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LOWER BADENIAN SEA-LEVEL DROP ON THE WESTERN BORDER OF THE TRANSYLVANIAN BASIN: FORAMINIFERAL PALEOBATHYMETRY AND STRATIGRAPHY

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Abstract: The marine Lower Badenian deposits from the western border of the Transylvanian Basin belong to the Gârbova de Sus Formation, lithologically dominated by algal-bioclastic limestones. The rich and well preserved foraminiferal assemblages correspond to planktonic foraminiferal Zone M5b-M6 (Berggren et al. 1995) and the "Upper Lagenid Zone" of the Central Paratethys. The sediments are set in two sequences of about 20 m in thickness, the first mostly siliciclastic, displaying coastal onlap, and the second mainly carbonatic, with a regressive character. The sedimentary and paleontological features reflect sea level changes, the main event — recorded between the first and the second sequence — probably being correlable with a global sea-level drop in the Middle Miocene (15.5–16 Ma).

Key words: Transylvanian Basin, Badenian, sequence stratigraphy, lithostratigraphy, foraminifera.

Introduction

The molasse sedimentation in the Transylvanian Basin started during the Middle Miocene (Badenian/Langhian), over the post-tectogenetic (Senonian–Burdigalian) cover.

The Middle Miocene sedimentary formations from the western border of the Transylvanian Basin have been studied since the second part of the 19th century, particularly by the fossil faunas of echinids and bivalves. Most of these deposits belong to the *Gârbova de Sus Formation* (Langhian/Badenian — Upper Lagenid Zone, Filipescu & Gîrbacea, in press).

The purpose of this study is to emphasize some particular events in the biostratigraphical and sedimentological record of the Gârbova de Sus Formation. The observations on the foraminiferal assemblages and sedimentary sequences have focused on the main sections and especially the type section of Gârbova de Sus (Pârâul Pietrii Creek). The results of our investigations enable us to make correlations with the corresponding intervals of the Central Paratethys.

Lithostratigraphy

The type section of the Gârbova de Sus Formation is located close to the northwestern limit of the Gârbova de Sus village. The locality is situated southwest of the city of Aiud, 8 km west of the E81 European road (Fig. 1).

The lithology consists of lower Badenian carbonate sands and especially algal-bioclastic limestones. The most typical sequences occur at Gârbova de Sus, Lopadea Veche, Podeni, and Moldoveneşti. The formation is about 35–40 m thick, and extends along the common border of the Transylvanian Basin and the Apuseni Mountains for more than 40 km, between the Arieş and Ampoi rivers.

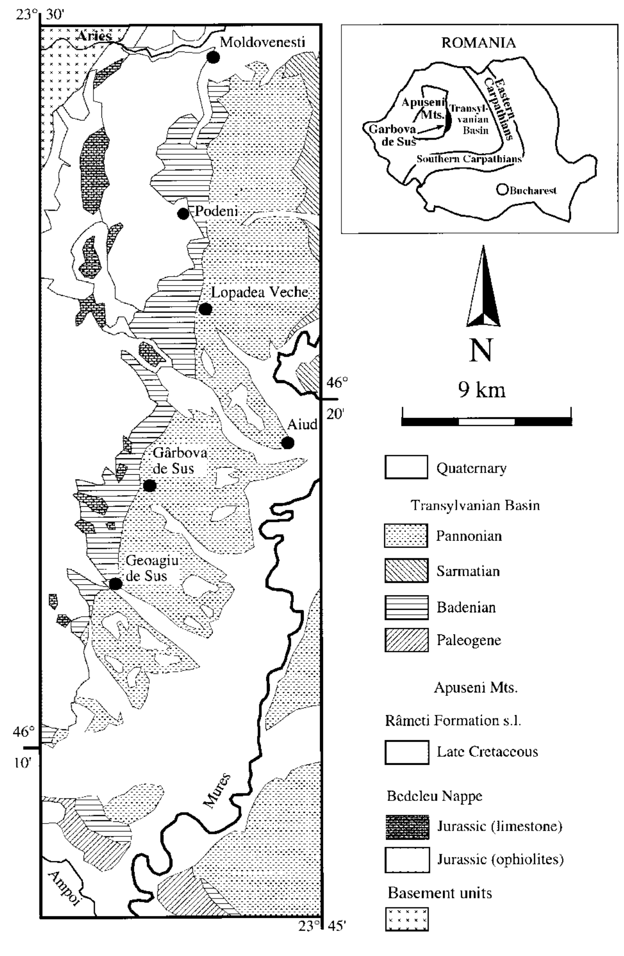

Fig. 1. Geological map of the western border of the Transylvanian Basin (after Lupu et al. 1967).

The formation, synchronous with the upper part of the Dej Formation (Popescu 1970), lies transgressively over the Bedeleu Nappe (late Jurassic–early Cretaceous) or the post-austric Râmeţi Formation s.l. (late Cretaceous), of the eastern part of the Apuseni Mountains (Fig. 1, Fig. 2). It is usually overlain by the Pannonian siliciclastic deposits with brackish to fresh-water faunas of the Lopadea Formation (Lubenescu & Lubenescu 1977). The hiatus associated with the unconformity between the Badenian and the Pannonian strata diminishes or disappears laterally. Thus, in the Podeni area reef and coastal sabkha deposits are observed, which are separated here as the Cheia Formation (Filipescu 1996) — middle Badenian/latest Langhian (see also Ghergari et al. 1991). The Cheia Formation corresponds to the salt deposits from the middle part of the Transylvanian Basin. The following marine Kossovian deposits are separated here as the Pietroasa Formation (Filipescu 1996), overlain by brackish Sarmatian deposits belonging to the Măhăceni Formation (Filipescu 1996). Taken together, the Cheia and Pietroasa formations are equivalent to Mireş Formation of Popescu (1972).

The distinctive algal-bioclastic limestones from the upper and middle part of the formation can be separated as a member — the Podeni Limestone of Mészáros (1991); the Buha Limestone of Popescu et al. (1995). The most representative sections of the member are situated at Podeni and Lopadea Veche, north of Gârbova. The member is delimited by the siliciclastites from the lower part of the formation and by the fine sediments with foraminifers and bivalves from its top. Sometimes it is directly overlain by the younger formations.

