BASIN ANALYSIS OF TANJERO FORMATION IN SULAIMANIYA AREA, NE- IRAQ

A THESIS

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SUMMARY

Tanjero Formation is an Upper Cretaceous (Campanian-Maastrichtian) unit, which crops out within the Imbricated and High Folded Zones in Northeastern Iraq. It stretches as narrow northwest-southeast belt near and parallel to the Iranian border. The formation mainly consists of alternation of clastic rocks of sandstone, marl and calcareous shale with occurrence of very thick conglomerate and biogenic limestones.

On the basis of main lithological distribution, in this study, the formation is divided into three parts (lower, middle and upper parts). These parts are correlated across six different sections, which are representing the available outcrops in Sulaimaniya Governorate except one section inside Iranian land. The correlation is based on lithology and stratigraphic position of distinctive conglomerate and its derivative sandstones, which are discussed in detail in different localities. The lower part (lower regressive part) is mainly composed, on the lower slope and basin, of thick aggradation of sandstone (100-400m), whereas on the shelf it is dominated by 500m thick succession of conglomerate. The middle part (middle transgressive part) is composed of 100-300m of bluish white marl and marly limestone on the slope and basin whereas it changes to calcareous shale on the shelf and to 20-50m thick of red claystone inside incised valleys along low stand coastal area. The upper part (upper regressive part) is chiefly consisting of 50-200m thick mixed carbonate-siliciclastic successions. The constituents of this succession are alternation of biogenic limestone and calcareous shale with miner amount of sandstone and conglomerate.

The composition of the conglomerates and the derivative sandstones is studied petrographically in detail and plotted on compositional tetrahedrons. Both rocks are mainly composed of the same type of rock clasts of chert and limestone. These clasts are dominantly derived from the Qulqula Radiolarian Formation with minor influx of igneous clasts from ophiolite source area. From the source area, these sediments are transferred to the low stand fan delta by river flooding. After that, storm and turbidity currents reworked them into deeper water through submarine fans. It is inferred that during sea level fall, the deep basin has become so shallow that the suitable situation was created for generation of storm deposits (tempestites), which are characterized hummocky cross stratification.

In this study many sedimentary structures are found in the formation such as skolithos and Cruziana trace fossils, escape structure, HCS, cross bedding, interference and traverse ripple marks, imbricated pebbles, sole marks and plant debris. Most of these structures are found in the lower part (in the low stand sandstone wedge) and few ones in the upper one but the middle part contain none of them. The paleocurrent analyses, as revealed by these structures, are presented in rose and stereonet diagrams show south and southwest directions.

The facies model of turbidite and tempestite are combined in one general model of lowstand fan delta, which shows prograding of shallow facies on deep marine ones. The environment, the position of the shelf, slope and basin of are plotted on map and discussed. Planktonic forams and Nereite trace fossil situations, in different parts of the formation, are treated. The possibility of the fossils (forams and radiolaria) reworking is also discussed in different environments. The environment of the formation is highly variable, concerning depth; it ranges from continental to deep marine environment while the salinity ranges from fresh river water to brackish and normal marine water. Water turbidity changed from highly turbid water in the incised valleys and in front of submarine fans to totally clear water at the time of reef growth in the upper part of the formation. These are reflected by existence of Kometan-like (pelagite facies), Shiranish-like (hemipelagite facies),

Aqra-like (reefal facies) and Red Bed Series-like lithologies (fine and coarse mollasse facies) respectively in addition to typical lithology of Tanjero Formation (flysch facies).

On the basis of the sequence stratigraphy, the whole Upper Cretaceous succession is divided into two identified depostional sequences, named upper and lower sequences. About 80% of thickness of the Tanjero Formation is deposited in upper sequence, which is bounded by SB1 and SB2 from below and above respectively. The rest (about 20%) of the formation is deposited in lower sequence. The SB1 is regarded as the major erosional and unconformity surface, which extended down the basin paleoslope from Chuarta area to Sharazoor plain during lower Maastrichtian. Thick conglomerate and sandstone wedges are deposited on this surface by forced regression. The regression may have resulted from tectonically enhanced eustatic sea level fall. At the top and directly below Red Bed Series, the formation ended by relatively thin conglomerate. This conglomerate, as an unconformity, exists only in some places and changes to correlative conformity in others. Therefore it is regarded as SMST, which is deposited as a result of basin fill (normal regression). Between the two-sequence boundaries and within upper sequence, LST, TST, HST and SMST are identified in addition to their surfaces.

The erosion of the shelf of the lower sequence shaped channels and incised valleys. More than four major incised valleys are found in the sediment of the previous HST (shelf of lower sequence). The sediments of these valleys consist of low stand wedge of conglomerate and high stand red claystone. Above the sandstone wedge at Dokan, Chaqchaq valley, Sharazoor and Piramagroon plains the transgressive surface can be seen clearly which is represented by sudden change of sandstone to marl with some interbeded marly limestone. This surface is the starting point for the deposition of thick transgressive system tract on the shelf. On the slope and basin it is relatively thin (30- 90m), which is lithologically similar to the lithology of Shiranish Formation (marl and marly limestone), of marine environment. The maximum flooding surface and possible condensed sections are discussed in detail.

In this study the basin of the formation is combined (tectonically) with that of the underlying Shiranish Formation and named Upper Cretaceous Zagros Early Foreland Basin instead of previous miogeosyncline. In this basin Tanjero Formation is deposited in the near shore depositional area, which is called Upper Cretaceous Depocenter, whereas, the underlying Shiranish Formation is mainly deposited in the deeper central part of the basin, which is called Upper Cretaceous Basin Center. The advancing of the hinterland (Iranian plate front) is very clear from southwest position changing of the shelf about 20km. The shelf of lower sequence was near the Iranian border during Upper Campanian while it migrated to the area around Chuarta and Mawat Towns during middle Maastrichtian. Moreover, in the chapter of tectonics, all old ideas of the tectonic of the basin are discussed and several new ones by the author are introduced.

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CHAPTER ONE:

INTRODUCTION

Basin analysis involves making an interpretation of the development, evolution, architecture and fill of a sedimentary basin by examining geological variables associated with the basin. The geological variables include all branches of geology. But, in the present study, the emphasis is put on traditional and sequence stratigraphy, lithology, sedimentary structures, facies association and fossil contents of the depostional area. All these are inspected in the field and lab for deduction of the environment, paleocurrent direction, basin fill architecture and tectonic of the basin in addition to the correlation and subdivision of the rock body of the formation.

Basin analysis provides a foundation for transferring known information into unknown regions in order to predict the nature of the basin where evidence is not available. This can assist the exploration and development of energy, mineral and other resources that may occur within sedimentary basins.

During fieldwork, the author observed many sedimentary structures and lithological changes, which are not studied before thoroughly. These observations revealed the need for additional detailed study of the formation as concerned with new division, environment and tectonic of the basin of the formation. The most important observation is the occurrence of thick succession of conglomerate along the northeastern boundary of the formation near the Iranian border in Mawat, Chuarta and Qaladiza areas. Another observation is the recording of thick succession of bluish white marl and marly limestone in the formation at the southwestern boundary of the formation at Sharazoor and Piramagroon plains in addition to Chaqchaq valley and Dokan area. Furthermore, the author has come across many new sedimentary structures, which were not mentioned before by previous workers. These observations gave hope for giving new modifying the old ones about environment, stratigraphy, tectonic of Tanjero Formation.

1.1-Location and Geomorphology

The studied area is located at Sulaimaniya Governorate, northeastern Iraq between Iranian borders on the northeast and Darbandikhan and Koyia towns in the south and southwest. This area is located between latitudes 35^{o} 10^{-} and 36^{o} 30^{-} north and longitudes 46^{o} 10^{-} and 44^{o} 40^{-} east. The studied area now covered by high mountains trending northwest –southeast. In the same direction and between these mountains exist narrow or wide subsequent (strike) valleys. The mountains and valleys are dissect by, at least, two consequent large valleys in which the river Little Zab and Diala Rivers flow. In this Governorate, the outcrops of the formation generally consist (as mentioned by previous workers) of thick alternation of dark green marl or calcareous shale and sandstone or siltstone. In the upper part, in some areas, the formation contains interbeds of conglomerate and biogenic limestone (Al –Mahaidi, 1975).

1.2-Geological Setting

The studied area is located south of Zagros Thrust Belt, which is developed from the basin fill of the Neo-Tethys Sea and colliding of Iranian and Arabian plates. Structurally the studied area is located within High Folded and imbricated Zones (Buday and Jassim 1987)(Fig.1.1 and 1.2), which is characterized anticlines and synclines (Fig.1.3) which are nearly coinciding with above mentioned mountains and valleys. Nearly two thirds of the formation outcrops are located in the High Folded Zone while the rest is located within the Imbricated Zone (Miogeosyncline). The formation is located at the core of the synclines (inside valleys) only whereas their continuation along the axis and limb of the anticline is removed by erosion. The strata of the formation are highly deformed inside synclines showing minor folding and flowage of the incompetent beds such as marl and calcareous shale.

The weathering resistive limestone of Qamchuqa, Balambo and Kometan Formations are covering surface of anticline. In the core of some of these anticlines, Jurassic rocks are exposed such in Piramagroon, Sara, Kurra Kazaw and Karokh anticlines (Fig1.2). The northern limit of Tanjero outcrop distribution nearly coincides with the boundary between Thrust and Imbricated Zones (Fig.1.1), whereas the southern boundary nearly coincides with the boundary between High and Low Folded Zones.

In the whole studied area, as a rule Shiranish Formation underlies Tanjero Formation gradationally. The contact is marked at the first appearance of gray sandstone or siltstone beds at the top of Shiranish Formation (bluish white marl and marly limestone) and starting of olive green lithology of Tanjero Formation. According to Bellen *et al.*, (1959) In the High Folded Zone Kolosh Formation overlies the formation unconformably.

While in the Imbricated Zone, according to Lawa *et al.,* (1998), Red Bed Series overlie the formation conformably. The type section of the formation is located at Sirwan valley near Halabja town about 50 km to the southeast of Sulaimaniya City (Bellen *et al*. 1959)

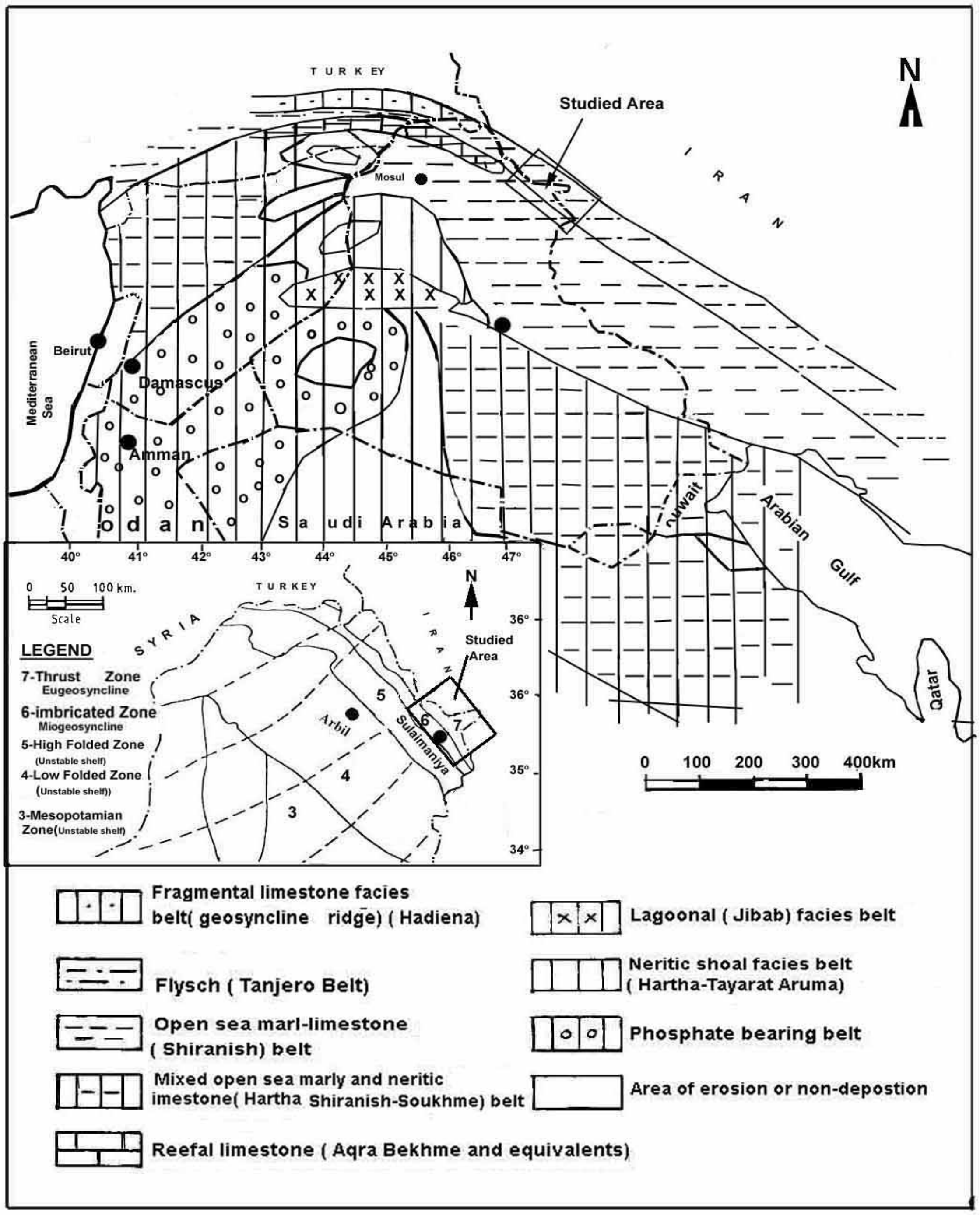


Fig. (1.1) The upper map: Upper Campanian- Maastrichtian facies distribution showing the location of Tanjero and Shiranish Formation (Buday 1980), Lower left map: Tetonic map of Northern Iraq (Buday and Jassim, 1987). The Studied area in this study is shown in both maps.

1.3 Studied Sections

For detailed study of the formation, eight sections (Fig. 1.2A) are selected. The stratigraphic and structural condition of these sections are shown either by photos or diagrams, they are as follows:

1.Iran Section (Plate2.5.1), 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.

2.Qashan sction, located directly to the south of Qashan Bridge along the road between Yalanquz and Dreh Villages.

2.Tagaran Section at 35^0 39^- $48.3^=$ and longitude 450 29^- $52.5^=$, located southwest of Tagaran village about 7 km to the south of Chuarta town.

3.Kato Mountain Section, at latitude 35^0 40^- $39.1^=$ and longitude 450 37^- $25.7^=$ which is located 4 km to the east of Chuarta town, near Suerala village (Fig.1.2 and 2.1) and (Plate 5.2).

4-Type Section (Sirwan valley) (Plate2.2.2) at latitude 35^0 06^- $53.3^=$ and longitudes 45^0 54^- $13^=$ at the intersection of latitude 35^0 59^- $00.2^=$ and longitude 45^0 35^- $16^=$.

5.Malkandi Section, located at 35^0 35^- $21.6^=$ and longitude 450 27^- $47.8^=$ directly to the north of Sulaimaniya City at the foothill of Goizha Mountain, at this locality, the thick sandstone and conglomerate beds form many hills, known as Malkandi Hills. On the hill, many building stone quarries exist which caused exposing of fresh outcrops.

6.Dokan Section (Fig. 1.2) at 35^0 56^- $35.6^=$ and longitude 440 56^- $50.6^=$, is located 1km to the southwest of the dam (Plate2.2.1).

7-Kometan village section (Plate2.3.1) in Naudasht valley at the latitude: 36^o 24^- $26^=$ longitude: 44^o 57^- $38^=$. It is located at the toe of Qandil Mountain.

8.Kometan village section is located at 1km north of Kometan village in Naudasht valley

1.4- Aim of the study

The main objective of this work is to study the basin analysis of the Campanian -Maastrichtian rocks in the Sulaimaniya area, which is mainly concentrated on the Tanjero Formation. This is based on the available and the inferred evidence and plans to study the following:

1.New division of the formation taking into consideration all the exposed outcrops by study of the outcrops in the field for discovering all the vertical and lateral changes in lithology.

2.Description and analyzing litho sections in order to establish depostional environment through facies analysis

3.Studying sedimentary structures and analyzing them for inferring paleocurrent and depostional systems and processes.

4.Sequence stratigraphic analysis for dividing the rock body of the formation into the naturally occurring depositional sequences and system tracts.

5. Combining all type of study for considering depostional history and the tectonics of the basin of Tanjero Formation.

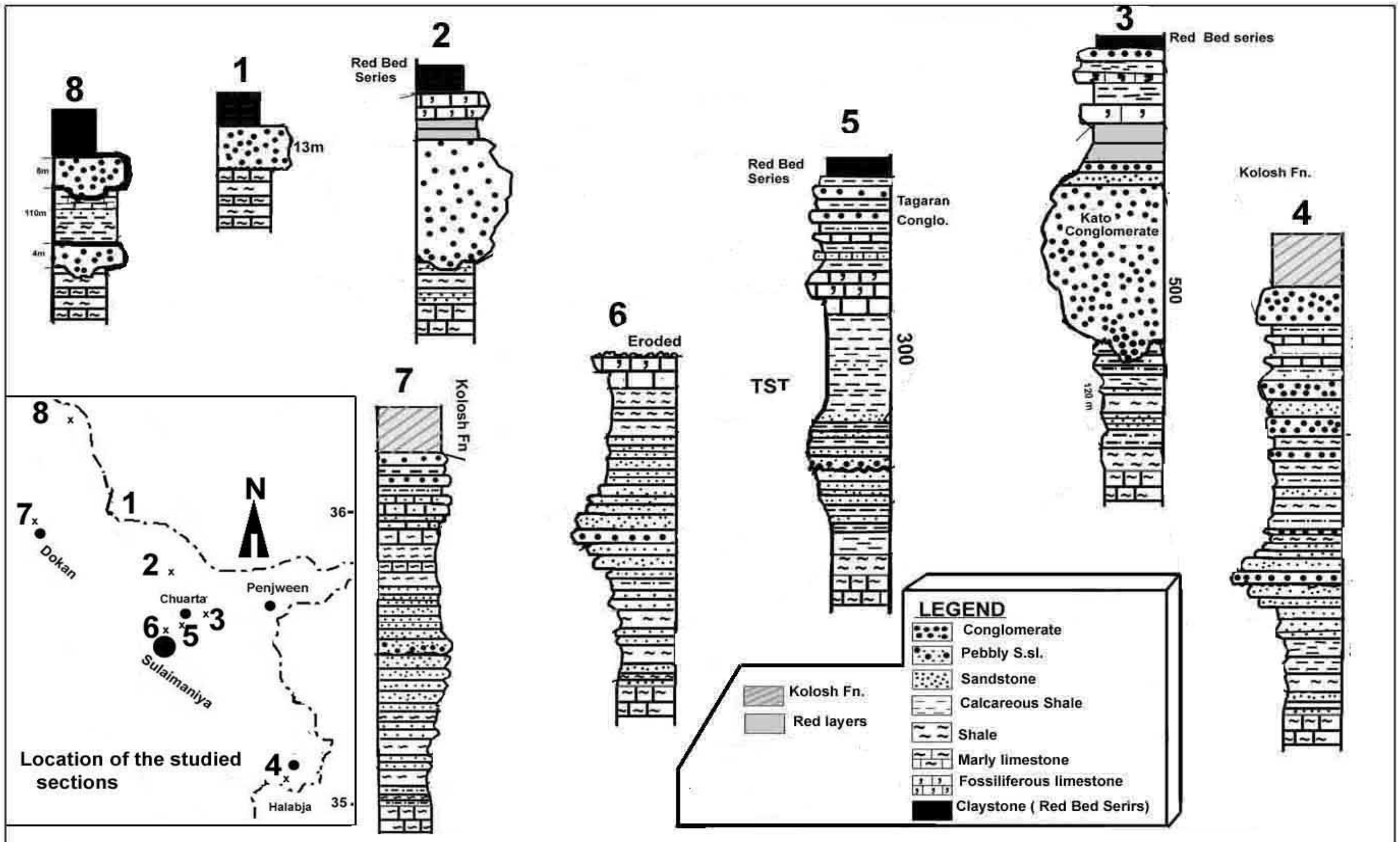


Fig. (1.1 A) Location and collumn of the studied section, 1) Iran section, 2) Qashan section, 3) Kato section, 4) Sirwan section, 5) Tagaran section, 6) Malkandi section, 7) Dokan section, 8) Kometan village section(Qandil Mountain toe)

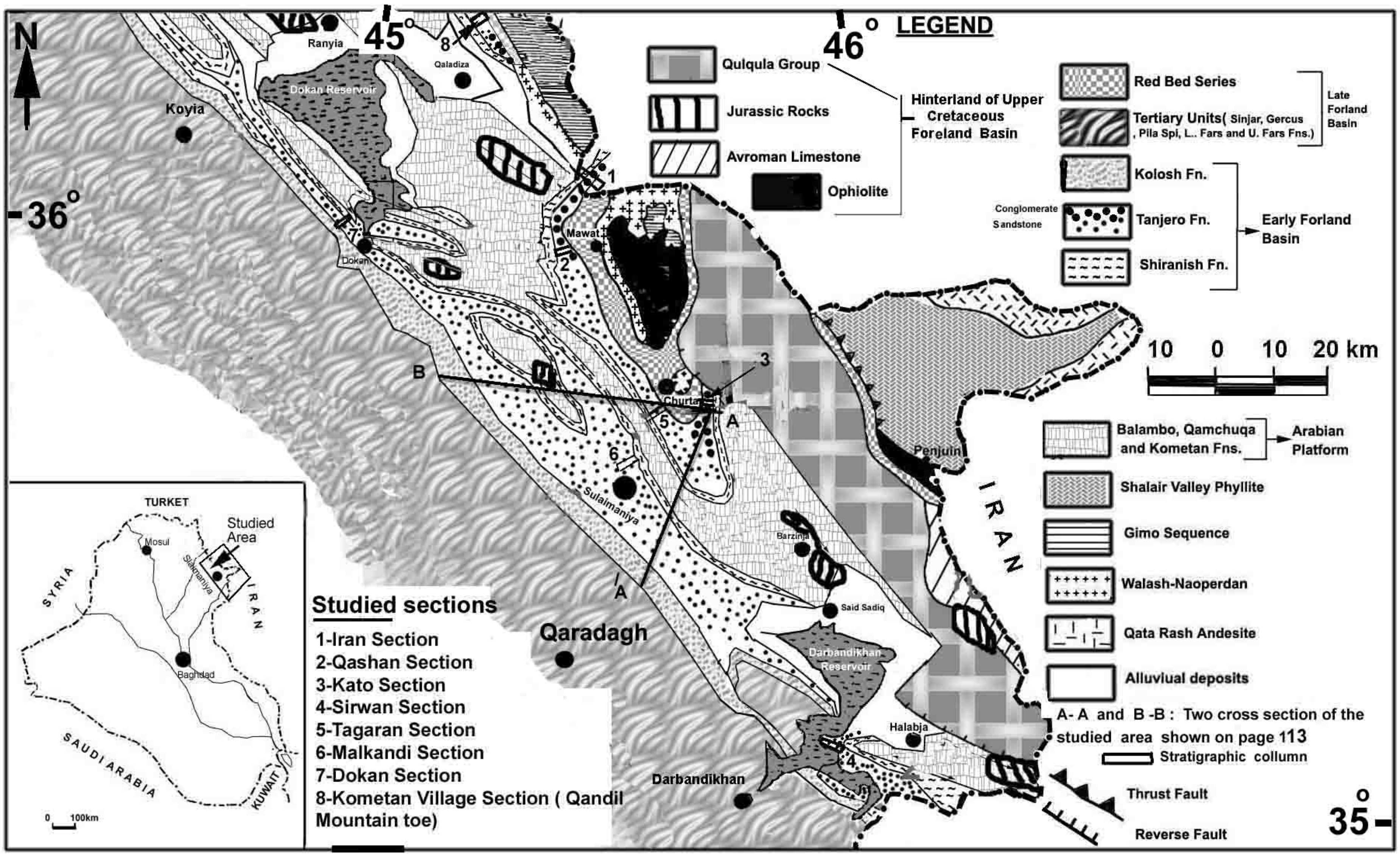


Fig. (1.2) Geological map of the studied area, showing the formations deposited in the early and late foreland basins. Modefied from Jassim and Al-Hassan (1977).

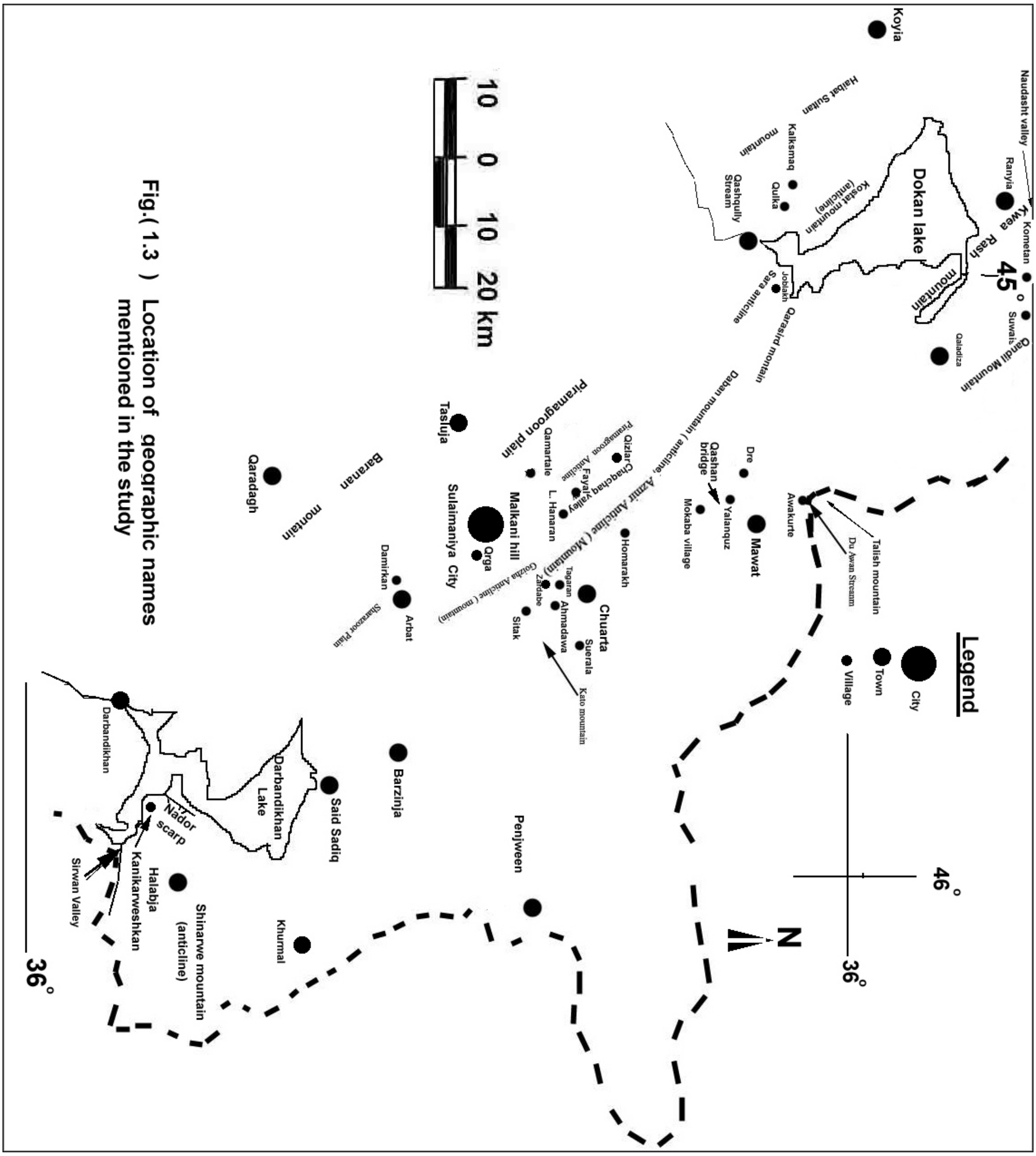


Fig.(1.3) Location of geographic names mentioned in the study

1.5-Method of Study;

1- Fieldwork to record all lithologic change and sedimentary structures by using map, compass and GPS (Geographic Positioning System). This is to make correlation between different part of the formation in distal and proximal area. The work concentrated on areas near Iranian border such as Mawat, Chuarta, Qandil mountain toe and Naudasht valley in addition to limited area inside Iran border at northwest of Mawat town (Fig.1.1, 1.2 and 1.3).

2-Study of about 150 thin sections of the collected samples of all outcrops of area and point counting to calculate the percentage of constituent of rock fragments and minerals.

3-Achieving point counting for conglomerate by using steel net (prepared for this study), which is equally divided to 122 squares and each has 2.7 cm of dimension. In the field the net is placed on the conglomerate and the measurement is done for all clasts larger than 2mm.

In this study a chart is prepared for visual estimation of percentage of clasts and matrix of the conglomerates. This chart is used for those outcrops located in rough and steep slopes where point counting cannot be done. The chart arranged by photographing different proportions, as a mixture, of sand and gravel as shown in (Plate 1.1). This mixture mimics conglomerate of Tanjero Formation as concerned to percentage of gravels and matrix.

4.Cooking of some samples of marl and calcareous shale for extraction of planktonic forams for inferring environment.

6.The directional sedimentary structures (uni-and bi-directional structures) are analyzed by using RockWare program for plotting on stereonet and rose diagrams. The same program is used for plotting the sandstones and conglomerates on the triangles by using Ternary File. Then, the triangles are combined by using Photoshop program for drawing tetrahedrons

1.6-Definition of repeatedly used terms and phrases

The following terms and phrases are used frequently, so for more understanding of the study and avoiding confusion, the following definitions are given:

1. Wherever the phrases " lower part", "middle part" and "upper part" are used. They refer to new divisions achieved in this study for Tanjero Formation.

2. Kato conglomerate

Refers to (20- 500m) thick conglomerate exposed east of Chuarta and south of Mawat towns in addition to northwest of Qaladiza and Qandil Mountain foothill. It is mainly composed of chert and limestone clast. This conglomerate is deposited in the basin- marginal area, while its equivalents (relatively thick sandstone succession) is located at distal-basin areas.

3. Kato Red Layers

In this study a 50m succession of red layers are found inside the Tanjero Formation (Plate 5.3.5) and (Fig.2.4). They consist of red claystone, sand stone with thin lenses of conglomerate. The best outcrop of this succession is located at the southwestern side of Kato Mountain between Kani Sard and Chingian villages at longitude $35^{0}\,38^{-}\,54.6^{=}$ and latitude $45^{0}\,35^{-}\,5.5^{=}$.

When one observes closely these beds, he cannot differentiate them from the famous Red Bed Series. But it can be only distinguished by stratigraphic position, which is located between lower and upper parts of the formation (between Kato conglomerate and carbonate-siliciclastic successions). As will be shown later these layers belong to the middle part of the Tanjero Formation and are deposited as incised valley fills.

4. Kato Mixed Carbonate-Siliciclastic Successions

This succession is located above the Kato Red Layers and below Tagaran Conglomerate, which consists (in some place) of more than 10 thick couplets of fossiliferous limestone and calcareous shale (Plate5.3.4). This succession was previously called Aqra lens. The best outcrops exist at the western side of the Kato mountain at southeast of Chuarta town and the other crop out located near Qshlagh and Mokaba village between Mawat and Chuarta towns.

5.Tagaran Conglomerate: Refers to thick lenses (5-60m) of para- and petromictic conglomerate exist at the top of Tanjero Formation (upper most part) directly below Red Bed Series. It consists from rounded pebbles of igneous rocks (44%), chert (15%) and limestone (16%) rock fragments. The name derived from Tagaran Village where more than 3 lenses of this conglomerate are outcropped 400m to the south of the village. It also exists in Dokan area; in the upper part of the formation while in Sirwan Valley exist in all parts in different proportions.

6. Typical lithology of Tanjero Formation:

This lithology when mentioned, it refers to alternation of thick or thin beds of sandstone and calcareous shale or marls with or without thin conglomerate beds. As will be shown later it derived from Kato Conglomerate.

7. Lower Sequence (Campanian-Lower Maastrichtian Sequence)

The sediments of Tanjero Formation are deposited in two depostional sequences, lower and upper ones. They belong to Campanian-Lower Maastrichtian and Middle –Upper Maastrichtian ages respectively. So in this study the lower sequence refers to sequence, which makes up only 20% of the rock body of the Tanjero Formation. It can be distinguished only in the proximal area (Chuarta and Mawat area) where in distal area it grades into Shiranish Formation.

8. Upper Sequence (Middle –Upper Maastrichtian Sequence)

This sequence is the main sequence in which nearly all previously known lithology of the formation is deposited. In this sequence more than 80% of rock body of the formation is located between two unconformities, which can be identified in proximal and distal area easily.

9. Proximal area

Refers to that part of the Tanjeo basin, which is located near to the source area of Tanjero Formation. In this study proximal area includes Chuarta, Mawat, Du Awan, and Qandil mountain foothill area in addition to Naudasht valley.

10. Distal area

Refers to that part of the basin including locations far from source area, which include Sharazoor and Piramagroon plains in addition to Dokan Area.

1.7-Previous Work

According to Bellen *et al*. (1959), Tanjero Formation is first defined and described under the name of Tanjero clastic Formation by Dunnington in 1952. He selected the type section at Sirwan Valley, 1km to the south of Kani Karweshkan village, near Halabja Town (Fig.1.2) and at the right bank of Sirwan River (upstream of Dialla River).

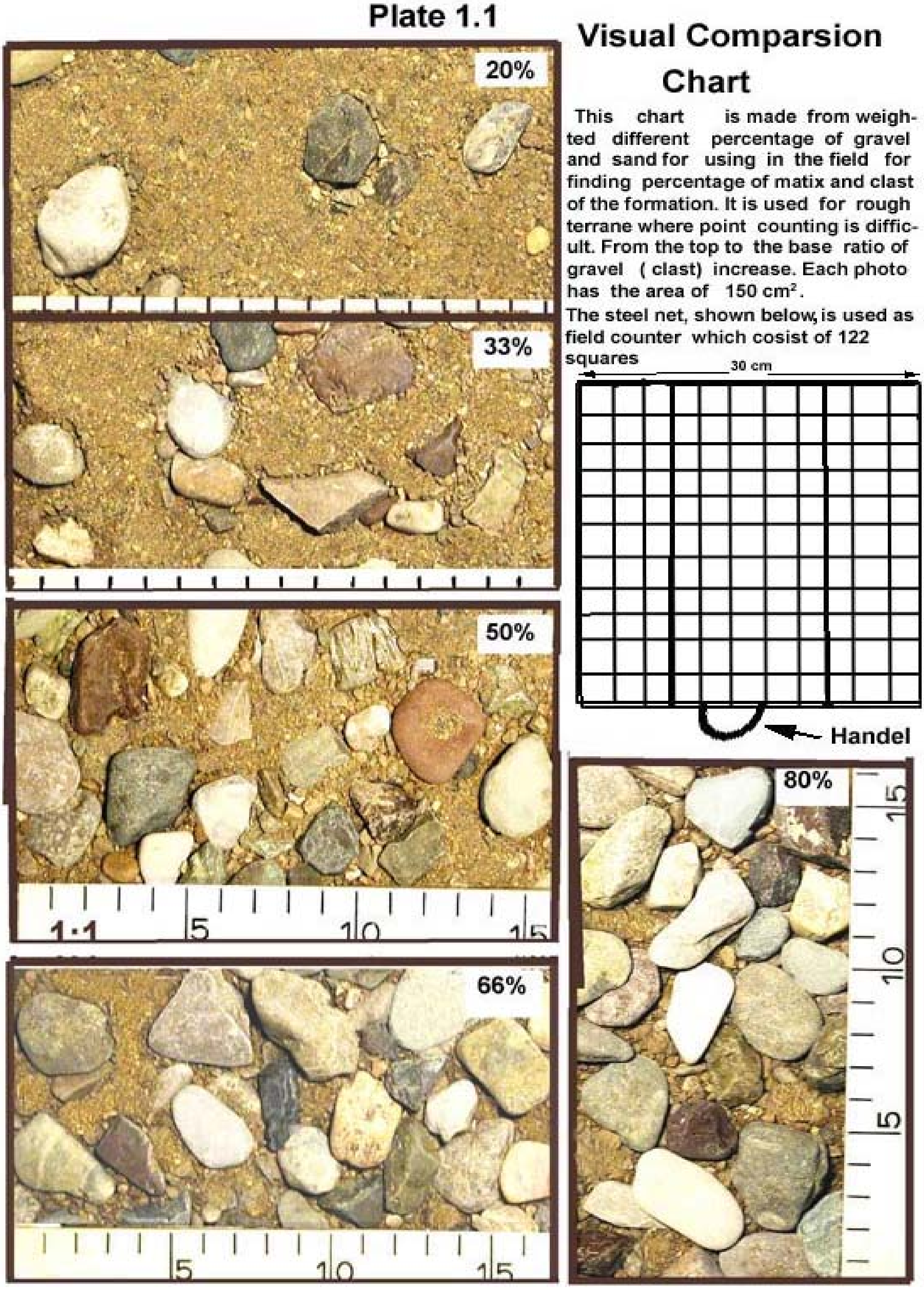
Kassab (1972 and 1975) studied biostratigraphy of the formation and gave the age of Late Campanian –Maastrichtian to the formation. Al-Mehaidi (1975) discussed briefly the stratigraphy and tectonic of the formation within the Chuarta area and mentioned the occurrence of the Aqra Formation in the upper part of Tanjero Formation as a lentil.

Bellen *et al*. (op. cit.) has described briefly the distribution, age, lithology, fossil content, and stratigraphy of the formation, in addition to surface distribution at different localities in northeastern Iraq. Al-Rawi (1981) studied in detail the sedimentology, and petrology of the formation in selected section (Sulaimaniya, Dokan and Rawandoz sections). He mentioned that lower part at Sulaimaniya has shallow environment of deposition and concluded that the paleocurrent is toward northwest and flow parallel to the axis of the Tanjero trough. He studied in detail the clay mineralogy and sandstone of the formation. He also classified the sandstones according to Pettijohn (1975) and plotted them on triangles.

Abdul-Kireem (1986 a) studied the formation within stratigraphy of Upper Cretaceous and Lower Tertiary of Sulaimaniya- Dokan Region. He suggested removing the word " clastic " from the name of the formation and to put the lower part with Shiranish Formation. Abdul-Kireem (1986b) studied planktonic forams and stratigraphy of Tanjero Formation. He assigned, for the formation, the age of Middle-Late Maastrichtian in Dokan area.

Saadallah and Hassan (1987) made sedimentological analysis of the formation in selected sections from Dokan and Sulaimaniya areas. They concluded that the paleocurrent is toward west and southwest. The most recent and detailed study is that of Jaza (1992) which is concerned with sedimentary facies analysis of the formation in selected sections from Sulaimaniya district. He recognized the turbidite and submarine fan (as depositional feature of the basin) in the formation. He divided the rock body of the formation into sixteen lithofacies and suggested further detailed study of the formation to reconstruct depositional model for the whole basin and its relation to tectonics. Minas (1997) studied sequence stratigraphy of the formation and put Tanjero Formation in deeper environment than Shiranish Formation and regarded the formation as a transgressive part of the cycle. Lawa *et al*. (1998) studied carbonate layers in the upper part of the formation at Chuarta-Mawat area and conclude that these beds belong to Aqra Formation, which interfingered with Tanjero Formation. Al–Rawi and Al-Rawi(2002) studied the formation as turbidite example of flysch type in northeast and north of Iraq. They concluded that the formation deposited in deep environment except the limestone beds, which are deposited in shallow one.

Plate 1.1



CHAPTER TWO:

STRATIGRAPHY AND PETROGRAPHY

2.1- Old dipartite division

Dunnington (1952 in Bellen *et al*. 1959) divided the formation, on the basis of lithology, in the type section, into two parts, i.e. lower and upper parts. He cited that the upper part consists of silty marls, siltstone, sandstone, conglomerate and sandy biogenic detrital limestone; this part is 1532 meters thick. According to him, the lower part is 484 meters thick and composed of pelagic marl with some siltstone and rare marly limestone.

The above division is based only on the lithologic variation of the type section in the Sirwan valley and had not taken into consideration the other areas. This division is later, followed by all other researchers such as Buday (1980), Al-Rawi (1981), Abdul-Kireem (1986a), Jaza, (1991) Saaddlla and Hassan (1987).

2.1- New Tripartite division

In the present study, the authur subdivided the formation into three parts on the following principles:

1. On the basis of lithologic variation in the whole Sulaimaniya area which includes Chuarta-Mawat area, Chaqchaq and Shadalla valleys, Sharazoor and Piramagroon plains in addition to the Dokan area and the foothill area of Qandil mountain (Naudsht valley). So this new division is representative of more than %90 of the outcrops in Sulaimaniya Governorate. Using beds of distinctive lithology (marker bed).

2. This division is aided by correlation of the lithologies of the formation on the basis of time equivalent intervals over the whole area including one section inside Iran (Fig. 2.3 and plate 2.5).

3.The division is agreed with the result of sequence stratigraphy (see chapter five)

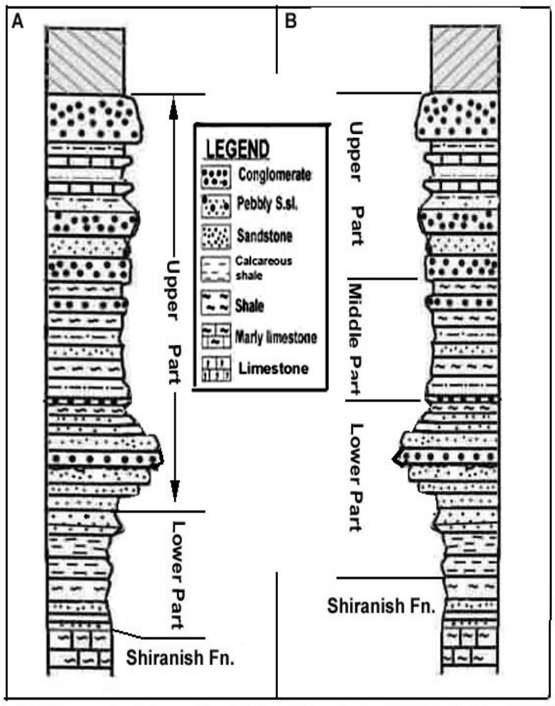
4.The division depends on the complete understanding of the major and minor structural complication of the studied area (Fig.6.1) so that the confusion of middle part with Shiranish Formation could be avoided.

5. The new division is based on the facts (deduced from field work) that the old division cannot be applied to many areas near source rocks (proximal areas) such as, Chuarta, Mawat, Qaladiza and Qandil foothill areas. This is also true for some distal areas such as Piramagroon and Sharazoor plains. The three parts are as follows:

2.1.1-Lower Part

The lithology of this part has highly variable lateral grain size distribution. The thick succession of conglomerate is dominant at areas such as toe the Qandil Mountain, Chuarta and Mawat areas (Fig. 2.3 and Plate 2.3 and 2.5). These areas are called proximal area (part of the basin that is near to source area). It changes to sand and calcareous shale at Sharazoor and Piramagroon plains in addition to Dokan area. These areas are called distal area (part of the basin that is far from the source area). Along lower part of both limb of Azmir-Goizha anticline, sandstone and conglomerate exist together. The base of the sections at these areas, are characterized by relatively thick beds of coarse and clean sandstone, which form many small elongate ridges (Plate2.1and 2.2). This coarseness is coinciding with occurrence of lowest sea level fall during which incised valleys are scoured. Compositionally, both conglomerate and sandstone nearly composed of chert and limestone rock fragments with minor amount of shale and igneous fragments (Fig.2.6). Nearly all-typical lithologies of the formation are included in this part. At the top, it ends with sudden change of sandstone to marl or calcareous shale.

The thickness is variable, which ranges from 50 to 1000m. The lithology and thickness depend on the distance from the delta mouth and shoreline. The lower boundary of this part coincides with the conventional boundary of Shiranish and Tanjero Formations. This boundary is gradation and begins with first appearance of clastic sediment (thin sandstone or siltstones) at the top of Shiranish Formation. The figure at the right shows the division of Dunnington (1952 in Bellen 1959) and new division of this study.



Fig(1.2) Comparsion between the division of Dunnington (1952 in Bellen,1959) (A) and new division of the present study(B)

The previous lower part of Dunnington (1952 in Bellen *et al*. 1959) can be assigned as the transition zone (interval) with underling Shiranish Formation. The thickness of this part is 50 - 100 meters at some locality of Chuarta area such as near, Mara Rash village and Azmira Bichkola valley. At the west of Homarakh village the Lower Part is only represented by dark green calcareous shale with interbed of siltstone, yet it can be separated from middle part by changing to bluish gray marl and marly limestone. The highest thickness is recorded at type locality, which reaches more than 1000 meters. Nearly all sedimentary structures that indicate shallow environment are found in this part. At some localities in the Naudasht valley (Qandil mountain toe) the lower part is represented by 4m of coarse conglomerate (Plate2.3.2).

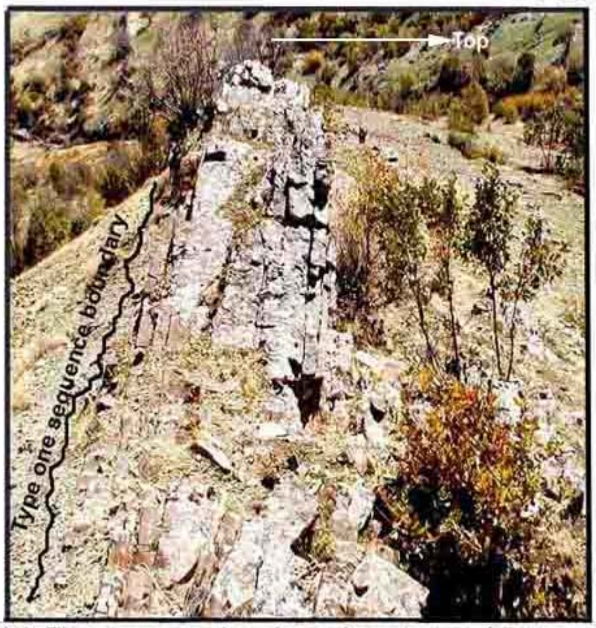
2.1.2 - Middle Part

The lithology of this part is generally finer than those of the lower and upper parts. They consist, in Chuarta area and Sirwan Valley of Calcareous shale (or olive green marl). However, in some localities such as Dokan (Qashqulley), Chaqchaq valley and Piramagroon -Sharazoor plains, it is very similar to Shiranish Formation, which is composed of light bluish white marl with occasional intercalation of thin beds of marly limestone (Plate2.5.3). This part begins from the top of the Lower Part and ends with the first appearance of calcareous sandstone or biogenic limestone. The thickness of this part in Chuarta and Mawat areas reaches about 300m, which thins toward the southwest and reaches 100m in some places.

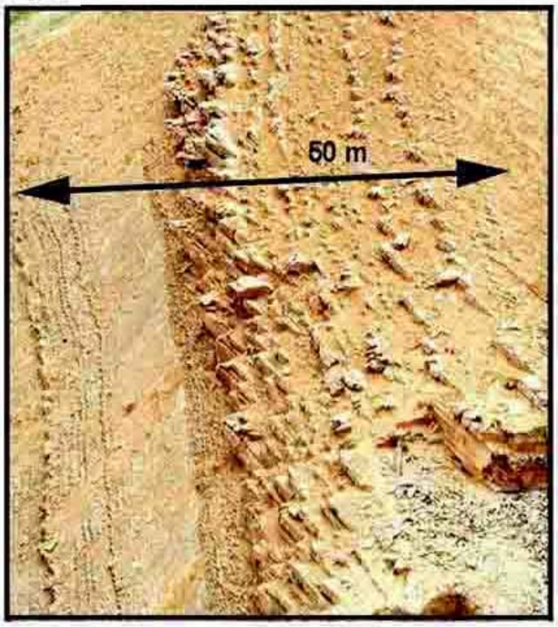
All previous studies have not dealt with areas where this part is well developed and exposed. Therefore these studies are conducted on those areas that are very similar to the type section. In my opinion, the lithology of the type section and other similar areas are representing the areas, which are located in front of low stand fans, which are more clastic- rich than nearby inter-fan areas. The deep and interfan areas are containing Shiranish like lithology, which represent about 60% of Tanjero Formation outcrops (outcrops associated with Shiranish-like lithology).

In all section, this part is easily distinguished from lower and upper parts except at the type locality, which is differentiated by very thick beds of dark green calcareous shale (marl) with less content of conglomerate and sandstone as compared to the other two parts (Plate 2.2.2). At Dokan area the thickness of middle part is 130 m. At this area the bluish marl and marly limestone occasionally intercalated with thin lamina of dirty sandstone (greywacke). At the area south of Goizha-Azmir-Sara anticlines it consists of bluish marl with interbed of marly limestone. While at the northeastern limbs of these anticlines it changes to thick (300m) dark green Calcareous shale. At southwestern side of Kato Mountain this part is represented by nearly 50m of red layers, which are composed of red claystones and sandstone with some thin bed of conglomerate (Plate5.3.5). At the extreme western end of the studied area (Naudasht valley, Qandil mountain toe) (inside Rozhga Village) it changes to 10 m of marl and marly limestone (Plate2.3.2), whereas in the same valley north of Kometan village (at N: 36^{o} 24^{-} $23.5^{=}$ E: 44^{o} 58^{-} $2.1^{=}$) it consisted of 110m of bluish white marl and minor green calcareous shale and sandstone located between two thick conglomerate (Plate 2.3.1).

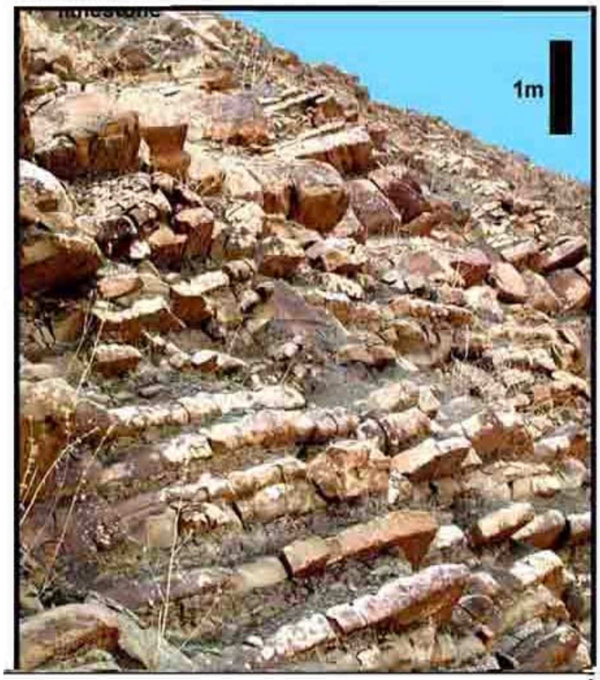
Plate 2.1



(1) The most weathering resistant part (5m thick) of ridge at 2.5km southeast of Qizlar village. It is composed of thick and clean (mature) sandstone.It is a part of low stand sandstone wedge about 400m thick



(2) The same sandstone beds near Lower Hanaran Village in Chaqchaq valley. At this place the beds are thinner than that of Qizlar village. Moreover at this locality they contain no conglomerate interbeds.



(3) The same sandstone bed at Dokan area 3km east of Dokan Bridge. At this place the bed are thinner and less mature than that of Qizlar village. Moreover at this locality they contain no conglomerate interbeds.This pakage represent the lower part of the thick lowstand wedge only.

