FLYSCH – MOLASSE SEDIMENTS OF THE PALEOGENE FORELAND BASIN OF NORTH ARABIA, SHIRANISH AREA, NORTH IRAQ

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ABSTRACT

The Paleogene clastic strata of northern part of Iraq are represented by the Kolosh Formation (Paleocene – Early Eocene) and the Gercus Formation (Middle – Late Eocene). Detailed investigations of these strata at Shiranish area of north Iraq including stratigraphic association, lithofacies type, petrographic investigation, and mineralogical analysis of heavies and clay fractions disclose the geological aspects and the nature of the Paleogene Foreland Basin, which is developed along the north – northeastern margin of the Arabian Plate.

Analysis of lithofacies association of the Kolosh sediments shows that it represents a distal turbidite facies of an unattached submarine fan complex that is developed far from feeding channel systems. The Gercus lithofacies is characterized by predominant continental section with a possibility of shallow marine influence near the bottom of the section.

The petrographic analysis of sandstones from both units shows the predominancy of lith-arenite type with significant occurrence of feldspar, igneous and metamorphic rock fragments in Gercus samples. Petrofacies analyses of these sandstones show that the Kolosh sandstones were derived from “Recycled Orogen” province, and developed as a part of the foreland system. The Gercus sandstones show similar tendency with clear effect of arc-volcanicity. Heavy and clay minerals analysis show assemblages, which support similar interpretation.

The sediments of Kolosh and Gercus formations are believed to represent the flysch – molasse facies of the distal part of the Paleogene Foreland Basin, which is developed in North Iraq as result of the advancing Bitlis Nappes onto the northern Arabian margin.

رواسب الفليش- المولاس لحوض الفورلاند الباليوجيني في شمال الصفيحة العربية، منطقة شيرانش، شمال العراق

باسم عبد الخالق القيم، ماجد مجدي المتولي و بهجت يوخنا نيسان

المستخلص

تتمثل طبقات الباليوجين الفتاتية في الجزء الشمالي من العراق برواسب تكوين الكولوش (الباليوسين - الإيوسين المبكر) وتكوين الجركس (الإيوسين الأوسط – الإيوسين المتأخر). لقد بينت الدراسة التفصيلية لهذه الرواسب من حيث العلاقات الطبقية، أنواع السحنات الرسوبية والتحليل البتروغرافي والمعدني في منطقة شيرانش، شمال العراق، خصائص وطبيعة الحوض الرسوبي الفورلاندي الذي نشأ عند الحافة الشمالية – الشمالية الشرقية للصفيحة العربية.

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أوضح التحليل السحني لرواسب تكوين الكولوش بأنها تمثل سحنات الرواسب العكرة البعيدة لمعقد مروحة بحرية منفصلة عن قناة التغذية الرئيسية. تتصف سحنات تكوين الكولوش بمقطع من الرواسب القارية مع احتمال وجود تأثيرات بحرية في الأسفل.

اظهر التحليل البتروغرافي للصخور الرملية لكلا التكوينين بأنها من نوع الرمال الفتاتية مع غلبة وجود الفلدسبار والفتات النارية والمتحولة الأصل في صخور تكوين الجركس. أظهر التحليل الصخاري السحني للصخور الرملية ان أصل رواسب الكولوش من إقليم "اوروجيني معاد" تجمعت ضمن حوض الفورلاند. أما رواسب الجركس فقد أظهرت أصول متشابهة مع تأثير واضح لبركانيات قوسية (Arc). كما أظهر تحليل المعادن الثقيلة لهذه الرواسب استنتاجات متشابهة.

إجمالا تمثل رواسب تكويني الكولوش والجركس رواسب الفليش والمولاس لحوض الفورلاند الباليوجيني الذي تطور في شمال العراق نتيجة تقدم كتل معقد بيتليس على حافة الصفيحة العربية.

INTRODUCTION

The Paleogene strata of north Iraq are represented by thick section of clastic sediments of the Kolosh Formation (Paleocene – Early Eocene) and the Gercus Formation (Middle – Late Eocene). A complete section of these strata is exposed at Shiranish area in the extreme part of north – northwest Iraq. Carbonate units, which characterize the transaction between these units, elsewhere in northeastern part of Iraq are missing here.

The measured section is taken in Shiranish Islam village, which is located about 15 Km north of Zakho (Fig.1). The Gercus Formation's red sediments are exposed along the downhill road after crossing a high ridge of the weathering-resistant limestone of the Pila Spi Formation on the southern flank of the Shiranish anticline (Fig.2). The Kolosh Formation's gray clastics occupy a strike valley, which separates the Pila Spi ridge from the core of the anticline (Fig.3a).

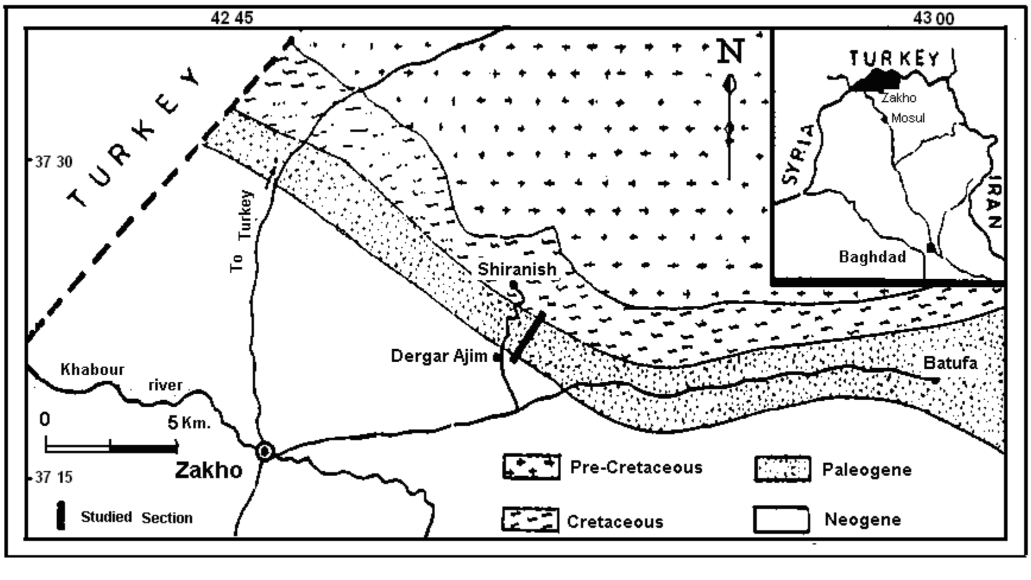

Fig.1: General geologic map of the studied area showing location of the studied section (geology from Sissakian, 2000)

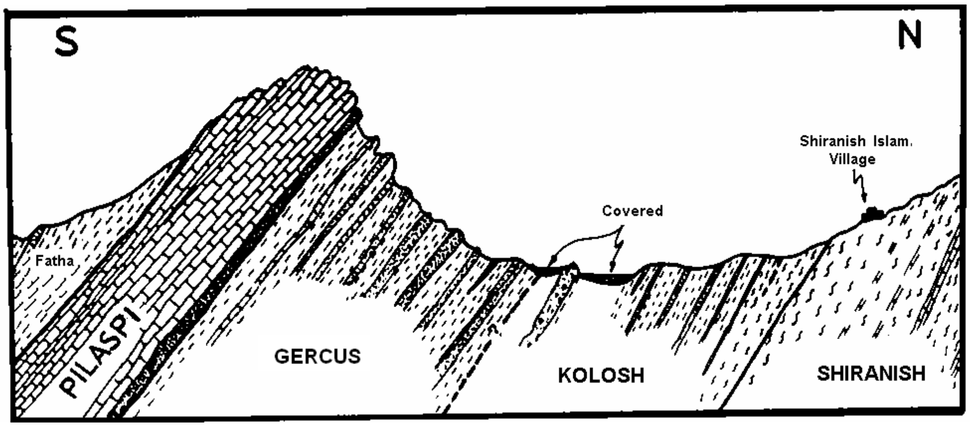

Fig.2: Schematic geologic cross section in Shiranish area, showing Late Cretaceous – Paleogene succession

The Kolosh Formation is underlain by the pelagic marlstone and marly limestone of the Late Cretaceous Shiranish Formation (Al-Qayim *et al*., 1988a). The contact between the two formations seems to be gradational and represented by continuous section of bluish gray marlstone (Fig.4a). Paleontological evidences, however, indicate the occurrences of stratigraphic gap that extends from the uppermost Maastrichtian to the Early Thanetian (Al-Qayim and Al-Shaibani, 1989).

