ISSN 2079-0864, Biology Bulletin Reviews, 2020, Vol. 10, No. 4, pp. 368–382. © Pleiades Publishing, Ltd., 2020.
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Jurassic Ostracods of the European Part of the Former Soviet Union: Research Challenges and Successes

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Received October 9, 2019; revised October 10, 2019; accepted October 10, 2019

Abstract—Interest in the Mesozoic ostracods of the Russian Plate first emerged in the 1930s due to industrial-scale oil and gas prospecting. This article provides informative summaries of all significant publications of the past century devoted to the Middle and Upper Jurassic ostracods of the Russian Plate and its framing: the Dnieper–Donets Depression, the northwestern sink of Donbass, Moscow, Ukraine, Pechora, and Volga–Ural syneclises, and the Crimean–Caucasian and Central Asian regions. The history of research on Jurassic ostracods in the European part of the former Soviet Union is divided into three periods, each of which is of particular importance and meets the specific requirements of its time.

Keywords: history of science, ostracods, the Jurassic, Russian platform
DOI: 10.1134/S207908642004009X

INTRODUCTION

Industrial-scale oil and gas prospecting in the European part of the former Soviet Union is fraught with certain difficulties, since strata that are potentially productive for hydrocarbon extraction lie at different depths within the sediment cover of the Russian Plate (RP), i.e., they are located in a closed area, and drilling is needed to reach them. It is necessary to determine the geological time and paleoecological conditions of their formation as accurately and reliably as possible in order to distinguish and delineate these sedimentary bodies.

Ammonites, a group of cephalopod mollusks, represent the most accurate biological chronometer that can be used to distinguish between the time intervals of minimal possible duration in the Mesozoic sedimentary rocks. The most reliable and detailed scale (the ammonite standard) based on ammonite evolution was developed for the Jurassic RP; virtually all problems of applied geology can be solved with this scale. However, this method has its drawbacks, because ammonite shells are most often found in open geological sections (in quarries, ravines, and coastal cliffs) and are much less likely to be present in borehole cores. The dating of core samples from different depths is associated with the analysis of small samples of material; therefore, the development of other scales parallel to the ammonite standard is necessary. These scales should be developed for microscopic organisms that are abundant and often present throughout the borehole section. The study of fossil ostracods, microscopic benthic crustaceans, is of particular interest, since their ability to resettle and migrate was very limited due to the lack of planktonic larvae (the absence of the planktonic stage in the life cycle of ostracods). This feature, combined with extremely high sensitivity to environmental changes, makes ostracods the most reliable indicators of the paleoecological conditions of the past.

Systematic studies of ostracods began in the Soviet Union. The first micropaleontological laboratory in the Soviet Union was organized at the All-Union Research Institute of Oil and Gas Prospecting in Leningrad in the 1930s. Rich ostracod assemblages were identified in marine sediments of the Middle and Upper Jurassic of the southeastern part of the RP, Western Kazakhstan, and Mangyshlak during the initial period, the period of exploration (1937–1949).

The subsequent period, termed the period of accumulation (1955–1978), required the classification of an enormous number of taxa and, consequently, the description of many new genera and species and the collection of information on their stratigraphic distribution. Unfortunately, the importance of ostracod stratigraphy was not fully recognized. The ostracod-based assessment of deposit age appeared unreliable, since the time interval could sometimes encompass several eras. The full stratigraphic ranges of the species were analyzed, and, since the species were interpreted quite widely at that time and often turned out to be composite, they spanned unjustifiably long periods of time. The enormous amount of material, which pre-

cluded sufficiently careful analysis, was one of the sources of taxonomy problems, along with the poor technical capability at that time (as compared with the present). At that time, almost all experts in Mesozoic ostracods worked at industrial organizations and had to adhere to rigorous timelines of report preparation and submission. The taxonomic confusion was aggravated by the lack of high-quality images of ostracods in publications and often by the formal approach to the description of genera and species. Thus, many taxa described at that time are composite morphogroups, which often included representatives of different families, in addition to multiple related species.

In addition to problems with ostracod classification, a methodologically disadvantageous approach was used to identify their stratigraphic significance. As a rule, ostracods were regarded as accompanying fauna that were confined to different ammonite zones at best and characteristic of stage or substage in the worst case. This approach led to the pooling of species lists for different, easily distinguishable assemblages that formed stratigraphic sequences and to the loss of very important information on the detailed partition and correlation of deposits based on ostracod species. Generalization of the lists, along with a broad interpretation of species and the facial dependence of ostracods (which hinders long-distance correlations), precluded the recognition of the stratigraphic importance of this group. Therefore, ostracods were not even used to distinguish beds within individual sections, and no stratigraphic schemes for ostracods were created during this period.

The primary accumulation of information about the Jurassic ostracods of the European part of the former Soviet Union was virtually completed by the end of the 1960s. A long break in ostracod research ensued, with only one published study on ostracods of the Timan–Pechora Basin (Lev and Kravets, 1982). The accumulation of information on the systematic composition of ostracods and their distribution in various facies of the Middle and Upper Jurassic stages of the northwestern sink of the Donbass (Donets Basin), the Dnieper–Donets depression (DDD), and Uzbekistan was completed a decade later, by the end of the 1970s.

The first publications on the Jurassic ostracods of the Crimean Mountains appeared only in the early 1990s. These studies do not fit into the proposed chronology of ostracod research based on methodological approaches and ostracod use in biostratigraphy, but they still should be attributed to the second period.

The third, or stratigraphic, period refers to the time period of the 1990s to the present. Researchers returned to the systematic study of RP ostracods only at the end of the 20th century. The progress in the modern taxonomy of ostracods, which is associated with the introduction of scanning microscopes and the biological features of the group taken into account during classification, necessitated the revision of the taxa already published and the description of new taxa. Consequently, the stratigraphic ranges of the revised genera and species were reconsidered. Conversely, the modern requirements for detailed stratigraphic studies (at the zonal and subzonal levels) and the development of a new generation of regional schemes led to revision of the stratigraphic significance of ostracods and promoted the search for new methodological approaches to increase it. It should be noted that the images of ostracods in all of the works published during this period were registered by scanning microscopes.

