

1 *Ostrea edulis* at shipwrecks in the Dutch 2 North Sea

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15 **Abstract**

16 During diving expeditions in July and September 2019 two live European flat oysters (*Ostrea edulis*) were
17 observed by SCUBA divers. The first oyster was found lying amongst coarse shelly material in the scour
18 hole around shipwreck #3251, 37 nautical miles north west of Texel (NL). The second oyster was found
19 on the Gustav Nachtigal wreck, 6 nautical miles north of Schiermonnikoog (NL). Additional shipwrecks
20 were also inspected for *O. edulis* individuals but no live specimens were observed, although on 9 out of
21 11 inspected locations empty, fossil *O. edulis* shells were found. The September dive on the #3251
22 shipwreck revealed the presence of several large empty flat oyster shells, some of which were attached
23 to each other, with up to three individuals in a cluster. This implies that the area around the #3251
24 shipwreck was a suitable location for flat oysters in the past and that oyster larvae are still capable of
25 reaching the location. The findings suggest that shipwrecks and their surroundings are promising
26 locations for future *O. edulis* restoration projects.

27

28 Keywords: *Ostrea edulis*, native oyster, European flat oyster, North Sea, shipwreck, artificial reef, Dutch
29 continental shelf.

30 **INTRODUCTION**

31 The European flat oyster *Ostrea edulis* once formed an extensive population in offshore Dutch waters
32 (Olsen, 1883), that has been overfished and was decimated around 1900 (Kamermans et al., 2018).
33 Nowadays, the flat oyster is considered extinct offshore in the Netherlands (Berghahn and Ruth, 2005;
34 Christianen et al., 2018; Kamermans et al., 2018). Although coastal populations have been reported
35 recently in the south of the Netherlands, near shore and offshore in Belgium and in the Dutch part of the
36 Wadden Sea (Bos et al., 2019; Christianen et al., 2018; van der Have et al., 2017; Kerckhof et al.,
37 2018), no living *O. edulis* of natural origin have recently been recorded in Dutch offshore waters north of
38 the Offshore Wind Farm Egmond aan Zee (OWEZ) where the most northern recent living offshore oyster
39 in the Netherlands was found (Bouma and Lengkeek, 2013, but see Kerckhof et al., 2018).

40 Here we report the most northern findings of live *O. edulis* specimens in the Dutch North Sea, on
41 shipwrecks and their surrounding scour holes.

42 **MATERIALS AND METHODS**

43 In July and September 2019 a group of SCUBA divers visited 22 wrecks in the Dutch and British part of
44 the southern North Sea (Table 1). The SCUBA divers performed a visual biodiversity inventory for a wide
45 range of species and collected specimens for later identification, as described in Schrieken et al. (2013).

46 During these expeditions a wreck of an unknown steam ship (wreck number #3251) 37 nautical miles
47 north west of the island of Texel (NL) was visited on 6 July and 14 September 2019. The wreck is located
48 at 53.457°N 3.911°E (Figure 1), on a sandy bottom in a maximum water depth of 30 meters. Based on
49 the size of the screw and rudder blade, participating archaeologists judged the wreck to be from a cargo
50 vessel (personal communication Betty van den Berg and Robertino Mulder, Dive the North Sea Clean
51 Foundation). Given that the vessel was a steam ship, it is likely to have been wrecked roughly 100 years
52 ago.

53 On 11 and 21 September 2019 the wreck of the Gustav Nachtigal was visited. The Gustav Nachtigal was
54 a speedboat escort ship, attacked and sunk in 1944 and is since then located at 53.600°N 6.133°E, in 23
55 meters water depth, 6 nautical miles north of Schiermonnikoog.

56 During all dives, visited wrecks were inspected for presence of live *O. edulis* specimens. If present,
57 specimens were collected if possible, or photographed when collection was not possible. In July, presence
58 of empty valves of *O. edulis* around shipwrecks was registered as an indication of historic presence of *O.*
59 *edulis* in the area. Furthermore, during the visit of wreck #3251 in September, empty *O. edulis* valves
60 were collected. The length and width of a selection of the collected specimens was measured to the
61 nearest mm.

62 Identification of *O. edulis* was based on a clear flattened right valve and concave left valve and round
63 appearance, in combination with an irregular and rough surface of the shell when visible. Also, *O. edulis*
64 has a relatively straight opening compared to *Crassostrea gigas*. In the collected specimen, presence of
65 chomata in the hinge was confirmed, which is an important characteristic to differentiate between *O.*
66 *edulis* and *C. gigas* (Amaral and Simone, 2014; Kerckhof et al., 2018).

67 RESULTS

68 During the first dive in July 2019 on the #3251 shipwreck one live individual of *Ostrea edulis* was
69 observed. The flat oyster was present lying flat on top of the coarse shelly seabed of the scour holes
70 directly surrounding the shipwreck. The shells around the oyster consisted of *Neptunea* spp., *Ensis* spp.,
71 *Laevicardium* spp. and other smaller shelly material. The oyster appeared to have originally been
72 attached to the shelly material but was now much larger than the fragment it was attached to. The
73 original attachment fragment could not be further identified. In addition to a live specimen several empty
74 grey single valves of much older European flat oysters were observed, which is common around many
75 shipwrecks in the southern North Sea (personal observation by the authors), but none were collected in
76 July. The specimen was collected for confirmation in the Wageningen Marine Research benthic laboratory
77 and stored in ethanol 99% in the Wageningen Marine Research reference collection (number
78 2019IRC010030). The specimen measured 68 x 78 mm (Figure 2) and was estimated to be 3-4 years
79 old. Since the oyster was found at the end of a dive, no search for additional oysters could be performed
80 at that point. Every other shipwreck visited after that during the July and September expeditions was
81 inspected for oyster presence as well. Only grey, old oyster valves were observed on most other
82 shipwrecks visited in July (Table 1).

83 During a dive on the Gustav Nachtigal wreck on 11 September, a live adult flat oyster was observed
84 (Figure 3), after which it was again observed on 21 September. The oyster was located in a sheltered
85 area, under a small overhang. It was attached to vertical standing inside material of the wreck itself and

86 was not surrounded by other large sessile organisms. The estimated length of the oyster was 14-18 cm,
87 with an estimated width of 10-14 cm. The specimen was photographed *in situ* but not collected.

88 Grey, old oyster valves were not registered in September, except on the #3251 shipwreck. Here, several
89 empty valves were observed and some larger specimens were opportunistically collected. Several of the
90 observed valves were found to be growing attached to other *O. edulis* shells, with up to three valves per
91 cluster (Figure 4). The valves were between 89 and 120 mm long and between 76 and 115 mm wide
92 (Table 2).

