Pakistan Journal of Hydrocarbon Research
Vol. 8, No. 1 (January 1996). p.1-24. 8 Figs. 3Plts

Late Cretaceous to Early Eocene Foraminiferal Biostratigraphy of the Rakhi Nala Area, Sulaiman Range, Pakistan

Jamil Afzal[1]

ABSTRACT

Shaly intervals from Late Cretaceous to Early Eocene sediments of the Rakhi Nala Section (Sulaiman Range) were analysed for the foraminiferal microfauna (planktons, smaller and larger benthics). The faunal record is interpreted for the precise age and paleoenvironments. These fresh results, in the light of modern biostratigraphic knowledge, are compared with the previous biostratigraphic informations available about this area. Several discrepancies regarding the litho and biostratigraphy from the previous literature were addressed and tried to remove.

INTRODUCTION

The Rakhi Nala section (29° 59',70° 03'), located in the middle part of the Sulaiman Range of Pakistan, is situated about 40 km South-Southwest of Dera Ghazi Khan, Punjab province (topographic sheet 39 G/1) (Figure1). Thick and complete sequence of sediments ranging in age from Cretaceous to Eocene are well exposed along the Gaj-Fort Munro road. The section known from the beginning of the century is a reference section for the relevant formations of the Sulaiman Range. It is well known outside of Pakistan too, not only due to its completeness of sediments but also due to its fossil contents, especially of microfaunas. The main objectives of the study were:

a) to clarify the different and contradicting biostratigraphical results as reported in the literature.

b) to investigate Cretaceous to Early Tertiary rocks based on a new set of world-wide accepted standard foraminiferal zonations and

c) to acquire new data for describing their paleoenvironments.

GEOLOGICAL SETTING

The main sedimentary basin of Pakistan is the Indus Basin, which is subdivided into three parts, Upper, Middle and Lower Indus sub-basins. The studied section of the Rakhi Nala is situated in the middle part of the Indus Basin which is called the Sulaiman Province as well. The Indus Basin as a whole belongs to the western part of the Indo-Pakistan Plate. Paleozoic to Mesozoic sediments of the eastern fold belt of the Indus Basin were deposited on a broad shelf area of the passive continental margin of the Indo-Pakistan Plate (Bannert, 1992). The fold belt developed since the Paleocene as a result of the main collision of the Indo-Pakistan Plate with the Eurasian Plate (Bannert, 1992). The studied area as well as sample locations are shown in Figure1

Cretaceous to Eocene sediments are named in this paper according to the nomenclature of Shah (1977) and in descending order are mentioned below (Figure2).

Early Tertiary: Kirthar Formation, Ghazij Formation, Dunghan Formation, Ranikot Group (Khadro and Bara formations)
Late Cretaceous: Pab Sandstone , Fort Munro Formation, Mughal Kot Formation, Parh Limestone, Goru Formation, Sembar Formation

SHORT HISTORY OF THE PREVIOUS WORK

The geological and paleontological investigations of the famous Rakhi Nala section of the Sulaiman Range started with the publication of Vredenburg (1908). He described larger foraminifers (*Orbitoides*) from the Cretaceous units.

Eames (1952a,b) based his pioneer works on direct lithological observations. He measured and named the different lithological units of the Rakhi Nala section from Late Cretaceous to Late Eocene (Figure3). The different lithological units were subdivided into local zones, local stages and local series. Eames (1952 a,b) used the foraminiferal record for the corresponding age assignments.

Nagappa (1959) summarized the available lithological and faunal informations of the Rakhi Nala section and other areas of the Indus Basin and surrounding areas. He developed a regional depositional history of the Cretaceous to Eocene sediments of the India-Pakistan-Burma region.

A second phase of investigation of the Rakhi Nala section started when the Hunting Survey Corporation (1961) under the Colombo Plan Project, measured and sampled the Cretaceous to Tertiary rocks of the Rakhi Nala section. These samples were later on studied by various authors as given below.

Bayliss (1961) described larger foraminifers from Cretaceous to Late Eocene strata. Latif (1961) studied Tertiary planktonic foraminifers and developed a planktonic

[1] Hydrocarbon Development Institute of Pakistan, Islamabad.

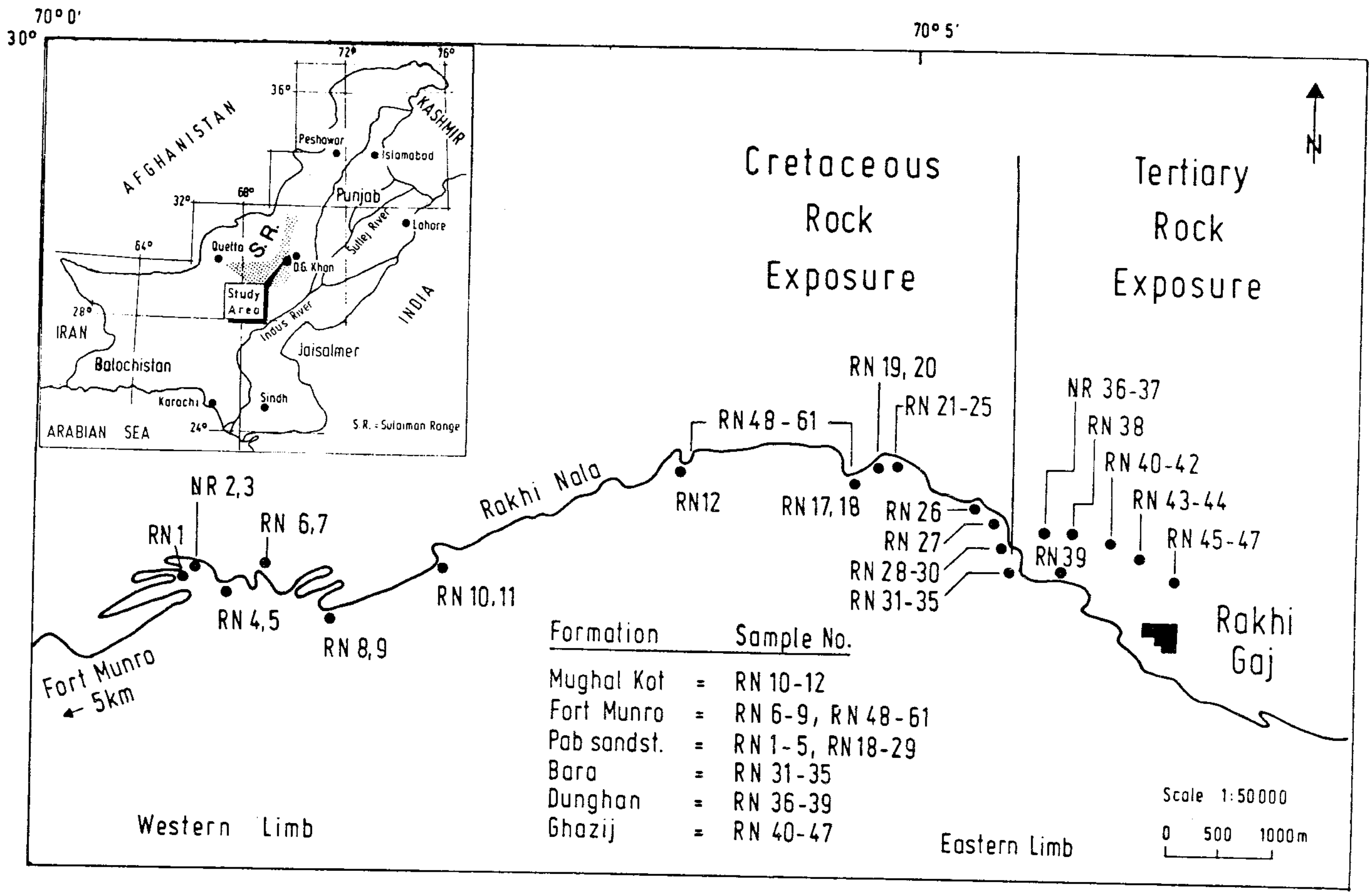


Figure 1- Map representing the study area and sampling locations along the Rakhi Nala section.

foraminiferal zonation. He subdivided Late Paleocene to Early Eocene sedimentary interval in to five zones.

Marks (1962) selected some of the Cretaceous samples from the above mentioned set of samples and presented a statistical relationship among different parameters of the various species of *Orbitoides* (larger foraminifera) from the Mughal Kot and the Fort Munro Formations (the "*Orbitoides* Limestones and Shales" of Eames, 1952a).

Samanta (1973) reported results on Tertiary planktonic foraminifers from the same set of samples. He recognized eight Paleocene to Eocene planktonic foraminiferal zones following the zonation of Bolli (1957a).

Since 1985, a third phase of investigation started under the Pakistan-German Technical Cooperation Project between the Hydrocarbon Development Institute of Pakistan (HDIP, Islamabad) and the German Geological Advisory Group of the Federal Institute for Geosciences and Natural Resources (BGR, Hannover). Several field parties sampled different areas in Pakistan including the Rakhi Nala section in order to evaluate the hydrocarbon potential of strata dated biostratigraphically by means of index fossil groups (foraminifers, calcareous nannoplankton and dinoflagellates)(Porth and Hilal Raza, 1990).

Kothe (1988) investigated samples from the Late Cretaceous part of the Rakhi Nala section for the nannofossil record and applied a calcareous nannoplankton zonation. The Tertiary sediments were dated with the help of both nannofossils and dinoflagellates and zonations were presented.

Weiss (1988, 1993) reported planktonic and larger foraminifers from the same samples (as investigated by Kothe, 1988) of the Cretaceous to Eocene rocks of the Rakhi Nala section and correlated eight larger foraminiferal assemblages of Maastrichtian to Eocene age with standard planktonic foraminiferal zonation of Caron (1985) and Toumarkine and Luterbacher (1985).

LITHOSTRATIGRAPHY AND SAMPLING

In 1990, HDIP/BGR field party carried out another reconnaissance field trip to the Rakhi Nala area covering the section from Rakhi Gaj up to Fort Munro. The lithological units, as seen in the field, were identified following the descriptions of Eames (1952a) and Shah (1977). Samples were collected from the Late Cretaceous Mughal Kot Formation to the Early Eocene Ghazij Formation. The Mughal Kot Formation was measured in detail and sampled systematically, while other formations were sampled randomly in sequence. Sample locations were marked as accurate as possible according to the lithological description of Eames (1952a) (Figure 1,4 and 6). The samples were preferably collected from the shaly and marly intercalations of these units in order to obtain washed

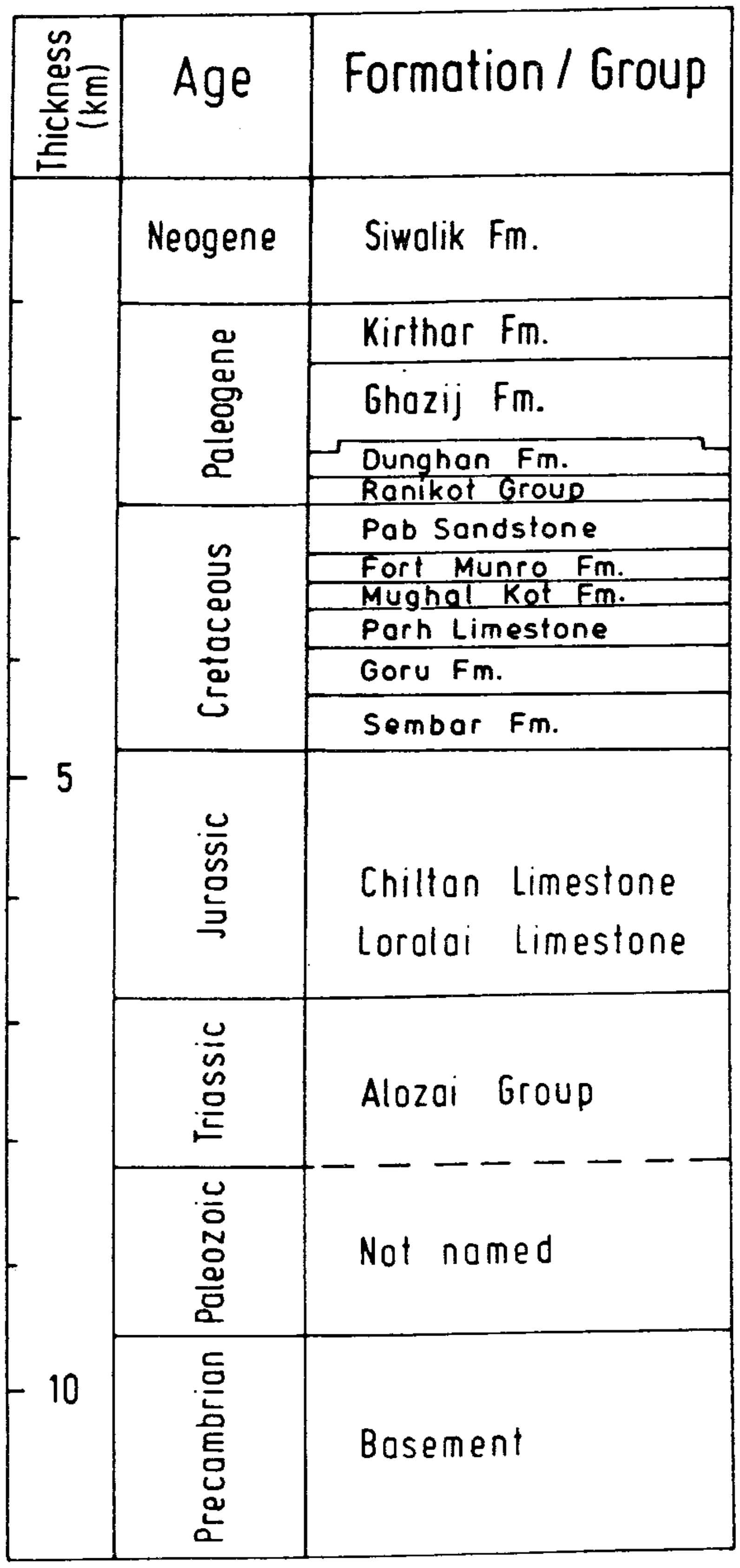


Figure 2- Generalised stratigraphic sequence of the Sulaiman Range (after Jadoon et al. 1992).

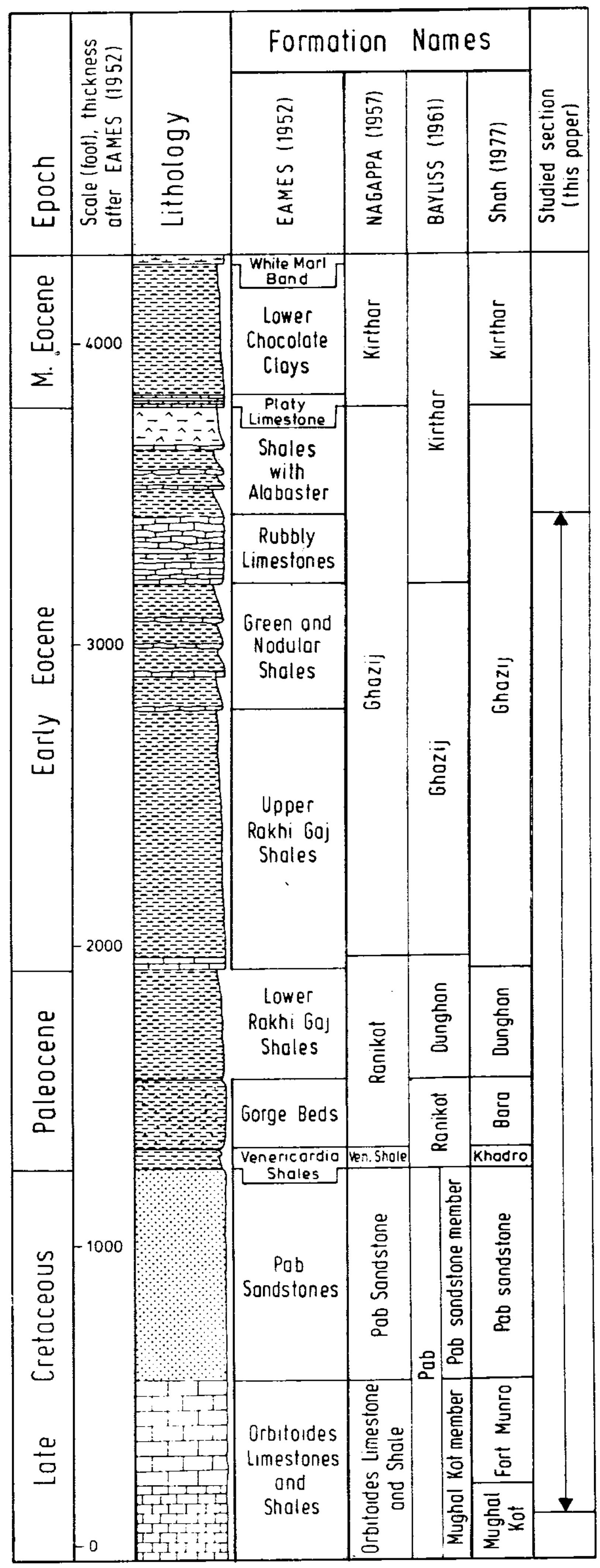


Figure 3- Generalised litholog of Late Cretaceous to Early Eocene rock units of the Rakhi Nala section in relation with the formational nomenclature used by different authers.

residues from where isolated specimens of the foraminiferal fauna could be identified.

