

## ORIGIN AND TAXONOMY OF THE QUATERNARY PONTO-CASPIAN FORAMINIFERA

Yanko-Hombach, V.<sup>1,2</sup>

Department of Physical and Marine Geology, 2, Shampansky Per., Odessa I.I. Mechnikov National University,  
Odessa 65058, Ukraine

*valyan@onu.edu.ua*

Avalon Institute of Applied Science, 976 Elgin Ave, Winnipeg MB R3E 1B4, Canada, 2

*valyan@avalon-institute.org*

**Keywords:** autochthons, allochthons, endemics, Mediterranean immigrants, Paratethys relics

### Introduction

During the Tertiary, the Paratethys Sea covered the region north of the Alps from Central Europe to the Aral Sea in Western Asia. From the Pliocene epoch onward (5 mya), the Paratethys became progressively shallower and was subdivided into several inland seas that were at times completely separated from each other. Many of these would disappear before the start of the Pleistocene, but today, only the Ponto-Caspian basins remain.

The Ponto-Caspian is defined here as a chain of intercontinental basins that encompasses the Caspian, Black, Azov seas, the Kerch Strait, the Manych Valley, and their coasts. During the Quaternary, the Black Sea was repeatedly connected with the Caspian Sea via the Manych outlet as well as with Mediterranean Sea through the Bosphorus or Izmit Bay-Sapanca Lake-Sakarya Valley (Figure 1). This predetermined environmental conditions and hydrologic regimes of the Ponto-Caspian basins and imposed specific impacts on diverse biological populations, including foraminifera.

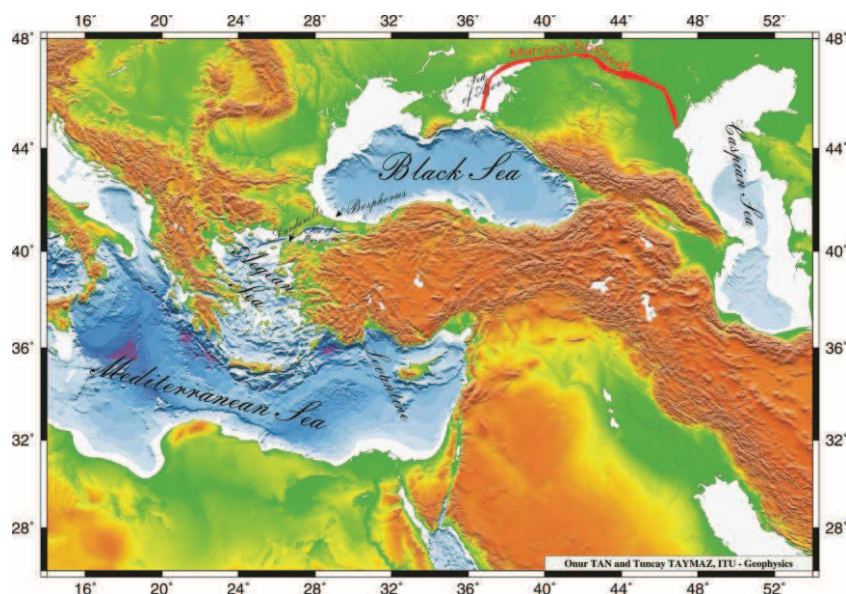


Figure 1. The Ponto-Caspian: the Manych Spillway (in red) which presumably connected the Caspian and Black Sea from time to time and served as a passage for Caspian taxa to immigrate into the Pontic basin.

Application of foraminifera to high-resolution stratigraphy and paleoenvironmental reconstructions requires precise taxonomic identification of species and their further integration into the general system of foraminifera. As of today, foraminiferal taxonomy relies largely on a phenetic species concept (e.g., Loeblich and Tappan, 1988) that classifies foraminifera by their morphological similarities, which can also be caused by environmental variations. As a consequence, it is often difficult to make a decision whether morphological variations are genotypic or ecophenotypic.

