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1 **An interdisciplinary approach to Recent/Final Neolithic coastal gallery graves in Brittany,**
2 **western France. The 3D-structure, origin of rock material and paleoenvironmental setting of**
3 **the Kernic and Lerret monuments.**

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13 **Abstract :**

14 This article presents an interdisciplinary study carried out on two Recent/Final Neolithic gallery
15 graves (Kernic and Lerret) located on the northwestern coast of Brittany (western France). These
16 monuments show striking similarities in terms of architectural style and geographical position. This
17 paper aims to provide a better understanding of the construction strategy of these monuments by : (i)
18 determining the origin of the megalithic blocks from petro-structural analyses, (ii) reconstructing the
19 coastal environments from the analysis of sediment cores, and (iii) defining the place of these
20 monuments in the territories from intervisibility analysis. The study reveals important differences
21 between the two monuments. The Lerret gallery grave was erected in direct proximity to a unique
22 source of rock material on the margins of a marshland zone. In contrast, the Kernic monument shows a
23 deliberate diversification of stone extraction sites and was established on the edge of an estuary. An
24 intervisibility analysis shows a dense network of visual interconnections between the megalithic tombs
25 in the study area, in which the two monuments occupy very different sites. The social dimensions of
26 stone selection and the geographical location of Recent/Final Neolithic funerary monuments are also
27 discussed in an enlarged regional context.

28 **Keywords :** Gallery grave; Recent/Final Neolithic, megalithic tombs ; rock material; coastal
29 paleoenvironment ; petro-structural, paleoenvironmental and intervisibility analyses

30 1. Introduction

31 Megalithic monuments are one of the most emblematic manifestations of European Neolithic
32 populations. The age, number, and importance of these constructions in western France make this
33 region a key-area for investigating European megalithism (e.g. [Patton 1993](#) ; [Paulsson, 2019](#)). The
34 emergence and development of monumental architecture in Brittany as early as the Middle Neolithic
35 (ca. 4700 cal. BC) has been the focus of many recent studies (e.g. [Cassen, 2009](#); [Cassen et al., 2000](#) ;
36 [Tinévez et al., 2012](#) ; [Large, 2014](#) ; [Cousseau, 2016](#); [Cousseau et al., 2020](#)). However, thus far much
37 less attention has been paid to analyses of Recent and Final Neolithic (3800 - 2150 cal. BC)
38 monumental architecture ([Laporte et al., 2011](#)).

39 The study of the origin of the rocks used to build the megalithic monuments in Brittany is quite new.
40 The identification of stone material was carried out on the Barnenez cairn, Plouezoc'h, Finistère ([Giot
41 et al., 1995](#)) and on the great stelae of the Golfe du Morbihan ([Querré et al., 2006](#); [Bonniol and
42 Cassen, 2009](#); [Cassen et al., 2016](#)), revealing displacements over several kilometers.
43 Micromorphological analyses of megalithic slabs ([Sellier, 1995, 2013](#); [Mens, 2008](#)) have shown how
44 the natural outcrops were exploited. The use of different types of rock is also discussed in a
45 technological and symbolic interpretation of megalithic monuments ([Mens et al., 2021](#)). However,
46 despite the qualitative contribution of all these studies, few publications provide detailed geological
47 data about the areas surrounding the megalithic remains. The location of the exploited rock outcrops is
48 most often based on the 1:50 000 geological maps produced by the BRGM (Bureau de Recherches
49 Géologiques et Minières), while the potential sources of extraction are rarely researched ([Chauris,
50 2009, 2021](#)). We propose here a new investigation of the Lerret and Kernic gallery graves, based on
51 the methodology recently applied by [Caroff et al. \(2016\)](#) and [Le Gall and Caroff \(2018\)](#) to Iron Age
52 stelae in South Brittany. This approach involves the comparative petro-structural study of the material
53 of both monuments, and the rock outcrops exposed in their surroundings. The micromorphology of
54 each individual megalithic slab is also examined following the approaches developed by [Sellier \(1995,
55 2013\)](#) and [Mens \(2008\)](#). In the case of the Kernic gallery grave, our morphological approach was
56 completed by the construction of 3D models.

57 The majority of the megalithic sites in Brittany are located in coastal areas ([Giot et al., 1998](#)). Some
58 are currently submerged or overlaid by sand dunes ([Giot and Morzadec, 1992](#); [Giot, 1998](#); [Cassen et
59 al., 2010](#); [2019](#)), highlighting significant coastal paleogeographic changes since the Neolithic in
60 response to the relative sea-level rise. However, studies of megalithic monuments also integrating
61 reconstructions of paleo-coastal environments are relatively new, such as those concerning the Molène
62 archipelago (Finistère) ([Pailler et al., 2011](#); [Stéphan et al., 2019](#)) and Quiberon Bay (Morbihan)
63 ([Cassen et al., 2012](#); [Baltzer et al., 2015](#)). Paleoenvironmental reconstructions provide supplementary
64 evidence for understanding the reasoning used by Neolithic people for their site selection and their
65 organisation of coastal territories. The Lerret and Kernic gallery graves studied in this paper are
66 located on the foreshore, submerged daily by tides. During the Neolithic period, these two monuments
67 must have occupied a very different position, and in order to examine their similarities and differences
68 in terms of rock supply strategies and choice of location, it is essential to provide information on their
69 respective palaeoenvironments. For this objective, four core samples were collected and analysed from
70 Kernic Bay. The palaeoenvironmental reconstructions of the Lerret monument are only constrained by
71 the results of previous research ([Zeist, 1963](#); [Giot et al., 1965](#); [Hallégouët et al., 1971](#); [Goslin et al.,
72 2015](#); [Stéphan et al., 2015](#)).

73 Our study also includes visibility analyses that are increasingly applied to European megalithic
74 monuments (e.g. [Wheatley, 1995](#); [Gillings, 2009](#); [Ortiz, 2016](#); [Caruana and Stroud, 2020](#)). This type
75 of investigation helps to identify the spatial and structural relationships between the monuments and
76 their natural and cultural environments (e.g. [Caruana and Stroud, 2020](#)). Visibility analyses were never
77 carried out on the megalithic sites in our study area. The few studies performed in Brittany ([Roughley
78 and Shell, 2004](#); [López-Romero González de la Aleja, 2008a](#); [2008b](#)) highlighted the role of
79 intervisibility in the organisation of Neolithic landscapes ([E. López-Romero González de la Aleja,
80 2008b](#)).

81

82 2. General setting

83 2.1. Archaeological setting

84 The earlier gallery graves identified in Brittany were erected during the second half of the 4th
85 millennium, i.e. during the Recent and Late Neolithic. They are the result of a regional evolution of
86 monumental constructions characterized by the progressive enlargement of the burial chamber to the
87 detriment of the access structures and the surrounding barrow (L'Helgouach, 1965; Boujot and Cassen,
88 1992). They are representative of the collective burial sites that appear during the Recent Neolithic in
89 North-West Europe (Salanova et al., 2017).

90 In Brittany, the architecture of gallery graves is quite uniform (L'Helgouach, 1965). The monuments
91 consist of a strongly elongated rectangular central burial chamber, usually delimited by megalithic
92 slabs. Located on the main axis of the monument, the entrance is generally marked by a system
93 limiting access and sometimes preceded by a short vestibule. Some gallery graves have an additional
94 chamber next to the burial chamber called a cella. Although rarely preserved, the barrows are mainly
95 composed of loose sediment with a central mass of small blocks. They are frequently delimited by
96 large, vertically positioned slabs, called peristaliths.

97 Around 140 gallery graves have been documented in Brittany (L'Helgouach, 1965). In contrast to
98 the passage graves, characteristic of the Middle Neolithic and constructed between ca. 4300-3800 cal
99 BC mainly along the coast (Cassen et al., 2009), the gallery graves are located both in coastal regions
100 and inland.

101 While gallery graves are the prevailing type of funerary architecture during the Recent and Final
102 Neolithic in Brittany, they are not the only manifestation of burial practices during this period
103 (L'Helgouach, 1965; Joussaume and Laporte, 2006). Monuments with similar architectural
104 characteristics (V-shaped passage graves, lateral entrance graves, and angled graves) were also
105 constructed during this period (eg. L'Helgouach, 1965 ; Patton 1993). The older megalithic tombs are
106 frequently re-used and/or re-arranged by Recent and Final Neolithic populations (e.g. Port-Blanc,

107 Saint-Pierre-Quiberon, S Brittany; Gaillard, 1883; Schulting, 2005; La Torche, Plomeur, W Brittany,
108 Milon and Giot, 1947; Souc'h, Plouhinec, W Brittany, Le Goffic, 2006)

109 The pottery discovered in the gallery graves places them in the local Recent and Final Neolithic
110 traditions (e.g. Blanchard, 2017). They show a strong affinity with groups identified in the Paris Basin
111 between 3350 and 2550 cal BC (Salanova et al., 2011). Bell Beaker pottery (2550-1950 cal BC) is also
112 frequently found in these monuments (Salanova and Sohn, 2007; Nicolas et al., 2019).

113 The funerary practices linked to gallery graves in Brittany are very poorly understood as few of them
114 have yielded human remains (e.g. La Torche, Plomeur, W Brittany; Milon and Giot, 1947; le Tertre de
115 L'Église, Plévenon, N Brittany; Harmoï, 1909; Beaumont à Saint-Laurent-sur-Oust, S Brittany,
116 Tinévez, 1988; Tinévez et al., 1990). The closest and most well studied examples come from the
117 funerary ensembles of the Paris Basin (Marçais, 2016; Salanova et al., 2017), which attest to collective
118 burial practices (successive deposition in a single monument). From 2500 cal BC, gallery graves were
119 frequently reused by Bell Beaker peoples for individual burials (Salanova and Sohn, 2007).

120 In NW Armorica, the Leon domain contains 29 gallery graves and/or lateral entrance graves (Fig. 1a)
121 (Sparfel et al., 2004; Sparfel and Paillet, 2009). About half of them are situated in a small coastal area
122 between the Tresseny and Kernic bays, where the Kernic and Lerret monuments in this study are
123 located (Fig. 1b).

124 **2.2. Geological setting**

125 The Kernic and Lerret monuments are situated on the northwestern coast of the Leon metamorphic
126 domain (LMD) in NW Brittany (Fig. 1a). The rocky substratum exposed in these areas is dominated
127 by granitoids and medium-grade metamorphic terranes (gneiss, micaschists, and amphibolites) that
128 recorded strike-slip ductile shearing, synkinematic granitizations, and exhumation processes during a
129 collision stage of the Variscan orogeny in the time-span 320-300 Ma (Goré and Le Corre, 1987; Le
130 Gall et al., 2014; Authemayou et al., 2019). During the last 300 Ma, most parts of the Variscan
131 mountainous belt in Armorica, including the LMD, existed as emerged areas that experienced
132 erosional processes (Bonnet et al., 2000). During recent times (last 10 ka years), the onshore/offshore

133 boundary of the Armorica island recorded successive fluctuations of the relative sea-level (RSL), in
134 relation to paleo-climate changes. These changes are documented for the Kernic and Lerret
135 monuments under study (see section 2.3). They are both located on the c. 292 Ma-old Brignogan-
136 Plouescat granite (Georget, 1986; Marcoux et al., 2009) that fringes part of the LMD to the north (Fig.
137 1a). The two individual intrusions are sinistrally offset (c. 7 km) on both sides of the Porspoder-
138 Guisseny ductile shear zone (Fig. 1a) (Marcoux et al., 2004). These deeply eroded granitic massifs are
139 extensively exposed along coastal sections where they are locally overlain by Quaternary-Recent
140 (dominantly sandy) deposits.

