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Middle-Late Permian and Early Triassic foraminiferal assemblages in the Western Salt Range, Pakistan

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Naveed Ur Rahman[1, 2]; Haijun Song[2]; Benzhong Xian[1]; Saif Ur Rehman[3]; Gohar Rehman[4]; Abdul Majid[5]; Javed Iqbal[6]; Gulfam Hussain[7]

[1] *College of Geosciences, China University of Petroleum Beijing, 102200, China.*

[2] *State Key Laboratory of Biogeology and Environmental Geology, School of Earth Sciences, China University of Geosciences, Wuhan 430074, China.*

[3] *Department of Earth Sciences, University of Sargodha, Pakistan.*

[4] *College of Construction Engineering, Jilin University, Changchun 130026, China.*

[5] *School of Geosciences, China University of Petroleum (Huadong), China.*

[6] *School of Environmental Studies, China University of Geosciences Wuhan, 388 Lumo Road, Wuhan 430074, China.*

[7] *Institute of Tibetan Plateau Research, Chinese academy of Sciences, Beijing 100101, China.*

Abstract

A newly obtained foraminiferal assemblage from the Guadalupian–Lopingian, and Induan of the Western Salt Range (Pakistan) comprises 47 species (including 7 species of fusulinoideans) of 24 genera and 71 species (including 9 species of fusulinoideans) of 41 genera, in the Nammal and Zaluch sections, respectively. Our results show that only 4 species went extinct during the Guadalupian–Lopingian mass extinction (GLME), suggesting the GLME was minor for smaller foraminifers in the Salt Range. Most species went extinct during the Permian-Triassic mass extinction (PTME), except the two survivor genera, *Nodosinelloides* and *Planiinvoluta*. During the end-Permian mass extinction, the majority of the species became extinct in the lower part of the Chhidru Formation, because they were not tolerant to the terigenious-clastic input in the upper part of the Chhidru Formation. The extinction process of foraminifers in the Nammal and Zaluch sections has been documented for the first time. Five foraminiferal assemblages are established in the shallow marine shelf deposits of Western Salt Range, i.e. Wordian *Geinitzina araxensis* assemblage in tide-influenced subaqueous delta to middle shelf environment, Capitanian *Baisalina pulchra* assemblage and Wuchiapingian *Codonofusiella schubertellinoides* assemblage in inner-outer shelf carbonate deposits, Changhsingian *Colaniella pseudolepida* assemblage and Induan *Nodosinelloides-Planiinvoluta* assemblage in mixed siliciclastic–carbonate shelf setting. The *Baisalina pulchra* and *Codonofusiella schubertellinoides* assemblages have wide geographic distribution and have been found in Transcaucasus, China, Turkey, Crimea and Oman. The other three assemblages (i.e. *Geinitzina araxensis*, *Colaniella pseudolepida*, and *Nodosinelloides-Planiinvoluta* assemblages) found in this study are likely local/regional assemblages. The foraminifers were observed with the standard microscopic system Leica-DM500. A total of 681 specimens of foraminifers are reported in the Zaluch Group and Mianwali Formation of Nammal and Zaluch sections. Five hundred ninety-nine smaller foraminifers specimens were recovered. Among the smaller foraminifera, *Nodosinelloides*, *Pachyphloia*, *Geinitzina*, *Colaniella*, *Hemigordius*, *Tuberitina*, and *Langella* are the most dominant genera. Larger foraminifera genera include *Nankinella*, *Codonofusiella*, *Reichelina*, *Necdetina* and *Pisolina*, represented by 82 specimens. A total of 3 classes (e.g. Nodosariata, Fusulinata, and Tubothalamea) and seven orders (i.e. Miliolida, Spirillinida, Lagenida, Parathuramminida, Endothyrida, Fusulinida, and Earlandiida) are identified in the current study. Among them, Lagenida becomes the most dominant by diversity and abundance. Shannon diversity and other indices rise progressively from Wordian to Changhsingian in the shallow marine sediments before dropping to zero in the Early Triassic mixed siliciclastic–carbonate shelf deposits.

Keywords:
Guadalupian-Lopingian; Induan; foraminifera; fusulinids; mass extinction; Salt Range

1. Introduction

There were two mass extinction events of the Middle Permian to Early Triassic, i.e. the Guadalupian-Lopingian (GLME) and the Permian-Triassic mass extinctions (PTME) (**Stanley and Yang, 1994; Jin et al., 1994; Fan et al., 2020**). The extinction rate of the GLME was around 67% based on the number of genera (**Bond et al., 2010**), and previous studies have shown a temporal link between the GLME and the Emeishan Volcanism (**Zhou et al., 2002; Wignall et al., 2009; Bond et al., 2010**).

Corresponding author: Name Haijun Song
e-mail address: haijunsong@cug.edu.cn

The PTME, as one of the most severe biotic crises of the Phanerozoic, eliminated over 90% of marine species (**Erwin, 1993; Song et al., 2013**), and led to the collapse of the marine ecosystems (**Song et al., 2018**). The initial pulse of Siberian Traps sills and contemporaneous volcanic activities around the Paleotethys Ocean have been considered as the potential trigger of the PTME (**Campell et al., 1992; Yin and Song, 2013; Burgess et al., 2017; Chu et al., 2020**). The foraminifers were among the main victims of these two extinction events. Large-tested fusulinids (e.g. schwagerinids, neoschwagerinids, and verbeekinids) completely vanished during the GLME (**Sheng and Jin, 1994; Ota and Isozaki, 2006; Groves and Wang, 2013**). All fusulinids and most of the small foraminifers went extinct during the PTME (**Tappan and Loeblich, 1998; Groves et al., 2005, 2007; Song et al., 2007, 2009**).

The Salt Range area is of special interest for the study of Middle-Late Permian and Triassic faunas and strata. Conodonts, gastropods, bivalves and ammonoids (**Wardlaw and Pogue, 1995; Brühwiler et al., 2011; Wasmer et al., 2012; Kaim et al., 2013**) have been studied in the Salt Range and they provide an excellent stratigraphic framework. Fusulinids are one of the most important index microfossils in the Carboniferous and Permian due to their worldwide distributions and accurate stratigraphic ranges. Smaller foraminifers are used to study the extinction processes and patterns in the Paleotethys (**Song et al., 2007, 2009; Korchagin, 2011**). However, there are only a few studies on the Permian and Triassic foraminifers in the Salt Range and Trans Indus Range (**e.g. Dunbar, 1933; Douglass, 1970; Kummel, 1970; Nakazawa and Dicking, 1985; Okimura, 1988; Jenny-Deshusses and Baud, 1989; Mertmann, 2000**). *Codonofusiella laxa* (**Douglass, 1970**) and *Monodiexodina kattaensis* (**Schwager, 1887**) have been reported in the Jan Sukh Member of the Amb Formation in the Salt Range and the Kishor Range (**Dunbar, 1933; Douglass, 1970; Mertmann, 2000**). **Kummel** (**1970**) described a few small benthic foraminifera (i.e., *Colaniella*, *Climacammina*, and *Brunsiina*?). The representatives of the genus *Colaniella* from the Salt Range were mainly reported by **Jenny-Deshusses and Baud** (**1989**). **Okimura** (**1988**) described five new species of *Colaniella* (an index genus of the Late Permian), including *Colaniella minuta*, *C. zaluchense*, *C. pseudominima*, *C. cuneiformis*, and *C. pseudolepida*, in the Kalabagh Limestone Member of the Wargal Limestone. The presence of *Colaniella* is a significant sign of the Wuchiapingian stage (**Jenny-Deshusses and Baud, 1989**). More recently **Mertmann** (**2000**) identified foraminiferal assemblages of three suborders (i.e. Fusulinina, Rotaliina and Miliolina) in the Salt Range and Trans Indus Range. **Nakazawa and Dicking** (**1985**) described the Permian formations in detail and established *Reichelina-Colaniella-Codonofusiella* assemblage in the Chhidru Formation of the Nammal, Chhidru, and Zaluch sections. The species of fusulinids *Neoschwagerina margaritae* (**Deprat, 1913**), *Schubertella* sp., and *Sphaerulina* sp., found in the lower part of the Wargal Limestone, point to the Capitanian Stage (**Mertmann, 2000**). **Tayyab et al.** (**1981**) reported *Codonofusiella* from the middle part of the Wargal Limestone that strongly, although not categorically, points to the Wuchiapingian age (**Waterhouse, 2010**). The presence of *Reichelina* sp., *Nankinella* sp., *Nanlingella simplex* (Sheng & Chang, 1958), *Codonofusiella* sp., and *Staffella* sp. in the upper part of the Wargal Limestone and Chhidru Formation confirms the Lopingian epoch (**Mertmann, 2000**). This study aims to investigate Middle Permian-Early Triassic foraminiferal assemblages in the Salt Range, Pakistan, focusing on their biostratigraphy.

2. Geological setting

In the area of today's Salt Range, a huge carbonate platform was established on the Gondwana continental crust during the Permian, being a part of the northern Indian plate (**Dunbar, 1933; Mertmann, 2000**). During the Early Triassic, the Pangea Supercontinent was surrounded by two broad oceans, namely the Panthalassa and the Tethys, and numerous microcontinents (i.e. Cathaysian and Cimmerian) intersected both oceans (**Tozer, 1982; Ricou, 1994; Ehiro et al., 2005**) (see **Figure 1**). The Salt Range was situated on the northern margin of the Gondwana, at a paleolatitude of ~30° S (**Smith et al., 1994; Stampfli and Borel, 2002**).

The Permian successions in the Salt Range can be subdivided into two main groups (see **Figure 2**), representing two distinct depositional settings: a shallow marine Tethyan succession, i.e. the Middle-Late Permian Zaluch Group, and a continental Gondwana succession, i.e. the Early Permian Nilwahan Group (**Wardlaw and Pogue, 1995**; **Jan et al., 2009**). The Zaluch section of the Western Salt Range is a type locality of the Zaluch Group comprising the Amb Formation, Wargal Limestone, and Chhidru Formation (**Teichert, 1966**). The Amb Formation was formed in a tide-influenced subaqueous delta to middle shelf environment with varying sea level (**Wadood et al., 2022**). The Amb Formation, being composed of shale, sandstone and limestone, belongs to the Wordian, based on conodont stratigraphy (**Wardlaw and Pogue, 1995**). An unconformity separates the Amb Formation from the Wargal Limestone (**Wardlaw and Mei, 1999**). Lithological unit of the Wargal Limestone includes limestone and dolomite and upper contact with the Chhidru Formation is interfingering (**Nakazawa and Dickins, 1985; Mertmann, 2003; Shah, 2009**). Small foraminifers and numerous megafossils from the Wargal Limestone, comprising gastropods, corals, and brachiopods were described by **Nakazawa and Dickins** (**1985**). The age of the Wargal Limestone is Capitanian to Wuchiapingian based on conodont data reported by **Wardlaw and Pogue** (**1995**).

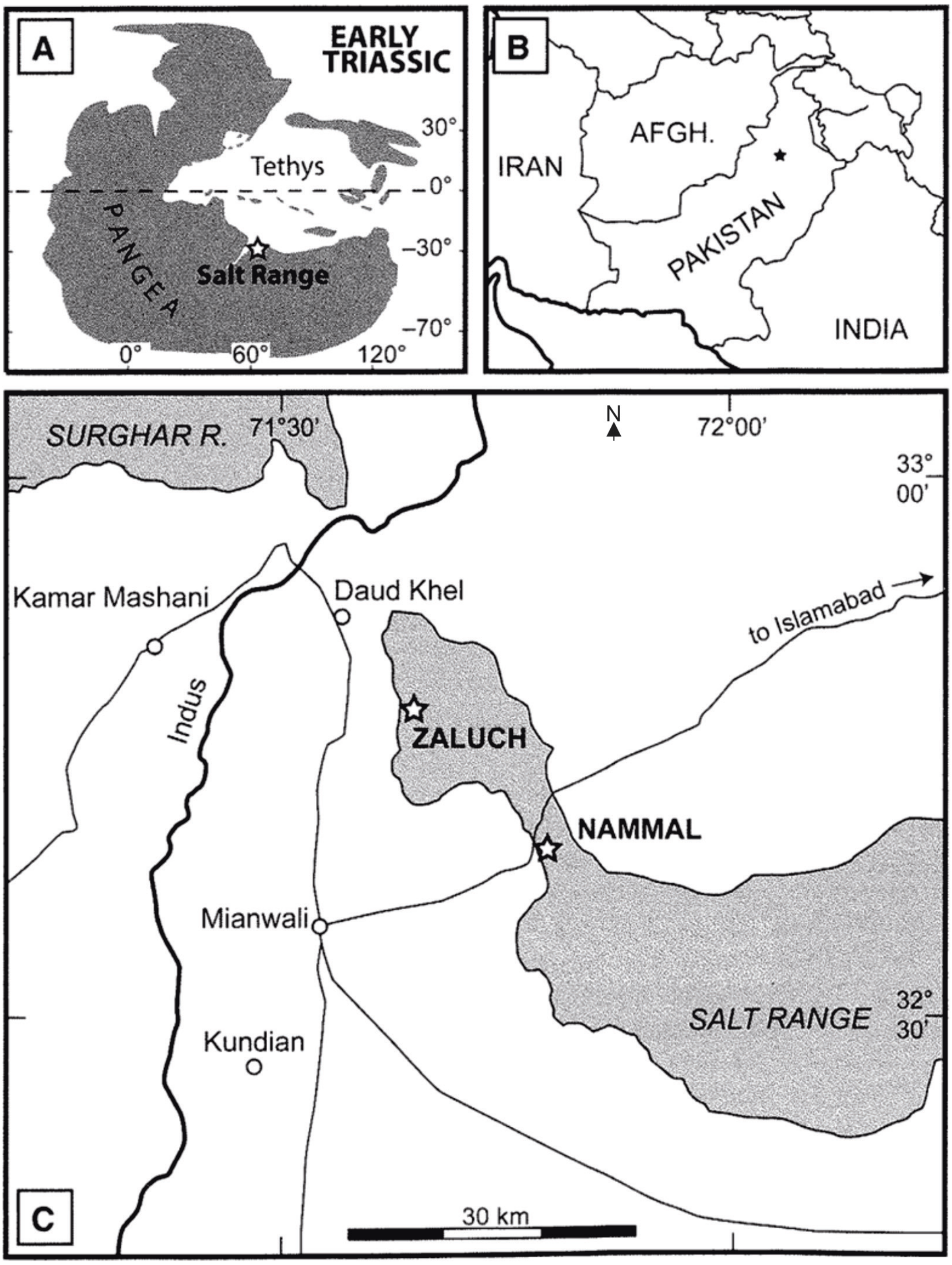
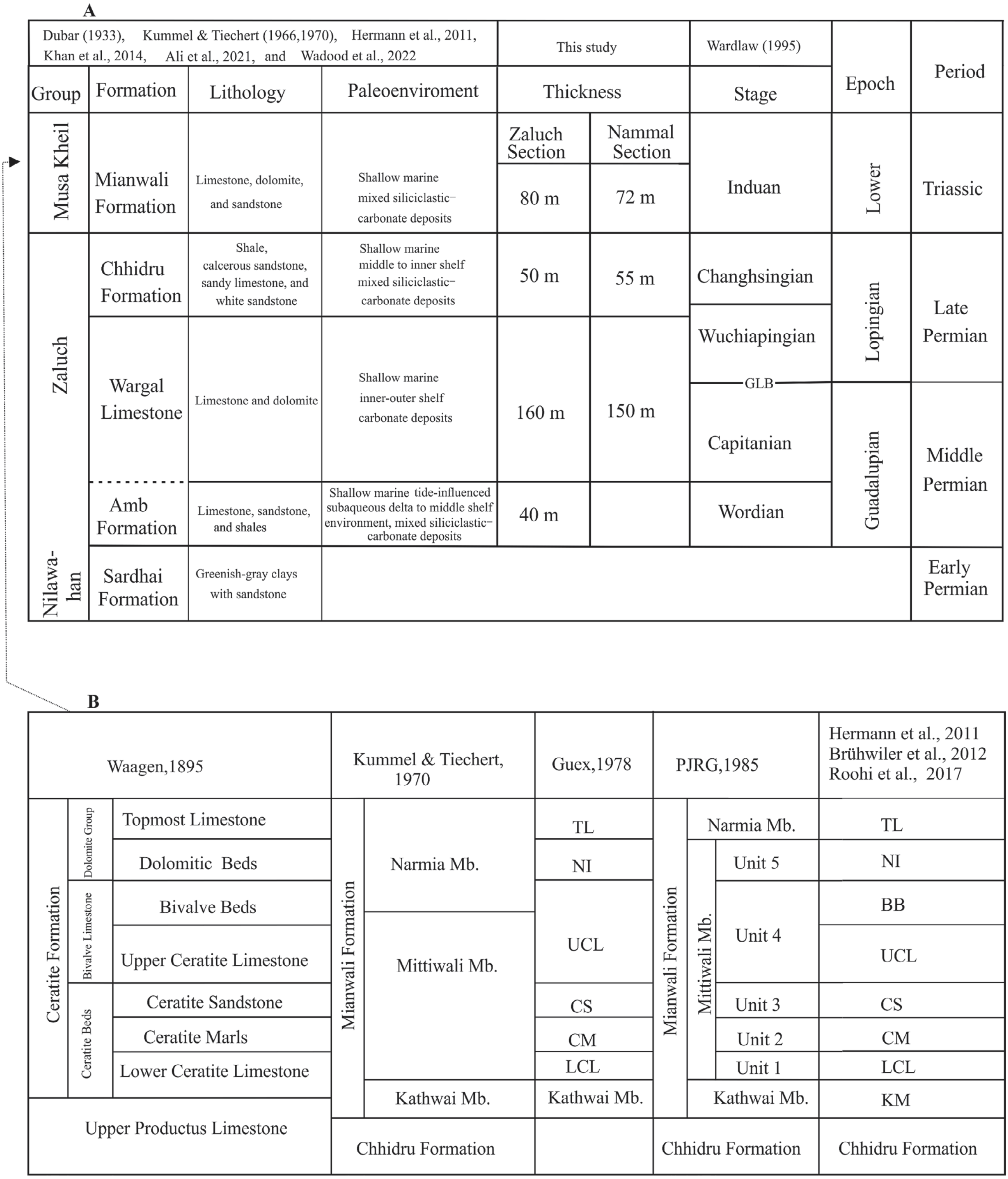


Figure 1: (A) Paleogeographical map of the Early Triassic with paleo-position of the Salt Range (**Brühwiler et al., 2011**). (B) Map of Pakistan with an indication of the studied area (star). (C) Map of the Salt Range with an indication of the studied sections (stars).

