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# Biostratigraphy of the Konkian (Middle Miocene of the Eastern Paratethys) deposits of Southern Ukraine based on foraminifera

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## Abstract

The Konkian (Middle Miocene) foraminiferal assemblages and molluscs from five Wells situated in Southern Ukraine were studied in order to correlate the palaeoecology and biostratigraphy of the coeval palaeobasins with different environmental conditions. The article contains comprehensive analysis of controversial issues of the Konkian stratigraphy of the Eastern Paratethys and additional keys for determination of Konkian development phases by foraminifera and molluscs. Five stenohaline normal-marine, two euryhaline and one mixed foraminiferal assemblage were identified in different levels in the investigated wells with the analysis of their accordance to different molluscs assemblages. The study defines an isochronous foraminiferal assemblage for some wells, suggests a palaeoecological and stratigraphic reconstuction of the middle Miocene sediments in the Eastern Black Sea Region and recognizes two models of development of the Konkian foraminiferal assemblages. These models show the differences between environmental conditions in the shallow-water basin of the Eastern Black Sea Region and deeper water basin of the Kerch Peninsula at that time. While the Eastern Black Sea Region was influenced by frequent and abrupt changes in environmental conditions during almost all Konkian time, a relatively deeper basin of the Kerch Peninsula had a successive phase. The late Konkian time created similar depositional conditions for both basins.

## 1. INTRODUCTION

The Konkian is the Middle Miocene stage of the Eastern Paratethys that corresponds to the NN6-NN7 Nannoplankton Zone (NEVESSKAYA et al., 2005), to the Serravallian of the Global Time Scale and to the upper Badenian (Kosovian) of the Central Paratethys (HILGEN et al., 2012). The Karaganian/Konkian boundary is dated at 13.4 Ma, and the Konkian/Sarmatian boundary is dated at 12.65 Ma (PALCU et al., 2017). The Konkian (upper Badenian) time is characterized by a marine transgression which reactivated connections between the Central and Eastern Paratethys. The preceding Karaganian time was characterized by euryhaline conditions which correspond to the Badenian Salinity Crisis in the middle Badenian of Central Paratethys (e.g. MURATOV & NEVESSKAYA, eds., 1986; PERYT, 2006). After the Konkian (upper Badenian), the Sarmatian basin was characterized by palaeoenvironmental changes and the appearance of an endemic fauna in the Eastern and Central Paratethys. (e.g. MURATOV & NEVESSKAYA, eds., 1986; NEVESSKAYA et al., 2005; HILGEN et al., 2012).

The aim of this study is to understand how the foraminiferal assemblages developed and to show the differences between the shallow-water and deeper water basins in the Konkian. The results are discussed in the context of temporal and spatial changes of foraminiferal species diversity and presented together with the analysis of molluscs as an additional group in the various Konkian facies of the Southern Ukraine.

## 2. THE KONKIAN REGIONAL STAGE OF THE EASTERN PARATETHYS

### 2.1. Peculiarities of the Konkian stratigraphy of the Eastern Paratethys

The first stratigraphic studies of the Neogene of the Eastern Paratethys were based on identification of mollusc assemblages. If certain species of molluscs were traced in sections, then these deposits were defined as the same age and such mollusc associations were identified as "Beds with molluscs" (e.g. ANDRUSOV, 1917; ARKHANGUELSKY, 1930). Several "Beds with molluscs" were determined in the Konkian deposits: Beds with *Venus konkensis* in the Northern Black Sea Region of the Southern Ukraine (SOKOLOW, 1899), were named later as the Veselyanka Beds by MERKLIN (1953); the Pholadidae Beds on the Kerch Peninsula of the Southern Ukraine (ANDRUSOV, 1917); the Kartvel Beds in Georgia (DAVITASHVILY, 1930); the Sartagan Beds in Transcaspian (ZHIZHCHENKO, 1937a, b). The Kartvel Beds are characterized (Fig. 1) by Pholadidae (*Barnea pseudoustjurtensis* BOGATCHEV, *B. ustjurtensis* (EICHWALD), *B. kubanica* (ZHIZHCHENKO) *B. scrinia* (BOGATSCHEV) etc.); the Sartagan Beds are defined as deposits with a rich marine stenohaline Konkian mollusc fauna; the Veselyanka Beds are defined as deposits with euryhaline Konkian molluscs (MERKLIN, 1953; VERESHAGIN & MIRONOVA, 1982; MURATOV & NEVESSKAYA, eds., 1986). Later, such Beds with molluscs were found in the Konkian of other areas of the Eastern Paratethys (e.g. VARENTSOV, 1950; MERKLIN, 1953; MURATOV & NEVESSKAYA, eds., 1986). Shallow-water Konkian deposits often comprise Beds with *Ervilia trigonula* SOKOLOV or Beds with *E. trigonula* and *Barnea pseudoustjurtensis*, *B. kubanica* in the Southern Ukraine (MOLYAVKO, 1960; BARG, 1969). Therefore, they were called the "*Ervilia*-Pholadidae Beds" and were also considered as Kartvel Beds (BARG, 1969).

The age of the Kartvel Beds has been under discussion. These Beds were defined as belonging to both the Karaganian and the Konkian regiostages based on the mollusc species composition (Pholadidae) (ZHIZHCHENKO, 1937a, 1937b; BURIAK, 1965). They were also considered as the final stage of the Karaganian (SUDO, 1961; NEVESSKAYA et al., 2005) or were

determined as the individual Kartvelian regiostage (ZHGENTI, 1976; ILYINA, 2000; ZHGENTI & MAISSURADZE, 2016).

The presence of typical Konkian species of foraminifera (*Varidentella reussi sartaganica* KRASHENINNIKOV, *Nodobaculariella konkensis* BOGDANOWICZ, *Nonion tauricus* KRASHENINNIKOV, *Reussella spinulosa* (REUSS), *Cassidulina bulbiformis* KRASHENINNIKOV, *Discorbis kartvelicus* KRASHENINNIKOV, *D. supinus* KRASHENINNIKOV etc.) and ostracods (*Leptocythere distenta* SCHNEIDER, *Loxoconcha spongiosa* LJULJEV, *Trachyleberis lascarevi* SCHNEIDER etc.) in the Kartvel Beds is a sufficient basis to determine them as the Konkian regiostage (Fig. 1) (KRASHENINNIKOV, 1959; BARG & IVANOVA, 2000; KRASHENINNIKOV et al., 2003; BARG & STEPANIAK, 2003; BONDAR, 2004; PRISYAZHNYUK et al., 2007; GOLOVINA et al., 2009; VERNIGOROVA, 2009; IVANOVA, 2012; VERNYHOROVA, 2014, 2015a, b, 2016).

The Konkian age of the Sartagan Beds, was confirmed not only on the basis of molluscs but also by normal-marine assemblages of Konkian foraminifera (Fig. 1) such as *Quinqueloculina minakovae ukrainica* DIDKOWSKI, *Varidentella reussi sartaganica*, *Nodobacullariella konkensis*, *N. didkowskii* BOGDANOWICZ, *Articulina vermicularis* BOGDANOWICZ, *Melonis soldanii* (ORBIGNY), *Borelis melo* (FICHTEL & MOLL), *Cassidulina bulbiformis*, *Discorbis kartvelicus*, *D. supinus*, *Reussella spinulosa*, etc. (KRASHENINNIKOV, 1959; DIDKOVSKIY, 1959; DJANELIDZE, 1970) and the Konkian ostracods such as *Trachyleberis semiornara* LJULJEV, *T. golubjatnikovi* SCHNEIDER, *T. lascarevi*, *Leptocythere distenta*, *Loxoconcha spongiosa*, *Aglaiocypris konkensis* SCHNEIDER, *Aurila similis* (REUSS) etc. (BARG & STEPANIAK, 2003; BONDAR, 2004; PRISYAZHNYUK et al., 2007).

The Konkian age of the Veselyanka Beds, except for molluscs, is also confirmed by euryhaline assemblages of Konkian foraminifera (Fig. 1) such as *Nonion tauricus* KRASHENINNIKOV, *Elphidium farsiensis* KRASHENINNIKOV, *E. horridum* BOGDANOWICZ, etc. (KRASHENINNIKOV, 1959; DIDKOVSKIY, 1959; DJANELIDZE, 1970) and the Konkian ostracods (BARG & STEPANIAK, 2003; BONDAR, 2004; PRISYAZHNYUK et al., 2007). According to the recent research on the Konkian/Sarmatian boundary in Georgia, the Sarmatian age was suggested for the Veselianka Beds. This conclusion was drawn from a comparison of foraminiferal assemblages from the Veselianka Beds with those from the Sartagan Beds and the lower Sarmatian deposits (KOIAVA et al., 2016). However, these foraminiferal data were not consistent with other palaeontological data (e.g. molluscs, ostracods) from the Konkian deposits which suggested a Konkian age for the Veselianka Beds (e.g. MERKLIN, 1953; MURATOV & NEVESSKAYA, eds., 1986).

