**MINERAL COMPOSITION OF HOST SEDIMENTS INFLUENCES
THE FOSSILIZATION OF SOFT TISSUES**

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15 Cambrian Lagerstätten host rocks are frequently composed of kaolinite and chlorite in varying
16 amounts; accordingly, our goal was to study the preservation potential of crustaceans in these
17 two clays. We conducted long-term experiments (12-18 months; the longest duration of
18 actualistic taphonomy experiments from published literature) on the decay of *Artemia salina* in
19 these clay sediments. The degree of preservation, transformed mineralogical composition of the
20 sediments, and the elemental composition of the naupliar remains were examined. We
21 demonstrate that the kaolinite and chlorite sediment enhanced the preservation (in the kaolinite
22 the effect was considerably higher than in the chlorite) compared to the sediment-free control.
23 pH inside the sediments dropped to 6.5-7.1 and was even lower (<4) around the buried carcasses,
24 facilitating the dissolution of clays. This phenomenon was confirmed by mineralogical analyses
25 of the experimental sediments, which showed mineralogical signatures of such dissolution and
26 new mineral phases. According to the variations in the dissolved minerals in the sediments,
27 different cations entered the buried remains as was shown by the multiple EDX-analyses. An
28 increased level of Mg was detected in the carcasses buried in chlorite while Al and Si
29 concentrations were higher in the kaolinite; in both cases, Ca rapidly entered the decaying tissues
30 from marine water. Bacteria underwent similar mineralization as the macroremains and
31 apparently had no direct effect on the mineralization. The results confirmed an important role of
32 dissolved Al-ions in preservation of soft-bodied organisms in clay-dominated sediments and
33 explained wide variation in chemical composition of their fossils.

34 **Keywords:** Lagerstätten, fossilization, decay, clay, chlorite, soft bodied organisms

INTRODUCTION

Konservat -Lagerstätten are deposits that contain fossils of exceptionally preserved soft-bodied organisms. Although such deposits have been known for more than a century, the mechanisms of their formation remain elusive. Recent studies have demonstrated that sediments have a strong effect on soft tissue preservation and mineralization: 1) Sediments, especially fine-grained ones, can limit oxygen influx and thus form low-oxygen or dysoxic environments relatively shallow within the sediment column (Allison 1988; McCoy et al. 2015a, 2015b; Naimark et al. 2016a, 2016b). 2) Limited diffusion imposed by fine-grain sediments can serve to impede sulfate reduction and organic degradation due to constriction of sulfate transport through the sediment and eventual exhaustion of S and Fe in the immediate surroundings of the buried organism (Hammerlund et al. 2011; Gaines et al. 2012; McCoy et al. 2015b). 3) Fine mineral particles can adhere to organic surfaces producing a cast of the buried carcass; this process has been shown to be promoted by the presence of bacterial exopolymers on the surface of the carcasses (Martin et al. 2004). 4) Clay sediments (kaolinite) favor preservation by delaying the decay via the tanning effect of Al ions released through the dissolution of the kaolinite (Wilson and Butterfield 2014; Naimark et al. 2016a, 2016b; 2018a). The rate of dissolution of kaolinite correlated to the degree of preservation of buried crustaceans: the faster the dissolution, the better the preservation (Naimark et al. 2018a). 5) Toxicity of some clays was proposed to affect the preservation of soft tissues by impeding the proliferation of organic-degrading marine bacteria (McMahon et al. 2016).

Here we extend the role of sediments from impeding decay to promoting specific mineralization of soft bodied remains. We show that sediments may produce a pool of mineralizing elements depending on specific clay hydrolysis. Our previous experimental work (Naimark et al. 2016a, 2016b) demonstrated that the presence of sediment affected mineralization in fresh water environment; it has been shown that kaolinite and montmorillonite, for example, help to induce differential mineralization. The mechanism for this was suggested to

61 be acidification which had been maintained in an experiment for at least two years in fresh water
62 conditions (Naimark et al. 2016*b*). However there is reasonable doubt (expressed by a number of
63 the reviewers of our published papers, though see Zhu et al. 2006; Shao et al. 2016) that the same
64 effect of acidification will be relevant for marine environments with strong buffering capacity.
65 Moreover, the measured pH in the taphonomic experiments with decay of fish (Berner 1968;
66 Allison 1988) was higher than 8. We can test this “acidification” hypothesis: if acidity does
67 change within marine sediment, then the elemental composition of the buried bodies will change.
68 However, if marine buffer works against clay hydrolysis, there will be little or no difference
69 between carcasses buried in different clays and in marine water.

70 Previous studies have demonstrated that kaolinite (at least some kinds of it) may increase
71 acidity without any organic supplements (in both freshwater and marine media), thus it
72 inevitably facilitates preservation and mineralization (Wilson, Butterfield 2014, see
73 measurements of pH for their controls, Naimark et al. 2018*a*), while other clays presumably do
74 not have such acidifying capacity. It means that in other clays, neither preservation nor
75 mineralization are expected. Thus, the main goals of this work are to test marine water buffering
76 and acidification in different clays, and to show specific manifestation of acidification. Another
77 goal was to trace the sources of different elements which may enter the carcasses either from
78 water or from sediment.

79 We carried out a series of experiments with kaolinite and chlorite, the most common
80 aluminosilicates in Cambrian Lagerstätten host rocks (e.g. Le Boudec et al. 2014; Forchielli et al.
81 2014; van Roy et al. 2015; Kimmig and Pratt 2016; Antoshkina et al. 2017). The experiments
82 continued for 12-18 months. At the end of this time we analyzed (i) the degree of preservation of
83 the buried organisms, (ii) the mineral composition of the sediments, and (iii) the elemental
84 composition of the exhumed carcasses. We expected these characteristics to be correlated if the
85 preservation and mineralization of soft tissues depended on mineral dissolution. If the dissolution
86 occurs, we anticipate to detect mineral transformations and new mineral phases and,

87 simultaneously, the mineralization of organic remains by the dissolved and released ions.
88 Additionally if Al-ions (a tanning agent) are released from sediment into surrounding media, the
89 degree of preservation would appear to be higher than in sediments with a negligible influx of
90 Al-ions.

91 MATERIALS AND METHODS

92 **Design of the experiment**

93 The homogeneously mixed clay suspensions were poured into high tubes (50-70 cm in
94 height and 1.5 cm in diameter). 200-300 mg of dead nauplii of *Artemia salina* were put on top of
95 the suspension in each tube, and then the carcasses and mineral particles were allowed to settle
96 together. The nauplii accumulated in the middle or in the upper part of the kaolinite sediment but
97 (always) within the sediment layer. The chlorite particles sank down faster than the kaolinite, so
98 the majority of nauplii concentrated at the upper part and at the surface of the sediment. That's
99 why in the case of the chlorite, after the sediment with the nauplii settled, we added a small
100 portion of sediment to cover the nauplii that was lying on top of the sediment. The bright orange
101 coloration of the nauplii carcasses was highly visible in both sediments. The tubes were sealed
102 by one layer of paraffin film, which decreases evaporation and gas exchange but does not block
103 these processes completely. The experimental tubes stayed undisturbed in the dark at room
104 temperature (25-28°C) before being unpacked for analyses.

