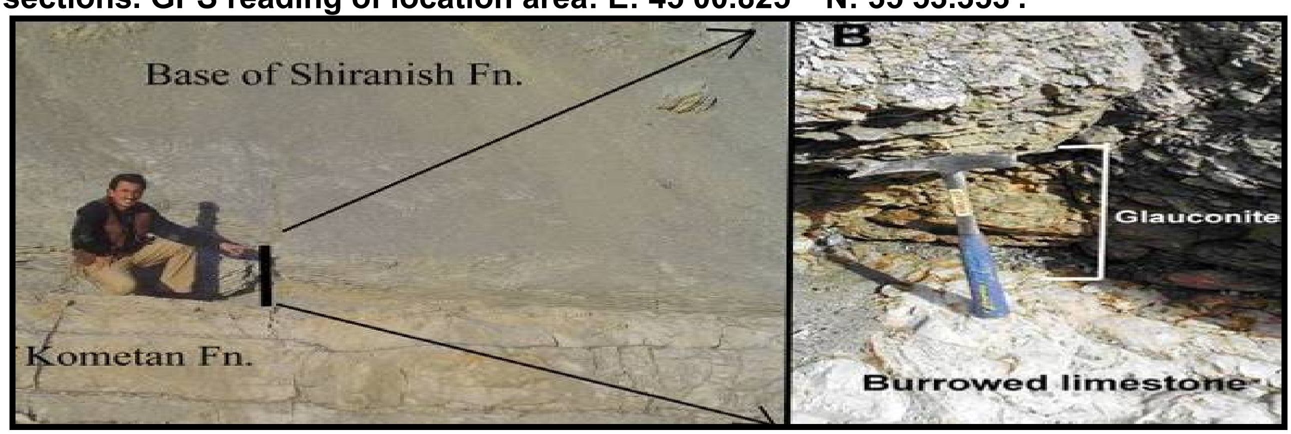

Fig.2.20: Contact between Kometan and Shiranish Formations at Upper Dokan (Rekawa village). The contact is sharp between the two formations. Photo B: a close look of the 20 cm glauconite bed at the base of Shiranish Formation and burrowed limestone at the top of the Kometan Formation. GPS reading of both location area: E: 35^{o} 56^{-} $24.24^{=}$ N: 45^{o} 00^{-} $39.79^{=}$.

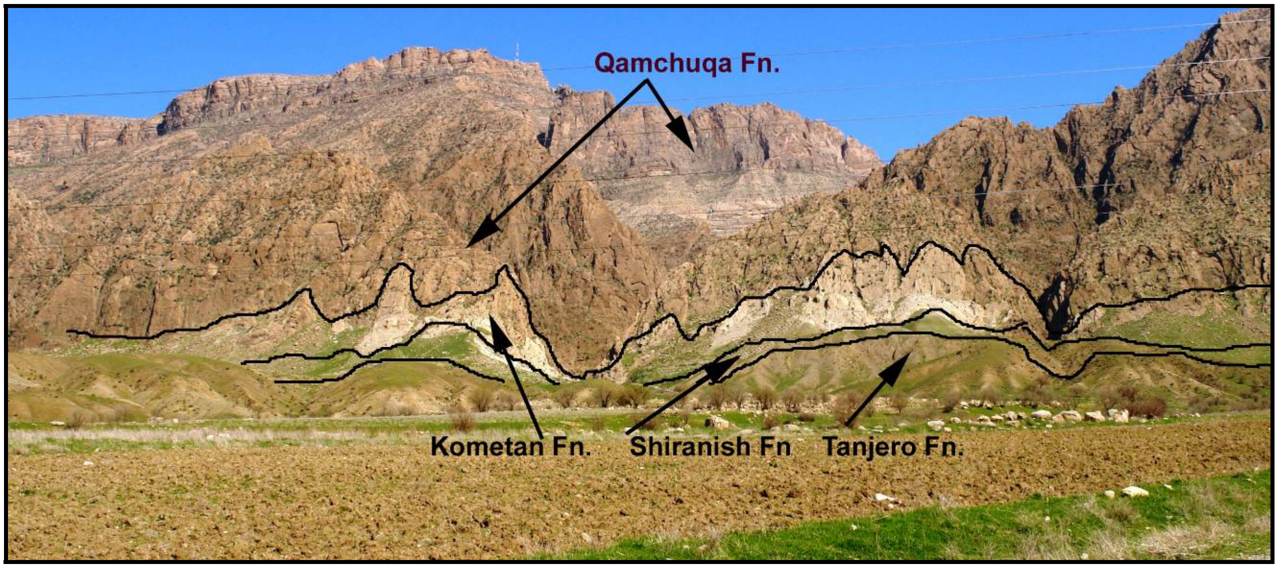

Fig. 2.21: The exposed formation in the Qamchuqa Gorge section.

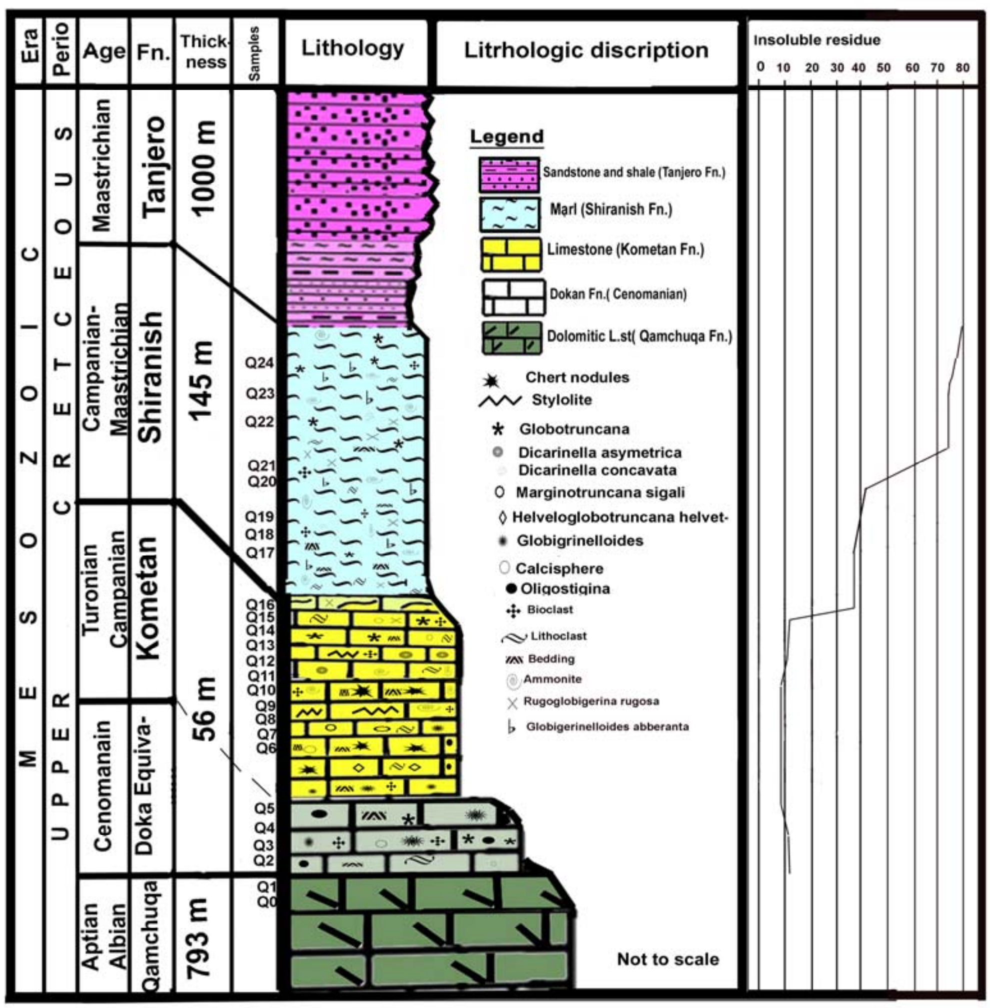

Fig. 2.22: Stratigraphic column of the Qamchuqa Gorge section.

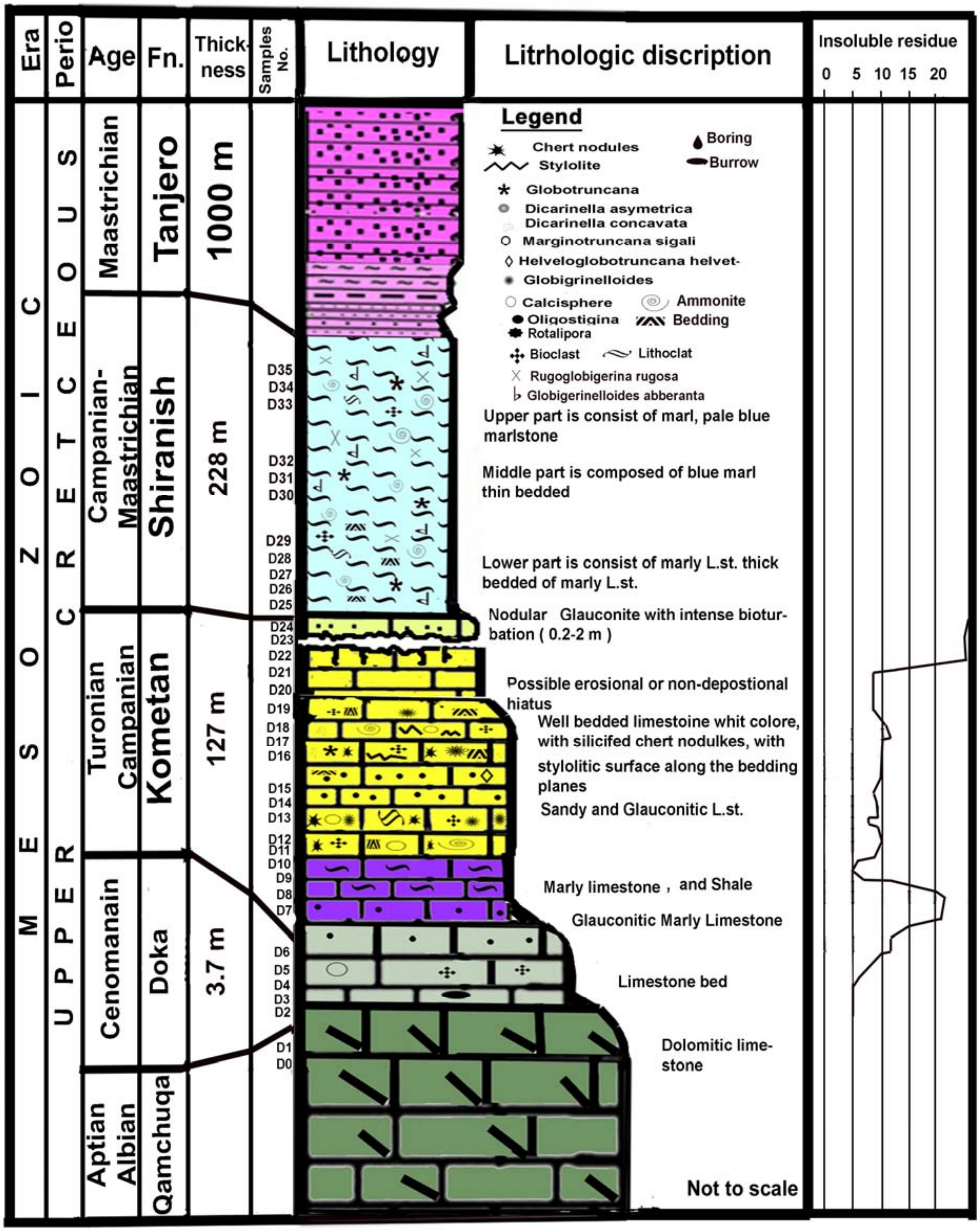

Fig. 2.23: Stratigraphic column of the Dokan section.

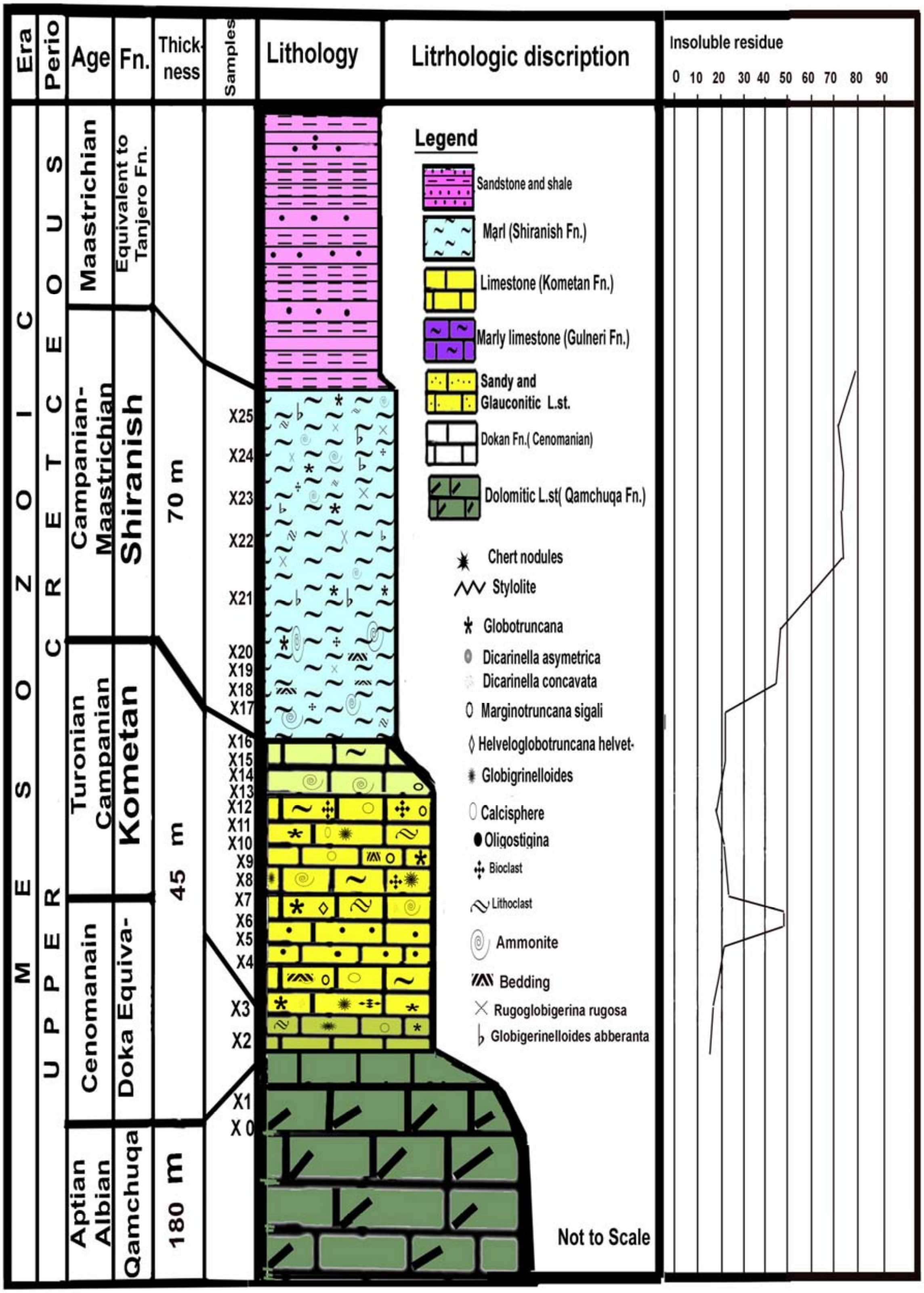

Fig. 2.24: Stratigraphic column of the Safeen Section.

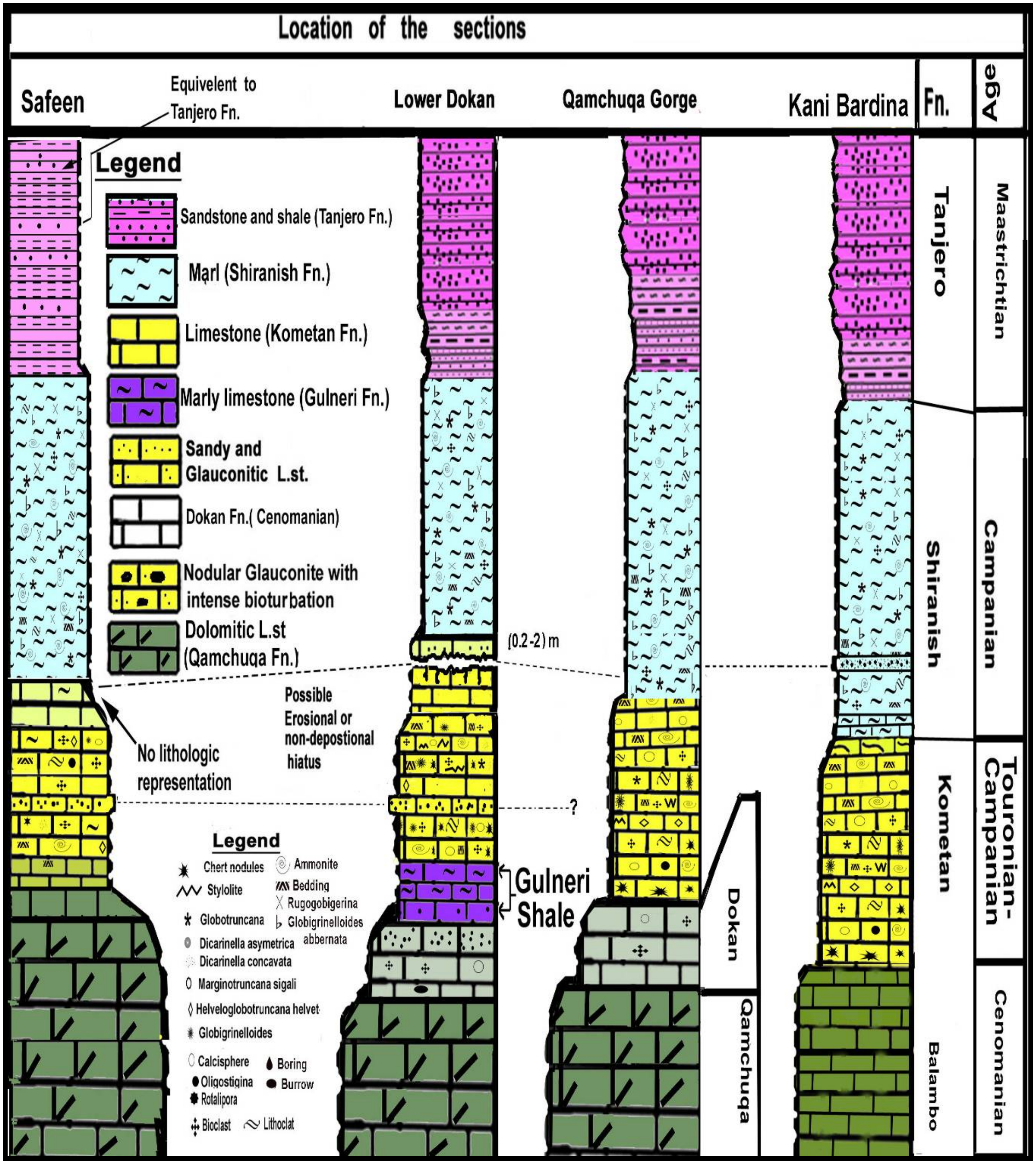

Fig.2.25: Stratigraphic column of the studied outcrop sections showing units, constituents and correlation (as based on glauconite beds).

Chapter Three

LITHOFACIES AND ENVIRONMENT

3.1- Preface

The lithofacies of Upper Cretaceous rocks (Dokan, Gulneri and Kometan Formations) in the Qamchuqa gorge, Dokan and Safeen Mountain are studied in this study. The classification of Dunham (1962) for limestone is utilized (Fig.4.1). All the studied formations show low diversity of facies and have common characteristics which manifested by fine grain lithologies contain and planktonic foraminifera. In the facial study one important issue arise which is the coexistence of two types of constituent in each facies. The first one is limestone matrix (rocks background) which consists of lime mud and the second is limestone allochems (planktonic whole skeleton grains).

The lime mud (micrite), as all limestone, can be derived from any source and depth but the grains are derived from near the water surface of the Upper Cretaceous Sea. Therefore, unlike the shallow platform carbonates, the grains are not related to the sea bottom on which the facies of the present study are deposited and lithified. Therefore the Dunham (1962) classification, as an environment indicator, can not be applied when both the matrix and allochems percentages are encountered. This is because, when these percentages are encountered they give relatively apparent high energy environment and shallow depth but the actual depth of all the encountered formation are mainly deposited in low energy and deep environments. Therefore, in the present study, the allochems, when they are consisted of planktonic skeletons, are not considered in the energy that indicates the name of the facies and only low energy mudstone is used. However, in the present study, the mudstone contains so much different constituent that can be classified in to several lithofacies.

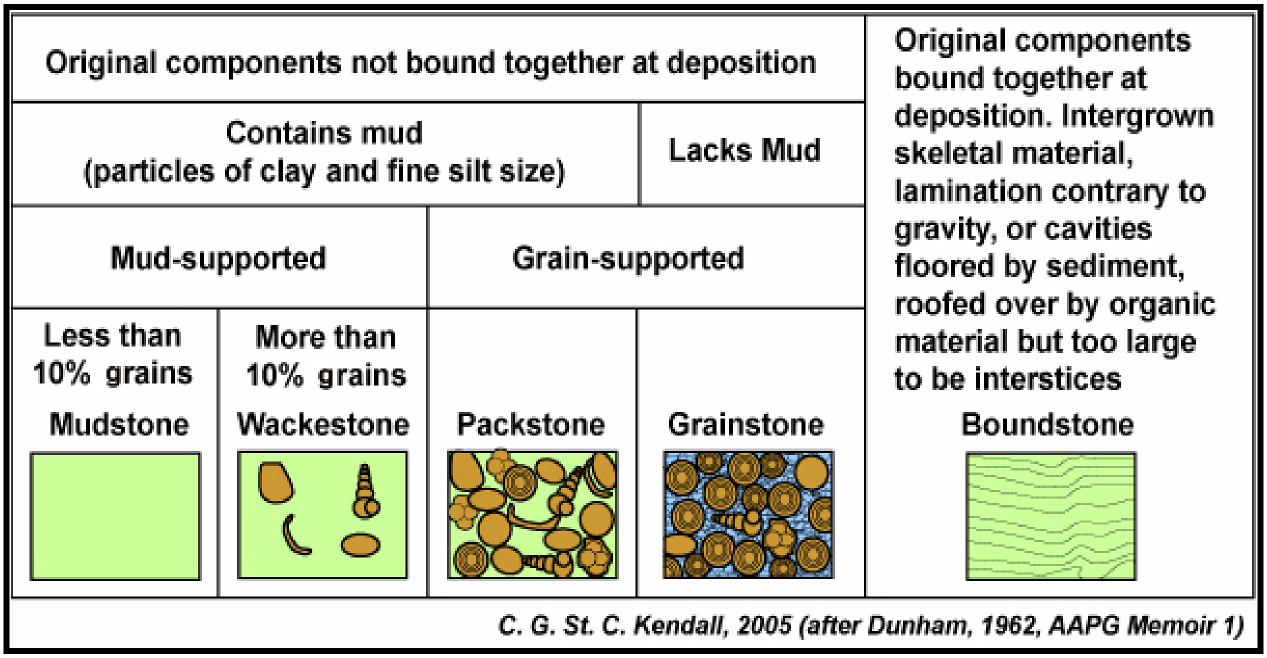

Fig.3.1: Classification of carbonate rocks (Dunham, 1962) which cannot be used for most carbonates of the studied areas.

3.2-Lithofacies

3.2.1- Planktonic foraminifera bearing mudstone lithofacies

This facies is comprised all Dokan Limestone Formation, most part of Gulneri and Kometan Formations, which is composed of white, well-bedded, Globigerinal-Oligosteginal limestone. According to Dunham, (1962) classification can be called planktonic foraminiferal mudstone or pelagic limestone, in traditional naming. This facies is divided into following subfacies form base of the bottom of section to their top.

3.2.1.1- Oligosteginal bearing lithofacies

This facies is characteristics of Dokan Formation which consist of thick beds of light grey fine grain limestone. In thin section it contains abundant (about 60%) globular oligosteginal planktonic forams (calcisphere) with some other forams (Fig.3.2). This facies is very important because it represent both vertical and lateral transitional facies change of shallow Arabian Platform from shallow marine environment to deep of both Kometan and Balambo Formations. The vertical transition is found in this study while the lateral facies change of the Arabian platform is proved by Ameen (2008) who found that Qamchuqa Formation is laterally changes to Balambo Formation through this facies.

