Science Frontiers
2021; 2(2): 17-27
http://www.sciencepublishinggroup.com/j/sf
doi: 10.11648/j.sf.20210202.11

Foraminiferal Assemblage from Lockhart Limestone of the Lesser Himalaya, Abbottabad District, Northern Pakistan

Khalid Khan[1], Khalid Latif[2, *], Muhammad Azhar Farooq Swati[3], Muhammad Rafiq[3], Syed Mamoon Syar[4], Mohibullah Mohibullah[5], Hafiz Shahid Hussain[2]

[1]Exploration Department, Oil & Gas Development Company Limited, Islamabad, Pakistan

[2]National Centre of Excellence in Geology, University of Peshawar, Khyber Pakhtunkhwa, Pakistan

[3]Department of Geology, University of Peshawar, Khyber Pakhtunkhwa, Pakistan

[4]Department of Geology, University of Malakand, Khyber Pakhtunkhwa, Pakistan

[5]Department of Geology, University of Balochistan, Quetta, Pakistan

Email address:

khalidlatif@uop.edu.pk (K. Latif)

[*]Corresponding author

To cite this article:

Khalid Khan, Khalid Latif, Muhammad Azhar Farooq Swati, Muhammad Rafiq, Syed Mamoon Syar, Mohibullah Mohibullah, Hafiz Shahid Hussain. Foraminiferal Assemblage from Lockhart Limestone of the Lesser Himalaya, Abbottabad District, Northern Pakistan. *Science Frontiers.* Vol. 2, No. 2, 2021, pp. 17-27. doi: 10.11648/j.sf.20210202.11

Received: July 3, 2021; **Accepted**: July 26, 2021; **Published**: August 9, 2021

Abstract: The Lockhart Limestone is well-established in different areas of division Hazara in the northern Pakistan. This study is an attempt to perform micropaleontological analysis of the Lockhart Limestone at the Changlagali section in district Abbottabad. The limestone at the study section is recorded to be 110 m thick, grey in color, medium-grained, hard, nodular and fossiliferous. It is thin to medium-bedded in the basal part, massive and brecciated to nodular in the middle part, and medium-bedded to massive and nodular in the upper part. It has been examined for foraminifers (planktic, smaller benthic and larger benthic) in order to outline foraminiferal biostratigraphy. A sum of 22 rock samples were collected from the Lockhart Limestone and thin sections were prepared for petrography. Subsequently, twenty-nine species, including five planktic, and eight smaller and sixteen larger benthic species, from fourteen genera were identified. Biostratigraphic zonations have been established on the basis of planktic foraminifers and integrated into standard planktic foraminiferal biozones. Biostratigraphically significant planktic foraminifers recorded were used to establish three biozones; Globorotalia angulata zone (Middle Paleocene age), Globorotalia pseudomenardii zone (late Paleocene age) and Morozovella velascoensis zone (Late Paleocene to Early Eocene age). Present micropaleontological analysis confirms that the Lockhart Limestone at the Changlagali section of Hazara area was deposited in the Middle to Late Paleocene age.

Keywords: Foraminifera, Biostratigraphy, Paleocene, Lockhart Limestone, Pakistan

1. Introduction

The Lockhart Limestone developed under stable, broad shelf/ramp settings in most parts of the Hazara area [1]. The larger benthic foraminifers (LBFs) constitute a major part of the fauna reported from the Lockhart Limestone. These include some very significant (age diagnostic) species like, *Lockhartia haimei* (Davies) and *Lockhartia conditi* (Nutall), which have been recorded in the (Lockhart Limestone) in the Kala Chitta Range [2]. LBFs were also recorded in the Paleocene limestones of Thal, Ranikot and Salt Range [3]. Paleocene of Northern Somaliland and Qatar also deposited significant assemblages of LBFs [4]. *Miscellanea miscella* (d'Archiac and Haime) was recorded in the Upper Paleocene formations of Kala Chitta Range [2] and from the Upper Ranikot of Sindh [4]. *Operculina subsalsa* (Davies and Pinfold) was reported from the Upper Paleocene of Kala Chitta Range and *Discocyclina ranikotensis* (Davies) was described from the Middle to Upper Paleocene of Salt Range, Upper Paleocene of Thal and Upper Ranikot [3]. Alongside LBFs, smaller benthic foraminifera have been also reported, but they are not significant for establishing stratigraphy because of their long stratigraphic range (i.e. mostly ranging from Late Paleozoic to Recent e.g. *Textularia* sp. (Haque),

Textularia punjabensis (Haque), *Bigenerina* sp. (d'Orbigny), *Biloculina contraria* (d'Orbigny) etc. Nevertheless, few smaller benthic species are recorded only in the Paleocene succession, e.g., *Cibicides multifarious* (Schwager), which has been reported from the Upper Paleocene succession in the western Salt Range [5].

Latif identified the following species from Lockhart Limestone, Galis Group in Hazara, *Pseudogloborotalia ranikotensis*, *Pleurostomella rimosa*, *Rotalia perovalis*, *Rotalia trochidiformis*, *Lockhartia haimei*, *Lockhartia conica*, Bigenerina sp., *Miscellanea miscella*, Textularia sp., *Discocyclina seunesi* and *Discocyclina ranikotensis* [3]. Kureshy reported larger foraminifera from Tertiary beds of Indus basin, Pakistan, *Miscellanea miscella*, *Lockhartia conica*, *Lockhartia tipperi*, *Lockhartia conditi*, *Assilina subdaviesi*, *Assilina dandotica*, *Daviesina bramkampi*, *Operculina subsalsa* [6]. Furthermore, *Lockhartia conica*, *Lockhartia haimei*, *Globorotalia angulata*, *Pseudohastigerina* sp., *Cibicides multifarious*, *Textularia* sp., *Quinqueloculina* sp., *Bigenerina* sp., *Quinqueloculina lamarckiana* and *Biloculina contraria* have been reported from Kotal Pass Section [7].

The present study aims at the micropalaeontological analysis of Lockhart Limestone at Changlagali section of district Abbottabad in Hazara division. The section has excellent exposure of the Lockhart Limestone, comprising of light to dark grey, fossiliferous, nodular limestone with occasional shale. The study deals in reporting the foraminifera from the Lockhart Limestone to establish a biostratigraphic framework in the studied section along with its comparison to other areas.