The paleoenviroment of the Wargal Limestone and the Chhidru Formation are inner-outer shelf carbonate and middle to inner shelf mixed siliciclastic–carbonate deposits, respectively (**Khan et al., 2014; Ali et al., 2021**). The base of the Chhidru Formation consists of 6-13 m thick shale (**Teichert, 1966**) and calcareous sandstone with a few sandy beds of limestone. Regression occurred and white sandstone deposited during Changhsingian (see **Figure 15** in **Shen et al., 2006**). The foraminiferal faunas from the Chhidru Formation can be correlated with those from the Wujiaping Formation of South China and assigned to the late Wuchiapingian by **Nakazawa and Dickins** (**1985**). **Wardlaw and Pogue** (**1995**) confirmed that the age of the Chhidru Formation is Changhsingian by conodont data, whereas the base of this formation is Wuchiapingian. In the Salt Range, the Lower Triassic succession (mixed siliciclastic–carbonate shelf deposits) is subdivided into 6 lithological units



A

Dubar (1933), Kummel & Tiechert (1966,1970), Hermann et al., 2011, Khan et al., 2014, Ali et al., 2021, and Wadood et al., 2022				This study		Wardlaw (1995)		
Group	Formation	Lithology	Paleoenviroment	Thickness		Stage	Epoch	Period
				Zaluch Section	Nammal Section			
Musa Kheil	Mianwali Formation	Limestone, dolomite, and sandstone	Shallow marine mixed siliciclastic–carbonate deposits	80 m	72 m	Induan	Lower	Triassic
Zaluch	Chhidru Formation	Shale, calcerous sandstone, sandy limestone, and white sandstone	Shallow marine middle to inner shelf mixed siliciclastic–carbonate deposits	50 m	55 m	Changhsingian	Lopingian	Late Permian
	Wargal Limestone	Limestone and dolomite	Shallow marine inner-outer shelf carbonate deposits	160 m	150 m	Wuchiapingian GLB Capitanian	Lopingian Guadalupian	Late Permian Middle Permian
	Amb Formation	Limestone, sandstone, and shales	Shallow marine tide-influenced subaqueous delta to middle shelf environment, mixed siliciclastic–carbonate deposits	40 m		Wordian	Guadalupian	Middle Permian
Nilawa-han	Sardhai Formation	Greenish-gray clays with sandstone						Early Permian

B

Waagen,1895			Kummel & Tiechert, 1970		Guex,1978	PJRG,1985			Hermann et al., 2011 Brühwiler et al., 2012 Roohi et al., 2017
Ceratite Formation	Dolomite Group	Topmost Limestone	Mianwali Formation	Narmia Mb.	TL	Mianwali Formation	Narmia Mb.		TL
		Dolomitic Beds			NI		Mittiwali Mb.	Unit 5	NI
	Bivalve Limestone	Bivalve Beds			UCL			Unit 4	BB
		Upper Ceratite Limestone		Mittiwali Mb.					UCL
	Ceratite Beds	Ceratite Sandstone			CS			Unit 3	CS
		Ceratite Marls			CM			Unit 2	CM
		Lower Ceratite Limestone			LCL			Unit 1	LCL
Upper Productus Limestone				Kathwai Mb.	Kathwai Mb.		Kathwai Mb.		KM
			Chhidru Formation			Chhidru Formation			Chhidru Formation

Figure 2: (**A**) Lithostratigraphic and Chronostratigraphic chart of the Zaluch Group and the Mianwali Formation (**Wardlaw and Pogue, 1995**). (**B**) Lithostratigraphic nomenclature of the Late Permian Chhidru Formation and the Early Triassic Mianwali Formation.

as following (from top to bottom): Topmost Limestone (TL), Niveaux Intermédiaires (NI), Bivalve Beds (BB), Upper Ceratite Limestone (UCL), Ceratite Sandstone (CS), Ceratite Marls (CM), Lower Ceratite Limestone (LCL), and Kathwai Member (**Waagen, 1895; Kummel, 1970; Guex, 1978; Nakazawa and Dickins, 1985; Hermann et al., 2011; Roohi et al., 2017**).

The position of the Permian-Triassic boundary, marked by the first occurrence of conodont species *Hindeodus parvus* (**Kozur and Pjatakova, 1976; Yin et al.,**

2001) is unclear in the Salt Range area, partly because of the diachronicity of lithological boundaries (**Hermann et al., 2011; Brüehwiler et al., 2012**). **Nakazawa and Dickins** (**1985**) subdivided the Kathwai Member into three parts at the Nammal section, and reported *Hindeodus parvus* (Kozur and Pjatakova, 1976) and *Hindeodus minutus* (Ellison, 1941) in the middle and lower parts, respectively. Therefore, the Permian-Triassic boundary was placed in the middle part of the Kathwai Member. *Hindeodus parvus* was also found near the base of the Kathwai Member by **Wardlaw and Mei** (**1999**) without stating the exact section. **Mertmann** (**2003**) wrote that the lowermost part of the Kathwai Member is locally preserved and composed of dolomitic sandstone. At the Nammal section, the negative carbon isotopes excursion, which has been described worldwide from the Permian-Triassic boundaries, occurs in the lowermost part of the Kathwai Member (**Baud et al., 1996**).

3. Materials and Methods

The fieldwork was conducted at the Nammal and Zaluch sections of the Western Salt Range and a total 148 samples were collected. The measured thickness of outcrops in the Zaluch section are 40 m, 160 m, 50 m, 80 m for the Amb Formation, Wargal Limestone, the Chhidru Formation and the Mianwali Formation, respectively (see **Figure 2A**). For the Wargal Limestone, Chhidru Formation, and Mianwali Formation, the measured thicknesses of outcrops in the Nammal section are 150 m, 55 m, and 72 m, respectively. The samples were collected from an outcrop with facies variation. Each sample was sliced into thin sections. Every thin section has been micorpetrographically analysed with special attention on foraminifers. Thin sections were studied using a polarized-light microscope (Leica-DM500) and photomicrographs were taken with an attached 10-megapixel digital camera. All specimens identified in this work are deposited in the School of Earth Sciences, China University of Geosciences, Wuhan, China.

3.1. Diversity indices

The total number of individuals for each species was subsequently counted, as well as their abundance (**Supplemental data S-1**) and stratigraphic distribution patterns, illustrated in **Figures 4** and **5**. For that purpose, the total number of individuals was plotted against the total number of species using the PAST software (**Hammer et al., 2017**) in order to compare the foraminiferal assemblage diversity and species richness in relation to the sampling number. The Shannon Diversity Index is calculated as (H = −åPi.ln Pi). The proportion of species i to the total number of species (Pi=n/N; n: individuals of a given type/species; N: total number of individuals) is computed and thereafter multiplied by the natural logarithm of this proportion. Diversity of order is calculated as the number of species of individual order divided by a total number of species in the same assemblage of the same time interval (e.g. diversity of Wordian Lagenida = 17/27). Relative abundance is calculated (Pi=Ni/N) as the number of individual (specimens) species in the assemblage divided by a total number of individuals in the assemblage of the same time interval.

3.2. Cluster and Rarefaction analysis

To analyse the similarities of foraminiferal assemblages in the studied two sections during the Middle Permian-Early Triassic age, we used the paired group algorithm with the Bray-Curtis similarity (or distance) index (**Parker and Arnold, 1999; Hammer and Harper, 2006; Schröder-Adams et al., 2008**). Our database includes taxa at the species level as well as their relative abundances (in percentages) in each section and interval (see **Supplementary data S-2**). We encompassed 47 and 39 species for the Wuchiapingian (*Codonofusiella schubertellinoides* assemblage), and 30 and 24 species for the Changhsingian (*Colaniella pseudolepida* assemblage) in the Zaluch and Nammal sections, respectively. To calculate the cluster trees, the cluster analyses were carried out using PAleontological STatistics (PAST), Version 3.16 (**Hammer et al., 2017**). Foraminiferal faunas with high similarity are largely clustered on one tree, with a similar similarity coefficient between these. Rarefaction (species accumulation curve) based on samples or individuals is an interpolation approach for estimating how many species would be observed for any lesser or bigger number of samples or individuals (**Raup, 1975**). We followed the samples base rarefaction methodology of **Colwell et al.** (**2004**). PAleontological STatistics (PAST), Version 3.16 (**Hammer et al., 2017**), was used to perform rarefaction analysis. A total of 97 and 51 samples were evaluated for sample-based rarefaction in the Zaluch and Nammal sections, respectively.

4. Results

4.1. Zaluch section

Five foraminiferal assemblages including *Geinitzina araxensis*, *Baisalina pulchra*, *Codonofusiella schubertellinoides*, *Colaniella pseudolepida*, and *Nodosinelloides-Planiinvoluta* assemblages are identified in the Zaluch section of Western Salt Range. They are shown in **Figures 3-4**.

4.1.1. Geinitzina araxensis assemblage

The *Geinitzina araxensis* assemblage is distinguished in the Amb Formation of the Zaluch section (Samples ZA-1–ZA-19). This assemblage corresponds to the conodont *Hindeodus excavatus*-*Merrillina galeata* Zone of the Wordian Stage, according to **Wardlaw and Pogue** (**1995**) (see **Figure 4**). The assemblage is dominated by smaller foraminifers including 27 species of 13 genera (see **Table 1 & 2**), and is represented by *Nodosinelloides camerata* (**Miklukho-Maklay, 1954**), *N. aequiampla* (**Zolotova and Baryshnikov, 1980**), *N. netschajewi* (**Cherdyntsev, 1914**), *N. shikhanica* (**Lipina, 1949**), *N. longissima* (**Suleymanov, 1949**), *N. longa* (**Lipina, 1949**), *N.* sp., *Nodosaria sumatrensis* (**Lange, 1925**), *Geinitzina taurica* (**Sellier de Civrieux and Dessauvagie, 1965**), *G. primitiva* (**Potievskaya, 1962**), *G. araxensis* (**Pronina, 1989**), *Pachyphloia schwageri* (**Sellier de Civrieux and Dessauvagie, 1965**), *P. robusta* (**Miklukho-Maklay, 1954**), *P. ovata* (**Lange, 1925**), *P.* sp., *Calvezina ottomana* (**Sellier de Civrieux and Dessauvagie, 1965**), *Cryptomorphina limonitica* (**Sellier de Civrieux and Dessauvagie, 1965**), *Tuberitina maljavkini* (**Suleymanov, 1948**), *T. collosa* (**Reitlinger, 1950**), *Diplosphaerina inaequalis* (**Derville, 1931**), *Hemigordius spirollinoformis* (**Wang, 1982**), *Hemigordius* sp., *Glomospirella spirillinoides* (**Grozdilova and Glebovskaya, 1948**), *Ammodiscus* sp., *Multidiscus* sp., *Earlandia* sp., and *Globivalvulina pulchra* (**Reitlinger, 1950**). *Geinitzina araxensis* forms 3.92% of the total abundance and has not been found in other assemblages. *Nodosinelloides* sp. (18.63% abundance), *Diplosphaerina inaequalis* (10.78%), *Earlandia* sp. (8.82%), *Pachyphloia* sp. (5.88%), and *Tuberitina collosa* (3.92%) are abundant species in *Geinitzina araxensis* assemblage. We identified 102 specimens from 20 thin sections in the Amb Formation. The Order Lagenida is represented by 64 specimens in 17 species of 5 genera. The most abundant genera are *Nodosinelloide*, *Pachyphloia*, and *Geinitzina*. The Order Miliolida is composed of 5 specimens in 3 species of 2 genera. The Order Parathuramminida consists of 17 specimens in 3 species of 2 genera. The orders Spirillinida and Earlandiida include 5 specimens in 2 species of 2 genera and 9 specimens in 1 species, respectively (see **Table 1**). The Order Endothyrida has the lowest abundance (2 specimens) and diversity with only *Globivalvulina* sp. The *Geinitzina araxensis* assemblage is dominated by Lagenida (63% of total species richness). In addition, diversities of Miliolida, Parathuramminida, Spirillinida, Endothyrida and Earlandiida are 11.1%, 11.1%, 7.4%, 3.7% and 3.7%, respectively (see **Figure 3A**). The Shannon diversity, Dominance, Evenness and Equitability index varied from 0-2.50 (avg. 0.96), 0-0.91 (avg. 0.44), 0.74-1 (avg. 0.95) and 0.89-1 (avg. 0.96), respectively, in the current assemblage. The assemblage indices (e.g. Shannon diversity so on) is relatively low compared to the younger (e.g. *Baisalina pulchra* assemblage) assemblage in the Zaluch section (see **Table 3**).

4.1.2. Baisalina pulchra assemblage

The *Baisalina pulchra* assemblage is identified in the lower part of the Wargal Limestone (Samples ZW-1–ZW-4) (see **Figure 4**). The assemblage includes 9 species of 7 genera (see **Table 1 & 2**): *Glomomidiella* sp., *Baisalina pulchra* (**Reitlinger, 1965**), *Hemigordiopsis* sp., *Hemigordius longus* (**Grozdilova, 1956**), *Neodiscus guangdongensis* (**Hao and Lin, 1982**), *Earlandia* sp., *Nodosinelloides shikhanica* (Lipina, 1949), *Glomospira tianmenensis* (**Zheng and Lin, 1978**), and *Globivalvulina bulloides* (**Brady, 1876**). Among them, *Baisalina pulchra*, *Glomomidiella* sp., and *Earlandia* sp. are the most abundant species, whereas the total abundance of *Glomomidiella* sp., *Baisalina pulchra*, *Earlandia* sp. are 17.39%, 17.39%, and 30.43%, respectively. The *Baisalina pulchra* has a global distribution and is known from South China, Turkey, Transcaucasus and Crimea (**Pronina, 1988; Pronina and Nestell, 1997; Kotlyar et al., 1999; Turhan et al., 2004; Zhang et al., 2015**) (see **Figure 6**). Therefore, the name of the assemblage is based on the *Baisalina pulchra* species (see **Figure 8G-H**). A total of 23 specimens were identified from 4 thin sections in this assemblage. The Order Miliolida is represented by 11 specimens in 5 species of 5 genera. The orders Earlandiida, Endothyrida, Spirillinida and Lagenida represent 1 species, whereas the specimens in the aforementioned orders are 7, 3 and 1, respectively (see **Table 1**). Miliolida is the dominating order and occupies 55.6% of the total assemblage (see **Figure 3B**). In addition, each of the other four orders (i.e. Spirillinida, Lagenida, Earlandiida and Endothyrida) represent 11.1% (see **Figure 3B).** For the *Baisalina pulchra* assemblage, Shannon Diversity Index (0.50-2.01, avg. 1.26), Simpson's Dominance Index (0.32-0.85, avg. 0.58), Evenness Index (0.82-0.83, avg. 0.83) and Equitability Index (0.72-0.92, avg. 0.82) measured by PAST software (version 3.16) (see **Table 3**). The assemblage indices are higher than that in the *Geinitzina araxensis* assemblage, but lower than the same measure in the younger assemblages (*Codonofusiella schubertellinoides* assemblage).

4.1.3. Codonofusiella schubertellinoides assemblage

This assemblage is established in the Wargal Limestone of the Zaluch section (Samples ZW-5–ZW-17) due to the appearance of the species *Codonofusiella schubertellinoides* (see **Figure 8L-P**) as a characteristic taxon, representing 5.52% of total abundance. The assemblage includes 47 species of 26 genera (see **Table 1 & 2**), among which, 27 species were already present in the previous assemblages (i.e. *Geinitzina araxensis* and *Baisalina pulchra* assemblages) and above (i.e. *Colaniella pseudolepida* and *Nodosinelloides-Planiinvoluta* assemblages) (see **Figure 4**), represented by *Calvezina ottomana* (**Sellier de Civrieux and Dessauvagie, 1965**), *Nodosinelloides longissima* (**Suleymanov, 1949**), *N. aequiampla* (**Zolotova and Baryshnikov, 1980**), *N. netschajewi* (**Cherdynzev, 1914**), *N. potievskayae* (**Mamet and Pinard, 1996**), *N. camerata* (**Miklukho-Maklay, 1954**), *N. shikhanica* (**Lipina, 1949**), *N.* sp., *Geinitzina primitiva* (**Potievskaya, 1962**), *G. taurica* (**Sellier de Civrieux and Dessauvagie, 1965**), *Pachyphloides* *inflatus* (**Miklukho-Maklay, 1954**), *Pachyphloia robusta* (**Miklukho-Maklay, 1954**), *P. ovata* (**Lange, 1925**), *P. schwageri* (**Sellier de Civrieux and Dessauvagie, 1965**), *P.* sp., *Colaniella minima* (**Wang, 1966**), *C. pseudolepida* (**Okimura, 1988**), *C. zaluchense* (**Okimura, 1988**), *Frondina permica* (**Sellier de Civrieux and Dessauvagie, 1965**), *Neodiscus guangdongensis* (**Hao and Lin, 1982**), *Hemigordius longus* (**Grozdilova, 1956**), *Diplosphaerina inaequalis* (**Derville, 1931**), *Earlandia* sp., *Globivalvulina bulloides* (**Brady, 1876**), *Dagmarita* sp., *Neoendothyra* sp., and *Reichelina changhsingensis* (**Sheng, 1958**) (see **Figure 4**). Twenty species are characteristic of this assemblage consisting of fusulinids and smaller foraminifers represented by *Codonofusiella erki* (**Rozovskaya and Rauzer-Chernousova, 1965**), *C. schubertellinoides* (**Sheng, 1956**), *C.* (?) *minuta* (**Sheng, 1956**), *C.* sp., *Nankinella minor* (**Sheng, 1956**), *N.* sp., *Necdetina taurica* (**Altiner et al., 2007**), *Pisolina excessa* (**Lee, 1934**), *Nodosinelloides mirabilis caucasica* (**Miklukho-Maklay, 1954**), *N. sagitta* (**Miklukho-Maklay, 1954**), *Ichthyofrondina palmata* (**Wang, 1974**), *Langella imbecilla* (**Lin et al., 1990**), *L. perforata* (**Sellier de Civrieux and Dessauvagie, 1965**), *L.* cf. *pulchra* (**Lange, 1925**), *Frondinodosaria* sp., *Geinitzina uralica* (**Suleymanov, 1949**), *Agathammina* sp., *Orthovertellopsis proteaeformis* (**Vachard et al., 2015**), *Charliella altineri* (**Gaillot and Vachard, 2007**), and *Deckerella* sp. There were several predominant species in *Codonofusiella schubertellinoides* assemblage such as *Nodosinelloides* sp. (12.88% abundance), *Necdetina taurica* (6.13%), *Nodosinelloides camerata* (4.91%) and *Globivalvulina bulloides* (4.29%). Thirteen thin sections were examined from the *Codonofusiella schubertellinoides* assemblage at Zaluch section, yielding 163 specimens. A total of 94 specimens were found, representing 27 species and 10 genera of the Order Lagenida. The Order Fusulinida is composed of 38 specimens in 9 species of 5 genera. The Order Endothyrida is represented by 14 specimens in 5 species of 5 genera. The Order Miliolida is represented by *Neodiscus guangdongensis*, *Hemigordius longus*, *Agathammina* sp., and *Orthovertellopsis proteaeformis* with a total six specimens. The orders Parathuramminida and Earlandiida are represented by single occurrences of *Diplosphaerina inaequalis* and *Earlandia* sp., containing five and six specimens, respectively (see **Table 1**). The dominating Order Lagenida contains 57.44% of the total species. The diversity of foraminifers in the orders Fusulinida, Endothyrida, Miliolida, Earlandiida and Parathuramminida are 19.5%, 10.64%, 8.51%, 2.13% and 2.13%, respectively (see **Figure 3C**). The Shannon diversity, Dominance, Evenness and Equitability Index are ranging from 0.56-2.40 (avg. 1.78), 0.38-0.89 (avg. 0.78), 0.74-1 (avg. 0.87) and 0.81-1 (avg. 0.92), respectively (see **Table 3**). The Shannon diversity and Dominance Index are higher than older (for instance, *Geinitzina araxensis* assemblage) and younger (e.g. *Colaniella pseudolepida* assemblage) assemblages in the Zaluch section. These two indices depict that foraminifera were abundant and diversified in the Wuchiapingian Wargal Limestone.

