STRATIGRAPHY AND BASIN ANALYSIS OF RED BED SERIES AT NORTHEASTERN IRAQ / KURDISTAN REGION

A THESIS

SUBMITTED TO THE COLLEGE OF SCIENCE, UNIVERSITY OF SULAIMANI, IN PARTIAL FULFILLMENT OF THE REQUIRMENTS FOR DEGREE OF DOCTORATE OF PHILOSOPHY IN GEOLOGY

BY:

Sherzad Tofiq Mohamad Al Barzinjy

M. Sc. IN GEOLOGY/1989

Supervised by:

Dr. Ali Mahmood Surdashy

Assistant Professor

MARCH 2005 A.D ***NAOROZ 2704 KU***

ACKNOWLEDGEMENTS

I am deeply indebted to Dr. Ali Mahmood Surdashy **for his undertaking the task of supervising this thesis and for offering many suggestions and corrections during all stages of the work. My best thanks to the Dean of the College of Science** (Dr. Parykhan Mohamad Abdulrahman) **and also the head of the Department of Geology for their generous help and assistance throughout this work especially offering the available facilities. I would like to express my gratitude to the university presidency for providing the financial support for transportation (during fieldwork) and printing the draft and final copy of this work.**

My sincere thank to my friends (Dr.Kamal Haji Karim and Khalid Mahmood Ismail) **from the Department of Geology, University of Sulaimani for helping in fieldwork and photographing many features in this thesis. I would like to thank my friends (**Yousif Mahmood Osman)**, reporter of the Department for providing me with suitable computer software for the program used in this study, and (**Mr. Serwan Hama Ahmed**). I also express my gratitude to (**Salahaddin Saeed Ali**), the Dean Assistant, for reading the original manuscript and suggesting many corrections. Finally, I would like to express my special appreciation for my wife,** Zheyan**, for her patience during the preparation of this work.**

Sherzad

March,2005

Abstract

The Red Bed Series is a Paleocene- Eocene unit, which crops out mainly within the Imbricated Zone and partially within Thrust Zone in Northeastern Iraq. It stretches as narrow northwest-southeast belt near and parallel to the Iranian border. The series mainly consists of alternation of thick beds of clastic rocks of red claystone, sandstone and conglomerate.

On the basis of stratigraphy and lithology the series is divided, in Chwarta-Mawat area, into six units. Unit One is composed of red fine clastics (red claystone and bluish white marl), while change to sandstone in eastern end of Qandil Mountain toe. Unit two consists of about 17m of chert and limestone conglomerate with prevalence of red color. Unit three consists of more than 500m of thick-bedded gray sandstone with interlayers of claystone. This unit contains many sedimentary structures such as cross bedding; ripple mark, flute cast, plant debris and lamination. Unit four consists of alternation of red layers of claystone, sandstone with lenses of conglomerate. Unit five is most obvious and thickest unit of the series in all area except the western part of Qandil area, which change to claystone and sandstone. It consists of chert; limestone, igneous and metamorphic gravel in Chwarta-Mawat area, while in eastern part of Qandil mountain toes, near Suwais village, it includes only chert and limestone pebbles and boulders. But the western part of the mountain is similar to that of Chwarta-Mawat area as concerned to the type of gravel. This unit contain obvious imbricate pebbles and large scale cross bedding. The upper most part (unit six) consists of marl, claystone with some sandstone and a layer of fossiliferous limestone at the base of the unit . These units are correlated across five different sections, which are representing the available outcrops in Sulaimaniya and Arbil Governorates . The correlation is based on lithology and stratigraphic position of the units.

In sequence stratigraphy, the rock body of the series is divided into three depostional sequences, (lower, middle and upper depostional sequences). Each of these is further analyzed into their systems tracts. The systems tracts of the units are lowstand, highstand, and transgressive systems tract. The most obvious one is lowstand systems tract and consists of Lowstand wedge about 1000m of boulder and block polymictic conglomerate. During lowstand many incised valleys scoured in the sediment of the previous highstand which is filled by coarse conglomerate.

Great variations, in different areas, in lithofacies of each systems tract is detected, that is due to the shallowness of the environment. The correlation of systems tracts of the Red Bed Series at Chwarta, Mawat and Qandil mountain areas, at the Imbricated Zone, with the equivalent parts of the Kolosh and Gercus Formations at distal area (High Folded Zone) was the important part of sequence stratigraphy work. This correlation is the first one done for the different sections of the Red Bed Series in one side and with Kolosh, Gercus Formations in other side. By this correlation, the previous age of the Red Bed Series also changed from Paleocene –Miocene age to Paleocene - Eocene age only. Another result of the correlation is that the series and the formations sharing the same depostional basin and they represent lateral facies changes of each other. In this basin, the Red Bed Series is deposited in rapidly subsiding coastal area of the Early Foreland basin while the Kolosh Formation is deposited in deeper part of the basin.

The environment of the series is highly variable; mainly consist of high gradient braided streams which transfer coarse and fine sediment to alluvial fan which merge into lowstand fan delta when reaches the main water body of the foreland basin. As concerning with the depth, it ranges from continental to shallow marine environment while the salinity ranges from dominant fresh river water to brackish and possible of invading of normal marine water occasionally. Water turbidity changed from highly turbid water in the incised valleys and in front of alluvial fans to normal marine water.

Petrographic analysis revealed that the source area of each one was different. Even the source area of each section was different in different times. The clasts were dominantly derived from the Qulqula Radiolarian Formation at the area of eastern part of the Qandil mountain toe while that of Chwarta-Mawat are derived from the Qulqula Radiolarian and ophiolite source rocks in adition to Walash Naoperdan group . The source area is consisted of overthrusted sheets of frontal part of Iranian plate. In this study many sedimentary structures are found in the series such as, cross bedding, ripple marks, imbricated pebbles, laminations, and plant debris. Most of these structures are found in the unit three (sandstone unit) and few ones found in the upper conglomerate. The paleocurrent analyses, as revealed by these structures, are presented as rose diagrams shows south and southwest directions.

LIST OF CONTENTS

List of Photographs

List of Figures

List of Tables

CHAPTER ONE

1.1- Preface

The Red Bed basin, as a part of the Neotethys, was strongly deformed by the Alpine Orogeny and was active from Jurassic till Miocene where a huge thickness of sediments was accumulated. These sediments now exposed on the surface as different types of stratigraphic units such as the Balambo, Kometan, Shiranish and Tanjero Formations, in addition to the Red Bed Series and Naoperdan Shaly Group. The basin has a complicated history of development and tectonics, this history was demonstrated by different characteristics of these stratigraphic units. Among these units and in the present study, the tectonic framework and sedimentation(basin analysis) of the Red Bed Series was studied.

Basin analysis involves the interpretation of the growth, evolution, building, and fill of a sedimentary basin by examining different geologic variables associated with the basin. The geologic variables include all branches of geology, but in the present study, the emphasis was put on traditional and sequence stratigraphic analysis based on detail study of exposed sections throughtout the studied area. The detailed field and lab studies directed towards paleoenvironmental interpretation to interpret basin fill architecture and tectonics of the basin, in addition to the correlation and subdivision of the Red Bed Series. Observations during the last few years showed the probability of achieving more accurate study than that was done before.The most important duty is to establish relations between the Red Bed Series located in the Imbricated Zone (proximal area) with Kolosh and other Formations in the High and Low Folded Zones (distal area). In the present study there are attempt to answer many of the questions rasied since 1980 by Buday about subdivisions, age, paleogeographic reconstruction, and correlation of the Red Bed Series

1.2-Location and Geomorphology

The studied area is located within Sulaimaniya and Arbil Governorates in northeastern Iraq. It stretches as narrow belt from Nalparez, southeast, to Qandil mountain toe and Roste valley near Haji Omaran at the northwest (Fig1.1). The main outcrop of the studies series is located at Chwarta and Mawat area. This area is located between latitudes $35^{o}\ 35^{-}\ 12^{=}$ and $36^{o}\ 40^{-}\ 23^{=}$ to the north and longitudes $45^{o}\ 55^{-}\ 33^{=}$and $44^{o}\ 40^{-}\ 20^{=}$ to the east. The studied area now covered by high mountains trending northwest –southeast. In the same direction and between these mountains there is narrow or wide subsequent (strike) valleys. The mountains and valleys are dissected by, at least, two large consequent valleys and tens of smaller ones. The large valleys are those in which the Little Zab and Diala Rivers flow. The outcrops of the series consist mainly of alternation of thick beds of red claystone, sandstone and conglomerate. In the upper part (in some areas) the formation contains interbeds of biogenic limestone (Al –Mehaidi, 1975).

1.3-Geological Setting

The studied area is located at the southern boundary (in front) of the Zagros Thrust Belt, which is developed from the basin fill of the Neo-Tethys and colliding of the Iranian and Arabian plates. Structurally, the series is located within two different zones. The outcrops of Chwarta – Mawat areas and Roste Valley are located in the Imbricated Zone while that of Penjween and Qandil Mountain toe are located exactly on the boundary between the Imbricated and Thrust Zone of Buday and Jassim (1987) (Fig.1.1 and 1.2). Because of intense imbrication, the area is characterized by obscured anticlines and synclines which have been stacked together as very thick and tight packages which was overturned toward southwest. This imbrication includes the Red Bed Series and other units such as Qulqula, Balambo and Kometan Formations.

Buday (1980), Buday and Jassim (1987) and Lawa *et al*., (1998) called the two tectonic zones of distribution of the Series, miogeosyncline and Euogeosyncline respectively. The Tanjero Formation underlies directly the Series; Karim (2004) regarded the basin of latter formation and Kolosh Formations as Zagros Early Foreland Basin. In the Chwarta and Mawat area the Series is underlain and overlain by Tanjero Formation and Naoperdan Group respectively. The contact of the series with the group is not clear but previously mentioned to be tectonic Al-Mehaidi (1975), Buday (1980) Surdashy (2001). While the contact with the Tanjero Formation is gradation (Lawa et al., 1998), Karim (2004) mentioned to be gradation in some places and unconformable in others.

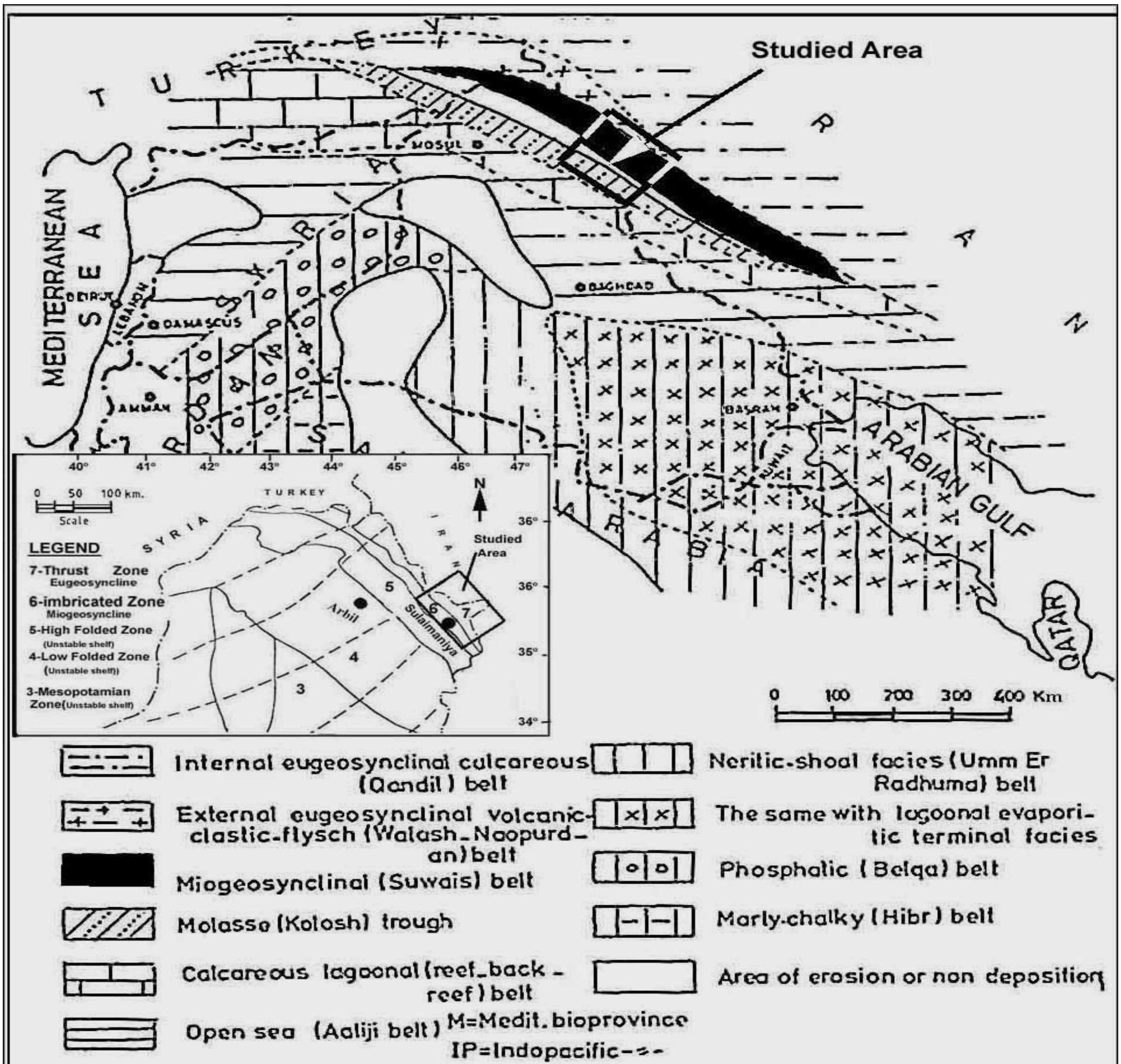
The tectonic setting of the series during Paleocene and Eocene will be discussed in Chapter Six. The tectonic setting of the present time as can be seen in the field is extremely complicated by commutative deformations from Eocene till the present. In Chwarta–Mawat area, now, the ophiolite (Photo1.1) rests on the Red Bed Series. Particularly as in Grdasha Mountain, near Taza De, Barda Zard and Ganka villages. In other places the Qulqula can be seen in contact and above the Red Bed Series, such as those along Kanarow Valley and along line connecting Tazade and Sinjale villages. In Qandil area same relation can be seen. In Penjween area the Red Bed Series rests on Qulqula Formation, especially around Milakawa Mountain at south of Penjween Town.

1.4- Studied Sections

For detailed study of the formation, six sections are selected (Fig1.2 and.1.5) The stratigraphic and structural condition of these sections are shown either by photos or diagrams, these are:

1- Iran Section; it is located within Iran near the border with Iraq on the right bank of Du Awan (extreme upstream of Dokan Lake) 4 km west of Iraqi Awa Kurte village (Photo2.6A).

2-Khewata section; is directly located to the east of Khewata Bridge along the right bank of Khewata stream (Photo 2.4) and (Fig.2.1).



Fig(1.1)Paleocene-Lower Eocene Facies map of Middle East (Budau, 1980), with general location of studied area

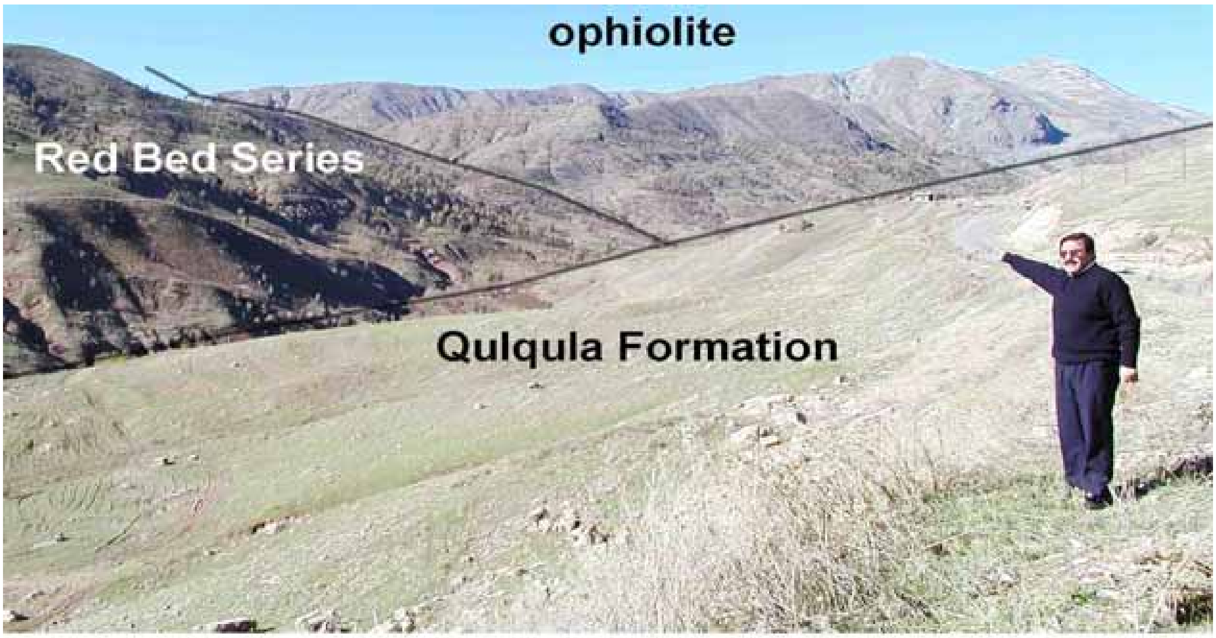
3-Tagaran Section at 35^{0} 39^{-} $48.3^{=}$ and longitude 45 29^{-} $52.5^{=}$, the base of the section is directly located to the northwest of Tagaran village while its top located directly to the east of Chwarta Town at 20 km to the northwest of Sulaimaniya city (Photo2.1)

4-Type Section (Suwais village section) at the intersection of latitude 35^{0} 59^{-} $00.2^{=}$ and longitude 450 35^{-} $16^{=}$. It is located directly to the northwest of Suwais village at the toe of Qandil Mountain 20km to the northwest of Qaladiza town, (Photo 2.10A) and (Fig.1.3 and fig.2.2).

5-Kometan village section in Naudasht valley at the latitude: 36^{o} 24^{-} $26^{=}$ longitude: 44^{o} 57^{-} $38^{=}$. It is located at the toe of Qandil Mountain at 1.5 km north of Kometan Village (Photo2.7) and (Fig.2.7)

6-Roste Valley section, located inside Roste valley at the area between Haji Omaran and Soran Valley(Photo2.9) and (Fig.2.3)

It worthy to mention that the Penjween outcrops mostly covered by alluvium and serpentinite, therefore no section is taken.



Photo(1.1) Kanarw valley at 300m south of Kanarw t0wn in which the ophiolite and Qulqula Formation and Red Bed Series are existing together.

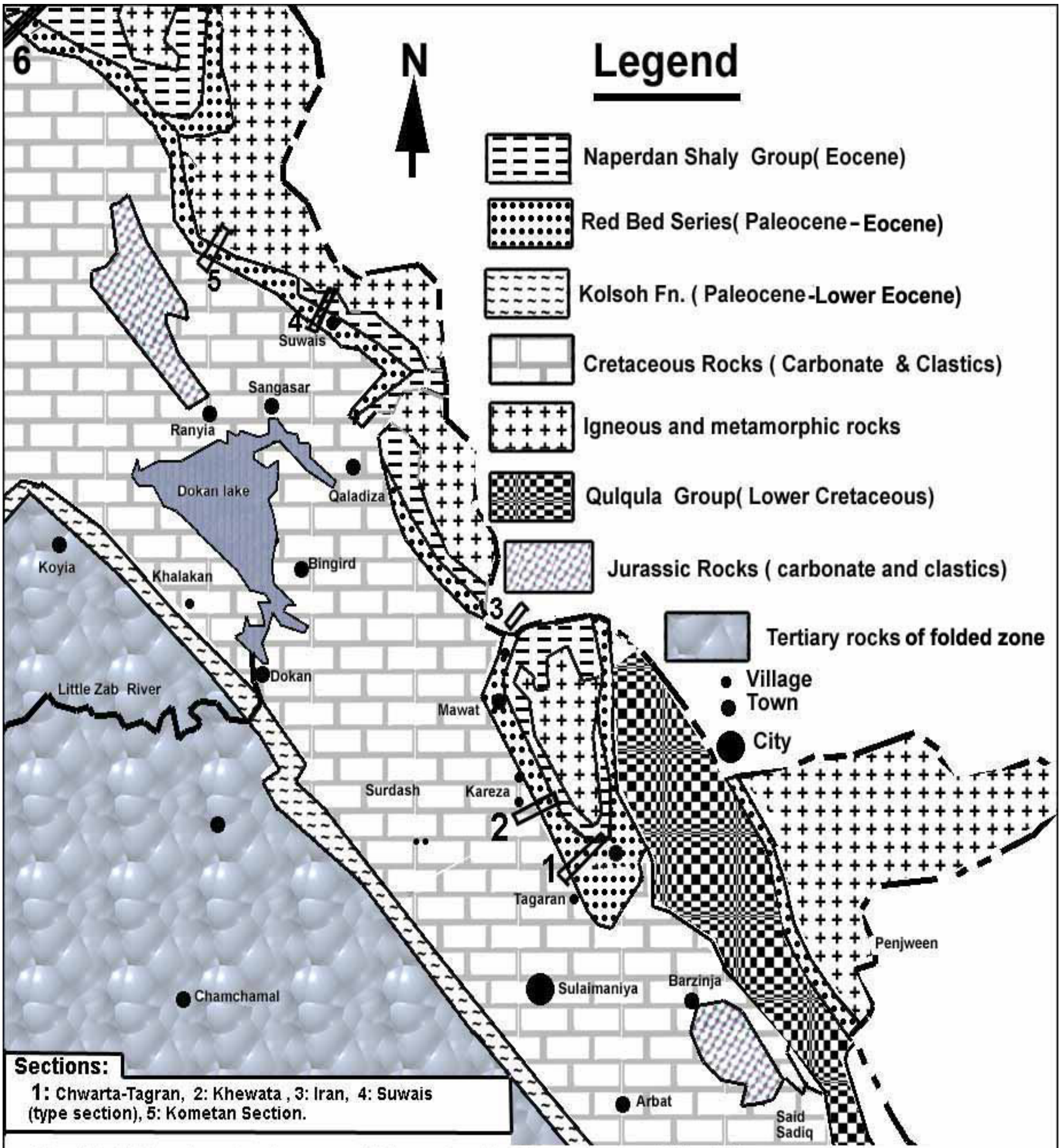


Fig.(1.2)Geological map of the studied aera, modified from Jassim and Al- Hassan(1977)

1.5- Aims of the study

The main aims of this work are to study the basin development of the Paleocene-Eocene successions, known as Red Bed Series in the Sulaimaniya, Arbil areas, which mainly appear on the Tanjero Formation.

This is based on the available and the inferred evidence and the study include the following:

1. New divisions of the series, taken into considerations, all the exposed outcrops by examining the outcrops in the field, to record all the vertical and lateral changes.

2. Descriptions and analyzing the different lithofacies in order to establish the depostional environment, this includes the study of sedimentary structures and paleocurrent analysis to interpret different depositional processes.

3. Sequence stratigraphic analysis in order to interpret the effect of sea level changes and subsidence on the development of third and fourth order cycles and determines the controlling components (eustasy and tectonic subsidence).

4. To interpret the tectonic framework of sedimentation and paleogeography of the Red Bed Series.

5. To establish the relations between the Red Bed Series and contemporaneous formations in the High and Low folded Zones such as Kolosh and Gercus Formations.

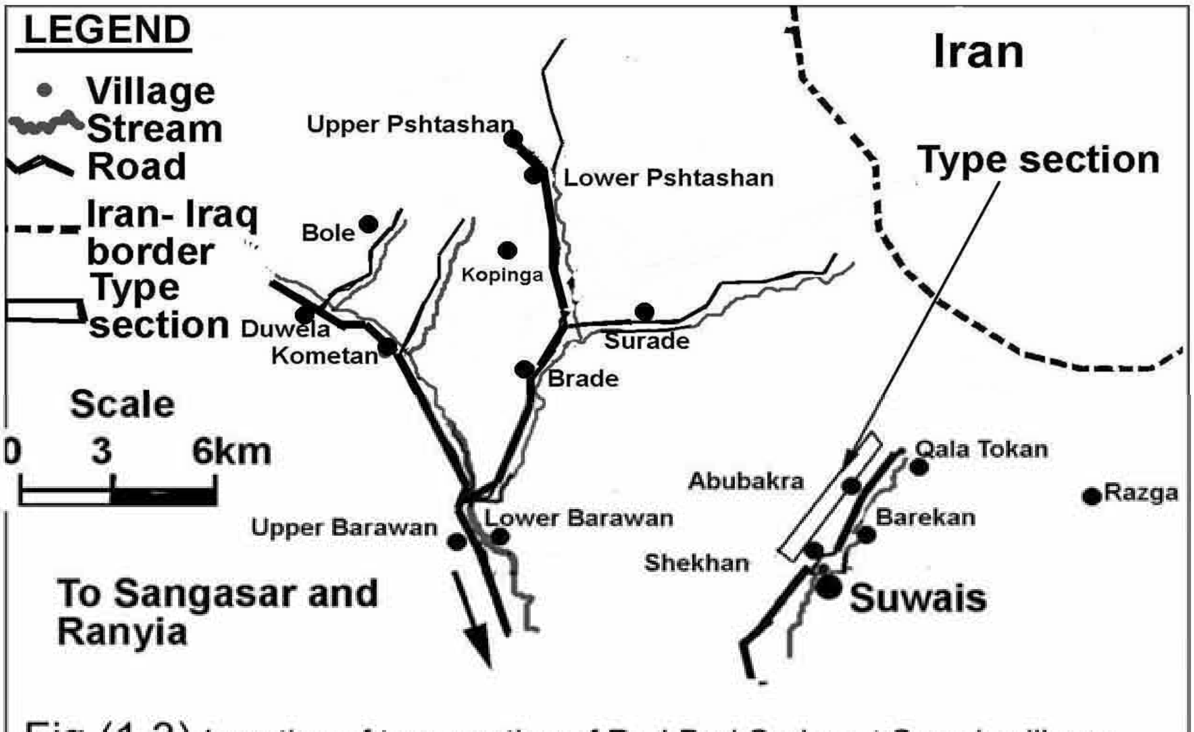


Fig.(1.3) Location of type section of Red Bed Series at Suwais village

1. 6- Methodology

1-Study of all outcrops in detail as well as petrographic study of more than 100 thin sections. Then point counting to calculate the percentage of different

2-The conglomerates were studied in the field for constituent minerals of the sandstones. lithology, structures, and directions. The percentage of the conglomerate is calculated by measuring the percentage of clasts by using the charts prepared by Folk et al., (1970) and Tucker (1989) for visual estimation percentage of the rock constituents by comparison.

3-Correlation between the different units of the series in the Imbricate Zone and equivalent successions at the High and Low Folded Zones. This is done by using the geologic map of the area where all lithologic changes in addition to sedimentary structures were recorded.

4- Point counting for conglomerates in order to determine the percentage of the main components.

5- Cooking of some samples of marl and red claystone for extraction of fossil content for inferring environment and age determination.

6- Using the Rock Ware program for plotting the directional sedimentary structures (uni-and bi-directional structures) on stereonet and plotting rose diagrams. The same program is used for plotting the sandstones and conglomerates on the Ternary compositional diagrams. Then, using the Photoshop program for drawing tetrahedrons combines the triangles.

1.7-Previous studies

The Series was first described by Bolton (1958d) as a Suwais Red Beds (the name comes from Suwais village) in the Imbricate Zone bout 20km to the North of Sangasar town to the north of the Ranyia Town. It is not clear why did Bolton named the series “Suwais Beds “while the type section is near Bra De village which is located at about 15 km to the west of the Suwais village (Fig.1.3) even the lithology of the series near the latter village is exceptionally different from that of the type section. He divided it into four units (parts), they are as follows from bottom to top of the outcrop section:

1-Unit 1, Consists of different type of limestone beds (fossiliferous, detrital and conglomeratic limestone)

2. Unit 2, this unit overlying the previous one and consists of fine clastics (ferruginous red shale and blue siltstone) with some interlayers of limestone conglomerate. The thickness of this unit is about 300m.

3. Unit 3, Polymictic conglomerate containing boulder and blocks of limestones, chert, igneous and metamorphic rock fragments.

4. Unit 4, Composed of marly shale and sandstone with some conglomerate.

At Chwarta area and in the same manner Al-Mehaidi (1975), divided the Series into four parts (Fig.1.4). But his division did not include the first unit of Bolton (1958d). Instead, he separated the second unit of Bolton into two parts he named them unit one and unit two from the bottom to the top. The other units of the two authors are nearly coinciding. Karim (1975) studied the Series paleontologically and clamed that the age of the series is Miocene. Buday (1980) reviews the earlier studies about the series with citation of regional distribution and interpretation of different lithologies. Al-Ameri et al. (1990) studied the palynology of the Unit one of Suwais Red Beds in Chwarta Area; they concluded that this unit is deposited during Santonian. Lawa *et al*. (1998) recorded gradational contact between Red Bed Series and Tanjero Formation in Chwarta area; While Karim (2004) recorded both gradational and unconformable contact in different localities in Chwarta and Qandil area.

Al-Qayim (2000) studied sedimentation and tectonic environment of the Suwais Red Beds from northeast margin of the Arabian plate. He concluded that the unit indicates flysch type sequence of variable facies. Lawa (2004,p.222,224 and 231) showed by sketch that the Red Bed Series is deposited during Paleocene and in an intermountain basin above the sea level in which the Kolosh formation located to the southwest of that of the series. He separated both basins from each other by mountain ranges.

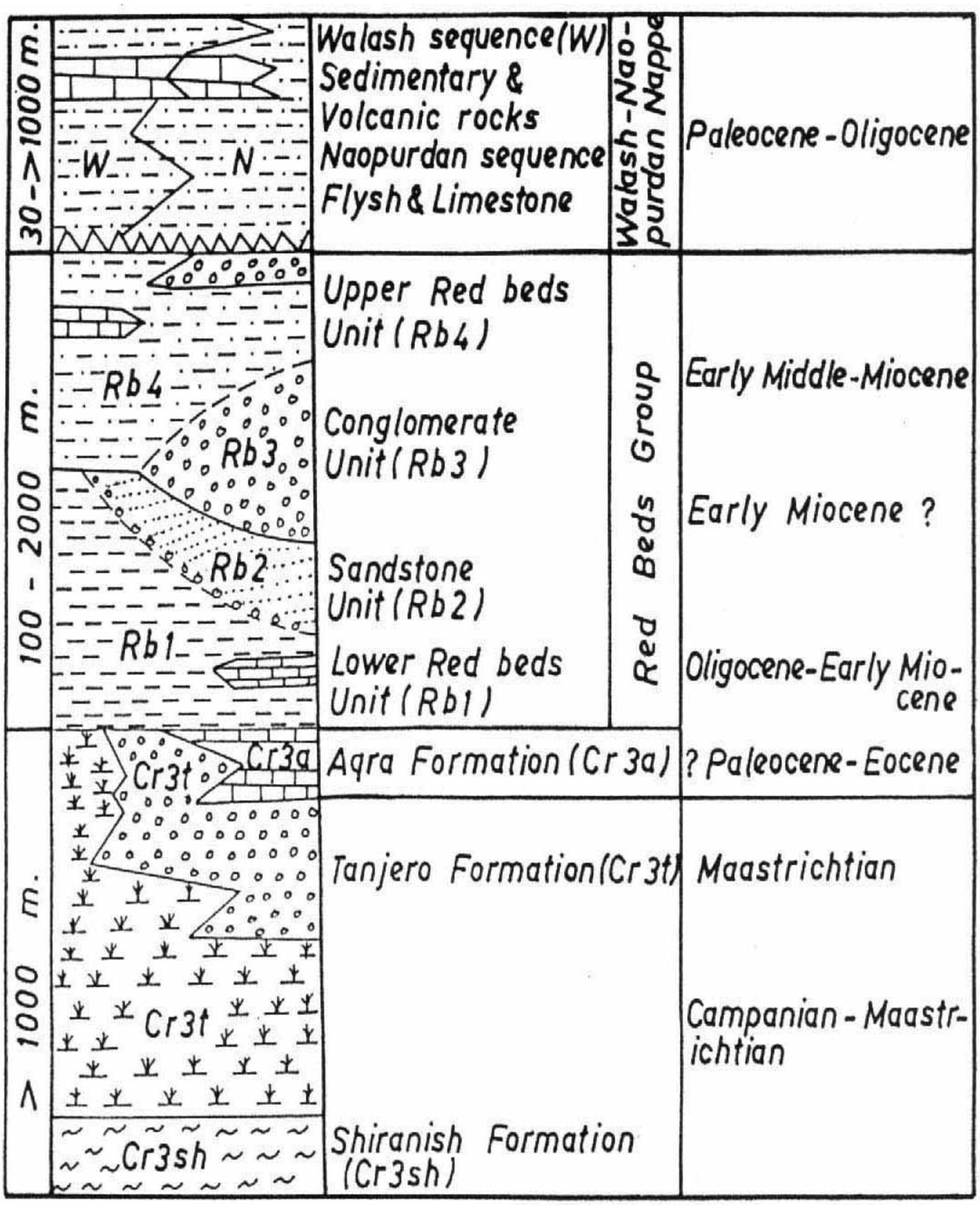


Fig. (1.4) Stratigraphic column of Chwarta area Drawn by Al-Mehaidi (1975)

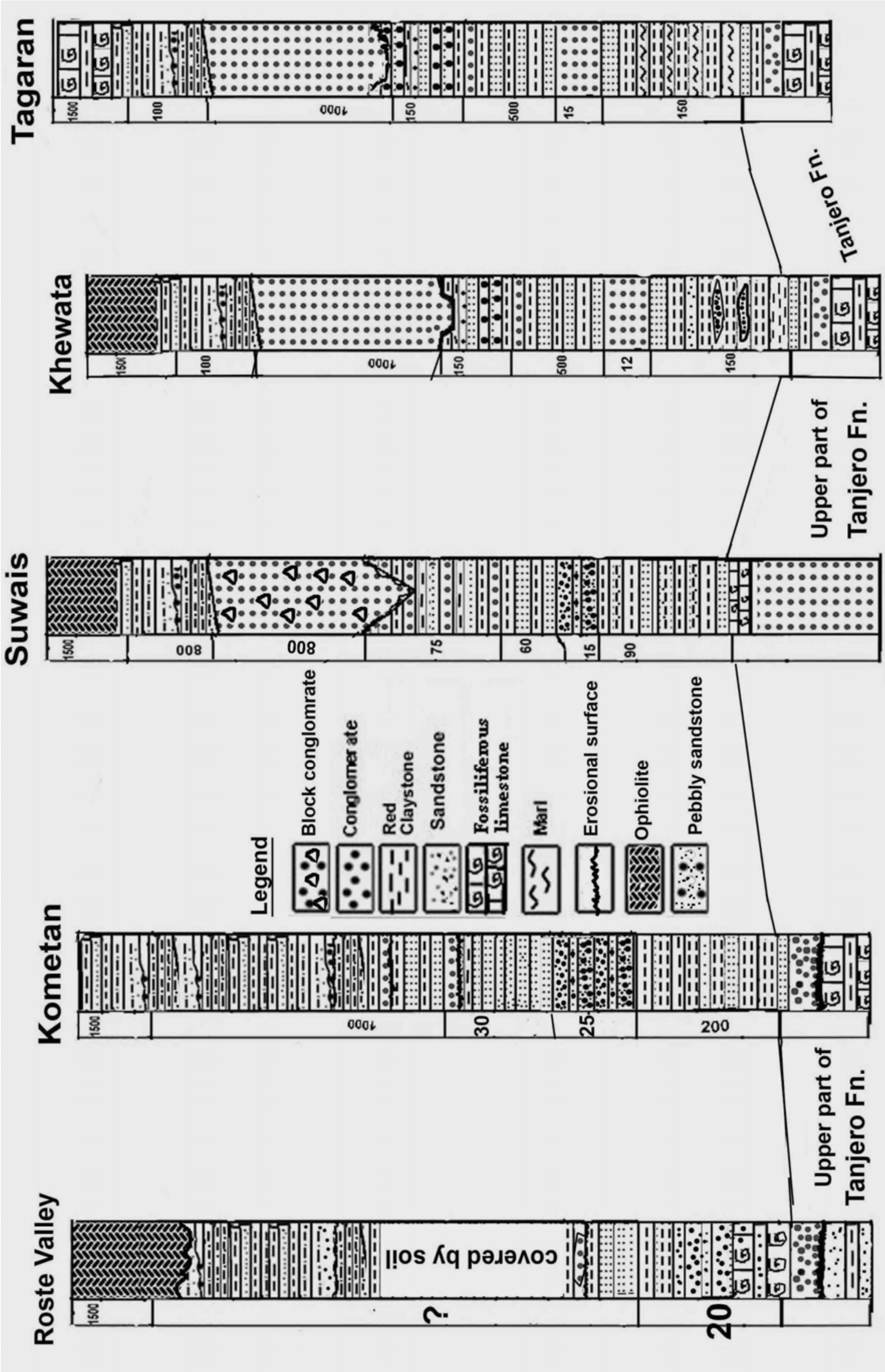


Fig.(1.5) Studied sections of the Red Bed Series

CHAPTER TWO:

STRATIGRAPHY AND LITHOLOGY

2.1-Preface

In this chapter, a detailed study of the exposed sections of the Red Bed Series and extensive fieldwork at different settings is presented towards a reasonable and meaningful subdivision of the studied successions as well as correlation with equivalents in other areas.

2.2- Divisions of the Red Bed Series

2.2.1-Bolton division

The first definition and division of the series was made by Bolton (1958d), he divided it to four units as follows:

1-Unit 1, Consists, at the lowermost beds, of different type of limestone beds (fossiliferous, detrital and conglomeratic limestone) interbedded with red ferruginous shale at upper part. Their thicknesses range between 50-100m. They contain many indigenous Cretaceous fossils such as rudists; large forams etc., and were considered to be of Late Maastrichtian age.

2- Unit 2, this unit overlies the previous one and consists of fine clastics (ferruginous red shale and blue siltstone) with some interlayers of limestone conglomerate. The thickness of this unit is about 300m and according to Buday (1980), the age of this unit is Paleocene – Lower Eocene. He had regarded this unit as flysch type sediments.

3- Unit 3, Polymictic conglomerates containing boulder and blocks of limestone, chert, and igneous and metamorphic rocks fragments. The chert clasts were derived from the Qulqula Formation. The thickness of this unit reaches 400m in Chwarta area and 200m at the type area. This unit represents talus sediments. In the present study this conglomerate is called Chwarta Conglomerate.

4- Unit 4, Composed of marly shale and sandstone with some conglomerate and layers of reddish or gray nummulitic limestone. The thickness of this unit reachs 800m in the type area.

2.2.1.1-Discussion of the Bolton division

Field observations showed that this division is not applicable for the Red Bed Series because unit one of Bolton (1958d) is proved, in this study, to be belonging to the upper most part of Tanjero Formation. This is because of the following:

A- Bellen *et al*. (1959), Buday (1980) attributed these beds to Aqra tongue while Lawa *et al.* (1998), in Chwarta area, studied similar beds and proved that they belong to the interfingering of Aqra Formation with Tanjero Formation.

B- Very recently Karim (2004) proved that these fossiliferous limestone beds with shale and red claystone are belonging to Tanjero Formation. He called the alternations of these layers “Mixed carbonate-siliciclastic succession”. Moreover, he found the equivalent of these beds in Dokan area at the upper part of the formation.

C- In some places such as right bank of Khewata stream. The alternation of red claystone and shale with fossiliferous limestone represent the gradational contact between the Red Bed Series and the Tanjero Formation. The limestone contains Upper Cretaceous fossils such as large forams, echinoderms, and rudist.

2.2.2- Divisions of Al- Mehaidi (1975)

At Chwarta area, Al-Mehaidi (1975) suggested another division, which is different from that of Bolton mentioned above. Field study showed that the division of Al-Mehaidi is more accurate than that of Bolton. He didn't include Unit one of Bolton from his division. Instead, it appears that he subdivided the Unit Two of Bolton into two units. He named these two units as Unit One and Unit Two from the bottom to the top (Fig.1.4). The divisions of Al-Mehaidi (1975) are as follows:

2.2.2.1-The Lower Red Bed Unit

The thickness of this unit ranges between (0-400m) and consists of interbedded red and grey silty shale and claystone, radiolarian chert, arenite, lithic arenite, gray detrital limestone (calcarenite) and thin beds of conglomerate.

2.2.2.2-The Sandstone Unit

It is rest on the Lower Red Beds and has a thickness of (0-500m). This unit, to the southeast of Chwarta town, is directly overlying The Tanjero Formation. Thin beds of conglomerate, which indicate unconformity between the two units, mark the contact with lower Red Beds Unit, in most of the area.

2.2.2. 3- The Conglomerate Unit

This Unit forms a thick lens (0-900m) of poorly sorted polymictic conglomerate. The rock fragments range from pebble to boulder and mostly consist of limestone, igneous and metamorphic rock fragments. In the present study it is called Chwarta Conglomerate.

2.2.2. 4-The Upper Red Bed Unit

This unit consists of grey, red and greenish calcareous lithic arenite, silty shale and marl, polymictic conglomerates and thin beds of coralline limestones. This unit is overlies the conglomerate unit and represents a shallow marine environment.

2.2.3 -New division of the Red Bed Series in the present study

As generally agreed that the depositional environment of the series is shallow, mainly continental, therefore, a unified division for all areas might not be suitable. Instead a new division of each area would be more convenient to achieve and finally to correlate the divisions in different areas together.

2.2.3.1-Chwarta - Mawat area

In the present study, detailed fieldwork showed that the series is well developed in Chwarta-Mawat area and the maximum units can be distinguished in this area. So this area is suggested to be standard for comparing and dividing for other areas. The Red Bed Series is divided into the following units from the bottom to the top of outcrop sections:

Uhit One (Lower Fine Red Clastics)
Unit Two (Lower Conglomerate Unit)
Unit Three (Sandstone Unit)
Unit Four (Mixed fine and coarse clastic unit)
Unit Five (Upper conglomerate or Chwarta Conglomerate)
Unit Six (Upper fine clastics)

The description of these units is as follows:

2.2.3.1.1- Unit One (Lower red fine clastics)

This unit represents the lower 200m of the sections of Red Bed Series that located directly above the Tanjero Formation. It consists of red claystone and siltstone with interbed of sandstone and rare lenses of conglomerate. At the southeast of Chwarta and at 1km to the northeast of Tagaran village, this unit comprised of rhythmic alternation of red and bluish white claystone and sandstone (Photo2.1, 2.3A and 2.4). Toward Mawat (to the west) the percentage of conglomerate increases and the bluish white layers become thinner and coarser in grain size. Inside Iran this unit is about 60m thick and contain a bed of bluish white marl about 10m.thick.

The cooked samples of this bed yield no any fossils to indicate the age or environments. In many places, as 600m west of Kani Sard and west of Shams Awa villages, there is a layer of white clay (soil). This layer covers the unit, which has the thickness of 0.5 -4m. This clay is studied by Mohyaidin and Merza (2004), they concluded that they are composed of calcareous materials and generated by weathering of recent alluviums derived from the Kometan and Balambo Formations. Field study shows that their conclusion is correct.

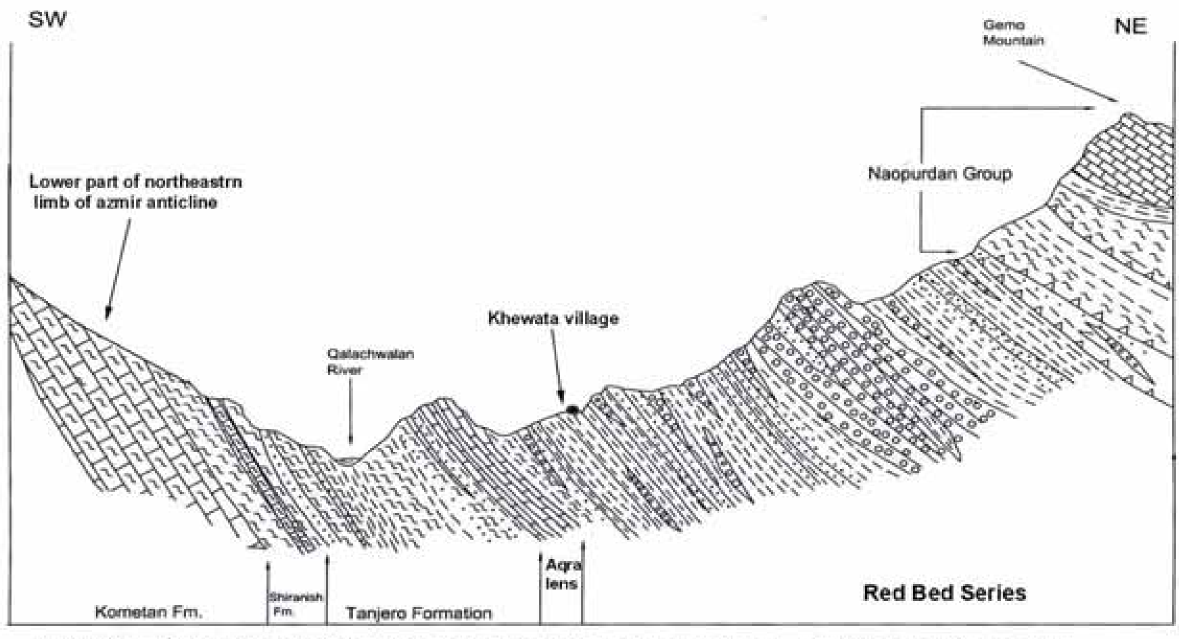
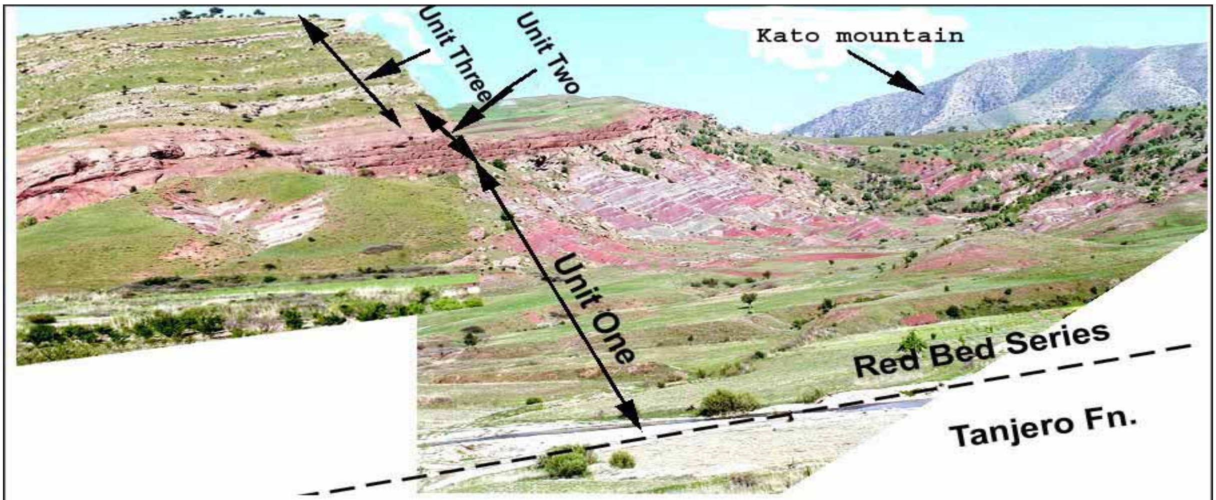


Fig.(2.1) Schematic geological cross section of Khewata area

2.2.3.1.2- Unit Two (Lower Conglomerate Unit)

This unit is located above Unit one and has a thickness of 16m (Photo2.1) and (fig. 2.1 and 2.4). It is well outcropped at the east of Tagaran villages and has a predominant red or brown color. Texturally the clasts consist of pebble and boulder with some blocks, while the matrix consists mainly of coarse sandstones. Compositionally, different types of limestones and cherts are the only constituents of the clasts and matrix. This type of conglomerate is called oligomictic conglomerate by Pettijohn (1975) and Selley (1988). Texturally, it is badly sorted and sub-rounded. In Mawat area, in contrary to Chwarta area, this unit, contains igneous and metamorphic clasts. This is clear at the east of the Suraqallat village where the thickness of the unit changes to 9m.