105 Tests were carried out after 9, 12 and 18 months for the kaolinite, detecting minor
106 changes during last 6 months (Naimark et al., 2018a). That's why similar tests for the chlorite
107 sediment were taken after 9 and 12 months. The marine sediments without nauplii served as
108 controls (one tube for each clay) for the assessment of any changes in mineral composition and
109 pH. The chlorite control was opened after 12 months, and the kaolinite control after 18 months.
110 The sediment-free decay in artificial marine water (ASW) was used to compare the degree of
111 preservation at 9 and 18 months.

Our experimental design imitates rapid deposition under a sediment layer, which is believed to be a common condition for Cambrian Lagerstätten formation (Dzik et al. 1997; Zhu et al. 2001; Ivantsov et al. 2005; Gabbott et al. 2008; Webster et al. 2008; Lin et al. 2010; Gaines et al. 2012; Forchielli et al. 2014). Thus experiments presented here, provide more realistic perspective for clarifying the mechanisms of Lagerstätten formation, and for revealing a specific pattern in the retardation of decay and the onset of mineralization (Naimark et al. 2016a, 2016b; 2018a).

Materials

We used *Artemia salina* (Branchiopoda, Crustacea) as a model organism. Its decay has been studied more extensively than that of other crustacean species (Gostling et al. 2009; Raff et al. 2013; Butler et al. 2015; Naimark et al. 2016a, 2016b; 2018a, 2018b). In addition, its small size and the large number of specimens in subsamples from each tube allow for a quantitative assessment. In our experiment, early instars (L1, L2) produced from the eggs after 36-48 hours of incubation were buried. The animals were killed by keeping them in fresh water for 4-6 hours.

Unsterilized artificial sea water (brand “Tetra”; salinity 24‰, pH 7.4-7.6; Na:Mg:Al:Si:K:Ca:Fe:S:Cl =24:7.19:0.02:0.02:3.8:2.71:1.6:0.05:58.9 wt% from X-ray fluorescent analysis) was prepared according to the instructions for this brand.

Kaolin from the Polog deposit (Ukraine, 97% of kaolinite in a purified sample) was used to prepare the sediment. The chlorite sample (clinochlore) came from the collection of Fersman Mineralogical Museum (Moscow). The kaolinite and chlorite chemical compositions are shown in Table 1. The clay samples were ground finely in an agate mortar; then the clay was mixed in settled tap water, equilibrated for half a minute, allowing large and/or heavy particles to gravitate to the bottom, and finally, the upper portion (approximately 2/3 of the suspension) was decanted. This upper portion was dried, ground again and mixed in marine water in a proportion of 3g/100 ml. The final suspensions were actively mixed with bubbling from an air pump for 48 hours to remove clay pellets.

138 **Analytical procedures**

139 Degree of preservation was quantified through the following protocol: 0.5-1 mL probes
140 of the sediment with the carcasses were transferred to a Petri dish and supplemented with
141 approximately 5 mL of (ASW) water. Under such conditions, the remains were visible under
142 optical microscopy (ZeissStemi SV11) and were observed to be floating above the thin layer of
143 sediment evenly spread in the bottom of the Petri dish. The nauplii carcasses were subdivided
144 into 5 groups according to the qualitative assessment of the preservation of the appendages and
145 gut (Naimark et al. 2018b). As the decay pattern in clay sediments differs from that in marine
146 water, these groups do not correspond directly to stages of decay described earlier (Gostling et
147 al. 2009). Group 1 represents well-preserved specimens with 3 pairs of appendages bearing
148 multiple stiff setae, filter combs, especially on antennae II and the mandibles; the gut, or at least
149 its colored content, remained distinct and properly positioned inside the body. Group 2 consists
150 of empty cuticular sacs with 3 well-preserved pairs of appendages but with a completely
151 damaged/dissolved gut. Group 3 included specimens with partially damaged appendages; the
152 gut, defined by its colored content, is partly to fully decomposed, its content released into the
153 body cavity. Group 4 includes specimens with highly damaged appendages without their distal
154 parts. Carcasses without any appendages as well as separate recognizable body fragments were
155 referred to as group 5. Assessment of the decay categories was performed immediately after
156 unpacking the tubes without any special chemical fixing. We repeated the same assessments in
157 2-3 probes for sediments. Unlike other experiments with comparatively large animals (Briggs
158 and Kear 1993; 1994; Wilson and Butterfield 2014), we were able not only to give a descriptive
159 pattern of decay, but also count the specimens in each decay group within the samples (Gostling
160 et al. 2009). The bias of assigning a specimen to a group in regards to their mechanical
161 distortions was considered to be minimal as no separate appendages were discernable in the
162 probes of these sediments (though according to our unpublished data, such bias appeared to be

considerable in some other sediments, for example, chamosite, or in the case of lower density of buried carcasses).

To estimate the degree of preservation, we used the number of well-preserved specimens against the number of poorly preserved (i.e. $gr1+gr2/(gr3+gr4+gr5)$). Such an approach allowed us to express in figures the observed qualitative patterns of preservation. A higher proportion of representatives from the first two decay groups indicated overall better quality of preservation. Though this approach gives only a rough estimate of the degree of preservation, it is based on real morphological features of decay and, thus, captures some real aspects of the phenomenon (Naimark et al. 2018b). For both sediments, the number of specimens in the decay groups were averaged across the counts from the probes and the degree of preservation was calculated on the base of these averaged numbers.

Fine anatomical structures of the carcasses, distribution of bacteria, and elemental composition of bodies and bacteria were studied under SEM (Zeiss EVO-50) and associated SEM/EDX (energy dispersive X-ray spectroscopy INCA Oxford 350). To prepare the samples for SEM analysis, the nauplii were rinsed of salts and clay particles by transferring them several times to a new vial with tap water until the water in the vial stayed visibly clean. Usually 5-6 transfers with 10 minutes intervals between them were required to achieve the result (otherwise salts and clay would mask fine details and bias the elemental composition of the carcasses).

SEM analysis was performed with the carcasses placed on glass supports, and SEM/EDX on copper supports to allow for measurement of the Si content. EDX analysis included both point analyses and elemental mapping.

