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Biostratigraphy of larger foraminifera in the Eocene (upper Ypresian-lower Bartonian) sequences of the Southern Slope of the Western Caucasus (Russia, NE Black Sea). Correlation with regional and standard planktonic foraminiferal zones

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ABSTRACT

The biostratigraphic analysis of two Eocene (Upper Ypresian-Lower Bartonian) sections located on the Southern Slope of the Western Caucasus (Inal and Loo sections in the Tuapse and Sochi districts, respectively) was carried out using planktonic and larger foraminifera. The planktonic foraminiferal assemblages recorded in these southern sections were similar to those recorded in the North Caucasian region and enabled to recognize the lower Ypresian to lower Bartonian zones of the local Caucasian biostratigraphic scale. The turbiditic sedimentary processes recorded in these sections affected the composition of larger foraminiferal assemblages, which is mostly represented by nummulitids and orthophragmines. Although the larger foraminiferal assemblages are typical of the Peritethys and also resemble those reported in the Northern Caucasian region, the Tethyan SBZ zonal scheme could be applied and SBZ11 to 15/16 zones were identified (at least late Ypresian to middle Lutetian). This integrated study improves the correlation between the planktonic and benthonic local biostratigraphic scales in the Caucasus and allows their correlation with the standard and other biostratigraphic scales in neighbouring Tethyan regions.

KEYWORDS **Lower/Middle Eocene. Larger and planktonic foraminifera. Biostratigraphy. Caucasus. Perithetys.**

INTRODUCTION

A detailed Paleogene biostratigraphy based on planktonic and larger foraminifera has been established long time ago at the Northern Slope of the Great Caucasus, where Paleocene-Eocene depositional units that record deep-to-shelf depositional environments show wide geographic distribution and continuous outcrops. Therefore, the current Caucasus biostratigraphic zonal scheme is based on pretty well studied type sections in the Northern Caucasus, and has been successfully applied in the neighbouring western and northern regions of southern Russia and Crimea (Akhmetiev and Beniamovski, 2003; Koren', 2006).

On the contrary, due to more complex tectonic structure and less continuous outcropping of the paleogene successions on the Southern Slope of the Western Caucasus, biostratigraphic research was seriously hampered and delayed until middle of the last century. Paleocene-Eocene successions on the Southern Slope of the Western Caucasus consists of deep-water carbonate turbidite deposits, turbidite-like carbonate-terrigenous deposits, and mudstone dominated units, whose planktonic foraminifer assemblages were studied lastly in the early 1960s. The most comprehensive review of the Paleogene stratigraphy of the Southern Slope of the Western Caucasus region is a monograph by Grossgeim (1960). The description of several sections along the Black Sea coast from Anapa to Sochi and of the Paleogene sequence of the Abkhazian zone near the border between Russia and Georgia were provided there, with special emphasis on their foraminifer assemblages (Fig. 1). Larger foraminifera from this part of the Caucasus were described only in one paper (Metalnikov, 1935), in which six Lower Eocene species (from a modern view) of *Nummulites* were described from sections along rivers Loo, Psakho and Mzymta (Sochi district). Three of these species (*Nummulites murchisoni* RÜTIMEYER 1850, *N.* aff. *irregularis* DESHAYES 1838 and *N.* sp.) were described from Loo river section.

The main purpose of our research from 2005 was to accurately correlate the Upper Paleocene and Eocene formations of the Southern Slope with the Regional Caucasian and Standard biostratigraphic scales. The study of larger foraminifera distribution in the frame of planktonic foraminifer zones was the most important target of this research. This paper deals with presenting the composition of the planktonic and larger foraminifer assemblages in the study area and to discuss the previously established Eocene biostratigraphic subdivision.

GEOLOGICAL SETTING

The folded-block structure of the Great Caucasus includes the margins of the Scythian and Transcaucasus plates, as well as the Alpine and Kimmerian folded zones situated between them. The Paleogene deposits of the study area are located in the Novorossiisko-Lazarevskaya and Chwezhipsinskaya structural-facial folded zones of the Alpine orogen (Khain, 2001). They are exposed in a reduced number of areas in the western part of the region but more widely in the eastern part (Fig. 1). These two folded zones fringe the Abkhazskaya structural zone of the Transcaucasus plate to the south-east.

With regard to paleogeography, the Paleocene-Eocene sediments of the Novorossiisko-Lazarevskaya and Chwezhipsinskaya zones (Fig. 1) were deposited along the axis and slope of an E-W trending deep-water back-arc basin fringed to the south-east by a shallow shelf developed on a relic arc basin (Abkhazskaya zone) and to the north by the outer continental shelf of the Scythian plate. The Early Paleocene mixed terrigenous-carbonate turbidite deposits changed in the Late Paleocene to finer-grained, turbidite-like sediments. Thus, while the Selandian is represented by carbonate-muddy "subflysch" facies, the Thanetian corresponds to siliceous, organic matter rich mudstones**.** The Paleocene/Eocene boundary is characterized by a carbonate content increase. The Early Eocene is represented in the Novorossiisko-Lazarevskaya zone (Fig. 1) by calcareous mudstones with thin limestone and marl intercalations that can be attributed to a marly "subflysch" succession, whereas the Middle-Upper Eocene is made up by marls. The Eocene deposits of the Chwezhipsinskaya zone (II in Fig. 1) correspond to a terrigenous-carbonate "subflysch" facies and are characterized by the presence of graded carbonate turbidites, thick limestones with interbedded marls, and slump bodies. Graded siliciclastic turbidites are conspicuously absent in the study area. Furthermore, inorganic clastic sediments are scarce in both sections and, when present, are fine-grained. These characteristics suggest a long distance from the siliclastic source areas to the depositional zones.

Two classic Lower Paleogene sections, described by Grossgeim (1960), were selected for this study (Fig. 1). The Inal section (Tuapse district) in the Novorossiisko-Lazarevskaya structural-facial zone (1 and I in Fig. 1), which is quite simple in terms of tectonic structure, was chosen as suitable for establishing an accurate biozonation. Moreover, since three species of *Nummulites* had previously been discovered in the Loo section (Sochi district, Chwezhipsinskaya structural-facial zone; 2 and II in Fig. 1), this section was selected not only for biostratigraphic study but also for further sampling and analysis of larger foraminifera. The composition and distribution of larger foraminifer assemblages are known to be significant for the stratigraphy in other areas with turbiditic sedimentation (e.g., the Alps, the Carpathians or Georgia).

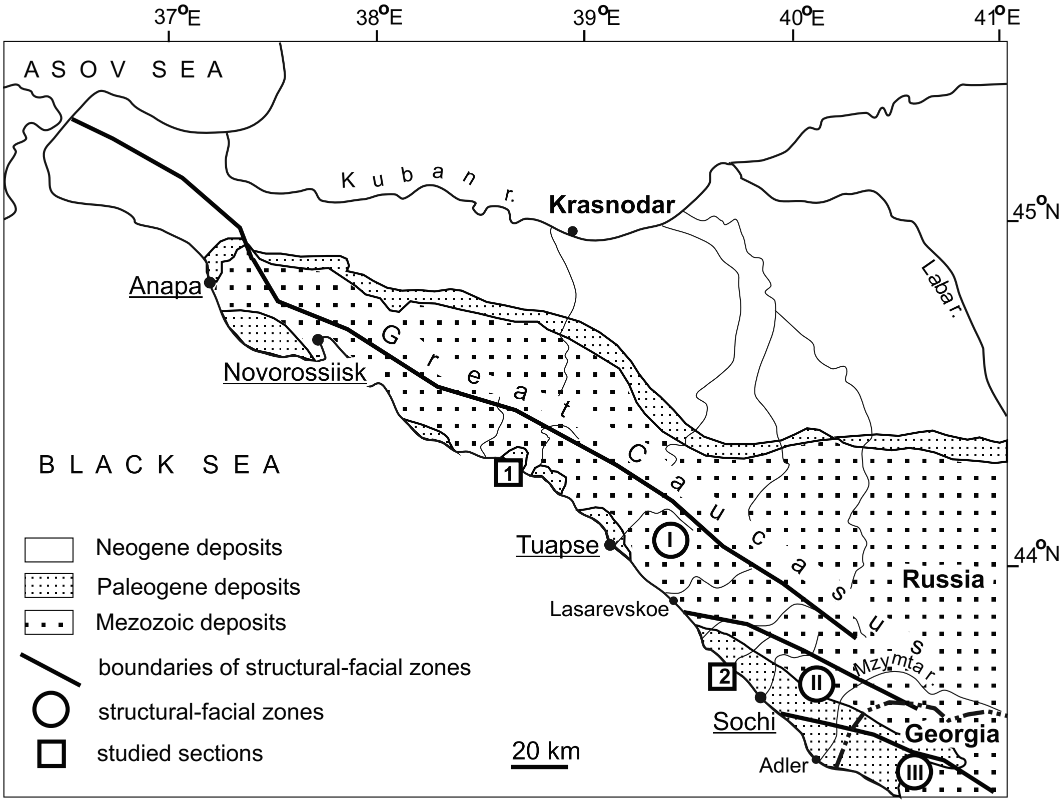

FIGURE 1 | **Location of studied sections. 1) Inal section; 2) Loo section. Structural-facial zones. I) Novorossiisko-Lazarevskaya; II) Chwezhipsinskaya; III) Abkhazskaya.**

METHODOLOGY AND SYSTEMATIC CRITERIA

Sampling and material

Different types of samples were collected from the Inal and Loo sections (Figs. 2 and 3). Forty samples of mudstones and marls were processed following standard methods of washing out through a sieve with 70 μm cells, and their residues were analysed for planktonic foraminifera. The classification by Subbotina et al. (1981), as modified by Bugrova (2005), was used to classify planktonic foraminifer species. Examples of planktonic foraminifer specimens are shown in Fig. 4. The regional Caucasian planktonic foraminifer zones (Koren', 2006), which are defined as intervals comprised between the first occurrences of zonal species, are used for biostratigraphic purposes. Their correlation with the Standard planktonic foraminifer and nannoplankton scales (Gradstein et al., 2004) is shown in Fig. 5. According to this regional zonation, the Ypresian Stage is subdivided into the lower Ypresian *Morozovella subbotinae* s.l. zone and the upper Ypresian *Morozovella aragonensis* s.l. zone. In combination with the planktonic foraminifer analyses, six samples collected from critical levels of both sections were examined by E.A. Shcherbinina for calcareous nannoplankton.

Statistically significant amounts of larger foraminifera were found in 13 limestone or marl samples. Their tests were recovered from limestones either by mechanical processes or by dissolving them in acetic acid with dehydrated cooper sulphate and later rewashing in roast soda solution. The textural analysis of hard rock samples was supplemented with 20 thin sections (Figs. 6 and 7). Loose specimens of larger foraminifera were washed out only from two marl samples. In all cases for specific and subspecific determinations, larger foraminifer specimens (approximately 130) were thin sectioned along their equatorial planes (Figs. 8 and 9).

Criteria for systematic classification of larger foraminifera

Different classification approaches were used for larger foraminifera determination: the classification by Schaub (1981) for large-sized *Nummulites* belonging to the *N. nitidus*, *N. pratti*, *N. distans* and *N. irregularis* groups; the classification by Jarzeva et al., (1968) and Blondeau (1972) for small-sized, Lutetian "northern *Nummulites*" belonging to the *N. variolarius* group; and the biometrical classification by Less (1987, 1998) for orthophragmines.