Subsequent authors, according to their own results and interpretations, carried on to change the lithological boundaries of the rock units (Figure3). The resulting discrepancies are discussed later in detail. Following the lithostratigraphical nomenclature of Shah (1977), a brief description of the formations based on field observations of the present author and their relation to the lithologies of Eames (1952a) is added.

Mughal Kot Formation

The formation comprises the "Inoceramus Clays", the "Badded Clays" and the lower part of the "*Orbitoides* Limestones and Shales" of Eames (1952a). It consists of dark-grey to bluish, bedded, calcareous mudstones and shales. The contact with the overlying Fort Munro Formation is covered along the road side, the lower contact was also not exposed. Only the upper part of the formation was sampled (samples RN 10-12),

Fort Munro Formation

In the middle part of the Sulaiman Range area, the formation consists of the upper part of the "*Orbitoides* Limestones and Shales" of Eames (1952a). Its basal part shows brownish-grey, thin bedded to bedded argillaceous limestone beds, partly nodular, and contains several shaly to marly intercalation. The limestone contains common fossil debris, larger benthic foraminifers (*Orbitoides).* The middle part is covered by talus and consists of argillaceous limestones with thick shaly intercalations. The upper part is a grey to dark-grey, thin bedded, sandy limestone with reddish-brown, laminated, sandy partings showing low angle cross beddings. Borrow fillings, common benthic foraminifers, bioclasts, molluscan shells, and sea urchins were observed.

The upper contact with the Pab Sandstone is conformable outside the area studied here (Shah 1977). In the Rakhi Nala section a low angle (more or less 5 degree) unconformity was observed. The Fort Munro Formation was measured and sampled systematically. The thickness is about 178 m. Fourteen samples (RN 48-61) were collected. Additional 4 samples (RN 6-9) were randomly taken. Their data are included within their nearby systematically taken samples (Figure1). Samples containing additional data are marked with an asterisk on the distribution charts (Figure4).

Pab Sandstone

Pab Sandstone lies above the Fort Munro Formation. It is a thick sequence of whitish to light-brown, weathering yellowish-brown, thick bedded to massive, medium to coarse-grained quartzose sandstone showing common low angle cross stratification, common clay pebbles and channel fillings. Along the traverse, 11 samples (RN 19-29) were collected while additionally 5 samples were randomly collected from this formation.

Ranikot Group

The group consists of two formations, which correspond to the "*Venericardia* Shales" and the "Gorge Beds" of Eames (1952a).

Nagappa (1959) placed the "Gorge Beds" within his Ranikot Series as its lower part. Bayliss (1961) considered both the "*Venericardia* Shales" and the "Gorge Beds" as equivalents to the Ranikot Series. Shah (1977) mentioned the lithological units as Khadro and Bara Formation, respectively.

Khadro Formation

The Khadro Formation corresponds to the "*Venericardia* Shale" of Eames (1952a). It consists of greenish-grey shales and calcareous sandstones (Shah, 1977). The formation was not sampled during this study.

Bara Formation

The Bara Formation corresponds to the "Gorge Beds" of Eames (1952a). It consists of dark-to medium-grey, grey to brownish-grey sandstones, sandy limestones with occasional dark-gray shale interclations. No fossil content was observed neither in the field nor in the washed residues. Five samples (RN 31-35), one from the lower part and four from the middle part were collected from this formation.

Dunghan Formation

According to Shah (1977), this formation is restricted to the "Lower Rakhi Gaj Shales" of Eames (1952a). Nagappa (1959) placed this unit within his Ranikot Series as its upper part. Bayliss (1961) separated the "Lower Rakhi Gaj Shales" of Eames (1952a) from the Ranikot Series of Nagappa (1959) and called it Dunghan Formation including a basal limestone bed, the so-called Irregularies Bed, of the "Upper Rakhi Gaj Shales" of Eames (1952a).

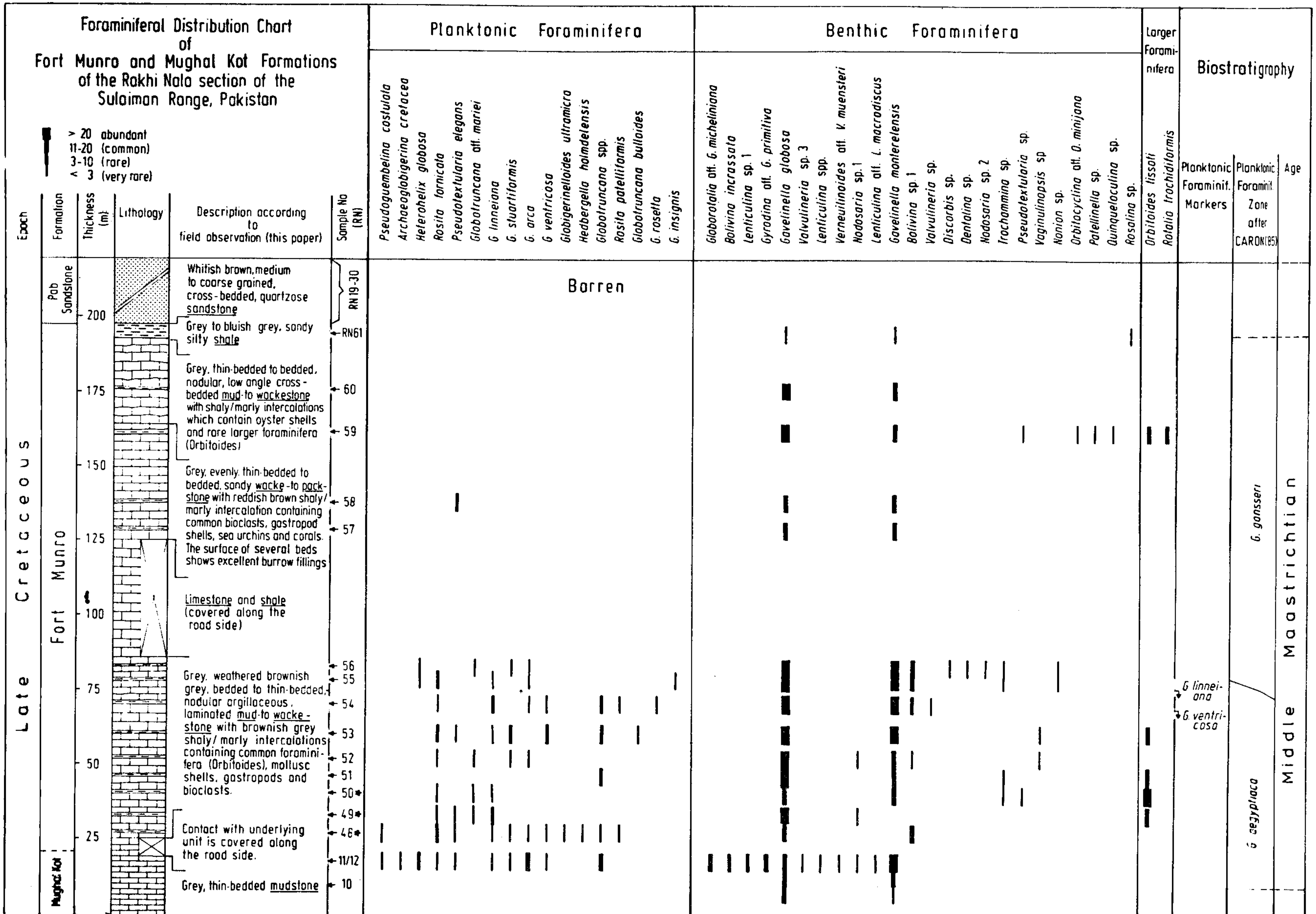
The Dunghan Formation consists of dark greenish-gray to bluish-gray shales. The contact with the overlying Ghazij Formation is gradational. Four samples (RN36-39), one from the lower and three from the upper part were collected.

Ghazij Formation

This formation comprises four lithological units termed by Eames (1952a), the "Upper Rakhi Gaj Shales" the Green and Nodular Shales", the "Rubbly Limestones", and the "Shales with Alabaster".

Nagappa (1959) considered these units as belonging to his Lakhi Series. Bayliss (1961) restricted the term Ghazij Formation to the lower two units and included the upper two units within his Kirthar Formation. Both Nagappa (1959) and Bayliss (1961) placed the lower boundary of the Lakhi Series or their equivalent rock units (Ghazij Formation) at the top of the Irregularis Bed, while Shah (1977) included this limestone bed within the Ghazij Formation.

The lower part of the formation corresponding the lower two units of Eames (1952a) consists of thick greenish shales with some nodular limestone beds. The upper part corresponding to the upper two units of Eames (1952a)



(* data from additional Samples, RN6-9, are included) consists of a thick nodular limestone sequence with thin, greenish-gray, shaly interclations followed by a band of massive gypsum. Eight samples (RN 40-47) were collected from the "Upper Rakhi Gaj Shales" the "Green and Nodular Shales" and the "Rubbly Limestones" of Eames (1952a).

MATERIAL, METHOD AND PRESERVATION

Standard technique was used to wash the shaly/marlstone samples, for each approximately 200 gm. The dried residue was passed through a set of sieves to split the sample into fractions of different size. Larger foraminifers were picked over 500 micron sieve while planktons and smaller benthic foraminifers were picked over a sieve greater than 200 micron.

It was attempted to pick as many specimens as possible from the washed residues. The distribution values of foraminifers are presented semi-quantitatively, based on the number of specimens of each species per equal volume of washed residue: very rare = less than 3 specimens, rare = 4-10 specimens, common = 10-25 specimens, and abundant = more than 25 specimens. To find out different ratios, for example the ratio of the planktonic to benthic foraminifers (P/B ratio), the abundances are converted into percentages.

Cretaceous planktonic foraminifers were identified following mainly Robaszynski, Caron, Gonzalez & Wonders (1984) and Caron (1985), while Tertiary planktonic foraminifers were identified mostly after Bolli (1957a), Blow (1979) and Toumarkine & Luterbacher (1985). Smaller benthic foraminifers were identified according to Haque (1956), Murray (1961), Loeblich & Tappan (1987), Jenkins & Murray (1989) Bolli, Beckmann & Saunders (1994) and Namoura & Brohi (1995), while larger foraminifers were identified after Davies & Pinfold (1937), Smout (1954), Nagappa (1959), Hottinger (1960), Marks (1962), Bayliss (1961), Schaub (1981) and Weiss (1993).

BIOSTRATIGRAPHIC RESULTS AND DISCUSSION

Late Cretaceous Foraminifers

In total about 40 samples from the Late Cretaceous interval were investigated, 3 samples from the Mughal Kot Formation, 22 samples from the Fort Munro Formation and 16 samples from the Pab Sandstone.

The Pab Sandstone was found to be completely barren of foraminifers. Mughal Kot Formation and the lower part of the Fort Munro Formation yielded rare planktonic foraminifers. Smaller benthic foraminifers are rare to common throughout the interval, whereas larger foraminifers are common in the *middle part and rare to absent in the upper part of the Fort* Munro Formation. No larger benthic *foraminifers were observed in the top most part of the Mughal Kot Formation,*

About 16 planktonic,2 larger benthic and many smaller benthic foraminiferal species were identified from the Cretaceous units (Figure 4). Due to the very poor preservation of the smaller benthic foraminifers, which are taxonomically not so well known as the planktonic foraminifers, an open nomenclature was used occasionally for some of the benthic specimens.

The planktonic foraminiferal assemblage from the top of the Mughal Kot Formation (RN12-10) to the middle part of the Fort Munro Formation (RN48-56) is given below. Based on these species, two planktonic foraminiferal zones are recognized.

Globotruncana linneiana, G. arca, G. ventricosa, G. bulloides, G. rosetta, G. insignis, G. mariei, Globotruncanita stuartiformis, pseudoguembelina costulata, Archaeoglobigerina cretacea, Rosita fornicata, R. patelliformis, Heterohelix globosa, Hedbergella holmdelensis, Pseudotextularia elegans and *Globigerinelloides ultramica.*

Globotruncana aegyptiaca Zone

Age :Early to Middle Maastrichtian

Type :Interval zone

Definition :Interval between the first occurrence of *Globotruncana aegyptiaca* (base) to the first occurrence of *Gansserina gansseri* (top)

Formation :Top of the Mughal Kot Formation to the middle part of the Fort Munro Formation

Interval :RN 11-55

Comments :The base of the zone is not proved. *Globotruncana aegyptiaca* and *Gansserina gansseri* were not observed in this section. According to the international stratigraphic ranges, the last occurrences of the *Globotruncana ventricosa* and *G. Linnaeana* indicate the upper limit of *G. Gansseri* Zone and it is the same level where *G. gansseri* appears (Caron, 1985). Therefore, the last occurrence of both these species (in sample RN 54 and RN 55 respectively) were used here to mark the top of the *G. agyptiaca* Zone.

Gansserina gansseri Zone

Age : Middle to Late Maastrichtian

Type :Interval zone

Definition :Interval between first occurrence of *Globotruncana gansseri* (base) to the first occurrence of *Abathomphalus mayaroensis* (top).

Formation :Fort Munro Formation

Interval :RN 56-61

Comments :Only parts of this zone were represented by long-ranging planktonic foraminifers. Because of the shallowing upward sequence of the sediments, planktonic foraminifers disappear while only common to abundant smaller and larger benthic foraminifers were observed. Therefore, a question can be raised about the upper limit of this zone.

Species	Campanian	Maastrichtian	Authors
	------- - - -		PAPP (1955, 1956)
	-------		KÖHLER (1962)
Orbitoides tissoti	-------------		VAN GORSEL (1978)
	-------------		HAYNES (1981)
	--------------	--------------	NEUMANN (1984)
		-------------	WEISS (1993)
	--------		PAPP (1955, 1956)
	------------	------------	KÖHLER (1962)
Orbitoides media	- -------		VAN GORSEL (1978)
	- -------		HAYNES (1981)
	-----------	-----------	NEUMANN (1984)
		-----	ROBASZYNSKI et al. (1985)
		-------------	WEISS(1993)
		------	PAPP (1955, 1956)
Omphalocyclus macroporus		- - - -------	HAYNES (1981)
		------	ROBASZYNSKI et al. (1985)
		- - - -------	WEISS (1993)

Figure 5- Stratigraphic ranges of selected Late Cretaceous larger foraminifera.

Discussion on the Age of Fort Munro Formation

From the Cretaceous sediments, samples mainly from the Fort Munro Formation were investigated, whereas few samples from the top of the underlying Mughal Kot Formation were analyzed. As a whole, the sediments correspond to the "*Orbitoides* Limestone and Shales" of Eames (1952a).

Williams (1959) placed the whole sequence between the Parh Limestone and the Pab Sandstone near Mughal Kot area under the Mughal Kot Formation but he recognized the upper part as Fort Munro Limestone member. He reported larger foraminifers, such as *Omphalocyclus macroporus* and *Orbitoides* spp. from the later, and dated the Fort Munro Limestone member as Maastrichtian.