To measure pH, samples (1 mL) were taken by a pipette first from the water column 10 cm above the sediment and then from the middle of the sediment after the accurate decanting of water above the sediment. All pH measurements were performed within 2 days after the tubes had been opened; during this time the samples were stored at -5°C. Liquid samples were tested according to the standard protocol using a single electrode pH-meter, preliminarily calibrated in

189 a standard buffered solution. The 1 mL portions of the sediment were stirred using a vortex type
190 stirrer without preliminary filtration until a uniform suspension was formed, and then the pH was
191 measured with the same pH-meter 3 times for each sample (thus the results represent a range of
192 these measurements).

193 For the mineralogical analysis, samples were taken from the middle of the sediment layer
194 and then investigated by Simultaneous Thermal Analysis (STA) that combines differential
195 scanning calorimetry (DSC) and thermogravimetry (TG). DSC detects thermal changes (caused
196 by exothermic or endothermic reactions) in a sample in response to gradual heating and cooling.
197 It shows phase transitions and structural changes in the sample by reference to an inert sample.
198 TG measures mass loss as a function of gradual heating: for clay minerals, dehydration,
199 desorption, and interlayer water are important parameters. Together with DSC curves, they make
200 it possible to identify the minerals. TG/DSC curves were recorded with the STA equipment
201 (NETZSCH STA 449 F3 Jupiter®) at a heating rate of 10°C/min at room atmosphere.

202 RESULTS

203 **Pattern of decay and degree of preservation**

204 The decay in both sediment types displayed similar patchy patterns albeit with
205 differences in the relative timing (Figs. 1A-1D). Darkening of the kaolin occurred within 2-3
206 days and was followed by the formation of white spots around every carcass (Figs. 1C, 1D, white
207 arrowheads). Thin light layers appeared in the zones with a high concentration of nauplii. These
208 changes in coloration marked the onset of anaerobic conditions in the sediment. In the dark-
209 green chlorite, the darkening was not obvious, but similar white spots appeared within 3-4 days.
210 There were no such spots around the eggs of the *Artemia*, or they were extremely thin rims and
211 visible only in the chlorite (Fig. 1D, black arrowheads). The controls without the nauplii
212 displayed neither darkening nor spots.

213 The naupliar remains in the chlorite were represented mostly by groups 3 and 4 (Fig. 2A,
214 2F): while in the kaolinite, group 1 and the exuvia-like group 2 dominated (Fig. 2B, 2H). The

remains from the sediments were resistant to mechanical manipulations, the rinsing procedure, and drying for SEM. The remains from the marine water easily disintegrated when they were taken and rinsed (if compared with the same manipulations of the carcasses from the sediments), so it was difficult to prepare the specimens for SEM imaging (Fig. 2C represents one of the best preserved specimens) and SEM-EDX analysis.

The carcasses from the sediments were preserved better than those from the marine water without sediments (Table 2). According to the suggested way for expressing degree of preservation, after 9 months it was estimated as 5.08 for those in the kaolinite, 0.35 for the chlorite, and just 0.02 for marine water (compare the amount of each decay group in Table 2). By 18th month, it decreased in the kaolinite as well as in the chlorite, while in the AMW, the degree of preservation stayed more or less the same remaining the lowest among our samples.

The bacterial population in the kaolinite revealed by the SEM imaging was less abundant than those in the chlorite (Fig. 1E, Figs. 2F, 2G). Only one bacterial shape (elliptical, sometimes in short chains) dominated in the kaolinite population. In the chlorite, bacteria were dispersed evenly upon the organic surface; at least two types (cocci-like and rod-like ones) appeared to be visibly abundant (Fig. 1G). However, we did not find any affinity of the types of bacteria to any region of a naupliar carcass, as had been reported previously (Raff et al. 2013).

pH variations

In the chlorite, the pH in the water above the sediment appeared to be higher than the pH within the sediment: at 9 months the values were 8.1-8.2 (see Methods for the range) in the water samples and 7.17-7.18 in the sediment; at 12 months the values became 8.38-8.48 in the water and 6.96-7.1 within the sediment. In the kaolinite, the pH also decreased inside the sediment: 6.57-6.64 and 6.63-6.65 at 9 and 18 months respectively and 7.5 and 7.7 respectively in the water above. However, the pH inside the kaolinite sediment of the *Artemia*-free control was higher than in the water above: 7.9 inside the sediment compared to 7.5 in the water (we did not have the same measurements for the *Artemia*-free chlorite).

241 **Mineralogical transformations**

242 To recognize mineralogical transformations in the clays, we compared the buried nauplii
243 sediments with the controls without nauplii (Table 3).

244 Mass loss indicators upon heating in the temperature ranges 50-250°C and 410-610°C
245 (Tmax1 and Tmax2 endothermic effects) calculated according to TG curves reflect dissolution of
246 kaolinite and its transformation into amorphous aluminosilica gel. Mass loss in two kaolinite
247 controls after 5 and 25 months were found to be close to each other – 32 and 37% respectively.
248 Calculated mass losses (Tmax1) for the kaolinite sample with nauplii after 18 months amounted
249 to 46%, which is significantly higher than 25 month control (Fig. 3A, Table 3). The difference
250 indicates accelerated dissolution of kaolinite in the presence of decaying organics.

251 The kaolinite sample with nauplii is characterized by a shift of the integral Tmax2
252 endoeffect to higher temperatures as compared to both controls. Conversely, for the sample with
253 nauplii, in Tmax2 region, an additional endoeffect at 520°C can be reconstructed via detecting
254 secondary peaks in the DSC-curve (see inset curves in Fig. 3A showing analytical separation of
255 the integrated endoeffect). The combination of these data indicates appearance of both larger and
256 smaller particles as compared to controls. Some of these small particles are shown in Fig. 3B;
257 they have a regular hexagonal shape. Apart from this additional endoeffect, the appearance of a
258 smaller sized phase is indicated by a decrease of temperature and intensity of Tmax3 exoeffect
259 (T 932°C vs. 984 in the controls). The increased size phase appears due to agglutination of
260 particles and formation of larger aggregates (McCoy et al. 2015b). Smaller particles could appear
261 due to recrystallization of dissolved material which follow from their highly regular shape.

262 An increase of asymmetry of Tmax2 observed in the sediment with nauplii (Table 3) may
263 account for the degradation of mineral structure of the kaolinite.

264 Thus, STA analysis revealed a disordering structure and appearance of new size phases in
265 the kaolinite, as well as increased amorphous phase in the kaolinite with nauplii as compared to
266 the control without nauplii (for more detailed analysis see Naimark et al. 2018a).

