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Planktonic foraminiferal biostratigraphy and depositional setting of the Cretaceous Parh Limestone, Quetta, western Sulaiman Fold-Thrust Belt, Balochistan, Pakistan

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Abstract

Parh Limestone at Hanna Lake and Murree Brewery sections, Quetta, yield a rich and diverse planktonic foraminifera comprising of forty-three species from fifteen different genera. This highly diverse assemblage is characterized by many short-range species suggesting *Globotruncana ventricosa* Biozone of middle-late Campanian for the Parh Limestone in the Quetta region. The *Globotruncana ventricosa* co-occur with the stratigraphically older taxa *Dicarinella asymetrica* and *D. concavata,* which is interpreted as an upward extension of these taxa to younger global *G. ventricosa* Biozone in this part of the eastern Tethys. The upward extension of *D. asymetrica* and *D. concavata* to *G. ventricosa* Biozone is supported by the high diversity of planktonic foraminifera characterized by the appearance of many species of *Globotruncana, Heterohelix, Pseudotextularia* and *Ventilabrella* which is a typical character of G. ventricosa Biozone recorded in other Tethyan regions, as well.

The Parh Limestone was also studied for microfacies analysis to understand the depositional setting. Two microfacies, including Globotruncana-rich Mud-Wackestone microfacies (KP-1) and Globotruncana-Heterohelix Wacke-Packstone microfacies (KP-2) have been recognized. Based on these microfacies, an outer ramp to open basinal depositional setting has been assigned to the Parh Limestone in the study area.

Keywords: Cretaceous; Planktonic foraminifera; biostratigraphy; *Globotruncana ventricosa;* Parh Limestone; Sulaiman Fold-Thrust Belt.

1. Introduction

Foraminifera are marine protozoans represented by more than 38000 living and fossil species and constitute about 38% of the protozoans (Boltovskoy and Wright, 1976; Jones, 2014). They are widespread in current oceans with a substantial impact on the marine biosphere and contributing about 25% of the carbonate production (Langer, 2008). They appeared first in Early Cambrian, their Palaeozoic and Triassic forms had a benthic life style (Culver, 1991; Pawlowski et al., 2003), whereas the planktonic forms appeared first in Jurassic (Hart et al., 2003). Planktonic foraminifera have a broad latitudinal distribution from tropics to higher latitudes, representing nine biogeographic provinces from Arctic to Antarctic. This reflects their sensitivity to variation in temperature and climate (Belyaeva, 1963; Armstrong and Brasier, 2005). In geological record, their alternate periods of adaptive radiation and decline are related to changes in sea level, climate, temperature and salinity which have made them useful tools for palaeoecologic, palaeobiogeographic, palaeoceanographic and palaeoclimatic reconstructions (Frerichs, 1971; Fischer and Arthur, 1977; Hart, 1980; Wonders, 1980; Caron and Homewood, 1983; Leckie, 1989; Sliter, 1992; Sliter and Leckie, 1993; Khan et al., 2017). Their excellent fossil record, rapid evolution, high abundance and taxonomic diversity have proved to be very useful in understanding their evolutionary history (Silva and Sliter, 1999). These traits have made them one of the most important fossil group to correlate marine sedimentary strata from Jurassic onwards (Caron, 1985; Sliter, 1989; Sliter and Leckie, 1993; Sari, 2006, 2009;

BouDagher-Fadel, 2015; Jaff et al., 2015; Brovina, 2017). The Cretaceous Period is characterized by many short ranging foraminiferal species, which allows for high resolution biozonation. So far, 31 standard planktonic foraminiferal biozones have been identified in the Cretaceous marine strata of Europe (Sliter, 1989; Sliter and Leckie, 1993; Hardenbol et al., 1998).

The Cretaceous of Pakistan preserves thick marine succession in the Upper Indus Basin and the Sulaiman and Kirthar belts (Jones, 1961; Shah, 2009). Parh Limestone forms a part of the thick Cretaceous succession of the Sulaiman-Kirthar fold-thrust belts (Jones, 1961), and it has wide lateral extension of more than 1000 km with many thick outcrops exposed from Bella in the south to Mughal Kot and Dera Ghazi Khan in the north (Fig.1). The term Parh Limestone was introduced by Blanford (1879) and the name Parh is derived from the Parh Range. The section in the upper reaches of the Gaj River has been designated as its type section, where it is about 268 m thick, whereas in the Mughal Kot Gorge it is about 384 m thick and in some areas it attains a maximum thickness of about 600 m (Shah, 2009; Khan, 2012). In the study area Hanna Lake and Murree Brewery it has thickness of a 52 and 46 m respectively. Parh Limestone is medium to thin bedded hard limestone, with varying colours, such as, white, cream, light grey, dark grey, it also contains subordinate marls and calcareous shales (Fatmi, 1977; Khan, 2012). In the Sanjavi area of the Ziarat district thin bedded chert and in the Mughal Kot Gorge black shales are present, reflecting a very deep and anoxic environmental conditions (Jones, 1961; Khan, 2012). The lower contact is sharp with the underlying Cretaceous Goru Fomation in most of the Sulaiman and Kirthar belts, whereas in Mughal Kot area, it directly overlies the Cretaceous Sembar Formation (Khan, 2012). The upper contact is disconformable with the Fort Munro Formation in the western Sulaiman Fold-Thrust Belt such as Quetta, Ziarat and Harnai and in the eastern parts of the Sulaiman Fold-Thrust Belt such as the Mughal Kot Gorge, the upper contact of Parh Limestone is disconformable with the overlying Mughal Kot Formation (Shah, 2009; Khan, 2012; Khan, 2017).