2. Geological Settings

The area under investigation lies along the Nathiagali-Muree Road, near Changlagali, in Hazara Division (NW Hiamalayan Fold and Thrust Belt). The area lies in the district Abbottabad, and is situated about 68 km northeast of Islamabad. The area is located between latitude 34° 5′ 10″ and longitude 73° 15′ 20″. It covers the toposheets 43 F/8 and 43 G/5 of the Geological Survey of Pakistan. Panjal Thrust bounds the area in the north and Muree Fault in the south [8] (Figure 1).

The lithologic log of the measured stratigraphic section of Lockhart Limestone in the study area is given in Figure 2. Figure 3 shows predominant lithology and upper and lower contacts of Lockhart Limestone.

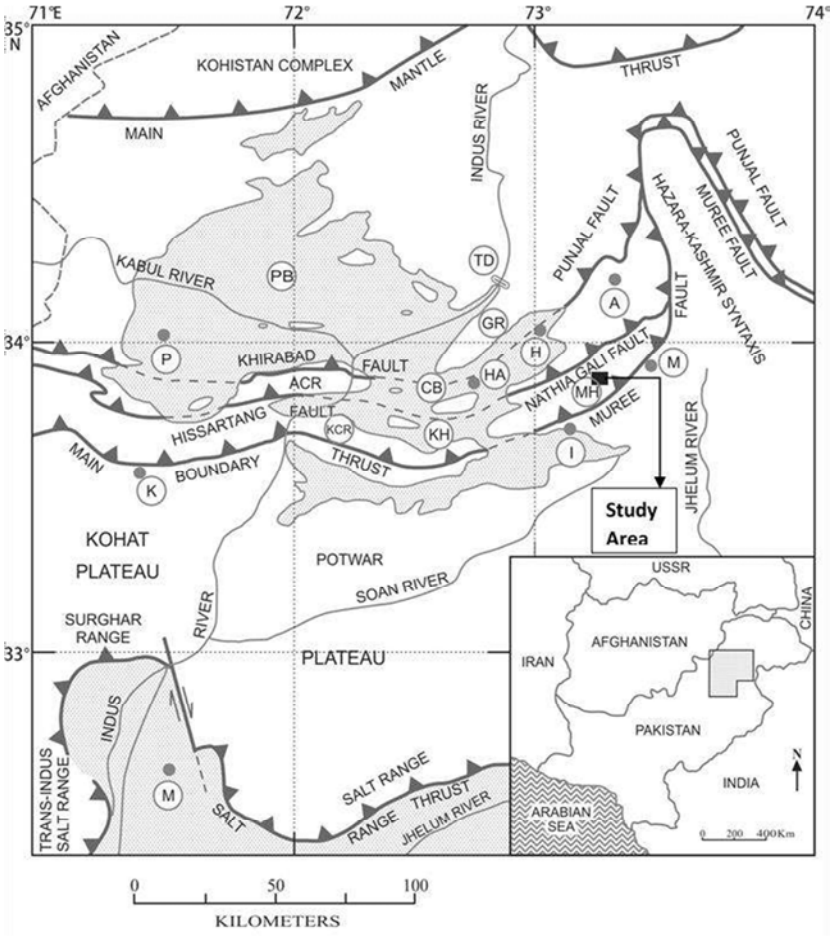


Figure 1. *Tectonic map of Northern Pakistan, Showing major structural boundries. P=Peshawar; PB=Peshawar Basin; TD=Terbela Dam; A=Abbottabad; M=Muree; I=Islamabad; MH=Margalla Hills; H=Haripur; GR=Gandghar Range; HA=Hasan Abdal; KH=Kherimar Hills; CB=Cambellpore Basin; ACR=Attock-Cherat Range; KCR=Kala Chitta Range; K=Kohat; M=Mianwali (modified after [8]).*