The history of research on Jurassic ostracods of the RP and its framing is considered in more detail below.

EXPLORATION PERIOD

E.G. Sharapova's studies of the Upper Jurassic and Neocomian ostracods of the Emba and Ozinki areas of the southeastern framing of the RP should be regarded as the first research on the Mesozoic ostracods of the former Soviet Union (Sharapova, 1937, 1939). A number of new species described from these areas are widely represented in RP deposits of the same age identified later by P.S. Lyubimova in the Volga–Ural area (Lyubimova, 1955b). Diagnoses of 12 species of the genera *Eucythere* Brady, 1868 and *Cythereis* Jones, 1849 from the Middle Volgian substage and, partially, the Lower Cretaceous are given in an article on the Mesozoic of the Emba oil-bearing region (Sharapova, 1937). Thirty-nine species, including 22 new species, and assemblages characteristic of the Middle Volgian substage (Panderi and Virgatus zones), Neocomian, Aptian, Albian, Campanian, and Maastrichtian were described in the next article on ostracods from the Upper Jurassic and Cretaceous deposits of the Ozinki oil-bearing region (Sharapova, 1939). The type collections for these publications were lost during the Second World War; therefore, the identification of neotypes for the species described by Sharapova is required. The assignment to genera is outdated and also requires revision, which has already been performed for some of the species.

An essay on the Middle Jurassic ostracods of Nordvik and Mangyshlak and the systematic significance of ostracod shell structures (muscle scars, hinge, and others) (Sharapova, 1947) was published a decade later by E.G. Sharapova and M.I. Mandel'shtam in Volume VIII (Jurassic system; lower and middle substages) of the *Atlas of the Reference Forms of Fossil Faunas of the USSR*. Sharapova described four new species of the genus *Cytherissa* Sars, 1928 and three species of the genus *Orthonotacythere* Alexander, 1933 from the Bathonian of Nordvik (these taxa are now assigned to other genera). Mandel'shtam described two new species of the genus *Darwinula* Brady et Norman, 1889 from the Bajocian of Mangyshlak and a new genus *Palaeocytheridea* with five species from the Upper Bajocian and Bathonian deposits of Mangyshlak; the

latter description was very brief and the type species was not indicated. The description of the genus in this work is not valid according to the rules of the International Code of Zoological Nomenclature (ICZN), article 13.3.

Another paper by Mandel'shtam that included the descriptions of new ostracod taxa from the Middle Jurassic of Mangyshlak fully compliant with the ICZN was published a month later in the same year (Mandel'shtam, 1947). He identified new genera *Palaeocytheridea*, *Aequacytheridea,* and *Timiriasevia;* each genus included several new species. He also described new species of the genera *Protocythere* Triebel, 1938 and *Darwinula*. The genus *Palaeocytheridea* Mandelstam, 1947 was later revised (Tesakova, 2013a,b, 2014); the genus *Aequacytheridea* Mandelstam, 1947 was classified as a synonym of the genus *Schuleridea* Swartz et Swain, 1946 (Howe et al., 1961); and the genus *Timiriasevia* Mandelstam, 1947 was recognized as valid.

A brief description of ostracod families Cytheridae, Paradoxostomidae, and Cytherellidae with representatives most often found in the Upper Jurassic marine deposits is given in Volume IX (Jurassic system; upper section) of the *Atlas of the Reference Forms of Fossil Faunas of the USSR* (Mandel'shtam, 1949); the major generic features and diagnostic tables are also given for four genera (*Palaeocytheridea*, *Protocythere*, *Bythocythere* Sars, 1865, and *Cytherella* Jones, 1849) and 20 species (ten of them new) from the Callovian–Middle Volgian deposits of the Middle Volga region, Obshchy Syrt, and the environs of Lake Inder. This volume of the *Atlas of the Reference Forms of Fossil Faunas of the USSR* remained confidential and classified "For official use" for several years. Therefore, it is not referenced in the monograph (Lyubimova, 1955b), and all species described by Mandel'shtam in 1949 are described again as new species in this monograph. It is necessary to say that the assignment of these species to genera (except for *Bythocythere calloveica* Mand. in Lyub., 1955) has been revised by now. Moreover, Mandel'shtam provided the descriptions of the new genera *Pontocyprella*, *Protoargilloecia,* and *Procytheropteron* for Lyubimova's monograph, and the type species of these genera were identified by Lyubimova.

The next important period in the study of Jurassic ostracods of European Russia that began with this work by Mandel'shtam (Lyubimova, 1955b) was associated with the names of six other experts. Mandel'shtam, for his part, continued publishing the descriptions of some new taxa from the Upper Jurassic of the Middle Volga region, Obshchy Syrt, and the environs of Lake Inder (Mandel'shtam et al., 1957; Netskaya et al., 1958; Mandel'shtam and Shneider, 1963).

THE PERIOD OF ACCUMULATION

P.S. Lyubimova, T.N. Khabarova, V.N. Preobrazhenskaya, F.I. Kats, M.N. Permyakova, and A.S. Masumov worked very productively at that time. A considerable amount of data on the systematic composition and stratigraphic distribution of the Middle and Upper Jurassic ostracod fauna of the Volga region, Central Chernozem region (CChR) and the southwestern (Donbass and DDD), southeastern (Obshchyi Syrt, Emba region, and Uzbekistan) and southern (Crimea) framing of the RP was collected in their studies.

Lyubimova started the systematic studies of the Mesozoic ostracods of the Middle Volga region, Emba region, and Obshchy Syrt in 1946 (Lyubimova, 1955a, 1955b, 1961, 1972; Mandel'shtam et al., 1956; Lyubimova et al., 1960b). Khabarova studied the ostracods of the Saratov region (Khabarova, 1955, 1961), and Preobrazhenskaya, the Jurassic ostracods of the Central Chernozem region (Orel, Bryansk, Voronezh, and Kursk regions) (Preobrazhenskaya, 1958, 1961, 1962, 1964, 1966a, 1966b, 1968).

