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MIOCENE MOLLUSKS AND CALCAREOUS NANNOPLANKTON ASSEMBLAGES FROM THE BOROD FORMATION (BOROD BASIN, ROMANIA)

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Abstract. The Miocene Borod Formation (Popa, 1998) consists of grey and blackish, sometimes green-violet siltic marls with interbeded silts and also sands with coals. Borehole 575, located on the Cetea Valley, crossed the deposits of the Borod Formation on a thickness of 250 m. The mollusk fauna was assigned to three assemblages: 1) *Pirenella - Theodoxus - Tympanotonos* (brackish assemblage), 2) *Turritella - Anadara* (normal marine assemblage) and 3) *Alvania-Ringicula - Pyramidella* (supporting a wider range of salinity). The mollusk assemblages are considered of Eggenburgian - Badenian age.The nannoplankton is very scarce at the level of the first and the third mollusk assemblages. Only the second mollusk group is associated with a representative calcareous nannoplankton assemblage with *Helicosphaera ampliaperta* (NN4 Zone), *Calcidiscus leptoporus* (NN4b) and also *Calcidiscus annula* (NN5a). The investigated samples from borehole 575 are not very rich in nannoplankton and lack *Sphenolithus heteromorphus* (NN5 Zone). The calcareous nannoplankton assemblages are considered of Ottnangian – probably also Badenian age.

Keywords: Miocene, Mollusks, Nannoplankton, Borod Formation, Borod Basin, Romania

GEOLOGICAL AND STRATIGRAPHICAL SETTING

The Borod Basin evolved during the Neogene under peculiar circumstances, proved by the character of the sediments and by the faunal associations. The age of the deposits, especially of those in the basal part of the Neogene succession has been largely debated during the last five decades.

The Neogene succession in the eastern part of the Borod Basin consists of marls, clays and subordinately sandstone, microconglomerate, silts, sands, gravel, tuffs and coal. The specific lithological features that resulted from the basin evolution allow the separation of distinctive lithostratigraphic units, following the international rules for nomenclature.

The distinctive lithologic character of the deposits in the basal part of the Neogene succession was underlined by Nicorici et al., 1977, who separated several horizons in five boreholes drilled west of Borod (Topa de Criş, Borozel, Cetea): "gray sandy marls with *Cerrites* and *Ammonia*" - an equivalent of the *Borod Formation* (Popa, 1998). "Valea Cetea Beds", defined from borehole samples on Cetea valley by Moisescu (1990) can also be regarded as an equivalent unit.

The prominent pelitic character - as a principal and subordinated criterion, and the presence of a rich malacological association are the specific features of these deposits which enable their identification without difficulties.

The Borod Formation consists mainly of gray to blackish, sometimes greenish-violet siltic, fine micaceous marls and clays, interlayered with silts, sands and coal. Only accidentally, thin layers of sandstone and microconglomerate can be found.

The stratotype of the formation is to be found on the Lupului brook, a left tributary of the Băiţa valley, about 150 m from the confluence, where 7-8 m long deposits outcrop on the right bank.

The deposits of the Borod Formation transgressively overlie the metamorphic rocks of the Plopiş Mountains and are, in their turn, transgressively covered by younger Neogene formations; the limits were intercepted only in boreholes. They outcrop as a lath 250-300 m wide between Cetea and Răchiţii valleys, in the neighborhood of the mesometamorphic rocks of the Plopiş Mountains. Towards south, they are covered by younger Neogene formations. The southern limit is represented by Cornitel fault, which is oriented parallelly with the Borod valley. Eastwards, these deposits were noticed in boreholes up to the junction of Borod with Cornitel valleys.

Some authors suggested that these deposits could extend up to the sources of the Măgura valley (Şuraru & Şuraru, 1973), based on the fauna mentioned by Lázár (1910) on the Hăiturii brook; due to the lack of outcrops and mining works, there are no arguments for this statement. In our opinion, it is possible that the deposits of the Borod Formation could extend up to the Hăiturii brook, but not further: the core samples evidenced younger deposits further from this limit. Westwards, the deposits of this formation were observed up to Gheghie locality. Their thickness varies between 100 - 240 m.

Borehole 575 is situated in the Cetea Valley and crossed the deposits of the Borod Formation in the 290 - 75 m interval (Fig. 1).

The samples collected from this interval consist of mollusks-rich, very well preserved assemblages; on the contrary, nannoplankton assemblages are scarce.

MOLLUSK ASSEMBLAGES

The mollusk fauna has been assigned to three assemblages. In the sediments from the base of the borehole there is a large interval (290 – 219 m), in which only gastropods opercula are present (Fig. 1-3, Pl. I).

In the 190 – 182 m interval *Pirenella – Theodoxus – Tympanotonos* assemblage (Fig. 4-11, Pl. I; Fig. 1-2, Pl. II) was found, consisting of bivalves (*Polymesoda*, oysters fragments) and gastropods: *Pirenella plicata* div. ssp., *Theodoxus, Tympanotonos, Terebralia, Melanopsis*. The specimens are well preserved and they show different ontogenetic stages. The gastropods prevail, especially *Pirenella* genus.

The assemblage with *Pirenella - Theodoxus - Tympanotonos* is typical for brackish waters – thus a salinity between 16,5 - 20 ‰ - and indicates a shallow water environment, rich in oxygen.

