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Bivalve-Based Stratigraphy of the Toarcian of Eastern Siberia and Northeastern Russia (Family Oxytomidae Ichikawa, 1958). Part 3. Toarcian–Lower Aalenian Zonal Scale Based on Oxytomids. Bivalve-Based Stratigraphy and Correlation

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Abstract—As a methodological basis for spatio-temporal modeling of the studied sedimentary series, the relational-genetic space-time concept of Steno–Vernadsky and V.I. Vernadsky's paradigm of biological time. The biochronological approach to the development of a zonal scale as an independent methodological direction is defined. Based on a revision of the phylogenetic system of the family Oxytomidae, a spatiotemporal framework of the zonal scale was constructed. The direction of the time scale is determined by the sequence of index species interconnected by a single chronocline of changes in the states of the characters of the ligament block. The direction of evolution in the phylogenetic lineage *Meleagrinella–Arctotis*, combined with periods of stable state of some characters, has its own (relational) time, therefore the scale is considered as biochronological and is a tool for dating sediments. According to paleontological and stratigraphic criteria, the elementary divisions of the scale—Oxyto-zones are phylozones, deposits containing the species representing segments of the phylogenetic lineage of the genera *Meleagrinella* and *Arctotis*. The updated Toarcian and Lower Aalenian zonal scales consist of six oxyto-zones. In the boundary deposits of the Upper Pliensbachian, Beds with Meleagrinella deleta are recognized. In the Upper Aalenian–Lower Bajocian boundary deposits, Beds with Arctotis sublaevis are recognized. In the Upper Toarcian–Lower Aalenian, an auxiliary biostraton is recognized—parallel Beds with Oxytoma jacksoni. The correlation potential of the scale was assessed based on tracing oxyto-zones in sections of Eastern Siberia, Northeast Russia, Germany, France, Western and Arctic Canada. In the terminal part of the Pliensbachian, the Beds with Meleagrinella deleta are recognized in the Siberian, Far Eastern and Western European paleobiogeographic provinces within the Arctic and Boreal-Atlantic regions. In the Lower Toarcian, the Meleagrinella golberti and Meleagrinella substriata oxyto-zones of were identified in the Arctic, Boreal-Atlantic and Boreal-Pacific paleobiogeographic regions. In the upper part of the Toarcian and in the Aalenian–Lower Bajocian, the Meleagrinella prima, Arctotis marchaensis, Arctotis similis oxyto-zones and Beds with Arctotis sublaevis were recognized in the Siberian and Far Eastern provinces within the Arctic paleobiogeographic region, parallel Beds with Oxytoma jacksoni were traced in the Arctic and Boreal-Pacific paleobiogeographic areas. Tracing oxyto-zones and Beds with oxytomids allows the intra- and interregional correlation at the zonal and substage levels.

Keywords: concepts of time, time-space, biochronological approach, zonal scale

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INTRODUCTION

The development of zonal scales belongs to the group of retrospective geological studies that can only be characterized at the level theoretical constructs and concepts that are inaccessible to direct observation, but hypothetically deducible in a logical way (Kosygin, 1970). Three concepts of time are mainly used for spatio-temporal modeling of historical-genetic processes: *substantial, relational* and *relational-genetic*. Depending on the use of each of them in constructing zonal scales and stratigraphic schemes, different interpretations of both existing stratigraphic units and their time equivalents can be obtained (Gladenkov, 2004). The absolute mathematical time concept, as introduced by I. Newton, that exists independently of any perceiver and progresses at a consistent pace without any relation to anything external, took shape in the substantial concept of time and is still preserved in the practice of stratigraphic research. A. Einstein's theory of relativity did not change the concept of time as an external measure, but influenced the methodology for determining simultaneity (Simakov, 1999). Simakov (1995), based on N. Steno hypothesis of the possibility of interpreting the spatial relationships of geological bodies from the observational frame of time sequence (Steno, 1957) and Vernadsky's space-time concept (Vernadsky, 1932) of a single indivisible space-time, connected these ideas within the framework of the relational-genetic concept of time. Aksenov (2000), based on Vernadsky's (1988) paradigm of biological time, according to which life is the source of the duration of time and has the basic characteristics that determine space (Vernadsky, 1988), came to the idea that absolute time and absolute space, which Newton attributed to the immaterial order of being, can be replaced with the development of science by biological space-time (Aksenov, 2000).

Biostratigraphic, chronostratigraphic and ecostratigraphic approaches are more often used for stratigraphic classification, while the biochronological approach is used to a lesser extent. The biostratigraphic approach is based on the natural sequential change of faunal and floristic assemblages throughout the section (Stepanov and Mesezhnikov, 1979). In chronostratigraphy, time is first subdivided, and then conventional units of time are imposed on the sequence of events regardless of their integrity. The ecostratigraphic approach is based on the natural sequential change in the states of the earth's crust and biosphere (Krassilov, 1977).

The biostratigraphic approach is based on the substantial concept of time and is based on the concept suggesting that simultaneity of geological beds is determined by their confinement to moments of absolute time, recorded by the units of the International Stratigraphic Scale and regional stratigraphic scales. The chronostratigraphic approach is also based on the substantial concept of time, while the fixation of the boundaries of chronostratigraphic units is determined on the basis of international agreements. The ecostratigraphic approach is based on the relational concept of geological time and suggests that moments of geological time correspond to successive stages of stabilization of the Earth's crust and biosphere. In recent decades V.V. Chernykh has been actively developing theoretical foundations of the method of zonal biochronology, as an independent direction in stratigraphy. Describing the concept of "zonal biochronology," he emphasizes that zonal biochronological scales are built on an evolutionary basis (Chernykh, 2016). This suggests that the author of the idea of autonomy of zonal biochronology, as an independent direction in stratigraphy, the only difference between the biochronological approach and the biostratigraphic one is the difference in the methods for constructing paleontological scales—either on an evolutionary phylogenetic basis or using all other criteria. According to Chernykh (2005) biochronological scales (BCS) include evolution-based scales with a precise definition of the boundaries of units drawn at the event of "emergence of a taxon" in the evolutionary sequence of related forms (Chernykh, 2005). Other concepts were also associated with the same concept: the biochronological scale is a scale of historical, eventful, qualitative time (Chernykh, 2014); the biochronological scale is a model representation of chronological time in the form of a sequence of the smallest chronological units—zones (Chernykh, 2016); the biochronological scale is a model of biochronological calculation of geological time, imprinted in the section in the form of signatures of certain events in the development of a given group of organisms (Chernykh, 2020). The purpose of zonal biochronological scales seemed equally ambiguous. On the one hand, it was argued that "the only purpose of the BHS is the subdivision of sections and the correlation of stratigraphic boundaries of stratigraphic units" (Chernykh, 2016, p. 104), on the other hand, it was stated that "the zonal method makes it possible to "measure geological time" with completely objective events from the life of the organic population of the Earth" (Chernykh, 2016, p. 230).

The main purpose of zonal scales for parastratigraphic faunal groups is in additional opportunities for intra- and interregional correlations (Zakharov et al., 1997). Another purpose of zonal scales is dating the deposits. The currently existing parallel Jurassic zonal scales for parastratigraphic groups (Shurygin, 1986, 1987a, 1987b; Repin and Polubotko, 1996, 2004; *Resheniya*..., 2009; Shurygin et al., 2011) are based on the ideas of their authors about the intervals of co-occurrence of species, forming the basis of zonal assemblages, the sequence of these assemblages and the chronometric duration of existence relative to the units of the local ammonite scale. Scales based on the integration of intervals of co-occurrence of taxa separated by large genetic distances are based on ecostratigraphy. In scales constructed from polytaxon zones, the simultaneity of stratigraphic assemblages is determined either by paleocommunities belonging to the same paleoenvironments, depending on abiotic factors, or by belonging to certain stages of the evolution of the communities themselves. The boundaries of these zones (usually the lower ones) are fixed in sections not by changes in the taxonomic composition of assemblages, but by the sequence of strata that differ in taxonomic composition, structure of assemblages, and patterns of change in assemblages in recurrent facies. The boundaries between adjacent biostratons in a sequence always have an interval of uncertainty (Shurygin et al., 2000).

METHODS

The spatiotemporal design of the proposed scale is implemented using the relational-genetic Steno–Vernadsky concept of time. This approach is based on the concept of the indivisibility of space and time. Dating geological events uses a biochronological approach, which is based on V.I. Vernadsky's paradigm of biological space-time. According to this paradigm, living matter is the only terrestrial phenomenon in which space-time is manifested (Vernadsky, 1980).

The space-time of living matter is characterized by a geologically eternal change of generations for all organisms; death is the destruction of space-time of the body of organisms; over the course of geological time, this phenomenon is expressed by an evolutionary process that abruptly changes the morphological form of organisms and the rate of generation change; time goes in one direction, in the direction of the outburst of life and creative evolution (Vernadsky, 1988). The simultaneity of biochronostratons, identified biochronologically, is based on the assumption that they belong to the same class of planetary biogeospheric events that determine the duration of moments of geological time. The measurement of the time of geological events within the framework of this paradigm is the measurement of the lifetime of organisms associated with their living space. In the biochronological approach, morphogenetic distances between selected reference points for marks of internal biological space-time are a metric of geological space-time.

A biochronological scale is a time-space model constructed on the basis of the pattern of evolution of organisms preserved in the form of biofossils (Lutikov, 2023a). Measurement refers to the procedure by which the measured object is compared with some standard and receives a numerical expression on a certain scale (Yadov, 1972). Measuring the time of sediment formation using a biochronological scale is a procedure by which the evolutionary sequence of organisms determines how each geological object under study is assigned to some unit of its own time-space scale.

If the direction of evolution is combined with its periodicity, then it has its own time and can be a tool for dating geological events (Krassilov, 1977).

Time Scale Directionality

The proposed zonal scale is based on the phylogenetic sequence of species belonging to the genera *Meleagrinella* and *Arctotis*, interconnected by a single chronocline of evolutionary changes. The direction of morphogenesis in the *Meleagrinella–Arctotis* series is reflected in the sequence of states of the ligament block that do not repeat each other. The boundaries of zones in the scale are established based on the appearance in phylogeny of new species of a single lineage, and species are fixed by the appearance of characters characterizing the corresponding phase of morphogenesis. When establishing the discreteness of taxa, the author adhered to the evolutionary concept of the species by J.G. Simpson. According to this concept, a species has a temporal extension and has a specific role, which is to adapt to the environment throughout its existence (Simpson, 2006). The discreteness of taxa was determined by a complex of morphological characters. Distances of morphogenesis with relatively stable states of characters characterizing the taxon correspond to the time of existence of the taxon. Due to individual variability in characters, boundaries between taxa sometimes have intervals of uncertainty. The pronounced discreteness of some taxa can be explained by the incompleteness of the geological record (Darwin, 1872), although the quantum nature of the formation of some characters and, accordingly, new taxa cannot be ruled out.

Periodization of the Scale

Periods of stable state of internal and external characteristics of shells allow periodization of the scale. By weighing 31 characters in chronological sequence determined using a separate Boreal ammonite scale, periods of relatively stable states were recognized within the family Oxytomidae for 19 taxonomically significant characters in the Pliensbachian-Aalenian interval (Fig. 1). The change in the type of the posterior wing of the left valve in the genus *Meleagrinella* is taken as the basis for the periodization of the scale in the Late Pliensbachian–Late Toarcian (Lutikov and Arp, 2023a). The change in the shape of the byssal ear in combination with a change in the type of the anterior wing of the left valve in the genus *Arctotis* is accepted as the basis for the periodization of the scale in the Late Toarcian–Aalenian interval (Lutikov, 2021).

In the course of studying morphogenesis in the *Meleagrinella deleta–Meleagrinella golberti–Meleagrinella substriata–Meleagrinella (Meleagrinella) prima* chronocline, it was established that against the background of evolutionary changes in the ligament block, changes in the types of the posterior wing occurred from straight to rocker-shaped, S-shaped and arched (Lutikov and Arp, 2020a). As a result of studying morphogenesis in the chronocline of *Meleagrinella (Meleagrinella) prima–Arctotis (Praearctotis) marchaensis–Arctotis (Praearctotis) similis–Arctotis (Arctotis) tabagaensis–Arctotis (Arctotis) sublaevis*, it was established that against the background of evolutionary changes in the ligament block, changes in the types of the forewing occurred from "paraboloid" to "trapezoid", then to "hyperboloid" and to "S-shaped". In the series *Arctotis (Arctotis) tabagaensis–Arctotis (Arctotis) sublaevis*, the shape of the right valve changes from flat to concave.

Position of Oxyto-Zones in Geological History

Standard ammonite scales in the Jurassic act as a theory for the completeness of stratigraphic history. Since parallel biochronological scales have their own space-time, their duration can only be determined with an accuracy of the elementary operational unit accepted in the geological record—a zone or subzone. It is not possible to use a parallel scale division to determine the duration of standard scale units. As Academician B.S. Sokolov emphasized, "with all the

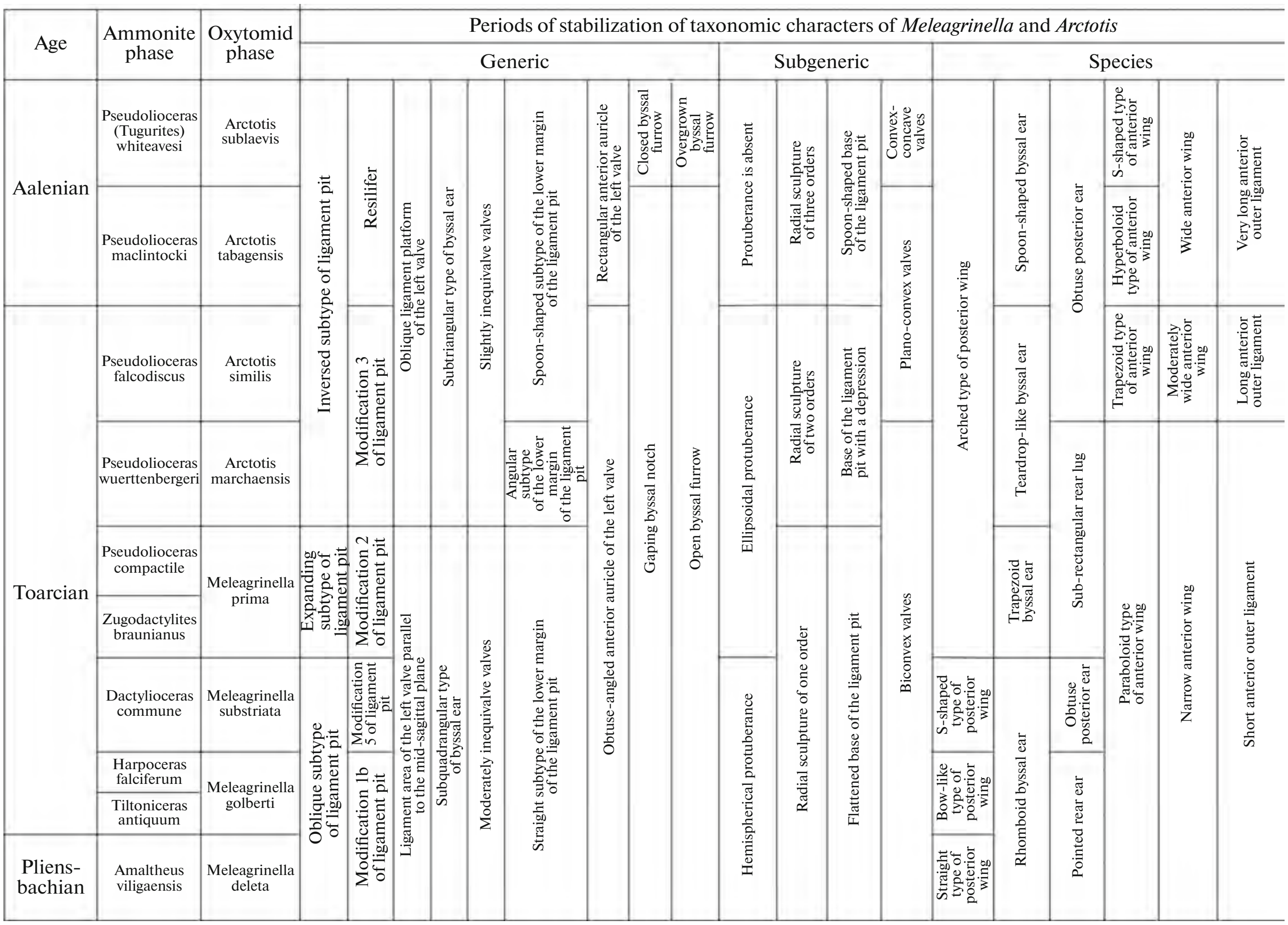

Fig. 1. Periodization of the oxytomid scale based on intervals of the stable state of traits.

importance of the paleontological assemblage for characterizing both regional and chronostratigraphic units, the boundaries of the units should be established based on the study of only one group, otherwise several boundaries will arise, which is completely unacceptable" (Sokolov, 1971, p. 174). Revision of standard scales and justification for identifying new spatio-temporal divisions in the general sequence of events of the geological record of the Earth will inevitably lead to a revision of the parallel scale but will not affect the internal content of this scale if the scale is built on correct phylogenetic hypotheses. The oxytomid zonal scale was developed jointly with the Toarcian–Aalenian ammonite zonal scale on the same sections of Eastern Siberia and Northeastern Russia (Knyazev et al., 2003). To determine the stratigraphic position of the oxyto-zones and Beds with oxytomids in the general sequence of ammonite zones, the section along the Astronomicheskaya River was chosen as the reference section of the Lower Toarcian, for the Upper Toarcian—the section of Anabar Bay, for the Lower Aalenian—the section along the Motorchuna River.

Stratigraphy of Sections and Correlation of Oxyto-Zones

The essence of the phylogenetic method in biostratigraphy is the transformation of evolutionary relationships between organisms preserved as biofossils into temporal relationships between the beds containing these fossils (Krassilov, 1977). The division of the studied sections was carried out using an evolutionary approach (Stepanov and Mesezhnikov, 1979) and was based on the sequence of emergence of new taxa in the phylogeny of the family Oxytomidae. The simultaneity of the formation of deposits in the time frame specified by the oxytomid scale is determined by the belonging of these deposits to one of the classes of sequential events in the *Meleagrinella–Arctotis* phylogenetic series.

Stratigraphy of sections and correlation of oxyto-zones involved the sequential implementation of the following operations:

(a) stratigraphic subdivision of exposures of Toarcian sedimentary marine strata using lithologic-facies and paleontological-taphonomic characteristics into discrete biostratons, identification of local biostratigraphic units—beds with fauna, and correlation of outcrops;

(b) generalization of paleontological characteristics for structural-facies zones, identification of regional biostratigraphic units—oxyto-zones and correlation of sections within the regions of Eastern Siberia and Northeastern Russia;

(c) generalization of paleontological characteristics for paleobiogeographical regions and regions, the use of oxyto-zones to correlate strata between regions within the Panboreal super-region.

To assess the correlation potential of the scale, the sequence of oxyto-zones established in the reference sections was traced in a series of Toarcian–Aalenian sections of Eastern Siberia (Molodo, Syungyude, Markha, Tyung, Vilyui rivers, boreholes of the Vilyui Syneclise) and Northeastern Russia (Saturn, Brodnaya, Start rivers), as well as in the section of the Ludwigskanal in Southern Germany.

ZONAL SCALE

To establish the chronology of the Toarcian-Aalenian evolutionary transformations that determine the proper space-time scale, the boreal zonal standard was used (Zakharov et al., 1997; Shurygin et al., 2011), as well as ammonite scales developed for the Pliensbachian, Toarcian and Aalenian of Northwestern Europe (Hillebrandt et al., 1992; Dommergues et al., 1997; Page, 2003). The first version of the Lower Toarcian scale for bivalves was presented at the VIII All-Russian meeting "Jurassic system of Russia: problems of stratigraphy and paleogeography" (Lutikov and Arp, 2020b). In 2022, new information was obtained on the structure of the ligament block in the syntype of *Meleagrinella substriata* from the type collection, and the ontogeny of the ligament block and microsculpture of the ostracum in the East Siberian *"Meleagrinella faminaestriata"* (=*Meleagrinella prima* sp. nov.) and *Arctotis marchaensis* (Petrova) were studied. (Lutikov and Arp, 2023a). The modernized biochronological scale of the Toarcian is based on the results of a revision of the genera *Meleagrinella* and *Arctotis* (Fig. 2). According to paleontological and stratigraphic criteria (*Stratigraficheskii...*, 2019), oxyto- zones are phylozones—deposits hosting species that represent segments of the phylogenetic lineage of the genera *Meleagrinella* and *Arctotis*. The lower boundary of the oxyto-zones in the scale is defined by the first appearance of the index species. The Beds with oxytomids are classified as auxiliary biostratigraphic units and represent deposits containing fossil remains belonging to the family Oxytomidae. In one case, Beds with oxytomids were identified in deposits in which zonal index species and oxyto-zone assemblages were not found, and index species established for such deposits did not form short evolutionary distances with the main phylogenetic group forming the chronocline (in the species index of the Beds with Oxytoma jacksoni, the number of characters defining taxonomic similarity with index species of oxyto-zones is reduced). In other cases, Beds were identified in sediments in which the taxonomic similarity of zonal index species with index species from underlying or overlying sediments had not been studied (for the index species of the Beds with Meleagrinella deleta, the evolutionary distances with other representatives of the genus *Meleagrinella* found in the Pliensbachian deposits; the index species of the Beds with Arctotis sublaevis has not clearly defined evolutionary distances with other Middle Jurassic representatives of the genus *Arctotis*).

The zonal scale, based on the phylogenetic sequence of genera and species of the genera *Meleagrinella* and *Arctotis*, reflects the main stages of development of the family Oxytomidae, which occurred synchronously over vast territories. The relationships between the modern ammonite scales of the Toarcian and Aalenian, the existing parallel scales for bivalves, and the scale for oxytomids are presented in Figs. 3 and 4.

In specific sections, oxyto-zones and Beds with oxytomids are recognized as discrete parts of sections, characterized by the presence of index species in them. To subdivide and correlate formations and their parts, along with tracing the sequence of index species in different sections, it is necessary to trace the sequence of accompanying zonal species of bivalve mollusks. For parts of the sections not characterized by zonal species and zonal complexes, the correlation was carried out taking into account information on other faunal groups—ammonites and foraminifers. This scale was the basis of the detailed correlation of sections of Eastern Siberia and Northeastern Russia.

Below is the sequence and characteristics (from bottom to top) of the zonal divisions of the scale, performed on the basis of an analysis of the stratigraphic intervals of the distribution of index species and zonal assemblages in five structural-facies zones (SFZ) of Eastern Siberia, one stratigraphic zone (SZ) of the Northeastern Russia and in region of the Franconian Alb in southern Germany.

Beds with Meleagrinella deleta

Nomenclature. Beds with Praemeleagrinella deleta as an auxiliary biostratigraphic unit were first recognized at the top of the Airkat Formation in the section of Cape Tsvetkov and were correlated with the upper zone of the Pliensbachian, Amaltheus viligaensis Zone (Lutikov et al., 2022).

Index species. *Meleagrinella (Praemeleagrinella) deleta* (Dumortier, 1869).

Characteristic assemblage of the Beds include the following bivalves: *Meleagrinella (Praemeleagrinella) sparsicosta* (Petr.), *Meleagrinella (Praemeleagrinella?) tiungensis* (Petr.), *Meleagrinella (Praemeleagrinella?) oxytomaeformis* Polub., *Ochotoclamys*

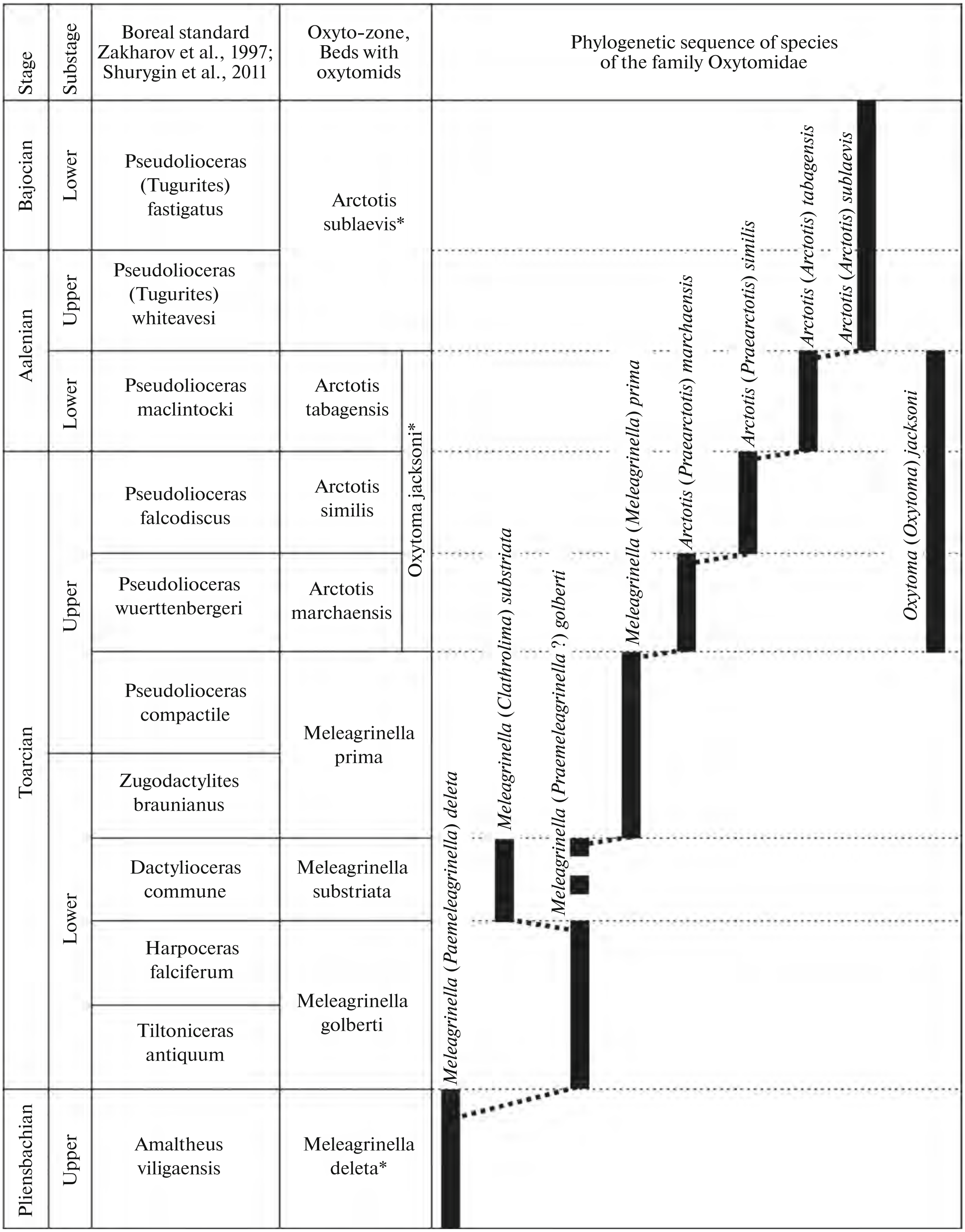

Fig. 2. Zonal subdivision of the Toarcian–Lower Aalenian and boundary intervals of the upper Pliensbachian and upper Aalenian–lower Bajocian based on the phylogenetic sequence of species of the family Oxytomidae. Vertical wide solid lines are biozones of index species of oxyto-zones and Beds with oxytomids. Thin dotted lines indicate branches of the supposed phylogenetic lineages. The vertical dotted line shows a putative segment of the *Praemeleagrinella* lineage.

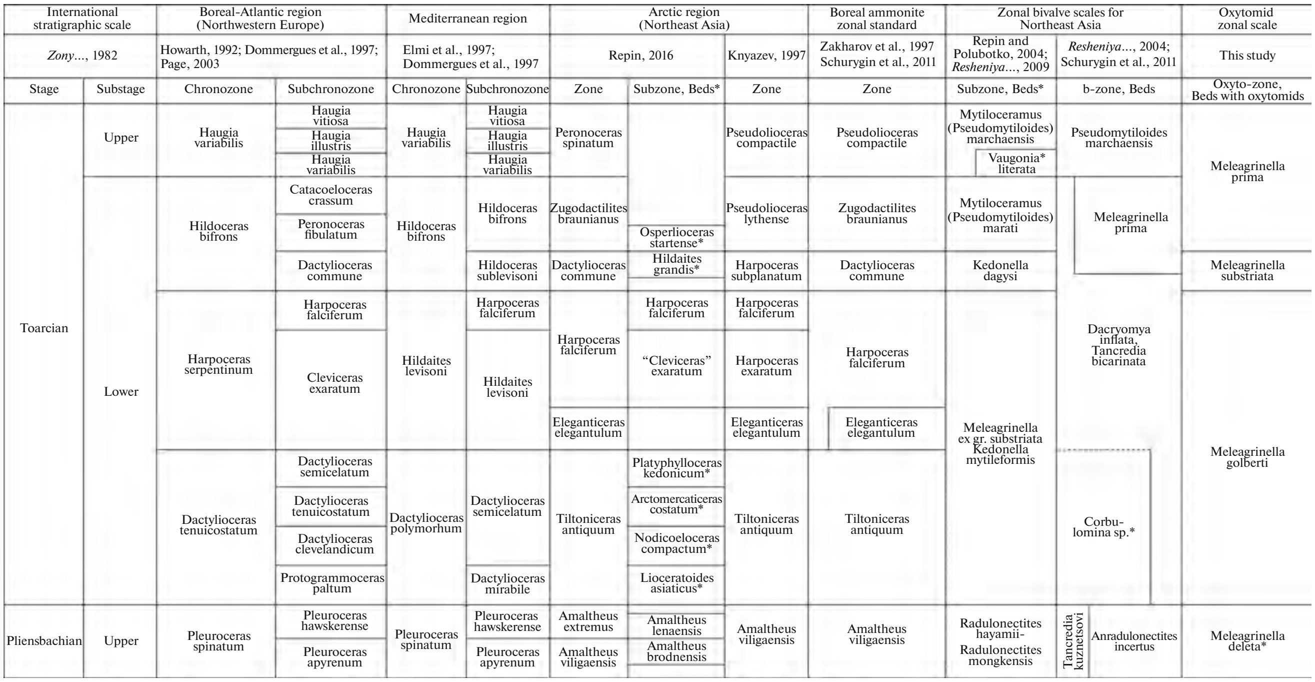

Fig. 3. Correlation of zonal scales for ammonites and bivalves of the upper Pliensbachian zone—the upper Toarcian lower zone.

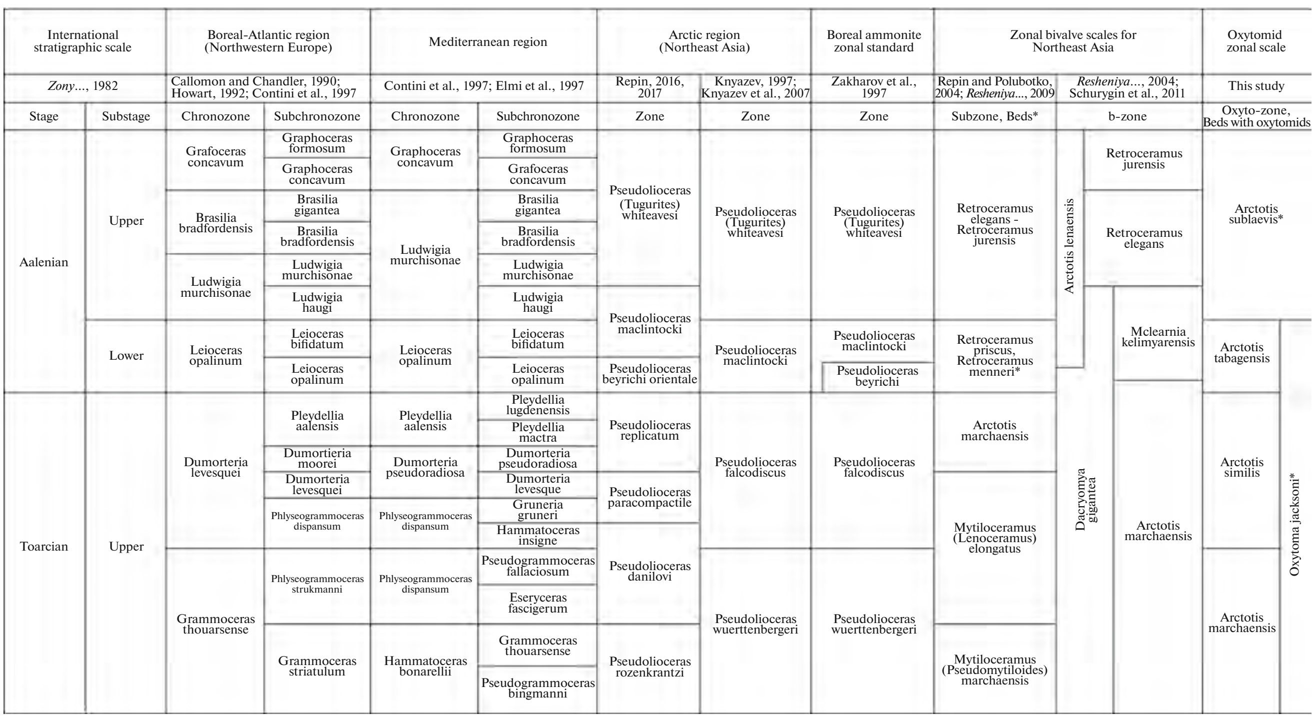

Fig. 4. Correlation of zonal scales for ammonites and bivalves of the upper Toarcian (without the lower zone) and Aalenian.

grandis Polub., *Anradulonectites levis* (Polub.), *Anradulonectites anabarensis* Schuryg. et Lut., *Kolymonectes* aff. *terekhovi* Polub., *Siungiudella parvula* Lutikov, *Oxytoma inaequivalvis* Sow., *Pseudolimea philatovi* (Polub.), *Liotrigonia lingonensis* (Dum.), *Pseudomytiloides?* sp. ind., *Lenella tiungensis* Kosch., *Lenella kedonensis* (Polub.).

Definition of boundaries and substantiation of age. The species *Avicula (=Praemeleagrinella) deleta* was first described from the upper part of the Pliensbachian of France and is listed alongside the ammonite *Pleuroceras spinatum* (Bruguiere) (Dumortier, 1869, p. 293). In the section of the Astronomicheskaya River, Beds with Praemeleagrinella deleta occupy a position at the level of finds of ammonites *Amaltheus extremus* Repin and *Amaltheus viligaensis* Tuchkov. The Beds are widespread in various facies areas of Eastern Siberia and characterize the upper Pliensbachian zone. Based on the findings of the index species, the beds were traced in the terminal part of the Airkat Formation on the Anabar River and Cape Tsvetkov, Kyra Formation on the Kelimyar River, Motorchuna Formation on the Motorchuna River, Suntary Formation at the Pravoberezhnyi and Tenkelyakh drilling sites.

The lower boundary of the Beds with Praemeleagrinella deleta is defined by the appearance of the index species. The age of the Beds was determined based on the presence of an index species in the Pleuroceras spinatum Zone (Dumortier, 1869) and the correlation of the Pleuroceras spinatum Zone with the Amaltheus viligaensis Zone in Eastern Siberia and Northeast Russia (Dagys, 1976). The Beds roughly correspond to the Amaltheus viligaensis Zone of the Boreal standard zonal scale (Zakharov et al., 1997; Shurygin et al., 2011). The upper limit is drawn by the appearance of *Meleagrinella (Praemeleagrinella?) golberti*, the index species of the overlying oxyto-zone.

R e m a r k s. The lower boundary of this biostratum is not clearly defined. The phylogenetic connections of the species *Meleagrinella* (*Praemeleagrinella*) *deleta* with *Meleagrinella (Praemeleagrinella?) tungensis*, *Meleagrinella (Praemeleagrinella) sparsicosta*, *Meleagrinella (Praemeleagrinella?) ptchelincevae*, *Meleagrinella (Praemeleagrinella?) oxytomaeformis*, *Meleagrinella (Praemeleagrinella?) ansparsicosta*, known in the Upper Pliensbachian of Eastern Siberia and North-East Russia, have not been fully studied. Therefore, this biostraton is considered in the rank of Beds. In Anabar Bay, the Beds with *Meleagrinella deleta* include the upper part of the succession containing *Tancredia kuznetsovi Petr*. The Beds with *Tancredia kuznetsovi* were recognized based on the epibole of the taxon as an auxiliary biostratigraphic unit in sections of Eastern Siberia in the volume of the upper Pliensbachian zone (Shurygin, 1986). The lower boundary of the Beds was conditionally correlated with the boundary of the *margaritatus* and *viligaensis* zones, the upper boundary of the Beds was correlated with the base of the Toarcian (Shurygin, 1987a). The distribution of this species in Pliensbachian sections has a wider geochronological range than the established range of the biostraton under consideration. In the section of the Anabar River, this species was recorded from the level immediately above the find of the ammonites *Amaltheus (Amaltheus) margaritatus* Montfort, *Amaltheus (Amaltheus) talrosei* Repin, *Amaltheus (Amaltheus)* cf. *conspectus* A. Dagys, *Amaltheus (Nordamaltheus) brodnaensis* Repin, *Zetoceras zetes* (Orbigny) (Meledina and Shurygin, 2001). In the section of the western coast of Anabar Bay, this species appears in the part of the section above the finds of the ammonites *Amaltheus stokesi* (Sowerby), together with the ammonites *Amaltheus* sp., not identified to species (*Stratigrafiya*..., 1976). In sections on the Tyung and Vilyui rivers, the species *Tancredia kuznetsovi* is recorded in the second and third members of the Tyung Formation. The first appearance of this species on the Tyung River was recorded directly above the first member containing the ammonites *Amaltheus* sp. (Knyazev et al., 1981). In Northeastern Russia in the Bulun River basin, the appearance of the species *Tancredia kuznetsovi* was recorded at the same levels as the ammonites of the Amaltheus talrosei Zone (Milova, 1988). Thus, the *Tancredia kuznetsovi* Biozone covers the two upper Pliensbachian zones, therefore the stratigraphic range of the Beds with Tancredia kuznetsovi should be considered more broadly, i.e., to correspond to the margaritatus and viligaensis zones.

C o r r e l a t i o n. The Beds with Praemeleagrinella deleta correlate with the upper part of the Anradululonectites incertus Zone of the zonal bivalve scale of Eastern Siberia (Shurygin et al., 2011) and with the upper part of the Radululonectites hayamii–R. mongkensis Zone of the zonal scale for bivalves adopted for Northeastern Russia (*Resheniya*..., 2009) (Fig. 3).

Meleagrinella golberti Oxyto-Zone

N o m e n c l a t u r e. The zone is recognized to replace the previously proposed “Praemeleagrinella sp. 1” and “Praearctotis sp. 1” zones (Lutikov and Arp, 2020b). The bivalve Meleagrinella ex gr. substriata and Kedonella mytileformis Zone corresponding to the Tiltoniceras antiquum and Harpoceras falciferum ammonite zones was first proposed by Repin and Polubotko (2004) for Northeastern Russia. Specimens of *Meleagrinella* from the lower two Toarcian zones from sections of Eastern Siberia, Northeastern Russia and Germany were previously identified as *Meleagrinella substriata* (Knyazev et al., 2003), *Meleagrinella (Praemeleagrinella)* sp. 1 and *Praearctotis* sp. 1 (Lutikov and Arp, 2020a). As a result of the revision, they were assigned to the new species *Meleagrinella (Praemeleagrinella?) golberti* Lutikov et Arp, 2023. The *Meleagrinella golberti* Oxyto-zone corresponds to the *Tiltoniceras antiquum* and *Harpoceras falciferum* zones of the Boreal standard scale (Zakharov et al., 1997; Shurygin et al., 2011).

I n d e x s p e c i e s: *Meleagrinella (Praemeleagrinella?) golberti* Lutikov et Arp, 2023.

S t r a t o t y p e o f o x y t o - z o n e: Northeastern Russia, Levy Kedon River basin (Astronomicheskaya River) (Fig. 61, Outcrop 2, Beds 5–14). Thickness 34.6 m.

T h e z o n a l a s s e m b l a g e of the oxyto-zone includes the following species of bivalves: *Kedonella brodnensis* Polub., *K. mytileformis* (Polub.), *K. dubius* (Sowerby), *Dacryomya jacutica* (Petr.), *Tancredia stubendorffi* Schmidt., *Liostrea (Deltostrea) subtaimyrensis* Milova, *Corbulomina* sp., *Meleagrinella (Praeme-*

leagrinella?) aff. *golberti*, *Entolium kedonensis* Milova, *Nicaniella* sp.

Definition of boundaries and substantiation of age. The lower boundary of the oxyto-zone is defined by the first appearance of the index species. The upper boundary is drawn along the base of the Meleagrinella substriata Oxyto-zone. The chronological range of the oxyto-zone is determined by the sum of tail-zones of the index species in all known sections.

In the section on the Astronomicheskaya River, the first appearance of the species *Meleagrinella (Praemeleagrinella?) golberti* was recorded 2.2 m above the level with the last Pliensbachian ammonites *Amaltheus (Amaltheus) viligaensis* (Tuchkov). At the base of the Toarcian, the index species was found together with *Tiltoniceras antiquum* (Wright), *Dactylioceras crosbeyi* (Simpson), and *Nodicoeloceras catinus* Fischer. The latest records of the index species were found together with *Harpoceras falciferum* (Sowerby). On the Brodnaya River, coquinae with *Meleagrinella (Praemeleagrinella?)* aff. *golberti* Lutikov et Arp, 2023 were found together with *Harpoceras falciferum* (Sowerby).

On the Kelimyar River, the first appearance of the index species was recorded in the interval of 0.7–0.8 m from the base of the Kelimyar Formation. At the level of 1.0 m the ammonite *Tiltoniceras* sp. ind. in the interval of 1.0–1.1 m, the index species was found together with *Cleviceras exaratum* (Young et Bird), and *H. falciferum* (Sowerby) (Knyazev et al., 1984).

In Southern Germany, near Dörlbach in Bavaria, the index fossil was found in a layer of "Laibstein II". The ammonites *Cleviceras exaratum* (Young et Bird) and *C. elegans* (Sowerby), and *Harpoceras serpentinum* (Schlotheim) were also found together with index spcies. In Northern Germany, near Adenstedt in Lower Saxony, the index species was discovered in the section of a temporary construction site, along with the ammonite *Hildaites murleyi* (Moxon).

In England, at Port Mulgrave (Yorkshire), the species "*Meleagrinella substriata*" (=*M. (Praemeleagrinella?) golberti*) is found together with *Protogrammoceras paltum* (Buckman) and *Eleganticeras elegantulum* (Young et Bird), *Lytoceras crenatum* (Buckman), *Cleviceras exaratum* (Young et Bird), *C. elegans* (Sowerby), *Hildaites murleyi* (Moxon) (Caswell et al., 2009; Morris et al., 2019).

In Western Canada on Scalp Creek (Southern Alberta) the species "*Meleagrinella* sp." *(=M. (Praemeleagrinella?) golberti)* was found along with *Cleviceras exaratum* (Young et Bird) (Martindale and Aberhan, 2017).

Thus, the Meleagrinella (Praemeleagrinella?) golberti Biozone correlates with the *Tiltoniceras antiquum* and *Harpoceras falciferum* zones of the Boreal ammonite scale (Zakharov et al., 1997; Shurygin et al., 2011) and, accordingly, the *Dactylioceras tenuicostatum* and *Harpoceras serpentinum* zones of the Subboreal scale (Page, 2003). The stratigraphic range of the oxyto-zone corresponds to the *Tiltoniceras antiquum* and *Harpoceras falciferum* zones of the Boreal ammonite scale (Zakharov et al., 1997; Shurygin et al., 2011).

Correlation. The Meleagrinella golberti Oxyto-zone corresponds to the lower part of the Dacryomya inflata and Tancredia bicarinata b-Zone, including the Beds with Corbulomina sp. of the parallel zonal scale for bivalves (Shurygin et al., 2011). The oxyto-zone corresponds to the Meleagrinella ex gr. substriata, Kedonella mytiliformis Zone of the zonal scale for bivalves adopted for Northeastern Russia (*Resheniya*..., 2009) (Fig. 3).

In southern Germany in the Franconian Alb (Dörlbach, Germany), the oxyto-zone includes the lower part of the Posidonienschiefer Formation (thickness up to 0.35 m) (Fig. 5, Beds 7–10).

Member Laibstein I (Fig. 5, Bed 7) contains the bivalves *Kedonella dubius* (Sowerby), *Nicaniella* sp. and the ammonites *Tiltoniceras antiquum* (Wright), *Cleviceras exaratum* (Young et Bird), *Hildaites murleyi* (Moxon), *Lytoceras ceratophagum* (Quenstedt) (Arp et al., 2021). Private collectors in the area have found *Eleganticeras elegantulum* (Young et Bird), but the exact position of these ammonites within the Laibstein I nodule level is unknown.

Member Laibstein II (Fig. 5, Bed 8) contains the bivalves *Meleagrinella golberti, Kedonella dubius* (Sowerby), *Camptonectes subulatus* (Münster in Goldfuss, 1835), *Goniomya rhombifera* (Goldf.), etc., and the ammonites *Cleviceras elegans* (Sowerby), *C.* cf. *exaratum* (Young et Bird), *Harpoceras serpentinum* (Schlotheim), *Nodicoeloceras crassoides* (Simpson), *Dactylioceras semiannulatum* Howarth, etc. The "Fish Scale Bed" Member (Fig. 5, Bed 9) contains the bivalves *M. (Praemeleagrinella?) golberti, Kedonella dubius* (Sowerby) and the ammonite *Cleviceras elegans* (Arp et al., 2021). This part of the section (Fig. 5, Beds 7–10) correlates with the *Dactylioceras tenuicostatum* and *Harpoceras serpentinum* zones of the Subboreal ammonite scale (Page, 2003).

In the Levy Kedon stratigraphic zone, the oxyto-zone is recognized in the section on the Astronomicheskaya River (Fig. 61, Beds 5–14), on the Saturn River (according to Knyazev et al., 2003, Beds 1–9) (Fig. 62, Beds 1–9), on the Brodnaya River (Fig. 63, Beds 16–18), based on finds of a zonal assemblage with *Meleagrinella golberti, Kedonella brodnensis* Polub., *K. mytiliformis* (Polub.). In the Leno-Anabar structural-facies zone (SFZ), the oxyto-zone is recognized in the section on the Kelimyar River. The lower part of the Kurung Subformation (0–3.0 m) belongs to the oxyto-zone (Fig. 39, Outcrop 5, Bed 3a; Outcrop 14, Bed 4; Outcrop 16, Beds 3–4). The oxyto-zone is distinguished by the findings of a zonal assemblage with *Meleagrinella golberti, Kedonella mytiliformis*, and *Dacryomya jacutica*. The Oxyto-zone has a thickness of about 3.0 m. In the Suntary SFZ, the oxyto-zone

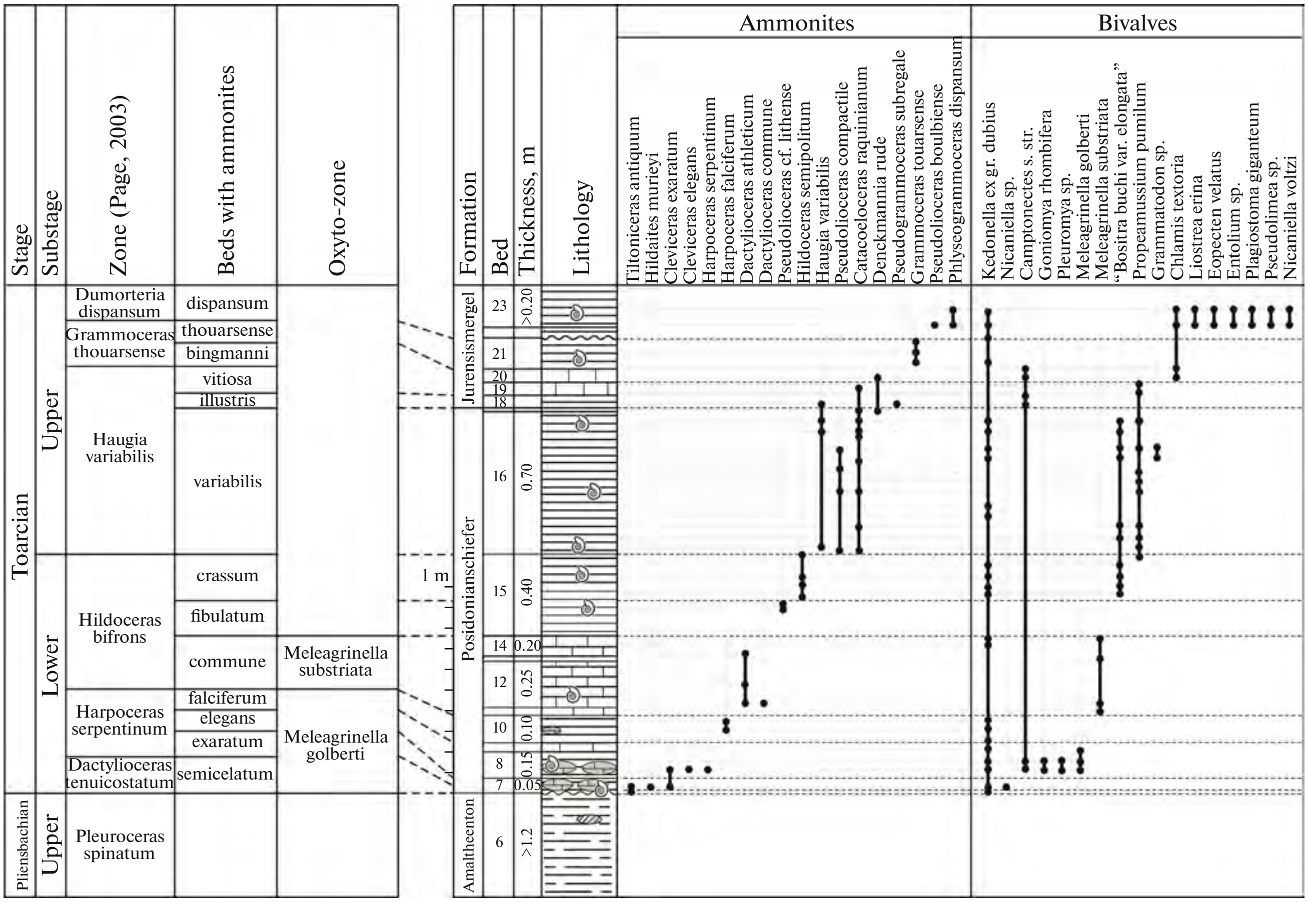

Fig. 5. Stratigraphy of Toarcian deposits of the Ludwigskanal section (Dörlbach, Southern Germany) based on the distribution of ammonites (Arp et al., 2021) and index species of oxyto-zones (Lutikov and Arp, 2023b).

includes member I and the lower part of member II of the Suntary Formation (according to Knyazev et al., 2003, Tyung River, Outcrop 13, Beds 1–6; Outcrop 14, Beds 1–4; Outcrop 15a, Beds 1–2). The oxyto-zone is distinguished by the findings of a zonal assemblage with *Meleagrinella golberti, Kedonella mytileformis, Dacryomya jacutica, Tancredia stubendorffi* Schmidt, *Liostrea (Deltostrea) taimyrensis*. The ammonites *Eleganticeras elegantulum* (Young et Bird), *Harpoceras exaratum* (Young et Bird), and *H. falciferum* (Sowerby) are found in this part (Knyazev et al., 2003). The apparent thickness of the Oxyto-zone on the Tyung River about 13 m. On the Vilyui River and the Markha River, the oxyto-zone is recognized by the presence of a zonal assemblage with *Meleagrinella golberti, Kedonella mytileformis, Dacryomya jacutica, Tancredia stubendorffi, Liostrea (Deltostrea) taimyrensis* (according to Knyazev et al., 2003, the Vilyui River, Outcrop 19, Beds 15–18; Markha River, Outcrop 6, Beds 6–7). Based on the findings of the *Meleagrinella golberti* index species, the oxyto-zone was established in the Ottur area (Markha–Vilyui interfluve).

In the Zhigansk SFZ (Motorchuna River), the oxyto-zone includes the lower 4.2 m of the Suntary Formation. The oxyto-zone is distinguished by the findings of a zonal assemblage with *Meleagrinella golberti, M. (Praemeleagrinella?)* aff. *golberti, Kedonella brodnensis, K. mytiliformis* (Fig. 51, Outcrop 3, Beds 2–3).

In the Nordvik SFZ (Anabar Bay), most of the Kiterbyut Formation belongs to the oxyto-zone based on finds of a zonal assemblage with *Meleagrinella golberti, Kedonella mytileformis, Dacryomya jacutica* (Fig. 20, Outcrop 5, Bed 64, lower 19.0 m).

Meleagrinella substriata Oxyto-Zone

N o m e n c l a t u r e. It is identified for the first time in the established chronostratigraphic volume. The oxyto-zone correlates with the Dactylioceras commune (=Harpoceras subplanatum) Zone of the Boreal ammonite scale (Zakharov et al., 1997; Knyazev et al., 2003; Shurygin et al., 2011) and the Hildoceras bifrons Zone (=Dactylioceras commune Subzone) of the Subboreal ammonite scale (Page, 2003).

I n d e x s p e c i e s: *Meleagrinella (Clathrolima) substriata* (Münster), 1831.

S t r a t o t y p e o f o x y t o - z o n e: Northeastern Russia, Levy Kedon River basin (Astronomicheskaya River), thickness 11.8 m (Fig. 61, Outcrop 2, Beds 15–19).

Zonal assemblage of the oxyto-zone includes the species of bivalves: *Propeamussium pumilum* (Lam.), *Astarte plana* Milova, *Cucullaea saturnensis* Milova, *Oxytoma* aff. *startense* Polub., *Mytiloceramus (Lenoceramus) viliuensis* Polub., *Tancredia bicarinata* Schurygin, *Modiolus tiungensis* Petr.

Definition of boundaries and substantiation of age. The lower limit is set by the appearance of the index species. The upper boundary is drawn along the base of the Meleagrinella prima Oxyto-zone. The chronological volume of the Oxyto-zone is determined by the sum of tail-zones of the index species in all known sections. In the stratotype of the Astronomicheskaya River, the index species *Meleagrinella (Clathrolima) substriata* appears together with *Dactylioceras commune* (Sowerby). The latest findings of the index species are reported from the beds without ammonites below the level of occurrence of *Pseudolioceras lythense* (Young et Bird), *Zugodactylites braunianus* (d'Orbigny) (Fig. 61, Outcrop 2, Bed 19).

On the Tyung River, the index species *Meleagrinella (Clathrolima) substriata* was found together with *Dactylioceras commune*; on the Vilyui River—at the level of finds of *Dactylioceras* spp.

In the section of the Ludwigskanal (Dörlbach, Germany), the index species was found with the ammonites *Dactylioceras commune, D. athleticum* in the "Dactylioceras-Monotis-Bed" member belonging to the Posidonienschiefer Formation (Fig. 5, Beds 12–14).

The chronological range of the oxyto-zone corresponds to the Dactylioceras commune (=Harpoceras subplanatum) Zone of the Boreal ammonite scale (Zakharov et al., 1997; Knyazev et al., 2003; Shurygin et al., 2011) and the Dactylioceras commune Subzone (Hildoceras bifrons Zone) of the subboreal ammonite scale scales (Page, 2003).

Correlation. The Meleagrinella substriata Oxyto-zone corresponds to the upper part of the Dacryomya inflata and Tancredia bicarinata b-Zone of the parallel bivalve zonal scale (Shurygin et al., 2011). In the bivalve zonal scale adopted for the North-East of Russia, the M. substriata Oxyto-zone corresponds to the Kedonella dagysi Zone (*Resheniya*..., 2009) (Fig. 3).

In southern Germany in the Franconian Alb, the Meleagrinella substriata Oxyto-zone includes the bituminous mudstone member and the "Dactylioceras-Monotis-Bed" member (total thickness 0.4 m) of the Posidonienschiefer Formation (Fig. 5, Beds 11–14). They contain the bivalves *M. (C.) substriata* and *Kedonella dubius*. This part of the section belongs to the Hildoceras bifrons Zone (D. commune Subzone) of the Subboreal ammonite scale (Page, 2003).

In the Levy Kedon region, the oxyto-zone is recognized on the Astronomicheskaya River (Fig. 61, Outcrop 2, Beds 15–19) and on the Saturn River (Fig. 62, Outcrop 1, Beds 10–16) based on finds of a zonal assemblage with *M. substriata* (Münster), *Propeamussium pumilum* (Lam.), *Astarte plana* Milova, *Cucullaea saturnensis* Milova, and *Oxytoma* aff. *startense* Polub.

In the Lena-Anabar structural-facies subregion (Kelimyar River), the index species of the zone was not found. The clays of the Kurung subformation contain bivalves characteristic of the M. substriata Oxyto-zone: *Lenoceramus viliuensis, Propeamussium pumilum* (Fig. 44, Outcrop 14, Bed 5). *Dactylioceras* sp. were found 6.0 m from the base of the Kurung Subformation. ind. (Fig. 47, Outcrop 16, Bed 5) (Devyatov et al., 2010), and 7.0 m from the base of the Kurung Subformation A.V. Golbert discovered *Zugodactylites braunianus* in 1983 (Fig. 47, Outcrop 16, Bed 6) (Knyazev et al., 2003). Beds with Lenoceramus viliuensis and Beds with Zugodactylites braunianus on the Kelimyar River occupy a position in the section between the M. golberti Oxyto-zone and the Pseudomytiloides marchaensis b-Zone. This part of the section corresponds to the Dactylioceras commune (Harpoceras subplanatum) and Zugodactylites braunianus (=Pseudolioceras lythense) zones of the Boreal ammonite scale (Zakharov et al., 1997; Knyazev et al., 2003; Shurygin et al., 2011).

In the Suntary structural-facies subregion (Tyung River), the oxyto-zone includes the upper part of the second member of the Suntary Formation. The oxyto-zone is distinguished in the section on the Tyung River by finds of a zonal assemblage with *M. substriata, Lenoceramus viliuensis* Polub., *Tancredia bicarinata* Schurygin (according to Knyazev et al., 2003, Tyung River, Outcrop 13, Bed 7; Outcrop 14, Beds 5– 6; Outcrop 15a, Beds 3–4; Outcrop 15, Bed 2). Ammonites from this level include: *Dactylioceras commune, D. amplum* Dagys, *D. kanense* McLearn, *D. suntarense* Krymgholz, *D. crassifactum* (Simpson), *Catacoeloceras crassum* (Young et Bird) (Knyazev et al., 2003). On the Vilyui River, the oxyto-zone is distinguished by finds of a zonal assemblage with *M. substriata* (Münster), *Lenoceramus viliuensis, Tancredia bicarinata* (according to Knyazev et al., 2003, Vilyui River, Outcrop 19, Bed 11). On the Markha River the species index has not been found. In the upper part of the second member and in the lower part of the third member, Beds with L. vilujensis are recognized, which correspond to the Dactylioceras commune (=Harpoceras subplanatum) Zone of the Boreal ammonite scale (Zakharov et al., 1997; Knyazev et al., 2003; Shurygin et al., 2011) and correlate with the Meleagrinella substriata Oxyto-zone (Fig. 56, Outcrop 6, Beds 4–6; Outcrop 10, Beds 4–7; Outcrop 10, Bed 9). The Oxyto-zone is identified in the section of Borehole 350 of profile 1060 of the Tenkelyakh drilling site based on finds of the index species (Fig. 11, unit III–lower unit IV).