Classifying foraminifera by morphological criterion only may lead to an appearance of species with wide geographic and stratigraphic distribution, e.g., *Ammonia beccarii* (Linné). To avoid this, a complex analysis of various characteristics of foraminiferal tests in conjunction with environmental preferences of a given taxon is needed. The molecular concept (e.g., Holzmann, 2000) can open new perspectives for the taxonomy of recent foraminifera because molecular systematics will allow clear definitions of existing taxa and investigation of hidden genetic subdivisions (sibling species). However, as of today, it is in the early stages of its development, meaning that no sufficient data bank has yet been established.

This presentation outlines the origin and taxonomy of the Ponto-Caspian Quaternary foraminifera that can be used for reconstructing the geological history of the region, including water exchange between the neighboring basins.

As a part of the study, a direct comparison of the Ponto-Caspian low rank taxa (species and subspecies) with the original collections of d'Orbigny, Schlumberger, and Le Calvez in the Museum of Natural History, Paris; L. Maysuradze in the Institute of Paleobiology in Tbilisi; and A.K. Bogdanowicz in Krasnodar was performed by the author in various stages of the research. The generic classification of Orlov (1959) and Loeblich and Tappan (1988) has been used for classification of high rank taxa. The Reference Collection of Ponto-Caspian Quaternary foraminifera is stored at the Paleontological Museum of Odessa I.I. Mechnikov National University, Ukraine (No 3906). At present, 165 low rank taxa are on file.

### Material and methods

Foraminifera along with geological properties of sediments were studied in 112 coastal outcrops, many of which are Ponto-Caspian stratotypes (Yanko, 1989, 1990a); 56 boreholes (e.g., Yanko and Gramova, 1990) and ~4000 gravity/vibrocres from the Black and Caspian seas; 18 boreholes from the Bosphorus Strait, the Sea of Marmara (e.g., Yanko et al., 1999), Izmit Gulf and Sakarya (Meriç et al., 1995) and supplemented by hundreds of  $^{14}\text{C}$ ,  $^{230}\text{Th}/\text{U}$  and Electron Spin Resonance (ESR) dates. The Eastern Mediterranean foraminifera of the Israeli offshore area and Iskenderun Bay, Turkey, were investigated in 425 samples recovered by gravity core, box-corer, and grab as part of the international AVICENNE project (Yanko et al., 1998; 2006). The location maps of studied materials are provided in Yanko (1989, 1990a), Basso et al. (1994), Meriç et al. (1995), and Yanko et al. (1998).

The methods used in taxonomic identification are described in Yanko (1989). They include: a complex study of external and internal test morphology, wall ultrastructure and chemical content of the tests taking into account di- and trimorphism in selected taxa (*Ammonia*, for example). Thin cross-sections and molds of the tests were prepared for the majority of the Rotaliida to define their taxonomic position. All low rank taxa were imaged by SEM.

### Results

In our work, we follow the Russian divisions of the Quaternary System, which separates the Quaternary into the Eopleistocene (1.8-0.78 Ma), the Neopleistocene (0.78-0.01 Ma), and the Holocene (0.01-0.0 Ma) (Zhamoida, 2004). The boundary between the Eopleistocene and Neopleistocene coincides with the Matuyama-Brunhes reversal, which is readily traced in both the Pontic and Caspian regions at the bottom of the Lower Chaudian and Gurian horizons, and the Apsheronian and the Bakinian horizon, respectively.

In the Caspian region, the Eopleistocene is represented by the Apsheronian horizon; the lower Neopleistocene by the Bakinian horizon; the middle Neopleistocene by the lower Khazarian horizon; the upper Neopleistocene by the upper Khazarian and Khvalynian horizons; and the Holocene by the Mangyshlakian, Chelekenian, Derbenian, and Recent beds (Yanko-Hombach, 2014).

