DEPOSITIONAL ENVIRONMENTS OF THE MISRI BANDA AND PANJPIR FORMATION PESHAWAR BASIN (N-W.F.P.)

By

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M Sc. (PESHAWAR)

NATIONAL CENTRE OF EXCELLENCE IN GEOLOGY
UNIVERSITY OF PESHAWAR

1995

بسم الله الرحمن الرحيم

IN THE NAME OF
"ALLAH"
The Most Merciful
The Most Gracious

FAQIR JAN. Printing Press Peshawar Plaza Liaqat Bazar Pesh. Cantt

Depositional Environments of the Misri Banda and Panjpir Formation Peshawar Basin (N-W.F.P.)

Dissertation submitted to the National Centre of Excellence in Geology, University of Peshawar, in partial fulfillment of the requirements for the degree of Master of Philosophy.

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DEDICATION

I dedicate this work to my family, every member of which gave me affection, inspiration and assistance to achieve this goal.

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ACKNOWLEDGEMENT

I sincerely acknowledge Dr. Saifullah Khan Tanoli, Assistant Professor, National Centre of Excellence in Geology , University of Peshawar for his keen supervision, guidance, suggestions, frequent field trips and critical review of the manuscript of the dissertation. Thanks are also extended to Mr. Muhammad Hanif Assistant Professor of Geology Department , University of Peshawar, for his guidance and support both in field and laboratory work, and encouragement in completion of this work.

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ABSTRACT

The Early to Late Ordovician Misri Banda Formation of Peshawar basin is an approximately 280 meters thick siliciclastic sequence of interbedded fine to medium grained quartz arenites and shales. On the basis of sandstone to shale ratios, bed thickness and characteristics, sedimentary structures, five lithofacies are recognised. These are lithofacies MB1, basal conglomerate and sandstone lithofacies; MB2 cross laminated sandstone lithofacies; MB3 medium grained quartz arenite lithofacies MB4 laminated shale lithofacies and MB5, sandstone interbedded with shale lithofacies. These lithofacies are interpreted to have been deposited in foreshore (intertidal) to shelf below the storm wave base. Lithofacies MB1 was essentially deposited on beach to foreshore environments. The lithofacies MB2 was deposited in a shoreface set up and lithofacies MB3 on foreshore. Lithofacies MB4 and MB5 were deposited in shelf environment. The former one in deeper and below storm wave base while the last one in a comparatively shallow set up. The deposition of these lithofacies when viewed in a chronological order indicates transgressive regressive trends of the sea at the time of their deposition.

Similarly five lithofacies were identified in about a 800 meters thick Panjpir Formation of Silurian age. These are lithofacies PF1, argillite; PF2, papery laminated shale with sandstone lensoid bodies; PF3, argillite with interbeds of sandstone; PF4, bioturbated quartz arenite and PF5, calcareous sandstone and sandy limestone with dark grey shale. These lithofacies are interpreted to have been deposited in shelf to foreshore set up. Lithofacies PF1 was deposited in shelf with partially restricted environments which prevailed up to the deposition of lithofacies PF2. However, the environments became open and shallower during the deposition of lithofacies PF3 and PF4 which were deposited in shallow shelf and foreshore set up respectively. The deposition of lithofacies PF5, as interpreted, in restricted shelf indicates another deepening episode.The overall stratigraphic arrangements of the lithofacies of Misri Banda Formation and Panjpir Formation with MB1 the oldest and PF5 the youngest lithofacies, suggest several transgressive and regressive episodes and therefore several parasequence boundaries are identified within these formations.

CHAPTER 1

INTRODUCTION

The strata studied in this research work include the Misri Banda Formation and the Panjpir Formation of Late Ordovician and Silurian age in part of Peshawar basin.

1.1 LOCATION AND ACCESSIBILITY

The present work is carried out in outcrops exposed in Nowshera and Swabi Districts. The outcrops are exposed in the form of isolated low lying hills aligned in an east-west direction extending for a distance of fifty kilometres. The sectiones measured and investigated include, Kandar , Turlandi and Misri Banda sections in Nowshera district and Ambar, Shah Mansoor, Panjpir and Boqa Kandao sections in Swabi district. The study area lies between Longitude 71 50' to 72 40' and Latitude 33 50' to 34 40'.

All the sections are easily accessible due to a network of metalled roads. Kandar village locality is on the main Nowshera-Mardan road whereas Turlandi and Misri Banda localities are on an auxiliary road which shoots out from main Nowshera-Mardan road at Risalpur and leads to Pir Sabak, on the left bank of river Kabul. Misri Banda and Turlandi are also accessible from Akora Khattak by local boats on the other side of the river Kabul.

Ambar, Shah Mansoor, Panjpir and Boqa Kandao localities are easily accessible from Jehangira-Swabi road which shoots out at Jehangira from the main G.T. road.

1.2 GEOGRAPHY OF THE AREA

The climate of the area is dry to subtropical with hot summers and moderate winters. The maximum temperature ranges from ~126 °F (~48 °C) maximum during summers, to

~43° F (~1 °C), minimum during winter.The rainy seasons are from January to March and July to September during which rainfall is comparatively frequent.

The area is thickly populated and the average concentration of population is 500-559 persons per square kilometre (Survey of Pakistan, 1985). Pushto is the mother tongue of the people of the area but they can understand and speak Urdu. The people of the area are among the most educated people of the rural areas of N.W.F.P. They are popular for their hospitality and cooperation. Main sources of income of the people in the area include agriculture, government and private jobs and jobs in the Middle-East. The main crops include tobacco, wheat, sugar cane, maize etc.

1.3 GEOLOGICAL SETTING

The study area is in the eastern part of the Peshawar intermountane basin which lies at the southern margin of the Pakistan Himalayas. Regionally it is bounded by Attock-Cherat range on the south and on the east and west by Gandghar and Khyber ranges respectively (fig. 2.1). To the north and northwest of the Peshawar basin the strata includes metasediments intruded by granitic rocks of the northern edge of the Indian plate (Pogue et al., 1992). Locally the study area extends from southwestern to the northeastern part of the basin in which a well established Paleozoic sequence is exposed (Stauffer, 1968; Pogue and Hussain 1986). Stratigraphic details are given in a separate chapter on the stratigraphy.

1.4 PREVIOUS WORK

First of all Martin and others (1962) gave the geological account of the rocks of northeastern Peshawar basin and divided the rock sequence in "Swabi-Chamla

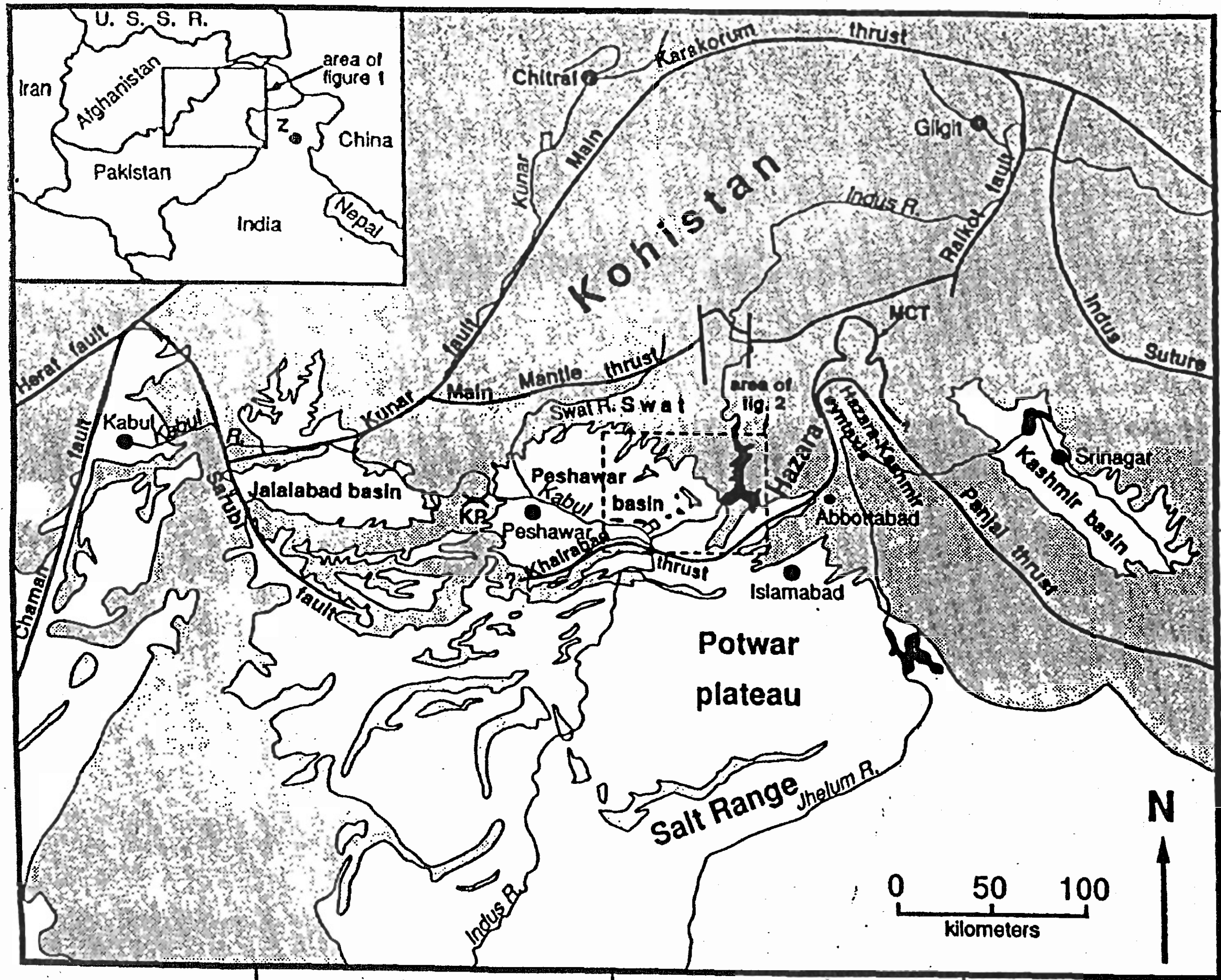


Fig.1.1 Index map of Peshawar basin showing selected major Himalayan faults. After Yeats and Lawrence(1984).Shaded areas are pre-Quarternary rocks.

sedimentary group," and "lower Swat-Buner Schistose group". Davies and Ahmad (1963) described orthoconic nautiloids from the hills south of Swabi indicating a Paleozoic age. Teichert and Stauffer (1965) for the first time discovered the Silurian-Devonian reef rocks near the town of Nowshera. Stauffer (1968) described the reef complex and also reported other probable localities of Paleozoic rocks from northern Pakistan. Ali and Anwar (1969) described the stratigraphy of the Nowshera reef complex. Latif (1970) collected corals from the Nowshera Formation at Pir Sabak and suggested the possibility of Carboniferous age. Fuch (1975) described the stratigraphy of the rocks exposed near Swabi and Nowshera areas. Pogue and Hussain (1986) established a revised stratigraphy and modified the previous stratigraphic nomenclature of the southern Peshawar basin based on systematic geological mapping and discoveries of trilobite trace fossils of Early to Middle Ordovician age. Khan (1992) presented his M.Phil thesis on the stratigraphic and structural set-up of northeastern Peshawar basin.

1.5 PRESENT WORK

Present work is the first sedimentological account of the Misri Banda Formation and Panjpir Formation. The research is restricted to outcrops in Nowshera and Swabi Districts. Following are the main objectives.

1) Sedimentology of the Misri Banda and Panjpir Formation.

Noisedimentological work has to date been undertaken on the Misri Banda Formation (Ordovician) and Panjpir Formation (Silurian). This is the first comprehensive sedimentological analysis of these formations in the area. This will make the major part of this thesis. It will include,

- Detailed facies analysis.
- Reconstruction of depositional environments.
- Reconstruction of the paleobasin.

2) Overall discussion on the stratigraphy of the area.

Since the stratigraphy has been modified drastically by Pogue and Hussain (1986), there are still some confusions and problems with this nomenclature as well. Suggestions for further improvement of the revised stratigraphic nomenclature by Pogue and Hussain (1986) will also be incorporated in this thesis.

3) Sequence stratigraphy of the Misri Banda and Panjpir Formations.

Since no sequence statigrapic work has been done on this Paleozoic succession, it will be the first intodúctory work.

1.6 METHODOLOGY

This research work included both field and the laboratory work. Field work was carried out at several localities including the two type localities, Misri Banda and Panjpir. The main aims of the field work were,

- Detailed lithological investigations for the recognition of lithofacies.
- Sample collections and taking photographs.

Laboratory work included,

- Drawing of lithologic columns.
- Petrography of samples collected.
- Preparation and selection of photographs.

1.7 LAYOUT

The thesis consists of two sections. Following the present chapter, some parts of which are largely based on previously published literature and unpublished thesis and reports, part I (Chapter 2) is concerned with the lithostratigraphy of the Paleozoic sequence in the area. A comprehensive treatment is given to all the previous literature, a brief account of the previous and a detailed account of the recently modified stratigraphic nomenclature, by Pogue and Hussain (1986), is given. Finally problems with the existing nomenclature are outlined for further improvement.

Part II of the thesis constitutes chapter 3-5 which summarizes the sedimentology. The chapters have been designed to group together the lithofacies in a chronological order. Each lithofacies is described and interpreted. Chapters 3-4 describes the sedimentology of the Misri Banda Formation and Panjpir Formation respectively whereas in chapter 5 sequence sratigraphy of both the Misri Banda Formation and Panjpir Formation is discussed.

CHAPTER 2

STRATIGRAPHY

The Paleozoic stratigraphic nomenclature has recently been drastically revised for the Peshawer Basin. Both the earlier and revised nomenclatures are discussed and compared in this chapter.

2.1 PREVIOUS STRATIGRAPHIC NOMENCLATURE

Earliest attempt on the stratigraphy of the area was made by Martin and others (1962). They assigned the name Swabi-Chamla Sedimentary Group to the rocks in the northeastern part of the Peshawar intermontane basin. They further subdivided the group into the following rock units:

- Kala Limestone and Dolomite
- Swabi Quartzite
- Swabi Pebbly Shale

.......Unconformity......

- Chamla Quartzite
- Chamla Shale and Phyllite

However until then nothing was known about the age of these rocks. Davies and Ahmad (1963) reported nautiloids from the Kala Limestone to the south of Swabi (Kala village) and assigned it Silurian-Devonian age. In the southern Peshawar basin, Nowshera and adjoining areas, the presence of Paleozoic rocks was first confirmed by Teichert and Stauffer (1965). Barnett and others (1966) assigned Late Silurian to Early

Devonian age to these rocks on the basis of conodonts zonation. Stauffer (1968) divided the stratigraphic sequence of Nowshera area into three formations which range in age from Late Silurian to post Early Devonian.

- Misri Banda Quartzite --- Post-Early Devonian
- Nowshera Formation------- Late Silurian to Early Devonian
- Kandar Phyllite---------- Late Silurian

Latif (1970) introduced the name Pir Sabak Formation for the upper part of the Nowshera Formation by finding of ampleximorph corals of Carboniferous age in the hillock of the Pir sabak. However, this age was rejected by Talent and Mawson (1979) on the basis of identification of early Devonian Conodonts from the stratigraphically highest beds of the Nowshera Formation.

2.2 REVISED AND MODIFIED NOMENCLATURE

Pogue and Hussain (1986) after systematic geological mapping and discovery of trilobite trace fossils of early to middle Ordovician age, revised and modified the stratigraphic nomenclature of the southern Peshawar basin. The rocks of the Nowshera area were then traced towards Swabi on the basis of similarity in lithology and conodonts revelations. In Swabi area conodonts of late Devonian and Carboniferous age have also been identified.

