PETROGRAPHIC AND BIOSTRATIGRAPHIC STUDIES ON SEDIMENTARY SEQUENCES OF MULTANAI AREA, PISHIN BASIN, BALOCHISTAN, PAKISTAN

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Abstract: *The paper presents "Petrographic and Biostratigraphic Studies of Sedimentary Sequences on Multanai Area, Pishin Basin, Balochistan, Pakistan". The Multanai area of Pishin Basin has three dominant rock formations exposed against the Zhob Ophiolite and Thrust Belt. These rock formations are Eocene Nisai Formation overlain by Khojak Formation of Oligocene-Miocene age. The Khojak Formation consists of two Members: Murgha Faqirzai Member and Shaigalu Member. The topmost formation, which overlies the Shaigalu Member is Multanai Formation of Pliocene age. The field relations and lithologies are presented. The Nisai Formation (1027m), Murgha Faqirzai (1200m) and Shaigalu Members (3000m) of the Khojak Formation, are being studied petrographically for the first time, describing their mineral composition and biostratigraphy. Twenty samples were studied for the lithologic composition of Nisai Formation (eleven), Murgha Faqirzai Member (four) and Shaigalu Member (five). Another twenty samples were studied for biostratigraphic information of Nisai Formation (four), Murgha Faqirzai Member (fourteen) and Shaigalu Member (two). This pertinent information rendered mineral composition of the above mentioned formations and biostratigraphic data for determining their ages and provenance which indicated that their source material was transported from Afghanistan. The Nisai Formation consists of rocks, such as, basal breccia, biomicrite wackestone-packstone, biomicrite packstone to grainstone, sparitic litharenite, intrasparite clastic rocks and bioclastic micritic grainstone. The bioclasts found in these rocks are Nummilites perforatus, Alveolina sp, Assilina granulosa, Discocyclina dispensa. The Murgha Faqirzai Member is comprised of rocks, which are mostly bioclast (Nummulites fichteli) supported litharenite derived from granite and volcanic source rocks. The rocks of Shaigalu Member are of clastic nature with bioclast fragments of mollusca and gastropoda. The rocks are mainly cherty quartzitic and bioclast fragments supported.*

Keywords: Petrography, biostratigraphy, Nisai, Murgha Faqizai and Shaigalu Member, Eocene-Oligocene, Pishin Basin, Multanai Area, Balochistan

INTRODUCTION

The Multanai block is situated in the north-eastern part of the Pishin Basin, Balochistan-Pakistan and is located around the Nisai-Murgha Faqirzai Rud area, northwest of Muslim Bagh, N Balochistan (Fig.1). The study area falls in Toposheet No. 34 M/16 of Survey of Pakistan (Scale 1: 50,000) and can be approached from Muslim Bagh through Nisai on Quetta-Zhob Road and from Nisai via a shingle/jeepable road at a distance of 12km towards north (Fig. 1). The present research work is an outcome of a geological survey, which was conducted in the Multanai area, Pishin Basin as regular study program of the Paige Limited, to evaluate hydrocarbon potential and to thoroughly investigate the exposed rock succession. The stratigraphic column of the study area is comprised of Eocene to Pliocene-Pleistocene formations. These formations constitute the entire rocks exposure of the study area (Table 1).

The Multanai area has three dominant rock formations exposed against the Zhob Ophiolite and Thrust Belt. These major formations include: the Eocene Nisai Formation, Oligocene-Miocene Khojak Formation and Pliocene Multanai Formation (younger molasses). The Khojak Formation consists of two members: Murgha Faqirzai Member and Shaigalu Member.

The Nisai Formation has a thrust faulted contact with a mélange zone. The zone along this thrust has ultramafic-mafic and volcanogenic rocks occurring as breccia and chunks.The Nisai Formation is overlain by Khojak Formation. The upper contact of Nisai Formation with Murgha Faqirzai Member is unconformable represented by the conglomeratic jumbled mass of angular, sub-rounded to rounded pebbles, cobbles and boulders of limestone, marl, jasper and sandstone. The topmost formation, which overlies the Shaigalu Member of the Khojak Formation is Multanai Formation of Pliocene age.