141 *2.3. Geomorphological setting*

142 The coastal morphology in Northern Léon is characterized by a wide rocky platform (Léon plateau)
143 that extends more than 5 km seaward with a gentle slope on the intertidal and subtidal domains
144 (Hallégouët, 1971). The wind and wave climates are energetic and strongly seasonally-modulated
145 (Bentamy and Croize-Fillon, 2014). High-energy winter swells and storm waves come from the W-
146 NW with wave heights frequently exceeding 5 m. The tidal range reaches up to 7.2 m for spring tides
147 and 3.45 m for neap tides. On the submerged part of the Léon plateau beaches and associated dune
148 barriers isolate large wetlands. Contact between the coastal platform and the continental part of the
149 plateau consists of a partly tectonic paleo-scarp 30 m to 50 m-high (Fig. 1b). The map trace of the
150 scarp is cut by a series of deeply incised river valleys in the bedrock, the lower parts of which have
151 been subject to significant sediment filling over the last ca. 7,000 yrs (e.g. Stéphan et al. 2015). The
152 Lerret and Kernic gallery graves are located on the eastern shore of the Tresseny and Kernic bays,
153 respectively (Fig. 1b).

154 The NW coast of Brittany is considered to have been a tectonically stable region during the Holocene
155 (Ters, 1986; Morzadec-Kerfourn, 1995). The main dynamical event results from the hydrostatic
156 loading of the English Channel platform during the Holocene marine transgression. According to
157 Lambeck 1997, the Léon coasts recorded a subsidence of 1.5 m over the last 6 kys. The post-glacial
158 RSL changes recently reconstructed along the western coast of Brittany have shown that the rate of
159 marine transgression slowed down to 1 ± 0.2 mm.yr⁻¹ from 7000 cal BP to present times (Stéphan and

160 Goslin, 2014; García-Artola et al., 2018). A RSL reconstruction based on 28 index points and seven
161 freshwater limiting points dates indicates a position at -7.5 ± 0.8 m at ca. 6900 cal. BP (García-Artola
162 et al., 2018). In response to the RSL rise slowdown, modern coastline and coastal barriers formed with
163 basal *Phragmites* peats occupying the base of the coastal sequences. In Brittany, these deposits have
164 been dated at between 7,000–4,500 cal BP and suggest a large extension of swampy environments
165 beyond relatively stable coastal barriers (Morzadec-Kerfourn, 1974; Goslin et al., 2013; Stéphan et al.,
166 2015). The sedimentary coastal sequences of Western Brittany record a rapid change in coastal
167 environments between 2,900 and 2,500 cal BP. Sharp erosional contacts and/or sedimentary hiatuses
168 are systematically observed, indicating increased hydrodynamics and barrier breaching (Goslin et al.,
169 2013, 2015; Fernane et al., 2014; Stéphan et al., 2015; Ehrhold et al., 2021). From ca. 2,700 cal BP
170 until present-day, marsh sedimentary sequences record continuous accretion, and result in a new
171 period of coastal barrier stabilization (Stéphan, 2011; Stéphan et al., 2015). However, coastal sand-
172 dune systems appear to have experienced several phases of destabilization over the past 6,000 years.
173 Four periods of coastal dune mobilisation have been recently identified at 4,250-4,100 cal BP, 3,250-
174 2,400 cal BP, 1,050-700 cal BP, and 350-110 cal BP from the dating of interbedded archaeological
175 remains in sand dunes (Gorczynska et al. 2022).

176 During the 18th and 19th centuries, the inner parts of many estuarine mouths in Brittany were
177 empoldered for agricultural and sanitary issues. As such, the inner part of Tresseny Bay was
178 transformed into meadows by a drainage system after the construction of a tide-mill in the 17th century
179 (Fig. 2), whilst two dikes were built in the 1820s to drain the maritime marshes located in the lower
180 valley of the Kerallé River (Kernic Bay).

181 **3. Methodology**

182 Our study of the Kernic and Lerret gallery graves is based on an innovative and multidisciplinary
183 approach including a large panel of complementary analyses. First, the architecture of the monuments
184 and the morphology of their constitutive blocks was investigated using a 3D-imagery analysis.
185 Secondly, identification of the nature of the rock material and the location of potential sources of
186 extraction were determined from a comparative petro-structural analysis of megalithic slabs and the

187 surrounding rocky substratum. The paleoenvironmental setting of the two monuments was
188 reconstructed and then discussed in reference to the Neolithic cultural landscape through an
189 intervisibility analysis.

190 **3.1. 3D-imagery**

191 To define the structural arrangement of the two monuments, 3D surveys were conducted at low tides
192 using photogrammetry. The images were captured by a ground-based operator with a Nikon D5000
193 camera (number of images = 465 and 453 for the Kernic and Lerret monuments, respectively) and the
194 point clouds were calculated using Agisoft Metashape 1.6.3. software. The merging, cleaning,
195 meshing, and interpolation of the point clouds to produce a digital elevation model (DEM) were
196 conducted using CloudCompare v2.12 software. Unfortunately, the point cloud acquired on the Lerret
197 monument was unusable. Concerning the Kernic monument, a second 3D-model was produced with a
198 terrestrial laser scanner (TLS, Riegl VZ-400) from nine point clouds.

199 The scale and positioning of the elaborated DEMs were provided by accurate measurements of targets
200 scattered on the ground by the Differential Global Positioning System (Topcon Hiper V). All
201 measurements have been calibrated using the geodesic marker from the French datum and the
202 geodesic network provided by the National Institute of Geography (IGN).

203 **3.2. Morphology of the slabs**

204 Megalithic slabs are known to show structures of both natural (erosional) or anthropogenic origins
205 which can pre- or post-date their erection. Pre-megalith features are commonly evidenced on opposite
206 facets displaying contrasted morphologies as a function of their inner *vs* external position in the initial
207 source-rock massif. External or *weathered faces* usually show a curved surface which may further
208 bear erosional features, such as bowl-like depressions, grooves, or striaes (Sellier, 1991, 1995, 2013;
209 Mens, 2008). On the other hand, inward-facing or *fresh faces* generally display a more planar and
210 sometimes slightly concave geometry, with a more angular shape. When showing erosional features,
211 the latter are necessarily post-megalith structures. One major interest of post-megalith structures is that
212 they may provide diagnostical criteria about natural (geological/erosional) or human (transport,

213 reusing, restoration) events post-dating the megalith building stage. Evidence for minor human
214 reshaping was recognized from typical structures such as: (i) notches, mortises, or splinters resulting
215 from pull-out, handling, or removal activities, and (ii) modification of block surfaces from polishing,
216 hammering, or sculpted iconography (Boujot and Cassen, 1992; Boujot and Mens, 2000; Hinguant and
217 Boujot, 2008, 2010; Cassen et al., 2014, 2016). In the present case, the entire microstructure pattern
218 observed on the Kernic and Lerret megalithic slabs has been systematically diagnosed and referenced
219 following rules established by Sellier (1991, 1995, 2013).

220 *3.3. Identification of potential source-rock material*

221 One main objective of the present work is to identify potential extraction sites for the slab material
222 involved in the two studied megaliths. That should in turn provide insights into the strategy used by
223 Neolithic people to select and transport source-rock material. For this purpose, the comparative
224 petrographic and structural analyses of the megalithic slabs and their respective surrounding rocky
225 substratum was performed, both in the field and in laboratory. The petrographic diagnosis of hand-
226 specimens in the field has been completed by the microscopic inspection of collected rock samples.
227 This study chiefly concerns country-rock samples and only a small number of thin sections were made
228 from the slab material (in nearly detached fragments) for preservation purposes. As mentioned above
229 (see section 3.2), the morphological analysis of each individual megalithic slab was performed with
230 the goals of: (i) establishing correlations with geological structures observed in the surrounding
231 country-rocks and (ii) discriminating geological vs anthropometric structures. The great majority (if
232 not all) of the megalithic stones typically display a 3D-slab morphology that results from the
233 intersection of three nearly orthogonal (2 x 2) and planar surfaces. Most of the 3D-shaped slabs show
234 two prominent dimensions, referred to as the length (L) and the height (H), and one minor thickness
235 dimension (T), with $L > H \gg T$. Each dimension (L, H, and T) of a given 3D-slab is determined by
236 the spacing of one facet population. Without any strong evidence for significant human reshaping,
237 most of the slab facet patterns are assumed to correspond to geological structures in the initial source-
238 rock material. The magmatic (granitic) vs tectonic origin of these planar surfaces is deduced from the
239 Variscan geological context of the studied megaliths. The tectonic structures are genetically related to

240 either a ductile and pervasive strain (foliation, shear zones,...), or a brittle and more widely spaced
241 deformation (fractures *sensu lato*).

242 **3.4. Slabs weight estimates**

243 The volume of the exposed parts of the Kernic gallery grave slabs was estimated from the TLS
244 surveys. The volume determination was executed with CloudCompare software via the volume 2.5D
245 function. For the Lerret gallery grave, the volume of the slabs was estimated from their dimensions (W
246 x H x T) measured on site. Since this method overestimates the real volume of the slabs, the initial
247 values have been corrected. Considering that the geometry of the slabs in the two monuments is
248 similar, a correction coefficient has been defined from the data collected on the Kernic monument. It is
249 defined as the average difference in block volumes calculated by two methods (3D surveys and block
250 dimensions) and expressed as a percentage. From the volume of the blocks, the weight was determined
251 using the mean density of granitic material estimated at 2667 kg/m³ (Daly et al., 1966).

252 **3.5. Paleoenvironmental reconstructions**

253 For the Lerret monument, paleogeographic interpretations were based on previous studies of the
254 Holocene deposits in the inner part of the mouth of the Tresseny River (Goslin, 2014; Goslin et al.,
255 2015; Stephan et al., 2015). They were complemented by geomorphological and archaeological data
256 collected in both the northern and western parts of the estuary (Zeist, 1963; Giot et al., 1965;
257 Hallégouët et al., 1971).

258 For the Kernic monument, a set of four vibracores was collected in the inner part of the mouth of the
259 Kerralé River (Kernic Bay) in order to reconstruct the lithostratigraphy of the Holocene deposits and
260 to deduce the paleoenvironmental changes that occurred in the time-span from the Neolithic to the
261 present day. The ground surface elevation was measured relative to the French ordnance datum (NGF)
262 using a TopCon HyperV Differential GPS. The lithofacies that compose the Holocene sedimentary
263 successions were described in terms of texture, organic content, and foraminiferal assemblages.

264 Their interpretation as depositional environments was done in agreement with classic models (Reineck
265 and Singh, 1980; Allen, 2000, 2003), regional studies of estuarine and coastal areas (Billeaud et al.,

266 2007, 2009; Lespez et al., 2010; Stéphan, 2011; Stéphan et al., 2015) and by comparisons with modern
267 coastal sediments in NW Brittany (Hallégouët, 1971; Guilcher et al., 1990). Seventeen carbon-rich
268 sediment samples were collected for AMS 14C dating performed at the « *Laboratoire de Mesure du*
269 *Carbone 14* » (Saclay, France) and at the « *Beta Analytic* » (Miami, USA). As recommended by
270 several authors (Gehrels et al., 1996; Törnqvist et al., 1998; Gehrels, 1999), the radiocarbon
271 measurements have been limited to *in situ* detrital fragments of halophilic plants in order to minimise
272 errors due to possible contamination by older or younger carbon from rootlet penetration or washed
273 material. All conventional radiocarbon dates (this work, previous studies) were calibrated with OxCal
274 v.4.4.4 software (Bronk Ramsey, 2021) using the IntCal20 calibration curve (Reimer et al., 2020). All
275 dates are reported with a 2σ (95%) confidence interval in Tab. 1. The paleogeographic analysis in the
276 Kernic Bay area was completed by geomorphological and archaeological data previously acquired in
277 the northern part of the estuary by Briard et al. (1970) and Morzadec-Kerfourn (1974), in addition to a
278 series of geotechnical surveys referenced by BRGM (<https://infoterre.brgm.fr/>).

