

Late Palaeocene- Early Eocene *Morozovella* from Pondicherry Area, Cauvery Basin, Southern India

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Abstract

This paper records the occurrence of fourteen species of well-preserved planktonic foraminiferal genus *Morozovella* viz., *Morozovella aequa*, *M. angulata*, *M. subbotinae*, *M. gracilis*, *M. velascoensis*, *M. formosa*, *M. apantesma*, *M. acutispira*, *M. praeangulata*, *M. oclusa*, *M. acuta*, *M. conicotruncata*, *M. lensiformis*, and *M. crater* from several outcrops sections in the Pondicherry area, southern India. The recorded planktonic foraminiferal genus is useful for biostratigraphic purpose and indicates late Palaeocene-early Eocene (P3-E4 Zone) for the study area. These species are distinctive of tropical and subtropical environments of late Palaeocene and early Eocene

Keywords: *Morozovella* Foraminifera; Pondicherry; Palaeocene; Eocene; Cauvery Basin; Southern India

Introduction

The Pondicherry area includes the northernmost of the three outcrops of marine sediments and occupy an area of nearly 30 sq. miles NW of Pondicherry. The study area is situated to the NE of the city of Pondicherry where Palaeocene to early Eocene rocks are well exposed. The present field investigation led to the recognition of a well-defined stratigraphic section in the village of Saidarpet (N 11°59'36.7":E79°45'0.5"); calcareous marlstone and claystone were collected from the NE of the village Tiruchitrabalam – Saidarpet (N 12°00'5.3": E79°46'33.6") and calcareous fined grained sandstone, behind the temple of the village Papanchavadi (N12°00'49.0":E79°46'08.7") and in the pond section of the village Ravathamkuppam (N12°00'55.7":E79°46'33.6") in the Pondicherry area (Figure 1).

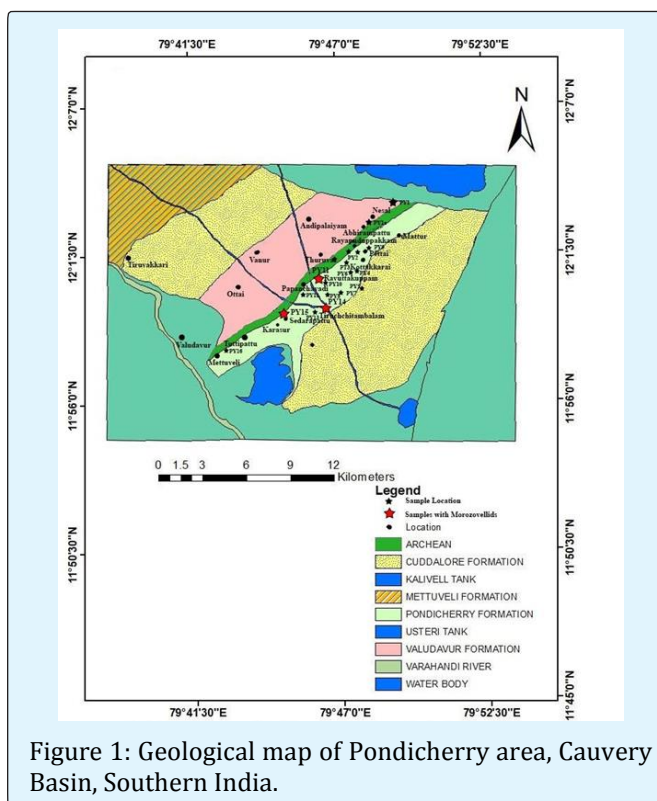


Figure 1: Geological map of Pondicherry area, Cauvery Basin, Southern India.

The Palaeocene –Eocene sediments of the Pondicherry area is known for its microfossil content and were studied by number of workers on various aspects [1-14]. Samples were collected from various outcrop sections and were processed in the laboratory for foraminifera using standard processing technique, have yielded abundant well preserved planktonic foraminifera belonging to the genus *Morozovella*, which are well known guide fossils of the Palaeocene - Eocene age.