Nagappa (1959) following Eames (1952a) commented that the "*Orbitoides* Limestones and Shales" are Campanian to Maastrichtian in age.

Hunting Survey Corporation (1961) and Bayliss (1961) placed all the Cretaceous units of Eames (1952a) under the name Pab Formation, which were separated in two parts, the Pab Sandstone member and Mughal Kot Limestone member. From the later, Bayliss (1961) reported larger foraminifers, such as *Orbitoides media* in association with *Omphalocyclus macroporus, Siderolites* sp. and *Discorbis* sp. and he dated this part as Maastrichtian.

Marks (1962) reported larger foraminifers, such as *Orbitoides tissoti minima, O. tissoti compressa, and Siderolites* cf. *calcitrapoides*, from this unit ("*Orbitoides* Limestone and Shale" of Eames (1952a) and dated it as Middle to Late Campanian.

Later on, Shah (1977) raised the rank of the Fort Munro Limestone member of Williams (1959) to a formation which was considered as Campanian to Maastrichtian.

Weiss (1993) summarized "Inoceramus Clays", the "Bedded Clays" and "*Orbitoides* Limestones and Shales" of Eames (1952a) under the name Mughal Kot Formation following Williams (1959). His Mughal Kot Formation corresponds to both the Mughal Kot and the Fort Munro formations according to Shah (1977). He reported the "Inoceramus Clays" and the "Bedded Clays"of Eames (1952a) as barren of planktonic foraminifers, whereas the *Orbitoides* Limestone and Shale sequence contains abundant to rare larger foraminifers such as *Orbitoides tissoti, O. media and Omphalocyclus macroporus.* Based on these he dated the *Orbitoides* Limestone sequence as Early Maastrichtian.

In the light of the above mentioned references, it is difficult to evaluate the exact age of the Fort Munro Formation. The authors mostly based the age of the formation on larger foraminifers and it is obvious that more or less the same species were reported, but their age assignments are different ranging from Middle Campanian to Early Maastrichtian. Therefore, a summary diagram was prepared to compare the stratigraphical ranges of some of the common larger foraminiferal species in other areas as given by different authors (Figure 5).

As far as the planktonic foraminiferal data in this report is concerned, it was not possible to place late Cretaceous planktonic foraminiferal zonal boundaries exactly. The reason most probably, be the shallowing upward sequence of sediments causing unfavorable conditions for planktonic foraminifers. All planktonic foraminiferal species, identified here, range stratigraphically from Campanian to Maastrichtian. According to Caron (1985) *Globotruncana linneiana* and *G. ventricosa*, which get extinct just before the *Globotruncana aegyptiaca-Gansserina gansseri* zonal boundary here in this section disappear slightly before that horizon where all planktons disappear. Following Caron (1985) the last occurrence of these species is taken as the upper limit of the *Globotruncana aegyptiaca* Zone (Middle Maastrichtian).

The nannofossils from the Cretaceous part of the Rakhi Nala section, as shown by Kothe (1988), indicate the presence of the CC 22 Zone of Sissingh (1977) ("Bedded Clays" and basal part of *Orbitoides* Limestone, dated as Campanian) and the CC 23 Zone (most of the *Orbitoides* Limestone, dated as Maastrichtian), which are based on last occurrences of zonal and additional species. It is not mentioned whether these last occurrences are stratigraphically and/or paleoenvironmentally caused.

The larger foraminiferal species *Omphalocyclus macroporus*, which is considered to be restricted to the

Maastrichtian, was reported by Williams (1959) from the Mughal Kot area. It is also reported and photographed by Bayliss (1961) and Weiss (1988, 1993) from the "*Orbitoides* Limestone and Shale" of the Rakhi Nala section.

Moreover, Dorreen (1974) reported two zones of the Maastrichtian, the *Gansserina ganssen* Zone and *Contusotruncana contusa* Zone (equivalent to the *G. gansseri* Zone of Caron, 1985) from strata between the Parh Limestone and Pab Sandstone (equivalent to the Mughal Kot Formation) in the Gaj River section of the Balochistan area of Pakistan. Her Mughal Kot Formation is equivalent to Mughal Kot and Fort Munro Formation at Rakhi Nala section (see also Namoura and Brohi, 1995).

Therefore, from combined interpretation of nannofossil, larger benthic and planktonic foraminiferal data and the ages of the equivalents of the Fort Munro Formation in other areas, the most appropriate conclusion is that the age of the Fort Munro Formation is Maastrichtian, fitting within the planktonic foraminiferal *Globotruncana aegyptiaca* to *Gansserina gansseri* Zones.

Early Tertiary Foraminifers

Seventeen samples from the Tertiary interval of the Rakhi Nala section were analyzed (Figure 6). The Bara Formation (RN 31-35) is completely barren of foraminifers. The Dunghan Formation (RN 36-39) has shown that its lower part is also barren of foraminifers while the upper part yielded some Early Eocene foraminifers. The Ghazij Formation (RN 40-47) yielded common to rare planktonic and smaller benthic foraminifers throughout whereas common larger foraminifers were recovered from the middle to upper part of the Ghazij Formation (RN 42-47).

Following Berggren and Miller (1988), planktonic foraminiferal zonations were recognized as follows:

Morozovella aragonensis/Morozovella formosa Zone, P 7

Age :Early Eocene

Type :Concurrent range zone

Definition :Interval between the first occurrence of *Morozovella aragonensis* (base) to the last occurrence of *M. formosa* (top).

Interval :Sample RN 36-39

Formation :Dunghan (upper part)

Other planktonic foraminifers are: *Subbotina linaperta, S. triangularis, Morozovella aragonensis, M. formosa gracilis, M. formosa formosa, M. aequa dolabrata, M. acuta, Acarinina wilcoxensis wilcoxensis, A pentacamerata, A. wilcoxensis strabocella, A. pseudotopilensis, A. broedermanni, Muricoglobigerina soldadoensis soldadoensis* and *Pseudohastigerina wilcoxensis.*

Morozovella aragonensis Zone, P8 (not identified here)

Age :Early Eocene

Type :Partial range zone

Definition :Interval between the last occurrence of *Morozovella formosa* (base) to the first occurrence of *Planorotalites palmerae* (top).

Interval :Not sampled

Formation :Ghazij Formation

Remarks :Because of the large sampling gap between samples RN 39 and RN 40, this zone could not be identified.

Subbotinae inaequispira Zone, P 9

Age :Early Eocene

Type :Partial range zone

Definition :Interval between the first occurrence of *Planorotalites palmerae* (base) to the first occurrence of *Hantkenina nuttalli* (top).

Interval :Samples RN 40-61

Formation :Ghazij

Other planktonic foraminifers are: *Subbotina linaperta, S. frontosa, Acarinina pentacamerata, A. pseudotopilensis, A. wilcoxensis strabocella, A. aspensis, A. hagni, Acarinina aff. camerata, A. spinuloinflata, Planorotalites ex gr. palmerae-pseudoscitula, Turborotalia griffinae* and *Pseudohastigerina wilcoxensis.*

Characteristic larger foraminifers are: *Nummulites hoogenradi, N. globulus, N. crasseomata, N. atacicus, Assilina granulosa, A. spinosa, Operculina jiwani, Lockhartia hunti, L. conditi, L. hunti var. pustulosa and Discocyclina cooki.*

Discussion on the Age of Dunghan Formation

Eames (1952b) did not mentioned foraminiferal fauna from the "Lower Rakhi Gaj Shales" which is here named as the Dunghan Formation.

Nagappa (1959) stated that these beds are virtually barren of foraminifers. He also commented that only the upper beds are characterized by the first occurrence of planktonic foraminifers, such as species of *Globigerina* and *Globorotalia*, and other smaller benthic foraminiferal species. He considered that the fauna is probably of Paleocene age and the beds might be equivalents of the Ranikot Series of Sind (Lower Indus Basin).

Balyiss (1961) reported that the shaly part of these beds are barren of larger foraminifers. He mentioned that the sediments are attributed to the late Paleocene *Globorotalia velascoensis* Zone. He placed the upper boundary of the Dunghan Formation at the top of the first thin limestone bed, the so-called "Irregularis Bed" which yielded first Early Eocene larger foraminifers, such as *Nummulites atacicus, Assilina granulosa* and other (Nagappa 1959).

Latif (1961) placed the upper limit of the Dunghan Formation at the base of the Irregularis Bed. He reported a number of planktonic species, such as *Globorotalia pusilla pusilla , Gr. aff. pseudomenardii, Gr. rex, Gr. aequa, Gr. compressa, Gr. elongata, Gr. velascoensis, Gr. angulata, Gr. aragonensis, Gr. broedermanni, Globigerina soldadoensis, G. triloculinoides* and other. Based on these species, he recognized three zones, *Globorotalia angulata Zone, Gr. crater Zone* and *Gr. rex* Zone, and dated the formation as Paleocene.

The occurrence of Paleocene and Eocene species suggest that for some of the Paleocene species he used a broad definition. But cannot be further commented without proper examination of his collection.

Samanta (1973) reported that the lower part of the Dunghan Formation is barren of foraminifers. He described planktonic foraminifers from the upper part of the Dunghan Formation, such as *Globigerina soldadoensis, G. triangularis, G. triloculinoides, Globorotalia velascoensis, Gr. aequa, Gr. acuta, Gr. angulata, Gr. aragonensis, Gr. aspensis, Gr. broedermanni, Gr. chapmani, Gr. esnaensis, Gr. formosa formosa, Gr. formosa gracilis, Gr. marginodentata, Gr. occlusa, Gr. pseudomenardii, Gr. subbotinae, Gr. velascoensis, Gr. wilcoxensis* and others. Based on these species, he dated the Dunghan Formation as Paleocene to Early Eocene. Many of his species have been recovered during the present study.

Kothe (1988) investigated samples from the "Lower and Upper Rakhi Gaj Shales" and based on the nannoplankton, she recognized NP 4,7 and 9 zones.

Weiss (1993) placed the Gorge Beds s.l. (= sensu lato), which include the "Venericardia Shales" and the "Gorge Beds" of Eames (1952a) under the name Dunghan/Ranikot Formation which corresponds to the Khadro and Bara Formations of Shah (1977). The Gorge Beds s.l. were sampled by Weiss (1988). The "Lower and Upper Rakhi Gaj Shales" of Eames (1952a) were not strictly separated lithologically and biostratigraphically and were placed under the Ghazij Formation. Weiss (1993) confirmed the presence of many planktonic foraminifers reported by Latif (1961) and Samanta (1973), i.e. *Globorotalia angulata, Gr. pseudomenardii, Gr. pusilla, Gr. velascoensis, Gr. formosa formosa, Gr. aragonesis* and others. Based on these Weiss (1993) recognized several planktonic foraminiferal zones, for instance *Planorotalites pusilla pusilla - Morozovella angulata* Zone, *Pl. pseudomenardii - Morozovella velascoensis* Zone and *M. formosa* Zone, indicating a Middle Paleocene to Early Eocene age for the interval of the "Lower and Upper Rakhi Gaj Shales" of Eames (1952a).

The results of the present study are shown in Figure 6. The basal part of the Dunghan Formation is barren of foraminifers, as reported above. The samples studied here were not taken as densely as studied by Balyiss (1961) and Latif (1961). Especially the middle part of the Dunghan was not sampled. Therefore, most of the Paleocene zones, such as *Planorotalites pusilla pusilla* Zone, *Morozovella angulata* Zone, *Pl. pseudomenardii* Zone and *M. velascoensis* Zone according to Toumarkine and Luterbacher (1985) as reported by Weiss (1993) under his Ghazij Formation, and their equivalents, as reported earlier by Latif (1961) and Samanta (1973), are not proved. Thus, the present study does not provide further informations on the oldest age of the Dunghan Formation . Only one zone, *Morozovella formosa* Zone (P7) of Early Eocene, was recognized. The present results regarding the top of the Dunghan Formation are in accordance with Samanta (1973) and Weiss (1993).

Discussion on the Age of Ghazij Formation

According to Shah (1977), the Ghazij Formation, as referred here, corresponds to the lithologies of Eames (1952a) ranging from the base of the Irregularis Bed, which is the top most part of the "Lower Rakhi Gaj Shales", to the base of the "Platy Limestone" of Eames (1952a).

Eames (1952b) has subdivided the sediments, which are summarized as Ghazij Formation including the "Upper Rakhi Gaj Shales", "Green and Nodular Shales", "Rubbly Limestones" and "Shales with Alabaster", into several units based on the total fauna. These units were subdivided into several local zones, local stages and local series. He mentioned larger foraminifers, such as *Assilina granulosa, A. leymeriei, Nummulites irregularis, Alveolina ovoidea, Rotalia trochidiformis, Dictyoconoides vredenburgi* and others, from these units and dated them as Early Eocene.

Nagappa (1959) reported a similar larger foraminiferal fauna, such as *Assilina granulosa, Nummulites irregularis, N. atacicus, N. pinfoldi* from the unit which is here called Ghazij Formation (his Laki Series) and placed it within the Early Eocene.

Bayliss (1961) incorporated the two basal units of Eames (1952a), the "Upper Rakhi Gaj Shales" and the "Green and Nodular Shales", within his Ghazij Formation, while the upper two units, "Rubbly Limestones" and "Shales with Alabaster", represent the lower part of his Kirthar Formation. He described Early Eocene larger foraminifers from the two formations, such as *Nummulites atacicus, N. globulus, N. hoogenradi, N. fossulata, N. crasseomata, Assilina granulosa, A. laminosa, A. daviesi, Orbitolites complanatus, Alveolina oblonga, A. lepidula, A. globosa, Lockhartia conditi, and Discocyclina archiaei* and dated them as Early Eocene.

Latif (1961) reported several planktonic foraminiferal species from the lower half of the Ghazij Formation, such as *Globorotalia palmerae, Gr. esnaensis, Gr. broedermanni, Gr. pusilla pusilla, Gr. aff. pseudomenardii, Gr. aequa, Gr. rex, Globigerina soldadoensis, G. linaperta* and other species on open nomenclature. Based on these species, he identified four planktonic foraminiferal zones, such as *Globigerina* sp. 5, *Hastigerina pseudoiota, Globigerina esnaensis, and Globorotalia* sp. 4 Zones, and dated the unit as Early Eocene. Most of his zones which are based on open nomenclature are local zones. As such they can not be correlated exactly with international planktonic foraminiferal zonations.

Samanta (1973) did not discussed in detail the lithology and limits of his Ghazij Formation. He appears to follow Bayliss (1961). He reported 11 planktonic foraminiferal species from the lower half of his Ghazij Formation, such as *Globigerina soldadoensis, G. mckannai, Globorotalia aspensis, Gr. broedermanni, Gr. esnaensis* and placed his Ghazij Formation in the *Globorotalia aspensis-Globorotalia esnaensis* Zone of Early Eocene. Many of his species were identified from the lower half of the Ghazij Formation (=the Ghazij Formation of Samanta 1973). The present results are in accordance with these results.

Kothe (1988) reported the corresponding units of the Ghazij Formation as completely barren of nannoplankton, only some dinoflagellates were reported from the Ghazij Formation of Shah (1977). Based on these, she described a local dinoflagellate zone (Pak D-IX) from the upper part of the Ghazij Formation. She correlated this zone with NP 12 to early NP 14 (equivalent to planktonic foraminiferal zoned P 7-9), and dated the formation as middle to late Early Eocene. This broad age assignment is still in accordance with the present results.

