

MICROFORAMINIFERS OF THE CALLOVIAN AND CRETACEOUS SEDIMENTS OF UKRAINE

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For the first time in Ukraine in Callovian and Cretaceous sediments the microforaminifers were found. They were established during the study of Mesozoic sediments palynocomplexes of 17 outcrops and wells Volyno-Podolska plate, Ukrainian Shield, the outskirts of Donbass, Priazov, Black Sea basin and the Crimea. The method of preprocessing sediments for microforaminifers was corrected. The paleontological characteristics Callovian, Berriasian, Aptian, Albian, Cenomanian, Turonian, Coniacian, Campanian and Maastrichtian deposits for microforaminifers showed in four phototables is augmented.

Key words: microforaminifers, Callovian and Cretaceous sediments, Ukraine.

МІКРОФОРАМІНІФЕРИ КЕЛОВЕЙСЬКИХ ТА КРЕЙДОВИХ ВІДКЛАДІВ УКРАЇНИ

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Вперше на території України в келовейських та крейдових відкладах виявлено мікрофорамініфери. Вони встановлені при вивченні палінокомплексів у мезозойських відкладах 17 відслонень та свердловин Волино-Подільської плити, Українського щита, окраїн Донбасу, Приазов'я, Причорноморської западини та Криму. Відкореговано методику первинної обробки порід для мікрофорамініфер. Доповнена палеонтологічна характеристика келовейських, беріаських, аптських, альбських, сеноманських, туронських, коньякських, кампанських та маастрихтських відкладів за мікрофорамініферами, що відображені у чотирьох фототаблицях.

Ключові слова: мікрофорамініфери, келовейські та крейдові відклади, Україна.

МИКРОФОРАМИНИФЕРЫ КЕЛЛОВЕЙСКИХ И МЕЛОВЫХ ОТЛОЖЕНИЙ УКРАИНЫ

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Впервые на территории Украины в келловейских и меловых отложениях выявлены микрофораминиферы. Они установлены при изучении палинокомплексов в мезозойских отложениях 17 обнажений и скважин Волыно-Подольской плиты, Украинского щита, окраин Донбасса, Приазовья, Причерноморской впадины и Крыма. Откорректировано методику первичной обработки пород для микрофораминифер. Дополнена палеонтологическая характеристика келловейских, берриаских, аптских, альбских, сеноманских, туронских, коньякских, кампанских и маастрихтских отложений данными по микрофораминиферам, что отображено в четырех фототаблицах.

Ключевые слова: микрофораминиферы, келловейские и меловые отложения, Украина.

Introduction

Today, only few experts determine Mesozoic foraminifera in thin sections and macerates. Ukraine do not have such specialists. Therefore, we summarized literature data, which covers the study of microforaminifers of Mesozoic rocks of different continents, studied and described the material collected on the territory of Ukraine.

A common feature for all foraminifera (secretion and agglutinated) is the presence of pseudochitinous base of their shells. Pseudochitinous lining (membrane, layer) is a thin layer of organic matter that forms the inner layer of foraminifera shells. The thickness of the pseudochitinous membrane in different kinds is different, so the findings do not correspond to the actual composition of foraminifera in the rock. Sometimes microforaminifers do not have the membrane but only the loculum substituted by rock. Microforaminifers – thick or thin fine "shell" forms of foraminifera from 30 to 150, sometimes up to 250 microns in size [Петросьянц и др., 1990]. Microforaminifers are often present in palynological samples as fragments that can be presented as the whole (or almost whole) samples of the original loculum, and as individual loculum or two, three or more connected loculums. Microforaminifers have an organic shell – pseudochitine that is by the chemical composition close to exine of spores,

pollen and some mushrooms – close to albuminoid protein matter, similar to keratin by the contents of sulfides. Acid resistance is explained by the composition of membrane or inner walls of individual microforaminifera loculums.

History of the study

The term *microforaminifers* was introduced by O. Wetzel [Wetzel, 1957] for the linings of young or undeveloped parts of foraminifera and their chitinous shells. The microforaminifera objects are mentioned in the work of L. Wilson and W. Hoffmeister [Wilson, Hoffmeister, 1952]. They found the microforaminifers in palynological samples. Due to their small size (according to most authors less than 150 µm) the term *microforaminifers* became common, but many people considered it inappropriate to use the name and offered other synonyms: scytinascia, basal membrane, chitinous lining, chitinous microforaminifers, tectinoid primitive foraminifera and tectinoid linear procula, nanoforaminifers, palynoforaminifers, microforaminifera lining, pseudochitinous microforaminifers [Deřk, 1964; Milk, Sotak; 1998; Петросьянц и др., 1990; Stancliffe, 1996; Глужбар, 1983; Lantos et al., 1996]. All these names have been caused by problems with the uncertainty of foraminifera chemical composition, biogenic original and the taphonomic conditions. In the

paper of N. Pantic, Z. Bajraktarevic [Pantic, Bajraktarevic, 1988] the authors found palynoforaminifers and ascertained that nanoforaminifers are distinguished from palynoforaminifers because they are carbonate and silicic nanofossils. A.D. Cohen, A.L. Guber found where in palynological species appear pseudochitinous "microforaminifers" [Cohen, Guber, 1968]. They studied the Quaternary foraminifera from brackish water peat in southwestern Florida. They dipped each type in a small amount of 30% hydrochloric acid and watched its influence through binocular microscope with a measuring scale. The researchers concluded that not every kind has visible pseudochitinous remains. The authors calculated the number of loculums and on this basis concluded that the calcite and hydrochloric acid interaction resulted in organic base release which compressed, and the size reducing reached 40%.

Although the origin of "pseudochitinous microforaminifers" is experimentally shown but the doubts remain. There is no assurance that along with the common foraminifers that appear as a result of rock processing by salt or hydrofluoric acid there are similar to them residues without mineral shell or lost it on the stage of diagenesis. This statement of course contradicts the idea that chitine and pseudochitine are unstable and easily destroyed by bacteria if they are not protected by an inorganic matter. It is known that after the death of the animal the pseudochitinous base of shell decays [Глузбар, 1983] and it is required special conditions for this natural process not to happen. Moreover, pseudochitine (tectine), compared with chitine of arthropods, is soluble in mineral acids (eg. in 10-15% hydrochloric acid and alkalis) [Глузбар, 1983]. This is contrary to the obvious number of pseudochitinous microforaminifers findings. Ukrainian palynologists always marked the microforaminifers in palinospectrums of different ages [Глузбар, 1983; Фуртес, 1987; Чорна, 1972; Федорова, 2006], but they were not investigated in detail and rarely showed on phototables.