Materials and Methods

Twenty-four Samples were collected from the study area for the planktic foraminiferal study. Major lithology of the section is Calcareous Sandstone and Marl contains numerous ichnofossils and larger benthic foraminifera. The sample collected from the field was disaggregated for

microfossil separation following standard procedure as detailed in our previous papers [14].

Planktonic Foraminifera

Planktic foraminifera are generally common to abundant throughout the carbonate facies of the Pondicherry sequence. The angulo-conical *Morozovella* constitutes the dominant element in the assemblage and are represented by fourteen species, viz., *Morozovella aequa*, *M. angulata*, *M. subbotinae*, *M. gracilis*, *M. velascoensis*, *M. formosa*, *M. apantesma*, *M. acutispira*, *M. praeangulata*, *M. occlusa*, *M. acuta*, *M. conicotruncata*, *M. lensiformis* and *M. crater* are of late Palaeocene – early Eocene in age are reported from these sediments (Plates 1&2). The *Morozovella velascoensis* is the highly specialized angulo-conical form with large, conical test, wide open umbilicus with prominent peripheral keel is the most distinctive and dominant form in the fauna [14].

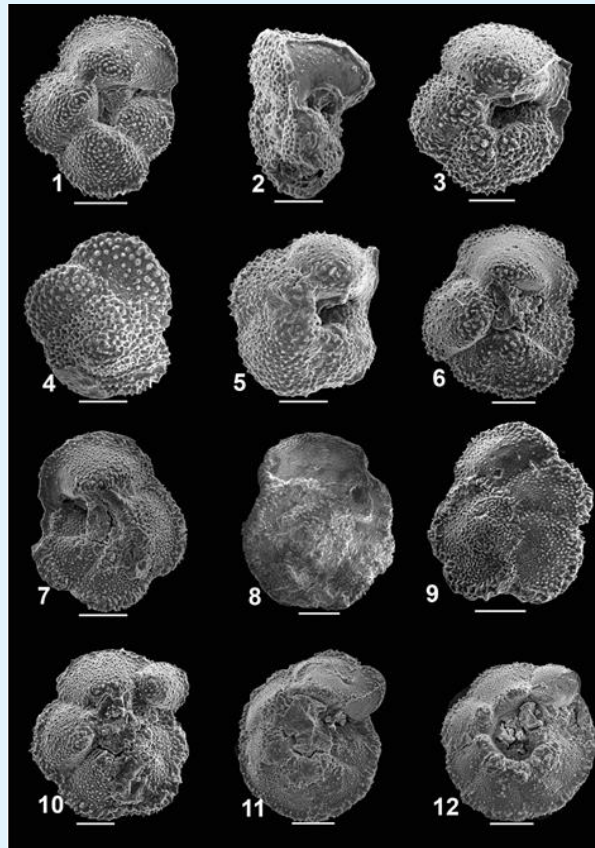


Plate 1: *Morozovellids* from Ravathamkuppam(PY11) and Saiderpet-Tiruchitrabalam cross-road sections(PY14). Scale bar = 100 μ m. Figure 1 & 2 *Morozovella aequa* Samples PY14a, PY11a, b, c ; Figure 3 *M. lensiformis* sample PY14a; Figures 4&5 *M. crater* sample PY14a; Figure 6 *M. gracilis* sample PY14a; Figure 7 *M. subbotinae* sample PY14a; Figure 8 *M. conicotruncata* sample PY14c; Figure 9 & 10 *M. formosa* sample PY14a ; Figure 11&12 *M. velascoensis* sample PY14a.