4.1.4. Colaniella pseudolepida assemblage

The *Colaniella pseudolepida* assemblage is established in the Chhidru Formation (Samples ZC-1–ZC-19) of the Zaluch section. There are 30 species of 16 genera, among which, 7 species are characteristic for this assemblage only, and 23 taxa are inherited from the previous assemblages (see **Figure 4**). The characteristic taxa of the assemblage include *Climacammina* sp., *Colaniella cylindrica* (**Miklukho-Maklay, 1954**), *C. minuta* (**Okimura, 1988**), *Pseudocolaniella xufulingensis* (**Wang, 1966**), *Pseudocolaniella* sp., *Robuloides lens* (**Reichel, 1946**), and *Nodosaria delicata* (**Wang, 1976**). The holdover species are represented by *Diplosphaerina inaequalis* (**Derville, 1931**), *Tuberitina collosa* (**Reitlinger, 1950**), *Earlandia* sp., *Geinitzina taurica* (**Sellier de Civrieux and Dessauvagie, 1965**), *Pachyphloides inflatus* (**Miklukho-Maklay, 1954**), *Nodosinelloides aequiampla* (**Zolotova and Baryshnikov, 1980**), *N. camerata* (**Miklukho-Maklay, 1954**), *N. netschajewi* (**Cherdynzev, 1914**), *N. shikhanica* (**Lipina, 1949**), *N. potievskayae* (**Mamet & Pinard, 1996**), *Pachyphloia robusta* (**Miklukho-Maklay, 1954**), *P. ovata* (**Lange, 1925**), *P.* (**Sellier de Civrieux and Dessauvagie, 1965**), *P.* sp., *Frondina permica* (**Sellier de Civrieux and Dessauvagie, 1965**), *Colaniella minima* (**Wang, 1966**), *C. pseudolepida* (**Okimura, 1988**), *C. zaluchense* (**Okimura, 1988**), *Globivalvulina bulloides* (**Brady, 1876**), *Dagmarita* sp., *Neoendothyra* sp., and *Reichelina changhsingensis* (**Sheng, 1958**). The species *Colaniella pseudolepida* (see **Figure 9G-I**) is a characteristic and dominant taxon of the assemblage, and forms 10.91% of total abundance. *Nodosinelloides* sp., *Nodosinelloides camerata*, *Pachyphloia robusta* and *Diplosphaerina inaequalis* are the most abundant smaller foraminifera species in this assemblage, accounting for 17.27%, 8.18%, 8.18% and 7.27%, respectively. Only one fusulinoidean species (*Reichelina changhsingensis*) is found in the *Colaniella pseudolepida* assemblage at both the Zaluch and Nammal sections. Twelve species of this assemblage are dispersed throughout the Zaluch Group of the Zaluch section (see **Figure 4**). In this assemblage, 110 specimens were recovered from 19 thin sections. The *Colaniella pseudolepida* assemblage is composed of diverse lagenides, which include 88 specimens in 22 species of 8 genera. Four species of four genera were identified from 7 specimens in the Order Endothyrida from the *Colaniella pseudolepida* assemblage. The Order Parathuramminida is represented by 9 specimens in 2 species of 2 genera. The orders Fusulinida and Earlandiida include *Reichelina changhsingensis* and Earlandia sp., respectively, with the former having only one specimen and the latter having five (see **Table 1**). The La-

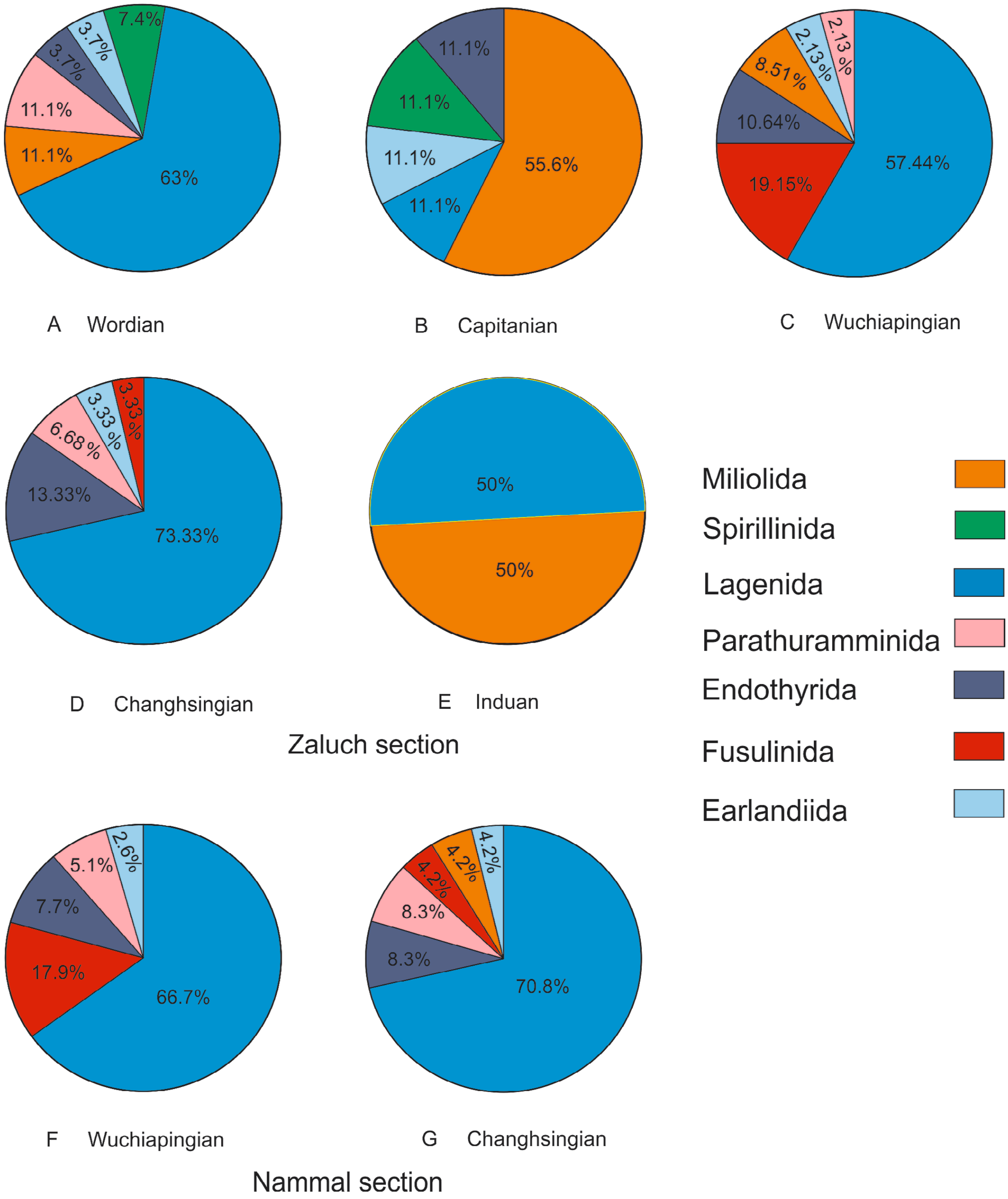


Figure 3: Diversity of the various orders constituting the assemblages of foraminifera of the Zaluch and Nammal sections.

genida is the dominant order and forms 73.33% of the total assemblage. The diversity of foraminifers in the Order Endothyrida is 13.33 %, Parathuramminida is 6.68 %, Fusulinida and Earlandiida are 3.33 % (see **Figure 3D**). The Shannon Diversity and Equitability Index ranged from 0.69-2.90 (avg. 1.59) and 0.67-1 (avg. 0.93), respectively. Shannon Diversity Index is lower than Wuchiapingian but higher than Wordian, Capitanian and Induan assemblage. The Evenness Index ranged from 0.55-1, with an average of 0.89. Shannon Diversity, Equitability and Evenness indices are categorized as higher category, suggest the presence of foraminifera in

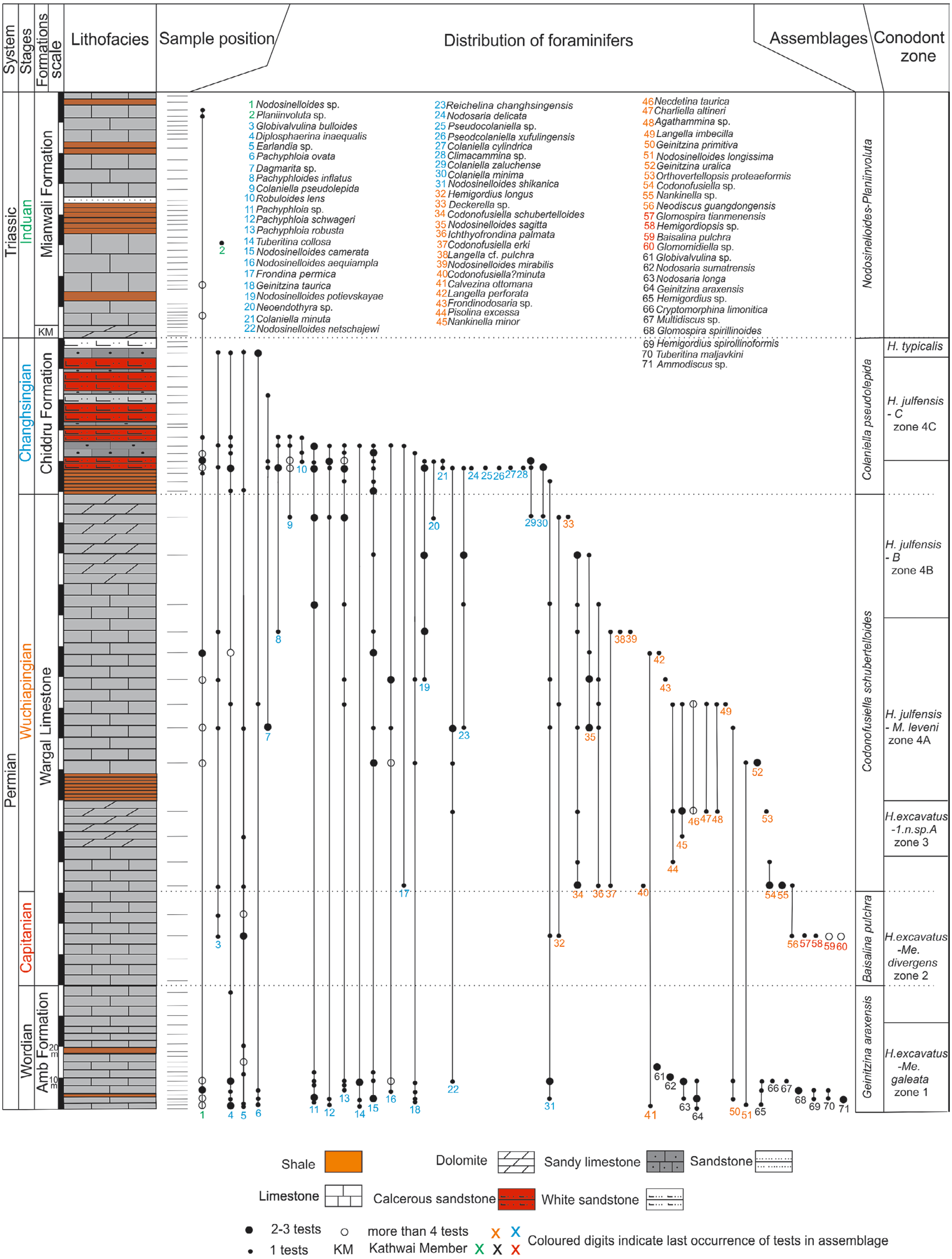


Figure 4: Stratigraphic occurrences of foraminifera and conodont zones of the Zaluch section (conodont data from **Wardlaw and Pogue, 1995**).

Table 1: Species and Genus diversity distribution of the main foraminifer groups in the Zaluch and Nammal sections.

Age	**Order**	**Zaluch section**				**Nammal section**			
		Species	**Genus**	**Specimens**	**Thin sections**	**Species**	**Genus**	**Specimens**	**Thin sections**
Wordian	Lagenida	17	5	64	20				
	Miliolida	3	2	5					
	Parathuramminida	3	2	17					
	Spirillinida	2	2	5					
	Earlandiida	1	1	9					
	Endothyrida	1	1	2					
Capitanian	Miliolida	5	5	11	4				
	Spirillinida	1	1	1					
	Lagenida	1	1	1					
	Earlandiida	1	1	7					
	Endothyrida	1	1	3					
Wuchiapingian	Lagenida	27	10	94	13	26	12	104	12
	Fusulinida	9	5	38		7	3	42	
	Endothyrida	5	5	14		3	3	30	
	Miliolida	4	4	6					
	Parathuramminida	1	1	5		2	2	9	
	Earlandiida	1	1	6		1	1	2	
Changhsingian	Lagenida	22	8	88	19	17	6	65	15
	Endothyrida	4	4	7		2	2	6	
	Parathuramminida	2	2	9		2	2	4	
	Earlandiida	1	1	5		1	1	5	
	Fusulinida	1	1	1		1	1	1	
	Miliolida					1	1	1	
Induan	Lagenida	1	1	13	41				24
	Miliolida	1	1	1					

the *Colaniella pseudolepida* assemblage was evenly distributed. For the Dominance Index results ranged from 0.50-0.94, with an average of 0.72, categorized as low category (for *Codonofusiella schubertellinoides* assemblage an average dominance 0.78), indicating that foraminifera are not very dominant. These four indices (see **Table 3**) suggest that the condition of the Chhidru Formation was favourable for the habitat of foraminifera.

4.1.5. Nodosinelloides-Planiinvoluta assemblage

Most of the species disappeared in the Upper Permian Chhidru Formation and did not cross the Permian-Triassic boundary, except the small and primitive genus *Nodosinelloides* with higher tolerance of anoxia (see **Figure 4**). Therefore, this assemblage contains only two taxa, *Nodosinelloides* sp. and *Planiinvoluta* sp. The *Nodosinelloides* sp. includes 13 specimens and is the dominant taxon representing 92.8% (13/14 specimens*100) of total abundance compared to *Planiinvoluta* sp., which contains only one specimen (7.14% abundance). The diversity of foraminifers is dominated by Lagenida 50% (1/2 species*100) and Miliolida 50% (see **Figure 3E**). The Shannon Index (a measure of entropy) is calculated using the number of individuals and taxa. The value varies from 0 (single-taxon foraminifers) to high values (many taxa, each with few individuals) for foraminifers. The Shannon Diversity and Dominance indices represent zero in the Induan assemblage, whereas Evenness represents 1. These indices suggest that the Induan environment was unsuitable for foraminifer survival.

4.2. *Nammal section*

The foraminiferal composition and distribution of the Nammal section are depicted in **Figures 3** and **5**. Two assemblages of foraminifers are distinguished in the Wargal Limestone and Chhidru Formation of the Nammal section, i.e. (1) Wuchiapingian *Codonofusiella schubertellinoides* assemblage and (2) Changhsingian *Colaniella pseudolepida* assemblage.

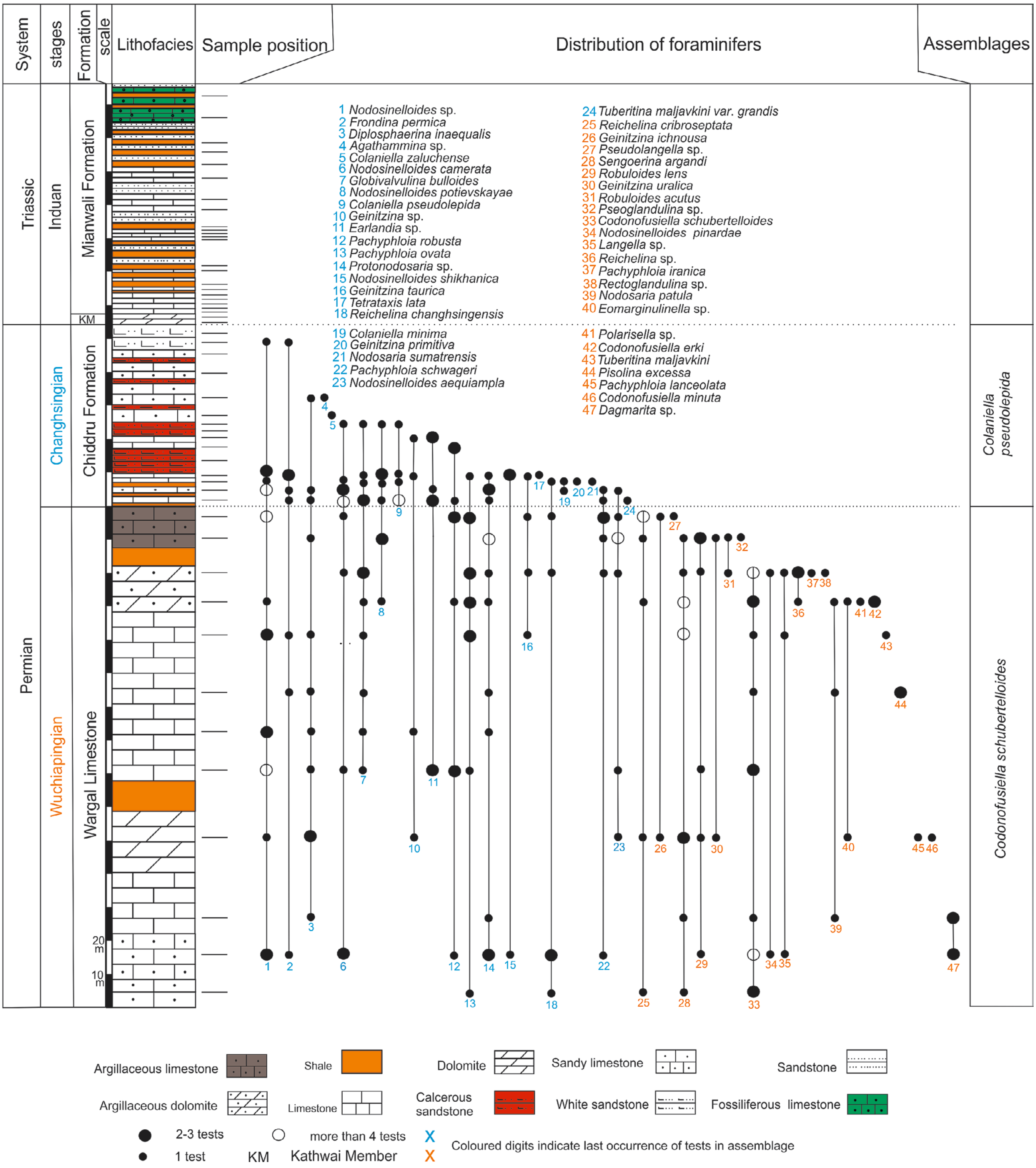


Figure 5: Stratigraphic occurrences of foraminifera in the Nammal section.