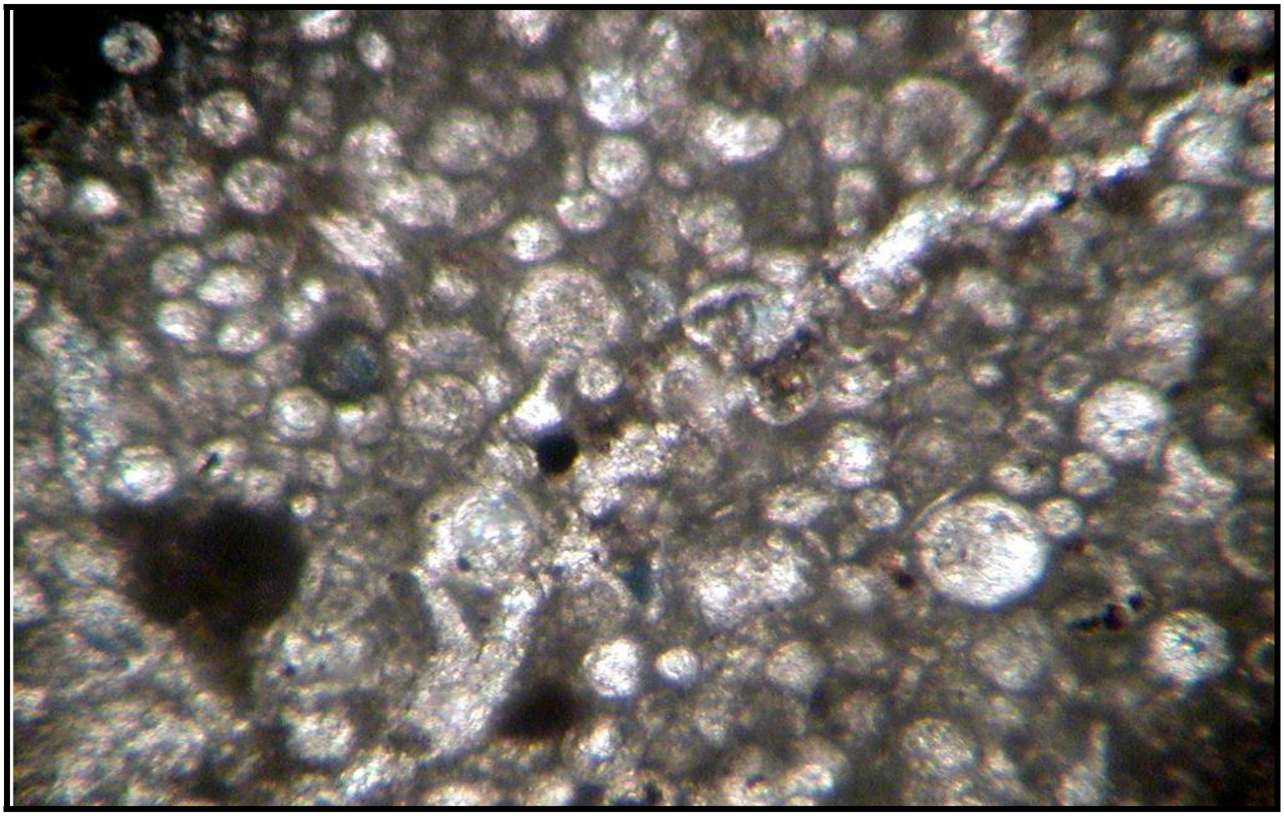

Fig.3.2: Globular oligostegina planktonic forams (calcisphere) in Dokan Formation in Dokan section.

3.2.1.2- Globigerina bearing fine grain limestone lithofacies

This facies constitutes most thickness of Kometan Formation which appears in the field as white well bedding fine grain limestone. In thin section it contains scares to abundant globigerina planktonic forams (less than 50%). This facies represents marine water in the studied areas. This is because the facies vertical facies trend appears in this depth. As the Qamchuqa, Dokan and Kometan Formation are deposited in the shelf, slope and basinal environment respectively.

3.2.1.3- Bored planktonic bearing mudstone lithofacies

This facies is found at one stratigraphic levels inside the Kometan Formation at it's top near it's contact with Shiranish Formation which overlain by Glauconitic bearing mudstone. This facies is well developed and has the thickness of 10cm and can be called hardground which bored by vertical and inclined shaft (Tubes). The shafts are filled with glauconite or glauconitic carbonate. In some case these shafts show branching (Fig.3.6). Their diameters are ranging from 1cm to 2.5cm with less than 12cm in length and they have one entrance, which is open to the upper erosional surface. These shafts are regarded as boring traces because of the following four points; the first one is that the boundary between the tubes and the host rock (Kometan Formation) is sharp. This is unlike burrowing which doesn't cut sharply through the fabric of the ground. The second point is the lithological difference between the fillings of the shafts and those make up the host rock. The former is composed of glauconitic carbonate with some pelecypod shells, while the later shows same lithology of Kometan Formation, which is similar to planktonic foraminifer's mudstone.

The third one is the existence of glauconite inside the shafts (tubes), which may be regarded as a type of synsedimentation mineralization. These three above points are given by Frey, (1975) for differentiation of borings from burrows. Moreover, glauconite (as a type of mineralization) also can be considered as a hardground indicator. The fourth is that in some place the bored bed is very hard as compared to the rest of Kometan Formation. In Upper Dokan, the bored bed is so hard that hardly can be broken by a hammer (Fig.3.3). The boring nature and their filling materials indicate hardground in which the dwelling borings are drilled in the lithified sediments of the Upper Cretaceous substrates, which now form the upper most part of the Kometan Formation.

Fig.3.3: Contact between Kometan Formation and Shiranish Formation at Upper Dokan section, 2km to the south of Joblakh village at the spring shore of Dokan Lake. The contact consist bored and burrowed limestone which twice harder than normal Kometan limestone.

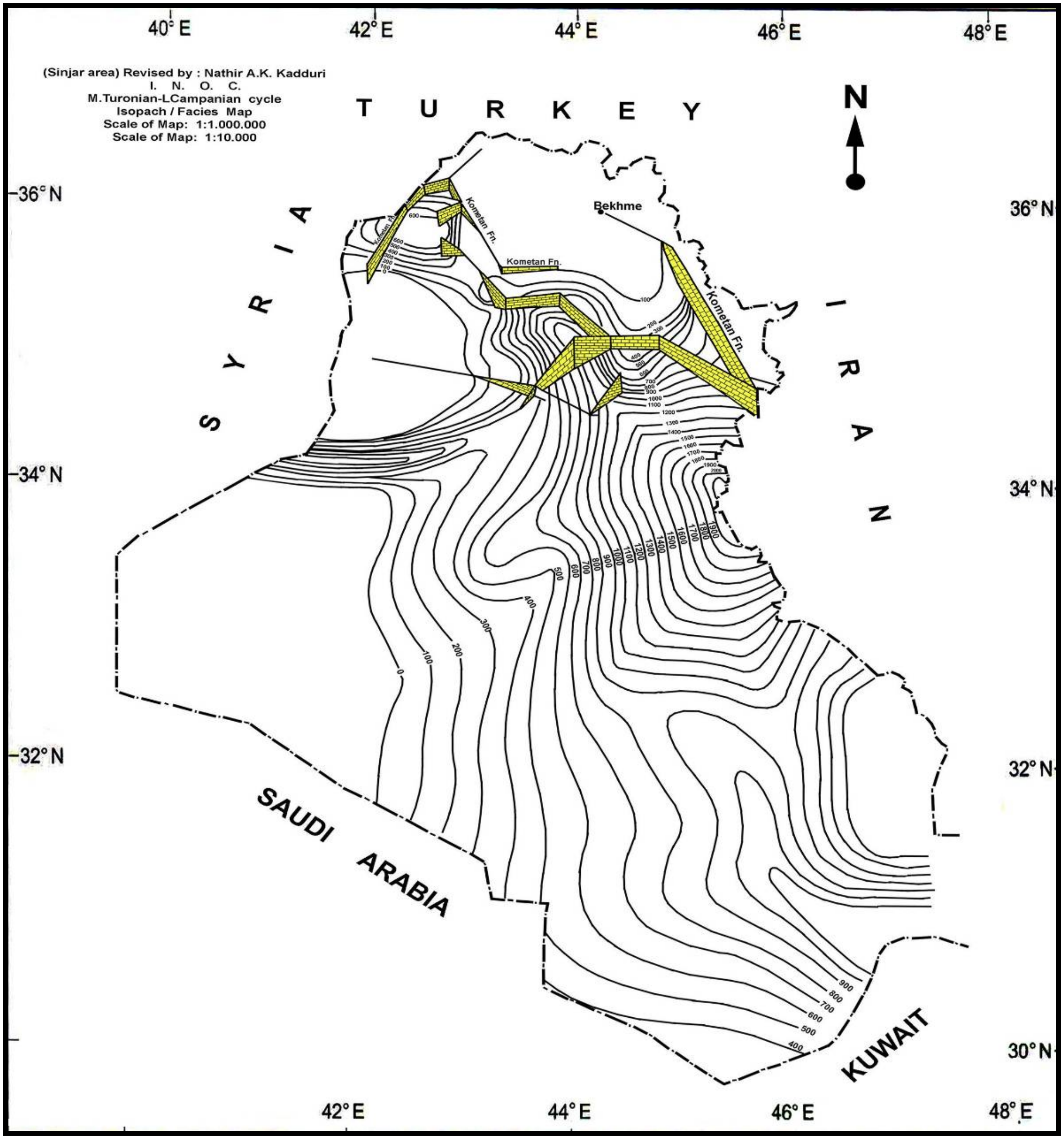

Fig.3.4: Isopach map of Kometan Formation (Kadouri, 2001).

3.2.1.4- Hardgrounds

Hardground is a zone at the sea bottom , usually few cm thick , the sediment of which is lithified to form a hardened surface , often encrusted , discolored , bored, hummocky shape and solution-ridden. It implies a gap in sedimentation and may be preserved stratigraphically as an unconformity (Bate and Jackson (1980). Hardgrounds are omission surfaces at which early cementation have produced a lithified sea floor (Bromley, 1978). Strictly, the omission surface itself represents the hardground. These surfaces may be recognized by the presence of abrasion, encrustations and borings and may cut across fossils and sedimentary structures. Some hardgrounds are developed from loose sediments, through firmgrounds, to lithified layers, and indicate a progressive hardening which is characterized by a change in the fauna, particularly the burrowing organisms, and by sedimentary features (Tucker, 1991).

According to Gruszczynski, et al., (2002), the most widely accepted factors that have significant control on the genesis of widespread regional hardgrounds is eustatic sea level change, locally altered by tectonics. This means two alternative ways can be considered for stopping the calcium carbonate sedimentation with references to either regressive or transgressive sequences. The first is, the minimum amount of water over a seafloor causing either all the carbonate sediment to be swept away at even the lowest hydrodynamic activity, or enrichment of runoff in carbon dioxide and bicarbonate because of increased erosion of soils. The second way, the rapid deepening of seawater led either to increased hydrodynamic activity replacing areas of sediment erosion and deposition, in shallow waters, or to increase of carbon dioxide and bicarbonate within the bottom carbonate system because of cooling, in deeper waters.

The Late Turonian - Coniacian hardground of the Man Gyshlak Sea developed within the transgressive sequence, similarly to other Cretaceous hardgrounds described from France (Jarvis and Gale, 1984) and Britain (Jarvis and Woodroof, 1984). However, in our case there are neither signs of very strong hydrodynamic activity, as in the Recent example of the Persian Gulf (Shinn, 1969), nor dramatic change of the sedimentary regime below and above the hardground which might be interpreted as sudden deepening (Purser, 1969) (Fig.3.5).

It appears that hardgrounds can be formed in different depth and environment when there is slow rate of deposition or removal of sediment on carbonate sea bottom surface. The hardground near the contact between Shiranish and Kometan formations are formed during general transgression when some shallowing occurred at the emend of Kometan Formation (Fig.3.3).

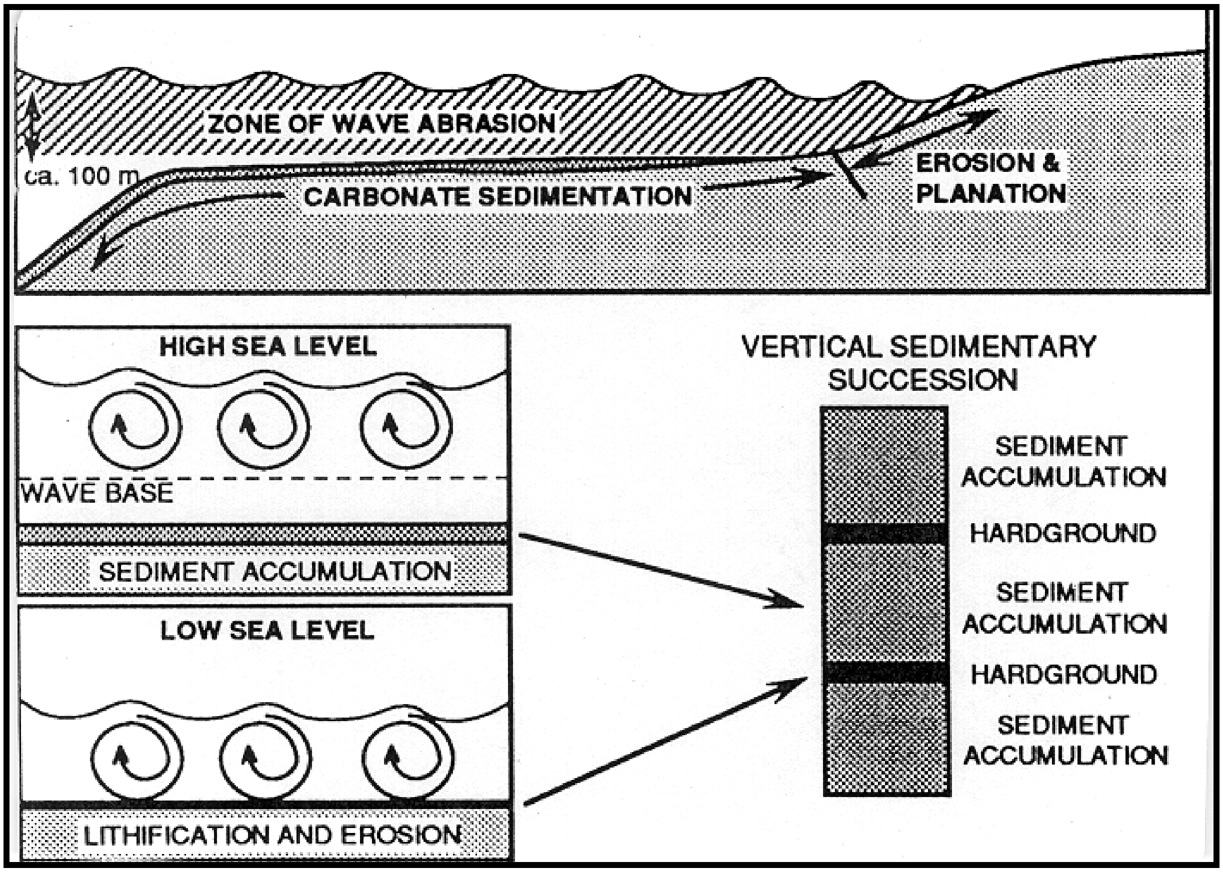

Fig.3.5: Schematics illustration how to formed hardground and sediment accumulation related to the sea-level changes (Fursichetal, 1981).

3.2.1.5- Glauconite bearing mudstone

This is represented by at least three beds inside the Kometan Formation. The first bed located at the base of Kometan Formation directly above Gulneri Shale Formation and about 15cm thick while the second is located about 6m above the latter formation inside the former one (Fig. 3.17). The third bed (the thickest one) is located at the top of the Kometan Formation about 2m below the contact with Shiranish Formation (Fig.3.6). The second and third beds are associated with highly bioturbation and hardground. The second one exists in the Safeen section which is located several meters above equivalent of Dokan Formation.

Under polarized microscope, the thin section of this bed contains 20% glauconite, 40% planktonic foraminifera and pelecypod shells; 40% lime mud and spary calcite. Few large Ammonites are also found (in addition to many small bean-size pelecypods, these macro fossils are also found together in shallow marine shelf by Wignall and Pickering, (1993), While Robinson, (1995) explained the extinction of Ammonites and rapid decline of some pelecypods to biogenic acidic rain during Campanian and Maastrichtian ages. Karim et al (2000) studied trace fossils at the contact between Kometan and Shiranish formations and mentioned that the contact is associated with hardground and an omission surface and glauconitic limestone which is deposited in shallow environments.

Cloud (1955) considered that glauconite requires a normal salinity with moderate depth of neritic environments. According to Blatt et al., (1980) glauconite is formed in marine environment of very slow rate of deposition by early diagenitic processes through replacement of biotite, when sufficient K and Fe are available. Bromely, (1975), recorded association of glauconite and phosphate as indicators of omission surface, (a thin bed of very slow rate of deposition) .He is also emphasized minerlization (glauconite in present study) as a distinguishing factor for hardground.

The present study, glauconite, in the three horizons, are of medium sand size, in hand specimens they appear as point-like black grains in the light grey background. While in the thin section they have grass-green color and most have irregular shape and shows smooth surface with low relief lobes. In Sinjar area, Al-Anbaawy and Sadek (1978) found 10 meters of glauconitic limestone near the middle of Shiranish formation (Fig.3.29). This aids that this mineral can be formed at any stratigraphic position if the environment is suitable and not necessary to be restricted to boundary of the formation and to large unconformity as previously indicated by Bellen et al., (1959) and Buday (1980). He is also emphasized minerlization (glauconite in present study) as a distinguishing factor for hardground. In present study, glauconites grain are of medium sand size, in hand specimens they appear as point-like black grains in the light grey background. While in the thin section they have grass-green color and most of the grains have elongate or ovoid form resembling fecal pellets. In recent years Brodie and Kemp (1995), distinguished oval and sharp boundary pellets in Quaternary sediments from Peru, which they attributed them to fecal pellets of surfacial deposit-feeder organisms.

In addition to the three horizons, glauconite is occurring as sporadic grain in the boundary between Dokan and Qamchuqa Formation. These grains are showing clear late diagenetic origin as they show replacement of planktonic foraminiferas (Fig.3.8).

Fig.3.6: Left: Less than one meter of glauconitic mudstone, 1km south of Dokan dam site. Right: Vertical boring in the hardground at the top of Kometan Formation, near Upper Dokan Tourism village.

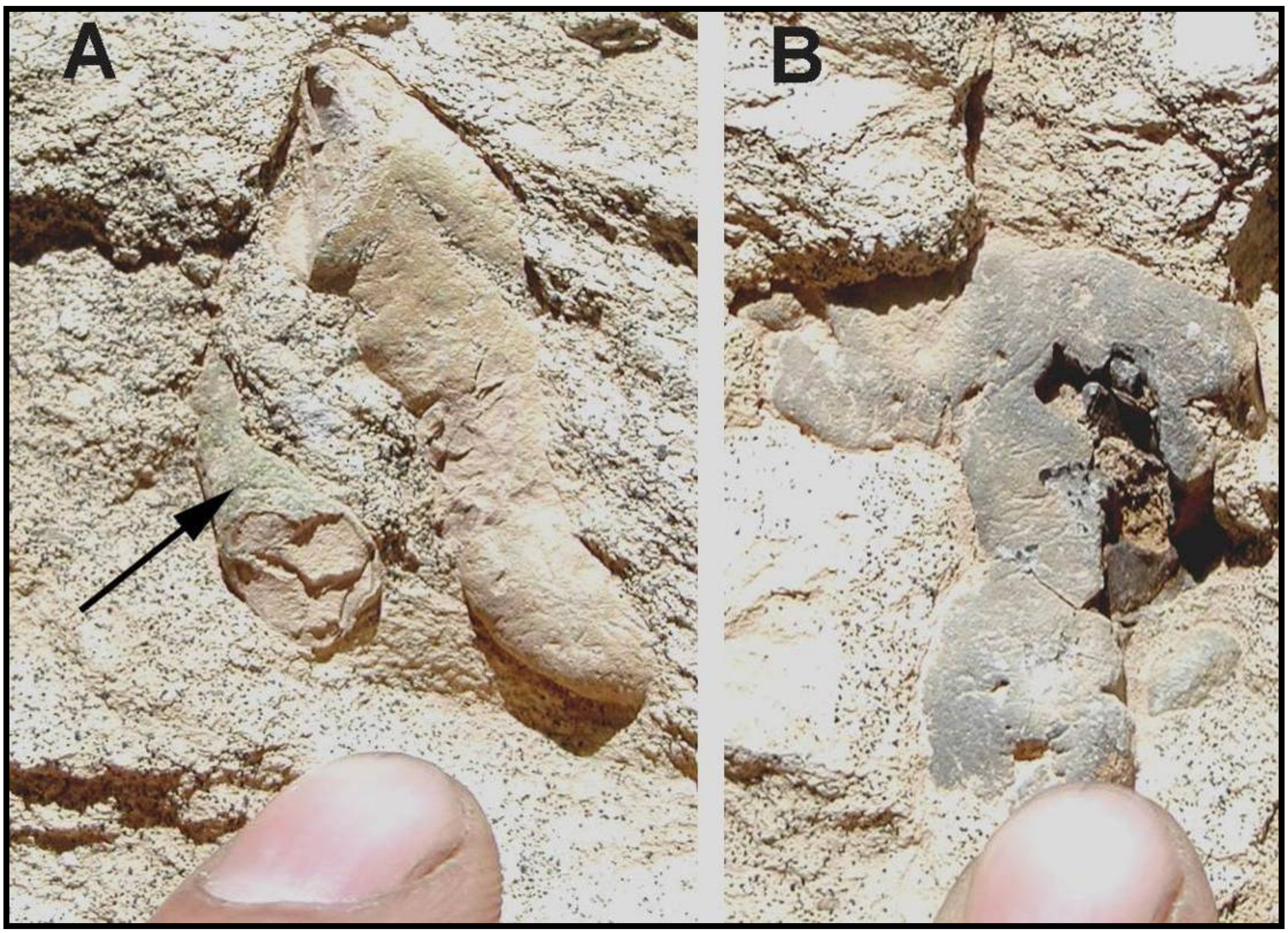

Fig.3.7: Three elongated pebbles in the glauconitic limestone, the left one is coated with green pigment as indicated by arrow nodules of the lower Dokan section(Karim, 2006), which assumed by Bellen et al (1959) as conglomerate.

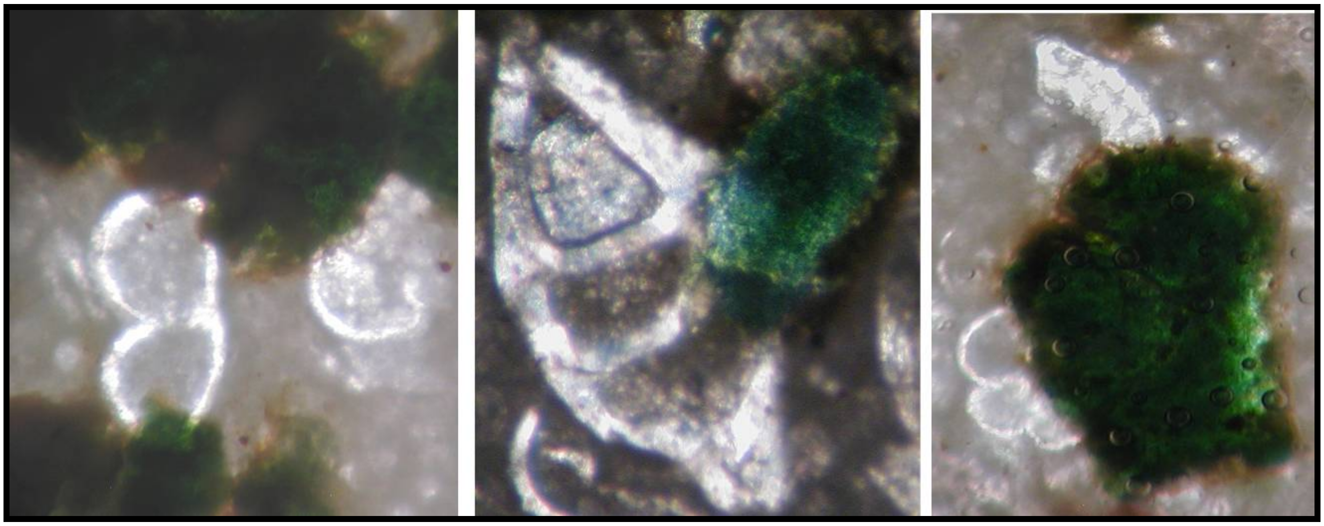

Fig.3.8: Three thin section photos show diagenetic glauconite that replacing planktonic foraminiferas in the boundary between Dokan and Qamchuqa Formations.

