THE USE OF PARALLEL BIOZONAL SCALES FOR REFINED CORRELATION IN THE JURASSIC OF THE BOREAL REALM

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ABSTRACT

Based on the study of numerous Lower and Middle Jurassic sections of the Russian Arctic, independent zonal scales for bivalves, foraminifera, and ostracodes were developed. In each zonal scale, parallel (for different facies) thick and thin zones can be distinguished on the basis of the distribution of the benthos in the ecological zones of the paleoseas. The age and stratigraphic volume of the proposed zones have been determined based on ammonites and correlated by marker levels through intermediate sections. For the Lower and Middle Jurassic of Asiatic Russia, 31 bivalve zones, 24 foraminiferal zones, and 9 ostracode zones were established. There are a number of biostratigraphic markers within the biozones which correlate well with sections in Western Europe, the Canadian Arctic, and northern Alaska. The boundaries of zones defined by different groups do not coincide, and therefore it is possible to recognize and to correlate the intervals representing the ceiling of the different zones (inside zonal correlation) in sections. The use of these scales for correlation of sections from middle Siberia, western Siberia, northeast Russia, and elsewhere yields excellent results.

INTRODUCTION

Lower Jurassic sediments in northern Russia (especially Siberia) are characterized by an abundance of bivalves, foraminifera, ostracodes, and, more rarely, ammonites. In addition, these parastratigraphic units are typical for transitional marine (from marine to terrestrial) layers within Lower and Middle Jurassic strata. These strata are widespread in western Siberia and are known to be important oil and gas reservoirs (e.g., the Sherkalinskaya and Tyumenskaya Formations). It is necessary to use biostratigraphic markers correlated with the general biostratigraphic scale for the detailed subdivision and correlation of these strata and for the estimation of the stratigraphic range of formations.

Usually, ammonites are the basis for correlation. Because the rarity or absence of ammonites in the study area (Fig. 1) makes it difficult to make detailed correlations between the numerous outcrops and core samples, other groups of macro- and microfauna have been used usually to correlate these assemblages to stages, substages, and ammonite zones. However, boreal benthos have been considered extremely endemic and confined to specific facies.

METHODS AND DISCUSSION

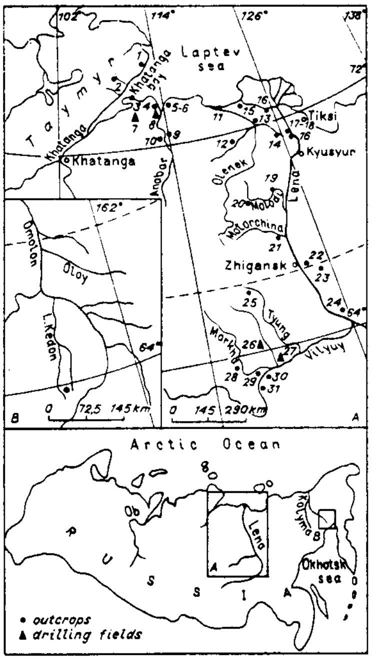


Fig.1. Locations of Lower and Middle Jurassic marine deposits in the Asian part of Russia (A--northern Siberia, B--northeast Russia). 1,2, Eastern Taymyr; 3, Yuryung-Tumus Peninsula; 4-6, Anabar Bay; 7, wells in the Suolama area; 8, wells in the Vostochnaya area; 9, 10, Anabar River; 11, Cape Tumul; 12-14, Olenek River basin; 15, 16, Lena River delta; 17-21, Eastern Priverkhoyansk; 22-24, Western Priverkhoyansk; 25-31, Vilyuy syneclise.

Bivalves, foraminifera, ostracodes, and other groups throughout the North Asian part of Russia have been studied during the last two decades by Russian paleontologists (Zakharov and Shurygin, 1978; Shurygin and Lutikov, 1991; Nikitenko, 1991, 1992; and others). These investigations showed that benthic assemblages in different boreal paleoseas, in Russia and abroad, are more closely related than previously thought. Consequently, these groups can be used for zonal subdivision and detailed correlations over large areas (Shurygin, 1986, 1989; and others).

