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International Journal of Paleobiology & Paleontology

Reticulate *Nummulites* (*N. fabianii* Linage) and Age of the *Pellatispira*-Beds of the Drazinda Formation, Sulaiman Range, Pakistan

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Research Article

Volume 2 Issue 1

Received Date: January 08, 2019

Published Date: January 21, 2019

Abstract

The Eocene shallow marine *Pellatispira*-beds in the upper part of the Drazinda Formation represent the latest phase of Cenozoic Tethyan marine deposition in the Sulaiman Range, West Pakistan. The unit consists of stratigraphically important taxa as *Heterostegina*, *Silvestriella, Pellatispira*, a new *Baculogypsina* (possibly ancestral to modern *Baculogypsina*) and reticulate *Nummulites* implying a latest middle to late Eocene (late Bartonian-Priabonian) age. A more precise age of the unit requires the biometric study of reticulate *Nummulites*, the evolutionary scheme of which is better known from the peri-Mediterranean region in the Tethys. This group, which was subdivided into a series of successive chrono-species based on the biometry of inner cross-diameter of proloculus and changes in the types of granulation/reticulation on the test surface in the late Eocene-late Oligocene interval, appears to have a significant biostratigraphic potential for a high-resolution biostratigraphy in the peri-Mediterranean region (Western Tethys). The reticulate *Nummulites* in two samples from Rakhi Nala and Zinda Pir, ZP22 and RNB10, were studied and compared with those from the peri-Mediterranean region. The isolated specimens have a weak surface granulation externally, a distinct small umbonal granule (pile) and typical reticulation. The samples ZP22 and RNB10 from Zinda Pir and and Rakhi Nala sections have an average inner cross diameter of proloculus of 152.0 and 153.0 μm respectively. The reticulate *Nummulites* in both samples are assigned to *N. hormoensis*, a chrono-species characteristic for the shallow benthic zone (SBZ 18), referable to latest Bartonian-early Priabonian time interval. Since *Heterostegina* in peri-Mediterranean region and in Pakistan belongs to different lineages, a correlation of *N. hormoensis* in the studied samples with the well-established evolutionary scheme of *Heterostegina reticulata* and *H. armenica* lineages from the Western Tethys was not possible.

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Keywords: Reticulate *Nummulites;* Biometry; Priabonian; *Pellatispira*-beds; Drazinda Formation; Pakistan

Abbreviations: ZP: Zinda Pir; LBF: Larger Benthic Foraminifera; SBZ: Shallow Benthic Zone; RNB: Rakhi Nala-B

Introduction

The late Bartonian-Priabonian boundary corresponds to a major faunal turnover in the Tethyan shallow marine ecosystems. Some new foraminiferal taxa, such as *Heterostegina*, *Pellatispira*, *Silvestriella* appear for the first time, while major groups of large *Nummulites* and alveolinids disappear during Bartonian and early Priabonian. A high-resolution dating of the shallow marine Priabonian deposits is, however, difficult due to the inadequate data showing the possible evolutionary changes in these foraminiferal taxa. Several groups, such as reticulate *Nummulites* and genus *Heterostegina* in the peri-Mediterranean region appear to have the potential for a better biostratigraphic subdivision of shallow marine deposits due to the morphological changes recorded in the internal part of the test and their morphometric characterization.

Reticulate *Nummulites* occur rather sporadically in the *Pellatispira*-beds, the highest part of the Drazinda Formation in the Sulaiman Fold Belt, West Pakistan (Figures 1 & 2). This group (*N. fabianii* lineage) occurs in late Lutetian to lower Chattian shallow marine deposits in Tethys [1-6]. Although *Nummulites fabianii* lineage was relatively well studied for its morphometric aspects in the peri-Mediterranean region (from Europe to Turkey and Armenia) [2,4-5], very poor information is available for the Eocene representatives in Indian Subcontinent [1,6]. In the peri-Mediterranean region (Western Tethys) the evolutionary succession of *Nummulites fabianii* lineage consists of *N. bullatus- N. garganicus- N. hormoensis- N. fabianii- N. fichteli- N. bormidensis*, ranging in age from late Lutetian to early Chattian [7]. The evolution of this group in Western Tethys was quantifed based on the inner-cross diameter of the proloculus, ranging from 70-80 to almost more than 400 µm [4,7]. Type of the granulation on the test surface was also utilized in species discrimination.