In the 174 – 172 m interval the fauna is dominated by *Turritella* genus with specimens in various stages of development. Other gastropods are also to be found: *Teinostoma, Dorsanum, Hinia, Clavatula, Odostomia, Eulimella, Ringicula*. Among bivalves *Anadara, Corbula,*

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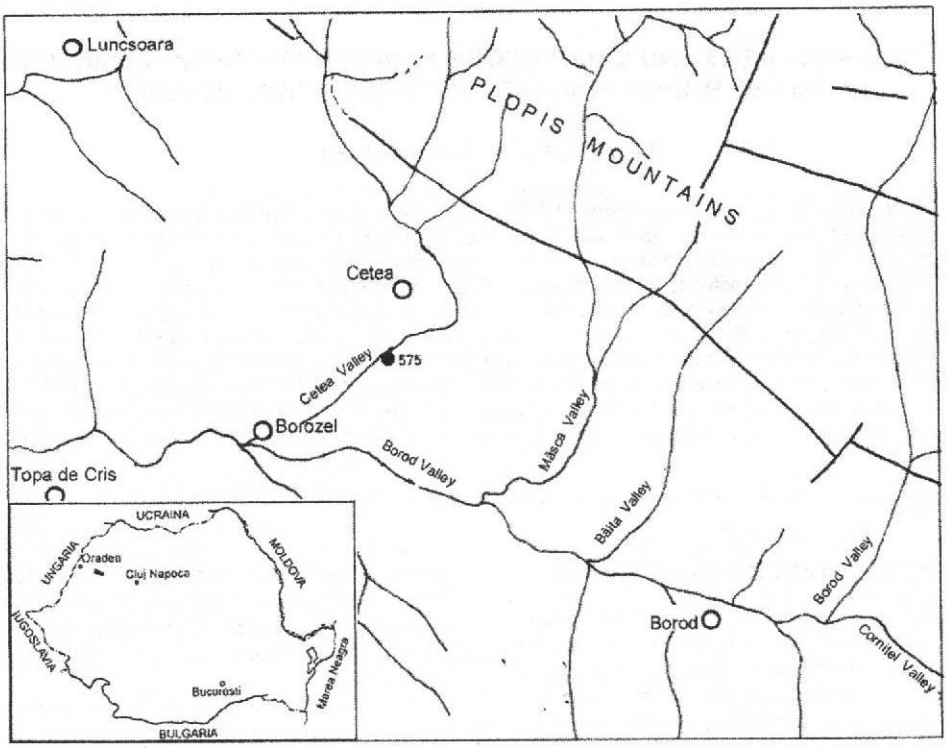

Fig. 1. Location of Borehole 575 in Borod Basin

Loripes are present. The *Pyramidellidae* family is numerically well represented. This assemblage indicates a sublittoral, shallow (20 - 30 m) environment, with a normal marine salinity (< 30 ‰), in which streams were very active. The fauna in this interval belongs to *Turritella – Anadara* assemblage (Fig. 3-10, Pl. II).

The third interval (148 – 94 m) includes a small-sized mollusks fauna in which *Pyramidellidae* family prevails: *Turbonilla, Chrysallida, Odostomia, Eulimella, Pyramidella* with well preserved specimens. This assemblage also contains forms of: *Alvania, Calyptraea, Ringicula, Cerithiopsis, Teinostoma, Euspira.*

Bivalves are represented by few taxa:*Obsoletiforma, Spisula, Gouldia, Corbula.* In this interval, besides the taxa presented previously, pellomorphosed specimens *Pirenella, Theodoxus, Tympanotonos, Melanopsis* were found.

The assemblage indicates a normal marine saline environment (< 30 ‰, or even less, 20-25 ‰), mainly due to the presence of genera *Pyramidella, Ringicula, Alvania, Cerithiopsis, Turbonilla* and of the echinid spicules. This assemblage was separated as *Alvania – Ringicula – Pyramidella* assemblage (Fig. 11-12, Pl. II; Fig. 1-11, Pl. III; Fig. 1-6, Pl. IV).

The following observations are worth mention ing when analyzing the stratigraphical distribution of the taxa in Central Paratethys (*Table 1*):

- some of the species are widely spread in Lower and Middle Miocene (Badenian) deposits: *Anadara diluvii, Spisula subtruncata triangula, Corbula gibba, Theodoxus pictus pictus, Euspira catena helicina, Calyptraea chinensis, Pyramidella plicosa.*
- some of the taxa were noticed only in the Lower Miocene deposits; more than that, some of them characterize only the Eggenburgian: *Pirenella plicata* div. ssp., *Tympanotonos margaritaceus grateloupi, Melanopsis impressa monregalensis.* Within the Borod Formation these taxa - excepting the last species - occur in the same association in borehole 575.
- a great number of species occur in Central Paratethys areas only within Badenian deposits: *Obsoletiforma kokkupica, Alvania venus danubiensis, A. montagui ampulla, Turritella cf. partschi, Cerithiopsis tuberculatis astensis, Odostomia dispar, O. perrara, O. subintermedia, Eulimella nitidissima, Chrysallida interstincta, C. sacyi, Turbonilla scala, Ringicula costata.* These species predominantly occur in the same association at the upper part of the deposits included in the Borod Formation, as noticed in borehole 575; other species are included in the assemblage with Turritella-Anadara;
- the assemblage with *Pirenella - Theodoxus - Tympanotonos* is very similar with the fauna of the Eggenburgian faciostratotypes from Austria (Mold and "Judenfriedhof") and Slovakia (Sverepec and Vel'ká Causa), but also with the fauna of the Hida Formation (Ottnangian); this fact was noticed also by Şuraru & Şuraru (1973).

NANNOPLANKTON ASSEMBLAGES

The nannoplankton assemblages from borehole 575 are generally scarce.

A representative calcareous nannoplankton assemblage with *Helicosphaera ampliaperta* Bramlette & Wilcoxon 1967, the index species for NN4 Zone (Martini, 1971), was identified in the interval of the mollusk assemblage with *Turritella – Anadara,* which is the normal marine assemblage (Fig. 2). *Helicosphaera ampliaperta* was found in the 173.7 – 170 m interval and at m 137.7, respectively in the *Turritella – Anadara* and *Alvania -Ringicula - Pyramidella* assemblages.