Mineralogical transformations of the chlorite can be revealed in comparison of the original dry sample with the nauplii-free control (Fig. 3C) and of the nauplii-free control with the sample with nauplii (Fig. 3D). The first pair demonstrated small and insignificant differences; the most obvious one is the shift of the second endoeffect (T 700-900°C). For chlorites this high-temperature interval reflects changes in a talc-like layer, while the lower temperatures are referred to a brucite-like layer. Thus the shift in the second endoeffect resulted from changes in the talc-like layer. The overall similarity indicates that the ASW only moderately changed mineralogical properties of the chlorite.

The difference between the control and the sample with nauplii seems much stronger. Two endothermic effects on the DSC curves changed: both effects shifted to lower temperatures. Mass loss indicator (TG curves) in the first T range (500-700°C) increased from 7.3% (control) to 8.6% (samples with nauplii). In the second T range (700-900°C) it increased from 3.5 to 4.06%, respectively. First endoeffect corresponds to dehydroxylation of a brucite-like layer, and the second of a talc-like layer. Conversely, the brucite-like layer transformations in the sample with nauplii are detectible from the greater asymmetry of the left shoulder of the first endoeffect (540°C). This probably accounts for the relative increase of Fe in the brucite layer. Moreover, the DSC curve of the sample with nauplii shows new endoeffects: one at 798.6°C, which is characteristic for a magnesite (MgCO_3), and another at 670°C, which is referred to as siderite (FeCO_3).

Thus, the shifts in DSC and TG curves provides evidence for the destruction of the brucite-like layer and accelerated leaching of Mg and Fe ions with a faster process for Mg.

Elemental composition of the carcasses

The elemental composition of the exhumed naupliar carcasses obtained from the SEM-EDX analysis may reflect not only their own set of elements, but also elements from any residual salts from the ASW and adhered clay particles. The former could result from an imperfect rinsing procedure, and the volume of this surplus can be estimated by the amount of Cl, which

293 was virtually absent in the original minerals and in the live *Artemia* carapaces. In the exhumed
294 remains, the Cl content was high only in the ASW-controls (Table 4). The high Cl content in
295 these samples is accounted for by difficulties in the washing procedure, as the carcasses from the
296 ASW were extremely fragile. Thus we did not compare the ASW control with the other samples.
297 In the other samples, the Cl content was relatively low, therefore we can ignore the residual sea
298 salts. The second possible source of bias in the elemental composition is the adhered clay
299 particles. However, for the point analyses of the body tissues or bacteria, we chose areas with no
300 visible particles (i.e., areas, where such contaminant mineral particles were smaller than ten
301 nanometers). Moreover, if the particles remained adhered to the surface even after 5-6 rounds of
302 rinsing, its presence in the body composition may hardly be considered as a foreign impurity.

303 The elemental composition of the carcasses differed in the kaolinite and chlorite. In the
304 kaolinite, the naupliar tissues incorporated additional of Al, Si, and Ca (Naimark et al. 2018a;
305 Figs. 4A, 5A, Table 4). The ratio of Al to Si was close to the original kaolinite sample. Ca was
306 detected on the elemental map in concordance with carbon: the more carbon, the more intense
307 the signal of Ca. The Ca distribution upon the organic surface looked more even than Si and Al,
308 possibly indicating a weaker relation of Ca to kaolinite particles. As bacteria is believed to
309 mediate calcification of organic tissues (Frankel, Bazylinski 2003, Benzerar et al. 2004; Raff et
310 al. 2008; Butler et al. 2015), we compared the amount of Ca in the naupliar tissues and in the
311 bacteria: it was somewhat higher in the naupliar tissues than in the bacteria (table 4, Fig. 4). Mg
312 appeared in minute quantities, and Fe was not detected in the elemental composition of the
313 carcasses.

314 In the chlorite, Mg and Ca entered the naupliar tissues, as indicated by the point elemental
315 analysis (Table 4). Considered separately, the analyses of mineral particles, bacteria, and the
316 naupliar bodies show different elemental composition (Table 4, Figs. 4B, 5B). The results show
317 that the buried nauplii accumulated Mg and Ca, but not Fe. The accumulation of Mg was already
318 high by the 9th month, and became even higher by the 12th month. The Mg to Si ratio was

319 slightly higher in the carcasses than in the original chlorite and in the mineral particles adhered
320 to the carcasses. The increase of Ca looked even more pronounced than Mg since the original
321 mineral and adhered mineral particles contained a negligible amount of Ca (Fig. 4). The
322 distribution of Ca repeated the carbon distribution.

323 The bacteria also contained a higher amount of Ca in comparison with the original
324 chlorite. However, by the 9th month, the amount of Ca in the bacteria was considerably lower
325 than in the body tissues, although by the 12th month this difference disappeared. As for Mg, the
326 bacteria had the same amount as in the carcasses at the 9th month and less at the 12th month.

327 DISCUSSION

328 **Conditions inside the sediments**

329 The pattern of changes in the sediment appearance, the degree of preservation, pH,
330 elemental composition, and mineral transformations suggest concordant processes in the system.
331 The darkening of the kaolinite and the appearance of white spots indicate the onset of anaerobic
332 conditions inside the sediment, despite the presence of oxygenated media above the sediment.
333 Such a difference in the reconstructed oxygenation between the water and sediments (i.e.
334 oxygenated water and euxinic sediments) has been proposed for several Lagerstätten, including
335 the Sirius Passet Lagerstätte (Le Boudec et al. 2014; Forchielli et al. 2014) and the Mazon Creek
336 Pits with concretions (Cortoneo et al. 2016) among many others. Indeed, this redox boundary
337 setting was probably not uncommon in Lagerstätten taphonomy.

338 Anaerobic degradation of organic matter inside fine grain sediment generated an acidic
339 environment. We showed that both the kaolinite and chlorite maintained slightly acidic
340 conditions (around pH 6.3-7.1), lower than in the water above the sediment, for over a year . In
341 the previous experimental works on decay in AMW (Sagemann et al. 1999; Briggs and Kear
342 1993; 1994), a similar drop in pH ranging between 6.3-6.9 was noted. However this drop lasted
343 for 10 days (Briggs and Kear 1993; 1994) to a month (Sagemann et al. 1999) returning to basic
344 values afterwards. Meanwhile, in our experiments, a low pH was maintained for a year. Given

the typically low pH (around 6.5) of the top layer of oceanic sediments (Zhu et al. 2006; Shao et al. 2016), the phenomenon shown in our experiment seemed to reflect the real conditions of burying.

Moreover, the microenvironment around the decaying carcasses where the white spots formed may have had an even lower pH than in the sediments (see very interesting work on the fine-scale measurement of pH inside the top layer of marine sediments with buried worms: Zhu et al., 2006). These spots are believed to have formed due to accumulation of the acidic products of the anaerobic decay of the soft tissues. As the eggs produced much less decayed organics, such white spots were not as common.

