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Age Assignments of Larger Foraminiferal Assemblages of Maastrichtian to Eocene Age in Northern Pakistan

By

WOLFGANG WEISS*)

With 12 Text-figures and 9 Plates

ABSTRACT

Geological, microfaunal and biostratigraphical records were obtained from selected sections of the Upper Indus Basin of northern Pakistan (the western Salt Range, the Kohat area, the Sulaiman Range).

Eight assemblages of larger foraminifers were identified within the Late Cretaceous and Early Paleogene formations. They were dated as exactly as possible by means of Tethyan planktonic foraminifers. Several refinements of previous age assessments were obtained. The larger foraminifers which were identified are important for establishing a firm age of the shallow marine formations. They support the knowledge of the paleobiogeography of the larger foraminifers within the eastern Tethys realm.

ZUSAMMENFASSUNG

Es werden geologische, mikrofaunistische und biostratigraphische Ergebnisse dargestellt, die aus Untersuchungen an Referenzprofilen des oberen Indus-Becken im nördlichen Pakistan (der westlichen Salt Range, der Kohat-Region und der Sulaiman Range) gewonnen wurden.

Acht Großforaminiferen-Gesellschaften aus der jüngsten Oberkreide und dem Paläogen wurden festgestellt. Sie wurden mit Hilfe der tethyalen Standardgliederung nach planktonischen Foraminiferen so genau wie möglich datiert. Dadurch können frühere Altersangaben verfeinert werden. Die Kenntnis der verschiedenen Großforaminiferen-Gesellschaften hat wesentliche Bedeutung für die Biostratigraphie der flachmarinen Sedimente der Region. Die Beobachtungen bekräftigen die Kenntnisse zur paläobiogeographischen Verbreitung der Großforaminiferen der östlichen Tethys.

1. INTRODUCTION

The author participated in several reconnaissance field parties in the Upper Indus Basin of northern Pakistan in 1985 and 1986. The biostratigraphy and paleoenvironment of late Mesozoic and Paleogene formations of the Upper Indus Basin, in particular that of the Salt Range, the Kohat area and the Sulaiman Range, were studied on the basis of microfossils, with preference on planktonic and larger foraminifers (WEISS 1988).

The main objectives of the microfaunal and foraminiferal studies were (1) to compare Cretaceous and Paleogene reference sections in several areas of northern Pakistan (the western Salt Range, the Kohat area and the Sulaiman Range), (2) to ascertain the biostratigraphic ages of the Mesozoic and Cenozoic formations and express these ages preferably in terms of modern standard planktonic foraminiferal zonation, and (3) to describe the widely distributed assemblages of larger foraminifers of the different Upper Indus formations and to integrate these assemblages as exactly as possible into the standard Cretaceous and Cenozoic planktonic foraminiferal zones.

*) Dr. WOLFGANG WEISS, Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Stilleweg 2, D-30655 Hannover

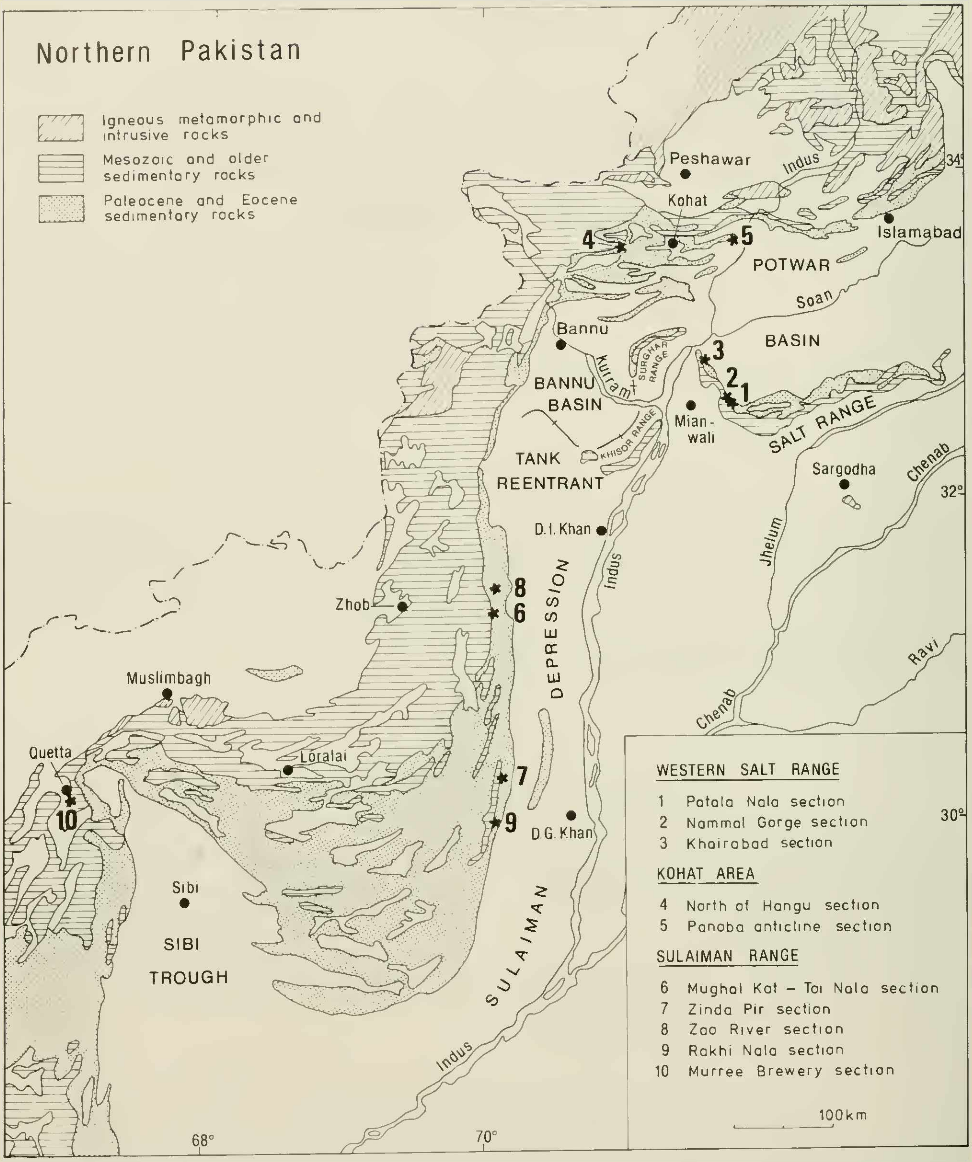

Fig. 1: Location map of investigated sections of the Upper Indus Basin (after EAMES 1952, Geological Map of Pakistan 1:2 000 000 1964, SHAH 1977 and PORTH & KAMRAN in PORTH & HILAL A. RAZA 1988).

The distribution of the larger foraminifers of the Upper Cretaceous and Paleogene presented in this paper is based on regional standard sections (Fig. 1) which were more or less continuously sampled. Samples would be taken preferably at the base and the top of the formations and at several horizons within the formations which were found to reflect typical lithologies or were found remarkable either through changing lithology or through different faunal contents as seen from visual inspections.

The studied intervals are from the following sections and areas:

- the western Salt Range:

(1) the Paleogene interval of the Patala Nala section;
(2) the Paleogene interval of the Nammal Gorge section;
(3) the Paleogene interval of the Khairabad section;

- the Kohat area:
  - (4) the Createaceous to Paleogene interval of the section North of Hangu;
  - (5) the Paleogene interval of the Panoba Anticline section;
- the Sulaiman Range:
  - (6) the Jurassic to Paleogene interval of the Mughal Kot-Toi Nala section;
  - (7) the Paleogene interval of the Zinda Pir section;
  - (8) the Eocene interval of the Zao River section;
  - (9) the Cretaceous to Paleogene interval of the Rakhi Nala section;
  - (10) the Cretaceous to Paleogene interval of the Murrey Brewery Gorge section.

About 158 microfaunas from washed residues of shales and marls and about 100 thin sections from limestone samples are reported here. Stratigraphic assignments and formation determinations of the studied intervals of the sections were done mainly according to the literature (SHAH 1977, PORTH & HILAL A. RAZA 1990a, b) and field observations. Composition of microfaunas and in particular the distribution of planktonic and larger foraminifers which were investigated in detail are given in Figs. 2-11.

Cretaceous and Paleogene foraminiferal taxonomy and zones are adopted mainly from BOLLI (1957, 1966), BLOW (1969, 1979), POSTUMA (1971), STAINFORTH et al. (1975), ROBASZYNSKI & CARON (1979), ROBASZYNSKI et al. (1984), CARON (1985), and TOUMARKINE & LUTERBACHER (1985) for the planktonic foraminifers, and from DAVIES & PINFOLD (1937), SMOUTH (1954), NAGAPPA (1959), HOTTINGER (1960), ADAMS (1970), KURESHI (1975, 1978) and SCHAUB (1981) for the larger foraminifers.

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2. GEOLOGICAL SETTING

The Indus Basin of Pakistan is subdivided in two basins, the Upper Indus Basin and the Lower Indus Basin, each consisting of several subbasins, ranges, plateaus, provinces (SHAH 1977, PORTH & HILAL A. RAZA 1990a, b). The various structural elements which are arranged in a garland-like pattern along the Indo-Pakistan-Eurasian plate convergence in Pakistan belong to different tectonic units, the Hazara Block and the Sulaiman Block, of the Indo-Pakistan Plate which is separated by the Makran-Khojak-Pishin Flysch Belt from the Afghanistan and Turan Blocks of the Eurasian Plate (BANNERT 1992: fig. 1).

The locations of the studied sections of the Upper Indus Basin (the western Salt Range, the Kohat area, the Sulaiman Range) which belong to the Hazara Block and the Sulaiman Block of the Indo-Pakistan Plate are shown in Fig. 1.

Mesozoic and Paleogene sediments of the eastern fold belts of the Upper Indus Basin (as well as of the Lower Indus Basin) are deposited on a broad shelf area of the passive continental margin of the Indo-Pakistan Plate (BANNERT 1992). The fold belts originated since the Paleocene as a result of the main collision of the Indo-Pakistan Plate with the Eurasian Plate (BANNERT 1992: 7).

The formations of the Salt Range comprise successions of stable-platform, marine sediments of Late Precambrian and Cambrian, Permian, Triassic, Jurassic, Cretaceous (questionable), Paleogene age, followed by Early Miocene to Pleistocene molasse sediments (GEE 1980, 1989).

In the northwestern Kohat area (the Kohat Salt Region) the surface formations are equally of shallow marine platform type and are of Tertiary to Quaternary age. Late Cretaceous sediments with poor ammonite and foraminiferal biostratigraphy (LATIF 1970, FATMI 1973, SHAH 1977) are exposed occasionally in the cores of the anticlines.

In the Sulaiman Range shallow marine shelf sediments have been documented for the Permian to the Late Eocene (SHAH 1977). Paleogene shallow marine sediments of the Sulaiman Range show some differences in both facies and biostratigraphy from those of the western Salt Range and the Kohat area, reflected by lithology or microfauna.

3. RESULTS

3.1 REFINEMENTS OF THE REGIONAL STRATIGRAPHY

The succession and microfaunal biostratigraphy of the Mesozoic and Cenozoic formations of the Upper Indus Basin of northern Pakistan has been summarized by a number of authors which gave a large amount of informations (e. g. NUTTALL 1925, 1926, DAVIES 1926, 1927, DAVIES & PINFOLD 1937, EAMES 1952, GILL 1952, 1953, HAQUE 1956, SMOUT & HAQUE 1956, NAGAPPA 1959, HUNTING SURVEY CORPORATION 1961, MARKS 1962, LATIF 1963, 1964, ADAMS 1970, FATMI 1973, KURESHY 1966, 1969, 1971, 1972, 1974, 1975, 1976, 1977, 1978, SHAH 1977, PORTH & HILAL A. RAZA 1990a, b). New biostratigraphic results are available from studies on calcareous nannofossils and dinoflagellates by KOTHE (1987, 1988), of benthic and planktonic foraminifers by BUTT (1987, 1991), NASEER A. SHAFIQUE & VON DANIELS (1990) and JAMIL AFZAL & VON DANIELS (1991).

The revised nomenclature for the stratigraphic units of the Cretaceous and Paleogene in northern Pakistan, set up by the Stratigraphic Committee of Pakistan (FATMI 1973, SHAH 1977), is followed here with minor modifications.

Biostratigraphic age assignments of the different Upper Cretaceous and Paleogene formations and related lithostratigraphic units on the basis of foraminiferal data from the author's studies are shown in Figs. 2-11.

The following results should be mentioned:

1) According to planktonic foraminifers, the beginning of the pelagic Goru Formation in the Mughal Kot-Toi Nala section and the Murree Brewery Gorge section of the Sulaiman Range (Figs. 7-8) was dated as late Early Cretaceous and equivalent to the planktonic foraminiferal *Rotalipora ticinensis* and *Rotalipora appenninica* Zones of Late Albian. According to planktonic foraminifers described by GIGON (1962) and

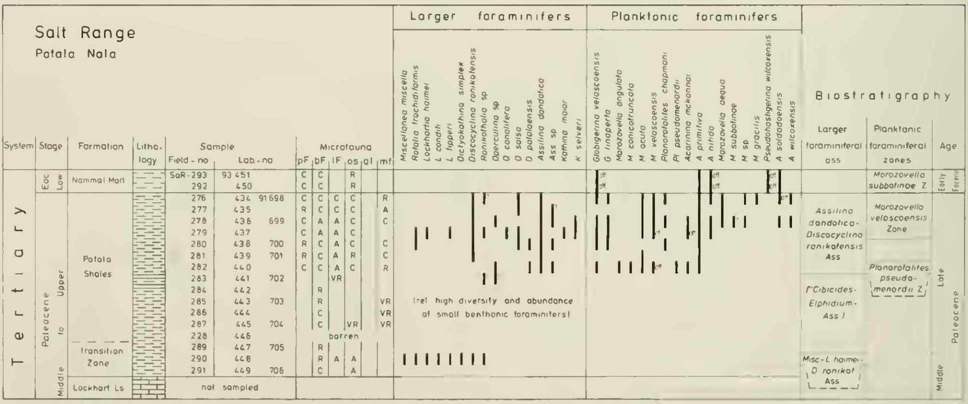


Fig. 2: Distribution of larger and planktonic foraminifers of the Patala Nala section, western Salt Range.

Abbreviations used in Figs. 2-12.

Microfauna:
- rad = radiolarians
- pF2 = planktonic foraminifers
- bF = benthic foraminifers
- lF = larger foraminifers
- os = ostracods
- al = algae
- mf = mesofauna

Planktonic foraminiferal genera: A. = *Acarinina*, Ab. = *Abathomphalus*, „G." = *Globigerina*, G. = *Globotruncana*, Gt. = *Globigerinatheka*, H. = *Hantkenina*, M. = *Morozovella*, O. = *Orbulinoides*, Pl. = *Planorotalites*, T. = *Turborotalia*, Tr. = *Truncorotaloides*.

Larger foraminiferal genera: Ass. = *Assilina*, D. = *Discocyclina*, Dictyoc. = *Dictyoconoides*, Dictyok. = *Dictyokathina*, Fl. = *Flosculina*, L. = *Lockhartia*, Misc. = *Miscellanea*, N. = *Nummulites*, Omphaloc. = *Omphalocyclus*, Orb. = *Orbitoides*, Rot. = *Rotalia*, Sid. = *Siderolites*.

Cretaceous planktonic foraminiferal zones according to CARON (1985), Paleogene planktonic foraminiferal zones according to TOUMARKINE & LUTERBACHER (1985).

Lithological symbols used in Figs. 2-11

- = conglomerate
- = sandstone, partly calcareous
- = claystone, shale, partly sandy or calcareous
- = limestone
- = marl
- = gypsum

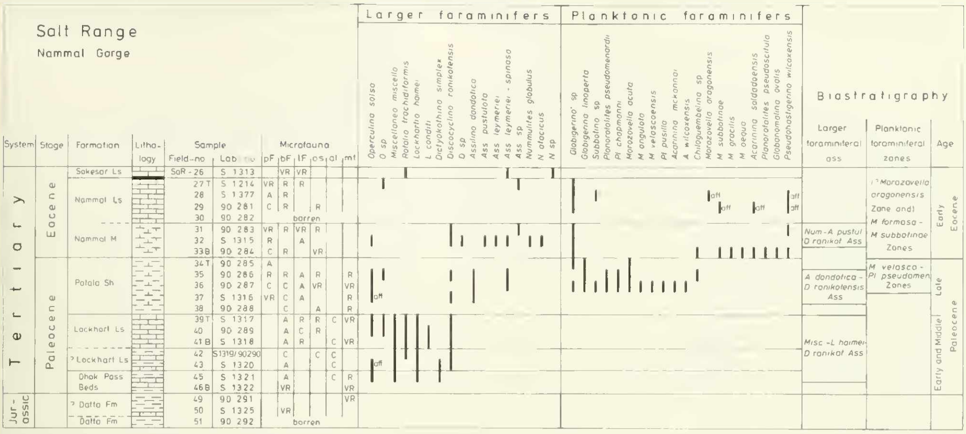


Fig. 3: Distribution of larger and planktonic forаminiinfers of the Nammal Gorge section, western Salt Range. Abbreviations see Fig. 2.