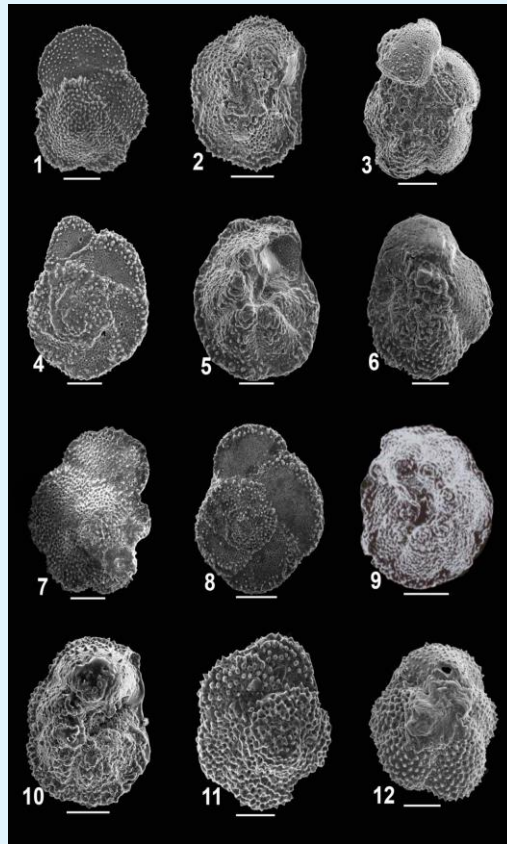


Plate 2: Morozovellids from Ravathamkuppam (PY11) and Saiderpet-Tiruchitrabalam cross-road sections (PY14). Scale bar = 100µm. Figure 1 & 2. *M. acutispira* sample PY14c; Figure 3 *M. preangulata* sample PY14c; Figure 4 & 5 *M. occlusa* [15] samples PY14a, b, c; Figure 6&7. *M. angulata* sample PY11d, PY14b, PY14c; Figure 8 ,9 & 10. *M. acuta* (Toulmin) samples PY14a, b, c; 1947) ; Figure 11 &12 *M. apantesma* sample PY14c.

The muricate planktonic foraminiferal genera *Morozovella* are extensively utilised as palaeoclimatic studies and are important markers in Palaeocene – Eocene planktonic foraminifera biostratigraphy. *Morozovella* were prominent surface dwellers within the tropical and subtropical fauna [16,17], The recorded *Morozovella* species indicates that these sediments have been deposited during late Palaeocene – early Eocene age (P3-E4).

Diagnostic Characters of the Morozovella Species

Morozovella velascoensis is characterised by relatively large robust, plano-convex, nearly circular, moderately lobulated test; composed of about 15-16 chambers arranged in 2½ to 3 whorls; last whorl with 6-7 (rarely 8) anguloconical chambers whose tips surround a moderately open umbilicus surrounded by an rim of fused

muricae; umbilical sutures radial, depressed, strongly curved raised and beaded on spiral side; wall finely perforated, distinctly muricocarinate periphery, but the spiral chamber surfaces often nearly free of muricae; aperture low, interiomarginal, umbilical- extraumbilical arch. *Morozovella velascoensis* has a wide geographic distribution but is a predominantly (sub)tropical to temperate form; it has not been recorded from high northern or southern (subantarctic) latitudes. The disappearance of this taxon is a distinct biostratigraphic event that is used to define the boundary between Zones P5 and P6, which occurs in Paleocene/Eocene boundary as denoted in the Belgian and/or London-Hampshire Basin(s) of northwestern Europe [18]. This species occurs at Zone P3b to Zone P5 [19]. The LAD of *Morozovella velascoensis* marks the base of zone E3 / top of E2 [20]. Last occurrence (top): at top of E2 zone (55.2Ma, in Ypresian stage). Data source: zonal marker [20]. First

occurrence (base): near base of P3b subzone (61.3Ma, in Selandian stage). Data source: Olsson, et al. [19]. This species occurs at P5 Zone in the study area (Plate 1: Figures 11 & 12).