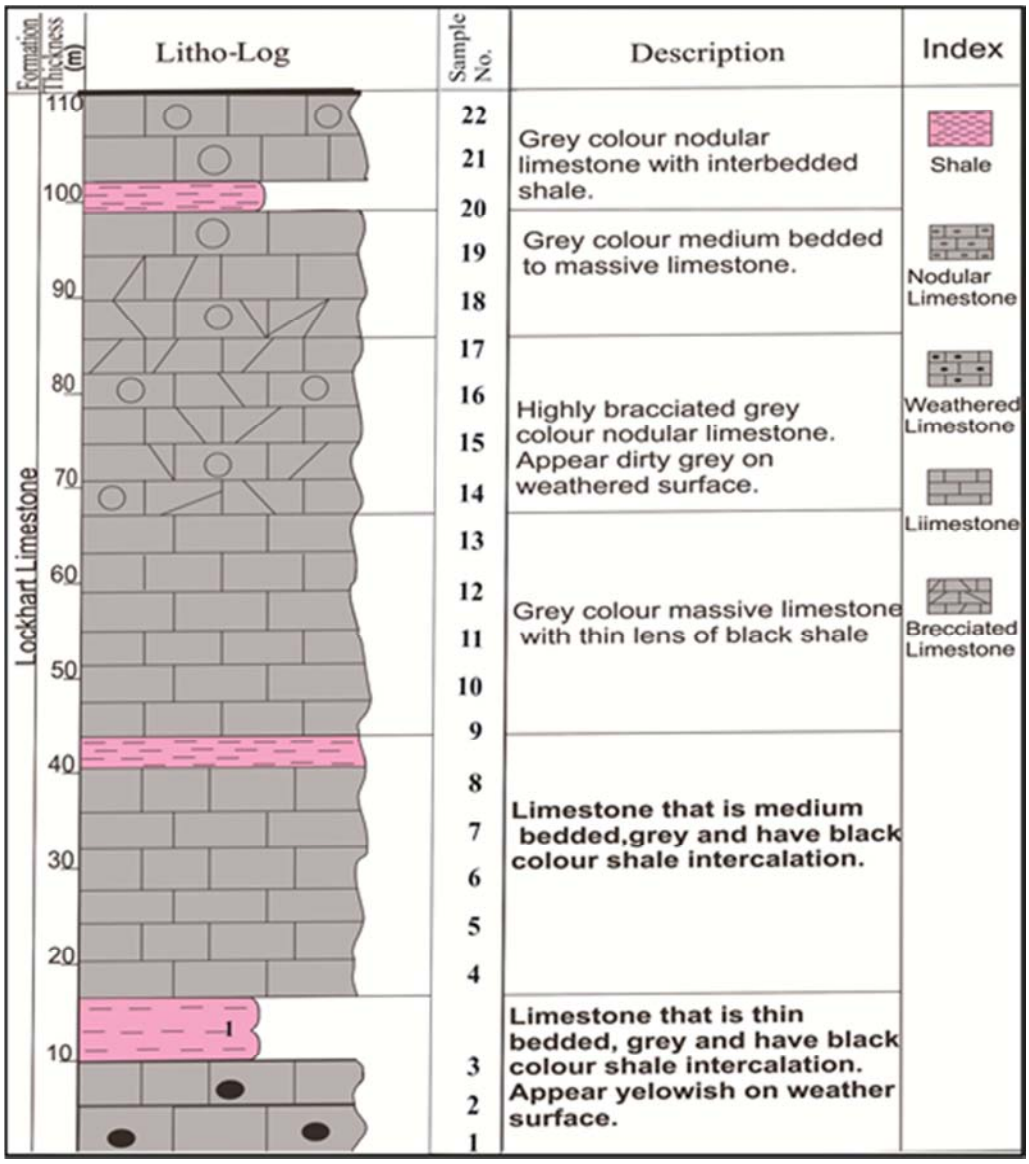


Figure 2. *Lithologic log of the measured stratigraphic section of Lockhart Limestone, Changlagali section, Hazara area.*

The study area consists of the rocks from Pre-Cambrian to Eocene age [9]. The Pre-Cambrian succession comprises of Hazara Formation, which is exposed in the area mostly along thrust faults. The Pre-Cambrian rocks are unconformably overlain by Cambrian Abbottabad and Hazira formations. The Cambrian succession is unconformably overlain by the Jurassic strata, which consist of the Samana Suk Formation. The Samana Suk Formation is disconformably overlain by the Cretaceous strata consisting of the Chichali, Lumshiwal and Kawagarh formations. A gradational contact exists between the underlying Chichali Formation and the overlying Lumshiwal Formation. The Lumshiwal Formation is disconformably overlain by the Kawagarh Formation. The Paleocene succession, i.e., Hangu Formation, Lockhart.

Limestone and Patala Formation, disconformably overlie the Cretaceous succession in the study area. The Kawagarh Formation is overlain by the Hangu Formation, which has its upper contact with the Lockhart Limestone (Figure 3). The Hangu Formation in the study area is dominantly comprised of a few meters' thick shale interbedded with lenticular coal seams in its upper part [10]. A gradational contact exists between the Lockhart Limestone and Patala Formation. The Patala Formation consists of green and brown to buff colored shale with interbeds of nodular limestone [9]. The Paleocene succession is conformably overlain by the Eocene succession, which comprises of the Margalla Hill Limestone and the Chorgali Formation. The Miocene Murree Formation lies at the top of the whole sedimentary succession.

Thickness of Lockhart Limestone is recorded to be around 200 m in the Hazara area [11] (Figure 3), however, it is 110 m thick at the Changlagali section. Generally, the limestone is grey in color, medium-grained, hard and nodular, with subordinate shales. It is thin to medium-bedded in the basal part, massive and brecciated to nodular in the middle part, and medium-bedded to massive and nodular in the upper part. The weathered surfaces indicate solution weathering. On fresh surface it is generally dark grey and give fetid smell by hammering. Nodularity increases toward its contact with

overlying shale of Patala Formation. In the middle part of the unit calcite veins are common. The Lockhart Limestone in the study area is highly fossiliferous. Microfossils are expressed on the weathered surface in the form of tiny specks. The nodular character of limestone is inferred to be of sedimentational origin. The argument of such an origin is supported by the fact that the nodules are more frequent where shale and limestone are inter bedded. The nodule size ranges from 6-8cm in length and 4-6 in width. The limestone is rich in organic matter and has a sharp fetid smell when stricken with hammer.

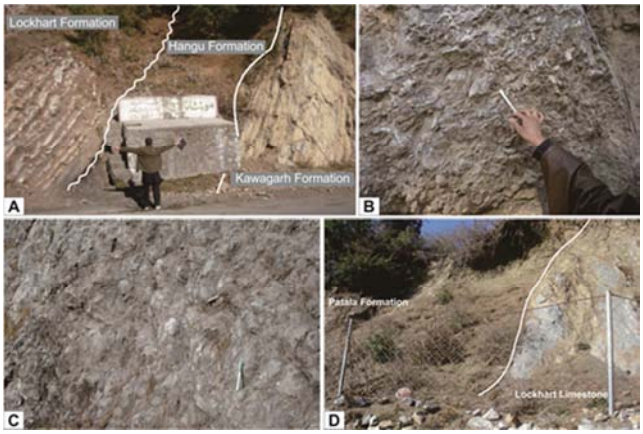


Figure 3. *Outcrop features of the Lockhart Limestone, Changlagali section, Hazara area. (A) Unconformable contact between Kawagarh Formation and Lockhart Limestone; (B) Brecciation in Lockhart Limestone; (C) Nodularity in Lockhart Limestone; (D) Contact of Lockhart Limestone with Patala Shale.*

3. Materials and Methods

The present study is carried out, included measurement, sampling and logging of the Lockhart Limestone along.

Nathiagali-Murree road at Changlagali in Abbottabad district. Total 22 samples collected from the Lockhart Limestone were processed for lab investigation, where they were cut into rectangular slabs using diamond blade saw. These slabs were then mounted on glass slides using epoxy glue. It is then polished with the help of a series of abrasive powder (400 to 800 meshes) to achieve a thickness of around 30 micron. The photographic study of thin sections was conducted by using standard polarizing microscope. On the basis of collected data, the fossils were interpreted by comparing with the available literature.

4. Foraminiferal Assemblage

The limestone is characterized by a variety of faunal assemblages which include larger benthic, smaller benthic and planktic foraminifera (Figures 4-8). Total twenty-nine foraminifera species identified, which include five planktic species, eight smaller benthic species and sixteen larger benthic species which are given in Figure 9 and comparative zonal scheme of various authors are also shown in Figure 10.