(4)The same sandstone beds(package) at Sirwan valley (type section). The photo shows the 80m of the lower part(low stand wedge). It consists of alternation of sandstone calcareous shale with interbeds of conglomerate.

To the far west at the area between Diana and Mergasur towns (outside of the studied area and at N: 36^{o} 47^{-} $9^{=}$ E: 44^{o} 24^{-} $2.2^{=}$) it changes to 2m of white fine grain limestone. This limestone is lithologically very similar to Kometan Formation (Plate 5.3.1). This part, as will be shown later, represents mainly the sediments of transgression phase (Transgressive system tract)

2.1.3-Upper Part

At Chuarta and Mawat area, the lithology of this part consists of sediments, which occurs as succession of thick alternation of milky which fossiliferous limestone beds and black silty calcareous shale or marl. The beds are arranged in couplets of marl-limestone. Their numbers are more than 10 couplets in some localities and their maximum development exists at south and southwest of Chuarta and Mawat towns. These biogenic limestone beds thicken on conglomerate otherwise thin. At south of Mawat Town, all the couplets join together to form very thick and massive fossiliferous limestones which reach the thickness of (100m) at immediately to the south of Pazaro village and contain rudist, gastropod, echinoderm, coral and large forams. This part begins at the top of the middle part and ends with the appearance of Red Bed Series (at Chuarta area) and Kolosh Formation at other area.

In this study this part (upper part) is called Kato Mixed Carbonate - Siliciclastic Succession. It is named after the Kato Mountain, which has thickness in the range of 30-200m. This succession also occurs in Dokan area but thins to about 50 m of thin and thick light brown marly and sandy limestones with occasional intercalation of calcareous shale, sandstone and few thin lenses of conglomerate. In the type section area (Sirwan Valley) it consists of very thick interval of dark green shale and conglomerate with some interlayers of bioclast limestone (Plate2.4.1 and 2.4.2). The top of this part and below Red Bed Series, in some locality such as Tagaran, Dokan and type section, contains several thick lenses of conglomerate of Tagaran type.

The Upper Part is eroded at Chaqchaq and Shadalla valleys and Sharazoor and Piramagroon plains or may be covered by alluvium. At the Chaqchaq valley the lower contact of this part is located along the axis of a syncline south of Qulqula Village on the road to Qizlar Village. At this locality a 2m thick biogenic limestone (*Omphalocyclus* -bearing limestone) is exposed which can be correlated with the lowest biogenic limestone at south of Chuarta and Mawat towns. At Naudasht valley this part is represented by 2m of fossiliferous limestone (rudist, pelecypods, gastropods bearing limestone) and 8 m conglomerate of Kato type (Plate2.3.1). As will be shown later this part mainly represents the sediments of normal regression (high stand system tract and shelf margin system tract).

2.2 - Call for supplementary reference section of the formation.

According to North American Commission on Stratigraphic Nomenclature (1983), reference section is very valuable in definition and revision of geologic units. It is convenient to indicate and define new type section for Tanjero Formation for the following reasons:

The water of Darbandikhan reservoir covers important part of the original type section, especially its contact with Shiranish Formation. In this connection the North American Commission on Stratigraphic Nomenclature (1983) is permitted to assign neostratotype when the stratotype is covered.

The lithology of the type section is not the representative of the formation (as proved by the author) and only stand for Sirwan Valley. Even in the Tanjero valley, from which the name came, has very different lithology. This section does not demonstrate regional validity, as assigned by the above-mentioned Commission. Moreover the supplementary reference sections, according to the commission, are often designated to illustrate the diversity or heterogeneity of a defined unit or some critical feature not evident or exposed in the stratotype.

When a new type section is selected in the Chuarta area or around Sulaimaniya City its lithology will stand for at least 80% of the outcrops of the formation. This new section will show the different parts of the formation and environment can be deduced easily.

According to sequence stratigraphy, the new sections will give clear subdivision of the formation into system tract. So two supplementary sections are drawn, as shown in the Fig. (2.1 and 2.2) at Kato Mountain and Dokan area and one photo given for the section north to Mokaba village (Plate 2.2.3).

2.3-Description of Kato mountain section

The Kato mountain section is selected as supplementary section due to the following:

1.The thick succession of the proximal sediments (Kato conglomerate) is exposed clearly.

2. The red layers of the middle part (Kato red layers) and the Kato mixed carbonate- siliciclastic succession are well developed in this area and have clear contact with Red Bed Series

3.It can be reached easily through paved road and only 20km far from Sulaimaniya city.

4.The lower sequence, in this area, has enough thickness (about1 50) meters to be studied. This sequence is located below Kato conglomerate and Shiranish Fn. (see fig. 2.1A).

Kato Mountain is a high homocline, from the surrounding valley bottom; the mountain is about 550 meters high. The upper 350 meters of its eastern scarp slope is totally formed from Kato conglomerate (Plate 2.6.1 and 2.6.4), while the lower 150m consists of sandstone and calcareous shale of lower sequence of Tanjero Formation. The lowest 50m of the scarp, near the valley bottom, composed of Shiranish Formation. Along western and southern sides (dip slope) of the homocline, the conglomerates thin rapidly as a wedge toward south and southwest and plunge under the middle part. Along the toe of dip slop the Kato red layers (20-50m thick) are exposed on the top of Kato conglomerate and overlaid by mixed carbonate-siliciclastic succession. The thick limestone beds of this succession form may small ridges along the southern and western side of the mountain. Tagaran conglomerate is located above the succession and below Red Bed Series. The contact between This Series and Tanjero formation can be seen clearly to the west of Ahmad Awa and Sirawezha villages (Fig. 2.4 and 2.5).

The section of Kato Mountain is lithologically unusual as compared to original definition of the formation, because it contains about 500m of conglomerate and overlain by 50m of red layers of claystone. These layers (Plate5.3.5) are located between Kato Conglomerate (top of lower part) and mixed carbonate-siliciclastic (upper part or Aqra lens). Al-Mehaidi (1975) surveyed the Chuarta area. He put both Kato conglomerate and Kato red layers in the upper part of the formation and in Red Bed Series respectively. Field observation revealed that this conglomerate plunge under the middle part and it's equivalent sandstones (with conglomerates) are located at lower part of the Tanjero formation at distal area. Toward south and southwest the conglomerate laterally change relatively rapidly to typical lithology of the formation along the depositional strike, whereas the change along the paleoslope (along the elongation of the fans) is gradation.

In analogy with the published papers of Nichols, (1999); Vincent, *et al*., 998, Emery and Myers, (1996) and Haq, (1991), the thick wedge and lenses of conglomerate can be regarded as incised valley and channel fill. In the present study many of these valleys and channels are found (see sequence stratigraphy in chapter five) which are formed when the shelf of the lower sequence is exposed to erosion and invaded by rejuvenated rivers during low stand system tracts or forced regression. So the Kato conglomerate includes both continental and submarine conglomerates. The submarine ones are including the channel bed-load conglomerate, which deposited on bottom of fan feeder channels. Through these channels the conglomerate may be transported to relatively long distance such as those rare beds seen in the Sharazoor and Piramagroon plains (Fig. 1.3). In contrary to these Minas, (1997, p. 123 and 124) put all the lower part of Tanjero Formation in highstand system tracts and he put the conglomerate at the upper part of the formation.

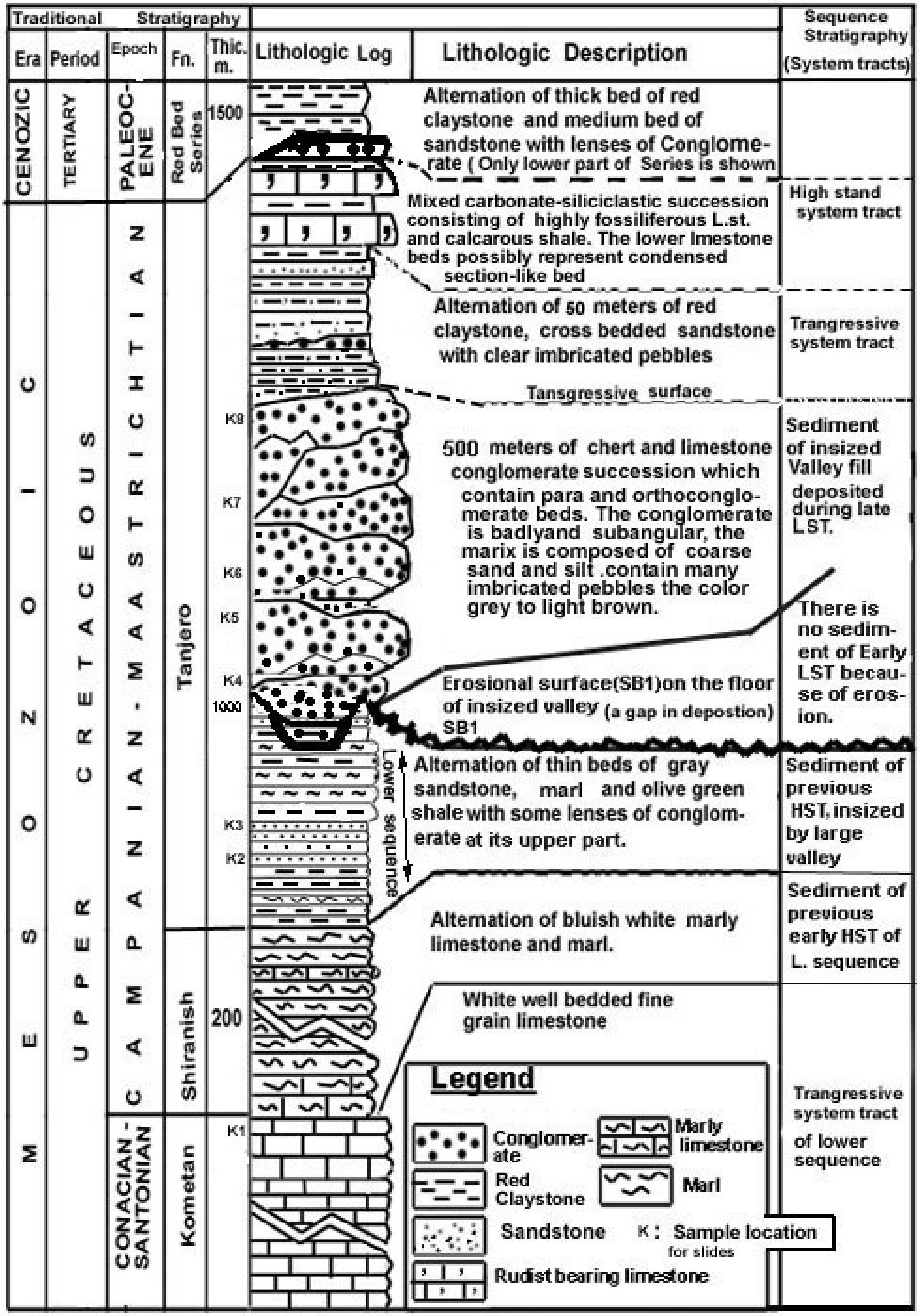
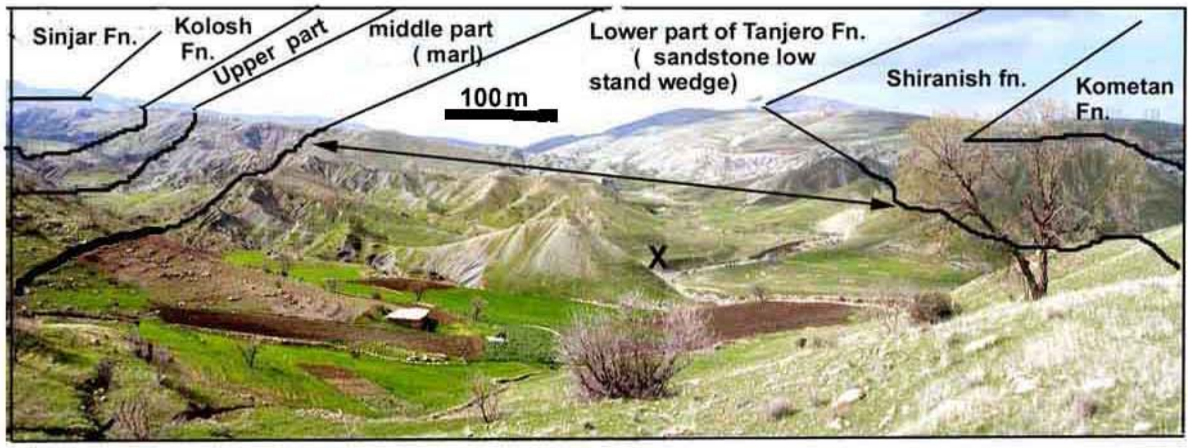
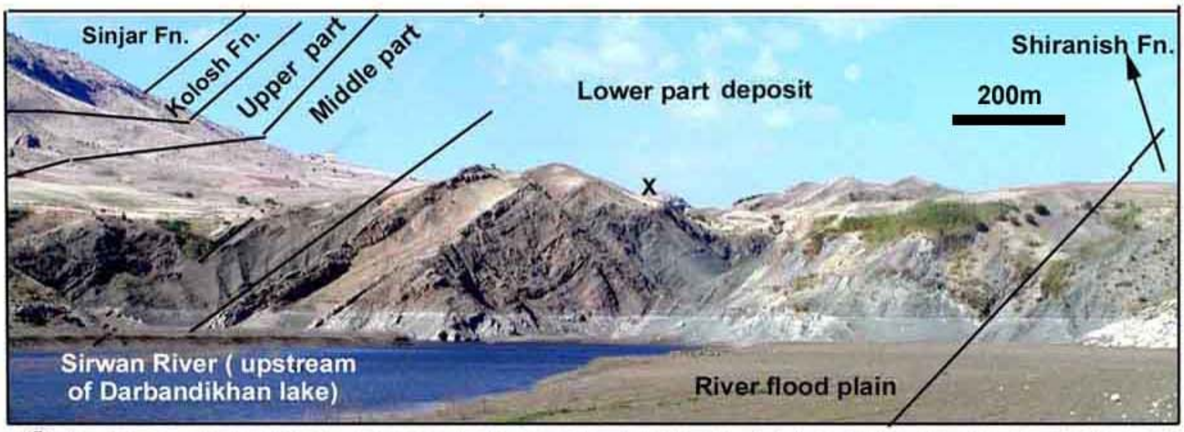


Fig. (2.1A) Stratigraphic column of Kato Mountain, southeast of Chuarta area. The base located at N: 35° 39′ 5.4″ , E: 45° 56′ 25,3 ″
(The column is not to sclae)

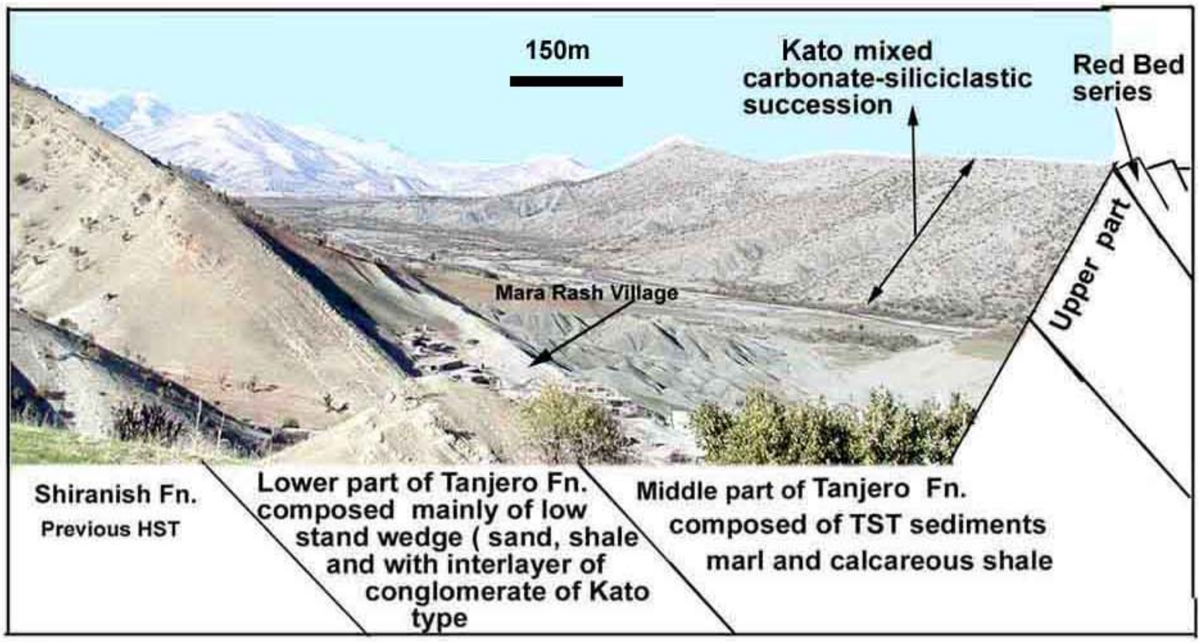
Plate 2.2



(**1**) The three part of Tanjero Formation as outcropped at Dokan area, 1km southwest of Dokan dam site . The location of the point indicated by letter (X) is N:35° 46' 25.1" , E: 44° 56' 45.4"



(**2**) The three part of Tanjero as outcropped along the right bank of Sriwan river, 1km south of Hana Zalla Village . The location of the point indicated by letter (X) is N:35° 7' 23.5" , E: 45° 56' 17.6"



(**3**) The three part of Tanjero as outcropped along the left bank of Mokaba stream, 15 km west og Chuarta town. The section pass through Mara Rash village , direcrtly at west the connectiong point of Khewatw and Qalla Chullan streams .

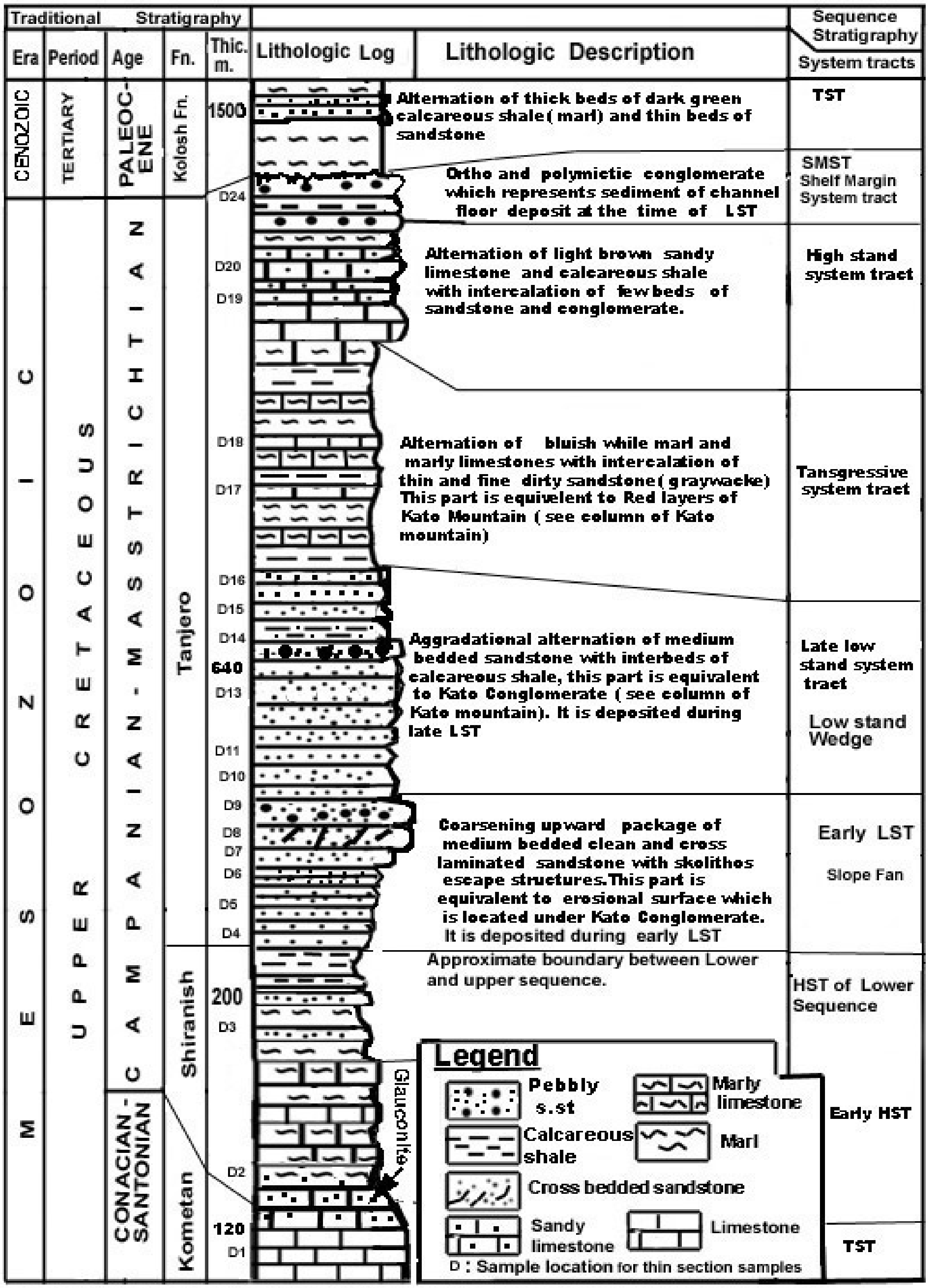


Fig. (2.2) Stratigraphic column of Dokan area showing traditional and sequence stratigraphy subdivision (The lower, middle and Upper parts refer to new division) see the Fig.(2.3) for correlation with Kato column. (The column is not to scale)

2.4- Kato conglomerate as key of the correlation

The division of the formation into three parts is based on field correlation depending on distinctive types of lithology and surfaces beds. The most important type of lithology used in correlation is thick-bedded (in some place about 500m thick) of conglomerate (with its derivative sandstones). The transgressive surface above the Kato conglomerate also can be used for correlation, but it gives the same result as the conglomerate. This conglomerate crops out along the strike at the proximal area and thin out along the dip direction toward south and southwest and descending under the typical lithology of the formation. The exposures of this conglomerate stretch as straight belt from the east of Chuarta to the south of Mawat to Iranian border at the northwest of latter town. Along the same belt it crops out at northwest and west of Qalla Diza Town and it continues northwestward along the foothill of Qandil Mountain inside Shahiddan and Naudasht valleys (Fig. 1.3 and 2.3 and Plate 2.3).

The nearest outcrop to Sulaimaniya City is located at southeast of Chuarta Town, there the strata dip 40 degrees toward southwest and they form a high ridge locally known as Kato Mountain. Another near outcrop is located west and south of Mawat Town, which extend, nearly parallel to strike, toward northwest from Mokaba village and enter the Iranian border at the west of Iraqi Awa Kurte village (Plate 2.5.1 and 2.5.2). The elongation occurs along both sides of Kareza and Du Awan streams at south and northwest of Mawat town respectively. The thickness of the conglomerate at both localities is variable but in some sections reaches about 500m and in this study it is called Kato conglomerate and its equivalents are found in the whole basin and used for accurate correlation.

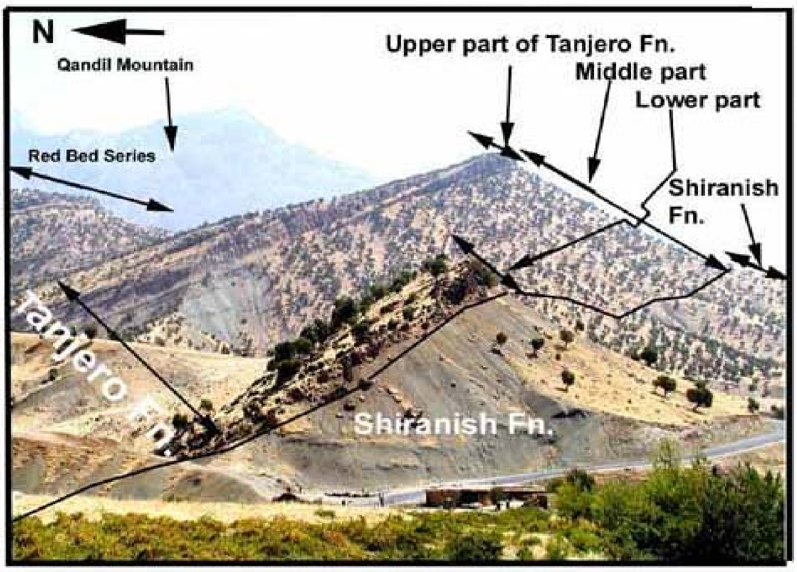
2.5 - Petrography of Kato Conglomerates

This conglomerate (in the above localities) is composed of clasts (boulders, pebbles and cobble) of chert (54%), limestone (35%) and shale (9.1 %) (Plate 2.6.1, 2.6.2 and 3.7). The matrix consists of terrigenous sand, silt with some reworked radiolarian fossils (Plate2.6.2). The cement material is rare and consists of silica and calcite (Plate 2.4A.2). The percentage of limestone grain is more in the matrix than in the clasts. This may be attributed to the fact that most limestone clasts are broken down into matrix during transportation from source areas while cherts, generally remained with less grain size changes. This is due to wearing resistance of chert as compared to limestone. The layers of this conglomerate have two types of textures:

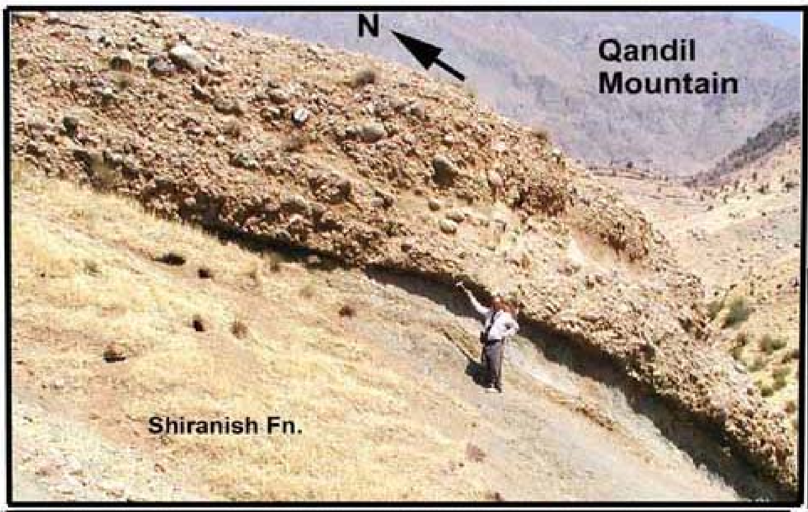
1.Grain (clast) supported layers or beds. **2.** Matrix supported layers.

The numbers of imbricated pebbles are more in the first type (Plate 3.7) generally the imbrication is not well developed as compared to recent similar sediments. This might be attributed to rareness of platy gravel in the source area, which is mainly more or less yield equant grain of chert and limestone. Both types are badly sorted and have moderate roundness. Selley

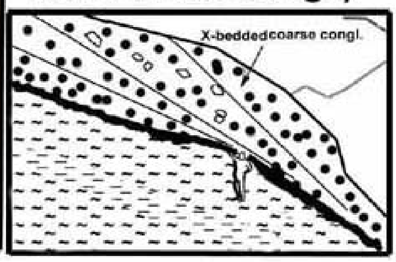
Plate 2.3

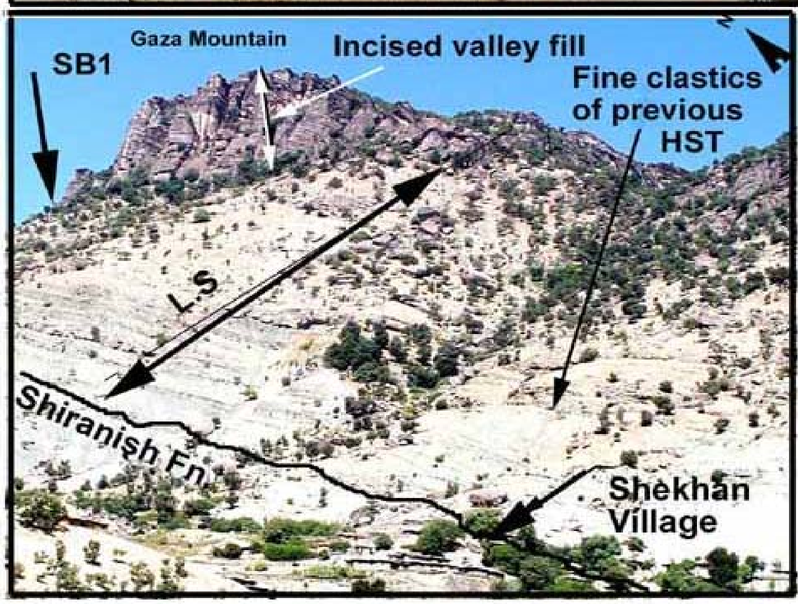


(1) Two thick coarse conglomerate bed in the Naudasht valley (Qandil Mountain toe). The photo is taken from inside Kometan Village toward east. They stand for lower and upper sequence boundary of the upper sequence. Both showing sudden lateral thickness changes.The three parts of this study are very cleár espicíally the two regressive parts



(2) Cross bedded boulder conglomerate rests on Shranish Fn unconformably at 1km to the west of above village. It is represent SB1 of the upper sequence (same position as Kato congl.)





(3) 200m thick Kato conglomerate at north of Suwais Village at toe of Qandil mountain, about 20 km to the northwest of Qala Diza Town. The black line shows the lower sequence (L.S). The conglomerate is reppresenting the incised valley fill deposited during late low stand time. they valleys are score during major sea level fall.

(1988), called the former orthoconglomerate and the latter paraconglomerate. Compositionally, the whole succession is called polymictic conglomerate. This is because it consists of clasts of different lithologies, i.e. limestone and chert with rare shale.

This conglomerate, being hard and firmly indurated, is used as millstone in the old type of water and hand mills. According to resident villagers in the area (village dweller around Kato Mountain), all the water mills in the Sulaimaniya Governorate were using this type of conglomerate in the past for making millstones. During trips, many abandoned millstones are observed near their quarries around the northern peak of the mountain (Plate5.2).

The most important characteristics that make the Kato conglomerate to be used for correlation in the studied area are as the follows:

A. Contain no clast of igneous and metamorphic rocks. This is ascertained in the field by inspection of more than 10000 pebbles and boulders in different localities. This is true for the area of Chuarta, Mawat and Qala Diza, whereas in Halabja area (type section) and Naudasht valley it contains about 10% igneous and metamorphic grains.

B- Another property that makes the conglomerate to be used for correlation is high thickness (500m in some place), which has derivative sandstone of high thickness in distal area too.

C. The bulk composition of the conglomerate (as mentioned above) exactly resembles the lithology, which according to Buday (1980) and Karim, (2003a) is composed of bedded chert, limestone, marl and shale. So there is close compositional correlation between the lithology of Qulqula Formation and sediment of Tanjero Formation. The above two authors also mentioned that former formation contain thick beds of marl. Therefore, the marls and calcareous shales in the middle and upper part of Tanjero Formation are derived mainly from erosion of these beds. The name of Kato conglomerate is not only used for the conglomerate of Kato Mountain but also used for all conglomerates having the same lithology and the same stratigraphic position. It also exposed in the following areas:

1.In extreme proximal area such as the Iranian section, the whole Tanjero Formation is represented by 150m thick succession of conglomerate (Kato type conglomerate)(Plate2.5.2) in between Shiranish and Red Bed Series. It is thins rapidly toward the border with Iraq and becomes 13m thick at the left bank of Doo Awan stream (Plate2.5.1 and Fig.2.3). The rest of this conglomerate (as the only representative of Tanjero Formation) on the Shiranish Formation is returned to most landward extend of the formation where the slope was so steep that all sediments of the Lower Sequence is eroded by stream incision and erosion.

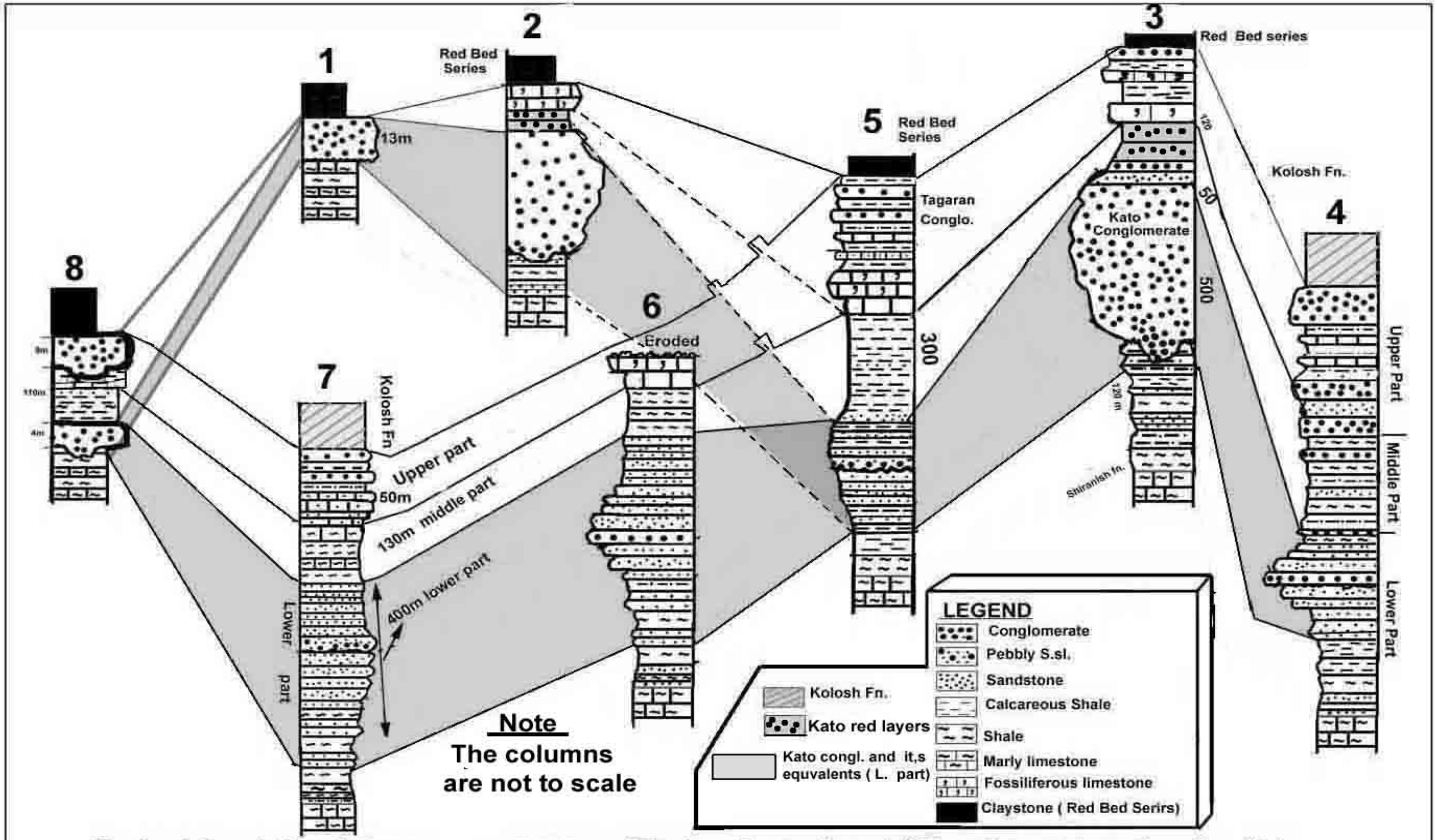


Fig. (2.3) Corelation between sections of Tanjero Formation at different areas based on the Kato conglomerate position and their equvelents 1) Iran section, 2) Qashan section, 3) Kato section, 4) Sirwan section, 5) Tagaran section, 6) Malkandi section, 7) Dokan section, 8) Kometan village section(Qandil Mountain toe)

2. Qashan Bridge (10km west of Chuarta town), the conglomerate is located at the top of typical lithology (alternation of sandstone and calcareous shale) of the lower sequence of Tanjero Formation. It thins rapidly toward south and east where it is also replaced by typical lithology of Tanjero Formation. It is apparently located at the upper part of the formation; but when the complex structure of the area is sloved it is clear that it is overlain by 30m of red layers, then comes (60m) of massive rudist and other fossils bearing limestone at the top of the formation and below Red Bed Series (Fig.2.3). When one compares between this conglomerate and its equivalent in the distal area, it appears that it is located at the lower part.

3. Suwais Village section (20km northwest of Qala Diza Town) and Kometan Village section (35km northwest of the latter town) have nearly similar lithologies as those of Kato Mountain except for absence of Mixed carbonate siliciclastic succession (Plate2.3.3).

3. At the mid- distance between proximal and distal area such as the area near Binawella village, south of Tagaran, Homaragh village, and west of Qizlar villages, Kato conglomerate (with its erosional surface) is standing for by sandstone interbed by 1-3m conglomerate beds (Fig.2.3).

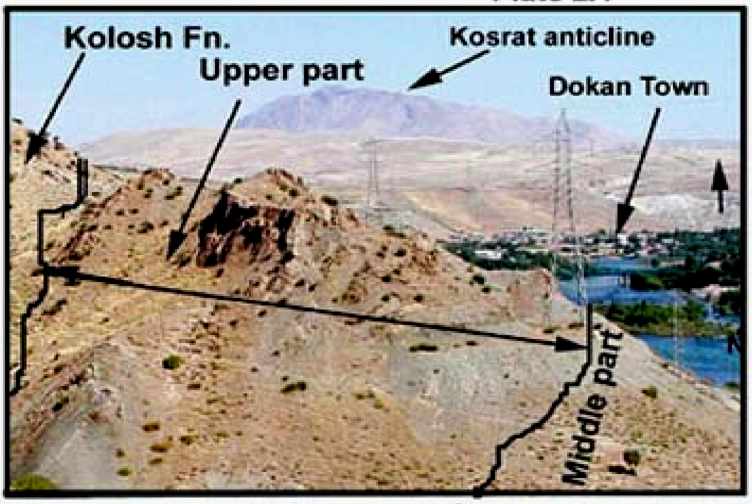
4. At Sharazoor and Piramagroon plains and Dokan area, the conglomerate represented by thick succession of sandstone and calcareous shale with rare lenses of conglomerate.

In Chuarta area, Al-Mehaidi (1975) showed this conglomerate at the upper part of Tanjero Formation as lateral change of fossiliferous limestone. But the position of this conglomerate, in the present study is placed in the lower part of the Tanjero Formation (Fig.2.3 and 2.2) through extensive fieldwork. This is because its equivalent sandstone (at distal area) is located in the lower part and the underlying erosional surface (unconformity) is located under typical lithology of the formation near the boundary with Shiranish Formation. Putting the conglomerate in the lower part is depending on the area where typical lithology of the formation is more obvious than the proximal area where the conglomerate is more abundant and thicker. The Kato Conglomerate thins gradually toward south and southwest with the decrease of the grain size, instead the sandstone succession becomes thicker (on the slope and basin floor) at the expense of the conglomerate. This sandstone makes more than 90% of the total sandstone of Tanjero Formation. Some of these sandstones in the area between proximal and distal area (slope) have light color of gray or green (weathering-dark red or brown) and clean texture (arenite). Toward the basin the grain size decreases and the weathering red color changes to gray greywacke.

2.6-Petrography of sandstones equivalent to Kato conglomerate

They have nearly the same constituents of the Kato Conglomerate (resemble Qulqula Formation). Most samples of this sandstone are composed of chert and limestone clasts with

Plate 2.4



(1) Upper part at Qashqully pinic area , South of Dokan Town. It is equvelent to mixed carbonate - siliciclastic succe-ssion in Chuarta an Mawat area. It is composed of alternation of thin and thick light brown marly and sandy limestones with occasional intercalation of calcareous shale, sandstone and few thin lenses of conglomerate.

(2) The same succssion (as shown in the photo above) in the southwest of Dokan Town which is forming ridge about 50 thick. It is returned to HST and SMST. It is contain some sedimentary structures as seen in the lower part such ripple mark trace fossils.

(3) Kato conglomerate which fills one of the Incised valleys at north of Suwais village(Qandil Mountain toe). The deposits of these valleys shows sudden lateral thickness change as shown here.

less than 15% of matrix. This type of sandstone is called chert-limestone arenite (or lithic arenite) (Fig.2.6). But when classification of Al –Rawi (1982), this sandstone will be mainly called carbonate arenite (Fig. 2.5A) while they called lithicarenite in the classification of both Folk, (1974) and Pettijohn (1957). In other places, especially at the distal area it changes occasionally to greywacke. It is possible that these places are not affected by storm and the sediments only deposited by turbidity currents. Both type of sandstone contain less than 15% of igneous rock fragments. The presence of igneous clasts in the sandstone and their absence in the Kato conglomerate can be attributed to the following:

1.It is possible that the original size of igneous clast (more or less altered to serpentinite) and shale clasts is disintegrated into sand size during transportation as a result of their soft nature.

2.It is possible that their source area of ophiolite be located in greater distance than that of the chert and limestone (Qulqula Formation) (Fig.6.5). Therefore, they might be traveled for long distance and reworked for several times before reaching the present site of deposition.

3. It is possible that minor amounts of igneous sand grains came from the possible fans and incised valleys, which are located outside the studied area. So it is possible that the sandstones equivalent to Kato conglomerate be contaminated by igneous clast bearing turbidity currents from submarine fans located outside the studied area.

Reworked Radiolaria are invariably present ranging from 5% to 20% (Plate2.4A.3). In this study they are grouped with chert rock fragments in point counting. These fossils can also be seen clearly in the groundmass of Kato conglomerate.

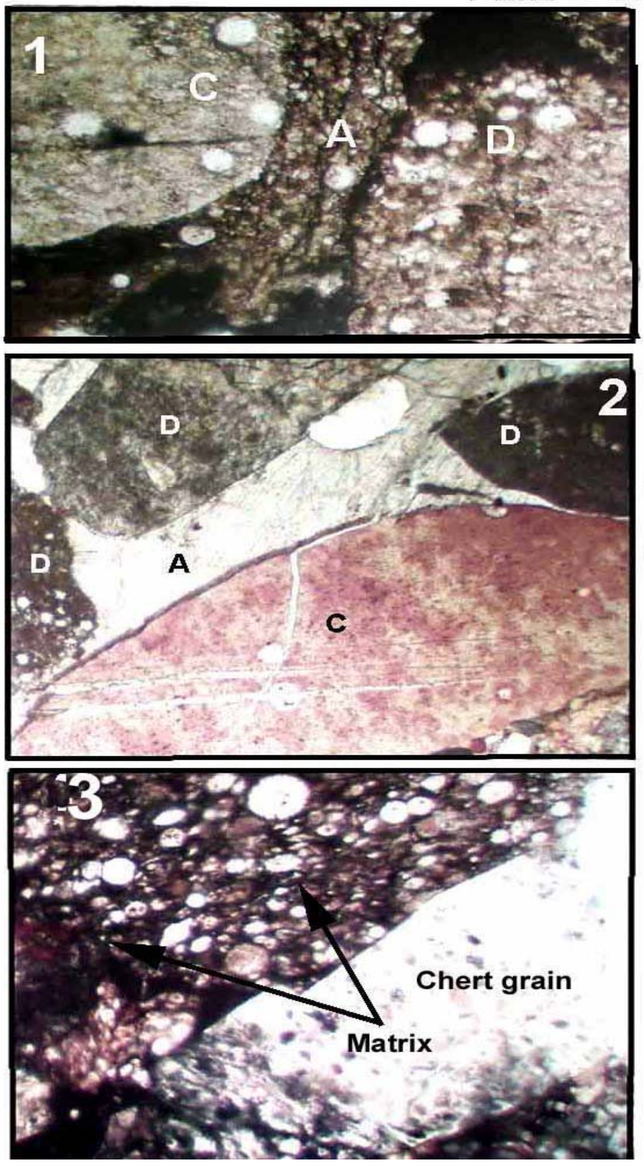
The sandstone equivalent to Kato conglomerate contains terrigenous limestone fragments more than chert (Fig.2.6). These limestone grains are dark in color and derived from Qulqula Formation. Most probable source is the bituminous limestones of the latter formation, which are called “black limestone” by Karim (2003a) and Karim (2003b). Some of these grains are siliceous. Because of their dark color, some grains appear as shale and may be mistaken for them. They show high degree of compaction because of deep burial or tectonic stresses so one can see the rare shale grain highly deformed in addition to breakage of radiolaria and chert grains. In some cases calcite cements are crushed due to compaction which are giving rise to a texture resemble terrigenous grain.

The shale grain, most possibly derived from lower sequence of the formation in the basin of the formation during river incision to the shelf (see the chapter of the sequence stratigraphy). Therefore most of them are not regarded as clastic terrigenous component but as intraformational clasts (intraclasts). So these rare grains can be excluded from plotting on the tetrahedrons without affecting the lithology of the formation and source area as shown by the tetrahedrons.

The sandstone contains very minor amount of detrital quartz and feldspar (less than 2 %). The porosity-depleted nature of this sandstones is likely reasoned to the fact that the limestone grains are bituminous, siliceous or dolomitic which all are relatively dissolution resistive as compared to pure limestone. Another reason for absence of porosity is the absence of the feldspar grains. According to Mansurberg, (2001) the dissolution of feldspar grains lead to secondary porosity.

The texture and sorting of the sandstone depends on the means and locations of deposition of the sandstone in the Upper Cretaceous basin. Generally those deposited in the shallow and storm dominated environment have clean texture (arenite) which is interpreted as tempestite (storm deposit) Einsele (2000). These are abundant in the area north of Sulaimaniya, Chaqchaq valley, Mokaba and Mara Rash Village. But those deposited by turbidite in deeper water may have matrix-supported texture. These sandstones are more abundant in the distal area such as south of Sulaimaniya city and Dokan area in addition to Sharazoor and Piramagroon plains.

Plate 2.4A



(1) Some sandstone of Tanjero are binded by matrix(A) of silty materials with radiolarian fossils. In this microphoto the matrix is sandwiched between two grains of limestone (C and D) by compaction. S.No. 10 PPL , X10 ,Malkandi section.

(2) Most sandstones are binded by Calcite cement (A) The grains are chert (C)and sliceous limestone(D) clasts S.No. 15. XN, X10 Dokan section.

(3) The marix of some sandstones and conglomerates of Tanjero Fn. consist mostly of reworked radiolarian fossils

(4) graded bedding as seen in thin section, S. No. 6 , X6 Tagara section normal light.

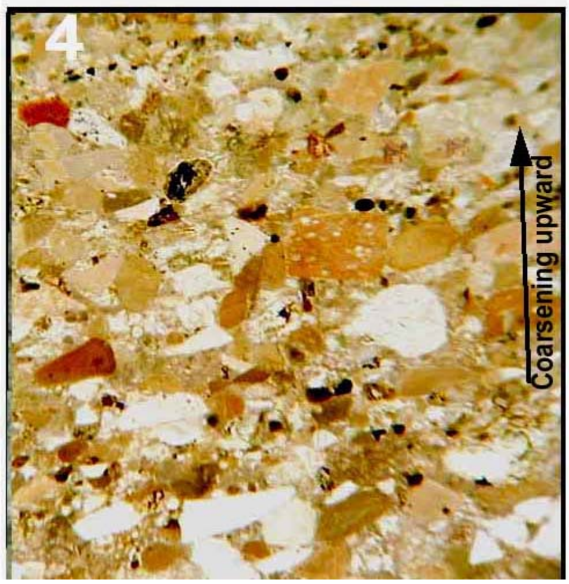
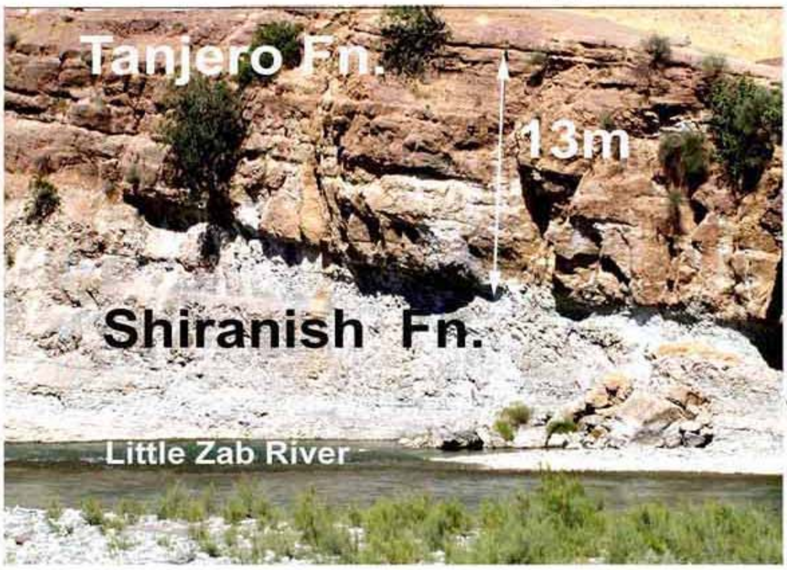
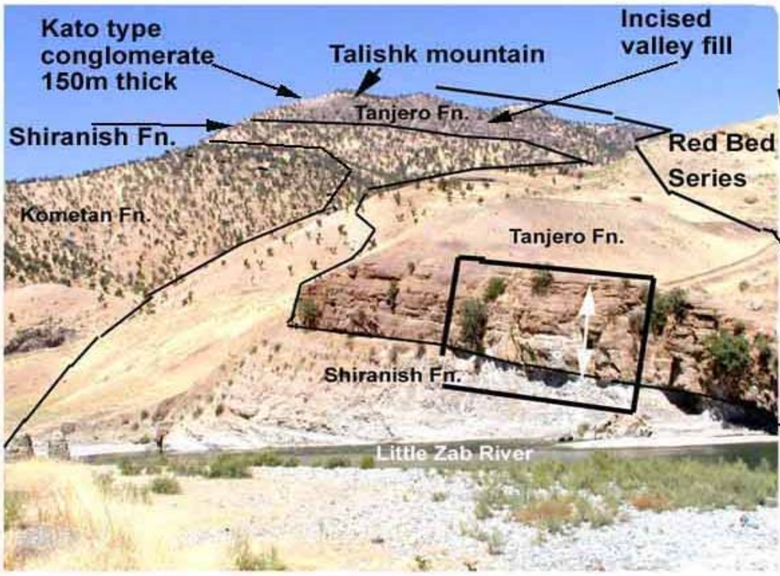


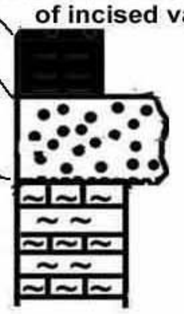
Plate 2.5



(1)Sharp erosional contact between Lower Part of Tanjero Formation (Kato Conglomerate) and Shiranish Formation .This vertical section is exposed at the left bank of Little Zab (Du Awan) River at the border between Iran and Iraq. The contact is sequence boundary(SB1)between the two formation. It is composted only from chert and limestone gravels and boulders

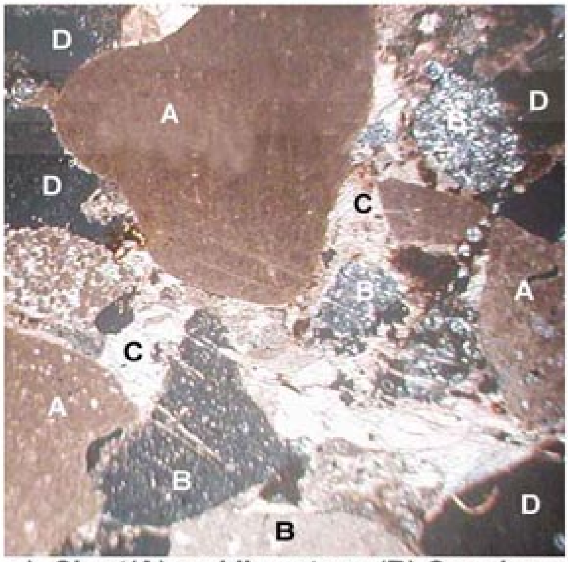


(2) The general view of outcrop of Kato conglomerate inside Iran. The section in the above photo is indicated by black frame. It can be seen that is thins from 150 to 13m from representing the sediments center and sides of incised valley

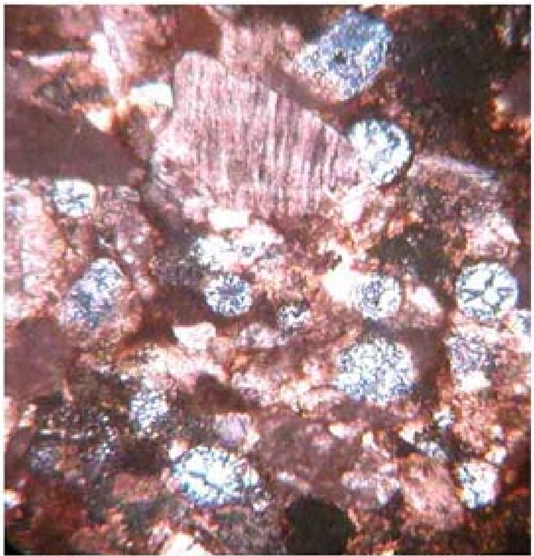


(3) Alternation of bluish white calcareous shale and marl of the middle part of Tanjero Fn. exposed in the Chaqchaq valley north of Hanaran village. This part is previously mistaken for Shiranish Fn. But in this study is regarded as TST which overlies the lowstand sandstone wedge.