Morozovella aequa is having subquadrate, plano-convex, muricocarinata test with moderately lobulate peripheral outline and 4 (less commonly 5) chambers in last whorl; intercameral sutures on umbilical side straight; radial; raised, curved on spiral side, umbilicus narrow, low apertural slit extending to periphery; test surface covered with muricae, on umbilical shoulder and along peripheral margin [19]. *Morozovella aequa* is a geographically widespread species, having been recorded from areas circumscribed by latitudes 50°N (Goban Spur, northeastern Atlantic Ocean) [21] and 50°S (Falkland Plateau) [22]; it occurs as far south as nearly 60° (Kerguelen Plateau) [23] during the brief early Eocene (Zone P6) temporal excursion of (sub)tropical *Morozovellids*. [19]. This species occurs at Zone P4c to Zone P7 [19]. Last occurrence (top) at top of E5 zone (50.7Ma, in Ypresian stage). First occurrence (base) at base of P4c subzone (57.8Ma, in Thanetian stage). Data source: Olsson, et al. (1999) [19]. This species occurs at P4-P5 Zone in the study area (Plate 1: Figures 1 & 2).

Morozovella acuta is conicotruncate, distinctly muricocarinata test with 5 chambers in last whorl; intercameral sutures radial, depressed on umbilical side and strongly recurved and tangential, distinctly ornamented on, and flush with, spiral side; periumbilical collar weakly to moderately well-ornamented with muricate; umbilicus wide and open but narrow in more tightly coiled individuals; aperture interiomarginal, umbilical-extraumbilical with well-developed, triangular, circumumbilical "teeth". [19]. *Morozovella acuta* is an essentially subtropical to tropical form with somewhat narrower biogeographic distribution than *M. velascoensis* [15,19]. This species occurs at Zone P4b to Zone E2 (top) [24] Zone P4b to Zone P5 (top). Several authors suggest that *M. acuta* occurs somewhat higher than *M. velascoensis*. Last occurrence (top) at top of E2 zone (55.2Ma, in Ypresian stage). First occurrence (base) near base of P4b subzone (60.2Ma, in Selandian stage). Data source: Berggren, et al. (2006) [24]. This species occurs at P4 Zone in the study area (Plate 2: Figures 8,9 & 10).

Morozovella acutispira is characterised by lenticular to subcircular, plano-convex to biconvex test with apiculate early whorls and lobulate outline, 4-6 chambers in last whorl; umbilical sutures radial, slightly curved, depressed; spiral sutures curved, raised and ornamented by the extension of the strongly muricate keel; chambers tend to

be flattened along the peripheral margin; aperture a low, interiomarginal, umbilical-extraumbilical arch extending from a narrow, deep umbilicus [19]. The geographic distribution of this morphospecies appears characteristic of subtropical to tropical regions as does that of *occlusa* [19]. This species occurs near the Zone P3/P4 boundary to the top of Zone P4b [19]. Last occurrence (top) at top of P4b subzone (57.8Ma, in Thanetian stage). First occurrence (base) at top of P3b subzone (60.8Ma, in Selandian stage). Data source: Olsson, et al. (1999) [19]. This species occurs at P5 Zone in the study area (Plate 2: Figures 1 & 2).

Morozovella occlusa is characterised by plano-convex to low biconvex, nearly circular test, 4-6 (rarely up to 8) chambers in last whorl, coalescing in a circular, subacute, weakly to moderately muricate umbilical shoulder and forming a narrow, deep umbilicus; umbilical sutures depressed, radial; elevated and beaded, tangentially curved on spiral side; sutures between final and penultimate whorl coarsely muricate; periphery distinctly muricocarinata; aperture an interiomarginal, umbilical-extraumbilical arch [19]. This species is widespread in the low to middle latitudes [19]. This species occurs at the Top of Zone P3b; Zone P4-P5 [19]. Last occurrence (top) at top of E2 zone (55.2Ma, in Ypresian stage). First occurrence (base) near top of P3b subzone (60.8Ma, in Selandian stage). Data source: Olsson, et al. (1999) [19]. This species occurs at P5 Zone in the study area (Plate 2: Figures 4 & 5).