As obvious from the existing published literature, the LBFs significantly contribute to the fauna recorded in the Paleocene rocks. They include some significant age diagnostic species like *Lockhartia haimei* [12], *Lockhartia conditi* [13], *Miscellanea miscella* [14] *Operculina subsalsa* [15], *Discocyclina ranikotensis* [12].

Currently, six LBF genera were identified, including Lockhartia, Miscellanea, Assilina, Discocyclina, Ranikothalia and Orbitosiphon. Among the smaller benthic foraminifera five genera are recorded which include Textularia, Quinqueloculina, Biloculina, Triloculina and Nodosaria. These are not significant for stratigraphic determinations due to their long stratigraphic range i.e. mostly ranging from Late Paleozoic to Recent. Among the planktic foraminifera three genera Globorotalia, Globigerina and Morozovella are recorded. These are very important for stratigraphic determination for their short stratigraphic range i.e. mostly ranging from late Paleocene to Early Eocene.

The following are the foraminifera found, and identified accordingly:

Triloculina sp. (Figure 4A)
2003. *Quinqueloculina* sp. [16], pl. 2, figure 164 & 165.
Biloculina sp. (Figure 4B)
2005. *Biloculina contraria* [7], vol. 15, pl. 4, figure 10.
Quinqueloculina vulgaris (Figure 4C)
1896. *Quinqueloculina vulgaris* [17], pl. 32, Figure 3a-c
Lockhartia sp. (Figure 4D)
1932. *Lockhartia haimei* [12], vol. LVII, pl. 2, figures 4-6.
Quinqueloculina lamarckiana (Figure 4E)
1956. *Quinqueloculina lamarckiana* [5], pl. 32, figures 3a-c.
Lockhartia tipperi (Figure 4F)
2005. *Lockhartia tipperi* [7], vol. 15, pl. 1, figure 4.
Miscellanea sp. (1) (Figure 5A)
1976. *Miscellanea miscella* [3], pl. 13, figures 1-4.
Assilina spp. (Figure 5B)
2005. *Assilina* sp. [7], vol. 15, pl. 2, figure 6.
Miscellanea miscella (Figure 5C)
1853. *Nummilites miscella* [14], pl. 35, figures 4a-4c.
Nodosaria sp. (Figure 5D)
1956. *Nodosaria contorta* [5], vol. 1.
Ranikothalia sindensis (Figure 5E)
1927. *Operculina sindensis* [18], vol. LXXXIII, pl. 19, figures 10-13.
Textularia sp. (1) (Figure 5F)
2005. *Textularia* sp. [7], vol. 15, pl. 3, figure 2.
Assilina laminosa (Figure 6A)
1976. *Assilina laminosa* [3], pl. 11, figure 5.
Assilina granulosa (Figure 6B)
1976. *Assilina granulosa* [3], pl. 11, figure 1.
Assilina exponens (Figure 6C)
1967. *Nummulites exponens* [19], pl. 41, figures 14a-e.
Assilina dandotica (Figure 6D)
1937. *Assilina dandotica* [15], vol. XXIV, pl. 4, figures 1-3.
Miscellanea sp. (2) (Figure 6E)
1954. *Miscellanea meandrina* [20], pl. 10, figures 1-4.
Lockhartia conica (Figure 6F)

1954. *Lockhartia conica* [20], p. 53, pl. 4, figures 1-3.
Ranikothalia nuttalli (Figure 7A)
1927. *Nummulites nuttalli* [18], vol. LXXXIII, pl. 18, figures 3, 4, pl. 19, figures 1-9.
Orbitosiphon sp. (Figure 7B)
1937. *Lepidocyclina (polylepidina) punjabensis* [15], vol. XXIV, pl. 5, figures 1-8, 14, 16.
Ranikothalia sp. (Figure 7C)
1996. *Ranikothalia nuttali* [21], pl. 1, figure 10.
Globorotalia compressa (Figure 7D)
1957. *Globigerina compressa*, [22] vol. 215, pl. 40-60.
Globorotalia pseudomenardii (Figure 7E)
1957. *Globorotalia pseudomenardii* [22], vol. 215, pl. 40-60.
Globigerina linaperta (Figure 7F)
1940. *Globigerina linaperta* [23], vol. 69, pl. 13, figures 54-57.
Morozovella velascoensis (Figure 8A)
2005. *Morozovella velascoensis* [7], vol. 15, pl. 3, figure 10b; pl. 4, figure 8.
Quinqueloculina sp. (Figure 8B)
2005. *Biloculina contraria* [7], vol. 15, pl. 4, figure 12.
Textularia sp. (Figure 8C)
1956. *Textularia* sp. [5], vol. 1, pl. 9, figures 10a-b.
Discocyclina sp. (Figure 8D)
1927. *Discocyclina ranikotensis* [18], vol. LXXXIII, pl. 21, figures 10.
Globorotalia angulata (Figure 8E).