279 3.6. *Intervisibility analysis*

280 The intervisibility analysis was conducted on all gallery graves (or/and lateral entrance graves) dating
281 to the Recent and Final Neolithic. It also includes the only Middle Neolithic passage grave of
282 Brétouaré. In fact, the re-use of passage graves during the Early/Final Neolithic has been documented
283 at numerous sites (see section 2.1) and their importance in the patterning of landscapes during the
284 Recent and Final Neolithic is frequently highlighted (eg. Blanchard, 2017, p. 297). Without
285 archaeological research, it is not possible to confirm that the Brétouaré passage tomb has been re-used
286 but its barrow is still partly preserved (about 2 m height). In view of its topographical position, it must
287 have been largely visible in the landscape throughout the Recent and Final Neolithic.

288 A DEM at 5 m resolution was obtained by interpolating data from the Litto3D© (for the coastal area)
289 provided by the SHOM (<https://data.shom.fr>) and BDAlti (for the inland areas) provided by the IGN.
290 The sea surface was simulated at -3.39 m asl corresponding to the mean tidal level in this region at
291 around 2900 cal BC (García-Artola et al., 2018).

292 The intervisibility analysis was conducted with the QGIS 3.10.13 A Coruña software using the
293 Viewshed analysis plugin (Čučković, 2016). The observation points were positioned in the centre of
294 the monuments. In the case of destroyed monuments, their position was estimated according to the
295 available documentation. The observer height was systematically set at 1.7 m corresponding to the
296 average height of a mature adult. The target height selected in the parameters was 1 m for the gallery
297 graves and 1.4 for the Brétouaré passage tomb. This target sizes are within the barrows size estimated
298 for these structures. The extent of view was set arbitrarily at 15 km.

299 In order to describe the resulting visibility network and to identify the relationships between the place
300 of the monuments within it and their architectural characteristics, six indices partly inspired by social
301 network analysis (SNA) were calculated. Degree (i), closeness (ii), and betweenness (iii) centrality
302 indexes are classic tools of SNA and were calculated using the Visone 2.20 software
303 (<https://visone.ethz.ch/index.html>). Connection success index (iv) is defined as the percentage of
304 visible target sites in a set of evaluated target sites (Čučković, 2014a). The visual connection of the
305 gallery graves with the Brétouaré passage tomb was also expressed as the passage grave connection
306 index (v): 1 = presence of the visual connection to the Brétouaré monument, 0 = no connection. Lastly,
307 the architectural characteristics of the gallery graves have been synthesised in an « architectural
308 complexity index » (vi) defined as the sum of the values arbitrarily attributed to each structural
309 element (1 = presence of cella ; 0.5 = supposed cella ; 1 = presence of peristhalit ; 0.5= supposed
310 peristhalit). To evaluate the association between the resulting indices, a Sperman correlation analysis
311 was performed with XLSTAT software (<https://www.xlstat.com/fr/>) and significant differences were
312 accepted at $p < 0.05$.

313 4. Results

314 4.1. The Lerret gallery grave

315 The Lerret gallery grave is located at the mouth of the small Quillimadec River, on the northern edge
316 of the Tresseny embayment, west of the study area (Fig. 1b). Because of its low topography (1.50 m
317 asl) on the beach, the basal and southern parts of the monument continuously lie in sea-water whilst
318 the entirety of the monument is intermitently submerged during high tides (Fig. 2b).

319 **4.1.1. Architectural and archaeological data**

320 Though being long recognized by previous archeologists (Devoir, 1913; L'Helgouach, 1965; Giot et
321 al., 1998; Sparfel and Paillet, 2009), the Lerret megalith has never benefitted so far from accurate
322 investigations. Only the central part of the 13 m-long monument, i.e. the burial chamber, is currently
323 preserved. No barrow neither peripheral structures have been yet identified. The grave is oriented N-S
324 with the entrance to the north (Fig. 2a). The chamber is limited by 18 supporting stones, 13 of them
325 still stand up in their original position, whereas the five remaining ones are laying down inside the
326 chamber. The width of the monument increases from c. 1.50 m over its 5 m-long northern part up to 3
327 m southward (Fig. 2a). Its 1.30 m height is determined by the dimension of the orthostats. The three
328 cover slabs are preserved, but in a collapsed position (slabs n° 9, 23, 24 in Fig. 2a). Lastly, the bedside
329 slab which closes the chamber to the south is currently inaccessible as it is constantly submerged. No
330 radiometric age dating yet exists for the Lerret monument, but its Recent/Late Neolithic age is
331 confidently deduced from its architectural style.

332 **4.1.2. 3D-morphostructural analysis and weight determination**

333 Only 18 (of 25) slabs of the Lerret megalith have been accurately studied (Supporting Information 1),
334 as the others are inaccessible. They all display regular slab 3D-shapes (Fig. 3a). The dimensions (L, H,
335 T) of the pilars are slightly lower than those of the cover slabs and are in the ranges 0.48-2.1 m (1.8 m
336 in average) for L, 0.20-0.50 m (0.36 m in average) for T and 0.36-1.76 m for H (0.92 m in average).
337 The cover slab dimensions are 1.0-1.5 m (1.3 m in average) for L, 1.8-2.45 m (2.11 m in average) for
338 H and 0.4-0.5 m (0.45m in average) for T (Supporting Information 1). The morphological analysis of
339 the blocks is difficult because most of their surfaces are highly weathered and further covered by
340 seaweeds and marine organisms (barnacles), especially the partly immersed ones. As a result, 12
341 blocks (of 24) show at least one facet of undetermined nature (Supporting Information 1).
342 Nevertheless, 21 *fresh faces* (over 34) have been identified, principally in the southern part of the
343 monument (Supporting Information 1).

344 Very few marks of stone extraction made by Neolithic people have been identified (Fig. 3b), and from
345 their discrete location on individual blocks they rather suggest that the latter were only locally

346 reshaped, probably for a better fitting of juxtaposed blocks. Similarly, no evidence of modification of
347 the slabs surfaces was observed. Evidence for post-megalith damage and sampling have been noted.
348 Though being partly collapsed, the eastern wall appears to be laterally disrupted (Fig. 2a).
349 These empty spaces might correspond to original parts of the dry stone wall that are no longer
350 preserved. A mixed technique like this, using both rocky slabs and dry stone, is very rare, but has been
351 observed in similar monuments elsewhere in NW France (L'Helgouach, 1965). A more likely
352 hypothesis is that the missing pilars and cover slabs were removed during post-megalithic times. The
353 uppermost parts of two pilars (slabs 3 and 4) from the western wall have been sliced off, probably
354 relatively recently, as suggested by the identification of metallic edge marks (Fig. 3c). More generally,
355 the fact that the Lerret monument shows very little evidence of human reshaping during Neolithic
356 times might reflect the will of these people to directly extract granitic slabs displaying regular 3D-
357 shapes.

358 The average weight of the slabs is estimated at 1.88 T. The heaviest slabs were used to cover the
359 monument. The two well-preserved capstones (no. 23 and 24 in Fig. 2a) are approximately 3.21 and
360 2.28 T respectively, while the mean weight of the pillars is 0.77 T. The total weight of the monument's
361 slabs is estimated at 17.87 T.

362 ***4.1.3. Petrographic and structural analyses of the megalithic slabs***

363 The existence of dense coating materials excludes the exhaustive petro-structural analysis of the 24
364 slabs, and only 18 of them have been accurately determined. They are all composed of a leucogranitic
365 material, dominated by a quartz-K/feldspar-biotite porphyroblast assemblage, averaging 1 cm in size
366 and depicted on the thin section of the slab n°24 in Fig. 3e. This rock correlates with the finer-grained
367 facies of the Brignogan porphyroid granitic country-rock. The proportion of strained and unstrained
368 (or little) slabs is equal (x 9). The two types of rock material show no specific distribution in the
369 megalith arrangement (Fig. 2a). The strained ones display an internal planar fabric systematically
370 parallel to the greatest facet (H x L) of the slabs. The tectonic origin of this fabric is argued by the
371 alignment of deformed porphyroblasts in pervasive foliation (flattening plane) and/or shear surfaces
372 imaged on the thin section in Fig. 3e. The remaining, and much less deformed (or unstrained), granitic

373 slabs are composed of >2 cm K-feldspar porphyroblasts and smaller quartz-biotite assemblages that
374 tend to be oriented in a weak foliation planar fabric, as shown in the microscopic view of slab n°19 in
375 Fig. 3d.

376 *4.1.4. Potential source-rock material*

377 The Lerret megalith occurs on the northern flank of the N110°-oriented, and c. 1 km-wide Tresseny
378 coastal embayment, at the transition between: (i) the westernmost edge of the Brignogan granite (NE)
379 and (ii) its metamorphic country-rocks (dominantly migmatites) and intrusive granitoids (SW) (Fig.
380 1a). The two parallel (N110°E) faults that limit the Tresseny graben-like depression are probably
381 extensional structures that post-date to the south the N70°E Porspoder-Guisseny sinistral shear zone
382 separating migmatites (N) and the c. 300 Ma-old Ploudalmezeau granite (S) (Marcoux et al., 2004).
383 The rocky substratum of the Lerret gallery grave is exposed as a discrete inlier of Brignogan
384 porphyroid granite (Fig. 4a). Its petrology is relatively homogeneous and dominated by quartz, K-
385 feldspar porphyroblasts, commonly >5 cm-long, and abundant biotite (Fig. 4c).

386 Strong correlations between the petrography of the Lerret gallery grave slabs and their immediate
387 granitic country-rocks suggest a local origin of the megalithic material. The potential extraction sites
388 must also satisfy two supplementary structural criteria dealing with the presence of (1) orthogonal
389 joint networks and (2) a pervasive foliation/shear planar fabric parallel to one joint network as
390 observed in the nine strained slabs.

