Sequence Stratigraphy of the Mixed Carbonate-Siliciclastic System of the Eocene Nisai Formation, Pishin Basin: Distribution of Source Rocks and Reservoir Facies*

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Abstract

The Paleocene ophiolite obduction divided the Neo-Tethys oceanic floor into the Indus Basin on the Indian Shield and the Pishin Basin between the Ophiolites and Afghan Block. The basin started to receive sediments in Eocene times from the northeast direction that continued until Pleistocene. The unexplored sediments of the Pishin Frontier Basin of Pakistan deserves a sequence stratigraphic approach as a first-hand exploration tool. The Early to Late Eocene Nisai Formation, which is a mixed carbonate-siliciclastic system, is focused upon for its physical stratigraphy, sedimentary facies, depositional environments and biostratigraphy in order to outline the source rocks and reservoir facies within the sequence stratigraphic framework.

Within the Nisai Formation, one 2nd order sequence and nine 3rd order sequences have been identified in two surface sections. Their regional correlation through fine-tuned dating helped to develop a basin fill model and to understand facies dynamics. A facies belt comprising a wide range of carbonate and siliciclastic facies characteristic of shallow marine inner shelf to a slope basinal setting is associated with these sequences and represents southwestward progradation. Four horizons showing two types of source rock facies (dark gray to black shales and black limestone) mostly associated with transgressive and highstand system tracts are delineated. The lowstand deposits (conglomerates, coquinal limestone and calcareous sandstones) and highstand deposits (coquinal and reefal limestone) from the basinal turbidites and shelf settings, respectively identified, are the potential reservoirs facies. This study indicates that the Nisai Formation possesses a complete petroleum system with multiple source rock and reservoir targets for future exploration.

Introduction

The Pishin Basin is the southern part of Katawaz Basin lying within Pakistan territory (Figure 1). A thick sedimentary fill of this basin, ranging in age from Eocene to Recent, received limited attention for its hydrocarbon potential. Out of the three marine sedimentary units, i.e. Nisai, Murgha, Faqirzai and Shaigalu, the oldest is the Nisai Formation, which is a mixed carbonate-siliciclastic system, and exhibits good exposures along the margin of the basin and qualifies as an exploration target. After acquiring the concession in this block, Paige Limited has tried to build a systematic geological database. This paper is a brief extract of the key geological data (Paige Limited, 2002) to demonstrate the hydrocarbon potential of the Nisai Formation in the framework of sequence stratigraphy. This effort is based on surface geological information in conjunction with laboratory support as no seismic survey has been conducted so far in this basin.

Geological Setting

The Pishin Basin is bounded by Chaman Transform Fault in the west and Zhob Valley Thrust in the east (Figure 1). The basin is a younger Tertiary basin of Median category (Ahmad,1991; Ahmad, 1998) where the exposed sedimentary rocks are not older than Early Eocene. The basin owes its origin to the Paleocene India-Asia collision that resulted in subduction of Indo-Pak Plate under the Eurasian Plate and obduction of oceanic material (ophiolites). The ophiolites are exposed in scattered form along the Chaman Fault as well as near the Zhob Valley Thrust comprising pillow basalts and dykes (Figure 2).

The sedimentary history of the Pishin Basin is linked with the drifting and collision of the India Plate with the Eurasian Plate and rising of mountain ranges and collision zone in the northeast of the basin which served as a siliciclastic source. The paleogeography of Pishin Basin during the Eocene time was in the form of a NE-SW trending narrow elongated trough representing a gap between the Zhob Ophiolites and Kabul Block. Sedimentation of the Nisai Formation in this trough commenced during Early Eocene mainly as carbonate buildups overlying the Tethys sea floor of Mesozoic age with several episodes of siliciclastic supply from the northeast. This trough during the Eocene-Oligocene time was broadened due to the northward shift of Kabul Block (Bannert et al., 1992) and started to receive siliciclastics representing Murgha Faqirzai Formation.

The main collision phase of the Himalayan uplift initiated due to collision of the northern margin of India with Eurasia. It was followed by oblique collision of the northwestern margin of India with Afghan Block in Miocene time. As a result, the sediments of Pishin Basin were thrusted over mainly Mesozoic strata of the Indus Basin along a thrust zone in the east. The ophiolites seem to continue under the sediments of the Pishin Basin as remnants of the Neotethys oceanic crust (Farah and Zaigham, 1979). The gravity model (Khurshi et al., 1992) suggests that the western margin of India subsided and loaded with undeformed sediments of Pishin Basin prior to convergence. The Sulaiman Fold Belt was developed in response to this convergence with a considerable thickness of sediments. The gravity modeling indicates that the Sulaiman Foreland and Thrust Belt is underlain by 15-25 km thick transitional crust which was a part of Gondwana before its break up (Early Mesozoic). Two levels of deformation exist, one within the crust resulting from horizontal compression and overlying thrust load, and the second within the thick overlying sediments where the exact level of deformation is not known. The presence of ophiolites and Tertiary sediments of Pishin Basin suggests a margin that is in its initial stage of convergence. The existence of large Katawaz Block between India and Afghan Block during India-Eurasia convergence has restricted shortening in Pishin Basin and adjoining northern Sulaiman Fold Belt.

The Pishin Basin is comparable to a number of the world‟s producing basins, e.g. Kutei, Tarakan, Barito, Gippsland, Taranaki, Maracaibo and Upper Magdalena Valley (Ahmad,1991; Ahmad, 1998). The Pishin Basin is a monocyclic sedimentary basin. Its sedimentary fill, which has been generally miss-termed as „flysch,‟ represents a normal marine to deltaic sequence of deposition. These sediments were not associated with any trench setting and the sedimentation took place in a subsiding shelf margin. Typical marine shales and nummulitic/alvelolinal limestones were laid down during commencement of sedimentation during the Eocene and were later replaced by clastics during Oligocene-Miocene time. The marine sedimentation was terminated at the end of the Miocene period when collision between the Indian Plate and Afghan Block took place. Consequently the sediments were deformed into wide synclines separated by relatively tight anticlines.

Field Area, Materials and Methods

For the present study, data of Nisai sediments exposed at three localities, between Muslimbagh in the west and Zhob in the east, are compiled (Figure 3). These localities are Nisai Section (A), Khutkandi Section (B) and Sharan Tangai Section (C). These exposures offer an excellent opportunity to envisage the architecture of the Nisai Basin during Eocene time. A generalized stratigraphic column of the basin is presented in Figure 4. A large number of samples were collected for biostratigraphic, sedimentological, reservoir and source rock geochemical parameters.

Sequence stratigraphy is a powerful tool to reveal the stratigraphic architecture of a sedimentary system. Sequence stratigraphy from outcrop scale data requires the completion of several steps during the course of data analysis. In this study the steps followed are: (i) identification of depositional facies types, their depositional environments and paleo-bathymetry in order to know the trends of increase and decrease in accommodation space, (ii) identification of important surfaces such as relation to subaerial exposures, ravinenments, flooding and hardgrounds, etc., and depositional sequences in individual sections, (iii) high resolution dating of the sediments based on planktonic and larger foraminifera, (iv) comparison of the Nisai sequences with that of the global scenario, (v) lateral correlation of the sequences and surfaces, and (vi) construction of basin fill model and facies maps to outline the areas favorable for potential source rocks and reservoir facies.

Nisai Formation Lithostratigraphy

The available information on the stratigraphic units of this basin is very scanty. The regional reconnaissance work of Hunting Survey Corporation (Hunting Survey Corporation Ltd., 1960) provides basic information on the stratigraphy of this basin. They proposed the name Nisai for a group of facies including various types of shale, marl, sandstone, limestone and conglomerate/breccia. The lower contact of the Nisai carbonates is mostly with the lava flow (Gansser, 1979; Allemann, 1997). Based on field observations, various facies of the Nisai

Formation have been described and reported similar contact relationships (Yasin and Ashraf, 1995). However, in the three studied sections the formation was observed thrusted upon the younger sediments (Multana/Bostan).

Nisai sediments comprise several carbonate and clastic facies recognizable in the field. It is predominantly limestone (larger foraminiferal limestone, coquina limestone, reefal limestone, pelagic limestone, and nodular limestone) with shale (dark gray to black shale, shale with sandy intercalations), subordinate sandstone (calcareous sandstone, burrowed sandstone) and conglomerate (conglomerate, gritty layers, limestone conglomerate, debrites). Detailed lithology of the Nisai Formation is presented in Figure 5 and Figure 6 and legend for abbreviations is shown in Figure 7.

Facies Zones

The formation seems to have been deposited in marine conditions between paleodepths 50 m and 200 m as interpreted from its "Midway Type Fauna" to a shallow setting of 10 m or less. It is divisible into 5 units. In these units a larger number of clastic and carbonate facies have been observed in the field. These facies under the microscope show microfacies which can be used for assessing their depositional environments. These facies have been categorized in facies zones, which are outlined below.

At least 11 major carbonate and clastic facies are distinguished in the field which correspond to the 4 main bathymetric zones: (1) lagoonal zone, (2) platform edge or shoal zone, (3) outer shelf zone, and (4) slope-basinal zone. These facies and microfacies are presented in Figure 14, Figure 15 and Figure 16.

Lagoonal Zone

1) Miliolidal calcareous sandstone
2) Burrowed sandstone

Platform Edge or Shoal Zone

1) Nummulitic grain-rudstone
2) Alveolinal pack-grainstone
3) Reefal limestone

Outer Shelf Zone

1) Foraminiferal mud-wackestone (nodular limestone)

Slope-Basinal Zone

1) Planktonic foraminiferal marl and mud-wackestone
2) Black laminated mud-wakestone
3) Hemipelagic gray-black shale
4) Larger foraminiferal pack-rudstone
5) Calcareous sandstone and grit

Biostratigraphy

The Nisai sediments are rich in microfossils comprising foraminifera, gastropods, pelecypods, echinoderms, bryozoa and algae. High resolution dating of the strata is achieved based on two groups of foraminifera, i.e. larger and planktonic. The major part of the larger foraminiferal population consists of Alveolina, Assilina, Nummulites, Discocyclina, etc. The planktonic foraminifera are also encountered at various horizons. Therefore, to achieve fine-tuned dating, a biochronostratigraphic time scale tied with larger foraminiferal zones is mainly followed with minor amendments based on local conditions (Berggren et al., 1998; Serra-Kiel et al., 1998). Almost all the zones are established based on the standard zonal markers and have been outlined (Figure 8). The biostratigraphic resolution has been found very useful in establishing the correlation of various facies.