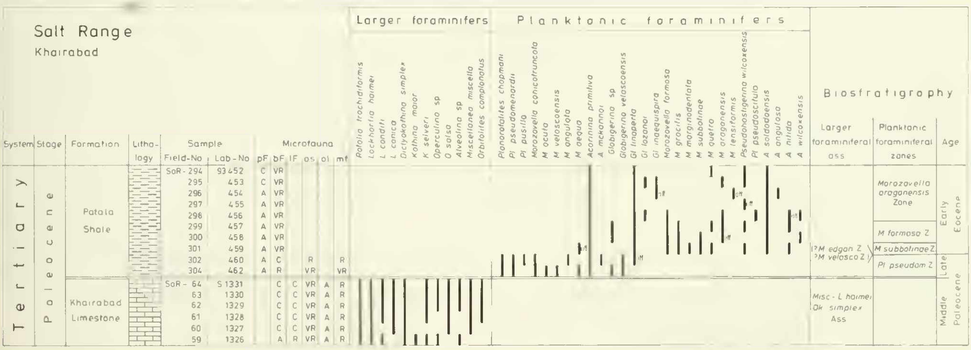


Fig. 4: Distribution of larger and planktonic foraminifers of the Khairabad section, western Salt Range. Abbreviations see Fig. 2.

Fritz & Khan (1967), the upper limit of the Goru Formation could be assigned within an interval between the Early-Middle Cenomanian *Rotalipora reicheli* Zone to Early/Middle Campanian *Globotruncana ventricosa* Zone of planktonic foraminifers.

There are no supporting data by the author's studies based on planktonic foraminifers proving the correlation of the Goru Formation (Late Albian to Late Turonian-Early Coniacian) of the Sulaiman Range with the generally unfossiliferous Lumshival Sandstone Formation of the western Kohat area (Shah 1977: 54) which was assigned to be of Aptian-Early Albian(!) age. The Lumshival Sandstone Formation underlies the Late Cretaceous Darsamand Limestone of the Kawagarh Formation (Porth & Hilal A. Raza 1990a: fig. 4; Porth & Hilal A: Raza 1990b: fig. 2) (see below).

2) There is a remarkable facies and paleoenvironment change between the Parh Formation which is lithologically similar to the underlying Goru Formation (Hunting Survey Corporation (1961) and Kureshi (1978) included these strata in the Parh Group!) and the overlying Mughal Kot Formation, as seen in the Mughal Kot-Toi Nala section (Fig. 7; compare also Eames 1952, Williams 1959, Shah 1977). The change of facies was dated, according to planktonic foraminifers, as close to Late Turonian to Early Coniacian times (see below).

The Parh Formation consists of pelagic, light-grey limestone and marlstone sequences (about 300 m thick) and is similar to that of the Goru Formation (about 120 m thick), whereas the Mughal Kot Formation (about 1150 m thick; thicknesses according to Shah 1977 and Porth 1990b) comprises conglomerates, thick shale and marlstone sequences. Several sequences are showing slumping and gliding, as repeatedly observed during field parties in the Mughal Kot-Toi Nala and the Rakhi Nala sections. The facies change from pelagic ocean floor sediments to flyschoid foredeep sediments is indicated by microfossils by the complete lack of autochthonous foraminifers within lower parts of the Mughal Kot Formation. No foraminiferal data were obtained from this formation except for scarce reworked and fragmented foraminiferal tests. Most of the samples are completely barren of foraminifers (compare Fig. 7).

From the Parh Formation one sample (SmR-131) taken 5 m below the top of the formation yielded planktonic foraminifers with *Marginotruncana pseudolinneiana* Pessagno and *Heterohelix* specimens close to *Heterohelix moremanni* (Cushman)

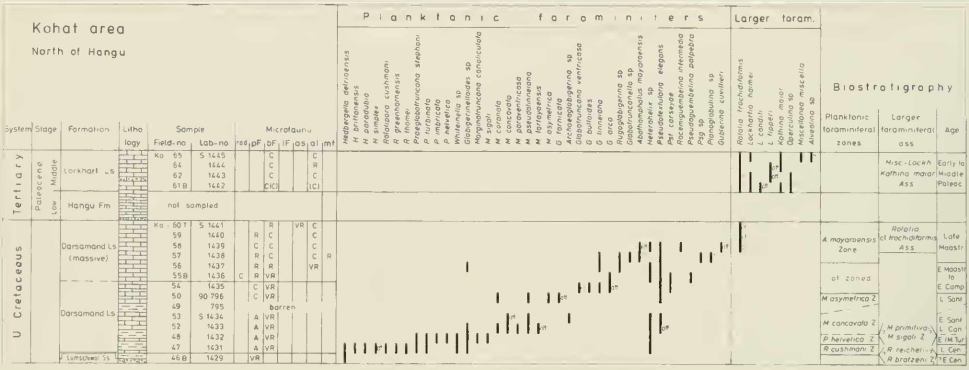


Fig. 5: Distribution of larger and planktonic foraminifers of the North of Hangu section, Kohat area. Abbreviations see Fig. 2.

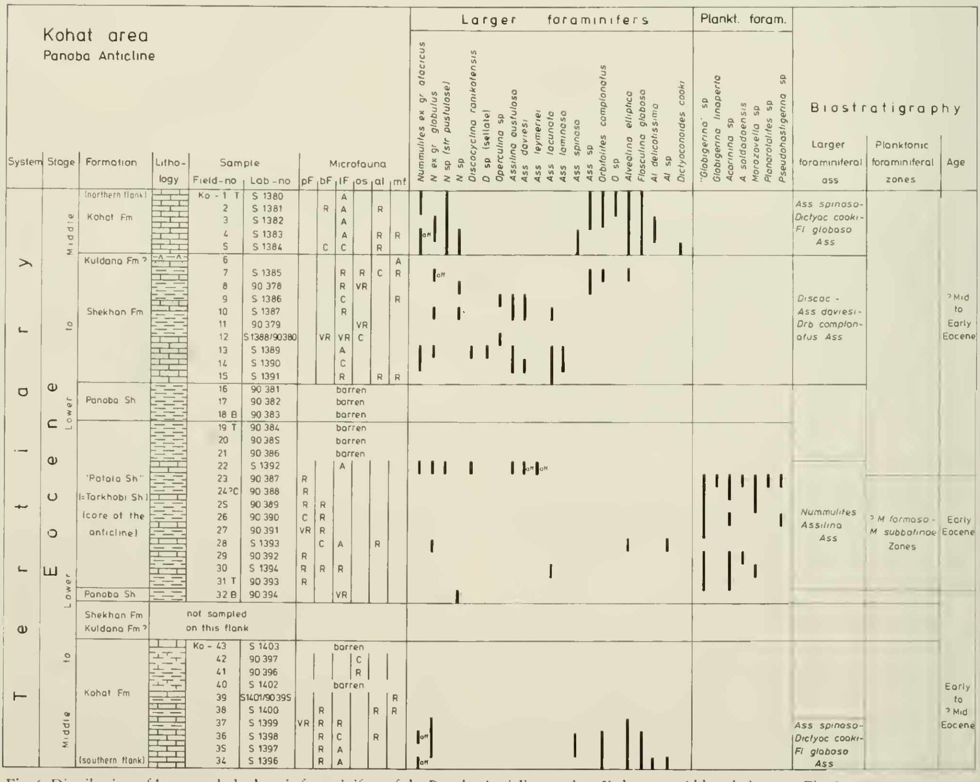


Fig. 6: Distribution of larger and planktonic foraminifers of the Panoba Anticline section, Kohat area. Abbreviations see Fig. 2.

and *Heterohelix reussi* (CUSHMAN). Another sample (SmR-132) from about 30 m below the top has shown poor planktonic foraminifers from which specimens of the high-spired *Praeglobotruncana turbinata* (REICHEL) were identified. The last occurrence of high-spired praeglobotruncanids is within the Middle Turonian, whereas the range of *Marginotruncana pseudolinneiana* PESSAGNO is from Middle Turonian to Early Coniacian according to ROBASZYNSKI & CARON (1979). Therefore, the top of the Parh Formation of the Mughal Kot-Toi Nala section of the Sulaiman Range was dated as belonging to the planktonic foraminiferal *Marginotruncana sigali* to *Marginotruncana primitiva* Zones (Fig. 7) which are of Late Turonian to Early Coniacian according to CARON (1985: fig. 3).

3) In the Murree Brewery Gorge section of the Sulaiman Range (Fig. 11), the limestones of the pelagic Goru and Parh

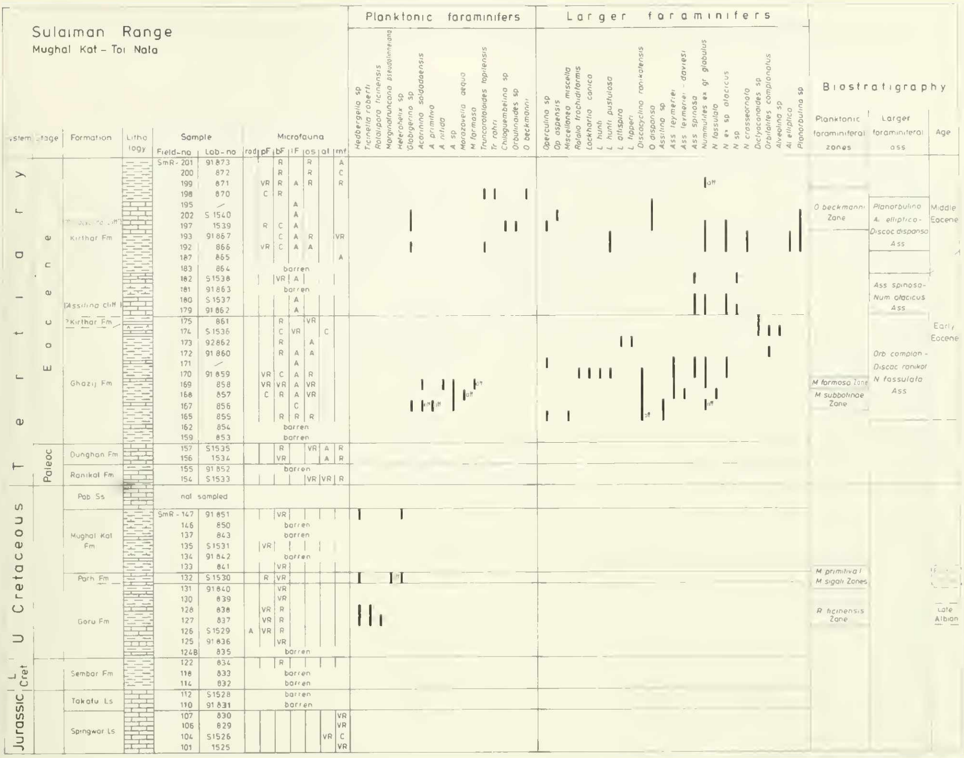


Fig. 7: Distribution of larger and planktonic foraminifers of the Mughal Kot-Toi Nala section, Sulaiman Range. Abbreviations see Fig. 2.

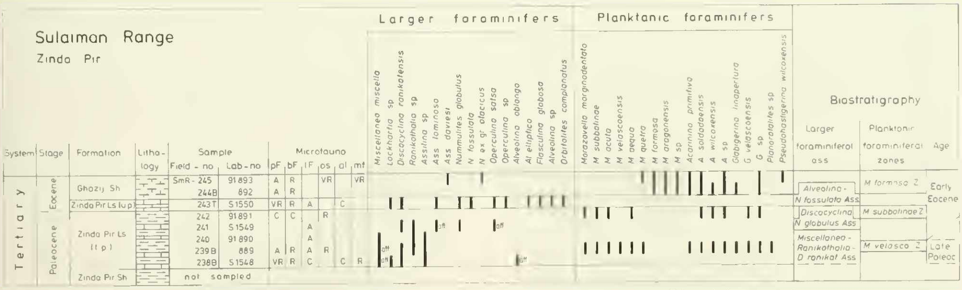


Fig. 8: Distribution of larger and planktonic foraminifers of the Zinda Pir section, Sulaiman Range. Abbreviations see Fig. 2.

Formations show low sedimentation rates (the limestones are altogether about 120 m thick) and contain well-preserved and abundant planktonic foraminifers, such as globotruncanids, hedbergellids and heterohelicids. Planktonic foraminiferal zones from the Late Albian *Rotalipora appenninica* Zone to the Late Santonian *Marginotruncana asymetrica* Zone have been identified (Fig. 11). They confirm former age determinations by ALLEMANN (1979). The transition from the Goru Formation to the Parh Formation is either within the interval of the *Marginotruncana sigali* and the *Marginotruncana primitiva* Zones or within the interval of the *Marginotruncana primitiva* and *Marginotruncana concavata* Zones. The age assignment is Early to Late Coniacian according to CARON (1985: fig. 3). The transition is characterized by the disappearance of high trochospiral praeglobotruncanids, i. e. *Praeglobotruncana turbinata* (REICHEL), and by the appearance of early globotruncanids, i. e. *Globotruncana fornicata* PLUMMER.

All limestones from the Murree Brewery Gorge section contain highly diverse and abundant planktonic foraminifers with many keeled species, the sequence must have originated in a tropical oceanic facies. The pelagic part of the Upper Cretaceous sequence of the Murree Brewery Gorge section represents „the floor of Neo-Tethyan ocean between the northern margin of the Indo-Pakistan Plate and the southern

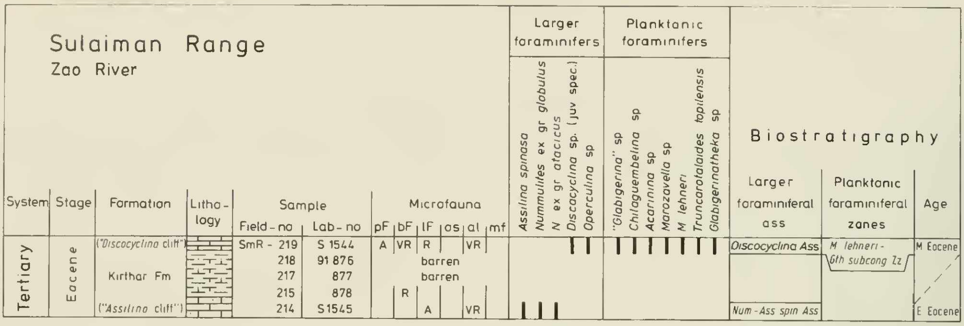


Fig. 9: Distribution of larger and planktonic foraminifers of the Zao River section, Sulaiman Range. Abbreviations see Fig. 2.

Eurasian margin" (BANNERT 1992: 7). The top of the Parh Formation is of Late Santonian age in this section, as dated by the *Marginotruncana asymetrica* Zone of planktonic foraminifers.

4) The onset of drastic shallowing of the Late Cretaceous ocean is indicated in the Upper Indus Basin of northern Pakistan by the *Orbitoides* Limestone sequence which overlies the flyschoid „Bedded Clays" in the well-known Rakhi Nala section of the Sulaiman Range (Fig. 10). Former age determinations with larger foraminifers, i. e. *Orbitoides* species, as near the base of the Maastrichtian (MARKS 1962) are confirmed by the co-occurrence of *Orbitoides media* (D'ARCHIAC) and *Omphalocyclus macroporus* (LAMARCK) which indicates an Early Maastrichtian according to VAN GORSEL (1978).

A second phase of shallowing, indicated within the Sulaiman Range by the Pab Sandstone sequence of the Mughal Kot-Toi Nala section and the Rakhi Nala section (Figs. 7, 10) and by the shallow water Upper Cretaceous part of the Brewery Limestone sequence of the Murree Brewery Gorge section (Fig. 11), was dated - following ALLEMANN (1979) - now as Late Maastrichtian on the basis of assemblages of larger foraminifers, such as *Siderolites calcitrapoides* LAMARCK and *Orbitoides media* (D'ARCHIAC) (older part of Late Maastrichtian) and *Siderolites calcitrapoides* LAMARCK and *Rotalia* cf. *trochidiformis* (LAMARCK) (younger part of Late Maastrichtian).

Parts of the massive sequence at the top of the Darsamand Limestone of the section North of Hangu in the Kohat area (Fig. 5) which are characterized by similar morphotypes of *Rotalia* cf. *trochidiformis* (LAMARCK) as found in the Murree Brewery Gorge section (Fig. 11) are within the planktonic foraminiferal *Abathomphalus mayaroensis* Zone of the Late Maastrichtian. This corroborates Late Maastrichtian determinations of the Pab Sandstone sequence (SHAH 1977: 50) and of the Upper Cretaceous part of the Brewery Limestone sequence (ALLEMANN 1979) which might be equivalents of this facies type at the top of the Darsamand Limestone.

5) From the Darsamand Limestone Formation of the section North of Hangu, Kohat area (Fig. 5), Late Cretaceous planktonic foraminiferal zones reported already by LATIF (1970) are now extended, ranging from the Early Cenomanian *Rotalipora brotzeni* Zone through the Late Maastrichtian *Abathomphalus mayaroensis* Zone. Despite not proved in detail, probably due to inadaequate sample intervals, all planktonic foraminiferal zones of the Late Cretaceous might be present in this sequence. Hiatuses were not observed.

6) In the Cenozoic shallow water sections of the western Salt Range, i. e. the Nammal Gorge and the Patala Nala sections (Figs. 2-3), and probably in the Kohat area too (Figs. 5-6), there is a ternate subdivision of the Paleocene sediments based on differences in lithology and microfaunas (SHAH 1977): (a) the Dhak Pass Beds or Hangu Formation of Early Paleocene, (b) the Khairabad Limestone or Lockhart Limestone Formation of Early to Late or Middle Paleocene, and (c) the Patala Shales of Late Paleocene.