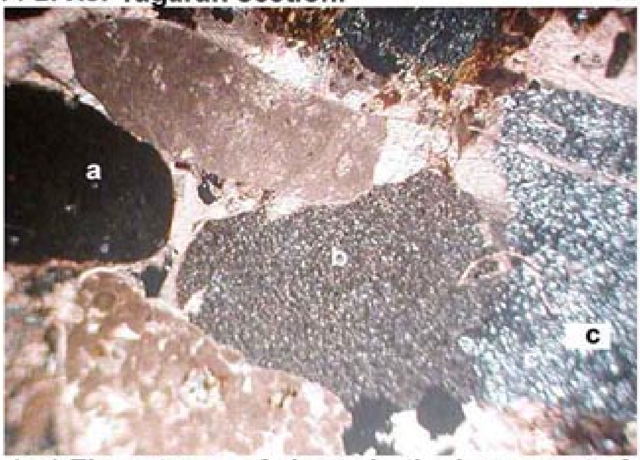
Plate 2.6



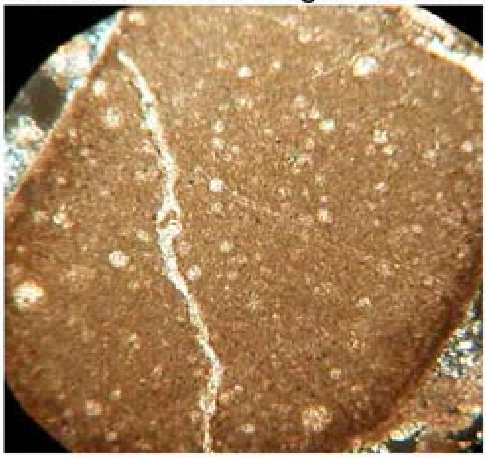
(1) Chert(A) and limestone (B) Conglomerate of Lower part of the formation, binded by calcite cement (C). The pores (D) are grinding resistance grains (may be chert) PPL. X5. Tagaran section.



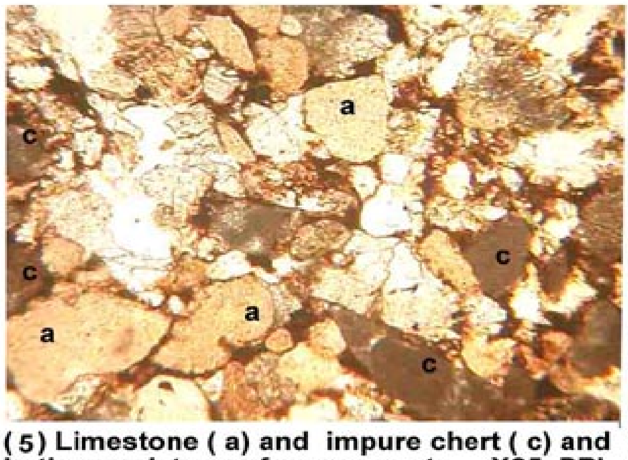
(2) Nearly all sandstone beds of the lower part contain 2-10% of reworked radiolarian fossils. In the photo more than 7 fossils are shown. other grains are limestone and chert grains. C.N .X50



(3) Three types of cherts in the lower part of the formation. Croarsely (c), finely (b) and cryptocrystalline (a). C.N. X5. Malkandi section



(4) The rounded lithoclast of limesone contains radiolarian fossils. X.N, X8. Malkandi section



(5) Limestone (a) and impure chert (c) and in the sandstone of upper part. X25, PPl Dokan section.

(6) The sand fraction of the formation occasionally contains less 10% green serpeninite (A). Lower part of Tagaran section. X25. C.N.

Table (2.1) Location, percentage of constituents and type of conglomerates in Tanjero Formation at proximal area.

Location name and GPS reading of N and E.	Grain type %				Descriptive name	Bed thickness (m)	Genetic name	Sorting and roundnes	Stratigra-phic position
	Chert	limestone	others	matrix					
Naudasht valley N: 36^{o} 24^{-} $6^{=}$ E: 44^{o} 58^{-} $38^{=}$	45	25	8 ign	20	block congl.	3.3	Para- congl.	Bad subangular	Lower part
Naudasht valley N: 36^{o} 24^{-} $27.8^{=}$ E: 44^{o} 58^{-} $2.8^{=}$	20	50	5 ign	24	Boulder Congl.	4.5	Para- congl.	Bad subangular	Lower part
Naudasht valley N: 36^{o} 24^{-} $23.5^{=}$ E: 44^{o} 58^{-} $2.1^{=}$	25	35	6 ign	31	Pebble congl.	4	Para- congl.	Bad subangular	Lower part
Naudasht valley N: 36^{o} 25^{-} $3^{=}$ E: 44^{o} 57^{-} $9.7^{=}$	38	40	0	22	Pebble Congl.	0.5	Para- congl.	Bad subangular	Upper part
Naudasht valley N: 36^{o} 25^{-} $3.3^{=}$ E: 44^{o} 57^{-} 40.1	20	12	0	68	Pebble congl.	2	Para- congl.	Bad subangular	Upper part
Naudasht valley N: 36^{o} 24^{-} $30^{=}$ E: 44^{o} 57^{-} $28^{=}$	32	38	5 ign.	25	Boulder congl.	4	Para- congl.	Bad subangular	Lower part
Suwais Village N: 36^{o} 21^{-} $45.3^{=}$ E: 44^{o} 4^{-} $48.7^{=}$	41	31	7 shale	21	Pebble Congl.	55	Para- congl.	Bad and subangular	Lower part
Suwais Village N: 36^{o} 21^{-} $41.7^{=}$ E: 45^{o} 3^{-} 55.6	52	23	0	25	Pebble Congl.	120	Para Congl	Bad and angular	Upper Part
Suwais Village N: 36^{o} 21^{-} $58^{=}$ E: 45^{o} 3^{-} $56.2^{=}$	49	26	12 shale	13	Pebble Congl.	120	Ortho Congl	Bad and angular	Upper part
Iran N: 35^{o} 37^{-} $20.6^{=}$ E: 45^{o} 35^{-} 16.4	43	40	5 shale	12	Boulder congl.	13	Ortho Congl	Bad and subangular	Lower part
Iran N: 36^{o} 37^{-} $21^{=}$ E: 45^{o} 57^{-} 34	42	32	12 shale	14	Boulder congl.	13	Ortho Congl	Bad and subangular	Lower part
Qashan Bridge N: 35^{o} 52^{-} $2.3^{=}$ E: 45^{o} 24^{-} $8.3^{=}$	60	30	0	20	Boulder congl.	100	Para- congl	Bad and subangular	Lower part
Qashan Bridge N: 35^{o} 52^{-} $30^{=}$ E: 45^{o} 24^{-} 28	60	30	0	20	Boulder congl.	100	Para- congl	Bad and subangular	Lower part
Qashan Bridge N: 35^{o} 52^{-} $2.4^{=}$ E: 45^{o} 24^{-} $7.3^{=}$	54	38	8 shale	20	Boulder congl.	40	Para- congl	Bad and subangular	Lower part
Qashan Bridge N: 35^{o} 52^{-} $1.9^{=}$ E: 45^{o} 57^{-} $5.7^{=}$	65	18	0	17	Boulder congl.	40	Para- congl	Bad and subangular	Lower part
Dree Village N: 35^{o} 51^{-} $41^{=}$ E: 45^{o} 23^{-} $57.7^{=}$	41	28	9 Shale	22	Boulder congl.	28	Para- congl	Bad and subangular	Lower part

Notes

1.For the limit of clasts and matrix percentage the classification of Folk (1954 in Pettijohn, 1975) is used
2.Composition and color of chert and limestone clasts are widely variable.
3.The igneous clasts are consisting of only basic plutonic ones.
4. All percentages are measured by volume and the reworked radiolarian fossils are grouped with chert percentage

Table (2.2) Location, percentage of constituents and type of conglomerates in Tanjero Formation near the distal area for Tagaran (upper six rows) and Kato conglomerates.

Location name and GPS reading of N and E.	Grain type % Chert	limestone	others	matrix		Descriptive Name	Bed thick. (m)	Genetic name	Sorting and roundnes	Stratigraphic position
Dokan N: 36° 56′ 5.1″ E: 44° 57′ 37.5	24	21	43 ign.	12		Pebble Congl	0.33	Ortho Congl	Moderate, rounded	Upper part
Dokan N: 36° 55′ 23″ E: 44° 57′ 40.1″	30	23	36 ign.	11		Pebble Congl	1.2	Ortho Congl	Moderate, rounded	Upper part
Tagaran Village	10	16	58 ign.	20	No cement	Boulder congl.	100	Para-congl	Moderate, rounded	Upper part
Zarda bee Village	12	14	54 ign.	20	No cement	Pebble congl.	3	Para-congl	Moderate, rounded	Upper part
Qashlaq village N: 35° 43′ 39.2″ E: 45° 29′ 9.3″	7	12	29 ign.	50	No cement	Pebble congl.	0.9	Para-congl	Moderate. rounded	Upper part
Qashlaq village N: 35° 43′ 39.8″ E: 45° 29′ 9.1″	9	14	37 ign.	50	No cement	pebble congl.	1.2	Para-congl	Moderate, rounded	Upper part
Arbat (Shinke Hill) N: 35° 26′ 52.3″ E: 45° 33′ 20.5″	7	21	0	72		Pebbly congl.	1.5	Para-congl.	Bad, Angular	Lower part
Sirwan valley N: 35° 7′ 23.5″ E: 45° 52′ 17.6″	27	22	12 s.st	39		Boulder congl.	2.3	Para-congl.	Bad, subngular	Lower part
Sirwan valley N: 35° 7′ 28.9″ E: 45° 53′ 50.6″	30	18	9 shale	43		pebble congl.	6	Para-congl.	Bad, rounded	Top of Upper part
Qizlar village N: 36° 56′ 5.1″ E: 44° 57′ 37.5	34	19	8 shale	39		Pebble Congl	2	Para-congl.	Bad, Angular	Lower part
Qizlar village N: 36° 56′ 35.1″ E: 44° 57′ 30.2	18	11	10 Shale	69		Pebbly Congl	2	Para-congl.	Moderate, subrounded	Lower part
Southeast of Kurdsat N: 35° 35′ 59.1″ E: 45° 27′ 39.4″	31	23	8 shale	38		Cobble Congl.	0.	Para-congl	Moderate, subangular	Lower part
North of Kurdsat N: 35° 35′ 59.1″ E: 45° 27′ 40″	42	25	0	10	23 Silica cement	Cobble Congl.	0. 3	0rtho congl.	Moderate, subangular	Lower part
North of Kurdsat N: 35° 35′ 59″ E: 45° 27′ 42.2″	40	28	0	15	27 Silica cement	Cobble Congl.	0. 3	0rtho congl.	Moderate, subangular	Lower part
Malkandi Hills N: 35° 35′ 21.1″ E: 45° 27′ 48″	61	23	6 shale	10	1.9	Grit	1.3	Ortho congl	well and angul	Lower part
Malkandi Hills N: 35° 35′ 24.4″ E: 45° 27′ 46″	35	15	5 S.St	45	4	Pebble congl 4	1.2	Para-congl	Bad and subangular	Lower part
Malkandi Hills N: 35° 35′ 24.9″ E: 45° 27′ 44.7″	13	9	10 shale	68	2	Pebble congl.	2	Para congl.	Bad and rounded	Lower part
Malkandi Hills N: 35° 35′ 24.9″ E: 45° 27′ 44.7″	66	I0	4 shlae	10	1.5	Pebble Congl.	0.5	ortho-congl	Bad and subangular	Lower part
Malkandi Hills N: 35° 35′ 17.4″ E: 45° 27′ 49.1″	15	12	5 shale	68	2	Pebble congl	1.7	Para-congl	Bad and rounded	Lower part

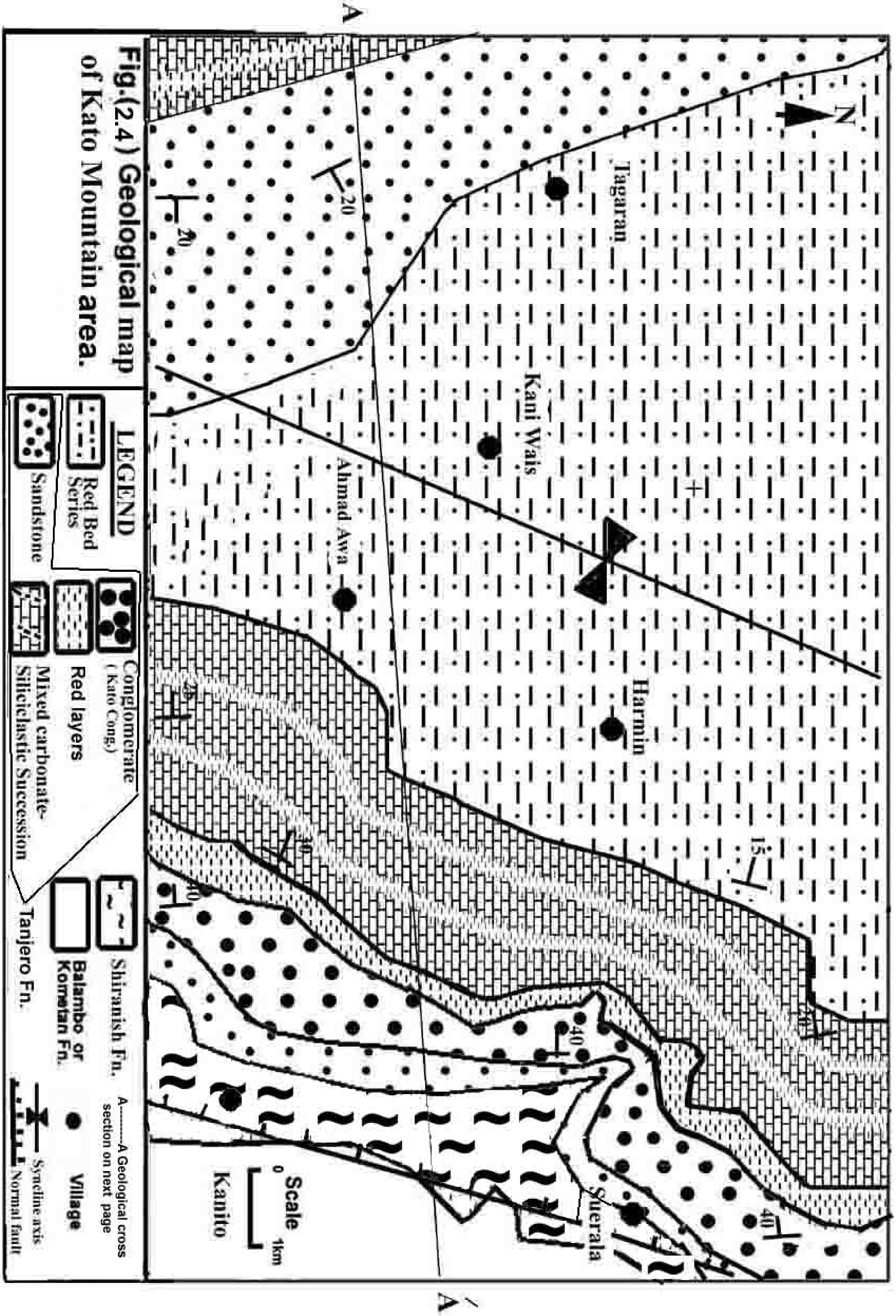


Fig.(2.4) Geological map of Kato Mountain area.

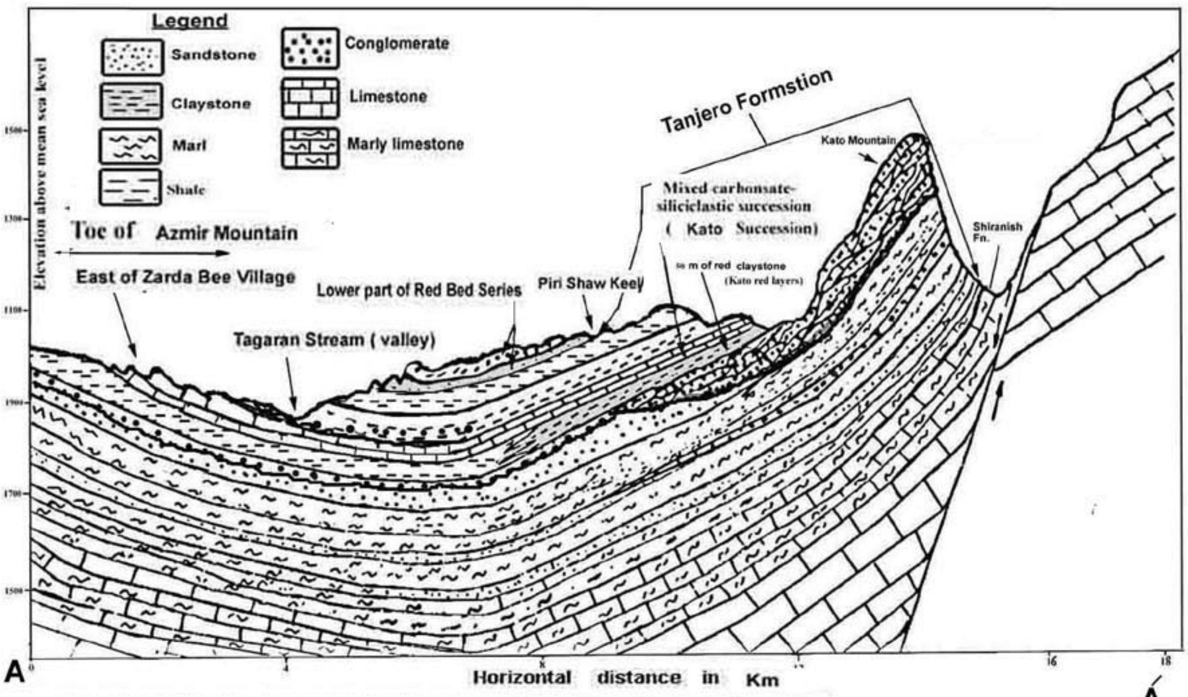


Fig. (2.5) Geologic cross section passing through Kato Mountain

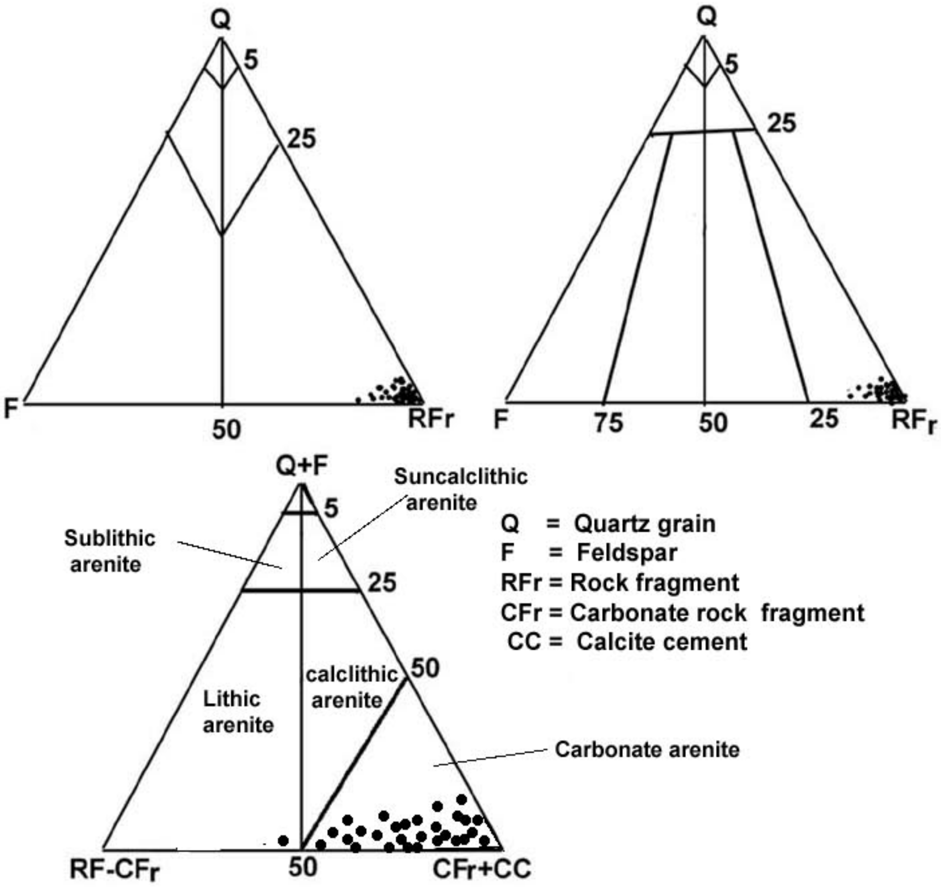
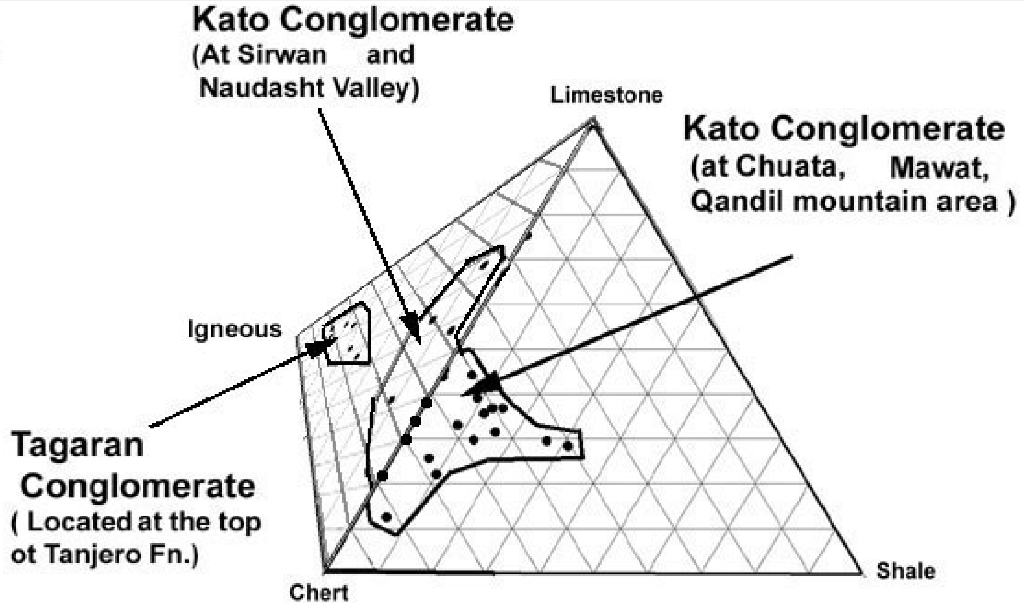


Fig.(2.5A) Classication of sandstone of Tanjero Formation according to A) Pettijohn, 1975. B)Folk, 1974 . C) Al-Rawi, 1982

A



B

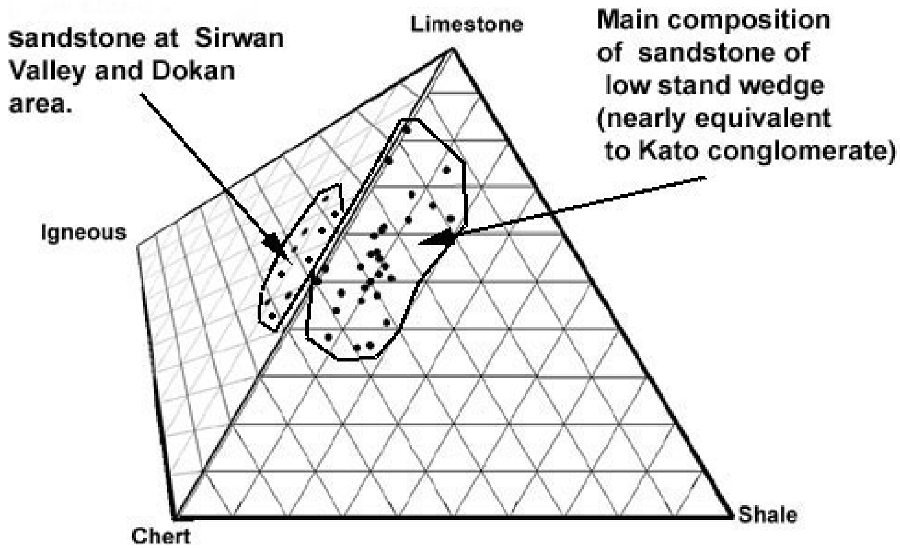


Fig.(2.6) Plotting of Terrigenous rock fragments of conglomerates (A) and sandstones(B) of Tanjero Formation on the igneous-limestone-shale-chert tetrahedron.

Note

1. Most shale grains (clasts) are derived from reworking of the previous HST sediments of Tanjero Formation so they are regared as intraformational clast (intraclasts) and not as terrigenous sediments. Therefore some of these shale grain are not repesented on the terahedron.
2. The limestone clasts are mostly derived from the bituminous limestone (black limestone of Karim, 2003a and Karim 2003b) These clasts may appear , in thin section, as shale clasts, so in this study this is considered during thin section study.

Table (2.3) Constituent percentage of the sandstones of the low stand wedges (nearly equivalent to Kato conglomerate)

Sample No.	Chert	Limestone	Igneous	Shale	Cement
M3	23	55	0	9	13
M4	32	40	0	8	20
M5	38	40	0	9	13
M7	31	49	0	7	13
M8	19	60	0	0	21
M9	20	59	0	7	14
M10	32	44	0	9	15
M11	39	44	0	0	17
M12	32	49	0	8	11
M14	35	41	0	8	16
M!5	41	30	0	12	17
M16	36	36	0	15	13
M17	28	54	0	6	12
M18	30	52	0	5	13
K2	29	41	0	11	19
K3	37	47	0	0	16
D5	12	62	0	10	16
D6	14	47	0	13	26
D7	14	47	0	13	20
D8	26	39	0	8	26
D9	35	41	0	11	13
D10	46	33	0	7	14
D11	31	41	0	5	23
D12	42	43	0	0	15
D13	39	40	0	5	16
D14	42	33	0	15	10
Tag3	46	35	3	6	15
Tag4	35	46	4	6	10
Tag5	37	33	0	5	23
Tag6	26	41	6	9	20
Tag7	15	70	0	0	15
Sr3	19	61	8	4	13
Sr4	22	52	7	0	29
Sr5	28	44	10	0	18
Sr6	42	36	5	0	27
Sr7	46	35	10	0	14
Sr8	35	43	0	11	12
Sr10	24	41	7	8	20
Sr11	28	33	12	5	22
Sr12	26	44	5	0	26

Note: 1-Nearly all samples can be called Chert-limestone lithicarenite.
2-M: Malkani section, **D**: Dokan section, **Tag**: Tagaran section and **Sr**: Sirwan Section.

CHAPTER THREE:

SEDIMENTARY STRUCTURES AND PALEOCURRENT ANALYSIS

3.1-Sedimentary structures

Many sedimentary structures, such as, mechanical (physical) and biogenetic sedimentary structures are found in the lower and upper parts of the formation. Except bedding, no other sedimentary structures are found in the middle part. Most of these structures, as allocated to Tanjero Formation and to the author's awareness, are recorded for the first time in the Tanjero Formation. All these structures have environmental and paleocurrent importance, which can be very useful in basin analysis of the formation. The deep environment of previous workers is attributed to the fact that opportunity for shallow environment structures preservation is less than that of deeper ones in sedimentary records. Wave and current erosions and bioturbation commonly attack and obscure shallow ones while deep structures normally away from these enemies. Tanjero Formation has gradational and intertonguing stratigraphical relationship with Shiranish Formation (Bellen *et al.* 1959), therefore, some parts of the of the formation show deep environment. The good preservation of sedimentary structures in these deep parts was highly over estimated and applied to overall formation.

In the present study, at least half of the formation thickness proved to be deposited in shallower water than that assigned before (regarded as trench or geosyncline). The lower and upper parts are deposited in shallow environments, which is equivalent to slope and shelf environment while the middle part (of present study) is deposited in deep basinal environment. This is also true for lithologies near the base of the lower part, which represents transitional interval with Shiranish Formation. The paleocurrent of the formation is deduced to be mainly toward south and southwest. These all inferred from the following structures:

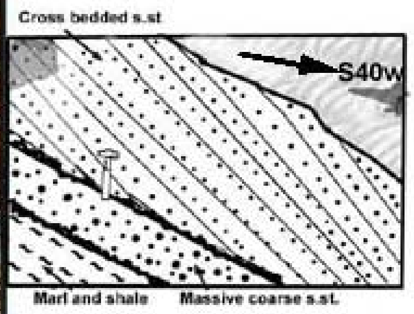
3.1.1- Cross-stratification

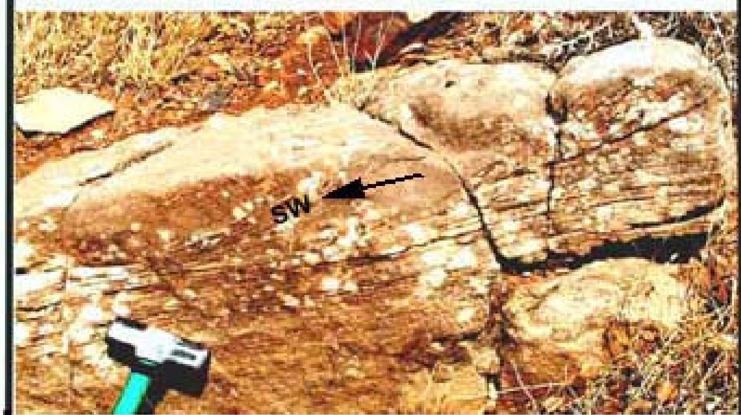
It is defined as arrangement of strata inclined at an angle to the main stratification. In the Tanjero Formation it is subdivided in to the following:

Plate 3.1

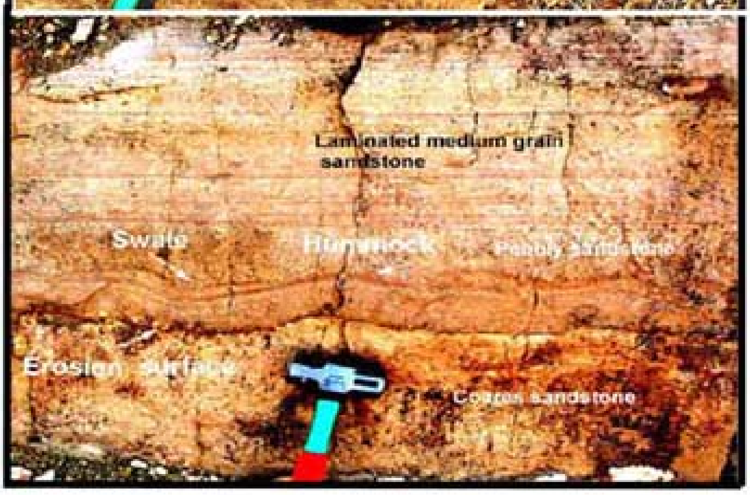
(1) Thick bed of coarse and cross bedded sandstone exposed at 1km to the north of Sulaimaniya City on the Malkandi Hill west of water tank at latitude: 35° 35' 21.6" and longitude : 45° 27' 47.8" This cross bedding is the largest one found in Tanjero Formation. The pale-ocurrent direction is toward S40W.

(2) This photo shows the part enclosed in the black frame in the above photo. As it found in lower part (LST) therefore, it formed in shallow high energy environment .

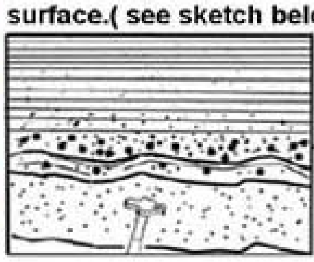




(3) Trough cross-bedding at the southwest limb of Azmir Anticine. Along the toe of this anticline from Qirga to Qizlar villages, different type and scale of cross beddings and laminations are existing, most of them show SW paleocurrent dirction.



(4) Exposed section, showing possible tempestite deposit which is represented by hum-mocky cross-stratification. The depression(swale) and the dome (hummock) are rested and overlain by lamina parallel to the surface.(see sketch below)



A) According to of strata as cited by Blatt *et al*.(1980):

1- Cross lamination, where are cross strata are thinner than 1cm.
2- Cross bedding, in which are cross strata thicker than 1cm.

Cross laminations are present in the lower part of Tanjero formation in the distal area (Dokan town, south of Sulaimaniya City and Chaqchaq valley). They are commonly associated with ripple mark (Plate 4.2.1 and 4.2.2) and bioturbation of escape structures. They are found mostly in fine- to medium-grained sandstone. According to Allen and Allen (1990, p.271), they were formed by migration of ripple marks (wave ripple marks) and confined to less than 200 m depth. In the upper part few cross lamination is found in bioclast limestone in Chuarta area (500 m to the southeast of Zardabe Village). In this locality it is associated with cross- bedding, while in the middle part, this type of sedimentary structures is not found. The Cross bedding, in the formation, is divided, according to shape, into the following types:
1**.**Trough cross- bedding. 2.Plannar cross-bedding. 3.Hummocky cross stratification.

Many large and medium scale trough and plannar cross bedding are found in the lower part in the Malkandi section and Chaqchaq valley. These structures are observed in medium and coarse-grained clean (arenite) sandstone, while in the upper part they only exist in the bioclast limestone at the south of Tagaran village. In the lower part, the largest cross bedding is seen in a bed of coarse sandstone (1.5m thick) at north of Sulaimaniya City (Plate 3.1.1, 3.1.2 and 3.1.3).

Cross bedding exists in several environments; they are more common in river point bars, tidal channels, and delta and shelf environment. In this connection Potter *et al*., (1980) included cross-bedding in shallow shelf only, while Blatt *et al.,* (1980) showed trough cross bedding, found in tidal flat, much similar to that found in Tanjero Formation. They also mentioned to occur in clastic dominated shelves. According to Nichols (1999, p.206) trough cross-bedding are normally absent in depth greater than 100.

As will be discussed later, the cross-laminations are formed below fair weather base (above storm wave base) in relatively deep environment while the cross bedding are formed above fair weather base in the mid or inner shelf at the time of maximum regression phase. The presence of these shallow environment cross beddings in Tanjero are attributed to the fact that during the lower part the sea level was so lowered and became shallow water in deep basin (equivalent to shelf as concerned to water depth). In the area of Qandil foothill area (Naudasht valley) exceptionally large cross bedding is found (Plate 2.3.2) which shows south paleocurrent directions. But most cross-beddings and cross laminations show southwest paleocurrent direction. It is worthy to mention that the middle part of the formation contain no cross bedding because of deep environment of deposition because of deep environment of deposition.

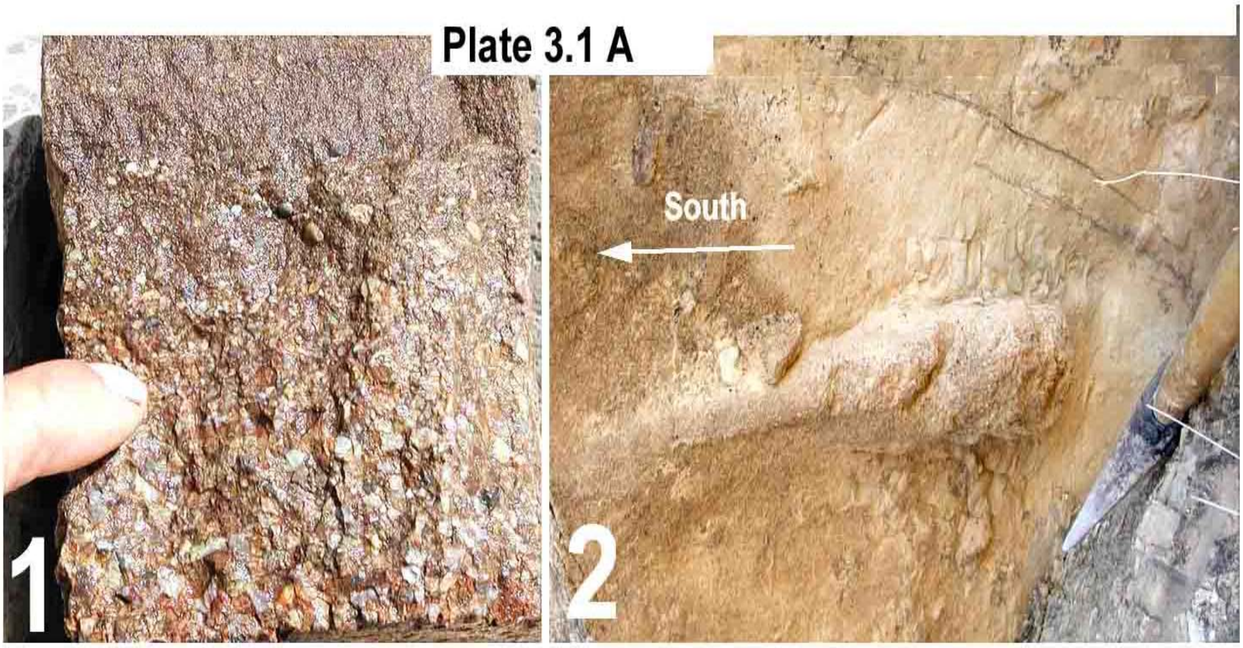
3.1.2- Flute cast

This structure is scoured by turbulent eddy turbidity currents, which is, in plain view, narrower at one end and widening out on the tapered end. Flute cast can be found in Tanjero formation but most of them observed on the lower surface of toppled or dislocated block of sandstone. However few ones are fond in their original depostional place (Plate 3.1A.2), which can be used for paleocurrent indication. The peaks of these structures point toward up current

3.1.3- Graded bedding

Gadded bedding is most common sedimentary structure in the Tanjero formation. This is attributed to the fact that most sediments of the formation are deposited by either turbidity current or by storm generated geostrophic current (Fig. 4.3A). It occurs in both sandstone and pebbly sandstone (Plate 2.4A.4 and 3.1A.1) as normal grading (fining upward). According to Pettijohn (1975) gadded beds are deposited from waning turbulent flow and may range in thickness from a centimeter to one or more meters. This structure is a part of ideal cycle called the Bouma cycle (Fig.4.1B). In Tanjero formation, this ideal cycle (or sequence) can not be found only one or more parts can be seen (Plate3.1A.1).

Plate 3.1 A



(1) Graded bedding(normal) in conglomeratic sandstone of lower part near Lower Hanaran village, Chaqchaq valley.
(2) flute cast showing south paleocurrent direction near Joblakh village, Dokan area

3.1.4-Hummocky cross stratification (HCS)

According to Tucker (1991) this structure is characterized by gently curved, low angle (less than15 degrees) cross laminations which are arranged in convex-upward (hummock) and concave downward (swale) pattern .The lower boundary of the sets is erosional. The laminae are nearly parallel to the erosional surface and thicken laterally which become fan-like. All these characteristics cannot be developed ideally and cannot be distinguished easily in cross sections except when three-dimension outcrop sample is available In the Tanjero Formation similar structures are found in the lower part in the intermediate area between distal and proximal area (Plate 4.3.1, 4.3.2, 4.3.1.3). The following four points are giving additional evidence for existence of hummocky cross stratification in Tanjero Formation.

1.In Dokan area at 450m to the west of Joblakh village and near tourist village, a three-dimensional sample is found which has most prerequisites of HCS (Fig. 4.2).

2.Walker, (1984, p.150) mentioned that in core samples, the criteria for distinguishing HCS are the intersected low angle laminations (Plate 4.31 and 4.3.2) and bioturbated mudstones (Plate 3.4). These lamination and bioturbation are very common in the lower part of Tanjero Formation at north of Sulaimaniya city at east and west of checkpoint.

3.Walker, (1984, p.200) mentioned association of *Skolithos* and *Cruziana* ichnofacies (see section 3.1.3.2 and 3.1.3.5) with Hummocky cross stratification. He added that reworking of pre-existing sediment by storm form escape trace fossil. In Tanjero Formation and in the lower part these structure are found near each other in clean sandstone (arenite) (Plate 3.2.1 and 3.2.2), which are evidence for presence HCS.

4.For other evidence see Tempestite in the section (4.1.2).

3.1.5 -Biogenic sedimentary structures

Both Frey (1973) and Simpson (1975) used the term biogenic sedimentary structure “bioturbation structures” for all sedimentary structures formed by organisms. According to Einsele (1998) the bioturbation structures are widely common in shallow marine environments where different tempestites are deposited. In Tanjero Formation these structure are as follows:

3.1.5.1-Skolithos trace fossils

They are simple, tube-like, vertically oriented burrow that typically shows a much greater length versus width. *Skolithos* is interpreted as a dwelling burrow made by a suspension-feeding animal. These structures are found in coarse and medium grained sandstone beds of the lower part of Dokan section and Malkandi section. They are appearing as straight or slightly inclined burrows and most of them arranged normal to bedding planes. These traces are 5 to 50cm long and 2 to 3.5 cm wide (diameters). They are found in calcareous shale, siltstone and sandstone and two types of this structure are found:

3.1.5.2 -Skolithos escaping structure

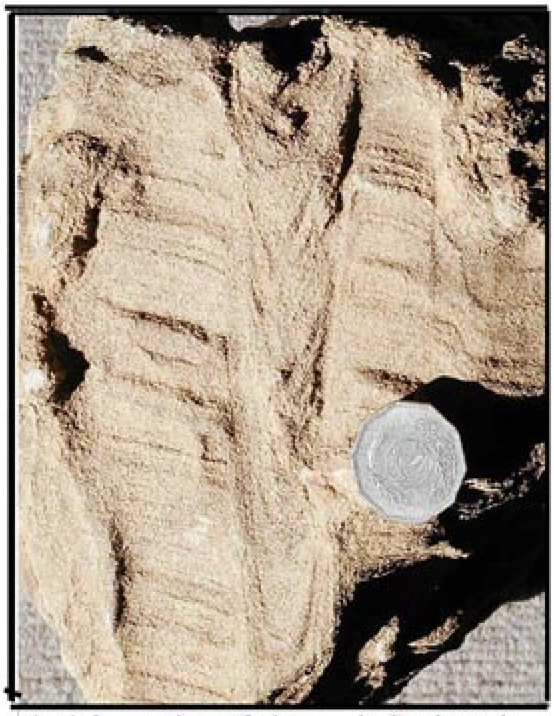
It consists of vertical shafts in the laminated sandstone. In the longitudinal section, the shaft lamina is deflected downward forming U-in-U laminations and spreites structures (Plate3.2.2 and 3.6.2). The laminas in some case are continuous across the structure, while in cross section the structure consisted of circular laminae arranged concentrically. They exist in a laminated medium to thick beds of sandstone. These beds are coarse grained and 10 to 30 cm thick, which may be cross-bedded and rippled at the top (Plate 3.6.3). These traces exist in laminated sandstone. Under microscope, two types of the lamina can be recognized. They consist of alternation of dark and light color lamina. The dark one contains more limestone grain than the light one which is chert rich. In other cases they consist of coarse and fine sand.

Those found in Malkandi section have large size and showing clear and well-developed spreites (Plate 3.2.2 and 3.6.2), while those of Dokan section have no obvious spreites. In less than half meter three structures of this type are observed in the same bed (Plate 3.2.1 and 3.6.3). These structures, occasionally, are wider in the bottom than the top. They clearly represent behavior of the organism, possibly gastropod and bivalves, in respect to the rate of sedimentation in shallow marine environments where storm erode sediments and redeposit them in deeper environment.

Simpson (1975) called this type of structure *fugichina* (escaping structure**)**. Rhoads (1975, p.155) mentioned that organism buried below the unit would burrow this newly deposited sediment upward to make connection with sediment surface for escape. He showed escape structure similar to those that exist in the formation made by the bivalve *Mya arenaria* in tidal flat sediment of the North Sea. He also mentioned that after storm, sediments are rapidly deposited, producing laminated post storm unit (tempestite unit). He added Seilacher (1967), Doyle and Bennett (1998) included similar structure in *Skolithos* ichnofacies, which exists in high energy near shore environment. Lawa (1998) studied same structures in Injana and upper part of Fat,ha Formation. He attributed these structures to brackish coastal and fluviatile environment.

Plate 3.2

(1) A section of intensively bioturbated laminated sandstone bed, showing vertical trace fossil, Malkandi section, 2 km north of Sulaimaniya.



(2) A section of clean boiturbated sandstone bed showing escape trace fossil, L.P of the formation 2.5km northeast of Daraban village

(3) A section of clean sandstone (arenite) bed showing vertical Skolithos trace fossil, may be dwelling structure filled by more coarser sandstone, L.P of the formation l.5km To the northwest of Upper Hanaran Village.

(4) Branching boring trace fossil on the surface of coarse sandstone bed . Some part of the the tace filled with clay sandstone. Upper part of the formation ,it is clear that formed in semi-lithified sandstone. Dokan section, Dokan area.

3.1.5.3-Skolithos dwelling structure

It consists of smooth vertical cylindrical burrow without spreites. As compared to the host rocks they are filled with finer sediments. They are about 15- 50 cm long and with a diameter of 2-3 cm (Plate 3.3.1, 3.3.2 and 3.3.3). They are found in the lower part of the formation in both Malkandi and Dokan sections.

3.1.5.4-Horizontal and inclined borings

The horizontal types of these biogenic structures are found in the lower part of Dokan area and the inclined ones exist in lower part of Chaqchaq valley. The former consists of branching horizontal grooves about 1cm wide, 0.5 cm deep and 40 cm long. It is found on the upper surface of coarse sandstone bed. They are branching from both sides to secondary groove (Plate 3.2.4). It is obvious from the constant diameter of the boring that it, as a whole, is made by single organism for protection against predators. It is possible that the boring is made at the interface of sandstone, from below and shale above, but later the shale is removed by erosion.

The inclined borings consist of inclined shafts drilled in the medium grained sandstone and filled by coarse sandstones, the boring nature of these traces is clear because:

A-The horizontal boring has no side ridges (flank) as borrowings have. This means that the sediment was semi-lithified when formed. Moreover the sediments that fill the interior of the trace are different from that which makes up the wall of the trace.

B-Both horizontal and vertical ones have sharp boundaries and contrasted lithologic differences.

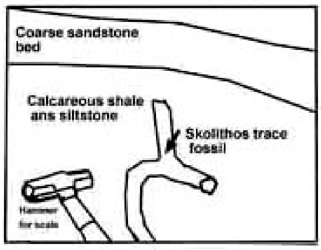
When all published classification (e.g. Seilacher, 1967, Tucker, 1991 Potter *et al.,* 1980 see fig. 4.3) of trace fossils are surveyed, the accurate position of this type is not accurately clear. But Warme (1975, p.205) showed meandering and slightly inclined boring of polychaete worm in intertidal of California. This boring is similar; in many aspects to that found in Tanjero Formation, especially both have branching and same size (Plate 3.2.4). It seems that this trace is transitional type between *Trypanite* and *Glossifungite* ichnofacies as it may be excavated in slightly consolidated sediment in shallow environment.

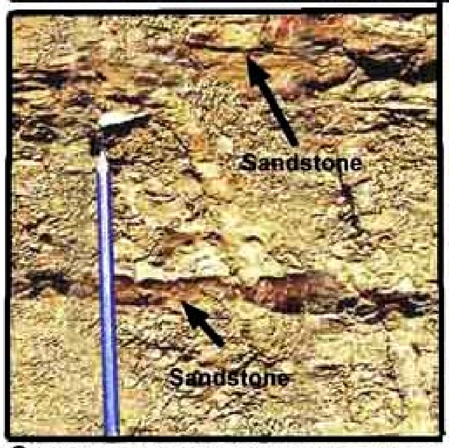
3.1.5.5-Cruziana assemblage trace fossils

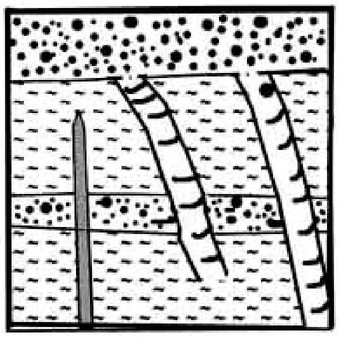
These structures are found on the top of medium and coarse-grained sandstone, nearly in all sections. In Malkandi section, medium thick sandstone (lithicarenite) beds of the formation are excavated for building stones in the past. There, the lithology of the formation organized in beds of both coarse and medium grained sandstones with many interbed of conglomerate. The burrowings are very common and can also be seen on surfaces of building stones used in the past inside Sulaimaniya City.

Plate 3.3

(1) Vertical branching Skolithos trace fossil in silty marl of the L.P. of Tanjero Formation. The trace lead to the overlying massive sandstone bed which is totally bioturbated (A). The marl is deposited below fairweather base and the sandstone is deposited by storm event. Malkandy section, 1km north of Sulaimaniya City.







(2) Two vertical Skolithos trace (left) fossils In the silty marl, of L,P. of Tanjero Fn. The Traces pass the sandstone bed in the middle of the photo along the way to upper massive sandstone bed in response to rapid sedimentation. GPS Location is N: 35° 35' 21.6", E: 45° 27' 47.8". The right Phpto shows branching Planolite trace fossils found in one of the limestone bed of upper mixed carbonate - sliciclastic succession. Location is 2km northeast of Siramerg Village, Chuarta area At N: 35° 40' 7.6", E: 45° 31' 2.8". The right sketch is illustrating the elements of left photo.

(3) Association of the inclined Skolithos(A) and Horizontal (B) trace fossil in silty marl of the L.P. of Tanjero Formation. The traces pass to thick massive sandstone bed.The sharp contact (X) between the sanstone and the boiturbated marl are deposited in outer & inner shelfs respectively. During the LST, this part of the basin was so shallowed that became a shelf as concerned to depth of water.

The burrowing traces mostly consist of straight and horizontal or slightly curved burrows (Plate3.4.). Most of them have smooth surface while few have side ridges (Plate3.4.2). In some cases, they are branching (Plate 3.3.2) especially those found in the upper part of the formation (in limestone beds of mixed carbonate-siliciclastic succession). In literature, similar structures are considered to *Thalassinoides and Planolite* trace fossils, which are included in Cruziana assemblage by Kennedy (1975). Latter traces are found in both shallow and deep environment, by Chamberlain (1975, p.446) who published sketches of burrowing of recent non-marine aquatic environments, which closely resemble those found in Tanjero Formation. He attributed these structures to moving snail, shrimp, and mayfly and caddisfly larvae on the soft sediments.