Indeed, there are practically no fast-evolving eurytopic benthic groups other than the bivalve *Retroceramus*, the foraminifera *Lenticulina* and *Anmarginulina*, and the ostracode *Camptocythere*. Thus, it is possible to use parastratigraphic groups based on multitaxonomic zonal scales, using bivalves, foraminifera, ostracodes, and others (Fig. 2) for zonal subdivisions and for detailed operational correlations in geological and exploration investigations. These zonations can include concurrent range zones, ecologic zones, or groups of parallel lineage zones, among others.

We have observed marked macro- and micro-cyclic deposits, with recurrent facies, in the Lower and Middle Jurassic that contain recurring benthic associations. The variable distribution of the benthos in these cycles reflects their differentiation into ecological zones which were subparallel to the shore (Zakharov and Shurygin, 1978; Shurygin, 1979; and others). These zones have been delineated and the major components of their paleocommunities reconstructed (Fig. 3).

At present, lateral benthic sequences have been reconstructed for Siberian Jurassic epicontinental seas and their evolution through time has been estimated (Zakharov and Shurygin, 1978; Bogolepov, 1983). The structure of the lateral sequences is controlled by the topography of the basin. The taxonomic diversity within each basin depends on paleogeography and evolution within each basin.

Complex (about 6-member) and simpler (2-3-member) lateral sequences have been reconstructed for Siberian paleoseas. The following features have been recognized: (1) the upper part of the sublittoral, which is characterized by stable associations of life forms and features frequent changes of taxa, (2) the middle part of the sublittoral, characterized by frequently changing dominant associations, and (3) the lower part of the sublittoral, characterized by essentially stable associations and taxonomic structures (Zakharov and Shurygin, 1985) (Fig. 3). It should be noted that different groups of benthos change at different rates for both taxa and life forms and, consequently, zones based on other taxa do not coincide with the evolutionary stages of ammonites, which are the basis for the development of the ammonite zonal scale.

Thus, for developing independent zonal scales based on different groups of benthos, one can use the regularities in evolution within lateral sequences and the change in dominant forms within them.

The tracing of biostratigraphic markers and the correlation of zones between them (Fig. 3) have been used for developing the bivalve, foraminiferal, and ostracode zonal scales. Some parts of the Jurassic section have good biostratigraphic markers because they have the same faunal assemblages and lithology over vast areas of the boreal basin. The formation of these strata was eustatically controlled. For example, lower Toarcian black shales (the Kiterbyutsky horizon of central Siberia; the Togursky horizon in western Siberia; the lower part of the Suntarskaya Formation in the Priverkhoyansk and Vilyuy basins) are present, not only within northern Russia, but on the shelf of the Barents Sea and throughout the boreal realm (Western Europe, Canada, Alaska, and elsewhere).

The bivalve zones developed in our investigations are similar to the ecological zones of Krasilov (1977); they are portions of sections where there are recurrent associations of bivalves in recurrent facies. A sedimentation cycle (Karogodin, 1976; Haq et al., 1988) is the minimum stratigraphical portion where there is complete paleontological characterization of the bivalve zone. Bivalve, foraminiferal, and ostracode zonal boundaries are drawn according to the appearance of new associations or at boundaries of intervals where the maximum occurrence of typical species from the main part of the assemblages coincide.

The dating of bivalve, foraminiferal, and ostracode zones with respect to the general stratigraphic scale, and the definition of their stratigraphic range in this scale, are defined by ammonites in bivalve zones. The dating of bivalve, foraminiferal, and ostracode zones is also assisted by use of biostratigraphic markers within these scales which correlate well with those in the sections of Western Europe, the Canadian Arctic, northern Alaska, and elsewhere (for example, in the Bajocian, the bivalve zone *Retroceramus lucifer* and the foraminiferal zone *Riyadhella sibirica*; in the Toarcian, the foraminiferal zone *Ammobaculites lobus* and *Trochammina kisselmani*, ostracode zones *Trachycythere verrucosa* and *Camptocythere occalata*, the bivalve zone *Dacryomya inflata* and *Tancredia bicarinata*, and others).