The thickness of the Kolosh Formation is about 180 m and generally is represented by alternations of thin sandstone layers with thick gray shale interlayers (Fig.4). Deposition of its sediments is developed mainly during Middle to early Late Paleocene time (Al-Qayim *et al*., 1988b). The sediments of the Kolosh Formation are known from other areas of north and northeast Iraq and considered to represent a flysch facies of the Paleogene Foreland Basin (Dunnington, 1958; Bellen *et al*., 1959; Ditmar *et al*., 1972 and Al-Qayim, 1993). The contact with the overlying Gercus Formation is not well exposed and partly concealed under the recent valley sediments (Fig.4e).

The Gercus Formation, on the other hand consists of 205 m thick red claystone and subordinate sandstone horizons. These sediments are believed to represent a fluvio – deltaic facies of the Middle – Late Eocene cycle of northeast Iraq (Al-Rawi, 1980; Al-Qayim *et al*., 1994 and Ameen, 2006). Its upper contact with the overlying Pila Spi Formation is sharp and characteristically marked by a thick horizon of conglomerate and breccia (Fig.2).

The general sedimentological features of the Kolosh and Gercus formations have being discussed by many workers from other areas of northeast Iraq. For example the Kolosh Formation's sediments have being examined at Jabal Maqlub (Al-Omari and Sadiq, 1973), Darbandikhan area (Al-Mashaikhi, 1979), Dohuk area (Salman, 1979), Shaqlawa area, (Al-Qayim and Salman, 1986), Haibat Sultan area, (Al-Qayim and Nissan, 1989 and Al-Qayim and Al-Shaibani, 1989), Bekhme area (Al-Qayim and Al-shaibani, 1995), Sulaimaniah area (Lawa, 2004). The Gercus Formation receives relatively less attention and few areas have being examined such as Shaqlawa area (Al-Rawi, 1980; Al-Qayim *et al*., 1994 and Ameen, 2006), Aqra area, (Al-Qayim, 1995b), Sulaimania area (Lawa, 2004 and Ameen, 2006).

The sediments of the Kolosh and Gercus formations in northeast Iraq are believed to represent the flysch and the molasse facies, respectively, of the Paleogene Foreland Basin of the Zagroside Orogeny (Ditmar *et al*., 1972; Al-Qayim, 1993 and 1995a and Lawa, 2004).

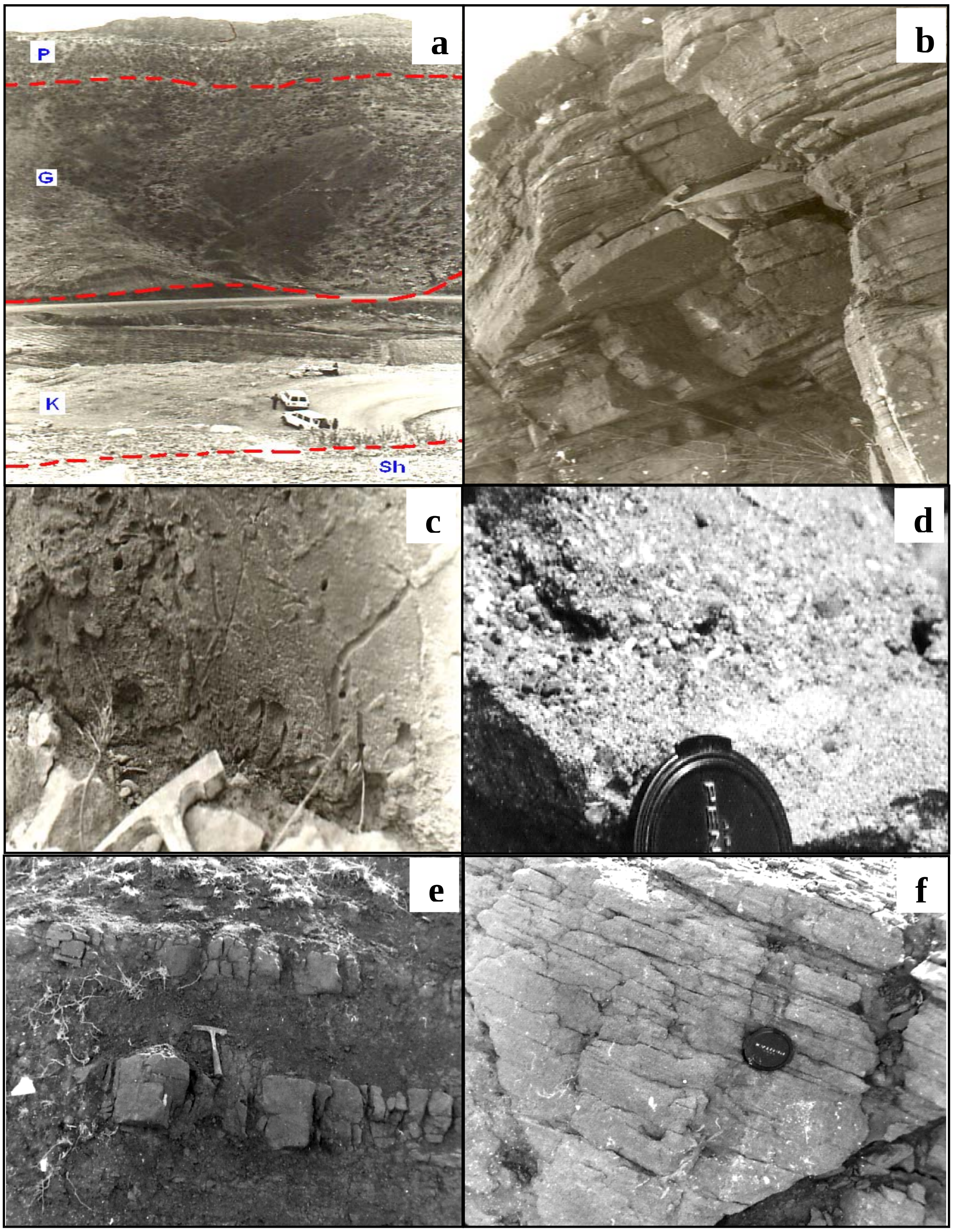

Fig.3: Field photos of the Gercus Formation
(a) General view of the succession in Shiranish area
(b) Thin bedded sandstone horizon of the lower part of Gercus Formation
(c) Worm tubes (arrows) of the middle part of Gercus sequence
(d) Channel conglomerate horizon of upper part of the formation
(e) Thin sandstone beds alternate with reddish claystone interlayers of the middle part
(f) Thick horizon of thin bedded sandstone reappears again in the upper part of the Gercus Formation

