ISSN 0145-8752, Moscow University Geology Bulletin, 2010, Vol. 65, No. 4, pp. 223–228. © Allerton Press, Inc., 2010.
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On the Characteristics of the Ammonitico Rosso Facies in Callovian (Middle Jurassic) Sediments near Planerskoe (East Crimea)

E. Yu. Baraboshkin[a], M. A. Rogov[b], and V. S. Mileev[a]

[a]*Faculty of Geology, Moscow State University, Moscow, 119991 Russia*

[b]*Geological Institute, Russian Academy of Sciences, Pyzhevskii per., Moscow, 119017 Russia*

Received September 16, 2009

Abstract—A condensed section of the Ammonitico Rosso facies has been described and studied for the first time in East Crimea. The Middle Callovian age of the sediment sequence was justified based on ammonites (the Reineckeia anceps zone). It is assumed that the sequence formed due to a eustatic rise of the sea level (sequence J2.4).

DOI: 10.3103/S0145875210040010

INTRODUCTION

In 2002, near the Yanyshar bay, north–northeast of Cape Lagernyi, the authors examined a sequence of Callovian sediments belonging to the Ammonitico Rosso facies (hereinafter AR), which was already reported previously [Mileev et al., 2004; Baraboshkin, 2009]. Structurally, the region in question is located in the extreme eastern portion of the Sudak sector of the Mountainous Crimea. It is characterized by the development of nearly east–west thrust faults and south verging covers. The covers are disrupted by south dipping steep listric faults with similar orientations, and also by steep cross shifts, normal faults, and upcast faults. The examined sediment sequence is situated within a small tectonic block that is confined by faults. For this reason, it is difficult to determine its exact position in the general sequence of the Bathonian-Callovian sediments. However, the presence of the Ammonitico Rosso facies in the sequence of the Callovian sediments in Crimea allows refining the details of the geological history of this region.

STRUCTURE OF THE SEQUENCE (Fig. 1)

The sequence is located near the path running to Cape Lagernyi, 150–200 m southwest of a dirt road going down to the Yanyshar bay (44°58.388′ N, 35°19.220′ E, elevation 104 ± 6 m in the WGS-84 system). The rocks of the Lower Bathonian substage are represented by greenish gray clays with lenses of weathered, ferruginized oolite marls up to 2 m thick and up to 10–15 m long (Fig. 2b) that contain ammonites *Paroecotraustes (Nodiferites)* sp., *Procerites (Siemiradzkia)* cf. *lenthaensis* (Arkell), and Phylloceratids. Lower Callovian sediments that are also present in some of the tectonic blocks were formed by a clay mass with siderites and interbedded sandstones [Muratov et al., 1969]. To the west of the fault that confines the Callovian rock exposures, the following sediments are exposed (from bottom to top):

1. Brownish gray clays with 20–30 cm lenses of light gray marls in the upper 1 m layer. Microscopically, the marls are mudstones and wackestones with rare ammonite bioclasts, few recrystallized radiolarians and coccoliths, and small secondary disseminations of iron hydroxides (Fig. 2c). In the lower 1 m layer, *Macrocephalites verus* Buckman and *Holcophylloceras* sp. were observed; 50 cm higher, on the surface of the layer, there are a number of ferruginized nuclei of small (0.5–1 cm in diameter) ammonites that primarily belong to Phylloceratids: *Adobofoloceras* (Fig. 3.2), *Holcophylloceras* (Fig. 3.9), and *Ptychophylloceras* (Fig. 3.1). *Paralcidia* cf. *subcostaria* (Opp.) (Fig. 3.3), *Lissoceras* sp. (Fig. 3.7), *Macrocephalites* cf. *gracilis* (Spath) (Fig. 3.5), *Pleurocephalites* sp. (Fig. 3.6a and b), Grossouvriinae gen. indet. (Fig. 3.4), and *Gowericeras* sp. (Fig. 3.8) are encountered less frequently. The remains of benthic life (bivalves and gastropods) are sporadic. *Holcophylloceras* similar to those encountered in clays were observed in marl lenses in the upper portion of the layer. The top was washed out. The thickness of the layer is over 3.5 m.