93 DISCUSSION

94 To date, the European flat oyster was considered extinct offshore in the northern area of the Dutch part
95 of the North Sea. Only in southern Dutch North Sea waters and in the Wadden Sea flat oysters had been
96 observed recently (Bouma and Lengkeek, 2013; Christianen et al., 2018; Kamermans et al., 2018;
97 Kerckhof et al., 2018). During visits of over 100 ship wrecks between 2010 and 2019 by the same group
98 of wreck divers, no other live flat oysters were observed offshore (personal observations by the authors),
99 with exception of locations in the south of the Netherlands and Belgium (Kerckhof et al., 2018).
100 Furthermore, recent investigations of fouling communities on oil and gas structures near shipwreck
101 #3251, did not reveal any flat oysters (Coolen et al., 2018), nor did a study of rocky reefs in the Borkum
102 Reef grounds near the Gustav Nachtigal wreck (Coolen et al., 2015a).

103 The first oyster was found amongst the coarse shelly material present in the scour pits around the ship
104 wreck. Oysters are known to prefer clean shells as settling substrate (Brett et al., 2011). Given that
105 shipwrecks tend to be covered in extensive marine growth (Coolen et al., 2015b; Gittenberger et al.,
106 2013; Lengkeek et al., 2013), the shelly material was surprisingly clean. Shelly material as observed
107 around the #3251 wreck, is very common near offshore shipwrecks in the North Sea (personal
108 observation by authors). Therefore, these clean shells in the scour pits may be suitable material for
109 larval settlement if the locations are within reach from a source population.

110 The finding of the second oyster on a shipwreck implies that wreck material, if not already fully covered
111 by other organisms competing for settlement space, has the potential to be suitable settling substrate
112 too. The less exposed locations of both oysters suggest that flat oysters could have (competitive)
113 advantage of reduced current velocities. The size of the second oyster shows that there are still some
114 older oysters present above the Dutch Wadden islands. Observations reported by Kerckhof et al. (2018)
115 also included an oyster sheltered by wreck material, attached to steel parts of the wreck (personal
116 observation Joop W.P. Coolen).

117 To assess the potential to restore offshore flat oyster populations, Kamermans et al. (2018) investigated
118 the dispersal potential of flat oysters in Dutch waters by modelling the distribution of larvae from a set of
119 hypothetical source locations in offshore wind farms. The general direction of dispersal of the larvae was
120 oriented south to north along the southern Dutch coast, and west to east above the Wadden Islands. A
121 study of *Mytilus edulis* larval dispersal in the same area predicted similar distribution paths (Coolen et
122 al., 2019). This suggest that source locations for the observed oysters must have been south of the
123 #3251 wreck and west of the Gustav Nachtigal. However, none of the larval dispersal scenarios explored
124 by Kamermans et al. (2018) included larval source locations that included the location of these wrecks.
125 Based on this we hypothesise that the source of the oysters found here must have been present at an
126 unknown offshore location for the #3251 wreck and unknown location, possibly more near shore, for the
127 Gustav Nachtigal wreck. Given that both oysters were several years old, they cannot have originated
128 from the flat oysters that were introduced to the Luchterduinen wind farm, Gemini wind farm nor Borkum
129 Reef grounds in 2018 (Sas et al., 2019). As *O. edulis* has been found in the Wadden Sea (Figure 1), this
130 might have been the source for the Gustav Nachtigal oyster, although larvae sources on other artificial or
131 natural reefs in the neighbourhood cannot be excluded.

132 The presence of a live specimen as well as empty and clustered valves, suggest that the area around the
133 #3251 shipwreck was a suitable location for flat oysters in the past and that oyster larvae are still
134 capable of reaching the location. The findings suggest that shipwrecks and their surroundings are
135 promising locations for future *O. edulis* restoration projects.

136 CONCLUSION

137 Clean shelly material present in scour pits around shipwrecks and sheltered areas on shipwreck material
138 may be suitable for settlement of European flat oyster larvae. An adult population of reproducing flat
139 oysters must be present in offshore Dutch North Sea waters, although their exact locations remain
140 unknown.

141 ACKNOWLEDGEMENTS

142 We thank the volunteers and board members of the Duik de Noordzee Schoon Foundation who organised
143 the diving expedition. Furthermore we thank the crew of the Cdt. Fourcault (IMO 7304675; NV Seatec)
144 and Wilhelmina (MMSI 244100334). Without their professional support at all levels, the wreck dives
145 would have been impossible. We are grateful to the participating divers and organisations such as the
146 Zabawas foundation, who all contributed to the funding of the diving expedition. Part of the work

147 reported in this publication was funded through the NWO Domain Applied and Engineering Sciences
148 under Grant 14494; the Nederlandse Aardolie Maatschappij BV, Wintershall Holding GmbH, Neptune
149 Energy and Energiebeheer Nederland B.V. We thank Babeth van der Weide for confirming the
150 identification of the collected *O. edulis* specimen and Jan Tjalling van der Wal for creating the plot with
151 locations.

152 **Ethics approval and consent to participate**

153 Not applicable

154 **Consent for publication**

155 Not applicable

156 **Availability of data and materials**

157 All data generated or analysed during this study are included in this published article. The datasets
158 generated during and/or analysed during the current study are available in the DASSH repository, [url will](#)
159 [be provided once available, we submitted the data on 10 December 2019.](#)

160 **Competing interests**

161 **The authors declare that they have no competing interests**

162 **Funding**

163 Part of the work reported in this publication was funded through the NWO Domain Applied and
164 Engineering Sciences under Grant 14494; the Nederlandse Aardolie Maatschappij BV, Wintershall Holding
165 GmbH, Neptune Energy and Energiebeheer Nederland B.V. These funding bodies had no role in the
166 design of the study and collection, analysis, and interpretation of data and in writing the manuscript

167 **Authors' contributions**

168 JWPC: designed research; performed research; analyzed data; wrote the paper
169 UvD: performed research, wrote the paper

170 FD: designed research, performed research, wrote the paper
171 EW: performed research, wrote the paper
172 RO: designed research, performed research, analyzed data, wrote the paper
173 BD: performed research, wrote the paper
174 OGB: designed research, performed research, analyzed data, wrote the paper
175 All authors read and approved the final manuscript.