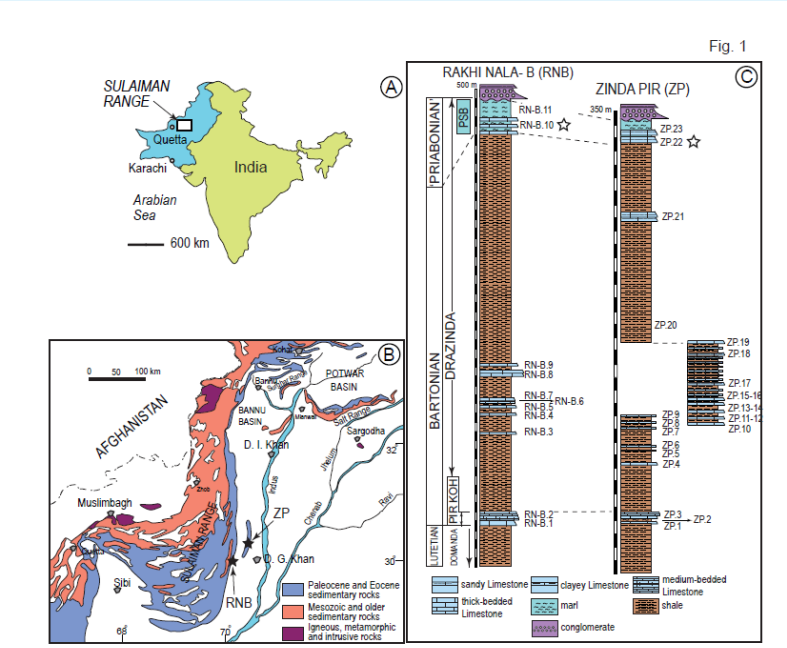

Figure 1: Location of Sulaiman Range in Pakistan (A), Simplified geological map of the Sulaiman Range and position of studied sections, ZP and RNB (B), Generalised stratigraphy and position of the *Pellatispira*-beds in the upper portion of Drazinda Formation (C). Map is simplified from Kazmi & Rana [8]. Stars indicate the samples with reticulate *Nummulites*. PSB: *Pellatispira*-beds.

Figure 2: View of *Pellatispira*-beds in Rakhi Nala.B and Zinda Pir (ZP) sections and sampling points for reticulate *Nummulites*.

We here carried out a biometric study on the reticulate *Nummulites* from the *Pellatispira*-beds of the Drazinda Formation in Sulaiman Fold Belt (west Pakistan) to assess their taxonomy and to compare them with the Western Tethyan reticulate *Nummulites* with biometric data. The age of the *Pellatispira*-beds in the uppermost part of the Drazinda Formation, previously invariably assigned to Priabonian, is reinterpreted in the light of new data.

Geological Setting and Age of the 'Pellatispira-Beds' (Drazinda Formation) in the Sulaiman Fold Belt

The Sulaiman fold belt is a lobate structure in East Pakistan that constitutes a major part of the Lower Indus Basin to the south of the suture zone of the India-Eurasia collision [8] Figures 1A-C. A marine transgression in middle Eocene influenced a large area including the Lower Indus Basin, leading to the deposition of a thick sequence of shallow-marine carbonates and clastics. These deposits contain various marine mammals, decapod crustaceans and abundant larger benthic foraminifera (LBF).