Parh Limestone is documented to contain abundant and diverse planktonic foraminiferal assemblages (Khan, 2012). Though the earliest reports of rich and abundant occurrences of planktonic foraminifera in the Parh Limestone date back to mid-twentieth century (Williams, 1959; Gigon, 1962), but later only few studies of biostratigraphic significance have been conducted (Jones, 1961; Smewing et al., 2002; Kazmi, 1988). The formation is dated as Barremian-Campanian in Kach-Ziarat area, Santonian to late Campanian in the southern Kirthar Belt and the most recent studies of Khan (2012) has assigned Aptian to Early Maastrichtian age for the Mughal Kot section. However, in Quetta and surroundings, no detailed biostragraphic studies have been conducted for the Parh Limestone. This paper aims to (a) document planktonic foraminiferal fauna of the Parh Limestone from the outcrops exposed in Hanna Lake and Murree Brewery sections, (b) establish high resolution biostratigraphy on the basis of obtained assemblages, (c) compare recovered planktonic foraminiferal assemblages with previous studies conducted on the Parh Limestone and elsewhere in other parts of Tethys and (d) to assign depositional environments to Parh Limestone based on field and microfacies analysis.

2. Geological setting

The Sulaiman Fold-Thrust Belt (SFTB) is 75 to 200 km wide and 630 km long arcuate, south-convex belt. The belt is truncated by Main Boundary Thrust and Salt Range Thrust in the north and bounded by the Quetta Syntaxis and Kirthar Belt in the south. The Zhob Valley Thrust and Pishin Belt bounds the SFTB in the west and towards east the folds gradually lose their amplitude and merge with the Indus foredeep and platform respectively (Bender and Raza, 1995; Kazmi and Jan, 1997). The SFTB comprises up to 10 km thick mostly sedimentary and subordinately volcanogenic succession from Triassic till Pleistocene (Kassi et al., 2009). The SFTB is located on the northwestern margin of Indo-Pakistan Plate; it folded after the Indian-Eurasian collision, which started between 65 and 55 Ma (Powell, 1979; Le Pichon et al., 1992). The Indian plate underwent basement segmentation, which is responsible for the development of south-convex Sulaiman Arc between Sulaiman and Kirthar basement faults (Searle et al., 1987; Bannert et al., 1992; Beck et al., 1995; Rowley, 1996; Searle et al., 1997). The Muslim Bagh-Zhob Ophiolite, west of the SFTB, were also obducted onto the passive margin of the Indian Plate along Zhob Valley Thrust during this phase (Alleman, 1979; Sarwar, 1992; Ahmed, 1996; Gnos et al., 1996; Kakar et al., 2012). The Himalayan-sourced flysh deposition in Pishin Belt (Remnant Tethys Ocean) continued until Late Oligocene, in Miocene the deposition switched towards developing Sulaiman and Kirthar foredeeps in the east (Qayyum et al., 1996). After the final closure of the northwestern margin of the Indian Plate along the left lateral Chaman-Nushki Fault (Furuya and Satyabal, 2008), the locally sourced mollasse deposits of Urak and Sibi Group started depositing in the Sulaiman–Kirthar foreland and foredeeps replacing the Himalayan sourced clastic deposits (Kassi et al., 1987).

3. Materials and methods

The Hanna Lake section is located within the Hanna Village (N 30◦15′85″ E 67◦ 058′ 808″), 20 km northeast of the Quetta City and Murree Brewery Section (N 30◦11′21″ E 66◦ 056′ 45″) is located at about 3 km in the northwest of the main campus of the University of Balochistan, Quetta (Fig. 1, 2). Outcrops of the Parh Limestone in the Hanna Lake and Murree Brewery sections were measured, and 86 limestone samples were collected with an interval of about 0.5 to 2 m (Figs. 3, 4). All samples were thin sectioned, photographed for planktonic foraminifera with Leica Microscope (Leica DM 750 P) in the petrography lab of the Centre of Excellence in Mineralogy, University of Balochistan, Quetta. The solid specimens could not be extracted due to indurated nature of the limestones. For taxa identification and microfacies establishment, standard published literature has been used (e.g. Wilson, 1975; Sliter, 1989, 1992; Pessagno, 1967; Premoli-Silva and Sliter, 1994; Robaszynski et al., 2010; Postuma, 1971; Flügel, 2004; Khan, 2012).