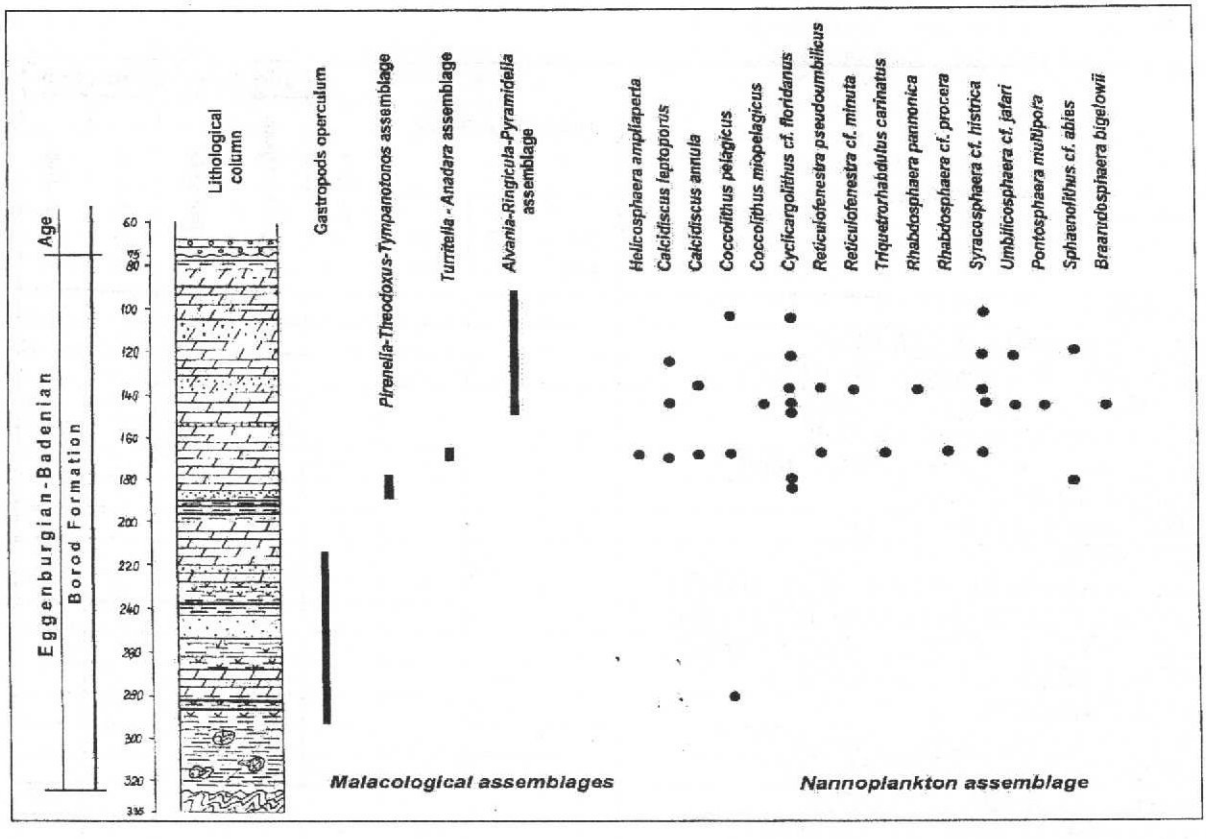

Figure 2 - Distribution of the mollusk assemblages and calcareous nannoplankton in Borod Formation (Borehole 575)

In the first interval, the assemblages consist of *Helicosphaera ampliaperta* Bramlette & Wilcoxon 1967 (Fig. 7a,b, Pl. IV), *Calcidiscus leptoporus* (Murray & Blackman 1898) Loeblich & Tappan 1978 (Fig. 9a,b, Pl. IV), *Coccolithus pelagicus* (Wallich 1877) Schiller 1930, *Triquetrorhabdulus* sp. and *Thoracosphaera* sp.

At 137.7m the assemblage consists of *Helicosphaera ampliaperta* Bramlette & Wilcoxon 1967, *Cyclicargolithus floridanus* (Roth & Hay 1967) Bukry 1971, *Reticulofenestra pseudoumbilicus* (Gartner 1967) Gartner 1969, *R. minuta* Roth 1970, *Syracosphaera histrica* Kamptner 1941 (Fig. 8, Pl. IV).

By definition, the last occurrence of *Helicosphaera ampliaperta* marks the top Zone NN4 (Martini, 1971). *Helicosphaera ampliaperta* generally does not occur in open-ocean sediments and seems to prefer cooler water temperatures.

Calcidiscus leptoporus was considered the index species for NN4 b (Mărunţeanu, 1992).

Geminilithella rotula (Kamptner 1956) Backman 1980, which is considered the index species for the NN5 a Subzone (Mărunţeanu, 1999), was found at several levels: m 173.50, m 137.70, m 103, which corresponds to *Turritella – Anadara* and *Alvania-Ringicula-Pyramidella* assemblages respectively (Fig. 2).

Unfortunately the species *Geminilithella rotula* (Kamptner 1956) Backman 1980 is not accompanied by *Sphenolithus heteromorphus* Deflandre 1953, the index species of NN5 Zone (Martini, 1971), which could prove doubtlessly the stratigraphic position of the samples.

At m 142, the assemblage consists of *Coccolithus miopelagicus* Bukry 1971, *Calcidiscus leptoporus* (Murray & Blackman 1898) Loeblich & Tappan 1978, *Cyclicargolithus floridanus* (Roth & Hay 1967) Bukry 1971, *Syracosphaera histrica* Kamptner 1941, *Braarudosphaera bigelowii* (Gran & Braarud1953) Deflandre 1947 and *Umbilicosphaera* cf. *jafari* Muller 1974.