In the Pontic region, the Eopleistocene is represented by the Gurian horizon; the lower Neopleistocene by the Chaudian horizon that possesses at its top the Karadenizian beds corresponding to the first Pleistocene intake of Mediterranean water and fauna into the Chaudian basin; the middle Neopleistocene by the Old Euxinian and Uzunlarian horizons; the upper Neopleistocene by the Karangatian, Tarkhankutian, and Neoeuxinian horizons; and the Holocene by the Old Chernomorian and Neochernomorian beds. Some researchers (Balabanov, 2007; Yanko-Hombach, 2007; Martin and

Yanko-Hombach, 2011) consider that sea level during the Holocene rose gradually with an oscillating mode. In the Holocene, they noted not less than 5 transgressive and regressive phases in turn, complicated by smaller rhythmic.

The Pontic basin was connected to the Caspian in the Early Chaudian, Early Old Euxinian, Early Uzunlarian, and Late Neoeuxinian times. During these connections, Caspian foraminifera immigrated from the Caspian to the Pontic basin but not *vice versa*. The Pontic basin was connected to the Mediterranean one in the Karadenizian, Late Old Euxinian, Middle-Late Uzunlarian, Early-Middle-Late Karangatian, Tarkhankutian, and Old Chernomorion and Neochernomorion time. The most powerful Mediterranean transgression, that increased salinity in the Pontic basin up to 33 psu, occurred in Karangatian time (MIS 5e).

During these connections, foraminiferal fauna immigrated into the Pontic basin either from the Caspian or Mediterranean basins. The immigrant taxa are called allochthons, while endemics and Parathetys relics are autochthons. The former immigrated into the Ponto-Caspian at various times either from the neighboring seas (external allochthons) or from one part of the Ponto-Caspian to another (internal allochthons) that can be also considered as autochthons for the entire Ponto-Caspian.

In total, the Ponto-Caspian foraminifera are represented by 165 low rank taxa from seven orders (Figure 2).

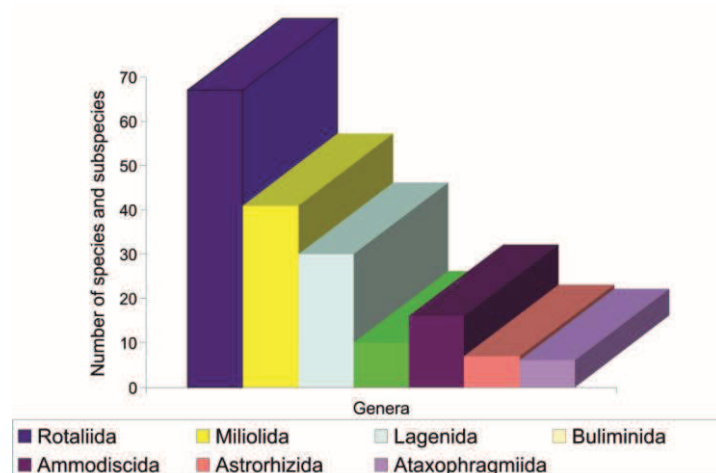


Figure 2. Number of low rank taxa in orders of the Ponto-Caspian foraminifera.

Among the low rank taxa, 148 are calcareous and 17 agglutinated. There is only one planktonic species, *Globoquadrina dutertrei* (d'Orbigny) that is present in the Karangatian horizon only; the rest of the taxa are benthic.

The Caspian foraminifera are either endemics (88%) or external allochthons (12%). The Pontic foraminifera include Mediterranean immigrants (88%), endemics (7%), Caspian immigrants (5%), and Parathetys relics (2%) (Figure 3).