The ternate subdivision of the Paleocene was not clearly identified in the Sulaiman Range sections (Figs. 7, 10).

The Patala Shales of the type region (the Patala Nala) and the Nammal Gorge of the Sulaiman Range are characterized by abundant macrofossils and microfossils (molluscs, smaller and larger benthic foraminifers, planktonic foraminifers, ostracods, and others; Figs. 2-3) (HAQUE 1956, SHAH 1977). According to the charcteristic biofacies which was found to be autochthonous, the Patala Shales (s. s. = sensu stricto) of the Salt Range are restricted to stable shallow water environments, i. e. to inner parts of the Sublittoral (environment assignments are according to BOLTOVSKOY & WRIGHT 1976). The conspicuous macrofossil and benthic foraminiferal assemblages of typical Patala Shales, as expressed in the pioneer publications of DAVIES & PINFOLD (1937) and HAQUE (1956), is significantly different from those of lithological similar, but very dark-grey shale sequences which were sampled from tectonically unstable parts of the Salt Range, e. g. at the Khairabad section (Fig. 4) (see also JAMIL AFZAL & VON DANIELS 1990), or from the Panoba Anticline section of the Kohat area (Fig. 6). The Paleocene interval of the later sections is distinctly different in litho- and biofacies: the colour is very dark-grey to black, the interbedded limestones and marly claystones contain allochthonous larger foraminifers as well as few and very badly preserved smaller benthic and planktonic foraminifers which are different from the Patala Shales s. s. in species composition and age. These shale sequences might be deposited in an unfavourable, probably bathyal environment. As these shales - the former Tarkhobi Shales of EAMES (1952) - are of Early Eocene age and different in lithofacies and biofacies, the term „Patala Shales" (s. l. = sensu lato) should be given at least in quotation marks.

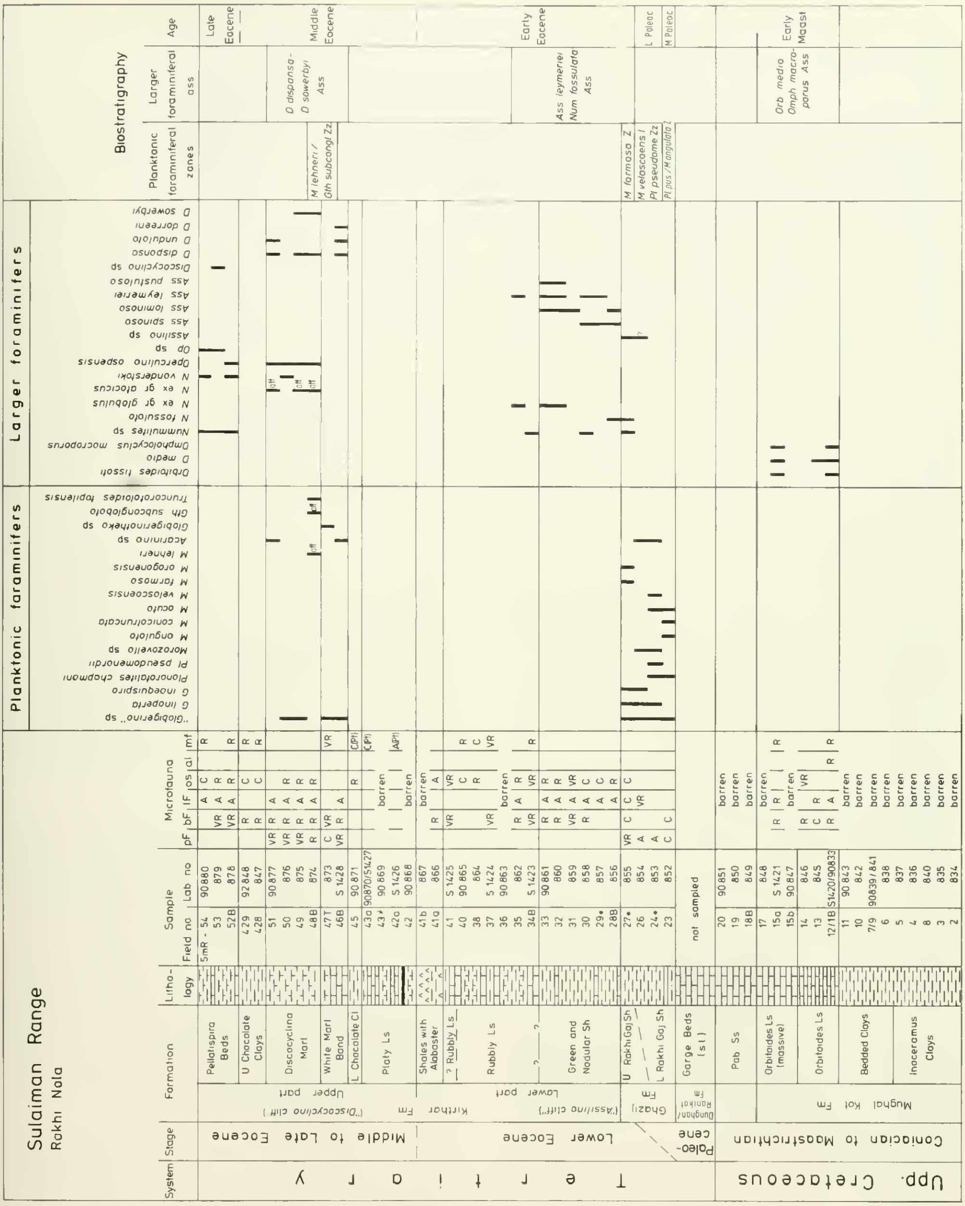


Fig. 10: Distribution of larger and planktonic foraminifers of the Rakhi Nala section, Sulaiman Range. (Under sample no. SmR-24*, SmR-27*, SmR-29* data from additional samples are included). Abbreviations see Fig. 2.

7) The Paleocene-Eocene boundary of the Patala Nala and the Nammal Gorge sections of the western Salt Range (Figs. 2-3) is characterized by a sedimentary change from brownish fossiliferous sandstones in the uppermost part of the Patala Shales to dark grey fossiliferous shales of the lowermost Nammal Marls (compare Haque 1956: pl. 1). The planktonic foraminiferal *Morozovella velascoensis* Zone of the Late Paleocene and the *Morozovella subbotinae* Zone of the Early Eocene were identified close to this facies change, whereas the *Morozovella edgari* Zone of the basal Early Eocene was not definitely identified, probably due to a short sedimentary break at the Paleocene-Eocene boundary or insufficient sampling

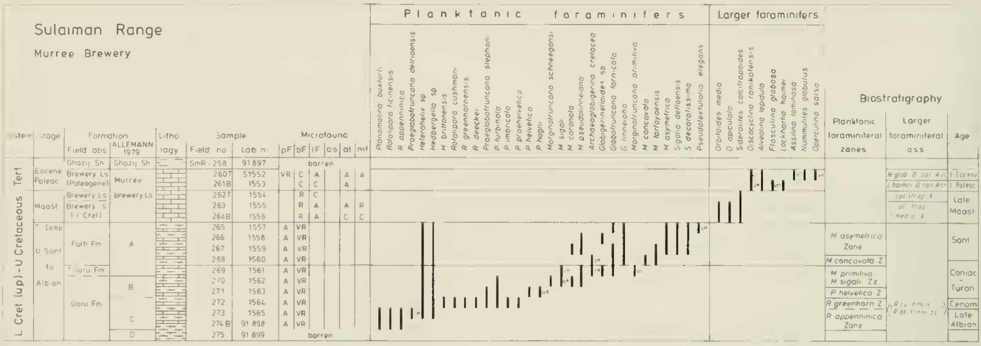


Fig. 11: Distribution of larger and planktonic foraminifers of the Murrey Brewery Gorge section, Sulaiman Range. Abbreviations see Fig. 2.

intervals. In the Mughal Kot-Toi Nala section and the Rakhi Nala section of the Sulaiman Range (Figs. 7, 10), the Paleocene-Eocene boundary expected within the Ghazij Shales and between the Lower and Upper Rakhi Gaj Shales (SHAH 1977: 70) was not definitely recognizable due to very bad preservation of morozovellids.

8) The Early Eocene part of the Brewery Limestone in the Murree Brewery Gorge section of the Sulaiman Range (Fig. 11) is characterized by a *Nummulites globulus-Operculina salsa* Assemblage of larger foraminifers. According to BLONDEAU (1972) and SCHAUB (1981), *Nummulites globulus* LEYMERIE is restricted to Early Eocene, whereas according to BAYLISS (1961: 97/98) *Nummulites globulus* LEYMERIE is present up to the Middle Eocene of the Kirthar Formation.

The Early Eocene part of the Brewery Limestone (Fig. 11) correlates (a) with the upper part of the Zinda Pir Limestone which shows a characteristic *Alveolina-Nummulites fossulata* Assemblage (Fig. 8), and (b) with parts of the Gazij Formation which are characterized by the *Orbitolites complanatus-Discocyclina ranikotensis-Nummulites fossulata* Assemblage (Fig. 7). These assemblages of larger foraminifers which were not found outside of the Sulaiman Range contain the first small, but definitive *Nummulites* specimens with *Nummulites globulus* LEYMERIE as the most common species and are assigned to be of Early Eocene (see above).

9) The Green Shales and the Nodular Shales of EAMES (1952) from the Rakhi Nala section of the Sulaiman Range (Fig.10) are characterized by an *Assilina leymeriei-Nummulites fossulata* Assemblage of larger foraminifers. *Nummulites fossulata* DE CIZANCOURT is known from Early Eocene according to this author and was found to be a larger foraminiferal index marker for the Early Eocene interval of the Rahki Nala section. Based on the characteristic larger foraminiferal assemblage, the Green and Nodular Shales could be correlated with basal parts of the Kirthar Formation of the Mughal Kot-Toi Nala section (Fig. 7) which contains an *Assilina spinosa-Nummulites atacicus* Assemblage as well as with the „*Assilina* cliff" of the Zao River section (Fig. 9). These assemblages of larger foraminifers are further characterized by specimens of *Discocyclina ranikotensis* DAVIES which disappears at the top of the assemblage (Fig. 12).

10) The Early-Middle Eocene boundary was expected at the base of Platy Limestone of the Rakhi Nala section (Fig. 10; and EAMES 1952) or between the less prominent Early Eocene „*Assilina* cliff" and the prominent Middle Eocene „*Discocyclina* cliff" of the Mughal Kot-Toi Nala and Zao River sections of the Sulaiman Range (Figs. 7, 9). The „*Discocyclina* cliff" which might be paleoenvironmentally a submarine barrier is named after characteristic field morphology and composition of limestones consisting of abundant, sometimes monospecific *Discocyclina* specimens (*Discocyclina dispansa* (SOWERBY), *Discocyclina sowerbyi* NUTTALL, and - less common - *Discocyclina undulata* NUTTALL and *Discocyclina dorreeni* BAYLISS). The *Discocyclina* specimens are associated often with *Alveolina elliptica* (SOWERBY) and *Planorbulina* sp. The „*Discocyclina* cliff" was dated with planktonic foraminifers and is within the interval from the *Globigerinatheka subconglobata* to the *Orbulinoides beckmanni* Zones according to TOUMARKINE & LUTERBACHER (1985: fig. 1).

3.2 ASSEMBLAGES OF LARGER FORAMINIFERS

Because of paleoenvironmental and paleobiogeographical limitations, there is no standard zonation accepted world-wide for the larger foraminifers of the Mesozoic and Cenozoic. There are several regional and interregional successions of Cretaceous and Tertiary larger foraminifers. The most relevant to the Indus Basin are the Late Cretaceous orbitoidal foraminiferal zonation (VAN GORSEL 1978), the Tertiary Letter Classification (ADAMS 1970), the Tertiary larger foraminiferal zones of Pakistan (KURESHY 1978) and the phylogeny of various lineages of Paleogene alveolinids and operculinids, nummulitids and assilinids, as described by HOTTINGER (1960, 1977), BUTT (1987, 1991), BLONDEAU (1972) and SCHAUB (1981). They include detailed microfaunal and stratigraphical informations of earlier workers (e. g. NUTTALL 1925, 1926; DAVIES 1937; DE CIZANCOURT 1938; GILL 1952, 1953; SMOUTH 1954; SMOUTH & HAQUE 1956; NAGAPPA 1959; MARKS 1962; SEN GUPTA 1963).

The larger foraminiferal associations which were identified during this study in the Upper Cretaceous and Paleogene sections of northern Pakistan are understood here as assemblages of paleoenvironmental significance (compare NICORA et al. 1986).

The Paleogene assemblages may be assigned to „Tertiary a1 (Late Paleocene)", the „Tertiary a2 (Early Eocene)" and

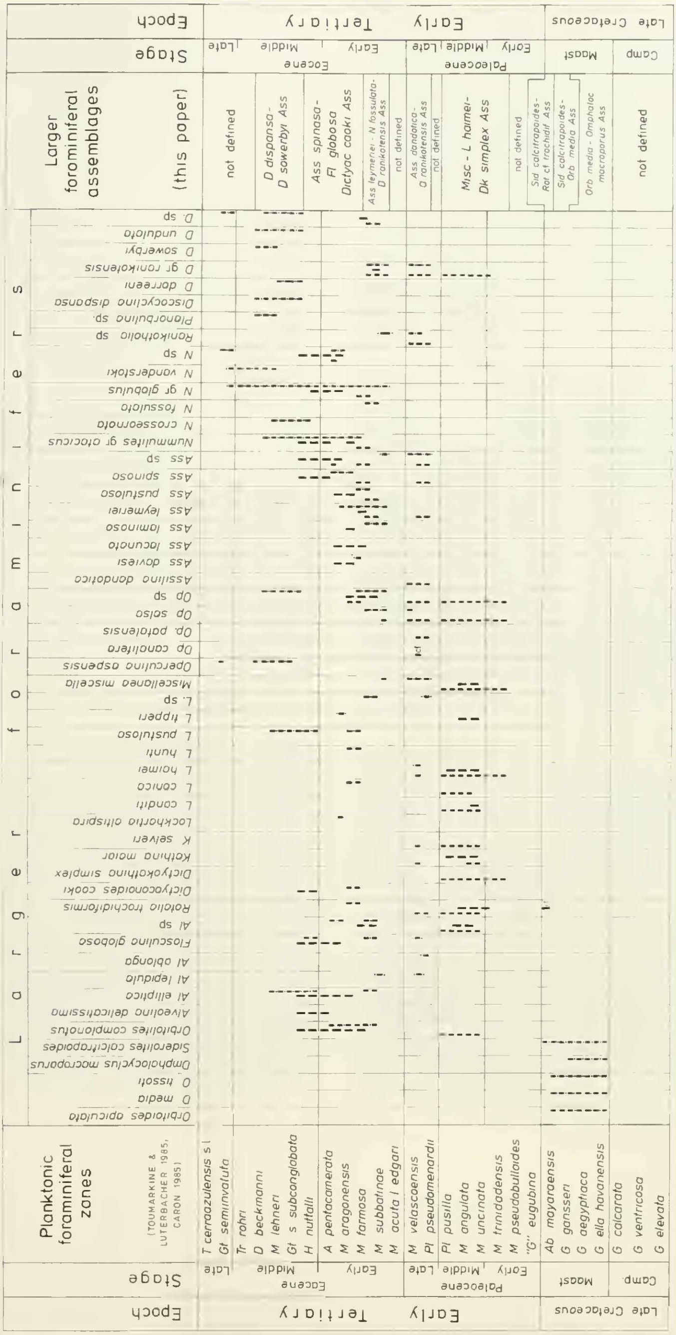


Fig. 12: Distribution of assemblages of larger foraminifers of latest Cretaceous and early Paleogene age in the Upper Indus Basin of Northern Pakistan.

Short-dashed line summarizes the author's data of the western Salt Range sections, long-dashed line summarizes the author's data from the sections of the Kohat area, dotted line summarizes the author's data of the Sulaiman Range sections. Abbreviations see Fig. 2.

„Tertiary a3 (Middle Eocene)" of the Letter Stage Classification (ADAMS 1970). Correlation to the „Lower Paleocene (Danian) *Daviesina langhami* Zone", the „Upper Paleocene (Landenian) *Nummulites nuttalli* Zone", the „Lower Eocene (Ypresian) *Assilina granulosa* Zone" and the „Middle Eocene (Lutetian) *Nummulites beaumonti* Zone" of KURESHY (1978) is possible, but less precise due to differences in species assemblages.

The biostratigraphic assignment of larger foraminiferal assemblages was determinated following HAAK & POSTUMA (1975), CARON (1985) and TOUMARKINE & LUTERBACHER (1985) on the basis of the associated planktonic foraminifers with which larger foraminifers were found in some favourable instances. The co-occurrence of larger and planktonic foraminifers indicates in general a paleoenvironment within outer parts of the Sublittoral. It was not possible in any case to assign individual larger foraminifer species precisely to planktonic foraminiferal zones. The natural habitat and deposition area of most of the larger foraminiferal specimens are shallow-water paleoenvironments which are not preferred by planktonic foraminifers. These paleoenvironmental differences are the main reason for uncertainties in the positions of the first and last occurrences of larger foraminiferal species of Fig. 12.