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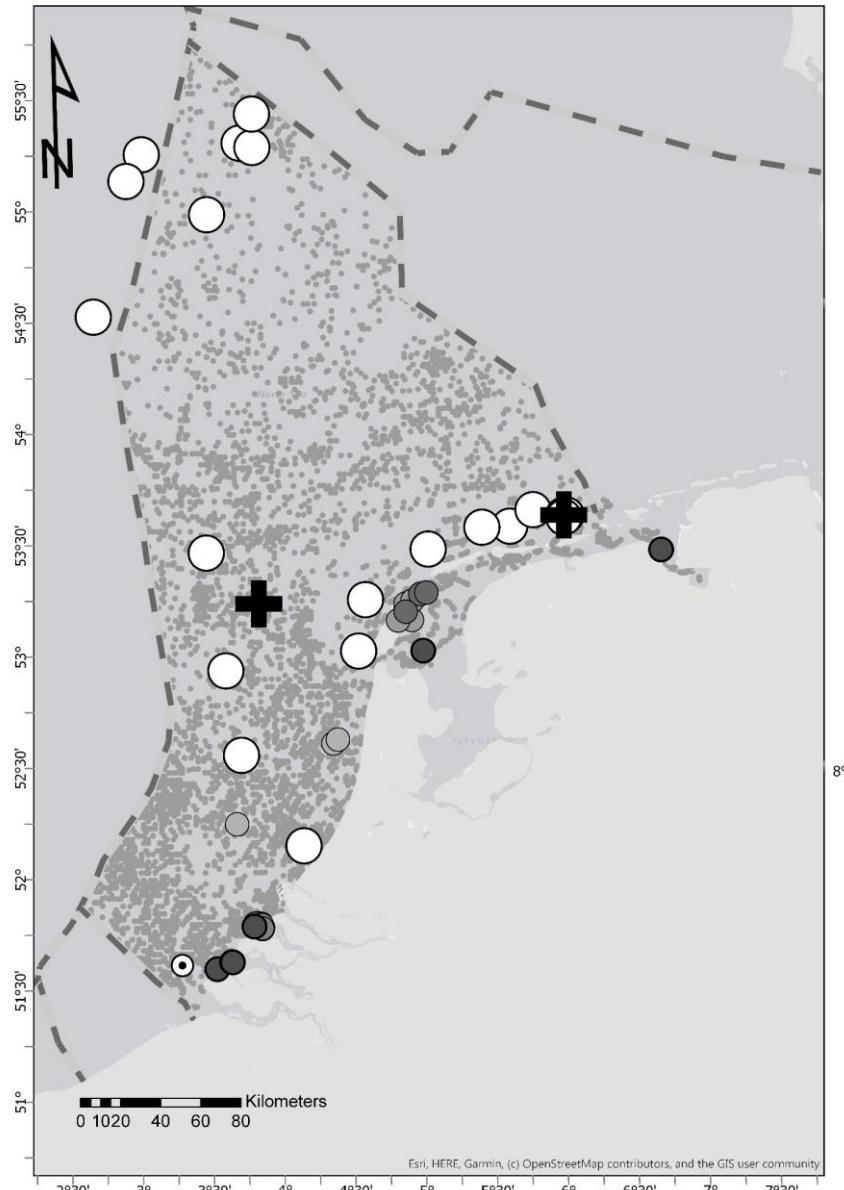
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226

227 **Figures and tables**



228

229 **Figure 1. Locations of sightings of *Ostrea edulis*.**

230 Black plus signs: sightings on the #3251 and Gustav Nachtigal wrecks. Large white dots: absence
231 observations on all other wrecks inspected in July and September 2019. Medium sized grey dots off the
232 coast: sightings offshore (OWEZ windfarm and HMS Aboukir; Kerckhof et al., 2018). Medium sized white
233 dot with black centre: unconfirmed sighting offshore (Christiaan Huygens wreck; Kerckhof et al. [2018]).
234 Medium sized light grey and intermediate grey dots: sightings during dedicated one-time inventories
235 (Bos et al., 2019; Christianen et al., 2018; van der Have et al., 2017). Dark grey medium sized dots:
236 presence observations from fish and shell fish surveys extracted from FRISBE-database (data 2007-
237 2017), Wageningen Marine Research. Small grey (background) dots: absence sightings from fish and

238 shellfish surveys (Bos et al., 2019; Christianen et al., 2018; van der Have et al., 2017). Striped line:
239 Borders of exclusive economic zones of Belgium, the Netherlands, Germany, Denmark and United
240 Kingdom. Tick borders with degrees north and east in WGS84.



241
242 **Figure 2. *Ostrea edulis* on #3251 wreck**
243 Top view photograph of the live *Ostrea edulis* individual found on the seabed amongst the shelly material
244 around the #3251 wreck in July 2019, with ruler (cm).
245



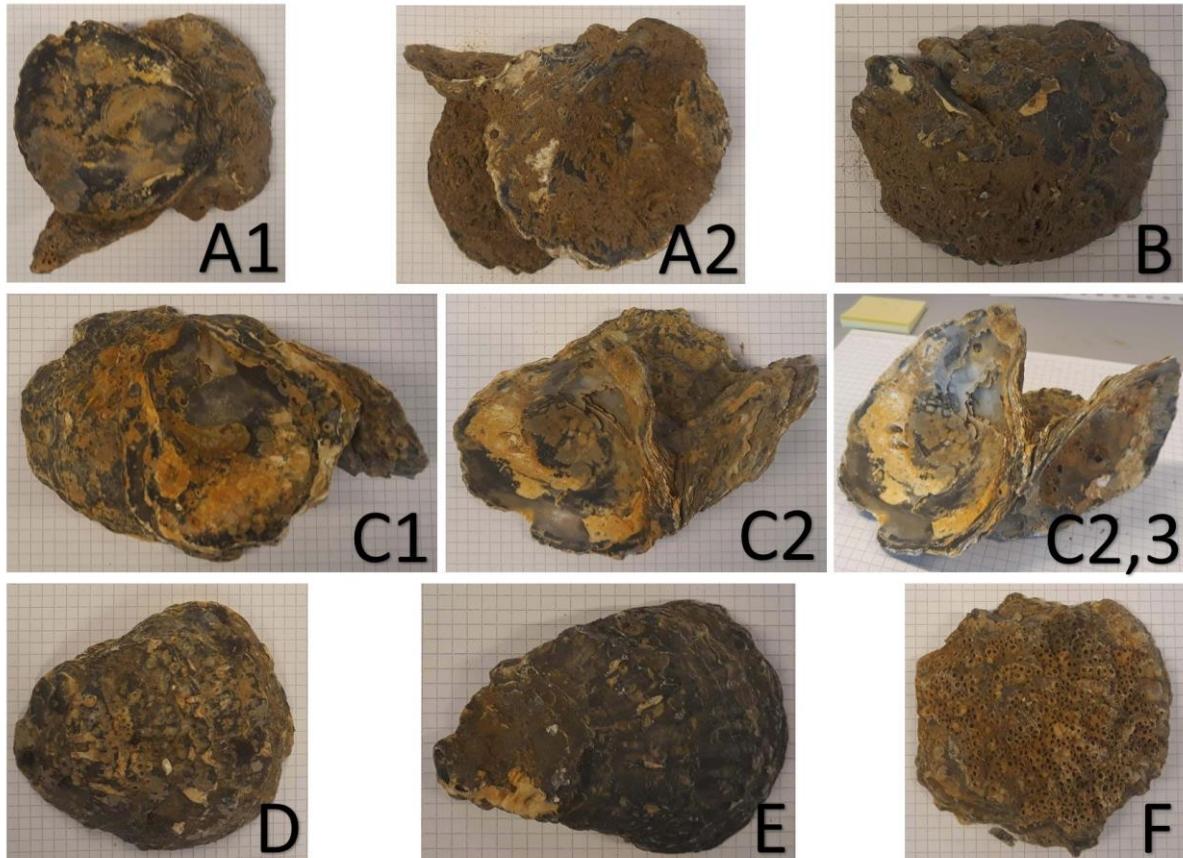
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247 **Figure 3. *Ostrea edulis* on Gustav Nachtigal wreck**

248 Photographs of the live *Ostrea edulis* individual found on the shipwreck of Gustav Nachtigal in September

249 2019.