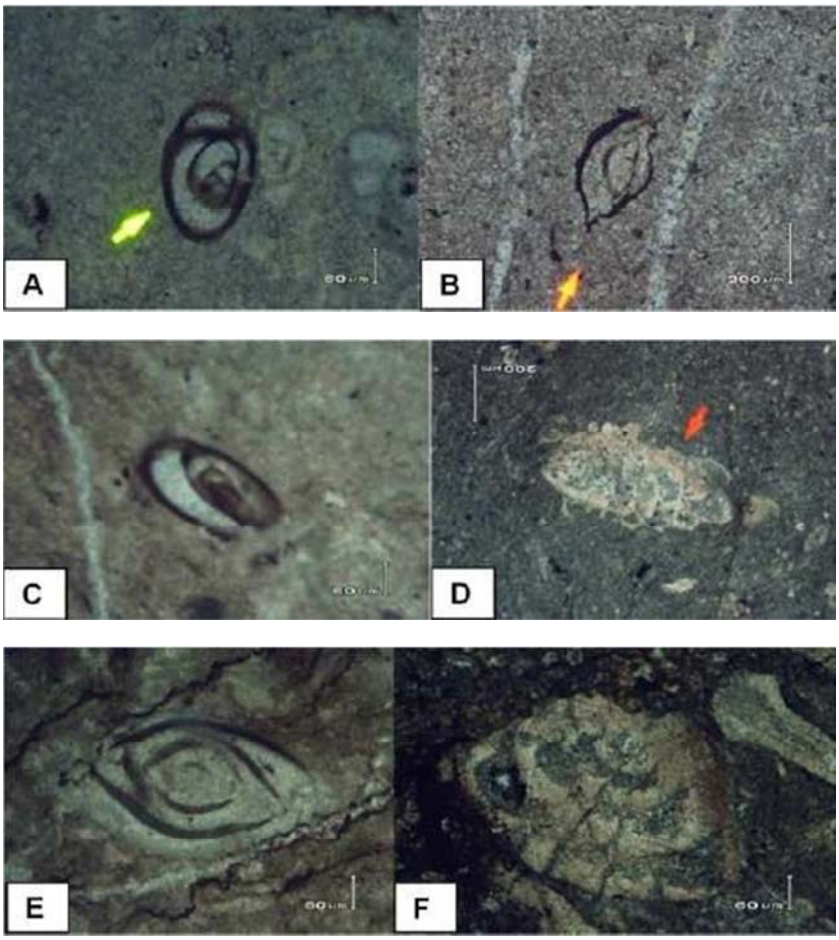
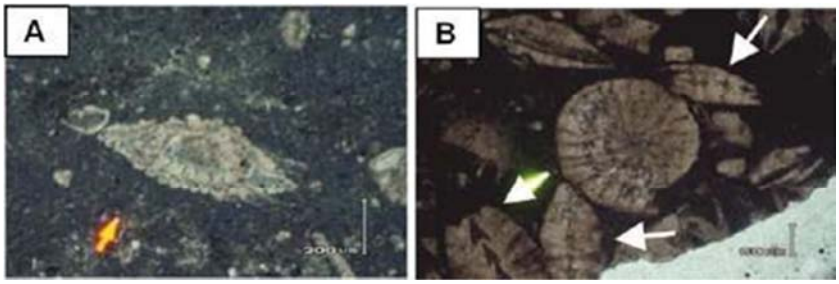


Figure 4. *A: Triloculina* sp.*; B: Biloculina* sp.*; C: Quinqueloculina vulgari; D: Lockhartia* sp.*; E: Quinqueloculina lamarckiana; F: Lockhartia tipperi.*



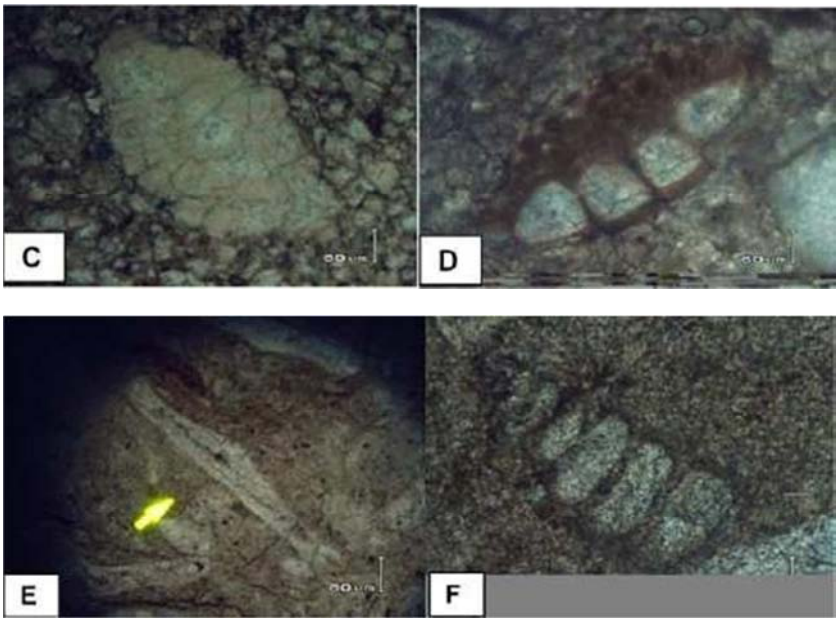


Figure 5. *A: Miscellanea* sp.*; B: Assilina* spp. *(indicated by arrows); C: Miscellanea miscella; D: Nodosaria* sp.*; E: Ranikothalia sindensis; F: Textularia* sp.

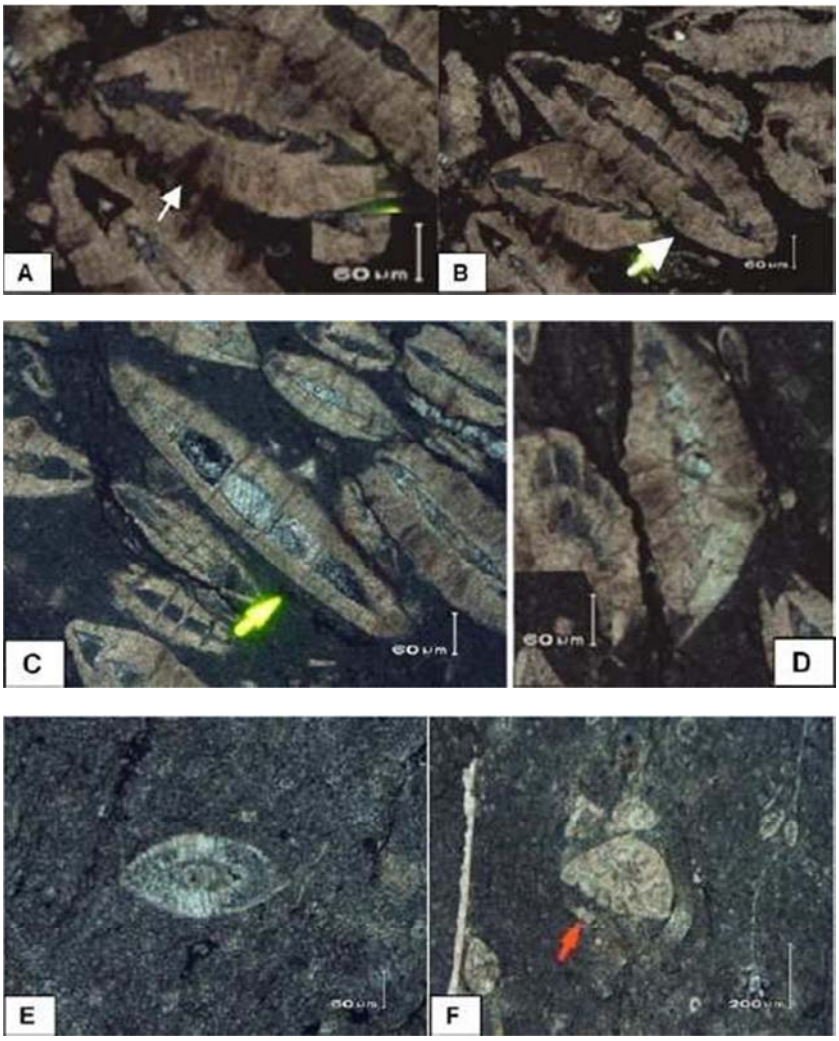


Figure 6. *A: Assilina laminose (indicated by arrow); B: Assilina granulosa (indicated by arrow); C: Assilina exponens (indicated by arrow); D: Assilina dandotica; E: Miscellanea* sp.*; F: Lockhartia conica.*