However, it was found by several authors (cit. below) that some species of larger foraminifers, such as *Omphalocyclus macroporus* (LAMARCK), *Siderolites calcitrapoides* LAMARCK, *Assilina dandotica* DAVIES, *Discocyclina ranikotensis* DAVIES, *Discocyclina dispansa* (SOWERBY) and *Discocyclina sowerbyi* NUTTALL, have a restricted distribution both in facies and biostratigraphy. These species are of importance for the determination of the biostratigraphical age of assemblages containing larger foraminifers only.

Several sections revisited and sampled were investigated earlier by DAVIES & PINFOLD (1937) (the Nammal Gorge section), EAMES (1952) (the Rakhi Nala section), BAYLISS (1961) (the Rakhi Nala section), MARKS (1962) (the Rakhi Nala section), SAMANTA (1972) (the Rakhi Nala section), LATIF (1972) (the section North of Hangu), ALLEMAN (1979) (the Murree Brewery Gorge section) and (GEE 1980) (other sections of the Salt Range and the Kohat area).

The distribution of larger foraminifers of Late Cretaceous and Early Paleogene as derived from the above mentioned regional sections is shown in Fig. 12.

The following assemblages of larger foraminifers have been identified and are described as follows.

3.2.1 Cretaceous

Orbitoides media-Omphalocyclus macroporus Assemblage

Age: Early Maastrichtian

Remarks: This assemblage of larger foraminifers is characterized by the co-occurrence of *Orbitoides media* (D'ARCHIAC), *Orbitoides apiculata* SCHLUMBERGER (which represents the final stage of the *Orbitoides* lineage (VAN GORSEL 1978: 31), *Orbitoides tissoti* SCHLUMBERGER, *Omphalocyclus macroporus* (LAMARCK) and *Siderolites calcitrapoides* LAMARCK. Variations of subspecies of *Orbitoides tissoti* SCHLUMBERGER from the Late Cretaceous of the Rakhi Nala section are described in detail by MARKS (1962).

The assemblage was found typically within the *Orbitoides* Limestone sequence of the Rakhi Nala section of the Sulaiman Range (Fig. 10). It is consistent with the „*Orbitoides* limestones and shales" of EAMES (1952) which were subdivided later (SHAH 1977) in a lower part assigned to the Mughal Kot Formation and an upper part assigned to the Fort Munro Formation. Due to the evident conformity based on larger foraminiferal assemblage, this part of the Fort Munro Formation which represents the upper part of „*Orbitoides* limestones and shales" of EAMES (1952) is re-included in the Mughal Kot Formation.

The *Orbitoides media-Omphalocyclus macroporus* Assemblage is dominated by abundant *Orbitoides* specimens. It indicates a shallow water environment and may be assigned to middle parts of the Sublittoral (MARKS 1962). *Omphalocyclus macroporus* (LAMARCK) is probably a marker sensitive to successive shallowing of sea level; it was found throughout the *Orbitoides* Limestone sequence but in less abundance within upper parts of the *Orbitoides* Limestone sequence underlying the near-shore, unfossiliferous Pab Sandstone Formation.

The stratigraphic distribution of the above mentioned *Orbitoides* species and in particular that of *Omphalocyclus macroporus* (LAMARCK) seems to be highly restricted and may be assigned approximately to the Early Maastrichtian (VAN GORSEL 1978).

Siderolites calcitrapoides-Orbitoides media Assemblage

Age: early Late Maastrichtian

Remarks: This assemblage is characterized by abundant specimens of *Siderolites calcitrapoides* LAMARCK co-occurring with thickly lenticular specimens of *Orbitoides media* (D'ARCHIAC), *Orbitoides tissoti* SCHLUMBERGER and *Orbitoides apiculata* SCHLUMBERGER. *Omphalocyclus macroporus* is not present probably due to paleoenvironmental reasons (see above). The gradual increase of the mean relative thickness of *Orbitoides* specimens is probably a response to increased water energy (compare MARKS 1962).

The assemblage was recognized in the basal Upper Cretaceous part of the Brewery Limestone within the Murree Brewery Gorge section of the Sulaiman Range (Fig. 11). It indicates a shallow water environment of middle to inner parts of the Sublittoral below or near the wave base.

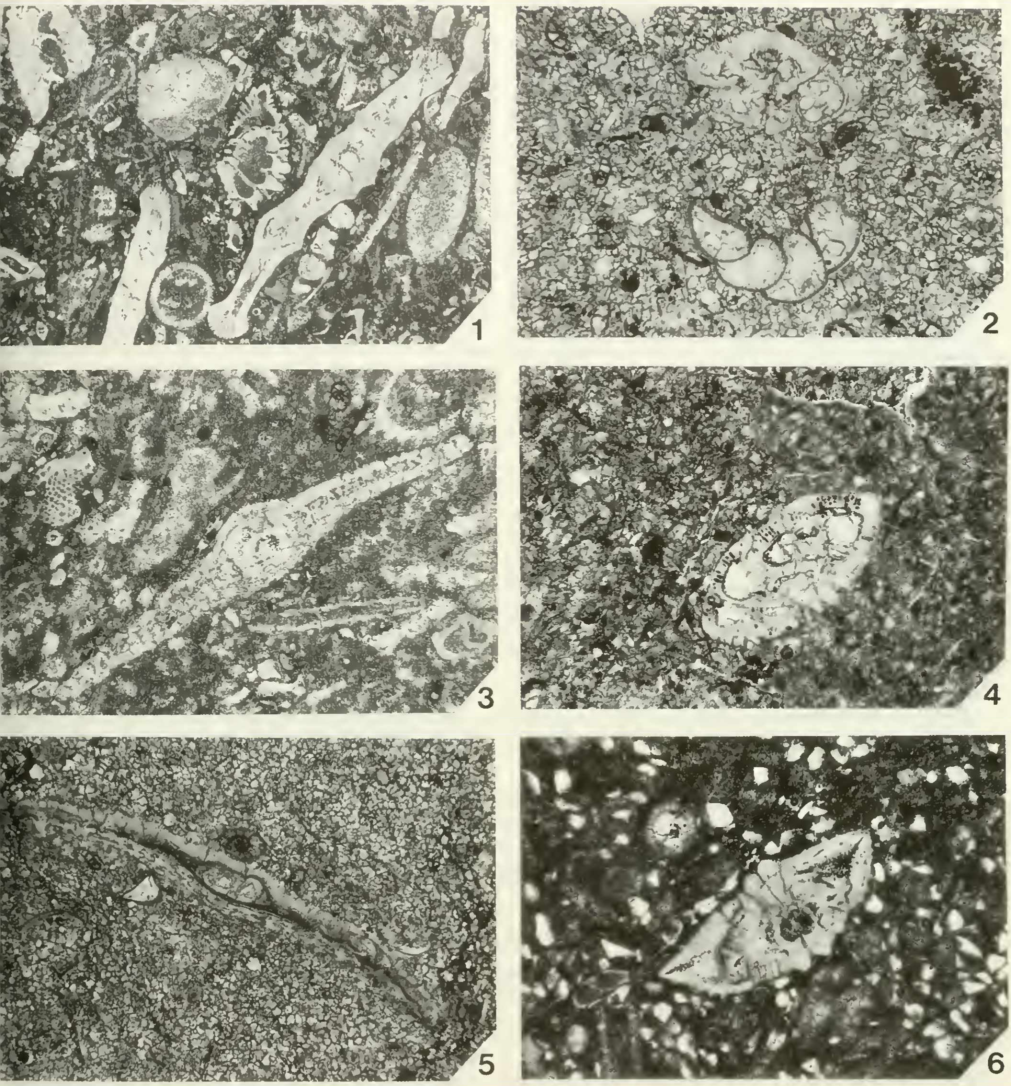
The above mentioned larger foraminiferal association is known from the European Late Maastrichtian (CONCLUSIONS/NICE 1983: 420, tab. 5b).

Siderolites calcitrapoides-Rotalia cf. *trochidiformis* Assemblage

Age: late Late Maastrichtian

Remarks: This larger foraminiferal association was found at the top of Upper Cretaceous sediments and contains rare specimens of *Siderolites calcitrapoides* LAMARCK and abundant specimens of *Rotalia* cf. *trochidiformis* (LAMARCK). Similar observations are known from the Qatar Peninsula (SMOUTH 1954).

The assemblage was observed in the topmost Upper Cretaceous part of the Brewery Limestone within the Murree



WEISS, W.: Maastrichtian to Eocene foraminiferal assemblages of Pakistan

Plate 1

Plate 1 Nammal Gorge section, Salt Range. Larger foraminifers.

Fig. 1 Algal-larger foraminiferal assemblage with *Operculina salsa* DAVIES, *Miscellanea miscella* (D'ARCHIAC & HAIME) and others. - SaR-39/S 1317; about 20 x; Middle Paleocene.

Fig. 2 *Lockhartia haimei* (DAVIES) and questionable *Cibicides* specimens within a sandy matrix. - SaR-40/S 1473; about 64 x; Middle Paleocene.

Fig. 3 *Discocyclina ranikotensis* DAVIES (juvenile specimen, probably A generation) and algal fragments. - SaR-39/S 1317; about 40 x; Middle Paleocene.

Fig. 4 *Lockhartia* aff. *conditi* (NUTTALL). - SaR-48/S 1323; about 48 x; Early to Middle Paleocene.

Fig. 5 *Dictyokathina simplex* SMOUTH. Note the thickened dorsal side and the layered ventral side. - SaR-42/S 1319; about 48 x; Early to Middle Paleocene.

Fig. 6 *Miscellanea miscella* (D'ARCHIAC & HAIME). - SaR-45/S 1321; about 48 x; Early to Middle Paleocene.

Brewery Gorge section of the Sulaiman Range (Fig. 11) and in uppermost parts of the massive Darsamand Limestone within the section North of Hangu in the Kohat area (Fig. 5). It indicates a very shallow paleoenvironment of inner parts of the Sublittoral.

In the section North of Hangu the assemblage is well above the base of the Late Maastrichtian *Abathomphalus mayaroensis* Zone of planktonic foraminifers and, therefore, may be assigned to the late Late Maastrichtian.

3.2.2 Paleocene

Miscellanea-Lockhartia haimei-Dictyokathina simplex Assemblage

Age: late Early to Middle Paleocene

Remarks: This assemblage of larger foraminifers is characteristic of the Lockhart (= Khairabad) Limestone sequence which contains a rich benthic foraminiferal assemblage (Davies & Pinfold 1937, Haque 1956). It is characterized mainly by abundant *Miscellanea miscella* (d'Archiac & Haime) and common *Lockhartia* specimens close to *Lockhartia haimei* (Davies). The assemblage is additionally characterized by species which occur sporadically, such as *Kathina major* Smouth, *Kathina selveri* Smouth, *Dictyokathina simplex* Smouth and *Discocyclina ranikotensis* Davies. The occurrence of these species may reflect minor regional differences of paleoenvironmental conditions or depositional depths of the Lockhart (=Khairabad) Limestone Formation. *Dictyokathina simplex* Smouth seems to be restricted to this interval.

The assemblage is accompanied by *Operculina salsa* Davies, the probable ancestor of *Ranikothalia* species (Hottinger 1977, Butt 1991). *Discocyclina ranikotensis* Davies is present as early as the Early-Middle Paleocene transition, if the transition coincides with the facies change from the Dhak Pass Beds into the Lockhart Limestone Formation of the Nammal Gorge section. *Orbitolites complanatus* Lamarck reaches its first abundance maximum during this interval.

The assemblage was observed with modifications (mentioned above) in the North of Hangu section of the Kohat area (Fig. 5) and the Nammal Gorge and Khairabad sections of the western Salt Range (Figs. 3-4). It was found in uppermost parts of the Dhak Bass Beds of the Nammal Gorge section (Fig. 3).

The *Miscellanea-Lockhartia haimei-Dictyokathina simplex* Assemblage has not been related to standard planktonic foraminiferal zonations directly due to the lack of planktonic index species. Shah (1977) places the Lockhart Limestone Formation within the Paleocene. The base of the overlying Patala Shales at the Khairabad section (Fig. 4) could be dated as belonging to the *Planorotalites pseudomenardii* Zone of the basal Late Paleocene. The underlying Hangu Formation (=Dhak Bass Beds) was dated as Early Paleocene (Shah 1977). Therefore, this assemblage of larger foraminifers which is typical of the Lockhart (=Khairabad) Limestone sequence may be assigned approximately to the Middle Paleocene or to an interval ranging from late Early Paleocene to Middle Paleocene, if uppermost parts of the Dhak Pass Beds are included.

Assilina dandotica-Discocyclina ranikotensis Assemblage

Age: Late Paleocene

Remarks: The assemblage is well defined biostratigraphically on the basis of planktonic foraminiferal *Planorotalites pseudomenardii* and *Morozovella velascoensis* Zones of the Late Paleocene (Figs. 2-3). It is characterized by the first appearance and abundance of true *Assilina* specimens (*Assilina dandotica* Davies, *Assilina leymeriei* d'Archiac & Haime, *Assilina spinosa* Davies) and by a first abundance maximum of *Discocyclina ranikotensis* Davies. It is associated with *Operculina salsa* Davies, *Operculina patalensis* Davies, not specified *Ranikothalia* specimens (see faunal reference list below) and rare specimens of *Lockhartia haimei* (Davies), *Kathina major* Smouth and *Kathina selveri* Smouth. The assemblage is accompanied by small benthic and planktonic foraminifers. It indicates a deeper water environment and may be assigned to outer parts of the Sublittoral.

Assilina dandotica Davies seems to be a larger foraminiferal marker species for the Late Paleocene Patala Shales of the Salt Range (Davies & Pinfold 1937) or the upper „Ranikot Group" (Schaub 1981: 206) as defined by Shah (1977).

The best occurrence of this larger foraminiferal assemblage was observed in the Patala Shales of the Patala Nala and the Nammal Gorge sections of the western Salt Range (Figs. 2-3) with the exception of the Khairabad section (Fig. 4) where the Patala Shales contain high percentages of planktonic foraminifers (Jamil Afzal & von Daniels 1991). In the Patala Shales from the Patala Nala type locality (Fig. 2) the assemblage of larger foraminifers occurs in higher parts of the Patala Shales, whereas lower parts of the Patala Shales are characterized by a relatively rich assemblage of small benthic foraminifers with dominant *Cibicides* and *Elphidium* specimens (called *Cibicides-Elphidium* Assemblage).

In the *Assilina dandotica-Discocyclina ranikotensis* Assemblage the *Miscellanea-Ranikothalia-Discocyclina ranikotensis* Assemblage from the lower part of the Zinda Pir Limestone (Fig. 8) is included due to planktonic foraminifers of the Late Paleocene *Morozovella velascoensis* Zone.

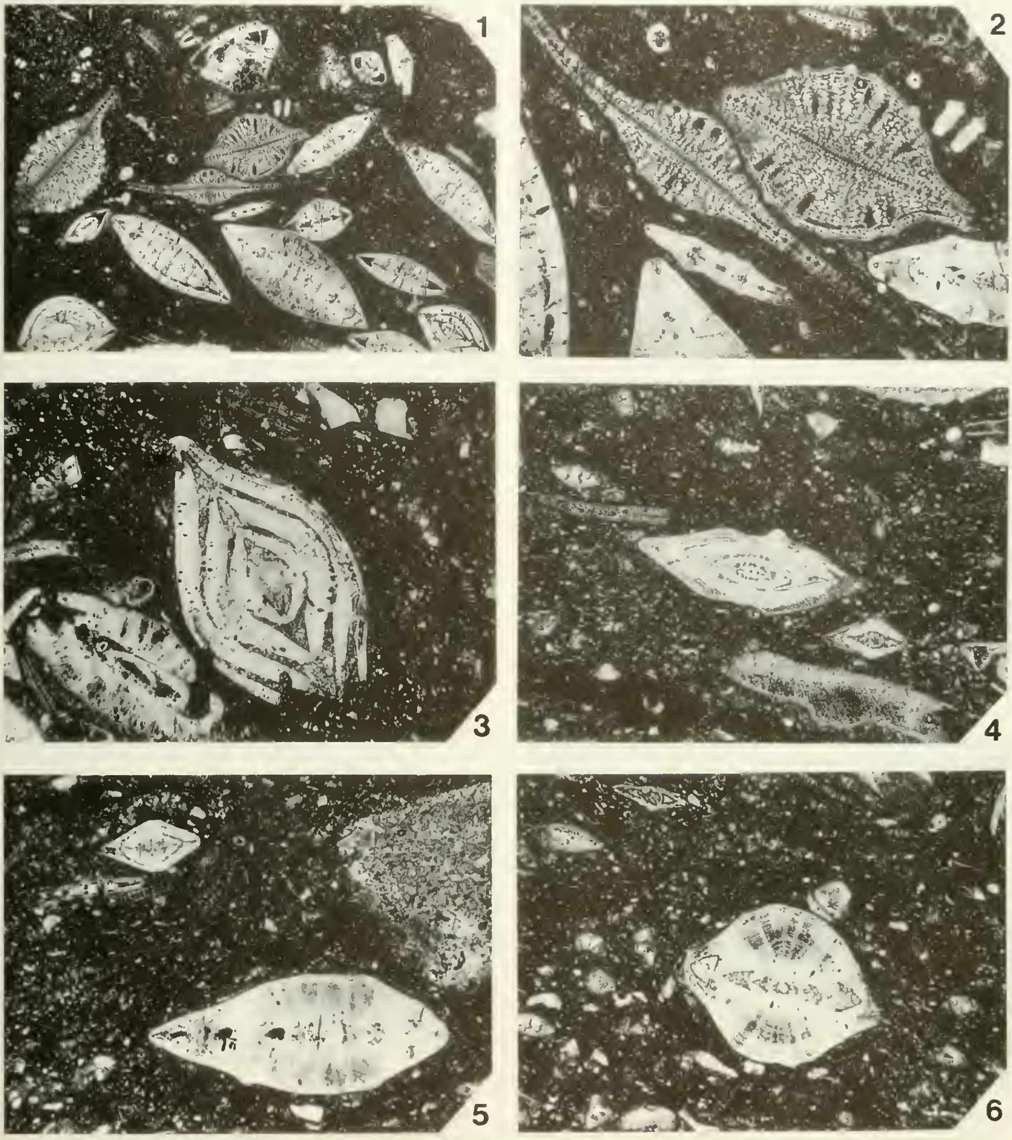
The *Lockhartia haimei-Discocyclina ranikotensis* Assemblage which was identified in basal parts of the Paleogene Brewery Limestone of the Murrey Brewery Gorge section (Fig. 11) represents, according to Hottinger (1978) (cit. by Alleman 1979: 217), the *Alveolina cucumiformis* Zone of the base of the Late Paleocene which correlates now, according to Schaub (1981), with the Late Paleocene *Morozovella velascoensis* Zone of planktonic foraminifers. The *Lockhartia haimei-Discocyclina ranikotensis* Assemblage is included in the *Assilina dandotica-Discocyclina ranikotensis* Assemblage.

