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THE OLIGOCENE FORAMINIFERAL BIOSTRATIGRAPHY OF PAKISTAN

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Key–words: Biostratigraphy, Foraminifera, Oligocene, Pakistan.

Abstract. The marine Oligocene deposits of Pakistan are exposed in the Baluchistan and Lower Indus Basins. The Baluchistan Basin deposits are referred to the Khojak Formation of Makran Group. They represent three planktic foraminiferal zones, the *Globigerina ampliapertura* Zone, *G. ciperoensis* Zone and *Globorotalia kugleri* Zone, corresponding to Early, Middle and Late Oligocene. The Lower Indus Basin deposits of Sind include the Kirthar and Nari Formations. On the basis of the larger Foraminifera these deposits are divided into *Nummulites fichteli* Zone (Early Oligocene), *N. fichteli/Lepidocyclina* (*E.*) *dilatata* Zone (Mid. Oligocene), and *L. dilatata* Zone (Late Oligocene). The Oligocene deposits are absent in the Upper Indus Basin due to the orogenic movement which took place at the end of the Eocene and continued in the Oligocene.

Introduction.

The Oligocene deposits are extensively exposed in the Baluchistan and the Lower Indus Basins of Pakistan. In the Upper Indus Basin the Oligocene deposits are missing. The Baluchistan deposits are of flysch type, rich in planktic and benthic Foraminifera. In the Lower Indus Basin these deposits are mainly carbonate with some intercalations of clastic sediments. A pronounced change in the sedimentation took place during the Oligocene time in Pakistan. The carbonate deposition which was most conspicuous in the Lower Indus Basin was replaced by clastic sedimentation in the Baluchistan Basin. This was followed by non deposition of Oligocene strata in the Upper Indus Basin, coinciding with the first orogenic movements responsible for the development of the Himalayan mountain ranges. Orogeny started in the Late Eocene and continued intermittently throughout the Cenozoic.

The Late Eocene–Oligocene deposits of the Baluchistan Basin designated as the Khojak Formation of the Makran Group are intruded by igneous rocks known as Shor Koh and Ras Koh intrusions. In the Lower Indus Basin the Oligocene deposits include the Upper Kirthar Formation and the Nari Formation of the Momani Group. These deposits are predominantly non clastic, but Upper

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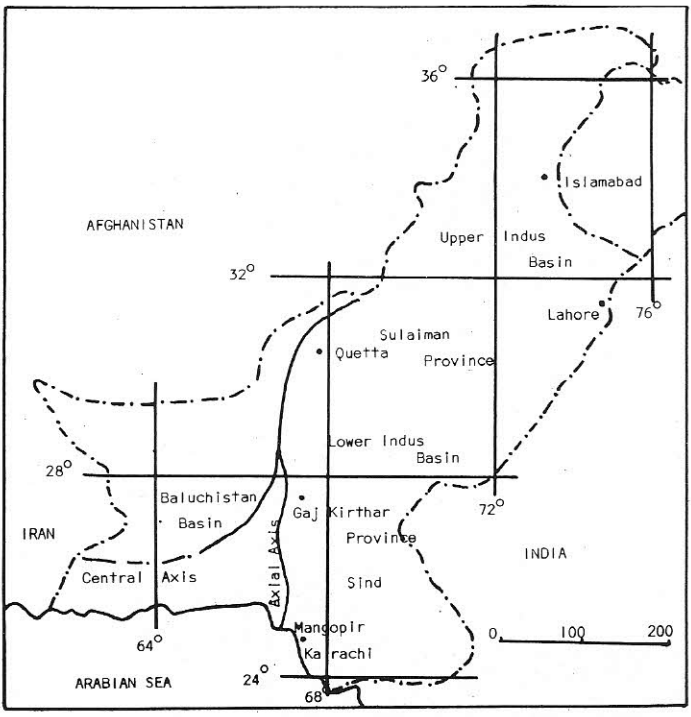
Nari is clastic and in part non. All are of marine origin and characterized by planktic and larger Foraminifera.