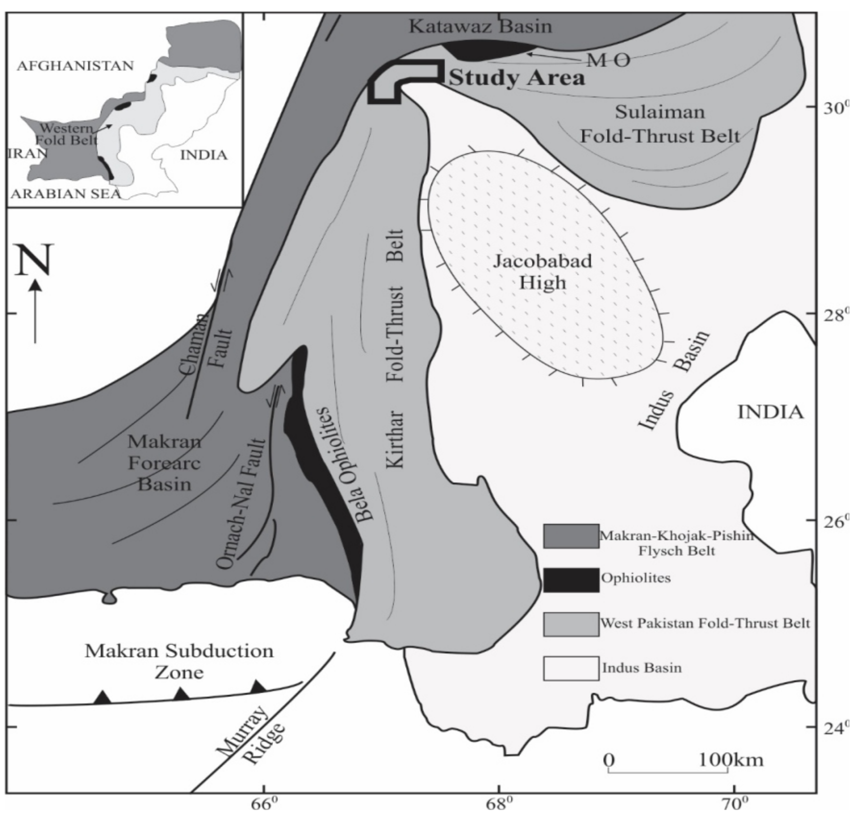

Fig. 1. Generalized geological and tectonic map of the southwest Pakistan. The study area is in extreme western proximity of Sulaiman Belt representing the Quetta Syntaxis (After Kasi et al., 2012).

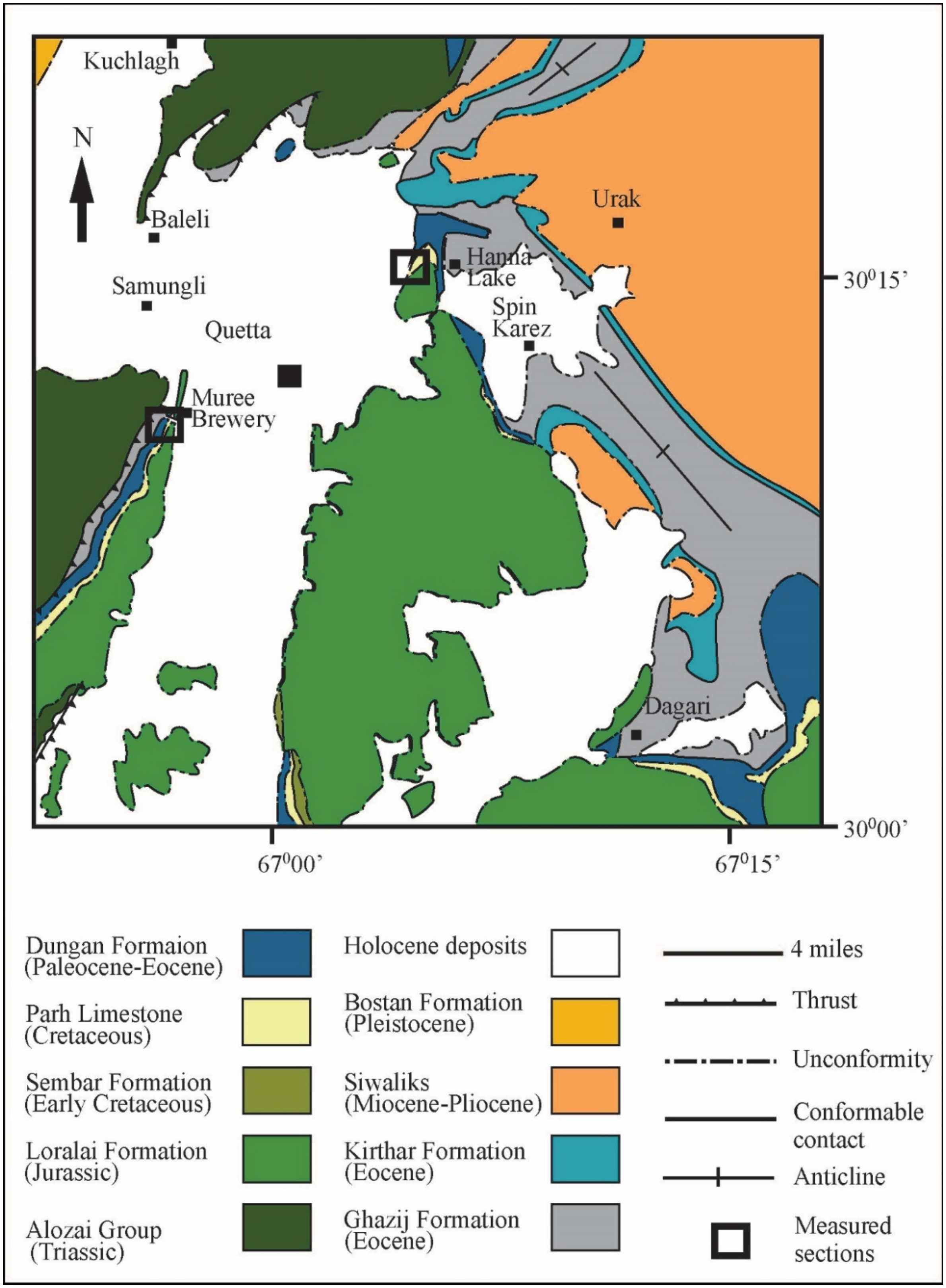

Fig. 2. Geological map of the Quetta are showing the distribution of the Parh Limestone (modified after Jones, 1961).

Fig. 3. Stratigraphic log showing the species distribution and diversity in the Parh Limestone at Hanna Lake Section.