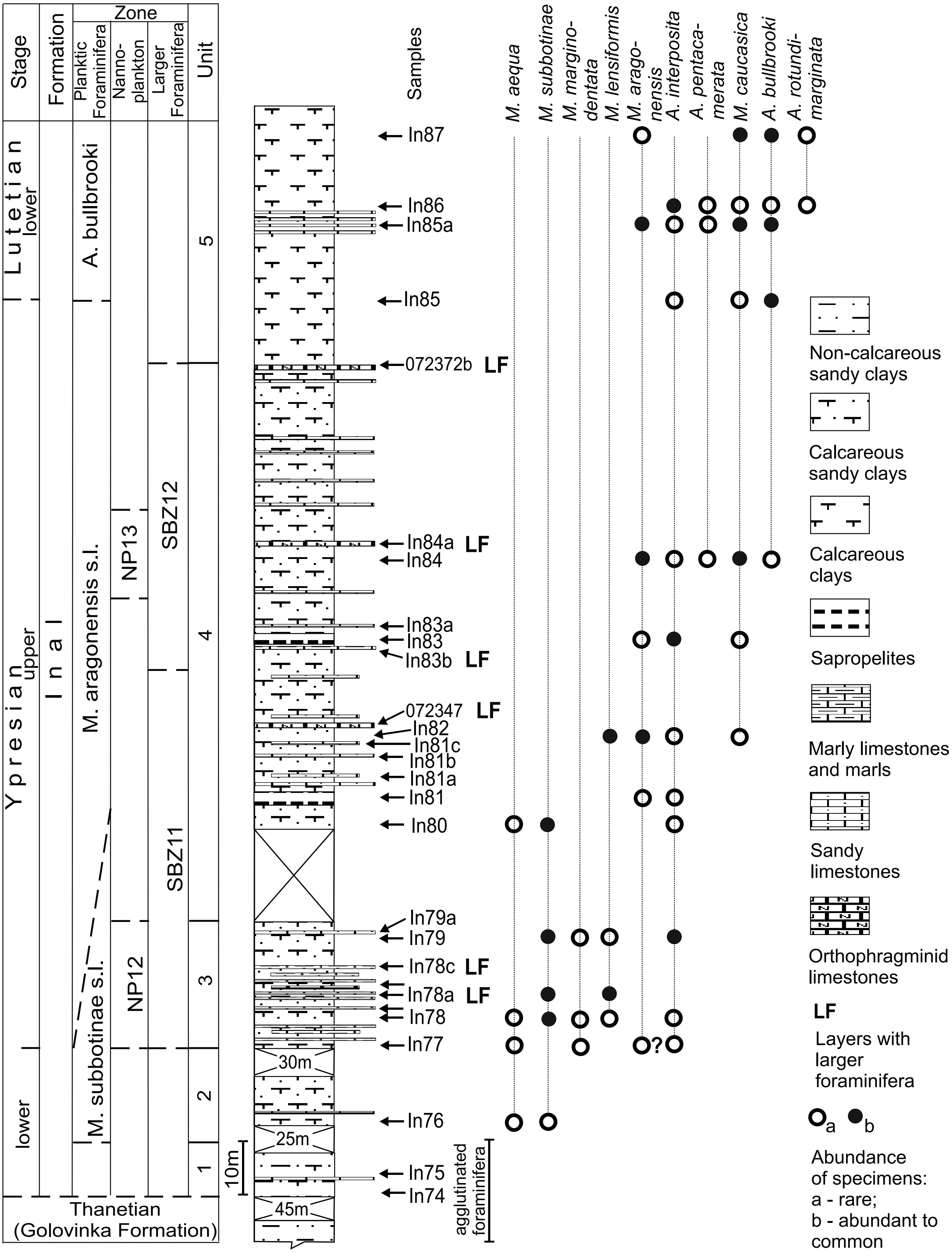

FIGURE 2 **Distribution of the most significant planktonic foraminifera in the Inal section.**

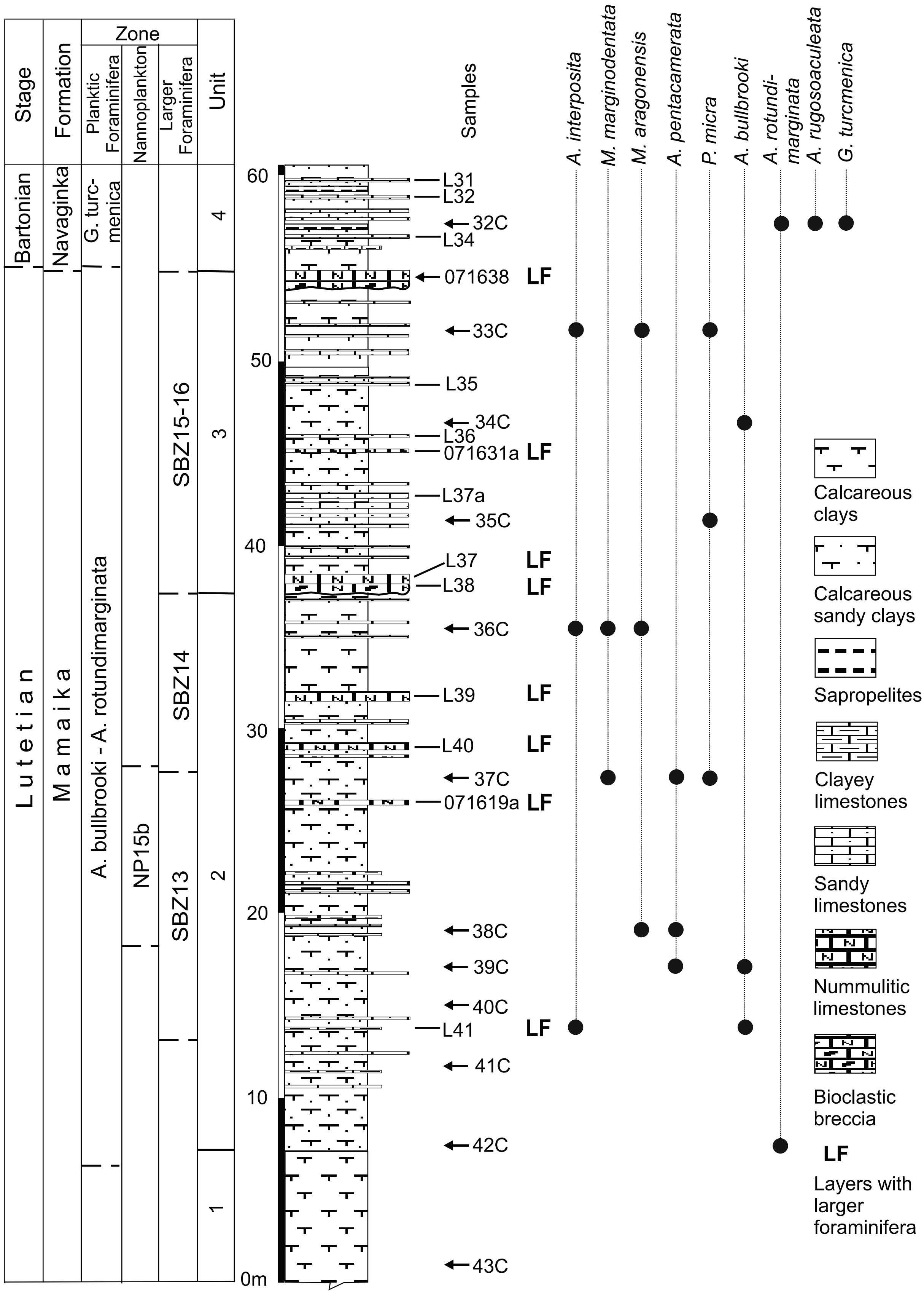

FIGURE 3 | **Distribution of the most significant planktonic foraminifera in the Loo section.**

According to Less (1998), the main parameter for the morphometric subdivision of orthophragmines into the so-called chronosubspecies is the outer cross-diameter of the deuteroconch in equatorial section (D1). The biometric data of this parameter in the orthophragmines studied from 13 samples are summarized in Table 1. We consider the biometric limits of subspecies (limits in variability of the deuteroconch size, as generalized in the classification by Less) as the basis for subspecies subdivision. On the other hand, determination of orthophragmines subspecies in a biometrical classification is more severely conditioned by preservation, representation and abundance of assemblages than in a typological classification. Given that mixed assemblages with taxa reworked from different stratigraphic levels, including correlative subspecies of an evolutionary lineage, are common in turbiditic deposits, we also used typological principles for the preliminary subdivision of orthophragmines subspecies from the mixed, poorly preserved allochthonous assemblages with heterochronic populations from calciturbidites of the Loo section, thus taking into consideration biometric data for each population. In samples with more or less monochronic assemblages the subspecific determination was given on the basis of the total number of specimens, as proposed by Less (1998). Orthophragmines were determined following an open nomenclature in the cases of very bad preservation or if too few (one or two) specimens per sample were available.

For the genus *Nummulites*, results of the statistical analyses of biometrical data of the inner cross diameter of the protoconch (P) are shown in Table 2. Due to the absence of microspheric specimens of large-sized Ypresian *Nummulites* and the limited number of whorls of their megalospheric morphotypes, most specimens were classified following an open nomenclature. However, the definition of their position within phylogenetic lineages on the basis of qualitative parameters (e.g., shape of septa