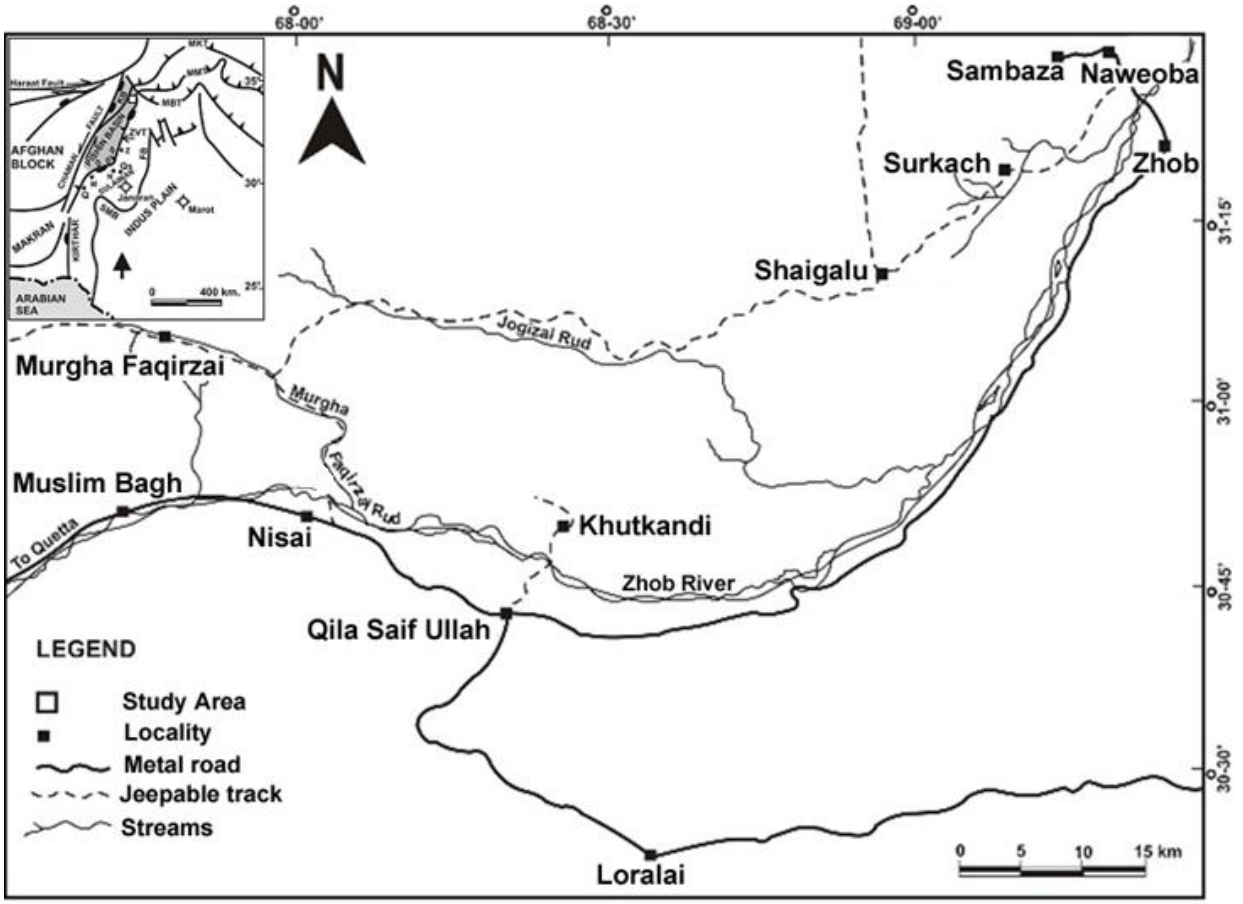

Fig. 1 Showing the Location of Pishin Basin (In-set Map) and Access Map of the Study Area, Multanai Block, in the North East of Pishin Basin-Pakistan (Modified after Nizami, *et al.*, 2008 and Ahmad and Afzal, 2002).

GEOLOGICAL SETTING

The Pishin Basin is, also, known as the Kakar Khorasan Flysch Basin (Kazmi and Jan, 1997) occupied the NW corner of the Indo-Pakistani Plate since Eocene epoch and now is lying along eastern and northeastern edge of Chaman Transform Fault and to the north of Zhob Ophiolite and Thrust Belt (Fig. 1). It is bounded to the south and east by the Zhob and Shinghar Chukhan Manda Faults respectively. Westwards it is terminated by the Chaman Transform Fault. As its geological locations suggests that it is sandwiched between two major tectonic features, i.e., Chaman Transform Fault and Zhob Valley Thrust (Kazmi and Jan, 1997). The Multanai Block area is intensely deformed structurally, which is evident from the high values of dip of beds and from presence of faults and folds in the area. Important structural elements of the area are thrust faults and folds (particularly tight anticlines and wide synclines). The Pishin Basin started receiving sediments from the north in Eocene times, which continued until Pleistocene (Ahmad, 1991). Structurally the area is represented by broad synclines and tight anticlines that are cut by reverse faults and thrust faults over the southern Zhob Ophiolites (Iqbal, 2004).

Nisai Formation

The term 'Nisai Group' was first used by the Hunting Survey Corporation (1961) for the complex assemblage of the sedimentary sequence comprising of limestones, shales, and subordinate sandstones. Shah (2009 and 1977) redefined these rocks as Nisai Formation. The basal black shale of the formation resemble in facies and fossil contents with shale of upperpart of the Paleocene-Eocene Patala Formation of Potwar Basin, Northern Pakistan (Ahmad and Afzal, 2002). This formation lithologically is dominated by a massive reefoid limestone of Eocene age based on larger foraminifera. The subordinate lithology comprises shale with minor local development of sandstone and conglomerate. The formation is about 1027m thick in the studied area. The sampling was carried out on the bases of variation observed in the field.

Table 1 Stratigraphic Column of the Study Area Showing the Entire Rock Exposure and Studied Formations (Bold) of the Multanai Block, NE Pishin Basin-Pakistan (Modified after Ahmad and Afzal, 2002)

<table>
<tr><td colspan="3">AGE</td><td rowspan="2">FORMATION</td><td rowspan="2">MEMBER</td></tr>
<tr><td>ERA</td><td>PERIOD</td><td>EPOCH</td></tr>
<tr><td rowspan="8">COENOZOIC</td><td colspan="2">Recent</td><td colspan="2">Alluvial Sediments</td></tr>
<tr><td colspan="4">Angular Unconformity</td></tr>
<tr><td rowspan="3">Neogene</td><td rowspan="2">Plio-Pliestocene</td><td colspan="2">Bostan</td></tr>
<tr><td colspan="2">Multanai</td></tr>
<tr><td>Miocene</td><td rowspan="2">Khojak</td><td>Shaigalu</td></tr>
<tr><td rowspan="3">Paleogene</td><td>Oligocene</td><td>Murgha Faqirzai</td></tr>
<tr><td colspan="2">Unconformity</td></tr>
<tr><td>Eocene</td><td colspan="2">Nisai</td></tr>
<tr><td colspan="5">Non-conformity</td></tr>
<tr><td>Mesozoic</td><td>Cretaceous</td><td colspan="3">Ophiolite Melange</td></tr>
</table>

A wide range of carbonate microfacies (Nizami, *et al.*, (2008) and siliciclastic facies characteristic of shallow marine to basinal setting are with these sequences. The organic rich facies i.e., the basal black shales and black limestone are associated with transgressive system tracts whereas low land deposits are conglomerates, sandstone etc. (Ahmad and Afzal, 2002). On the other hand organic and inorganic carbonates were formed in the basinal turbidities and shelf settings.

The Nisai Formation as a whole consists of limestones, marl, shale with subordinate sandstone and conglomerate. However, limestone of grey, dark grey, grayish brown colours and variable texture constitute the dominant lithology in many part of the basin. The limestone is massive, brecciated, reefoid and shelly. The argillaceous well bedded limestone of grey to black colour is also present. The shale beds are grey, green, maroon, yellow and brown, usually calcareous, flaky to fissile and sometimes are hard. The sandstone beds are grey, brown, green and whitish which weather to dark grey colours. They are generally fine-grained to very fine grained, poorly to sometimes well sorted.

