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Thalassinoides Burrows (Decapoda Dwelling Structures) in Lower Cretaceous Sections of Southwestern and Central Crimea

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Abstract—Burrows of *Thalassinoides*, which are attributed to the group of dwelling structures, occur in all the marine and coastal facies. The Lower Cretaceous sections of southwestern and central Crimea yielded the representative collection of *Thalassinoides* burrows belonging to the ichnospecies *Th. suevicus* (Rieth, 1932), which served as an object for this investigation. The burrows are confined to coarse-grained terrigenous, carbonate, and mixed sediments and contain assemblages of ichnofossils indicating coastal and shallow-water marine *Skolithos* and *Cruziana* ichnofacies. In the Mesozoic–Cenozoic, the producers of the *Thalassinoides* burrows were decapods, confirmed by finds of crayfish *Hoploparia* in them.

Keywords: ichnofossils, *Thalassinoides*, Lower Cretaceous, Crimean Mountains, paleogeography, paleoecology, ichnofacies

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INTRODUCTION

Despite the wide distribution of diverse trace fossils in the Lower Cretaceous sections of the Crimea, they have never been specially investigated before; therefore, the available data on these fossils are of little use for the facies analysis. Representatives of the ichnogenus *Thalassinoides* are widespread among such ichnofossils.

The first description of Lower Cretaceous *Thalassinoides* burrows (without illustrating them) was published by B.T. Yanin in 1978. Subsequently, in his monograph dedicated to decapods, Il'in (2005) repeated this information from unpublished materials and provided illustrations of some burrows left by crayfishes and crabs. Until recently, this monograph is a sole work among Russian publications, where finds of Decapoda body remains in burrows are used for interpreting their producers.

Information on the records of crustacean trace fossils in the Lower Cretaceous sections of the region under consideration is also available in some stratigraphic works: "*Thalassinoides*-type crustacean burrows" (Yanin and Vishnevskii, 1989), "*Thalassinoides*-type Decapoda burrows" (Baraboshkin and Yanin, 1977), and others.

Gorn (1963) reported abundant "worm crawling traces" in sandstones of the Krasnaya Gorka area in the Al'ma River basin, which appeared to represent crustacean burrows.

A unique collection including approximately 60 ichnofossil specimens attributed to the ichnogenus *Thalassinoides* from Lower Cretaceous sections of the Crimean Mountains was gathered by paleontologists and geologists from the Faculty of Geology of the Moscow State University (Fig. 1). A small collection of burrows is also stored in the museum of the Crimean Training–Scientific Center of the Faculty of Geology (MSU) located in the Prokhladnoe Settlement of the Bakhchisarai area. The above collections served as material for this work. The samples are stored at the Museum of the Earth' History (MSU), collection no. 109.

PALEONTOLOGICAL DESCRIPTION

I C H N O O R D E R CRUSTOLITHIDA VIALOV, 1966

Domichnians (*Domichnia*) are burrows, which were produced by decapods in unconsolidated sediments for permanent dwelling.

ICHNOFAMILY THALASSINOIDIDAE VIALOV, 1993, EMEND. YANIN ET BARABOSHKIN

Initially, Vialov (1966) defined this ichnofamily under the name Crustolithidae. However, in his two articles, which were published posthumously, this author changed the last name first to Ophiomorphidae Vialov (Vyalov, 1989) and, subsequently, to Thalassinoididae Vialov (Vyalov, 1993) including into the latter three ichnogenera: *Thalassinoides* Ehrenberg, *Radomorpha* Vialov, and *Ophiomorpha* Lundgren and ranking Crustolithida Vialov as an ichnoorder. Inasmuch as Vyalov provided no distinct diagnosis of this ichno-