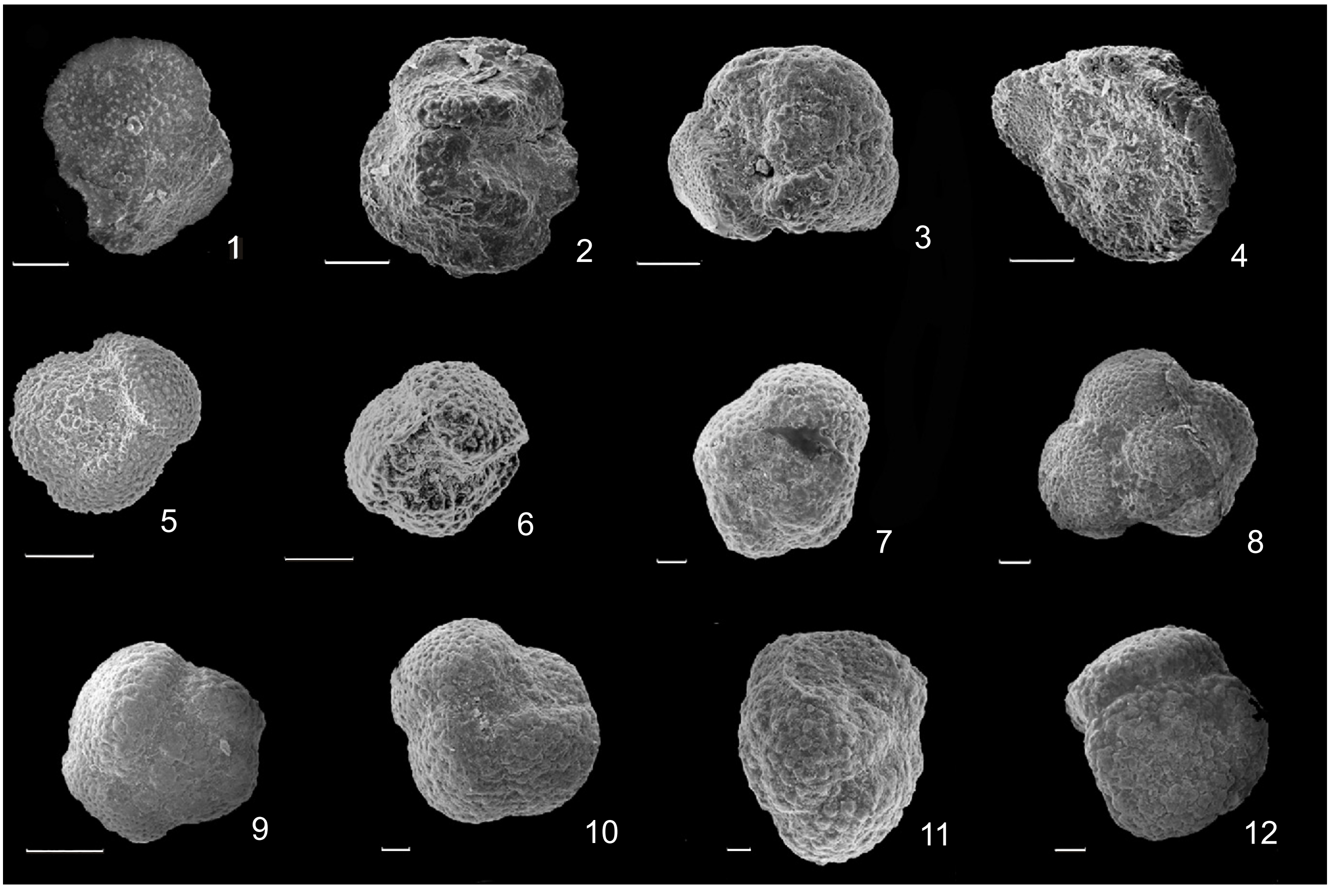

FIGURE 4 **Significant planktonic foraminifera from the Inal and Loo sections. 1,2: *Morozovella subbotinae* (Morozova 1939), 1) Spiral view, 2) Umbilical view (sample In76); 3) *M. lensiformis* (Subbotina 1953), umbilical view (sample In79); 4) *M. aragonensis* (Nuttall 1930), spiral view (sample In84); 5,6) *Acarinina bullbrooki* (Bolli 1957), 5) Spiral view, 6) Umbilical view (sample L41); 7) *Globigerina turcmenica* Chalilov 1948, umbilical view (sample 32C); 8) *Globigerina pseudoeocaena* Subbotina 1953, spiral view (sample L41); 9-11) *A. rugosoaculeata* Subbotina 1953, 9) Spiral view, 10) Umbilical view, 11) Edge view (sample 32C); 12) *A. rotundimarginata* Subbotina 1953, spiral view (sample 32C). Pictures 1-4) Inal section; 5-12) Loo section. Scale line in pictures 7,12: 30 µm. Scale line in the remaining pictures: 100 µm.**

and chambers, peculiarities of spire form) could be reliably achieved.

All the levels dated with larger foraminifera are correlated with the SBZ zones proposed for the western Tethys (Serra-Kiel et al., 1998).

LITHO AND BIOSTRATIGRAPHY OF THE STUDIED SECTIONS

Inal and Loo sections (Figs. 1 to 3) are characterized by widespread hemipelagic deposits, although other interbedded facies are frequent at certain levels (Figs. 6 and 7). Lithological aspects and results of biostratigraphic analysis are given for the whole Eocene Inal sequence and only for the upper part of the Eocene Loo succession, where larger foraminifera occur (Figs. 6 to 9). Distribution of marker (i.e., biostratigraphically significant) planktonic foraminifer species from each section is shown in Figs. 2 and 3, respectively, whereas that of all larger foraminifera from both sections is summarized in Fig. 10.

Inal section (Novorossiisko-Lazarevskaya structural-facial zone)

The Inal section (1 in Fig. 1) is located in Inal-bay, 5 km to the west of the Dzhubga settlement and 5 km to the south of the Bzhid village (Latitude 44º 19'N; Longitude 38º 37'E). At this locality the Eocene deposits constitute the inner part of a N-S trending syncline and are referred to as Inal Formation (Fm.), which is about 260 m thick. In this section, which was studied on the western limb of the mentioned syncline, the upper Paleocene boundary is tentatively defined by a carbonate content increase and the appearance of some significant planktonic foraminifer species.

The Inal Fm. is composed of greenish-grey calcareous mudstones with thin (5-20 cm) irregular intercalations of marls and bioclastic limestones (Fig. 2). The mudstones contain autigenic glauconite and fine sand-sized clastic material, such as abundant bioclasts, angular marl fragments, and scarce quartz and mica grains. Fossil remains include mainly planktonic foraminifera (up to 90%), small benthonic foraminifera, rare ostracods, and echinoid and mollusc fragments. Two sapropelite beds (samples In81 and In83 in Fig. 2) occur in the middle part of the section. This formation was split into five informal units:

Unit 1

This about 10 m thick unit is made up by slightly calcareous greenish mudstones with minor thin-bedded limestones. Only poorly-preserved agglutinated foraminifera occur in this unit, among which some species of the Northern Caucasia *Karreriella zolkaensis* regional biozone. This biozone covers the whole Thanetian and the base of Ypresian (Koren', 2006). A single specimen of *Nummulites* sp. was discovered in the upper part of the unit.

Unit 2

This unit is about 65 m thick and crops out overlying a concealed interval. It is composed of calcareous greenish mudstones with thin-bedded (1-3 cm) intercalations of foraminifer bearing limestones in its lower part. Despite being poorly preserved, planktonic foraminifer specimens could be classified as *Morozovella subbotinae* (Morozova 1939), *M. aequa* (Cushman and Renz 1942), *Globigerina velascoensis* Cushman 1925, *G. compressaeformis* Chalilov 1956, *G. nana* Chalilov 1956 and *Acarinina acarinata* Subbotina 1953. This assemblage belongs to the lower part of the *M subbotinae* s.l. zone.

Unit 3

This about 20 m thick is composed of alternating foraminifer bearing marls (Fig. 6, pictures 1-3), globigerinid packstones and wackestones (Fig. 6, pictures 4 and 5), and calcareous mudstones. Scattered glauconite and quartz grains are widespread in mudstones and marls. In addition to planktonic foraminifera, fragments of echinoids, fishes, mollusks, ostracods, radiolaria tests and benthonic foraminifera (textulariids, nodosariids, lagenids, anomalinids, nummulitids, and orthophragmines) were identified both in marls and mudstones. In the planktonic foraminifer assemblage some species of the upper part of the *M. subbotinae* s.l. zone were reported, such as *M. marginodentata* (Subbotina 1953), *M. lensiformis* (Subbotina 1953) and *M. aragonensis* (Nuttall 1930). Calcareous nannofossils yielded by samples In77, In78 and In79 are *Tribrachiatus orthostylus* (Shamrai 1963) and *Discoaster lodoensis* Bramlette and Riedel 1954, both characteristic of NP12-13 zones. Larger foraminifera are rather scarce in the marls, being represented by orbitoclypeids, rare discocyclinids and nummulitids with delicate tests (0.5-2 mm in size). In addition to Early Ypresian taxa, such as *Orbitoclypeus schopeni* (Checcia-Rispoli 1908) *crimensis* Less 1987 and *Asterocyclina taramellii* (Munier-Chalmas 1891), rare Late Ypresian *Discocyclina archiaci* (Schlumberger 1903) *bartholomei* (Schlumberger 1903) and *Nemkovella strophiolata* (Gümbel 1868) *fermonti* Less 1987 were identified, allowing attribution to SBZ11 zone (Figs. 8, 10A). In sample In78a, together with larger foraminifera, some warm-water small benthonic forms, characteristic of the Central Tethys, also occur, such as *Asterigerina* ex gr. *bartoniana* ten Dam 1944, *Epistominella impexa* Bugro-

VA 1989, *Coleites unicus* BUGROVA 1989, *Sphaerogypsina antiqua* BUGROVA 1989*, Cuvillierina* sp. and *Ornatanomalina* sp. Redeposited Maastrichtian and Danian foraminifera have been recorded in this interval.

Unit 4

This unit is 110 m thick, shows a gradual lower contact and its lower part consists of calcareous mudstones with intercalations of globigerinid limestones (up to 10 cm thick) and sapropelites (30-40 cm thick). These beds are overlain by reddish-brownish mudstones in the upper part (sample In84). Assemblages of planktonic foraminifera consist of common Upper Ypresian taxa, such as *Morozovella aragonensis* (NUTTALL 1930), *M. caucasica* (GLAESSNER 1937), *Acarinina pentacamerata* (SUBBOTINA 1947), as well as *Morozovella lensiformis* (SUBBOTINA 1953), *Acarinina interposita* SUBBOTINA

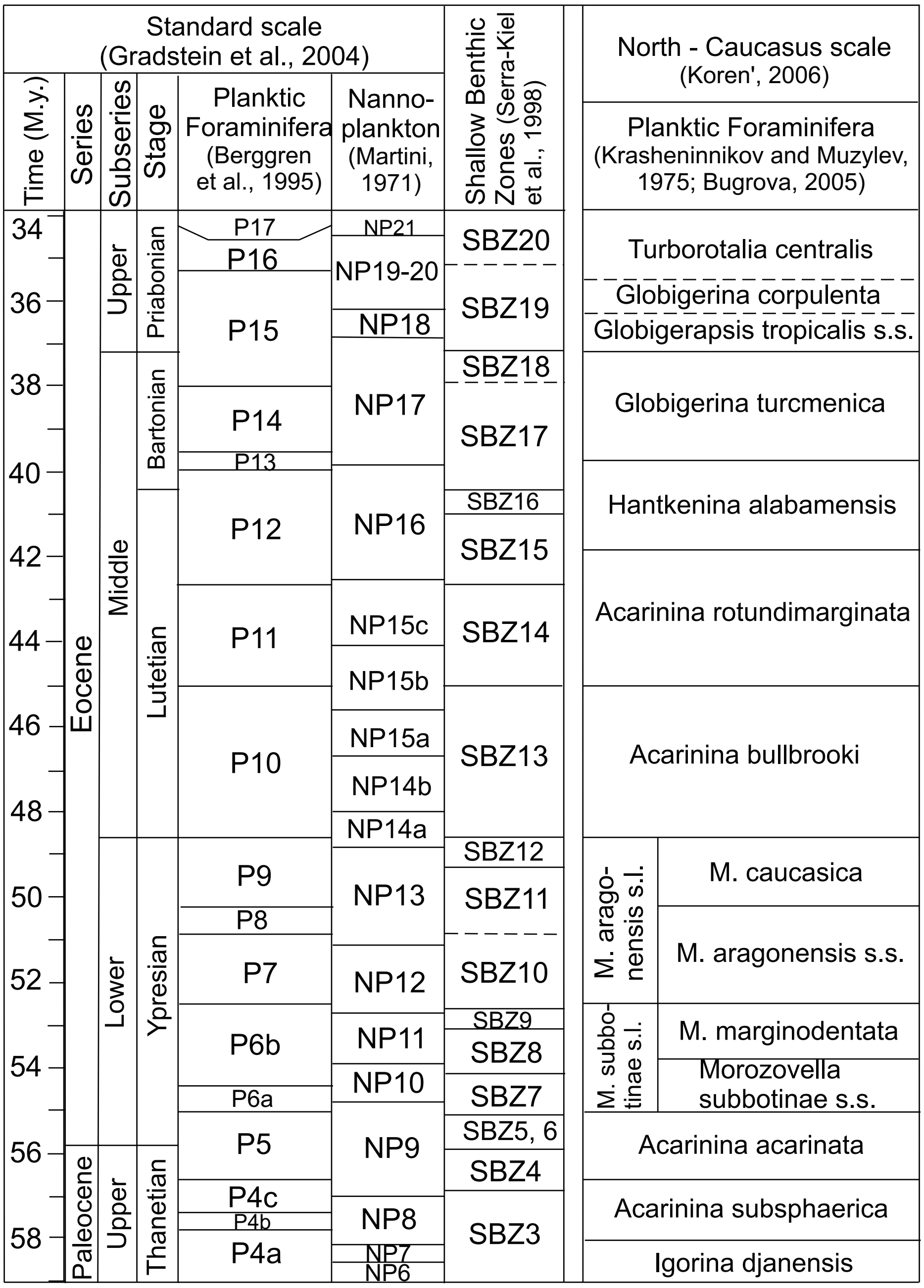

FIGURE 5 **Correlation of the North-Caucasian and Standard upper Paleocene-Eocene scales. Correlation between planktonic foraminiferal and calcareous nannoplankton zones is from Gradstein et al. (2004) and Berggren and Pearson (2005).**

