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An interdisciplinary approach to Late/Final Neolithic coastal gallery graves in Brittany, Western France: The 3D structure, origin of stone material, and paleoenvironmental setting of the Kernic and Lerret monuments

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Abstract

This article presents an interdisciplinary study of two Late/Final Neolithic gallery graves (Kernic and Lerret) located on the orthwestern coast of Brittany (Western France). These monuments show striking similarities in terms of architectural style and geographical position. This paper aims to provide a better understanding of the construction strategy of these monuments by (i) determining the origin of the megalithic blocks using comparative petro-structural analyses of blocks and surrounding rocks, (ii) reconstructing the coastal environment from sediment core analyses and (iii) defining the significance of these monuments in the territories from an intervisibility analysis. The study reveals marked differences between the two monuments studied. The Lerret gallery grave was erected close to a unique source of stone material on the margins of a marshland zone. In contrast, the Kernic monument, erected on the edge of an estuary, seems to have been built using a deliberate diversification of stone extraction sites. An intervisibility analysis shows a dense network of visual interconnections between a number of megalithic tombs present in the study area, where the two monuments occupy very distinct sites. The social implications of stone selection and the geographical location of Late/Final Neolithic funerary monuments are also discussed in an enlarged regional context.

KEYWORDS

coastal paleoenvironment, gallery grave, Late/Final Neolithic, megalithic tombs, paleoenvironmental and intervisibility analyses, petro-structural, stone material

1 | INTRODUCTION

Megalithic monuments are one of the most emblematic manifestations of European Neolithic populations. The age, number and importance of these sites in Western France make this region a key area for investigating European megalithism (e.g., Patton, 1993; Schulz Paulsson, 2019). The emergence and development of monumental architecture in Brittany as early as the Middle Neolithic (ca. 4700 cal. B.C. [calibrated Before Christ]) have been the focus of many recent studies (e.g., Cassen et al., 2009; Cousseau, 2016, 2020; Large, 2014;

Tinévez et al., 2012). However, thus far, much less attention has been paid to analyses of Late/Final Neolithic (3800–2150 cal. B.C.) monumental architecture (Laporte et al., 2011).

The study of the origin of the rocks used to build the megalithic monuments in Brittany is relatively new. The stone material from the Barnenez cairn, Plouezoc'h, (Northwestern Brittany, Giot et al., 1995) and the great stelae of the Gulf of Morbihan (Southern Brittany, Bonniol & Cassen, 2009; Cassen et al., 2016; Querré et al., 2006) was analysed, revealing a displacement of over several kilometres. Analysing the three-dimensional (3D) shape of megalithic slabs (Mens, 2008; Sellier, 1995, 2013) shows how the natural outcrops were exploited. The use of different types of rock is also discussed in a technological and symbolic interpretation of megalithic monuments (Mens et al., 2021). However, despite the qualitative contribution of these studies, few publications provide detailed geological data about the areas surrounding the megalithic remains. The location of the exploited rock outcrops is most often based on the 1:50,000 geological maps produced by the BRGM (Bureau de Recherches Géologiques et Minières), while the potential sources of extraction are rarely researched (Chauris, 2009, 2021). Here, we present a new investigation of the Lerret and Kernic gallery graves, based on the methodology recently applied by Caroff et al. (2016) and Le Gall and Caroff (2018) to Iron Age stelae in South Brittany. This approach involves the comparative petro-structural study of the material of both monuments and the exposed rock outcrops in their vicinity. The micromorphology of each megalithic slab is also examined following the approaches developed by Sellier (1995, 2013) and Mens (2008). In the case of the Kernic gallery grave, our morphological approach was completed by constructing 3D models.

The majority of the megalithic sites in Brittany are located in coastal areas (Giot et al., 1998). Some are currently submerged or overlaid by sand dunes (Cassen et al., 2010, 2019; Giot, 1998; Giot & Morzadec, 1992), highlighting significant coastal paleogeographic changes since the Neolithic in response to relative sea-level (RSL) rise. However, megalithic monuments studies that integrate reconstructions of paleocoastal environments are relatively new, such as those on the Molène Archipelago (Northwestern Brittany, Pailler et al., 2011; Stéphan et al., 2019) and Quiberon Bay (Southern Brittany, Baltzer et al., 2015; Cassen et al., 2012). Paleoenvironmental reconstructions provide additional evidence for understanding the reasoning used by Neolithic people for their site selection and the organisation of their coastal territories. The Lerret and Kernic gallery graves studied in this paper are located on the foreshore, submerged daily by tides. These two monuments most likely occupied very different positions during the Neolithic period. To examine their respective rock supply strategies and choice of location, we must use the information on their specific paleoenvironments. To this end, four core samples were collected and analysed from Kernic Bay. The paleoenvironmental reconstructions of the Lerret monument are based on previous research (Giot et al., 1965; Goslin et al., 2015; Hallégouët et al., 1971; Stéphan et al., 2015; Van Zeist, 1963).

Our study also includes visibility analyses that are increasingly applied to European megalithic monuments (e.g., Caruana & Stroud, 2020; Gillings, 2009; Ortiz, 2016; Wheatley, 1995). This type of investigation helps identify the spatial and structural relationships between the monuments and their natural and cultural environments (e.g., Caruana & Stroud, 2020). Visibility analyses have not yet been conducted on the megalithic sites in our study area. The few studies performed in Brittany (López-Romero, 2008a, 2008b; Roughley & Shell, 2004) highlighted the role of intervisibility in the organisation of Neolithic landscapes (López-Romero, 2008b).

2 | GENERAL SETTING

2.1 | Archaeological setting

The earlier gallery graves identified in Brittany were erected during the second half of the fourth millennium, that is, during the Late and Final Neolithic. At that stage, there was a regional evolution of monumental construction characterised by the progressive enlargement of the burial chamber to the detriment of the access structures and the surrounding barrow (Boujot & Cassen, 1992; L'Helgouach, 1965). This is representative of the collective burial sites erected during the Late Neolithic in North-West Europe (Salanova et al., 2017).

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

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

While gallery graves are the prevalent type of funerary monument during the Late and Final Neolithic in Brittany, they are not the only manifestation of burial practises during this period (Joussaume & Laporte, 2006; L'Helgouach, 1965). Monuments with similar architectural characteristics (V-shaped passage graves, lateral entrance graves and angled graves) were also constructed during this period (e.g., L'Helgouach, 1965; Patton, 1993). The older megalithic tombs were frequently reused and/or rearranged by Late and Final Neolithic populations (e.g., Port-Blanc, Saint-Pierre-Quiberon, Southern Brittany, Gaillard, 1883; Schulting, 2005; La Torche, Plomeur, Western Brittany, Milon & Giot, 1947; Souc'h, Plouhinec, Western Brittany, Le Goffic, 2006).