P = Pila Spi Formation, G = Gercus Formation, K = Kolosh Formation

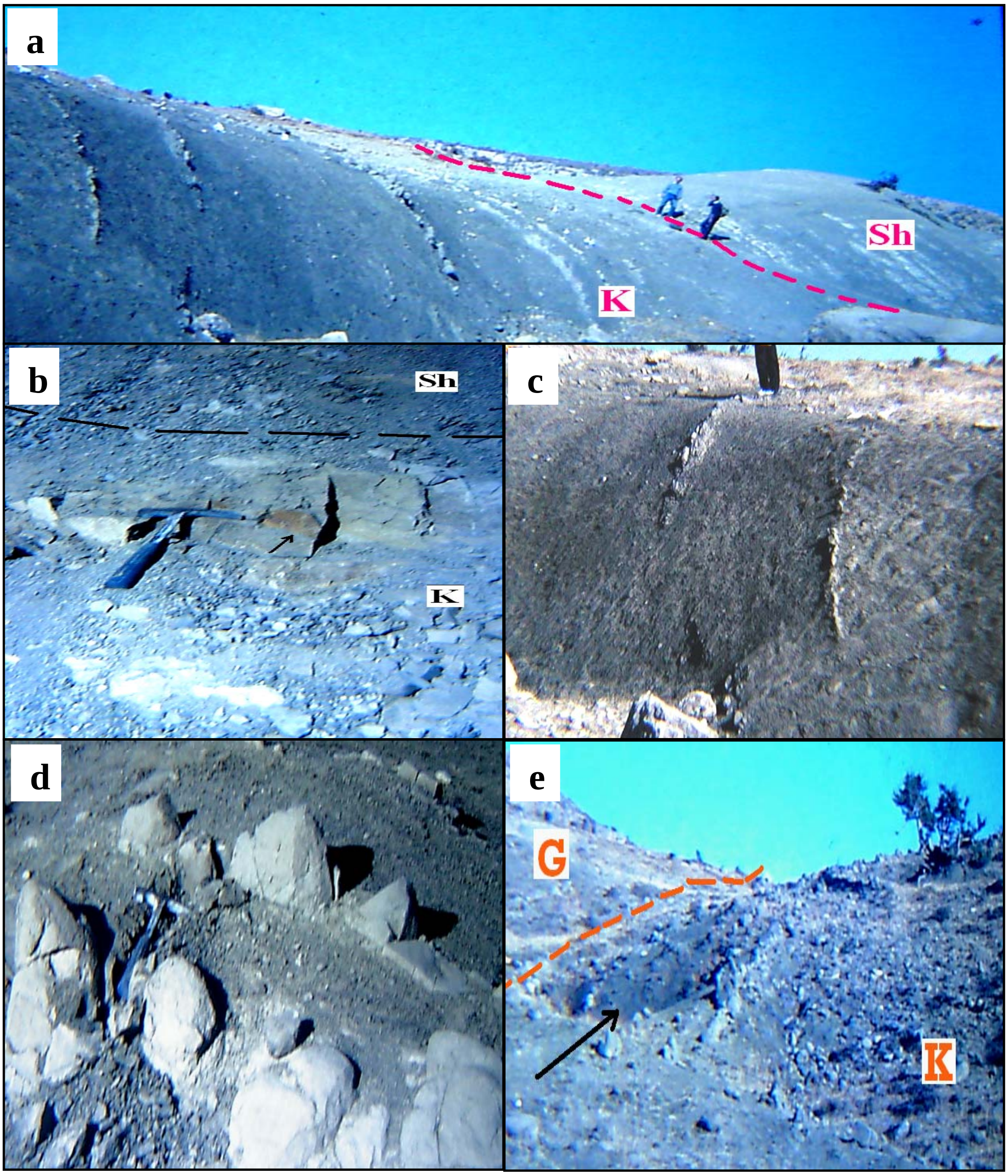

Fig.4: Field photo of Kolosh Formation (K)
(a) Contact between the Shiranish (Sh) and Kolosh formations
(b) Thin brownish crust on top of the sandstone beds of the lower lithologic association of the Kolosh section
(c) Thin sandstone beds and thick shale interlayers of the lower part
(d) Amalgamated sandstone beds of the middle lithologic association
(e) Silty to sandy shale of the upper part of the Kolosh Formation
(G) Gercus Formation

STUDY METHODS

The goal of this work is to reveal the sedimentological characters of Kolosh and Gercus formations in the study area and to establish a better understanding of their depositional history and sedimentary basin evolution. A detailed stratigraphic section has being measured and 80 rock samples being collected from both units covering important lithologic types. Thirty five thin sections were made for petrographic examination. Point-count technique was used to estimate modal compositional data. Eighteen sandstone samples were treated to separate their heavy minerals content. Claystone and marlstone samples from both units were examined by X-ray diffractometer to determine their clay mineral assemblages.

LITHOFACIES ASSOCIATIONS

- **Kolosh Formation**

The general lithologic characters of the Kolosh Formation's sediments in the studied area do not differ much from its lithologies elsewhere. Its thickness here, however, is relatively thin as compared to its counter parts in northeastern Iraq. It is also lacking the subordinate conglomerate and the fossiliferous limestone and dolostone horizons, i.e. fingers of the Sinjar and Khurmala formations that characterize its upper part in other localities.

The percentage of the sandstone seems to be also small comparatively (Al-Qayim, 1995a). The formation in this area can be divided into three lithofacies associations (Fig.5). These are from bottom to top:

A) Lower Lithofacies Association

The thickness of this unit is about 40 m. It is almost similar to the upper part of Shiranish Formation and is characterized by bluish gray marlstone, which become alternating with greenish gray, thin (<15 cm) sandstone beds of (2 – 3) m apart (Fig.4a and c). The upper surface of these sandstones is often covered by thin crust of brownish ferrous siltstone (Fig.4b). Sandstone beds are often graded with sharp lower boundary. Some of these beds are commonly associated with local concentration of plant debris. Laterally, sandstone beds thin or die out with thicker shale interlayers (up to 5 m thick). In cases like this, white thin (<5 cm) pelagic chalky limestone beds appear instead. The upper part of this association shows introduction of grayish nodular marly limestone beds (Fig.5).

The lithofacies association of this part seems to resemble the medium grained turbidite model of Pickering *et al*. (1986). It shows lithologic characters similar to those of a detached lobe of a submarine fan complex (Einsele, 2000). The infrequent occurrence of the sandstone beds in this section indicates a basin ward part of the lobe.

B) Middle Lithofacies Association

This association represents the middle and the thickest (60 m) part of the Kolosh Formation. It is characterized by greenish gray, medium grained, thick (20 – 60 cm) to massive and sometimes nodular sandstone beds, which alternate with dark gray, silty, calcareous, and fossiliferous shale interlayers (Fig.5). The sandstone beds are sometimes amalgamated (Fig.4d) and include characteristic *Scolicia* trace fossils. The cyclic nature of this association and its lithologic characters, as well as the common appearance of the *Scolicia* ichnofossils of the nereites ichnofacies of Frey and Seilacher (1980) all indicate association with the proximal part of the detached submarine fan lobe (Einsele, 2000).

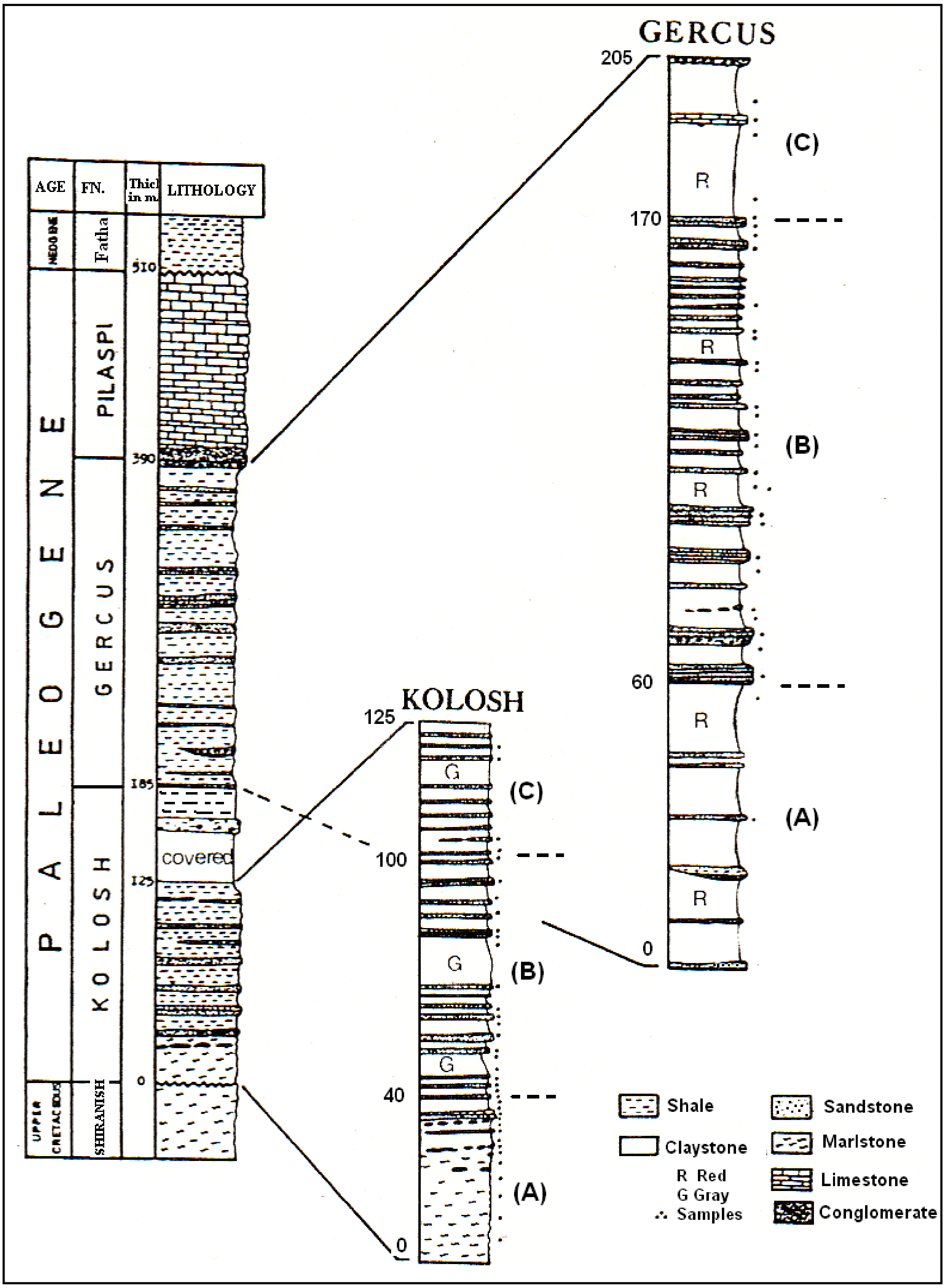

Fig.5: Stratigraphic column of the Kolosh and Gercus formations in Shiranish area showing their lithologic associations