In the Nordvik structural-facies subregion (Anabar Bay), the oxyto-zone is recognized based on the index species and a zonal bivalve assemblage (Fig. 20, Outcrop 5, Bed 65 (topmost part)–Bed 75). The oxyto-zone probably includes the terminal part of the Kiterbyut Formation (about 4.2 m), in which *Dacryomya* *jacutica* (Petr.), *Tancredia bicarinata* Zakh are found. et Schur, which correlates with the D. commune (=Harpoceras subplanatum) Zone of the Boreal ammonite scale based on the finds of *Dactylioceras* sp. ind. (*Stratigrafiya*…, 1976; Knyazev et al., 2003). The oxyto-zone includes the lower part of the Eren Formation, in which *M. (Clathrolima) substriata, Lenoceramus viliuensis, Modiolus tiungensis* Petr., *Liostrea (Deltostrea) taimyrensis* and ammonites *Dactylioceras commune, D. suntarense* Krymgholz, *Catacoeloceras crassum* were found (Knyazev et al., 2003).

In the Zhigansk structural-facies subregion (Motorchuna River) the zone has not been established. This part of the Toarcian section is probably obscured by a gap in observations.

Meleagrinella prima Oxyto-zone

N o m e n c l a t u r e. The Oxyto-zone was introduced to replace the *Praearctotis milovae* Zone (Lutikov, 2021) due to the re-identification of the index species (Lutikov and Arp, 2023b). The Meleagrinella prima Oxyto-zone correlates with the Zugodactylites braunianus (=Pseudolioceras lythense) and Pseudolioceras compactile Zones of the Boreal standard.

I n d e x s p e c i e s: *Meleagrinella (Meleagrinella) prima* Lutikov, 2022.

S t r a t o t y p e o f o x y t o - z o n e: Eastern Siberia, Anabar Bay, Outcrop 5, Beds 76–79, thickness 22 m (Fig. 20).

P a r a s t r a t o t y p e o f o x y t o - z o n e: Northeastern Russia, Levy Kedon River basin (Astronomicheskaya River), thickness 8.4 m (Fig. 61, Outcrop 2, Beds 20–21).

Z o n a l a s s e m b l a g e o f t h e o x y t o - z o n e includes the bivalves: in the lower part—*Pseudomytiloides oviformis* (Khudyaev in Krymgholz et al., 1953), *P. marati* Polub., *Meleagrinella (Clathrolima)* sp., *Oxytoma kirinae* Velikz., *O.* ex gr. *kirinae* Velikz.; in the upper part—*P. marchaensis* (Petr.), *Camptonectes* s.str., *Praebuchia ? faminaestriata* (Polub.), *Oxytoma startense* Polub., *Oxytoma* aff. *startense* Polub., *Modiolus numismalis* Opp., *Tancredia securiformis* (Dunk.), *Tancredia nalednensis* Milova.

D e f i n i t i o n o f b o u n d a r i e s a n d s u b s t a n t i a t i o n o f a g e. The lower boundary of the Meleagrinella prima Oxyto-zone is established by the first appearance of the index species. The upper boundary is drawn along the base of the Arctotis marchaensis Oxyto-zone.

The age of the oxyto-zone on the ammonite scale is determined by the sum of tail-zones of the index species in all known sections. In the section of Anabar Bay, *M. (M.) prima* Lutikov occurs together with *Zugodactylites braunianus* (Orb.) and *Pseudolioceras lythense* (Y. et B.), in the section of the Markha River, the species occurs together with *Z. braunianus*. In the North-East of Russia, on the Astronomicheskaya River, the index species was found together with *P. compactile* (Simps.), *Porpoceras vortex* (Simps.), *Collina gemma* Bonarelli (Fig. 61, Outcrop 2, Bed 20). The Meleagrinella prima Oxyto-zone reliably corresponds to the Zugodactylites braunianus (=Pseudolioceras lythense) and Pseudolioceras compactile Zones of the Boreal standard (Zakharov et al., 1997; Knyazev et al., 2003; Shurygin et al., 2011).

C o r r e l a t i o n. The Meleagrinella prima Oxyto-zone corresponds to the upper part of the Meleagrinella faminaestriata b-Zone and the Pseudomytiloides marchaensis Zone of the Boreal bivalve standard zonal scale (Shurygin et al., 2011). In the zonal scale for bivalves adopted for the North-East of Russia, the M. prima Oxyto-zone corresponds to the Mytiloceramus (Pseudomytiloides) marati and M. (P.) marchaensis zones (*Resheniya*…, 2009).

In the stratotype in Anabar Bay, the M. prima oxyto-zone is identified in the middle part of the Eren Formation based on finds of a zonal species and a zonal assemblage with *Modiolus numismalis* Opp., *Tancredia securiformis* (Dunk.), *Camptonectes* s.str., *Pseudomytiloides oviformis* (Khudyaev in Krymgholz et al., 1953), *P. marchaensis* (Petr.) (Fig. 10, Outcrop 5, Beds 76–79; Outcrop 4, Beds 18–22).

In the Levy Kedon stratigraphic zone, the oxyto-zone is characterized by the presence of *M.* (*M.*) *prima* and zonal complex including *Pseudomytiloides marchaensis*, *Oxytoma startense Polub*., and *Praebuchia*? *faminaestriata*, in the sections of the Astronomicheskaya River (Fig. 61, Outcrop 2, Beds 20–21) and the Saturn River (Fig. 62, Outcrop 1, Bed 17—lower 1.5 m of Bed 18; according to Knyazev et al. (2003) Outcrop 1, Beds 15–16). The index species was not present in the part of the section corresponding to the Zugodactylites braunianus Zone.

In the Leno-Anabar structural-facies subregion (Kelimyar River), the index species of the zone was not found. The clays of the Kelimyar Formation contain bivalves characteristic of the Oxyto-zone: *Camptonectes* s.str., *Pseudomytiloides marchaensis* (Fig. 47, Outcrop 16, Bed 7).

In the Suntary structural-facies subregion oxyto-zone was established in the Markha River section and in the boreholes of the Tenkelyakh area based on finds of *M. (M.) prima* and a zonal assemblage with *Pseudomytiloides oviformis, Pseudomytiloides marchaensis* (Fig. 57). The zone includes the upper part of the third member of the Suntary Formation. From this part are the ammonites *Zugodactylites braunianus* (Orbigny), *Catacoeloceras crassum* (Young et Bird), *Pseudolioceras compactile* (Simpson) (Knyazev et al., 2003). In the Zhigansk structural-facies subregion (Motorchuna River) the zone has not been established. Presumably, this part of the Toarcian section is hidden by a gap in observations. In southern Germany in the Franconian Alb (Dörlbach, Germany), the zonal complex of bivalves of the Meleagrinella prima Oxyto-zone has not been established.

In the Ludwigskanal section, in the "Bifrons Shale" Member, 0.4 m thick (Fig. 5, Member 15), the bivalves *Pseudomytiloides dubius* (Sowerby), *Bositra buchi* var. *elongata* (Goldfuss) and ammonites *Hildoceras semipolitum* Buckman (2, 17, 18 and 22 cm below the top); *Pseudolioceras* cf. *lythense* (Young et Bird) (20 cm below the top), *Phylloceras heterophyllum* (Sowerby) (28 cm below the top) (Arp et al., 2021). In this section, based on the co-occurrence of the ammonites *Pseudolioceras* cf. *lythense* and *Hildoceras semipolitum,* the Lower Toarcian Catacoeloceras crassum Subzone of the of the subboreal ammonite scale (Page, 2003) correlates with the Zugodactylites braunianus (=Pseudolioceras lythense) Zone of the Boreal ammonite scale (Knyazev et al., 2003). In the "Variabilis Shale" Member (Fig. 5, Member 16), 0.7 m thick, bivalves were found: *Bositra buchi* var. *elongata*, *Pseudomytiloides dubius, Propeamussium pumilum* (Lamarck), *Grammatodon* sp. and ammonites: *Haugia variabilis* (d'Orbigny) (13 cm below the top), *Pseudolioceras compactile* (13, 19, 21, 24, 25, 37 and 65 cm below the top), *Catacoeloceras raquinianum* (d'Orbigny) (3, 7, 13, 15, 19, 22, 37, 38 and 53 cm below the top), *Denckmannia* cf. *rude* (Simpson), *Haugia jugosa* (Sowerby), *Mucrodactylites mucronatus* (d'Orbigny), *Lytoceras* cf. *cornucopia* (Young et Bird), *L. sublineatum* (Oppel), *Hildoceras* cf. *semipolitum* Buckman (Arp et al., 2021). Thus, in this section, based on the co-occurrence of the ammonites *Pseudolioceras compactile* and *Haugia variabilis*, the Upper Toarcian Haugia variabilis Zone of the Subboreal ammonite scale (Page, 2003) correlates with the Pseudolioceras compactile Zone of the Boreal ammonite scale (Knyazev et al., 2003) (Fig. 3).

Arctotis marchaensis Oxyto-Zone

N o m e n c l a t u r e. This zone in this chronostratigraphic range was first proposed by Lutikov (2021). As a zonal subdivision of the stratigraphic scheme of Siberia, the Arctotis marchaensis b-Zone was first established in Shurygin as corresponding to the upper part of the Upper Toarcian–lower part of the Lower Aalenian. Accordingly, the upper boundary of the Toarcian (the boundary of the Lower and Middle Jurassic) was drawn within the Arctotis marchaensis b-Zone (Shurygin et al., 2000; Shurygin, 2005). Due to the revision of the species *Arctotis marchaensis* (Petrova) (Lutikov, 2021), the range of the Arctotis marchaensis Oxyto-zone was changed compared to the range of the Arctotis marchaensis standard b-Zone. In this work, the Arctotis marchaensis Oxyto-zone is correlated with the Pseudolioceras wuerttenbergeri Zone of the Boreal standard.

I n d e x s p e c i e s: *Arctotis (Praearctotis) marchaensis* (Petrova, 1947).

S t r a t o t y p e o f o x y t o - z o n e: Eastern Siberia, Anabar Bay, Outcrop 5, Beds 80–88, thickness 27.4 m (Fig. 20).

B i v a l v e z o n a l a s s e m b l a g e: *Oxytoma jacksoni, Oxytoma* ex gr. *jacksoni* (Pomp.), *Luciniola* sp.

D e f i n i t i o n o f b o u n d a r i e s a n d s u b s t a n t i a t i o n o f a g e. The lower boundary of the Praearctotis marchaensis Oxyto-zone is established by the appearance of the index species. The upper limit is established by the appearance of the species *Arctotis (Praearctotis) similis* Velikzh. The age of the oxyto-zone relative to the ammonite scale is determined by the sum of tail-zones of the index species in all known sections. In the section of Anabar Bay, the index species occurs in the middle part of the Eren Formation above the level with *Zugodactylites braunianus* (Orb.) and below the level with *Pseudolioceras falcodiscus* (Quenstedt) (Knyazev et al., 1991, 2003). In the Markha River section, the species *Arctotis (Praearctotis) marchaensis* (Petr.) occurs below and above the level with *Pseudolioceras wuerttenbergeri* (Denckmann). The Praearctotis marchaensis Oxyto-zone corresponds to the Pseudolioceras wuerttenbergeri Zone of the Boreal standard (Zakharov et al., 1997; Shurygin et al., 2011).

C o r r e l a t i o n. The Arctotis marchaensis Oxyto-zone is established for sediments formed in depositional settings of a shallow marine near-shore zone. The oxyto-zone corresponds to the lower part of the Arctotis marchaensis b-Zone of the bivalve Boreal standard for (Shurygin et al., 2011). In the North-East of Russia in the section of the Letnyaya River, the following taxa have been reported from the lower half of the Pseudolioceras danilovi Zone: *Arctotis* aff. *marchaensis* (Petr.), *Lenoceramus* sp. and *Camptonectes* sp. (Repin and Polubotko, 1993; Polubotko and Repin, 1994). The Arctotis marchaensis Oxyto-zone conditionally corresponds to the lower half of the local Pseudolioceras danilovi ammonite Zone (Repin, 2017) (Fig. 4).

Arctotis similis Oxyto-Zone

N o m e n c l a t u r e. This zone was first proposed by Lutikov (2021). The Arctotis similis Oxyto-zone corresponds to the Pseudolioceras falcodiscus Zone of the Boreal standard (Zakharov et al., 1997).

I n d e x s p e c i e s: *Arctotis (Praearctotis) similis* Velikzhanina, 1966.

S t r a t o t y p e o f o x y t o - z o n e: Eastern Siberia, Cape Tsvetkov, Outcrop 5, Beds 3–5 (Fig. 35), thickness 67.0 m.

P a r a s t r a t o t y p e o f t h e o x y t o - z o n e: Eastern Siberia, Anabar Bay, Outcrop 5, Beds 89–91 (Fig. 20), thickness 22.9 m.

Z o n a l a s s e m b l a g e o f t h e o x y t o - z o n e includes the bivalves: *Propeamussium olenekense* (Bodyl.), *Dacryomya gigantea* Zakh. et Schur., *Maclearnia kelimyarensis* Zakh. et Schur., *Malletia amygdaloides* (Sow.), *Nuculana acuminata* (Goldf.).

D e f i n i t i o n o f b o u n d a r i e s a n d s u b s t a n t i a t i o n o f a g e. The lower boundary of the Arctotis similis Oxyto-zone is established based on the appearance of the index species, the upper boundary—by the appearance of the index species of the overlying Arctotis (Arctotis) tabagensis (Petr.) Oxyto-zone.

The age of the oxyto-zone relative to the ammonite scale is determined by the sum of tail-zones of the index species in all known sections. In the section of Anabar Bay, *Arctotis (Praearctotis) similis* is found in the Horgo Formation, in the scree of the beds with the ammonite *Pseudolioceras* sp. (cf. *maclintocki* Haugh.) (*Stratigrafiya*..., 1976), reidentified as *Pseudolioceras falcodiscus* (Quenstedt) (Knyazev, 1991). In the section of Cape Tsvetkov (Eastern Taimyr), according to the author, the index species occupies a position below and above the level with *Pseudolioceras* cf. *falcodiscus* (Quenstedt) (Lutikov et al., 2022). In the Motorchuna River section, representatives of *Arctotis (Praearctotis) similis* Velikzh. distributed in the Suntary Formation at the level of finds of *Pseudolioceras falcodiscus* (Quenstedt) (Knyazev et al., 1991), *Pseudolioceras motortschunense* Repin (Repin, 2017) and below the level with *Pseudolioceras maclintocki* (Haught.) (*Stratigrafiya*..., 1976). The Arctotis similis Oxyto-zone reliably corresponds to the Pseudolioceras falcodiscus Zone of the Boreal standard (Zakharov et al., 1997).

Correlation. The Arctotis similis Oxyto-zone is established for sediments formed in depositional settings of a shallow marine near-shore zone. The oxyto-zone corresponds to the upper part of the Arctotis marchaensis b-Zone and the lower part of the Maclearnia kelymiarensis b-Zone of the zonal scale of the bivalve Boreal standard (Shurygin et al., 2011). In the North-East of Russia in the section of the Viliga River sediments with *Pseudolioceras replicatum* were reported to contain *Arctotis* cf. *marchaensis* (Petr.), *Propeamussium olenekense* (Bodyl.), *Camptonectes* sp., *Malletia* ex gr. *amygdaloides* (Sow.) (Repin and Polubotko, 2015a). The oxyto-zone conditionally corresponds to the upper part of the *Pseudolioceras danilovi* local ammonite Zone, as well as the Pseudolioceras paracompactile and Pseudolioceras replicatum local ammonite zones of Northeastern Russia (Repin, 2017) (Fig. 4).

Arctotis tabagensis Oxyto-Zone

Nomenclature. First proposed by Lutikov (2021).

Remarks. The Arctotis lenaensis B-Zone was recognized by B.N. Shurygin as corresponding to the upper part of the Lower Aalenian, Upper Aalenian and the entire Bajocian (Shurygin, 1986; Shurygin et al., 2011). In this work, the b-zone is subdivided into the Arctotis tabagensis Oxyto-zone (Lower Aalenian), Beds with Arctotis sublaevis (upper Aalenian–lower Bajocian), and Beds with Arctotis lenaensis (upper Bajocian–lower Bathonian).

Index species: *Arctotis (Arctotis) tabagensis* (Petrova, 1953).

Stratotype of oxyto-zone: Eastern Siberia, Cape Tsvetkov, Outcrop 5, Beds 6–8; Aprelevskyi Formation, Bed 9—Arangastakh Formation, thickness 58.0 m.

Parastratotype of oxyto-zone: Eastern Siberia, Motorchuna River, Outcrop 4, Suntary Formation (Bed 3), Syungyuyudin Formation (Beds 4–6), thickness 23.8 m.

Zonal assemblage of oxyto-zone includes the bivalves: in the lower part—*Arctica humiliculminata* Schur., *Astarte meeki* Stant., *Musculus* sp.; in the upper part—*Retroceramus elegans* Kosch., *Retroceramus menneri* Kosch.

Definition of boundaries and substantiation of age. The lower boundary of the Arctotis tabagensis oxyto-zone is defined by the appearance of the index species, the upper boundary is defined by the appearance of *Arctotis* (*Arctotis*) *sublaevis* (Bodyl.)—the index species of the overlying beds. The age of the oxyto-zone relative to the ammonite scale is determined by the sum of tail-zones of the index species in all known sections.

At Cape Tsvetkov (Eastern Taimyr), *Arctotis (Arctotis) tabagensis* (Petr.) is distributed above the level with *Pseudolioceras* cf. *falcodiscus* (Quenstedt). In the section of Anabar Bay, this species was found in the condensed bed at the base of the Arangastakh Formation together with *Retroceramus elegans* Kosch. and *Retroceramus jurensis* Kosch. below the level with *Pseudolioceras (Tugurites) whiteavesi* (White) (Meledina and Shurygin, 2000). In the Motorchuna River section, it is found in the same bed with *Pseudolioceras maclintocki* (Haught.) (Stratigrafiya, 1976). The Arctotis tabagensis Oxyto-zone is reliably correlated with the Pseudolioceras maclintocki Zone of the Boreal standard (Shurygin et al., 2011) (Fig. 4).

Correlation. The Arctotis tabagensis Oxyto-zone corresponds to the upper part of the Maclearnia kelymiarensis b-Zone and the lower part of the Retroceramus elegans b-Zone of the zonal scale of the Boreal standard for bivalves (Shurygin et al., 2011). In the Northeastern of Russia in the section of the Akachan and Allah-Yun rivers, the sequence of sandstones and siltstones with the Early Aalenian *Pseudolioceras maclintocki* (Haught) contains *Arctotis marchaensis* (Petr.), *Arctotis* aff. *similis* Velikzh., listed together with *Propeamussium olenekense* (Bodyl.), *Mytiloceramus priscus* Sey (*Resheniya*..., 1994). The oxyto-zone tentatively corresponds to the Pseudolioceras beyrichi orientale local Zone and the lower part of the Pseudolioceras maclintocki local Zone of Northeastern Russia (Repin, 2017) (Fig. 3).

Beds with Oxytoma jacksoni

Nomenclature. The Beds with Oxytoma jacksoni and Variamussium olenekense were previously considered in the section of the Viliga River in the range of the Pseudolioceras maclintocki Zone (Polubotko and Repin, 1974). The Beds with Oxytoma jacksoni are recognized for the first time in the proposed stratigraphic range.

Index species: *Oxytoma (Oxytoma) jacksoni* (Pompeckj, 1899).

Type section of the Beds: Eastern Siberia, Kelimyar River, Outcrop 5, Eren Formation, Beds 80–88, Horgo Formation, Beds 89–91, thickness 50.3 m (Fig. 40).

Definition. The beds are recognized by the presence of the following bivalves: *Oxytoma (Oxytoma) jacksoni* and *Oxytoma (Oxytoma)* ex gr. *jacksoni* (Pompeckj).

Definition of boundaries and substantiation of age. In the section of the Viliga River, *Oxytoma jacksoni* appears below the level of *Pseudolioceras* cf. *replicatum* Buckm. and is also common in sediments with *Pseudolioceras maclintocki* (Repin and Polubotko, 2015a). Taking into account the new zonal scheme of Repin (2016, 2017), the Oxytoma jacksoni Biozone in Northeastern Russia corresponds to the upper part of the Toarcian and Lower Aalenian. In the Kelimyar River section, this species appears above the level with *Pseudolioceras compactile* and occurs in the beds with *Grammoceras* sp. ind. and *Pseudolioceras* sp. ind. (ex gr. *wuerttenbergeri*) in Outcrop 7. The latest finds of *Oxytoma jacksoni* on the Kelimyar River are confined to horizons below the level with *Retroceramus* ex gr. *elegans* in Outcrop 7 (Fig. 42) and below the level with *Pseudolioceras beyrichi* in Outcrops 17 and 18 (Fig. 36). In this section, the Oxytoma jacksoni tail-zone correlates with the Arctotis marchaensis, Arctotis similis, and Arctotis tabagensis oxyto-zones. In the area of Cape Tsvetkov, this species first appears below the level with *Pseudolioceras falcodiscus*. In this section, the Oxytoma jacksoni tail-zone is correlated with the Arctotis marchaensis, Arctotis similis, and Arctotis tabagensis oxyto-zones. In the section of Anabar Bay, the Oxytoma jacksoni tail-zone correlates with the Arctotis marchaensis and Arctotis similis oxyto-zones. In the Saturn River section, the Oxytoma ex gr. jacksoni tail-zone corresponds to the Pseudolioceras wuerttenbergeri and Pseudolioceras falcodiscus zones. Thus, the Oxytoma jacksoni tail-zones in the sections of the Kelimyar River, Eastern Taimyr and the Viliga River have a wider stratigraphic range than in Anabar Bay and Saturn River sections. The lower boundary of the Beds with Oxytoma jacksoni in the scale is defined by the appearance of the index species and is combined with the lower boundary of the Arctotis marchaensis Oxyto-zone and, accordingly, with the boundaries of the Pseudolioceras compactile and Pseudolioceras wuerttenbergeri zones. The upper boundary is defined by the disappearance of the index species and is conditionally drawn at the level of the Lower-Upper Aalenian boundary.

Remarks. The relationship of biozones of species close to *Oxytoma jacksoni* (*Oxytoma muensteri, Oxytoma kirinae, Oxytoma ferrugineum*) recorded from Toarcian-Aalenian deposits of Eastern Siberia and Northeastern Russia, is not fully studied. Therefore, this biozone is considered at the rank of Beds. *Oxytoma jacksoni* was first described by J.F. Pompeckj from deposits of presumably Aalenian of Franz Josef Land (Pompeckj, 1899). Specimens of *Oxytoma jacksoni* were collected by G. Flebold and E. Tozer from scree and were presumably associated with the Beds with Leioceras opalinum and Pseudolioceras maclintocki of Arctic Canada (Frebold, 1958, pp. 14–15). Thus, the age of Beds with Oxytoma jacksoni in sections of Franz Josef Land and Arctic Canada may be Late Toarcian-Early Aalenian.

Correlation. In Eastern Siberia and Northeastern Russia, the Beds with Oxytoma jacksoni are established for depositional settings of a wide deep shelf and correspond to the Arctotis marchaensis, Arctotis similis and Arctotis tabagensis oxyto-zones (Lutikov, 2023a). The stratigraphic range of the Beds with Oxytoma jacksoni corresponds to the *Pseudolioceras wuerttenbergeri, Pseudolioceras falcodiscus,* and *Pseudolioceras maclintocki* zones of the Boreal standard (Zakharov et al., 1997) (Fig. 4).

Beds with Arctotis sublaevis

Nomenclature. In the accepted nomenclature and chronostratigraphic range, the Beds with *Arctotis sublaevis* were identified by the author (Lutikov, 2021). In this work, the Beds with *Arctotis sublaevis* are dated as Upper Aalenian–Lower Bajocian.

Remarks. V.I. Bodylevsky, who coined the name *Arctotis,* used the name *Arctotis lenaensis* (Lah.) for the Aalenian-Bajocian forms, and the name *Arctotis sublaevis* (Bodyl.) for the Bajocian-Bathonian forms (Bodylevsky and Shulgina, 1958). Based on these erroneous conclusions, the name *Arctotis lenaensis* was chosen as the index of the zone for Lower Aalenian–Lower Bajocian bivalves (Shurygin, 1986). When conducting a revision of Jurassic and Cretaceous representatives of the genus *Arctotis* (Lutikov and Shurygin, 2010), it was found that the lectotype of the species *Arctotis lenaensis* (Lah.) originates from deposits that, in the modern interpretation of the Boreal ammonite scale, belong to the Upper Bajocian (Morton et al., 2020). On the other hand, the holotype of *Arctotis sublaevis* (Bodyl.) comes from a borehole core. 1-r (Nordvik Peninsula), from a depth of 92.5 m and is very close to our specimens found in the section of the Anabar River, in the Late Aalenian-Early Bajocian? deposits, therefore, the name *Arctotis sublaevis* (Bodyl.) is accepted to designate the Siberian Late Aalenian–Early Bajocian taxon, and *Arctotis lenaensis* (Lah.) is used for the Late Bajocian-Bathonian taxon.

Index species: *Arctotis (Arctotis) sublaevis* (Bodyl.).

Type section of the Beds: Eastern Siberia, Anabar Bay, Outcrop 5, Arangastakh Formation, Beds 92b–102, thickness 70.4 m (Fig. 21).

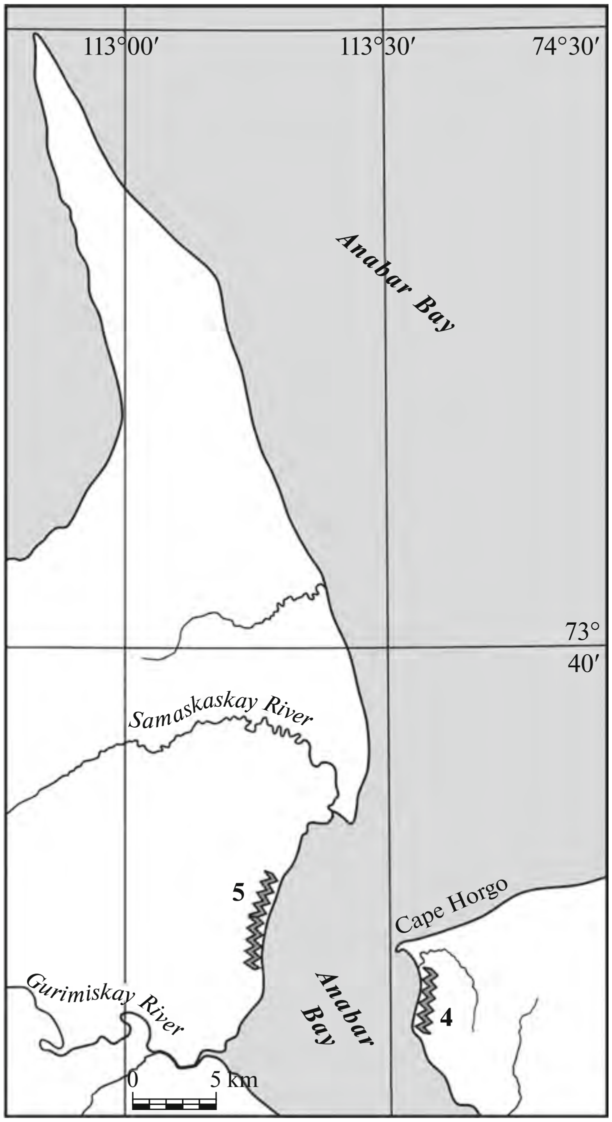

Fig. 6. Location of the Lower and Middle Jurassic sections of Anabar Bay.

C h a r a c t e r i s t i c a s s e m b l a g e includes the following bivalve species: *Retroceramus mongkensis* Kosch., *Retroceramus jurensis* Kosch., *Retroceramus lucifer* (Eichw.), *Retroceramus clinatus* Kosch.

D e f i n i t i o n o f b o u n d a r i e s a n d s u b s t a n t i a t i o n o f a g e. The lower boundary of the Beds with Arctotis sublaevis is established by the appearance of the index species. The upper limit is drawn by the appearance of *Arctotis (Arctotis) lenaensis* (Lahusen). The exact dating of the upper boundary is not certain.

The age of the Beds relative to the ammonite scale is determined by the sum of the tail zones of the index species in all known sections. In the section of Anabar Bay, this taxon is distributed in sediments attributed to the Upper Aalenian, together with the ammonites *Pseudolioceras (Tugurites) whiteavesi* (White) (Meledina and Shurygin, 2000). In the section of the Sungyuyude River In, this taxon is recorded at the same level with the lower Bajocian ammonites—*Pseudolioceras (Tugurites) fastigatus* (Westerman) (*Stratigrafiya*..., 1976). The Beds with Arctotis sublaevis reliably correspond to the Pseudolioceras (Tugurites) whiteavesi (Upper Aalenian) and Pseudolioceras (Tugurites) fastigatus (Lower Bajocian) zones of the Boreal standard (Zakharov et al., 1997).

C o r r e l a t i o n. The Beds with Arctotis sublaevis correspond to three b-zones of the zonal scale of Eastern Siberia: Retroceramus jurensis, Retroceramus lucifer, and Retroceramus clinatus b-zones (Shurygin et al., 2011). The Beds with Arctotis sublaevis correspond to three zones of the Northeastern Russia bivalve zonal scale: Retroceramus elegans–R. jurensis, Retroceramus lucifer and Retroceramus clinatus (*Resheniya*..., 2009) (Fig. 4).

STRATIGRAPHY AND CORRELATION OF SECTIONS BASED ON BIVALVES

Between 1980 and 1988, the author, a member of a team, studied the main sections of the Lower Jurassic, which are the reference for the dissection of Toarcian–Aalenian deposits in five structural-facies zones of Eastern Siberia and in one stratigraphic region of North-East Russia. Ideas about the sequence of Toarcian-Aalenian sedimentary strata in the territory of Eastern Siberia and Northeastern Russia are based on the lithostratigraphic division of sections performed by V.P. Devyatov (Knyazev et al., 1991). Descriptions of sections are given based on field observations. The sections were subdivided and correlated using the zonal scale for oxytomids. When correlating sections, the following principles were applied: paleontological succession of Zhiro-Sulavi-U. Smith, biostratigraphic division and correlation of W. Smith, chronological interchangeability of Meyen's features (Stepanov and Mesezhnikov, 1979; Nikitin and Zhamoida, 1984). In the absence of index species in the strata of the zonal scale for oxytomids, the correlation of individual parts of the sections was carried out taking into account the sequence of zonal complexes of bivalve mollusks. When determining whether sections belong to structural-facial and stratigraphic zones, the author was guided by the zoning schemes for Lower and Middle Jurassic deposits in Eastern Siberia and North-East Russia, adopted by Interdepartmental regional stratigraphic meetings (*Resheniya*..., 1981, 2009).

Anabar Bay Section

Based on the composition and type of sediments, thickness and completeness of sections, the Lower and Middle Jurassic strata of Anabar Bay belong to the Nordvik structural-facies zone (*Resheniya*..., 1981). The outcrops of the western and eastern shores of Anabar Bay (Fig. 6) were studied by the author together with V.P. Devyatov (lithology) and V.G. Knyazev (ammonites) in 1984. Photographs were taken by N.N. Sobolev

Fig. 7. Northern part of Outcrop 4 on the eastern shore of Anabar Bay. A valley with a snowfield is the beginning of a description of the section.

Fig. 8. General view of Outcrop 4 on the eastern shore of Anabar Bay. The valley of a creek on the right margin of the outcrop is the end of the description of the section.

(VSEGEI) in 2007, M.A. Rogov in 2008 and kindly provided to the author.

Outcrop no. 4

On the eastern shore of Anabar Bay, in the Toar-Aalenian part of the section, the Kiterbyut, Eren, Horgo and Arangastakh formations are exposed. The outcrop is a steep cliff 70–80 m high. The length of the outcrop is approximately 3 km. The description of the outcrop begins from the middle part of the outcrop at a distance of about 5.0 km south of Cape Horgo (Fig. 7). Towards the south, in the area of Cape Eren, bedrock outcrops are hidden in the valley of the creek (Fig. 8).

Lower and Middle Jurassic deposits on the eastern shore of Anabar Bay are deformed by numerous faults cutting them with an amplitude of up to 40 meters or more (Basov et al., 1967). Descriptions of the section of the eastern shore indicated different apparent thicknesses of the Lower Toarc clay member—21 m (Saks et al., 1963, p. 23), 22 m (Basov et al., 1967) and 18.5 m (Devyatov, 2000).

Kiterbyut Formation. The lower part of the formation is located in an uplifted block (Fig. 9). The description of the section begins 10 m to the right of the fault.

Bed 1, visible thickness 18.5 m. The clays are argillite-like, massive, dark gray, alternating with brownish clays, with spots and thin layers of jarositization, viscous. From a level of 11.1 m there are lenses (thickness 2–3 cm) of limestone. The bed contains rare pebble-like, flat (0.5 × 7 cm) pyrite nodules. At the level of 13 m along the bedding planes there are accumulations of fine carbonized plant detritus. The *Dacryomya* shells in the interval of 13.5–17.5 m are scattered throughout the bed, buried parallel to the bedding. At the levels of 16.0 and 16.5 m there are lenses of shell rock with *Dacryomya*. At the level of 17.5 m there is a horizon of infrequent lens-shaped (0.15 × 2.5 m) limestone nodules. It lies at the base of the yellow layer (thickness 0.4 m). Above it there are silty clays. The boundary with the overlying bed is very rapid, but gradual (Fig. 9).

Bivalves: *Tancredia stubendorffi* Schmidt (very few) (1 m); *Dacryomya jacutica* (Petr.) (very common) (level 16.0 and 16.5 m—Sample 20).

Ammonites Dactylioceras? sp. ind., the exact location of which is not specified were recorded from the clayey strata of the “Kiterbyut Horizon” on the eastern shore of Anabar Bay (Saks et al., 1963, p. 23).

Fig. 9. Outcrop no. 4. Near-fault contact of the Eren and Kiterbyut formations. The Kiterbyut Formation (dark gray Beds) is to the right of the fault; the Eren Formation (light gray Beds) is to the left of the fault.

In 200 m north of the fault, the top of the Kiterbyut horizon is at a height of 5.2 m, and at the fault—1.0 m from the edge. The displacement amplitude is 20 m.

Eren Formation

Bed 2, thickness 3.5 m. The boundary of Bed 1 and 2 is drawn by the change in color in the outcrop wall. At the base there are brown silty clays. From a level of 0.5 m—gray silts. The rocks are massive. The bedding is parallel, close to horizontal from 0.7 m from the bottom of the bed, due to the alternation of light and dark gray very thin layers of clay. From the level of 3.0 m—calcareous siltstones.

Bed 3, thickness 8.5 m. At the base of the lens (thickness up to 1.0 m) of calcareous siltstone, reddish from the surface—horizon 1. At the base of the siltstones there are shell lenses. The silts are clayey, finely interbedded with thin beds of clay (up to 1 cm thick). The lamination is wavy, less often parallel. At a level of 2.2 m there is a Bed (5 cm) of sideritized red siltstone. From a level of 6.5 m, siltstones predominate. Beds of clays are rare. In the interval of 7.5 m—8.3 m there is calcareous siltstone with thin parallel lamination, turning into thin oblique wedge-shaped acute-angled lamination along strike. In the interval of 8.3—8.5 m there is siltstone and horizon II is the beginning of Bed 4. In Bed 3 at a height of 2.2 m there is an interbed of 5 cm of red sideritized siltstone. At several levels (2.2; 4.4; 5.0 m) there are shell lenses of *Dacryomya* shells, confined to the upper parts of calcareous nodules. Under the concretions of the overlying bed, in the silt bed, there is shell rock with *Dacryomya* and *Tancredia*. In the clay interbeds the fauna is scattered.

Bivalves: *Dacryomya jacutica* (Petr.) (abundant)—entire shells, *Tancredia stubendorffi* Schmidt (common) (2.2; 4.4; 5.0 m; Sample 21—8.5 m).

Bed 4, thickness 12.5 m. At the base—horizon II (0.7—0.8 m) of silty, light gray limestone, containing individual valves and entire *Tancredia* shells. The Bed is represented by coarse-grained siltstone, slightly sandy, dense, greenish-bluish-gray, with thin interbeds of brownish clay and interbeds (up to 2—3 cm) of sand. In the middle part of the bed there is a thin horizontal lamination. At a level of 5.5—6.0 m there is a bed of massive sandy siltstone. At a height of 6.0 m there is a sideritization layer. The higher bed is repre-

Fig. 10. Coquina accumulations of *Dacryomya* and *Tancredia* in Bed 6, Outcrop 4 of Anabar Bay.

sented by greenish-gray horizontally bedded fine-grained, silty sands, with thin interbeds of brownish clays. In the interval of 7.0–8.5 m there are siltstones with clay interbeds. At a level of 8.5 m there is a jarositization lens with pyrite cakes. The last 0.5 m of siltstone becomes calcareous, with developed cross-bedding, and with a ledge visibly protruding from the vertical wall.

Bivalves: *Dacryomya jacutica* (Petr.) (abundant), *Tancredia stubendorffi* Schmidt (abundant) (Sample 22.0–0.7 m); level 4.0 m—*Dacryomya jacutica* (Petr.) (very common)—isolated valves parallel to the bedding, *Tancredia stubendorffi* Schmidt (common)—isolated valves parallel to the bedding, sorted convex side up, *Pleuromya* sp. (rare) in the living position; level 5.5 m—*Dacryomya jacutica* (Petr.) (very commonly), *Tancredia stubendorffi* Schmidt (very commonly)—coquinae contain whole shells and individual valves (Sample 23); levels 6.1; 8.7; 8.9 m—*Tancredia stubendorffi* Schmidt—coquinae dominated by small shells; the number of left and right valves is the same; level 12 m—*Tancredia stubendorffi* Schmidt—lenticular coquinae in siltstone (Sample 24).

Bed 5, thickness 5.8 m. At the base, horizon III (up to 0.5 m) of calcareous siltstone is platy along strike, with large oblique wedge-shaped bedding. From a level of 1.0 m from the base, the siltstones become clayey and darken. The color is dark greenish-gray. The lamination ranges from thin horizontal to wavy. Higher in the beds, interbeds (2–5 cm) of light wavy- and horizontally bedded silts dominate, alternating with thin layers (up to 1 cm) of brownish clay. The silts form oblique flat wedge-like lamination. In the upper part of the bed, the clayey silts are uniform. At a height of 3.3 m, there is a coquina bed of shells of *Dacryomya* and rare *Tancredia*. At a level of 4 m, the bed contains scattered small *Tancredia* shells. The bed terminates under the turf, with brownish-gray platy sandstones beds, with thick (every 0.3 m) coquinae (10–12 cm each).

Ammonites: Taxa thought to be *Dactylioceras commune* (Sow.), *D. suntarense* Krimh. and *Catacoeloceras crassum* (Young et Bird) were identified from this bed (Knyazev et al., 1993, 2003).

Bivalves: *Dacryomya jacutica* (Petr.) (abundant), *Tancredia stubendorffi* Schmidt (many)—in coquinae (3.3 m).

Bed 6, thickness 7.7 m. At the base—horizon IV with nodules (thickness 1.4 m) of platy calcareous siltstone, with lenses of coquina at the base and at other levels. The same platy rocks are located on the edge in the northern part of the outcrop at the outcrop with coordinates 73°29′12.2″ N; 113°33′25.6″ E (according to N.N. Sobolev, VSEGEI) (Fig. 10).

The bed is represented by alternating gray sandstones, with a brownish surface, with parallel and oblique bedding, with interbeds (1–3 cm) of dark gray clayey siltstones, varying in thickness from 7 cm to 0.5 m. In the bed at different levels there are lenses and Beds of shell rocks with belemnites. At a level of 5.5 m there is a clay bed with coquinae (10 cm). Above it is an extended lens (thickness 0.3 m) of wavy and oblique siltstone. At the level of 6.0 m there is a lens (thickness 15 cm) of siltstone. Above there is an alternation of siltstones and dark gray clays. The bedding surfaces are wavy.

Bivalves: at the base—*Dacryomya jacutica* (Petr.) (frequent), *Tancredia stubendorffi* Schmidt (abundant)—coquinae; at the level of 6.0–7.0 m—*Lenoceramus viluiensis* Polub. (rare)—deformed individual valves, *Modiolus tiungensis* Petr. (frequent)—isolated valves in coquinae (Sample 25).

Bed 7, thickness 5.0 m. At the base the sandstone (0.5 m) is fine-grained, gray with a faint greenish tint, massive below, horizontally and wavy-laminated in the middle part, cross-laminated in the upper part. Below (2.5 m) there is interbedding of fine-grained gray sandstones with a slight greenish tint with coquinae (0.2–0.5 m) and interbedding packages of thin beds of sandstone, siltstone and brown clay. The higher bed is represented mainly by siltstones with thin (up to 5 cm) beds of brownish clays. Thin cross-bedding predominates in the siltstones.

Bivalves: at the base—*Dacryomya jacutica* (Petr.) (very frequent), *Tancredia stubendorffi* Schmidt (frequent)—coquinae, *Modiolus tiungensis* Petr. (rare)—evenly scattered throughout the bed.

Bed 8, thickness 2.9 m. At the base there is a bed of sandstone (1.0 m) with lenses of coquina, consisting of numerous rostra of belemnites and shells of bivalves, somewhat regularly oriented. The strike azimuth is 300°. The sandstones are loose, finely parallel-laminated, mostly horizontally laminated, massive at the base. The sandstones are fine-grained and very silty. At the very top, the sandstones are cross-bedded. In the upper half of the bed there are lenses of dark gray, slightly brownish clays (thickness up to 10 cm). At the very top there is a bed (15 cm thick) of alternating silt and clay. The bed terminates with extended lenses (thickness up to 20 cm) of calcareous siltstone, dark gray, reddish on the surface, containing at the top extended lenses of coquinae with many belemnites.

Bivalves: *Dacryomya jacutica* (Petr.) (many), *Tancredia stubendorffi* Schmidt (many)—in coquinae (Sample 4, basal part); scattered in cross-bedded sandstones and siltstones *Tancredia stubendorffi* Schmidt (rare)—large shells in the living position.

Bed 9, thickness 8.9 m. At the base there are calcareous siltstone concretions, changing along the strike into coquina lenses (up to 15 cm thick) with ammonites, belemnites and bivalves. The lower 1.0 m of the bed is represented by frequent (every 10–20 cm) interbedding of cross-bedded fine-grained silty sandstones and clays. The higher bed is represented by alternation of sandstones and clays, brownish, reddish on the surface. At the level of 3.7 m there is an interbed (3–7 cm) of calcareous gray siltstone with pyrite inclusions, with nest-shaped coquinae. Poorly preserved *Meleagrinella* shells, sorted by size with a predominance of small individuals, form lenticular coquinae. Along the bed there are lenses with bivalves, a mass of belemnites and rare pebbles of yellowish siltstone.

Ammonites: at the base—*Zugodactylites braunianus* (Orb.), *Pseudolioceras lythense* (Y. et B.), *Catacoeloceras crassum* (Young et Bird) (Knyazev et al., 2003).

Bivalves: at the base—*Meleagrinella (Clathrolima)* cf. *substriata* (Muenst.) (rare), *Dacryomya jacutica* (Petr.) (many), *Tancredia stubendorffi* Schmidt (many), *Tancredia bicarinata* Schur. (frequent), *Tancredia securiformis* (Dunk.) (rare) (Sample 27a); in the range of 3.7–8.9 m—*Dacryomya jacutica* (Petr.) (many), *Tancredia bicarinata* Schur. (many), *Modiolus tiungensis* Petr. (rare), *Tancredia stubendorffi* Schmidt (rare), *Meleagrinella (Clathrolima)* cf. *substriata* (Muenst.) (many)—*Meleagrinella* shells are entire, sorted by size with a predominance of small-sized individuals, lenticular coquinae (Sample 6). In coquinae at the base of the bed—vertebrae and bones of reptiles (krs-1, krs-2).

Bed 10, thickness 3.8 m. The sandstones are light gray, fine-grained with a greenish tint, silty, massive below, obliquely bedded above, in places carbonate, having a reddish tint on the surface. In the upper part there are siderite nodules (0.15 × 0.3 m), lenses of shell rocks with fragments of bivalves, and lenses of jarositization.

Bivalves: *Dacryomya jacutica* (Petr.) (frequent), *Tancredia bicarinata* Schur. (frequent), *Tancredia securiformis* (Dunk.) (frequent).

Bed 11, thickness 1.0 m. Siltstones are dark gray with interbeds of sandy dark greenish-gray siltstones. A bed of coquina one shell thick composed of large *Tancredia* are confined to the base of sandy beds. At the top of the bed there is a thin layer of jarositization.

Bivalves: *Dacryomya jacutica* (Petr.) (frequent), *Tancredia bicarinata* Schur. (frequent), *Tancredia securiformis* (Dunk.) (frequent)—isolated shell scattered throughout the bed and coquinae "one shell thick"; *Meleagrinella (Meleagrinella) prima* Lutikov (Okuneva) (frequent)—in coquinae.

Bed 12, thickness 1.6 m. The sandstones are dark gray, dense, silty, fine- to medium-grained, with bushy grain, sideritized, massive, banded. At a height of 0.7–1.1 m there is a Bed (1.0 m) of sideritized red sandy siltstone from the surface. This level is overlain by a bed of earthy, lumpy sandstone containing siderite nodules, and above is another 0.5 m of dark-gray laminated sandy siltstone. The upper boundary is clear—based on the change in color and structure of the rocks.

Bivalves: in the interval 0–0.5 m from the base of the bed—*Dacryomya jacutica* (Petr.) (frequent), *Tancredia bicarinata* Schur. (many), *Meleagrinella (Meleagrinella) prima* (many)—scattered whole shells with a predominance of small specimens (Sample 30); at the level of 0.5 m—*Meleagrinella (Meleagrinella) prima* Lutikov (many), aggregated coquinae (Sample 29); at the level 0.7 m, *Pseudomytiloides oviformis* (Khudyaev in Krymgholz et al., 1953) (frequent)—aggregated coquinae (Sample 27).

Bed 13, thickness 5.7 m. The sandstones are gray with a faint greenish-bluish tint, fine-grained, silty, massive, with thin rare lenses of jarositization and with pyrite. They contain extended lenses of siderite. The sandstones are interbedded with interbeds of sideritized mudstones, which along the strike transform into sandy red siderites on the surface, which occupy levels: 1.8–2.1; 2.8–3.0; 3.2–3.3; 3.4–3.6; 4.0–4.1 m. At the level of 3.1 m there is a thin coquina bed of large *Tancredia*, in one shell thick; at levels 4.0 and 4.7 m—lenses with coquinae of large *Tancredia*, small and large *Praearctotis*, "smooth" pseudomytiloides and belemnites.

Bivalves: *Meleagrinella (Meleagrinella) prima* Lutikov (frequent)—isolated valves dominated by small-sized individuals, *Pseudomytiloides oviformis* (Khudyaev in Krymgholz et al., 1953) (rare), *Tancredia securiformis* (Dunk.) (frequent)—isolated valves (Sample 31, 32).

Bed 14, thickness 2.3 m. The sandstones are fine- and medium-grained, massive below, reddish on the surface, sideritized and earthy when freshly fractured. At the top, cross-bedded sandstones and from a height of 1.1 m turn into dark gray cross-bedded siltstones with a greenish tint, with thin layers and lenses of highly clayey siltstones, fine-grained, light gray, wavy-, oblique- and lenticular sandstones.

Bivalves: *Meleagrinella (Meleagrinella) prima* Lutikov (many), *Pseudomytiloides oviformis* (Khudyaev in Krymgholz et al., 1953) (abundant), *Tancredia securiformis* (Dunk.) (very frequent), *Liostrea taimyrensis* Zakh. et Schur. (rare), *Modiolus tiungensis* Petr. (rare) (Sample 32a, 33, near the base).

Bed 15, thickness 4.5 m. Sandstones are silty, fine-grained, gray, massive, horizontally and cross-laminated, with interlayers of mudstone (thickness up to 0.7 m). At a height of 1.1–1.7 m there are bun-shaped concretions and lenses of siderites. Interbeds of 1.1–1.7 m have a syneresis crack in the upper part in a thin (0.5 cm) film of argillite, characteristic of coastal, including littoral, or deltaic deposits. At the level of 4.5 m there is a siderite lens (thickness 15 cm). The upper part of the bed is sandstone with cross-bedding and with lenses of coquinae.

Bivalves: *Pseudomytiloides marchaensis* (Petr.) (rare), *Camptonectes* s.str. (rare), *Liostrea taimyrensis* Zakh. et Schur. (frequent)—shells conjoined together, *Modiolus tiungensis* Petr. (rare)—accumulations of individual valves and entire shells in coquina (Sample 34, 1.5 m).

Bed 16, thickness 2.0 m. At the base there is a thin (1.5 cm) bed of earthy sandstone with "ribbed" pseudomytiloides, in places with siderite lenses. The higher bed is represented by interbedding of sandstones, which predominate from a height of 0.8 m, and clayey siltstones. At a height of 1.5 m with a clear, relatively flat boundary, there lies a light gray fine-grained horizontally bedded siltstone with a faint greenish tint. Above are lens-shaped siltstones with a lens of *Pseudomytiloides* and other bivalves.

Bivalves: *Pseudomytiloides marchaensis* (Petr.) (abundant), *Dacryomya* sp. 1 (frequent), *Tancredia securiformis* (Dunk.) (rare) (Sample 35, basal part).

Bed 17, thickness 2.2 m. At the base, the sandstone is siderite, reddish on the surface, with lenses of coquina made of differently oriented shells of *Pseudomytiloides* and *Tancredia*. Siltstone with lenses of coquina.

Bivalves: *Pseudomytiloides marchaensis* (Petr.) (frequent), *Tancredia* sp. 1 (rare).

Bed 18, thickness 5.2 m. At the base of 0.6 m there is interbedding of earthy-gray with a greenish tint of medium-grained cross-bedded sandstones with clayey silts. At the base there is shell rock with *Arctotis, Tancredia,* and *Camptonectes*. At a height of 1.0 m there is a lens with large *Arctotis* shells, often oriented with the convex valve up, and rarely down. From a height of 1.6 m there is interbedding of siltstones with dark gray, fissile mudstones. From a level of 3.0 m there is an alternation of dark (clayey) and light siltstones. The mudstones contain shells of *Tancredia* (up to 6 cm) and *Modiolus*. The bed terminates under sandstone. At the top of the bed thin, initially wavy, then oblique bedding is observed.

Bivalves: At the base of the bed—*Pseudomytiloides marchaensis* (Petr.) (frequent), *Tancredia securiformis* (Dunk.) (rare), *Arctotis (Praearctotis) marchaensis* (Petr.) (very frequent), *Liostrea taimyrensis* Zakh. et Schur. (rare), *Camptonectes s.str.* (very rare) (Sample 36); at the level 1.0 m—*Arctotis (Praearctotis) marchaensis* (Petr.) (many)—lenticular accumulations of isolated, oriented parallel to bedding (Sample 37); at the level 1.6 m—*Modiolus* sp. (rare), *Tancredia securiformis* (Dunk.) (rare), *Nuculoma* (?) sp. (Sample 38).

Bed 19, thickness 6.0 m. At the of the bed—coquina bed "on shell" thick, composed of complete shells. The sandstones are light gray with a faint greenish tint, fine-grained, with large cross-beds at the bottom. At levels 2.5; 3.3 m shell lenses (1–1.5 cm) with *Arctotis*. From 3.3 m, the mudstones are dark gray with a brown tint and layers of siderite nodules. In the upper part, the sandstones are horizontally and cross-bedded. At a height of 3.8–4.0 m there is a layer of sideritization, in the middle part with lenses of earthy sand. Above it, there are the silty mudstones, dark gray with a greenish (olive) tint, fissile.

Bivalves: at the base—*Tancredia securiformis* (Dunk.) (rare), *Arctotis (Praearctotis) marchaensis* (Petr.) (rare) (Sample 39); at the level 1.0 m—*Arctotis (Praearctotis) marchaensis* (Petr.) (abundant) (Sample 40); in the interval 2.5–3.3 m—*Tancredia securiformis* (Dunk.) (frequent), *Luciniola* sp. (frequent) (Sample 41); at the level 3.5 m—*Modiolus numismalis* Opp. (Sample 42).

Bed 20, thickness 2.3 m. Sandstones fine-grained, light gray with a slight greenish tint, cross-laminated, with extended lenses of brownish clays at the top (thickness 2–10 cm), with inclusions of pyrite, jarositized on the surface.

Bivalves: *Arctotis (Praearctotis) marchaensis* (Petr.) (frequent)—accumulations near fossil wood, *Tancredia securiformis* (Dunk.) (rare)—scattered throughout the bed.

Bed 21, thickness 1.8 m. Sandstones dark greenish-gray, sideritized, reddish, with interbeds of mudstone. From 0.5 m, the bed is represented by light gray fine-grained sandstone with two thin, consistent layers of brown clay. The bedding is horizontal. The upper boundary is clear and even, marked by the in the change in rock composition.

Bivalves: *Arctotis (Praearctotis) marchaensis* (Petr.) (very frequent), *Tancredia securiformis* (Dunk.) (rare)—debris near the shell rock (Sample 43, basal part); *Homomya* sp. (rare)—complete shells, scattered throughout the bed, in a living position.

Bed 22, thickness 7.1 m. At the base of the bed there are thin lenses of sandstone with rare pebbles. Near the base there are dark gray clayey siltstones with lenses of light gray sandstones. With 1.0 m about Beds of silty clays. At the level of 3.0 m there are siltstones. From 3.5 m the siltstones become darker and interbed with clayey varieties. In the upper half of the bed there are interbeds of light gray siltstones. The concretion bed contains pyrite of various shapes and sizes.

Horgo Formation

Bed 23, visible thickness 12.7 m. At the base there is a consistent layer (0.3 m) of light gray, fine-grained sandstone (Fig. 11). In the interval of 0.3–1.6 m, there is interbedding of half-meter-high sideritized sandstones with the beds of siderites and thin-bedded earthy-gray sideritized sandstones. The bed is represented in the lower part by greenish-gray, then light gray with a weak greenish tint, fine-grained silty sandstones with wavy and oblique bedding. The sandstones contain interbeds of varying thickness (every 0.5–0.7 m) of sideritized silty mudstones. In the interval of 0.3–1.6 m, there is interbedding of half-meter-high sideritized sandstones with beds of siderites and thin bedded earthy-gray sideritized sandstones. The bed is composed in the lower part of greenish-gray, then light gray with a weak greenish tint, fine-grained silty sandstones with wavy and oblique bedding. The sandstones contain interbeds of varying thickness (every 0.5–0.7 m) of sideritized silty mudstones. At a level of 1.6 m, under the nodules, coquinae of fragments and scattered bivalves occur. In the interval of 1.6–3.2 m platy rocks with inclusions of pebbles, coquina lenses with intact shells, detritus and wood fragments are found. At a height of 3.2 m there are coquinae with belemnites, pebbles, boulders and clays. The coquinae contain whole shells and fragments of bivalves, detritus and parts of wood are found. From a level of 3.6 m, dark gray fragmented mudstones with lenses of light gray siltstones. With 5.0 m of beds of light gray, sandy siltstone. From a level of 5.5 m, the sandstones are light gray, fine-grained, with lumpy units. From a level of 9.0 m, sandstones with interbeds of dark gray mudstones, including thin beds of siltstones. In the interval of 10–12.5 m, the bed is represented by highly sandy, coarse-grained light gray siltstones, with fairly frequent lenses and interbeds of dark gray mudstones. These beds are overlain with turf.

Ammonites: *Pseudolioceras falcodiscus* (Quenst.). Bivalves: at the level 1.6 m—*Luciniola* sp. (many), *Dacryomya* sp. 1 (very frequent), *Tancredia* sp. 1 (very frequent), *Arctotis (Praearctotis) similis* Velikzhanina (very frequent)—small, isolated valve (Sample 44); at the level 3.2 m—*Arctotis (Praearctotis) similis* Velikzhanina (very frequent), *Liostrea taimyrensis* Zakh. et Schur. (frequent), *Tancredia* sp. 1 (very frequent), *Tancredia* sp. 2 (frequent), *Dacryomya* sp. 1 (frequent) (Sample 45)—coquina lenses with individual valves and fragments of valves.

Further, the section is interrupted by a large normal fault, the amplitude of which cannot be estimated (Fig. 11).

The Arangastakh Formation is exposed in a block about 100 m long (Fig. 12).

Bed 24, thickness 0.5 m. The clayey silty sandstones are dark gray, horizontally and lenticularly cross-bedded. The bivalves *Retroceramus elegans* Kosch were found from the nodules at the boundary with the fault plane (Sample 46).

Bed 25, visible thickness 19.5 m. The bed is represented by gray, lumpy, bedded, loose siltstones (Fig. 13).

In the middle part of the member there is a bed of fine-medium-grained carbonate sandstone, with a yellow surface (thickness 2.0–2.5 m). In the upper part of the bed (6.0 m) there are loose lumpy-bedded sandstones, fine-medium-grained, detrital, gray in color, containing small, scattered pebbles of black chert and lens-shaped accumulations of large *Retroceramus* shells

Bivalves: *Retroceramus* ex sp. ind., *Panopea?* sp., *Cardinia?* sp. were found in nodules on the right edge of the outcrop.

From this part of the section, *Retroceramus jurensis* Kosch., "*Arctotis* ex gr. *lenaensis* Lah." (=*Arctotis sublaevis*, author's note) (Stratigrafiya, 1976). Further, the section is interrupted by a creek valley. Upstream the river, Anabar, behind the creek, the outcrop is

Fig. 11. Contact of the Eren and Horgo formations—yellow line. Contact of the Horgo and Arangastakh formations—red line (fault). Photo was taken by M.A. Rogov in 2008.

Fig. 12. Outcrop of the Arangastakh Formation on the eastern shore of Anabar Bay.

Fig. 13. Siltstones of the Arangastakh Formation in Outcrop 4.

intensively divided into blocks and is represented by Middle Jurassic (Bathonian–Callovian) deposits. A stratigraphic scheme and bivalve-based correlation of the Toarcian-Aalenian beds in Outcrop 4 is shown in Fig. 14.

Outcrop no. 5

The most complete section of Pliensbachian-Aalenian deposits is observed in the coastal cliffs of the western coast of Anabar Bay. It contains all six oxytozones and two beds with oxytomids of the oxytomid biochronological scale. The outcrop is located 5–10 km north of the Gurimiskai River mouth (Fig. 6). The sandstones of the Chaidakh Formation of Norian–Rhaetian age (Dagys and Kazakov, 1984; Lutikov et al., 2009) are overlain by Lower Jurassic deposits, represented by four formations, with angular unconformity. From bottom to top, the following are exposed: Zimnyaya Formation (Rhaetian–Lower Pliensbachian), Airkat Formation (Upper Pliensbachian), Kiterbyut Formation (Lower Toarcian), Eren Formation (Lower–Upper Toarcian), Horgo Formation (Upper Toarcian), Arangastakh Formation (Lower–Upper Aalenian). The description of the outcrop is given starting from the upper beds of the Airkat formation (Member 4 after Knyazev et al., 1991).