The pottery discovered in the gallery graves is formed in the style of the local Late and Final Neolithic cultures (e.g., Blanchard, 2017). It shows a strong affinity with groups identified in the Paris Basin between 3350 and 2550 cal. B.C. (Salanova et al., 2011). Bell Beaker pottery (2550–1950 cal. B.C.) is also frequently found in these monuments (Nicolas et al., 2019; Salanova & Sohn, 2007).

The funerary practices linked to gallery graves in Brittany are very poorly understood, as few of the sites have yielded human remains (e.g., La Torche, Plomeur, Western Brittany; Milon & Giot, 1947; le Tertre de L'Église, Plévenon, Northern Brittany; Harmois, 1909; Beaumont à Saint-Laurent-sur-Oust, Southern Brittany, Tinévez, 1988; Tinévez et al., 1990). The closest and best-studied examples come from the funerary ensembles of the Paris Basin (Chambon & Salanova, 1996; Marçais, 2016; Salanova et al., 2017), which attest to collective burial practices (successive deposition in a single monument). From 2500 cal. B.C. onward, gallery graves were frequently reused by Bell Beaker peoples for individual burials (Salanova & Sohn, 2007).

In Northwestern Armorica, the Léon domain contains 29 gallery graves and/or lateral entrance graves (Figure 1a) (Sparfel & Pailler, 2009; Sparfel et al., 2004). About half of them are situated in a small coastal area between the Tresseny and Kernic Bays, where the Kernic and Lerret monuments in this study are located (Figure 1b).

2.2 | Geological setting

The Kernic and Lerret monuments are situated on the northwestern coast of the Leon metamorphic domain (LMD) in North-West Brittany (Figure 1a). The rocky substratum exposed in these areas is dominated by granitoids and medium-grade metamorphic terranes (gneiss, micaschists and amphibolites) that recorded strike–slip ductile shearing, synkinematic granitisations and exhumation processes during a collision stage of the Variscan orogeny during 320–300 million years ago (Ma) (Authemayou et al., 2019; Gore & Le Corre, 1987; Le Gall et al., 2014). During the last 300 Ma, most parts of the Variscan mountainous belt in Armorica, including the LMD, emerged and experienced erosional processes (Bonnet et al., 2000). During recent times (last 10 ka years), the onshore/offshore boundary of the Armorica Peninsula recorded successive RSL fluctuations linked to paleoclimatic changes. These changes are documented for the Kernic and Lerret monuments under study (see Section 2.3). They are both located on the ca. 292-Ma-old Brignogan–Plouescat granite (Georget, 1986; Marcoux et al., 2009) that fringes part of the LMD to the north (Figure 1a). The two individual intrusions are sinistrally offset (ca. 7 km) on both sides of the Porspoder–Guisseny ductile shear zone (Figure 1a) (Marcoux et al., 2004). These deeply eroded granitic massifs are extensively exposed along coastal sections, where they are overlain by recent Quaternary (dominantly sandy) deposits.

2.3 | Geomorphological setting

The coastal morphology in Northern Léon is characterised by a wide rocky platform (Léon plateau) that extends more than 5 km seaward with a gentle slope on the intertidal and subtidal domains (Hallégouët, 1971). The wind and wave climates are energetic and strongly seasonally modulated (Bentamy & Croize-Fillon, 2014). High-energy winter swells and storm waves come from the W–NW, with wave heights frequently exceeding 5 m. The tidal range reaches 7.2 m for spring tides and 3.45 m for neap tides. On the submerged part of the Léon plateau, beaches and associated dune barriers isolate extensive wetlands. Contact between the coastal platform and the continental part of the plateau consists of a partly tectonic paleoscarp 30–50 m high (Figure 1b). The edge of the scarp is cut by a series of deeply incised river valleys in the bedrock, the lower parts of which have been subject to significant sediment filling over the last ca. 7000 years (e.g., Stéphan et al., 2015). The Lerret and Kernic gallery graves are located on the eastern shore of the Tresseny and Kernic Bays, respectively (Figure 1b).

Brittany's northwestern coast is considered to have been a tectonically stable region during the Holocene (Morzadec-Kerfourn, 1995; Ters, 1986). The main dynamic event was a consequence of the hydrostatic loading of the English Channel platform during the Holocene marine transgression. According to Lambeck (1997), the Léon coasts recorded a subsidence of 1.5 m over the last 6 kyr. The post-glacial RSL changes recently reconstructed along the western coast of Brittany have shown that the marine transgression rate slowed to 1 ± 0.2 mm year^{-1} from 5050 cal. B.C. to the present (García-Artola et al., 2018; Stéphan & Goslin, 2014). An RSL reconstruction based on 28 index points and seven freshwater limiting points dates indicates a position of −7.5 ± 0.8 m at ca. 4950 cal. B.C. (García-Artola et al., 2018). In response to the RSL rise slowdown, modern coastline and coastal barriers formed, with basal *Phragmites* peats occupying the base of the coastal sequences. In Brittany, these deposits have been dated to 5050–2550 cal. B.C. and suggest a significant extension of swampy environments beyond the relatively stable coastal barriers (Goslin et al., 2013; Morzadec-Kerfourn, 1974; Stéphan et al., 2015). The coastal sedimentary sequences of Western Brittany recorded a rapid change in coastal environments between 950 and 550 cal. B.C. Sharp erosional contacts and/or sedimentary hiatuses are systematically observed, indicating increased hydrodynamics and barrier breaching (Ehrhold et al., 2021; Fernane et al., 2014; Goslin et al., 2013, 2015; Stéphan et al., 2015). From ca. 750 cal. B.C. until the present-day, marsh sedimentary sequences record continuous accretion, resulting in a new period of coastal barrier stabilisation (Stéphan, 2011; Stéphan et al., 2015). However, coastal sand-dune systems appear to have experienced several destabilisation phases over the past 6000 years. Four periods of coastal dune mobilisation have been recently identified at 2300–2150 cal. B.C., 1300-450 cal. B.C., 900–1250 cal. A.D. (calibrated Anno Domini) and 1600–1840 cal. A.D. from the dating of interbedded archaeological remains in sand dunes (Gorczyńska et al., 2023).

