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1 Spirally-coiled radiolarians in the latest Jurassic–earliest Cretaceous

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10 **Keywords:** Jurassic–Cretaceous, Mariana Trench, mutant, Nassellaria, radiolarian,
11 siliceous shell

12
13 Polycystine radiolarians have siliceous shells. The shells of Nassellaria, one of the
14 major orders of radiolarians, are generally tower-like. Spiral structures are known in the
15 shells (e.g. Sashida and Tonishi, 1991) and spines (e.g. De Wever *et al.*, 2003) of other
16 radiolarians; however, none with spiral shells had been found in Nassellaria. We found
17 two different genera of Nassellaria with spiral shells from the latest Jurassic–earliest
18 Cretaceous sample from the Mariana Trench. The findings are extremely rare and are
19 important when considering the shell formation in radiolarians.

20 The sample is a laminated tuffaceous radiolarian claystone or clayey radiolarite
21 collected from the Mariana Trench oceanward slope (147° 50.6'E/15° 28.7'N: 6,316 m
22 water depth) by “Shinkai 6500” of JAMSTEC (Japan Agency for Marine-Earth Science
23 and Technology). Because of the occurrences of the *Loopus primitivus* (Matsuoka and
24 Yao) and *Pseudodictyomitra carpatica* (Lozyniak) (Matsuoka, 1998), the sample was
25 considered to correspond to the lower part of the *Pseudodictyomitra carpatica* Zone
26 (KR1) (uppermost Tithonian to lower Berriasian, uppermost Jurassic–lowermost
27 Cretaceous) by Matsuoka and Ito (2019). Further detailed information on the sample
28 and cooccurring radiolarian species are mentioned in Matsuoka (1998).

29 The sample yielded two specimens having spiral shells. Such specimens are called
30 “spiral-mutant” in this article. The first specimen of the spiral-mutant belongs to
31 *Svinitzium pseudopuga* Dumitrica (Figure 1). The shell of the spiral-mutant specimen
32 appears to be uncoiled up to the third septa from the top, but from the fourth septa
33 onward, the shell tilts in opposite directions on the front side (Figure 1A1, A2) and the
34 back side (Figure 1A3, A4), indicating a spiral coiling structure. In contrast, all the septa
35 of the normal specimens (Figure 1B, C) are parallel and uncoiled. The second specimen
36 belongs to *Xitus* Pessagno (Figure 2). Oblique septa can be observed in the lower part of

37 the shell of the spiral-mutant specimen (Figure 2A); parallel septa are recognized in the
38 normal specimens (Figure 2B, C).

39 Some researchers have observed the growth processes of radiolarian skeletons (e.g.
40 Anderson, 1981; Matsuoka, 1992; Suzuki, 2006; Ogane *et al.*, 2010; Lazarus *et al.*,
41 2021). Lazarus *et al.* (2021, p. 58) showed Nassellaria specimen and noted, “the degree
42 to which cellular growth control mechanisms are increasingly limited in effectiveness as
43 growth extends further away from the point of origin (the first cephalic segments).” The
44 spiral-mutant specimens shown in this article seem to have an uncoiled structure in the
45 upper part of the shell (Figures 1A, 2A), consistent with the description by Lazarus *et al.*
46 (2021).

47 Shells of a unicellular organism has strictly-formed parts according to its “body
48 plan” and parts that are not. The former parts are essential for survival and are
49 ecologically relevant. The accumulation of examples, such as the spiral-mutant
50 specimens reported in this study, should lead to a better understanding of the shell
51 formation with intracellular roles and growth processes of radiolarians. Further, this will
52 be an important knowledge for radiolarian paleoecology and taxonomy.

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58 59 **References**

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86 Author contributions

87 A. M. treated the samples, made a prepared slide, and photographed the radiolarian
88 images of scanning electron microscope. H. Y. observed the prepared slide and took a
89 picture. T. I. prepared the text and figures. All the authors contributed to the writing of
90 the paper.
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Captions

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94 **Figure 1.** **A**, “Spiral-mutant” specimen of *Svinitzium pseudopuga* Dumitrica. A1 to A4
95 shift the focus to the same specimen. **B, C**, Normal specimens of *Svinitzium*
96 *pseudopuga* Dumitrica. Scale bars are 50 μm . Specimen number: B, 21489; C,
97 21490. All specimens were extracted from the sample collected from the Mariana
98 Trench.

99 **Figure 2.** **A**, “Spiral-mutant” specimen of *Xitus* sp. **B, C**, Normal specimens of *Xitus* sp.
100 Scale bars are 50 μm . Specimen number: A, 20957; B, 20982; C, 21538. All
101 specimens were extracted from the sample collected from the Mariana Trench.

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