In the Tanjero Formation most *Cruziana* and *Skolithos* trace fossils are attributed to either pelecypods or gastropods. The only fossil recorded in the lower part, which may be responsible for above traces, is pelecypods (Plate5.4.3). The rareness of fossil in lower is attributed to susceptibility of the pelecypods to dissolution as their shell composed of aragonite. But in the upper part both fossils are very abundant especially in the limestone beds

Finally it is worth to mention that these traces belong to Cruziana Ichnofacies because:

1. They exist, as *Cruziana*, in coarse and medium grained sandstones and they resemble them except in the lack of striate markings on the lobes (flanks).
2. They exist in the lower part of the formation. Therefore this part deposited in the in shallow water during sea level fall as will be mentioned in sequence stratigraphy (chapter five).

3.1.6-Body fossils

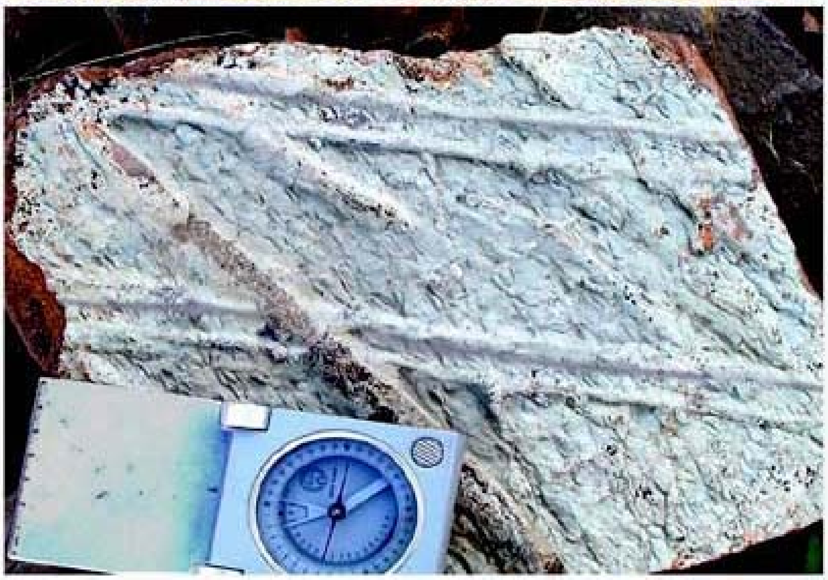
3.1.6.1-Plant remains (debris or fragments)

Nearly all sections and outcrops of lower part of Tanjero Formation, as Dokan, Chuarta, Malkandi, Qrga, Chaqchaq Valley and Sirwan Sections contain plant remains, such as, folio, piece of branches and worn parts of cuticles (Plate 3.5. 1 and 3.6.4). so these remains can be regarded as incomplete body fossils. These remains are found on the surface or inside the medium bedded sandstone and they commonly appear as light or dark carbonized brown pieces of different size. Under binocular microscope minute plant structures (fibers) of these debris can be seen (Plate3.6.1). In Sirwan section (type section) a petrified non- carbonized or non-oxidized wood is found (Plate3.5.2) in thick bed of conglomerate. This piece seems like a piece of recent dried wood. In some localities, the elongated axes of these remains are generally arranged, showing paleocurrent direction toward southwest and in some cases even southeast (Fig.3.1). But in other places they show or less random distribution.

In some sections such as Chaqchaq valley, exactly between Fayal and Lower Hanaran villages (northwest of Sulaimaniya city) and Malkandi hill more than 15 horizons are found in an

Plate 3.4

(1) Horizontal burrows (planolite) on a thick, coarse and clean sandstone bed in L.P. of Tanjero Formation. In this study it is regarded a type of Cruzian assemblage as done by Kennedy, (1975). They are formed below fairweather base after the event of storm or turbidity current when the envirnnment became calm. Malkandy section, 2km north of Sulaimaniya.



(2) Two ridged horizontal trace fossils of genus Aulichnites (Cruziana ichnofacies) intersecting with cylindrical burrow on lower surface of sandstone bed. Lower Part of Tanjero Formation at about 350 m east of Mara Rash Vuillage, Chuarta area.

(3)Highly bioturbated sandstone bed showing cross section of horizontal trace fossils. The diameter is abuot 1cm so it may be returned to Planolite genus. It is found in the Middle Part , about 50m above its contact with the Lower Part in Chuarta area at the valley of Azira Bichkolla. It is mostly consisting of condensed section (MFS). The penci is 16cm long and 0.6cm thick.

Location:

Latitude: 35° 39' 36.4"

Longitude: 45° 30' 6"

interval of 20m at the Lower Part of the formation, which contain clear and densely distributed plant remains. Moreover they are occasionally associated with cross lamination, and included in beds that generally have light color (light brown).

In Tanjero Formation these fragments are transported to the basin from coastal area incised or from source area by river flooding. They may be introduced to the basin from the incised valleys by large current generated by storm and deposited in shallow environments with sand or gravels. They may be reworked by storm as tempestite sediments and transported to deeper environment by turbidity current through the fan channels. Another possibility for presence of plant debris is that mentioned by Einsele, (1990 and 2000) that supratidal seaweed 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 shore. Smith and Jacobi (2001,p.336 and p.338) found carbonized and wood fragments in low stand sand in the Canadaway Group from New York State. The fragments that are found by him are similar to those found in Tanjero Formation.

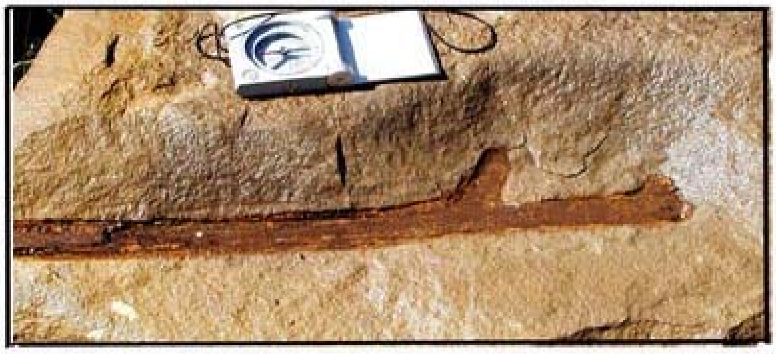
3.1.6.2-Grass body- fossils structure

This type of structure is found in the uppermost part below the contact with Kolosh Formation in Dokan area. It is located on the left bank of Little Zab River about 400 meters down stream of the Dokan Bridge (Plate 3.5.3 and 3.5.4). It is well known as Qashqully picnic area. There, the upper part of the formation exists as a 50 m thick package of light brown calcareous sandstones, with occasional pebbly sandstone. These beds form many small ridges along the river. Some of these beds contain iron oxides laminae and concretions, which are possibly deposited in shallow environment. On the surface of one of these beds, the author has found many small clusters of complete herb-body fossils.

These structures consist of the mold of complete grass, which directly reflect morphology of the plant at the time of its burial. The framework of the plants consists of main stems, dendritic branches and small bulbous elongate leaves. The leaves exist at the end of each branch (Plate3.5.3). The roots of these plants are not found with them so this means that they transported to site of deposition from continental source area. As there is no any carbonaceous remain with these fossils, so it is evident that the grasses are buried when they are alive and green.

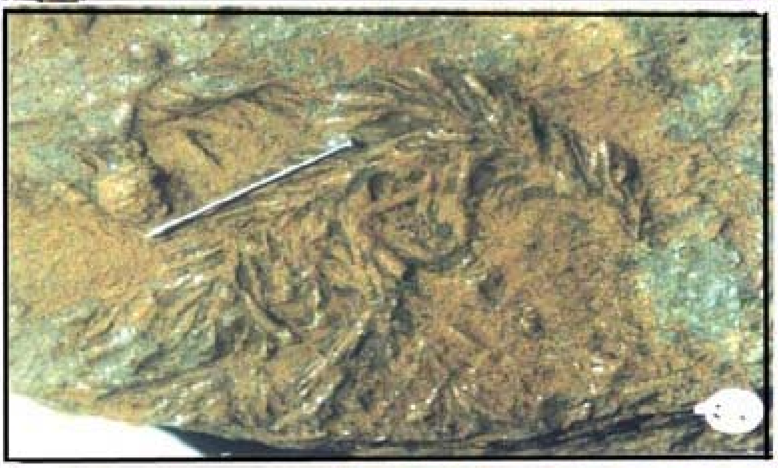
Sarjent (1975, p.163) interpreted this structure as body- fossils. This is because, as he added, it reflects the shape of the plant at the time of death. In Tanjero Formation, these plants with associated lithology prove the shallowness upper part of the formation. This is because all

Plate 3.5



(1) Carbonized 50 cm long plant stem found in coares sandstone of Lower Part of Tanjero at 450m southeast of Qamar Telly village, the elongate axis is directed toward S-N which indicate southern direction of Paleo-current.

(2) Petrified 15 cm long and 3cm thick plant steam found in thick conglom-erate bed of the Lower Part of Tanjero at 50m northeast of Nawar Village, Sirwan Valley, Halaja Area, type section of the formation.



(3) Petrified grass body fossil found in thick pebbly sandstone of L.P of the formation at 2km to the south of Dokan Dam on the right bank of Little Zab River (Qashqully stream). The nedle is 2.5cm long.

(4) General view of the above sample, the area enclosed in the white circle is enlarged in the above photo. These grass body fossils are possibly belong to genus Crinum.

collectively (brown color, iron oxides, pebbly sandstones and grass molds) indicate shallow environments for deposition of this interval. In this study the shallowness of the upper part is due to sediment fill. The occurrence of plant body fossils in Tanjero Formation proves wet, worm and stormy of climate of the Maastrichtian age at the studied area.

3.1.6.3-Rudist, gastropod, pelecypods and large foram biostromes

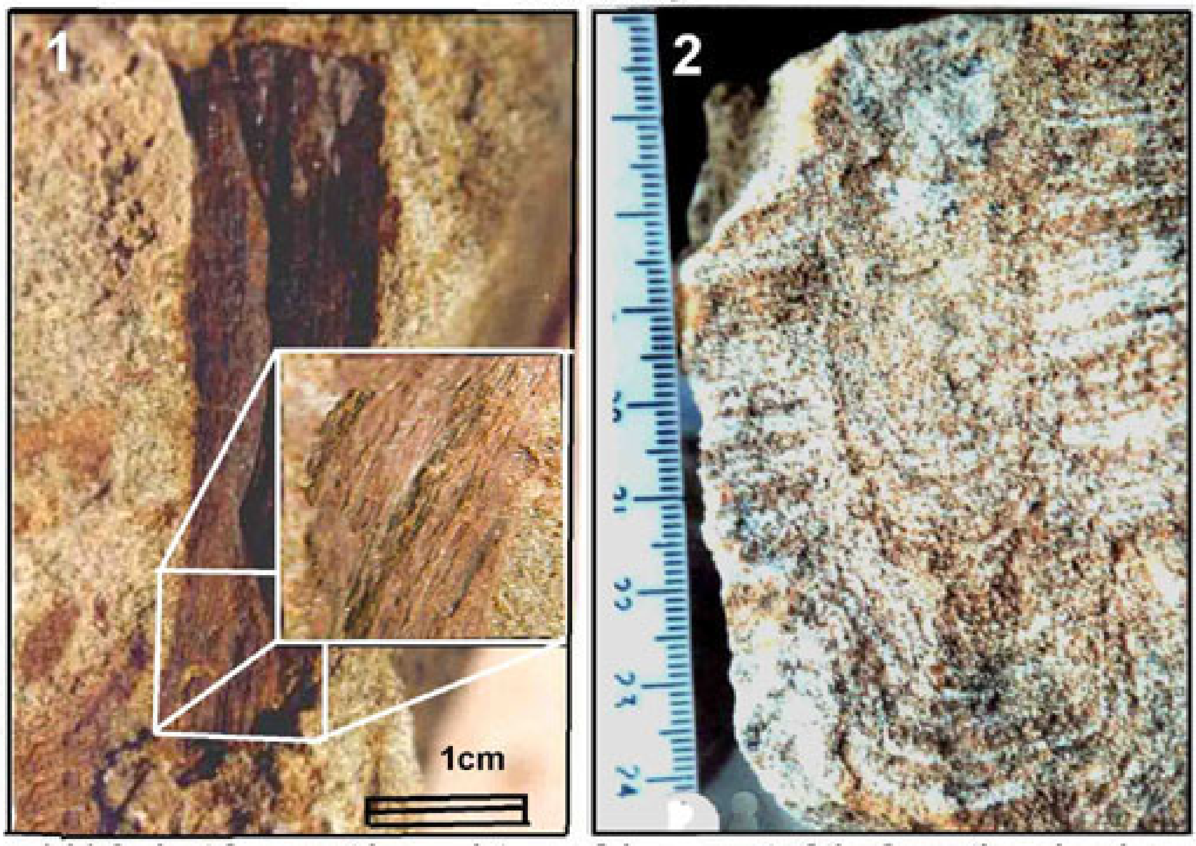
Krumblein and Sloss (1963) used the term biostrome as an external biogenic sedimentary structure. Tanjero Formation in Chuarta and Mawat areas contains many rudist and gastropod and pelecypods carbonate biostromes. They are more than 10 beds have thickness of 1-10m in Chuarta area (Plate 5.3.4). In Dokan area, many thin beds of bioclasts limestone (or sandy limestone) exist with two thick ones; one of them exists in lower part and the other in the upper parts.

In Chuarta area, these beds consist wholly or partially of large rudist, gastropod and pelecypods with large forams and echinoderms. During fieldwork many evidence of *in situ* death of rudists are found. In one case, about 1km to north of Kani Sard village (Chuarta area) there are two thick bed of fine grain limestone contain sporadic large and inequivalve rudists.

The autochthonous nature of these fossils is shown by existence of both valves together side by side (Plate 5.5.7). The same thing is also true for large pelecypods which both valves remained together indicating no transportation (Plate 4.4.4) In the same area and south to Tagaran village, there is another thick bed, which consist wholly of elongate, straight, cylindrical rudists, which arranged parallelly but show no sign of transportation and wearing. The most noticeable criterion is that these beds are alternating with calcareous shale in upper part of the formation.

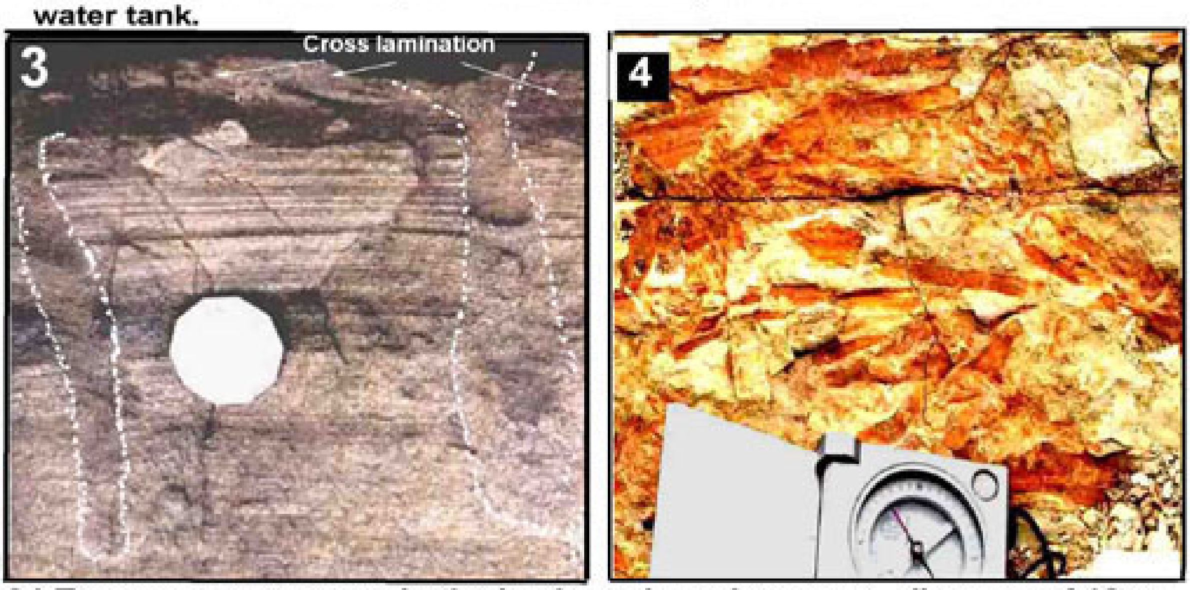
Buday (1980), Al-Shibani *et al.*, (1986) and Lawa *et al.,* (1998) treated these beds as Aqra tongues or lenses within Tanjero Formation. But in this study included in the Tanjero Formation and called Kato mixed carbonate –siliciclastic succession. In my opinion, these biogenic beds have the most important environment indicators than the other structures discussed above. This is because, Kuffman (1974), mentioned that rudists were lived in shallow, warm and clear environment, at depth of no more than 50 meters. My observation revealed that these biostromes beds exist, in many places; on dirty sandstone beds or calcareous shale in formation and it is clear that the rudists colonized on them, especially on the thick silty marl beds or shale without any evidence of transportation. This type of occurrence can be explained in very simple sedimentological process in the basin of Tanjero Formation. The

Plate 3.6



(1) A plant fragment in sandstone of lower part of the formation showing minute structues of the origional plant. Dokan section.

(2) U-U-shaped escape structure in clean and well sorted coarse sandstone of the lower part at Malkandi hill, at 1km to the northwest of water tank.



(3) Two escape structure in the laminated sandstone at distance of 12cm , the sample is cross laminated at the top.

(4) Oxidixed brown plant debris, showing parallel arrangment found in the lowstand sandstone wedge at 500m southwest of Fayal village in Chaqchaq Valley. They are directed toward southeast northwest as shown by Compass neddle.

process included deposition of clastic sediments supplied by river turbidity current from newly elevated source areas and from reworking of beach sediment then deposition in shallow environment as storm generated beds (tempestites) on the rudist ones. During flooding of rivers or during wet and stormy periods the sand or shale beds are deposited while during dry and calm environment rudists were given opportunity to survive and build biostromes. After the return of clastic influx, the rudists were vanished. In this manner recolonization and taphonomy continued for several times in stratigraphic record of the upper part of formation.

The previous studies regarded Tanjero environment as a deep bathyal and abyssal marine environment in which turbidity currents have occurred. According to these studies occurrence of rudist in this type of environment needs catastrophic episode or event, which must include uplift and subsidence of the basin to hundreds or even thousand meters. In this connection Al-Shibani *et al*., (1986) mentioned that these beds are representing shelf environment and they formed by vertical movement of a deep-seated basement blocks. Conversely, Einsele (1998) mentioned that within turbidite sediments biogenic carbonate beds are formed during highstand system tracts during which clastic sediments decrease. This latter idea is more compatible with the field evidences because the clastic sediments under and above the biostromes show no sign of any catastrophic events of the type of vertical uplift and because these sediments are similar to other parts of the formation

Our explanation for rudist biostromes occurrence in Tanjero Formation is well matched with what is happening now in shallow seas where many beautiful reefs (biohermes) and biostromes depart life by pollution or natural events every year.

The clastic influx and its discontinuity in certain basins might be attributed to:

A-Lateral river channel migration during relatively long time, which cause changing of sediment rate influx.

B- Changing of climate during which long-term dry and wet periods occur successively due to Milankovitch cyclicity band. These differences in climate, if occurred during deposition of Tanjero Formation, might have changed the type of the shelf from clastic dominated shelf (deposition of marl, siltstone and sandstone) to carbonate dominated shelf (see Blatt *et al*., 1980) during which rudist biostromes is deposited. Therefore, in the present study this alternation of the upper part is called mixed carbonate-siliciclastic succession.

C- Wearing out of source area and reaching local base level. Gallaway (1989) confirmed that terrigenous sediment supply is determined by source area and regional climate.

D-Exposure of weathering resistant rocks in the source areas after erosion of soft ones, causes decrease of the clastic influx but exposure of loose and weak rocks ones increases sediments supply.

E-Sea level rise and fall lead to decrease and increase of sediment respectively. These sea level changes in Tanjero Formation possibly coincide with Milankovitch spectrum (band) for astronomical climate change.

3.1.7 -Trace fossil and rate of sedimentation in Tanjero Formation

The source area is characterized by relatively soft rock (erodible rocks) and high tectonic activity. Therefore huge quantity of sediments is delivered to Tanjero depositional basin by rivers. This fact is truly demonstrated by habit of the organism during high rate of sedimentation. Blatt *et al*. (1980, p.196) mentioned that the organisms, resting just below sediment surface, are covered by rapid influx of sediment, they will burrow (vertically) to new surface and produce new sets of resting traces. The following examples manifest the response of organism to high rate of sedimentation in Tanjero Formation:

At distal area of Tanjero basin (slope area) such as Dokan area, several 10cm thick beds are penetrated by Skolithos escape trace fossils (Plate 3.6.3). At the middle distance between distal and proximal area slope such as north of Sulaimaniya City, many a 30 cm thick beds can be observed penetrated by the escape traces. At the latter locality one can see abundant dwelling Skolithos trace fossils (Plate3.3.1and 3.3.3). Some of these traces are more than 70cm in length and found in both silty marl and in clean sandstone (Plate 3.2.3). It is most possibly that these traces are imprinted in tempestite (storm deposit) and in small-scale turbidity flow. But large-scale turbidity flow gives no opportunity to the organism to make escape or dwelling traces as they wiped out from the previously deposited beds. The maximum time span for escape trace fossil is no more than one year. It is possible that some bed, which contains escape structure, is deposited in one day. From this, it appears that the sedimentation rate was very high. In some case it possibly reached more than 30cm in one day. The rapid deposition is associated with erosion so that the calculation of actual duration time (in years) of deposition of the Formation cannot be done from the thickness of the sediments divide by the number beds. This erosion is indicated by truncation of sandstone beds (Plate 4.3.3) by storm or turbidity currents.

At Malkandi section a large scale cross bedding is found with foresets thickness of more than 1.5m thick (Plate 3.1.1and 3.1.2). According to Blat et al. (1980, p.132) single cross-stratified bed without major break, may be deposited in a period not exceeding few day. So the rate of sedimentation, in some time, about 1m at no more tan week.

3.2-Paleocurrent Analysis

For paleocurrent analysis, most of the sedimentary structures, discussed above, are used in addition to types and textures of sedimentary rocks deposited during Upper Cretaceous. According to these variables the paleocurrent direction is indicated accurately to be mainly toward south and southwest.

The variables used for indication of the paleocurrent are as follows:

3.2.1- Type of sedimentary rocks

When looking at the facies distribution map of Upper Cretaceous one realizes that the reefal limestones (Aqra-Bekhme Formation) are mainly located at northwest of the main basin of Tanjero and Shiranish Formations (Fig.1.1).

The occurrence of this limestone at west and northwest of the basin is indirect indication that paleocurrent direction was not toward northwest or west as mentioned before (Al-Rawi, 1981) and Saadalla and Hassan, 1987). This is because the reefs exist at these directions and they growing away from turbidity, which mainly moves along paleocurrent direction. The differences of direction of previous studies are possibly returned to the fact that all condacted at the distal part of the basin where the paleocurrent direction is not much clear or may have much direction.

3.2.2- Lithologic change and grain size distribution

The grain size change of Kato Conglomerate is from north toward south and southwest. The conglomerates are elongate and thin across depostional dip (across paleoslope). The elongation of conglomerates and decrease of grain size is generally toward south and southwest. The incised valley and associated submarine channels and canyons govern the southward elongation of the conglomerate. The most basin ward extension of the conglomerate is seen 3km southwest of Arbat town near Damirkan Village. When a straight line connects Kato and Damirkan village it gives nearly the southern direction of paleocurrent and both subaerial and submarine erosion trend (Fig. 3.3 and 6.5).

The same thing is true for the Kato-type conglomerate at west and south of Mawat area where the incised valley and associated submarine channel fan feeder is elongate to Tasluja Town at 20 km southwest of Sulaimaniya city (Fig.1.3 and 4.4).

3.2. 3-Thickness of the sediments

The maximum thickness of the formation is recorded in the type section in Sirwan valley. In Chuarta area reaches 1500m while in Dokan area is only 630m, which thins northwestward to about 50m.

This general increase of thickness toward southeast is indirect evidence that the paleocurrent is toward south and southwest. In other sides the isopach and accommodation maps of Upper

Cretaceous are showing the thickest and deepest sediment and accommodation at the area south of the studied area especially, the east and northeast of Baghdad City (see Minas, 1997, p.89 and 92)

3.2.4-Unidirectional sedimentary structures

They are those structures, which indicate one direction of flow (vectorial direction), which may have unique direction and take one value of 0 to 360 degrees. The most important unidirectional sedimentary structures, in Tanjero Formation, are imbricate pebbles, cross bedding, asymmetrical ripple marks and flue casts. Nearly more than 60% of the imbricate pebbles in Kato conglomerate (Plate 3.7.1, 3.7.2, 3.7.3 and 3.7.4) are directed toward south and the other ones may have any direction but mostly bearing toward southwest and southeast.

3.2.4.1- Ripple Marks

The interference ripples marks are very common in the north and northwest of Sulaimaniya city, where one can see tens of them at different horizons within the lower part (Plate 4.2.1, 4.2.2, 4.2.3). These ripple marks occur in the middle of the lower part of the formation. The peak of these structures is mainly pointing toward S65W (Fig.3.1.B). Similar ripples exist in the upper part of the formation in Dokan area, on the right bank of the Qashqully stream and north of Qulka village. At these localities, the paleocurrent direction is toward south.

An elongate symmetrical ripple is found at the area between Diana and Mergasur towns on the right bank of Balakian stream (Plate 4.2.3). They consist of numerous long parallel ridges. These ridges are more or less equidistant and trending in straight or gently curved lines at right angle to the current by which they are formed. Some crests of these ripple marks split (bifurcate). Potter and Pettijohn (1964) and Tucker, (1991, p.28) found similar types of the ripple marks in near shore and lacustrine environments. The latter author attributed these ripples to the wave movement.

3.2.5- Bi-directional sedimentary structures

The bi-directional sedimentary structures are those ones, which have two opposite directions indicating only line of movement not unique direction. Each of these structures has direction ranging from zero to 180 degrees. These structures are as following:

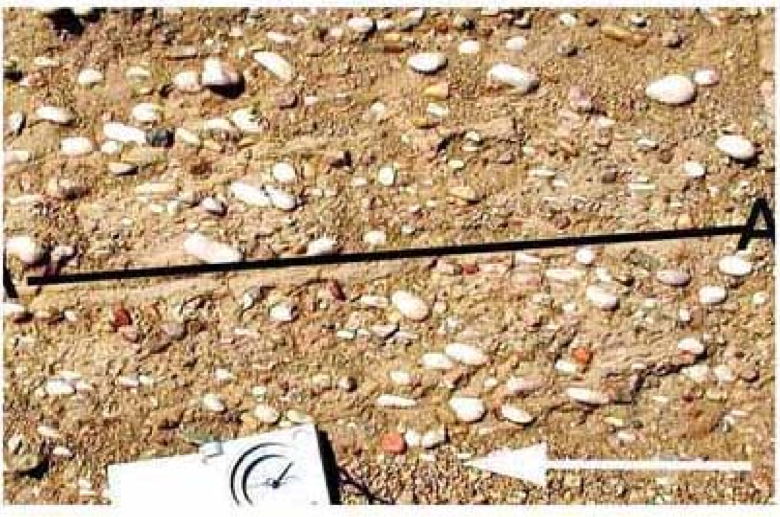
A- Elongate Rudist and Belemnite fossils: These two fossils are found together in the same bed in the upper part of the formation at Chuarta area. In this area the mixed carbonate-siliciclastic succession is well developed. The lowest limestone bed, in some locality, composed entirely of a stack of elongate rudist and belemnites body fossils. Their length range between 10-30cm (Plate 5.4.1 and 5.4.2) and they have straight shell or slightly curved. Their directions are generally toward southwest.

Plate 3.7

(1) Imbricated chert pebbles in Kato Conglomerate near Qashan Brigde, east of Mawat Town.The white long line and short ones indicate bedding plane and angles of imbrication respectively. The white arrow shows paleocurrent direction (south)

(2) Imbrication of chert pebbles of Kato Conglomerate at Kato mountain about 1.5 km south of Kanito village east of Chuarta Town.
N: 35° 39' 15.4"
E: 45° 36' 26"

(3) About 20 imbricated chert and one limestone (X)pebbles at the 2km west of Kanito Village showing paleocurrent direction of S10W.
N: 35° 38' 56.4"
E: 45° 36' 0.5"



(4) Imbrication of limestone and chert pebbles in the last conglomerate beds at the top of the type section about 1.5km south of Nawar village 10km southeast west of Halabja Town. A-A is a bedding plain used as a base line for measuring imbrication pebbles. The arrow indicate southern dirction(paleocurrent)

B. Plant debris

These debris are discussed in detail in section (3.1.3.6). Their paleocurrent significance is less important than above-mentioned directional structures, because:

1-They are transported into the basin during the river flooding. But most of the debris are deposited at the end of the storm when the energy is so weak that they take no certain directions.

2- As they are normally elongate uni-polar so they indicate two opposite direction (not one direction of movement) of the paleocurrent. Potter and Pettijohn (1977, p.374) mentioned that plant fragment indicate only line movement of paleocurrent. However, at many locality compass reading of plant debris are taken and their direction are plotted on the rose diagram (Fig. 3.1.D).

3.2.6- Stereonet- and rose-diagram plotting

For the plotting data of the unidirectional and bi-directional sedimentary structures, the Windows based RockWare program is used as follows:

1- The original azimuth data of the compass readings are taken in the field as compass quadrant readings, but for entering the PC they were converted to their equivalent azimuthal readings.

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. Most localities of the studied area have dip amount less than 30 degrees such as, lowland of Chuarta –Mawat area, Sharazoor-Piramagroon plains, Dokan area and Chachaq valley. While Kato mountain and Sirwan Valley have more than 30 degrees of tilting.

3-The attitude of imbricated pebbles (Plate3.7.1and 3.7.2-3) 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 azimuthal data by using Dip Direction Format for drawing the stereonet diagrams (Fig.3.2 and table 3.1) The flute cast and cross bedding has fewer occurrences than imbricate pebbles. So they are used in field to support and confirm the direction shown no the stereonet. Cross bedding and laminations have more dispersed direction but the more obvious ones give southwest and south direction.

4- Ripple marks, elongate fossil shell, plant debris are numerous in the lower part and upper part of the formation so one can measure tens of these directional structures. The azimuths of these structures are plotted on the rose diagram using Rose files of RockWare program. The option of “full rose” and “bi-directional” are given to the program when the bi-directional sedimentary structures are entered while for unidirectional ones “half rose” and “unidirectional” option is activated (Fig.3.1, Table 3.2 and 3.3).

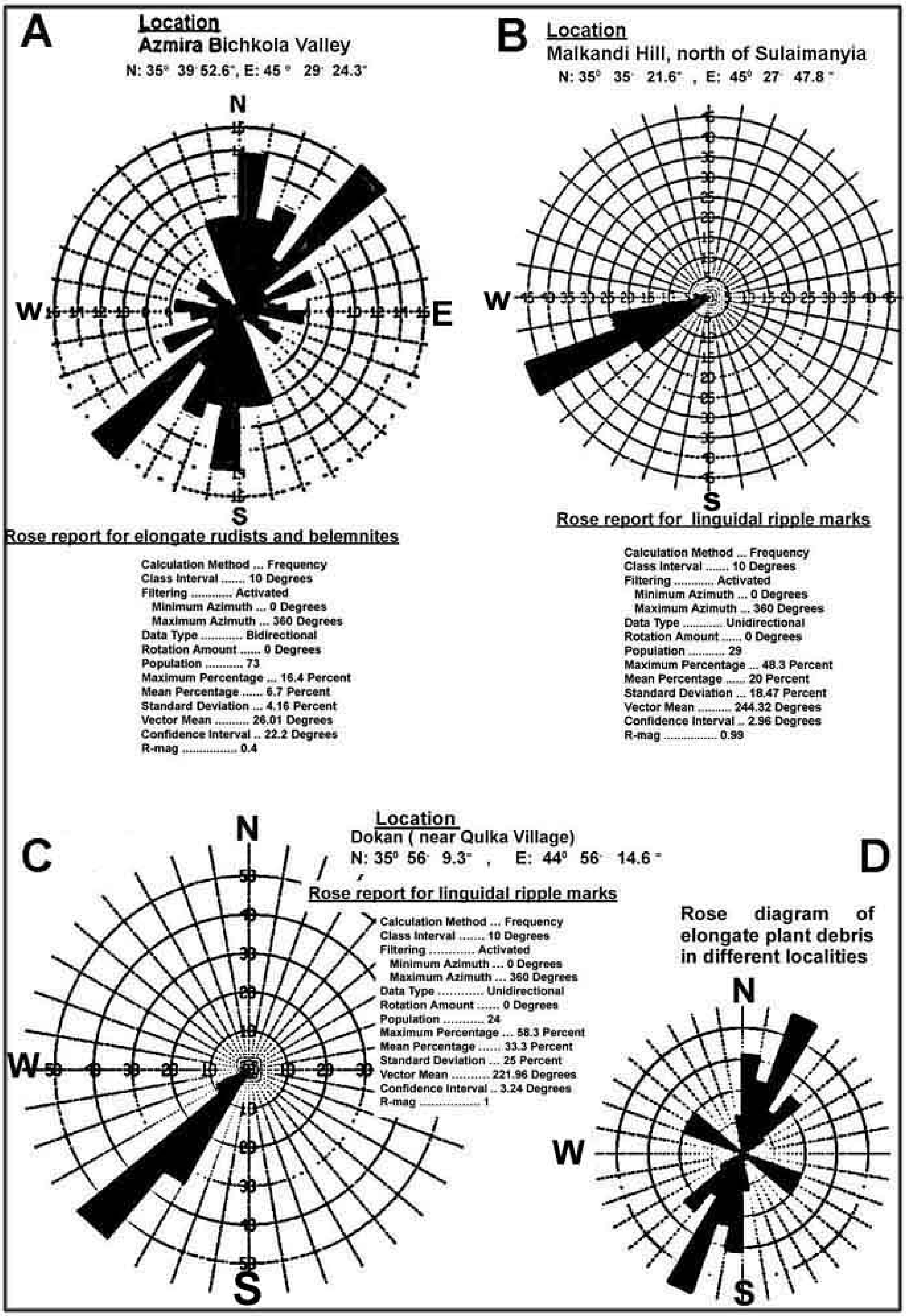


Fig. (3.1) Rose diagram drawn by PC when the data in the table (3.1-2) entered . The general direction of paleocurrent is southwest.

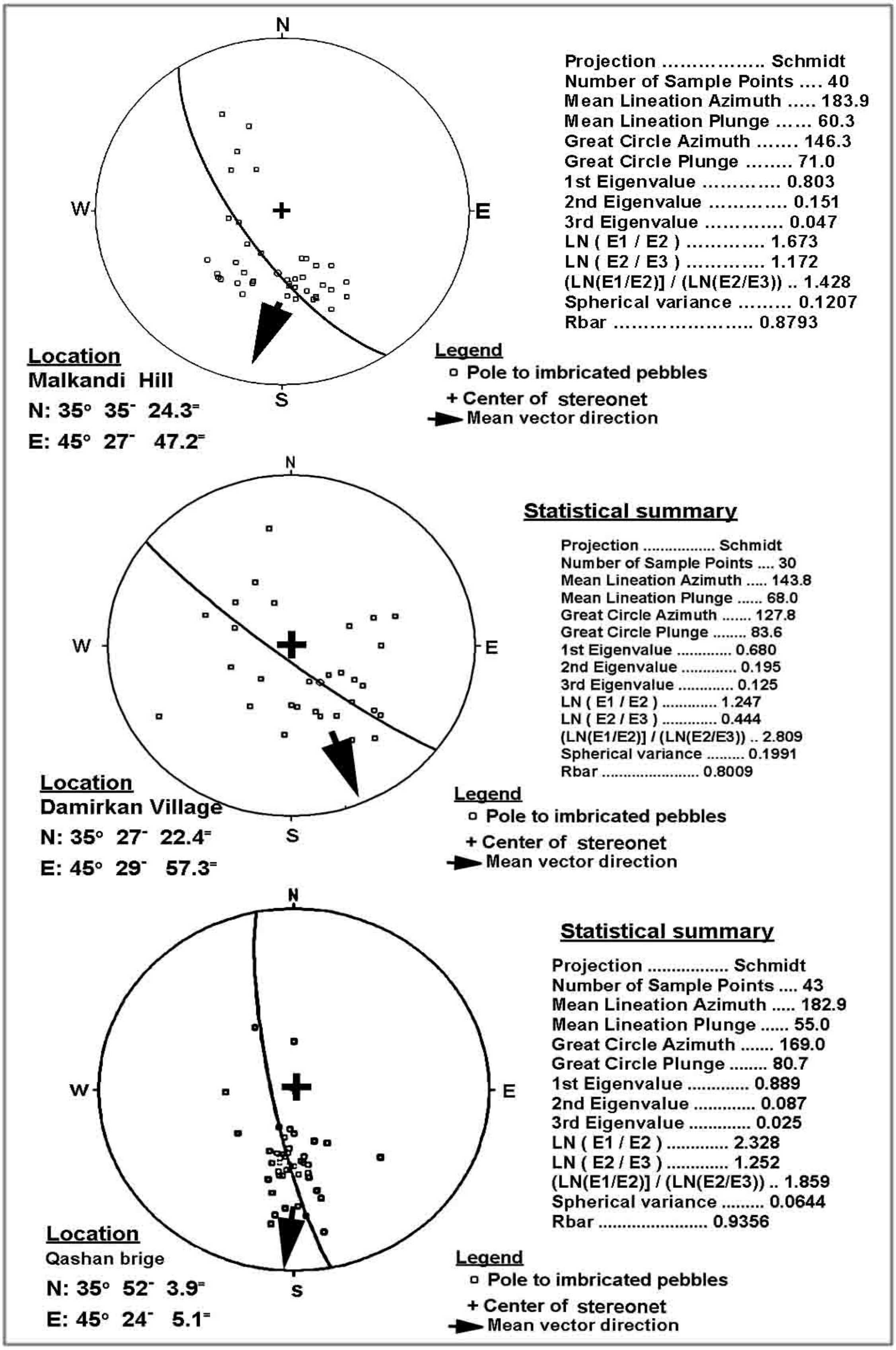


Fig. (3.2) Stereonet diagram showing paleocurrent direction of imbricate pebbles of three localities on the outcrop of Tanjero Formation.

5-Many structures are photographed in their original position with indication of their azimuth. These photos give powerful evidence for the direction of paleocurrent (Plate 3.7). The clearest photos are taken at the Sirwan valley for imbricated pebbles at the near boundary with Kolosh Formation. At this place the plunging (dipping) of the platy pebbles are so clear that one cannot find similar ones in gravels of recent rivers and alluvial fans (Plate 3.7.4) which show south direction. Another place, which show clear eyewitness paleocurrent direction, is a very good developed channel filled with conglomerate at the Kato Mountain. There, visual inspection of imbricated pebbles inside the channel without any calculation can easily prove the southern direction of paleocurrent at this location (Plate3.7.2, 2.7 and 2.8).

Unfortunately and in spite of serious fieldwork the conglomerate of the lower sequence is not found in this study. This may be attributed to post deposition erosion of these conglomerates as a result of uplifting of their position (with their position possibly located in Thrust Zone). But it is possible that the so-called" Qulqula Conglomerate Formation" may have close relation with conglomerate of lower sequence, which deposited at least 10 km far from the upper one (see the figure below which shows relation between upper and lower sequence conglomerate). The study of this conglomerate may reveal farther and better paleocurrent study during lower sequence.

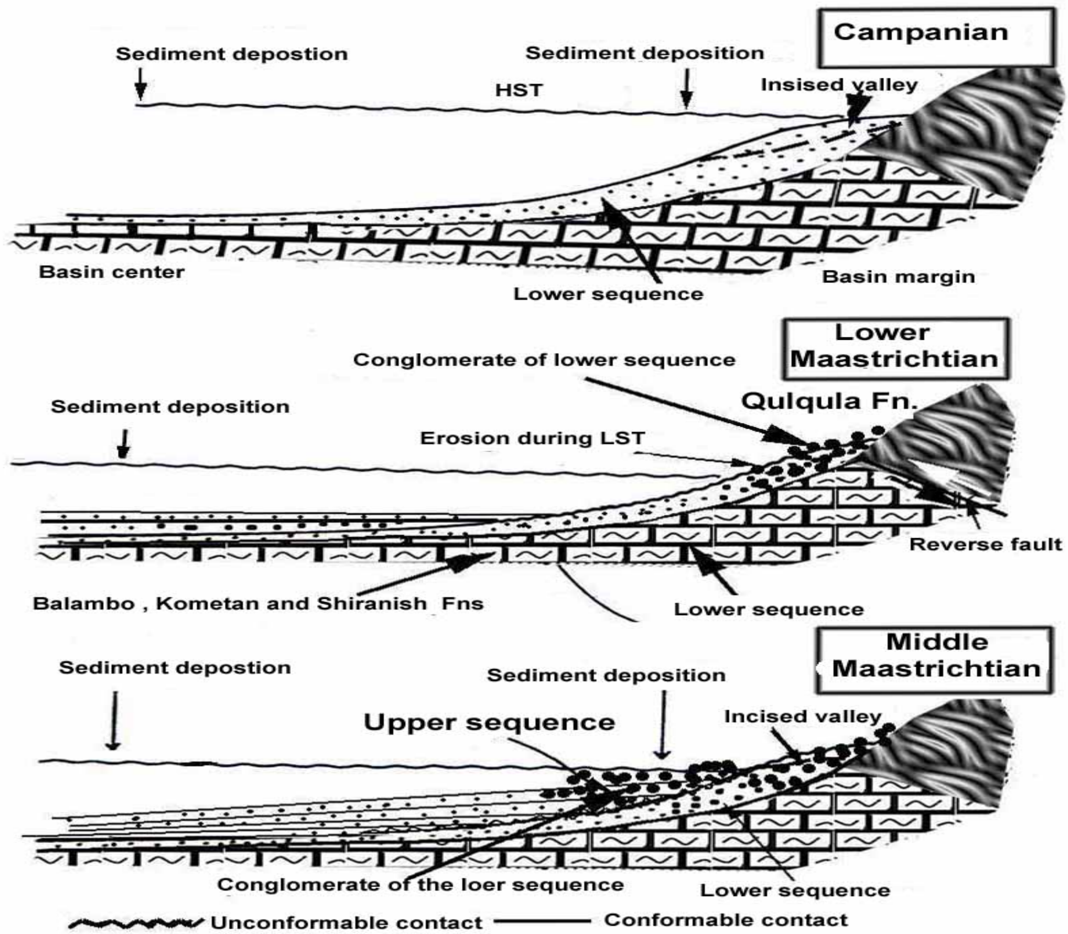


Fig. (3.2 A) general relation between Lower and upper sequences

Table 3.1 Compass reading of plunge azimuth (Left column) and angle of Plunge (right column) of imbricated pebbles of conglomerate at: 1.Malkandi Hill (N: 35^{0} 35^{-} $21.6^{=}$ E: 45^{0} 27^{-} $47.8^{=}$), 2. Damerkan, Arbat (N: 35^{0} 27^{-} $22.4^{=}$ E: 45^{0} 29^{-} $57.1^{=}$) , 3. Qashan Bridge, Mawat (N: 35^{0} 51^{-} $24^{=}$ E: 45^{0} 24^{-} $29.3^{=}$). These data are given as entered into the PC to draw rose diagram (see fig. 3.2).

1		2		3	
Azimuth	Plunge angle	Azimuth	Plunge angle	Azimuth	Plunge angle
20	**63**	**40**	**43**	**9**	**40**
10	**52**	**40**	**32**	**8**	**60**
5	**32**	**25**	**22**	**352**	**31**
240	**51**	**357**	**41**	**348**	**48**
45	**22**	**45**	**22**	**355**	**60**
225	**35**	**335**	**25**	**358**	**55**
345	**45**	**355**	**35**	**4**	**56**
350	**33**	**150**	**23**	**11**	**49**
310	**55**	**340**	**45**	**10**	**38**
314	**43**	**344**	**33**	**11**	**32**
5	**30**	**75**	**20**	**360**	**35**
5	**35**	**145**	**35**	**351**	**41**
280	**54**	**330**	**44**	**347**	**52**
20	**34**	**131**	**30**	**14**	**30**
90	**64**	**160**	**44**	**15**	**35**
270	**43**	**356**	**33**	**9**	**30**
280	**70**	**333**	**40**	**5**	**29**
280	**60**	**344**	**40**	**355**	**33**
280	**46**	**355**	**36**	**357**	**39**
10	**60**	**30**	**40**	**360**	**20**
12	**34**	**82**	**24**	**4**	**27**
14	**52**	**44**	**42**	**20**	**30**
350	**33**	**350**	**33**	**15**	**43**
50	**75**	**150**	**55**	**10**	**34**
12	**43**	**42**	**43**	**50**	**31**
260	**66**	**340**	**44**	**340**	**25**
290	**60**	**330**	**30**	**3**	**37**
50	**51**	**55**	**41**	**7**	**31**
14	**44**	**24**	**44**	**310**	**49**
330	**55**	**342**	**45**	**330**	**28**
280	**67**	**351**	**37**	**5**	**18**
280	**44**	**320**	**34**	**351**	**39**
10	**34**	**30**	**34**	**349**	**70**
325	**63**	**335**	**53**	**9**	**65**
352	**53**	**352**	**43**	**10**	**22**
330	**34**	**339**	**24**	**350**	**35**
325	**66**	**325**	**51**	**20**	**18**
280	**54**	**320**	**45**	**7**	**40**
170	**47**	**21**	**37**	**353**	**34**
150	**56**	**21**	**36**	**150**	**33**
				180	**22**
				88	**29**

Table 3.2 Azimuth of elongate plant debris measured in different localities such as Mokaba, Chaqchaq valley, Qamartelly Village (foot hill of Piramagroon), Dokan area and Makandi Hill. All six columns are entered into the PC as one continuous column when RockWare Program is used.

90	210	110	180	186
135	214	110	180	190
140	220	126	187	198
130	190	117	186	200
139	195	120	180	205
151	185	112	177	206
154	200	115	176	200
167	200	112	185	209
167	200	112	190	210
163	90	123	170	211
170	93	124	196	207
178	90	220	184	208
183	230	220	222	211
181	240	226	122	217
178	230	230	209	200
167	234	233	206	205
189		228	199	208
210		226	196	

Table 3.3, 1. Athimuthal compass reading of 72 elongate rudist and belemnite body fossils at Azmira Bechkola Valley (N: 35^{o} 39^{-} $52.6^{=}$, E: 45^{o} 29^{-} $24.3^{=}$)Fossils. 2. Azimuth of 29 linguidal ripple marks at Malkandi Hill (N: 35^{0} 35^{-} $21.6^{=}$, E: 45^{0} 27^{-} $47.8^{=}$), 3. 2. Azimuth of 24 linguidal ripple marks at Dokan area (N: 35^{0} 56^{-} $9.3^{=}$, E: 44^{0} 56^{-} $14.6^{=}$).

1. Elongate body fossil					2. Linguidal ripple mark (Malkandi)		3. Linguidal ripple Mark (Dokan)	
50	360	61	3	308	240	234	220	220
42	5	33	8	348	240	233	221	216
316	73	5	296	345	260	243	217	224
90	5	65	42	25	250	247	230	223
60	340	20	25	5	270	244	218	215
20	39	55	45		240	240	226	228
70	18	352	10	89	240	245	219	224
11	65	10	12	4	235	250	227	217
12	48	355	5	345	250	252	221	225
90	45	88	31	350	255	230	217	215
29	44	45	45	90	240	235	224	222
8	66	49	29	300	245	250	225	230
360	45	5	38	295	240	252		
90	355	355	20	348	235	246		
		360	354	80		245		
		45	360	345				
		308		45				

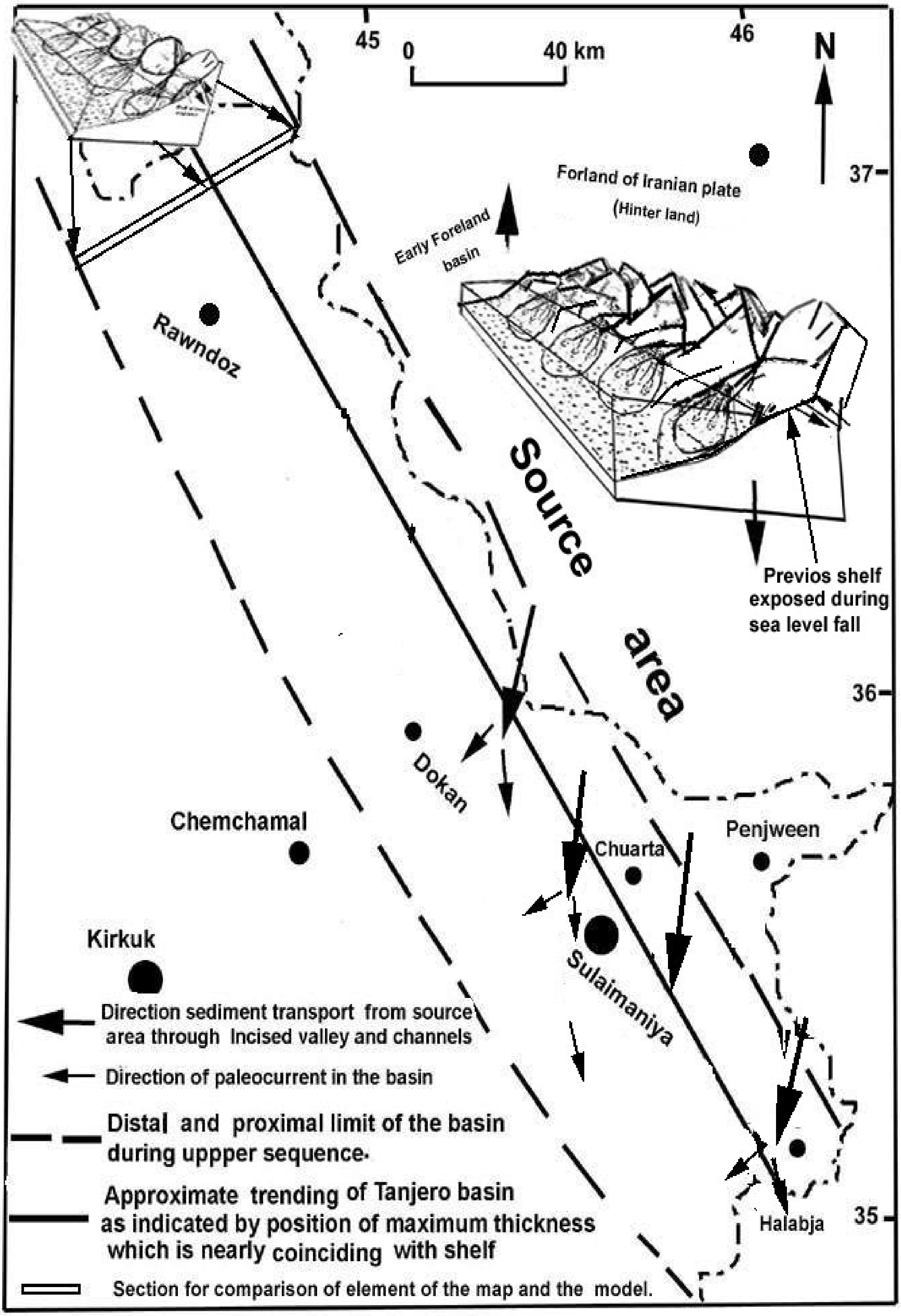


Fig.(3.3) General basin trend and paleocurrent direction of Tanjero Formation during upper sequence.