C) Upper Lithofacies Association

The thickness of this part is 25 m with its upper part being concealed below valley fill sediments (Fig.5). It is characterized by medium to thinly bedded, pinkish to red, coarse grained sandstone beds, which alternate with thick (3 – 4 m) reddish gray, silty to sandy shale interlayers (Fig.4e). The nature of its lithologic association indicates a distal part of the detached submarine fan lobe (Einsele, 2000). In general, the succession of the Kolosh Formation’s sediments at this area reflects variable progradational rate of generally low density turbidity currents, which characterize a detached submarine fan complex.

- **Gercus Formation**

The general lithologic characters of the Gercus Formation suggest a subdivision into three different lithologic associations (Fig.5). These are from bottom to top:

A) Lower Lithofacies Association

This part is about 60 m thick and is generally characterized by pinkish gray, thick (0.5 – 2 m) sandstone horizons, which alternate with thick (up to 15 m), red, silty claystone layers (Fig.5). The sandstone beds are thinly bedded or laminated, calcareous and coarse grained (Fig.3b). The lower part of this association includes conglomeritic or pebbly sandstone unit of channel geometry (Fig.3d).

B) Middle Lithofacies Association

This association constitutes the main part of the formation. It is about 110 m thick and generally consists of gray, thick (up to 5 m) and medium to thinly bedded sandstone horizons. These horizons alternate with (1 – 3) m thick red claystone interlayers (Fig.5). The bottom of some sandstone beds includes vertical and horizontal worm tubes of Skolithos Ichnofacies (Fig.3c). Towards the top of this association the sandstone layers become thinner (20 – 200 cm), more frequent, red, fine grained and argillaceous (Fig.3e).

C) Upper Lithofacies Association

Generally, the upper part of the formation is about 30 m thick and is characterized by red silty claystone with occurrence of up to 2 m thick, whitish, chalky, and calcareous claystone, near the top. The lack of any marine fossils, the dominant red coloration, the predominant clastic component and analogy with other sections in other areas of northeast Iraq suggest a long lasting continental to sub-continental conditions (Al-Rawi, 1980 and 1983 and Dhannoun *et al*., 1988). Shallow marine influence, however, has being reported from some areas (Al-Qayim, 1993; Lawa, 2004 and Ameen, 2006) but could not be approved in Shiranish area. The consistent covering of the Kolosh flysch by the Gercus Formation is always considered as an evidence for the molasse origin of these subcontinental red clastics (Dunnington, 1958, Ditmar *et al*., 1972 and Al-Qayim, 1995b).

PETROGRAPHY

The petrographic examination was carried out on 35 thin sections (15 from Kolosh Formation and 20 from Gercus Formation). The examined samples are mainly sandstone. The other rock types such as claystone, marl and shale were examined by X-ray diffractometer. The estimated percentage for the various petrographic constituents was done by using point count technique. The examined sandstone samples of both formations are generally of lithic – arenite type (Folk, 1974). Rock fragments, calcite cement, and matrix are the most common constituents. Grain size ranges from fine to very coarse sand. The shape of the grains generally tends to be subangular. The relative abundance of the major constituents of the studied samples and their vertical variations within each formation is shown in Fig. (6).

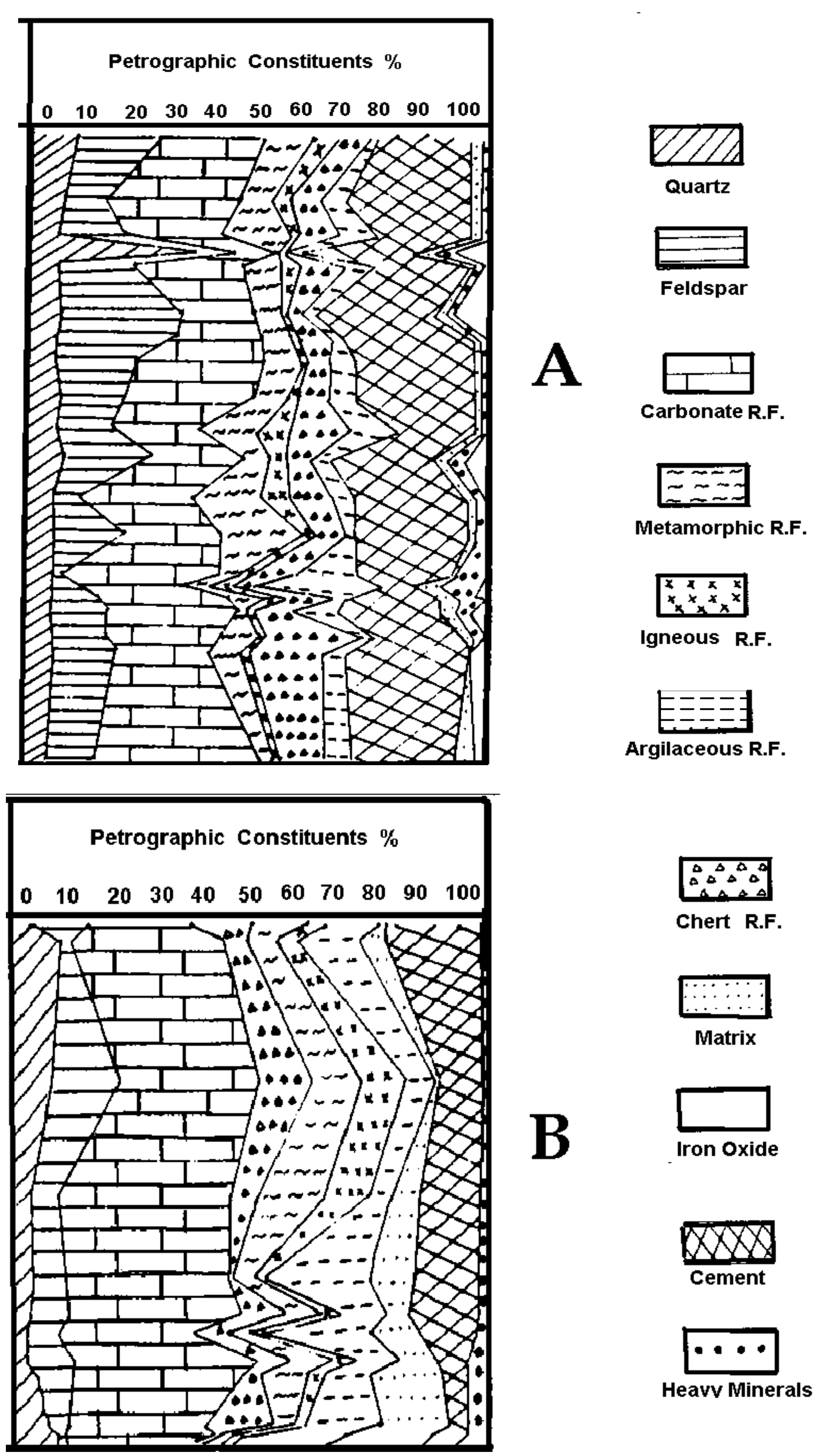

Fig.6: The relative abundance and vertical distribution of the major petrographic constituents of Gercus Formation (A) and Kolosh Formation (B), in Shiranish Area

The result of the petrographic analysis is briefly discussed below.