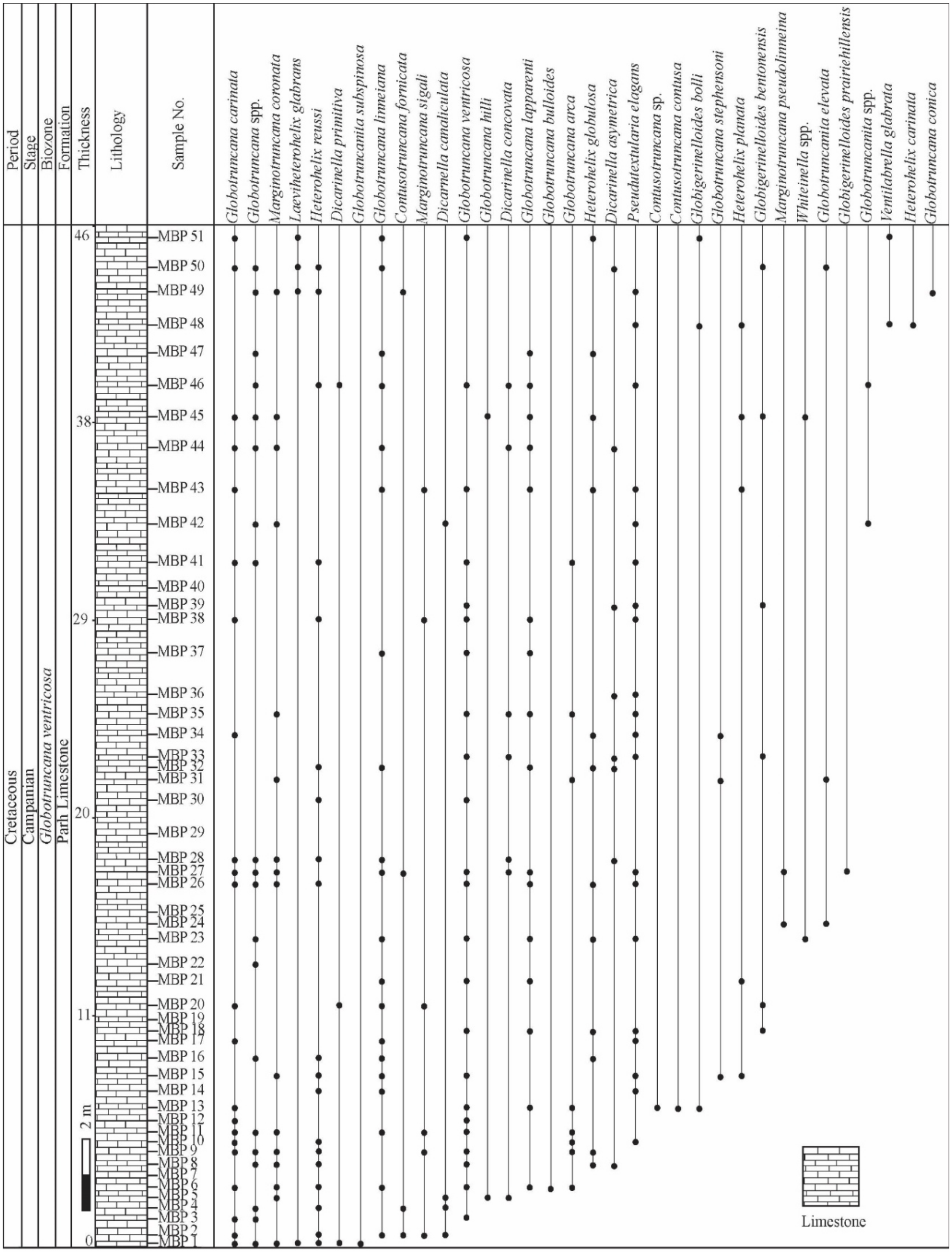

Fig. 4. Stratigraphic log showing the species distribution and diversity in the Parh Limestone at Murree Brewery Section.

4. Biostratigraphy

Parh Limestone at Hanna Lake and Murree Brewery, Quetta has yielded a well-preserved, rich and diverse assemblage of planktonic foraminifera represented by some forty-three species from fifteen different genera. These include many biostrati-graphically important taxa which are useful in constraining age of the Parh Limestone. Based on identified assemblages *Globotruncana ventricosa* Biozone has been identified (Figs. 3-6)

Definition: 'The first appearance of *Globotruncana ventricosa* at the base of the sections continuing through the top of the sections.''

Other associated species of the zone: *Dicarinella concavata, D. asymetrica, D. hagni, D. primitiva, D. canaliculata, Globotruncana carinata, G. linneiana, G. arca, G. bulloides, G. lapparenti, G. conica, G. stephensoni, G. hilli, Globotruncanita subspinosa, G. elevata, Globotruncanella havanensis, Heterohelix reussi, H. globulosa, H. planata, H. carinata, Psedutextularia elegans, Globigerinelloides prairiehillensis, G. bolli, G. bentonensis, Contusotruncana fornicata, C. contusa, Marginotruncana coronata, M. sigali, M. marginata, M. schneegansi, M. pseudolinneina, Ventilabrella glabrata, Laeviheterohelix glabrans, Praeglobotruncana stephani, Whiteinella brittonensis,* and species of *Globotruncanita, Hedbergella, Globotruncanella, Marginotruncana, Aragonia, Contusotruncana, Globotruncana,* and *Whiteinella* (Figs. 3-6)

Remarks:

The co-occurrence of *D. concavata, D. asymetrica* and *Globotruncana ventricosa* suggests either *Globotruncana ventricosa* is older and appeared here earlier in this part of the eastern Tethys or the stratigraphic ranges of *D. concavata* and *D. asymetrica* extend younger to *Globotruncana ventricosa* global Biozone of middle-late Campanian age. The later is possibly confirmed by the high diversity of planktonic foraminifera typified by the appearance of various species such as *Heterohelix planata, Globotruncana carinata, G. arca, G. lapparenti and Globotruncanita subspinosa,* which don't occur in the *D. concavata* and *D. asymetrica* biozones. *G. ventricosa* Biozone is also supported by the presence of taxa such as *Pseudotextularia elegans, Ventilabrella glabrata, Laeviheterohelix glabrans* which are not recorded from older *D. asymetrica* and *D. concavata* biozones. High diversity in this Biozone is also noticed by various authors, such as Sliter (1989) and Khan (2012).