Airkat Formation

Bed 62, thickness 4.0 m. At the base of the bed, there is a layer of calcareous siltstone (thickness 0.2–0.6 m), to which concretions of the underlying bed are occasionally associated. The concretion bed is massive and hard. The upper part of the formation is platy siltstone. Alternating brownish and gray stripes give freshly fractured nodules a striped texture. The upper boundary of the formation is gently undulating, with small asterisk glendonites and disturbance ripples occurring. The bed is represented by sandy siltstones, dense, strong, gray, in a wet state with a greenish tint, with lumpy and uneven platy sections. Lenticular beds of dark gray clays (thickness 1–5 cm) are located unevenly in the bed and emphasize the constrictions of siltstone layers, that is, actually lens-like beds. Up the bed, the rocks become argillaceous. The bivalves are scattered throughout the bed and form coquina lenses.

Bivalves: base—*Meleagrinella (Praemeleagrinella) deleta* (Dum.) (abundant), *Tancredia kuznetsovi* Petr. (very frequent), *Pleuromya galathea* Agass. (very fre-

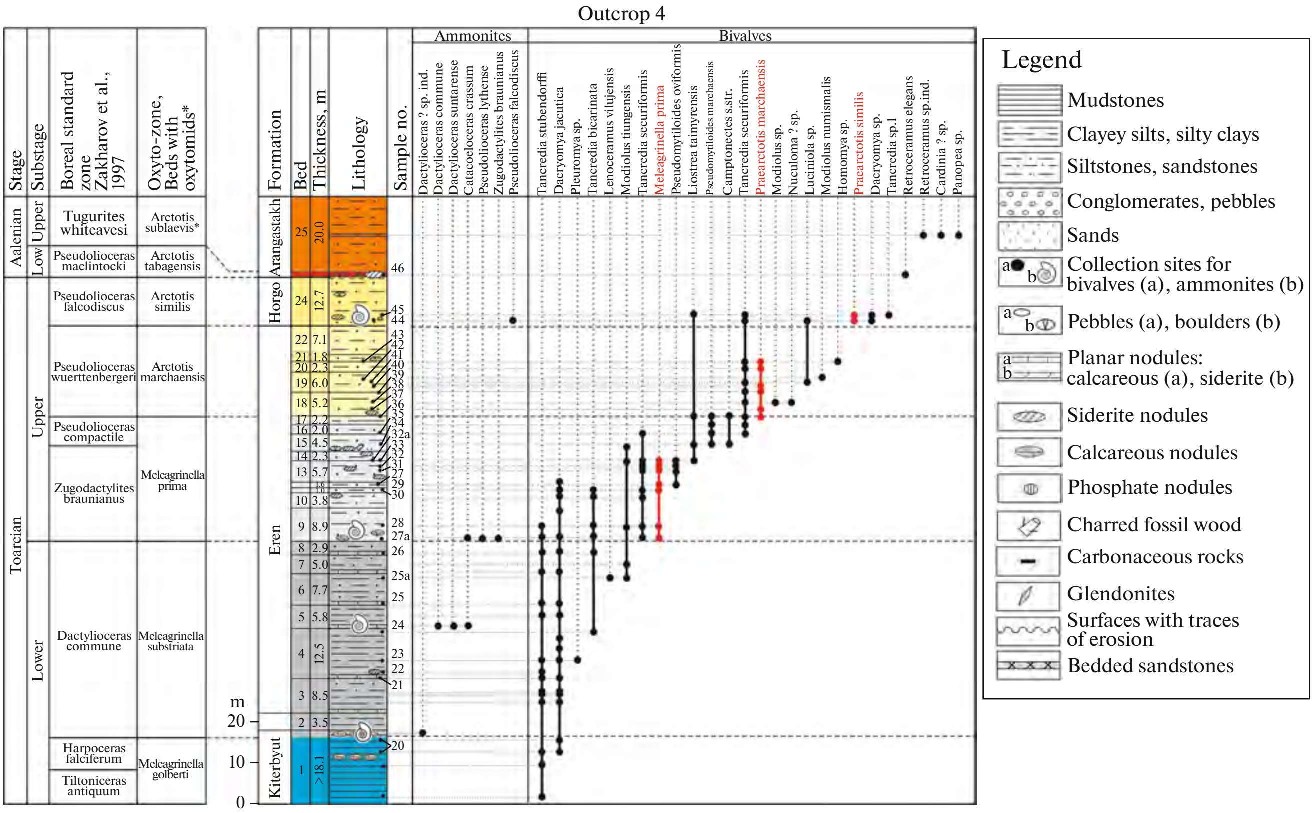

Fig. 14. Stratigraphy of Toarcian-Aalenian deposits in Outcrop 4 of Anabar Bay based on the distribution of index species and zonal assemblages of the oxytomid scale. In the lithological column, oxyto-zones and Beds with oxytomids are highlighted in different colors. In the table of taxon distribution intervals, the tail-zones of oxyto-zone index species are shown in red.

quent), *Panopea elongata* Kosch. (frequent), *Pholadomya idea* Orb. (rare), *Rideria formosa* Polub. (rare), *Kolymonectes terekhovi* (Polub.) (rare), ichtyosaur vertebrae (Sample 93, 93-p).

Bed 63, thickness 4.2 m. The siltstones are sandy, yellow-brownish, with interbeds of silty clays, greenish- and yellowish-gray in the weathered state, dark gray in the fresh state, highly jarositized. The rocks contain single crystals of glendonite, most often located with their long axis along the bedside, but sometimes at an angle to it. At the base of the bed and above there are broken-down lenticular and spherical (12 cm in diameter) nodules, sometimes with single glendonite crystals. At levels 1.8; 2.5; 4.0 m—coquina lenses.

Bivalves: level 1.8 m—*Meleagrinella (Praemeleagrinella) deleta* (Dum.) (abundant), *Meleagrinella (Praemeleagrinella) sparsicosta* (Petr.) (rare), *Tancredia kuznetsovi* Petr. (rare), *Modiolus* sp. (rare), *Pleuromya galathea* Agass. (very frequent)—coquina of isolated valves (Sample 94); level 2.9 m—*Meleagrinella (Praemeleagrinella) deleta* (Dum.) (abundant), *Meleagrinella (Praemeleagrinella) sparsicosta* (Petr.) (rare), *Tancredia kuznetsovi* Petr. (rare), *Pleuromya galathea* Agass. (very frequent)—coquina composed of isolated valves (Sample 95).

Bed 64, thickness 2.2 m. Silty clays, in the lower part with thin lens-like beds of sandy, surface-gray, yellowish silt. The rocks are dark gray, finely lumpy to lumpy at the top. At different levels there are partly broken-down, irregularly isometric and elongated nodules. At a height of 1.6 m there is a lens of large *Meleagrinella*.

Bivalves: *Meleagrinella (Praemeleagrinella) sparsicosta* (Petr.) (very rare)—individual valves are scattered throughout the bed; in the shell lens there are poorly preserved shells; reptile vertebrae (level 1.6 m—Sample 96, level 1.0 m—Sample 96p).

The series corresponding to Beds 63–64, contain foraminifers: *Ammodiscus siliceus* (Terquem), *Trochammina lapidosa* Gerke et Sossip., *Glomospira* ex gr. *gordialis* (Parker et Jones), *Recurvoides taimyrensis* Nikitenko, *Cornuspira liasina* Terquem, *Kutsevella barrowensis* (Tappan) and others (Nikitenko, 2009, p. 101).

Kiterbyut Formation

Bed 65, thickness 23.2 m. Finely pulverized clays, jarositized on the surface and along cracks, greenish-yellow, dark gray when freshly fractured, viscous below, with gypsum-plastered rostra of belemnites, including large specimens. The rocks are platy or structureless (especially the lower 0.45 meters). The clays are ferruginous in areas along cracks and have a brown color. At the level of 3.4 m there are calcareous-clayey nodules. At the level of 4.0 m there are jarositization lenses with nests and nodules of pyrite. From a height of 9.5 m, lenses of light gray thin-platy silty clay, harder than the rocks of the bed, are found. At a level of 10.0 m light gray lens-shaped interbeds of horizontally laminated silt are observed. At a level of 15 m from the base of the Kiterbyut Formation there are shell lenses with bivalves. The clays are dark gray. At a level of 22.5 m from the base there are small (10.0 × 0.3 m) concretions of light gray, yellowish clayey silt, platy, sideritized on the surface. The clays are dark gray, very finely bedded. The upper boundary of the bed is drawn based on the change in the jointing and composition of the rocks.

Bivalves: at the level 10 m—*Kedonella mytileformis* (Polub.) (rare), *Dacryomya jacutica* (Petr.) (rare), in the interval 15.0–15.2 m—*Dacryomya jacutica* (Petr.) (frequent), *Kedonella mytileformis* (Polub.) (many), *Meleagrinella (Praemeleagrinella?) golberti* Lutikov et Arp (rare)—coquina accumulation composed of poorly preserved shell; in the bed, there are scattered entire shells of *Pleuromya* sp. (rare) (Sample 97); in the interval 20.2–21.2 m—*Dacryomya jacutica* (Petr.) (abundant), *Meleagrinella (Praemeleagrinella?) golberti* Lutikov et Arp (many), *Tancredia stubendorffi* Schmidt (rare), *Kedonella mytileformis* (Polub.) (many)—lens-like coquinae; in the bed and scattered deformed shells of *Dacryomya* (Sample 98).

Foraminifers: in the lower part—*Trochammina kisselmani* Sapjanik et Sokolov, *Triplasia kingakensis* Loeblich et Tappan, *Ammobaculites lobus* Gerke et Sossip., *Bulbobaculites strigosus* (Gerke et Sossip.), *Saccammina inanis* Gerke et Sossip., *Kutsevella barrowensis* (Tappan), et al.; in the upper part—*Trochammina kisselmani* Sapjanik et Sokolov, *Ammodiscus glumaceus* Gerke et Sossip. (Knyazev et al., 2003; Nikitenko, 2009).

Eren Formation

Bed 66, thickness 1.0 m. The clays are dark gray, reddish on the surface, ferruginous, thin platy to foliated, in the upper part of the bed with interbeds (5 cm) of gray siltstone.

Bed 67, thickness 9.0 m. Siltstones light gray, brownish in beds from plant detritus, platy, massive. At a height of 2.4–3.6 m there is a horizon of lens-shaped nodules of calcareous siltstone with asymmetrical ripple marks along the bedding. Half a meter above this horizon similar nodules are observed. In the lower horizon of a part of the shell rock lens with similar-sized shells of *Dacryomya*, *Tancredia* and belemnites, clay pebbles are found. Lenses of *Dacryomya* are found in the rocks. The bed terminates below bed of limestone.

Bivalves: *Dacryomya jacutica* (Petr.) (very frequent), *Tancredia stubendorffi* Schmidt (very frequent)—coquina accumulation and scattered distorted shells.

Bed 68, thickness 11.1 m. This bed begins with a layer of brownish-gray calcareous siltstone. It contains oscillated shells of *Dacryomya*. Siltstones are light gray. From a level of 4.0 m there are pyrite nodules, mostly discoidal. From a height of 4.2 m, the sandstones are calcareous and brownish-gray siltstones. At a height of 5.4 m there is a layer of gray sandy siltstone, which contains yellow clay nodules 0.1 × 0.2 m. At a height of 8.4–8.8 m there is a layer of sandy siltstone.

Bivalves: *Dacryomya jacutica* (Petr.) (abundant), *Tancredia stubendorffi* Schmidt (very frequent)—shell accumulations of whole shells and individual valves in concretions and lenses.

Bed 69, thickness 3.7 m. The base of Bed 69 is 1.0 m above the waterline. It begins with a bed (up to 0.5 m) of dark gray and brownish gray calcareous siltstone, banded due to siderite. In the upper part of the formation there are lenses and layers of coquina. In one of the lenses there are shells of *Dacryomya* and *Tancredia*, numerous bones and vertebrae of reptiles. Dark gray silty clays and light gray clayey and sandy silts (thickness 0.1–0.5 m), alternating with each other. The bed is dominated by silts.

Bivalves: *Dacryomya jacutica* (Petr.) (frequent), *Tancredia stubendorffi* Schmidt (abundant). At the base—reptilian vertebrae (Sample 99p).

Bed 70, thickness 4.0 m. At the base, light gray, sandy calcareous siltstones (0.5 m), containing nodules of limestone, calcareous, dark gray siltstone. At a height of 1.2 m there is a similar bed. The siltstones are platy and lumpy, light gray, becoming sandier up the section, with the thinnest lenses (up to 1 cm) and thin lens-shaped beds of dark gray silty clays. Individual beds, and sometimes large sections of the bed, are jarositized, and pyrite nodules are found. Along the bed at different levels there are shell lenses with fragments and scattered valves of *Tancredia* and frequent lenses (thickness up to 6 cm), almost entirely composed of belemnite rostra (Fig. 15).

At a height of 2.8 m in the shell rock there are reptile bones. In the top part of the bed there is a layer of sandstone (apparent length about 30 m, thickness up to 0.4 m), pinching out to the south.

Bivalves: *Tancredia stubendorffi* Schmidt (abundant)—coquina accumulations of whole shells without sorting (Sample 100, 1.0 m).

Bed 71, thickness 1.0 m. At the base of the bed there is coquina with belemnites, and siderite-clay pebbles. At the level of the base of the bed there is a thin (0.1 m) lens of calcareous siltstone, with burrows oriented perpendicular to the depth and along the surfaces of the nodules. The sandstones are silty, greenish-gray, light, fine-grained, 0.4 m cross-bedded below, lenticular-bedded above due to layers of dark gray silty clays.

Bed 72, thickness 5.5 m. At the base there are lens-shaped nodules (length up to 5.0 m, thickness up to 1.2 m) of calcareous siltstone with a "cone-in-cone" texture (Fig. 16). The concretion contains three levels

Fig. 15. Coquina lens with belemnite rostra.

of coquina with bivalves, cap-shaped gastropods, belemnites, and ammonites. The siltstones are light gray, sandy, with lens-shaped beds of silty sands and thinner layers of dark gray clays (rare). The coquina interbed contains flat pyrite nodules and other nodules of various shapes.

Ammonites—*Dactylioceras commune* Sow.; bivalves—*Tancredia stubendorffi* Schmidt (abundant)—coquina accumulations in 1–2 complete assorted shells, *Dacryomya jacutica* (Petr.) (many), *Modiolus tiungensis* Petr. (rare), *Lenoceramus viluiensis* Polub. (very rare) (Sample 101. 0–1.0 m).

Bed 73, thickness 10.2 m. At the base there is a sheet-like horizon of calcareous siltstone (thickness up to 1.5 m). Alternation of sandy (light) and clayey (darker) varieties of gray siltstone (thickness of beds up to 1.0 m) and rarer thin beds of dark gray clay. Lenses of shell rock with belemnites are very common; they contain pyrite discoid nodules.

Ammonites—*Dactylioceras commune* (Sow.). Bivalves—*Tancredia stubendorffi* Schmidt (abundant)—shell accumulations mainly of fragments, *Liostrea* ex gr. *taimyrensis* Zakh. et Schur. (very rare).

Bed 74, thickness 1.8 m. At the base there is a bed of light gray calcareous siltstone (thickness up to 0.4 m), along strike containing a lens (0.3 × 12 m) of calcareous siltstone, sideritized and laminated. At the bottom of the lens there is a “cone-in-cone” texture (thickness up to 10 cm). The bed is composed of alternating sandy, light siltstones with layers of dark gray silty clay (every 0.5–0.7 m). The clays contain coquinae with belemnites and vertebrae of ichthyosaurs.

Bed 75, thickness 9.8 m. At the base there is a layer of light gray calcareous siltstone. At a height of 0.5 m there is a lens (1 × 6 m) of calcareous siltstone, yellowish from the surface. Above 1.0 m, the siltstones are sandy and sandy, light gray, with interbeds of clay. From 4.0 m there are spheroidal nodules (diameter 5–7 cm, rare up to 15 cm) of slightly calcareous siltstone and lenses with belemnites and bivalves. At a height of 4.6 and 8.1 m there are large (0.6–1.0 m × 10–15 m) lenses of calcareous siltstone, yellowish on the surface; in the upper half of the bed there are lenses of jarositization and pyrite. In the interval of 5–6.0 m there are frequent loaves (0.1 × 0.5 m) or small loaves of yellowish-gray siderite with a reddish-brown surface. At levels of 8.3 and 8.5 m there are lenses of coquina with belemnites.

Bivalves: at the level 4.5 m—*Meleagrinella (Clathrolima)* cf. *substriata* (Muenst.) (frequent)—aggregated coquinae of isolated valves, *Tancredia bicarinata* Schur., *Dacryomya jacutica* (Petr.) (frequent).

Fig. 16. Nodules with a cone-in-cone texture at the base of Bed 72.

Bed 76, thickness 9.3 m. At the base there is a flat lens of siderite. Above 2.0 m, the sandstones are silty, light gray, with lenses saturated with clayey material, which are associated with siderite loaf-shaped nodules (thickness up to 20 cm, length 0.5 m). Above 2.0 m, the siltstones are sandy, gently undulating and cross-bedded. In sandstones the fossils (sorted) are represented by belemnites, coquinae with bivalves. Large fragments of wood are found in coquinae, and siderites in expanded intervals are up to 0.4–0.5 m thick. At a height of 5.6 m in the coquina, a small vertebra was found.

Ammonites—*Zugodactylites ex gr. braunianus* (Orb.), *Pseudolioceras* ex gr. *lythense* (Y. et B.). Bivalves: at the level 5.6 m—*Meleagrinella (Meleagrinella) prima* Lutikov et Arp (frequent)—aggregated coquinae, *Dacryomya jacutica* (Petr.) (rare), *Tancredia bicarinata* Schur. (very frequent) (Sample 102); at the level 7.3 m—*Tancredia bicarinata* Schur. (abundant)—lenses of coquina with scattered intact small and large valves (Sample 103).

Bed 77, thickness 6.5 m. At the base interbedding of earthy-gray sandstones and siderites (thickness 0.7 m) with coquinae of bivalves. Siltstones are sandy and clayey, gray and light gray, predominantly platy, less often lumpy, with an uneven distribution of silt-clay material and frequent lens-shaped thin layers of lenticular-bedded clays containing lenticular (0.1 × 2.0 m) nodules of reddish-brown siderite. The bed contains pyrite nodules (length up to 0.7 m). In coquinae the bases are large *Tancredia* and aggregations of *Praearctotis*. The latter are found on bedding planes and throughout the bed.

Bivalves: at the base—*Meleagrinella (Meleagrinella) prima* Lutikov et Arp (frequent, very frequent)—aggregated coquinae with intact individual large and small shells, *Tancredia bicarinata* Schur. (many)—lenses of coquina with scattered whole valves not sorted by size (Sample 104); in the interval 4.0–4.2 m—*Pseudomytiloides oviformis* (Krymgholz et al., 1953) (frequent)—aggregated coquinae of poorly preserved shells, associated with interbeds of glauconite sandstone, *Meleagrinella (Meleagrinella) prima* Lutikov et Arp (frequent, very frequent)—aggregations of small shells, *Tancredia securiformis* (Dunk.) (rare)—isolated valves (Sample 105).

Bed 78, thickness 3.7 m. At the base, alternating earthy-gray sandstones and burgundy-brown siderites with coquina lenses (thickness 0.8 m). The bed is represented by very frequent alternation (the thickness of the interbeds is 10–15 cm) of gray and dark gray, sandy and more clayey siltstones, in the upper half with numerous thin lenticular layers of silt-clay material, emphasizing the lenticular bedding. The rocks are platy, with nodules and cakes (up to 0.7 m long) of pyrite. In the upper part of the bed there are thin lenses of sandstone.

Bivalves: in the basal coquinae—*Pseudomytiloides marchaensis* (Petr.) (abundant), *Tancredia securiformis* (Dunk.) (frequent), *Modiolus tiungensis* Petr. (abundant) (Sample 106); at the level 1.8 m—*Camptonectes* s.str. (rare)—isolated valves, associated with fossilized wood fragments (Sample 107).

Bed 79, thickness 2.5 m. The lower boundary of the bed is distinct. At the base, the sandstones are light gray with a faint greenish tint, with lumpy platy units. In the lower 1 meter of the bed there are 4 lenticular interbeds of dark gray brownish clay with lenses of sand. In the upper half of the bed there are loaf-shaped concretions (from 0.1 × 0.3 m to 0.1 × 1.5 m) of reddish-brown and yellow siderite. The upper boundary of the bed is distinct, uneven, wavy (0.5 × 15.0 m), emphasized by a layer of clay at the base with coquina lenses and siderite pebbles. Sandstones contain small lenses of coquina with fragments of shells of bivalves.

Bivalves: *Pseudomytiloides marchaensis* (Petr.) (abundant), *Tancredia securiformis* (Dunk.) (rare) (Sample 110.2–2.5 m).

Bed 80, thickness 3.6 m. At the base is an interbed (thickness up to 0.25 m) of "brecciated" leptochlorite sandstones, with an uneven distribution of clayey-siderite material with clayey pebbles and shell accumulations. In coquinae there are shells of *Praearctotis* and *Pseudomytiloides*, inclusions of pyrite. The bed in the lower part (thickness up to 2.5 m) is represented by interbedding of lens-shaped thin silty-sandy layers and silty-clayey layers. In the interval (2.5–3.7 m) two interbeds of sandstone separated by a layer (10 cm) of clay. Sandstones are lenticular-banded. The upper boundary is uneven and wavy, following the change of rocks.

Bivalves: basal part of the bed—*Pseudomytiloides marchaensis* (Petr.) (very frequent), *Tancredia securiformis* (Dunk.) (rare), *Dacryomya jacutica* (Petr.) (rare), *Liostrea taimyrensis* Zakh. et Schur. (very rare), *Camptonectes* s.str. (rare) (Sample 108); level 0.2–0.5 m—*Pseudomytiloides marchaensis* (Petr.) (very frequent), *Camptonectes* s.str. (rare) (Sample 109); level 2.9 m—*Arctotis (Praearctotis) marchaensis* (Petr.) (very frequent), *Oxytoma jacksoni* (Pomp.) (very rare)—lenses of coquina with isolated poorly preserved valves, near the coquina—scattered individual valves of Praearctotis, buried convex side upward (Sample 111); in the interval 2.9–3.5 m—*Pseudomytiloides marchaensis (Petr.)* (frequent)—aggregations of coquina, *Arctotis (Praearctotis) marchaensis* (Petr.) (frequent), *Camptonectes* s.str. (rare), *Tancredia securiformis* (Dunk.) (rare) (Sample 111a); upper part of the bed (Sample 111b).

Bed 81, thickness 4.9 m. At the base interbed sandstone is gray with a greenish tint, weakly leptochlorite, fine-grained, clayey-silty with an uneven distribution of siderite material and shell lenses. The sandstones are dark gray, with a large admixture of silty material.

Bivalves: at the base—*Arctotis (Praearctotis) marchaensis* (Petr.) (very frequent)—isolated valves and whole shells of different sizes; *Modiolus numismalis* Opp. (many), *Tancredia* sp. 1 (rare)—fragments of valves; in coquina—*Oxytoma* ex gr. *jacksoni* (Pomp.) (1 mold with shell matrix remains), *Camptonectes* s.str. (very rare), *Luciniola* sp. (many) (Sample 112); within the bed—*Arctotis (Praearctotis) marchaensis* (Petr.) (very frequent)—isolated valves and entire shells in lenses (1.0 m long), *Tancredia* sp. 1 (very frequent)—complete shells.

Bed 82, thickness 1.8 m. At the base of the bed up to 0.4 m—alternating interbeds of dark gray silty clays, lenses of light gray sand with a weak greenish tint, lenses of silty sands, lenses of pyrite, lenses of coquinae with bivalves. In the interval 0.4–0.7 m, the siltstones are light gray, thin-platy, lenticular-laminated. There are underwater landslide deformations in the siltstone at the level of 0.5–0.8 m. From the level of 0.7 m, the sandstones are silty, with large lenticular bedding. The upper border is distinct, even.

Bed 83, thickness 3.7 m. At the base interbed (thickness 5–7 cm) of yellowish, gray sideritized sandstone with coquina lenses in one shell from fragments of *Tancredia* and whole shells of small Praearctotis, belemnites and fragments of bivalves, segments of crinoids, fragments of charred wood. Up to a level of 2.0 m, the bed is composed of alternating lenticular layers (thickness up to 7 cm) of sandy and clayey siltstone, light and darker, with thin wavy lens-shaped extended layers of dark gray fissile clay. The rocks contain nodules (up to 3–5 cm in diameter) of pyrite, confined to sand layers. In the interval 2–3 m the bed is represented by light-colored sandstones.

Bed 84, thickness 1.5 m. At the base the sandstones are dark gray, with pyrite and coquinae nodules. The lower half of the bed is represented by dark gray, in thin layers, almost black coarse-grained leptochlorite sandstones with thin lenses, interbeds of dark gray clays. The upper half of the bed is represented by massive light gray carbonate sandstones with a faint greenish tint. Their calcareous part is isolated into large loaf-shaped (4–5 m long) nodules, densely packed. The gaps between them are filled with sideritized yellowish-gray sandstones, reddish on the surface, with fine clay gravel.

Bivalves: level 0–0.8 from the base—*Arctotis (Praearctotis) marchaensis* (Petr.) (very frequent), *Camptonectes* s.str. (frequent), *Modiolus numismalis* Opp. (many) (Sample 113).

Bed 85, thickness 3.1 m. At the base, there is an interbed (0.1 m) of dark greenish-gray viscous clays with lenses of strong silts. Up to a level of 1.3 m, the bed is represented by dark gray clayey siltstones with an uneven distribution of clayey and sandy material (including lenses, thin layers). In the interval 1.3–1.9 m, interbeds (0.1 m) of light gray siltstone appear. Up the section, the bed is represented by light gray with a greenish tint silty sandstones with large lenticular bedding. The bedding is thin, parallel, and emphasized by clay interbeds. In sandstones at different levels there are lenses of *Praearctotis* and *Modiolus* (thickness up to 10 cm). In the top of the bed along the strike there are lenses with *Arctotis*, belemnites, with long axis oriented along the azimuth of 260°–290°, thin alluviums of leptochlorite sandstone were also found here.

Bivalves: *Arctotis (Praearctotis) marchaensis* (Petr.) (very frequent), *Modiolus numismalis* Opp. (rare)—aggregated burial of whole shells, *Pleuromya* sp. (rare)—isolated valves throughout the bed.

Bed 86, thickness 4.2 m. At the base, there are lenses of earthy gray leptochlorite sandstones with coquinae. Up to a level of 1.1 m, dark gray clayey siltstones are lenticular-bedded, with interbeds of sandy siltstone (thickness up to 10 cm). Higher up, the sandstones are silty, light gray with a faint greenish tint, finely parallel-laminated, coarsely lenticular-laminated. At the level 2.7 m there is a consistent interbed (0.5–1 cm) of dark gray clay. At the top of the bed there is a bivalve layer. The upper boundary of the bed is distinct and gently undulating.

Bivalves: *Arctotis (Praearctotis) marchaensis* (Petr.) (very frequent), *Modiolus numismalis* Opp. (rare)—aggregated burials of complete shells, *Pleuromya* sp. (rare)—isolated valves throughout the bed.

Bed 87, thickness 2.6 m. Bed 87, thickness 2.6 m. At the base interbed (0.1 m) earthy gray sandstone with coquinae, with lenses of leptochlorite dark sandstone with areas of sideritization and lenses of clays emphasizing wavy and lenticular bedding. Above, up to the level of 1.1 m, there is interbedding of lneticular layers (from 3–5 to 10 cm) of light gray sandstones and clayey siltstones with thin clay interbeds. In the interval 1.1–2.6 m, dark gray, brownish clayey siltstones predominate, with sandstone lenses (0.05 × 1.5 m). At a height of 1.8 m there is a flat fragment (3 × 10 × 40 cm) of pyritized wood. In clays there are pyrite cakes, in sandstones there are isometric pyrite nodules and pyritized shells. Higher up, from 2.6 m, the bed contains siderites, earthy sandstones, and coquinae.

Bivalves: *Arctotis (Praearctotis) marchaensis* (Petr.) (many), *Homomya* sp. (rare)—whole shells scattered throughout the bed, in the living position, *Tancredia* sp. 1 (rare)—fragments near coquina, *Luciniola* sp. (rare).

Horgo Formation

Bed 88, thickness 2.6 m. At the base there is an interbed of brownish-gray sideritized sandstone (thickness 0.6 m), with pyrite lobes, with coquina lenses (thickness up to 0.3 m). Lenses coquina (thickness up to 0.3 m) consist of shells of *Dacryomya*, large *Tancredia*, belemnites (the strike azimuth of the long axis of the rostrum is 260°) and fragments of ammonites. Above, the bed is composed of sandstones, to varying degrees silty, predominantly platy (thick and thin platy), light and yellowish-gray, in a fresh fracture with a weak greenish tint, in the lower part sideritized, clayey. The rocks are parallel- and cross-laminated, with large lenticular beds, sometimes cut off by interbeds of sideritized clays. At levels of 1.6 and 2.3 m there are lenses (up to 0.6 m) of siderite, transforming along strike into lens-shaped clay interbeds. Siderites are brownish-red on the surface, interbeds of sideritized clays are brownish-yellow. Siderites are pyritized. The bed terminates at the level of a change in the section.

Bivalves: *Homomya* sp. (very frequent), *Dacryomya* sp. 1, *Tancredia* sp. 1—complete shells, scattered throughout the bed, buried in the living position.

Bed 89, thickness 4.3 m. At the base there are sideritized nodules with shell accumulations of bivalve fragments. Sandstones are silty, platy, light gray.

Bivalves: basal part—*Luciniola sp.* (many), *Dacryomya sp.* (many), *Tancredia* sp. 6 (very frequent), *Arctotis (Praearctotis) similis* Velikzhanina (rare)—fragments, *Maclearnia* sp. ind. (rare)—coquina aggregations (Sample 114); *Dacryomya* sp. 1 (very frequent)—complete shells, scattered throughout the bed.

Bed 90, thickness 4.1 m. The boundary with the underlying sediments is indistinct, since the packages of lens-shaped clay interbeds along the strike sometimes contain rather large lenses of sandstone. The bed is composed of alternation of darker clayey, lighter sandy interbeds of siltstone with the similarly thin (from 2–3 to 10 cm) lenticular interbeds of light gray sandstone. The distribution of clayey material is uneven; there are pyrite nodules, and at a height of 0.5–1.0 m there is a sandstone bed with sharp lens-shaped interbeds of silty-clayey material. The lower package of interbedding (interval 0–0.5 m) contains large lenses of light gray sandstone with parallel bedding. In coquinae—pebbles of clays and siderites.

Bivalves: *Arctotis (Praearctotis) similis* Velikzhanina (rare), *Oxytoma jacksoni* (Pomp.) (very rare), *Luciniola* sp. (rare), *Dacryomya* sp. (many), *Tancredia* sp. 1 (very frequent), *Liostrea taimyrensis* Zakh. et Schur. (rare), *Maclearnia* sp. ind. (rare)—coquina accumulations from fragments of shells and individual valves at the base of the bed (Sample 115, from the bed).

Bed 91, thickness 14.5 m. At the base the sandstone is brown-gray. The bed is represented by a rhythmic alternation of darker clayey, lighter sandy interbeds of siltstone with a thickness of 2.0–3.5 m. In the lower part there are darker rocks—interbedding of clayey and sandy silts with interbeds of clay. At the level 2.0 m extended lenses of yellowish limestone from the surface. At the level 6.5 m—boulder (20 × 20 cm) and wood remains. At the level 7.3 m lenses of coal with fragments of pyritized wood are observed. The upper interbed (thickness 0.5–0.7 m) is calcareous.

Fig. 17. Contact of the Horgo and Arangastakh formations in Outcrop 5.

Bivalves: isolated valves of *Tancredia* sp. 1 (rare), *Pleuromya* sp. (rare).

The upper boundary of the bed is distinct, with traces of erosion.

Arangastakh Formation

The Arangastakh Formation rests on the eroded, ocher surface of sandstones of Bed 91 (Fig. 17).

Bed 93, thickness 4.2 m. At the base, there is an interbed (0.2 m) sand is gray, loose, with lenses of dark clay. At the base of the interbed there are coquina lenses, pebbles and an ammonite fragment. The bed is composed of gray clayey, sandy-clayey siltstones with sandstone lenses, with multiple pyrite nodules. The bedding, emphasized by alluviums of detritus and thin lenses of clay, is gently wavy, lens-shaped, and obliquely parallel in some layers. The bed terminates with the change in lithology. The border is gradual.

Bivalves: *Arctica humiliculminata* Zakh. et Schur. (many), *Pleuromya* sp. (frequent), *Homomya* sp. (very frequent).

Bed 94, thickness 6.8 m. At the base, there is a thin layer of clay. Siltstones are highly clayey, dark gray, platy, with many pyrite nodules (these are, rather, silty clays in lenses), from a level of 1.0 m quickly turning into sandy silts, light gray, lenticular- and gently wavy-(thin)-laminated due to alluvium of clay material. Up the section the silt becomes very sandy. At a height of 5.5–6.0 m there is a lens of platy, weakly calcareous siltstone with lenticular bedding. In sandy siltstones up the section the number of clayey interbeds decreases.

Bivalves: *Arctica humiliculminata* Zakh. et Schur. (very frequent), *Homomya* sp. (very frequent).

Bed 95, thickness 4.0 m. At the base is a lens of calcareous siltstone, with interbeds of dark gray platy clays up to 1.1 m thick, with *Retroceramus* and other bivalves. Sandstones are silty, fine-grained, platy, gray with a greenish tint, up to 1.0 m from the base with pyrite nodules. The upper boundary is marked by a change in lithology.

Bivalves: *Retroceramus mongkensis* Kosch., *R. menneri* Kosch., *Arctica humiliculminata* Zakh. et Schur. (very frequent), *Maclearnia* sp. ind., *Dacryomya* sp. 2, *Tancredia* sp. 2 (Sample 117, basal part).

Bed 96, thickness 9.4 m. At the base there is a horizon of calcareous sandstone nodules. The clays are silty, dark gray, platy, with lenses of jarositization and pyrite nodules; from 1.0 m, lenses of light silt appear in the bed, and from 1.5 m, lenses of sand appear. Above, clayey and sandy siltstones, in the interval 3.1–3.3 m, weakly calcareous, with shell rock. At a height of

4.7 m, the same lens is extended, with pebbles, wood fragments, and shells *of Arctotis, Dacryomya, Tancredia*, and *Retroceramus*. The bedding is lenticular. The bed terminates below a bed of tabular sandstone with a coquina at the base.

Bivalves: *Arctotis (Arctotis) sublaevis* (Bodyl.) (many), *Arctica humiliculminata* Zakh. et Schur. (abundant), *Dacryomya* sp. 2, *Tancredia* sp. 2 (frequent).

Bed 97, thickness 2.5 m. At the base, there are lenses of coquinae of left valves if *Arctotis*. Sands and sandstones are silty, gray with a greenish tint, platy. From a height of 1.6 m, sandstones with clay interbeds, turning into clayey silts. At a height of 1.8 m, there is an *Arctotis* coquina bed made of large shells (*Arctotis* is also found up the section), and from a height of 2.5 m, platy siltstones begin, light greenish-gray, in areas of lenses and layers, calcareous along the strike, turning into real concretionary layers with coquina and thick lenticular bedding.

Bivalves: *Arctotis (Arctotis) sublaevis* (Bodyl.) (many), *Retroceramus mongkensis* Kosch., *Arctica humiliculminata* Zakh. et Schur. (abundant), *Tancredia* sp. 2 (very frequent).

Bed 98, thickness 6.0 m. At the base there is a horizon of platy sandstone nodules, brown on the surface. The siltstones are light gray with a slight greenish tint, sandy, at the bottom up to 1.1 m lenticular-calcareous and pass along the strike into true calcareous siltstones. On the bedding planes, ripples of disturbances and, less commonly, currents are clearly visible. From a level of 5.4 m there is interbedding of siltstones with layers of dark gray clays. The bed ends below the sandstone bed. The upper boundary is distinct and even. The bed contains numerous coquinae with *Arctotis*, other bivalves, ammonites, and retroceramids. *Arctotis* shells are found in carbonate nodules (0.15 × 0.8 m), in which they form accumulations of large and medium-sized shells (Fig. 18).

In the interval 1.1–1.5 m from the base of the bed, there is an interbed of clay, containing a large (0.2 × 7.0 m) lens of siderite with *Arctotis* (Fig. 19). Along strike, the clays wedge out.

Ammonites: *Pseudolioceras* (*Tugurites*) *whiteavesi* (White).

Bivalves: *Arctotis (Arctotis) sublaevis* (Bodyl.) (abundant)—scattered throughout the bed and buried without sorting or orientation, in lenses the left valves are nested into each other, large shells predominate; *Retroceramus mongkensis* Kosch., *Arctica humiliculminata* Zakh. et Schur. (very frequent), *Maclearnia* sp. ind., *Tancredia* sp. 2, *Homomya* sp., *Pleuromya* sp. (Sample 120, basal part). In a separate outcrop located the Saibylakh Creek about 2.5 km from the mouth, fossils were found in calcareous sandstones. Ammonites: *Tugurites whiteavesi* (White), bivalves: *Arctotis (Arctotis) sublaevis* (Bodyl.), *Retroceramus mongkensis* Kosch., *Arctica humiliculminata* Zakh. et Schur., *Tancredia* sp. 2, *Maclearnia* sp. ind. (Sample 122).

Bed 99, thickness 4.0 m. At the base, there is an interbed of brown-gray strong leptochlorite sandstone with pyrite, with a coquina lens at the base. These sandstones quickly grade into dark gray clayey siltstones, and from a height of 1.0 m into lenticular-silty and silty clays. Rare spherical (20 cm in diameter) nodules are found from the same level. The most frequent concretions are in the upper half of the bed at levels of 2.0 and 2.6 m. These are lenses (0.15 × 1.5 m), loaf-shaped nodules (0.15 × 0.5 m) and rare spheroidal nodules (diameter 0.25 m). The bed terminates by the change in lithology.

Bivalves—*Arctotis (Arctotis) sublaevis* (Bodyl.), *Nuculana (Jupiteria) acuminata* (Goldf.), *Retroceramus mongkensis* Kosch., *Arctica humiliculminata* Zakh. et Schur., *Maclearnia* sp. ind., *Tancredia* sp. 2, *Homomya* sp., *Pleuromya* sp.

Bed 100, thickness 2.6 m. Silstones dark gray, clayey-sandy, lumpy, with ripples of currents and waves visible in some interbeds, platy (at levels 0.4; 1.4 m), lenticular-bedded (0.2 × 2.5 m); with coquinae from Arctotis and less common Inoceramus. The surface color is ashy. At 0.4 m from the base of the layer there is a horizon of loaf-shaped concretions (0.2 × 0.7 m) of calcareous siltstone, in the interval 0.4–2.6 m there are individual nodules, sometimes palmate-shaped. At the top of the layer are many coquina lenses. The upper boundary of the bed is distinct, based on the change in lithology.

Bivalves—*Arctotis (Arctotis)* sublaevis (Bodyl.), *Nuculana (Jupiteria) acuminata* (Goldf.), *Retroceramus* spp., *Arctica humiliculminata* Zakh. et Schur., *Maclearnia* sp., *Tancredia* sp. 2, *Homomya* sp., *Pleuromya* sp. 2.

Bed 101, thickness 3.1 m. At the base there is an interbed of sandy silt of variable thickness with lenses of *Arctotis*. The clays are dark gray, platy. Up the section, the clays become more silty and in the uppermost 0.5–0.7 m there are light gray silts with an uneven distribution of clay material. The clays of the bed are ferruginized in areas and contain lenses of silt in the middle part. At the very top of the layer there are lenses cut from above (0.1 × 0.5 m) of platy sandy siltstone, with lenticular bedding, with coquina at the base. The bed ends below the level of erosion. The upper border is distinct and smooth.

Bivalves—*Arctica humiliculminata* Zakh. et Schur., *Tancredia* sp. 2.

Bed 102, thickness 15.0 m (visible). At the base there is an interbed of greenish-gray gravel, variable thickness (up to 10 cm), sometimes fissured, with coarse sand, with lenses of small pebbles, small blocks and boulders. The bed is composed of light gray fine-grained silty sands and dense sandy silts with a slight greenish tint. In the lower 0.5 m of the bed there are lenses of calcite tubes with fragments of valves and wood, lenses of gravel-sand material with pebbles and, less commonly, boulders. At a height of 0.8 m, nodules of sideritized calcareous siltstone occur. Individual

Fig. 18. Accumulations of *Arctotis (Arctotis) sublaevis* (Bodyl.) shells in a concretion.

loaf-shaped nodules (0.1 × 0.15 m) of siderites are located at the level 1.7 m. At a height of 5.3–5.4 m, the sandstones are weakly calcareous and consistent along strike. At a height of 7.6 m (sometimes 7.2)–7.9 m the rocks are calcareous. At a height of 11.2–12.3 m there is a layer of calcareous sandstone with a reddish surface is recorded. This is overlain by another 2.7 m of the section. Thin (<1 cm) extended lens-shaped clay interbeds are observed after 0.5–2.5 m. In the bed there are shells of *Pleuromya* in the living position, and occasionally vertical passages of sandworms. Clay interbeds are almost always associated with coquinae. The bed contains scattered gravel, pebbles, and boulders.

Bivalves: *Arctotis (Arctotis) sublaevis* (Bodyl.), *Retroceramus lucifer* (Eichw.).

To the north, the section is interrupted by the valley of Shirokiy Creek, located in front of Cape Saibylakh.

A bivalve-based scheme of stratigraphy and correlation of the Pliensbachian-Aalenian in Outcrop 5 of Anabar Bay is shown in Fig. 20.

Division and Correlation of Pliensbachian-Aalenian Deposits in the Section of Anabar Bay

The litostratigraphy of the series is based on the studies of M.A. Levchuk, B.N. Shurygin and V.P. Devyatov (Levchuk, 1985; Shurygin et al., 2000).

Airkat Formation. The Late Pliensbachian Airkat Formation crops out in the Nordvik and East Taimyr structural-facies zones. The recognition in the formation of two lower zonal divisions of the Upper Pliensbachian—the Amaltheus stokesi Zone, and above—Beds with A. margaritatus- is substantiated by ammonites in sections of the Anabar River and Anabar Bay. The upper part of the Airkat Formation belonged to the Beds with Amaltheus sp.; the latter were compared with the Pleuroceras spinatum Zone in the standard scale (*Resheniya*..., 1981; *Zony*..., 1982). For the uppermost part of the Airkat Formation, which is not characterized by ammonites, the upper Pliensbachian Tancredia kuznetsovi b-Zone was proposed as an auxiliary biostratigraphic unit (Meledina and Shurygin, 2001). Previous studies considered the Amaltheus viligaensis Zone as a succession that included Members 13–15 of the Airkat Formation with a total thickness of about 44 m (according to Shurygin et al., 2000). Research in this work has established that, apparently, only Member 15 (according to Shurygin et al., 2000) with a thickness of 10.4 m should be assigned to the Amaltheus viligaensis Zone.

Kiterbyut Formation. In Eastern Siberia, the Kiterbyut Formation is recorded in the East Taimyr and Nordvik structural-facies zones. The age of the formation was substantiated by finds of ammonites: *Elegan-*

Fig. 19. Lens-like aggregation of shells of *Arctotis (Arctotis) sublaevis* (Bodyl.) (Photograph by M.A. Rogov, 2008).

ticeras? sp. ind. in Borehole 26 of the Suolemskaya area (Suolema–Anabar interfluve) 3.3 m from the base of the Kiterbyut Formation (Knyazev et al., 1991), *Dactylioceras*? sp. ind. in the upper part of the Kiterbyut Formation and *Dactylioceras* sp. indet. collected loose in the talus of this formation in Outcrop 4 on the eastern shore of Anabar Bay (Saks et al., 1963). It was assumed that the Kiterbyut Formation overlies the Airkat Formation with a gap corresponding to the Dactylioceras tenuicostatum Zone of the northwestern European standard (*Resheniya*..., 1981; Shurygin et al., 2000; Knyazev et al., 2003). In the section of Anabar Bay, the Kiterbyut Formation was considered within the Harpoceras falciferum and Dactylioceras commune ammonite zones (Shurygin et al., 2000).

The stratigraphic range of the formation is considered to be correlated to the range of the Tiltoniceras antiquum, Harpoceras falciferum, Dactylioceras commune zones of the Boreal standard (Lutikov, 2023b).

Eren Formation. In Eastern Siberia, the Eren Formation crops out in the Nordvik structural-facies zone. In the section of Anabar Bay, the formation was considered to be correlated to the Dactylioceras commune and Zugodactilites braunianus ammonite zones and the lower two zones of the Upper Toarcian (Shurygin et al., 2000; Knyazev et al., 2003). The age of the formation was based on ammonites found in the middle part of the formation: *Dactylioceras athleticum, Dactylioceras commune, Dactylioceras suntarense, Zugodactilites braunianus, Catacoeloceras crassum, Pseudolioceras lythense* (Knyazev et al., 1993, 2003). In the section of Anabar Bay, the formation was considered to correspond to the Lower–Upper Toarcian (Shurygin et al., 2000).

The stratigraphic range of the formation is considered correspond to that of the Dactylioceras commune, Zugodactilites braunianus, Pseudolioceras compactile, and Pseudolioceras wuerttenbergeri zones of the Boreal standard (Lutikov, 2023b).

Horgo Formation. In Eastern Siberia, the Horgo Formation crops out in the Nordvik structural-facies zone. The upper boundary of the formation bears traces of redeposition—an interbed, saturated with pebbles, boulders, charred wood and fragments of bivalve shells (Knyazev et al., 1991). The formation was dated using ammonite finds: *Pseudolioceras* sp. (cf. *maclintocki* Haugh.) was found in the scree (*Stratigrafiya*..., 1976), and later reidentified as *Pseudolioceras falcodiscus* (Knyazev, 1991). In the section of Anabar Bay, the formation was considered to correspond to the range of the Upper Toarcian Pseudolioceras falcodiscus and the Lower Aalenian zones (Shurygin et al., 2000).

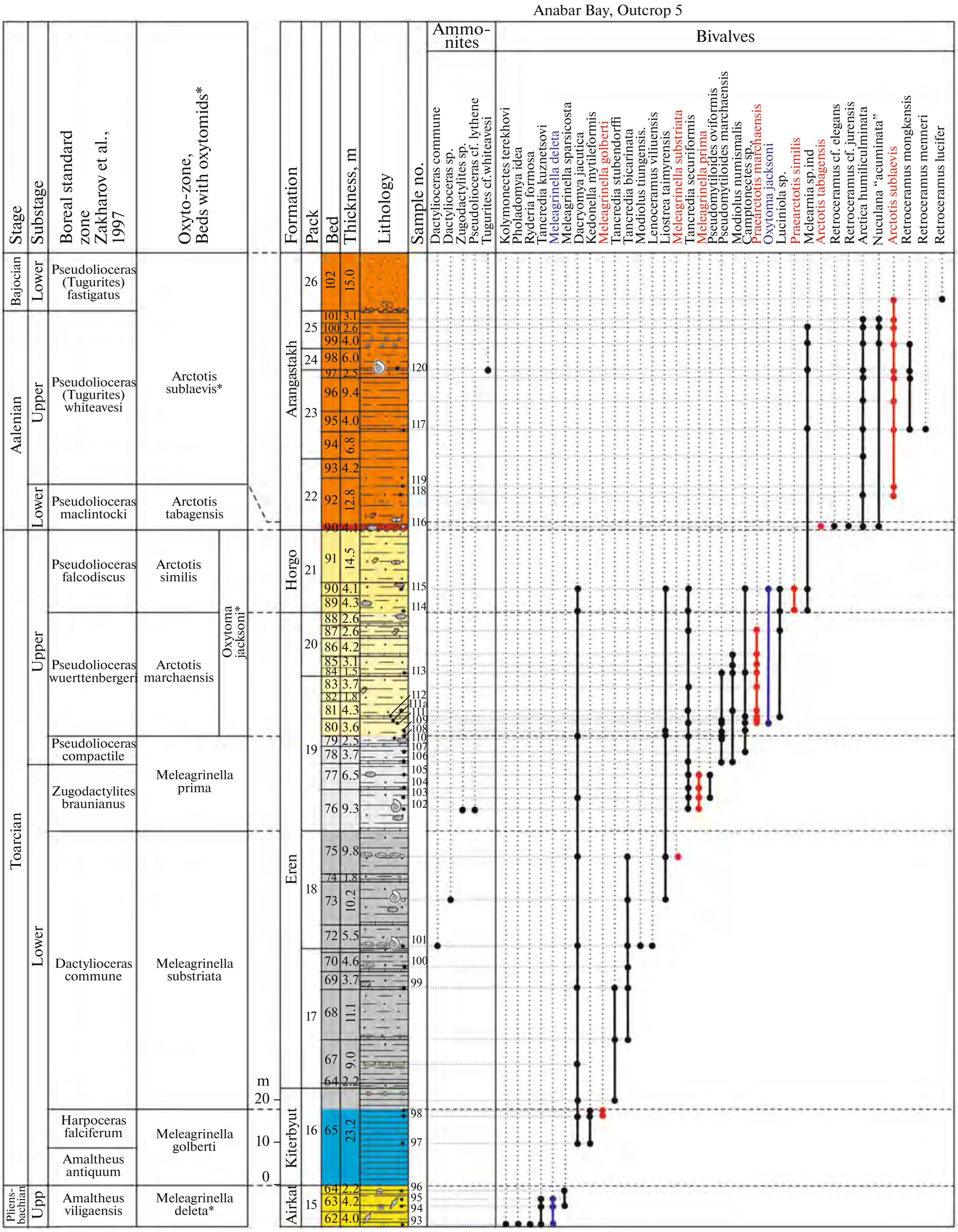

Fig. 20. Stratigraphy of Pliensbachian-Aalenian deposits in Outcrop 5 of Anabar Bay based on the distribution of index species and zonal assemblages of the oxytomid scale. Legend see in Fig. 14. In the table of intervals of distribution of taxa, the tail-zones of index species of oxyto-zones are shown in red, and Beds with oxytomids are shown in blue.

The stratigraphic range of the formation is considered to be within the range of the Upper Toarcian Pseudolioceras falcodiscus Zone (Lutikov, 2023b).

Arangastakh Formation. According to modern concepts, it is assumed that the Arangastakh Formation overlies the Horgo Formation with a stratigraphic gap corresponding to almost the entire Lower Aalenian and, possibly, the lower part of the Upper Aalenian (*Stratigrafiya*..., 1976; Meledina and Shurygin, 2000; Shurygin et al., 2000). The age of the formation was based on the ammonites *Pseudolioceras (Tugurites) whiteavesi* (White), *Erycitoides?* cf. *howelli* (White), *Stephanoceras*? sp. and retroceramid assemblages as Late Aalenian–Early Bajocian (Stratigrafiya, 1976; Meledina and Shurygin, 2000; Nikitenko et al., 2013). According to other data, the age of the retroceramic complex, found in the basal bed of sandstone with pebbles and coquinae at the base of the formation, was considered Early Aalenian (Basov et al., 1967; Koshelkina, 1974). From this point of view, the stratigraphic range of the formation corresponds to the Pseudolioceras maclintocki, Pseudolioceras (Tugurites) whiteavesi, and Pseudolioceras (Tugurites) fastigatus zones.

A scheme of stratigraphy and correlation of Pliensbachian-Aalenian deposits of Anabar Bay based on the distribution of index species and zonal assemblages of the oxytomid scale is presented in Fig. 21.

Based on the distribution of index species and zonal assemblages of bivalves in Outcrops 4 and 5 (Figs. 14 and 20), the Upper Pliensbachian-Upper Aalenian succession of Anabar Bay is subdivided into six oxyto-zones and two Beds with oxytomids.

Beds with Meleagrinella deleta. The beds with Meleagrinella (Praemeleagrinella) deleta were first established to index the stratigraphic interval corresponding to the upper Pliensbachian zone in the section of Cape Tsvetkov area (Eastern Taimyr) (Lutikov et al., 2022). In the section of Outcrop 5 of Anabar Bay, Beds 62–64 of the Airkat Formation (Fig. 20) (Member 15 after Shurygin et al., 2000) correspond to the Beds with Meleagrinella deleta and correlate with the Amaltheus viligaensis Zone of the Boreal standard (Zakharov et al., 1997). The terminal sequence of the Airkat Formation contains the index species *Meleagrinella (Praemeleagrinella) deleta* and a characteristic zonal assemblage with *Kolymonectes terekhovi, Rideria formosa* Polub.*, Modiolus* sp. 1. The thickness of the Beds is 10.4 m.

The accompanying foraminiferal assemblage, represented by *Ammodiscus siliceus, Trochammina lapidosa, Glomospira* ex gr. g*ordialis, Recurvoides taimyrensis, Cornuspira liasina, Kutsevella barrowensis*, characterizes the lower part of the JF9 zone, the full stratigraphic range of which in the north of Siberia covers the Amaltheus viligaensis and Tiltoniceras antiquum zones (*Reshenie*..., 2004).

Meleagrinella golberti Oxyto-zone. This zone was first proposed to index the stratigraphic interval corresponding to the Tiltoniceras antiquum, Harpoceras falciferum zones for the Nordvik structural-facies zone (Lutikov and Arp, 2023b).

In Outcrop 4, the oxyto-zone includes Bed 1 without an upper part. The upper boundary is drawn by the disappearance of bivalve assemblage at the level of the horizon with nodules–17.1 m from the base of the bed (Fig. 14). Oxyto-zone is identified by the zonal bivalve assemblage with *Tancredia stubendorffi, Dacryomya jacutica*.

In Outcrop 5 of Anabar Bay, the oxyto-zone includes the lower part of Bed 65. The oxyto-zone is established by the presence of the index species *Meleagrinella (Praemeleagrinella?) golberti* and a characteristic bivalve assemblage with *Kedonella mytileformis, Tancredia stubendorffi, Dacryomya jacutica*. The upper boundary of the Oxyto-zone is drawn by the disappearance of bivalve assemblage at the level of 21.2 m (Fig. 20). The total thickness of the oxyto-zone is 21.2 m.

The lower part of the Kiterbyut Formation in the section of Anabar Bay corresponds to the Meleagrinella golberti Oxyto-zone and correlates with the Tiltoniceras antiquum, Harpoceras falciferum zones of the Boreal standard of the Toarcian Stage.

Data on foraminifers do not contradict this conclusion. The accompanying foraminiferal assemblage, represented by *Trochammina kisselmani, Ammobaculites lobus, Saccammina inanis,* and *Triplasia kingakensis*, characterizes the Trochammina kisselmani F-Zone, which in the north of Siberia corresponds to the Tiltoniceras antiquum, Harpoceras falciferum, Dactylioceras commune, and Zugodactilites braunianus zones (Sapyanik, 1991b).

The **Meleagrinella substriata Oxyto-zone** was first proposed to index the stratigraphic interval corresponding to the Dactylioceras commune Zone for the Levy Kedon stratigraphic zone (Lutikov and Arp, 2023b).

In Outcrop 4, the oxyto-zone includes the upper part (about 1.0 m) of the Kiterbyut Formation and Beds 2–8 of the Eren Formation. In Outcrop 5, the oxyto-zone includes the upper part (about 2.0 m) of the Kiterbyut Formation and Beds 66–75 of the Eren Formation. The oxyto-zone is identified by the index species *Meleagrinella (Clathrolima) substriata* and the zonal bivalve assemblage with *Lenoceramus viluiensis, Modiolus tiungensis, Tancredia bicarinata* (Figs. 14, 20). The total thickness of the oxyto-zone is 59.7 m.

Meleagrinella prima Oxyto-zone was first proposed was proposed to index the stratigraphic interval corresponding to the Zugodactilites braunianus and Pseudolioceras compactile zones for the Nordvik structural-facies zone (Lutikov and Arp, 2023b).

In Outcrop 4, Beds 9–17 of the Eren Formation are included in this oxyto-zone. In Outcrop 5, the oxyto-zone includes Beds 76–79 of the Eren Formation. The oxyto-zone is identified by the index species *Meleagri-*

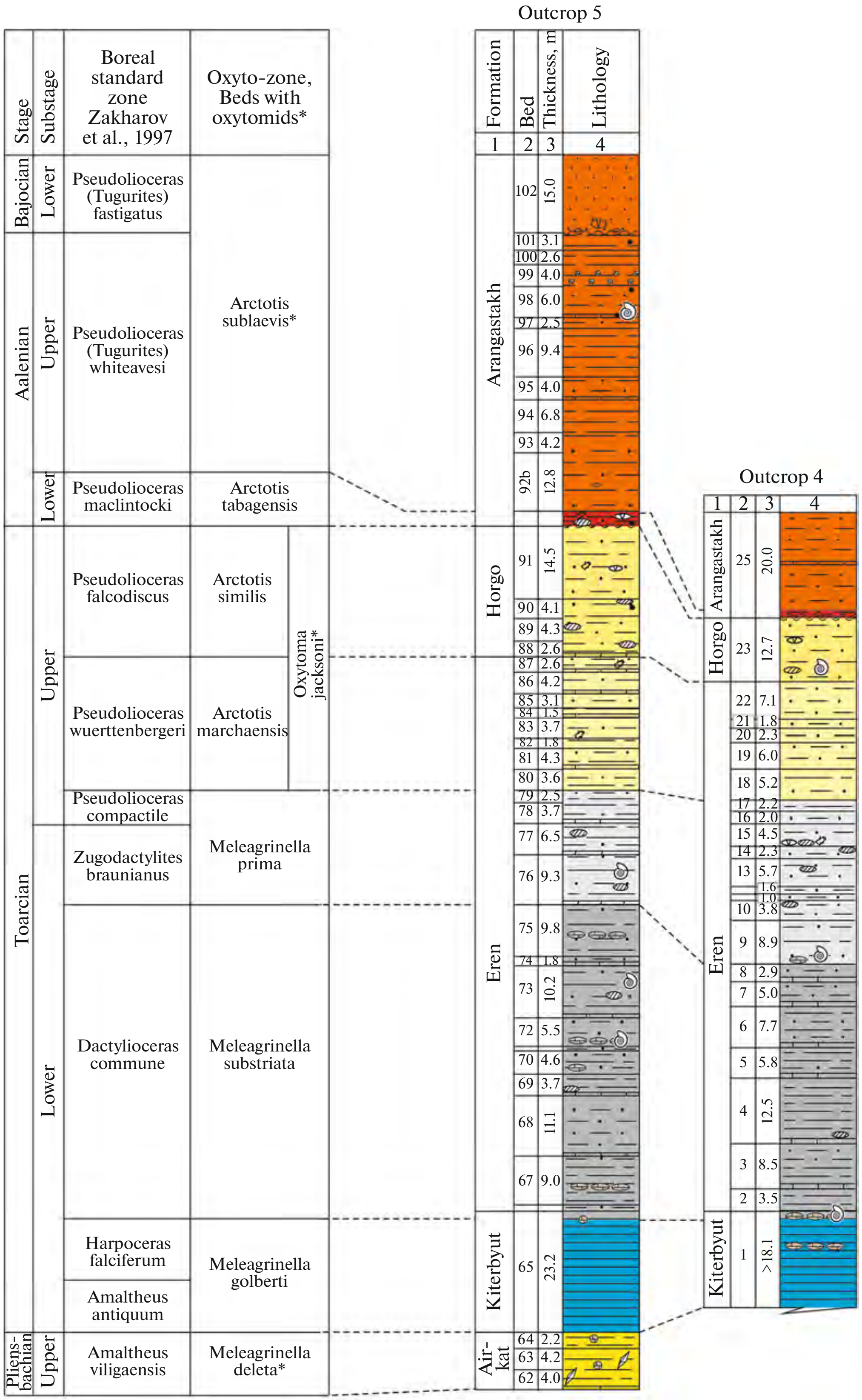

Fig. 21. Scheme of stratigraphy and correlation of Pliensbachian-Aalenian deposits of Anabar Bay based on the distribution of index species and zonal assemblages of the oxytomid scale. Legend see in Fig. 14.

nella (Meleagrinella) prima and zonal bivalve assemblage with *Pseudomytiloides oviformis, Pseudomytiloides marchaensis, Modiolus numismalis, Liostrea taimyrensis, Camptonectes* s.str., *Tancredia securiformis* (Figs. 14, 20). The total thickness of the oxyto-zone is 32.0 m.