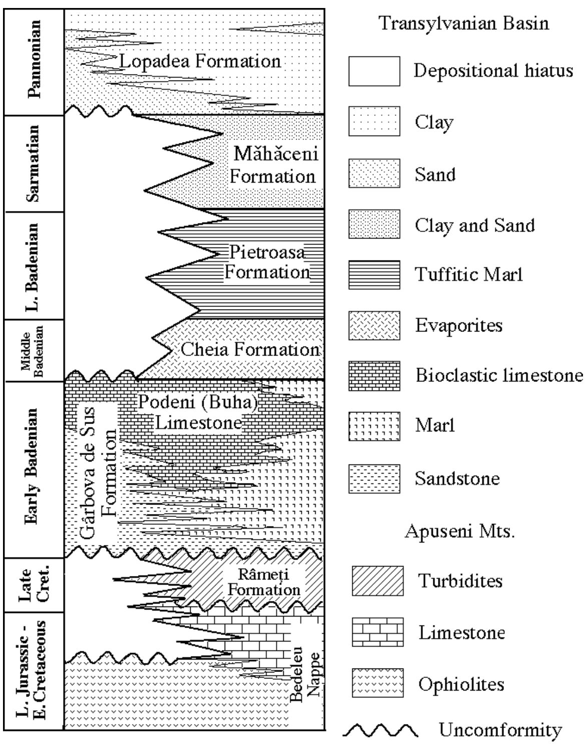

Fig. 2. Lithostratigraphy of the Neogene formations from the western border of the Transylvanian Basin.

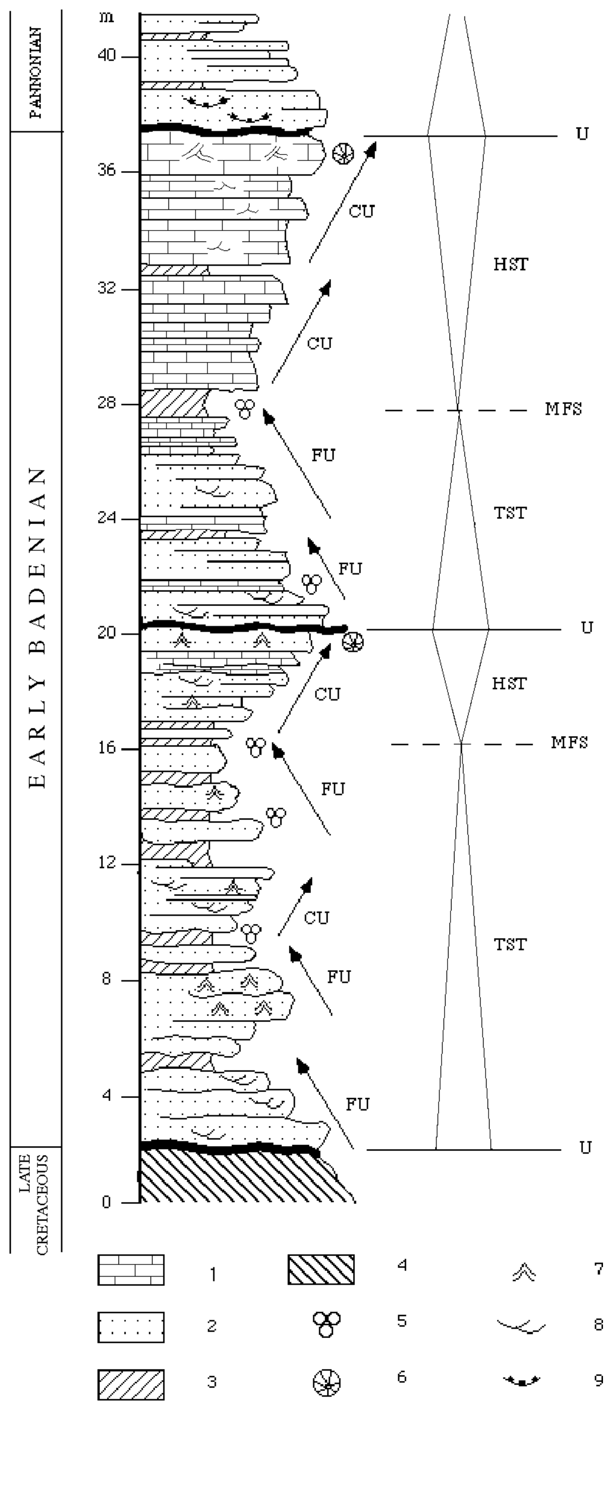

Fig. 3. Lithology and sedimentary sequence of the Gârbova de Sus Formation type section. After Hosu & Filipescu (1996). **1** — bioclastic limestone; **2** — microconglomerate and calcarenite; **3** — marl, clay; **4** — turbidites; **5** — microfauna abundance; **6** — macrofauna abundance; **7** — ripples; **8** — cross-bedding; **9** — channels; **U** — unconformity; **TST** — transgressive stand; **MFS** — maximum flooding surface; **HST** — high stand; **FU** — finig upward tendency; **CU** — coarsening upward tendency.

Sequence stratigraphy

According to Hosu & Filipescu (1996), the Gârbova de Sus Formation is bound by two unconformities (Fig. 3). The sediments comprise two sequences: the lower (15–20 m thick) mostly siliciclastic, displaying coastal onlap, and the upper (15–20 m thick) mainly carbonatic, with a regressive pattern. The sediments of both sequences belong to the inner platform, indicating the presence of the transgressive and high stands, separated by maximum flooding surfaces.

In the **lower sequence**, the sediments belong mainly to the transgressive systems track, and are grouped in progressively thinner parasequences with a retrogradational stacking pattern, as a response to an important sea level rise. The first recorded fossils are algae, echinids and molluscs. The abundance of microfauna in this sequence is associated with the maximum flooding surface, corresponding to a major condensation sequence. Towards the upper part of the sequence, a progradational tendency has been attributed to a high stand, which leads to the end of the first sequence.

The **upper sequence**, starts with siliciclastic deposits (transgressive lag), followed by upper shoreface to lagoonal algal-bioclastic deposits. The maximum flooding surface is represented by fine sediments with foraminifers. The following pattern of the parasequences suggests the progradation tendency in a mainly carbonatic environment.

The sea-level change observed between the lower and upper sequences may be the expression of an important global event. The unconformity probably can be associated with the sea-level drop at 15.5–16 Ma (Fig. 4) — according to the eustatic curve of Kennett (1985) — as a response to global cooling and ice growth in Antarctica.

Fauna — composition, biostratigraphy, environment

The most complete synthesis of geological and palaeontological data from the Gârbova de Sus Formation was carried out by Koch (1900). Vadász (1915) studied the rich echinoid fauna from Gârbova, and in the last decades Gábos & Ghiurcă (1969) documented the small echinids, Nicorici (1975) the pectinids, and Ghiurcă (1974) the bryozoans.

Although Koch (1900) mentioned the existence of several foraminiferal species, no significant studies have been made on this group until the present.