The Nisai Formation in section-A is of Early (?) to Late Eocene age. The lower half of its thickness yielded recognizable planktonic foraminifera indicating Zone P10 to Zone P14, whereas in the upper half the recovery of planktonic foraminifera is poor due to tight limestone facies. Nevertheless, the section may range up to Zone P16 (?). The Nisai sediments correspond to the shallow benthic zones SB13 to SB20. In the middle part of the section recovery of larger foraminifera decreases, thus the precision becomes limited. In section-B, isolated exposures of shallow marine carbonates are rich in larger foraminifera and dated as Middle Eocene, Zone SB13. In section-C the black shale exposed at the base of the section is Early Eocene P8/9 in age. The lower part of the Nisai sediments represented by pelagic carbonates have been found to range in age from Zone P11to Zone P15 of planktonic foraminifera. The shallow marine carbonates range in age from Zone SB13 to Zone SB20 of larger foraminifera. The detailed biostratigraphic data sheet is beyond the scope of this paper, however, dating of the sediments is given in the summary diagrams of the two sections of the Nisai Formation (Figure 5 and Figure 6).

Sequence Stratigraphy

The Nisai Formation as a whole represents one super sequence of 2nd order, starting from the latest Ypresian and ending at Priabonian. This super sequence starts with the supply of siliciclastics (turbidites) and development of shallow water carbonates during the lowstand which is followed by maximum sea level rise that laid down slope deposits above the shallow water carbonates. The highstand stage presents the development of coquinal/reefal and nodular limestone facies. This sequence is equivalent to global TA3-lower TA4 sequence (Haq, 1987). Within this sequence, nine 3rd order sequences are recognized which match well with the global scenario (Haq, 1987).

Based on the limited field information supported with lab results, a basin fill model is presented (Figure 9) and facies maps for various sequences are reconstructed in the present day tectonic settings (Figure 10, Figure 11 and Figure 12). This effort will enable the explorationist to envisage the basinal architecture and in planning for exploration strategies. The model suggests carbonate development along the periphery of the basin with carbonate turbidite down thrown (east to west) in the southwest and siliciclastic supply from the northeast. The facies association suggests a NE-SW deepening trend into the basin, which corresponds well with the gravity modeling (Paige Limited, 2001). Detailed descriptive criteria for sequential breakup is not addressed here, however a brief description with characteristics of each sequence is given as below:

Sequence Nis-1 and Nis-2

The basal part of Nis-1 sequence is unexposed in all the studied sections. In section-A the lower part of this sequence is shale dominated which was deposited during the lowstand and various coquinal limestone beds, which moved down slope during the highstand stage having source of autochthonous limestone development around section-B. Whereas in section-C this shale horizon contains numerous thin sandstone/siltstone beds and limestone development in the upper part. The upper sequence boundary is marked below the sandstone and conglomerate beds in section-A, which are deposited during the lowstand of sequence Nis-2 and limestone conglomerate in section-C. The Nis-2 sequence also contains down slope moved coquinal limestone beds in section-A while this horizon in section-C is dominated by shallowing upward platform facies (alveolinal/nummulitic limestone). The upper sequence boundary is marked at the carbonate debrite in section- A and alvelolinal limestone facies in section-C. The shale in sections-C of sequence Nis-1 indicates good source rock potential. The limestone and calcareous sandstone beds of both sequences may have some reservoir potential. (Figure 5, Figure 6, Figure 9 and Figure 10a).

Sequence Nis-3

This is a key sequence to correlate the events in the basin representing a wide spread major sea level rise in the entire area which resulted in deposition of slope facies (planktonic foraminiferal marl and mudstone) immediately above the platform limestone facies. During the highstand, larger foraminifera coquinal beds started to appear in the upper part of the sequence and finally terminated at the debrite bed suggesting a possibility of uplift in the lagoonal area (Figure 5, Figure 6, Figure 9 and Figure 10b). As the rocks have been tectonically overthrusted, therefore, position of its platform edge and lagoonal setting is not easy to map within available data.

Sequence Nis-4

A new cycle of rapid sea level rise resulted in the deposition of dark gray to black shale (basal black shale) in both sections. However during the lowstand, sandstone could reach around the section-C. This shale is rich in planktonic foraminifera in both localities and has reasonably good source rock potential (Figure 5, Figure 6, Figure 9 and Figure 11a).

Sequence Nis-5

During the transgressive system tract of this sequence, pelagic limestone (slope facies) in section-A, the dark gray shale was trapped in areas around section-C. At the highstand stage the pelagic limestone transformed into black limestone. During the late highstand siliciclastics entered into the carbonate system. Numerous extensively burrowed sandstone beds are encountered in section-C (Figure 5, Figure 6, Figure 9 and Figure 11b). This event of clastic activity can be observed even in section-A in the form of a thin sandstone/siltstone bed, which is picked to interpret the sequence boundary. These sandstone beds in section-C have good reservoir potential.

Sequence Nis-6

Immediately above the sandstone, a thin-bedded limestone interval is present which is dark gray to black in section-A, and coquinal/reefal limestone of platform setting in section-C. The latter may have a good reservoir character. The sequence boundary is subtle in both sections and tentatively marked at the termination of the carbonate system and entry of fine clastics into the basin (Figure 5, Figure 6, Figure 9 and Figure 11b). The black limestone has a good source rock potential as in the previous sequence.

Sequence Nis-7

The thick shale interval in section-A as compared to the thin shale horizon in section-C suggests lowstand conditions, whereas the transgressive stage is again interpreted by the occurrence of relatively deeper marine limestone. However, in section-C this event is represented by coquinal/reefal limestone which may have a good reservoir potential (Figure 5, Figure 6, Figure 9 and Figure 12a). The sequence boundary is subtle and unidentifiable in section-C but tentatively marked at the termination of carbonate system.

Sequence Nis-8

Thick shale interval in section-A and its near absence in section-C suggest lowstand conditions. The transgressive stage resulted in deposition of pelagic limestone, which at the highstand gradually transformed into shallow water nodular limestone. This event in section-C presents development of coquinal limestone, which during the late highstand received a clastic supply. The resultant sandy bed is picked to interpret the sequence boundary (Figure 5, Figure 6, Figure 9 and Figure 12a).

Sequence Nis-9

In section-A, occurrence of a limestone interval of pelagic facies immediately above the shallow water nodular limestone of the previous sequence suggests a new phase of sea level rise for a short duration. This limestone gradually transformed again into nodular limestone at the highstand stage. This event in section-C is represented by development of thin shale beds at the base and nodular and coquinal limestone at the top of the sequence. A 7 m thick conglomerate bed in section-A and thick shaly/sandy sequence of Murgha Faqirzai is an event of almost permanent termination of the predominant carbonate system, and is hence taken as the sequence boundary. The coquinal and nodular limestones may have reservoir potential.

Petroleum System

The Pishin Basin has an area of 20,000 sq km within the Pakistani territory where 5-6 km thick sedimentary rocks are the products of a single 1st order cycle of marine sedimentation. These sediments contain horizons suitable for the generation, accumulation and entrapment of oil and gas. The systematic sedimentary analysis has helped to distinguish various source and reservoir prone facies in the sequence stratigraphic framework, which have been proved through laboratory support (Paige Limited, 2002). Within the Nisai Formation four source rock intervals comprising shale and limestone are identified, whereas five potential reservoir horizons of both carbonate and siliciclastic origin (turbidites, nodular limestone, reefal/coquinal limestone, burrowed sandstone) have been worked out (Figure 13). The outcrop views and microfacies are shown in Figure 14, Figure 15 and Figure 15. The joint and fracture systems are supposed to enhance the reservoir potential of the carbonate reservoir horizons in the subsurface. Occurrence of seeps (Paige Limited, 2002) along the thrust zone at the southern periphery of the basin supports the presence of exploration-worthy structural leads of Paige‟s block in the basin. The microseep data over the structural leads strengthen the confidence level in having both oil and gas in the basin.

Source Rock Distribution

Basin fill model and facies maps demonstrate vertical and lateral distribution of source rock prone facies (Figure 10, Figure 11, Figure 12 and Figure 13). Two types of source rock facies are identified in three distinct horizons.

1) Dark Gray to Black Shales

The first type of source rock is dark gray to black shale associated with transgressive system tract of sequence Nis-4 (Plate 1c). The shale is considered to be linked with basal black shales in the subsurface and may be termed as basal black shale. This shows similarity in facies and organic richness with the upper part of Paleocene/Eocene Patala shale of the oil producing Potwar Depression. Further northwestward in the center of the basin the shale is supposed to carry well developed condensed section, hence has better source rock parameters. The gray shale associated with the lowstand of sequence Nis-1 also possesses good TOC value. These source rocks are distributed throughout the basin (Figure 14a).

2) Black Limestone

The second type of source rock is black limestone associated with the highstand system tract of sequences Nis-5 and Nis-6 (Figure 14b and Figure 16a). This limestone possesses fairly high TOC value and resembles in physical character and microfacies with Habib Rahi Limestone (oil shale) of Sulaiman Range having very high TOC. The organic rich limestone is restricted to the northwestern deeper part of the basin. Laboratory support proved that these horizons have fair to high organic content.

Potential Reservoir Facies

The sequence stratigraphy is particularly helpful for establishing the petroleum system in the basin. The basin possesses carbonate development around the shelf margin, which had been shed into basin but was restricted in the southwestern side. The siliciclastic source was releasing sediments from the northeastern side. The coarse clastics were trapped in the northeast whereas fine clastics dispersed farther southwestward. The overall pattern of basin fill model presents southwestward progradational architecture with retrogradation in the middle part of the Nisai Formation. The southwestward prograding lagoonal-shoalforeshoal- outer shelf to slope facies belt exhibit several potential reservoir facies (Figure 13).

