6. CORRELATION AND AGE

In the recent past Tertiary planktonic foraminiferal biostratigraphy has been given a great attention because of its use in the establishment of precise and relatively high-resolution biostratigraphy. This biostratigraphic work has provided an excellent basis for regional and interregional correlation (Figure 12) applicable to the Tertiary marine sedimentary sequences. Initially Paleogene biostratigraphic subdivisions were established separately in two different geographic areas, in Caucasus, Eastern Hemisphere (Subbotina, 1953; Krasheninnikove, 1965a, b; 1969), and in the Western Hemisphere, Trinidad (Bolli, 1957a, b).

6.1 Correlation of the Paleogene biozone established in this study with internationally recognised Paleogene schemes in low latitude regions

For the low latitude areas, several Paleogene biostraigraphic schemes have been established and recognised all over the world. One is represented by Bolli's zonation and it's revised one (Bolli, 1957, 1966; Toumarkine and Luterbacher, 1985). The other one is the P-zonation of Blow (1979) and its modification by Berggren et al. (1988; 1995). For the Paleocne zonation, Berggren and Norris (1997) however, the clad and stratigraphic ranges of many Paleocene species differ from Blow's original description. Recently, Berggren and Norris (1997) and Olsson et al. (1999) published the updated versions for the Paleocene P-zonal system biostratigraphy and the phylogeny.

The Paleocene-Eocene planktonic foraminiferal fauna recovered from the Paleocene-Eocene marine sedimentary sequence of the Sulaiman Range contains abundant tropical and subtropical indices and hence international zonal schemes of Berggren et al. (1995), Berggren and Norris (1997) and Olsson et al. (1999) are applicable to it. However, ranges of some zonal marker species are not clearly distinguished due to their rare or sporadic occurrences resulting in considerable uncertainty in the placement of some zonal boundaries. Moreover, some previously recognised marker species such as *A. subsphaerica* and *A. soldadoensis soldadoensis* are found overlapping, therefore in this study (for some parts) new zonal markers are introduced for zonal definitions and their subdivisions.

The correlation of the established biostratigraphic zones herein the Sulaiman Range with internationally recognised zonal schemes (Bolli, 1957, 1966; Premoli Silva & Bolli, 1973; Blow, 1979; Toumarkine & Luterbacher, 1985; Berggren & Miller, 1988; Berggren et al., 1995; Berggren & Norris, 1997 and Olsson et al., 1999) is discussed at in chapter 5.

6.2 Correlation of the Paleogene biozones established in this study with those of other established in other parts of the Southern Indus Basin.

There are very few works published on the planktonic foraminiferal biostratigraphy from the Southern Indus Basin. Latif (1961; 1964) has described planktonic foraminifera of the Rakhi Nala section but his work is of very primitive nature. The definitions and boundaries are not clear and these biozones can not

be correlated precisely with established biozones herein as well as with the international zonal schemes. Samanta (1973) and Dorreen (1974), however, have established relatively better biostratrigraphic zones in the Rakhi Nala section (Sulaiman Range) and in the Gaj river section (Kirthar Range), respectively. A correlation of the established biostratigraphic zones in the Sulaiman Range in this study with the zones of Samanta (1973) and Dorreen (1974) is given Figure 12.

Globorotalia angulata and *G. velascoensis* zones of both Samanta (1973) and Dorreen (1974) can be correlated with the *M. angulata-Glb. pseudomenardii* IZ and *Glb. pseudomenardii* TRZ of this study, respectively. Both of them have established the *G. velascoensis* zone instead of internationally recognised *Glb. pseudomenardii* TRZ. Moreover, both the *M. angulata-Glb. pseudomenardii* IZ and *Glb. pseudomenardii* TRZ of this study are further subdivided into two fold subdivision. Now again both Samanta (1973) and Dorreen (1974) have established the *G. aequa* and *G. rex* zones, respectively, instead of the *M. velascoensis* Zone established in international schemes (Figure 12). These two zone of them are quite big and are equivalent to both the *M. velascoensis* IZ (P5) and *M. velascoensis –M. formosa formosa/ lensiformis* Interval subzone (P6A) of this study.

Globorotalia formosa formosa Zone of Samanta (1973) is equivalent to both P6A and P7 zones of this study whereas Dorreen (1974) has established a very big zone *G. aragonensis* which is equivalent to P6B, P7, P8 and P9 zones of this study. *G. aspensis/ G. esnaensis* Zone of Samanta (1973) may be equivalent to both Zone P8 and the lower part of Zone P9 of this study.