The Arctotis marchaensis Oxyto-zone in the established chronostratigraphic volume was proposed for indexing the stratigraphic interval corresponding to the Pseudolioceras wuerttenbergeri Zone of the Boreal standard for the Nordvik structural-facies zone (Lutikov, 2021).

In Outcrop 4, the oxyto-zone is classified as a sequence that includes Beds 18–22 of the Eren Formation. The oxyto-zone is identified by the index species *Arctotis (Praearctotis) marchaensis* and the zonal bivalve assemblage with *Luciniola* sp. (Fig. 14).

In Outcrop 5, the oxyto-zone includes the sequence including Beds 80–87 of the Eren Formation, based on the presence of the index species Arctotis (Praearctotis) marchaensis and the zonal bivalve assemblage with *Oxytoma jacksoni,* and *Luciniola* sp. The total thickness of the oxyto-zone is 24.8 m (Fig. 20).

Arctotis similis Oxyto-zone. This oxyto-zone in the established chronostratigraphic range was proposed to index the stratigraphic interval corresponding to the Pseudolioceras falcodiscus Zone of the Boreal standard for the Nordvik structural-facies zone (Lutikov, 2021).

In Outcrop 4, Bed 23 of the Horgo Formation is assigned to the oxyto-zone. The oxyto-zone is distinguished by the index species *Arctotis (Praearctotis) similis* Velikzh. and zonal bivalve assemblage with *Tancredia* sp. 1., *Dacryomya* sp. 1 (Fig. 14). The apparent thickness of the oxyto-zone is 12.7 m (Lutikov, 2021).

In Outcrop 5, the oxyto-zone includes Beds 88–91 of the Horongho Formation. The oxyto-zone is identified by the index species *Arctotis (Praearctotis) similis* and the zonal bivalve assemblage: *Maclearnia* sp. ind., *Dacryomya* sp. 1. The total thickness of the oxyto-zone 25.5 m (Fig. 20).

Arctotis tabagensis Oxyto-zone. This zone was proposed to index the stratigraphic interval corresponding to the Pseudolioceras maclintocki Zone of the Boreal standard for the Nordvik structural-facies zone (Lutikov, 2021).

In Outcrop 4, the oxyto-zone includes the lower 1.4 m of Bed 92 of the Arangastakh Formation. The oxyto-zone is distinguished by the presence of a zonal bivalve assemblage with *Retroceramus elegans* (Fig. 14). In the section of the eastern coast of Anabar Bay, *Retroceramus* cf. *mongkensis* Kosch., *Retroceramus* ex gr. *elegans* Kosch., Arctica sp. nov. (=*Arctica humiliculminata* Schur., comm. by O.A. Lutikov), "*Arctotis lenaensis* Lah." (=*Arctotis tabagensis*, comm. by O.A. Lutikov), *Tancredia* cf. *gigantea* Vor. (in litt.) (=*Tancredia* sp. 2, comm. by O.A. Lutikov) (Stratigrafiya, 1976, Member 22).

In Outcrop 5, the oxyto-zone includes a series including the basal interbed of the Arangastakh Formation, based on the presence of the index species *Arctotis (Arctotis) tabagensis* and the zonal bivalve assemblage with *Retroceramus elegans, Arctica humiliculminata, Nuculana (Jupiteria) acuminata, Tancredia* sp. 2 (Fig. 20). The total thickness of the oxyto-zone is 1.5 m. From the interbed at the contact of the Horgo and Arangastakh formations on the western coast of Anabar Bay, *Retroceramus elegans* Kosch., *Retroceramus jurensis* Kosch. were recorded (Meledina and Shurygin, 2000).

In the section along the southern coast of Anabar Bay in the section of Cape Horgo—the mouth of the Muus-Khaya River, Koshelkina (1974) identified *Retroceramus menneri* Kosch. from this bed and up to the level of 8.8 m, and *Retroceramus jurensis* Kosch from the higher parts of the section.

Presumably, only the lower non-retroceramid part of the oxyto-zone with *Arctotis tabagensis*, which is characterized by *Oxytoma jacksoni* and *Propeamussium olenekense*, is missing in the section.

Beds with *Arctotis sublaevis* were established to index the stratigraphic interval corresponding to the Upper Aalenian–Lower Bajocian in Eastern Siberia (Lutikov, 2023a). In Outcrop 4, the biostraton includes Bed 25 (without the basal part—1.0 m). The visible thickness of the oxyto-zone is 19.5 m (Fig. 14).

In Outcrop 5, the biostraton includes Bed 92 (without the basal part—1.5 m) and Beds 93–102. The biostraton is identified by the presence of the index species *Arctotis (Arctotis) sublaevis* and the zonal assemblage bivalves: *Retroceramus mongkensis* Kosch., *Retroceramus menneri* Kosch. (Fig. 20). The thickness of the beds is 68.9 m.

Section in the Area of Cape Tsvetkov (Eastern Taimyr)

Based on the lithology of sediments, thickness and completeness of sections, the Lower and Middle Jurassic strata of the Cape Tsvetkov area belong to the East Taimyr structural-facies zone (*Resheniya*..., 1981). The section was studied many times by specialists from VNIGRI, IGiG (INGG) SB USSR Academy of Sciences (RAN), VSEGEI and SNIIGGiMS. In the Lower and Middle Jurassic parts of the section on the coast of the Khatanga Bay, six formations have been identified: Zimnyaya, Airkat, Kiterbyut, Korotkiy, Aprelevskiy and Arangastakh (Shurygin et al., 2000). With varying degrees of certainty, units of the general stratigraphic scale have been established in the section: Hettangian–Lower Pliensbachian, Upper Pliensbachian, Lower and Upper Toarcian, Lower and Upper Aalenian (Shurygin et al., 2000; Knyazev et al., 2003; Nikitenko, 2009). Toarcian and Aalenian deposits emerge crop out in coastal cliffs (outcrops 4 and 5) along the western shore of Khatanga Bay and in coastal creeks (outcrops 5 and 7/1) 4.1–6.2 km southwest of the head of Utina Bay (Fig. 22).

The section was studied by the SNIIGGiMS team in 1987. The section was described by O.A. Lutikov and V.V. Sapjanik in 1987 and supplemented by data from A.S. Alifirov, who studied this section in 2014. Paleontological determinations were made by O.A. Lutikov based on fossil collections in 1987 and supplemented with information based on the collections of B.N. Shurygin in 1976 and A.N. Aleynikov in 2014 (Lutikov et al., 2022). Ammonites were identified by V.G. Knyazev and co-authors (Knyazev, 1991; Knyazev et al., 1993). The coordinates of outcrops and outcrops of beds were determined by A.N. Aleynikov in 2014. Photos taken by A.S. Alifirov (INGG) in 2014.

Outcrop no. 4

Outcrop No. 4 is represented by a coastal cliff about 15 m high, stretching for 1 km along the western shore of Khatanga Bay to the southwest of the head of Utinaya Bay (Fig. 23). The outcrop reveals Upper Pliensbachian and lower Toarcian sediments. The description begins from the base of Bed 11, located 4.9 km from the head of Utinaya Bay (Fig. 24).

Airkat Formation. It is composed of alternating units of dark gray clays, clayey siltstones, light gray sandstones and sandy siltstones. Nodules and concretions of pyrite, fragments of wood, and small plant detritus are scattered throughout the series. The thickness of the formation in the area of Cape Tsvetkov is 268 m (Saks et al., 1978). This paper describes the characteristics of the upper member of the formation (Outcrop 5, Unit 13, Beds 10–16 in Levchuk, 1985).

Bed 11. It begins with a horizon of reddish-brown surface nodules of calcareous siltstone (thickness about 1.0 m). Higher up there is an alternation of sandy siltstones and dense siltstones. At the level 1.2 m from the base there is a horizon of nodules (thickness up to 0.5 m) of calcareous siltstone. The bed contains many pebbles, jarositization spots, and rounded nodules of greenish-gray sandstone. Thickness 2.0 m.

Bivalves *Homomya* sp.

Foraminifers: *Hyperammina neglecta* Gerke et Sossip., *Glomospira* ex gr. *gordialis* (Park. et Jon.), *Trochammina sablei* Tappan, *Astacolus* ex gr. *varians* (Borneman), *Dentalina* ex gr. *communes* Orbigny.

Bed 12. Siltstones dark gray, massive, with pebbles and boulders. Thickness is 2.5 m.

Bivalves: *Harpax laevigatus* (Orb.).

Bed 13. Silts sandy, finely fragmented, with jarosite spots and pebbles. At the base—interbed (1.0 m) of pebblestone with huge boulders (up to 1.0 m). Above are dark gray siltstones with a bluish tint, massive. The thickness of the bed is 3.0 m.

Bivalves *Harpax laevigatus* (Orb.).

Bed 14. Silts sandy, dark gray, fissile, with numerous lenses of pebbles and scattered pebbles. Many spots of jarositization. Several levels contain concretions (0.2 × 0.5 m) of calcareous siltstone. Thickness is 5.0 m.

Bivalves: *Harpax laevigatus* (Orb.).

Foraminifers: *Recurvoides taimyrensis* Nikitenko, *Saccammina ampulacea* Schleifer, *Hyperammina neglecta* Gerke et Sossip., *Glomospira* ex gr. *gordialis* (Park. et Jon.), *Ammodiscus siliceus* (Terquem), *Trochammina sablei* Tappan, *Kutzevella barrowensis* (Tappan), *Bulbobaculites strigosus* (Gerke et Sossip.).

These beds are overlain by a series, which during fieldwork in 1987 had been described as a single Bed 15. Subsequent laboratory studies divided the bed into two parts based on lithological and paleontological characteristics. Bed 15a is assigned to the Airkat Formation, and Bed 15b to the Kiterbyut Formation.

Bed 15a. Silts clayey, dark gray, fissile, with abundant jarosite stains, with pebble interbeds with bivalves and gastropods. In the upper part of the bed (0.5 m) there are frequent *Homomya* shells buried in the living position. This part of the bed, according to M.A. Levchuk, belonged to the Kiterbyut Formation (Member 14, Bed 9; Levchuk, 1985), according to the present author—to the Airkat formation. Thickness 2.5 m.

Bivalves: *Praemeleagrinella deleta* (Dumortier), *Neocrassina (Siungiudella)* cf. *parvula* Lutikov (Sample TF-11). *Homomya* sp. (according to B.N. Shurygin).

Foraminifers: at the level 2.0 m from the base of the bed—*Hyperammina neglecta* Gerke et Sossip., *Glomospira* ex gr. *gordialis* (Parker et Jones), *Ammodiscus siliceus* (Terquem), *Trochammina sablei* Tappan, *Kutzevella barrowensis* (Tappan), *Recurvoides taimyrensis* Nikitenko.

Higher up the section there lies a formation that, during fieldwork in 1976, was described as a single unit (Outcrop 5, Unit 14, Beds 5–8 according to Levchuk, 1985). Based on lithology and fossils, the series is now divided by the present author into several beds. Beds 15b, 16a and 16b are considered part of the Kiterbyut formation. Bed 16c is assigned to the Korotkiy Formation (Fig. 25).

Kiterbyut Formation. Clays finely fragmented, gray to black, yellow-gray, in outcrops—with a brownish tint, in places plastic, with carbonate nodules, in areas highly jarositized. The thickness of the formation in the area of Cape Tsvetkov, according to M.A. Levchuk, is 27.7 m (Unit 14, Beds 5–9 according to Levchuk, 1985), according to the present author—20.7 m.

Bed 15b. Clays dark gray, finely fragmented, with jarosite spots. At the level 0.5 m from the base—there is a horizon of spherical nodules of calcareous siltstone, yellowish-gray from the surface. At the level of 2.5 m, there is a horizon of loaf-shaped concretions (0.15 × 0.4 m) of calcareous siltstone. Thickness is 3.7 m.

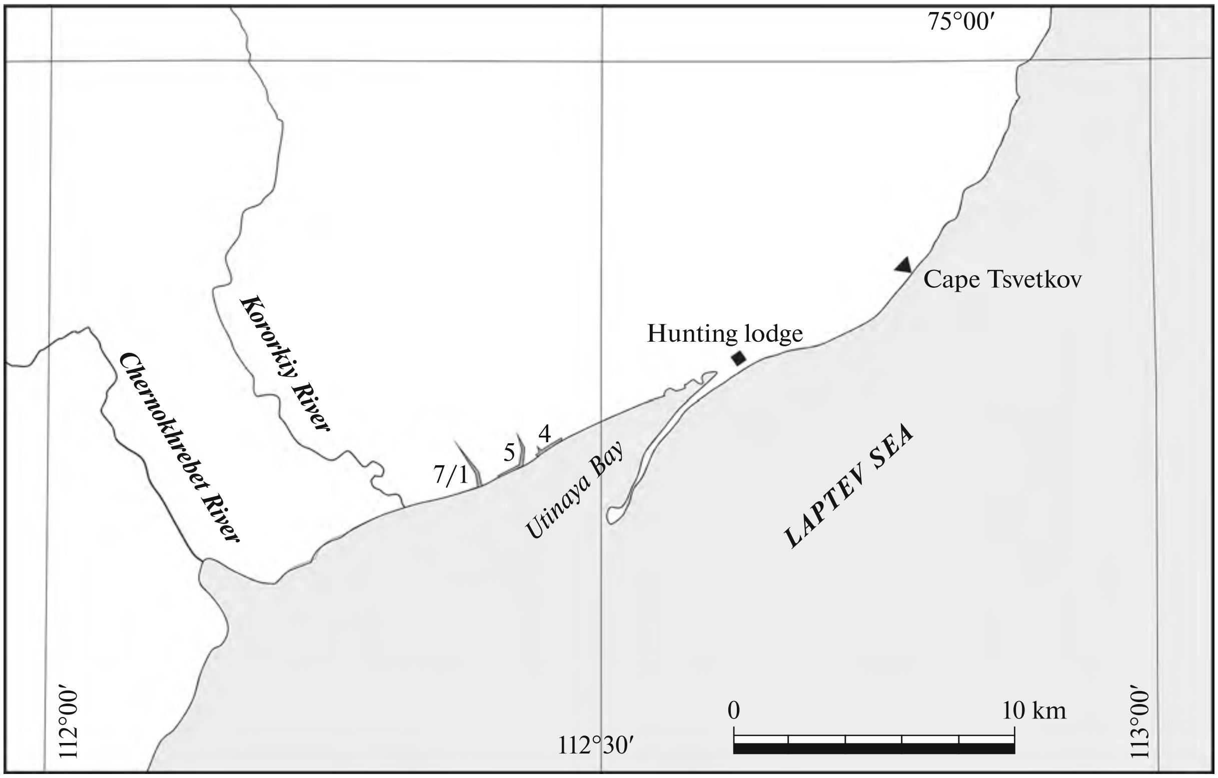

Fig. 22. Studied outcrops in Eastern Taimyr.

Fig. 23. General view of the Pliensbachian–Aalenian outcrops located along the western shore of Khatanga Bay. Photo by N.N. Sobolev (VSEGEI), 2007.

Fig. 24. Outcrop 4. Outcrops of Beds 11–15a of the Airkat Formation. Photo by A.S. Alifirov, 2014.

Foraminifers: *Trochammina kisselmani* Sapjanik et Sokolov (dominant), *Saccammina inanis* Gerke et Sossip., *Ammodiscus glumaceus* Gerke et Sossip., *Ammobaculites lobus* Gerke et Sossip., *Bulbobaculites strigosus* (Gerke et Sossip.), *Lenticulina toarcense* (Payard), *Recurvoides taimyrensis* Nikitenko.

Bed 16a. At the base clay dark gray, strongly ochreous, foliated, becoming finely scaly (1.0 m). Above there is an alternation of foliated clays, yellowish-brown on the surface, light gray in fresh fractures, and clayey silts, reddish on the surface, dark gray and gray in fresh fractures. At the base is a lens of pinkish clays,

Fig. 25. Outcrop 4. Outcrops of Beds 15b–16b of the Kiterbyut Formation. Photo by A.S. Alifirov, 2014.

very viscous, with rostra of belemnites. At 2.0 m from the base there is a horizon of light gray nodules (0.4 × 0.15 m) of calcareous clays, brownish-gray on the surface. At the level 2.5 m—horizon of nodules reaching up to 1 m in diameter. At the level 3.0 m—horizon of scattered loaf-shaped nodules with *Dacryomya*. Thickness 6.0 m.

Bivalves: *Dacryomya jacutica* (Petr.), abundantly presented from the level of 2.5 m.

Foraminifers: *Saccammina inanis* Gerke et Sossip., *Ammodiscus glumaceus* Gerke et Sossip., *Bulbobaculites strigosus* (Gerke et Sossip.), *Hyperammina neglecta* Gerke et Sossip., *Ammobaculites lobus* Gerke et Sossip., *Trochammina kisselmani* Sapjanik et Sokolov, *Triplasia kingakensis* Loeblich et Tappan.

Bed 16b. In 1987, the bed was covered by a glacier; the description was made based on data from 1976. The clays are gray, fissele, with jarosite spots, and in places heavily ochreous. At 1.0, 1.9, 2.4, 3.5 m from the base there are horizons of loaf-shaped concretions (0.2 × 0.7 m) of calcareous clays. 1.0 m below the top there is an interbed of platy, silty mudstone. Small compressed bivalves shells are scattered at the bottom of the bed. In the middle part of the bed there are entire ferruginous rostra of belemnites, in the upper part (1.0 m from the top) there are shells of bivalves, buried without orientation, sometimes in a living position, but compressed from the umbonal region. Thickness 11.0 m.

Bivalves: *Dacryomya jacutica* (Petr.).

Korotkiy Formation. A uniform thickness of dark gray clays and mudstones (silty and silty) with numerous rows of calcareous-clay nodules and pyrite nodules (Shurygin et al., 2000). The overall thickness of the formation in the area of Cape Tsvetkov, according to Levchuk (1985), is 92.1 m, according to new data—103.5 m. The difference in thickness estimates is explained by the error in measurements of the series partially covered by glaciers and the addition to the formation of Bed 16c. Coordinates of the mouth of the creek: 74°54.548′ N, 112°28.39′ E. Bed 16c crops out in the wall of the coastal cliff to the northeast of the creek, Beds 17b–18 were studied in the wall of the coastal cliff to the southwest of the creek, Bed 17a is exposed on the right side of the creek valley (Fig. 26).

Bed 16c. When the section was studied by Lutikov and Sapyanik (1987) the bed was covered by a glacier. The characteristics of the bed are given according to the field descriptions of Shurygin (1976) and Alifirova (2014). The clays are dark gray, fissile, ochreous, in places with yellowish ocher spots, with interbeds of plastic clays. At the base is a horizon of gray, irregularly shaped calcareous nodules (0.05 × 0.3 m). Up to a level of 1.1 m from the base, the bed is saturated with small nodules of various shapes, including spherical ones. At 1.1 and 2.0 m from the base there are horizons of bun-shaped concretions with a thickness of about 0.15 m. At 1.3 m and 1.6 m from the base there are two thin platy concretionary horizons. At 2.3 m from the base there is carbonized wood and a nodule (diameter about 1.5 m). Under the very edge of the slope there are gray nodules up to 0.3 m long. Concretions emerge in the valley (higher in the section). In the thickness there are many rostra of belemnites and crushed *Dacryomya* shells, in the lower part of the bed there are coquinae with an abundance of whole *Dacryomya* shells. The bed belonged to the Kiterbyut Formation (Outcrop 5, Unit 14, Bed 5 according to Levchuk, 1985); according to new data, it belongs to the Korotkinsk Formation (Lutikov et al., 2022). Thickness 6.5 m.

Bivalves *Dacryomya jacutica* (Petr.).

Bed 17a. Mudstone silty, gray, fissiled, ocher in places, with a mass of bivalves and scattered belemnites. At the base of the bed is a lens of plastic yellowish clay. Bivalves *Dacryomya jacutica* (Petr.). Thickness 1.7 m.

Bed 17b. Silts clayey, dark gray, lumpy, with ocher spots. At the base is a horizon of thick cake-shaped nodules (0.3 × 1.5 m) of calcareous siltstone, with bivalves and remains of fish fins. At levels 1.2, 1.8. 3.2, 4.5 m from the base—horizons of ellipsoidal nodules (0.3 × 0.4 m), composed of calcareous silt, brown on the surface, dark gray in fresh fractures, with fauna. Thickness 4.9 m.

At the level 1.8 m from the base (Sample TF-12) in 1987 O.A. Lutikov found an ammonite identified as *Catacoeloceras crassum* (Y. et B.) (Knyazev et al., 1993). Bivalves *Dacryomya jacutica* (Petr.) (Sample TF-13, basal part of the bed; 3.2 and 4.5 m above the base).

Foraminifers: *Saccammina inanis* Gerke et Sossip., *Ammodiscus glumaceus* Gerke et Sossip., *Hyperammina neglecta* Gerke et Sossip., *Trochammina kisselmani* Sapjanik et Sokolov, *Globulina jurensis* Kisselman.

Bed 18. Silts clayey, dark gray, ocher. At the base is a horizon of loaf-shaped concretions (0.3 × 1.2 m). At the level 1.2 m from the base, bun-shaped nodules

Fig. 26. Outcrop 4. Outcrops of Beds 16c–18 of the Korotkiy Formation. The arrow shows the occurrence of the ammonite *Catacoeloceras crassum*. Photo by A.S. Alifirov, 2014.

are brown on the surface, light gray in fresh fractures, with shell accumulations of bivalves and gastropods. At the level 2.0 m from the base—a horizon of loaf-shaped nodules with conchoidal jointing. Bed thickness 2.8 m.

Bivalves: *Mytiloceramus (Lenoceramus) vilujensis* (Polub.), *Oxytoma* sp. ex gr. *kirinae* Velikzch., belemnites, gastropods (Sample TF-14, level 1.2 m from the base); *Mytiloceramus (Pseudomytiloides) oviformis* (Khudyaev in Krymgholz et al., 1953), *Oxytoma* sp. ex gr. *kirinae* Velikzch., *Dacryomya jacutica* (Petr.), *Malletia* aff. *amygdaloides* (Sow.) (Sample TF-15/1, level 2.0 m from the base). The top of the bed contains *Phylloceras* sp. ind. (coll. by A.N. Aleynikov, 2014). Bivalves: *Mytiloceramus (Pseudomytiloides) marchaensis* (Petr.) (Sample TF-15/2, interval 2.0–2.8 m from the base).

Foraminifers: *Saccammina inanis* Gerke et Sossip., *Astacolus praefoliaceus* (Gerke), *Bulbobaculites strigosus* (Gerke et Sossip.), *Evolutinella barrovensis* (Tappan), *Lenticulina praemulta* Sapjan.

Beds 17a, 17b and 18 belong to Member 15 (Outcrop 5, Member 15, Beds 1–4 according to Levchuk, 1985).

A scheme of stratigraphy and correlation of Toarcian-Aalenian deposits based on bivalves in the Outcrop 4 section of the Cape Tsvetkov area is shown in Fig. 27.

The overlying strata was studied in outcrop no. 5 (Fig. 23).

Outcrop no. 5

The outcrop is located in the creek of an unnamed stream flowing into the Khatanga Bay. The mouth of the stream is located 5.4 km southwest of the head of Utinaya Bay. The place where the description of Bed 1 begins is located at a distance of about 150 m from the mouth. According to paleontological and taphonomic characteristics, outcrop no. 5, without a gap, builds on outcrop No. 4. Coordinates of the starting point of the description: 74°54.491′ N, 112°27.569′ E.

Korotkiy Formation. During field work in 1987 and 2014, the contact between the Korotkiy and Kiterbyut formations in Outcrop 5 was covered by a glacier. Silty clays of Bed 1 are exposed directly above the glacier (Fig. 28).

Bed 1, visible thickness 20.6 m. Clays silty, dark gray, finely fragmented. At the base of the bed and at levels 2.0; 6.0; 7.3; 9.2 m from the base—there are horizons of calcareous siltstone nodules, red-brown on the surface and gray in fresh fractures. Individual nodules were found at levels of 8.5 and 10 m (bed belongs to Member 16 according to Levchuk, 1985). A fragment of the ammonite *Phylloceras* sp. ind. was found in the concretions at the base of the bed.

Bivalves: *Mytiloceramus (Pseudomytiloides) marchaensis* (Petr.), *Oxytoma sp.* ex gr. *kirinae* Velikzch., *Dacryomya jacutica* (Petr.) in concretionary interbeds (Sample TF-16, interval from the base of the bed—2.0 m). *Dacryomya gigantea* Zakh. et Schur., *Liostrea taimyrensis* Zakh. et Schur. are scattered throughout the bed. (Sample TF-17).

The upper part of Bed 1 contains the bivalves *Pseudomytiloides marchaensis* (Petr.), "*Meleagrinella* ex gr. *sparsicosta* (Petr.)" (=*Arctotis (Praearctotis) marchaensis* (Petr.), *comm. by O.A. Lutikov*), "*Dacryomya inflata* (Ziet.)" (=*Dacryomya jacutica* (Petr.), *comm. by O.A. Lutikov*), *Camptonectes* s.str. (Shurygin and Levchuk, 1982).

Foraminifers: *Ammodiscus glumaceus* Gerke et Sossip., *Saccammina inanis* Gerke et Sossip., *Astacolus praefoliaceus* (Gerke), *Lenticulina praemulta* Sapjan, *L. dorbignyi* (Roemer), *L. toarcense* (Payard). At the level of the second concretion horizon (6.0 m from the base) Saccammina compacta Gerke and Trochammina taimyrensis Sapjan appear.

Bed 2, thickness 41.9 m. Silts clayey, dark gray, ferruginous in places, and finely fragmented. At the base there is a horizon of ellipsoidal (1.0 × 0.1 m) and bun-shaped calcareous siltstone nodules, consistent along the strike, containing bivalves. At levels 2.2, 4.3 m from the base there are horizons of nodules composed of calcareous siltstone, reddish-brown on the surface, gray in fresh fractures (the bed belongs to Unit 17 according to Levchuk, 1985).

Bivalves *Oxytoma* ex gr. *jacksoni* (Pomp.), complete shells in nodules (Sample TF-18, basal part of the bed). *Dacryomya gigantea* Schur. and *Liostrea taimyrensis* Zakh. et Schur. Are scattered throughout the bed (Sample TF-19; Sample 100f, 102f, 103f).

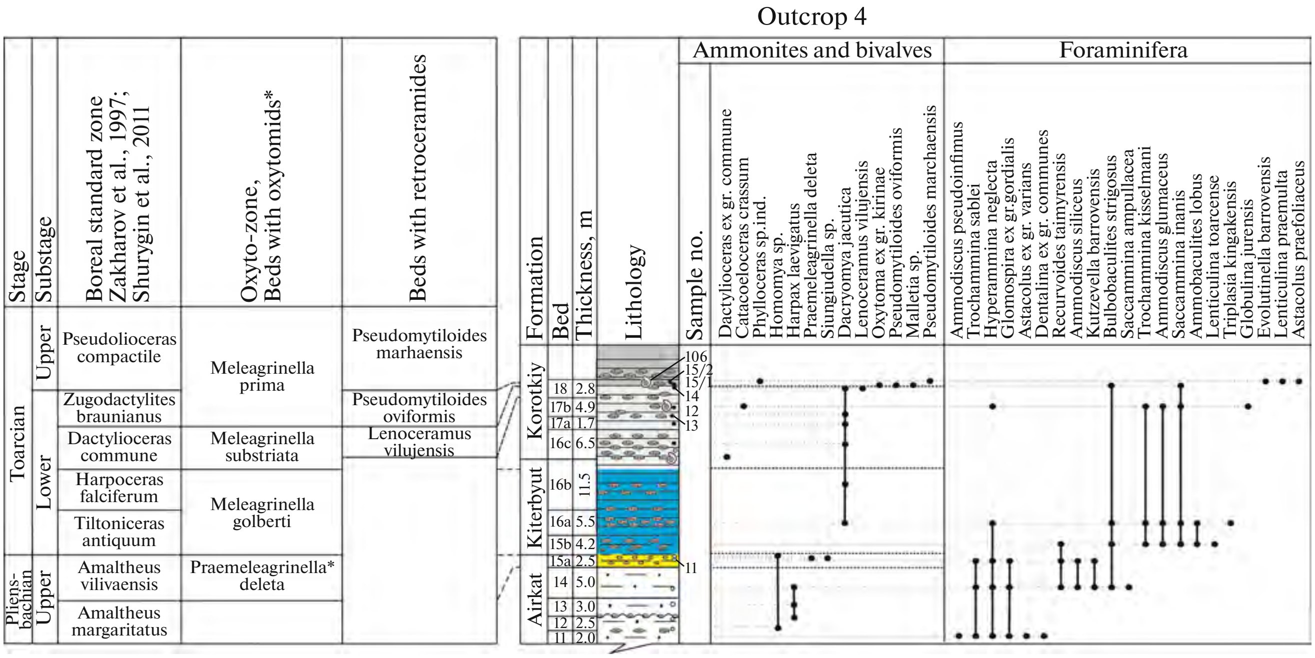

Fig. 27. Stratigraphy of Pliensbachian–Toarcian deposits in the Cape Tsvetkov area based on the distribution of zonal assemblages of the oxytomid scale. Legend see in Fig. 14.

The upper part of Unit 17 (12 m from the base) yielded *Arctotis* sp. ind. (Shurygin and Levchuk, 1982). These specimens were tentatively assigned to *Arctotis (Praearctotis) similis* Velikzh. (Lutikov et al., 2022).

Foraminifers: *Saccammina* ex gr. *inanis* Gerke et Sossip., *Ammodiscus glumaceus* Gerke et Sossip., *Astacolus praefoliaceus* (Gerke), and *Lenticulina praemulta* Sapjan.

Overlying sediments are exposed on the left and right sides of the creek at a distance of about 80–40 m from the shore of Khatanga Bay (Fig. 29).

Bed 3, thickness 9.6 m. Silts dark gray, fragmented. At the base there is a consistent horizon of calcareous siltstone nodules (0.1 × 0.4 m). At levels 7.6; 7.9; 8.3 and 9.0 m from the base—horizons of ellipsoidal nodules of calcareous siltstone. At the level 9.35 m—spherical nodules (0.15 m in diameter) of calcareous siltstone (Fig. 29).

Bivalves *Arctotis (Praearctotis) similis* Velikzh., forming aggregated accumulations of individual well-preserved valves (near the top); *Liostrea taimyrensis* Zakh. et Schur. are scattered throughout the bed (Sample TF-19, Sample 107f), Dacryomya gigantea Schur. (Sample 108f).

The upper part of the bed yielded *Dacryomya gigantea* Zakh. et Schur., *Nuculana (Jupiteria)* ex gr. *acuminata* (Goldf.) (Sample 110f); *Dacryomya gigantea* Zakh. et Schur., *Luciniola* sp., *Pleuromya* sp. (Sample 111f) (coll. by A.N. Aleynikov).

Foraminifers: *Saccammina compacta* Gerke, *Ammodiscus glumaceus* Gerke et Sossip., *Astacolus praefoliaceus* (Gerke).

Bed 4, thickness 9.5 m. Silts clayey, dark gray, finely fragmented. At the base consistent marking horizon (0.4 m) of calcareous siltstone, gray in fresh fractures, reddish-yellow from the surface, highly fractured. At 0.2 m above there is a consistent horizon of bun-shaped calcareous nodules. At levels 4.0; 7.0 m from the base—horizons of calcareous siltstone nodules (Fig. 30).

The bivalves *Dacryomya gigantea* Zakh. et Schur. are found in the lower part of the bed.

Foraminifers: *Ammodiscus glumaceus* Gerke et Sossip., *Verneuilinoides syndascoensis* (Scharovskaja), *Saccammina compacta* Gerke, *Trochammina taimyrensis* Sapjan., *Lenticulina praemulta* Sapjan.

Bed 5, thickness 6.0 m. Silts clayey, dark gray, finely fragmented. At the base consistent nodule horizon (2.0 × 0.4 m) calcareous siltstone, gray in fresh fractures, reddish on the surface. At the level 3.7 m from the base—a horizon of ellipsoidal nodules (0.3 × 0.15 m) of calcareous siltstone, bluish on the surface, gray in fresh fractures, containing bivalves. From a level of 4.0 m, the bed can be traced from the mouth of the creek along the shore of the bay.

An ammonite was discovered in a concretion at the level 3.7 m from the base of the bed in 1987, which was identified as *Pseudolioceras* cf. *falcodiscus* (Quenst.) (Sample TF-20-A; Knyazev et al., 1991) (Fig. 31).

Fig. 28. Cape Tsvetkov area. Exposure of Bed 1 in Outcrop 5.

Fig. 29. Cape Tsvetkov area. Exposure of Beds 2–3 on the left side of Outcrop 5.

Fig. 30. Cape Tsvetkov area. Exposure of Bed 4 on the right side of Outcrop 5.

Bivalves *Malletia* ex gr. *amygdaloides* (Sow.) (Sample TF-21, basal part); *Propeamussium olenekense* Bodyl., *Maclearnia kelimyarensis* (Zakh. et Schur.) (very frequent), gastropods (Sample TF-20, 3.7 m above the base); *Arctotis (Praearctotis) similis* Velikzh., forming aggregated accumulations of isolated valves of poor preservation in calcareous nodules (Sample TF-22, 4.0 m from the base). At the level 5.0 m *Arctotis (Praearctotis) similis* Velikzh., *Propeamussium olenekense* Bodyl. (Sample 113f) were found.

Foraminifers: *Ammodiscus glumaceus* Gerke et Sossip., *Saccammina compacta* Gerke, *Trochammina taimyrensis* Sapjan., *Verneuilinoides syndascoensis* (Scharovskaja).

The overlying Beds 6–9 were traced in the coastal cliff (about 15 m high) of outcrop 5 on the western shore of Khatanga Bay (Fig. 32). The beginning of the description of Bed 6 is located at a distance of about 20 m from the mouth of the creek in the direction to the southwest. The mouth of the creek is located at a distance of 5.4 km from the head of Utinaya Bay. The coordinates of the mouth of the creek are 74°54.417′ N, 112°27.561′ E.

The assemblage of foraminifers in Beds 1–5, represented by *Ammodiscus glumaceus*, *Saccammina compacta*, *Trochammina taimyrensis*, *Verneuilinoides syndascoensis*, *Lenticulina praemulta*, *Lenticulina multa* Schleifer., *Astacolus praefoliaceus*, *Saccammina inanis* Gerke et Sossip., *L. dorbignyi*, *L. toarcense*, characterizes the Trochammina taimyrensis F-Zone, which in Northern Siberia corresponds to the Upper Toarcian–Lower Aalenian (Sapjanik, 1991a, 1991b).

Aprelevskuy Formation (Beds 6–8). The Aprelevskiy Formation and its contacts with the Korotkiy Formation below and with the Arangastakh Formation above were studied in an extended coastal cliff about 15 m high, located on the western coast of the Khatanga Bay (Figs. 32, 33).

Bed 6, thickness 9.0 m. Silts are dark gray, finely fissile, ferruginous in places. At the base consistent double horizon (up to 1.0 m) of calcareous siltstone, with pebbles and boulders (up to 0.15 m), wood fragments. At the level 1.5 m from the base of the bed there is a horizon of calcareous siltstone nodules. At the top of the bed, the rock contains an admixture of sandy material.

Bivalves: at the base of the bed were found *Arctotis (Arctotis)* ex gr. *tabagensis* (Petr.), *Propeamussium olenekense* Bodyl., *Malletia ex gr. amygdaloides* (Sow.), *Nuculoma* sp. (Sample TF-23). *Oxytoma* ex gr. *jacksoni* (Pomp.), *Arctica humiliculminata* Schur., *Astarte meeki* Stant., and *Musculus* sp. have been listed from this bed (Shurygin and Levchuk, 1982). In the valley of an unnamed creek (Outcrop no. 7/1) at a distance of 311 m from the mouth, a similar assemblage of bivalves was found, including *Propeamussium olenekense* Bodyl., *Oxytoma* ex gr. *jacksoni* (Pomp.) (Sample 81f; collected by A.N. Aleynikov).

Foraminifers: rocks at the base of the bed contain *Ammodiscus glumaceus* Gerke et Sossip., *Saccammina*

Fig. 31. Exposure of Beds 5–7 in the right side of Outcrop 5 and in the coastal cliff of the western coast of Khatanga Bay. The discovery point of the ammonite *Pseudolioceras* cf. *falcodiscus* (Quenst.) is indicated by an arrow.

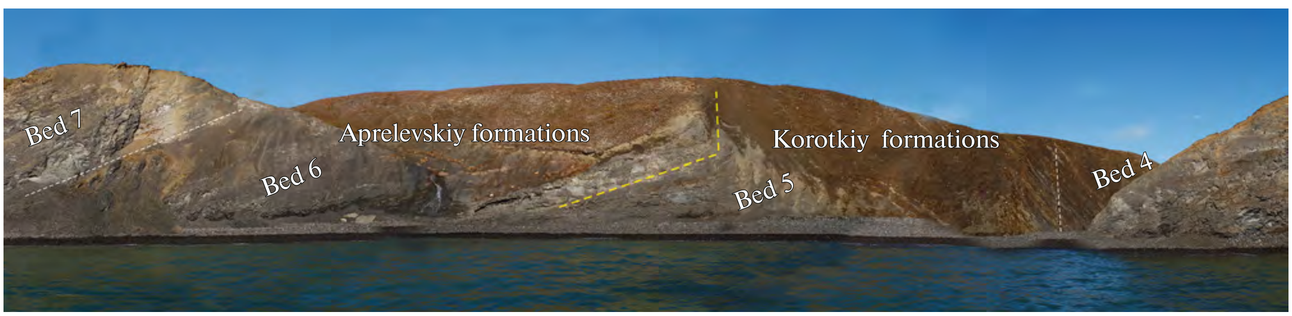

Fig. 32. Outcrop 5. Contact of the Korotkiy and Aprelevskiy formations. The yellow dotted line is the boundary of formations, the white dotted line is the boundary of formations.

compacta Gerke, *Trochammina taimyrensis* Sapjan., *Verneuilinoides syndascoensis* (Scharovskaja), *Lenticulina praemulta* Sapjan., while *Lenticulina multa* Schleifer appear beginning from the level of 2.5 m.

Bed 7, thickness 15.0 m. Silts are sandy, finely fissile, dark gray, with multiple pancake-shaped and globular pyrite nodules. At the base there is a thin interbed (0.1 m) of calcareous siltstone.

Bivalves *Luciniola* sp., *Malletia* ex gr. *amygdaloides* (Sow.) (Sample TF-24). According to B.N. Shurygin and A.S. Alifirov, the bed contains frequent *Arctica humiliculminata* Schur., *Arctotis (Arctotis) tabagensis* (Petr.) (Fig. 34).

Foraminifers: *Astacolus praefoliaceus* (Gerke), *Saccammina* sp., *Globulina* sp., *Marginulina* sp. (collected by A.N. Aleynikov).

Bed 8, thickness 34.0 m. Siltstones sandy, dark gray, massive. At the base there is a thick horizon of nodules (0.6 × 2.0 m) of calcareous siltstone, gray in fresh fractures, reddish from the surface.

Bivalves: *Malletia amygdaloides* (Sow.), *Pleuromya* sp. (Sample TF-25); accumulations of shells of *Arctotis (Arctotis) tabagensis* (Petr.) (Sample TF-26, lower part). According to B.N. Shurygina, the bed contains *Retroceramus* sp. ind., *Tancredia* sp. ind.

Arctotis (Arctotis) tabagensis (Petr.) were found in the valley of an unnamed creek (outcrop no. 7/1) at a distance of 200 m from the mouth (Sample 82f; collected by A.N. Aleynikov).

The accompanying assemblage of foraminifers in Beds 6–8, represented by *Ammodiscus glumaceus*, *Saccammina compacta*, *Trochammina taimyrensis*, *Verneuilinoides syndascoensis*, *Lenticulina praemulta*,

Fig. 33. Outcrop 5. Contact of the Korotkiy and Arangastakh formations. The yellow dotted line is the boundary of formations.

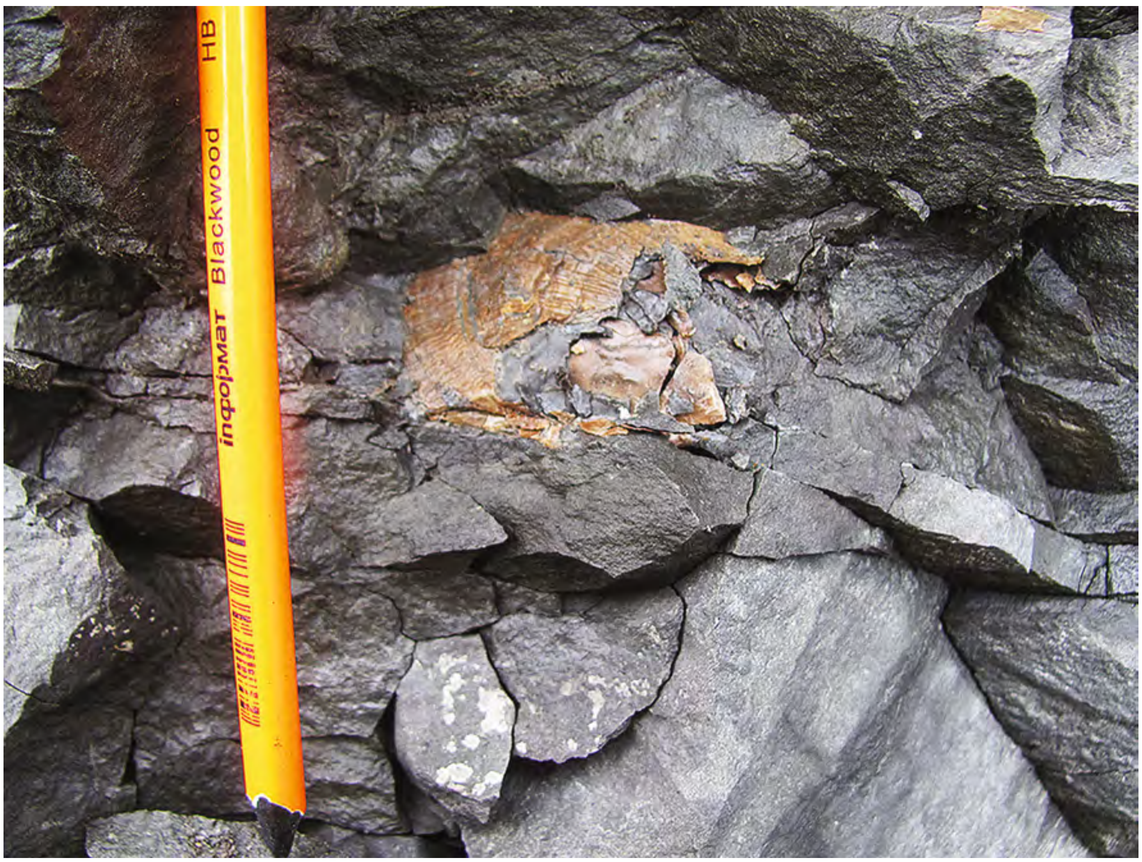

Fig. 34. Aggregation of *Arctotis (Arctotis) tabagensis* (Petr.) shells in Bed 7 of Outcrop 5 of the section in the Cape Tsvetkov area. Pencil height 15 cm.

Lenticulina multa Schleifer, and *Astacolus praefoliaceus*, suggests the Trochammina taimyrensis F-Zone, which in northern Siberia corresponds to the Upper Toarcian–Lower Aalenian (Sapjanik, 1991b). Thus, the upper boundary of the Aprelevskiy Formation does not extend beyond the Lower Aalenian.

Arangastakh Formation. The contact between Arangastakh and Apelevskiy formations is located at a distance of 5590 m from the head of Utinaya Bay (Fig. 22).

Bed 9, thickness 7.5 m. The siltstones are sandy, dark gray, greenish on the surface, with rare spots of jarosite. At the base interbed of greenish-gray sandstone with pebbles, boulders, pieces of wood and bivalves, about 0.2–0.3 m thick. At 0.5 m from the base there is a concretionary interbed (0.5 m) of calcareous siltstone. At 1 m from the base there is a horizon of concretions (0.5 × 1.5 m) of calcareous siltstone, gray in fresh chips, reddish-yellow on the surface. At 1.8 m from the base there are spherical nodules 0.5–0.7 m in diameter. In the upper part there are siltstones with pyrite nodules and fragments of wood. The bivalves *Retroceramus elegans* (Kosch.) (Sample TF-27, basal part), *Retroceramus menneri* (Kosch.), Maclearnia ex gr. kelimyarensis Zakh. et Schur. (Sample TF-27A), *Arctotis (Arctotis) tabagensis*

(Petr.), *Arctica humiliculminata* Schur., *Nuculana (Jupiteria)* cf. *acuminata* (Goldf.). were found in the scree of the upper part of the bed.

Foraminifers: at the top of the bed—*Trochammina taimyrensis* Sapjan. The higher horizons of the Arangastakh Formation contain the foraminifers *Trochammina praesquamata* Mjatliuk, *Lenticulina nordvikensis* (Mjatliuk), *Ammodiscus arangastachiensis* Nikitenko (collected by A.N. Aleynikov).

The stratigraphy and correlation scheme of Toarcian-Aalenian deposits based on bivalves in the Outcrop 5 section of the Cape Tsvetkov region is presented in Fig. 35.

Stratigraphy of Pliensbachian-Aalenian Deposits in the Cape Tsvetkov Area

The lithostratigraphic division of the reference section of the East Taimyr structural-facies zone is based on the studies of M.E. Kaplan, M.A. Levchuk, V.P. Devyatova and B.N. Shurygin (Kaplan et al., 1974; Levchuk, 1985; Shurygin et al., 2000).

As a result of studying the section by the author in 1976 and colleagues from SNIIGGiMS and INGG SB RAS in 2014, new data were obtained that made it possible to clarify the lithostratigraphic division, detail the biostratigraphic division of the section, and clarify the age of the formations (Lutikov et al., 2022).

Airkat Formation. In the section of the Cape Tsvetkov region, the formation was previously considered in the stratigraphic range of the Upper Pliensbachian and contained the Velata viligaensis and Anradulonectites incertus b-zones (Shurygin et al., 2000). The upper part of the formation and the contact with the overlying Korotkiy Formation were studied in Outcrop 4 (Fig. 22). In the terminal part of the formation, the Beds with Praemeleagrinella deleta were identified in the stratigraphic range of the Amaltheus viligaensis ammonite Zone (Lutikov et al., 2022).

Kiterbyut Formation. In the section of the Cape Tsvetkov region, the formation was previously considered in the stratigraphic range of the Lower Toarcian without the lower ammonite zone (Shurygin et al., 2000). The paleontological characteristics of this part of the section (Beds 15b, 16a, 16b—lower part) were studied in Outcrop 4 (Fig. 27). The sequence is characterized by an abundant *Dacryomya jacutica* and an accompanying foraminiferal assemblage with *Triplasia kingakensis, Trochammina kisselmani, Ammobaculites lobus*. No index species of oxyto-zones were found in it. Based on similar lithological and faunal characteristics, the sequence is correlated with sediments belonging to the Kiterbyut Formation in the section of Anabar Bay. The stratigraphic range of the sequence corresponds to the Tiltoniceras antiquum, Harpoceras falciferum zones and the lower part of the Dactylioceras commune Zone of the Boreal standard (Lutikov et al., 2022).

Korotkiy Formation. In the Cape Tsvetkov area, the formation was previously considered in the stratigraphic volume of the Lower Toarcian—Lower Aalenian (Shurygin et al., 2000). The ammonites *Dactylioceras commune* (Kaplan et al., 1974), *Catacoeloceras crassum* (Knyazev et al., 1993), and *Pseudolioceras (Pseudolioceras) falcodiscus* (Knyazev, 1991) were recorded from it. The stratigraphic range of the formation is assumed to be the range of the Dactylioceras commune (upper part), Zugodactilites braunianus, Pseudolioceras compactile, Pseudolioceras wuerttenbergeri and Pseudolioceras falcodiscus zones of the Boreal standard (Lutikov et al., 2022).

Aprelevskiy Formation. In the section of the Cape Tsvetkov region, the formation was previously considered in the stratigraphic range of the Lower—Upper Aalenian (Shurygin et al., 2000; Meledina and Shurygin, 2000). The stratigraphic volume of the formation is assumed to be in the Lower Aalenian range (Lutikov et al., 2022).

Arangastakh Formation. In the section of the Cape Tsvetkov region, the formation was previously considered in the stratigraphic range of the Upper Aalenian—Lower Bajocian (Shurygin et al., 2000; Meledina and Shurygin, 2000). The stratigraphic range of the formation is assumed to be in the Lower Aalenian—Lower Bajocian (Lutikov et al., 2022).

In the Pliensbachian-Lower Toarcian part of the section, the complete sequence of index species of the zonal scale for oxytomids has not been established. Based on the distribution of other bivalves, this part of the Cape Tsvetkov section is divided into the Beds with oxytomids and Beds with retroceramids (Lutikov et al., 2022).

Beds with Praemeleagrinella deleta were recognized at the top of the Airkat Formation in Outcrop 4 in the Cape Tsvetkov section (Fig. 27) (Lutikov et al., 2022). The Beds with Praemeleagrinella deleta as a special stratigraphic unit (*Stratigraficheskii*..., 2019) correspond to the Amaltheus viligaensis Zone.

The overlying series with *Dacryomya jacutica* and the accompanying foraminiferal assemblage with *Triplasia kingakensis, Trochammina kisselmani* and *Ammobaculites lobus* in Outcrop 4 of the Cape Tsvetkov section (Fig. 27), based on correlation with the sequence with similar faunal characteristics in Anabar Bay section, corresponds to the two lower zones of the Toarcian of the Boreal standard (Lutikov et al., 2022).

Beds with Lenoceramus vilujensis were recognized at the base of the Korotkiy Formation in Outcrop 4 of the section of the Cape Tsvetkov (Fig. 27) (Lutikov et al., 2022). The Beds with Lenoceramus vilujensis as a special stratigraphic unit (*Stratigraficheskii*..., 2019) correspond to the Dactylioceras commune zone of the Boreal standard.

Beds with Pseudomytiloides oviformis were recognized in the lower part of the Korotkiy Formation in Outcrop 4 Cape Tsvetkov (Fig. 27) (Lutikov et al.,

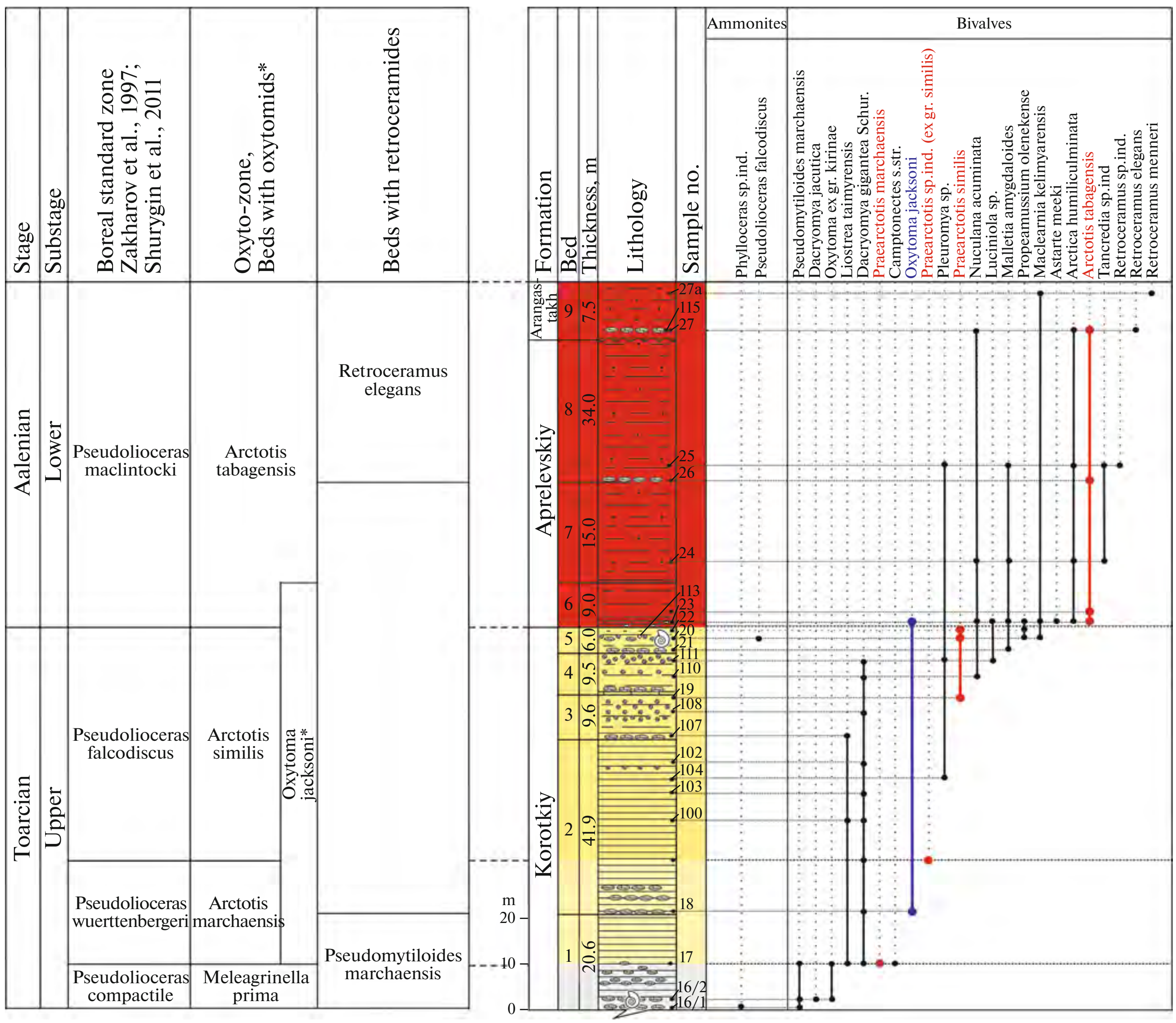

Fig. 35. Stratigraphy of Toarcian-Aalenian deposits in the Cape Tsvetkov area based on the distribution of index species and zonal assemblages of the oxytomid scale. Legend see in Fig. 14.

2022). The Beds with Pseudomytiloides oviformis as a special stratigraphic unit (*Stratigraficheskii*..., 2019) correspond to the Zugodactilites braunianus Zone of the Boreal standard.

Beds with Pseudomytiloides marchaensis were recognized in the middle part of the Korotkiy Formation in Outcrop 4 (Fig. 27) and in Outcrop 5 (Fig. 35) in the Cape Tsvetkov section (Lutikov et al., 2022). The Beds with Pseudomytiloides marchaensis as a special stratigraphic unit (*Stratigraficheskii*..., 2019) correspond to the Pseudolioceras compactile and Pseudolioceras wuerttenbergeri zones of the Boreal standard.

Meleagrinella prima Oxyto-zone. The sequence, including the Beds with Pseudomytiloides oviformis and the lower (non-*Arctotis*) part of the Beds with Pseudomytiloides marchaensis, corresponds to the Meleagrinella prima Oxyto-zone.

Based on the distribution of index species and zonal assemblages of bivalves of the oxytomid zonal scale, the Late Toarcian-Aalenian part of the section of the Cape Tsvetkov region in Outcrop 5 is subdivided into three oxyto-zones and one parallel Beds with oxytomids (Fig. 35).

Arctotis marchaensis Oxyto-zone. In Outcrop 5, the upper part of Bed 1 (10.6 m) and the lower part of Bed 2 (12 m) of the Korotkiy Formation are assigned to this oxyto-zone. The oxyto-zone is distinguished by the findings of the index species *Arctotis (Praearctotis) marchaensis* and the zonal assemblage with *Oxytoma jacksoni* (Pomp.), *Dacryomya gigantea* Zakh. et Schur. The thickness of the oxyto-zone 22.6 m.

Arctotis similis Oxyto-zone. In Outcrop 5, the oxyto-zone includes the upper Bed 2 and Beds 3–5 of the Korotkiy Formation. The oxyto-zone is distinguished by the index species *Arctotis (Praearctotis) similis* and the zonal assemblage of bivalves with *Propeamussium olenekense, Maclearnia kelimyarensis, Malletia amygdaloides, Nuculana acuminata*. The thickness of the oxyto-zone is 55.0 m (Fig. 35).

Arctotis tabagensis Oxyto-zone. In outcrop no. 5, the oxyto-zone is represented by a succession that includes Beds 6–9 of the Aprelevskiy Formation and lower Bed 9 of the Arangastakh Formation. The oxyto-zone is recognized by the index species *Arctotis (Arctotis) tabagensis* and the zonal assemblage of bivalves with *Retroceramus elegans, Retroceramus menneri, Arctica humiliculminata*. The thickness of the oxyto-zone is 65.5 m (Fig. 35). Data on foraminifera do not contradict this conclusion. The accompanying assemblage of foraminifers in Bed 9, represented by *Trochammina taimyrensis* Sapjan., characterizes the Trochammina taimyrensis F-zone, which in the north of Siberia corresponds to the Upper Toarcian–Lower Aalenian (Sapjanik, 1991b).

Beds with *Oxytoma jacksoni*. In Outcrop 5, this biostraton includes the upper part of Bed 1 and Beds 2–5 of the Korotkiy Formation, and Bed 6 of the Aprelevskiy Formation (Fig. 35). The Beds are identified by the index species *Oxytoma jacksoni*.