The middle to upper Eocene sedimentary sequence in the Sulaiman Range is subdivided into the Habib Rahi, Domanda, Pirkoh and Drazinda formations, which were collectively named as 'Kirthar' by Blanford [9]. The Drazinda Formation, more than 380 and 300 m thick in Rakhi Nala and Zinda Pir respectively, consists of dark-brown to greenish-gray shale and subordinate marl and limestone beds containing LBF, bivalves, bryozoans and echinoids in its lower and middle, and pale yellowish-green *Pellatispira*-bearing marls in the upper part. Orthophragminids occur abundantly in the lower-middle part of the Drazinda Formation while upper part yields mostly nummulitids, such as *Heterostegina*, reticulate *Nummulites* and calcarinids such as *Pellatispira* and *Silvestriella*. The Drazinda Formation is unconformably overlain by coastal deltaic to fluvial deposits of the Oligocene Chitarwatta Formation.

The Drazinda formation was previously dated as middle to late Eocene based on calcareous nannofossils [10], planktonic foraminifera [11-13], and larger benthic foraminifera [14-16]. According to Köthe, et al. [10], the age of Drazinda formations in the Rakhi Nala section is Middle Eocene to Priabonian based on nannoplankton zones NP 16-19/20. Samanta [11] recorded *Globorotalia crassata/ Truncorotaloides topilensis*, *Truncorotaloides rohni* and *Globigerina officinalis* zones in the 'Upper Kirthar' Formation in the Rakhi Nala section, suggesting late Middle to late Eocene age for this part of the succession. Afzal, et al. [12] identified P14 planktonic foraminiferal zone in the Drazinda Formation, suggesting (early) Bartonian age for the part of the Drazinda Formation below the *Pellatispira*-beds. Warraich, et al. [13] identified P13-15 planktonic foraminiferal zones in the Drazinda Formation that suggest a Lutetian/Bartonian-Priabonian age for this part of the sequence. The upper part of the Drazinda Formation, the *Pellatispira*-beds, yielded NP18-19/20 calcareous nannofossil assemblages in the Rakhi Nala section pointing out Priabonian age [10]. Özcan, et al. [14,15] assigned a Priabonian age to the *Pellatispira*-beds based on the occurrence of *Silvestriella tetraedra* (Gümbel), *Pellatispira madaraszi* (Hantken), *Heterostegina indusensis* Özcan, Ali, Hanif, *Assilina* ex. gr. *alpina* (Douvillé), *Nummulites hormoensis* Nuttall & Brighton and *Linderina* sp. The *Pellatispira*-beds also contain the earliest ancestral forms of the genus *Baculogypsina* (Sacco), which has a stratigraphic range of Pliocene to recent [16]. The Drazinda Formation has been deposited in the shelf lagoon and shoal environments. The *Pellatispira*-beds of this unit have been deposited in the outer shelf setting [18].

Materials and Methods

Reticulate *Nummulites* have been identified only in the upper part of Drazinda Formation ('*Pellatispira* beds' of Eames, [19]) in two classical sections, the Rakhi Nala (RNB) and Zinda Pir (ZP) sections, located 55 and 35 km

east and north-west of Dera Ghazi Khan respectively (Figures 1 & 2). Only the samples RNB-10 (29°57'16.04"N, 70°7'11.13"E) and ZP22 (30°19'56.65"N, 70°29'39.48"E) have yielded reticulate *Nummulites*. From two samples, after washing and sieving, matrix-free calcarinid specimens could be isolated. Specimens were studied in oriented sections for features, exhibited externally, and in the equatorial layer of the test. The studied material is deposited in the collections of Ercan Özcan at İstanbul Technical University.

Reticulate Nummulites in Western Tethys

Reticulate *Nummulites* are common in late middle and upper Eocene shallow marine deposits in Tethys. Because of characteristic features of the test surface, the identification of the group among the nummulids is rather easy, though the species concept is complicated [2,4,20]. The most common and rather well known one is the *N. fabinaii* lineage, consisting of several species that are stratigraphically arranged based on the test features and inner cross diameter of proloculus [4] (Table 1, Figure 3).