391 Excepting a few large-scale boulders of isotropic (unstrained) granites (outcrop n° 4 in Figs. 4a, h),
392 most of the granitic rocks exposed on the c. 100 m-long coastal section in the Lerret site are intensely
393 fractured, and thus satisfy, at first approximation, the first structural criteria above. However, a number
394 of 3D-fractured granitic zones have been cancelled because of the greater (outcrop n° 5, Figs. 4a, g) or
395 smaller (outcrop n° 6, Figs. 4a, f) dimensions of the resulting slab-like blocks. Site n° 3 (Fig. 4a) has
396 also been ruled out because of the lack of one joint population, which results in over-sized (L) slabs. In
397 suitable fractured areas (outcrops n°1 and 2, Figs. 4a, b, i), the porphyroid granite is cut by a steeply-
398 dipping (70°) joint network, oriented N80°E with an average spacing of 20-40 cm, that parallels a
399 pervasive shear fabric. The latter is well expressed in the thin section in Fig. 4d as cm-spaced surfaces,

400 the sinistral sense of displacement along them is deduced from the sigmoid shape of the foliation
401 planes (elongated quartz-biotite assemblage). This ductile shear-related strain is attributed to the
402 regional-scale Porspoder sinistral shear zone that extends c. 1 km further south. In the field, the
403 composite (brittle/ductile) planar fabric is dissected at high angle by a more widely-spaced and
404 steeply-dipping joint pattern, oriented N135°E (outcrop n°1) and N160°E (outcrop n° 2) (Figs. 4b, i).
405 Their intersection results, in addition to a much less regular orthogonal joint system, to 3D-slabs
406 showing comparable dimensions (lengths in the range 0.95-1.80 m) with the Lerret megalithic slabs
407 (Supporting Information 1). It is thus argued that the sheared granite exposed in sites 1-2, c. 50 m
408 away from the Lerret gallery grave, represents a potential source-rock for its strained constitutive
409 slabs. A second possible extraction zone of deformed granites with suitable 3D-fabrics is observed at
410 site 7 (Figs. 4a, e). There, the dominant joint pattern is nearly vertical and oriented N120°E, with a
411 regular spacing of 25-50 cm, parallel to foliation planes. The second submeridian joint network is
412 vertical (Fig. 4e). Site 7 is located at c. 200 m away from the Lerret megalith (Fig. 4a). Potential
413 extraction sites of the remaining (x 8) little deformed slab population should occur in the unsheared
414 granitic bands observed within the PGSZ shear zone in the vicinity of the Lerret monument (Fig. 4a).

415 **4.1.5. Paleoenvironmental setting**

416 In the inner part of Tresseny Bay, south of the Lerret gallery grave, a set of 19 cores was previously
417 studied by Goslin (2014), Goslin et al. (2015), Stéphan et al. (2015), four of which are presented in
418 Figs. 5 and 7 (G-C11, G-C2, G-C1, G-C3). The base of the succession consists of well-humified basal
419 peat (with a mean thickness of 1 to 1.5 m) covering a weathered granite. The base of this deposit was
420 dated to 4452-4346 cal BC at core G-C2 and to 2842-2476 cal BC at core G-C3. The presence of
421 *Phragmitus Australis* macroremains and a very low amount of foraminifera both indicate a back-
422 barrier brackish marsh (Stéphan et al., 2015). This basal deposit evolves into a 0.15 m thick black-peat
423 layer, dated at 2800-2600 cal BC, that indicates the onset of slightly regressive conditions towards the
424 highest marsh deposit environments on the site (Goslin, 2014; Goslin et al., 2015). A coarse sand unit
425 overlies the basal peat at a depth of -2.2 m asl. The sharp transition suggests a rapid change toward
426 high hydrodynamic conditions. The age of this environmental change at ca. 950-750 cal BC is argued

427 by a series of five radiocarbon dates obtained for the sandy-silty unit overlying the coarse sand layer
428 and indicates a very high sedimentation rate (Fig. 7). The absence of foraminifera and the low density
429 of detrital plant fragments suggest a sandflat environment (Goslin et al., 2013; Stephan et al., 2015).
430 The upper part of the succession is formed by an organic-rich fine sand unit within the seaward cores
431 and reed peat containing *Phragmitus Australis* macroremains in the landward cores. The foraminiferal
432 assemblages indicate a gradual change from a sandflat to a salt-marsh between 230 and 1400 cal AD
433 (Stéphan et al., 2015).

434 On Vougot beach (Fig. 5), in the northwestern part of Tresseny Bay, two cores (V-1 and V-3) were
435 analysed by Goslin et al. (2013, 2015) and Goslin (2014). Core V-3 revealed a 0.65 m thick basal peat
436 deposit overlying a pre-Holocene (Pleistocene loess) surface at -3.5 m asl (Fig. 7). The base of this
437 deposit was dated to 5008-4838 cal BC (Goslin et al., 2013) and its top is eroded and currently
438 exposed (Goslin, 2014). The macroremains of *Phragmitus Australis* and the absence of foraminifera
439 suggest a marsh or brackish swamp environment.

440 The base of the V-1 succession is also formed by a 60 cm thick peat deposit overlying a pre-Holocene
441 surface (Pleistocene loess) at -1.25 m altitude and dated to 2841-2467 cal BC (Goslin et al., 2013).
442 The absence of foraminifera and the macroremains of *Phragmitus Australis* indicate a former marsh or
443 brackish swamp environment. This basal unit is overlaid by a 1.6 m thick layer of white sand (between
444 -0.55 and 0.75 m asl) and becomes gradually more organic at the top. The 0.1 m upper section
445 corresponds to the peat deposit exposed at the surface (Goslin et al., 2013; Goslin, 2014).

446 At Curnic (Fig. 5), to the west of Vougot beach, a paleosoil formed on the Pleistocene silt (loess) and
447 containing numerous archaeological remains (ceramic pieces, knapped and polished stone tools, and a
448 series of fireplaces) was discovered in the intertidal zone (Briard et al., 1960; Giot et al., 1965; Giot,
449 1966). Analysis of the archaeological remains and radiocarbon dating indicate a Middle to Recent
450 Neolithic settlement (ca. 4800-3200 cal BC). All the remains were subsequently overlaid by a 12 cm-
451 thick peat deposit containing macroremains of *Phragmitus Australis* (Giot et al., 1965) (Fig. 7).
452 Palynological analysis of the peat indicates a marsh environment with occasional freshwater ponds
453 (Zeist, 1963).

454 At Tresseny (Fig. 5), to the north of the Lerret gallery grave, an archaeological settlement with similar
455 characteristics as the Curnic site was documented in the intertidal area (Hallégouët et al., 1971). The
456 ceramic pieces and the knapped and polished stone tools are contained in a paleosoil developed on
457 Pleistocene silt (loess) and overlaid by a 0.1 m thick peat deposit (Fig.7). No radiocarbon dating was
458 obtained, but the analysis of the archaeological remains indicates a Middle to Late Neolithic settlement
459 (ca. 4600-2150 cal BC) (Hallégouët et al., 1971).

460 **4.2. The Kernic gallery grave**

461 The Kernic gallery grave is located on the northern edge of Kernic Bay where the Kerallée River flows
462 into the sea (Fig.1b). Because of its low altitude (2.30-3.50 m asl), the monument is partly submerged
463 during high tides (Fig. 4b).

464 ***4.2.1. Architectural and archaeological data***

465 The Kernic monument is one of the only coastal megaliths which has been the subject of previous
466 archaeological investigations (Lecerf, 1983, 1984, 1985). The Kernic gallery grave is a 13.6 m
467 elongated monument, oriented NNE-SSW (Fig. 8a). It is composed of a tomb chamber and a terminal
468 cell also referred to as a 'cella' (L'Helgouach, 1965). The 9.7 x 1.3 m tomb chamber is 1.2-1.6 m high
469 as deduced from the dimensions of the orthostats. It is bounded by 15 pilars (Fig. 8a). Two blocks are
470 currently missing (n W6 and E6), but their respective dug pits have been identified during previous
471 archaeological investigations. The entrance to the south is limited by two blocks (PFw and S on
472 Fig. 8a). On its northern part, a 2.9 x 1.50 m annex cell, located behind the bedside slab, displays a
473 subtriangular shape (Fig. 8a). None of the initial capstones is still present.

474 The Kernic gallery grave was probably originally enclosed in a barrow no longer preserved. The only
475 preserved remains are parts of : i) the internal wall, still present on the cella area and ii) a peristalith
476 composed of slabs along most of the length of the monument, with the exception of its northern part.
477 The initial dimensions of the barrow are estimated at 15-16 x 6 m.

478 The archaeological artefacts collected during previous investigations are ceramic pieces, knapped and
479 polished stone tools, in addition to ornamental elements (Lecerf, 1985). The Kernic gallery grave has

480 not been dated by radiocarbon methods, but its archaeological style, as well as its composite
481 archaeological remnants, all indicate its Recent/Late Neolithic age. Evidence exists for the re-use of
482 the Kernic galley grave as a funeral monument by Bell Beaker populations (Nicolas et al., 2013),
483 while Bronze age ditches, bounded by standing stones, present in the vicinity of the Kernic site, are
484 tentatively regarded as parts of a field system (Lecerf, 1985; Blanchet et al., 2019) (Fig.8a).

485 ***1.1.1.3D-morphostructural analysis and weight determination of slabs***

486 In its present state, the Kernic megalith is composed of 62 individual blocks standing up vertically in
487 the ground as the preserved parts of the tomb chamber, the cella, the internal walls and the peristalith
488 (Fig. 8a). Nearly all of them display regular 3D-shapes (Fig. 9), but with variable dimensions
489 accurately measured from our 3D-model (Supporting Information 2). L ranges from 0.31 to 1.87 m
490 (0.80 m in average) and T from 0.12 to 0.68 m (0.37 m in average). Because of recent damage, the
491 initial H dimension is not always preserved (see below) and it currently ranges from 0.30 to 1.65 m.
492 (Supporting Information 2). The slabs forming the gallery grave systematically show greater
493 dimensions than those used in the peristalith. The average height of the preserved slabs constituting
494 the burial chamber and the cella is 1.23 m, while that of the slabs of the peripheral parts is only
495 0.69 m.

496 Discriminating initial *weathered* and *fresh faces*, as well as identifying natural microforms or human
497 reshaping, are made difficult because most of the block facets are relatively eroded under atmospheric
498 agents and sea action, and also because those partly immersed are commonly covered by seaweeds
499 and lichens. Most of the studied slabs (39) display both *weathered* and *fresh faces* (eg. Figs. 9a, b).
500 Eight of them show two opposite *fresh faces* whereas two opposite exposed surfaces are observed on
501 four slabs. There are 11 slabs that display one or more surfaces of undetermined origin. The most
502 planar surfaces (*fresh faces*) are principally pull-out ones forming the internal wall of the grave gallery
503 and the cella. This pattern is not systematically observed in the peristalith, since eight slabs (of 30)
504 show a reverse orientation. Following criteria used by Sellier (2013), erosional forms have been
505 evidenced on only 18 slabs (Supporting Information 2). They chiefly consist of upper grooves, the pre-
506 or post-megalith origin of which is not firmly established.

507 Very few slabs show evidence for artefacts synchronous to the building of the megalith. A few splinter
508 marks are present on slabs from the grave gallery (eg. Figs. 9b, c) and might have been made for a
509 better jointing of the slabs. No evidence for hammering or polishing has so far been observed. By
510 contrast, the re-use of slabs in post-megalith times has been argued by Lecerf (1985) in the grave
511 gallery by two missing pilars (n°W6 and E4 in Fig. 8a) currently deduced from their dug pits.
512 Evidence for recent re-use is also found in the sliced uppermost parts of pilars in the cella (n°Wa, Wb,
513 Wc, and Ea in Fig. 8a) and in the burial chamber (n° W7, W8, E6, and E7 in Fig. 8a). That results in
514 their reduced height in the range 0.30-0.98 m. However, traces of slicing from metallic edges are not
515 present, contrary to reshaped megaliths observed in other sites. These sliced upper parts usually form a
516 horizontal surface, further intersected by a smaller and inclined surface (Fig. 9d). The techniques used
517 for these cuttings remain unknown. The presence of capstones over the burial chamber is also
518 questionable, but is here confidently predicted from comparisons with other megalithic monuments in
519 Brittany (L'Helgouach, 1965a). A number of slabs are also currently missing on the eastern and
520 western parts of the peristalith, while they have been totally removed to the north (Fig. 8a).