3.2.1.6- Chert nodules and stylolite bearing mudstone

These facies recorded in Kometan Formation which consists of decimeter-scale beds. It contains different size chert nodules, distributed on bedding planes and inside them with large scale. This facies is recorded only in the areas that surround Dokan Dam and associated with large scale stylolites (Fig.3.9). They can be seen clearly on bedding surfaces and on planes cutting the beds vertically such as surface of joints, road cut and erosional cliffs. They exist as oblate or irregular bodies and range in size from cobble to pebble. They are occasionally joined together laterally through neck-like connection. Their surfaces are light brown and generally smooth or may be knobby.

The internal color is black or greenish gray and shows no internal organization. However the color becomes darker towards the center of the nodules. Their longitudinal axes are mainly arranged parallel to bedding planes and they have been no preferred azimuthal direction (as measured in horizontal plain). But there are some oblique and even vertical nodules (Fig.3.9). Occasionally the nodules join together and form a net- like structures. Nodules are more frequently associated with stylolites and both generally concentrated along or near bedding plains. The stylolites are well developed and appear, in sections cut normally to bedding planes, as an irregular zigzag high amplitude lines (Fig.3.11) but, in sections parallel to bedding (in this case can be seen in three dimensions), they are appear as very rough surfaces and their peaks are perpendicular to the bedding surface.

Limestone undergoes pressure dissolution under a few hundred meters of overburden. The pressure dissolution is often found to be distributed not evenly through the rock but at certain horizons (Bathurst 1978). In limestone, surfaces parallel to the horizontal become sites of pressure dissolution and are seen as distinct partings in the succession which are often distributed along bedding planes. The surfaces are characterized in outcrops by slight concentrations of clay or other insoluble material which is left as a residue when the calcium carbonate is dissolved. In limestone bedding planes may not represent primary depositional surfaces at all, they can be diagenetic in origin and may even cut across depositional bedding. The pressure solution surfaces within a limestone are rarely flat horizontal planes. Under greater overburden pressures the irregular nature of the surface becomes more apparent as stylolites form (Tucker &Wright 1990). These are surfaces within the rock which are seen as complex, highly irregular fine lines in vertical section. They are picked out by concentrations of iron oxide or clay left as a residue when the calcium carbonate dissolves. Extreme examples of pressure solution and forming of stylolite result in loss of most of the calcium carbonate leaving only isolated nodules of limestone in a wavy-bedding mudstone. Nodular limestone of this type are likely to have contained a high proportion of insoluble clay either disseminated throughout the rock or more commonly concentrated into muddier layer. Pressure solution tends to accentuate irregular distributions of clay and limestone.

Philip et al*.,* (1995) have observed, in this facies, presence of sponge spicules, echinoids, red algae, annelids, and small benthic foraminifera. Ameen (2008) found chert nodules in the Lagoonal limestone of Qamchuqa Formation. He attributed their development to the episode of slow sedimentation during sea level rise with a paleo water depth just above or around storm wave base.

Blatt et al., (2006) mentioned that chert in limestone typically occurs as nodules that are irregularly shaped usually structureless, dense masses of microcrystalline quartz. They further added that the chert nodules occur most commonly in limestones of micritic facies because the organisms which are the source of the silica are of silt size and are deposited in quite water environment with the microcrystalline carbonate.

Al-Barzinjy (2008) studied the origin of the chert nodules in the Dokan areas (around the Dam site) and concluded that generated by diagenetic processes during burial through replacement and displacement of limestone. This does not mean that there is no early digenetic chert nodules, as Al-Rawi (1988) found in his study of the Western Desert, clear thin section photos of chert nodules, which contained distinctive nummulites. Unlike nodules of Kometan Formation, these are certainly of early diagenetic origin. Recently Sharp et al., (2002) studied the origin of isotope cyclicity in the bands (rings) in the chert nodules. They attributed this cyclicity to the thermal changes due to convection system.

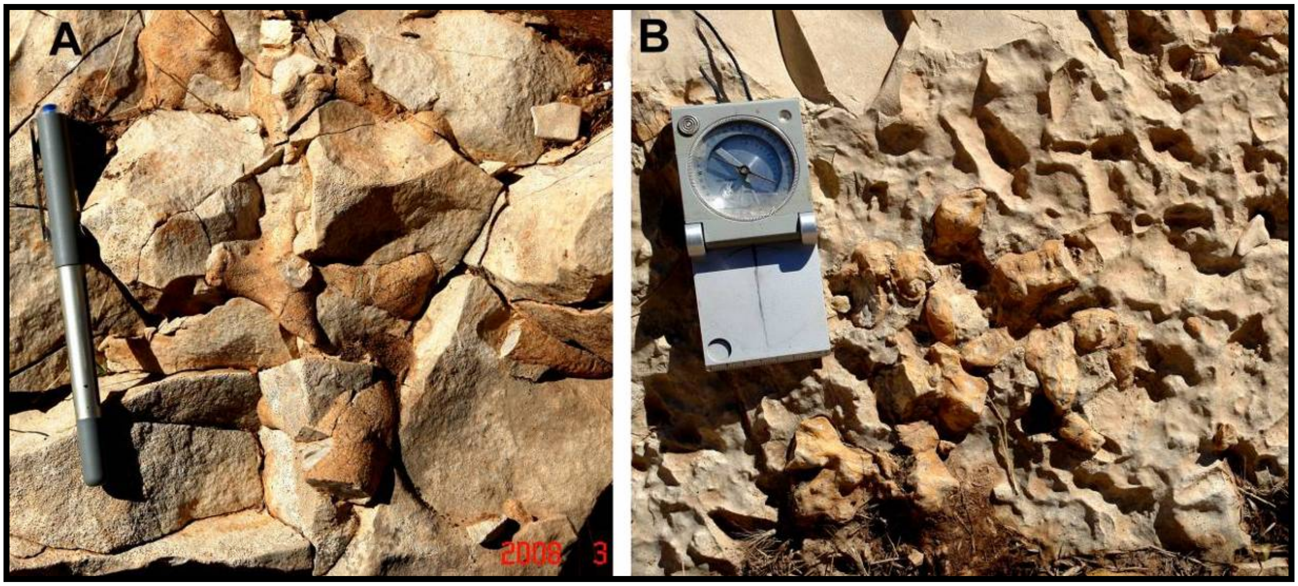

Fig.3.9: Random distribution of chert nodules elongated axis in the Dokan area.

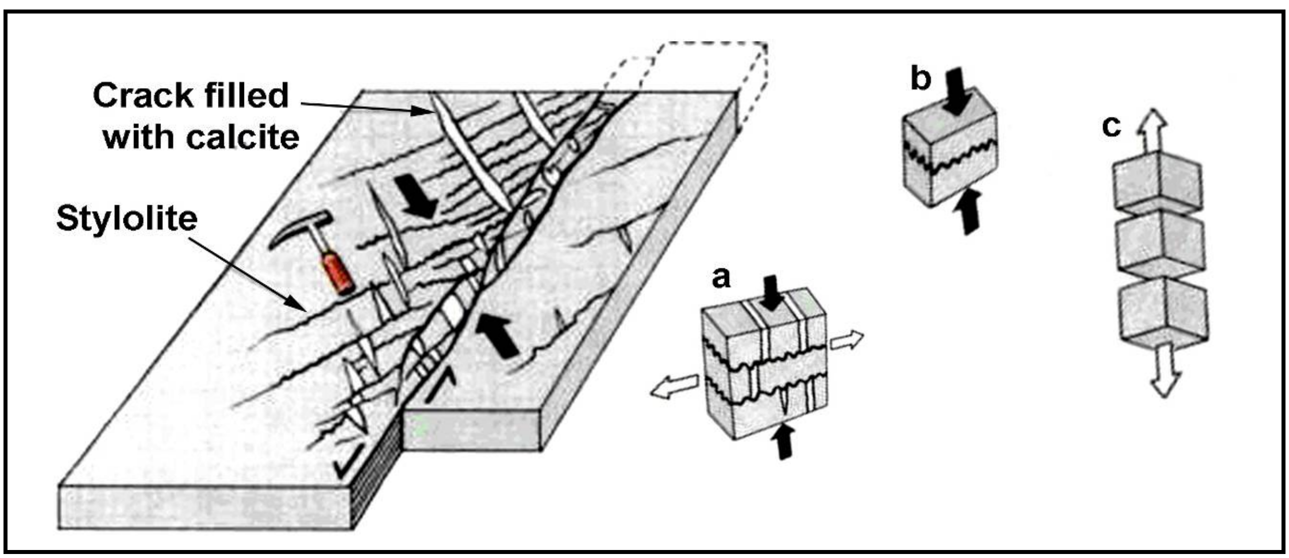

Fig.3.10: Mechanics of stylolites development in Kometan Formation by lithostatic pressure, a: associate with tension cracks, b: without tension cracks, c: unloading joints.

Fig.3.11: Well developed stylolite as appear cross section in Kometan Formation in Dokan area.

3.2.1.6.1- Computer data plotting of chert nodules long axis

The directions of 404 (elongate) chert nodules are measured randomly in three different localities, out side the area of the study of the Barzinjy (2008). Two of them of are located on the southwestern and northeastern limb of Kostrat Anticline (about 2okm northwest of Dokan Dam site). The other one is the northeastern limb of Kara Sard Anticline (about 10km to the northeast of dam site) using Brinton Compass which are arranged as azimuthal compass reading (Table3.1). Then the data was used for drawing rose diagram by Windows- based Rockwork program (Fig.3.12). The diagrams show random distribution of the elongated direction of the nodules.

This proves that the nodules are developed by diagenetic processes during deep burial before the folding of the area. The diagram shows slight polarity in the direction of northeast-southwest and northwest-southwest. This minor polarity is not known but the analysis of chert nodules around dam site by Barzinijy (2008) revealed the possibility of stretching by late deformation tectonic stresses. The stylolites peaks (as seen in three dimensions) are gained random distribution too (Fig.3.10 and 3.13).

Therefore, both stylolites and chert nodules are developed (grown) together in a late diagenetic environment of high load pressure (lithostatic pressure) before folding of the area and devote any shear (directional) stress in their original growth. But Taha *et al*. (1995) have recorded opposite conclusion to the present one. They found that stylolites peaks are directed nearly toward north south and east west.

Table (3.1) Compass azimuth readings of 404 elongated chert nodules in Kometan Formation, Dokan area. The readings are arranged in twelve columns as originally measured in the field and feed in to the P.C.

NE-Limb of Kostrat anticline					Southwestern limb of Kosrat anticline	
1	2	3	4	5	6	7
44	328	334	270	350	25	280
30	332	330	45	282	90	10
75	335	343	45	280	360	20
10	331	3	35	12	282	350
360	42	10	270	15	278	320
15	10	54	340	70	12	45
15	75	340	342	55	76	60
90	70	80	90	30	28	75
11	348	350	360	240	292	354
80	350	360	20	30	310	25
20	295	325	272	327	52	52
360	52	300	70	15	60	350
10	298	275	90		42	358
12	18	83	10		32	354
60	18	30	90		12	40
40	30	19	50		20	
5	72	9	290		60	
45	25	87	342		292	
20	50	82	10		330	
88	270	348	64		325	
30	265	70	360		290	
80	335	20	283		310	
75	3	338	286		346	
15	360	320	276		298	
300	65	56	322		46	
315	58	16	27		290	
310	60	278	70		290	
345	63	64	296		6	
335	270	6	40		70	
318	298	278	322		60	
278	318	94	322		2	
275	292	60	340		20	
358	322	335	270		300	
338	328	16	290		360	
315	356	10	10		360	
305	350	330	304		18	
15	360	300	335		325	
40	20	12	90		330	
85	70	330	54		275	

Northeastern limb of Qara Sard anticlines				
8	9	10	11	12
299	360	50	30	340
278	80	330	318	285
290	70	322	90	330
292	90	350	85	342
70	30	70	348	338
340	80	309	10	335
354	360	283	345	
50	10	45	60	
280	40	290	325	
350	90	48	10	
300	20	35	290	
340	70	298	10	
340	45	330	52	
20	90	320	338	
338	280	35	350	
35	70	318	360	
330	290	320	340	
350	285	350	330	
12	360	335	5	
70	330	32	360	
40	270	355	330	
60	270	304	18	
62	50	40	358	
58	350	10	60	
20	45	12	360	
80	90	75	28	
60	60	360	4	
80	50	85	8	
203	35	20	5	
360	30	90	348	
70	50	22	62	
40	360	80	315	
80	270	68	30	
35	20	64	90	
80	290	280	78	
90	80	320	20	
325	90	90	10	
300	300	345	10	
30	350	345	90	
340	310	20	85	
315	20	8	75	
85	280	360	50	
40	70	80	8	
38	325	70	35	

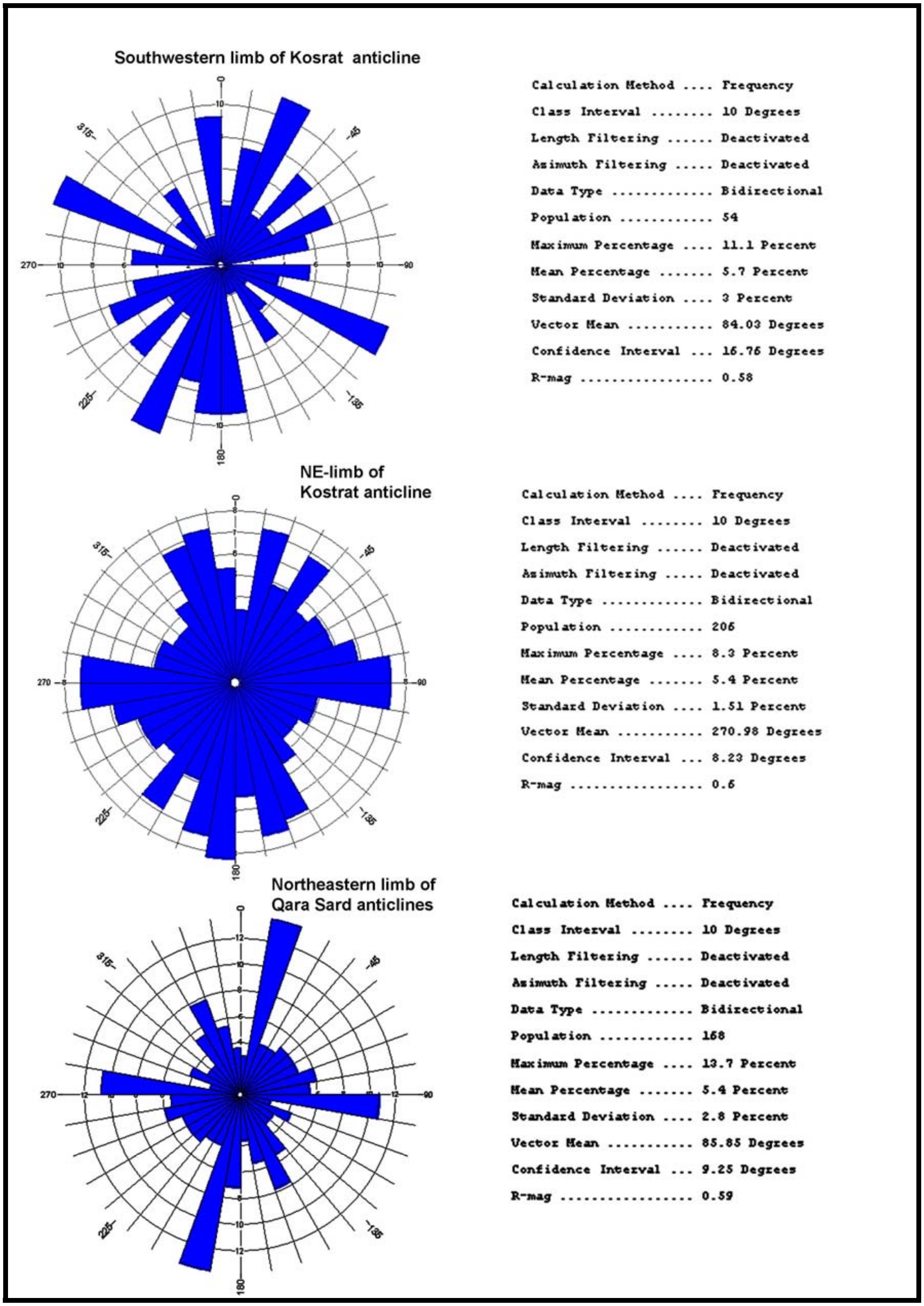

Fig.3.12: Rose diagram of the elongate chert nodules in Kometan Formation in three different stations outside Dokan Area.

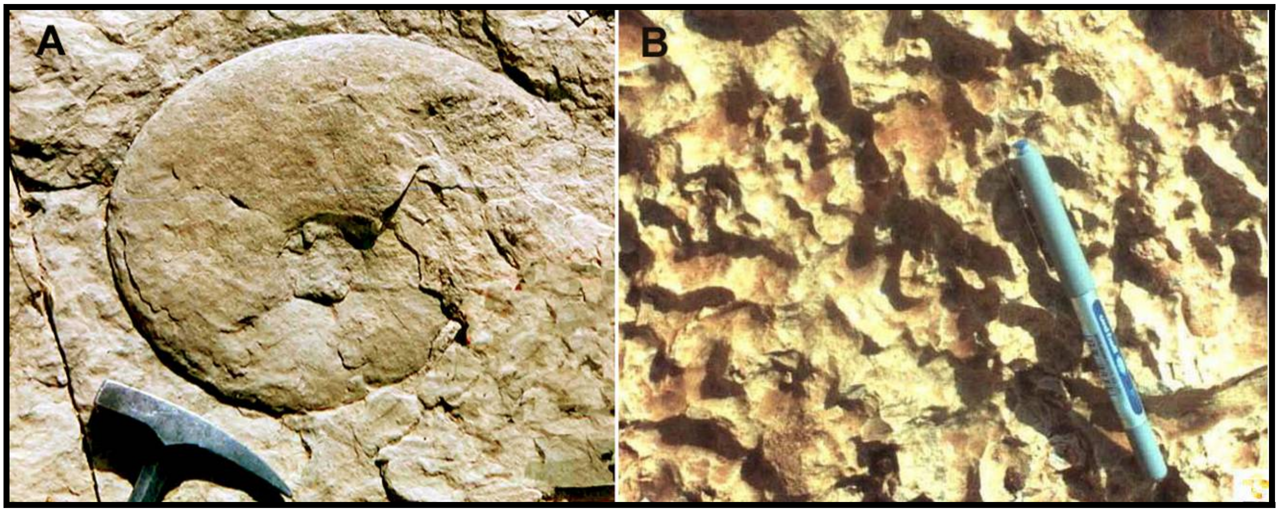

Fig.3.13 : A) ammonite at the top of the Kometan Formation. B) Stylolite peaks as can be seen in three dimension view which shows random distribution of peaks.

3.2.2- Laminated shale lithofacies

This facies is exists inside the Gulneri Shale Formation which has been mentioned previously that, at Dokan Dam site, the formation consists of about 2m of black, bituminous, finely laminated, calcareous shale with some glauconite and cellophane in the lower part. In the present study, the following facts are inferred about this facies:

First, the field and thin section study showed that the formation at the dam site (type section) contain only about 20% of the shale-like lithologies. The rest (about 80%) is composed of limestone and marly limestone with some marls and glauconite (Fig. 3.14 3.15 and 3.16). Second, the previously mentioned shale which reaches about 20% of the thickness of the formation contains high content of the planktonic formas (Fig. 3.15). This high content of forams is not normal for shale as there is not in literature any citation of this type of concentration of forams in shale. Potter, et al (1980) in their famous book on shale (Sedimentology of Shale) has given the following percentages for shale mineral constituents: 58%, 28%, 6%, 5%, 2%, for clay minerals, quartz, feldspar, carbonate and iron oxides respectively. These percentages are not recorded in so called" shale" in Gulneri Shale Formation. Some samples are studied under normal light and fluorescent microscopes for identifying organic materials. These materials includes: Alginite, Leptodetrinite, Bituminite, Organo mineral complex and Organic amorphous particles (table 3.2).

Table (3.2) Classification of the Organic matter in Gulneri Formation under normal and fluoresces microscope.

Under normal light microscope	Under Fluoresces microscope
1.Alginite. (colorless if colony but yellow if single) 2.Leptodetrinite. (like as Alginite) 3.Bituminite. (colorless) 4.Organo mineral complex. (brown) 5.Organic amorphous particle (dark) 6.Foraminifera (colorless)	1.Alginite. (pale yellow) 2.Leptodetrinite. (pale yellow and brown) 3.Bituminite. (dark brown to pale brown) 4.Organo mineral complex. (dark brown) 5.Organic amorphous particle.(dark) 6.Foraminifera (blue)

Third, the so called " 20% shale" exists, in outcrops, as laminae that are bend ,as black and hard rocks, around limestone pillow-like bodies (nodules) (Fig.3.14). They appear, in thin section, as black highly deformed rock. The deformations are so intense that the laminae appear under microscope as schist as they have foliation-like texture and contain globular foram deformed to elongate masses (Fig.3.15). These features show that these laminae are formed by pressure through dissolution of limestone and the insoluble residue which are accumulated and compacted as laminae of dark color shale around the limestone pillows. This aided by occurrence of cast and mold of limestone bodies inside the formation (Fig.3.13). This process is discussed Walness (1979) through which dark color solution seams are generated by pressure.

As concerned to nodular limestone (which characteristics of Gulneri Shale), Nicholes (1999) mentioned that the extreme pressure solution and stylolitization result in loss of most of the calcium carbonate leaving only isolated nodules of limestone in a wavy-bedding mudstone. Nodular limestone of this type are likely to have contained a high proportion of insoluble clay either disseminated throughout the rock or more commonly concentrated into muddier layer. Pressure solution tends to highlight irregular distributions of clay and limestone. Therefore, In our estimate, the thin packages of laminae of shale and nodules in Gulneri shale are formed by the processes described by Nichols(1999).

Fig.3.14: Right: Limestone (L), marly limestone (ML) and Black shale (BS) some limestone changed to pillow (PL). Left: effect of pressure on the limestone which it changed to pillow mass some of which bend around others.

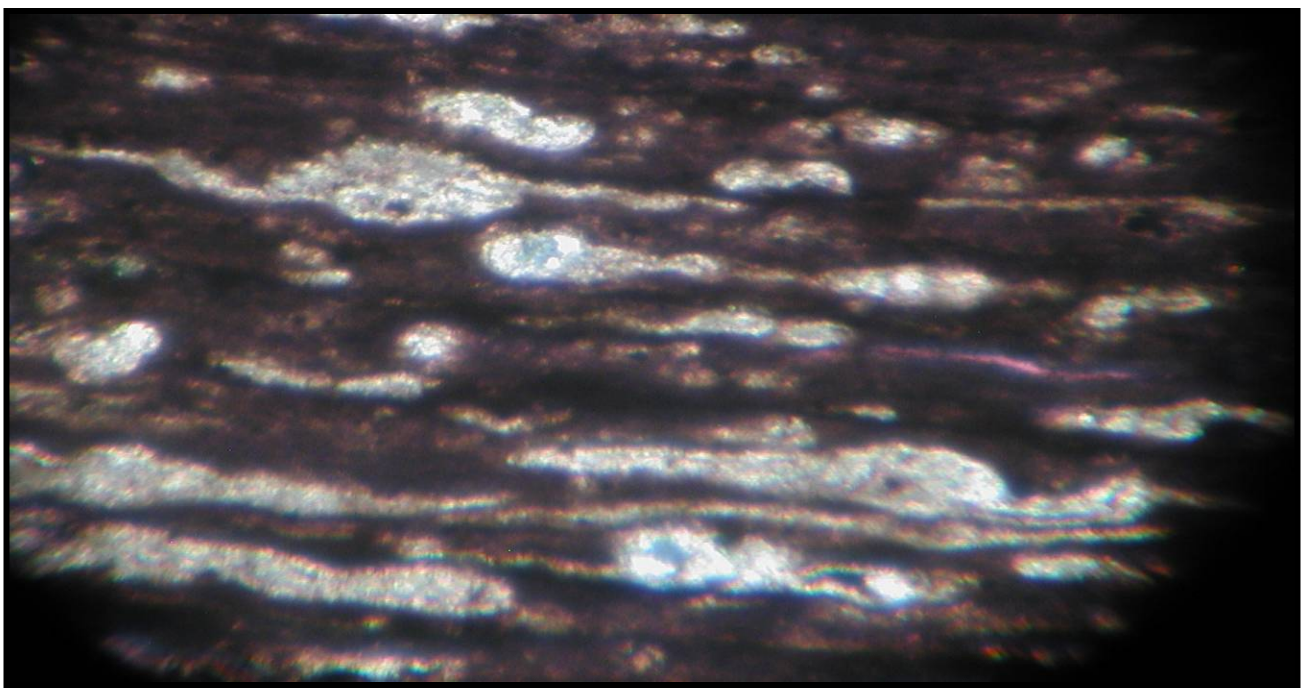

Fig.3.15: The globolar planktonic foram is stretched to elongated masses which resemble lineation or foliation by pressure in Gulneri Shale Formation.