The stratigraphic significance of microforaminifers is controversial, some scientists reject their biostratigraphic value [Глузбар, 1983], the other scientists use them for partition of sections [Лебедева, Никитенко, 1998; Никитенко, Глинских, 2006]. The stratigraphic distribution range of microforaminifers - Paleozoic – Pleistocene.

There is no doubt in the importance of microforaminifers for clarifying the conditions in which sedimentation took place, they can be used to characterize the different environments of marine sedimentation. K. Faegri, J. Iversen in 1950 said that chitine shell remaining after the destruction of calcareous shells of foraminifera, can only serve as proof of the marine origin of sediments [Петросьянц и др., 1990]. The 90 th century studies indicate that the species with the coarse primary loculum were confined to the warm waters with good light to surface waters. Instead, the species with the small original loculum indicate the growth suppression in deep water conditions [Петросьянц и др., 1990]. Thus, the morphological differences of embryonic and juvenile stages also allow to reconstruct the environmental conditions.

Materials and Methods

In our practice we tried to investigate microforaminifers for the first time. It was created the group of scientists from different fields: the palynologist, and Jurassic and Cretaceous microfauinists. The first task of palynologist was the preprocessing of rocks and detection of faunal remnants of all ages in macerates. There were studied the rocks of outcrops as well as from wells of Callovian age, Early and Late Cretaceous of Ukraine. Moreover, we compared the microforaminifers with the shell of organic matter (pseudochitine) from different lithological composition rocks. The second task of microfauinists was to determine the types of microforaminifers, study their systematic diversity, and establish the differences between complexes of microforaminifers of all ages and their comparison with normal size foraminifers in the samples of the same age.

The material for our study were Jurassic and Cretaceous samples, which were selected from 17 outcrops and wells in Ukraine: *Volyno-Podilska Plate* – borehole 42, drilled near the village of Mala Hlusha, Kamin-Kashyrsky district, Volyn region; borehole 31, drilled near the city of Lutsk; outcrop near the village of Zavadivka, Ternopil region; *Ukrainian shield* – four outcrops in Kaniv district – Melanchyn Potik, Malyy Pekarskyi Yar, Kholodnyi Yar, and Kostyannetskyi Yar and borehole 8562, drilled near the village of Polohy, Pereyaslav-Khmelnytskyi district, Kyiv region; *Donbass margins* – outcrop

near the villages of Rovenky and Hlafyryvka, Lugansk region; outcrop 1 km from the village of Zbirne (Krutenka ravine) Lutuhy district, Lugansk region; outcrop near the town of Heorhiyivka (Konoplyanka ravine) Lugansk region; *Azov region* – borehole 97, drilled in the eastern part of the village of Pokrovo-Kireyevo; *Black Sea basin* – boreholes 0121 and 0123 near the Bashtanka city, Mykolayiv region; and *Crimea* – outcrop near the village of Krasnoselivka, Tonasu river (Berriasian), Belohirsk district, outcrop near the Kacha river, Verhorichya city (upper section), Bakhchisaray district and borehole Simferopol-1, drilled in the foothills of the Crimea 1 km to the south-east from the village of Dymytrovo (Fig. 1).

Jurassic and Cretaceous sediments of these areas previously have been stratified by O.A. Shevchuk on the results of palynological studies (spores, pollen, dinocysts) [Шевчук, 2006, 2009, 2012; Доротяк и др., 2009; Стратиграфія..., 2013].

Maceration of species was performed by separation standard methods proposed by V.P. Hrychuk [Методические..., 1986], but with some amendments. It is believed that organic layers of very fine foraminifera were

coloured by Fe-oxide naturally during the early diagenesis. It protected them from destruction and made them visible in macerates [Milk, Sotak, 1998]. Microforaminifera linings or membranes are rarely preserved. In the classical method of foraminifera identifying they can be lost during the washing off because they are too fine. But microforaminifera can be removed using corrected initial processing of rocks for palynological analysis. The preparing procedure is complex. The dense rock was slightly comminuted, and more often macerated in water for one day. The decarbonatization of carbonate rocks was conducted in two phases: quenching with 30% hydrochloric acid and boiling in dilute hydrochloric acid. Microforaminifera lining is removed from the sand and clay rocks by dissolution of rocks with fossils in a diluted hydrochloric acid (10-15%), as the result the shell dissolves. After frothing the thin "glacial" membrane formed, which was destroyed by undiluted rectified alcohol. Then the rock was immersed in 40% hydrofluoric acid and boiled for 10 minutes. Then the rock was poured by hydrochloric acid again. In primary treatment an important role plays the lithological composition of rock. We conducted the