The foraminiferal associations are very rich and diverse, especially in the lower part of the sequence, where sublittoral species prevail in fine sediments. The associations are similar to those described by d'Orbigny (1846) from the Vienna Basin.

Among benthics, a large abundance of the lagenids is observed (Pl. III–V). Many of the species are in common with the "Upper Lagenid Zone" (Papp & Turnovski 1953) of the Badenian, thus allowing correlation of the sequences with the corresponding interval in the Central Paratethys.

In addition to Lagenidae, the benthic associations include a large number of other calcareous species (Pl. II, IV–VI), and also agglutinated taxa (Pl. I). The benthic associations are accompanied by a large number of planktonics, belonging to the "Orbulina suturalis[1] Biozone" M5b-M6 Zone (Berggren 1995).

The microfauna also includes other fossil groups, such as the bryozoans (*Cellaria, Crisia*), brachiopods (*Argyrotheca, Megerlea*) and ostracods (*Aurila, Parakrithe, Xestoleberis*).

The macrofauna usually consists of brachiopods, echinoids, and especially bivalves (pectinids and ostreids) belonging to the "Neopycnodonte navicularis Biozone" (Lubenescu et al. 1977). The uppermost level with macrofauna contains a large number of *Terebratula grandis* Blum. and *Isocardia cor* Linné.

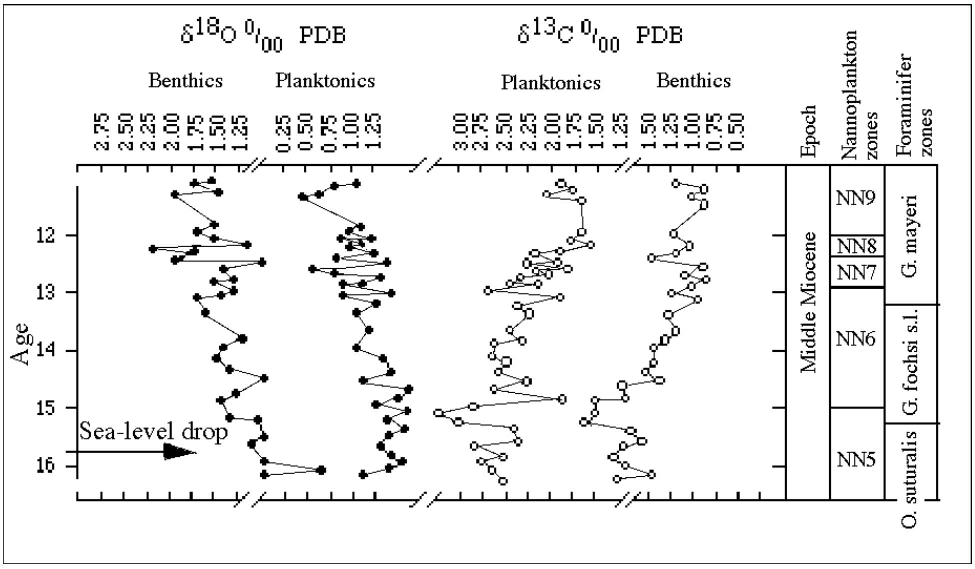

Fig. 4. Benthic and planktonic ^{18}O and ^{13}C fluctuations during Middle Miocene and biostratigraphic zonation for calcareous nannoplankton and planktonic foraminifers in SE Pacific (after Kenett 1985). The shifts of ^{18}O and ^{13}C ratios indicate a sea-level drop between 15.5 and 16 Ma, possibly recorded on the western border of the Transylvanian Basin.

[1] *Orbulina suturalis* Brönnimann 1951 = *Candorbulina universa* Jedlicka 1934 (*Orbulina universa* d'Orbigny 1846, non 1839)