At m 121.80 *Cyclicargolithus floridanus* (Roth & Hay 1967) Bukry 1971, *Umbilicosphaera jafari* Muller 1974, *Syracosphaera histrica* Kamptner 1941, *Sphenolithus* cf. *abies* Deflandre 1954 are present. These latter two assemblages corresponding to *Alvania-Ringicula-Pyramidella* assemblage, do not contain index fossils, but certainly are of Middle Miocene age.

The presence of *Braarudosphaera bigelowii* (at the m 142) is an indicator of shallow waters, low salinity and high turbidity.

The nannoplankton is very scarce or absent at the level of the first assemblage of mollusks (*Pirenella-Theodoxus-Tympanotonos*).

In conclusion, the samples analyzed can be considered of Ottnangian, probably also Badenian age based on the calcareous nannoplankton. The nannoplankton assemblages found in borehole 575 Cetea indicate the presence of zone NN4, with *Helicosphaera ampliaperta* and implicitly the existence of the Ottnangian, according to Rögl (1996, 1997) (Chira in Popa et al. 1997).

CONCLUSIONS

The oldest Neogene deposits in the eastern part of the Vad - Borod depression belong to the Eggenburgian. The Eggenburgian transgression in the area is documented by the presence of the brackish macrofaunal assemblages with *Pirenella-Theodoxus-Tympanotonos,* which were met both in outcrops (Lupului brook) and in borehole 575 and other boreholes.

Table 1

SPECIES	BOREHOLE 575			Stratigraphic distribution				
	94 148	172 174	182 190	Egerian	Eggenburgian	Ottnangian	Badenian	Sarmatian
BIVALVES								
Anadara (Anadara) diluvii (LAMARCK)		+		x	x	x	x	
Loripes (Microloripes) dentatus (DEFRANCE)		+			x	x	x	
Obsoletiforma kokkupica (ANDRUSSOV)	+						x	x
Spisula subtruncata triangula RENIERI	+				x	x	x	
Polymesoda convexa convexa (BRONGNIART)			+	x	x			
Gouldia minima (MONTAGU)	+						x	
Corbula (Varicorbula) gibba (OLIVI)	+			x	x	x	x	
GASTROPODS								
Theodoxus (Vittoclithon) pictus pictus (FERUSSAC)	+		+	x	x	x	x	
Alvania venus danubiensis COSSMANN & PEYROT	+						x	
Alvania (Alvania) cf. montagui ampulla (EICHWALD)	+				x		x	
Teinostoma (Solariorbis) woodi (HOERNES)	+	+				?x	x	
Turitella cf. partschi ROLLE		+					x	
Melanopsis impressa monregalensis SACCO	+		+		x	x		
Pirenella plicata papillata (SANDBERGER)	+		+	x	x			
Pirenella plicata trinodosa SCHAFFER	+			x	x			
Pirenella plicata quinquenodosa SCHAFFER	+		+	x	x			
Tympanotonos margaritaceus grateloupi ORBIGNY	+		+		x			
Terebralia bidentata bidentata (DEFRANCE IN GRAT.)			+	x	x	x	x	
Cerithiopsis tubercularis astensis COSSMANN	+						x	
Calyptraea (Calyptraea) chinensis (LINNÉ)	+			x	x	x	x	
Euspira catena helicina (BROCCHI)	+			x	x	x	x	
Dorsanum nodosocostatum (HILBER)	+	+				x	x	
Hinia basteroti MICHELOTTI		+					x	
Clavatula jouanneti DESMOULINS		+				x	x	
Pyramidella plicosa (BRONN)	+				x	x	x	
Odostomia subintermedia (COSSMANN & PEYROT)		+					x	
Odostomia (Brachystomia) dispar BOETTGER	+						x	
Odostomia perrara BOETTGER	+						x	
Eulimella (Ebala) nitidissima (MONTAGU)	+	+					x	
Chrysallida (Parthenina) interstincta (MONTAGU)	+						x	
Chrysallida (Pyrgulina) sacyi (COSSMANN & PEYROT)	+						x	
Turbonilla scala (EICHWALD)	+						x	
Ringicula (Ringiculocosta) costata (EICHWALD)	+						x	

Moisescu & Popescu (1980) considered that the Lower Miocene macrofaunal assemblage from Borod Basin proves the existence of the *Chlamys gigas* Zone belonging to Aquitanian (sensu Eggenburgian), even if the index species of the type assemblage was missing.

A similar case was mentioned in the Váh valley, Horná Nitra area (Slovakia), where within the Eggenburgian transgressive deposits brackish molluskan assemblages with *Tympanotonos, Melanopsis, Clithon* and *Crassostrea gryphoides* were identified (Hudáckova et al., 1996).

The deposits were probably formed in the northern part of the present day Borodului Basin. This area represented a marginal domain of the Lower Miocene basin that covered both the Transylvanian Depressions - in which the Coruş, Chechiş and Hida Formations were forming during the Eggenburgian - Ottnangian (Nicorici & Mészáros, 1994), and the Şimleu Depression. In the eastern part, near Zalău, within the gray silty clays, a microfaunal assemblage similar to that found within the Chechiş Formation was previously identified (Papaianopol et al., 1983). Mărunţeanu (1989) mentioned a nannoplankton assemblage with *Discoaster druggii* (NN2 Zone) (Upper Aquitanian - Lower Burdigalian).

As a result of the extensional tectonics during the Badenian, the Borod Basin was formed. The formation of the deposits in the lower part of the Borod Formation and those belonging to the Lower Badenian in the same area of development, at least in the eastern part of the basin, pleads for the idea that originally the basin was not very wide.

The Badenian, respectively Upper Badenian deposits were mentioned also westwards, near Aleşd

(Nicorici et al., 1982).

During the Badenian a general transgression was recorded within the whole Paratethys area, causing an invasion of warmer waters which favourized the development of rich molluskan assemblages. The separation from the Mediterranean domain was compensated by the formation of some connections oriented towards the south Asian areas during the Kossovian.