During the 18th and 19th centuries, the inner parts of many estuarine mouths in Brittany were empoldered for agricultural

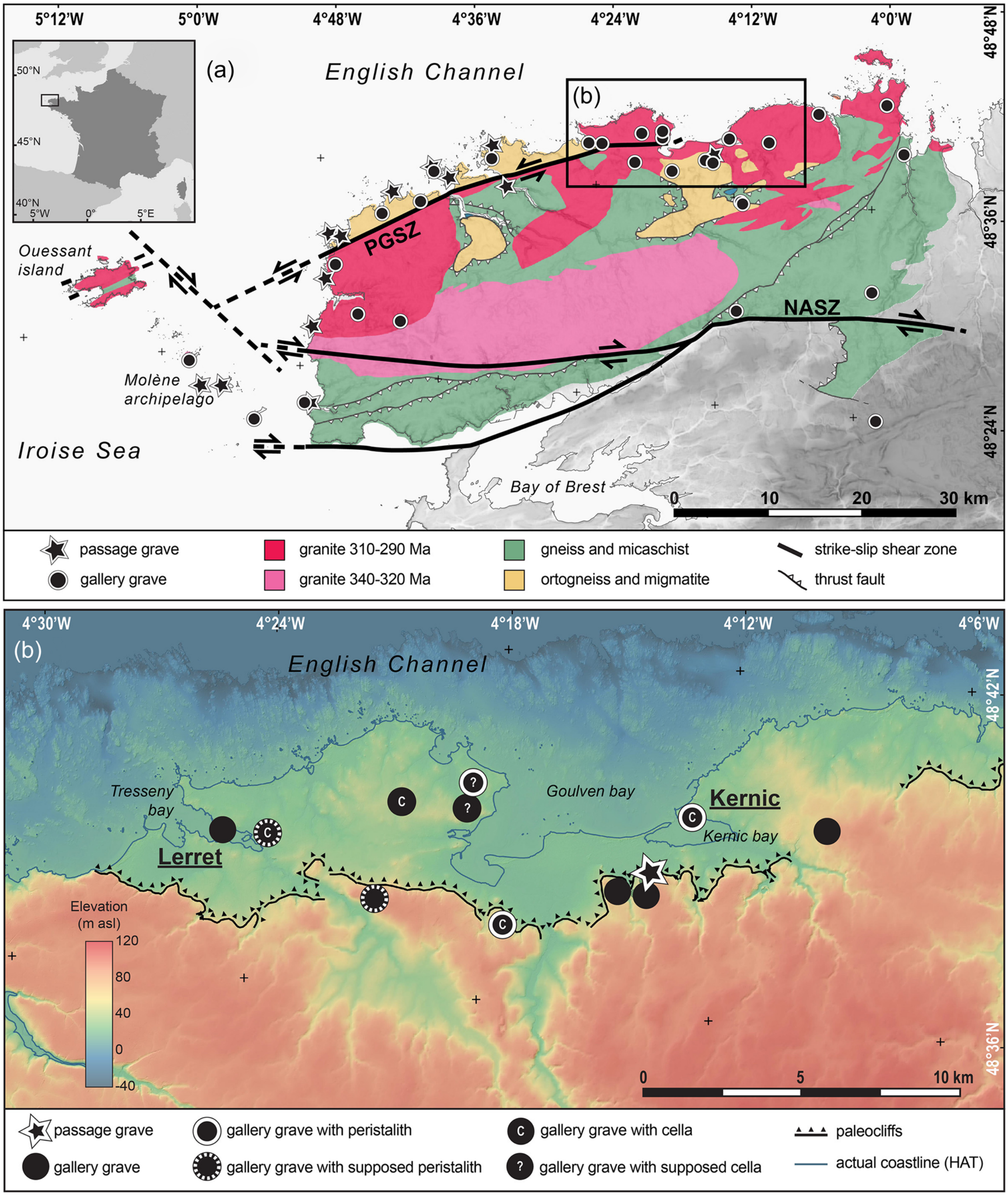

FIGURE 1 Location maps of Neolithic megaliths (including the Lerret and Kernic sites under study) in the Léon domain, Western France. (a) Simplified geological map. Modified from Caroff and Le Gall (2013). The location of the megalithic tombs is from Sparfel et al. (2004) and Sparfel and Pailler (2009). (b) Topo-bathymetric map of the Lerret–Kernic coastal area under study. Modified from Hallégouët and Moign (1976), Hallégouët (1978), Suanez and Cariolet (2010) and Stéphan et al. (2018). HAT, highest astronomical tide; NASZ, North Armorican shear zone; PGSZ, Porspoder–Guisseny shear zone. [Color figure can be viewed at wileyonlinelibrary.com]

and sanitary issues. As such, the inner part of Tresseny Bay was transformed into meadows by a drainage system after the construction of a tide mill in the 17th century (Figure 2), while two dikes were built in the 1820s to drain the maritime marshes located in the lower valley of the Kerallé River (Kernic Bay) (Table 1).

3 | METHODOLOGY

Our study of the Kernic and Lerret gallery graves is based on an innovative and multidisciplinary approach, including a large panel of complementary analyses. First, the architecture of the

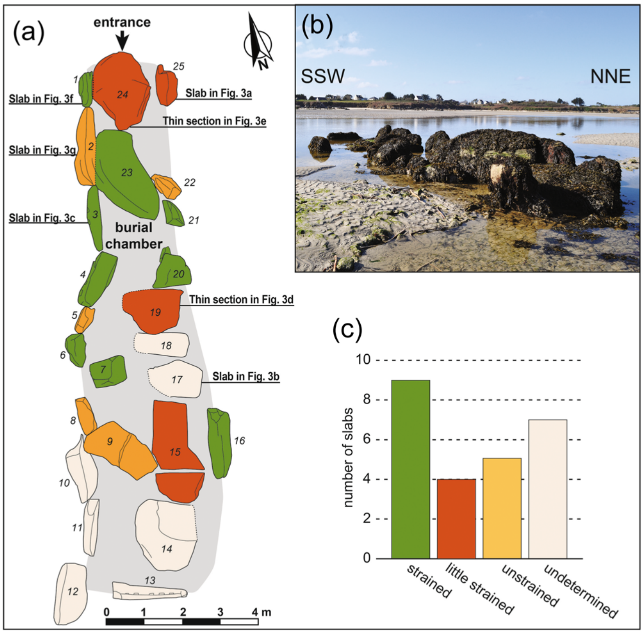

FIGURE 2 Main structural features of the Lerret gallery grave. (a) Plan view showing the spatial distribution of the various granitic rock types as defined in (c). Modified from Sparfel and Pailler (2009). Some of the numbered slabs are cited in the text. (b) View (looking to the northwest) of the megalith at low tide. (c) Graph showing the respective number of each petro-structural rock type population. NNE, north-northeast; SSW, south-southwest. [Color figure can be viewed at wileyonlinelibrary.com]

monuments and the morphology of their constitutive blocks have been investigated using a 3D-imagery analysis. Second, identification of the nature of the stone material was performed and the location of potential sources of extraction was determined by a comparative petro-structural analysis of megalithic slabs and the surrounding rocky substratum. The paleoenvironmental setting of the two monuments was reconstructed and then discussed in reference to the Neolithic cultural landscape through an inter-visibility analysis.