Weiss (1988, 1993) restricted the term Ghazij Formation to the "Lower and Upper Rakhi Gaj Shales" of Eames (1952a). The upper three units of the Ghazij Formation, "Green and Nodular Shales", "Rubbly Limestones and "Shales with Alabaster' of Eames (1952a), were placed as lower part of the Kirthar formation. Therefore, the lower Early Eocene part of his Kirthar Formation is part of the Ghazij Formation of Shah (1977). Weiss (1993) reported that this part is completely barren of planktonic foraminifers, while larger foraminifers are present, such as *Nummulites fossulata, Assilina spinosa, A. laminosa, A. leymeriei, A pustulosa.* Based on these larger foraminifers, he described as *A. leymeriei - N. fossulata* Assemblage Zone of Early Eocene for this part of the Ghazij Formation. From the lowermost part of the *A. leymeriei - N. fossulata* Assemblage Zone of Early Eocene which is clearly the top most part of Ghazij Formation (the middle and upper parts of the "Rubbly Limestones" and the "Shales with Alabaster" of Eames, 1952a), no planktonic and no larger benthic foraminifers were reported. Based on previous investigations and present results, it looks quite reasonable to consider the lower half of the Ghazij Formation as presented by the *Morozovella aragonensis* Zone (P8, supposed to be present) to the *Subbotina inaequisipira* Zone (P9) of Berggren & Miller (1988). In the upper half, the planktonic foraminifers are rare to absent but common larger foraminifers of Early Eocene age are present. No typical Middle Eocene species was reported neither previously nor in the present investigation. Based on larger foraminiferal species, as *Assilina granulosa - Nummulites crasseomata - N. hoogenradi -Dictyoconoides cooki* Assemblage is defined. This assemblage may be correlated with the P9 Zone of Berggren & Miller (1988).

ZONAL CORRELATION AND AGE ASSIGNMENTS

Since the present study is based on the analysis of larger sample intervals, the zonal boundaries are difficult to be correlated exactly. Nevertheless, based on the informations given by the authors mentioned above, the zonal boundaries can be re-evaluated in the light of present status of knowledge.

A zonal correlation diagram showing the most important Early Tertiary planktonic foraminiferal and nannoplankton zonations published by Bolli (1957, 1966), Bolli & Cita (1960), Luterbacher & Premoli-Silva (1964), Blow (1969, 1979), Martini (1971), Premoli-Silva & Bolli (1973), Stainforth et al. (1975), Toumarkine & Luterbacher (1985) and Berggren & Miller (1988) is given including the zones known from the Rakhi Nala section as reported by Latif (1961), Samanta (1973) and Weiss (1993) (Figure 7).

Late Cretaceous Zonation

Although many authors have published data on the Cretaceous sediments of Rakhi Nala section, only sporadic data of planktonic foraminifers were reported Nagappa (1959).

Kothe (1988) identified the *Tranolithus phacelosus* Zone (CC23) of Sissing (1977), which has been correlated with planktonic foraminiferal *Globotruncanita calcarata* to *Globotruncanella havanensis* Zones (Late Campanian to Early Maastrichtian) of Caron (1985). Weiss (1993) did not report planktonic foraminifers from this interval but he correlated a Larger foraminiferal *Orbitoides media-Omphalocyclus macroporus* Assemblage Zone with the *Globotumcanella havanensis* and *Globotruncana aegyptiaca* Zones of Early Maastrichtian age.

Early Tertiary Zonation

Before the 1960's only sporadic occurrences of planktonic foraminifers from the Rakhi Nala section were known Nagappa (1959).

Latif (1961) was the first who proposed a zonation scheme of the complete Tertiary interval. He defined zonal boundaries based on the abundance of the respective species. Latif (1961) and later on Samanta (1973) tend to develop planktonic foraminiferal zonations of acme nature. Samanta (1973) however, gave criteria to define zonal boundaries. He appeared to follow Bolli & Cita (1964) and Luterbacher & Premoli-Silva (1964). A number of problems were faced to correlated these different zonations which are discussed below.

Problem 1

McGowran (1968) tried to re-interpret the zones of Latif (1961) and correlated with the standard planktonic Zones. The occurrence of *Gr. pseudomenardii* before *Gr. ehrenbergi* from his *Gr. angulata* Zone, needs verification where as the occurrence of his *Gr.* aff. *pseudomenardii* together with Early Eocene species is of particular interest to verify the total range of this characteristic species in the Sulaiman Range.

Samanta (1973) reported the co-occurrence of both *Gr. pseudomenardii and Gr. ehrenbergi*, from the same

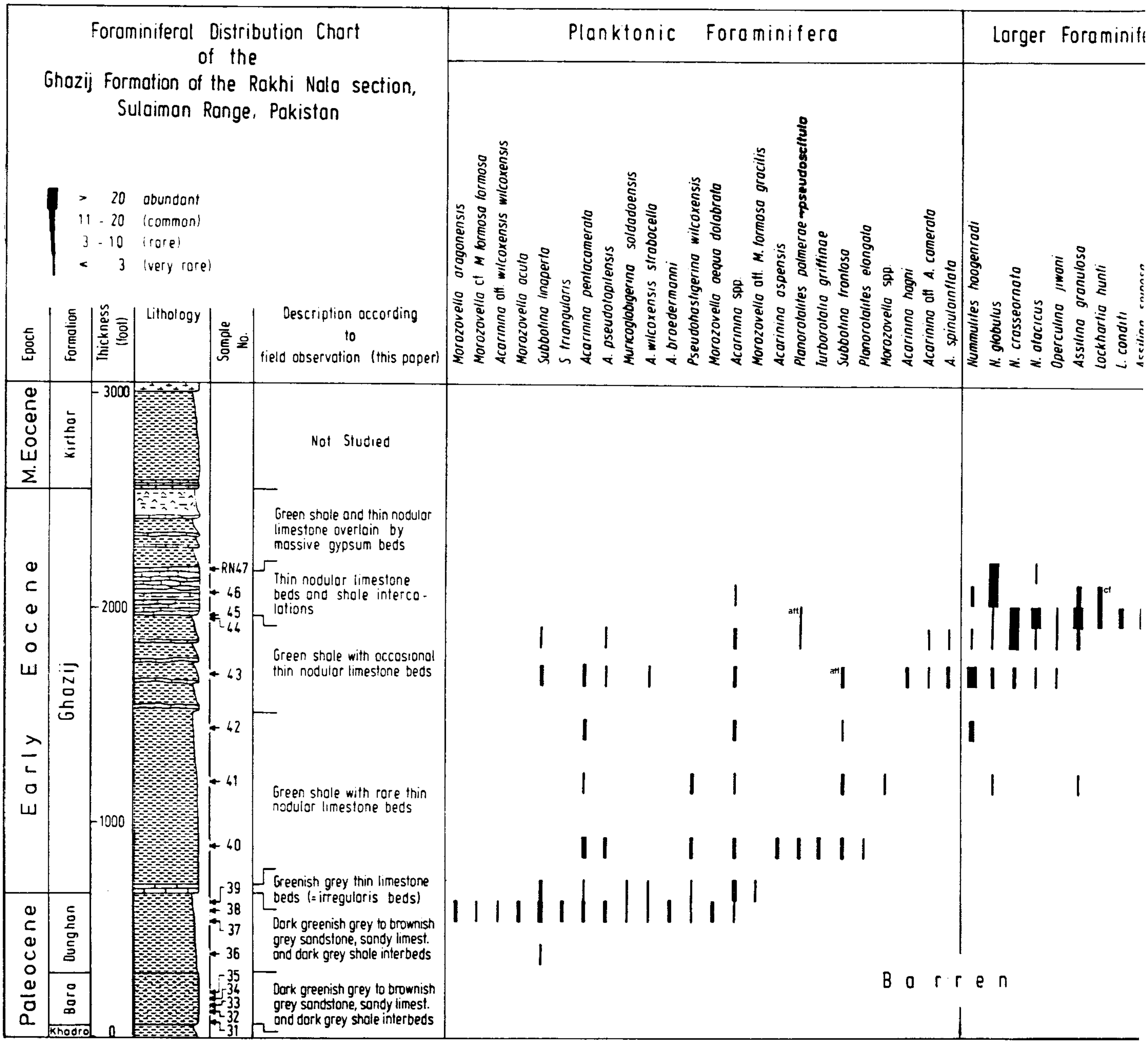


Figure 6- Distribution of Early Tertiary planktonic and benthic (larger and smaller) foraminifera.

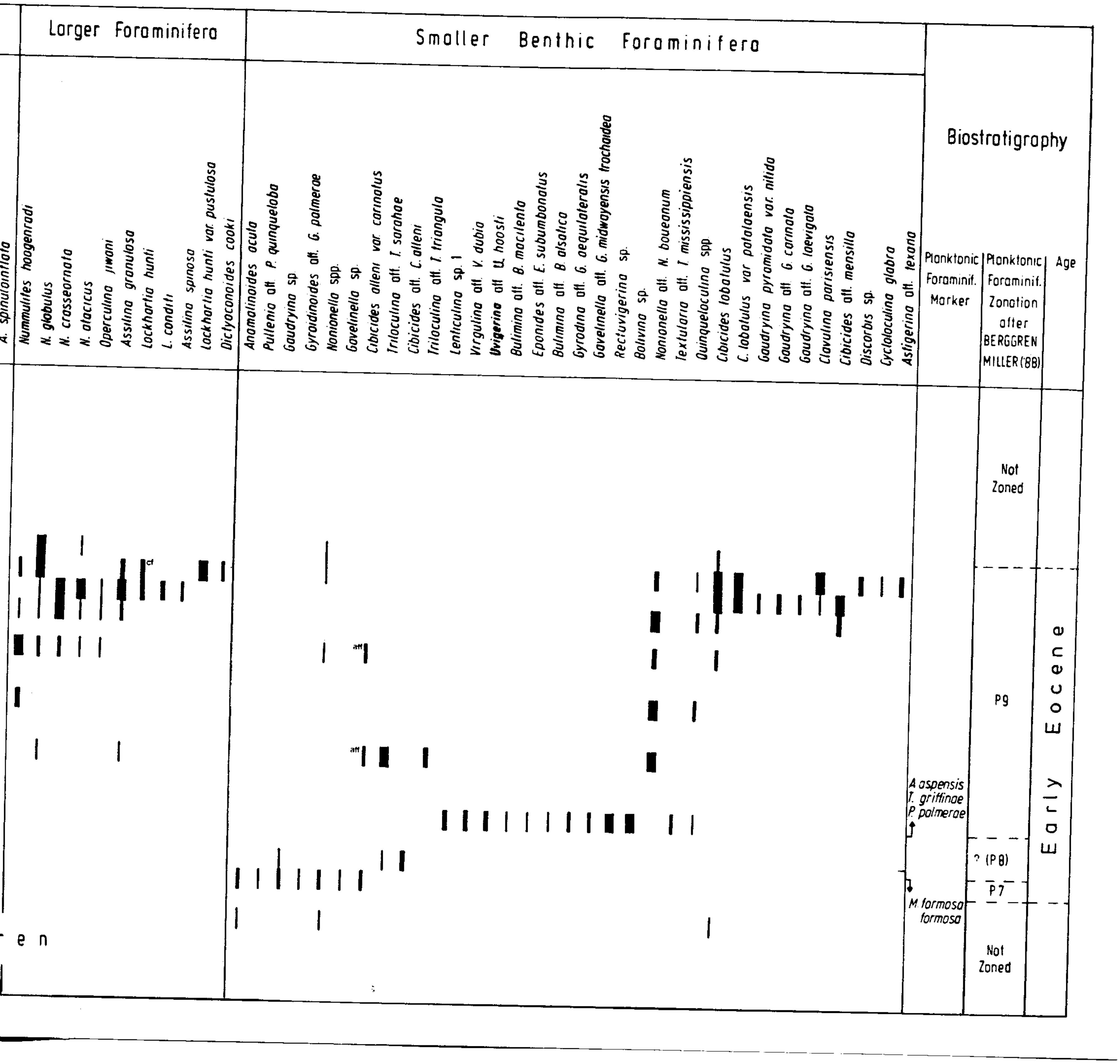


Figure 6- Distribution of Early Tertiary planktonic and benthic (larger and smaller) foraminifera.

stratigraphical horizon. Weiss (1993) reported only *Gr. pseudomenardii* from this level.

Because the upper most part of *Gr. angulata* Zone of Latif (1961) show the presence of *Gr. pseudomenardii*, therefore, the *Gr. angulata* Zone of Latif is correlated with the P3 and base of P4 Zones of Berggren & Miller (1988) where as zones of Samanta (1973) below the FO of *Gr. pseudomenardii* are correlated with P3.

Problem 2

A problem regarding the Rakhi Nala biostratigraphy is the separation of *Globorotalia crater* FINLAY from *Gr. velascoensis* (CUSHMAN) and *Gr. caucasica* (GLAESSNER). The second zone of Latif (1961), the *Globorotalia crater* zone is based on the common occurrence of *Gr. crater.* From the reference list, it seems that he followed Hornibrook (1958), who for the first time illustrated the holotype of *Gr. crater.* This illustration shows a great similarity with *Gr. caucasica* and *Gr. velascoensis.* Blow (1979) examined FINLAY's paratypes of *Gr. crater* and concluded that the illustration as given by Hornibrook (1958) was not correct (Blow, 1979, p. 996), also see comments of Berggren (1977). Latif (1961) reported *Gr. velascoensis* from a limited interval of his *Gr. crater* Zone which is from the middle part of the Dunghan Formation. It is more or less the same stratigraphic interval from where Nagappa (1959) reported *Globorotalia aff. velascoensis* while Samanta (1973) and recently Weiss (1993) reported *Gr. velascoensis.* There is a strong possibility that Latif's *Gr. crater* is actually a form related to *Gr. velascoensis.* Moreover, *Gr. crater* is always reported from the Early Eocene (P 6b to P 11 Zone, according to Blow, 1979). Therefore, the *Gr. angulata* Zone of Latif (1961), which shows co-occurrence of both *Gr. pseudomenardii* and *Gr. velascoensis*, (his *Gr. crater*) can be correlated with most of the P4 and P5 Zones of Berggren & Miller (1988).

Similarly, Samanta (1973) defined his *Globorotalia velascoensis* Zones as an interval between the first occurrence of *Gr. velascoensis* and the first occurrence of *Gr. subbotinae.* But his *Gr. velascoensis* appears much earlier than *Gr. pseudomenardii.* Therefore, his *Gr. velascoensis* Zone is correlated with parts of the P4 and P5 Zones. Weiss (1993) identified this interval as equivalent of the standard *Planorotalites pseudomenardii-Morozovella velascoensis* Zones (lower part) equivalent to P4-P6a Zones of Berggren & Miller (1988).

The base of the *Globorotalia aequa* Zone of Samanta (1973) is defined by the first appearance of Gr. subbotinae, *Gr. marginodentata* and *Gr. wilcoxensis.* The base is also marked by the disappearance of *Gr. velascoensis.* Samanta (1973) correlated correctly this zone with the *Gr. rex* Zone of Bolli (1957). Subsequent studies confirmed that *Gr. rex,* which is now *Gr. subbotinae* (Stainforth et al. 1975), and *Gr. velascoensis* occur together for a short period of time at the end of the P5 Zone of Blow (1979). Toumarkine & Luterbacher (1985) and Berggren & Miller (1988). The occurrence of *Gr. subbotinae* has been used as a marker of the P6 Zone of Blow(1979) and that of P6a Zone Berggren & Miller (1988). Therefore, *Gr. aequa* Zone of Samanta (1973) is here correlated with P6a Zone.

Problem 3

In the Rakhi Nala section, Latif (1961) identified the *Globorotalia rex* Zone in sample 3572. At the base of this zone he reported Early Eocene species such as Gr. rex (=*Gr. subbotinae*), *Gr. aragonensis* and *Gr. broedermanni* together with Paleocene species, such as *Gr. compressa* and *Gr. pusilla* which might be a reworked element or a contamination because their stratigraphic ranges do not fit together. Latif (1961) placed this zone as a part of the Late Paleocene which was placed by the original authors (Bolli 1957a, Bolli & Cita 1964) at the basal part of the Early Eocene.

According to McGowran (1968), the co-occurrence of *Gr. aragonensis* with Paleocene species requires explanation. Ignoring the presence of *Gr. aragonensis* he correlated *Gr. rex* zone with the standard planktonic foraminiferal *Gr. velascoensis* Zone of Bolli (1957a).

Samanta (1973) studied the same stratigraphic interval. From sample 3138, he reported the last occurrence of *Gr. velascoensis.* In the next sample above (3572, not 3672) which is according to the scale approximately 25 feet higher, he reported *Gr. formosa formosa* and *Gr. broedermanni* where as from a slightly higher level, he reported *Gr. aragonensis.*

Weiss (1993) reported the co-occurrence of *Gr. formosa* and *Gr. aragonensis* from the same level which was confirmed by this study.