The Konkian regiostage was subdivided into three substages: Kartvel Beds, Sartagan Beds and Veselyanka Beds by MERKLIN (1953). However, there are researchers who do not support Merklin's point of view since the Konkian sections in different areas of the Eastern Paratethys have different and irregular deposit patterns with various "Beds with molluscs" (VARENTSOV, 1950; BULEISHVILI, 1960; NOSOVSKIY, 1960; CHIKOVANI, 1964; BARG, 1969; 2008; PRISYAZHNYUK et al., 2007; VERNIGOROVA, 2008, 2009, 2012). Also, some sections may have several levels with the same type of fossiliferous beds, while in others some horizons of such beds are missing (review presented in VERNIGOROVA, 2009). In addition, the Konkian deposits in Southern Ukraine comprise molluscs or foraminiferal assemblages with both normal-marine and euryhaline species (DIDKOVSKIY, 1959; MOLYAVKO, 1960; BARG, 1969; VERNIGOROVA, 2012).

As a result, researchers have two different opinions on the Konkian stratigraphy (Fig. 2). The first group considers that the Kartvel Beds, the Sartagan Beds and the Veselyanka Beds represent development phases in the Konkian basin (MERKLIN, 1953; BARG, 1993; BARG & STEPANIAK, 2003; IVANOVA, 2012; STARIN, 2012; KOIAVA et al., 2016). They are therefore used in regional stratigraphy as the Konkian substages. The second group thinks that these beds can be associated with different environmental conditions which could appear at different times during the Konkian. So they are used as additional biostratigraphic subdivisions such as "Beds with fauna" (according to ZHAMOIDA, ed., 1977; TESLENKO, ed., 1997; GOZHYK, ed., 2012) in the local stratigraphy for the correlation of sections and palaeoenvironmental reconstructions of separate areas (VARENTSOV, 1950; BULEISHVILI, 1960; CHIKOVANI, 1964; BURIAK, 1965; PRISYAZHNYUK et al., 2007; VERNYHOROVA, 2014, 2015a, b, 2016).

Thus, today the terms the Kartvel Beds, the Sartagan Beds and the Veselyanka Beds are not clearly defined, as they can refer to stratigraphic horizons or palaeoecological conditions. So, there are problems in the case of their use for the correlation when it is necessary to compare deposits with the same names but they can have different semantic meanings. Therefore, it is possible to agree with the proposal of ILYINA (2000) not to divide the Konkian stage into several substages and not to call these units by their own names such as the Kartvel Beds, the Sartagan Beds and the Veselyanka Beds. However in the case when a researcher decides to divide the Konkian into substages it is proposed to use the terms: lower, middle and upper Konkian substages. If a re-

| | Kartvel Beds | Sartagan Beds | Veselyanka Beds |
|---|---|---|---|
| Mollusca | *Barnea pseudoustjurtensis, B. ustjurtensis, B. kubanica, Ervilia trigonula* | Konkian characteristic species; predominance of stenohaline species of genera: *Chama, Chlamys, Anadara, Turreitella, Spiratella* etc. | Konkian characteristic species; predominance of euryhaline species of genera: *Parvivenus, Alvenius, Parvicardium, Sandbergeria* etc. |
| Foraminifera | Konkian characteristic species; but there aren't specific and characteristic species for identification just these beds. There are several assemblages with different paleoecological characteristics | Konkian characteristic species; predominance of stenohaline species of genera: *Lagena*, *Nodobacullariella, Spirolina*, *Globulina*, *Virgulina*, *Reussella*, *Pyrgo*, etc. | Konkian characteristic species; predominance of euryhaline species of genera: *Elphidium*, *Nonion*, *Ammonia*. Presence of a small number of normal-marine species of genera: *Bulimina*, *Cassidulina*, *Quinqueloculina* etc. is possible |

**Figure 1.** Typical species of molluscs and foraminifera from the Konkian of the Eastern Parethetys (according to ZHIZHCHENKO, 1937a, b; MERKLIN, 1953; KRASHENINNIKOV, 1959; BARG, 1969; IVANOVA, 2012, etc.).

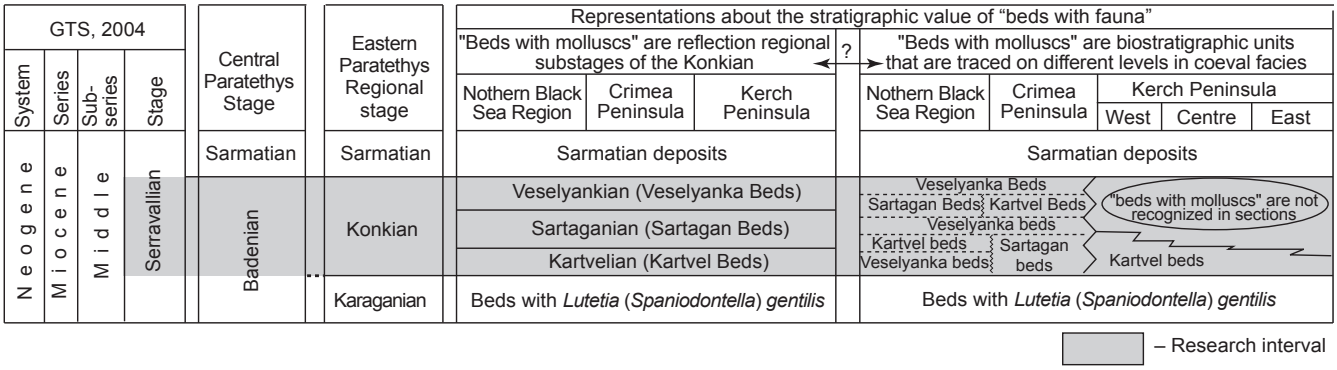


**Figure 2.** The different understanding of stratigraphic value of the Kartvel Beds, Sartagan Beds and Veselyanka Beds in the Southern Ukraine deposits in stratigraphic schemes of the Konkian of the Eastern Paratethys.

searcher still decides to use individual names for these substages then it is proposed not to call them as Beds, but rather the Kartvelian substage, the Sartaganian substage and the Veselyankian substage (e.g. MAISSURADZE et al., 2014; PALCU et al., 2017). In addition, since the initial criteria for recognition of the Konkian substages were not universal, it is necessary to clarify the definitions for each of these substages by adding criteria to aid more accurate recognition of them in sections. At the same time, it is necessary to take into account the fact that the different facies of the Konkian deposits in the Eastern Paratethys generally contain stable species assemblages of fauna with certain palaeoecological characteristics that are separate biostratigraphic subdivisions "Beds with the fauna" (according to ZHAMOIDA, ed., 1977; TESLENKO, ed., 1997; GOZHYK, ed., 2012). In this case, it has been proposed to not call these subdivisions names such as the Kartvel Beds, the Sartagan Beds, the Veselianka Beds, but to name them after the characteristic fossils (e.g. limestones with *Ervilia trigonula*, *Barnea pseudoustjurtensis*) (VERNYHOROVA, 2014, 2015a,b, 2016).

## 2.2. Criteria for determination of the initial (early) and final (late) development stages of the Konkian basin by molluscs and foraminifera

Since the different Beds with fauna may occur at different stratigraphic levels of the Konkian of the Eastern Paratethys they are not unique for particular development phases of the Konkian basin. Therefore, additional criteria for determination of the development stages of the Konkian basin are needed. Experience in the study of foraminifera and molluscs in the Konkian deposits from different areas of the Southern Ukraine, the Ciscaucasus and the Mangyshlak Peninsula (VERNIGOROVA et al., 2006, 2009; VERNIGOROVA, 2008, 2009, 2012; GOLOVINA et al., 2009; BRATISHKO et al., 2015) allows the definition of additional criteria for determination of the initial (early) and final (late) development stages of the Konkian basin (VERNYHOROVA, 2015a; POPOV et al., 2016).

An initial stage of the Konkian basin development may be recognized by a specific foraminiferal assemblage with a predominance of the genera *Cassidulina* and *Discorbis* (*Cassidulina bulbiformis*, *C. bogdanowiczi* KONENKOVA, *Discorbis kartvelicus* etc.) (Fig. 3). This regular trend can be observed in some relatively deep Konkian deposits (clays and marls) of the eastern part of the Crimean Peninsula, the Kerch Peninsula and the Ciscaucasus (KRASHENINNIKOV, 1959; BOGDANOWICZ, 1965; VERNYHOROVA, 2015a; POPOV et al., 2016; PALCU et al., 2017). This stage is clearly visible only in the most complete Konkian sections. Otherwise the stage is difficult to identify, because similar foraminiferal assemblages are present in different Konkian stratigraphic horizons, especially in the shallow-water deposits (VERNYHOROVA 2014, 2015a, b, 2016). Criteria for determining of the initial (early) development phase of the Konkian by molluscs are also not yet clearly defined. The early Konkian may contain Beds with *Ervilia* and Pholadidae. However, as has been indicated above, they are also present in other stratigraphic horizons.