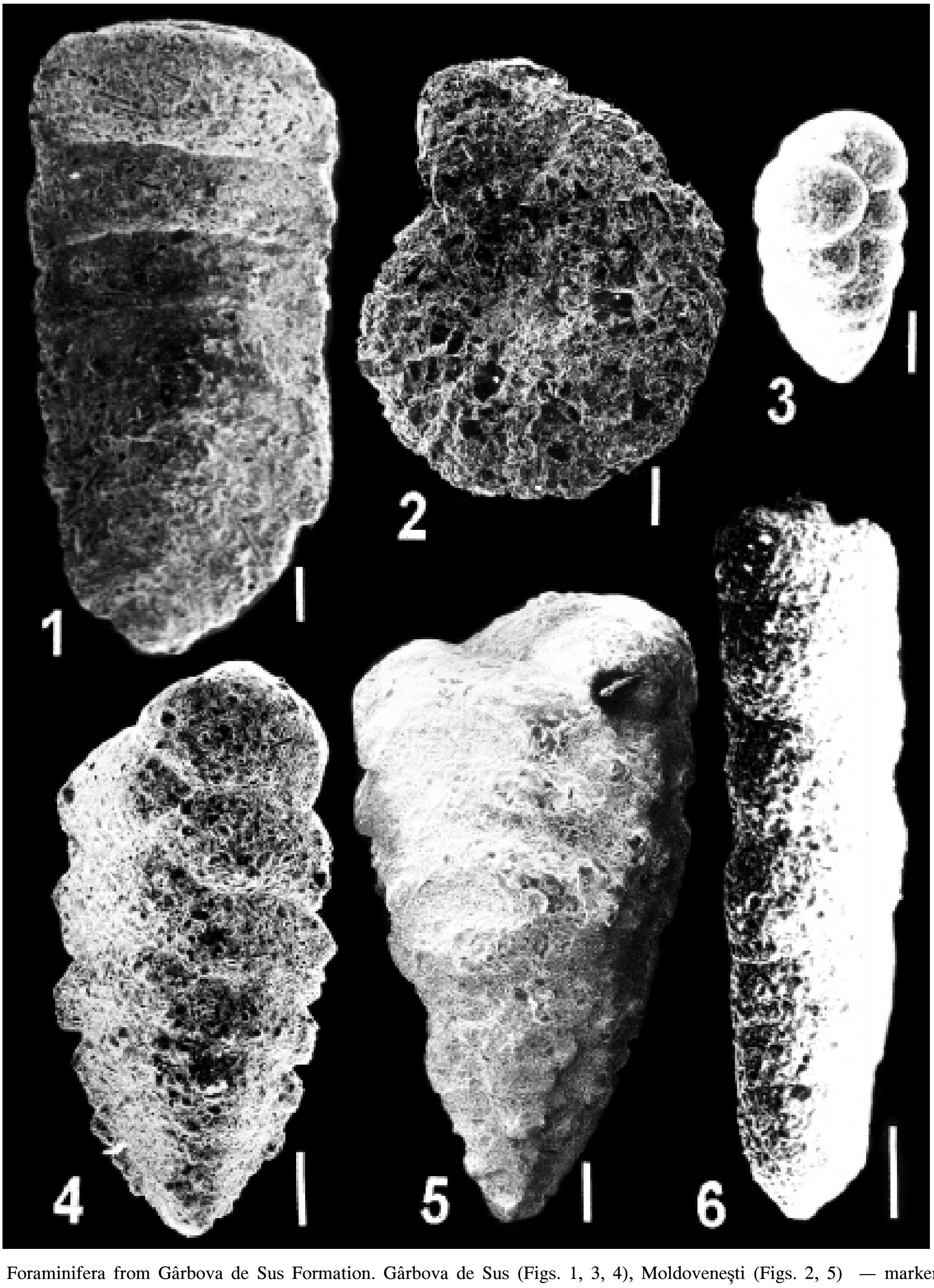

Plate I: Foraminifera from Gârbova de Sus Formation. Gârbova de Sus (Figs. 1, 3, 4), Moldoveneşti (Figs. 2, 5) — marker length 0.1 mm. **Fig. 1.** *Vulvulina pennatula* (Batsch). **Fig. 2.** *Reticulophragmium crassum* (Reuss). **Fig. 3.** *Karreriella bradyi* (Cushman). **Fig. 4.** *Textularia mariae* d'Orbigny. **Fig. 5.** *Paragaudryina mayeriana* (d'Orbigny). **Fig. 6.** *Martinottiella communis* d'Orbigny.

The Badenian sedimentation in this area commenced with coarse and fine sands, typical of a nearshore or beach environment. As the process continued, the sands became interfingered with marls and limestones, very rich in foraminifera (the planktonic taxa reach about 20 %). The fossil associations of the carbonate facies also include oysters and rhodolites.

Agglutinated foraminifera occur in all depths, as well as on all types of substratum, representing approximately 20 % of the benthic associations. Intraspecific variations in the type and the dimensions of the agglutinated granules are also observed. At certain levels pseudopored species (e.g. *Spirorutilus*) are found, probably related to the increased

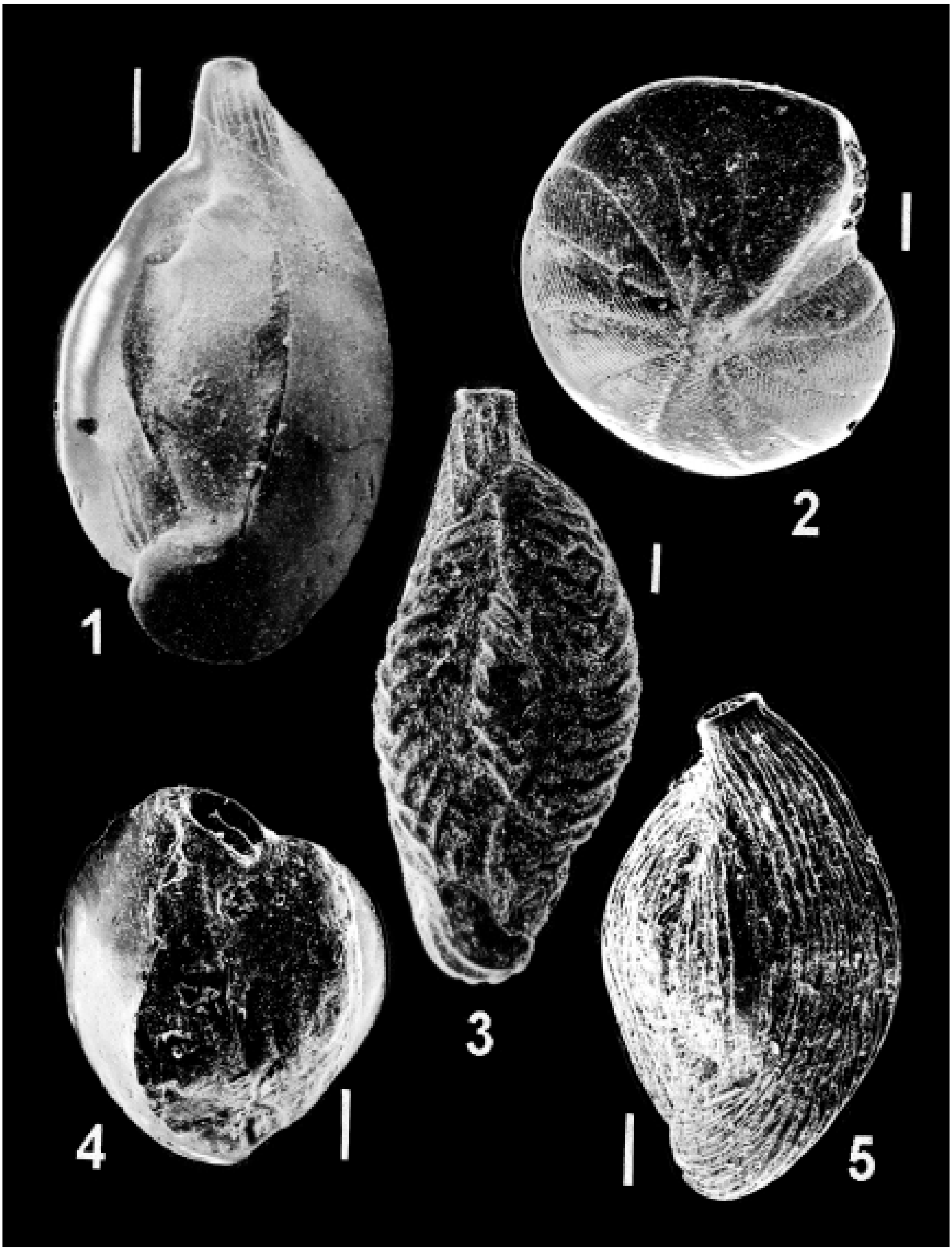

Plate II: Foraminifera from Gârbova de Sus Formation. Gârbova de Sus (Figs. 1, 3, 5), Geoagiu de Sus (Figs. 2, 4) — marker length 0.1 mm. **Fig. 1.** *Adelosina longirostra* (d'Orbigny). **Fig. 2.** *Dendritina haueri* d'Orbigny. **Fig. 3.** *Cycloforina reticulata* (Karrer). **Fig. 4.** *Lachlanella incrassata* (Karrer). **Fig. 5.** *Cycloforina vermicularis* (Karrer).

needs in gas exchanges, due to a slight deepening of the substratum.