Therefore, *Gr. rex* Zone of Latif (1961) and *Gr. formosa* Zone of Samanta (1973) are correlated with the standard planktonic foraminiferal *Gr. subbotinae* and *Gr. formosa* Zones of Toumarkine & Luterbacher (1985) or with P6c to P7 Zones of Berggren & Miller (1988). whereas the *Gr. formosa* Zone of Weiss (1993) is correctly defined according to the given references.

This interpretation reflects a probable time gap, which is equivalent to the P6 Zone of Blow (1979), to an interval from the *Morozovella edgari* Zone to the lower part of the *M. subbotinae* Zone of Toumarkine & Luterbacher (1985), or to the P6c Zone of Berggren & Miller (1988). Similarly, the results of Weiss (1988, 1993) show a time gap which might have existed from the base of the *M. edgari* to the top of the *M. subbotinae* Zone or, most probably, up to the lower part of the *M. formosa* Zone. This gap might also result from large sampling intervals. The time gap cannot be concluded from the results of Kothe (1988), because the Early Eocene interval which she reported is barren of nannoplankton.

Problem 4

The Globorotalia sp. 5 Zone of Latif (1961) is difficult to correlate. This species with 5 globular chamber in last whorl can be related to *Gr. pentacamerata*, therefore, tentatively correlated with *M. aragonensis* Zone of Toumarkine & Luterbacher (1985), lower part of P9 Zone of Blow (1979) and P8 of Berggren & Miller (1988).

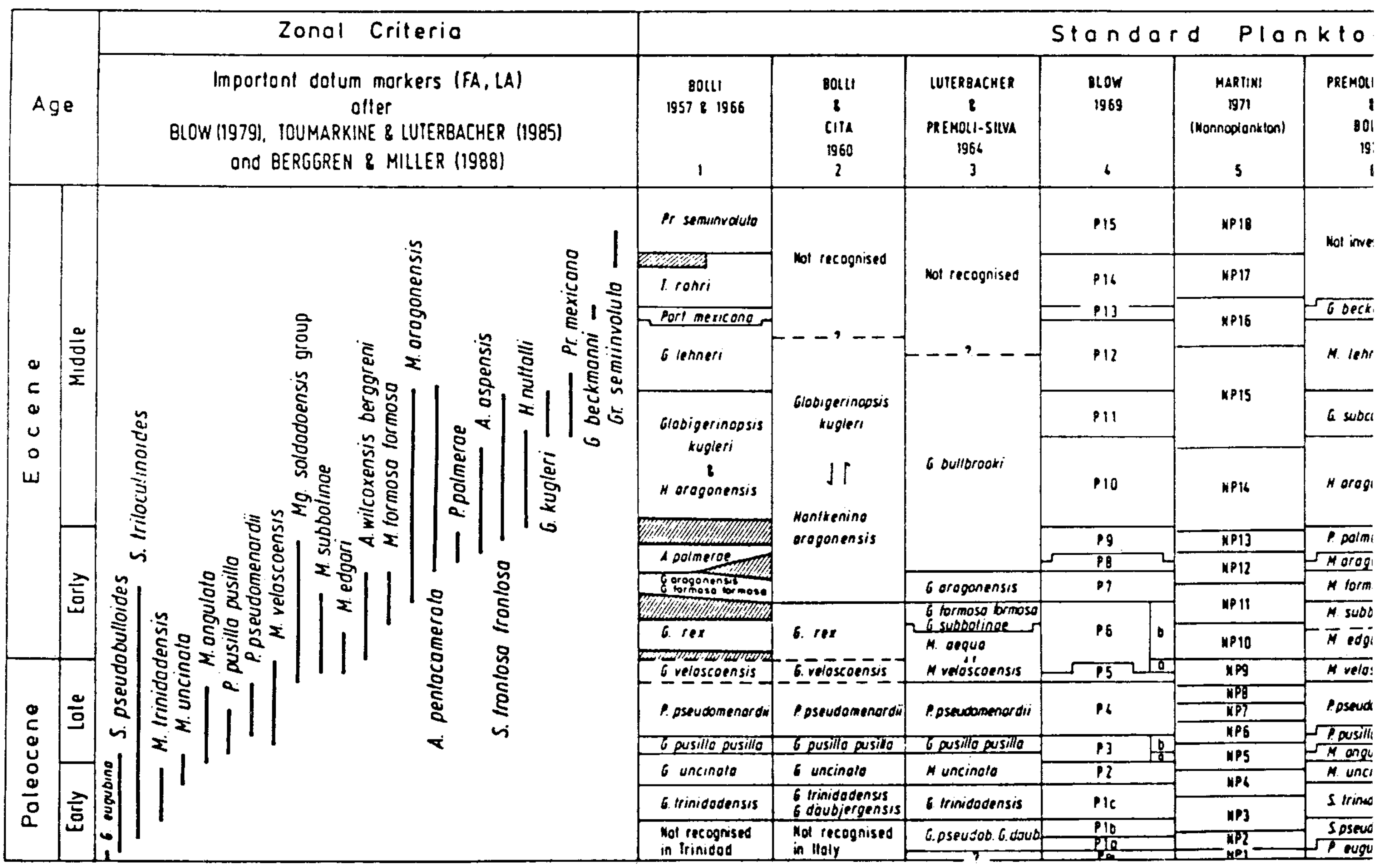


Figure 7- Correlation of the various Paleocene-Eocene standard planktonic foraminiferal zonations in comparison with the local zonations in Rakhi Nala area proposed by different authors.

A = Acarinina, G = Globigerina, H = Hantkenina,
M = Morozovella, Mg = Muricoglobigerina, P = Planorotalites, Gr = Glogigerinithica, S = Subbotina

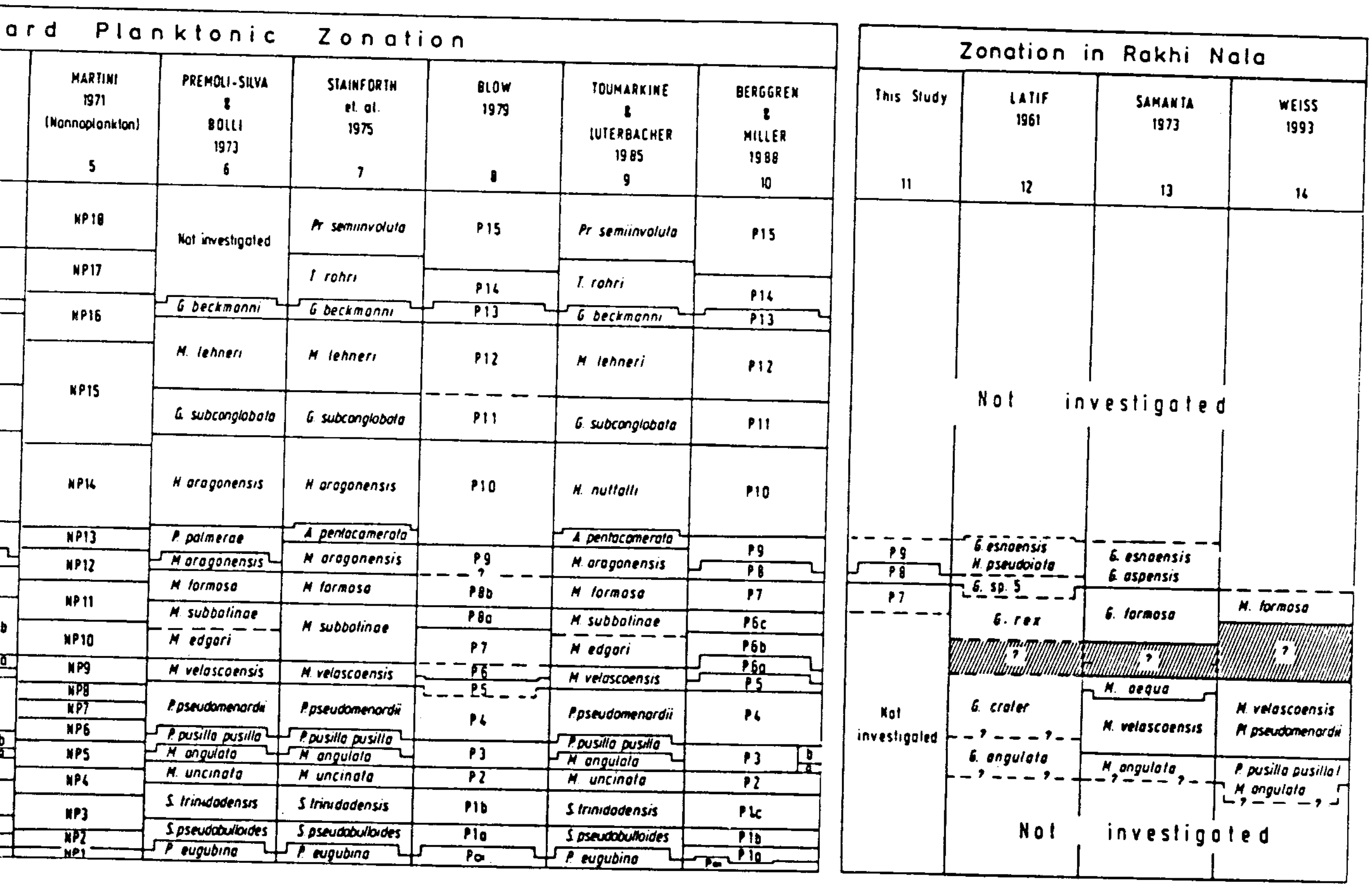


Figure 7- Correlation of the various Paleocene-Eocene standard planktonic foraminiferal zonations in comparison with the local zonations in Rakhi Nala area proposed by different authors.

A = Acarinina, G = Globigerina, H = Hantkenina,
M = Morozovella, Mg = Muricoglobigerina, P = Planorotalites, Gr = Glogigerinithica, S = Subbotina

Problem 5

The next two zones of Latif (1961), *Hastigerina pseudoiota* and the *Globigerina esnaensis* Zones, are also of acme nature which are likewise difficult to correlate exactly. According to Blow (1979) *Hastigerina pseudoiota* HORNIBROOK (1958) is a junior synonym of *Pseudohastigerina wilcoxensis* CUSHMAN & PONTON (1932) ranging from P6b to P12 Zone.

The *Globorotalia esnaensis* Zone is based on the abundantly present *Globorotalia esnaensis*. Blow (1979) considered this species as a junior synonym of *Globorotalia (Acarinina) wilcoxensis* ranging from P6a to P7 Zone of Berggren & Miller (1988). Latif (1961) reported *Gr. palmerae* from this zone which is restricted to P9 Zone according to all the references. The typical form of this species is not observed rather an intermediate form between *Planorotalites pseudoscitula* and *P. palmerae* has been observed in the lower part of Ghazij shale.

On the other hand, Samanta (1973) reported *Gr. aspensis* which is ranging from P9 to P10 Zone from his *Gr. aspensis* to *Gr. esnaensis* Zone. This species has also been observed in this interval. He himself tentatively correlated his *Gr. aspensis* to *Gr. esnaensis* Zone with the *Gr. aragonensis* Zone of Bolli (1957a) which is partially correct in the author's view.

Therefore, based on the discussion of species, *Hastigerina pseudoiota* and *Globorotalia esnaensis* Zones are correlated with P9 Zone of Blow (1979), with the *Morozovella aragonensis* and *A. pentacamerata* Zones of Toumarkine & Luterbacher (1985), or with P8 to P9 Zone of Berggren & Miller (1988).

PALEOCENE/EOCENE BOUNDARY

Within the Dungan Formation (Lower Rakhi Gaj Shale), there is possibility of a time gap or a condensed section which might be close to the Paleocene/Eocene boundary. As a whole this unit represent very slow sedimentation rate. About 775' thick interval of Lower Rakhi Gaj shale is a chronostratigraphic unit representing a time interval from *M. angulata* (P3) to *M. formosa* (P7) Zones of Berggren and Miller (1988) as evidenced through all the previous and partially in present planktonic foraminiferal studies. Additionally Kothe (1988) identified nannoplanktons NP4 to NP9 Zones of Martini (1971) within the same interval, also indicating slow sedimentation rate approximately in 7-9 million years of time span in contrast to the 3630' thick Ghazij shale ranging in age from P8 to P9 Zones of Berggren & Miller (1986) representing approximately 2 million years of sedimentation time.

Following all the previous and fresh studies the result which is more prominent is the occurrence of *M. formosa* Zone just above the *M. velascoensis* Zone near the top most part of the Dunghan Formation. Samanta (1973) has reported the last occurrence of *Gr. velascoensis* at sample 3138, and from the next sample 3572 (about 25' higher) he reported the first occurrence of *Gr. formosa formosa*. By definition this very short sedimentary interval (not studied by either of the author) must be attributed to the P6c Zone of Berggren & Miller (1988) considering the last and the first occurrences are evolutionary disappearances and appearances, respectively. If this interval belongs still to parts of the *Gr. velascoensis* and/or the *Gr. formosa* Zones, it is likely that a hiatus might exist.

PALEOENVIRONMENTS

Informations regarding the paleoenvironments of the different formations of the Rakhi Nala section were briefly summarized by Nagappa (1959), Bayliss (1961) Kothe (1988) and Weiss (1988)

Presently, paleoenvironments of the Cretaceous to Eocene sediments are based on the qualitative and semi-quantitative analysis of planktonic and benthic foraminifers, presence and absence of the larger foraminifera, Plankton/benthic ratio which provides informations about the distance from the shore line (Grimsdale & Morkhoven, 1955), keeled/non keeled ratio of the planktonic foraminifers which reflect water depth relationship (Hart, 1980).

Although the preservation of the foraminifers is poor, however an attempt is made to show the diversity pattern in the sediments which is also a useful paleoenvironmental parameter to know about the water depth.

Late Cretaceous Formations

The top of the Mughal Kot Formation and the base of the Fort Munro Formation show a relatively high P/B ratio, a relatively high number of keeled planktonic foraminiferal species, and a relatively high diversity of planktonic and benthic foraminifers (Figure 8). This may indicate deposition in an open marine, outer shelf paleoenvironment deeper than 100 meter water depth. The benthic foraminiferal genera present are *Lenticulina, Nodosaria, Bolivina, Gyrodina, Gavelinella* indicating a relatively deeper level of water depth (Murray 1991). This is also supported by the absence of larger foraminifers.

The lower-middle part of the Fort Munro Formation shows a very low P/B ratio, scarce keeled planktonic foraminiferal species and low planktonic and benthic foraminiferal diversity (Figure 8). The situation may be interpreted still as an open marine, outer shelf but tending progressively to shallowing conditions. The dominance of *Gavelinella* accompanied by *Nodosaria, Bolivina* favors relatively intermediate water conditions on the shelf (Silter & Baker, 1972; Murray, 1991). The interpretation is also favored by the presence of larger foraminifers which are observed later in this section. The upper part of the Fort Munro Formations observed quite barren of planktonic foraminifers. A level where abundant larger foraminifers were observed is also in this part indicating shallow marine environments. Kothe (1988) reported rare nannoplankton from this level. Therefore, the interval may indicate inner shelf conditions.