1) Turbidites

The lower part of Nisai Formation exposed in section-A has thick turbiditic sediments deposited on the slope (sequences Nis-1 and Nis-2). The coquinal beds (Figure 16e), calcareous sandstone (Figure 16b) and conglomerates of these sequences may have some reservoir character. Further westward in the subsurface thick deposits of basin floor fan having good reservoir character are expected to occur.

2) Carbonate Debrites

Thin beds of carbonate debrites (Figure 15b) occur at the base and top of the sequence Nis-3 are supposed to exist throughout the basin having good chances of porosity development.

3) Shallow Marine Nodular Limestone

A light gray, fossiliferous nodular limestone of fore-shoal to outer shelf setting from the highstand system tract of the sequences Nis-8 and Nis-9 (Figure 15a) is a potential reservoir facies and exhibits similarities with the oil producing Lower Eocene Sakesar Limestone of the Potwar Depression. The joint and fracture systems are supposed to enhance the porosity/permeability element in the subsurface. This facies is likely to exist in the subsurface of the northeastern part of the basin.

4) Burrowed Sandstone

The highstand deposits of the sequence Nis-5 comprise an interval of burrowed sandstone of shallow marine, inner shelf setting (Figure 15d). The physical appearance as well as laboratory data indicates good porosity values. This reservoir facies is restricted in the northeastern part of the basin.

5) Reefal and Coquinal Limestone

The highstand system tracts of sequences Nis-7 to Nis- 9 are dominated by dark gray, thick bedded foraminiferal coquinal and coral-bryozoan reefal limestone facies. The laboratory data indicates good porosity parameters for this facies (Figure 16f), which is restricted in the northeastern part of the basin.

Seals

The shale dominated siliciclastic sediments in the Pishin Basin, though limiting the opportunity to develop clastic reservoirs, nevertheless exhibits a greater potential for producing source rocks and seals. All shaly horizons of the Nisai and overlying Murgha Faqirzai formations deposited in response to the transgressive system tracts should have wider areal extent and provide excellent seals to the porous reservoirs. A number of seals are mentioned in the petroleum system chart (Figure 13).

Conclusions

This study is a first attempt to use sequence stratigraphy to understand the basinal architecture and petroleum system of the Pishin Basin. The study is based on limited field observations linked with laboratory support. The salient features of this study are presented as below:

1) About 1100 m of the Nisai mixed carbonate-siliciclastic system represent one 2nd order sequence with nine 3rd order sequences, which show resemblance with the global scenario.

2) More than 10 major facies are recognized in the facies belt characterizing lagoonal to basinal settings. The basin-fill model presents southwestward progradation of the facies belt.

3) Two types of source rock facies, (1) dark gray to black shale distributed throughout the basin, and (2) black limestone restricted in the southwestern part of the basin have been identified. Most of the source rock intervals are associated with transgressive and highstand system tracts.

4) Five potential reservoir targets are delineated. Turbidite system of LST of sequences Nis-1 and Nis-2 is restricted in the southwestern area; burrowed sandstone and reefal/coquinal limestone associated with HST are restricted to the northeastern part, whereas nodular limestone of HST and carbonate debrites of LST are distributed throughout the basin.

5) A number of shaly horizons associated with TST having regional extent are present to serve as seals.

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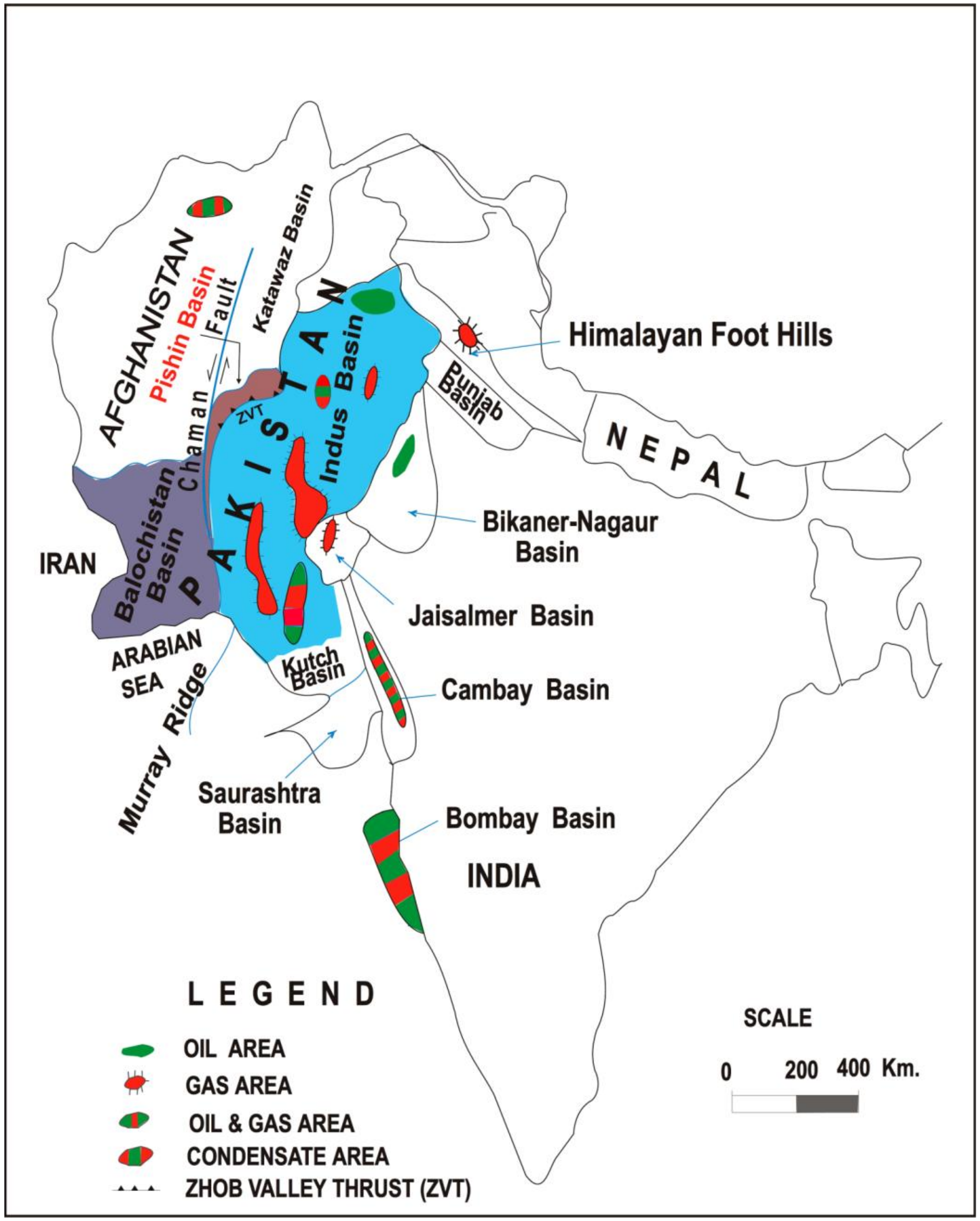

Figure 1. Location map of Pishin Basin.

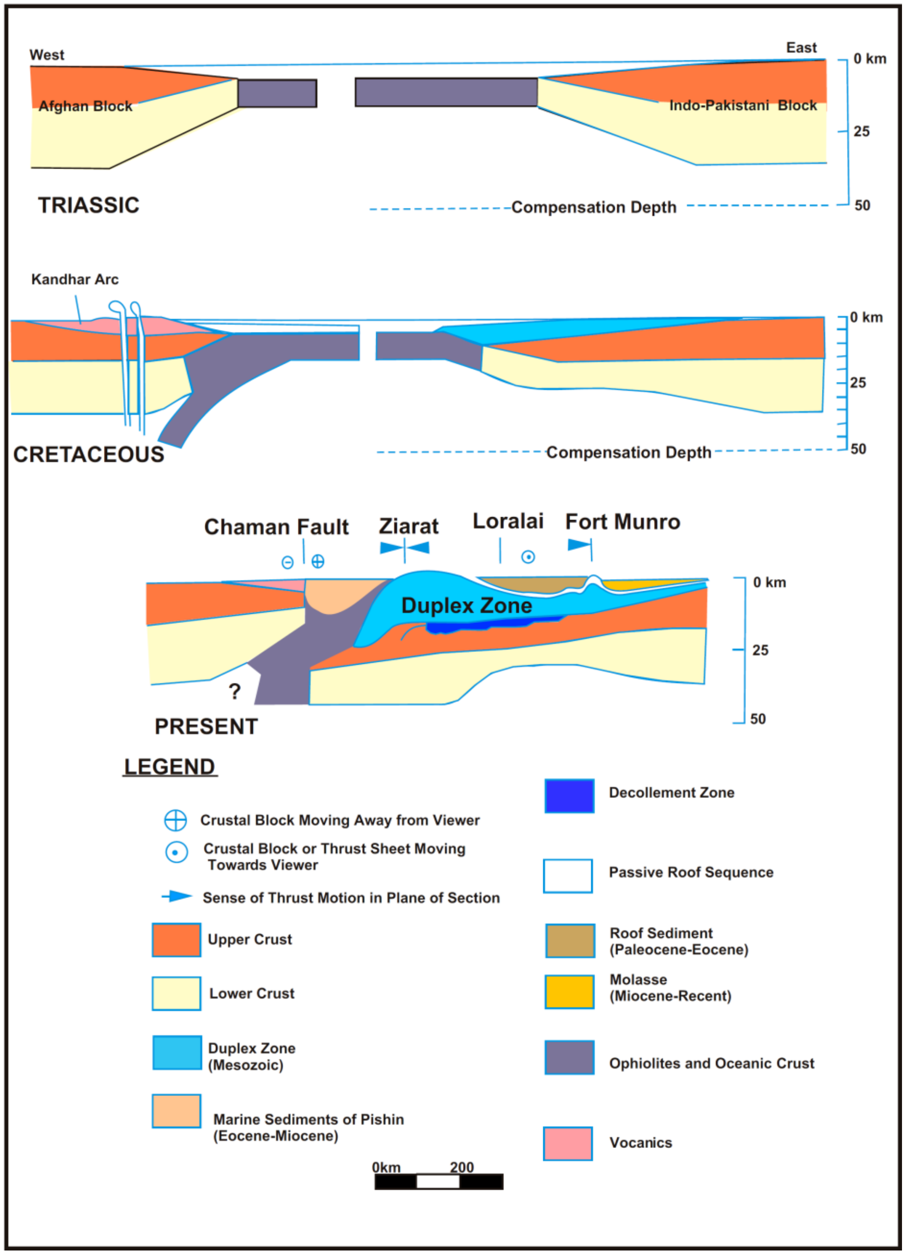

Figure 2. Schematic tectonic model of Sulaiman Fold Belt and Pishin Basin based on regional gravity data (modified after Khurshid et al., 1992).