Though in the widely studied western Tethyan region there are no such reports of co-occurrence of *G. ventricosa* with *D. asymetrica* and *D. concavata* (Sliter, 1989; Sliter and Leckie, 1993; Sari, 2006, 2009). However, in the eastern Tethys in the Cretaceous sediments of Tibet, China, *G. ventricosa* is reported to co-occur with *D. asymetrica* (Willems et al., 1996). Further studies may reconfirm their co-occurrence in other parts of the eastern Tethys. In the Exmouth Plateau, Australia *G. ventricosa* has been documented from older sediments of Santonian age, and it may be of low biostratigraphic value outside the Tethyan region.

5. Petrographic properties and depositional setting

In order to understand the depositional setting of the Parh Limestone, microfacies analysis were carried out using variation in carbonate petrographic textures and biota. Based on 86 field samples, picked with an interval of about 0.5 to 2 m, two (2) microfacies have been recognized within the Parh Limestone at Hanna Lake and Murree Brewery sections. The representative samples of these facies are given in figure 7.

KP-1: Globotruncana-rich Mud-Wackestone Microfacies:

This microfacies is represented by 13 samples at Hanna Lake (HLP) section and 15 samples at Murree Brewery (MBP) section. This microfacies dominantly consist of fossiliferous micritic mud (Fig. 7.1). The fossil grain concentration ranges from 5% to 20% with an average value of 8%. Fractures are