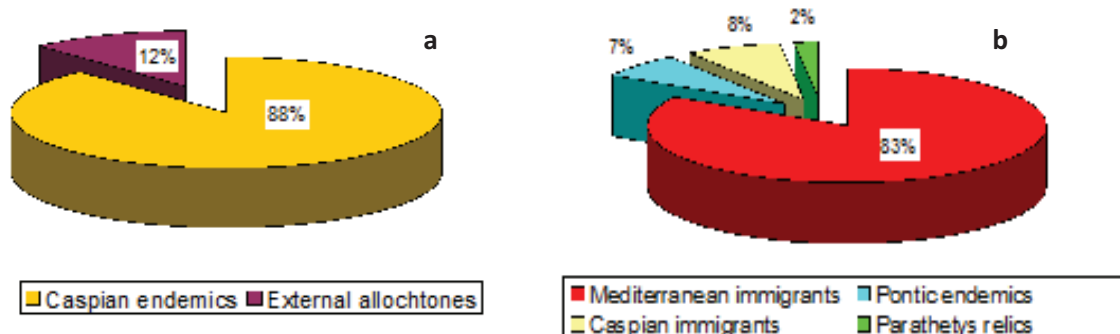


Figure 3. Origin of the Caspian (a) and Pontic (b) foraminifera

## Caspian region

Benthic foraminifera are represented by 17 genera that include 25 low rank taxa. Among the genera, 25% are known from the Paleozoic, 25% are from the Mesozoic, 19% are from the Paleogene, 30.4% are from the Neogene, and 0.6% are from the Quaternary. The Caspian endemics are mostly (62%) agglutinated forms. Two genera—*Mayerella*, Yanko 1987 and *Birsteiniolla*, Mayer 1974—and 22 low taxa are endemics. The rest—*Elphidium gunteri* Cole (present in the Eopleistocene only), *Miliammina fusca* (Brady), and *Trichochyalus aguajoi* (Bermudez)—are external allochthons well known as cosmopolitan species distributed in brackish environments around the world. Two more cosmopolitan species, *Ammobaculites exiguus* Cushman et Brönnimann and *Jadammina polystoma* Bartenstein et Brand, are represented in the Caspian by subspecies. No immigrants from the Pontic basin are present. All this suggests that Caspian foraminiferal fauna are largely inherited from the Tethys and underwent internal evolution within the basin that was isolated from the World Ocean for a very long time.

## Pontic region

The origin of the Pontic foraminiferal fauna is totally different from the Caspian one. Benthic foraminifera are represented by 55 genera that include 154 low rank taxa. There is only one agglutinated genus (*Psammosphaera*) that is known from the Early Paleozoic, all other genera are known from the Cenozoic: Paleocene (*Porosononion*), Eocene (*Elphidium*), Miocene (*Ammonia*), Early Pliocene (*Aubignyna*), and Late Pliocene (*Mayerella*). The last genus is endemic while all others are widely distributed in the Eastern Paratethys (Maysuradze, 1980). The dominant role (81%) in assemblages is played by representatives of the families of Ammonitidae (*Ammonia*) and Elphidiidae (*Porosononion* and *Elphidium*). The genus *Ammonia* is represented by ten species: Mediterranean immigrants *Ammonia agoiensis* Yanko, *A. ammoniformis* (d'Orbigny), *A. beccarii* (Linné), *A. compacta* Hofker, *A. parkinsoniana* (d'Orbigny), and *A. tepida* (Cushman); Pontic endemics: *A. novoeuxinica* Yanko, *A. caucasica* Yanko, and *A. parasovica* Shchedrina and Mayer; and Caspian immigrant *A. caspica* Shchedrina. Each species has own morphological affinities, stratigraphic and ecological preferences (Yanko, 1990b).

The genus *Porosononion* includes *Porosononion subgranosus* (Egger), *P. martkobi* Bogdanowicz, and *P. submartkobi* Yanko. The former was first described from the Miocene of Germany. It is widely distributed in the Sarmatian and Meotian of the Crimean-Caucasian region and Precarpathians (Voloshinova and Dain, 1952; Serova, 1955). In the Quaternary, this species is represented by two subspecies, which appear in two different stratigraphic levels. Subspecies *P. subgranosus mediterranicus* Yanko is distributed from Karadenizian time up to the present. Subspecies *P. subgranosus pshadicus* Yanko is known from the Old Euxinian-Early Uzunlarian only. Species *P. martkobi* played a significant role in the Early Sarmatian (Bogdanowicz, 1947). It has three subspecies: Early Sarmatian *P. martkobi martkobi* Yanko and two from the Pleistocene, *P. martkobi ponticus* Yanko, and *P. martkobi tschaudicus* Yanko. All *Porosononion* low rank taxa are holeuryhaline (1-26 psu) well adapted to a wide range of salinities.