521 The weight of 61 of the 62 slabs of the Kernic gallery grave has been estimated and averages 0.63 T
522 (Supporting Information 2), but it changes significantly in relation to a slabs position in the
523 monument. The average weight of the interior parts of the monument (burial chamber + cella + front)
524 is 1.04 T and those of the peristhalith and the internal walls is 0.32 T. The heaviest element is the
525 “*table de chevet*” (n°N1 in Fig.8a), which weights 4 T. The total weight of the slabs is estimated at
526 38.49 T. The weight of porphyroid facies and medium-grained facies slabs is nearly equal and
527 represents 14.74 and 13.34 T, respectively. The total weight of the fine-grained facies slabs is slightly
528 lower at only 10.41 T.

529 **1.1.2. Petrographic and structural analyses of the megalithic slabs**

530 The 61 slabs involved in the Kernic megalith are all composed of a leucogranitic material, dominated
531 by quartz and K-feldspar porphyroblasts. However, the size and relative abundance of these
532 constitutive minerals and those of white (muscovite) vs black (biotite) micas allow us to discriminate
533 three distinct petrographic facies with porphyroblasts > 2-3 cm in porphyroid facies, averaging 1 cm in

534 medium-grained facies, and < 1 cm in fine-grained facies (Figs. 10a, b, c, d). The microscopic
535 inspection of a fine-grained granitic slab (Pw5 in Fig. 10d) confirms the modest size of the
536 porphyroblasts and shows the relative abundance of biotites and plagioclases.

537 The spatial distribution and relative proportion of each type of granitic material in the Kernic megalith
538 are depicted in Figs. 8a, c. The medium-grained granitic slabs are more numerous (27, i.e. 44%) and
539 preferentially form the peristalith. The porphyroid and fine-grained slabs are equally present (17, i.e.
540 28%), the former ones appear as the main component of the gallery grave. Such a distribution is
541 assumed not to be hazardous and to have been dictated from the greater, and more suitable,
542 dimensions of the porphyroid slabs for the construction of the gallery grave.

543 Strong correlations between the three granitic facies identified both in the megalithic slabs and the
544 various types of granites in the surrounding Plouescat intrusion allow us to regard the latter as the
545 potential source-rocks of the Kernic megalith slabs. Then, identifying specific extraction sites can be
546 attempted using complementary structural criteria.

547 The facet pattern of the Kernic slabs shows no evidence of human reshaping, except for the very
548 recent (post-megalith) reworking of a few of them. They are thus assumed to correspond to natural
549 planar fabrics that were exploited by Neolithic people for easier splitting of the granitic country-rocks
550 (eg. Figs. 9a, b). Evidence for internal pervasive ductile strains have not been observed in the slab
551 granitic material. The planar fabric outlined by aligned K-feldspar porphyroblasts on the upper surface
552 of slab n° Pw2 (Fig. 10d) has a magmatic origin and results from the magma flowing during the
553 intrusion of the pluton. Consequently, nearly the entirety of the facet patterns in the Kernic megalith
554 correspond to brittle fractures (joints), as those typically form during the cooling stage of any
555 magmatic intrusions. A similar 3D-orthogonal joint network should be necessarily displayed by the
556 three petrographic facies of the Plouescat granitic country-rocks in order to be regarded as potential
557 extraction sites.

558

559

1.1.3. Potential extraction sites

560 The Kernic site occurs at the western extremity of the ca. 30 x 15 km Plouescat granitic pluton, on the
561 northern flank of an EW-oriented coastal embayment occupied by recent sediments (Fig. 11a). The
562 metamorphic host-rocks of the granite are only exposed as a small patch of orthogneiss (Plounevez-
563 Lochrist formation) at the southern end of Porz Meur beach (Fig. 11a) (Chauris et al., 1998). The
564 Plouescat leucocratic granite comprises three distinct map-scale petrographic facies that differ about
565 the dimensions of their common constitutive minerals, i.e. quartz, K-feldspar, white (muscovite) and
566 black (biotite) micas (Fig. 11a, b, c, e). (I) In a central position, the Brignogan facies *sensu stricto* is a
567 porphyroid granite with porphyroblasts usually > cm's (Fig. 11c). It is surrounded by two narrow belts
568 of (ii) medium-grained granite (Cleder facies) (Fig. 11b) (iii) A third fine-grained facies (Mogueriec)
569 with <2 cm's porphyroblasts is extensively exposed further south (Fig. 11e). The only tectonic
570 deformation recorded by the Plouescat intrusion are variously-oriented fracture networks, without any
571 evidence of ductile strain. The Kernic site occurs on the southernmost edge of the Brignogan
572 porphyroid granite (Fig. 11a). The closest potential extraction site forms a shallow platform in the
573 intertidal zone at the western extremity of the Porz Meur beach (outcrop n°5 in Fig. 11a). There, the
574 Brignogan granite is dissected by three regular and orthogonal joint networks (Fig. 11c): (i) the most
575 prominent joint pattern is oriented N135°E, in a nearly vertical attitude, and with a regular spacing of
576 0.4-0.7 m. These surfaces are disrupted by (ii) a steeply-dipping joint network, oriented N60°E, that
577 results in slab lengths in the range 0.2-2 m. (iii) A third, and less regular fracture population,
578 perpendicular to the two former ones, determines slab heights of c. 1 m (Fig. 11c). The 3D-
579 morphology of the resulting fractured blocks is quite similar to those of the porphyroid megalithic
580 slabs, hence allowing us to identify a first potential extraction site at c. 600 m NW of the Kernic site
581 (Fig. 11a). Extraction sites for the medium-grained megalithic slabs are documented in the Cleder-type
582 granite exposed at the northeastern end of the Porz Meur beach (outcrop n°6 in Fig. 11a). There, the
583 morphology of the shallow granitic platform is shaped by a joint network dipping shallowly at 20° to
584 the west, with an average spacing of 0.6 m (Fig. 11b). A second joint population, oriented N150°E in a
585 vertical position, determines, in addition to a more irregular third one, 3D-blocks displaying

586 dimensions slightly greater than, but still suitable with, those of the petrologically similar slabs in the
587 megalith. It is thus argued that the NE granitic shore of the Porz Meur beach represents a second
588 extraction site, c. 700 m away from the Kernic megalith (Fig. 11a).

589 The potential source-rocks of the fine-grained megalithic material was investigated in the closest
590 Mogueriec-type granite exposed south of the Kerallée River (outcrop n°8 in Fig. 11a). Under the
591 microscope, the exposed leucogranitic rock shows a mineral assemblage composed of quartz-
592 K/feldspar-biotite porphyroblasts, < 1 cm, and subsidiary plagioclases (Fig. 11e), i.e. similar to the
593 petrology of the slab sample PW5. Most of the granitic outcrops are dissected by two orthogonal joint
594 networks, a vertical one (oriented N100°E) and a second one in a horizontal position. The resulting
595 3D-fractured blocks (Fig. 11e) correlate with many of the megalith slabs, hence suggesting the
596 location of a third source-rock, at c. 1 km south of the Kernic megalith (Fig. 11a).

597 **4.2.2. Paleoenvironmental setting**

598 Four vibracores were collected in the inner part of the Kerallé River (Fig. 12).

599 In core ANE-C1, sampled in the most seaward part of the Kerallé river valley (Fig. 12), the base of the
600 Holocene deposits was not reached (Fig.13). The lowermost part of the sedimentary sequence is
601 composed of a 5.4 m-thick silty sand unit containing estuarine carbonate foraminifera assemblages
602 typical of the intertidal zone (dominated by species *Elphidium sp.* and *Milliammina fusca*) (Fig. 13).
603 This deposit, dated between 4653-4452 and 1609-1437 cal BC, is thus confidently interpreted as an
604 intertidal sand flat. This unit is in turn overlain by 0.2 m-thick sandy silt deposit. The foraminiferous
605 assemblage dominated by *J. macrescens* and *T. inflata* indicates the salt-march environment. The
606 upper part of the core ANE-C1 contains 2.2 m-thick alternating deposits of organic-rich silt and silty
607 peat dated between 1609-1437 cal BC and 434-601 cal AD. The absence of foraminifera indicates a
608 freshwater marsh environment (Fig.13).

609 Core ANE-C3 was collected in the inner part of the Kerallé river valley (Fig. 12). The lower part of
610 the sequence consists of a peat silt unit 0.7 m-thick (Fig.13) covering a weathered granite at -6.39 m
611 asl. The absence of foraminifera suggests a freshwater marsh environment. This unit is overlain by a

612 0.78 m-thick sandy silt layer, and becomes more organic at the top. The foraminiferal assemblages
613 indicate a gradual change from a tidal flat to a salt-marsh environment. This deposit was dated from
614 5305-5064 cal BC to 5310-5079 cal BC. Between -4.87 and -5.58 m asl a peat layer devoid of
615 foraminifera indicates the development of freshwater wetlands. This peat is in turn overlain by a new
616 deposit of sandy silt 0.71 m thick evolving to an organic silt. The foraminiferal assemblages suggest a
617 progressive transition from a tidal flat to a salt marsh environment between 4707-4509 cal BC and
618 4234-3990 cal BC. The upper part of the core ANE-C3 contains 7.8 m-thick alternating deposits of
619 organic-rich mud and muddy peat. The absence of foraminifera indicates a freshwater marsh
620 environment (Fig.13).

621 Cores ANE-C2 and ANE-C4 were collected in the Le Kerrus river valley, a tributary of the Kerallé
622 River (Fig. 12). At core ANE-C2, the Holocene deposits overlay a weathered granite surface at -4.9 m
623 asl (Fig. 13). The lower part of the sequence is composed of a 1.73 m-thick peaty silt, the base of
624 which dates to 5008-4838 cal BC. The absence of foraminifera suggests a freshwater marsh
625 environment. This basal unit is overlaid by a 2.21 m thick layer of silt and peat silt containing
626 estuarine foraminifera assemblages typical of the upper part of salt marsh (dominated by species
627 *Jadammina macrescens* and *Trochammina inflata*). At -0.74 m asl this deposit then evolved into a
628 0.83 m-thick silt unit dated between 3628-3375 cal BC and 2343-2136 cal BC. The characteristics of
629 the sediments and the absence of foraminifera suggest the formation of a floodplain. Its eroded surface
630 is overlain by a sandy layer dated around 2342-2136 cal BC and interpreted as a channel-fill deposits.
631 The upper part of the sequence is composed of a peat and peat silt unit. The nature of the deposit and
632 the absence of foraminifera both indicate a freshwater marsh environment in perennially saturated
633 flood basin.

634 Core ANE-C4 comprises 4.35 m-thick Holocene sediments resting on top of a granite surface at 1.85
635 m asl (Fig. 14). The lower part of the sequence is composed of a 3 m-thick peat silt unit. Its base dates
636 to 1218-1016 cal BC. The upper part of the sequence is composed of a peat unit. No marine influences
637 have been detected in this sequence.

638 West of Kernic Bay, four geotechnical surveys (B1, B2, B3, B4 in [Figs.12 and 14](#)) were conducted in
639 the back of the Kerrema dune complex (<https://infoterre.brgm.fr/>). At B4, the 1 m-thick Holocene
640 deposits overlie a granite surface at 5.1 m asl. Its position and nature are indicative of terrestrial
641 sediments ([Fig.14](#)). At B1 and B3, fine sand deposits overlay the pre-Holocene altered granite at -6.5
642 and 0.6 m asl, respectively ([Fig. 16](#)). Their sand flat or aeolian environment is not firmly established.
643 At B2, a 7 m-thick peat deposit overlying a granite surface at -1.9 m asl ([Fig.16](#)) may represent a
644 marine or a freshwater marsh environment.

