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On the Boreal Genus *Buchia* (Bivalvia) from the Tithonian of the Lesser Caucasus

V. A. Zakharov* and A. A. Kasumzade**

**Geological Institute, Russian Academy of Sciences, Moscow, Russia*
***Institute of Geology, National Academy of Sciences of Azerbaijan, Azerbaijan, Baku*

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Abstract—Two species of the genus *Buchia*, *B. mosquensis* (Buch) and *B.* ex gr. *terebratuliodes* (Lah.) found in the Tithonian of the Lesser Caucasus (40° N) are described. Geographic distribution of the Kimmeridgian and Tithonian representatives of the genus in marginal areas of the Tethys–Panthalassa Superrealm is analyzed. Migration of buchiids into lowermost latitudes of the Northern Hemisphere coincided in time with episodes of the biota geographic homogenization. The joint occurrence of two above species facilitates correlation of the middle–upper Tithonian and middle–upper Volgian boundary beds. As is suggested, past seaways connected seas of central Russia and Transcaucasia in the relevant period of geological time.

Key words: buchiids, Tithonian Stage, Kimmeridgian Stage, Lesser Caucasus, migration, Peri-Tethys.

INTRODUCTION

Bivalves of the genus *Buchia* represent fossil mollusks most widespread in Upper Jurassic and Lower Cretaceous (Neocomian) marine deposits of the Boreal regions. In the Late Jurassic and earliest Cretaceous, buchiids inhabited epicontinental and marginal seas of the Northern Hemisphere of the Earth mostly northward of the latitude 50° N. A high stratigraphic significance of buchiids is doubtless because of a high rate of their morphogenesis, broad geographic distribution, independence of the facies control, and easy identification in representative collections. The *Buchia* species have been most effectively applied to correlate deposits in the Panboreal Realm and Boreal–Peritethyan ecotone. The problem of Boreal–Tethyan correlation has been under keen attention during the entire 20th century and is vital at present. Accordingly, each occurrence of *Buchia* remains in distribution areas of Tethyan deposits is of interest for stratigraphy. In addition, new data on southern distribution limits of Tethyan sediments reveal the communication ways between northern and southern sea basins in particular epochs and are useful for considering the interaction of Boreal and Tethyan water masses (the Boreal–Tethyan impacts on biota). Keeping all this in mind, we feel it necessary to inform the geological community about *Buchia* species first found in the Transcaucasia (Karabakh Mountains).

STRATIGRAPHIC SECTION AND LEVELS OF *BUCHIA* REMAINS

Buchia remains of the Tithonian Age have been found first and identified by one of the authors (Kasumzade, 2000) in the Yukhary Gushchular section, the Karabakh Mountains, Azerbaijan Republic (Fig. 1).

This section situated 500–700 m eastward of the Yukhary Gushchular poultry farm includes the Tithonian and adjacent beds (Kasumzade, 2000; p. 138). The following section members are exposed on the right-hand side of a nameless river in the deep canyon between the "Lachyn Gayasy" and "Gadzhar Gayasy" (Fig. 2):

Kimmeridgian

(1) Tuffaceous conglomerate; fissures widespread in the rock and thin (0.3–0.4 m) intercalations of brick-red limestone are filled in with calcite (80–100 m).

Lower Tithonian

(2) Basal bed; the bed is composed of porphyrite and limestone pebbles, the latter containing *Haploceras* sp., *Glochiceras* sp. indet. (determinations of M.R. Abdulkasumzade), *Anisocardia* sp., and *Pygope* sp. indet. Khalilov and Aliev (1970) also reported on occurrence of *Hybonotyceras beckeri* (Neum.), *Haploceras carachties* (Zeuschn.), *Lamellaptychus beyrichi* (Oppel), *L. lamellosus* Traut., *Pygope janotor* (Pict.), and other forms in the bed (3–10 m).