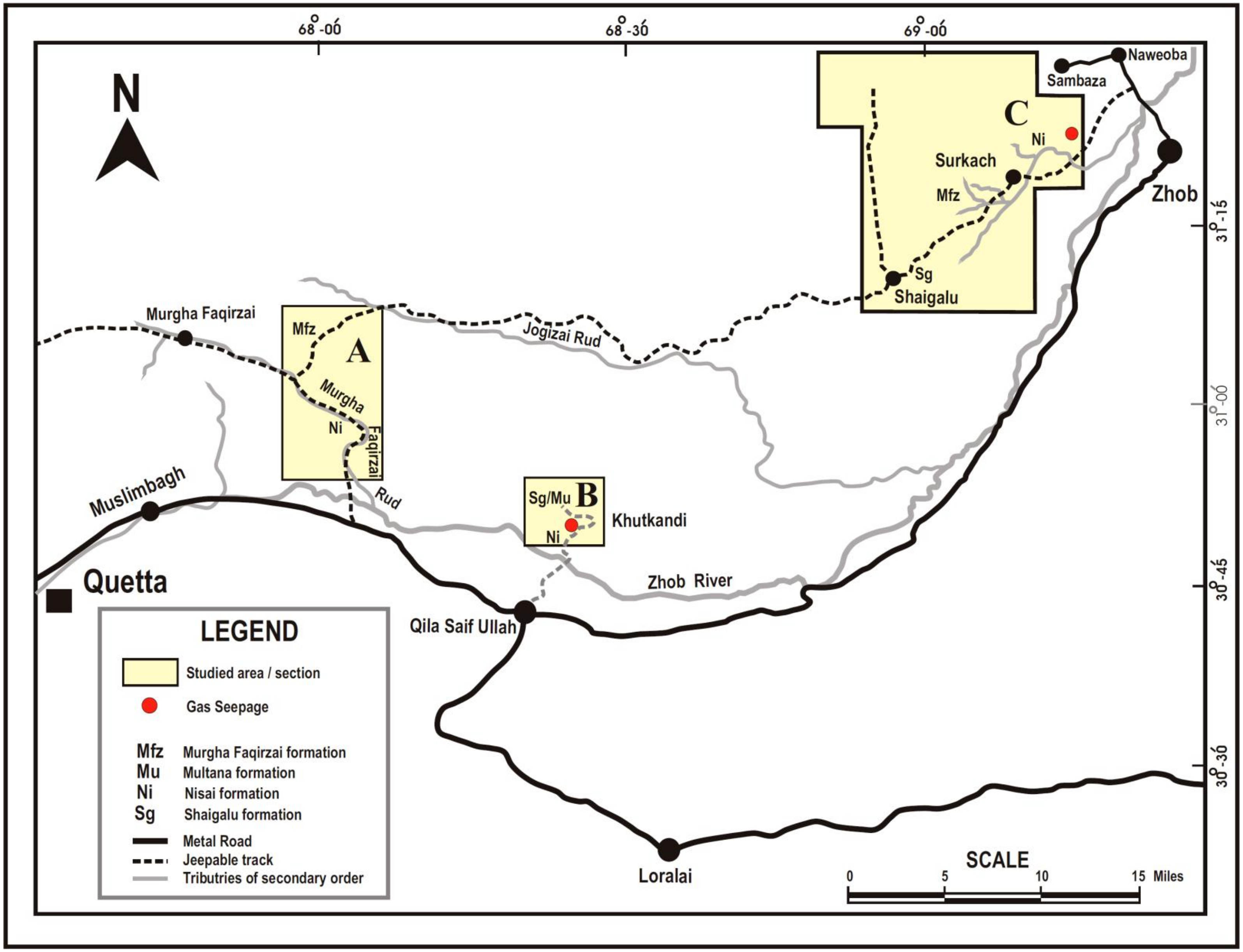

Figure 3. Location of studied sections/areas from Pishin Basin.

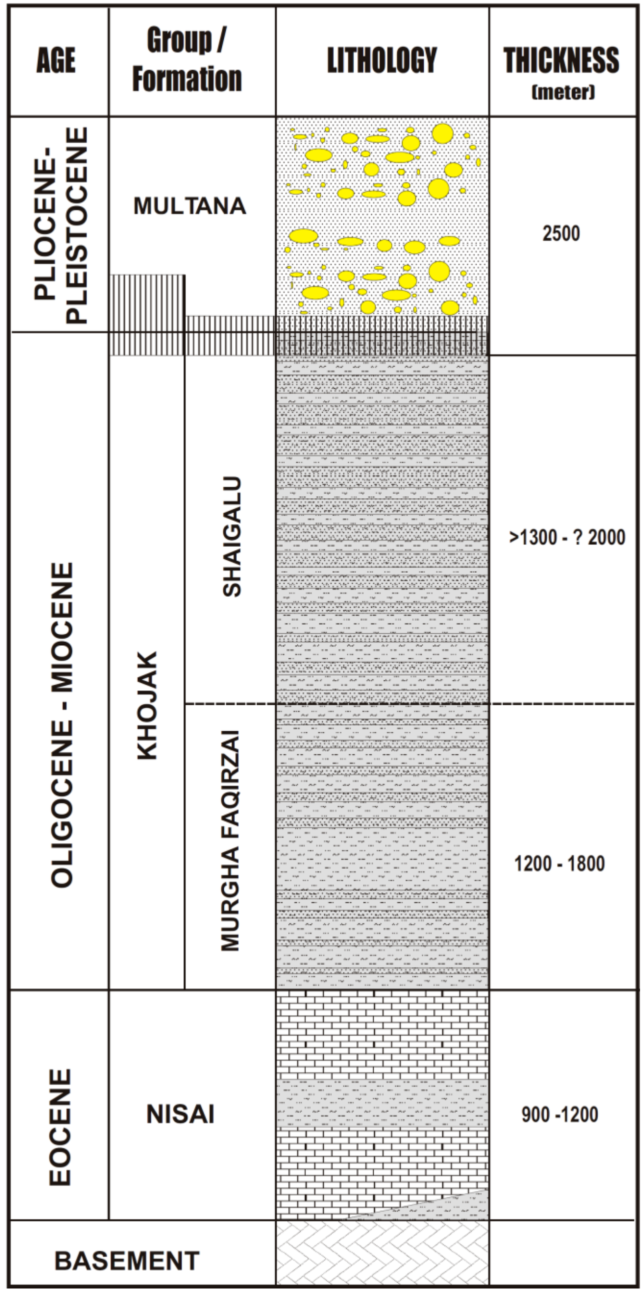

Figure 4. Generalized stratigraphic column of Pishin Basin.

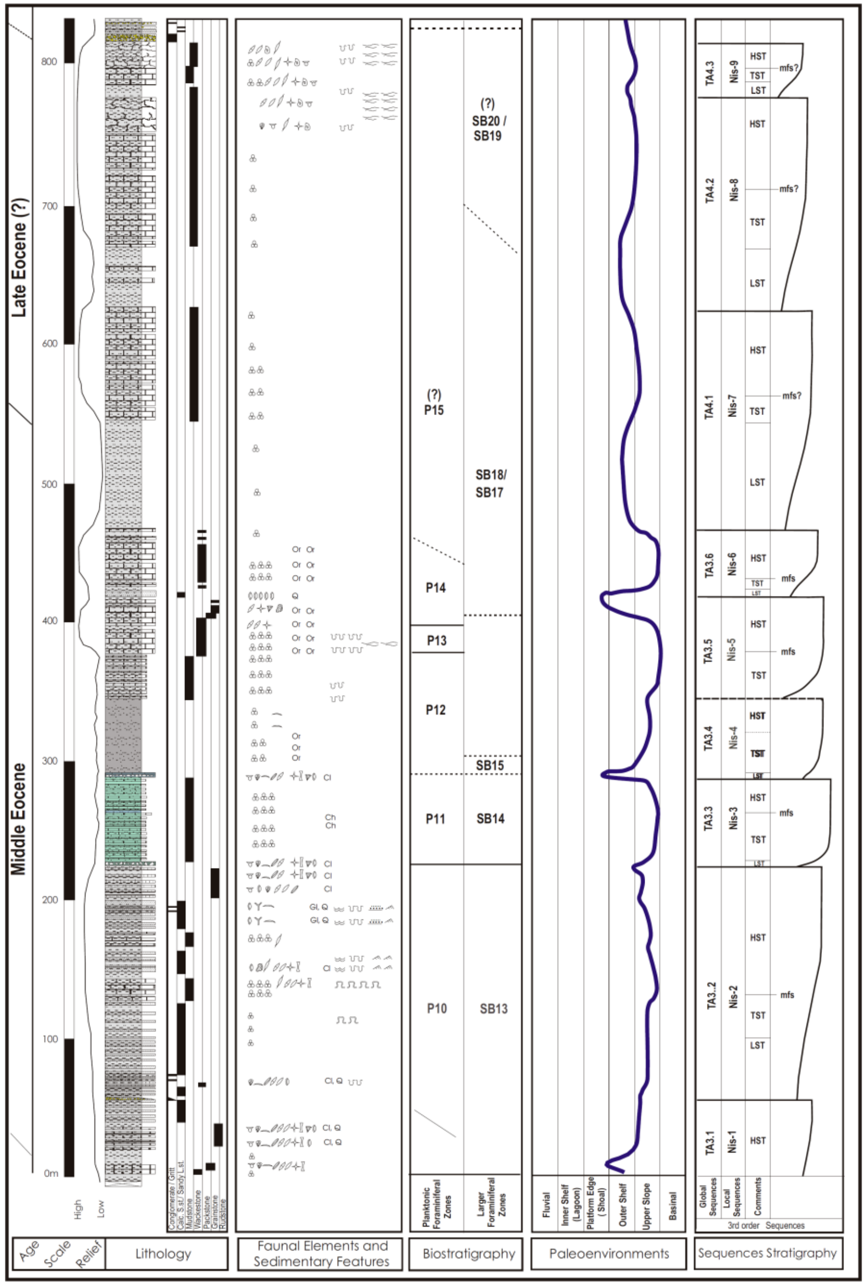

Figure 5. Lithostratigraphic, biostratigraphic and sequence stratigraphic summary of Nisai Formation exposed in section-A.