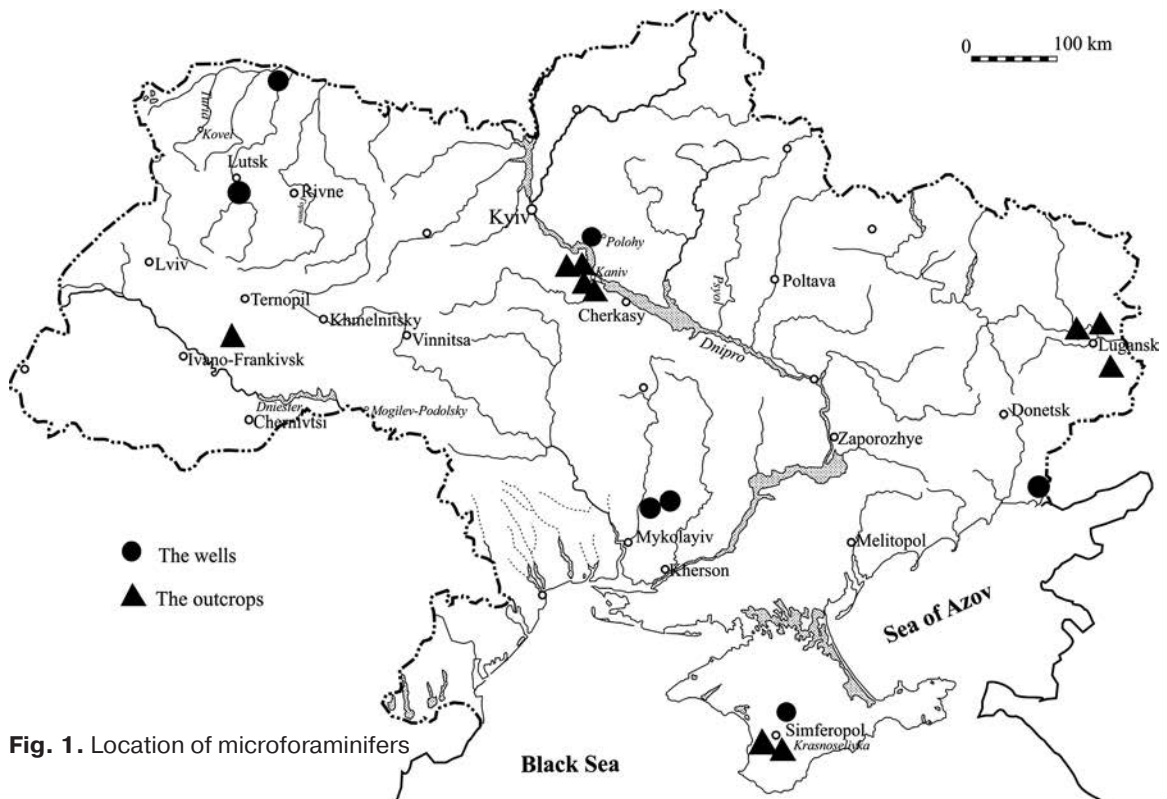


Fig. 1. Location of microforaminifers

additional heat treatment of carbonate rocks in hydrochloric acid, for some species the dispersion was carried, at the end - a heavy liquid separation. After each procedure the samples were repeatedly washed with distilled water at intervals of 2-3 hours. Alkalis and nitric acid, mostly were not used. We also conducted an experiment, emphasized by E.A. Gluzbar [Глузбар, 1983], and repeated maceration of samples of Upper Cretaceous (Cenomanian–Coniacian) sandy limestone, calcareous sandstone and chalk from the borehole 42 without separation in heavy liquids. The fragments of limestone and chalk were gradually dissolved in hydrochloric acid to the total destruction. Microforaminifers were recorded in these samples in large amounts. But the most numerous pseudochitinous microforaminifers were found in clays and siltstones (Callovian) borehole 8562, where all the technique stages were used.

In clay sediments of borehole 97 the microforaminifers were found in almost all studied samples. When macerating of these rocks there was used the method proposed by T.V. Shevchenko [Шевченко, 2006]. When processing all standard steps were used and in addition the samples were boiled in hydrofluoric acid. In carbonate sediments of borehole 42 the microforaminifers were found in all palynosamples from Cenomanian to Coniacian. In primary treatment of these rocks we used only the samples in hydrochloric acid, then the finely dispersed membrane was taken and studied under a microscope. Centrifuge and separation in heavy liquids were not involved.

We conducted laboratory studies and ascertained that the number of microforaminifers species that were saved after treatment with hydrochloric acid (chitinoid microforaminifers) is very small, but the long heat treatment with hydrofluoric acid (or hydrochloric – depending on lithology) provided the strength of these species and microforaminifers "formed" – decreased. Exsept microforaminifers (nanoforaminifers) after this treatment, in palynospectra the fungal spores (conidia mostly) are observed in large quantities.

Diagnosis and measurement of microforaminifera shells in macerates were conducted on biological microscope MBI-6 or Erhaval. A measurement of microscopic objects was conducted by special nozzles to microscopy and advanced computer programs. For viewing

under a microscope the macerates were used rather than regular samples. This enabled us to move the microscopic foraminifera species. Further, the microfaunists made a general idea of the morphology of shells. Then they divided them on features specific to families and genera. The nature of wall and structure type of shells are the most important features to distinguish a major taxon. The presence and the division nature of loculums is a feature of family and genera. The form of shell, cross-section nature, loculum shape, their number, septal sutures nature are generic and specific features. The nature and position of the mouth are basically fungible, but the structure details have species character. The further study allows us to determine the details of the structure. They may be the main distinguishing features of some species of Jurassic and Cretaceous.

Research results

The studied microforaminifers have a different form. As the shell is not preserved, we can not argue whether these forms are secretion or agglutinated, so we used the classification of M.H. Deak [Deak, 1964]. In the palynological samples were found all three types identified by M.H. Deak: the first – single row straight form (Table I, Fig. 1; Table III, Fig. 7), the second – a spiral drawn in one or three planes (Table I, Fig. 2-11; Table II, Fig. 1-9; Table III, Fig. 4, 6, 8-12; Table IV, Fig. 2, 3, 7) and the third – spherical and coiled loculums that make each other (Table I, Fig. 12; Table III, Fig. 5; Table IV, Fig. 1, 4-6). These pseudochitinous microforaminifers are well developed ("adult") shells consisting of 5-12 loculums. Another subtype of the second type can be microforaminifers that could have the initial loculum (and their lining), but after the primary processing they were dissolved. Therefore, these forms when the shells dissolved have voids in the center (Table III, Fig. 7, 12, maybe Fig. 11) and are similar to the Albian species *Trochiliascia cuvillieri* Deak, which is defined by Loeblich A.R., Jr., and Tappan H. [P. 212, Pl. 846. Fig. 11, Loeblich, Tappan, 1988]. This subtype is found only in Cretaceous sediments. Also there were found 3 microforaminifera samples of the fourth type – straight, sometimes two row, that are substituted by silicon rock (Table III, Fig. 1-3). These microforaminifera specimens were studied in chemical laboratory of PDRHP "Piv-