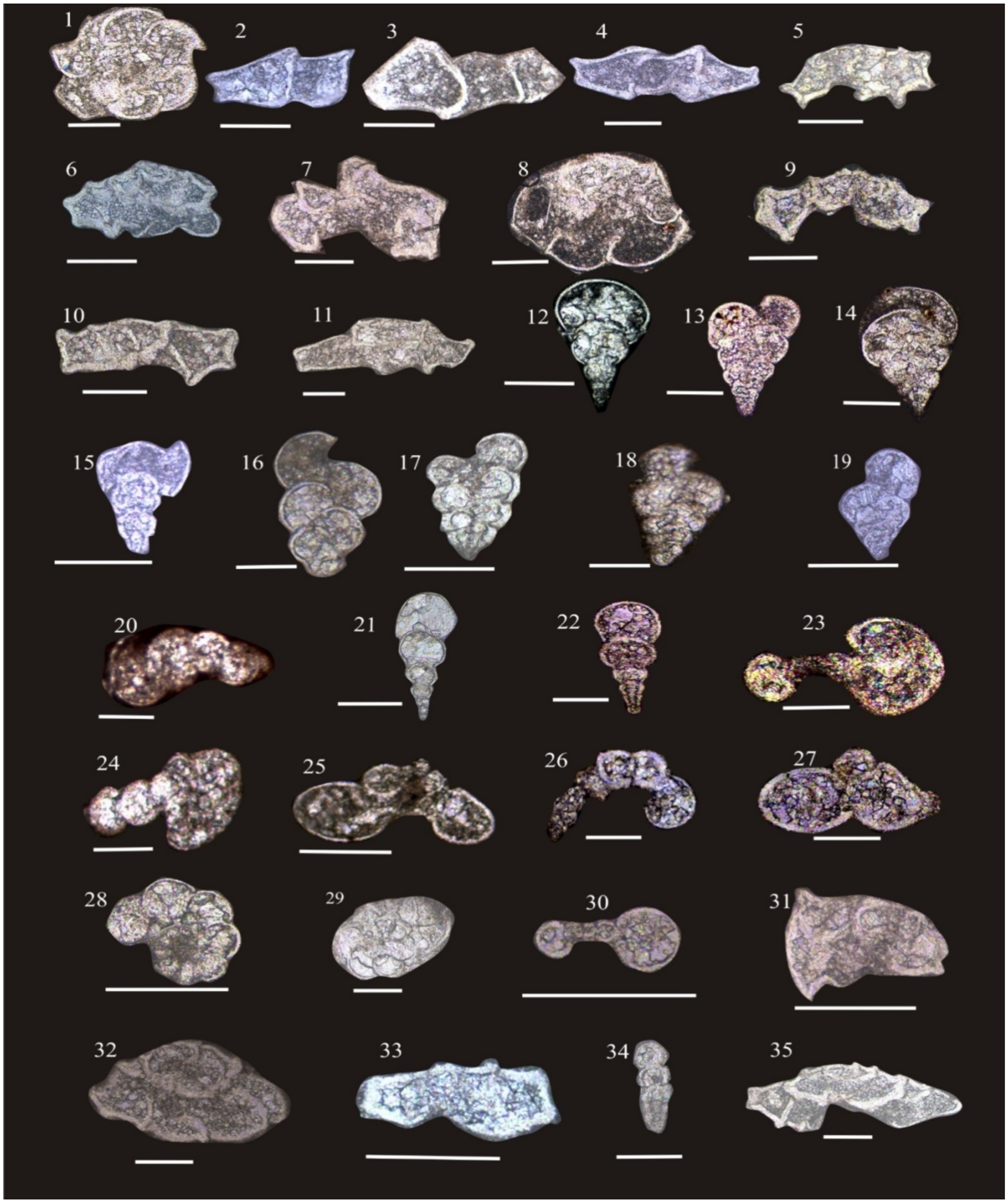

Fig. 4. Thin-section images of the Late Cretaceous planktonic foraminifera of the Parh Limestone, Hanna Lake and Murree Brewery sections, Quetta. 1-2, *Globotruncana* spp., 1, HLP-11; 2, MBP-11. 3-4, *Globotruncana carinata,* 3, HLP-1; 4, MBP-11; 5, *Globotruncana linneiana,* HLP-8. 6-7, *Globotruncana arca,* 6, MBP-2; 7, HLP-4. 8, *Globotruncana bulloides,* HLP-17. 9-10, *Globotuncana ventricosa,* 9, HLP-14; 10, MBP-27. 11, *Globotruncana lapparenti,* MBP-26. 12-13, *Heterohelix reussi,* 12, HLP-33; 13, HLP-26. 14-15, *Heterohelix* spp., 14, HLP-14; 15, MBP-17. 16-17, *Heterohelix globulosa,* 16, HLP-1; 17, MBP-47. 18-19, *Heterohelix planata,* 18, HLP-1; 19, MBP-15. 20, *Hedbergella* sp., HLP-1. 21-22. *Pseudotextularia elegans,* 21, MBP-38; 22, HLP-4. 23-24, *Globigerinelloides bolli,* 23, HLP-6; 24, HLP-3.25, *Globotruncanella havanensis,* HLP-1. 26-27, *Globotruncanella* spp., HLP-1. 28, *Globigerinelloides prairiehillensis,* MBP-27. 29, *Globotruncana conica,* MBP-50. 30, *Globigerinelloides bentonensis,* HLP-4. 31, *Globotruncanita elevata,* HLP-4. 32, *Globotruncanita subspinosa,* HLP-4. 33, *Globotruncana hilli,* MBP-5. 34, *Heterohelix carinata,* MBP-48. 35, *Globotruncana stephensoni,* 35, MBP-31. Scale for all images is 200 μm.