Lyubimova (1956), Kats (Kats, 1957; Kats and Shaikin, 1969), and Permyakova (Permyakova, 1968, 1969, 1970, 1971, 1973, 1974a, 1974b, 1974c; 1975a, 1975b; Kaptarenko-Chernousova et al., 1966; Pyatkova and Permyakova, 1978) studied the northwest sink of Donbass and the DDD in the southwestern framing of the RP. Masumov studied the Jurassic ostracods of the southeastern framing of the RP (Uzbekistan) (Masumov, 1966a, 1966b, 1973; Mandel'shtam and Masumov, 1968; Masumov and Bykovskaya, 1975).

The lists of ostracod assemblages characteristic of the Middle Bajocian, Upper Oxfordian, and Kimmeridgian of the northwestern margin of Donbass, Callovian–Volgian of the Middle Volga region, and Lower Volgian of the Ural–Volga interfluve and Obshchyi Syrt were first presented by Lyubimova (1955a) at the All-Union Meeting on the development of a unified stratigraphic scheme for the Mesozoic deposits of the Russian Plate.

New ostracod assemblages were identified and the ones previously known for the Middle Triassic, Bajocian, Bathonian, Callovian, Oxfordian, Kimmeridgian, Lower, Middle, and Upper Volgian, and, partially, Neocomian were substantially expanded in Lyubimova's monograph on the ostracods of the Middle Volga region and Obshchy Syrt (Lyubimova, 1955b). Changes in the species composition at the borders of large stratigraphic units were revealed at the same time. The work was of particular importance, because it contained descriptions and images of 98 ostracod species, of which 71 were new. Unfortunately, the paleontological plates included drawings, similarly to almost all Soviet studies of that time, and no photographs of ostracods were given. This considerably hinders the processing of these data at present, especially

because drawings do not fully reflect the holotype morphology. Lyubimova's descriptions of species are were often the descriptions of only one valve of a holotype. However, the outlines of the left and right valve are seldom identical and sometimes dramatically different in ostracods. Therefore, if the new species did not have a characteristic ornamentation or had smooth valves, as observed, for example, for the genera *Schuleridea*, *Galliaecytheridea* Oertli, 1957 or *Procytherura* Whatley, 1970, species identification could be difficult or turn out incorrect. It is necessary to add that the methodology for describing ostracods in the Soviet Union in the 1950s and 1960s was not as refined as it is now or as was then customary in Western Europe; therefore, such sections as "comparison" and "variability" often contained formal descriptions that did not always reflect important information on the species. As a result, discrepancies between the textual description of the species, the image of the holotype in the publication, and the holotype itself can be identified as the researchers work with the type collections at present. These difficulties arise when working with Lyubimova's monograph and all subsequent publications of this author; the same applies to the articles by Khabarova and Preobrazhenskaya. Ostracod photographs appeared in Preobrazhenskaya's later works, but the image quality was still very low.

Thirty-seven species are described in Lyubimova's extensive article on the ostracods of the northwestern sink of the Donetsk fold structure (Lyubimova, 1956), and 30 species and one variety are marked as new. The species *Aequacytheridea translucida* with the holotype (no. 138–17) from the Lower Callovian of the Kanev region is described as one of the new species. The same species was described under the same name from the Middle Callovian of the Samara Luka in the 1955 monograph, but a different holotype was proposed (no. 117–124). As apparent from the images, it is indeed the same form broadly distributed in the Lower and Middle Callovian of the RP (as confirmed by materials collected by the author of the present article) and presently assigned to the genus *Schuleridea*. Moreover, Lyubimova identified ostracod assemblages of the Triassic, Upper Bajocian, Lower Callovian, Upper Oxfordian, and Kimmeridgian, and was the first to compare the Jurassic ostracod assemblages of Donbass to the assemblages of the same age from Poland, France, Volga region, and Kazakhstan.

Mandel'shtam and Lyubimova described 10 ostracod genera encountered in the Jurassic deposits in the extensive review of 1956 (Mandel'shtam et al., 1956).

The monograph by Lyubimova and coauthors dedicated to the Mesozoic and Cenozoic ostracods of the West Siberian lowland was published in 1960 (Lyubimova et al., 1960a). The Jurassic ostracods are represented by a scarce assemblage of three freshwater taxa in the Callovian, a similarly scarce marine complex in the Oxfordian, and a substantially more representative ostracod assemblage from the Kimmeridgian. Almost all ostracods were described as new species, but this does not appear justified in some cases, because the images of some holotypes are very similar to the drawings of the Upper Jurassic ostracods of the Volga region from Lyubimova's 1955 monograph. The need for revision and thorough verification of the type collection is obvious.

The study (Lyubimova, 1961) includes a brief overview of research on the Jurassic ostracods in the Soviet Union and the data on ostracods identified from the Bleicheri Zone in the Ulyanovsk Volga region, on the change in ostracod composition at the boundary of Panderi and Virgatus zones at the Obshchy Syrt, and on some distinctive features of the sequence of ostracod assemblages in the sections of the Volga region and Obshchy Syrt. Three dramatic changes in the taxonomic composition of ostracod assemblages were noted in the Triassic–Lower Cretaceous interval: they occurred at the boundary of the continental Triassic and the marine Jurassic, the Kimmeridgian and the Lower Volgian substage, and the Jurassic and the Cretaceous. A sequence of several assemblages that differed from each other with regard to species composition and partially with regard to the genus composition was traced for the Bajocian–Oxfordian interval. The similarity of the species composition of the Upper Jurassic ostracods of the Middle Volga region and Obshchy Syrt to the Ural–Emba region assemblages of the same age and a higher taxonomic diversity of the former was noted for the first time, along with the low similarity between the former and the Donbass ostracod fauna of the same age. Lyubimova explained this by the alternation of marine and continental sediments in the Upper Jurassic of Donbass, in contrast to the Volga region and Obshchy Syrt, where only marine sediments were found (the Callovian was also assigned to the Upper Jurassic at that time).