Kelimyar River Section

Based on the composition and type of sediments, thickness and completeness of sections, the Lower and Middle Jurassic strata in the Kelimyar River basin belong to the Leno-Anabar structural-facies zone (*Resheniya*..., 1981). Currently, the Kyrin (Hettangian–Late Pliensbachian), Kelimyar (Toarcian–Lower Bathonian), and Chekurov (Lower–Upper Bathonian) formations are recognized here (Shurygin et al., 2000). The Kelimyar Formation is divided into two parts, the lower part is assigned to the Kurung Subformation, the overlying part is assigned to the Kulumas Subformation (Nikitenko et al., 2011). An alternative formation subdivision was presented by a VNIGRI team, who identified 12 new formations in the Lower and Middle Jurassic instead of the three previously known (Galabala et al., 1990), which became the subject of discussion (Shurygin et al., 2000).

In 1980 and 1983 by the author together with V.P. Devyatov (lithology), V.G. Knyazev (ammonites), and V.V. Sapjanik (foraminifers) studied the most representative Pliensbachian-Aalenian sections of the Lena-Anabar structural-facies zone in the coastal cliffs of the Kelimyar River (Olenek River basin) (Fig. 36).

This work uses the formation scheme adopted by specialists from SNIIGGiMS and INGG (Shurygin et al., 2000; Nikitenko et al., 2011). The description of the section begins from the upper part of the Kyrin Formation (fourth member according to Knyazev et al., 1991). Lists of foraminifera in outcrops 5, 14 and 16 are given according to B.L. Nikitenko (Devyatov et al., 2010). Most photographs courtesy of B.L. Nikitenko.

Outcrop 5

The outcrop is located on the right bank of the Kelimyar River, 2.6 km in a straight line to the northeast from the mouth of the Urukite River (Fig. 36). It is a steep rock outcrop 200 m long and about 15 m high (Fig. 37). The section was described by V.P. Devyatov in 1980, supplemented by the author in 1983 and by Devyatov et al. (2010).

Kyrin Formation. *Fourth Member.* (Beds 1–2). Visible thickness 3.25 m. The section was opened on the right side of the outcrop. The following beds are exposed above the water line:

Bed 1, thickness 2.5 m (visible). Clays silty, dark gray, with spots of jarosite in organic matter, with rare pebbles and small boulders. At the level of 2.0 m the clays become dark greenish.

Bivalves: *Harpax laevigatus (Orb.)* (very frequent), brachiopods (0.5 m); *Harpax laevigatus* (Orb.) (very frequent), *Modiolus scalprum* (Sow.) (Sample 1011, 1.3 m); *Ochotochlamys grandis Polub*. (rare) (Sample 130, 2.0 m); *Anradulonectites anabarensis* Schur. et Lut. (rare), *Ochotochlamys grandis* Polub. (Sample 130a, 2.3 m)—buried parallel to the bedding, both on convex left and flat right valves, sometimes with *Harpax* shells attached to them.

Foraminifers: *Ammodiscus siliceus*, *Trochammina lapidosa*, *Hyperammina odiosa*, *Ammobaculites alaskaensis*, *Ichthyolaria terquemi*, *Anmarginulina arctica*, *Conorboides buliminoides*.

Bed 2, thickness 0.85 m. The clays are yellowish-brown, viscous, with frequent pebbles and shell lenses with bivalves and brachiopods.

Bivalves *Harpax laevigatus* (Orb.) (very frequent) (Sample 131, 0.2 m); *Anradulonectites anabarensis* Schur. et Lut. (frequent), *Ochotochlamys grandis* Polub. (frequent), *Homomya* sp. (rare), *Meleagrinella (Praemeleagrinella) deleta* (Dum.) (frequent), *Kolymonectes* aff. *terekhovi* (frequent), *Pseudolimea philatovi* (Polub.) (rare), brachiopods (Sample 132, 0.65 m; Sample 1012, from the bed).

Foraminifers: *Hyperammina odiosa*, *Trochammina lapidosa*, *Ammodiscus siliceus*, *Glomospira* ex gr. *gordialis*, *Recurvoides taimyrensis*.

Kelimyar Formation. *Kurung Subformation.* The subformation is traced in a series of outcrops (nos. 5, 14, 16) (Fig. 36). The lower boundary of the Kelimyar Formation is very distinct and even (Fig. 38).

Bed 3a, thickness 3.7 m. At the base, there is an interbed (20–30 cm) of black sapropelic clays with the smell of bitumen. The clays are finely elutriated, bitu-

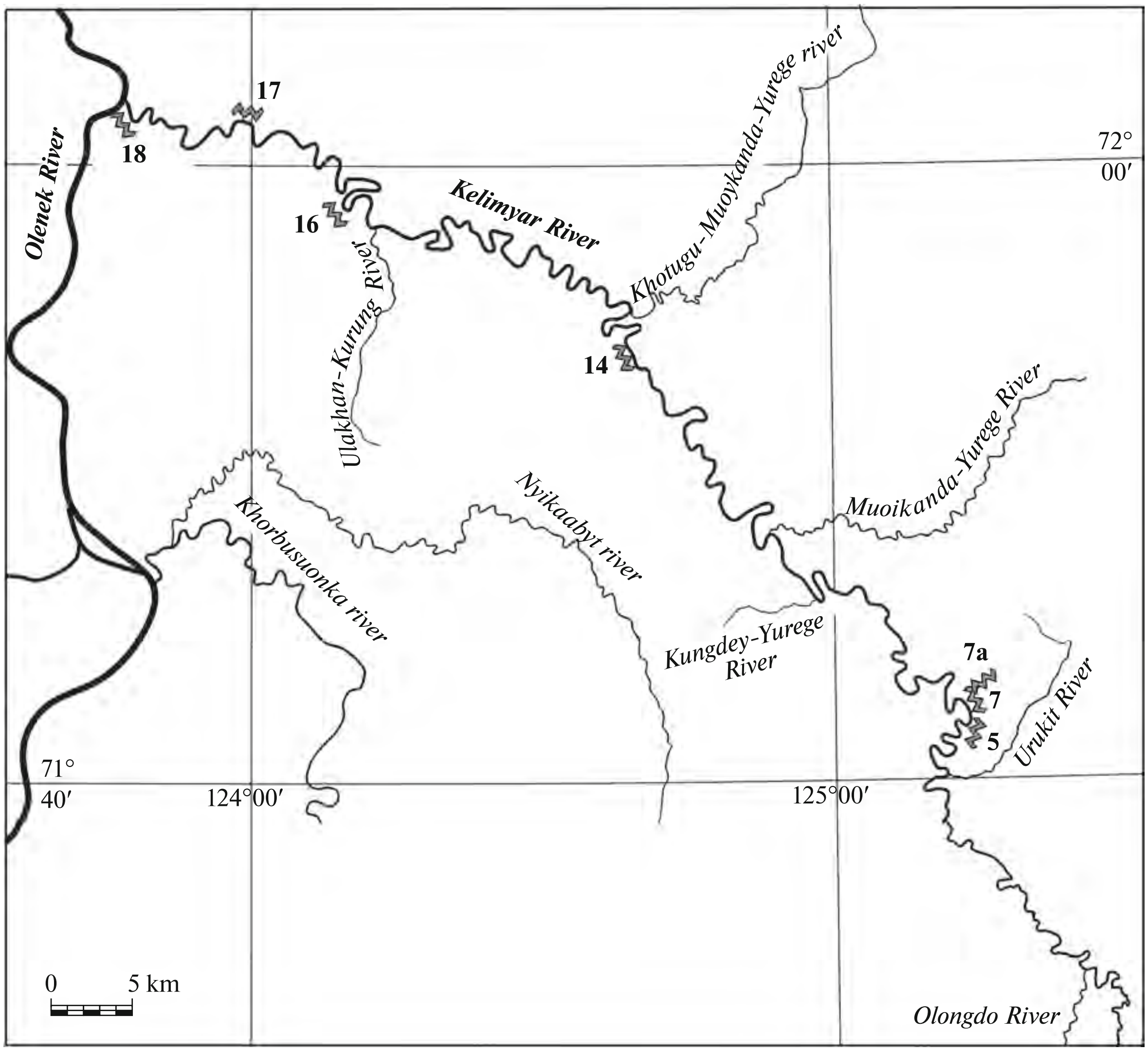

Fig. 36. Studied outcrops on the Kelimyar River.

minous, dark greenish-gray, almost black, with many large gypsumed rostra of belemnites. These are overlain by carbonate brown nodules at the base with a "cone-in-cone" texture. Above, the clays are dark greenish-gray, yellowish-gray and brownish-gray to black, with phosphate concretions. A number of loaf-shaped concretions are observed in the clays. The long axis of the nodules is slightly inclined towards the base of the bed. The rocks of the bed are intensely jarositized.

Bivalves *Meleagrinella (Praemeleagrinella?) golberti* Lutikov et Arp (Sample 1013, basal part; Sample 133, 1–3 m); *Liostrea (Deltostrea)* ex gr. *taimyrensis* Zakh. et Schur.

Foraminifers: *Trochammina kisselmani*, *Lenticulina* sp., *Recurvoides* sp. (ex gr. *taimyrensis*), *Cornuspira* sp., *Verneuilinoides* sp., *Saccammina inanis*, *Bulbobaculites strigosus*, *Evolutinella taimyrensis*.

Kulumas Subformation. *Bed 3b, thickness 3.8 m*. In the lower part of the bed there are lenses of yellowish-gray viscous clays. The clays are dark gray, sometimes with a yellowish tint, wavy and lenticular-bedded. At different levels there are phosphate concretions, less often pyrite. Rare sapropelite interbeds and lenses are found.

Foraminifers: *Trochammina kisselmani*, *Bulbobaculites strigosus*. In the upper part of the bed—*Saccammina inanis*, *S. ampullacea*, *Glomospira* ex gr. *gordialis*, *Evolutinella zwetkovi*.

Bed 4, thickness 2.8 m. Clays dark gray, with a greenish tint, platy, with phosphate nodules. At the level is a 1.5 m horizon of ellipsoidal carbonate nodules (thickness up to 0.3 m) with a cone-in-cone structure.

Ammonite: *Pseudolioceras compactile* (Simps.) (0.7 above the base) (Knyazev et al., 1984). Bivalves: *Dacryomya jacutica* (Petr.) (rare), *Oxytoma* aff. *startense* Polub. (rare) (Sample 1015).

Foraminifers: *Trochammina taimyrensis*, *T. kisselmani*, *Saccammina inanis*, *S. ampullacea*, *Reophax*

Fig. 37. Kelimyar River, Outcrop 5. The beginning of the description is in the right valley.

metensis, *Evolutinella zwetkovi*, *Ammodiscus glumaceus*, *A. siliceus*, *Kutsevella barrowensis,* etc.

Bed 5, visible thickness 7.0 m. At the base of the bed, there is an interbed of coquina with abundant belemnites and bivalves. The clays are dark gray, silty, platy, fissile in fractures, with jarosite stains. At a height of 2.3; 2.7 and 5.2 m horizons of loaf-shaped and lens-shaped (0.15 × 1.0 m) siderite nodules with abundant belemnites and bivalves. At a height of about 6 m above the basal part, a steeply dipping transecting crack filled with calcite is observed, overlain by Middle Jurassic deposits. Bajocian-Bathonian bivalves were found on the towpath.

Fossils: *Oxytoma jacksoni* (Pomp.), *Liostrea taimyrensis* Zakh. et Schur. (Sample 1019, from the bed), *Pseudomytiloides* sp. (Sample 134.0.7 m; Sample 135, 1.3 m).

Foraminifers: *Trochammina taimyrensis*, *Verneuilinoides syndascoensis*, *Evolutinella zwetkovi*, *Ammodiscus glumaceus*, *A. siliceus*, *Lenticulina multa*, *Nodosaria pulchra,* etc.

A stratigraphic scheme of the Pliensbachian-Toarcian deposits in Outcrop 5 (Kelimyar River) based on the distribution of index species and zonal assemblages of oxyto-zones is shown in Fig. 39.

Outcrop 7

Located on the right bank of the Kelimyar River, 3.6 km in a straight line from the Urukite River (Fig. 36). It is a coastal cliff about 20 m high (Fig. 40).

Kelimyar Formation. Kulumas Subformation

Bed 1, visible thickness 2.4 m. Silts dark gray, with a small admixture of fine-grained sand (up to 1.5%) and very rare inclusions of fine gravel, dark gray, massive, with spots of jarositization along organic remains. At a height of 1.3 m and at the top there are horizons of sideritized limestone nodules reddish-brown on the surface. At the top of the bed there are interbeds of variable thickness (1–3 cm), represented by very viscous dark greenish-gray clay.

Ammonites: *Grammoceras* sp. ind. (Devyatov et al., 2010). Bivalves: *Nuculana acuminata* (Goldf.), *Dacryomya* ex gr. *gigantea* Schur.

Foraminifers: *Lenticulina praemulta*, *Ammodiscus pseudoinfimus*.

Bed 2, thickness 4.7 m. Silts clayey, dark greenish-gray, very dense, with pillow-like jointing, and with small stains of jarositization. At a height of 0.5; 2.3 and 4.6 m horizons of small loaf-shaped calcareous nodules, red-brownish from the surface. At the top of the bed, lenses (up to 3.0 m) of silty-calcite material with a faintly visible "cone-in-cone" texture can be observed.

Bivalves level 1.5 m: *Nuculana acuminata* (Goldf.), *Maclearnia kelimyarensis* (Zakh. et Schur.), *Oxytoma jacksoni* (Pomp.), *Dacryomya* ex gr. *gigantea* Zakh. et Schur., *Thracia* sp., *Pleuromya* sp., *Homomya* sp., *Tancredia* sp. (Sample 140, 140a).

Foraminifers: *Riyadhella syndascoensis*, *Nodosaria metensis*, *Pseudonodosaria pygmea*, *Dentalina pseudocommunis*, *Astacolus dubius*, *Glomospira gordialis*, *Citharina proxima*, *Lenticulina adverse*, *Ammobaculites strigosus*, etc.

Bed 3, thickness 8.2 m. Silts clayey, dark gray, platy, with a constant admixture of fine-grained sand and very rare flat well-rounded large sandstone pebbles (found at a height of 1.2 m). At levels 1.3; 4.6; 5.7; 7.0 m concretionary horizons of brownish, yellowish-gray lens-shaped nodules of sideritized limestone. At the top of the bed there is an extended lens of light gray sandy siltstone (flagstone) with a greenish tint, on the lower surface with asymmetrical ripples, and on the upper surface with numerous trace fossils. The bed contains bivalves: *Oxytoma*—up to the level of 3.0 m, above—rare *Malernia*.

Ammonites: Late Toarcian ammonites were found at the bottom of the bed (0.5 m above the base)—*Pseudolioceras* sp. ind. (ex gr. *wuerttenbergeri*) (Devyatov et al., 2010).

Bivalves: at the level 2.0 m—*Oxytoma jacksoni* (Pomp.) (very frequent), *Propeamussium olenekense* Bodyl., *Maclearnia kelimyarensis* (Zakh. et Schur.), *Dacryomya gigantea* Zakh. et Schur., *Homomya* sp., *Nuculana acuminata* (Goldf.) (1.9 m—Sample 139; 4.2 m—Sample 138).

Foraminifers: *Kutzevella operta*, *Lenticulina multa,* etc.

Outcrop 7a

Located on the right bank of the Kelimyar River between peaks 335 m in the north and 368 m in the south in the creek valley of Outcrop 7. It is a cliff about 50 m high, on the right slope of an unnamed stream

Fig. 38. Contact of the Kyra and Kelimyar formations.

(Fig. 41). Since Bed 3 of Outcrop 7 is traced directly into the valley, the numbering of beds in Outcrop 7a is preserved.

Bed 4, thickness 17.5 m. At the base the same interbed of siltstone as at the top of the Bed 3 in Outcrop 7. Silts clayey, dark gray, with a greenish tint on the surface, platy, with stains of jarositization over fossils. At the base of the bed there is a horizon of rare large (0.3 × 1.0–3.0 m) lenticular-shaped calcareous-clay nodules. At a height of 1.7 m, extremely rare phos-

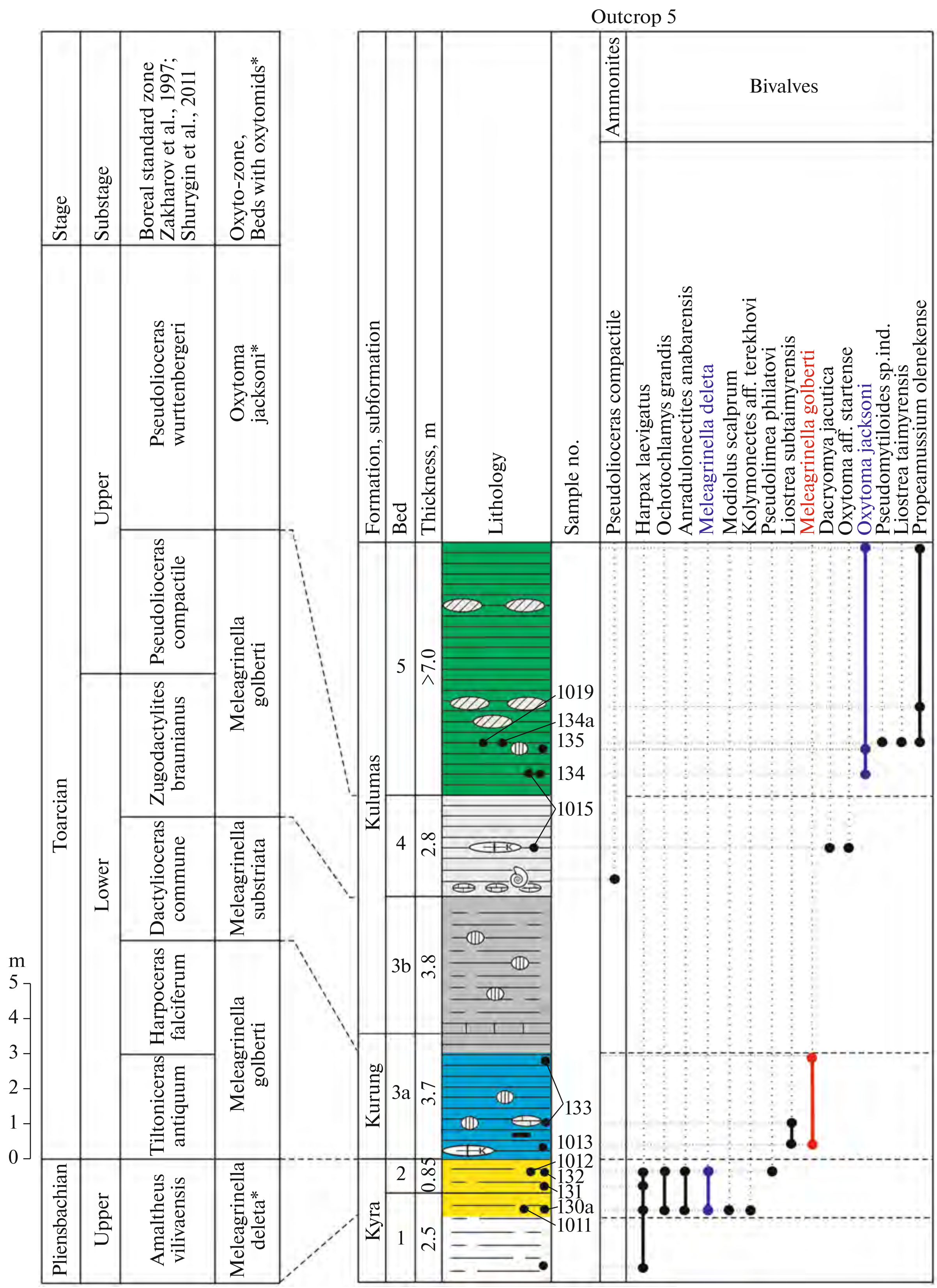

Fig. 39. Stratigraphy of Pliensbachian-Toarcian deposits in Outcrop 5 (Kelimyar River) based on the distribution of index species and zonal assemblages of the oxytomid scale. Legend see in Fig. 14.

Fig. 40. Kelimyar River. Outcrop 7.

phorite nodules were found. Concretionary horizons are recorded at levels 4.3; 9.1; 10.0; 10.5; 12.0; 13.0 m and are represented by small calcareous-clayey, dilapidated nodules with a bright red surface. At the top of the bed there is a double bedded horizon of phosphate-clayey sandy siltstone at the bottom and calcareous siltstone at the top.

Bivalves: *Propeamussium olenekense* Bodyl. (frequent), *Oxytoma jacksoni* (Pomp.), *Thracia* sp., *Maclearnia kelimyarensis* (Zakh. et Schur.), *Nuculana acuminata* (Goldf.). (Sample 142).

At the level 11.8 m a nodule contained *Pleuromya* sp., *Arctotis* sp. ind. (Sample 1032).

Foraminifers: *Kutzevella operta*, *Lenticulina toarsense*, *L. nordvikensis*, at the top of the bed—*Trochammina praesquamata,* etc.

Bed 5, thickness 3.6 m. Silts clayey, dark gray, platy, up to a height of 2.5 m, highly oxidized, brownish, with spots of jarositization. At the level 2.1 and 3.6 m horizons are yellow from the surface, light gray in fresh fractured calcareous-clayey nodules (0.5 × 0.25 m). At the top of the bed at the level of 3.35 m there are large boulders of sedimentary rocks.

Bivalves: *Propeamussium olenekense* Bodyl. (many), *Nuculana acuminata* (Goldf.) (Sample 145), *Arctotis (Arctotis) tabagensis* (Petr.) (very rare) (Sample 1032).

Bed 6, thickness 3.4 m. At the base—in places a double horizon of nodules. The horizon emphasizes the lenticular structure of the boundary beds, which apparently correspond to erosion. Silts are clayey, dark gray, unevenly platy. At a height of 2.0 and 2.9 m there are horizons of sideritized limestone, with first occurrences of *Retroceramus*.

Ammonites: *Phylloceras* sp.

Bivalves: *Retroceramus* sp. ex gr. *elegans* Kosch. (Sample 143).

A stratigraphic scheme of Pliensbachian-Toarcian deposits in Outcrops 7 and 7a on the Kelimyar River based on the distribution of index species and zonal assemblages of oxyto-zones is shown in Fig. 42.

A stratigraphic scheme of Pliensbachian-Toarcian deposits in Outcrops 7 and 7a on the Kelimyar River based on the distribution of index species and zonal assemblages of oxyto-zones is shown in Fig. 42.

Outcrop 14

Located on the left bank of the Kelimyar River, 3.5 km upstream the mouth of the Hotugu-Muy-okanda-Yurege River (Fig. 36). It is a steep cliff about 300 m long and 25–30 m high (Fig. 43).

Kyra Formation. ***Fourth Member.*** At 0.3 m from the waterline, a horizon of siderite limestone nodules

Fig. 41. Kelimyar River. Outcrop 7a.

emerges from under the towpath. The same horizon—at the level 0.6 m. Higher in the section:

Bed 1, thickness 2.7 m (visible). Silts dark greenish-gray, sandy, strong, unevenly platy, with small limestone pebbles, jarosite stains over fossils, and with siderite nodules.

Bivalves: *Harpax spinosus* (Sow.), *Siungiudella parvula* Lut. (Sample 1076, from the bed), brachiopods.

Foraminifers: *Ammodiscus siliceus*, *Trochammina lapidosa*, *Hyperammina odiosa*, *Glomospira* ex gr. *gordialis*.

Bed 2, thickness 7.6 m. Silts greenish-gray, sandy, unevenly plated, with small limestone pebbles, gravel, jarosite spots in organic matter, and fragments of carbonized wood. At the level 0.9–1.0 m rare siderite concretions. At the level 3.5 m horizon of nodules (up to 0.15 × 3.0 m) of sideritized limestone. At an level of 5.0; 7.0; 7.5 m there are lenticular siderite nodules.

Bivalves: *Harpax spinosus* (Sow.), *Anradulonectites anabarensis* Schur. et Lut. (rare), *Homomya* sp. (Sample 1077, from the bed), brachiopods.

Foraminifers: *Ammodiscus siliceus*, *Saccammina* sp., *Reophax* ex gr. *metensis*, *Trochammina lapidosa*, *Hyperammina odiosa*, *Glomospira* ex gr. *gordialis*.

Bed 3, thickness 1.3 m. All shades of yellow, bluish-gray when freshly fractured, very viscous and plastic.

Bivalves: *Anradulonectites anabarensis* Schur. et Lut. (rare), *Pseudolimea philatovi* (Polub.), *Siungiudella parvula* Lut., *Harpax laevigatus* (Orb.) (Sample 1078a, from the bed; Sample 164, level 0.3 m), brachiopods.

Foraminifers: *Ammodiscus siliceus*, *Jaculella jacutica*, *Reophax* ex gr. *metensis*, *Trochammina lapidosa*, *Hyperammina odiosa*, *Glomospira* ex gr. *gordialis*, *Recurvoides taimyrensis*, *Kutsevella barrowensis*.

Kelimyar Formation. Kurung Subformation

Bed 4, thickness 3.5 m. The lower boundary distinct, even. At the base there is an interbed of clays (up to 0.6 m) black, thin-sheet-wavy or earthy, with poorly preserved belemnites. At this level there is a horizon of calcareous ellipsoidal septarian nodules (thickness up to 0.2 m) with a cone-in-cone texture. In the interval 0.1–1.1 m, black bitumen shales with ellipsoidal nodules. Above (from 0.7 m), the clays are dark gray and yellow-gray, plastic. From 1.1 m, the clay is dark gray with a bluish tint, plastic. From 1.8 m, the clays are brown on the surface, dark gray in fresh fracture, from thin platy to foliated. From 3.2 m the clays are dark gray to black, thinly-platy.

Ammonites: *Harpoceras exaratum* (Y. et B.), *Harpoceras falciferum* (Sow.) (Knyazev et al., 2003).

Bivalves: *Kedonella mytileformis* Polub. (Sample 1081, basal part; Sample 162, 0.5–0.6 m); *Meleagrinella (Praemeleagrinella) golberti* Lutikov et Arp (Sample 163, 0.7–0.8 m; Sample 165, 1.0–1.1 m; Sample 1078, 1.3 m).

Foraminifers: at the base (0.6 m)—*Ammodiscus siliceus*, *Hyperammina odiosa*, *Recurvoides* ex gr. *taimyrensis*, *Trochammina lapidosa*, *Glomospira* ex gr. *gordialis*, *Reophax* ex gr. *metensis*, *Trochammina* ex gr. *kisselmani*, *Kutsevella barrowensis*. *Ammodiscus glumaceus*, *Trochammina kisselmani*, *Evolutinella taimyrensis*, *Hyperammina odiosa*, *Saccammina inanis*, *Ammoglobigerina canningensis*, *Bulbobaculites strigosus* appear higher up in the section.

Kelimyar Formation. Kulumas Subformation

Bed 5, thickness 4.2 m. Clays silty, dark gray, greenish, with stains of jarosite over fossils, and with phosphorite nodules. At the level 0.8 m, lens of yellow clays. At the level 2.9 there is an interbed of black clay.

Ammonites: *Phylloceras* sp. ind. (Sample 1082, from the bed; Sample 166, 0.6 m).

Bivalves: *Oxytoma* aff. *startense* Polub., *Propeamussium pumilum* (Lam.) (rare), *Lenoceramus* sp. ind. (ex gr. *vilujensis* Polub.) (level 2.7 m—Sample 167); *Astarte plana* Milova (Sample 1082, from the bed); *Dacryomya jacutica* (Petr.) (very frequent), *Liostrea (Deltostrea) taimyrensis* Zakh. et Schur. (abundant), *Homomya* sp. (interval 2.5–3.5 m, Sample 168).

Foraminifers: *Ammodiscus siliceus*, *A. glumaceus*, *Reophax* ex gr. *metensis*, *Bulbobaculites strigosus*, *Trochammina kisselmani*, *Evolutinella taimyrensis*, *Ammobaculites* ex gr. *lobus*.

Bed 6, thickness 2.0 m. At the base there is a small interbed of carbonaceous clay. Silts clayey, dark gray, brownish, unevenly platy, with pyrite nodules. At the level 1.3 m long nodules with belemnites and oysters.

Bivalves: *Pseudomytiloides marchaensis* (Petr.), *Pleuromya* sp., *Dacryomya jacutica* (Petr.), *Liostrea taimyrensis* Zakh. et Schur. (Sample 169a, 1.3 m).

Foraminifers: *Ammodiscus siliceus*, *A. glumaceus*, *Saccammina inanis*, *Trochammina* ex gr. *taimyrensis*, *Evolutinella zwetkovi*.

Bed 7, thickness 2.3 m. Silts clayey, dark gray, brownish on the surface, with jarosite stains, with phosphorite nodules at levels of 0.3 and 0.7 m. In the interval 0.9–1.0 m, siderite concretions are red-brownish on the surface, yellowish-gray in fresh fracture, along strike there are phosphorite nodules. In the interval 1.6–1.7 m there are phosphorite nodules, along the strike there are nodules (0.2 × 0.1 m) of siderite limestone, red-brown from the surface.

Bivalves: *Camptonectes* s. str., *Dacryomya jacutica* (Petr.) (very frequent), *Pseudomytiloides marchaensis* (Petr.), *Homomya* sp., *Astarte plana* Milova, *Pleuromya* sp. From the level 0.7–1.0 m, *Oxytoma jacksoni* (Pomp.) (abundant) (Sample 170; Sample 1083, from the bed) enter. At the level of 1.5 m *Propeamussium olenekense* Bodyl. (frequent) enter, along with *Oxytoma jacksoni* (Pomp.) (abundant), *Liostrea (Deltostrea) taimyrensis* Zakh. et Schur. (abundant), *Dacryomya jacutica* (Petr.) (very frequent), *Astarte plana* Milova (frequent) (Sample 171).

Foraminifers: *Ammodiscus glumaceus*, *Trochammina* ex gr. *taimyrensis*, *Evolutinella zwetkovi*, *Saccammina inanis*, *Glomospirella* sp., *Verneuilinoides* ex gr. *syndascoensis*.

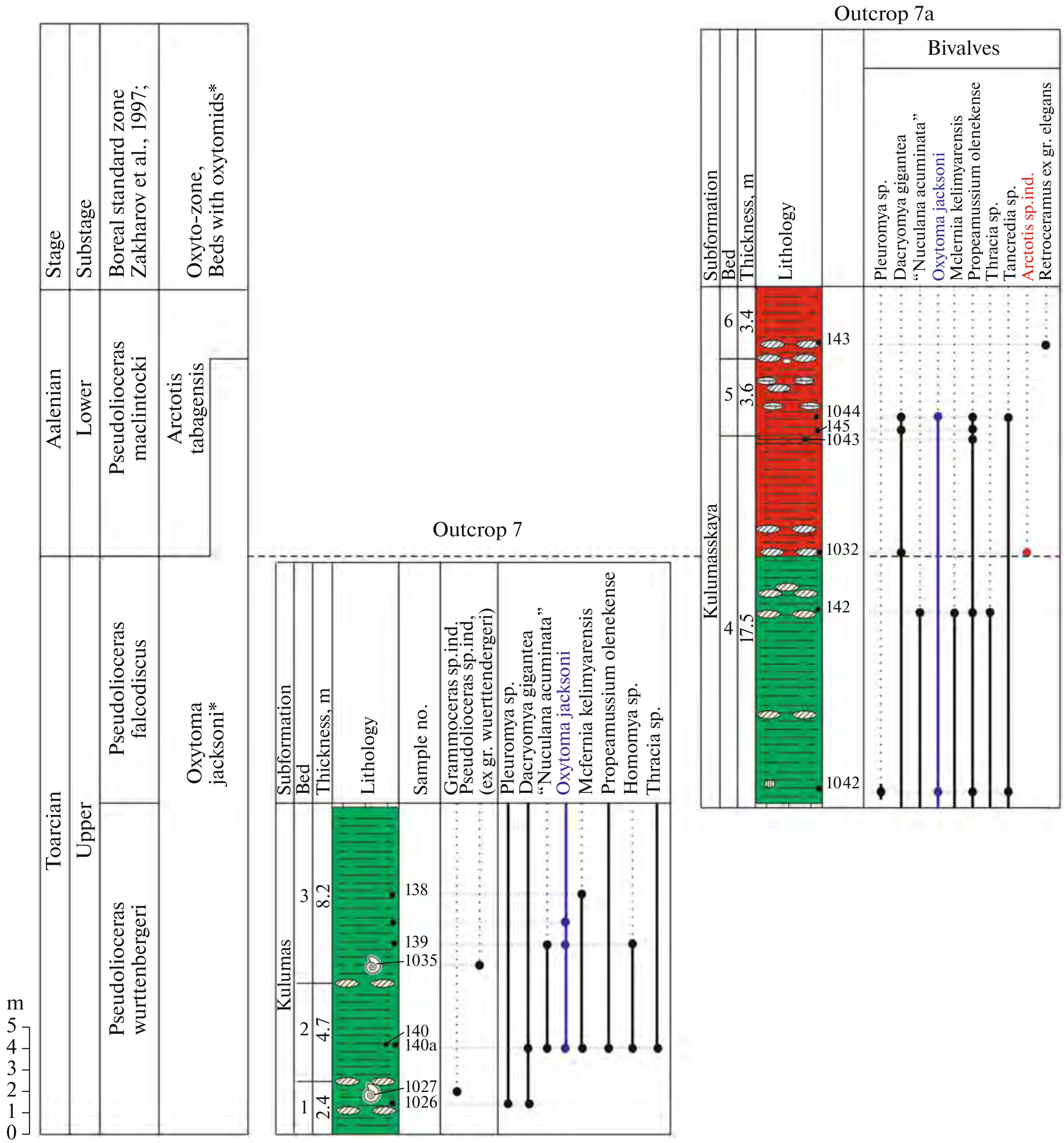

Fig. 42. Stratigraphy of Toarcian-Aalenian deposits in outcrops 7 and 7a (Kelimyar River) based on the distribution of index species and zonal assemblages of oxyto-zones. Legend see in Fig. 14.

Bed 8, thickness 9.0 m (visible). Silts clayey, dark gray, unevenly platy, with jarosite stains. At levels 0.5; 1.7 m horizons of siderite limestone nodules, reddish-brown on the surface, yellow-gray in fresh fracture. At levels 4.6; 5.5; 6.1; 7.1; 9.0 m horizons of ellipsoidal nodules of sideritized limestone. At levels 7.6; 8.5 m horizons of phosphorite nodules.

Bivalves: *Oxytoma jacksoni* (Pomp.) (abundant), *Propeamussium olenekense* Bodyl. (frequent), *Liostrea (Deltostrea) taimyrensis* Zakh. et Schur. (abundant), *Astarte plana* Milova (Sample 172, 4.4 m; Sample 1084, from the bed).

A stratigraphic scheme of the Pliensbachian-Toarcian deposits in Outcrop 14, on the Kelimyar River

Fig. 43. Kelimyar River, Outcrop 14. Top of the "yellow" layer—boundary of the Kyra and Kelimyar formations.

based on the distribution of index species and zonal assemblages of oxyto-zones is presented in Fig. 44.

Outcrop 16

Located on a large bend of the left bank of the Kelimyar River, 2.0–3.0 km downstream the mouth of Ulakhan-Kurung Creek (Fig. 36). It represents an extended coastal cliff with a height of 5.0 to 11.0 m.

Kyra Formation. ***Fourth Member*** (Beds 1–2). At the upstream end of the outcrop, at a height of 1.0 m from the waterline, Upper Pliensbachian silts and clays with horizons of calcareous siderite nodules are exposed (Fig. 45).

Bed 1, thickness 9.6 m (visible). Silts clayey, dark gray with a greenish tint, unevenly platy, dense, sandy in areas, with fragments of carbonized wood, pyrite nodules, pebbles, gravel, limestone boulders with attached *Harpax* shells (Fig. 45).

At levels 2.5; 3.0; 4.2, there are lenticular-separate ellipsoidal nodules of calcareous siderite. At a height of 6.0 m there is a consistent horizon of lenticular-ellipsoidal nodules of calcareous siderite, yellowish on the surface, yellowish-gray in fresh fracture. At levels 6.7; 7.1; 9.4 there are similar horizons. In the interval 9.0–9.5 m there are individual nodules.

Bivalves: *Harpax spinosus* (Sow.) (frequent).

Foraminifers: *Ammodiscus siliceus*, *Trochammina lapidosa*, *Hyperammina odiosa*, *Ammobaculites alaskaensis*, *Kutsevella barrowensis,* etc.

Bed 2, thickness 1.6 m. Silts clayey, dark gray, bluish, yellow on the surface, lumpy.

Bivalves: *Harpax laevigatus* (Orb.) (frequent) (Sample 1095, from the bed); *Anradulonectites anabarensis* Schur. et Lut. (frequent), brachiopods, gastropods (Sample 1094, from the bed); level 1.1 m—*Ochotochlamys grandis* Polub. (frequent), *Harpax laevigatus* (Orb.) (frequent) (Sample 174a).

Foraminifers: *Ammodiscus siliceus*, *Hyperammina odiosa*, *Trochammina lapidosa*, *Recurvoides taimyrensis*, *Kutsevella barrowensis.*

Kelimyar Formation. ***Kurung Subformation***. The Toarcian strata rests on the "yellow bed" of the Pliensbachian deposits with a smooth and sometimes uneven lower boundary.

Bed 3, thickness 1.4–1.6 m. Silty clays, dark brownish-gray, foliated (0.0–0.06 m). Interbed of coal (0.06–0.065 m). Shales dark gray with a yellowish tint (0.065–0.24 m). Carbonate nodules with a cone-in-cone texture at base (0.24–0.5 m). Clayey shales (0.5–1.2 m). Shales becoming clays (1.2–1.4 m).

Ammonites: *Tiltoniceras* sp. ind. (Lutikov and Arp, 2023a) (interval 0.5–1.2 m—Sample 1097), *Harpoceras exaratum* (interval 0.5–1.2 m—Sample 1099, 1100), *Harpoceras falciferum* (interval 1.2–1.4 m—Sample 1097, 1098) (Golbert et al., 1985).

Bivalves: *Meleagrinella (Praemeleagrinella) golberti* Lutikov et Arp., *Nicaniella* sp. (Sample 1097, 1.0–1.2 m; Sample 1100, 1.0–1.2 m); *Kedonella mytileformis* Polub., *Dacryomya jacutica* (Petr.), *Pleuromya* sp., *Homomya* sp. (Sample 1092, 1.3 m; Sample 1096, 1.4–1.6 m; Sample 178).

Foraminifers: at the base of the bed—*Recurvoides taimyrensis*, *Trochammina* ex gr. *lapidosa*, *Trochammina kisselmani*, *Ammobaculites lobus.* Higher up—*Trochammina kisselmani*, *Evolutinella taimyrensis*, *Ammobaculites lobus*, *Bulbobaculites strigosus*, *Lenticulina* sp., *Dentalina kiterbutica*, *Globulina sibirica,* etc.

Bed 4, thickness 2.5 m. The clays are silty, shale, dense, dark gray, with phosphorite nodules.

Ammonites: *Dactylioceras* ex gr. *commune* (Sow.) (Knyazev et al., 1984; Golbert et al., 1985).

Bivalves: *Homomya* sp., *Dacryomya jacutica* (Petr.) (Sample 179, 1.0 m).

Foraminifers: *Trochammina kisselmani*, *Evolutinella taimyrensis*, *Ammobaculites lobus*, *Bulbobaculites strigosus*, *Saracenaria* ex gr. *obesa*, *Lagenammina jurassica,* etc.

Bed 5, thickness 2.5 m. At the base of the bed there is a thin carbonaceous layer. Higher up the clays are schistose. At a height of 0.2 m there is interbed (0.2 m) of viscous clays with pyrite nodules. At a height of 1.6 m there is a thin carbonaceous layer.

Bivalves: *Dacryomya jacutica* (Petr.) (Sample 174, 1.3 m; Sample 1096, 1.4–1.6 m).

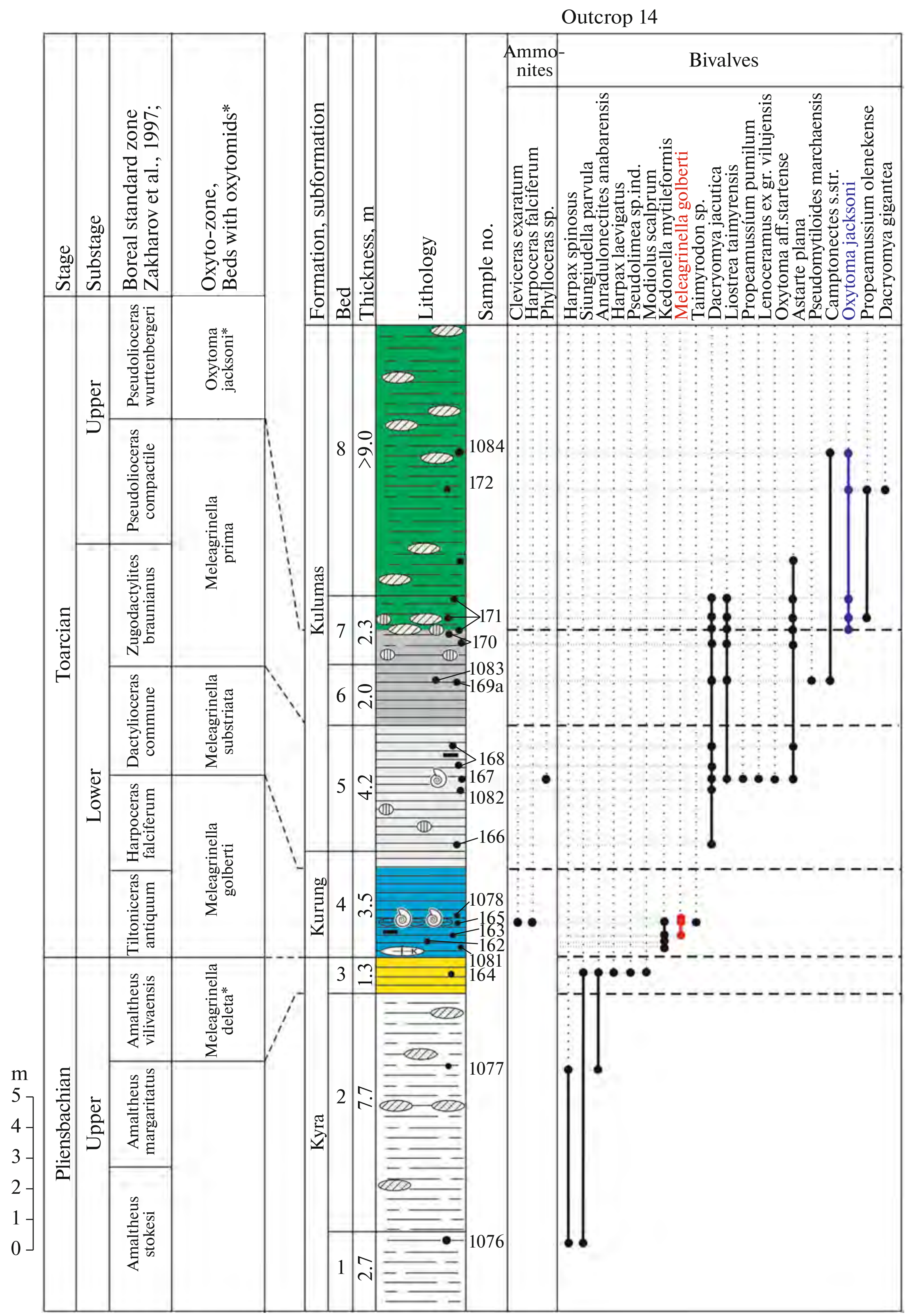

Fig. 44. Stratigraphy of Pliensbachian-Toarcian deposits in Outcrop 14 (Kelimyar River) based on the distribution of index species and zonal assemblages of the oxytomid scale. Legend see in Fig. 14.

Fig. 45. Outcrop 16 on Kelimyar River. Clayey silts of the Kyra Formation with boulders and attached *Harpax* shells.

Foraminifers: *Trochammina kisselmani*, *Evolutinella taimyrensis*, *Ammobaculites lobus*, *Bulbobaculites strigosus,* etc.

Kelimyar Formation. ***Kulumas Subformation.*** At the upstream end of the outcrop, silts with horizons of lower and upper Toarcian calcareous siderite nodules are exposed (Fig. 46).

Bed 6, thickness 1.9 m. The bed rests on underlying rocks with a distinct and even boundary, represented by the replacement of lighter (oxidized) rocks of the Kurung subformation with dark gray platy silty clays. At the boundary of the beds there are oval concretions of phosphorites with faunal remains. Similar levels are typical for the entire bed. Silts are clayey, dark gray, platy. At the top of the bed at the level is 1.9 m, a horizon of lenticular nodules of calcareous-clayey composition with a "cone-in-cone" texture, with lenses of belemnites in the middle part, shells of bivalve mollusks on the upper surface and inside, carbonized wood fragments are recorded.

Ammonites: *Phylloceras* sp. ind.—in phosphorite nodules, *Zugodactylites braunianus* (Orb.)—0.6 m above the base (Knyazev et al., 1984, 2003), *Pseudolioceras replicatum* Buckman—0.5 m below the top (Repin, 1991, 2017); *Harpoceras* sp. ind (ex gr. *subplanatum* (Oppel)—at the top of the bed (Devyatov et al., 2010).

Bivalves: *Dacryomya jacutica* (Petr.) (very frequent) (Sample 175, 0.3–0.5 m); *Homomya* sp. (very frequent), *Pleuromya* sp. (very frequent) (Sample 176, 0.8–1.2 m); *Pseudomytiloides marchaensis* (Petr.) (abundant), *Oxytoma* aff. *startensis* Polub. (rare), *Astarte plana* Milova (frequent), *Liostrea (Deltostrea) taimyrensis* Zakh. et Schur. (abundant), gastropods (Sample 177, top).

Foraminifers: *Trochammina kisselmani*, *Bulbobaculites strigosus*, *Saccammina inanis*, *Ammodiscus glumaceus*, *Evolutinella taimyrensis.*

Bed 7, thickness 5.9 m. Silts clayey, dark gray, less often finely pulverized, with nodules of sideritized phosphorites on the surface, with small specks of jarosite around organic remains. At a height of 0.7 m, a horizon of lenticular calcareous-clayey nodules with a "cone-in-cone" texture, with belemnite lenses in the middle part, shells of bivalve mollusks on the upper surface and inside; at a height of 3.5; 3.8 m horizons of lens-shaped nodules with a "cone-in-cone" texture. At a height of 3.0 m throughout the outcrop there is a thin layer of clay (0.01–0.02 m) with a coquina of bivalves and belemnites. At a height of 5.9 m there is a horizon of nodules.

Ammonite: *Pseudolioceras beyrichi orientale* Repin—level 3.5 m (Repin, 1991, 2017).

Fig. 46. Outcrop 16 on Kelimyar River. Exposures of the Kulumas Subformation.

Bivalves: *Pseudomytiloides marchaensis* (Petr.) (abundant), *Oxytoma* aff. *startense* (Polub.) (rare), *Dacryomya jacutica* (Petr.) (very frequent), *Liostrea (Deltostrea) taimyrensis* Zakh. et Schur. (abundant), *Astarte plana* Milova (frequent), *Camptonectes* sp. 1 (rare), *Homomya* sp., brachiopods, gastropods (Sample 1093b, 1093v, basal part; Sample 180, 0–0.5 m; Sample 1101, 0.7 m; Sample 181, 0.5 m; Sample 182, 1.5 m; Sample 1102, 1.5 m). In the interval 3.5–3.8 m—*Oxytoma jacksoni* (Pomp.) (abundant), *Propeamussium olenekense* Bodyl. (frequent), *Liostrea (Deltostrea) taimyrensis* Zakh. et Schur. (abundant), *Luciniola* sp., *Pleuromya* sp. (rare) (Sample 183).

Foraminifers: *Ammodiscus glumaceus*, *A. siliceus*, *Saccammina inanis*, *Astacolus praefoliaceus*, *Globulina sibirica*, *Lenticulina multa*; from the upper part of the bed—*Verneuilinoides syndascoensis*, *Kutsevella indistincta*, *Lenticulina dorbignyi*, *Astacolus figurata*, *Trochammina taimyrensis*.

Bed 8, thickness 2.8 m (visible). At the base of the bed there is a horizon of rare lens-shaped, surface reddish-brown nodules of calcareous-clayey composition (0.15 × 0.7 m). Silts clayey, dark gray, with jarosite specks and belemnite lenses. At the level 0.4 m more consistent horizon (from 0.1 × 0.5 to 0.3 × 2.5 m). The same nodules were found at levels 0.6; 1.5; 1.8; 2.3 m.

Bivalves: *Dacryomya jacutica* (Petr.) (rare), *Camptonectes* sp. 1 (rare), *Propeamussium olenekense* Bodyl. (frequent) (Sample 184, 0–1.0 m); *Oxytoma jacksoni* (Pomp.) (abundant), *Propeamussium olenekense* Bodyl. (frequent), *Liostrea (Deltostrea) taimyrensis* Zakh. et Schur. (abundant), *Tancredia securiformis* (Dunk.), *Dacryomya gigantea* Zakh. et Schur. (very frequent), *Astarte plana* Milova (frequent), *Homomya* sp., *Grammotodon* sp., *Luciniola* sp., *Malletia amygdaloides* (Sow.), *Pleuromya* sp. (Sample 185, 1.0–2.5 m, Sample 1103–1106, from the bed); *Maclearnia kelimyarensis* Zakh. et Schur. (Sample 186a, collected loose).

Foraminifers: *Ammodiscus glumaceus*, *A. siliceus*, *Saccammina inanis*, *Astacolus praefoliaceus*, *Lenticulina multa*, *Verneuilinoides syndascoensis*, *Trochammina taimyrensis*.

A stratigraphic scheme of the Pliensbachian-Toarcian deposits in Outcrop 16 on the Kelimyar River based on the distribution of index species and zonal assemblages of oxyto-zones is shown in Fig. 47.

Subdivision and Correlation of Pliensbachian-Aalenian Deposits in the Section on the Kelimyar River

Kyra Formation. The Hettangian-Late Pliensbachian Kyra Formation crops out in the Leno-Anabar structural-facies zone. The formation was dated by finds of ammonites—*Psiloceras olenekense* (Dagys et al., 1978), *Psiloceras planorbis* (Galabala et al., 1989), *Psiloceras* aff. *planorbis, Psiloceras olenekense, Psiloceras calliphyllum, Schlotheimia primula* (Knyazev and Kutygin, 2004), *Amaltheus* sp. (Knyazev et al., 1984), *Amaltheus* ex gr. *brodnensis* (Galabala et al., 1990). For the upper part of the Kyra Formation, the Velata viligaensis and Anradulonectites incertus b-zones in the range of three Pliensbachian ammonite zones were proposed as auxiliary biostratigraphic units (Shurygin et al., 2000).

Kelimyar Formation. In the section on the Kelimyar River, the formation was considered in the stratigraphic range of the Lower Toarcian–Bathonian (Shurygin et al., 2000). In accordance with the modern scheme of correlation of the standard ammonite scale of the Middle Jurassic of Western Europe and the standard Boreal ammonite scale (Morton et al., 2020), the Kelimyar Formation based on finds of Late Bajocian ammonites *Arctocephalites* spp. in its upper part (Devyatov et al., 2010) should be assigned to the Lower Toarcian–Upper Bajocian. It was assumed that the Kelimyar Formation overlies the Kyra Formation with a gap corresponding to the Dactylioceras tenuicostatum Zone of the northwestern European standard (*Resheniya*..., 1981). In Outcrop 16 near the base of the formation, O.A. Lutikov discovered an ammonite, which was identified by G. Arp (University of Götting, Germany) as *Tiltoniceras* sp. ind. This made it possible to substantiate the presence of the lower Toarcian Zone in this section (Lutikov and Arp, 2023a). Thus, the idea of a regional gap at the Pliensbachian-Toarcian boundary in Eastern Siberia (*Resheniya*..., 1981) is questioned.

Kurung Subformation. For the first time, the subformation was recognized instead of the Kurung Member by Nikitenko et al. (2011). The Early Toarcian age of the Kurung Subformation was based on the ammonites *Harpoceras* cf. *exaratum, Harpoceras falciferum, Dactylioceras* ex gr. *commune* (Knyazev et al., 1984). The upper boundary of the Kurung Subformation was drawn within the Dactylioceras commune ammonite Zone based on finds of *Dactylioceras* sp. ind. in the scree of its upper part of the member (Devyatov et al., 2010). These studies have established that the stratigraphic volume of the Kurung Subformation corresponds to the Tiltoniceras antiquum, Harpoceras falciferum, Dactylioceras commune zones of the Boreal standard (Zakharov et al., 1997; Shurygin et al., 2011).

Kulumas Subformation. First established by Nikitenko et al. (2011). The age of this part of the Kelimyar Formation was previously considered Early Toarcian–Bathonian based on ammonites: *Dactylioceras* ex gr. *commune, Zugodactilites braunianus, Pseudolioceras compactile, Pseudolioceras beyrichi* (Knyazev et al., 1984, 1993, 2003; Knyazev, 1991), *Grammoceras* sp. ind., *Pseudolioceras* sp. ind. (ex gr. *wuerttenbergeri*) (Devyatov et al., 2010); *Pseudolioceras* ex gr. *alienum, Pseudolioceras replicatum, Pseudolioceras* cf. *beyrichi*, *Pseudolioceras beyrichi orientale* Repin, *Pseudolioceras* aff. *maclintocki* (Repin, 1991, 2017); *Arctocephalites* spp. (Devyatov, 2000). In accordance with the current correlation scheme of the standard Middle Jurassic ammonite scale of Western Europe and the standard Boreal ammonite scale (Morton et al., 2020), the Kulumas subformation belongs to the Lower Toarcian–Upper Bajocian. Establishing the boundaries of ammonite zones in the section is difficult due to the rare occurrence of ammonites.

Using the zonal scale for oxytomids, the Pliensbachian-Aalenian sequence in the Kelimyar River section is divided into three oxytomid zones and two biostratons in the rank of Beds with oxytomids:

Beds with Meleagrinella deleta. The beds were recognized in the upper part of the Kyra Formation. In outcrops they are distinguished by a yellow-brownish color (Fig. 38). The Beds with Meleagrinella deleta in Outcrop 5 include the upper part of Bed 1 (0.5 m) and Bed 2, in Outcrop 14—Bed 3, in Outcrop 16—Bed 2 (Fig. 48). The Beds are characterized by the index species *Meleagrinella (Praemeleagrinella) deleta* and a zonal assemblage with *Kolymonectes* ex gr. *terekhovi, Siungiudella parvula, Anradulonectites anabarensis* (Lutikov, 1984; Shurygin and Lutikov, 1991). The thickness of the beds is about 1.6 m. The Beds with Meleagrinella deleta correlate with the Amaltheus viligaensis Zone of the Boreal standard (Zakharov et al., 1997). The accompanying assemblage of foraminifera, represented by *Trochammina lapidosa, Recurvoides taimyrensis, Kutsevella barrowensis*, etc., characterizes the lower part of the JF9 Zone, the full stratigraphic volume of which corresponds to the Amaltheus viligaensis and Tiltoniceras antiquum zones (*Reshenie*..., 2004).

Meleagrinella golberti Oxyto-zone. In Outcrop 5, the oxyto-zone refers to the bottom of Bed 3a. In Outcrop 14 this includes the lower part of Bed 4, in Outcrop 16 it includes Bed 3 and the lower part of Bed 4 (Fig. 48). The oxyto-zone was established by the presence of the index species *Meleagrinella (Praemeleagrinella?) golberti* and the zonal assemblage with *Kedonella mytileformis, Dacryomya jacutica*. The upper boundary of the oxyto-zone in the section is drawn conditionally, based on the latest finds of the index species approximately at the level of 3.0 m in Outcrop 5. The total thickness of the oxyto-zone is 3.0 m. In the Kelimyar River section, the Meleagrinella golberti Oxyto-zone based on ammonites correlates with the *Tiltoniceras antiquum, Harpoceras falciferum zones* of the Boreal standard of the Toarcian Stage.

The accompanying assemblage of foraminifers, represented by *Trochammina kisselmani, Ammobaculites lobus*, characterizes the lower part of the Trochammina kisselmani F-zone, which in the north of Siberia corresponds to the Tiltoniceras antiquum,

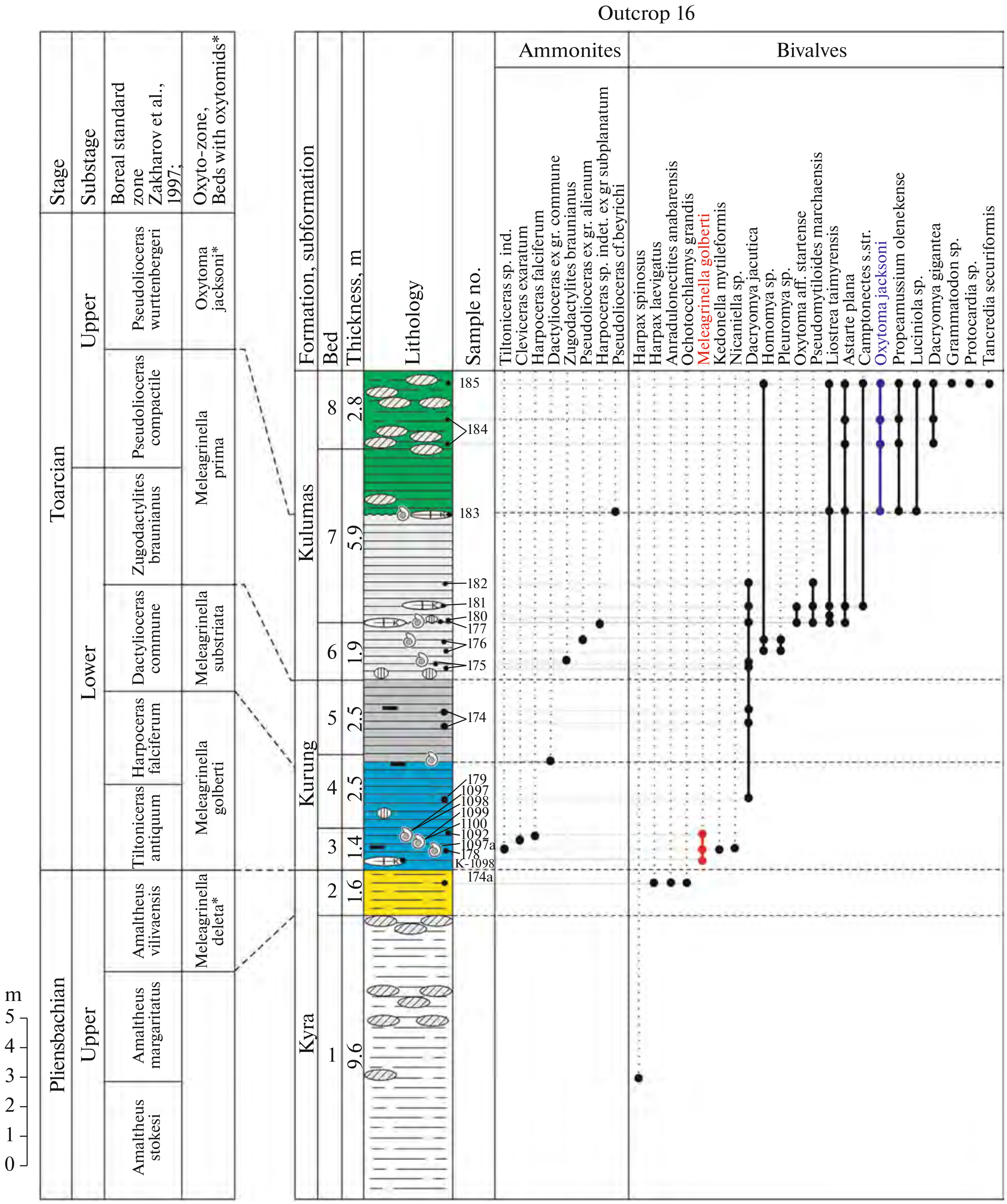

Fig. 47. Stratigraphy of Pliensbachian-Toarcian deposits in Outcrop 16 (Kelimyar River) based on the distribution of index species and zonal assemblages of the oxytomid scale. Legend see in Fig. 14.