Photo(2.1) Unit one, two and three as appear in the Tagaran section

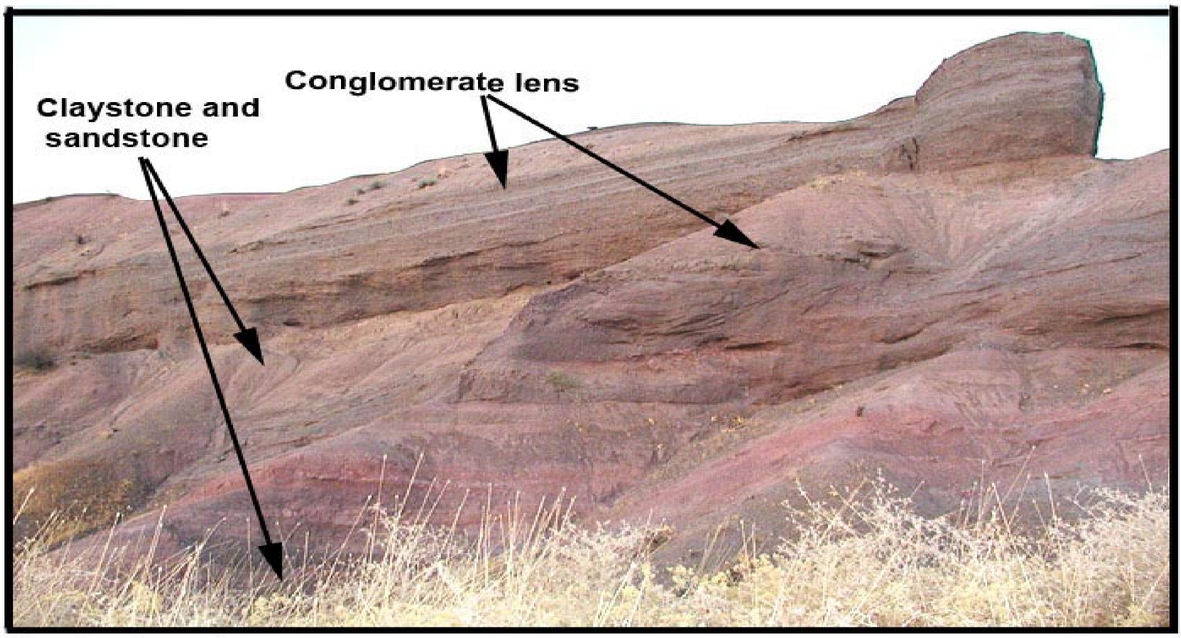
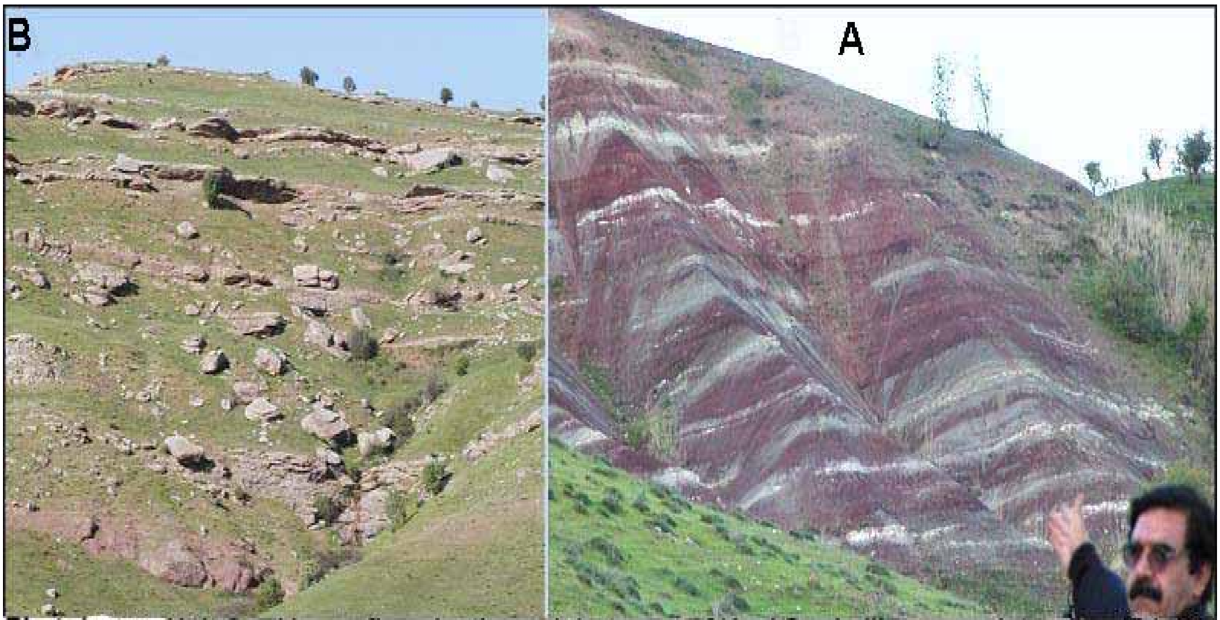


Photo (2.2) Unit four of Tagaran section, composed of Mixed fine and coarse lithologies ,

2.2.3.1.3- Unit Three (Sandstone Unit)

This unit is very distinctive and very thick (about 500) in the Chwarta area (Photo2.1 and 2.3B). In this area, this unit consists of alternation of thick, succession of coarse and gray sandstone (arenite). These sandstone beds alternate with thick beds of brown claystone and siltstone. The sandstone beds can be traced laterally for more than 10kilometers and make many geomorphological features such as Questas and Hogbacks in the area. The prominent feature a long the outcrops of this unit is the resting of tens of blocks of sandstone on the scarp slope of the Questas and hogbacks, which are detached from their original place by toppling and sliding (Photo 2.3A).

At the south and southwest of Mawat town the thickness of this unit decreases and become less than 70m. In all areas this unit contains many sedimentary structures such as cross bedding, lamination, ripple marks, plant debris, flute casts and tool marks; it is possible that these sedimentary structures are the transitional features between the Red Bed Series and Kolosh Formation (see chapter three). The thin section study of this unit showed that the sandstone composed of carbonate (52%) chert and quartz (40%) and Igneous rock fragments (8%), (Fig.2.10). Texturally and genetically the sandstone of this unit can be classified as lithic arenite. This is because the matrix is less than 25% (when the division of Dott(1964) and Pettijohn et al. (1987) is used). The cement material is not much clear but some of them have calcite cement. It has a moderate sorting and subrounded texture which indicate a relatively rapid deposition.



Photo(2.3) A) Unit One(lower fine clastics unit) at west of Kani Sard village consist red and bluish white claystone and siltstone. B) UnitThree (Sandstone Unit) at west of Tagarasn village

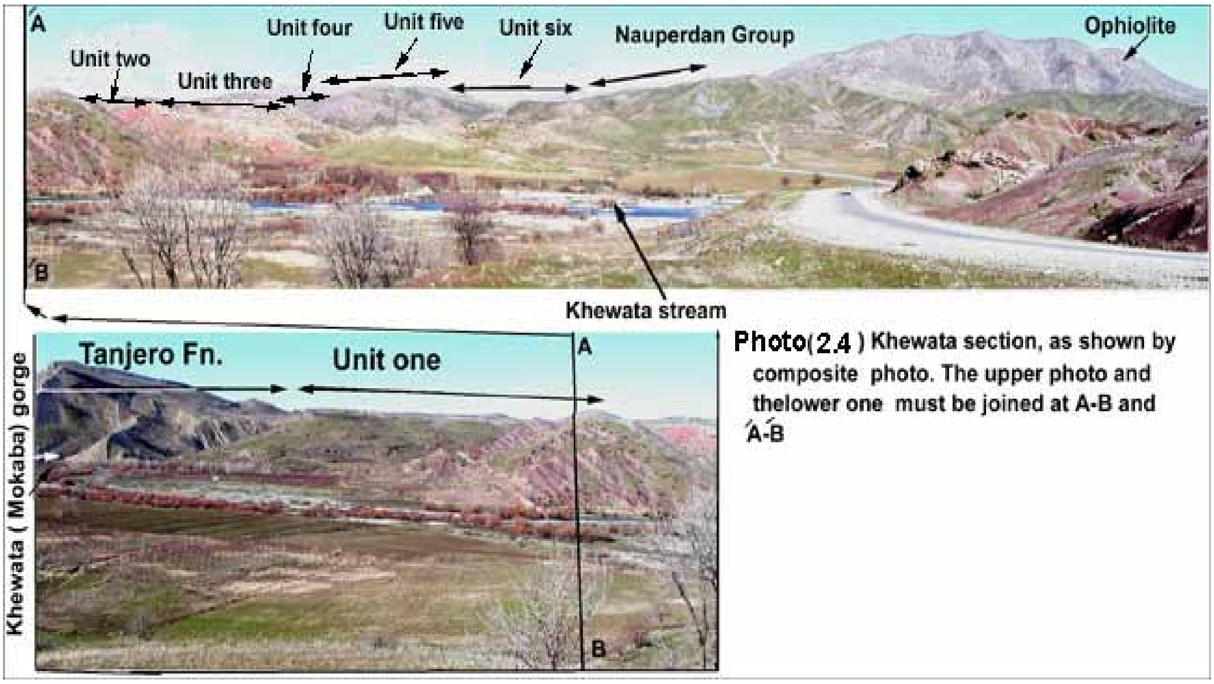
2.2.3.1.4- Unit Four (Middle coarse and fine clastic unit)

This unit is located on the Sandstones unit and characterized by its red color and contains red claystone, sandstone and conglomerate with predominance of fine clastics (Photo2.2 and 2.4). The claystone of this unit is similar to that of unit one (lower fine clastics) but without the bluish white layers, while the sandstone layers nearly contain the same constituent of unit three (sandstone unit). The conglomerate of this unit, as compared to that of unit two, has more sorting and roundness and contains igneous and metamorphic clasts. The thickness of this unit reachs 150m. (Fig.2.4).

2.2.3.1.5- Unit Five (Upper conglomerate or Chwarta Conglomerate)

At Chwarta-Mawat area, this unit consists of thick successions of conglomerate (about 1000m thick) which contains different types of clasts such as limestone, chert, igneous and metamorphic rock fragments (Fig.2.4). At the area around Suwais village, it contain only limestone and chert clasts. The grain size of this unit ranges from granules to blocks (Photo 3.3 and 3.4). The blocks mainly belong to black or gray limestone of Qulqula Formation with block of serpentinite (altered peridotite).

Bolton (1958) and Al- Mehaidi (1975) called this unit “Unit Three “. Generally the sediments of the unit are subangular and badly sorted suggesting near source area and steep gradient of the transport surface. We have seen flat large blocks (weighted 50kg) in Chwarta Mawat area. The flatness of these blocks is such that



Photo(2.4) Khewata section, as shown by composite photo. The upper photo and thelower one must be joined at A-B and Á-B́

they transported only by sliding not rolling. The texture reveals that transportation is not by debris flow because the blocks are found in orthoconglomerate (grain supported conglomerate).

The field point counting by using comparison chart showed that most grains are derived from Qulqula Radiolarian Formation (chert and limestone) and few ones have the source of Ophiolite and limestones of Walash-Nauperdan Series. The percentage of these grains is 55%, 30 and 15 respectively. At Suwais village the conglomerate has coarser texture and compositionally contains clasts of chert and limestone derived from Qulqula Formation. Field and laboratory studies showed that stratigraphic position of this unit is uncertain; this is because of the following:

A) In Chwarta area, this unit contains boulders, blocks (Photo3.6A) and pebbles of gray and milky Nummulite and Alveolina bearing limestones

(Photo4.1 and 4.2). These fossils also reported by Omari and Sadiq (1977) in Chwarta area. The age of these fossils is Lower to Middle Eocene. These clasts are derived from source area of Walash-Naoperdan Series. This proves that the age of unit five (unit three of Bolton) is younger than the Walash-Naoperdan Series. This means that this unit has no stratigraphic relation with the units one, two, three, four and six.

B) Surveying the Sarsir Mountain especially it's northern and southern side, the absence of any exposure of this unit was noted, while there is thick succession of this unit on the southern side of the mountain. As the paleocurrent in this unit is towards south, it should be thicker and coarser at the northern side of the mountain. This observation prove that the unit is deposited as an alluvial fan (or as a Talus) Buday (1980) on the regional paleoslope of Eocene which now partly represented by Chwarta-Mawat area for more evidence see section (4.2.1 and 6.5). During Eocene, other units of series (with Walash- Naoperdan Series) are exposed along the regional paleoslope. The sudden uplift activated erosion of the existed outcrops in relatively arid climate.

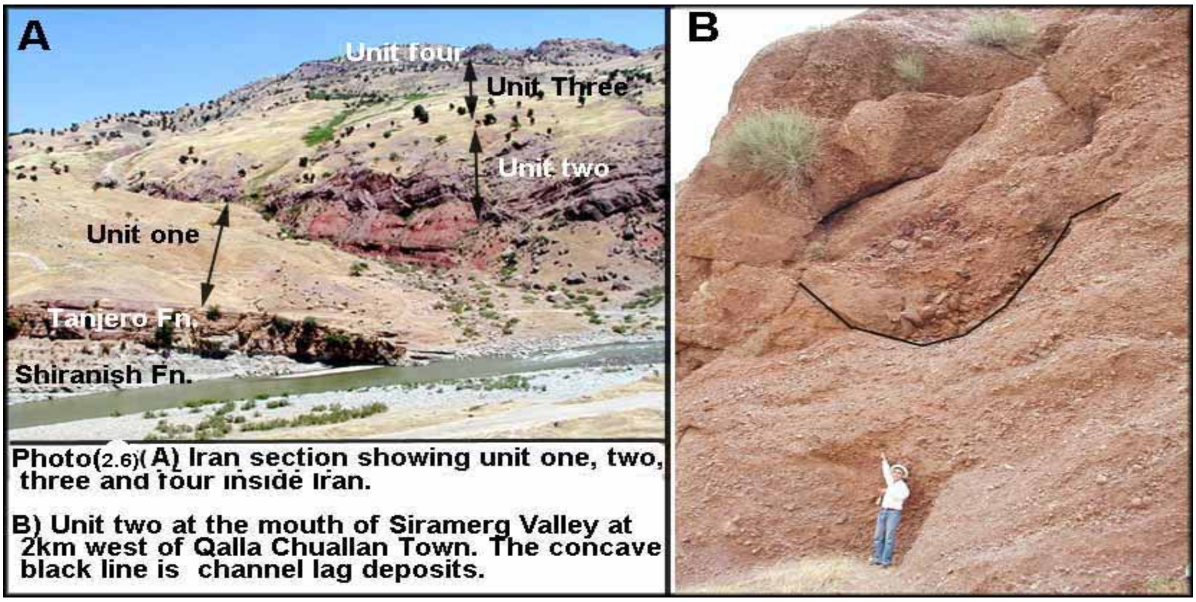
C) At the southern side, the dip of the layers of the conglomerate is less than the dip of the other units of Red Bed Series. The dip of the layers is nearly 20 degrees while the dip of other units reaches 30 degrees. This means that the conglomerate deposited on the slope of the terrestrial lands, which were surrounding the basin of the Red Bed Series during late Eocene. The deposition occurred in an onlapping manner, which causes decrease of the slope.

As a result of this fact the stratigraphy and division of the Red Bed Series must change totally and unit five must be separated from other units and put at the top of the Walash –Nauperdan Series not at the middle of Red Bed Series. Therefore its name and position must be change, from unit three in previous studies, to new name or even may be designated as a new formation. To simplify and to avoid repetition of Unit Five, the present study named it

Chwarta conglomerate. For more detail see Chapter Five,(Sequence Stratigraphy).

One can see on the outcrop sporadic blocks on surface outcrop of this unit in Chwarta-Mawat and Qandil area some block weighted more than 300kg (Photo2.5). Omari and Sadiq (1977) mentioned that this unit contains fossiliferous pebbles and boulders belong to Naoperdan Group so he assigned the age to be younger than the Eocene.

Photo (2.5) Blocks of limestone of Qulqula Formation on the surface of outcrop of unit five at southest of Chwarta town.



Photo(2.6)(A) Iran section showing unit one, two, three and four inside Iran.

B) Unit two at the mouth of Siramerg Valley at 2km west of Qalla Chuallan Town. The concave black line is channel lag deposits.

2.2.3.1.6-Unit Six (Upper fine clastics)

It is composed of calcareous shale, brown claystone, marl and sandstone with some conglomerate. The lower part of this unit contains interval of fossiliferous limestone. The fossils include coral (Photo4.3), green algae, pelecypods and oysters. Buday (1980) mentioned the presence of nummulitic in the same unit in Chwarta area. But in the present study it has not found. The thickness of this unit reachs 800m in the type area, but in Chwarta-Mawat area, the thickness of this unit reachs 100m.(Fig.2.4). In most areas this unit is covered by soil and sediment or it can not separate from Walash-Naoperdan Series. In Rosty valley and west of Dina town it partially covered by ophiolite in tectonic relationship.

2.2.3.2 -Divisions of Suwais Village section (Southeastern end of Qandil mountain toe)

This section is located at the southeastern end of Qandil Mountain at 30km to the northeast of Ranyia Town directly to the north of Suwais Village (type locality of the series) near the border of Iran. Field study showed that the description of the series does not belong to one single section but it has taken from the combinations of two sections at two nearby localities. These localities are Suwais village and Pshtashan Village to the north (Fig.1.3). Therefor the best outcrop to be taken as type section is the section of Tagaran. The Red Bed Series around Suwais village is more sandstone and conglomerate rich and its units are not well developed as compares to Tagaran section (Fig.2.6). The units are as following:

2.2.3.2.1 - Unit One (Lower Fine Red Clastics)

This unit is located directly on the Tanjero Formation. It consists mainly of sandstone rich with gray color and has the thickness of 90m. (Fig 2.6). The red color, which is noticeable in Tagaran section, does not exist in this area. Thin section studies revealed that sandstone consists mainly of limestone and chert clasts, which are derived from Qulqula Formation provenance with some igneous rock fragments of Ophiolite origin.

.2.2.3.2.2 -Unit Two (Lower Conglomerate Unit)

This unit consists of two beds of conglomerate exclusively composed of limestone and chert fragment. This unit has the thickness of 15m but the red color cannot be seen, which is very observable in the Chwarta-Mawat area. The grain size is finer than that of Tagaran section, which contains no boulders and blocks (Fig.2.6).

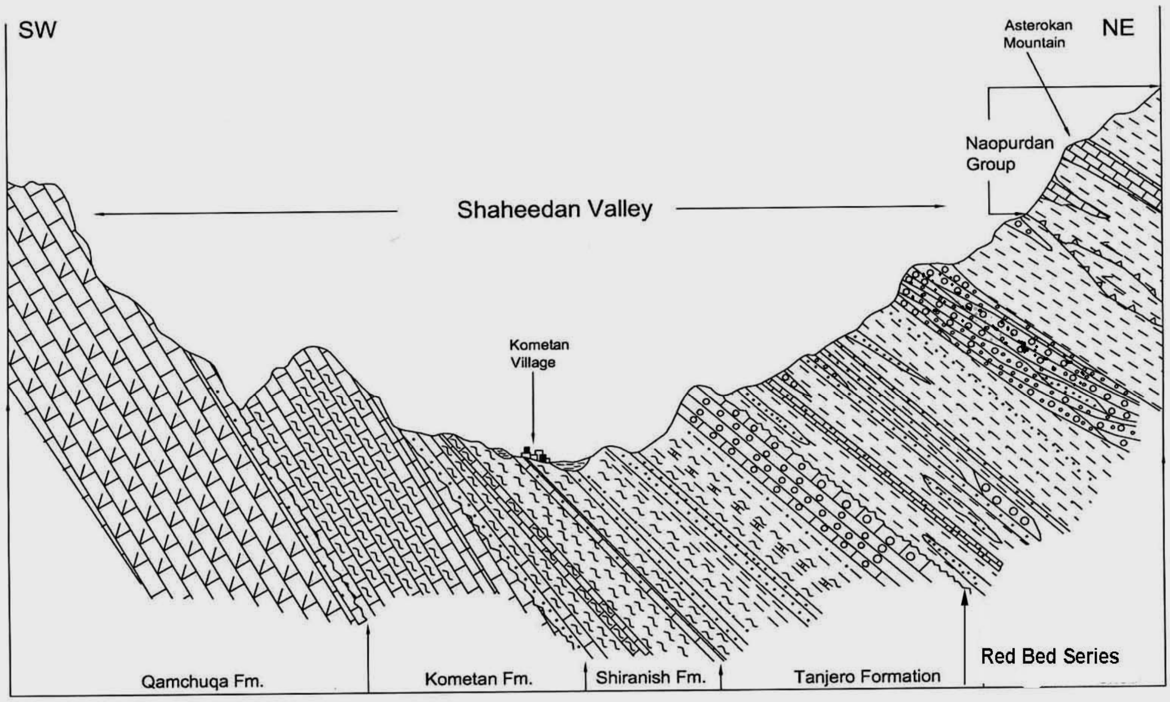


Fig.(2.2) Schematic geological cross section of Shahidan Valley near Kometan Village

2.2.3.2.3 - Unit Three (Sandstone Unit)

This unit is nearly similar to Unit Three (Sandstone Unit) in color and lithology of the Tagaran section with a thickness of nearly 60m. The main difference is that in the latter area the sandstone contains more grains of chert, limestone and lesser amount of igneous and metamorphic rock fragments as compared to Chwarta – Mawat and Qandil foothill area (photo 2.10).

2.2.3.2.4 - Unit Four (Mixed Fine and Coarse Clastic Unit)

This unit is nearly similar to that of Chwarta-Mawat area, which consists of alternation of coarse and fine clastics (Red claystone, sandstone and conglomerate). The color is the same as that of Tagran section, while in this area, it contains no clasts of igneous and metamorphic rocks, and the thickness is about 75m (Fig.2.6).

2.2.3.2.5 - Unit Five (Chwarta Conglomerate)

This unit is similar to that of Chwarta-Mawat area in color (grey). But the section differs in the absence of Igneous and metamorphic clasts (Fig.2.6). Moreover the limestone clasts are larger and more abundant than the chert ones. Some of the limestone clasts consist of blocks which may reach in weight 200kgs. The percentage of limestone and chert clasts is 72 and 38 respectively. The field and thin section inspection of the pebbles, boulders and blocks revealed that they derived from Qulqula Formation. While the same unit in Chawrta-Mawat area derived from more than one source rocks including the Qulqula Formation, Ophiolite and metamorphic rocks in addition to Walash-Naoperdan Series. The thickness of this unit cannot be measured as it shows possible imbrication of the blocks on each others so that the thickness is doubled. However the apparent thickness is about (800 m).

2.2.3.2.6 – Unit Six (Upper fine clastics)

The top of the Suwais section is covered by soil and alluvium so that we are not able to study it (Photo2.10A). The thickness is about 800m.

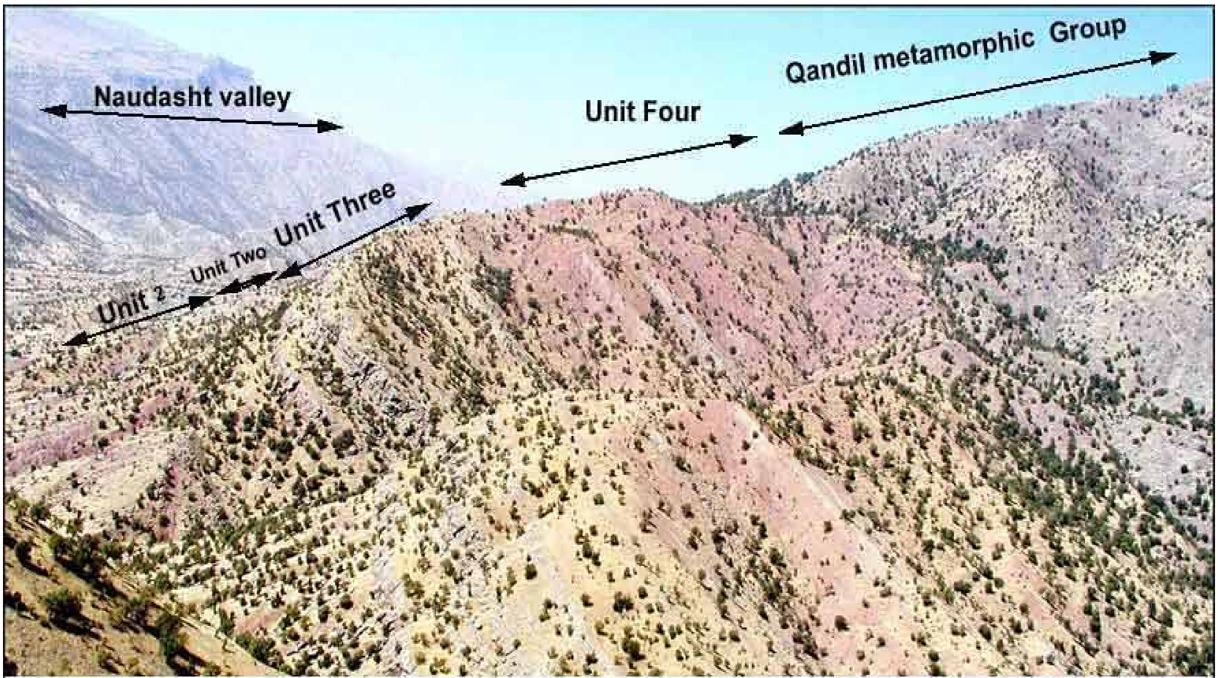


Photo (2.7) Kometan section at northwest of Kometan village at Qandil mountain toe

2.2.3.3-Devisions at Qandil mountain toe and Roste valley

Most units at these areas either not exist or not developed well (Photo2.9). For example, at the north of Kometan village, units one and two are well developed while unit three is thin and contain several bed of conglomerate (Fig.2.7). Units four, five and six all make thick successions of fine clastic with some lenses of conglomerate. In this area it is obvious that the upper conglomerate (unit five of this study) is not present. It seems that the latter two units were deposited as a thick aggradational pile of fine clastics in a relatively low energy environment. These sediments are similar to that of unit six. The conglomerates, in this area, are rare and contain lesser amount of igneous and metamorphic rock fragments as compared to Chwarta Mawat area.

At Roste valley all the representative lithologies of the Red Bed Series are fine clastics (red claystone with some sandstone). At these areas coarse units are not present especially unit five (unit three of Bolton).

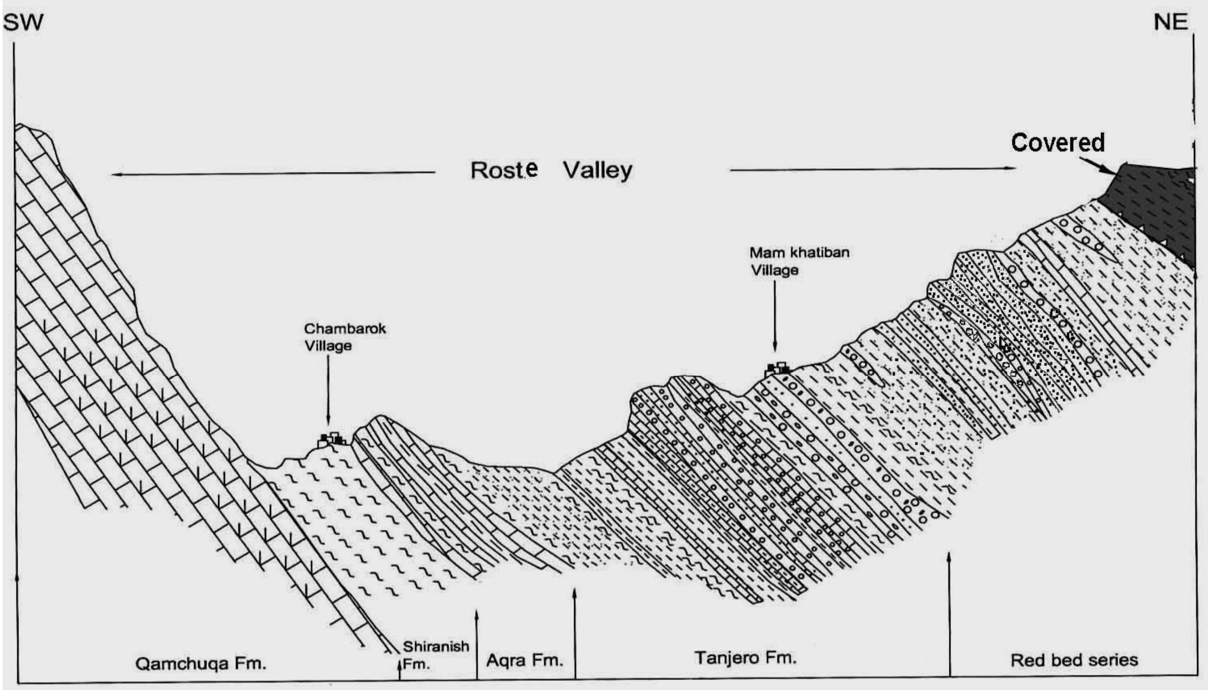


Fig.(2.3) Schematic geological cross section of Roste Valley

The problem is that one did not know whether the units are not deposited during their respective time or they are deposited as fine clastic because of persistence of relatively calm environment. At the base of Red bed series, in this valley, there are 15m thick alternations of fossiliferous limestone (in situ) and conglomerate beds. Thin section study revealed that limestone beds were deposited in their original place (not reworked) while the conglomerate bed seems to be intraformational (Fig2.3).

2.3-Origin of red color in the Red Bed Series

Field study in the source area of Red Bed Series at the north and northeast of the studied area showed that Qulqula Formation contain many thick successions of red color (Photo2.8). These successions consist of red shale, brown siliceous shale, red and brown cherts. They are seen clearly to the north of Kanarw town (Chwarta area), especially near Dere , Basine, , Bewre, Mirana, and Kani Showan villages, in addition to the east of Nalparez Town in Penjween area. In later area and in some place, the red shale changes to highly deformed brown jasper. The red intervals, in the Qulqula

Formation, constitute more than half of the total thickness of the formation. Karim (2003a) observed similar lithologies in the formation in the area that is located between Chwarta and Said Sadiq Towns.

As mentioned before Qulqula Formation is the main source area of the Red Bed Series. Therefore the origin of the red color is mainly attributed to the erosion of the observed red and brown successions in the Qulqula Formations. Previously, the red color of the red beds was attributed to the oxidation of iron in the continental environment during deposition (Blatt et el. 1980 and Potter et al. 1980). According to Al-Qayim (2000), the red color of the Red Bed Series is most likely originated from thermodynamic alteration due to thrusting of the Iranian blocks over the flysch trough of Arab plate margin during late phase of Alpine Orogeny. But the homogeneity of the red colors in the claystones and some conglomerate refuse these ideas, at least for the series in the studied area. This is because the oxidation, as diagenetic processes, cannot generate homogenous red or brown color in the thick bed. It can generate spotted or amalgamated color. In this connection(Harmann, 1963, in Turner, 1979) mentioned that diagenetic color of continental red beds is characterized by the occurrence of grey and green zones or white mottled zones within predominantly red successions that cut across the depositional boundaries. Eren (2001) mentioned that after reviewing of Turner (1980), Pye (1983), Friedman et al. (1992), Einsele (1992), there are two hypothesis which show the staining of sediments (the red color). The first hypotheses suggest that hematite is detritally derived from lateritic soils. The second hypotheses suggest that hematite forms authigenitically after deposition and by alteration of iron bearing detrital grains.

Another evidence for affecting of the source area on red color is the regular alternation of red and bluish white layers of claystone and sandstone in some places (Photo2.3A). Among these places we mention, the east of Tagaran and south of Kani Sard villages. Moreover, the contacts between both layers are sharp and not gradational. The red and white layers are derived from sources with the respective colors (i.e. Red shale and bluish white marl of Qulqula Formation). Gavrilov (2002) mentioned that in some cases, (Fe) might penetrate into underlying and overlying sediments as the stage of diagenetic compaction changing primarily white sediments to a red color. Irregularity in staining caused the spot appearance of deposits. In the Red Bed Series the red color is existed in narrow strip controlled during deposition by the limit of the costal area where there is no reduction environment, but the red interval of Qulqula may be 100km wide and 100m thick.

As the bluish white layers are not affected by the red color so the diagenetic or oxidation is excluded for main source of red color of Red Bed Series. We do not refuse the enhancement of the red color by oxidation but the main color is due to the source area, which is homogenized during transport by the rivers. The oxidation is happened during exposure of the red intervals of the Qulqula Formation, the same thing may also happen during transportation of these sediments. The dissolved oxygen may be incorporated with the existed (Fe) ions in the sediment of the Qulqula Formation. Many other authors argued that red color is attributed to pigmentary hematite which is derived from either weathering of source area or sediments previously deposited in a parallic oxidizing environments (Lajoie and Chagnon, 1973, in Turner, 1979).

The detritus of Kolosh and Tanjero Formations are believed to be partly derived from Qulqula Formation, but their colors are green and buff, this is because these formations have deep deposits and with organic matter shows dark color, but when one sees the shallow facies their color become light or brown which appear in Qallachwalan area.

2.4-Classification of the Red Bed Series sandstone

Classification of sandstone and conglomerate have many restrictions which include wide variations of lithic clasts and mineralogical constituents of the sandstones of the Red Bed Series from one unit to others. Even same unit show large lithologic change laterally. For example, unit one, in the south of

Chwarta town contains no igneous clasts but they increase laterally toward Mawat area. Another restrictions is that, traditional (common) method of classification of Folk (1974) and Pettijohn (1975) by equilateral triangle can not be used (Fig. 2.5A and B).

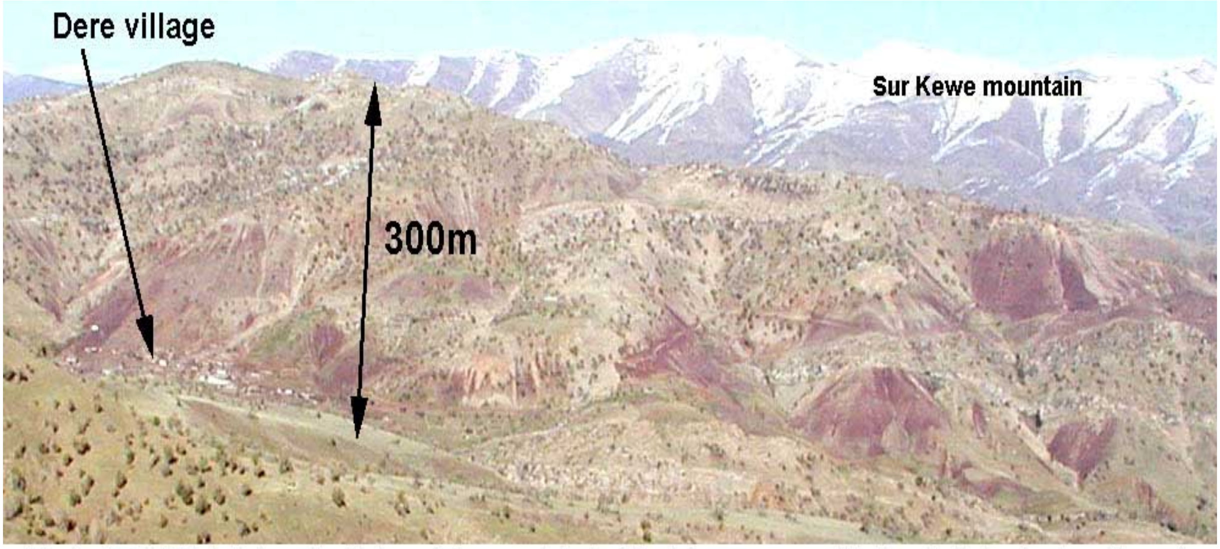


Photo (2.8) Thick interval which mainly consisted of Red ferrogenous Shale of Qulqula Formtion at 10km to the northeast of Chwarta town. It most probably responsible for red colour of Red Bed Series.

This is because the sandstones of the Red Bed Series is generally contain no feldspars or contain very little amount. So the triangle of the above author can not be used more successfully. While that of Al-Rawi (1982) is the most suitable than the others but it gives no convincing result (Fig.2.5C). This is because he did not put an apex for chert, which is common in the sandstone of the Red Bed Series.

Another classification adopted in this study in which the apexes of the equilateral triangle are assigned to represent limestone, chert +quartz and igneous rock clasts (grains). The igneous rock clasts consist of altered peridotite and gabbros clasts. The chert clasts include all type of cherts such as red (jasper), black (bituminous), clayey chert, limey chert and others in addition to quartz. This classification can also be applied to the conglomerate of the Red Bed Series. For this classification the thin sections of the sandstones are studied under polarizer microscope and point counting is achieved for the calculation of the constituents.

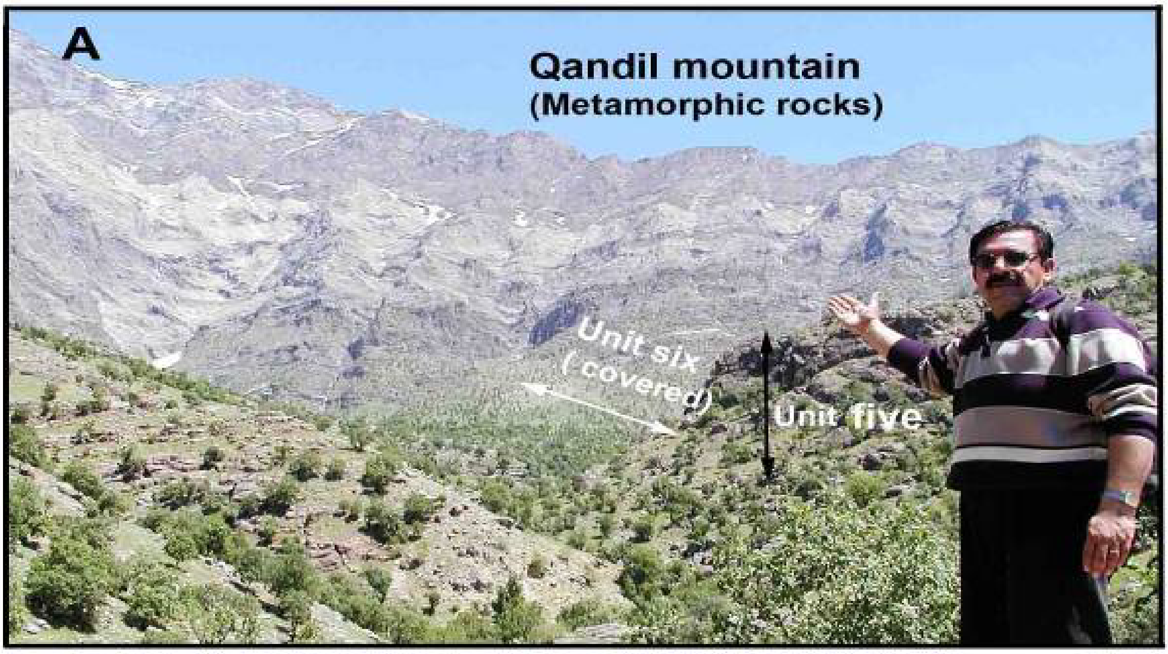
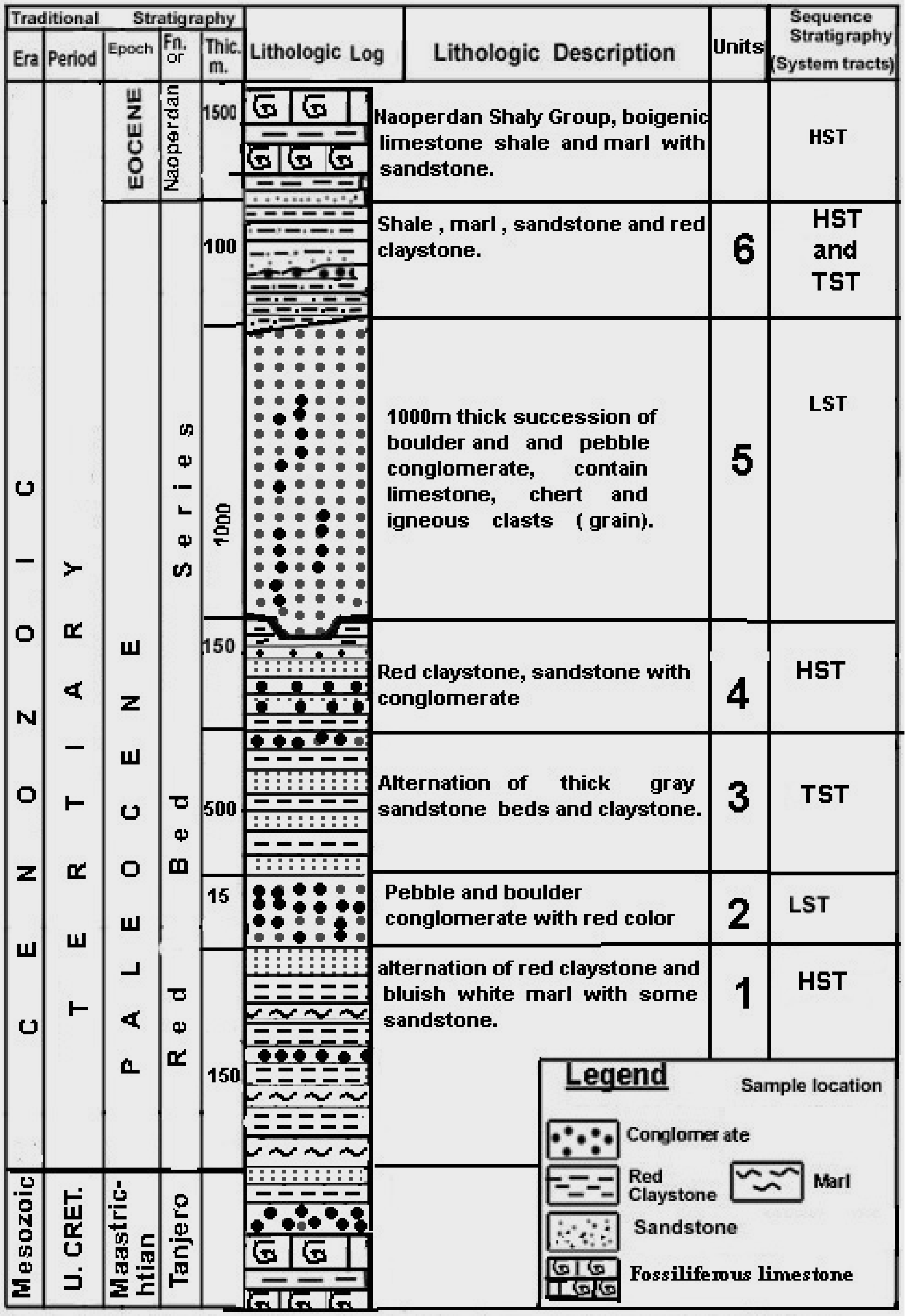


Photo (2.9) A) Unit five at Qandil mountain toe, at north-west of Suwais Village.B) A thin bed of limestone and lens of pebbly sandstone in the unit one at north of Kometan village , Naudasht valley.



Figure(2. 4) Stratigraphic column of outcrop section of Red Bed Series at west of Tagaran village before Tectonic correction. (not to scale)

The constituents of conglomerates are estimated by using comparison chart of Folk et al. (1970) and Tucker (1988). The comparison is done visually in the field, and the result is arranged in the tables (2.1, 2.2, 2.3, 2.4, and 2.5) and plotted on the compositional triangle (Fig 2.8 and 2.9). Quartz grains are not plotted on the triangle, because most of them were grown as secondary grains and derived from Qulqula Formation before erosion (many large secondary crystals was found in the Qulqula Formation).

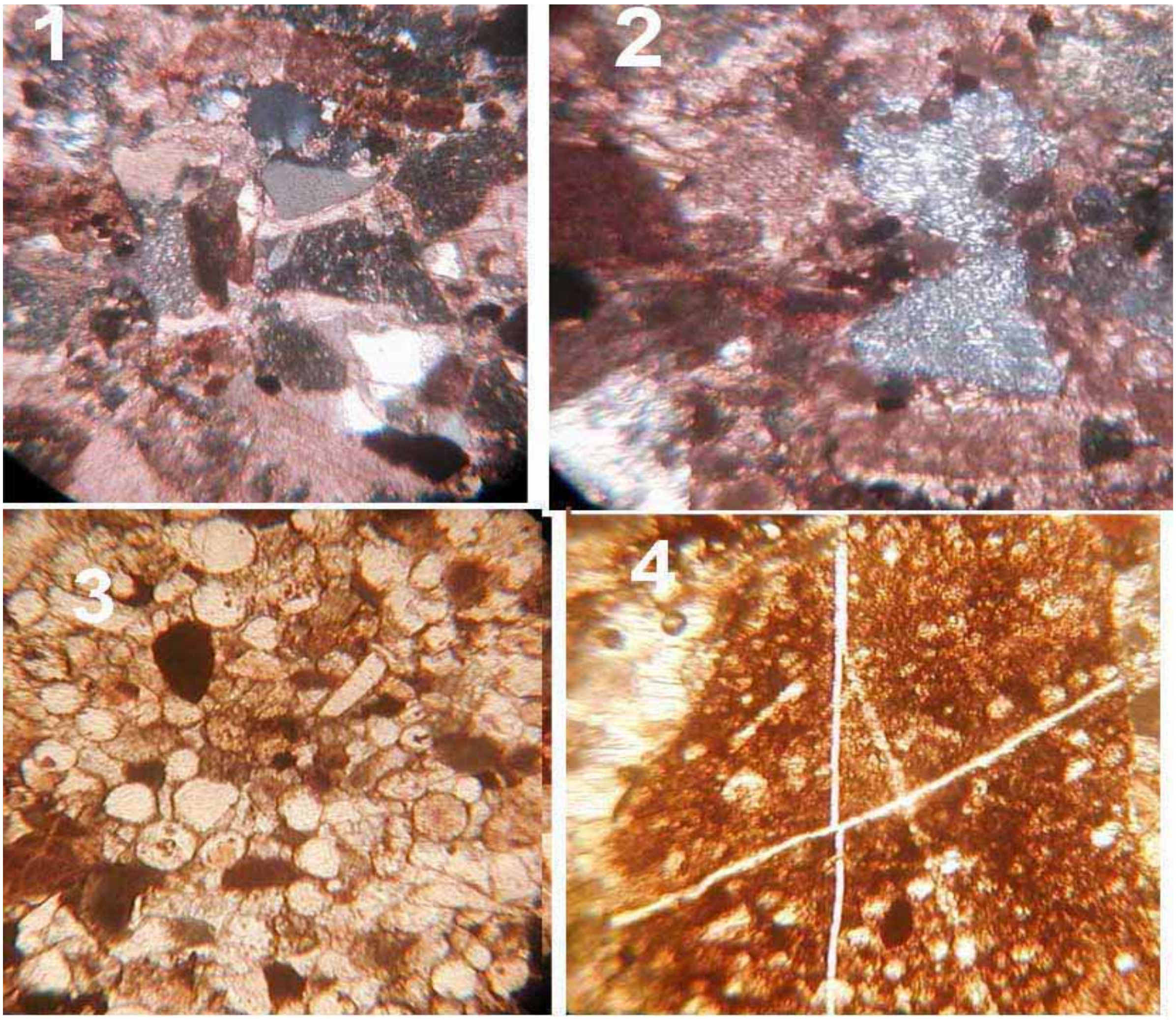
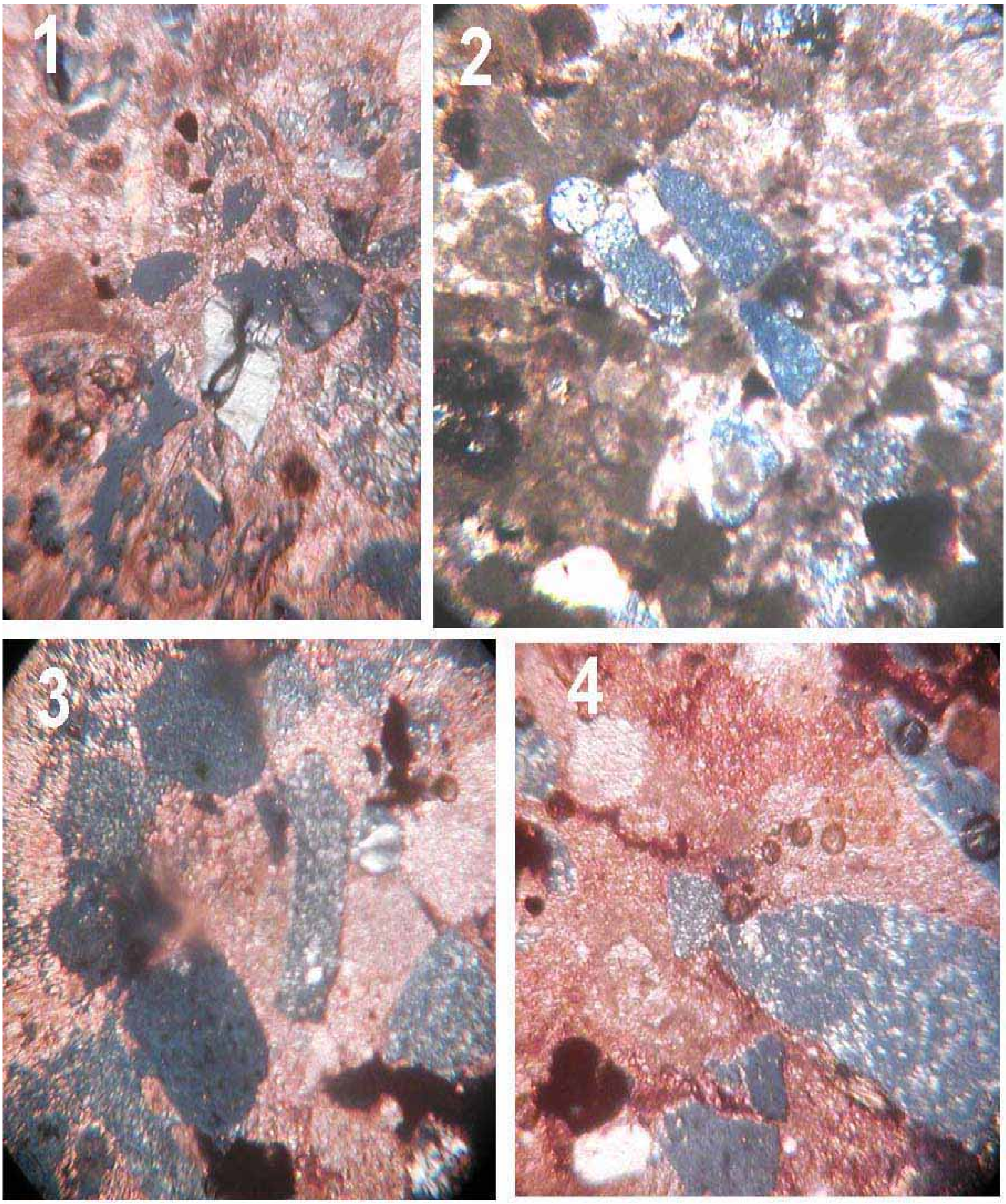


Photo (2.10) 1, 2: Sandstone of Red Bed Series composed of limestone (gray) , chert (black) clasts with some quartz (white). Sample No. T5 and T7 , X40, XP., Tagaran section.
3: Radiolaria fossil in the sandstone of unit three, S.N. 3, PPL, 40X
4: LImestone clast contain radiolaria derived from Qulqula Fn. 20X.