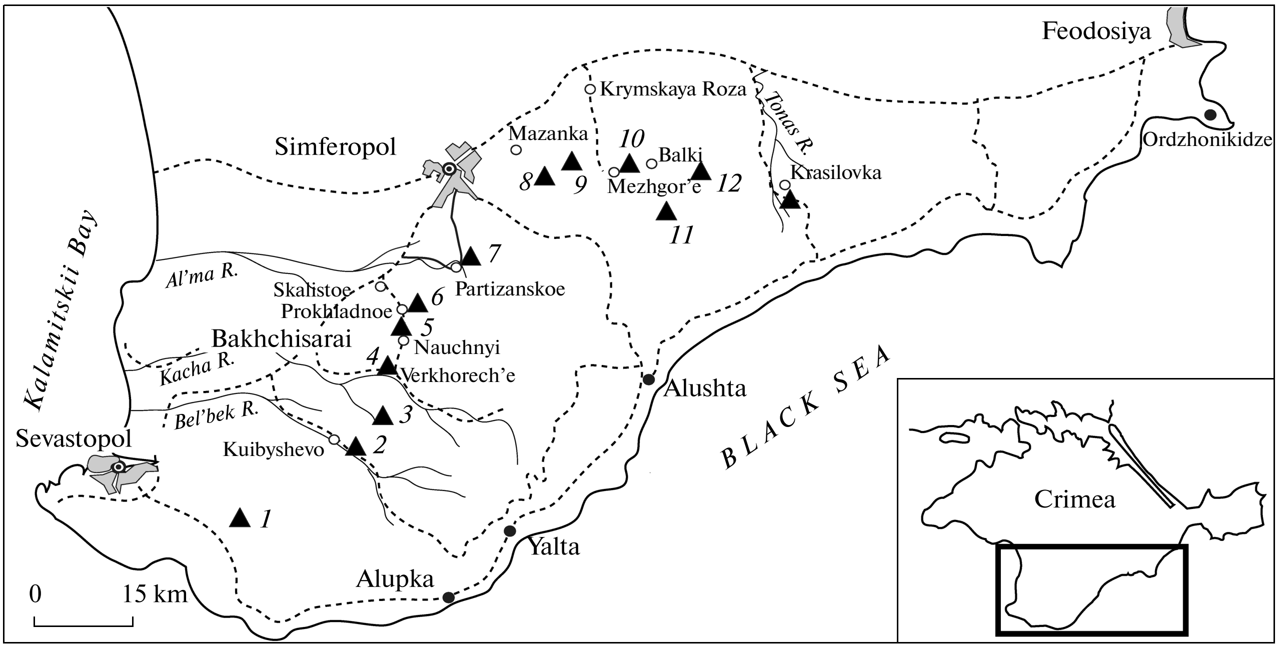


Fig. 1. Schematic location of sections with *Thalassinoides* remains. (*1*) Chernaya River basin: Kuchki and Rodnoe settlements; (*2*) Bel'bek River basin: Kuibyshevo, Verkhnyaya Golubinka, Sbrosovyi Gully; (*3*) Kharu River basin: Kermenchik and Peshchernoe settlement, Kaya Tepe Mount; (*4*) Kacha River basin: Belaya and Rezanaya mounts; (*5*) Kacha–Bodrak river interfluve: Koyas Dzhilga Ravine, Sel'bukhra, Prisyazhnaya, and Dlinnaya mounts, Patil and Prokhladnoe Settlement, Mender Ravine; (*6*) Bodrak River basin; (*7*) Al'ma River: Partizanskoe Settlement, Krasnaya Gorka Mount; (*8*) Zuya River basin: Balanovskoe water-storage basin, village of Petrovo, Fundukly Ravine; (*9*) Beshterek River basin: Lesnosel'e, Solovievka, and Mazanka settlements; (*10*) Burul'cha River basin: Mezhgor'e and Pasechnoe settlements; (*11*) Karabi Yaila: Kazanlyk, Lanchin areas; (*12*) Sarysu River basin: Blagodatnoe Settlement, Belaya, Mount Tyus Saigin Ravine, Novoklenovo Settlement.

family, we fill in the gap, changing its generic composition.

The burrows are straight or twisting, less commonly, polygonal, without lining or covered by very thin rarely preserved film; casts of burrows exhibit a smooth or raised surface. The ichnofamily includes three ichnogenera: *Thalassinoides* Ehrenberg, *Spongeliomorpha* Sapora, and *Radomorpha* Vialov. It differs by the lack of tubular lining with the nodular structure from the ichnofamily Ophiomorphidae Vialov and by the lack of lining and by straight to curved (nor spiral–helical) burrows, frequently with development of horizontal polygonal systems from the ichnofamily Gyrolithidae.

Ichnogenus *Thalassinoides* Ehrenberg, 1944

Thalassinoides[1]: Ehrenberg, 1944, p. 358; Vyalov, 1966, p. 70; 1989, p. 75; Sellwood, 1971, p. 589; Bromley and Frey, 1974, p. 329; Yanin, 1978, p. 177; Frey and Howard, 1985, p. 394 (synonymy); Myrow, 1995, p.60; Manley and Lewis, 1988 (absent in the reference list), p. 23; Schweigert, 1998, p. 4 (synonymy); Kim and Pickerill, 2002, p. 52; Kappel, 2003, p. 50 (synonymy); Ekdale and Bromley, 2003, p. 204; Gianetti and Monaco, 2004, p. 79; Il'in, 2005, p. 107; Seilacher, 2007, p. 54; Monaco and Checconi, 2008, p. 156; Singh et al., 2008, p. 829.

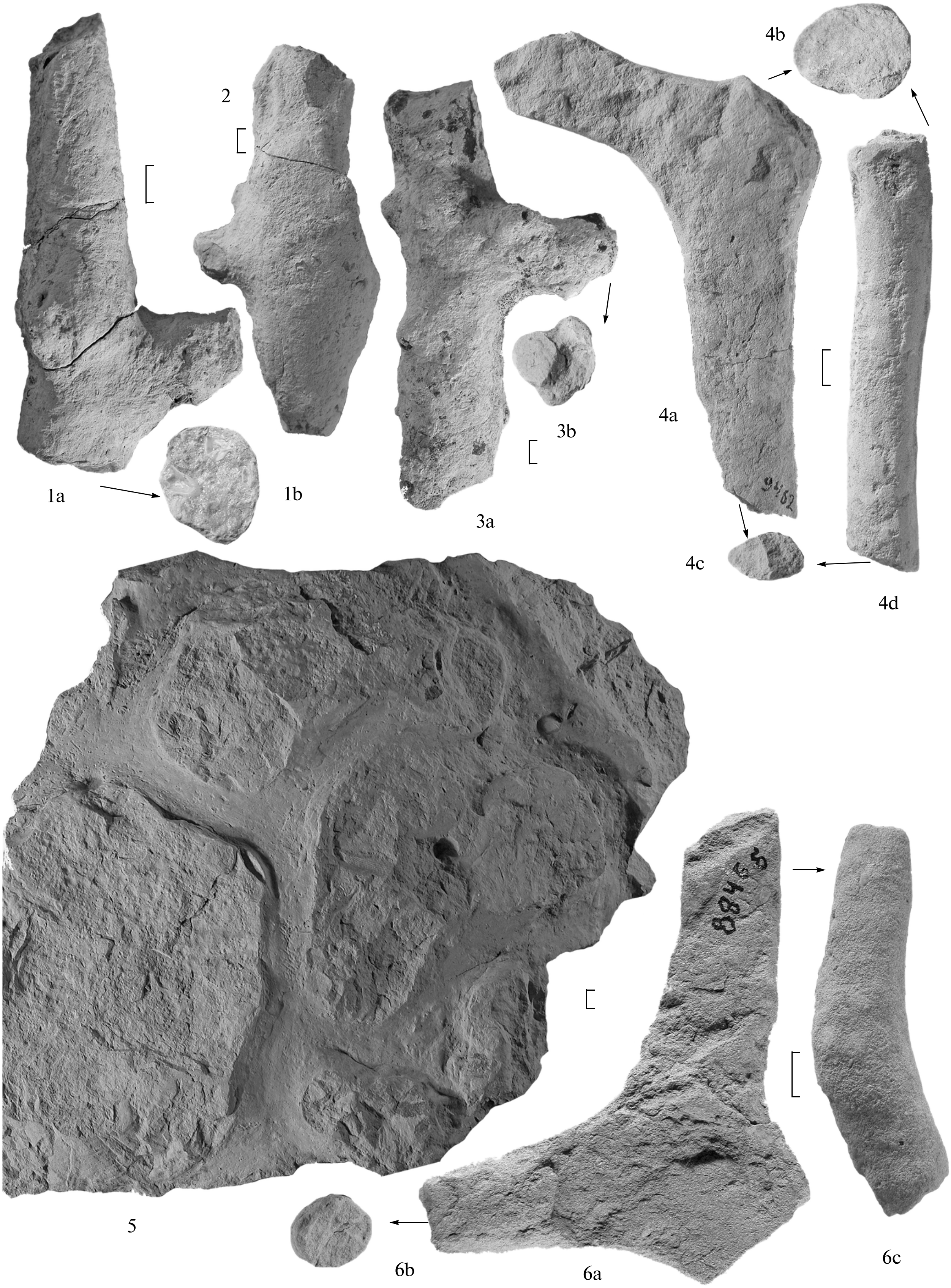
Spongelomorpha: Fürsich, 1973, p. 729 (partly).