Paleogeography and stratigraphy.

The sedimentary deposits of Pakistan belong to three distinct sedimentary basins (Kureshy, 1972). These basins are the Baluchistan Basin, the Lower Indus Basin, and the Upper Indus Basin, the first two containing the Oligocene deposits. The Oligocene stratigraphy of these basins are separately discussed and the geographic position of these basins is shown in Text–fig. 1.



Text–fig. 1 – Map showing sedimentary basins of Pakistan.

Baluchistan Basin. This basin extends from 66° east longitude to the border with Iran. It is bounded by Afghanistan to the North and by the Arabian sea to the South. The Tertiary deposits of the Baluchistan Basin are predominantly of flysch origin with abundant calcite veins: they are much distorted by tectonic movements.

The Khojak Formation of the Baluchistan Basin was assigned to the Oligocene by Cheema et al. (in Shah, 1977) under the guidelines of the stratigraphic

code of Pakistan. These deposits were previously assigned to Siahan and Panjgur Formations by Hunting Survey Corporation (1960), although they were originally assigned to Khojak by Vredenburg (1909). The Khojak Formation consists of alternating shales and sandstones of huge thickness; it is overlain by the Hinglaj Formation of Miocene age in the central Makran region of the Baluchistan Basin.

Lower Indus Basin. The Lower Indus Basin lies south of 32° latitude N and is bounded by the Baluchistan basin to the west and by the Indian shield to the east. The Oligocene deposits include both clastic and non clastic sediments referred to the Kirthar and Nari Formations. The Kirthar Formation ranges in age from Middle Eocene to Middle Oligocene (Kureshy, 1980). The upper part of the Kirthar Formation of Oligocene age is a limestone deposit rich in larger Foraminifera. The Lower Nari Formation is mainly limestone but the Upper Nari Formation is composed of sandstone, shale and some limestone. Cheema et al. (in Shah, 1977) placed this formation in the Momani Group, which also includes the Gaj Formation of Lower Miocene age. The Nari Formation is overlain by the Miocene Gaj Formation and underlain by the Kirthar Formation.

Upper Indus Basin. This basin lies north of 32° latitude N in the northern part of the country. No Oligocene deposits are exposed. Middle Eocene deposits are succeeded by the Lower Miocene Murree Formation of the Rawalpindi Group. This hiatus in deposition resulted from the Himalayan orogeny which began during Eocene–Oligocene time and continued throughout the Cenozoic.

Towards the end of the Eocene a distinct upheaval took place in Pakistan, which marked the commencement of the formation of Himalayan mountain ranges. The great thickness of sediments which have accumulated in the Tethys sea was compressed and emerged as the sea becomes shallower and restricted in extent. As a result marine Oligocene and Miocene deposits were restricted in occurrence to the southern part of the Lower Indus Basin and were completely missing from the Upper Indus Basin. Although marine Oligocene deposits are quite abundant in the Baluchistan Basin, they were severely affected by the tectonic movements during the Himalayan orogeny. The stratigraphic succession and the relationship of the various formation of these basins is shown in Table 1.

Biostratigraphy.

The foraminiferal assemblages are the most diagnostic for biostratigraphic studies of the Oligocene deposits of Pakistan. On the basis of the restricted stratigraphic ranges of the planktic and the larger Foraminifera several biostratigraphic zones were recognized in the Baluchistan and the Lower Indus Basins of Pakistan. The clastic Oligocene deposits of the Baluchistan Basin are rich in planktic Foraminifera, whereas the Lower Indus Basin deposits of clastic and

non clastic origin, are characterized by both larger and planktic foraminiferal assemblages. These assemblages are discussed separately under their respective sedimentary basins.