The presence of the Lower Badenian in the eastern part of the Borod Basin was only assumed, based on the presence of some ostracods belonging to *Falunia* genus (Papaianopol et al., 1984). According to the same authors, the presence of Upper Badenian deposits is demonstrated by the presence of the foraminiferal assemblage with *Bogdanowiczia pocutica*, identified between Cetea and Gheghie villages.

The macrofaunal assemblage with *Alvania-Ringicula-Pyramidella* that could plead for the presence of the Badenian evolved in the eastern part of the basin under peculiar circumstances. The dominance of minutins, some of them being described also by Nicorici (1974) from the Badenian deposits from Tusa (Şimleu Basin), suggests possible links between the two basins. The existence of some connections between the two basins is also demonstrated by the presence of Badenian deposits at Poieni - Ciucea which are "trapped" between crystalline formations (Nicorici, 1969).

As a consequence, we attribute the Borod Formation to the chronostratigraphical interval Eggenburgian-Badenian.

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PLATES

Plate I

Fig. 1-3. Gastropods operculum – m 237.80 (X 10); m 280.50 (X1)
***Pirenella – Theodoxus – Tympanotonos* assemblage**
Fig. 4-5. *Theodoxus* (*Vittoclithon*) *pictus pictus* (FERUSSAC) – m 188.30 (X2)
Fig. 6. *Melanopsis impressa monregalensis* SACCO – m 186.70 (X1)
Fig.7-9. *Pirenella plicata papillata* (SANDBERGER) – m186.50; m 98.60; m 186.50 (X 1)
Fig. 10-11. *Pirenella plicata quinquenodosa* SCHAFFER – m 98.60; m 186.50 (X 1)

Plate II

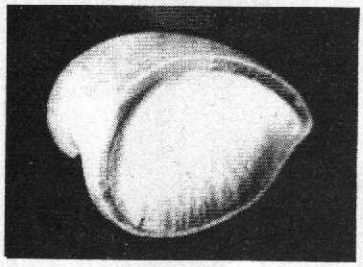
Fig. 1. *Tympanotonos margaritaceus grateloupi* ORBIGNY – m 98.60 (X1)
Fig. 2. *Terebralia bidentata bidentata* (DEFRANCE in GRATELOUP) – m 186.70 (X 1)
***Turritella – Anadara* assemblage**
Fig. 3. *Anadara (Anadara) diluvii* (LAMARCK) – m 173.50 (X1)
Fig. 4-6. *Turritella cf. partschi* ROLLE – m 173.70 (X2); m 173.00 (X1); m 173.70 (X1)
Fig. 7. *Clavatula jouanneti* DESMOULINS – m 173.00 (X 1)
Fig. 8. *Odostomia subintermedia* COSSMANN & PEYROT – m 173.00 (X 20)
Fig. 9-10. *Teinostoma (Solariorbis) woodi* (HOERNES) – m 172.00 (X 10)
***Alvania – Ringicula – Pyramidella* assemblage**
Fig. 11-12. *Obsoletiforma kokkupica* (ANDRUSSOV) – m 126.50 (X 10)

Plate III

Fig. 1. *Gouldia minima* (MONTAGU) – m 121.10 (X 25)
Fig. 2. *Corbula* (*Varicorbula*) *gibba* (OLIVI) – m 142.20 (X 5)
Fig. 3-4. *Alvania venus danubiensis* COSSMANN & PEYROT – m 147.70 (X 10); m 121.50 (X 17)
Fig. 5-6. *Alvania montagui* cf. *ampulla* (EICHWALD) – m 147.70 (X 15); m 121.50 (X 25)
Fig. 7. *Cerithiopsis tubercularis astensis* COSSMANN – m 121.50 (X 25)
Fig. 8. *Euspira catena helicina* (BROCCHI) – m 147.70 (X 1)
Fig. 9. *Dorsanum nodosocostatum* (HILBER) – m 147.70 (X 2)
Fig. 10. *Pyramidella plicosa* (BRONN) – m 142.20 (X 10)
Fig. 11. Odostomia (*Brachystomia*) *dispar* BOETTGER – m 121.10 (X 25)

Plate IV

Fig. 1. *Eulimella* (*Ebala*) *nitidissima* (MONTAGU) – m 121.10 (X 20)
Fig. 2. *Chrysallida* (*Parthenina*) *interstincta* (MONTAGU) – m 121.10 (X 25)
Fig. 3. *Chrysallida* (*Pyrgulina*) *sacyi* (COSSMANN & PEYROT) – m 142.20 (X 10)
Fig. 4-5. *Turbonilla scala* (EICHWALD) – m 142.20 (X 15)
Fig. 6. *Ringicula* (*Ringiculocosta*) *costata* (EICHWALD) – m 147.70 (X 20)
Calcareous nannoplankton
Fig. 7 a,b. *Helicosphaera ampliaperta* BRAMLETTE & WILCOXON – m 173.70, a-N II, b-N +, (X 2000)
Fig. 8. *Syracosphaera histrica* KAMPTNER – m 142.00, N +, (X 2000)
Fig. 9 a,b.*Calcidiscus leptoporus* (MURRAY & BLACKMAN) LOEBLICH & TAPPAN – m 173.70, a-N II, b-N +, (X 2000)



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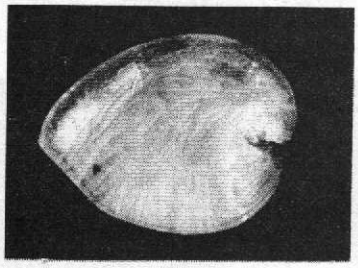