Photo(2.11) Sandstone of Kolosh Formation which can be compared with that of Red Bed Series, especially unit one and two, All Photos contain limestone (gray) chert (black) and quartz (white) Sampls from middle part of Kolosh Formation, XP, 40X

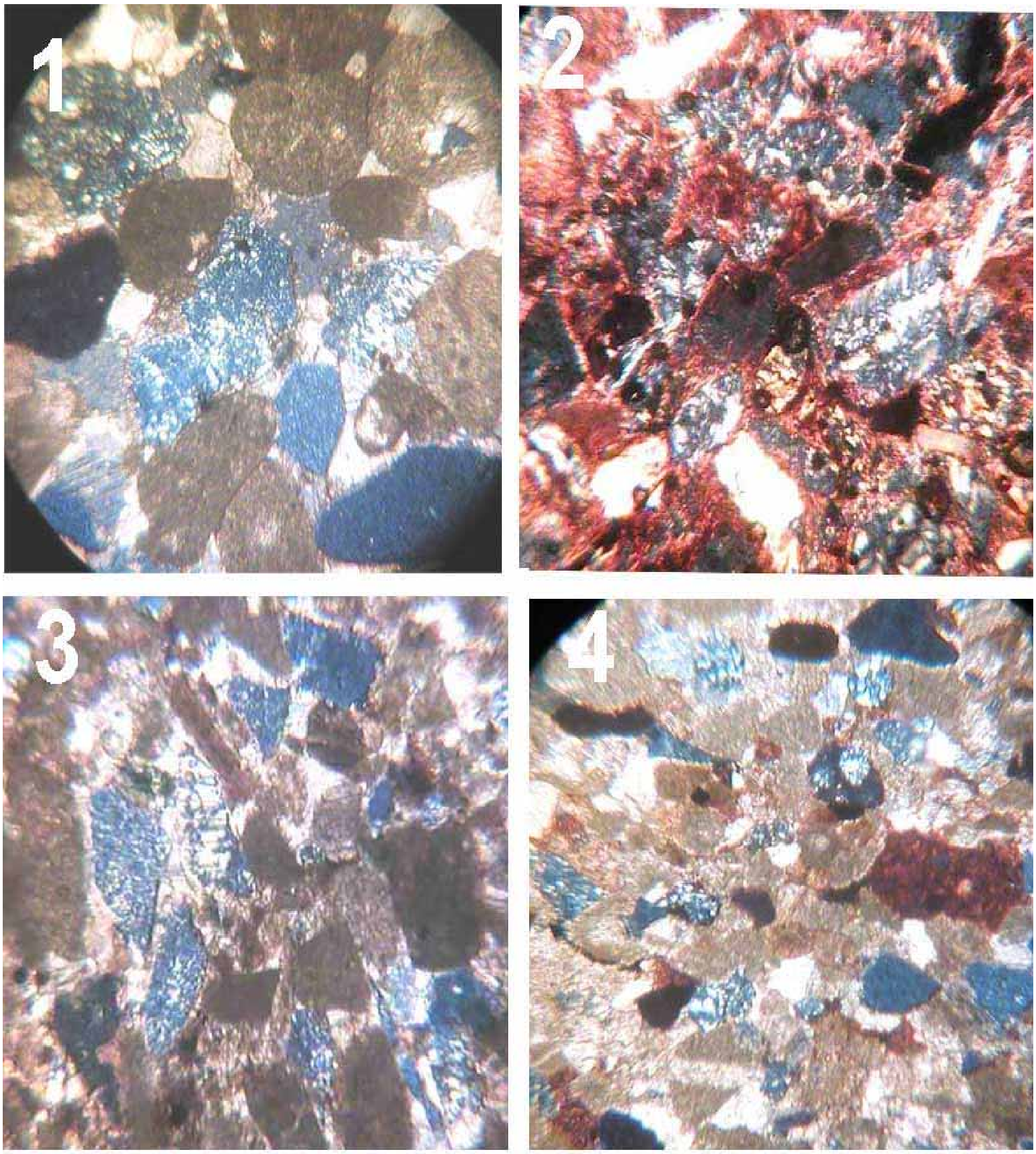


Photo (2.12) Thin section of Gercus Formation for comparision with sandstone and conglomerate of Red Bed Series. Most sandstones of formation (1, 3 and 4) is similar to the composition of unit five at the Suwais village as both contain mainly limestone (gray) and chert (black) clasts. While photo 2 is similar to unit five at Chwarta area as it contain igneous clasts in addition to chert and limestone ones.

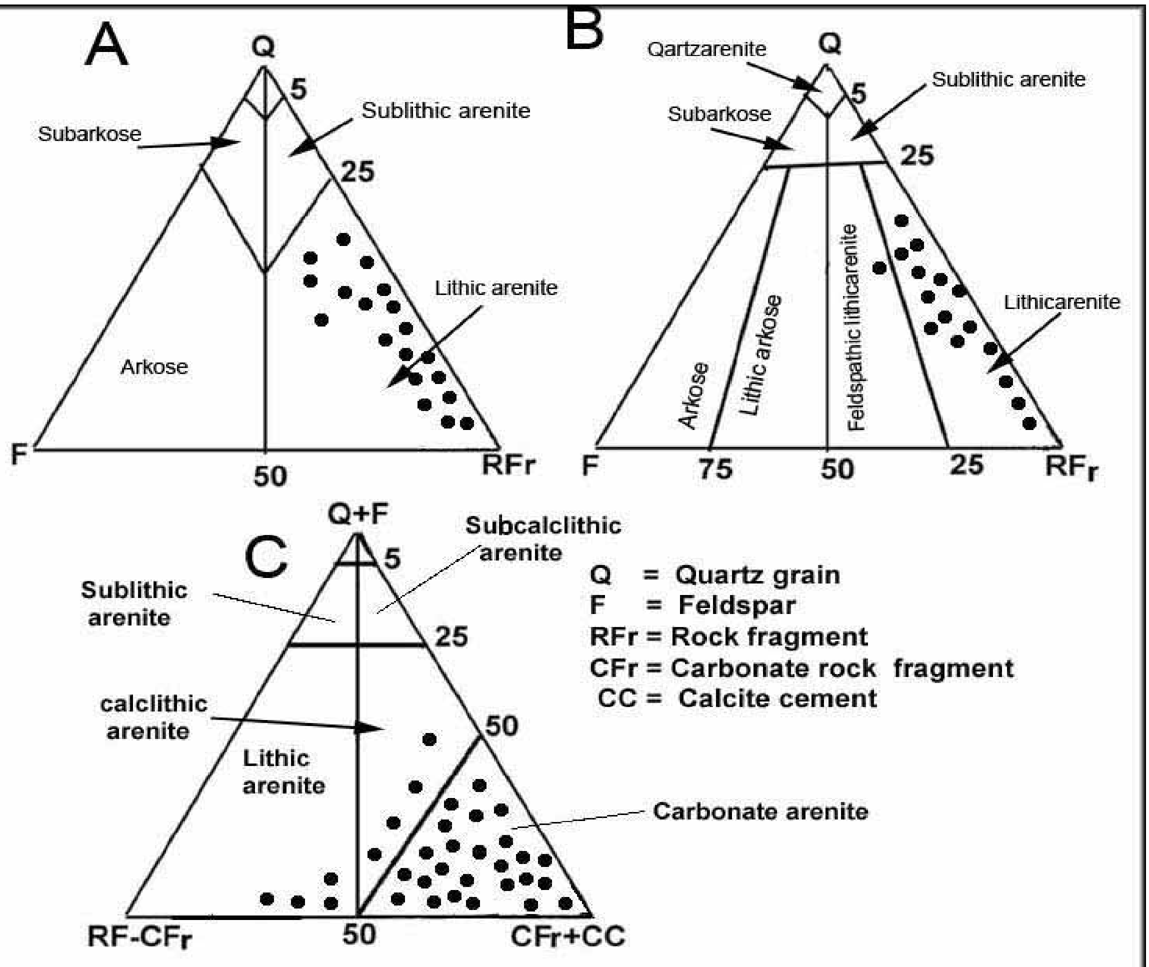


Fig.(2.5) Classication of sandstone of Red Bed Series according to A) Pettijohn, 1975. B)Folk, 1974. C) Al-Rawi, 1982

Table(2.1)constituent of unit three at Khewata section

Sample no.	(%) Chert	(%) Limestone	(%)Igneous and Metamorphic	(%)Quqrtz grains
1	30	31	32	7
2	27	37	32	4
3	22	38	29	11
4	37	36	27	---
5	34	40	23	3
6	25	56	17	2
7	30	50	11	9
8	34	46	16	4
9	43	43	14	---
10	47	36	17	---
11	31	51	8	10
12	30	61	3	6
13	41	51	2	6
14	43	50	7	---
15	44	46	7	3
16	53	40	4	3
17	53	35	7	5
18	51	31	11	7
19	62	34	4	---
20	59	30	9	2
21	56	21	13	10
22	61	24	6	9
23	66	18	4	12
24	48	34	16	2
25	41	37	19	3

Table(2.2) Constituent of unit two at Tagaran section

Sample no.	(%)Chert	(%)Limestone	(%)Igneous and Metamorphic
1	15	84	1
2	20	78	2
3	25	75	-
4	25	72	3
5	31	69	-
6	35	63	2
7	38	60	2
8	41	59	-
9	44	55	1
10	45	55	-
11	50	50	-
12	54	44	2
13	60	40	-
14	47	50	3
15	46	51	3
16	58	41	1
17	61	37	2
18	29	71	-
19	34	64	2
20	39	61	-
21	44	54	2
22	51	46	3
23	57	43	-
24	53	46	-
25	33	66	1

Table(2.3) Constituent of unit two at Khewata section

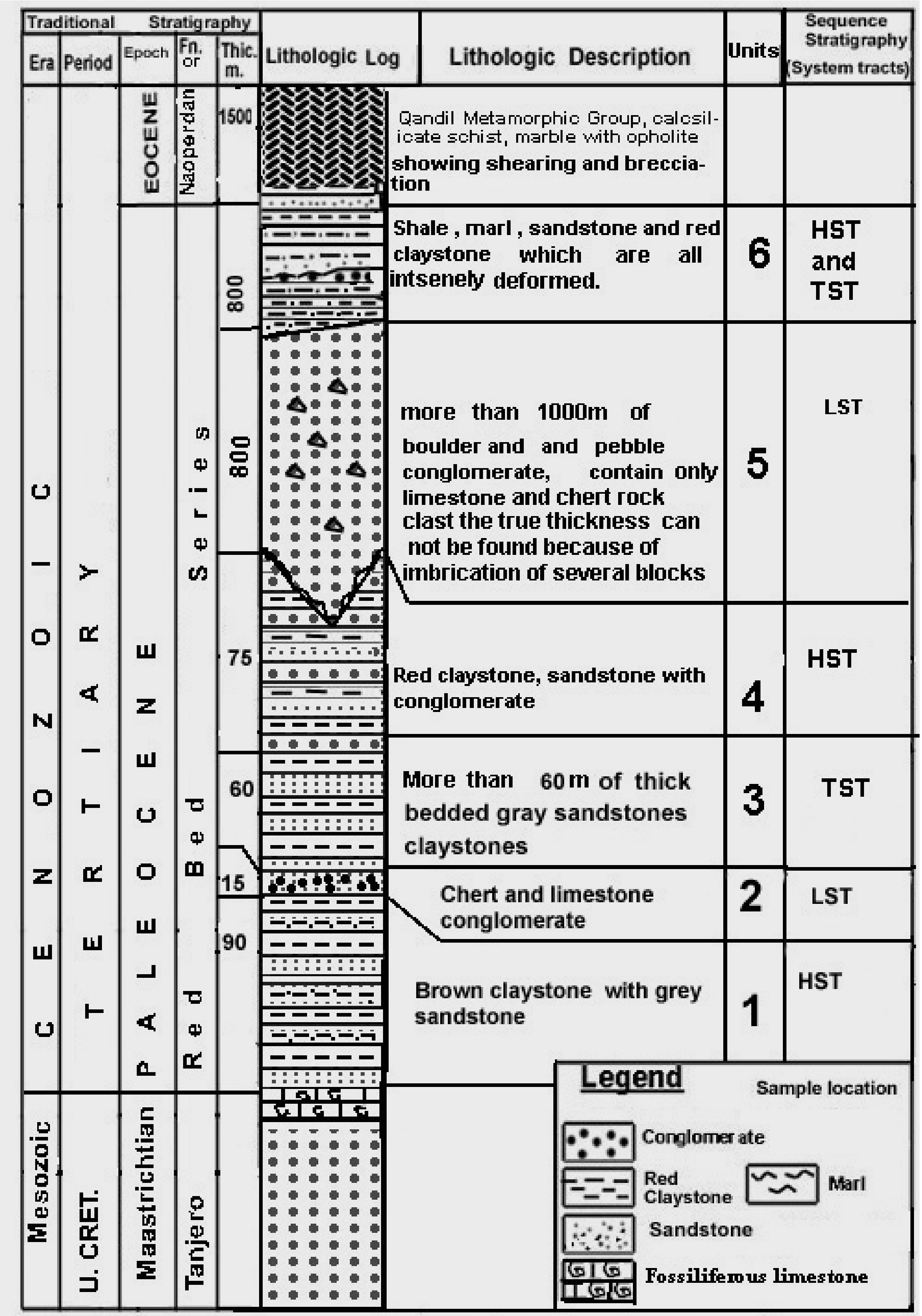
Sample no.	(%)hert	(%)Limestone	(%)Igneous and Metamorphic
1	34	44	22
2	36	46	18
3	44	42	14
4	48	36	16
5	58	36	6
6	66	28	6
7	42	48	10
8	35	52	13
9	28	58	14
10	35	57	8
11	22	64	14
12	25	67	8
13	22	73	5
14	37	56	7
15	53	40	7
16	61	31	8
17	42	48	10
18	34	55	11
19	63	33	4
20	31	56	13
21	33	53	14
22	50	44	6
23	58	36	6
24	68	21	11
25	53	38	9

Table(2.4) Constituent of unit five at Qalachwalan section

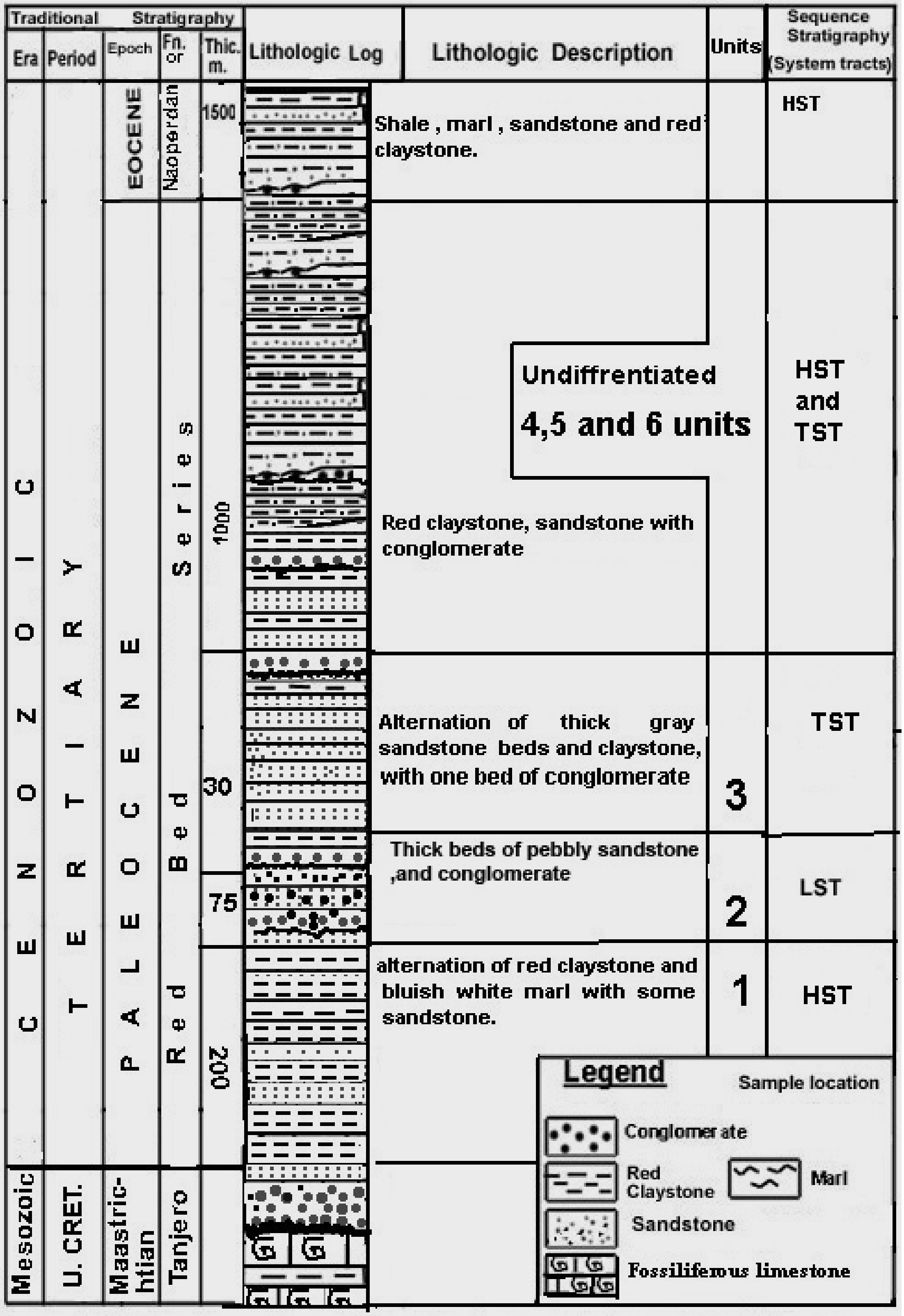
Sample no.	(%)Chert	(%)Limestone	(%)Igneous and Metamorphic
1	25	47	28
2	34	41	25
3	30	50	20
4	26	56	18
5	23	64	13
6	34	52	14
7	36	46	18
8	46	42	12
9	46	37	17
10	45	32	23
11	28	44	28
12	52	26	22
13	54	31	15
14	56	27	17
15	59	26	15
16	61	25	14
17	67	19	14
18	65	27	8
19	52	36	12
20	61	27	12
21	49	42	9
22	32	47	21
23	39	45	16
24	57	36	19
25	44	46	8

Table(2.5)Constituentt of unit two at Suwais section

Sample no.	(%)Chert	(%)Limestone	(%)Igneous ana Metamorphic
1	65	35	---
2	57	41	---
3	54	42	---
4	55	45	---
5	49	48	---
6	48	44	---
7	43	52	---
8	46	54	---
9	40	57	---
10	33	63	---
11	36	64	---
12	29	68	---
13	22	76	---
14	18	77	---
15	34	66	---
16	45	55	---
17	37	63	---
18	39	61	---
19	58	42	---
20	45	55	---
21	62	38	---
22	60	40	---
23	51	49	---
24	49	51	---
25	53	47	---



Figure(2.6)Stratigraphic column of outcrop section of Red Bed Series at northeast of Suwais Village (type section), before tectonic correction. (not to scale)



Figure(2.7)Stratigraphic column of outcrop section of Red Bed Series at Qandil mountain toe (Kometan village) . not to scale

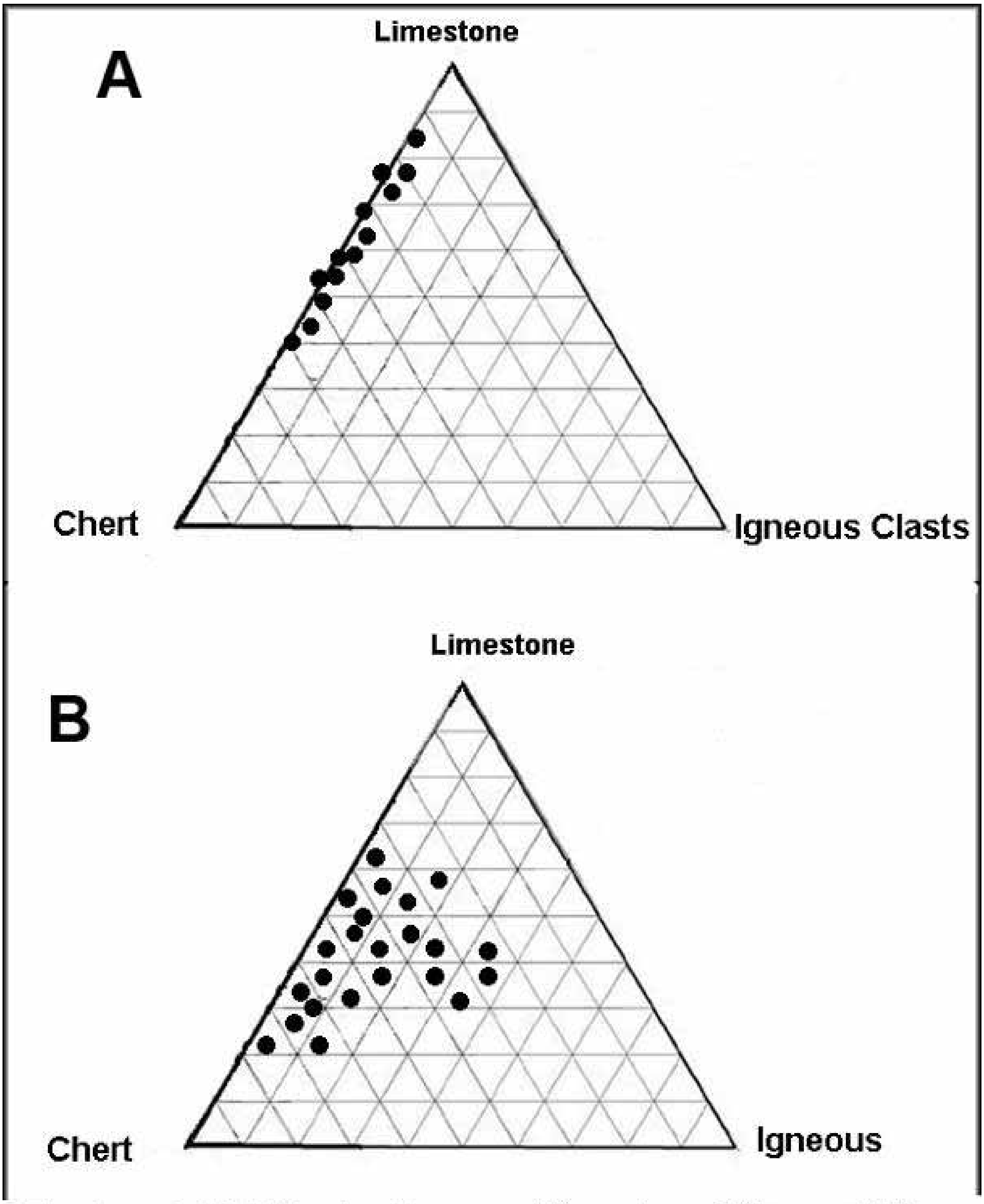


Fig.(2.8) A) Lithologic constituents of the unit five (Chwarta conglomerate) at Suwais village area.

B) Lithologic constituents of the unit five (Chwarta conglomerate) at Chwarta-Mawat area.

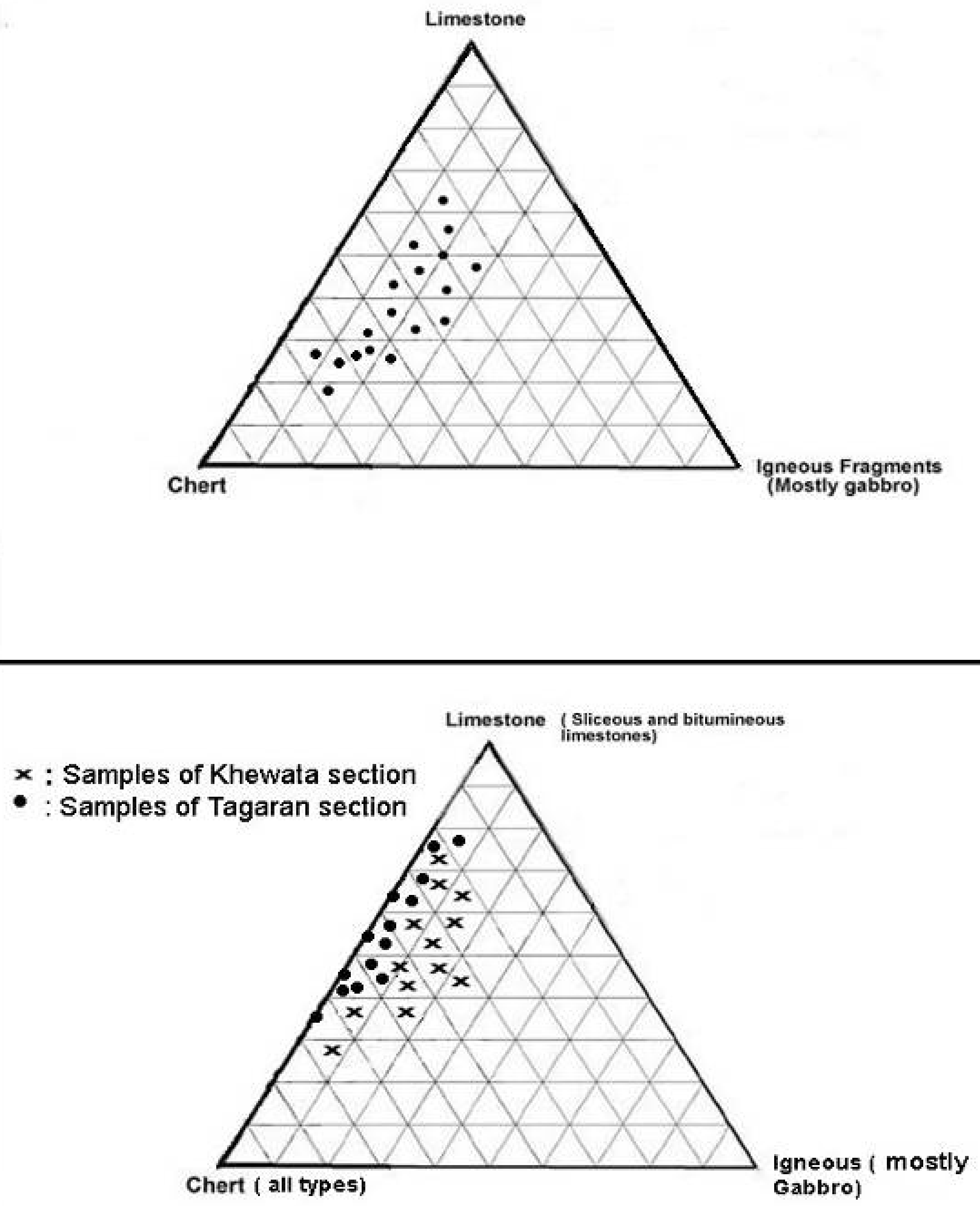


Fig.(2. 9) Lithological constituent of the unit three (sandstone unit)

Below: lithological compostion of the unit two (lower conglomerate unit)

CHAPTER THREE

SEDIMENTARY STRUCTURES AND PALEOCURRENT ANALYSIS

3.1-Preface

Sedimentary structures are essential characteristics for paleoenvironmental interpretations. They reflect the hydrodynamics of the transporting agents and reflect modes of transportation and deposition and may also indicate the paleocurrent direction.

3.2-Sedimentary structures

When one compares between Red Bed Series and other units such as Tanjero Formation, he realizes that this series is poor in sedimentary structures and the existed ones are badly developed and rare. However, during extensive fieldwork, several sedimentary structures are found such as, mechanical (physical) sedimentary structures.

Most of these structures are found in the unit three and five of Red Bed Series at Chwarta-Mawat area such as cross bedding, lamination, ripple marks and plant debris. No other sedimentary structures are found in the other parts except bedding. Most of these structures, as concerned to Red Bed Series, are recorded for the first time in the series. All these structures have stratigraphic and paleocurrent importance, which can be very useful in basin analysis of the Series. These structures are wave and storm generated processes and resulted from meteorological forces acting on the continental sediments, such as fluvial and alluvium and deltaic deposits in the shallow water. According to (Reading, 2004), the nature of sedimentary structures is controlled by

1-Energy level of hydraulic regime.

2-Type of sediment available.

3-Direction of wave and storm-generated currents, with respect to shore line or intra shelf sediment sources.

4-Amount of subsequent post waves or storms physical and or biological reworking .

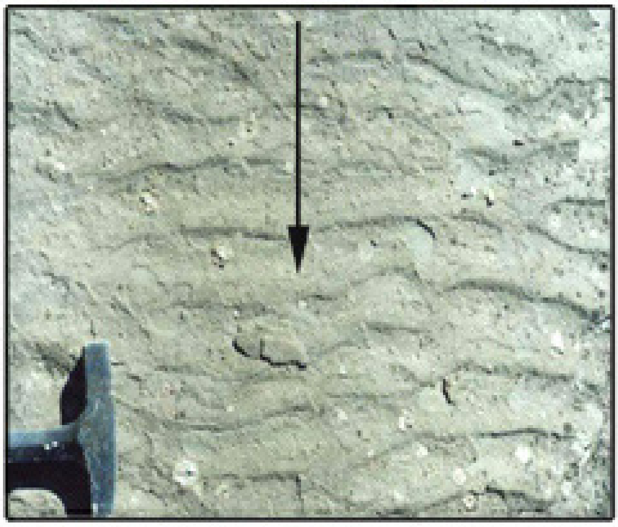
5-Water depth.

3.2.1- Cross bedding

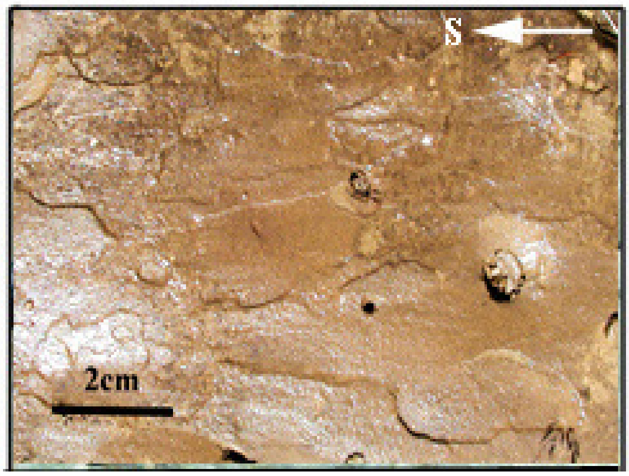
It was defined as arrangement of strata (more than 1cm thick) inclined at an angle to the main depostional bedding plane. According to Allen and Allen (1990, p.271), small scale cross bedding and cross laminations, are formed by the migration of ripple marks (wave ripple marks) and confined to less than 200 m depth. In the Red Bed Series and in unit three (sandstone unit) several beds are found contain medium and large scale trough cross bedding, these cross bedding are large scale and exist occasionally in thick and massive sandstone beds, which may indicate deposition in the delta environment (Photo 3.2Aand B). Ainsworth and Crowley (1994, p. 690) found cross beddings, which are formed in the upper shoreface as a part of the megaripples, they resemble to those of the Red Bed Series. Because of limited out crops and number of cross bedding one can not decide the exact environment of deposition, but when the flute and groove casts are in countered it is possible to be formed in delta front. According to Nichols (1999, p.206), trough cross beddings is normally absent in depth greater than 100m. In unit five (Chwarta conglomerate) one can find large scale cross bedding which are more than two meters long and thickness of each layer is more than 5cm. The layers contain imbricated pebbles and they consisted of orthoconglomerate. Therefore, they interpreted to be deposited in the braided streams as inter-channel bars (Photo 3.5A).

Photo(3.1)

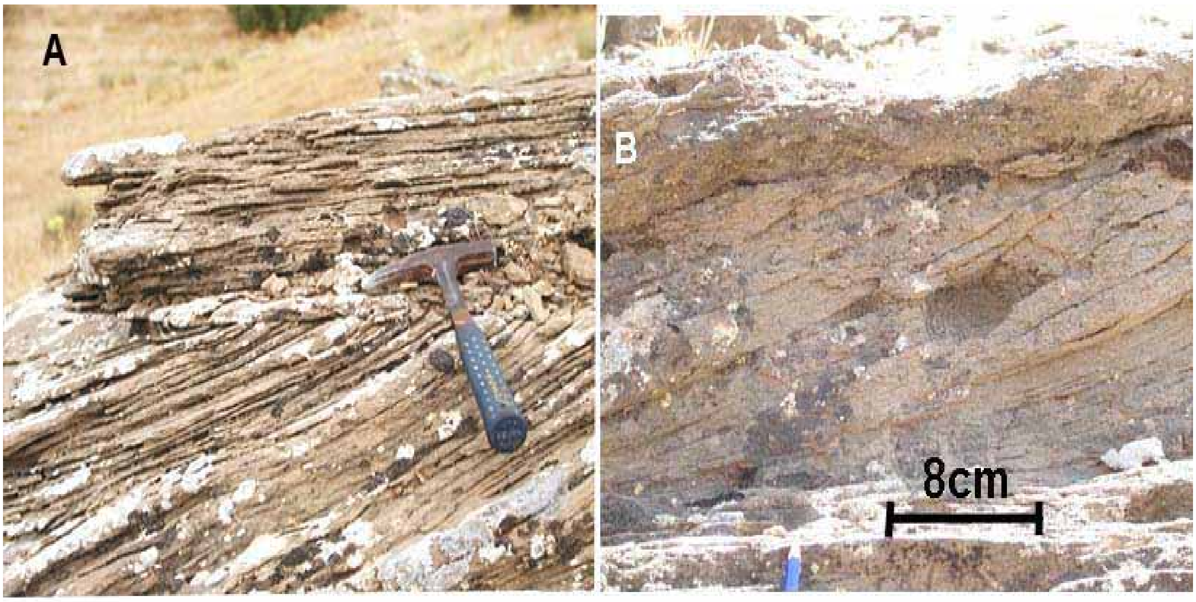
(1) Plant debris inside a sandstone bed of Lower part of Red Bed Series.
It is found in Chwarta area between Mokaba and Suraqalat villages.
They are probably deposited on the surface of a point bar during flooding.



(2) Small scale and sinuous asymmetrical ripple marks which found on the surface of a sandstone bed in the lower part of Red Bed Series in Chw arta area near Mokaba Village on the left side of main road between Mokaba and Mawat. The arrow indicats direction of flow.



(3)
Parting lineations on the surface of a sheet of laminated sandstone at west of Qalachualan bridge. They indicated S-N paleocurrent direction but when associated cross bedding is encountered, the paleocurrent is toward south.



Photo(3.2) A- Trough cross bedding at the east of Khewata village in the unit three. B- cross lamination at the northeast of Tagaran in the unit three.

Photo(3.3)large scale cross bedding in the unit five at south of Chwarta Town.

Cross bedding exists in several environments; they are more common in river point bars, tidal channels, deltas and shelf environment. In this connection Potter *et al*. (1980) included cross bedding in shallow shelf only, while Blatt *et al (*1980) mentioned that it occures in clastic-dominated shelves. The trough axis and maximum dip direction of foresets are directions of the paleocurrent flow. The paleocurrent direction inferred by these structures indicates a southwest direction.

Many Large-scale low-angle cross bedding has been found in U&nit Five (Chwarta conglomerate) (Photo3.3). They are most probably formed in braided bar or lateral accretionary point bar.

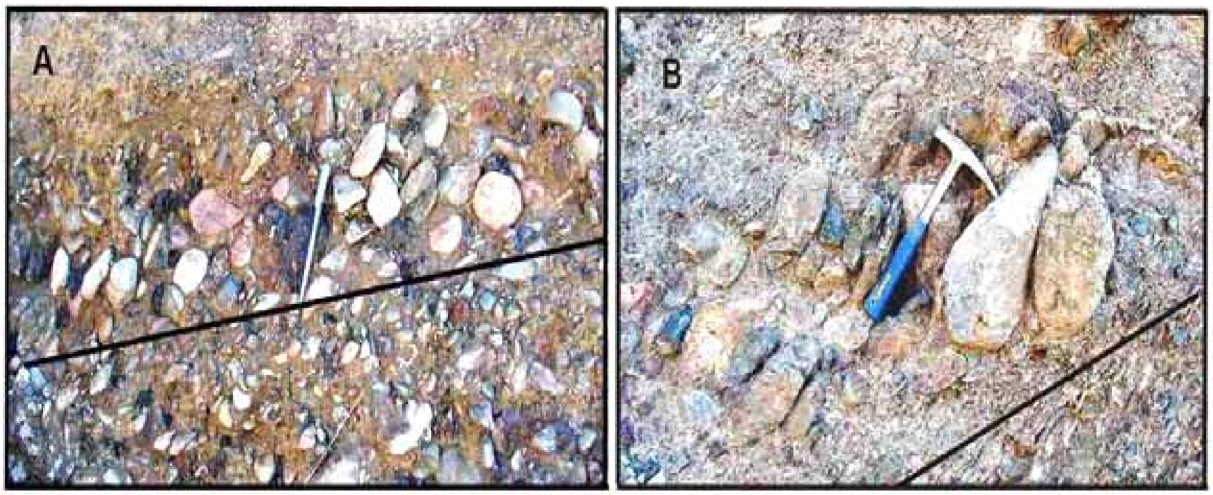
3.2.2-Pebble Imbrication

These structures can be defined as preferred orientation of disk-shaped or elongate fragments (pebbles) at an angle to the bedding. It is common on streambeds where flowing water tilts the pebbles under the effect of the upper flow regime near the bottom of the stream. Potter and Pettijohn, (1977) gave a detail review of the relationship between grain orientation and current direction. Most studies show that flat gravels conglomerate elongate parallel to the current direction on the channel floor and the clasts dip up-current direction.

The flat surfaces of these pebbles dip upstream. These structures are very common and well developed in the conglomerate of unit five of the Red Bed Series in Chwarta-Mawat and Qandil area (Photo 3.4 and 3.6A) while, they are less common in the conglomerate of unit two and other units. The paleocurrent displayed by these structures show a clear south and southwest direction.

3.2.3- Parting lineation (current lineation)

This structure is very common on the surface of the sandstone unit (unit three) in the Mawat-Chwarta and Qandil area. This unit contains abundant well-developed lamination.



Photo(3.4)A- Clear imbrication of some pebbles of Upper Conglomerate south of Chwarta Town. B- Imbrication of some pebbles west of Chwarta Town. Black lines indicate depositional bedding plane

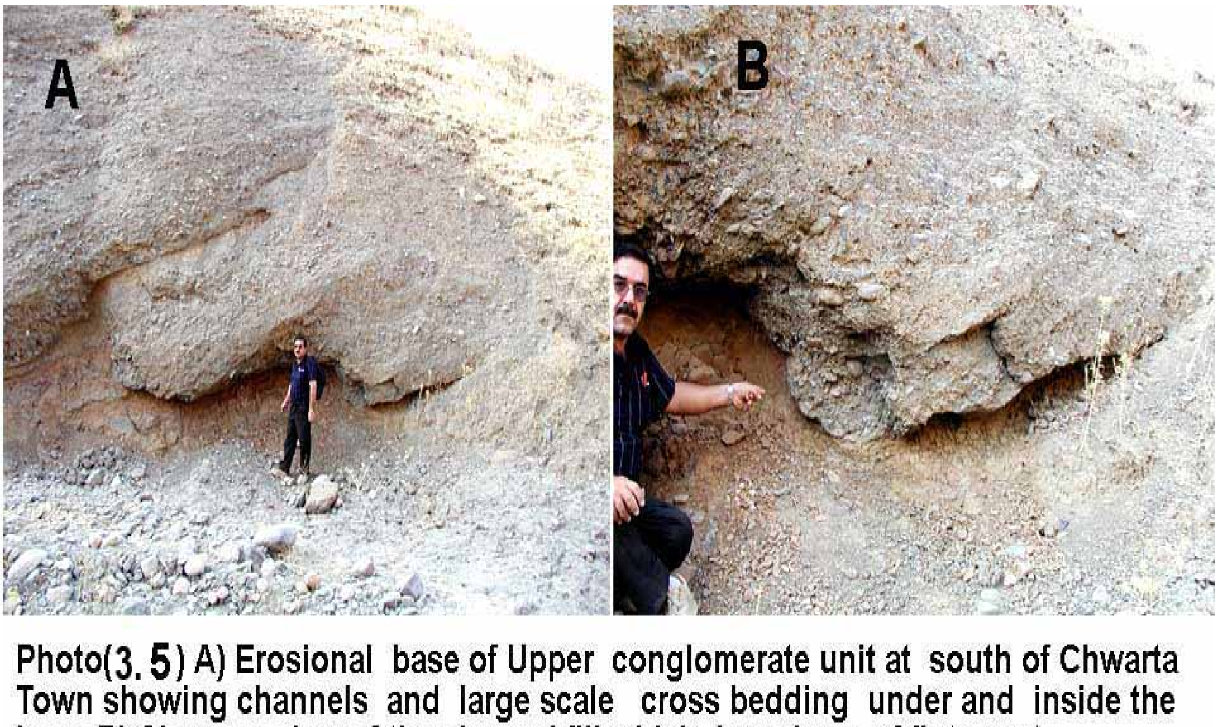
In weathered outcrop they appear like the stacked pages of the book (Photo 3.1.3 and 3.8.A). Allison et al (2003) found similar laminations in muddy sandstone on the surface of lower delta plain of late Holocene Gange-Brahmaputra of Bingladish. The lamination is present as internal structure of sandstone beds and they are parallel to the bounding surfaces. The laminations are developed by alternation of clean sand and clayey sand. According to Pettijohn (1975) they are formed by minor fluctuation in velocity of the depositing current.

On the upper surface of some of the laminae one can see clear parting lineation, which consists of parallel ridges and groves (low amplitude irregularities) of few millimeters wide and many centimeters long (Photo 3.1.3). According to Yagishita (1994) this structure is attributed to bottom flow. These structures are bidirectional (only indicate trend of current) in which the direction of current is parallel to parting lineation so the paleocurrent indicated by them is towards north-south trend but when incorporated with the result of cross bedding, the paleocurrent direction is towards the south and southwest. According to Pettijohn et al. (1987) this structure occurs in many environments.

3.2.4- Flute casts

Flute casts are predepositional sedimentary structures, they occur on the surface between beds which were formed before deposition of the overlying beds. They form in large scales when the source area is near the depositional environment. This kind of sedimentary structure will form in a facies which passes downward into the turbidite deposits on the channels floor (Selley, 1988).

Clear flute casts were found in unit three in Chwarta area at 100m west of Diralla village on the road between Chwarta and Mawat towns. This structure is associated with grove cast, striation casts and channels (Photo3.7.A). These structures are narrower, in plain view, at one end and widening out at the tapered end, which is scoured by eddy turbulent currents.



Photo(3. 5) A) Erosional base of Upper conglomerate unit at south of Chwarta Town showing channels and large scale cross bedding under and inside the bars. B) Close up view of the channel fill which has shape of flute cast.

In the Red Bed Series it was observed in their original position, on the base of gently dipping thick sandstone beds. The undersides (sole) of the beds are exposed because of removal of soft clay beneath them. The paleocurrent direction revealed by them is variable, towards the southwest and south. The long direction shows the trend of paleocurrent while the peaks (blunt end) of these structures point towards the up current direction.

The importace of these flute casts and associated tool marks is that they are found in what is called molasse facies. Previously it was mentioned to be characteristic of flysch deposits (Pettijohn, 1975, Blatt et al., 1980). But Pettijohn et al. (1987, p.326) cited that they exist in all environments except eolianites. Shanmugan (2002) Mentioned that flute casts are not necessarily indicative of turbidite deposition but in reality they indicate only flow erosion, not deposition.

In addition to those, which exist in unit three, unit five (Chwarta conglomerate) contains large flute casts (hole cast) at the base of the braid bars and conglomerate lenses (photo 3.5B). According to Bloom (1998) these casts represent the holes scored when two braid channels meet (Fig.3.1). At the point of meeting (confluent) the velocity and erosion increase which form flute cast – like a hole. The large flute casts in unit five, indicate the south direction of paleocurrent. This south direction also ascertained by measuring plunge direction of imbricated pebbles in the same conglomerate (Photo 3.3) and (Fig.3.3).

3.2.5- Plant remains (debris or fragments)

These remains were found on the surface or inside the medium bedded sandstone of the unit three in both laminated and massive sandstone. They appear as light carbonized brown pieces (Photo3.1.1). These remains are found near Tagaran village at south of Chwarta town and near Suraqalat village at the east of Mawat.