The final development phase of the Konkian basin can be defined more precisely. These sediments comprise not only euryhaline species of molluscs and foraminifera which are typical for the Konkian basin but also a small amount of early Sarmatian species (e.g. molluscs – *Obsoletiforma lithopodolica ruthenica* (HILBER*), Ervilia dissita dissita* (EICHWALD) small-sized tests; foraminifera – *Elphidium horridum*, *Porosononion mart-*

| Regio-stage | Phase of development | Molluscs | Foraminifera |
|---|---|---|---|
| Konkian | late | Predominance of Konkian euryhaline species and presence of a small number of the early Sarmatian species (e.g. *E. dissita dissita*, *Obsoletiforma lithopodolica ruthenica*; their shells have small sizes) | Predominance of Konkian euryhaline species and presence of a small number of the early Sarmatian species (e.g. *E. horridum*, *Porosononion martkobi*, *Nonion bogdanowichi* ) |
| | middle | A variety of molluscs and foraminiferal Konkian assemblages that have different paleoecological characteristics. It is depend on environmental conditions in different areas of the Konkian basin especially in shallow-water deposits. | |
| | early | ? | Konkian characteristic species; reduced species composition of assemblages; normal-marine species; predominance of the genera *Cassidulina* and *Discorbis* (e.g. *C. bulbiformis*, *C. bogdanowiczi*, *D. kartvelicus*) |

**Figure 3.** Characteristics of the Konkian development phases based on foraminifera and molluscs (VERNYHOROVA, 2015a).

*kobi* (BOGDANOWICZ), *Nonion bogdanowiczi* VOLOSHINOVA). This regular trend can be observed in the Konkian sediments of the Northern Black Sea Region (including the Konkian stratotype), on the Kerch Peninsula, the Ciscaucasus and the Mangyshlak Peninsula (SOKOLOW, 1899; LIVEROVSKAYA, 1935; 1960; BOGDANOWICZ, 1965; VERNIGOROVA et al., 2009; VERNYHOROVA, 2014; BRATISHKO et al., 2015; PALCU et al., 2017).

## 3. THE KONKIAN LITHOFACIES OF THE SOUTHERN UKRAINE

The Konkian deposits of different lithofacies features are widespread in the Southern Ukraine (Figs. 4, 5). Shallow-water deposits (3-25 m thick) have accumulated in the Northern Black Sea Region and in most parts of the Crimean Peninsula (e.g. MOLYAVKO, 1960; BARG & STEPANIAK, 2003). Different types of limestones (Hladkivka Formation, Tarkhankut Formation, Mekenziev Strata) prevail in the western part of the Northern Black Sea Region and in the western and southern parts of the Crimean Peninsula; sands and sandstones (Novokakhovka Formation) are more abundant in the south-east of the Northern Black Sea Region and in the northern and central parts of the Crimean Peninsula; laminated green-grey clays with varying sandy admixtures (Tymoshivka Formation) occur in the north-eastern part of the Northern Black Sea Region (VERNYHOROVA, 2015b, 2016). The Konkian deposits in these areas have sedimentation hiatuses and these strata are not stratigraphically complete (MOLYAVKO, 1960; DIDKOVSKIY & KULICHENKO, 1975, VERNYHOROVA, 2015b, 2016).

More deep-water deposits (36-155 m thickness) are monotonous dark gray clays, partially laminated with rare sandy admixtures that have accumulated in the Kerch Peninsula and in the south-eastern parts of the Crimean Peninsula. They differ from other Konkian deposits of the Southern Ukraine by their lithological peculiarities and occurrence of more deep-water species of fauna (e.g. ANDRUSOV, 1917; OSIPOV, 1927; ARHANGUELSKY, 1930; ARKHANGUELSKY, ed., 1940; MOLYAVKO, 1960; BARG & STEPANIAK, 2003; VERNYHOROVA, 2014). These Konkian deposits represent a complete stratigraphic sequence and all of them are combined in the Petrovske Formation (VERNIGOROVA et al., 2012; VERNYHOROVA, 2014).

## 4. MATERIALS AND METHODS

The Konkian deposits were studied in five wells from several regions of the Southern Ukraine (Figs. 4, 6). There are four wells from the Eastern Black Sea Region (upper part of the Tymoshivka Formation): Well 8z (altitude – 69.5 m; thickness of the Konkian deposits – 4.2 m; 26 samples selected); Well 9 (altitude – 69.7 m; thickness of the Konkian deposits – 1.7 m; 24 samples selected); Well 6 (altitude – 30.5 m; thickness of the Konkian deposits – 5.0 m; 33 samples selected); Well 8m (altitude – 86,0 m; thickness of the Konkian deposits – 10.0 m; 47 samples selected) and one Well from the Kerch Peninsula (Petrovske Formation): Well 20 (altitude – 17.0 m; thickness of the Konkian deposits – 51.0 m; 82 samples selected). The stratigraphic sequence of these deposits was determined on the basis of foraminiferal and mollusc assemblages. Mollusc data from Well 8z were defined also by PRISYAZHNYUK et al., 2007 and were used in this research. During analysis, data on the Konkian foraminiferal and molluscs assemblages and lithological features of the Konkian deposits from other areas of the Southern Ukraine from published literature (e.g. DIDKOVSKIY, 1959; MOLYAVKO, 1960; BARG, 1993; BARG & IVANOVA, 2000) and industrial-geological reports (1947–2015) were also utilised.

The selection and determination of all species of foraminifera was made from 300 g of sediment sample that was previously washed through a 76 μm sieve (e.g. VERNIGOROVA et al., 2006; VERNIGOROVA, 2008). Descriptions and images of foramini-

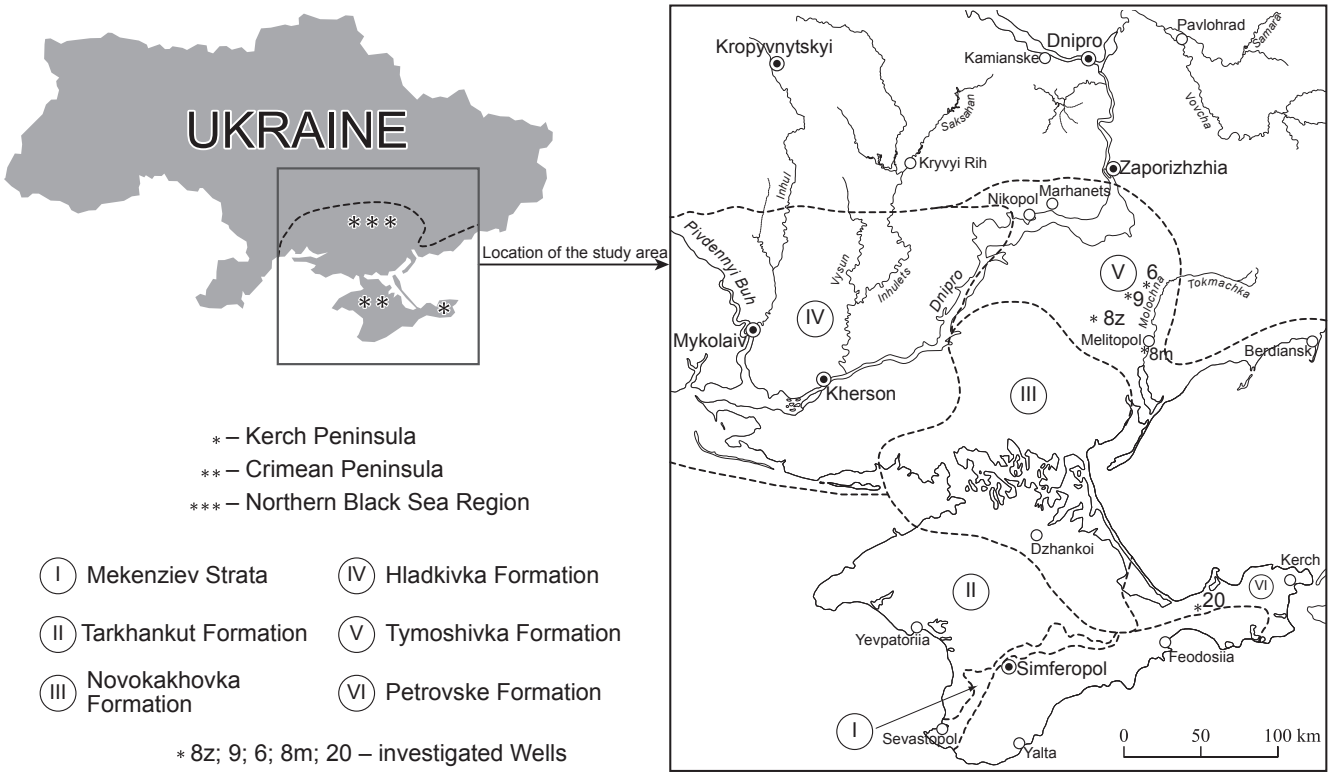


**Figure 4.** Location map of the studied wells in different facies of the Eastern Black Sea Region and the Kerch Peninsula.