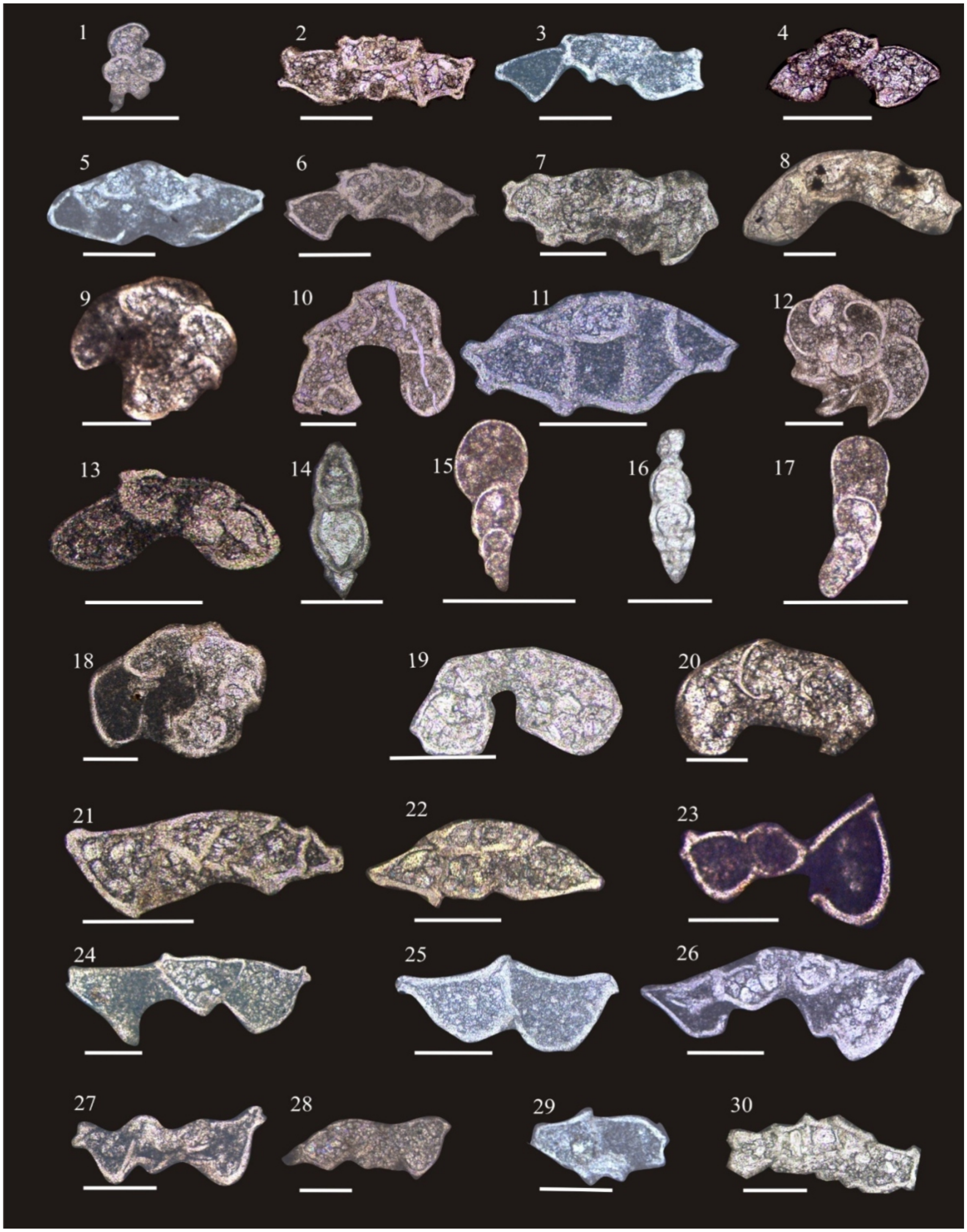

Fig. 5. Thin-section images of the Late Cretaceous planktonic foraminifera of the Parh Limestone, Hanna Lake and Murree Brewery sections, Quetta. 1, *Aragonia* sp., HLP-3.2-3, *Marginotruncana coronata,* 2, HLP-4; 3, MBP-1. 4, *Marginotruncana schneegansi,* HLP-7.5-6, *Marginotrucana sigali,* 5, MBP-2; 6, HLP-4. 7, 9, *Contusotruncana fornicata,* 7, MBP-27; 9HLP-5. 8, *Marginotruncana marginata,* HLP-33. 10, *Contusotruncana contusa,* HLP-4. 11-12. *Globotruncanita* spp., 11, MBP-9; 12, HLP-4.13, *Praeglobotruncana stephani,* HLP-29.14-15, *Laeviheterohelix glabrans,* 14, MBP-35; 15, HLP-4. 16-17, *Ventilabrella glabrata,* 16, MBP-48, 17; HLP-4. 18, *Whiteinella brittonensis,* HLP-17.19-20, *Whiteinella* spp., 19, MBP-23; 20, HLP-9. 21-22. *Dicarinella primitiva,* 21, HLP-14; 22, HLP-6.23-25, *Dicarinella concavata,* 23, HLP-23; 24, HLP-12; 25, MBP-5.26-27, *Dicarinella asymetrica,* 26, MBP-11; 27, HLP-22. 28, *Dicarinella hagni,* HLP-7. 29, *Dicarinella canaliculata,* MBP-2. 30, *Marginotruncana pseudolinneina,* MBP-24. Scale for all images is 200 μm.

widely present while most of them are filled with calcite (Fig. 7.1A). At places fractures filled with ferroan material in the form of pyrite and ferroan calcite cements (Figs. 7.1C, 7.1I)). Dominant biota are planktonic foraminifera, e.g., *Globotruncana, Dicarinella, Marginotruncana, Heterohelix, Whiteinella, Globigerinelloides* and some radiolarians (Fig. 7.1). Dolomitization is present at places. Dolomite rhombs are euhedral floating in micritic background while complete dolomitization is present at places (Figs. 7.1F, 7.1G, 7.1I)).

Interpretation:

This microfacies is dominated by micritic mud matrix which directly indicates a low energy deep marine environment (Flügel, 2004). The presence of planktonic foraminifera and radiolarians suggests an outer ramp to basin setting comparable to the depositional setting of Flugel's (2004) RMF5 and Wilson's (1975) SMF-3 (Fig. 8). Based on these evidences an outer ramp setting is suggested for this microfacies while dolomite is formed during secondary diagenetic process.

KP-2 Globotruncana-Heterohelix Wacke-Packstone Microfacies:

This microfacies is established on 22 samples from Hanna Lake section and 36 samples of Murree Brewery section. Major portion of this microfacies consists of matrix with substantial amount of bioclastic grains (Fig. 7.2). The grains are in a range of 10% to 60% with an average value of 30%. This microfacies contains fractures and calcite-filled veins of late diagenetic episode (Figs. 7.2A, 7.2F). Dominant biota are planktonic foraminifera, e.g., *Globotruncana, Heterohelix, Globigerinelloides, Contusotruncana, Pseudotextularia, Marginotruncana, Dicarinella, Hedbergella* and few radiolarians (Figs. 7.2D, 7.2E)).

Interpretation:

Presence of considerable amount of matrix shows a low energy condition below storm wave base (SWB) (Flügel, 2004). The abundance of planktonic foraminifera also supports a low energy environment of outer ramp setting (Flügel, 2004; Fig. 7.2). In correlation with ramp facies models of Flügel (2004), this microfacies is correlative with RMF-2. The evidence supports an outer ramp setting for this microfacies with a slight approach to middle ramp.

The microfacies distribution shows that Globotruncana-Heterohelix Wacke-Packstone Microfacies (KP-2) is widely distributed in the Parh Limestone while Globotruncana rich-Mud-Wackestone Microfacies (KP-1) is repeated at places. The depositional model shows that at studied sections, Parh Limestone is deposited in outer ramp to open basinal marine settings. At other places, the facies of Parh Limestone represent a broader setting extended from shore to outer ramp environment (Khan, 2012) (Fig. 8).

6. Conclusions

The following conclusions have been drawn from this study:

(1) The Parh Limestone at Hanna Lake and Murree Brewery has yielded rich and diverse planktonic foraminiferal assemblage comprising of forty-three species belonging to fifteen different genera.

(2) Based on the recovered assemblage *G. ventricosa* Biozone (middle to late Campanian) has been assigned to the Parh Limestone in the study area.

(3) The stratigraphically older taxa, such as, *D. concavata, D. asymetrica* co-occur with *G. ventricosa* in the studied samples; this is considered as an upward extension of *D. concavata* and *D. asymetrica* as the recovered assemblage is characterized by high diversity and the appearance of many species of *Heterohelix, Globotruncana, Pseudotextularia* and *Ventilabrella* which is a typical character of *G. ventricosa* Biozone.

(4) Based on two microfacies recognition, an outer ramp to open basinal marine environment has been assigned to the Parh Limestone.