As noted above, the evolutionary rates within individual zones of lateral sequences are not the same. Usually, the lower members of the lateral sequences are of longer duration and are more varied in lateral distribution. Consequently, parallel "thick" and "thin" (in terms of stratigraphic range) bivalve zones are recognized in the scale. This makes possible the correlation of different facies intervals using transitional sections, or the dating of deposits when there is not

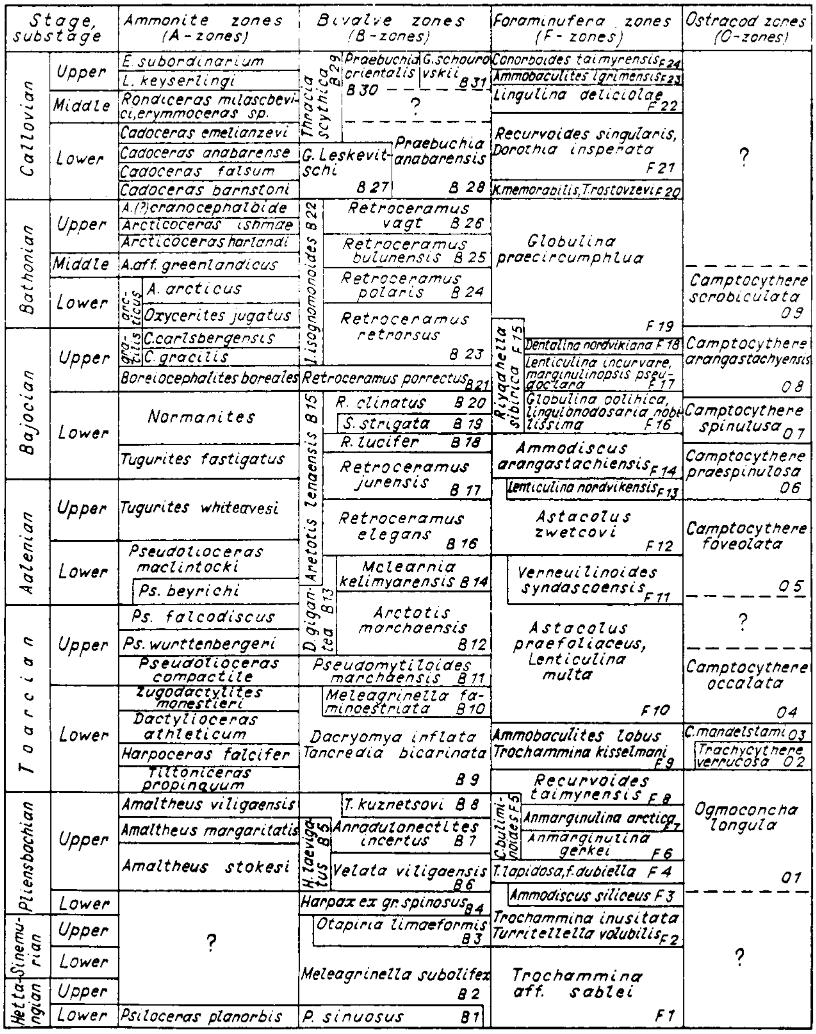


Fig.2. The combined parallel zonal scales of the Lower and Middle Jurassic of Siberia based on bivalves, foraminifera, and ostracoda. B1, F1, O1, etc.-- zone abbreviations used in other figures.