The *Ostracods* chapter in *Stratigraphy of the USSR* (Lyubimova, 1972) presented the history of the studies on ostracods of the Volga–Ural region, Ukraine, Central Chernozem region, Western Siberia, Mangyshlak, Turkmenistan, Uzbekistan, Nordvik, and the Lena–Olenek region. The author was the first to analyze the distribution of different families in the Jurassic and to note that the freshwater ostracods of the Darwinulidae family were the most numerous in the Middle Jurassic. Representatives of the Cyprididae and Cytherididae families were found throughout the Jurassic section, but the Volgian was the time of their prime. The Paradoxostomatidae family first appeared in the Callovian, but never developed to a considerable degree. The Cytherellidae family is known since the Middle Jurassic, and the Volgian was the time of its prime. The Bairdiidae and Healdiidae families were not widespread during the Jurassic.

Khabarova described seven new species from the Bajocian of the Don–Medveditsa dislocations

(Khabarova, 1955). Her later studies of abundant and diverse material on the foraminifers and ostracods of the Saratov Volga region enabled the identification of Foraminifera zones in the Jurassic deposits and the assembly of lists of ostracod species characteristic of these zones (Khabarova, 1961). She characterized easily recognizable ostracod assemblages for the upper part of the Upper Bajocian (Parkinsonia doneziana Zone), Lower Callovian (Macrocephalites macrocephalus and Chamoussetia chamousseti zones), Middle (Kosmoceras jason and Erymnoceras coronatum zones) and Upper Callovian (that she believed to encompass the Quenstedtoceras keyserlingi, Peltoceras athleta, Q. lamberti, and Q. mariae ammonite zones), Oxfordian (which was subdivided into two sections with Cardioceras cordatum and Amoeboceras alternans zones at that time), Kimmeridgian (dated according to the foraminifer species composition), and the Middle Volgian substage (the Dorsoplanites panderi Zone). These characteristic assemblages are quite consistent with modern ideas on the distribution of ostracods along the stratigraphic interval of the Middle and Upper Jurassic of the RP.

The *Fundamentals of Paleontology* is a large and important reference work that cannot be overlooked. The chapter on ostracods was published in 1960 in the volume named *Arthropods: Trilobite-Like and Crustaceans*. Lyubimova developed the diagnostic criteria for the genera of the Cypracea superfamily, Mandel'shtam contributed to the general overview text and provided the genus descriptions for the Volganellacea, Cypracea, and Cytheracea subfamilies and for some genera of the suborder Platycopa (Kashevarova et al., 1960; Lyubimova et al., 1960b; Mandel'shtam and Polenova, 1960; Mandel'shtam and Shneider, 1960).

V.N. Preobrazhenskaya studied the Jurassic ostracods of the Orel, Bryansk, Voronezh, and Kursk regions. Her studies of invertebrates, spores and pollen, as well as microfauna, including ostracods, in the core material from the Kursk region and samples from the outcrops of the right bank of the Don within the Voronezh region enabled her to divide the Jurassic deposits of this area into Bajocian, Bathonian–Callovian, Middle Callovian, Oxfordian, Kimmeridgian, and Lower Volgian substage for the first time. Brief lists of the most characteristic ostracod species of the Callovian, Kimmeridgian, and Lower Volgian were published (Preobrazhenskaya, 1958).

Another article (Preobrazhenskaya, 1961) includes a list of several ostracod species from the Lower Volgian deposits and two species from the Kimmeridgian of the Kursk Magnetic Anomaly (KMA). Only Foraminifera were found in the Bajocian, Bathonian, Callovian, and Oxfordian. The dependence of microfauna assemblages on the facies attribution was emphasized.

Preobrazhenskaya gave a speech on the significance of ostracods for the stratigraphy of Jurassic deposits of the KMA area at the Interregional Geological Meeting on Geology and Mineralogy of the Central Chernozem region in the following year (Preobrazhenskaya, 1962). She mentioned a number of indicator species characteristic of the Bajocian–Bathonian, Middle Callovian, Lower Oxfordian, Kimmeridgian, and Middle Volgian substage and emphasized that the fauna in question was not encountered in the Middle Oxfordian.

The lists of ostracod species characteristic of the Lower and Middle Callovian, Oxfordian, Upper Kimmeridgian, and Lower and Middle Volgian of the KMA area were published later (Preobrazhenskaya, 1964). These diverse assemblages are easy to distinguish, quite uniform over the area, and much more sensitive to the environmental condition changes than the foraminifers are, and this makes them especially important for the stratigraphy of the area. Ostracods were more abundant and occurred more often in the lower part of the Oxfordian than in its upper part. In this article, Preobrazhenskaya mentioned the facies association of some taxa and the relationship between the shell valve sculpture and the changing paleobasin conditions, in addition to presenting a table with the stratigraphic distribution of all ostracod species encountered in the Jurassic of the KMA. The names of some species were marked with sp. nov. in two paleontological plates with images (drawings) of stratigraphically significant species. However, the descriptions of these species, holotype numbers, or places, where the collections were preserved, were not mentioned in the article. Thus, the new species presented in the article cannot be considered valid.

Important taphonomic observations on the distribution of foraminifers and ostracods in the Jurassic rocks of the Central Chernozem Region were published in 1966 (Preobrazhenskaya, 1966a). Moreover, analysis of the distribution of foraminifers with different shell types (agglutinated and calcareous) and ostracods with different sculpture types in sediments with different pyrite and glauconite abundance enabled the identification of the main environmental factors that affected the distribution of these microbenthos groups. They are salinity, gas regimen, and the nature of the substrate. Indicator species for the different conditions were identified. Thus, foraminifers of the genus *Ammodiscus* Reuss, 1862 could live in oxygen-depleted habitats, whereas the genera *Glomospira* Rzehak, 1885, *Haplophragmoides* Cushman, 1910, and *Ammobaculites* Cushman, 1910 needed good aeration. Ostracods of the genera *Galliaecytheridea* and *Reticythere* Gruendel, 1978 are indicative of desalination.