The Nisai Formation is considered Early to Late Eocene on the basis of foraminiferal population consisting of *Alveolina, Assilina, Nummulite, Discocyclina* (Ahmed and Afzal, 2002). The Nisai Formation was deposited in marine conditions from 200m to 50m to as shallow environment as 10m or less.

Khojak Formation

The Khojak Formation conformably overlies the Nisai Formation (Shah, 2009, HSC, 1961 and Vredenburg, 1909). It is divided into Lower Murgha Faqirzai and Upper Shaigalu Members. The age of formation ranges from Eocene to Early Miocene.

Murgha Faqirzai Member: It is comprised of grey, green to brown calcareous and arenaceous shales. It, also, contains turbidites, prodelta-type laminated mudstone to upward thickening sandstone sequences (Kazmi and Jan, 1997). This Member is widely exposed in the Pishin Basin as part of the Axial Belt. The thickness of the Member is 1200m in the Murgha Faqirzai stream section.

The contact of Murgha Faqirzai Member with Nisai Formation is unconformable as mentioned above in the Nisai Section whereas its upper contact is conformable and gradational with the Shaigalu Member of Miocene age.

The Murgha Faqirzai Member contains a number of foraminiferas, molluscs and echinoids (Hunting Survey Corporation, 1961). The Oligocene foraminifera, like, *Lepidocycliona dilalata, Nummulites fichteli and N. intermedius* are found.

Out of these, however, the *Nummulites fichteli* is a diagnostic index fossil of the Oligocene age (Plate A, Fig. 1). However, presence of *Nummulites perforatus* in the lower beds is suggestive of an Eocene age (Plate A, Fig. 2) for the lower part of the Murgha Faqirzai Member.

Shaigalu Member: The Shaigalu sandstone sequence of Hunting Survey Corporation (1961) has been termed as Shaigalu Member (Shah, 2009).

The Shaigalu Member is mainly composed of fine to medium grained sandstone which is dark grey on fresh surface whereas its weathered color is dark brown to grayish brown. Quartz veins criss-cross the sandstone at some places. It, also, contains laminated light grey shales which are mainly splintery.

The Shaigalu Member is medium to thick bedded, showing cross stratification, poorly sorted, calcareous, micaceous and protoquartzitic to orthoquartzitic sandstone with interaformational conglomerate. It is characterized by the upward fining sequence, multicoloured mudstones and paleosols. Therefore this Member has been interpreted as deltaic plain deposits. The Member is medium to thick bedded, which sometimes contains calcareous bands. The thickness of Member in the studied area is about 3000m. Its lower contact with Murgha Faqirzai Member is conformable and transitional.

Shah (1977) has assigned Miocene age to this Member on the basis of mammal fossils and correlated it with Murree Formation of Potwar Basin, Pakistan.

The cross-bedding and lithology show that the Member was deposited in fluvial environment. Angular to subangular nature of grains show that the provenance is not far away. Interaformational conglomerates mark each uplift cycle in the area.

MATERIALS AND METHODS

The Khojak Formation consists of two Members: Murgha Faqirzai Member and Shaigalu Member. The Nisai Formation (1027m), Murgha Faqirzai (1200m) and Shaigalu Members (3000m) of the Khojak Formation, are being studied petrographically for the first time, describing their mineral composition and biostratigraphy. Considering the rock forming minerals and fossil contents as the basic rock constituents, systematic sampling for detailed microscopic study was carried from each exposed lithostratigraphic unit. Twenty (20) fresh rock samples were collected from the outcrops for petrographic studies and another twenty (20) samples were collected from fossiliferous zones for paleontological and biostratigraphic studies.

All the 40 rock samples were cut to make thin sections preparation, which were made according to International standard and practice. Petrographic studies were carried out all of them under polarizing microscope and presented under the heading of petrography. These investigations include: grain size, shape, minerals and rock-clast relationship. The details like mineral composition, rock fragments, bioclasts and their respective percentages, etc. are grouped under the subheading rock constituents.

RESULTS AND DISCUSSON

Twenty samples for petrographic and twenty other samples for biostratigraphic studies were procured. In this way a total of forty rock samples were studied in this investigation. The sampling was carried out on the bases of variations observed in field. In the biostratigraphic descriptions only those voids or opening are mentioned which are primary.

Petrographic Description

General: Twenty samples were studied for petrography. Eleven of them were from Eocene Nisai Formation, four samples from Oligocene Murgha Faqirzai Member and five samples from Miocene Shaigalu Member of Khojak Formation.

The Nisai Formation samples are of limestones which are bioclast fragments supported micrite and ferroan micrite cemented by sparite. Another major facies is of quartz/lithoclast micrite. Two samples, ST-1 and ST-15, are breccia of lithoclasts coarse up to pebbles.

The Oligocene Murgha Faqirzai rocks, under the microscope, are mainly very fine-grained to medium-grained litharenite rocks. Their clasts are, also, cemented by post deposition circulating carbonate solutions depositing spary calcite in the interstices. The origin of these rocks is suggestive to be from granitic and volcanic source rocks.

The Miocene Shaigalu Member of the Khojak Formation shows that the two samples are very fine to medium-grained litharenite, the grains of which are cemented by sparitic calcite. The source (provenance) of these rocks is, also, from granitic and volcanic rocks.

Two samples, sample ST-19 and ST-20, happened to be anomalous and do not relate to sedimentary formations. The sample ST-19 is an altered rock of ultramafic origin and sample ST-20 is of volcanic origin, as it is mainly chalcedonic/cherty clast bearing but all the clasts have been cemented by volcanic material, like volcanic glass.

Nisai Formation: The rock samples, ST-2, ST-3, ST-5, ST-7, ST-8, ST-11, ST-14, ST-15 and

ST-18, were studied under the microscope. These are mainly of limestone which consists of two to three major components identified under the microscope. They are micrite with (sometimes) ferroan micrite, bioclast/fragments of fossils, and sparite. The minor minerals associated are hematite/ limonite and pyrite. These rocks are extremely fine-grained in which micrite is dominant as micritic groundmass. It is cut by veinlets 2 to 5mm in thickness where spary calcite crystallizes in which sparite grains are 0.1 to 0.4mm in thinner veins and 1 to 5.3mm in thicker veins (Sample ST-2). The micrite occurs as rounded clasts (Sample ST-18) along with bioclasts recrystallized to sparite. The micrite mass hosts bioclastic grains. Most of the bioclasts have sizes 0.1 to 0.5mm, however, larger bioclasts are in ST-18 (up to 1.1mm) and ST-15 (up to 2.7mm). The quartz particles are very fine-grained to 2.2mm whereas chert clasts are 2 to 3mm in size (ST-1) and in ST-13 the grain size is 0.04 to 0.15mm (ST-13).