Baluchistan Basin. The Oligocene planktic Foraminifera are recorded from the Khojak Formation, divided into three biostratigraphic zones (Kureshy, 1977). Those zones are, *Globigerina ampliapertura* Zone, the *G. ciperoensis* and *Globorotalia kugleri* Zones, corresponding to the Early Oligocene, the Middle Oligocene and the Late Oligocene respectively. The planktic foraminiferal fauna of the Baluchistan Basin includes: *Globigerina ampliapertura* Bolli, *G. parva* Bolli, *G. ciperoensis* Bolli, *G. senilis* Hedberg, *G. venezuelana* Hedberg, *G. officinalis* Subbotina, *G. tripartita* Koch, *G. trilocularis* d'Orbigny, *G. pseudovenezuelana* Blow & Banner, *G. yeguaensis* Weinzierl & Applin, *Globorotalia nana* Bolli, *G. opima* Bolli, *G. praebulloides* Blow, *G. mayeri* Cushman & Ellisor, *G. kugleri* Bolli, *Catapsydrax dissimilis* (Cushman & Bermudez), *C. unicavus* Bolli,

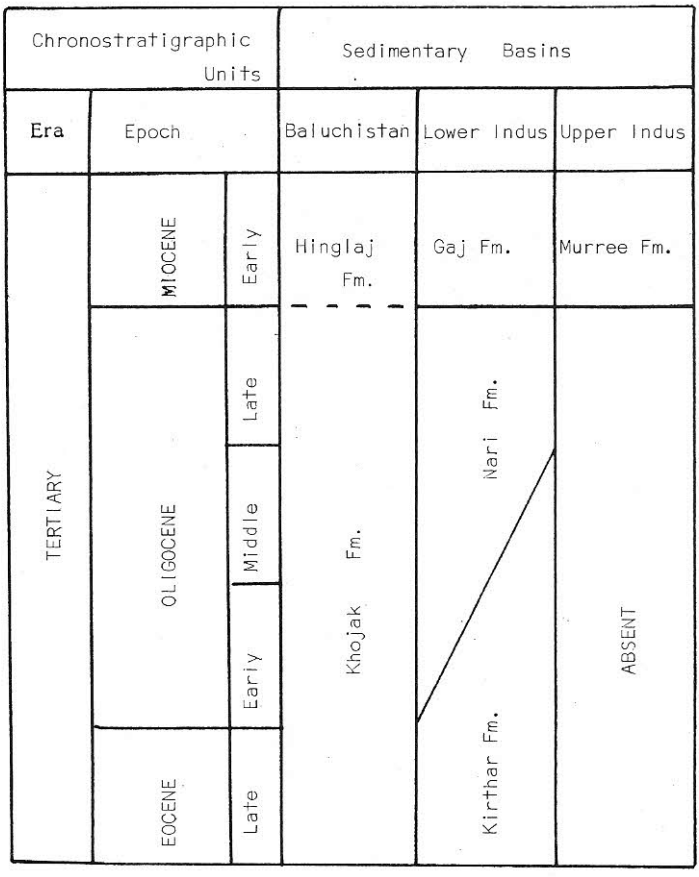


Table 1 – Generalized stratigraphic succession of Oligocene of Pakistan.

Loeblich & Tappan, and *Globigerinita pera* (Todd). The stratigraphic ranges of these taxa are shown in Table 2.

Lower Indus Basin. The Oligocene deposits of the Lower Indus Basin are both clastic and non clastic, and are characterized by the larger and planktic Foraminifera.

The Oligocene larger Foraminifera of the Upper Kirthar and Nari Formations were previously described by Kureshy (1970, 1975, 1978, 1980). In 1978 the author divided the Oligocene carbonate deposits into three biostratigraphic zones based on the larger Foraminifera, corresponding to the three fold divisions of the Oligocene. The *Nummulites fichteli* Zone correponds to the Early Oligocene, the *N. fichteli/Lepidocyclina* (*E.*) *dilatata* Zone corresponds to Middle Oligocene, and the *L. dilatata* Zone of Late Oligocene. The characteristic species of these zones are: *Nummulites fichteli* (Michelotti), *N. intermedius* (d'Archiac) B form of *N. fichteli, Lepidocyclina* (*E.*) *dilatata* (Michelotti), *L. undosa* Cushman, *L. foresti* Vaughan, *L. canellei* Lemoine & Douvillé, *L. pustulosa* Douvillé, *Heterostegina involuta* Silvestri, *Cycloclypeus communis* Martin, *Spiroclypeus bullbrooki* Vaughan & Cole, and *Operculina* sp.