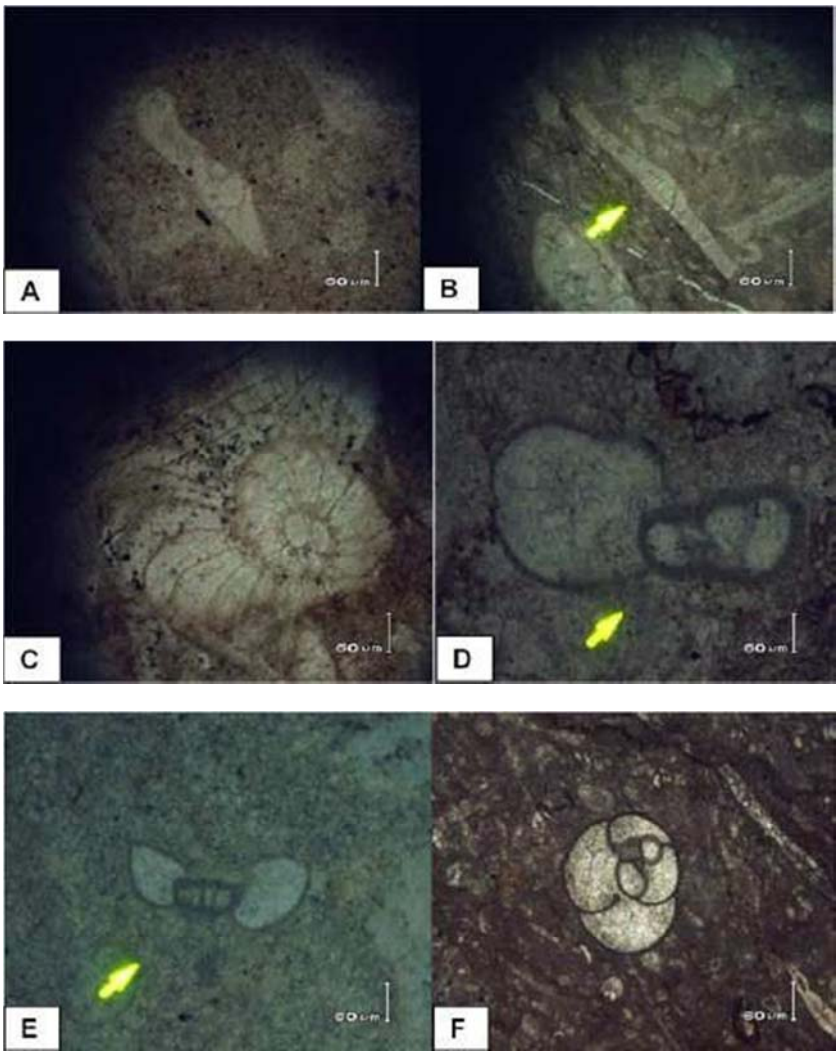


Figure 7. *A: Ranikothalia nuttalli; B: Orbitosiphon* sp.*; C: Ranikothalia* sp.*; D: Globorotalia compressa; E: Globorotalia pseudomenardii; F: Globigerina linaperta.*

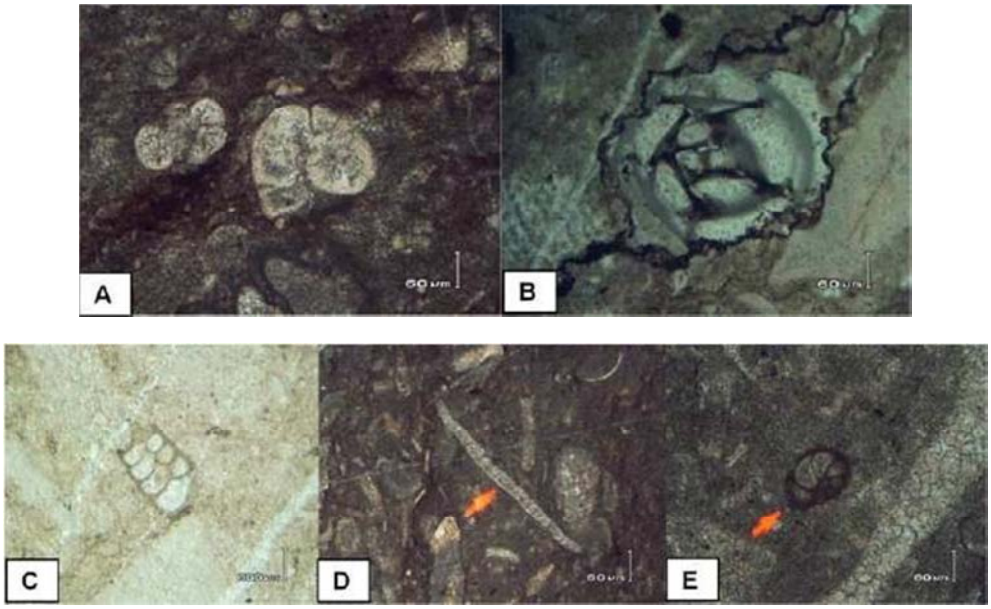


Figure 8. *A: Morozovella velascoensis; B: Quinqueloculina* sp.*; C: Textularia* sp.*; D: Discocyclina* sp.*; E: Globorotalia angulata.*