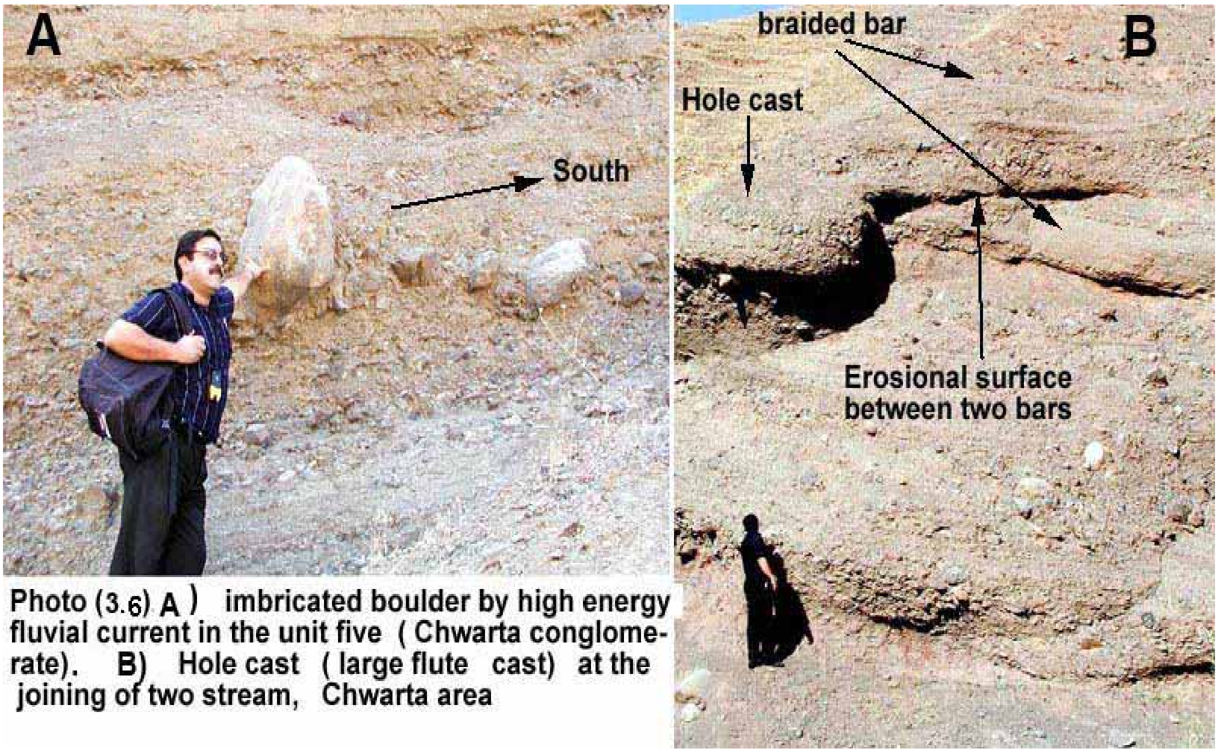


Photo (3.6) A) imbricated boulder by high energy fluvial current in the unit five (Chwarta conglomerate). B) Hole cast (large flute cast) at the joining of two stream, Chwarta area

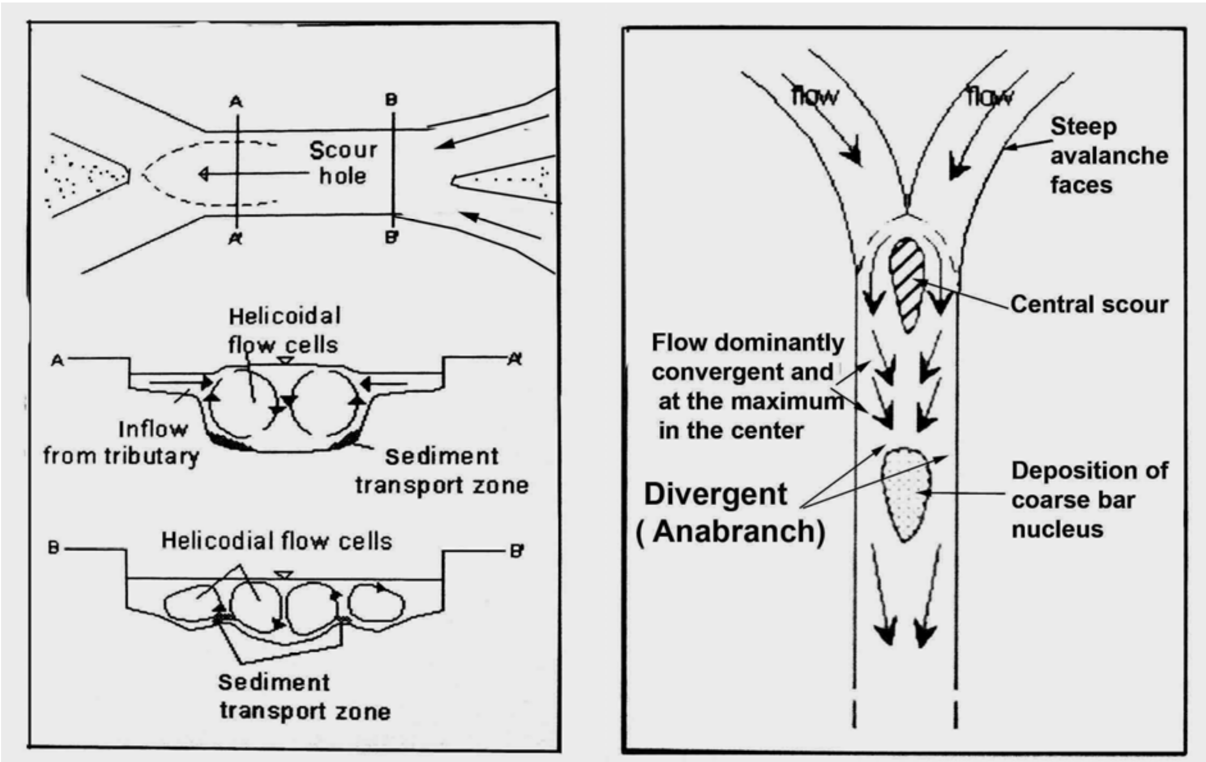


Fig.(3.1) Process of convergent and divergent of two braches of braided streams forming braided bar and scour hole in the unit five. See above photos (3.6). Modified from :www.geog.nottingham.ac.uk.

Another possibility for the presence of plant debris is that, which is mentioned by Einsele (1990 and 2000) where supratidal seaweeds and other plants might be eroded by storm and then deposited, forming tempestite in the beach. Ainsworth and Crowley (1994, p.683) mentioned that concentration of plant debris suggests proximity to the shore. Smith and Jacobi (2001, p.336 and p.338) have found carbonized remains and wood fragments in low stand sand in the Canadaway Group from New York State. Potter and Pettijohn (1977, p.374) mentioned that plant fragment indicates only line movement of the paleocurrent. As plant remains are relatively rare in the Red Bed Series so they are not much useful for paleocurrent indication. However they show north-south trend of paleocurrent.

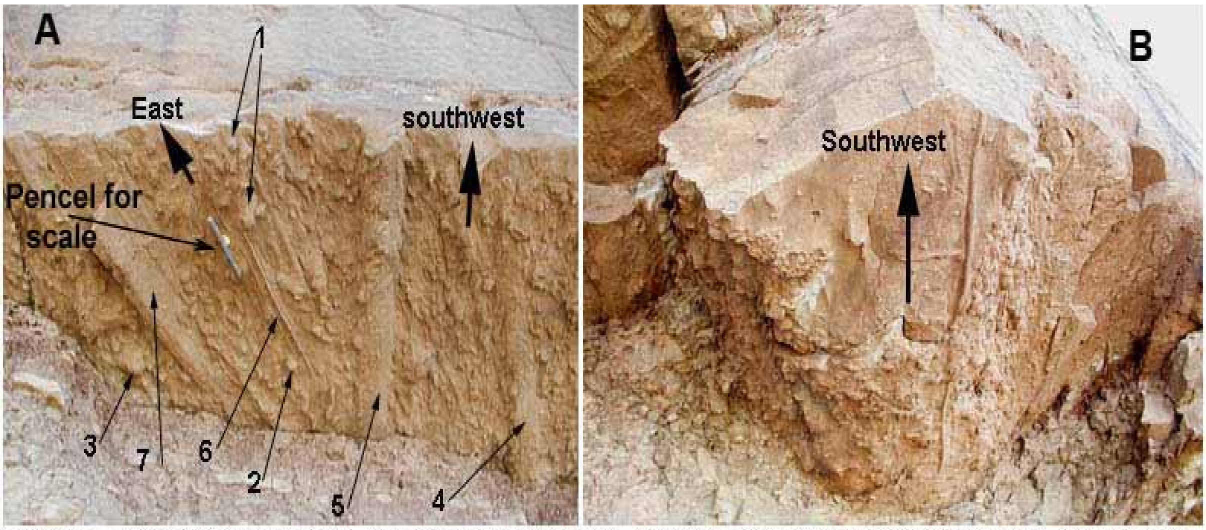


Photo (3.7)A: Flute cast(1,2,3) , small and large drage grove casts (4,5)and striation cast(6,7), B: small channel eroded in the red claystone showing drage grove cast. Both photo is related to the undeside (at the base) of thick sandstone bed of unit three at chwarta area, 100 at the west of Diralla village. The paleocurrent is toward east and southwest as indicated by black arrows.

3.2.6- Ripple Marks

Both linguidal and interference ripple marks (Photo 3.1.2) are abundant in Unit Three (sandstone unit) in Chwarta area especially at south and west of Chwarta Town. While the traverse ripple marks was found in the same unit and at the areas between Khewata and Mawat area. The peaks of the former ripples are mainly pointing towards the south.

The latter ripples consist of numerous long parallel crests. These ridges are more or less equidistant and trending in straight or gently curved lines at right angle to the current by which they were formed. Potter and Pettijohn (1977), and Tucker, (1991) found similar types of the ripple marks in near shore and lacustrine environments. The latter author attributed these ripples to the wave movement.

3.2.7- Truncation of layers

Truncation of sedimentary beds by erosion is common in all units of the Red Bed Series, which may be called cut-and- fill sedimentary structures. This is due to the shallow environment of the series, which contain several types of bed forms such as small and large scale cross beds, dune and antitune and bars in the meandering stream and braided streams. The turbulent flow of streams and currents can erode the preexisting layers. This erosion can be seen as sharp contact between different lithologies and resting of two beds in angular relation over each other (Photo 3.8). The truncations are more obvious in unit two, three and five (Photo 3.5B and 3.8) which are deposited inside scored valleys during low stand system tracts in coastal areas. The paleocurrent direction can be deduced from these structure which shows southwest direction (Photo 3.9).

3.3- Paleocurrent analysis

According to Mial (1990), paleocurrent analysis can provide information about four main aspects of basin development:

1-The direction of the local or regional paleoslope, which reflects tectonic subsidence patterns.

2-The direction of sediment supply to the basin.

3-The geometry and trend of lithologic units

4-The depositional environment

Photo(3. 8), A- Laminated sanstone (papary sandstone) at the northeast of Tagaran village. B- Gastropod body fossil at the base of Red Bed Series, it found at the top of a 3m thick conglomerate bed between the series and Tanjero Formation. It slightly weared during transporting and indicates southeast paleocurrent direction, Qandil mountain toe.

The paleocurrent direction of the Red Bed Series is very clear in the field when one observes imbricate pebbles, cross bedding, flute cast and channels. These structures show southwest and south direction of paleocurrent (Fig.3.3). Many of these structures are shown by photos in their original position. In these photos the directions of paleocurrents are indicated by arrows. In spite of these, some data area recorded in the field to be represented as graphical mean of paleocurrent. For the plotting data of the unidirectional sedimentary structures, the Windows based RockWare program is used as follows:

1- The original attitude of the structures (dip and direction angle of imbricate pebbles and cross bedding are recorded in the field by using the compass.

2- The effect of tectonic tilt is corrected, by using stereonet where the tilt is more than 30 degrees. Potter and Pettijohn (1977, p.374) Tucker (1988, p.41) gave this limit for tilt correction and they mentioned that tilt, below 30 degrees needs no correction. The strata of the Red Bed Series, in all localities of the studied area have a dip amount less than 30 degrees such as at the lowland of Chwarta –Mawat and Qandil mountain areas.

Table (3.1) Compass reading of azimuth of elongate axis of imbricate pebbles at ,
A: Qandil Mountain, east of Brade Village. B: West of Khewata Village.
C: South of Chwarta town

A	B	C
191	171	90
195	186	180
189	225	252
200	257	148
211	175	221
187	235	232
195	255	184
199	197	171
230	193	180
215	198	31
242	189	170
189	142	251
266	270	247
190	135	214
182	128	165
180	190	199
241	183	197
188	174	155
120	175	177
122	230	260
254	212	224
158	144	220
250	157	215
232	155	112
170	242	154
193	240	181
250	186	223
184	175	223
230	194	210
143	222	230
176	200	325
	220	150

3-The attitude of imbricated pebbles and cross bedding are plotted on the Schmidt stereonet by carefully treating the data and their arrangement because they must be formatted either according to *Dip Direction* or according to *Right Hand Rule*. In the present study, the compass readings are arranged (or converted) to the Right Hand Rule Format for drawing the stereonet diagrams. Flute casts has fewer occurrences than imbricate pebbles. So they are used in the field to support and confirm the direction shown on the stereonet. Cross bedding and laminations have more dispersed direction but the more obvious ones give south-southwest direction.

4- Ripple marks, elongate pebbles, elongate body fossils (Photo 3.8.B) were found in unit three (sandstone unit) and unit five and their azimuths are plotted on the rose diagram using Rose files of RockWare program. The option of "full rose" and "bi-directional" were given to the program when the bi-directional sedimentary structures are entered while for unidirectional ones "

half rose" and "unidirectional" option is activated (Fig.3.2 and 3.4, tables 3.1 and 3.2).

When one observes the result of the present study and that of Tanjero Formation achieved by Karim and Surdashy (2005), he realize that the paleocurrent was relatively stable for long time. This time includes the interval from Campanian to, at least, Eocene. This direction was towards south-southwest.

Table (3.2) Compass reading of azimuthal plunge direction (Left column) and angle of Plunge (right column) of imbricated pebbles of conglomerate at , A) northeast of Qalla Chualan town in unit five . B) Southwest of Mawat town. C) North of Kometan Village.

A		B		C	
Direction	angle Plunge	Direction	angle Plunge	Direction	angle Plunge
		300	31	320	36
		346	46	357	31
		322	38	355	36
		55	34	350	50
330	37	309	28	60	31
336	32	333	30	353	27
336	34	349	50	357	49
355	22	60	23	43	20
360	44	49	36	351	41
345	37	342	26	70	35
355	40	335	29	357	43
358	32	345	43	69	33
45	35	55	36	40	12
50	22	30	39	51	35
3	45	40	35	70	42
22	37	358	36	10	26
330	41	43	23	350	43
360	23	36	43	36	43
22	30	341	51	357	47
36	39	344	24	33	10
54	41	5	35	62	31
333	52	27	36	43	44
324	40	337	31	341	22
12	52	360	24	15	35
9	26	19	37	36	49
322	50	41	30	355	39
346	50	355	32	22	38
3	33	356	47	300	34
22	30	56	23	74	44
6	42	47	44	350	22
13	32	307	42	357	37
358	35	345	33	23	27
355	38	347	38	2	50
304	19	21	45	34	50
33	43	34	42	351	54
332	25	358	38	15	31
308	28	345	12	332	43
30	36	34	37	54	39
		324	50	319	33
		347	22	22	34
		30	43	352	40
		10	47	100	37
		22	31	43	45
		48	21	34	27
		50	37	70	38
		33	35	60	25
		308	25	348	41

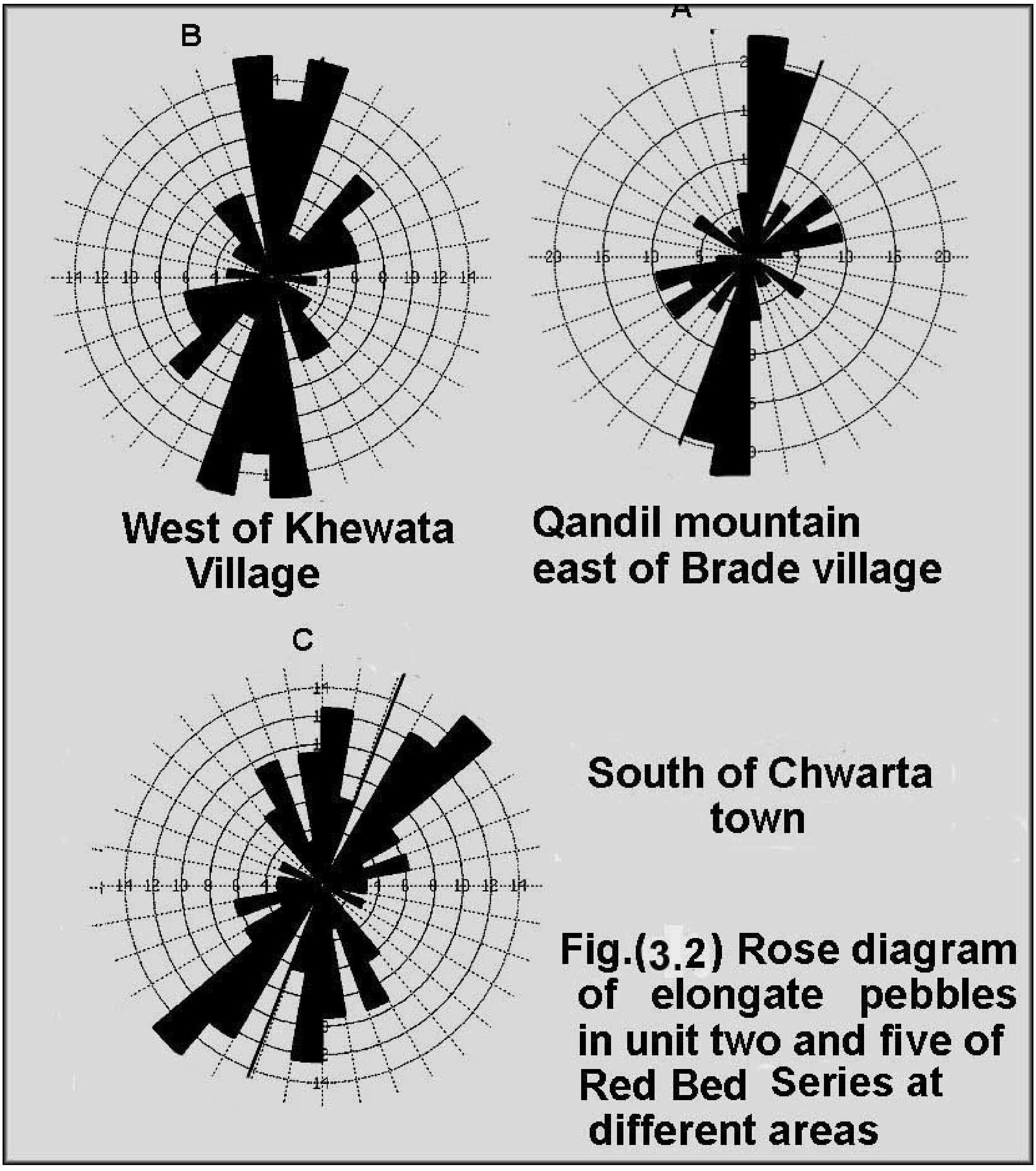
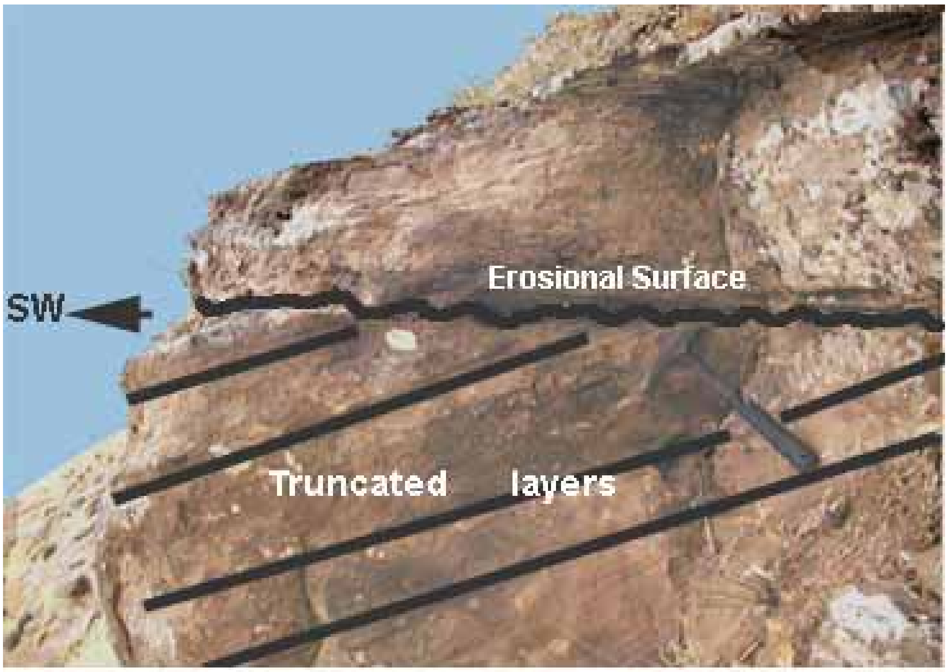


Fig.(3.2) Rose diagram of elongate pebbles in unit two and five of Red Bed Series at different areas



Photo(3.9)Truncation of sandstone layers by erosion, possiblly inside channels, unit thrtee west of Qala Chuallan bridge, Chwarta area.

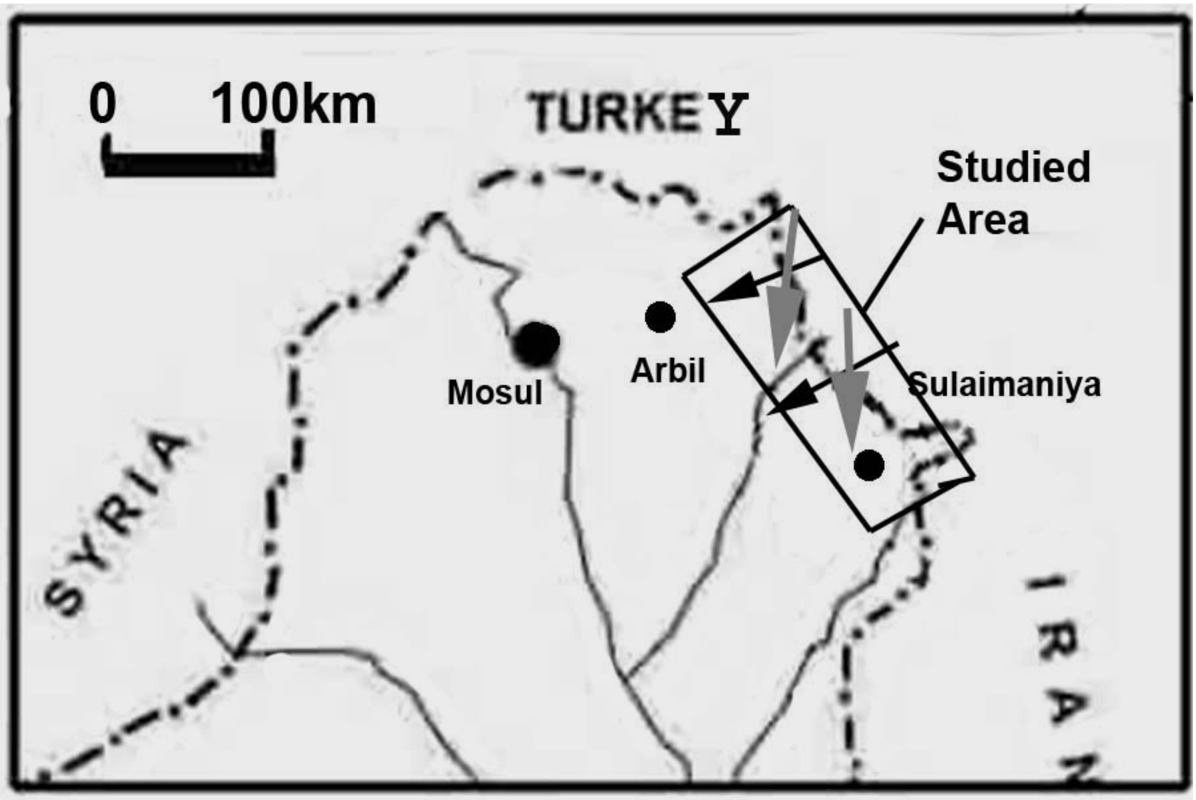


Fig.(3.3) Paleocurrent of Red Bed Series during depostion of units 1,2,3,4, and 6 (black arrows) while that of unit 5 indicated by grey arrows.

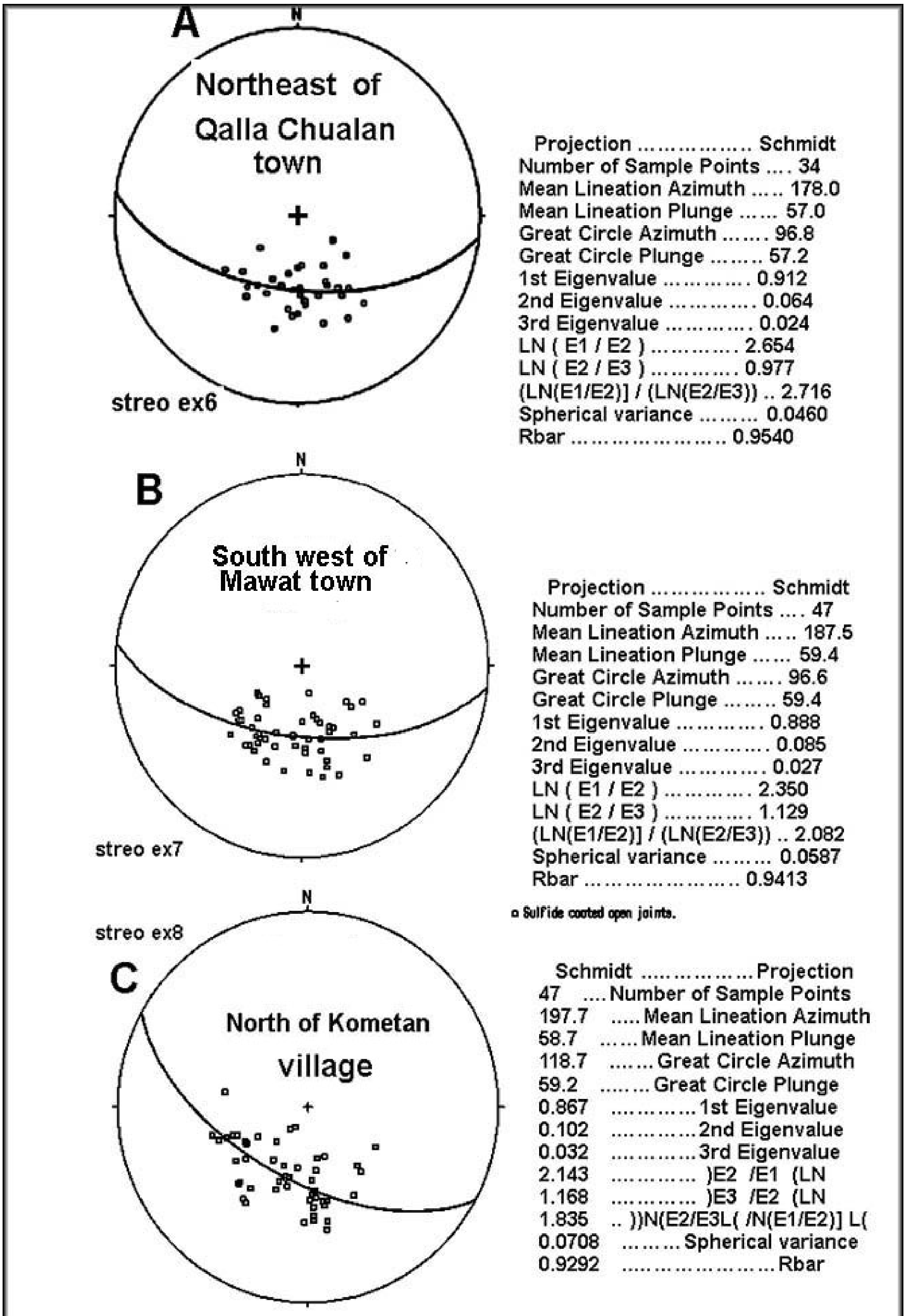


Fig. (3.4)Streonet projection of imbricated pebbles of unit five of Red Bed Series at diffrent areas as indicated on the diagrams

CHAPTER FOUR

LITHOFACIES AND DEPOSITIONAL ENVIRONMENTS

4.1-Preface

The environment of the Red Bed Series was swinging during the total time span of Paleocene and Eocene in response to the eustatic sea level changes, tectonic subsidence, uplift, and sediment fill in addition to the possibility of the effect of climate. Accordingly, in the basin, the environment was changing both in time and space mainly as a result of relative sea level changes. The variations of environment are demonstrated by lateral and vertical lithological changes, so that the shoreline was shifting continuously, especially during TST and LST. The depostional environments were mainly continental, ranging from proximal alluvial fan to fan delta environment. During Paleocene these environments were located in the coastal area of the deep marine basin in which the Kolosh Formation was deposited (Fig.4.8). During Eocene the deep environment of the Kolosh Formation is changed to shallow one either by sediment fill or by uplift of the area of coverage.

In the position of Kolosh Formation, shallow environment Sinjar Formation and continental Gercus Formation are deposited while their counter part (Red Bed Series) was continued in deposition in more contrasted environments ranged between alluvial fan to marine coastal area. During Paleocene the coastal area was located in the Imbricated Zone (as now a days called), Buday, 1973 in Omari and Sadiq, 1977, while the deep basin (Kolosh Formation) was located at the present high folded zone which were located to the north - northeast and were changed to continental one. During Eocene this continental areas extends from Imbricated Zone to the boundary between Low and High Folded Zone.

4.2-Lithofacies of the Red Bed Series

As the environment was highly variable (lateral changes) many different lithofacies were deposited. Seven major lithofacies were recognized in the studied area, they are as the following:

4.2.1- Grain-supported Boulder Conglomerate Lithofacies(A)

This lithofacies makes up both unit five (Chwarta conglomerate) and unit two. This facies mainly consisting of gravel, boulder and block conglomerate. It has gray or red color and the matrix consists of medium or nearly coarse sand. It is characterized by pebble orientation (imbrication) and large-scale cross bedding**.** The texture is mainly clast supported with the presence of minor amount of matrix–supported conglomerates. According to Einsele (2000) the clast supported conglomerate were deposited in river channel as bedload deposits in steep gradient alluvial fan or fan delta while Shao *et al.* (2003) attributed the matrix-supported conglomerate to the debris–flow deposit. Conglomerate deposited by debris flow is rare in Red Bed Series, it may exist in Units One and Four as a small lenses. Pettijohn (1975) and Selley (1988) named the former and the latter conglomerates as orthoconglomerate and paraconglomerate respectively.

It is obvious from the size of clasts, thickness, amalgamated form (no stratification), large scale cross bedding and erosional hole, that it was deposited in a braided stream with high discharge feeding alluvial fan. Then alluvial fan reaches the see water of Paleocene- Eocene basin and forming a fan delta (or lowstand fan delta). The alluvial fan was deposited in wide incised valleys during a major sea level fall (lowstand system tract). The successive channel lag deposits are so closely stacked that there are no intervening sandstone and claystone deposits. The matrix of these conglomerates is composed of coarse and medium sand. The deposition of sand with gravel is described by Rust and Koster (1984, p.54), they attributed the grains-supported gravel to the deposition from bedload sediments by energetic aquaeous flow. They added that the sand remains in suspension (which transported to deeper water), but when the flow velocity decrease the sand infiltrates into the space between the frameworks of the particles. This is possible to occure in alluvial fan and marine environment. Einsele (2000, p.41) mentioned that interstices of gravels are later filled with sand during low water period.

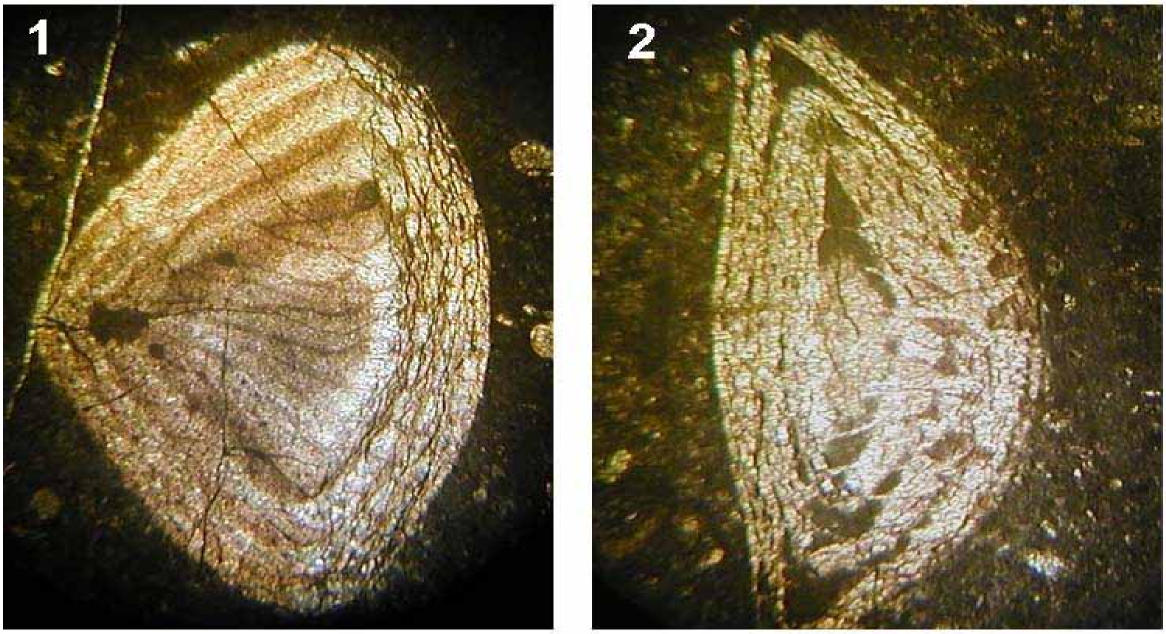


Photo (4.1) Two species of nummulite which are found in the Chwarta conglomerate(unit Five) at north of Chwatra town . They are most probably belong to Walash- Naoperdan Series.

The coarsest sediments (block and boulder) represent channel lag deposits while the rare sandstone were deposited as longitudinal bar and sieve sediments (Fig.4.1). Some clasts have the size of blocks and weighted more than 200kg. From these, it is evident that the source area was a recently elevated terrain in that time and most probably deposited in fault-bounded alluvial fan with rapidly subsiding area of deposition. This lithofacies is characteristic of unit two and five; more detail is given about lithology and geographic distribution (in chapter two). In unit five (Chwarta conglomerate), this facies has aggradation stacking pattern with a thickness of 200-1000m while that of unit two has the thickness of less than 15meters.

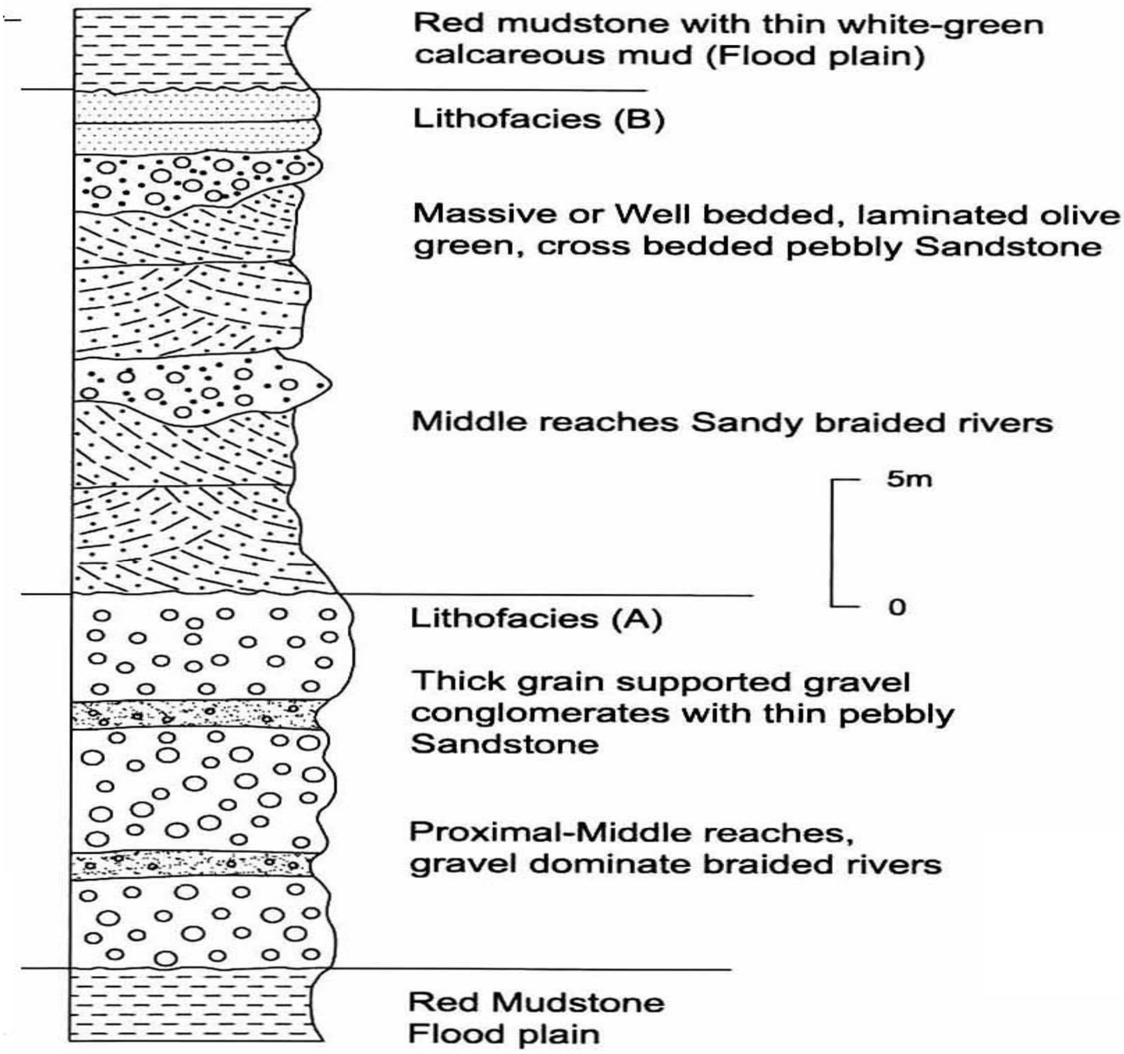
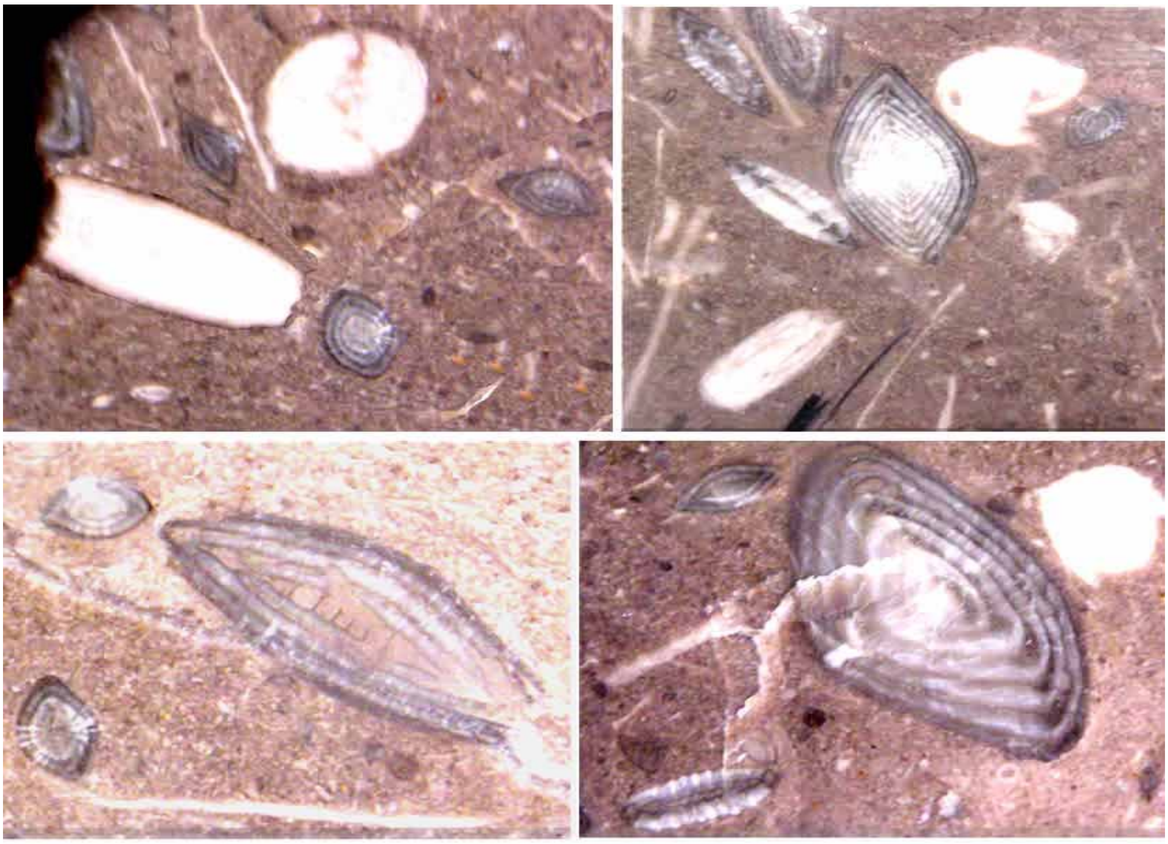


Fig.(4.1) Part of the section at Khewata showing lithofacies (A) and (B)

4.2.2- Massive (or well bedded) cross bedded pebbly sandstone Lithofacies (B)

This facies exist in units three and four. It also exists rarely at the base of unit one in Khewata section. It may represent the middle reach bar or point bar of braided rivers (Fig.4.1). This facies is more clear in unit two at the Qandil mountain toe near the Kometan Village. At this locality, it is associated with facies C and A.



Photo(4.2) Nummulite (Grey) and alveolina of several species which are found in boulders of Unit five (Chwarta conglomrate) of Red Bed Series. They all belong to Eocene and most possibly derived from Naoperdan Series. Normal light , 5X.

4.2.3-Matrix-supported Conglomerate Lenses Lithofacies (C)

This facies exists as lenses inside red claystones. When one observes this facies across certain traverse it alternates with red claystone or sandstone. But when it is seen from considerable distance, it appears as a multistory pattern (Fig.4.2). The distance between one story and the other ranges between one to five meters. The conglomerate is mainly matrix -supported and has lighter color than the surrounding claystone. In some cases the color of conglomerate lenses are gray as could be seen in the area between Chwarta and Mawat Towns. In rare cases, with this lithofacies and associated red claystone, one

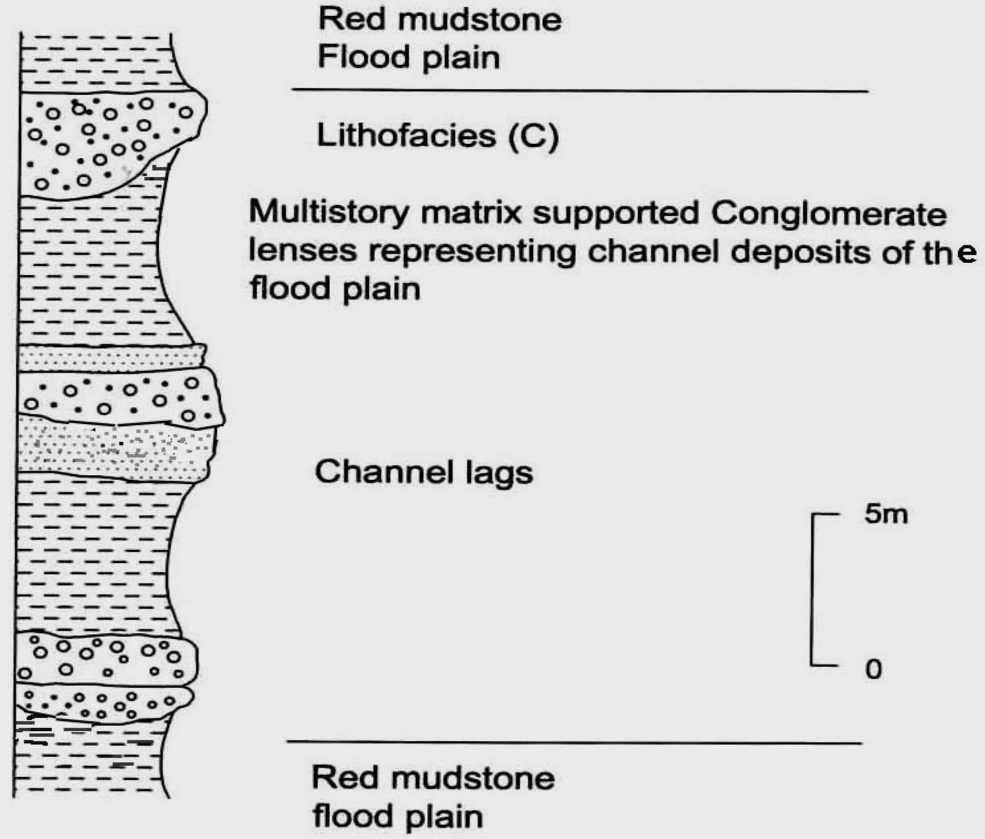


Fig. (4.2) Part of the section at Khewata showing Lithofacies (C)

can find thin beds of white carbonate laterally disappear at the distance of 50 meters at the west of Sura Qalat and in thin section it is appeared as clayey limestone and show motling.

The environment of this facies with the surrounding terrigenous claystone belongs to deposits of meandering river, which controlled by structure. The conglomerate represents the channel lag deposits while the red claystone belongs to flood plain deposits. The sandstone is deposited from crevasse splay or low energy point bars. As a result of vertical aggradation and lateral migration, the conglomerate appears as multistory building in vertical outcrop section.

4.2.4- Laminated, Cross-Bedded Sandstone Lithofacies (D)

This facies exists only in unit three of the present division (unit two of the previous divisions). It locally consists of thick bedded grey sandstone locally laminated and cross bedded with claystone and siltstone (Photo3.2A and B). It has coarse-grained texture and may be pebbly at the base of the beds. This facies is thicker and coarser in the Qandil mountain area, where it contains lenses of conglomerate.

The lamination in this facies is so developed that they resemble the pages of an open book; therefore it is called papery sandstone (3.8A). On the surface of the sandstone sheets, one can see parting lineation (photo3.1.3). According to Selley (1988, p.93), laminated sandstone is usually formed by the upper flow regime (laminar flow). He added that, it occurs in diverse sedimentary environments ranging from fluvial channels to beaches and delta fronts. Another characteristic feature of this facies is the erossive base, which is associated with striation, drag cast (groove cast), flute cast and small channel (Phot3.7). In rare cases, the sandstone is gravely at the base. The environment of this facies is probably of fluvial environment of sand-dominated distal braided river.

According to Mial (1985), this type of river is located at the distal area of alluvial fan, which characterized by wide channel and linguoid sand bar. The claystone that associated with this facies is attributed, in this study, to over bank fine distal braided plain and delta front environment (Fig.4.3). Einsele (2000) mentioned that low gradient; low relief channels and bars characterize this type of rivers. He added that the main sediment types are massive, laminated and cross-laminated sandy silt.

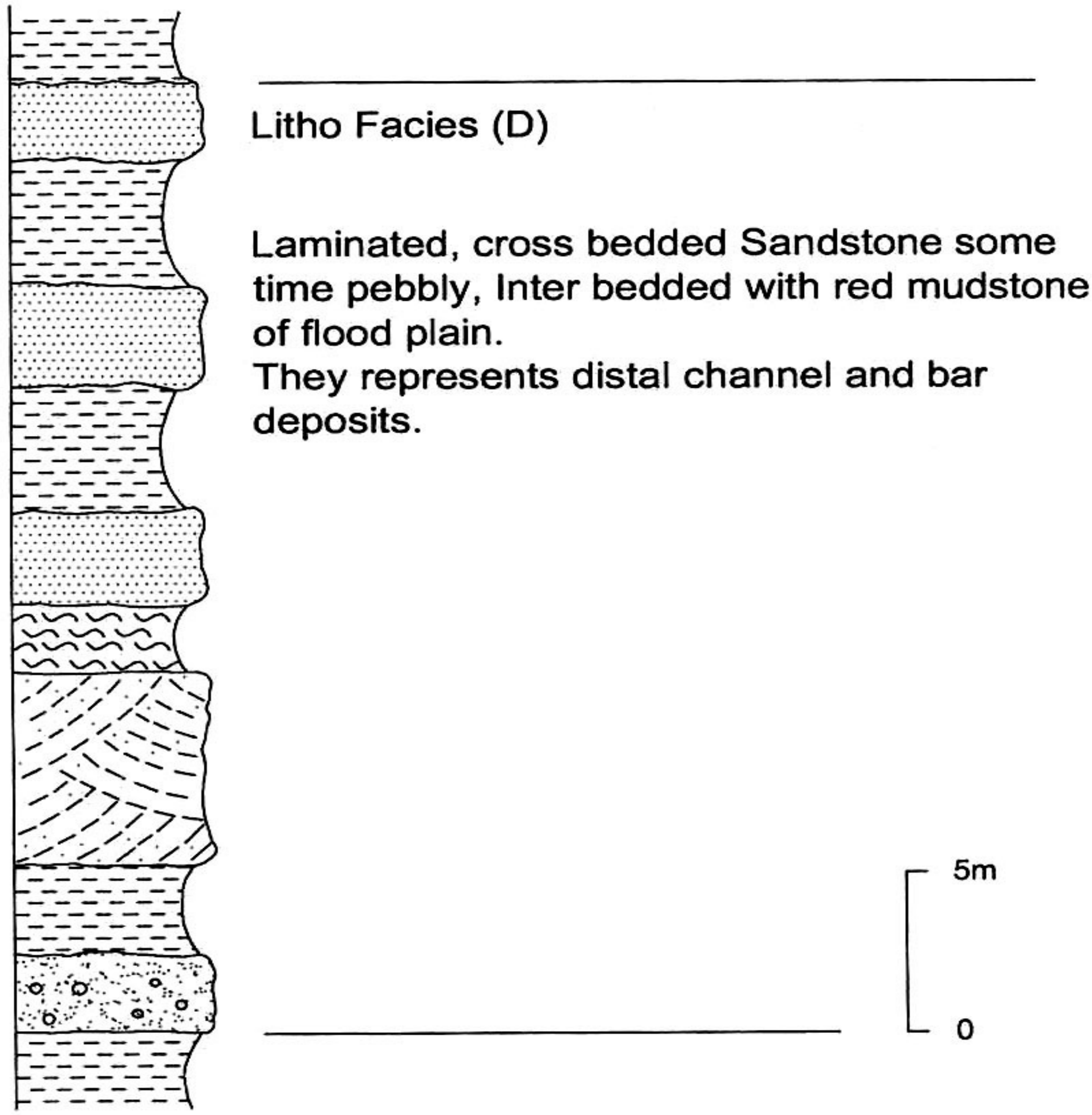


Fig. (4.3): **Part of the section at shahedan showing the succession of lithofacies (D).**

This type of environment can be applied to Units One and Three in the Chwarta-Mawat, which are mainly, consist of sandstone, red claystone and silt stone. The continuity of the sandstone beds to several kilometers attributed to lateral migration with little contemporaneous subsidence during deposition of this facies (Fig.4.4)

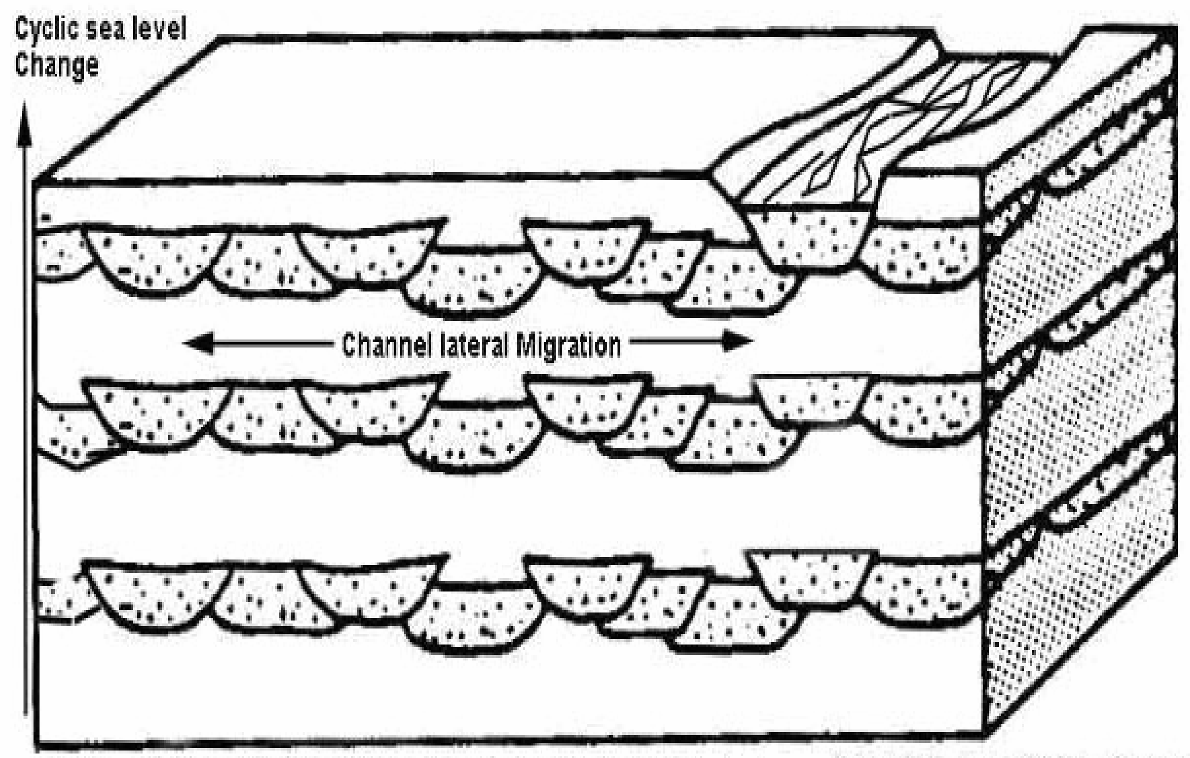


Fig.(4.4)Block diagram showing depostion of unit three (sandstone unit) by channel fill and lateral channel migration with relatively little subsidence .