(3) Limestone; rock is sandy, containing tuffaceous material. The member lower part (up to 1 m) contains abundant columnals of crinoids. *Lamellaptychus* cf. *beyrichi* and *Buchia* sp. indet. (ex gr. *Mosquensis*) are found in the middle part, and abundant fragments of oyster and brachiopod shells are confined to the upper one. Khalilov and Aliev (1970) described *Subplanites*

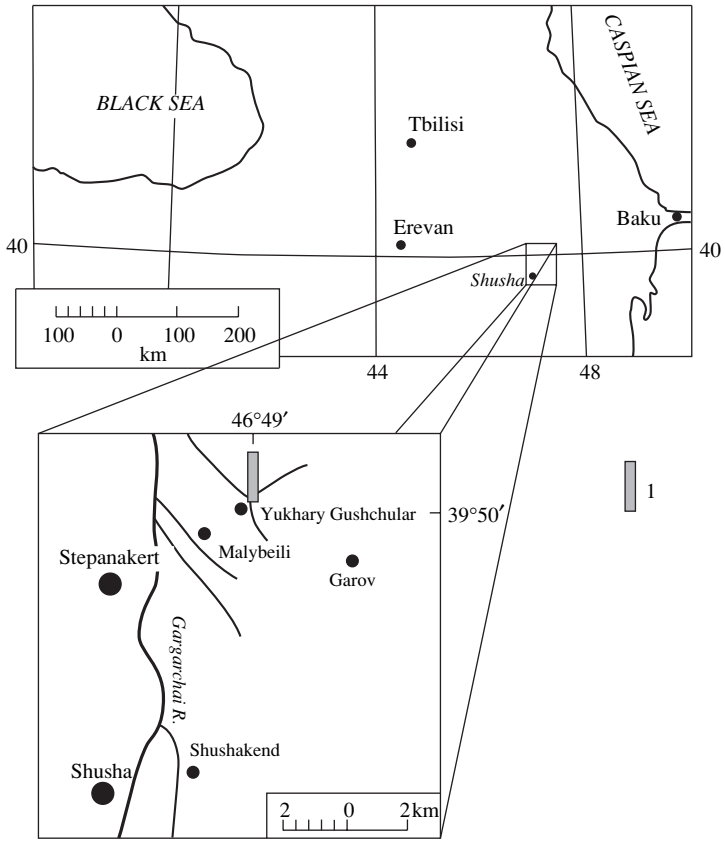

Fig. 1. Locality of the Upper Jurassic–(?)Berriasian section (1) studied in the Lesser Caucasus (Azerbaijan, Karabakh Mountains, Yukhary Gushchular Village).

cf. *contiguus* (Cat.) and *Punctaptychus punctatus fractocosta* from the level of 20 m above the member base (65–67 m).

(4) Limestone, gray to dark gray, organogenic-detrital, gravely and massive; rock is of cross-bedded structure (60–70 m).

(5) Limestone, gray to light pinkish gray, organogenic-detrital, locally compact, of gravely-sandy texture; in addition to large pebbles, separate boulders incorporated in the rock are up to 0.3–0.5 m in diameter. The member yields *Lamellaptychus beyrichi beyrichi* (Oppel) and undeterminable remains of belemnites, brachiopods, and echinoids (25–30 m).

Middle–upper Tithonian

(6) Limestone, light pinkish gray, sandy, paralaminated, containing abundant though poorly preserved shells of bivalves; species *Buchia mosquensis* Buch and *B.* ex gr. *terebratuloides* (Lah.) are identified among the latter (11–12 m).

(7) Conglomerate-like limestone; pebbles of gray to greenish gray hard limestones are up to 0.2–0.4 in diameter (1.5 m).

(8) Limestone, gray to light pinkish gray, contains tuffaceous material of sand size-range (5.0–6.0 m).

(9) Limestone, gray to light pinkish gray, conglomerate-like, contains sandy admixture (2.0–2.5 m).

(10) Limestone, light pinkish gray, organogenic-detrital, flaggy, contains tuffaceous sandy admixture (1.5–2.0 m).

Berriasian (?)

(11) Limestone, light pinkish gray, gravely, thick-bedded to massive; the member lower part is exposed in a precipice (20–25 m) and the upper one in stepwise cliffs (about 30 m). Near the member base, there are sporadic lenses and interlayers of loose tuffaceous sandstone and gravelstone with clay admixture. Faunal remains found in the member are *Lamellaptychus beyrichi* (Oppel), *Ctenoides* sp., and *Arctostrea* cf. *rectangularis* (Roemer). Khalilov and Aliev (1970) reported an occurrence of *Lamellaptychus beyrichi* (Oppel), *Hibolites* sp. indet., and *Duvalia* sp. indet. The upper contact of the member is tectonic, overridden by different Albian horizons (55–60 m).