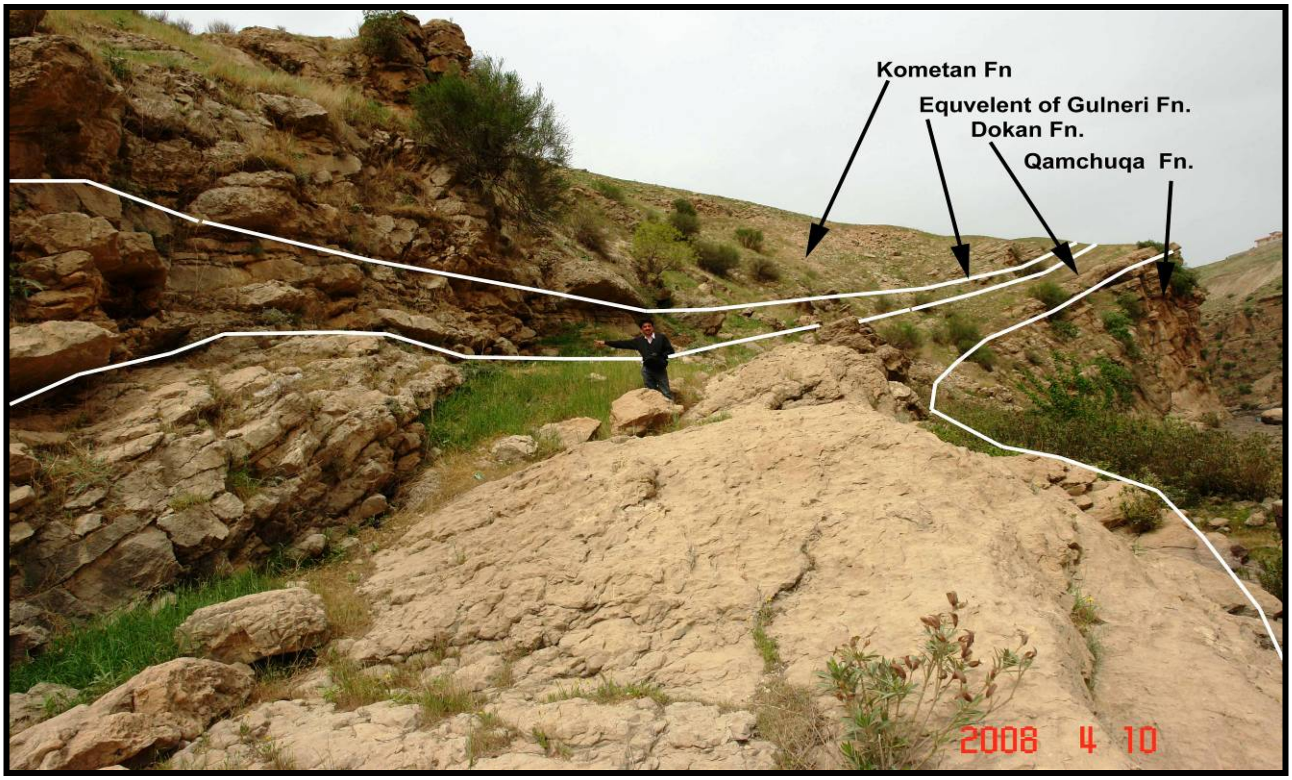

Fig.3.16: Equivalent of the Gulneri Shale and Dokan Formations in the down stream valley of the Lesser Zab River 500m north of Lower Dokan Town.

3.2.3- Pelecypod-bearing Lithofacies

This facies consists fully of large and tectonically deformed pelecypod skeletons (Fig. 3.17). It exists only in one section (Lower Dokan section) inside the upper part of Shiranish Formation as a 12cm thick biostrome at left bank of Little Zab River, directly north of Lower Dokan Town (Fig.3.17 and 3.24). The skeletons are so deformed that the genus can not be identified but the possibility of rudist is not excluded as, like rudist, the shells are replaced by secondary calcite. This facies can not be called rudstone because it seems that the skeletons are not transported but the floatstone can be used.

Castro, et al*.,* (2001) have used the term rudist floatstone or rudstone for this facies. Al-Sharhan (1995) has recorded rudist conglomeritic floatstone in the Mishrif Formation with lime mudstone and wackstone in the Middle Cretaceous rudist bearing carbonate in Arabian Gulf. These facies (rocks) are interbedded with thin partings and beds of buff to gray shale. Polmar *et al*.(2005) found rudist pillarstone of Hippuritid types. Wilson (1975) has cited the following facts about rudists (Fig.4.12):

They are important reef-formers of the Late Cretaceous, but also common in Middle Cretaceous strata. They are known in back-reef biostromes, at tops of shelf mounds and, in the Middle Cretaceous, commonly at shelf margins and on fore-slopes where they were associated with and gradually replaced by corals, spongiomorphic hydrozoans, red algae, and sponges. The shallow water coral forms seem to be replaced at some quieter water shelf edges by the rudists. Cretaceous algae are abundant in the carbonate realm and the major algal groups generally occur with certain of the major rudist groups Radiolited with the red algae in the outer shelf margin position. Rudists are shallow water dwellers and they are common in the Middle East. Rudists or molluscs are common components through the Early Cretaceous of the Tethyan seas.

Fig.3.17: A) outcrop section of pelecypod bearing lithofacies (as bed 12cm thick). B) Surface of the rudist biostrome, near the top of Shiranish Formation at 1.5kms south of Dokan Dam site.

3.2.4- Intraclastic floatstone

This facies consists of grains larger than sand size which floating or embedded in fine matrix of lime mudstone (Emery and Klovan, 1971). This facies is rare in the studied area as exists only in one section (Lower Dokan section) and associated with intense burrowing, boring and hardground. It contains of rip-up angular and discoidal clasts (gravel-sized) of Kometan Formation embedded in the fine grain matrix of lime mud and some glauconite grains (Fig.3.19). The thin section of the grains show that they are derived from nearby underlying Kometan beds which contain Santonian-Early Campanian planktonic foraminifera. Abawi et al (2008) found four intraformational clasts in the Bekhme Formation

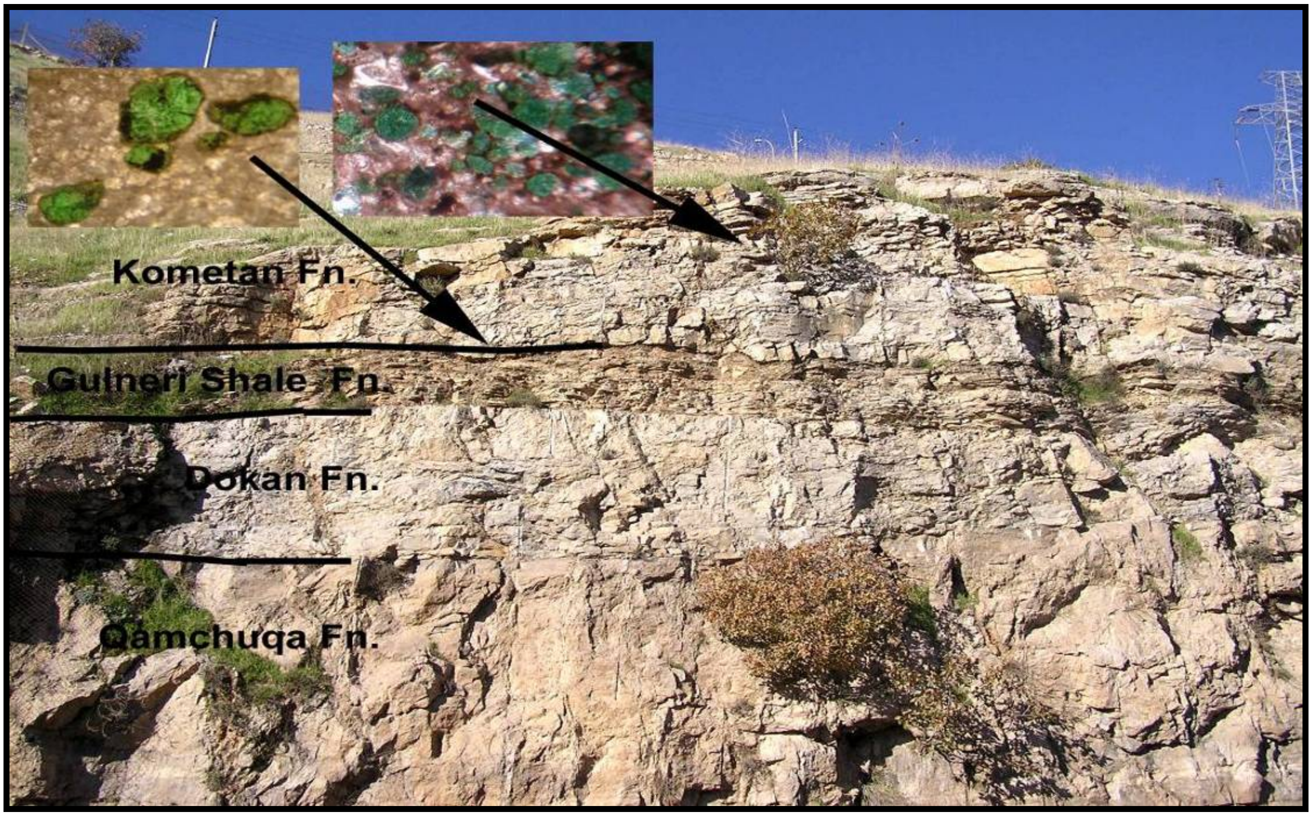

Fig.3.18: Road cut at the down stream of Dokan Dam site shows the formation and location of glauconite horizons.

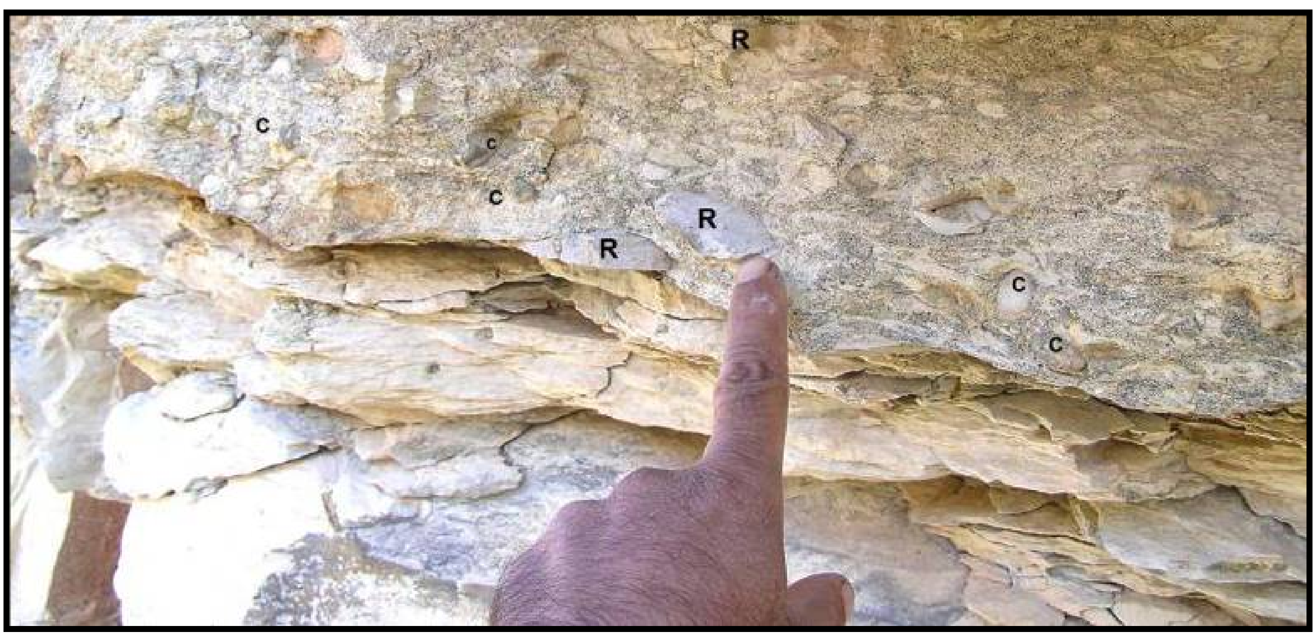

Fig.3.19: Intraformational clasts (rip–up clasts) at the base of glauconite limestone near the contact between Kometan and Shiranish Formations near the Dokan dam site. R: Rip-up clasts, C: chert nodules.

3.2.5- Planktonic foraminifera bearing marl lithofacies

This facies is the most abundant one in the studied formation as it constitutes nearly the whole thickness of the Shiranish Formation. It contain about 1-20% planktonic foraminifera the rest consist of clayey mudstone (marl). The insoluble residue is more than 30 percent. It contains occasionally rare glauconite and large ammonite fossils at the lower part. Karim (2006) and Surdashy (2006) have recorded more than 100m of this facies inside Tanjero Formation in Dokan, Sulaimanyia and Sharazoor areas. Karim *et al.* (2008) have showed by conceptual model that this facies (as Shiranish Formation) is lateral facies change of Tanjero Formation which both deposited in Early Zagros Foreland Basin. From the definition of Tanjero and Shiranish Formations, it appears that sandstone and shale of former formation change laterally to latter formation in Kirkuk area.

From the above citation appear that this facies is deposited as distal turbidite facies (hemipelagite) which according to Karim and Surdashy (2005) it derived mainly from the soft source area that was mainly consisted of uplifted Qulqula Radiolarian Formation.

3.3- Ichnofacies

Ichnofacies is association of environmentally related trace fossils, which generally reflect activity of soft- bodied organism (Catuneanu, 2006). As a sedimentary facies, it is defined by the types of trace fossils exist within, below or above sediments (Frey, 1975). According to Pembrerton (2001), each ichnofacies include a different type of trace fossils (Table 3.2). Although evidences like, lithology and body fossils can be used for environmental deduction, the trace fossils are very helpful in unfossiliferous successions. The traces fossils reflect, the effect of organism in homogenizing fine-grained sediments via arranging sediments in different packing mode, reflecting the activity of these organisms within sediments (Flugel, 1982). These activities represent digging or burrowing of sediments during syn-or post-deposition (Greensmith, 1971). When lithified rocks suffer from organism activity, the term bioerosion is utilized instead.

In the studied formations, the ichnofacies have low diversity and occurrence, only in the lower and upper parts of Kometan Formation which contain some trace. These features are mainly attributed to certain type of ichnofacies that reflects activity of organism in sediment in certain environment. Three types of ichnofacies are observed, they are Chondrite, Trypanites and Planolite.

3.3.1- Chondrite ichnofacies (Feeding structures)

The first established by Chamberlain, (1971) as a bathymetric zone indicator, transitional between Nereite and Zoophycos ichnofacies. It is recorded in the upper most part of Kometan Formation, and because of deep environment (as deduced from body fossils and lithology), it encountered as a subichnofacis of major Nereite ichnofacies. This exists in turbidite sediments, while condrite is found in deep marine carbonate rocks. The form and size of these trace fossils are similar to that given by Teichert, (1975), in his description, they consist of small plantlike dendritic patterns of regularly branched, cylindrical tunnels and shafts. The individual tunnels are neither crossing each other nor interpenetrating and their diameters are about 0.5 to 3mm, while their lengths reach more than 5cm (Fig.3.20). The origin of these traces are not clear, however, Frey, (1975) attributed them to soft-bodied unpreservable animals and (Seilacher, 1967) regarded them as burrows formed by feeding structures of sediment eating animals, while Bates and Jackson (1980) defined them as dwelling or feeding burrows of marine worms. According to Gingras (2002) the chondrites are dominated ichnofabric in low levels of oxygen in the water column.

Fig. 3.20: Chondrite trace fossil found in the upper part of Kometan Formation to the east of the Khalakan Village.

3.3.2-Trypanites Ichnofacies (Dwelling structures)

According to Walker (1984), Trypanites are associated with rocky coasts, reefs, hardgrounds, and other types of discontinuity or unconformity surfaces, and their substrate consists generally of calcium carbonate. He also mentioned that, most of the traces are dwelling structure excavated by suspension feeders and they are intergradational with Glossifungite ichnofacies, indicating important bioerosion agent, in addition to their acceleration of physical erosion. Catuneanu (2006) mentioned that they are association of various boring traces on a lithified substrate (hardground) that occurs in the marine shallow environment (shelf and shoreface). Bromley (1972) recommended Trypanites to include all pouch-like, single-entrance excavation that is made by bivalves and other organisms. In the Kometan Formation, three evidences are found for Trypanites ichnofacies and associated hardgrounds. The **first** is omission surfaces with consist of intensely burrowed glauconite rich mudstone, which contains dolomite filled small shaft and tunnel about (1–3) cm wide and (4–7) cm long (Fig.3.22). The **second** is that associated with borings which have sharp boundaries and filled with light green glauconite (Fig. 3.22). The **third** is the occurrence of sharp erosional surface below the omission surface (crude erosional surface) (Fig. 3.22). The **fourth** is the occurrence of pelecypod fossils with the ichnofacies which were observed by Karim, *et al.,* (2006).

3.3.3- Planolite Ichnofacies

This trace fossil, in the upper part of Kometan Formation, consist of straight to gently curved, cylindrical or nearly cylindrical burrows filled with material different from that composing the matrix. The burrows are more or less horizontal, or oblique to bedding planes, penetrating sediment in irregular courses. They exist in the sediment that overlying above the hardground and in which trypanite traces exist. During and after the generation the glauconite rich sediment was accumulated on the hardground which extensively burrowed as planolite trace fossils (Fig.3.21). In literature, similar structures are considered to *Thalassinoides and Planolite* trace fossils, which are included in Cruziana assemblage by Kennedy (1975) and Catananue (2006). Latter traces are found in both shallow and deep environment, by Chamberlain (1975).

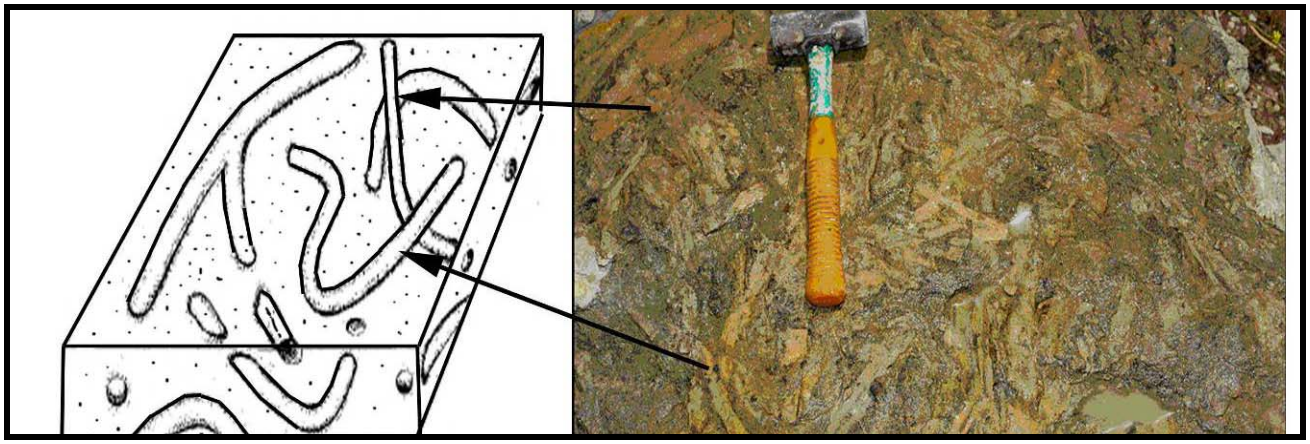

Fig.3.21: Planolite trace fossils in the glauconitic limestone at the contact between Kometan and Shiranish Formations near Dokan Dam site.

Table (3.3) Classification of ichnofacies based on substrate, environment and related traces (Catuneanu, 2006).

Substrate	Ichnofacies	Environment		Trace fossils
Softground, *nonmarine*	Termitichnus	Subaerial	No flooding: paleosols developed on low watertable alluvial and coastal plains	*Termitichnus, Edaphichnium, Scaphichnium, Celliforma, Macanopsis, Ichnogyrus*
	Scoyenia	Freshwater	Intermittent flooding: shallow lakes or high watertable alluvial and coastal plains	*Scoyenia*, vertebrate tracks
	Mermia		Fully aquatic: shallow to deep lakes, fjord lakes	*Mermia, Gordia, Planolites, Cochlichnus, Helminthopsis, Palaeophycus, Vagorichnus*
Woodground	Teredolites	Marginal marine	Estuaries, deltas, backbarrier settings, incised valley fills	*Teredolites, Thalassinoides*
Softground, *marginal marine*	Psilonichnus		Backshore ± foreshore	*Psilonichnus, Macanopsis*
Hardground	Trypanites	Marginal marine to marine	Foreshore - shoreface - shelf	*Caulostrepsis, Entobia*, echinoid borings (unnamed), *Trypanites*
Firmground	Glossifungites			*Gastrochaenolites, Skolithos, Diplocraterion, Arenicolites, Thalassinoides, Rhizocorall.*
Softground, *marine*	Skolithos	Marine	Foreshore - shoreface	*Skolithos, Diplocraterion, Arenicolites, Ophiomorpha, Rosselia, Conichnus*
	Cruziana		Lower shoreface - inner shelf	*Phycodes, Rhizocorralium, Thalassinoides, Planolites, Asteriacites, Rosselia*
	Zoophycos		Outer shelf- slope	*Zoophycos, Lorenzinia, Spirophyton*
	Nereites		Slope - basin floor	*Paleodictyon, Helminthoida, Taphrhelminthopsis, Nereites Cosmorhaphe, Spirorhaphe*

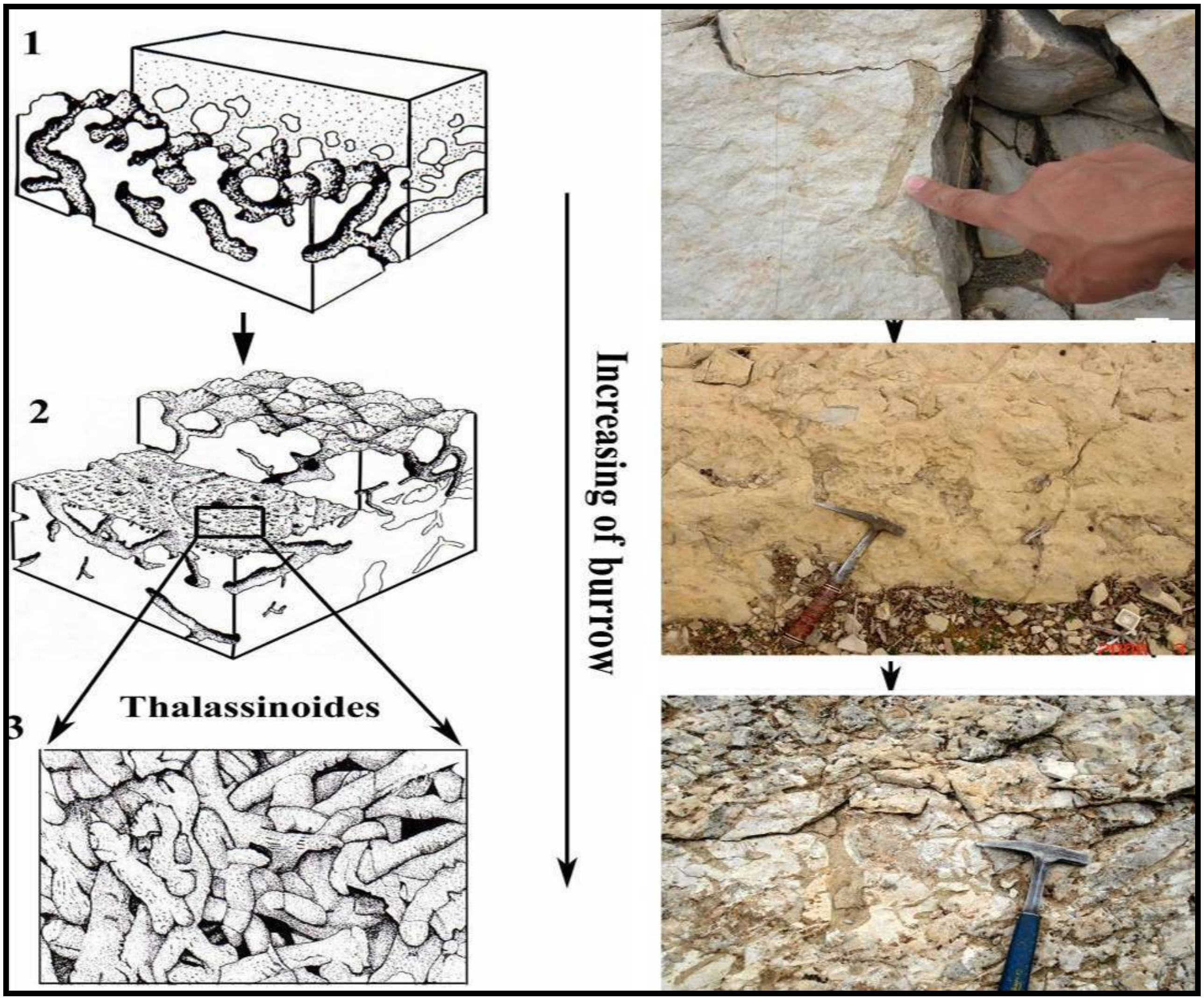

Fig.3.22: Different stages of burrows and boring (from A to C), which are represented the Thalassinoides on the surface (from 1 to 3).