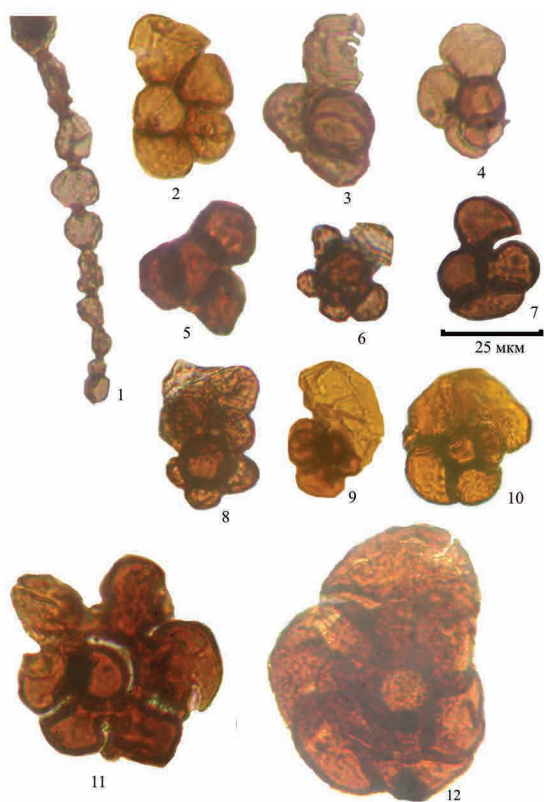


Table I. Microforaminifera of the Callovian sediments of Ukraine. Increasing x650

Fig. 1. *Subreophax* cf. *multilocularis* Haesler, borehole 8562, (Callovian). Fig. 2. *Subtrochammina* cf. *constricta* Haeus, borehole 8562 (Callovian). Fig. 3, 4. *Subtrochammina* cf. *globigeriniformis* (Parker et Jones), borehole 8562 (Callovian). Fig. 5-9. *Subtrochammina* sp., borehole 8562 (Callovian). Fig. 10. *Subrecurvoides* cf. *disputabilis* Dain., borehole 8562 (Callovian). Fig. 11. *Subhaplophragmoides* aff. *nonioninoides* (Reuss), near the town of Kaniv (Callovian). Fig. 12. *Subtrochammina* cf. *kumaensis* Levina, near the town of Kaniv (Callovian)

nichgeologiya". It should be noted that these forms were found in samples which are not applied in a heavy liquid separation. All other specimens had the pseudochitinous shell. Also there was found the multi-vertical uniaxial microforaminifera of *Nodosaria* type (Table III, Fig. 13), which can not be attributed to the described four types (not seen in classifications of M.H. Deak and R.P.W. Stancliffe), so we have singled out it as a fifth type.

The main problem in microforaminifera systematic position study is that only the inner organic layer of shells is preserved and we do not know which was the outer wall – agglutinated



Table II. Microforaminifera of the Callovian sediments of Ukraine. Increasing x650

Fig. 1-3. *Subhaplophragmoides* cf. *canariense* Orb., borehole 8562 (Callovian). Fig. 4-6. *Subkutsevella* cf. *haplophragmoides* (Fur. et Pol.), borehole 8562 (Callovian). Fig. 7-9. *Subtrochammina* cf. *inflata* (Montagu), borehole 8562 (Callovian)

or calcareous. The microforaminifera found are very small, ranging from 30 to 130 microns. The most common explanation for this is that they represent juvenile forms. However, they may represent a dwarf forms of adults living in poor conditions. We have studied the adult foraminifera shells in the same samples. Therefore, we believe that as there are the foraminifera lining and reduced in the initial processing foraminifera loculums, then the shells were slightly larger. But there are the representatives of dwarf forms. In determining the microforaminifera we followed the modern classification of Jurassic and Cretaceous foraminifera. Therefore, we believe that the organic remains of even very small foraminifera should be considered in the overall system of foraminifera, without creating a separate form classification. And if the names of generic microforaminifera taxa will repeat the name of normal size foraminifera, in order to avoid confusion, we decided to use the proposed by N.K. Lebedeva and B.L. Nikitenko [Лебедева, Никитенко, 1998] prefixes Sub- and Micro-. One of the meanings of "Sub-" in Latin is



Table III. Microforaminifera of the Cretaceous sediments of Ukraine. Increasing x650

Fig. 1. *Subheterohelix* cf. *globulosa* (Ehr.), outcrop near the villages of Rovenky and Hlafyryvka (Turonian). Fig. 2. *Subgaudrinopsis* cf. *plotnikovae* Loeb. et Tapp., (borehole Simferopol-1), (Albian-Cenomanian). Fig. 3. *Subgaudrinella* cf. *umokderensis* Aleks., Crimea (outcrop near the Kacha river) (Aptian). Fig. 4. *Subhedbergella* cf. *globigerinellinoides* (Subb.), borehole 0121 (Albian). Fig. 5. *Subtrochammina* cf. *nana* (Brady), borehole 0123 (Aptian). Fig. 6. *Subhedbergella* cf. *planispira* (Tapp.), borehole 0121 (Albian). Fig. 7. *Subsherochorella* cf. *minuta* (Tapp.), borehole 97 (Maastrichtian). Fig. 8. *Subtrochiliascia* cf. *cuvillieri* Deak, borehole 42 (Cenomanian). Fig. 9. *Subknasteria* cf. *spiralis* Macko, borehole 97 (Maastrichtian). Fig. 10. Fragment of the microforaminifera, borehole 97 (Maastrichtian). Fig. 11. *Subhemicyclammina* cf. *sigali* Maync, borehole 97 (Maastrichtian). Fig. 12. *Subtrochiliascia* sp., borehole 97 (Maastrichtian). Fig. 13. *Subspirocyclina* cf. *choffati* Munier-Chalmas, borehole 42 (Coniacian)