Photographs of Jurassic ostracods and foraminifers from the Bajocian–Bathonian, Middle Callovian, Oxfordian, Kimmeridgian, and Lower Volgian substage of the Voronezh anteclise were first published in the large monograph named *Stratigraphy of Jurassic*

and Lower Cretaceous Deposits of the Central Chernozem Region (Preobrazhenskaya, 1966b), which also contained a detailed overview of the geological history of the region reconstructed on the basis of facies analysis using paleontological data. The shorter versions of the lists of Middle Callovian and Lower Oxfordian ostracods borrowed from the earlier studies were reproduced in the text. Some ostracod species were again mentioned as new (sp. nov.), but descriptions were not provided and holotype numbers and the collections storage areas , were not mentioned, and therefore these taxa are also not valid.

Preobrazhenskaya's last publication on ostracods (Preobrazhenskaya, 1968) mentioned six ostracod species from the Middle Volgian Virgatus Zone, which were most common for the KMA, and descriptions of five species, three of them new, were provided.

Kats continued the research on ostracods from the Jurassic of the DDD (1957). Her studies of the cores from the wells of left-bank Ukraine enabled substantial expansion of the data collected earlier (Lyubimova, 1956). Ostracod diversity was the highest in the Upper Bajocian and Middle Callovian, for which lists were compiled and published (without images); the author emphasized that almost all species were encountered in the area for the first time. Lower Bajocian and Lower Bathonian faunas were represented by small numbers of taxa. Kats compared the systematic composition of the Upper Bajocian ostracod fauna of the western sink of Donbass and its northwestern margin and concluded that the aquatic organisms in the part of the DDD adjacent to the Donbass lived in shallower habitats.

Kats described new ostracod genera and species of the Cyprididae and Cytherididae families in collaboration with Mandel'shtam, Shneider, and Z.V. Kuznetsova in the same year; the taxa were of different ages and originated from different regions of the former Soviet Union. She identified a novel genus *Naviculina* from the Bathonian of Ukraine, and Mandel'shtam described a novel genus *Rubracea* from the Callovian of the Saratov Trans-Volga region. Lyubimova identified new species of these genera (Mandel'shtam et al., 1957). Kats and Shaikin subsequently published a report (Kats and Shaikin, 1969) of the identification of ostracods from a variegated lagoon-continental stratum of the northwestern part of the DDD. Ostracod and charophyte studies enabled the first paleontological substantiation of the Volgian age of this stratum, which was previously arbitrarily assigned to the Kimmeridgian, Volgian, or undivided Kimmeridgian–Volgian deposits. The authors studied the ecological characteristics of ostracods and charophyte algae and concluded that a lagoon habitat existed in the DDD area during the late Kimmeridgian and, primarily, during the first half of the Volgian age.

Permyakova made an enormous contribution to the research on the Triassic and Jurassic ostracods of the DDD. She was the first to present the lists of reference ostracod species from the Middle and Upper Jurassic of the platform part of Ukraine and to identify the most characteristic species for the Bajocian, Bathonian, Callovian, Oxfordian, and Kimmeridgian of the DDD at the Ukrainian-Moldavian colloquium on the microfauna of Jurassic sediments (Kaptarenko-Chernousova et al., 1966). She was also the first to characterize the distribution of ostracods in the Lower Bajocian and in the Niortense, Garantiana, and Doneziana zones of the Upper Bajocian of the DDD and Donbass margins (Permyakova, 1968). She subsequently published the descriptions of four new species of the genera *Cytherella*, *Schuleridea*, *Procytheridea* Peterson, 1954 and *Orthonotacythere* from the Bajocian of the DDD (Permyakova, 1969). Her study of ostracods of the genus *Glyptocythere* Brand et Malz, 1962 widespread in the Bajocian and Bathonian of Europe was published in the following year. Five species of this genus were described from the Bathonian deposits of the DDD: three of them were new and two had not been encountered in Ukraine earlier (Permyakova, 1970). The history of research on the Mesozoic and Cenozoic ostracods of Ukraine was described in great detail in the book on the fossil microfauna of Ukraine (Permyakova, 1971). New ostracod species of the genus *Southcavea* Bate, 1964 from the Bajocian–Bathonian deposits of the DDD were described in a later work (Permyakova, 1973).

Three of Permyakova's articles were published in 1974. The first of them presented the descriptions of five ostracod species of the genus *Palaeocytheridea* from the Middle Jurassic deposits of the DDD (Permyakova, 1974a). Four of them were new and the fifth had not been found in Ukraine before; a very detailed and well-executed description of this genus was also given. The second article contained the descriptions of species of the genus *Procytheridea* from the Middle Jurassic deposits of the DDD: three species were new and one species was encountered in Ukraine for the first time (Permyakova, 1974b). The strict confinement of these species either to the Bathonian or to the Upper Bajocian was noted. Three species of the subgenus *Praefuhrbergiella* Brand et Malz, 1962 were described in the third study (Permyakova, 1974c). One of them was encountered earlier in the Middle Callovian–Lower Oxfordian of the Donetsk and Chernigov regions, another, in the Middle Jurassic of Mangyshlak, and the third one (a new species) was described from the Upper Bajocian of the DDD.

The next study (Permyakova, 1975a) was devoted to the genus *Lophocythere* Sylvester-Bradley, 1948, which is widespread in the Jurassic deposits of the DDD, and another study published in the same year (Permyakova, 1975b) presented the history of research on the Jurassic ostracods of Ukraine and the analysis of stratigraphic distribution of ostracod assemblages from the Lower, Middle, and Upper Jurassic at the territories of Ukraine, Middle Volga region, France,

Switzerland, and Germany. According to the author, it was extremely difficult to trace individual substage over a large territory using the ostracod assemblages. However, common species could be identified in the adjacent areas on the stage scale, and such species were listed for the Callovian and Oxfordian of Ukraine and the Middle Volga region.