- **Kolosh Formation**

Lithic fragments of the Kolosh Formation's sandstones are dominated by carbonate rock fragments. Their average percentage in the examined samples reaches 32%. Grains are coarse grained, subrounded, and mainly of micritic type (Fig.7a), with occasional fossiliferous or fossil grains (Fig.7b). Other rock fragments, which show modest occurrences includes: metamorphic 7.3%, chert 6.9% and igneous 4.1%, beside argillaceous rock fragments 6.9%. Quartz and feldspar grains are less common as compared to the Gercus Formation's clastics. Detrital quartz, here is generally of monocrystalline type, with average percentage of 3.6% and commonly of fine sand size. Feldspar, on the other hand has 7.2% and commonly consists of K-feldspar type with occasional occurrence of plagioclase. Matrix is usually of low contents (9.8%) and has micritic origin, which is mixed with argillaceous materials. Carbonate cement is more common (11.6%) and often occurs as microsparite and/ or sparry calcite. It seems that it is partly developed by recrystallization of carbonate matrix (Fig.7a)

- **Gercus Formation**

The basic components of the Gercus Formation's detrital sands are lithic fragments, which are dominated by carbonate rock fragments (24.5%). These grains are of micritic and pelloidal limestone types with some effect of recrystallization (Fig.7c and d). Others remain intact with its original fabric and usually of coarse sand size. Metamorphic rock fragments occur in fairly good amount (8.5%) and distributed consistently through the whole section (Fig.6). Igneous rock fragments occur in relatively less amount (3.0%). Both grain types show relative abundance at the middle and upper parts of the section (Fig.6). Chert fragments are relatively common (9.0%), especially in the lower part of the formation. They usually occur as subrounded to subangular fine sand grains (Fig.7e). Argillaceous rock fragments are less common (6.9%) and show variable vertical distribution through out the section (Fig.6). Quartz grains are generally of monocrystalline type, fairly common (13.5%), and persistent in their distribution. Feldspar grains are relatively abundant (14.5%), especially in the middle part, as compared to the Kolosh Formation's sandstones (Fig.6). Grains are coarse grained, subangular in shape, and mainly of K-feldspar type (Fig.7f). Matrix of the Gercus Formation's sandstone occurs in low percentage (2.7%) and mainly of micritic type. The low amount of the matrix in the Gercus Formation's sandstones is unexpected for a mud-dominated sequence. It is possible that the deposition of these sandstones took place in vigorous environmental conditions, which could have sorted out the fine detritus. The high amount of carbonate cement, in most of the examined samples (Fig.6A), is possibly related to the good amount of the micritic matrix, which have been changed into calcite cement by diagenetic recrystallization processes that reduce the matrix overall amount. Iron oxide cement notably exists (2.0%) and occurs as thin coating to the detrital grains or fillings of some void spaces or as impregnation of the porous argillaceous detrital grains (Fig.7c and e).

PETROFACIES ANALYSIS

This analysis is intent to recognize the provenance and tectonic environment of the source area of the studied sandstones by using its detrital modal data. The compositional percentages were calculated into triple categories of two major application, following the method of Dickinson and Suczek (1979) and Dickinson *et al*. (1983). Both applications of QFL (Quartz – Feldspar – Lithic Fragments) and QmFLt (Quartz monocrystalline – Feldspar – Lithic Fragments + chert) were attempted to sandstones of both Kolosh and Gercus formations (Fig.8).

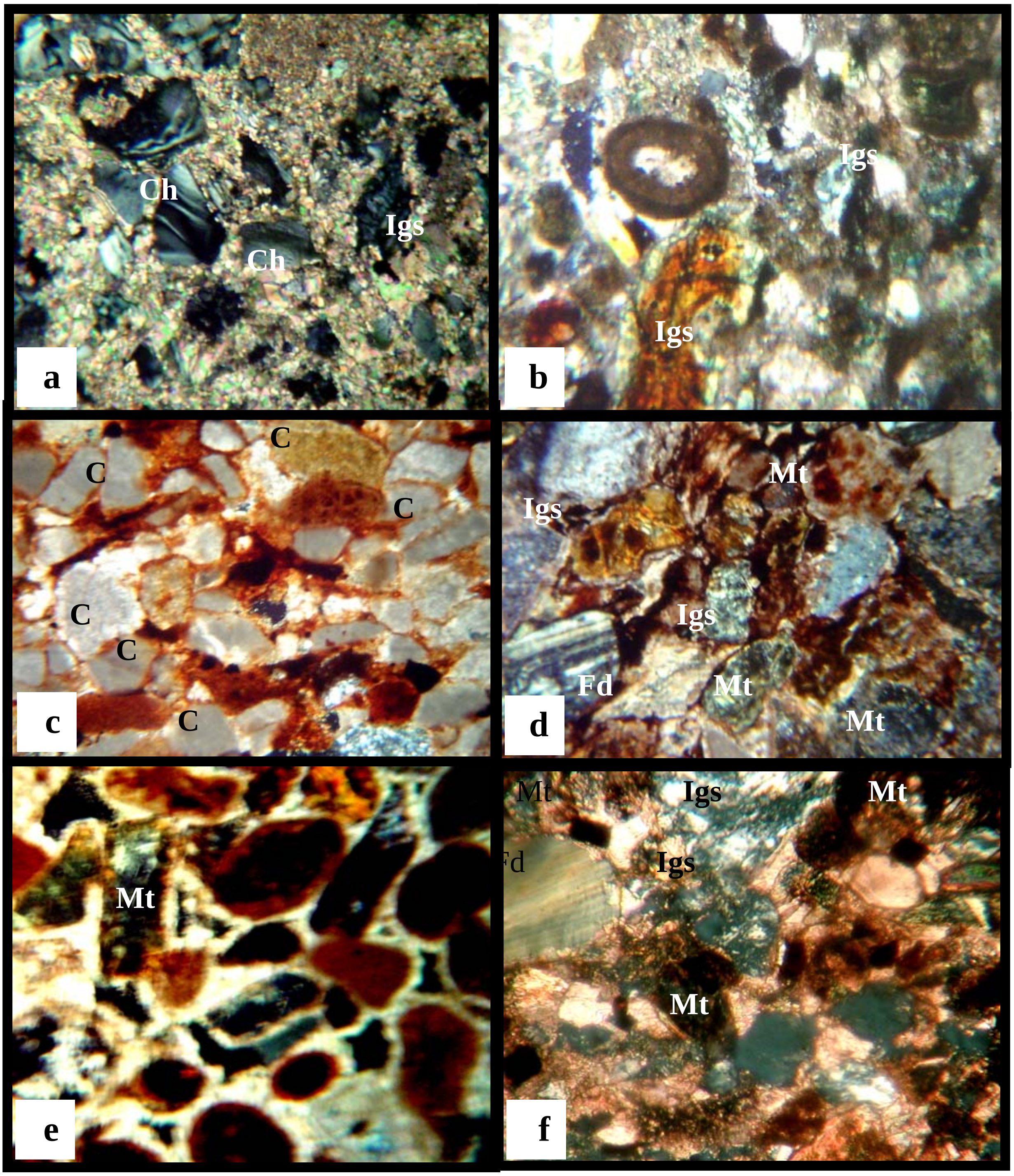

Fig. 7: Photomicrographs of sandstones from Kolosh (a and b) and Gercus (c, d, e and f) formations

(a) Metamorphic rock fragments in micritic matrix
(b) Carbonate rock fragment and skeletal grains
(c) Lithic rock fragment dominated by carbonates and argillaceous type
(d) Sandstone rich in feldspar (Fd) and basic igneous rock fragments
(e) Rounded carbonate and angular igneous lithic fragments in carbonate cement
(f) Igneous lithic fragments and feldspar in micritic matrix. All photos are crossed nicols and 40X magnification. Ch-Chert F., C-Carbonate R.F., Mt-Metamorphic R.F., Igs-Igneous R.F

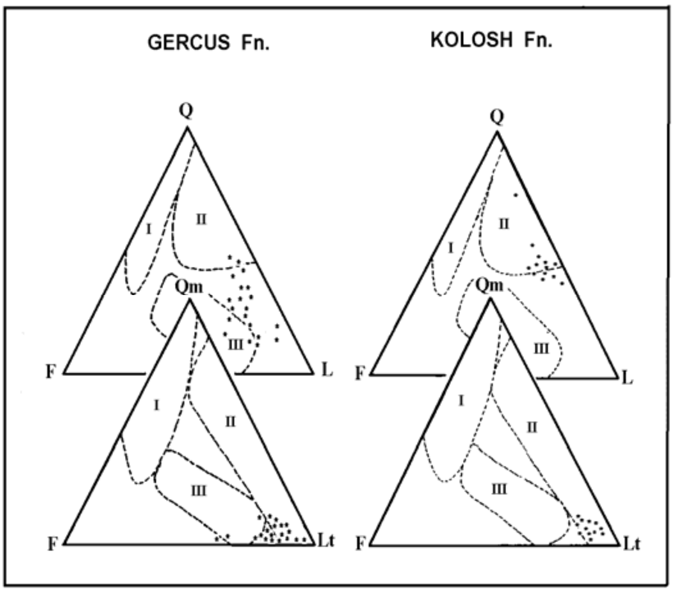

Fig.8: Petrofacies analysis of Kolosh and Gercus sandstones of both QFL and QmFLt plots, showing their provenance. Modal data based on petrographic point count estimations (I) Continental Block, (II) Recycled Orogen, (III) Magmatic Arc

The sandstone of the Kolosh Formation, which is characteristically of lithic – arenite type is generally associated in both applications with the "Recycled Orogen" field and particularly at its lower end. Such tendency, which reflects certain variance of the studied samples, is considered to indicate a provenance characterized by either foreland uplift and/ or subduction complex. The relatively, low amount of quartz, feldspar, and chert detrital grains in these sandstones indicate low ratio of oceanic/ continental components (Schwab, 1984), which favor the foreland uplift setting (Dickinson and Suczeck, 1979).