The revised Paleozoic stratigraphic sequence by Pogue and Hussain (1986) in Peshawar basin with brief description of formations is given in the table 2.1. Figure 2.1 shows a general geologic map and figure 2.2 stratigraphic correlation of the study area. In figgure 2.1 and 2.2 A includes the Kandar, Turlandi and Misri Banda localities whereas

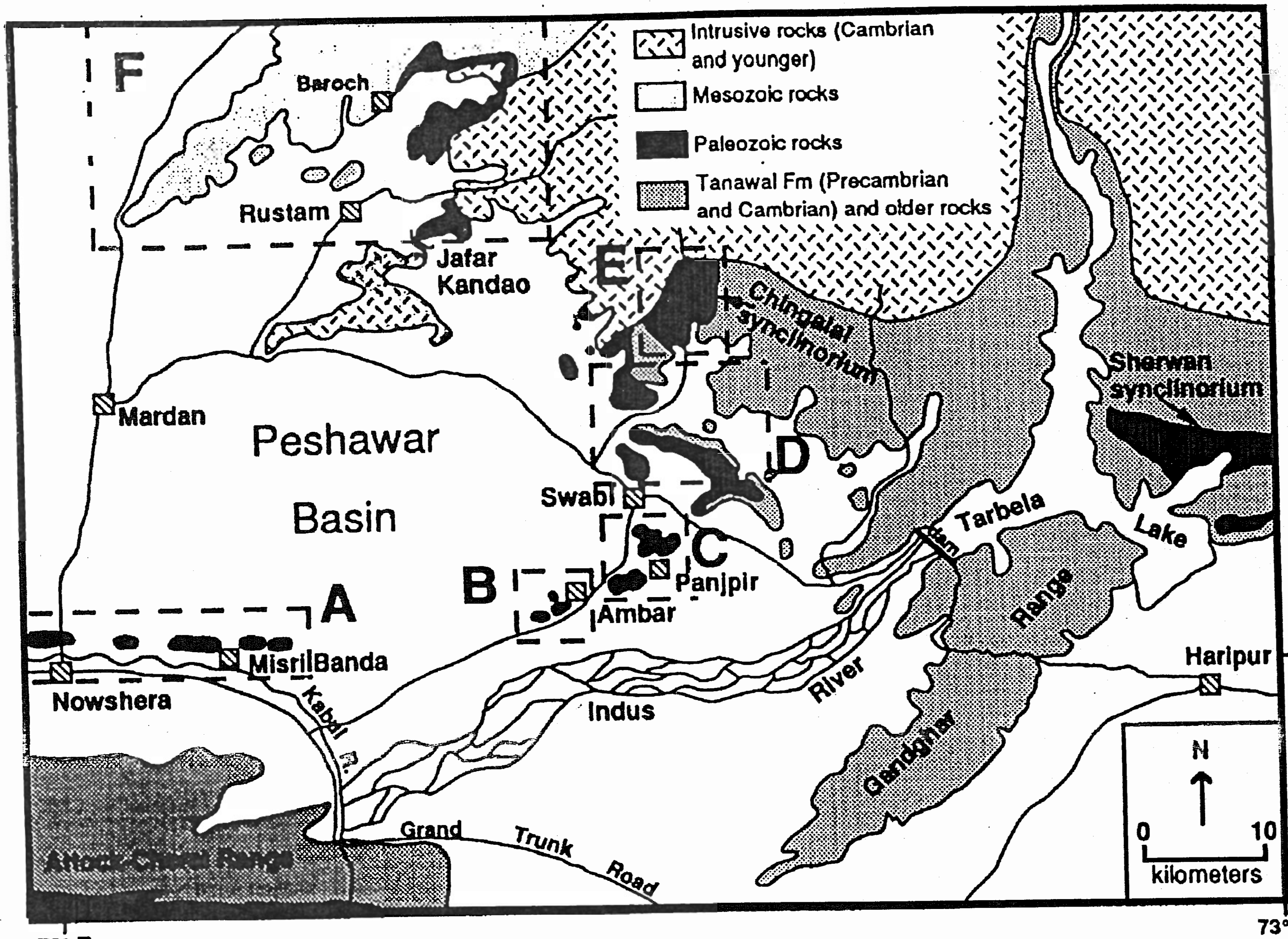


Fig 2.1 Generalized map of eastern Peshawar basin showing areas for composite stratigraphic columns of (fig.2.2), after Pogue et. al. (1992).

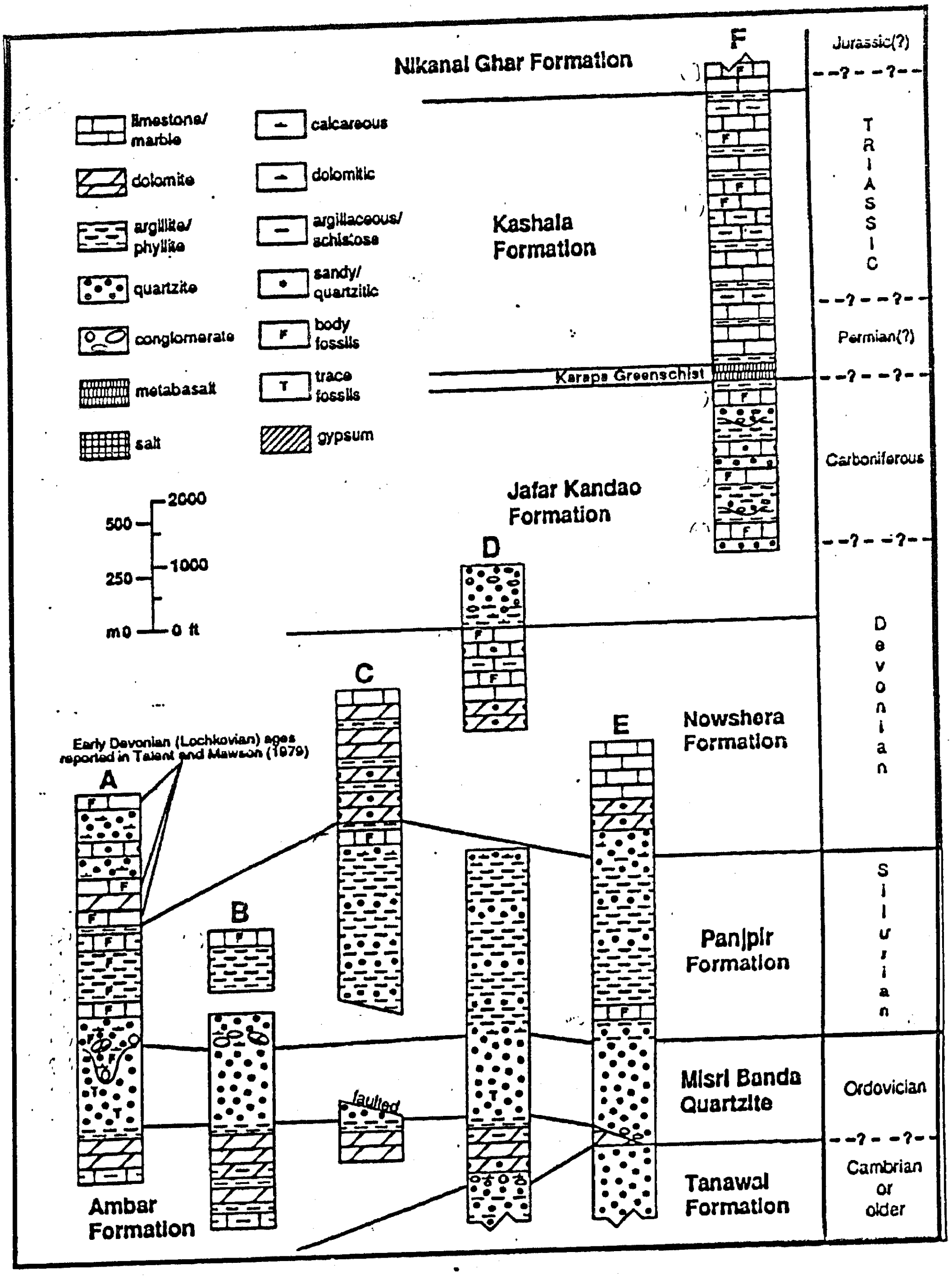


Fig. 2.2 Stratigraphic correlation in the study area after Pogue and Hussain (1986)

TABLE 2.1 PALEOZOIC STRATIGRPHIC SUCCESSION IN THE PESHAWAR BASIN (AFTER POUGE ET AL.,1992)

FORMATION	AGE	LITHOLOGY	FOSSILS	CORRELATION	OLD NOMENCLATURE
Jafar Kandao Formation	Carboniferous (Kinderhookian - Atokan)	Argillite with subordinate limestone, argillaceous quartz arenite and conglomerate.	Conodonts.	Phyllite interbedded limestone sequence overlying reef complex at Ghundai Sar of Khyber Agency.	Swabi Shales of Martin et al. (1962).
Nowshera Formation	Devonian (Lochkovian - Frasian)	Limestone and dolomitic limestone, calcareous quartz arenite with subordinate argillite.	Corals, brachiopodes, gastropodes, cephalopodes, stromatoporoids, and conodonts.	Reef complex at Ghundai Sar of Khyber Agency.	Nowshera Formation of Stauffer (1968), Kala Limestone and Maneri Marble of Martin et al. (1962).
Panjpir Formation	Silurian (Rlandoverian - Pridolian)	Argillite and phyllite with crinoidal limestone and quartz arenite.	Crinoids, conodonts.	Phyllite and interbedded limestone sequence below reef complex at Ghundai Sar of Khyber Agency.	Kandar Phyllite of Stauffer(1968), Swabi and Chamla Shale of Martin et al. (1962).
Misri Banda Formation	Early to Middle Ordovician (Tremadoc - Liandelio)	Quartz arenite with clay interbeds .	Cruziana and skolithus (ichno fossils).	Qurtzite member of Abbottabad Formation in Sherwan area to the west of Panjal Thrust.	Misri Banda Quartzite of Stauffer (1968), Swabi and Chamla Quartzite of Martin et al. (1962).
Ambar Formation	Cambrian ?	Dolomite, dolomitic limestone, calcareous quartzite and subordinate argillite.	No fossils are found.	Abbottabad Formation in Hazara.	Stauffer's Nowshera Formation. Kala Limestone and Dolomite of Martin et al.(1962).

B, C and D indicate Ambar, Panjpir and Shah Mansoor and Boqa Kandao localities respectively.

2.3 DISCUSSION ON THE MODIFIED STRATIGRAPHIC NOMENCLATURE

Pogue and Hussain (1986) for the first time did a detailed and systematic mapping of the area which unveiled some major drawbacks in the previous stratigraphic nomenclature. Besides introducing a new formation (Jafer Kandao Formation) they carried out two major corrections in the previous stratigraphic nomenclature.

1) They changed the age and position of the Misri Banda Formation which was assigned in the previous stratigraphic nomenclature based on the following two points:

a) Discovery of trace fossils cruziana rugosa d,obigny (Early to Middle Ordovician) in the upper shale beds of the Misri Banda Formation.

b) By knowing that the quartzite at Misri Banda are lithologically different from the quartzite lying above the Nowshera Formation, (Misri Banda Quartzite of Stauffer 1968).

2) They introduced the name Panjpir Formation for the Kandar Phyllite of Stauffer (1968) on the basis of presence of lithologies such as argillite, shale, limestone and quartz arenite in it as well.

Neverthless, within the revised stratigraphic scheme of Pogue and Hussain (1986) and Pogue et al. (1992), there are still some unsolved problems. For example these authors are still not sure about the basal contact of the Panjpir Formation which they earlier considered conformable (Pogue and Hussain, 1986) and later on unconformable

(Pogue et al., 1992 ; Hussain et al., 1991). Also for the formation names Pogue and Hussain (1986) and Pogue et al. (1992) have used the name Misri Banda Quartzite while Hussain et al. (1991) have used the name Misri Banda Formation. The name Misri Banda Quartzite is objectionable from two reasons:

1) As it is having considerable amount of argillite in its upper part which are 20% to 30% by volume to quartz arenite in Boqa Kandao area and more than 10% in Misri Banda area. So it can not be named MIsri Banda Quartzite. It should be rather be called Misri Banda Formation.

2) The word quartzite was of course used in the older literature but now it is obsolete and the word quartz arenite is currently used for sandstone having 90% or more than 90% quartz grains, (Pettijhon, 1984).

Lower contact of the Panjpir Formation is not clearly defined by Pogue and Hussain(1986). They have described it as unconformable and the unconformity is marked by a discontinuous bed of conglomerate which is locally exposed at about one kilometer to the east of Turlandi village in Nowshehra area. However after a detailed survey of the outcrop it was found that the conglomerate beds are lying unconformably over the planar sandstone and limestone interbeds of the underlying Ambar Formation (fig. 2.3a, b). At type locality the lower contact was interpreted as faulted (Pogue et al., 1992) due to which the conglomerate unit was missing in that area and the argillites of the Panj Pir Formation are lying over a 10-15 meters thick quartz arenite of the Misri Banda Formation which in turn are lying over a thick sequence of limestone of the Ambar Formation. Similar is the case in Boqa Kandao area where Misri Banda Formation interpreted by Pogue and

a.

b.

Fig. 2.3a, b The thick conglomerate beds of Misri Banda Formation marking its uncoformable contact with the underlying Ambar Formation.

Hussain(1986) have alternations of quartz arenite with argillite of considerable thickness which is confusing the contact between Misri Banda Formation and Panjpir Formation as at type locality the lower most lithology is argillite.

At the end of this discussion there are some suggestions which can further improve the modified stratigraphic nomenclature.

1) The name Misri Banda Quartzite should be revised as Misri Banda Formation as done by Hussain et al. 1990.

2) Further work on regional scale should be carried out for establishing the nature of contacts of Panjpir Formation.

CHAPTER 3

FACIES ANALYSIS OF THE MISRI BANDA FORMATION

Misri Banda Formation is comprised of dominantly quartz arenite to subarkose types of Sandstone with a considerable amount of mud. It is exposed in the form of a series of low lying hills. Except at its type locality and Boqa Kandao section where it is poorly exposed and its upper contact with the Panjpir Formation is presently confusing. After carrying out field work at Misri Banda, Boqa Kandao Shah Mansoor, Ambar, and Turlandi five lithofacies were identified in this formation on the basis of differences in lithology, variation in bedding style and characteristic internal organization. These lithofacies are;

1. Lithofacies MB1 - Basal conglomerate and sandstone.
2. Lithofacies MB2 - Cross laminated sandstone.
3. Lithofacies MB3 - Medium-grained Quartz arenite.
4. Lithofacies MB4 - Laminated Shale.
5. Lithofacies MB5 - Sandstone interbedded with shale.