The ostracod section in the paleontological reference book on the Jurassic ostracods and foraminifera of Ukraine (Pyatkova and Permyakova, 1978) is the most important work by Permyakova. It includes 156 ostracod species with drawings and synonyms indicated. Unfortunately, drawings are not an equivalent replacement for photographs, and this is a setback of an otherwise excellent study.

Permyakova continued the studies of Ukrainian ostracods afterwards. She emphasized the stratigraphic importance of these fossils and described two characteristic assemblages from the Volgian of the DDD (a lagoon-continental one and a marine one), which she correlated with Volga region, KMA, Cis-Caspian, and Crimean assemblages of the same age (Permyakova, 1990).

Permyakova started studying the ostracods of the Mountain Crimea at the same time. The first data on the Oxfordian and Tithonian ostracods of this region are presented in the explanatory note to the stratigraphic scheme of the Jurassic deposits of the Mountain Crimea (Permyakov et al., 1991a). Four species, mostly those of the genus *Bairdia* M'Coy, 1844, were identified in the lower subformation of the Yaila Formation (Middle to Upper Oxfordian). A more representative assemblage of 9 species was identified in the lower subformation of the Deimen-Deri Formation (Early–Middle Tithonian). More detailed information on the Lower and Middle Tithonian ostracods is presented in an article collection (Permyakov et al., 1991b) that describes a combined assemblage of more than 30 forms. The ostracods of the Lower Tithonian are scarce and poorly preserved. The Middle Tithonian assemblage is abundant and diverse; it includes forms common for assemblages from the Middle Volga region, DDD, Ural–Emba region, Italy, and the Czech Republic.

The Jurassic ostracods of Central Dagestan were mentioned by Kasimova et al. (1956). Z.V. Kuznetsova identified three new species from the Upper Aalenian of the Ulluchai section but did not publish any descriptions or images; thus, the species are not valid; she also mentioned numerous finds of sculptured progonocytherids in the Bajocian, but these finds could not even be assigned to any genus because of poor preservation.

Ostracods of the southeastern framing of the RP are known from the Jurassic of Uzbekistan. Masumov (1966a) described several new species of the genera *Paracypris* Sars, 1866, *Schuleridea*, *Galliaecytheridea*, *Tetracytheridea* Bate, 1963, *Pyrocytheridea* Lyubimova, 1955, and *Acrocythere* Neale, 1960 and identified a new genus, *Raphicytheridea,* from the Lower Callovian of the southwest Gissar. A second article published in the same year (Masumov, 1966b) included the description of new taxa: the new genus *Protoeucytherura* (a genus identified by Masumov and subsequently reduced to a synonym of *Marslatourella* Malz, 1959 by the same author) and new species of the genera *Marslatourella*, *Cytheropterina* Mandelstam, 1956, and *Bythocytheremorpha* Mandelstam, 1958 from the same section. Masumov described new Early Callovian ostracods of the genera *Aparchitocythere* Swai et Peterson, 1985, *Parariscus* Oertli 1959, *Stravia* Neale, 1962, and *Marslatourella* in an article written in collaboration with Mandel'shtam; the article also contained a description of the new genus *Memoria* Mandelstam, gen. nov. and a new species of the genus *Nodophthalmocythere* Malz, 1958 (Mandel'shtam and Masumov, 1968).

An extensive monograph on the Jurassic ostracods of Uzbekistan (Masumov, 1973) includes the descriptions of approximately 70 species and subspecies of more than 35 genera and subgenera. The summary contains a brief biostratigraphic characteristic of the Jurassic of Uzbekistan and the characteristic ostracod assemblages of the Lower Jurassic, Upper Bajocian, Lower and Upper Bathonian, Lower Callovian, Oxfordian, and presumably undifferentiated Kimmeridgian–Tithonian. The identified assemblages can be reliably traced over the entire territory of Uzbekistan and contain a number of elements common for Western Europe (England, France, and Germany) and Volga region assemblages of the same age. Some conclusions on the paleoecological and paleogeographic conditions of the Jurassic basin of Uzbekistan and its relations with other basins are also drawn. Masumov stated that he Lower Callovian ostracods from the western side of the Tuarkyr anticline differed significantly from the coeval complexes of Western Europe and Central Asia (Ustyurt, Southern Cis-Aral region, Bukhara–Khiva region, and southwestern spurs of the Gissar Range and its southern slope) (Masumov and Bykovskaya, 1975). Four new species of the genus *Lophocythere* and one of the genus *Bythocytheremorpha* are described in the article; T.A. Bykovskaya coauthored two of the descriptions.

O.M. Lev studied the northeastern framing of the RP. She identified 12 ostracod assemblages in the Middle–Upper Jurassic of the Timan–Pechora province (Lev and Kravets, 1982), one for each of the Lower–Middle Bathonian, Upper Bathonian, Lower, Middle and Upper Callovian, and Upper Kimmeridgian, three for the Middle Volgian substage, and three for the Upper Volgian substage. Unfortunately, the complete species lists of the assemblages, species descriptions, and images were not included in the article, and thus it is extremely difficult to correlate these assemblages to the ostracod scale of the RP.

STRATIGRAPHIC PERIOD

This period (from the 1990s to the present) is reflected in the works of N.N. Kolpenskaya, E.M. Tesakova, Yu.N. Savel'eva, B.L. Nikitenko, L.A. Glinskikh, and Ya.A. Shurupova.

Kolpenskaya's first article included a description of five new ostracod species from the Kimmeridgian and Volgian deposits of the Pechora River basin (Kolpenskaya, 1993). She compiled short lists (two to three characteristic species) for the Middle Callovian (Coronatum–Jason zones), Middle Oxfordian (Ilovaiskyi–Zenaidae zones), and Upper Oxfordian (Serratum Zone) for the regional stratigraphic scheme of the Jurassic deposits of the Voronezh anteclise (*Ob'yasnitel'naya zapiska* ..., 1993).