2. Pinkish brown nodular limestones that form a bed, which protrudes in the topography of the slope. Microscopically, these limestones are bioclast wackestones that contain rare ammonite nuclei with micritic shells and redeposited nodules with corroded surfaces, along which microstylolites develop (Fig. 2d). The nodules, like the ammonite nuclei are formed by darker wackestone. The prevailing bioclast are echinoderms and fragments of mollusks (predominantly ammonites); serpulidae, radiolarians, and coccoliths are less frequent. The content of silty quartz grains is less than 1%. Disconnected pebbles of black phosphorites are present at the bottom of the layer; these peb-

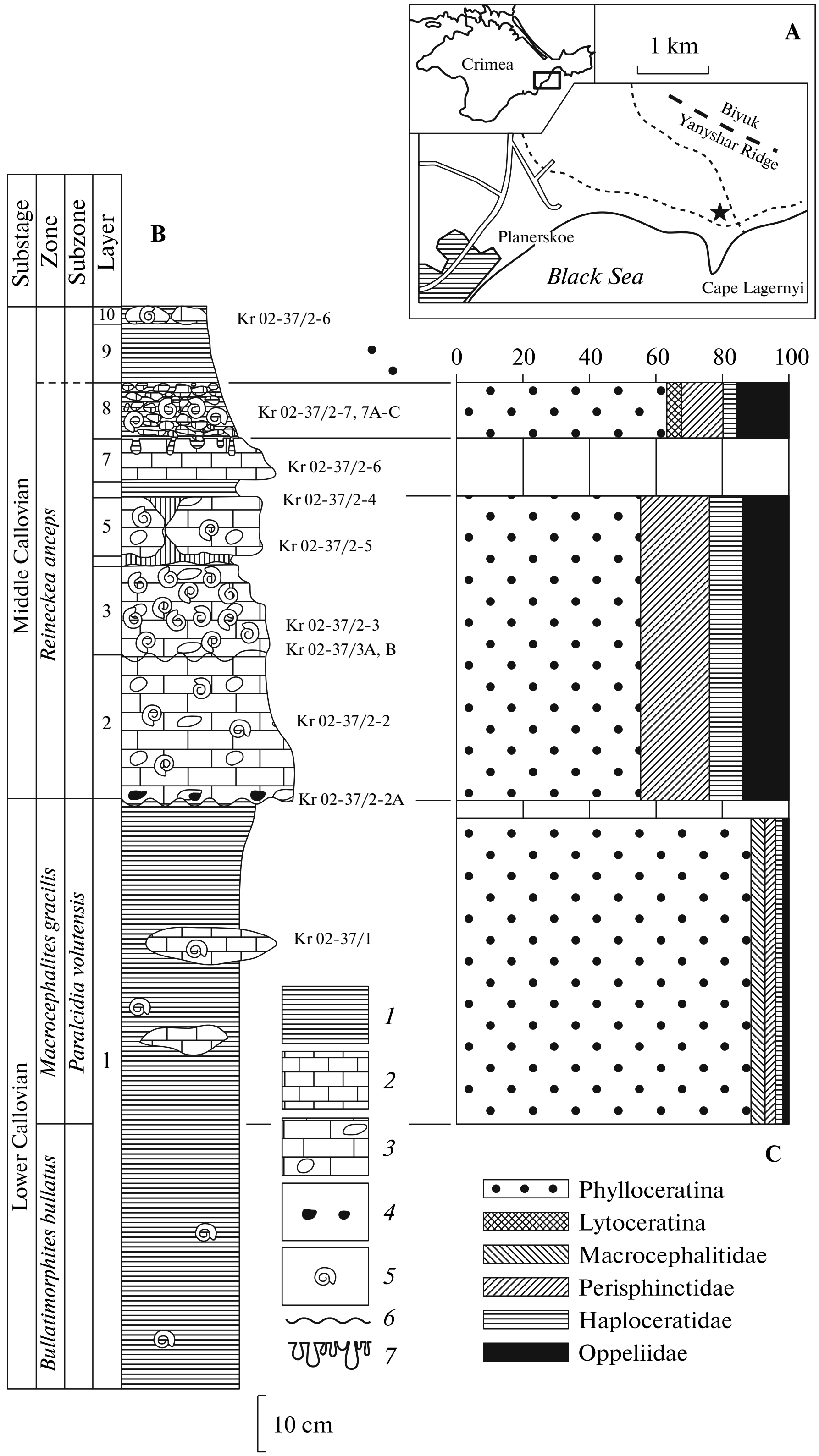

Fig. 1. Location map, the structure of the section, and the distribution of the principal groups of ammonites: (a) Location map of the section (marked with an asterisk); (b) Structure of the section (the right edge of the column reflects the morphology of the exposures); (*1*) Calcareous clays; (*2*) Mudstones and wackestones; (*3*) Wackestones with calcareous nodules; (*4*) Phosphorites; (*5*) Nuclei of ammonites; (*6*) Erosion boundaries; (*7*) Perforated boundaries; (c) Distribution of the principal groups of ammonites (designated with different symbols) in layers 1, 2–4, and 8.