3.1 | 3D imagery

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

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

3.2 | Morphology of the slabs

Megalithic slabs often show features of both natural (erosional) or anthropogenic origins, which can pre- or post-date their erection. Premegalith features are commonly found on opposite facets, displaying contrasted morphologies as a function of their inner versus external position in the initial source-rock massif. Outer or *weathered* faces usually show a curved surface that may bear erosional traces, such as bowl-like depressions, grooves or striations (Mens, 2008; Sellier, 1991, 1995, 2013). On the other hand, inward-facing or *fresh* faces generally display a more planar and sometimes slightly concave geometry with a more angular shape. When the *fresh* faces show erosional traces, they necessarily happened post-megalith erection. One major point of interest in post-megalith traces is that they may provide diagnostical criteria for natural (geological/erosional) or human (transport, reusing, restoration) events post-dating the megalith building stage. Evidence for minor human reshaping was recognised from typical features such as (i) notches, mortises or splinters resulting from pull-out, handling or removal activities and (ii) modification of block surfaces from polishing, hammering or sculpted iconography (Boujot & Cassen, 1992; Boujot & Mens, 2000; Cassen et al., 2014, 2016; Hinguant & Boujot, 2008, 2010). In the present case, the entire microstructure pattern observed on the Kernic and Lerret megalithic slabs has been systematically diagnosed and referenced following rules established by Sellier (1991, 1995, 2013).

3.3 | Identification of the potential source of stone material

One main objective of the present work is to identify potential extraction sites for the slab material involved in the two studied megaliths. This should in turn provide insights into the strategy used by Neolithic people to select and transport their source of stone material. To this end, the comparative petrographic and structural analyses of the megalithic slabs and their surrounding rocky substratum were performed in the field and at the laboratory. The microscopic inspection of collected rock samples completed the petrographic diagnosis of hand specimens in the field. This study chiefly concerns country-rock samples, and only a small number of thin sections were made from the slab material (in nearly detached fragments) for preservation purposes. As mentioned above (see Section 3.2), the morphological analysis of individual megalithic slabs was performed with the goals of (i) establishing correlations with geological structures

TABLE 1 Details of all radiocarbon dates (this work, previous studies).

Location	Core	Depth in the core (m)	Elevation (m NGF)	Lab. code	14C a B.P.	±	δ 13C	Cal. B.P. (2σ) Maximum	Cal. B.P. (2σ) Minimum	Cal. B.P. (2σ) Median	Cal. B.C./A.D. (2σ) Maximum	Cal. B.C./A.D. (2σ) Minimum	Cal. B.C./A.D. (2σ) Median	Material	Source
Bay of Tresseny	G-C2	0.55	3.20	UBA 15681	431	28	−28.5	527	338	497	1423	1612	1453	Halophytic plant remains	Stéphan et al. (2015)
Bay of Tresseny	G-C2	1.15	2.60	UBA 15682	1819	28	−28.4	1820	1624	1718	130	327	232	Halophytic plant remains	Stéphan et al. (2015)
Bay of Tresseny	G-C2	1.55	2.20	UBA 15683	2522	32	−27.6	2740	2492	2591	−791	−543	−642	Halophytic plant remains	Stéphan et al. (2015)
Bay of Tresseny	G-C2	2.01	1.74	UBA 15684	2732	36	−25.7	2924	2757	2820	−975	−808	−871	Halophytic plant remains	Stéphan et al. (2015)
Bay of Tresseny	G-C2	2.85	0.90	UBA 17893	2657	22	−25.8	2843	2741	2761	−894	−792	−812	Halophytic plant remains	Stéphan et al. (2015)
Bay of Tresseny	G-C2	3.40	0.35	UBA 17894	2690	27	−26.0	2849	2754	2786	−900	−805	−837	Halophytic plant remains	Stéphan et al. (2015)
Bay of Tresseny	G-C2	3.70	0.05	UBA 17895	2689	22	−28.3	2849	2753	2780	−900	−804	−831	Halophytic plant remains	Stéphan et al. (2015)
Bay of Tresseny	G-C2	3.70	0.05	UBA 15685	2666	25	−27.1	2848	2742	2767	−899	−793	−818	Halophytic plant remains	Stéphan et al. (2015)
Bay of Tresseny	G-C2	4.50	−0.75	UBA 17896	4148	34	−28.1	4827	4536	4692	−2878	−2587	−2743	Halophytic plant remains	Stéphan et al. (2015)
Bay of Tresseny	G-C2	4.55	−0.80	Poz-49796	4165	35	−28.0	4830	4579	4707	−2881	−2630	−2758	Halophytic plant remains	Goslin et al. (2015)
Bay of Tresseny	G-C2	4.95	−1.20	UBA 17897	4795	24	−24.7	5588	5477	5519	−3639	−3528	−3570	Halophytic plant remains	Stéphan et al. (2015)
Bay of Tresseny	G-C2	5.87	−2.12	UBA 15686	5563	31	−28.8	6401	6295	6348	−4452	−4346	−4399	Detrital *Phragmites*	Stéphan et al. (2015)
Bay of Tresseny	G-C3	5.14	0.90	UBA 15459	4054	32	−29.4	4791	4421	4527	−2842	−2472	−2578	Detrital *Phragmites*	Stéphan et al. (2015)
Bay of Tresseny	Vougot-1	2.35	−1.10	UBA 15461	4039	38	−28.1	4790	4416	4504	−2841	−2467	−2555	Detrital *Phragmites*	Goslin et al. (2013)
Bay of Tresseny	Vougot-3	0.63	−3.50	UBA 15460	6033	29	−23.4	6957	6787	6876	−5008	−4838	−4927	Detrital *Phragmites*	Goslin et al. (2013)
Bay of Tresseny	Le Curnic	0.35	−1.35	GsYA	4525	140	N/A	5573	4849	5171	−3624	−2900	−3222	Charcoal	Giot et al. (1965)

TABLE 1 (Continued)