The chemistry of the spots in the kaolinite and chlorite may be different, but in both cases their formation likely depended on the low pH. In the kaolinite, the white spots marked a discoloration of the sediment – darkened through synthesis of hydrotroilite (the formation of dark hydrotroilite ($\text{FeS} \cdot n\text{H}_2\text{O}$) is a very common chemical process in modern muddy sediments). Hydrotroilite decomposes quickly at low pH, and/or when it is exposed to oxygenated environments. Thus white spots in the kaolinite indicate a decrease in pH, probably lower than pH 6 (Evangelou and Zhang 1995; Rickard and Luther 2007).

In the chlorite, the whitening around the carcasses was due to other chemical reactions because there was no darkening of the background that would be indicative of hydrotroilite accumulation. The spots in the chlorite sediment appeared on the third to fourth day, just as in the kaolinite. It means that the spots in the chlorite sediment were possibly also due to acidification, and that a period of 3-4 days was enough for the accumulation of acidic products around the carcass. Thus in the chlorite, the discoloration also occurred very quickly, immediately upon the accumulation of decay products. Our auxiliary experiments, in which we showed the time discoloration of the chlorite at various pH, revealed that this pH might be lower than around 4.

370 Thus the processes of decay in the sediments and the initial mineralization proceeded in a
371 semi-closed system with a decreased rate of diffusion in an acidic environment at pH lower than
372 6. This inevitably directs speculations on preservational mechanisms including data on isotopic
373 record to acidic, low-oxygen environments inside sediments.

374

375 **Decay and preservation**

376 The degree of preservation appeared to be highest in the kaolinite, lower in the chlorite,
377 and lowest in the marine water without any sediment. Low preservation was inferred from
378 smaller ratio of representatives of the morphological groups 1 and 2. In the AMW control, these
379 groups were mostly absent (Table 3). These groups (especially group 2) are related to the
380 stabilization of the external tissues by certain chemico-physical reactions.

381 In kaolinite, such stabilization and subsequent retardation of the decay seemed to be more
382 pronounced. It should be noted that recalcitrance of the chitinous material of the *Artemia*
383 carapace failed to ensure the preservation in the marine water and appeared to be less effective in
384 chlorite than in kaolinite. Thus, presence of recalcitrant tissues such as chitin alone failed to
385 provide good preservation of a soft-bodied animal remains; other conditions likely favored the
386 preservation of chitinous remains in Lagerstätten.

387 A reduced pH, especially within the white spots, promoted the dissolution of both clays.
388 It is well known that kaolinite dissolves rapidly in organic acids producing Al and Si in a more
389 or less congruent ratio or with some excess Al (Huang, Keller 1971; Chin, Mills 1991; among
390 others). The mineralogical analysis of the kaolinite probes with *Artemia* confirmed such
391 dissolution as it revealed an amorphous aluminosilicate phase (see also in Naimark et al. 2018a).
392 Thus, Al and Si were released into the media and, as a result, they appeared in greater amount in
393 the elemental composition of the buried remains after 9 and 12 months in a stoichiometric ratio.

394 Al-ions bonded with peptide residues produced insoluble complexes (tanning)
395 unavailable for bacterial degradation, providing high preservation in the kaolinite.

396 However, Al appeared in a very low amount in the chlorite-hosted carcasses in
397 comparison with the kaolinite-hosted carcasses. Al could accumulate due to degradation of a
398 talc-like layer, but there was no strong signal for its degradation in the STA. Since more
399 aluminium was released into the solution during the acidic hydrolysis of kaolinite compared to
400 chlorite, the tanning process in kaolinite was more intensive, especially in the first month of
401 decay. This may be a likely reason for better preservation of carcasses in kaolinite than in
402 chlorite.

403 **Mineralization of the carcasses**

404 The main new elements detected in the carcasses were Si, Al, Mg, Ca, and Fe. These
405 elements entered the tissues while they were buried. In both kaolinite and chlorite, the amounts
406 of Al, Mg, and Ca, relative to Si, increased from 9 to 12 months (Table 4, Fig. 4), indicating the
407 onset of mineralization.

408 As followed from elemental point analyses, Al/Si ratio in the carcasses from both
409 sediments was approximately the same as in the clay particles around the bodies, indicating a
410 congruent dissolution.

411 The chlorite dissolution resulted predominantly in the release of Mg, while Fe was
412 detected in a lesser amount. The dissolution manifested itself in the erosion of the brucite-like
413 layer of the chlorite, and in the formation of the new Mg-containing phases, probably magnesite.
414 A new Fe-containing mineral phase (according to DSC effects it is probably siderite) was also
415 registered in STA though the signal was weak.

416 Accordingly, the released Mg appeared in a predictable manner in the exhumed remains.
417 Mg was higher in the chlorite-hosted carcasses than in the kaolinite-hosted carcasses reflecting
418 the elemental composition of the clays (Table 1).

419 Conversely, Fe appeared in only a small amount in the chlorite-buried carcasses (Fig.
420 5B), and it was probably undetectable in the kaolinite-buried carcasses reflecting its very low
421 concentration in the kaolinite.

422 In both clays, the buried remains acquired higher amounts of Ca when compare to clay
423 particles. As shown in the SEM imaging of the carcasses, neither Ca nor Mg were transformed to
424 calcite or dolomite. Probably, the Ca and Mg reacted with certain organic molecules or
425 complexes. One of the possible ways of Ca bonding is saponification, the reaction resulting in
426 the formation of palmitates and stearates from the hydrolysis of lipids, which has been shown in
427 taphonomic experiments with decaying fish (Berner 1968; Allison 1988). Though saponification
428 occurred in basic environments in experiments with fish, the reaction of lipid hydrolysis, which
429 produced long-chained carbonic acids for this reaction, also occurs readily in acidic
430 environments, and thus certain lipid derivatives may bind Ca and Mg. Other chemical processes
431 with decaying organics may also be involved in the bonding of Ca and Mg. Further diagenesis of
432 buried remains transforms this bonded Ca and Mg into other minerals.

433 There was only a negligible amount of Al in the ASW. Thus, Al detected in the carcasses
434 originated from the dissolution of the minerals.

435 The source of Mg in the carcasses seems to be sediments rather than salts from the
436 surrounding water. If Mg entered the tissues from the marine water then it is expected to appear
437 in similar amounts in kaolinite- and chlorite-buried carcasses and in the ASW-control remains.
438 However, there was little Mg in the ASW-control remains and in the kaolinite-hosted carcasses,
439 and in some carcasses from kaolinite it was not detected at all. Meanwhile in the chlorite-hosted
440 carcasses Mg became a regular and readily detectable supplement.