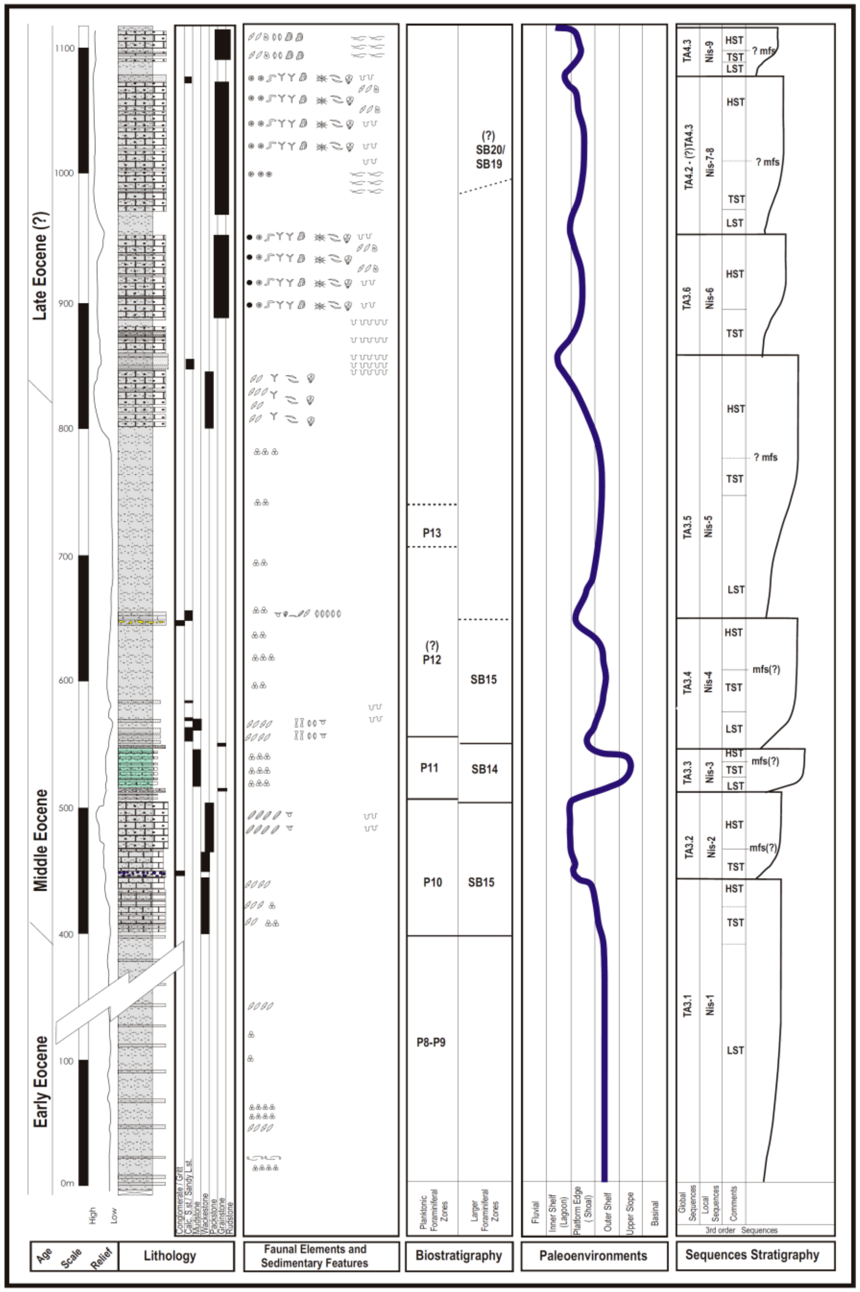

Figure 6. Lithostratigraphic, biostraigraphic and sequence stratigraphic summary of Nisai Formation exposed in section-B.

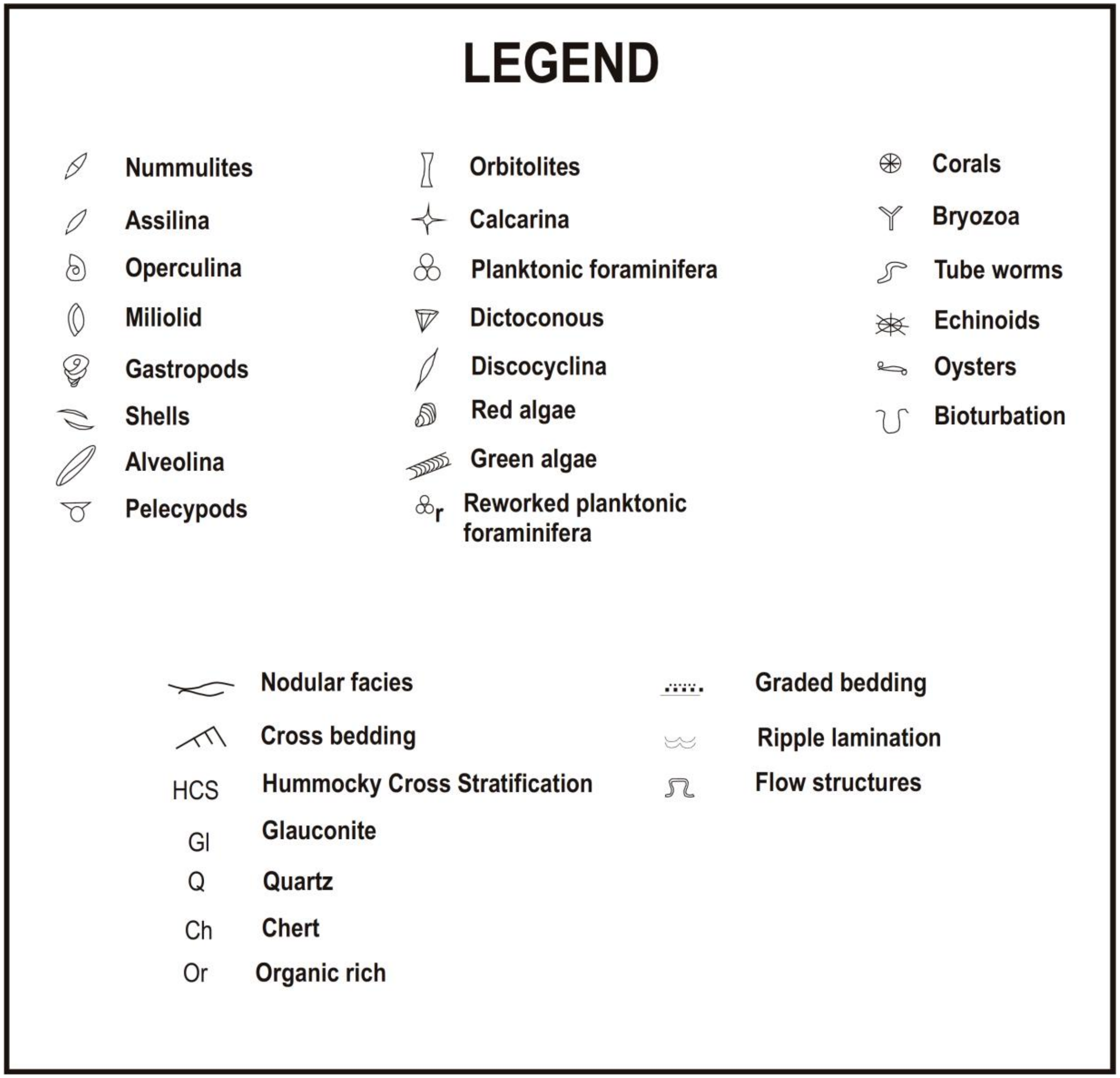

Figure 7. Explanation of the subdivisions used in Figure 5 and Figure 6.