Kolpenskaya's Candidate's Dissertation (PhD thesis) is based on the Upper Jurassic ostracods of the Pechora River basin, the interfluve of Kama and Vyatka rivers, the Upper Volga, and the Trans-Volga region, and it includes descriptions of characteristic and new species and the first correlation of RP beds with ostracods to the ammonite scale (Kolpenskaya, 1995). Additional systematic studies based on the materials from this dissertation were conducted in collaboration with British colleagues (Wilkinson et al., 1997, 1998). The continuation of stratigraphic studies involved the processing of core materials from a number of boreholes in Bryansk and Moscow regions; as a result, brief descriptions of ostracod assemblages and lists of species characteristic for the substage of the Callovian were published (Kolpenskaya et al., 1999).

Kolpenskaya also made a valuable contribution to the reference work *Practical Manual on Microfauna. Mesozoic Ostracods* (volume 7) (Kolpenskaya, 1999). The book presents the modern systematics of ostracods on the supraspecific level, provides descriptions of many genera, and contains photographs of Mesozoic ostracods made with a scanning microscope. The images of some holotypes of the species from the Volga–Ural area (Lyubimova, 1955b) are found in the book, and some controversial issues in the systematics of Mesozoic ostracods are discussed. The use of ostracods in the Mesozoic biostratigraphy and ostracod-based stratigraphic schemes proposed for some regions (Andreev et al., 1999; Kolpenskaya, 1999; Nikolaeva et al., 1999) are discussed in the geological part.

The ostracod assemblages of the Middle–Upper Jurassic of the Belgorod region were described in a subsequent work (Kolpenskaya, 2002). Four ostracod assemblages characteristic of the Upper Bajocian–Lower Bathonian, Oxfordian, Kimmeridgian, and Middle Volgian were identified and substantiated based on the results of core analysis from several boreholes. All complexes are clearly traceable (along the boreholes) in the studied area.

Nikitenko used Kolpenskaya's data on ostracod distribution in the Upper Jurassic of the Timan–Pechora area (Kolpenskaya, 1995) supplemented by his own data to develop a scheme of ostracod-based zonal partitioning of the Jurassic in this area (*Unifitsirovannaya*..., 2012). He identified four ostracod zones that encompassed the deposits from the Upper Bajocian to the Upper Callovian and six more zones in the Upper Kimmeridgian–Lower Cretaceous (Berriasian) sediments, a total of ten zones. Identification of the three lowermost zones (Upper Bajocian–Middle Callovian) was based on the genus *Camptocythere* Triebel, 1950, similarly to the ostracod stratigraphy of the Lower and Middle Jurassic of the Siberia (Nikitenko, 2009).

Upper Callovian ostracods of southwestern Tatarstan were studied by Glinskikh and mentioned in the article (Mitta et al., 2014).

Tesakova's studies on the Jurassic ostracods started from the Callovian and Oxfordian of the Moscow syneclise. The first publication included lists of species from Ryazan, Moscow, and Yaroslavl regions and emphasized the difference between the Oxfordian and Callovian assemblages, with a lower diversity and predominance of small ostracods characteristic of the former (Tesakova, 1996). The first images of ostracods of the Moscow and Ryazan regions and their distribution in the Callovian substages was published in the atlas *Fossils of the Callovian Stage of Central Russia* (Gerasimov et al., 1996). Tesakova presented and published the results of other studies in the abstracts and materials of international, Russian, and regional conferences, which are not cited here, because references to them are given in the review articles. The short communications are mentioned only if they contain important results not yet included in peer-reviewed papers.

Tesakova's Candidate's Dissertation based on ostracods from the Callovian and Oxfordian of Central Russia (Ryazan, Moscow, Kostroma, and Kursk regions, and Mordovia); the dissertation included a combined list of 54 species, with monographic descriptions of 41 species, 11 of which are new (Tesakova, 2000). Five beds with ostracods were identified for the Lower (the Calloviense Zone), Middle, and Upper Callovian, and Lower and Middle Oxfordian. These results were subsequently published in the monograph (Tesakova, 2003). Some identifications of genera and species were refined or corrected in Tesakova's later studies.

A number of publications contain descriptions of new taxa of the subgenus, species and subspecies rank from Lower Callovian of the Kursk (Tesakova et al., 2009) and Saratov (Tesakova and Sel'tser, 2013; Tesakova, 2013a) regions, Belarus (Makhnach and Tesakova, 2015); the Callovian of Central Dagestan (Glinskikh and Tesakova, 2020); and the Middle Jurassic of southern Germany (Franz et al., 2009). The results of revision of Lyubimova's and Mandel'shtam's collections (Lyubimova, 1955b; Man-

del'shtam, 1947), including the genus *Palaeocytheridea* Mandelstam, 1947, are presented in publications (Tesakova, 2013a, 2013b, 2014).

The stratigraphic significance of ostracods was subsequently studied and reflected in articles and some conference abstracts based on the materials for the Upper and Middle Jurassic of Saratov (Kiselev et al., 2006; Tesakova, 2008; Tesakova and Sel'tser, 2013; Tesakova et al., 2017a; Shurupova and Tesakova, 2017), Kostroma (Tesakova et al., 2012), Ryazan (Tesakova et al., 2017b), Moscow (Tesakova, 2017a), and Kursk (Tesakova, 2013c) regions, Central Poland (Tesakova et al., 2008), Southern Germany (Franz et al., 2009), and Northern Switzerland (Tesakova, 2017c). The zonal scale based on the Middle and Upper Jurassic ostracods of the RP correlating to the ammonite zones (Tesakova, 2012) and biohorizons (Tesakova, 2014a, 2015; Tesakova et al., 2017a, 2017b) is currently the most detailed of the micropaleontological RP scales, second to the ammonite standard only (Rogov, 2017; Kiselev and Rogov, 2018). The first version of this scale published in the *Unified Regional Scheme of the RP Jurassic* (Tesakova, 2012) was considerably reduced at the insistence of the editor-in-chief; therefore, it has lost its practical significance and is not recommended for use. The resulting scheme validated for the reference sections and a large number of RP boreholes includes 9 zones, 8 subzones, and 11 beds with ostracods that are complex strata (Oppel or migration strata), and three additional phylozones based on the evolution of the genus *Palaeocytheridea*. The ostracod strata of RP correlated to those of Poland, Northern and Southern Germany, France (the Paris Basin), and England, and the reference pan-European levels were identified (Tesakova, 2014a, 2015). This scale was subsequently detailed for the Middle and Upper Callovian (Tesakova et al., 2017a, 2017b), and the development of parallel phylogenetic scales based on ostracods of the genus *Lophocythere* Sylvester-Bradley, 1948 was initiated (Shurupova and Tesakova, 2019).