The Gercus Formation's sandstones, on the other hand show, some how, different tectonic environment and provenance. In both applications (QFL and QmFLt), the samples show distribution among the areas between "Recycled Orogen" (II) and the "Magmatic Arc" provenance (III) (Fig.8). This distribution involves immature sandstone, rich in lithic fragments.

The specific distribution of the samples at the lower end of the magmatic arc provenance indicates an association with an undissected arc rich in volcanic detritus (Dickinson and Suczeck, 1979).

The abundant amount of feldspar, igneous and metamorphic rock fragments in the Gercus Formation's sandstones witness the influence of the volcanic activities. The uplifted foreland setting of the source area, however, still represents the major tectonic aspect of these detrital sediments.

HEAVY MINERALS ANALYSIS

Heavy minerals analysis was carried out on eighteen samples from Gercus and Kolosh formations (9 samples from each). Samples were treated with 10% HCl to dissolve carbonates. The residues were processed with bromoform (Sp. Gr. 2.89), in order to separate heavy minerals according to the method suggested by Rittenhouse (1943). The heavy minerals fraction was examined under the polarizing microscope for identification and semi-quantitative estimation of its amount (Table 1).

The heavy minerals content is generally low in the sandstones of both formations. It is mainly composed of opaque minerals including: chromite, magnetite, hematite, pyrite, and chrome-spinal. Smaller amounts of hornblende, chlorite, and epidote are recorded in most of the examined samples of both formations, and very small amount of zircon and tourmaline recorded in some of the samples. Rare occurrences of biotite, garnet, rutile, muscovite, sericite, serpentine, topaz, and kayanite are also observed.

Members of the actinolite – tremolite series, glauconite and sphene, are recorded in Kolosh Formation only. Glauconite grains are recorded in the lowermost part of the Kolosh Formation only. Their presence indicate an aerobic or slightly reducing conditions and low rate of sedimentation (Pettijohn, 1975), at the deep marine facies of this part of the Kolosh Formation. The persistent occurrence of chromite and serpentinite, in both formations, imply the contribution of ophiolite suites to these sandstones. The biotite and the abundant opaques of these sediments, on the other hand, are taken to indicate an important participation of volcanic suites in the source area (Manutsoglu *et al*., 1997), although metamorphic suites have being reported from other areas (Al-Qayim and Shihab, 1996).

In comparison between the two formations, both seem to be dominated by the occurrence of opaque minerals. The occurrence of chromite, rutile, and magnetite together suggests that basic igneous rocks form, at least, part of the source area. The occurrence of hematite in Gercus Formation's sandstones is possibly derived by oxidation and/ or alteration of other Fe-rich minerals during transportation, deposition, and early diagenesis (Al-Rawi, 1983 and Dhannoun *et al*., 1988). The possible occurrence of metamorphic rock exposures at the source area is indicated by recognition of kayanite, garnet, actinolite – tremolite, chlorite, as well as blue green hornblende (Milner *et al*., 1962; Fuechtbauer, 1974 and Freidman and Johnson, 1982).

CLAY MINERALOLOGY

Eight samples from both Gercus and Kolosh formations (four samples each) were analyzed by X-ray diffractometer in order to determine the types and relative abundance of clay minerals, in both formations as well as elucidating any differences between them.

The procedures of Carroll (1970) are used herein for the preparation of clay samples. Separation of less than 2 micron size fraction was done following Folk (1974). Heating and ethylglycolation treatment of the samples was following Carroll (1970) and Grim (1968). The prepared samples were analyzed by X-ray diffraction method, using Philips PW 1050.

Identification processes for clay minerals chart were done following Grim (1968), Carroll (1970), Millot (1970) and Thorez (1975). The relative abundance of the identified clay minerals was estimated on the bases of the height and width of the characteristic deflection peaks after Carroll (1970) and Carver (1971). The identified minerals and their relative abundance are summarized in Table (2), whereas the diffractograms are shown in Fig. (9).

The clay mineral assemblages of the two studied formations show clear differences in both composition and distribution. The palygorskite mineral is restricted to the uppermost part of the Gercus Formation only, whereas, it is absent in the Kolosh Formation.The formation of palygorskite takes place either in epicontinental seas and lakes as chemical sediments, or by destruction of former clays during early diagenesis (Singer, 1980 and Dhannoun *et al*., 1988). Therefore, the restricted occurrence of the palygorskite to the Gercus Formation's sediments imply that these sediments have, at least, partly formed under continental conditions. The occurrence of kaolinite and palygorskite together suggests an intense weathering and less relief of source area (Deconinick and Bernoulli, 1991). Illite is recognized in the lower part of the Kolosh Formation only. Grim (1968) and Millot (1970) had concluded that the presence of illite along with chlorite indicates shale and metamorphic rocks in the source area.

Table 1: Heavy mineral assemblages and their relative abundance in sandstones of the Kolosh (A) and Gercus (B) formations
(B: 60 – 30%, C: 30 – 15%, D: 15 – 7.5%, E: 7.5 – 3%, F: 3 – 2%, G: 2 – 1%, H: <1%)

A Heavy Minerals / Kolosh Samples	Chromite	Hematite	Magnetite	Pyrite	Chrom-Spinel	Hornblend	Chlorite	Epidote	Actino-Trem	Zircon	Tourmaline	Garnet	Biotite	Muscovite	Sericite	Serpentinite	Topaz	Rutile	Kyanite	Glauconite	Sphene
K-18	E	C	C	C	C	B	D	G	B	H	–	H	–	–	–	C	–	H	–	D	–
K-22	E	G	G	G	G	B	E	G	C	–	–	–	H	–	–	G	–	H	H	F	H
K-33	E	E	E	F	F	B	E	C	E	H	H	–	H	–	–	H	–	–	–	F	H
K-43	E	E	E	F	F	C	C	D	E	H	H	H	–	–	H	–	–	H	–	F	–
K-60	E	E	E	F	F	C	C	E	E	H	H	H	–	–	–	G	–	G	–	G	–
K-70	E	D	E	G	E	C	D	F	E	H	H	H	H	H	–	G	G	–	–	G	–
K-77	F	D	C	C	E	C	C	F	E	H	E	H	H	H	G	C	C	–	H	H	–
K-105	F	D	D	G	E	D	C	F	G	H	E	G	H	H	G	H	H	H	H	–	H
K-155	F	D	D	F	E	C	D	G	–	–	G	G	–	G	C	H	H	H	H	–	H

. . . cont. table 1

B Heavy Minerals / Gercus Samples	Chromite	Hematite	Magnetite	Pyrite	Chrom-Spinal	Hornblend	Chlorite	Epidote	Zircon	Tourmaline	Garnet	Biotite	Muscovite	Sericite	Serpentinite	Topaz	Rutile	Kyanite
G-2	D	D	C	E	C	B	E	H	H	H	–	H	–	–	–	H	V	H
G-24	D	D	B	E	C	E	B	C	H	–	H	–	H	–	H	–	H	–
G-28	D	D	B	E	G	C	C	G	–	H	–	H	–	H	–	–	H	–
G-38	D	D	D	E	G	C	D	G	G	G	H	–	H	–	–	H	–	H
G-43	D	D	B	E	–	B	E	G	–	–	H	H	–	–	H	–	H	–
G-50	D	D	E	D	H	E	B	H	G	–	H	–	H	–	G	–		H
G-64	D	E	E	D	G	B	E	H	–	H	–	–	H	H	H	–	G	–
G-79	D	E	G	D	G	B	E	G	H	H	H	H	–	H	H	H	H	H
G-114	C	F	G	E	G	B	E	F	H	H	H	H	H	H	H	G	G	G