The conglomerate beds comprise the basal lithofacies of the Misri Banda Formation and marks its unconformable contact with the underlying Ambar Formation. Pogue et al. (1992) wrongly interpreted it as the basal part of the Panjpir Formation. But after a very detailed fieldwork it was found that the conglomerate beds are lying unconformably over the planar interbeds of sandstone and dolomite of the underlying Ambar Formation (fig. 2.3a, b). Lithofacies MB1 and MB2 are repeated in the sequence and represent the major portion of the Misri Banda Formation. The contact between lithofacies MB3 and MB4 is gradational, however the contact between MB2 and MB3 is sharp to erosive. Each

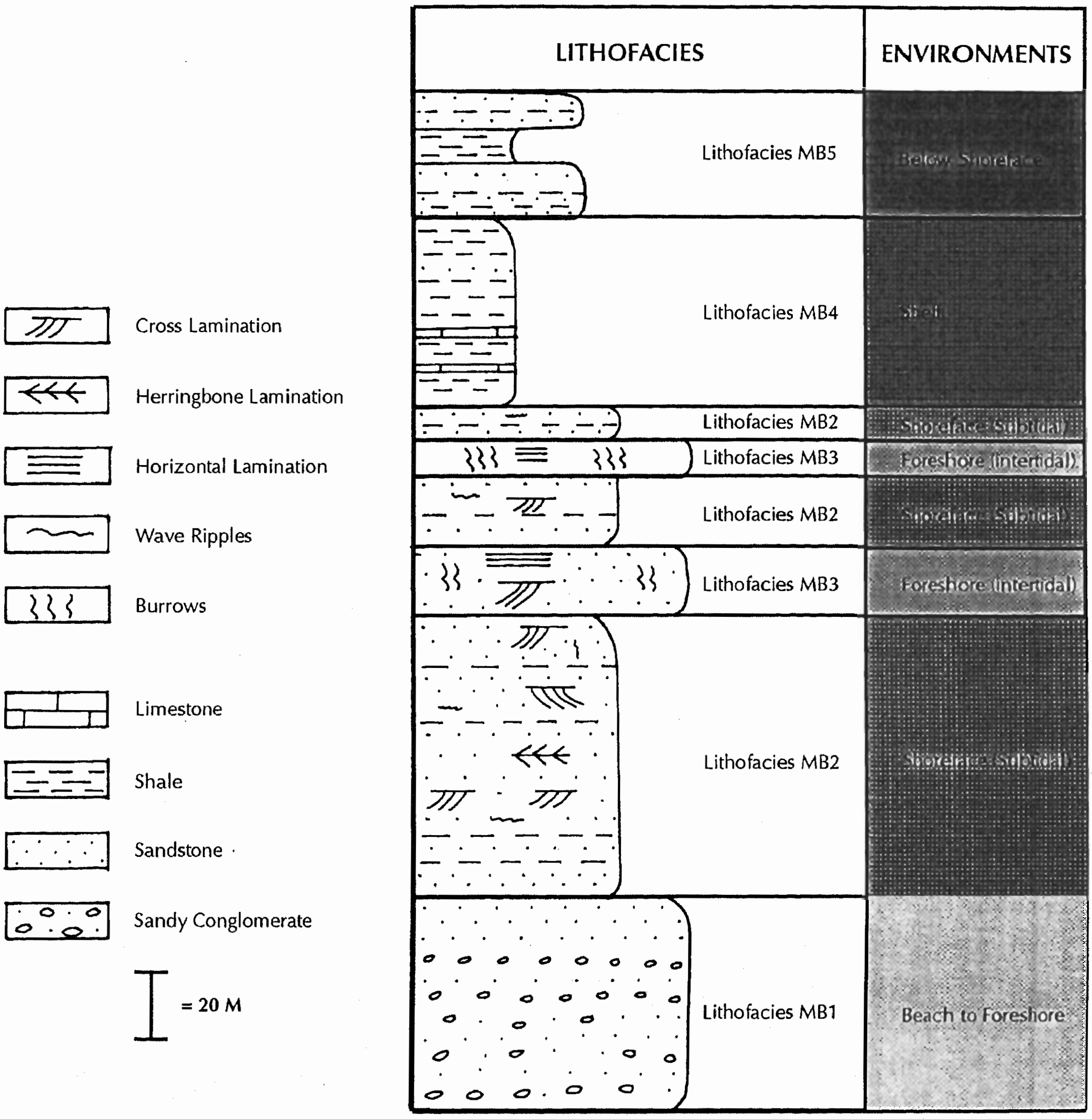


Fig. 3.1 Generalized lithologic column of the Misri Banda Formation showing lithofacies and environments of deposition.

TABLE 3.1 SUMMARY OF LITHOFACIES OF THE MISRI BANDA FORMATION .

LITHO-FACIES	LITHOLOGY	CONTACTS	COLOR	UNIT THICKNESS (M)	BED THICKNESS (CM)	BED FORMS	BEDDING PLANES	SEDIMENTARY STRUCTURES AND FOSSILS	OTHER CHARACTERISTICS	ENVIRONMENTS
MB1	Conglomerte to conglomeratic sanstone to sandstone.	Upper gradational Lower unconfomable.	Grey .	60	20-80	Sheets , persistant at outcrop level.	Sharp.	Gradded to inversely gradded beds , preffered orientation of clasts, horizental bedding and localised crossbedding .	Dolomite clasts are larger subangular and quartz arenite clasts are small and rounded. Sand content increases upto 100% sandstone in the upper portion .	Beach to Foreshore.
MB2	Fine to medium grained quartz arenite with shale interbeds.	Upper gradational Lower covered.	Pinkish to light grey to brownish.	33	5-50	Planar and persistant.	Rippled.	Wave ripples , crossbedding and herringbones and rare skolithus burrows.	The bed thickness is less in the lower part and the ripples are delicate than the upper part .	Shoreface (Subtidal).
MB3	Medium to coarse grained quart arenite .	Upper gradational Lower gradational	Clear white to light grey.	33	20-80	Planar and persistant .	–	Skolithus, herringbones and horizontal lanination.	Amalgamated beds having little or no shale .	Foreshore (Intertidal).
MB4	Shale	Upper gradational Lower sharp to erosive.	Brown to yellowish to greenish grey.	54	-	–	–	Horizental lamination and cruziana ichno fossils .	In the middle portion limestone lenses and in the upper portion sandstone beds and lenses are rarely present.	Outer to middle shelf.
MB5	Sandstone inter bedded with shale.	Upper gradational - Lower gradational .	Light grey.	50	5-40	Planar and persistant to lenticular.	Wavy to planar.	Massive to horizontally laminated .	Very poorly exposed .	Below Shoreface.

lithofacies is described and interpreted separately. Table (3.1) summarizes the characteristics of the facies recognized in the Misri Banda Formation and figure 3.1 is showing the generalized lithologic column with lithofacies and environments of depositions.

3.1 LITHOFACIES DESCRIPTION AND INTERPRETATION

Lithofacies MB1: Basal conglomerate and sandstone.

Location: Turlandi

Description

This lithofacies was studied at Turlandi, where it has a lateral extent less than a kilometer and at Misri Banda and Boqa Kandao localities the equivalent zone is marked by a 5-10 m thick clay while at Shah Mansoor the beds of lithofacies MB2 are lying directly over the beds of Ambar Formation and lithofacies MB1 is missing. Lithologicaly this lithofacies varies from conglomerate to conglomeratic sandstone and sandstone proportions are high. Both the conglomerate and pebbly sandstone are alternating with each other but upward the sandstone content increases and the conglomerate grades into sandstone. Both the grain size and bed thickness decreases upward.

The sandstone of the lithofacies is medium-to-coarse grained and pebbly with pebbles and cobbles of quartz arenite and dolomite. In this lithofacies generally the pebbles within the quartz arenite are well rounded whereas those of dolomite are angular, subangular and rounded showing comparatively less distance of transportation (fig. 3.2). The quartz clasts generally range between 2 to 10 cm in diameter whereas those of dolomite range even up to a meter in length and rarely several meters in length. The

Fig. 3.2 The matrix supported conglomerate of lithofacies MB1 with large subangular dolomite and comparatively smaller and rounded quartz arenite clasts.

conglomerate is matrix supported and the matrix is generally the coarse sandstone. Internally it looks massive to horizontally bedded and the pebbles and cobbles seem to be having a preffered orientation parallel to bedding. Generally it looks gradded but some beds give the impression of inverse grading.The individual bed thickness varies between 20-80 cm. The estimated thickness at Turlandi of the lithofacies is about 60 m.

Interpretation

This basal lithofacies represents an unconformity with the underlying Ambar Formation. The overall features such as its more or less continuous sheet like beds, the graded to inversely graded nature and horizontal to occasional cross bedded internal organization can occur in any environment. However, the maturity of the quartz arenite clasts indicates its long transportation and/or longer period high energy subjection compared to the sub-angular and bigger clasts of dolomite (cf. Pettijhon, 1984; Reineck and Singh, 1980) and very high energy environments of deposition (Tanoli and Pickerill 1988). The increasing proportions of sand beds indicates the deepening and transgressive phase of the sea. However its localized occurrence is pointing towards an uneven topographic setup as at one point the deposition of lithofacies MB1 was in progress and on the other location laterally equivalent red clay. The clay might have been deposited in an adjoining flood plain area or in the tidal flat zone in the transitional environments. This scenario suggests a very uneven topography of the paleoshoreline. The extraordinary large size of the dolomite clasts and their low roundness indicates their very short transport and reworking such as would be the case in a beach rock eroded breccia (Roep et al., 1979) possibly of the underlying Ambar Formation. Bourgeois, (1980) interpreted such a set up in the Cretaceous Cape Sebastian Sandstone, Oregon, USA as foreshore to shoreface deposition in a transgressive phase. In the present situation and the context of the overlying lithofacies MB2, lithofacies MB1 is suggested to have been deposited in a very high energy beach to foreshore zone of a transgressing sea.

Lithofacies MB2: Cross-laminated sandstone.

Locations: Misri Banda, Boqa Kandao, Shah Mansoor and Ambar.

Description

This lithofacies overlies lithofacies MB1 and has a gradational lower contact. Lithologically the lithofacies MB2 is predominantly composed of thin to medium bedded sandstone with subordinate interbeds of shale. The shale is generally bioturbated. The sandstone varies from pinkish to light grey to greyish brown in colour and is fine-to-medium grained. The beds are persistent at outcrop level and the individual bed thickness ranges from 5 - 18 cm in the basal and 12 to 65 cm in the upper part of the lithofacies. The sandstone beds are generally separated by thin beds of clay but sometimes look amalgamated, especially in the upper horizons where the clay beds are thin or rare. Internally most of the beds are cross-laminated, however, evenly laminated beds are also present, which are comparatively more common in the lower part (fig.3.4). Cross lamination is from small scale in lower horizons to large scale in upper horizons and usually planar (Mckee and Weir, 1953, Reineck and Singh, 1980) with foresets dipping gently to moderately and becoming tangential with the lower bedding plane. Foresets are generally dipping bi-directionally and sometimes herringbone cross lamination are found (fig.3.5). The upper bedding planes are generally wave rippled (fig.3.6). The ripples are

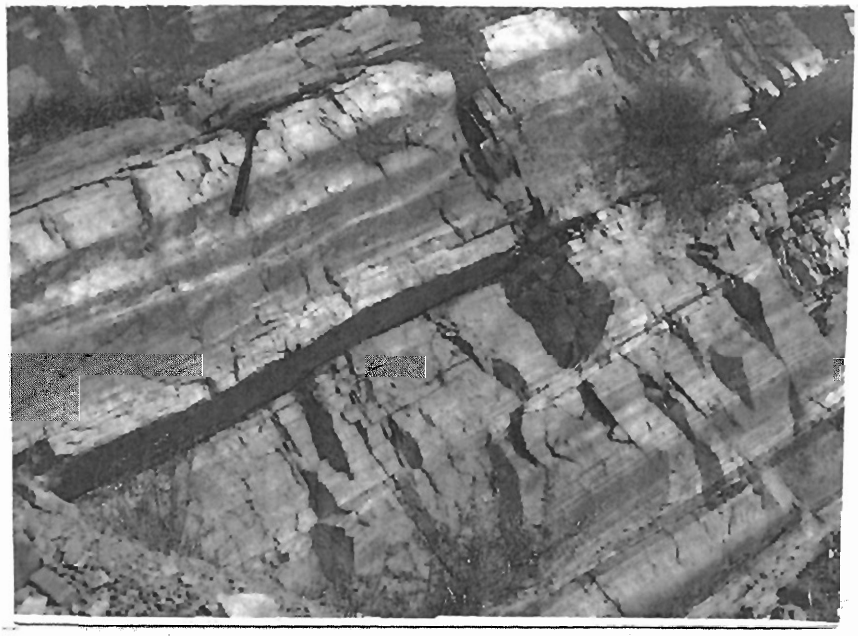


Fig.3.3 The medium bedded sandstone of lithofacies MB2. The beds are planar and demonstrate consistency in thickness laterally.

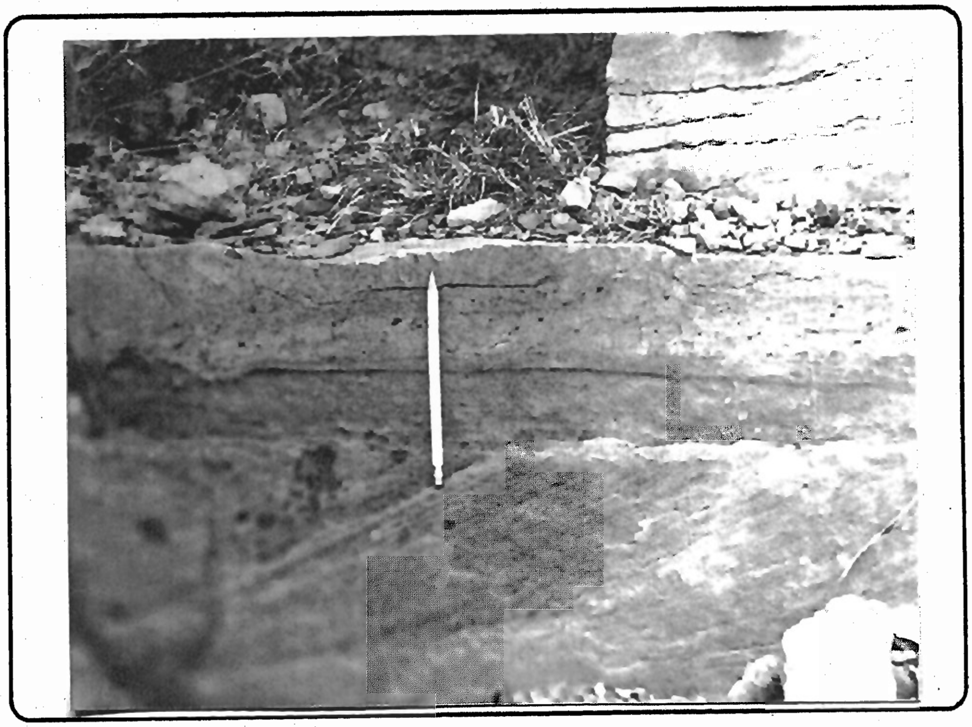


Fig.3.4 The alternating horizontal and cross laminations in sandstone beds of litho-
-facies MB2.

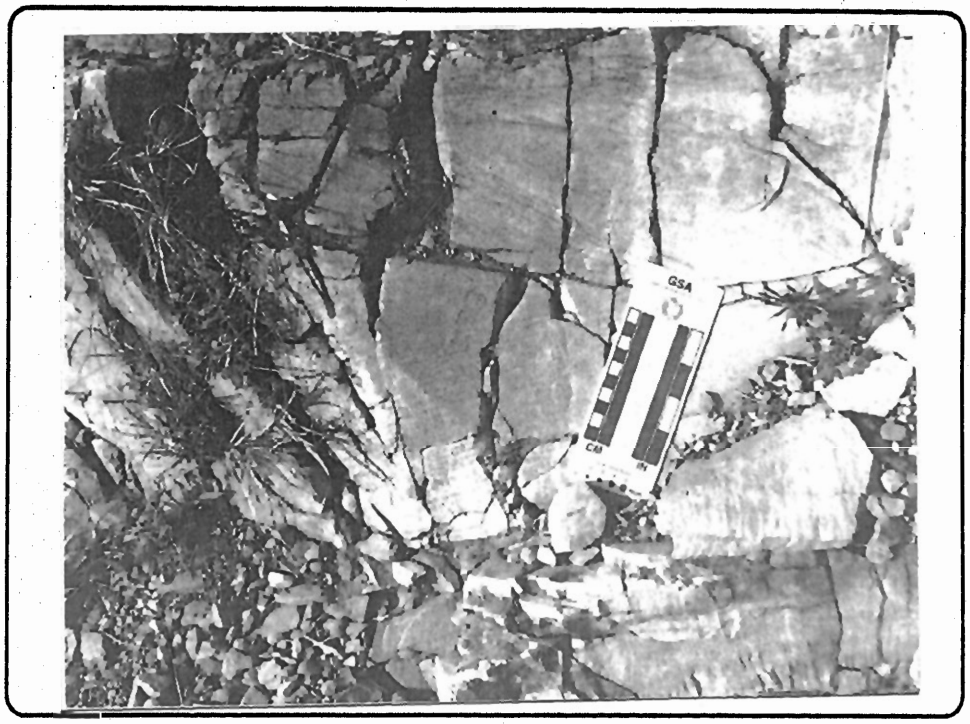


Fig.3.5 Herringbone cross laminations in sandstone beds of lithofacies MB2.