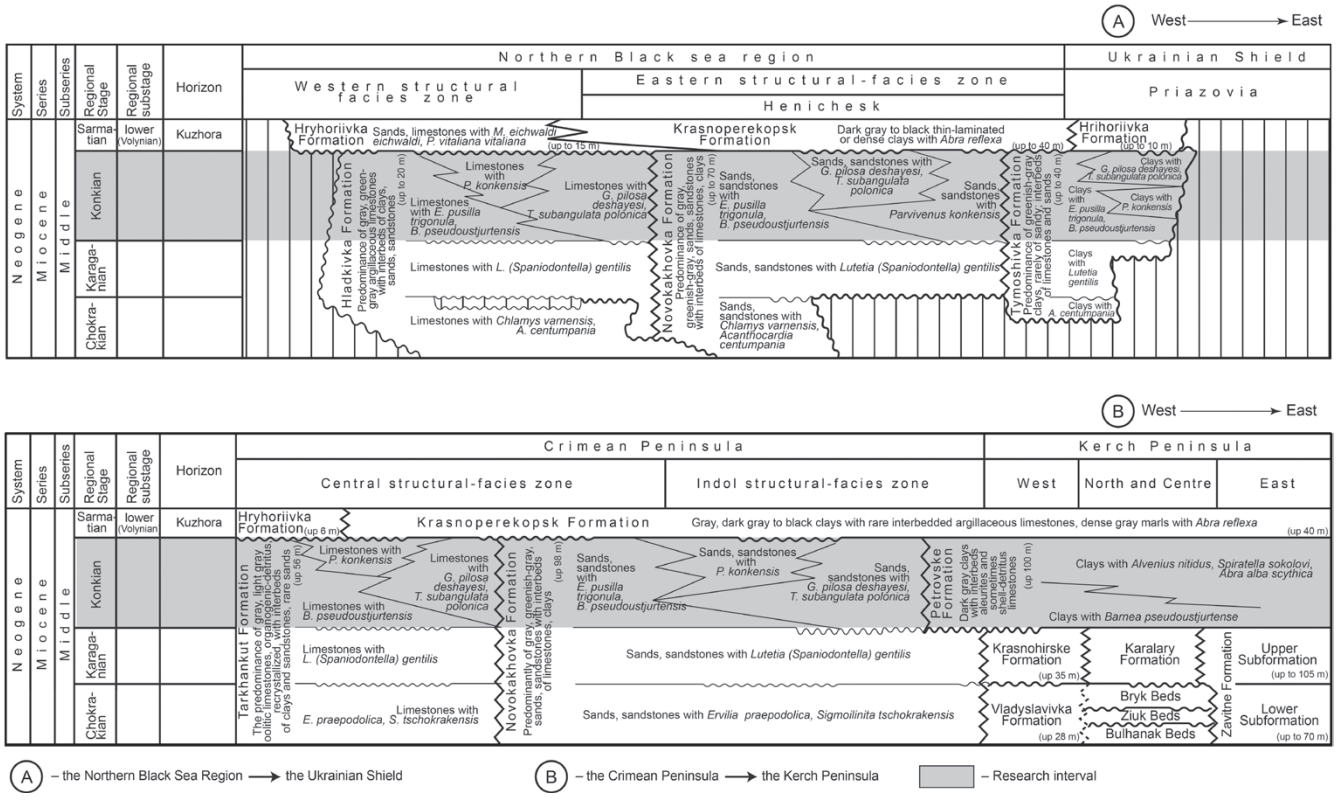


**Figure 5.** Stratigraphic scheme of the Konkian deposits of the Southern Ukraine (according to VERNYHOROVA, 2014, 2015a, b, 2016).

fera from the Neogene deposits of the Eastern Paratethys were used for their species determination (KRASHENINNIKOV, 1959; BOGDANOWICZ, 1952; DJANELIDZE, 1970; BUGROVA et al., 2005). Molluscs were extracted first, both from the vicinity of the wells and then during sample processing in the laboratory. Traditional conchological methods were used to identify molluscs (ILYINA, 1993; NEVESSKAYA et al., 1993).

The number of tests of each foraminifera species was counted in each sample for each well. Species were considered dominant when their percentage of tests was more than the percentage of tests of other species. The foraminiferal assemblages were compared based on the similarity of foraminifera species composition and the presence of the same dominant species. A definition of normal–marine, euryhaline, and mixed foraminiferal assemblages became possible after assessment of the palaeoecological characteristics of the foraminifera species composition of each assemblage. Comprehensive analysis of the data obtained from the Konkian stratigraphy of the Southern Ukraine is represented here. Descriptions and graphic presentation of qualitative and quantitative analyses of foraminiferal assemblages in the Konkian deposits from each of these wells is described in detail in: VERNIGOROVA, 2008, 2009, 2012; VERNIGOROVA et al., 2009.

Palaeoecological characteristics of foraminifera and molluscs (their classification as stenohaline, normal-marine and euryhaline species) is based on data from: ARKHANGUELSKY, ed., 1940; MERKLIN, 1953; DIDKOVSKIY & KULICHENKO, eds., 1975; MURATOV & NEVESSKAYA, eds., 1986; DIDKOVSKIY, 1959; KRASHENINNIKOV, 1959; BOGDANOWICZ, 1965; DJANELIDZE, 1970; ILYINA, 2000; MAISSURADZE et al., 2014; ZHGENTI & MAISSURADZE, 2016, etc.

Analysis of changes of foraminifera and molluscs species composition gave possibility to understand the peculiarities of the development of different regions of southern Ukraine in Konkian time. Palaeoecological and stratigraphic reconstruction of the middle Miocene deposits of the Eastern Black Sea Region was created using palaeoecological, bio- and lithostratigraphic data that were obtained both from published literature and the author's research (e.g. ARKHANGUELSKY, ed., 1940; DIDKOVSKIY, 1959; MOLYAVKO, 1960; BARG, 1969, 2008; PRISYAZHNYUK et al., 2007; VERNIGOROVA, 2008, 2009, 2012; VERNIGOROVA et al., 2009; VERNYHOROVA, 2014, 2015b, 2016).

## 5. RESULTS AND DISCUSSION

### 5.1. Peculiarities of foraminifera and molluscs assemblages in the Konkian deposits of the studied area

Five stenohaline normal-marine (NM1-NM5), two euryhaline (EH1, EH2) and one mixed (MX) foraminiferal assemblages were identified within the cores of the investigated wells at different levels (Figs. 7, 8). They are characterized by the predominance of either normal-marine or euryhaline foraminiferal taxa (e.g. KRASHENINNIKOV, 1959; BOGDANOWICZ, 1965; DJANELIDZE, 1970; KRASHENINNIKOV et al., 2003) or an equal number of marine and euryhaline foraminiferal taxa (DIDKOVSKIY, 1959; VERNIGOROVA, 2012) accordingly.

Assemblage NM1 is characterized by dominant species: *Quinqueloculina minakovae ukrainica*, *Q. pseudoangustissima* KRASHENINNIKOV, *Q.* ex gr. *consobrina* ORBIGNY, *Varidentella reussi sartaganica*, *Triloculina inflata* ORBIGNY, *T. ebersini* DIDKOVSKIY, *Globulina gibba* ORBIGNY and subdominant species: *Triloculina inornata* ORBIGNY, *Spiroloculina konkensis* BOGDANOWICZ, *Sigmoilina* sp., *Florilus boueanus* ORBIGNY, *Nonion* sp.1, *Elphidium joukovi* SEROVA, *Ammonia* ex gr. *beccarii* (LINNÉ). It was determined in three wells in the eastern part