Petrographically different elements of Nisai Formation are studied in detail. The brief description of which is presented below and their amount (%) is given in Table 2.

The micrite in these rocks is 30 to 65% except in two facies which are sandy (ST-1 and ST-13), where micrite is 9 and 10% respectively and quartz 30% and 47% respectively.

Ferroan Micrite is 10 to 18% in four rocks samples, i.e., ST-3, ST-5, ST-7 and ST-17.

Sparite is invariably presented in all the rocks (Table-2) from 13% to 30% (ST-11).

Bioclasts are present in all the rocks except in samples, ST-1, ST-3, and ST-13. In all other rocks bioclasts are 5% to 47%. Quite high numbers of bioclasts are found in ST-8 (47%), ST-14 (35%) and ST-11 (30%) as shown in Table 1.

Pyrite is quite low (1 to 2.5%) in these rocks, however, quite significant.

Hematite/Limonite are, also, ubiquitous but are very low in amount as well (0.5% to 3%) except in ST-13 where they are anomalously high up to 10%.

Quartz in two rocks is 30% (ST-1) and 47% (ST-13), where it is part of calcareous sandstone in Nisai Formation. 2% quartz is found in ST-14. Here it is authigenic and does not have detrital nature rather it has crystallized in situ (in the interstices).

ST-1 and ST-15 have fine-grained to granule size grains, termed as microbreccia, where ST-15 is granular to pebbly rock. ST-1 has 30% chalcedony (jasper) as granules while quartz is present in interstices with chalcedony. Calcareous material acts as cement there. In ST-15 there are three types of clasts of micrite (30%), arenaceous micrite (10%) and ferroan micrite (32%). ST-15 may be named as intrasparitic pebbly rock. Muscovite/biotite (3%), argillite (8%) and zircon (0.5%) are found only in ST-13. It constitutes an arenaceous facies in Nisai Formation.

From the petrographic analyses it appears that the Nisai Formation consists of wide varieties of rocks as breccia rocks (ST-1), Biomicritic wackstone-packstone rocks (ST-2 and ST-3), biomicritic packstone rocks (ST-5 and ST-7) biomicritic packstone to grainstone rocks (ST-11), sparitic lithorenite rocks (ST-13), skeletal grainstone (ST-14), intrasparite clastic rock (ST-15) and bioclastic micritic grainstone (ST-18).

The sample ST-19 is different from the litharenites. It is a reconstituted chlorite-talc-carbonate rock from ultrabasic mass with grain size very fine grained talc to coarser minerals, like chlorite, calcite and chromite (1.5 to 4 mm). This rock sample is reconstituted rock from the ultramafic stuff, and consists of chlorite (35%), talc (10%) and chromite 4% (No change was noticed in chromite). These grains are cemented by carbonate solution to a new rock called chlorite-talc-carbonate rock.

Murgha Faqirzai Member: Five samples, ST-9, ST-10, ST-12, ST-16 and ST-17 of this rock were studied petrographically. The results of which are presented in Table-3. These rocks are silt size and fine-grained to medium-grained litharenites. Quantitatively their grain size is 0.05 to 0.5 mm (ST-9), 0.12 to 0.3 mm (ST-10) 0.05 to 0.12 mm (ST-12), 0.1 to 0.28 mm (ST-16). The quartz grains are angular to subangular and sometimes sub-rounded to rounded and equant (ST-17) as well. Plagioclase is in subhedral to anhedral form with polysynthetic twinning. Calcite (Sparite) appears to be secondary and in most cases crystallizing in the interstices (ST-9). It, also, shows polysynthetic twinning (ST-9), however with high birefringence. Clasts of chert are very frequent in minor amount exhibiting salt and pepper texture. Clasts of argillite are sub-rounded and lath-like encrustation of limonite is masking some of grains.

Under the petrographic microscope constituent elements were recognized and their quantity was determined (Table 3) of the Murgha Faqirzai Member. Details are given below:

Quartz: 40% to 48% in samples ST-9, ST-10, ST-12, ST-16 and St-17

Plagioclase: 4% to 10% in all the five samples

Microcline: is found 4% and 3% only in samples, ST-9 and ST-10 respectively.

Micrite: 3% to 16% found in all the five samples

Sparite: 10% to 12% found in all the five samples

Chert: 5 to 10% found in all the five samples

Argellite: It is not found in ST-9. However, it is present 5 to 15% in ST-10, ST-12, ST-16 and ST-17.

Muscovite/Biotite: Present 3 to 8% in all the five samples

Hematite/limonite: Found in four samples from 4 to 6% except ST-9

Volcanic glass/clasts: 8% in three samples except ST-16 and ST-17

Voids: were seen amounting to 3% in St-9.

Zircon: It was seen in two samples, i.e., 0.1 % in ST-12 and 1% in ST-16.

The petrographic composition of rocks of the Murgha Faqirzai Member shows that they are mostly litharenties having source areas consisting of granites and volcanic rocks. These rocks have been cemented by carbonate circulating solution after the deposition of the clastic material.

Shaigalu Member: Five samples of Shaigalu Member were studied petrographically. The recorded constituents are presented in Table 3. Two of them, ST-4 and ST-6 represent rocks, which are very fine-grained to medium grained litharenites. In ST-4 general grain size of quartz is 0.1 to 0.27mm. It is angular to sub-angular in shape and is quite fresh. Sparite occurs as clasts as aggregate of very fine-grains of 0.01 to 0.03mm. The secondary sparite occurring in interastices is euhedral to subhedral (0.05mm). The texture of ST-6 is, also, of clastic nature with grains of about 0.1 to 0.35mm in size. Quartz grains are angular to subangular whereas plagioclase and microcline occur as subhedral and twinned. The spary calcite, also, shows twinning. A metamorphic clast of well aligned texture was, also, found.