Fig.3.6 Wave ripples on the bedding plane of the sandstone beds of lithofacies MB2.

both small with sharp crests and large and with flat crests. The sandstone to clay ratio is generally in the range of 75 to 90 %. The clay is greenish to dark grey, blocky to evenly laminated and consists of occasional flasers and lamination of sandstone in it. It is persistent at outcrop level and some beds are considerably thick. The maximum thickness at Boqa Kandao is 50 to 60 meters.

Interpretation

The variability in the thickness of sandstone beds and sedimentary features, like wave ripples, small scale and large scale cross bedding, suggests that environment was changing to a comparatively high energy environment during the deposition of this lithofacies (Tanoli and Pickerill 1988). However, as a whole, the sedimentary features like even lamination alternating with the cross lamination (Reineck and Singh, 1972 ; Brenchley and Pickerill, 1980), herringbone cross-lamination , wave ripples, intensity and frequency of tidal slack-water mud suspension deposits (Clifton, 1981) suggest a subtidal environment, extending from partially intertidal to subtidal . Facies, similar to the lower beds of lithofacies MB2, have been described by Brenchley and Pickerill (1980) from Berwyn Hill, North Wales who have interpreted it as deposits of relatively tranquil muddy subtidal environment. Due to the absence of conglomerate lithofacies MB1 in Boqa Kandao, it is suggested that this area was smooth tidal flat where mixed clay and sand sedimentation was going on. As sea transgressed over this flat subtidal high energy environments were developed where more thicker and proportionally more sandstone was depositing.

Lithofacies MB3: Medium grained quartz arenite.

Location: Misri Banda, Boqa Kandao, Shah Mansoor and Ambar.

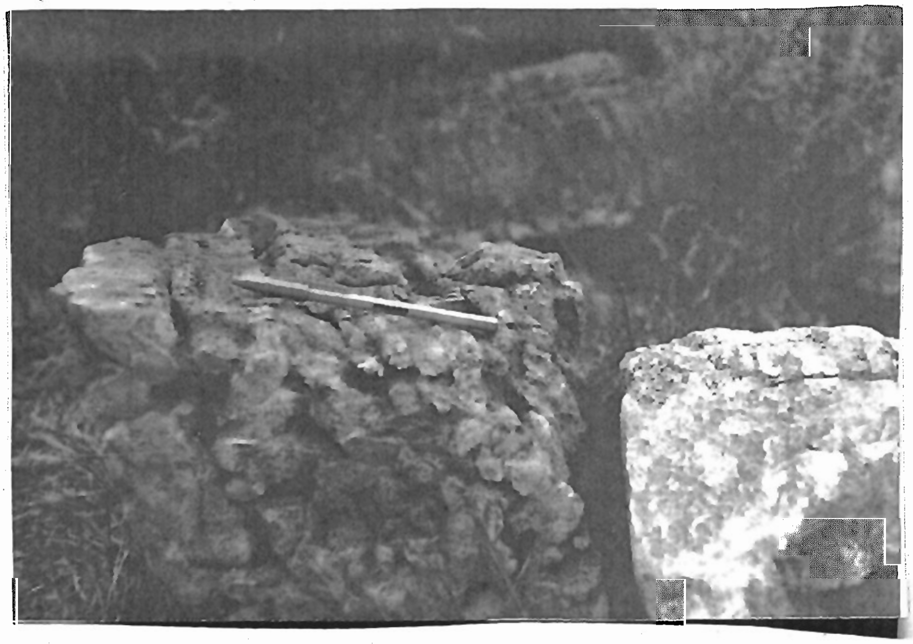
Description

This lithofacies is repeated several times in the middle part of the Misri Banda Formation and is cyclic with lithofacies MB2. It is exposed widely but its best exposure is in Boqa Kandao where its maximum thickness is about 30 m. Generally, this lithofacies comprises clear white to light grey quartz arenite which is medium- to fine-grained. The beds are persistent at outcrop level and have an individual bed thickness from 20 to 80 cm. The beds are mostly amalgamated and the sandstone is 90 to 100% as compared to shale. Sedimentary features include planar crosslamination, horizontal lamination and Skolithos burrows. However, the depositional features are somewhat ambiguous due to intensive bioturbation and compositional homogeneity. The cross-lamination are bidirectional, sometimes herringbones in nature and have gently dipping foresets. Skolithos burrows are abundant in this lithofacies (fig. 3.7a, b). Their diameter ranges from 0.5 to 1.5 cm. and their length is from 15 to 30 cm and sometimes even more. They have formed intensively reworked zones in this lithofacies.

Interpretation

characteristics such as, compositional homogeneity, textural maturity, lateral bed persistence, gently dipping cross-lamination, horizontally stratified beds, the absence of interbedded shale and the presence of skolithos ichnofacies in the strata of lithofacies MB3 are collectively indicative of relatively high level of wave or current energy and suggests a nearshore marine setting (cf. Davies et al, 1971; Davies and Ethridge, 1971;

a.



b.

Fig. 3.7a, b Skolithus burrows in the beds of lithofacies MB3. These burrows range from 0.5 to 1.5 cm in diameter and 15 to 30 cm in length.

Clifton et al, 1973 ;Cotter, 1983; Frey and Pemberton, 1984). Similar facies have been interpreted to represent foreshore to upper shoreface environments (for example, see Young and Reinson, 1975; Carter, 1978; Jansa 1975). The occurrence of herringbone cross-lamination indicates bed load transport and bipolar reverse in flow direction which is typical of tidal influence (Reineck, 1963; Reineck and Singh, 1980). The well developed skolithos burrowed zones made by suspension feeders are developed in very high energy environments such as would be present in the fore shore to intertidal environments (Rhodes, 1967 ; Jansa, 1975). The horizontally stratified beds are interpreted as foreshore beach deposits formed under upper flow regime conditions. Similar facies have been discussed by Jansa (1975) from the Monkman Quartzite, North eastern, British Columbia, Canada. It is concluded that the lithofacies MB3 was deposited in a tide dominated beach or foreshore and upper shoreface environments.

Lithofacies MB4: Laminated shale.

Location: Misri Banda, Boqa Kandao.

Description

This lithofacies is well exposed at Misri Banda in the main stream and at Boqa Kandao. Its maximum thickness at Misri Banda is 54 m whereas at Boqa Kandao its approximate thickness is more than 40 m. Characteristically lithofacies MB4 comprises of shale with thin interbeds and lenses of limestone and sandstone (fig. 3.8). The lower portion of the lithofacies is nearly 100% shale, the middle portion is having limestone interbeds/lenses while the upper portion contains thin interbeds of sandstone. The shale is brown to yellowish brown to greenish grey, evenly laminated and fissile at places. The

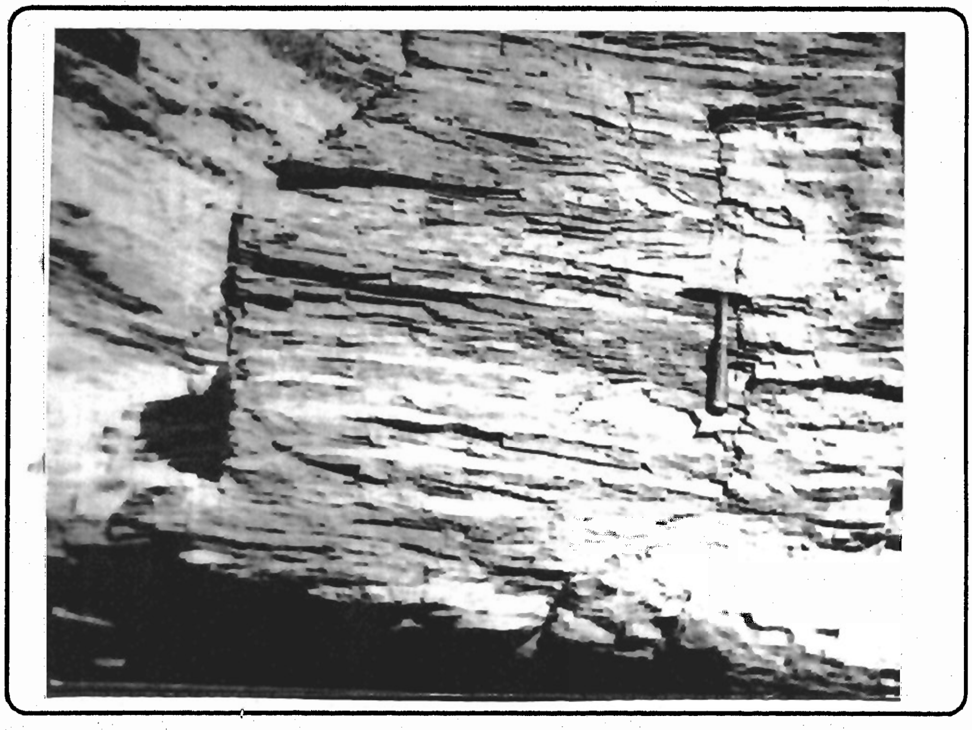
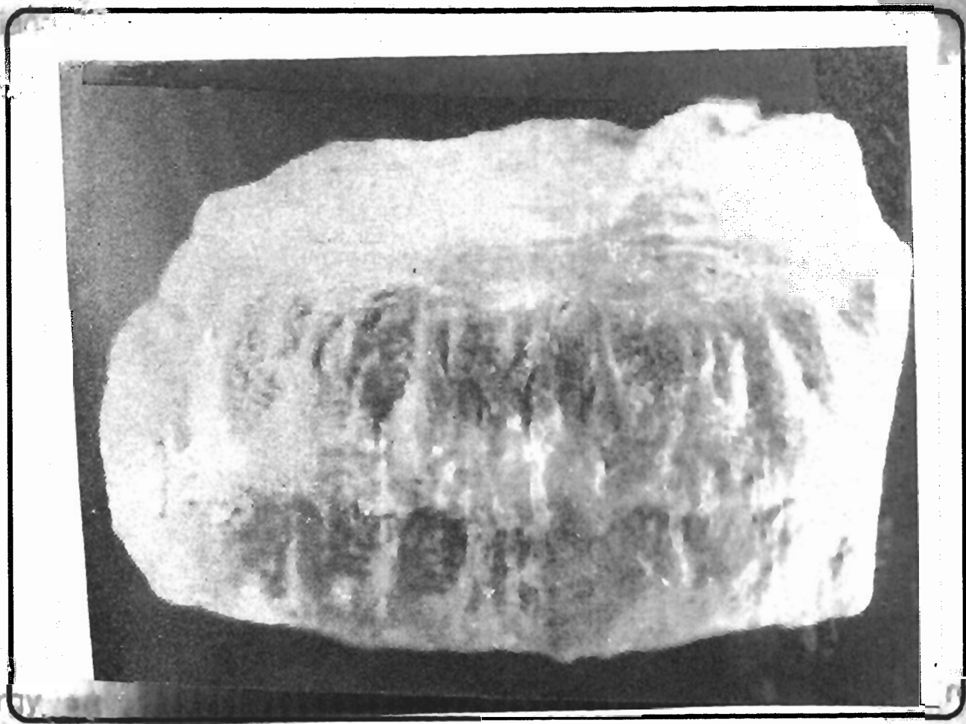
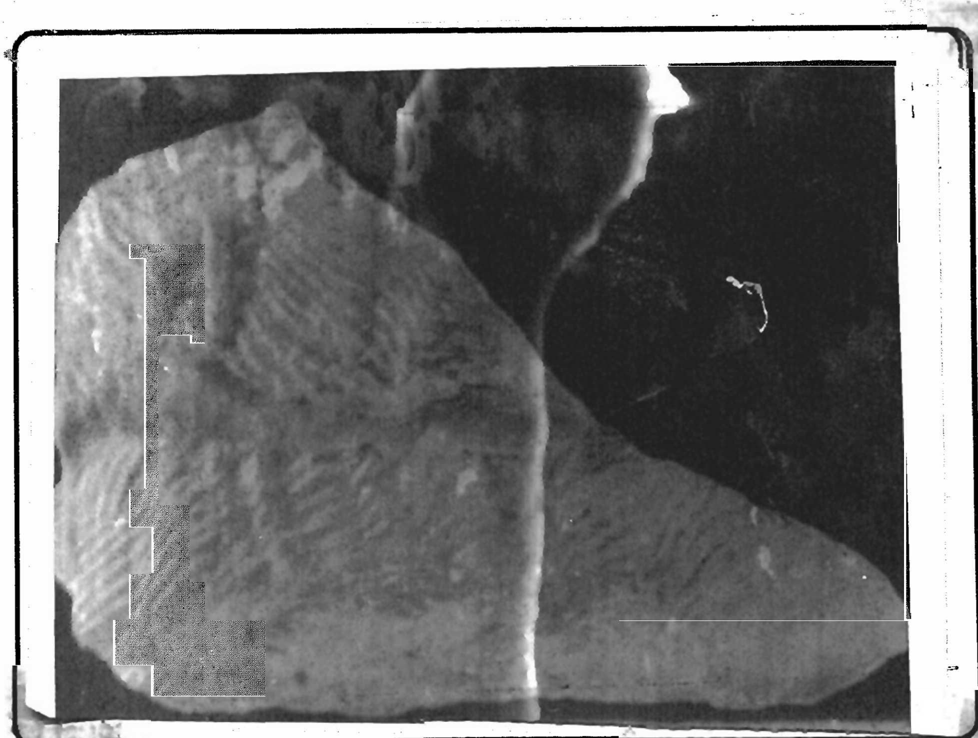


Fig. 3.8 Shale in the lower part of lithofacies MB4.



a.



b.

Fig. 3.9a, b Trace fossil cruziana rugosa in the beds of lithofacies MB4.

yellowish brown beds are calcareous whereas greenish grey beds are non calcareous. Cruziana Rugosa d Obigny trace fossils have been reported from this lithofacies (Pogue and Hussain, 1986) (fig. 3.9a, b).

Limestone is micritic and is basically a mudstone (Dunham, 1962) with some fossils. Sandstone is light grey to pinkish grey and fine to medium grained. Internally the beds may be massive or evenly laminated. This lithofacies passes gradationally into lithofacies MB5 and the upper boundary is placed where the proportions of sandstone to shale reaches 50%.

Interpretation

Predominance of clay in this lithofacies suggests its deposition in a generally low energy shelf environment where chiefly muddy sediments were accumulating. Occasional bioturbation by Cruziana ichnofacies suggests relatively high sedimentation rates or unfavourable conditions(e.g. low oxygen) for the colonization of most benthic fauna and, therefore, deeper water (Tanoli and Pickerill, 1988). Presumably the muds were deposited from suspension and material was introduced by wave and, or current activity (c.f Simonson, 1984 ; Swift et al., 1986); Tanoli and Pickerill, 1988). The interbedded sandstone beds in the upper horizon are best interpreted as having been periodically introduced by relatively high energy storm related currents (c.f. De Raff et al, 1977 ; Brenchley et al 1979., Kreisa, 1981; Morton, 1981; Tanoli and Pickerill, 1988). However, the absence of sandstone in the lower and middle horizons and the occurrence of mudstone suggest even deeper environments up to outer shelf (Potter et al. 1980). Middle part of lithofacies with shale dominance represents the relatively deepest environments and, therefore, records maximum transgression. The lower part and the upper part of the lithofacies with increased sandstone beds reflect relatively shallower shelf environments. The overall nature of the lthofacies suggest transgressive and regressive trends of the sea.