Type species: *Thalassinoides callianassae* (Ehrenberg) from the Burdigalian Stage of the Vienna basin (Ehrenberg, 1944, p. 358).

Description. Burrows and systems of burrows consisting of vertical or inclined cylindrical shafts and horizontal tunnels, solitary, straight, or forming branched size-variable interlacements (labyrinths, nets with polygonal meshes) (Fig. 1; Plate I, fig. 5). External surfaces of burrow casts are usually smooth, although frequently bearing longitudinal irregular to, less commonly, regular ridges and grooves (Plate II, fig. 3) representing scratching traces left by limbs of animals. The tubular wall lining is usually missing or not preserved; rare specimens have a very thin smooth envelope. Cross sections of shafts and tunnels are characterized by size-variable diameters ranging from a few millimeters to 22 cm (Rodríguez-Tovar et al., 2008); locally, burrows bifurcate in the Y or T manners with their diameters increasing at bifurcation sites to form bulbs and irregular inflations. In outcrops, burrows are mostly represented by casts; fragments of shafts are usually characterized by circular cross sections, while tunnels exhibit oval or ellipsoidal sections depending on host rock lithology. Some tunnels and shafts demonstrate local inflations. In some speci-

[1] Hereinafter, synonymy is strongly reduced and includes only the most important works and works that were ignored by predecessors.

Plate I



mens, shafts grade at their distal ends into complex polygonal horizontal systems with regular or irregular meshes. Locally, short dead-end chambers diverge in the fan-shaped manner from lower ends of shafts. The burrows are mostly confined to coarse-grained rocks primarily representing incoherent sediment: littoral and upper littoral sandstones and, less commonly, to bioclastic–ooid pack- to grainstones. The burrows were passively backfilled by gravitational processes.

Species composition. In the recent literature, the number of species attributed to the ichnogenus *Thalassinoides* varies from five (*Th. paradoxicus* (Woodward, 1830), *Th. saxonicus* (Geinitz, 1842), *Th. suevicus* (Reith, 1932), *Th. ornatus* Kennedy, 1967, and *Th. horizontalis* Myrow, 1995) (Kim and Pickerel, 2002) to ten including *Th. callianassae* Ehrenberg, 1944, *Th. tandoni* Badve et Ghare, 1978, *Th. bacae, Th. foedus* Mikuláš, 1990 (Ekdale et Bromley, 2002), *Th. minimus* Aron, and *Th. sifangpoensis* Wang, 2004. The validity of species *Th. callianassae* Ehrenberg, *Th. foedus* Mikuláš, *Th. minimus* Aron, and *Th. tandoni* Badve et Ghare is doubted ((Fürsich, 1973; Rodríguez-Tovar et al., 2008). Of the above species, *Thalassinoides suevicus* (Reith) and *Th. paradoxicus* (Woodward) are most frequently mentioned in publications.

There are also other species such as *Thalassinoides ciliensis* Zhang et Wang, 1996, *Th. minor* Zhang et Wang, 1996, and *Th. teichformis* Cui et Mei, 1998, the taxonomic position of which is unknown to us.

The uncertainty of features in many species hampers their identification, which requires revision of these forms with reference to European and American collections.

Comparison. The ichnogenus under consideration differs from: *Radomorpha* Vialov, 1966 by mostly smooth walls of burrows (in the latter, they are covered by many rough longitudinal wrinkles); from *Spongeliomorpha* Sapora, 1887 by the lack of spherical chambers located at tunnel bifurcation sites and raised above them (D'Alessandro et al., 1995) and peculiar rhombic ornamentation (de Gibert and Ekdale, 2010); from *Ophiomorpha* Lundgren, 1891 by short shafts and lack of granular ornamentation. The morphologically close ichnogenus *Steinichnus* Bromley et Asgaard, 1979 distributed in continental facies (Hasiotis et al., 2006) differs from the ichnogenus *Thalassinoides* by the lack of dichotomic branching of chambers.