The samples from the Pab Sandstone were found completely barren of foraminifers (Figure 4). Bayliss (1961) also reported it barren of foraminifers and interpreted this formation as deposited in shallow marine conditions possibly of sand bar type. Kothe (1988) reported some nannoplankton species from this unit and commented it as open marine. Because the Pab Sandstone contains several shaly

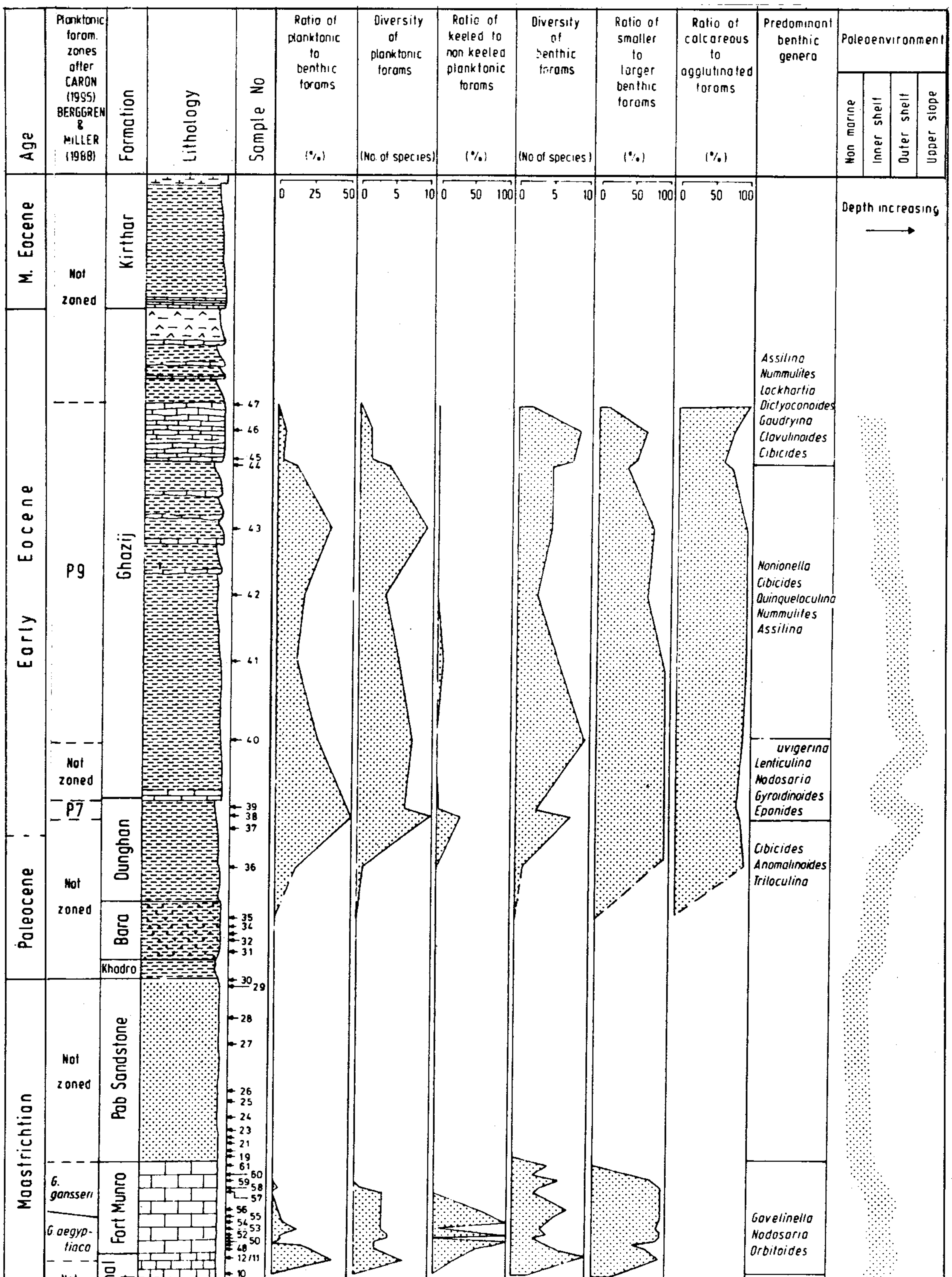


Figure 8- Statistical presentation of various foraminiferal parameters and paleoenvironmental interpretation.

intercalations, it may be considered to be deposited under very shallow to slightly open marine conditions which were favourable for some species of the nannoplankton.

Early Tertiary Formations

There are no data from the Khadro Formation while the Bara Formation was found completely barren of foraminifers by Nagappa (1968), Bayliss (1961), Latif (1961), Samanta (1973), Weiss (1993), and the author's study (Figure 6, 8). There is also no nannoplanktons Kothe (1988).

The lower part of the Dunghan Formation is barren of all kind of foraminifera whereas the upper part of the Dunghan Formation yielded both planktonic and smaller benthic foraminifers. A relatively high P/B ratio, a higher keeled to non-keeled planktonic foraminiferal ratio, and a relatively high faunal diversity (Figure 8) may indicate an open marine, outer shelf paleoenvironment. The benthic foraminiferal association consisting of specimens of *Anomalinoides, Pullenia, Gaudryina, Nonionella* and *Cibicides alleni* may also indicate shallow outer shelf conditions (Murray, 1991). Complete absence of larger foraminifers from this interval favor this interpretation.

The lower part of the Ghazij Formation yielded common planktonic foraminifers. Moderately high P/B ratio, higher keeled to non-keeled planktonic foraminiferal ratio, high diversity indicate an outer shelf paleoenvironment which is in agreement with the common occurrence of *Uvigerina, Lenticulina, Nodosaria* and *Gyrodinoides specimens*. The absence of larger foraminifers also favored this interpretation.

Near the middle part of the Ghazij Formation, planktonic foraminifers are reduced in specimen numbers and diversity whereas new elements of larger foraminifers are introduced. The accompanying benthic foraminiferal fauna consists of specimens of *Nonionella, Cibicides, Quinqueloculina, Assilina and Nummulites*. This situation may indicates inner to middle shelf paleoenvironment.

In higher parts, a sudden jump in the P/B ratio (sample RN 43) is observed together with an increase in the diversity of planktonic foraminifers that exceeds the diversity of smaller benthic foraminifers. Larger foraminifers are still increasing in number. This may indicate a slight rise of the sea level or a deepening of the basin. Still higher, the P/B ratio decreases abnormally. A remarkable decrease of planktonic foraminiferal diversity and an increase of the benthic diversity is observed. At this level, agglutinated benthic foraminifers started to increase progressively together with an increase of larger benthic foraminifers. This indicates a rapid shallowing and an inner shelf paleoenvironment may be interpreted. The increase of agglutinated benthic foraminifers indicates a change in water properties at the water-sediment interface, possibly controlled by the oxygen content and supply of organic matter to the sediments. Low oxygen conditions may be inferred near the top of the Ghazij Formation.

The topmost part (Shale with Alabaster) was not sampled but the presence of thick gypsum beds with shale intercalations just above the shallow marine sediments of rubbly limestone indicate shallow marine, restricted conditions.

COMPARISON WITH BIOSTRATIGRAPHY OF UPPER INDUS BASIN

During the course of this study, striking similarities between the litho and biostratigraphical results of the Rakhi Nala area with that of the Khairabad area (Western Salt Range) of the Upper Indus Basin were observed (Afzal, in prep.). Almost the same situation was published earlier by Kothe (1988), Afzal & von Daniels (1991), and Weiss (1988, 1993).

At the western Salt Range, a completely pelagic sequence of Late Paleocene to Eocene rocks is exposed where the Paleocene-Eocene boundary lies within dark-gray shales of the Patala Formation (an outer shelf facies ranging in age from P6-P8b zones of Blow,1979), overlain by limestone and shale sequences of the Nammal Formation (an outer to middle shelf facies ranging in age from P8b-P9 zones). The Nammal Formation is exactly equivalent of Ghazij Formation (which range in age from P8 to P9 Zone according to Blow, 1979) which in turn is also overlain by massive gypsum deposits. This striking comparison in terms of sediments, their age relationship and their environment of deposition indicates a great similarities in the paleogeographic set up on the western margin of the Indian Plate and formation of isolated restricted basins at the terminal E. Eocene time.

The shallowing upward sequence and the restricted marine conditions at both localities, as discussed above and additionally, thick evaporite deposit in Kohat (Jatta gypsum equivalent to Sakesar and Chorgali formations in Potwar depression) and an unconformity between Laki and Kirthar in parts of Sind (Kadri 1995, P. 113) close to the end of Early Eocene (P9) Zone are indicative of a widespread regression traceable throughout the Indus Basin. This in turn, is in accordance with the global sea level curve of Haq et al. (1988), showing a remarkable drop of sea level at the top of his TA2 super cycle.

CONCLUSIONS

Based on the analysis of 61 samples from the Late Cretaceous to Early Eocene marine sediments of the Rakhi Nala section (Sulaiman Range, Pakistan), biostratigraphical and paleoenvironmental data of foraminiferal investigations are presented. Due to large sampling intervals, not all previous results, as published in the large number of references, could be confirmed. Nevertheless, an attempt was made to provide a comprehensive comparison of present results with existing data in the light of present status of knowledge. Many lithostratigraphical and biostratigraphical problems, which were known before or hidden, are addressed in this study. It has been tried to give a satisfactory explanation where it was possible. The present results are a synthesis of all informations available including new data.

Lithostratigraphical and biostratigraphical informations about the well known Rakhi Nala section have been published since the beginning of this century. Contradictions regarding the different lithological units and their boundaries were found to be the main reason for creating great confusion. The lithological units and their boundaries mentioned here are homogenized according to Shah (1977).

The previously existing biostratigraphical data and planktonic foraminiferal zonations as derived from planktonic foraminiferal species are evaluated. Planktonic foraminiferal zones given by different authors are reinterpreted and correlated according to the modern definition of planktonic foraminiferal zones after Berggren & Miller (1988).

The Late Cretaceous *"Orbitoides* Limestones and Shales" of Eames (1952a), which was divided in two parts, the Mughal Kot Formation and the Fort Munro Formation Shah (1977), were dated as a whole as Campanian (Marks, 1962), as Campanian to Maastrichtian (Nagappa, 1959; Kothe, 1988), or as Maastrichtian (Bayliss, 1961; Weiss, 1993). The age of both formations was accepted as Campanian to Maastrichtian (Shah, 1977). The present study shows that the upper part of the "*Orbitoides* Limestones and Shales" of Eames (1952a), which is equivalent to the Fort Munro Formation, is clearly Middle Maastrichtian in age. Two planktonic foraminiferal zones, the *Globotruncana aegyptiaca* and *Gansserina gansseri* Zones of Caron (1985) have been recognized. For the underlying Mughal Kot Formation, it looks reasonable to consider its age as Late Campanian to early Maastrichtian.

The age of the Early Tertiary "Lower Rakhi Gaj Shale" of Eames (1952a), which is equivalent to the Dunghan Formation Shah (1977), was also questionable, whether the unit is restricted to the Paleocene (Nagappa, 1959; Bayliss, 1969; Latif, 1961 and Kothe, 1988) or extended to the Eocene (Samanta, 1973; Weiss, 1993). The results of this study are in agreement with the results of Samanta (1971) and Weiss (1993) that the age of the Dunghan Formation has to be extended to the Early Eocene. The age of the Paleocene part of the formation could not be confirmed. The presence of the *Morozovella formosa* Zone of Toumarkine & Luterbacher (1985), which is equivalent to the P 7 Zone of Berggren & Miller (1988), is confirmed just below the Irregularis Limestone Bed (base of Ghazij).

The age of the Early Tertiary unit between the base of the "Irregularis Bed" and the base of the "Platy Limestone" of Eames (1952a), which is equivalent to the Ghazij Formation Shah (1977), is in accordance with previous results. Two planktonic foraminiferal zones, *Morozovella aragonensis* Zone (its upper part) and *Acarinina pentacamerata* Zone of Toumarkine & Luterbacher (1985), which are equivalent to the P 9 Zone of Berggren & Miller (1988), have been identified in the lower half of the Ghazij Formation. The lower part of the *Morozovella aragonensis* Zone (=P 8 of Berggren & Miller, 1988), which could not identified, is expected at the base of the Ghazij Formation.

The upper half of the Early Eocene Ghazij Formation is barren of planktonic foraminifers but based on common occurrence of larger foraminifers, was dated as Early Eocene. According to the co-occurrences of larger foraminiferal species, an *Assilina granulosa - Nummulites crasseornata - Nummulites hoogenradi - Dictyoconoides cooki* Assemblage is established and correlated with the P 9 Zone of Berggren & Miller (1988).

The foraminiferal fauna of the Middle Maastrichtian Fort Munro Formation indicates an open marine outer shelf paleoenvironment. The overlying Pab Sandstone Formation is considered as shallow marine.

The Late Paleocene-Early Eocene Dunghan Formation indicates an open marine outer shelf paleoenvironment. The lower half of the overlying Ghazij Formation indicates deposition in an open marine, outer shelf paleoenvironment whereas its upper half reflects progressively shallowing paleoenvironments from shallow outer shelf to inner shelf. The top of the Early Eocene Ghazij Formation indicates completely restricted marine paleoenvironments.

A time gap or a highly condensed section comprising the *Morozovella edgari* Zone and the lower part of the *M. subbotinae* Zone (P 6b Zone) with in the zonation proposed by Latif (1961) and Samanta (1973) or comprising the *M. edgari* Zone and the base of the *M. formosa* Zone (P6b to P7 Zone) by Weiss (1993) is expected within the Dunghan Formation based on species occurrences. This gap can be attributed to twenty five feet interval (not studied before). It is recommended to investigate this interval in detail.

The Paleocene-Eocene boundary lies near the top of the Dunghan Formation. The situation found in the Rakhi Nala area (Sulaiman Range, Lower Indus Basin) is similar to that found in the Khairabad section (western Salt Range, Upper Indus Basin) where this boundary lies within the dark-gray shales of the Patala Formation. The overlying Early Eocene Ghazij and Nammal Formations respectively range in age from P8 to P9 Zones at both localities having more or less similar paleoenvironments. Both formations are overlain by gypsum deposits which reflect that at these localities Late Paleocene to Early Eocene sedimentation may have been carried out more or less in the same water depth range on the western margin of the Indian Plate and formation of several isolated restricted basins at the termination of E. Eocene time which in turn is in accordance with the global sea level lowering as shown by Haq (1988) at the top of his TA 2 super cycle.

ACKNOWLEDGEMENTS

The author is grateful to Hilal Raza Director General HDIP for providing an opportunity to work in Federal Institute of Geosciences and Natural Resources, to Dr. Asrar M. Khan (Office Incharge of Biostratigraphic Laboratory of the HDIP) and Dr. Jurgan (Project Leader of the BGR in Pakistan) for suggesting this study and for the necessary arrangements.

I especially thank my counterpart Dr. Weiss (BGR) for stimulating discussions and helpful comments on many topics during my stay in Hannover. Thanks are also due to Dr. Fenner (Head of the Paleontological Section of the BGR) for managing and solving different problems. Special appreciation is given to Dr. von Daniels (NLfB) for helpful discussions and providing a large volume of literature. Thanks are also to Dr. Kothe and Dr. Cepek (BGR) for their help.

I thank Mrs. Stager (BGR) taking the photomicrographs using the scanning electron microscope (SEM), and Mrs. Engel (BGR) making the drawings.

This study was financially supported by the Carl-Duisberg-Gesellschaft (CDG).

REFERENCES

Afzal ,J. and von Daniels, C.H., 1991, Foraminiferal biostratigraphy and paleoenvironment interpretation of the paleocene to Eocene Patala and Nammal Formations from Khairabad-East, Western Salt Range, Pakistan: Pak. Jour. Hyd. Res, Islamabad., v.3, n.2, p.61-79.

Bannert, D., in cooperation with Amjed Cheema, Abrar Ahmed and U. Schaffer., 1992, The Structural Development of Western Fold Belt, Pakistan: Geol. Jb., Hannover, B 80, p. 3-60.

Bayliss, B.B., 1961, An investigation of certain larger fossil foraminifera from Pakistan: Ph. D. Thesis, Geol. Dept., Univ. Wales, Cardiff (unpublished), 253p.

Berggren, W.A. and Miller, K.G., 1988, Paleogene tropical planktonic foraminiferal biostratigraphy and magnetobiochronology: Micropaleontology, v.34, n.4, p.326-380.

Blow, W.H., 1969, Late Middle Eocene to Recent planktonic foraminiferal biostratigraphy: Proc. 1. Internat. Confer. Planktonic Microfossils, Geneva, v.1, p.199-422.

Blow, W.H., 1979, The Cenozoic Globigerinida, Leiden (Brill)., 3 v, 1413p.

Bolli, H.M., 1957, The Genera Globigerina and Globorotalia in the Paleocene: Lower Eocene Lizard Spring Formation of Trinidad, B.W.I, Bull U.S. Nat. Muz., 215: p.61-81.