Lithofacies MB5: Sandstone interbedded with shale.

Location: Misri Banda and Boqa Kandao.

Description

This lithofacies is distinguished from lithofacies MB4 by the presence of 50 to 75 % sandstone as compared to shale. Its upper boundary is not exposed at Misri Banda and Boqa Kandao sections. This lithofacies is generally comprised of fine to medium grained sandstone interbedded with shale (fig. 3.10.). At Misri Banda section the lower and upper horizons of the lithofacies are having higher percentage of sandstone, up to 75%, however in the middle part the percentage of sandstone reduces to nearly 50%. Sandstone beds are thin to medium thick with individual bed thicknesses ranging from 5-40 cm. They are massive to evenly laminated, persistent at out-crop level, especially in the upper horizon, however, sometimes they may become lenticular to wavy (Reineck and Wunderlich, 1968; Reineck and Singh, 1980).

The lower bedding planes of the sandstone beds with interbedded shale are sharp and wavy whereas upper bedding planes are usually sharp but sometimes appear gradational. The shale is grey to greyish brown and range in thickness from thin beds to more than a meter. At Misri Banda the exposed thickness of this lithofacies is 33 m whereas at Boqa Kandao its estimated thickness is more than 50 meters.

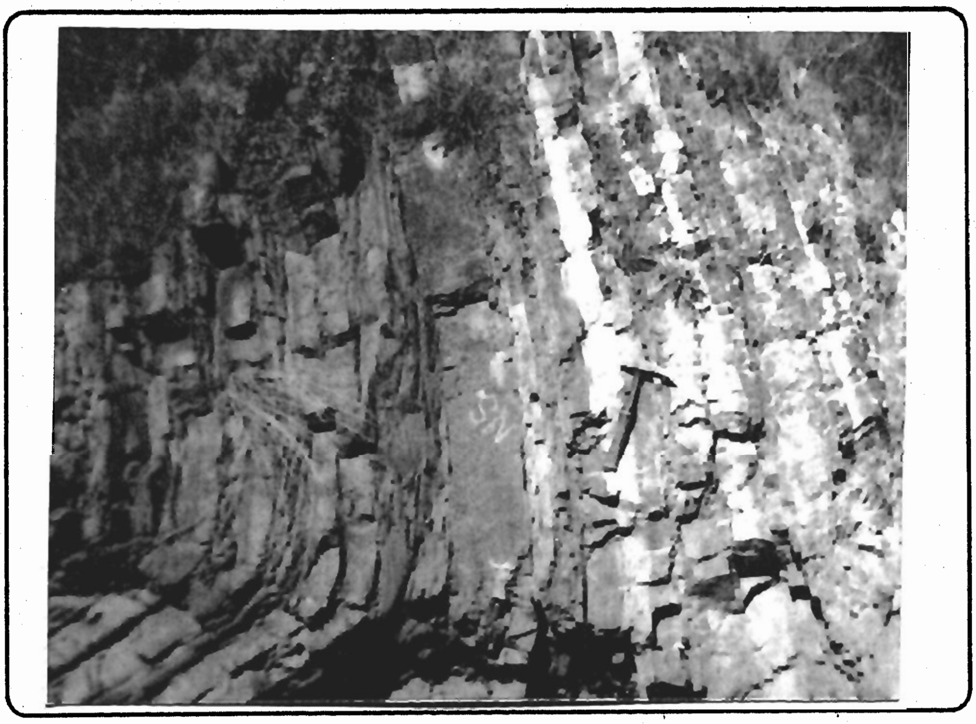


Fig.3.10 Sandstone interbedded with shale in lithofacies MB5 showing sharp contacts between sandstone and shale.

Interpretation

The greater proportion of sandstone to shale and the greater thickness of the sandstone beds suggest comparatively shallow water conditions of deposition than, the gradationally underlying lithofacies MB4 (cf. Brenner and Davies, 1973; Goldring and Bridges, 1973; Bourgeois, 1980; Simonson, 1984 ; Aigner,1985 Tanoli and Pickerill, 1988). Presumably the deposition of sandstone beds is related to the rising energy levels in inner to middle shelf environments. The sharp lower bedding planes of the sandstones beds reflect sudden input of sand most likely during storm conditions in the shelf. This is further supported by the upper flow regime developed internal organization in the sandstone beds (Tanoli and Pickerill, 1988). The presence of considerable amount of shale and the absence of amalgamated beds further supports its deposition below shoreface or even lower shoreface as well. The greater proportions of sandstone in upper and lower horizons compared to the middle part suggest the cyclic fall and rise of the sea or cyclic availability of the sand by the waves and currents.

3.2 FACIES ASSOCIATION AND ENVIRONMENTAL SYNTHESIS

The vertical lithofacies sequence for the exposed sections of the Misri Banda Formation are illustrated in (fig 3.1). Only at Boqa Kandao and Misri Banda sections all the lithofacies are exposed. The facies analysis of the Misri Banda Formation conclude that:

1) The lithofacies MB1 was deposited in beach to very shallow shoreface environments making base of a transgressive phase which is obvious from the change in lithology from thick-bedded conglomerate to medium to thin bedded sandstone.

2) Lithofacies MB2 was deposited in a deepening upward environment, upper to lower shoreface. The occurrence of directly overlying lithofacies MB3, a foreshore to upper shoreface deposit was the result of a renewed regression. The cyclicity of the lithofacies MB2 and MB3 indicates the cyclic phases of regression and transgression at the time of deposition. However, strong tidal activity prevailed throughout the deposition of lithofacies MB2 and MB3.

3) During the deposition of lithofacies MB4 low energy shelf conditions prevailed where chiefly muddy sediments were accumulating, However, the thin beds of sandstone were introduced during periodically high energy conditions (Simonson, 1984; Aigner, 1985; Brenchley, 1985; Tanoli and Pickerill, 1988). These sandstone beds, generally increase in abundance and thickness stratigraphically upward towards the overlying lithofacies MB5 of the formation. This also suggests a shallowing upward trend (regressive phase). The entire lithofacies MB4 was deposited below the storm wave-base whereas some part of the MB5 may have been deposited between storm and fair weather wave base.

3.3 PROVENANCE OF THE MISRI BANDA FORMATION

The current research work was mainly oriented towards the study of field and outcrop features. In other words, emphasis was on the primary depositional features for facies analysis and environmental reconstruction. However, random sampling was carried out of the Misri Banda Formation at Misri Banda and Shah Mansoor was carried out for the purpose of microscopic and provenance studies. Fifty thin sections were studied thoroughly and the percentages of different minerals were established by visual estimation

TABLE 3.2 DESCRIPTION OF THIN SECTIONS OF MISRI BANDA FORMATION.

Sr No	Mineral Composition %age	Texture	Diagenetic Effects
MBQM-9	Quartz mono crystalline with undulatory extinction 90% , Plagioclase 8% , Microcline 1% , Mica 1%.	Medium grained, angular to subangular, moderately sorted.	No cement is seen, the grains are tightly compacted with sometimes sutured contacts.
MBQM-11	Quartz mono crystalline with undulatory extinction 92% ,Plagioclase 5% , Mica 3%.	Medium grained, sub angular to sub-rounded, poorly sorted.	Cement is silica.
MBQM-13	Quartz mono crystalline with undulatory extinction 91% , Plagioclase 7% , Microcline 1% , Mica 1%.	Medium grained, angular to sub-angular, moderately sorted.	No cement is seen, the grains are tightly compacted with sometimes sutured contacts.
MBQM-14	Quartz mono crystalline with undulatory extinction 89% Plagioclase 5% , Microcline 5% , Mica 1%.	Medium grained, subangular, moderately sorted.	No cement is seen, the grains are tightly compacted with sometimes sutured contacts.
MBQM-18	Quartz mono crystalline with undulatory extinction 88% ,Microcline 8% , Plagioclase 4%.	Medium grained, subangular to sub-rounded,poorly sorted.	No cement is seen, the grains are tightly compacted with sometimes sutured contacts.
MBQM-20	Quartz mono crystalline with undulatory extinction 85% , Plagioclase 12% , Microcline 2% , Mica 1%.	Medium grained, angular to sub-angular, moderately sorted.	Little cement is seen, the grains are tightly compacted with sometimes sutured contacts.
MBQM-22	Quartz mono crystalline with undulatory extinction 93% , Plagioclase 5% , Mica 2%.	Fine to medium grained, subangular to sub rounded, moderately sorted.	Silica cement is present a grain to grain contacts is flat.

* MBQM - Misri Banda Formation, Misri Banda Section
* MBQSh- Misri Banda Formation, Shah Mansoor Section

Table continued.

Sr No	Mineral Composition %age	Texture	Diagenetic Effects
MBQM-23	Quartz mono crystalline with undulatory extinction 87% , Plagioclase 12% , Microcline 1% .	Medium grained, subangular, poorly sorted.	No cement is seen, the grains are tightly compacted with sometimes sutured contacts.
MBQM-24	Quartz mono crystalline with undulatory extinction 92% , Microcline 5% , Plagioclase 2% , Mica 1%.	Medium grained, subangular, poorly sorted.	No cement is seen, the grains are tightly compacted with sometimes sutured contacts.
MBQM-26	Quartz mono crystalline with undulatory extinction 89% , Plagioclase 8% , Microcline 3%.	Fine grained, subangular to sub-rounded, moderately sorted.	Mud is present between the grains, cement is silica.
MBQM-28	Quartz mono crystalline with undulatory extinction 97% , Mica 2%, Plagioclase 1%.	Fine grained, subangular, poorly sorted.	Mud is present between the grains, cement is silica, the grains are having preferred orientation.
MBQSh-1	Quartz mono crystalline with undulatory extinction 97% ,Mica 5% , Plagioclase 2%.	Fine grained, subangular to sub-rounded, poorly sorted.	No cement is seen, the grains are tightly compacted with sometimes sutured contacts.
MBQSh-3	Quartz mono crystalline with undulatory extinction 98% , Plagioclase 2%.	Medium grained, subangular to subrounded, poorly sorted.	Mud is present between grains. Cement is silica.
MBQSh-4	Quartz mono crystalline with undulatory extinction 98% ,Plagioclase 2%.	Fine to medium grained, sub-angular to subrounded, poorly.	Silica cement is present and grain to grain contact is flat.
MBQSh-5	Quartz mono crystalline with undulatory extinction 93% , Plagioclase 4% , Microcline 3%.	Fine to medium grained, sub-angular to subrounded, moderately sorted.	Cement is present, the grains are tightly compacted with sometimes sutured contacts.

* MBQM - Misri Banda Formation, Misri Banda Section
* MBQSh- Misri Banda Formation, Shah Mansoor Section

and comparison.

Mineral Composition and Texture

The characteristics of fifteen selected samples studied in thin sections are given in table 3.2.The dominant mineral being quartz ranges from 88 to 98 % in various samples. It is generally a monocrystalline variety with an undulatory extinction under the crossed nicols. It is fine- to medium-grained and subangular to subrounded. Usually it is moderately sorted but sometimes it is poorly sorted.

The second dominant mineral is feldspar, in which plagioclase and microcline being the two dominant varieties. Plagioclase is 2 to 12 % and microcline is 1 to 3 %. Mica is also seen in nearly all the thin sections and ranges from 1 to 2 % . Sometimes chlorite is also seen as the alteration of mica.

The high percentage of quartz compared to feldspars, mica and other heavy minerals makes it a mature sandstone. The shape of the quartz grain and absence of the polycrystalline quartz further support it, as polycrystalline quartz is less stable compared to monocrystalline quartz (Pettijhon, 1984; Voll, 1960).

Interpretation

The quartz grains characteristics such as subangular to subrounded shape, the absence of the rounded quartz overgrowths and the presence of plagioclase and microcline suggest it as the first cycle sand (Pettijohn, 1984).

According to Blatt and Christie (1963) undulatory extinction of quartz could be related to the metamorphosed source, however, undulatory extinction is not a definitive guide to the provenance .Its undulatory extinction could be due to the post depositional

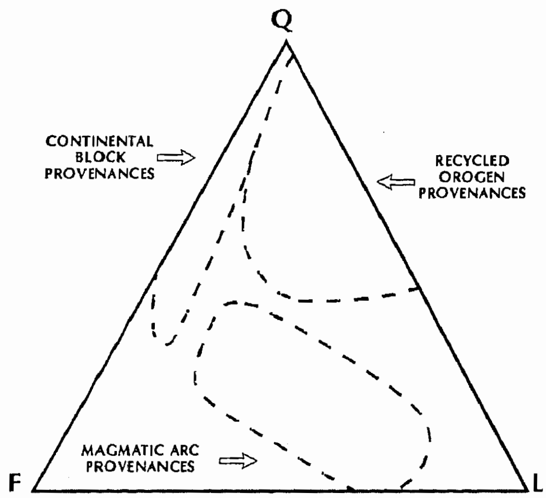


Fig. 3.11a Triangular QFL plot showing mean framework modes for sandstone suits derived from different types of provenances (after Dickenson & Suzek, 1979). Q= total quartz grains, F= total feldspar, L= is total unstable lithic fragments.

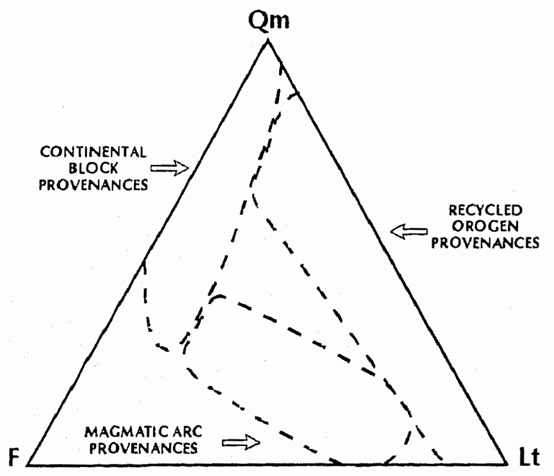


Fig. 3.11b Triangular QmFLt plot showing mean framework modes for sandstone suits derived from different types of provenances (after Dickenson & Suzek, 1979). Qm= monocrystalline quartz grains, F= total feldspar, Lt= total polycrystalline lithic fragments, including stable polycrystalline quartzose and unstabe L varieties.

high pressure and compaction demonstrated by its sutured grain to grain contacts.

Compositionally the sandstone suites of the Misri Banda Formation falls in the framework of continental block provenances of Dickenson and Suzek (1979) (fig. 3.11a, b). However, as interpreted its deposition in a shallow marine set-up this sand was subjected to high energy waves and currents. Keeping in view, its aerial distance and the mineralogical composition and texture, the provenance of the Misri Banda Formation was most likely a pluton body such as the Mansehra Granite. Mansehra Pluton is Cambrian in age (LeFort , et al.,1980) and could easily be a major source to these sediments. Although, older Tanawal Formation also consists of comparable lithologies to that of the Misri Banda Formation suggesting the existence of suitable older source to that of Mansehra Granite as well.

CHAPTER 4

FACIES ANALYSIS OF THE PANJPIR FORMATION

The Panjpir Formation is dominantly composed of argillite with considerable amounts of sandstone and limestone intercalations. Except at the stratotype, where approximately 800 m thick stratigraphic section is well exposed, elsewhere the exposures are very poor. At its type locality Pogue and Hussain (1986) and Pogue et al. (1992)have considered lower contact of the Panjpir Formation as faulted. West of Misri Banda near Turlandi they have suggested this contact to be unconformable and marked by a well exposed conglomerate unit. Nevertheless, this conglomerate lies at the base and not top of the Misri Banda Formation. Four sections were studied and measured for this research project which includes Panjpir (the stratotype), Ambar, Turlandi and Kandar. For environmental reconstructions five lithofacies are identifiable within the formation which in ascending order are:

PF5 - Calcareous sandstone and crinoidal limestone interbedded with dark grey shale.

PF4 - Bioturbated quartz arenite

PF3 - Argillite with sandstone interbeds.