The miliolids (Pl. II) lived mainly as epiphytic forms, either on hard and soft substratum or in interstitial spaces at the sediment — water interface. Species associated with a soft substratum (fine sediments) have an elongated, ovoidal, smooth shape, while those that lived on hard substrata have a flatenned discoidal shape. The heavy ornamentation, resulting in the occurrence of irregular forms, is typical of mobile coarse sediment. In the Gulf of Aqaba, Reiss & Hottinger

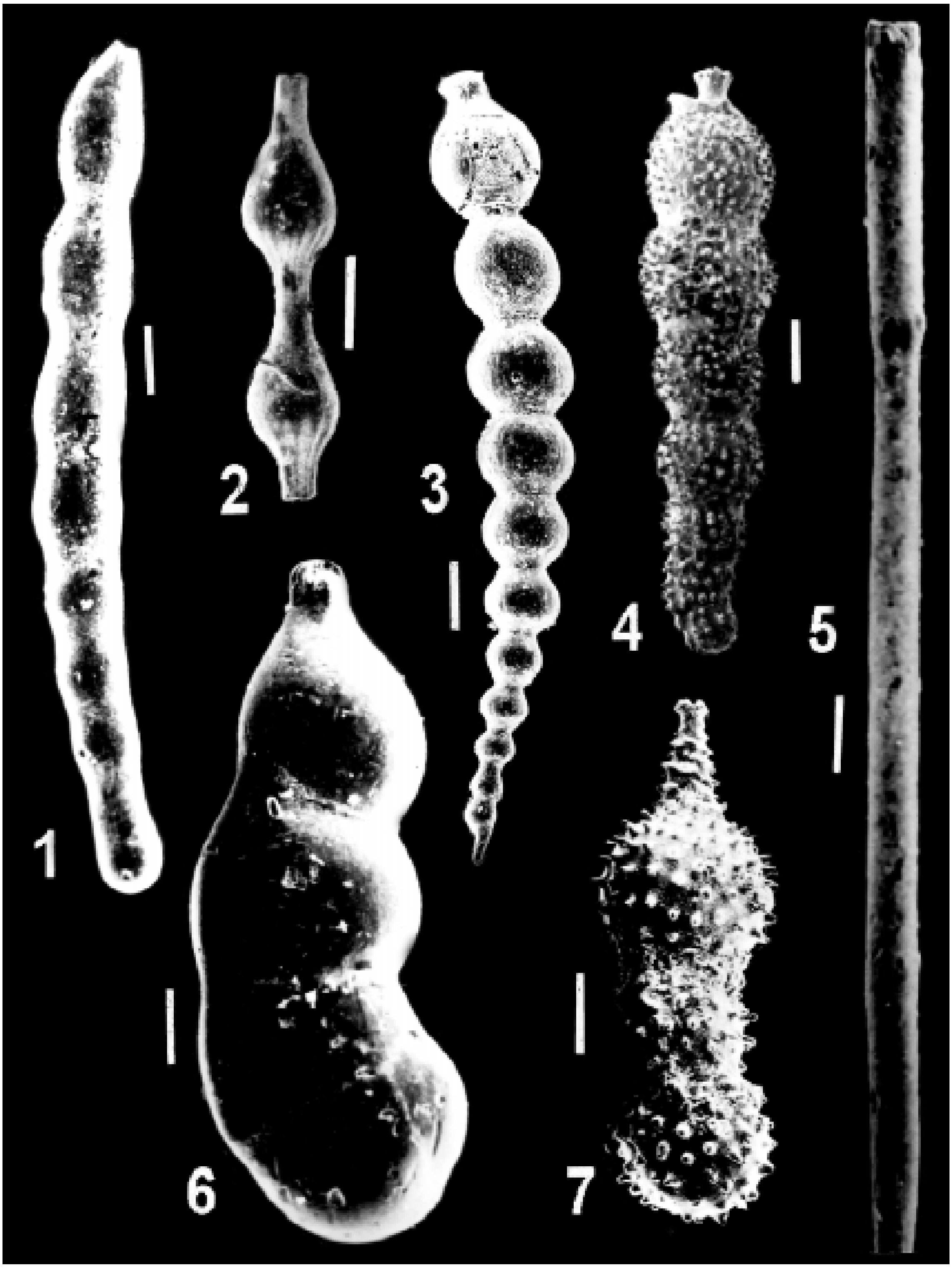

Plate III: Foraminifera from Gârbova de Sus Formation. Gârbova de Sus — marker length 0.1 mm **Fig. 1.** *Laevidentalina elegans* (d'Orbigny). **Fig. 2.** *Nodosaria pyrula* d'Orbigny. **Fig. 3.** *Stilostomella adolphina* (d'Orbigny). **Fig. 4.** *Marginulina hirsuta* d'Orbigny. **Fig. 5.** *Neugeborina longiscata* (d'Orbigny). **Fig. 6.** *Dimorphina variabilis* (Neugeboren). **Fig. 7.** *Amphicoryna hispida* (Soldani).

(1984) registered a severe reduction in miliolids at the 50 m isobath (from 50 % to less than 10 % in the foraminiferal associations). A similar significant reduction has been recorded next to the unconformity surface separating the two sequences of the Gârbova de Sus Formation.

The lagenids are very frequent close to the interval of maximum flooding in the lower sequence, their presence usually suggesting depths up to 70 m. Their frequency is severely diminished above the unconformity surface, along with most of the subtropical species. This suggests a temperature drop asso-