3.4- Depositional Environment

The depositional environment of the formations such as Dokan, Gulneri and Kometan Formations are indicated, previously, as isolated small basins. This is shown in the time expanded stratigraphic column by Bellen, et al., (1959) and Buday (1980) in which these formations are nearly bounded in all sides by unconformity indicating small and isolated basins(Fig.3.23).The high bitumen content and dwarfed fossils in the some aforementioned formation were deposited in a euxinic environment (Jassim and Goff, 2006).

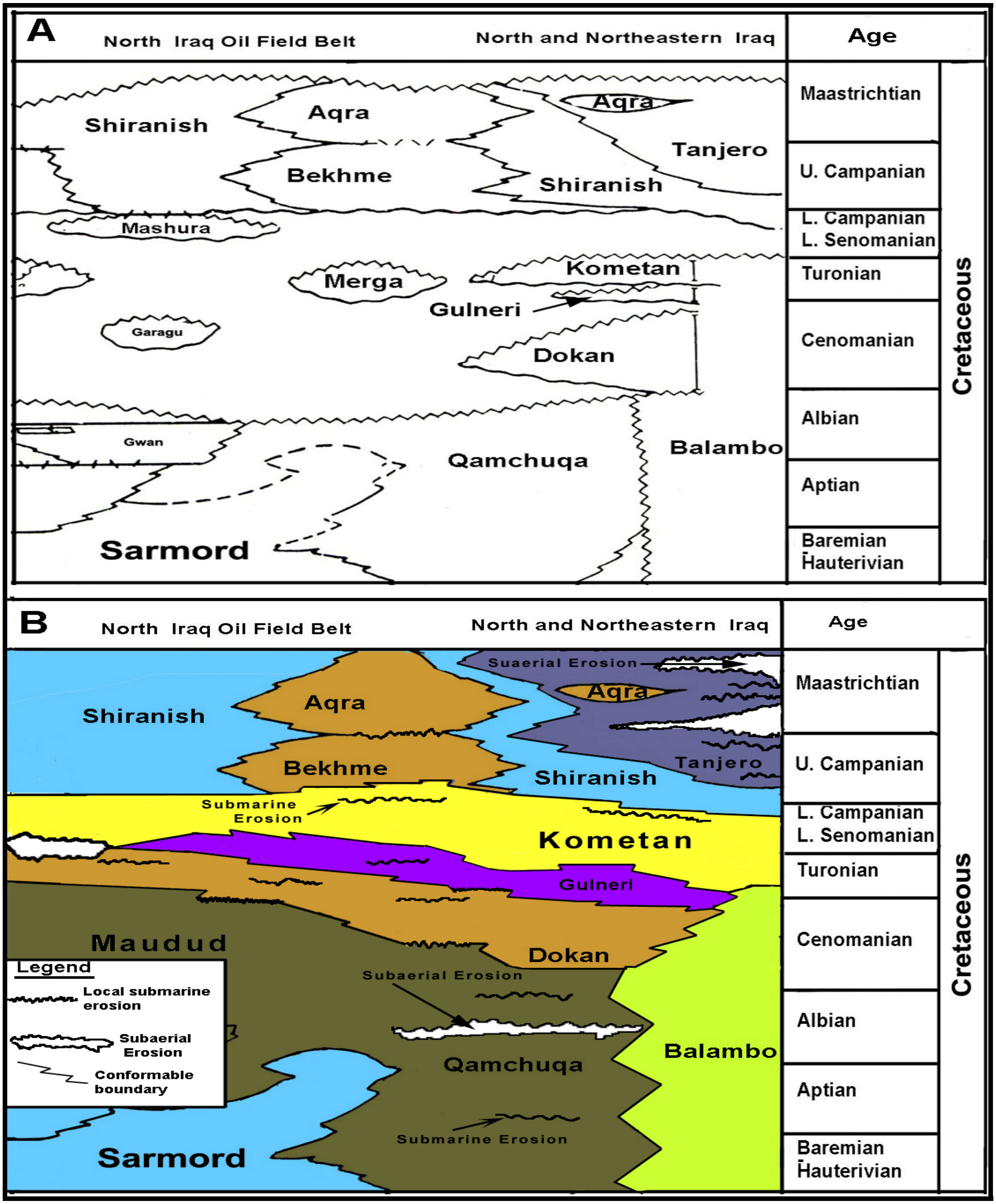

Fig.3.23:A) Time expanded stratigraphic (chronostatigraphic) column of the Late Cretaceous Formations showing that Kometan, Dokan and Gulneri Shale Formations are deposited in local isolated basins bounded by unconformity Bellen *et al* (1959). B) Modification of the column as a result of the present study.

Aqrawi (2008) has assigned the carbonate of Dokan Formation as the deposit of sub-basinal environment. This is very important when combined with reefal facies of Qamchuqa Formation (as cited by Ameen, 2008) for putting Dokan Formation as transition between Qamchuqa (platform carbonate) and Kometan Formations (basinal carbonate). This is because the transition between platform and basinal is the subbasinal environment.

The observed field and thin section study and facies analysis shows deepening of the depositional environment of the formations. This deepening was started from Qamchuqa Formation (reefal facies) and ended by Kometan Formation (deep pelagic or basinal facies) passing through intermediated stages which represented by Dokan and Gulneri Formations (oligosteginal subbasinal facies). This is because the transition between platform and basinal is the subbasinal environment. This is show that this study does not go with the ides of Bellen (1959), Buday (1980) and Jassim and Goff, (2006).

The thin section study showed that Dokan and Gulneri Formations contain abundant planktonic foraminifera (Figs.3.2 and 3.14). This doest not aid the previous assumption of the environment as euxinic because it is possible that the organic materials of the Gulneri Shale Formation are depositional but may be introduced during migration of these materials. The filtering is aided by content of high proportion of fine grain materials such as marl and clay which performed as filter for insoluble residue in the watery solution from Qamchuqa Formation to the surface. The Dwarfed fossil in the formation is attributed to some restriction of the basin at an intermediate phase between reefal and basinal environment. In this phase Dokan and Gulneri Formations are deposited during partially opened lagoonal environment of Qamchuqa Formation to basinal environment of Balambo Formation.

In other side, the existence of two beds of glauconite in Dokan and Gulneri Formations (at the base of the former and top of the later formations) prove that the environment was normal marine and more or less circulated. This is because, according to Blatt *et al* (1980), glauconites are formed in marine environment of very slow rate of deposition by early digenetic processes through replacement of biotite, when sufficient K and Fe are available.

By benthonic foraminifera analysis, Al-Dolamee (1988) mentioned that Middle bathyal environment (depth 500-1500m) has been determined for the Shiranish Formation in Sinjar area, with influence of turbidity currents and slumping.

The Shiranish Formation is deposited in outer shelf and basinal (Jassim and Goff, 2006), In the lower Shiranish Formation member the species diversity is greater, sediments are though to have been deposited in deeper water (middle slope depth) than the sediments of the upper Shiranish member (outer shelf depth), depositional environments 200-800 meter deep in a continental margin trough of the Tethys which are defined by the presence of depth restricted benthonic Foraminifera genera (Abdul-Kireem,1983).The prevailed environment, during sedimentation of Shiranish Formation is interpretated and correlated by faunal content, and the microfacies fabrics together with the clay minerals. Facies show that sediments of the Shiranish Formation have been deposited under shallow marine moderately energetic and weakly oxidizing alkaline conditions, and Shiranish Formation comprises the globigerinal marls and limestones of the Late Campanian–Maastrichtian transgressive cycle. (El-Anbaawy and A. Sadek, 1978) (Fig.3.28). Karim, (2005) mentioned that Shiranish Formation consists of marl and marly limestone (hemipelagite) and it deposited in the offshore of the Late Cretaceous Zagros Foreland basin (Fig. 4.11).

The Shiranish Formation represents the basinal facies of the Late Campanian Maastrichtian sedimentary cycle of north Iraq and it occupies an extensive area over the unstable platform region of the Arabian plate it is generally characterized by uniform lithology of bluish gray Globigerina marlstone and marly limestone (Al-Qayim, 1992).

3.4.1- Outer shelf and basinal (Kometan Formation)

Sediments of Kometan Formation were deposited in different environments ranging from shallow shelf restricted (Oligosteginal facies) to open marine (Globigerinal facies), (Jassim and Goff, 2006). Kometan formation is widespread in central, northern and Northeastern Iraq which are follows Ditmar and the Iraqi-Soviet team, (1971).

According to Westphal, and Munnecke (2003), a contrasting picture is drawn for the Cretaceous, when, in addition to the shelfal limestone-marl alternations, deep-sea pelagic alternations emerged (Fig.2.20). For the first time in Earth’s history, voluminous carbonate sediments accumulated in pelagic settings as result of the evolution and mass occurrence calcareous plankton. Large parts of the young Atlantic Ocean seafloor were located above the carbonate compensation depth, and accumulation of calcitic sediments was favored. In contrast to the shelfal alternations, depositional aragonite clearly did not play an important role; this is supported by the accumulation of such successions below the aragonite Compensation depth (e.g., Freeman and Enos, 1978).

In deep-sea pelagic settings, fundamentally different type of limestone-marl alternations formed: little or no aragonite was available for differential diagenesis as described here therefore, early cementation played a lesser role (low diagenetic potential after Schlager and James, 1978; Herbert, 1993), and compaction is ubiquitous in both marl and limestone beds. These new types of pelagic rhythmites, which are formed from the Cretaceous onward, occupy a sedimentary setting hitherto not typical for limestone-marl alternations, whereas aragonite-driven rhythmite continued to form in shallow-water–influenced settings.

3.4.2- Shiranish Formation

Al-Qayim (1992) suggested deep marine ramp for environment of Shiranish Formation in type locality which effected by turbidite and tempestite. The Shiranish Formation is deposited in outer shelf and basinal (Jassim and Goff, 2006). Abdul-Kareem (1983) mentioned that in its lower member the species diversity is greater and assumed to be deposited in deeper water (middle slope depth) whiles the sediments of the upper member is shallower (outer shelf depth about 200-800 meters deep) (Fig.3.27). El-Anbaawy and A. Sadek (1978) concluded, on the basis of the faunal content clay mineral and microfacies, that the formation is deposited under shallow marine moderately energetic and weakly oxidizing alkaline conditions. They added that Shiranish Formation comprises the globigerina marls and limestone of the Late Campanian–Maastrichtian transgressive cycle. Karim, (2005) mentioned that the Shiranish Formation consist of marl and marly limestone (hemipelagite) and it deposited in the offshore of the Late Cretaceous Zagros Foreland basin.

Fig.3.24: A: a lensoidal 10m thick pelecypod rich limestone inside Shiranish Formation at northeastern side of Kato mountain, 7km southeast of Chuarta City. This local limestone may be formed as mound in relatively deep water. B: Deformed pelecypods as collected from one horizon inside, the mound deposits.

3.5 - Bedding plane and environment control

Beds are enclosed (bounded) by sharply defined upper and lower surfaces or bedding planes, these surfaces are easiest physical features of sedimentary rocks to identify on outcrop and subdivided succession of sedimentary rocks into beds. Bedding planes generally represent a change in the conditions of sedimentation. The changes may have been subtle or short-lived (Tucker, 1991). According to Bate and Jackson (1980), they referred to bedding plane as plane of discontinuity along which a rock tent to split or break readily.

Kometan Formation is composed of well bedded limestone succession in which the beds are separated by clear bedding surface or bedded plane (Fig.3.25 and 3.26). These bedding plane are exist in all outcrops either contain stylolites or not which denote that these surfaces are depositional not diagenetics.

As previously mentioned, the environment of studied formations is relatively deep, so nearly all deposition is occurred below fair weather wave base. While it is possible to say bedding plane is developed during short and severe storm base. It is possible that the bedding planes are suffered from some erosion by currents that are generated by the storms. This erosion may be associated with some shells and sand concentration (with some bioturbation) which are called by Kendall (2005) as event concentration (Fig.3.26). During erosion, some clays are brought to the basin by the storm and deposited which now can be seen on bedding plane of Kometan Formation. When erosion and nondepostion continuous for some time, a composite concentration is developed while in long time hital concentration is formed. The hiatal may contain intense glauconitization and bioturnbation with possible hardground (Fig.3.3). The hiatal is found in the contact between Kometan and Shiranish Formations in the lower part of Kometan Formation near the boundary with Gulneri Shale Formation.

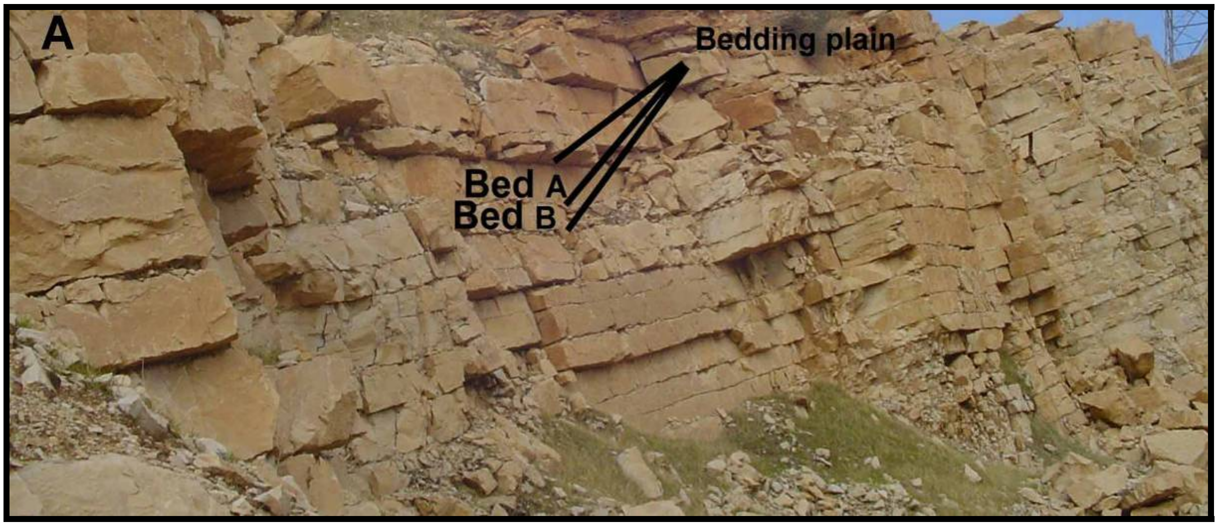

Fig.3.25: shows beds and bedding plains in Kometan Formation in sections A) Beds and bedding plains in Kometan Formation in Dokan Dam (upper Dokan section).

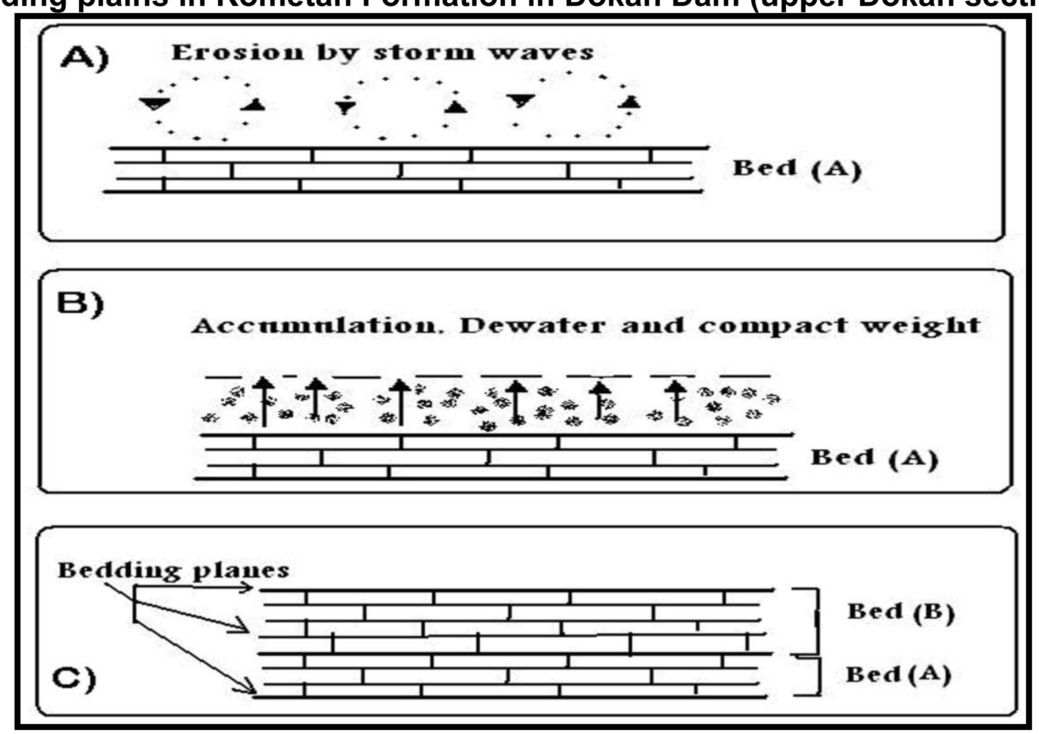

Fig.3.26: Generation of bedding planes. A) Erosion by storm waves .B) Accumulate, dewater and compact weight C) bedding planes formed. (Modified after Kendall, 2005).

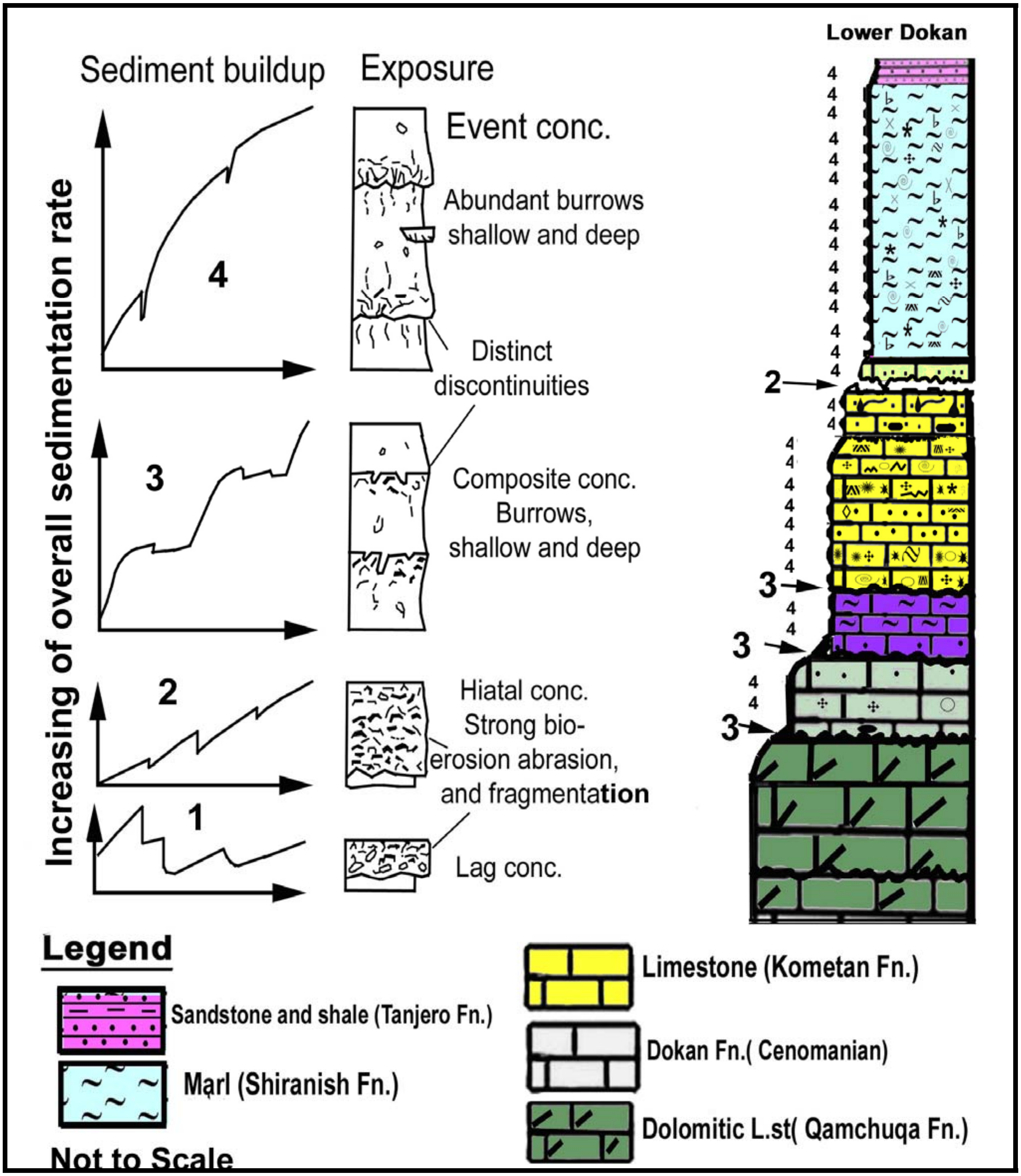

Fig.3.27: Event, composite and hiatal concentration by Einsele (2000) as applied on the studied formations. These events are the represent the maximum recorded discontinuity in the formations. They are submarine and have short duration which are do not represent the unconformity that mentioned in the previous studies.

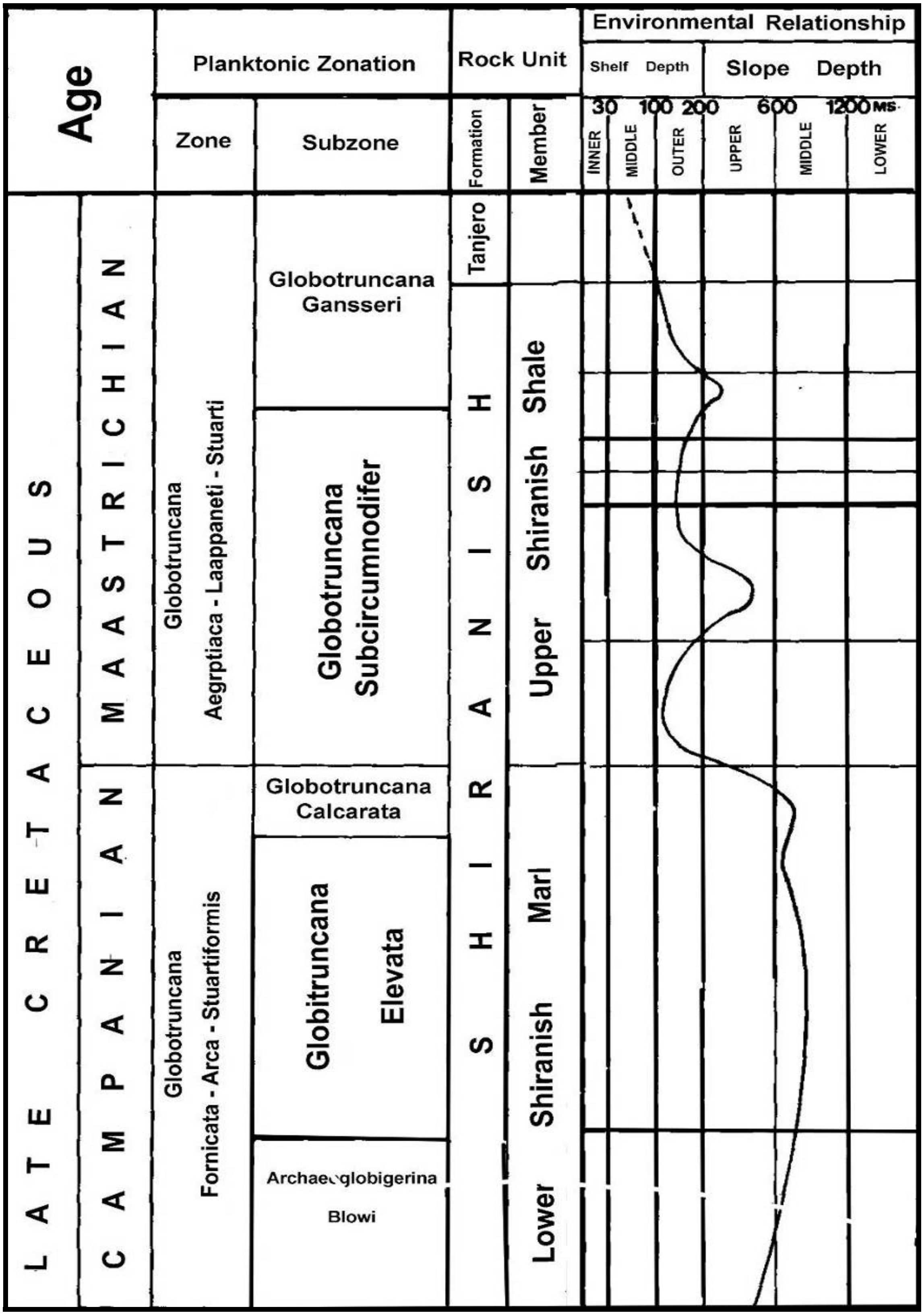

Fig. 3.28: Bathymetry of the foraminifera assemblages of the Shiranish Formation (Modified after Abdel-Kireem, 1983).