Location	Core	Depth in the core (m)	Elevation (m NGF)	Lab. code	14C a B.P.	±	δ 13C	Cal. B.P. (2σ) Maximum	Cal. B.P. (2σ) Minimum	Cal. B.P. (2σ) Median	Cal. B.C./A.D. (2σ) Maximum	Cal. B.C./A.D. (2σ) Minimum	Cal. B.C./A.D. (2σ) Median	Material	Source
Bay of Tresseny	Le Curnic	0.35	−1.35	GsYAbis	4675	130	N/A	5657	4972	5384	−3708	−3023	−3435	Charcoal	Giot et al. (1965)
Bay of Tresseny	Le Curnic	0.50	−1.50	GsYB	5980	145	N/A	7242	6488	6831	−5293	−4539	−4882	Charcoal	Giot et al. (1965)
Bay of Tresseny	Le Curnic	0.40	−1.40	GsY345	5510	250	N/A	6891	5738	6308	−4942	−3789	−4359	Charcoal	Giot (1966)
Bay of Kernic	ANE-C1	0.8	2.427	SacA-55027	1535	30	−28.7	1517	1350	1403	434	601	547	Halophytic plant remains	This study
Bay of Kernic	ANE-C1	2.415	−2.415	SacA-55029	3245	30	−25.7	3558	3386	3455	−1609	−1437	−1506	Halophytic plant remains	This study
Bay of Kernic	ANE-C1	5.625	−5.625	SacA-55033	4425	30	−27.1	5275	4871	5011	−3326	−2922	−3062	Sandy-mud (bulk)	This study
Bay of Kernic	ANE-C1	7.965	−7.965	SacA-55034	5700	30	−23.7	6602	6401	6477	−4653	−4452	−4528	Sandy-mud (bulk)	This study
Bay of Kernic	ANE-C2	3.965	0.665	SacA-55055	3575	30	−27.1	3975	3728	3875	−2026	−1779	−1926	Halophytic plant remains	This study
Bay of Kernic	ANE-C2	4.725	−0.095	SacA-55056	3795	30	−29.3	4291	4085	4179	−2342	−2136	−2230	Halophytic plant remains	This study
Bay of Kernic	ANE-C2	5.735	−1.105	SacA-55057	4720	30	−27.1	5577	5324	5450	−3628	−3375	−3501	Halophytic plant remains	This study
Bay of Kernic	ANE-C2	9.515	−4.885	SacA-55050	7815	35	−27.7	8698	8458	8588	−6749	−6509	−6639	Sandy-mud (bulk)	This study
Bay of Kernic	ANE-C3	1.5	3.45	Beta − 573653	1880	30	−27.5	1870	1714	1784	81	236	166	Halophytic plant remains	This study
Bay of Kernic	ANE-C3	3.54	1.41	SacA-55039	2790	30	−32.5	2963	2785	2891	−1014	−836	−942	Halophytic plant remains	This study
Bay of Kernic	ANE-C3	4.95	0	Beta − 570608	4100	30	−24.9	4813	4449	4611	−2864	−2500	−2662	Halophytic plant remains	This study
Bay of Kernic	ANE-C3	7.745	−2.795	SacA-55036	5275	30	−29.5	6183	5939	6075	−4234	−3990	−4126	Halophytic plant remains	This study
Bay of Kernic	ANE-C3	8.725	−3.775	SacA-55041	5760	30	−26.7	6656	6458	6559	−4707	−4509	−4610	Halophytic plant remains	This study
Bay of Kernic	ANE-C3	9.745	−4.795	SacA-55040	6265	30	−26	7265	7028	7211	−5316	−5079	−5262	Silty peat (bulk)	This study
Bay of Kernic	ANE-C3	10.585	−5.635	SacA-55052	6235	30	−28.9	7254	7013	7159	−5305	−5064	−5210	Halophytic plant remains	This study

(Continues)

TABLE 1 (Continued)

Location	Core	Depth in the core (m)	Elevation (m NGF)	Lab. code	14C a B.P.	±	δ 13C	Cal. B.P. (2σ) Maximum	Cal. B.P. (2σ) Minimum	Cal. B.P. (2σ) Median	Cal. B.C./A.D. (2σ) Maximum	Cal. B.C./A.D. (2σ) Minimum	Cal. B.C./A.D. (2σ) Median	Material	Source
Bay of Kernic	ANE-C4	3.725	2.455	SacA-55047	3070	30	−28.1	3366	3185	3286	−1417	−1236	−1337	Halophytic plant remains	This study
Bay of Kernic	ANE-C4	4.345	1.835	SacA-55046	2925	30	−28.7	3167	2965	3073	−1218	−1016	−1124	Halophytic plant remains	This study
Bay of Kernic	Pors Guen	0	2.87	Gif 710	3390	120	N/A	3965	3379	3643	−2016	−1430	−1694	Peat (bulk)	Morzadec-Kerfourn (1974)
Bay of Kernic	Pors Guen	0.5	2.37	Gif 711	4120	40	N/A	4823	4523	4655	−2874	−2574	−2706	Peat (bulk)	Morzadec-Kerfourn (1974)

Note: Calibrated age based on the IntCal20 calibration curve (Reimer et al., 2020).

Abbreviations: A.D., Anno Domini; cal. B.P., calibrated Before Present; N/A, not available; NGF, Nivellement Général de la France.

observed in the surrounding landscape and (ii) discriminating geological versus anthropometric structures. Most (if not all) of the megalithic stones typically display a 3D-slab morphology resulting from the intersection of three nearly orthogonal (2 × 2) and planar surfaces. Most of the 3D-shaped slabs show two prominent dimensions, referred to as the length (*L*) and the height (*H*), and one minor thickness dimension (*T*), with $L > H \gg T$. Each dimension (*L*, *H* and *T*) of a given 3D slab is determined by the spacing of one facet population. Without strong evidence for significant human reshaping, most slab facet patterns are assumed to correspond to geological structures in the initial source-stone material. The magmatic (granitic) versus tectonic origin of these planar surfaces is deduced from the Variscan geological context of the studied megaliths. The tectonic structures are genetically related to either a ductile and pervasive strain (e.g., foliation and shear zones) or a brittle and more widely spaced deformation (fractures sensu lato).

3.4 | Slabs' weight estimates

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

3.5 | Paleoenvironmental reconstructions

For the Lerret monument, paleogeographic interpretations were based on previous studies of the Holocene deposits in the inner part of the mouth of the Tresseny River (Goslin, 2014; Goslin et al., 2015; Stéphan et al., 2015). They were complemented by geomorphological and archaeological data collected in the estuary's northern and western parts (Giot et al., 1965; Hallegouet et al., 1971; Van Zeist, 1963).

For the Kernic monument, four vibracores were collected in the inner part of the mouth of the Kerralé River (Kernic Bay) to reconstruct the lithostratigraphy of the Holocene deposits and to deduce paleoenvironmental changes that might have occurred from the Neolithic to the present-day. The ground surface elevation was measured relative to the French ordnance datum (Nivellement Général de la France) using a TopCon HyperV Differential GPS. The various lithofacies in the Holocene sedimentary successions were described in terms of texture, organic content and foraminiferal assemblages. Their interpretation as depositional environments was discussed with regard to published models (Allen, 2000, 2003; Reineck & Singh, 1980) and regional studies of estuarine and coastal areas (Billeaud et al., 2007, 2009; Guilcher et al., 1990; Hallegouet, 1971; Lespez et al., 2010; Stéphan, 2011; Stéphan et al., 2015). Twelve samples were selected for microfaunal identification. All samples were wet-sieved. Only the fraction between 63 and 500 µm was retained for analysis. Identification, observation and counting of the foraminifera were performed using a binocular loupe. Approximately 300 individuals were systematically researched to obtain a statistically representative result. The relative abundance of each species was expressed as a percentage of the total population. Seventeen carbon-rich sediment samples were collected for AMS 14C dating performed at the *Laboratoire de Mesure du Carbone 14* (Saclay, France) and at the *Beta Analytic* (Miami, FL, USA). As recommended by several authors (Gehrels, 1999; Gehrels et al., 1996; Törnqvist et al., 1998), the radiocarbon measurements were limited to in situ detrital fragments of halophilic plants to minimise errors due to possible contamination by older or younger carbon from rootlet penetration or washed material. All conventional radiocarbon dates (this work, previous studies) were calibrated with OxCal v.4.4.4 software (Bronk Ramsey, 2021) using the IntCal20 calibration curve (Reimer et al., 2020). All dates are reported with a 2σ (95%) confidence interval in Table 1. The paleogeographic analysis in the Kernic Bay area was completed with geomorphological and archaeological data previously acquired in the northern part of the estuary by Briard et al. (1970) and Morzadec-Kerfourn (1974), in addition to a series of geotechnical surveys referenced by BRGM (https://infoterre.brgm.fr/).