Under the microscope the constituent elements found and studied in samples, ST-4 and ST-6 are documented as under:

Quartz: 40% and 25% respectively

Plagioclase: It is 9% in ST-6

Microcline: It is found only in ST-6 up to 5%.

Micrite: It is presented in ST-6 up to 8%.

Sparite: 10% and 18% respectively

Chert clasts are 4% and 5% respectively.

Argillite, also, occur as clasts which are in fact clasts having very fine grains of illite and kaolinite. In ST-4 the amount of argillite clasts is 25% and in ST-6 it is 8%.

Volcani-clasts: 10% and 7% respectively

Other minor constituents include: Muscovite 5% in ST-6, hematite/limonite 2% and 5% in ST-4 and ST-6 respectively.

Voids are up to 5% by volume in ST-6.

Petrographic study of these two samples of the Shaigalu Member reveals that both the samples are of litharenite and they are from the provenances of granite, volcanic rocks and metamorphites.

Two samples, ST-19 and ST-20, were, also, studied petrographically. ST-19 is sparite (51%), chlorite 15% & talc (10%) bearing and ST-20 contains chert (80%), volcanic clasts (12%) and chlorite (8%). The sample, ST-20 is a volcani-clastic rock which has clasts of 4 to 12 mm of chalcedony.

Table 2 Showing the Petrographic Composition of the Eocene Nisai Formation

Parameters	**ST-1**	**ST-2**	**ST-3**	**ST-5**	**ST-7**	**ST-8**	**ST-11**	**ST-13**	**ST-14**	**ST-15**	**ST-18**
Micrite	9	65	65	35	52	30	42	10	33	30	43
Ferroan-Micrite	15	-	10	18	10	-	-	10	-	10	30
Micrite Arenaceous	-	-	-	-	-	-	-	-	-	30	25
Sparite	13	20	15	23	15	20	25	15	25	20	1.5
Bioclastic Fragments	-	13	-	20	18	47	30	-	35	5	0.5
Pyrite	-	1.5	2.5	1	2	1	1	-	-	-	-
Hematite/ Limonite	3	0.5	2.5	3	3	2	2	10	2	-	-
Voids	-	0.5	5	-	-	-	-	3	3	-	-
Quartz S.S.T	30	-	-	-	-	-	-	40	2	-	-
Chalcedony Jasper	30	-	-	-	-	-	-	-	-	-	-
Muscovite Biotite	-	-	-	-	-	-	-	3	-	-	-
Argillite	-	-	-	-	-	-	-	8	-	-	-
Zircon	-	-	-	-	-	-	-	0.5	-	-	-

Table 3 Showing the Petrographic Composition of the Members of the Khojak Formation

Parameters	Miocene Murgha Faqirzia Member				Oligocene Shaigalu Member				
	ST-4	ST-6	ST-19	ST-20	ST-9	ST-10	ST-12	ST-16	ST-17
Quartz	40	25	-	-	48	40	43	41	44
Plagioclase	9	9	-	-	10	7	4	10	8
Microcline	-	5	-	-	4	3	-	-	-
Micrite	-	8	-	-	3	7	16	8	10
Sparite	10	18	51	-	10	12	10	10	10
Chert	4	5	-	80	10	8	5	8	5
Argillite	25	8	-	-	-	5	5	8	15
Muscovite / Biotite	-	5	-	-	4	6	3	8	3
Hematite/Limonite	2	5	-	-	-	4	6	6	5
Volcanic Glass/ Clasts	10	7	-	12	8	8	8	-	-
Voids	-	5	-	-	3	-	-	-	-
Zircon	-	-	-	-	-	-	0.1	1	-
Chlorite	-	-	35	8	-	-	-	-	-
Talc	-	-	10	-	-	-	-	-	-
Chromite	-	-	4	-	-	-	-	-	-

Biostratigraphic Description

General: Twenty samples were, also, provided for biostratigraphic studies by PAIGE Limited, Islamabad of Multanai Block No. 3168-1. In the biostratigraphic descriptions only those voids or opening are mentioned which are of primary origin. Four samples of them were of the Eocene Nisai Formation, fourteen from the Oligocene Murgha Faqirzai Member and two of them were only from the Miocene Shaigalu Member. Their results are presented in Tables 4 to 6.

The samples of Nisai Formation have been designated numbers as Bio-7, Bio-13, Bio-14 and Bio-20 (Table 4). These four samples are of limestones, which are bioclast supported micrite and ferroan micrite and bioclast supported sparite (Scoffin, 1987). The only non-bioclast fragments are of quartz 5% and lithoclast 7% in Bio-14. Three samples contain age diagnostic fossils of Eocene. They are *Nummulites perforatus* and *Alveolina sp* (Bio-13), *Assilina granulosa*, *Discocyclina disponsa* and *Nummulites sp*. (Bio-14) and *Discocyclina disponsa* (Bio-20). Sample No. Bio-7 does not contain any foram except coral clasts.

The samples taken from the Oligocene Murgha Faqirzai Member include: Bio-1, Bio-2, Bio-3 Bio-4, Bio-5, Bio-8, Bio-9, Bio-11, Bio-12, Bio-15, Bio-16, Bio-17, Bio-18, and Bio-19 and were studied under the polarizing microscope. The details of petrographic and biostratigraphic investigations are shown in Table-5. The age diagnostic foraminifera, the Oligocene *Nummulites fichteli* was identified in sample Bio-2 (Plate A, Fig. 1). The other samples are mostly bioclasts of the *Nummulites fichteli* and quartz supported micrite/ferroan micrite. Three samples Bio-8, Bio-9 and Bio-11 do not contain index fossil but are included in the Oligocene on the basis of their superposition.

The Miocene Shaigalu Member is represented by two samples Bio-6 and Bio-10. They are cherty quartzitic clasts and molluscan bioclast fragments supported micrite (Table 6).

Nisai Formation: Four rock samples were studied from Nisai Formation for biostratigraphical studies. They are Bio-7, Bio-13, Bio-14 and Bio-20. They are bioclast supported micrite/ferroan micrite. They are limestone in three cases and dolomite in one case (Bio-13) and have mostly three four major components. The minor minerals are hematite/limonite (2 to 3%) and quartz in one case (about 5%). Void opening are 2 to 3% in three samples. Bioclasts are 2.5 to 4.5 mm in size in Bio-7, 2 to 5.5 mm and 0.2 to 0.6 mm in Bio-13, 10 to 15 mm and 3 to 8 mm in Bio-14, 1.5 to 5.3 mm and 0.4 to 1.0 mm in Bio-20. Other grains which are coarser enough to be measured are of sparite 0.1 to 0.3 mm. The dolomite rhombs in Bio-13 are 0.3 mm across.