The paleogeographic aspects of the chorological distribution of ostracods in Western and Eastern Europe are addressed in a number of publications (Tesakova, 2003, 2014a, 2014c; Tesakova and Glinskikh, 2020; Tesakova and Rogov, 2004a, 2005; Tesakova et al., 2008; Makhnach and Tesakova, 2015).

The ecological capabilities of this group of crustaceans enabled the reconstruction of the paleobathymetric and paleotemperature curves for the Upper and Middle Jurassic of the RP (Tesakova, 2014a, 2014b), and these curves were consistent with the global climatic and bathymetric trends calculated with different methods (Sahagian et al., 1996; Hallam, 2001; Ogg and Hinnov, 2012) to a high precision. Significant refinement of paleotemperatures and relative paleodepths and the identification of the parameters of various paleoenvironments turned out to be possible for individual regions and intervals of the geological history (Tesakova, 2008, 2013c, 2017b;Tesakova and Rogov, 2004b; Tesakova et al., 2015, 2017b; Shurupova et al., 2016; Wierzbowski et al., 2018). Taphonomic analysis of the Tithonian and Berriasian ostracod assemblages of the Eastern Crimea showed that these assemblages could be used as indicators of ancient turbidites (Tesakova and Savel'eva, 2005).

Comprehensive foraminifer- and ostracod-based paleoecological reconstructions are presented in the literature (Tesakova et al., 2017b; Ustinova and Tesakova, 2015, 2017). A positive correlation between the quantitative characteristics of ostracods and petromagnetic parameters in the sections was revealed (Pimenov et al., 2007, 2009; Stepanov et al., 2019).

A new technique based on the analysis of the age structure (age of moulting stages) of species-indices of a certain set of conditions enables rapid and accurate assessment of the trend of certain events within a section (Tesakova, 2011). The ratio of large and small size clusters in the ostracod assemblages enables the reconstruction of the relative depth (Tesakova and Shurupova, 2018). The latter publication is the most complete and up-to-date survey of the paleoecological methods in ostracod research, in which the possibilities and limitations of each method are evaluated.

Ostracods from the Tithonian–Berriasian boundary beds of the Eastern Crimea (Arkadyev et al., 2006; Tesakova and Savel'eva, 2005) and the Bajocian–Bathonian of the North Caucasus (Mitta et al., 2017, 2018), and their biostratigraphy and paleoecology were studied by Savel'eva.

Shurupova's contribution to biostratigraphy is associated with the use of the heterochrony in the ontogeny of the zonal indicator species, which enables further zone subdivision. V.E. Livental was the first to use the heterochrony in the ontogeny of the ostracod species *Cryptocyprideis bogatschovi* (Livental, 1929) to partition the Pliocene of Azerbaijan (Livental, 1949). However, the example of the species *Palaeocytheridea* (*P.*) *kalandadzei* Tesakova, 2013 and *Camptocythere* (*C.*) *lateres* Tesakova et Schurupova, 2017 from the Upper Bajocian–Lower Bathonian of the Saratov region showed that the trend in the evolution of the morphology of adult shells over time was similar to the ontogenetic trend. This proves that the tracing of evolutionary boundaries within the strata according to the first appearance of adult specimens with modified sculptures is justified. Thus, the heterochrony method (the Livental's method) was expanded and refined (Shurupova and Tesakova, 2017a, 2017b, 2017d).

Shurupova's studies of ontogeny and sexual dimorphism of the Callovian ostracods of the genera *Lophocythere* and *Palaeocytheridea* from the Central Russian Sea are very promising for an update of the systematics and phylogeny and the identification of new species (Shurupova and Tesakova, 2017c; Shurupova and Tesakova, 2019). The accelerated evolution of males

was demonstrated for fossil ostracods (Shurupova and Tesakova, 2018).

CONCLUSIONS

Thus, the efforts of many researchers to identify the stratigraphic significance of the Jurassic ostracods of the Russian Plate resulted in the development of a detailed scale for this group. The perception of ostracods in applied geology has changed fundamentally in the past century, and this was reflected by a consistent and regular sequence of several research periods: the exploration period, the accumulation period, and the stratigraphic period.

It is necessary to note that the ostracod-based zonal scale, which is the most detailed and universal among the presently available micropaleontological scales for the Jurassic of the Russian Plate, is based on the sequence of ostracod assemblages determined by the changes in the paleogeographic conditions; i.e., the subdivisions of this scale are Oppel strata or complex strata. Phylogenetic ostracod scales based on the evolution of different genera should be developed to eliminate the possible effects of heterochrony of the boundaries of Oppel strata upon intra- and interregional correlation (within the Russian Plate and the entire Europe). In other words, modernization of Tesakova's Oppel zone scale via reconstruction of the lineages of Jurassic ostracods of the Russian Plate at the genus level is planned for the nearest future. Studies of this type will inevitably lead to a revision of the systematic composition and the identification of new taxa of different ranks that require descriptions. The author hopes that it will soon be appropriate to speak of the fourth, evolutionary, period in the history of research on the Jurassic ostracods of the Russian Plate.

FUNDING

The study was performed in fulfillment of the State Assignment themes no. 0135-2019-0062 (GIN RAS) and AAAA-A16-116033010096-8 (Moscow State University) and with partial support from the Russian Foundation for Basic Research, project no. 18-05-00501.

COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interests. The authors declare that they have no conflicts of interest.

Statement on the welfare of animals. This article does not contain any studies involving animals performed by any of the authors.

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Translated by S. Semenova