3.2.3 Eocene

Assilina leymeriei-Nummulites fossulata-Discocyclina ranikotensis Assemblage

Age: Early Eocene

Remarks: This assemblage is a composite of several time-equivalent associations of larger foraminifers from the studied Upper Indus sections and includes



WEISS, W.: Maastrichtian to Eocene foraminiferal assemblages of Pakistan — Plate 2

Plate 2 Nammal Gorge section, Salt Range. Larger foraminifers, Early Eocene.

Fig. 1 Larger foraminiferal assemblage with *Discocyclina ranikotensis* DAVIES, *Discocyclina* sp., *Assilina laminosa* GILL, an intermediate specimen between *Assilina leymeriei* D'ARCHIAC & HAIME and *Assilina spinosa* DAVIES, *Nummulites globulus* LEYMERIE, *Lockhartia haimei* (DAVIES) and others. - SaR-32/S 1315; about 12 x.

Fig. 2 *Discocyclina ranikotensis* DAVIES, *Discocyclina* sp. and others. Note the different thicknesses at the poles. - SaR-32/S 1315; about 30 x.

Fig. 3 *Nummulites globulus* LEYMERIE (corroded) and others. - SaR-32/S 1315; about 30 x.

Fig. 4 ?*Nummulites fossulata* DE CIZANCOURT and others. - SaR-32/S 1315; about 30 x.

Fig. 5 *Assilina laminosa* GILL, *Nummulites globulus* LEYMERIE, fragments of *Discocyclina* specimens and others. - SaR-32/S 1315; about 30 x.

Fig. 6 *Assilina* aff. *laminosa* GILL and others. Note the reduced diameter and the increased thickness. - SaR-32/S 1315; about 30 x.

(a) the *Nummulites-Assilina pustulosa-Discocyclina ranikotensis* Assemblage of the Nammal Gorge section, western Salt Range (Fig. 3),

(b) the *Nummulites-Assilina* Assemblage and probably the *Discocyclina-Assilina daviesi-Orbitolites complanatus* Assemblage of the Panoba Anticline section, Kohat area (Fig. 6),

(c) the *Orbitolites complanatus-Discocyclina ranikotensis-Nummulites fossulata* Assemblage of the Mughal Kot-Toi Nala section, Sulaiman Range (Fig. 7),

(d) the *Discocyclina-Nummulites globulus* Assemblage and the *Alveolina-Nummulites fossulata* Assemblage of the Zinda Pir section, Sulaiman Range (Fig. 8),

(e) the *Assilina leymeriei-Nummulites fossulata* Assemblage of the Rakhi Nala section, Sulaiman Range (Fig. 10) and

(f) the *Nummulites globulus-Operculina salsa* Assemblage of the Murree Brewery Gorge section (Fig. 11).

Apart from species modifications mentioned above the assemblages are characterized by increased numbers of *Assilina* specimens and by the appearance of the first *Nummulites* specimens. These two well-known groups of larger foraminifers are represented mainly by abundant *Assilina leymeriei* D'ARCHIAC & HAIME, *Nummulites globulus* LEYMERIE and *Nummulites atacicus* LEYMERIE which occurs in younger parts of the assemblage. Additional species are *Assilina laminosa* GILL, *Assilina pustulosa* DONCIEUX and *Nummulites fossulata* DE CIZANCOURT.

The assemblage is also characterized by a second abundance maximum of *Discocyclina ranikotensis* DAVIES which was found to be common in more fine-grained sediments, by *Orbitolites complanatus* LAMARCK which occurs in more coarse-grained sediments, and by abundant alveolinids (*Alveolina elliptica* (SOWERBY), *Flosculina globosa* (LEYMERIE)) which occur in quite shallow water environments. *Ranikothalia* specimens have their last occurrence within basal parts of this assemblage, *Discocyclina ranikotensis* DAVIES disappears at the end of this assemblage, and *Nummulites fossulata* DE CIZANCOURT is restricted to this assemblage.

The biostratigraphic age assignments with planktonic foraminifers as defined by TOUMARKINE & LUTERBACHER (1985) are as follows:

(a) the *Nummulites-Assilina pustulosa-Discocyclina ranikotensis* Assemblage of the Nammal Gorge section (Fig. 3) was found in higher parts of the Nammal Marls. Lower parts of the Nammal Marls have been dated as belonging to the *Morozovella subbotinae* and *Morozovella formosa* Zones of the Early Eocene,

(b) the *Nummulites-Assilina* Assemblage of the Panoba Anticline section (Fig. 6) occurs in the „Patala Shales" (see above) and was dated with co-occurring planktonic foraminifers as close to *Morozovella subbotinae* and *Morozovella formosa* Zones of the Early Eocene. The *Discocyclina-Assilina daviesi-Orbitolites complanatus* Assemblage which was identified from the Shekhan Formation of the Panoba Anticline section (Fig. 6) is included here due to Early Eocene age assignments by SHAH (1977: 759). This assemblage of larger foraminifers is still uncertain biostratigraphically and somehow transitional concerning the age assignment. In certain beds of the Shekhan Limestone sequence of the Panoba Anticline section (Fig. 6) there are rare, but remarkable *Discocyclina* specimens which show a distinct sellate test morphology similar to that of the Middle Eocene *Discocyclina sowerbyi* NUTTALL. These specimens of *Discocyclina* might be the probable ancestor of *Discocyclina sowerbyi* NUTTALL.

(c) the *Orbitolites complanatus-Discocyclina ranikotensis-Nummulites fossulata* Assemblage of the Mughal Kot-Toi Nala section (Fig. 7) occurs within the Ghazij Formation and indicates by co-occurring planktonic foraminifers the *Morozovella subbotinae* and *Morozovella formosa* Zones of the Early Eocene,

(d) the *Discocyclina-Nummulites globulus* Assemblage from the topmost part of the lower part of the Zinda Pir Limestone and the *Alveolina-Nummulites fossulata* Assemblage of the upper part of the Zinda Pir Limestone (Fig. 8) are of Early Eocene age too as confirmed by the same planktonic foraminiferal zones mentioned above,

(e) the *Assilina leymeriei-Nummulites fossulata* Assemblage of the Rakhi Nala section (Fig. 10) was found within upper parts of the Upper Rahki Gaj Shales, the Green and Nodular Shales and basal parts of the Rubbly Limestone. It could not been dated exactly by means of planktonic foraminifers due to the presence of long-ranging species. The age assignment as Early Eocene is according to EAMES (1952) and NAGAPPA (1959). Upper parts of the Upper Rakhi Gaj Shales were assigned to planktonic foraminiferal *Morozovella formosa* Zone of the Early Eocene,

(f) the *Nummulites globulus-Operculina salsa* Assemblage of the highest parts of the Paleogene Brewery Limestone (Fig. 11) does not contain planktonic foraminifers. The Early Eocene age assignment is according to ALLEMANN (1979).

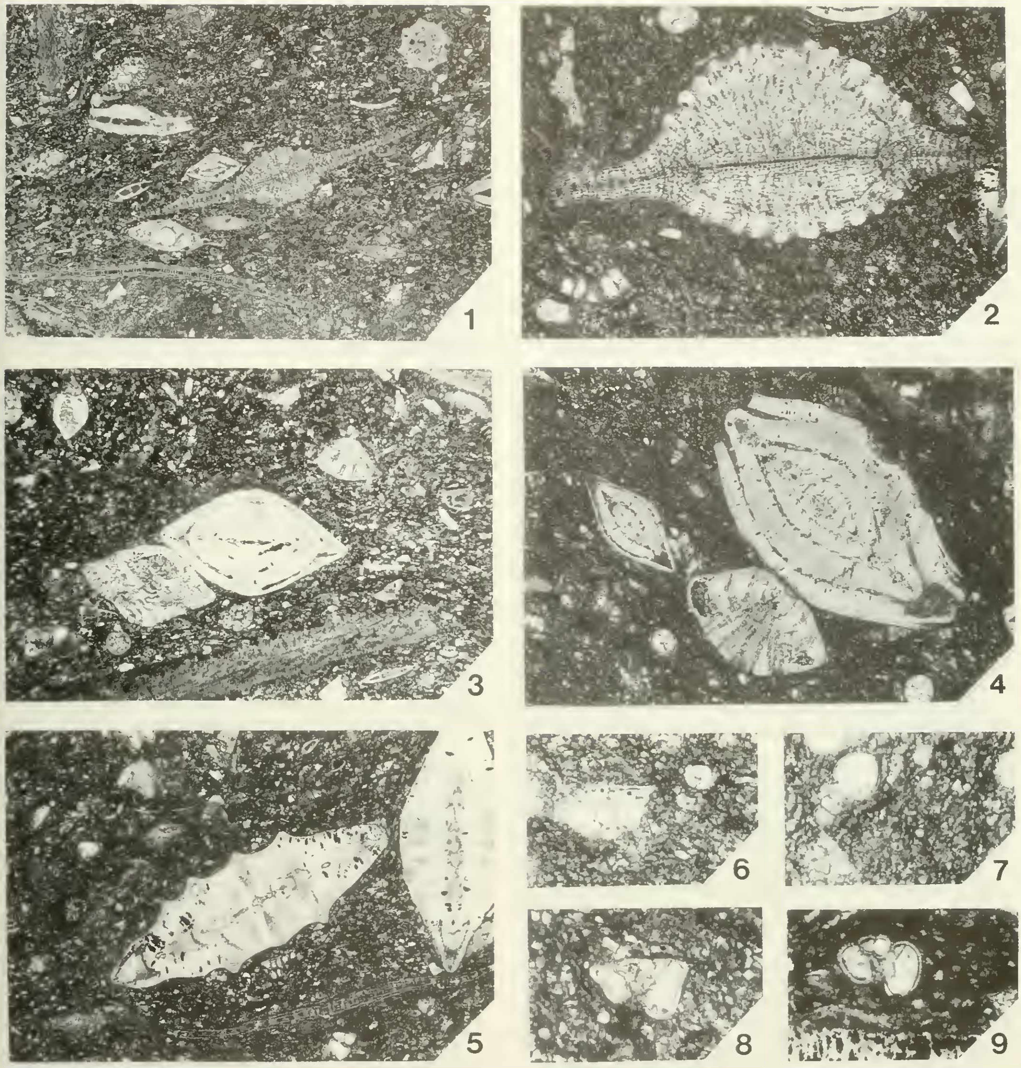
Assilina spinosa-Flosculina globosa-Dictyoconoides cooki Assemblage

Age: late Early Eocene to early Middle Eocene

Remarks: The *Assilina spinosa-Flosculina globosa-Dictyoconoides cooki* Assemblage is intermediate between the *Assilina leymeriei-Nummulites fossulata-Discocyclina ranikotensis* Assemblage of undoubtfully Early Eocene age (discussion above) and the *Discocyclina dispansa-Discocyclina sowerbyi* Assemblage of undoubtfully Middle Eocene age (discussion below).

The assemblage of larger foraminifers is likewise a composite characterized by a predominance either of *Assilina spinosa* DAVIES and other assilinids, such as *Assilina lacunata* DE CIZANCOURT and *Assilina spinosa* DAVIES, which occur in more coarse-grained and probably more turbulent shallow water environments, or by a remarkable predominance of *Flosculina globosa* (LEYMERIE) and *Alveolina elliptica* (SOWERBY) which were found in more fine-grained and probably quite shallow water or lagoonal environments. The environments may be indicative of inner parts of the Sublittoral.

Dictyoconoides cooki (CARTER) seems to be restricted to this interval. *Orbitolites complanatus* LAMARCK and *Nummulites* specimens of both the *Nummulites globulus* and *Nummulites atacicus* group are present.



WEISS, W.: Maastrichtian to Eocene foraminiferal assemblages of Pakistan — Plate 3

Plate 3 Nammal Gorge section, Salt Range. Larger and planktonic foraminifers.

Fig. 1 Larger foraminiferal assemblage with *Discocyclina ranikotensis* DAVIES, *Nummulites globulus* LEYMERIE, *Nummulites* sp., *Assilina* sp. and others. Matrix with many planktonic foraminifers. - SaR-32/S 1315; about 8 x; Early Eocene.

Fig. 2 *Discocyclina* sp. and others. Note the asymmetric thickness at the poles and the numerous polar bosses. - SaR-32/S 1315; about 30 x; Early Eocene.

Fig. 3 *Nummulites globulus* LEYMERIE, *Rotalia trochidiformis* (LAMARCK) and others. - SaR-32/S 1315; about 30 x; Early Eocene.

Fig. 4 *Nummulites atacicus* LEYMERIE, *Lockhartia* aff. *haimei* DAVIES and others. - SaR-32/S 1315; about 20 x; Early Eocene.

Fig. 5 *Assilina* aff. *pustulosa* DONCIEUX, *Assilina laminosa* GILL and others. - SaR-32/S 1315; about 30 x; Early Eocene.

Fig. 6 *Morozovella* aff. *subbotinae* (MOROZOVA). - SaR-28/S 1377; about 60 x; Early Eocene.

Fig. 7 ?*Pseudohastigerina wilcoxensis* (CUSHMAN & PONTON). - SaR-28/S 1377; about 60 x; Early Eocene.

Fig. 8 *Morozovella* aff. *gracilis* (BOLLI). - SaR-32/S 1315; about 60 x; Early Eocene.

Fig. 9 ?*Acarinina wilcoxensis* (CUSHMAN & PONTON). - SaR-32/S 1315; about 60 x; Early Eocene.

A more precise age of this assemblage was not verified by planktonic foraminifers. The *Assilina spinosa-Flosculina globosa-Dictyoconoides cooki* Assemblage was observed only from the Kohat Formation of the Panoba Anticline section, Kohat area (Fig. 6) which is of late Early Eocene to Middle Eocene age following SHAH (1977).

Discocyclina dispansa-Discocyclina sowerbyi Assemblage

Age: Middle Eocene

Remarks: This assemblage of larger foraminifers is well defined in age on the basis of Middle Eocene *Globigerinatheka subconglobata* and *Orbulinoides beckmanni* Zones of planktonic foraminifers and includes

(a) the *Planorbulina-Alveolina elliptica-Discocyclina dispansa* Assemblage of the Mughal Kot-Toi Nala section (Fig. 7),

(b) the *Discocyclina* Assemblage of the Zao River section (Fig. 9), and

(c) the *Discocyclina dispansa-Discocyclina sowerbyi* Assemblage of the Rakhi Nala section (Fig. 10).

It is characterized by the occurrence of *Discocyclina dispansa* (SOWERBY) and *Discocyclina sowerbyi* NUTTALL. They occur together with specimens of *Nummulites globulus* LEYMERIE and *Nummulites atacicus* LEYMERIE, *Operculina aspensis* COLOM, *Alveolina elliptica* (SOWERBY) and *Planorbulina* sp.

The assemblage is attributed to an open neritic, shallow-water environment of outer parts of the Sublittoral. It is widely distributed within the Pakistan-Indian bioprovince (SEN GUPTA 1963).

3.2.4 Remarks on Larger Foraminiferal Paleobiogeography

Paleobiogeographic considerations of Cretaceous and Paleogene larger foraminiferal assemblages from the Upper Indus Basin sections were not a main topic of investigations presented here. A comprehensive interpretation of biogeographic pattern of larger foraminifers requires basically detailed knowledge of type material of the abundant taxa of larger foraminifers which is essential to solve many problems of taxonomic interpretations still existant. Therefore, few aspects of larger foraminiferal paleobiogeography are given here as well as additional informations as they are related to the studied sections.

The importance of the shallow marine Paleogene sequences of Pakistan for the understanding of distribution of Paleogene larger foraminifers, and in particular that of the nummulitids and assilinids, is documented in many publications (cited already above and below) and is summarized for instance by BLONDEAU (1972) and KURESHI (1975, 1978). They accentuate that Paleogene shallow water carbonate deposits of Pakistan are essential of tropical and subtropical larger foraminiferal assemblages of the Far East and are a center of the Indo-Pakistan Province of the eastern Tethys region.