PF2 - Papery laminated argillite with sandstone lensoid bodies.

PF1 - Argillite.

Figure 4.1 shows the generalized lithologic column and table 4.1 summarises the charateristics of the lithofacies of the Panjpir Formation.

4.1 FACIES DESCRIPTION AND INTERPRETATION

Lithofacies PF1: Argillite

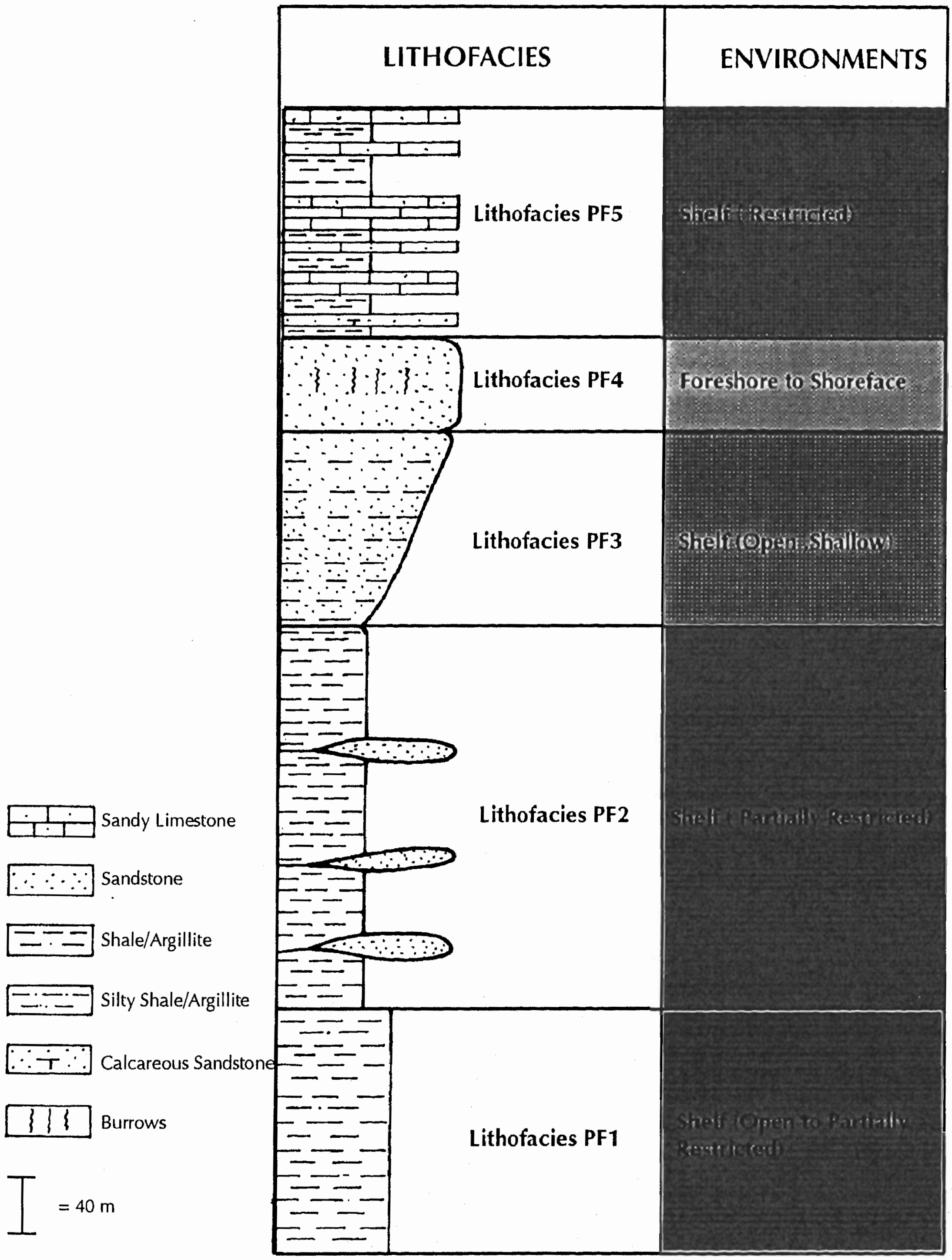


Fig.4.1 Generalized lithologic column of the Panjpir Formation showing lithofacies and environments of deposition.

TABLE 4.1 SUMMARY OF LITHOFACIES OF THE PANJPIR FORMATION.

LITHO-FACIES	LITHOLOGY	CONTACTS	COLOR	UNIT THICKNESS (M)	BED THICKNESS (CM)	BED FORMS	BEDDING PLANES	SEDIMENTARY STRUCTURES AND FOSSILS	OTHER CHARACTERISTICS	ENVIRONMENTS
PF1	Argillite .	Upper gradational and - Lower faulted and covered.	Greenish grey.	165	-	Sheets .	Sharp.	Blocky to horizontally laminated.	Have rare pyrite nodules and non calcareous in nature.	Shelf (open to partially restricted).
PF2	Papery laminated shale with sandstone lensoid bodies .	Upper gradational Lower gradational.	Shale dark grey and sandstone white to light grey.	255	70-110	Shale sheets. Sandstone lensoid bodies.	Sharp and erosive.	Horizontal lamination in shale. Sandstone beds looks massive and have burrows.	Have abundant pyrite nodules.	Shelf (restricted).
PF3	Interbedd sandstone and shale	Upper gradational -Lower gradational	Shale is greenish grey and sandstone white to light gtey.	115	0.5-20	Persistant planar sheets.	Sharp and errosive.	Horizontal lamination and trace fossils ,synsedimentary structures .	Sandstone prorortions insreases in the upper part.	Shallow shelf.
PF4	Bioturbated quartz arenite.	Upper sharp and errosive -Lower gradational .	White to light grey.	50	<40	Sheets , sometime channelized.	Sharp.	Horizental lamination , crossbedding and possibly skolithus.	Locally channelized and have the features of subaerially exposure.	Foreshore to shoreface.
PF5	Sandy limestone and calcareous sandstone alternated with units of dark grey (black) shale .	Upper gradational - Lower sharp to errosive.	Shale black. Sandstone and limestone yellowish to brownish.	~230	7-30	Shale sheets. limestone and sandstone beds and lenses.	Sharp and erosive.	Crinoides and nautilides. Horizental lamination.	The shale is black carbonaceous.	Deep shelf (restricted).

315

Location: Panjpir, Boqa Kandao.

Description

Facies PF1 is poorly exposed at Boqa Kandao, but well exposed at Panjpir with an estimated thickness of 165 m. It is the basal lithofacies of the Panjpir Formation and its contact with the Misri Banda Formation is faulted, (Pogue and Hussain, 1986).

Lithologically it is argillite (cleaved shale) which is silty in nature. It is light grey to greenish grey in colour and internally blocky to parallel laminated and fissile (fig. 4.2). Beds are sheets like and are persistent at outcrop level. It is non-calcareous and consists of rare pyrite nodules. It passes gradationally into lithofacies PF2.

Interpretation

The greenish grey colour of the argillite is typical of marine shale (Potter et al., 1980). Its internal blocky to horizontally parallel stratification indicates its deposition from suspension and that the sedimentation rates were high at that time. The occurrence of pyrite nodules is suggestive of somewhat restricted conditions of deposition (Pettijohn, 1984). The conditions of survival for marine fauna were not siutable and the absence of marine fauna is attributed either to: 1) the depleted oxygen conditions in restricted environments and/or 2) high clastic input at the time of deposition (Enos, 1974). All the above clues suggest the deposition of lithofacies PF1 in partially restricted shelf with moderate to high clastic input during its deposition (Potter et al., 1980).

Lithofacies PF2: Laminated shale with sandstone lensoid bodies.

Location: Panjpir

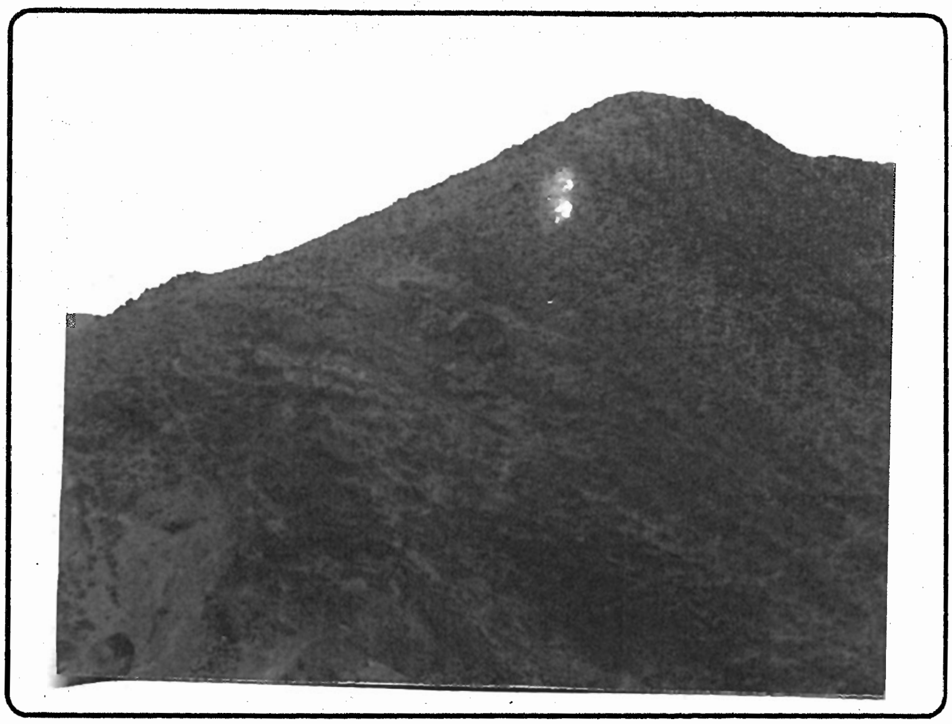
Description

It is thinly, rather papery laminated shale, with frequently alternating sandstone lensoid bodies (fig. 4.3a, b). The shale is light to dark grey, non calcareous and with abundant pyrite nodules. Pyrite nodules are polygonal which when dissolved leave polygonal casts. The sandstone is basically quartz arenite of grey to white colour and medium to coarse grained to locally pebbly in nature (fig. 4.4). Its beds range in thickness from 70 cm to 110 cm and pinch out over a small distance at outcrop level. The sandstone beds are amalgamated with one another. These bodies are sharply based in the ambient papery shale. The internal organization of the sandstone beds is not clear but looks homogenized due to bioturbation. The estimated thickness of this lithofacies PF2 is 255 m. It is gradational with the overlying lithofaices PF3. The pyrite nodules are found in abundance on the upper and lower contacts of the sandstone units embedded in the thin paper laminated shale (fig. 4.5).

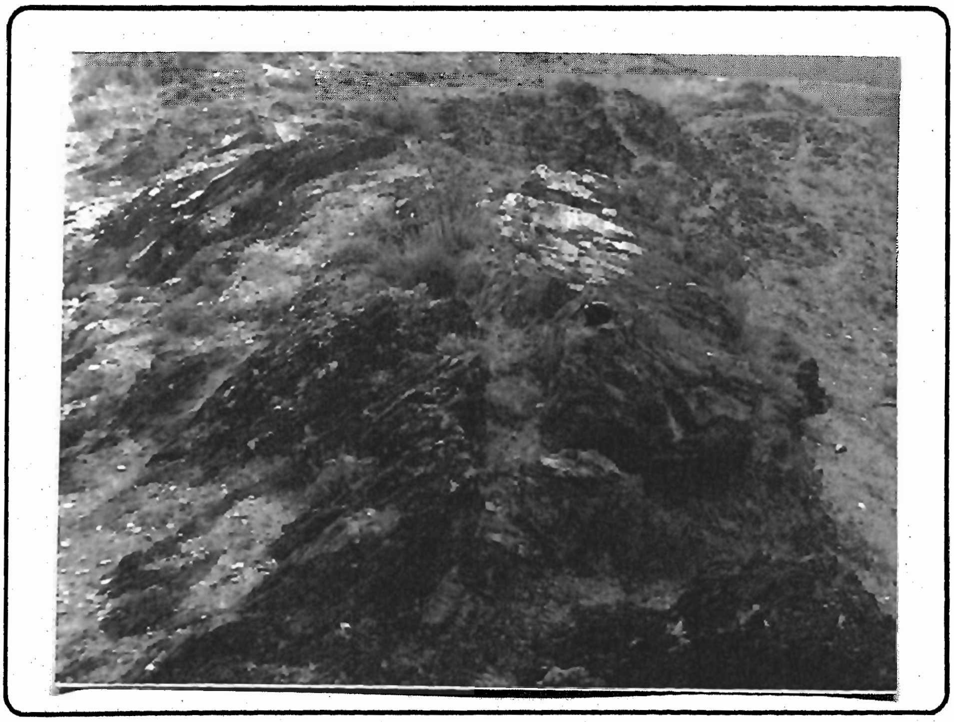
Interpretation

The dark grey colour of the shale and its papery lamination indicates the deposition of lithofacies PF3 in very restricted rather euxinic conditions (Potter et al., 1980 ; Enos 1974). It is further confirmed by the presence of abundant pyrite nodules (Pettijohn, 1962). The sharp contacts of the lenticular sandstone units indicate that they were deposited in channelized horizons which were most likely developed in river tributaries within the shallow shelf. Most of these tributary related sediments have been reworked by shallow sea precesses after avulsion of the river channel. Only the basal deeply burried within channel zones escaped reworking and are now preserved in the form of sandstone lensoid bodies. Crimes (1977) mentioned that even skolithus ichnofacies may appear in

Fig.4.2 Greenish grey and blocky argillite of lithofacies PF1.



a.



b.

Fig. 4.3a, b Sandstone lensoid bodies in the papery laminated shale of lithofacies PF2.

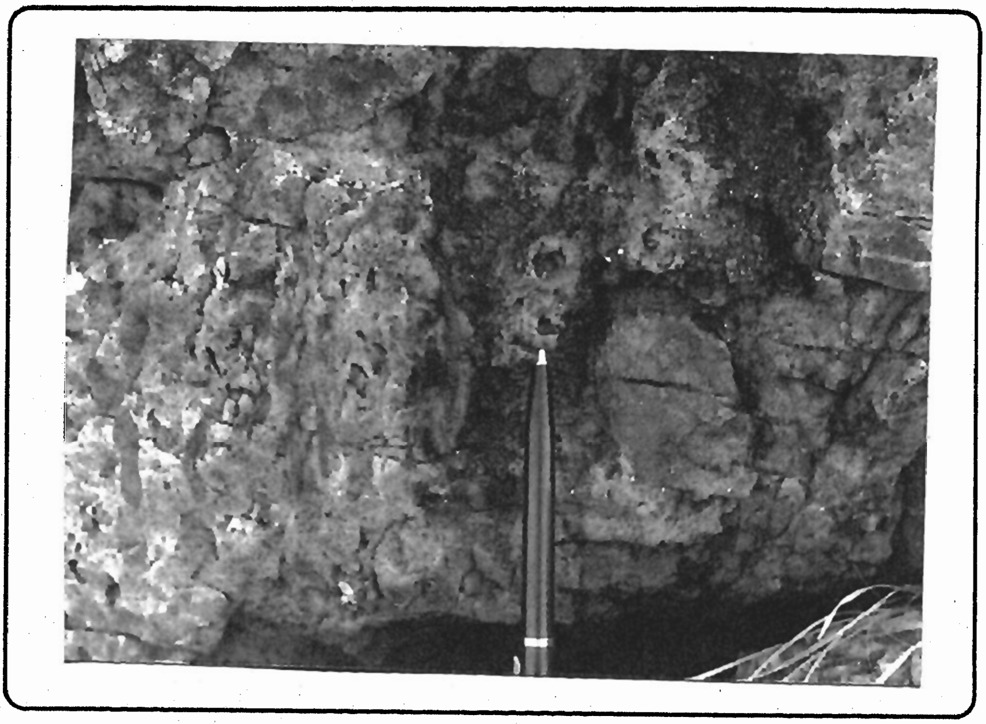


Fig.4.4 Pebbly and bioturbated sandstone in sandstone lensoid bodies of lithofacies PF2.