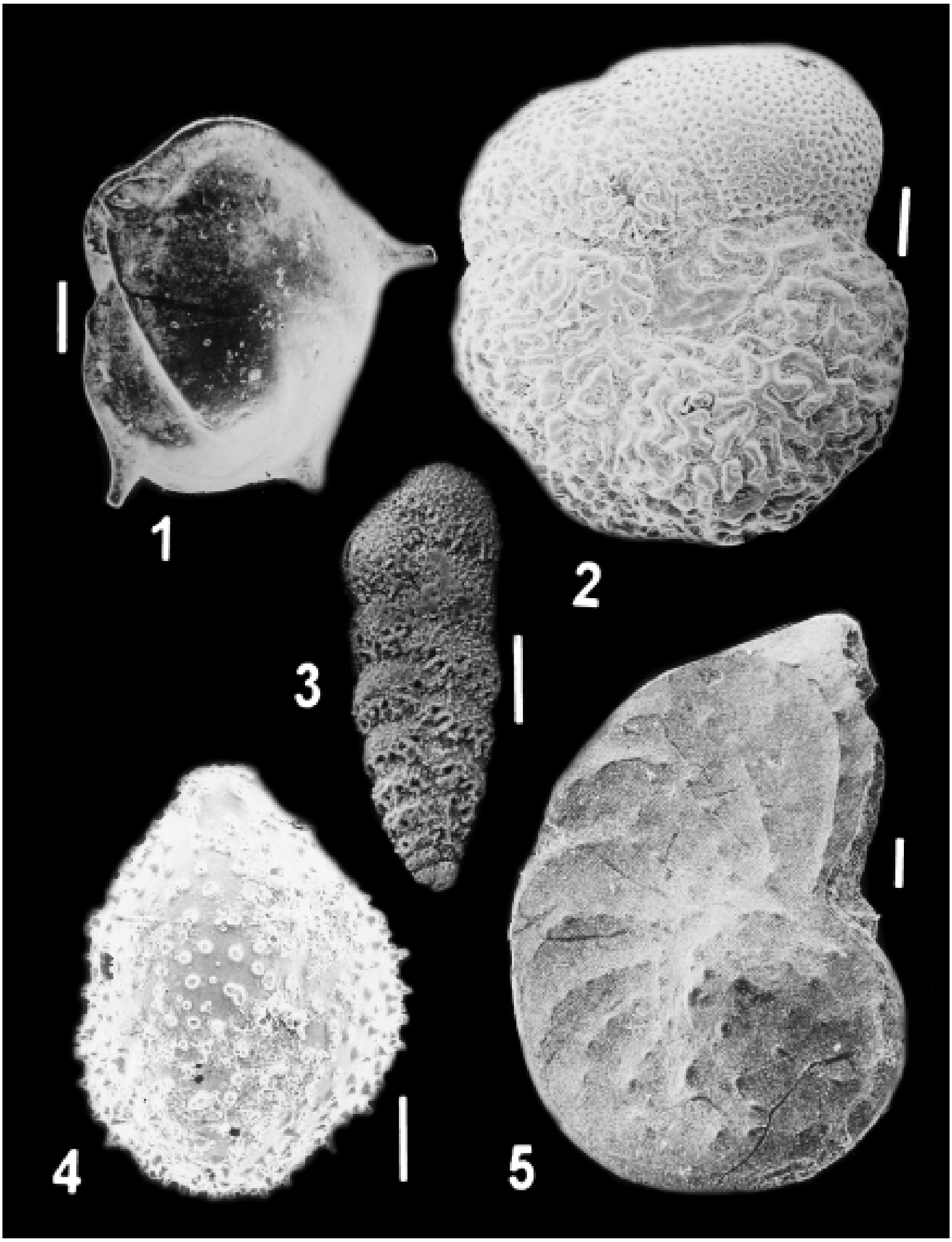

Plate IV: Foraminifers from Gârbova de Sus Formation. Gârbova de Sus (Figs. 1–4), Moldoveneşti (Fig. 5) — marker length 0.1 mm **Fig. 1.** *Lenticulina calcar* (Linne). **Fig. 2.** *Anomalinoides farctus* (Fichtel & Moll). **Fig. 3.** *Bitubulogenerina reticulata* Cushman. **Fig. 4.** *Globulina spinosa* d'Orbigny. **Fig. 5.** *Planostegina costata* (d'Orbigny).

ciated with the unconformity surface, which can probably be related to the global sea-level event mentioned above.

The bolivinids reach 10–15 % and the uvigerinids do not exceed 10 % of the benthic assemblage. Only in the marls above the Podeni Limestone (Lopadea Veche) the *Uvigerina* species are more abundant (20 %), a consequence of brief deepening of the substratum.

The sea-level drop in the middle part of the formation brought favourable life conditions for larger foraminifera — *Planostegina costata* d'Orbigny, *Amphistegina hauerina* d'Orbigny,