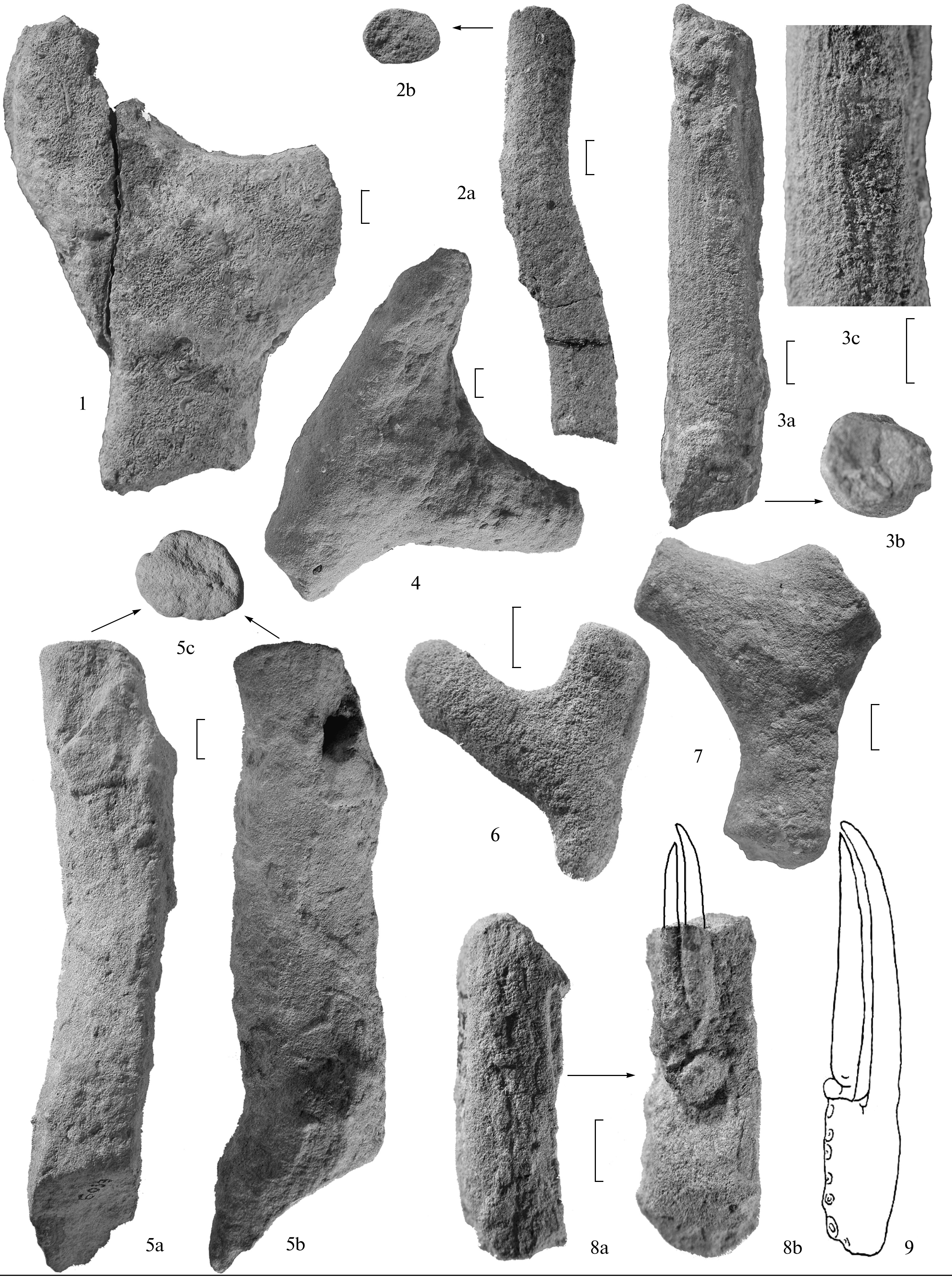
Remarks. Dissimilar to Fürsich (1973), who included *Thalassinoides* into the synonymy of *Spongeliomorpha*, we consider it, following (Vyalov, 1966; Seilacher, 2007), as an autonomous ichnogenus, since its representatives distinctly differ by their morphological features both from *Ophiomorpha* and *Spongeliomorpha* forms. At the same time, it should be noted that depending on lithology *Ophiomorpha* may acquire morphological features of *Thalassinoides*, while the latter may become similar to *Gyrolithes*. Such phenomena are observable in recent and fossil materials (Bromley and Frey, 1974; Uchman, 2009).

H. Ehrenberg, the author of the ichnogenus *Thalassinoides*, who described it from Miocene sands of Austria, considered the latter as representing Decapoda burrows. Subsequently, Ehrenberg (1944) attributed them to the new ichnospecies *Thalassinoides callianassae* based on the find of an Anomura chela in a single burrow cast. The last author noted that burrows of *Thalassinoides* are recorded in Europe and Japan in the Triassic to Miocene to, probably, Pliocene sections. Burrows from coeval sections of different areas could be produced by different species of the genera *Callianassa, Notopocoystes* (Bishop et al., 1992), and close genus *Upogebia*, which belong to the infraorder Anomura. In addition, other researchers (Neto de Carvalho et al., 2007) found abundant well-preserved specimens of the Decapoda species *Mecochirus rapax* (Harbort) in *Thalassinoides* burrows, including *Th. suevicus* (Rieth) in the lower Barremian sections of Portugal. In Antarctica, fragments of the deepwater crayfish *Antarctidromia inflata* Förster (suborder Brachyura) were extracted from the large *Thalassinoides* burrow (Uchman and Gádzicki, 2010). The Miocene burrows of *Th. suevicus* (Rieth) yielded remains of crayfishes *Ommatocarcinus corioensis* (Bromley, 1966), which may exemplify commensalism (Seilacher, 2007).