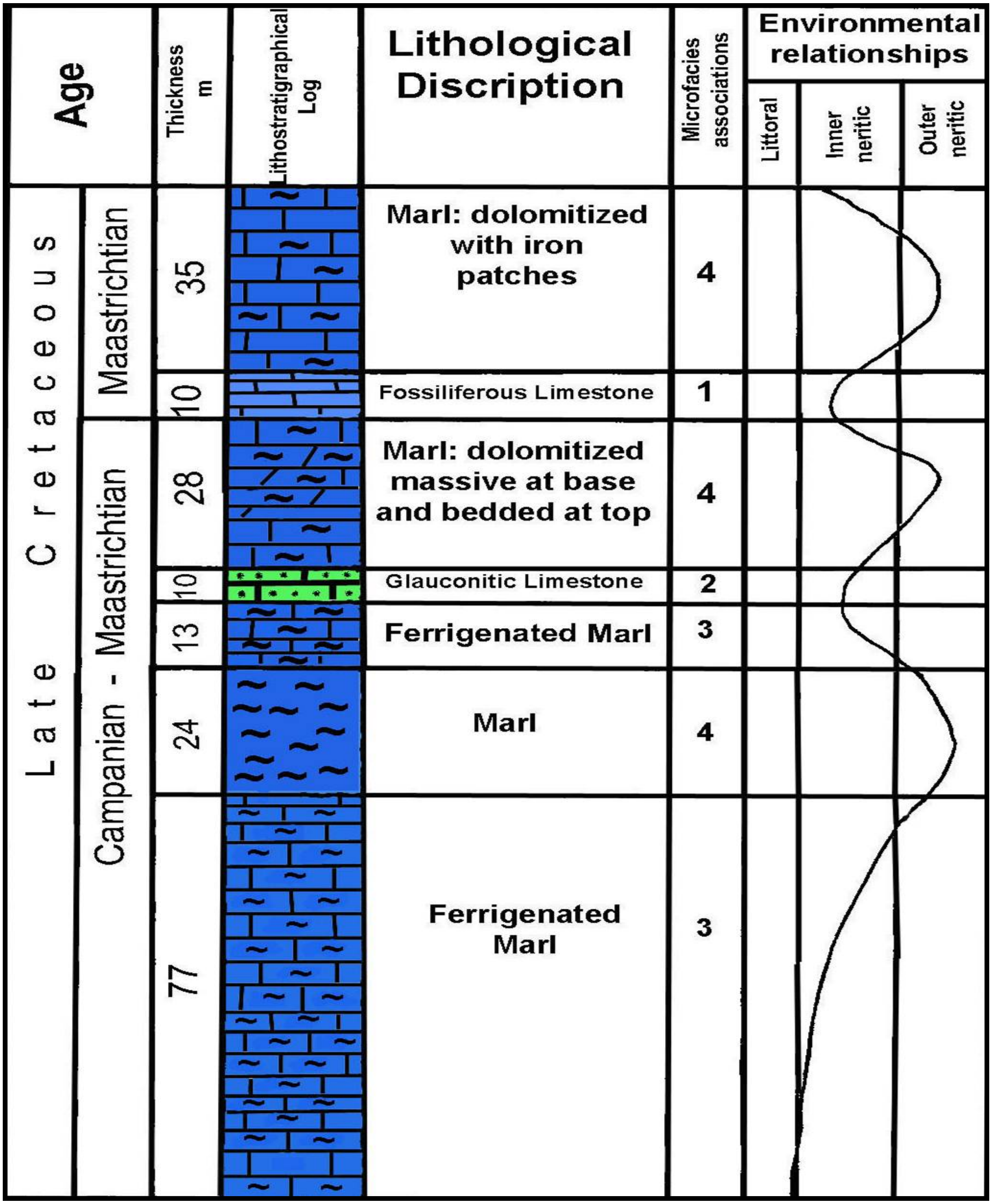

Fig. 3.29: Schematic illustrated environmental deposition of Shiranish Formation in Northern Iraq. (Modified by El-Anbaawy and Sadek, 1978).

Table (3.4) Assemblages of Upper Cretaceous benthonic Foraminifers of the Shiranish Formation, arranged in stratigraphic order and according to bathymetric significance. (Modified by Abdul-Kareem, 1983).

Campanian (Middle slope habitat)	
Ammodiscus cretaceous (Reuss)	Glomospira corona
Cushman et Jarvis	
Bathysiphon brosgei Tappan	Osangularia corderiana (d
Orbigng)	
Chilostomella trinitatensis Cushman et Todd	Praebulimina venusae
(Nauss)	
Dorothia oxycona (Reuss)	Pullenia cretacea Cushman
Gaudryina rugosa d' Orbigny	Rzehakina epigone (Rzehak)
Campanian-Maastrichtian (Boundary – Upper slope habitat)	
Gaudryina rugosa d Orbigny	Marginulinopsis cretaceous
(Cushman)	
Gavelinella pseudoexcolata (Kalinin)	Neoflabellina woodi (Nakkady)
Gyroidinoides nitidus (Reuss)	Spiroplectammina laevis
(Roemer)	
Lenticulina macrodiscus (Reuss)	Stensioina pommerana
Brotzen	
L. secans (Reuss)	
Maastrichtian (Outer shelf habitat)	
Bolivina incrassate (Reuss)	Pleurostomella subnodosa
(Reuss)	
Gavelinella velascoensis (Cushman)	Praebulimina
kickapooensis (Cole)	
Gyroidina cretacea (Garsey)	Spiroplectammina laevis
(Roemer)	
Lenticulina macrodiscus (Reuss)	Stensioina pommerana
(Brotzen)	
L. secans (Reuss)	Trochammind diagonis
(Carsey)	
Marginulinopsis cretaceous (Cushman)	

CHAPTER FOUR

TECTONIC DEVELOPMENT AND DEPOSITIONAL HISTORY

4.1-Tectonic history

To establish, realistic tectonic model and depositional history that agree with field and laboratory data of the Late Cretaceous formations, the following points must be mentioned:

A–Buday (1980) has divided the rocks of the Late Cretaceous in to several cycles and subcycles on the basis of break in sedimentation and tectonic phases, which cause widespread regression and subaerial erosion as show*n* time expanded stratigraphic column by Bellen et al., (1959). These cycles are as follows:

According to Buday (1980) the Cenomanian Maastrichtian in Iraq is generally divided in to the following three subcycles:

1. Cenomanian–Early Turonian Subcycle, during which Rutba, Ahmadi, Mishrif, Dokan and Upper Balambo Formations are deposited.
2. Turonian–Early Campanian Subcycle in which Kometan, Gulneri, Khasib, Tanuma, and Sadi Formations are deposited
3. Late Campanian–Maastrichtian Subcycle, during which Shiranish and Tanjero Formations are deposited.

According to Buday (1980) these cycles or subsycles are associated with intense tectonic activity, regression, emergence and erosion, some of which were prevailed in all Iraqi territory. However, in the studied area, these subcycles are not identified and the only cycle that recognized in the studied area is that during which 500m of conglomerate (as proximal sediments of Tanjero Formation) deposited during Lower Maastrichtian (see Karim, 2004 and 2006, Karim and Surdashy, 2005a and 2005b). Unfortunately, nothing is mentioned about this important cycle by Buday (op. ct).

B-Recently Karim (2004) indicated that the contact between Cretaceous and Tertiary is gradation in Dokan and south of Sulaimanyia city and there is no break in sedimentation such that previously described. This is also proved by biozontion by Sharbazery (2008) who showed that across the boundary there is no missing age including Danian. Karim *et al.,* (2008) studied the contact between Shiranish and Kometan Formations in six different sections and refused the previous unconformable contact on which the Late Campanian–Maastrichtian subcycle is established. They drew a tectonic and paleogeographic model to show the gradation boundary between the two formations in the Early Cretaceous Foreland Basin (Fig. 4.4).

C- According to Bellen et al (1959), the Dokan limestone comprises the sediments of an intra Cenomanian transgression, and follows upon an eroded surface which was dictated by post-Albian or Late-Albian regression. They added that it is followed by the Gulneri shale, which contains the sediments of a later (early but probably not earliest Turonian) transgression, following a second probably intra-Cenomanian regression. Kometan comprises the sediments of a Turonian transgression following a very early Turonain emergence.

According to this author, two transgression and regression occurred during deposition of Dokan and Gulneri Formations. They meant by regression and transgression that intense tectonic uplift (equivalent to the type one sequence boundary) and subsidence occurred as can be seen from Late Cretaceous time expanded stratigraphic column of the (Fig.2.1). But as we see later both formation are deposited during one transgression.

D- Buday (1980) gave strange ideas about basin of Gulneri Formation. He mentioned that it occupies a somewhat peculiar position within the Turonian-Lower Campanian Subcycle, because it is separated by breaks from the underlying Cenomanian and the overlying Turonian units. He further added that it represents the sediments of a relic sea, existing between the regression of the Cenomanian and the transgression of the Turonian. A possible exception might be in the Injana section. Based on the evidence of the high bitumen content and a dwarfing of the fossils, the environment of the formations was euxinic.

The author means by Relic Sea that it deposited during tectonic uplift by which most area become terrestrial and only Relic Sea remained in which Gulneri Formation was deposited. But as can be seen later, the formation is deposited in the same basin of Kometan and Shiranish Formations during transgression.

After, reviewing the most important modification of the geology of the area which manifested by removing all unconformities that indicated before, it is possible to starting the depositional history and the related tectonic of Late Cretaceous. The removing of the unconformities enables the present study to remove the cycles and combine all formations in one large foreland basin with a continuous history of deposition.

The previous cycles had segmented the rocks and history of the area into several separated and unrelated tectonic events that occurred in different basins. But due to recent ideas, the ideas of the Eu–and miogeosyncline of Bolton (1959) and Buday (1980) has refused by the tectonic scenario of Numan (1997) but this scenario seems that is not applicable in the studied area as concerned to stratigraphy and tectonics (Fig.4.1). Therefore, the present study tries to unify the major cycles in one single basin and tectonic model that is more applicable with the evidences field in the studied area.

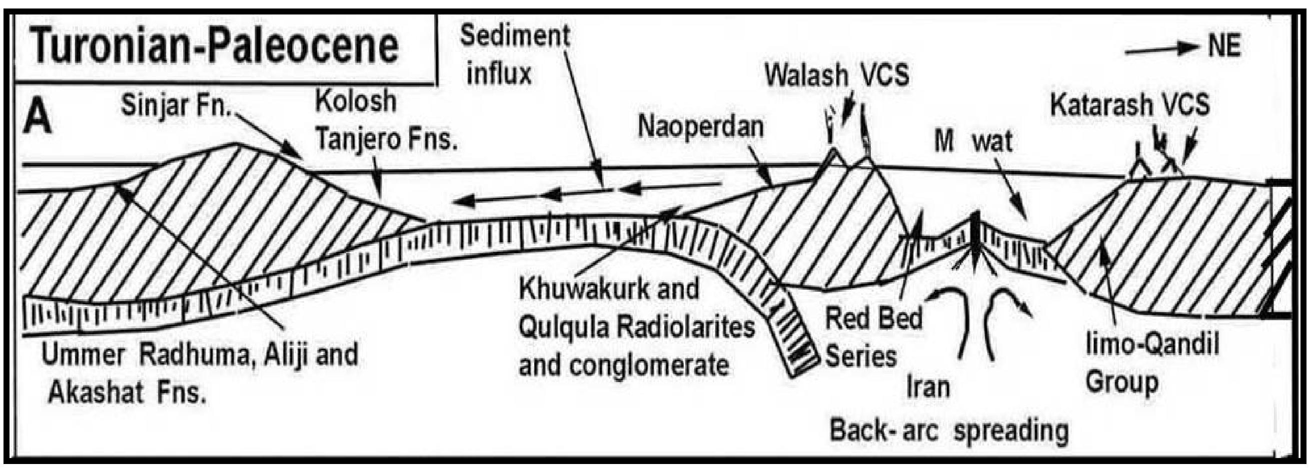

Fig.4.1: the tectonic model of Numan (1997) in which the position of Kometan, Dokan, Gulneri and Shiranish Formations are not indicated.

To start construct the basin, it must be started from known historical step that predates or postdates the Late Cretaceous during which Dokan, Gulneri, Kometan and Shiranish Formations are deposited. As known steps, the Maastrichtian tectonic and depositional history is well studied, in the studied area, by Karim (2004 and 2006), Karim and Surdashy (2005a and 2005b). This is true for Lower Cretaceous (Valanginian-Cenomanian) which has been studied in similar manner by Ameen (2008). We start from late Lower Cretaceous history set-up and try to combining it with that of Maastrichtian going through Cenomanian–Campanian.

According to Ameen (2008), during Cenomanian, the shallow marine reefal limestone of Qamchuqa Formation was depositing in the studied area which was making up a part of Arabian platform. During Late Cenomanian the studied area began to change from shallow marine to deeper water gradually. This gradual change is represented by Dokan Formation which has the intermediate characteristics between Kometan and Qamchuqa Formation. According to Ameen (2008) this environment change is attributed to approach of the huge column of Radiolarian and ophiolite (as accretionary prism in front of the southwest advancing front of Iranian plate, to the Arabian Platform (Fig.4.5). Under the load of the accretionary prism, the previous forebulge on which Qamchuqa Formation was deposited tectonically subsided (Fig. 4.2). By this subsidence Kometan Formation began to deposit.

Before deposition of Kometan Formation, and during deposition of Dokan Formation, the lagoon sediment that was associated with the reefal limestones Qamchuqa Formation was suffered from intense submarine erosions. According to Ameen (2008) this erosion attributed to the subsidence of the barrier (reef core, which before subsidence protected the lagoon from open marine wave and current. The product of this erosion was deposited as Gulneri Shale Formation during drowning (transitional phase before complete drowning) of the Arabian platform. After the deposition of this formation, the platform had transformed to deeper water and in which planktonic foraminifera and lime mud are deposited simultaneously.

In the studied area, this fact is aided by two characteristic of the Gulmeri Formation. The first one is that Gulneri Formation contains marl and marly limestone in addition to some shale. The shale and the marl are deposited during high rate of submarine erosion while marly limestone is deposited during quiescence of erosion. Later during deep burial the marly limestone bed change to ball and pillow-like structures that most possibly assigned as conglomerate previously by Bellen et al(1959) (Fig.4.3). The second is that toward southwest (toward the lagoonal limestone) the thickness of Gulneri Formation increases such as in Kirkuk which is reaches about 20m (Buday, 1980 and Sarraj, 2007). In addition to these subsidence and erosions, the studied area was relatively calm and no important tectonic events were taking place during Early Late Cretaceous except further drowning.

Due to the subsidence (or drowning of the platform, the reefal limestone in the studied area stepped back towards northwest and south which reach the west Baghdad during Maastrichtian (Fig. 4.3).

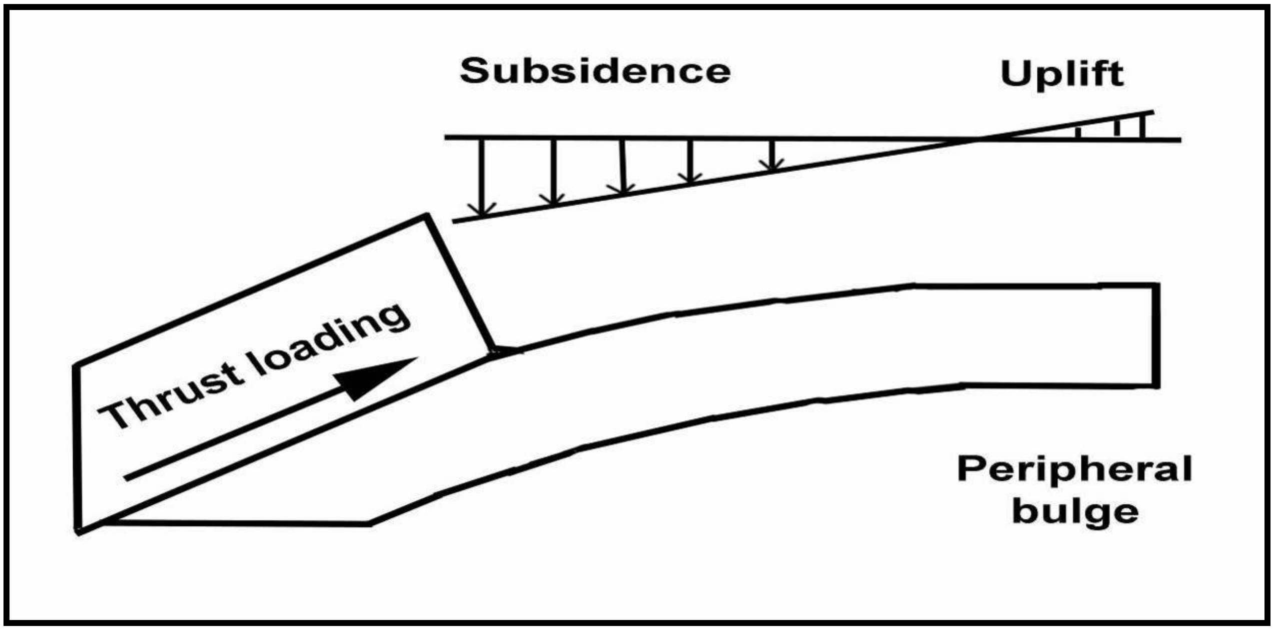

Fig.4.2: Mechanic of forebulge generation by thrust loading (Einsele, 2000).

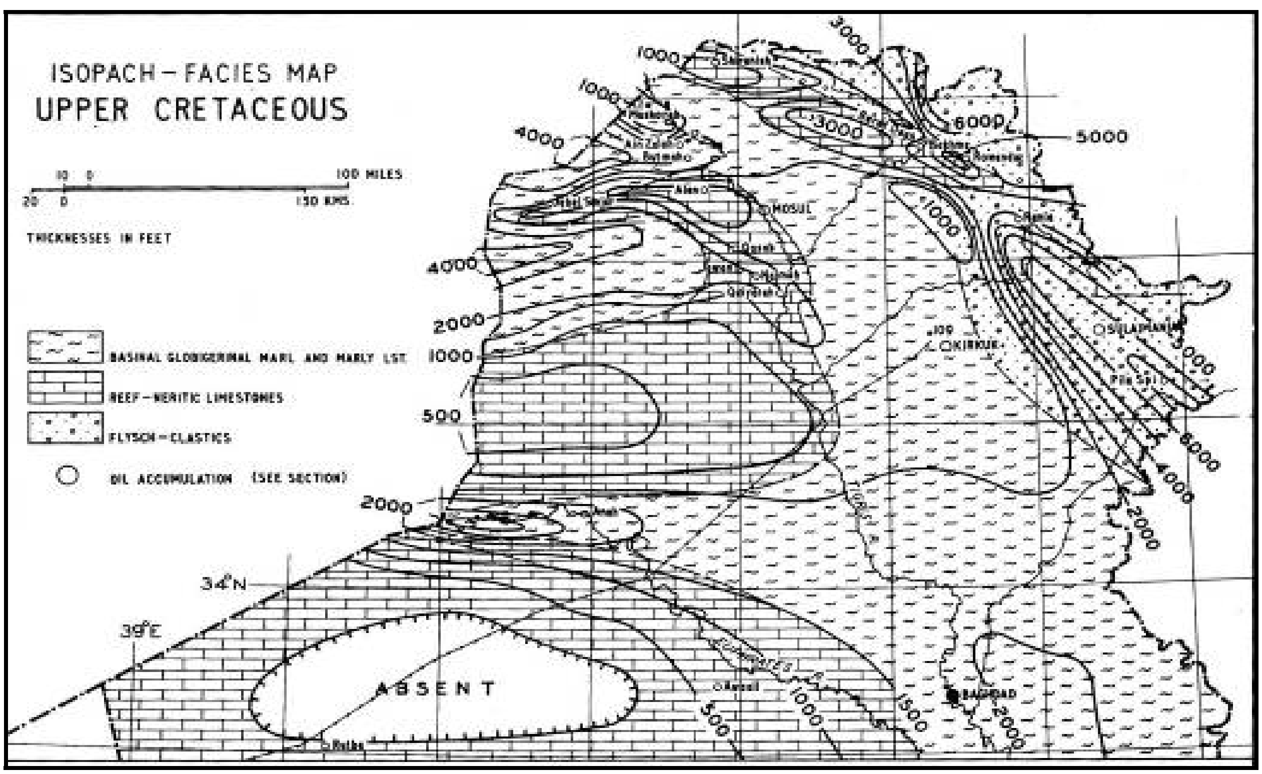

Fig.4.3: Isopach facies map of Late Cretaceous (Dunnington, 1958) shows migration of reefal limestone to western Iraq from northeastern Iraq from Early to Late Cretaceous. This migration possibly is related to forebulge retreat and drowning of the studied area.

4.2- Major events of Early Cretaceous

According to Ameen (2008), inside Iran and near to the present location of Sanandaj-Sirjan belt, the oceanic part of the Iranian and Arabian plates had collided (senso strico) and divergent boundary is generated by which Iranian plate obducted over Arabian one during Berremian. By this obduction, the previously deposited radiolarites and ophiolites had begun to accumulate in the trench between the two plates forming accretionary prism. Between the prism and Balambo Formation the radiolarites were continuously deposited in the trench (Fig. 4.12 D). He added that During Valanginian to Cenomanian, the accumulation and southwest migration of the wedge (or prism) were continuous. This forced the basin of Qamchuqa Formation to subside and uplift in different times under the effect of loading and relaxation (when principles of basin analysis of Allen and Allen, 1990 and Einsele, 2000 are used). This oscillation can be seen in the field in the form of the alternation of lagoonal and reefal limestone or dolostone.

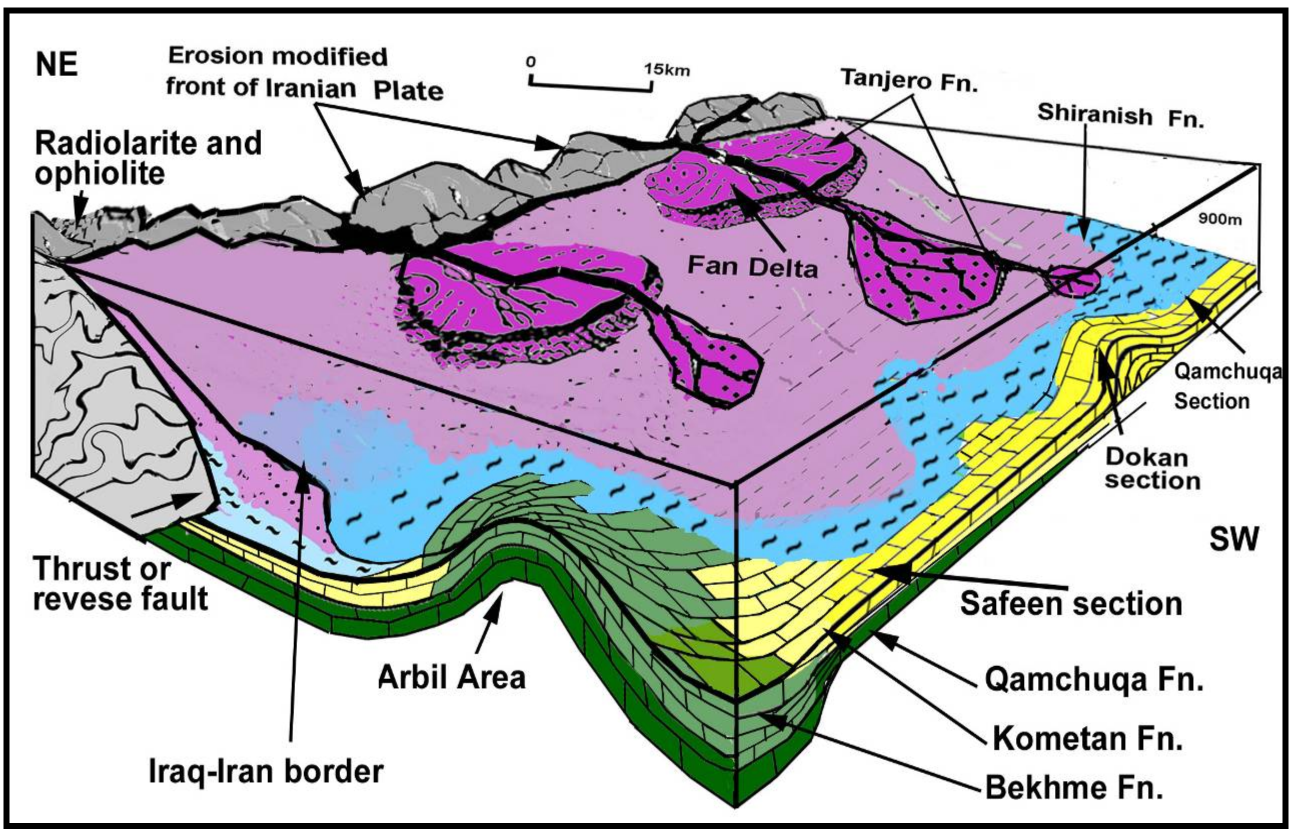

Fig.4.4: A Model for interpreting and indicating the location where the contact between Kometan and Shiranish Formation is deposited during Lower Campanian in the newly developed foreland basin (Modified from Karim et al., 2008).