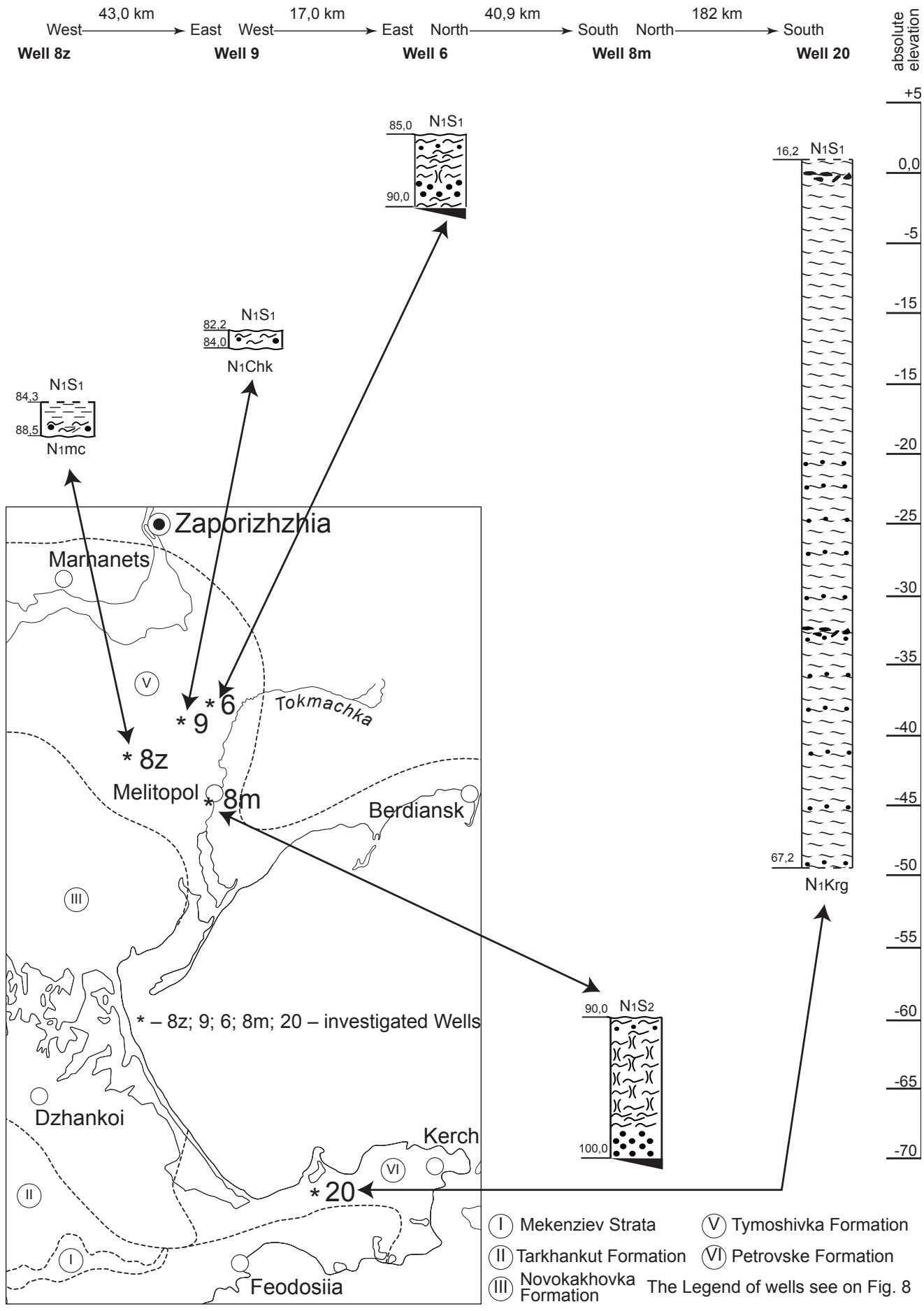


**Figure 6.** Location of the wells and schematic section of the Konkian deposits from Wells 8z, 9, 8m, and 20.

of the Northen Black Sea Region (Figs. 6, 8). The Well 8z (88.3-87.8 m) is characterized by the interbedding of light yellow-grey and green-grey loose or dense argillaceous limestones. Well 9 (83.0-82.65 m) is characterized by light-gray with a greenish tinge, dense, laminated, carbonate clays with sandy grains on bedding planes. Well 6 (87.15-87.0 m) is characterized by black with a greenish tinge argillite clays. Different molluscs were found together with this foraminiferal assemblage (Figs. 7, 8). Namely, rare shells of *Mytilaster volhynicus* (EICHWALD), *Ervilia pusilla trigonula* SOKOLOV, *Gibbula* aff. *bajarunasi* (KOLESNIKOV), *Nassarius* aff. *karaganicus* (ZHIZHCHENKO) were observed in Well 8z; similar molluscs species composition and also many shells of *Ervilia pusilla trigonula* were found in Well 9; *Nassarius* aff. *karaganicus*, *Ervilia pusilla trigonula* and rare *Hydrobia* sp., *Alvenius nitidus* (REUSS) were found in Well 6. These are normal-marine mollusc assemblages (Fig. 7) or Sartagan Beds (in the sense of MERKLIN, 1953; MURATOV & NEVESSKAYA, eds., 1986). Also the numerous shells of ostracods, remnants of bryozoans and echinoid radiole were found together with this foraminiferal assemblage (Figs. 7, 8).

Assemblage NM2 is characterized by a small number of specimens of: *Quinqueloculina gracilis* KARRER, *Q.* aff. *guri-*

| Wells (interval, m) | 8z (88,5-87,8m); 9 (83,0-82,65 m); 6 (87,15-87,0 m) | 8z (87,8-87,0 m) | 8z (86,9-86,3 m) | 6 (87,3-87,2 m 85,8-85,0 m) | 20 (67,2-18,1 m) | 9 (83,7-83,0 m); 6 (87,0-86,6 m); 8m (96,75-96,7 m 93,5-93,45 m) | 9 (84,0-83,7m); 6 (88,5-87,5 m 87,35-87,3 m 86,6-85,8 m); 8m (100,0-96,5 m) | 8z (86,3-84,3 m); 20 (18,1-16,2 m) |
|---|---|---|---|---|---|---|---|---|
| | Eastern part of the Nothern Black Sea Region | | | | Kerch Peninsula | Eastern part of the Nothern Black Sea Region | | Kerch Peninsula |
| Foraminiferal assemblages | **Beds with predominance of normal-marine species** | | | | | **Mixed assemblage MX** | **Beds with predominance of euryhaline species** | |
| | **assemblage NM1** | **assemblage NM2** | **assemblage NM3** | **assemblage NM4** | **assemblage NM5** | | **assemblage EH1** | **assemblage EH2** |
| | **Dominant species:** *Q. minakovae ukrainica*, *Q. pseudo-angustissima*, *Q.* ex gr. *consobrina*, *V. reussi sartaganica*, *Triloculina inflata*, *T. ebersini*, *Globulina gibba*<br><br>**Subdominant species:** *T. inornata*, *S. konkensis*, *Sigmoilina* sp., *F. boueanus*, *Nonion* sp.1, *E. joukovi*, *A.* ex gr. *beccarii* | **Small sizes, poor preservation, small number of shells:** *Q. gracilis*, *Q. minakovae ukrainica*, *Q.* ex gr. *consobrina*, *Q.* aff. *guriana*, *Q. angustissima*, *V. reussi sartaganica*, *T. inflata*, *G.gibba*, *D. supinus*, *D. squamulus*, *Spirolina* sp., *F. boueanus*, *Nonion* sp., *A.* ex gr. *beccarii* | **Equal quantities of shells:** *H.* aff. *podolica*, *Hauerina* sp. 1, *Hauerina* sp. 2, *Discorbis* sp. 1, *Discorbis*? sp. 2 | **Dominant species:** *R. spinulosa*, *S. austriaca*, *S.* aff. *bidentata*, *D.* cf. *haueri*, *B. melo*<br><br>**Subdominant species:** *V. reussi sartaganica*, *Nonionella ventragranossa*, *N. tauricus*, *El. antonina*, *Elphidium* sp. | **Different quantitaties of shells throughout the section:** *Q. gracilis*, *Q. guriana*, *B. floridana*, *B. dilatata*, *N. elongata*, *U. gracilissima*, *Fursenkoina schreibersiana*, *G.* aff. *austriaca*, *D. kartvelicus*, *Cassidulina* sp. | **Equal quantities of shells:** Large shells of euryhaline species: *Porosononion subgranosus*, *E. aculeatum*, *A.* ex gr. *beccarii*<br><br>**and small shells of stenohaline species:** *B. dilatata*, *N. elongata*, *U. gracilissima*, *Fursenkoina schreibersiana*, *G.* aff. *austriaca*, *R. spinulosa*, *Discorbis* sp.1, *Cassidulina* sp. | **Dominant species:** *P. subgranosus*, *El. macellum*, *A.*ex gr. *beccarii*<br><br>**Subdominant species:** *Fl. boueanus*, *Q.* aff. *guriana*, *V.reussi sartaganica*, *Discorbis* sp., *N. tauricus*, *El.joukovi* | **In upper parts of some Konkian sections**<br><br>**The same species compositions as EH1 assemblage and also admixture of shells of the Early Sarmatian species:** *E. reginum*, *E. horridum*, *Q. consobrina sarmatica*, *Articulina* sp., *Entosolenia* sp. |
| Molluscs assemblages | **Normal-marine: Well 8z** rare shells of *M. volhynicus*, *E. pusilla trigonula*, *G.* aff. *bajarunasi*, *N.*aff. *karaganicus;* Bryozoans, echinoid radiole<br><br>**Well 9** similar on well 8z but has also many shells of *Ervilia pusilla trigonula*; Bryozoans, echinoid radiole<br><br>**Well 6** *N.* aff. *karaganicus* *E.pusilla trigonula*, *rare:Hydrobia* sp., *Al.nitidus*, Bryozoans, echinoid radiole | **Beds with Pholadidae: Well 8** many shells of *Barnea pseudoustjurtensis* single shells of *E. pusilla trigonula*, *Hydrobia* sp. | **Beds with Ervilia and Pholadidae: Well 8z** many shells of *E. pusilla trigonula*, *Barnea pseudoustjurtensis, Hydrobia* sp. and shells detritus | **Normal-marine: Well 6** *Anadara turonica, V. (Polititapes) vitaliana*, *P. praeplicata*, *E. pusilla trigonula*, *Obsoletiforma lithopodolica ruthenica*, *Retusa* sp., *N.millepunctata* | **Rare shells throughout the section Well 20: 45,7-18,1 m** *S. konkensis*, *Alvenius nitidus*, *Mactra* sp., and shells detritus<br><br>**Beds with Pholadidae Well 20: 54,7-45,7 m** many shells of *Barnea pseudoustjurtensis* and shells detritus | **Euryhaline and Spirialis***:* **Well 8m: 96,7; 93,5 m** *Alvenius nitidus*, *E. pusilla trigonula*, *Cardium* sp., *Venus* sp. and plus *Spiratella* sp.<br><br>**Beds with Pholadidae Well 9: 83,50-83,32 m** many shells of *Barnea pseudoustjurtensis* and shell detritus<br><br>**Shells detritus Well 9: 83,7-83,5 m 83,3-85,8 m Well 6: 88,0-87,5 m 87,0-86,6 m** | **Euryhaline: Well 6: 88,5-87,5 m 87,35-87,3 m; 8m: 96,2-93,8 m 93,0-91,6 m 91,1-90,0 m** *A. nitidus*, *E. pusilla*, *Venus* sp.<br><br>**Beds with Pholadidae Well 8m: 100,0-97,8 m 96,4-96,2 m**<br><br>**Beds with Ervilia Well 9: 84,0-83,93 m; Well 6: 86,6-85,8 m** many shells of *E. pusilla trigonula* | **Euryhaline: Well 8z** rare shells of *Hydrobia* sp., *E. pusilla trigonula*, *Alvenius nitidus* and some terrestrial species<br><br>**Shells detritus and rare small shells of *Cardium* sp. Well 20: 18,1-16,2 m** |