The following larger Foraminifera are recorded from the Nari Formation

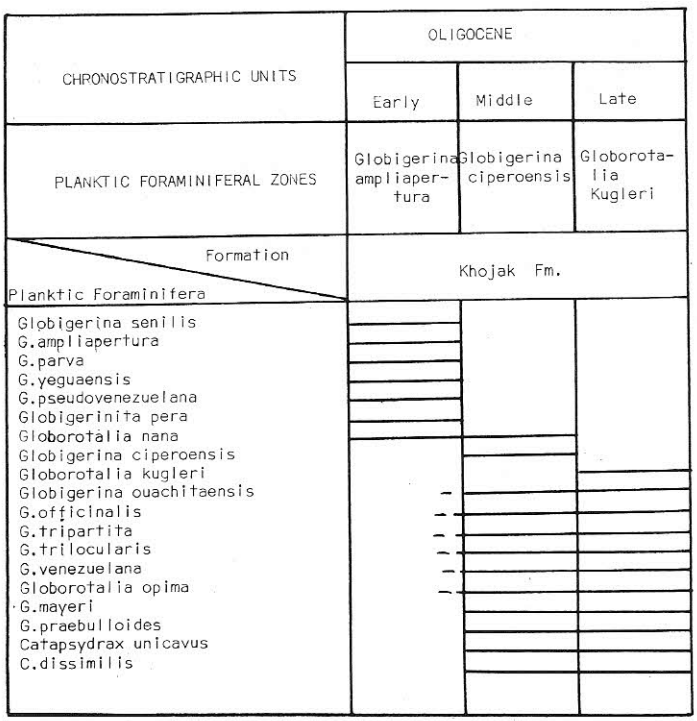


Table 2 – Stratigraphic ranges of Oligocene selected planktic Foraminifera of Pakistan (Baluchistan Basin).

of Mangopir: *Spiroclypeus leupoldi* Van der Vlerk, *S. bullbrooki* Vaughan & Cole, *S. margaritatus* (Schwager), *S. tidoenganensis* Van der Vlerk, *Lepidocyclina pustulosa* Douvillé, *L. glabra* Rutten, *L. mantelli* (Morton), *L. bornensis* (Provale), *L. parva* Oppenoorth, *L. undosa* Cushman, *L. canellei* Lemoine & Douvillé, *L. foresti* Vaughan, *Cycloclypeus communis* Martin and *Heterostegina antillea* Cushman (Kureshy, 1982 a). The following planktic Foraminifera are recorded from the Nari Formation of Gaj River Section of the Lower Indus Basin: *Globigerina ouachitaensis gnaucki* Blow & Banner, *G. ciperoensis* Bolli, *G. officinalis* Subbotina, *G. baconica* Samuel, *G. angiporoides minima* Jenkins, *G. oligocaenica* Blow & Banner, *G. senelis* Bandy, *G. venezuelana* Hedberg, *G. cancellata* Pessagno, *Globorotalia opima* Bolli, *G. nana* Bolli, *G. munda* Jenkins, *G. praebulloides occlusa* Blow & Banner, *Catapsydrax dissimilis* (Cushman & Bermudez), and *Globigerinita pera* (Todd). The above planktic assemblages of Nari Formation belong to the *Globigerina ciperoensis* Zone of Middle Oligocene, which was described from the Baluchistan Basin by Kuresky (1977). The stratigraphic ranges of Oligocene larger Foraminifera are shown in Table 3.