4.3- Major events of Late Cretaceous

After the deposition of Kometan Formation, the two continental parts of the Iranian and Arabian Plates were collided. Slightly before collision, the trench was filled with scraped off sediments (radiolarites) and ophiolites. These materials are uplifted and thrown onto the subsided continental part of the Arabian Plate. The uplifted and over–thrown materials have formed positive land in the suture zone of the two plates. According to Karim (2004) Karim and Surdashy (2005b and 2006), due to this colliding, the studied area was transformed from passive margin to active Early Zagros Foreland Basin. According to these authors, Shiranish, Tanjero and Kolosh Formations are deposited in this foreland basin. They added that the collision changed the accretionary prism to source areas (orogenic belt) for Late Cretaceous sediments such as Shiranish and Tanjero Formations. This collision is manifested by about 500m of gravel and boulder conglomerate that can be seen at Chuarta, Mawat and Qandil areas. Under the conglomerate the unconformity is found which is only ascertained unconformity. The present study which belong to the late Campanian and Early Maastrichtian which is studied by Karim (2004) Karim and Surdashy (2005b and 2006).

4.3.1- Drowning of Arabian platform

In the studied area and during the considered time segment (Cenomanian- Late Campanian), one of the important events is the drowning Arabian platform which started to subside relatively rapidly at Late Cenomanian. This drowning generated a great role in development of the stratigraphy of the studied area which manifested by deposition of Dokan Formation which is assigned as sediments of transition from normal platform to drowned platform. Gulneri Formation is the product of drowning activated erosion of pre-drowning lagoonal sediments. In other side, Kometan is sediments of drowning phase. Therefore, the growing process is given important attention in this study and literatures.

4.3.1.1- Drowning in literature

The drowning of carbonate is inability of the platform to keep pace with the rate of relative sea level rise which is a well known phenomenon in carbonate platforms (Schlager, 1981). Platform drowning may occur in various tectonic settings: foreland basins (Robertson 1988; Galewsky 1998), extensional basins (Bice and Stewart 1990), Pull-apart basins (Duncan et al., 1999). According to (Tucker, 1991), drowned platforms are ones which is relatively rapid sea-level rise, so that deeper water facies are deposited over shallow water facies and many pelagic limestones were deposited in these situation. (Mutti et al., 2005) have mentioned that platform drowning can be controlled by many factors, including rapid eustatic sea-level raise, crustal subsidence, ecological stress, water temperature, upwelling of cold deep water and the rate of sediment production and removal.

Carbonate productivity is related to water depth, if there is an abrupt relative sea level rise due to tectonic subsidence or eustatic sea level changes and an area which had formerly been a site of shallow marine carbonate deposition may become too deep for the production of much sediment this is called the drowning of a platform (Nichols, 1999). Einsele (2000) referred to the drowning as give-up phase of the relation of the carbonate platform with sea level change. He mentioned that it happens when the relative sea level rise exceeds the carbonate growth by which the deepwater carbonate and hardground overlies the shallow water carbonate.

According to Catanenue (2006), the drowning represents the final stage in the evolution of a carbonate platform, prior to the return to a clastic dominated environment. Once the platform is drowned below the photic limit, filling of the available accommodation during subsequent highstand normal regression may only be achieved by means of siliciclastic progradation. He added that sedimentary processes during drowning already resemble clastic patterns of sediment dispersal. This is particularly evident in the distal shelf to deep-water settings as the lack of carbonate production coupled with hydraulic instability at the erosion of the shelf edge caused by rapid base-level rise result in the erosion of the shelf edge region and the formation of a healing phase wedge that onlaps the continental slope just as in the case of pure clastic systems. Drowning is called type A (drowning) response of the platform to sea level change by Kendall and Schlager (1981).

The other two types are Type B (catch up-survival of rim and patches) and Type C (Keep up-upbuilding and outbuilding) (Fig.4.7)

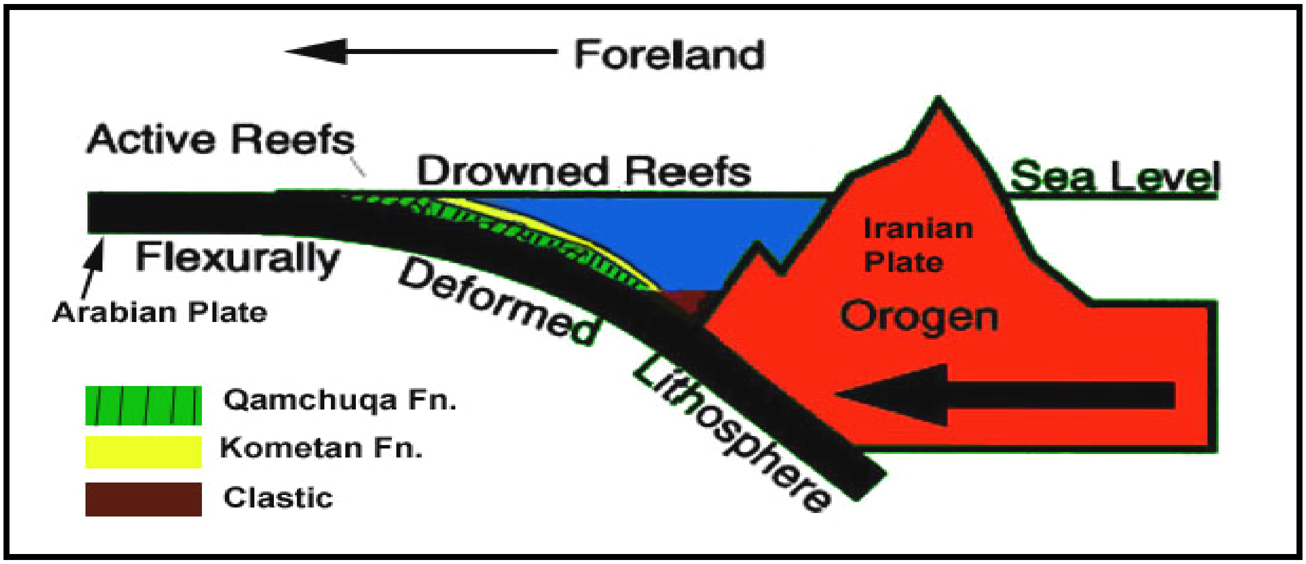

Fig.4.5: Tectonic drowning of the carbonate platform by flexure of continental lithosphere under the load of overriding plate (Galewsky, 1989) which can be applied to the Kometan Formation with some modification.

Emery and Myers (1996) have given the following important Paragraphs about drowning platform which make platform unconformity (type three sequence boundary) which can be applied on Dokan, Gulneri Shale, and Kometan Formations:

As well as starting catching and keeping up, carbonate systems will also give up. Rapid, but short lived sea-level rise may outpace carbonate platform growth, but once the rate of sea level rise slows down, all other things being equal, the carbonate platform may be restored to productive health. However, there are several environmental factors which are independent to sea level change that may seriously slow down carbonate development. As well as the appropriate light and temperature requirements, there are at least five additional controls that need to be considered nutrient supply clastic input, oxygenation, salinity and prediction. For more detail on mechanisms of platform drowning the reader is referred to Schlager (1992). In the fossil record, the term (drowning unconformity) has been coined (Schlager 1989), this unconformity can have developed only when the carbonate platform top was flooded i.e. within the transgressive or highstand systems tract. Drowning unconformities have several distinctive properties which in detail differentiate them from sequence boundaries. First, there is usually a very rapid change from shallow water carbonate to deep shelf, slope or basinal deposits. Observation by the author of cores taken from the top of Miocene carbonate platform, offshore central Vietnam, show a change from shallow water platform carbonate sedimentation through a drowning sequence of deeper water Foraminifera, with evidence of marine condensation, including glauconite and phosphates and finally into basinal mudstones. This transition takes place over several to a few tens of meters but represents several millions years worth of sedimentation."

An intermediate version of complete platform drowning is backstepping or retrogradation. This may take place in scale of a single platform, where the platform margin retreats away from incoming siliciclastics, such as in the Devonian build-ups of western Canada (Stoakes and Wendte 1988; Scaturo et al., 1989). In short, the most important point about platform drowning is that it can be controlled entirely by environmental factors; sudden rapid rises in sea level may outpace carbonate production temporarily, but deterioration in the environment of the carbonate factory through any of the mechanisms discussed above is more likely cause of large-scale platform demise.

4.3.1.2- Causes of carbonate platform drowning:

4.3.1.2.1- Nutrient supply

Low nutrient environments are most favorable for organic carbonate growth, particularly reefs. In high-nutrient settings, carbonate-secreting framework-building corals are replaced by fleshy algae, sponges or soft corals. Modern examples include the East Java Sea, Indonesia, where corals are scarce below 15m and are replaced by green algal. The lack of reefs is interpreted to be the result of upwelling nutrient-rich waters, which stimulate the growth of coral competitors (Roberts and Phipps, 1988)

4.3.1.2.2- Siliciclastic input

Clay particles in suspension in the water column will inhibit light penetration, significantly reducing or preventing reef growth. In addition, coral polyps and many predecessor framework building forms were, unable to deal with clay particles during feeding.

Circumstance evidence of carbonate demise by clastic input in the geological record is demonstrated by seaward stepping Miocene carbonate systems from south to north across the Luconia province, offshore Sarawak, Malaysia, away from northward prograding delta systems (Epting, 1989). Note that changes in water salinity or nutrient content associated with a siliciclastic depositional system such as a delta may be the prime cause of carbonate production demise.

4.3.1.2.3- Salinity variation

Changes of salinity may exert a dramatic effect on carbonate productivity, particularly that of reefs. In the Holocene, broad, shallow lagoonal on flat-topped carbonate platforms acquired highly variable salinities. The seaward ebb flow of the unfavorable bank water killed the reefs, which also became overwhelmed by seaward transport of carbonate fines from the lagoonal (Neumann and Macintyre, 1985).

4.3.1.2.4-Oxygenation

When oxygen is depleted, reefs will die. However, the evidence for massive carbonate demise resulting from oxygen deficiency is indirect. Schlager and Philip (1990) have used evidence for Cretaceous oceanic anoxia and compared this with the frequency of Cretaceous carbonate platform demise to indicate a possible causal link.

4.3.1.2.5-Predation

The importance of predation on carbonate communities is well-documented from modern day examples. The Crown of thorns starfish blight, which threatened to wipe out large tracts of the Great Barrier Reef, is well-known. However, it is difficult, if not impossible, to demonstrate clearly the effect of predation in the fossil record, and is currently unknown on the scale of an entire carbonate platform.

4.3.1.3- Phases of Drowning

The drowning phases of the Northeastern margin of the Late Cretaceous Arbian Platform can be established depending on the existing lithology, fauna and the facies of the stratigraphic units which are described in detail (see chapter three). For decoding the characteristic and timing of the phase, the works of Kendall and Schlager (1981), Read (1988), Blomeier (1999), Schlager (1998), (Galewsky, 1989), Ameen(2008) about drowning platform are divided to four phase according to the depositional environments and facies analysis:

1-Pre-drowning phase (Qamchuqa Formation).

2- Drowning phase or transitional to post drowning phase (Gulneri Shale and Dokan limestone Formations).

3- Post drowning phase (Kometan Formation).

4- Burial Phase: Siliciclastics prograding on the Arabian Platform (Shiranish and Tanjero Formations).

4.3.1.3.1- Pre-drowning phase

In this phase the platform is continuous in growing and there is balance between growth in photoic zone and subsidence (or sea level rise). This phase is called Type C (Keep up-upbuilding and outbuilding of shallow water carbonate) by Kendall and Schlager (1981) which can be applied to Qamchuqa Formation.

4.3.1.3.1.1- Platform interior

The succession is deposited on the platform top are characterized by limestone/marl alternations, which are separated by distinct exposure surfaces. The marls are usually badly exposed and the lateral varying limestones consist of pel- and biopelmicrites (wackestones), pure micrites or dismicrites (mudstones), and algal mats. Horizontal laminations are frequent and are formed by lateral component enrichments or the occurrence of interlamellar, long-stretrched cavities. These primary patterns are frequently destroyed by bioturbation, resulting in an irregular arrangement of the components and the formation of stromatactis-like structures that are filled with micrite and or blocky cements. Occasionally pelsparites (grain to packstones), cemented by radial-fibrous and blocky cements, are interbedded within the successions. They are characterized by an irregular, nest-like distribution of poorly sorted components with a bimodal grain size distribution.

These characteristics can be applied on the lagoonal limestones of Qamchuqa Formation which are discussed in detail sedimentologically by Ameen (2008). He cited that these limestones are deposited behind a reef on the Arabian Platform interior (Fig.4.6). The facies that are found by this latter author are benthonic foraminifera mudstone and wackstone with chert nodules on the bedding surfaces. These facies are those that are related to relatively deep platform interior lagoon but he did not found inertial facies of the lagoon.

4.3.1.3.1.2- Platform slope:

The pre-drowning succession of the middle slope section is characterized by thick-bedded, coarse-grained and poorly sorted limestones. The carbonates (mainly bio- ,biopelsparites and-micrites) all can be assigned to (grain- to wackstones, rudstones, flotstones). The processes a heterogeneous matrix with strongly varying amounts of microsparite and orthosparite. The arenitic to ruditic components are dominated by shallow marine bioclasts. On the toe of slope, the succession consists of medium-bedded marls and limestones with two different microfacies type.

These characteristics can be applied to the reefal and fore reef facies of Qamchuqa Formation that are discussed in detain by Ameen (2008). He cited that these limestones are deposited on the reef of the Arabian Platform margin (Fig.4.6). The facies that are found by him are bioclast and ooids grainstone (or packstone), floatstone, bindstone and rudstone.

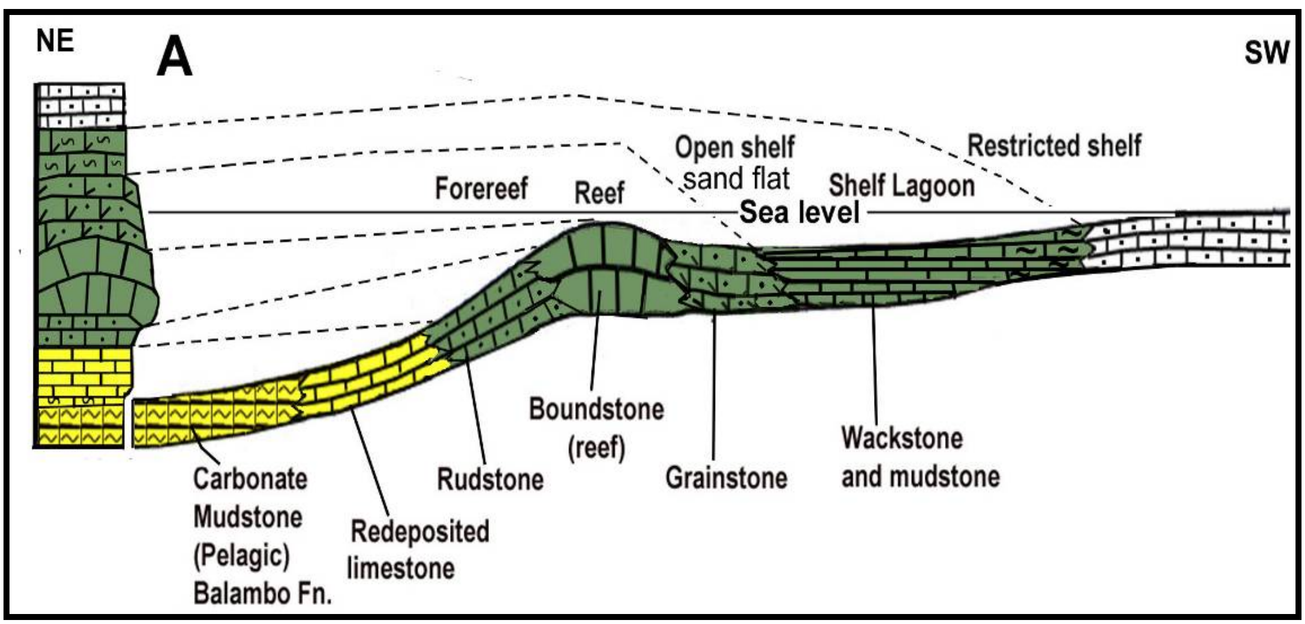

Fig.4.6: Environmental and topographic distribution of the rocks of Qamchuqa Formation by Ameen (2008). These rocks represent pre-drowning facies.

4.3.1.3.2- Drowning phase (Transitional to post drowning phase)

Drowning in this phase is the resulted from the complete failure of a reef or platform to keep pace with a relative rise of sea level so that it leaves the realm of shallow water carbonate sedimentation becoming submerged below the euphotic zone. The process is complete only when neritic carbonate production has ceased and truly deep-water conditions have been established (Kendal and Schlager, 1981).

This phase is very clear in the field and thin sections as there are about 5m of oligostiginal limestone with some glauconites which is represented by Dokan Limestone Formation and about 1.5 of marly and marly limestone (with some shale). As mention in the section (2.3 and 4.9) these two formations are transitional between shallow marine Qamchuqa Formation and deep marine Kometan Formation, therefore they represent the transitional phase to post drowning. The gradual but slightly rapid change from shallow marine to deep water facies is represented by both Dokan limestone and Gulneri Shale Formation and in the field and lab the facies with even the color show intermediate characteristics between the two end members referred to above.

Previously, Buday (1980) mentioned that the Gulneri Shale Formation occupies a somewhat peculiar position within the Turonian-Lower Campanian Subcycle, because it is separated by breaks from the underlying Cenomanian and the overlying Turonian units. It represents the sediments of a relic sea, existing between the regression of the Cenomanian and the transgression of the Turonian. As mentioned in the description of Dokan and Gulneri formations, that they have very limited distribution in the studied area. But, in this study, it is considered as sediment of the drowning phase of a large shallow basin (Arabian Platform basin).

4.3.1.3.2.1-Platform top

According to Schlager (1998), the drowning succession reflects an abrupt and fundamental change of the depositional environment within the platform interior. The shift from a mud dominated facies (pre-drowning) to densely packed biosparites reflect to a change from prevailing quiet-water conditions to an open marine environment with high energy waves and current activity above the storm wave base.

The sediment of this facies is not clear in the studied area but Ameen, (2008) mentioned that the environment of Qamchuqa Formation was calm and lagoonal sediments of the Qamchuqa Formation was relatively deep in most times and prograded (covered) by reefal coarse bioclasts. Therefore (as cited by him) they later dolomitized when covered by lagoonal sediments. In the studied area, the most upper beds of Qamchuqa Formation are dolomitized and upwards change to glauconitic limestone (Dokan Limestone and Gulneri Shale Formation). It is possible that studied area consisted of upper forereef not the platform top, therefore the facies mentioned by Schlager (1998) not found, in the studied area due to deepness. But it is possible that to the south or the southwest could be found outside the studied areas.

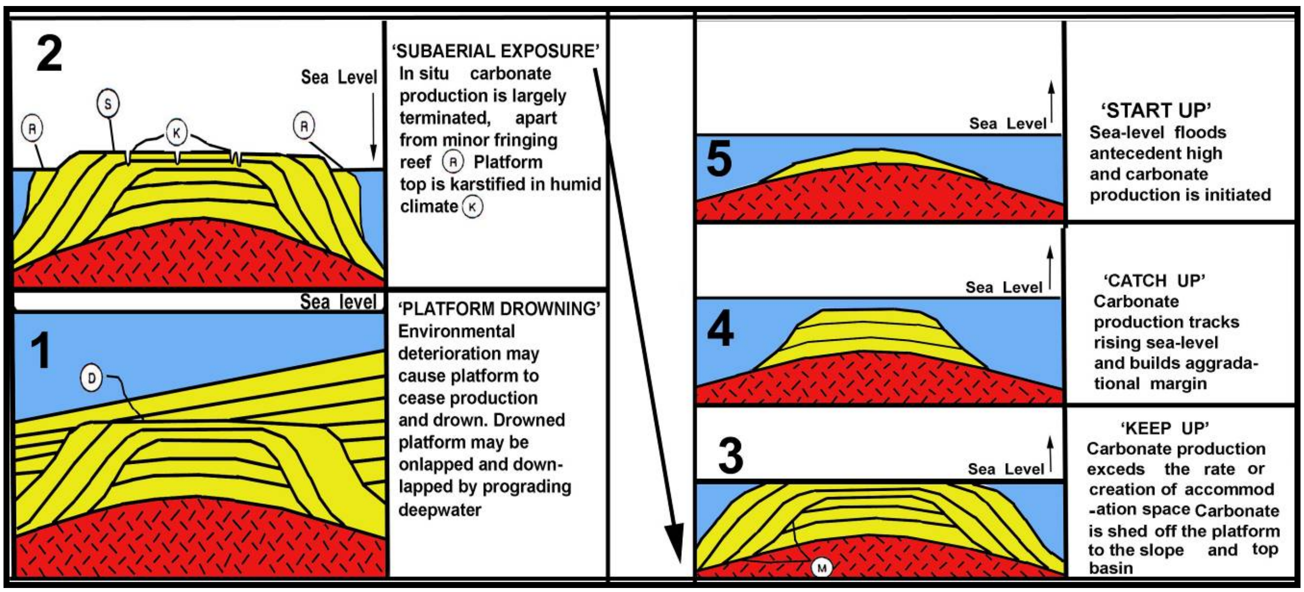

Fig.4.7: Different response of an isolated platform (as an example) to the sea level change. 1: Drawing (sudden sea level rise),Give up. 2: Exposure and karstification (unconformity surface), 3: Exceeding of carbonate production the sea level rise (Keep Up), 4: Carbonate production keeps normal relation (tracking) with the sea level rise (Catch up), 5: Initiation of production in a threshold depth (After Catunerne 2006).

4.3.1.3.2.2- Platform slope

The drowning sediments deposited on the mid- and lower slope is clear in the studied area which is reflected by a fundamental modification of the depositional environment of the carbonate of the Arabian platform which is changed from massive dolostone to well bedded pelagic limestone. The sediments of the drowning phase sequence are characterized by the deposition of specific, non-skeletal grains and a low diversity biofacies. In the studied area this facies is represented Dokan and Gulneri Shale Formation (fine grain and grey oligostiginal limestone) without sea bottom fossils skeletons except those settled from surface of the sea.

4.3.1.3.3- Post- drowning phase (Kometan Formation)

4.3.1.3.3.1- Entire platform area

According to Kendall and Schlager (1981), within all successions the sediment fabric and microfacies reflect a uniform depositional environment across the entire platform. Fine grained limestones containing pelagic organisms point to sedimentation within an open marine, deep marine environment below storm wave base. Extensive bioturbation of all sediments reflect oxic bottom waters as well as continuous pore water circulation within the sediment.

In the studied area this facies is represented by fine grain, occasionally, bioturbated limestone of Kometan Formation. Kometan formation is deposited on drowned Arabian Platform which represented by deposition of the deep-water facies of Kometan Formation on shallow water facies of Qamchuqa Formation passing with transitional lithology which represented by Dokan and Gulneri Formations (Figs. 4.8 and 4.9).

According to Kendall and Schlager (1981) vertical transition from shallow platform to deeper water facies of the post drowned phase may be abrupt or graduation. It may be marked by basal lime sands and gravels that result from migration of a higher- energy transgressive environment over the low energy platform interior. As the studied area is represent mainly the Arabian platform margin, therefore, only the shales or marls (Gulneri Shale Formation) are existed but it is possible that lime sand and gravel sand can be found in the platform interior in the Low Folded Zone. This is added by Dunnington (1958) who showed, by dawning, the erosion surface above and below the Turonian marls and limestones below Kirkuk area (Fig. 4.10).