Bolli, H.M., 1966, Zonation of Cretaceous to Pliocene marine sediments based on planktonic foraminifera: Bol. Inform. Assoc. Venez. Geol., Min. and Petrol., v.9, p.3-32.

Bolli, H.M. & Cita, M.B., 1964, Upper Cretaceous and Lower Tertiary planktonic foraminifera from the Paderno d'Adda Section, Northern Italy: 21 Intl. Geol. Congr. Copenhagen, v.5, p.150-161.

Bolli, H.M., Beckmann, J.P. & Saunders, J.B., 1994, Benthic foraminiferal biostratigraphy of the south Caribbean region, Cambridge (Cambridge University Press).

Caron, M., 1985, Cretaceous planktonic foraminifera, *in* Bolli, H.M., Saunders, J.B. and Perch-Nielsen, K eds., Plankton Stratigraphy, Cambridge, v.1, p.17-86.

Cushman, J.A. & Ponton, G.M., 1932, Foraminifera of the Upper, Middle and part of the Lower Miocene of Florida: Bull. Florida State. Geol. Surv., v.9, p.1-147.

Davies, L.M. and Pinfold, E.S., 1937, The Eocene beds of the Punjab Salt Range: Mem. Geol. surv. India, Paleontologica Indica, N.S., Calcutta., v.24, n.1, p.1-79.

Dorreen, J.M., 1974, The Western Gaj river section, Pakistan, and the Cretaceous Tertiary boundary: Micropaleontology, v.20, p.178-193.

Eames, F.E., 1952a, A contribution to the study of the Eocene in western Pakistan and western India. A. The geology of the standard section in the Western Punjab and the Kohat District: Quart. Jour. Geol. Soc. London., v.107, p.150-171.

Eames, F.E., 1952b, A contribution to the Eocene in western Pakistan and western India. D. Discussion of the fauna of certain standard sections, and their bearing on the classification and correlation of the Eocene in western Pakistan and western India: Quart. Jour. Geol. Surv. London., v.107, p.173-200.

Grimsdale, T.F. and Morkhoven, F.P.C.M. van., 1955, The ratio between pelagic and benthonic foraminifera as a means of estimating depth of deposition of sedimentary rocks: Proc. 4th World Petrol. Congr., Rome, sect. v. 1, p.73-491.

Haq, B.U., Hardonbol, J. and Vail, P.R., 1988, Mesozoic and Cenozoic chronostratigraphy and eustatic cycles, *in* Wilgus, C.K. et al, eds., Sea Level Changes, An Integrated Approach, SEPM, spec. publ. Tusla., v.42, p.71-108.

Haque, A.F.M.M., 1956, The smaller Foraminifera of the Ranikot and the Lakhi of the Nammal Gorge, Salt Range: Mem. Geol. Surv. Pakistan, Palaeontologica Pakistanica, v.1, p.1-300.

Hart, M.B., 1980, A water depth model for the evolution of the planktonic Foraminiferida: Nature, v.286, p.252-254.

Haynes, J.R., 1985, Foraminifera, London (Macmillan), 433p.

Hornibrook, N. de B., 1958, New Zealand Upper Cretaceous and Tertiary foraminiferal zones and some other correlations: Micropaleontology, v.4, p. 25-38.

Hottinger, L., 1960, Recherches sur less Alveolines du Paleocene et de l'Eocene: Schweiz. palantol. Abh. Basel., 75/76: 18 pls., 117 figs., 243p.

Hunting Survey Corporation., 1961, Reconnaissance geology of part of West Pakistan (Colombo Plan Cooperative project): Toronto, 555 p.

Jadoon, I. A. K, R. D. Lawreence and R. J. Lillie, 1992, Balanced and retrodeformed geological cross-section from the frontal Sulaiman lobe, Pakistan: duplex development in thick strata along the western margin of the Indian plate: *in* K McClay, eds., thrust Tectonic s: Chapman & Hall, p. 343-356.

Jenkins, D.G. and Murray, J.W., 1989, Stratigraphic Atlas of Fossil Foraminifera, Sec. ede., Chichester (Ellis Horwood), p.593.

Kadri, I.B., 1955, Petroleum Geology of Pakistan,(Ferozsons) Lahore, Pakistan, 275p.

Kothe, A., 1988, in cooperation with A.M. Khan and M. Ashraf, Biostratigraphy of the Surghar Range, Sulaiman Range and Kohat area, Pakistan, according to Jurassic through paleogene calcareous nannofossils and dinoflagellates: Geol. Jb., Hannover, B 71, p.3-87.

Latif, M.A., 1961, The use of pelagic Foraminifera in the subdivision of the Paleocene-Eocene of the Rakhi Nala, West Pakistan: Geol. Bull. Panjab Univ. Lahore., v.1, p.31-46.

Latif, M.A., 1963, Some related groups of pelagic foraminifera in the Paleocene-Eocene of the Rakhi Nala, West Pakistan: Geol. Bull. Panjab Univ, Lahore., v.3, p.19-24.

Loeblisch, A.R., Jr. and Tappan, H., 1987, Biostratigraphia del limite Cretaceo-Terziario nell' Appennino Centrale: Riv. Ital. Paleontol. Stratigt., v.70, n.1, p.67-128.

Luterbacher ,H & Premoli-Silva, I, 1964, Biostratigraphy del limite Cretaceo-Tertiaro nell' Appennnion.-Riv Ital. Paleontolog. Stratigr., 70(1): 67-128: Milano.

Marks, P., 1962, Variation and evolution in Orbitoides from the Cretaceous of the Rakhi Nala, West Pakistan: Geol. Bull. Panjab Univ, Lahore., v.2, p.15-24.

Martini, E., 1971, Standard Tertiary and Quaternary calcareous nannoplankton zonation, *in* Farinacci, A.,eds, Proc. 2nd. Planktonic Conf. Roma, v.2, p.739-785.

McGowran B., 1968, Late Cretaceous and Early Tertiary correlation in the Indo-pacific region: Mem. Geol. Soc. India, Bangalore, v.2, p.335-360.

Murray, J.W., 1991, Ecology and palaeoecology of Benthic Foraminifera, England (Longman), 397p.

Nagappa, Y., 1959, Foraminiferal biostratigraphy of the Cretaceous-Eocene succession in the India-Pakistan-Burma region: Micropaleontology, v.5, n.2, p.145-192.

Neumann, M., 1990, Le genre *Orbitoides*: analyze de donnees statistiques por la differenciation des especes: Cah. Micropal., Paris, N.S., n.5, p.5-54.

Nomura, R. and Brohi, I.A., 1995, Benthic foraminiferal fauna during the time of Indian-Asian contact, in southern Balochistan, Pakistan: Mar. Micropal., v.24, n.3/4, p.205-214.

Papp, A., 1955, Orbitoides aus der Oberkreide der Ostalpen (Gosauschichten): Sitzber. Osterr. Akad. Wiss., Math, Naturw. Kl., Wien, v.1, n.164, p.303-315.

Papp, A., 1956, Orbitoiden aus dem Oberkreideflysch des Wienerwaldes: Verhandl. Geol. Bundesanst., n.2, p. 133-143.

Porth, H. and Hilal A. Raza., 1990, On the geology and hydrocarbon prospects of Sulaiman province, Indus Basin, Pakistan: BGR/HDIP Report, Hannover, 127 p.

Premoli-Silva, I. and Bolli, H. M., 1973, Late Cretaceous to Eocene planktonic foraminifera and stratigraphy of Leg 15 sites in the Caribbean Sea: Initial Repts. DSDP, Washington, v.15, p.499-547.

Robaszynski, F., Caron, M., Gonzalez, J.M. and Wonders, A., 1984, Atlas of Late Cretaceous Globotruncanids: Rev. Micropaleont, Paris, v. 26, n.3-4, p.145-305.

Robaszynski, F., Bless, J.M., Felder, P.J., Foucher, J.C., Legoux, O., Manivit, H., Meesen, J.P.M.T. and van der Tuuk, L.A., 1985, The Campanian-Maastrichtian boundary in the chalky facies close to the type-Maastrichtian area: Bull Center Rech. pau, v.9, n.1, p.1-113.

Samanta, B.K., 1973, Planktonic foraminifera from the Palaeocene-Eocene succession in the Rakhi Nala, Sulaiman Range, pakistan: Bull. Brit. Mus. (Nat. Hist.), London, v.22, n.6, p.421-482.

Schaub, H., 1981, Nummulites et Assilines de la Tethys paleogene. Taxinomiew, phylogenese et biostratigraphie: Schweiz. Palaontol. Basel., Abh., 104, 236 p.105 (Atlas 1): pls. 1-48; 106 (Atlas 2): pls. 49-97; Basel.

Shah, S.M.J., 1977, Stratigraphy of Pakistan, Mem. Geol. Surv. Pakistan, Islamabad, v.12, p.1-138.

Sissingh, W., 1977, Biostratigraphy of Cretaceous calcareous nannoplankton: Geol. Mijnbouw, v.56, n.1, p.37-65.

Sliter, W.V. and Baker, R.A., 1972, Cretaceous bathymetric distribution of benthic foraminifera: Jour. Foram. Res. v.2, n.4, p.167-183.

Smout, A.H., 1954, Lower Tertiary foraminifera from the Qatar peninsula: London, 96p.

Stainforth, R.M., Lamb, J.L., Luterbacher, H., Beard, J.H. and Jeffords, R.M., 1975, Cenozoic planktonic foraminiferal zonation and characteristics of index forms; Paleontol. Contrib. Univ. Kansas, Lawrence/Kansas, v. 62, 425p.

Toumarkine, M. and Luterbacher, H., 1985, Paleocene and Eocene planktonic foraminifera, *in* Bolli, H.M., Saunders, J.B. and Perch-Nielson, K., eds, Plankton Stratigraphy, v.1, p.87-154.

Van Gorsel, J.T., 1987, Late Cretaceous Orbitoidal foraminifera, *in* Hedley, R.H. & Adams, C.G, eds, : Foraminifera, London v.3, p.1-120.

Vredenburg, W., 1908, The Cretaceous Orbitoides from India: Rec. Geol. Surv. India, v.36, p.171-213.

Weiss, W., 1988, Larger and planktonic foraminiferal biostratigraphy of the Cretaceous and the paleogene in the Salt Range, the Kohat area and the Sulaiman range, Pakistan: BGR Report, Hannover (unpub.) v.57, p. .

Weiss, W., 1993, Age assignments of larger foraminiferal assemblages of Maastrichtian to Eocene age in northern Pakistan: Zitteliana, Munchen, (HAGN/HERM-Festshrift), v.20, p.223-252.

Williams, M.D., 1959, Stratigraphy of the Lower Indus Basin, West Pakistan: Proc. 5th World Petrol. congr. New York, n.1, 19, p.377-390.

Appendix:
List of taxa identified in this study

Late Cretaceous;
Planktonic foraminifers

Archaeoglobigerina cretacea (D'ORBIGNY), 1840
Globigerinelloides ultramicra (SUBBOTINA), 1949

Globotruncana arca (CUSHMAN), 1926

Globotruncana bulloides VOGLER, 1941

Globotruncana linneiana (D'ORBIGNY), 1839

Globotruncana insignis GANDOLFI, 1955

Globotruncana mariei BANNER & BLOW, 1960

Globotruncana rosetta (CARSEY), 1926

Globotruncana ventricosa WHITE, 1928

Globotruncana stuartiformis (DALBIEZ), 1955

Hedbergella holmdelensis OLSSON, 1964

Heterohelix globulosa (EHRENBERG), 1840

Pseudoguembelina costulata (CUSHMAN), 1938

Pseudotextularia elegans (RZEHAK), 1891

Rosita fornicata (PLUMMER), 1931

Rosita patelliformis (GANOLFI), 1955

Larger foraminifers

Rotila trochidiformis (LAMARCK), 1804

Orbitoides tissoti SCHLUMBERGER, 1902

Benthic foraminifers

Bolivina arkadelphiana midwayensis CUSHMAN & PARKER, 1936

Coryphostoma incrassata (REUSS), 1851

Globorotalites michelinianus (D'ORBIGNY), 1804

Gyroidinoides primitiva HOFKER, 1957

Verneuilinoides muensteri REUSS, 1854

Lenticulina macrodiscus

Gavelinella monterelensis MARIE, 1941

Early Tertiary:

planktonic foraminifers

Acarinina aspensis (COLOM), 1954

Acarinina broedermanni (CUSHMAN & BERMUDEZ), 1949

Acarinina camerata (KHALILOV), 1949

Acarinina hagni (GOHRBRANDT), 1967

Acarinina pentacamerata ()SUBBOTINA), 1947

Acarinina pseudotopilensis (SUBBOTINA), 1953

Acarinina spinuloinflata (BANDY), 1949

Acarinina wilcoxensis wilcoxensis (CUSHMAN &

PONTON), 1932

Acarinina wilcoxensis strabocella (LOWBLICH & TAPPAN), 1957

Morozovella aequa dolabrata JENKINS, 1965

Morozovella acuta (TOULMIN), 1941

Morozovella aragonensis (NUTTALL), 1930

Morozovella formosa gracilis (BOLLI), 1957

Morozovella formosa formosa (BOLLI), 1957

Muricoglobigerina soldadoensis soldadoensis (BRONNIMANN), 1952

Planorotalites elongata (GLAESSNER), 1937

Planorotalites pseudoscitula (GLAESSNER), *1939*

Pseudohastigerina wilcoxensis (CUSHMAN & PONTON), *1932*

Subbotina frontosa (SUBBOTINA), *1953*

Subbotina linaperta (SUBBOTINA), 1953

Subbotina triangularis (WHITE), 1928

Turborotalia griffinae BLOW, 1979

Larger foraminifers

Assilina granulosa (D'ARCHIAC), 1847

Assilina spinosa DAVIS, 1937

Dictyoconoides cooki (CARTER), 1861

Lockhartia conditi (NUTTALL), 1926

Lockhartia hunti OVEY, 1947

Lockhartia hunti var. pustulosa SMOUTH, 1954

Nummulites atacicus LEYMERIE, 1846

Nummulites crasseornata (HENRICI), 1934

Nummulites globulus LEYMERIE, 1846

Nummulites hoogenraadi (DOORNINK), 1932

Operculina jiwani DAVIS, 1937

Smaller Benthic foraminifers

Anomalinoides acuta PLUMMER, 1927

Asterigerian cuniformis HAQUE, 1956

Asterigerina texana HAQUE, 1956

Bulimina alsatica CUSHMAN & PARKER, 1937

Bulimina macilenta CUSHMAN & POTON, 1936

Cibicides alleni var. carinatus HAQUE, 1956

Cibicides lobatulus (WALKER & JACOB), 1798

Cibicides lobatulus var. patalaensis HAQUE, 1956

Cibicides mensilla SCHWAGER, 1883

Clavulina parisiensis D'ORBIGNY, 1826

Cycloloculina glabra WOOD & HAQUE, 1956

Eponides subumbonatus REUSS,

Gaudryina carinata FRANKE, 1914

Gaudryina laevigata FRANKE, 1914

Gaudryina pyramidata var. nitida HAQUE, 1956

Gaudryina dayi WHITE, 1928

Gaudryina midwayensis trochoidea PLUMMER, 1926

Nonionella boueanum (D'ORBIGNY), 1846

Pullenia quinqueloba REUSS, 1851

Textularia mississippiensis CUSHMAN, 1922

Triloculina sarahae HAQUE, 1956

Uvigerna hoosti RANKNI

Virgulina cylindrica CUSHMAN & BERMUDEZ, 1937

Virgulina dubia HAQUE, 1956

PLATE 1

Cretaceous Planktonic Foraminifers from the Rakhi Nala section (Sulaiman Range, Pakistan) (Scale bar = 100um)

Figure 1 *Globotruncana arca* (CUSHMAN) sample RN 55, Fort Munro Formation

Figure 2 *Globotruncana arca* (CUSHMAN) sample RN 50, Fort Munro Formation

Figure 3 *Rosita fornicata* (PLUMMER)
sample RN 53, Fort Munro Formation

Figure 4 *Rosita fornicata* (PLUMMER)
sample RN 48, Fort Munro Formation

Figure 5 *Globotruncanita stuartiformis* (DALBIEZ)
sample RN 48, Fort Munro Formation