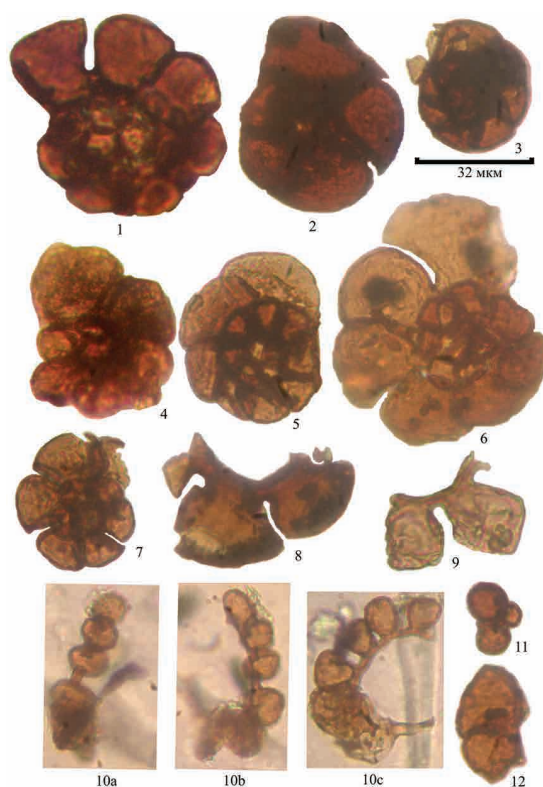


Table IV. Microforaminifera of the Cretaceous sediments of Ukraine. Increasing x650

Fig. 1. *Submarginotruncana* cf. *marginata* (Reuss), borehole 42 (Coniacian). Fig. 2. *Subvalvulinera* cf. *nonioninoides* Bandy, borehole 97 (Maastrichtian). Fig. 3. *Subgyroidinoides* cf. *turgidus* (Hag.), borehole 97 (Maastrichtian). Fig. 4. *Subkutsevella* cf. *pseudogoodlandensis* (Mjatl.), near the village of Krasnoselivka, Crimea (Berriasian). Fig. 5. *Subglobotruncanita* cf. *stuarti* (Lappar.), borehole 97 (Maastrichtian). Fig. 6. *Subglobotruncana* cf. *lapparenti* Brotz., borehole 97 (Maastrichtian). Fig. 7. *Subglobotruncana* cf. *ventricosa* White, borehole 97 (Maastrichtian). Fig. 8, 9, 11, 12. Fragment of the microforaminifera, borehole 97 (Maastrichtian). Fig. 10 a, b, c. Fragments of the same microforaminifera with spherical cameras in different projections, borehole 97 (Maastrichtian)

"inside" or "under". Thus, the generic names of microforaminifera taxa will reflect the closeness to the genera of existing natural system foraminifera classification and at the same time by the prefix Sub- emphasize their size. We also offer to combine the microforaminifera in a common natural classification system with the simple foraminifera. In this case, you can use this group fully in solving problems of biostratigraphy and biofacial analysis.

Given all the above described details of our research we supplemented the paleontological characteristics of Callovian, Berriasian, Aptian, Albian, Cenomanian, Turonian, Coniacian, Campanian and Maastrichtian deposits with data on microforaminifers (Fig. 2).

Microforaminifers found in Callovian deposits samples (**borehole 8562**, 145.25 m), which are the lower part of Ichnyanska suite, composed of calcareous sandstone, siltstone and siliceous clays. There were found the microforaminifers *Subhaplophragmoides* cf. *canariense*

Period	Epoch	Stage	Lithology	Mikroforaminifers																		Features of the primary rocks processing													
				Benthic									Planktonic																						
				Agglutinated									Secretion	Planktonic									Unspecified systematic origin												
Cretaceous	Late	Maastrichtian	clay dark gray, sandy	Subreophax cf. multilocularis	Subherchorella cf. minuta	Subrochammina sp.	Subrochammina cf. kumaensis	Subrochammina cf. constricta	Subrochammina cf. globigeriniformis	Subrochammina cf. nana	Subrochammina cf. inflata	Subrecurvoides cf. disputabilis	Subhaplophragmoides aff. nonioninoides	Subhaplophragmoides cf. canariense	Subgaudryinella cf. umokderensis	Subhemicyclammina cf. sigali	Subpirocyclina cf. choffati	Subkusevella cf. haplophragmoides	Subkusevella cf. pseudogoodlandensis	Subgaudryinopsis cf. plotnikovae	Subvalvulineria cf. nonioninoides	Subgyroidinoides cf. turgidus	Subglobotruncamita cf. stuarti	Subheterohelix cf. globulosa	Subhedbergella cf. globigerinellinoides	Subhedbergella cf. planispira	Subglobotruncana cf. lapparenti	Subglobotruncana cf. ventricosa	Submargino truncana cf. marginata	Subrochiliascia cf. cuvillieri	Subrochiliascia sp.	Subnasteria cf. spiralis	Uncertain systematic form of belonging	Tom and damaged forms	1.Demineralization in 10% HCl 2.Boiling in 40% HF 3.In heavy liquid separation (potassium iodide and cadmium)
		Campanian	marl																																1.Demineralization in 30% HCl 2.Boiling in 40% HF 3.Some samples in heavy liquid separation
		Coniacian	calcareous rocks																																1.Demineralization in 30% HCl
		Turonian	chalk, sandstones clay																																1.Demineralization in 30% HCl
		Cenomanian	black clay carbonaceous, white chalk																																1.Demineralization in 30% HCl 2.Boiling in 40% HF 3.In heavy liquid separation some samples
	Early	Albian	sand, clay, sandstone, siltstones, siliceous rocks																															1.Demineralization in 10% HCl 2.Boiling in 40% HF 3. Centrifugation 4. In heavy liquid separation	
		Aptian	gray clay with aleurites																															1.Demineralization in 10% HCl 2.Boiling in 40% HF 3.Centrifugation 4.In heavy liquid separation	
		Berriasian	clay green-gray, aleurites, marls																															1.Demineralization in 10% HCl 2.Boiling in 40% HF 3.Centrifugation 4.In heavy liquid separation	
	Jurassic	Middle	Callovian	sandstones calcareous, siltstones siliceous, brown clay																														1.Demineralization in 10% HCl 2.Boiling in 40% HF 3.Centrifugation 4.In heavy liquid separation	

Legend: — 1-3 pieces — 3-10 pieces — 10-20 pieces — 20-30 pieces

Fig. 2. Stratigraphic distribution of typical microforaminifers in Jurassic and Cretaceous sediments of Ukraine

Orb., *Subkutsevella* cf. *haplophragmoides* (Fur. et Pol.), *Subtrochammina* cf. *inflata* (Montagu), *Subtrochammina* cf. *constricta* Haesler and *Subtrochammina* spp. – in large quantities and *Subtrochammina* cf. *globigeriniformis* (Parker et Jones), *Subrecurvodes* cf. *disputabilis* Dain., *Subreophax* cf. *multilocularis* Haesler. There are the damaged form microforaminifers. These deposits were previously stratified by the authors according to palynological analysis and foraminifers [Шевчук, 2012; Стратиграфія..., 2013]. There were established the Callovian palynological and dinocyst complexes characterizing the Ctenidodinium ornatum-Ctenidodinium continuum zone, which corresponds to the upper parts of lower and middle Callovian. There are acritarchs, plant tissues, pteridophytes spores in perispores, pigment flakes of insects (butterflies) and body parts of insects.