In earlier works, the described section is attributed either to the lower Tithonian (Khalilov and Aliev, 1970), or to the Kimmeridgian–lower Tithonian interval, a part of the Barremian included (Abdulkasumzade, 1988; Gasanov, 1994; Babaev and Abdulka-

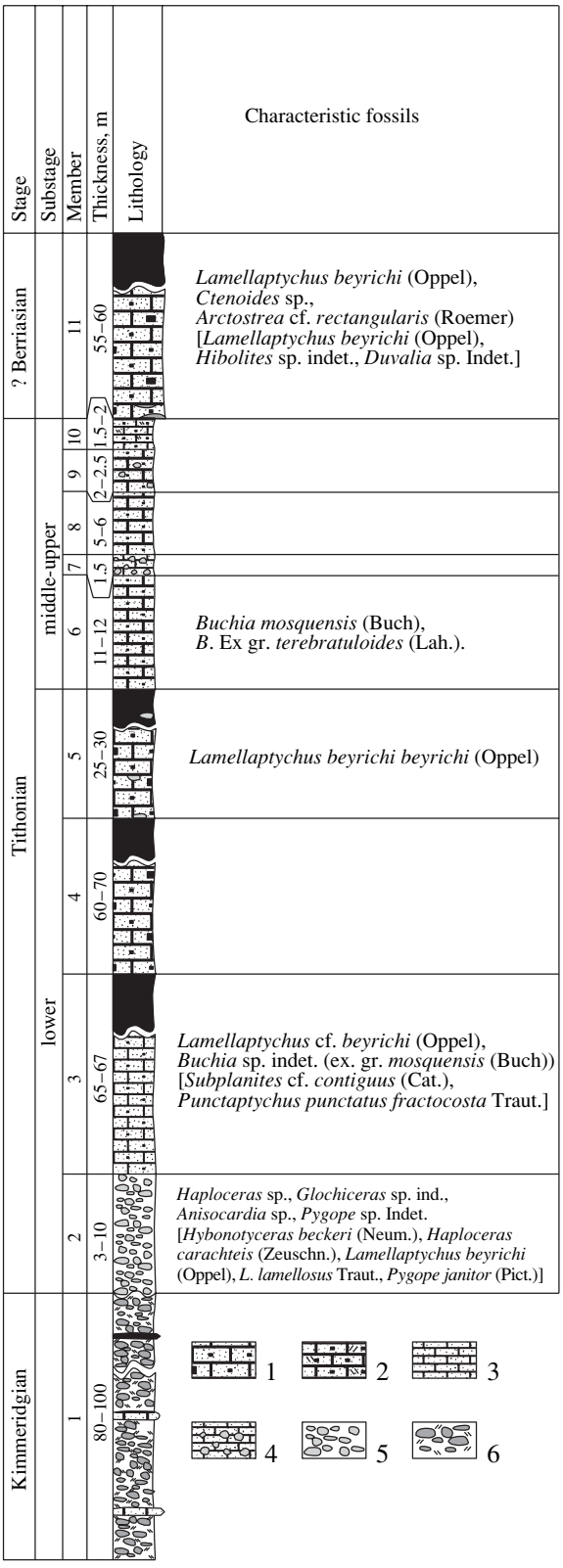

Fig. 2. Lithostratigraphy of the Kimmeridgian, Tithonian, and (?)Berriasian sediments near the Yukhary Gushchular Village: (1) sandy or gravely limestone; (2) sandy tuffaceous limestone; (3) limestone; (4) conglomerate-like limestone; (5) conglomerate; (6) tuff conglomerate (taxa in square brackets are cited from Khalilov and Aliev, 1970).

sumzade, 1997). In opinion of Kasumzade (2000), the section spans all the Tithonian substages and exhibits gradual transition to the Berriasian. In distinction from conclusions of our predecessors, we believe, based on paleontological data presented above, that the Gushchular Formation is not older than the early Tithonian and not younger than the Tithonian–Berriasian transition all along the strike.

Haploceras carachteis (Zeuschn.) and *Pygope janitor* (Pict.) from the basal bed substantiate, along with *Subplanites* cf. *contiguous* (Cat.) and *Punctaptychus punctatus fractocosta* (Traut.) found near the base of Member 3, the early Tithonian age of respective interval (Khalilov and Aliev, 1970). The late Kimmeridgian index species *Hybonotyceras beckeri* (Neum.) found in the basal bed is redeposited in opinion of Khalilov and Aliev.