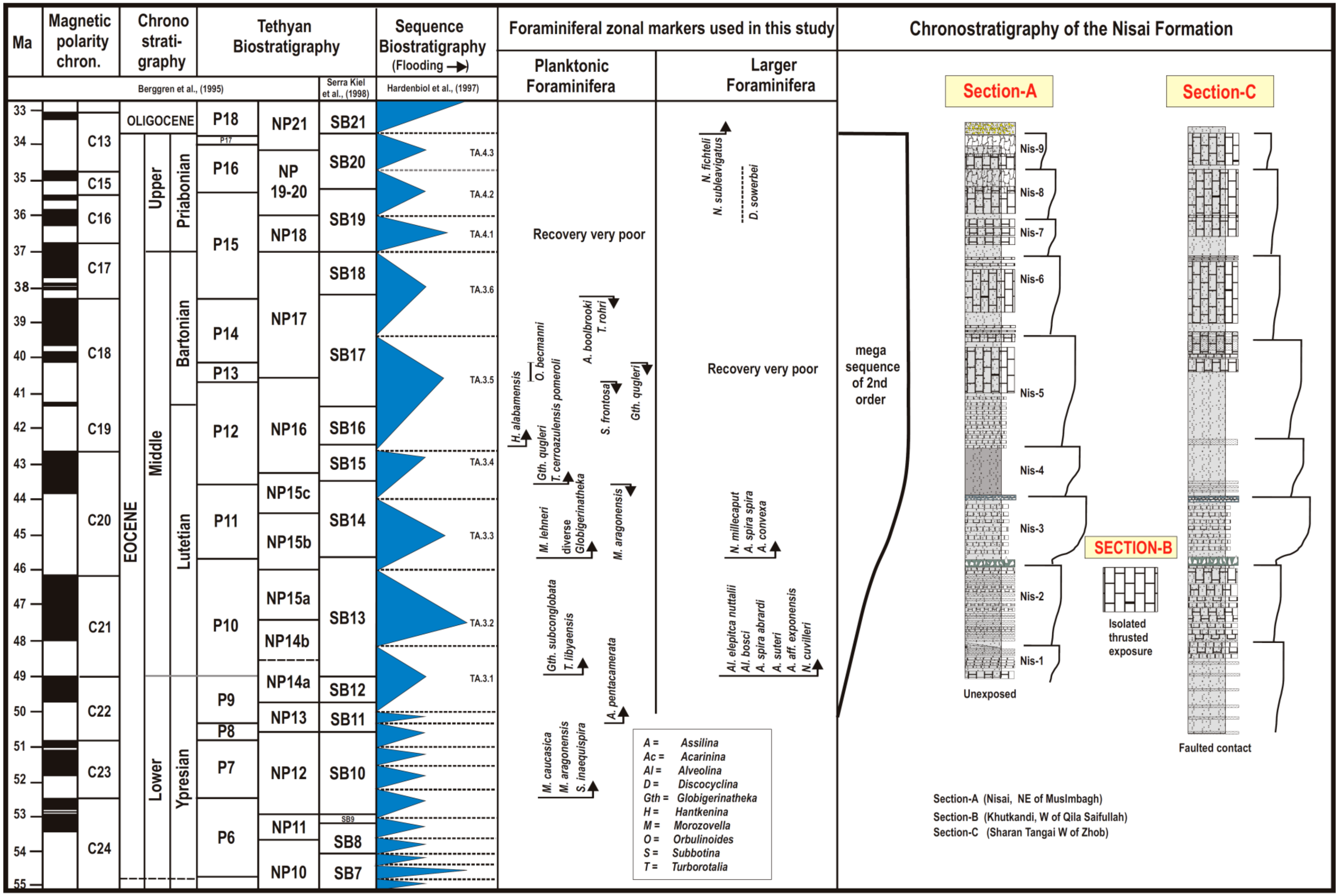

Figure 8. Paleogene time scale after Berggren et al. (1998) and Serra-Kiel et al. (1998) and global sequence stratigraphic scenario. Standard planktonic and larger foraminiferal markers used in this study with sequence stratigraphic summary of sections A and C.

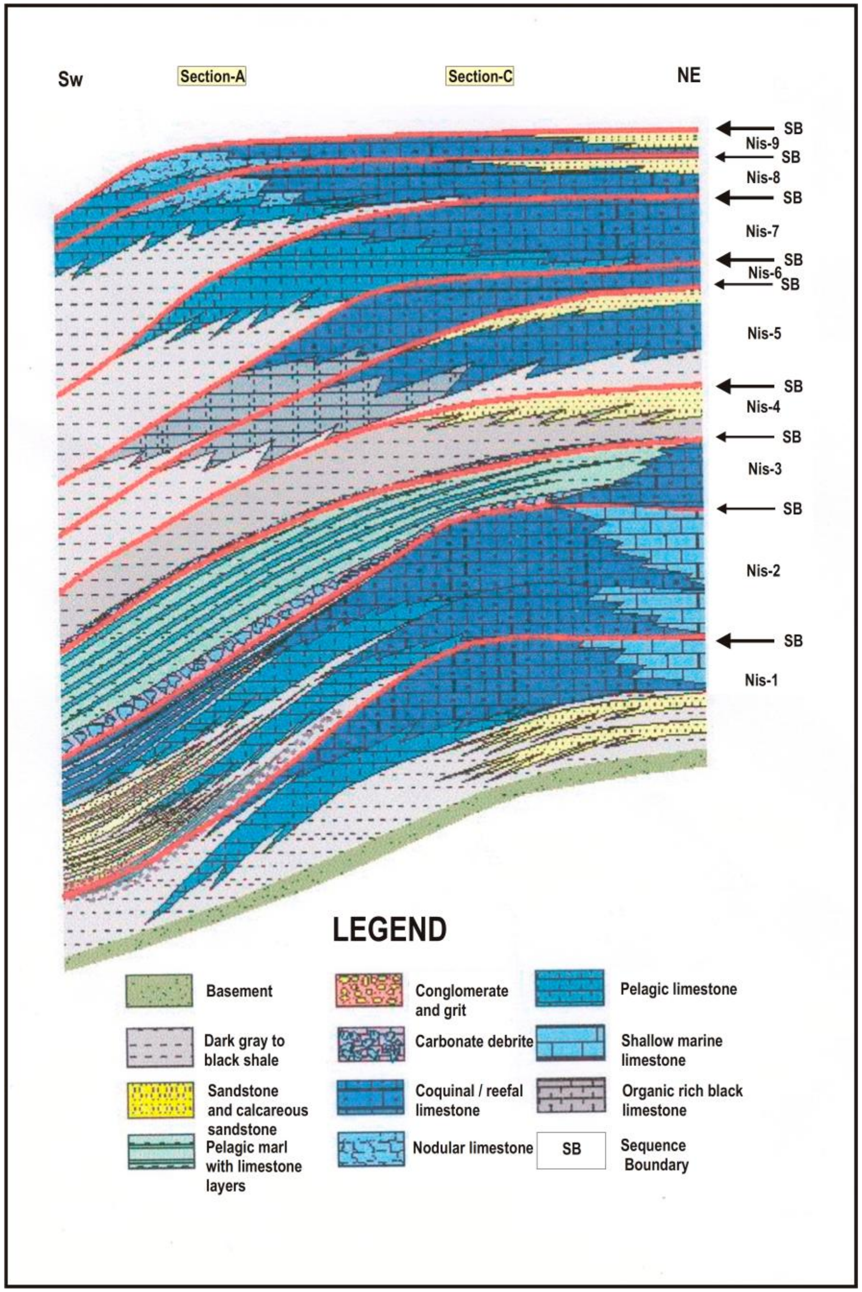

Figure 9. Basin fill model of Pishin Basin.

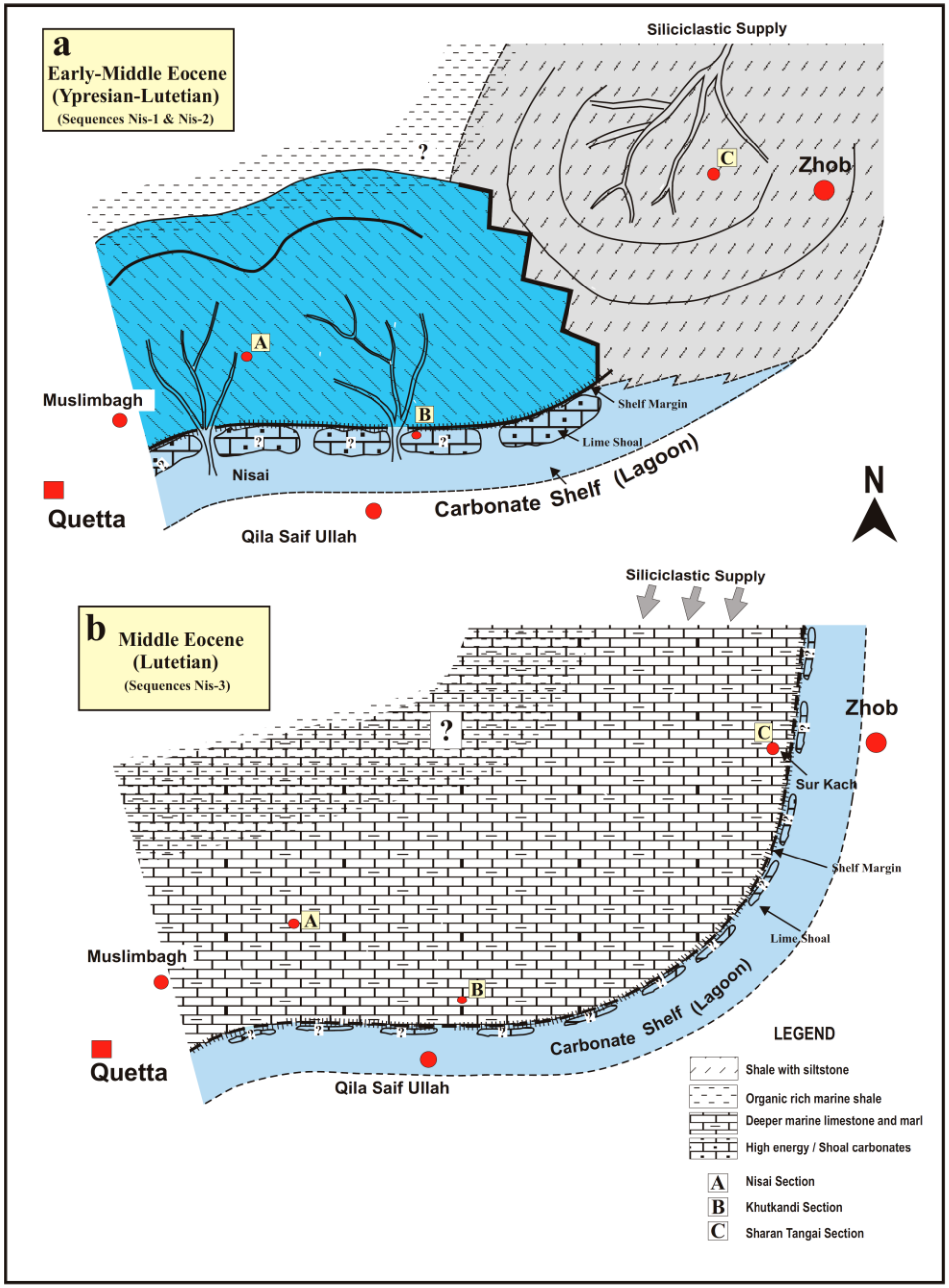

Figure 10. Facies maps: (a) sequences Nis-1 and Nis-2, (b) sequence Nis-3.