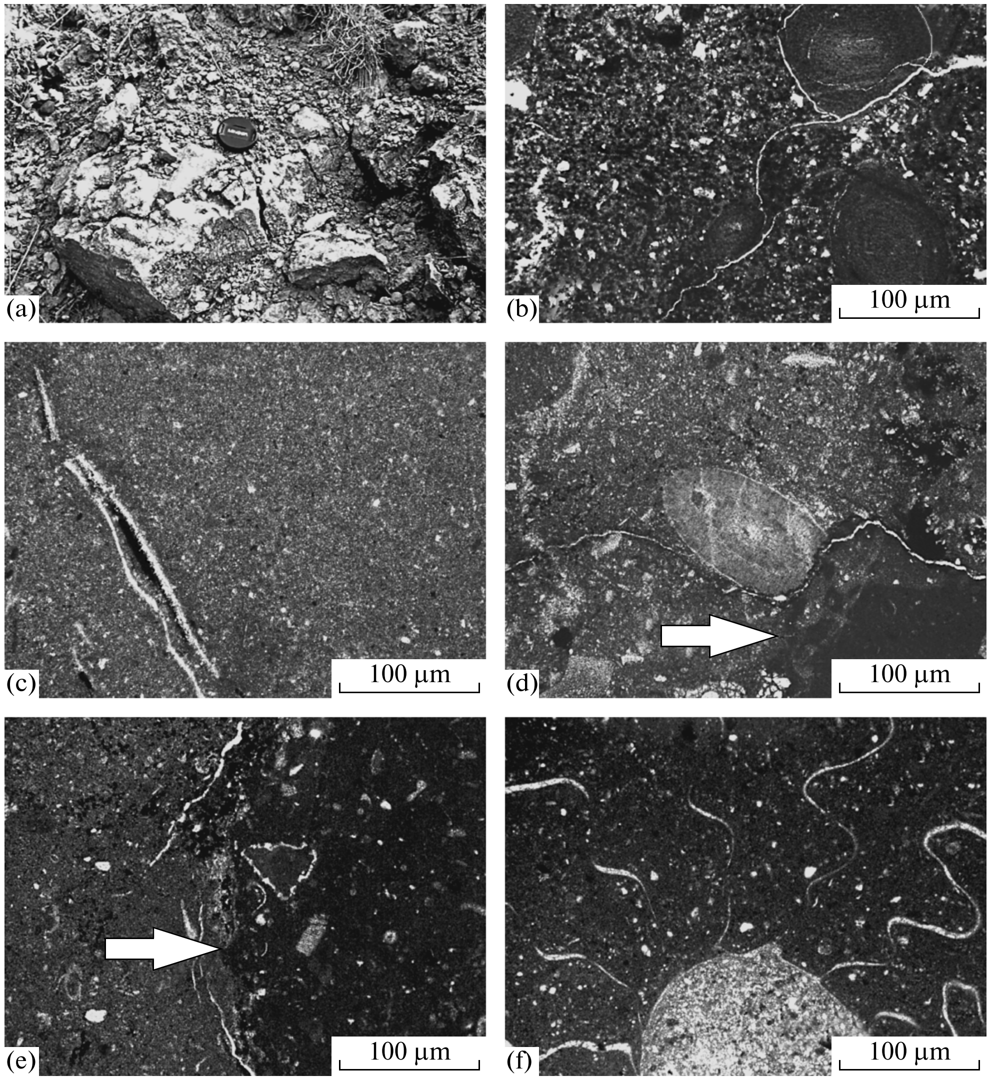

Fig. 2. Visual appearance of the sequence ((a) layers 2 and 3) and the principal rock types in thin sections: (b) weathered oolite marl, Upper Bathonian, thin section Kr02-37-A-2, parallel nicols; (c) bioclast mudstone, Lower Callovian, layer 1, thin section Kr02-37/1, crossed nicols; (d) bioclast wackestone with a large bioclast of an echinoderm in the center, the arrow indicates the boundary of a redeposited nodule, Middle Callovian, layer 2, thin section Kr02-37/2, parallel nicols; (e) bioclast wackestone (bioclasts of: r. radiolarians, c. echinoderms, and n. coccoliths), the arrow indicates the boundary of a redeposited nodule, Middle Callovian, layer 2, thin section Kr02-37/3V, parallel nicols; (f) ammonite nucleus filled in with bioclast wackestones; the interior of the shell and the umbilicus are filled in with different types of rocks, Middle Callovian, layer 8, thin section Kr02-37/7, parallel nicols.

bles are formed by collophane with an admixture of silty quartz grains (<1%) and are cut by fractures filled in with calcite blocks. The ammonites are represented by Phylloceratids; apart from Phylloceratids, *Choffatia* sp., *Rossiensiceras* ex gr. *metomphalum* (Bon.), and *Lissoceras voultense* (Opp.) were encountered. The top was washed out. The thickness is 0.25 m.

3. Limestones (wackestones) similar to those observed in layer 2, but more clayey (Fig. 2e). Some of the ammonite nuclei are subparallel to the bedding; the upper parts of the nuclei are dissolved, and the lower parts have a preserved micritic shell. The surfaces of the nodules are corroded. The ammonites encountered are *Choffatia* sp., *Calliphylloceras* sp., and *Lissoceras* sp. The top has indications of washing out and dissolution. The thickness is 0.15 m.

4. Greenish calcareous clays. The thickness is 0.02 m.

5. An interlayer of greenish white nodular limestones that consist of large contiguous lenses of an irregular shape. Microscopically, these rocks are similar to those observed in layers 2 and 3, but the matrix is even more clayey. Limonite (?) crusts developed around some of the nodules. The top was possibly dissolved. The thickness is 0.1 m.