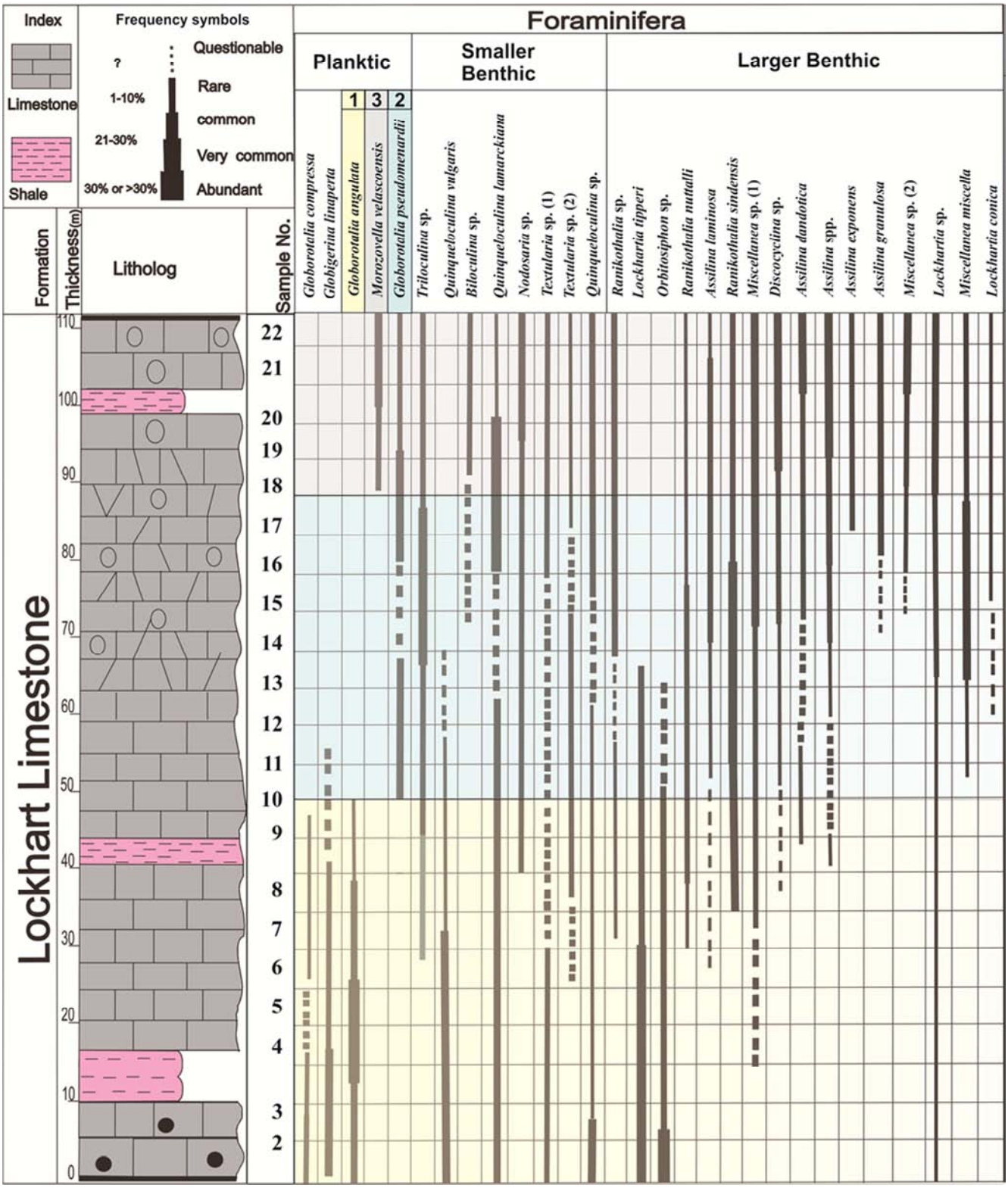


Figure 9. *Shows distribution of planktic, and smaller and larger benthic foraminifera species in Lockhart Limestone, Changlagali section, Hazara area.*

5. Planktic Foraminiferal Zonations

The planktic assemblages of the recorded foraminifers are comparatively scarce than smaller and larger benthics, however, are characterized by few very important zonal markers like; *Globorotalia angulata*, *Morozovella velascoensis* and *Globorotalia pseudomenardii* which made them an important tool for biostratigraphic analysis and its integration with standard stratigraphic zonations.

In the present study the following are the biostratigraphic zonation established based on planktic foraminifera:

5.1. Globorotalia angulata Zone

This zone is defined as the total range of the *Globorotalia angulata* (interval between first appearance in sample 1 till the appearance of next index species, *G. pseudomenardii* in sample appearance of the next index species, *M. velascoensis* in 10. Other chaharacteristic planktic species of this zone are *Morozovella angulata, Globigerina tarobaensis, Subbotina lozanoi prolata* [7, 25] and *Globigerina linaperta*.

This interval coincide with P3 zone of [26, 27], *Morozovella angulata* and *Planorotalites pusilla pusilla* zone of [28], P3a, b zones of [29], *Morozovella angulata* and *Igorina albeari* zones of [30] and *Morozovella angulata* zone of [7] (Figures 9, 10). It is also equivalent to *Morozovella angulata* and *Igorina pusilla pusilla* zones of [31, 32]. This zone has been assigned Middle Paleocene age by the above mentioned researchers.

5.2. Globorotalia pseudomenardii Zone

This zone is defined as the total range of *Globorotalia pseudomenardii* from its first appearance in sample 10 till the sample 18. Other characteristics planktic species of this zone are *Planorotalites pseudomenardii*, *Planorotalites abundocamerata*, *Pseudohatigerina* sp. [7, 25].

This interval concedes with P4 zone of [26], *Planorotalites pseudomenardii* zone of [28], *Planorotalites pseudomenardii* zone of [27], *Planorotalites pseudomenardii* and *A. soldodensis* zone of [29], *Planorotalites pseudomenardii* zone of [30] (Figure 10). This zone has been assigned Late Paleocene age by the above mentioned researchers.

5.3. Morozovella velascoensis Zone

This zone is defined as the partial range of the *Morozovella velascoensis* from its first appearance in sample 18 till the last sample of the formation. Other characteristics planktic species of this zone are *Glogorotalia palmarae* and *Globigerina primitiva* [7, 25, 27].