3.6 | Intervisibility analysis

The intervisibility analysis was conducted on all gallery graves (or/and lateral entrance graves) dating to the Late and Final Neolithic. The analysis also includes only the Middle Neolithic passage grave of Brétouaré. In fact, the reuse of passage graves during the Late/Final Neolithic has been documented at numerous sites (see Section 2.1), and their importance in the patterning of landscapes during the Late and Final Neolithic is frequently highlighted (e.g., Blanchard, 2017, p. 297). Without archaeological research, it is not possible to confirm that the Brétouaré passage tomb has been reused, but its nearly 2-m-high barrow is still partly preserved. Given its topographical position, it must have been largely visible in the landscape throughout the Late and Final Neolithic.

A DEM at a resolution of 5 m was obtained by interpolating data from the Litto3D© (for the coastal area) provided by the SHOM (https://data.shom.fr) and BDAlti (for the inland areas) provided by the IGN. The sea surface was simulated at −3.39 m above sea level (masl), corresponding to the mean tidal level in this region at around 2900 cal. B.C. (García-Artola et al., 2018).

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

To describe the resulting visibility network and to identify the relationships between the place of the monuments within it and their architectural characteristics, six indices partly inspired by social network analysis (SNA) were calculated. Degree (i), closeness (ii) and betweenness (iii) centrality indexes are classic tools of SNA and were calculated using Visone 2.20 software (https://visone.ethz.ch/index.html). The connection success index (iv) is defined as the percentage of visible target sites in a set of evaluated target sites (Čučković, 2014a). The visual connection of the gallery graves with the Brétouaré passage tomb was also expressed as the passage grave connection index (v): 1 = *presence of the visual connection to the Brétouaré monument*, 0 = *no connection*. Lastly, the architectural characteristics of the gallery graves have been synthesised in an "architectural complexity index" (vi) defined as the sum of the values arbitrarily attributed to each structural element (1 = *presence of cella*; 0.5 = *supposed cella*; 1 = *presence of peristalith*; 0.5 = *supposed peristalith*). A Spearman correlation analysis was performed using XLSTAT software (https://www.xlstat.com/fr/) to evaluate statistical dependence between the resulting index. A significance level of the relationship was accepted at ρ value < 0.05.

4 | RESULTS

4.1 | The Lerret gallery grave

The Lerret gallery grave is located at the mouth of the small Quillimadec River, on the northern edge of the Tresseny embayment, west of the studied area (Figure 1b). Because of its low topography (1.50 masl) on the beach, the basal and southern parts of the monument continuously lie in seawater whilst the entirety of the monument is intermittently submerged during high tides (Figure 2b).

4.1.1 | Architectural and archaeological data

Despite having long been recognised by previous archaeologists (Devoir, 1913; Giot et al., 1998; L'Helgouach, 1965; Sparfel & Pailler, 2009), the Lerret megalith has not yet benefitted from an in-depth investigation. Only the central part of the 13-m-long monument, that is, the burial chamber, is currently preserved. No

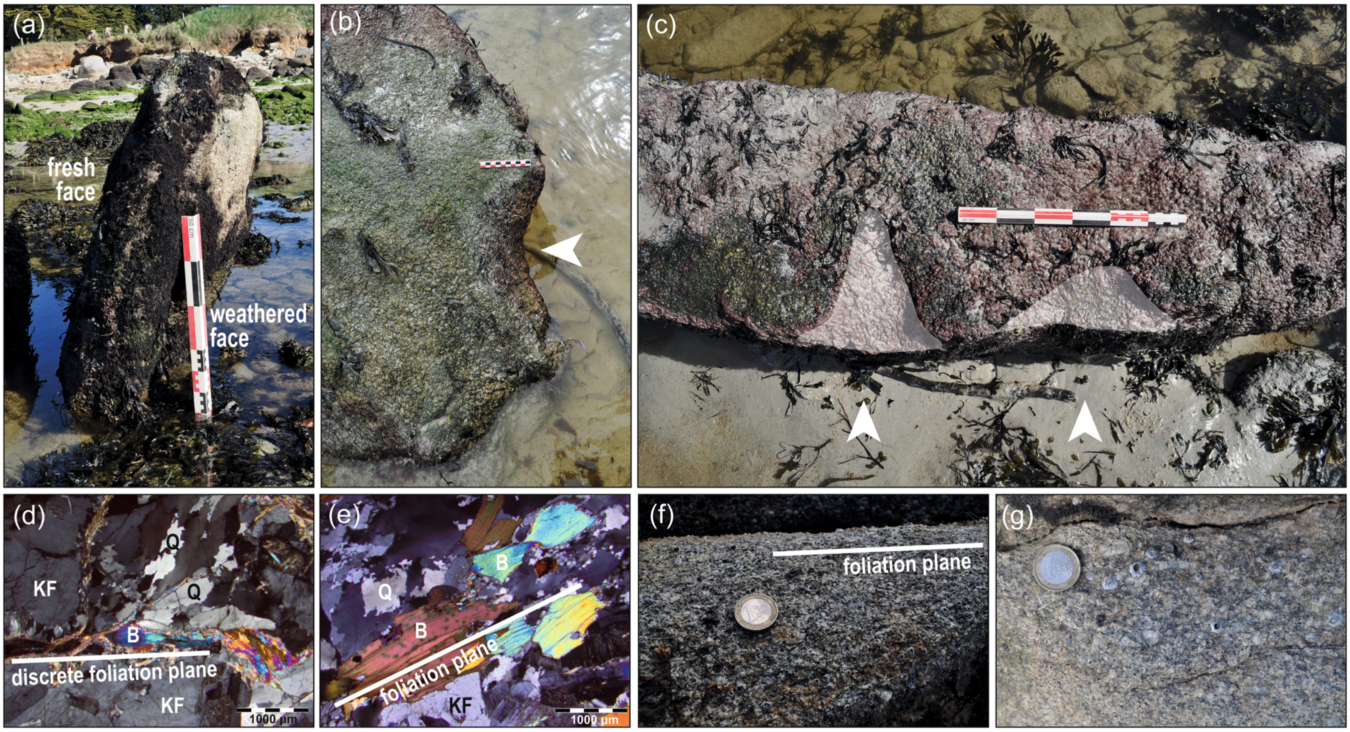

FIGURE 3 Morphological and geological structures of individual granitic slabs in the Lerret gallery grave. Location of slabs in Figure 2a. (a) Fresh and weathered faces were identified on slab no. 25. (b) Mark of removed material attributed to the Neolithic period on slab no. 17. (c) Metallic edge marks identified on block no. 3. (d) Thin section of the little strained granitic slab no. 19. Discrete foliation planes (ductile strain) are outlined by elongated minerals such as quartz (Q), K‐feldspars (KF) and biotites (B). Crossed nicols, ×25. (e) Thin section of the little strained slab no. 24. Traces of foliation planes outlined by elongated quartz (Q) and biotites (B). Crossed nicols, ×25. (f) Macroscopic view of the strained granitic slab no. 1. (g) Macroscopic view of the unstrained granitic slab no. 2. [Color figure can be viewed at wileyonlinelibrary.com]