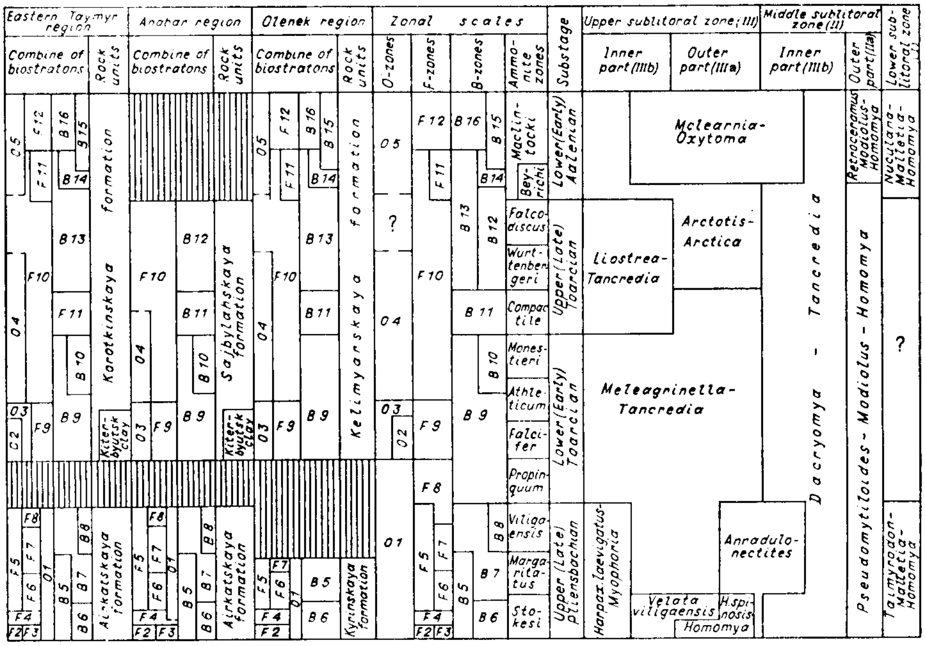


Fig.3. The combined parallel zonal scales of the Lower Jurassic and Aalenian in a typical region (northern middle Siberia, see Fig.1) based on the distribution of benthos (at left; for example, bivalve associations) and zones in Jurassic Siberian seas (at right).

enough data in one of the scales. It is necessary to correlate sequences of biozones with each other, but not bivalve zone with bivalve zone. The probability of mistakes in these correlations, using the sequence of events as a correlation feature, is reduced.

Parallel independent zonal scales of foraminifera, ostracodes, and others have been developed for numerous Jurassic sections of northern Russia. The boundaries of these zonal scales do not coincide because the evolutionary rates and the migratory and adaptive capacities of these faunal groups are different. Thus, the combination of all these scales gives a detailed sequence of events (changes in assemblages within different groups and their combinations) that is a good tool for reliable intrazonal correlation (Fig. 4). Overlapping intervals of biozones in parallel independent scales makes it possible to correlate outcrop and core sequences and to estimate lateral pinch-outs and the range of stratigraphic hiatus (Fig. 5).

RESULTS

For the Lower and Middle Jurassic of Siberia, 31 bivalve zones, 24 foraminiferal zones, and 9 ostracode zones have been recognized (Fig. 2). Simultaneously, parallel independent scales of pollen zones and dinoflagellate cyst zones have been developed for this age (Ilyina, 1985). Some of these zones are well recognized in Jurassic sections of Canada, Alaska, Western Europe, and elsewhere (Poulton et al., 1982; Wall, 1983; Nagy and Johansen, 1991). Unfortunately, direct correlations with stratotypes of stages are not possible. Recognized zones have been described in many publications where type sections and their paleontological descriptions have been given (Shurygin, 1986; Knyazev et al., 1991; Nikitenko, 1991, 1992; and others).

The most abundant and well-known species are used as typical species. Moreover, some new index species have been used to make scales more detailed. They are not widely known in the literature or are described as different species by different authors.

A short listing of the most important index species is given below.

SYSTEMATICS

Order Foraminiferida Eichwald, 1830
Suborder Textulariina Delage and Herouard, 1896
Superfamily Ammodiscacea Reuss, 1862
Ammodiscus siliceus (Terquem, 1862)
Pl. 1, Fig. 9.

Synonymy: see Nikitenko, 1991.
Distribution: Lower Jurassic in Europe, Siberia, Alaska, Canada.

Turritellella volubilis: Gerke and Sossipatrova, 1961
Pl. 1, Fig. 2.

Turritellella volubilis: Gerke, 1961, p. 136, pl. 16, Fig. 3; Sapyanik and Sokolov, 1991, pl. 8, Fig. 15.
Distribution: Upper Sinemurian - lower part upper Pliensbachian in Siberia.

Superfamily Trochamminacea Schwager, 1877
Trochammina aff. *sablei* Tappan, 1955
Pl. 1, Fig. 1.

Distribution: Hettangian - lower Sinemurian in Siberia.