441 In contrast to Mg, the source of Ca was mostly salts from AMW. Kaolinite did not
442 contain Ca but it was detected in the tissues (Fig. 5A). Chlorite contained Ca but in much smaller
443 amounts than Mg; meanwhile Ca appeared in the chlorite-buried carcasses in greater amounts
444 than Mg (Fig. 4B, 5B). The ratio Ca:Mg was 3-3.5 higher in the chlorite-buried carcasses
445 (Ca>Mg) than in the original ASW, thus to obtain such high Ca in the carcasses the
446 accumulation through active and/or selective processes was required.

Summarizing the results, we can see that different new elements entered the decaying tissues as they released to the media from dissolving minerals: Mg in the chlorite and Al in the kaolinite. Calcification seems to be an active/selective process which extracts Ca from all possible sources. Fe was either undetectable or in negligible amounts in the carcasses, but it undoubtedly entered from the dissolving minerals. It becomes clear from this perspective that soft tissues may be mineralized by different elements according to the variations of their host sediments, but it is Ca which is anticipated to be the most frequent mineralizing element.

Bacterial influence

Both the bacteria and the naupliar remains accumulated Ca and Mg (Table 4, fig. 4). The simple transmission of mineralizing elements by bacteria to a decaying tissue could produce a pattern where Mg and Ca content increased within and in close proximity to bacteria, and with decreased Ca and Mg concentrations further away from bacteria. However, the revealed pattern suggests a more or less even distribution of Ca and Mg on bacteria (and with slightly higher concentration in the carcasses). Besides, the point analyses of the carcasses tested the regions clear of bacterial particles but Ca and Mg were just as high there. Ca and Mg bonding might proceed parallel and independently in the bacteria and in the carcasses, producing the similar pattern due to similar chemical reactions with organic molecules.

Overall, the bacteria affected the degradation of organics in a predictable manner: the higher the abundance and diversity of the bacteria, the faster the decay (see also Naimark et al. 2018). Besides the Al release, the difference in the bacterial population was probably another reason for the lower preservation in chlorite when compare with kaolinite. Therefore, in soft tissue preservation, mechanisms for limiting bacterial presence and inhibition of bacterial growth play an important role (McMahon et al. 2016). Only rapid sulfate/iron reduction in extremely hot or acidic environments could probably override the degrading activity of common bacteria that trigger mineralization and ferritization. In other, less extreme, environments a bacterial presence would negatively affect the possibility of soft tissue preservation.

CONCLUSIONS

1. The fine-grain sediments promoted the preservation of soft-bodied animals in marine environments via increasing acidity. This appeared to be true not only for kaolinite which is prone to acidify environment, but also for the chlorite which does not spontaneously reduce pH. In both clays, the degree of preservation was much higher than in the sediment-free ASW control.

2. A key role is played by the restriction of diffusion in a fine-grained system. Under conditions of limited diffusion, the oxygen supply in the vicinity of the buried organism is quickly exhausted, and then the processes of bacterial degradation of organic matter switch to anaerobic pathways. In this semi-closed environment, areas with high acidity (low pH) formed, followed by accelerating decomposition of mineral particles within these areas. As a result, the rates of bacterial growth decreased, and the yield of reactive metal cations increased.

3. Depending on the composition and properties of the minerals, the organic tissues of the buried organisms uptake various cations. The acidic hydrolysis of kaolinite resulted in Al and Si dominating the solution, so the organic residues started to be mineralized precisely by these elements.

When the chlorite with a high Mg content dissolved, the brucite-like layer was primarily destroyed, resulting in the rapid release of Mg into the solution. Therefore, in the chlorite-hosted nauplii, an increased content of Mg was observed.

4. In both clays, an increased amount of Ca was detected in the buried remains. Its accumulation in the organic residues can be explained only by chemical processes that selectively extract Ca from water and, to a lesser extent, from the minerals. Bacterial participation in this process is not yet obvious, although their role in the rapid degradation of buried tissues is apparent. For example, in the ASW control bacteria led to the high degree of degradation of organic remains, and not to their calcification.

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627 Table 1. Chemical composition of the original prepared samples of kaolinite and chlorite re-
628 calculated as of the oxides wt%.

elements	CO ₂	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	K ₂ O	CaO	TiO ₂	MnO	Fe ₂ O ₃	P ₂ O ₅	SO ₃	Σ
Kaolinite	13.95	<0.1	0.21	36.83	45.81	0.49	0.35	0.84	<0.01	1.31	0.03	<0.01	99.82
Chlorite	12,11	<0.02	30.33	20,74	27.03	<0.02	0.22	0.59	0.1	8,63	0.16	0.05	100

629

630 Table 2. Relative number of preservational morphological groups 1 to 5 and the degree of
 631 preservation of nauplii of *A.salina* in the kaolinite sediment (Kaol), chlorite sediment (Chlr) and
 632 in marine water (ASW) after 9 and 12-18 months of the experiment.

Preservational groups	1	2	3	4	5		
Morphology / sediment	slightly damaged cuticle, all limbs and gut preserved (%)	slightly damaged cuticle, all limbs preserved (%)	moderately damaged cuticle, gut, and limbs (%)	shape of a body preserved, limbs partly preserved (%)	separate limbs, body remains without limbs (%)	Number of specimens from 1-1,5 ml (100%)	Degree of preservation: (gr1+gr2)/(gr3+gr4+gr5)
Kaol: 9 mns	49.5	34.9	?	1.8	11.9	109	5.1
Kaol: 18 mns	17.5	42.3	11.34	9.3	19.59	197	2.07
Chlr: 9 mns	2.5	23.3	14.2	20.8	39.1	197	0.35
Chlr: 12 mns	5.3	10.2	16.1	25.5	42.9	149	0.18
ASW: 9 mns	0	2	10	88		46	0.02
ASW: 18 mns	6.3	1.25	11.2	23.8	57.5	80	0.08

633

634 Table 3. Mineralogical changes in the sediment samples derived from DSC/TG; Kaol – the
635 kaolinite sediment with nauplii, C-Kaol – kaolinite control without nauplii, Chlr – the chlorite
636 sediment with nauplii, C-Chlr – the chlorite sediment without nauplii; numbers after
637 abbreviations indicate months the experiment, nd – not determined. See also Fig.3

Sediments / time of incubation (months)	Tmax1 endoeffect, °C	Mass loss 50-210°C, %8.	Tmax2 endoeffect, °C	Mass loss 410-610°C, %	Clay content, %*	Dehydroxylation entalpy, J/g*	Asymmetry index ofTmax2*	Tmaxexoeffect, °C	Intensity of the exoeffect2,J/g*
Kaol-18	163.4	45.86	569.5	6.69	48.1	118.7	1.6	933	0.5
C-Kaol-5	140.9	32.12	540.3	8.56	61.6	172.2	1.3	980.2	3
C-Kaol-25	143	37.94	554	8,12	58.42	187.9	1.4	981	3
Chlr-9	85	0,28	609	7,37	nd	nd	nd	869	nd
Chlr-12	125	0,46	603	8,32	nd	nd	nd	843	nd
C-Chlr-12	125	0,13	615,5	7,64	nd	nd	nd	839,9	nd
Interpretation of the effects									
Kaol vs. C-Kaol	Faster dissolution and accumulation of amorphous phase, degradation of mineral structure, formation of larger and smaller particles in Kaolcompared to C-Kaol								
Chlr vs. C-Chlr	Degradation of the brucite layer with increased output of Mg, formation of new Mg-containing phases and possible Fe-containing phases.								