645 North of the Kernic gallery grave, a 0.6 m-thick zone of peat deposits exposed in the intertidal zone
646 overlies Pleistocene loess at about 2.4 m asl. ([Briard et al., 1970](#) ; [Morzadec-Kerfourn, 1974a](#))
647 ([Figs.13, 16](#)). Its base is a charcoal level that dates to 2874-2574 cal BC. Palynological analyses
648 indicate a freshwater marsh environment ([Morzadec-Kerfourn, 1974a](#)). The top of the unit, dating to
649 2016-1430 cal BC, contains sparse dinoflagellate cysts that reflect periodic intrusions of seawater into
650 the marsh at that time ([Morzadec-Kerfourn, 1974a](#)).

651 **4.3. Intervisibility analyses**

652 The results of the intervisibility analysis of 12 monuments (including the Brétouaré passage grave and
653 11 gallery graves) are synthesized in [Fig. 17](#). Of the 133 evaluated connections, 32 are positive. All
654 monuments are visually linked and eight of them have more than one connection. The two gallery
655 graves under study show a strongly contrasted pattern. The Lerret gallery grave has only one visual
656 connection with the Languerc'h monument (locality Kerlouan). It is characterized by low values of the
657 centrality index (degree = 0.18, closeness = 0.32, betweenness = 0) and low connection success index
658 (10%). By contrast, the Kernic gallery grave is connected to three other sites, including the Brétouaré
659 passage grave. The used indexes show higher values as compared to the Lerret monument (degree =
660 0.55, closeness = 0.41, betweenness = 0.02, connection successes = 27%) ([Supporting Information 3](#)).

661 The analysis reveals the central place of the Brétouaré passage grave (Plounévez-Lochrist) in this
662 theoretic network. It is connected to the largest number of sites ($n = 6$) and has the highest index
663 values ([Fig. 15](#)). A Spearman's rank test shows a significant positive correlation between the

664 architectural complexity of gallery graves and their visual connection to the Brétouaré passage grave
665 ($p = 0.025$, $r = 0.469$).

666 5. Discussions and interpretations

667 5.1. Two strategies for the exploitation of rock material

668 This study reveals contrasting strategies of rock exploitation for the Lerret and Kernic gallery graves.

669 Petrographic and structural analyses of the Lerret monument slabs show strong correlations with the
670 granitic outcrops present in proximity to the site. Three potential extraction sites (outcrops 1, 2, and 7
671 in Fig. 4) have been identified. They all supply similar rock material and are located at a short distance
672 from the monument (50 m for outcrops 1 and 2, 200 m for outcrop 7). Each of them was able to
673 provide a sufficient quantity of slabs for the total construction. The micromorphological analysis of
674 the slabs reveals a dominance of *fresh faces*, suggesting the exploitation of a single rock outcrop
675 (Mens, 2008). Thus, parties that constructed the Lerret monument appeared to have focused their
676 efforts on the intensive exploitation of a single, local rock outcrop. This strategy potentially reduced
677 the energy required for construction by limiting the transport of the megalithic slabs. The availability
678 of building material may also have determined (at least in part) the erection site of the monument.

679 The petro-structural analysis of the Kernic monument slabs shows a very different pattern of rock
680 exploitation. Our study confirms the local origin of granitic material in agreement with Chauris
681 (2021), but it also suggests the existence of three extraction sites in three facies of the Brignogan-
682 Plouescat granitic complex. The three identified outcrops could have supplied all of the slabs for the
683 construction of the Kernic monument and neither of them is located in the immediate proximity of the
684 monument. This result seems to be confirmed by the morphological analysis of the slabs since a large
685 number of them present weathered faces indicating primary exploitation of the rocky outcrops (Mens,
686 2008) and a multi-source supply. The distance between the megalithic monument and the potential
687 extraction sites (up to 1 km) also indicates that the choice of the monument implantation was not
688 determined by the availability of construction material. However, the location of potential sites should
689 be considered with caution. Indeed, it is possible that several of the outcrops exposed during the

690 construction period are no longer visible, either as a result of quarrying, or due to recent overlying by
691 sand dune deposits after the Neolithic period (see Section 5.5). Thus, the distance between the supply
692 sources and the Kernic monument may have been shorter than estimated by this study. However, it is
693 clearly established that the three facies were not collected from a single site. The intentional
694 diversification of the supply sources, which implies displacement of blocks over several hundred
695 meters, appears very likely and required increased energy for their transport.

696 In agreement with the particular architecture of the two monuments, the differences in the choice of
697 stone extraction strategies between the two gallery graves may reflect the different status of the two
698 communities at their origin. Indeed, the Kernic gallery grave has a much more monumental
699 appearance than the Lerret monument, mainly due to the existence of external structures such as the
700 peristalith and the monumental facade. As a result, its construction required about three times as many
701 megalithic blocks. The total weight of the lithic material transported is thus twice as great. The
702 builders of the Kernic megalith were able to mobilize more resources, which also suggests greater
703 political and economical power.

704 *5.2. A functional and symbolic interpretation of the construction material diversification*

705 Regarding the selection of stones in the passage grave construction, it is a pivotal issue to understand
706 whether the decision to use certain stone types was based on functional considerations or rather on
707 esthetic or symbolic reasons. In fact, the use of different rocks can be based on the slab size or on the
708 mechanical constraints they should support in the construction. This interpretation has been applied to
709 various monuments, such as the passage grave of Puigseslloses, Barcelona, Spain (Vicens et al., 2010),
710 the monument of La Varde in Guernsey, Channel Islands, United Kingdom (Bukach, 2003) and to the
711 megalithic complex of Bougon, Deux-Sèvres, France (Mohen and Scarre, 1993; Scarre, 2004).
712 Concerning the two Neolithic monuments under study, this interpretation may only be applied to the
713 Kernic grave. Indeed, the granitic rocks used in the Kernic gallery grave appear to have very similar
714 mechanical characteristics. No organisation of granitic facies according to block size or location was
715 identified, so the mechanical properties of the rocks clearly did not determine the constructors' choice.

716 A second issue concerns the potential inclusion of architectural elements from older monuments. This
717 kind of re-use has been frequently documented in Brittany, particularly in passage graves ([Laporte et](#)
718 [al., 2011](#)), such as the sculpted stele of Locmariaquer, which was broken and incorporated into two
719 burial monuments ([Le Roux, 1985](#)). However, this type of re-use appears unlikely in the case of the
720 Kernic gallery grave. Indeed, none of the slabs show modifications (engravings, removals or
721 regularisation of the surfaces) in an irregular position with regard to the architecture. The study area
722 also seems to have been sparsely occupied during the Middle Neolithic as only one passage grave (the
723 Brétouaré monument) has been documented so far ([Sparfel and Pailler, 2010](#)).

724 Lastly, the diversification of construction material may also result from practical constraints linked to
725 work organisation. It is possible that each outcrop was successively quarried after the abandonment of
726 the previous one. This abandonment of supply sources may be due to the depletion of natural outcrops,
727 but also to changes in the construction project. However, the data collected in this study do not
728 confirm this hypothesis, as it was previously highlighted that each outcrop identified was able to
729 supply all of the blocks necessary for the construction. Similarly, the Kernic monument shows a
730 coherent and uniform architectural plan and appears to be the result of a single architectural project.
731 The 'random' arrangement of the facies also suggests that the three supply sources were used
732 simultaneously. Thus, the choice to use different rock material seems to be deliberate and determined
733 at the beginning of the monument's construction.

734 The symbolic and aesthetical qualities of the rocks have also often been considered in the megalithic
735 monuments in France (e.g. [Gouézin, 2017](#); [Mens et al., 2021](#)). Some monuments, such as the Dissignac
736 tumulus (Saint-Nazaire, Loire-Atlantique) and the Dolmen de la Croix (Pornic, Loire-Atlantique), are
737 composed of very contrasting rock types and colours ([Mens et al., 2021](#)). The disposition of the
738 different stones is very ordered and certain characteristics such as the preferential placement of the
739 light-coloured stones at the entrance are present in many monuments. Therefore, the physical
740 characteristics of the rocks seem to contribute to a particular symbolism. However, [Scarre \(2004\)](#)
741 attenuates this interpretation and notes that the diversity of rocks used in the monuments might only
742 refer to the diversity of the surrounding geological context. It is perhaps the symbolic value of the

743 natural outcrop that is incorporated into a monument beyond these physical characteristics (Scarre,
744 2004). That is supported by the integration of a few worked blocks in a number of megalithic
745 monuments. The aim to include natural rocks in monuments appears especially strong for Recent and
746 Final Neolithic periods, as a number of them were built on the basis of natural rock outcrops (Gouézin,
747 2015, 2017).

748 The three granitic facies used for the Kernic gallery grave do not display particularly contrasting visual
749 characteristics, and the arrangement of stones is also very irregular. It is perhaps the symbolic value of
750 rocks as much as the element of the surrounding landscape which was significant for those
751 constructing the Kernic gallery grave, a symbolic value whose nature remains to be specified.

752 The identity value of specific rock types has been argued by Bukach (2003) about the Guernsey and
753 Jersey Islands passage graves. According to this author, stones from prominent geological complexes
754 could be imbued with both the sacred and mythical nature of the landscape. They can provide symbols
755 of identity and place, both within and between communities. The Kernic gallery grave may show this
756 type of association between places and different human groups unified during the construction of a
757 collective funeral monument. The quantity of each facies block and their irregular arrangement seem
758 to confirm this hypothesis. It was previously highlighted that the extraction of the slabs from the three
759 outcrops was probably carried out simultaneously. This suggests the existence of three distinct human
760 groups engaged in the extraction and transport of stones. The number and total weight of blocks on
761 each facies is nearly equal. It is therefore possible that each of these groups contributed a similar effort
762 to the construction of the Kernic gallery grave. The construction and utilization of collective burials,
763 such as gallery graves, is generally attributed to societies based on lineage (Gallay, 2011) or clan
764 systems (Testart, 2005, 2012). In this regard, it can be questioned whether the Kernic monument was
765 built as a collective burial of three clans (or lineages) forming part of a single community.

766 *5.3. The distribution of gallery graves in the study area*

767 Analyzing the spatial distribution of collective burials in the study area reveals differences between the
768 Lerret and Kernic gallery graves. It seems that the constructors of the Lerret monument had a much
769 smaller territory than those of the Kernic gallery grave.

770 In contrast to the Middle Neolithic monuments, the collective burials never occur in great
771 concentrations (L'Helgouach, 1956, 1965). Exceptionally, they are grouped by two or three
772 monuments as at Laniscat, Côtes-d'Armor (Le Roux, 1975, 1977). More generally, there is no more
773 than one gallery grave in a current locality (L'Helgouach, 1956). A collective tomb (or more rarely a
774 small grouping) seems to be representative of a single community (of the village type) in a given
775 territory. Furthermore, the access to the tomb may be reserved for the entire community or, on the
776 other hand, only for the members of one or several clans (or lineages) (Masset, 1997; Chambon, 2003;
777 Marçais, 2016). The existence of clustered monuments in relatively limited spatial areas can be
778 understood in two ways. Firstly, there may exist a chronological gap between each of the monuments
779 in the same group. A new monument could be erected if the older one is considered insufficient or
780 inadequate for the needs of the community that increased with time. Secondly, within each
781 community, several clans (or lineages) of similar importance and perhaps in competition, may coexist.
782 In this case, each of them may have its own burial monument located on the territory of the
783 community. The two hypotheses can also be combined with the emergence of important new clans (or
784 lineages) over time, possibly causing a territorial division in some cases.