Morozovella angulata is characterized by by muricate, nonspinose angulo-conical test, spiral side flat, early chambers slightly elevated, 10-12 chambers arranged in 2½ whorls, 4-6 chambers in final whorl, periphery lobulate, (sub)acute, imperforate band (muricocarina) developed along peripheral margin; weak circumumbilical collar formed around narrow, deep umbilicus by elevated chambers, particularly last chamber; sutures depressed, straight, radial on umbilical side, strongly recurved on spiral side; aperture, low, interiomarginal, umbilical- extraumbilical low arch with weakly developed lip [19]. This form is essentially restricted to (sub)tropical to temperate regions; it has not been reliably reported from high northern or southern (subantarctic) regions [19]. This species occurs at Zone P3 to lower Zone P4 [19]. The FAD of *Morozovella angulata* marks the base of zone P3a / top of P2 [20]. Last occurrence (top) within P4a subzone (60.52-60.73 Ma, top in Selandian stage). First occurrence (base) at base of P3 zone (62.3Ma, in Danian stage). Data source: zonal marker [20]. This species occurs at P3a- P4 Zone in the study area (Plate 2: Figures 6 & 7).

Morozovella apantesma is having panoconvex, umbilicoconvex, test with lobulate, weakly muricocarinat periphery; 4-5 chambers in last whorl, inflated to subangular on umbilical side, moderately convex, triangular (lunate) in edge view; intercameral sutures on umbilical side depressed, radially curved and slightly depressed on spiral side; umbilical side distinctly muricate, coarsely perforate on spiral side; umbilicus relatively narrow, deep; aperture an interiomarginal, umbilical-extraumbilical arch with narrow, continuous intraperiumbilical lip [19]. This species is distributed in Northern middle latitudes to the Southern Ocean [19].

This species occurs at Zone P3b to Zone P4c [19]. Last occurrence (top) at top of P4c subzone (57.1Ma, in Thanetian stage). First occurrence (base) at base of P3b subzone (61.3Ma, in Selandian stage). Data source: Olsson, et al. (1999) [19]. This species occurs at P3b- P4 Zone in the study area (Plate 2: Figures 11 &12).

Morozovella subbotinae is distinguished by its relatively large and strongly muricocarinat test, and the circumumbilical elevation/extension of the chambers and weakly ornamented circumumbilical chamber tips [24]. Widely distributed in (sub)tropical assemblages in Atlantic, Indo-Pacific, and typical Tethyan biogeographies and as far south as 60° S in association with the early Eocene extra-tropical excursion of carinate morozovellids on the Kerguelen Plateau (ODP Site 738; ODP Site 747; text-figure 24;) [19,25,23]. We have found that *M. subbotinae* has its FAD at the base of P5 zone (57.1Ma, in Thanetian stage). Data source: Berggren, et al. (2006) [24]. This species occurs at Zone P5 to Zone E5. Its LAD is used to denote the boundary between Zones E5 and E6. The premature disappearance of *M. subbotinae* (within Zone P6b = E4) at Indian Ocean Site 213 is ascribed to gradually increasing dissolution in the early Eocene (Berggren & Pearson 2006). The LAD of *Morozovella subbotinae* marks the base of zone E6 / top of E5. Last occurrence (top) at top of E5 zone (50.7Ma, in Ypresian stage). Data source: zonal marker [20]. First occurrence (base) at base of P5 zone (57.1Ma, in Thanetian stage). Data source: Berggren, et al. (2006) [24]. This species occurs at P5 Zone in the study area (Plate 1: Figure 7).