Plate A

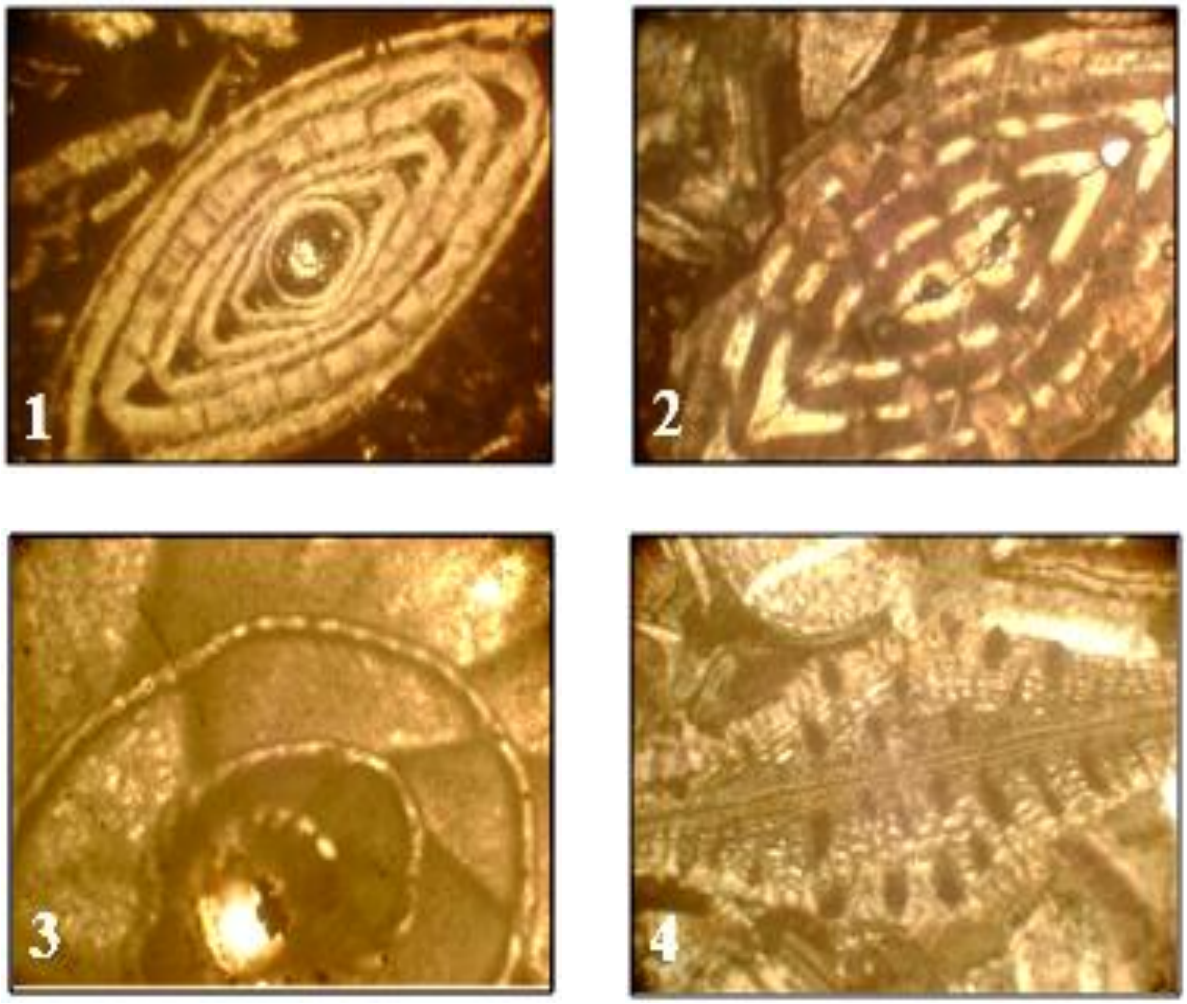

Fig. 1 Photomicrograph displays an age diagnostic foraminifera, *Nummulites fichteli* (Michelotti), indicating the Oligocene age of the Murgha Faqirzai Member of the Khojak Formation (PPL, unstained, 20 X) Sample Bio-2

Fig. 2 Photomicrograph displays age diagnostic foraminifera, *Nummulites perforatus* (Monfort), indicating the Upper Eocene age found in the Murgha Faqirzai Member of the Khojak Formation (PPL, unstained, 20 X) Sample No. Bio-1

Fig. 3 Photomicrograph displays an Eocene foraminifera, *Alveolina sp.* found in the Nisai Formation (PPL, unstained, 20 X) Sample No. Bio-13

Fig. 4 Photomicrograph displays a foraminifera, *Discocyclina dispansa* found in the Nisai Formation (PPL, unstained, 20 X) Sample No. Bio-20