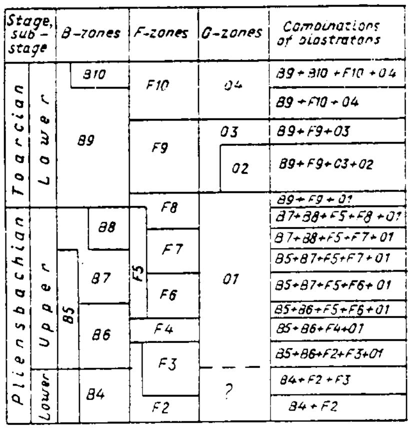


Fig.4. An example of the use of combined parallel zonal scales for identification of detailed (intrazonal) portions of sections.

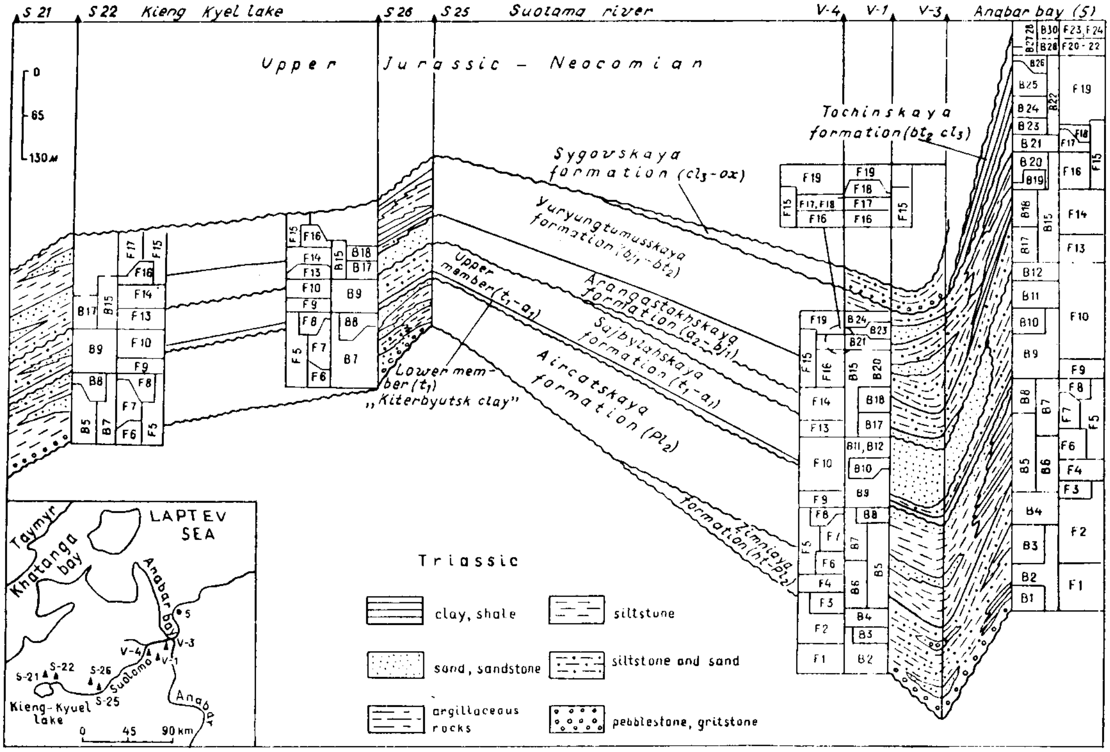


Fig.5. Geologic profile of the Lower and Middle Jurassic and correlation of wells and outcrops in the Anabar-Nordvik region (see lower left corner) according to combined parallel zonal scales.

Trochammina inusitata Schleifer, 1961
Pl. 1, Figs. 3, 4.

Trochammina inusitata Schleifer: Gerke, 1961, p. 146, pl. 18, Figs. 3-5; Sapyanik and Sokolov, 1991, pl. 9, Fig. 5.
Trochammina sp. 4965: Poulton et al., 1982, p. 62, pl. 5, Figs. 7, 8.
Distribution: Upper Sinemurian - lower part upper Pliensbachian in Siberia, Sinemurian in Canada.

Trochammina lapidosa Gerke and Sossipatrova, 1961
Pl. 1, Figs. 5, 6.