Acarinina sold. soldadoensis/ A. sold. angulosa – H. nutalli Interval Zone (P10) of this study which belongs to the earliest middle Eocene is established for the first time and has not been recognised by either Samanta (1973) or Dorreen (1974). Now in all three sections, an interval which either produce no or very poorly preserved planktonic foraminifera and is cover upper part of the Shaheed Ghat Formation, Baska Formation, and lower two members of the Kirthar Formation. Similar observations were noted by Samanta (1973) at Rakhi Nala section, however, Dorreen (1974) has established the *H. dumblei* zone equivalent to this barren interval from Gaj River section from the Kirthar Range.

Globorotalia crassata/ T. topilensis Zone of Samanta (1973) may be equivalent to both P12 and P13 zones of the present study and his *T. rohri* Zone is correlateable with P14 Zone of this study. Dorreen (1973), however, has established a single zone (*Globigeropsis kugleri* Zone) which is equivalent to P11, P12 and P13 zones of this study. The P13 Zone of this study which is Total Range Zone of a very distinctive species *(Orbulinoides beckmanni)* and has world-wide recognition is established for the first time from the Sulaiman Range. Nobody has even documented this species from any previously studied sections. Last Zone (P15) of this study can be correlated to *Globigerina officinalis* and *Globorotalia cerroazulensis* Zones of Samanta (1973) and Dorreen (1974), respectively.

The most important point to note is the present study provides more precise and small zones (high-resolution) that can exactly be correlated with internationally established zones. For the definitions of the upper and lower limits of all the zones, world-wide recognised last appearance datums (LAD) or first

appearance datums (FAD) are used. In contrast the zones established by previous workers (Samanta, 1973; Dorreen, 1974) lacks resolution, proper definitions and hence are difficult to compare.

6.3 Age assignment

Twelve biostratigraphic zones are established in the Paleocene-Eocene sequence of the Sulaiman Range that consists of the Dunghan, Shaheed Ghat, Baska and Kirthar Formations in ascending order. After precise correlation of these zones with internationally established zones, the age assignment to these formations is discussed as following.

6.3.1 Dunghan Formation

Dunghan Formation has yielded a rich faunal assemblage of late Paleocene to early Eocene planktonic foraminifera and based on them following five biostratigraphic zones are established; *Morozovella angulata/ Globanomalina pseudomenardii* Interval Zone, *Glb. pseudomenardii* Total Range Zone, *M. velascoensis* IZ, *M. subbotina* Partial Range Zone, and *M. formosa formosa* IZ. Among them three biozones (*Morozovella angulata/ Globanomalina pseudomenardii* Interval Zone, *Glb. pseudomenardii* Total Range Zone and *M. velascoensis* IZ) belong to late Paleocene whereas two of them; *M. subbotina* Partial Range Zone, and *M. formosa formosa* IZ belong to early Eocene.

Hence late Paleocene through early Eocene (61my to 50.7my) age is assigned to the Dunghan Formation.

6.3.2 Shaheed Ghat Formation

Lower part of the Shaheed Ghat Formation has produced well preserved and abundant planktonic forminifera whereas the upper part has produced very poorly preserved to no planktonic forminifera. Following five biostratigraphic zones are established in the lower part of this formation: *M. subbotina* Partial Range Zone, *M. formosa formosa* IZ, *M. aragonensis* IZ, *Glb. palmerae-A. sold. soldadoensis/ A. sold. angulosa* IZ and *A. sold. soldadoensis/ A. sold. angulosa-Hantkenina nutalli* IZ.

Based on the biostratigraphic position of these above mentioned five biozones, early Eocene through early middle Eocene age (50.7 my to 48.4my) can be assigned to the Shaheed Ghat Formation.

6.3.3 Baska Formation

Baska Formation hasn't produced any determinable planktonic foraminifera and therefore no age can be assigned to it. However, as Baska Formation stratigraphically lies between the Shaheed Ghat and Kirthar Formations and corresponds to an interval that is equivalent to two internationally established biozones (P10, P11), therefor it may have early middle Eocene age.

6.3.4 Kirthar Formation

The Kirthar Formation consists of four lithostratigraphic members: Habib Rahi Limestone Member, Sirki Member, PirKoh Limestone and Marl Member and

Drazinda Member in ascending order. Lower two members (Habib Rahi Limestone Member, Sirki Member) have not produced any identifiable planktonic foraminifera, however, upper two members (PirKoh Limestone and Marl Member and Drazinda Member) have yielded well preserved and abundant to common planktonic foraminifera. The following four biostratigraphic zones are established from the upper two members of the Kirthar Formation: *M. lehneri* IZ, *Orbulinoides beckmanni* IZ, *O. beckmanni-Truncorotaloides rohri* IZ *and Tr. rohri- Subbotina officinalis* IZ.

Now based on the biostratigraphic positions of these planktonic foraminiferal zones middle middle Eocene to early late Eocene age (41.1my to 37.6my) is assigned to the Kirthar Formation.