4.2.1. Codonofusiella schubertellinoides assemblage

The *Codonofusiella schubertellinoides* assemblage is distinguished in the Wargal Limestone. The fusulinoideans consist of 42 specimens in 7 species of 3 genera, i.e. *Codonofusiella schubertellinoides* (**Sheng, 1956**), *C. erki* (**Rozovskaya and Rauzer-Chernousova, 1965**), *C. minuta* (**Sheng, 1956**), *Reichelina cribroseptata* (**Erk, 1942**), *R. changhsingensis* (**Sheng, 1958**), *R.* sp. and *Pisolina excessa* (**Lee, 1934**). The smaller foraminifers in the assemblage are abundant and comprise of 145 specimens in 32 species of 18 genera and are *Pachyphloia robusta* (**Miklukho-Maklay, 1954**), *P. schwageri* (**Sellier de Civrieux and Dessauvagie, 1965**), *P. lanceolata* (**Miklukho-Maklay, 1954**), *P. iranica* (**Bozorgnia, 1973**), *P. ovata* (**Lange, 1925**), *Nodosinelloides pinardae* (**Groves and Wahlman, 1997**), *N. aequiampla* (**Zolotova and Baryshnikov, 1980**), *N.*

camerata (**Miklukho-Maklay, 1954**), *N. shikhanica* (**Lipina, 1949**), *N.* sp., *N. potievskayae* (**Mamet and Pinard, 1996**), *N. patula* (**Miklukho-Maklay, 1954**), *Polarisella* sp., *Geinitzina ichnousa* (**Sellier de Civrieux and Dessauvagie, 1965**), *G. uralica* (**Suleymanov, 1949**), *G. taurica* (**Sellier de Civrieux and Dessauvagie, 1965**), *G.* sp., *Langella* sp., *Frondina permica* (**Sellier de Civrieux and Dessauvagie, 1965**), *Pseudolangella* sp., *Eomarginulinella* sp., *Protonodosaria* sp., *Robuloides acutus* (**Reichel, 1946**), *R. lens* (**Reichel, 1946**), *Sengoerina argandi* (**Altiner, 1999**), *Dagmarita* sp., *Tuberitina maljavkini* (**Suleymanov, 1948**), *Diplosphaerina inaequalis* (**Derville, 1931**), *Rectoglandulina* sp., *Pseudoglandulina* sp., *Earlandia* sp., and *Globivalvulina bulloides* (**Brady, 1876**) (see **Figures 8-10**). The species *Codonofusiella schubertellinoides* is dominant and dispersed through the interval as compared to other species of *Codonofusiella* and forms 11.23% of total abundance (see **Figure 5**). This assemblage is also dominated by *Sengoerina argandi* (10.70%), *Nodosinelloides* sp. (9.63%), *Protonodosaria* sp. (6.42%), and *Pachyphloia ovata* (6.42%). Scarce species *Pachyphloia lanceolata*, *P. iranica*, *Tuberitina maljavkini*, *Polarisella* sp., *Rectoglandulina* sp., *Pseudoglandulina* sp., and *Pseudolangella* sp., *Codonofusiella erki*, and *C. minuta* are less abundant (one or two specimens per thin section). In this assemblage, we have reported 187 specimens from 12 thin sections. The Order Lagenida is represented by 104 specimens in 26 species of 12 genera. In terms of abundance and taxonomic diversity, the Lagenida has become increasingly dominating. The Order Endothyrida is comprised of 30 specimens in 3 species of 3 genera. The Order Parathuramminida is represented by 9 specimens in 2 species of 2 genera. *Earlandia* sp. is the only representative of the Order Earlandiida, having two specimens (see **Table 1**). The diversity of smaller foraminifers belonging to the orders Lagenida, Endothyrida, Earlandiida and Parathuramminida totals 66.7%, 7.7%, 2.6%, and 5.1%, respectively, whereas the diversity of fusulinids is 17.9% (see **Figure 3F**). Both the Shannon Diversity Index (1.48-2.49, avg. 2.08) and Dominance Index (0.73-0.90, avg. 0.85) are higher in this assemblage, whereas the Evenness Index (0.69-1.00, avg. 0.86) and Equitability Index (0.86-1.00, avg. 0.93) are consistent with the *Codonofusiella schubertellinoides* assemblage of the Zaluch section (see **Table 3**).

4.2.2. Colaniella pseudolepida assemblage

The foraminifers of this assemblage are represented by 24 species of 13 genera (see **Table 1 & 2**), among which 8 species are characteristic for this assemblage only and 16 taxa are holdovers from the previous assemblage. The genus *Palaeofusulina* (**Deprat, 1912**), which is one of the best indicators of the Changhsingian age, was not found during this study. The assemblage is composed of three species of *Colaniella*, e.g. *Colaniella zaluchense* (**Okimura, 1988**), *C. pseudolepida* (**Okimura, 1988**), and *C. minima* (**Wang, 1966**). Compared to the other species of *Colaniella*, *Colaniella pseudolepida* is dominant and dispersed (see **Figure 5**). *C. pseudolepida* is characteristic taxon of the assemblage and represents 8.54% of total abundance. Other prominent species in this assemblage, *Nodosinelloides camerata* and *Nodosinelloides* sp., occupy about 10.98 percent of overall abundance, while *Nodosinelloides aequiampla* and *Frondina permica* account for 9.76 percent and 7.32 percent, respectively. Only one fusulinoidean species is found in this assemblage and is represented by *Reichelina changhsingensis* (**Sheng, 1958**), which is a holdover from the previous assemblage. The characteristic species of the assemblage include *Tuberitina maljavkini* var. *grandis* (**Reitlinger, 1950**), *Agathammina* sp., *Tetrataxis lata* (**Spandel, 1901**), *Colaniella minima* (**Wang, 1966**), *C. pseudolepida* (**Okimura, 1988**), *C. zaluchense* (**Okimura, 1988**), *Nodosaria sumatrensis* (**Lange, 1925**) and *Geinitzina primitiva* (**Potievskaya, 1962**). The inherited species from the older assemblage include *Diplosphaerina inaequalis* (**Derville, 1931**), *Frondina permica* (**Sellier de Civrieux and Dessauvagie, 1965**), *Nodosinelloides aequiampla* (**Zolotova and Baryshnikov, 1980**), *N. camerata* (**Miklukho-Maklay, 1954**), *N. shikhanica* (**Lipina, 1949**), *N. potievskayae* (**Mamet and Pinard, 1996**), *N.* sp., *Pachyphloia ovata* (**Lange, 1925**), *P. robusta* (**Miklukho-Maklay, 1954**), *P. schwageri* (**Sellier de Civrieux and Dessauvagie, 1965**), *Geinitzina taurica* (**Sellier de Civrieux and Dessauvagie, 1965**), *G.* sp., *Protonodosaria* sp., *Globivalvulina bulloides* (**Brady, 1876**), *Earlandia* sp., and *Reichelina changhsingensis* (**Sheng, 1958**) (see **Figure 5**). Species *Diplosphaerina inaequalis*, *Nodosinelloides* sp., and *Frondina permica* are dispersed throughout the strata of the Nammal section (see **Figure 5**). *Colaniella pseudolepida* assemblage has yielded a total of 82 specimens from 15 thin sections. The foraminiferal assemblage in the Nammal section is dominated by the Order Lagenida, which is represented by 65 specimens in 17 species of 6 genera. The orders Endothyrida, and Parathuramminida include 6 and 4 specimens in 2 species of 2 genera, respectively. The orders Earlandiida, Fusulinida and Miliolida are represented by 5 and 1 specimen in 1 species, respectively (see **Table 1**). The Order Lagenida is the dominant one and forms 70.8% of the total assemblage (see **Figure 3G**). The diversity of the orders Parathuramminida, Endothyrida, Earlandiida, Miliolida, and Fusulinida are 8.3%, 8.3%, 4.2%, 4.2%, and 4.2%, respectively (see **Figure 3G**). The Shannon Diversity, Dominance, Evenness and Equitability indices fluctuated from 0-2.34, (avg. 1.17), 0-0.90, (avg. 0.56), 0.83-1 (avg. 0.96) and 0.91-1 (avg. 0.97), respectively, lesser than older assemblage. Both the Shannon diversity and Dominance indices are inferior than in the *Colaniella pseudolepida* assemblage of the Zaluch section, while the Evenness and Equitability indices are higher than in the former assemblage (see **Table 3**).

5. Discussion

5.1. Correlation between Zaluch and Nammal sections

We have established five and two foraminiferal assemblages in Zaluch and Nammal sections, respectively. The details of each assemblage are given in section 4. The *Codonofusiella schubertellinoides* and *Colaniella pseudolepida* assemblages of Nammal section are well correlated with the same assemblages determined in the Zaluch section. The common foraminifera species of the Wuchiapingian *Codonofusiella schubertellinoides* assemblage in both sections are represented by 19 species of 10 genera, such as *Geinitzina uralica*, *G. taurica*, *Nodosinelloides aequiampla*, *N. shikhanica*, *N. potievskayae*, *N. camerata*, *N. sp.*, *Pachyphloia robusta*, *P. ovata*, *P. schwageri*, *Frondina permica*, *Pisolina excessa*, *Codonofusiella erki*, *C. schubertelloides*, *C. minuta*, *Reichelina changhsingensis*, *Globivalvulina bulloides*, *Dagmarita sp.*, and *Diplosphaerina inaequalis*. The mutual species of Nammal and Zaluch sections in the Changhsingian *Colaniella pseudolepida* assemblage include 15 species of 8 genera, e.g. *Nodosinelloides shikhanica*, *N. potievskayae*, *N. camerata*, *N. sp.*, *Pachyphloia robusta*, *P. ovata*, *P. schwageri*, *Colaniella minima*, *C. pseudolepida*, *C. zaluchense*, *Geinitzina taurica*, *Frondina permica*, *Globivalvulina bulloides*, *Earlandia sp.*, and *Reichelina changhsingensis* (see **Table 2**). Lagenida is of high abundance (57.67% and 55.61%, respectively) and high diversity (57.44% and 66.7%, respectively) during the Wuchiapingian (*Codonofusiella schubertellinoides* assemblage), for the Zaluch and Nammal sections (see **Figure 3** & **Table 1**), whereas Fusulinida is the second most dominated order by diversity (19.5% and 17.9%, respectively) and abundance (23.31% and 22.46%, respectively). Parathuramminida and Earlandiida have the lowest abundance (3.07% and 3.68% and 4.81% and 1.07%, for the Zaluch and Nammal sections, respectively) and diversity (2.13% and 2.13% and 5.1% and 2.6%, for the Zaluch and Nammal sections, respectively).

For the Zaluch and Nammal sections, Lagenida is dominated by diversity (73.33% and 70.8%, respectively) and abundance (80% and 79.27%, respectively) in the Changhsingian *Colaniella pseudolepida* assemblage (see **Figure 3** & **Table 1**). Lagenida abundance and diversity are nearly identical in both sections. The corresponding diversity (13.33% and 6.68% and 8.3% and 8.3%, for the Zaluch and Nammal sections, respectively) and abundance (6.36% and 8.18% and 7.32% and 4.88%, for the Zaluch and Nammal sections, respectively) are found in the orders Endothyrida and Parathuramminida. The orders Earlandiida and Fusulinida occur sporadically and reach their lowest diversity (3.33% and 3.33% and 4.2% and 4.2%, respectively) and abundance (4.55% and 0.91% and 6.10% and 1.22%) at the Zaluch and Nammal sections.

The Shannon diversity (avg. 2.08) and Simpson's Dominance Index (avg. 0.85) are higher in the Nammal section than those in the Zaluch section (e.g. avg. H = 1.78 & D = 0.78), whereas the Evenness and Equitability index values exhibited relatively slight variation and were determined to be comparatively uniform across all samples of the Zaluch and Nammal sections during the Wuchiapingian (see **Table 3**). In contrast, the Shannon Diversity, and Simpson's Dominance, Evenness and Equitability indices are lower in the Nammal section than those in the Zaluch section throughout the Changhsingian.

The differences and similarities between foraminifera assemblages of studied sections were then verified using a Q-Mode cluster analysis (based on relative abundances of species). Cluster analysis (also known as segmentation analysis or taxonomy analysis) is a numerical method for identifying homogenous subgroups in a population by reducing within-group differences and maximizing between-group differences (**Cherchi et al., 2009**). Furthermore, the similarity measured by cluster analysis obviously shows that the Nammal and Zaluch assemblages (Wuchiapingian) form one group, sharing a similarity coefficient up to 77%. The similarity coefficient within the Changhsingian *Colaniella pseudolepida* assemblage, constituting 68% for both Zaluch and Nammal sections. As such, foraminiferal assemblages are more closely related in biotic compositions and closer diversity indices in both sections (see **Figure 11**).

The decline in foraminifer biodiversity between the Middle Permian and the Early Triassic is not due to sampling bias, according to subsample analyses. Sample-based rarefaction was performed on the Middle Permian-Induan data set of the Zaluch section and the Late Permian-Induan data set of the Nammal section (see **Figure 12**). When the randomly subsampled number reaches 97 (Zaluch) and 51 (Nammal), the diversity patterns in our two localities of samples intervals are revealed to be complete.

5.2. Correlation with other regions of the world

5.2.1. Wordian

The Wordian age of the *Geinitzina araxensis* assemblage is confirmed by the conodont zone (*Hindeodus excavatus*-*Merrillina galeata* Zone) in the Amb Formation (**Wardlaw and Pogue, 1995**) (see **Figure 6**). The species of *Geinitzina araxensis* had been reported in the *Paratirolites kittli* Zone of the Dorashamian Stage of Transcaucasus (**Pronina, 1989**), in the Changhsingian Changxing Formation of South China (**Song et al., 2007**), in the Wuchiapingian exotic limestone blocks of Alma River Basin, Crimea (**Pronina and Nestell 1997**), and in the Capitanian Episkopi Formations of Hydra Island, Greece (**Wignall et al., 2012**). This (*Geinitzina araxensis*) indicates that smaller foraminifer species have a wide stratigraphic distribution. The *Geinitzina araxensis* assemblage has a similar age to assemblages

Table 2: Correlation of foraminifera in the Nammal and Zaluch sections.

Stage	Orders	Species	Zaluch	Nammal
Wordian	Lagenida	*Cryptomorphina limonitica*	√	
		Calvezina ottomana	√	
		Geinitzina araxensis	√	
		Geinitzina taurica	√	
		Geinitzina primitiva	√	
		Nodosaria sumatrensis	√	
		Nodosaria longa	√	
		Nodosinelloides camerata	√	
		Nodosinelloides aequiampla	√	
		Nodosinelloides netschajewi	√	
		Nodosaria shikhanica	√	
		Nodosinelloides longissima	√	
		Nodosinelloides sp.	√	
		Pachyphloia ovata	√	
		Pachyphloia schwageri	√	
		Pachyphloia robusta	√	
		Pachyphloia sp.	√	
	Miliolida	*Multidiscus* sp.	√	
		Hemigordius spirollinoformis	√	
		Hemigordius sp.	√	
	Parathuramminida	*Tuberitina maljavkini*	√	
		Tuberitina collosa	√	
		Diplosphaerina inaequalis	√	
	Spirillinida	*Ammodiscus* sp.	√	
		Glomospirella spirillinoides	√	
	Endothyrida	*Globivalvulina* sp.	√	
	Earlandiida	*Earlandia* sp.	√	
Capitanian	Miliolida	*Glomomidiella* sp.	√	
		Baisalina pulchra	√	
		Hemigordius longus	√	
		Neodiscus guangdongensis	√	
		Hemigordiopsis sp.	√	
	Lagenida	*Nodosinelloides shikhanica*	√	
	Spirillinida	*Glomospira tianmenensis*	√	
	Earlandiida	*Earlandia* sp.	√	
	Endothyrida	*Globivalvulina bulloides*	√	
Wuchiapingian	Lagenida	*Geinitzina primitiva*	√	
		Geinitzina uralica	√	√
		Geinitzina taurica	√	√
		Geinitzina ichnousa		√
		Geinitzina sp.		√
		Pachyphloides inflatus	√	
		Langella imbecilla	√	
		Langella perforata	√	
		Langella cf. pulchra	√	
		Langella sp.		√
		Nodosinelloides sagitta	√	
		Nodosinelloides mirabilis	√	

Table 2: Continued

Stage	Orders	Species	Zaluch	Nammal
		Nodosinelloides longissima	√	
		Nodosinelloides aequiampla	√	√
		Nodosinelloides netschajewi	√	
		Nodosinelloides shikhanica	√	√
		Nodosinelloides potievskayae	√	√
		Nodosinelloides camerata	√	√
		Nodosaria patula		√
		Nodosinelloides pinardae		√
		Nodosinelloides sp.	√	√
		Polarisella sp.		√
		Pachyphloia robusta	√	√
		Pachyphloia ovata	√	√
		Pachyphloia schwageri	√	√
		Pachyphloia lanceolata		√
		Pachyphloia iranica		√
		Pachyphloia sp.	√	
		Colaniella minima	√	
		Colaniella pseudolepida	√	
		Colaniella zaluchense	√	
		Frondinodosaria sp.	√	
		Calvezina ottomana	√	
		Ichthyofrondina palmata	√	
		Frondina permica	√	√
		Pseodolangella sp.		√
		Protonodosaria sp.		√
		Eomarginulinella sp.		√
		Rectoglandulina sp.		√
		Pseoglandulina sp.		√
		Robuloides acutus		√
		Robuloides lens		√
	Fusulinida	*Nankinella* sp.	√	
		Nankinella minor	√	
		Necdetina taurica	√	
		Pisolina excessa	√	√
		Codonofusiella erki	√	√
		Codonofusiella schubertelloides	√	√
		Codonofusiella minuta	√	√
		Codonofusiella sp.	√	
		Reichelina changhsingensis	√	√
		Reichelina cribroseptata		√
		Reichelina sp.		√
	Endothyrida	*Charliella altineri*	√	
		Globivalvulina bulloides	√	√
		Deckerella sp.	√	
		Dagmarita sp.	√	√
		Neoendothyra sp.	√	
		Sengoerina argandi		√