The case of drowning similar to Qamchuqa Formation and deposition of Kometan Formation is mentioned by Einsele (2000) who stated that drowned or subsided carbonate platforms may be referred to as Pelagic Carbonate platforms (Kometan Formation). At an intermediate depth between shallow water and true pelagic carbonate deposition, the platforms are still exposed to current action. He farther added the sediments overlying older carbonates or other rocks therefore tend to become discontinuous and interrupted by intervals of omission and erosion (sharp contact below Gulneri Formation). They are characterized by irregular bedding and nodular appearance, red color, ferromanganese nodules, corrosion surfaces and hardgrounds with sessile fauna. Laterally the condensed horizons of platforms may show transitions to clastic shelf sediments or to brecciated, gravity-deformed re-sedimented slope deposits. Sediments similar to those of ancient pelagic platforms have been observed on some deep marginal and oceanic plateaus of the modern oceans.

According to Föllmi (2003), the onset of drowning appears to be diachronous, and its evolution is by stepwise onlap onto the platform while termination of drowning appears in all cases synchronous. Catanuneu (2006) mentioned that the period of time required from a formation of drowning unconformities may span the entire stage of shoreline transgression, during which interval, the surface gradually expands (and younger) in a shoreward direction. Thus the land ward termination of the drowning unconformities may be significantly younger than it is deep-water position and age equivalent to the maximum flooding surface that the tops the deep-water healing–phase wedge. The lack of chronostratigraphic significant diminishes the value of drowning unconformities in a sequence stratigraphic framework, even though they may be mapped with relative ease on seismic lines as high amplitude (but time transgressive) reflections. The time-transgressive character of drowning unconformities and their formation within the marine environment during stages of abrupt water deepening makes them equivalent to the trend within flooding surfaces discussed in the case of clastic systems. Drowning unconformities may therefore be regarded as a special type of flooding surface, applicable to carbonate systems, which developed when the sea floor drowns to water depths below photic zone. This unconformity is not applicable to siliciclastic successions as according to Schlager (1991) and Catananue (2006) there is minor erosion in very local area. Moreover than that is this only unconformity (discontinuity) in topography between underlying shallow and overlying carbonate.

4.3.1.4- Burial Phase: Siliciclastics prograding on the Arabian Platform

The age of this phase is Middle Campanian (as dated by nanofossils in this study) which coincides with the first appearance of clastic sediments on the Arabian platform in the studied area. The first arrival is represented by the lower part of Shiranish Formation which consists of marl and marly limestone. In this study, this formation assigned as clastics is depending on the many authors that are assumed marl and marly limestone as slope and basin plain distal turbidite facies (hemipelagite), among the these authors we mention: Reading, 1978; Blatt et al,1980; Mail,1990, and Einsele, 2000. Dunnington, 1958, showed that both Shiranish and Tanjero Formations change both laterally and vertically to each other (Fig.4.11). In recent years Karim (2004), Karim and Surdashy (2005a) and Karim et al(2008), discussed in detail how both deposited and derived from one source area of the Early Zagros Foreland basin(Fig.4.12). Karim and Surdashy (2006) concluded that Campanian and Maastrichtian sediments are embraced with in two depositional sequence, both contain Shiranish-like lithology.

Therefore, the first influx of the Shiranish Formation is suggested, in the present study, as the beginning of the beginning of clastic burial of the Arabian Platform. After deposition of the hemeplagite the pure clastic of Tanjero Formation is deposited which shows gradual increase of grain size caliber from clay to bounder. The influx of the clastics was associated with the main tectonic event of Zagros Fold-Thrust Belt during which the orogenic belt is generated from which the clastics of both formations are derived. This clastic burial over the Arabian Platform is due to continental Arabian and Iranian plate colliding by which the paleocurrent direction is changed from northeast to southwest direction (Karim and Surdashy, 2005a). The sediment influx (paleocurrent) was from southwest during deposition of Gulneri and Kometan Formations. But, when the Iranian plate is thrusted over the Arabian plate, the direction of sediment transport, in studied area was changed toward southwest as indicated by black arrows in the (Fig. 4.5).

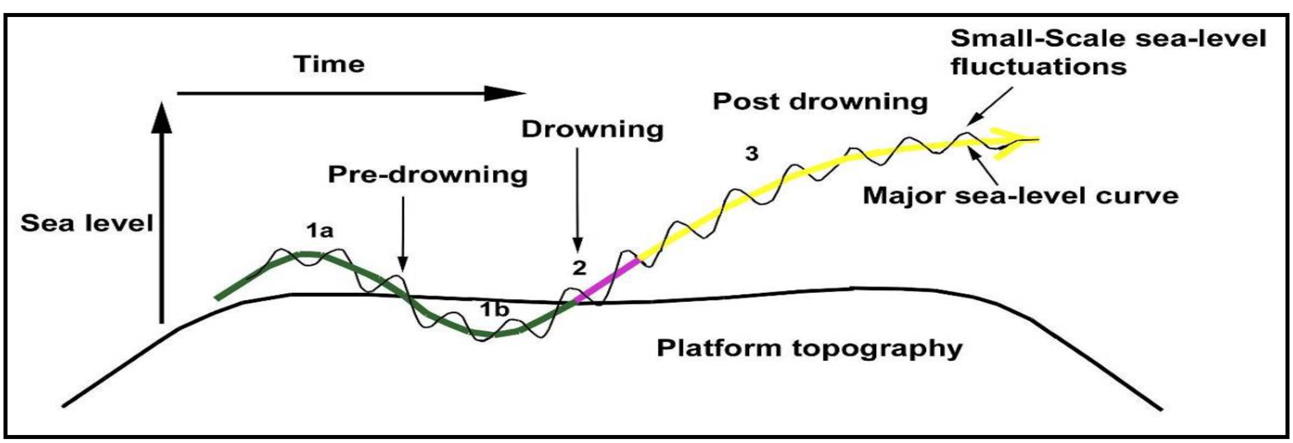

Fig.4.8: Sea-level variations and drowning stages. 1a) Pre-drowning phase and carbonate production within platform interior (lagoonal facies of Qamchuqa Formation). 1b) Pre-drowning phase and sea-level subaerial exposure of the platform (reefal facies of Qamchuqa Formation). 2) Renewed flooding of the platform top at the beginning of the drowning phase (Dokan and Gulneri Formations). 3) Gradual transition to deep-marine sedimentation during the post-drowning phase (Kometan and Shiranish Formations) (Modified by Blomeier et al., 1999).

Field study and literature review show that both the drowning and burial phases are not isochronous when the neighboring areas are considered. In Arbil and Dohuk areas the Arabian platform, in the same tectonic position as the studied area, remained not drowned and not covered by clastic till the Maastrichtian. This can be seen in the Recent study of Abwai *et al.,* (2008) whom inferred that the age of the most upper part of Bekhme Formation (Arabian platform) is Upper Campanian and Shiranish Formation is Maastrichtian. Dunnington (1958) showed that southwest migration of neritic limestone which appeared in the Qaiyarah area in the figure (4.10). Ameen (2008) discussed the problem of the remaining these areas no submerged as compared to Qamchuqa Formation. He attributed the remaining of the Arabian platform, in the Dohuk area, not drowned to diverting of depositional axes toward north during Upper Cretaceous and to irregularities of the tectonic front of Iranian plates.

According to these facts a tectonic and depositional historical model is drown which shows the phases of the closure of the Southern Neo-Tethys which started from Early Cretaceous and finished at end of Late Cretaceous. This is done depending on literature and result of the present study take in consideration the boundary condition outside the studied areas. In this connection, Schlager (1991) mentioned that the drowned platforms are covered by pelagics, hemipelagics or terrigenous siliciclastics. These sediments (or rocks) are equivalent (in the present study) to Kometan, Shiranish and Tanjero Formation respectively.

The present tectonic setting of the Zagros Fold–Thrust belt is also considered in the studying the tectonic history of the Arabian platform. This setting shows many thrusted sheets of older rocks over newer ones. Now, Qulqula Radiolarian Formation (radiolarite and pelagite) can be seen thrusted over the Arabian Platform as can be seen in the sections to the in the Qandil mountains and Halabja Areas. When the thrusted sheets that are enclosed in the sections are balanced or returned back to their approximate original position, a crude tectonic model of the Early Cretaceous can be envisaged.

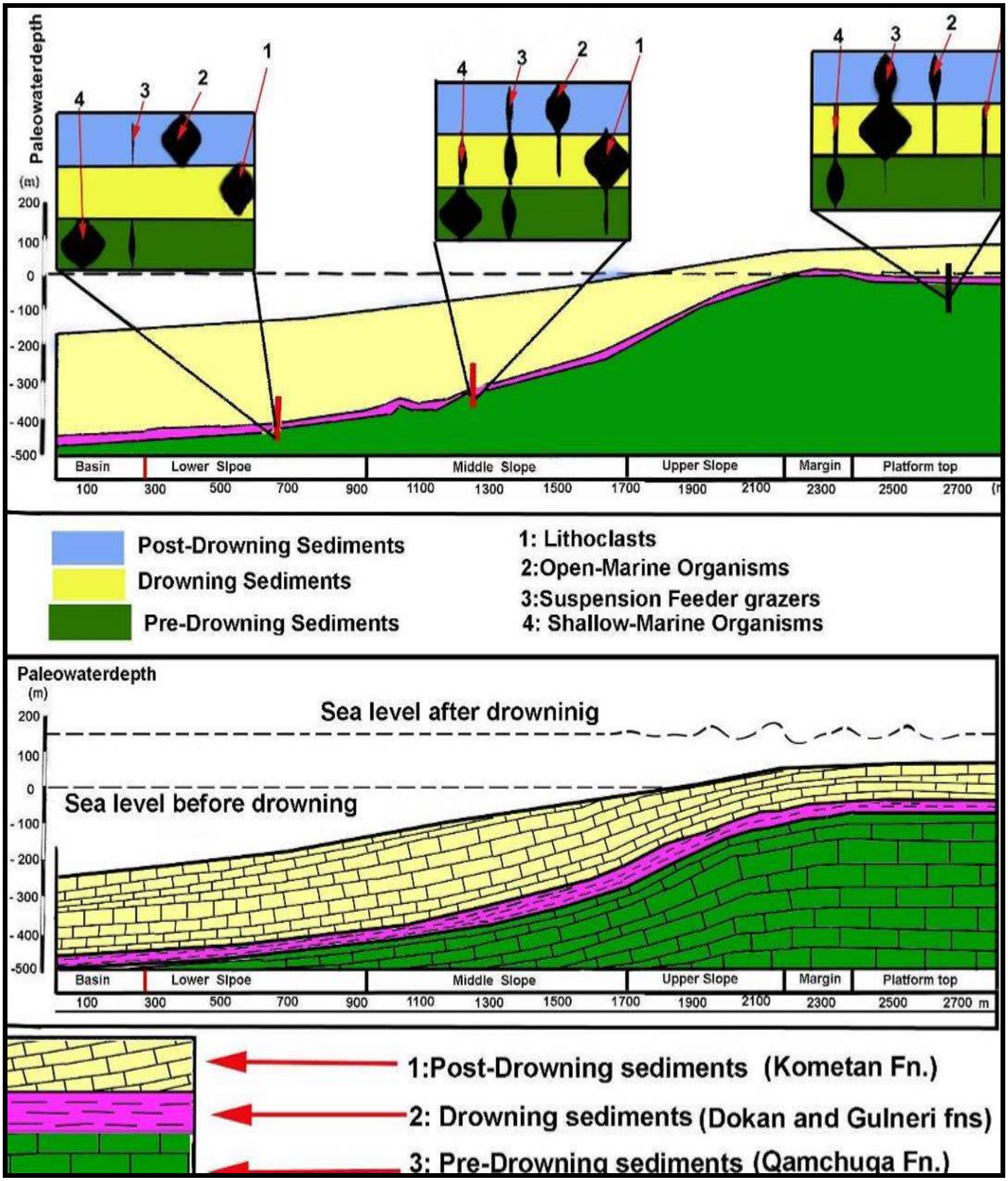

Fig.4.9: Distribution of the Drowning phase in carbonate platform (Modified by Blomeier et al., 1999).

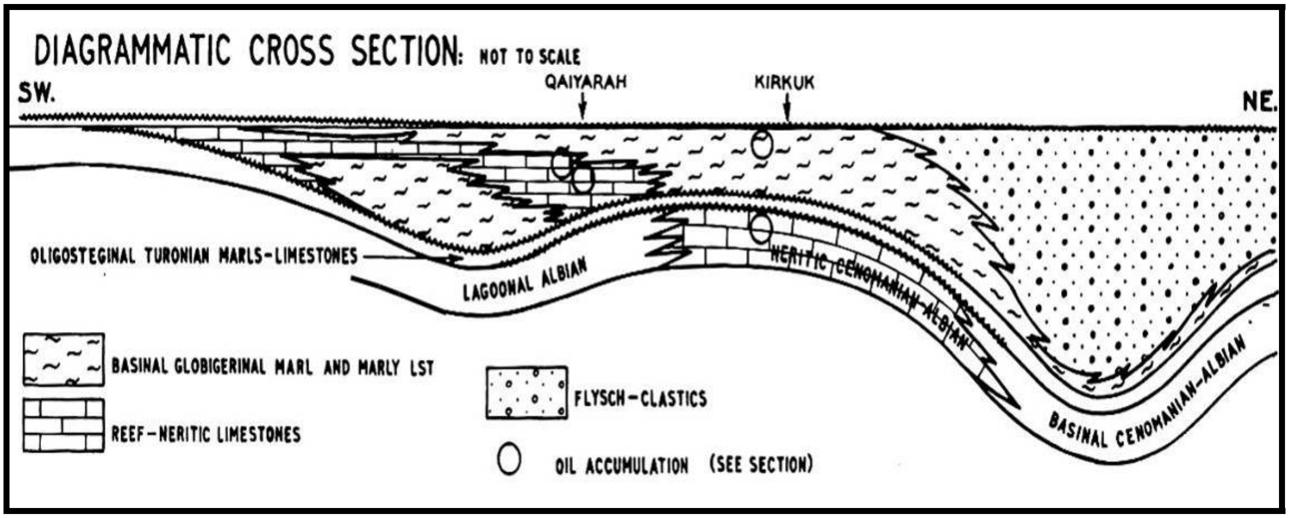

Fig.4.10: Cross section of NE-SW direction passing by studied and Kirkuk areas (Dunnington, 1958) which shows the erosion surface above and below the Turonian marls and limestones below Kirkuk area.

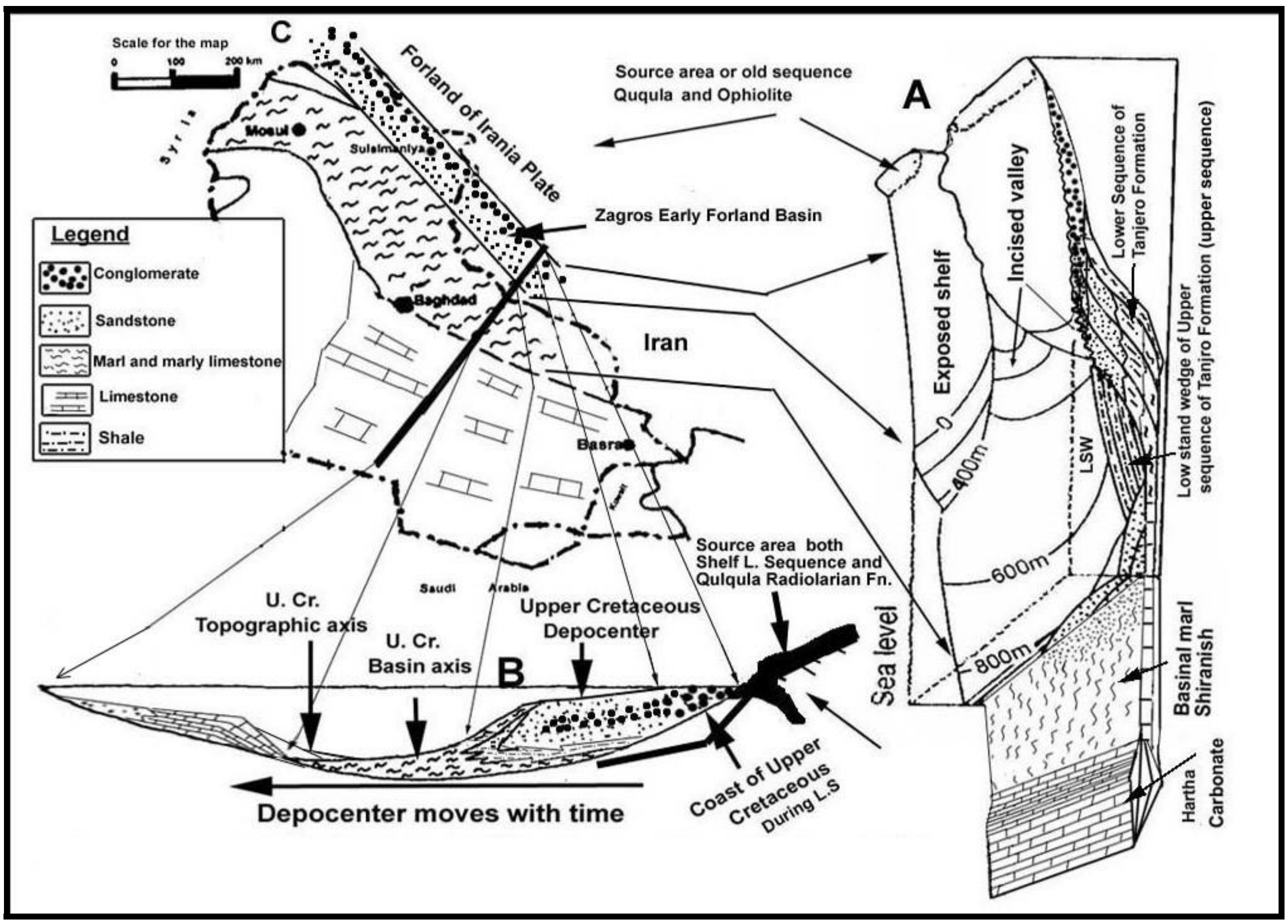

Fig.4.11: Overview of covering part of the Arabian Platform during Late Cretaceous by Tanjero and Shiranish Formations (Karim and Surdashy, 2005b).

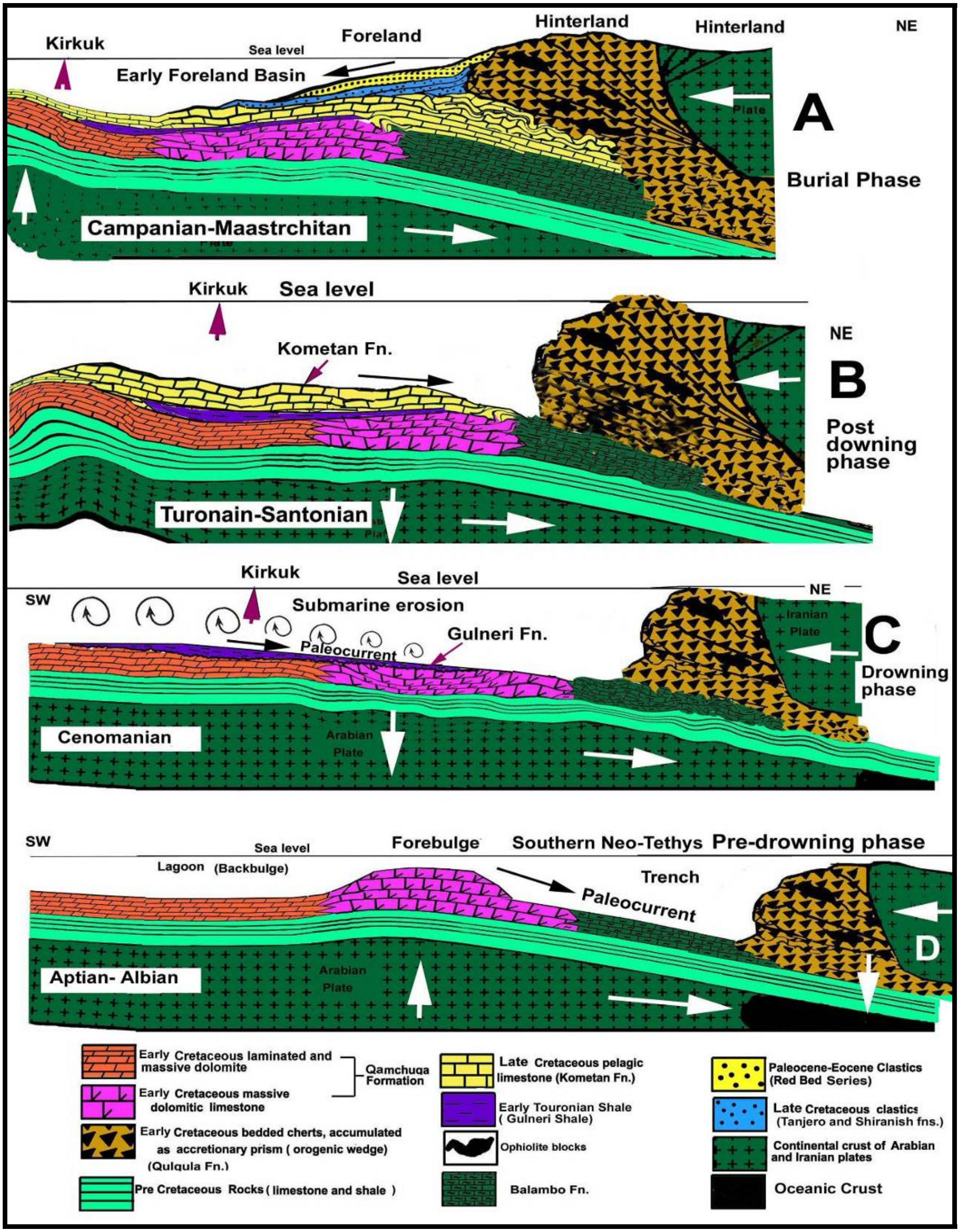

Fig.4.12: Combination of tectonic and depositional history of Lower Upper Cretaceous basin as considered in this study. A: From Karim and Surdashy (2005), B and C: Model of Present study in which drowning and submarine erosion can be observed. D: From Ameen (2008).

4.4-CONCLUSIONS

This study concluded the following:

1- The lithology of Dokan limestone Formation represents transition from shallow platform facies Qamchuqa Formation to deep pelagite Kometan Formation.

2-Gulneri Shale Formation contains minor shale which is formed by pressure solution and mainly consists of marl and marly limestone (as ball and pillow structures), marly limestone and marl. It is sediments of drowning phase (lithology of syn-drowning) deposited as result of erosion of Arabian platform after flooding and opening to open sea wave and currents circulation.

3-The contacts between Dokan Formation with both Qamchuqa and Kometan Formations are conformable (transitional boundary) which contain no conglomerate paleosol and karstification. But there are some evidences of submarine erosion.

4- Dokan and Gulneri Shale Formations are deposited during deepening of the studied area (during drowning of the Arabian platform as represented by Qamchuqa Formation in the studied area).

5- Three bed of glauconite bearing limestone beds are found at the base, 6m above the base and at the top of Kometan Formation. Most of these glauconites are formed by diagenesis and show cross cutting relation with fossils.

6-The previously mentioned micropebbles, at the contact of Shiranish Formation and Kometan Formation, proved, in this study, that they are nodules and formed by diagenesis not by sedimentation as mentioned previously.

7-Dokan and Gulneri Shale Formations are deposited on the outer shelf while the Kometan Formation is deposited on the slope and basin plain.

8-The Kometan Formation is represented by sediments of the post drowning phase of Arabian platform.

9-Historically, and as concerned to drowning, Shiranish Formation is assigned as sediments of burial phase of Arabian platform by siliciclastics.

10-The subsidence of the platform was attributed to southwest advancing of tectonic front of the Iranian plate which exerted high horizontal and vertical load stress on the studied area which consequently forced to drowning (or subsiding).

11- After drowning and deposition of Kometan Formation, Iranian front is climbed on to the Arabian platform and the northeast of the studied area uplifted as orogenic wedge due to colliding of continental parts of Iranian and Arabian plates. By this the southern new Tethys is closed and the studied area transformed from fore deep to foreland basin.

12- The association of chert nodules and well-developed relatively large-scale stylolites are recorded in Dokan area.

13- The stylolite surfaces and long axes of nodules are parallel to bedding surface while stylolite peaks are normal to beddings.

14- Both field observations and rose diagram showed that chert nodule and stylolites have random distribution and have no preferred direction. They are developed under high load pressure by diagenetic processes.

15-In the studied formations, the ichnofacies have low diversity and occurrence, only in the lower and upper parts of Kometan Formation contain some trace. These features are mainly attributed to a certain type of ichnofacies that reflects activity of organism in sediment in certain environment.

16-For the first time the sediment of Middle Campanian is found in Kurdistan by Nano fossils.

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