Taxon	Pmean (µm)	Test surface	Age	SBZ zone
N. bullatus	65-100	Granules, no reticulation	Late Lutetian to basal Bartonian	SBZ 16 to early 17
N. garganicus	100-140	Heavy granules, reticulation	Early to middle late Bartonian-basal Priabonian	late SBZ 17 to SBZ 18B
N. hormoensis	140-200	Heavy granules, umbo, reticulation	Latest Bartonian-Early Priabonian	SBZ 18A-C
N. fabianii	200-300	Weak granules, umbo, heavy reticulation	Priabonian to early Rupelian	SBZ 19-21
N. fichteli	200-300	Weak reticulation to irregular mesh	Late Priabonian to late Rupelian	SBZ 20-22A
N. bormidiensis	300-	Irregular mesh	Early Chattian	SBZ 22B

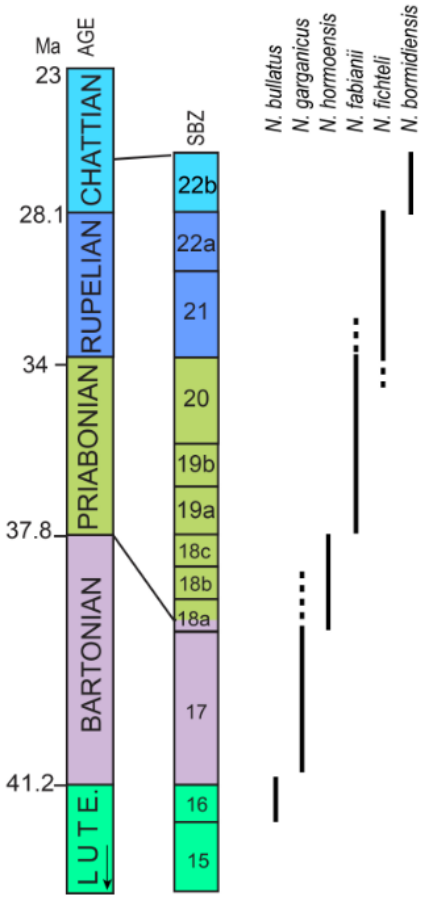

Table 1: Subdivision of *N. fabianii* lineage in Tethys [3,7] and its correlation to shallow benthic zones [4,7].

Although the ancestry to this lineage is not clear, the oldest species appears to be *N. bullatus* with small test size and proloculus (Figures 3A-C).