Trochammina lapidosa: Gerke, 1961, p. 147, pl. 17, Figs. 2-3; pl. 122, Fig. 3; Sapyanik and Sokolov, 1991, pl. 9, Fig. 9.
Trochammina ex gr. *inflata* (Montagu): Gerke, 1961, p. 144, pl. 17, Fig. 1.
Distribution: Upper Pliensbachian in Siberia.

Superfamily Verneuilinacea Cushman,1911
Riyadhella sibirica (Myatlyuk, 1939)
Pl. 1, Figs. 20, 21.

Synonymy: Yakovleva, 1973.
Distribution: Lower Bajocian - lower part lower Bathonian (lower part of ammonite zone *Oxycerites jugatus*) in northern Russia, Barents Sea, and Canada.

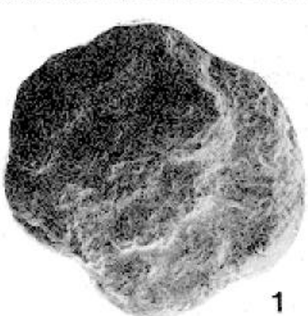
Verneuilinoides syndascoensis (Sharovskaya, 1958)
Pl. 1, Figs. 15, 16.

Verneuilina syndascoensis: Sharovskaya, 1958, p. 40, pl. 2, Figs. 1-2.
Riyadhella pseudosyndascoensis: Sokolov, 1985, p. 68, pl. 1, Figs. 4-8; Sapyanik and Sokolov, 1991, pl. 21, Fig. 5.
Verneuilinoides sp. 1: Wall, 1983, p. 268, pl. 1, Figs. 22, 23.
Riyadhella syndascoensis (Sharovskaya): Sapyanik and Sokolov, 1991, pl. 11, Fig. 1.
Verneuilinoides subvitreus: Nagy and Johansen, 1991, p. 24, pl. 4, Figs. 20-28.
Distribution: Upper part upper Toarcian - lower Aalenian in Siberia, Barents Sea, upper Toarcian in North Sea, lower Aalenian in Canada.

Suborder Lagenina Delage and Herouard, 1896
Superfamily Nodosariacea Ehrenberg, 1838
Lenticulina nordvikensis (Myatlyuk, 1939)
Pl. 1, Figs. 7, 8.

Cristellaria nordvikensis: Myatlyuk, 1939, p. 235, pl. 2, Fig. 16.
Lenticulina nordvikensis (Myatlyuk): Sapyanik, 1991, p. 108, Fig. 3; Sapyanik and Sokolov, 1991, pl. 22, Fig. 4.
Distribution: Upper Aalenian in Siberia and northeast Russia.