Harpoceras falciferum, Dactylioceras commune and Zugodactilites braunianus zones (Sapjanik, 1991b). Pliensbachian *Recurvoides taimyrensis, Trochammina* ex gr. *lapidosa* were found together with Toarcian taxa. Close associations are established at the base of Bed 4 of Outcrop 14 (0–0.6 m from the base), at the base of Bed 3 of Outcrop 16 and at the base of Bed 4 of Outcrop 14. The assemblage is typical of the upper (Toarcian) part of the Recurvoides taimyrensis JF9 f-zone (Devyatov et al., 2010).

Meleagrinella substriata Oxyto-zone. In Outcrop 14, the oxyto-zone is conventionally considered as a series that includes the upper part of Bed 4 (about 0.5 m) and Bed 5 (Figs. 44, 48). The oxyto-zone is established according to the zonal assemblage of bivalves: *Lenoceramus* ex gr. *vilujensis, Propeamussium pumilum,* and *Oxytoma* aff. *startense*. The total thickness of the oxyto-zone is 4.7 m. In Outcrops 5 and 16, the oxyto-zone is not identified and is distinguished conditionally by its position in the section (Fig. 48).

Meleagrinella prima Oxyto-zone. In Outcrop 14, Bed 6 is conditionally assigned to this oxyto-zone (Fig. 44). In Outcrop 16, the oxyto-zone conventionally includes Bed 6 and the lower part of Bed 7 (Fig. 47). The oxyto-zone is established based on a zonal assemblage of bivalves with *Pseudomytiloides marchaensis, Camptonectes* s.str. The thickness of the Oxyto-zone 1.9–2.0 m.

Beds with *Oxytoma jacksoni*. In Outcrop 5, Bed 5 is assigned to this biostraton (Fig. 39). In Outcrop 7, the Oxytoma jacksoni Beds include the succession composed of Beds 1–6 (Fig. 42). In Outcrop 14, these beds include the series of Beds 7–8 (Fig. 44). In Outcrop 16, the series includes Bed 7 (interval 3.5–5.9 m) and Bed 8 (Fig. 47). The Beds are identified by the index species *Oxytoma jacksoni* and the zonal assemblage of bivalves with *Propeamussium olenekense* (Bodyl.), *Dacryomya gigantea* Zakh. et Schur., *Maclearnia kelimyarensis* Zakh. et Schur., *Luciniola* sp.

The accompanying foraminiferal assemblage, represented by *Trochammina taimyrensis, Ammodiscus glumaceus, A. siliceus, Saccammina inanis, Astacolus praefoliaceus, Lenticulina multa, Verneuilinoides syndascoensis*, characterizes the Trochammina taimyrensis F-Zone, the stratigraphic range of which in the north of Siberia corresponds to the Pseudolioceras compactile–Pseudolioceras maclintocki zones (Sapjanik, 1991b).

Arctotis tabagensis Oxyto-zone. In Outcrops 7 and 7a the oxyto-zone includes the top of Bed 4 and Beds 5–6. The oxyto-zone is distinguished by the presence of *Arctotis* sp. in the section. ind. (ex gr. *tabagensis*) and a representative of the zonal assemblage *Retroceramus* ex gr. *elegans*. The apparent thickness of the oxyto-zone in Outcrop 7a is 12.7 m (Fig. 42). In the Kelimyar River section, the Arctotis tabagensis Oxyto-zone correlates with the Pseudolioceras maclintocki Zone of the Boreal standard of the Toarcian Stage.

The position of the boundary between the Toarcian and Aalenian in the Kelimyar River section is not clear and is the subject of debate. Yu.S. Repin proposed to draw the boundary between the Toarcian and Aalenian in the section along the Kelimyar River in Outcrop 16 at 3.5 m from the base of Bed 7 at the level with *Pseudolioceras beyrichi orientale* (Repin, 1991, 2017). However, in the higher part of the section in Outcrop 7, the Late Toarcian *Grammoceras* sp. ind. (Bed 1) and *Pseudolioceras* sp. ind. (ex gr. *wuerttenbergeri*) (Bed 3) (Devyatov et al., 2010) (Figs. 42, 48). In the proposed scheme of division of the Kelimyar River section, the boundary between the Lower and Middle Jurassic is drawn at the base of the Arctotis tabagensis Oxyto-zone, the lower boundary of which in Outcrop 7a is combined with a concretionary Bed 11.8 m from the base of Bed 4, according to the appearance of *Arctotis* sp. in the section. ind. (ex gr. tabagensis). At the same level there is a change in foraminiferal assemblages. In the upper part of Bed 4, the associated foraminiferal assemblage represented by *Trochammina praesquamata, Kutzevella operta*, characterizes the Beds with *Trochammina praesquamata*. In northern Siberia, the appearance of *Trochammina praesquamata* was compared with the interval of distribution of the ammonites Pseudolioceras maclintocki (Sapjanik, 1991b). The stratigraphic volume of the Trochammina praesquamata JF15 f-Zone in northern Siberia was considered to range from the upper part of the Lower Aalenian, the upper Aalenian and the lower part of the Upper Bajocian (Nikitenko, 2009).

Motorchuna River Section

Based on the composition and type of sediments, thickness and completeness of sections, the Lower and Middle Jurassic strata in the Motorchuna River basin belong to the Zhigansk structural-facies zone (*Resheniya*..., 1981). In the same zone there are sections more characterized by ammonites along the Sungyuyude and Molodo rivers. The sections were repeatedly studied by teams from the Arktikrazvedka trust, the USSR Academy of Sciences, the Institute of Arctic Geology, the Yakut Geological Department, VNIGRI and SNIIGGiMS. In the modern version of the "Regional stratigraphic scheme of the Lower and Middle Jurassic of Siberia", five formations are recognized in the Lower-Middle Jurassic part of the section in the Zhigansk structural-facies zone: Motorchuna, Suntary, Kystatym, Horongho and Dzhaskoy. With varying degrees of justification, divisions of the general stratigraphic scale have been established in the section: Hettangian–Lower Pliensbachian, Upper Pliensbachian, Toarcian, Aalenian, Bajocian and Bathonian (Shurygin et al., 2000). Hettangian–Sinemurian, Pliensbachian, Toarcian and Aalenian deposits emerge on the surface in the coastal cliffs of the Motorchuna River and along its tributaries (Fig. 49).

The section was studied by the author together with V.G. Knyazev (ammonites) and V.V. Sapjanik (foraminifera) in 1986. The Toarcian–Aalenian section, more saturated with ammonites, in the basin of the Sungyuyude and Molodo Rivers was studied by V.G. Knyazev, V.P. Devyatov (lithology) and V.V. Sapjanik (foraminifers) in 1983. The present author identified the bivalves based on the fossil collections in 1978 and 1983. and supplemented with information from the published sources (Test et al., 1962). Information on ammonites is cited from publications (Bid-

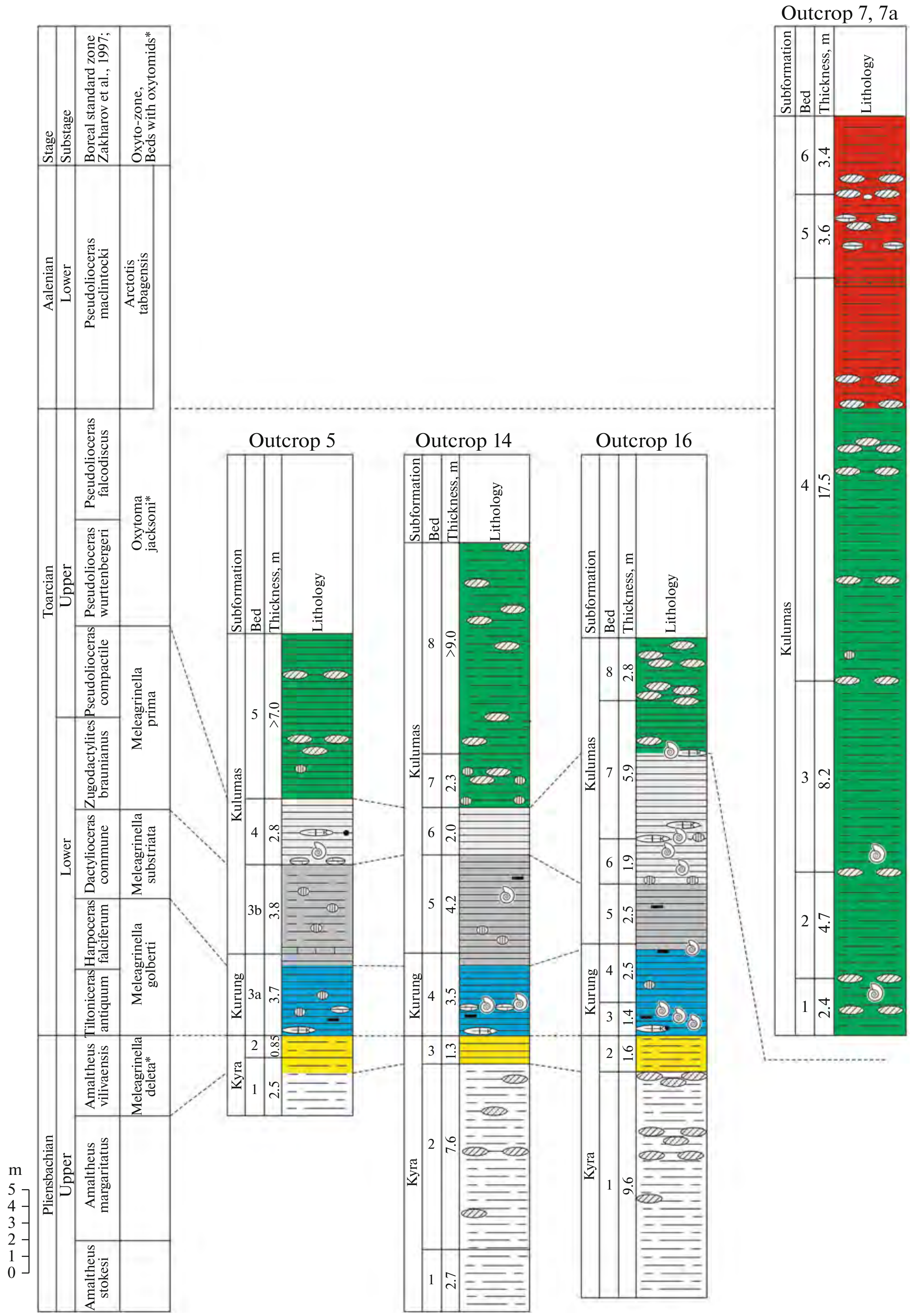

Fig. 48. Stratigraphy and correlation of Pliensbachian-Toarcian deposits along the Kelimyar River based on the distribution of index species of oxyto-zones and zonal assemblages. Legend see in Fig. 14.

zhiev and Minaeva, 1961; Kirina, 1971; *Stratigrafiya*..., 1976; Knyazev, 1991; Knyazev et al., 2007; Repin, 2017). Information on foraminifers was kindly provided by V.V. Sapjanik. Photographs by the author.

Outcrop 1

Located on the left bank of the Motorchuna River, 0.5 km downstream the mouth of the Sien-Yurege River (Fig. 49). The upper part of the Motorchuna Formation is exposed in a high coastal cliff (Fig. 50).

Motorchuna Formation. Recognized by Kirina et al. (1978). According to lithology, the formation is subdivided into four members (Knyazev et al., 1991). This paper describes the fourth unit exposed in Outcrop 1. The outcrop has no visible contact with the overlying Toarcian succession.

Fourth Member

Bed 12, visible thickness 2.0 m. The clays are silty, dark gray, fissile, interbedded with tobacco-colored clays. At the level 1.5 m there is an interbed of tobacco-colored sand. The bed ends with a layer of thinly laminated dark gray with a brown tint of clay with coal lenses.

Bivalves: *Pleuromya* sp.

Foraminifers: *Ammadiscus pseudoinfimus*, *Glomospira gordialis*, *Giperammina neglecta*, *Trochammina inflataeformis.*

Bed 13, thickness 5.5 m. Clays silty, dark gray, fissile, interbedded with tobacco-colored clays. At the level 1.5 m there is an interbed of tobacco-colored sand. The bed ends with a layer of thinly laminated dark gray with a brown tint of clay with coal lenses.

Bivalves: *Anradulonectites anabarensis* Schur. et Lut. (rare), *Harpax laevigatus* (Orb.) (rare), *Meleagrinella deleta* (Dum.), *Siungiudella parvula* Lutikov (frequent) (Sample 205).

Foraminifers: *Trochammina sablei*, *Ammodiscus glumaceus,* etc.

Bed 14, visible thickness 2.0 m. Clays are silty, brownish-gray, fissile, with stains of jarositization and spherical nodules at the level of 0.5 m.

The observation gap is about 5 m.

Bed 15, visible thickness 5.5 m. The sands are gray-yellow, ferruginous in places, and loose. At the base of the bed there is is a horizon of calcareous flagstone with a thickness of 0.3 m. At the level of 4.0 m glendonites are present.

From the upper part of the Motorchuna Formation Yu.S. Repin listed *Amaltheus lenaensis* Repin (Repin, 2016). The exact location of the ammonite in the section is unknown.

Foraminifers: *Haplophragmoides barrowensis*, *Trochammina sablei,* etc.

Outcrop 3

Located on the right bank of the Motorchuna River, 0.5 km upstream the mouth of the Balagannakh-Yurege River, 200–300 m up an unnamed stream (Fig. 49). After a gap in observations (about 10 m) the following succession is exposed:

Motorchuna Formation

Bed 1, visible thickness 3 m. Greenish and bluish clays, viscous, with nodules that are heavily ferruginized on the surface.

Bivalves: *Harpax laevigatus* (Orb.) (rare), *Panopea lahuseni* Kosch. (Sample 211, level 2.7 m).

Foraminifers: *Trochammina sablei*, *Ammodiscus pseudoinfimus*, *Glomospira gordialis*, etc.

Suntary Formation

Bed 2, thickness 4 m. At the base the nodules are calcareous, with belemnites. The clays are dark gray, thin-bedded, with jarosite spots. At different levels there are calcareous, round siltstone concretions.

Bivalves: *Kedonella brodnensis* Polub. (rare), *Kedonella mytileformis* Polub. (many) (Sample 212, from the bed).

Bed 3, visible thickness 10 m. At the base there is an interbed of calcareous nodules brownish-reddish from the surface. The clays are bluish-gray with a greenish tint, viscous, with jarosite spots, gradually turning into brownish, fissile clays. At the level 1.5 m, bun-shaped nodules of dense siltstone are reddish on the surface and gray in fresh fracture.

Bivalves: *Kedonella mytileformis* Polub. (many, frequent), *Meleagrinella (Praemeleagrinella?) golberti* Lutikov et Arp in litt. (frequent), *Meleagrinella (Praemeleagrinella?)* aff. *golberti* Lutikov et Arp (Sample 213, basal part).

Foraminifers: *Ammodiscus graniferis*, *Triplasia kingakensis* Loeblich et Tappan (pers. Comm. By V.V. Sapjanik).

A scheme of stratigraphy and correlation of Pliensbachian-Toarcian deposits in Outcrops 1 and 3 (Motorchuna River) based on the distribution of index species and zonal assemblages of oxyto-zones is presented in Fig. 51.

Outcrop 4

Located on the right bank of the Motorchuna River, 6 km downstream the mouth of the Suordakh River (Fig. 49). The upper part of the Suntary Formation is exposed from above the water line, (Fig. 52). Outcrop 4 stratigraphically follows Outcrop 3 with a gap in observation of about 20 m.

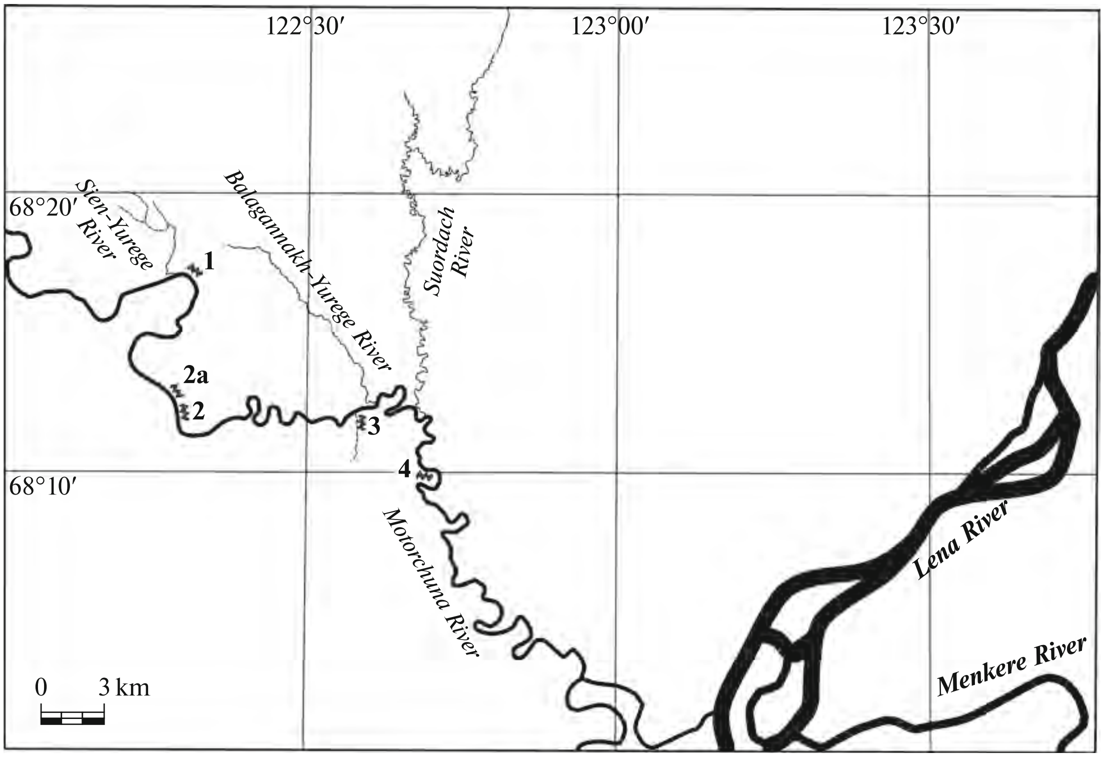

Fig. 49. Studied outcrops on the Motorchuna River.

Suntary Formation

Bed 1, visible thickness 4.5 m. Silty clays and highly clayey silts, dark brownish-gray, fissile, with jarosite stains, with multiple levels of discoidal pyrite nodules and nodules of silty limestone, often highly oxidized from the surface.

Bivalves: *Taimyrodon* sp. (Sample 215, upper part).

Foraminifers: *Verneuilinoides (=Riyadhella) syndascoensis,* etc.

Bed 2, thickness 7 m. Clays silty, dark gray, with jarosite stains, with interlayers of calcareous clay nodules with phosphate-calcareous porphyroblasts. The bed terminates with a continuous horizon of calcareous siltstone (thickness 0.4–0.6 m).

Ammonites: in the lower part of the bed—*Pseudolioceras falcodiscus* (Quenst.) (Knyazev et al., 1991). *Pseudolioceras maclintocki* (Haught.) was cited from a horizon below the top (Stratigrafiya, 1976).

Bivalves: in the lower part of the bed—*Arctotis (Praearctotis) similis* Velikzhanina (frequent), *Malletia amygdaloides* (Sow.), *Dacryomya* sp., *Nuculana acuminata* (Goldf.) (Sample 216).

In the siltstone horizon at the top—*Arctotis* cf. *tabagensis* (Petrova) (rare), small *Mytiloceramus (Pseudomytiloides)*? ex gr. *elongatus* Kosch., *Arctica humiliculminata* Schur. (frequent), *Goniomya* sp., gastropods (Sample 217).

Foraminifers: *Ammodiscus glumaceus,* etc.

Bed 3, thickness 4.5 m. Silts are dark gray, fissile, with stains of jarositization.

Bivalves: in the interval 2.0–4.5 m—*Arctotis (Arctotis) tabagensis* (Petrova) (frequent), *Propeamussium olenekense* Bodyl. (very rare), *Malletia amygdaloides* (Sow.) (frequent), *Pleuromya* sp. ind. (very rare), gastropods (Sample 218).

Foraminifers: *Lenticulina nordvicensis,* etc.

Kystatym Formation. Lower Subformation. Lower beds of the formation were studied in the right side of Outcrop 4 (Fig. 53).

Bed 4, thickness 2.0 m. At the base there is an interbed pebbles (up to 10 cm) with coal lenses. Sandstone dark gray, loose, with jarosite spots and pyrite nodules.

Bivalves: *Arctotis (Arctotis) tabagensis* (Petrova) (frequent)—throughout the bed there are accumulations of complete shells, *Retroceramus* ex gr. *elegans* Kosch., *Goniomya* sp.

Bed 5, thickness 7.5 m. Interlayering of sandy siltstones and siltstones. The lower 1.5 m are dark gray sandstones, brownish on the surface, with pebbles, gradually turning into dark gray siltstones, with jarosite stains. The bed terminates with a thick (0.6 m) horizon of calcareous, platy siltstone, with a clay crust on the surface.

Bivalves: *Arctotis (Arctotis) tabagensis* (Petrova) (frequent)—scattered in the lower part of the bed, *Retroceramus* ex gr. *elegans* Kosch., *Goniomya* sp., in the upper part of the bed—*Malletia amygdaloides* (Sow.).

Bed 6, thickness 9.8 m. At the base—dark gray, sandy siltstones, gradually turning into brownish siltstones,

Fig. 50. Motorchuna River, exposures of the Motorchuna Formation in Outcrop 1.

with jarosite stains. At levels 7.0; 8.0; 9.3 m nodule horizons with coquinae. Bivalves: *Retroceramus* ex gr. *elegans* Kosch.—coquina accumulations of whole shells.

A stratigraphic scheme of Toarcian-Aalenian deposits in Outcrop 4 based on the distribution of index species and zonal assemblages of oxyto-zones is shown in Fig. 54.

Stratigraphy and Correlation of Pliensbachian-Aalenian Deposits in the Motorchuna River Section

This work uses the stratigraphy of formations adopted for the Zhigansk structural-facies zone by specialists from SNIIGGiMS and INGG (Devyatov et al., 1988; Shurygin and al., 2000; Knyazev et al., 2007).

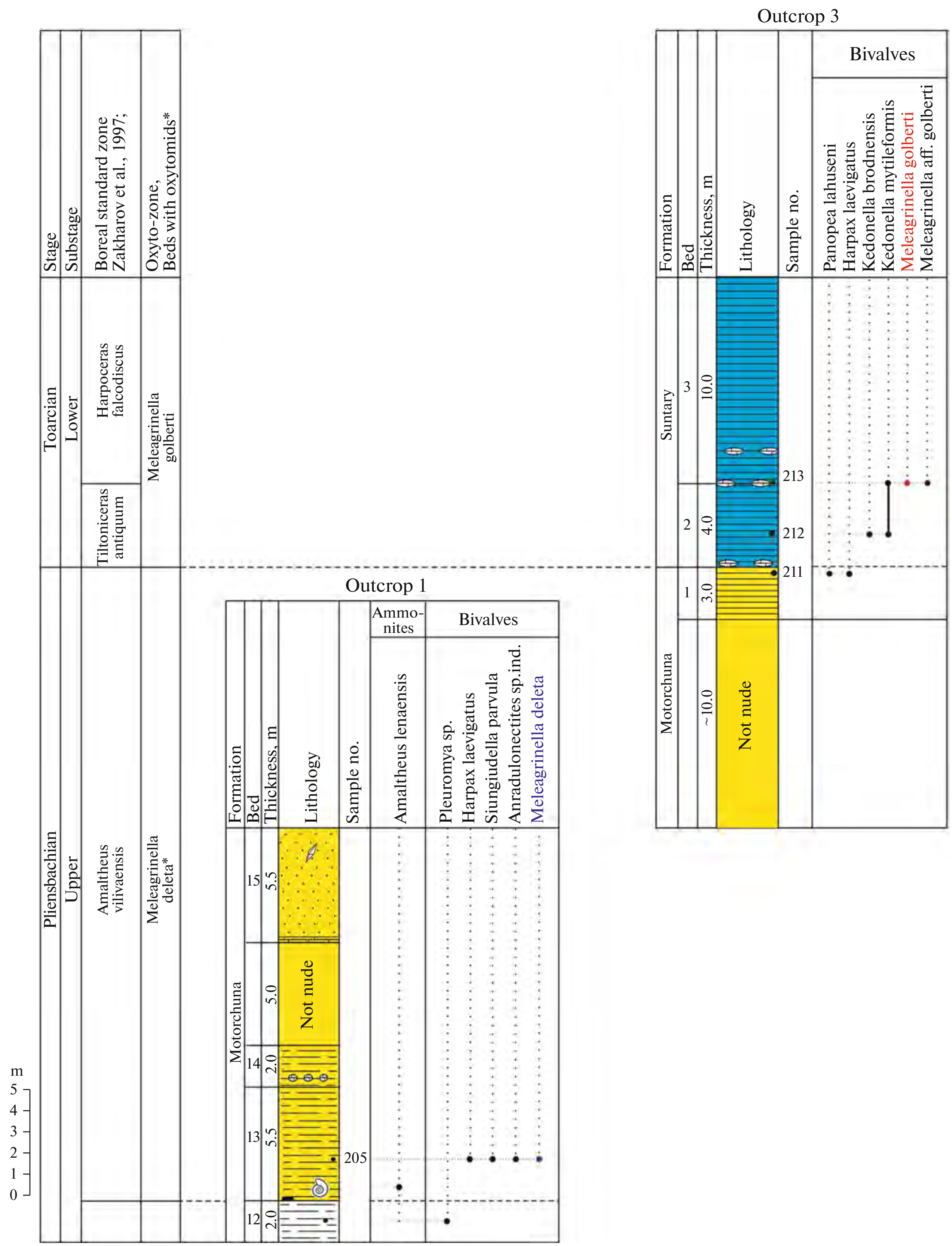

Fig. 51. Stratigraphy and correlation of Pliensbachian–Toarcian deposits along the Motorchuna River based on the distribution of oxyto-zone index species and zonal assemblages. Legend see in Fig. 14.

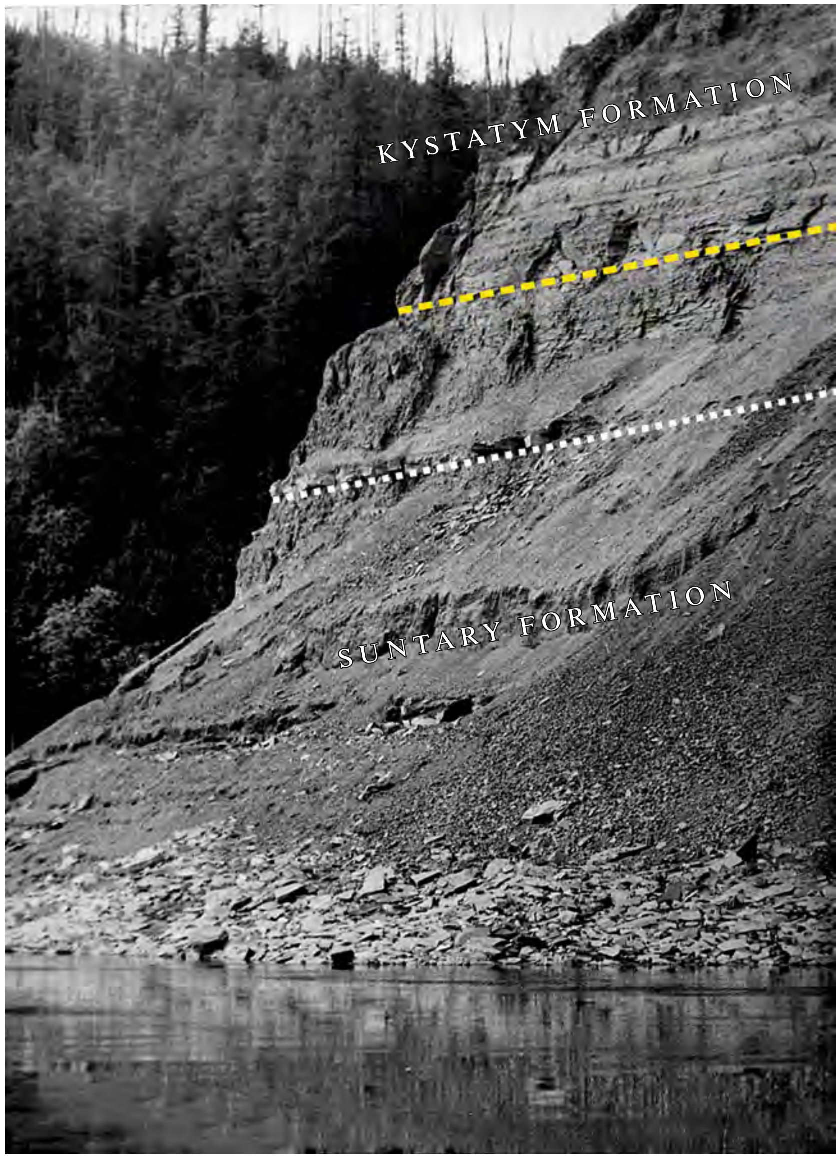

Fig. 52. Motorchuna River, left part of outcrop 4, contact of the Suntary and Kystatym formations. The yellow dotted line is the boundary of the formations, the white dotted line is the Toarcian-Aalenian boundary.

Motorchuna Formation. The age of the Motorchuna Formation was substantiated by Hettangian-Sinemurian bivalves (Bidzhiev, 1965; Devyatov et al., 1991) and Late Pliensbachian ammonites—*Amaltheus* sp., *Amaltheus arcticus* Kosch., *A. brodnensis ventrocalvus* Repin, *A.* ex gr. *margaritatus* Montf. (Kirina et al., 1978). *Amaltheus lenaensis* Repin was listed from the upper part of the Motorchuna Formation (Repin, 2009, 2016).

Suntary Formation. The Suntary Formation, represented predominantly by clays, was first recognized in the Lower–Middle Jurassic section by Yu.L. Slastenov and co-authors in 1976 with a stratotype on the Vilyui River. The Suntary Formation was dated Toarcian–Lower Aalenian (Slastenov et al., 1976). In the sections of the Motorchuna River, Syungyude and Molodo the formation was first traced by V.P. Devyatov et al., 1988; Knyazev et al., 1991. The age of the series assigned to the Suntary Formation in the Zhigansk structural-facies zone was substantiated by finds of Toarcian ammonites: *Dactylioceras gracile* Simps. (Eseleekh-Yurege River—left tributary of the Molodo River), *Pseudolioceras* sp. (Kisilik River—left tributary of the Sungyuyude River) (Bidzhiev and Minaeva, 1961), *Pseudolioceras falcodiscus* (Motorchuna River, 6 km downstream the mouth of the Suordakh River; Sungyuyude River) (Knyazev et al., 1991, 2007), *Pseudolioceras maclintocki* (Motorchuna River, 6 km downstream the mouth of the Suordakh River) (*Stratigrafiya*..., 1976).

Fig. 53. Motorchuna River, right part of Outcrop 4, exposures of the Kystatym Formation.

From this part of the section along the Motorchuna River W.E. Koshelkina cited *Leda acuminata* (Goldf.), *L.* ex gr. *jacutica* Petr., *Arctotis marchaensis* Petr., *Pleuromya* sp., *Phacoides* sp. (Koshelkina, 1959). In the sediments penetrated by Borehole K-65, and on the Muna River section found: *Leda acuminata* (Goldf.), *L.* ex gr. *jacutica* Petr., *Pseudomonotis substriata* Muenst., *Pseudomonotis* aff. *marchaensis* Petr., *Mytiloides quenstedti* Pcel., *M.* aff. *amygdaloides* (Goldf.), *Tancredia* aff. *namanaensis* Petr., *T. stubendorffi* Schm. (Test et al., 1962). Using the biochronological oxytomid scale, three oxytomid zones have been reliably established in this section.

Kystatym Formation. The Nizhnyaya Kystatym and Verkhnyaya Kystatym formations were first identified by V.A. Vakhrameev and Yu.M. Pushcharovsky on the right bank of the Lena River in the area between Horongho and Kystatym capes. The bivalves *Inoceramus formosulus* Voronetz, *In. ussuriensis* Vor. and *Eumorphotis lenaensis lenaensis* Lah., for the Verkhnyaya Kystatym—*Inoceramus elongatus* Kosch. and *In. lenaensis* Kosch. The age of the Nizhnyaya and Verkhnyaya Kystatym formations (=subformations according to *Resheniya...*, 1981) was determined as Aalenian-Bajocian based on their position in the section between the Upper Liassic (=Toarcian) and the Horongho Formation, which contains the ammonites *Arctocephalites* cf. *arcticus* (Newton), considered Bathonian (Vakhrameev and Pushcharovsky, 1954; Vakhrameev, 1958). In accordance with the modern comparison scheme of the standard Middle Jurassic ammonite scale of Western Europe and the standard Boreal ammonite scale (Morton et al., 2020), the age of the Horongho Formation is late Bajocian.

From a sequence of dark gray with a brownish tint fragmented siltstones overlying a member of dark gray sandy and clayey siltstones of the Suntary Formation in the Motorchuna River and Sungyuyude sections, Z.V. Koshelkina defined a bivalve assemblage including *Arctotis lenaensis* Lah., *Retroceramus ussuriensis* Vor., *R. menneri* Kosch., *R. quenstedti* Pcel., *R.* ex gr. *kolymaensis* Bel., *R. aequicostatus* Vor., *R.* ex gr. *retrorsus* Keys., *R.* ex gr. *formosulus* Vor., *Tancredia* ex gr. *stubendorffi* Schm., *Leda* sp., *Modiolus* sp., *Pleuromya* sp., *Phacoides* ex gr. *balkhanensis* Peel. She attributed this sequence to the Lower Aalenian. The overlying succession of light gray fine- and coarse-grained sandstones with loaf-shaped and lenticular interbeds of fine- and medium-grained calcareous sandstones, with rare *Phacoides* ex gr. *balkhanensis* Peel., *Retroceramus* ex gr. *retrorsus* Keys., presumably considered Late Aalenian (Koshelkina, 1959). S.D. Dmitriev subdivided the Lower-Middle Jurassic section in the Motorchuna-Molodo interfluve into the Middle Liassic, Toarcian, Syungyuyudinsky, Nizhnyaya Kystatym, Verkhnyaya Kystatym and Horongho formations. The "Syungyude" Formation, in the understanding of S.D. Dmitriev, is represented by alternating mudstones and siltstones with interbeds of fine-grained

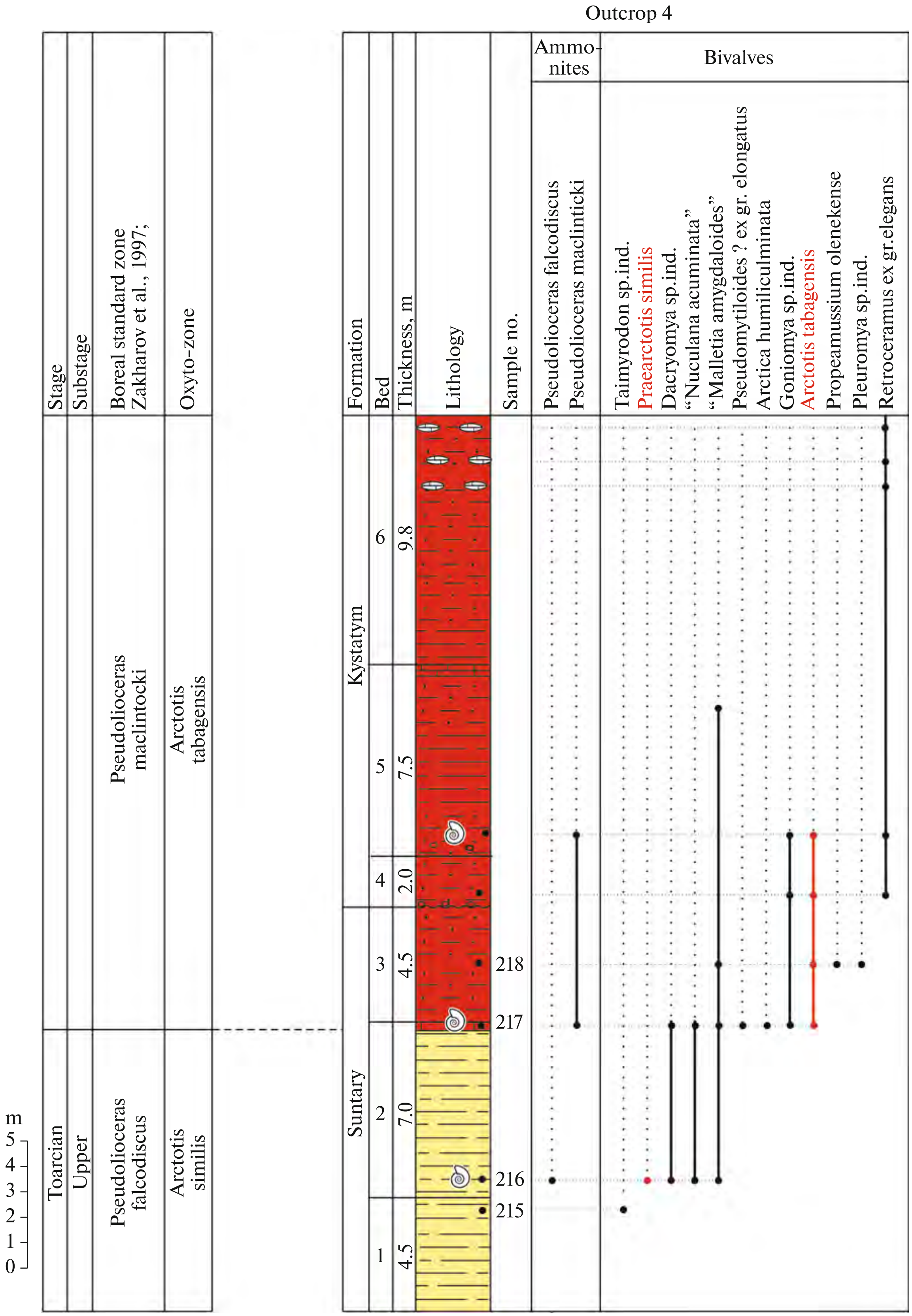

Fig. 54. Stratigraphy of Toarcian-Aalenian deposits in Outcrop 4 (Motorchuna River) based on the distribution of index species of oxyto-zones and zonal assemblages. Legend see in Fig. 14.

calcareous sandstones, with a total thickness of 35 to 50 m, and he assigned it to the Lower Aalenian based on Z.V. Koshelkina's data. The stratotype of the formation was not designated (Dmitriev, 1968). Later T.I. Kirina et al. recognized the "Sungyuyude" Formation with a stratotype on the left bank of the Sungyuyude River for the Zhigansky type of section. It was believed that this sequence, with a stratigraphic gap corresponding to the Toarcian, overlies the Motorchuna Formation and is overlain by the Kystatym Formation, corresponding to the Early Bajocian–Early Bathonian (Kirina et al., 1978). At the same time, T.I. Kirina et al. included the clay member considered by S.D. Dmitriev as Toarcian in the "Sungyuyude" Formation. T.I. Kirina and co-authors correlated the "Sungyuyude" Formation with the Aalenian–Lower Bajocian interval (Kirina et al., 1978; *Resheniya*..., 1981). Later V.P. Devyatov proposed to consider the lower, clayey strata overlying the Motorchuna Formation in the Motorchuna River and Sungyuyude sections as part of the Suntary Formation, and the higher sandy strata to be attributed to the Nizhnyaya Kystatym Subformation (Knyazev et al., 2007). Devyatov et al. (1988) considered the "Sungyuyude" Formation of T.I. Kirina et al. to be invalid. Yu.S. Repin and I.V. Polubotko considered that the "Sungyuyude" Formation of S.D. Dmitriev and Kystatym formations differ profoundly in material composition, thickness and stratigraphic position and form a consistent succession in the section (Repin and Polubotko, 2015b).

In the type section of the Kystatym Formation at Cape Kystatym, there are no lower Beds with Arctotis tabagensis and Retroceramus ex gr. elegans exposed on the Motorchuna River. In this work, the Toarcian-Early Aalenian clayey strata on the Motorchuna River are considered to be part of the Suntary Formation, and the overlying Aalenian-Bajocian strata are assigned to the Kystatym Formation based on the research of V.P. Devyatov and co-authors (Devyatov et al., 1988; Knyazev et al., 2007). The age of the Nizhnyaya Kystatym subformation was dated Early Aalenian based on finds of the ammonites *Pseudolioceras maclintocki* approximately at the level of 3–3.6 m above the base (Bidzhiev and Minaeva, 1961; *Stratigrafiya*..., 1976).

Based on the distribution of index species and zonal assemblages of bivalves in the Pliensbachian-Aalenian deposits of the Motorchuna River section (Figs. 51, 54), 3 oxyto-zones and the Beds with oxytomids were established in the Zhigansk structural-facial zone.

Beds with Meleagrinella deleta. The Beds with Meleagrinella deleta in Outcrop 1 include Beds 12–15, and in Outcrop 3—Bed 1 of the Motorchuna Formation (Fig. 51). The Beds are characterized by the index species *Meleagrinella (Praemeleagrinella) deleta* and an assemblage with *Siungiudella parvula, Anradulonectites* sp. ind. The total thickness of the strata is about 31 m. The accompanying assemblage of foraminifera, represented by *Trochammina sablei*, *Haplophragmoides barrowensis, Ammodiscus glumaceus*, characterizes the upper part of the Trochammina sablei F-Zone, which in northern Siberia corresponds to the two upper Pliensbachian zones (Sapjanik, 1991b). The Beds with Meleagrinella deleta are conditionally correlated with the Amaltheus viligaensis Zone of the Boreal standard (Zakharov et al., 1997).

Meleagrinella golberti Oxyto-zone. In Outcrop 3, the oxyto-zone includes Beds 2 and 3 (Fig. 51). The oxyto-zone was established by the presence of both the index species *Meleagrinella (Praemeleagrinella?) golberti*, and the zonal assemblage with *Kedonella brodnensisis, Kedonella mytileformis, (Praemeleagrinella?)* aff. *golberti*. The upper boundary of the oxyto-zone in the section is drawn at the top of the bed 3. The total thickness of the oxyto-zone is 14.0 m. The Meleagrinella golberti Oxyto-zone correlates with the Tiltoniceras antiquum, Harpoceras falciferum zones of the Boreal standard of the Toarcian Stage.

Arctotis similis Oxyto-zone. In Outcrop 4, Beds 1 and 2 of the Suntary Formation are assigned to the oxyto-zone (Fig. 54). The oxyto-zone is distinguished by the index species *Arctotis (Praearctotis) similis* and zonal assemblage bivalves with *Malletia amygdaloides, Nuculana acuminata*. Visible thickness of the oxyto-zone is 11.5 m. The Arctotis similis Oxyto-zone correlates with the Pseudolioceras falcodiscus Zone of the Boreal standard of the Toarcian stage.

In the Motorchuna River section, the Meleagrinella substriata, Meleagrinella prima, and Arctotis marchaensis Oxyto-zones are not identified. It is likely that the corresponding part of the Motorchuna River section is hidden by omissions in observations, since it is not exposed.

Arctotis tabagensis Oxyto-zone. In Outcrop 4, the oxyto-zone includes the top of Bed 2 and Beds 3–6 (Fig. 54). The oxyto-zone is recognized by the presence of the index species *Arctotis tabagensis* and zonal bivalve assemblage with *Arctica humiliculminata* Schur., *Retroceramus* ex gr. *elegans*. The studied thickness of the oxyto-zone in the outcrop is 23.8 m. *Pseudolioceras maclintocki* was found at the top of Bed 2 in the marker layer of calcareous siltstone in the upper part of the Suntary Formation. The Arctotis tabagensis Oxyto-zone in this section correlates with the Pseudolioceras maclintocki Zone of the Boreal standard of the Toarcian Stage. Based on the conducted analysis, the terminal Beds of the Suntary Formation and the lower subformation of the Kystatym Formation in this section are assigned to the Arctotis tabagensis Oxyto-zone and are considered Lower Aalenian.

Markha River Section

According to the composition and type of sediments, thickness and completeness of sections, the Lower and Middle Jurassic strata in the Markha River basin, Vilyui, Tyung belong to the Suntary structural-facies zone (*Resheniya*..., 1981). The Lower and Middle Jurassic outcrops were studied by the author in the coastal cliffs of the Markha River in 1986 and Vilyui River in 1987 and 2021. Based on materials shared by colleagues, sections along the Tyung River, boreholes of the Tenkelyakh, Pribrezhny, and Ottur sites were studied. Lithostratigraphy of series is based on the studies of V.P. Devyatov (Knyazev et al., 1991). In the Suntary structural-facies zone, the following formations were recognized: Ukugut (Hettangian–Lower Pliensbachian), Tyung (Upper Pliensbachian), Suntary (Toarcian–Lower Aalenian) and Yakut formations (Aalenian–Bathonian) (Shurygin et al., 2000). In the Markha River valley, a series of outcrops expose Pliensbachian-Aalenian deposits (Fig. 55). Outcrop 6 was described by V.G. Knyazev in 1978. Outcrops 6a and 10 were described by the author, who studied them together with V.G. Knyazev (ammonites) and V.V. Sapjanik (foraminifers) in 1986.

Outcrop 6

This outcrop is located on the right bank of the Markha River below the mouth of the Sobo River (Fig. 55). As in 1978 the outcrops were described from top to bottom, the description and association of samples with the fauna in 1986 was also made from top to bottom. Under the soil and plant layer at the top of the coastal cliff the following beds are exposed:

Suntary Formation

Bed 1, visible thickness 2.0 m. Silts are clayey, brown, fissile at the top of the bed. Along the bedding planes and along the cracks there are crystals of calcite and traces of ferrugination. At the base of the bed, consistent along the strike, is an interbed (thickness 0.5 m) of calcareous siltstone, light gray on the weathered surface and blue-gray on the fresh fracture, which contains rounded nodules (up to 0.3 m) of the same composition. On the outer surface of these nodules and less commonly inside them, there are aggregated accumulations and single specimens of *Pseudomytiloides* of various sizes from 0.5 to 3.0 cm.

Bivalves: *Pseudomytiloides marchaensis*, *Dacryomya jacutica*, *Modiolus numismalis* (Sample 223, 223a—basal part of the bed).

Bed 2, thickness 2.0 m. Silts clayey, bedded, bluish on a weathered surface and dark gray when freshly fractured. At the bottom of the bed there is an interbed of septarian sandy siderites (thickness 0.4 m) red-brown on the weathered surface and dark gray on the fresh fracture. Along bedding planes and along cracks there are crystals of calcite. In the bed and inside the nodules there are numerous aggregations of *Pseudomytiloides* ranging in size from 0.5 to 4.0 cm and single *Arctotis*.

Bivalves: *Praearctoris marchaensis*, *Pseudomytiloides marchaensis*, *Dacryomya jacutica* (Sample 227k—from the bed).

Bed 3, thickness 8.5 m. Clays light gray, weathered to blue, with thin (20 cm) interbeds of brownish-brown silts. Throughout the bed there is calcite and traces of ferrugination. At 1.0 m from the base of the bed there is an interbed of elongated calcareous concretions with charred wood trunks (1.0 × 0.4 m). At the top of the bed there is a consistent interbed of spherical nodules of light gray limestone (0.9 × 0.4 m), enclosing cylindrical phosphate nodules with an abundant fauna of *Pseudomytiloides*, oysters, *Oxytoma*, *Dacryomya* and belemnites. Slightly rounded pebbles up to 3 cm in diameter were also found here. The lower boundary of the bed is drawn along the change of rocks and is emphasized by pebbles of brown clay. In the bed of many small nut-shaped and ovoid phosphate nodules with a fauna of small *Dacryomya* and ammonites, rare belemnites are found.

Ammonites: *Zugodactylites braunianus*, *Catacoeloceras crassum* (Knyazev et al., 2003).

Bivalves: *Pseudomytiloides oviformis*, *Meleagrinella (Meleagrinella) prima*, *Dacryomya jacutica*, *Liostrea (Deltostrea) taimyrensis*, *Oxytoma kirinae*, *Dacryomya jacutica* (Sample 228, 228a—1 m from the bed; Sample 229—throughout the bed; Sample 228).

Bed 4, thickness 4.5 m. Clays silty, dark gray, platy, rusty-brown on the surface, ferruginous; calcite crystals are found along the bedding planes. The lower boundary is drawn along the base of light gray marly limestone, the lower and upper surfaces of which have a “cone-in-cone” texture.

Bivalves: *Lenoceramus vilujensis*, *Dacryomya jacutica* (Sample 231r, 240, 240a).

Bed 5, thickness 0.5 m. Clays brownish-gray on the weathered surface and bluish when freshly fractured, viscous. The lower boundary is emphasized by a 3-cm layer of highly ferruginous bright brown sandstone. At the base, there is a layer of quartz gravel, diabase, reptile bones and crushed belemnites.

Ammonites: *Dactylioceras* sp. (Knyazev et al., 2003).

Bed 6, thickness 1.3 m. Silts are highly sandy, greenish-tobacco in color. The bed contains many small round, ovoid and elongated phosphorite nodules up to 3–5 cm in size. These concretions contain small gastropods, *Pleuromya*, small *Dacryomya*, vertebrae, bones of large vertebrates, and belemnites. At the base of the bed there is a highly weathered marly interbed with the fauna of gastropods, belemnites, and *Dacryomya*. At the base there is an interbed (20 cm) of black and white sands. The lower boundary is not even.

Bivalves: *Kedonella mytileformis*, *Dacryomya jacutica*, *Liostrea (Deltostrea) taimyrensis*, *Tancredia bicarinata*, *Pleuromya* sp. ind. (Sample 251).

Bed 7, thickness 9.0 m. Clays from light gray to black-brown, with interbeds of sandstones, marls and limestones. In the bed and in the interbeds, ovoid nodules with a fauna of small gastropods, crustaceans, poorly preserved bivalves and belemnites were found. At the base there is a gravelite interbed.

Bivalves: *Dacryomya jacutica*.

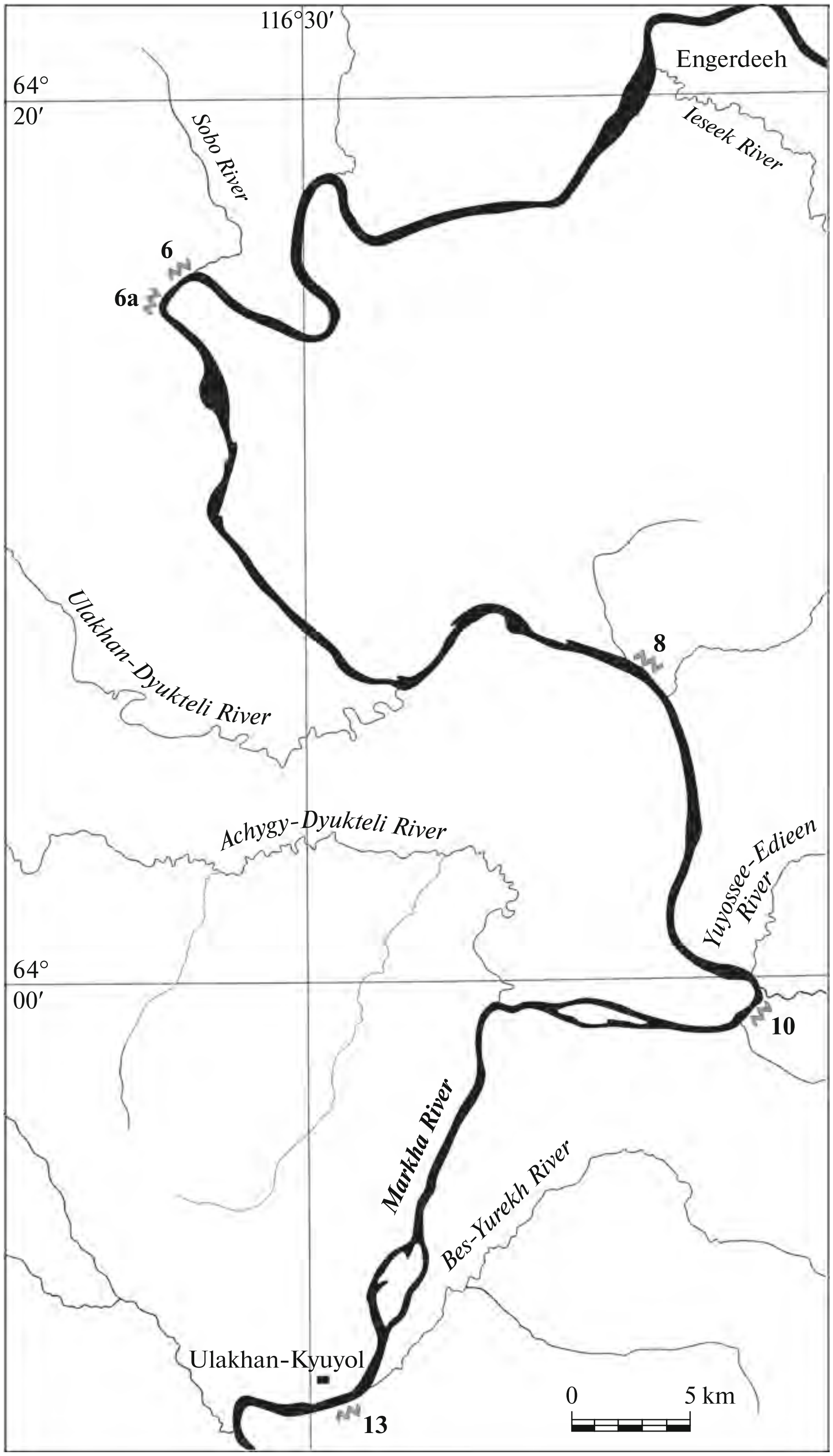

Fig. 55. Studied of outcrops at Markha River.

Tyung Formation

Bed 8, thickness 1.2–4.0 m. Sands yellowish, with interbeds (up to 10–20 cm) of brown clays. The conglomerate at the base of the bed contains shells of *Harpax* and *Pleuromya*.

Bivalves: *Pleuromya* sp. ind., *Harpax laevigatus*. In Outcrop 6a, located 300 m downstream the mouth of the Sobo River, *Lenella tiungensis* and *Loitrigonia lingonensis* were found in the sands of the Tyung Formation.

A stratigraphic scheme of the Pliensbachian-Toarcian deposits in Outcrop 6 is shown in Fig. 56.

Outcrop 10

Located on the left bank of the Markha River, 0.35–0.5 km downstream the mouth of the Lohaiy River (Fig. 55). In a coastal cliff about 80 m high, Lower and Middle Jurassic deposits opened up by clearing in ditches are exposed in several outcrops. From top to bottom the following beds are exposed:

Outcrop no. 1. Located 0.35 km below the mouth of the Lohaiy River.

Yakut Formation

Bed 1, visible thickness 1.0 m. Alternation of light gray and brownish-brown sands, loose, with layers (up to 2 cm) of coals and pebbles. The lower boundary is drawn by an interbed (up to 0.1 m thick) of pebbles made of quartz grains and spherical sandstone oolites.

Bed 2, thickness 3.0 m. Sands are light gray, fine-grained, interbedded with coals in the upper part. At the level 1.2 m below the top is a horizon of siderite sandstone nodules, gray on the surface, brown inside, dense. Coal lenses are scattered throughout the bed. At the base of the bed there is a lens (1.0 × 10.0 m) of gray, dense, thin-slabbed, cross-bedded sandstone.

Bed 3, thickness 1.8 m. Alternation of light gray and brown sands, cross-bedded, with layers of coal.

Suntary Formation.
Lohaiy Beds

Bed 4, thickness 7.8 m. Alternation of green-gray silty clays, brownish-yellowish clayey-sandy silts, sandy gray silts, brown thin-platy silts. The lower boundary is even, based on the change of rocks.

Bed 5, visible thickness 0.5 m. Sands light gray, loose, with multiple discoidal concretions (thickness up to 7 cm) of brown sandstone on the surface, light gray in fresh fracture, sometimes inky, dense.

Outcrop no. 3. Located on the left bank of the Markha River, 0.5 km downstream of the mouth of the Lohaiy River. Here a marker horizon with multiple nodules of Bed 5 is exposed. Bed 5 is overlain by:

Bed 5, thickness 1.2 m. Alternation of gray sands and brown-yellow silts. At the level 0.6 and 0.9 m below the top there are consistent horizons of siderite sandstone, reddish-brown on the outside, light gray in fresh fracture. At the base of the bed there is a horizon (thickness 0.2 m) of the same sandstones.

Bed 6, thickness 1.8 m. Sands light gray, loose, with individual carbonate sandstone nodules of irregular shape. At the level of 0.3 m below the top, there is a horizon of carbonate sandstone, greenish-gray, dense. The lower boundary, even—based on the change of rocks, is emphasized by individual pyrite concretions of irregular shape. At the base there is an interbed of reddish-brown pyritized sandstone with conglomerate consisting of quartz, flints, charred wood.

Bed 7, thickness 11.9 m. In the upper part, in the interval 11.9–6.6 m, there are silts sandy, gray with a bluish tint; in the lower part, the silts are brown, platy. In the upper part of the bed there are numerous irregularly shaped pyrite concretions and charred tree trunks. At the base of the bed is a concretional horizon (0.3 m) of sideritized siltstone, with *Maclernia, Praearctotis, Tancredia, Dacryomya, Modiolus,* and *Pleuromya*.

Bivalves: at the level 1.8 m above the base of the bed—*Praearctoris* ex gr. *marchaensis* (frequent), *Maclearnia kelimyarensis* (rare), *Dacryomya* sp. ind. (rare), *Tancredia* sp. ind. (rare), *Tancredia securiformis* (rare). At the base of the bed—*Maclearnia kelimyarensis* (very frequent), *Praearctoris marchaensis* (frequent), *Modiolus numismalis* (rare), *Tancredia securiformis* (very frequent), *Tancredia* sp. ind. (frequent), *Pleuromya* sp. ind. (frequent).

In the middle of the bed along the strike of the bed in Outcrop no. 2, located on the left bank of the Markha River 0.4 km below the mouth of the Lohaiy River, downstream of the *Arctotis (Praearctotis)* River sp. ind., *Tancredia securiformis, Dacryomya* sp., *Tancredia* sp. ind., *Pleuromya* sp. ind., gastropods.