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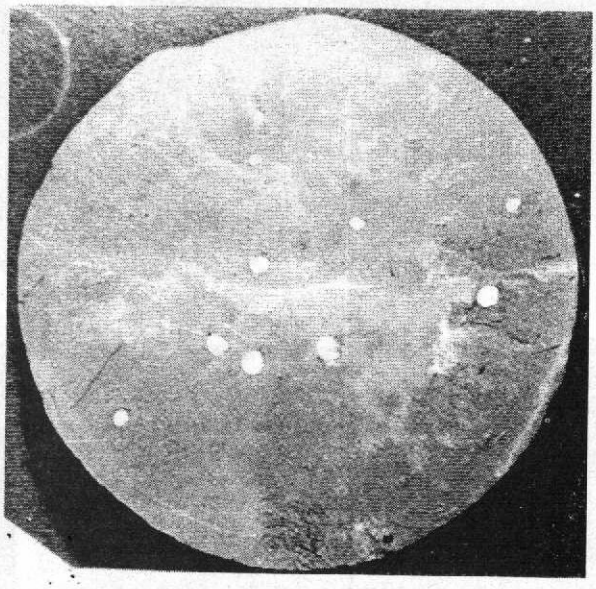

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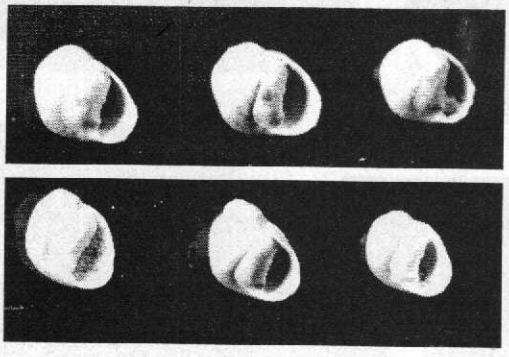

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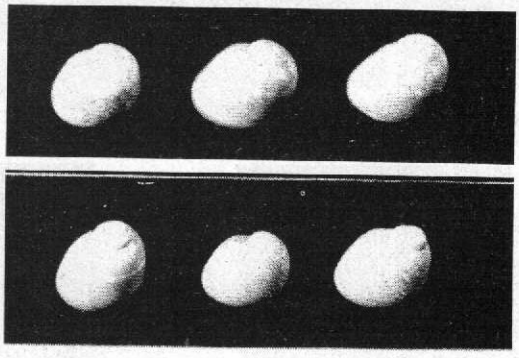

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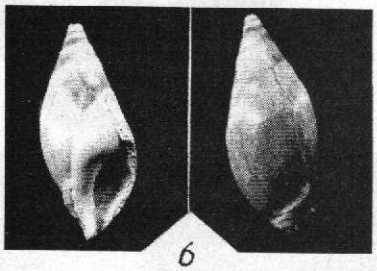

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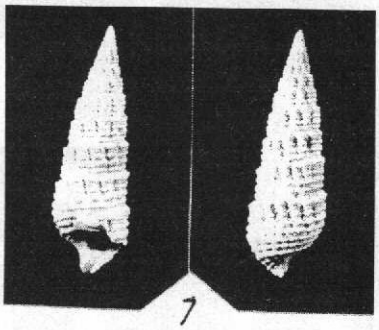

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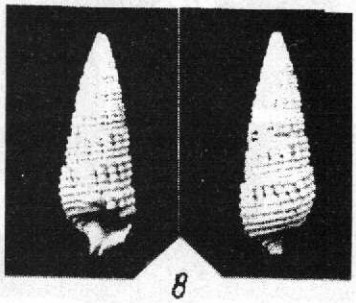

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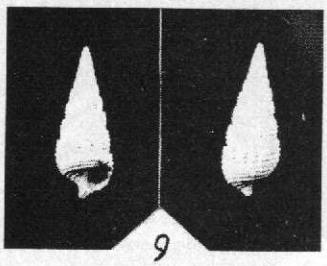

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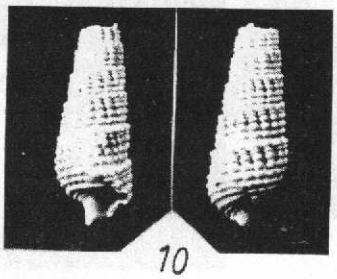

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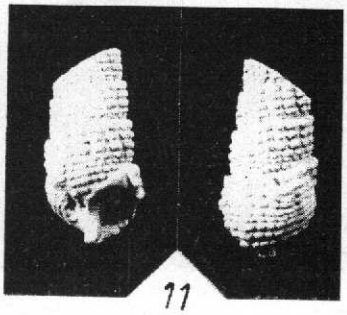