Sellwood (1971) described the find of the crustacean species *Glyphaea udressieri* (Meyer) inside a *Thalassinoides* burrow from the Bathonian sections of Oxfordshire (southern England). Similar to the recent genus *Callianassa* and the similar genus *Upogebia*, *Glyphaea* is a decapod from the division Anomocardia known from the Mesozoic until recently. It may be

Plate I. *Thalassinoides suevicus* (Rieth).
Bar is 1 cm; arrow shows the area of the cross section or additional side view in the photo.
(1) specimen 109/1, tunnel bifurcation: (1a) side view, (1b) cross section; bioclastic limestones, Karabi Yaila Mountains, Kazanlyk area, bulldozer excavation; lower Berriasian, *Pseudosubplanites ponticus* Zone; collection by B.T. Yanin of 1986.
(2) specimen 109/2, tunnel branch, ibid.
(3) specimen 109/3, tunnel bifurcation: (3a) side view, (3b) cross section, ibid.
(4) specimen 109/4, tunnel bifurcation: (4a, 4d) side view, (4b, 4c) cross section; fine-grained sandstones, Burul'cha River, Mezhgor'e Settlement, height 515.0; upper Berriasian; collection by B.T. Yanin of 1987.
(5) specimen 109/5, polygonal system of tunnels; clayey limestones, Sarysu River, Novoklenovo Settlement, stud farm area; lower Berriasian; collection by B.T. Yanin of 1987.
(6) (3) specimen 109/6, tunnel bifurcation: (6a, 6c) side view, (6b) cross section; sandstones, Zuya River, Fundukly Ravine, Petrovo Settlement outskirts; upper Berriasian; collection by B.T. Yanin of 1986.

Plate II



assumed that the burrows described in the above work were produced by decapods from this division, rather then from the section Thalassinidea Dana (Birshtein, 1960). Our collection also includes fragments of *Thalassinoides suevicus* (Rieth) burrows with fragments of chelae belonging to the crustacean species *Hoploria dentata* (Roemer) and *H. longimana* (Sowerby) (Plate II, fig. 8).

Following the proposal by Vialov (1966) to subdivide the genus *Thalassinoides* in two ichnospecies based on burrow sizes and suggestion by Fürsich (1973) on morphological subdivision of burrows, we attribute forms described below to the ichnospecies *Th. suevicus* (Rieth) (burrow diameter 15–33 mm). Identification of ichnospecies based on diameter of their burrows is conditional since any selection includes specimens of different sizes, which correspond to different growing stages of their producers. Therefore, it is necessary to deal with larger burrows belonging to adult specimens.

Paleontological characteristics. Representatives of the genus *Callianassa* (shrimps) may serve as present-day analogs of Cretaceous crustaceans. They permanently occupy the burrow and rarely leave it. Shrimps feed on small organisms and organic detritus, extracting particles from water using a filtration system using cilia on limbs. Some *Callianassa* representatives extract food from sediments by sieving them through parapodia cilia. They dwell in warm oceanic waters, and form large populations in the littoral, sublittoral, and bathyal zones. Other recent burrow producers similar to *Thalassinoides* are the crustaceans *Glypturus, Upogebia, Pestarella* (Dworschak et al., 2006), ocypodid crabs *Uca*, ghost crabs *Ocypode* and *Helice*, shrimps from the family Alpheidae, *Axius, Axiopsus, Glypturus*, and others, burrow shapes of which substantially depend on the habitat and feeding modes (Griffis and Suchanek, 1991) and may be variable within a single species (Berkebusch and Rowden, 2000). Some burrows morphologically similar to *Thalassinoides* were produced by life activity of Polychaete worms *Nereites* (Dashtgard and Gingras, 2005), amphibians *Amphisbaena* Hembree and Hasiotis, 2006), and fishes *Lesueurigobrius* (Bromley, 1996); Paleozoic burrows were produced by trilobites, anemones, and worms (Ekdale and Bromley, 2003).

More detailed information on ecology of recent *Callianassa* species is available in (Makarov, 2004; Dworschak et al., 2006).

Distribution. The ichnogenus under consideration is characterized by the worldwide distribution (Cambrian?–Recent), including Crimea (Upper Jurassic–middle Eocene).

***Thalassinoides suevicus* (Rieth, 1932)**

Plate I, figs. 1–8; Plate II, figs. 1–6

Cylindrites suevicus: Rieth, 1932, p. 274, plate 1, figs. a, b, plate 2, fig. a, plate 3, figs. a, b.

Thalassinoides suevicus: Frey and Howard, 1985, p. 394, text-figs. 5.8, 16.4, 19/1A (synonymy); Kim, 1991, p. 27, fig. 2 (synonymy); Schweigert, 1998, p. 14, plate 7, fig. 1 (synonymy); Lappel, 2003, p. 51, plate IV, figs. 1, 3, 6 (synonymy); Seilacher, 2007, p. 54, plate 18.

Spongeliomorpha suevica: Fürsich, 1973m p. 730, text-fig. 6 (partly).

Thalassinoides visargiae: Fiege, 1944, p. 416, text-fig. 4; Il'in, 2005, p. 110, text-figs. 17A–17C.

Lectotype. *Cylindrites suevicus*: Rieth, 1932, p. 274, plate 1, figs. a, b.