CHAPTER FOUR:

SEDIMENTARY FACIES AND DEPOSITIONAL ENVIRONMENTS

4.1- Facies analysis

4.1.1-Turbidite facies

The facies analysis of the Tanjero Formation, as concerned with turbidite facies are pretty well presented by Jaza (1991), who divided the rock body of the formation into sixteen individual facies and five standard facies models. These facies model are as follows:

1.Coarse-grained turbidite facies model, **2**. Medium-grained turbidite facies model

3.Fine-grained turbidite facies model, **4.** Chaotic facies model, 5**.** Pelagite facies model

The present study agrees with these facies models, which are given by the above-mentioned author. Therefore, they are not repeated, in stead many new facies are introduced and described. Among these facies are those deposited by storms, which form certain sediments called tempestite. Therefore two general facies model are drawn as follows:

1.The first facies model belongs to prograding of coarse grain delta sediments (possibly alluvial fan) on the deep marine ones (Fig.4.1A). From this model two minor models are derived for tempestite (storm deposits) (Fig.4.1C) and turbidite (Fig.4.1B). Each of the minor models has specific facies association more or less different from each other.

2. The second model (Fig.4.1D) is drawn for the mixed carbonate-siliciclastic succession, which exist at the upper part of the formation. Both models are showing shallowing upward succession (coarsening upward succession).

The facies description begins with those located at the base of the section of models as follows:

A- Planktonic foram bearing mudstone (Pelagite facies)

This facies consist of fine grain mudstone limestone (lime mud) with common indigenous planktonic forams (Plate 5.3.1, 5.3.2 and 5.3.3). In the field, it exists as thin or thick beds of gray (white weathering) limestone. They exist only at the distal area of the basin in the middle part and at the base of lower part near the boundary with Shiranish Formation. In the latter part this facies occur as very thin beds in the marl, whereas in the middle part, it exists as more common and thicker beds.

B. Planktonic foram- bearing clayey mudstone (hemipelagite facies).

This facies contain less planktonic forams and more fine clastics (clays and silts) than facies (A). It exists as relatively thick beds of bluish white marl with thin beds of clayey siltstone in the lower and middle part. It mainly exists at the intermediate area between distal and proximal area such as Chaqchaq and Shadalla valleys and northeastern limb of Goizha and Azmir anticlines. In these areas the middle part mainly consist of this facies. As mentioned before this facies resembles Shiranish Formation in color and lithology.

C. Terrigenous sandy mudstone

This facies consist of olive green sandy mudstone (calcareous shale). The cooked (baked) samples of this facies contain terrigenous chert and limestone sand and silt grains with some reworked radiolaria and very rare planktonic forams. This facies occur mainly at the proximal area (south of Chuarta and Mawat Towns) and occasionally contain bioturbated sandstone and lensoidal conglomerate. This facies change down- and up-dip the depostional slope to hemipelagite and red layers respectively. In the upper part of the formation, this facies make up the siliciclastic part of mixed carbonate-siliciclastic succession (Fig.2.1 and plate 5.3.5)

D. Deep basin sandstones and conglomerates facies (Flysch facies)

These facies are studied in detail by Jaza (1991) and divide into three classes and six groups. Each group is divided into several individual facies on the basis of internal organization and means of deposition. These facies, collectively, have the form of wedges and consist of thin succession of sandstone at the distal area. Toward the proximal area the share of conglomerates (Kato type) increase. They are generally characterized by graded bedding; sole mark sedimentary structures and moderately sorted. In these sediments all variations of ideal facies model of Bouma, 1962 and Lowe (1982) can be found (Fig. 4.1C).

These sediments belong to the lower part of the formation and deposited during regression (sea level fall) by allocyclic processes. The sediment of these facies bypassed the shelf during river flooding and deposited on the slope toe as a wedge. During the regression, the deep basin became so shallow that in some sites of the lower part, hummocky cross-stratification, escape trace fossil and large scale cross bedding are imprinted in the sandstone (Plate 4.3. 1 and 4.3.2) (Plate 3.2.1 and 3.2.2) (Plate 3.1.1, 3.1.2 and 3.2.3). In these deep basin- shallow water environments sediments are reworked by both storm and turbidity currents separately or simultaneously. Thus, in addition to turbidite facies, facies of tempestite (storm deposits) are found. As these facies were not recorded before therefore, it is discussed in detail in this study in the section (4.1.2).

E. Channel and valley fills clast supported conglomerate facies (coarse mollasse facies)

This facies exist as very thick (500m) succession of coarse conglomerate (Kato conglomerate). They occur as lensoidal body along depostional strike and as wedge along depostional slope. Al-Mehaidi (1975) included this facie in the Red Bed Series. The petrography, stratigraphy and distribution of this facies is discussed in section (2.3 and 2.4). It is worthy to mention that the facies D (the flysch facies) are derived from this facies. This become clear when what mentioned by Rust and Koster (1884, p.54) is applied. They attributed the framework (grains)-supported gravel to the deposition from bed-load by energetic aquaeous flow. They added that sand remain in suspension (which transported to deeper water and deposited as facies D), when the flow velocity decrease the sand infiltrates into the space between framework particles.

F. Terrigenous red clastic facies (fine mollasse facies)

This facies consists of red or brown claystone, sandstone and few lenses of conglomerate. It exclusively exists in the extreme proximal area and rest at the top of the facies (E). The succession of this facies is called, in this study, Kato red layers. Facies E and F can be called mollase facies because they are less rhythmic and show less graded bedding than flysch facies (facies E) in addition to occurrence of shallow marine limestone (facies G) at it's top.

G. Biogenic limestone facies (oyster, coral, gastropods bearing limestone facies)

This facies comprise the carbonate part of the Kato mixed carbonate-siliciclastic succession (see section), which is discussed in the chapter of sedentary structure under the title of biostromes structures. This facies occasionally change to bioclastic limestones (coquinas), which are derived from the fossils forming the biostromes. In some places, the coquinas are cross-bedded and extensively burrowed.

4.1.2 Tempestite Facies

Tempestite is storm deposit, which shows evidence of violent disturbance of pr-existing sediments, followed by their rapid re-deposition in shallow environments (Ager, 1974). Tempestites are sheet-like sand, silt and mud beds of considerable lateral extending. They are formed by storm wave, which have strong impact of subtidal sediments by stir up sand and pebbles, seaweed, various shells debris and fine grain materials. After the storm has waned, the suspended material is redeposited either directly at the site of wave erosion (site of reworking as tempestite) or transported by suspension into deep water and deposited as turbidite. The grain size of tempestite varies greatly. They range from coarse-grained sand and gravel to silt and mud. The same grain sizes also reworked in carbonate sediments such as bioclast sandstone, wackestone and packstone.

Common phenomena in the proximal tempestite facies (near shore area) are amalgamation and cannibalism. These terms signify that either pre-existing thick sediments are truncated, or that thin tempestites are completely reworked by subsequent storm. As a result, the old materials of older tempestite are incorporated into new ones. This process may occur repeatedly, until vary big storm event produce a bed, the base of which can be preserved.

Borrows exhumed and partly washed out by storm action are subsequently filled with settling sediments. The fossil community re-colonizes either the top of the tempestite or erosional surface that were not covered by storm bed especially in-elevated proximal region. Relatively firm, coarse substrate attracts oyster, gastropods, pelecypods, and firm ground burrower of Glossifungites association (Einsele, 2000). (The fossils of these organisms are extensively abundant in the upper part of the formation forming thick fossiliferous limestone beds. Some other beds show many evidence indicating that they were reworked by storm especially limestone beds near the top of mixed carbonate-siliciclastic interval, which are cross-bedded).

In distal zone with thin tempestite and rare reworking by successive storms, burrowing by post-event benthonic organism can markedly obscure storm event stratification (This is observed clearly in Tanjero Formation (Plate3.2.1, 3.2.2 and 3.4.3). In sequence stratigraphy, tempestite requires either terrigenous sediment influx or significant biogenic carbonate production, which must not be diluted by siliciclastic Tempestite probably formed during sea level fall and are preserve best when deposited at the lowest sea level stand (Einsele, 1998).

4.1.2.1-Proximal- distal facies change of tempestite

Tempestites deposited close to the coastline are called proximal tempestite (Fig. 4.1 C), those deposited basin ward at great distance from these sediment sources are called distal tempestite. The proximal tempestite facies contains large scale hummocky cross stratification and has no muddy interbeds. But the distal ones are thin, fine grain and show the same inorganic sedimentary structures as distal turbidite in their faunal characteristics and vertical facies trend (differing by existence of HCS in tempestite). The interval between proximal- distal tempestite (intermediate tempestite) is characterized by thick and often amalgamated tempestite with increase of muddy intercalation (the area occupied by Azimr, Goizha, Daban and Sara anticlines). This interval may be zone of sediment by passing and tempestite tends to change laterally in thickness and frequently pinch out.

The clearest evidence of tempestite can be seen along the southwestern limb of Goizha, Azmir and Qarasard anticlines. While the area to the south and southwest of the Sulaimaniya city shows little evidences of tempestite, which represents the area of distal tempestite.

4.1.2.2-Tempestites in Tanjero Formation

The sediments of Tanjero Formation are deposited in different environments ranging from deep basin to fluviatile (continental deposits). The sediments were delivered to the delta by river-generated turbidity pluses from source area (Qulqula Formation) or the sediment of previous shelf eroded to shallow water after exposure. These sediments deposited mainly as prograding low stand fan delta. After deposition, they are they reworked from shallow water, into deeper water by:

1-By storm and current, which erode and mix sediment with water, then transport them to deeper water. Where the sediment rests below fair weather base and above storm wave base keep the imprint of storm action in the form of hummocky cross stratification. The storm also generates turbidity current, which carries sediment to deeper water and deposits as turbidite as shown by walker 1984 in the fig.(4.3).

2- Reworking by slumping, sliding and mass flow of the accumulated sediment on the delta front by effect of large storms and possibly earthquakes. These processes generate turbidity current, which transports sediments into different depth ranging from shelf to basin across the slope forming turbidite sediments.

3- Reworking by stream and valley incision: During sea level fall the existed shelf and upper slope were exposed and incised by valleys and canyons. This type of reworking is more important in Tanjero Formation. The reworked sediment of the shelf and new sediment supplied by river were bypassed to lower slope and basin floor. It is possible that these sediments were again reworked from lower slope by storm forming tempestite after changing of slope from deep basin-deep water setting to deep basin- shallow water one after prominent sea level fall.

4.1.2.3-Evidence for tempestite in Tanjero Formation

Many line of evidence exist in lower part of Tanjero Formation which prove that this part is deposited in shallow storm dominated water (originally deep basin and change to shallow water by sea level fall) located above storm wave base. Below are the evidence:

1.The most important evidence for tempestite is the extensive occurrence of plant debris (leaf and trunk fragments) on the top or inside the sandstone beds (Plate 3.6.4 and 3.5.1). On these beds, the debris forms a horizon about 1 to 5cm thick. In some localities more than 15 horizons are found at interval of 20 m of the lower part (lowstand wedge) of the formation. The sizes of these fragments decrease across depostional strike. The source of these debris are derived from terrestrial near shore plants which are destroyed to small pieces (1cm to more than 25 cm in length) and then carried by water or wind to the shallow water and there deposited by settling after the storms or stream floods are stopped.

2.Existence of hummocky and swale cross stratification (Fig.4.2, plate 4.1.2 and 4. 4.3).

3.According to Einsele, (1990) the grain size of the tempestite decreases perpendicular to depostional strike, which in turbidite the grain size may increase. This is what seen in some area for Tanjero Formation, where grain size, decreases toward south and southwest. Nichols (1999, p.280) mentioned that storm sand tend to become thinner more distally. This is also applicable for some part of Tanjero Formation.

4.Many vertical escape burrows are recorded in the many thick and thin sandstone beds of the lower part of the formation (Plate3.2.1 and 3.2.2). They possibly represent the escape burrow of organisms that became buried during the storm event.

5.Some sandstones of the lower part are clean and well sorted (Plate2.6.3 and 2.6.6). In this connection Emery and Myers (1996) mentioned that progradational, storm-dominated parasequences are generally simple, clean, and coarsening upward which is similar with lower part of Tanjero Formation.

6.The lower part of the formation, in many localities contains tens of thin and thick sandstone beds all end with small or large type of ripple marks. These ripples are more or less resembling linguoidal ripples (Plate 4.2.1 and 4.2.2). Pettijohn and Potter (1964) called these ripples interference ripples and Ainsworth and Crowley (1994, p.688) recorded and published same type of ripple, they returned these ripples to storm deposit (tempestite).

7.The maximum width (along paleo-current direction) of the Tanjero Formation (at certain time) is about 45km (Fig.1.1). This width is nearly equal to the travel distance of storm sand from coastline in the recent shelves as mentioned by Reineck and Singh, (1980, p.374).

4.1.2.4- Facies model of tempestite

Although it is difficult to find complete ideal facies model for tempestite in the formation but from different variation of facies association (incomplete model), the ideal one can be established (Fig.4.1C). According to Ensiele (2000) the difference between turbidite and tempestite model is that tempestite model contains hummocky cross-stratification. The siliciclastic facies model of tempestite mainly consists of the association of the following facies from base to the top of column of model.

1. Normally graded sandstone facies

This facies consists of graded massive sandstone (may be pebbly)(Plate 4.1.2 and 4.3.2). The base of this facies consists of storm erosion surface, which may be undulatory or flat. This surface has sole marks and clasts of pebbles. It is deposited by upper flow regime by rapid event.

2.Hummocky cross-stratified sandstone

It is consist of clean and fine to medium grain sandstone with low angle cross- lamination dipping no more than 15 degrees which is called hummocky cross-stratification (see section3.1.2 for more detail). This structure deposited by combined flow of storm wave and storm induced geostrophic current.

3. Parallel laminated sandstone facies: Located on the hummocky cross-stratified facies consist of plane laminated fine grain sandstone with possible escape structures (Plate 3.2.1and 3.2.2). It is deposited by laminar upper flow regime.

4.Cross stratification sandstone facies

This facies contain wave ripple mark and current ripple marks showing cross lamination (Plate 4.3.1 and 4.3.2). It is deposited by lower flow regime oscillatory currents due to waning effect of storm. The surfaces of this facies contain plant debris or *planolite* trace fossils (Plate 4.3.1).

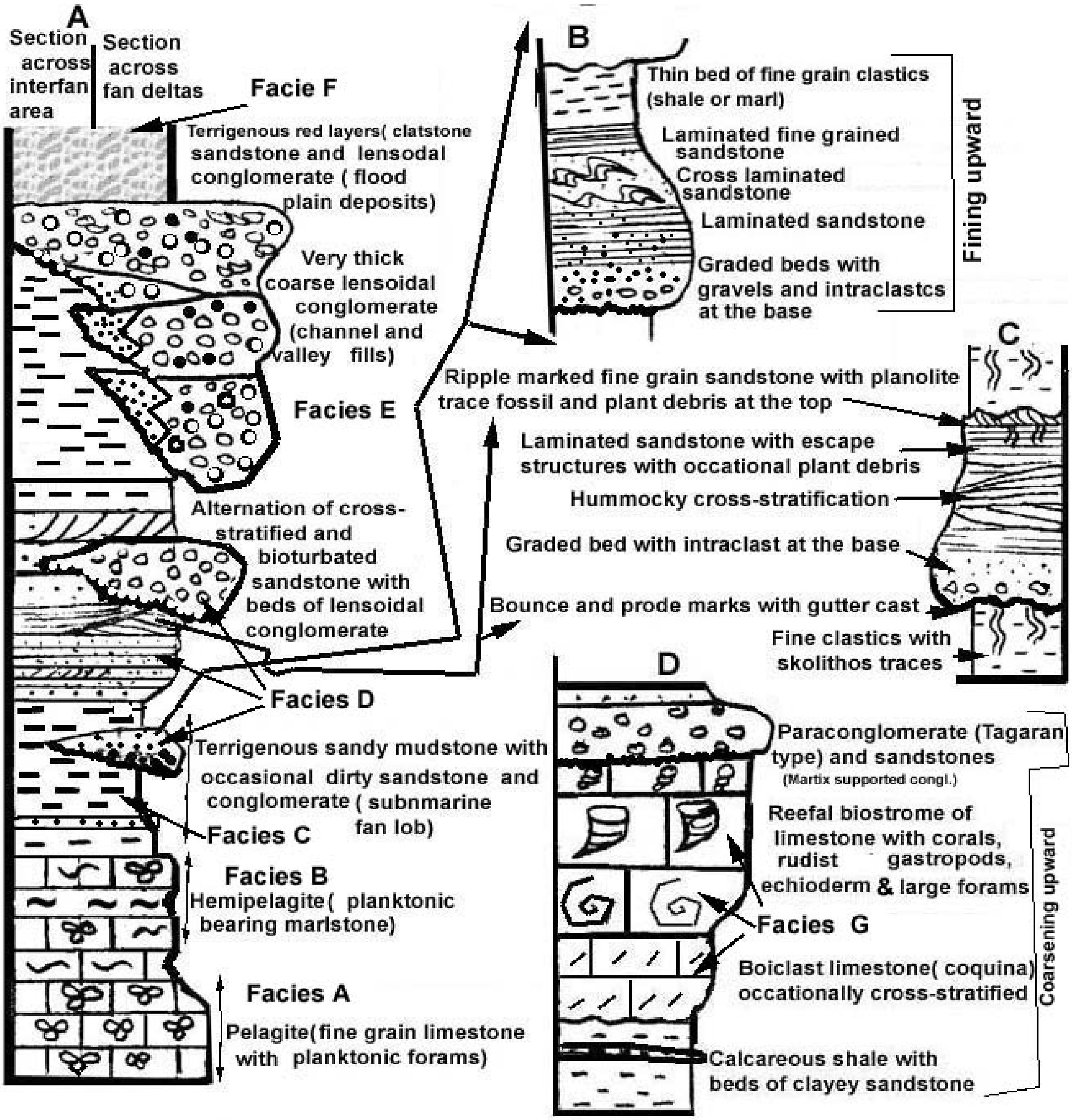


Fig.(4.1) A)General facies model of Tanjero Formation showing prograding delta sediments (siliciclastic) on deep marine ones, B) Facies model of turbidite, C) Facies model of tempestite D) General facies model of upper part (mixed carbonate-siliciclastic

5.Bioturbated mudstone facies

This facies consist of sandy or silty calcareous terrigenous mudstone (calcareous shale). It is occasionally bioturbated (Plate 3.3.3) and deposited below fair weather wave base during post storm calm period, which reflect the final fall-out of storm derived fine sediments.

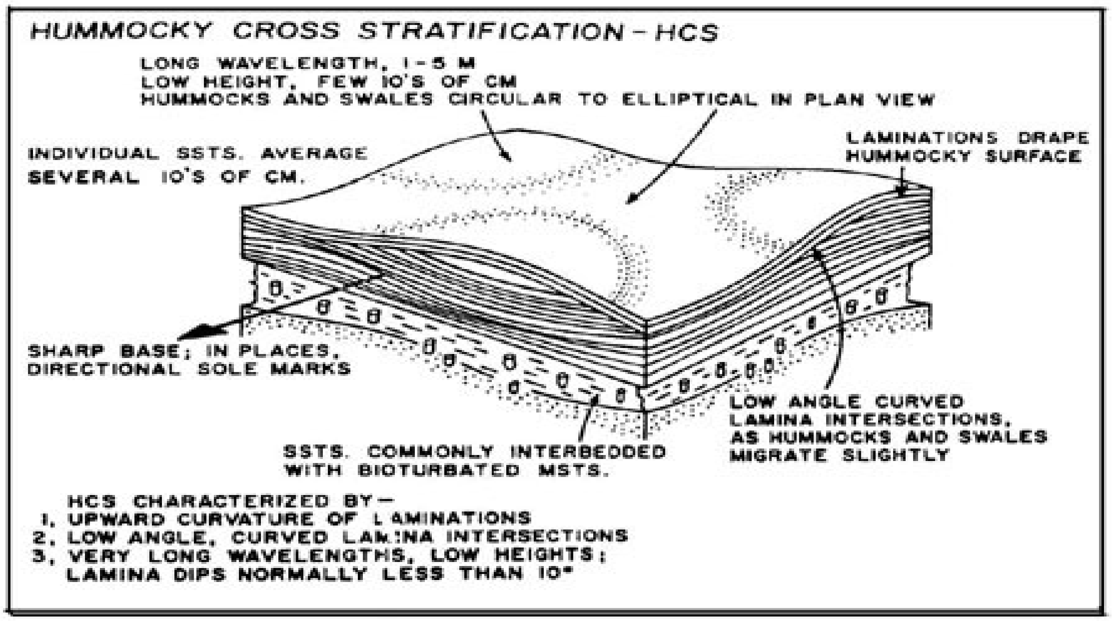


Fig. (4.2) Comparison between sketch of hummocky cross stratification (above) (Walker, 1984) and photo of the same structure(below) in the lower part of Tanjero Clastic Formation at Dokan area, 2km east of torism village. One can observe the parallelism of laminae above all the surface of hummock and swale.

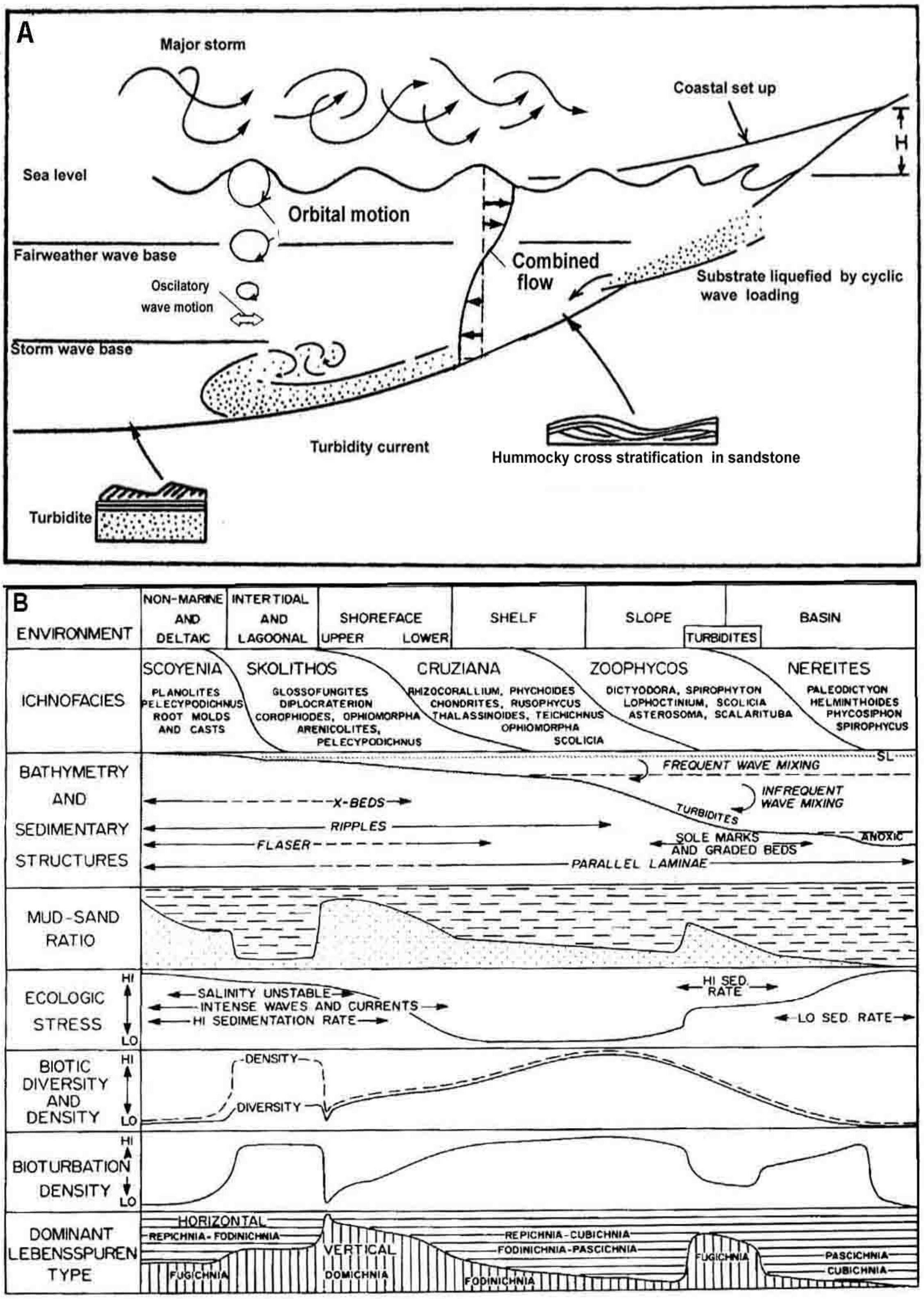
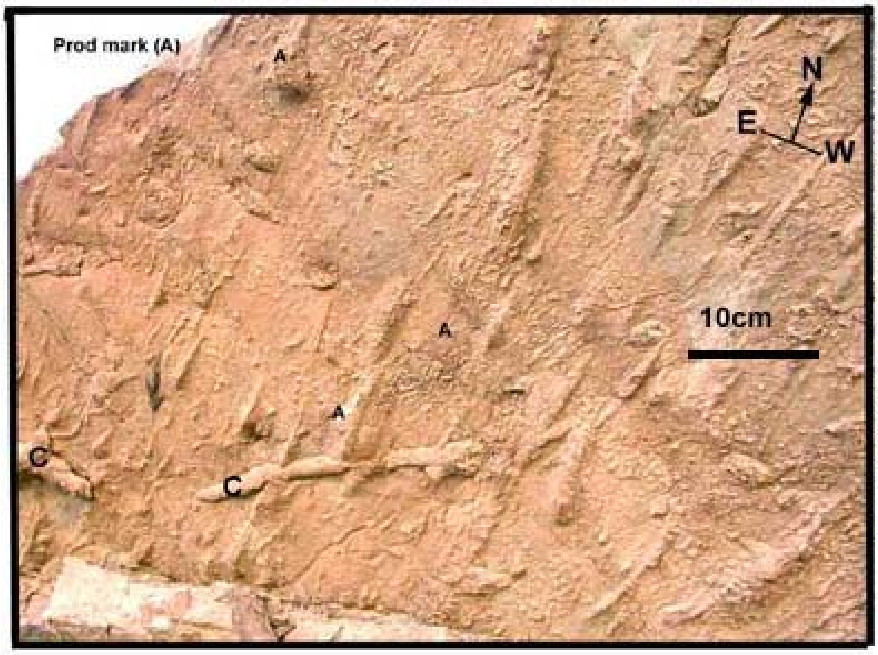


Fig. (4.3) A) Cross section of storm dominated shelf (Walker, 1984) used for illustrating deposition of some beds in the lower and upper parts. It shows that storm caused cyclic loading of the substrate by storm waves and may liquefied the substrate. The liguefied sediments may flow and accelarate basiward , transforming into turbidity current. Deposition from this flow below storm wave base would result in turbidite with Bouma sequences. Above storm wave base, wave reach the bottom and rework the turb-dity current deposits into hummocky cross stratification. HCS could also from above fairweather wave base , but would probably be reworked into other sedimentary structures. It is worth to mention that some part of the lower part is changed to shelf as regarded to water depth so the above processes are occured with in it.

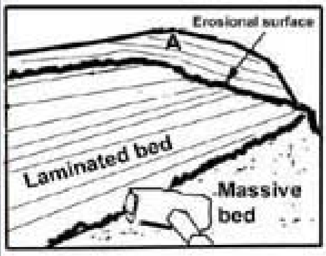
B) Suggested interrelationships between depostional environment and trace fossils (types and abundences) after Potter *et al.*(1980)

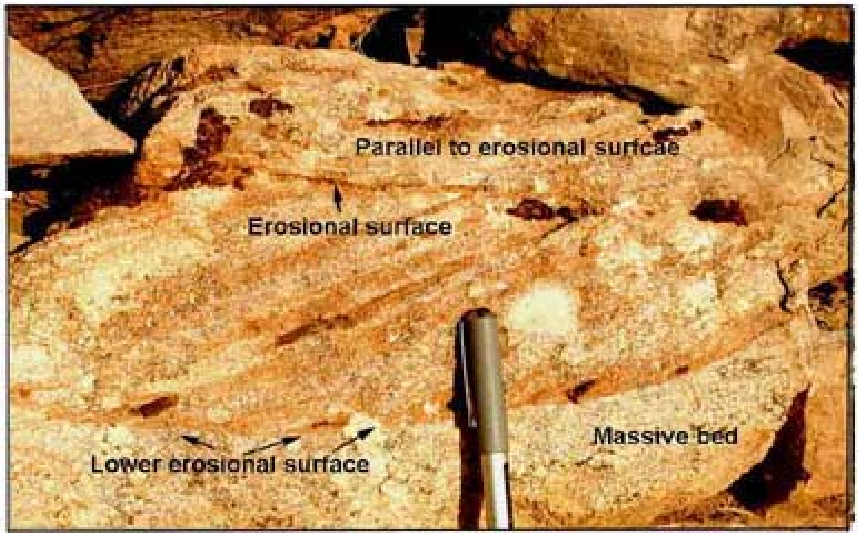
Plate 4.1



(1)Tool marks (prod and drage cast) on the lower surface of a 60 cm thick coarse sandstone bed at north of Sulaimaniya city. The elongate sole marks are crossed by planolite trace fossils (C). These stuctures have south-north direction but when the other structures taken into consideration, the direction is toward south.

(2)Hummocky cross-statification, which is consisting of set of lamina (A) at the top overlying an erosional surface parralelly. See the lower right sketch for more detail. Lower part of the formation 500 south of Chuarta check point.





(3) Possibly swale cross stratification consist of two sets of lamina forming trough. The two sets separated by an erosional surface, the upper set arranged parallel to erosional surface. This structure possibly formed by storm erosion and deposited , lower part of formation.

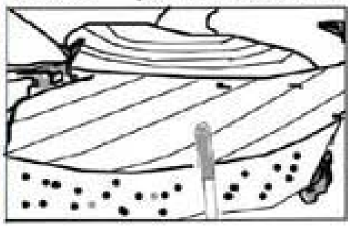


Plate 4.2

(1) Interference ripple marks (or asymmetrical ripple mark) in the upper part of the Tanjero Formation on the surface of calcareous medium grained sandstone bed exposed at Dokan area, L at. 35° 56' 9.3 ", Long. 44° 56' 14.6" . This type of ripple marks are very common in this part of the formation they are simillar to lingouidal ripple marks. The peak of these ripples are directed toward S30W. This also equal to paleocurrent dirction at this locality.

(2) Interference ripple marks (or asymmetrical ripple mark) in the lower part of the Tanjero Formation on the top of 20 cm thick medium grained sandstone bed exposed in the small valley at north of Sulaimaniya City. This type of ripple marks are very common in the lower and upper part of the formation The direction of paleocurrent is nearly S35W as indicated by the black arrow.

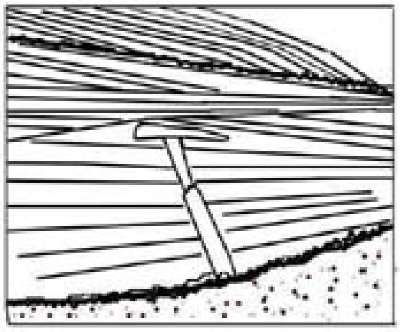
(3) Elongate branching symmetrical ripple marks, exposed in the lower part of the formation at the right bank of Balakian stream, 4 km west of Diana Town.

Location:
Latitude: 36° 46' 9"
Longitude: 44° 24' 2.2"

Plate 4.3

(1) Low angle intersected lamination is supposed by Walker (1984)as an indicater for HCS. Lower Part of Tanjero Formation contain many of these lamination in the area between Arbat, - at the east, and Dokan at the west. This photo is taken at Malkandy Hill, 1km to the north of Sulimaniya. The hammer head is 16 cm long.

(2) An other low angle lamination which underlain by erosional surface which scored in massive sandstone bed. The whole photo possibly represents hummocky



(3) This photo is taken at 400m south of Qamar Telly Village, Piramagroon area, in the Lower Part of Tanjero Formation which shows truncation of sandstone beds. This returned to erosion by high energy storm at shallow environment. It may be regarded as large cross bedding, the direction of inclined strata are toward south, this means that paleocurrent is toward south also.

4.2-Environment of deposition

In the basin of Tanjero Formation, stratigraphy, sedimentary structures, facies analysis, environment and tectonic are all so interrelated that one cannot discuss one of them without referring to the others. Therefore, in the previous chapters more or less evidence, about environment, is given forcefully for representation items more understandably. But in the present section additional items are analyzed and details are given to previously mention ones.

Several facts are found in this study or published before. They are all valuable for indicating actual environment and basin analysis for the formation. The actual environment of Tanjero Formation depends on the position of Tanjero and Shiranish Formation in the whole basin of Upper Cretaceous. This work tries to know, by facies analysis, sedimentary structures and sequence stratigraphy, which one is deposited in shallow environment. According to the below facts, Tanjero Formation is deposited in shallower depositional environment as compared to Shiranish Formation.

A-The gradational contact with Shiranish Formation is the most valuable evidence for shallowness of some part of Tanjero Formation. This is because of the following:

1.Because of gradational contact, the two formations can be put in single basin and in one cycle as lateral or vertical facies changes of each other by applying Walther law (in Blatt *et al.*, 1980 and Holland, 1998).

2.Tanjero Formation contains more clastics sediments, including beds of conglomerate, and less planktonic forams than Shiranish, which, in the studied area, is composed of marl and marly limestone. Therefore, according to all known sedimentological principles, the former formation has shallower environment than the latter one.

3.According to Abdul Kareem (1986), Shiranish Formation has continental slope environment.. In the present study it was proved that upper and lower part and deposited in shelf environments or in basin equivalent to shelf in depth (e.g., slope or basin during sea level fall).

B-Within the whole cycle two parts of the formation represent regressive episode (low stand system tract as will be seen in chapter five). This is because it started from deep marine (Shiranish Fn.), passed through shallower water environment (Tanjero Fn.) and then terminated by subaerial erosion or continental deposit (Red Bed Series in Chuarta area and basal conglomerate of Kolosh Fn. in other areas). This suggestion is exactly opposite to the idea of previous studies, which regarded the formation as transgressive depositional sequence or high system tract within the Upper Cretaceous cycle. Some of these studies put Shiranish Formation in shelf environment (see Minas, 1997, p.123, Al-Qayim and Al-Shaibani, 1989, p.48).

C- The third stratigraphical evidence for shallowness of Tanjero Formation and the whole cycle being regressive one is what observed by Lawa *et al*, (1998) in the Chuarta area. There they found that the formation is gradational with Red Bed Series. As the environment of this unit is mainly transitional (deltaic) and continental (fluviatile) so the environment of underlying Tanjero Formation must be transitional (Shelf and slope) between deep marine and continental environment. Al-Qayim and Nisan (1989) used same principles for environment assigning of Sinjar Formation in Haibat Sultan area.

D-Tanjero Formation basin was not narrow trough as thought before. This is because the paleocurrent direction and sediments influx were always from north and northeast. This fact is inferred by sedimentary structures and gradual decrease of sediments grain size toward south and southwest. In this connection Blatt *et al*., (1980) and Pettijohn (1975) used grain size changes as paleocurrent indicator.

If the basin was a narrow trough, it must show the evidence of double opposite direction of paleocurrents and sediment influx. Moreover trough is two-sided basin, which in case of Tanjero Formation must have southwestern and northeastern sides. All studies dealing with this formation have not recorded this type of situation. The present study proves that the paleoslope of the basin was toward south and southwest (Upper Cretaceous regional slope) and did not form any trough-like basin as thought before (see Numan 1997,p.94). In vertical and lateral relation, the facies dislocation of Gallaway (1989, p. 39) can be applied on both Shiranish and Tanjero Formations as gradual shallowing and shifting of shallow facies over deep ones.

The evidence showed that within this basin Shiranish was deposited in the deepest part while Tanjero and Hartha Formations have occupied borderlines from the active margins and stable shelf respectively. The former is deposited in the clastic dominated basin margin and carbonated dominated shelf respectively. In this basin where condition was suitable, Aqra and Bekhme were deposited on possibly submerged paleo-highs when water clearance and nutrient are encouraged. The following facts prove that the Shiranish Formation is deposited in deeper environment than Tanjero Formation:

1.The Tanjero Formation contains all the sedimentary structures mentioned in chapter three, while Shiranish Formation do not contain any of them.

2.Tanjero Formation grade laterally and vertically to red beds and conglomerate (continental or very shallow sediments).

3.Tanjero Formation contains less planktonic (most possibly some of them reworked) forams and more benthonic fossils of (forams, gastropods, pelecypods) than Shiranish Formation.

4.Contain lenses or tongues of reefal limestone of Kato mixed siliciclastic-carbonate succession (previously called Aqra lens).

4.2.1-Lithology and environment

As can be deduced from facies analysis, sedimentary structures and trace fossils the environment of Tanjero Formation was extremely variable in time and space. As concerned to depth of the environment it ranges from terrestrial to deep marine. While the turbidity changes from totally turbid environment to clear water ones. The salinity ranged from normal marine to fresh water. The river freshwater is changed to brackish water in the incised valleys before entering of normal saline marine water. These environments are reflected by the following lithologies:

4.2.1.1-Kometan-like lithology (facies A):

Represented by fine grain and planktonic foram-bearing limestone (Plate5.3.1 and 5.3.3). It exists in the middle part of the formation and deposited in deep and clear water pelagic environment during maximum flooding of Tanjero basin. When the basin setting of Kendall (1992 in Warren, 1999) is considered this facies is deposited in deep water- deep basin setting.

4.2.1.2- Shiranish-like lithology (facies B):

Exists at the base of the lower part and in the middle part of the formation (Plate 2.5.3) and deposited in deepwater environment (on the slope) during TST in slight turbid water.

4.3.1.3-Flysch deposits of thick low stand wedge (facies D):

Consist of alternation of thin beds of sandstone and calcareous shale forming typical lithology of Tanjero Formation (Plate 2.1and 2.6), deposited by submarine turbidity current (turbid water environment) on the slope toe during LST in deep basin-shallow water setting. These sediments are very important for indicating slope and shelf as they are bypassed the shelf and deposited on the slope toe. Some of these sediments are deposits by storm (in stormy offshore environment) forming tempestite when the depth of water lowered by sea level fall in the deep basin.

4.2.1.4-Aqra-like lithology (facies G):

Represented by reefal biogenic limestone (see Kato mixed carbonate siliciclastic succession) (Plate 5.4.1, 5.4.2 and 5.5 and 4.3), which exist in the upper part of the formation and deposited in shallow stormy environment (shelf environment) and clear water during HST of the Tanjero basin. This due to high content of rudist, large foram, gastropod, echinoderm and others. This facies deposited in shallow basin-shallow water setting

4.2.1.5-Red Bed Series- like lithology (facies F):

Represented by red claystone (see Kato Red Layers) (Plate 5.3.5), which is equivalent to middle part of the formation and deposited in the incised valley during TST above the LST conglomerate wedge. These layers are, most possibly, deposited in brackish and moderate turbid and oxidizing water of estuaries.

4.2.1.6-Mollase–like lithology (facies E):

Represented by 500m of poorly sorted and surrounded conglomerate (see Kato Conglomerate) (Plate 5.1and 5.2), which is deposited in the incised valley during LST above the floor of the incised valleys. Flooded braided rivers possibly deposited this conglomerate.

4.2.2-Shelf-slope setting versus ramp setting

Many lines of evidence exist that the continental margin, on which Tanjero basin is deposited, has shelf-slope profile. So the following evidence exclude the ramp profile:

1. The position of shelf break (offlap break) of the lower high stand system tract can be indicated. This is because thick lowstand wedge can be seen at the area of Chaqchaq and Shadalla valley in addition to northern boundary of Piramagroon -Sharazoor plains. So these areas represent the slope. The shelf break is probably located near summit of Goizha, Azmir, Daban and Qarasird Mountain (or anticlines). This thick wedge of sandstone is not present in north and northeast to the latter anticlines. This means that the summits of these anticlines indicating shelf break and nearly all sandstone bypassed it and deposited on the lower slope.

2.The existence of incised valleys fill (Kato conglomerate and red claystone layers) at the Mawat and Chuarta area, prove that this area northeast to these towns were forming the shelf during lower (former) HST and coastal area during upper (next) HST.

3.Another evidence for shelf-slope profile is the high thickness of the LST, which is in some place more than 500m. For this, Haq, (1991) and Emery and Myers (1996) mentioned that low stand wedge in ramp setting is relatively thin. It is possibly that the shelf of the lower sequence is developed by high sedimentation on the front advancing of Iranian plate and coalesce of several coarse sediment alluvial fans. The rapid deposit and burial of coarse sediment prevented them from reworking into deeper water, thus a clastic dominated platform (or fan delta front) is developed which was modified (flattened) by wave

4.2.3-The environmental classification

In previous studies the correlation for time equivalent parts and lithologies of the formation was not done. Therefore, the depostional environment of the Tanjero Formation is mainly assigned on the basis of entire lithology of the formation collectively. But the realistic environmental classification of Tanjero Formation is impossible without detailed correlation and referring to the three parts introduced in this study (see section 2.1.2). The sedimentary structures and trace fossils are widely utilized for indication of environment.

The environment of the formation was swinging during the total time span of Campanian Maastrichtian as a response to eustatic sea level change, tectonic uplift and sediment fills in addition to possibility of participation of climate. Accordingly in the basin, the environment was changing both in time and space as a result of sea level change. These changes are demonstrated by lateral and vertical lithological changes. So the shoreline was changing continuously especially during TST and LST.

Even the depocenter (Upper Cretaceous depocenter) also changed with time in response to sea level change. Depocenter is shifted from shelf (at sea level rise) to slope during sea fall (Fig. 6.5). But in this study, for convention the depocenter is indicated at the slope toe, which is supposed to hold maximum sedimentation during sea level fall.

4.2.3.1-Geographic boundaries of depostional environments of the sequences

The depocenters (depostional center) of the formation was shifting southwestward continuously. When the early (previous) depocenter was filled with sediments, the erosion began by river rejuvenation after retreating of the sea from the shelf. Thus the depocenters translated to deeper part of the basin (to slope toe). The studies of sedimentary structures and sediment stacking pattern proved that two main movements in the depocenter occurred. This is associated with two low stand system tract and related TST and HST forming two sequences. The location of depostional environment of these two sequences are as follows:

4.2.3.1.1-Geographic boundary of depostional environments of Upper sequence

4.2.3.1.1.1- Position of shoreline of the upper sequence

The shoreline during LST was changing relatively speedily and constantly so that the position not much certain. The possible most basinward location far reached may be slightly below shelf brake mentioned above. But during the HST, the approximate position was slightly north to Khurmal, Chuarta, Mawat and Qala Diza towns in addition to Qandil Mountain toe (Fig.4.4).

4.2.3.1.1.2- Shelf break boundary of upper sequence

The location of shelf break can be indicated by the disappearance of the thick fossiliferous limestone beds of Kato mixed carbonate-siliciclastic successions. This boundary elongates during HST as a southeast- northwest line from Shinarow, Goizha, and Azmir and to Kewa Rash Mountains (or anticlines) (Fig.4.4).

4.2.3.1.2-Geographic boundary of depostional environments of lower sequence

The location of shelf, slope and basin of the lower sequence is less obvious because of very limited outcrops in the studied area. The only clear outcrop is located at Kato Mountain. At this area, its lithology is equivalent to that of slope of the upper sequence at Chaqchaq, Shadalla valleys. The distance between these two locations is about 20km.

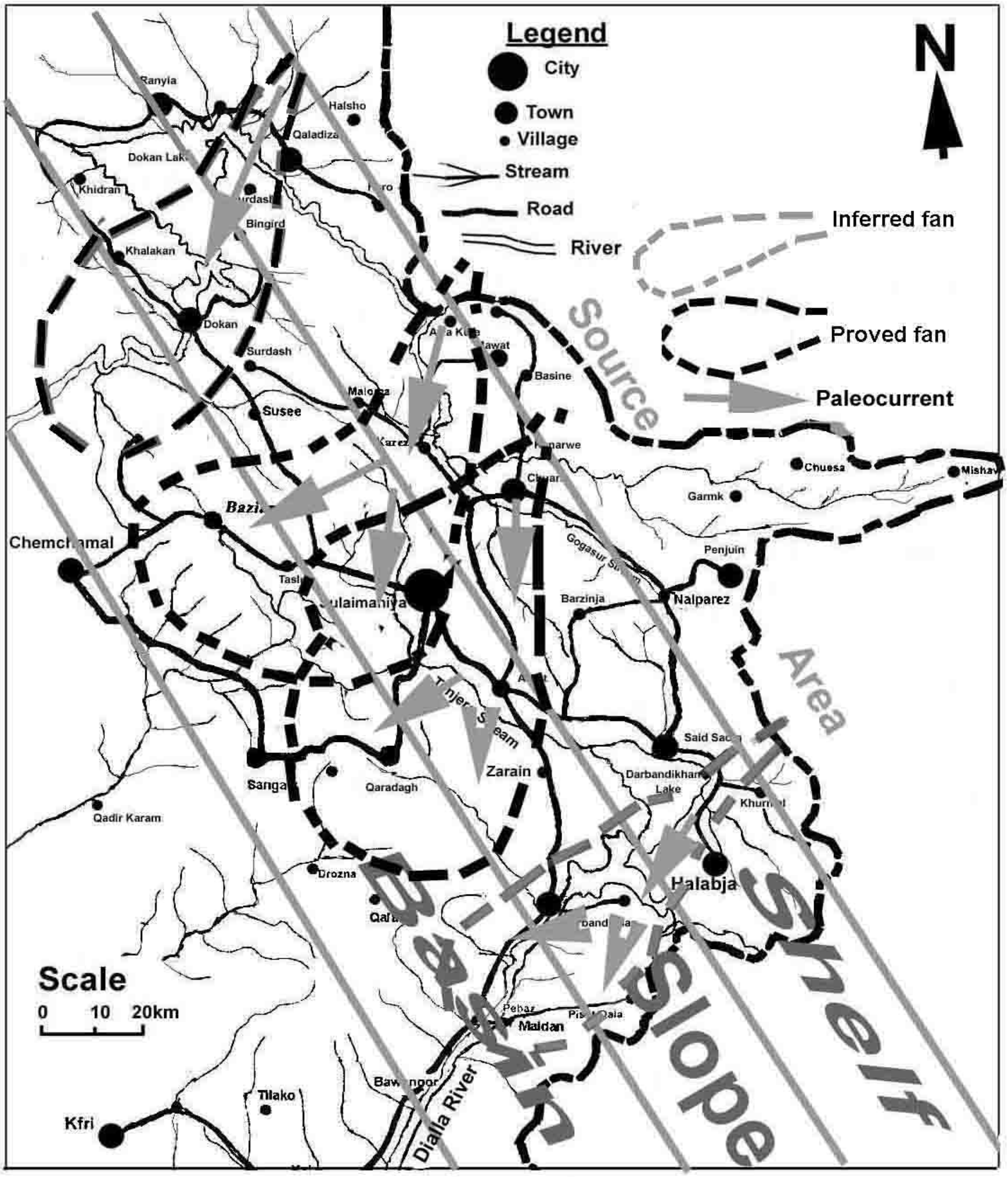


Fig.(4.4) Approximate location of the shelf, slope and basin during the upper sequence (during deposition of HST). But during LST, the three environments possibly were more southwestward than HST.

At the Sharazoor and Piramagroon plain, this sequence, can hardly be recognized for its very low thickness and it is mixed or merged in to Shiranish Formation.

4.2.3.1.2.1-Shoreline location of the lower sequence

The shorelines of both sequences were more than 20 km beyond (separated from) each others. So, when this distance is measured from the shoreline of upper sequence, the shoreline of the lower sequence was nearly coinciding with present Iraq -Iran boundary (Fig.4.5).

4.2.3.1.2.2-Shelf break location of lower sequence

The shelf brake of the lower sequence most probably coincides with shoreline of upper sequence. This means that the shelf break is located under the Kato conglomerate in Chuarta and Mawat areas, while the slope is located at the south and southwest of this shelf break i.e. the area between Chuarta and Mawat in one side and Sulaimaniya city in the other side.

4.2.4-One basin instead of two

Previously the depostional area of Tanjero Formation was divided into two basins, Al-Rawi, (1981) called them: southern and northern troughs. The axis of the southern trough goes through the type section in Sirwan valley, at the southeast, and Dokan town at the northwest. While the northern trough axis goes by Rawandoz town and Mergasur village from southeast and northwest respectively. The distances between these two axes along the dip and strike is about 40 and 60 km respectively. But in the present study, only one single southeast- northwest trending basin is inferred. This is because of the following:

1. When one connects the similar lithologies inside the basin, he gets the straight lines, parallel to which the axis of the basin can be drawn (Fig. 3.3, 4.4 and 4.5). This axis, in the present study, is shifting more northward than the related axis in the previous studies. So one connects the slope during upper sequence, the axis connects the type section (south of Halabja Town) Turkish border at northwest of Haji Omaran Town (Fig. 3.3).

2.The separation of the basin into two troughs (basin), as suggested by previous workers, is most possibly based on available outcrop inside the synclines. The two axes are so drawn that trending parallel to the axis of anticlines (or coincide with axes of Sirwan and Balakian synclines). The axes of these anticlines are not assured to be parallel to the axis of the Upper Cretaceous foreland basin. All the present anticline is returned to post cretaceous period deformation. According to Al-Surdashy. (Personal communication), the mean movement direction of the Arabian Plate during Upper Cretaceous was N50E (S50W for Iranian Plate) but changed to N25E during Tertiary. The present axis of anticline better fit with the latter direction than the former. The axis, which is indicated in this study (Fig.3.3), is agreed with the direction given by Surdashy.

3.The new axis is most suitably fit the distribution map of the formation which has nearly equal distance with the southern boundary (Fig.3.3).