4.2.5-Red-brown Mudstone Lithofacies (E)

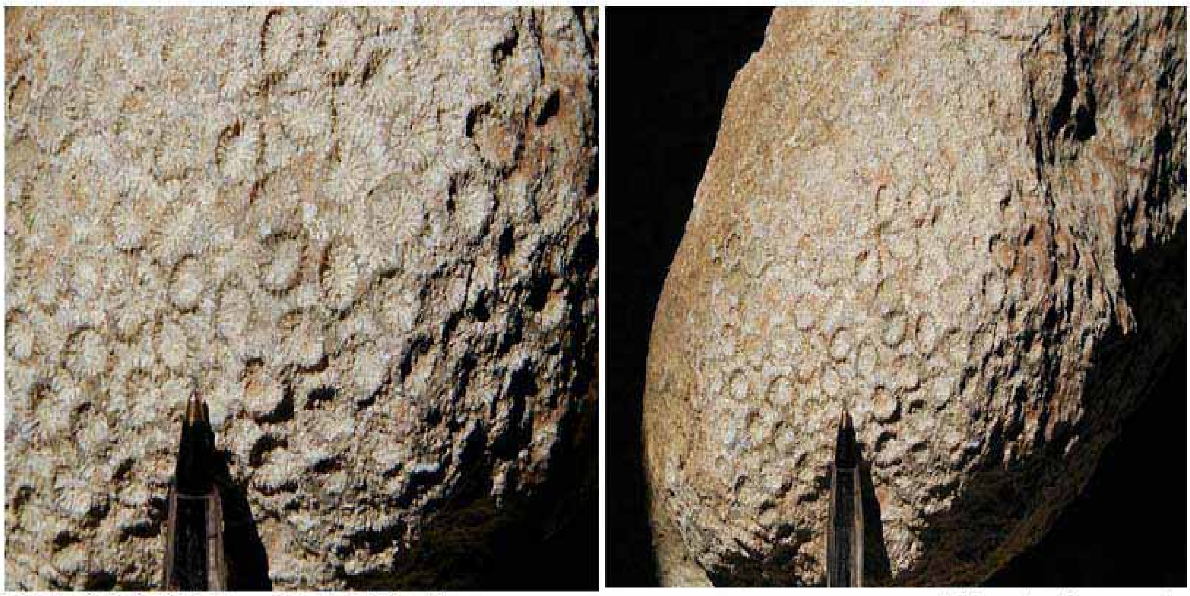
This facies consists of massive or thick beds red or brown claystone and siltstone with sandstones and rare lenses of conglomerates. It is occasionally laminated and is the most common lithology of units One and Six. It also exists in other units, except Units Five and Two, in more or less proportion.

This facies has different depositional environment. In unit one, it is most probable, that this facies is deposited on the floodplain of the meandering and braided rivers (Fig.4.5), while in units such as, Three and Six; they may belongs to the delta front and delta plain deposits at the distal area of the alluvial fan where the fan reaching the marine water. On other side this facies may represent the transition from alluvial fan to marine deposit of the Kolosh Formation. In this connection, Mial (1992, p.138), recorded such type of

transition and called it “interfingering of alluvial succession with marine deposits”. He added that in some basins, the wedge of fluvial sediments, up to hundred meters thick, are interbedded with marine shoreface deposits.
In this study, the exact position of interbedding of alluvial and shelf deposits is located at the present position of Azmir, Goizha, Sara anticlines, but unfortunately the sediment of these areas were removed by erosion.

4.2.6-Thin-bedded carbonate lithofacies (F)

This lithofacies exist inside Unit One which consists of several thin beds of carbonate materials inside red claystone and sandstone. Under polarizer it appears as fine-grained and clayey limestone (crystalline argillaceous). They can be seen for only a distance of 400m and laterally change to red claystone. They exist in Chwarta-Mawat, and Qandil area (Photo 2.9B). It is probable that this facies is deposited either in oxbow lakes or in the lakes on the delta plains.



Photo(4.1a) Colony of coral in the base of the unit six ,cropped out at 3km to the west of Chwarta Town which proves gradtion of alluvial (fan delta) environment to shelf one. The related bed found by joined group of geologists from Geological survey of Baghdad and Sulaimanyia.

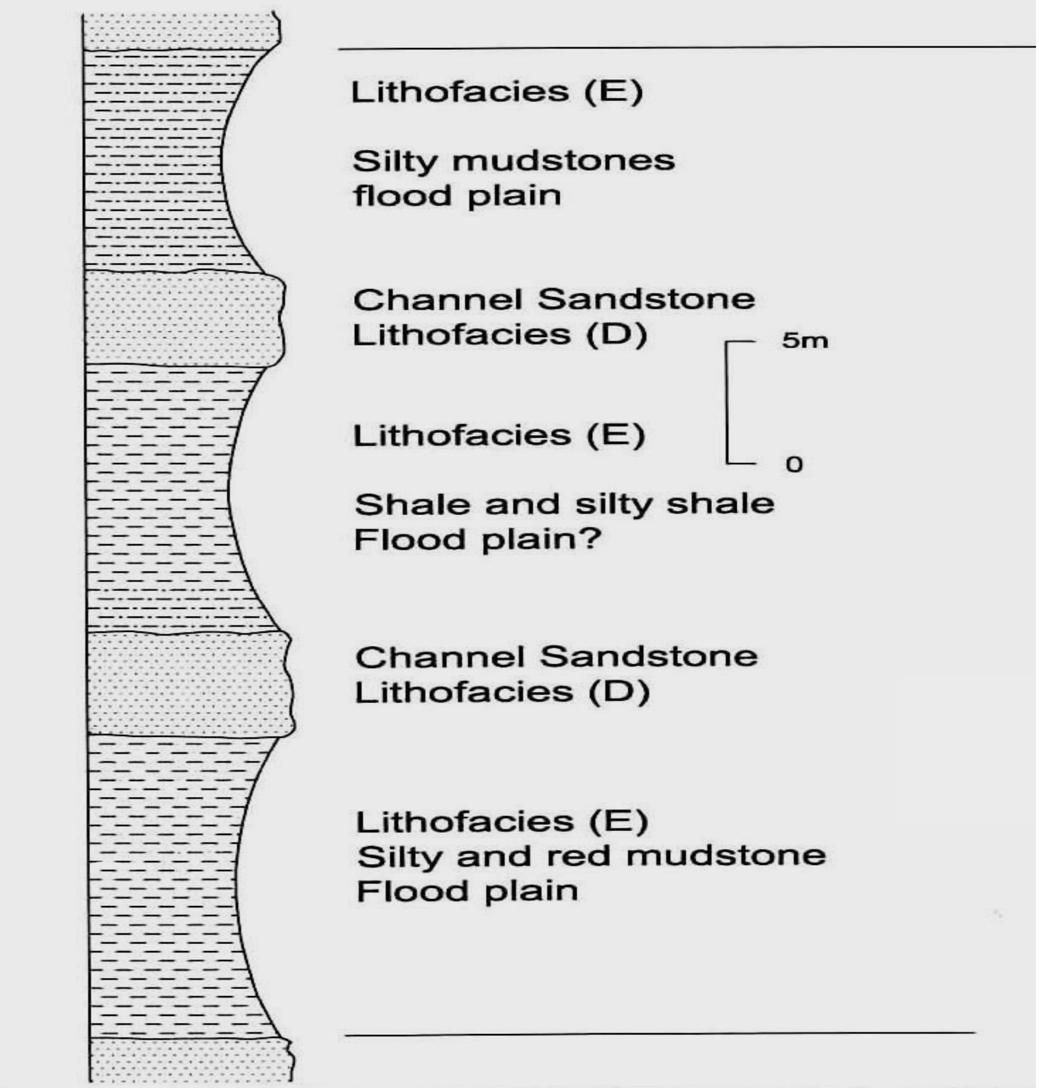


Fig. (4.5): Part of the section at Khewata showing lithofacies (D) and (E).

4.2.7- Fossiliferous Carbonate Lithofacies (G)

This lithofacies is very unusual in the Red Bed Series as it contain clear coral colony (Photo4.3), large gastropods and oysters. It is originally found by a team of geologist from Directorate of Geological Survey of Baghdad and Sulaimanyia at the 3km west of Chwarta town at the base of Unit Six. The coral colonies exists as separate blocks (patches) in the most highly deformed bioclastic and fossiliferous background limestone materials. This is returned to competent coral colonies blocks as compared to incompetent background limestone. This facies is also associated with bioclastic limestones and underlain by green marl. In other sections, this facies is not found. The existence of this facies, as indicator of marine environment, may be due to the formation of in land bay in Chwarta area, where shallow marine conditions existed. This bay may represent the extension of a valley land ward in North-South trend where corals grown on its hard base (fluvial deposits of previous incised valley).

Karim (2004) found the same growth of the corals on the conglomerate of the incised valley within the Tanjero Formation.

4.3- Depositional Model and Climate

It can be inferred from the above discussed facies and sedimentary structures that the best depostional model for the Red Bed Series is alluvial environment model in arid climate. According to Pettijohn et al. (1987) this environment is subdivided into fan, alluvial plain and delta. He added that sand is the component of all three but, in the fan, it may be subordinate as compared to coarser debris and to fine silts and clays in the delta. Bloom (1998, p.247) mentioned that alluvial fan and delta are two depostional landforms that form from abrupt loss of competences in the stream. He added that delta are mostly subaqueous form while the alluvial fan are subaerial forms deposited when stream channel loss water by infiltration, decrease its gradient, or widen abruptly. Moreover, he confirmed that both alluvial fan and delta may merge (join) and many deltas may cap by low gradient alluvial fan.

Field study and facies analysis showed that the above facts about alluvial fans and delta are applied for the Red Bed Series. This is because more evidence of sedimentogy and lateral facies changes exists which proved that Units One and Six are deposited in delta depostional environment and Units Two and Five deposited in alluvial fan environment while Units Three and Four deposited in braided delta environment, where the base level of the river too much lowered by the uplift of the source area and the alluvial fan prograde seaward and combined with sea water, in this case it is called lowstand fan delta, which formed during seal level fall and associated with valley incision.

This type of environment prevailed during deposition of Units Two and Five. The environments are bordered from north and northeast by thrust fault on which the overthrusted sheets of Iranian plate advanced towards the southwest (Fig.6.6 and 6.7).

The fluctuation of sea level fall caused rise and fall of the existed base level of rivers. In response to this the process is changed from erosion to deposition and grain sized also changed from boulder to sand and clays in different environment. The change of environment was occurred in repeated cyclic manner, which is manifested by coarsening upward stacking of sediments. The lithology of all cycles of eustatic sea level change and tectonic phases are not represented now in the area. This is due to the erosion by which most of the fine sediments (claystone and siltstone) were removed.

The environment of the Red Bed Series grades to that of the Kolosh Formation via transitional environment, by possibly terregenous dominated shelf. When the sediment of the Red Bed Series accumulated at the delta front and on delta plain, they reworked into deeper part of the Paleocene foreland basin through submarine channels. The reworking was resulted from generation of turbidity current by slump, slide and wave and currents mixing sediments.

Recently, Zelilidis et al. (2002) Studied similar occurrence of gradation environment, from alluvial fan into deep marine turbidite. In his study of Mesohellenic Basin evolution of Greece (Miocene–Oligocene), he showed that the basins (such as that of Iraqi Paleocene) is divided into several formations. The proximal area (near shore), shelf and basin consisted of conglomerate (Fan delta conglomerate), sandstone and deep sandstone and shale respectively. In the same way Emery and Myers (1996, p.128) mentioned that lateral change of fluvial architecture reflects the reduced fluvial gradient from the hinterland to the margin of the marine basin.

Therefore, this arrangement of the sediment and environment as studied from Greece by Zelilidis (op.cit) is similar to our discovery of combining both Red

Bed Series with Kolosh and Gercus Formations in the studied area. If we suppose that the environment, in certain location and time in the studied area, was proximal braided river (alluvial fan apex), this environment was changing with time. The change is from alluvial plain (braided plain) to delta plain (paralic environments) and delta front occasionally (Fig.4.7 and 4.8). This is due to high tectonic activity of the studied area, which was probably aided by eustatic sea level change.

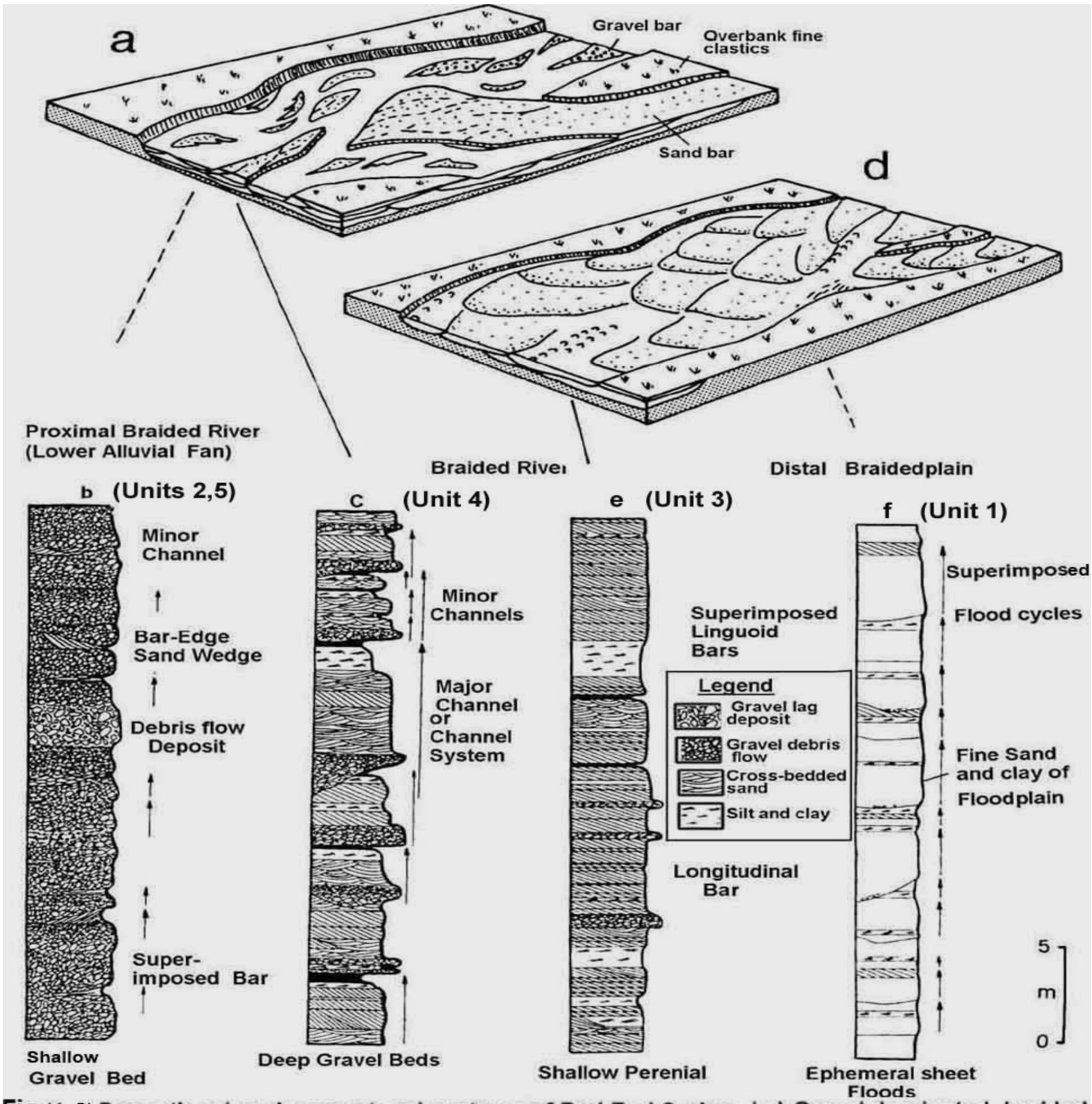


Fig.(4. 6) Depostional environment and systems of Red Bed Series , (a) Gravel dominated braided river as a feeder of alluvial fan at proximal area. (d) Sand dominated braided river at distal area with inguoid sand bar. (b,c,e,f) lithologic column of the envoronments during deposation of several cycles. Modified from Einsele(2000) and applied on Red Bed Series.

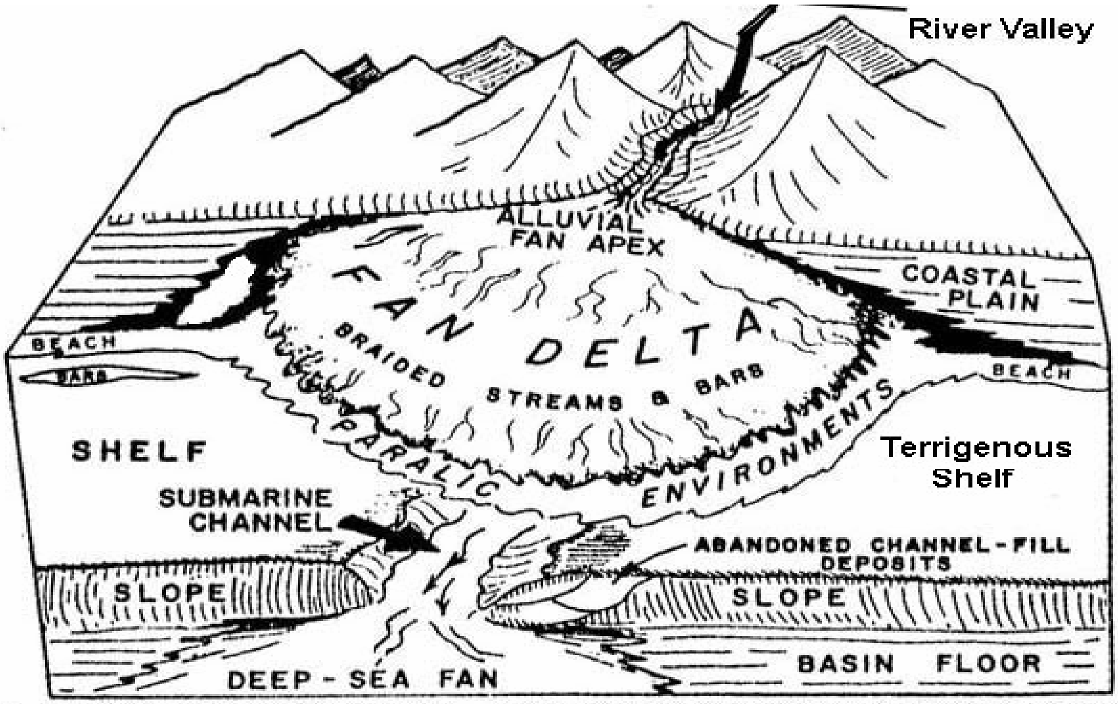


Fig. (4.7) The most close model (in literature) to the Red Bed Series and Kolosh Formation . The fan delta-alluvial fan and slope- basin areas can be representative for Red Bed Series and Kolosh Formations respectively. While the shelf represent the transition between the two units · Drawn by Link et al., 1976, in : Pettijohn et al.(1987)

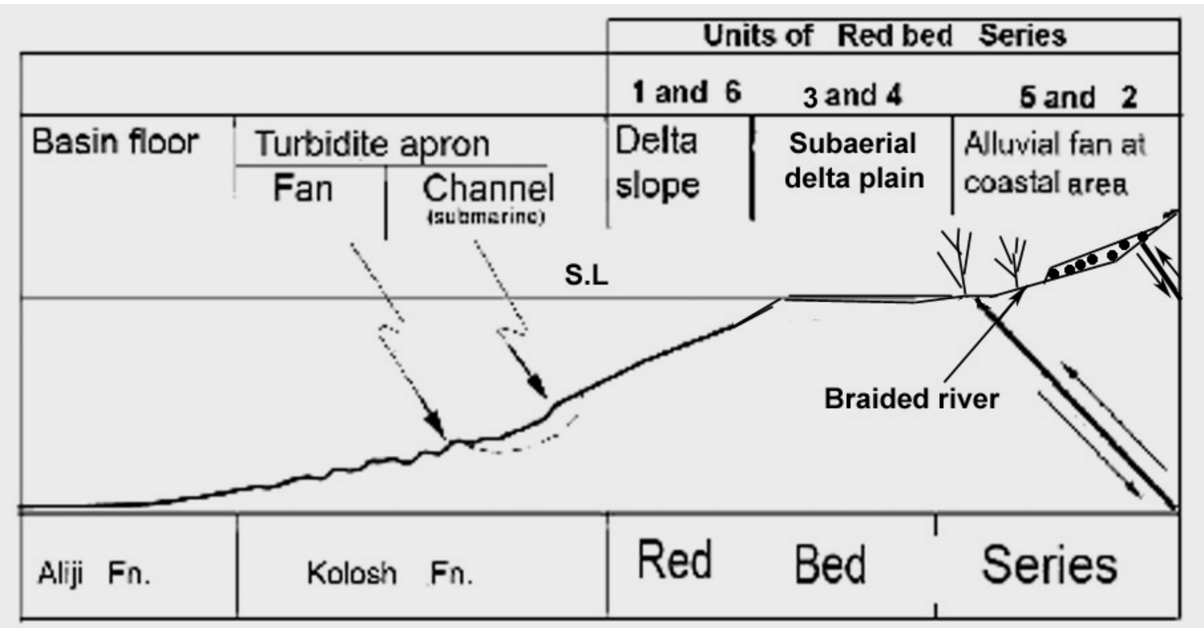


Fig.(4.8A) Position of Kolosh Formation and Red Bed Series In the Foreland basin of Paleocence.

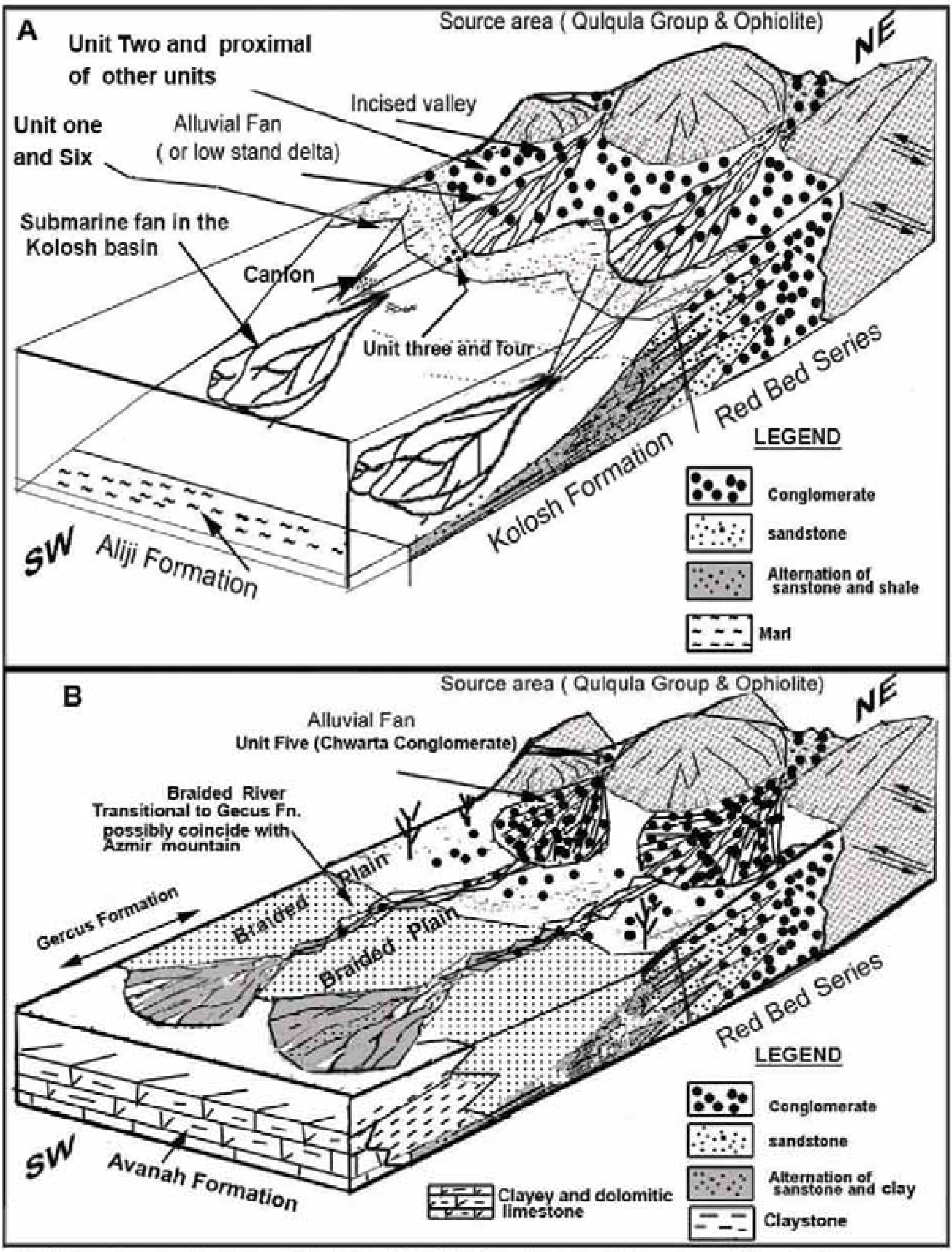


Fig.(4.8B) Depostional model of Red Bed Series during Paleocene (A) and Eocene

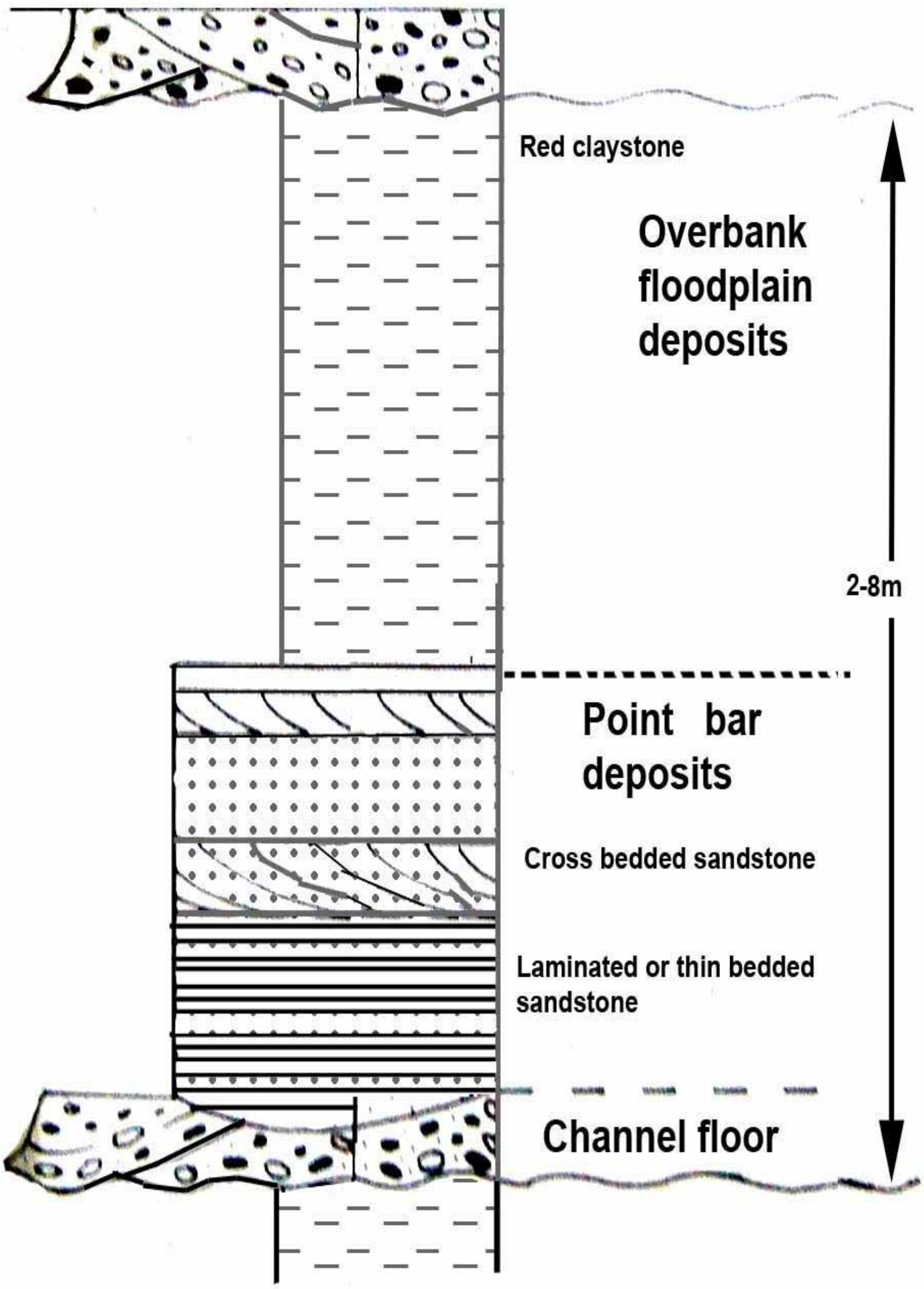


Fig.(4.9) Lithology and environment of one cycle of unit three.

CHAPTER FIVE

SEQUENCE STRATIGRAPHY

5.1-PREFACE

Sequence stratigraphy is a new tool for more accurate basin analysis than the traditional stratigraphy. This is because traditional stratigraphy divides the outcrop section of certain area in term of similar lithologies while sequence stratigraphy divides the sections according to equivalent lithologies and equivalent times intervals. Therefore sequence stratigraphy is not concerned so much with the lithology as do the traditional stratigraphy.

Emery and Myers (1996) defined sequence stratigraphy as *“subdivision of sedimentary basin fill into genetic packages (depositional sequence) bounded by unconformity and their correlative conformities”.* Previously no one has studied sequence stratigraphy of the Red Bed Series. Karim (2004) has studied the sequence stratigraphy of the underlying Tanjero Formation in the same studied area. He cited that the rock of the most upper part of the Tanjero Formation represent shelf margin system tract (SMST).

For the division of the rock body of the series, into depostional sequences, the method of Vail et al. (1977) is used, the method of Galloway (1989) (Genetic sequence) is not used because the Red Bed Series is mainly deposited in the continental environments, so no condensed sections can be found easily and they have very limited outcrops. That’s why Galloway method

(1989) could not be used in this study. Before the study of the sequence stratigraphy of the series the following points should be considered:

1-Only one narrow strip of outcrop is available for the study. This prevents wide and accurate sequence stratigraphy study of the series.

2- Although the lower boundary of the series is clear, which is indicated by Karim (2004) as unconformable in some places (as in Qandil mountain toe) and conformable in others (as in Chwarta area) but the upper boundary with Naoperdan shaly Group is not clear. Previously this contact mentioned to be tectonic by Al-Mehaidi (1975), Buday (1980) and Surdashy (2001).

3. It is agreed that the series has shallow environment (mainly continental), therefor the lithology and facies change dramatically both laterally and vertically. This makes study of sequence stratigraphy of the series difficult. Moreover, this environment may cause erosion of some of the systems tract especially those, which have fine grain lithology such as transgressive systems tracts.

Extensive lateral fieldwork is achieved to find all sedimentary facies deposited in response to relative sea level change. Finally, these facies are organized in system tracts (LST, TST, and HST) and the associated sequence boundaries are identified. The systems and boundaries rarely can be seen in one continuous surface section.

5.2-Contact between the Red Bed series and the Tanjero Formation

The contact was cited previously to be gradational by Lawa *et al*. (1998) while Karim (2004) recorded both gradational and unconformable contact at Chwarta-Mawat area. Moreover, the latter author mentioned that the contact is totally unconformable at the Qandil mountain toe. So he concluded that the upper most part of the Tanjero Formation represent shelf margin system tract (SMST) in Chwarta-Mawat area and underlain by SB2, while in Qandil area the upper part of Tanjero Formation underlain by SB1.

In the present study this conclusion is assigned as a starting point for the discussion of the sequence development of the Red Bed Series.

5.3- Relation of the series with the other formations

The basin analysis of the Red Bed Series could not be completed without sequence stratigraphy study. For accurate analysis of the basin, the series must be correlated with other units (formation). For this the study of the Red Bed Series is expanded from proximal area (area of the series outcrop at Chwarta, Mawat and Qandil areas) to the distal area (Dokan area and Sharazoor plain, at south of Sulaimaniya City). Field study and literature review showed that the closest and synchronous (time equivalent) unit is the Kolosh Formation. According to our assumption both Red Bed Series, and Kolosh Formation are deposited in one single basin as a time lateral equivalents (Fig.5.2). This relation is approved for lower and middle parts of the Red Bed Series with Kolosh Formation according to the following recorded facts:

1. The ages of the Kolosh Formation, as given by Bellen, *et al*. (1959) and Buday (1980), was Paleocene-Lower Eocene while that of the Red Bed Series is highly doubtful but roughly assigned to be Paleocene to Miocene. This shows that some parts of the series are time equivalent to the Kolosh Formation.

2. The pebbles and boulders of Naoperdan, as mentioned by Omari and Sadiq (1977), are ascertained in this study and found in the Red Bed Series so there is a direct evidence to prove that some part of the series is younger than Eocene.

3.Karim, (2004) found that 500m conglomerate of the Tanjero Formation at proximal area (same area of the series) has equivalence of nearly 400m of sandstone with some interbed of conglomerate at distal area (Dokan area and Sharazoor plain). When this fact applied to the Red Bed Series, the equivalent of all units of the Red Bed Series in the distal area must be found too. The fieldworks were successful, for finding this fact in the area of exposing of the Red Bed Series and the Kolosh Formation.

It was found that at the base of the Kolosh Formation in Dokan area, there are many intervals of brown calcareous shale (or brown calcareous red claystone). These intervals have deep environment (pelagic) and contain Paleocene planktonic forams and exist above the conglomerate between Kolosh and Tanjero Formations.

These intervals can be correlated easily with Unit One of the Red Bed Series in Chwarta- Mawat area, which has generally a fine-grained and red color lithology. That unit of the series is equivalent to the Unit Two of Bolton (1958) and Mehaidi (1977). Hoy and Ridyaway, (2003) mentioned that lateral changes in depositional systems are related to variation in tectonic subsidence at different parts of the basin.

Even the equivalent of bluish white layers of sandstone and siltstone in the unit one of the series (Photo2.3A) can be distinguished in the lower part of the Kolosh Formation as bluish white marl and marly limestone.

Another interval of Kolosh Formation, which can be correlated with the Red Bed Series, is its middle part. This part of Kolosh Formation can be correlated with the conglomerate of Unit Two of the Red Bed Series on the bases of lithology, paleocurrent and stratigraphic position, as concerned to lithology, both have the same constituent of clasts (limestone, chert, igneous and metamorphic rock fragments). While the measured paleocurrent in both units is toward southwest (about S70W) and both contain same sedimentary structures. In the correlated parts of both the Red Bed Series and Kolosh Formation same type of flute cast and same direction of arrangement were found (photo 3.7, 5.1, and 5.3).

Photo(5.1) Well developed flute casts on the lower surface of a sandstone bed (The bed is overturned) in the Kolosh Formation at Dokan area, 3km southwest of the Dam site, near Kolka Village. By these flutes, the paleoc-urrent can be correlated with those exist the Red bed Seris (see photo 3.7).

Unit Two of the Red Bed Series, in Chwarta area, consists of chert and limestone pebbles only, while in Mawat area consists of chert, limestone, igneous and metamorphic pebbles, therefore it is the most possible that lithology of the middle part of the Kolosh Formation is derived from that conglomerate of Mawat area, especially during early lowstand, in which huge amount of gravels and sands transported southwestwards and deposited as Kolosh Formation. The sandstone reached the present position of the Kolosh Formation at the south of Dokan area (distal area of Paleocene basin), while the gravels deposited, most probably, at the intermediate area between Mawat and Dokan area, but these deposits now can not be seen because of erosion.

4. For establishing a relation between lower parts of the Red Bed Series and the Kolosh Formation and according to the above facts, a sketch is drawn. It shows the lateral change of lithology down the basin paleoslope of the Paleocene. In traditional stratigraphy this lateral change of lithology, from coastal area to center of the basin, is assigned now as the Red Bed Series and Kolosh Formation (Fig. 5.2).

5. The discovery of reefal limestone (photo4.3) in upper part of the Red Bed Series is evidence of gradation of fluvial environment of the Red Bed Series with normal marine one of the Kolosh Formation.

6. As mentioned in the section (2.2.3.1.5), unit five is younger than the Eocene which contain boulder of the Naoperdan Series. Fieldwork, depending on the lithology, thickness and stratigraphic position, proved that this unit is equivalent to the Gercus Formation. This is based on the extensive survey in the area at the boundary between Low and High Folded Zones (area of exposure of the Gercus Formation). These areas include east, north and west of Darbandikhan town in addition to Bazian and Haibat Sultan Mountain. At these areas all the conglomerates are studied lithologically and stratigraphically. The closest one is that of Gercus Formation which in some places have a thickness of 60m, and it is located at the top of the formation (Photo 5.2). The grain size range from pebbles to granules and the grains has more roundness and sphericity than its equivalent at proximal area (unit five or Chwarta Conglomerate) from which they derived. The conglomerates of the

Gercus Formation contain similar types of cherts and limestones gravels as that of Unit Five of the Red Bed Series.

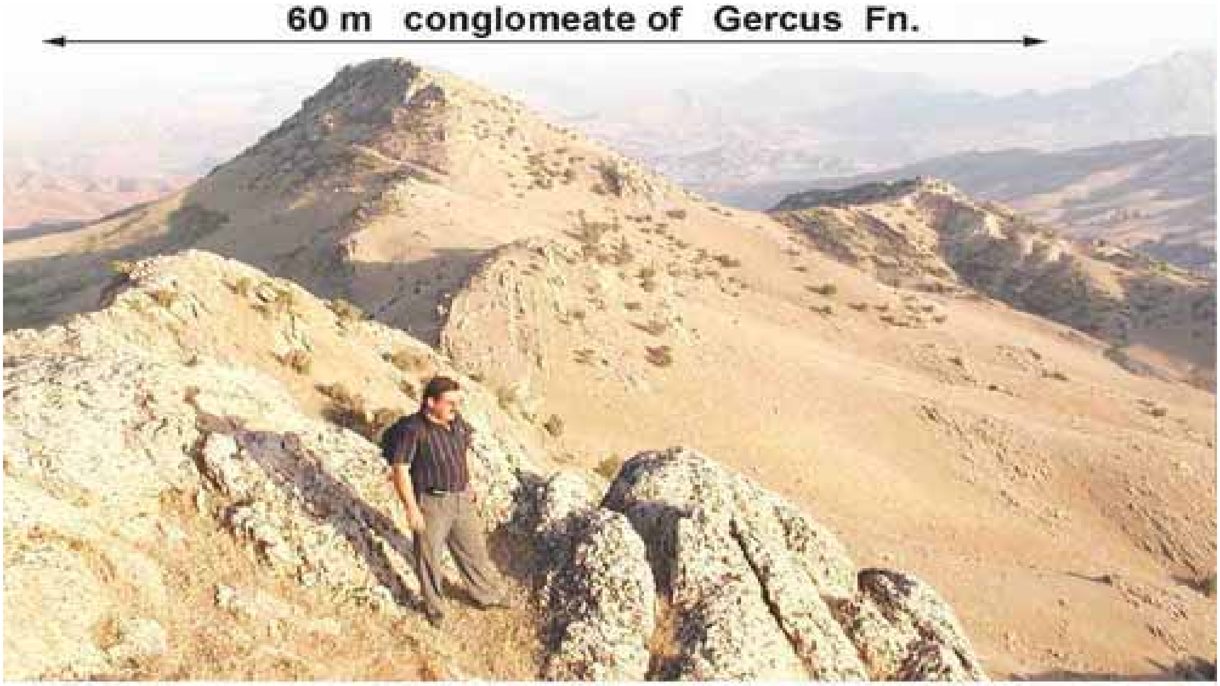


Photo (5.2) 60 meters of chert and limestone conglomerate at 10km north of Darbandikhan town. It is lithologically very close to to Chwarta conglomerate

The conglomerate of the Gercus Formation contains grey or milky gravels, which resemble that of Walash-Naoperdan Series. The thickest exposure of conglomerate of the Gercus Formation is located at 10km north of Darbandikhan town. At this locality the conglomerate form a mountain called Barda Asin Mountain (Photo5.2). The same conglomerate is recorded by Karim (1999 in press) in Sartak-Bamo area, which has thickness of 70m and interbedded with sandstone. As will be seen later this conglomerate with Chwarta conglomerate represents sediment of incised valley during Eocene.

Field study failed to find positive relation between this conglomerate and the conglomerate of the Lower Fars and Pila Spi Formations. This is because the gray limestone (as gravel) of Naoperdan is not observed in all areas of occurrence such as Darbandikhan, Darbandi Bazian and Haibat Sultan Mountain. In this conglomerate, the carbonate gravels are totally composed of porcelaneous white limestones, which are belonging to Avanah Formation.

This conglomerate is studied in detail by Ameen (2002 in press). He called it Lower Fars Formation basal conglomerate. Karim (1999) recorded the existence of the Avanah Formation above the Pila Spi Formation at the area east of Darbandikhan Town.

5.4- Depositional sequences and systems tracts of the Red Bed Series

In this study, the whole rock body of the Red Bed Series except unit five (Chwarta Conglomerate) is divided into three main depositional sequences. But the latter conglomerate will be discussed separately. Beside the main sequences, this study does not exclude existence of other minor depostional sequence within the main ones but the study of these minors make the Red Bed Series more complex tobe understandable and to be conclusive. The main sequences are as follows:

Photo(5.3) About 250m of sandstone rich interval. A) in Kolosh Fn. at Dokan area which is equivalent to 500m of sandstone of the Red Bed Series. B) ripple mark in same formation and interval.

5.4.1- Lower depositional sequence

5.4.1.1- Highstand systems tract (unit one)

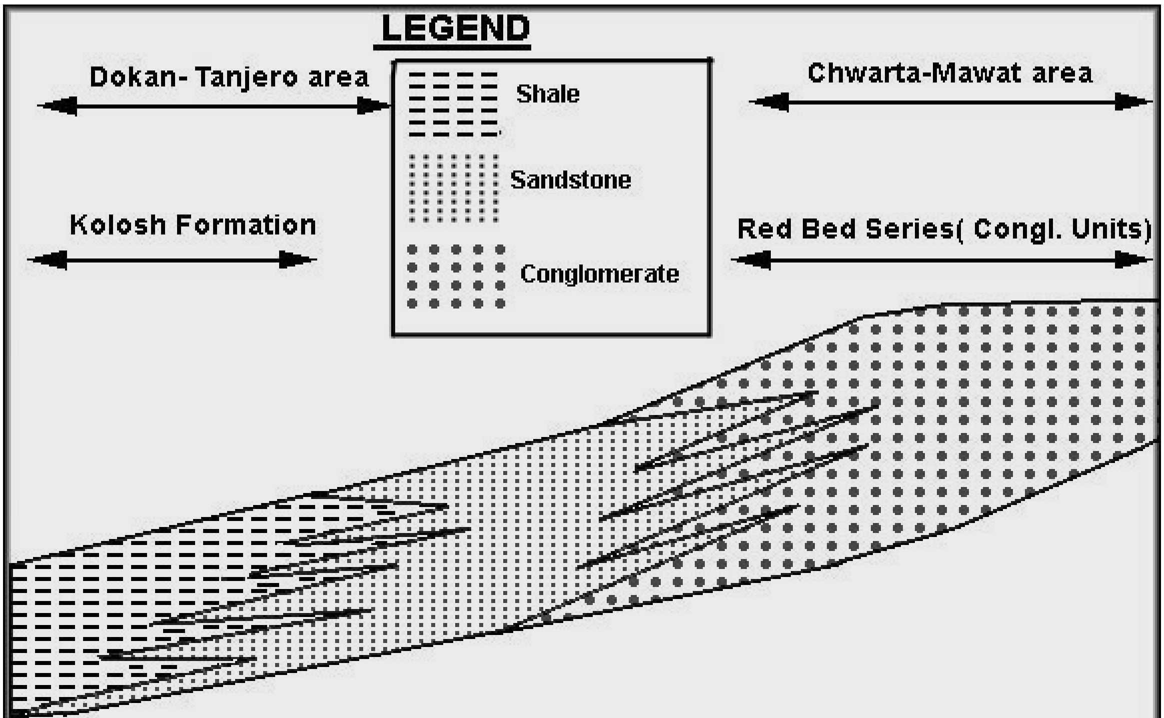
According to Karim (2004), the upper most part of Tanjero Formation is shelf margin systems tract (SMST). Therefore, Unit One, which is directly overlying this part of Tanjero Formation, can be identified as high stand systems tract

(HST). This unit consists of red claystone and sandstone. In some localities it consists of alternation of red claystone and bluish white siltstone (or sandstone). This systems tract has aggradational pattern of deposition. Toward northwest (toward Mawat and Qandil Mountain), the lithology of this system tract changes from claystone and siltstone to claystone with lenses of conglomerate. The transgressive systems tract of the lower depositional system is not found in the Red Bed Series. It is possible that the underlying dark shale beds which are located on the top of the Tanjero Formation (which is not mentioned by Karim, 2004) may represent a Maximum Flooding Surface(MFS).