**Figure 7.** General characteristics of foraminiferal and mollusc assemblages in the studied Wells (for detailed analyses of these assemblages in the Konkian deposits of each of these wells see also: PRISYAZHNYUK et al., 2007; VERNIGOROVA, 2008, 2009, 2012; VERNIGOROVA et al., 2009).

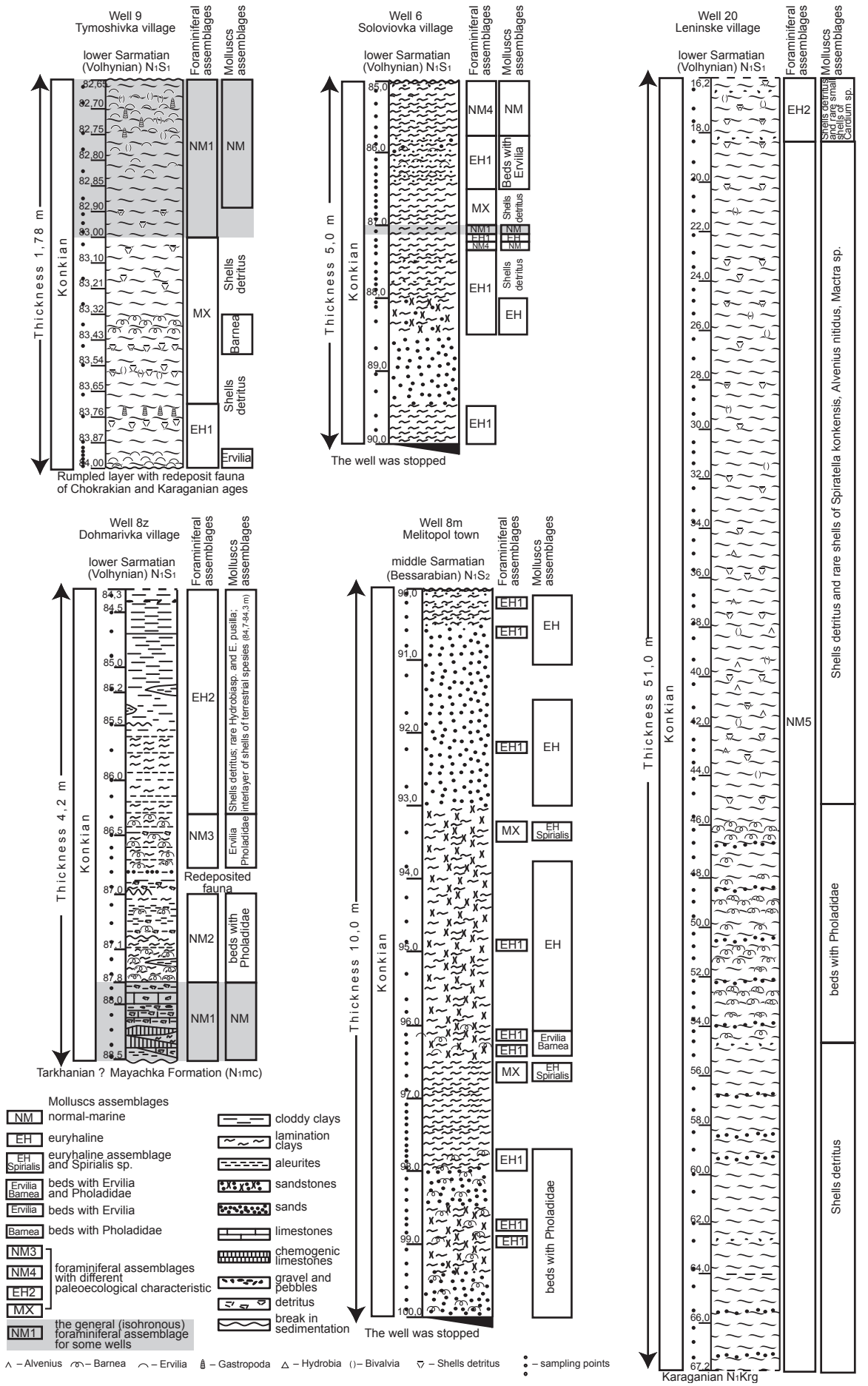


**Figure 8.** Distribution of foraminiferal and molluscs assemblages in the Konkian deposits of the studied wells.

*ana* DJANELIDZE, *Q. minakovae ukrainica*, *Q.* ex gr. *consobrina*, *Q. pseudoangustissima*, *Varidentella reussi sartaganica*, *Triloculina inflata*, *Globulina gibba*, *Discorbis supinus*, *D. squamulus* (REUSS), *Spirolina* sp., *Florilus boueanus*, *Nonion* sp., *Ammonia* ex gr. *beccarii*. It was determined in Well 8z (87.8-87.0 m) in the eastern part of the Northen Black Sea Region (Figs. 6, 8). This interval is characterized by dark grey viscous clays with aleurite powders grains on bedding planes. The numerous mollusc shells of *Barnea pseudoustjurtensis* and fragments of *Ervilia pusilla trigonula* and *Hydrobia* sp. were found together with this foraminiferal assemblage (Figs. 7, 8). These are Beds with Pholadidae (Fig. 7) or Kartvel Beds (in the sense of Merklin, 1953; MURATOV & NEVESSKAYA, eds., 1986).

Assemblage NM3 is characterized by equal quantities of poorly preserved tests: *Hauerina podolica* SEROVA, *Hauerina* sp. 1, *Hauerina* sp. 2, *Discorbis* sp. 1, *Discorbis*? sp. 2. It was determined in Well 8z (86.9-86.3 m) in the eastern part of the Northern Black Sea Region (Figs. 6, 8). These deposits are characterized by interbeddings of greenish-light-grey aleurites and darker clays. The numerous mollusc shells of *Barnea pseudoustjurtensis*, *Ervilia pusilla trigonula* and single shells of *Hydrobia* sp. were found together with this foraminiferal assemblage (Figs. 7, 8). These are Beds with Ervilia and Pholadidae (Fig. 7) or the Kartvel Beds (in the sense of BARG, 1969).