Description. The species produces systems of burrows consisting of vertical and inclined cylindrical shafts and horizontal solitary or complex branched tunnels. The walls of burrows are lacking tubular lining, smooth, locally with poorly expressed longitudinal grooves or ridges (scratches left by limbs on the burrow walls and reflected in the casts), frequently with swellings and dichotomic Y- and T-shaped bifurcations of burrows (Fig. 2a; Plate I, figs. 1–6; Plate II, figs. 1, 4, 6, 7). The shafts terminate with dead-end bifurcations (up to six) diverging in different directions from the shaft axis (Table II, fig. 4). Diameters of shafts and tunnels vary from 15 to 33 mm to reach

Plate II. *Thalassinoides suevicus* (Rieth).
Bar is 1 cm; arrow shows the area of the cross section or additional side view in the photo.
(1) specimen 109/7, shaft bifurcation, side view; bioclastic limestones, Burul'cha River, village of Pasechnoe; upper Berriasian; collection by B.T. Yanin of 1978.
(2) specimen 109/8, fragment of a tunnel: (2a) side view, (2b) cross section; sandy limestones, Kacha River, Rezanaya Mount; lower Valanginan; collection by B.T. Yanin.
(3) specimen 109/9, fragment of a tunnel: (2a) side view, (2b) cross section, (3c) striate ornamentation on the tunnel surface; sandstones, Kharu River, Kaya Tepe Mount; upper Berriasian; collection by B.T. Yanin of 1986.
(4) specimen 109/10, shaft bifurcation, side view; sandstones, Kacha River, Belaya Mount, near the transmission tower; upper Valanginian, *Eleniceras tauricum* Zone; collection by E.Yu. Baraboshkin of 1991.
(5) specimen 109/11, fragment of a tunnel: (5a, 5b) side view, (5c) cross section; sandstones with phosphorites, Prokhladnoe Settlement, Dlinnaya Mount; lower Hauterivian; collection by B.T. Yanin of 1969.
(6) specimen 109/12, shaft bifurcation, side view; oolitic sandstone, Bel'bek River, village of Golubinka, Sbrosovyi Gully; lower Valanginian; collection by B.T. Yanin.
(7) specimen 109/13, tunnel bifurcation; oolitic sandstone, Bel'bek River, Golubinka, Sbrosovyi Gully; lower Valanginian; collection by B.T. Yanin of 1975.
(8) specimen 109/14, shaft fragment: (8a) side view, (8b) side view with chela of the crayfish *Hoploparia longimana* (Sowerby); sandstones, Kacha River, Rezanaya Mount; lower Hauterivian, *Leopoldia desmoceroides* Zone, collection by B.T. Yanin.
(9) drawing of the chela of *Hoploparia longimana* (Sowerby) (after Pockrandt, 1982, fig. 7).

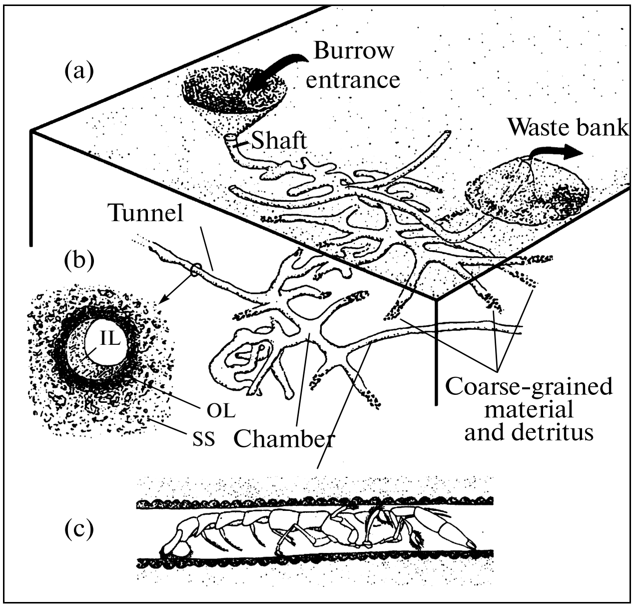


Fig. 2. Schematic structure of burrows of recent callianassids, producers of *Thalassinoides*. (a) burrow systems; (b) cross section of the burrow: (IL) inner mucous lining, (OL) outer surface (lining); (SS) surrounding sediment; (c) *Callianassa* in the burrow (after Grenfell and Hayward, 1995, modified).

60 m at bifurcation sites. The shafts and tunnels are accompanied by complex horizontal systems consisting of anastomosing tunnels that form meshes of different shapes (from regular hexagonal with uniform meshes to irregular polygonal nets with shape- and size-variable meshes) (Fig. 2a; Plate I, fig. 5). Unfortunately, no sites marked by transitions of shafts to these horizontal systems were found.

Burrows were passively backfilled either with host or overlying sediments. Locally, the backfill is destroyed faster that the host rock and burrows appear to be represented by entirely or partly hollow channels.

Comparison. From the most close ichnospecies *Th. callianassae* Ehrenberg, the species under consideration differs by smaller sizes of burrows (15 to 33 mm versus 34 to 50 mm). This category likely includes also the largest burrows of *Th. suevicus* described in (Monaco and Gianetti, 2002; and others).