Table 2: Relative abundance of clay minerals identified from Gercus (G) and Kolosh (K) samples (C: Common, M: Major, R: Rare)

Sample No. / Clay Minerals	G.1	G.44	G74	G.92	K.155	K.24	K.14	K.00
Palygorskite	C	C	–	–	–	–	–	–
Vermiculite	M	M	C	–	M	–	–	–
Chlorite	R	R	R	C	–	R	–	–
Chlorite – Vermiculite CH – V	–	–	M	–	–	–	–	–
Kaolinite	R	R	–	R	–	R	–	–
Montmorillonite	–	–	–	M	–	M	–	C
Illite	–	–	–	–	–	–	M	M

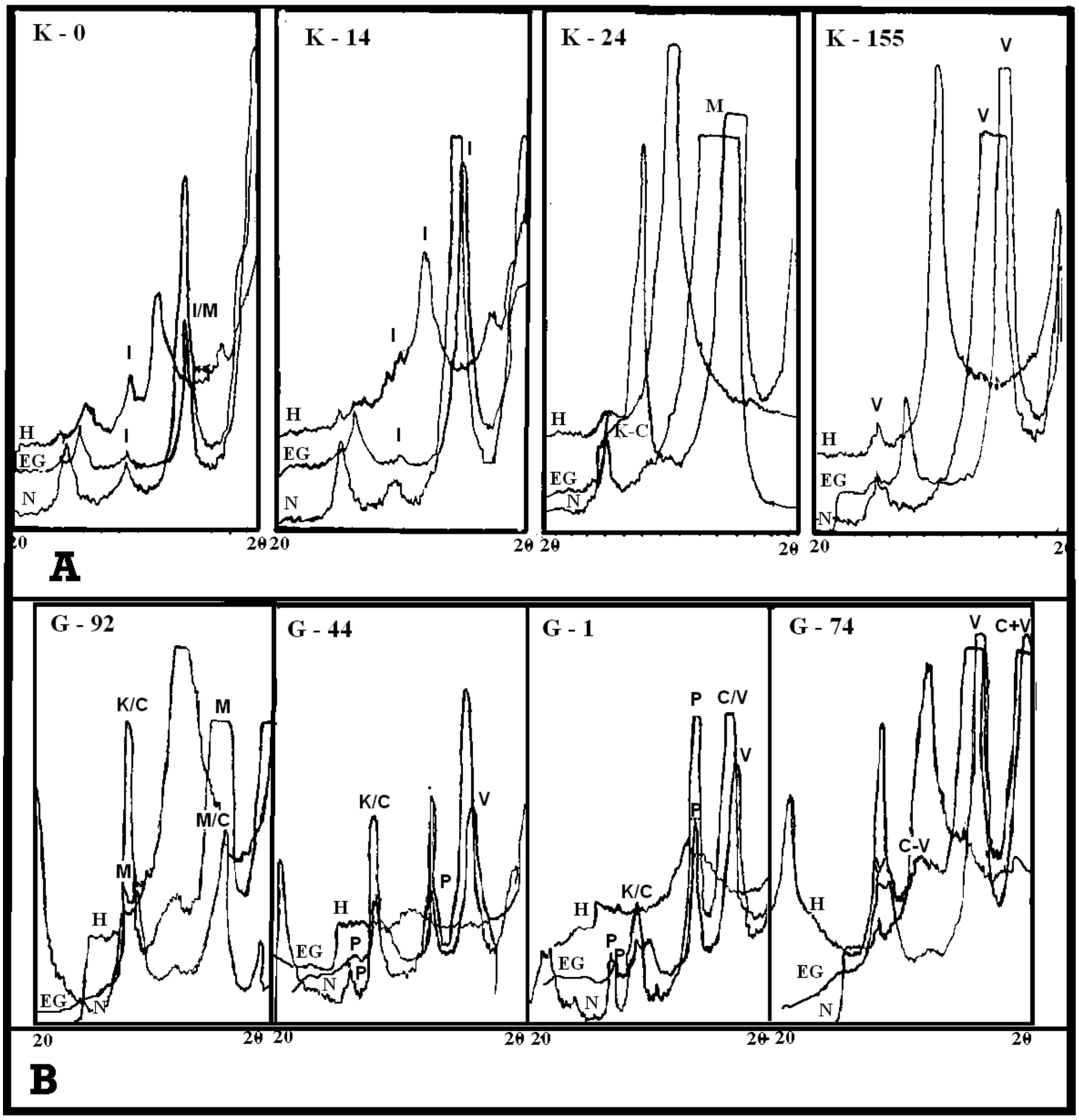

Fig.9: Diffractograms of representative samples from Kolosh (A) and Gercus (B) formations (H: Heated, EG: Ethylglycolitic, N: Normal, V: Vermiculite, M: Montmorillonite, I: Illite, P: Palygorskite, K: Kaolinite, C: Chlorite, C+V: Chlorite – Vermiculite mixed layer)

SEDIMENTARY BASIN EVOLUTION

The Paleogene sediments of the Kolosh and Gercus formations in Shiranish area seem to show a great resemblance to their counterpart's characters at the northeastern part of the basin, i.e. Bekhme, Shaqlawa, Haibat Sultan, Dokan, Taslujah, Qara Dagh, Derbandikhan areas. In all these areas the sediments of Kolosh and Gercus formations were proven to show evidences of flysch and molasse facies, respectively (Al-Rawi, 1980; Al-Qayim and Salman, 1986; Al-Qayim *et al.*, 1988a; Al-Qayim *et al.*, 1988b; Al-Qayim *et al.* 1994 and Al-Qayim and Al-Shaibani, 1995). Both formations represent an integral sequence of basin-fill stage of the Paleogene Foreland Basin, which is developed between the advancing orogenic front of the protozagroside and the Arabian margin on the other side (Al-Qayim, 1993 and 1995 and Alavi, 2004). The advancing orogenic front is believed to represent a subduction complex (Al-Qayim, 1993 and 1995), or an obducted slivers (Jassim and Goff, 2006) of ophiolite and radiolarite, which are equivalent to the Zagros Massif. This uplifted complex had significantly contributed to the abundant clastics wedge of the Paleogene Foreland Basin. Similarly, the sediments of Kolosh and Gercus formations of Shiranish area are believed to have been deposited in similar foreland setting, but probably of different components. The advancing orogenic front of this area belongs to the Bitlis Massif of southeast Turkey, which is obducted over the northern margin of the Arabian Plate (Robertson, 2000). The Shiranish area seems to represents the distal part of the basin, which extends over most of north – northwestern part of Iraq. The proximal part of the basin covers the southeastern part of Turkey (Hakkari area) and known as the "Cungus" Paleogene Basin (Sengor and Yilmaz, 1981). The distal part of this basin is developed over northern Iraq and continues into Shiranish area and southwards (Fig.10).

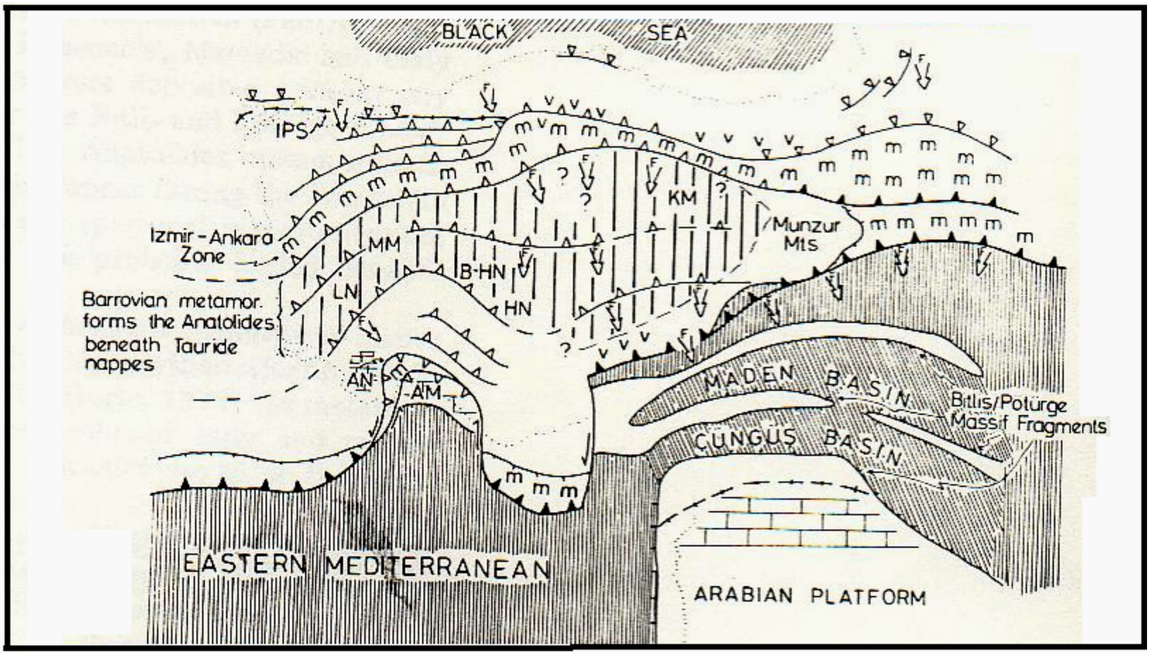

Fig.10: Paleotectonic map of Early – Middle Eocene of Southeastern Turkey
(from Sengor and Yilmaz, 1981)