Fig.4.5 Polygonal pyrite nodules on the upper bedding plane of sandstone in sharp contact with papery laminated shale of lithofacies PF2.

substantially deeper environments if food supply, hydrographic and substrate characteristics are suitable. Therefore the deposition of lithofacies PF2 took place in a restricted shelf with coarser sediments input from river tributaries.

Lithofacies PF3 : Argillite with sandstone interbeds.

Location : Panjpir

Description

Lithofacies PF2 passes gradationally into lithofacies PF3 which consists of interbedded shale and sandstone. Shale is greenish grey, horizontally laminated and is in the form of sheets which are persistent laterally (fig. 4.6). The sandstone is alternating with the thin unit of shale in the form of laminae and thin beds with a few centimetre thickness. The frequency and thickness of sandstone beds varies but generally increases towards the upper portion of the lithofacies. The sandstone is fine to medium grained and its beds are sharply based. Horizontal lamination and synsedimentary deformation and organic trails probably of nerite ichnofacies are found in the mid and upper portion of this lithofacies. In the upper parts the sandstone is dominant with subordinate argillite and the sandstone beds increases in thickness up to more than 40 cm.

Interpretation

The overall features such as interbedded argillite and sandstone sheets, their internally parallel lamination, the synsedimentary deformation and the organic trails at the base of sandstone beds indicates the deposition of shale in a low energy environments from suspension in normal weather (Reineck and Singh, 1980; Walker, 1976). The sandstone beds, however, are storm sheets as having sharp bases which indicates sudden

Fig.4.6 The thin interbedded sandstone and shale in lithofacies PF3 showing sharp contacts between sandstone and shale.

emplacement (Tanoli and Pickerill, 1988). The organic trails could possibly be of the nerite assemblages (Chamberlain, 1971; Crimes, 1973; Pickerill, 1980). The rhythmic and alternating bedding of sandstone with shale through out the lithofacies is suggestive of the rhythmic sand influx which could be the result of periodic climatic changes (Reineck and Singh, 1980). However, the increasing sandstone ratio in the upper portion of the lithofacies is suggesting a shallowing upward trend (Tanoli and Pickerill, 1988). Its conformability with lithofacies PF2 suggests that the shelf was no more restricted at the time of deposition of this lithofacies and a shallowing upward trend prevailed up to the top of lithofacies PF3. The upper part of this facies was deposited in a more shallow open shelf with a frequent and greater influx of sand.

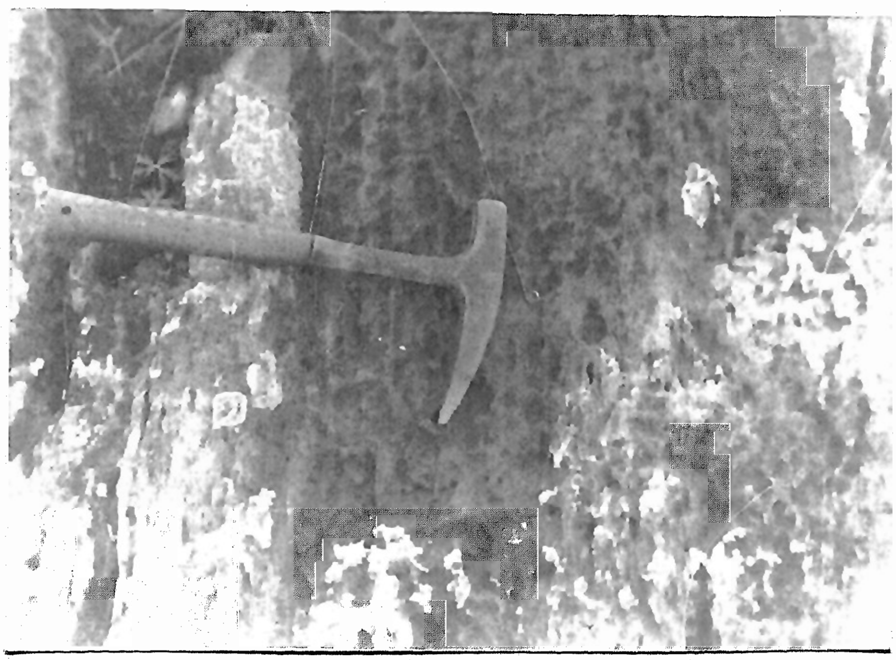
Facies PF4: Bioturbated quartz arenite.

Location: Panjpir

Description

Lithofacies PF3 passes gradationally into lithofacies PF4 which lihtologically is quartz arenite. The quartz arenite beds are composite and amalgamated and individually beds are generally more than 40 cm thick (fig. 4.7a, b). It is fine-to medium-grained and white to light grey in colour and very hard to break. The high bioturbation has made its internal organization confusing, however, some cross beds could be identified in it. The beds are generally in the form of sheets but sometime looks channelized. Beds seems to be persistent at outcrop level. The top of this lithofacies is marked by an iron leaching horizon. The bioturbation, though not very clear, is that of skolithus ichnofacies. The overall thickness of the lithofacies is more than 60 m at Panjpir section.

a.



b.

Fig. 4.7a, b Sandstone beds of lithofacies PF4 in outcrop and close-up.

Interpretation

The amalgamation and channelized nature of the beds indicates its deposition in very high energy environment where clay could not settle due to continuous agitation by waves and currents. Whatever little was able to deposit would have been eroded during raised energy conditions. The presence of skolithus burrows is further confirming it as these are found in high energy environments like foreshore and upper shoreface environments (Frey and Pemberton, 1984). This lithofacies was, therefore, deposited in progressively shallowing upward conditions (prograding).Due to continuous progradation the sea was withdrawn from the area and consequencely subaerial exposure took place. This is supported by the iron leaching horizon at the top of this lithofacies. So the deposition of lithofacies PF4 might have occurred in foreshore to shoreface environment.

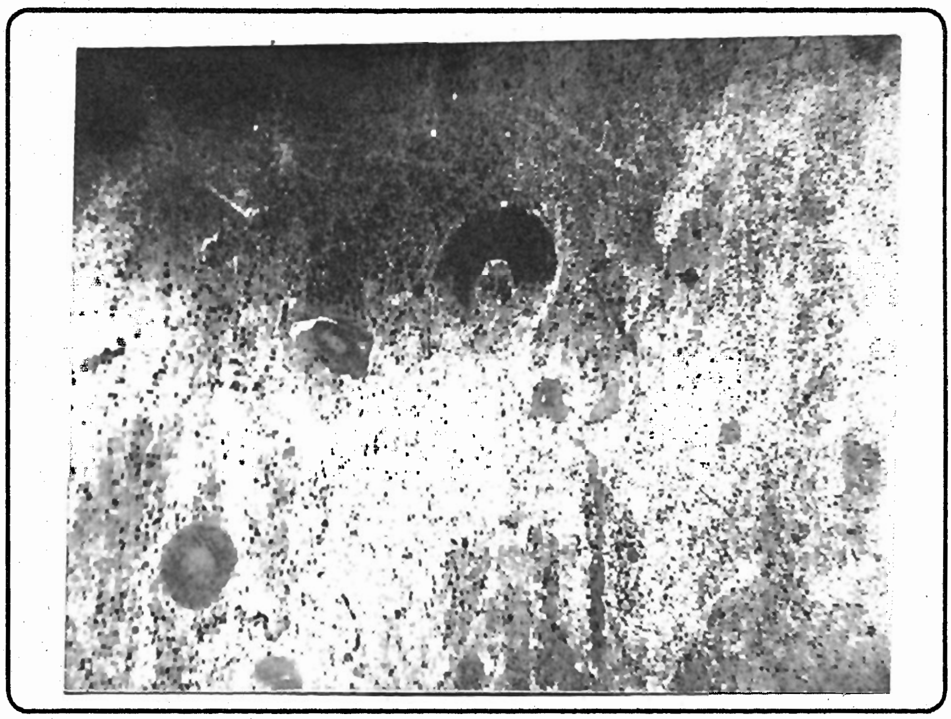
Lithofacies PF5: Calcareous sandstone and crinoidal limestone with dark grey shale.

Location: Panjpir, Turlandi, Kandar

Description

This is the only lithofacies of the Panjpir Formation which is well exposed regionally in the study area. Overall thickness of this facies is about 230 m. The alternations of black carbonaceous shale units with Crinoidal limestone and calcareous sandstone beds is common (fig. 4.8). The sandstone beds are present only in the lower part of the lithofacies. However, shale and limestone comprise the major part of the lithofacies. Sometimes shale is dominant and sometimes limestone. Limestone is a packstone to wackstone (Dunham, 1962). The allochems are mainly crinoids (fig. 4.9a, b) but rare orthoconic nautiloids and bivalves are also present(fig.4.10). It is grey to yellowish brown in colour and looks somewhat sandy. Beds range in thickness from 7 cm to a maximum of 30 cm. Beds are generally continuous sheets and are persistent at outcrop level. When in contact with

Fig. 4.8 Calcareous sandstone and sandy limestone of lithofacies MB5 demonstrating sharp contacts with the dark grey carbonaceous shale.



a.

b.

Fig. 4.9a, b Crinoids in thin section and outcrop of lithofacies PF5.

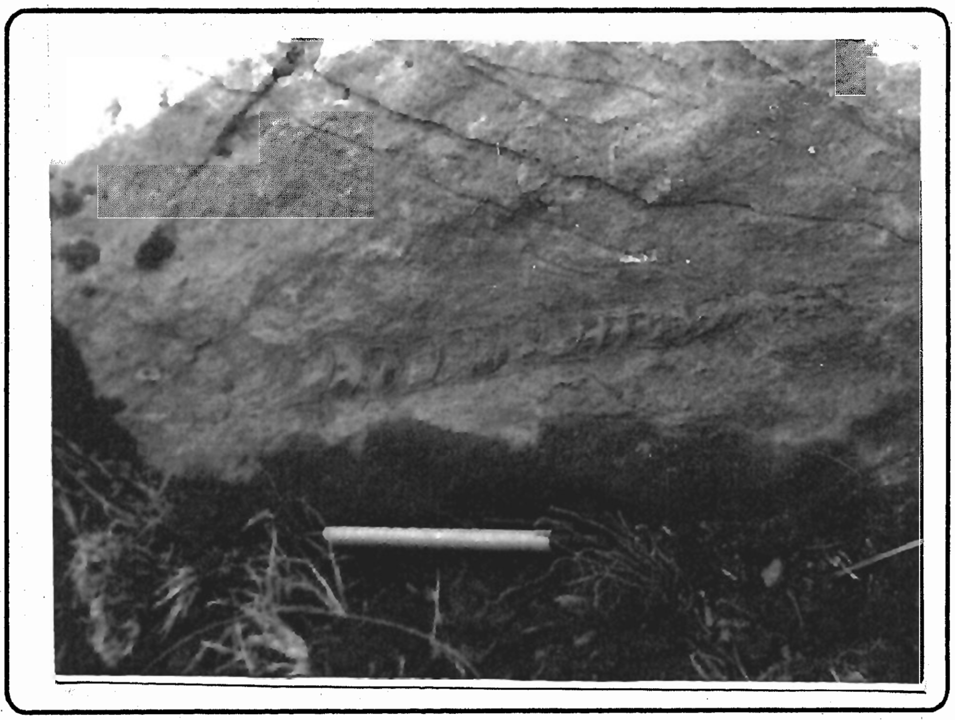


Fig.4.10 Orthoconic nautiloids in limestone of lithofacies PF5.

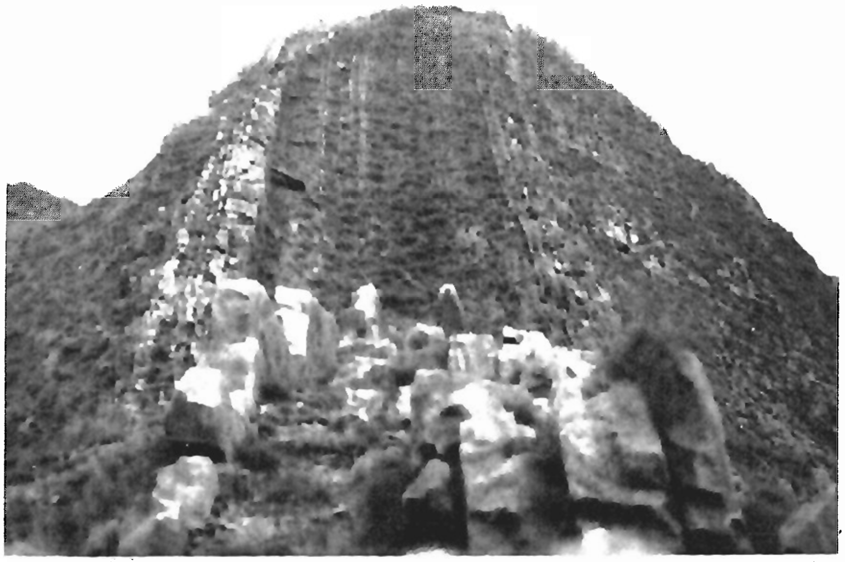


Fig.4.11 Topography contrast of the planar crinoidal limestone beds in the middle, and the dark grey carboneceous shale in lithofacies PF5.

black carboniferous shale they have sharp contacts. The sandstone is fine-to medium-grained and is having sharp contacts with shale. Its bed thickness varies from a few cm to about 40 cm. Internally it is massive to parallel laminated.

The interbedded dark grey carbonaceous shale is non calcareous with no fossil content in it. Internally it is parallel laminated and is in the form of sheets which have a regional lateral extent. Occasionally calcareous sandy lenses are present in these shales. The individual shale unit range in thickness from a meter to ten meters.

Interpretation

More detailed sedimentologic work to divide this lithofacies into subfacies is beyond the scope of this research work. Therefore, all the units despite of different lithologies is interpreted as one lithofacies. The dark grey rather black colour of the shale and its internal horizontal laminated organization suggests its deposition in strongly reducing or anoxic environments (Enos & Moore, 1983). Its lamination and extensive sheet geometry is indicative of the ocean basin which was very restricted. While the alternating crinoidal limestone beds have crinoids in abundance with rare orthoconic nautiloids of normal marine environments. Crinoids especially are the inhabitants of neritic zone (Jones, 1956) and comparatively are shallow water organisms (Moore et al., 1952). Their presence with shale of euxinic environments is enigmatic.

However, the sharp contacts of crinoidal limestone and sandstone beds, the geometry and thickness of the beds and the presence of fossils in the sandstone beds suggests it as deposited by storm currents in a semi-restricted depositional set up where originally the deposition of laminated carbonaceous shale was in progress. Davies (1977) interpreted such a case of Hare Fjord Formation of the Sverdrup Basin, Arctic Archipalago as a crinoidal turbidite. However, in the present situation this lithofacies overlies lithofacies

PF4 with an aerial exposure and as a result could not be of deep basinal origin. Therefore, its deposition might have occurred in a restricted shelf where originally black laminated shale was depositing and the sandy crinoidal beds and sandstone beds were deposited by periodic storms in the basin. The crinoidal allochems and carbonate mud was probably derived from the deeper forereef (James and Ginsburg, 1979) of the overlying Nowshera Formation.