Table 2: Continued

Stage	**Orders**	**Species**	**Zaluch**	**Nammal**
	Miliolida	*Neodiscus guangdongensis*	√	
		Hemigordius longus	√	
		Orthovertellopsis proteaeformis	√	
		Agathammina sp.	√	
	Parathuramminida	*Diplosphaerina inaequalis*	√	√
		Tuberitina maljavkini		√
	Earlandiida	*Earlandia* sp.	√	√
Changhsingian	Lagenida	*Nodosinelloides aequiampla*	√	√
		Nodosinelloides netschajewi	√	
		Nodosinelloides shikhanica	√	√
		Nodosinelloides potievskayae	√	√
		Nodosinelloides camerata	√	√
		Nodosaria sumatrensis		√
		Nodosaria delicata	√	
		Nodosinelloides sp.	√	√
		Pachyphloia robusta	√	√
		Pachyphloia ovata	√	√
		Pachyphloia schwageri	√	√
		Pachyphloia sp.	√	
		Colaniella minima	√	√
		Colaniella pseudolepida	√	√
		Colaniella zaluchense	√	√
		Colaniella cylindrica	√	
		Colaniella minuta	√	
		PseudoColaniella xufulingensis	√	
		Pseudocolaniella sp.	√	
		Geinitzina taurica	√	√
		Geinitzina primitiva		√
		Geinitzina sp.		√
		Pachyphloides inflatus	√	
		Robuloides lens	√	
		Frondina permica	√	√
		Protonodosaria sp.		√
	Endothyrida	*Globivalvulina bulloides*	√	√
		Climacammina sp.	√	
		Dagmarita sp.	√	
		Neoendothyra sp.	√	
		Tetrataxis lata		√
	Parathuramminida	*Diplosphaerina inaequalis*	√	√
		Tuberitina collosa	√	
		Tuberitina maljavkini grandis		√
	Earlandiida	*Earlandia* sp.	√	√
	Fusulinida	*Reichelina changhsingensis*	√	√
	Miliolida	*Agathammina* sp.		√
Induan	Lagenida	*Nodosinelloides* sp.	√	
	Miliolida	*Planiinvoluta* sp.	√	

Table 3: Comparison of Shannon Diversity Index (H), Simpson's Dominance Index (D), Evenness and Equitability between the Zaluch and Nammal sections.

Age	Ranging	Shannon_H	Simpson_1-D	Evenness_e^H/S	Equitability_J	Section
Wordian	Minimum	0.00	0.00	0.74	0.89	Zaluch
	Maximum	2.50	0.91	1.00	1.00	
	Average	0.96	0.44	0.95	0.96	
Capitanian	Minimum	0.50	0.32	0.82	0.72	
	Maximum	2.01	0.85	0.83	0.92	
	Average	1.26	0.58	0.83	0.82	
Wuchiapingian	Minimum	0.56	0.38	0.74	0.81	
	Maximum	2.40	0.89	1.00	1.00	
	Average	1.78	0.78	0.87	0.92	
	Minimum	1.48	0.73	0.69	0.86	Nammal
	Maximum	2.49	0.90	1.00	1.00	
	Average	2.08	0.85	0.86	0.93	
Changhsingian	Minimum	0.69	0.50	0.55	0.67	Zaluch
	Maximum	2.90	0.94	1.00	1.00	
	Average	1.59	0.72	0.89	0.93	
	Minimum	0.00	0.00	0.83	0.91	Nammal
	Maximum	2.34	0.90	1.00	1.00	
	Average	1.17	0.56	0.96	0.97	
Induan	Minimum	0	0	1		Zaluch
	Maximum	0	0	1		
	Average	0	0	1		

zones from other regions such as the *Geinitzina jucunda* assemblage of the Maokou Formation from the Tieqiao section of South China (**Zhang et al., 2015**), the *Neoschwagerina haydeni* assemblage of the Damingshan Formation in Paleotethyan seamounts of Yunnan (**Ueno et al., 2003**), the *Neoschwagerina* Zone of the Iwato and Mitai formations in Japan (**Kobayashi, 2012**), the middle-late Murgabian biozone of the Ruteh Formation in Iran (**Nejad et al., 2015**), the smaller foraminifers *Neodiscus millioides* Zone, *Geinitzina lata* Zone, and *Cornuspira baissalensis-Reitlingeria vediensis* Zone of Transcaucasus (**Pronina, 1988**), the *Afghanella tereshkovae* assemblage from the Saiq Formation in Oman (**Forke et al., 2011**), and the *Dunbarula-Cornuspira* assemblage from the lower part of the Curkurkoy Formation in Turkey (**Şahin et al., 2012**). Most of the above-mentioned assemblage zones, however, have distinct foraminifera species than the *Geinitzina araxensis* assemblage of the Salt Range, implying a significant level of foraminifers heterogeneity in the Zaluch section during the Wordian. The Murgabian *Neoschwagerina craticulifera* Zone in the black limestones of Baške Oštarije and Brušane localities (Velebit Mt., Croatia) (**Sremac, 1991**) correlated with the *Geinitzina araxensis* assemblage of Salt Range. Among them, the common foraminifer species include *Hemigordius* sp., *Globivalvulina* sp., and *Pachyphloia* sp. The *Neoschwagerina craticulifera* Zone contains *Baisalina pulchra* in the fourteen localities, marking the Capitanian age.

5.2.2. Capitanian

The Capitanian age of the *Baisalina pulchra* assemblage is confirmed by the *Hindeodus excavates-Merrilli-*

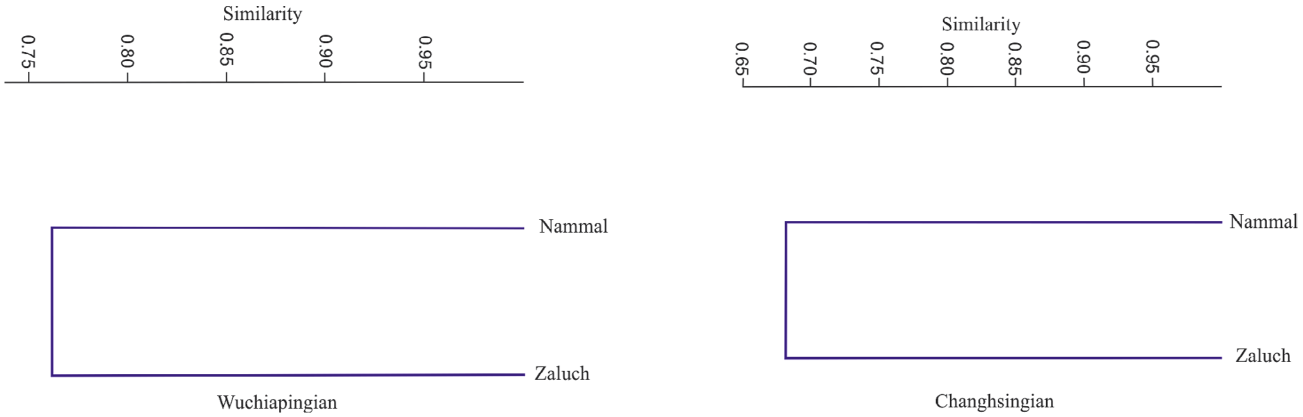


Figure 11: Dendrograms of cluster analyses (Bray–Curtis similarity; unweighted pair-group mean averaging clustering) of the Nammal and Zaluch sections, tested for the *Codonofusiella schubertellinoides* and *Colaniella pseudolepida* assemblages.

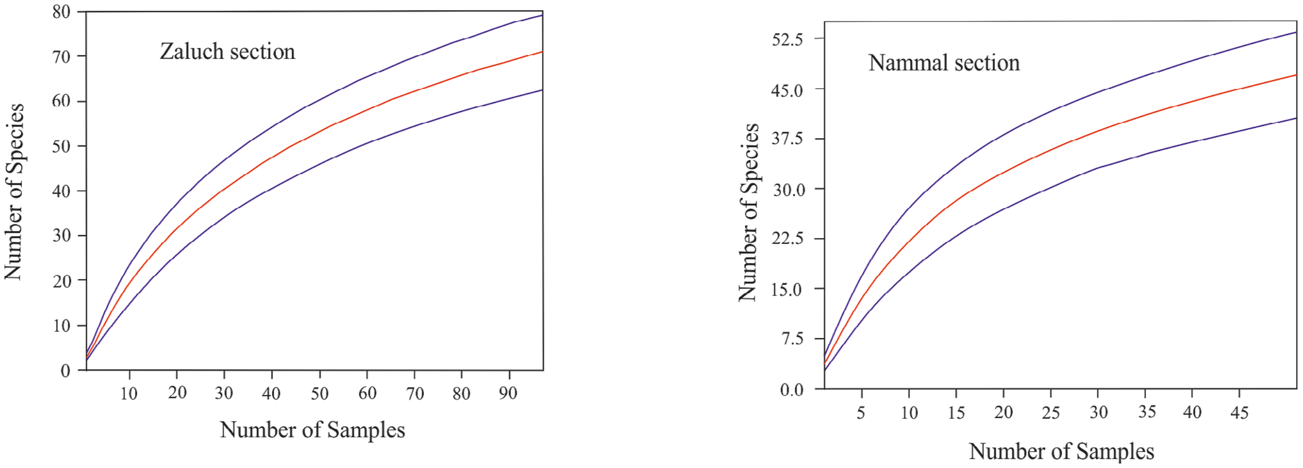


Figure 12: Sample-based rarefaction curves for the Zaluch and Nammal sections. The red line represents the rarefaction curve and the double blue lines represent 95% confidence intervals.

na divergens Zone (**Wardlaw and Pogue, 1995**). Moreover, **Pronina (1988)** used *Baisalina pulchra* as an index species of the Midian. The presence of *Baisalina pulchra* in the Salt Range permits us to correlate it with the *Baisalina pulchra* assemblage of South China (**Zhang et al., 2015**), Turkey (**Leven and Okay, 1996; Turhan et al., 2004**), and Crimea (**Pronina and Nestell, 1997; Kotlyar et al., 1999**), *Baisalina pulchra* Zone in Transcaucasus (**Pronina, 1988**), the *Dunbarula* aff. *pusilla*-*Chusenella* assemblage of the Ruteh Formation of Iran (**Nejad et al., 2015**), *Shanita amosi*-*Hemigordiopsis renzi*-*Basalina pulchra* assemblage of Thailand (**Dawson et al., 1993**) and *Pseudodunbarula arpaensis* Zone of Saad and Arqov Formations of Israel (**Orlov-Labkovsky, 2004**) (see **Figure 6**). The common species include *Baisalina pulchra*, *Hemigordiopsis* sp., and *Globivalvulina bulloides*.

Hemigordiopsis subglobosa-*Chusenella douvillei* assemblage of the Xiala Formation in Lhasa Block (**Zhang et al., 2010, 2016**), *Neoschwagerina margaritae* assemblage of the Damingshan Formation in Paleotethyan seamounts of Yunnan (**Ueno et al., 2003**), the *Lepidiolina multiseptata* assemblage of the Taishaku limestone (**Kobayashi, 2010**) and Miharaiyama area in Japan (**Kobayashi, 2006**), *Hemigordius irregulariformis* and *Hemigordiopsis orientalis* Zones in Transcaucasus (**Pronina, 1988**), the *Sphairionia sikuoides*-*Shanita amosi* assemblage in the Saiq Formation of Oman (**Forke et al., 2011**), the *Eopolydiexodina*-*Chusenella* assemblage from the Curkurkoy Formation in Turkey (**Şahin et al., 2012**), and *Hemigordiopsis renzi* assemblage in the Cyprus near Riatiko (**Nestell and Pronina, 1997**) have Capitanian/Midian age, equivalent in age to the *Baisalina pulchra* assemblage of the Salt Range. It is important to note that, as for the Capitanian assemblages, the *Baisalina pulchra* assemblage of this study does not have mutual species with the above-mentioned assemblages, suggesting a high heterogeneity of foraminifera during the Capitanian in the Zaluch section.

5.2.3. Wuchiapingian

Codonofusiella is an index fossil for the Wuchiapingian Stage according to the **Shen and Henderson (2014)**. The Wuchiapingian age is also supported by conodont zones (e.g. *Hindeodus excavatus* Zone, *Hin-*

deodus julfensis-*Mesogondolella leveni* Zone, and *Hindeodus julfensis* Zone) in the Wargal Limestone (**Wardlaw and Pogue, 1995**). *Codonofusiella schubertellinoides* assemblage in the Salt Range appears to be correlative with the *Nanlingella simplex*-*Codonofusiella kwangsiana* Zone of South China (**Rui et al.,1984**), the *Codonofusiella schubertellinoides* assemblage from both the Xainza area of Lhasa (**Zhang et al., 2014; Zhang and Wang, 2017**) and the Aseelah Unit of Oman (**Hauser et al., 2000**), the *Codonofusiella kwangsiana* Zone of the Shifodong Formation in the Shifodong section of Yunnan (**Ueno and Tsutsumi, 2009**), the *Codonofusiella kwangsiana* Zone in the Arqov Formation of Israel (**Orlov-Labkovsky, 2004**), the *Codonofusiella erki* assembalage in the exotic limestone blocks, Crimea (**Pronina and Nestell, 1997; Kotlyar et al., 1999**), and the *Paraglobivalvulina mira–Pesudotristix* assemblage of the Ruteh Formation in Iran (**Nejad et al., 2015**) (see **Figure 6**). Other common foraminifera in the aforesaid regions include *Ichthyofrondina palmata*, *Langella perforata*, *Nankinella minor*, *Nankinella* sp., *Codonofusiella schubertellinoides*, and *Codonofusiella erki*. The *Gallowayinella meitienensis* Zone in South China (**Sheng and Jin, 1994**), *Nanlingella suzukii* Zone of the Mitai Formation in Japan (**Kobayashi, 2012**), *Paradagmarita flabelliformis*, *Nodosaria transcaucasica* and *Paraglobivalvulina mira*-*Pseudotristix solida* Zones in Transcaucasus (**Pronina, 1988**), and the *Reichelina*-*Neoendothyra* assemblage from the Kizilbag Formation in the Karadere Köyü section of Turkey (**Şahin et al., 2012**) are of Wuchiapingian age. Based on a similar Permian Stage (Wuchiapingian), the above-mentioned assemblage zones are associated with the Salt Range *Codonofusiella schubertellinoides* assemblage.

5.2.4. Changhsingian

The Changhsingian age of the *Colaniella pseudolepida* assemblage of the Salt Range is confirmed by the conodonts of the *Hindeodus julfensis* Zone and *Hindeodus typicalis* Zone in the Chhidru Formation (**Wardlaw and Pogue, 1995**). The *Colaniella pseudolepida* assemblage in the Salt Range can be correlated to the *Palaeofusulina sinensis* Zone of the Dajiang section of South China and Iwai-Kanyo area from Japan (**Kobayashi, 1997; Song et al., 2009**), *Colaniella*-*Reichelina* assemblage in the upper part of the Xiala Formation (**Qiao et al., 2018**), and the *Reichelina pulchra*-*Colaniella parva*-*Dilatofusulina orthogonios* Zone of the Gyanyima Formation in Lhasa (**Wang et al., 2010**), *Palaeofusulina minima* and *Palaeofusulina sinensis* Zones of the Shifodong Formation in a Paleo-Tethyan seamounts of Yunnan (**Ueno and Tsutsumi, 2009**), the Yellic Member of the Cekic Dagi Formation and Yugluk Tepe Limestone Formation of Turkey (**Groves et al., 2005**), and the *Reichelina media* Zone of the Arqov Formation of Israel (**Orlov-Labkovsky, 2004**). The shared species with the above assemblage zones comprises *Nodosinelloides camerata*, *Pachyphloia robusta*, *Pachyphloia ovata*, *Pachyphloia schwageri*, *Frondina permica*, *Globivalvulina bulloides*, *Diplospherina inaequalis*, *Colaniella minima*, *Colaniella minuta*, *Colaniella cylindrica*, and *Reichelina changhsingensis*. The *Neoendothyra reicheli* assemblage in the Hambast Formation of Iran (**Mohtat-Aghai and Vachard, 2005**), *Lingulina ornata*, *Rectoglandulina micula*, *Nodosaria doraschamesis* Zones of smaller foraminifers in Transcaucasus (**Pronina, 1988**), and the *Paradagmarita monodi* assemblage in the Saiq Formation of Oman (**Forke et al., 2011**) have Changhsingian age. The above-mentioned assemblage zones are related to the Salt Range *Colaniella pseudolepida* assemblage based on Changhsingian Stage.

5.2.5. Induan

The *Nodosinelloides*-*Planiinvoluta* assemblage in the Salt Range can be correlated with *Nodosaria expolita* assemblage in Italy (**Groves et al., 2007**) and Slovenia (**Nestell et al., 2011**), as well as *Nodosinelloides aequiampla* assemblage of South China (**Song et al., 2007, 2009**) based on *Nodosinelloides* sp. Finally, *Nodosaria elabugae* assemblage in Turkey (**Groves et al., 2005**) has Induan age, which corresponds to the Salt Range *Nodosinelloides*-*Planiinvoluta* assemblage.

5.3. Foraminiferal variations during the GLME

The studied area does not yield fusulinid in the Capitanian Stage, only smaller foraminifers. Four species, i.e. *Glomomidiella* sp., *Baisalina pulchra*, *Hemigordiopsis* sp., and *Glomospira tianmenensis* went extinct during the Capitanian and 18 survival species passed through the Guadalupian−Lopingian boundary, suggesting smaller foraminifers in the Salt Range have not been seriously affected by the Guadalupian−Lopingian mass extinction (GLME). Previous studies reported that mostly fusulinids went extinct during the GLME and smaller foraminifers were safe to escape from this extinction (**Loeblich and Tappan, 1988; Erwin, 1993; Leven, 1993, 2003**). *Baisalina pulchra* had been found in the Midian deposits of Transcaucasus (**Pronina, 1988**), the Maokou Formation of South China (**Zhang et al., 2015**), exotic limestone blocks, Alma River basin, Crimea (**Pronina and Nestell, 1997; Kotlyar et al., 1999**), the Sakarya Composite Terrane and the Karakya complex of Turkey (**Leven and Okay, 1996; Turhan et al., 2004**), suggesting that this species was globally recovered in the Capitanian strata. *Baisalina pulchra* may have only been extirpated (extinct locally) in the Salt Range.