5.4.2- Middle depositional sequence

5.4.2.1- Lowstand systems tract (unit two)

This systems tract is consisting of the red colored conglomerate between unit one and unit three. In Chwarta area, these conglomerates consist of exclusively of chert and limestone clasts (boulder and pebble). While towards west the shares of igneous and metamorphic clasts gradually increase. The



Figure(5.1) Possible relation between Kolosh Formation and Red Bed Series during depostion of the unit one, two and three of Red bed Series.

underlying surface is sharp and undulated, therefore it is erosional and type two sequence boundary (SB2) which formed during early LST according to the following:

A-This conglomerate is regarded as orthoconglomerate, as it has grain supported texture and contains clasts range from pebble to boulder, it even contains sporadic blocks.

B-In Chwarta area and Qandil Mountain, the conglomerate can be traced laterally for several kilometers.

C-The conglomerate bed represents incised valley fills. In these valleys the conglomerate fills the channel floor (as lag deposits) deposited during sea level fall.

D- Before the deposition of this conglomerate, it was possible that huge quantity of fine red clastics of the previous highstand systems tract may be eroded and transported to the basin (distal) area (location of Kolosh Formation). This extensive erosion is probably responsible for the brown and red interval at the base of Kolosh formation. This conglomerate, in distal area and inside Kolosh Formation, has only fine grain equivalents.

5.4.2.2- Transgressive systems tract

The rock body of this systems tract is represented by thick succession (500m) of thick-bedded gray sandstone interbedded with light color claystone. The thickness of each bed ranges between 1m.to 6m. The succession has a clear aggradational pattern. This shows neither shallowing nor deepening. The sandstone unit (unit three) is assigned as transgressive system tracts because of the following:

1. It directly overlies the conglomerate of unit two. According to Emery and Myers (1996), this change from coarse sediments to fine one is evidence of transgressive system tract. Posamentier (2002) mentioned that transgressive system tracts are commonly sand prone and tend to be encased in shelf mudstone. He added that the area about 20km long and may be 17m thick. These characteristics are nearly coinciding with that of the Red Bed Series at Chwarta-Mawat area.

2. It contains many observed sedimentary structures such as cross bedding, ripple marks and laminations that prove it is deposited in less turbulent environment than the conglomerate. Another observed features are the continuity of the sandstone bedding for several kilometers.

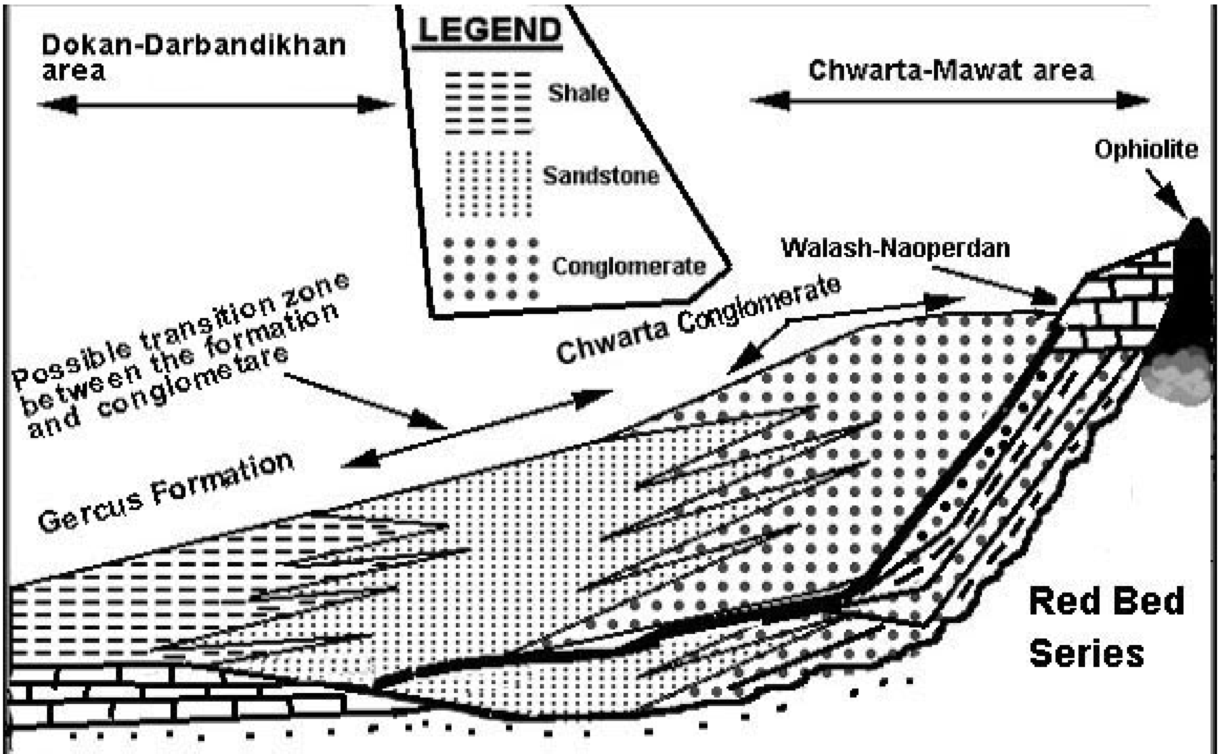
The environment of this facies is indicated as delta (Fig.4.8) and it is possible that occasionally flooded by marine water during short sea level rise.

5.4.2.3- High stand systems tract

This system tract is composed of thick alternation of sandstone, conglomerate and claystone with prominent red or brown color. The lithology of this system tract belongs to that of unit four which has thickness of about 150m. Smith and Jacobi (2001, p.22) have found several shallowing-upward parasequence which they grouped them into aggradational or progradational parasequences. In Red Bed Series, the alternation of several successions of sandstone, conglomerate and claystone can be compared with shallowing parasequences of the above authors. The existence of conglomerate may be attributed to unusual large storm or may be returned to braided delta (Fig.6.4).

Because of contrasting lithologies (competent and incompetent beds), the area of the outcrop of this systems tract is densely dissected by streams and forming badlands. In Roste valley this systems tract does not exist at all, instead its position is either covered or occupied by fine grain clastics. The red claystone, sandstone and conglomerate, can be deposited in delta front, delta mouth and delta feeder - channel respectively.

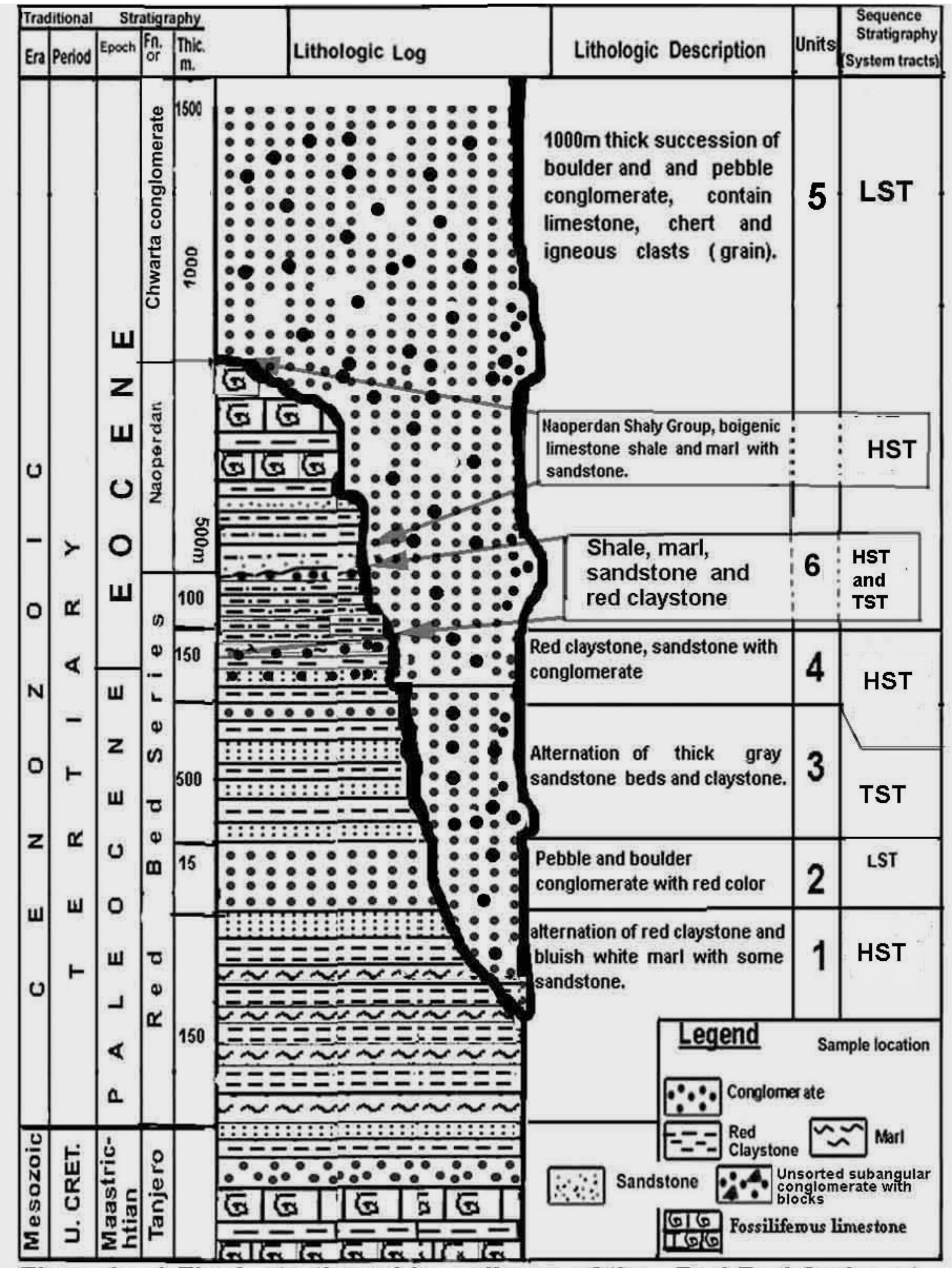
The red claystone, sandstone and conglomerate, are belonging to deposits of river systems, which has intermediate characteristics between braided and meandering streams.



Figure(5.2) Possible relation between Gercus Formation and Red Bed Series during depostion of the unit five (Chwarta conglomerate)

5.4.3- Upper depositional sequence

This system tract is not ordinary in out crop and field stratigraphic succession. In the field, this systems tract is started with low stand systems tract of 1000 m conglomerate (Chwarta conglomerate). But originally the conglomerate is not related to the Red Bed Series, as it contains fossils of Walash –Naoperdan Series. So, in this study, the upper depositional sequence is supposed to be covered by Chwarta conglomerate. This depositional sequence consists of unit six (unit five is excluded from the Red Bed Series).



Figure(5.3) Final stratigraphic collumn of the Red Bed Series at Chwarta area when the result of the present study is encountered The Chwarta conglomerate has erosional relation with other units

5.4.3.1- Transgressive and highstand systems tract

The fine clastic (claystone, marl and sandstone) with lensoidal beds of reefal limestone is the clear evidence for the transgressive or high stand system tract. But, because of the covering by Chwarta conglomerate and soil, the two systems tracts ca not be separated. The only sign for the transgressive systems tract (at the base of unit six) is the local existence of green marl, fossiliferous reefal limestone at the north of Shams Awa Village in Chwarta-Mawat area. The rest of the fine clastic, with conglomerate at the top, represent high stand systems tract.

The low stand systems tract is not clear, it may be incorporated with the Chwarta conglomerate. While the Walash-Naoperdan can be regarded as the high stand systems tract

5.4.4- Unknown Lowstand systems tract

In Chwarta-Mawat and some part of Qandil mountain area, this systems tract is very well developed which is represented by more than 1000m of pebble and boulder conglomerate (Chwarta Conglomerate). It contains all types of gravels such as igneous, metamorphic, chert and limestone clasts. The most important fact about this conglomerate is that it contains fossiliferous limestone pebbles and boulders of Naoperdan Series (Photo 4.3). This means that this conglomerate is younger than this latter Series (Fig.5.3) and overlying all the Red Bed Series and Naoperdan Series erosionally (unconformity). So in this study this unit is excluded from the Red Bed series, and in some places this unit inter bedded with other units of the Red Bed Series, which may be due to the tectonic imbrication with other units. The position of this conglomerate in the stratigraphy of the area and its systems tracts are unknown. At the distal area (South of Sulaimaniya and Dokan area) great efforts were exhausted to find the equivalent of this conglomerate. This is because the thickness of this conglomerate is so high (about 1000m.) that must have equivalent in other areas towards the basin center of the Eocene.

The lithologic correlation showed that the Gercus Formation is more close to this system tract. Although same fossils are not found in the conglomerate of Gercus Formation but many types of gravels were found which have the same type of lithology i.e. grey or milky limestone. The absence of the Alveolina and nummulite forams in the conglomerate of the Gercus Formation may be attributed to the diagenetic processes, which attacked more easily, the smaller gravel of Gercus Formation than the larger one of the Chwarta Conglomerate. Another reason is the longer distance of transportation (25km) of the latter gravels, which is mechanically deformed during rolling. The continuous rolling, during transport, homogenizes the texture of the gravels.

Chwarta conglomerate is underlain by a clear erosional surface, which stand for type one sequence boundary (SB1). The shape of the conglomerate is lensoidal, representing an incised valley fill during sea level fall. In this connection Haq (1991) mentioned that during low stand systems tract when the relative sea level begins to raise slowly the stream incision is stopped and the existed incised valley may begin to be filled with coarser braided stream sediments. Shao et al. (2003), have found conglomerate of braided stream which nearly the same as that of the Red Bed Series as concerned to thickness, sedimentary structures and associated lithofacies. Einsele (1998, p.338 and 339) mentioned that during late lowstand the lowermost portion of incised valley is filled with coarse fluvial sediment (gravel in case of Red Bed Series) of braided stream. This conglomerate also exists at the eastern part of Qandil mountain toe at north of Suwais village while at the western part of the mountain it change to fine clastic which is more representative of high stand systems tract than lowstand systems tract.

5.4.5-Erosional surfaces and unconformities below and inside the wedges

Field study showed that erosional surfaces exist below the conglomerates of units two and five. These surfaces are formed due to either sea level fall or uplift of the coastal area (Mawat and Chwarta areas). During exposure the rejuvenation and incision of river occurred by lowering of the base level. The river erosion of the previous coastal area scored incised valleys. The erosional surface is coinciding with the valley floor. The largest and most obvious valley is that, which extend from Chwarta to the north of Darbandikhan town. This valley is filled with 1000m and 60m of conglomerate at the two places respectively.

These erosional surfaces as unconformities, changes to several unconformities towards south and southwest downdip. This occurred during successive flooding of the rivers, each ones carried huge quantity of gravel, sand and mud (clays). Most of the mud and sand carried to the deep parts of the basins and deposited as either Kolosh Formation during Paleocene at distal area of the basin or as Gercus Formation during Eocene. While conglomerate, sandstone and claystone were deposited as river and alluvial fan in near coastal area (proximal area). Emery (2002) mentioned that the low stand systems tract (sea level fall) must have time equivalent subaerial unconformity at the proximal area. This citation can be applied to the Red Bed Series (Unit Two and Five) and sandstone and conglomerate of Gercus and Kolosh Formations. The litholgy of Units Two and Five as discussed previously imply that they are deposited in continental environment so the erosional surfaces are subaerial unconformities.

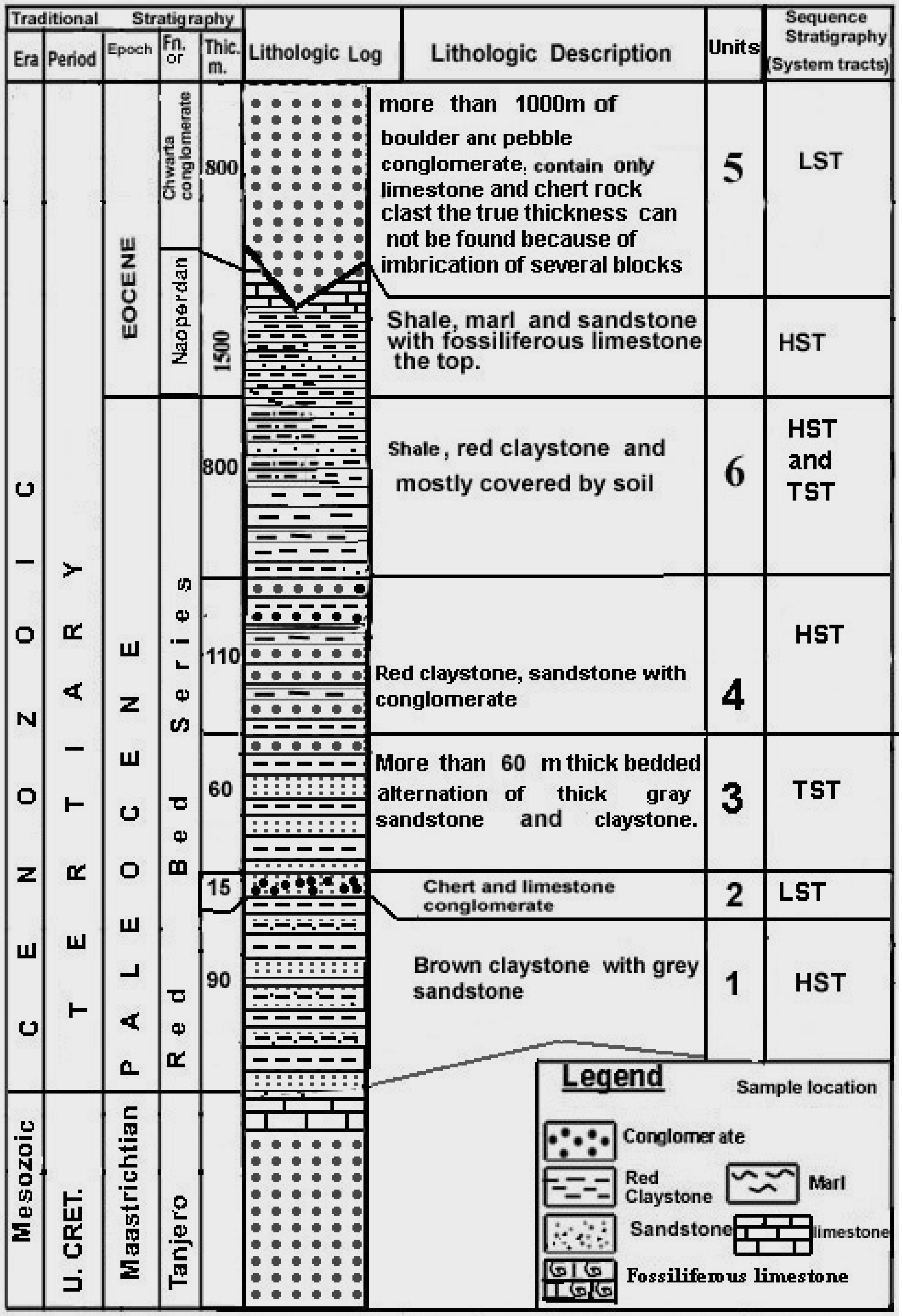
In addition to the underlying erosional surface (unconformity), Unit Five (Chwarta conglomerate) contains many erosional surfaces between the stacked lenses of conglomerate. On these surfaces the sand and other materials are transported to the basin. So it is supposed, that each sandstone or conglomerate bed of the Gercus Formation is time equivalent to one of the erosional surfaces. Along down dip extension of these surfaces in the Eocene basin from Imbricated Zone to the south of High Folded Zone each surface splits into several smaller surfaces. In the literature, similar types of unconformities are cited by Potter and Pettijohn (1977, p.295), in basin margins, they called them “compound unconformity”. In some places of the distal area the surfaces become correlative conformity.

5.4.6-Incised valleys and their sediment fill

The conglomerates of Unit Two and Five belong to sediments of incised valley fill. This can be proved by observing the clear imbricated pebbles (Photo 3.4 and 3.6) and large scale cross bedding in addition to their general lensoidal form (Photo 3.3 and 3.5A). Blatt *et al*. (1980, p.640) mentioned that in braided stream deposits imbrications of pebbles are well developed.

During sea level fall the shelf of the basin (or coastal area) of the Red Bed Series is exposed to subaerial erosion and fluvial incision. This is initiated when the stream base level was lowered. The base level change is shown by Stephen and Dlrymple (2002) schematically for alluvial systems during LST, TST and HST (Fig.5.5).

The number of these valleys cannot be indicated because of lateral coalesce of these valleys and their sediment. Therefore, thick pile of conglomerate can be traced laterally for tens of kilometers. It is possible that the sand of the Red Bed Series, Kolosh and Gercus Formations are supplied from these valleys. The sediment transferred from source by braided stream and when these valleys reach the main body of the sea, they form lowstand fan delta (Fig.6.4). The incised valleys, now can be identified by their sediment fills, which have lensoidal form of conglomerate and underlain by relatively soft sediments, such as those of Units One and Four.The coarse sediments (gravel and boulders) are laid on the braided delta as bed load deposits while the sand fractions were farther transported to the distal area and deposited in the deeper part of the basin as the Kolosh Formation (as turbidite) during Paleocene, while during Eocene they are deposited as the Gercus Formation.



Figure(5.4) Stratigraphic column of outcrop section of Red Bed Series at type section (Suwais village) , after tectonic correction.

This type of deposition of sand and gravel is well documented by Bhattacharaya and Willis (2001) during the study of lowstand delta in the Frontier Formation in USA.The width of these valleys is larger than those, found by Karim (2004) in the Tanjero Formation, and that of latter Formation is about 2km. in width while that of the series reachs 4km. Mial (2002) found incised valleys, which have a width of 4km in Malay Basin in Southeast Asia. While Samuel et al. (2003) found incised valley of 6km width in front of Nile Delta which belongs to Pliocene age and eroded during sea level fall on the shelf and upper slope. The high width of the valleys found in the Red Bed Series is due to the low relief, which associates with possible lateral migration of braided streams (Surdashy personal communication).

According to Einsele (2000), the valley fill mainly consists of coarse-grained (pebble size) fluvial deposits. He adds, that, these sediments overlain by sediments of brackish and estuarine water. According to Emery and Myers, (1996, p.140) as a result of river rejuvenation, incised valleys commonly contain the coarsest sediment available locally. They believed (p. 137), if the new river tracks were steeper than equilibrium river profile, the river would firstly straighten coaurse and then incise to form a valley. Furthermore, they mentioned that these valleys are important because they represent unequivocal evidence of a sequence boundary and they can form stratigraphic traps for hydrocarbons.

The conglomerate of the Red Bed Series is deposited during late lowstand systems tract. In this connection, Haq (1991) mentioned that during lowstand systems tract, when the relative sea level begins to climb slowly, the stream incision is stopped and the existed incised valley may begin to be filled with coarser braided stream sediments (coarse conglomerate in case of the Red Bed Series).

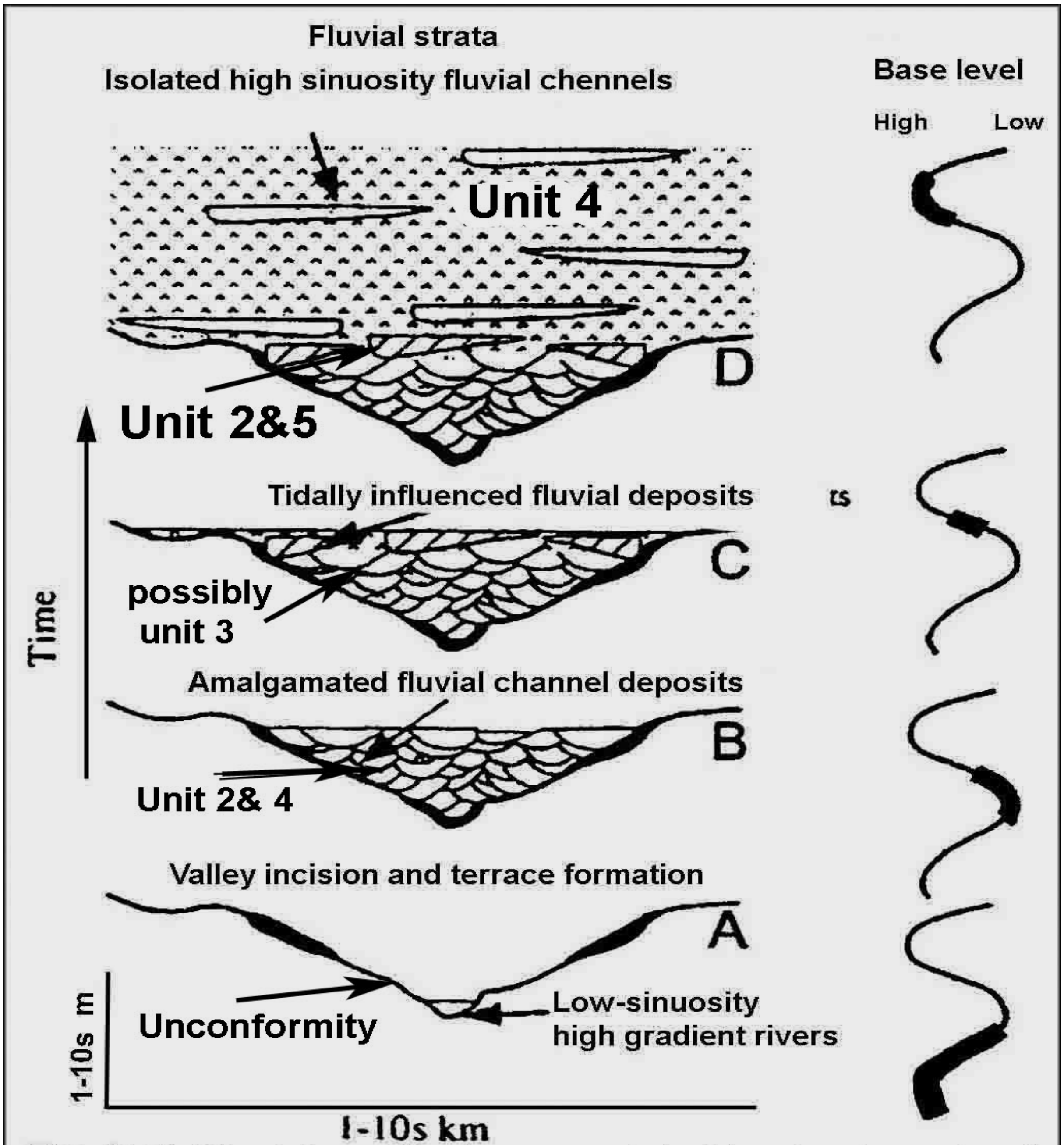


Fig. (5.5) Alluvial architecture as related to simple cycle of base level fluctuation (Stephen and Dalrymple, 2002)

5.4.7-Sediment of the incised valleys during TST

When one loocks at the sediment above the conglomerate of the lowstand systems tract he realizes that their sediments mainly consist of claystone, sandstone without conglomerate. But that of lowstand systems tract contain abundant conglomerate. This is agreed with the observation of Vincent et al. (1998, p.335) that the coarse braided fluvial facies are more prevalent in lowstand and early transgressive systems tract while fine grain meandering fluvial facies are developed in the late transgressive and highstand system tract. It was observed in this study that, in most cases, both sediments of transgressive and highstand systems tracts have red color and contain some beds of conglomerate. It is well known that conglomerate is mainly deposited during sea level fall (Lowstand systems tract). But in case of the Red Bed Series they exist as a miner component of Transgressive and Highstand systems tract. This is attributed to general continental environment of the Red Bed Series.

The sea level fall, during deposition of the Red Bed Series, is probably due to the phases of tectonic uplift of the source area and subsidence of the basin. But the shallowness of the sediments of the highstand systems tract supposed tobe due to tectonic uplift and sediment fill. The sediment fill caused decrease in basin depth by more than 500meters from the top of conglomerate of unit two to the top of sediment of transgressive systems tract (unit three).

The braided deposit during lowstand systems tract is changed (more or less) to meandering fluvial deposits. In this type of deposit and according to Eiensele, (2000) it may include coarse sediments (conglomerate) and fine ones at the point bars.

5.4.8- Condensed section

Condensed sections as thin marine stratigraphic horizons are composed of pelagic and hemipelagic sediments characterized by very slow sedimentation rate (Loutit *et al.* 1988). Within depostional sequence, the condensed section occurs partly at the top of transgressive system tract and partly within high stand system tract. They represent the maximum landward extent of marine condition. Marine condensed sections are created by sediment starvation and thus, characterized by apparent hiatus, thin zones of burrowed and somewhat lithified beds (Haq, 1991).

In the Red Bed Series one cannot find any condensed sections, but when the whole basin is specified, they can be found inside the Kolosh Formation. They exist as thin pelagic and hemipelagic thin layers at the lower part of the formation (Fig.5.7). The interval that contains condensed section is time equivalent to the transgressive or highstand systems tract (unit one and three) of the lower and middle sequence (Photo 2.1 and 2.3). The green marl at the top of Unit Four and the reefal limestone at the base of Unit Six may be reported as equivalent to the condensed section. The reefal limestone at the base of Unit Six may be correlated with the Sinjar Formation. This is because in the section (5.3), the relation between the Red Bed Series and the Kolosh Formation is stated. Moreover than that Unit Four can be correlated with the conglomerate and sandstone that exit, at some places, between Kolosh and Sinjar Formations.

5.4.9- Forced regression

The main succession of the Red Bed Series is sandwiched between a forced regression and normal regression from the base and the top respectively as follows:

Posamentier *et al.,* (1992) defined forced regression as basinward movement of the shoreline, caused by relative sea-level fall and independent sediment supply. While Ainworth and Crowley (1994) defined it as progradational of the shoreline in response to relative sea-level fall in which the rate of sediment supply exceeds the rate accommodation space added. Gayara and Al-Ubaidi (2000) found sediments, which are attributed by them to the deposition by forced regression and they concluded that it was deposited during sea level fall, which exceeded the rate of subsidence. This is recorded in Amij siliciclastic –carbonated succession from western Iraq.

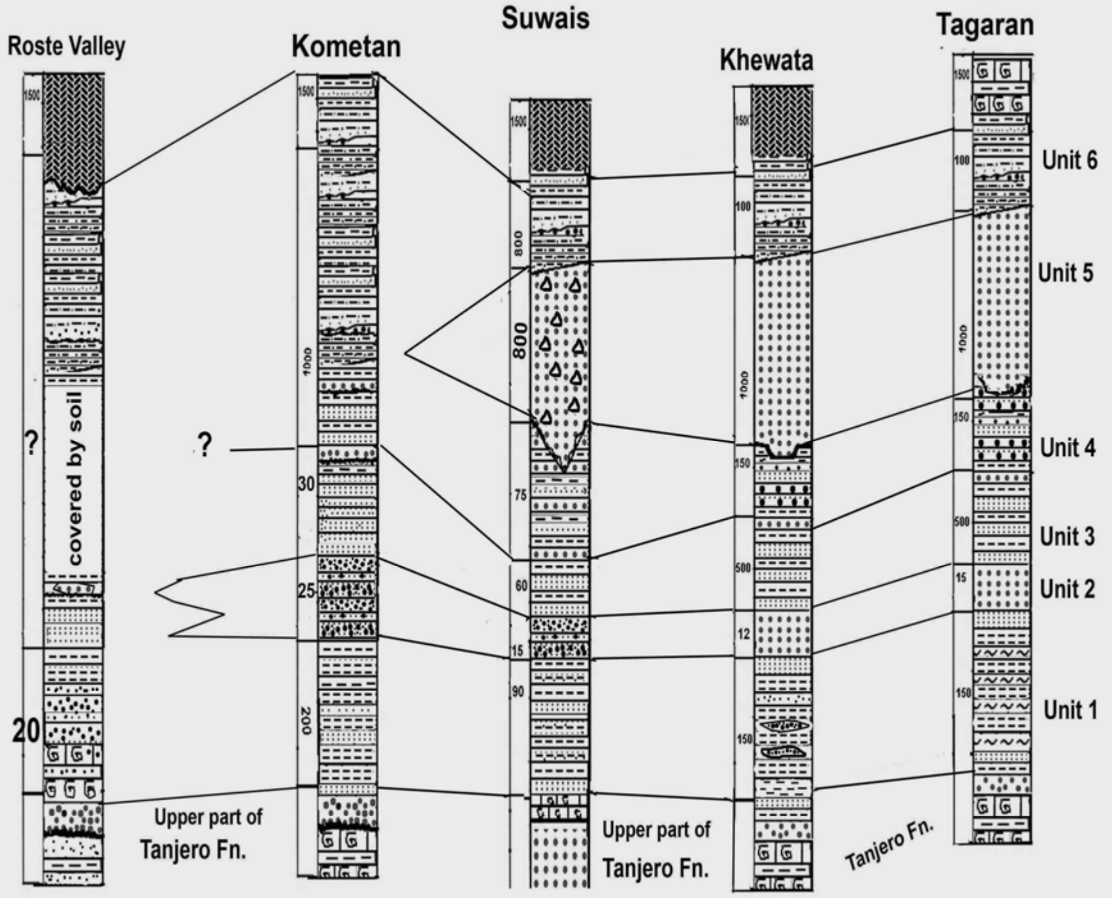


Fig.(5.6) Correlation of different units of Red Bed Series in the studied sections .
The legends are shown on the stratigrahic columns. (not to scale)

The most important evidence of the forced regression in the Red Bed Series, during certain time interval, is rapid coarsening upward, i.e. the resting of 1000m of boulder and block conglomerate, in case of unit five, on the finer sediments of other units and 16m. in case of unit two. In this study, unit five is separated from other units of the Red Bed Series and positioned at the top of Walash–Naoperdan Series in unconformable relationship.

As a result of the forced regression, the thick pile of lowstand systems tract is deposited unconformably over highstand system tract. This forced regression is affected by tectonic uplift of the source area and enhanced by eustatic sea level fall and may be enhanced by sediment fill, for example

150m. Sediments of unit one and about 700m. of deposits (unit three, four, and six) below unit five. The erosional surface below unit two and five represent the most intense tectonic periods coinciding with syntectonic deformation of the area (uplift of the source area). These surfaces are overlying unconformably units one of the Red Bed Series and Walash-Naoperdan Series respectively. The lithology of the Red Bed Series revealed that the source area (hinterland) was mainly comprised of accretionary prism of Qulqula Radiolarian Formation and the ophiolite (Fig.6.6 and 6.7).

Unit two of the Red Bed Series represents low amplitude of sea level change as compared with unit five, and bounded below by type two-sequence boundary (SB.2), which formed during the early lowstand systems tract and no fluvial deposits were appeared.

5.5-Sea level fluctuations and Wheeler diagram

Wheeler diagram is time expanded lithological column, which shows the time span of systems tracts and gaps (non-deposition or erosion) between systems tracts (Fig. 5.7). The lower part of the Red Bed Series (Unit One) is represent HST bounded below by a maximum flooding surface MFS, this surface is represented by a thin dark shale bed at the top of underlying Tanjero Formation in Tagaran area while in Mawat it is represented by both fossiliferous limestone and shale. This parasequence consists of an aggradational succession of red claystones and sandstones of the floodplain deposited during sea level highstand with moderate rate of subsidence. The lithology changes mainly into sandstone mainly at the eastern part of Qandil Mountain.

The subsequent sea level fall with a relatively low rate of subsidence reflected in valley incision, channel clustering and sediment by pass. Unit Two was deposited during this episode of lowstand and bounded below by a type two sequence boundary (SB2) Fig (5.8), which was formed during the early LST where fluvial deposition occurred, then, followed by the deposition of relatively thin red conglomerates of Unit Two during the late LST. This parasequence (LST) was the result of forced regression, a process that is a direct result of relative sea level fall, and may be enhanced relatively by the effect of the sediment influx (Posamentier et al., 1992).

The lithology of the next relative sea level rise TST is well demonstrated by thick deposition of retrogradational succession of fluvial deposits of Unit Three (Fig.5.7 and 5.8). This gradual sea level rise accompanied by gradual subsidence led to the deposition of this thick parasequence of sandstone and red claystone.

Unit Four was deposited during relative sea level stillstand with continued moderate rate of subsidence and relative sea level fall (one cycle). This parasequence HST is represented by lithology of sandstone conglomerate and shale, which shows a progradational succession of fluvial facies. Unit Six on the other hand, was deposited during a relatively rapid sea level rise, where thin shallow marine facies TST retrogrades on Unit Four. The coaral and limestone bed (facies) may represent equivalent to condensed section. This was followed by a progradational delta front or delta plain facies deposited as HST. This parasequence is bounded at the top by a type one sequence boundary (SB1) separating the Red Bed Series from the overlying thick boulder conglomerate (Unit Five of traditional stratigraphy). Rapid sea level falls, which greatly enhanced by tectonic instability. This instability is, accompanied with high rate of subsidence and high sediment influx resulted in the formation of such huge thickness.

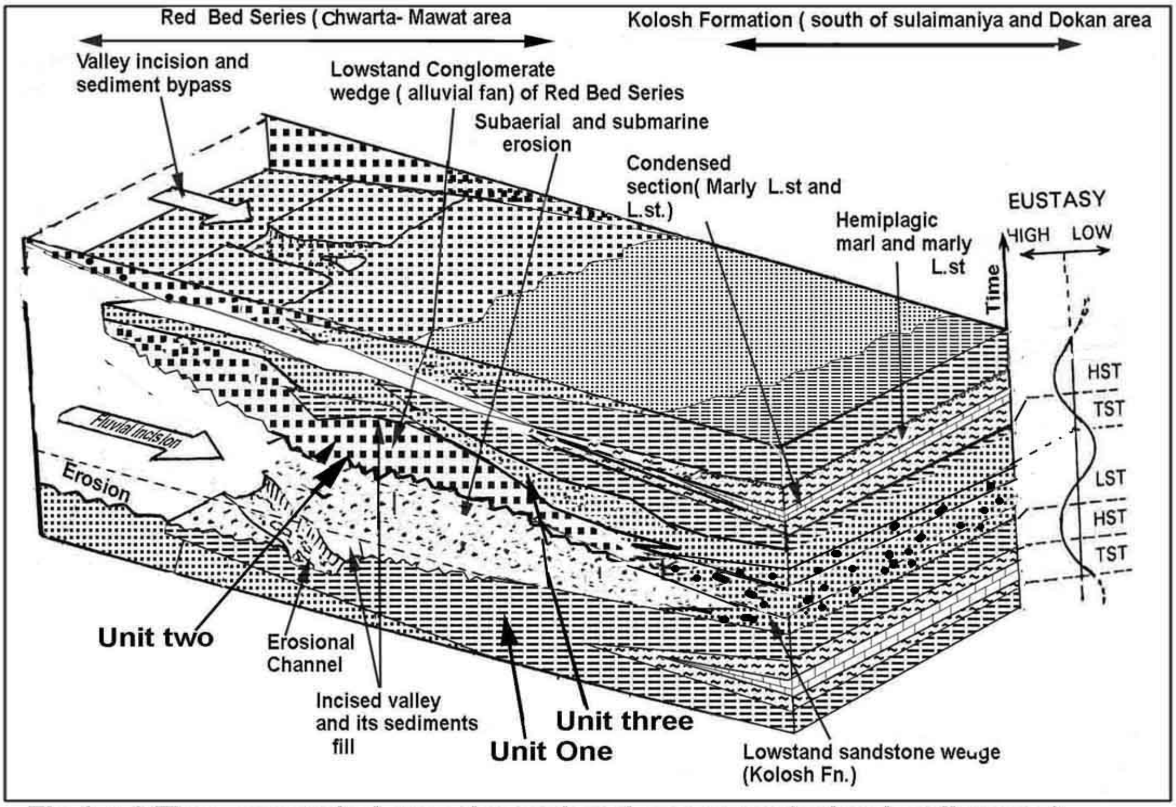


Fig.(5.7) Time expanded two depostional sequence(wheeler diagram) of Red Bed Series (unit five is not shown)

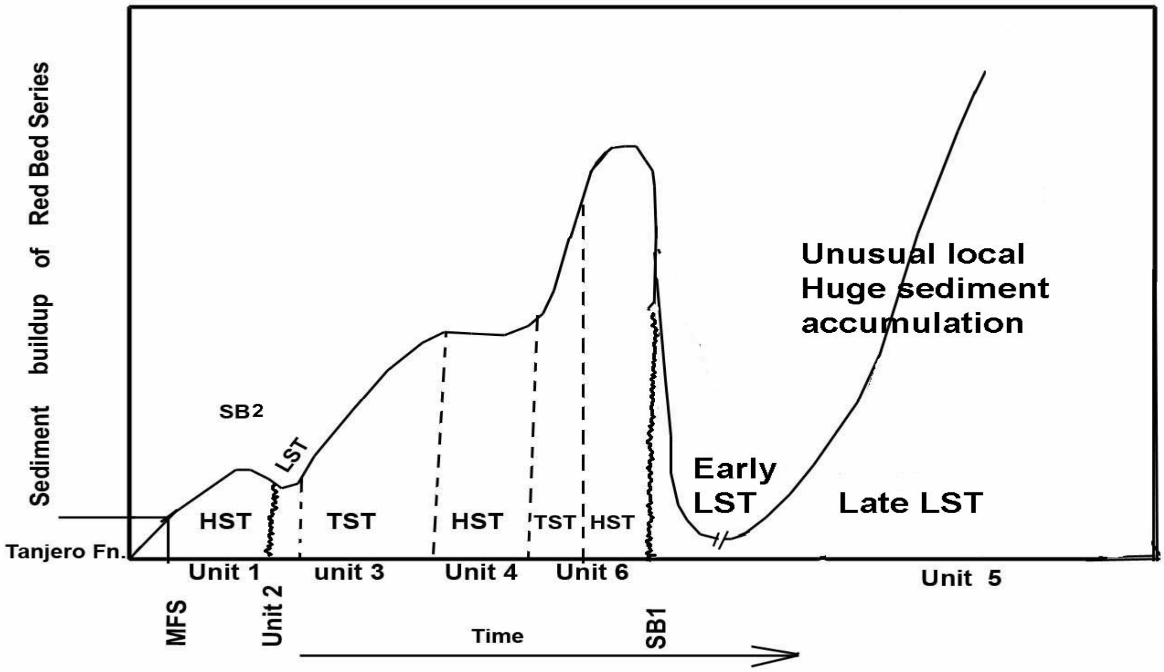


Fig.(5.8) 4th order sea level curve, showing the timing of the Red Bed Series units and the nature (magnitude and amplitude) during the depostion of each units.

5.6 -Base level transfer cycle

Several fourth order cycles can be recognized within different units of the Red Bed Series. These cycles reflect a generally asymmetrical base level transfer cycles (BLTC), they also reflect fourth order relative S.L. flactuation, as well as the imbalance between the accommodation space and sediment influx. Unit one which represent a third order HST can be divided into several base level transfer cycle (BLTC). The difference between the Early and Late HST is very clear (Fig 5.9). The Early HST consists of a relatively thin fourth order (BLTC) due to the reduced accommodation rate in an area of moderate subsidence , whereas the Late HST consists of thicker cycles due to increased accommodation at the start of S.L. fall, this has reflected in the formation of thick aggradational to progradational floodplain facies.

Unit three (TST) can also be divided into several fourth order base level transfer cycle (BLTC), they reflect minor fluctuation within the rising sea level curve (Fig 5.10). In this case successive sea level rises and stillstands are reflected by a succession of floodplain (TST) and channel sand (HST) facies stacking pattern. A minor S.L. fall is represented by a minor valley incision and deposition of the conglomerate facies.

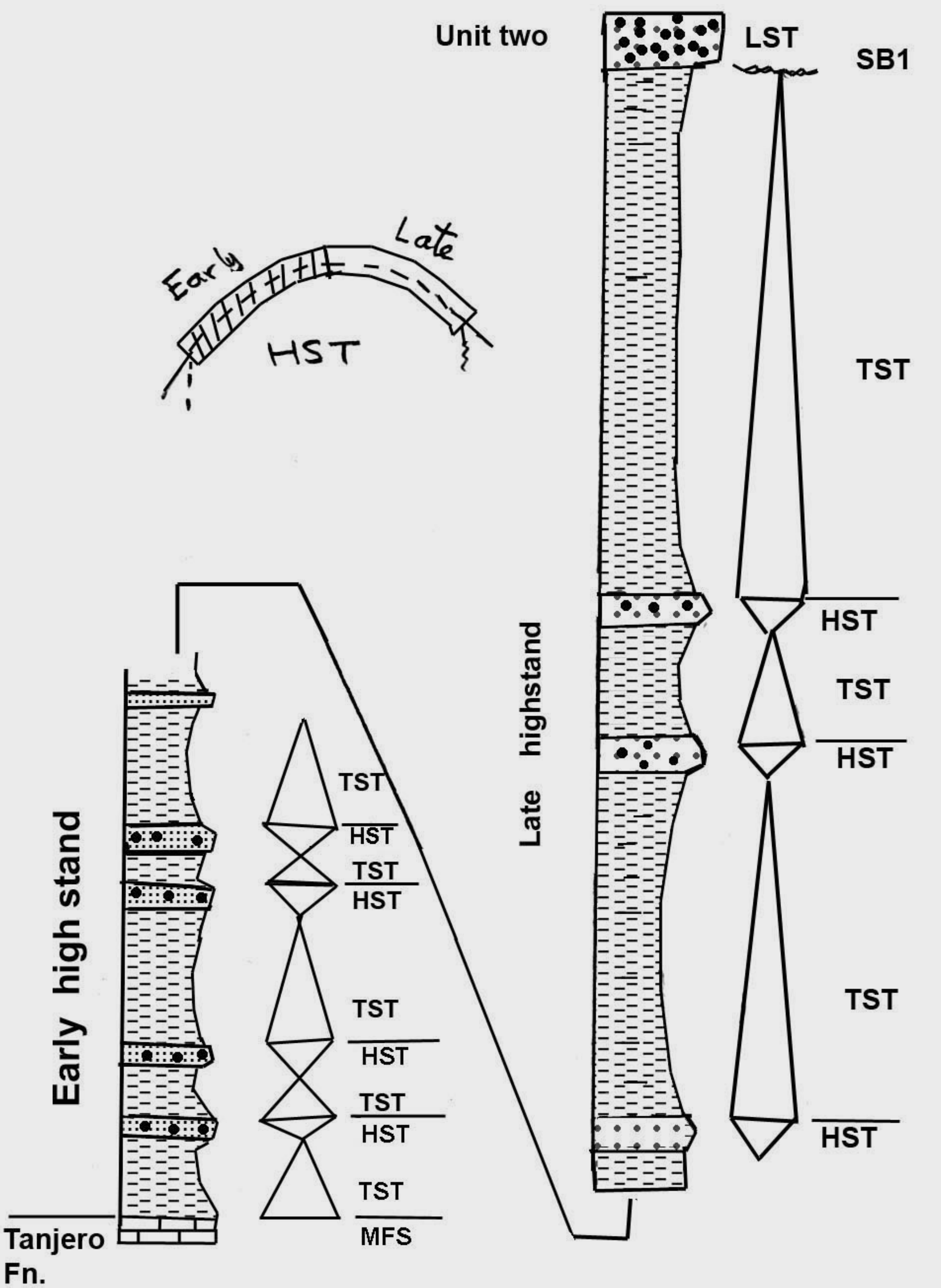


Fig.(5.9) Sequence stratigraphic subdivisions of unit one showing 4th order BLTC within 3rd order HST section at Khewata

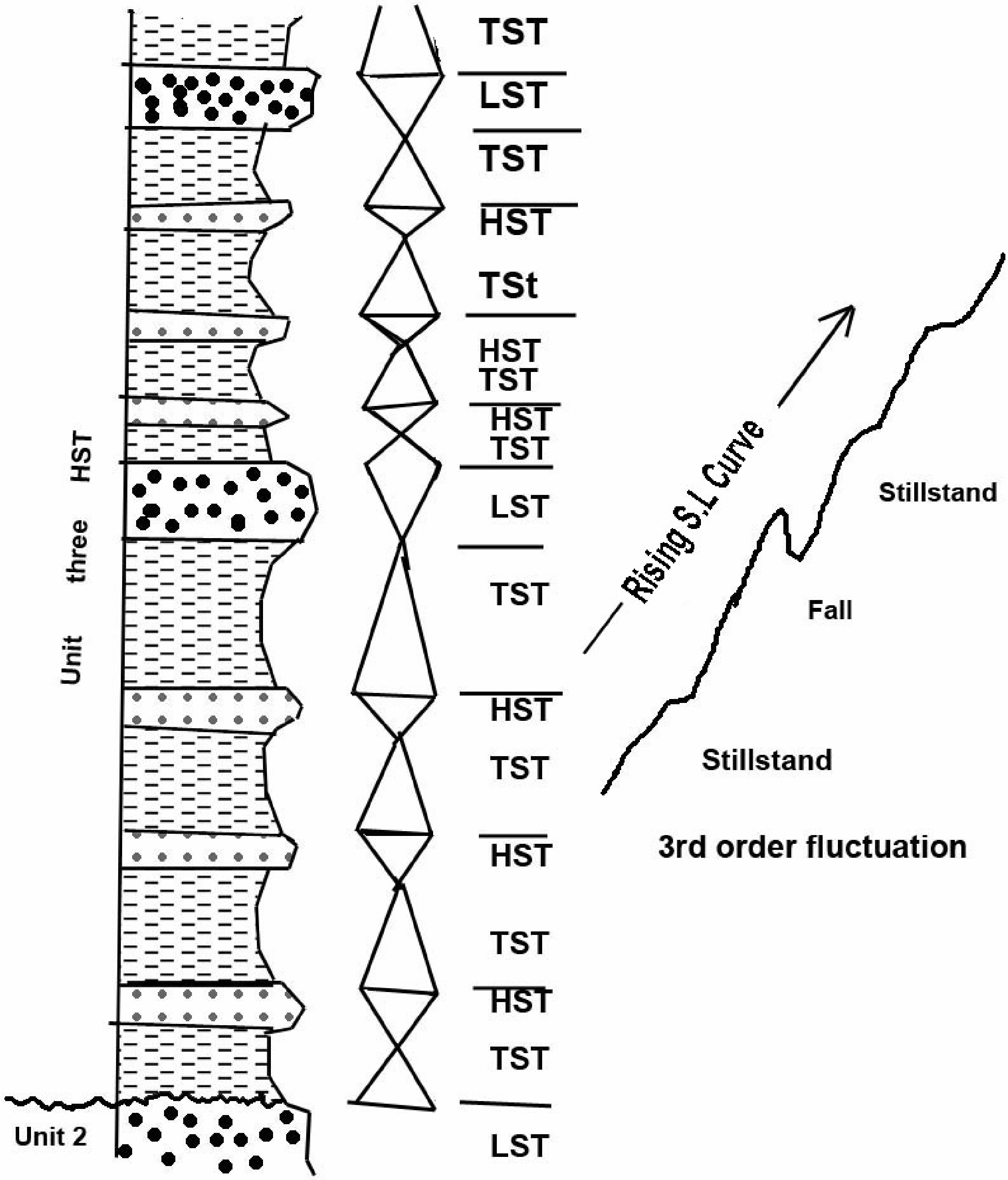


Fig.(5.10) Sequence stratigraphic subdivisions of the unit 3 showing 3rd order BLTC within 4th order HST of Khewata section.