Assemblage NM4 is characterized by the dominant species: *Reussela spinulosa*, *Spirolina austriaca* ORBIGNY, *Dendritina* cf. *haueri* ORBIGNY, *Borelis melo* and subdominant species: *Varidentella reussi sartaganica*, *Nonionella ventragranossa* KRASHENINNIKOV, *Nonion tauricus*, *Elphidium antonina* KRASHENINNIKOV, *Elphidium* sp. It was determined in two levels of Well 6 (87.3-87.2 m; 85,8-85.0 m) in the eastern part of the Northern Black Sea Region (Figs. 6, 8). These deposits are characterized by greenish-dark-grey dense clays. The numerous mollusc shells have been found together with this foraminiferal assemblage (Figs. 7, 8). There are *Anadara turonica* (DUJARDIN), *Venerupis* (*Polititapes*) *vitaliana* (ORBIGNY), *Plicatiforma praeplicata* (HILBER), *Ervilia pusilla trigonula*, *Obsoletiforma lithopodolica ruthenica*, *Retusa* sp., *Natica millepunctata* LAMARK. These are normal-marine molluscs assemblages (Fig. 7) or Sartagan Beds (in the sense of Merklin, 1953; MURATOV & NEVESSKAYA, eds., 1986).

Assemblage NM5 is characterized by different abundances of foraminiferal tests in each sample without an obvious predomination of a particular species: *Quinqueloculina gracilis*, *Q. guriana*, *Bolivina floridana* CUSHMAN, *B. dilatata* REUSS, *Neobulimina elongata* (ORBIGNY), *Uvigerina gracilissima* POBEDINA, *Fursenkoina schreibersiana* (CZJZEK), *Guttulina* aff. *austriaca* ORBIGNY, *Discorbis kartvelicus*, *Cassidulina* sp. It was determined in Well 20 (67.2-18.1 m) in the western part of the Kerch Peninsula (Fig. 6, 8). These deposits are characterized by grey to light grey dense, thinly-laminated clays sometimes sandy, with aleurite powders on interbeddings. Rare mollusc shells of *Limacina konkensis* (ZHIZHCHENKO), *Alvenius nitidus*, *Mactra* sp., and shell detritus were found together with this foraminiferal assemblage (Figs. 7, 8). In addition, many shells of *Barnea pseudoustjurtensis* were found only in one part of the deposits (Well 20: 54.7-45.7 m) and these are Beds with Pholadidae (Fig. 7) or the Kartvel Beds (in the sense of MERKLIN, 1953; MURATOV & NEVESSKAYA, eds., 1986).

Assemblage EH1 is characterized by dominant species: *Porosononion subgranosus* (EGGER), *Elphidium macellum* (FICHTEL & MOLL), *Ammonia* ex gr. *beccarii* and subdominant species: *Florilus boueanus*, *Q.* aff. *guriana*, *Varidentella reussi sartaganica*, *Discorbis* sp., *Nonion tauricus*, *Elphidium joukovi*. It was determined in two Wells: 9 (84.0-83.7 m); 8m (in several samples in interval 100.0-96.5 m) and on three levels of Well 6 (88.5-87.5 m; 87.35-87.3 m; 86.6-85.8 m) in the eastern part of the Northern Black Sea Region (Fig. 6, 8). These deposits are characterized by greenish-dark-grey clays (Well 9); light-grey laminated clays with aleurite powders on interbeddings (Well 8m: 96.5-98.8 m), light-grey with a greenish tinge fine-grained, sometimes clayey quartz sands (Well 8m: 98.5-100.0 m ); interbeds of greenish-dark-grey dense clays and light-grey sandstones, with interbeds of light-grey quartz sands (Well 6: 88.5-87.3 m, 87.35-87.3 m, 86.6-85, 8 m). Different molluscs were found together with this assemblage (Fig. 7, 8). Rare mollusc shells of *Alvenius nitidus*, *Ervilia pussila trigonula*, *Venus* sp. were found together with this foraminiferal assemblage in Well 6 (88.5-87.3 m, 87.35-87.3 m) and in Well 8 (96.2-93.8 m; 93.0-91.6 m; 91.1-90.0 m). These are euryhaline mollusc assemblages (Fig. 7) or Veselyanka Beds (in the sense of Merklin, 1953; MURATOV & NEVESSKAYA, eds., 1986). Also, many shells of *Barnea pseudoustjurtensis* were found only in Well 8 (100.0-97.8 m; 96.4-96.2 m). These are Beds with Pholadidae (Fig. 7) or Kartvel Beds (in the sense of MERKLIN, 1953; MURATOV & NEVESSKAYA, eds., 1986). And also many shells of *Ervilia pussila trigonula* and mollusc detritus were found in Wells 9 and 6 (86.6-85.8 m). These are Beds with *Ervilia* and Pholadidae (Fig. 7) or Kartvel Beds (in the sense of BARG, 1969).

Assemblage EH2 is characterized by the same species composition as assemblage EH1 but also comprises some tests of the Early Sarmatian species: *Elphidium reginum* (ORBIGNY), *E. horridum*, *Quinqueloculina consobrina sarmatica* GERKE, *Articulina* sp., *Entosolenia* sp. This assemblage was determined in the upper part of the Konkian deposits before the Konkian/Sarmatian boundary in Well 8z (86.3-84.3 m) in the eastern part of the Northern Black Sea Region and Well 20 (18.1-16.2 m) in the western part of the Kerch Peninsula (Fig. 6, 8). It characterizes the final development stage of the Konkian basin (VERNYHOROVA, 2015a, b, 2016). These deposits are characterized by interbeds of greenish-light-grey aleurites and clays, bluish-light-grey non-laminated carbonate clays at the top of the interval (Well 8z); grey aleuritic, massive, thick-laminated clays with aleurite powders on interbeddings (Well 20). Rare mollusc shells of *Hydrobia* sp., *Ervilia pusilla trigonula*, *Avenius nitidus* and some terrestrial species in Well 8z and shells detritus with scarce small shells of *Cardium* sp. (Well 20) were found together with this assemblage (Figs. 7, 8). The Konkian age of deposits with this assemblage was confirmed in Well 8z by molluscs and ostracods (PRISYAZHNYUK et al., 2007).

Assemblage MX is characterized by equal abundance of large tests of euryhaline species: *Porosononion subgranosus*, *Elphidium aculeatum*, *Ammonia* ex gr. *beccarii* and small tests of stenohaline species: *Bolivina dilatata*, *Neobulimina elongata*, *Uvigerina gracilissima*, *Fursenkoina schreibersiana*, *Guttulina* aff. *austriaca*, *Reussela spinulosa*, *Discorbis* sp.1, *Cassidulina* sp. This assemblage was determined in different levels of three Wells: 9 (83.7-83.0 m); 6 (87.0-86.6 m); 8m (96,75-96,7 m; 93,5-93,45 m) in the eastern part of the Northern Black Sea Region. These deposits are characterized by light-grey carbonate dense clays (Well 9); black with a greenish tinge dense clays (Well 6); light-grey laminated clays with aleurite grains on interbeddings (Well 8m: 96.75-96.7 m) light-grey fine-grained, carbonate sandstones (Well 8m: 93.5-93.45 m). Different molluscs were found together with this assemblage (Fig. 7, 8). Namely, rare mollusc shells of *Alvenius nitidus*, *Ervilia pusilla trigonula*, *Cardium* sp., *Venus* sp. and *Limacina* sp. (mixed mollusc assemblage) were