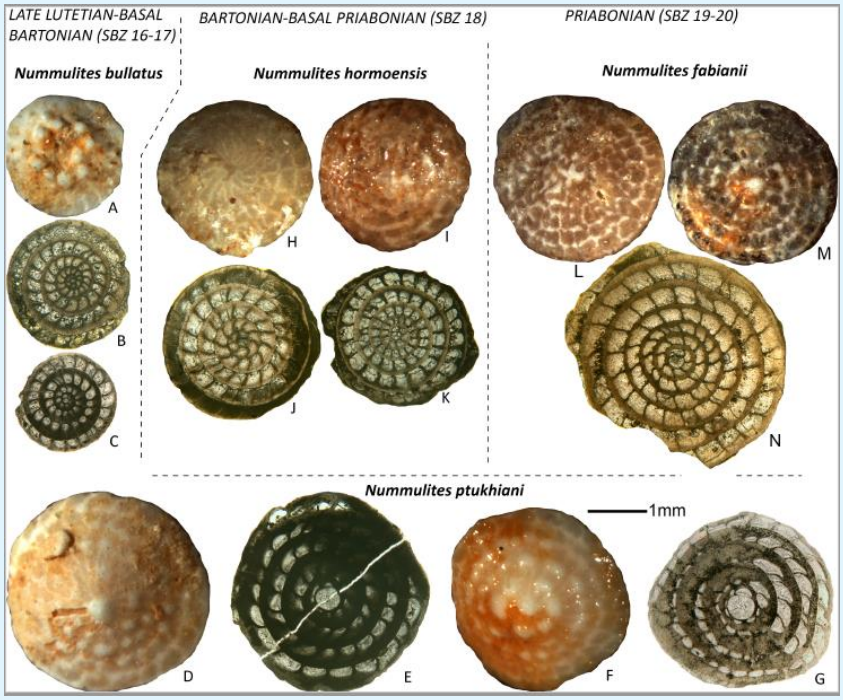

Figure 3: Eocene reticulate *Nummulites* in Tethys. Specimens in the upper part represent the some species in *N. fabianii* lineage and those in the lower part, *N. ptukhiani*. Note the changes in granulation and reticulation on the test surface and increase in the inner cross diameter of the proloculus in *N. fabianii* lineage. *Nummulites ptukhiani* has a larger proloculus than any species of *N. fabianii lineage*. This species co-occurs with *N. bullatus* in late Lutetian/early Bartonian transitional beds in Oman. A: SE4-20, B: SE12-10, C: SE7-15, D-E: SE4-29, F-G: SE7-11, H: ZP22-49, I: MÜFB9-1, J: RNB10-15, K: MÜFB9-8, L: WM5-32, M: WM5-45, N: WM9-9. SE: Specimens from Seeb Formation, Oman, ZP: from the *Pellatispira*-beds, Zinda Pir, Pakistan, RNB: from the *Pellatispira*-beds, Rakhi Nala, Pakistan, WM5: from Tahwah Formation, Wadi Musawa, Oman.

This species doesn't have reticulation but coarse granules in the central part of the test and is confined to upper Lutetian-basal Bartonian beds in Tethys. The reticulation becomes significant in the following stages in *N. hormoensis* and *N. fabianii* during Bartonian and Priabonian, whereas *N. fichteli* in Rupelian displays rather irregular mesh structure at the test surface. Meantime, granules become weak in Rupelian and early Chattian species, *N. fichteli* and *N. bormidiensis*. The inner cross-diameter of the proloculus appears to be the most significant evolutionary parameter to subdivide the *N. fabianii* lineage into species (Table 1). The increase of the average length of chambers in the third whorl is of secondary importance in recognizing the evolution of the group because it is affected also by ecological factors. The tightness/laxity of the spire and the relative width of the spiral cord in the third whorl are the functions of the paleoenvironment. *Nummulites ptukhiani*, originally described from Armenia, has large granules, reticulation and a much larger proloculus than any species of *N. fabianii* lineage (Figures 3D-G). We have identified this species in the same beds with *N. bullatus* in Oman. It appears that *Nummulites ptukhiani* belongs to another reticulate *Nummulites* lineage, which requires further studies to understand its phylogeny.

Results and Interpretation

The reticulate *Nummulites* specimens in two samples (ZP22 and RNB10) from *Pellatispira*-beds have a test

diameter ranging from 1.49 to 3.2 mm. The surface of the test is heavily reticulated with very weak granulation (Figures 4 A, E, I, M, Q). Most specimens possess a central boss (a thick granule) (Figures 4 A, E, I, M). The rounded proloculus is followed by a second chamber, which is slightly compressed along the axis of proloculus and second chamber. Second chamber is either same size or slightly smaller than the proloculus. The proloculus diameter in ZP22 and RNB10 ranges between 100-240 and 110-200 µm respectively (Table 2). The average inner-cross diameter in ZP22 and RNB10 is 152.0 and 153.0 µm respectively (Table 2, Figure 5). The chambers are arranged in 4 to 7 whorls. According to the inner-cross diameter, the specimens from both samples are assigned to *N. hormoensis* (Figure 5). However, the granulation in both samples is very weak.