250



251

252 **Figure 4. empty *Ostrea edulis* shells from #3251 wreck**

253 Top view photographs of a selection of the larger empty *Ostrea edulis* shells found in and around the
254 #3251 wreck in September 2019, with 5 mm grid, for sizes see Table 2. C2,3 with C2 on the left and C3
255 on the right.

256

257 **Table 1. Location information**

258 Wreck names/numbers or descriptions, positions (WGS84), survey dates, presence of live oysters or
259 empty shells on the wrecks visited.

Name	N	E	Date	Live oyster	Old oyster valves
Wreck #3251	53.24	3.86	6-7 & 14-9-2019	Present	Present
Wreck #4141	54.99	3.49	9-7-2019	Absent	Present
Wreck #38324 (T1)	55.31	3.75	9-7-2019	Absent	Present
Wreck #2892	55.29	3.85	10-7-2019	Absent	Present
Ernst 38	55.44	3.85	10-7-2019	Absent	Present
Wreck #4951 (T42) Dock	55.26	2.98	11-7-2019	Absent	Present
St Luke	55.14	2.86	12-7-2019	Absent	Present
Inger Nielsen	54.53	2.61	12-7-2019	Absent	Present
Submarine #621	53.47	3.47	13-7-2019	Absent	Absent
Wreck #3004	52.94	3.61	13-7-2019	Absent	Present
Hms Adder	52.15	4.17	14-7-2019	Absent	Present
Queenfort	52.56	3.72	7 & 15-7-2019	Absent	no data
Herman Hinrich	53.25	4.66	8-9-2019	Absent	no data
Wreck #1045	53.47	5.14	8-9-2019	Absent	no data
Wreck #559	53.56	5.76	9-9-2019	Absent	no data
Eurabia Sun	53.63	5.94	9-9-2019	Absent	no data
Gustav Nachtigal	53.60	6.13	11-9-2019	Present	no data
Condor	53.60	6.19	11-9-2019	Absent	no data
Sperrbrecher 102	53.60	6.19	12-9-2019	Absent	no data
Amerskerk	53.59	6.17	13-9-2019	Absent	no data
Sierra Umbria	53.56	5.55	13-9-2019	Absent	no data
Wreck #2843	53.02	4.60	14-9-2019	Absent	no data

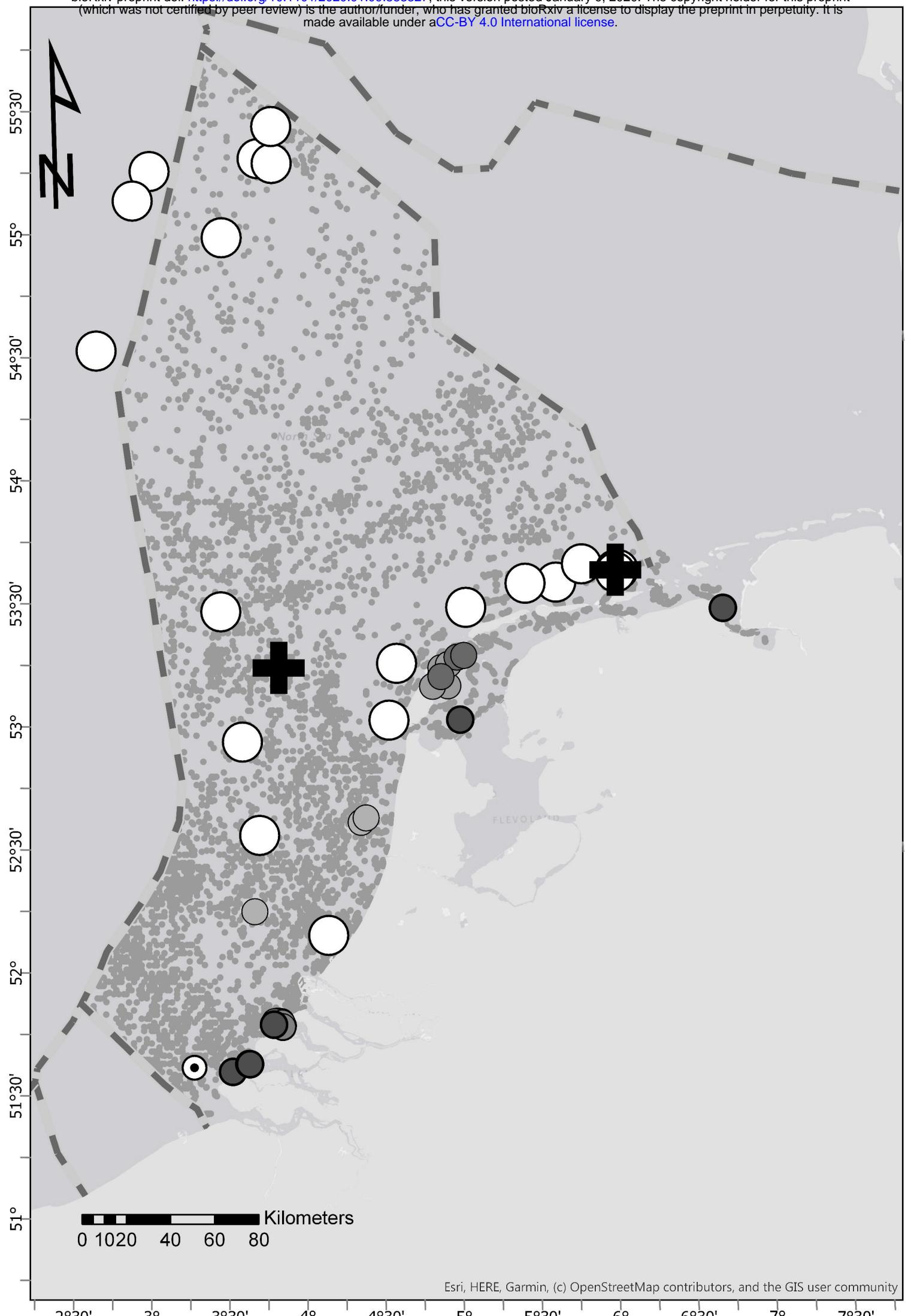
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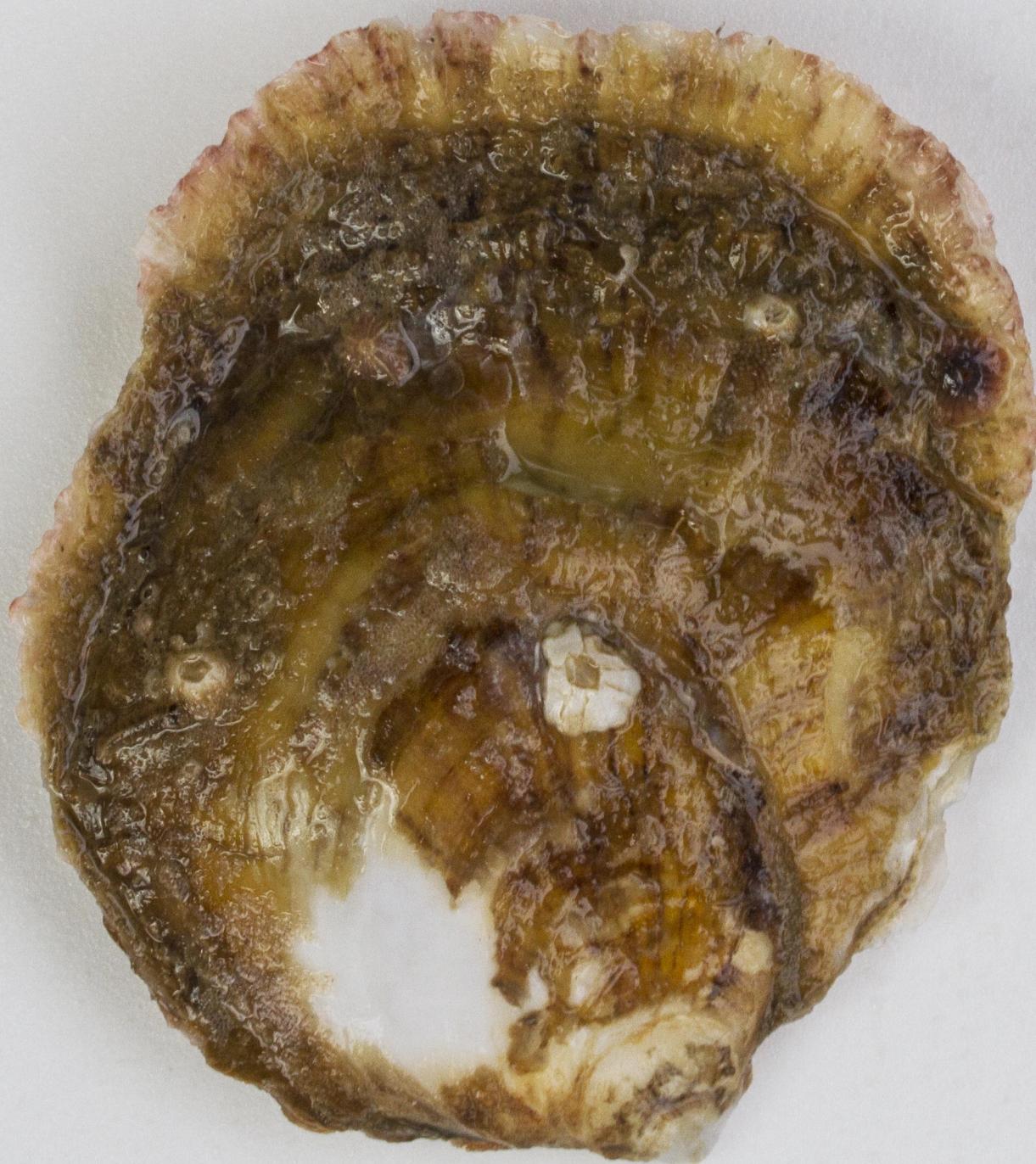
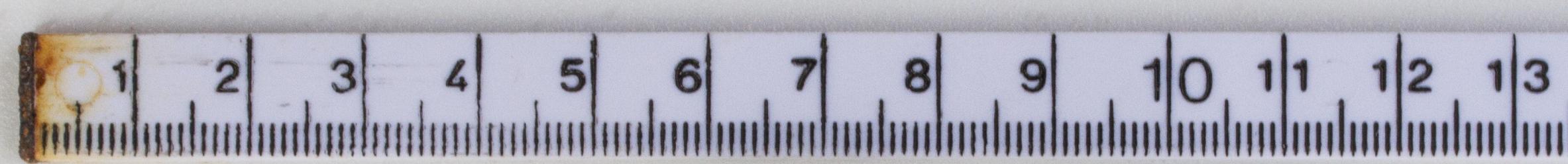
261 **Table 2. Measurements of empty shells from #3251 wreck**