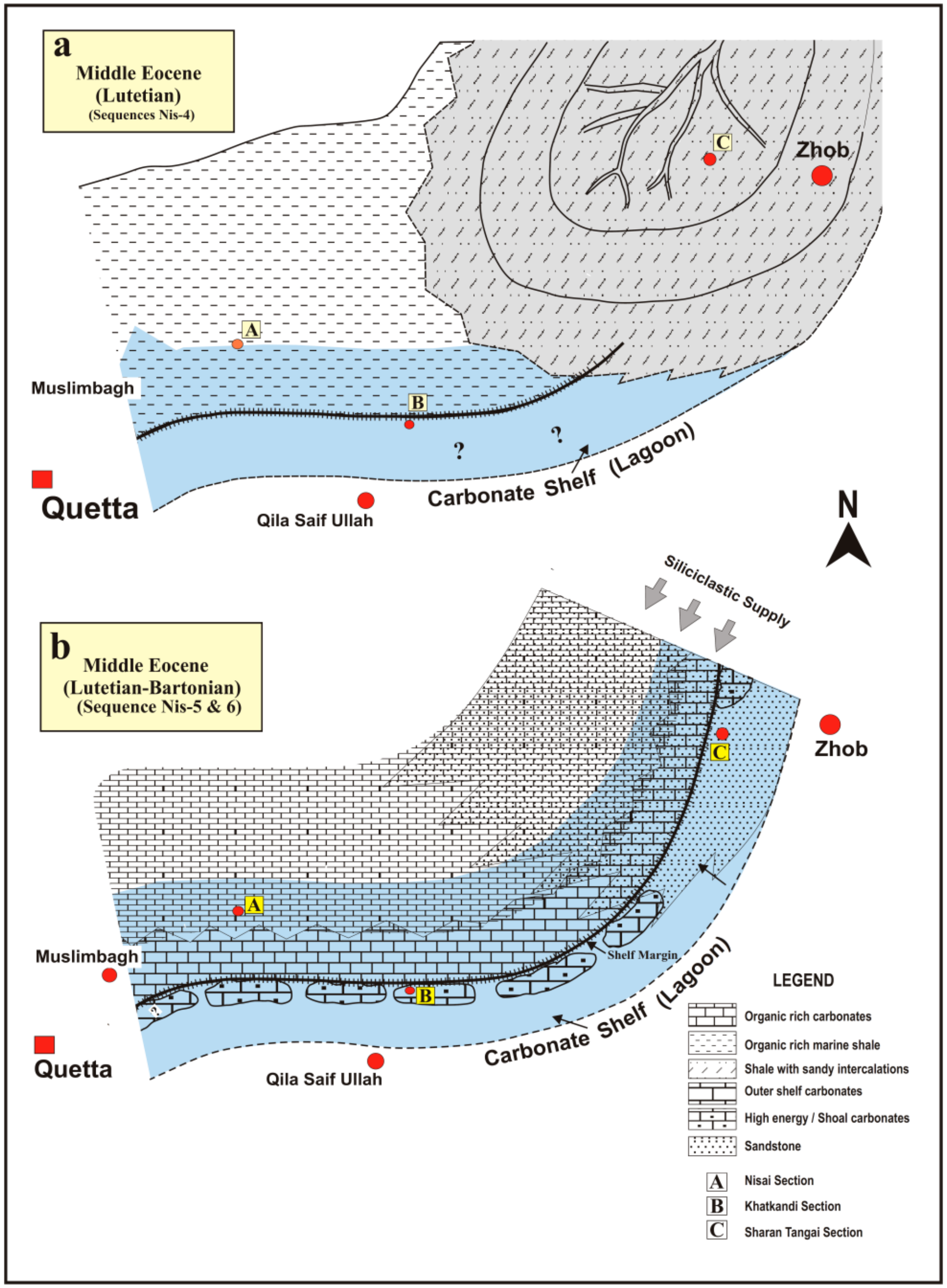

Figure 11. Facies maps: (a) sequence Nis-4, (b) sequence Nis-5 and Nis-6.

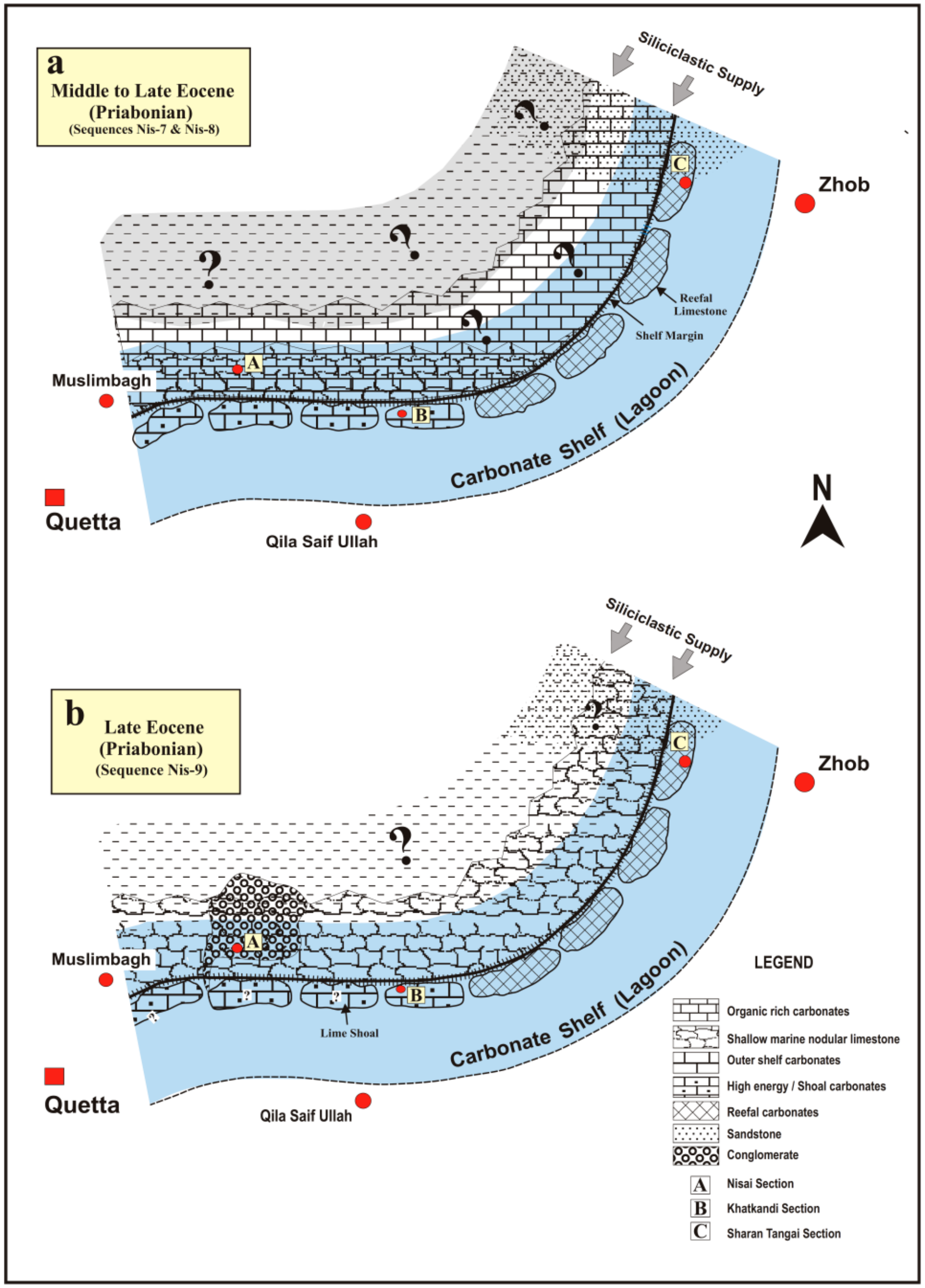

Figure 12. Facies maps: (a) sequences Nis-7 and Nis-8, (b) sequence Nis-9.

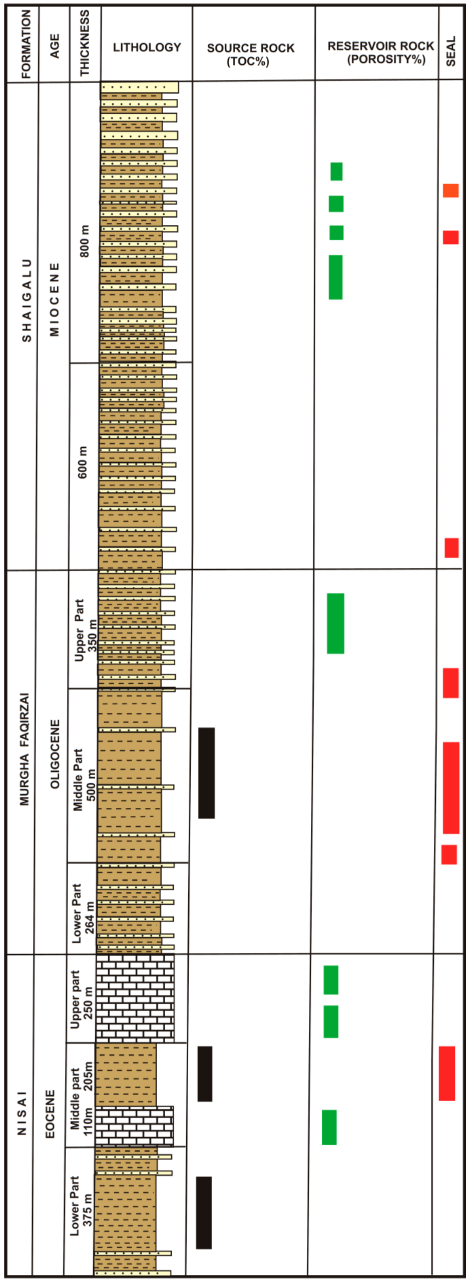

Figure 13. Petroleum system of Pishin Basin.