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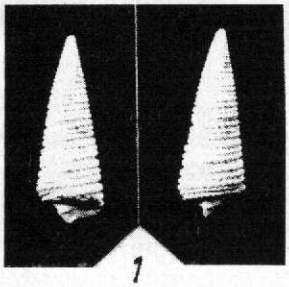
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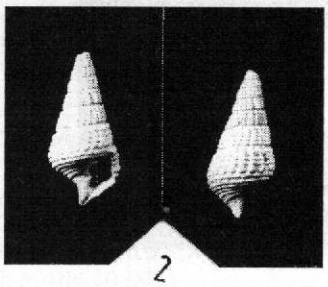
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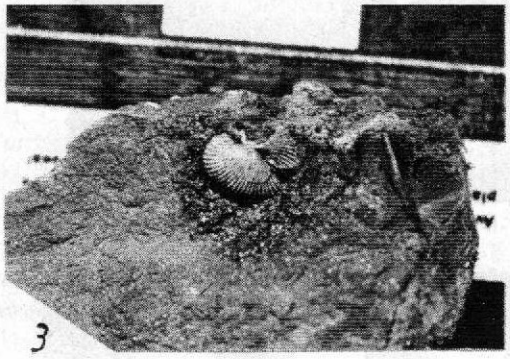
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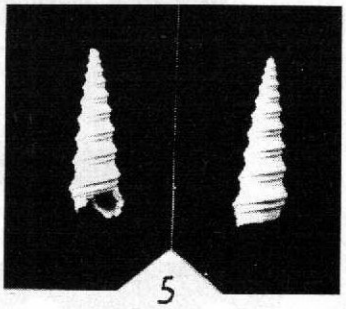
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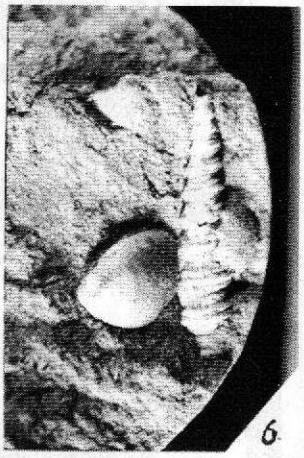
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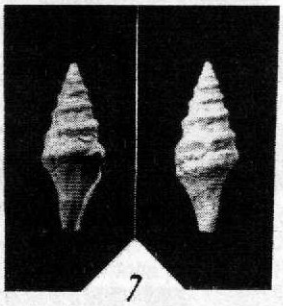
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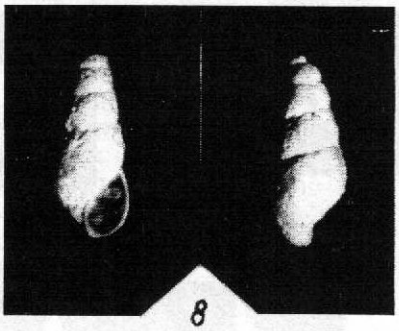
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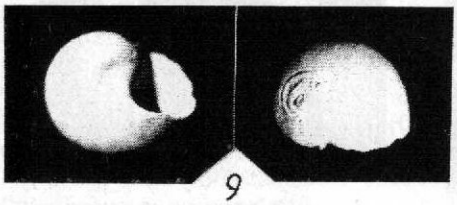
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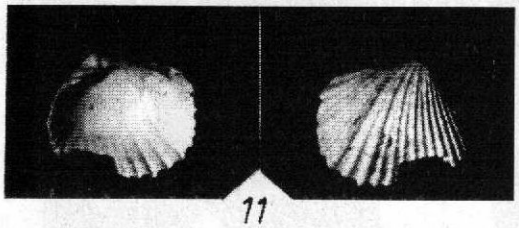
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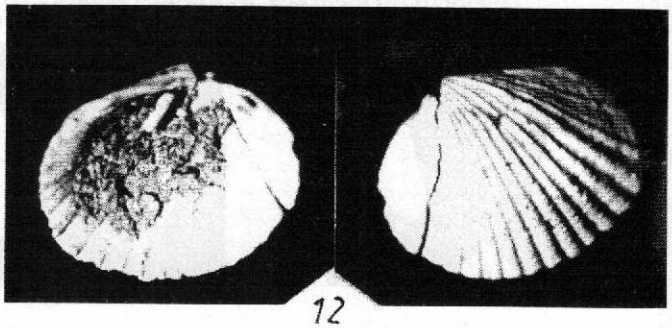
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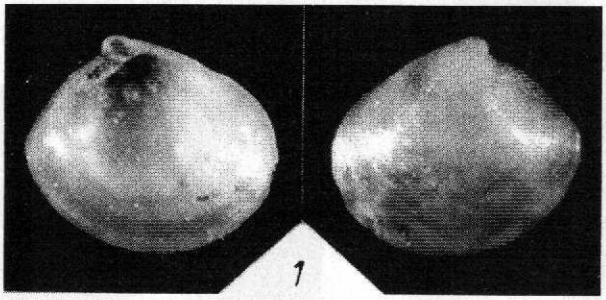

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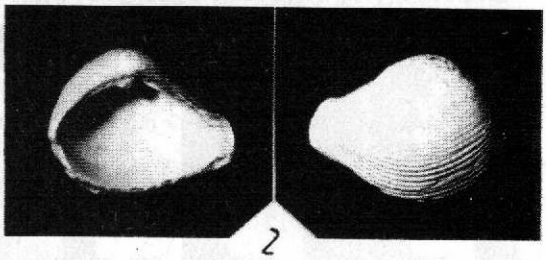

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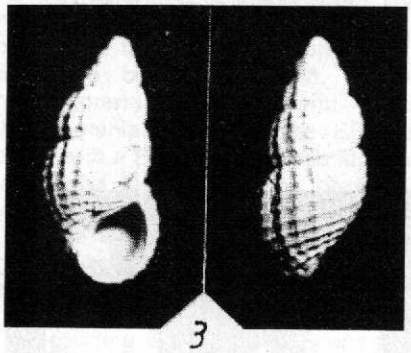

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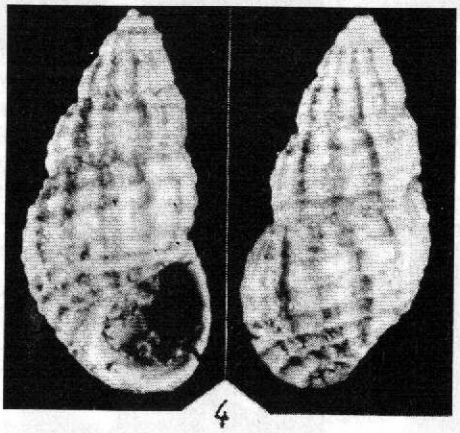

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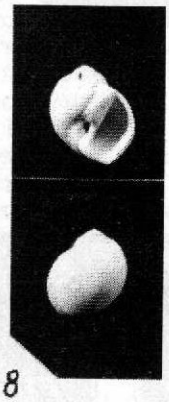

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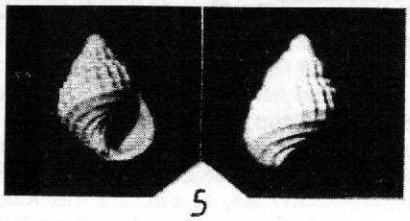