4. This study does not refuse the existence of miner irregularity in the basin but they are not in the scale to separate the basin into two ones

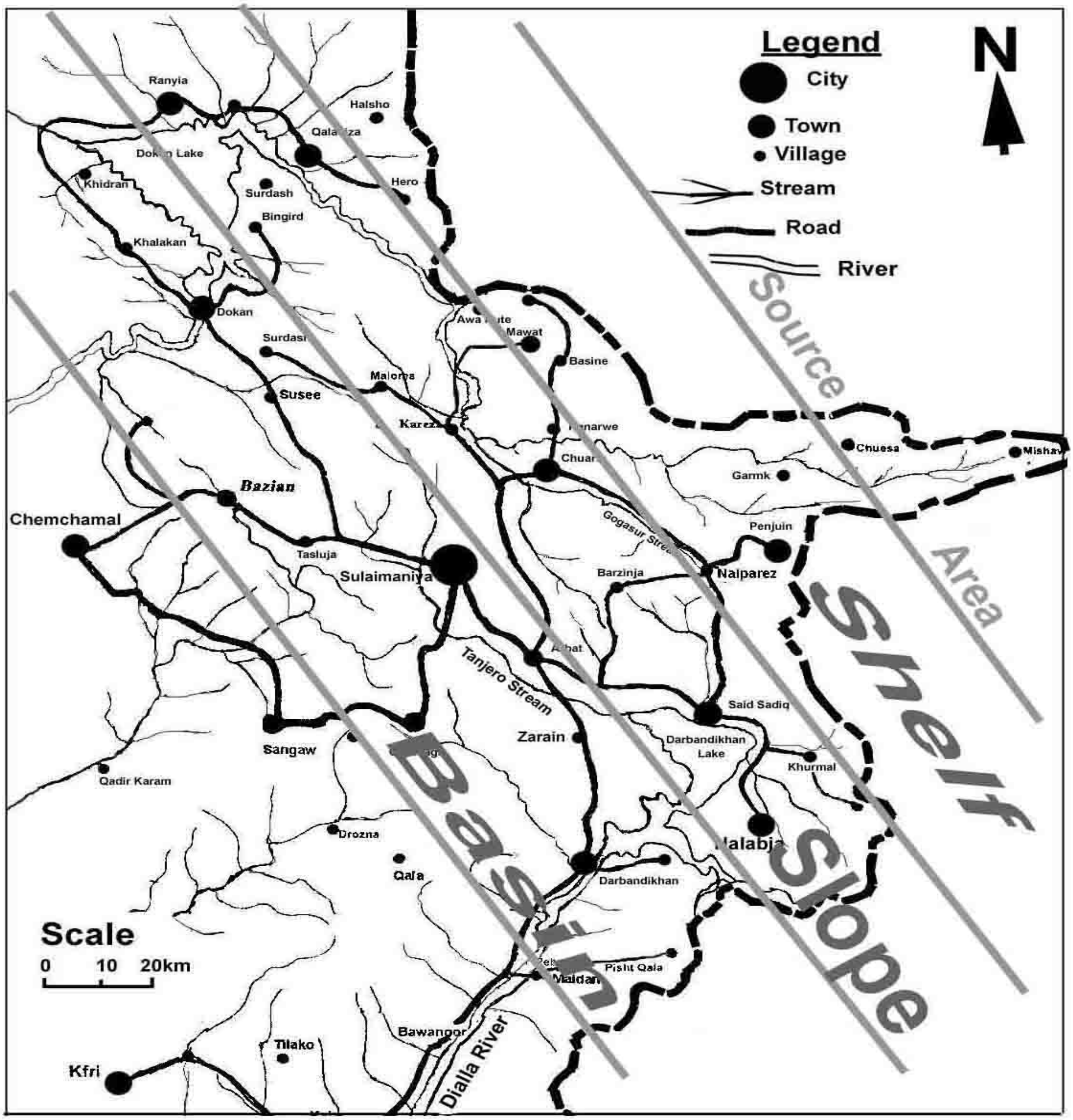


Fig.(4.5) Approximate location of the shelf, slope and basin during the lower sequence (during depostion of HST). But during LST, the three environments possibly were more southwestward than HST.

4.2.5-Position of planktonic forams and Nereite trace fossils in the environment of Tanjero Formation

All the previous studies depended on planktonic forams and *Nereite* ichnofacies for giving the formation deep-water marine (trench) environment. In present study, their presence in the formation is explained as follows:

4.2.5.1 Planktonic Foraminiferas

Among the cooked samples of Tanjero Formation, only the marl of TST (Middle part) and the transitional interval (lower part of Bellen et al., 1959) with Shiranish Formations yield planktonic forams. This interval consists of beds of marly limestone intercalated with thin sandstone laminae. In traditional stratigraphy, the transitional interval represent shallowing from deep to relatively shallower environment (e.g. from basin floor to slope environment). The shallowing is also associated with southwest advancing of sources area. So this interval contains abundant indigenous planktonic forams and can be extracted easily by cooking.

In sequence stratigraphy (see chapter five) this interval represents the beginning of low stand system tract (early stage LST). Therefore, in addition to indigenous forams, it may contain some species of older ages, reworked from the previous HST. In all sections, after these transitional intervals, the typical lithology of Tanjero formation comes which consists of alternation thin or thick beds of sandstone and calcareous shale with some interbeds of conglomerate. As previously mentioned this lithology is deposited during sea level fall, which forms low stand wedge and slope fans. So all the typical lithologies of the Tanjero Formation (lower part of the formation are reworked, therefore nearly all content the planktonic forams and Radiolarians are reworked from older sediments and rocks (Fig.4.6). Hence, the environmental and age deduction from these lithologies are not possibly correct.

But what is the actual environment and age of this lower part? For answering this question one must return to the sedimentary structures (chapter three). As concerned to these structures the most shallow environment indicator are located in this part of the formation, among these cross bedding, ripple mark structures, Skolithos and Cruziana ichnofacies. According to these structures and incised valleys, during deposition of this part the shelf is exposed and slope and basin is changed to shallower water than the previous HST. The tectonic enhanced sea level fall is estimated to be 300 m below previous HST. Regarding the depth of water (not profile), slope changed to shelf and basin to the slope. The cooked samples of this part yield reworked abundant siliceous radiolarians with rare reworked forams. After the lower part (forced regressive part) comes the middle part (transgressive part) during

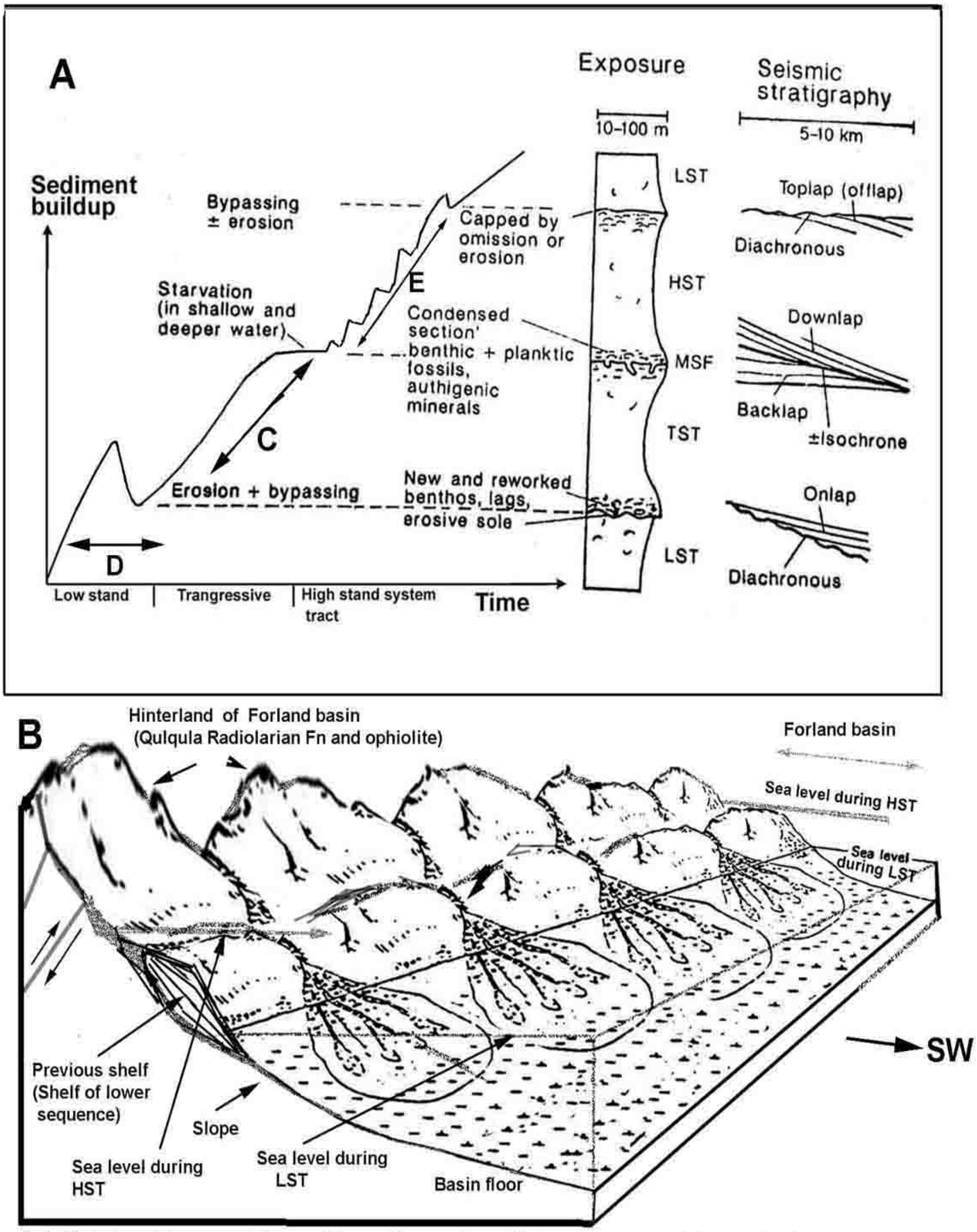


Fig. (4.6) A) The position of fossils and sediments reworking during one cycle of sea level change in Tanjero basin. During interval of (D) the old fossils and sediments are intensively reworked during deposition of formation. Only the interval of (c) yield indigenous (autochthonous) fosslis for paleontologic study. The interval (E) represent the depostion of upper part mixed carbonate-siliciclastic succession which contain some reworked forams, sediments &bioclasts The column of exposure, shown in the diagram (A) is valid only for shelf and slope. The sketch (A)is modified from Einsele(2000).

B) The model(low stand fan delta model) of the basin of the formation during LST where the previous shelf and slope fossils are reworked.

which the sudden deepening occurred for all the environments. The previous shelf has drowned again and marly limestone, hemipelagic marl and calcareous shale are deposited in the basin, slope and shelf respectively. The first two lithologies yield dependent on *planktonic* and benthonic forams for age and environment indication. The upper part (carbonate-siliciclastic succession), on the shelf, is composed of alternation of calcareous shale and fossiliferous limestone. Most of these fossils are found in their places (indigenous), which show no reworking (Plate 4.5). The cooked samples of the shale yield benthonic forams but no planktonic ones. While on the slope and basin the shale and limestone change to thin sandy limestone.

So, the presence of planktonic forams are returned to the following factors:

A. Deep water of transitional interval and middle part.

B. Reworking into lower part and some part of upper one by turbidity currents from lower sequence.

C. King (1975) mentioned that because of high concentration of $CaCO_3$ during Cretaceous, the planktonic forams were more abundant than present and other ages. Therefore it is possible that some shallow part of the formation contain planktonic forams than the present day analogues.

D. Many authors found planktonic forams in shallow environments, among these Lawa (1983) found certain species of planktonic forams in the fore reef facies of Aqra Limestone Formation in Aqra area. Moreover, Karim (1975) found many species have planktonic and benthonic forams in Red Bed Series in Chuarta area.

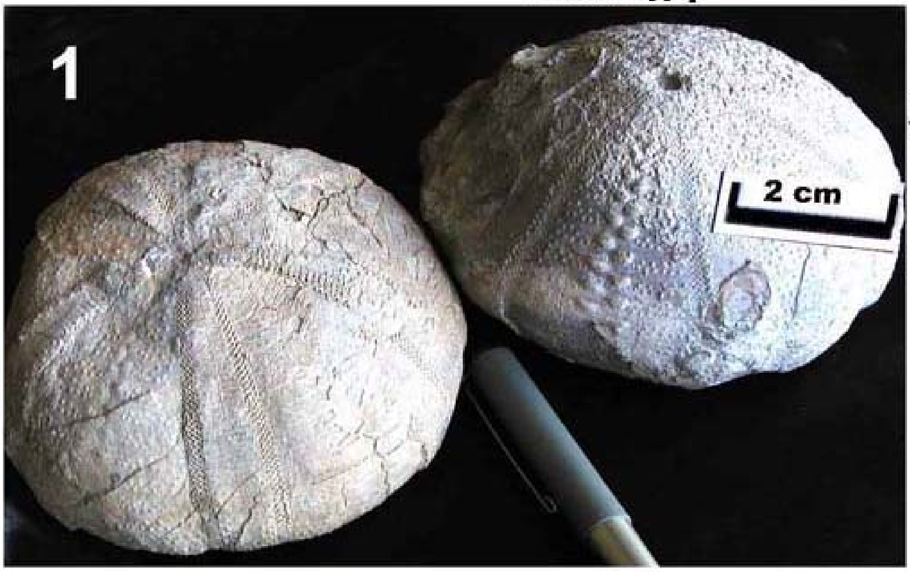
According to Boltovskoy and Wright (1976), planktonic forams generally avoid near-shore, shallow water area, but they are found only in coastal regions where there is no river mouth and the bottom slope is relatively steep. Bracier (1980, p.102) did not exclude planktonic forams from continental shelf. He showed graphically that their percentage decrease from outer shelf toward intertidal area.

E. The previous paleontological studies were conducted near the distal part of the Tanjero basin, the lithology of which is mainly marl or marly limestone.

F. Many authors recorded planktonic forams in some basin of stable and unstable shelves in the rocks of formations such as Umm Raduma and Kirkuk Group. So this proves that Tanjero Formation is not necessary to be deposited in trench and very deep environment.

G. According to Emery and Myers (1996) in nutrient starved basin (in this paper supposed to be Shiranish Formation), sediment bypass to the basin during lowstand (during Tanjero deposition) may increase nutrient supply to greater planktonic productivity. If this occurs, the distal of the lowstand wedge may be recognized by occurrence of planktonic fossils in condensed sections

Plate 4.4

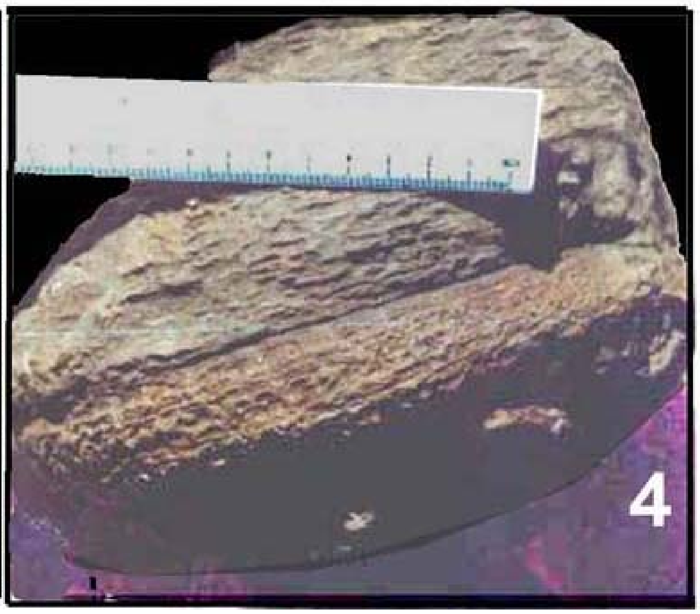


(1)Two echioderms showing different scalptures.They were found in the weathered clayey calcareous sandstones of the Upper Part of the formation south of Homaragh village, Chuarta area.

(2) Solitary corals (*Cyclolite*)were found in the weathered clayey calcareous sandstones of the Upper Part of the formation near Zardabe village, Chuarta area.

(3) A rudist as photographed at its place at Naud-asht valley. It exists, in Chua-rta area, in the upper part.

(4) Large pele-cypod found in the upper part of the formation at southwest of Tagaran Village.



and hemipelagic shale overlying the basin floor fan deposits. In the absence of fan, the fossils of the distal low stand condensed section will resemble those of the previous high stand.

4.2.5.2-Nereite Trace Fossils

These traces consist of complexly organized grazing, and feeding-dwelling traces. According to Walker (1984) they exist in flysch, flysch-like deposits, and pelagic mud. It is worth to mention two important points about these traces in Tanjero Formation:

A. These traces are all, without exception, found near the boundary with Shiranish Formation on the lower surface of thin sandstone beds. The interval in which most of these traces are observed can be regarded as the transition zone between the two formations. Therefore, these thin beds are deposited in the deepest environment of the formation where Tanjero Formation changes downward to Shiranish Formation at the transitional zone. This environment coincides with the slope toe before sea level fall.

B. In this study, these traces are found in Dokan area (distal area). So these traces exist in limited part of the formation and cannot be applied as environment indicator for the whole Formation. The deep environment of the transition zone is intermittently supplied by oxygen and food by turbidity current. The traces are formed after deposition of sand when the short calm period is prevailed in relatively deep water.

The extensive field observation failed to fine these types of trace fossils in other parts of the formation. The complex forms (Plate 4.5) of these traces are, as I guess, attributed to the habit of the worm-like organism, which prepared regular pattern of texture for camouflage (hide) against predators. Another possibility is intending to confuse the eye of large animals such as fishes so that cannot identify the exact position of worm in the feeding-dwelling framework of the traces. Previously the complexity and regularity of these traces were attributed by Nichols (2000) to the scarcity of nutrients and to move efficiently to exploit maximum food in the deep sediments.

Two main types of these traces are found:

A. *Paleodictyon:*

This type appears as regular hexagonal networks (cells). Both small and large network are found, the cell width of the first one is 3mm (Plate 4.5.3) while the other reached 2cm (Plate4. 4.4)

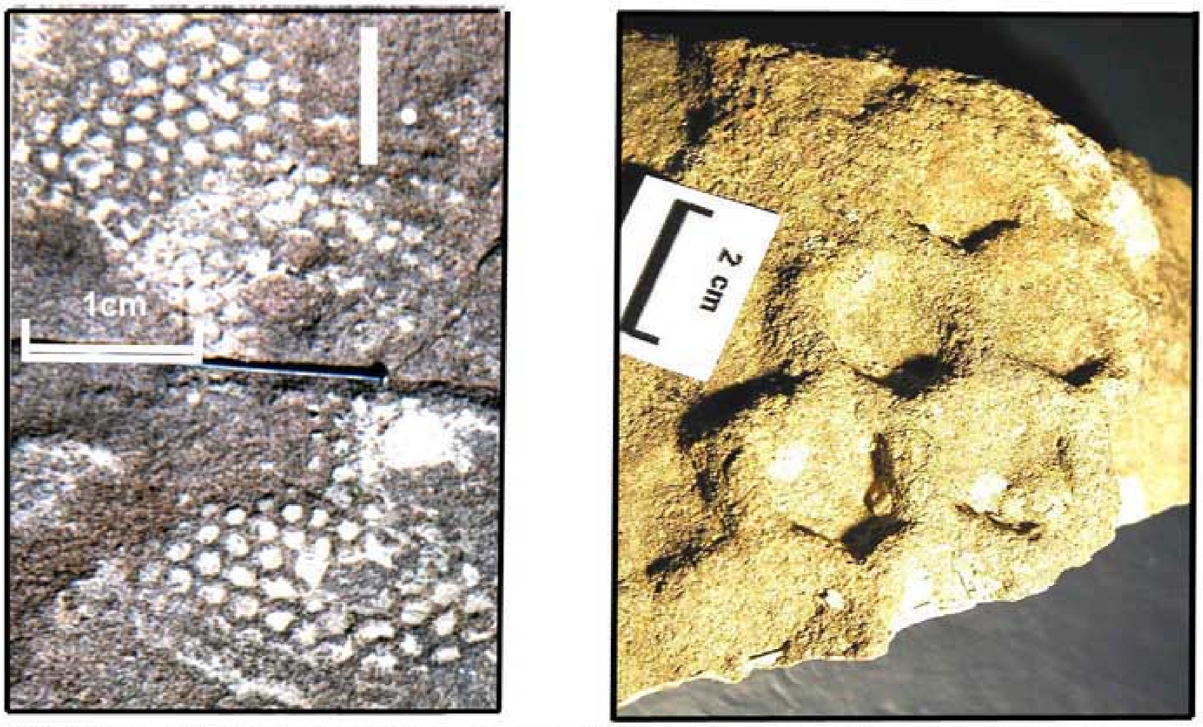
B. *Helminthoida*

It is narrow horizontal and meandering string- like traces. In the lower part of Dokan area this type of traces is found with complete worm body fossils. The size of these worms coincides with the size of most of *Helminthoida* trace fossils found in the formation (Plate 4.5.1 and 4.4.2).

Plate 4.5

(1) Petrified annelid(worm) body fossil, lower part of the formation, X4, Dokan section.

(2) Zigzag Nereite trace found in the same part as previos photo. It is possibly returned to same type of worm, X3.



(3) Paleodictyon trace fossil showing small (left) and large (right) hexagonal nets, they formed by organism for hiding (camouflaging) againt predatore in deep water.

Chapter Five:

Sequence stratigraphy

Sequence stratigraphy as a part of traditional stratigraphy is defined by Emery and Myers, (1996) *as subdivision of sedimentary basin fill into genetic packages (depositional sequence) bounded by unconformity and their correlative conformities.* Moreover they regarded the sequence stratigraphy as a tool for basin analysis and for more precise subdivision of the sedimentary rock record. In this study the method of Vail et al. (1977) is used for division of the rock body of the formation into depostional sequences, this is because the unconformities and correlative conformities can be identified. While the method of Galloway, (1989) is not used because it is difficult to be applied on Tanjero formation. the Clear sequence stratigraphical study of Tanjero Formation needs the followings:

1.Indication of the sequence stratigraphical position of the formation within both the stratigraphic column and relative sea level change of the studied area. For this, the author has tried to study at least a part of the basin fill succession which extend beyond Shiranish Formation. The time span and thickness of the part treated in this chapter depends on the position of the closest overlying and underlying unconformities and correlative conformities that bound the Tanjero Formation. At the advance steps of this study, it was obvious to me and surprising that one of the biggest sequence boundaries (SB1) is located within the Tanjero Formation. This means that the formation is subdivided to two sequences. This forced me to study and find the boundaries of both sequences wherever they are located.

2. Therefore, for finding the type one or two sequence boundary (SB1 or SB2), the extent of this study, has gone vertically beyond underlying Shiranish and Kometan Formations and overlying Red Bed Series.

3.Although the boundaries of the above Formations are studied, no correlation is done as concerned with traditional and sequence stratigraphy.

4.Extensive lateral fieldwork is done to find all sedimentary facies deposited in response to relative sea level change. Finally, these facies are organized in system tracts (LST, TST, HST and SMST) and the associated sequence boundaries are identified. The systems and boundaries rarely can be seen in one continuous surface section. As the seismic sequence stratigraphy is not used in this study, therefore different surface sections are studied and combined to compensate to the seismic lack.

The first one who classified the formation in viewpoint of sequence stratigraphy is Minas, (1997). His study depended on the previous traditional stratigraphic studies. He included the lower part and middle parts as sediment of TST and HST respectively. As will be discussed later in this study the result is exactly opposite. Before discussion of the system tracts, it is better to see the boundaries between Tanjero and adjacent formations. This is to find the certain starting point of sea level curve (relative sea level change) that enclosing Tanjero Formation in one or more of its cycles.

5.1-Boundary between Shiranish and Tanjero Formation

In all previous studies concerned with the two formations such as Bellen, et al. (1959) and Buday (1980), it was recoded that the contact between the two formations is gradational. But in the present study, at least in one locality, it was found that the contact is unconformable, as shown below:

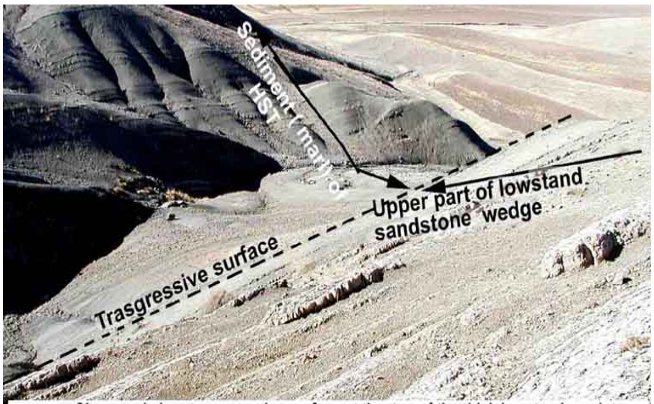
5.2 - Iran Section

This section located inside Iran near the border with Iraq (Fig.2.3 and Plate2.5.1 and 2.5.2) on the left bank of the Do Awan River (upstream of Little Zab River) about 4km to the west of Awa Kurte village and about 20 km to the northwest of Mawat Town at the intersection of N 35^{0} 37^{-} $20.6^{=}$ and E 45^{0} 35^{-} $16.4^{=}$. At this locality the Shiranish Formation (Bluish white marl and marly limestone) is overlain by 13 to 150m of conglomerate (Plate2.5.2) and Red Bed Series exist at the top of the conglomerate. This conglomerate belongs to Tanjero Formation because it is correlated with and traced laterally to Kato conglomerate. Moreover, it has similar lithological composition. Here the contact between Shiranish and the conglomerate is sharp and erosional. This is also true for one location at the toe of Qandil Mountain (Plate 2.5.2).

In spite of these two localities, in this study, boundary between the two formations is not regarded as unconformable. These erosional contacts are attributed to the deeper erosion so that the sediment of lower sequence (sediment of HST) (Fig.2.1) is all removed due to elevation of the area in the coastal area and incision by rejuvenated streams. The conglomerate represents coastal onlap of the conglomerate on the steep head of the incised valleys. The boundary between the two Formations is conformable in all other localities in side the basin. The conglomerate represents sequence boundary. Emery and Myers (1996, p.98) mentioned that the type one sequence boundary is associated with superimposition of shallow or non-marine deposit on deeper one (when the conglomerate regarded as non-marine (or shallow marine) deposits and the marl as deep one).

5.3-Contact between Shiranish and Kometan Formations

All the sections inspected in the studied area have gradational contact. So, primarily appear that there is no major break in the sedimentation of Upper Cretaceous except the one inside the Tanjero Formation which represented by Kato conglomerate and its equivalent lithologies.



Sharp and clear transgressive surface at the top of the thick lowstand sandstone wedge directly at the west of Kurdsat satalite center, about 1.5km north of Sulaimaniya city.

So the sequence stratigraphic position of the below formations (Fig.2.2) are as follows in the depostional sequence of the area:

Qamchuqa Formation… LST

Kometan Formation… TST

Shiranish Formation… early HST

Tanjero Fn…late HST, LST, TST and HST

Only the detail of the last formation is made and other ones are outside the range of the present study.

5.4-System Tracts of Tanjero Formation

The sequence stratigraphy study of Tanjero Formation, in the study area, has much restriction, due to the followings:

1.Absence of the reflection seismic data for the studied area. This makes the study of the stacking pattern of the system tracts and parasequences difficult.

2.Most parts of the formation are removed by erosion. This is because the formation has relatively soft lithology except Kato conglomerate. The remained and exposed parts exist only in the NW-SE trending synclines (Fig.1.2). Some layers can be traced along their depostional strike for several kilometers and cannot be traced across their depostional dip. The latter direction is the most useful but disrupted by the elevated anticline in between synclines.

3.The outcrops are intensely deformed and refolded so that, in one section, the lower part for example, is repeated several times.

However the sequence stratigraphic setting and the subdivision are established and depending on the following factors:

1-Three-dimensional lithological correlation and facies changes (Fig. 5.3 and 5.4)

2-Sedimentary structures, 3-Trace fossil, 4-Finding certain marker bed or beds

5-Traditional stratigraphic position of the formation among the older and younger units

5.4.1-Lowstand-system tract of Tanjero Formation

It is most probable that the typical lithology of the Tanjero Formation (lower part of the new division) is deposited as lowstand system tract. This is according to the following:

1.In the field and in the proximal area Chuarta and Mawat, Qaladiza and Qandil mountain toe area, when one cross the upper part of Shiranish Formation, Tanjero Formation begins with alternation of thin sandstone between thick dark green calcareous shale, this suddenly change to thick succession of boulder and gravel coarse conglomerate beds (Kato Conglomerate). This type of upward lithological change, represents incised valley sediment overlying the fine sediment of previous HST unconformably. The conglomerate is deposited during late stage of LST when sea level slowly rises This is because it equivalent to the low stand wedge on the slope toe. During this slow rise, coarse conglomerate is deposited which shows aggradations stacking pattern demonstrated by 500m of coarse conglomerate beds of nearly same thickness and grain size. The erosional surface below the conglomerate (Fig.2.1 and Plate 5.2) is a major unconformity of the Upper Cretaceous. It also stands for a type one-sequence boundary (SB1) on which the sediments are bypassed from the coastal area of prograding fan delta to prodelta slope and basin plain during relative sea level fall. This surface can be identified from Kato Mountain to south of Sulaimaniya city at distance of 25km. This distance is equal to 30km if folding shortening is eliminated. Near Tanjero stream it changes to correlative conformity, which change to coarse and fine sandstone.

In the toe of northeastern limb of the Goizha and Azmir and Daban anticlines also can be seen in certain places, such as Azimra Bichkola valley, north of Bnawella village in addition to Mararash village. The sediments above the erosional surface show that the shoreline and facies belt is probably shifted basin ward from the mountain to the north of Sulaimaniya city during Upper Cretaceous sea fall.

All mentioned for the area between Kato Mountain and Sulaimaniya city is also true for the following areas:

A. The area between Mawat Town and Kizlar Village in the Chaqchaq valley.

B. The area around Suwais village and Naudasht valley.

C. Type section at Sirwan valley and Khurmal town (the proximal area inferred indirectly to be near Khurmal town by applying the distance of the two areas of A and B.

The proximal sediments (conglomerate) do not exist in the Khurmal area due to erosion. But their positions are inferred for the sediment of distal area in Sirwan valley and Dokan area. The model for the basin (Fig.6.5) can also predicts the delta mouth sediments.

2.At the distal area such as Dokan area, Sharazoor and Piramagroon plains, when one crosses the boundary between the two formations, bluish white marl changes to sandstone and calcareous shale. Emery and Myers (1996) regarded this type of change as indication of low stand system tract in deep marine environment.

In the present study, the environment of boundary between Shiranish and Tanjero Formations can be regarded as deep environment. The further advance into Tanjero Formation the sandstone increases and changes to a thick 100-400m sandstone wedge, the base of which consists of clean succession 10-40m thick of sandstone with cross lamination and Skolithos escape structures (Plate 2.1 and 3.2). This succession is equivalent to the erosional surface under the Kato conglomerate (for simplicity it can be assumed as time equivalent of lower part of Kato conglomerate and represent the deposit of the extreme shallowing during lowstand system tract. The whole sandstone wedge is equivalent or derived from Kato conglomerate (Fig.5.4).

5.4.2- Components of LST

A. Lowstand fan

As known, the lowstand system tract consists of two parts; lowstand wedge and lowstand fan. Low stand fan in turn is divided into slope fan and basin floor fan. Tanjero Formation, as has limited outcrops and lack seismic data, so the lowstand fans are not clear. But some dirty sandstone beds exist which may represent basin floor fan. These beds are as follows:

1. At Sirwan, Chaqchaq valleys and Dokan area there are two beds of either coarse dirty sandstone or paraconglomerate near the transition zone between Shiranish and Tanjero Formations. These beds are isolated in the marls or calcareous shale. The position of these beds in the succession of the formation and relative sea level change suppose that they deposited during early phase of low stand time when the relative seal level fall was at its maximum rate.

2. These beds are generally massive and dirty (matrix supported) so they, most probably, deposited by debris flow and slumping of the shelf edge (shelf break).

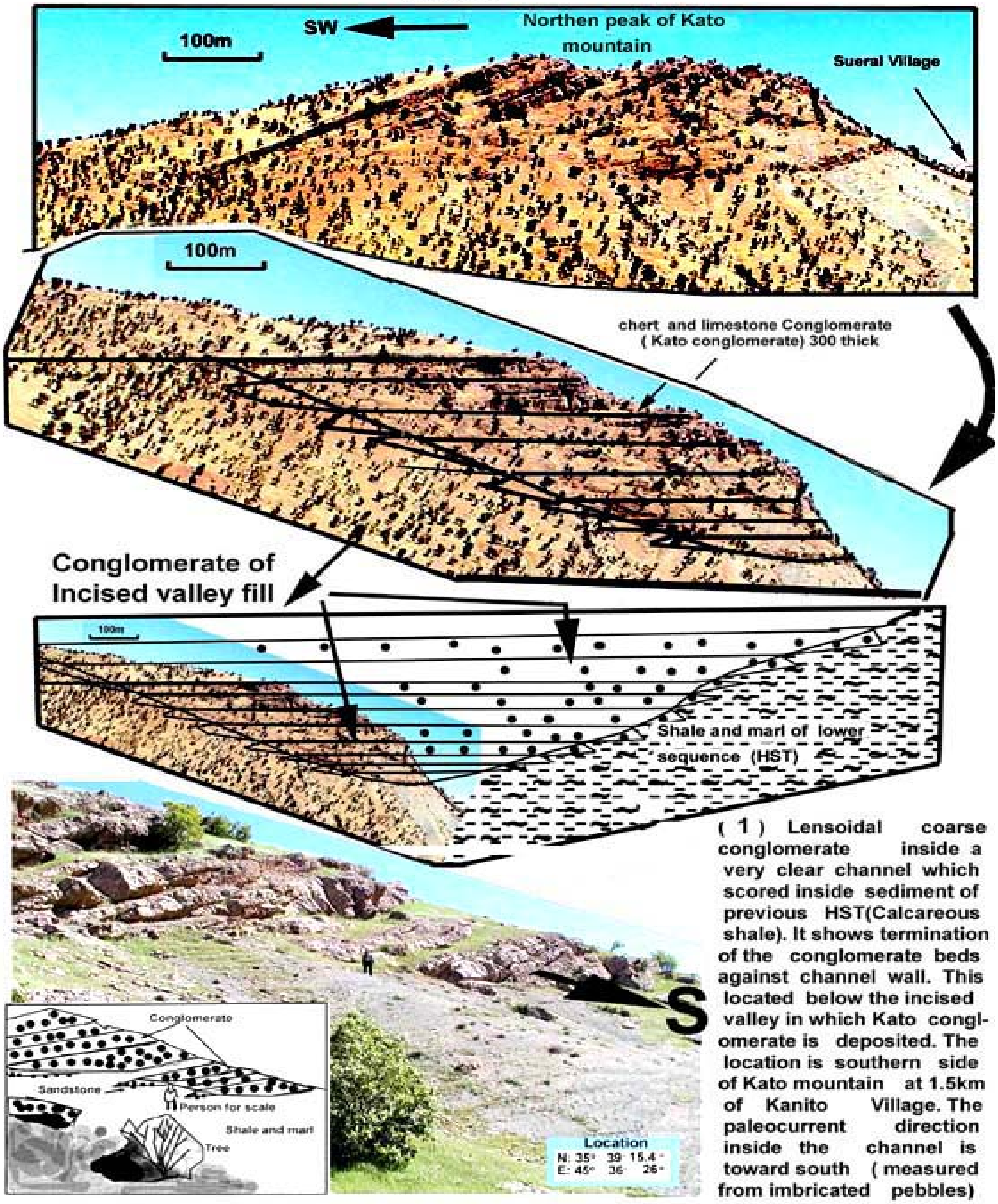
3. Above these two beds comes very clear lowstand wedge. The base of this wedge consists of 4-10m thick package of coarse and clean sandstone. This package is in most case associated with conglomerate. The position of this package between basin floor fan and lowstand wedge possibly comprises the slope fan (Plate 2.1). The beds of this fan contain such sedimentary structures that indicate the shallowest environment of the formation during deposition of the lower part (LST) of formation.

B. Low stand wedges

In contrast to lowstand fans, lowstand wedges are very clear as these wedges make up 70% of the whole succession of the lower part of the formation (Plate2.2 and 5.2). The typical lithology of Tanjero formation consists of these wedges and the slope fans. The wedge is conglomerate-rich in the proximal area, which is represented by 500m of Kato conglomerate. But they are sandstone-rich in the distal area (at Chaqchaq and Shadalla valleys and along foothill area of Azmir and Goizha mountains). The distal sandstone wedge is correlative to the Kato conglomerate.

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 Tanjero Formation) of braided stream. Therefore all thickness of Kato conglomerate (conglomerate wedge) and most

Plate 5.1



(1) Lensoidal coarse conglomerate inside a very clear channel which scored inside sediment of previous HST(Calcareous shale). It shows termination of the conglomerate beds against channel wall. This located below the incised valley in which Kato congl-omerate is deposited. The location is southern side of Kato mountain at 1.5km of Kanito Village. The paleocurrent direction inside the channel is toward south (measured from imbricated pebbles)

Plate (2) Upper photo shows cross section of tilted beds of Kato conglomerate directly to the west of Suerala Village, The conglomerate suposed to be deposited in an incised valley. The Middle photo shows the beds when the amount of tilt is corrected to the rigional postion of depostion. Lower photo and the sketch shows, the form right side of the valley (or canyon) is constructed on the basis of the pattern of the beds of the left side. The photo and the sketch shows only part of the valley.

of distal sandstone wedges are mainly deposited during late lowstand time when the sea level fall stabilized for considerable time and subsequent slow rise. The thickness and grain size of the wedges are depending on the distance from the shoreline and limit of downward shift of coastal onlap. The wedges show aggradations to progradation stacking patterns with nearly same thickness of the beds.

The most important characteristics of sandstone wedge are their abundant content of plant debris (Plate 3.5 and 3.6) on surface of sandstone beds. These plant fragments are derived from plants grown inside incised valleys and on the surface of alluvial fans sediment during middle Maastrichtian. They were then, eroded by severe current of sediment influx from hinterland by river. The incised valleys of the shelf and upper slope are flooded during early slow rise of sea level and during late lowstand forming some swamp and estuaries with possible plant growth.

5.4.3-Erosional surfaces and unconformities below and inside the wedges

As previously mentioned a major erosional surface (SB1) exists below the Kato conglomerate. This surface is formed after the exposure of the shelf (Mawat and Chuarta areas). During exposure the rejuvenation and incision of river occurred. The river erosion of the shelf and upper slope scored incised valleys. The erosional surface is coinciding with the valley floor.

This erosional surface, as an unconformity, changes to several unconformities toward south and southwest down dip. This occurred during gradual fall of sea level, overlain by more or less thick beds of conglomerate (Fig.5.4). The down dip extension of this surface, with associated conglomerate, reaches the middle part of Sharazoor and Piramagroon plains (to positions beyond Arbat and Piramagroon towns respectively). In literature similar type of unconformities are cited by Potter and Pettijohn (1977, p.295) in basin margins, they called them "compound unconformity". In some places of the plains, the surface becomes correlative conformity. These latter places are representing the area between the fans (Fig.2.3) where the conglomerate changes to sandstones.

The sandstones have coarse and clean texture with high thickness near the base of the wedge. Both thickness and grain size decrease downward and upward of the sections. Downward, the lithology changes to bluish marl of Shiranish Formation and to marl of Middle Part at the top of the wedges.

A. Incised valleys and their sediment fills

During sea level fall the shelf and upper slope of the Tanjero Formation is exposed to subaerial erosion and fluvial incision. This is initiated as the stream base level is lowered. At least, four incised valleys are indicated, each one associated with its prograding lowstand fan delta and different sediments (chert and limestone) of the valley fill. Three of them are discovered and mapped (depending on availability of outcrops) in the field from shoreline (proximal area) till the distal (basin) area.

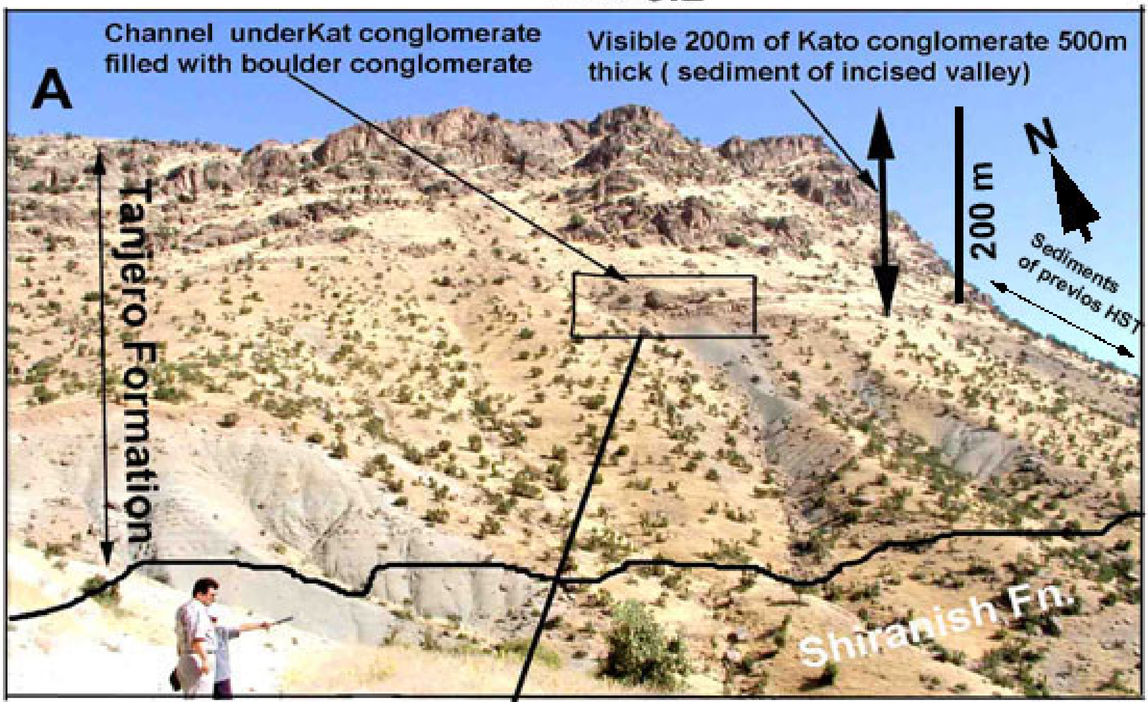
The characteristics of the three mapped valleys (Plate 2.5.2, 2.3.3 and 5.1) are used for inferring other one. This latter valley is deduced from the lithology of the formation in the basin-distal area at Sirwan valley. At this area the lithology and sedimentary structures are compared with the lithologies of mapped ones at the equivalent locations.

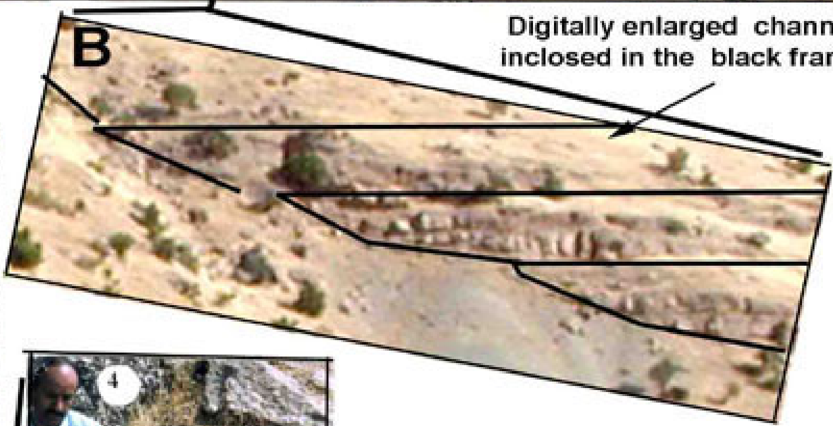
These valleys descend from north and northeast toward south and southwest. The first one, with the associated fan, starts from the area around Mawat area, passing by Qizlar Village at the head of Chaqchaq valley and end at the area around Tasluja Town in the Piramagroon plain. The second mapped one (starts from the east of Chuarta town and descends to the south and southeast and ends at the Sharazoor plain at the southwest of Arbat Town near Damirkan Village (6km southwest of the Town). The other one extend from Suwais Village to Dokan area. Many evidence exist that the fan associated with this valley has many lobes the largest one delivered thick alternation of conglomerate and sandstone beds to the north of Sulaimaniya city.

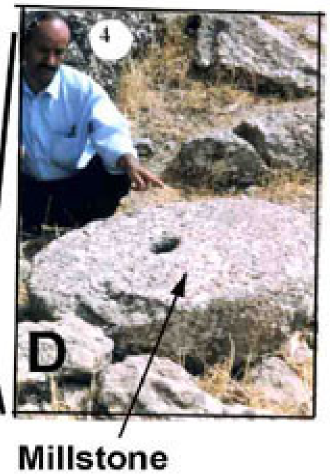
The width of these valleys is more than 2km and their lengths are more than 9 km. The sediments of these valleys filled; on the previous highstand shelf area, with 500m of Kato conglomerate and about 50 m of red layers (Plate 5.1 and 5.2). The thickness and grain size of this conglomerate changes rapidly and laterally in distance of one or few kilometers (Plate 2.5.2). In some cases the thickness change, along the depostional strike, from 500 to 10m in distance of two kilometers and grain size change to sandstone in the same distances. This sedimentological phenomena also observed by Karim (1997) in Gercus Formation in Sartaq-Bamo Area.

Nowday, the hard and well lithified conglomerate of these valley form high mountains such as Kato, Gaza and Talishk Mountains. These mountains are formed by reciprocal of topography. The conglomerate of Tanjero formation is deposited during late low stand system tract. In this connection Haq (1991) mentioned that during low stand system tract when the relative sea level begins to rise 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 Tanjero Formation). The evidence, which proves that Kato conglomerate is deposited subaerially in the proximal area, is that red layers overlie it. These layers represent deltaic deposits during TST. At Iranian section this conglomerate (13-150m thick) rest directly on Shiranish Formation. This condition is reflect the most landward occurrence of the incised valleys deposits where the conglomerate terminated (on-lapped) against the steep slope of the source area.

Plate 5.2







(1) The most powerful paleocurrent indicator is existance of a channel (B) under 200 m of conglom-erate(A) ateastern side of southern peak of Kato mountain.The imbricated pebbles inside thechannel indicate southern direction of paleocurrent.

(2) A cliff of Kato conglomerate (c) at southern side of northern peak. The conglomerate is used at past and now extensively for making millstone (D) for water mills in Sulaimaniya governorate. One can see tens of abandoned millstone in their quarries. The using of this conglomerate for millstone due to itshardness and toughness .

The shape of the valleys and their sediment fills can be reconstructed from some outcrop sections exist in the studied area. One of these sections (Plate 5.1.1) can be seen at the northern part of Kato Mountain directly west of Suerala village. This section is scored by recent stream perpendicularly on the elongation of Kato conglomerate. The section shows thick beds of the conglomerate, which are tilted at about 35 degrees toward southwest. When one correct the tilting and return the beds to original depositional situation, the form of the valley can be understood clearly which has obtuse v-shaped form (Plate 5.1.2). This latter photo or plate shows only part of the valley, which is not more than 1km wide. The obtuse shape of the valley is most possibly attributed to the fact that the incised valleys were scoured in soft sediments (partially lithified calcareous shale and marl of the HST deposits of lower sequence). The thickest and thinnest parts of the conglomerates exists at center and side of valley respectively (Plate 2.5.2). Although the original outlook of the conglomerate layers in the incised valleys are tilted and mostly eroded but the form and wideness of one valley is reconstructed in the plate. In the field the bottom of the valleys (as shown by sediments fills) is convex downward and planner at the top (Plate 5.1.2). The precise position of the Kato and Tagaran conglomerates is shown in sequence stratigraphic model. In the model, the system tracts are illustrated by the wheeler diagram (time expanded section) and depth section. These sections are so drawn to pass through the incised valleys (Fig.5.3).

According to Emery and Myers, (1996, p.140) as a result of river rejuvenation; incised valley commonly contains the coarsest sediment available locally. They added (p. 137) if the new river coarse is steeper than equilibrium river profile, the river would firstly straighten coarse 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 hydrocarbon

B. Possible incised canyon

According to Bate and Jackson (1980) a canyon is defined as erosional geomorphologic features, which are long, deep, relatively narrow steep-sided valley confined between high and nearly vertical walls in mountainous area, often with a stream at the bottom. According to Emery and Myers (1996, p.140) the thickness of incised valley fill cannot exceed 100m but submarine canyon can exceed this thickness. In the studied area, there are many places (at proximal area); the thickness of the Kato conglomerate reach 500m. But the sides of the valleys are not steep. These suppose that these locations (Kato mountain and south and west of Mawat town) are position of Upper Cretaceous canyons that developed by subaerial and possibly by submarine erosion. These canyons are most possibly located on the previous lower shelf and upper slope.

Field studies showed that the floor of the canyons (base of Kato conglomerate) is resting sharply on the alternation of calcareous shale and sandstone of HST of the previous shelf (Plate 5.2) and (Fig 2.1). The scouring of the deep canyon is attributed to the softness of the lithology on which the regression (sea level fall) occurred on the previous HST. This softness is resulted from the lapse of short time between previous HST and the new LST that caused rejuvenation of the stream and canyon formation.

C. Channels and their sediment fills

In the definition of canyons, it was mentioned that there is a stream on the bottom. This is also true for the incised valleys. Lots of evidence has been observed in the field, which show channels on the floor of the incised valleys:

At southeastern side of Kato mountain very clear channel is exposed under the Kato Conglomerate. It is filled with about 20m wide coarse conglomerates and located inside the calcareous shale of sediment of HST of the lower sequence (Plate 5.1 and 5.2). The layers of the conglomerate pinch out rapidly against the channel wall and in some cases change to sandstone on the paleo flood plain. The pinching out give the conglomerate lensoidal form.

The channel shows at least two stages of incision at different levels. The lower level is narrower than the upper one; they represent the depth reached by the stream during consecutive during falling by coarse sediment in late lowstand system tract when the sea level gradually rises. The streams were, most possibly, of braided type by which the thick pile of Kato conglomerate is laid down during late LST.

D. Sediment of the incised valleys during TST

At southwestern side of Kato Mountain there are abnormal occurrence of 50m of red layers (red beds), which are composed of red claystones and sandstone with intercalation of some thin bed of conglomerate (Plate 5.3.5 and fig.5.3). The author called these layers "Kato Red Layers" (see section 1.3C). Kato conglomerate underlies these layers and rudist-bearing limestone of upper part (Kato mixed carbonate-siliciclastic succession which previously called Aqra lens) overlies these layers. This latter succession is composed of more than 10 fossiliferous layers alternate with calcareous shale and marls (Plate 5.3.4). The thickness reaches, in some place, more than 200m.

These red layers are also present at the area south of Mawat town near Qashan Bridge and directly east of Yalanqoz village (N: 35^{o} 51^{-} $24^{=}$, E: 45^{o} 24^{-} $29.3^{=}$), which reach only 20 m in thickness. These exist in the proximal area (near source area) while they are not observed in the distal area. Their equivalent lithology in the latter area is marl on the slope and calcareous shale one shelf area. The red layers and their equivalent represent the sediment of transgressive system tract (TST), which are deposited during the valleys flooding. When one observes closely these beds, one cannot distinguish them from the famous Red Bed Series. It can be differentiated by stratigraphic position, which is located between lower and upper parts of the formation (between Kato conglomerate and Kato mixed carbonate-siliciclastic succession).

These red layers have very great importance in the study of Tanjero Formation because one can make ultimate decision that the Kato Conglomerate was representing continental or coastal area deposits and not deep deposits. This is because the cooked samples of these layers yield no planktonic forams. During the late LST the Kato Conglomerate (those exist only in proximal area which have high thickness) is deposited after that during rapid flooding of early TST, the deposition of the conglomerate sequestered and red claystone is deposited instead.

5.5-Transgressive system tract

The deposit of the transgressive system tract is very clear which is overlying directly the low stand system tract (lowstand sandstone wedge and Kato conglomerate) of the formation. This deposit consists of bluish marl in the Sulaimaniya, Sharazoor and Piramagroon areas, whereas in Chuarta and Mawat area it consists of thick succession of dark green calcareous shale with some marls which change to red layers (see section) at south of Yallanqoz village and southern side of Kato mountain inside incised valleys. At Sirwan valley the lithology of HST is nearly the same as Chuarta with some sandstone layers and rare conglomerate intercalation, while in Dokan area it is relatively thin (no more than 130 meters).

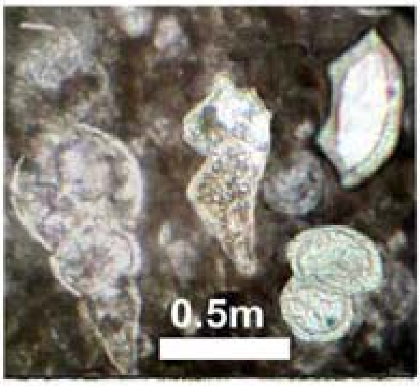
During deposition of this system, Tanjero environment has suffered sudden deepening demonstrated in the field by sudden vertical change of sandstone of LST to hemipelagic marls, while at Kato Mountain, the conglomerate, it changes with the same manner to Red claystone. Because of deepening, this system tract has no sedimentary structures and fossils found in the lower LST and upper HST. They contain only Upper Cretaceous planktonic forams.