The genus *Elphidium* is represented by twelve low rank taxa. Among them, there is the endemic species *E. caspicum* Mayer of Caspian origin. This species shows some similarities with *Elphidium gunteri* Cole but differs in having a smaller number of chambers, interseptal bridges in sutures, a coarser wall, and finer granulation compared to *E. gunteri*. The stratigraphic position (Sarmatian, Pliocene) and wide distribution of *E. gunteri* in Eastern Paratethys (Maysuradze, 1971) enable us to consider this species as an ancestor for *E. caspicum*. The latter is represented by the four subspecies: Caspian *E. caspicum caspicum* Yanko and Pontic *E. caspicum azovicum* Yanko, *E. caspicum karadenizum* Yanko, and *E. caspicum uzunlarum* Yanko.

There were eight waves of major foraminiferal migration into the Black Sea from the Mediterranean, corresponding to major sea-level changes in the World Ocean: (1) early Neopleistocene, (2 and 3) middle Neopleistocene, (4 and 5) late Neopleistocene, and (6 to 8) Holocene. In the course of each wave, new taxa arrived into the Pont. The fourth wave of immigration was the most powerful, bringing into the Pontic basin 54 Mediterranean low rank taxa, many of which do not live in the Black Sea today. This speaks in favor of much higher salinity than that of today (~33 psu) for the Karangatian basin. The eighth wave of migration brought into the Black Sea 34 Mediterranean low



rank taxa that live in the Black Sea today. These two waves can be used as markers in geologic sequences. The former corresponds to the Mikulino interglacial (MIS 5e) while the latter corresponds to the Holocene optimum. The other waves of immigration were somewhat weak, especially the seventh one, and corresponded to the low amplitude warmings during interglacials or at the end of glacial periods. It must be noted that many Mediterranean immigrants appeared in the Pontic basin repeatedly. However, each wave of immigration had its own specifics and, together with evolutionary transformations of foraminiferal fauna, can be used for stratigraphic and paleogeographic purposes.

## Conclusions

1. The Caspian foraminiferal fauna are shallow, highly endemic (92%), and contain many agglutinated (61%) species and subspecies.
2. The Pontic foraminiferal fauna are characterized by insignificant endemism (0.6%) but a large number (83%) of Mediterranean and Atlantic (mainly boreal) forms.
3. Specific Ammonitidae-Elphidiidae image of the Ponto-Caspian foraminiferal assemblages indicates a tendency of forming foraminiferal fauna from a limited number of shelf genera of the southern genesis *Ammonia*, *Elphidium*, and *Porosonion* typical for the southern closed and semi-closed seas.
3. All Pontic foraminifera are shallow, most probably due to the shallowness of the Bosphorus or any other strait that connected the Pontic and Mediterranean basins to each other.
4. The low number of high rank taxa (orders) is a result of low salinity of the Ponto-Caspian and its restricted connection to the open ocean. A similar observation was made by Gudina (1976) for the Pleistocene northern seas. As such, it mirrors a general tendency of forming foraminiferal fauna from a limited number of euryfascies orders (Ammodiscida, Astorhizida, Ataxophragmiida, Buliminida, Lagenida, Miliolida, Rotaliida) under abnormal hydrological conditions of the internal and marginal seas.

## Acknowledgments

This study is a contribution to IGCP 610 project “From the Caspian to Mediterranean: Environment change and human response during the Quaternary.”