1953, *A. pseudotopilensis* SUBBOTINA 1953, *Globigerina composita* KOPAEVITCH 1970, *G. pseudoeocaena pseudoeocaena* SUBBOTINA 1953, *G. inaequispira* SUBBOTINA 1953, *Pseudohastigerina micra* (Cole 1927), *P. wilcoxensis* (Cushman and Ponton 1932), *Subbotina linaperta* (FINLAY 1939), *Globigerinatheka* (?) *micra* (SCHUTZKAYA 1958) and *Planorotalites pseudoscitulus* (GLAESSNER 1937), which correspond to the *M. aragonensis* s.l. zone. Rare *Acarinina bullbrooki* (BOLLI 1957) specimens occur in the upper part of the unit. A calcareous nannoplankton assemblage of the *D. lodoensis* (NP13) zone was determined in sample In84. Unit 4 shows three intercalations of well-bedded limestones (packstones) that contain millimetre-thick lenses of globigerinid marls. Quartz grains laminae, glauconite and dark mudstone fragments are also widespread (Fig. 6, pictures 6 and 7). These limestones are mainly composed of orthophragmines ("orthophragminid limestone"), the most abundant rock-forming taxon being *Orbitoclypeus douvillei douvillei* (SCHLUMBERGER 1903). The occurrence of *Nummulites nitidus* DE LA HARPE 1883 in the lower intercalation allows its attribution to the Late Ypresian (probably SBZ11 zone). The occurrence of transitional morphotypes between *Orbitoclypeus schopeni* (CHECCIA-RISPOLI 1908) *crimensis* LESS 1987 and O. *schopeni schopeni* (CHECCIA-RISPOLI 1908) in the middle intercalation (sample In84a) enables correlation with the SBZ12 zone. According to Less (1998), *O. schopeni schopeni* with deuteroconch >500 μm in diameter appeared in the Middle Lutetian. However, in regions of the Northern Peritethys (e.g., N. Aralian, N. Caucasus) *O. schopeni* with deuteroconch 500-600 μm in size also occurs in the *Nummulites polygyratus* zone, which correlates with the SBZ12 zone (Zakrevskaya, 2005). The assemblage of the upper intercalation (sample 072372b) includes *Orbitoclypeus douvillei* (SCHLUMBERGER 1903) n. ssp. Gibret (Fig. 8, picture 20) characteristic of the Early Lutetian (Less, 1998).

Unit 5

This 60 m thick unit is composed of soft, greenish, pure calcareous mudstones with rare, thin (up to 10 cm) irregular intercalations of globigerinid packstones. Planktonic foraminifera are abundant (up to 90% of the fossil assemblage) and are represented by species of the *A. bullbrooki* zone: *Acarinina bullbrooki* (BOLLI 1957), *A. pentacamerata* (SUBBOTINA 1947), *A. interposita* SUBBOTINA 1953, *Morozovella caucasica* (GLAESSNER 1937), *M. aragonensis* (NUTTALL 1930), *Globigerina composita* KOPAEVITCH 1970, *G. pseudoeocaena pseudoeocaena* SUBBOTINA 1953, *Subbotina linaperta* (FINLAY 1939), *Globigerinatheka* (?) *micra* SCHUTZKAYA 1958 and *Pseudohastigerina wilcoxensis* (CUSHMAN and PONTON 1932) occur throughout the unit, while rare *Acarinina rotundimarginata* SUBBOTINA 1953 occur in its upper part. In addition to planktonic foraminifera, many radiolarian tests were observed. In spite of the presence of the Middle Lutetian zonal species *Acarinina rotundimarginata* in the uppermost part of the section, we consider that the Middle Lutetian age is not reliably established, since in the Crimean Bakhchisarai section the first specimens of *Acarinina rotundimarginata* appear in the *A. bullbrooki* zone (Zernetski et al., 2003).

Meaning of the biostratigraphic and depositional record

Taking everything into account, three planktonic foraminifer zones can be distinguished in the Inal section: *Morozovella subbotinae* s.l., *M. aragonensis* s.l. and *Acarinina bullbrooki*. Unfortunately, due to wide sample spacing and/or scarcity of key species, the zonal boundaries could not be precisely placed in some cases. Thus, the position of the boundary between the *M. subbotinae* s.l. and M. *aragonensis* s.l. zones is questionable. The upper part of the *M. subbotinae* s.l. zone or the base of the *M. aragonensis* s.l. zone might be placed at the base of Unit 3 on the basis of the occurrence of rare specimens of *M. aragonensis*. However, the occurrence of *Discocyclina archiaci* (SCHLUMBERGER 1903) *bartholomei* (SCHLUMBERGER 1903) in the same level suggests a Late Ypresian age (SBZ11 zone), which would imply full assignment to the *M. aragonensis* s.l. zone.

Larger foraminifer zones SBZ11 and SBZ12 are distinguished by distinct assemblages from two successive thicker intercalations of foraminifera bearing beds. The occurrence of one Early Lutetian subspecies (*Orbitoclypeus douvillei* (SCHLUMBERGER 1903) n. ssp. Gibret) in the upper part of the section does not justify attribution to the SBZ13 zone, as demonstrated by the age of these deposits established by means of planktonic foraminifera. However, it should be highlighted that the ages established by planktonic foraminifera, larger foraminifera and calcareous nannoplankton match pretty well with the standard correlation scheme (Fig. 5).

It can be concluded that the globigerinid marls that include small larger foraminifera are hemipelagic deposits that show special features produced by current reworking of some of their components (bioclasts and marl clasts), and that they most likely accumulated at the toe of a submarine slope. Given this setting, the larger foraminifera that are represented by relatively deep-water morphotypes could have been reworked downslope from the outer shelf. The organodetrital "orthophragminid limestones" have a shallower origin and might indicate a latest Ypresian basin shallowing.

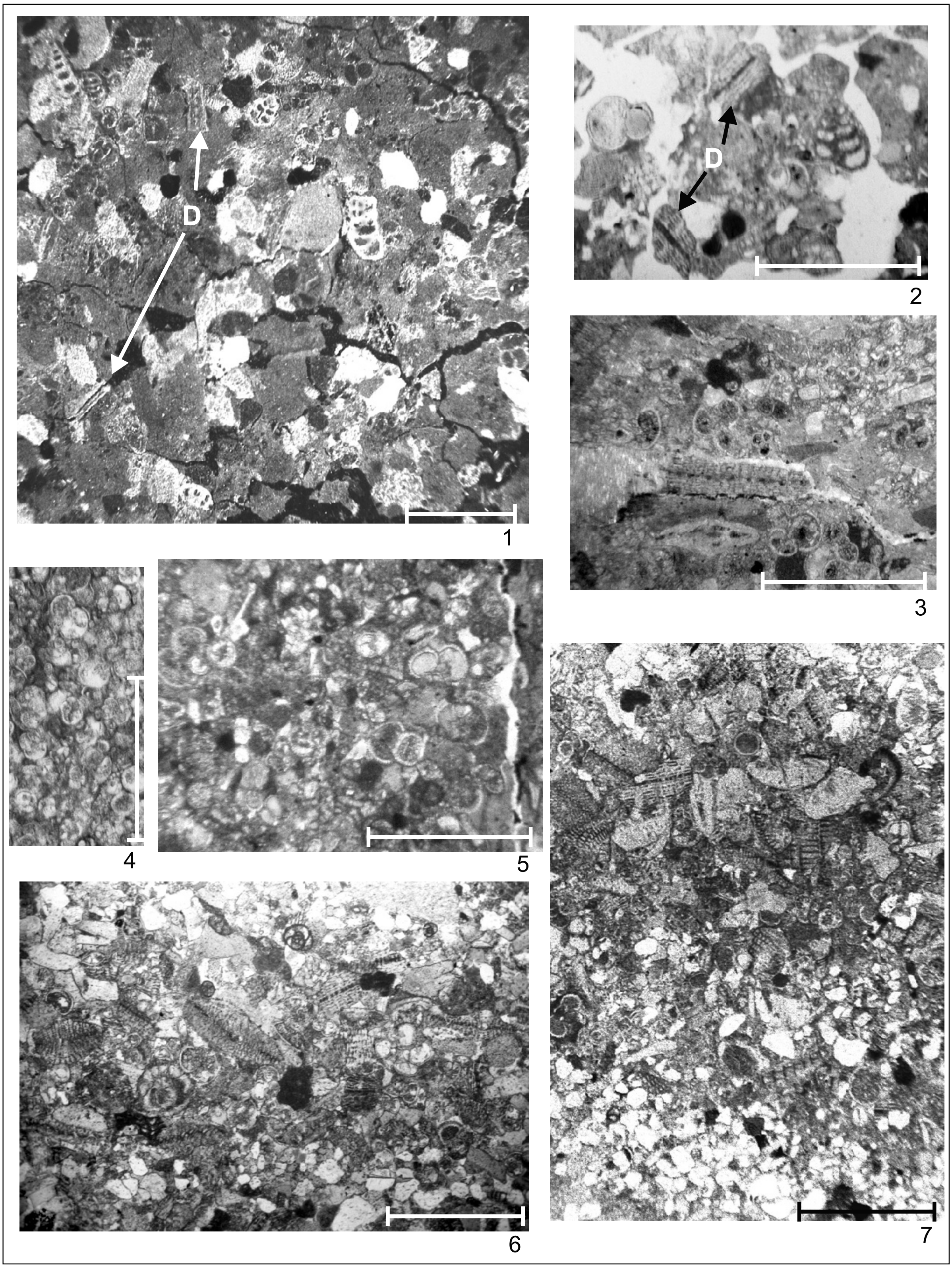

FIGURE 6 **Larger foraminifera bearing facies from the Inal section. 1) Quartz grain bearing marl with small (mainly benthonic) foraminifera and scarce small discocyclinids, D) (sample In78a); 2) Mudstone with discocyclinids, D) globigerinids, textulariids (sample In78a); 3) Fragment of marl with globigerinids, *Discocyclina* (in the centre) and *Nummulites* (sample In78a); 4,5) Intercalation of globigerinid packstone (respectively samples In77 and In78a); 6,7) Poorly sorted orthophragminid packstone with sand laminae, clay chips, small benthonic and planktonic foraminifera (sample In84a). Scale line in all the pictures: 1 mm.**