785 The spatial distribution of gallery graves in our study area seems to support such a general pattern. If
786 we consider monuments less than one kilometre distant as groupings, the distribution of collective
787 burials is very uniform. For the majority, the closest monuments are located at a distance between 3.9
788 and 4.3 km. However, there are exceptions to this pattern, of which the Lerret monument is an
789 example. It is located only 1.3 km from the Languerc'h gallery grave. It is impossible to determine
790 whether the two monuments represent two distinct communities or two clans (or lineages) forming
791 part of the same community. However, in both cases, the constructors of the Lerret gallery grave
792 probably occupied a smaller territory than the communities at the origin of other burial monuments in
793 the study area, such as the Kernic gallery grave.

794 ***5.4. Intervisibility analysis and territory patterning***

795 The intervisibility analysis carried out in this study reveals a relatively dense visual connection
796 network furthermore strongly structured by the Brétouaré passage grave (Fig. 15). It also emphasizes

797 some differences between the two monuments. The Kernic gallery grave seems to have an important
798 place in this theoretical network, while the Lerret monument appears as a more subsidiary feature.

799 *5.4.1.Limits of the method*

800 Three main limits of this analysis can be highlighted. (i) Firstly, the visual barriers represented by the
801 vegetation are complex to consider. However, palynological research indicates that the coastal areas of
802 Brittany were cleared during Middle Neolithic times (e.g. [Morzadec-Kerfourn 1974](#); [Marguerie 1992](#)).
803 In particular, in the study area, fire clearing has been documented as early as ca. 2900-2600 cal BC
804 ([Morzadec-Kerfourn 1974a](#)). It is therefore possible that the densely populated coastal areas in the
805 Neolithic period displayed an open landscape, largely devoid of dense forest vegetation. [Cummings](#)
806 [and Whittle \(2004\)](#) also highlight the high variability of vegetation cover, partly as a result of seasonal
807 variations. Thus, due to the spatial and temporal complexities of the vegetation patterns through time,
808 analyses conducted on uncovered ground seem appropriate ([Čučković, 2014b](#)). (ii) Additional visual
809 barriers may result from palaeogeographical changes that have occurred since the Neolithic period.
810 Indeed, the sea level variations as well as morphological and climatic factors have led to major
811 changes on the coastal zone (see [section 5.5](#)). In our study, only sea level rise was considered and
812 simulated at the mean tidal level around 2900 cal BC. There is a large amount of paleogeographical
813 evidence for this area (see [section 5.5](#)). Unfortunately, the evidence is insufficient to permit the
814 creation of an accurate DTM that would have taken into account all the environmental changes (filling
815 of coastal valleys, formation of dune complexes...). From this point of view, the results presented in
816 this paper are preliminary and will need to be developed in the future. (iii) Thirdly, the intervisibility
817 analysis is based on an inherently incomplete set of archaeological data. Some monuments have
818 disappeared; their architecture and location are only recorded in ancient documents. In addition, in the
819 study area, only the Kernic gallery grave has benefited from previous archaeological investigations.
820 The monuments' architecture is mainly known from descriptions and analysis of the exposed
821 structures.

822 For these reasons, and considering the character of the investigated sites, the intervisibility
823 connections identified should be interpreted with caution. The resulting network is considered here as

824 a synthetic picture of possible connections (perhaps even symbolic) rather than an established
825 communication network.

826 *5.4.2. Intervisibility links with the passage grave - a prestige element for the gallery graves?*

827 Our intervisibility analysis shows the cohesion of the monument group under study. Indeed, all the
828 megalithic tombs in the study zone are potentially visually interconnected. The density and the
829 architectural resemblance, as well as the strong visual connectivity of the monuments, may indicate a
830 coherent territorial and/or political unit composed of several distinct, but strongly connected
831 communities.

832 Secondly, our analysis highlights the centrality of the Brétouaré passage grave in this theoretical
833 network and the visually linked gallery graves are also the most architecturally complex monuments.
834 In a society where reference to the ancestors (real or mythical) must have been very strong, it is
835 possible that the visual link to an older monument may have been an important element when selecting
836 the erection sites of new monuments (e.g. [Wheatley 1995](#)). The co-visibility with a passage grave may
837 thus have increased the significance of the gallery grave.

838 In this perspective, and with regards to the existing monument groups described in section 5.3, it is
839 possible to detect a hierarchy between the gallery graves under study with 3 types of sites: (i) The
840 most important and architecturally complex monuments have a direct link to the Brétouaré passage
841 grave and show more visibility links with other monuments (e.g. Kernic, Mentoull Kereoc, Cosquer;
842 [Fig. 15](#)) Some of them occupy a central place in a group as described in [section 5.3](#) (e.g. Queran,
843 Languerc'h; [Fig.15](#)). (ii) The gallery graves forming part of a group and considered as subsidiary
844 features are architecturally less complex and present links only with the central tomb of the group (e.g.
845 Dievet, Lerret; [Fig. 15](#)). (iii) Lastly, the discrete monuments without any visible link with the
846 Brétouaré passage grave also present less complex architectures (e.g. Kerbervez, Crec'h ar Vren, [Fig.](#)
847 [15](#)).

848 According to this interpretation, the Lerret and Kernic monuments are assumed to occupy a distinct
849 position within this theoretical network.

850 *5.5. Palaeoenvironmental reconstructions and their implications*

851 *5.5.1. Palaeogeography of the Tresseny Bay (Lerret gallery grave)*

852 The paleogeographic reconstruction of Tresseny Bay (Lerret gallery grave) for the Neolithic period is
853 incomplete, but it can be partly achieved by combining morphological and core sedimentological data.

854 Similar to other coastal areas in Brittany (e.g. [Morzadec-Kerfourn, 1974](#); [Goslin et al., 2013, 2015](#);
855 [Stéphan et al., 2015](#)), the first phragmites-dominated swamps formed at around 4900 cal BC in the
856 lower part of Tresseny Bay (core V-3, [Figs. 5, 7](#)), and then at around 4400 cal BC in its inland section
857 (core G-C2 [Figs. 5, 6](#)). The development of the oldest basal peat occurred under the combined
858 influence of the slowing down of the Holocene sea level rise ([Goslin et al., 2013, 2015](#); [García-Artola](#)
859 [et al., 2018](#)) and the stabilization of the first coastal barriers ([Morzadec-Kerfourn, 1974](#); [Stéphan et al.,](#)
860 [2015](#), [Gorczynska et al., 2022](#)).

861 Around 2700 cal BC, the sedimentary records show an expansion of wetlands throughout the bay. In
862 the lower part of the bay, phragmite-dominated swamps and freshwater ponds developed (core V-1
863 and Curnic site [Figs. 5, 7](#)). In the inner part of the valley, the peat deposit records a decrease in marine
864 influence (core G-C2, [Figs. 5, 6](#)). [Stéphan et al. \(2015\)](#) also revealed the extent of salt-marshes in other
865 Brittany coastal systems during this period. This expansion probably resulted from the development of
866 gravelly or sandy coastal barriers that provided sheltered conditions for high-marsh development
867 ([Stephan et al., 2015](#)). Unfortunately, determining the exact position of such a system in Tresseny Bay
868 from current data is a difficult task. However, the formation of freshwater marshes on Curnic Beach
869 ([Van Zeist, 1963](#)) and the development of peat deposits at the Tresseny site ([Hallégouët et al., 1971](#))
870 indicate that the bay was largely protected from marine influence during Final Neolithic times and that
871 a coastal barrier system may have developed in its lower part. With respect to this pattern, the Lerret
872 gallery grave, which is currently located in the upper part of the bay, was constructed in a protected
873 environment close to a high salt-marsh or freshwater swamps.

874

875 **5.5.2. Palaeogeography of the Kernic Bay (Kernic gallery grave)**

876 The paleoenvironmental evolution of Kernic Bay during the Neolithic-Bronze Age was defined from
877 the analysis of sedimentary cores recorded in the inner part of the mouth of the Kerrallé.

878 The presence of foraminifera in the organic deposits at the base of the sedimentary sequences in core
879 ANE-C3 attests to marine influence in the lower Kerrallé valley as early as 5400-5200 cal BC. As
880 mentioned by many authors (Morzadec-Kerfourn, 1969; Goslin et al., 2015; Stéphan et al., 2015), the
881 deposition of peat material at the base of the NW Brittany coastal sedimentary sequences is associated
882 to the formation of extensive phragmite marshes around the present-day shoreline position at the
883 beginning of the Neolithic period (see section 5.4.1).

884 From ca. 4500 cal BC, the lower Kerrallé river valley was transformed into an estuarine mouth
885 composed of (i) an intertidal sand flat at the ANE-C1 coring point, (ii) a salt marsh at the ANE-C2
886 coring point, and (iii) a freshwater marsh environment at the ANE-C3 coring point. This spatial
887 distribution of depositional environments persisted until ca. 2200 to 1500 cal BC. Located more
888 seaward, the Kernic archaeological remains were built along this estuarine mouth. Although no coring
889 was done in front of the archaeological site, we can assume that the Kernic gallery grave
890 topographically dominated a coastal landscape characterized by intertidal sand-flats.

891 The development of large transgressive dune complexes in Brittany, such as the Keremma complex
892 (Fig. 12), post-dates the Neolithic period (Gorzynska et al., 2022). Archaeological remains of the Iron
893 Age and/or Medieval periods discovered in palaeosols located at the base of the aeolian deposits
894 confirm that the principal phase of dune formation occurred after the construction of the Kernic
895 monument (Giot and Marguerie, 1994). It is possible that in the Neolithic period, small coastal sand
896 barriers were formed, establishing an evolutive basis for the present dune complex. However, their
897 development in this period seems insufficient as to permit the formation of wetlands in the
898 southwestern part of the estuary. Indeed, the geotechnical surveys (core B-3 and B-1 in Figs. 12, 14)
899 conducted in this area reveal mainly sandy sedimentation, hence suggesting a sand-flat environment.
900 In accord with this data, it appears that Kernic Bay was significantly more opened to the sea at the
901 moment of the monument's construction than at the present.

902 *5.5.3. The role of valleys and estuaries in Recent/Final Neolithic landscape patterns*

903 Our paleogeographic analysis reveals that the two monuments under study were built and used in quite
904 different paleo-environments. The Lerret gallery grave was erected close to a marshland zone
905 (brackish or freshwater), while the Kernic monument was constructed along an estuary, widely open to
906 the sea. This suggests a quite distinct role for the two coastal systems in the Recent/Final Neolithic
907 cultural landscape. Tresseny Bay appears to be at the periphery of the group of monuments. It may
908 have been a territorial limit to all the communities established in this area. In contrast, Kernic Bay and,
909 more largely Goulven Bay, seem to be in the centre of this territory. The orientation of the gallery
910 graves suggests the importance of this maritime area for all of these communities. Indeed, the Kernic
911 monument, but also those of Mentoull Kereoc and Cosquer, present facades facing towards the bay.
912 The Brétouaré passage grave is a major landmark in this coastal landscape. It appears that in the case
913 of Kernic Bay (and more generally Goulven Bay) the maritime space is integrated into the
914 communities' territory and has a particular importance in its organisation. Anthropological studies
915 have highlighted that maritime spaces (and also lakes or rivers), in some geographical and cultural
916 contexts, can be the subject of a physical and mental territorialization by communities (e.g. [Bataille](#)
917 [Benguigui, 1992](#); [Calandra, 2018](#); [Cormier-Salem and Mbaye, 2018](#)). With this perspective, the
918 inclusion of rocks from the two shores of the estuary in the Kernic monument could be very symbolic.
919 It involves the transport of blocks over a maritime zone. The monument could thus be a visible and
920 lasting demonstration of navigation techniques. But it may also indicate a symbolic integration of this
921 maritime territory into the Kernic monument and thus perhaps into the territorial system of the
922 community(ies) that constructed it.