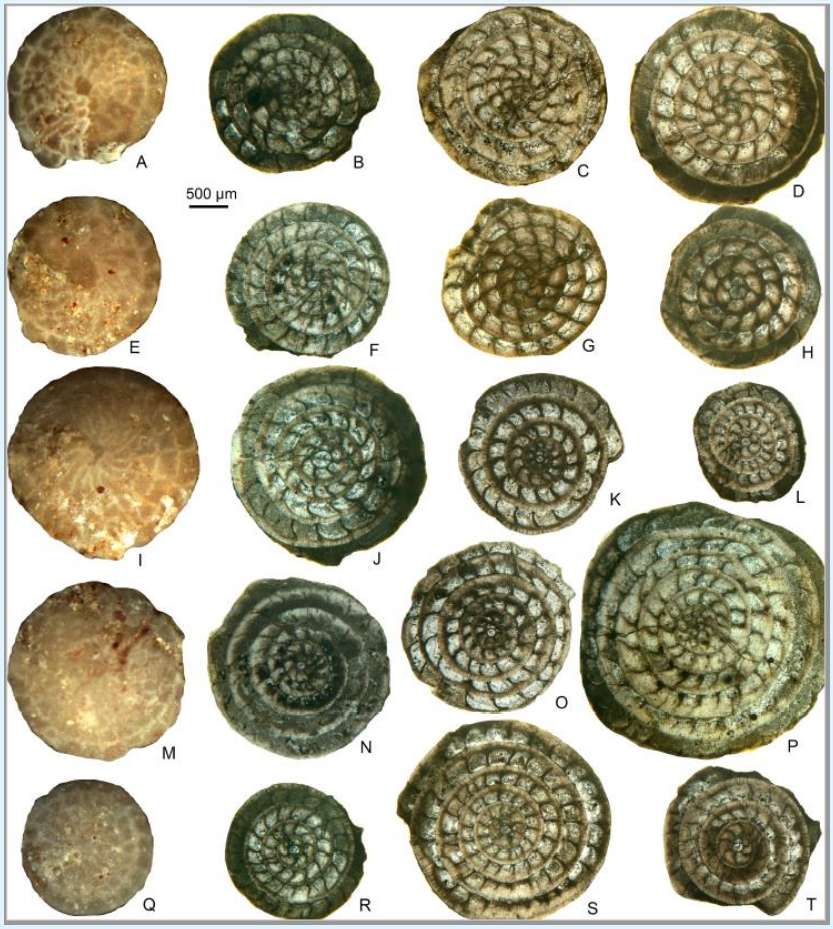

Figure 4: External views (A, E, I, M, Q) and equatorial sections (B-D, F-H, J-L, N-P, R-T) of reticulate *Nummulites* from the *Pellatispira*-beds. A–B: ZP22-39, C: RNB10-14, D: RNB10-15, E–F: ZP22-41, G: RNB10-18, H: RNB10-53, I–J: ZP22-49, K: ZP22-89, L: ZP22-87, M–N: ZP22-50, O: ZP22-92, P: ZP22-62, Q–R: ZP22-53, S: ZP22-94, T: ZP22-81.

Parameters	Proloculus diameter P (µm)			First two whorls diameter d (µm)			Third whorl average length of chambers L=d×π/N (µm)			
Sample	№	range	mean ± s.e.	№	range	mean± s.e.	№	range	mean ±s.e.	
RN.B-10	8	110 – 200	153± 11	6	875 – 1200	1058± 51	6	172 – 237	219	± 9
ZP.22	22	100 – 240	152± 8	16	750 – 1385	1059± 41	12	157 – 263	203	± 9

Table 2: Statistical data of *Nummulites hormoensis* from samples ZP22 and RNB10.