Regional correlation.

The Oligocene larger and planktic foraminiferal assemblages of Pakistan are cosmopolitan in occurrence and resemble the Oligocene fauna of the Ca-

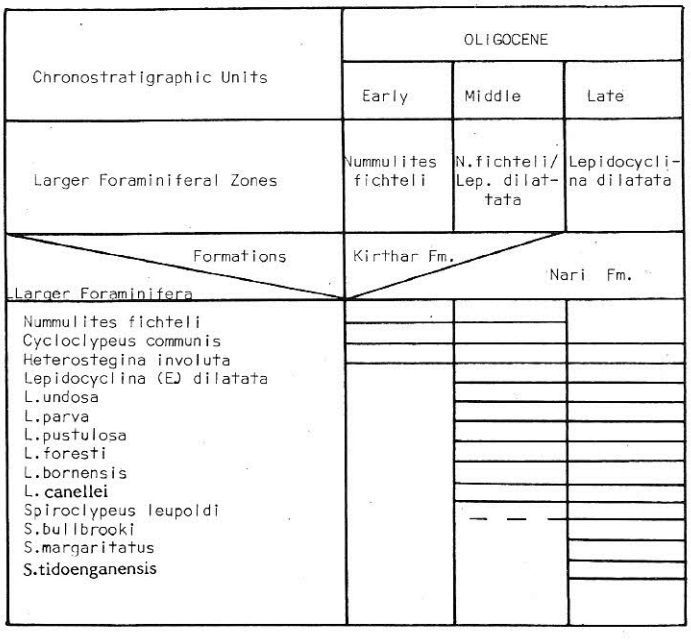


Table 3 – Stratigraphic ranges of Oligocene selected larger Foraminifera of Pakistan (Lower Indus Basin).

ribbean region. The planktic Foraminifera closely resemble those of Trinidad, whereas the larger Foraminifera show close affinity to the Oligocene larger foraminiferal assemblages from Far East, particularly from Philippines.

Planktic Foraminifera. The Oligocene planktic Foraminifera of Pakistan resemble the planktic Foraminifera of Trinidad described by Bolli (1957). The common assemblages of these areas are: *Globigerina ampliapertura* Bolli, *G. tripartita* Koch, *G. venezuelana* Hedberg, *G. ciperoensis* Bolli, *Globorotalia mayeri* Cushman & Ellisor, *G. opima* Bolli, *G. kugleri* Bolli, *Catapsydrax dissimilis* (Cushman & Bermudez), and *C. unicavus* Bolli. Fleisher (1977) described the Oligocene planktic Foraminifera from the Indian Ocean and stated that Oligocene foraminiferal fauna are very poor in the deep sea cores. Unconformities frequently represent long period of time of non deposition. Intense calcium carbonate dissolution also has drastically altered the species composition of the Oligocene and substantially increased the difficulty involved in correlation and age determination. However, Fleisher (1977) zoned these assemblages on the basis of Bolli's (1977) zonation with some modification.

Larger Foraminifera. The Oligocene larger Foraminifera of Pakistan have also been recorded from Oligocene deposits around the world particularly in Indo–Pacific region. Nuttall (1926) reported *Lepidocyclina dilatata* from the Nari Formation of Sind, Pakistan. Vaughan and Cole (1941) reported the *Lepidocyclina canellei, L. foresti, L. mantelli, L. undosa, Spiroclypeus bullbrooki* and *Heterostegina antillea* from the Oligocene deposits of Trinidad and Cole (1952) reported *Lepidocyclina canellei, L. mantelli, L. undosa* and *Heterostegina antillea* from the Oligocene deposits of the Panama Canal zone and vicinity.