Morozovella gracilis is distinguished by its planoconvex to moderately biconvex test, with lobulate peripheral margin ornamented with a well-developed muricocarina; 5-6 essentially equidimensional chambers in last whorl; umbilical intercameral sutures radial, straight, depressed; on spiral side strongly curved, distinctly muricate except for penultimate/ultimate chamber suture which is straight giving cuneiform shape to final chamber;

umbilical surface covered with muricae, spiral side weakly muricate except for concentration of muricae along intercameral sutures and peripheral margin of ultimate whorl; small sutural openings along margin/junction of ultimate/penultimate whorl resulting from chamber addition along topographically separated/elevated muricate edges; umbilicus narrow, deep; aperture a low interiomarginal, umbilical-extraumbilical arch extending towards, but not to, the peripheral margin [19]. This is a geographically widespread morphospecies recorded predominantly from (sub)tropical biogeographies. It occurs as far south as nearly 60° at ODP Sites 738 [26] and 747 [23] on the Kerguelen Plateau, southern Indian Ocean, as part of the earliest Eocene extra-tropical excursion of *Morozovellids* [19]. This species occurs in Zone P5 to Zone P6b [19]. Last occurrence (top) at top of E5 zone (50.7Ma, in Ypresian stage). First occurrence in upper part of E2 zone (55.4Ma, in Ypresian stage). Data source: Olsson, et al. (1999) [19]. This species occurs at P5 Zone in the study area (Plate 1: Figure 6).

Morozovella conicotruncata is characterized by subcircular, moderately lobulate, low trochospiral test with 5-7 subangular, inflated, essentially equidimensional chambers in last whorl, spiral side flat to slightly convex in early whorls; umbilical sutures straight to weakly curved, radial, incised; spiral sutures distinctly curved, incised; axial periphery (sub)acute, peripheral muricocarina variable, generally fused on early chambers of last whorl while later chambers generally subrounded; umbilicus narrow, deep; aperture a low interiomarginal, umbilical-extraumbilical slit [19]. As with its closely related sister taxon *angulata*, this form has a predominantly tropical to temperate distribution (< 45° N and S) and has not been reliably reported from high northern or southern (subantarctic) latitudes. It occurs in Zone P3 to lower Zone P4. Last occurrence (top) at top of P4 zone (57.1Ma, in Thanetian stage). First occurrence (base) near base of P3 zone (62.1Ma, in Danian stage). Data source: Olsson, et al. (1999) [19]. It is a common and distinct form in our material and is observed in Zone P4 (Plate 1: Figure 8).

Morozovella praeangulata is characterised by planoconvex, moderately lobulate test with 5-6 tangentially elongate chambers in last last whorl; umbilical sutures straight to weakly curved, depressed/incised; spiral intercameral sutures incised, weakly muricate, strongly recurved; peripheral margin strongly muricate but not muricocarinat; umbilicus narrow, deep with aperture an interiomarginal, umbilical-extraumbilical slit extending nearly to the peripheral margin [19]. This species has been identified in few

localities suggests a low to middle latitude distribution [19]. *Morozovella praeangulata* occurs in Zone P2 to Zone P3a [19]. Last occurrence (top) at top of P3a subzone (61.3Ma, in Selandian stage). First occurrence (base) near base of P2 zone (62.6Ma, in Danian stage). Data source: Olsson, et al. (1999) [19]. This species occurs at P3a Zone in the study area (Plate. 2: Fig.3).

Morozovella formosa is characterized by its relatively large, robust test, 6-7 (rarely 8) chambers and strongly muricate keel. It is distinguished from its antecedent *M. gracilis* by its larger, more robust test, larger number of chambers in the last whorl and wider umbilicus, and from its partially contemporaneous homeomorph, *M. crater*, by its more lobulate periphery and larger number of chambers in the final whorl and less ornamented test [24]. Widely distributed in (sub)tropical regions (Caribbean Sea, Atlantic, Pacific, Tethyan, Indian and Austral Oceans) [24]. This species occurs at the base of Zone E4 to top of Zone E6 [24]. Last occurrence (top) at top of E6 zone (50.2Ma, in Ypresian stage). Data source: Berggren, et al. (2006) [24]. First occurrence (base) at base of E4 zone (54.6Ma, in Ypresian stage). Data source: zonal marker [20]. This species occurs in E4 Zone (within Zone P6 = E4) (Plate 1: Figures 9&10).