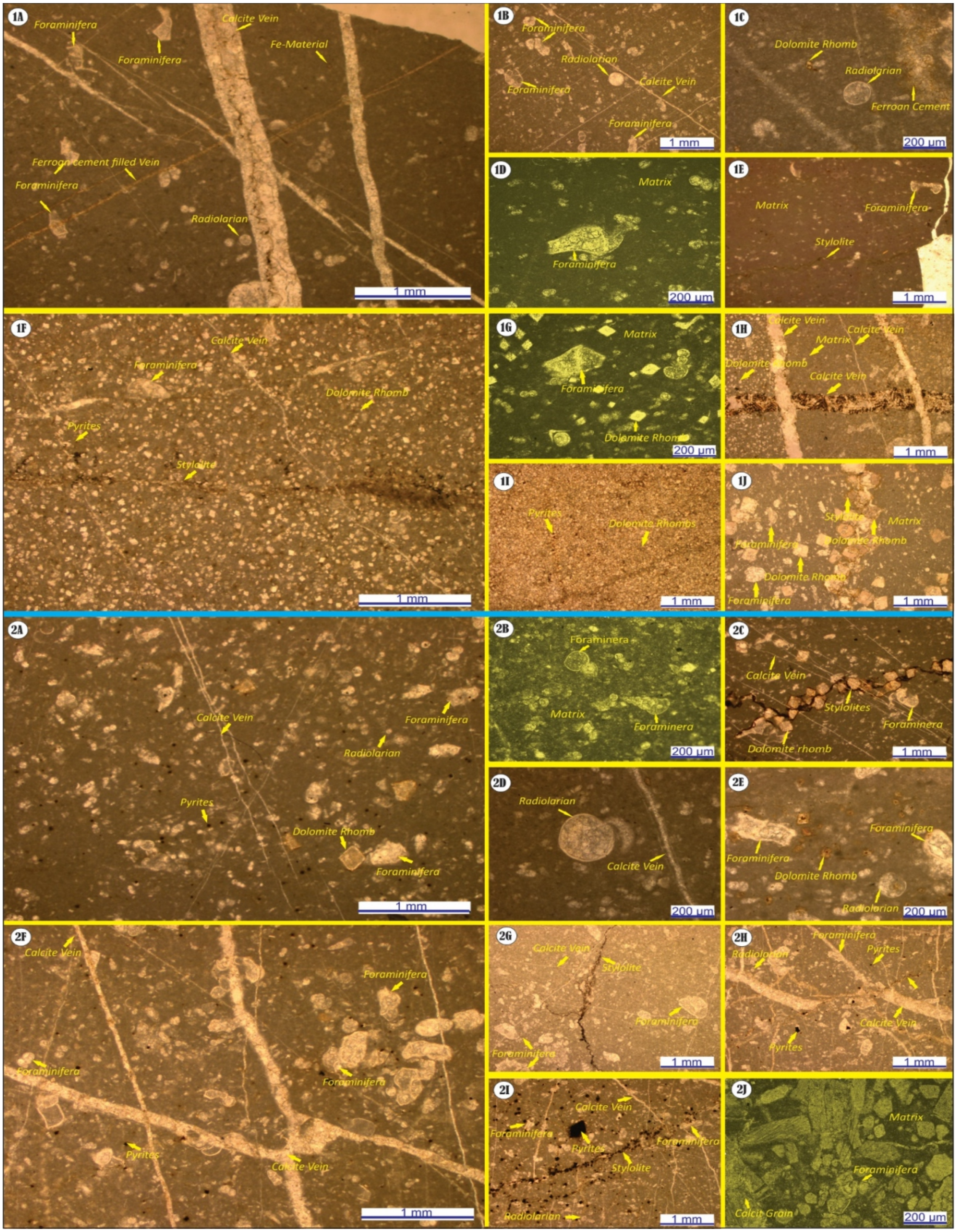

Fig. 5. Figure showing petrographic textures under the microscope. KP-1 (Figs. 1A-1J): Globotruncana rich mud-wackestone microfacies. These representative images mostly consist of micritic matrix (Figs. 7.1A, 7.1E) while some of these represent planktonic foraminifera (Figs. 7.1D, 7.1G), calcite filled veins (7.1A), dolomite (7.1F, 7.1I, 7.1H), ferroan cements (Fig. 7.2C), stylolite (Fig. 7.2F) and radiolarians (7.1B, 7.1C). KP-2 (Figs. 7.2A-7.2J): Globotruncana-Heterohelix wacke-packstone microfacies. Matrix is represented in figs. 7.2A, 7.2D, calcite filled veins are shown in figs. 7.2F, 7.2I, planktonic foraminifera present in figs. 7.2B, 7.2F, 7.2H, radiolarians are present in figs. 7.2A, 7.2D, pyritization is commonly seen in Fig. 7.2I, and stylolites are present in figs. 7.2G, 7.2I.

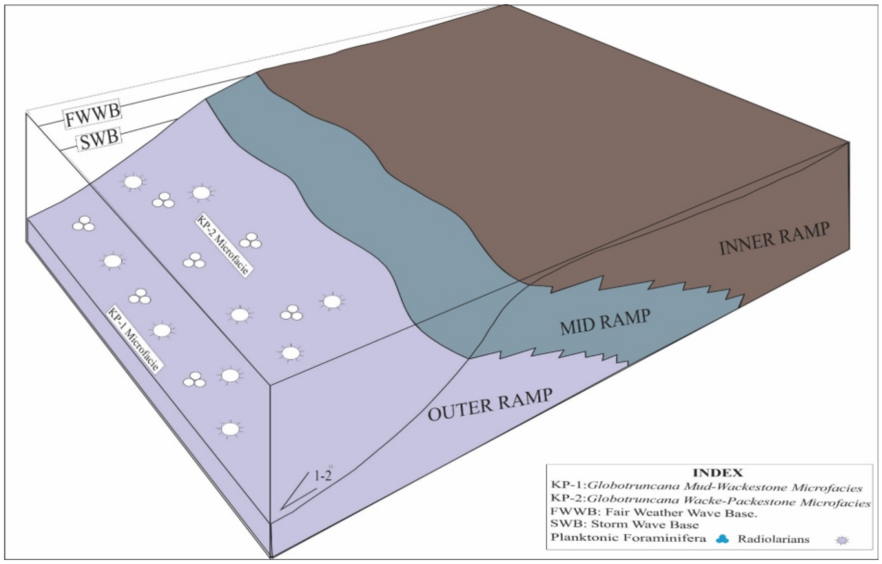

Fig. 5. Depositional Model for the Parh Limestone showing an extended outer ramp setting.

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