5.4. Foraminiferal variations during the PTME

In the Western Salt Range region, 37 species of foraminifera went extinct in the Chhidru Formation (Changhsingian) of the Nammal and Zaluch sections (see **Figures 4-5 & Table 2**) during the Permian-Triassic mass extinction (PTME). The species *Globivalvulina*

International Time scale	Tethyan Time scale	South China	Lhasa	Palaeotetyan seamounts	Japan, Thailand	Iran, Slovenia	Transcaucasus	Oman, Itlay	Turkey, Crimea	Israel, Cyprus, Croatia	This study	Conodont zones
		(1) - (3)	(4) - (6)	(7)	(8)	(9) - (12)	(13)	(14) - (17)	(18) - (19)	(20) - (22)		
Induan		*Nodosinelloides aequiampla*				*Nodosaria-expolita*		*Nodosaria-expolita*	*Nodosaria-elabugae*		*Nodosinelloides-Planiinvoluta* assemblage	
Changhsingian	Dorashamian	*Palaeofusulina sinensis*	*Colaniella-Reichelina* *Reichelina pulchra-Colaniella-parava-Dilatofusulina-orthogonios*	*Palaeofusulina sinensis* *Palaeofusulina minima*	*Palaeofusulina sinensis*	*Neoendothyra reicheli*	*Nodosaria doraschamensis* *Rectoglandulina micula* *Lingulina ornata*	*Paradagmarita-monodi*	*Pachyphloia ovata* - *Frondina permica*	*Reichelina media*	*Colaniella pseudolepida* assemblage	*Hindeodus typicalis* *Hindeodus julfensis*
Wuchiapingian	Dzhulfian	***Gallowayinella meitiensis*** *Nanlingella simplex-Codonofusiella kwangsiana*	*Codonofusiella schubertelloides*	*Codonofusiella* cf. *kwangsiana*	*Nanlingella suzukii*	*Paraglobivalvulina mira-Pseudotristix*	*Paradagmarita flabelliformis* *Nodosaria transcaucasica* *Paraglobivalvulina mira-Pseudotristix solida*	*Codonofusiella schubertelloides*	*Codonofusiella erki* *Reichelina-Neoendothyra*	*Codonofusiella kwangsiana*	*Codonofusiella-schubertelloides* assembalge	*Hindeodus julfensis* *Hindeodus julfensis-Mesogondolella leveni* *Hindeodus excavatus*
Capitanian	Midian	*Baislina* cf. *pulchra* *Hemigordiopsis* sp.	*Hemigordiopsis subglobosa* - *Chusenella douvillei*	*Neoschwagerina margaritae*	*Lepidolina-multiseptata Shanita amosi-Hemigordiopsis renzi-Baislina pulchra*	*Dunbarula* aff. *pusilla-Chusenella*	*Hemigordius irregulariformis* *Hemigordiopsis orientalis* *Baislina pulchra*	*Sphairionia sikuoides-Shanita amosi*	*Eopolydiexodina* - *Chusenella* *Baislina pulchra*	*Pseudodunbarula arpaensis* *Hemigordiopsis renzi*	*Baisalina pulchra* assembalge	*Hindeodus excavatus-Merrilina divergens*
Wordian	Murgabian	*Geinitzina jucunda*		*Neoschwagerina haydeni*	*Neoschwagerina* Zone	*Neoschwagerina simplex*	*Cornuspira baissalensis-Reitlingeria vediensis* Zone *Geinitzina lata* Zone *Nedodiscus millioides* Zone	*Afghanella tereshkovae*	*Dunbarula-Cornuspira*	*Neoschwagerina craticulifera*	*Geinitzina araxensis* assemblage	*Hindeodus excavatus-Merrilina galeata*

Figure 6: Correlation of Guadalupian–Lopingian and Induan foraminifera. References are (1) Zhang et al., 2014. (2) Sheng and Jin, 1994; Rui et al., 1984. (3) Song et al., 2007, 2009. (4) Zhang et al., 2016; Zhu, 1982. (5) Zhang et al., 2014. (6) Qiao et al., 2018. (7) Ueno et al., 2003, 2009. (8) Kobayashi, 1997, 2006; Kobayashi et al., 2009, 2012; Dawson et al., 1993. (9) Nejad et al., 2015. (10) Mohtat and Vachard, 2005. (11) Baghbani, 1997. (12) Nestell et al., 2011. (13) Pronina, 1988. (14) Vachard et al., 2002. (15) Forke et al., 2011. (16) Hauser et al., 2000. (17) Groves et al., 2007. (18) Şahin et al., 2012. (19) Groves and Altiner, 2005; Kotlyar et al., 1999; Pronina and Nestell, 1997; Turhan et al., 2004. (20) Nestell and Pronina, 1997. (21) Orlov-Labkovsky, 2004. (22) Sremac, 1991.

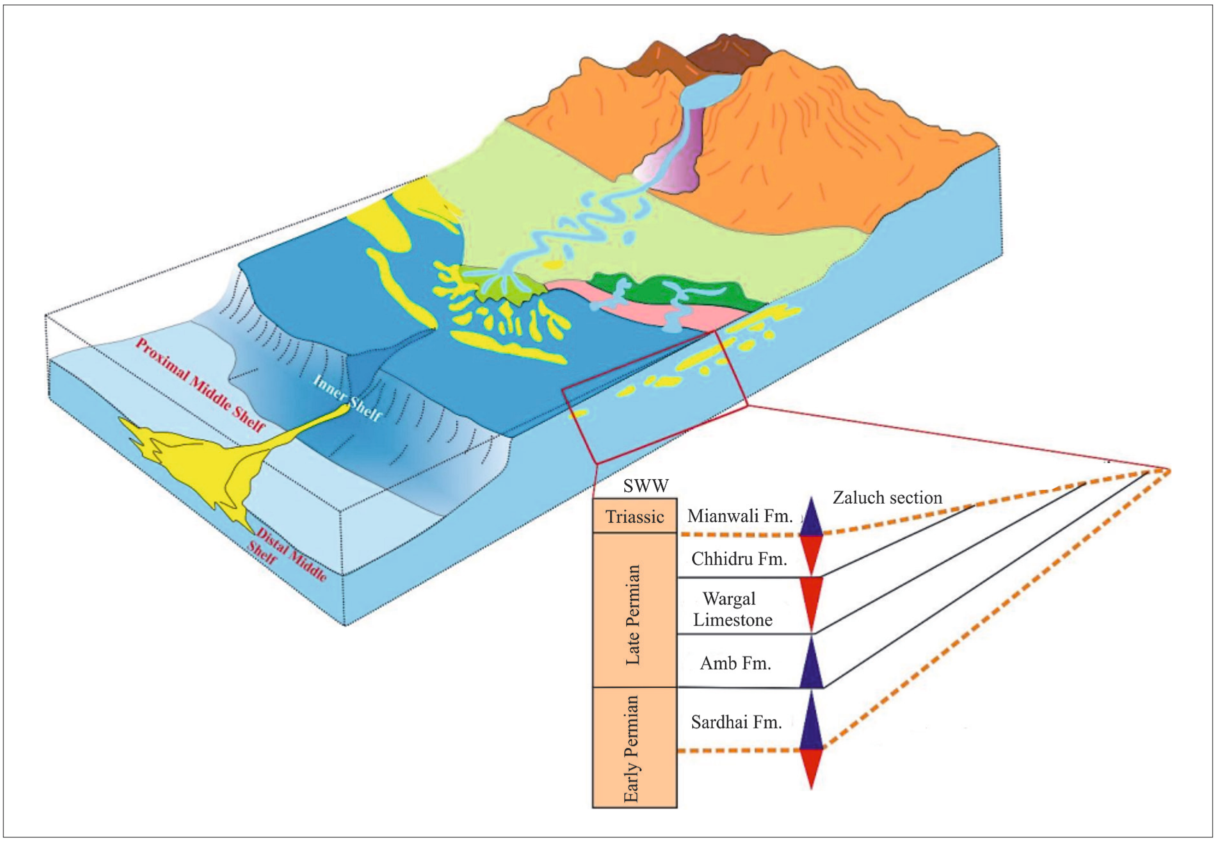


Figure 7: Depositional model of the Zaluch section (modified after **Ali et al., 2021**).

bulloides, *Diplosphaerina inaequalis*, *Earlandia* sp., *Pachyphloia ovata*, *Nodosinelloides* sp., and *Frondina permica* disappeared near the Permian-Triassic boundary (see **Figures 4-5**). Only one survivor species (*Nodosinelloides* sp.) passed through the Permian-Triassic boundary (see **Figure 4**). The *Nodosinelloides* sp. has been found in the basal Triassic in numerous sections, e.g. the Meishan section in South China (**Song et al., 2007**), the Lukač section in Slovenia (**Nestell et al., 2011**), and the Tesero section in northern Italy (**Groves et al., 2007**). Paleoenvironments are different in various regions during the Late Permian, for instance, Transitional Dolomite and Sandy Dolomite (shallow marine carbonate) in the Rizvanuša section (Croatia) (**Fio et al., 2010**), shallow platform carbonate facies are recorded at Cili and Dajiang, South China (**Liu et al., 2020**) and shallow marine mixed siliciclastic–carbonate shelf deposits in the Chhidru Formation of the Nammal and Zaluch sections (**Ali et al., 2021**). Foraminifera are also susceptible to clastic influx in the environment; certain species prefer a carbonate-rich habitat, while others can survive in the clastic environment. **Kumar and Saraswati** (**1997**) reported that larger foraminifera also differ in their susceptibility to clastic influx in the environment. *Spiroclypeus* and *Sorites* prefer a carbonate-rich environment whereas *Miogypsina* is most tolerant to terrigenous input. The intrusion of clastic sediments could reduce the foraminifera species' abundance (**Youssef et al., 2021**). The top of the Viking Formation in central Alberta (Canada) reveals coarser clastic input and a decline in overall species diversity (**Stritch and Schröder-Adams, 1999**). So here in this study, the Chhidru Formation has mixed siliciclastic–carbonate shelf deposits, certain species went extinct near the Permian-Triassic boundary, while the majority of the species vanished in the lower part of the aforementioned formation, because they (extinct species in lower part of the Chhidru Formation) could not tolerate the terrigenous-clastic input in the upper part of the Chhidru Formation. A similar extinction occurred in the Sandy Dolomite of the Rizvanuša section (Croatia). The Late Permian foraminifera disappeared in the lower part of Sandy Dolomite and did not extend to the Permian-Triassic boundary (see **Figure 2 in Fio et al., 2010**), as in the Dajiang section of South China (see **Figure 3 in Song et al., 2009**). Paleoenvironmental variation can lead to the disappearance of foraminifers, but this is not their actual extinction horizon. For instance, the species *Nodosinelloides camerata* did not reach the PTB and disappeared in the lower part of the Chhidru Formation in the Zaluch section, because the aforesaid species is not tolerant to the terrigenous-clastic input in the upper part of the Chhidru Formation, but the same species (*Nodosinelloides camerata*) became extinct near the PTB of the Dajiang section (see **Figure 3 in Song et al., 2009**).

Toxic chemicals generated by the massive igneous province of the Siberian Traps and minor volcanic activity in the Palaeotethys Ocean (**Yin and Song, 2013; Burgess et al., 2017**) are another possible driver of foraminiferal migration. The Siberian Traps, in particular, produced massive amounts of hazardous substances, such as toxic metals (**Sanei et al., 2012**), noxious gases (**Keller and Kerr, 2014**), and chars (**Grasby et al., 2011**), perhaps turning the surface of seawaters into a toxic soup in which foraminifers could scarcely survive. According to **Liu et al.** (**2020**), foraminifera migrated to deeper water to avoid scorching and toxicity in shallow waters caused by the Siberian Traps and coeval volcanic activity around the Paleotethys Ocean. Therefore, the scarcity of foraminifers in the upper part of the Chhidru Formation are a possible migration of foraminifers from inner shelf towards the distal middle shelf (see **Figure 7**) to avoid scorching and toxicity caused by the Siberian Traps and coeval volcanic activity during the End Permian mass extinction.

6. Systematic Palaeontology

Most foraminifera and microproblematica are described and discussed below (see **Figures 8-9**). The classification of foraminifers is based on Nejad et al. (2015), Pawlowski et al. (2013), Vachard et al. (2010), Gaillot & Vachard (2007), Hance et al. (2011) and Tappan and Loeblich (1988). The following are the abbreviations: N = Nammal section; Z = Zaluch section; n = Number of specimens; A = Amb Formation; W = Wargal Limestone; C = Chhidru Formation; M = Mianwali Formation.

Phylum Foraminifera
Class Nodosariata Mikhalevich, 1993
Order Lagenida Lankester, 1885
Family Colaniellidae Fursenko, 1959
Genus *Colaniella* Likharev, 1939
Type of species: *Colaniella minima* Wang, 1966
(Fig. 9D-F)

1966 *Colaniella minima* Wang; p. 211, 219, Pl. 1, figs. 1-9.

1988 *Colaniella minima* Wang; Okimura, fig. 6. 16-19.

2000 *Colaniella* ex gr. *minima* Wang; Jenny-Deshusses et al., fig. 3. 1-2, 4, 7a.

2002 *Colaniella* aff. *minima* Wang; Skourtsos et al., fig. 2. 3-4.

2004 *Colaniella minima* Wang; Zhang, Pl. 3, figs. 38-41.

Measurements: The number of chambers in test range from 5 to 10, the chamber is bowel shape gradually increased, width of test from 0.16-0.36 mm, height of the test from 0.30-0.62 mm, width/height ratio 0.43-0.64, diameter of proloculus from 0.03-0.11 mm, height of the last chamber of test 0.03-0.07 mm. n=3

Remarks: The shell is round and oval in shape, comparable to the specimens reported by **Okimura** (**1988**).

Occurrence: Discovered in Xixou of Shanxi, Xufuling of Jiangxi (Upper Permian) (**Wang, 1966**) Dzhulfian

Mount Parnon, Greece (**Skourtsos et al., 2002**), Uppermost Permian Japan (**Ishii et al., 1975**).

Colaniella pseudolepida Okimura, 1988

(Fig. 9G-I)

1988 *Colaniella pseudolpida* Okimura; fig. 6. 28-32.

1989 *Colaniella pseudolpida* Okimura; Jenny-Deshusses, Pl. 28 a 32.

Measurements: A test consists of 8 to 10 chambers., big, acorn shape, it has a subovoid shape in a longitudinal section. In the early stages, the chamber grows swiftly, whereas the development rate is slower in the middle stages. The last chamber is somewhat distended. The width of the test is between 0.18-0.29 mm, the height of the test ranges from 0.34 to 0.68 mm, the width/height ratio is between 0.43-0.53, the diameter of the proloculus us from 0.02 to 0.06 mm, and the height of the last chamber of the test is 0.02-0.07 mm. n=3

Remarks: the oblique and longitudinal shell is very closed to the specimens reported by **Okimura** (**1988**).

Occurrence: Discovered in horizons 10, 8, 12 and 13 (Kalabagh Limestone Member), some transverse sections from horizon 16, 17 horizons (the lower part of the Chhidru Formation) in the Zaluch I section of Salt Range (**Okimura, 1988**).

Family Geinitzinoidea Bozorgnia, 1973

Genus *Geinitzina* Spandel, 1901

Type of Species: *Geinitzina araxensis* G. Pronina, 1989

(Fig. 10J-K)

1988 *Geinitzina araxensis* G. Pronina; Pl. 2, figs 30-31.

2005 *Geinitzina araxensis* G. Pronina; Groves et al, fig. 20. 7-14.

2007 *Geinitzina araxensis* G. Pronina; Song et al., fig. 2, V.

2011 *Geinitzina araxensis* G. Pronina; Nestell et al., Pl. 2, fig 21.

2012 *Geinitzina araxensis* G. Pronina; Wignall et al., fig.10. D.

Measurements: The test specimen can have up to 6-8 chambers. The width of the test is 0.10-0.18 mm, the height of the test is 0.12-0.24 mm. The width/diameter ratio ranges between 0.68-0.78, the diameter of the proloculus is 0.02-0.32 mm, and the height of the last chamber of the test is 0.02-0.03 mm. n=2

Remarks: The chamber is round and short comparable to *Geinitzina araxensis* G. Pronina.

Occurrence: This species discovered in *Paratirolites kittli* zone of the Dorashamian stage of the Late Permian in Transcaucasia (**Pronina, 1989**), Permian-Triassic boundary of Meishan section (**Song et al., 2007**), Capitanian Hydra island, Greece (**Wignall et al., 2012**), Changhsingian Bellerophon Formation, Slovenia (**Nestell et al., 2011**).