Morozovella crater is characterised by 4½ to 5 essentially equidimensional chambers in last whorl, thickened circumumbilical rim of elevated chamber shoulders, strongly limbate sutures on spiral side [24]. Widely distributed in (sub)tropical areas of Atlantic, Mediterranean/ Tethyan, Pacific Oceans and austral regions [24]. This species occurs in Zone E4 to Zone E9 [24]. Last occurrence (top) in upper part of E9 zone (43.4Ma, in Lutetian stage). First occurrence (base) in lower part of E4 zone (53.8Ma, in Ypresian stage). Data source: Berggren, et al. (2006) [24]. This species occurs at E4 Zone ((within Zone P6 = E4) Zone in the study area (Plate 1: Figures 4 & 5).

Morozovella lensiformis is characterized by its subquadrate, involute, biconvex test with narrow umbilicus; test covered by moderately to densely distributed, blunt muricae obscuring, in some instances, the peripheral muricocarina; 4-4½ chambers in last whorl. Later forms exhibit transitional features to plano-convex, multicameral *M. aragonensis* [24]. Relatively common in (sub)tropical areas; South Atlantic Ocean, Indo-Pacific, North Caucasus, among others [24]. This species occurs at the base of Zone E4 to Zone E6 [24]. Last occurrence (top) in mid part of E6 zone (50.4Ma, in Ypresian stage). First occurrence (base) at base of E4 zone (54.6Ma, in Ypresian stage). Data source: Berggren, et al. (2006) [24]. This

species occurs at E4 (within Zone P6 = E4) Zone in the study area (Plate 1: Figure 3).

Discussion and Conclusions

All of the samples analysed contained abundant planktonic foraminifera and the samples from Ravathamkuppam and Trichitramblam (PY14a, b & c, PY11a, b, & c) are dominated by the genus *Morozovella*. The samples are typically characterised by species of *Morozovella* viz., *Morozovella aequa*, *M. angulata*, *M. subbotinae*, *M. gracilis*, *M. velascoensis*, *M. formosa*, *M. apantesma*, *M. acutispira*, *M. praeangulata*, *M. occlusa*, *M. acuta*, *M. conicotruncata*, *M. lensiformis*, and *M. crater* indicating planktonic foraminiferal Zones P3- E4 (late Palaeocene- early Eocene).

Morozovella aequa is a geographically widespread species, having been recorded from Goban Spur, northeastern Atlantic Ocean, Falkland Plateau, Kerguelen Plateau during early Eocene. *M. angulate* is reported from high northern or southern (subantarctic) regions. *Morozovella subbotina* widely distributed in (sub) tropical assemblages in Atlantic, Indo-Pacific, and typical Tethyan biogeographies of early Eocene. *M. gracilis* is a geographically widespread and recorded predominantly in (sub) tropical biogeographies on the Kerguelen Plateau, southern Indian Ocean, as part of the earliest Eocene. *M. velascoensis* occurs in Paleocene/Eocene boundary in the Belgian and London-Hampshire Basin(s) of northwestern Europe. *M. formosa* widely distributed in (sub) tropical regions in Caribbean Sea, Atlantic, Pacific, Tethyan, Indian and Austral Oceans. *Morozovella apantesma* is distributed in Northern middle latitudes to the Southern Ocean. *M. acutispira*, is characteristic of subtropical to tropical regions. *M. praeangulata*, species distributed in a low to middle latitude. *M. occlusa*, species is widespread in the low to middle latitudes. *M. acuta*, is an essentially subtropical to tropical form occurs in Indian Ocean. *M. conicotruncata* distributed predominantly in tropical to temperate distribution. *M. lensiformis* is relatively common in (sub) tropical areas; South Atlantic Ocean, Indo-Pacific, and North Caucasus. *M. crater* is widely distributed in (sub) tropical areas of Atlantic, Mediterranean/ Tethyan, Pacific Oceans and Austral regions. The species of *Morozovella* recovered from the study area is distinctive of tropical and subtropical environments of late Palaeocene- early Eocene.

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