Plate B

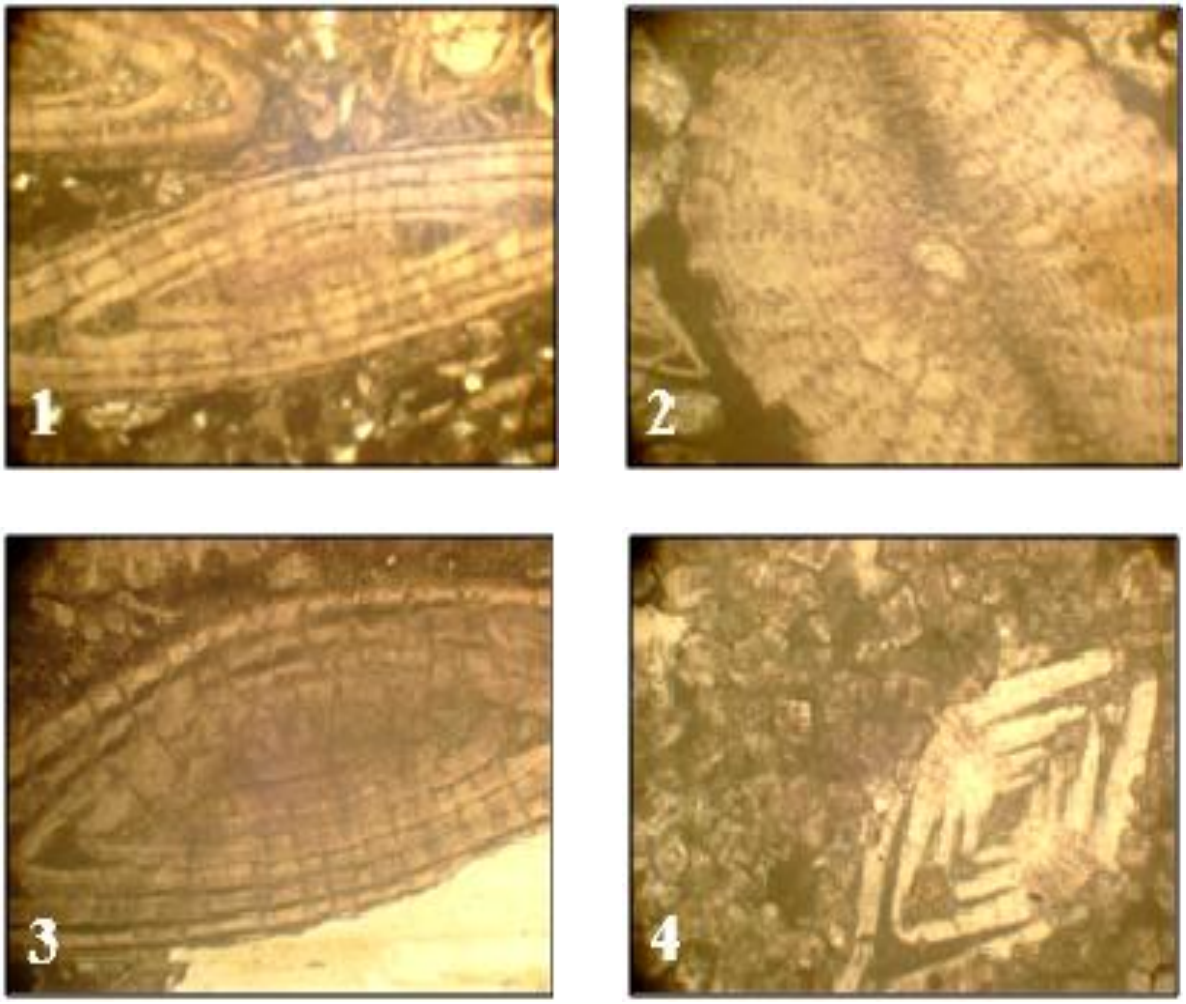

Fig. 1 Photomicrograph displays an age diagnostic foraminifera, *Nummulites fichteli* (Michelotti), indicating the Oligocene age of the Murgha Faqirzai Member of the Khojak Formation (PPL, unstained, 20 X) Sample Bio-19

Fig. 2 Photomicrograph displays an age diagnostic foraminifera, *Discocyclina dispansa* (Sowerby), indicating the Eocene age of the Nisai Formation (PPL, unstained, 20 X) Sample Bio-20

Fig. 3 Photomicrograph displays an age diagnostic foraminifera, *Nummulites fichteli* (Michelotti), indicating the Oligocene age the Murgha Faqirzai Member of the Khojak Formation. (PPL, unstained, 20 X) Sample Bio-4

Fig. 4 Photomicrograph displays an age diagnostic foraminifera, *Nummulites mamillatus* (Fichtel and Moll), indicating the Eocene age indicating the Eocene age of the Nisai Formation (PPL, unstained, 20 X) Sample Bio-13b

Table 4 Showing the Petrographic Composition and Bioclasts of the Eocene Nisai Formation

Parameters	**Bio-7**	**Bio-13**	**Bio-14**	**Bio-20**
Micrite	30	15	7	20
Ferro-Micrite	-	8	10	12
Sparite	35	3	10	18
Dolomite	-	48	-	-
Bioclasts	30	21	55	40
Quartz	-	-	5	-
Chert	-	-	-	2
Hematite/Limonite	2	3	3	8
Plagioclase	-	-	-	-
Lithoclasts	-	-	7	-
Voids	3	2	3	-
Bioclast Type	Corals	*Alveolina sp*., *Nummulites perforatus*	*Assilina granulosa*, *Discocyclina dispensa*, *Nummulites sp*.	*Discocyclina dispensa*

Table 5 Petrographic Composition and Bioclasts of the Oligocene Murgha Faqirzai Member of the Khojak Formation

Parameters	**Bio-1**	**Bio-2**	**Bio-3**	**Bio-4**	**Bio-5**	**Bio-8**	**Bio-9**	**Bio-11**	**Bio-12**	**Bio-15**	**Bio-16**	**Bio-17**	**Bio-18**	**Bio-19**
Micrite	10	3	9	8	20	30	25	25	15	20	8	51	20	15
Ferroan Micrite	1.5	30	18	20	-	-	-	-	-	-	10	-	15	7
Sparite	1.0	5	15	3	15	20	15	30	-	10	3	10	10	5
Quartz	-	1.5	10	5	7	22	20	27	32	-	12	-	-	12
Chert	-	0.5	3	-	-	-	-	-	3	-	-	-	-	-
Bioclast	60	60	45	58	56	15	1	2	20	63	55	35	37	47
Voids	0.5	-	-	6	2	-	-	1	-	-	4	4	-	-
Hematite/ Limonite	-	-	-	-	-	10	5	4	10	7	8	-	8	8
Plagioclase	-	-	-	-	-	3	6	2	15	-	-	-	-	3
Lithoclasts	5	-	-	-	-	-	24	8	-	-	-	-	10	3
Muscovite/ Biotite	-	-	-	-	-	-	4	-	0.5	-	-	-	-	-
Microcline	-	-	-	-	-	-	-	1	3	-	-	-	-	-
Bioclast Type	*Nummulites fichteli, N. perfora-tus, N. mamilatus*	*Nummulites fichteli*	*Nummulites fichteli*	*Nummulites fichteli, and Assilina granulosa*	*Corals and Molluscan shells*	*Molluscan shells*	*Deformed bivalves*	*Nummulites fichteli*	*bivalves*	*Nummulites fichteli*	*Nummulites fichteli*	*Nummulites fichteli*	*Nummulites fichteli and Discicyclina dispensa*	*Nummulites fichteli*

Table 6 Petrographic Composition of the Miocene Shaigalu Member of the Khojak Formation

Parameters	Bio-6	Bio-10
Micrite	58	25
Ferroan Micrite	-	10
Sparite	20	15
Dolomite	-	-
Bioclasts	5	40
Quartz	10	7
Chert	8	-
Hematite/ Limonite	2	3
Plagioclase	5	1
Lithoclasts	-	-
Voids	2	-

Biostratigaphically studied samples under the polarized microscope were investigated in detail. The different constitutents, thus determined, are presented in Table 4.