5.6-Highstand-system tract

In Tanjero Formation, this system tract consists of mixed siliciclastic-carbonate succession. This succession is more than 150m thick in some places and consisting of alternation of thick beds of biogenic limestone and calcareous shale on the shelf (Chuarta area). The biogenic limestone laterally changes, in most cases, to sandy limestone or calcarenite (detrital limestone). Fossils of rudists, belemnites, and gastropods (or their bioclast) are densely concentrated in some beds of biogenic limestone (Plate 5.4 and 5.5). Other beds contain pelecypods, large forams (*Discocyclina, Loftusia, Amphalocyclus*), echinoderm and pelecypods or

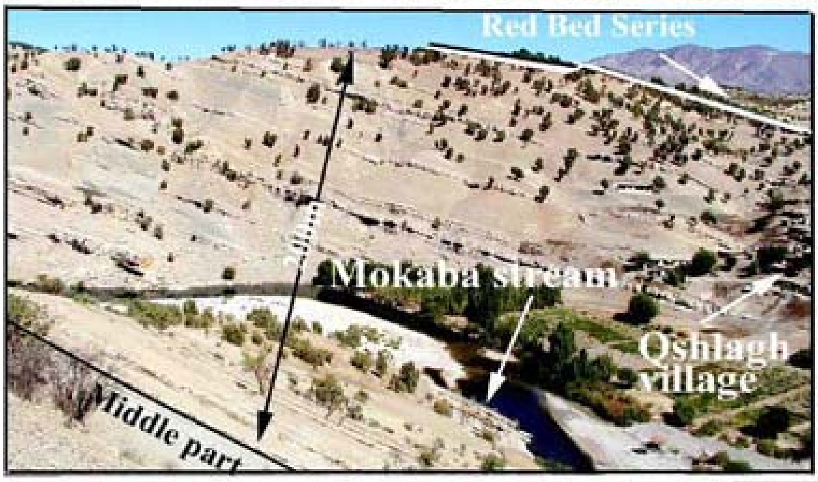
Plate 5.3

(1) This 1.5 m thick white and fine grain limestone is most well developed condensed-like section in the middle part of Tanjero Formation. It is expoed on the left bank of Ballakian stream between Diana and Mergasur at N; 36° 47' 56.2", E: 44° 22' 55.1"

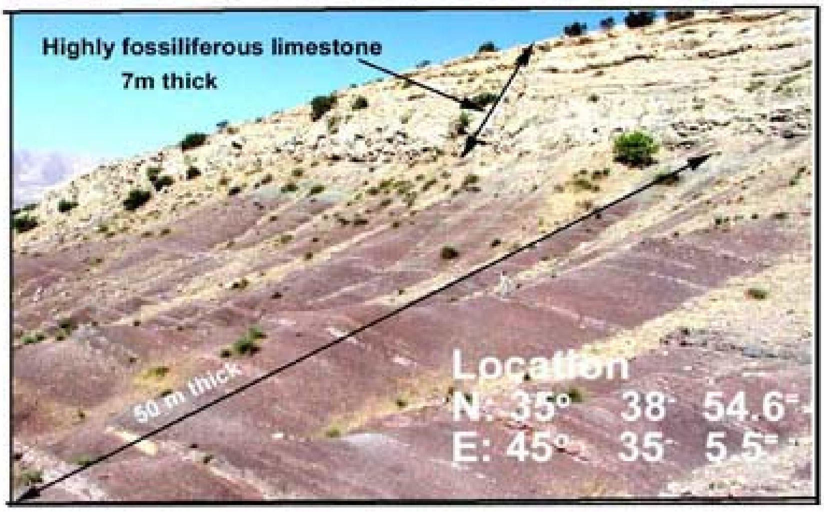


(2) The same bed (most possibly) the western end of Naudasht valley inside Razhwan village. At this locality it changes to marly limestone about 3.5m thick This bed and the above one are representing the deposits of maxium flooding of the sea at the end of TST when the clastic influx is stopped.

(3)Different genus of planktonic forams found in the above limestone. S.No. 95



(4) This alternation of carbonate and clastic (calcareous shale) is called Kato mixed carbonate-siliciclastic succession which exposed along right bank of Mokaba stream at 2km east of Mokaba village. The succession is deposited during HST directly below Red Bed Series. The limestone beds contain different assemblages of Large fossils (rudist, large forams, pelecypods, echinoderm and gastropods. previosly called Aqra lense.



(5) These succession of red layers (similar to Red Bed Series lithologically) but stratigraphically located between the Aqra lense (Mokaba succession) and Kato conglomerate. The lhighly fossiliferous limestone at 5he top(8m) Thick is represent more or less condensed- like section or equvelent to condensed section. This layer are called Kato Red Layers which represent the TST sediment of incised valley fills overlying sediment late LST of Kato onglomerate (their bioclast). In many places the calcarenite beds are cross-bedded and burrowed by *Planolite* and Cruziana trace fossils.

The repetition of these beds suggests aggradation parasequence (Plate 5.3.4). Above the mixed carbonate-siliciclastic parasequence come another parasequence, which consist of alternation of calcareous shale, sandstone and conglomerate (of Tagaran type). This pure clastic parasequence grades vertically into Red Bed Series. This parasequence does not exist in all places such as near Mokaba village where the biogenic limestone grade in to Red Bed Series). So the contact of the Red Bed Series and Tanjero Formation (including Aqra Lentile) is gradational in some place and unconformable in others. The unconformable contact is very clear near Zarda Bee village and at Barda Qal and Siramerg valleys.

The explanation of Haq (1991, p.22) can be accepted for alternation of biogenic carbonate and calcareous shale in Tanjero basin. He mentioned that during lowstand, siliciclastic is deposited while in highstand carbonate is deposited. This is true when each thick couplet of carbonate – shale is regarded as minor forth or fifth order cycles which suffered from the high and low stand (Fig.5.1). The field evidence in Chuarta agreed with that mentioned by Haq (op.cit) that in such successions limestones are mostly deposited in the early high stand when the accommodation on the shelf is plentiful, while during the late high stand, in Chuarta area, shale, sand and conglomerate are deposited when accommodation decreases and shore line prograde basinward as can be seen near Zarda Bee village.

5.4.6-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).

Only few of these characteristics fit some beds within Tanjero Formation, so no typical condensed sections are found. This may be returned to high sedimentation rate of formation in the relatively active foreland basin and to shallower water than Shiranish Formation. This latter formation contains at least one typical condensed section, which is located at the top (in Dokan area) of the formation in the middle of the formation (in Chuarta area). But, in the Tanjero Formation, the beds resembling or related to condensed section are as following:

A. In the proximal area (coastal area during LST) directly above Kato Red Layers, comes a bed of shelf biogenic limestone (7m thick) (Plate 5.3.5). The position of this bed is directly above TST can be confidently regarded as a kind of condensed section or proximal equivalent deposit of a

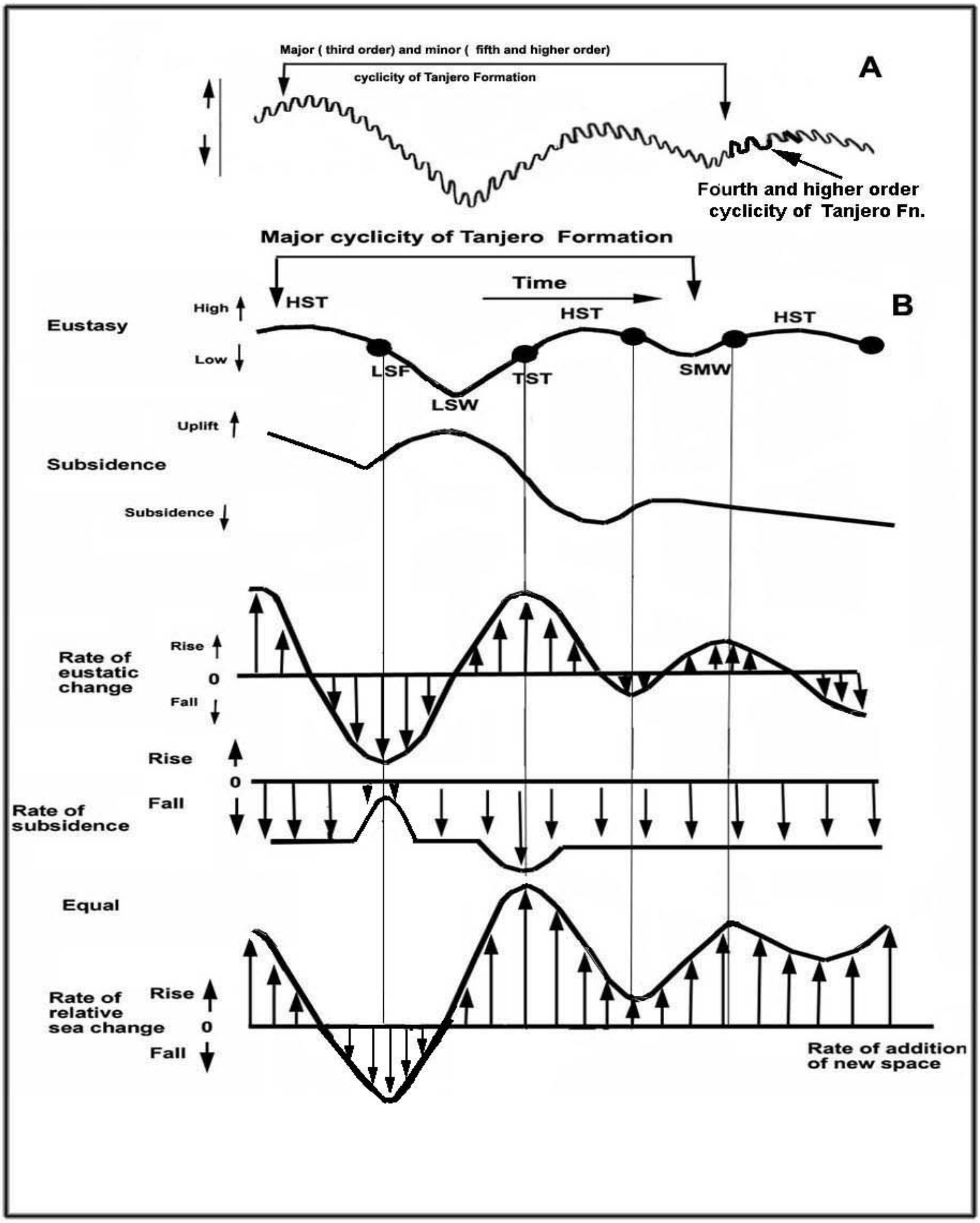


Fig. (5.1) Relative sea level change as function of eustatic change (A, fourth order and fifth order and higher. B, third order) and tectonic subsidence. The curves are deduced from the stacking pattern (system tracts) of different parts of Tanjero Formation.

condensed section. It is deposited during maximum flooding of the sea (maximum landward extend of marine condition of Tanjero Formation) when the basin starved as concerned to terrigenous clastic influx from source area. This bed consists of several horizons of limestones rich in Upper Cretaceous fossils (Plate 5.5) with or without their bioclasts.

B. On the shelf (toe of northeastern limb of Azmir, Goizha anticlines) very thick TST calcareous shale is capped by biogenic limestone (0.3 – 2m). The fossils content shows densely populated by diverse organisms such as elongate rudist (Plate 5.4.1 and 5.4.2), belemnite and gastropod this assemblage laterally changes to other ones such as: pelecypods (*Gryphaea*), large forams, and echinoderm, large ammonite (Plate 5.5.1) in other places changes to bioclast of these organisms. This type of bed is not unique but repeat several times upward in the HST.

C. The most well developed condensed section-like bed is a fine grain gray (white weathering) limestone occur nearly at the middle of the formation at west of Diana town on the left bank of Balakian stream (GPS reading: N: 36^{o} 47^{-} $56.2^{=}$, E: 44^{o} 22^{-} $55.1^{=}$) . This bed is 1.5 m thick and lithologically very similar to Kometan Formation both in color and lithology as it contains Upper Cretaceous planktonic forams (Plate 5.3.1 and 5.3.3).

D. In the Piramagroon and Sharazoor plain in addition to Dokan area, there are many thin beds and lamina of marly limestone in the middle part (TST). These may be regarded as relatively a kind of condensed section that represents time of non-deposition.

5.8-Shelf margin system tract (SMST) and type two-sequence boundary (SB2)

As mentioned above an alternation of dark color conglomerate (Tagaran type) and shale (with or without sandstone) exist, in some places, at the top of Kato mixed carbonate – siliciclastic succession. The thickness of this succession is about 50m near Tagaran and Zarda Bee villages. In the other area (with same tectonic setting) such as area around Mokaba, Homarakh, Konamassi and Harmin villages these conglomerates are not present. But the succession goes more or less gradationally to Red Bed Series. This type of contact and lithologic change is evidence of shelf margin system tract at the end of basin fill of Tanjero Formation and the underlying surface is type two-sequence boundary. This SB2 may be changed to SB1 in other area such as toe of Qandil Mountain at the north of Kometan village (Plate 2.3.1 and 2.3. 2). This lateral change of sequence boundary and system tract type may be returned to high tectonic of the source area and part of the basin.

Emery and Myers (1996) mentioned that SB2 and overly shelf margin system tract might be very difficult to recognize in outcrops. They added that could be differentiated from underlying HST by subtle (minor) unconformity.

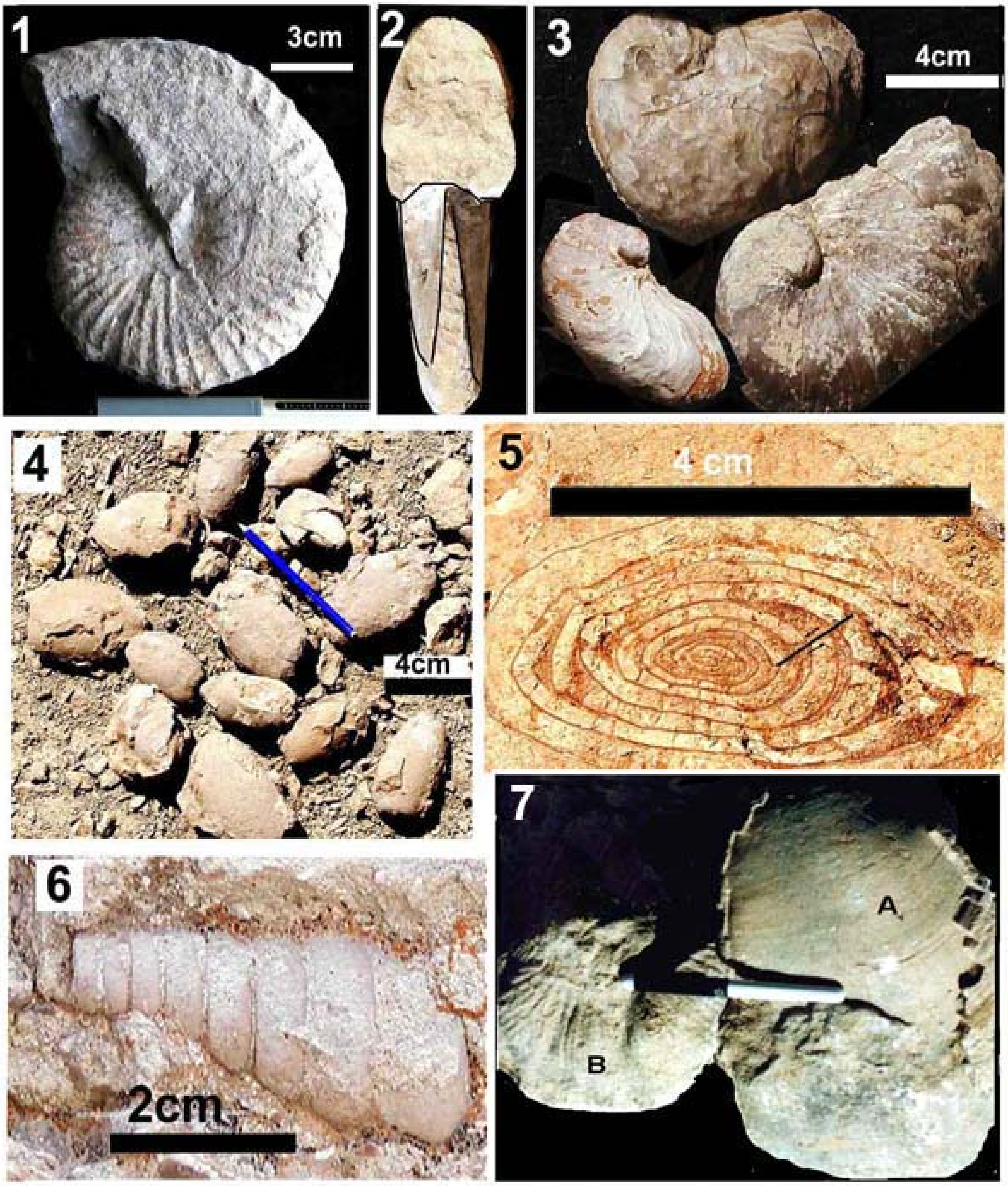
Plate 5.4

(1) Elongate and cylinrical rudist, form a bed 1.2m thick at upper part of Tanjero Formation at Azmira Bichkolla valley, Chuarta area. At the lower left, its cross section is shown. The bed which is contained this type of fossils located directly above the calcareous shale of the Middle part.

(2)Parallel arrangment of broken rudist fossils in the same bed mentioned above, they either brocken by current or by load pressure of the overlying strata. Beds, like this are alternating with typical lithology (s.st, marl) of Tanjero Formation. This type of fossil and alternation proves that upper part of Tanjero formation has shallow environment. The pencil is 14cm long.

(3) The only fossil mold found in the lower part of the formation is this pelecypod, found in the coarse sandstone near Qizlar Village, Gawra hill. This organism is probably responsible for most relatively large vertical and horizontal trace fossils. The scarcity of this fossils is due to its aragonitic shell which dissolves easily in permeable sandstone.The needle is 2.5cm long.

Plate 5.5



Different fossils genera in upper part (mixed carbonate- siliciclastic succession) of Tanjero Formation. Only the photo No. 7 is belong to middle part. 1) Large Ammonite, upper part, Barda Qal Valley, Chuarta. 2) The front view of the same Ammonite. 3) Oysters (***Exogyrea*** **). 4) Gasropod (** ***Actenonella*** **) with its cross section(5) southwestern side of Kato Mountain**

6) Gastropod (***Turritella*****) at same locality of sample (4).**

7) Large rudist body fossil, the main shell (A) is about 30cm high 15 wide while the cap (B) is smaller, Southwestern side Kato mountain .

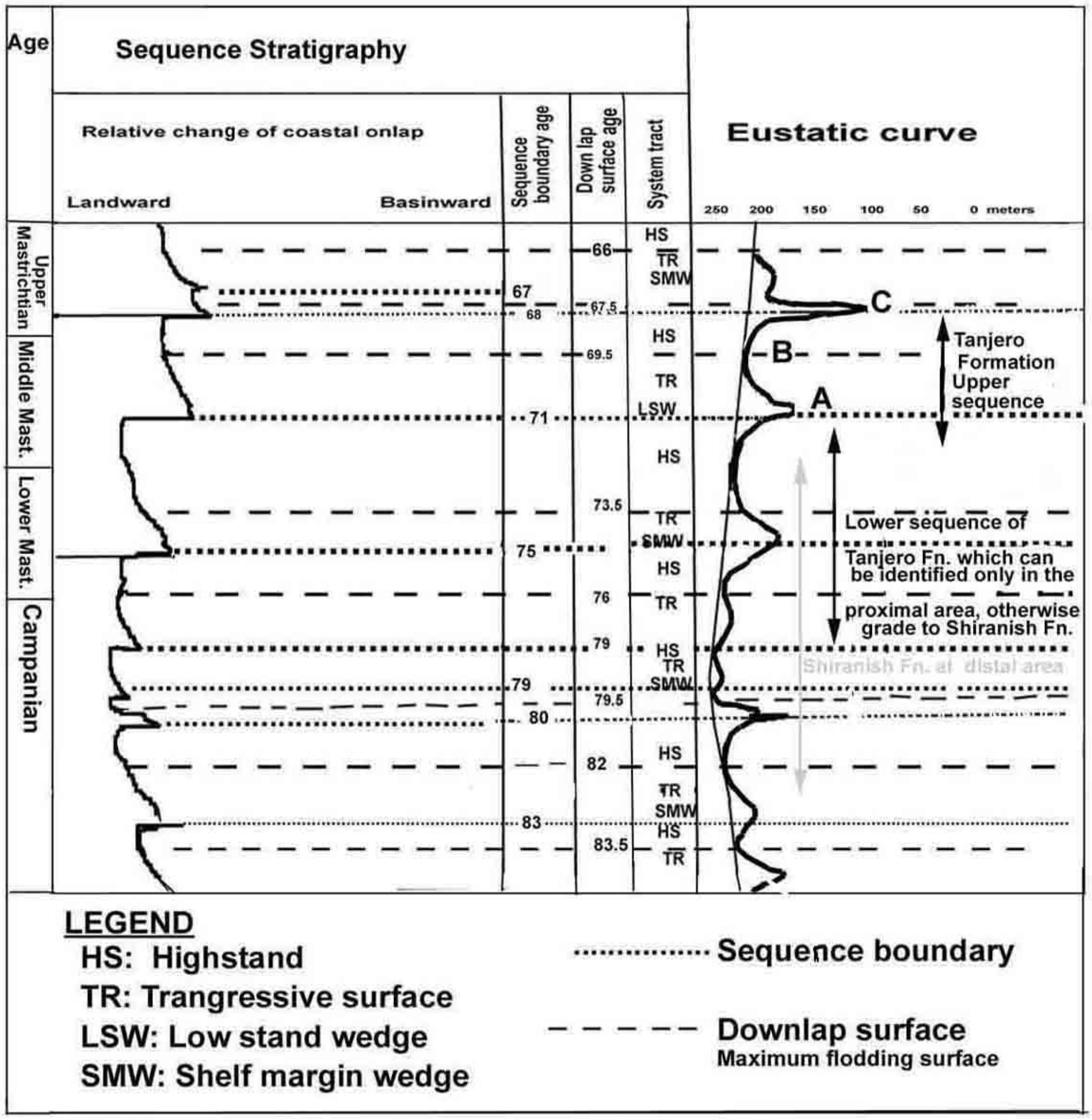
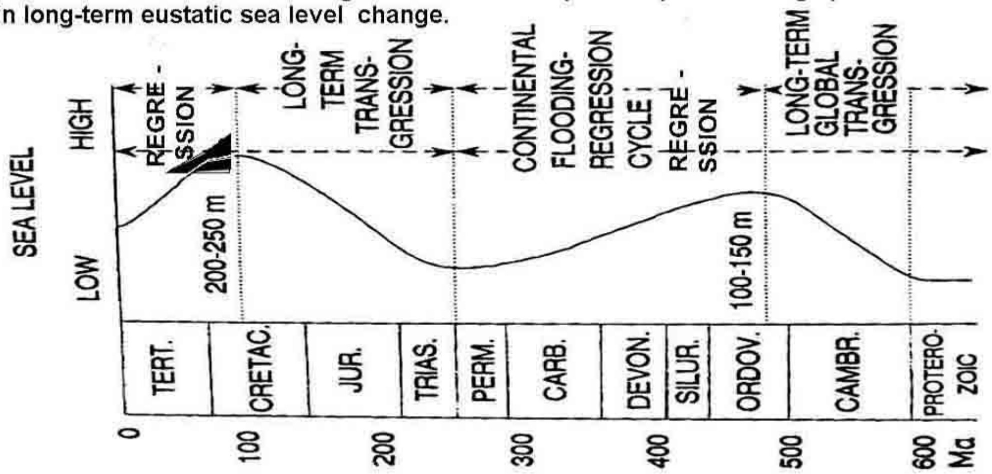


Fig. (5.2) Eustaic sea level and coastal onlap changes of Upper Cretaceous (modified from Haq *et al.* (1987). If the age of Tanjero Fn. is Midlle and Upper Maastrichtian(Abdul-Kareem 1986), the position of the system tract can be A, B, and C, for low, transgressive and high stand system tracts respectively. These system tracts are deposited during upper sequence which some of them enhanced by tectonics uplift and subsidence. These system tract are coinciding with lower , middle and upper parts. The diagram below shows postion (black traingle) of both sequences within long-term eustatic sea level change.



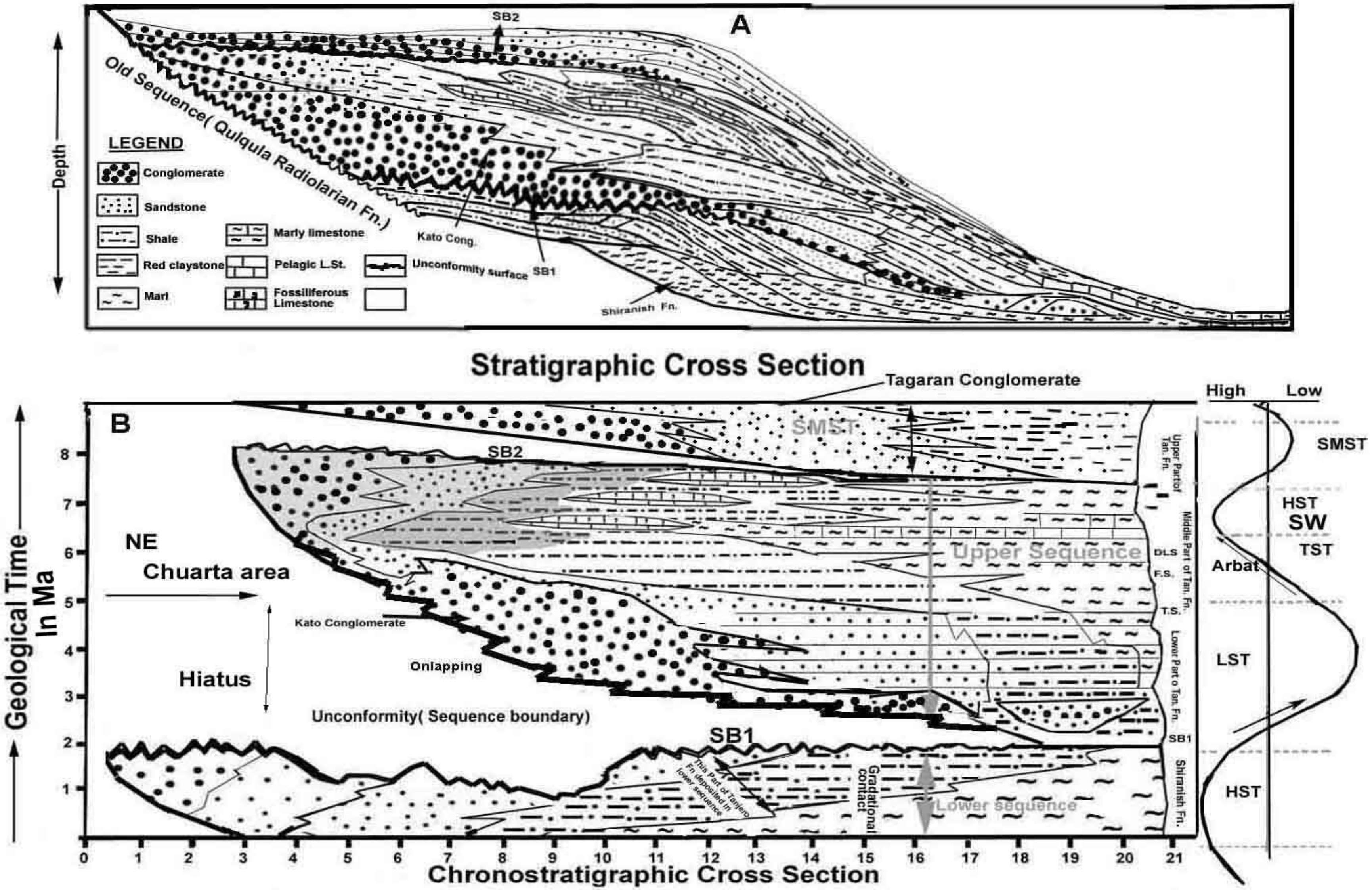


Fig. (5.3) Sequence stratigraphic depositional model showing depostional system tracts (in depth (A) and geologic time (B))
Both models are drawn according to accurate field works and applicable for the areas of incised valleys with the associated fans
The model is mainly fit the active foreland basin with tectonic uplift. The models are extending from Chuart to south of Arbat

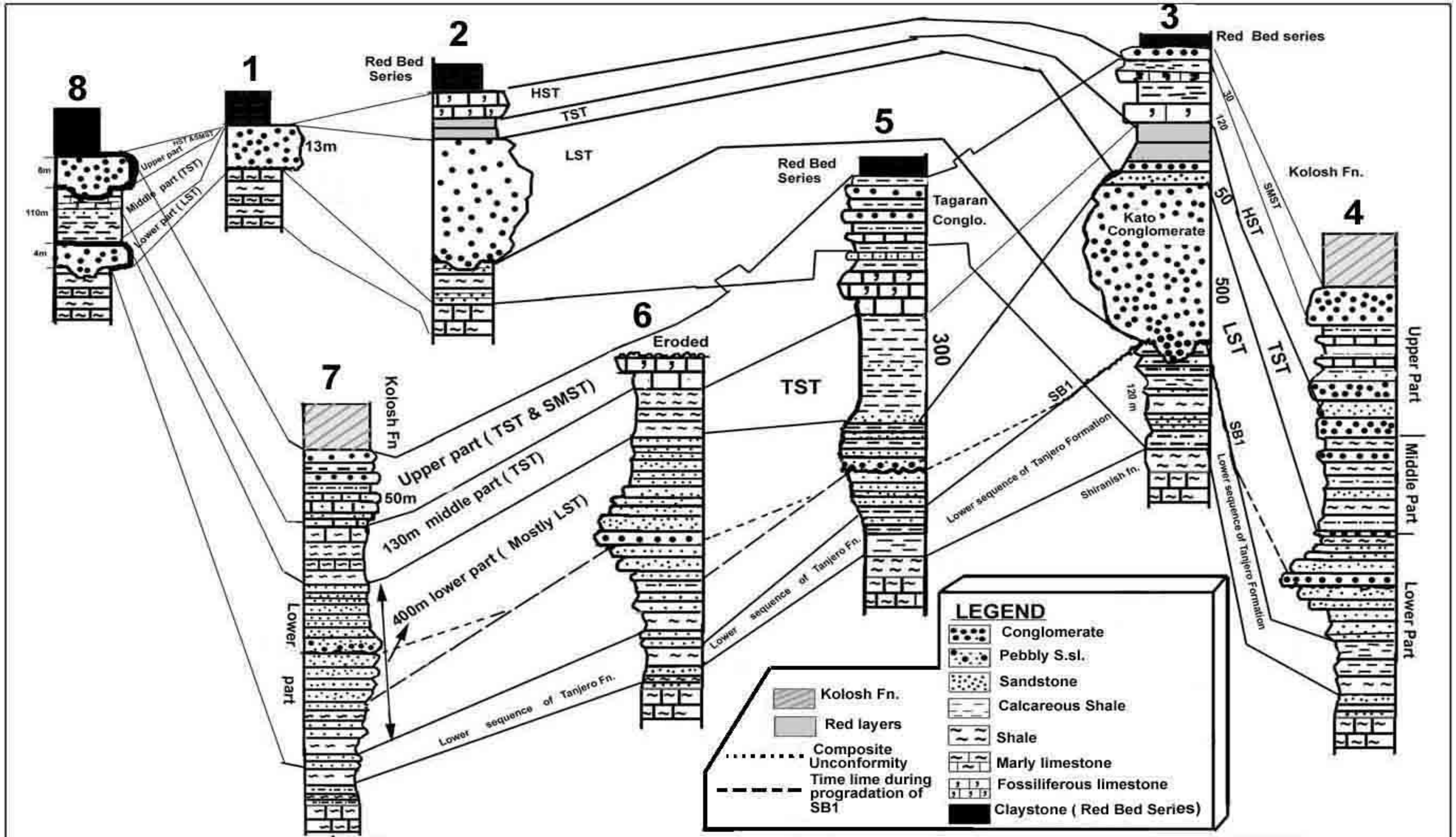


Fig. (5.4) Correlation between sections of Tanjero Formation at different areas showing system tracts based on the Kato conglomerate postion and their equivalents . 1) Iran section, 2) Qashan section, 3) Kato section, 4) Sirwan section, 5) Tagaran section, 6) Malkandi section, 7) Dokan section, 8) Kometan village section(Qandil Mountain toe)

CHAPTER SIX:

TECTONIC AND DEPOSITIONAL HISTORY OF THE TANJERO BASIN

One can infer from the facies distribution maps given by Buday, (1980) that the basins paleogeographic slope direction (depositional dip) was toward northeast during Lower Cretaceous till Middle Turonian. During later ages (Coniacian and Santonian) the general basin paleoslope direction was reversed 180 degree toward southwest during Upper Cretaceous. This reversal is associated with colliding of continental parts of Arabian and Iranian Plate after deposition of Qamchuqa and Balambo Formation in the studied area. This colliding occurred after the oceanic crust is exhausted and then the two related continents are collided. Before the studied area was passive continental margin (carbonate platform) and bordered from the north by subduction trench (active continental margin). The collision finally changed the subduction to positive land and studied area to foreland basin (Fig 6.3 and 6.5). According to (Karim, 2003a), during this processes, the previously deposited Qulqula Formation compressed, as accretionary prism, between two plates and uplifted forming positive land and source area.

According to Buday (1980, p.402) the miogeosyncline was separated from unstable shelf by a ridge. He mentioned that the continuation of this ridge is not clear enough in the area southeast of Ranyia Town (the studied area). In the present study, the absence of this ridge is proved in the area of Sulaimaniya Governorate. It is observed that the present position of Azmir, Goizha, Piramagroon (Fig.6.1), Sara, Qarasard and Kosrat anticlines (Fig.1.2 and 1.3) was part of the slope of the Tanjero basin, while the present position of Haibat Sultan, Tasluja and Baranan homocline most possibly comprised part of the basin plain of the formation. The deposition, bypassing and erosion of sediment occurred extensively during deposition of Tanjero Formation on the position of former anticlines(Azmir, Goizha…). So there were not any major irregularities (submerged paleohigh or geoflexture) in the basin of Tanjero Formation, in the studied area, during deposition. The possible tectonic are observed activities as following:

1. At the beginning of the lower sequence (proved to include Kometan, Shiranish and part of Tanjero Formation (see fig.2.1 and 2.2) the studied area suffered from clear deepening which is demonstrated by deposition of deep pelagic Kometan Formation over shallow marine reefal Qamchuqa Formation LST sediments. This transgression may be reflection of prominent subsidence due to tectonic loading of the existed platform. The over loading is happened by

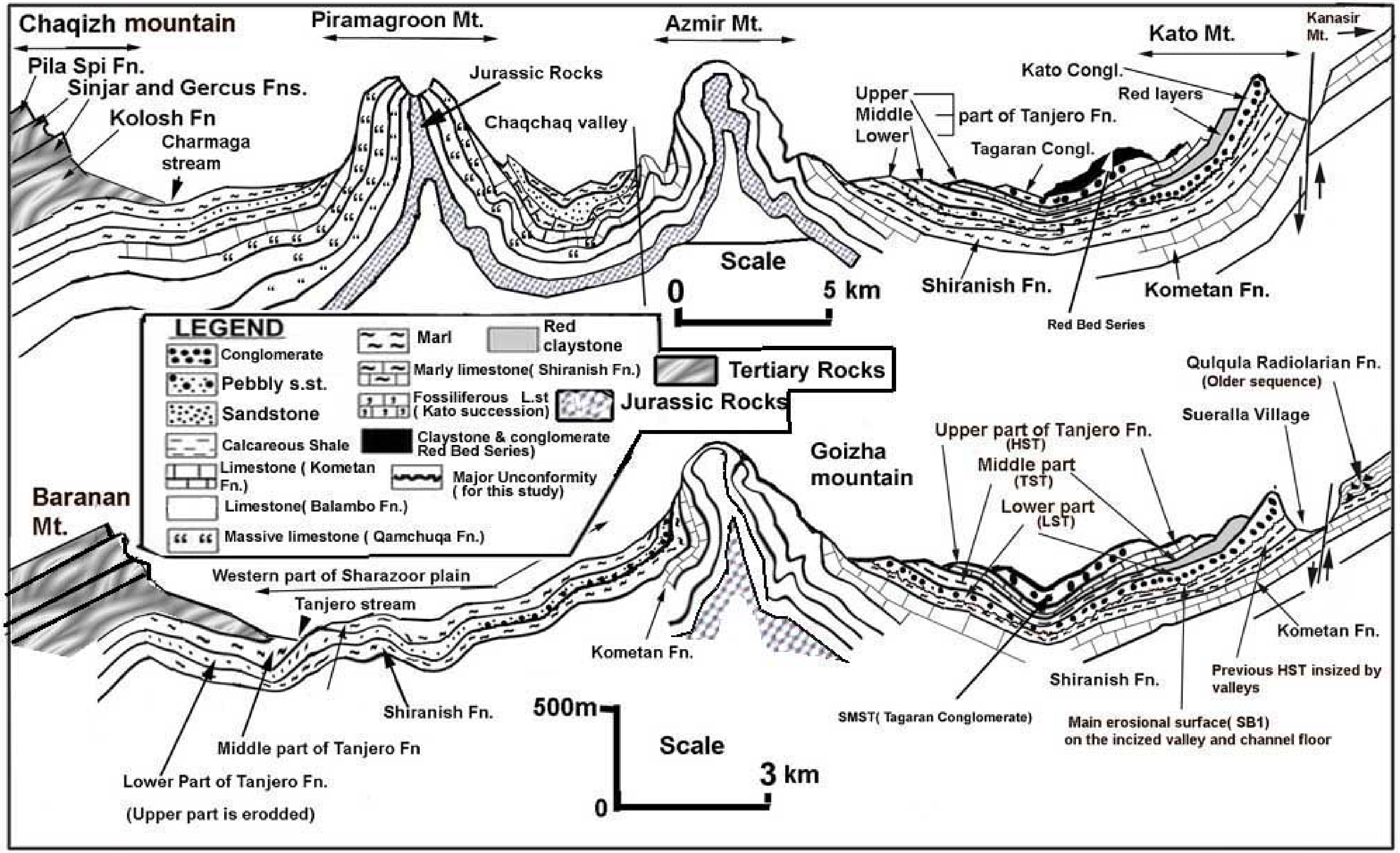


Fig. (6.1) Two cross sections connecting Kato mountain to the Chaqizh mountain (upper one) and Baranan Mountain. The first one passing through the axis of main fans while the scond one passing through one of the interfan lobes of Upper Cretaceous. The figure shows the new divisson, sequence stratigraphy of this study and ultimate deformation.

colliding of Iranian and Arabian plate by which the former thrusted over the latter and advanced toward position of the Tanjero basin. The thrusting uplifted the area, which is located to the north and northeast of the studied area (source area). This is probably started from Campanian and continues till the beginning of Tertiary and forming active continental margin. Uplifting created a southwest advancing positive tectonic front (frontal part of Iranian plate). The continuous erosion of this front shed large quantity of clastic sediment into the Tanjero basin. It is possible that later in the early Tertiary, the position of the slope was acted as geoflexture for the existing present anticlines.

2. The sequence stratigraphy proved that the facies of the Tanjero Formation have migrated to south and southwest in such way that the position of the shelf, slope and basin is changed during lower and upper sequence mostly by forced regression. This regression is due to eustatic sea level change with the aid of tectonic uplift of source area and possibly the basin.

3. The high thickness and coarseness of the Kato conglomerate is evidence for above-mentioned facts. The high tectonic and elevated source area is opposed in the basin by slight subsidence and general gradual shallowing, which is in some time intervals, demonstrated by incised valleys. In some cases, they have scoured the shelf down into the Shiranish Formation such as the Iran and Qandil sections (Fig.6.1and Plate 2.5). At Iranian section the thickness of formation consists only of Kato conglomerate, and typical lithology of Tanjero Formation is absent.

6.1-Previous Ideas About Tectonic of the basin

Previous worker have published the following ideas on tectonic of Tanjero Formation:

6.1.1- Miogeosyncline idea

According to these ideas, the formation is deposited in miogeosyncline realm (deep marine trough) in which flysch sediments are deposited by turbidity currents (Buday, 1980; Buday and Jassim 1987, Kettaneh and Sadik, 1989 and Lawa *et al*., 1998).

6.1. 2- Tanjero Formation: Two tectonically separate parts

Depending on grain size and thickness, Buday (1980) separated the lower and upper parts of Bellen *et al.* (1959) into two tectonically separate parts. He regarded the upper part as typical orogenic flysch and the lower part as normal open marine with sporadic influx of silty terrigenous clastic.

But, in the present study, both parts are included in a single basin and formed by same tectonics. The only difference between both is the closeness of one part to source area (or more shallowness) than the other part. The separation of formation into two different parts, on the basis of lithology and in single section, is not true. This is because the fine and coarse clastics of Tanjero Formation, as proved in this study, are changing position down paleoslope and in some cases along the depostional strike of the basin. This is attributed to facies dislocation (facies migration) (Fig.6.3). The types of lithology, in the Tanjero basin, depend on the position of incised valleys and associated lowstand fans. So the extension of a certain basin cannot be indicated by single or set of lithologies but they must be indicated by all possible lithological changes associated with all environments and sedimentological processes in certain basins. Even the basin in which Aqra-Bekhme is deposited cannot be separated from the basin of Tanjero-Shiranish basin because aggradation of reefal limestone of Aqra-Bekhme Formation can be seen which is similar to the aggradational wedge of sandstone (LST wedge) in the Tanjero formation.

6.1. 3- Pre-collision set-up idea

Jaza (992) put the Tanjero Formation in a subduction trench between Iranian and Arabian plate. On the same principle Numan (1997) put Tanjero basin between the two plates before collision of the continental crusts. In his model (pre-collision set-up of Iraqi plate tectonics), he indicated Tanjero basin on a NE sloping passive margin, which is separated from the shelf by a depositional ridge on which Aqra-Bekhme Formation is deposited (Fig.6.2 A and 6.3).

6.1.4-Shiranish and Tanjero Formations: Two tectonically different basins

When one reads about sedimentology and basin model of the two formations in previous studies the authors have separated them into two different facies (flysch and non- flysch facies) and two different basins (active and non-active). Even the source area of the two formations is separated. Bellen et al. (1959) and Buday, (1980), Kettaneh and Sadik, (1989), mentioned these ideas directly or indirectly.

But in the present study, both formations are considered as lateral and vertical facies change of each other and the differences between the two formations are only attributed to nearness to the shore and source rocks not to tectonism. Now these types of facies can be clearly explained by relative sea level change in sequence stratigraphy. In the present study both Shiranish (or Shiranish-like lithology) and Tanjero Formation are combined in single depostional sequence and even in single system tract (when distal and proximal lithologies of HST and TST is considered). In all ancient and recent basins, it is normal to see the near shore (proximal area) to has more uplifting and sedimentological activities than the central part of the basin. This fact is interpreted previously, as regarded to Tanjero Formation, deposited during abnormal tectonic activity.

6.1.5-Tanjero Formation: Transgressive sediment

Previously Tanjero Formation was considered as transgressive sediments Buday (1980,p.402) and Minas (1997). Other authors mentioned intense subsidence of the Upper Cretaceous basin (Marouf, 1999).

But in the present study it is proved that nearly all the typical lithology of the formation is deposited during major forced regression (LST), which is discussed in detail (see chapter five).

6.2-Present ideas

The following ideas of the present study is based depend on fieldwork, recent new sedimentological and stratigraphical principles, in addition to regional geology of the Middle East.

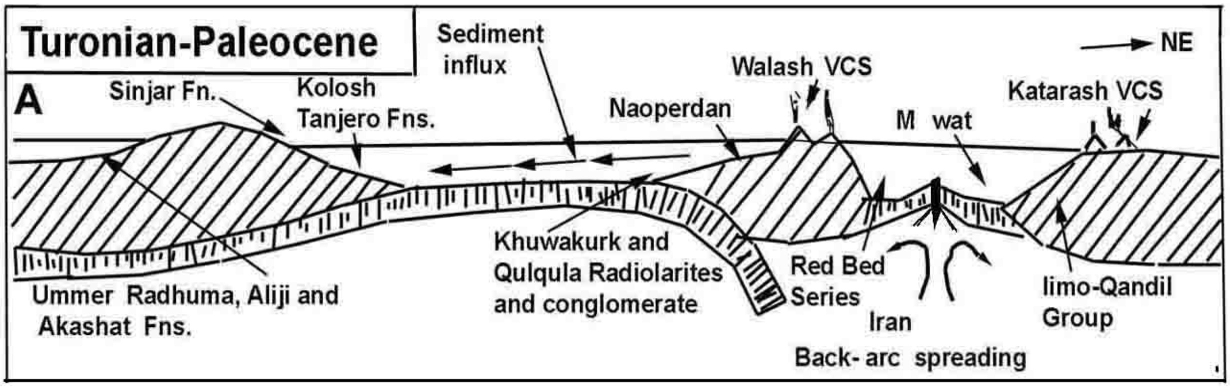
6.2.1-Shiranish and Tanjero Formations: same tectonic setting

While the tectonic of Tanjero Formation is exaggerated in the above-published ideas, nothing is mentioned about tectonic of Shiranish Formation. In the present study, Tanjero Formation is neither sedimentologically nor tectonically separated from basin of Shiranish Formation. Also the unstable shelf and previous miogeosyncline is united in single basin named Upper Cretaceous Early Foreland Basin, all these are deduced from the following:

1. The contact between the two formations is gradational and they laterally interfingering Bellen et al. (1959) and Buday, 1980). This was also observed in the field by the present author. The same above authors mentioned that Shiranish basin extends to unstable shelf (to near central Iraq) (Fig. 6.4). Therefore, according to traditional and sequence stratigraphy, both formations form one sequence, one depositional basin, and affected by one cycle of sea level changes. Therefore both formations must be put in one single basin of same tectonic setting.

In all areas of distribution of both formations, the extent of Shiranish Formation is more than Tanjero Formation. Therefore the former formation acts as a carpet for the latter one. I called this relation between the two formations " a **sleeping man on a carpet**" which means that Tanjero is the man and Shiranish Formation is the " carpet".

2.The paleocurrent direction (see section 3.2) indicates the general direction of south and southwest, which shows no any separation of the region called "miogeosyncline" and "unstable shelf" from each other during Upper Cretaceous. Previously these two zones were assigned for sedimentation of Tanjero and Shiranish Formation respectively. In the present study the miogeosyncline basin (previously assigned basin for Tanjero formation) is changed to **Upper Cretaceous depo-center** and unstable shelf to **Upper Cretaceous basin center** (Fig.6.4). Both basin center and depo-centers combined to form a broad southwest sloping **Zagros Initial foreland basin**. Which bordered, from northeast, by recently uplifted (or over-thrusted) positive land, which was migrating continually. This land as a mountain belt was more likely dissected by initial drainage pattern which most possibly of parallel type (see Thornbury, 1969, p.121). This pattern is formed at the front of the thrust sheet (or reverse fault) formed a scarp (Thornbury, p. 239). This pattern included many deep valleys through which water and sediments of many small watersheds (possibly less



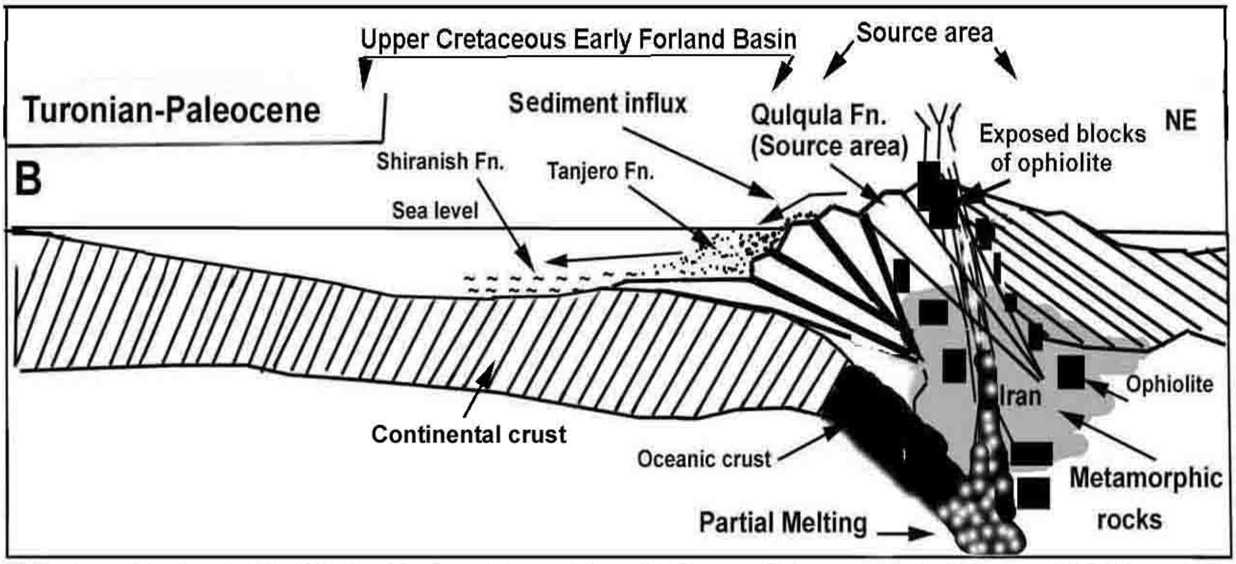


Fig.(6.2)Tectonic Model for Tanjero Formation, A) Pre-collision model of Numan(1997)
B) Post collision of the present study, which shows changing of paleo-slope direction from NE to SW.