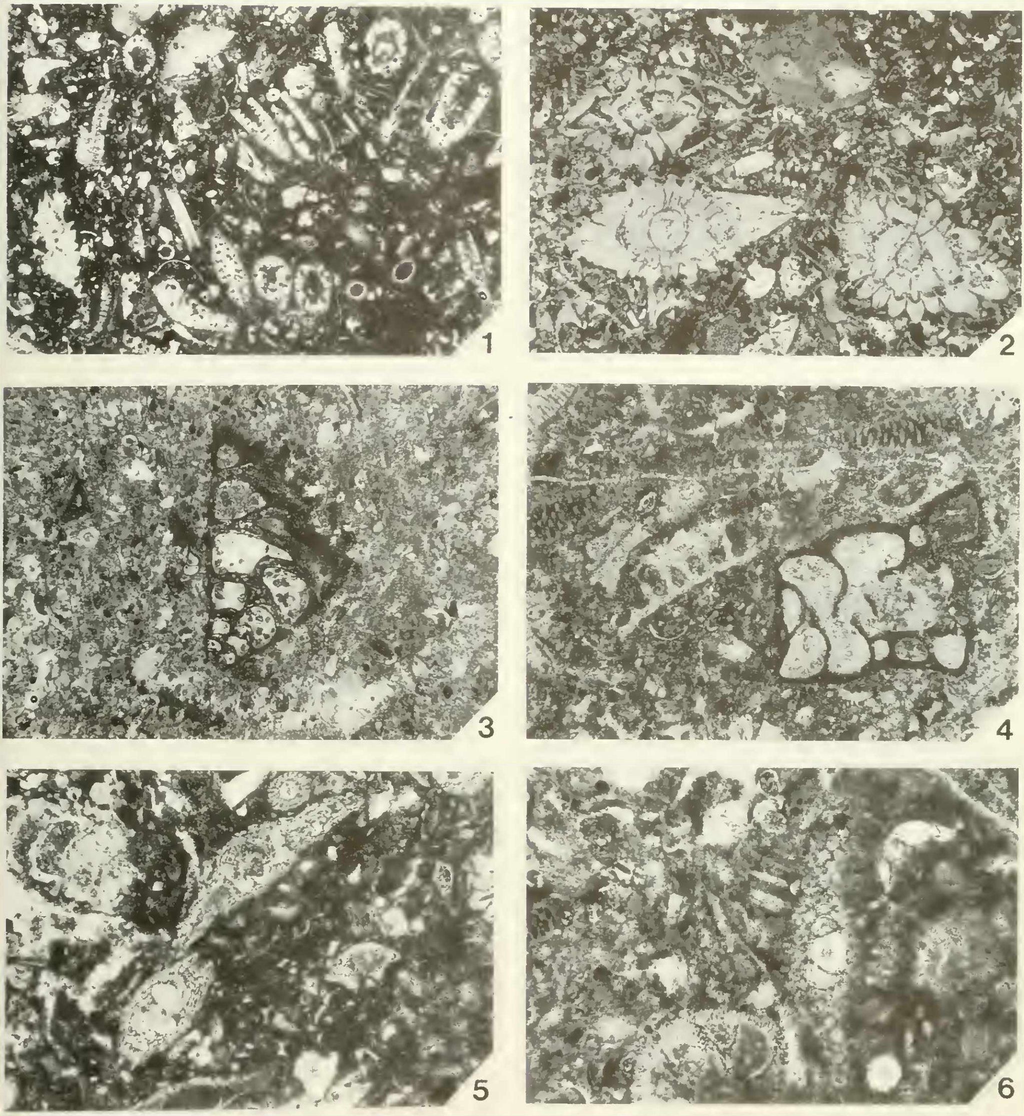
Paleocene and Eocene taxa of larger foraminifers from southern Tibet (WAN 1990) show close affinities to the species as described from Pakistan and emphasize the importance of the Indo-Pakistan region.

Larger foraminifers from the Baluchistan Basin, the Lower Indus Basin and the Upper Indus Basin of Pakistan were studied by many earlier paleontologists (SOWERBY 1837, D'ARCHIAC & HAIME 1853, CARTER 1861, NUTTALL 1926, DAVIES 1937, 1940, EAMES 1952, GILL 1953, SMOUTH & HAQUE 1956, NAGAPPA 1959, BAYLISS 1961, ADAMS 1970). Planktonic as well as larger foraminifers from Tertiary carbonate deposits of Pakistan were studied in detail by KURESHI (1966, 1969, 1971, 1972, 1974, 1975, 1978). This author has shown (and this is corroborated by the author's studies) that interregional stratigraphic correlation and paleobiogeographic comparison of larger foraminiferal assemblages is nevertheless complicated, even between the Paleogene deposits of the Baluchistan, Lower Indus and Upper Indus Basins, due to permanent problems of taxonomical interpretation of larger foraminifers and due to the restricted correlation of the stratigraphic ranges of larger foraminifers with planktonic foraminifers and other open marine microfossil groups. Comparison and correlation are also hampered because nowhere in Pakistan is a complete Tertiary carbonate sequence exposed in one stratigraphic section.

Concerning the geographic distribution of the Cretaceous orbitoidal foraminifers which „occupy a belt approximately parallel to present day low to low-middle latitudes in the Northern Hemisphere" (VAN GORSEL 1978), this author has distinguished two main larger foraminiferal provinces on a generic level: a „Caribbean" province of the western Tethys and a „Eurasian" province of the eastern Tethys. Orbitoid genera *Omphalocyclus* und *Orbitoides* which were found in the Late Cretaceous limestones of the Sulaiman Range belong to world-wide genera and are widely distributed in America, Europe and into the Far East (VAN GORSEL 1978). *Omphalocyclus* and *Orbitoides* were not found in the Kohat area.

Compared with the rich Paleogene larger foraminiferal assemblages of the Lower Indus Basin (KURESHI 1975, 1978), it seems that the number of larger foraminiferal taxa of the Upper Indus Basin is reduced, if the number of *Nummulites*, *Assilina*, *Discocyclina* and *Alveolina* species described are compared.

If groups of larger foraminiferal assemblages of the Sulaiman Range, the Kohat area and the western Salt Range of the Upper Indus Basin are compared, there are some interregional differences (Fig. 12). Alveolinids are rare in the Late Paleocene and Eocene sections of the western Salt Range. Nummulitids are more common in the Eocene intervals of the Sulaiman Range than in intervals of the western Salt Range and the Kohat area; *Nummulites fossulata* DE CIZANCOURT, *Nummulites crasseornata* (HENRICI) and *Nummulites vanderstoki* RUTTEN & VERMUNT were not found north of the Sulaiman Range which supports the assumption of a regional distribution pattern. Most of the Middle Eocene discocyclinids were found within the Sulaiman Range sections and were probably not able to immigrate and to occupy favourable paleoenvironments of the northern regions.



Weiss, W.: Maastrichtian to Eocene foraminiferal assemblages of Pakistan — Plate 4

Plate 4 — Khairabad section, Salt Range. Algal and larger foraminiferal assemblages.

Fig. 1 — Algal assemblage, mostly dasycladaceans and others. - SaR-59/S 1325; about 27 x; Middle Paleocene.

Fig. 2 — *Miscellanea miscella* (d'Archiac & Haime) and others. - SaR-64/S 1331; about 30 x; Middle Paleocene.

Fig. 3 — Large arenaceous specimen (triserial). - SaR-61/S 1328; about 30 x; Middle Paleocene.

Fig. 4 — *Orbitolites complanatus* Lamarck and others. - SaR-61/S 1328; about 30 x; Middle Paleocene.

Fig. 5 — *Discocyclina ranikotensis* Davies (juvenile specimens) and others. Note the two-chambered nucleoconch. - SaR-60/S 1327; about 40 x; Middle Paleocene.

Fig. 6 — *Discocyclina ranikotensis* Davies and others. Note the virtually three-chambered nucleoconch. - SaR-62/S 1329; about 40; Middle Paleocene.

4. SUMMARY

Late Cretaceous and Paleogene marine sediment sequences from the Upper Indus Basin of northern Pakistan (the western Salt Range, the Kohat area, the Sulaiman Range) were correlated on the basis of planktonic and larger foraminiferal assemblages. The studied sections are the Patala Nala section, the Nammal Gorge section, and the Khairabad section in the western Salt Range; the section North of Hangu and the Panoba Anticline section in the Kohat Area; and the Mughal Kot-Toi Nala section, the Zinda Pir section, the Zao river section, the Rakhi Nala section, and the Murree Brewery Gorge section in the Sulaiman Range. Cretaceous and Paleogene planktonic foraminifers of samples were used for comparison of various sections and areas as well as of different larger foraminiferal assemblages.

The assemblages of larger foraminifers identified are as follows:

(1) the *Orbitoides media-Omphalocyclus macroporus* Assemblage of Early Maastrichtian age,

(2) the *Siderolites calcitrapoides-Orbitoides media* Assemblage of early Late Maastrichtian age,

(3) the *Siderolites calcitrapoides-Rotalia* cf. *trochidiformis* Assemblage of late Late Maastrichtian age,

(4) the *Miscellanea-Lockhartia haimei-Dictyokathina simplex* Assemblage of late Early to Middle Paleocene age,

(5) the *Assilina dandotica-Discocyclina ranikotensis* Assemblage of Late Paleocene age,

(6) the *Assilina leymeriei-Nummulites fossulata-Discocyclina ranikotensis* Assemblage of Early Eocene age,

(7) the *Assilina spinosa-Flosculina globosa-Dictyoconoides cooki* Assemblage of late Early to early Middle Eocene age,

(8) the *Discocyclina dispansa-Discocyclina sowerbyi* Assemblage of Middle Eocene age.

Biostratigraphic analysis of microfaunas and in particular of planktonic and larger foraminifers revealed several first and last occurrences of planktonic and larger foraminifers in the sections of the western Salt Range, the Kohat area and the Sulaiman Range. They were used to refine regional stratigraphy.

The remarkable facies change from the pelagic Parh Formation to the flyschoid Mughal Kot Formation in the Mughal Kot-Toi Nala section was dated with the last occurrence of high-spired praeglobotruncanids and with the range of *Marginotruncana pseudolinneiana* as Late Turonian to Early Coniacian.

Stepwise regression during the Maastrichtian is documented in the Rakhi Nala section of the Sulaiman Range by the succession of different assemblages of larger foraminifers which indicate successively shallower environments within the *Orbitoides* Limestone Formation and by the facies change into the Pab Sandstone sequence.

Paleoenvironmental changes during the Paleogene have influenced the larger foraminiferal succession in particular at the Middle-Late Palaeocene boundary and the Palaeocene-Eocene boundary in the western Salt Range as well as in the Sulaiman Range. The shallow water carbonate facies ends in the western Salt Range near the end of the Early Eocene, in the Kohat area within the Middle Eocene and in the Sulaiman Range in the Late Eocene.

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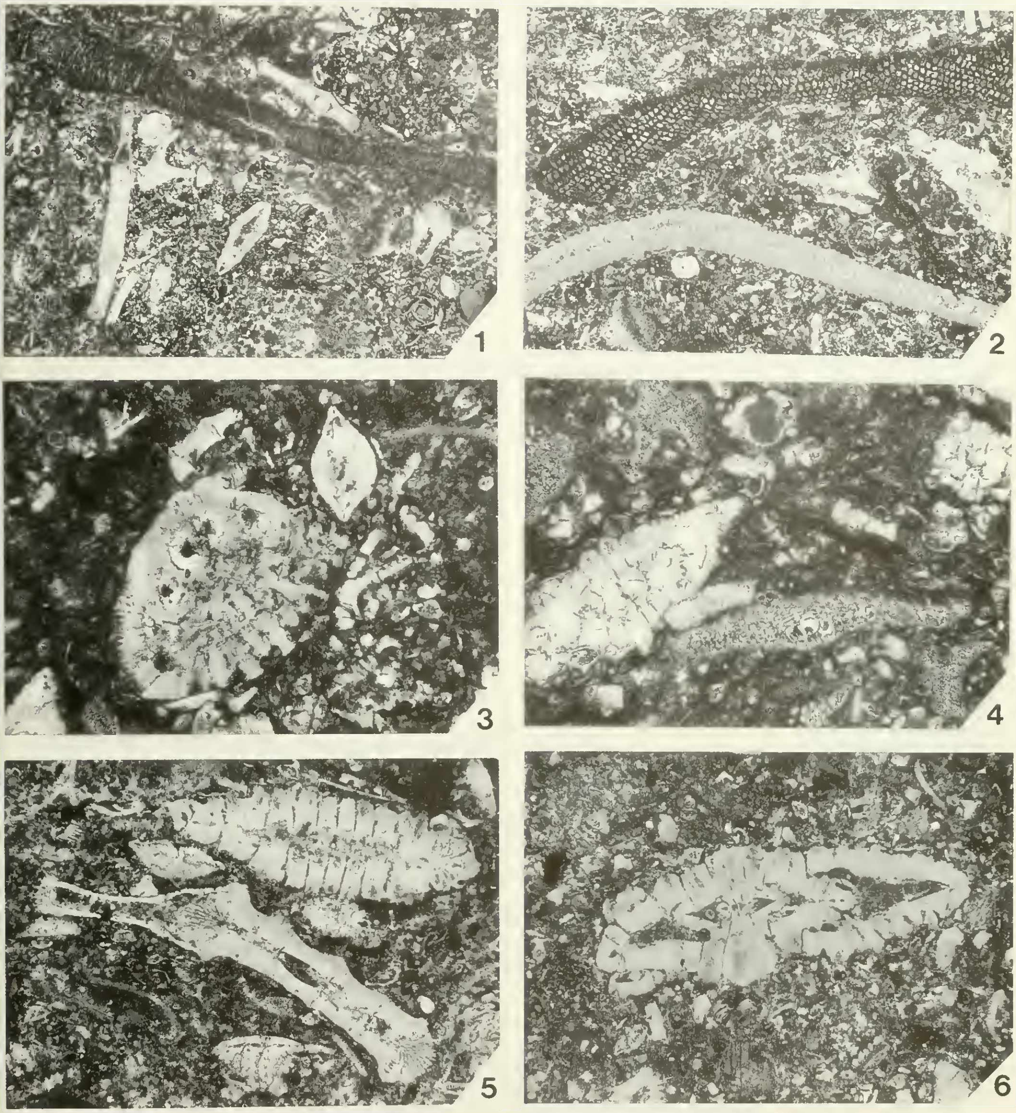

WEISS, W.: Maastrichtian to Eocene foraminiferal assemblages of Pakistan — Plate 5

Plate 5 Khairabad section, Salt Range. Larger foraminifers.

Fig. 1 Larger foraminiferal assemblage with *Orbitolites complanatus* LAMARCK, *Operculina salsa* DAVIES and others. - SaR-3/S 1309; about 6 x; Middle Paleocene.

Fig. 2 *Orbitolites complanatus* LAMARCK, *Dictyokathina simplex* SMOUTH and others. - SaR-3/S 1309; about 6 x; Middle Paleocene.

Fig. 3 *Lockhartia conditi* (NUTTALL), *Kathina* aff. *selveri* SMOUTH and others. - SaR-3/S 1309; about 40 x; Middle Paleocene.

Fig. 4 *Miscellanea miscella* (D'ARCHIAC & HAIME), ?*Dictyokathina simplex* (juvenile specimen) and others. - SaR-3/S 1309; about 30 x; Middle Paleocene.

Fig. 5 *Operculina salsa* DAVIES, *Miscellanea miscella* (D'ARCHIAC & HAIME) and others. - SaR-3/S 1309; about 23 x; Middle Paleocene.

Fig. 6 *Miscellanea miscella* (D'ARCHIAC & HAIME) and others. - SaR-3/S 1309; about 30 x; Middle Paleocene.

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Plate 6 Khairabad section, Salt Range. Larger foraminifers.

Fig. 1 Larger foraminiferal assemblage. - SaR-66/S 1334; about 6 x; Early Eocene.

Fig. 2 Larger foraminiferal assemblage with *Discocyclina ranikotensis* DAVIES, *Nummulites* aff. *atacicus* LEYMERIE and others. - SaR-66/S 1334; about 10 x; Early Eocene.