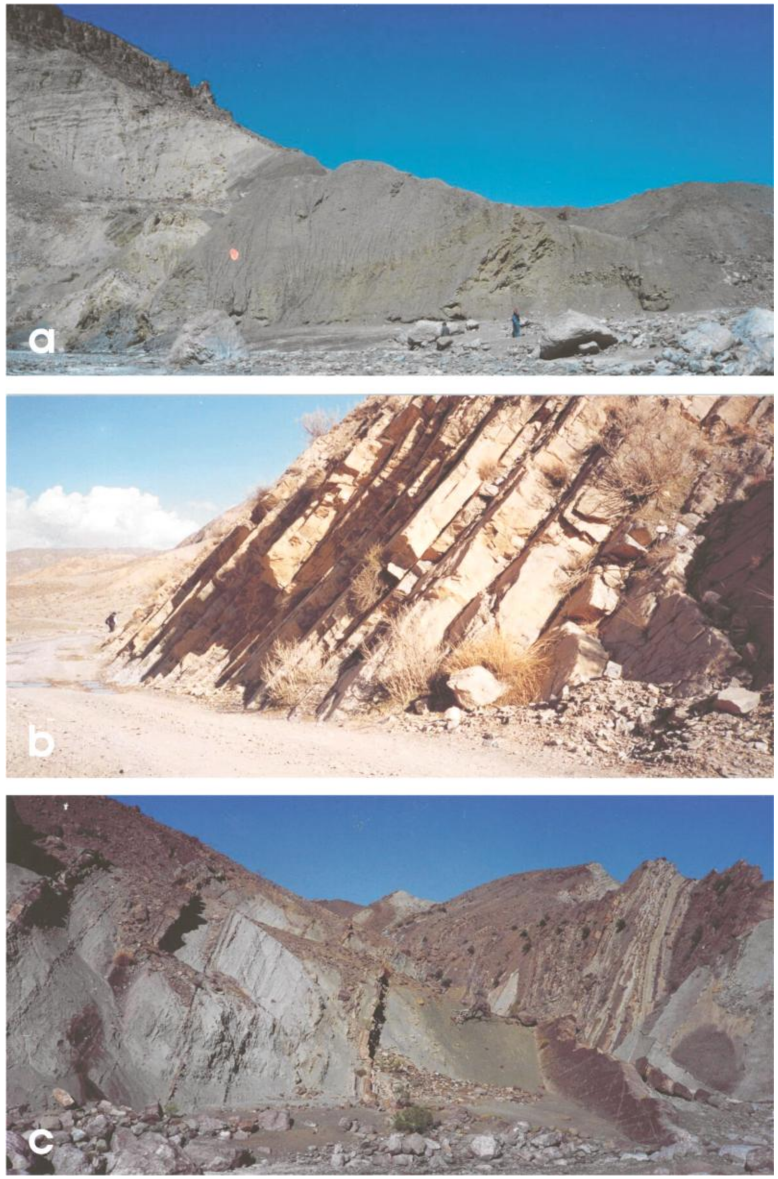

Figure 14.
a: Dark gray shale with organic-rich horizon exposed at the base of Nisai Formation in section-C (sequence Nis-1).
b: Black organic-rich limestone weathers yellowish brown exposed in the middle part of Nisai Formation in section-A (sequence Nis-5).
c: Dark gray to black shale gradually becomes marly in its upper part, exposed in the middle part of section-C (sequence Nis-4).

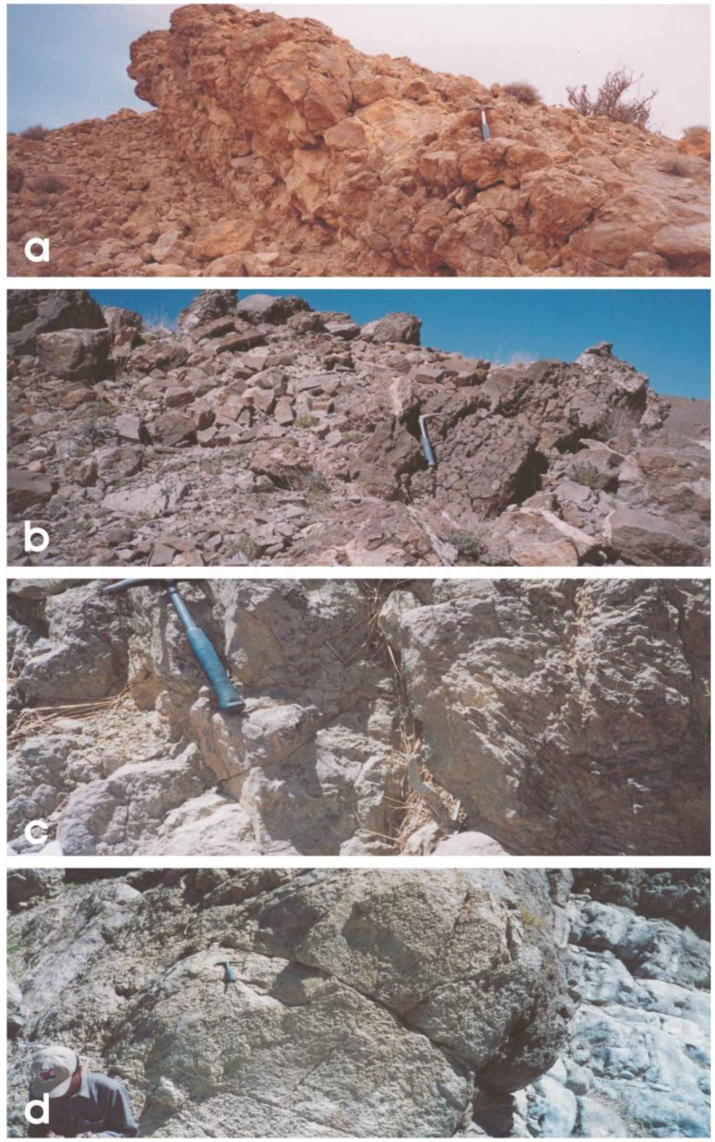

Figure 15.
a: Brownish gray, thick bedded, nodular limestone from the upper part of Nisai Formation exposed in section-A (sequence Nis-8).
b: Brownish gray, limestone debrite exposed in the middle part of Nisai Formation in section-C (sequence Nis-3).
c: Dark gray, thick bedded, coquinal reefal limestone from the upper part of Nisai Formation exposed in section-C (sequence Nis-6).
d: Light gray, extensively burrowed sandstone from the middle part of Nisai Formation exposed in section-C (sequence Nis-5).

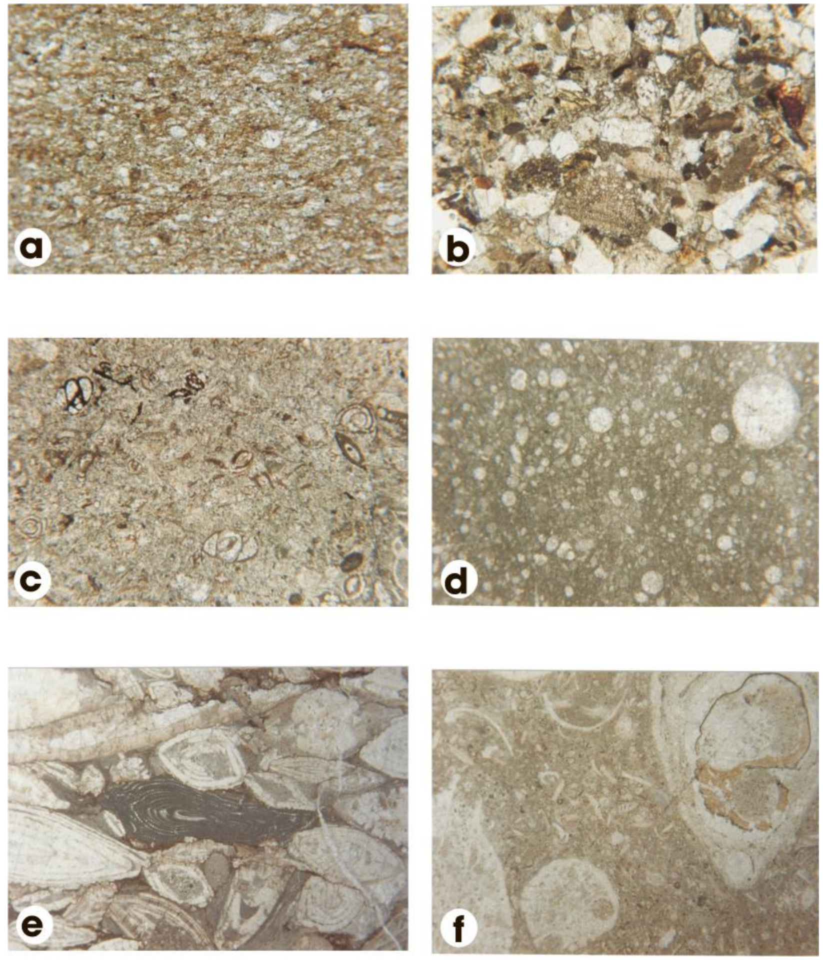

Figure 16.
a: Photomicrograph of organic-rich black limestone from the middle part of Nisai Formation exposed in section-A (sequence Nis-5).
b: Photomicrograph of calcareous sandstone bed from the turbidites in lower part of Nisai in section-A (sequence Nis-2). The microphotograph shows mixed bioclast, intraclast and quarts grains.
c: Photomicrograph showing Miliolidal wacke-packstone from middle part of Nisai Formation exposed in section-A (sequence Nis-6)
d: Planktonic foraminiferal wackestone: high percentage of Globigerinatheka from the middle part of Nisai Formation exposed in section-A (sequence Nis-3).
e: Photomicrograph showing larger foraminiferal coquinal limestone (Nummulites, Assillina and Alveolina) from the middle part of Nisai Formation exposed in section-A (sequence Nis-2).
f: Reefal limestone: pelecypodal, bryozonal, coral rudstone from upper part of Nisai Formation exposed in section-C (sequence Nis-8).