Geinitzina primitiva Potievskaya, 1962

(Fig. 10A-C)

2002 *Geinitzina primitiva* Potievskaya, Nejad, Pl. 4 fig. 9

2007 *Geinitzina primitiva* Potievskaya, Shabanian et al., Pl. 2 fig. 12

2014 *Geinitzina primitiva* Potievskaya, Yarahmadzahi et al., fig. 6.19-21

2016 *Geinitzina primitiva* Potievskaya, Yarahmadzahi et al., Pl. 1. fig. 20, Pl. 2, figs. 18, 21

Figure 8: (A-B) *Agathammina* sp., transverse section, A (ZW-8-12-10X); longitudinal section, B (ZW-11-21-10X); (C-F) *Glomomidiella* sp., C, axial section (ZW-3-11-10X); D, close to the axial section (ZW-3-27-10X); E, transverse section (ZW-3-10-10X); F, transverse section (ZW-3-24-10X); (G-H) *Baisalina pulchra* (**Reitlinger, 1965**); G, longitudinal section (ZW-3- 0120-10X); H, longitudinal section (ZW-3-0144-10X); (I-K) *Codonofusiella erki* (**Rozovskaya and Rauzer-Chernousova, 1965**); transverse sections, I (ZW-5-27-10X); J (ZW-14-22-10X); K (NW9-30-10X); (L-P) *Codonofusiella schubertellinoides* (**Sheng, 1956**); L, longitudinal section (ZW-16-17-10X); M, longitudinal section (NW1-17-10X); N, longitudinal section (NW2-47-10X); O, sagittal section (NW1-13-10X); P, sagittal section (NW5-14-10X); (Q-R) *Codonofusiella minuta* (**Sheng, 1956**); sagittal sections, Q (ZW-5-15-10X); R (NW4-10X017); (S-U) *Codonofusiella* sp., tangential sections, S (ZW-5-20-10X); T (ZW-5-22-10X); U (ZW-6-4-10X); (V-W) *Pisolina excessa* (**Lee, 1934**); axial sections, V (ZW-6-26-10X); W (ZW-11-3-10X); (X-Y) *Neodiscus guangdongensis* (**Hao and Lin, 1982**); X (ZW-5-23-10X); Y (ZW-3-31-10X); (Z-AA) *Hemigordius longus* (**Grozdilova, 1956**); axial section, Z (ZW-3-19-10X); AA (ZW-11-2-10X); (AB-AC) *Hemigordius spirollinoformis* (**Wang, 1982**); axial sections, AB (ZA-6-62-10X); AC (ZA-4-35-10X); (AD-AE) *Hemigordius* sp. AD (ZA-6-47-10X); AE (ZA-10X030); (AF) *Orthovertellopsis proteaeformis* (**Vachard et al., 2015**); axial section (ZW-8-38-10X); (AG-AH) *Nankinella minor* (**Sheng, 1955**); axial section, AG (ZW-7-6-10X); AH (ZW-11-5-10X); (AI-AJ) *Nankinella* sp., sagittal sections, AI (ZW-5-3-10X); AJ (ZW-5-38-10X); (AK) *Glomospira tianmenensis* (**Zheng and Lin, 1978**); spherical section (ZW-3-3-10X); (AL-AM) *Glomospirella spirillinoides* (**Grozdilova and Glebovskaia, 1948**); axial sections, AL (ZA-6-39-10X); AM (ZA-6-55-10X); (AN) *Necdetina taurica* (**Altiner et al., 2007**); axial sections, (ZW-11-34-10X); (AO-AQ) *Sengoerina argandi* (**Altiner, 1999**); tangential sections, AO (NW9-24-10X); AP (NW4-10X036); AQ (NW4-10X026); (AR) *Robuloides lens* (**Reichel, 1946**); axial section, (ZC-5-21-10X); (AS) *Robuloides acutus* (**Reichel, 1946**); axial section (ZC-5-21-10X); (AT-AU) *Langella* sp., transverse sections, AT (NW8-10X010); AU (NW-10-5-10X); (AV) *Rectoglandulina* sp., axial section (NW10-18-10X); (AW) *Pseudolangella* sp., axial section (NW11-10X); (AX-AY) *Protonodosaria* sp., AX (NW11-10X010); AY (NC4-49-10X); (AZ) *Hemigordiopsis* sp., axial section (ZW-3-22-10X); (BA-BC) *Diplosphaerina inaequalis* (**Derville, 1931**); BA (ZA-11-2-10X); BB (ZA-2-37-10X); BC (NW3-10X013); (BD) *Deckerella* sp., (ZW-17-2-4X); (BE-BF) *Tuberitina collosa* (**Reitlinger, 1950**); BE (ZA-8-35-10X); BF (ZA-4-51-10X); (BG-BH) *Tuberitina maljavkini* (**Suleymanov, 1948**); BG (ZA-4-6-10X); BH (ZA-6-43-10X); (BI) *Tuberitina maljavkini var. grandis* (**Reitlinger, 1950**); (NC1-30-10X); (BJ) *Tetrataxis lata* (**Spandel, 1901**); (NC4-20-10X); (BK) *Planiinvoluta* sp., (ZM-19-8-10X); (BL) *Eomarginulinella* sp., lateral section, (NW4-10X029); (BM) *Pseudoglandulina* (?) sp., (NW11-10X012). The scale bar is 200 µm.

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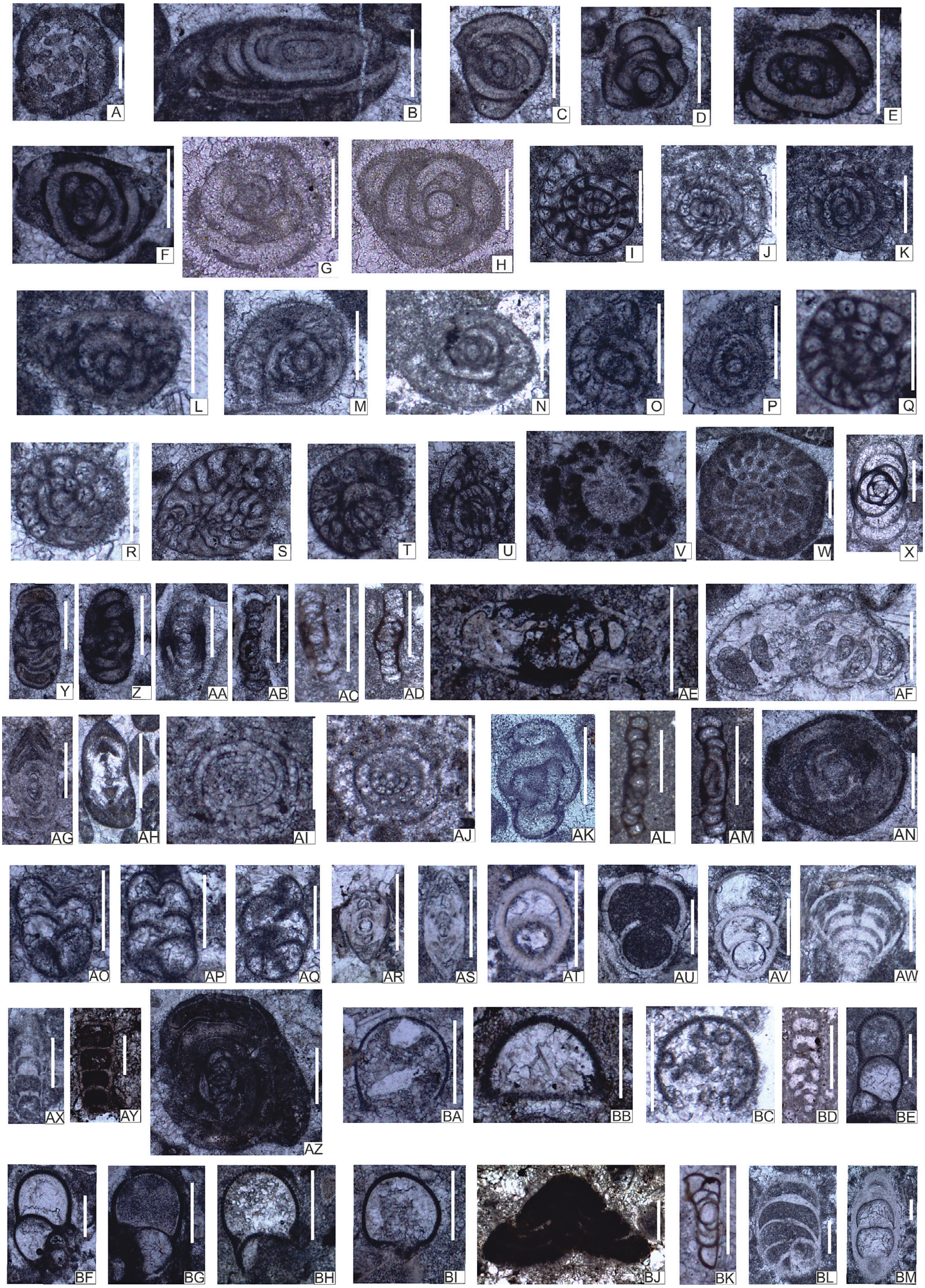
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Measurements: The specimens are composed of 3-5 chambers. The width of the test is 0.06-0.14 mm, the height of the test ranges between 0.11-0.25 mm, the width/height ratio is from 0.45 to 0.95, the diameter of the proloculus is 0.05-0.08, the height of the last chamber of the test is 0.02-0.04 mm. n=3

Remarks: In terms of the size and shape of the test, two specimens of our taxon are pretty similar to the holotype (4 chambers) of *Geinitzina primitiva* Potievskaya, however, the number of chambers (3 chambers) is lower.

Occurrence: Murgabian Zal and Illanlu areas, Iran (**Shabanian et al., 2007**), the Sakmarian Jammal Formation Lut block Central Iran (**Yarahmadzahi et al., 2014**), the Gzhelian Emarat Formation Central Alborz, Iran (**Yarahmadzahi et al., 2016**).

Family Pachyphloiidae Leoblich and Tappan 1984
Genus *Pachyphloia* Lange, 1925
Type of Species: *Pachyphloia ovata* Lange 1925
(Fig. 9N-P)

1925 *Pachyphloia ovata* Lange; p. 231, pl. 1. Fig. 24a, 24b.

1954 *Pachyphloia ovata* Lange; Miklukho-Maklay, p. 44-45, pl. 5, fig. 1.

1974 *Pachyphloia ovata* Lange; Wang, p. 287, pl. 149, fig. 13.

1981 *Pachyphloia ovata* Lange; Altıner, pl. 40, fig. 6-15.

1986 *Pachyphloia ovata* Lange; Kobayashi, pl. 2, figs. 14-18, 24, 25, 27-30, 32.

1989 *Pachyphloia ovata* Lange; Köylüoğlu and Altıner, pl. 8, fig. 1-7.

1991 *Pachyphloia ovata* Lange; Vachard and Ferriére, pl. 4, fig. 13.

2002 *Pachyphloia ovata* Lange; Songzhu et al., Pl. 1, fig. 2.

2004 *Pachyphloia ovata* Lange; Groves, Rettori and Altıner, fig. 7.1-7.3.

2004 *Pachyphloia ovata* Lange; Zuhui and Zuyin, Pl. 3, figs. 11-16.

2005 *Pachyphloia ovata* Lange; Kobayashi, figs. 3.7-3.11.

2005 *Pachyphloia ovata* Lange; Groves et al., figs. 20.15-20-27.

2006 *Pachyphloia ovata* Lange; Kobayashi, pl. 2, figs. 15-17, 20.

2007 *Pachyphloia ovata* Lange; Gaillot and Vachard, pl. 72, figs. 5, 23, pl. 73, figs.4, 8.

2009 *Pachyphloia ovata* Lange; Song et al., figs. 10.28- 10.30.

2019 *Pachyphloia ovata* Lange; Tian et al., fig. 6.V-W, fig. 8.e.

Measurements: The test encompasses 5-6 chambers. The width of test is 0.12-0.24 mm, the height of the test is between 0.19 and 0.43 mm, the width/height ratio is from 0.45 to 0.67, the diameter of the proloculus is 0.11-0.06 mm, the height of the last chamber of the test is 0.01-0.05 mm, and the wall thickness varies between 0.02 and 0.07 mm. n=3

Remarks: The form of the chamber and the shape of the test are quite similar to the holotype of *Pachyphloia ovata* Lange.

Occurrence: It was recovered from the Late Midian of Sumatra. It has also existed in the Changhsingian of Greece, Transcaucasia and southern China, Guadalupian-Lopingian of Italy, the Balkans, Iran, NW Caucasus, Transcaucasia, Pakistan, Japan, Indochina and New Zealand (**Gaillot and Vachard, 2007**).

Figure 9: (A) *Charliella altineri* (**Gaillot and Vachard, 2007**); transverse section (ZW-11-7-10X); (B-C) *Colaniella zaluchense* (**Okimura, 1988**); tangential section B (ZW-17-9-10X); longitudinal section C (NC10-12-10X); (D-F) *Colaniella minima* (**Wang, 1966**); longitudinal sections D (ZC4-10X038); E (NC3-26-10X); F (NC2-43-10X); (G-I) *Colaniella pseudolepida* (**Okimura, 1988**); G, longitudinal section (ZC8-10X022); H, transverse section (ZC-5-17-10X); I, longitudinal section (NC1-56-10X); (J) *Colaniella cylindrica* (**Miklukho-Maklay, 1954**); axial section (ZC4-10X033); (K) *Colaniella minuta* (**Okimura, 1988**); longitudinal section (ZC-5-26-10X); (L) *Pseudocolaniella xufulingensis* (**Wang, 1966**); longitudinal section (ZC4-4-10X); (M) *Pseudocolaniella* sp., nearly longitudinal section (ZC4-18-10X); (N-P) *Pachyphloia ovata* (**Lange, 1925**); longitudinal sections, N (NW10-3-10X); O (NW10-10-10X); P (ZA4-26-10X); (Q-S) *Pachyphloia robusta* (**Miklukho-Maklay, 1954**); longitudinal sections, Q (ZW-17-32-10X); R (ZA8-10X039); S (ZW17-14-10X); (T-V) *Pachyphloia schwageri* (**Sellier de Civrieux and Dessauvagie, 1965**); (T-U, axial lateral sections) T (ZC4-53-10X); U (ZA2-33-10X); frontal axial section V (NC2-39-10X); (W) *Pachyphloia iranica* (**Bozorgnia, 1973**); axial section (NW10-49-10X); (X) *Pachyphloia lanceolata* (**Miklukho-Maklay, 1954**); axial section (NW4-10X009); (Y-Z) *Pachyphloia* sp., Y, lateral section (ZC7-22-10X); Z, axial section (ZW-17-56-10X); (AA) *Geinitzina* sp., frontal axial section (ZC-5-19-10X); (AB-AD) *Nodosinelloides* sp. longitudinal sections, AB (NC4-53-10X); AC (ZC-6-26-10X); AD (ZC-6-40-10X); (AE-AG) *Nodosinelloides aequiampla* (**Zolotova and Baryshnikov, 1980**); axial sections, AE (ZA8-4-10X); AF (ZW9-5-10X); AG (ZW9-19-10X); (AH-AJ) *Nodosinelloides camerata* (**Miklukho-Maklay, 1954**); longitudinal sections, AH (ZA6-21-10X); AI (NW12-10X026); AJ (ZW17-67-10X); (AK) *Nodosinelloides longa* (**Lipina, 1949**); longitudinal section (ZA4-22-10X); (AL-AM) *Nodosaria sumatrensis* (**Lange, 1925**); axial sections, AL (ZA9-15-10X); AM (ZA9-25-10X); (AN-AO) *Nodosinelloides shikhanica* (**Lipina, 1949**); longitudinal sections, AN (ZA8-10X); AO (ZW3-14-10X); (AP, AZ) *Nodosinelloides netschajewi* (**Cherdynzev, 1914**); longitudinal sections, AP (ZA8-27-10X); AZ (ZC4-61-10X); (AQ) *Nodosinelloides longissima* (**Suleymanov, 1949**); longitudinal section, (ZA2-11-10X); (AR) *Nodosinelloides mirabilis caucasica* (**Miklukho-Maklay, 1954**); axial section, (ZW14-45-10X); (AS) *Nodosinelloides pinardae* (**Groves and Wahlman, 1997**); longitudinal section, (NW2-29-10X); (AT-AV) *Nodosinelloides sagitta* (**Miklukho-Maklay, 1954**); longitudinal sections, AT (ZW-13-24-10X); AU (ZW12-9-10X); AV (ZW12-13-10X); (AW) *Polarisella* sp.; longitudinal section, (NW9-24-10X); (AX-AY) *Nodosaria patula* (**Miklukho-Maklay, 1954**); longitudinal sections, AX (NW7-10X016); AY (NW3-10X002); (BA-BB) *Nodosinelloides potievskayae* (**Mamet and Pinard, 1996**); longitudinal sections, BA (NW9-8-10X); BB (NC1-4-10X). The scale bar is 200 µm. ➤


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Pachyphloia robusta Miklukho-Maklay, 1954

(Fig. 9Q-S)

1954 *Pachyphloia robusta* Miklukho-Maklay; Pl. 2, fig. 8.

1996 *Pachyphloia robusta* Miklukho-Maklay; Leven et al., Pl. 10, fig. 3.

2001 *Pachyphloia robusta* Miklukho-Maklay, Pronina-Nestell & Nestell, Pl. 3, fig 5-6.

2006 *Pachyphloia* cf. *robusta* Miklukho-Maklay; Gaillot, p. 168, Pl. I.26, figs. 9? 18, Pl. I.27,

fig. 3, Pl. I.28, fig. 15, Pl. III.13, fig. 6? Pl. VI.13, fig. 6.

2009 *Pachyphloia robusta* Miklukho-Maklay; Song et al., figs. 10.31-10.32.

2009 *Pachyphloia* cf. *robusta* Miklukho-Maklay; Ueno & Tsutsumi, fig. 11.32.

2010 *Pachyphloia* cf. *robusta* Miklukho-Maklay; Ueno & Tsutsumi, fig. 6.34.

2011 *Pachyphloia robusta* Miklukho-Maklay; Kobayashi & Altiner, Pl. 1, fig. 22.

2019 *Pachyphloia robusta* Miklukho-Maklay; Tian et al., fig. 6.X, fig. 8.c.

Measurements: The specimens contain up to 4-6 chambers. The width of the test is 0.10-0.26 mm, the height of the test is between 0.23 and 0.48 mm, the width/height ratio is from 0.45 to 0.71, the diameter of the proloculus is 0.03-0.05 mm, the height of the last chamber of the test is 0.02-0.06 mm, and the wall thickness varies between 0.02 and 0.09 mm. n=3

Remarks: the specimens of our taxon closely resemble to the holotype of *Pachyphloia robusta* Miklukho-Maklay in size and shape of the test, but several specimens of our taxon have less chambers than the holotype.

Occurrence: It was recovered from the (Upper Permian) Nikitina Formation, the Malya Laba River, Northern Causcasus, Southern USSR (**Miklukho-Maklay, 1954; Pronina-Nestell and Nestell, 2001**), the Upper Permian Wujiaping Formation Nanpanjiang Basin, China (**Song et al., 2009**), the Changhsingian Shifodong Formation Paleo-Tethyan seamount (**Ueno and Tsutsumi, 2009**), and the Lower Murgabian Çekiç Dagi Formation, Turkey (**Kobayashi and Altiner, 2011**).

Family Protonodosariidae Mamet & Pinard, 1992

Nodosinelloides longa (Lipona, 1949)

(Fig. 9AK)

1949 *Nodosaria longa* Lipina; Pl. 4, fig. 6.

2001 *Nodosinelloides longa* Lipina; Vachard & Kranier, Pl. 1, fig. 29, Pl. 5, figs. 49-53.

2002 *Nodosaria longa* Lipina; Zuhui and Zuyin, Pl. 4, fig. 21.

2009 *Nodosinelloides longa* Lipina; Krainer et al., Pl. 5, fig. 2,5, 6.

2013 *Nodosinelloides longa* Lipina; Alipour et al., fig. 5. 2.

2017 *Nodosinelloides longa* Lipina, Medadi et al., fig. 5, Pl. 3.

2017 *Nodosaria longa* Lipina; Dai et al., fig.5 a.

Measurements: The test consists of 8 chambers. The width of the test is 0.05 mm, the height of the test is 0.22 mm, the width/height ratio is 0.24, the diameter of the proloculus is 0.02 mm, the height of the last chamber of the test is 0.03 mm. n=1

Remarks: In terms of the number of chambers and the curved shape of the test, the specimen is extremely similar to the holotype of *Nodosinelloides longa* Lipona, 1949.