638 *can be estimated for kaolinite only

Table 4. Point analyses SEM-EDX (at 15 keV) of main constituting elements (wt% as oxides) on exhumed and rinsed nauplii; analyses were carried out for adhered mineral particles, bacteria and body tissues separately and averaged for every group, some of the points exemplified the body areas and bacteria are shown on Fig.1.

		Nº point	CO2	MgO	SiO2	Al2O3	FeO	CaO	Cl
9 months	mineral	Chlorite							
		1	14,87	9,24	7,08	5,78	3,19	0	0
		2	17,02	6,20	5,05	3,64	7,51	0	0
		3	14,91	9,28	7,05	5,54	3,18	0	0
		4	12,76	10,61	8,15	6,87	3,91	0	0
		Σ/n	14,89	8,83	6,83	5,45	4,45	0	0
	bacteria	5	26,78	0,15	0,39	0	0	0,56	0
		6	26,93	0,12	0,24	0	0	0,35	0
		7	26,92	0,09	0,26	0	0	0,39	0
		8	26,52	0	0,62	0	0	0,69	0,55
		9	26,84	0	0,49	0	0	0,29	0
		10	25,99	0,75	0,7	0,47	0,19	0,41	0,32
		11	26,47	0,26	0,69	0,28	0	0,43	0
		12	27,11	0	0	0	0	0,48	0
		13	27,00	0	0	0	0	0,33	0,59
		14	26,9	0	0,29	0	0	0	0,51
		15	26,99	0	0,51	0	0	0	0
		16	26,95	0	0,36	0	0	0,33	0
		17	27,00	0	0,19	0,11	0	0,32	0
		18	24,04	2,41	1,62	1,43	0,66	0,35	0,41
		19	23,84	2,79	1,82	1,31	0,58	0,35	0,41
		20	25,32	1,44	0,9	0,81	0	0,56	0,59
		21	26,01	0,37	0,77	0,46	0	0,59	0,74
		22	26,87	0	0,22	0	0	0,31	0,43
		23	26,84	0,35	0,61	0,25	0	0,60	0,66
		24	26,75	0	0,44	0	0	0,39	0,51
		25	26,77	0	0,26	0	0	0,38	0,39
		26	26,73	0	0,23	0	0	0,58	0
		27	26,68	0	0,54	0	0	0,77	0
		28	26,82	0	0	0	0	0	0,77
		29	27,06	0	0	0	0	0	0,85
		30	27,29	0	0	0	0	0	0
		31	26,89	0	0	0	0	0,47	0,8
		Σ/v	26,56	0,52	0,44	0,17	0,05	0,37	
	body	32	26,85	0,15	0,25	0	0	0,38	0,19
		33	26,92	0,13	0,24	0	0	0,25	0,18
		34	26,97	0	0,27	0	0	0,42	0
		Σ/n	26,9	0,09	0,25	0	0	0,35	0,12
12 months	mineral	35	10,61	13,09	8,84	7,91	3,71	0,58	0
		36	18,14	8,2	4,44	4,31	1,47	0,29	0
		37	17,99	7,79	4,58	4,15	1,99	0,25	0
		38	19,81	6,62	3,89	2,95	1,33	0,2	0
		39	20,55	6,07	3,47	2,91	1,33	0	0
		40	12,49	12,60	7,50	7,26	2,14	0,59	0

		41	9,78	14,29	9,61	7,89	2,69	1,13	0
		42	16,06	8,21	5,27	4,75	3,02	2,44	0
		43	7,29	14,87	10,54	8,89	4,26	0,96	0
		Σ/n	14,75	10,19	6,45	5,67	2,44	0,71	0
	bacteria	44	26,65	0	0,48	0	0	0,62	0,46
		45	26,65	0,32	0	0,23	0	0,74	0
		46	26,33	0,16	0,34	0,9	0	0,39	0,3
		47	27,29	0	0	0	0	0	0
		48	26,87	0	0	0	0	0,64	0
		49	27,21	0,19	0	0	0	0	0
		50	27,12	0,14	0	0	0	0,28	0
		Σ/n	26,52	0,21	0,19	0,25	0,03	0,39	0,13
	body	51	27,23	0	0	0	0	0,16	0
		52	26,28	0,76	0,53	0,51	0	0,25	0
		53	26,31	0,74	0,4	0,36	0	0,39	0
		54	26,96	0,13	0	0,09	0	0,24	0,13
		55	27,14	0	0	0	0	0,40	0
		56	26,18	0,78	0,33	0,24	0	0,76	0
		57	26,8	0,26	0,1	0	0	0,42	0
		58	26,36	0,47	0,47	0	0	0,67	0
		59	27,11	0,13	0	0	0	0,31	0
		60	26,4	0,60	0,28	0,25	0,18	0,45	0
		61	27,29	0	0	0	0	0	0
		62	26,24	0,78	0,43	0,31	0	0,45	0
		63	27,01	0,11	0	0	0	0,3	0
		64	26,99	0,21	0,1	0,12	0	0,12	0
		65	26,29	0,85	0,47	0,4	0	0,12	0
		66	26,4	0,51	0,33	0,28	0	0,66	0
		67	26,34	0,55	0,11	0	0	1,24	0
		68	27,11	0	0	0,12	0	0	0
		69	27,29	0	0	0	0	0	0
		70	27,07	0	0	0,12	0	0,17	0
		71	27,29	0	0	0	0	0	0
		72	26,9	0	0	0	0	0,81	0
		73	27,14	0	0	0	0	0,4	0
		74	26,93	0,08	0	0,08	0	0,19	0
		75	26,81	0	0,21	0	0	0,6	0
		Σ/n	26,79	0,28	0,15	0,11	0	0,36	0
	Kaolinite								
9 months	body	76	25,91	0	0	0,22	0	2,93	0
		77	26,82	0	0	0	0	0,26	0
		78	21,57	0	0	0	0	0,43	0
		79	21,03	0	0,93	0,85	0	0,69	0
		80	23,89	0,81	0,29	0,27	0	1,63	3,40
		81	23,47	0,52	0	0	0	3,87	0,64
		82	26,68	0,11	0	0	0	0,72	0,12
		83	26,50	0,1	0	0	0	0,52	0,09
		84	26,55	0	0	0	0	0,71	0
		85	25,48	0,13	1,39	0,53	0	0,64	0,17
		86	26,61	0,11	0,24	0,21	0	0,34	0,19
		87	26,82	0,13	0	0	0	0,41	0,22
		88	26,99	0	0	0	0	0,5	0,12
		89	25,59	0,21	0	0	0	0,39	0,33