Puri (1954) reported that species conspecific with *Nummulites fichteli, N. intermedius* and *Lepidocyclina mantelli* had been described from the Nari Formation. Hunting Survey Corporation (1960) assigned the Nari Formation to Oligocene/Miocene age and in the faunal list mentioned many diagnostic and stratigraphically restricted species of Eocene age. Adams (1967) divided the larger Foraminifera bearing Oligocene strata of Tethys and Indo–Pacific regions into three units, on the basis of the larger Foraminifera, the Lower Oligocene (Lattorfian) is characterized by *Nummulites*, the Middle Oligocene (Rupelian) by *Eulepidina* with *Nummulites* and the Upper Oligocene (Chattian) by *Eulepidina*. Adams (1970) further stated that the lower part of Nari Formation conformably overlies the Kirthar Formation, and assigned the larger Foraminifera of Nari Formation to Tc (Lower Oligocene), Td (Middle Oligocene) and Lower Te (Upper Oligocene). Khan (1969) stated that Upper Nari in Orangi, Karachi is of Upper Oligocene (Chattian) to Lower Miocene (Aquitanian) age, but in the Gaj River section the Nari Formation is of Middle and Upper Oligocene age. He listed *Spiroclypeus blanckenhorni ornata, S. ranjai, S. margaritatus, Eulepi-*

dina dilatata, E. formosa, Nephrolepidina angulosa, and *Miogypsinoides* sp. He further stated that abundant *Spiroclypeus* species are characteristic of Upper Nari and the first appearance of *Miogypsina* is characteristic of the Lower Miocene Gaj Formation. The above assemblages of Nari Formation as listed by Khan (1969) are diagnostic to Oligocene age (Clark & Blow, 1969; Adams, 1970).

Hashimoto et al. (1977) described the larger Foraminifera of Philippines and recorded the following assemblages from Tc, Td, and Te 1–4 stages of the "Letter Classification of East Indies", which equated to Oligocene. These species are: *Nummulites fichteli* (Michelotti), *N. intermedius* (d'Archiac), *Eulepidina dilatata* (Michelotti), *E. favosa* (Cushman), *Spiroclypeus leupoldi* Van der Vlerk, *S. tidoenganensis* Van der Vlerk, and *S. margaritatus* (Schlumberger). These assemblages are identical to the larger Foraminifera of Nari Formation of Pakistan.

Eocene–Oligocene boundary.

The Eocene/Oligocene boundary in Pakistan is well marked by the foraminiferal fauna, the planktic and larger forms being most diagnostic. On the basis of the planktic Foraminifera the extinction of *Globorotalia cerroazulensis* Cole marked the end of the Late Eocene. In general the extinction of *Hantkenina, Globigerapsis, Clavigerinella* and *Cribrohantkenina* marked the end of the Late Eocene and first appearance of *Cassigerinella* marked the beginning of Early Oligocene. The Eocene/Oligocene boundary is better recognized in Pakistan on the basis of the larger Foraminifera (Kureshy, 1982b). The larger Foraminifera genera *Assilina, Lockhartia, Discocyclina, Alveolina, Pellatispira, Dictyoconoides, Dictyoconus,* and majority of the species of *Nummulites* become extinct during the Eocene. The first appearance of *Nummulites fichteli, Cycloclypeus communis,* and *Heterostegina involuta* at the base of the Oligocene marked the Eocene/Oligocene boundary in Pakistan.

Bandy (1964) noted the extinction of *Hantkenina, Cribrohantkenina,* at the Eocene/Oligocene boundary. Bolli (1966) marked the Eocene/Oligocene boundary between *Globorotalia cerroazulensis* Zone (Upper Eocene) and *Cassigerinella chipolensis / Hastigerina micra* Zone of Lower Oligocene. Blow (1969) and Berggren (1971) placed the Eocene/Oligocene boundary between P17 (*Globigerina gortanii gortanii / Globorotalia centralis*) and P 18 (*Globigerina tapuriensis*) Zones. Clark and Blow (1969) stated that occurrence of *Discocyclina, Nummulites hormoensis, Pellatispira madaraszi* and *Chapmanina gassinensis* have been taken as indicating the Eocene. Although *Chapmanina gassinensis* is reported to occur in Early Oligocene in Northern Italy, these forms seem to occur in a horizon prior to the upper part of Zone P 17 and do not range into later part of Zone P17 or into Zone P18. Thus the Eocene/Oligocene boundary