Plate 1. 1. *Trochammina* aff. *sablei* Tappan, Anabar Bay, A12-27-2, Hettangian - lower Sinemurian, x72. 2. *Turritellella volubilis* Gerke and Sossip., Anabar Bay, A12-41-1, upper Sinemurian, x100. 3, 4. *Trochammina inusitata* Schleifer: 3, Eastern Taymyr, Z7-39-3, lower part of upper Pliensbachian, x90; 4, Anabar bay, A12-39-2, Upper Sinemurian, x65. 5, 6. *Trochammina lapidosa* Gerke and Sossip., Anabar Bay, upper Pliensbachian: 5, megalospheric specimen, A12-45-7, x50; 6, microspheric specimen, A12-50-2, x43. 7, 8. *Lenticulina nordvikensis* (Myatlyuk), Eastern Taymyr, upper Aalenian: 7, megalospheric specimen, Z5-23-3, x18; 8, microspheric specimen, Z5-23-2, x36. 9. *Ammodiscus siliceus* (Terquem), Anabar Bay, microspheric specimen, A12-48-2, upper Pliensbachian, x40. 10-12. *Conorboides buliminoides* (Gerke), upper Pliensbachian: 10, Yuryung-Tumus, Y5-1-2, x100; 11, Anabar Bay, A12-50-1, x100; 12, Yuryung-Tumus, Y5-1-21, x122. 13, 14. *Frondiculinita dubiella* (Gerke), Yuryung-Tumus, upper Pliensbachian: 13, microspheric specimen, Y892/37, x36,6; 14, megalospheric specimen, Y892/38, x36,6. 15, 16. *Verneuilinoides syndascoensis* (Sharovskaya): 15, Eastern Taymyr, Z1048/88, lower Aalenian, x61; 16, Anabar Bay, A11/15, upper Toarcian, x55. 17. *Dentalina nordvikiana* Nikitenko, Yuryung-Tumus, Y892/18, lower Bathonian, x67. 18, 19. *Globulina praecircumphlua* Gerke, Yuryung-Tumus, lower Bathonian: 18, Y19/81, x100; 19, Y19/82, x83. 20, 21. *Riyadhella sibirica* (Myatlyuk), Yuryung-Tumus, lower Bajocian: 20, Y20/24, x47; 21, Y20/23, x30. 22. *Ogmoconcha longula* Gerke and Lev, Anabar Bay, A125/2, upper Pliensbachian, x50. 23-25. *Camptocythere spinulosa* (Sharapova), Yuryung-Tumus, lower Bajocian: 23, Y201/3, x83; 24, Y201/4, x72; 25, Y201/5, x94.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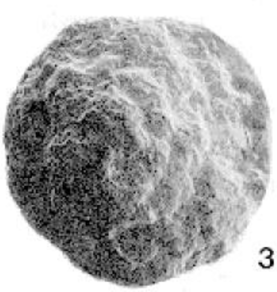
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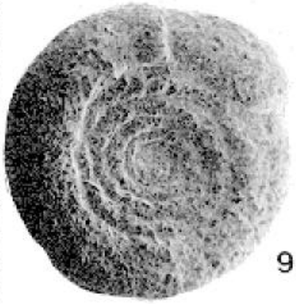
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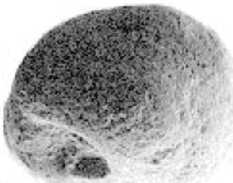
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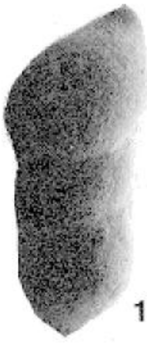
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Globulina praecircumphlua Gerke, 1961
Pl. 1, Figs. 18, 19.

Globulina praecircumphlua Gerke: Sapyanik and Sokolov, 1991, pl. 23, Fig. 7.
Distribution: Bathonian in Siberia.

Superfamily Robuloidacea Reiss, 1963
Frondiculinita dubiella (Gerke, 1957)
Pl. 1, Figs. 13, 14.

Synonymy: see Nikitenko, 1991.
Distribution: Upper Pliensbachian, *Amaltheus stokesi* ammonite zone in Siberia.

Suborder Robertinina Loeblich and Tappan, 1984
Superfamily Ceratobuliminacea Cushman, 1927
Conorboides buliminoides (Gerke, 1961)
Pl. 1, Figs. 10-12.

Discorbis? buliminoides: Gerke, 1961, pl. 120, Figs. 1-8; Sapyanik and Sokolov, 1991, pl. 10, Fig. 2.
Distribution: Upper Pliensbachian in Siberia.

Subclass Ostracoda Latreille, 1806
Order Podocopida Muller, 1894
Suborder Podocopina Sars, 1866
Superfamily Cytheracea Baird, 1850
Family Progonocytheridae Sylvester-Bradley, 1948
Camptocythere spinulosa (Sharapova, 1940)
Pl. 1, Figs. 23-25.

Cytherissa spinulosa: Sharapova, 1940, p. 126, pl. 1, Fig. 6; 1947, p. 212, pl. 44, Fig. 4.
Distribution: Lower Bajocian in Siberia.

Suborder Metacopina Sylvester-Bradley, 1961
Family Healdiacea Harlton, 1933
Ogmoconcha longula Gerke and Lev, 1958
Pl. 1, Fig. 22.

Ogmoconcha longula: Lev, 1958, p. 28, pl. 2, Figs. 3-6; pl. 3, Figs. 5-7.
Ogmoconcha ovata: Lev, 1958, p. 30, pl. 1, Figs. 1-2.
Ogmoconcha magna: Lev, 1958, p. 29, pl. 1, Fig. 3.
Distribution: Upper Pliensbachian - lower part lower Toarcian (*Tiltoniceras propinquum* zone) in Siberia and northeast Russia.

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