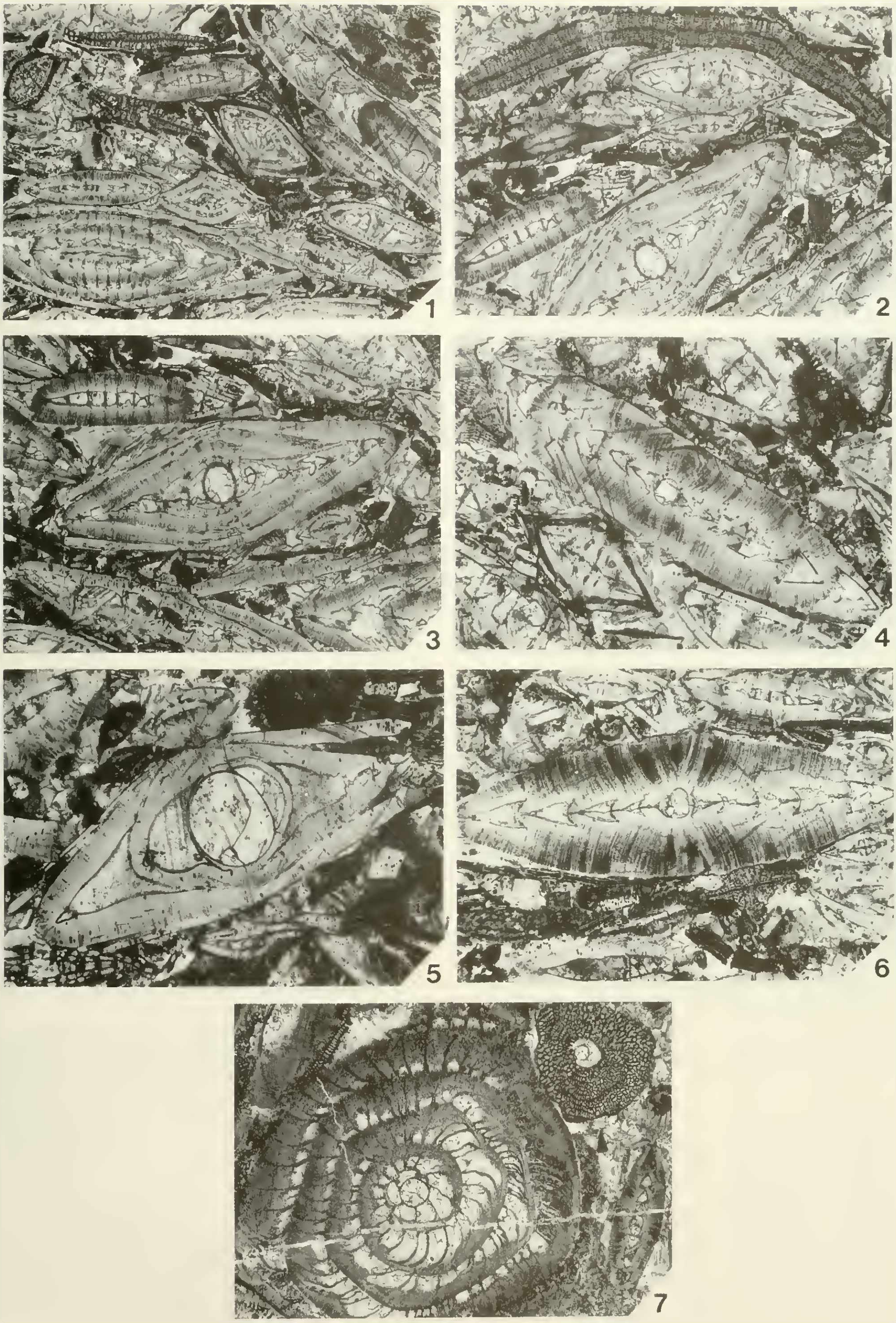
Fig. 3 *Nummulites* aff. *atacicus* LEYMERIE and others. - SaR-66/S 1334; about 10 x; Early Eocene.

Fig. 4 ?*Assilina* aff. *plana* SCHAUB and others. - SaR-66/S 1334; about 15 x; Early Eocene.

Fig. 5 *Nummulites* aff. *atacicus* LEYMERIE (juvenile specimen) and others. - SaR-66/S 1334; about 40 x; Early Eocene.

Fig. 6 *Assilina* aff. *leymeriei* D'ARCHIAC & HAIME and others. - SaR-66/S 1334; about 30 x; Early Eocene.

Fig. 7 Equatorial sections of ?*Assilina* aff. *plana* SCHAUB (questionable A generation) and *Discocyclina ranikotensis* DAVIES. - SaR-65a/S 1333; about 15 x; Early Eocene



Weiss, W.: Maastrichtian to Eocene foraminiferal assemblages of Pakistan

Plate 6

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Plate 7 North of Hangu section, Kohat Area. Larger foraminifers.

Fig. 1 Algal-foraminiferal assemblage. - Ko-59/S 1440; about 60 x; Late Maastrichtian.

Fig. 2 Algal assemblage, mostly dasycladaceans, and larger foraminifers. - Ko-61/S 1442; about 20 x; ?Early to Middle Paleocene.

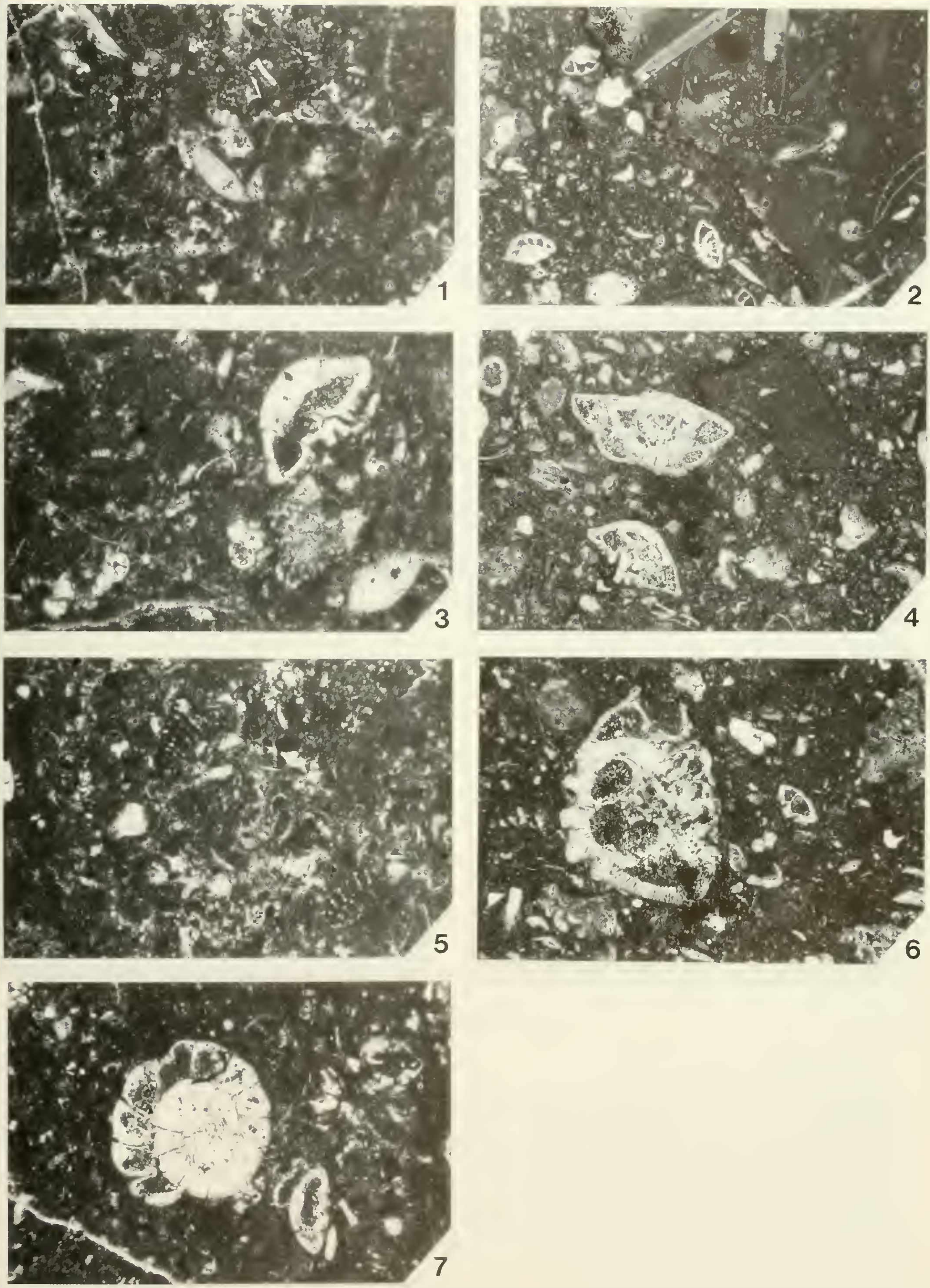
Fig. 3 *Rotalia* cf. *trochidiformis* (LAMARCK), *Gublerina* sp. (left) and others. - Ko-59/S 1440; about 60 x; Late Maastrichtian.

Fig. 4 *Rotalia trochidiformis* (LAMARCK), *Kathina major* SMOUTH and others. - Ko-61/S 1442; about 30 x; ?Early to Middle Paleocene.

Fig. 5 Questionable soritid specimens. - Ko-59/S 1440; about 46 x; Late Maastrichtian.

Fig. 6 Transitional specimen between *Lockhartia haimei* (DAVIES) and *Lockhartia altispira* SMOUTH and others. - Ko-61/S 1442; about 40; ?Early to Middle Paleocene.

Fig. 7 *Rotalia* cf. *trochidiformis* (LAMARCK) (horizontal section). Note the thin, laminated, radially fibrous calcite of the outer wall. - Ko-59/S 1440; about 40; Late Maastrichtian.



WEISS, W.: Maastrichtian to Eocene foraminiferal assemblages of Pakistan

Plate 7

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APPENDIX

Faunal reference list of larger foraminifers

Taxa of larger foraminifers identified in the samples are listed alphabetically with reference to their original description. Additional references of preferred modern nomenclature of larger foraminifers (including as far as possible A and B generations) are given showing typical species illustrations which were the base of determinations used here. Some taxa in open nomenclature are discussed.

Cretaceous

Omphalocyclus macroporus (LAMARCK, 1816)

= *Orbulites macropora* n. sp. - LAMARCK: 197.

= *Omphalocyclus macroporus* (LAMARCK) - NEUMANN (1958): 65-66; pl. 6, figs. 1-8; pl. 35, fig. 2; text-fig. 16a-b.

Orbitoides apiculata SCHLUMBERGER, 1901

= *Orbitoides apiculata* n. sp. - SCHLUMBERGER: 462; pl. 8, figs. 1, 4, 6; pl. 9, figs. 1,4.

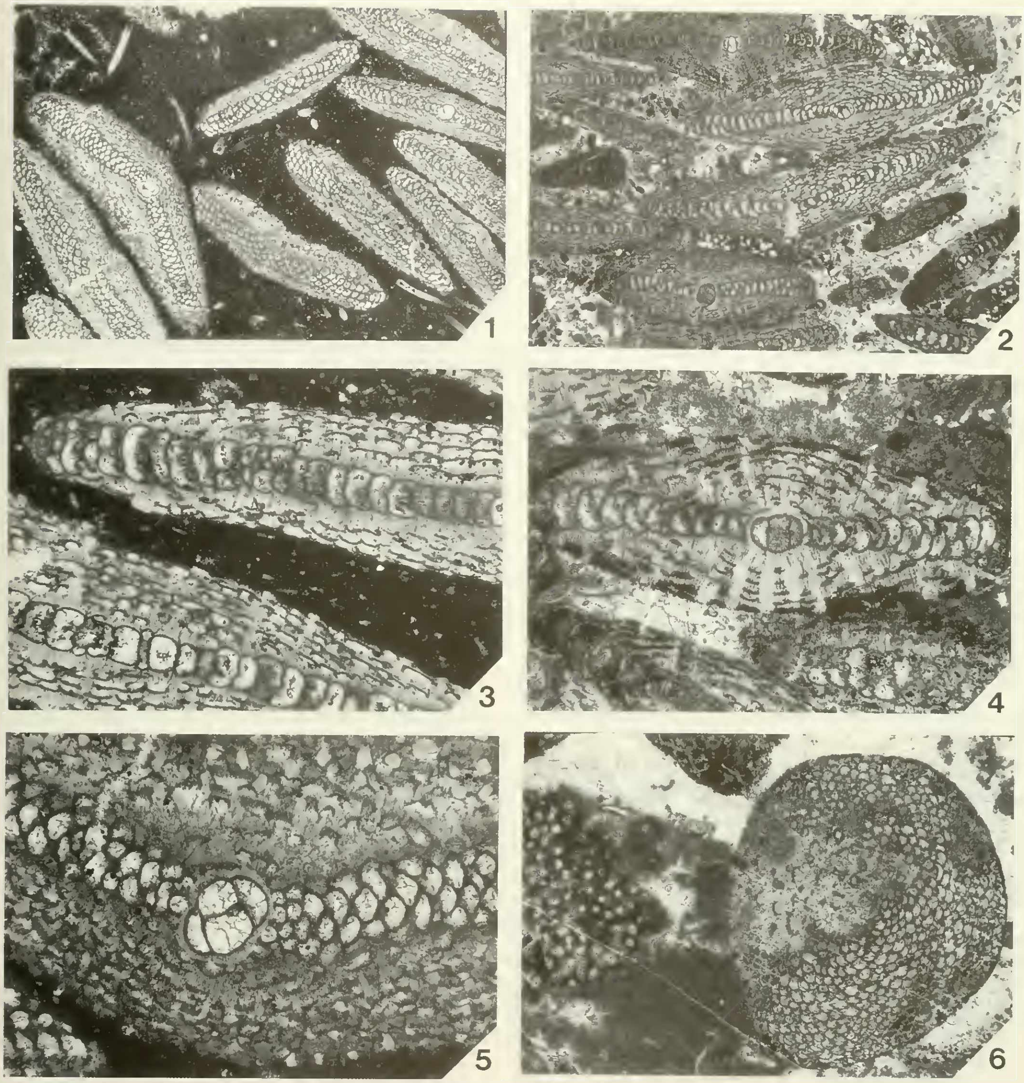
= *Orbitoides apiculata apiculata* (SCHLUMBERGER) - KUPPER (1954): 66-67; pl. 12, figs. 7-8;

= *Orbitoides apiculata* (SCHLUMBERGER) - NEUMANN (1958): 63-65; pl. 4, figs. 1-6; pl. 5, figs. 5-6; text-fig. 15a-b.

Orbitoides media (D'ARCHIAC, 1837)

= *Orbitolites media* n. sp. - D'ARCHIAC: 178;

= *Orbitoides media media* (D'ARCHIAC) - PAPP & KÜPPER (1953): 73; pl. 1, figs. 5-7; pl. 2, figs. 2-4;



WEISS, W.: Maastrichtian to Eocene foraminiferal assemblages of Pakistan

Plate 8

Plate 8 Rakhi Nala section, Sulaiman Range. Larger foraminifers.

Fig. 1 *Orbitoides tissoti* SCHLUMBERGER. Note the different sections probably indicating a low-energy depositional environment. - SmR-1/S 1419; about 6 x; Early Maastrichtian.

Fig. 2 *Orbitoides tissoti* SCHLUMBERGER. Note the predominant axial sections probably indicating a high-energy depositional environment. - SmR-1/S 1419; about 8 x; Early Maastrichtian.

Fig. 3 *Orbitoides tissoti* SCHLUMBERGER. Note the two and three tubelike stolons serving as a connection between chambers of the central layer. - SmR-1/S 1419; about 46 x; Early Maastrichtian.

Fig. 4 *Orbitoides tissoti* SCHLUMBERGER. Note the virtually three-chambered nucleoconch. - SmR-1/S 1419; about 40 x; Early Maastrichtian.

Fig. 5 *Orbitoides tissoti* SCHLUMBERGER. Note the quadrilocular nucleoconch surrounded by thick, perforated wall. - SmR-1/S 1419; about 46 x; Early Maastrichtian.

Fig. 6 *Orbitoides tissoti* SCHLUMBERGER. Note the arcuate equatorial chambers in a slightly oblique section. - SmR-1/S 1419; about 23 x; Early Maastrichtian.

= *Orbitoides media* (D'ARCHIAC) - NEUMANN (1958): 60-62; pl. 3, figs. 1-6; pl. 5, figs. 3-4; pl. 35, fig. 2; text-fig. 14a-d.

Orbitoides tissoti SCHLUMBERGER, 1902

= *Orbitoides tissoti* n. sp. - SCHLUMBERGER: 259; pl. 8, figs. 21-25.

= *Orbitoides tissoti tissoti* (SCHLUMBERGER) - PAPP & KUPPER (1953): 349; pl. 1, figs. 1-2; pl. fig. 2;

= *Orbitoides tissoti* (SCHLUMBERGER) - NEUMANN (1958): 56-60; pl. 1, figs. 1-9; pl. 2, figs. 1-4; pl. 5, figs. 1-2; pl. 35, fig. 1; text-fig. 13a-b.

Siderolites calcitrapoides LAMARCK, 1801

= *Calcarina calcitrapoides* (LAMARCK) - HOFKER (1926): 14-17; figs. 1-14.

<u>Paleogene</u>

Alveolina delicatissima SMOUTH, 1954

= *Alveolina delicatissima* n. sp. - SMOUTH: 83-84; pl. 14, fig. 13.

Alveolina elliptica (SOWERBY, 1840)

= *Fasciolites elliptica* n. sp. - SOWERBY: 329; pl. 24. fig. 17;

= *Alveolina elliptica* (SOWERBY) - HOTTINGER (1960): 146; pl. 12, figs. 1-3.

Alveolina lepidula SCHWAGER, 1883

= *Alveolina lepidula* var. A - SCHWAGER: pl. 25, figs. 3a-g;

= *Alveolina lepidula* var. A SCHWAGER - NUTTALL (1925): 439; pl. 24, figs. 1-2;

= *Alveolina* (*Glomalveolina*) *lepidula* SCHWAGER - HOTTINGER (1960): 57-58; pl. 1, figs. 25-29; pl. 2, fis. 9, 25; text-figs. 25, 29: 20-22, 80.

Alveolina oblonga D'ORBIGNY, 1826

= *Alveolina oblonga* n. sp. - D'ORBIGNY: 306, fig. 4;

= *Alveolina oblonga* D'ORBIGNY - NUTTALL (1925): 446; pl. 27, fig. 8;

= *Alveolina oblonga* D'ORBIGNY - HOTTINGER (1960): 141; pl. 9, figs. 4-16.

Assilina dandotica DAVIES, 1937

= *Assilina dandotica* n. sp. - DAVIES in DAVIES & PINFOLD: 28-29; pl. 4, figs. 1-3, 6-8;

= *Assilina dandotica* DAVIES - SCHAUB (1981): 206-207; pl. 84, figs. 1-16, tab. 18a.