is within Zone P17. Theyer and Hammond (1974) placed the Eocene/Oligocene boundary at 37.5 m.y.B.P., which falls within a long sequence of reversed magnetic polarity that may be correlated with the magnetic anomalies 12 and 13 of the sea spreading. Hardenbol and Berggren (1978) placed the Eocene/Oligocene boundary within Zone P17, marked by *Turborotalia cerroazulensis* (Late Eocene) and *Pseudohastigerina micra* Zone (Early Oligocene), which is radiometrically calibrated to 37 m.y.B.P. and correlated to 14 and 15 magnetic anomalies.

Oligocene–Miocene boundary.

The Oligocene/Miocene deposits of Pakistan are characterized by distinct assemblages of planktic and larger Foraminifera. The Oligocene/Miocene boundary is marked by the first appearance of the planktic Foraminifera *Globigerinoides* at the base of the Miocene (Kureshy, 1977, 1982 b), and by the extinction of the larger Foraminifera *Lepidocyclina* (*E.*) *dilatata* and *Spiroclypeus margaritatus* at the end of the Oligocene. The base of the Early Miocene (Aquitanian) is marked by the first appearance of the species *Miogypsina gunteri* and *Miogypsinoides dehaartii* (see Kureshy, 1978).

Bandy (1964) defined the Oligocene/Miocene boundary on the basis of the initial appearance of *Globigerinoides trilobus* datum at the base of Miocene. Bolli (1957, 1966) placed the Oligocene/Miocene boundary between the *Globorotalia kugleri* Zone (Upper Oligocene) and *Catapsydrax dissimilis* Zone (Lower Miocene). Blow (1969) and Bergreen (1971) placed the Oligocene/Miocene boundary between Zone N 3 (*Globigerina angulisuturalis*) and N 4 (*Globigerinoides primordius/Globorotalia kugleri* Zone) and recorded the *Globigerinoides* datum plane for the basal Miocene. Theyer and Hammond (1974) placed the Oligocene/Miocene boundary at the base of Zone N4 of Blow (1969) which coincides with a magnetic polarity epoch 21 at 23 to 24 m.y.B.P. Hardenbol and Berggreen (1978) estimated the duration of Oligocene as 13 m.y., between 24 to 37 m.y.B.P. Hashimoto et al. (1977) placed the Oligocene/Miocene boundary at the first appearance of *Miogypsina* species in basal Miocene in Philippines and correlated it with Blow's Zone N 4 by the first appearance of *Globigerinoides* datum.

Summary and conclusions.

The Oligocene deposits of Pakistan are characterized by clastic and non clastic facies which are exposed in the Baluchistan and Lower Indus Basins. These marine deposits are rich in foraminiferal assemblages. On the basis of the planktic and larger Foraminifera the Oligocene strata are divided into three biostratigraphic zones, corresponding to three fold divisions of Oligocene. The non

clastic facies of the Lower Indus Basin are divided into three zones: the *Nummulites fichteli* Zone, *N. fichteli/Lepidocyclina* (*E.*) *dilatata* Zone and *L. dilatata* Zone belonging to Early, Middle and Late Oligocene respectively.

The clastic deposits of the Baluchistan Basin are divided into three planktic foraminiferal zones, the *Globigerina ampliapertura*, the *G. ciperoensis*, and the *Globorotalia kugleri*, corresponding to Early Oligocene, Middle Oligocene and Late Oligocene respectively. Oligocene deposits are not represented in the Upper Indus Basin, due to the orogenic movement, which took place at the end of the Eocene and continued till the Oligocene, and which marked the beginning of the formation of the Himalayan mountain ranges.

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