12 months		90	26,92	0,09	0	0	0	0,57	0,14
		91	27,02	0,06	0	0	0	0,37	0,12
		92	26,82	0,13	0	0	0	0,27	0,21
		Σ/n	25,55	0,14	0,17	0,12	0	0,89	0,34
	miner	93	22,51	0,19	3,59	3,35	0	1,92	0,52
		94	20,65	0	5,65	5,39	0	1,28	0,19
		Σ/n	20,58	0,1	4,62	4,37	0	1,6	0,35
	bacteria	95	25,62	0	1,14	1,1	0	0,97	0,25
		96	26,7	0	0	0	0	1,22	0,41
		97	19,79	0	0,22	0,21	0	0,09	0,26
98		26,35	0,3	0	0	0	1,73	0,54	
	Σ/n	24,61	0,07	0,34	0,35	0	1,00	0,36	
body	99	25,02	0	1,7	1,65	0	1,14	0	
	100	26,09	0	0,69	0,73	0	0,77	0,47	
	Σ/n	25,55	0	1,19	1,19	0	0,95	0,24	
marine water									
18 months	bact	101	22,44	0,5	nd	0,19	0	0,87	0,68
		102	22,35	0,55	nd	0,15	0	1,15	1,47
		Σ/n	22,39	0,52	nd	0,17	0	1,01	1,07
	body	103	25,41	0,33	0,03	0	0	0,5	2,37
		104	25,96	0,33	0,04	0	0	0,6	1,09
		Σ/n	25,68	0,33	0,03	0	0	0,55	1,73

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Figure captions

Fig. 1. Decay pattern in the kaolinite and the chlorite after 12 months. (A) overall view of the kaolinite sediment with the buried nauplii of *A.salina*; close view of the rectangle area in (C). (B, D) the same for the chlorite sediment; because of the higher density of the chlorite sediment, its level was lower than that of the kaolinite sediment; in both B and C nauplii look as brownish material inside the light spots (white arrows) and *Artemia*'s eggs look as white spheres surrounded by very thin white spots (black arrows). (E) SEM close view of a surface of the nauplius exhumed from the kaolinite and prepared for SEM-EDX on a copper support. (F, G) the same for the chlorite; asterisks exemplify areas for SEM-EDX analyses of bacteria and body tissues, the numbers correspond with those in Table 4.

Fig.2. Examples of the exhumed nauplii after 12 months: (A) from the chlorite; (B) from the kaolinite; (C) the best preserved specimen from the sediment-free ASW; (D-H) close view of the nauplii; (D, G) chaetas of an antennal endopodite of the nauplii from the chlorite; (E) the same from the kaolinite; (F) antennal exopodites of the nauplii from the chlorite; (H) the same from the kaolinite; the preserved filter apparatus is very well visible.

Fig.3. STA of the kaolinite and chlorite after 12 months: (A) in kaolinite (arrowed inset: derived separation the of main endoeffect); (B) TEM of the kaolinite with naulii (18 months), small perfect crystal is circled, TEM at JEM 2100 (JEOL, Japan). (C, D) the samples of chlorite. In A, C, and D dotted line – original sample, dot-dash line – nauplii-free control, solid line – clay with nauplii.

Fig.4. Relative amount of elements (data from Table 4) in bacteria and body tissues after 9 and 12months: (A) in the kaolinite, (B) in the chlorite. Values for Al, Mg, Ca, Fe calculated as their wt% to Si wt%; 9-bact and 12-bact – bacteria after 9 and 12 months; 9-body and 12-body – naupliar tissues after 9 and 12 months; 5.24 is the value exceeded the scale; no data for the bacteria from the kaolinite at 9th month. CP – clay particles adhered to the bodies.

669 Fig.5. Elemental mapping of the remains exhumed from: (A) kaolinite (the mandible), (B)
670 chlorite (the antenna). SEM-EDX at 15 keV.

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Decay pattern in the kaolinite and the chlorite after 12 months. (A) overall view of the kaolinite sediment with the buried nauplii of *A.salina*; close view of the rectangle area in (C). (B, D) the same for the chlorite sediment; because of the higher density of the chlorite sediment, its level was lower than that of the kaolinite sediment; in both B and C nauplii look as brownish material inside the light spots (white arrows) and *Artemia*'s eggs look as white spheres surrounded by very thin white spots (black arrows). (E) SEM close view of a surface of the nauplius exhumed from the kaolinite and prepared for SEM-EDX on a copper support. (F, G) the same for the chlorite; asterisks exemplify areas for SEM-EDX analyses of bacteria and body tissues, the numbers correspond with those in Table 4.

113x70mm (300 x 300 DPI)

Examples of the exhumed nauplii after 12 months: (A) from the chlorite; (B) from the kaolinite; (C) the best preserved specimen from the sediment-free ASW; (D-H) close view of the nauplii; (D, G) chaetas of an antennal endopodite of the nauplii from the chlorite; (E) the same from the kaolinite; (F) antennal exopodites of the nauplii from the chlorite; (H) the same from the kaolinite; the preserved filter apparatus is very well visible.

69x56mm (300 x 300 DPI)

STA of the kaolinite and chlorite after 12 months: (A) in kaolinite (arrowed inset: derived separation the of main endoeffect); (B) TEM of the kaolinite with naulii (18 months), small perfect crystal is circled, TEM at JEM 2100 (JEOL, Japan). (C, D) the samples of chlorite. In A, C, and D dotted line – original sample, dot-dash line – nauplii-free control, solid line – clay with nauplii.

132x94mm (300 x 300 DPI)

Relative amount of elements (data from Table 4) in bacteria and body tissues after 9 and 12 months: (A) in the kaolinite, (B) in the chlorite. Values for Al, Mg, Ca, Fe calculated as their wt% to Si wt%; 9-bact and 12-bact – bacteria after 9 and 12 months; 9-body and 12-body – naupliar tissues after 9 and 12 months; 5.24 is the value exceeded the scale; no data for the bacteria from the kaolinite at 9th month. CP – clay particles adhered to the bodies.

66x23mm (300 x 300 DPI)

Elemental mapping of the remains exhumed from: (A) kaolinite (the mandible), (B) chlorite (the antenna).
SEM-EDX at 15 keV.

70x27mm (300 x 300 DPI)

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