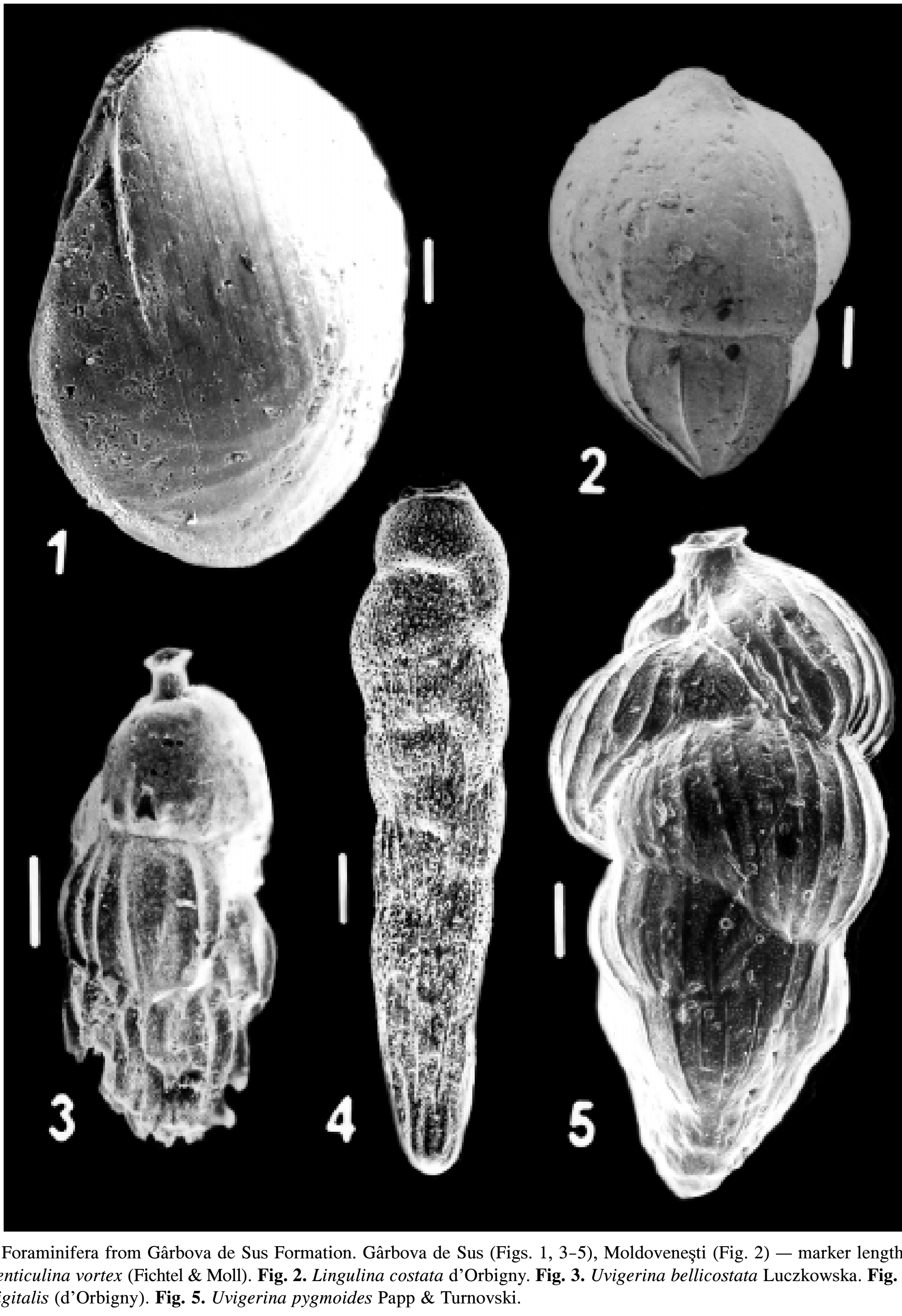

Plate V: Foraminifera from Gârbova de Sus Formation. Gârbova de Sus (Figs. 1, 3–5), Moldoveneşti (Fig. 2) — marker length 0.1 mm. **Fig. 1.** *Lenticulina vortex* (Fichtel & Moll). **Fig. 2.** *Lingulina costata* d'Orbigny. **Fig. 3.** *Uvigerina bellicostata* Luczkowska. **Fig. 4.** *Loxostomum digitalis* (d'Orbigny). **Fig. 5.** *Uvigerina pygmoides* Papp & Turnovski.

Amphistegina mammilla (Fichtel & Moll) — which occur in large quantities in carbonate sands and sandstones, sometimes forming exclusive beds. Those forms lived in the interstitions between clasts in subtidal areas, and are also present within the lagoonal laminated marls. The levels containing thick-walled *Amphistegina* suggest high energy, shallow water environments in front of marginal reefs or in channels. Thin walled specimens are usually associated with the lower sequence "Lagenid" interval, having analogs in modern seas at depths of 40–80 m. The species of *Amphistegina* usually share the

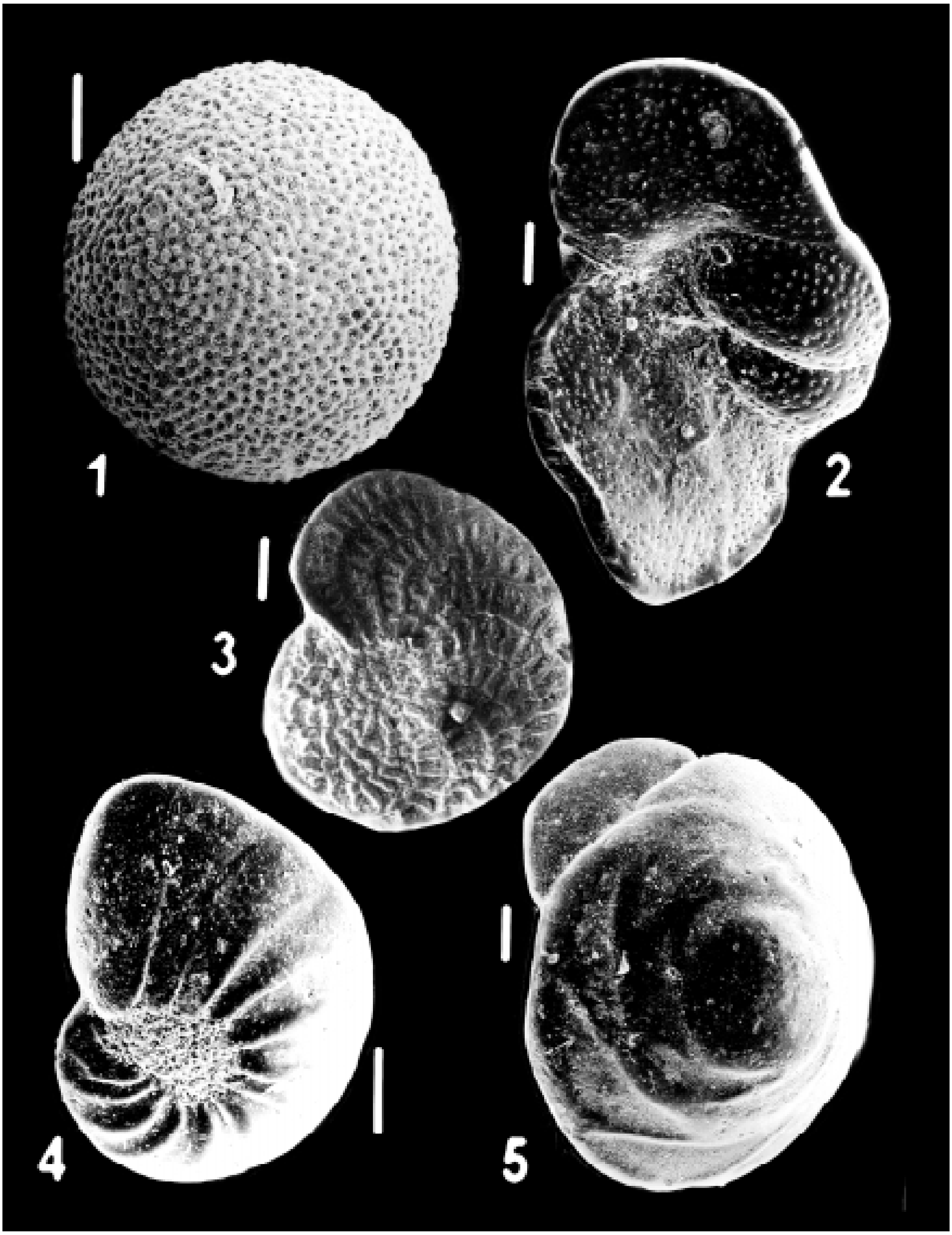

Plate VI: Foraminifera from Gârbova de Sus Formation. Gârbova de Sus (Figs. 1, 2, 4, 5), Moldoveneşti (Fig. 3) — marker length 0.1 mm. **Fig. 1.** *Candorbulina universa* Jedlicka. **Fig. 2.** *Lobatula lobatula* (Walker & Jakob). **Fig. 3.** *Elphidium fichtelianum* (d'Orbigny). **Fig. 4.** *Nonion commune* (d'Orbigny). **Fig. 5.** *Neoeponides schreibersi* (d'Orbigny).

hard substratum with other larger foraminifers, such as *Planostegina*. Their modern distribution is usually delimited by depths of 20–70 m, but in our case they can also occur in concentration levels at greater depths. The ratio between richly and poorly ornamented *Planostegina* decreases in the upper part of the formation, probably as an effect of a change in the environmental parameters, or another change related to the sea-level event mentioned above.