Presence of the middle–upper Tithonian deposits in the section can be suggested based on the found *Buchia* forms. In Boreal regions, the *Buchia mosquensis* stratigraphic range spans the interval of middle and upper Volgian substages. *B. terebratuloides* is dispersed throughout the upper Volgian Substage, being occasional in the basal Berriasian. Joint occurrence of two species in Boreal regions has not been reported earlier. Based on their coexistence in one rock sample studied, we tend to assume that relevant sampling level is near the middle–upper Volgian boundary, i.e., presumably near the boundary between the middle and upper Tithonian substages. It is necessary to keep in mind, however, that the last species is determined in the open nomenclature (*B.* ex gr. *terebratuloides*).

The lower part of Member 10, where we found *Lamellaptychus beyrichi* (Oppel), is presumably of Berriasian age. Stratigraphic range of this aptychus form corresponds to the Kimmeridgian–Valanginian interval. However, it is unlikely that the described section includes the Valanginian, because G.A. Aliev, who studied paleontological materials collected by Bairamov (1965), identified the following gastropod taxa characteristic of the Valanginian: *Nerinea renngarteni* Pcel., *N. upensis* Fogdt, *N. skelinensis* Pcel., *Ampulospira* sp., *Ptygmatis longa conica* Pcel., and *Multiptyxis* aff. *airiulensis* Fogdt. This assemblage is discovered southeastward of the study area in calcareous tuffstones, tuffaceous gravelstones, and tuffolavas of the Khonashenchai–Guruchai interfluve. Since none of these taxa has been encountered in the Yukhary Gushchular section, we attribute its upper interval to the Berriasian only.

The undivided Tithonian Stage has been described in several other sections situated in suburbs of the Yukhary Gushchular and Malybeili villages, on the Shusha Plateau, and elsewhere. However, *Buchia*

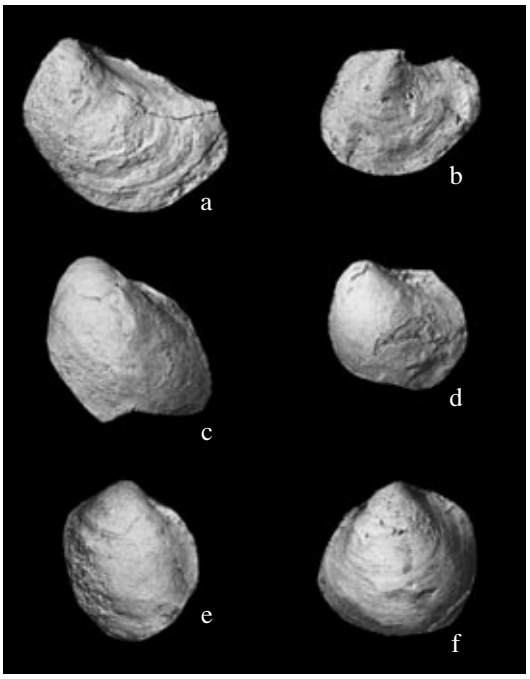

Fig. 3. *Buchia mosquensis* (Buch): (a) species no. BP–8575, left valve; (b) specimen no. BP–8576, right valve, magnification 2; (c) specimen no. BP–8577, right valve; (d) specimen no. BP–8578, left valve. *B.* ex gr. *terebratuloides* (Lahusen): (e) specimen no. BP–8579, left valve; (f) specimen no. BP–8580, right valve. Specimens are stored at the V.I. Vernadsky Geological Museum, Russian Academy of Sciences, collection no. BP.