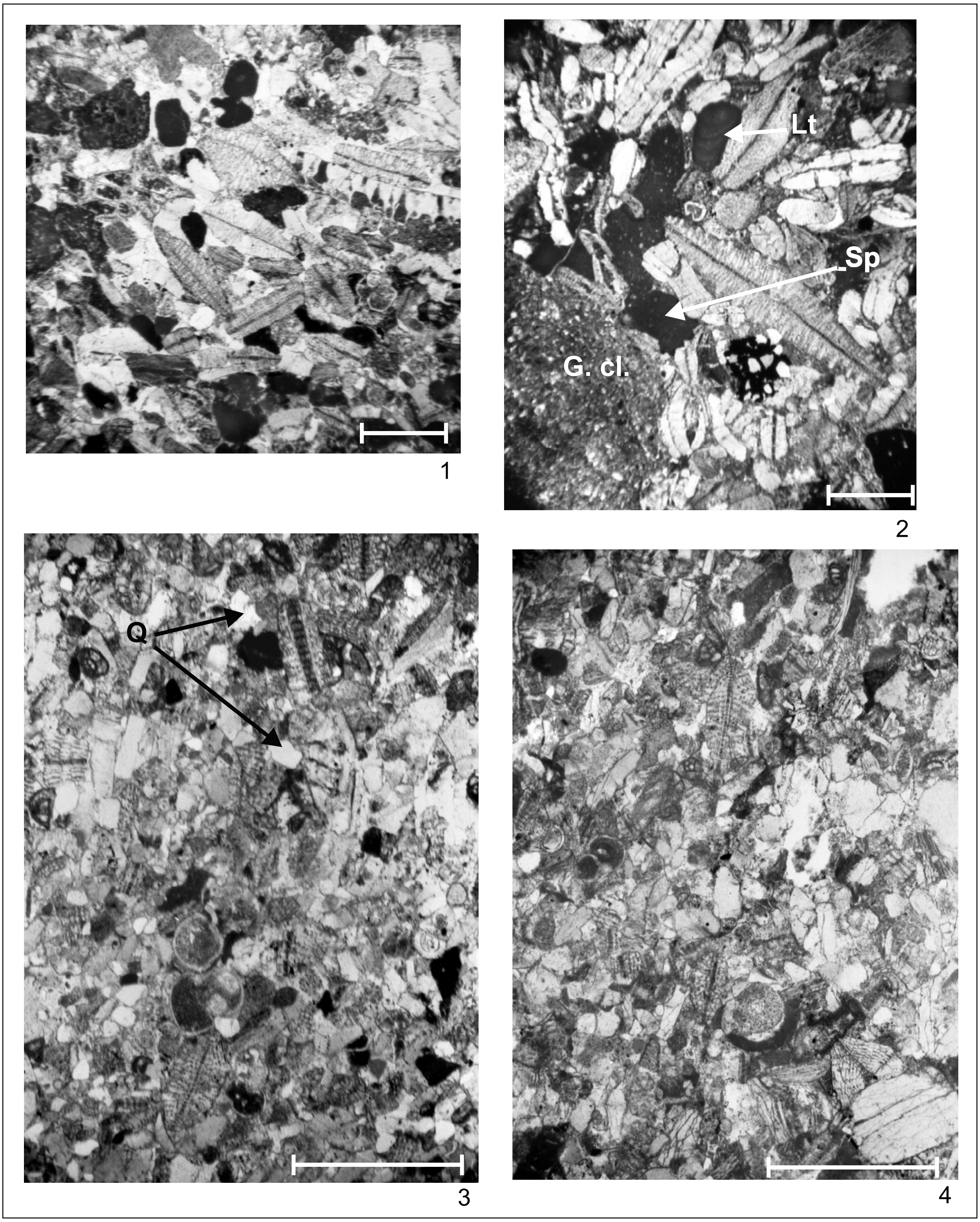

FIGURE 7 | **Larger foraminifera bearing facies from the Loo section. 1: bioclastic nummulitic limestone (grainstone) with clay chips (dark) (sample L37); 2: carbonate breccia with large clasts of globigerinid clay (G. cl.), sapropelite (Sp), fragments of Lithothamnium (Lt) (sample L38); 3 and 4: orthophragminid packstones with quartz grains (Q) (respectively samples L39 and L40). Scale line in all the pictures: 1 mm.**

Loo section (Chwezhipsinskaya structural-facial zone)

The Loo section is located in the River Loo valley, close to the Loo settlement (Latitude 43º 42'N; Longitude 39º 35'E; 2 in Fig. 1). Paleocene-Eocene successions crop out in both limbs of an E-W trending syncline, but they are better exposed on the southern limb, where the section was measured and sampled. According to previous data (Grossgeim, 1960), the whole succession includes the Lower-Middle Eocene Mamaika and the Upper Eocene Navaginka Formations.

The poorly exposed lower 300-400 m of the Mamaika Fm. consist of calcareous mudstones with calcareous siltstone intercalations. The overlying part of this formation consists of 50 m thick mixed carbonate-terrigenous turbidite deposits and about 100 m thick carbonate mudstones and marls with minor intercalations of microdetritic limestones. Microfossils from this interval were not analysed.

The section extends and is much better exposed along the Loo-Nizhnearmyanskaya Khobza road, where calciturbiditic alternations occur (Fig. 3). This part of the section belongs to the upper part of Mamaika (units 1-3) and Navaginka (unit 4) Fms and is characterized by larger foraminifer occurrences and described in detail below.

Unit 1

This 30 m thick unit is composed of calcareous greenish mudstones with low silt content and minor, thin intercalations of globigerinid limestones. Pyrite aggregates are widespread in the lower part (sample 44C). Only two planktonic foraminifer specimens of two species - *Globigerina pseudoeocaena* SUBBOTINA 1953 and *Acarinina* cf. *pentacamerata* (SUBBOTINA 1947)-, which unfortunately are not age determinative, were recorded. The contact with the overlying unit consists in a sharp change from greenish to reddish-brownish colour.

Unit 2

This unit is 30 m thick and composed of flysch-like facies including calcareous mudstones that bear sand-sized quartz grains, pyrite and glauconite, and interbedded limestones and marls. Both sand content and the number of limestone layers increase upwards. Reworked and redeposited planktonic foraminifera and nannofossils of Cretaceous-Eocene age occur in most of the samples, except in the lowermost ones. The basal part of the reddish-brownish mudstones yielded planktonic foraminiferal assemblages composed of *Acarinina rotundimarginata* SUBBOTINA 1953, *Globigerina pseudoeocaena* SUBBOTINA 1953 and *Subbotina frontosa* (SUBBOTINA 1953).

Thin-bedded greenish marls with quartz grains, glauconite, pyrite and fragments of white globigerinid packstones and wackestones overly the lower part of Unit 2. Abundant planktonic foraminifera are represented by *Acarinina bullbrooki* (BOLLI 1957), *A. interposita* SUBBOTINA 1953, *A.* cf. *rotundimarginata* SUBBOTINA 1953, *Pseudohastigerina wilcoxensis* (CUSHMAN and PONTON 1932) and *Globigerina pseudoeocaena* SUBBOTINA 1953. Orthophragmines are rare, small and poorly preserved, but *Orbitoclypeus schopeni schopeni* (CHECCIA-RISPOLI 1908) and *Nemkovella* cf. *bodrakensis* LESS 1987 specimens, which indicate an Early Lutetian age (zone SBZ13), were identified in sample L41.

This section continues with an irregular alternation of calcareous sandy mudstones and globigerinid limestones and marls. In the middle part of Unit 2 (samples 37C, 38C) calcareous nannofossil assemblages composed of *Chiasmolithus gigas* (BRAMLETTE and SULLIVAN 1961), *Ch. solitus* (BRAMLETTE and SULLIVAN 1961) and *Reticulofenestra umbilica* (LEVIN 1965) were found, which indicate the Middle Lutetian zone NP15b. Planktonic foraminifer assemblages from the same samples include *Morozovella margin-odentata* (SUBBOTINA 1953), *Globigerina velascoensis* (CHUSHMAN 1925), *Acarinina* cf. *pentacamerata* (SUBBOTINA 1947) and *Pseudohastigerina micra* (COLE 1927). Three limestone beds, up to 40 cm thick each, mostly composed of larger foraminifera, occur in the upper part of the unit (samples 071619a, L39 and L40). They consist of "orthophragminid packstones" with high sand content (Fig. 7, pictures 3 and 4) and thin intercalations (2-3 mm) of globigerinid marls. Despite displaying normal grading, these packstones show a good sorting of the constituent larger foraminifera, all having diameters of 1.5-2 mm. Late Ypresian *Nummulites* aff. *pratti* D'ARCHIAC and HAIME 1853 and *N. irregularis* DESHAYES 1838, as well as Lutetian *Nummulites variolarius* (LAMARCK 1804), *Discocyclina dispansa* (SOWERBY 1840) cf. *sella* (D'ARCHIAC 1850) and *Nemkovella strophiolata* (GÜMBEL 1868) were identified (Fig. 9, pictures 23, 27). Other bioclasts consist of echinoid, ostracod and mollusc fragments, and small foraminifer tests.

Unit 3

This 18 m thick unit begins with a 15-30 cm thick brownish bioclastic carbonate breccia. It consists of angular to rounded fragments of calcareous siltstone and calcareous mudstone lithoclasts (3-30 mm in size), embedded in a sandy-muddy matrix that includes *Nummulites* and other larger foraminifer tests, non-carbonate dark brown sapropelites, pyrite aggregates, rare quartz grains and autigenic glauconite, fragments of nummulitic limestones, single tests of small benthonic and planktonic foraminifera, and fragments of bryozoans, echinoids, mollusks and red algae. Larger foraminifera (large *Nummulites*) dominate in this reworked assemblage. Their tests are rounded, coated with mudstones and iron oxides, deformed and/or pressed one into another (Fig. 7, picture 2). The available data indicate that this breccia can be attributed to a slump deposit (Nemčok and Vanova, 1977). The larger foraminiferal assemblage consists of several heterochronic populations. Late Ypresian-Early Lutetian species include larger *Nummulites* attributable to the *N. distans*, *N. pratti*, *N. nitidus* and *N. irregularis* groups, as well as *Orbitoclypeus schopeni* (CHECCIA-RISPOLI 1908) *crimensis* LESS 1987, *Nemkovella strophiolata* (GÜMBEL 1868) *fermonti* Less 1987 and *Asterocyclina stella* (GÜMBEL 1861) *praestella* LESS 2005. Late Ypresian-Middle Lutetian species are represented by *Nummulites* cf. *alponensis* SCHAUB 1981 and *Orbitoclypeus schopeni schopeni* (CHECCIA-RISPOLI 1908). Small *Nummulites*, such as *N. variolarius* (LAMARCK 1804) and *N. orbignyi* (GALEOTTI 1837), as well as *Orbitoclypeus douvillei* (SCHLUMBERGER 1903) *chudeaui* (SCHLUMBERGER 1903), prevail among Middle-Late Lutetian forms (Fig. 9). This breccia grades upwards into a multicolour bioclastic nummulitic limestone that bears small fragments of mudstones and rare quartz grains (sample L37; Fig. 7, picture 1). The larger foraminifer assemblage of these limestones differs from that of the underlying breccia in the lower number of large *Nummulites* and in the occurrence of Middle Lutetian-Bartonian *Discocyclina pratti* cf. *pratti* (MICHELIN 1846) and *Discocyclina dispansa* (SOWERBY 1840) cf. *sella* (D'ARCHIAC 1850) (Fig. 9, pictures 24, 25). This nummulitic limestone is sharply overlain by a yellowish, coarse-grained bioclastic limestone layer, 40 cm thick, with small *Nummulites* (*N. variolarius* (LAMARCK 1804) and *N. anomalus* DE LA HARPE 1877).