barrow or peripheral structures have been identified as yet. The grave is oriented N–S, with the entrance to the north (Figure 2a). Eighteen supporting stones limit the chamber; 13 are still in their original upright position, whereas the five remaining ones are lying down inside the chamber. The width of the monument increases from ca. 1.50 m over its 5‐m‐long northern part up to 3 m southward (Figure 2a). The dimension of the orthostats determines its 1.30 m height. The three capstones are preserved, but in a collapsed position (slab nos. 9, 23 and 24 in Figure 2a). Lastly, the backstone, which closes the chamber to the south, is currently inaccessible as it is constantly submerged. The Lerret monument did not benefit from any radiometric age dating, but its Late/Final Neolithic age is confidently deduced from its architectural style.

4.1.2 | 3D‐morphostructural analysis and weight determination

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

A few Neolithic stone extraction marks have been identified (Figure 3b). From their discrete location on individual blocks, they suggest that the latter were only locally reshaped, probably to enable the juxtaposed blocks to fit more easily. Similarly, no evidence of modification of the slabs' surfaces was observed. Evidence for post‐megalith damage and sampling has been noted. Though partly collapsed, the eastern wall appears to be laterally disrupted (Figure 2a). These empty spaces might correspond to original parts of the dry stone wall that are no longer preserved. A mixed technique like this, using rocky slabs and dry stone, is rare but has been observed in similar monuments elsewhere in NW France (L'Helgouach, 1965). A more likely hypothesis is that the missing orthostats and capstones were removed during post‐megalithic times. The uppermost parts of two orthostats (slab nos. 3 and 4) from the western wall have been sliced off, probably relatively recently, as suggested by the identification of metallic edge marks (Figure 3c). More generally, the fact that the Lerret monument shows very little evidence of human reshaping during Neolithic times might reflect the will of these people to directly extract the granitic slabs that displayed regular 3D shapes.

The average weight of the slabs is estimated at 1.88 T. The heaviest slabs were used as a roof for the monument. The two well-preserved capstones (nos. 23 and 24 in Figure 2a) are approximately 3.21 and 2.28 T, respectively, while the mean weight of the orthostats is 0.77 T. The total weight of the monument's slabs is estimated at 17.87 T.

4.1.3 | Petrographic and structural analyses of the megalithic slabs

The existence of dense coating materials excludes the exhaustive petro-structural analysis of the 24 slabs, and only 18 have been accurately analysed. They are all composed of a leucogranitic material, dominated by a quartz–K-feldspar–biotite porphyroblast assemblage, averaging 1 cm in size and depicted on the thin section of the slab no. 24 in Figure 3e. This rock correlates with the finer-grained facies of the Brignogan porphyroid granitic country rock. The proportion of strained and unstrained (or little) slabs is equal (×9). The two types of stone material show no specific distribution in the megalith arrangement (Figure 2a). The strained ones display an internal planar fabric systematically parallel to the slabs' largest facet (*H* × L). The tectonic origin of this fabric is inferred from the alignment of deformed porphyroblasts in pervasive foliation (flattening plane) and/or shear surfaces imaged on the thin section in Figure 3e. The remaining and much less deformed (or unstrained) granitic slabs are composed of >2 cm K-feldspar porphyroblasts and smaller quartz–biotite assemblages that tend to be oriented in a weak foliation planar fabric, as shown in the microscopic view of slab no. 19 in Figure 3d.

4.1.4 | Potential source-stone material

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

Strong correlations between the petrography of the Lerret gallery grave slabs and their immediate granitic geological substrate suggest a local origin for the stone material. The potential extraction sites must also satisfy two additional criteria: (1) orthogonal joint networks and (2) pervasive foliation/shear planar fabrics parallel to one joint network, as observed in the nine strained slabs.

Very few outcrops of isotropic (unstrained) granites have been observed (outcrop no. 4 in Figure 4a,h). Most of the granitic rocks exposed on the ca. 100-m-long coastal section around the Lerret monument are intensely fractured, and thus satisfy the first structural criteria above. However, a number of 3D-fractured granitic zones were not considered because of the greater (outcrop no. 5; Figure 4a,g) or smaller (outcrop no. 6; Figure 4a,f) dimensions of their slab-like blocks. Site no. 3 (Figure 4a) has also been ruled out because of the lack of one joint network, which results in oversized (*L*) slabs. In suitable fractured areas (outcrop nos. 1 and 2; Figure 4a,b,i), the porphyroid granite is cut by a steeply dipping (70°) joint network, oriented N80° E with an average spacing of 20–40 cm, that parallels a pervasive shear fabric. The latter is visible in the thin section (Figure 4d) as centimeter-spaced surfaces; the sinistral sense of displacement along them is deduced from the sigmoid shape of the foliation planes (elongated quartz–biotite assemblage). This ductile shear-related strain is attributed to the regional-scale Porspoder sinistral shear zone that extends ca. 1 km further south. In the field, the composite (brittle/ductile) planar fabric is dissected at a high angle by a more widely spaced and steeply dipping joint pattern, oriented N135° E (outcrop no. 1) and N160° E (outcrop no. 2) (Figure 4b,i). Their mutual intersections, in addition to a much less regular orthogonal joint system, result in 3D-shaped slabs showing dimensions (lengths in the range 0.95–1.80 m) comparable to the Lerret megalithic slabs (Supporting Information 1). Thus, it is argued that the sheared granite exposed in sites 1–2, ca. 50 m away from the Lerret gallery grave, represents a potential rock source for the strained slabs. A second possible extraction zone of deformed granite with suitable 3D fabrics is observed at site 7 (Figure 4a,e). There, the dominant joint pattern is nearly vertical and oriented N120° E, with a regular spacing of 25–50 cm, parallel to the foliation planes. The second submeridian joint network is vertical (Figure 4e). Site 7 is located at ca. 200 m away from the Lerret megalith (Figure 4a). Potential extraction sites for the remaining (×8) little-deformed slab population should occur in the unstrained granitic bands observed within the PGSZ in the vicinity of the Lerret monument (Figure 4a).

4.1.5 | Paleoenvironmental setting

In the inner part of Tresseny Bay, south of the Lerret gallery grave, a set of 19 cores was previously studied by Goslin (2014), Goslin et al. (2015) and Stéphan et al. (2015), four of which are presented in Figures 5 and 7 (G-C11, G-C2, G-C1 and G-C3). The base of the succession consists of well-humified basal peat (with a mean thickness of 1–1.5 m) covering a weathered granite. The base of this deposit was dated to 4452–4346 cal.