Occurrence: It was recovered from the (Upper Carboniferous) Shak-tau Mountains, Kusyapkulovskiy and Yar- Bishkadak Massif, the Asselian-Sakmarian Grenzlan and Zweikofel Formations (**Vachard & Kranier, 2001**), the Permian Tempelfjorden Group, Norway (**Nakrem et al., 1992**), and the Asselian Dorud Formation, Iran (**Medadi et al., 2017**).

Figure 10: (A-C) *Geinitzina primitiva* (**Potievskaya, 1962**); longitudinal sections, A (ZA-4-40-10X); B (ZW-10-43-10X); C (NC3-23-10X); (D-E) *Geinitzina uralica* (**Suleymanov, 1949**); longitudinal sections, D (NW4-10X020); E (ZW9-8-10X); (F-H) *Geinitzina taurica* (**Sellier de Civrieux and Dessauvagie, 1965**); longitudinal sections, F (NW8-10X022); G (NW12-10X); H (NW10-7-10X); (I) *Geinitzina ichnousa* (**Sellier de Civrieux and Dessauvagie, 1965**); longitudinal section (NW12-10X008); (J-K) *Geinitzina araxensis* (**Pronina, 1989**); frontal longitudinal sections, J (ZA1-4-10X); K (ZA4-55-10X); (L-N) *Pachyphloides inflatus* (**Miklukho-Maklay, 1954**); longitudinal sections, L (ZC7-2-10X); M (ZC8-10X); N (ZC4-10X); (O-P) *Geinitzina* sp., longitudinal sections, O (NW6-3-10X); P (NW4-10X032); (Q) *Climacammina* sp., longitudinal section (ZC-4-1-4X); (R-S) *Ichthyofrondina palmata* (**Wang, 1974**), frontal longitudinal section, R (ZW-10-44-10X); subaxial section, S (ZW-11-23-10X); (T-V) *Frondina permica* (**Sellier de Civrieux and Dessauvagie, 1965**); longitudinal section, T (ZW-5-28-10X); lateral longitudinal section, U (NC2-48-10X); frontal longitudinal section, V (NC10-9-10X); (W) *Nodosaria delicata* (**Wang, 1976**); (ZC-4-36-10X); (X-Z) *Earlandia* sp., longitudinal sections, X (ZW-4-7-10X); Y (ZW-10-23-10X); Z (ZW-3-13-10X); (AA-AC) *Dagmarita* sp., lateral sections, AA (NW2-47-10X); AB (ZW-10-13-10X); AC (ZC-4-30-10X); (AD) *Langella imbecilla* (**Lin et al., 1990**); longitudinal section, (ZW-11-37-10X); (AE) *Langella perforata* (**Sellier de Civrieux and Dessauvagie, 1965**); axial frontal section, (ZW-13-2-10X); (AF) *Langella* cf. *pulchra* (**Lange, 1925**); longitudinal section (ZW-14-2-10X); (AG) *Frondinodosaria* sp., (ZW-12-34-10X); (AH-AI) *Ammodiscus* sp., AH (ZA-4-7-10X); AI (ZA-4-22-10X); (AJ-AK) *Neoendothyra* sp., AJ (ZW-17-17-10X); AK (ZC-5-64-10X); (AL) *Calvezina ottomana* (**Sellier de Civrieux and Dessauvagie, 1965**); (ZA-2-24-10X); (AM-AP) *Reichelina changhsingensis* (**Sheng, 1958**); longitudinal sections, AM (NW2-38-10X); AN (NW10-16-10X); AO (NW2-56-10X); AP (NC3-29-10X); (AQ-AS) *Reichelina cribroseptata* (**Erk, 1942**); longitudinal sections, AQ (NW12-10X044); AR (NW12-10X035); AS (NW12-10X039); (AT-AU) *Reichelina* sp.; transverse sections, AT (NW9-13-10X); AU (NW10-51-10X); (AV-AX) *Globivalvulina bulloides* (**Brady, 1876**); ventral view of tests, AV (ZW-10-26-10X); AW (ZW-4-28-10X); dorsal view of test, AX (ZW-5-26-10X); (AY) *Globivalvulina* sp.; AY (ZA-11-12-10X); (AZ) *Multidiscus* sp., (ZA-8-9-10X); (BA) *Cryptomorphina limonitica* (**Sellier de Civrieux and Dessauvagie, 1965**); frontal axial section, (ZA8-4X006). The scale bar is 200 µm.

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Nodosinelloides mirabilis caucasica Miklukho-Maklay, 1954
(Fig. 9AR)

1954 *Nodosinelloides mirabilis* caucasica n. subsp. Miklukho-Maklay; Pl. 2, figs. 1-2.

1978 *Nodosaria mirabilis* caucasica Miklukho-Maklay; Lin, p. 40-41, pl. 8, fig. 18.

1984 *Nodosaria mirabilis* caucasica Miklukho-Maklay; Kotlyar et al., pl. 1, fig. 12.

2001 *Nodosaria mirabilis* caucasica Miklukho-Maklay; Pronina- Nestell & Nestell, pl. 2, fig. 11.

2004 *Nodosaria mirabilis* caucasica Miklukho-Maklay; Zuhui and Zuyin, pl. 2, figs. 27-29.

2006 *Nodosinelloides mirabilis* caucasica Miklukho-Maklay; Gaillot, p. 130-131, Pl. I.29, fig. 13, Pl.I.30, fig. 24, Pl. I.31, figs. 1, 4, 16, Pl. I.32, fig. 13, Pl. I.34, fig. 3, Pl. II.27, fig. 5, Pl. II.28, fig. 4, 11, Pl. III.9, figs. 2, 12-13, 17, Pl. III.10, fig. 11, Pl. III.11, fig. 7, Pl. III.12, figs. 11, 16, Pl.III.21, figs. 13-14, Pl. III.26, fig. 19?, Pl. VI.11, fig. 17, Pl. VI.12, fig. 7.

2007 *Nodosinelloides mirabilis caucasica* Miklukho-Maklay; Grove et al., figs. 10.3, 10.10.

Measurements: The species of the test is composed of 12 Chambers. The width of the test is 0.16 mm, the height of the test is 0.87 mm, the width/height ratio is 0.18, the diameter of the proloculus is 0.03 mm, the height of the last chamber of the test is 0.12 mm. n=1

Remarks: The specimen is very similar to the holotype of *Nodosaria mirabilis caucasica* Miklukho-Maklay in the number of chambers and the shape of the test. The initial chambers from the proloculus side are narrow and small, but the last three chambers of the test are wider.

Occurrence: Discovered in the Upper Permian, the Nikitina Formation, the Malaya Laba River basin, North Caucasus, USSR (**Miklukho-Maklay, 1954**), and the Wordian to Changhsingian Dalan Formation, Iran (**Kolodka et al., 2012**).

Class Fusulinata Fursenko, 1958
Order Fusulinida Wedekind, 1937
Family Boultoniidae Skinner & Wilde, 1954
Genus *Codonofusiella* Dunbar & Skinner, 1937
Type of Species: *Codonofusiella schubertelloides* sheng, 1965
(Fig. 8L-P)

1965 *Codonofusiella schubertelloides* sheng; Rauzer-Chernousova, Pl. 3, fig. 6-9.

2000 *Codonofusiella schubertelloides* sheng; Hauser et al., fig. 4. 9.

2005 *Codonofusiella schubertelloides* sheng; Mohtat-Aghai & Vachard, Pl. 2, fig. 5-7.

2007 *Codonofusiella schubertelloides* sheng; Shabanian et al., Pl. 3, fig. 5.

Measurements: The test contains 2-3 whorls. The width of the test is 0.20-0.43 mm, the diameter of the test is 0.23-0.31 mm, the width/diameter ratio is 0.76-1.8, and the diameter of the proloculus is 0.01-0.09 mm. n=4

Remarks: The specimens of our taxon exhibit all morphological characteristics comparable to those of *Codonofusiella schubertelloides* sheng, (1965, Pl. 4, figs. 1-5, 11). This species also looks like *Palaeofuslina sinesis* sheng, but *Codonofusiella schubertelloides* can be differentiated by its endothyroid juvenarium.

Occurrence: Discovered in the (Upper Permian) Liangshan, the Southern Shensi province, northeast central China (**Sheng, 1956**), the Wuchiapingian Batain Plain, Oman (**Hauser et al., 2000**), the Hambast Formation, Iran **(Mohtat-Aghai and Vachard, 2005**), and the Midian-Dzhufian Episkopi Formation, Greece (**Grant et al., 1991**).

Codonofusiella erki Rauzer-Chernousova, 1965
(Fig. 8I-K)

1965 *Codonofusiella erki* Rauzer-Chernousova; Pl. 3, fig. 16-17, Pl. 4, fig. 3-5

1997 *Codonofusiella erki* Rauzer-Chernousova; Pronina & Nestell, Pl. 1, fig. 29.

1998 *Codonofusiella erki* Rauzer-Chernousova; Leven et al., Pl.3, fig. 22-27.

2004 *Codonofusiella erki* Rauzer-Chernousova; Labkovsky, Pl. 2, fig. 1.

2002 *Codonofusiella erki* Rauzer-Chernousova; Nejad, Pl. 6, fig. 9.

2013 *Codonofusiella erki* Rauzer-Chernousova; Davydov and Sakineh, Pl. 1, fig. 45.

Measurements: The test contains 2-3 whorls. The width of the test is 0.26-0.37 mm, the diameter of the test is 0.26-0.37 mm, the width/diameter ratio is 0.97-1.1, and the diameter of the proloculus is 0.05-0.07 mm. n=3

Remarks: The specimens are comparable to the transverse section of *Codonofusiella erki* Rauzer-Chernousova, (1965, Pl. 3, fig. 16) in the shape and size of the test.

Occurrence**:** The Dzhulfian Alma River Basin, Crimea (**Pronina, 1997**), the lower to upper Murgabian Ruteh Formation, Iran (**Vaziri, 2005**), and the Midian-Dzhulfian Arqov Formation, Israel (**Orlov-Labkovsky, 2004**).

Class Tubothalamea Pawlowski et al. 2013
Order Miliolida Lankester, 1885
Family Baisalinidae Loeblich & Tappan, 1986
Genus *Baisalina* Reitlinger, 1965
Baisalina pulchra Reitlinger, 1965
(Fig. 8G-H)

1988 *Baisalina pulchra* Reitlinger; G. Pronina, Pl. 1, fig. 29.

1993 *Baisalina pulchra* Reitlinger; Dawson et al., fig. 3.13.

1994 *Baisalina pulchra* Reitlinger; Dawson et al., fig. 5.11.

1996 *Baisalina pulchra* Reitlinger; Leven et al., Pl. 8, figs. 9,17.

2004 *Baisalina pulchra* Reitlinger; Turhan et al., fig. 6.

2005 *Baisalina pulchra* Reitlinger; Vaziri et al., Pl. 5, fig. 13-14.

2008 *Baisalina pulchra* Reitlinger; Vachard et al., fig. 3. 3-4.

2007 *Baisalina pulchra* Reitlinger; Shabanian et al., Pl. 1, fig. 11

2014 *Baisalina pulchra* Reitlinger; Sakineh Arefi Fard, fig. 6. 22, 23.

2015 *Baisalina* cf. *B. pulchra* Reitlinger; Zhang et al., fig. 5. AA.

Measurements: The test of the species includes 3-4 whorls. The width of the test is 0.24-0.31 mm, the diameter of the test is 0.17-0.29 mm, the width/diameter ratio is between 0.84 and 1.4, and the diameter of the proloculus is 0.02-0.04 mm. n=2

Remarks: The specimens are similar to those of *Baisalina pulchra* Reitlinger (1965, Pl. 1, figs. 15-18), with uniform oscillation and sharp variation in coiling axes of the last and early whorl, respectively.

Occurrence: Discovered in the Baysal Mountains, Transcaucasia, USSR (**Pronina, 1988**), the Middle Permian Rat Buri Limestone in the Phanga area, Thailand (**Dawson et al., 1993, 1994**), Midian Derbent Limestone, Turkey (**Turhan et al., 2004**), and the Capitanian Maokou Formation, China (**Zhang et al., 2015**).

7. Conclusion

Based on 148 samples from the Salt Range area of Pakistan, 71 species of foraminifers have been identified, that belong to 41 genera from the Zaluch Group and the Mianwali Formation in the Zaluch section and 47 species of 24 genera from the Wargal Limestone and the Chhidru Formation in the Nammal section. Five foraminiferal assemblages have been established in the shallow marine shelf deposits of the Western Salt Range, in ascending order, i.e. the *Geinitzina araxensis* assemblage, the *Baisalina pulchra* assemblage, the *Codonofusiella schubertellinoides* assemblage, the *Colaniella pseudolepida* assemblage, and the *Nodosinelloides*-*Planiinvoluta* assemblage, belonging to the Wordian, Capitanian, Wuchiapingian, Changhsingian, and Induan, respectively. Minor extinction of smaller foraminiferal species occurred at the Guadalupian–Lopingian boundary, where only four species went extinct, i.e. *Glomomidiella* sp., *Baisalina pulchra*, *Glomospira tianmenensis*, and *Hemigordiopsis* sp. A total of 37 species of 19 genera went extinct in the Chhidru Formation (Changhsingian). Most foraminifer species disappeared in the lower part of the Chhidru Formation, having low tolerance to the teriginous-clastic input in the upper part of the Chhidru Formation. Only two survival species *Nodosinelloides* sp., and *Planiinvoluta* sp. were found at the basal Triassic Mianwali Formation. During the Wuchiapingian and Changhsingian periods, the foraminiferal assemblages of the Zaluch and Nammal sections were composed of 19 common species from 10 genera and 15 common species from 8 genera, respectively. A total of 97 and 51 thin sections were examined from the Zaluch (Zaluch Group and Mianwali Formation) and Nammal (the Wargal Limestone, the Chhidru Formation and the Mianwali Formation) sections, respectively, yielding 412 and 269 specimens. Smaller and larger foraminifera include 599 and 82 specimens, respectively, communally in both sections. We have identified three main classes, i.e. Nodosariata, Fusulinata, and Tubothalamea and a total of seven orders, including Miliolida, Spirillinida, Lagenida, Parathuramminida, Endothyrida, Fusulinida and Earlandiida. The Order Lagenida and its families Protonodosariidae, Pachyphloiidae, Colaniellidae, and Geinitzinoidea were dominant and diverse. The Shannon Diversity Index and other indices are relatively higher for the Wuchiapingian-Changhsingian as compared to Wordian, Capitanian and Induan foraminiferal assemblages.

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SAŽETAK

Srednjopermski do kasnopermski i ranotrijaski foraminiferski skupovi u Western Salt Rangeu, Pakistan

Novodobiveni skup foraminifera iz epoha guadalupija i lopingija te induanija iz Western Salt Rangea (Pakistan) sastoji se od 47 vrsta (uključujući sedam vrsta porodice *Fusulinidae*) iz 24 roda i 71 vrste (uključujući devet vrsta porodice *Fusulinidae*) iz 41 roda Nammal i Zaluch sekcije, redom. Rezultati pokazuju da su samo četiri vrste izumrle tijekom masovnoga izumiranja u guadalupiju i lopingiju (GLMI), što upućuje na to da je GLMI imao manji utjecaj na manje foraminifere u Salt Rangeu. Većina vrsta izumrla je tijekom permsko-trijaskoga masovnog izumiranja (PTMI), osim dvaju preživjelih rodova, *Nodosinelloides* i *Planiinvoluta*. Tijekom masovnoga izumiranja krajem perma većina je vrsta izumrla u donjemu dijelu formacije chhidru, jer nisu bile tolerantne na terigeno-klastični unos u gornjemu dijelu formacije chhidru. Prvi put dokumentiran je proces izumiranja foraminifera u dijelovima Nammal i Zaluch. Pet grupa foraminifera prepoznato je u plitkim morskim naslagama šelfa Western Salt Rangea, tj. skup iz wordija *Geinitzina araxensis* u podvodnome okruženju delte do srednjega šelfa pod utjecajem plime, skup iz capitana *Baisalina pulchra* i skup iz wuchiapingija *Codonofusiella schubertelliner* u karbonatnim naslagama unutarnjega i vanjskoga šelfa, iz changhsinga skup *Colaniella pseudolepida* i iz induanija skup *Nodosinelloides-Planiinvoluta* u mješovitome siliciklastično-karbonatnome dijelu šelfa. Skupovi *Baisalina pulchra* i *Codonofusiella schubertellinoides* imaju široku geografsku rasprostranjenost i pronađeni su u Transkavkazu, Kini, Turskoj, na Krimu i u Omanu. Ostala tri skupa (tj. *Geinitzina araxensis*, *Colaniella pseudolepida* i *Nodosinelloides-Planiinvoluta*) pronađena u ovoj studiji vjerojatno su lokalni/regionalni skupovi. Foraminifere su promatrane standardnim mikroskopskim sustavom Leica-DM500. Ukupno je zabilježen 681 primjerak foraminifera u odjeljcima grupe Zaluch i Mianwali, formacije Nammal i sekcije Zaluch. Pronađeno je pet stotina devedeset devet manjih foraminifera. Među manjim foraminiferama *Nodosinelloides*, *Pachyphloia*, *Geinitzina*, *Colaniella*, *Hemigordius*, *Tuberitina* i *Langella* predstavljaju najdominantnije rodove. Veći rodovi foraminifera uključuju *Nankinella*, *Codonofusiella*, *Reichelina*, *Necdetina* i *Pisolina*, a predstavljeni su s 82 primjerka. Ukupno 3 razreda (npr. *Nodosariata*, *Fusulinata* i *Tubothalamea*) i sedam redova (tj. *Miliolida*, *Spirillinida*, *Lagenida*, *Parathuramminida*, *Endothyrida*, *Fusulinida* i *Earlandiida*) identificirana su u ovoj studiji. Među njima, *Lagenida* postaje najdominantnija po raznolikosti i obilju. Indeks raznolikosti Shannon i drugi indeksi progresivno rastu od wordija do changhsingiana u plitkim morskim sedimentima prije nego što padnu na nulu u ranotrijaskim mješovitim siliciklastično-karbonatnim naslagama šelfa.

Ključne riječi:
guadalupij-lopingij, induanij, foraminifera, fusulinidi, masovno izumiranje, Salt Range

Author's contribution

Naveed Ur Rahman conceptualized the study, conducted the literature review, identified foraminifera in petrographic thin sections, and wrote the manuscript. **Prof. Song Haijun** helped with concept development, supervision, funding, validation and writing the manuscript. **Prof. Xian Benzhong** took part in the diagnostic aspects of the research work, formatted all of the work according to the journal, and concluded the research work's findings. **Prof. Saif Ur Rehman**, **Gohar Rehman**, and **Abdul Majid** all helped with sample collection and fieldwork in the Salt Range. **Javed Iqbal** and **Gulfam Hussain** assisted with proofreading and plagiarism removal in English, as well as laboratory work and the conclusion of the research results.