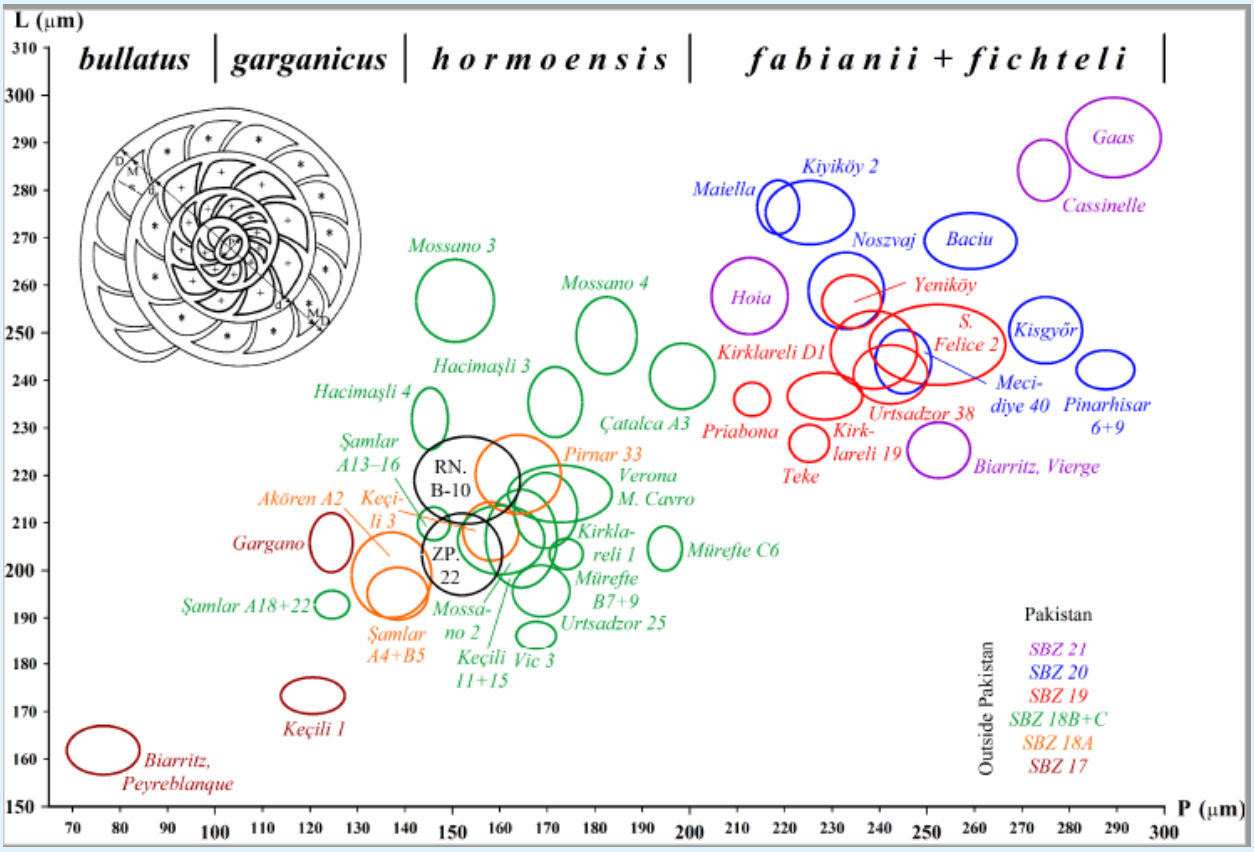

Figure 5: Bivariate P-L plot (proloculus diameter versus chamber length in the third whorl) for Eocene reticulate *Nummulites* populations from the *Pellatispira*-beds and some other localities [4,5,7,20] in the Tethys.