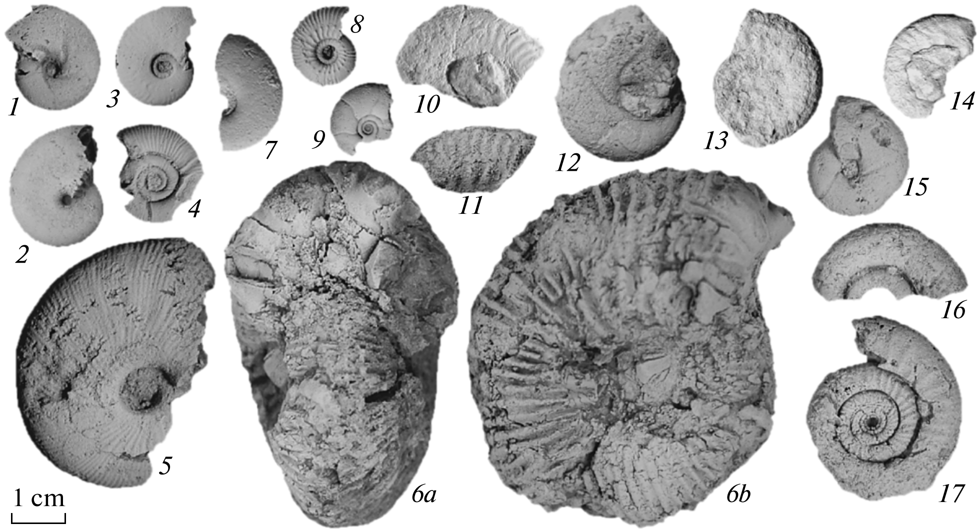

Fig. 3. Some ammonites from the examined sequence: 1–9. Lower Callovian, *gracilis* zone, voultensis subzone, layer 1: (1) *Ptychophylloceras* sp., spec. 107/1 from ESM MSU (the Earth Science Museum of the Moscow State University); (2) *Adobofoloceras* sp., spec. 107/2 from ESM MSU; (3) *Paralcidia* cf. *subcostaria* (Opp.), spec. 107/3 from ESM MSU; (4) Grossouvriinae indet., spec. 107/4 from ESM MSU; (5) *Macrocephalites* cf. *gracilis* (Spath), spec. 107/5 from ESM MSU; (6a) and (6b) *Pleurocephalites* sp., spec. 107/6 from ESM MSU; (7) *Lissoceras* sp., spec. 107/7 from ESM MSU; (8) *Gowericeras* sp., spec. 107/8 from ESM MSU; (9) *Hoclophylloceras* sp., spec. 107/9 from ESM MSU; (10–17) Middle Callovian, anceps zone, layer 8: (10) *Eulunulites* sp., spec. 107/10 from ESM MSU; (11) *Zieteniceras* cf. *zieteni* (Tsyt.), spec. 107/11 from ESM MSU; (12) and (15) *Ptychophylloceras* sp., ((12) spec. 107/12 from ESM MSU, and (15) spec. 107/15 from ESM MSU); (13) *Putealiceras* aff. *arkelli* (Zeiss), spec. 107/13 from ESM MSU; (14) *Brightia* sp., spec. 107/14 from ESM MSU; (16) Lytoceratina indet., spec. 107/16 from ESM MSU; (17) Grossouvriinae indet., spec. 107/17 from ESM MSU. The specimens are stored in the Earth Science Museum of the Moscow State University, collection 107.

6. Clays similar to those observed in layer 4. The thickness is 0.03 m.

7. Pinkish brown limestones. Microscopically, these limestones are mudstones with a poorly defined lamination and an admixture of silty quartz grains (<1%) and small undeterminable bioclasts (<5%). The top is even, occasionally perforated. The thickness is 0.07 m.