## References

- Balabanov, I.P., 2007. Holocene sea-level changes of the Black Sea. In Yanko-Hombach, V., Gilbert, A.S., Panin, N., and Dolukhanov, P. (eds.), *The Black Sea Flood Question: Changes in Coastline, Climate and Human Settlement*. Springer, Dordrecht, pp. 711-730.
- Basso, D., Spezzaferri, S., Yanko, V., Koral, H., Avşar, N., 1994. Cruise AVI-II: Preliminary data from Iskenderun Bay (Turkey). Atti della Accademia nazionale dei Lincei CCCXCI. Classe di scienze fisiche, matematiche e naturali, Rendiconti Lincei IX(V)-3:233–245.
- Bogdanowich, A.K., 1947. O rezultatakh izucheniia foraminifer miotsena Krymsko-Kavkazskoi oblasti [On results of foraminiferal study of Miocene foraminifera from the Crimean-Caucasian region]. In Furssenko, A.V. (ed.), *Mikrofauna neftnykh mestorozhdenii Kavkaza* [*Microfauna of the Caucasus Oil Fields*]. Gostoptekhizdat, Leningrad, pp. 3-33. (In Russian)
- Gudina, V.I., 1976. *Foraminifery, stratigrafiia i paleozoogeografiia morskogo pleistotsena severa SSSR* [*Foraminifera, Stratigraphy, and Paleogeography of the Marine Pleistocene of the North of the USSR*]. Trudy Instituta geologii i geofiziki, Akademiia nauk SSSR, Sibirskoe otdelenie 314. Nauka, Novosibirsk. (In Russian)
- Holzmann, M., 2000. Species concept in Foraminifera: *Ammonia* as a case study. *Micropaleontology* 46, (Supplement 1: Advances in the Biology of Foraminifera): 21-37.
- Loeblich, A.R., and Tappan, H., 1988. *Foraminiferal Genera and their Classification*. Van Nostrand Reinhold, New York.
- Martin, R.E., and Yanko-Hombach, V., 2011. Repeated freshwater discharge events stimulated rapid sea-level change in the Black Sea during the Holocene. In Buynevich, I., Yanko-Hombach, V., Gilbert, A.S., and Martin, R. (eds.), *Geology and Geoarchaeology of the Black Sea Region: Beyond the Flood Hypothesis*. GSA Special Paper 473. Geological Society of America, Boulder, Colorado, pp. 51-58.
- Maysuradze, L., 1971. *Foraminifery sarmata Gruzii* [*Foraminifera of Sarmatian in Georgia*]. Metsniereba, Tbilisi. (In Russian)