Member III (after Knyazev et al., 1991).

Bed 8, thickness 5.2 m. Silts clayey, dark gray, slabby. At the base there is a horizon (0.2 × 1.0 m) with concretions of calcareous siltstone. Above are spherical and fusiform nodules of calcareous sandstone. Scattered in the bed are individual concretions of sideritized siltstone, red-brown on a weathered surface, dark blue in fresh fracture, with *Arctotis*.

Ammonites: *Pseudolioceras compactile*—from the concretion horizon at the base of the bed (Sample 351).

Bivalves: *Praearctoris marchaensis*—2.7 m below the bed (Sample 233), in the interval 2.0–5.6 m (Sample 356, 357, 358), *Pseudomytiloides marchaensis*—in spherical nodules near the base of the bed (Sample 234), in the interval 0–2.0 m (Sample 352, 354), gastropods at the base of the bed (Sample 235-g).

Bed 9, thickness 3.5 m. Silts are clayey, dark gray, platy, with calcareous siltstone concretions with *Pseudomytiloides* and discoidal concretions with *Meleagrinella*. At the base of the bed there is a consistent marking horizon of calcareous siltstone (thickness up to 0.8 m). When tracing the lower marker horizon, it was established that its upper boundary is not even, with traces of erosion, above it is the accumulation of spindle-shaped nodules with coquinae of bivalves and belemnites, small pebbles, charred wood and phosphorite nodules.

Ammonites: *Dactylioceras* cf. *commune*—from the base of the bed (Repin, 1991).

Bivalves: *Pseudomytiloides oviformis*—in spheroidal concretions (Sample 234, 237—0.1 m above a marker horizon; Sample 240—0.3 m below the top), gastropods at the base of the bed (Sample 235-g), *Meleagrinella (Meleagrinella) prima* (Sample 236, 237—0.1 m above the marker horizon; Sample 238—from the base of the bed; Sample 239—0.3 m below the top), *Dacryomya jacutica*, *Tancredia bicarinata*, *Lenoceramus vilujensis*, *Oxytoma kirinae* (Sample 237a, 237b—0.1 m above the marker horizon). *Luciniola* sp. was found in the scree of the bed (Sample 241).

Bed 10, visible thickness 2.5 m. Clays dark greenish-gray, sandy, with lens-shaped inclusions of bluish-gray viscous clays. Throughout the bed, spherical and fusiform nodules of limestone are found, light gray on the weathered surface and bluish-green on the fresh fracture. The lower horizon of nodules (size 0.5 × 1.5 m) lies at the waterline. The bed contains many small (up to 0.3 m) flat and fusiform limestone nodules, which are randomly distributed. In approximately the middle of the bed, entire trunks of charred wood with *Liostrea* attached to them were found. The lower boundary of the bed continues below the waterline.

The stratigraphy of Toarcian-Aalenian deposits in Outcrop 10 is shown in Fig. 57.

Stratigraphy and Correlation of Pliensbachian-Aalenian Deposits in the Markha River Section

The lithostratigraphy in the Suntary structural-facies zone is based on the studies of V.P. Devyatov (Devyatov, 1985; Knyazev et al., 1991; Shurygin et al., 2000).

Tyung Formation. The formation was first recognized by T.I. Kirina in the Lower Jurassic section with a stratotype on the Tyung River 2.5 km upstream the mouth of the Ilin-Sala River. In the Suntary structural-facies subregion, the formation was established on the Tyung, Vilyui, Markha, Sinyaya, Linda rivers and in several boreholes (Kirina et al., 1978). The age of the formation was substantiated by Late Pliensbachian ammonites *Amaltheus margaritatus* (Montf.), discovered on the Vilyui River (Koshelkina, 1961). The formation was subdivided by T.I. Kirina into four packages, V.G. Knyazev et al. into three packages (Knyazev et al., 1981). The fourth member included a unit of shale-like clays in the sections of the Sinyaya and Vilyui rivers, from which belemnites with "Pliensbachian" bivalves were recorded. When the author re-examined the Vilyui River section together with N.G. Zverkov, A.P. Ippolitov and M.A. Rogov in 2021 established that the first poorly preserved belemnites *Arcocoelites* sp. ind. (identification by A.P. Ippolitov) appear in lenses of lithified ferruginous rocks at the boundary of the Tyung and Suntary Formations (Fig. 58). Bivalves are not found in the lenses.

The overlying dark gray clay unit also contains numerous weathered belemnite rostra. The clay member is dated to the Early Toarcian (Meleagrinella golberti Oxyto-zone) based on bivalves *Kedonella* ex gr. *mytileformis* Polub., found in a concretionary bed at the level of 1.2 m from its base. The age of the lens with belemnites is tentatively assumed to be Early Toarcian.

Suntary Formation. The Suntary Formation, represented predominantly by clays, was identified in the Lower—Middle Jurassic section by Yu.L. Slastenov in 1976 with a stratotype on the Vilyui River in the area of the Iligir River (Slastenov et al., 1976). The Toarcian age of the formation was based on the ammonites: *Eleganticeras elegantulum*, *Harpoceras exaratum*, *Dactylioceras commune*, *D. athleticum*, *D. suntarense*, *D. kaneense*, *D. crassifactum*, *D. amplum*, *Harpoceras subplanatum*, *Zugodactylites braunianus*, *Z. monestieri*, *Pseudolioceras compactile*, *Ps. wurttenbergeri,* etc. (Koshelkina, 1961; Slastenov, 1973; Slastenov et al., 1976; Knyazev et al., 2003). T.I. Kirina and her coauthors recognized the Lohaiy Beds with a stratotype on the Markha River at the mouth of the Lohaiy River within the Yakut Formation. (Outcrop 10). The thickness of the Beds was determined from 25 to 35 m. However, the area of their distribution was not indicated. The Beds were assigned to the upper Aalenian and the base of the Bajocian (Kirina et al., 1978; *Resheniya*..., 1981). The lower boundary of the Lohaiy Beds in the stratotype was located 8.8—10.9 m above the marker horizon of calcareous siltstone up to 1.2 m thick (Repin, 1991) and approximately corresponds to the base of Bed 7 in Outcrop 10 (Fig. 57). From the Lohaiy Beds, *Arctotis similis, Maclearnia kelimyarensis, Modiolus numismalis, Mytiloceramus* aff. *porrectus* (Eichw.), *Isognomon* sp. were listed. The rationality of distinguishing these beds at the rank of lithostraton of local scales still remains unclear. It was proposed to consider them as a member (lens) as part of the Yakut Formation (Shurygin and others, 2000). However, the most dramatic changes in the chemical and mineral composition of the rocks were recorded at the boundary of the Lohaiy Beds with the Yakut Formation, and not with the Suntary Formation (Devyatov, 1985, p. 87), therefore this lithostratum, apparently, should be attributed to the Suntary Formation.

Yakut Formation. The Yakut Formation, represented predominantly by sands and sandstones with siltstone units, conglomerate interbeds, lenses of coals and carbonaceous rocks, was identified in the Lower—Middle Jurassic section by Maksimov (1941) with a stratotype on the Lena River in the area of Yakutsk. Interbeds of marine origin with bivalves are not found everywhere in the Yakut Formation. The age of the Yakut Formation is considered to be Aalenian-Early Bathonian (Shurygin et al., 2000). In the Suntary structural-facies subregion on the Markha River, light gray sloping bedded sands with interbeds of pebbles and weakly cemented conglomerates lie above the Lohaiy Beds. The sands are characterized by rough sorting and contain scattered pebbles, carbonized plant detritus, interbeds and lenses of coals. Boulders and sometimes blocks of igneous and sedimentary rocks are associated with diastemas. In the Yakut Formation, the Beds with Arctotis lenaensis of late Aale-

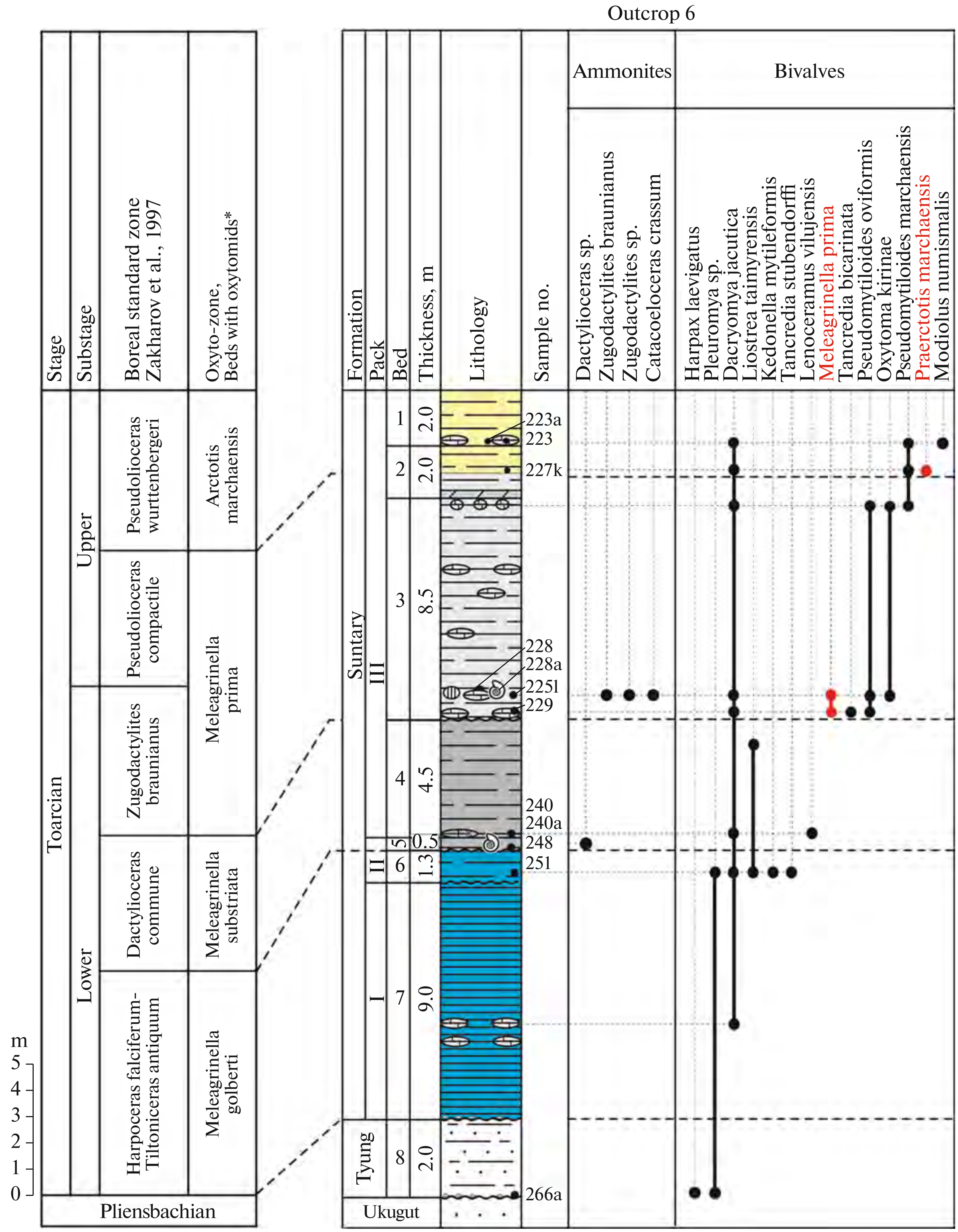

Fig. 56. Stratigraphy of Pliensbachian–Toarcian deposits in Outcrop 6 (Markha River) based on the distribution of oxyto-zone index species and zonal assemblages. Legend see in Fig. 14.

nian-Early Bajocian age were previously identified (Knyazev et al., 1991).

Based on the distribution of index species and zonal assemblages of bivalve mollusks in the Pliensbachian–Toarcian deposits of the section of the Markha rivers (Figs. 56, 57), Vilyui, Tyung and boreholes of the Tenkelyakh exploratory drilling site, six oxyto-zones and two were established for the Suntary struc-

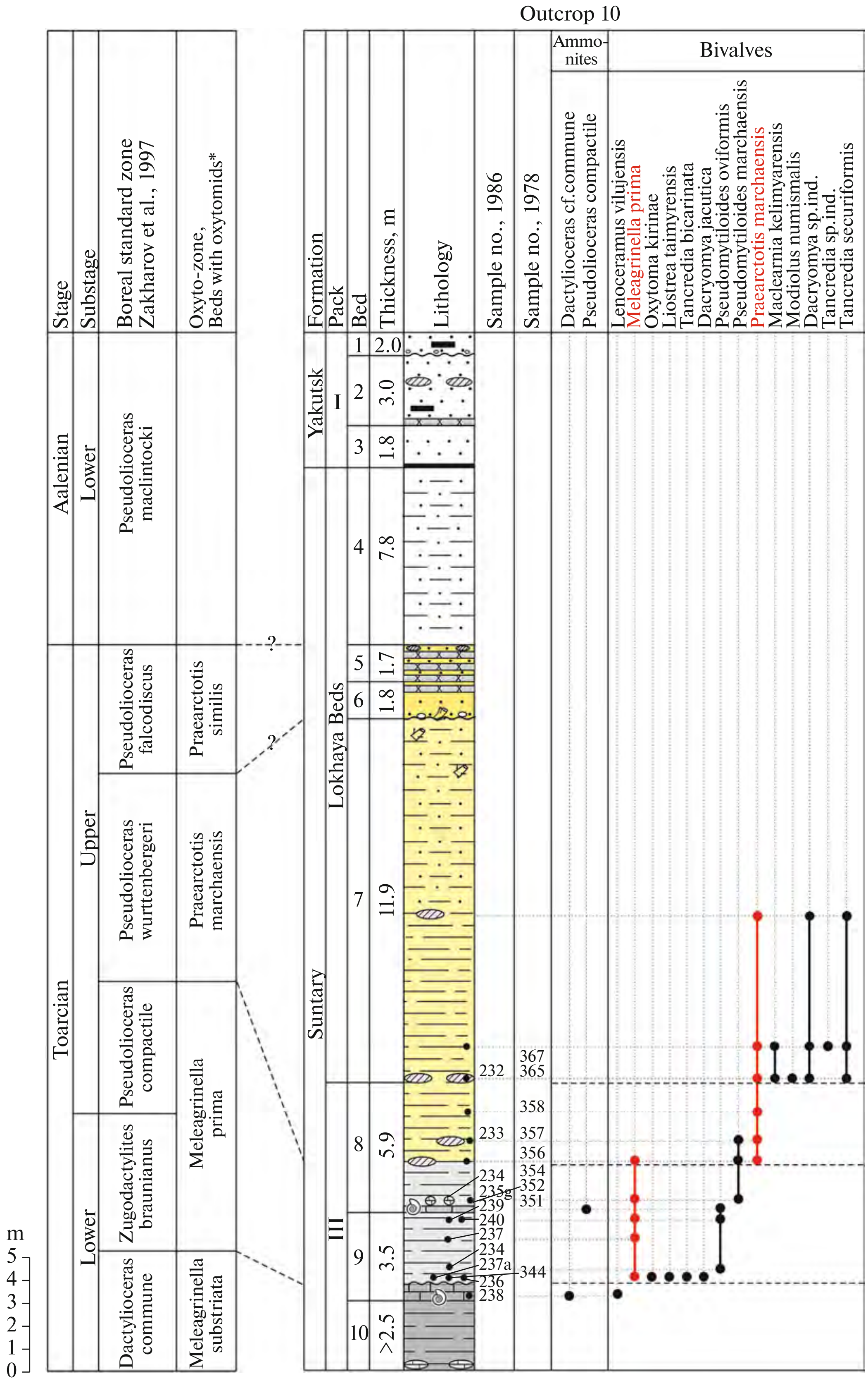

Fig. 57. Stratigraphy of Toarcian-Aalenian deposits in Outcrop 10 (Markha River) based on the distribution of oxyto-zone index species and zonal assemblages. Legend see in Fig. 14.

Fig. 58. Contact of the Tyung and Suntary Formations on the Vilyui River. Yellow dotted line—formation boundary, white dotted line—upper boundary of the lens, white arrow—coquina with belemnites.

tural-facies zone biostratum in the rank of Beds with oxytomids.

Beds with Meleagrinella deleta. Based on the finds of the index species, the Beds were traced in the base of the Markha River on the Tenkelyakha Site (Tyukyan-Markha interfluve) (line 160, Borehole 36, depth 94.2 m) and on the Right Bank site (Markha-Vilyui interfluve) (line 524, well 546.5, depth 18.6 m). At the top of the Tyung Formation on the Tyung River and Vilyui, the index species of the Beds with Meleagrinella deleta is not found; the species Meleagrinella sparsicosta is widespread here, the biozone of which in the section of Anabar Bay covers Beds with Meleagrinella deleta and older deposits. On the Markha River, the thickness of the Tyung Formation is small, and, apparently, here it is represented only by the upper member, since numerous *Liotrigonia lingonensis* found in it are characteristic only of the terminal part of the Pliensbachian in other sections of the Suntary structural-facies subregion (Vilyui River, Tyung).

Meleagrinella golberti Oxyto-zone. In Outcrop 6 at Markha River, the oxyto-zone includes Beds 6–7. The oxyto-zone is identified by zonal assemblage of bivalves with *Kedonella mytileformis*, *Tancredia stubendorffi*, and *Dacryomya jacutica*. The upper boundary is drawn by the appearance of assemblage bivalves of the overlying oxyto-zone at the base of Bed 5 (Fig. 56). The thickness of the oxyto-zone in Outcrop is 6–10.3 m.

Meleagrinella substriata Oxyto-zone. In Outcrop 6 on the Markha River, Beds 4–5 are assigned to the oxyto-zone. In Outcrop 10, the oxyto-zone includes a thickness that includes interbed at the base of Bed 9 and Bed 10. The oxyto-zone is established according to the zonal assemblage of bivalves with *Lenoceramus vilujensis*. The upper boundary in Outcrop 6 is drawn by the appearance of assemblage bivalves of the overlying oxyto-zone at the base of Bed 3 (Fig. 56), in Outcrop 10—1.0 m above the base of Bed 9 (Fig. 57). The thickness of the oxyto-zone is 5.0–7.5 m.

Meleagrinella prima Oxyto-zone. In Outcrop 6 at the Markha River, the oxyto-zone includes the strata that includes Bed 3 and the lower part of Bed 2; in Outcrop 10, the oxyto-zone includes the upper part of Bed 9 and the lower part of Bed 8. The oxyto-zone is identified by the index species Meleagrinella (Meleagrinella) prima and zonal assemblage of bivalves with *Pseudomytiloides oviformis, Pseudomytiloides marchaensis*. The thickness of the oxyto-zone is 9.5–16.0 m. The index species of the oxyto-zone was recorded in Borehole 350 of line 1060 of the Tenkelyakh area at a depth of 31.0 m (Fig. 59).

The Arctotis marchaensis Oxyto-zone. In the sections of the Suntary structural-facies subregion, this oxyto-zone is traced everywhere (Vilyui River, Markha, Tyung, boreholes). At the Markha River in Outcrop 6, the oxyto-zone includes the upper part of

Bed 2 and Bed 1 (Fig. 73); in Outcrop 10, the upper part of Bed 8 and Bed 7 are assigned to this oxyto-zone (Fig. 57). The oxyto-zone is identified by the index species *Arctotis (Praearctotis) marchaensis*. The total thickness of the oxyto-zone is about 15 m. The index species of the oxyto-zone was recorded in Borehole 350 of line 1060 of the Tenkelyakh area at a depth of 22.5 m (Fig. 59).

Arctotis similis Oxyto-zone. In the sections of the Suntary structural-facies subregion, this oxyto-zone is not traced everywhere. On the Markha River, *Arctotis (Praearctotis) similis* was recorded from a unit of sands with small ferruginous oolites, separated below by a thin conglomerate (Outcrop 15 according to T.I. Kirina) (Kirina, 1966, 1976). Presumably, this member corresponds to Beds 5 and 6 in Outcrop 10. The thickness of the oxyto-zone is about 3.5 m (Fig. 57). At the Vilyui River level, *Arctotis (Praearctotis) similis* was traced in outcrops 17 and 19 (according to Knyazev et al., 1991).

Arctotis tabagensis Oxyto-zone. In sections of the Suntary structural-facies subregion oxyto-zone is not traced everywhere. On the Lena River oxyto-zone is recognized in the upper part of the Suntary Formation in the section on Tabaginskiy Cape. This includes a sequence of gray platy sandstones, fine- and medium-grained, with pebbles of clayey rocks, 10 m thick, located below the cross-bedded sandstones of the Yakut Formation (Akimova, 2008). In the Markha–Tyukyan interfluve at the Tenkelyakh exploratory drilling site, the index species of the oxyto-zone was recorded along line 160, Borehole 36, at a depth of 26.0 m (Fig. 59).

Beds with Arctotis sublaevis. In sections of the Suntary structural-facies subregion, the Beds with Arctotis sublaevis are not traced everywhere. In the Tyung River section, the Beds with Arctotis sublaevis should presumably include Beds 10–16 of the Yakut Formation in Outcrop 15 (according to Knyazev et al., 1991). Based on finds of the species *Retroceramus jurensis*, which is part of the zonal assemblage of the biostraton, the Beds were traced at the Tenkelyakha exploratory drilling site in the Markha-Tyukyan interfluve along line 160 in Borehole 36, at a depth of 4.0 m (Fig. 59).

Sections along the Tributaries of the Levy Kedon River

Based on the composition and type of sediments, thickness and completeness of sections, the Lower and Middle Jurassic strata in the Levy Kedon River basin belong to the Levy Kedon stratigraphic zone (*Resheniya*..., 2009). Outcrops of the Lower and Middle Jurassic were studied by the author in the coastal cliffs of the tributaries of the Levy Kedon River in 1980 together with V.G. Knyazev (ammonites), V.P. Devyatov (lithology), V.V. Sapjanik (foraminifers) (Fig. 60).

The formation breakdown of the Toarcian strata and overlying deposits is the subject of discussion. According to the decisions of the 3rd Interdepartmental Regional Stratigraphic Meeting on the Precambrian, Paleozoic and Mesozoic Northeastern Russia (St. Petersburg, 2002), in the Lower–Middle Jurassic in the Levy Kedon stratigraphic zone there are: Brodnaya (Lower Pliensbachian), Nalednyi (Upper Pliensbachian), Start (Toarcian) and Saturn formations (Lower Bajocian) (Repin and Polubotko, 1996; *Resheniya*..., 2009). According to the ideas of specialists from SNIIGGiMS and INGG, the Toarcian sequence is divided into the Astronomicheskaya and Mrachnyi formations, the overlying deposits belong to the Eksa formation, presumably of Aalenian age (Knyazev et al., 2003).

Astronomicheskaya River Section

Outcrop 2 is located on the left bank of the Astronomicheskaya River, 6.0 km upstream of the mouth of Start Creek (Fig. 60). At a height of 1 m from the water's edge, the upper Beds of the Naledninskiy Formation are exposed. The section is stratotypical for two oxyto-zones of the biochronological scale.

Nalednyi Formation

Bed 1, visible thickness 1.1 m. Clays silty, horizontally bedded, dark gray, brownish and yellow. At a height of 0.15 m there are lenticular concretions of calcareous siltstone. At the level 1.0 m there is a lens of dark gray, fine-grained sandstone.

Bivalves: level 0.5 m—*Meleagrinella (Praemeleagrinella) deleta* (Dum.) (frequent), *Meleagrinella (Praemeleagrinella?) oxytomaeformis* Polub. (frequent), *Kolymonectes* aff. *terekhovi* (Polub.) (rare), *Oxytoma inaequivalvis* (Sow.) (rare) (Sample 43).

Bed 2, thickness 2.5 m. The siltstones are greenish-gray, sandy, massive and fissured at the top.

Ammonites: *Amaltheus viligaensis* (at the base and at the top of the bed).

Bivalves: lower part of the bed—*Meleagrinella (Praemeleagrinella) deleta* (Dum.) (frequent), *Liotrigonia* cf. *lingonensis* (Dum.), *Bureiamya ordinata* Polub. (frequent), *Harpax* ex gr. *spinosus* (Sow.) (very rare), *Pseudomytiloides?* sp. ind. (frequent), *Pleuromya* aff. *galathea* Agass. (rare), gastropods (Sample 45); upper part of the bed—*Oxytoma inaequivalvis* (Sow.) (rare), *Lenella kedonensis* (Polub.) (very rare), *Kolymonectes* aff. *terekhovi* (Polub.) (frequent), *Tancredia omolonensis* Polub. (rare), *Taimyrodon plinsbachensis* Schur., *Pseudomyiloides* sp. ind. (frequent) (Sample 46), brachiopods.

Bed 3, thickness 0.8 m. Siltstone clayey-sandy, yellowish-gray.

Ammonites: *Amaltheus viligaensis*.

Bivalves: in nodules in the bed—*Meleagrinella (Praemeleagrinella) deleta* (Dum.) (frequent), *Meleagrinella (Praemeleagrinella?) oxytomaeformis* Polub. (frequent), *Oxytoma inaequivalvis* (Sow.) (frequent),

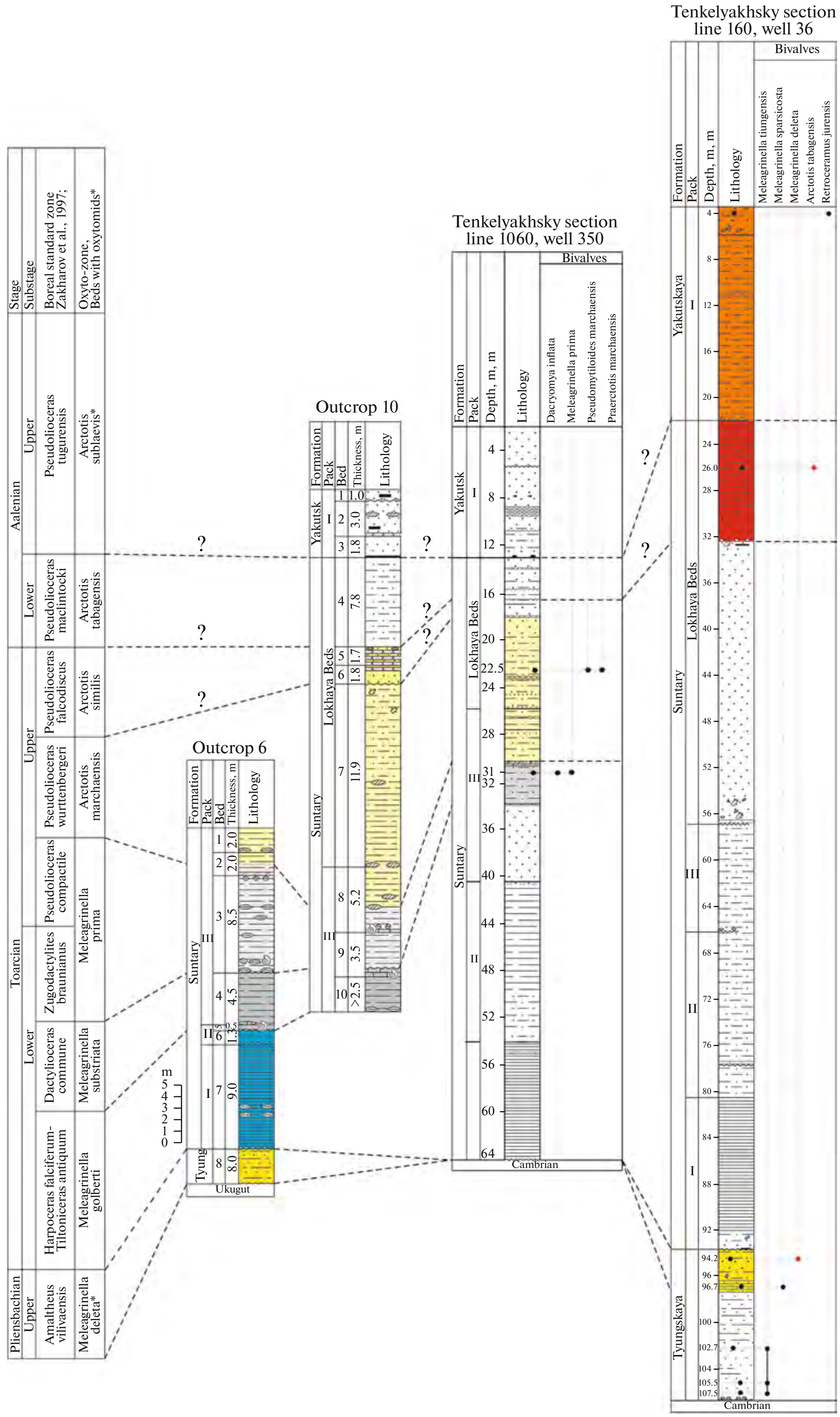

Fig. 59. Stratigraphy and correlation of Pliensbachian–Aalenian deposits in the Markha River basin and Tenkelyakh area based on the distribution of index species of oxyto-zones and zonal assemblages. Legend see in Fig. 14.

Kolymonectes aff. *terekhovi* (Polub.) (frequent), *Pleuromya* aff. *galathea* Agass., *Tancredia omolonensis* Polub., *Pseudolimea philatovi* (Polub.) (rare), *Schafaeutlia plinsbachensis* Schur. (rare) (Sample 48, Sample 49—scree of the bed), brachiopods.

Bed 4, thickness 1.2 m. Interbedding of dark and yellow-gray siltstones. At levels 0.1; 0.7; 1.0 m lens of sideritized siltstones. At the levels 0.1; 0.7; 1.0 m, sideritized siltstone lenses.

Start Formation. Lower subformation

Bed 5, thickness 10.0 m. Clays silty, with some fine-grained sand and occasional gravelly phosphate material. The rocks are dark gray, brownish on the surface. At the base at levels 0.8; 1.4; 2.4; 3.4; 4.2; 4.4; 6.0; 7.6; 8.1; 8.5; 9.4 m in the ditches, small (5–10 cm wide and 30–40 cm long) phosphate-calcareous nodules of silty mudstone were found. The upper boundary of the uneven layer, gently undulating with an amplitude of 1–3 cm per 0.5 m, follows a layer (2–5 cm) of yellow clays with lenses of carbonized plant detritus.

Ammonites: *Tiltoniceras antiquum*, *Coeloceras crosbeyi*, *Nodicoeloceras catinus* (Knyazev et al., 2003).

Bivalves: in concretions at the level 0.8 m—*Meleagrinella (Praemeleagrinella?) golberti* Lutikov et Arp (many), *Tancredia stubendorffi* Schmidt (many) (Sample 53); level 1.4 m—*Meleagrinella (Praemeleagrinella) golberti* Lutikov et Arp (frequent), *Entolium kedonense* Milova (rare) (Sample 54); level 2.4 m—*Meleagrinella (Praemeleagrinella?) golberti* Lutikov et Arp (very rare), *Pleuromya* sp. (very rare), *Entolium kedonense* Milova (very rare), *Pholadomya idea* Orb. (rare), *Pseudolimea philatovi* (Polub.) (Sample 55); level 6.0 m—*Entolium kedonense* Milova (rare), *Pholadomya idea* Orb. (rare), *Liostrea subtaimyrensis* Milova (rare) (Sample 56, 3.4 m; Sample 58a).

Bed 6, thickness 6.3 m. Clays slightly silty and silty, dark gray, massive, with horizontal microbedding, lenses of furialization. At the level 2.0; 2.3; 2.8; 3.3; 4.1; 4.6 m from the base - lens-shaped nodules of phosphate-calc-clay composition with an admixture of fine-grained silt, up to 0.15–0.25 m wide and up to 1.5–2.0 m long.

Bed 7, thickness 3.0 m. Siltstones are highly clayey, dark gray with a greenish tint, lenticular- and micro-horizontal-bedded. Up the section, the siltstones become sandy-clayey, greenish-gray, with nodules of phosphate-calcareous composition in the last meter. At the base and top of the bed there are interbeds of highly sandy coarse-grained siltstone, horizontally bedded, 5 cm thick. Rare belemnite rostra appear for the first time in this bed.

Bed 8, thickness 1.7 m. The siltstones are sandy, with an uneven distribution of clayey material, dark greenish-gray, in the weathered wall of the outcrop—yellowish, bluish, brownish, at the base—with lenses of highly sandy varieties. In the layer, especially at the bottom, there are many phosphate-calcareous nodules of clayey silt with sprinkles of fine-grained sand on bedding planes. Due to the heterogeneity of the rocks, the beds have a banded structure. Individual nodules along the strike transform into lens-shaped concretions (0.1–0.5 m). The upper boundary of the bed is determined by changes in the color and structure of the rocks.

Ammonites: *Eleganticeras elegantulum*, *E. connexivum*.

Bivalves: *Dacryomya jacutica* (Petr.), *Kedonella brodnensis* Polub., *Nicaniella* sp. (Sample 59, 61, 62).

Bed 9, thickness 0.7 m. Silts clayey, dark gray, horizontally bedded, with fragments of large ammonites (up to 30–35 cm in diameter). The upper and lower boundaries of the bed are unclear.

Ammonites: *Eleganticeras elegantulum*.

Bed 10, thickness 1.1 m. The siltstones are coarse-grained, sandy-clayey, massive, transforming up the section into clayey-sandy greenish-gray varieties. At the bottom of the bed there are rare phosphate nodules with imprints of fish and fragments of ammonite shell whorls. At a height of 0.8 m there are extended lenses of phosphate-calcareous limestone siltstone (0.1–5.0 m). The upper boundary of the bed is drawn along the carbon-clay bed.

Bivalves: *Homomya* sp. ind., *Kedonella brodnensis* Polub. (Sample 68).

Bed 12, thickness 5.0 m. Monolithic bed of dark gray clayey siltstones, with unclear lenticular bedding, emphasized by thin lenses of bleached rocks. The upper boundary of the bed is located at the base of a thick nodule horizon.

Ammonites: in the upper half—*Harpoceras exaratum*.

Bivalves: *Meleagrinella (Praemeleagrinella?) golberti* Lutikov et Arp (very frequent), *Nicaniella* sp. (Sample 66).

Bed 13, thickness 1.9 m. Silts are clayey, very dense, lenticular- and horizontally-bedded due to the addition of lighter material. In the upper part of the bed, the rocks have a greenish tint. At the base there are nodules of phosphate-calcareous composition, which along the strike transform into small ellipsoidal nodules with a separate core 4–5 cm in diameter and crusts of smoky or black calcite. Ellipsoidal and lenticular nodule formations are also found at levels of 0.35 and 1.2 m. The upper boundary of the bed is distinct, even.

Ammonites: *Harpoceras exaratum*, at the top of the bed—*H. falciferum*.

Bivalves: *Meleagrinella (Praemeleagrinella?) golberti* Lutikov et Arp (frequent), *Tancredia stubendorffi* Schmidt. (frequent), *Nicaniella* sp. (very frequent) (Sample 69).

Bed 14, thickness 3.9 m. The clays are silty, lenticular- and horizontally bedded due to the addition of silty material along the bedding. At the base, at a

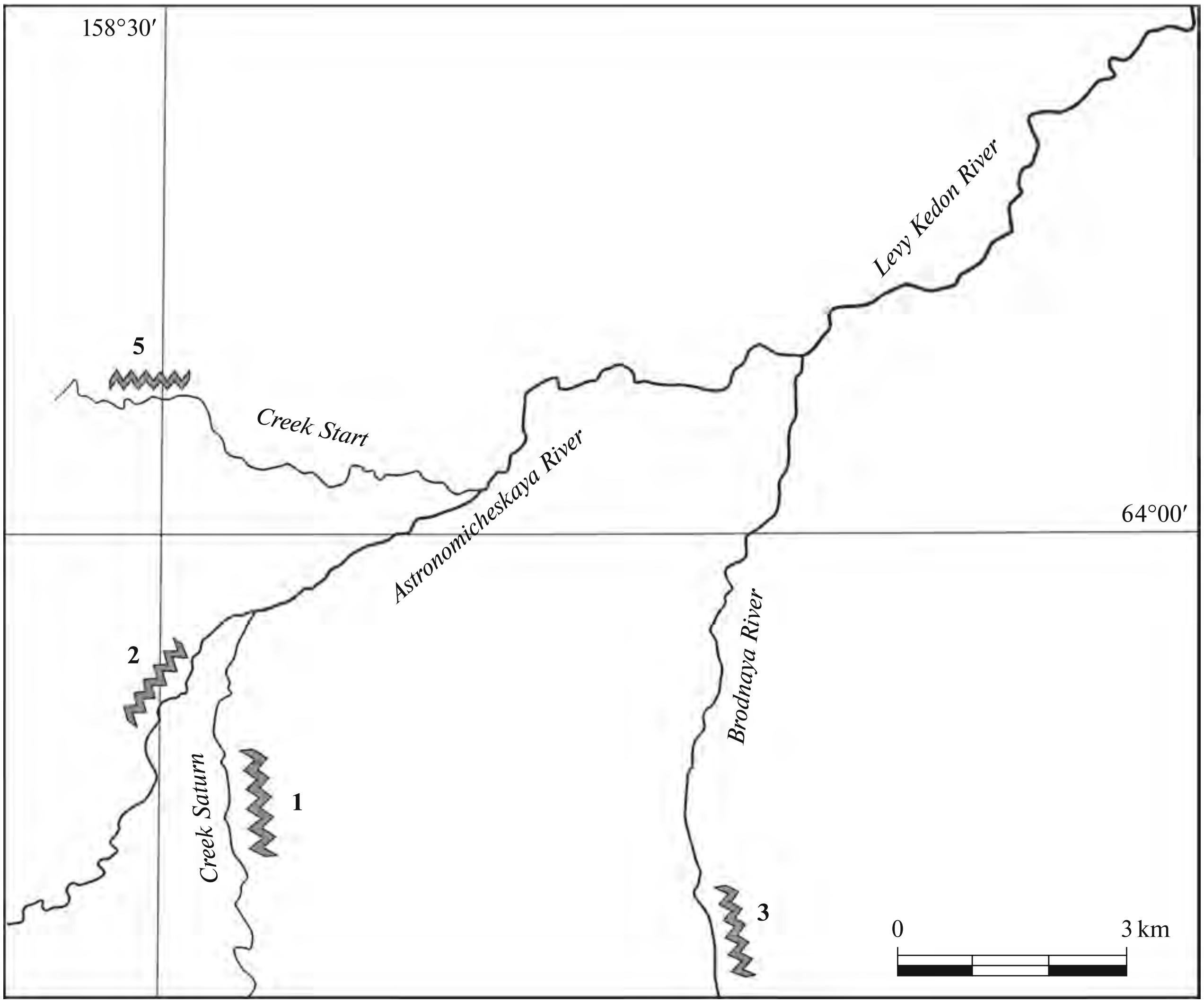

Fig. 60. Studied outcrops in the Levy Kedon River basin.

height of 1 and 2 m there are lens-shaped calcareous-clayey nodules, at the level 3.6 m—loaf-shaped nodules, at a height of 3.25 m—almost a layer of fused lenticular and ellipsoidal nodules up to 30 cm thick. The nodules, as usual, are fissured, the cracks are healed with calcite and gypsum. The upper boundary of the bed is drawn along the change of rocks.

Ammonites: *Harpoceras falciferum*.

Bivalves: *Dacryomya jacutica* (Petr.), *Kedonella mytileformis* Polub. (frequent), *Meleagrinella (Praemeleagrinella?) golberti* Lutikov et Arp (frequent), *Tancredia stubendorffi* Schmidt (very rare), *Nicaniella* sp. (rare), *Entolium kedonense* Milova (rare) (Sample 72).

Bed 15, thickness 0.8 m. Sandstone fine-grained, silty-clayey, phosphate-calcareous, massive, with an uneven distribution of clayey material, greenish-gray. From a level of 0.6 m, very dense nodule formations are found. At the base of the bed, the mass rostra of belemnites are oriented to the north, northeast. Lenses of carbonaceous material are also found here. Due to its oxidation and yellow spots in the weathered wall of the outcrop, the bed is well recognized in Outcrop 1 (Saturn Creek).

Ammonites: *Dactylioceras commune*.

Bivalves: *Meleagrinella (Clathrolima) substriata* (Muenster) (very rare) (Sample 74).

Bed 16, thickness 2.3 m. Silts below dark gray, above greenish-gray, horizontally bedded, clayey. At the level 1.3 m ellipsoidal very strong calcareous concretions with *Dactylioceras*. The lower boundary is drawn by the change in color and structure of the rocks, the upper—at the base of the thick nodule horizon.

Ammonites: *Dactylioceras commune.*

Bivalves: *Meleagrinella (Clathrolima) substriata* (Muenster) (rare), *Entolium kedonense* Milova (rare) (Sample 75).

Bed 17, thickness 3.9 m. Silts clayey, sandy, greenish-gray, dense, massive, yellowish, with several horizons of ellipsoidal calcareous-clayey nodules. It begins with a thick (0.3 m) horizon of ellipsoidal nodules of calcareous siltstone with ammonites (dactyloceratids). At a height of 0.8 m there is a horizon of concretions, close in shape to spherical, with ammonites (dactyloceratids). At the level of 1.0 m there is a marking interbed of many numerous nodules with inclusions of irregular shape. At a height of 1.7 m there is a horizon of rare ellipsoidal nodules with ammonites (dactyloceratids). At heights of 2.5 and 2.7 there are the same nodules.

Ammonites: *Dactylioceras kopiki* Rogov (Rogov and Lutikov, 2022).

Bivalves: at the level 0.8 m—*Meleagrinella (Clathrolima) substriata* (Muenster) (rare), *Entolium kedonense* Milova (rare) (Sample 77a).

Upper Subformation

Bed 18, thickness 3.2 m. Sands and silts coarse-grained, highly clayey, dark gray with a bluish tint, yellow in a weathered state, with rare horizons of calcareous-clayey sandstone nodules, with highly oxidized leptochlorite beans—a very characteristic feature of the overlying rocks. There are fragments of carbonized wood.

Bivalves: levels 1.4 and 2.8 m—*Meleagrinella (Clathrolima) substriata* (Muenster) (rare), *Entolium kedonense* Milova (rare), *Oxytoma* aff. *startense* Polub. (rare), *Propeamussium pumilum* (Lam.) (rare), *Astarte plana* Milova (rare) (Sample 81, 82).

Bed 19, thickness 1.6 m. Sands and silts coarse-grained, highly clayey, dark gray with a bluish tint, yellow in a weathered state, with very large loaf-shaped concretions of calcareous sandstone, with beans of oxidized leptochlorite and an uneven distribution of clayey material. The upper boundary of the bed is drawn by the change in color and structure of the rocks.

Bivalves: level 1.0 m—*Meleagrinella (Clathrolima) substriata* (Muenster) (frequent), *Astarte plana* Milova (very frequent), *Cucullea saturnensis* Milova (rare), *Goniomya rhombifera* (Goldf.) (rare), *Entolium kedonense* Milova (rare), *Pleuromya* sp. ind. (rare) (Sample 83).

Bed 20, thickness 4.9 m. Silts clayey, dark gray, with stains of oxidized varieties around fossils, massive, with nodules of phosphate-lime-clay composition with an admixture of silt. The upper limit of indistinct, gradual, is drawn according to the change of rocks.

Ammonites: *Pseudolioceras lythense*, *Zugodactylites braunianus*, in the middle part of the bed—*Z. pseudobraunianus*, *Z. exilis*.

Bivalves: level 3.9–4.6 m—*Meleagrinella (Meleagrinella) prima* Lutikov (very rare), *Tancredia nalednensis* Milova (very rare) (Sample 91).

Bed 21, visible thickness 3.5 m. The sandstones are greenish-gray, with ellipsoidal nodules scattered throughout the bed. The higher parts of the cut are covered with turf.

Ammonites: *Pseudolioceras compactile*, *Catacoeloceras confectum*, *Porpoceras vortex*, *Collina gemma*.

Bivalves: level 1.0–1.6 m—*Meleagrinella (Meleagrinella) prima* Lutikov (many), *Entolium kedonense* Milova (rare), *Pleuromya* sp. ind. (frequent), *Oxytoma startense* Polub. (frequent), *Praebuchia*? *faminaestriata* (Polub.) (frequent) (Sample 92), level 1.7–2.2 m—*Praebuchia*? *faminaestriata* (Polub.) (frequent), *Entolium kedonense* Milova (rare), *Goniomya rhombifera* (Goldf.) (frequent), *Liostrea* sp. ind. (frequent), *Lenoceramus* sp. ind., *Oxytoma startense* Polub. (frequent), *Pleuromya* sp. ind. (frequent), *Protocardia striatula* (Phill.) (Sample 93).

The stratigraphy of Pliensbachian-Toarcian deposits in Outcrop 2 is shown in Fig. 61.

Section on Saturn Creek

Outcrop 1 is located on the right bank of the Saturn River, 2.5 km above the mouth. Outcrop 20–40 m high was studied in four exposures (Fig. 60).

Exposure 1. Located on the right bank of Saturn Creek, 2.5 km upstream of the mouth.

Start Formation.
Lower subformation

Bed 1, thickness 1.5 m. Silts are dark and greenish-gray, small-platy, lenticular, jarositized, with rows of lenticular and ellipsoidal nodules of calcareous siltstone with large plant detritus, rare small fragments of carbonized wood.

Bed 2, thickness 0.4 m. Silts are dark gray with a yellowish tint, with lenses of coarse-grained greenish-yellow varieties, with siderite nodules. At the top of the bed there is a five-centimeter layer of platy horizontally bedded coarse-grained siltstone (flagstone)

Bed 3, thickness 1.1 m. Silts are dark gray with a yellowish tint, with lenses of coarse-grained greenish-yellow varieties, with siderite nodules. Includes two rows of ellipsoidal calcareous siltstone nodules. The upper boundary of the bed is drawn along the double interbed of wavy-bedded flagstone.

Bed 4, thickness 2.8 m. Silts dark gray with a greenish and yellowish tint, thin-platy and finely wavy-bedded. Darker varieties, enriched in plant detritus, are found in thin layers, which are especially numerous at the levels of ellipsoidal nodules of calcareous siltstone.

Ammonites: at the top of the bed—*Eleganticeras elegantulum*.

Exposure 2. Located 75 m upstream of the Saturn River from Exposure 1.

Bed 5, thickness 1.2 m. Silts highly clayey, oxidized, in lenses to a bright yellow color. In the middle and upper parts of the bed there are lenticular concretions of calcareous siltstone, which are replaced along the strike by nodules of the same composition.

Ammonites: *Eleganticeras elegantulum*, *E. connexivum*.

Bed 6, thickness 1.5 m. Clays dark gray, silty, small-platy, oxidized in places, brownish, with thin layers of silty or carbonaceous material, emphasizing the lenticular bedding of the rocks. In the middle part of the bed there is a horizon of small lens-shaped concretions.

Ammonites: *Eleganticeras elegantulum*, *E. connexivum*.

Bivalves: *Kedonella brodnensis* Polub., *Nicaniella* sp. (Sample 21, middle of the bed).

Bed 7, thickness 1.2 m. Silts are inequigranular, greenish-yellow-gray, clayey, massive, interbedded with dark gray platy, in the middle part there is a consistent horizon of carbonate nodules. In the lower part and base of the bed there are lenses of black shiny coal.

Ammonites: in the middle part of the bed—*Eleganticeras elegantulum*.

Bivalves: *Dacryomya jacutica* (Petr.) (Sample 22, middle of the bed).

Bed 8a, visible thickness 3.2 m. Silts are dark gray, unevenly platy, jarositized along cracks, with several horizons of carbonate nodules, accreted at the top of the bed.

Ammonites: in the upper part of the bed—*Harpoceras exaratum*.

Bivalves: *Dacryomya jacutica* (Petr.) (rare), *Meleagrinella (Praemeleagrinella) golberti* Lutikov et Arp (very rare) (Sample 23, 0.8 m).

Exposure 3. Located 50 m upstream of from Exposure 2 Saturn along Exposure 2. Bed 8 continues upwards. The section begins 8 m from the waterline. The base of Bed 8 in Exposure no. 2 at a height of 7.3 m, in Exposure no. 3 at an altitude of 8.9 m. Taking into account the dip of the beds in Exposure no. 3, there are another 2.0 m of Bed 8.

Bed 8b, visible thickness 2.0 m. Silts dark gray, unevenly platy, jarositized along cracks, with several horizons of carbonate nodules, accreted at the top of the bed.

Bivalves: *Dacryomya jacutica* (Petr.) (frequent), *Meleagrinella (Praemeleagrinella?) golberti* Lutikov et Arp (very rare), *Nicaniella* sp. (very rare), *Kedonella brodnensis* Polub. (very rare), *Kedonella mytileformis* (Polub.) (very rare) (Sample 24, 1.65 m; Sample 25, 2.0 m).

Bed 9, thickness 5.9 m. Silts highly clayey, dark gray, unevenly platy, fissured, jarositized in lenses, with three rows of carbonate nodules with aggregations of fossils. The upper boundary of the bed is drawn along the first thick layer (up to 0.5 m) of calcareous siltstone.

Ammonites: *Harpoceras falciferum*, *H. exaratum*.

Bivalves: *Dacryomya jacutica* (Petr.) (many), *Meleagrinella (Praemeleagrinella?) golberti* Lutikov et Arp (very rare), *Kedonella mytileformis* (Polub.) (very rare), *Nicaniella* sp. (frequent) (Sample 26, 0.2–1.3 m; Sample 27, 2.4 m).

Bed 10, thickness 0.8 m. Sands clayey-silty, highly weathered, grayish-yellow, in lenses to bright yellow, with a large number of belemnite rostra.

The lower and upper boundaries of the bed are unclear and gradual.

Ammonites: *Dactylioceras commune*, *Dactylioceras* sp.

Bivalves: *Dacryomya jacutica* (Petr.) (rare), *Meleagrinella (Clathrolima) substriata* (Muenster) (very rare), *Nicaniella* sp. (very rare) (Sample 28, 0.5 m).

Bed 11, thickness 3.2 m. Silts are coarse-grained, clayey, dark gray with a yellowish tint, fissured, with jarositization and rows of ellipsoidal nodules.

Ammonites: *Dactylioceras commune*, *Dactylioceras* sp., *Catacoeloceras crassum*.

Bivalves: *Meleagrinella (Clathrolima) substriata* (Muenster) (very rare), *Dacryomya jacutica* (Petr.) (very rare), *Nicaniella* sp. (very rare) (Sample 29, 0.8 m).

Bed 12, thickness 1.7 m. Silts are coarse-grained, clayey, dark gray with a yellowish tint, fissured, with jarositization and rows of spherical nodules of calcareous siltstone with accumulation of ammonite shells (0.5 m from the base). Below, their lens-shaped concretions are distinguished by a conchoidal structure (the outer shell is very strong, unlike the core) and unoriented accumulations of small shells of ammonites and bivalves.

Ammonites: in the lower part of the bed—*Harpoceras subplanatum*, *Dactylioceras commune*, *D. amplum*, *D. kanense*, *D.* sp., *Catacoeloceras crassum*.

Bivalves: *Meleagrinella (Clathrolima) substriata* (Muenster) (very rare) (Sample 12a).

Upper Subformation

Bed 13, thickness 3.0 m (Bed 13 after Knyazev et al., 2003). The sands are greenish and yellowish-gray, fine-grained, massive. At the base of the bed, consistent along strike, is a doubled horizon of lenticular and ellipsoidal carbonate, sometimes accreted calcareous siltstone nodules.

Ammonites: in the lower part of the bed—*Dactylioceras* sp.

Bed 14, thickness 0.7 m (Bed 14 after Knyazev et al., 2003). The sandstones are yellowish-gray, massive, very dense, lithified in layers, characterized by the presence of plant detritus and the sandy composition of carbonate nodules.

Bed 15, thickness 3.5 m (Bed 14a after Knyazev et al., 2003). Silts are clayey, ash-gray, bluish, unevenly platy. The rocks along the cracks are jarositized, around the inclusions they are brown. At a height of 0.5 m there is a horizon of ellipsoidal nodules with large ammonites (childoceradids) poorly preserved. At a height of 3.0 m there is a horizon of ellip-

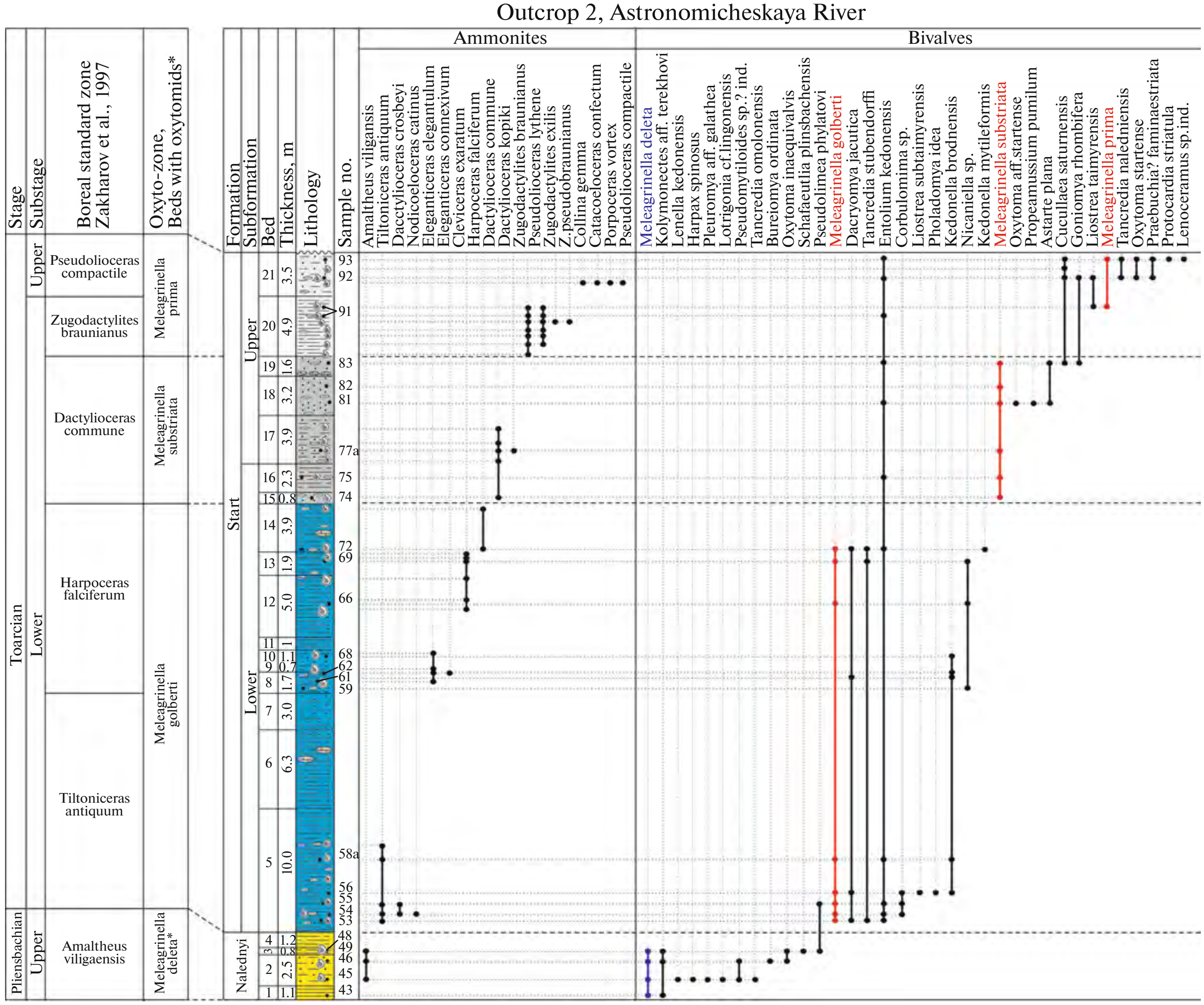

Fig. 61. Stratigraphy of Pliensbachian–Toarcian deposits in Outcrop 2 (Astronomicheskaya River) based on the distribution of index species of oxyto-zones and zonal assemblages. Legend see in Fig. 14.

soidal nodules to lenticular accreted nodules (thickness 0.5 m) of carbonate sandstone, greenish-gray, massive, with carbonized wood, belemnites, bivalves, small ammonites.

Ammonites: Hildoceratidae gen ind., Dactylioceratidae gen ind.

Bivalves: *Meleagrinella (Clathrolima) substriata* (Muenster) (frequent), *Astarte plana* Milova (very frequent) (Sample 30), cap-like gastropods.

Bed 16, thickness 0.5 m (Bed 14a after Knyazev et al., 2003). In the lower part (0.5 m) the sandstone is greenish-yellow, massive, loose, dense, with small-fragmented jointing, with a layer (5–7 cm) of bluish silt. The bed is fractured and oxidized, with belemnites.

Bed 17, visible thickness 0.8 m (Bed 14a after Knyazev et al., 2003). The silt is clayey, grayish-yellow, sometimes bluish, indistinctly bedded, viscous, with layers of bright-yellow viscous clay. The lower boundary is drawn along the interlayer (1–3 cm) with gravel—the erosional level, expressed by the coarsening of the material, fragments of belemnites and gruss of the underlying rocks. The bed ends with very destroyed concretions, with large *Astarte* and rare belemnites.

Higher in the section there are pebbles with an uneven lower boundary; they are located at different levels and are obviously the result of landslides. The upper boundary of the yellow silts Bed 17 is not even, does not coincide with the general dip of the beds. Above the level of 1.0 m from the base of Bed 16, dark gray clayey silts enter a multiple landslide block, in which Late Toarcian ammonites are found 3.0 m from the base of the bed, then again there are pebbles and immediately after them—sandstone with *Retroceramus*. There is another 10 m of overgrown slope to the top.

Bivalves: at the level 0.5 m—*Meleagrinella (Clathrolima) substriata* (Münster) (frequent), *Astarte plana* Milova (very frequent), *Entolium kedonensis* Milova (frequent) (Sample 32).

Exposure no. 4. Located on the right bank of the Saturn River 100 m upstream from Exposure no. 3. It exposes horizon of Bed 15. Beds 15–16 are well correlated between exposures no. 3 and no. 4. Bed 17 continues in Exposure no. 4.

Bed 15, visible thickness 2.0 m. Same rocks as in Bed 15 in Exposure no. 3. Silts are clayey, ash-gray, bluish, unevenly platy. The rocks along the cracks are jarositized, around the inclusions they are brown. In the roof there is a horizon of ellipsoidal to lens-shaped accreted concretions (thickness 1.25 m) of carbonate sandstone, greenish-gray, massive, with carbonized wood, belemnites, bivalves, small ammonites. Below (0.3 m) the nodule horizon there are coquina lenses with bivalves, belemnites and small ammonites.

Ammonites: Dactylioceratidae gen ind.

Bivalves: level 0.3 m below the marking horizon—*Meleagrinella (Clathrolima) substriata* (Muenster) (frequent), *Astarte plana* Milova (many), *Oxytoma* aff. *startense* Polub. (rare), *Liostrea taimyrensis* Zakh. et Schur. (very rare), *Entolium kedonensis* Milova (rare), *Goniomya rhombifera* (Goldf.) (rare) (Sample 31). In the marker horizon—*Astarte plana* Milova (very frequent), *Cucullaea saturnensis* Milova (rare), *Entolium kedonensis* Milova (very rare), *Goniomya rhombifera* (Goldf.) (frequent) (Sample 32), cap-like and conical gastropods, belemnites.