Assilina daviesi DE CIZANCOURT, 1938

= *Assilina daviesi* n. sp. - DE CIZANCOURT: 23; pl. 3, figs. 18, 25-26; tab. 2b (B generation);

= *Assilina daviesi* var. *nammalensis* n. subsp. - GILL (1953): 82; pl. 13, figs. 1-5 (A generation).

Assilina lacunata DE CIZANCOURT, 1946

= *Assilina umbilicata* n. sp. - DE CIZANCOURT: 23;pl. 3, figs. 19-20, 27 (B generation;

= *Assilina subumbilicata* n. sp. - DE CIZANCOURT: 24; pl. 3, figs. 21-23 (A generation);

= *Assilina lacunata* nom. nov. - DE CIZANCOURT (1946): 335;

Assilina laminosa GILL, 1953

= *Assilina laminosa* n. sp. - GILL: 83; pl. 13, figs. 14-17 (B generation);

= *Assilina sublaminosa* n. sp. - GILL (1953): 83; pl. 13, figs. 18-19 (A generation).

Assilina leymeriei (D'ARCHIAC & HAIME, 1853)

= *Nummulites leymeriei* n. sp. - D'ARCHIAC & HAIME: 153; pl. 11, fig. 9a-c;

= *Assilina leymeriei* (D'ARCHIAC & HAIME) - SCHAUB (1981): 196-197; fig. 113; pl. 71, figs. 56-74; pl. 72, figs. 1-53, tab. 16d.

Assilina pustulosa DONCIEUX, 1926

= *Assilina pustulosa* n. sp. - DONCIEUX: 52; pl. 5, figs. 36-43; pl. 6, fig. 1 (B generation);

= *Assilina subpustulosa* n. sp. - DONCIEUX (1926): 53; pl. 5, fig. 20; pl. 6, figs. 2-3 (A generation);

= *Assilina pustulosa* DONCIEUX - SCHAUB (1981): 207-208; fig. 115; pl. 84, figs. 28-50, 53, 59-96; tab. 18b.

Assilina spinosa DAVIES, 1937

= *Assilina spinosa* n. sp. - DAVIES in DAVIES & PINFOLD: 31-33; pl.4, figs. 11-12, 16-17 (B generation);

= *Assilina subspinosa* n. sp. - DAVIES in DAVIES & PINFOLD (1937): 33-34; pl. 4, figs. 19-20, 23-26 (A generation);

= *Assilina spinosa* DAVIES - SCHAUB (1981): 196; pl. 71, figs. 53-55.

Dictyoconoides cooki (CARTER, 1861)

= *Conulites cooki* n. sp. - CARTER: 83; pl. 15, figs. 7a-g;

= *Dictyoconoides cooki* (CARTER) - SMOUT (1954): 59-60; pl. 9, figs. 1-5.

Dictyokathina simplex SMOUTH, 1954

= *Dictyokathina simplex* n. sp. - SMOUTH: 64-66; pl. 8, figs. 1-11.

Discocyclina dispansa (SOWERBY, 1840)

= *Lycophris dispansa* n. sp. - SOWERBY: 327; pl. 24, figs. 16a-b;

= *Discocyclina dispansa* (SOWERBY) - NUTTALL (1926): 157; pl. 7, figs. 1-3, 5;

= *Discocyclina dispansa* (SOWERBY) - NAGAPPA (1959): 181; pl. 10, figs. 6-8;

= *Discocyclina dispansa* (SOWERBY) - SEN GUPTA (1963): 39; pl. 1, figs. 1-9.

Discocyclina dorreeni BAYLISS, 1961

= *Discocyclina dorreeni* n. sp. - BAYLISS: pl. 22, figs. 1-9. Probably the taxonomical status of this species is questionable.

Discocyclina ranikotensis DAVIES, 1927

= *Discocyclina ranikotensis* n. sp. - DAVIES: 281-282; pl. 22, figs. 10-12.

Discocyclina sowerbyi NUTTALL, 1926

= *Discocyclina sowerbyi* n. sp. - NUTTALL: 149; pl. 8, figs. 1-3;

= *Discocyclina sowerbyi* NUTTALL - NAGAPPA (1959): 181; pl. 11, figs. 1-2;

= *Discocyclina sowerbyi* NUTTALL - SEN GUPTA (1963): 41; pl. 2, fig. 2; pl. 3, figs. 1-10.

Discocyclina undulata NUTTALL, 1926

= *Discocyclina undulata* n. sp. - NUTTALL: 150; pl. 7, figs. 8-9; pl. 8,fig. 5;

= *Discocyclina undulata* NUTTALL - NAGAPPA (1959): 181; pl. 10, figs. 9-10.

Flosculina globosa (LEYMERIE, 1846)

= *Alveolina subpyrenaica* var. *globosa* n. subsp. - LEYMERIE: 359; pl. 13, fig. 10a-c;

= *Flosculina globosa* (LEYMERIE) - NUTTALL (1925): 435; pl. 23, figs.1-4; pl. 24, figs. 4-6;

= *Alveolina globosa* LEYMERIE - HOTTINGER (1960): 80; pl. 3, figs. 15-20.

Kathina maior SMOUTH, 1954

= *Kathina major* n. sp. - SMOUTH: 63-64; pl. 6, figs. 1-10.

Kathina selveri SMOUTH, 1954

= *Kathina selveri* n. sp. - SMOUTH: 62-63; pl. 6, figs. 11-13.

Lockhartia altispira SMOUTH, 1954

= *Lockhartia altispira* n. sp. - SMOUTH: 51-52; pl. 4, figs. 4-6.

Lockhartia conditi (NUTTALL, 1926)

= *Dictyoconoides conditi* n. sp. - NUTTALL: 119; pl. 11, figs. 7-8;

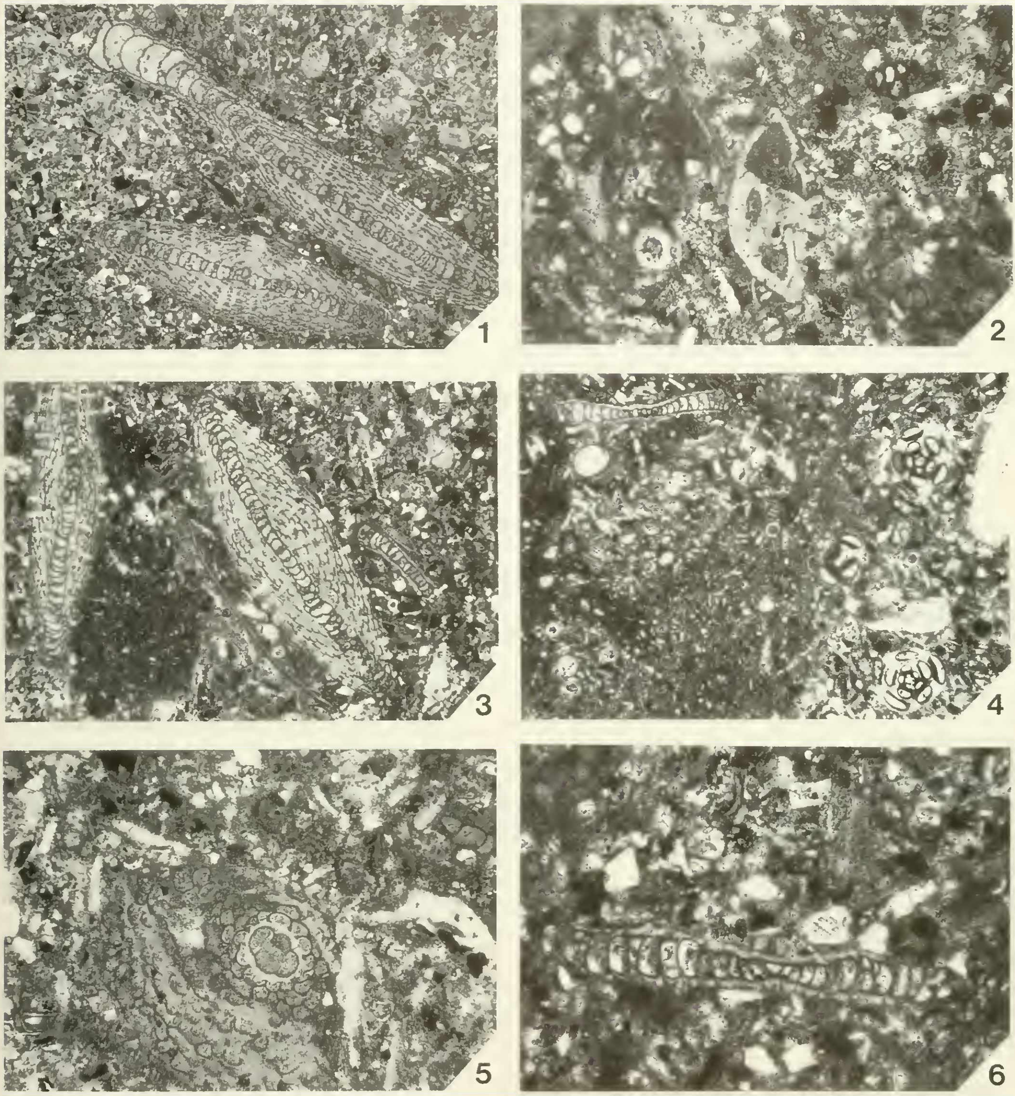
= *Lockhartia conditi* (NUTTALL) - DAVIES (1932): 408; pl. 2, fig. 7; pl. 4, fig. 7;

= *Lockhartia conditi* (NUTTALL) - DAVIES & PINFOLD (1937): 47-48; pl. 5, fig. 24;

= *Lockhartia conditi* (NUTTALL) - SMOUTH (1954): 55; pl. 5, figs. 16-19.

Lockhartia conica SMOUTH, 1954

= *Lockhartia conica* n. sp. - SMOUTH: 53; pl. 4, figs. 1-3.



WEISS, W.: Maastrichtian to Eocene foraminiferal assemblages of Pakistan — Plate 9

Plate 9 Rakhi Nala section, Sulaiman Range. Larger foraminifers.

Fig. 1 *Orbitoides tissoti* SCHLUMBERGER, *Orbitoides* aff. *media* (D'ARCHIAC) and others. - SmR-15/S 1421; about 8 x; Early Maastrichtian.

Fig. 2 ?*Rotalia* cf. *trochidiformis* (LAMARCK). - SmR-15a/S 1421; about 46 x; Early Maastrichtian.

Fig. 3 *Orbitoides tissoti* SCHLUMBERGER, *Omphalocyclus macroporus* (LAMARCK) and others. - SmR-15a/S 1421; about 20 x; Early Maastrichtian.

Fig. 4 Large miliolids, *Omphalocyclus macroporus* (LAMARCK) (left) and others. - SmR-15a/S 1421; about 23 x; Early Maastrichtian.

Fig. 5 Quadrilocular nucleoconch (= protoconch, deuteroconch, two auxiliary chambers) surrounded by a thick wall and several epi-auxiliary chambers of *Orbitoides tissoti* SCHLUMBERGER. - SmR-15a/S 1421; about 46 x; Early Maastrichtian.

Fig. 6 *Omphalocyclus macroporus* (LAMARCK) showing close affinities to juvenile specimens of *Orbitoides tissoti* SCHLUMBERGER. - SmR-15a/S 1421; about 46 x; Early Maastrichtian.

Lockhartia haimei (DAVIES, 1927)

= *Dictyoconoides haimei* n. sp. - DAVIES: 280-281; pl. 21, figs. 13-15;

= *Lockhartia haimei* (DAVIES) - DAVIES (1932): 407; pl. 2, figs. 4-6;

= *Lockhartia haimei* (DAVIES) - DAVIES & PINFOLD (1937): 45-46; pl. 7, figs. 9-13, 15;

= *Lockhartia haimei* (DAVIES) - SMOUTH (1954): 49-50; pl. 2, figs. 1-14.

Lockhartia hunti OVEY, 1947

= *Lockhartia hunti* n. sp. - OVEY: 573; pl. 10, figs. 1-6; pl. 11, fig. 1;

= *Lockhartia hunti* OVEY - SMOUTH (1954): 54; pl. 4, fig. 7.

Lockhartia hunti pustulosa SMOUTH, 1954

= *Lockhartia hunti* var. *pustulosa* n. subsp. - SMOUTH: 54-55; pl. 4, figs. 8-10.

Lockhartia tipperi (DAVIES, 1926)

= *Conulites tipperi* n. sp. - DAVIES: 247-248; pl. 18, fig. 8;

= *Lockhartia tipperi* (DAVIES) - DAVIES (1932): 407;

= *Lockhartia tipperi* (DAVIES) - DAVIES in DAVIES & PINFOLD (1937): 48-49; pl. 6, figs. 14-16; pl. 7, fig. 17;

= *Lockhartia tipperi* (DAVIES) - SMOUTH (1954): 55; pl. 4, figs. 11-13.

Miscellanea miscella (D'ARCHIAC & HAIME, 1854)

= *Nummulites miscella* n. sp. - D'ARCHIAC & HAIME: 345; pl. 35, figs. 4a-c;

= *Siderolites stampei* n. sp. - DAVIES (1927): 278; pl. 21, figs. 1-8;

= *Miscellanea miscella* (D'ARCHIAC & HAIME) - PFENDER (1935): 231-235, figs. 1-4; pl. 11, figs. 6-7; pl. 13, figs. 2-4;

= *Miscellanea miscella* (D'ARCHIAC & HAIME) - DAVIES & PINFOLD (1937): 43-45; pl. 6, figs. 1-3, 5, 7-8.

Nummulites atacicus LEYMERIE, 1846

= *Nummulites atacica* n. sp. - LEYMERIE (1846): 358; pl. 13, figs. 13a-e;

= *Nummulites atacicus* LEYMERIE - H. DOUVILLÉ (1919): 38, fig. 2; pl. 3, figs. 3-6 (B generation);

= *Nummulites subatacicus* n. sp. - H. DOUVILLÉ (1919): 41, fig. 3; pl. 3, figs. 7-8 (A generation);

= *Nummulites atacicus* LEYMERIE - SCHAUB (1981): 119-120; pl. 25, figs. 1-51; tab. 14i.

Nummulites crasseornata (HENRICI, 1934)

= *Camerina crasseornata* n. sp. - HENRICI: 32, 52; pl. 2, figs. 2-5, 12; text-fig. 15.

Nummulites fossulata DE CIZANCOURT, 1946

= *Nummulites fossulata* n. sp. - DE CIZANCOURT: 644, 648, 654; pl. 10, figs. 6-8; text-fig. 1.

Nummulites globulus LEYMERIE, 1846

= *Nummulites globulus* n. sp. - LEYMERIE (1846): 359; pl. 13, figs. 14a-d;

= *Nummulites globulus* LEYMERIE - SCHAUB (1981): 137-138; pl. 40, figs. 1-80; tab. 1f.

Nummulites vanderstoki RUTTEN & VERMUNT, 1932

= *Nummulites vanderstoki* n. sp. - RUTTEN & VERMUNT: 240; pl. 1, fig. 8a-b; pl. 2, figs. 6, 12.

Operculina aspensis COLOM, 1954

= *Operculina aspensis* n. sp. - COLOM: 183; pl. 10, figs. 6-8.

= *Operculina aspensis* COLOM - HOTTINGER (1977): 95; fig. 37o-v.

Operculina canalifera D'ARCHIAC & HAIME, 1853

= *Operculina canalifera* D'ARCHIAC & HAIME - NUTTALL (1926): 117; pl. 11, figs. 1-2.

Operculina patalaensis DAVIES, 1937

= *Operculina patalaensis* n. sp. - DAVIES in DAVIES & PINFOLD (1937): 38-39; pl. 5, figs. 6, 17, 19, 26 (B generation).

= *Operculina jiwani* n. sp. - DAVIES in DAVIES & PINFOLD (1937): 39-40; pl. 5, figs. 11-14, 16 (A generation).

Operculina salsa DAVIES, 1937

= *Operculina salsa* n. sp. - DAVIES in DAVIES & PINFOLD (1937): 37; pl. 5, figs. 1, 3, 7, 10, 15 (B generation);

= *Operculina subsalsa* n. sp. - DAVIES in DAVIES & PINFOLD (1937): 37; pl. 5, figs. 2, 4, 8-9 (A generation).

Orbitolites complanatus LAMARCK, 1801

= *Orbitolites complanatus* n. sp. - LAMARCK: 376;

= *Orbitolites complanata* LAMARCK - NUTTALL (1925): 447;

= *Orbitolites complanata* LAMARCK - DAVIES (1937): 66.

Ranikothalia sp.

Under this genus specimens were united which were either close to *Operculina sindensis* DAVIES, 1927, and *Operculina bermudezi* PALMER, 1934, which are regarded as *Ranikothalia sindensis* (DAVIES), or close to *Nummulites nuttali* DAVIES, 1927, which is regarded as *Ranikothalia nuttalli* (DAVIES) (compare HOTTINGER 1977: 50-52, BUTT 1987, 1991).

Rotalia trochidiformis (LAMARCK, 1804)

= *Rotalites trochidiformis* n. sp. - LAMARCK: 183-185;

= *Dictyoconoides newboldi* (D'ARCHIAC & HAIME, 1854) - DAVIES (1927): 279; pl. 22, figs. 1-4;

= *Rotalia trochidiformis* (LAMARCK) - SMOUTH (1954): 43-45; pl. 1, figs. 1-6.