In Callovian sediments near the town of **Kaniv** (Melanchyn Potik, Malyi Pekarskyi Yar, Kostyanetskyi Yar), which are represented by the Ivanytska suite deposits, composed of light-brown to black clay were found the microforaminifers *Subtrochammina* cf. *kumaensis* Levina and *Subhaplophragmoides* aff. *nonionoides* (Reuss). In these sediments there are the normal size foraminifera, bivalves, ostracods, sponge spicules, Callovian palynological complex, dinocysts, acritarchs and prasinophytes. The authors previously stratified these deposits by the flora and fauna groups as Upper Callovian [Стратиграфія..., 2013]. Microforaminifers were found in Late Albian sediments near the town of Kaniv in Kholodnyi Yar. The Albian deposits are represented by the Upper Albian sand with sandstone. Marine Albian sediments are composed of gray-green, glauconite, inequigranular sand with the layers and aggregates of greenish-gray glauconitic sandstone with remains of plants, wood debris and marine fauna. The microforaminifers *Subhedbergella* cf. *planispira* (Tapp.) and *Subgaudryinopsis* cf. *plotnikovae* Loeb. et Tapp. were found in these sediments. These deposits were previously stratified by palynological data (palynological complex, dinocysts) as Late Albian and according to spicule analysis as Cenomanian [Стратиграфія..., 2013].

In Berriasian deposits of Crimea near the village of **Krasnoselivka** (Tonas river and its tributaries) represented by the double-anchor suite (top), which is composed of greenish-gray

thin-slabby clay, siltstone and marl were found the microforaminifers *Subkutsevella* cf. *pseudogoodlandensis* (Mjatl.). These deposits were previously stratified by authors as Berriasian [Стратиграфія..., 2013; Доротяк и др., 2009]. There were defined the normal size foraminifera, bivalves, numerous small gastropods, sea urchin needles in these deposits and Berriasian palynological and dinocysts complex corresponding to the area Pseudoceratium pelliferum (Berriasian), the rare forms of fungal spores of phycomyces class – conidia.

In Aptian deposits of Crimea near the village of **Verkhorichchya** (Kacha river) represented by gray silty clays (Biasalinska suite) there are microforaminifers *Subgaudryinella* cf. *umokdrensis* Aleks. In the representatives of the family Verneuilinidae, to which also belongs this genus, researchers observe the presence of pseudochitinous inner layer [Введение..., 1981]. The Aptian palynological complex is established [Шевчук, 2009; Стратиграфія..., 2013].

In Aptian sediments, **borehole 0123** represented by sediments of Novooleksiyivska suite, which is composed of sandstones, siltstones, clays with limestone interlayers there are microforaminifers *Subtrochammina* cf. *nana* (Brady). The Novooleksiyivska suite corresponds to the Middle and Upper Aptian according to palynological complex and sometimes the Lower and Middle Albian according to foraminifers *Hedbergella aptica* Agal., *Cibicidoides djaffarovi* Agal. [Стратиграфія..., 2013].

In Albian sediments, **borehole 0121** (247.8-250.5 m) represented by sediments of Zakhidnomykolayivska series, which is composed of marl, sandstone, clay, chert there are microforaminifers *Subhedbergella* cf. *planispira* (Tapp.) and *Subhedbergella* cf. *globigerinellinoides* (Subb.). These deposits were previously stratified by palynological (palynological complex, dinocysts, acritarchs) and microfauna data as Albian [Стратиграфія..., 2013].

In Cenomanian deposits of Crimea, **borehole Simferopol-1** (3424-3425 m), which are represented by dark gray to black, clay, poor carbon, thin layered, dense shale there are microforaminifers *Subgaudryinopsis* cf. *plotnikovae* Loeb. et Tapp. These deposits were previously stratified by palynological data (palynological complex, dinocysts) as Cenomanian [Стратиграфія..., 2013]. There are also the fragments of sponge spicules and radiolarians.

In Cenomanian sediments, **borehole 42**, represented by the layers of inoceramus limestone there are microforaminifers *Subtrochiliascia* cf. *cuvillieri* Deak. These deposits were previously stratified according to palynological analysis [Шевчук, 2006; Стратиграфія..., 2013]. There were established the Cenomanian palynological and dinocyst complexes represented by *Ovoidinium* sp., *Litosphaeridium siphoniphorum* Cookson et Eisenack, *Cribroperidinium intricatum* Davey, *Epelidosphaeridia spinosa* Cookson and Hughes (Davey). There are also the spicules of sponges. In Turonian deposits of **borehole 42** represented by the lower subsuite of Zdolbunivska suite, which is composed of white porous soft chalk there are microforaminifers of uncertain systematic status, maybe *Subtrochiliascia* sp. These deposits were previously stratified according to palynological analysis [Шевчук, 2006; Стратиграфія..., 2013]. There were established the Turonian palynological and dinocyst complexes. In Coniacian deposits of **borehole 42** represented by the upper subsuite of Zdolbunivska suite, which is composed of white writing porous clay chalk there are microforaminifers *Subspirocyclina* cf. *choffati* Munier-Chalmas and *Submarginotruncana* cf. *marginata* (Reuss). These deposits were previously stratified according to palynological analysis [Шевчук, 2006; Стратиграфія..., 2013]. There were established the Coniacian palynological and dinocyst complexes characterizing the Subtilisphaera pontis–mariae zone, which corresponds to the upper Turonian – Coniacian.

In Turonian deposits, **borehole 31** (68.20 m), represented by writing chalk there are microforaminifers of uncertain systematic status. These deposits were previously stratified by palynological data (palynological complex, dinocysts) as Turonian [Стратиграфія..., 2013].