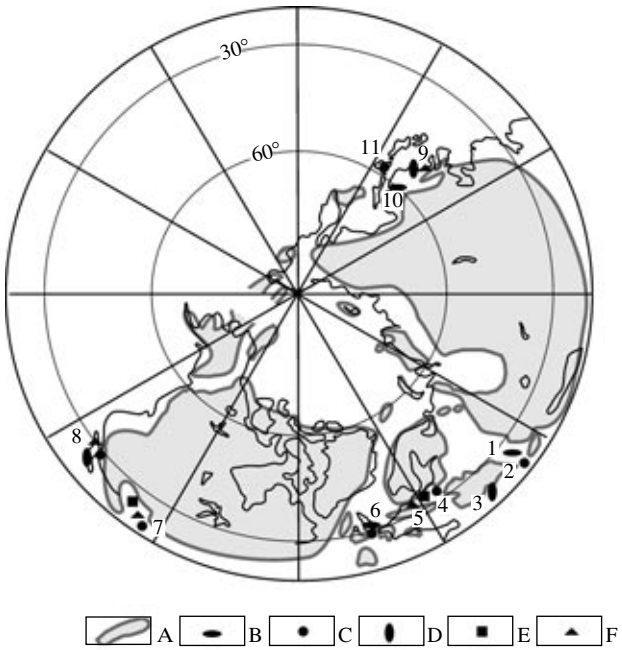

Fig. 4. Northern paleobasins and land areas (A) of the Tethys–Panthalassa Superrealm with indicated southernmost occurrences of buchiids of the early (B), middle (C), late (D) Tithonian and early (E), late (F) Kimmeridgian; numbers in the figure indicate the following regions: (1) circum-Caspian, (2) Lesser Caucasus; (3) Crimea, (4) Poland; (5) southern Germany; (6) southern England; (7) Mexico; (8) North California; (9) southern Primor'e; (10) northern Primor'e, and (11) Hokkaido.

remains have been found near the Yukhary Gushchular poultry farm only (Kasumzade, 2000).

MORPHOLOGY OF DISCOVERED SPECIES

The collection studied includes nearly 20 casts of fossil shells and 6 almost intact valves. Species *Buchia mosquensis* is represented by molds of three left and one right valves (Figs. 3a–3d). Well observable diagnostic features of the species are the curvoid ontogenesis, narrow elongated umbonal part, fine concentric growth lines, slightly prominent costae on the left valve, medium size of shells, and anteriorly projecting rounded margin of the right valve. Species *B.* ex gr. *terebratuloides* is represented by molds of two left and one right valves. In different Boreal sections, *B. terebratuloides* is of variable morphology. Of interest for comparison are varieties of this species from the Kashpir site near Syzran, the right bank of the Volga River. The upper Volgian Substage yields here two varieties of *B. terebratuloides*: small-sized spheroid shells and shells elongated in longitudinal direction. Both forms are encountered in the Transcaucasia, but they are in a poor preservation state (Figs. 3e and 3f), and we determine them in open nomenclature, leaving aside the precise identification.

GEOGRAPHIC DISTRIBUTION OF KIMMERIDGIAN AND TITHONIAN BUCHIIDS IN NORTHERN MARGIN OF THE TETHYS–PANTHALASSA SUPERREALM

In the Lesser Caucasus, *Buchia* species of the Tithonian are discovered for the first time at the latitude of 40° N, Karabakh Mountains, Azerbaijan. During the Kimmeridgian and Tithonian, this area was in the northern marginal zone of the Tethys–Panthalassa Superrealm. Remains of Kimmeridgian and Tithonian buchiids are known in all three continents of the Northern Hemisphere, in the regions occupied during the Late Jurassic by warm marginal seas of the Tethys (Fig. 4).

Early Kimmeridgian. In the West European province, buchiids migrated southward to the latitude of southern Germany (48°N; Zakharov, 1981; Kelli, 1990). In the Boreal Pacific province, differentiation of faunas was in contrast greater than in the Oxfordian. According to Imlay (1984, Figs. 4a and 4b), buchiids penetrated far to the south in northern Mexico.

Late Kimmeridgian. In the West European province (southern Germany, 48° N), Boreal-Arctic ammonites and buchiids coexisted in the late Kimmeridgian with Tethyan mollusks (Kelly, 1990). In the Boreal Pacific province, buchiids are known all along the coastal zone

of North America. In western Canada (49° N, British Columbia), occasional buchiids are encountered in association with Submediterranean ammonites of genera *Lithacoceras, Discosphinctoides, Aspidoceras*, and *Suboxydiscites* (Poulton *et al.*, 1988). The late Kimmeridgian age of this ammonite assemblage is established based on *Lithacoceras* and *Discosphinctoides* forms. In North California (38° N), representatives of the genus *Buchia* occur in association with the Arctic-Boreal *Amoeboceras (Amoebites)* and Submediterranean *Richeiceras* (Imlay, 1961). *Buchia mosquensis* (Buch) and *B. concentrica* (Sow.) from Mexico (20° N) are likely of the late Kimmeridgian age (Burckhardt, 1906; Imlay, 1980). Perfect figures of Late Jurassic *B. concentrica* and *B. tenuistriata* from the Sierrecilla de San Antonio locality of the Zuloaga (Oxfordian–Kimmeridgian) and La Caja formations, Zacatecas region, have been published by Buitron (1984) who reported their occurrence in association with ammonites *Idoceras*, presumably indicative of the terminal lower Kimmeridgian, and *Haploceras*, the latter characteristic of the upper Kimmeridgian and probably of the Tithonian. In the Far East coastal zone of paleoocean, buchiids migrated rather far to the south, to the latitude of 44° N (Sey and Kalacheva, 1992).