The stratigraphic range of *N. hormoensis* extends from shallow benthic zone (SBZ) 18A to 18C, which are referable to latest Bartonian and early Priabonian time interval after the modifications of Bartonain-Priabonian boundary with respect to time scale and its reinterpretation by Papazzoni, et al. [20]). The Bartonian/Priabonian boundary is recently in the process of its redefinition and it is placed at a lower stratigraphic level as to include much of the Upper Bartonian [22]. This interpretation, shown in Table 1, requires that *N. hormoensis* in Western Tethys is mostly confined to the early Priabonian. The associated larger foraminifera in the *Pellatispira*-beds are represented by *Silvestriella tetraedra* (Gümbel), *Pellatispira madaraszi* (Hantken), *Heterostegina indusensis* Özcan, Ali, Hanif, *Assilina* ex. gr. *alpina* (Douvillé), *Linderina* sp. and *Baculogypsina* n. sp. Figure 6. *Heterostegina* specimens in the *Pellatispira* beds in Zinda Pir and Rakhi Nala, represent a single homogenous population, characterised by a small, nearly flat to centrally slightly inflated test with characteristic surface granules, a small proloculus, and relatively tight early spirals Figure 6L-P. These specimens are not comparable to those from the Bartonian-Priabonian *Heterostegina* in the Western Tethys and Priabonian of Indo-Malayan region and Pacific, and thus a new species, *H. indusensis* n. sp., was created by Özcan, et al. [14]. Therefore, application of evolutionary scheme of *H. reticulata* lineage [4] for a high-resolution dating of the Priabonian deposits of the Sulaiman range is not possible.

Figure 6: Stratigraphically significant larger benthic foraminifera in the *Pellatispira*-beds. (A–G) *Silvestriella tetraedra* (Gümbel), A-B: ZP22-45, C: ZP22-119, D: DB5-1, E: DB5-2, F: DB5-3, G: DB5-4. (H–K) *Pellatispira madaraszi* (Hantken), H-I: RNB11-50, J: ZP22-46, K: ZP23-5. (L–P) *Heterostegina indusensis* Özcan, Ali, Hanif, L: ZP22-38, M: ZP22-100, N: ZP22-104, O: ZP22-74, P: ZP22-39. (Q–R) *Assilina* ex. gr. *alpina* (Douvillé), Q: RNB11-3, R: RNB11-33. (S–T) *Baculogypsina* n. sp., S: ZP22-78, T: ZP22-76. (U) *Linderina* sp. DB5-6. Note DB refers to a stratigraphic section (Domando Bridge) near D.I. Khan. *Pellatispira*-beds don't contain reticulate *Nummulites* but typical Priabonian fauna.

Conclusion

We for the first time present the biometric data of the reticulate *Nummulites* from the Priabonian of Pakistan. The reticulate *Nummulites* in the *Pellatispira*-beds have a small proloculus, in the range of 'primitive developmental stage' of *N. hormoensis* Nuttall and Brighton, a latest Bartonian- early Priabonian species in the Western Tethys sensu Less and Özcan [4]. This species is associated with *Silvestriella tetraedra* (Gümbel), *Pellatispira madaraszi* (Hantken), *Heterostegina indusensis* Özcan, Ali, Hanif, *Assilina* ex. gr. *alpina* (Douvillé), *Linderina* sp. and *Baculogypsina* n. sp. It is likely that *Nummulites fabianii* lineage shows a uniform distribution from peri-Mediterranean region to the Indian subcontinent and application of the biometric scheme of whole lineage may be possible in this part of the Tethys. This requires further studies on the primitive and advanced members of the lineage in a stratigraphic context. Our results provide information only for a part of the lineage and should be complimented by further data collected from different stratigraphic levels in the

Priabonian of the Indian subcontinent. We think that the age of *Pellatispira*-beds doesn't cover the whole Priabonian but only early Priabonian following the redefined correlation of the Bartonian-Priabonian boundary with geological time scale. Our data show that reticulate *Nummulites* have the potential for biostratigraphic applications in a wide area in the Tethys.

Acknowledgments

We are grateful to National Centre of Excellence in Geology, University of Peshawar, for providing travel support for the field work in the Sulaiman fold belt, West Pakistan.

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