We notice a change in the aspect of the faunas owing to the establishment of shallow carbonate sedimentation (mainly algal limestone) in the upper part of the section. The lagenids are scarce, but the "cibicids", elphidiids and some large foraminifers become more abundant.

Branched foraminifer (of Miniacina type) have been identified, especially on hard bottom. They are the short lived pioneers of the substratum, and are overlain by succeeding comunities of bryozoa and algae.

The elphidiids lived in significant communities only in the upper, shallower part of the formation. Their major frequency in modern seas is registered between 20 and 50 m.

The upper part of the Lower Badenian sequence also includes some planktonic foraminiferal levels (mainly with *Candorbulina universa* Jedlicka), but their frequency is lower than in the lower sequence.

Conclusions

The *Gârbova de Sus Formation* is the most distinctive lithostratigraphic unit of the Middle Miocene (early Badenian —Upper Lagenid Zone) on the western border of the Transylvanian Basin. It consists mainly of shallow water algal-bioclastic limestones associated with epiclastic deposits, all structured in two sequences, a lower transgressive one, mostly clastic, and a regressive upper one, mainly carbonatic.

The micropaleontologic and sedimentologic features clearly indicate a drop of the sea level at the middle part of the formation, probably related to global eustacy. A comparison of the observed paleobathymetric indicators with the global eustatic curves suggests a possible calibration of the sequence within the interval 15.5–16 Ma.

References

Berggren W.A., Kent D.W., Swisher C.C., Aubry M.-P., 1995: A revised Cenozoic geochronology and chronostratigraphy. Geochronology, time scales, and global stratigraphic correlations. *SEPM Special Publication,* 54, 129–212.

Filipescu S., 1994: Data concerning the Kossovian from Podeni (Western Border of the Transylvanian Basin). *Stud. Univ. Babeş-Bolyai, Ser. Geol. (Cluj),* XXXVIII / 2 (1992), 79–82.

Filipescu S., 1996: Middle Miocene Foraminifera from the western border of the Transylvanian Depression. *Anniversary Symposium "Ludwig Johann Neugeboren, 190 years" - Sibiu 24–25 May 1996. Convergenţe Transilvane, Forumul Democrat al Germanilor din România,* 4, 67–73 (in Romanian).

Filipescu S. & Gîrbacea R., (in press): Stratigraphic remarks on the Middle Miocene deposits from Gârbova de Sus (Transylvanian Basin, Romania). *Stud. Univ. Babeş-Bolyai, Ser. Geol. (Cluj).*

Gábos L. & Ghiurcă V., 1969: Echinide mici din faciesul recifal al Tortonianului din Transilvania. *Stud. Univ. Babeş-Bolyai, Ser. Geol. Geogr. (Cluj),* 2, 81–91.

Ghergari L., Mészáros N., Hosu A., Filipescu S. & Chira C., 1991: The gypsiferous Formation at Cheia (Cluj County). *Stud. Univ. Babeş-Bolyai, Ser. Geol. (Cluj),* XXXVI / 1, 13–28.

Ghiurcă V., 1974: Briozoarele tortoniene de la Gârbova de Sus (jud. Alba) (II). *Stud. Univ. Babeş-Bolyai, Ser. Geol.-Mineral. (Cluj),* 1, 57–62.

Hosu A. & Filipescu S., 1996: Sequence stratigraphy in the Middle Miocene deposits from Gârbova de Sus (Transylvanian Basin, Romania). *Studii şi Comunicări, Muzeul Judeţean Bistriţa,* 1/ 1995, 87–97, 4 pl.

Kenett J.P., 1985: Miocene to Pliocene oxygen and carbon isotope stratigraphy in the Southwest Pacific. Deep Sea Drilling Project Leg 90. *Init. Reports D.S.D.P. 90, Washington,* 1383–1411.

Koch A., 1900: Die Tertiaerbildungen des Beckens der Siebenbuergische Landestheile. II Neogen Abtheilung, Budapest, 1–370.

Lubenescu V. & Lubenescu D., 1977: Observaţii biostratigrafice asupra Pannonianului de la Lopadea Veche (Depresiunea Transilvaniei). *D. S. Inst. Geol. (Bucureşti),* LXIV / 4, 57–64.

Lubenescu V., Pavnotescu V. & Lubenescu D., 1977: Le Badénien de Copăceni - Tureni (NV de la Transylvanie). Zone a Neopycnodonte navicularis. *D. S. Inst. Geol. (Bucureşti),* LXIV/4, 147–158.

Mészáros N., 1991: Nannoplankton Zones in the Miocene Deposits of the Transylvanian Basin. *INA Newsletter 13/2, Prague Abstracts,* London, 59–60.

Nicorici E., 1975: Contributions a la connaisance des Pectinides badeniennes de la Roumanie (I). *Stud. Univ. Babeş-Bolyai, Ser. Geol. Geogr. (Cluj),* 32–37.

d'Orbigny A., 1846: Foraminiferes fossiles du Bassin Tertiaire de Vienne (Autriche). *Gide et Comp.,* Paris, XXXVII, 1–312, 21 pl.

Papp A. & Turnovski K., 1953: Zur Entwiklung der Uvigerinen im Vindobon (Helvet und Torton) des Wiener Beckens. *Jb. Geol. Bundesanst. (Wien),* 94, 1, 117–142.

Popescu Gh., 1970: Planktonic foraminiferal zonation in the Dej Tuff Complex. *Rev. Roum. Géol., Géophys., Géogr., Sér. Géol.,* 14, 2, 189–203.

Popescu Gh., 1972: Biostratigrafia depozitelor oligo-miocene de la sud de Preluca pe bază de foraminifere planctonice. *D. S. Inst. Geol. (Bucureşti),* LVIII/*3, 105–127,

Popescu Gh., Mărunţeanu M. & Filipescu S., 1995: Neogene from Transylvania Depression. Guide to Excursion A1. X Congr. RCMNS. *Romanian Journal of Stratigraphy*, 76, 3, 1–27.

Reiss Z. & Hottinger L., 1984: The Gulf of Aqaba. Ecological Micropaleontology. *Springer Verlag,* Berlin, Heidelberg, New York, Tokyo, 1–354.

Vadász E.M., 1915: Magyarorszag mediterran tuskesborui. *Geologica Hung.,* I, 67–227.