The Cungus basin is developed during Paleocene – Eocene time and reaches its maximum development during Eocene, after collision between the Bitlis Massif with the Arabian Platform (Fig.11A). It receives about 2000 m of flysch and olistostrom sediments mainly from the advancing nappes (Kamen-Kaye, 1971). These sediments show strong evidences of arc magmatism including calc – alkaline andesitic lava, pyroclasts, volcanogenic flysch, pillow lava, and recycled Tauride turbidite (Sengor and Kidd, 1979 and Sengor and Yalmiz, 1981). The influence of these Eocene arc-type volcanics seems to reach Shiranish area of the basin and have their signatures on the sediments of the Gercus Formation. The relatively high feldspar contents, the tendency towards magmatic arc provenance and the upward increase of the igneous and metamorphic rock fragments in the Gercus Formation all support that influence and approve the extension of the Cungus basin over Shiranish area and beyond. The evolution of this foreland basin, according to Sengor and Yilmaz (1981), seems to have being

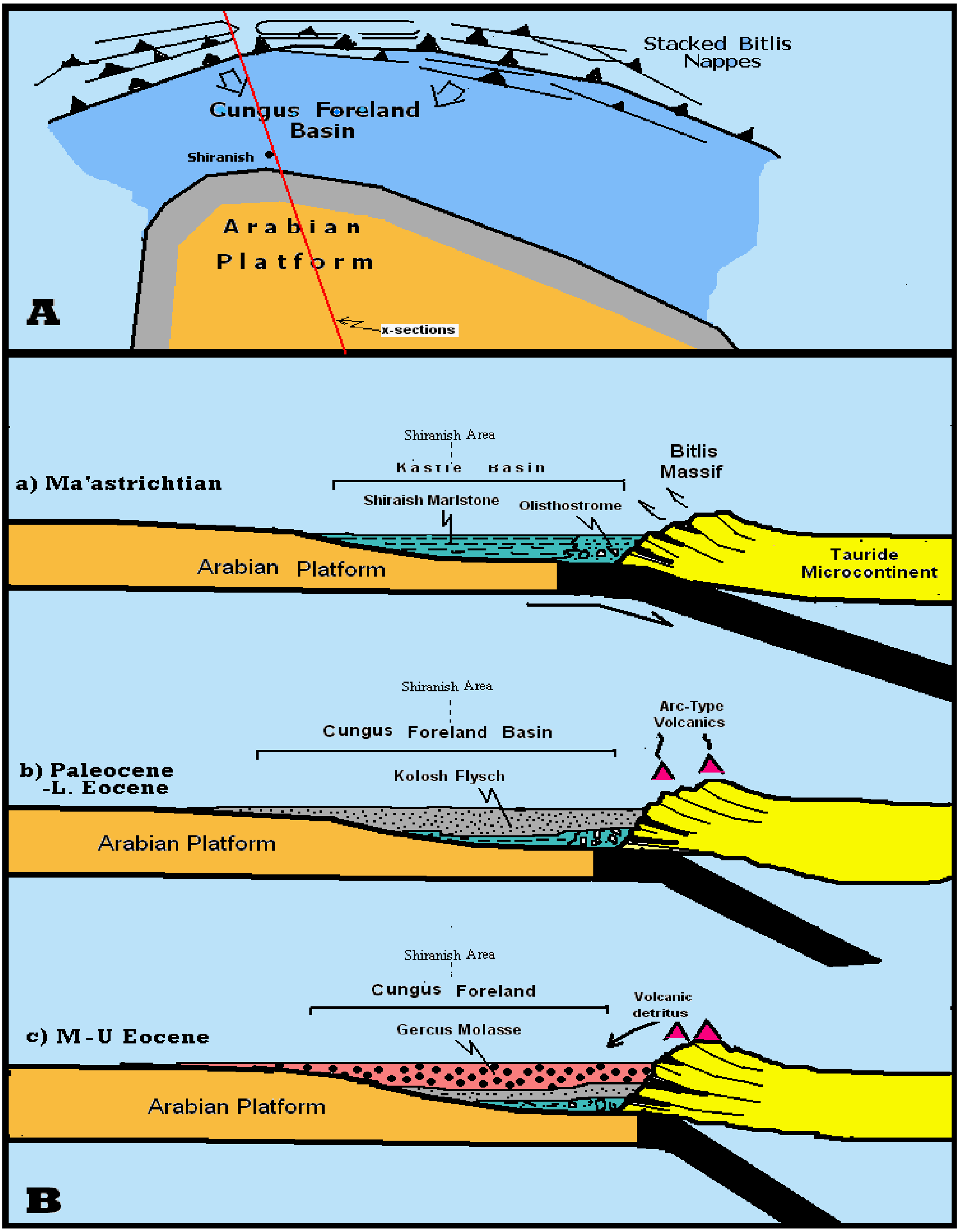

Fig.11: A schematic illustration of the evolution of the Paleogene foreland basin of North Iraq (A: Map view, B: Cross sectional presentation of basin evolution)

started over after filling of the precursor Maastrichtian foredeep “Kastle” basin of southeastern Turkey (Fig.11B). The flysch fill of the foreland basin began during the Paleocene – Early Eocene (Kamen-Kaye, 1971 and Sengor and Yilmaz, 1981), and represented in Iraq by the flysch-type sediments of the Kolosh Formation (Al-Qayim *et al*., 1988 a and b). The lacking of coarse clastics and other proximal facies such as olistostromes within the Kolosh Formation, in the studied area, imply a distal location from the uplifted and advancing orogenic front.

During the Early Eocene time and after shoaling of the flysch sequence the clastics fill of the basin changed into the sub-continental red beds of the Gercus molasses sediments. The Eocene arc magmatism of the Bitlis Massif (Sengor and Yalmiz, 1981), which is believed to represent a continental margin arc settings (Robertson, 2000) are reflected on the Gercus Formation’s sediments mineralogies and approve the unity of this extensive foreland basin of North Arabia. By the end of the Middle Eocene and after complete fill of the foreland, the area was subjected to marine transgression whereby the Pila Spi Formation of north Iraq and its equivalent the Midyat Limestone of southeast Turkey (Kamen-Kaye, 1971) was deposited over most of the Gercus Formation’s molasse. Owing to the extensive distribution of the sediments of Kolosh and Gercus formations over the northern part of Iraq, which reaches Mosul area, as in well Kand-1 (Bellen *et al*., 1959), this part of the foreland basin is considered to be wider and possibly less disturbed, as compared to its equivalent extension in the northeastern part of Iraq.

CONCLUSIONS

- The flysch – molasse sediments of the Kolosh and Gercus formations of Shiranish area, respectively, were deposited in an extensive foreland basin developed over the Northern Arabian margin during the Paleocene – Eocene period.
- This basin, which represents the distal part of the “Cungus Basin” of Southeast Turkey is developed as a result of the flexural subsidence of the Arabian Platform under the influence of the obducted nappes of the Bitlis Massif.
- The Eocene arc magmatism of the Bitlis complex is overprinted in the detrital grain type and mineralogies of the Gercus Formation’s sandstones.
- The overall sedimentological characters of the Gercus Formation’s clastics indicate subcontinental sequence of foreland molasse origin.
- The lithofacies association of the Kolosh Formation’s sediments suggests deposition in a detached submarine fan complex by a low - density turbidity currents.

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