The reworked breccia deposits are overlain by flysch-like deposits composed of calcareous sandy mudstones, with organic matter in some places, fine-grained sandy limestones and marls. Limestones are mostly foraminifer bearing wackestones to mudstones. Poorly diversified and poorly preserved planktonic foraminifera are mostly represented by small forms that include *Acarinina bullbrooki* (BOLLI 1957), *A. interposita* SUBBOTINA 1953, *Pseudohastigerina micra* (COLE 1927) and *Morozovella aragonensis* (NUTTALL 1930).

At the Unit 3 top another breccia bed that is overlain by nummulitic limestones, with a thickness of 60 cm, occurs (sample 071638). The depositional texture of this bed is similar to that described above for the bottom breccia. The larger foraminifer assemblage is poorly diversified, with rare orbitoclypeids and widespread small *Nummulites* of the *N. variolarius* group (Fig. 10B).

Unit 4

This thin (5.5 m thick) unit is made up by yellowish and pale-brown mudstones with sapropelite lenses, alternating with globigerinid sandy limestones. The transition from the underlying unit is gradual and marked by a colour change and increase in the amount of sand in the limestone facies. The identified planktonic foraminifera (*Acarinina rotundimarginata* SUBBOTINA 1953 and *Globigerina* (*Subbotina?*) *turcmenica* CHALILOV 1948) correspond to the Middle Lutetian and Bartonian in Crimea and Northern Caucasus.

Meaning of the biostratigraphic and depositional record

The chronostratigraphic position of Unit 1 is ambiguous due to the almost complete absence of planktonic foraminifera, which might have been caused by dissolution of carbonate tests in deep organic matter rich environments. The scarce recorded globigerinids may indicate either Late Ypresian or Lutetian age.

A normal stratigraphic succession cannot be established in the mixed planktonic foraminifer assemblages from Units 2 and 3, which resulted from turbidite sedimentation. However, and despite the poor diversity that characterizes these assemblages, those corresponding to the *Acarinina bullbrooki* and *A. rotundimarginata* zones were identified, which supports attribution of this interval to the lower-middle Lutetian. The Middle Lutetian age of Unit 2 is further supported by the calcareous nannoplankton determinations of NP15b zone. In spite of substantial re-deposition and mixing of larger foraminifer specimens, three levels that correlate with SBZ13, SBZ14 and SBZ15-16 zones occur in this part of the section (Figs. 3 and 10B).

Unit 4 is attributed to the Bartonian on the basis of the occurrence of the planktonic foraminifer zonal species *Globigerina turcmenica* CHALILOV 1948. This zone was defined in the Kuma Fm. (Northern Caucasus) and correlated with Navaginka Fm. on the basis of lithostratigraphic criteria, such as the occurrence of sapropelites in both formations (Keller and Menner, 1945; Grossgeim, 1960). However, given that sapropelites are comparatively scarce in the Navaginka Fm. of the Loo section, it was especially important to establish its biostratigraphic position. The identification of the zonal marker species of the Kuma Fm. in the Navaginka Fm. confirms their previously proposed lithostratigraphic correlation.

PALEOENVIRONMENTAL INTERPRETATION OF LARGER FORAMINIFER ASSEMBLAGES

All the larger foraminiferal assemblages recorded in the two mainly hemipelagic successions studied here can be interpreted as taphocenosis that resulted from rework-

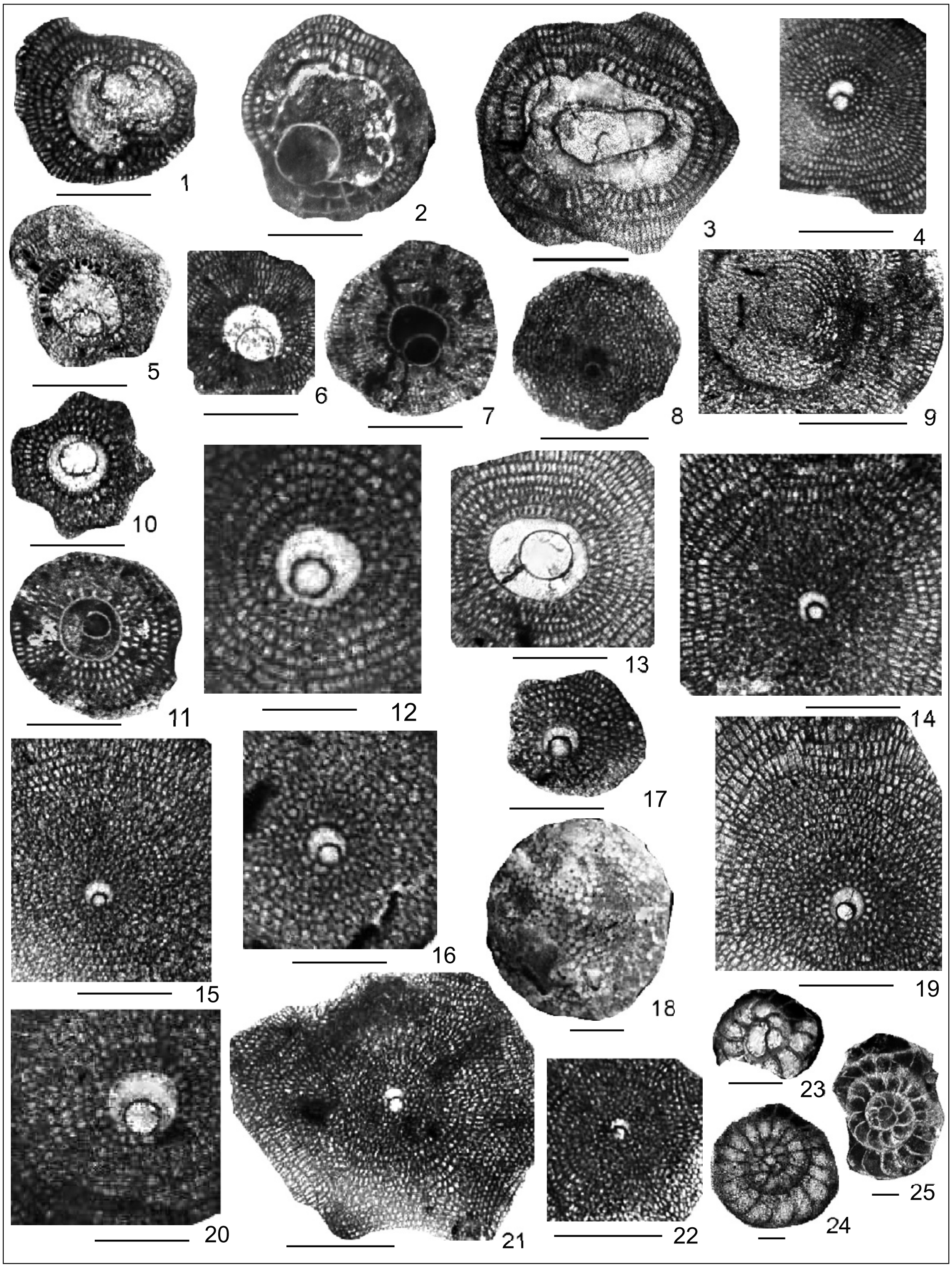

FIGURE 8 **Larger foraminifera from the Inal section. 1,2) *Discocyclina archiaci* (SCHLUMBERGER 1903) cf. *bartholomei* (SCHLUMBERGER 1903) (sample In78a); 3) *D. fortisi* (D'ARCHIAC 1850) *simferopolensis* LESS 1987 (sample In84a); 4) *D. augustae* WEIJDEN 1940 *sourbetensis* LESS 1987 (sample In78a); 5-7) *D. aquitanica* LESS 1987 (sample In78a); 8) *Nemkovella strophiolata* (GÜMBEL 1868) cf. *fermonti* LESS 1987 (sample In78a); 9) *Nemkovella* indet. sp. (sample In78a); 10,11) *Orbitoclypeus schopeni* (CHECCHIA-RISPOLI 1908) *crimensis* LESS 1987 (sample In78a); 12,13) *O. schopeni* ex. interc. *crimensis-schopeni*, (12- sample 072372b, 13- sample In84a); 14-19) *O. douvillei douvillei* (SCHLUMBERGER 1903) (14-16 sample 072347, 17- sample In78a; 18,19- sample In84a); 20) *O. douvillei* (SCHLUMBERGER 1903) n. ssp. GIBRET (sample 072372b); 21,22) *Asterocyclina taramellii* (MUNIER-CHALMAS 1891) (sample In78a); 23) *Nummulites* ex gr. *nitidus* DE LA HARPE 1883 (sample In78a); 24,25) *N. nitidus* DE LA HARPE 1883 (24- sample 072347, 25- sample In84a). Picture 9) B-generation; the rest of pictures A-generation. 18) Surface view; the rest of pictures- equatorial sections. Scale line in all the pictures 500 µm.**