- Maysuradze, L., 1980. *K paleobiologicheskoi istorii foraminifer pozdnego miotsena Chernomorsko-Kaspiyskogo basseina* [On the Paleobiological History of Miocene Foraminifera in the Ponto-Caspian Basin]. Metsniereba, Tbilisi. (In Russian)
- Meriç, E., Yanko, V., and Avşar, N., 1995. İzmit Körfezi (Hersek Burnu-Kaba Burun) Kuvaterner İstifinin foraminifer faunası [Foraminiferal fauna of the Quaternary sequence in the Gulf of İzmit (Hersek Burnu-Kaba Burun). In Meriç, E. (ed.), *Izmit Körfezi'nin Kuvaterner Istifi* [Quaternary Sequence in the Gulf of İzmit]. Deniz Harp Okulu Komutanlığı Basımevi, İstanbul, p. 105-152. (In Turkish with English summary)
- Orlov, Yu.A. (ed.), 1959. *Osnovy paleontologii* [Basics of Paleontology]. Gos. nauchno-tekhn. izd-vo lit-ry po geologii i okhrane nedr, Moscow. (In Russian)
- Serova, M.Ya., 1955. Stratigrafiya i fauna foraminifer miotsenovykh otlozhenii Predkarpatiya [Stratigraphy and foraminiferal fauna of Miocene deposits]. *Materialy po biostratigrafii zapadnykh oblastii Ukrainsskoi SSR* [Materials on the Biostratigraphy of the Western Regions of the Ukrainian SSR]. Gostoptekhizdat, Moscow, pp. 261-392. (In Russian)
- Voloshinova, N.A., and Dain, L.G., 1952. *Nonionidy, kassidulinidy i khilostomelidy. Iskopaemye foraminifery SSSR* [Nonionids, Cassidulinids, and Chilostomelids. Fossil Foraminifera of the USSR]. VNIGRI Proceedings 63. Gostoptekhizdat, Leningrad. (In Russian)
- Yanko, V. 1989. Chetvertichnie bentosnye foraminiferi Ponto-Kaspiia (Chernoe, Azovskoe, Kaspiiskoe i Aral'skoe moria): taxonomiia, biostratigrafiia, istoriia razvitiia, ekologiia [Quaternary Benthic Foraminifera of the Pontic-Caspian Region (Black, Azov, Caspian, and Aral seas) seas: Taxonomy Biostratigraphy, History, Ecology]. D.Sc. Thesis, Moscow State University, Moscow. (In Russian)
- Yanko, V.V., 1990a. Stratigraphy and paleogeography of marine Pleistocene and Holocene deposits of the southern seas of the USSR. *Memorie della Società Geologica Italiana* 44: 167-187.
- Yanko, V.V., 1990b. Chetvertichnie foraminiferi roda *Ammonia* v Ponto-Kaspiiskom regione [Quaternary foraminifera of the genus *Ammonia* in the Pontic-Caspian region]. *Paleontologicheskii zhurnal* 1: 18-26. (In Russian)
- Yanko, V., and Gramova, L., 1990. Stratigrafiia chetvertichnykh otlozhenii kavkazskogo shel'fa i kontinental'nogo sklona Chernogo moria po mikrofaune—foraminiferam i ostrakodam [Stratigraphy of the Quaternary sediments of the Caucasian shelf and continental slope of the Black Sea based on microfauna—foraminifera and ostracoda]. *Sovetskaya Geologiya* 2: 60-72. (In Russian)
- Yanko, V., Ahmad, M., and Kaminski, M. 1998. Morphological deformities of benthic foraminiferal tests in response to pollution by heavy metals: implications for pollution monitoring. *Journal of Foraminiferal Research* 28(3): 177-200.
- Yanko, V., Kennett, J., Koral, H., and Kronfeld, J., 1999. Stable isotopic evidence from Holocene Sea of Marmara sediments for two-way watermass interchange between the Black Sea and the Mediterranean Sea. *South African Journal of Sciences* 95(4): 201-204.
- Yanko-Hombach, V., 2007. Controversy over Noah's Flood in the Black Sea: Geological and foraminiferal evidence from the shelf. In Yanko-Hombach, V., Gilbert, A.S., Panin, N., and Dolukhanov, P. (eds.), *The Black Sea Flood Question: Changes in Coastline, Climate and Human Settlement*. Springer, Dordrecht, pp. 149-203.
- Yanko-Hombach, V., 2014. Quaternary ecostratigraphy and paleogeographic reconstructions of the Caspian region based on benthic foraminifera. In Gilbert, A.S., and Yanko-Hombach, V. (eds.), *Proceedings of the IGCP 610 Second Plenary Conference and Field Trip: "From the Caspian to Mediterranean: Environmental Change and Human Response during the Quaternary," 12-20 October 2014, Baku, (Azerbaijan)*. Nafta Press, Baku, pp. 162-170.
- Yanko-Hombach, V., Koral, H., Avşar, N., Motnenko, I., and McGann, M., 2006. Geomorphological, depositional, and foraminiferal indicators of Late Quaternary tectonic uplift in Iskenderun Bay, Turkey. In Dilek, Y., and Pavlides, S. (eds.), *Postcollisional Tectonics and Magnetism in the Mediterranean Region and Asia*. GSA Special Paper 409. Boulder, Colorado: Geological Society of America, pp. 591-614.
- Zhamoida, A.I., 2004. Problems related to the international (standard) stratigraphic scale and its perfection. *Stratigraphy and Geological Correlation* 12(4): 321-330. (Translated from *Stratigrafiia. Geologicheskaya Korrelyatsiya* 12(4):3-13. Nauka, Interperiodica.)