Micrite: It is 7% to 30% in all the four samples.

Ferroan-micrite in three samples is from 8 to12% except Bio-7 where it is not present.

Spary calcite: It is 3 to 35% and dolomite is found only in Bio-13 where it is the dominant mineral is found up to 48%.

Chert found only in Bio-20.

Hematite/limonite is, also, present in all the four samples from 2 to 8%.

Voids of 2 to 3% by volume were recorded in three samples except in Bio-20.

The diagnostic Eocene fossils were found in three samples, which include: *Alveolina sp,* (Plate A, Fig. 3), *Nummulites perforates* (Plate A, Fig. 2), *Assilina granulose*, *Discocylina dispensa* (Plate A, Fig. 4 and Plate B, Fig. 2), *Nummulites mammalitus* (Plate B, Fig. 4). In Bio-7 recrystallized corals were seen. However on the basis of superposition Bio-7 is included in Eocene. Based on the carbonate microfacies classification of Dunham (1962) of these rocks are identified as bioclastic wackestone to packstone, packstone to grainstone, grainstone, packstone to grainstone respectively.

Murgha Faqirzai Member: Fourteen samples of Murgha Faqirzai Member were studied. These include: Bio-1, Bio-2, Bio-3, Bio-4, Bio-5, Bio-8, Bio-9, Bio-11, Bio-12, Bio-15, Bio-16, Bio-17, Bio-18 and Bio-19. They were studied in details and their brief composition is given in Table 5.

The rocks are mostly bioclast supported micrite/ferroan micrite, where sparite acts as a cementing material. The bioclasts are 8 to 15 mm long and around with smaller bioclasts of 2 to 3 mm and around. The quartz grains are 0.05 to 0.14 mm and around. By the microscopic investigations different elements found are presented in Table-5.

Micrite: 3 to 51%, while ferroan micrite: 7 to 30% in seven samples.

Sparite: It is found in all samples from 3 to 30% except in Bio-12 where it is nil.

Quartz: It is found in 10 samples from 1.5 to 33% except Bio-1, Bio-15, Bio-17 and Bio-18 where it is not present.

Chert: It is found in Bio-2, Bio-3 and Bio-12: From 0.5 to 3%

Bioclasts are present in all the samples from 1 to 60%.

The index fossil of Oligocene age, *Nummulites fichteli* is recorded in eleven samples whereas others do have bioclasts, which are not diagnostic in samples, Bio-8, Bio-11 and Bio-12.

All the rocks of Murgha Faqirzai Member are bioclast supported litharenites. Oligocene age is assigned to the Murgha Faqqirzai Member on the basis of age diagnosing fossil: *Nummulites fichteli* (Plate A, Fig. 1 and Plate B, Fig. 1 and 3). The other Eocene fossils have been reworked and deposited along with *Nummulites fichteli* in the rocks of Oligocene Murgha Faqirzai Member.

Shaigalu Member: Two samples, Bio-6 and Bio-10 of the Shaigalu Member were studied under the polarizing microscope for Biostratigraphical purposes. These rocks are of clastic origin. Even the micrite is of clastic nature. These lithoclasts are angular to subangular, 1.5 to 3.0 mm in size and found in Bio-6 and with 0.6 to 1.2 mm size in Bio-10. The bioclasts are fragments (0.6 to 6.5 mm and 1.5 to 2.5 mm in both samples) of *mollusca* and *gastropoda* derived from older formations. The two samples were studied in details. Their brief composition is given in Table 6.

Sparite: Occurs as clasts of the size 0.1 to 0.5mm

Quartz grains: From 0.2 to 0.6 mm of size in Bio-10 and 0.2 to 0.3 in Bio-6

Micrite: 58% and 25% in Bio-6 and Bio-10 respectively. Ferroan micrite is present only in Bio-10.

Sparite as clasts and cement is 20% and 15% in both samples respectively.

Bioclasts are 5% and 40% in Bio-6 and Bio-10 respectively.

Quartz: It is 7% in Bio-10.

Chert: It is 8% in Bio-6.

Other minor constituents are hematite and/or limonite (2% and 3%) and plagioclase (5% and 1%).

Voids are found only in Bio-6 up to 2%.

The rocks are, therefore, cherty, quartzitic and bioclasts supported micrite (Bio-6). While Bio-10 is a bioclast supported micrite/ferroan micrite clastic rock. These two rocks have been included in Shaigalu Member on the basis of superposition/ field relation found in the study area.

CONCLUSIONS

The pertinent information, derived as a result of these investigations, provided mineral composition of the above mentioned formations and biostratigraphic data for determining their ages and provenance. Based on above research findings and discussion the following conclusions are drawn:

1. The source material of the studied rocks was transported from Afghanistan.
2. The Nisai Formation consists of rocks, such as, basal breccia, biomicrite wackestone-packstone, biomicrite packstone to grainstone, sparitic litharenite, intrasparite clastic rocks and bioclastic micritic grainstone. The bioclasts found in these rocks are *Nummilites perforatus, Alveolina sp, Assilina granulosa and Discocyclina dispensa*.
3. The Murgha Faqizai Member rocks of the Khojak Formation are mostly bioclast (*Nummulites fichteli*) supported litharenite derived from granite and volcanic source rocks.
4. The Shaigalu Member rocks of the Khojak Formation are of clastic nature with bioclast fragments of *mollusca* and *gastropoda*. The rocks are mainly cherty quartzitic and bioclast fragments supported.

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