Figure 6 *Globotruncanita stuartiformis* (DALBIEZ)
sample RN 52, Fort Munro Formation

Figure 7 *Rosita patelliformis* (GANDOLFI)
sample RN 11, Mughal Kot Formation

Figure 8 *Rosita patelliformis* (GANDOLFI)
sample RN 48, Mughal Kot Formation

Figure 9 *Globotruncana ventricosa* WHITE
sample RN 11, Mughal Kot Formation

Figure 10 *Globotruncana ventricosa* WHITE
sample RN 54, Fort Munro Formation

Figure 11 *Hedbergella holmdelensis* OLSSON
sample RN 48, Mughal Kot Formation

Figure 12 *Globigerinelloides ultramicra* SOBBOTINA
sample RN 48, Mughal Kot Formation

Figure 13 *Archaeoglobigernia cretaces* (D'ORBIGNY)
sample RN 12, Fort Munro Formation

Figure 14 *Pseudoguembelina costulata* (CUSHMAN)
sample RN 48, Mughal Kot Formation

Figure 15 *Pseudotextularia elegans* (RZEHAK)
sample RN 48, Mughal Kot Formation

Figure 16 *Heterohelix globulosa* (EHRENBERG)
sample RN 55, Mughal Kot Formation

PLATE 2

Tertiany planktonic foraminifers
from the Rakhi Nala section
(Sulaiman Range, Pakistan)
(Scale bar = 100um)

Figures 1-2 *Planorotalites palmerae* (CUSCHMAN & BERMUDEZ)-*P. pseudocitula* (GLAESSNAR) 1989
sample RN 20, Ghazij Formation

Figure 3 *Subbotian frontosa* (SUBBOTINA)
sample RN 42, Ghazij Formation

Figure 4-5 *Turborotalia griffinae* BLOW
sample RN 42, Ghazij Formation

Figure 6-7 *Acarinina aspensis* (COLOM)
sample RN 40, Ghazij Formation

Figure 8-9 *Acarinina spinuloinflata* (BANDY)
sample RN 43, Ghazij Formation

Figure 10-11 *Acarinina pentacamerata* (SUBBOTINA)
sample RN 40, Ghazij Formation

Figure 12 *Morozovella aff. formosa formosa* (BOLLI)
sample RN 40, Ghazij Formation
(Note the poor preservation)

PLATE 3

Cretaceous and Tertiary benthic
foraminifers from the Rakhi Nala section
(Sulaiman Range, Pakistan)
(Scale bar = 100 microns)

Figure 1-2 *Gyroidian aff. primitiva* HOFKER
sample RN 11, Mughal Kot Formation

Figure 3 *Globorotalites michelinianus* (D' ORBIGNY)
sample RN 11, Mughal Kot Formation

Figure 4 *Gavelinella aff. globosa* (BROTZEN)
sample RN 48, Mughal Kot Formation

Figure 5 *?Valvulineria* sp.
sample RN 48, Fort Munro Formation

Figure 6 *Lenticulina* aff. *macrodiscus*
sample RN 11, Mughal Kot Formation

Figure 7 *Nonionella* cf. *boueanum* (D'ORBIGNY)
sample RN 41, Fort Munro Formation

Figure 8 *Textularia* sp.
sample RN 61, Fort Munro Formation

Figure 9 *Vaginulinopsis* sp.
sample RN 53, Fort Munro Formation

Figure 10 *?Textularia* sp.
sample RN 59, Fort Munro Formation

Figure 11 *Coryphostoma incrassata* (REUSS)
sample RN 12, Mughal Kot Formation

Figure 12 *Nodosaria* sp. 1
sample RN 12, Mughal Kot Formation

Figure 13 *Bolivina* sp.
sample RN 48, Fort Munro Formation

Figure 14 *Virgulina dubia* HAQUE
sample RN 40, Ghazij Formation

Figure 15-16 *Uvigerina* sp.
sample RN 40, Ghazij Formation

Figure17 *Bulimina arkadelphiana midwayensis* CUSHMAN & PARKER
sample RN 48, Mughal Kot Formation

Figure 18-19 *Gaudryina* aff. *carinata* FRANKE
sample RN 45, Ghazij Formation

Figure 20 *Gaudryina nitida* HAQUE
sample RN 46, Ghazij Formation

Figure 21-22 *Clavulina parisiensis* (D'ORBIGNY)
sample RN 46, Ghazij Formation

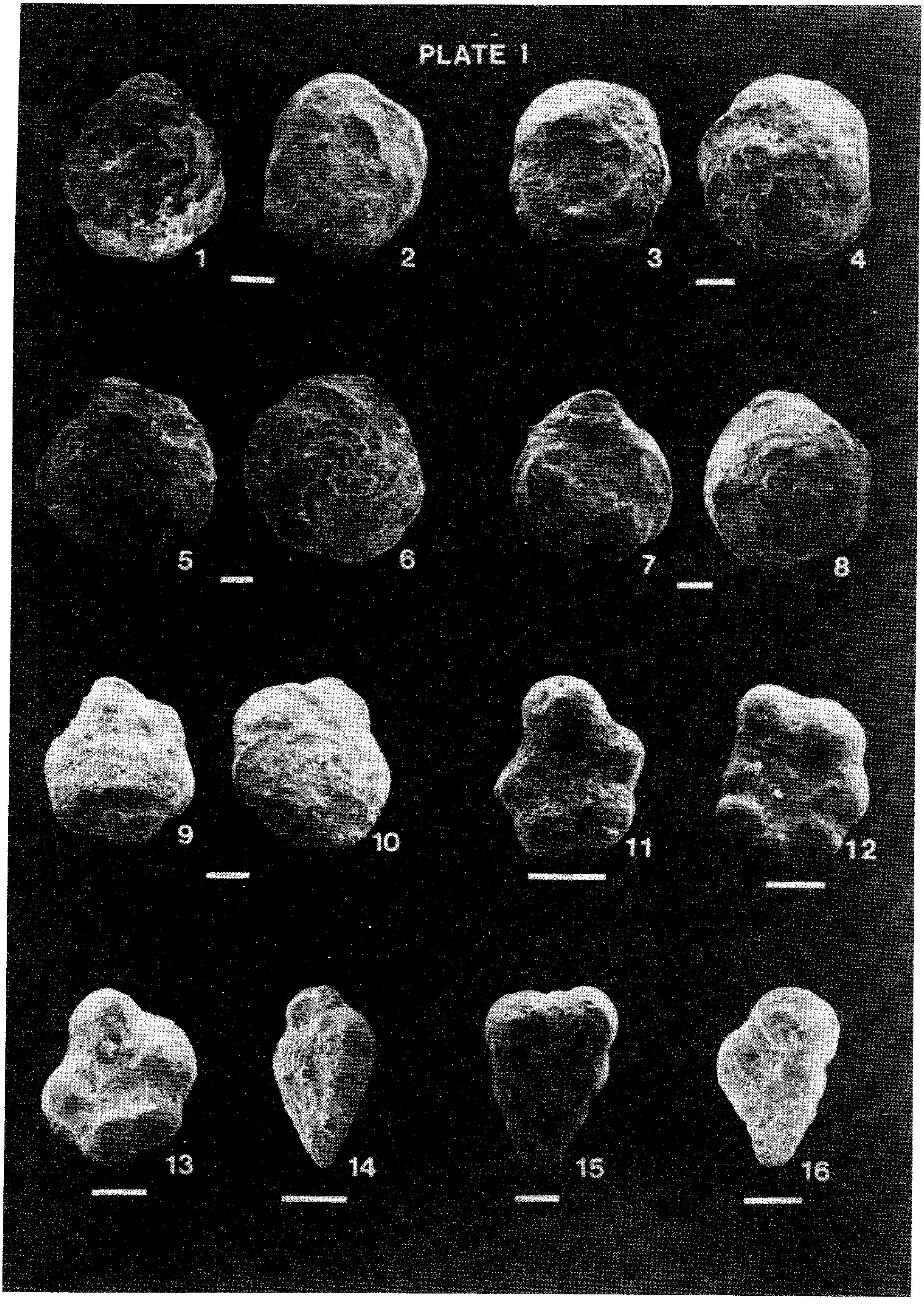


PLATE 1
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

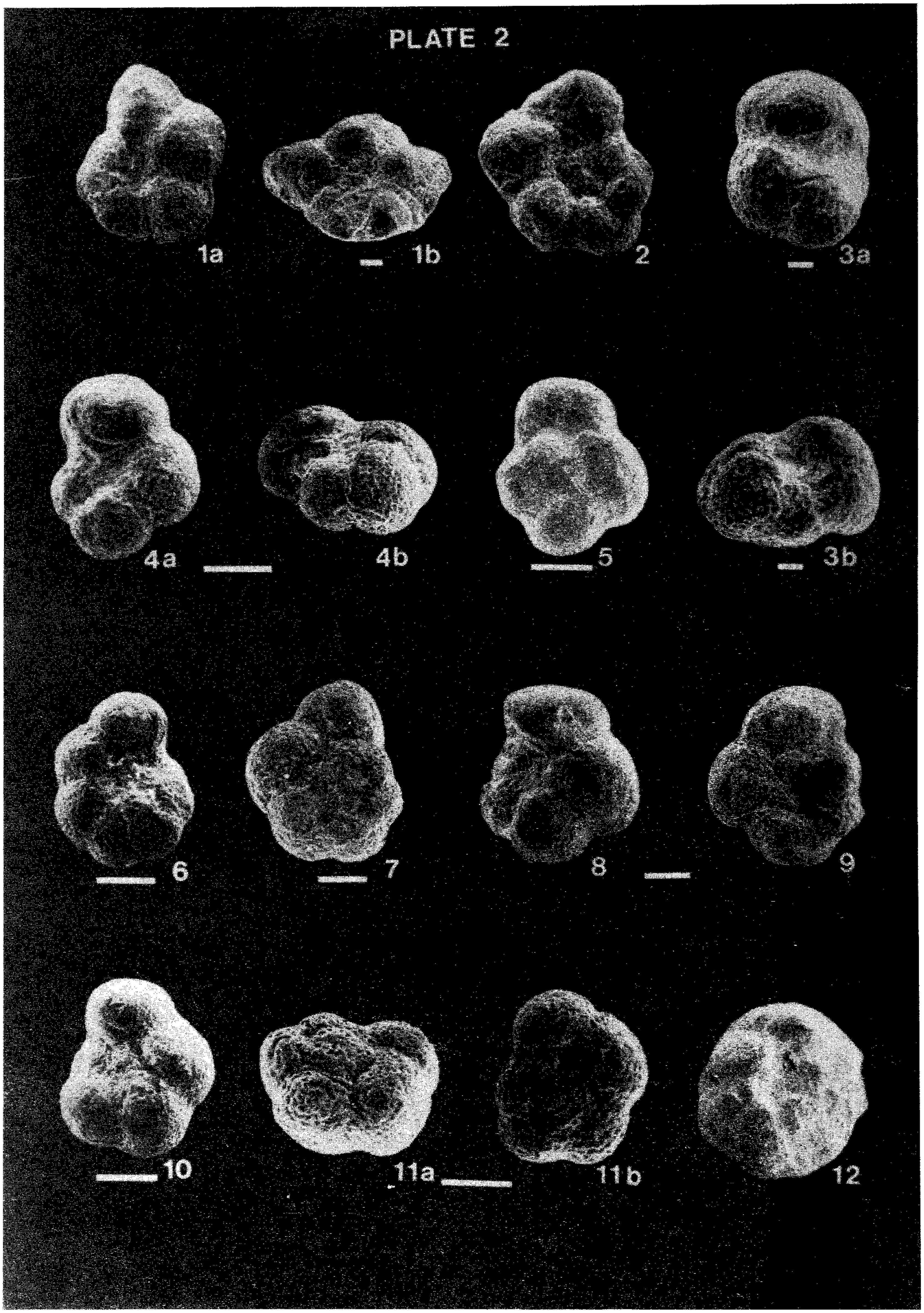


PLATE 2
1a
1b
2
3a
4a
4b
5
3b
6
7
8
9
10
11a
11b
12

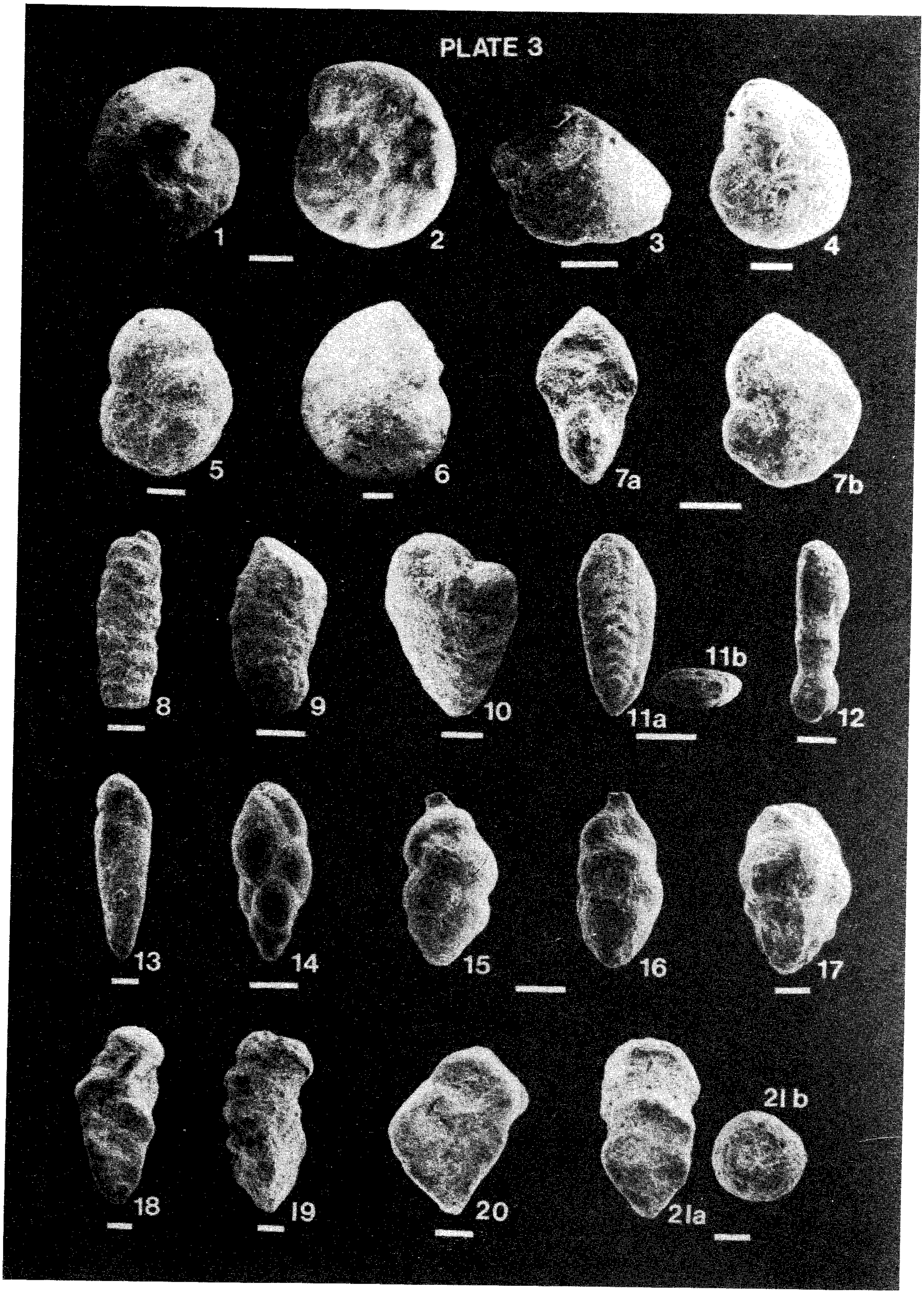


PLATE 3
1
2
3
4
5
6
7a
7b
8
9
10
11b
11a
12
13
14
15
16
17
18
19
20
21 b
21a