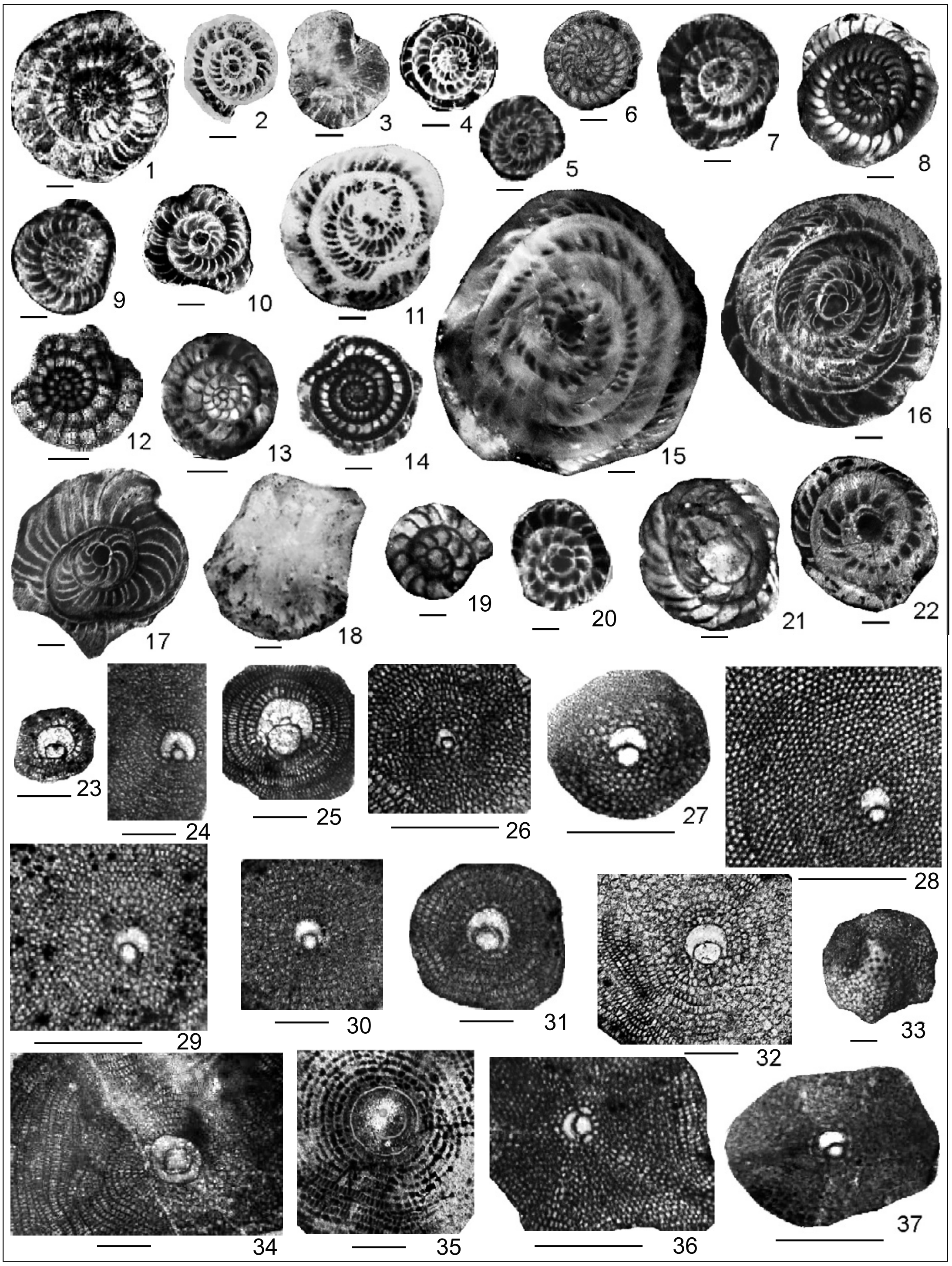

FIGURE 9 | **Larger foraminifera from the Loo section. 1-7) *Nummulites orbignyi* (Galeotti 1837) (1–3 sample 071638a, 4–7 sample L38); 8-11) *N.* aff. *prestwichianus* Jones 1862 (8-10 sample L38, 11- sample 071638a); 12-14 *N. variolarius* (Lamarck 1804) (12- sample 071638a, 13- sample L37, 14- sample L38); 15) *N.* cf. *alponensis* Schaub 1981 (sample L38); 16) *N.* cf. *archiaci* Schaub 1962 (sample L38); 17) *N. irregularis* Deshayes 1838 (sample L38); 18) *N.* aff. *formosus* de la Harpe 1883 (sample L38); 19,20) *N.* cf. *nitidus* de la Harpe 1883 (19- sample L38, 20- sample 071638a); 21- *N.* aff. *polygyratus* Deshayes 1838 (sample L38); 22) *N.* aff. *pratti* d'Archiac and Haime 1853 (sample L38); 23,24) *Discocyclina dispansa* (Sowerby 1840) cf. *sella* (d'Archiac 1850) (23- sample L39; 24- sample L37); 25) *D. pratti* cf. *pratti* (Michelin 1846) (sample L37); 26) *Nemkovella* cf. *bodrakensis* Less 1987 (sample L41); 27) *N. strophiolata* (Gümbel 1868) indet. ssp. (sample 071619a); 28,29) *N. strophiolata strophiolata* (Gümbel 1868) (sample L38); 30) *Orbitoclypeus douvillei* (Schlumberger 1903) n. ssp. Gibret (sample L38); 31-33) *O. douvillei* (Schlumberger 1903) *chudeaui* (Schlumberger 1903) (sample L38); 34) *O. varians* (Kaufmann 1867) cf. *scalaris* (Schlumberger 1903) (sample L37); 35) *O. schopeni schopeni* (Checchia-Rispoli 1908) (sample L38); 36) *Asterocyclina stellata* (d'Archiac 1846) *adourensis* Less 1987(sample L38); 37) *A. stella* (Gümbel 1861) *ex. interc. praestella-stella* (sample 071619a). 1,14) B-generation; the remaining pictures correspond to the A-generation. 3, 18, 33) surface views; the remaining pictures are equatorial sections. Scale line in all the pictures 500 µm.**

TABLE 1 **Statistical data of orthophragmines populations. N) Number of specimens; D1) Outer cross-diameter of deuteroconch; s.d.) Standard deviation; s.e.) Standard error.**

Species	Sample	N	D1 (_m)					Subspecies
			Min	Max	Mean	s. d.	s. e.	
Orbitoclypeus douvillei	In78a 072347 In84a L37	2 7 6 3	190 130 150 230	200 200 230 250	195,0 159,3 185,8 243,0	 22,4 32,3 11,5	 8,5 13,2 6,7	*douvillei douvillei*
	071638a	1			250,0			*douvillei* indet. ssp.
	072372b	7	275	350	314,3	24,4	9,2	*douvillei* n. ssp. Gibret
	L38 L37	8 4	300 300	450 450	373,7 375,0	47,5 64,6	16,8 32,3	*douvillei chudeaui* and *douvillei* n. ssp. Gibret
O. schopeni	In78a 072347	4 2	270 300	350 430	307,5 365,0	33,0	16,5	*schopeni crimensis* *schopeni* cf. *crimensis*
	In84a 072372b 071619a	5 4 2	400 375 380	500 490 500	460,0 448,0 440,0	46,9 52,0	21,0 26,0	*schopeni* ex. interc. *crimensis-schopeni*
	L40 L39	1 1			375,0 260,0			*schopeni* indet. ssp.
	L38	3	400	430	410,0	17,3	10,0	*schopeni crimensis*
	L41	3	500	550	533,3	28,9	16,7	*schopeni schopeni*
	L38 L37	5 3	500 500	620 600	548,0 533,0	57,6 57,7	25,8 33,3	*schopeni schopeni*
	071631a	1			700,0			*schopeni* indet. ssp.
	071638a	3	515	550	528,0	18,9	10,9	*schopeni schopeni*
	071638b	1			500,0			*schopeni* indet. ssp.
O. varians	L39 L38	2 2	220 200	250 220	235,0 210,0			*varians* cf. *angoumensis*
	071638a	1			175,0			*varians* indet. ssp.
	071638b	2	200	250	225,0			*varians* cf. *angoumensis*
	L37	2	340	400	370,0			*varians* cf. *scalaris*
Asterocyclina taramellii	In78a	7	75	100	90,0	8,7	3,3	
A. stella	072347	3	80	100	90,0	10,0	5,8	*stella praestella*
	In84a	2	80	95	87,5			*stella* cf. *praestella*
	071619a L38	3 3	90 100	155 125	111,2 115,0	29,6 13,2	14,8 7,6	*stella* ex. interc. *praestella-stella*
	L38	3	150	180	166,6	15,3	8,8	*stella stella*
	L37 071631a	2 1	75	100	87,5 90,0			*stella* cf. *praestella*
A. stellata	L38	3	158	175	167,6	8,7	5,0	*stellata adourensis*
Discocyclina augustae	In78a	4	110	150	125,0	19,2	9,6	*augustae sourbetensis*
D. aquitanica	In78a	4	300	375	331,2	33,8	16,9	
D. pratti	L37	2	550	600	575,0			*pratti* cf *pratti*
D. archiaci	In78a	2	600	750	675,0			*archici* cf. *bartholomei*
D. fortisi	In84a	2	900	920	910,0			*fortisi simferopolensis*
D. dispansa	L39 L37	1 2	 320	 360	350,0 340,0			*dispansa* indet. ssp *dispansa* cf. *sella*
Nemkovella cf. *bodrakensis*	L41	2	90	90	90,0			
N. indet. sp.	071619a 071631a	1 1			95,0 100,0			
N. strophiolata	In78a	2	95	100	97,5			*strophiolata* cf. *fermonti*
	In84a	3	100	125	115,0	13,2	7,6	*strophiolata fermonti*
	071619a	1			195			*strophiolata* indet ssp.
	L38	3	150	175	160,0	13,2	7,6	*strophiolata strophiolata*

TABLE 2 **Statistical data of *Nummulites* populations. N) Number of specimens; P) Inner cross diameter of protoconch; s.d.) Standard deviation; s.e.) Standard error.**

Nummulites group	Sample	N	P (_m)					Species
			min	max	mean	s.d.	s.e.	
N. nitidus	In78a	1			330			*N.* ex gr. *nitidus*
	072347	5	260	350	290	41,8	18,7	*N. nitidus*
	In84a	4	250	350	300	40,8	20,4	
	071619a	2	250	275	262,5			*N.* cf. *nitidus*
	L38	3	300	350	316,3	28,9	16,7	
	L37	3	250	300	270,0	26,5	15,3	
	071631a	4	225	350	281,2	55,4	27,7	
	071638a	2	350	400	375			
	L38	4	400	560	465	78,9	39,5	*N.* aff. *formosus*
	L37	3	400	500	433,3	57,7	33,3	
	071631a	1			450,0			
	071638a	2	350	450	400,0			
N. pratti	071619a	2	500	600	650,0			*N.* aff. *pratti*
	L39	1			600,0			
	L38	4	500	600	562,5	47,8	23,9	
	071638a	2	650	700	675,0			
	071638b	2	700	750	725,0			
N. distans	L38	5	700	1000	860,0	114,0	50,9	*N.* aff. *polygyratus*
	L38	4	450	500	475,0	28,8	14,4	*N.* cf.. *alponensis*
	071638a	2	500	600	550,0			
N. variolarius	L39	2	100	150	125,0			*N. variolarius*
	L38	6	100	150	118,3	18,3	7,5	
	L37	2	100	120	110,0			
	071638a	8	90	120	110,0	11,9	4,2	
	071638b	2	100	110	105			
	L38	5	160	220	196,0	21,9	9,8	*N. orbignyi*
	071638a	2	150	160	155,0			
	071638b	3	150	200	166,6	28,7	16,7	
	L38	4	200	230	213,7	16,0	8,0	*N.* aff. *prestwichianus*
	071638a	2	200	230	215,0			

ing and deposition of bioclasts from shallow to deep marine environments. In some cases this reworking has involved foraminifer remains of diverse ages, this fact resulting in heterochronic assemblages. However, according to the observed diversity, morphotypes and composition four types of foraminifer assemblages, which record diverse palaeoenvironmental conditions, are recognizable in the studied sections.