262 Lengths and widths in mm of a selection of the larger empty *Ostrea edulis* shells found in and around the
263 #3251 wreck in September 2019, as shown in Figure 3.

Cluster	Length	Width
A1	116	112
A2	107	99
A3	Small shell fragment not measured	
B	100	76
C1	106	94
C2	88	78
C3	89	81
D	120	104
E	118	83
F	99	115

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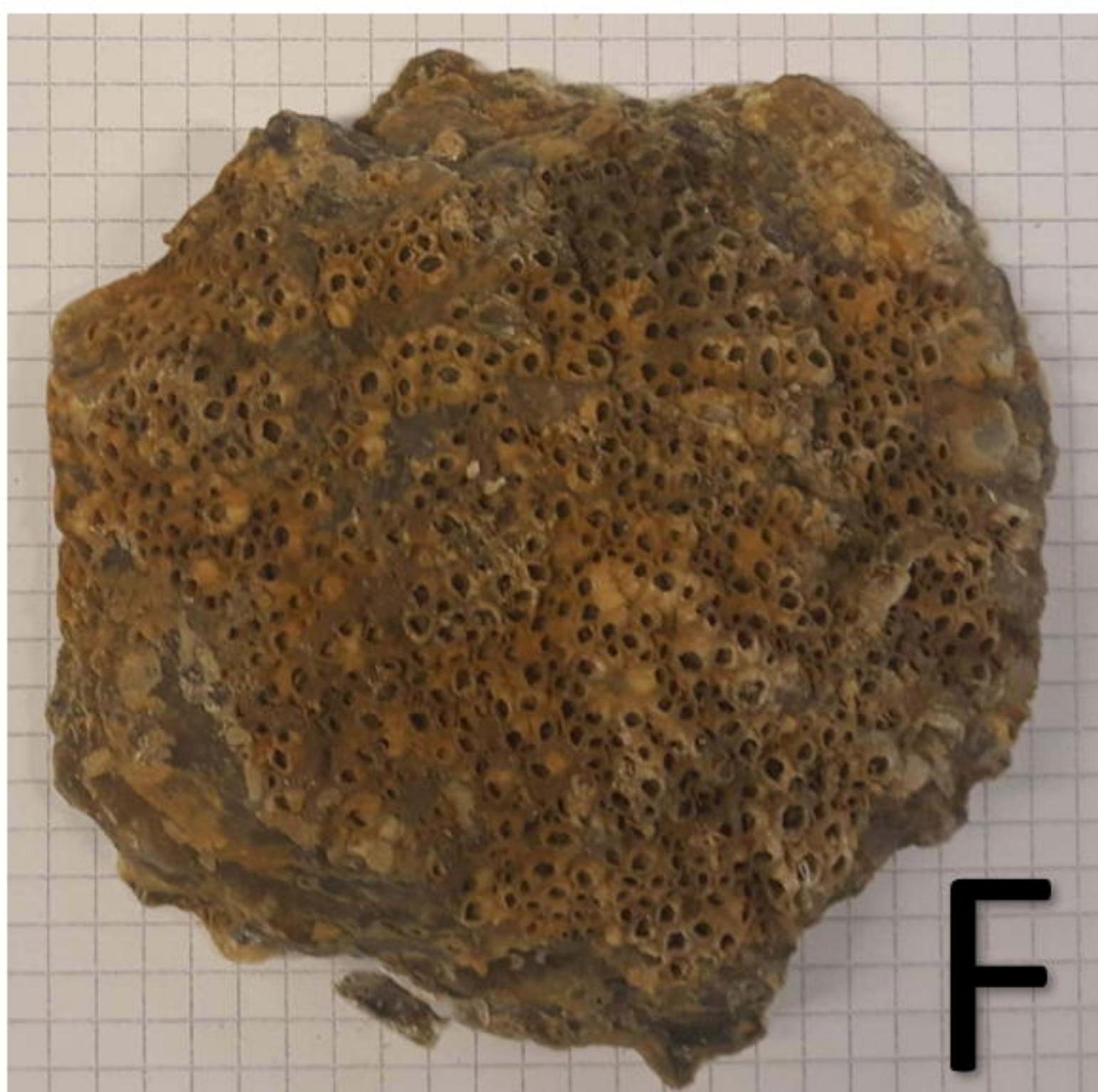
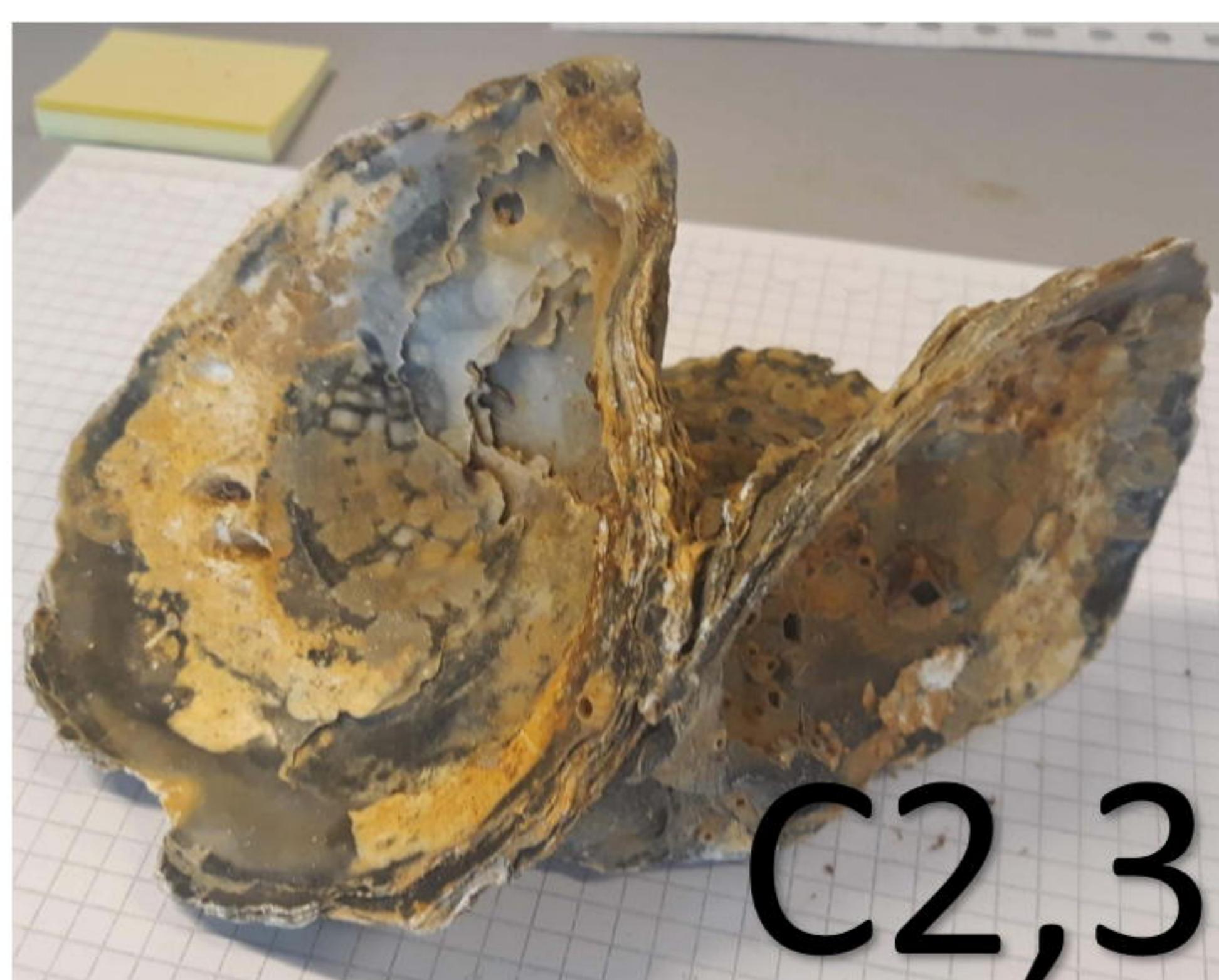