Distribution. Silurian?–Middle Triassic–Miocene. Crimea: lower Berriasian of the Sarysu River basin (Tyus Saigin Ravine, Enisarai, Belaya Mount, northern slopes of the Karabi Yaila Mountains, Novoklenovo Settlement), Bel'bek River basin (Golubinka and Solnechnosel'e settlements), Zuya River basin (Balanovskoe water-storage basin), Malyi Salgir River basin (village of Ivanovka); upper Berriasian: Zuya River basin (village of Petrovo, Fundukly Ravine), Burul'cha River basin (Mezhgor'e Settlement, Baksan Mount, height 515 m, village of Pasechnoe); lower Valanginian: Bodrak River basin (Prokhladnoe Settlement, Dlinnaya and Patil mounts), Bel'bek River basin (Golubinka Settlement); lower and upper Valanginian, lower Hauterivian: Kacha River basin (Verkhorech'e Settlement, Rezanaya and Belaya mounts); lower Hauterivian: Kacha River basin (Koyas Dzhilga and Kertmel'skii ravines), Bodrak River basin (Dlinnaya Mount); lower Barremian: Al'ma River basin (Kizilovka Settlement); upper Albian: Kacha River basin (Verkhorech'e Settlement, Belaya and Sel'bukhra mounts), Bodrak River basin (Prokhladnoe Settlement, Menderskii Ravine), Al'ma River basin (Partizany Settlement, Krasnaya Gorka and Lysaya mounts).

Material. Approximately 60 specimens represented largely by fragments of casts and burrow cavities in rocks.

PALEOGEOGRAPHIC SIGNIFICANCE OF *THALASSINOIDES* BURROWS

The *Thalassinoides* burrows are interpreted as domichnians, i.e., dwelling structures of fossil organisms. During their life time, these organisms formed a system of hollow tunnels in the middle well-ventilated ichnotier up to 75 cm deep (Bromley, 1966), which became passively backfilled with overlying sediments after the organism's death. In coherent sediments, they cross *Planolites* and *Trichichnus* burrows themselves being occasionally crossed by *Zoophycos* traces. Their backfill contains abundant secondary *Chondrites* (Bromley, 1996), which is determined by development of anoxia in burrow filling sediments. In incoherent sandy sediments, the *Thalassinoides* burrows are rarely crossed by other bioturbations.

The shape of burrows depends mostly on the feeding mode of crustaceans, not on the substrate type and is determined by peculiar features of individual *Thalassinoides* species (not genus) (Griffis and Suchanek, 1991). The burrows are highly variable in size (Monaco and Gianetti, 2002; Rodríguez-Tovar et al., 2008).

The *Thalassinoides* burrows occur practically in any facies (Monaco et al., 2007): salt marshes, tidal plains and channels, estuaries, barrier islands, beaches, delta fronts, prodeltas, inner and outer shelves including the pelagic Ammonitico Rosso facies. It is believed that they characterize usually diverse environments of coastal areas and shoals (Singh et al., 2008). Reports on *"Thalassinoides"* finds in terrestrial sediments (Kim and Pickerill, 2002) are most likely explained by their incorrect identification.

In most publications, *Thalassinoides* finds are mentioned from shallow-water *Glossifungites, Cruziana*, less commonly, *Skolithos*, and, occasionally, *Teredolites* ichnofacies. The *Thalassinoides* burrows are most abundant in coherent (clayey–silty) slightly compacted firmground of the *Glossifingites* ichnofacies, where diverse crustaceans populated spacious areas up to hundreds of square kilometers in size (Pemberton and MacEachern, 1995). The density of

Distribution of *Thalassinoides* in sections and ichnofacies of southwestern and central Crimea

Age	Locality				Lithology
	Ichnofacies	Southwestern Crimea	Central Crimea	Ichnofacies	
K_1al_3 – rostratum–perinflatum	Skolithos	(1) Chernaya River (4–6) Kacha–Bodak river interfluve			Quartz–glauconite sandstones
K_1al_3 – orbignyi		7) Al'ma River			Cross-bedded sandstones
K_1h_2–br_2	Cruziana				Cephalopod limestones
K_1h_1	Skolithos	(3–6) Kharu–Kacha–Bodrak river interfluve			Sandstones, gravely sandstones
K_1v_2			(8) Zuya River (9) Beshterek River	Skolithos	Sandstones, gravely sandstones, cross-bedded sandstones
K_1v_1					
K_1brs_2		(2) Bel'bek River	(8) Zuya River (10) Burul'cha River (12) Sarysu River		Sandstones, oncolitic limestones
K_1brs_1			(11) Karabi Yaila Mountain (12) Sarysu Rive		Sandstones, siltstones, conglomerates, limestones

Note: Numbers in columns correspond to number of localities in Fig. 1.

similar *Callianassa* populations may exceed 30 specimens per 1 m^2 (Makarov, 2004).

At the same time, there are data on the sufficiently wide *Thalassinoides* distribution in Mesozoic and Cenozoic both terrigenous and carbonate turbidites (Monaco et al., 2007) and in hemipelagic facies of muddy turbidites (Knaust, 200) and contourites (Wetzel et al., 2008). Similar burrows are recorded on recent oceanic slopes and rises at depths of approximately 1000–4000 M (Wetzel et al., 2008). In turbidites, the occurrence of *Thalassinoides* burrows is registered in facies of channels and scrolls, while they have never been found in interchannel areas and peripheral parts of turbidite fans (Monaco et al., 2010). It is assumed that at least some of fossil finds may be related to washing out of deepwater crustaceans from the incoherent substrate by turbidite flows and their transport with digging new burrows in deposited turbidite sediments and subsequent backfilling of burrows (Grimm and Föllmi, 1994). Judging from images of bioglyphs, crustacean burrows in turbidites represent domichnians similar to their counterparts on shoals, not escape traces. Therefore, it seems that they are most likely related to development of post-turbidite crustacean communities (Seilacher, 2007) disturbed by turbidity currents.