8. A subautochthonous conglomerate consisting of ammonite nuclei (<3 cm in diameter) and limestone nodules. Phylloceratids *Sowerbyceras* sp., *Holcophylloceras* ex gr. *mediterraneum* (Neum.), *Calliphylloceras* sp., and *Ptychophylloceras* sp. (Fig. 3.12 and Fig. 3.15) prevail among ammonites; Oppelliidae *Putealiceras* aff. *arkelli* (Zeiss) (Fig. 3.13), *Eulunulites pompoeckyi* (Par. et Bon.), *E.* sp. (Fig. 3.10), *Zieteniceras* cf. *zieteni* (Tsyt.) (Fig. 3.11), and *Brightia* sp. (Fig. 3.14), *Lissoceras* sp. indet., undeterminable Grossouvriinae (Fig. 3.13), and rare Lytoceratina indet. (Fig. 3.16) are encountered. Microscopically, the nodules are formed by wackestones with small bioclasts, including spherical radiolarians and coccoliths (the content of both is 1–3% each). Some of the ammonite nuclei have a different filling of the umbilical parts and the interior of the shells (Fig. 2f): the interior contains a considerable quantity of a clayey admixture; this indicates repeated redeposition of these. The thickness is 0.1 m.

9. Clays similar to those observed in layers 4 and 6. The thickness is 0.1 m.

10. An interlayer of calcareous nodules with a composition similar to that of layer 7. The thickness is 0.03 m.

In the slides that cover the limestone exposures, apart from ammonites, a few remains of brachiopods, echinoids, sponges, and serpulidae are observed.

STRATIGRAPHIC POSITION

These sediments were referred to the Yanyshar bed without separation for a long time [Muratov et al., 1969], but presently, they are classified as the Bathonian–Middle Callovian Kopsel' Suite [Permyakov et al., 1991].

Lower and Middle Callovian sediments are distinguished in the examined sequence. Based on the presence of *Macrocephalites verus* Buckman in the lower portion of layer 1, this interval can be referred to the Bullatimorphites bullatus zone. The ammonite complex observed in the upper portion of layer 1 is characterized by the presence of *Macrocephalites* cf. *gracilis* (Spath) and *Gowericeras* sp., which is typical of the Macrocephalites gracilis zone of the Submediterranean Lower Callovian and, based on the absence of Hecticoceratins, also typical of the Paralcidia volutensis subzone, which is parallelizable to the Proplanulites koenigi zone [Thierry et al., 1997]. In terms of preservation, this rock complex is almost identical to the complex of "dwarf ammonites" of the same age that was described by N.V. Beznosov and V.V. Mitta

[1996] in Western Turkmenistan; the latter contains somewhat fewer Phylloceratids and rare *Proplanulites*. Ammonite assemblages of the same age with a similar degree of preservation and a similar composition were also encountered in southeastern France [Elmi, 1967].

The ammonite assemblage also differs from the adjacent sequences of the same age situated west of Sudak that were examined by the authors previously [Rogov et al., 2002]: Oppelliidae prevail there against the background of coarser grained rocks; spheroceratides are also encountered.

The Middle Callovian limestones of the Ammonitico Rosso facies have a considerably different ammonite complex. Phylloceratids also prevail there in terms of quantity, but apart from them, Hecticoceratins occur, while Grossouvriinae become numerous (Fig. 1c). Grossouvriinae are predominantly represented by undeterminable juvenile ammonites and fragments of larger forms. Hecticoceratins *Putealiceras* aff. *arkelli* (Zeiss), *Eulunulites pompeckyi* (Par. et Bon., and *Rossiensiceras* ex gr. *metomphalum* (Bon.), and *Zieteniceras* cf. *zieteni* (Tsyt.) allow referring layers 2–8 to the Reineckeia anceps zone of the Middle Callovian.

CONDITIONS OF FORMATION AND OCCURRENCE

According to common notions, limestones of the AR facies form on submarine rises isolated from the addition of clastic material, at a depth of a few tens to a few hundreds of meters [Reading et al., 1990; Baraboshkin, 2009]. The occurrence of AR facies in the sequence of clayey pelagic sediments indicates that these sediments formed quite far away from the coast, but there are no good grounds to assume that there was a rise in that area. The examined rocks do not differ from typical AR facies in terms of their microscopic structure; the structure of the rocks characterizes the pelagic conditions of sedimentation accompanied by frequent breaks. Selective cementation leading to the formation of nodular wackestones can occur in different ways, but it is also caused by an interruption in sedimentation [Fluegel, 2004]. So, it can be concluded that the occurrence of the AR horizon in the sequence is an important event for the basin, which is associated with a slowdown in sedimentation and cessation of the addition of terrigenous material. Given the rapid diagenesis, the average rate of the formation of the sequence was ~0.2 cm per 1000 years, i.e., this is a supercondensed section [Baraboshkin, 2009].