In Turonian deposits, outcrop near the village of **Zavadivka**, represented by the sediments of lower subsuite of Dubovetska suite which is composed of white chalky creamy limestone there are microforaminifers *Subtrochiliascia* sp. There are also the Turonian palynological and dinocyst complexes, and fossil remains of fungi – conidia. These deposits were previously stratified according to palynological analysis as Turonian [Стратиграфія..., 2013].

Cenomanian-Turonian deposits of Lugansk region near the village of **Rovenky**, section

Hlafyryvka (sample 33) are represented by Slovyanohirska suite that composed of sand and calcareous sandstones. It was thought that the Cretaceous section of the village of Hlafyryvka is of Cenomanian age. In calcareous sandstone L.M. Yakushyn defined the bivalve mollusc *Nucula* cf. *pectinata* Sow., according to which the age of these rocks is considered as Cenomanian. From this section O.A. Shevchuk showed the palynocomplex and dinocysts characteristic of Cenomanian. There are the microforaminifers *Subheterohelix* cf. *globulosa* (Ehr.). However, the studied characteristic species of normal size foraminifera complex indicate the Early Turonian age: *Spiroplectamina cuneata* Vass., *Arenobulimina minima* Vass., zonal index species – *Globorotalites hangensis* Vass., *Gavelinella vesca* (N. Byk), *G. nana* Ak., *Brotzenella belorussica* (Ak.). By zonal type there is the *Globorotalites hangensis* area, the top of the lower Turonian. This foraminifera zone corresponds to the upper part of macrofauna zone *Inoceramus labiatus* of lower Turonian subformation [Стратиграфія..., 2013]. There was determined the impoverished foraminifera complex represented by small shallow water coastal forms. The foraminifer's shells are poorly preserved and depressed. There are phosphate foraminifera and ostracods, fragments of bryozoans and sponges spicules, sea urchins needles, single radiolarians and shark teeth.

In Campanian sediments from the outcrop near the village of **Zbirne** (1 km from the village of Krutenka, sample 21), belonging to the lower part of Sydorivska suite (bottom of the Upper Campanian) composed of light gray sandy marls there are microforaminifers of uncertain systematic association of the two types of spiral and spherical form with convoluted loculums. There are normal size and ferruginized foraminifera in this sample. The characteristic species of foraminifera: *Cibicidoides aktulagayensis* (Vass.), *C. voltzianus* (Orb.), *Heterostomella foveolata* (Marss.), *H. praefoveolata* Mjatl., *Voloshinovella laffitei* (Marie), *Brotzenella monterelensis* (Marie), *B. menneri* (Kell.), *Pseudouvirgerina cretacea Cushman*, which indicate the Upper Campanian zone *Brotzenella monterelensis* [Стратиграфія..., 2013]. There are ostracod valves. The Campanian palynological complex is represented by *Sphagnumsporites* sp., *Lycopodiumsporites* sp., *Osmundasidites* sp., *Todisporites* sp., *Matoniasporites* spp., *Lygodiumsporites* sp.,

Coniopterius sp., *Cyathidites* sp., *Alsophilla* sp., *Gleicheniidites laetus* (Bolch.) Bolch., *Plicifera delicata* (Bolch.) Bolch., *Ornamentifera echinata* (Bolch.) Bolch., *Pinus* spp., *Platysaccus* sp., *Pollenites* sp., *Oculopollis* sp., *Gothanipollis* sp., *Nudopollis* spp., *Extratiporo-pollenites clarus* Pfl., *Extratiporo-pollenites perforates* Zaklinskaja and dinocyst complex (typical: *Odontochitina* spp., *Isabelidinium* sp., *Avellodinium* sp., *Aldorfia deflandrei* (Clarke and Verdier) Stover and Evitt) and the remains of fossil fungi – conidia were found for the first time. It is the Upper Campanian according to macro- and microfauna [Стратиграфія..., 2013] and new palynological data.

In Campanian sediments, outcrop near the village of **Heorhiyivka** (Konoplyanka ravine, sample 42), Lugansk region, belonging to the lower part of Sydorivska suite (bottom of Upper Campanian) there are microforaminifers like *Subtrochiliascia* cf. *cuvillieri* Deak. In this sample we identified normal size foraminifera of Globorotalites emdyensis zone of Upper Campanian with a characteristic complex – *Ataxophragmium crassum caspium* Vass., *Cibicoides aktulagayensis* (Vass.), *C. voltzianus* (Orb.), *B. monterelensis* (Marie), *Globorotalites emdyensis* Vass., *Bolivinoidea delicatulus* Cushman. and lenticular foraminifera *Pseudosiderolites muschketovi* Zern. [Стратиграфія..., 2013]. There were found a shark tooth and ostracod shells. The Campanian palynological complex – *Lycopodiumsporites* sp., *Osmundasidites* sp., *Matoniasporites* spp., *Lygodiumsporites* sp., *Coniopterius* sp., *Cyathidites* sp., *Gleicheniidites laetus* (Bolch.) Bolch., *Plicifera delicata* (Bolch.) Bolch., *Pinus* spp., *Platysaccus* sp., *Pollenites* sp., *Oculopollis* sp., *Gothanipollis* sp., *Nudopollis* spp., *Extratiporo-pollenites perforates* Zaklinskaja, and dinocyst complex – *Aldorfia deflandrei* (Clarke and Verdier) Stover and Evitt, *Odontochitina costata* Alb. and the appearance of *Areoligera senonensis* Lejeune-Carpentier were found for the first time. Previously described by macrofauna – *Belemnitella langei* Schatsk., *Bostrychoceras polyplacum* (Roem.) belong to the Upper Campanian according to macro- and microfauna [Стратиграфія..., 2013] and new palynological data.