The long coexistence period of buchiids and Tethyan ammonites in the Pacific coastal zone of North America reflects most likely the influx of cold near-bottom waters from the north to the south.

Early Tithonian (early Volgian) time. Within the Boreal Atlantic province, buchiids of this time colonized northwestern Europe. They are known in southern England, northwestern France, northern and southern Germany, Austria, the Carpathian Mountains of Poland, and have reached the latitude of 48° N (Zakharov, 1981; Kelly, 1990; Kutek and Wierzbowski, 1986).

In the early Volgian time, the East European province was invaded by numerous genera of Tethyan ammonites prevailing in fossil assemblages (Zakharov and Rogov, 2003). Buchiids migrated simultaneously southward and reached the Orenburg region (51° N), where their remains are abundant in marly limestones (Zakharov, 1981).

In the Boreal Pacific province (northern Primor'e, 50° N), genus *Buchia* was dominant in benthic communities of the early Volgian (early Tithonian) time (Sey and Kalacheva, 1997). As is mentioned above, stratigraphic position of buchiids in central Mexico is unclear.

Middle Tithonian (middle Volgian) time. Buchiids of that time known from northwestern France, southern England, southern Poland, and the Czech Republic colonized seas of the West European province (Zakharov, 1981; Kelly, 1990). Migration of East European mollusks to the west was most likely caused by enhanced influence of boreal-arctic water masses (Fig. 4).

In the middle Volgian (middle Tithonian) time, buchiids dominated in benthic communities of Primor'e, the Far East region of the Boreal Pacific province (Fig. 4). Their remains are known from Hokkaido (Zakharov, 1981). In places, they occur in association with subtethyan trigoniids (Zakharov *et al.*, 1996), because northern boundary of the ecotone was displaced in the middle Volgian time for several degrees northward relative to its position in the Kimmeridgian Age.

In the Boreal Pacific province, buchiids are known from northern California, where they occur in association with Tethyan ammonites (Johnes *et al.*, 1969). The middle Volgian species *Buchia mosquensis* (von Buch) and *B. rugosa* (Fischer) are described, though without figures, from the *Durangites* Beds of central Mexico (20° N; Aguilera, 1895; Imlay, 1980). However, position of the genus *Durangites* from Mexico (and from Primor'e as well) in the standard West European ammonite zonation cannot be regarded as established unambiguously (Zakharov and Rogov, 2003). In opinion of Imlay (1980), the *Durangites–Kossmatia* assemblage existed in the initial late Tithonian. This dating supports the assumed cooling near the eastern coast of Paleopacific ocean in the latest Tithonian time (Jeletzky, 1984).

Late Tithonian (late Volgian) time. A vast regression of the late Volgian time resulted in deposition of Purbeckian lagoonal–continental facies and practically interrupted the sea regime in the West European province. The Boreal–Tethyan interchange of faunas almost ceased in Western Europe, and *Buchia* remains of that time are unknown here (Kelli, 1990).

Permyakov *et al.* (1991) described, though without figuring, *Buchia* species from the Tithonian of the Crimean Mountains (Fig. 4). In the upper Tithonian (Baidarskaya Formation), they found the late Volgian species *Buchia terebratuloides* (Lah.) and *B. obliqua* (Tull.) associated with *Haploceras tithonius* (Opp.) and *H. elimatum* (Opp.). Besides, *Buchia obliqua* (Tull.) and *B. volgensis* (Lah.) were found in beds of the Tithonian–Berriasian transition together with *Protetragonites* cf. *quadrisulcatum* (D'Orb.), *H. elimatum* (Opp.), *Substreblites zonarius* (Opp.), *Paraulacosphinctes senex* (Opp.), *P. transitorius* (Opp.), *Malbosiceras shaperi* (Pic.), and *Pseudosubplanites lorioli* (Zitt.).