CHAPTER SIX

TECTONIC AND DEPOSITIONAL HISTORY OF RED BED SERIES

6.1-Preface

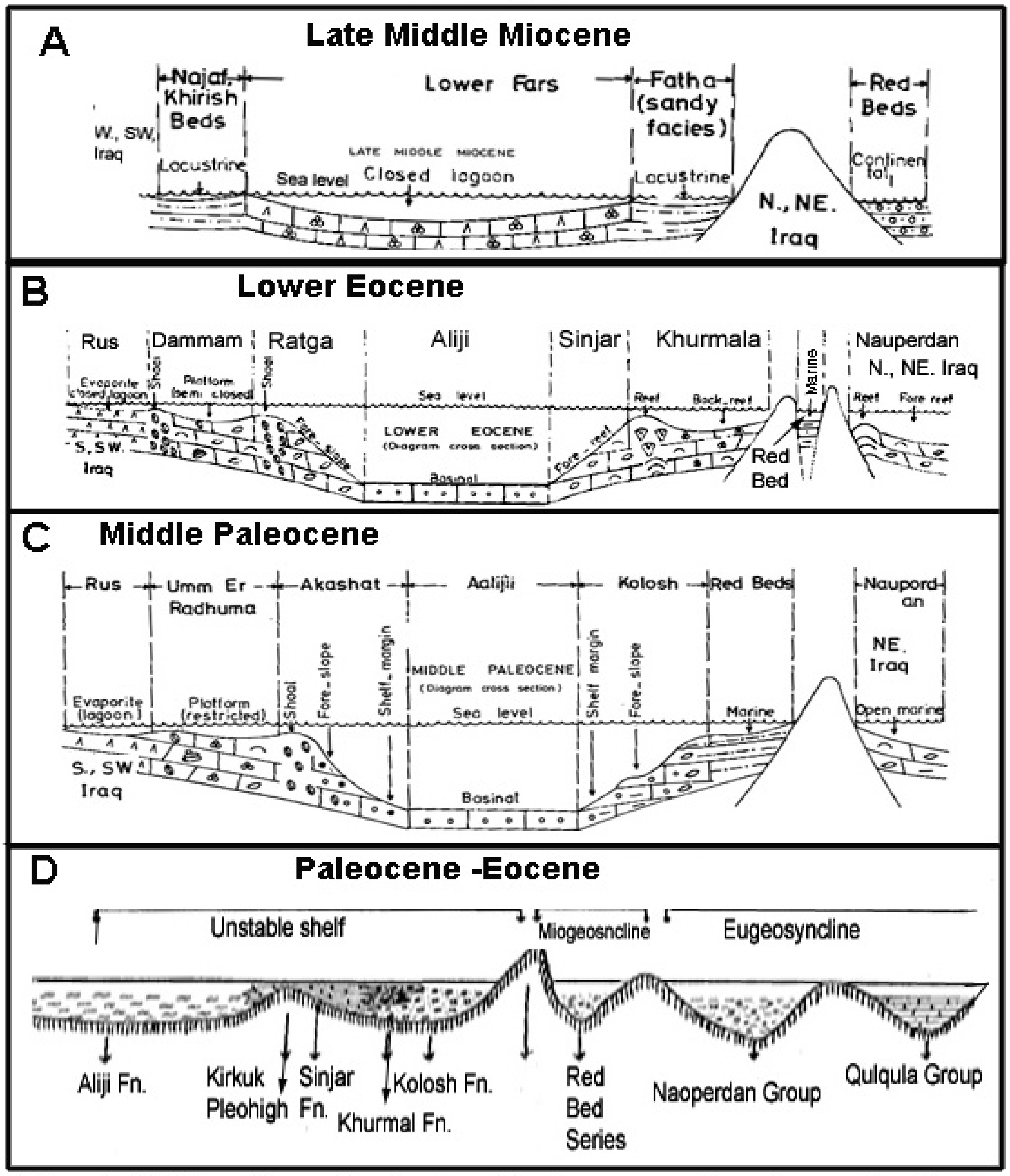
The distribution of the Red Bed Series sediments from Penjween to Haji Omran as a narrow belt infers that the setting of the basin is as elongate lake that filled with terrestrial (terrigenous) sediments. The model drawn previously show apparently this type of setting which shows that basin of Red Bed Series bounded by high paleohighs (Fig.6.1and 6.3). But the actual basin of the Red Bed Series, as inferred in the present study, was neither lake nor narrow sea, but it was large, wide and deep basin. Therefore one cannot establish tectonic setting and history of the Red Bed Series if does not consider its basin as single one, in which the known lithologies (conglomerate, sandstone and red claystone) of the Red Bed Series deposited. This is proved sedimentologically in field and in sequence stratigraphy (see Chapter Five) in which the basin of Red Bed Series is combined with the basin of the Kolosh and Gercus Formations. There are some evidences for the joining basin of the series and the formations. The first one is the **incompatibility of accumulation of 1000m of conglomerate in front of proposed paleohighs in Chwarta-Mawat area.** This paleohigh has put between the Red Bed Series and Kolosh

Formation by the previous studies. This paleohighs is assigned by Buday (1980), Al-Hashimi and Amer (1985). The position of the paleohigh coincide with Azmir, Goizha, Daban and Sara anticlines. Very recently this paleohigh was also confirmed by Lawa (2004, p.174) who mentioned that the “”Red Bed Series of Suwais Group separated from the Kolosh foredeep and Early Paleocene deposit of the Kolosh Formation””.

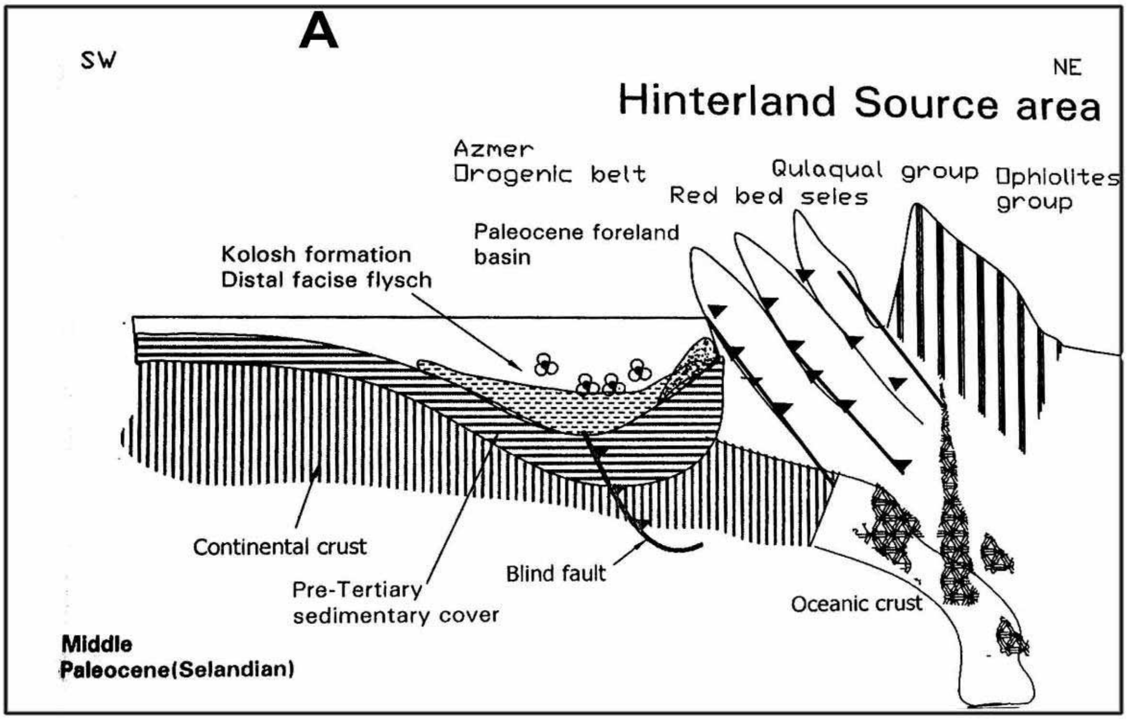
The observed incompatibility is demonstrated by occurrence of (1000m) of block and boulder conglomerate at short distance behind the paleohighs (Fig. 6.1B and D). This distance is not more than 6km from the summit of Goizha, Azmir and Daban, anticlines. The sedimentogical principle does not aid the existence of paleohigh in front of 1000m conglomerates. This is because of the followings:

1- Huge quantity of sandstones and claystone must be derived from 1000m of conglomerate (Chwarta conglomerate) and from the source area. Now this huge quantity is not present if we do not connect basin of the Red Bed Series with that of the Kolosh and Gercus Formations. When this connection is done the shale, sandstone and siltstone of these latter formations can be correlated with the conglomerate of Red Bed Series. When the complete connection between basin of the Red Bed Series with the Kolosh and Gercus Formations is done, all the sediments finer than conglomerate were transported to the deep basin of the later formations and deposited as sandstone, shale and marl (Fig.6.4). Therefore, the tectonic basin reconstruction of the Red Bed Series is based on the absence of the above anticlines at most times. In this basin , the Red Bed Series was deposited in a coastal area, that was covering Chwarta –Mawat area while the central area of the basin located at Sharazoor – Piramagroon plain in addition to present location of the anticlines.

2- Karim (2004), in the same area, cited that 500m conglomerate of Tanjero Formation in Chwarta- Mawat area has equivalent of 400m sandstone in Sharazoor-Piramagroon plain. He correlated both conglomerate and sandstone in the two areas and proved that both were time and lithologic equivalent.He measured the distance between the conglomerate and sandstone, after the removal of effect of folding, to about 25km. Therefore when the same principle is applied for the Kolosh Formation, it is obvious that



Figure(6.1) Diffrent type of tectonic and paleogeographic setups of Red Bed Series in diffrent ages by diffrent authors. A, B and C by Al-Hashimi(1985), D, by Surdashy (1998). It is proved, in the present study, that all these setups are not applicable for the Series.



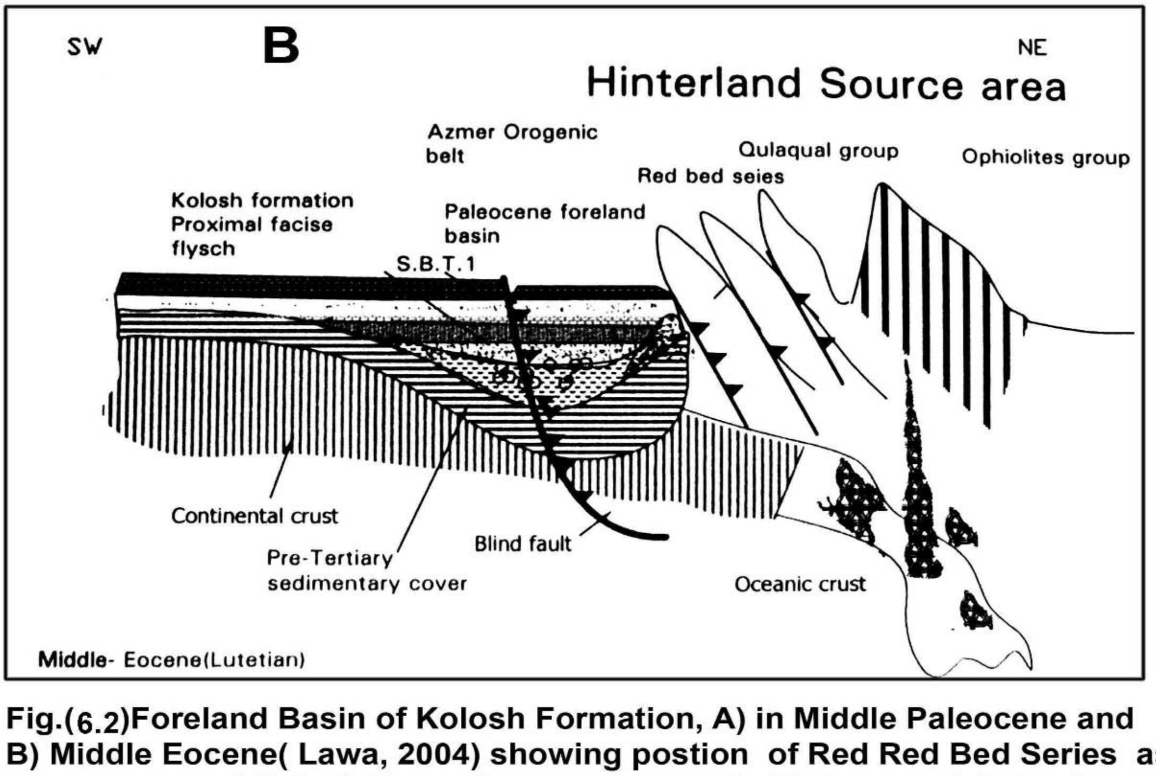


Fig.(6.2)Foreland Basin of Kolosh Formation, A) in Middle Paleocene and B) Middle Eocene(Lawa, 2004) showing postion of Red Red Bed Series as source area of Kolosh Formation or as separated intermountain basin.

the Kolosh and Gercus Formations are time equivalent to the Red Bed Series (or to some parts of the series).

3- The extensive fieldwork (in this study) failed to find the sediment of coastal area of Kolosh Formation. According to principle of sedimentology huge thickness of conglomerate must be deposited in coastal area of these two formations. As the Red Bed Series with Kolosh and Gercus Formations have nearly same age so the best coastal area, which fit with the basin of the Kolosh and Gercus Formations, is the depositional area of the Red Bed Series. It is worthy to mention that the previous studies have mentioned nothing about the coastal area of the Kolosh Formation.

4- The paleocurrent direction of Units Two, Three and Four of sediments of the Red Bed Series is toward southwest (Fig.3.2) while that of Unit Five (Chwarta conglomerate) point toward the south. The maximum development of the Kolosh formation exists at the same directions. In other side, the sediment of the Red Bed Series is deposited by rivers and alluvial fans, therefore, the paleohigh can not be put infront of the river, which transport sediments south of the Red Bed Series.

5- The measured paleocurrent of the Kolosh Formation in Dokan area at 500m to the west of Qulka village is same as that of the Red Bed Series at the 100m. West of Diralla Village, at Chwarta area. This paleocurrent is measured by Flute cast and channel in both units (Photo5.1). This also refuses the presence of paleohigh during deposition of most parts of the Red Bed Series.

6-The lithologic study of both units proved that both have same source areas. These source areas consisted of Qulqula Radiolarian Group and ophiolite complex. In addition to the above source areas, the upper part of the Red Bed Series (Chwarta Conglomerate) have a source area consisted of Walash – Naoperdan Series.

7-No clasts of Kometan, Shiranish and Tanjero Formations are found in the sediment of Red Bed Series; this proves that there was no prominent paleohigh to a scale shown by Al-Hashimi and Amer (1985), and Surdashy (1998) (Fig.6.1). If the paleohigh existed between the Red Bed Series and the

Kolosh Formation, the paleohigh must have neen suffered from erosion and supplied sediments to the basin of the Red Bed Series.

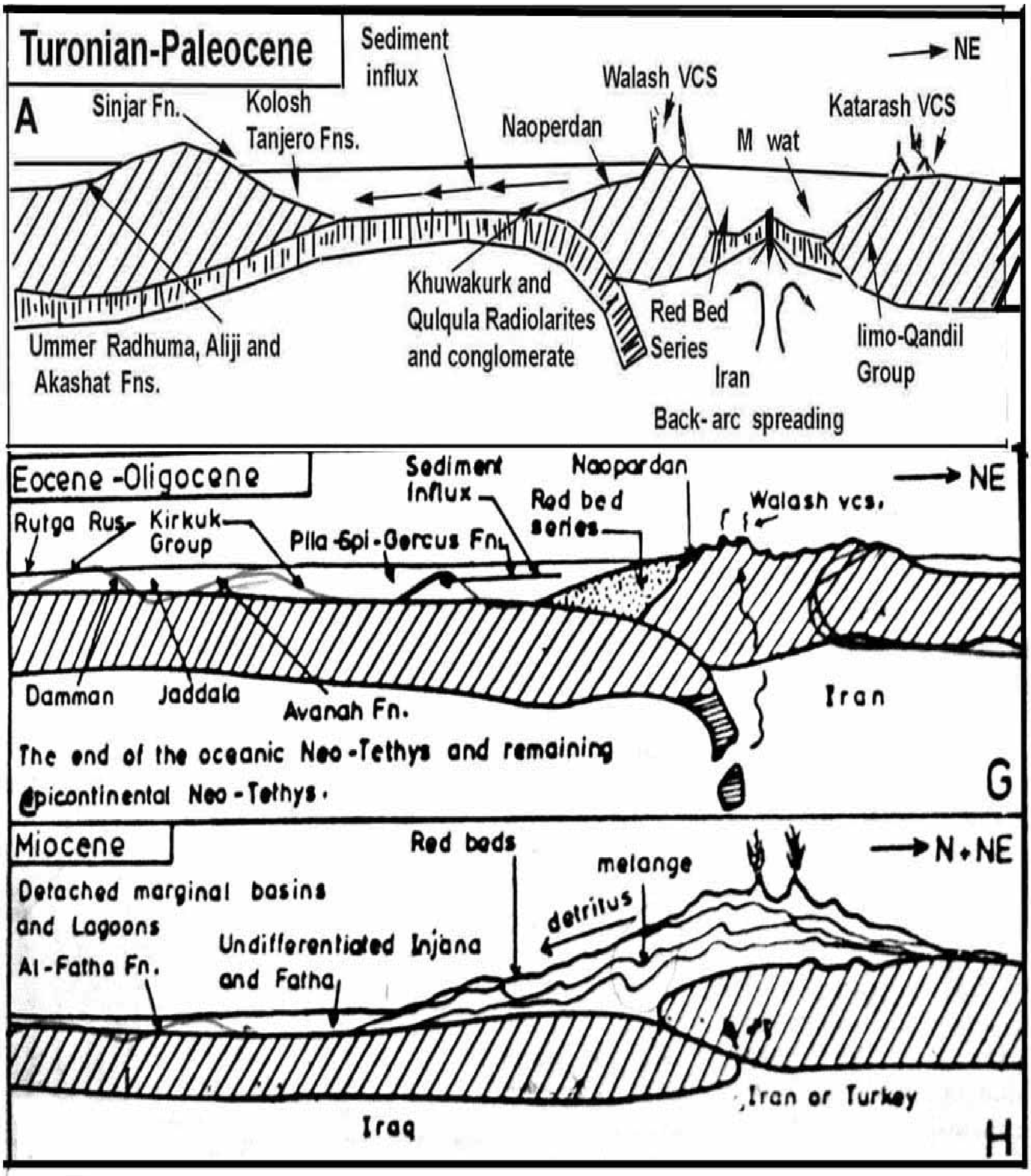


Fig.(6.3) Different stages of Evulotion of Red Bed Series as related to plate tectonics(Numan, 1997).

According to the above points, the sediments of the Red Bed Series, Kolosh and Gercus Formations are deposited in single basin (in most time) and nearly under the same tectonic effects and eustatic see level change. In other side, the series is deposited under effect of tectonic of Paleocene and Eocene only and not extending to Miocene as mentioned before. This is because, there is no evidence to show that the basin of the Red Bed Series is extended, in age, from Paleocene to Miocene as mentioned by Buday (1980), and Al-Mehaidi (1975, p. 36). But this does not means that in some time intervals there was no paleohigh. During deposition of Sinjar Formation and Naoperdan Series, the possibility of a submerged paleohigh must not be excluded. This paleohigh in the basin decreased the accommodation for clastic sediment to accumulate in high thickness and relatively wide distribution. This is because the paleohigh generate barrier in front of sediment transport and decreases the kinetic energy of the sediment and turbidity current obtain during free transport from source area and when the obstacles (paleo-highs) were not grown up. During existence of this paleohigh, only little fine clastics are deposited which were eroded later during sea level fall or reefal limestone had grown on them because of clastic decrease.

8- Red Bed Series can be correlated with the Kolosh Formation on the basis of lithology and paleocurrent as follows:

A- The red interval of lithology of the series is located near the base (Unit One and Two). The equivalent of the interval exists also at the base of Kolosh Formation at Dokan area at right bank of Qashqully stream, which consist of fine brown shale. The brown interval is more obvious at south Jally Village near the Gorge of Smaqully (North of Koyia town).

B- Karim (2004), found a para-and polymictic conglomerate, that exist at the top of the Tanjero Formation in Chwarta-Mawat area (He named it “Tagaran Conglomerate”). This conglomerate also exists at Dokan area and has same lithology as that of Chwarta area, and in both areas composed of rounded pebbles of igneous, metamorphic and sedimentary rocks.

C- The middle part of the Kolosh Formation, lithologically and stratigraphically is most probably equivalent to the conglomerate of Unit Two. Especially the sandstone of the Kolosh Formation is similar in their constituent to the conglomerate of Unit Two at Mawat and Qandil Mountain toe (Photo2.11).

6.2-Changing of the previous time expanded stratigraphic column of Tertiary

When one looks at the time expanded stratigraphic column of Tertiary drawn by (Jassim et al.,1984 in: Al-Rawi, 1977) (Fig.6.5A), he realizes that no position is indicated for Red Bed Series. Later all other authors worked on Tertiary of Iraq applied the same column without any changes (among these authors Buday, 1980, Buday and Jassim (1987). In the present study, as a result of lithologic correlation and sequence stratigraphic study, new relation with Kolosh and Gercus Formations is established and new expanded stratigraphic column of Tertiary is drawn (Fig. 6.5A and B) which shows that distribution of time and locality of Red Bed Series is located at the northeast of that of Kolosh and Gercus Formations with lateral possible interfingering relationship (Fig.5.2). Now the location of this interfingering is eroded and coincides with the position of Goezha, Azmir, Daban, Piramagroon, Sara and Kosrat anticlines.

6.3-One foreland basin for Kolosh Formation and Red Bed Series together

The term foreland basin is introduced by Dickenson (1974) on the principles that, mountain belt is associated with uplift of rock materials to several kilometers in height. Regions of subsidence, called foreland sedimentary basin, border the uplifted belts. These basins are “wedge shaped “in cross-section with depth that gradually decrease from the mountain belt towards the adjacent craton. He proposed two broad types of foreland basins:

1-Peripheral foreland basins, which are related to continent-continent collision.

2-Retro-arc foreland basins, which are related to the subsidence of oceanic lithosphere.

.

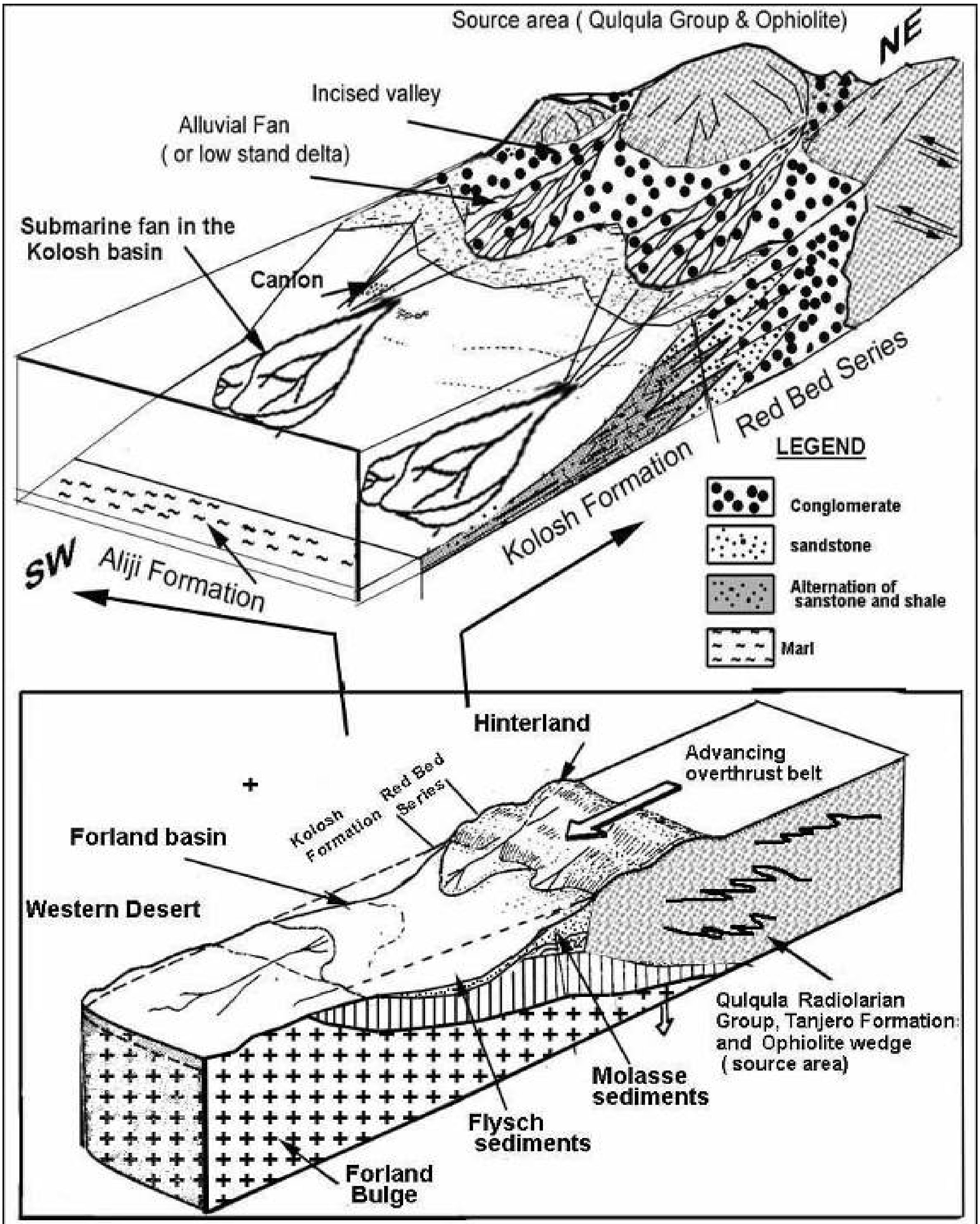


Fig. (6.4) Pleogeographic reconstruction of depostional environment ascombined with that of Kolosh Formation (upper Sketch) and tectonic setup of Red Bed Series as connected with that of Kolosh Formation during Paleocenc.

The basin and provenance of the Red Bed Series belong to type one in the above division. According to Einsele (2000) and Walker (1992), the thickest alluvial deposit occurs in several tectonic related basins, one of which is foreland basin. The thick accumulation (in some case reach 2500m) of conglomerate sandstone and red claystone in the basin of Red Bed Series (including basin of Kolosh Formation) is the evidence for foreland basin. Especially Karim (2004) proved that Tanjero Formation is deposited in an early foreland basin (He called it Early Zagros Foreland Basin). According to this tectonic setting, both Tanjero Formation and Shiranish Formations are deposited in one early foreland basin. So according to his suggestion the foreland basin started from upper Campanian. Al-Qayim (2000, p.112) is the first who showed that Kolosh Formation is deposited in foreland basin. The same type of basin is reported and showed by diagrams by Lawa (2004) for Kolosh Formation (Fig.6.2).

Dole *et al.,* (2001, p.111) mentioned that the sediments of the foreland basin are characterized by heterogeneous gravels, sands, and mud derived from orogenic belt. When the relation and correlation of the Red Bed Series and the Kolosh Formation is considered, it is obvious that both deposited in single foreland basin in coastal areas and off-shore respectively. The relation and correlation of both formations are discussed in Chapter Two and Three.
This foreland basin developed after colliding of Continental part of Arabian and Iranian Plate at Upper Cretaceous. This is associated with uplift of Qulqula Group and ophiolite complex with shedding huge quantity of sediments into the foreland basin during tertiary, which are deposited as the Red Bed Series, Kolosh and Gercus Formations. From Tertiary till now the continuous southwest advance of the frontal part of the plate, most probably, made

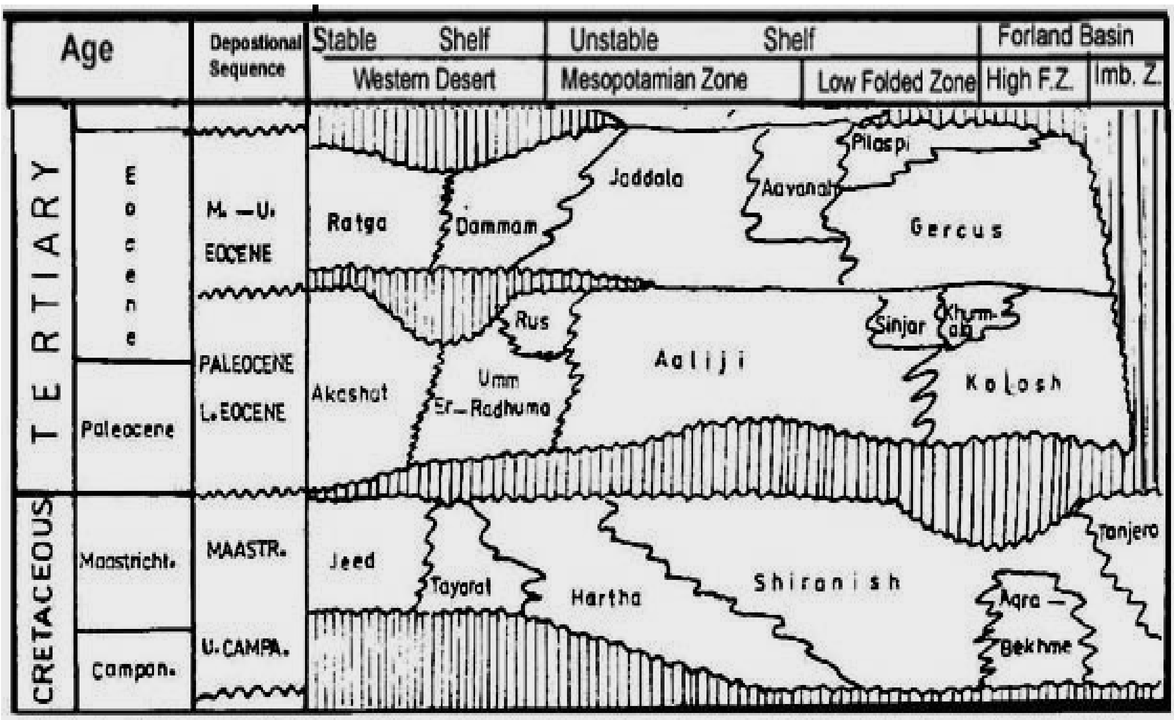


Fig. (6.4A) Time expaned stratigraphic column of Upper Cretaceous and Tretiary **(Jassim et al,1984) in:** **(Al-Rawi,1988) clear that the** postion of Red Bed Series is not Indicated.

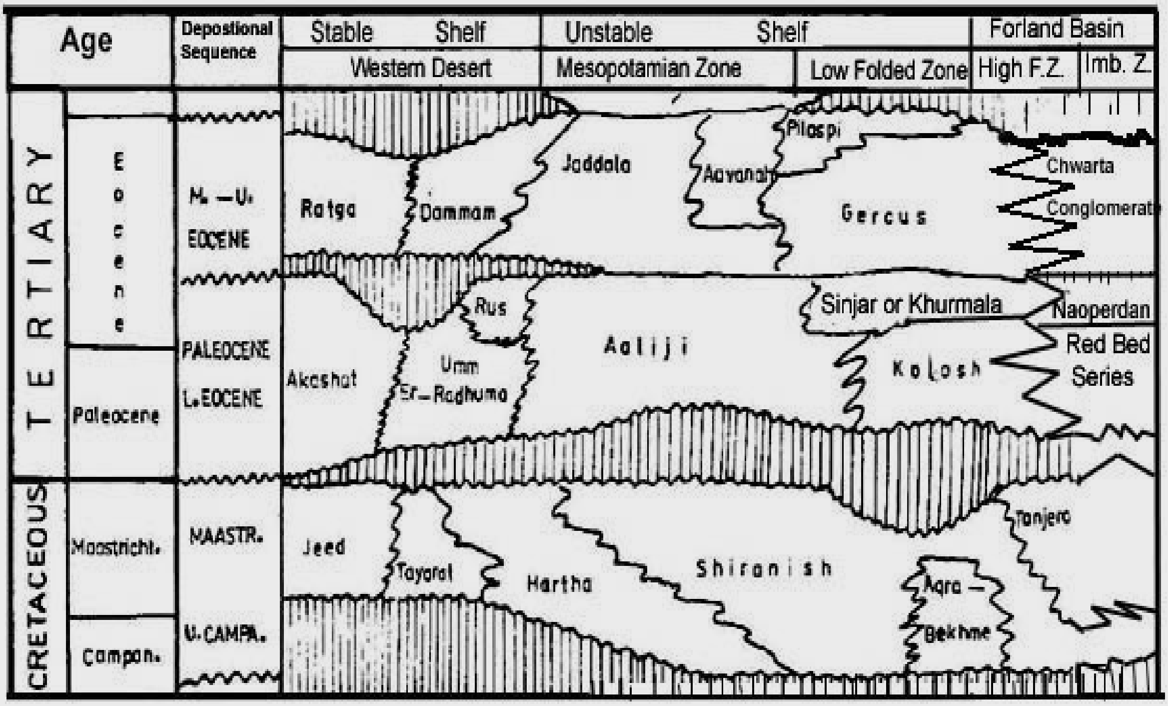


Fig (6.5B) Time expaned stratigraphic column of Upper Cretaceous and Tretiary (**above scketch**). The postion and relation of Red Bed Series with Kolosh **and Gercus Formation are** indicated as a result of the present study.

Some units of the Red Bed Series to be imbricated and the thickness appeared to be doubled. This phenomenon is not so clear in the field to be ascertained. But at least at one locality (near Suwais village) some sign of the imbrication can be seen in the unit five (Chwarta conglomerate). Buday (1980, p. 217) mentioned that the basin of the Kolosh Formation, in the unstable shelf, is separated from Red Bed Series in miogeosyncline. This tectonic separation of the two basins is based on the classic tectonic classification of the basins into many types of geosyncline. Numan (1997) separated tectonically and topographically Red Bed Series from Kolosh Formation.

In the present study, it is proved, in most time and in the studied area the basins of Red Bed Series and Kolosh Formation were combined during Paleocene and Eocene and cannot be separated tectonically and physiographically.

6.4-Alluvial fan development

Alluvial fans that progrades directly into standing body of water are termed fan delta or coastal alluvial fan. Alluvial fan and fan delta is sedimentary responses to flow expansion at basin margin, and so the identification of fan deposits in the ancient record may be a useful indicator of sharp basin – margin relief, commonly fault controlled (Mial, 1990). According to Burner and Smosa (2000) the fan delta in Spain during Carboniferous are formed in direct response to tectonic uplift along a nearby thrust-fault. Einsele (2000) observed coarsening upward alluvial fan (as seen in Red Bed Series from Unit One to Unit Five) that reflects growth during continuous faulting. Walker (1992) mentioned that alluvial deposits are sensitive indicators of allogenic processes, such as tectonism and base-level change. He also cited that the drainage (paleocurrent direction) and the orientation of proximal-distal facies change are basically perpendicular to basin margin (coastal area). He included foreland basin in this type of basin. Selley (1988, p.169) referred to the Alluvial fans as piedmont (mountain foot) fanglomerates, which are characterized by extremely coarse grain and poor sorting, by massive and sub-horizontal bedding and absence of fossils. He also attributed the great thickness of fanglomerates to repeated syn-sedimentary movement along fault scarp. The repeated fault scarp rejuvenation generates upward coarsening conglomerate cycles as fan prograding toward the basin depocenter.

The same results are cited by Blatt *et al*. (1980) and showed by diagram how a thick pile of alluvial fan is deposited in front of faults in a rapidly subsiding basin. Nearly all above mentioned characteristics (as mentioned by the authors) are more or less can be seen in the sediments of Red Bed Series which is deposited in front of advancing head of the Iranian plate. Unit Two, and Five all have the prerequisites for alluvial fan (low stand fan delta when reach water body) cited by above authors.

6.5- Provenance of Red Bed Series

It is clear from paleocurrent measurements that source area is located, directly, at the northern and northeastern of area of the present location of outcrops of the series. The lithology of the series showed that the most of the clasts are those that derived from Qulqula Formation, while those of ophiolite and Walash-Naoperdan Series are less and least common respectively. This arrangement of commonness of clasts is reversed in case of the closeness of source area. This is because the closest source area to the basin is the rocks of Walash-Naoperdan Series comes after it Qulqula and Ophiolite respectively. As a whole, the source areas are relatively close to the basin of deposition of the Red Bed Series. The closeness is demonstrated by subangularity of nearly all the clasts and the largeness of the clasts within the conglomerate. One can find blocks weighted more than 200kgm at Qandil mountain toe and 100kgm at Chwarta area (Photo3.6A). In the studied area, the source area changes from unit to others; even the same unit has different source areas for different localities. These changes are as the following:

1-At Chwarta and Mawat area, Unit One is completely derived from Qulqula Group, which is composed of limestone and chert pebbles and boulders. The limestone clasts are radiolarian fossil rich and grey or black in color.

2-At the same area, the source area of unit five (Chwarta conglomerate) changes to Qulqula Group, metamorphic rocks, ophiolite rocks and Naoperdan group. This mixture of many types of rocks may be attributed to:

A) Interconnection of more than two drainage basins in the source area so that each one responsible for influx of one type of rock clasts to the basin together or alone. When the lithology of rocks including one source area and change in other places, it attributed to abrupt change of provenance from local to more distant ones Ryu (2003). It is obvious from the lithology of Red Bed Series, that the valley streams through which the sediment transported were large and possessing high gradient as reflected by large transported clasts (block s).

B) The co-existence of three different clasts of different source areas are possibly attributed to deep dissecting of the source area by a large stream which caused consecutive exposing of several rock types along both sides of the valley.

C) Tectonic mixing during deformation of source area and during development of accretionary prism by continuous advancing of the thrust sheet towards southwest.

3- At Qandil mountain toe more than 70% of the clasts of Unit Five are limestone of Qulqula Group and the others are chert clasts.

4- The provenance of claystone and its red colors of Red Bed Series are attributed to the source area, which is rich in red jasper, brown shale and red siliceous shale of Qulqula Group (see section two for more details).

6.6- Relation between the Red Bed Series and Walash –Naoperdan Series

The most problematic issue in the tectonic and stratigraphy of the Imbricated and Thrust Zones is the uncertainty of the relationship between Walash – Naoperdan Series and other units in the two zones. Bellen, (1959) and Buday

(1980) and Buday and Jassim (1987) have not mentioned any things about the relation between the two series. Numan (1997) put each series in two different basins. He put Red Bed Series and Walash-Naoperdan Series in diverging basin and converging basins respectively (Fig.6.2). Al-Hashimi (1985) positioned the two series in two different local basin separated by emerged paleohigh (Fig.6.1B). In his model the former series located in southwestern basin while the latter is located in northeastern one. Al-Mehaidi (1975) and Surdashy (2001) indicated a tectonic boundary between Walash-Naoperdan and the Red Bed Series.

Previously Walash –Naoperdan Series was thought to be deposited at the extreme northern border of Iraq or even inside Iranian border. The field and sedimentological study do not aid this assumption and the existence of two different basins, which separated by emerged paleohigh. This is because type and amount of sediments are such that one can observe the continuous and high supply of coarse terrigenous clastics from north and northeast during nearly all time spans of Paleocene and Eocene. This huge quantity of sediment does not aid the existence of small source area or island between the two basins. Another reason is that, the reefal and pure limestone generally grows in the clear water, away from terrigenous clastic influx and tectonic activity. Therefore, we cannot put Walash –Naoperdan Series in the extreme northern boundary where is more clastic influx and tectonic activity than the the basin of the Red Bed Series. It is more convenient to put both series in the same basin. In this model (setting), Walash-Naoperdan Series is deposited during basin calm, and relative subsidence of the basin and source area). The most previous convenient model is that of Surdashy (1998), which positioned the two series in two basins, which separated by submerged paleohigh. But even this suggestion does not agree completely with field and sedimentological observations, which show existence of some stratigraphical relation between the two series.

According to the most previous models (see page 112), several parallel paleohighs extend in northwest-southeast direction, the first one located near the Iranian border while the second at 5km north to Sulaimaniya. The latter one coincides with Goizha, Sara, Daban and Kosrat anticlines. The sedimentological and structural evidences do not aid presence of these parallel-emerged paleohighs during Paleocene and Eocene. The thick accumulation of coarse sediments and southwestern paleocurrent direction refuse existence of the paleohighs because accommodation can not be created in narrow basin and to be continuous for long time during Paleocene and Eocene. As concerned to the structure, the present dip of the strata is not so steep to be accumulative of the dip angles from Paleocene to present.

In the present study, it is inferred that Unit Five (Chwarta Conglomerate) is not related to the Red Bed Series but it has different stratigraphic and tectonic setting which are not certain. Field study showed that this unit is younger than the Red Bed Series and the Naoperdan Series. This is because it contains reworked pebbles and boulders of the latter Series. The position of Chwarta Conglomerate between Units Four and Six may be attributed to the one of the following tectonic possibilities:

A- It is most possible that Chwarta conglomerate was representing alluvial fan, that were eroded from source area consisted of Qulqula Group, ophiolite and Walash –Naoperdan Series. The erosion is occurred at middle Eocene after deposition and uplift of the series. The Alluvial Fan is deposited unconformably on rocks of Paleocene and Lower Eocene (Fig.5.3 and 5.4 after tectonic correction). The deposition occurred as alluvial fan at the base of mountain range (on mountain toe) that surrounded the basin of Eocene. More specifically, the Chwarta conglomerate is deposited on the mountain slope bordering the coastal area of the Gercus Formation and Naopurdan Series, while the Gercus Formation itself deposited in the deltaic environment.

It is possible that the climate was semi-arid one and during the seasonal storm deep erosion scored deep incised valleys during sea level fall. The valleys later filled with boulder and block conglomerate forming alluvial fan. The paleocurrent direction of Unit Five is towards south while other units have southwest direction. The valleys were descending from north toward south due to the effect of tectonic stress and stream dissection now unit five appears as a depostional unit of the Red Bed Series.

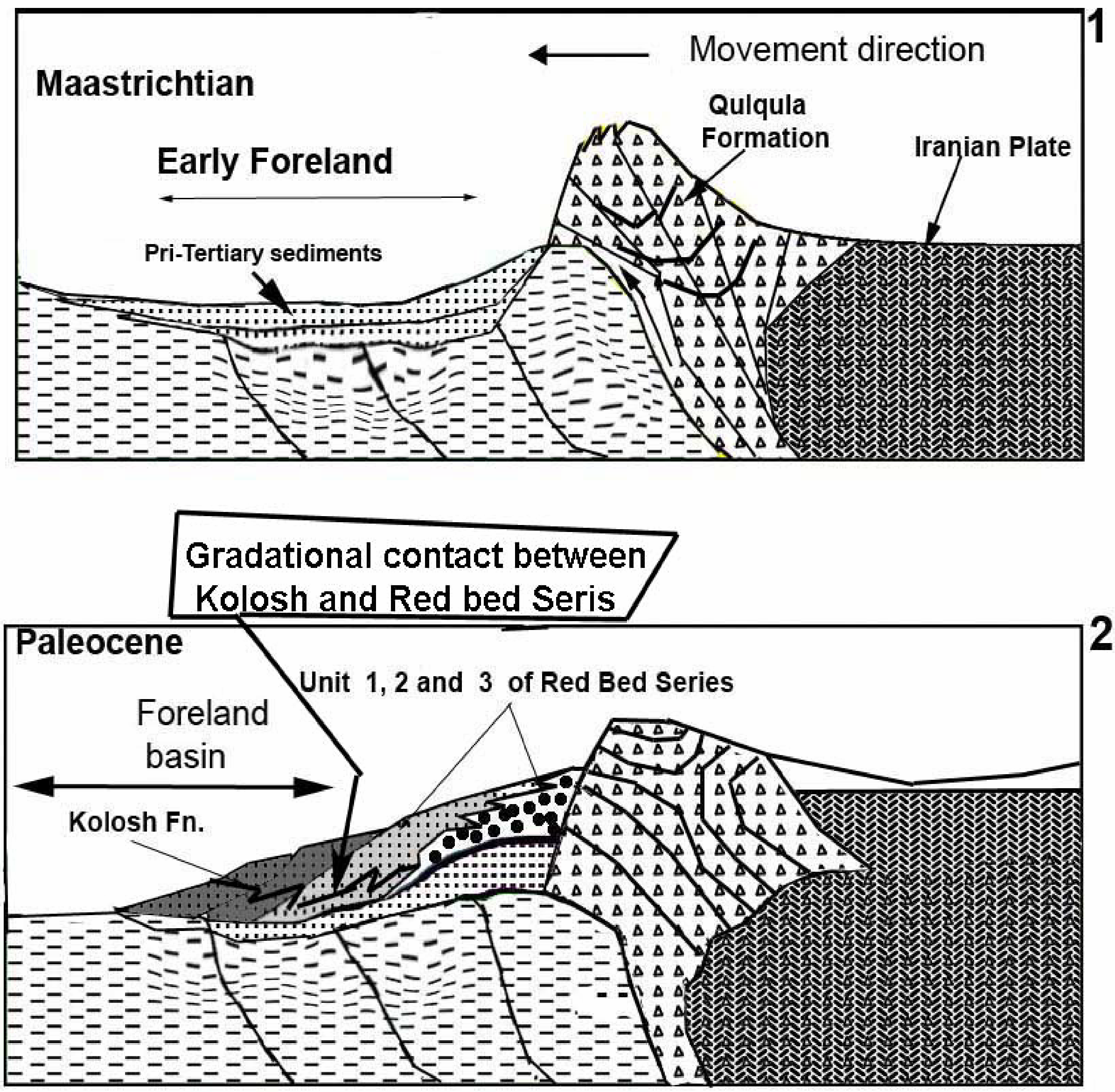


Fig.(6.6) Tectonic development of Red Bed Seies basin during Late Maastrichtian and Paleocene.

B- It is possible that the present position of unit five is stratigraphically in the right position (Fig.2.4 and 2.6 before tectonic correction). According to this, the nummulite in the pebbles and boulders may be belonging to an age (upper Paleocene) younger than Walash-Naoperdan.