4.2 FACIES ASSOCIATION AND ENVIRONMENTAL SYNTHESIS

The deposition of the Panjpir Formation mostly occurred in shelf i.e. inner to outer shelf. Lithofacies PF1 interpreted as deposited at outer shelf in somewhat restricted to open conditions. However, at the time of deposition of lithofacies PF2 the shelf was more restricted and shallower. Its shallowing and restriction is obvious from the thin papery laminated shale and the alternating sandstone lensoid bodies of river tributaries origin. Later on, lithofacies PF3 was deposited in an open and more shallower shelf as the sand was frequently available throughout the deposition of the lithofacies. The shallowing upward trend prevailed throughout the deposition of the lithofacies and is demonstrated by the increasing thickness and frequency of sandstone beds. This shallowing continued up to the top of lithofacies PF4 which is gradational in contact with the underlying lithofacies PF3 and is interpreted as deposited in a high energy foreshore to upper shore set up. The iron leaching horizon at the top of this lithofacies indicates the subaerial exposure before the deposition of overlying lithofacies PF5 which signals the onset of another transgression and return of marine environments. However, at the time of deposition of lithofacies PF5 the environments were again deepening and becoming semi-restricted shelf with slight anoxic conditions. The calcareous sandstone and sandy crinoidal limestone, were introduced by storms to the deeper and restricted set up.

Lithofacies PF5 is overlain by Nowshera Formation which is of shallower set up and thus confirming another shallowing episode.

CHAPTER 5

SEQUENCE STRATIGRAPHY

The lithofacies analysis of both Misri Banda and Panjpir Formations indicate several transgressive and regressive episodes of the sea. The overall behaviour of the sea level with respect to the strata of these formations is discussed here in this chapter.

5.1 SEQUENCE STRATIGRAPHY OF THE MISRI BANDA FORMATION

The Misri Banda Formation, as already mentioned in chapter 3, presents cyclic pattern of the lithofacies MB2 and MB3. These cycles could be parasequences which are the basic building block of systems tracks which are defined by Van Wagoner et al. (1990), as "relatively conformable, genetically related succession of beds or bed sets bounded by marine flooding surfaces or their correlative surfaces". The stratal sequence boundary is marked at the base of the Misri Banda Formation by a 5 to 10 meter thick red clay unit at the stratotype and Boqa Kandao sections and by a 60 meters thick conglomerate horizon at Turlandi section. No other sequence boundary was detected within the Misri Banda Formation . However, within the Misri Banda Formation , the sedimentation pattern is cyclic with the repetition of certain lithofacies making parasequences of Van Wagoner et al. (1990).

The conglomerate beds and red clay horizon of lithofacies MB1 marking the unconformable contact between the Misri Banda and the underlying Ambar Formation marks the subaerial exposure and erosion due to the complete withdrawal of the sea from the area. This boundary, therefore, represents a sequence boundary according to the definition of Van Wagoner et al. (1990).

Basal lithofacies MB1 to MB3 marks the basal parasequence which shows initially deepening conditions from lithofacies MB1 to MB2 and shallowing upward conditions from lithofacies MB2 to MB3. The base of the lithofacies MB1, which is also a sequence boundary, is the lower boundary of this basal parasequence and is the first marine flooding surface of the Misri Banada Formation (fig. 5.1).

The top of lithofacies MB3 is the upper boundary of this basal parasequence and is marked by intensive burrowing. Above this boundary second cycle starts with the deposition of lithofacies MB2, making the second phase of transgression, and as a result, marine flooding. This is overlain by more shallower strata of lithofacies MB3, marking another phase of regression which continued up to the top of MB3. The lithofacies MB3 is again followed by strata of lithofacies MB2 which are relatively deeper water in origin. The boundary between these two lithofacies marks a marine flooding surface and, therefore, a parasequence boundary. Lithofacies MB2 is very sharply followed by more deeper shelf clays of lithofacies MB4 suggesting a dramatic sea level rise. This sharp contact is the start of an other transgressive episode (marine flooding) and is indicative of another parasequence boundary. The sudden deepening of environment i.e. from shoreface to shelf could be due to any of the several reasons such as sudden subsidence due to tectonics, eustasy etc. This transgressive phase later on was followed by regressive trend which generally continued up to the top of the Misri Banda Formation, in the form of lithofacies MB5, in which sandstone increases upward with interbeds of shale. Above the basal sandstone unit which is overlain by shale (Fig. 5.1) a probable parasequence boundary may be present. Further detailed studies are required to establish sequence stratigraphy of the formation more accurately.

5.2 SEQUENCE STRATIGRAPHY OF THE PANJPIR FORMATION

As already mentioned, although not clearly seen the contact between the Misri

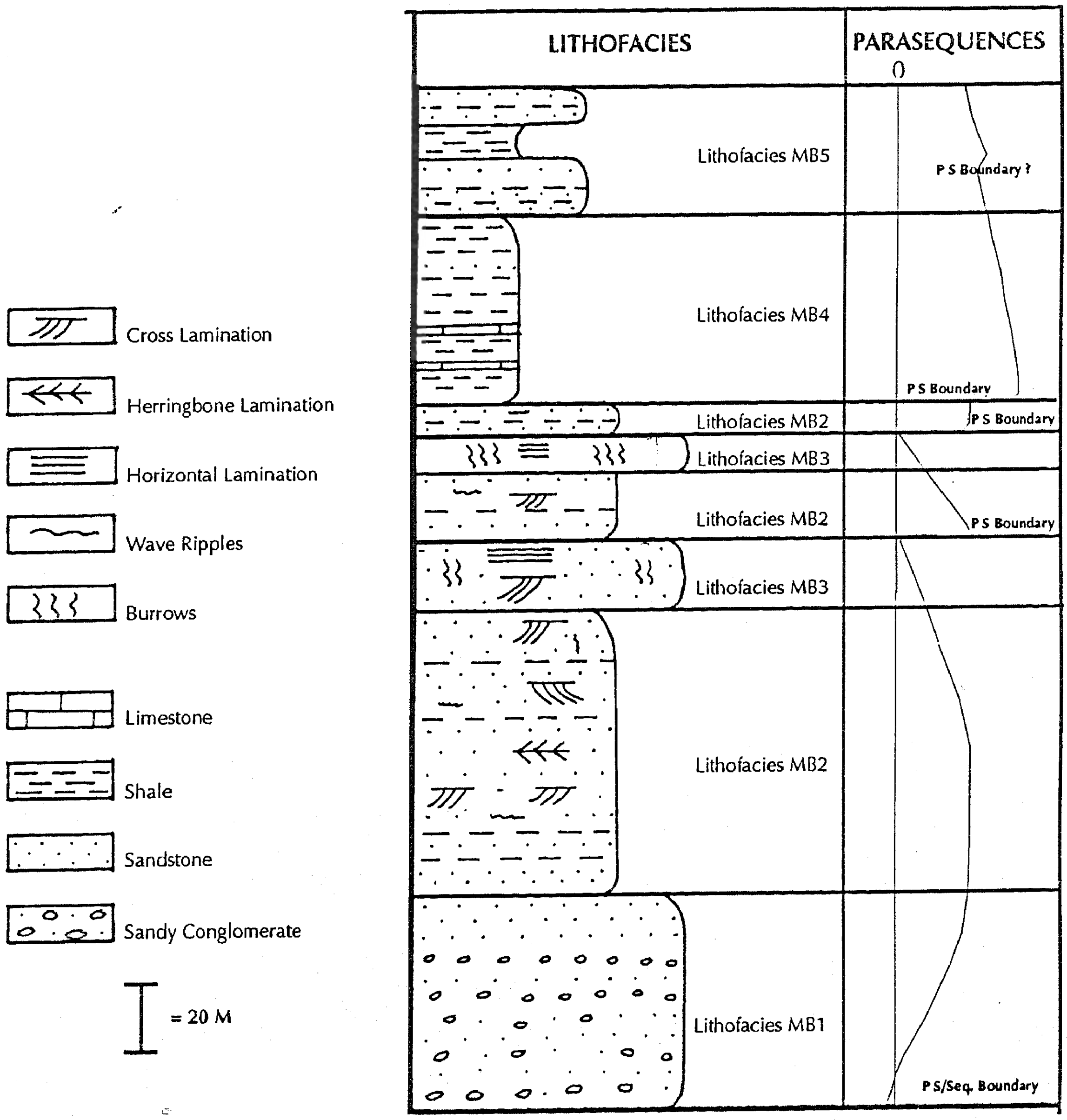


Fig. 5.1 Generalized lithologic column of the Misri Banda Formation showing lithofacies and parasequences.

Banda and the Panjpir Formation seems to be a conformable one. Consequently, the Panjpir Formation is the continuation of the stratal sequence from the base of the Misri Banda Formation. The regressive phase up to the exposed top of lithofacies MB5 was followed by a sudden transgressive phase which had deposited the argillite of the basal lithofacies, PF1, of the Panjpir Formation within a shelf setting. The contact of these two formations, therefore, may mark a sixth parasequence boundary. The basal parasequence of the Panjpir Formation was generated somewhere in the unexposed section between the Misri Banda and Panjpir formations as a result of transgressive phase after a regressive phase during the deposition of lithofacies MB5. This parasequence includes lithofacies PF1 to lithofacies PF4. A regressive phase, generally, prevailed through out the deposition of this parasequence. There is generally a gradual shallowing of environments from lithofacies PF1 to PF4 (fig. 5.2). Lithofacies PF1 was deposited in outer shelf environments in deeper water conditions and consists of only silty argillite and no sandstone. Whereas lithofacies PF2 was deposited in outer to middle shelf in relatively shallower set up and consists of sandstone lensoid bodies besides the shale. This coarsening and shallowing upward trend continued throughout the lithofacies PF3 and PF4. However, in lithofacies PF3 the thickness and frequency of sandstone beds increases and decreases several times, though, generally it is increasing upward. This indicates the possibilities of existence of several parasequences within the lithofacies PF3. Lithofacies PF4 consists of thoroughly bioturbated quartz arenites and its top is marked by iron leaching, suggesting a subaerial exposure. This upper boundary of parasequence at top of lithofacies PF4 is, therefore, a sequence boundary. Over this parasequence and sequence boundary, the lithology changes drastically within lithofacies PF5. Lithofacies PF5 consists of

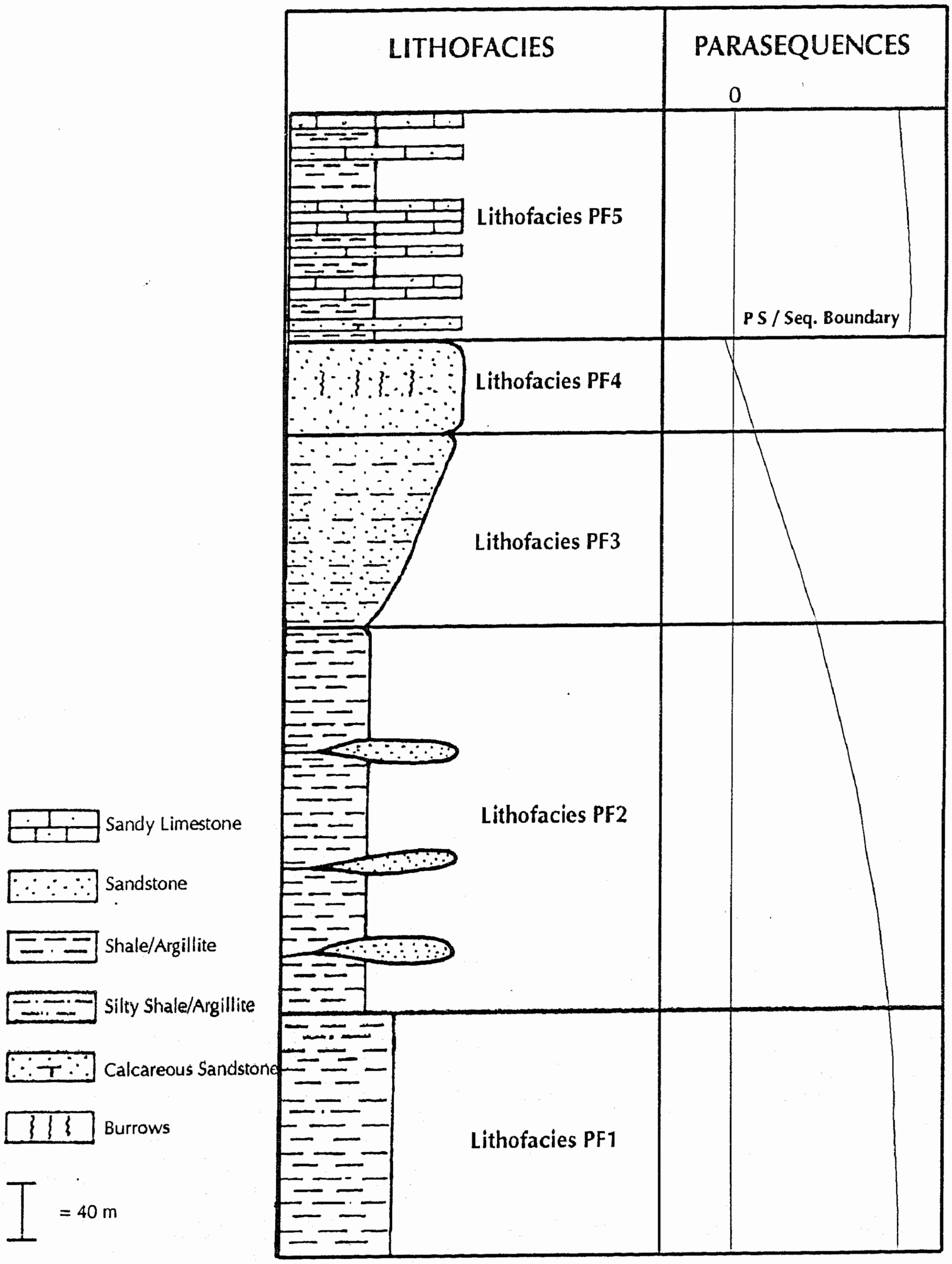


Fig.4.1 Generalized lithologic column of the Panjpir Formation showing lithofacies and parasequences.

interbeds of calcareous sandstone, shale and sandy limestone containing fossils. Within the shale horizons very thin sharply based sandstone beds are interbedded. Although in this study lithofacies PF5 is considered as one but detailed analysis may represent several lithofacies and a few parasequence boundaries may also be detected. Deeper and restricted conditions prevailed throughout the deposition of this parasequence up to the top of lithofacies PF5. However the overlying Nowshera Formation is a comparatively shallow water deposition. The upper boundary of this last parasequence of the Panjpir Formation could be somewhere within the Nowshera Formation.

5.3 CONCLUSIONS

The following generalized conclusions are drawn from the facies analysis and sequence stratigraphic analysis of the Misri Banda and Panjpir Formations.

1. The Misri Banda Formation was deposited in an overall shallow marine high energy environments. The shelf was both wave and tide dominated.
2. Several deepening and shallowing upward episodes of the sea and fining upward and coarsening upward cycles have been developed and also repetitions of lithofacies.
3. The base of the Misri Banda Formation is marked by a subaerial exposure and therefore marks a type1 sequence boundary. In addition, five parasequence boundaries are recognized within the formation.
4. The contact between the Misri Banda Formation and the Panjpir Formation is most likely conformable and not represented by an unconformity as suggested by Pogue et al. (1992).

5. The Turlandi conglomerate horizon marks the base of the Misri Banda Formation and not of the Panjpir Formation.

6. Lower two third of the Panjpir Formation generally marks a coarsening upward sequence starting from lithofacies PF1 to PF4.

7. Contact between lithofacies PF4 and PF5 marks subaerial exposure followed by marine flooding, therefore, a parasequence and a sequence boundary.

8. Lithofacies PF5 was deposited in a renewed transgression and consists of fossil containing horizons of limestone beds which are not found in the underlying lithofacies and this lithofacies ultimately grades into the overlying carbonates of the Nowshera Formation.

9. The lateral correlations of the lithofacies, as already mentioned in the earlier chapters, was not possible because of poor exosures at various localities. However, the enormous thickness of the Panjpir Formation at the stratotype and Boqa Kandao, as compared to exposures in Nowshera District, indicates that basin was possibly deeper and bigger in these areas. The presence of pyrite nodules and dark grey shales indicate its generally euxinic nature.

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