The results of quantitative examination of the principal groups of ammonites (Fig. 1c) indicate that all of the examined sediments formed in relatively deep water areas; this is also confirmed by the relative scarcity of infauna and the constant presence of coccoliths and radiolarians. The ammonites from layer 1 have a peculiar preservation, which is common for clayey facies of the Callovian–Lower Oxfordian in Europe: a small pyritized part of the phragmocones of the majority of the ammonites in this layer is preserved, while the exterior of the phragmocones and the body chambers are crushed. Pyritization of the phragmocones indicates rapid burial of the shells in anoxic sediments [Hudson and Palframan, 1969]. The phragmocones and body chambers of the Middle Callovian ammonites are filled in with clayey wackestone, and the ammonites have indications of rewashing. Some of the ammonites were apparently destroyed completely during redeposition, which led to the resulting diversity of the encountered forms. At the same time, Lytoceratids, being the deepest water representatives of the ammonites [Westermann, 1990] were first encountered only in layer 8. In our opinion, this indicates a deepening of the basin that was accompanied by an interruption in sedimentation and the formation of AR facies with normal aeration of the sediment.

Other boundary sequences of the Lower and Middle Callovian in the Mountainous Crimea have a different structure, which also reflects a deepening of the basin. In the area of the Tumanova Balka within Karadag and in the Sykht-Lar ravine near Mt. Perchem, the Lower Callovian sediments are represented by sandstones and siltstones with interbedded limestones that contain a number of ammonites in the upper portion (the michalskii and patina subzones [Rogov et al., 2002]). Similar limestones are also widespread higher, in the anceps zone of the Middle Callovian, in a similar fashion to the sequence in question.

Well-examined beds of the same age as the AR horizon were encountered in sediment sequences in Italy [Reading et al., 1990], the Carpathians [Sidorczuk, 2005], Spain [Molina et al., 1999], and the Central Pontides in Turkey [Rojay and Altiner, 1998]; in the two latter cases, the occurrence of AR facies coincides with the transgression and inundation of the exposed area of the carbonate platforms. In addition, AR sediments of a similar age, but apparently shallower, were encountered in a number of sediment sequences in the North Caucasus (Belaya, Urukh, Terek, Ardon, Fiagdon, Assa, Armkhi, and other rivers), and in the Mountainous Mangyshlak (Saradiirmen', Doshchan, and other sequences) [Baraboshkin, 2009], where the occurrence of these sequences also coincides with the beginning of extensive transgression in the entire region.

The above facts suggest that this level formed on a large territory due to a global eustatic rise of the sea level (sequence J2.4) and corresponds to the condensed Middle Callovian section [Vail et al., 1984].

CONCLUSIONS

1. The presence of a thin condensed section within the Ammonitico Rosso facies was detected for the first time in the sediment sequences in East Crimea.

2. The Middle Callovian age of this sequence (the Reineckeia anceps zone) was justified; the boundary between the Middle and Lower Callovian rocks was determined.

3. Based on the microscopic structure of the rocks and the distribution of the principal groups of ammonites, it was assumed that the sequence formed in pelagic conditions, with a deepening of the basin and an interruption in addition of terrigenous material.

4. This event is a reflection of a global eustatic rise of the sea level (sequence J2.4) [Vail et al., 1984].

ACKNOWLEDGMENTS

This work was supported by the Russian Foundation for Basic Research, grants nos. 07-05-00882, 09-05-00456, 10-05-00276, and 10-05-00308).

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