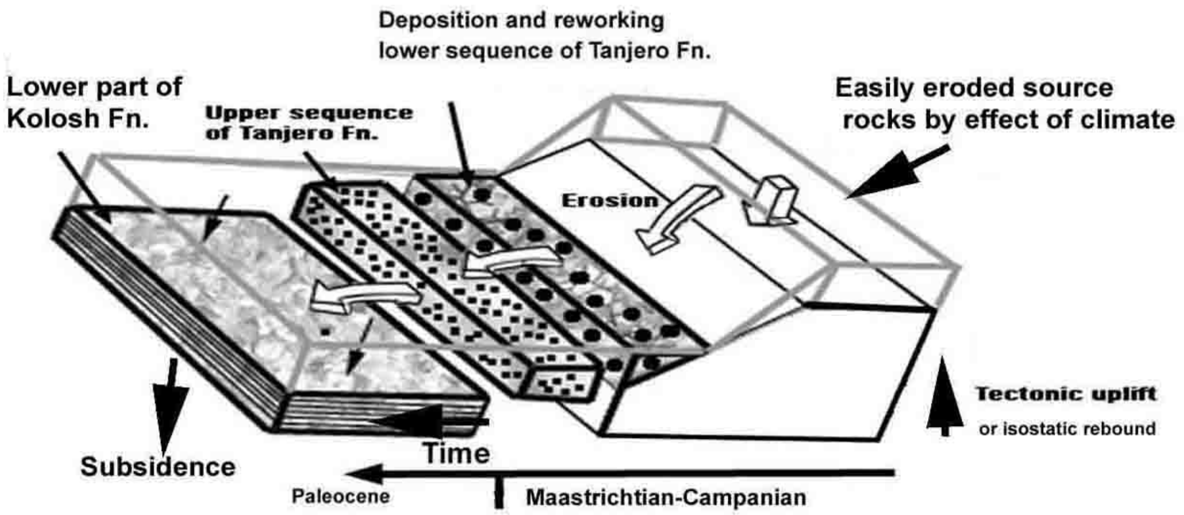


Fig. (6.3) Simplified model to illustrate the relation between lower and upper sequence of Tanjero Formation with Kolosh Formation. The Diagram also can be used for showing general trend facies migration.

than $400km^2$ for each drainage basin) were delivered (drained) to the basin (Fig. 6.5). During relative sea level fall (LST) these valleys, more and more advanced toward the basin by scoring of the delta plain and shelf sediments of previous HST. These valleys are called incised valleys; three of these valleys are ascertained and mapped in the field. These valleys are filled with Kato conglomerate on the shelf and with both alternation of sandstone and conglomerate on the Upper slope and sandstone and shale at lower slope and basin floor. In North America Bhattacharya and Willis (2001) described, in detail, a low stand system tract in foreland basin during Cenomanian. The content of the lowstand is much similar to that of lower part of Tanjero Formation in the view of lithology, trace fossil (cruziana and skolithos) and sedimentary structures (HCS, Cross bedding)

3. Although Kolosh Formation has nearly same lithology as the Tanjero Formation, it is tectonically separated from miogeosyncline and regarded as a unit of unstable shelf by above authors. In the present study, the three formations (Shiranish, Tanjero and Kolosh) have given same rank of tectonics (early foreland basin or syn -collision active margin). The only difference is the possible depocenter migration toward southwest for about 25 km (estimated only) as regarded to position Tanjero Formation. Even Aqra-Bekhme formation is included in the basin as reefal facies on local submerged paleohighs.

4-Recording of abundant plant debris is good evidence for existing of lands that surround the basin. For this and other evidence cited above the basin is called foreland basin.

6.2. 2-Initial (early) foreland basin

Bate and Jackson (1980) defined Foreland basin as:

A stable area marginal to an orogenic belt, toward which the rocks of the orogenic belt were thrust or over folded. Generally, the foreland is a continental part of the crust and is the edge of craton or platform area. In this study the Tanjero basin is considered to be initial foreland basin so the above definition can be applied to this basin when considerable amount of activity is given to the basin because of its early development. The applicability of the definition is attributed to the following:

1.The basin of Tanjero formation was relatively stable as compared to thrust sheets and over-folded area (source area of the formation). **2.**The basin shows no igneous activities.

3. On the other hand, the occurrence area of Qulqula Formation, Ophiolite Complex and Qandil Group represent the orogenic belt of the above definition.

4. As seen in sequence stratigraphy sea level fall and rise of the formation is nearly coinciding with the 3rd order eustatic sea level change (Fig.5.1 and 5.2).

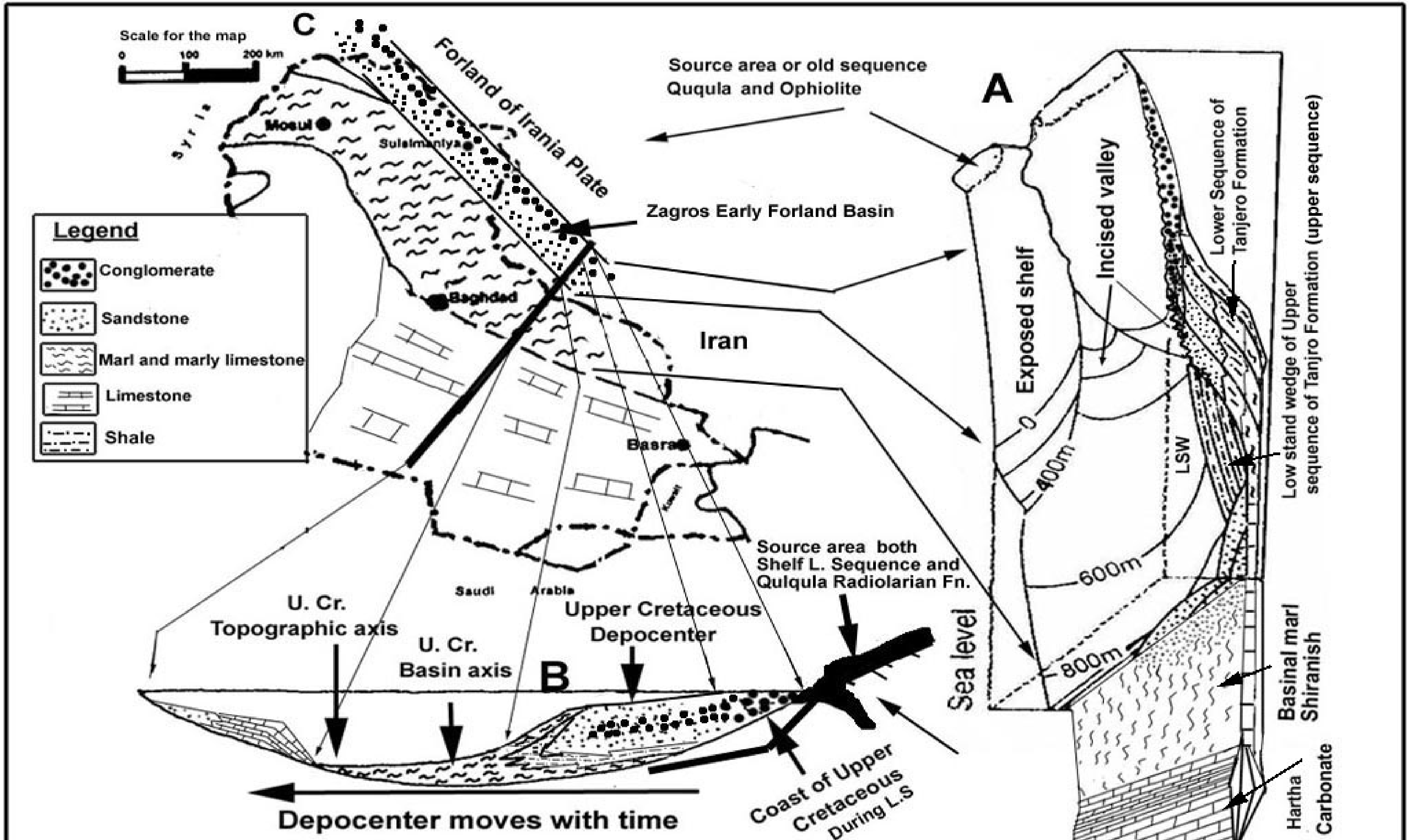


Fig.(6.4) Sequence depostional model (A) and general depositional model (B) as correlated with the Upprer Cretaceous lithofacies distribution map (C) The location of Tanjero Formation is valid only for upper sequence.

5.The basin of the Tanjero Formation is characterized by growth of the thickest and best reefal limestone such as Aqra-Bekhme Formation in addition to rudist bearing limestone of Kato mixed carbonate -siliciclastic succession of the upper part of the formation. This proves the relative stability of the basin with constant subsidence as all other basins. All these prove that the Tanjero basin was not tectonically so active such as estimated previously. This is true also for depth which was more shallow than that assigned before.

Einsele (2000, p.606) called this type of initial foreland basin " remnant basin" which is more active and deeper than the foreland basin. According to him it is largely filled with deep-water flysch sediments and confined with, on one side, by pre-existing passive continental margin(platform) (western desert in case of Iraq) with wedge of older clastics and carbonate sediments. On the other side, an approaching thrust belt confines the formation.

Qulqula Radiolarian Formation (accretionary prism) represented the thrust belt (in case of Tanjero basin) (Fig.6.2). This prism (after erosion) is shedding relatively large volume of various clastics in the form of turbidites and mass flow deposits into the basin. The actual position of Tanjero Formation may be located in transition zone between foreland and remnant basin.

Balambo and Qamchuqa Formations were forming the platform during Lower Cretaceous and Tanjero Formation started deposition on top of these formations after rapid subsidence. This rapid subsidence led to the deposition of Kometan Formation. Later, when the source area was uplifted and sea level was lowered (during most times) Tanjero formation was deposited.

In foreland basins, sediment shallows up from deep water to shallow marine and then continental sedimentation (Mail, 1995). This type of shallowing is exactly applicable for Tanjero Formation and Red Bed Series, which have gradation contact (in some place) in the area of the study. In this connection Doyle *et al*. (2001,p.111) mentioned that the sediments of foreland basin deposited in mostly river and deltaic environment and consist of heterogeneous gravel, sands and muds derived from orogenic belt.

6.2.3- Syn -collision idea

In contrary to pre-collision model, the present study assigned to the setting (tectonic model) of the Tanjero basin to syn-collision of the Arabian and Iranian plates (collision of their continental parts). The birth of Tanjero Formation started when Qulqula Radiolarian Formation (as an accretionary prism) was uplifted after the collision of the two plates. The relatively sudden start of the clastic influx and gradual increase of grain size to coarse conglomerate indicated uplift of the Qulqula Formation by thrusting or block faulting.

When an oceanic basin completely closed with the total elimination of oceanic crust by subduction, the two continental margins had been converged. Where two continental plates converge subduction does not occur because the thick, low-density continental lithosphere is too light to be subducted. In between these plates Qulqula Radiolarian Formation, as the softest rocks in the collision zone, is deformed and uplifted forming orogenic belt. This belt might be developed by collision of the plates, which involved a thickening of the lithosphere. As the crust thickens it undergoes deformation with occurrence of metamorphism in the lower part of the crust (e.g. Shalair Phyllite) and faulting with folding at shallower levels in the mountain belt. Finally the uplifted land may thrust and form thrust belt. The material of belt is moved outwards, away from the center of the orogenic belt. This caused the Tanjero and Kolosh Formation to be deposited by dislocation of depocenter toward southwest as the gradual moving or uplifting of source area (Fig.6.3).

6.2.4-Migration of depocenter

During fieldwork at the area of the study, two depocenter of Tanjero deposits were found. These depocenters belong to two different successive depostional sequences. The distance of migration is about 25km, which measures the distance between two identical lithologies in the two sequences. These two sequences are as follows:

6.2.4.1-Campanian-Lower Maastrichtian Sequence

This sequence can be identified easily in the Chuarta area. This sequence is partially eroded partially by overlying (SB1). These situations are very clear at Kato Mountain where this sequence is located under Kato conglomerate and the coarsest existed lithology consist of package of 30 m thick medium grain sandstone. This package represents sediment of LST. Similar package of the upper sequence is outcropped at south of Sulaimaniya City. The distance to the Kato Mountain and this latter locality is bout 25km when the folding shortening is considered. The identification of this sequence is very difficult in the distal area. This is because it either changes to Shiranish Formation or it interfingers, as fine sand, with marl of Shiranish Formation forming transitional zone between the two formations. The age of the two sequences is based on age of the formation at Dokan area, which is indicated by Abdul-Kireem (1986b see previous work in chapter one).

6.2.4.2-Middle –Upper Maastrichtian Sequence

This is the main sequence comprising more than 90% of previously known lithology of the formation. This sequence is discussed in detail in the subject of Sequence stratigraphy.

The 25 km migration of the depocenter is attributed to sea level change and basin fill which are both well enhanced by progressive southeast advancing of thrust sheet of Iranian plate.

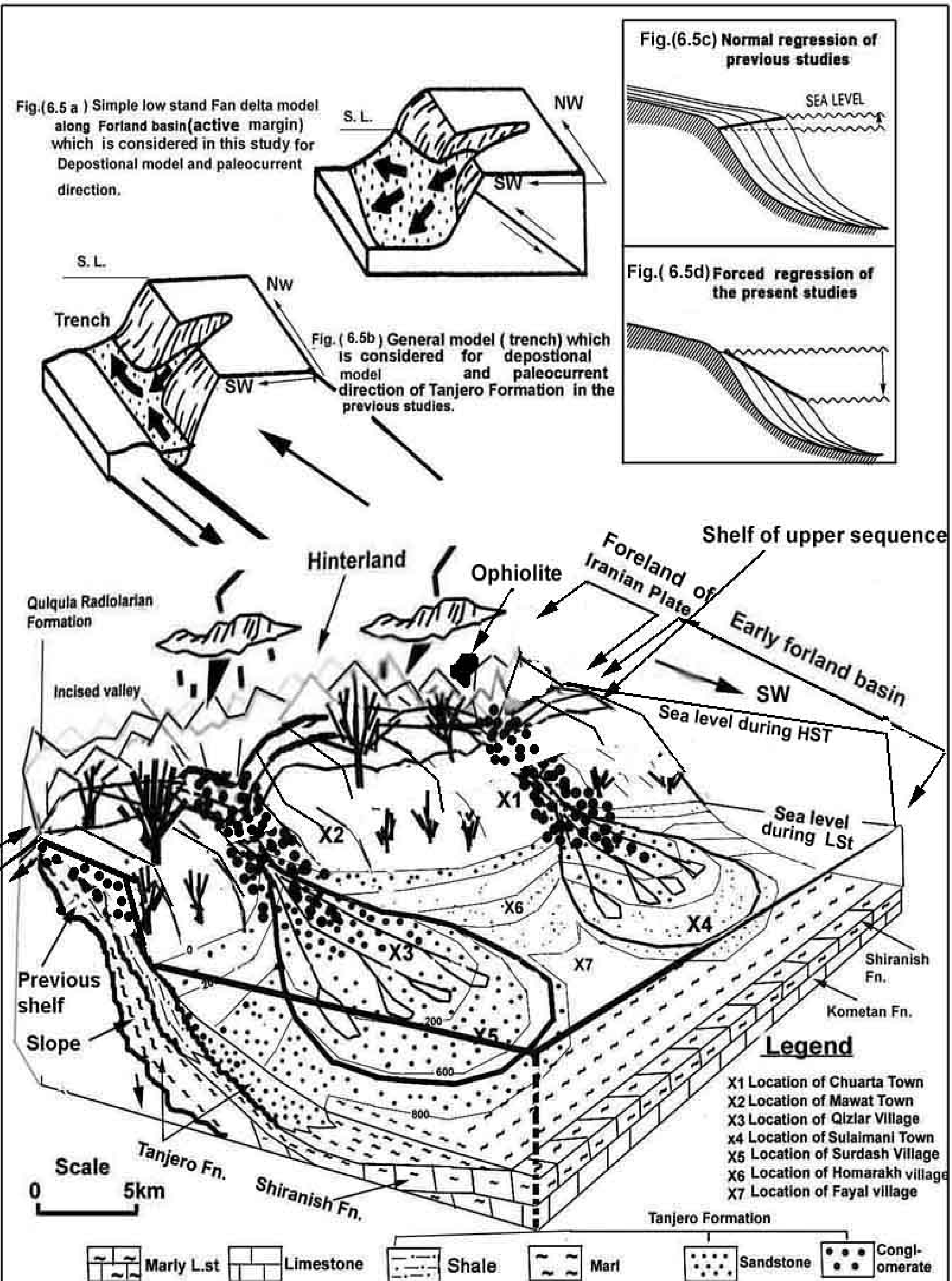


Fig. (6.5) Fan- Delta Model for Tanjero Formation, which shows gradation contacts and facies dislocation (migration) between conglomerate, sandstone, marl and marly limestone. The postion of the lithologies are valid only for the upper Sequence during Deposition of Low stand system (during forced regression).

6.2.5-Sediments: as an apparent indication of high tectonic

As mentioned before both Tanjero and Shiranish Formations were sharing same basin and exchanging position laterally and vertically (Fig.5.3) The Tanjero Formation basin was active and relatively high tectonic but when compared to Shiranish Formation, its tectonic is highly exaggerated this is due to the high thickness and alternation of coarse and fine sediments. This gives, apparently not really, the exceptionally high tectonics during deposition. But when one studies the nature and lithology of the source area, one realizes why the formation has high thickness and compositionally different lithologies.

In this study, the above two characteristics are attributed, partly, to the following:

- The source area (Qulqula Formation) is composed of 30% variegated marl, calcareous shale; 40% thin bedded chert and 20% of limestones. These sediments are easily weathered and eroded during Upper Cretaceous stormy climate.
- The source area, hinterland and foreland, was steep sloping and highly deformed during the colliding of the Arabian and Iranian plates (continental –continental colliding phase). It is likely that at that time the brittle bedded chert and soft marls are so intensely jointed and fractured that helped rapid weathering, the erosion and creation of deep valleys.
- The bedded cherts, although brittle, they shaped into hard and sharp edged boulder and gravel (with some blocks) by jointing. During transport in streams, these act as millstone for grinding and breaking up the clasts and the underlying rock too. All these helped enormous amount of material to be available for transporting and deposition in the basin of Tanjero Formation. It is worthy to mention that villagers, in the northeastern Iraq villages, use Kato conglomerate as a millstone (Plate 5.2.2) after shaping into large circular disk then used for grinding the wheat into flour by water-powered mills.
- The uplift of the source area is partly due to presence of the soft rocks mentioned above. These rocks sandwiched between the two plates as accretionary prism and uplifted by imbrications or forcefully emplaced upward by flowage like salt domes or tooth past (see Costa and Venderville, 2001 for principle of diapirism in convergent setting, p.123-151). The softness of these rocks also led the ophiolite to rest in the core or boundary of the prism and later outcropped during erosion of the source area. This is can be ascertained by the fact that the lower part (e.g., Kato conglomerate) of the Tanjero Formation does not contain any type of igneous boulders and gravels while the upper part contains these rocks.
- The high thickness may be partly returned to climate of Upper Cretaceous, which was stormy and wet. In this connection Haq (1991 p. 34) mentioned that increased albedo during

lowstand favors extreme climate, and this, in turn lead to enhanced thermal contrast of land and sea, between surface and bottom of seawater. He also added that the extreme climate increase weathering and erosion on land.

6.2.6 Forced and normal regression during deposition of Tanjero Formation

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

6.2.6.1-Forced regression

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 progradation of the shoreline in response to relative sea-level fall in which the rate of sediment supply exceeds the rate accommodation space added.

The most important evidence of the forced regression is rapid coarsening upward, i.e. the resting of coarse sediments on fine ones with erosional contact between the two. In Tanjero this arrangement of sediment is very clear in Kato Mountain (Plate 5.1.2 and 5.2) where coarse conglomerate (coastal sediments) rests on shale of shelf of the lower sequence. Moreover in Iranian section and Kometan section (Plate 2.5) Kato conglomerate rest on the pelagic marl of Shiranish Formation.

As a result of the forced regression, the thick pile of low stand system tract is deposited. This forced regression is affected by eustatic sea level change and most possibly enhanced by tectonic uplift of the source area. The uplift is also accompanied by progressive horizontal advancing (closing) of the source area.

The lithology of the Tanjero Formation revealed that the source area (hinterland) was mainly comprised of accretionary prism of Qulqula Radiolarian Formation and minor amount of ophiolite (exposed only during deposition of upper part), which was pushed southwestward toward early foreland basin (Shiranish and Tanjero basins). The grain size and roundness (fine grain size and rounded clasts) of the igneous pebbles showing that the outcrops of the ophiolite are located more remote distance than the chert ones.

6.2.6.2- Normal Regression

In contrast to forced regression at lower part of the formation, the upper part suffered from normal regression, which happened during highstand system tract. According to Einsele (2000) this type of regression also occurs during stable sea level and occurs as a result of sediment fill of the basin and not as a result of relative sea level fall. The arrangement of sediments is coarsening upward which shows no omission of any member of gradation facies succession.

In Tanjero Formation, this type of regression is occurred during deposition of the upper part in which the sediment supply exceeded the added accommodation space so that shallow bioclast and biogenic limestone, as a part of upper part, is deposited. In some places, the high stand Kato mixed carbonate-siliciclastic succession is overlain by Tagaran conglomerate, which may be the deposit of shelf margin system tract.

6.2.7-Low subsidence and high sea level fall

All authors previously studied Tanjero Formation, agreed that it is characterized by rapidly subsiding basin. But the present study proved the opposite (in the studied area), as follows:

As previously mentioned in this study, the typical lithology of the formation is deposited above an unconformity (SB1) during sea level fall (LST). This sea level fall occurred by forced regression. This means that the sea level falls were more than subsidence. It is most probable that the eustatic sea level fall is enhanced by tectonic uplift. This tectonic uplift is associated with source area and probably part of the basin (the shelf of lower sequence). The evidence of the tectonic enhanced eustatic sea level fall is the high thickness of incised valleys sediment fills. In discussion of the foreland basin, Einsele (2000,p.8) mentioned that clastic material influx from the rising mountain belt often keeps pace with or exceeds subsidence and cause basin filling. But during deposition of middle part the basin suffered from rapid clear subsidence demonstrated by deposition of Shiranish- like lithology (Pelagite and Hemipelagite facies).

6.2.8- Atlantic type continental margin

Atlantic and Pacific type continental margin (Dickinson 1971), as two different depostional basins between continental and oceanic floor, can be used for comparing with that of Tanjero Formation. When the comparison is made in all aspects, Tanjero basin is more similar to Atlantic type continental margin than Pacific one, while the previous studies such as Jaza (1991) and Numan (1977) put the formation in a basin more similar to Pacific type continental margin. This is because the latter margin has subduction trench and an under-thrusting oceanic plate while Atlantic type margin has no such features. According to Hyndman (1970, p.7) continental margin of the pacific type may revert to Atlantic type with dying out of under-thrusting of the oceanic plate under the continent, cessation of seismic activity, filling and uplift of the trench sediments, and welding of the continental to the oceanic plate. This was what happens to the basin where Tanjero formation is deposited. This is because the basin (or northern part (coastal area) of the basin) was most probably Pacific type during Lower Cretaceous (Qulqula and Balambo Formations) but changed to pacific type during collision of Iranian continent with Arabian one after dying out of oceanic plate and uplift of Qulqula formation, which according to Karim (2003a) was forming sediments of trench before colliding.

CONCLUSIONS

This paper has reached the following conclusions:

1. Many sedimentary structures, as related to the Tanjero Formation, are recorded for the first time and discussed in detail, such as, polygenetic conglomerate lenses and wedges, cross bedding, plant remains, grass-body fossils, rudist and gastropod biostromes, Skolithos trace fossils, trail structures and horizontal and vertical borings.
2. The paleocurrent is indicated by ripple marks, elongate fossils, cross bedding, plant fragments, imbricate pebbles in addition to direction of channel and incised valleys. Among these the uni- and bi-directional structures are plotted on stereonet and rose diagram. All proved southern and southwest paleocurrent direction.
3. According to these structures, the environment is inferred to be shallower than that suggested before. The environment is that of warm and storm-clastic dominated basin, which is equivalent to shelf and upper slope in depth. It is surrounded by source area of high topography (mostly Qulqula Formation). The conglomerates are deposited in near shore on the shelf while sandstone and silty marl deposited on the slope.
4. The process of deposition is mainly attributed to river and submarine turbidity current which during flooding intensely eroded the shelf of previous highstand and deposited in the new coastal area then reworked to deeper water by submarine turbidite and storm forming turbidite and tempestite respectively.
5. The previous two parts (lower and upper) of the formation are changed into three parts (lower, middle and upper). The lower and upper parts are deposited during forced and normal regression (LST and SMST) respectively while the middle is deposited during transgression (TST). Nearly 80% of the lithology of the formation is deposited during one complete sea level cycle forming one depostional sequence. This sequence divided into LST, TST and HST. The sequence overlain by shelf margin system tract (SMST) and underlain by SB1.
6. The lithology of the formation, in the studied area, is very simple and it is nearly a reflection of that of Qulqula Radiolarian Formation. It is mainly composed of chert, limestone and shale clastic terrigenous grains, which form thick sandstone and conglomerate beds. These two rocks change to shale and marl in deeper water. Where the clastic influx ceased, the biogenic limestone is deposited in the upper part of the formation, which with interbed of shale forms the mixed carbonate –siliciclastic succession.
7. At least four lowstand fan deltas are delineated in the area of the study. The sediment of these fans received sediment from uplifted Qulqula Radiolarian Formation by rivers. Another

source of sediment is reworking of sediment of previous high stand shelf, which after incision of river they removed to deeper water. The incision is due to exposure of the shelf (Mawat-Chuarta- Qaladiza – toe of Qandil mountain area) and upper slope (present position of Azmir-Goizha anticlines).

8. The basins of Shiranish and Tanjero Formations are combined in single basin called Zagros **Initial Foreland Basin**. Within this basin the near shore elongate belt where Tanjero Formation was deposited is called **Upper Cretaceous depocenter**. While that of Shiranish Formation (off shore basin) is called **Upper Cretaceous Basin Center**.
9. In contrast to previous studies, Shiranish formation is returned to deeper environment than Tanjero Formation. The former occupied the deepest part of the Upper Cretaceous basin and toward shore zone changed to the latter as lateral facies changes.
10. In the whole studied area the following system tracts are identified:

Qamchuqa Formation…….. LST

Balambo Formation … …..Distal LST

Kometan Formation……….TST

Shiranish Formation……….Early HST,

Tanjero Formation…………Late HST, LST, TST, HST and SMST.

The major transgression, in the studied area, happened during the end of deposition of Qamchuqa Formation. This transgression led to deposition of deep marine Kometan Formation as TST.

11. During fieldwork two large incised valleys with their associated low stand fans are found which filled with aggradation late lowstand conglomerate and transgressive red claystone. According to the lithology of these two fans in distal area, two additional fans are inferred.
12. The environment of the formation is highly variable as concerned to depth it range from continental to deep marine while the turbidity was ranged from river fresh water to brackish and normal marine water. Water turbidity changed from highly turbid water in the incised valleys and in front of submarine fans to totally clear water at the time of reef growth in the upper part of the formation. These reflected by existence of Shiranish-like, Kometan-like, Aqra-like, Red Bed-like and mollasse-like lithologies respectively in addition to flysch lithology as reflected by typical lithology of the formation.

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تحليل حوضي لتكوين تـا نجيرو في محافظة السليمانية ، شمال شرق العراق

الخلاصة

يتكون تكوين تـانجيرو من وحدة صخرية تعود إلى الكريتاسي الأعلى (كامبانيان-ماستريختيان) و تقع مكاشفه ضمن نطاق التراكب والطيات العالية في شمال شرق العراق ٠تمتد مكاشفه كنطاق ضيق بـاتجاه شمالغرب –جنوب الشرق قرب الحدود الايرانية٠ يشمل التكوين بصورة رئيسية من تبدل من صخور الفتاتية الرملية ولغرينية و المارل(أو الطفل الجيري) ويتغير إلى سمك كبير من مدملكات و الحجر الجيري ذات اصل حياتي في المنطقة قريبة من المصدر٠

على أساس توزيع رسوبي قسم العمود الصخري لتكوين إلى ثلاثة اقسام (السفلي و الوسطي و العلوي) وتم مضاهاة هذه الأقسام في ستة مقاطع مختلفة موزعة على مناطق قريبة والبعيدة عن المصدر و يحتوي على مقطع واحد داخل الأراضي الإيرانية ٠ إن المضاهاة أجريت على أساس المكونات الصخرية والموقع الطباقي للمد ملكات الدالة و الحجر الرملي المشتقة منها وتم شرحها بالتفصيل في مناطق مختلفة ٠ يتكون جزء السفلي (الجزء السفلي المتراجع) من تبادل سميك (١٠٠ــ ٤٠٠م) من الحجر الرملي (ارينايت وكريواكى)و المارل الجيري في المناطق البعيدة عن المصدر أما قرب مصدر يتكون من ٥٠٠م من المد ملكات ذات حبيبات الصوان و الحجر الجيري وان الرسوبيات النموذجية للتكوين محصورة داخل هذا الجزء ٠ الجزء الوسطى(الجزء الوسطى المتقدم) يتكون من (١٠٠ــ٣٠٠م) من مارل الجيري أو المارل الأبيض المزرق في المناطق بعد عن المصدر و الطفل الجيري ذات اللون الاخضر زيتوني فوق الرف و يتغير إلى طين الحمراء ذات سمك (٢٠ ــ٥٠ م) داخل الوديان المقتحمة (Incised valleys)على طول المناطق الساحلية ا ثناء المستوى البحري الواطئ أما الجزء العلوي (الجزء العلوي المتراجع) يتكون من (٥٠ ــ٢٠٠م) من تتابع مختلط من صخور كابوناتية و سليكلاستيكية ومكونات هذا الجزء عبارة عن تبادل من الحجر الجيري الحياتي و الطفل الجيري مع كميات قليلة من الحجر الرملي و المدلكات ٠ إن المكونات الرسوبية (في منطقة الدراسة) بسيطة حيث تتكون من الأحجام المختلفة من قطع صخور الصوان و الجير آلاتية من تكوين قولقولة راديولارية مع جزء بسيط من قطع الصخور النارية المنحدرة من الاوفيولايت ٠

تم أيجاد كثير من التراكيب الرسوبية في الجزء العلوي والسفلي و من بينها تراكيب آثار المتحجرات تابعة لسكوليسوس و كروزيانا و تراكيب الإفلات و HCS و الطبقات المتقاطعة و علامات النيم العرضية والمتداخلة و الحصوات المتراكبة وتراكيب السطوح السفلية و ركام النباتي ٠ معظم هذه التراكيب وجدت في الجزء السفلي و بعض الآخر في الجزء العلوي ولكن الجزء الوسطي لا يحتوي على هذه التراكيب ٠ استخدمت هذه التراكيب (خاصة التراكيب الأحادي الاتجاه) لإيجاد اتجاه التيار القديم بواسطة مخطط الروز و الستريونت حيث اظهر اتجاه جنوب و جنوب غربي ٠

في فصل البيئة تم إنشاء المود يل البيئي و النظام الترسيبي و حدد موقع الرف و منحدر و الجزء العميق من الحوض الترسيبي على الخريطة لكل من تتابع الترسيبي العلوي والسفلي وتم شرحهما بالتفصيل ٠ إن نظام الترسيبي عبارة عن ترافق دلتا و مراوح المسارات الواطئة (low stand fan- delta system of deposition) ٠ ترسب كل الجزء السفلي ضمن هذا النظام وكذلك ترسبات(SMST) الموجودة تحت سلسلة الطبقات الحمراء ٠في هذا النظام حدث إعادة الترسيب إلى الحوض العميق بواسطة التيارات العكرة والامواج الناتجة عن العواصف ونتج عنهما ترسبات العكرة و التمبستايت (tempestite) ٠ أهم مميزات التمبستايت هي (Hummocky cross stratification(HCS و آثار المتحجرات المذكورة أعلاه و الطبقات المتقاطعة الكبيرة التي وجدت في الجزء السفلي من التكوين ٠ طبقات العكرة شائعة اكثر في المناطق بعيدة عن المصدر (منطقة دوكان و سهلي شارةزوور و بيرة مكروون) ولكن على المنطقة المنحدر(شمال السليمانية و وادي جقجق و شمال دوكان) يكثر التمبستايت ٠

إن للتكوين بيئات مختلفة ، من حيث العمق يتغير من البيئة القارية إلي البحرية العميقة بينما يتغير الملوحة من المياه النهرية العذبة إلى المياه البحرية المالحة ٠ من حيث العكرة لها مدى العكرة الكاملة داخل الوديان المقتحمة و أمام المراوح تحت المائية ويتغير إلى المياه الصافية أثناء نمو الحيد في الجزء العلوي ، استنتج جميع هذه التغيرات بواسطة الصخرية المشابه للتكوين الشيرانش و الكوميتان و الاعقرة و السلسلة الطبقات الحمراء على التوالي وبإضافة الرسوبيات الفليش الممثلة بالرسوبيات

النموذجية للتكوين و المترسبة كوتد الركود الواطئ ٠ وجود الآثار المتحجرات التابعة للنيرات تم معالجتها في مختلف أقسام التكوين ٠ و تم شرح إعادة الترسيب الراديولاريا و الفورامنفرا الطافية في البيئات المختلفة ٠

قسم الجسم الصخري الكلي للطباشيري الأعلى على اساس ألطباقية التتابعية إلى التتابعين الرسوبيين حيث سميتا تتابع السفلي والعلوي ٠ ترسب ٨٠٪ من سمك التكوين ضمن التتابع العلوي والمحصورة بين SB1 و SB2 من الأعلى والأسفل على التوالي ٠ الباقي التكوين ٢٠٪ ترسب ضمن التتابع السفلي ٠ يعتبر (SB1) اهم سطح للتعرية وعدم التوافق الموجودة داخل التكوين حيث يمتد من منطقة جوارتا و ماوت إلى سهلي شارةزور و بيرةمكرون خلال عصر ماسترختيان اسفل ٠ و قد ترسب سمك كبير من حجر الرملي والمدملكات بشكل وتد على هذا السطح بواسطة التراجع الإجباري ٠ هذا التراجع نتجت من ا نخفاض مستوى السطح العالمي المعزز بحركات التكتونية ٠ فوق SB2 ترسبت سمك قليل من رسوبيات (SMST) خلال ماسترختيان أعلى و المتمثلة بوجود المدملكات (عدم التوافق) و الحجر الرملي بعض أماكن وعدم وجوده (توافق) في أماكن أخرى ٠ ترسيب (SMST) نتيجة لملء حوض التكوين مع نزول بسيط لمستوى البحر حيث اعتبر هذا الملء في هذا الدراسة كتراجع اعتيادي وليس إجباري ٠يمكن القول إن رسوبيات حوض مقدمة القارة الزاحفة والتابعة لكريتاسي الأعلى قد قسمت إلى القسمين خلال عمر تكوين تا نجرو بواسطة سطحي عدم التوافق و يتغير كلاهما إلى التوافق الرسوبي داخل الحوض العميق ٠ بين سطحين و ضمن تتابع الأعلى تم التعرف على نظم المسارات التالية (LST, TST, HST , SMST) بالإضافة إلى أسطح التابعة لهم ٠ أن الرسوبيات هذه المسارات عبارة عن نفس ما يحتوي ألاجزاء الثلاثة المذكورة الأعلاه ٠ نظم المسارات التتابع السفلي لا يمكن تميزها بسبب وجود مكاشف البحر العميق (المناطق البعيدة عن المصدر) فقط و اندماجهم معاً٠ تعرية (بواسطة الأنهار) الرف والمنحدر العلوي العائد للتتابع السفلي كونت القنوات والوديان و الخنادق المقتحمة ٠ و تم خلال هذه الأشكال نقل الترسبات و إعادة ترسيبها في بيئة عميقة ٠ هذا كله حدث أثناء تراجع الماء من الرف نتيجة لهبوط مستوى المياه و تراجع الإجباري أثناء ترسيب (LST) ٠ وجدت أربعة وديان مقتحمة داخل الرسوبيات (HST)السابق (رف التتابع السابق) حيث امتلأ هذا الوديان من بوتد من المدملكات الركود الواطئ (Low stand wedge) والحجر الطيني الحمراء التابع لنظام المسار التقدمي (TST)٠

فوق وتد الحجر الرملي وفي منطقة دوكان و وادي جقجق و سهلي شارةزوور و بيرةمكروون يمكن مشاهدة سطح التقدم البحري بشكل تغير سريع للحجر الرملي إلى المارل مع تداخلات من طبقات الرقيقة من حجر الجير المارلي ٠ هذا السطح عبارة من نقطة البداية لترسيب السميك من رسوبيات (TST) فوق الرف ٠ رسوبية هذه المسار يشبة كثيرا تكوين شيرانش في المناطق البعيدة من الساحل (على المنحدر و في البحر العميق) ولكن يتغير إلى الحجر الطيني الحمراء داخل الوديان ٠ سطح لتقدم بحري و مقاطع مركزة نقشت الذي تقع بين الجزء الوسطي والعلوي ٠ الجزء العلوي عبارة عن نظام لمسار الركود العالي الذي يتكون من تتابع من الطبقات المختلطة من الصخور الكاربوناتية و السليسيكلاستيكة (Mixed carbonate - siliciclastic succession) الذي ساد أثناء ترسيبه بيئة ضحلة علي الرف ذو جو و عاصف و ترسب فيها الحجر الجيري الحياتي و متكون من أصداف من رودست و امونايت و بطنية الأقدام و راسية الأقدام و الفورامنفرا الكبيرة ٠ هذا المسار تم تغطيته بسمك قليل من نظام مسار حافة الرف (SMST) ٠

في هذا الدراسةتم دمج تكتونيا الحوض الترسيبي للتكوين مع حوض تكوين شيرانش واقع تحتها ضمن حوض واحد و سمي حوض المقدمة القارة الزاحفة لكريتاسي العلوي عائد لحزام الزاجروس التكتونية (Zagros Upper Cretaceous Foreland Basin) وكذالك ويمكن تسميته بالحوض المتبقي (Remnant basin)٠ وضعت هذه التسمية الجديدة كبديل لمايوجيوسنكلاين السابق ٠ داخل هذا الحوض ترسبت تكوين تا نجرو في مناطق قريبة من الساحل وسمي مركز الترسيب كريتاسي العلوي (Upper Cretaceous depocenter) ولكن تكوين شيرانش ترسبت في المركز العميق للحوض حيث سمي مركز الحوض لكريتاسي العلوي ٠ تقدم مقدمة الصفحة إيرانية(مصدر الرسوبيات) واضح جدا من تغير مكان الرف التتابع العلوي والسفلي لمسافة ٢٠كم ٠ وكان موقع الرف السابق قريب من حدود الإيرانية أثناء كامباني العلوي ولكن هجر إلى منطقة جوارتا و ماوت في ماسترختيان الاوسط ٠ في هذا الفصل أعطيت خلاصة الأفكار التكتونية السابقة و كذلك الأفكار الجديدة للباحث ٠

شیکردنەوەی دەریای پێکهاتووی تانجەرۆ لە پارێزگای سلێمانی، باکووری ڕۆژهەڵاتی عێراق

پووختەی تێزەکە

پێکهاتوی تانجەرۆ وەکو یەکەیەکی کریتەیشەسی سەرووءِ{کاسپانیان ـ ماستەریختیان} دەرکەوتووە لەناوچەی تکتونی سەریەك کەوتووە وە ناوچەی چەماوە لە سەرووی ڕۆژهەلاتی عێراق٠ ئەم پێکهاتووە درێژ دەبێتەوە لە نزیك سنوری ئێران وەکو پشتێنەیەکی تەسك بەرەو سەردوی ڕۆژ ئاوا - خواروی ڕۆژهەڵات٠ پێکهاتووەکە پێکد ێت لە چینی یەك لەدوای یەکی بەردی لم و سیلت و مارل {یان شەیلی کلیسی } لەگەڵ ئەستورایەکی زۆری کونگلو مێرەیت و بەردی کلسی گیانداری لەناوچەی نزیك سەرچاوە ٠

لەم لێکۆلینەوەیەدا لەسەر بنچینەی دابەشبوونی لیسۆلوجی گشتی پێکهاتووە کەدابەش کرا بۆ سێ بەش , بەش ی خوارەوە و ناوەڕاست و سەرەوە ٠ ئەم بەشانە بەراورد کراون لە شەش بڕگەدا لەناوچەی دوورو نزیك لە سرچاوە ٠ یەکێك لەم بڕگانە لەناو خاکی ئێران دا وەرگیراوە بەراورد کردنەکە لەسەر بنچینەی لیسۆ لۆجی تاقانە بووە وە بە درێژی باسکراوە لە نوچەی جیاواز ٠ بەشیخوارەوە{بەشی خوارەوەی گەڕاوە} بەشێوەیەکی سەرەکی پێکهاتووەلە یەك لەدوای یەکی ئەستوری(٤٠٠ ـ ١٠٠م) بەردی لم و {ئارینایت و گرەیواکی} وە شەیلی کلیسی لە ناوچەی دوور سەرچاوە { سلوپی خوارەوە} بەلام لە نزیك سەرچاوە {لەسەر شێلفی پێشوو } پێکهاتوەلە {٥٠٠م} کۆنگلومێرینی بەردە چێرت و کلس {لیسبك کونگلومێر یت }٠ لیسۆلوجی نمونەی تکوینی تانجەرۆ لەم بەشەدا کۆبۆتەوە ٠ بەشی ناوەڕاست {بەشی ناوەراستی پێشڕەو } بەگشتی پێك دێت لە (١٠٠ ـ ٣٠٠م) لەمارلی شین باو یان سەوزی زەیتونی وەکلسی مارلی لە ناوچەی دوورە سەرچاوە وە لەسەر شێلف دەگۆڕیت بۆ (٢٠ـ ٥٠م) لەبەردی قوڕی سور لەناودۆلە دابڕاوەکان دا بە درێژای ناوچەی دابەزینە قەراغ دەریا بەلام بەشی سەرەوە (بەشی سەرەوەی گەڕاوە) بەگشتی پێکدێت لە (٥٠ـ ٢٠٠ م) لە تێکەڵەیەکی یەك لەدوای یەکی سلیسکلاستیك و کلس ٠ پێکهاتووی ئەم یەك لەدوای یەکی بریتیـیە کلسی گیانداری و شەیلی کلسی لە گەڵ کەمێك لە بەردی لم و کونگلومێرەیت ٠ لیسولوجی پێکهاتوی تانجەرۆ لە ناوچەی لێکۆڵینەوەدا ساکارەو بەگشتی پێکد ێت لە پارچەی بەردی چێرت و کلس کە بەسەرەکی لە پێکهاتووی قولقولەوە هاتووە لەگەڵ کەمێك پارچەی بەردیی ئاگرین لە لە ئۆفیۆلایتەوە هاتووە٠

لەم لێکۆڵینەوەیەدا گەلێك دروست بووی نشتوویی دۆزرایەوە وەکوو سکۆلیسۆس وە کروزیانە ئاسارە بە بەرد بوو وە دروست بووی دەربازبوون , وە HCS وە چینەیەك یەکتربڕەکان و ریپل مارکی پان ڕەوو بە یەکداچوو و هێلکە بەردی پاڵ یەك کەوتووە و ، بنکە نیشانە وە ووردە درەخت ٠زووربەی ئەمانە لە بەشی خووارەوەدا دۆزراوەتەوە وە هەندێکی تریان لە بەشی سەرەوەدا بلام بەشی ناوەراست هیچ لەم دروست بوانەی تێدا نیە ٠ ئاراستەی ڕێڕەوی ئاوی کون دیاری کراوە بەهۆی ئەم دروست بوونی نیشتنەوە (بە تایبەتی جۆری یەك ئارا ستەکان) کە ئاراستەی باشوورو باشوری ڕژئاوا پیشان دەدات ئەم دروست بوانە خراونەتە سەر هێڵ کاری ڕۆز (Rose diagram)وە ستیریونێتەوە ٠

لە سەربنچینەی زانستی چینە لە دوایی یەك (سکوێنس) هەموو چینەکانی کریتەیشەسیی سەروو دابەش کرابە دوو چینە لەدوای یەکی بەردی نیشتوو ٠ وە ئەم دوو لە دووای یەکە ناو نران لەدوا یەکی خواروو وە سەروو ٠ نزیکەی (٨٠٪) ی سیکوێنسی پێکهاتوی تانجەرۆ نیشتوە لە سکوێنس ی سەروو کەلە خوارەوەو سەرەوە دەورە دراوە بە(SB1) وە (SB2) ٠ بەشەکەی تری (٢٠٪) ی پێکهاتوە کە لە سکوێنس خوارەوە نیشتوە٠ (SB1) بریتیـیە لە سرەکی ترین رووی داخوران وئەنکۆنفۆرمبتی کە درێژی دەبێتەوە لە دەریا کەدا لەناوچەی چوارتاوە بۆ دەشتی شارەزووروپیرە مەگروون لەکاتی ماستەیختیانی خوارووداا ٠ پوازکی ئەستوری کونگلومێریت و بەردی لمی لەسەر ئەم رووە نیشتوە لەکاتی گە ڕانەوەی دەریای بەزۆر ٠ ئەم گەڕانەوە یە رووی داوە بە هۆی دابەزیینی ئاستی ئاوی جیهانییەوە کە یارمەتی دراو بەتەکتۆنی ٠ لە سەررووی (SB2) نیشتنی (SMST) ڕووی داوە کاتی ماستریختانی سەروو کە بریتیە لە ئەستووری کەم لە کۆنگلومێریت لە هەندێ شۆێن وە بەکۆنفۆرمیتی شۆێنی تر ٠ (SMST) نیشتوە بە هۆی پڕبوونی دەریاوە بە

نیشتوو وه بەهۆی گەرانەوەی ئاسایی دەریاوە (لەم باسەدا وا دا نراوە) ٠ لە بەر ئەوە من ئەتوانم بلێم کە دەریای فۆرلاندی سەرەتای کەریتاسی سەروو بەش بووە بەهۆی دوو ئەنکۆنفۆرمیتی لەتەمەنی پێکهاتوی تە نجەرۆدا کەلەناوقولاّیدا دەبێت بە کۆنفۆرمینی ٠ لە لە نێوان دوو رووەکەدا وە لە سکوینسی سەروودا توانرا (SMST, HST,TST, LS) بناسریتەوە لەگەڵ ڕووەکانیاندا٠ وە لیسۆلوجی ئەم سیستەم تڕاکانە هەمان شتەکە لە بەشی خوارەوە و ناوەڕاست و سەرەوەدا لە پێشەوە ناو براون ٠ سیستەم تراکی سکوێنسی خوارەوە نا توانرێت بناسرێتەوە چونکە تەنها بەردی دەریای قوڵی ئەو سکوێنسە بەدیار کەوتوە کە هەموو سیستەم تراکەکانی تێکەڵبوون ٠

داخوران و دوو بارە نیشتن بۆ ناو ژینگەی قوڵ ڕوویداوە بەهۆی جۆگەو دۆڵ و خندە قی دابڕاوەوە لە کاتی دەرکەوتنی هەوایی شێلف و سلوپی سەرەوەی ژینگەی پێکهاتووی تا نجرۆ بەهۆی دابەزینی ئاستی ئاوەوەو گەڕانەوەی بەزۆر لەکاتی (LST) ٠ زیاتر لە چوار دۆڵی دابڕاوی سەرەکی دۆزرایەوە لەناو نیشتوی (HST) پێشو (شێڵفی سکوێنی پێشوو) نیشتووی دۆڵە دابراوە کە بریتییە لە پوازکی بەردی لم و کۆ نگلۆمیریت و بەردی گڵی سووری نیشتوو لەکاتی (High stand) دا ٠ لە ناوچەی دووکان ودۆڵی چەقچەق و دەشتی شارزور و پیرەمە گروون رووی بەرووپێشرەو ئەتوانرێ بە روونی ببینرێ کەبرییتیە لە گۆڕانیخێرای بەردی لم بۆ بەردی مارڵ لەگەڵ هەندێ ناواخنی بەردی کلسی مارڵی ٠ ئەم رووە بریتیە لە خالی سەرەتایی نیشتنی بەستەیەکی سیستەم تراکی بەروپێش روەو کەلەلایەن لیسۆلۆجی یەوە زۆر لە پێکهاتووی شیرانش دەچێت لە ناوچەی دوورە سەرچاوە لە دەریای قوڵدا نیشتووە رووی بەرزترین لافاو وە بڕگەی چر گفتوگۆی لە سەرکراوە٠

بەشی سەرەوە بریتیە لە نیشتووی تێکەلاّوی کلس -سلیسیکالاستیک کە دەگەرێتەوە بۆ ژینگە ی تەنکی شە پۆدار٠ لەم ژینگەیەدا بەردی کلسی گیانداری (هەڵگری رۆدیست و ئامۆنایت و گاسترۆپۆدو پلیدسی) نیشتووە سکۆێنسی سەروو سەری گیراوە بەهۆی سیستەم تراکی شلێف مارجینەکە ئەستووری تارادەیەك کەمە٠

کەلە بەشی ژینگەدا مۆدیل ژینگەو سیستەمی نیشتن دروست کراوە وە شوێنی شێلف و سلۆپ وقولاّیی دەریای سکوینسپی سەرەوە و خوارەوە دیاری کراوە لە سە ر نەخشە و باس کراوە ٠ سیستەمی نیشتن دانراوە بە وەستانی نزمی دلتایی,و پانکەیی ٠ هە موو بەشی خوارەوە لەم سیستەمەدا نیشتوە وەهەروەها نیشتووی (SMST) کە لە خوار زنجیرەی چینە سوورەکانەوە (Red Bed Series) نیشتووە ٠ گواستنەوەی نیشتن لەم سیستەمەدا بۆ شۆێنی قوڵ بەهۆی شە پۆلی پیسەوە لە گەڵ بەشداری گێژەڵووکە کە بۆتە هۆی تێربیدایت و تێمپستایت بنیشێت لە پێکهاتووی تا نجەڕۆدا کە دەناسرێتەوە بە بوونی(HCS) کە لە گەڵیا شوێنەوارە بە بەردبووی تەنك وە چینە یەك بڕاوە گەورەکان هەیە٠ چینی تێربیدایین زۆرتر بلاّوە لە لەناوچەی دوورە سەچاوە (ناوچەی دووکان "خوارووی شاری سلێمانی و دەشتی شارەزوور) بەلاّم لەسەر سلۆپ (سەرووی شاری سلێمانی ودۆڵیچەق چەقو سەرووی‌دووکان) (تێمپستایت) زۆرترباوە لە تێر بیدایت لە بەشی خوارەوە سەرەوەی پێکهاتووە کە وە فوەرامنیفرای سەر ئاوکەتووە وە شوێنەوارە بە بەرد بووی نێرایت چارە کراوە لە بەشی‌جیاوازەکانی پێکهاتووەکە دا ٠ وە ئەگەری دووبارە نیشتنی فوارم و رادیولاریا باس کراوە لە هەموو ژینگە جیاوازەکاندا٠

لەم لێکۆڵینەوەیەدا ئاوەڕۆی تا نجرۆ بەستراوە بەوەی شیرانیشەوە کە کەوتۆتە خوارەوەی ٠ ئەم ئاوەڕۆیە ناو نراوە ئاوەڕۆی سەرەتای بەردەم فۆرلاندی زاگرۆز (یان ئاوەڕۆی ماوە) لەجیاتی ما یوجبو سنکلاینی کۆن ٠ لە ناو ئەم ئاوەڕۆیە دا پێکهاتوی تا نجەرۆ لە نزیك کەناردا نیشتووە کە پێی ووتراوە بنکەنیشتنی کریتاسی سەروو٠ بەلام شیرانیش لە ناو قووڵترین بەشی ئاوەڕۆکەدا نیشتوە کە پێی ووترا بنکەناوەراستی ئاوەڕۆی کریتاسی ٠پێشکەوتنی سەرچاوەی نیشتین سەر شاخەکان (پیشەوەی پلەتی ئێرانی) زۆ ر روونە کە رۆیشتووە بەرەو باشوری ڕۆژ ئاوا شوێن گۆڕینی کردوە (بازدانی شیلف بۆ ماوەی زیاتر لە ٢٠ کم) ٠ شێڵفی پێشوو لە نزیك سنوری ئێران بووە لە کاتی کامپانیانی سەرودا بەلاّم کۆچی کردووە بۆناوچەی دەوری شاری چوارتا و ماوەت لە کاتی ماستریختیانی ناوەڕاستدا٠ لەم بەشەدا هەموو بیرورا کونەکان لەبارەی تکنونی پێکهاتووە کە باسکراوە گەلێك بیروڕای نوسەر خراوتە ناو پاسەکەوە ٠

شیکردنەوەی دەریای پێکهاتووی تانجەرۆ لە پارێزگای سلێمانی ، باکووری رۆژهەلاتی عێراق

نامەیەکە

پێشکەش کراوە بە کۆلیجی زانست لە زانکۆی سێلمانی وەك بەشێکی تەواوکەر بۆ بەدەست هێنانی دکتۆرای فەلسەفە لە زانستی جیۆلۆجی دا

لەلایەن:

کمال حاجی کریم

ماستەر لە زانستی جیۆلۆجی دا/١٩٨٨

بەسەرپەرشتی

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