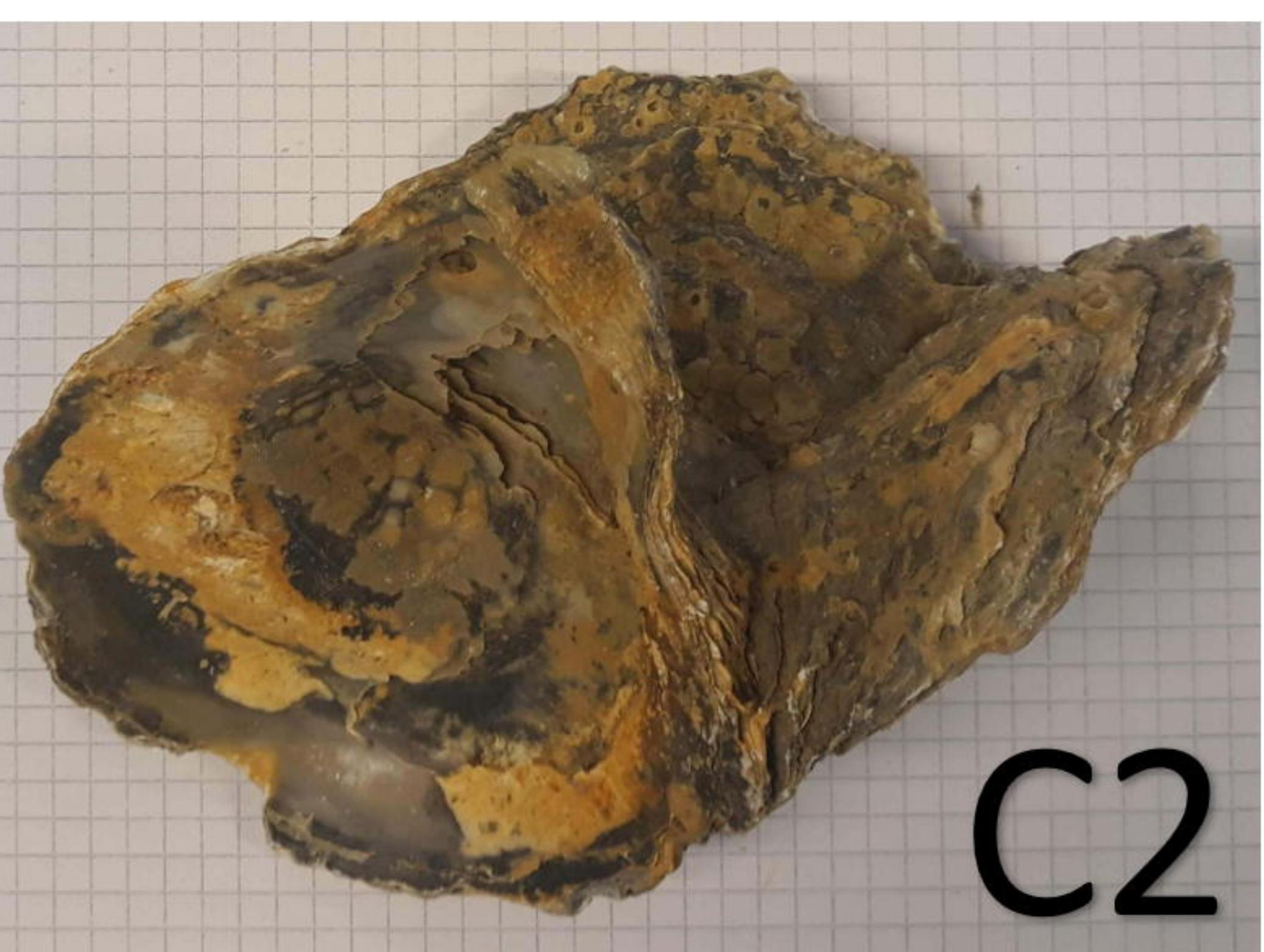
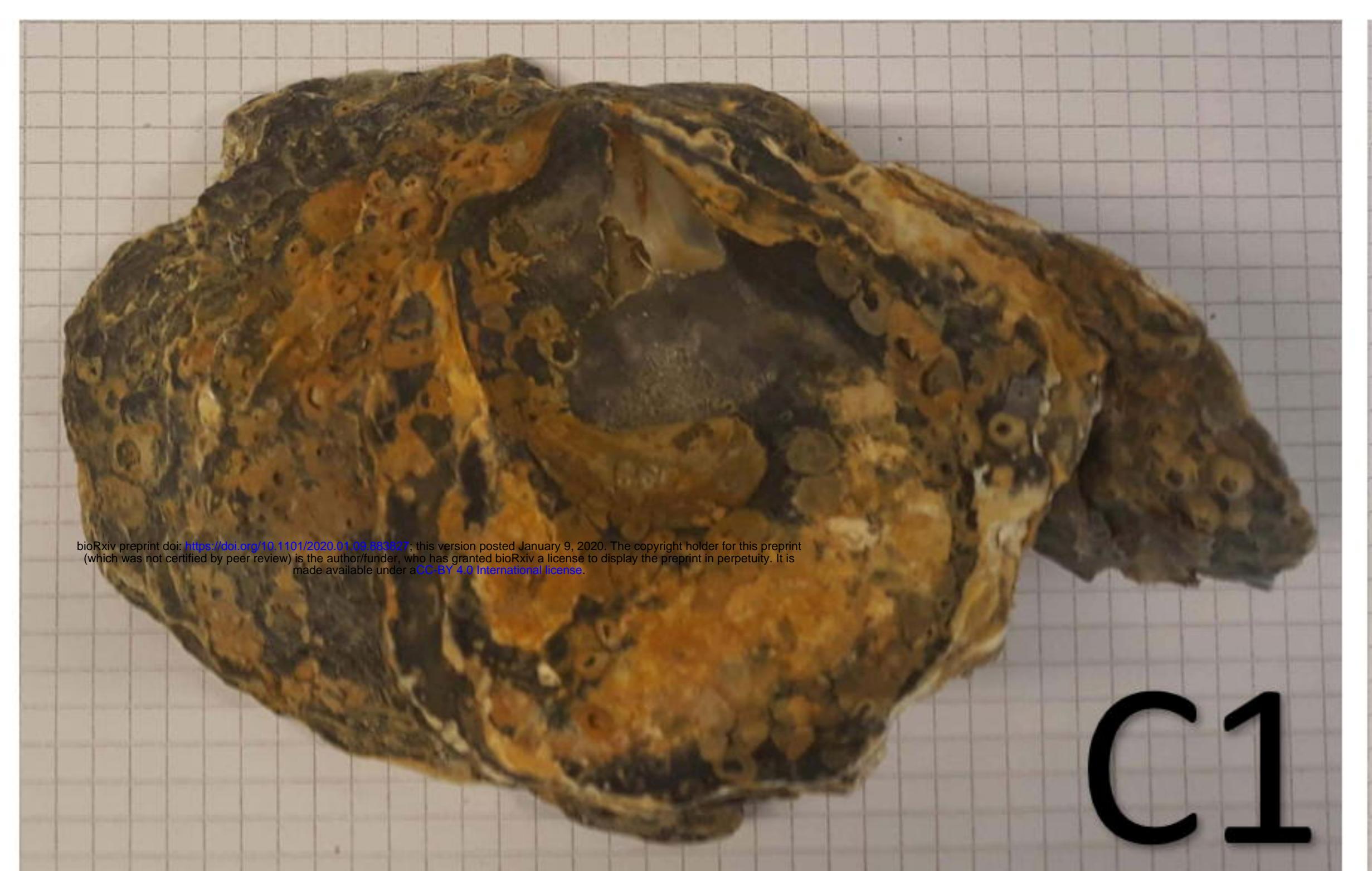
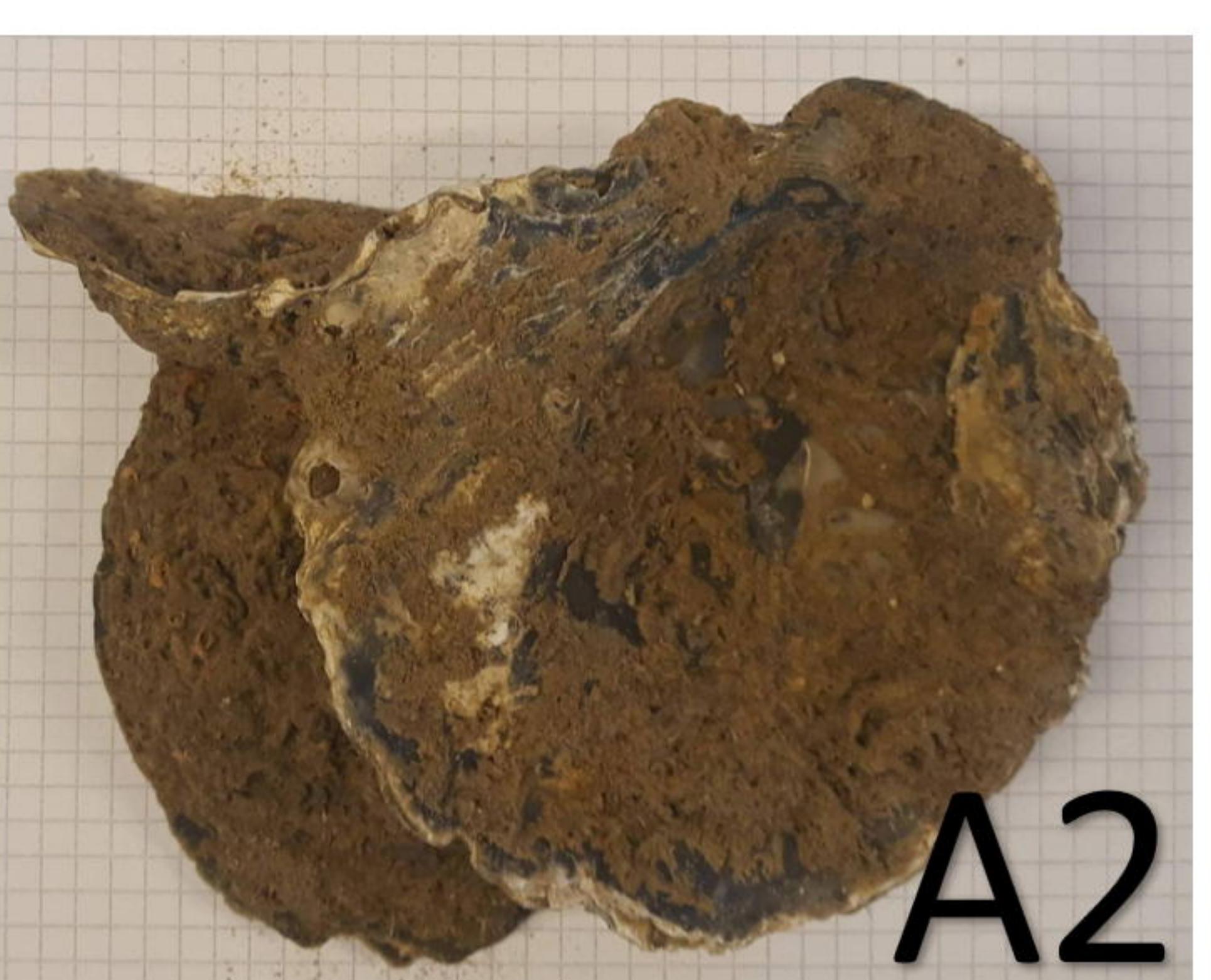
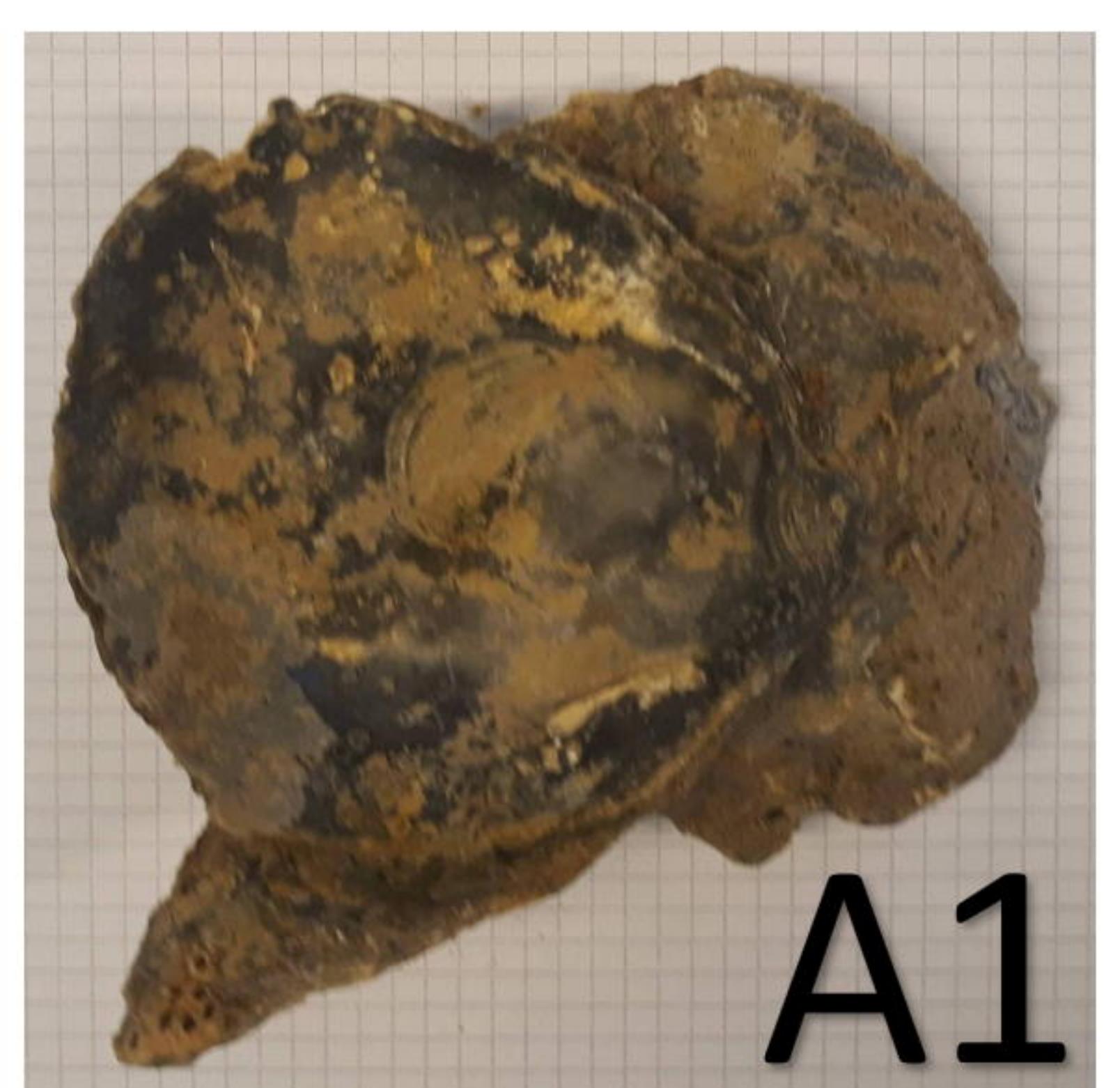






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