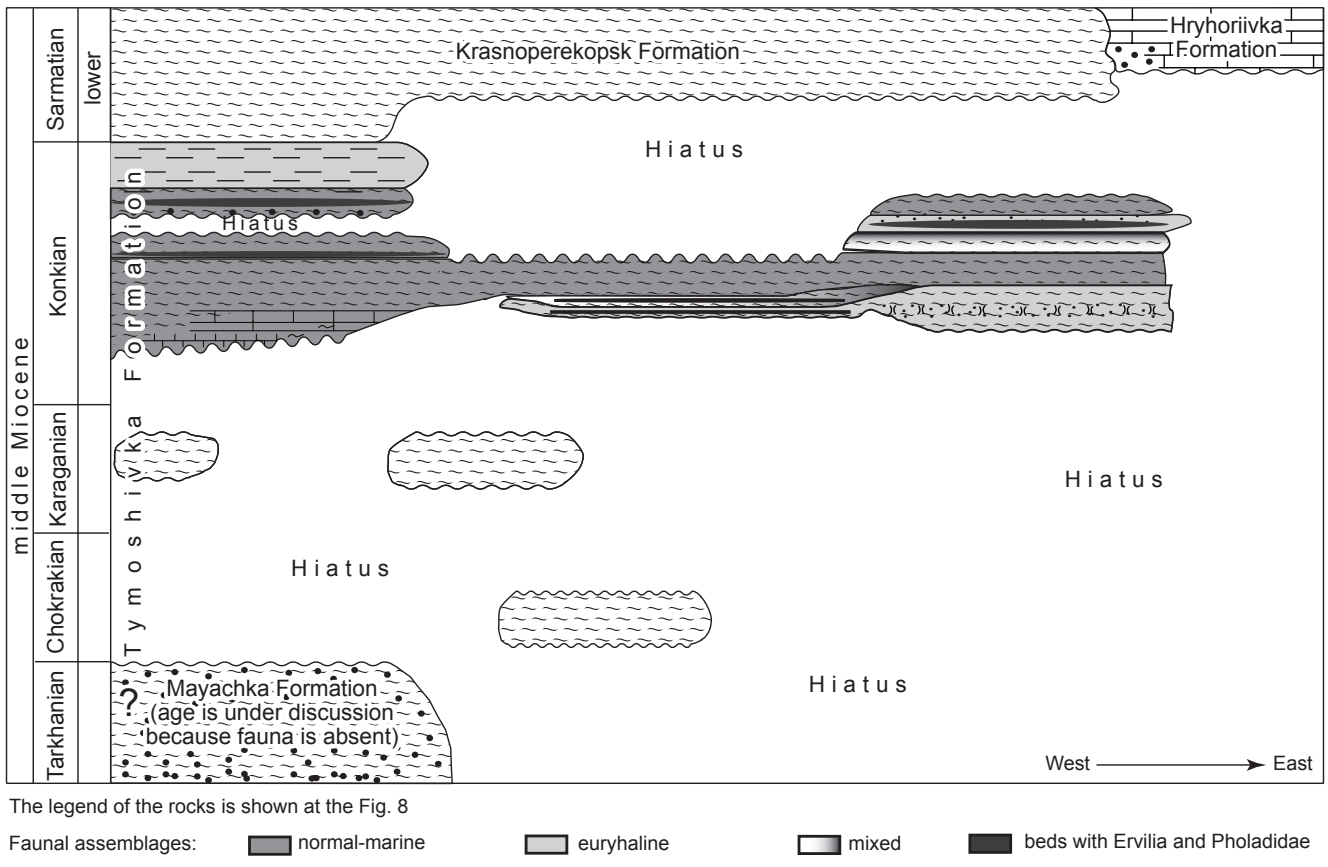


**Figure 9.** Palaeoecological and stratigraphic reconstruction of the middle Miocene deposits of the Eastern Black Sea Region.

found in Well 8m; the numerous molluscs shells of *Barnea pseudoustjurtensis* (Beds with *Pholadidae* – in the sense of MERKLIN, 1953; MURATOV & NEVESSKAYA, eds., 1986) were found in a thin layer in Well 9 (83.5-83.32 m); shells detritus were found in Well 6 and Well 9 (83.7-83.5; 83.32-83.0 m).

### 5.2. Biostratigraphic reconstruction of the Konkian deposits of the Southern Ukraine based on foraminifera

Shallow-water Konkian deposits of the Eastern Black Sea Region (Tymoshivka Formation) contain several foraminiferal assemblages with different taxonomic composition and palaeoecological characteristics. They occur together with different mollusc assemblages (Figs. 7, 8). Normal-marine foraminiferal assemblages (NM1-NM4) are accompanied by adequate mollusc assemblages (single levels of Wells 8z; 9; 6) and also by Beds with Pholadidae and by Beds with *Ervilia* and Pholadidae (two levels of Well 8z). The euryhaline foraminiferal assemblages (EH1; EH2) are accompanied by euryhaline mollusc assemblages (different levels of Wells 6; 8m) and also by Beds with Pholadidae and by Beds with *Ervilia* (different levels of Wells 9; 6; 8m). A mixed foraminiferal assemblage (MX) is accompanied by mixed mollusc assemblages (two levels of Well 8m) and also by Beds with Pholadidae (single level of Well 9). Also, some levels with different foraminiferal assemblages are composed only of the detritus of mollusc shells (different levels of Wells 8z; 9; 6). All these foraminiferal assemblages as well as mollusc assemblages have different and irregular positions in the Konkian deposits of the various wells. A similar sequence of such assemblages was found in the Konkian sections of shallow-water deposits in other areas of the Northern Black Sea Region (Hladkivka Formation, Novokakhovka Formation) and in the Crimean Peninsula (Mekenziev Strata, Tarkhankut Formation, Novokakhovka Formation) (e.g. DIDKOVSKIY, 1959; BARG, 1969, 2008; IVANOVA, 2012; VERNYHOROVA, 2015b, 2016, etc.).

The distribution of Konkian foraminiferal assemblages in more deep-water deposits of the Kerch Peninsula is significantly different from deposits of the coeval shallow-water sediments of the Northern Black Sea Region and the Crimean Peninsula. The lower and much thicker part of these deposits contains a normal-marine foraminiferal assemblage with a predominance of stenohaline species (Figs. 7, 8). A significant rearrangement of the species composition is observed only in the upper part of the Konkian deposits below the Konkian/Sarmatian boundary. These deposits contain a depleted foraminiferal assemblage with a predominance of euryhaline species and a minor admixture of the early Sarmatian species. The Kerch foraminiferal assemblages are similar to those from the relatively deep-water Konkian sediments of the Taman Peninsula and the Western Ciscaucasus (e.g. BOGDANOWICZ, 1965; GOLOVINA et al., 2009; VERNIGOROVA et al., 2006; POPOV et al., 2016; PALCU et al., 2017).

The analysis of foraminiferal assemblages with different species composition and palaeoecological characteristics revealed a common assemblage (NM1) in three Wells (8z; 9; 6) of the Eastern Black Sea Region (Figs.7; 8). Marine molluscs, bryozoans and echinoid radiole were also found together with this assemblage. Small distances between these Wells (43 and 17 km accordingly – see Fig. 6) allow consideration of these deposits with identical fauna as an isochronous level. This level was used as a benchmark for stratigraphic correlation, for identification of hiatuses and also for the reconstruction of palaeoenvironmental conditions during Konkian time in the research area. Namely, if we assume that the HM1 assemblage in different Wells was formed

contemporaneously then deposits with this assemblage represent a single biostratigraphic level and a marker for the stratigraphic evaluation of other horizons.

The final phase of development of the Konkian basin was determined in the upper part of Well 8z (the Eastern Black Sea Region) and Well 20 (the Kerch Peninsula) (Figs. 7, 8) based on the presence of the special foraminiferal assemblage (EH2) in these deposits.

Combining the data on changes of foraminiferal and molluscs assemblages with other bio- and lithostratigraphic data concerning the middle Miocene sediments of the investigated area (e.g. ARKHANGUELSKY, ed., 1940; DIDKOVSKIY, 1959; MOLYAVKO, 1960; BARG, 1969, 2008; PRISYAZHNYUK et al., 2007; VERNIGOROVA, 2008, 2009, 2012; VERNIGOROVA et al., 2009; VERNYHOROVA, 2015b; 2016) allowed the creation of palaeoecological and stratigraphic reconstruction of the middle Miocene sediments in the Eastern Black Sea Region (Fig. 9).

## 6. CONCLUSIONS

The study of spatial and temporal changes of foraminiferal assemblages in the Konkian deposits of Southern Ukraine indicate that the shallow-water basin of the Eastern Black Sea Region and the more deep-water basin of the Kerch Peninsula had different models of development during most of the Konkian period.

Two foraminiferal assemblages with different palaeoecological characteristics in the studied deposits of the Kerch Peninsula indicate two successive development phases of the relatively deep-water Konkian basin of this area. During the first, longer part of the Konkian, relatively stable marine conditions predominated, while the late period of existence of this palaeobasin is characterized by a sharp change to euryhaline conditions. Changes in foraminiferal assemblages in relatively deeper-water Konkian deposits of the Kerch Peninsula and the Ciscaucasus are similar. This indicates that basins with such types of sediments in the Eastern Paratethys had a similar pattern of development during the Konkian.

Many irregular vertical and lateral changes of foraminiferal assemblages with different palaeoecological characteristics and hiatuses observed in the shallow-water Konkian deposits of the Eastern Black Sea Region indicate that the palaeobasin in this area was influenced by frequent and abrupt changes in environmental conditions during most of the Konkian. Palaeoecological and lithological characteristics of the Konkian deposits of the Eastern Black Sea region are similar to those of other shallow-water coeval deposits of the Southern Ukraine, and it can be concluded that the development of the entire Northern Black Sea Region and most of the Crimean Peninsula were similar during this time period.

The late development phase of the Konkian was the same in both shallow-water deposits of the Eastern Black See region and more deep-water deposits of the Kerch Peninsula deposits. This phase was characterized by the presence of similar euryhaline assemblages of Konkian foraminifera (and molluscs) with a small admixture of the Early Sarmatian species.

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