The upper part of the Lockhart Limestone (sample 18-22) represent this interval at Changlagali section in Hazara. This is equivalent to P5 zone of [28-30], which is also equivalent to the zones of [31-35, 25]. This zone has its limits from Late Paleocene to early Eocene age as stated by the above mentioned researchers. In this study, however, the zone is confined to the Late Paleocene as the zone extends into the Patala Formation of the Late Paleocene to Early Eocene age [9].

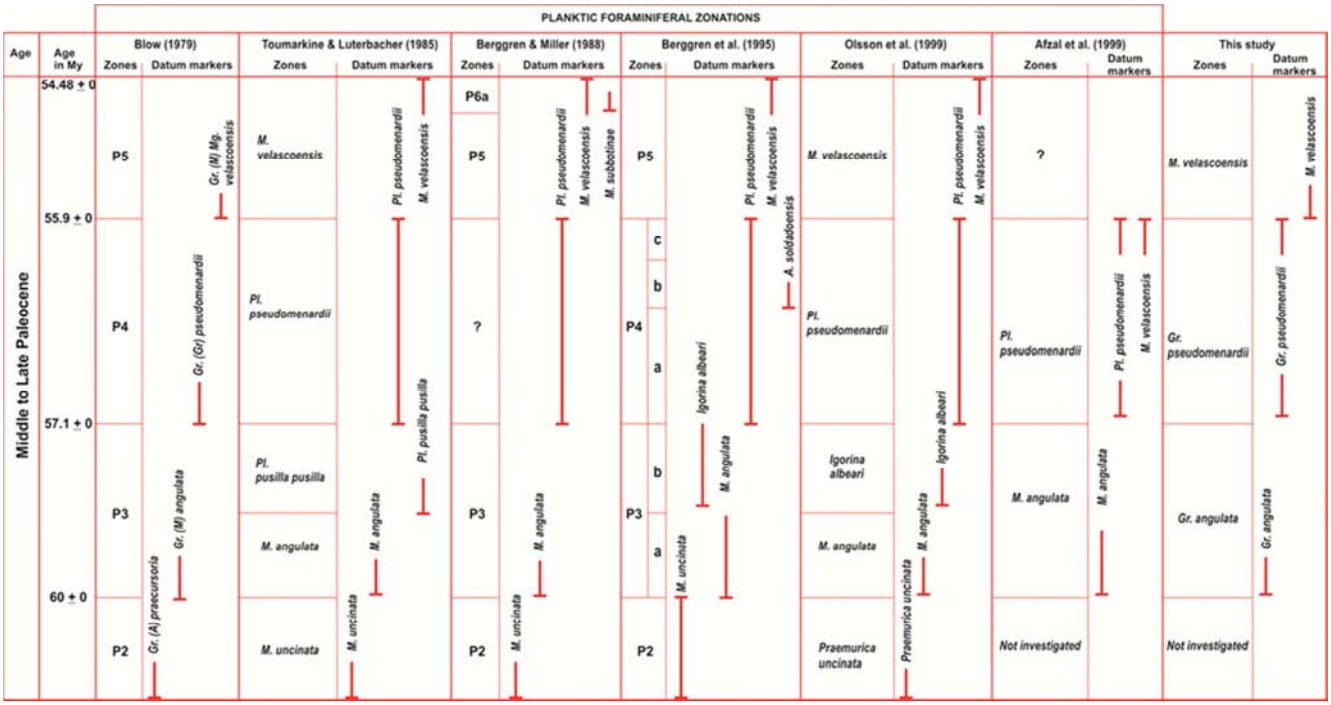


Figure 10. *Comparison of the important foraminiferal zonal schemes and marker species proposed by various researchers with Upper Paleocene with those used in this study (A: Acaranina, M: Morozovella, Pl: Planorotalites, Gr: Groborotalia and Mg: Muricoglobigerina); modified after [7]; million age is adopted from [25].*

6. Age of Lockhart Limestone

White and Afzal et al. proposed Middle Paleocene age for the *Globorotalia angulata* species [24, 7]. Afzal et al. identified it in lower part of the Lockhart Limestone at Kohat area, similar to its appearance in the lower part of the formation in sample 1 [7] (Figure 9). Berggren and Norris established an equivalent *Morozovella angulata* zone and assigned Middle Paleocene age to it [25]. Associated fauna in this zone are *Lockhartia conica*, and *Micellanea miscella* [14, 20, 5]. They are considered to be of Middle Paleocene in age. So the lower portion of Lockhart Limestone in current study is confirmed to be of Middle Paleocene age. Afzal et al. and Berggren and Norris mentioned *Planorotalites pseudomenardii* zone between the *Morozovella angulata*

zone and *Morozovella velascoensis* zone, which is equivalent to the *Globorotalia pseudomenardii* zone of [26], and proposed a Late Paleocene age for the *Planorotalites pseudomenardii/Globorotalia pseudomenardii* zone [7, 25]. In the current study *Globorotalia pseudomenardii* zone has been mentioned which indicates Late Paleocene age. According to Afzal et al., the *Morozovella velacoensis* species is of the Late Paleocene age [7]. Berggren and Norris extended the age of *Morozovella velascoensis* zone from Late Paleocene to Early Eocene, mentioning the upper limit of the *Morozovella velascoensis* extended to Early Eocene [25]. In Changlagali section, Hazara area the *Morozovella velacoensis* species appears in sample No. 18 of the Lockhart Limestone and lasts till the end of the formation. Associated foraminiferal fauna in *Morozovella velascoensis* zone include, *Lockhartia tipperi* of Upper Paleocene age [14, 36]. Other species of Early Eocene age in an association with *Morozovella velascoensis* are *Assilina subdaviesi*, *Assilina subspinosa* and *Globigerina linaperta* [15, 37]. Thus it can be interpreted that the uppermost part of the formation is extended to Lower Eocene.

7. Conclusion

The Lockhart Limestone contains a variety of stratigraphically significant foraminiferal species belonging to six larger benthic, five smaller benthic and three planktic genera. Three planktic foraminifral biozones were identified that are Middle Paleocene *Globorotalia angulata* zone, Late Paleocene *Globorotalia pseudomenardii* zone and Late Paleocene *Morozovella velascoensis* zone, respectively. In the light of the current comparative study, Middle to Late Paleocene age is confirmed for the Lockhart Limestone exposed at the Changlagali section of Hazara area.

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