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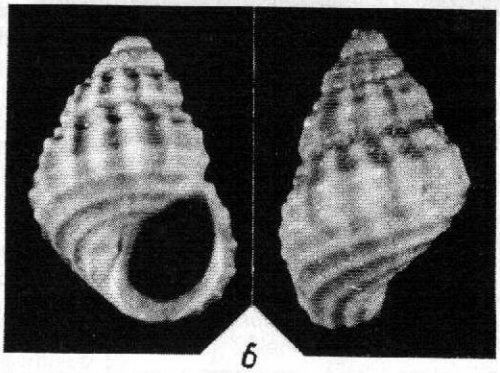

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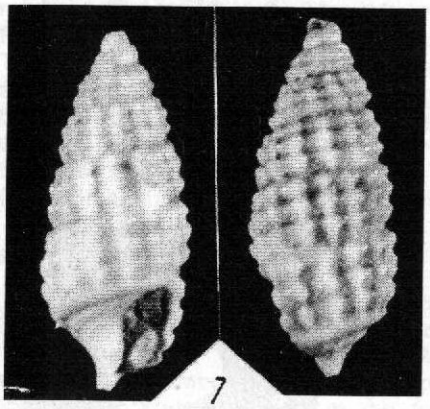

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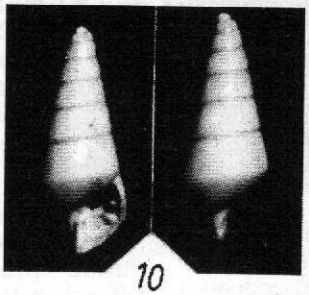

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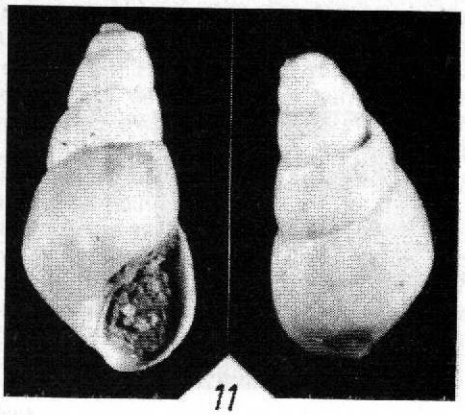

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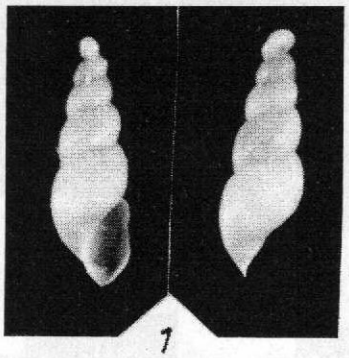

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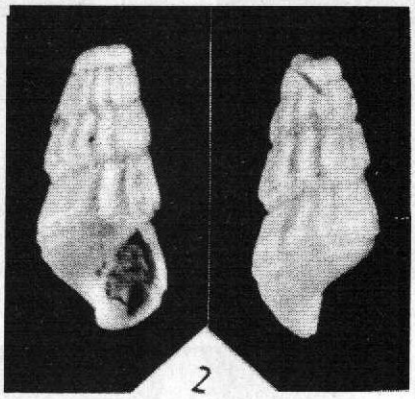

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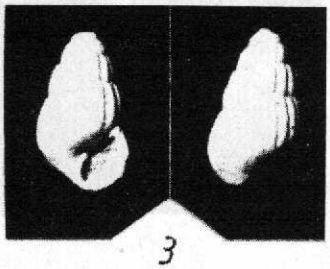

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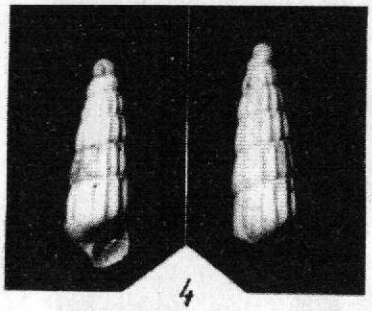

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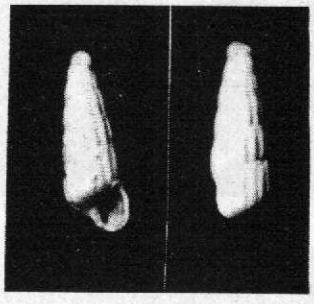

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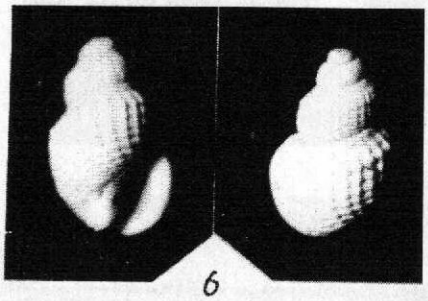

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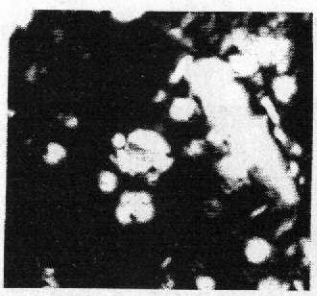

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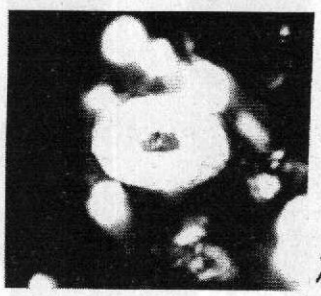

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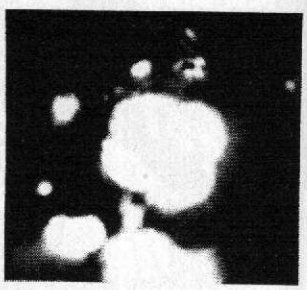

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