In the Boreal Pacific province, situation was almost without changes. In Primor'e, British Columbia, and northern California (Fig. 4), pelagic assemblages of Tethyan ammonoids coexisted in the terminal Jurassic with benthic assemblages of Boreal-Arctic buchiids (Johnes *et al.*, Imlay and Johnes, 1970; Sey and Kalacheva, 1999). Tithonian buchiids are also known from Cuba (Myczynsky, 1999), but we failed to identify them in reproduced figures even at the generic level.

BOREAL INVASIONS IN TETHYAN SEAS OF THE TERMINAL JURASSIC EPOCH

The southward expansion of *Buchia* habitat areas is commonly considered as a consequence of enhancing Boreal influence, i.e., of the Boreal seawater advancement southward (Baraboshkin, 2001). Geographic reorganization that opens seaways used to be considered as one of the factors, which controlled this advancement. Climatic fluctuations are suggested to be the other reason (Zakharov and Rogov, 2003). During the entire period of their existence, buchiids reached the lowermost latitude in the Kimmeridgian, and their southernmost occurrence locality is known in Mexico (Fig. 4). Near the Pacific coast of North America, buchiids existed throughout the Late Jurassic and Neocomian (Zakharov, 1981). In the late Tithonian and early Berriasian, they advanced along the Pacific coast of Asia as far to the south as the southern Primor'e and Hokkaido, i.e., to 43°–44° N (Zakharov, 1981; Sey and Kalacheva, 1995, 2000).

As is shown in earlier work on Boreal–Tethyan migrations of mollusks during the Late Jurassic and Early Cretaceous in the Panboreal Superrealm (Zakharov and Rogov, 2003; Figs. 6 and 7), the maximum southward advancements of boreal faunas took place in the Kimmeridgian and Valanginian. In the West European province, these events are recorded at the levels of the *Rasenia cymodoce* phase (late epoch of the early Kimmeridgian) and mid-early Valanginian (Zakharov and Rogov, 2003, Fig. 6; 2004, Fig. 3). In the initial middle Volgian time (*Dorsoplanites panderi* phase), boreal ammonites advanced to the latitude of 42° N. In the East European province, the southward advancement peaks of Boreal faunas are established at the levels of the same *Cymodoce* and *Panderi* phases. In sea basins of the Lesser Caucasus, buchiids appeared first (?) in the early Tithonian time. We do not exclude a possibility of their recurrent invasions in subsequent period and existence of *Buchia mosquensis* during the entire Tithonian Age until the end of the Jurassic. Data on Late Jurassic benthic foraminifers from southeastern areas of the Lesser Caucasus are of prime importance for understanding factors, which controlled the southern invasions of buchiids. In the Upper Jurassic (Oxfordian–Tithonian) part of the succession, benthic foraminifers are represented predominantly by cosmopolitan agglutinated forms (Voznesenskii *et al.*, 2002), while secretory forms most typical of the Tethys prevail in the higher stratigraphic interval (Valanginian–Aptian), being associated there with first pelagic forms. It is admissible that the Tethyan influence became prevailing over the Boreal one owing to changes in structure of water masses during the Kimmeridgian. As is known, buchiids are benthic byssiferous organisms of Boreal seas, which preferably dwelt in cool waters. Exactly the influx of cold seawater into deep settings of open shelf was main factor that favored penetration of buchiids into southern latitudes of the North Pacific during the Late Jurassic and Early Cretaceous (Zakharov, 1981).

CONCLUSION

The new locality of Boreal bivalves discovered in the Peri-Tethys northern zone modifies the former viewpoint on geographic distribution of the genus *Buchia* and is of importance for evaluating the genus potential in interregional correlation of two problematic stratigraphic subdivisions such as the Volgian and Tithonian stages. As is known, Tethyan ammonites actively migrated into Boreal seas in the early Tithonian time, and consequently, ammonite zones of the lower Tithonian and lower Volgian substages are well correlative (Rogov, 2004). However, Tethyan ammonites practically disappear from sections of the Volgian Stage above the *Panderi* Zone. This fact used to be regarded as indicative of geographic isolation of Boreal and Tethyan seas that interrupted the migration process. Representatives of the genus *Buchia* found in the Lesser Caucasus and Crimean Mountains suggest that seaways directly connecting southern and northern sea basin existed permanently or periodically, and consequently, it is possible to expect discovery of Tethyan ammonites in the middle and upper Volgian substages of the East European platform.

Reviewers L.A. Nevesskaya and K.I. Kuznetsova

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