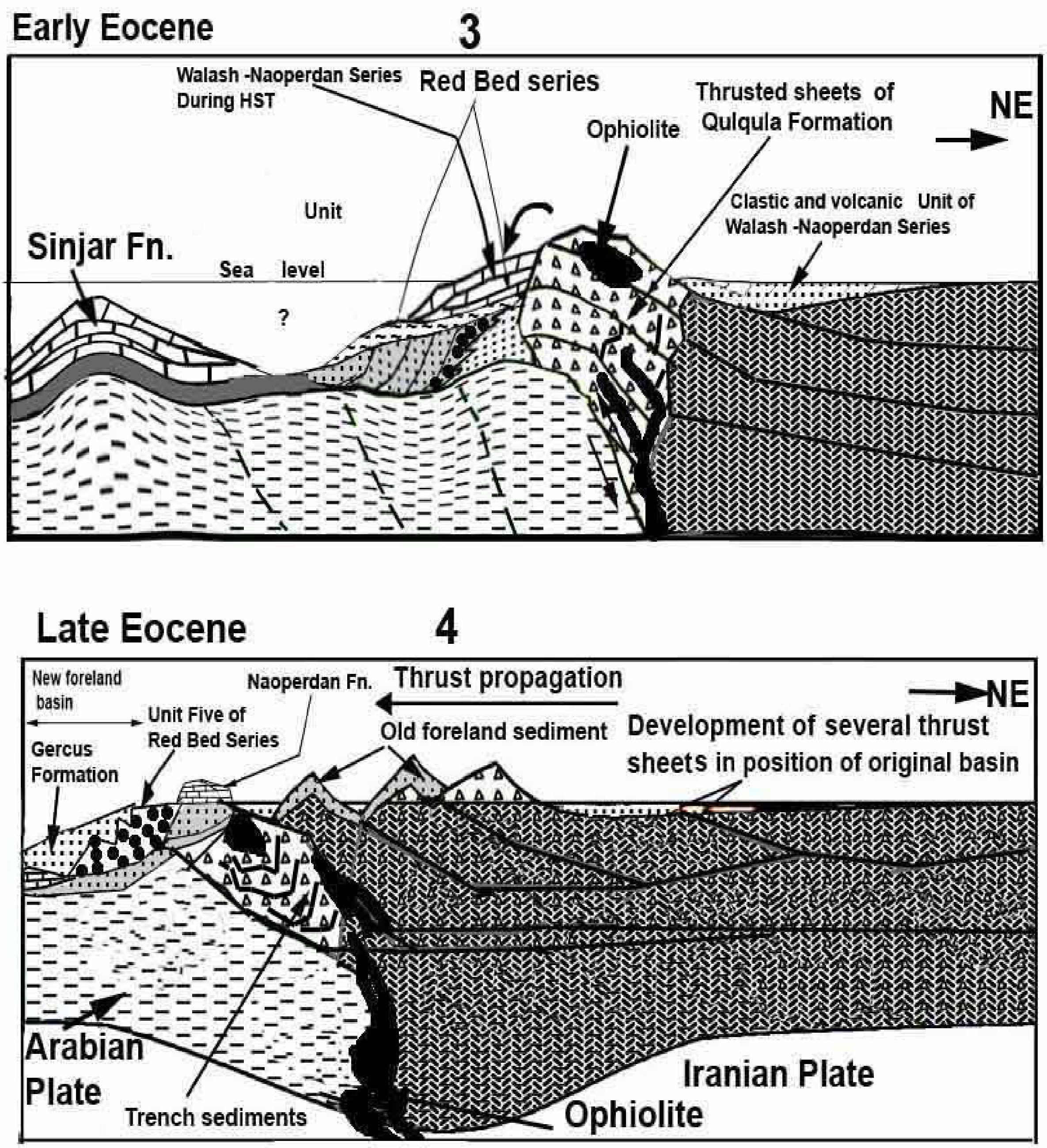


Fig. (6.7) Tectonic development of Red Bed Series in the foreland basin

During this age, nummulite-bearing layers are deposited and then eroded during early Eocene. For this assumption it is necessary to conduct precise boistratigraphic study for both Walash-Naoperdan series, and the pebbles and boulders in the Red Bed Series to prove the exact relation between the two units.

6.7-Paleo- Shoreline of Paleocene Foreland Basin

Nearly, all previous studies as mentioned before, have not indicated the paleoshore line of Paleocene – Eocene basin. This is because they all separated the basin of the Red Bed Series from that of the Kolosh Formation. These studies are regarded the present position of Goezha, Azmir, Daban and Kosrat mountains (or anticline) as the paleohigh which was separated the two basins.

Recently Lawa, (2004) indicated the shoreline of Paleocene foreland basin as a straight line passing through Dokan town from the northwest and coinciding nearly with the Tanjero River from southeast. But in the present study the shore line of the basin is indicated at the south of Mawat-Chwarta and Khurmal town, which nearly coincide with the maximum deposition of the Red Bed Series during HST (Fig 6.8). This indication is base on the combining of the two basins of the Red Bed Series and the Kolosh Formation in a single one. The combination of the two basins is achieved by detail field study of the lithology, facies, and sedimentary structures.

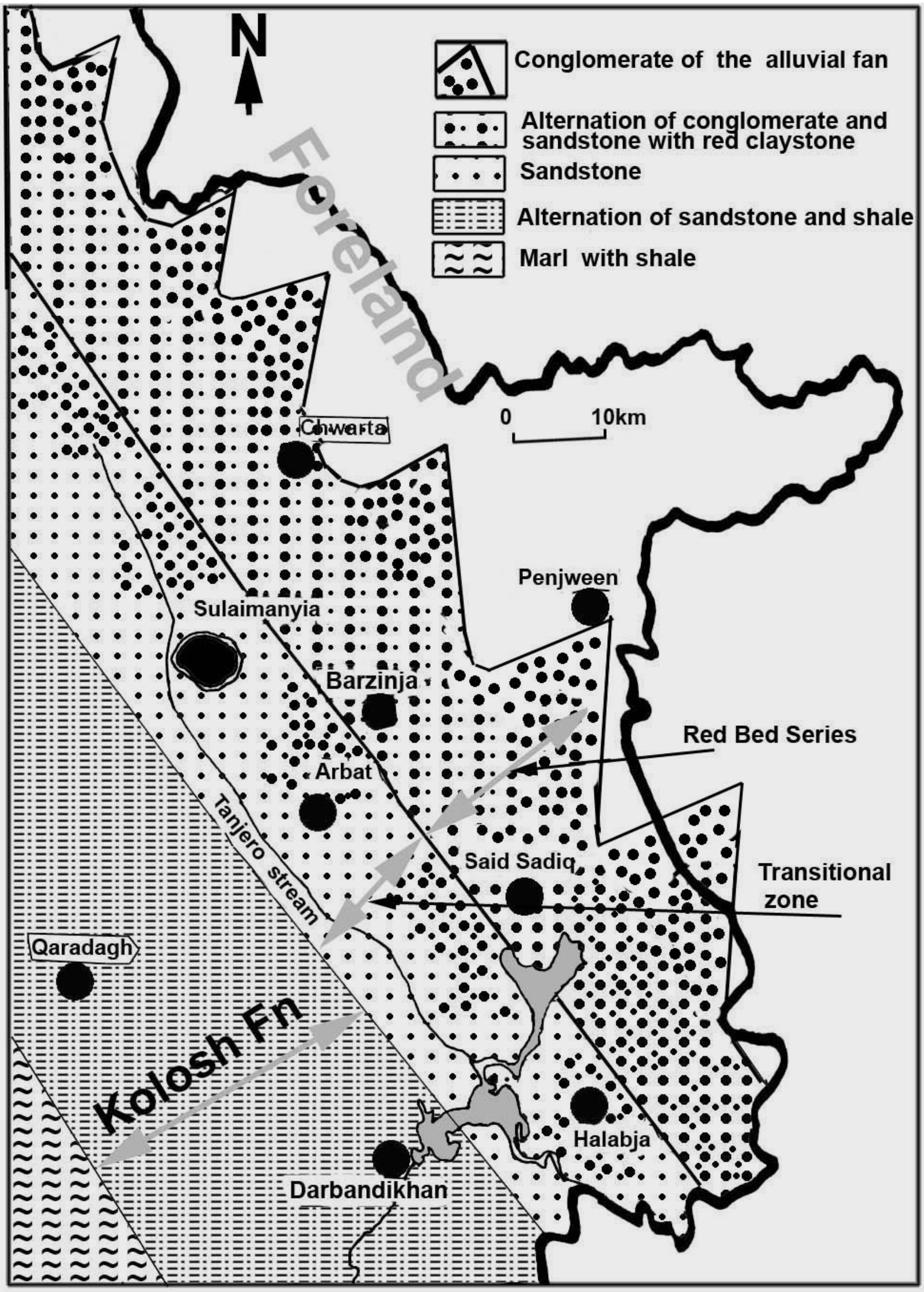


Fig. (6.8A) Extend of the Foreland basin during Paleocene in which both Kolosh Formation and Red Bed Series are deposited.

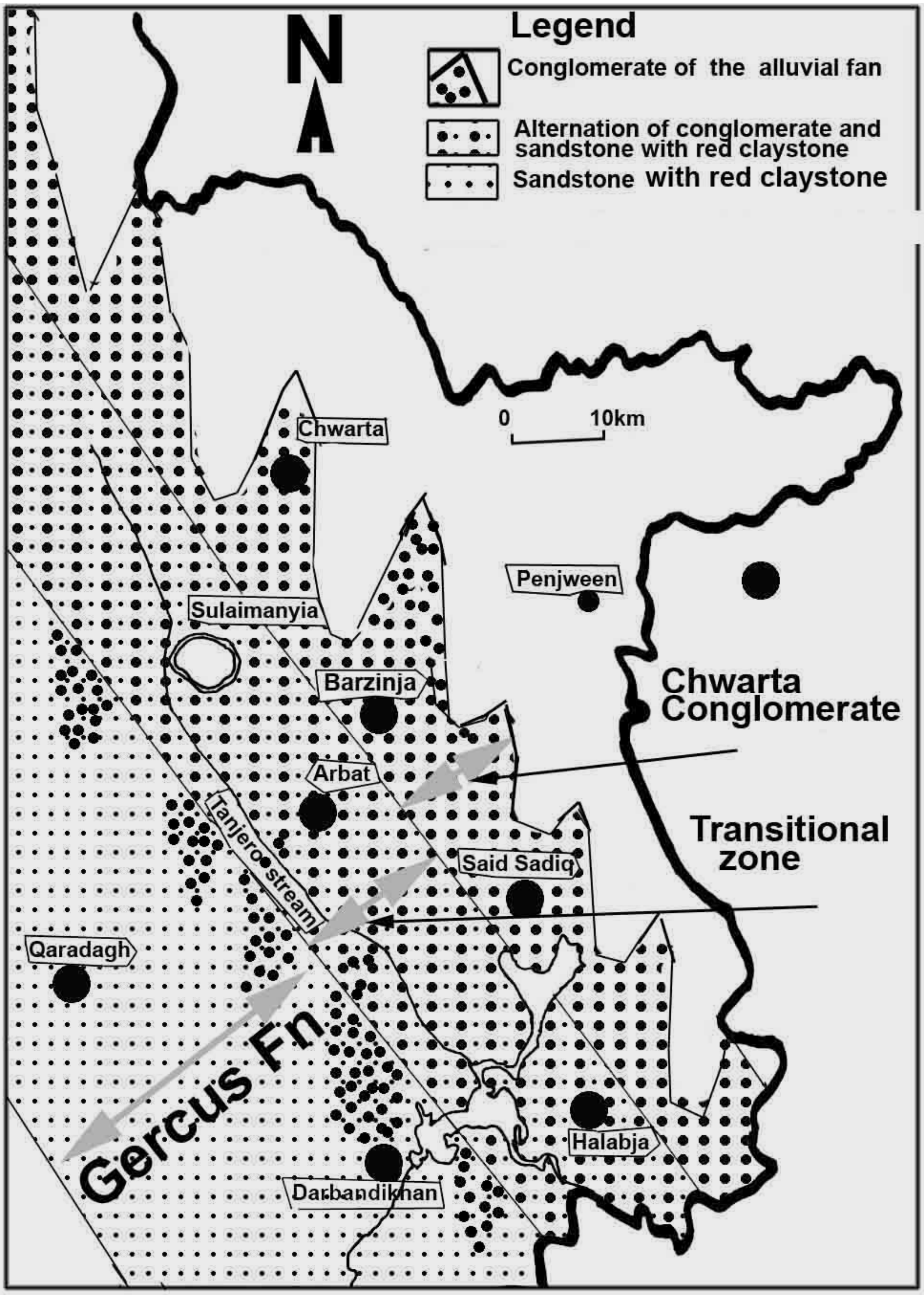


Fig.(6-8B) Extend of foreland basin during Eocene in which Gercus Fn and Red Bed Series are deposited

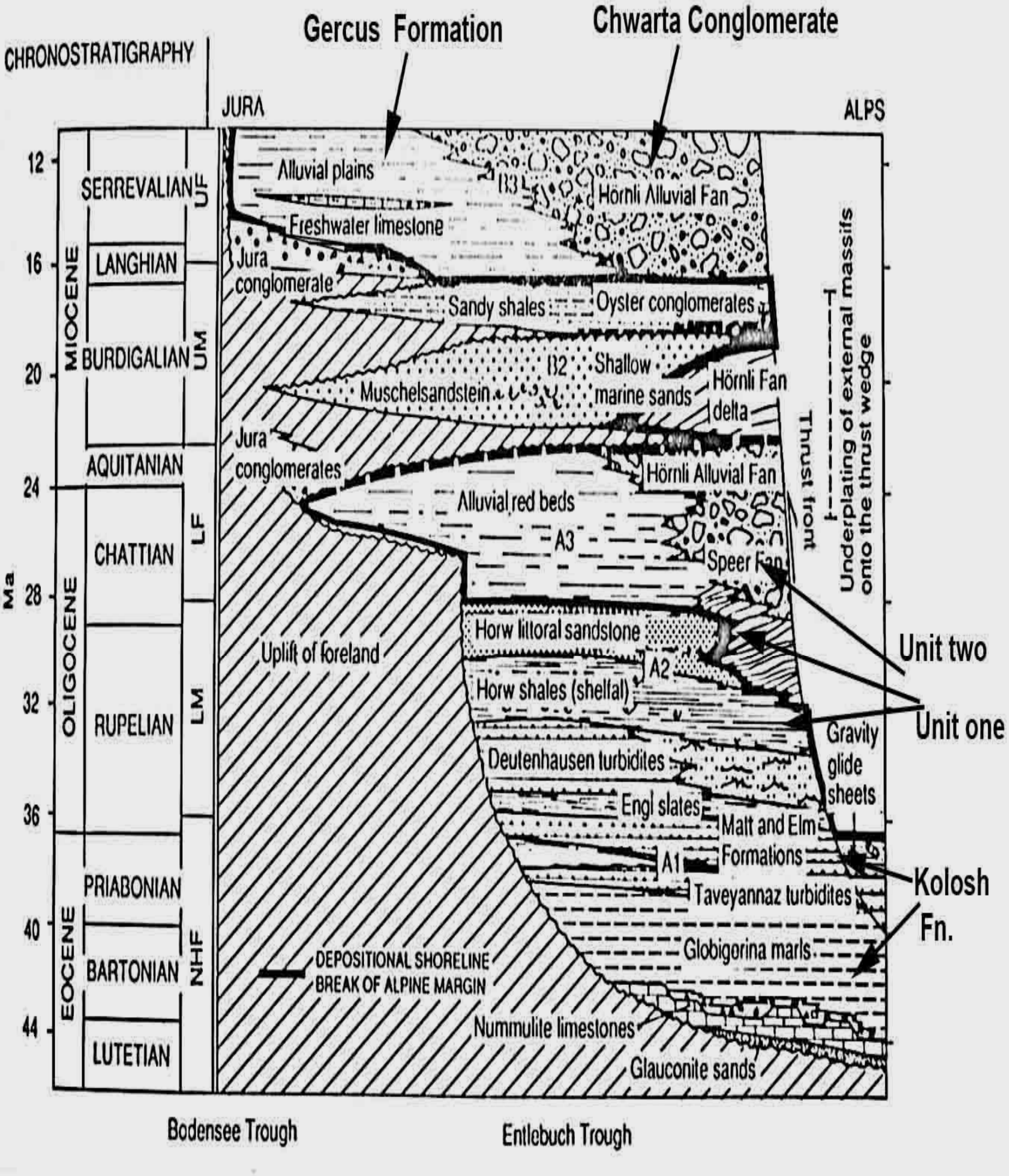


Fig.(6.8) Stratigraphic (time expanded) column of North Alpine Forland Basin compiled by Sinclair et al in: Allen and Allen 1990. The lithology, tectonic and environment of the area are nearly similar to that of Chwarta area. The comparison with units of Red Bed Series are shown on the right and upper margins

CONCLUSIONS

This thesis has the following conclusions:

1- On the basis of stratigraphy and lithology the series is divided in Chwarta-Mawat area, into six units in contrast to the previous studies, which divided the series into three units.

2-Unit One (at the base of the series) is composed of red fine clastics (red claystone and bluish white marl), while change to the sandstone in the area around Suwais Village. This unit represents deposits of HST and included in depostional sequence (lower sequence), which exist at the top of Tanjero Formation. It is possible that this unit deposited in either delta plain or in delta slope. The existence of the white thin bed clayey limestone is attributed to deposition in ponds in the delta plain.

3- Unit two consists of about 16m of chert and limestone conglomerate with prevalence of red color at Chwarta and Mawat area while the share of Igneous increases towards west. This unit deposited during sea level fall (regression or LST). The erosional base of this unit represents the starting point of the second sequence (middle sequence). The coarseness and badly sorting of this unit denote deposition in alluvial fan as channel lag deposits.

4-Unit three consists of more than 500m of thick-bedded gray sandstone with interlayers of grey to brown claystone. The sediment of this unit is overlying the LST and its deposits belong to TST of the middle sequence. Compositionally the sandstone consists of lithicarente with abundant content of limestone and chert clasts in addition to minor amount of quartz. The quartz grains are mainly derived from plutonic igneous rocks. The grains content of this sandstone is plotted on compositional triangle of Folk (1974), Pettijohn (1975) and Al-Rawi (1982).

5-Unit four consists of alternation of red layers of claystone, sandstone with lenses of conglomerate, which returned to episode of HST which the area suffered from slight base level uplift because of the sediment fill. The lithology of sandstone and conglomerate consisted of sedimentary, igneous and metamorphic clasts. Units one and two are correlated with the Kolosh Formation on the bases of lithology and stratigraphic position.

6-Unit five is the most obvious and thickest unit of the series in all areas except the western part of Qandil area (Naudasht valley), which change to claystone and sandstone. It consists of chert; limestone, igneous and metamorphic pebbles and boulders in Chwarta-Mawat area, while in eastern part of Qandil mountain toe, near Suwais village, it contains only chert and limestone pebbles and boulders. This unit, as low stand wedge, was deposited by forced regression during main sea level fall (LST) and has identified equivalent low stand sandstone wedge inside Gercus Formation. This unit represents obvious alluvial fan deposits, in which many braided bars observed during the field study. These bars shows large scale cross bedding , irregularities at their erosional base, holes and channels.

7-On the basis of fossils content it was proved, in this study, that unit five has no stratigraphic relation with the Red Bed Series. This is because this unit contains alveolina and nummulite, large forams, of Walash- Naoperdan Series.

8-In sequence stratigraphy, the rock body of the series is divided into three depostional sequences (lower, middle and upper depostional sequences). Each of these is further analyzed into their systems tracts. The systems tracts of the units are lowstand, highstand and transgressive systems tract. The most obvious systems tract is lowstand systems tract, which consist of Lowstand wedge about 1000m of boulder and block polymictic conglomerate. During lowstand many incised valleys scored in the sediment of the previous highstand which filled by coarse conglomerate. The closest (probably equivalent) formation to this unit in distal area is Gercus Formation. This is inferred on the basis of lithologic study of both units.

9-It was observed that, because of shallowness (mostly continental) of the environment the lithofacies of each systems tract is highly variable in different areas. The most important work in sequence stratigraphy is the correlation of systems tracts of the Red Bed Series at Chwarta, Mawat and Qandil Mountain area, at Imbricated Zone, with the equivalent parts of the Kolosh and Gercus Formations at distal area (High Folded Zone). This correlation is the first one done for the different sections of the Red Bed Series in one side and with the Kolosh Gercus Formations in other side.

10- By above correlation, the previous age of the Red Bed Series changed from Paleocene –Miocene age to Paleocene - Eocene age only.

11- Another very important result of this thesis is proving that the Red Bed Series and the Kolosh Formation sharing the same depostional basin and having the same tectonic setting, moreover, both representing lateral facies change of each other. This is also true for the relation of unit five (Chwarta conglomerate) with the Gercus Formation.

12-In this basin, the Red Bed Series is deposited in rapidly subsiding coastal area of the Early Foreland basin while the Kolosh Formation deposited in deeper part of the basin. The basin existed in front of the southwest advancing tectonic nape.

13-The environment of the series is highly variable; mainly consists of high gradient braided streams which transfer coarse and fine sediment to alluvial fan which merge into lowstand fan delta when reachs the main water body of foreland basin. The delta plain and front environments are not excluded. As concerning depth it ranges from continental to shallow marine environment while the salinity ranges from dominate fresh river water to brackish and possible invading of normal marine water occasionally inside the incised valleys. Water turbidity is changed from highly turbid water in the incised valleys and in front of alluvial fans.

14-The petrology of the sections showed that the source area of each one was different. Even the source area of each section was different in different times. The clasts are dominantly derived from the Qulqula Radiolarian Formation at the area of eastern part of Qandil mountain toe while that of Chwarta-Mawat area are derived from both Qulqula Radiolarian and ophiolite source rocks with share of Walash–Naoperdan series as less important source area. The source area was consisted of overthrusted sheets of frontal part of Iranian plate.

15-In this study many sedimentary structures are found in the series such as, flute cast, small and large scale cross bedding, ripple marks, parting lineation, imbricated pebbles, lamination, truncated layers and plant debris. Most of these structures are found in unit three (sandstone unit) and few ones are found in the upper conglomerate.

16-The paleocurrent analyses, as revealed by above structures, are presented on rose and stereonet diagrams shows southwest direction for units two, three and four while unit five shows clear southward paleocurrent direction.

17- The origin of the red color in the Red Bed Series is discussed and attributed to the derivation from source area (Qulqula Formation).

18-The tectonic setup of the series and the neighboring formations are discussed in detail. Tectonically, they all deposited in a foreland basin. This foreland basin was covering both the present days Imbricated and High Folded zones without existence of paleohigh (most times) in the basin of foreland basin. Both Red Bed Series and Kolosh Formation are affected by the same tectonic setting during Paleocene. During Eocene the tectonic activity was more intensified, which caused uplift both the basin and source area. This is manifested by a very thick accumulation (1000m) of polymictic conglomerate. In the distal area, instead of Kolosh Formation, Gercus Formation is deposited which is correlated with that 1000m. of polymictic conglomerate.

19- The time expanded stratigraphic column of the Tertiary is changed to agree with the result of this study. Red Bed Series is shown on this column as lateral gradation with both Kolosh Formation and Gercus Formation.

REFERENCES

Abdel-Kireem, M. R.1986a. Contribution to the stratigraphy of the Upper Cretaceous and Lower tertiary of the Sulaimaniya – Dokan region, Northeastern Iraq. N. Jb. Geol. Paleont. Abh.172 (1) pp.121-139.

Ainsworth, R. B. and Crowley, S. F. 1994. Wave–dominated near shore sedimentation and “forced” regression: post abandoned facies, Great Limestone Cyclothem, Stainmore, UK. Journal of the Geological Society, London, vol.151, pp.681-695.

Allen, P. A. and Allen, J. R. 1990. *Basin Analysis: Principles and Application*. Blackwell Scientific Publications, 450p.

Al-Ameri, T.K., Al-Rawi, I.K. and Khoshaba , B.N. 1990. Palynology of Unit one of Suwais Red Beds, Chwarta , Northeast Iraq. Iraqi Journal of Science. Vol.31, No.1.

Al-Hashimi, H., A. J. and Amer R., M. (1985). Tertiary Microfacies of Iraq. DGGSMI. Baghdad.p56.

Allison M. A., Khan, S.R., Goodberd, S.L. and Kuehl, S.A. 2003. Stratigraphic evolution of the Late Holocene Gange-Brahmaputra lower delta plain. Sedimentary Geology, vol. 155, pp317-342.

Al-Mehaidi, H. M. 1975. Tertiary Nappe in Mawat Range, N.E Iraq, Jour*. Geol. Soc. Ira*q, vol. 8, pp. 31-44. .

Al-Qayim, B. 2000. Sedimentation and tectonic environment of the Suwais Red Beds, NE-Margin of the Arabian plate-5th international on the geology of the Arab world, Egypt. Abstract book, p.112.

Al-Qayim, B. and Al-Shaibani, S. 1989. Stratigraphic analysis of Cretaceous –Tertiary contact, Northwest Iraq. Journal of Geological Society of Iraq, vol. 22, no. 1.

Al-Qayim, B. and Al-Shaibani, S. 1989– lithostratigraphy of Cretaceous - Tertiary transects Bekhme Gorge, Northwest Iraq. Iraqi Geological Journal vol. 28, no. 2.pp. 127-136.

Al- Rawi, Y. 1982. Carbonate-rich sandstone: occurrence, classification and significance. *Iraqi J. Sci.* Vol.23.No.3

Al-Shaibahi, S. Al-Qayim, B. and Salman, L. 1986. Stratigraphic analysis of Tertiary Cetaceous contact, Dokan area, North Iraq, *Journal of Geological Society of Iraq,* vol. 19, no. 2.

Ameen, B.M. 2002. Lithological indicators of Oligocene gap (unconformity) at the boundary between High and Low Folded Zones, NE-Iraq. Iraqi Journal of Geology (in press).

Bates, R. L., and Jackson, J.A.(ed.) 1980. *Glossary of Geology*, 2ed, American Geological Institute, 749 p.

Bellen, R. C. Van, Dunnington, H. V., Wetzel, R. and Morton, D., 1959. Lexique *Stratigraphique, Interntional. Asie, Iraq*, vol. 3c. 10a, 333 p.

Bhattacharya, J. P. and Willis, B.J. 2001. Low stands Delta in the Frontier Formation, Powder River Basin, Wyoming: Implications for sequence stratigraphic Models. AAPG Bulletin, Vol. 85. No. 2. Pp.261-294.

Blatt, H., Middleton, G. and Murray, R. 1980. *Origin of Sedimentary Rocks.* Second edition, Prentice Hall Pupl. Co., New Jersey, 782p. .

Bloom, A.,L. 1998. Geomorphology: A systematic Analysis Of Late Cenozoic Landforms. Third edition. Prentice Hall Publ. Co. 482p.

Bolton, C.M.G., **1958D**.The Geology of Ranya area. Site Inv Co. Upubl. Report, SOM Library, Baghdad.

Buday, T. 1980. In: *Regional Geology of Iraq:* Vol. 1, Stratigraphy, I.I.M Kassab and S.Z. Jassim (Eds) D. G. Geol. Surv. Min. Invest. Publ. 445p.

Buday, T. and Jassim, S.Z. 1987. *The Regional geology of Iraq: Tectonism Magmatism, and Metamorphism*. I.I. Kassab and M.J. Abbas (Eds), Baghdad, 445 p.

Bruner, K. and Smosa, R., 2000. Stratigrahic and tectonic relation in Spain cantabarian Mountain : Fan delta meets carbonate shelf. Journal of Sedimentary Rocks, Vol.70, No, 6.pp,67-84

Dickinson, W.R.1974. Plate Tectonic and sedimentation: in Dickenson, W.R. , 1974.Tectonic and sedimentation. Spec. Soc. Econ. Paleont. Miner. Tulsa,22,pp.1-17.

Dott, R. H. 1964. Wacke, Grewacke and matrix: approach to the immature sandstone classification . Journal of sedimentary Petrology Vol. 34 pp.625-632.

Doyle, P., Bennett, M. R. and Baxter, A.N. 2001. The Key to the Earth History: An Introduction to Stratigraphy. Second edition, John Wiley and Sons. New York. 293p.

Einsele, G. 1998. Event Stratigraphy: Recognition and interpretation of Sedimentary Even Horizons, in: Doyle, P. and Bennett, M. R.(editors). Un*locking the Stratigraphical Record*, John Wiley & Son, New York, and 532 p.

Einsele, G. 2000. *Sedimentary Basin: Evolution, Facies and Sediment Budget*. 2nd ed. Springer, Verlage Berlin 792p.

Emery, D. and Myers, K. 1996. *Sequence Stratigraphy.* Blackwell Scientific Limited. 297p.

Emery, A. F. 2002. Tectonic and eustatic signal in sequence stratigraphy of the Upper Devonian Canadaway Group, New York State (Discussion) AAPG, Vol.86, No. 4, p.695.

Folk, R.L. 1974. *Petrology of Sedimentary Rocks*. Hemhill Peb. Co. Texas, 182p.

Folk, R.L., Andrews, P.B. and Lewis, D.W. 1970. Detrital sedimentary rocks classification and nomenclature for use in New Zealand. N.Z.J. Geol. Geophsics . Vol.13.

Gallaway, E. W. 1989. Genetic stratigraphic sequences in basin analysis: Architecture and genesis of flooding- surface bounded depositional units. *AAPG*, vol.73, no. 2, p.125-142.

Gayara, A., K. and Al-Ubaidi, M.I. 2000. High resolution sequence stratigraphic analysis of the Amij siliciclastic – carbonate succession, western Iraq.Iraqi, J. Science , Vol.41C, No.4. pp.138-149.

Haq, B. U. 1991. Sequence stratigraphy, sea level change and significance for deep sea. Special. Publs. int. Ass. Sediment, 12. pp.. 12-39.

Holland, C. H. 1998. Chronostratigraphy (Global standard Stratigraphy): A personal Perspective, in: *Unlocking the Stratigraphical Record (Advance in Modern Stratigraphy).* John Wiley & Sons, New York, Toronto.

Hoy-Richard, G. and Ridway-Kenneth,D., 2003. Sedimentology and Stratigraphy of fan-delta and river –delta deposystems , Pennsylvanian Colorado , AAPG Bulletin, V.87, No.7, pp 1169-1191.

Smith,G. J. and Jacobi, R. D. 2001. Tectonic and eustatic signal in the sequence stratigraphy of the Upper Devonian CanadaWay Group, New York State, *AAP*, vol.85, No.2 Pp. 325-360.

Karim, K. H. 1999. Stratigraphy of Sartaq-Bamo Area from northeastern Iraq. Iraqi Geological Journal ,Vol.31, no. 1

Karim, K.H. 2004. Basin analysis of Tanjero Formation in Sulaimaniya area, NE-Iraq. Unpublised Ph.D. thesis, University of Sulaimani University, 135p.

Karim, K.H. 2003a. A conglomerate bed as a possible lower boundary of Qulqula Formation, from Chuarta-Said Sadiq area, NE-Iraq. Kurdistan Academician Journal (KAJ), University of Sulaimani ,**vol.2** Part A.

Karim, K.H. and Surdashy, A. M., 2005. Paleocurrent analysis Upper Cretaceous Foreland Basin: A case study for Tanjero Formation in Sulaimaniya area NE-Iraq. Iraqi Journal of Earth Science of Mosul University. (in press)

Karim, S. A. 1975. Biostratigraghy of the Red Bed Series, Chwarta, NE-Iraq. *Jour. Geol. Soc. Iraq, special issue*, pp.147-156.

Lawa, F.A. Al-Karadakhi, A. I, Ismail, K. M. 1998. An interfingering of the Upper Cretaceous rocks from Chwarta-Mawat Region (NE-Iraq). *Iraqi Geolo. Journal,* vol.31, no.2.

Lawa, F.A.2004. sequence stratigraphic analysis of the middle Paleocene – Middle Eocene in the Sulaimani District(Kurdistan Region). Unpublished Ph.D. thesis, University of Sulaimani.

Loutit, T. S., Hardenbol, J., Vail, P. R., and Baum, G.R. 1988. Condensed section: The key to the age dating and correlation of continental margin sequences. In: *sea level change: an integrated approach*.(Eds Wilgus. C. K., Hastings, B.S., Kendall, C. G. St. C., Posamentier, H., Ross, C. A. and Van Wagner , J*.) Soc. Econ. Paleontol. Mineral., Spec*., Publ.42. Pp.183-215.

Mail, A. D.1985. Architecture- element analysis: A new method of facies analysis applied to fluvial deposits. Earth Science Review, Vol. 22. pp. 261-308.

Mial, A. D. 1990. Principles of Sedimentary Basin Analysis, 2edition, Sringer-Verlage, 668p.

Mial, A. D. 1992. Collision related foreland basin in: *Tectonics of Sedimentary Basin* (Eds. R.V. Ingersol and C. J. Busby) pp 393-424. Black Science, Oxford?

Mail, A. D. 2002. Architecture and sequence stratigraphy of Pleistocene fluvial system in the Malay Basin based on seismic time –slice analysis. AAPG Bulletin. Vol. 86. no.7.pp1201-1220.

Mohyadin, I. M. j. and Merza, T.A. 2004. Composition and origin of white carbonate layer in Seramerg- Tagaran area, Sulaimani, Iraq. Journal of Zankoy Sulaimani, vol. 16. no.2, pp17-23.

Nichols, G. 1999. *Sedimentology, and Stratigraphy*, Blackwell Science Ltd., 355 p.

Numan, N.M.S., 1997. A plate tectonic scenario for the Phanerozoic succession in Iraq*. Iraqi Geological Journal*, **vol.30**, no. 2, pp.85-110.

Omari, F. S. and Sadiq, A., 1977.Geology of North Iraq, Mosul University Press.198p.

Pettijohn, F. J. and Potter, P. E. and Siever, R., 1987. Sand and Sandstone, 2nd edition, Springer-Verlag, Berlin, New York, 543 p.

Potter, P. E., and Pettijohn, F. J. 1977. Paleocurrents and basin analysis. 2nd edition, Springer Velage Berlin, 413p.

Pettijohn, F. J., 1975*.* Sedimentary Rocks*.* Third edition, Harper and Row Publ. Co., 627p.

Potter, P.E., Maynard, J. B. and Pryor, W.A. 1980. *Sedimentology of Shale: Study Guide and Reference Source*, Springer-Verlage, 306 p.

Posamentier, H.W., Allen, G.P., James, D. P. and Tesson, M. 1992. Forced regression in sequence stratigraphic framework: concepts, examples, and exploration significance. *AAPG Bulletin,* no. 79 pp. 1687-1709.

Posamentier, H. W., 2002. Ancient shelf ridge –A potentially significant component of the transgressive system tract: case study from offshore of northwest Java. AAPG Bulletin, **vol.86**, no. 1, pp75-106**.**

Reading, H. G., 2004. Sedimentary environment process, Facies and Stratigraphy,688p.Black well science . Third Edition (with corrections).

Rust, B. and Koster, E. 1984. Coarse alluvial deposit, In: Walker, R. G. (Editor). *Facies Models,* 2nd edition, Geosciences Canada Reprints,317p.

Ryu, I. C. 2003. Petrography diagenesis and provenance of Eocene Tyee Basin sandstone, southern Oregon Coast Range: New view from sequence stratigraphy. The Island Arc .Vol.12 pp.398-41.

Samuel, A., Kneller, B., Rasian, S., Sharp, A., and Parson,C.2003. Prolific Deep- marine slope channels of the Nile Delta , Egypt. AAPG. Vol.(87). No. 4. pp541-560.

Selley, R.C. 1988. *Applied Sedimentology*, Academic Press London. 448p.(RBS)

Shanmugam, G. 2002. Ten turbidite myths. Erath- Science Reviews, vol.58, pp.311-341.

Shao, L. , Zhang, P., Hilton, J., Gayer, R., Wang, Y., Zhao, C. and Luo, Z.,2003. Paleoenvironment and paleogeography of the Lower and lower Middle Jurassic coal measures in the Turpan-Hami oil-Prone coal basin, northwestern China. AAPG Bulletin , Vol.87, No.2. pp.335-355.

Skinner, B. J. and Porter, S. C. 1987. *Physical Geology*. Wiley & Sons New York, p. 750.

Smith, G. J. and Jacobi, R. D. 2001. Tectonic and eustatic signal in the sequence stratigraphy of the Upper Devonian CanadaWay Group, New York State, *AAP*, **vol.85**, No.2 Pp. 325-360.

Surdashy, A. M. 2001. Paleoenvironmental reconstruction by calcareous algae at Paleocene –Early Eocene in Northeastern Iraq. Journal of Zankoy Sulaimani, **vol.4**, no.1, pp.101-116.

Stephen, K. D. and Dalrymple. M. 2002. Reservoir simulations developed from an outcrop of incised valley fill strata. AAPG. Bulletin, Vol. 86, No. 5. pp.797-812.(RBS)

Tucker, M. E. 1991. *Sedimentary Petrology.* Blackwell Science Publication Co. 260p.

Walker, R. G. 1982. *Facies Model, 2nd Edition, Geosciences Canada Reprinted* Series1, 318p.

Yagishita, K. (1994). Antidune and traction- carpet deposits in deep-water channel sandstones, Cretaceous, British Columbia, and Canada**.** Journal of Sedimentary Research, Vol. A64, No. 1. pp34-54.

Van Wagoner, J. C., Jones, C.R. Mitchum, R.M.,Jr.,Campion,K.M. and Rahmanian, V.D. 1990. Siliciclastic sequence stratigraphy in well logs, cores and outcrops: Concepts for high resolution correlation of time and facies. *AAPG, Method in Exploration Series, Tulsa, 755p*.

Vail, P.R., Mitchum, R.M., Todd, R. G., Widmier, J.M. and Hatleid, W.G. 1977a. Seismic stratigraphy and global changes in sea level. In: *seismic Stratigraphy – Application to Hyrocarbon Exploration* (ed. by C. E. Payton). Memoir of the American Association of the Petroleum Geologists, Tulsa, vol. 26, pp49-62.

Vincent, S. J., Macdonald, D. I. M. and Gutterige, P. 1998. Sequence Stratigraphy*, in*: Doyle, P. and Bennett, M. R. (editors). *Unlocking the Stratigraphical Record*, John Wiley & Sons, New York, 532 p.

Zelilidis, A. , Piper, D. J. W. , Kontopoulos, N. 2002. Sedimentation and Basin Evolution of the Oligocene-Miocene Mesohellenic Basin, Greece. AAPG Bulletin, V.86, No.1, pp161-182.

ثوختة

ز ة ضينة سورةكان (ثاليؤسى -مايؤسى)كة دةردةكةون بة شيوةيةكي سةرةكي لة ناوضةي سةر يةك كةوتوو (Imbricated zone)وة بةشيوةيةكي كةم لة ناوضـةي (Thrust zone) لـة سـةرووي ؤذهةلا عيراق.ئةم ضينانة دريذدةبنةوة بة شيوةي ثشتينةيةكي تةسك لة سةرووي ڕؤذئاوا-خـوارووي ڕؤذهةلات,نزيك وة تةريب بة سنووري ئيران.ئةم ز ةية ثيكهاتووة لة ئالَوطؤريكي ضـةند ضـينيكي ئةستوور لة بةردي و قوڕ و كؤنطلؤم ةيت.

ثشت بةس بة ليسؤلؤجي و ستراتيطرا ,ز ةكة دابةشكرا بؤ شةش يةكـة لةناوضـةي ضـوارتا-ماوةت.يةكةي يةكةم ثيك ديت لة قوڕي سور و مارلَي سثي ش باو,ئـةم ثيكهاتةيـة لـة ناوضـةي ڕؤذهةلا شاخي قةنديل دةطؤريت بؤ بةردي ي.يةكةي دووةم ثيـك ديـت لـة ضـةند ضـينيكي كؤنطلؤم ةيت بة ئةستووري ١٧ م (حةظدة مةتر) كة دةنكؤلَةكا بريتية لة ضيرت وة بةردي كلـسي كة ڕةنطةكةيان سوورباوة.يةكةي سييةم ثيك ديت لة ضةند ضينيكي ئةستوري بةردي ي بة ڕةنطيكـي خؤلَةميشي وة ئةستوريةكةي زياترة لة ٥٠٠ م (ثينج سةد مةتر) وة ضةند ضينيك لة قوڕي سووريتيكةلَ بةم ضينة ئةستورانة دةبيت , ئةم يةكةية ضةند سترةكضةريكي نيـشتووي تيدايـة وةك ضـينة يـةكتر برةكـان,ڕيثـلَ مـارك وة فلـوت كاسـت,ثا ـاوةي ثارضـةي ڕووةكـي لةطـةلَ ضـينة وردينة(Lamination).يةكةي ضوارةم ثيك ديت لة ئالَوطؤايكي قواي سوور ,بةردي ـي,وة ضـةند ضاويك لة كؤنطلؤم ةيت (Conglomerate lenses).يةكةي ثينجةم كة طةورةترين يةكةية لة ڕووي

ئەستوريەوە وە لە زۆربەي شوينەكان دەردەكەويت بيجطە لە بەشي ڕۆذئاواي شـاخي قەنـديل كـە دەطۆڕيت بۆ بەردي ي و بەردي قوڕ.ئەم يەكە ئەستورە كە ثيكهاتووە لە كۆنطلۆم ەيت لە ناوضـەي ضوارتا-ماوەت دەنكۆلَەكا ثيكديت لە دەنكۆلَەي طەورە و بضوكي ضيرت ,بەردي كلسي,بـەردي ئاطرين و طۆڕو.بەلام لە بەشي ڕۆذهەلا شاخي قەنديل وە نزيك طوندي (سيوەيس) دەنكۆلەكا ئەم ضينة كۆنطلۆم ەيتة دەبيت بە ضيرت ,بەردي كلسي يـە تـە ا بـە هـەمان طـەورة و بـضوكي دەنكۆلَەوە.بەلام لە بەشي ڕۆذئاواي شاخي قەنديل دەنكۆلَەكا وەك ناوضەي ضوارتا-ماوەت وايە.ئـەم يەكەية دەنكۆلَەكا بە شيوەيەكي اوون و ئاشكرا ئاراستەي ثيوە ديارە ,وە هەروەها ضينة يـەكتر بـاي طەورەي تيداية.يەكەي شەشەم (بەشي سەرەوە) ثيك ديت لە مارلَ وە قوڕ لەطەلَ هەندي ضي بـەردي ي. كاري بەراورد كردن ئە ام درا بۆ سي يرطەي جياواز لە سي ناوضـەي جيـاواز دا لـە شـاري سليما ,بەراورد كردنەكە ثشت بەستوو بوو بـە ليـسۆلۆجي و شـوي سـتراتيطرا يەكـەكان.

بەليكۆلَينەوەي ضينة ستراتيطرا (Sequence stratigraphy) بەردەكا ز ەكە دابەشكرا بۆ سـي ضينة نيش (Three depositional sequence) كـە ئـەوانيش بـريتة لـە ضـينة نيـشتووي خواروو,ناوەااست,سەروو,وە ئەم ضينة نيشتووانەش شيتەلَ كران بۆ ضەند اياەوە سيستەميك وەك ڕيرەوە سيستەمي نزم(Low system tract)ڕيرەوە سيستەمي بەرز(High system tract)وە ڕيرەوە سيستەمي ثيشڕەو(Transgressive system tract)وە ڕيرەوە سيـستەمي ةـەراغي شـيلَظ (Shelf margin system tract).ڕوونترين و ئاشكراترين ڕيرەوە سيستەم بريتية لە ڕيرەوە سيستەمي نزم كە ثيكهاتووە لە (Low stand wedge) .كە ئەستوريەكەي دەطاتـە ١٠٠٠ م (هـەزار مـەتر) وە ثيكهـاتووە لـە كۆنطلۆم ەيت كە دەنكۆلَەكا قەبارەي جياوازيان هەية وە لـە ضـەند سەرضـاوەيەكي جيـاوازەوە

هاتوون(Polymictic conglomerate).لة كا ڕيرةوة سيستةمي نزم دا ضـةندين شـيوي دارمـاو (Incised valleys) هةڵكةندرا يان دروست بوو لة ناو ئةو نيشتوانةي كة ثيشتر نيشتبوون بة تايبة لة كا ڕيرةوة سيستةمي بةرزدا.ئةم شيوانة ثا بوونةتةوة بة كؤنطلؤم ةيت كة دةنكؤلكا طةورةن.

بة هؤي نزمي حةوزي نيش (ضحالة البيئة) طؤڕانكاريةكي زؤر دةبينريت لة ڕيرةوة سيستةمةكاندا وة لة ضةند شوينيكي جياوازدا.طرنطترين دةرئة امي ضينة ستراتيطرا بريتيـة لـة كـاري بـةراوردكرد (مضاهاة)رياةوة سيستةمةكا ز ة ضينة سوورةكان لة ناوضةي ضوارتا-ماوةت وة شاخي قةنديل لة ناوضةي سةريةك كةوتوو (Imbricated zone) لةطةلَ بةشة تةواوكةرةكةي لة ثيكهاتةي كؤلؤش كة دورة لة ساحلةوة(Distal area) ئةميش لة ناوضةي (High Folded Zone).

ئةم بةراوردة يةكةم كارة كة ئة ام دراوة بؤ ضةند باطةيةكي جياواز لة ضينة سـوورةكان لةلايـةك وة ثيكهاتةي كؤلؤش لةلايةك وة بةهؤي ئةم بةراوردةوة ئةو تةمةنةي كة درابوو بةم ز ةية لة ئيؤسـ - مايؤس طؤرا بؤ ثاليؤس -ئيؤسي خواروو وة دةرئة اميكي تر كة بةدةست طةيشت لةم بـةراوردة دا بريتية لةوةي كة هةردوو ثيكهاتةي كؤلؤش وة ز ة ضينة سوورةكان بةشداري دةكةن لة يةك حةوزي نيش دا وة هةردووكيان بريت لة طؤرانكاري لابةلاي فةيشزةكان (Lateral facies changes) لةم حةوزةدا ز ة ضينة سوورةكان دةستيان كردووة بة نيش لة ناوضةي سـاحيلدا (Costal area of Early Foreland Basin) كة سيفا دابةزي (هبوط) خيراي هةبووة,بةلام ثيكهاتةي كؤلؤش لة بةشة قولَةكةي حةوزةكةدا نيشتووة.

بيئةي ز ة ضينة سوورةكان زؤر طؤاا تيدا رووداوة كة بة طش بريتية لة ثرضة اووبار (Breaded river) كة هيزيكي طةورةي طواستنةوةي هةبووة بؤ دةنكؤلَةي قةبارة جياواز (طةورة,بضوك)كة دةبيتة هؤي دروستكرد (Alluvial fan) كة ئةميش تيكةلَ دةبيت وة يةك دةطريت بؤ دروستكرد (Fan delta) لة كا اياةوة سيستةمي نزم دا.

سةبارةت بة قولَي حةوزي نيش ,دةست ثيدةكات لة بيئةي وشكانيةوة (Continental) بؤ بيئةيـ ـةكي دةريايي نزم (Shallow marine) وة سويري ئاوةكةي دةكةويتة نيوان ئاوي ش ي اووبار تا ئـ ـاوي سويري دةريا.

ليسؤلؤجي باطةكان ئةوة اوون دةكاتةوة كة سةرضاوةي دلروست بوو يةكةكا ئةم ضينة سـ ـوورانة طؤااوة,بؤ وونة سةرؤضاوةي ضةند باطةيةك لة ناوضةيةكدا دةطؤايت بة ثيي طـ ـؤاا كـ ـات .ئـ ـةو دةنكؤلانةي دةبينريت لة ناو ضينة سوورةكاندا بة زؤري دةطةاينةوة بؤ ثيكهاتةي قولقولـ ـة اديـ ـؤلاري بةتايبة لة بةشي اؤذهةلا شاخي قةنديل بةلام لة ناوضةي ضوارتا-ماوةت دةنكؤلَةكان دةطةاينةوة بؤ ثيكهاتةي قولقولة اديؤلاري وة بةردي ئؤفيؤلايت.لةم تويذينةوةدا ضةندةها سترةكضةري نيشتوو بينراوة لةناو ئةم ز ةيةدا وةك ضينة يةكتر باةكان,ايثلَ مـ ـارك,دةنكؤلَـ ـة سـ ـةريةك كـ ـةوتووةكان,ضـ ـينة ووردينة,ثا اوةي رووةكي.زؤربةي ئةم سترةكضةرانة بينراوون لة ناو يةكةي سييةم دا وة كةميك لةناو كؤنطلؤم ةيت دا .ئةم سترةكضةرة نيشتووانة شيتةلَ كردنةوةيان بؤ كراوة بؤ دؤزينةوةي ريرةوي ئاو لة كؤندا وة بة هؤي رؤز دايةطرام دةركةوت كة ريرةوي ئاوي كؤن بـ ـةرةو خـ ـوارووو وة خـ ـوارووي رؤذئاواية.

ثيكهاتةي بةردي و شيكردنةوةي دةرياي ز   ةي ضينة سوورةكان

لة ثاريزطاي سليما   ،باكووري رؤذهةلآ عيراق

نامةيةكة

ثيشكةش كراوة بة كؤليجي زانست لة زانكؤي سيلما   وةك بةشيكي

تةواوكةر   بؤ بةدةست هينا   دكتؤر اي   فةلسةفة لة زانس

جيؤلؤجي دا

لةلايةن:

ش زاد توفيق   مد

ماستةر لة زانس   جيؤلؤجي دا/١٩٨٩

بةسةرثةرش

د. علي   مو د اسعد سووورداشي

ثرؤفيسؤري ياريدةدةر

ِريبةندا ٢٧٠٤ كوردي شوبا ٢٠٠٥

زاييِ