Bed 16, visible thickness 0.2 m. The sandstone is greenish-yellow, massive, loose, dense, with small lumpy units.

Bivalves: *Astarte plana* Milova (very frequent), *Cucullaea saturnensis* Milova (rare), *Entolium kedonensis* Milova (very rare), *Goniomya rhombifera* (Goldf.) (frequent), cap-like and conical gastropods, belemnites.

Bed 17, thickness 5.0 m (Bed 15 after Knyazev et al., 2003). At the base of the bed there is a consistent horizon of ellipsoidal nodules (30 × 70 cm) with large *Astarte*. Alternation of yellowish-gray, sometimes bluish silts, grayish-yellow sands and clayey silts. The lenticular bed is ochreous and jarositized. Throughout the bed there are nodules and small nodules with ammonites. The upper boundary of the bed passes at the base of the powerful horizon.

Ammonites: at the base, 3.0; 5.0 m—*Pseudolioceras lythense*, *Zugodactylites braunianus*, *Z. pseudobraunianus*, *Catacoeloceras crassum*.

Bivalves: 1.0 from the base—*Astarte plana* Milova (very frequent), *Entolium kedonensis* Milova (frequent) (Sample 33).

Bed 18, thickness 6.3 m (Bed 16 after Knyazev et al., 2003). The bed begins with a 1.5-meter interbed of carbonate sandy siltstone, greenish-gray, massive, with aggregations of sandstone, with which are associated aggregated burials of bivalves, wood fragments, belemnites and rare ammonites (dactylioceratids). Above are finely unevenly plated sandy silts, greenish-yellow, horizontally bedded, mostly. Sometimes there are interbeds of dark gray silts. At a height of 2.0 m there are many siderite nodules. There are also lenses of bright yellow and white clays, lens-shaped accumulations of belemnites. At a height of 2.1 and 2.6 m there are interbeds of lithified sandstone, turning into lens-shaped carbonate varieties with ammonites (*Pseudolioceras*), along with interlayers of yellowish clays.

In the lower 1.5 m of the bed, bivalves are buried in coquinae. The shells are mostly scattered; complete shells are rare. The valves are differently oriented and of different sizes. The valves of *Oxytoma* are nested one into another from small (1.0 cm) to large (5.0 cm). *Liostrea* specimens are presented in concretions either as separate valves or attached to plant remains, or form accumulations of the "bank" type. The shells are mostly (90%) large (6–7 cm). In individual aggregations, different taxa dominate: *Tancredia* are rare in aggregations of *Oxytoma*, but *Entoliuma* are very common. Among aggregations of *Tancredia*, small *Oxytoma* are common, large *Oxytoma* are rare. Belemnites are abundant. The fossils are also found separately throughout the bed.

Ammonites: in the lower part of the bed—*Pseudolioceras compactile*, *Catacoeloceras confectum*, *Porpoceras vortex*, *Collina gemma*; in the middle part of the bed—*Pseudolioceras wuerttenbergeri*.

Bivalves: 1.0 from the base of the bed—*Pseudomytiloides marchaensis* (Petr.) (rare), *Oxytoma startense* Polub. (abundant), *Liostrea (Deltostrea) taimyrensis* (many), *Entolium kedonensis* Milova (numerous), *Propeamussium pumilum* (Lam.) (rare), *Tancredia naledniensis* Milova (frequent), *Meleagrinella (Meleagrinella) prima* Lut. (rare) (Sample 34).

At the level 2.7 m *Oxytoma* ex gr. *jacksoni* (Pomp.) (rare), *Praebuchia*? *faminaestriata* (Polub.) (rare), *Pleuromya* sp. ind. (rare), appear for first time in nodules, *Oxytoma startense* Polub. (rare), *Entolium kedonensis* Milova (frequent), *Goniomya rhombifera* (Goldf.) (very frequent), *Tancredia naledniensis* Milova (frequent) (Sample 35), belemnites continue.

At the level 3.5 m—in a bed parallel to the bedding *Cucullaea saturnensis* Milova (rare) (Sample 36).

At the level 4.3 m—in concretions with *Pseudolioceras* nest-like burial of *Praebuchia*? *faminaestriata* (Polub.) (rare), *Oxytoma startense* Polub. (many), *Entolium kedonensis* Milova (frequent), *Pleuromya* sp. ind. (frequent) (Sample 37).

Bed 19, thickness 1.4 m (Bed 17 after Knyazev et al., 2003). At the base there is a horizon of siderite loaf-shaped nodules, very dense, with aggregations of bivalves. Silts large, finely plated, light greenish-gray, thinly horizontally bedded. On the bedding planes there are many moderately preserved fossils. At a height of 1.0 m there is a lens with a broken shells, whole ammonites and belemnites. At the same level there are phosphate nodules (3–4 cm). Above there are concretions with ammonites (*Pseudolioceras*).

Ammonites: *Pseudolioceras falcodiscus*.

Bivalves: at the base—*Tancredia naledniensis* Milova (frequent) (Sample 38). At the level 1.0 m—in lenses and nodules large *Oxytoma* ex gr. *jacksoni* (Pomp.) (rare), *Goniomya rhombifera* (Goldf.) (very frequent), *Entolium kedonensis* Milova (many), *Lenoceramus* sp. ind. (many), *Praebuchia*? *faminaestriata* (Polub.) (many), *Pleuromya* sp.ind. (rare) (Sample 39), belemnites.

Saturn Formation

Bed 20, thickness 3.5 m (Bed 18 after Knyazev et al., 2003). Sandstone dark gray to black, massive, fractured, with nest-like accumulations of ammonites, *Retroceramus* and other bivalves. In the sandstone there are lenses enriched with gravel and rare small pebbles. At a height of 1.5 m there are interbeds of light bluish-gray siderite, very strong and massive. Nearby are non-isolated "contractions" with sand. Higher in the section there is another 2.0 m of greenish-light gray, massive sandstone. Above it there is a thick bed of gray sandstone, the slope is covered with scree.

Ammonites: at the level 1.0 m—*Pseudolioceras falcodiscus*, *P. beyrichi* (Sample 41 f-a).

Bivalves: at the level 0.5 m—*Maclearnia kelymiarensis* Bodyl., *Arctotis* sp. ind. (rare); at the level 1.0 m—coquina lenses one or two shells thick with *Retroceramus elegans* Kosch., *Retroceramus popovi* Kosch. (many), *Retroceramus menneri* Kosch. (many), throughout the bed *Lenoceramus* sp. ind. (frequent); in the interval 1.3–1.5 m scattered *Goniomya rhombifera* (Goldf.) (very frequent), *Bureiamya* sp. (frequent), *Tancredia* sp. (rare), *Pholadomya* sp. (rare) (Sample 40 f-d).

Bed 20 contains: *Retroceramus elegans* (Kosch.), *R. lungershauseni* (Kosch.), *R. aequicostatus* (Vor.), *R. sibiricus* (Kosch.) (*Geologiya*..., 1970); *Retroceramus menneri* Kosch., *Retroceramus elegans* Kosch., *Retroceramus popovi* Kosch. (Koshelkina, 1974, 1980); *Mytiloceramus* cf. *jurensis* (Kosch.) (Stratigrafiya, 1976); *Retroceramus jurensis* Kosch., *R. mongkensis* Kosch., *R.* aff. *morii* (Hayamii), *R.* cf. *gizhigensis* Polub., *R. aequicostatus* (Vor.) (*Resheniya*..., 2009). Above Bed 20 in the coastal slope, about 20 m of greenish-gray, massive sandstones are fragmentarily exposed, presumably Upper Aalenian (Koshelkina, 1980) or Bajocian (*Resheniya*..., 2009).

The stratigraphy of Toarcian-Aalenian deposits in Outcrop 1 is shown in Fig. 62.

Section on the Brodnaya River

Located on the right bank of the Brodnaya River, 15 km upstream of the mouth (Fig. 60). The Upper Pliensbachian outcrops are 0.5 km long and 5–10 m high. The description of the section is begins from the upper beds of the Pliensbachian.

Nalednyi Formation

Bed 14, thickness 5.3 m. The sandstone is fine-grained, dark greenish-gray, dense, strong, massive, horizontally bedded, silty. At levels of 0.5; 3.5 and 4.5 m—clayey interbeds. The upper boundary of the bed is drawn by the change of rocks—even, distinct. At the top are fragments of charred wood, plant detritus, calcareous nodules, aggregated and lenticular coquinae with bivalves, brachiopods, gastropods and ammonites.

Ammonites: near the top of Bed 14—*Amaltheus extremus* Repin (Stratigrafiya, 1976), *Amaltheus viligaensis* Repin (Knyazev et al., 2003).

Bivalves: at the level 1.1 m—*Ohotochlamys grandis* Polub. (very rare), *Pholadomya idea* Orb. (rare), *Pholadomya ambigua* Sow. (rare), *Bureiamya ordinata* Polub. (very frequent), *Liotrigonia lingonensis* (Dum.) (very rare), *Harpax spinosus* (Sow.) (rare), *Pleuromya galathea* Agass. (frequent) (Sample 145).

At the level 5.3 m—*Kolymonectes* aff. *terekhovi* (Polub.) (very frequent), *Oxytoma inaequivalvis* (Sow.) (very frequent), *Tancredia omolonensis* Polub. (frequent), *Meleagrinella (Praemeleagrinella) deleta* (Dum.) (frequent), *Meleagrinella (Praemeleagrinella?) oxytomaeformis* Polub. (very frequent), *Ryderia formosa* (Vor.), *Pleuromya* aff. *galathea* Agass. (frequent), *Harpax* ex gr. *laevigatus* (Orb.), *Schafaeutlia plinsbachensis* Schur. (very frequent) (Sample 146).

Bed 15, thickness 2.5 m. Siltstones are yellowish-gray, dense, loose, ferruginous, finely fragmented, massive, sandy below, clayey above. At a height of 1.7–1.9 m there is a bed of carbonate siltstone with poorly preserved fauna. It contains aggregations of brown coarse-grained calcite nodules, rare aggregations of bivalves, and brachiopods. Above another 1 m there are yellowish-gray siltstones. At the top of the bed there is interbedding of yellowish-gray siltstones with thin carbonate lenses and thin (1–3 cm) black or yellow interbeds of clay. The bed ends with a layer (5 cm) of black mudstones. The upper boundary is distinct and even.

Bed 16, visible thickness 2.5 m. At the base there is a layer of limestone, below with ammonites and bivalves. Silts are dark gray, clayey, finely unevenly platy, massive. At a height of 1.8 and 2.5 m there are lens-shaped carbonate nodules. The basal layer looks "black" from the surface and is clearly visible in the outcrop. Ammonites in it form aggregated accumulations.

Ammonites: at the base—*Tiltoniceras antiquum*, *Dactylioceras pseudocommune*, *Coeloceras crosbeyi*.

Bivalves: *Corbulomima* sp. (very rare), *Pholadomya idea* Orb. (very rare), *Pseudolimea philatovi* (rare), *Liotrigonia lingonensis* (Dum.), *Pleuromya* aff. *galathea* Agass. (rare) (Sample 147, 2.5 m).

Above the slope is turfed and overgrown with larch trees. At a height of 16.5 m from the water's edge the following are exposed:

Bed 17, visible thickness 0.5 m. The sands are yellow-green and greenish-yellow, highly weathered, spotted due to jarositization lenses. At 0.4 m there is a coquina lens, consisting of bivalves. The upper boundary of the bed is indistinct, wavy (?)—interbed of yellow clay with abundant carbonized plant detritus. The top of this bed is cemented.

Bivalves: at the level 0.4 m—*Kedonella brodnensis* Polub. (very frequent), *Kedonella mytileformis* Polub. (rare) (Sample 148).

Bed 18, thickness 7.5 m. At the base of the bed there are lens-shaped dark nodules (thickness 5 cm). Silts are dark gray, small-platy, clayey, ferruginous along the cracks, brown. The rocks are horizontally bedded. At levels 1.5; 2.2; 2.5; 2.7; 3.5; 4.0 m—nodules with ammonites and bivalves. From a height of 4.0 m the rocks gradually become yellowish-gray. At levels 6.0; 6.6 m—lenses of carbonate mudstone, at a height of 6.5 m—layer of carbonate mudstone.

Ammonites: at the base—*Eleganticeras elegantulum*, *Harpoceras. sp.*, *Harpoceras falciferum*.

Bivalves: at the level 2.0 m—*Meleagrinella (Praemeleagrinella?) golberti* Lutikov et Arp (frequent) (Sample 149); at the level 2.7 m—*Nicaniella* sp. ind., *Meleagrinella (Praemeleagrinella?) golberti* Lutikov et Arp (very frequent) (Sample 150); at the level 3.5 m—*Meleagrinella (Praemeleagrinella?) golberti* Lutikov et Arp (very frequent) (Sample 151); at the level 6.5 m—*Meleagrinella (Praemeleagrinella?)* aff. *golberti* Lutikov et Arp (abundant), *Oxytoma* aff. *startense* Polub. (Sample 152).

The stratigraphy of Pliensbachian-Toarcian deposits in Outcrop 3 is shown in Fig. 63.

Stratigraphy and Correlation of Pliensbachian-Aalenian Deposits in the Levy Kedon River Section

This work uses the formations approved by the resolution of the Bureau of the Moscow Council on April 17, 2003, and adopted at the 3rd Interdepartmental Regional Stratigraphic Meeting on the Precambrian, Paleozoic and Mesozoic Northeastern Russia (*Resheniya*..., 2009).

Nalednyi Formation. This formation was named by I.V. Polubotko and Yu.S. Repin (Sey et al., 1992; Repin and Polubotko, 1996) with a stratotype on the right side of the valley of the Brodnaya River, at the mouth of Nalednyi Creek. Initially it was recognized as a horizon (*Zonalnaya*..., 1991). The Late Pliensbachian Nalednyi Formation crops out in the Levy Kedon and Aulandzha (Omolon-Gizhiga interfluve) stratigraphic zones, as well as in the Russkaya River zone. The recognition within the formation of two lower zonal divisions of the Upper Pliensbachian—the Amaltheus stokesi Zone, and above—Beds with A. talrosei is based on ammonites in the sections on the Brodnaya and Astronomicheskaya rivers. The upper part of the Nalednyi Formation corresponds to two local zones: Amaltheus viligaensis and Amaltheus extremus. Both zones were correlated with the Pleuroceras spinatum Zone of the Western European standard (*Resheniya*..., 2009; Repin, 2016). For the upper part of the Nalednyi Formation, one zone was recognized as an auxiliary biostratigraphic unit for the bivalves Radulonectites hayamii—Radulonectites mongkensis Zone in the range of three local Pliensbachian ammonite zones (*Resheniya*..., 2009). The upper zone of the Pliensbachian (Amaltheus viligaensis Zone) included the upper part of Member 24 and Members 25, 26 of the Nalednyi Formation (*Stratigrafiya*..., 1976).

Start Formation. Named by I.V. Polubotko and Yu.S. Repin. Initially, it was recognized as the Start horizon (*Zonalnaya*..., 1991), then as a formation (Sey et al., 1992; Repin and Polubotko, 1996).

In Northeastern Russia, the Start Formation crops out in the Levy Kedon and Dolamnan (Biliriken—Corcodon interfluve) stratigraphic zones. The formation is dated by ammonites *Nodicoeloceras catinus*, *Harpoceras subplanatum*, *Porpoceras vortex*, *Catacoeloceras crassum*, *Catacoeloceras confectum*, *Collina gemma*, *Pseudolioceras compactile*, *Pseudolioceras wuerttenbergeri*, *Pseudolioceras falcodiscus* (Knyazev et al., 2003); *Nodicoeloceras compactum*, *Coeloceras crosbeyi*, *Dactylioceras pseudocommune*, *Tiltoniceras antiquum*, *Eleganticeras elegantulum,* "*Cleviceras*" *exaratum*, *Harpoceras falciferum*, *Hildaites levisoni*, *H. murtleyi*, *Dactylioceras commune*, *D. athleticum*, *Zugodactylis braunianus*, *Z. monestieri*, *Catacoeloceras (Omolonoceras) proprium*, *Hildaites chrysanthemum*, *H. grandis*, *Pseudolioceras kedonense*, *Pseudolioceras gradatum*, *Peronoceras (Porpoceras) polare*, *Pseudolioceras rosenkrantzi* (*Resheniya*..., 2009), etc.

Saturn Formation. The formation was recognized by I.V. Polubotko and Yu.S. Repin in 2002 in the basin of the upper reaches of the Levy Kedon River (*Resheniya*..., 2009). The lower subformation includes a basal bed of tuff sandstones with pebbles and shell lenses from retroceramids at Saturn River and Start, which, according to some data, belonged to the Aalenian (Koshelkina, 1974, 1980; Knyazev et al., 2003), according to others—to the Lower Bajocian (*Stratigrafiya*..., 1976; *Resheniya*..., 2009). The thickness of the bed was determined from 2.8 to 3.8 m. On the one hand, the age of the bed was dated to the Early Aalenian based on the ammonites *Pseudolioceras maclintocki* (Koshelkina, 1974) and *Pseudolioceras beyrichi* (Knyazev et al., 2003), discovered on the Saturn River. On the other hand, the bed was considered Early Bajocian based on ideas about the age of the assemblage of retroceramids found in it, including *Retroceramus jurensis, Retroceramus menneri, Retroceramus*

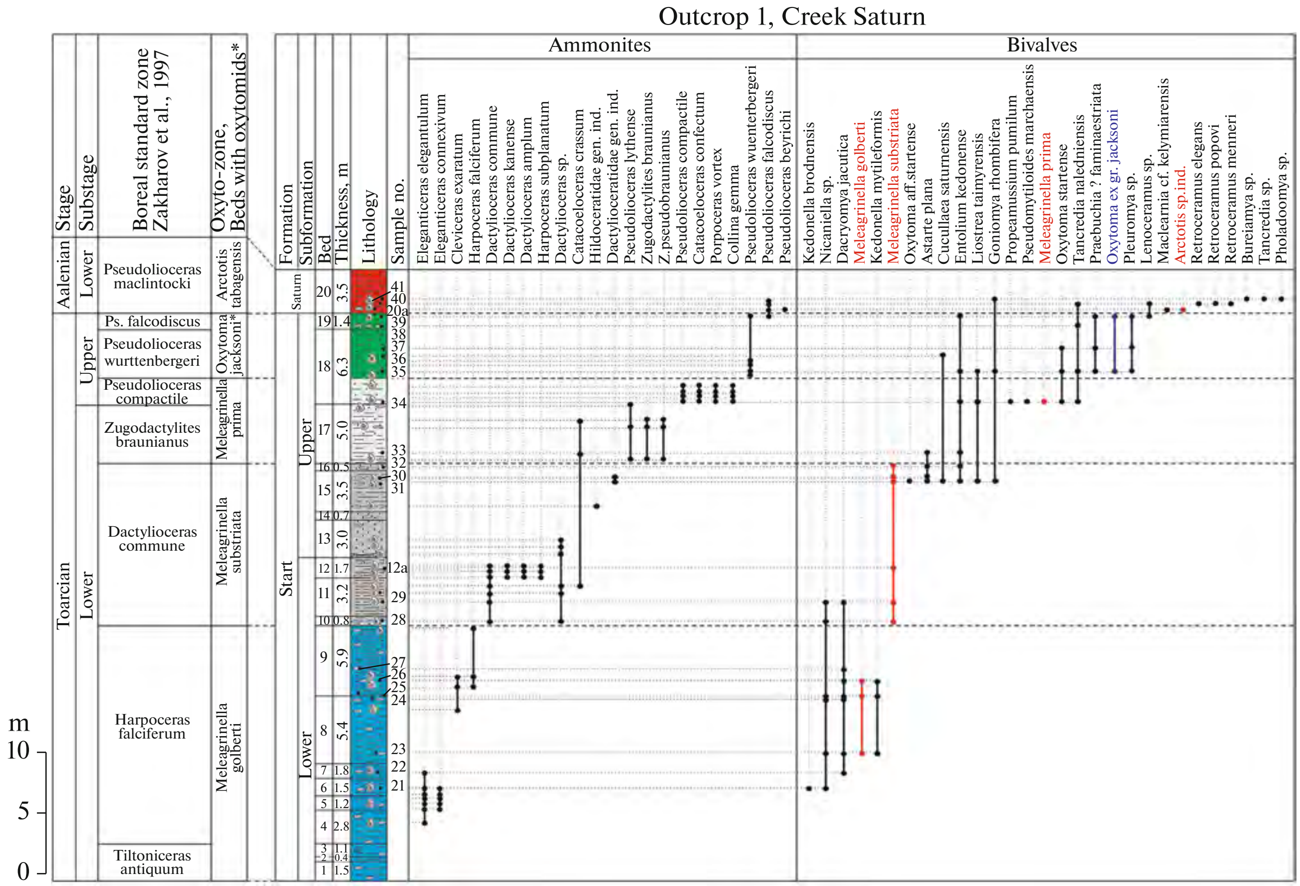

Fig. 62. Stratigraphy of Toarcian-Aalenian deposits in Outcrop 1 (Saturn River) based on the distribution of oxyto-zone index species and zonal assemblages. Legend see in Fig. 14.

mongkensis (*Resheniya*..., 1978). According to the Decisions of the 3rd Interdepartmental Regional Stratigraphic Meeting on the Precambrian, Paleozoic and Mesozoic Northeastern Russia (St. Petersburg, 2002), it is accepted that the Saturn Formation overlies the Start Formation with a stratigraphic gap corresponding to the three upper zones of the Toarcian and the entire Aalenian (*Resheniya*..., 2009). According to other data, there is no stratigraphic gap between the Start and Saturn formations (Knyazev et al., 2003).

Based on the distribution of index species and zonal assemblages of bivalves in the Pliensbachian-Aalenian succession, exposed in sections along the tributaries of the Levy Kedon River (Figs. 61, 62, 63), four oxyto-zones and two beds with oxytomids are recognized (Fig. 64).

Beds with Meleagrinella deleta. The beds are established in the terminal part of the Nalednyi Formation at the Astronomicheskaya and Brodnaya rivers (Fig. 61, 63). At the Astronomicheskaya River, the sequence including Beds 1–4 contains the index species *Meleagrinella (Praemeleagrinella) deleta* and a characteristic assemblage with *Kolymonectes* aff. *terekhovi* Polub., *Pseudomytiloides*? sp. ind., *Liotrigonia* cf. *philatovi*, *Meleagrinella (Praemeleagrinella?) oxytomaeformis* Polub., *Oxytoma inaequivalvis* (Sow.). Visible thickness is 5.6 m.

On the Brodnaya River, Bed 14 contains the index species *Meleagrinella (Praemeleagrinella) deleta* and a characteristic assemblage with *(Praemeleagrinella?) oxytomaeformis, Kolymonectes* aff. *terekhovi* Polub., *Pseudomytiloides*? sp. ind., *Liotrigonia philatovi, Ochotochlamys grandis* Polub. The thickness of the Beds is 7.8 m.

Meleagrinella golberti Oxyto-zone. The stratotype of the oxyto-zone is established in the Astronomicheskaya River section (Outcrop 2, Beds 5–14) (Fig. 61). Thickness in the stratotype 34.6 m. The bivalves in the stratotype of the oxyto-zone include: *Meleagrinella (Praemeleagrinella) golberti*, *Kedonella brodnensis*, *K. mytileformis*, *Dacryomya jacutica*, *Tancredia stubendorffi*, *Liostrea (Deltostrea) subtaimyrensis*, *Corbulomina* sp., *Entolium kedonensis*, *Nicaniella* sp.

The oxyto-zone is established in the Saturn River section (Outcrop 1, Beds 1–9) (Fig. 62). Visible thickness is about 21.0 m. The section contains the following bivalves: *Meleagrinella (Praemeleagrinella) gol-*

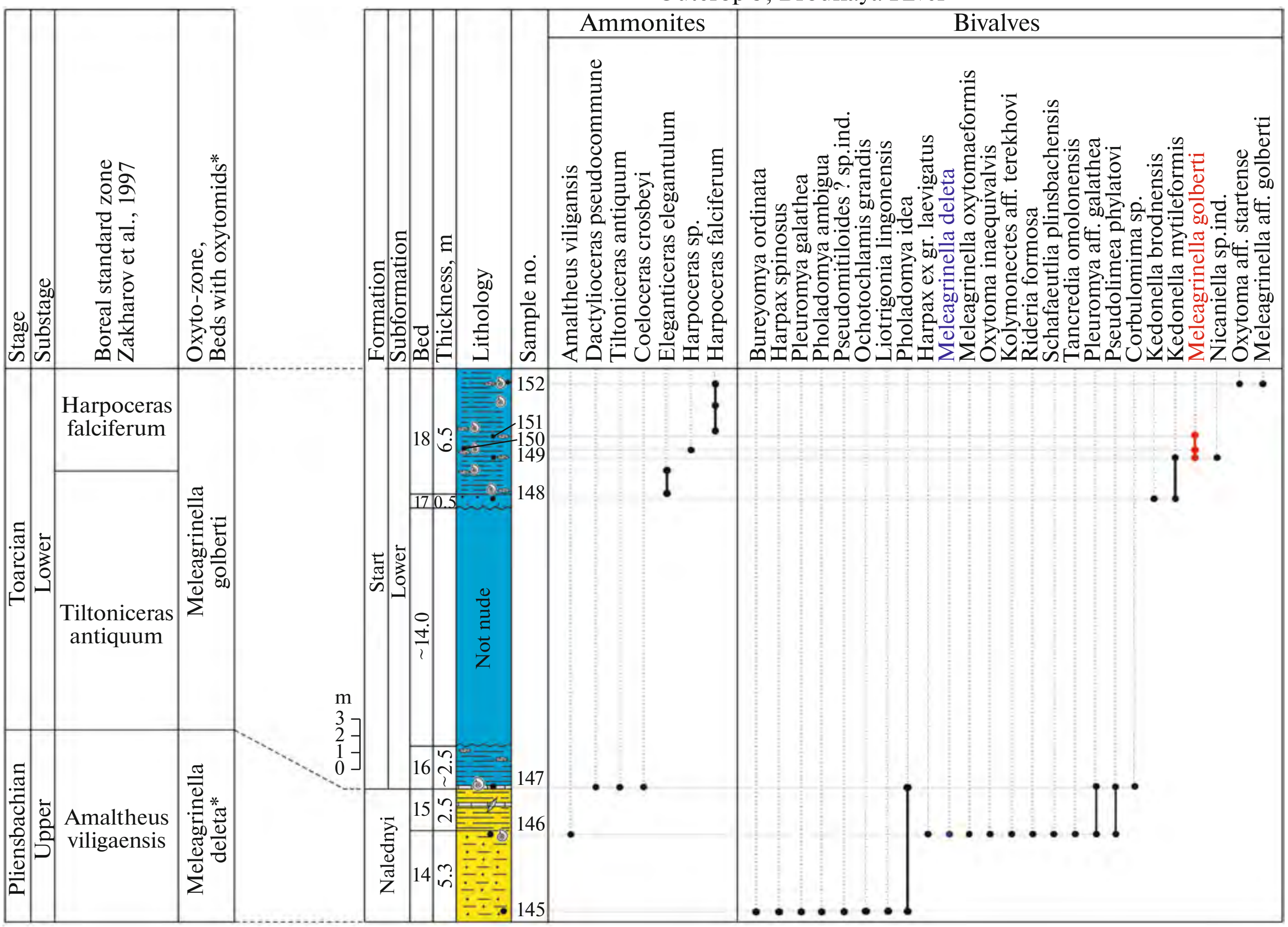

Fig. 63. Stratigraphy of Pliensbachian–Toarcianx deposits in Outcrop 3 (Brodnaya River) based on the distribution of index species of oxyto-zones and zonal assemblages. Legend see in Fig. 14.

berti, *Kedonella brodnensis*, *K. mytileformis*, *Dacryomya jacutica*, *Nicaniella* sp.

The oxyto-zone is recognized in the section of the Brodnaya River (Outcrop 3, Beds 15–19) (Fig. 63). Thickness about 23.5 m. The section contains the following bivalves: *Meleagrinella (Praemeleagrinella) golberti*, *Meleagrinella (Praemeleagrinella)* aff. *golberti*, *Oxytoma* aff. *startense*, *Corbulomina* sp., *Kedonella brodnensis*, *K. mytileformis*, *Nicaniella* sp.

The lower subformation and the lower parts of the upper subformation of the Start Formation correspond to the Meleagrinella golberti Oxyto-zone and correlate with the *Tiltoniceras antiquum, Harpoceras falciferum* zones of the Boreal standard of the Toarcian stage.

Meleagrinella substriata Oxyto-zone. The stratotype of this oxyto-zone was recognized in the section of the Astronomicheskaya River (Outcrop 2, Beds 15–19) (Fig. 61). Thickness in the stratotype 11.8 m. Species of bivalves that are found in the stratotype of the oxyto-zone include: *Meleagrinella (Clathrolima) substriata*, *Propeamussium pumilum*, *Astarte plana*, *Cucullaea saturnensis*, *Oxytoma* aff. *startense*.

The oxyto-zone was recognized in the section of the Saturn River (Outcrop 1, Beds 10–16) (Fig. 62). The thickness of oxyto-zone is 13.4 m. This section contains the following species of bivalves: *Meleagrinella (Clathrolima) substriata*, *Propeamussium pumilum*, *Astarte plana*, *Cucullaea saturnensis*, *Liostrea taimyrensis*, and *Goniomya rhombifera*.

The Meleagrinella substriata Oxyto-zone includes the upper part of the lower subformation and the lower part of the upper subformation of the Start Formation. The oxyto-zone correlates with the Dactylioceras commune Zone of the Boreal standard of the Toarcian Stage.

Meleagrinella prima Oxyto-zone. The oxyto-zone was recognized in the section of the Astronomicheskaya River (Outcrop 2, Beds 20–21) (Fig. 61). The thickness of the oxyto-zone is 8.4 m. The oxyto-zone is identified based on the index species *Meleagrinella (Meleagrinella) prima* and zonal assemblage of bivalves with *Pseudomytiloides marchaensis*, *Oxytoma startense*, *Camptonectes* s.str., *Tancredia nalednensis*, *Protocardia striatula*, *Praebuchia ? faminaestriata* (Polub.).

The oxyto-zone is found in a section of the Saturn River (Outcrop 1, Bed 17—lower 1.5 m Bed 18) (Fig. 62). The thickness of oxyto-zone is 6.5 m. The oxyto-zone identified by the index species *Meleagrinella (Meleagrinella) prima* and zonal assemblage of bivalves with *Pseudomytiloides marchaensis*, *Oxytoma startense*, *Camptonectes* s. str., *Tancredia nalednensis*.

The Meleagrinella prima Oxyto-zone is distinguished in the middle part of the upper subformation of the Start Formation. The oxyto-zone correlates with the Zugodactilites braunianus, Pseudolioceras compactile zones of the Boreal standard of the Toarcian Stage.

Beds with Oxytoma jacksoni. The beds are established in the Saturn River section (Outcrop 1, upper part of Bed 18, Bed 19) (Fig. 62). The thickness of the Beds is 6.2 m. The beds are identified by a zonal assemblage with *Oxytoma* ex gr. *jacksoni* and are compared in this section with the Pseudolioceras wuerttenbergeri and Pseudolioceras falcodiscus zones of the Boreal standard of the Toarcian Stage.

Arctotis tabagensis Oxyto-zone. In Outcrop 1, the oxyto-zone includes Bed 20 of the Saturn Formation. The oxyto-zone is distinguished by the presence of *Arctotis* sp. ind. and zonal assemblage of bivalves with *Retroceramus elegans, Retroceramus menneri* (Fig. 62). The thickness of the Oxyto-zone in the Saturn River section is about 2.5 m. It is possible that the Saturn River section lacks the lower, non-retroceramid portion of the Arctotis tabagensis Oxyto-zone, which is characterized by *Oxytoma jacksoni* and *Propeamussium olenekense*.

Beds with Arctotis sublaevis. In the higher part of the lower subformation of the Saturn formation, represented by yellowish-gray sandstones, medium-grained, with plant remains and fine detritus, up to 14 m thick, *Arctotis* ex gr. *sublaevis* Bodyl., *Homomya* sp., *Retroceramus* ex gr. *formosulus* (Vor.), *R.* ex gr. *freboldi* (Kosch.), *R.* ex gr. *ussuriensis* (Vor.). Above them are ferruginous sandstones with *Retroceramus* ex gr. *lucifer* (Koshelkina, 1974, p. 143, Beds 7–11). The age of the upper part of the lower subformation of the Saturn Formation is Late Aalenian–Early Bajocian based on the presence of the index species of the Beds with Arctotis sublaevis in it.

The scheme of stratigraphy and correlation of Pliensbachian-Aalenian deposits in the Levy Kedon River basin is shown in Fig. 64.

Assessing the Correlation Potential of the Scale

Findings of index species of the zonal scale for oxytomids in Toarcian deposits and boundary deposits of the Pliensbachian and Aalenian allow us to confidently subdivide the strata and correlate the corresponding parts of the sections. In the Late Pliensbachian deposits, Beds with Meleagrinella deleta are identified within the Arctic paleobiogeographic region (Northeastern Russia—Brodnaya, Astronomicheskaya Rivers; Eastern Siberia—Cape Tsvetkov region, Kelimyar River, Kyra-Khos-Teryuteekh, Motorchuna, Pravoberezhnyi site). The index species *Meleagrinella golberti* and *Meleagrinella substriata* are ubiquitous in Lower Toarcian deposits within the Panboreal paleobiogeographical superregion (Northeastern Russia—Saturn River, Astronomicheskaya; Eastern Siberia—Anabar Bay, Kelimyar River, Motorchuna, Vilyui, Markha, Tyung, Ottur Sites; Germany, England, Spitsbergen, Western Canada), which makes it possible to carry out interregional correlation at the zonal level. The index species *Meleagrinella prima* is found in a number of sections in Eastern Siberia (Vilyui River, Markha, Tenkelyakh Site, Anabar Bay) and Northeastern Russia (Astronomicheskaya River, Saturn, Start), which facilitates interregional correlation at the zonal level. The index species *Arctotis marchaensis* and *Arctotis similis* have been established in most sections of Eastern Siberia (Vilyui River, Markha, Motorchuna, Sungyuyude, Molodo, Anabarskaya Bay, Cape Tsvetkov), which allows for intraregional correlation at the zonal level. These taxa can probably be used to subdivide sections in Northeastern Russia when re-examining sections, since *Arctotis* finds from different places in this region have been repeatedly cited in open sources (Knyazev et al., 2003; *Resheniya*..., 2009; etc.). The index species *Arctotis tabagensis* is found in most sections of Eastern Siberia (Cape Tsvetkov, Motorchuna River, Molodo, Kelimyar, Anabarskaya Bay, Tenkelyakh Site, Tabaginsky Cape). Beds with Arctotis sublaevis were traced within Eastern Siberia (Kelimyar River, Anabar, Tyung, Anabar Bay) and Northeastern Russia (Saturn River). It has been established that the index species of the Beds, the bivalve *Oxytoma jacksoni* is ubiquitously present in many sections of Eastern Siberia (Kelimyar River, Molodo, Anabarskaya Bay, Cape Tsvetkov) and Northeastern Russia (Saturn River) in the Upper Toarcian, which allows for interregional correlation at the substage level. The index species *Arctotis sublaevis* is found in most sections of Eastern Siberia (Anabar, Kelimyar, Sungyuyude, Tyung rivers) and Northeastern Russia (Saturn River) in the Upper Aalenian, which allows interregional correlation at the substage level.

The use of the zonal scale for oxytomids for biostratigraphic studies made it possible to detail the division and clarify the stratigraphic ranges of some formations (Fig. 65). In the section of Anabar Bay, a more detailed than previously oxytomid-based stratigraphy of the Airkat, Kiterbyut, Eren, Horgo and Arangastakh formations became possible (Shurygin et al., 2000). At the top of the Airkat Formation, Beds with Praemeleagrinella deleta were established in the stratigraphic range of the upper Pliensbachian zone (Lutikov et al., 2022). The Kiterbyut Formation contains Meleagrinella golberti Oxyto-zone, which correlates with the Tiltoniceras antiquum and Harpoceras falciferum zones (Lutikov and Arp, 2023b). Thus, it is

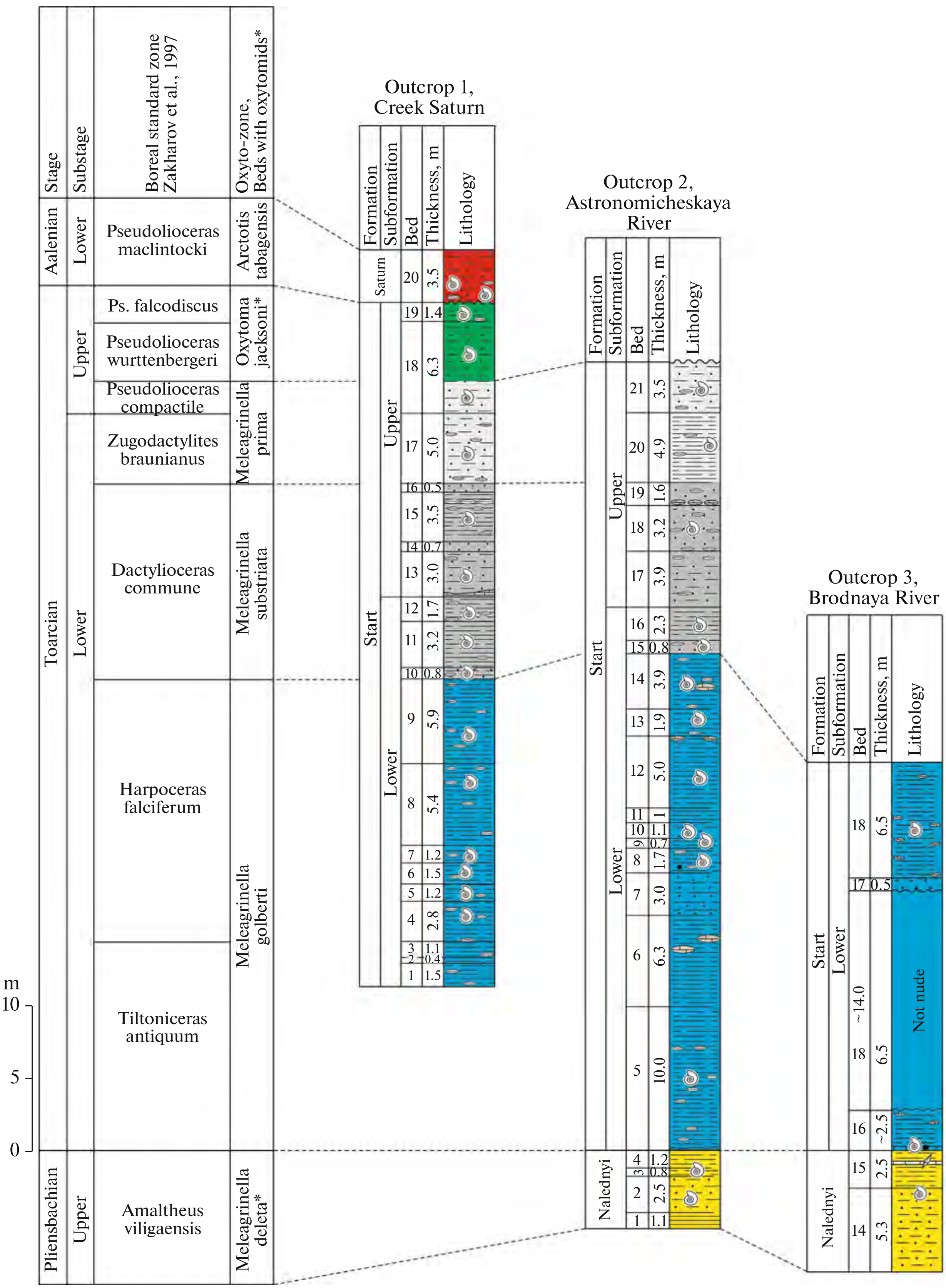

Fig. 64. Stratigraphy and correlation of Pliensbachian–Aalenian deposits in the Levy Kedon River basin based on the distribution of index species and zonal assemblages of the oxytomid scale. Legend see in Fig. 14.

assumed that the Kiterbyut Formation embraces a larger stratigraphic range than previously thought, since there is no sufficient evidence for a stratigraphic gap at the boundary of the Airkat and Kiterbyut formations with the fall of the lower Toarcian zone. The Eren Formation is divided into the Meleagrinella substriata, Meleagrinella prima and Arctotis marchaensis oxyto-zones, which correlate with the upper part of the Dactylioceras commune Zone and with the Lower Toarcian Zugodactilites braunianus Zone, with the Pseudolioceras compactile Zone of the upper Toarcian (Lutikov and Arp, 2023b). The Horgo Formation contains the Arctotis similis Oxyto-zone, which correlates with the Upper Toarcian Pseudolioceras falcodiscus Zone. In the lower part of the Arangastakh Formation, the Arctotis tabagensis Oxyto-Zone is established, which correlates with the Lower Aalenian Pseudolioceras maclintocki Zone (Lutikov, 2021). Thus, the Arangastakh Formation in the Nordvik structural-facies subregion apparently covers a larger stratigraphic volume than previously thought, since there is no sufficient evidence to prove the loss of the entire Lower Aalenian in the section of Anabar Bay, as previously thought (*Reshenie*..., 2004). The lower subformation of the Arangastakh Formation belongs to the Lower Aalenian–Lower Bajocian. Probably, in the section of Anabar Bay there is no lower part of the Aalenian, corresponding to the non-cynoceramic part of the Arctotis tabagensis Oxyto-zone and the upper part of the Beds with Oxytoma jacksoni.

In the Cape Tsvetkov section, a more detailed subdivision of the Korotkinskaya, Aprelevskiy and Arangastakh formations according to oxytomids was carried out than previously (Shurygin et al., 2000). In the upper part of the Airkat Formation, Beds with Meleagrinella deleta were identified. In the Kiterbyut Formation, Meleagrinella golberti Oxyto-zone was conventionally identified. In the lower part of the Korotkinsk Formation, the oxyto-zone Meleagrinella substriata is established. In the upper part of the Korotkiy Formation, the Meleagrinella prima, Arctotis marchaensis and Arctotis similis oxyto-zones are established, which correlate with the Upper Toarcian Pseudolioceras wuerttenbergeri, Pseudolioceras falcodiscus zones. In the Aprelevsky Formation and in the lower bed of the Arangastakh Formation, the Arctotis tabagensis Oxyto-zone was established, which correlates with the Lower Aalenian Pseudolioceras maclintocki Zone (Lutikov et al., 2022). In the section of the Kelimyar River, a more detailed subdivision of the Kyra and Kelimyar Formation based on oxytomids was carried out than previously (Shurygin et al., 2000). At the top of the Kyra Formation, the Beds with Meleagrinella deleta were recognized in the stratigraphic range of the upper Pliensbachian Zone (Lutikov et al., 2022). In the lower part of the Kelimyar Formation, the Meleagrinella golberti Oxyto-zone is established, which correlates with the Tiltoniceras antiquum and Harpoceras falciferum zones. The ammonite *Tiltoniceras* sp. was found in the same deposits. Thus, for the first time, evidence of the cooccurrence of the Kyrin and Kelimyar formations has been provided (Lutikov and Arp, 2023a, 2023b). The higher part of the Kelimyar Formation section is divided into the Meleagrinella substriata and Meleagrinella prima oxyto-zones, which correlate with the Lower Toarcian Dactylioceras commune, Zugodactilites braunianus zones and the Upper Toarcian Pseudolioceras compactile Zone (Lutikov and Arp, 2023b). The overlying sediments contain Beds with Oxytoma jacksoni, which correlate with the Pseudolioceras wuerttenbergeri, Pseudolioceras falcodiscus and Pseudolioceras maclintocki zones, and the Arctotis tabagensis oxyto-zone, which correlates with the Lower Aalenian Pseudolioceras maclintocki zone, is traced. Thus, there is justification for the assertion that the supposed stratigraphic gap within the Kelimyar Formation with the absence of the Upper Toarcian from the section (*Resheniya*..., 1981) is not justified.

In the Motorchuna River section, the Motorchuna and Suntary formations were subdivided using oxytomids. At the top of the Motorchuna Formation, the Beds with Praemeleagrinella deleta were established in the stratigraphic range of the upper Pliensbachian zone. At the base of the Suntary Formation, the Meleagrinella golberti Oxyto-zone is established, which correlates with the Lower Toarcian Tiltoniceras antiquum and Harpoceras falciferum zones. The upper part of the formation contains the Arctotis similis Oxyto-zone, which correlates with the Upper Toarcian Pseudolioceras falcodiscus Zone, and the Arctotis tabagensis Oxyto-zone, which correlates with the Pseudolioceras maclintocki Zone. Thus, the stratigraphic volume of the Suntary Formation in the Zhigansk structural-facies subregion embraces the entire Toarcian and Lower Aalenian. There are insufficient grounds to show the loss of the lower Toarcian zone from the Motorchuna River section, as previously thought (*Resheniya*..., 1981).

In the Markha River section and the Tenkelyakh drilling site, located in the Markha-Tyung interfluve, the Tyung and Suntary Formations were subdivided using oxytomids. The complete sequence of divisions of the scale for oxytomids (from bottom to top) was established: Beds with Praemeleagrinella deleta in the stratigraphic range of the upper Pliensbachian zone, Meleagrinella golberti Oxyto-zone in the range of Tiltoniceras antiquum–Harpoceras falciferum zones, oxyto-zone Meleagrinella substriata in the range of the Dactylioceras commune zone, oxyto-zone Meleagrinella prima in the Zugodactilites braunianus–Pseudolioceras compactile range zone, Arctotis marchaensis Oxyto-Zone in the range of the Toarcian Pseudolioceras wuerttenbergeri zone, oxyto-zone Arctotis similis in the range of the Pseudolioceras falcadiscus Zone and Arctotis tabagensis Oxyto-Zone, which correlates with the Pseudolioceras maclintocki Zone. Thus, the stratigraphic range of the Suntary

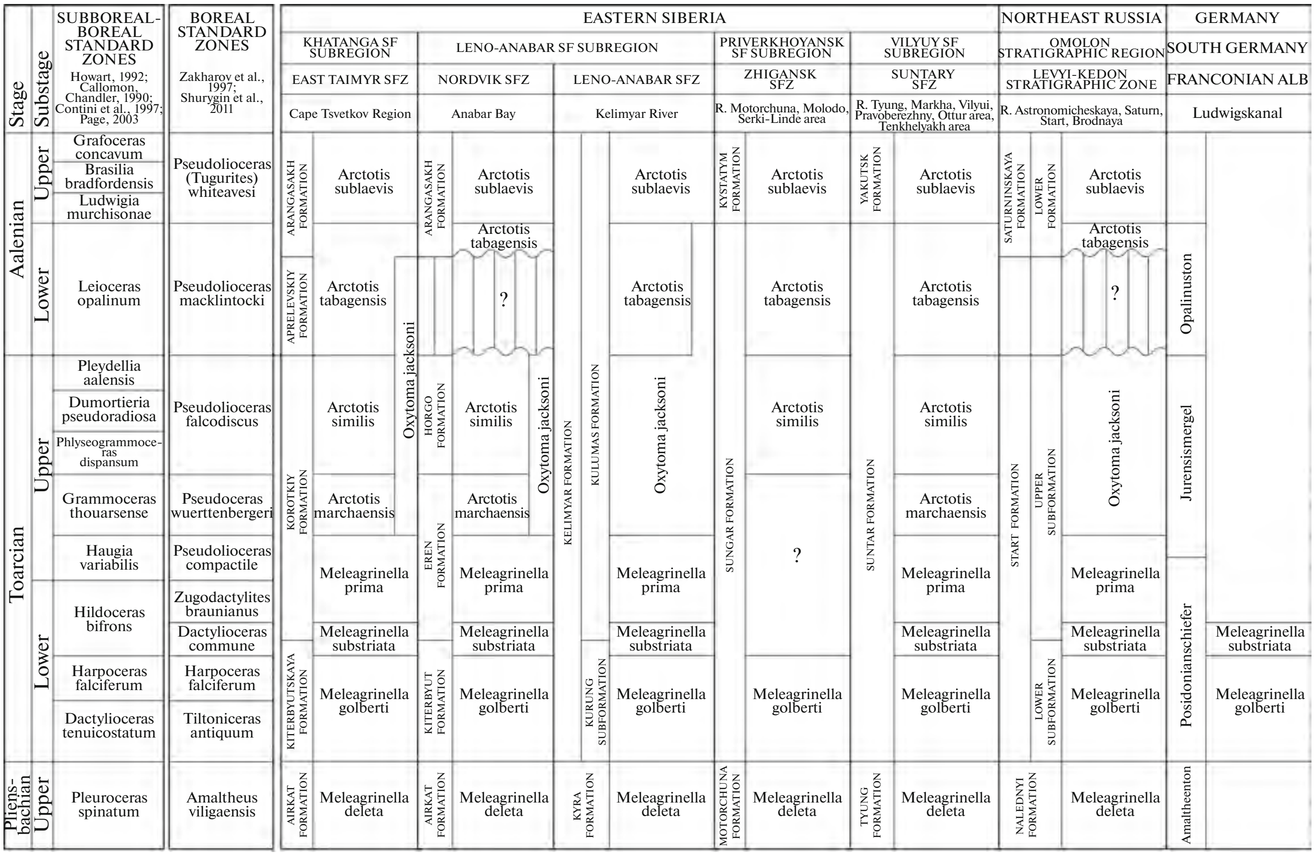

Fig. 65. Correlation of Toarcian deposits and boundary intervals of the upper Pliensbachian and Aalenian zones in Eastern Siberia, Northeastern Russia and Southern Germany based on section subdivision using the oxytomid scale.

Formation in the Suntary structural-facies subregion covers the entire Toarcian and Lower Aalenian. There are no sufficient grounds to prove the absence of the lower Toarcian zone from the Markha River, Vilyui and Tyung sections, as previously thought (*Resheniya*..., 1981).

In the Saturn River section, the Brodnaya and Start formations are subdivided based on oxytomids. The sequence of subdivisions of the scale for oxytomids (from bottom to top): Beds with Praemeleagrinella deleta in the stratigraphic range of the upper Pliensbachian zone, Meleagrinella golberti Oxyto-zone in the range of Tiltoniceras antiquum–Harpoceras falciferum zones, Meleagrinella substriata Oxyto-zone in the range of Dactylioceras commune zone, Meleagrinella prima Oxyto-zone in the range of the Zugodactilites braunianus–Pseudolioceras compactile zones. In the upper part of the Start Formation, Beds with Oxytoma jacksoni are identified, which correlate with the Pseudolioceras wuerttenbergeri and Pseudolioceras falcodiscus zones. Thus, the Start Formation apparently covers a larger stratigraphic volume than previously thought (*Resheniya*..., 2009), since there are no sufficient grounds for a stratigraphic gap at the boundary of the Start and Saturn formations with the absence of the upper Toarcian zones. The lower subformation of the Saturn Formation is assigned to the Lower Aalenian–Lower Bajocian. The Levy Kedon River section probably lacks the lower part of the Aalenian, corresponding to the non-inoceramid part of the Arctotis tabagensis Oxyto-zone.

CONCLUSIONS

As a result of a detailed study of shells of bivalves of the family Oxytomidae from numerous sections of Jurassic and Cretaceous deposits of Eastern Siberia, Northeastern Russia and Germany, as well as based on an analysis of the stratigraphic distribution of species belonging to the genera *Oxytoma, Meleagrinella* and *Arctotis*, the following results were obtained:

(1) Using the methods of age periodization and typification of the hinge apparatus, the morphogenesis of the ligament and byssal blocks in Jurassic and Cretaceous representatives of the family were studied. At the same time, it was possible to discover individual and age-related variability of the hinge apparatus of oxytomids, previously not described in publications and not used to characterize taxa, to establish the directions of morphogenesis within the family Oxytomidae, and to estimate the taxonomic weight of morphological characters and to classify species and

supraspecific taxa. Preliminary diagnoses (Lutikov and Shurygin, 2010; Lutikov et al., 2010) of generic, subgeneric and species taxa of the family Oxytomidae, which were previously made on the material available in 2010 and according to published data, have been clarified. New conclusions were obtained based on studying the morphology of the hinge apparatus in a larger number of representatives of the family, including type specimens of key taxa from the Hettangian–Valanginian of Russia, Germany, France and the USA, as well as a result of studying the microsculpture of some specimens of *Meleagrinella* and *Arctotis* using SEM. The total biodiversity of the studied taxa was 31 species belonging to three genera—*Oxytoma, Meleagrinella* and *Arctotis*.

(2) Comparative comparison of the types and subtypes of ligament pits, types of byssal notch, byssal groove and byssal appendage, identification of the prominence made it possible to reconstruct the family (genealogical) connections of various taxonomic groups. Based on the analysis of changes in the ligament pit during ontogenesis, the phylogeny of the Jurassic-Cretaceous genera *Oxytoma, Meleagrinella* and *Arctotis* was reconstructed, reflecting the direction of the spatiotemporal evolution of the family Oxytomidae.

(3) As a result of a revision of views on generic and species taxonomy within the family Oxytomidae (without the subfamily Maccoyellinae Waterhouse, 2008), a new taxon system was proposed:

Family Oxytomidae Ichikawa, 1958

Subfamily Oxytominae Ichikawa, 1958

Genus *Oxytoma* Meek, 1864 (Ladinian–Maastrichtian)

Genus *Meleagrinella* Whitfield, 1885 (Hettangian–Kimmeridgian)

Subgenus *Praemeleagrinella* Lutikov et Schurygin, 2010 (Hettangian–Pliensbachian, Early Toarcian?)

Subgenus *Clarthrolima* Cossmann, 1908 (Early Toarcian–Volgian)

Subgenus *Meleagrinella* s. str. (Early Toarcian–Late Cretaceous, Maastrichtian)

Genus *Arctotis* Bodylevsky, 1960 (Late Toarcian–Hauterivian)

Subgenus *Praearctotis* Lutikov et Schurygin, 2010 (Toarcian–Aalenian)

Subgenus *Arctotis* s. str. (Aalenian–Bathonian)

Subgenus *Canadotis* Jeletzky et Poulton, 1987 (Callovian?, Oxfordian–Volgian)

Subgenus *Canadarctotis* Jeletzky et Poulton, 1987 (Volgian–Hauterivian)

(4) In the Pliensbachian–Bajocian marine sediments on the territory of Eastern Siberia and Northeastern Russia, a phylogenetic sequence of eight taxa of the family Oxytomidae, belonging to the genera *Meleagrinella* and *Arctotis*, was established.

(5) Based on the Pliensbachian-Bajocian phylogenetic sequence in the Meleagrinella–Arctotis lineage, the zonal scale for bivalves has been modernized, making it possible to correlate coastal-marine deposits of Eastern Siberia and Northeastern Russia. To correlate the sediments of the deep shelf of these regions, parallel Beds with Oxytoma were identified and their relative spatiotemporal position within the scale was determined. In relation to the previously created zonal scales of Eastern Siberia, Northeastern Russia for bivalves (Repin and Polubotko, 2004; Shurygin, 2005), the new scale has elements of continuity—in characterizing the oxyto-zones, the previously established sequence of accompanying bivalves was used. The new scale has differences—it is based on the phylogenetic lineage of species of only one family, and the stratotypes of oxyto-zones are established in it. For the Toarcian–Lower Aalenian, the zonal scale includes six oxyto-zones. The boundary intervals of the upper Pliensbachian and upper Aalenian–lower Bajocian include two biostratons in the rank of Beds with oxytomids. The eight oxytomid zonal divisions, established on the basis of the phylogenetic lineage of taxa of the *Meleagrinella* and *Arctotis*, correspond to the stratigraphic sequence of the eleven ammonite zones of the Boreal zonal standard:

(1) Beds with Meleagrinella deleta (=Amaltheus viligaensis Zone)

(2) Meleagrinella golberti Oxyto-zone (=Tiltoniceras antiquum, Harpoceras falciferum zones)

(3) Meleagrinella substriata Oxyto-zone (=Dactylioceras commune Zone)

(4) Meleagrinella prima Oxyto-zone (=Zugodactylites braunianus, Pseudolioceras compactile Zones)

(5) Arctotis marchaensis Oxyto-zone (=Pseudolioceras wuerttenbergeri Zone)

(6) Arctotis similis Oxyto-zone (=Pseudolioceras falcodiscus Zone)

(7) Arctotis tabagensis Oxyto-zone (=Pseudolioceras maclintocki Zone)

(8) Beds with Arctotis sublaevis (=Pseudolioceras waiteavesi, Pseudolioceras fastigatus Zones). For the Upper Toarcian–Lower Aalenian deposits of the deepened shelf of the Eastern Siberia and North-East Russia, characterized by a unique assemblage of bivalves, parallel Beds with Oxytoma jacksoni (=Pseudolioceras wuerttenbergeri, Pseudolioceras falcodiscus, Pseudolioceras maclintocki zones).

(6) Based on tracking index species and zonal assemblages of oxyto-zones in sections of Eastern Siberia, Northeastern Russia and Germany, the correlation potential of the scale was assessed. In late Pliensbachian deposits, Beds with oxytomids are identified within the Arctic paleobiogeographic region. In early Toarcian deposits, two oxyto-zones are recorded within the Panboreal paleobiogeographic superregion. In the late Toarcian-early Aalenian deposits, four oxyto-zones and two biostratons in the rank of Beds

with oxytomids are recorded within the Arctic paleobiogeographic region.

(7) The effectiveness of the zonal scale for correlating Toarcian-Aalenian marine sediments of the Boreal type is substantiated. The index species of oxyto-zones—Meleagrinella golberti and Meleagrinella substriata—have been traced in most regions of the Northern Hemisphere, which makes it possible to carry out interregional correlation of Early Toarcian deposits at the zonal level. The oxyto-zone index species *Meleagrinella prima, Arctotis marchaensis, Arctotis similis* and *Arctotis tabagensis* were found in most sections of Eastern Siberia, enabling intraregional correlation of Late Toarcian-Early Aalenian deposits at the zonal level. The index species of the Beds with Oxytoma jacksoni in the stratigraphic range of two Upper Toarcian and Lower Aalenian ammonite zones are present in a number of sections of Eastern Siberia and Northeastern Russia, enabling interregional correlation at the substage level. Based on the identified continuous phyletic sequence of oxytomids at the Toarcian-Aalenian boundary in Eastern Siberia, the boundary of the lower and middle sections of the Jurassic system, drawn between the Arctotis similis and Arctotis tabagensis oxyto-zones, is more accurately fixed.

(8) The use of an oxytomid zonal scale made it possible to detail the stratigraphy and clarify the stratigraphic ranges of some Pliensbachian-Aalenian formations of Eastern Siberia and Northeastern Russia. Determining the completeness of sections using a scale is not always possible. Therefore, further detailing of the scale is necessary with the identification of subzones based on the study of changes in the morphology and microsculpture of shells in the ontogenies of already identified and new taxa.

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CONFLICT OF INTEREST

The author of this work declares that he has no conflicts of interest.

Reviewer V.A. Zakharov

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