In Maastrichtian sediments, **borehole 97** (43.25 m and 47.25 m), the East Sea of Azov, represented by dark gray sandy clay without carbonates (not showed in the scheme) there are microforaminifers *Subtrochiliascia* sp.,

Subknasteria cf. *spiralis* Macko, *Subvalvulineria* cf. *nonioninoides* Bandy, *Subglobotruncana* cf. *lapparenti* Brotz., *Subglobotruncana* cf. *ventricosa* White, *Subglobotruncana* cf. *stuarti* (Lappar.), *Subgyroidinoides* cf. *turgidus* (Hag.), *Subsherochorella* cf. *minuta* (Tapp.), *Subhemicyclammina* cf. *sigali* Maync and uncertain systematic form of belonging. There are many fragments of microforaminifers with dissolved loculums and fragments of spherical and convoluted loculum forms. The form shown in Table IV, Fig. 10 a, b, c is similar to the form of *Subtrochiliascia* cf. *cuvillieri* Deak, but we have a piece of lining, Fig. 10 which seems the similar, but by needle in macerate we can see the forms in different projections, as the Fig. 10b and 10c show that the form is spiral. The loculums of such microforaminifers like a strung on a spiral. There are also found a lot of broken damaged forms, Table IV, Fig. 11, 12 in this sample, it may be the result of initial processing stage, which was associated with prolonged centrifugation. L.F. Plotnikova found the complex of normal size foraminifera in these deposits: *Plectina ruthenica* (Reuss), *Cibicoides* cf. *voltzianus* (Orb.), *Cibicoides aktulagayensis* Vass, *Eponides conspectus* Vass, indicating the Early Maastrichtian. The dinocysts *Odontochitina* spp., *Odontochitina operculata* (O. Wetzel) Deflandre et Cookson, *Odontochitina costata* Alberta emend. Clarke Verdier., *Isabelidinium* sp., *Cerodinium* sp. were found in these sediments for the first time. The dinocysts dominate, namely *Spiniferites* spp., *Spiniferites ramosus* (Ehrenberg) Mantell, *Cleistosphaeridium* spp., *Cordosphaeridium* sp., *Oligosphaeridium* sp. There are rare exemplars of *Subtilisphaera* sp., *Hystrichodinium* sp., *Hystrichosphaeridium tubiferum* (Ehrenberg) Deflandre, *Operculodinium* sp., *Comparodinium* sp., *Achomosphaera* sp., *Deflandrea magna* Davey, *Cyclonephelium* Willams et Downie. For the first time in the studied territory of Maastricht sediments there was found the palynological complex, represented by: *Gleicheniidites laetus* (Bolch.) Bolch., *G. senonicus* (Ross.) Grig., *G. latifolius* Doring, *Lygodiumsporites subsimplex* (Bolch.) Bolch. There is gymnosperms pollen: pollen grains *Welwitschiapites* sp., *Araucariacites* sp., *Psophosphaera* sp., coniferous pollen of Pinaceae and Podocarpaceae genera (*Podocarpus* sp.). Pinaceous is represented by *Piceae* sp., *Cedrus libaniformis* Bolch., *Pinus* spp., *Pinus vulgaris*

Naum., *Pinus trivialis* Naum., *Pinus insignis* Naum. Angiosperm pollen: *Pollenites* sp., *Oculopollis* sp., *Nudopollis* spp., *Extratiporo-pollenites clarus* Pfl., *Extratiporo-pollenites vestifex* Pfl., *Basopollis* aff. *orthobasalis* Pfl., *Trudopollis spesiosus* Zaklinskaja, *Trudopollis nonperfectus* Pfl., *Trudopollis ordinates* Zaklinskaja, *Trudopollis pompeckji* (R.Pot.) Pfl. The Maastrichtian deposits that are dark gray sandy clay without carbonates are described for the first time. According to systematic composition and percentage of microphytofossils in a complex the age of rocks can be dated as the Early Maastrichtian.

Conclusions

On the results of microforaminifers in macerates of Mesozoic sediments of Ukraine there are the following conclusions.

It is corrected the technique of initial processing of rock used for palynological analysis to extract microforaminifers from the Mesozoic rocks. It should be noted that the samples of carbonate rocks that have been treated with hydrochloric acid, in macerates contained nanoforaminifera linings which were quite brittle to the touch, and sometimes were destroyed. The samples of marl and alurite rocks, after treatment with hydrochloric and hydrofluoric acids contained in macerates the microforaminifers with pseudochitinous membranes possible to turn and touch, they suffered a slight strain, but not destroyed. So the hydrofluoric acid hardened the pseudochitinous membranes. The use of alternative methods of detection and determination of the taxonomic composition of Jurassic and Cretaceous microforaminifers substantially complement the characterization of foraminifera complexes of the studied area.

To classify the new forms we compared Jurassic and Cretaceous microforaminifers found in Ukraine with similar fossils studied by European, American and Russian scientists.

Since we were able to trace the distribution and diversity of microforaminifers from Callovian to Maastricht, we concluded that the most

rich in microforaminifers is Callovian, Aptian, Albian and Maastrichtian sediments, and by the lithology – argillaceous rocks. The pictures of microforaminifers are showed in four tables.

A clear stratigraphic association of microforaminifera complexes and the study of dinocysts and palynological complexes and foraminifera in the macerates allowed us to refine the stratigraphic confinedness to foraminifera units of Jurassic and Cretaceous sections of Ukraine. Sediments that are rich in normal size foraminifers not always contain a large number microforaminifers. The explanation for this may be the small size of these forms we call microforaminifers and meet in palynospectra as linings. But these forms are probably lost by microfaunists during the initial processing, as the size of the filter is much larger. Therefore, the microforaminifers complement the data for the study of normal size foraminifera. As the lining is marked primarily by palynologists, the collaborative work is essential. The percentage of coincidence microforaminifers with foraminifers of normal size is very small at a kind level.

The study of microforaminifers is valuable information for paleontologist-faunist as it allows studying the fauna from the outcrop deposits and wells and compare micro- and macrofaunal remains.

All our previous results will be refined in the future and supplemented with new data. The authors are grateful for the valuable suggestions of colleagues microfaunists L.F. Plotnikova and T.S. Ryabokon.

Microforaminifers are indicators of paleogeographic and paleoecological conditions changes. Thus, this group is used for paleogeographic reconstructions, Sea Basin temperature assessing, cycles of sedimentation and conditions of stagnation. With comprehensive study of different groups of flora and fauna: foraminifera, microforaminifers, dinocyst, acritarchs and prasinophytes allow us to make a number of assumptions on paleobionomic conditions of sedimentation basin.

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Received
February 18, 2015