923 **6. Conclusions**

924 The Kernic and Lerret gallery graves under study were previously regarded as identical monuments,
925 constructed in similar environments. Our study, based on a number of interdisciplinary approaches,
926 instead reveals important differences between the two monuments in terms of architecture, source-rock
927 material, and geographical position. The Lerret monument was probably erected close to the stone
928 extraction sites in a marsh environment. The spatial analysis also indicates its subsidiary and

929 peripheral place in a group of megalithic monuments located in the study area. In contrast, the Kernic
930 gallery grave shows a deliberate diversification of rocky material with three potential supply sources,
931 the furthest of which is situated approximately 1 km from the monument. The Kernic monument was
932 built on the border of an estuary widely exposed to the sea and its construction required the transport
933 of the megalithic blocks through this maritime zone. This tomb also seems to occupy a more central
934 position in a group of clustered monuments.

935 We also propose a social interpretation of the obtained results. We suggest that in the case of the
936 Kernic monument the rocks carry a particular symbolism, referring to specific places in the landscape
937 and/or to human groups gathered in its construction. It also appears that some maritime areas such as
938 Kernic Bay had an important role in the patterning of landscapes during the Recent/Final Neolithic.
939 With regards to their architecture and geographical position, we also suppose that the visual
940 connection with the other megalithic sites, and in particular with the only passage grave, was an
941 important factor in the choice of the gallery graves location in this zone.

942 The new approach applied here to megalithic monuments is based on the precise identification of the
943 source-rock material, a fine reconstruction of the paleoenvironment and intervisibility analyses carried
944 out on a coherent set of sites. Addressing the petro-structural properties when combined to a 3D-
945 micro-morphological study provides a characterization of each block of the monuments. The
946 identification of potential sources of extraction has been carried out by a comparative study of the
947 petrographic, structural, and micromorphological characteristics of the blocks and those of the
948 surrounding country-rocks. This approach suggests that some megalithic sites show a deliberate
949 diversification of local source-rock material. It is also shown that 3D monument models are an
950 interesting support for this type of study, particularly in the case of sites with limited access. The
951 palaeogeographic research, conducted at the scale of each coastal system adjacent to the sites, shows
952 that major palaeo-environmental changes occurred in the two coastal areas and it further highlights the
953 disparities in their Holocene evolution, underlining the various responses of coastal systems to
954 Holocene sea level rise and climatic variations. Thus, it appears that using locally obtained data is a
955 pre-requisite for elaborating accurate palaeogeographical reconstructions to individual archaeological

956 sites. The intervisibility analysis carried out on all the Neolithic funerary megalithic monuments
957 present in the study area shows a dense network of visual connections, which seems to be a strong
958 element in the patterning of Neolithic coastal territories.

959 Our study shows the high potential of a multidisciplinary approach for studying megalithic
960 monuments, and the overlapping scales of the applied analyses allow the elaboration of several new
961 hypotheses about the social and territorial organisation of Neolithic societies. Finally, it demonstrates
962 that despite their extreme degradation, the Kernic and Lerret monuments are able to provide quite
963 fruitful information about the Recent/Final Neolithic societies and their relationships with the natural
964 environment.

965

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1408 **Figure captions:**

1409 **Figure 1 :** Location maps of Neolithic megaliths (including the Lerret and Kernic sites under study) in
1410 the Léon domain, western France. (a) Simplified geological map, modified from Caroff and Le Gall
1411 (2013). The location of the megalithic tombs is from Sparfel et al. (2004) and Sparfel and Pailler
1412 (2009). NASZ., North Armorican shear zone ; PGSZ., Porspoder-Guisseny shear zone. (b) Topo-
1413 bathymetric map of the Lerret-Kernic coastal area under study, modified from Hallégouët and Moign
1414 (1976), Hallégouët (1978), Suanez and Cariolet (2010), and Stéphan et al. (2018). HAT., Highest
1415 astronomical tide.

1416 **Figure 2:** Main structural features of the Lerret gallery grave. (a) Plan view showing the spatial
1417 distribution of the various granitic rock types as defined in Fig. 2c, modified from Sparfel and Pailler
1418 (2009). Some of the numbered slabs are cited in the text. (b) View (looking to the NW) of the megalith
1419 at low tide. (c) Graph showing the respective number of each petro-structural rock type population.

1420 **Figure 3:** Morphological and geological structures of individual granitic slabs in the Lerret gallery
1421 grave. Location of slabs in Fig. 2a. (a). Fresh and weathered faces identified on slab n° 25. (b) Mark of
1422 removed material attributed to the Neolithic period on slab n° 17. (c) Metallic edge marks identified
1423 on block n° 3. (d) Thin section of the little strained granitic slab n°19. Discrete foliation planes (ductile
1424 strain) are outlined by elongated minerals such as quartz (Q), K-feldspars (KF) and biotites (B).
1425 Crossed nicols, x 25. (e) Thin section of the little strained slab n° 24. Traces of foliation planes
1426 outlined by elongated quartz (Q) and biotites (B). Crossed nicols, x 25. (f). Macroscopic view of the
1427 strained granitic slab n° 1. (g) Macroscopic view of the unstrained granitic slab n° 2.

1428 **Figure 4:** Potential source-rock material for the Lerret gallery grave. (a) Detailed geological map of
1429 the Lerret monument area with the location of all investigated outcrops. The arrows indicate the
1430 distance between the megalith and possible extraction zones. (b). Structure of the highly fractured
1431 granitic country-rocks exposed at the potential extraction site n° 1. (c), (d) Macroscopic (c) and
1432 microscopic (d) views of the granite at site n° 1. Crossed nicols, x 25. Same abbreviations as in Figs.
1433 3d, e. (e) Highly fractured granitic country-rocks exposed at the potential extraction site n° 7. (f)

1434 Fractured granitic country-rocks exposed at site n°6 and assumed not to represent potential source
1435 material because of the small dimensions of the blocks. (g) Fractured granitic country-rocks exposed
1436 at site n°5. Its oversized blocks do not fit with the dimensions of the megalith slabs. (h) Unstrained
1437 granitic rocks exposed at site n°4, NW of the Lerret gallery grave. (i) Structure of the fractured
1438 granitic country-rocks occurring at the potential extraction site n° 2. Location of sites in [Fig. 4a](#).

1439 **Figure 5:** Geomorphological map of the Tresseny Bay area showing the location of archaeological
1440 sites (including the Lerret gallery grave) and the cores, modified from [Hallégouët \(1978\)](#) and [Suanez](#)
1441 [and Cariolet \(2010\)](#).

1442 **Figure 6:** Major sedimentological and paleontological attributes of the sedimentary succession cored
1443 at site G-C2 in Tresseny Bay, modified from [Goslin et al. \(2015\)](#) and [Stéphan et al. \(2015\)](#).

1444 **Figure 7:** Lithology, dating and elevation of all records in the Tresseny Bay area (according to data
1445 from [Zeist, 1963](#); [Giot et al., 1965](#); [Hallégouët et al., 1971](#); [Goslin et al., 2013, 2015](#); [Stéphan et al.,](#)
1446 [2015](#)). HSTL, high spring tide level; MTL, mean tide level.

1447 **Figure 8:** Main structural features of the Kernic gallery grave. (a) Plan view of the megalith (obtained
1448 from the photogrammetric 3D-model and completed by information collected during excavation
1449 stages) showing the spatial distribution of the various granitic rock types as defined in [Fig. 8c](#). Some
1450 of the numbered slabs are cited in the text. (b) View (looking to the SW) at low tide. (c) Graph
1451 showing the population of slabs of each granitic facies.

1452 **Figure 9:** Morphological features of the slabs forming the Kernic gallery grave, based on TSL 3D-
1453 surveys. (a) Fresh and weathered faces identified on slab n° N1. (b) Fresh and weathered faces, as well
1454 as marks of removed material attributed to the Neolithic period on slab n° E3. (c) Marks of removed
1455 material attributed to the Neolithic period on slab n° W1. (d) Marks of removed material, expressed by
1456 two surfaces in horizontal and inclined attitudes, and attributed to modern or contemporary human acts
1457 on slab n° E6. Location of slabs in [Fig. 8a](#).

1458 **Figure 10:** Petrography of the granitic material involved in the Kernic slabs. (a-d). Macroscopic views
1459 of : the porphyric slab n° Pw17 (a), the medium-graded slab n° W4 (b), the fine-grained slab n° E3 (c),
1460 and the medium-grained slab n° Pw2 (d). (e). Thin-section of the slab n° Pw5. Crossed nicols, x 25.
1461 Same abbreviations as in [Figs. 3d, e](#). Location of slabs in [Fig. 8a](#).

1462 **Figure 11:** Potential source-rock material of the Kernic gallery grave. (a) Detailed geological map of
1463 the Kernic area with the location of all investigated outcrops. Arrows indicate the distance between the
1464 megalith and possible extraction zones. (b) Petrography and structure of the Cleder medium-grained
1465 granite at the potential extraction site n° 6. (b₁) 3D-shaped blocks in a shallowly-dipping attitude
1466 position. (b₂) Macroscopic view. (b₃) Microscopic view. Crossed nicols, x 25. Same abbreviations as
1467 in [Figs. 3d, e](#). (c) Petrography and structure of the Brignogan porphyric granite at the potential
1468 extraction site n° 5. (c₁) 3D-shaped blocks in a vertical attitude displaying dimensions that fit with
1469 those of the megalith slabs. (c₂) Macroscopic view. (c₃) Microscopic view. Crossed nicols, x 25. Same
1470 abbreviations as in [Figs. 3d, e](#). (d) Petrography and structure of the Brignogan porphyric granite. (d₁)
1471 Vertical fracture pattern at site n° 1. (d₂) 3D-shaped blocks in a vertical position at site n°3. (e)
1472 Petrography and structure of the Mogueriec fine-grained granite. (e₁) 3D-shaped block displaying
1473 dimensions that fit with those of the megalith slabs. (e₂) Macroscopic view. (e₃) Microscopic view.
1474 Crossed nicols, x 25. Same abbreviations as in [Figs. 3d, e](#).

1475 **Figure 12:** Geomorphological map of the Kernic Bay area showing the location of archaeological sites
1476 (including the Kernic gallery grave) and cores, modified from [Hallégouët and Moign \(1976\)](#) and
1477 [Stéphan et al. \(2018\)](#).

1478 **Figure 13:** Major sedimentological, paleontological, and radiometric **data of** the sedimentary
1479 succession cored at sites ANE-C1 (a), ANE-C2 (b) and ANE-C3 (c) in Kernic Bay.

1480 **Figure 14:** Lithology, ages, and elevation data of all records in the Kernic Bay area ([Briard et al.,](#)
1481 [1970](#); [Morzadec-Kerfourn, 1974](#) and from BRGM, <https://infoterre.brgm.fr/>). Same abbreviations as in
1482 [Fig. 7](#).

1483 **Figure 15:** Intervisibility of the funerary megaliths in the study area with their centrality index and the
1484 connection success index. **(a)** Map of intervisibility connections identified between the megalithic
1485 sites; **(b)** Degree index for all investigated monuments; **(c)** Connection success index for all
1486 investigated monuments; **(d)** Betweenness index for all investigated monuments.

1487 **Table captions:**

1488 **Table 1:** Details of all radiocarbon dates (this work, previous studies). Calibrated age based on
1489 IntCal20 calibration curve (Reimer et al., 2020)

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