DISTRIBUTION OF *THALASSINOIDES* BURROWS IN LOWER CRETACEOUS SECTIONS OF SOUTHWESTERN AND CENTRAL CRIMEA

The analysis of the Crimean *Thalassinoides* finds shows that most their examined localities are dominated by shallow-water ichnofacies (table).

In lower and upper Berriasian sandstones, bioclastic and oncoid–bioclastic limestones, *Thalassinoides saevicus* (Rieth) occur in association with *Th.* isp., *Gyrolithes* isp., and *Ophiomorpha nodosa* Lundgren in different localities: Bel'bek River basin (Figs 1, *2*; Kuibyshevo and Verkhnyaya Golubinka settlements), Kharu River basin (Fig. 1, *3*; Peshchernoe Settlement area), Zuya River basin (Fig. 1, *8*; Balanovskoe water-storage basin, Fundukly Ravine), Beshterek River basin (Fig. 1, *9*; Lesnosel'e and Solov'evka settlements), Burul'cha River basin (Fig. 1, *10*; Mezhgor'e and Pasechnoe settlements), Karibi Yaila Mountains (Fig. 1, *11*; Kazanlyk and Lanchin areas), and Sarysu River basin (Fig. 1, *12*; village of Blagodatnoe, Belaya Mount, Tyus Saigin Ravine, Novoklenovo Settlement). The ichnofossil assemblage indicates belonging of host sediments to the ichnofacies *Skolithos*, while the invertebrate assemblage and structure of sections characterize coastal and shallow shelf environments (Lysenko and Yanin, 1979; Yanin and Baraboshkin, 2000, 2010; Baraboshkin and Enson, 2003).

In Valanginian and ~~lower~~ Hauterivian terrigenous sections, *Thalassinoides suevicus* (Rieth) occur together with *Th.* isp., *Planolites beverleyensis* (Billings), *Ophiomorpha nodosa* Lundgren, and *Skolithos* isp. in the following localities: Bel'bek River basin (Fig. 1, *2*; Sbrosovyi Gully), Kharu River basin (Fig. 1, *3*; Peshchernoe Settlement), Kacha and Bodrak river interfluve (Figs. 1, *4* and 1, *5*; Rezanaya and Belaya mounts, Koyas Dzhilga Ravine, Sel'bukhra, Prisyazhnaya, and Dlinnaya mounts, Patil and Prokhladnoe Settlement), Zuya River basin (Fig. 1, *8*; Balanovskoe water-storage basin, Fundukly Ravine), and Beshterek River basin Fig. 1, *9*; Mazanka ~~and Litvinenkovo~~ settlements). The ichnofossil assemblage also implies coastal and shallow shelf environments (Baraboshkin and Yanin, 1997; Baraboshkin, 1997). Noteworthy is the upper Valanginian (*Eleniceras tauricum* Zone) level with *Thalassinoides* burrows at the Rezanaya Mount in the Kacha River basin: burrows of this level yielded abundant body remains of the crayfish *Haploparia longimana* (Sowerby) and *H. dentata* (Roemer).

After fast deepening of the Crimean Mountains basin (Baraboshkin and Enson, 2003) in the late Hauterivian, the composition of ichnofossils changes and representatives of *Thalassinoides* isp. become extremely rare in upper Hauterivian–upper Barremian limestones of the "Ammonitico Rosso" facies missing in overlying clays. Their sole locality is known at the Al'ma River near the Partizanskoe Settlement (Fig. 1, *7*) Judging from depositional environments (Baraboshkin, 1997), these finds should be confined to the ichhnofacies *Cruziana*, although accompanying ichnofossils are unobservable.

Upward the section, *Thalassinoides suevicus* (Rieth) burrows are found in the upper Albian (*Hysteroceras orbignyi* Zone) estuary cross-bedded sandstones in the Al'ma River basin (Fig.1, *7*; Partizanskoe Settlement, Krasnaya Gorka Mount) together with *Th.* isp., *Ophiomorpha nodosa* Lundgren, *Gyrolithes* isp., *Skolithos* isp., and *Cylindrichnus* isp. The ichnofossil assemblage indicates belonging of sediments to the *Skolithos* ichnofacies.

The last level with finds of *Thalassinoides suevicus* (Rieth) in Lower Cretaceous sections of the Crimean Mountains corresponds to transgressively occurring ~~upper~~ Albian shallow-water glauconite–quartz sandstones and limestones (*Mortoniceras rostratum* and *Durnovarites perinflatum* zones) extending from the Chernaya River (Fig. 1, *1*; Kuchki and Rodnoe settlements) via the Bel'bek River basin (Fig. 1, *2*, Kuibyshevo and Verkhnyaya Golubinka settlements) and Kacha River basin (Figs. 1, *4* and 1, *3*) to the Bodrak River (Figs. 1, *5* and 1, *6*). In these localities, *Th. suevicus* (Rieth) is accompanied by *Th.* isp. and *Skolithos* isp. typical of the *Skolithos* ichnofacies.

CONCLUSIONS

As follows from presented data, the *Thalassinoides* burrows belong to the group of widespread dwelling structures. They are thought to be produced mainly by crustaceans, which is also confirmed by the Crimean finds, where the burrows contain remains of crayfishes *Haploparia.* Despite the relatively wide spectrum of settings with *Thalassinoides* finds, they are most common in shallow-water facies. The Lower Cretaceous sections of southwestern and central Crimea, where the ichnogenus *Thalassinoides* is represented by the sole ichnospecies *Th. suevicus* (Rieth) characterizing largely the *Skolithos* ichnofacies, are no exception. The sole exception is represented by the upper Hauterivian–upper Barremian interval, where *Th. suevicus* (Rieth) originates from the *Cruziana* ichnofacies (table).

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