Type 1 assemblage

This type of assemblage is typified by larger foraminifera assemblages from the upper Ypresian mudstones and marls of the Inal sections (Fig. 6, pictures 1-3) and from the lower Lutetian marls of the Loo section. It is characterized by the following features: (1) a low number of specimens in the studied samples (about 50 in Inal and about 10 in Loo), which might reflect low density of the original populations; (2) thin wall and small size of tests (average size is about 1.2 mm); and (3) dominance of orthophragmines, which suggests relatively deep water original conditions.

In spite of the above-mentioned characteristics, the diversity of orthophragmines observed in the samples is quite high, since all European orthophragmines genera are represented by seven different species, including different morphotypes with either small or large embryos, with either flat or inflate tests, as well as microspheric forms. In fact, the orthophragmine assemblage from the Inal section is more diversified than that in the autochthonous deep-water platform deposits of the northern Ustujrt and lower Volga (Zakrevskaya, 2005).

In addition, three species of nummulitids were found in the Inal section. The scarcity of *Nummulites*, their low diversity and their small tests differentiate this assemblage from upper Ypresian shallow water autochthonous assemblages of the North-Eastern Peritethys. The closest assemblage in terms of morphotypes and systematic composition occurs in the Northern Caucasus (Gubs river section), which can also be interpreted as an allochtonous assemblage.

It should be emphasized that the scarcity and low diversity of the early Lutetian orthophragmines from the

A

Shallow Benthic Zones (Serra-Kiel et al., 1998)	Samples	*Nummulites anomalus* de la Harpe 1877	*N.* ex gr. *nitidus* de la Harpe 1883	*N. nitidus* de la Harpe 1883	*Operculina karreri* Penecke 1885	*Orbitoclypeus douvillei douvillei* (Schlumberger 1903)	*O. douvillei* (Schlumberger 1903) n. ssp. Gibret	*O. schopeni* (Checcia-Rispoli 1908) *crimensis* Less 1987	*O. schopeni* ex. interc. *crimensis-schopeni*	*Asterocyclina taramellii* (Munier-Chalmas 1891)	*A. stella* (Gumbel 1861) *praestella* Less 1987	*Discocyclina aquitanica* Less 1987	*D. augustae* Weijden 1940 *sourbetensis* Less 1987	*D. archiaci* cf. *bartholomei* (Schlumberger 1903)	*D. fortisi* (d'Archiac 1850) *simferopolensis* Less 1987	*Nemkovella strophiolata* (Gumbel 1868) cf. *fermonti* Less 1987	*N. strophiolata* (Gumbel 1868) *fermonti* Less 1987
SBZ12	072372b	□		□			■		□								
	In84a	■		■	□	■			□		□				□		□
SBZ11	072347	□		■	□	■		□			□					□	
	In78a	□	□		□	□		■		■		□	□	□		□	

Abundance of specimens:
□ Rare
■ Abundant to common
x Presence

B

Shallow Benthic Zones (Serra-Kiel et al., 1998)	Samples	*Nummulites* cf. *nitidus* de la Harpe 1883	*N.* aff. *formosus* de la Harpe 1883	*N.* cf. *archiaci* Schaub 1962	*N.* aff. *pratti* d'Archiac et Haime 1853	*N.* cf. *distans* Deshayes 1838	*N.* aff. *polygyratus* Deshayes 1838	*N.* cf. *alponensis* Schaub 1981	*N.* ex gr. *leupoldi* Schaub 1951	*N. irregularis* Deshayes 1838	*N. variolarius* (Lamarck 1804)	*N. orbignyi* (Galeotti 1837)	*N.* aff. *prestwichianus* Jones 1862	*N. anomalus* de la Harpe 1877	*Operculina* cf. *karreri* Penecke 1885	*Orbitoclypeus douvillei douvillei* (Schlumberger 1903)	*O. douvillei chudeaui* (Schlumberger 1903)	*O. schopeni* (Checcia-Rispoli 1908) *crimensis* Less 1987	*O. schopeni schopeni* (Checcia-Rispoli 1908)	*O. varians* (Kaufmann 1867) cf. *angoumensis* Less 1987	*O. varians* (Kaufmann 1867) cf. *scalaris* (Schlumberger 1903)	*Asterocyclina stella* (Gumbel 1861) *praestella* Less 2005	*A. stella* ex. interc. *praestella-stella*	*A. stella stella* (Gumbel 1861)	*A. stellata* (d'Archiac 1846) *adourensis* Less 1987	*Discocyclina dispansa* (Sowerby 1840) cf. *sella* (d'Archiac 1850)	*D. pratti* cf. *pratti* (Michelin 1846)	*Nemkovella* cf. *bodrakensis* Less 1987	*N. strophiolata strophiolata* (Gumbel 1868)	*N. strophiolata* (Gumbel 1868) indet. ssp.
SBZ15-16	071638b		□		■						■	■		□					□	□										
	071638a	□	□		■		■	□			■	□	■	□		□			□											
	071631a	■	□				□							■					□			□								
	L37	□	□							□	■			□		□	■		□		□	□				□	□			
	L38	■	□	□	■	□	■	□		■	■	■	■	■			■	□	■	□			□	□	□				□	
SBZ14	L39				x				x		x			x	x			x		x						x				
	L40										x			x	x			x												
SBZ13	071619a	x			x				x	x				x				x					x					x		x
	L41																		□									□		

FIGURE 10 **Distribution of larger foraminiferal taxa: A – in the Inal section; B – in the Loo section. The age of two samples from the Inal section (In78c and In83b, depicted in Fig. 2) is not shown, as their specimens could not be reliably classified.**

Loo section could result not only from its deep-water environment, but also from the originally low larger foraminifer diversity demonstrated for that time in the Northern Peritethys (Zakrevskaya, 2004).

Type 2 assemblage

This assemblage is best represented by the upper Ypresian "orthophragminid limestones" of the Inal section (Fig. 6, pictures 6 and 7). Their packstone texture and the absence of siliciclastic mudstones, except for mudstone clasts, suggest relatively high-energy conditions. When compared with Type 1 assemblages, the larger foraminifer tests are larger (average size is about 2.5 mm), better preserved and show a more homogeneous shape. The systematic diversity is low (from 5 to 8 species and subspecies), most specimens (about 60%) pertaining to only two *Orbitoclypeus* species (*O. douvillei* and *O. schopeni*). Tests are mostly represented by macrospheric inflate morphotypes. The predominance of inflate orbitoclypeids evidences shallow marine palaeoenvironment. The closest orthophragminid assemblages with predominance of orbitoclypeids are those from Ypresian nummulitic limestones of Northern Caucasus (Gubs river) and Eastern Crimea (Nasypnoe village), but in these localities the diversity of larger foraminifera and other fossils, is much higher. In the nearby area of Abkhazia orthophragmines are absent from coeval deposits (Kacharava, 1981).

Type 3 assemblage

Middle Lutetian "orthophragminid limestones" of the Loo section typify the Type 3 assemblage (Fig. 7, pictures 3 and 4). The characteristics of this assemblage are similar to those of the Type 2: a well-sorted assemblage composed of small-sized, mostly inflate specimens and absence of microspheric forms. However, diversity is higher in Type 3 due to the occurrence of redeposited Ypresian forms, while test preservation is much worse. These contrasting characteristics were caused by turbiditic sedimentation.

Type 4 assemblage

Type 4 assemblage, represented by the larger foraminifera from carbonate breccias of the Loo section, is characterized by varied test sizes, morhotypes and systematic composition. Many large-sized specimens of *Nummulites* only have one or two whorls (Fig. 9, pictures 19-22). This is not interpreted as a result of an unusual growth, as long as some complete large tests also occur (Fig. 9, pictures 15 and 16), but as a result of test destruction. In fact, most tests are deformed, abraded and/or rounded. All these features are thought to be the consequence of mechanical deformation within slump bodies. On the contrary, all small-sized specimens are completely preserved. Interestingly, the assemblages are heterochronic, ranging from the Late Ypresian to the Middle Lutetian, a fact that reinforces their allochthonous nature. The systematic composition shows that the breccia assemblages, as well as those from the overlying nummulitic limestones of Late Ypresian to the Early Lutetian, include forms attributable to the *Nummulites distans*, *N. pratti*, *N. nitidus* and *N. irregularis* groups, which are typical of most Peritethyan regions (e.g., Crimea, Mangyshlak, Northern Aral, Northern Caucasus). Granulated *Nummulites* forms, characteristic of the Central Tethys are conspicuously absent. However lower Eocene orthophragmines are mostly represented by orbitoclypeids, which differentiate this assemblage from those of the Crimean and Transcaspian areas. Middle Lutetian specimens are better preserved. They are represented by both megalospheric and microspheric generations of small *Nummulites* included in the *N. variolarius* group, which is typical of the Northern Peritethys. Special emphasis deserve the orbitoclypeids, which are represented by an subspecies widely distributed in the Central Tethys (*Orbitoclypeus douvillei chudeaui*) but only known in Northern Caucasian localities in the Peritethys. Type 4 assemblages in both Ypresian and Lutetian times were probably formed in inner shelf conditions, as proved by the occurrence of red algae.

CONCLUSIONS

This study on the planktonic and larger foraminifera assemblages from hemipelagic and flysch-like Eocene successions of the southern part of the Western Caucasus provides the first published biostratigraphic data on these sequences, enables their correlation with other biostratigraphic scales, and makes more precise their age determination.

The composition of the planktonic foraminiferal assemblages reported in the southern Western Caucasus is similar to that typical in the Crimea-Northern Caucasian region. Nevertheless, it is slightly less diverse than in other nearby areas due to poor preservation. Therefore, on the basis of the observed similar taxonomic composition and bioevent succession, the Northern Caucasian planktonic foraminifer zonal scale can be applied also to the southern Western Caucasus. According to this scale, the Inal Fm of the Novorossiisko-Lazarevskaya zone corresponds to the Early Ypresian-Early Lutetian interval and contains assemblages of the *Morozovella subbotinae* s.l., *M. aragonensis* s.l. and *Acarinina bullbrooki* zones. Thus, the Early Ypresian age has first been established in this section. In the Loo section Early-Middle Lutetian and

Early Bartonian ages were established for the Mamaika and Navaginka Fms. Unfortunately, due to mixing of faunas by turbiditic deposition, the normal stratigraphic succession of bioevents and the precise zonal boundaries could not be accurately defined by means of planktonic foraminifera.

Larger foraminifer assemblages in the Inal section correlate with SBZ11 and SBZ12 zones of the Tethyan scheme. The orthophragmines and nummulitid species identified in the mixed assemblages of the Loo section belong to the Early, Middle and Middle-Late Lutetian SBZ13, SBZ 14 and SBZ15-16 zones.

Transport of larger foraminifer tests by turbidity currents led to their sorting and a lower systematic diversity in the recorded assemblages. However, the reworking of tests within slump deposits did not affect the composition of larger foraminifer assemblages. Despite widespread turbiditic reworking, four original ecological types of larger foraminifer assemblages were reconstructed. They cover different palaeoecological niches from inner (the most common in the turbiditic deposits) to outer shelf. The larger foraminifer assemblages resulting from reworking and transport into deep-water basin zones were most likely derived from the Central Caucasus mountain range.

All the assemblages of larger foraminifera reported in the study area resemble those of the Northern Caucasus zones. This resemblance points to the fact that in Eocene times the southern part of the Western Caucasus belonged to the Northern Peritethys biogeographic province.

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