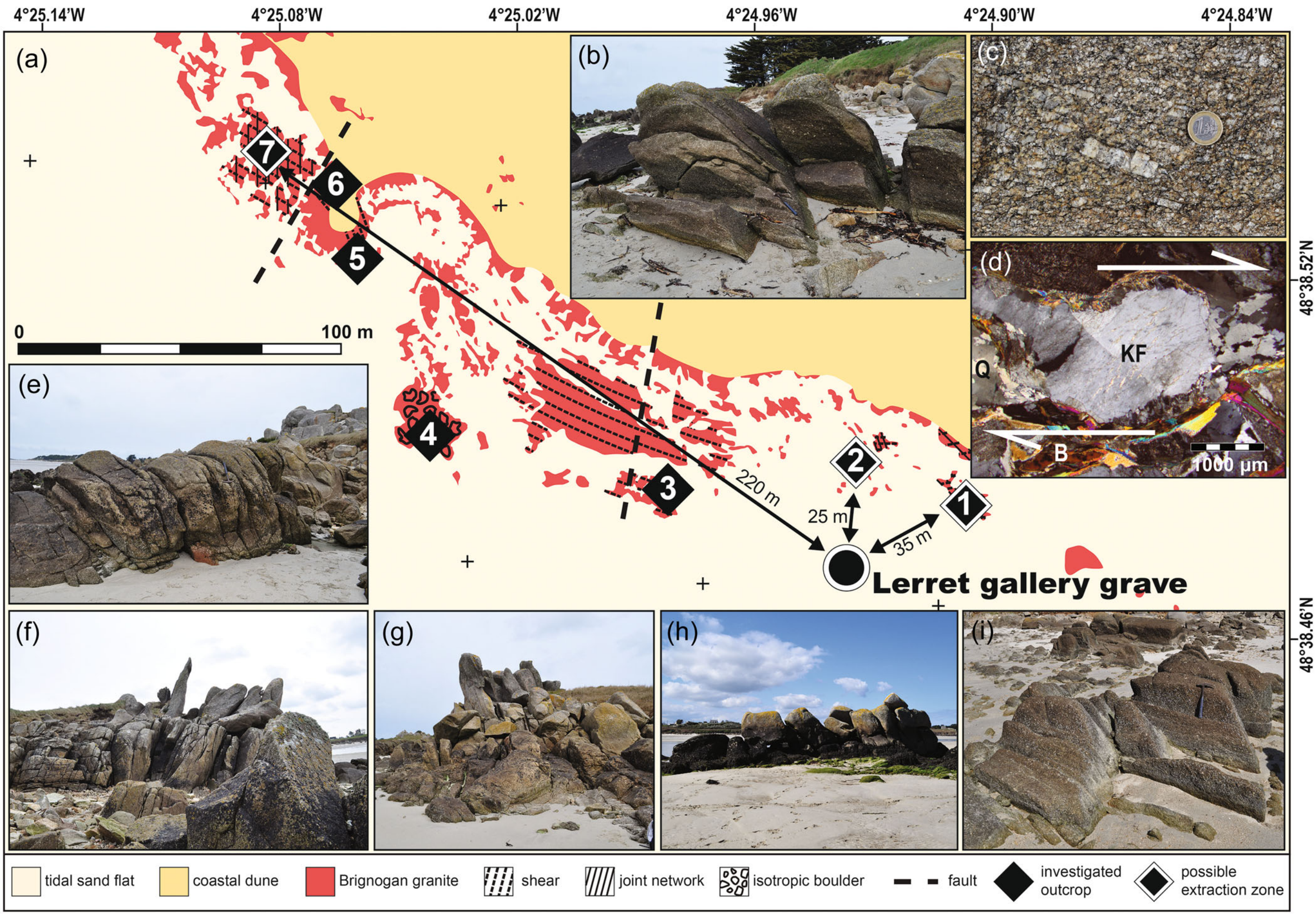

FIGURE 4 Potential source-stone material for the Lerret gallery grave. (a) Detailed geological map of the Lerret monument area with the location of all investigated outcrops. The arrows indicate the distance between the megalith and possible extraction zones. (b) Structure of the highly fractured granitic geological substrate exposed at the potential extraction site no. 1. (c, d) Macroscopic (c) and microscopic (d) views of the granite at site no. 1. Crossed nicols, ×25. Same abbreviations as in Figure 3d,e. (e) Highly fractured granitic geological substrate exposed at the potential extraction site no. 7. (f) Fractured granitic geological substrate exposed at site no. 6 and assumed not to represent potential source material because of the small dimensions of the blocks. (g) Fractured granitic geological substrate exposed at site no. 5. Its oversized blocks do not fit with the dimensions of the megalith slabs. (h) Unstrained granitic rocks exposed at site no. 4, NW of the Lerret gallery grave. (i) Structure of the fractured granitic geological substrate occurring at the potential extraction site no. 2. Location of sites in (a). [Color figure can be viewed at wileyonlinelibrary.com]

B.C. at core G-C2 and to 2842–2476 cal. B.C. at core G-C3 (Figures 6 and 7). *Phragmites australis* remains, along with low quantities of foraminifera, both indicate a back-barrier brackish marsh (Stéphan et al., 2015). This basal deposit evolves into a 0.15-m-thick black-peat layer, dated at ca. 2900–2600 cal. B.C., that indicates the onset of slightly regressive conditions towards the highest marsh deposit environments on the site (Goslin, 2014; Goslin et al., 2015). A coarse sand unit overlies the basal peat at a depth of −0.72 m asl. The sharp transition suggests a rapid change toward high hydrodynamic conditions. The age of this environmental change is between ca. 2900–2600 and 900–800 cal. B.C. A series of five radiocarbon dates obtained for the sandy–silty unit overlying the coarse sand layer indicates a very high sedimentation rate (Figure 7). Foraminiferal analysis indicated a low density of specimens (composed of agglutinated species such as *Entzia macrescens*, *Haplophragmoides wilberti*, *Trochammina inflata* and *Miliammina fusca*) (Stéphan et al., 2015). The scarcity of foraminifera is probably due to high sedimentation rates, in agreement with the low density of detrital plant fragments, which also confirms a sand-flat environment subject to relatively high hydrodynamic conditions and high sediment supply (Goslin et al., 2013; Stéphan et al., 2015). The upper part of the succession is formed by an organic-rich fine sand unit within the seaward cores, and reed peat containing *P. australis* remains in the landward cores. The foraminiferal assemblages (dominated by *Entzia macrescens*) indicate a gradual change from a sand flat to a salt-marsh between 230 and 1400 cal. A.D. (Stéphan et al., 2015).

On Vougot beach (Figure 5), in the northwestern part of Tresseny Bay, two cores (V-1 and V-3) were analysed by Goslin et al., (2013, 2015) and Goslin (2014). Core V-3 revealed a 0.65-m-thick basal peat deposit overlying a pre-Holocene (Pleistocene loess) surface at −3.5 m asl (Figure 7). The base of this deposit was dated to 5008-4838 cal. B.C. (Goslin et al., 2013) and its top is eroded and

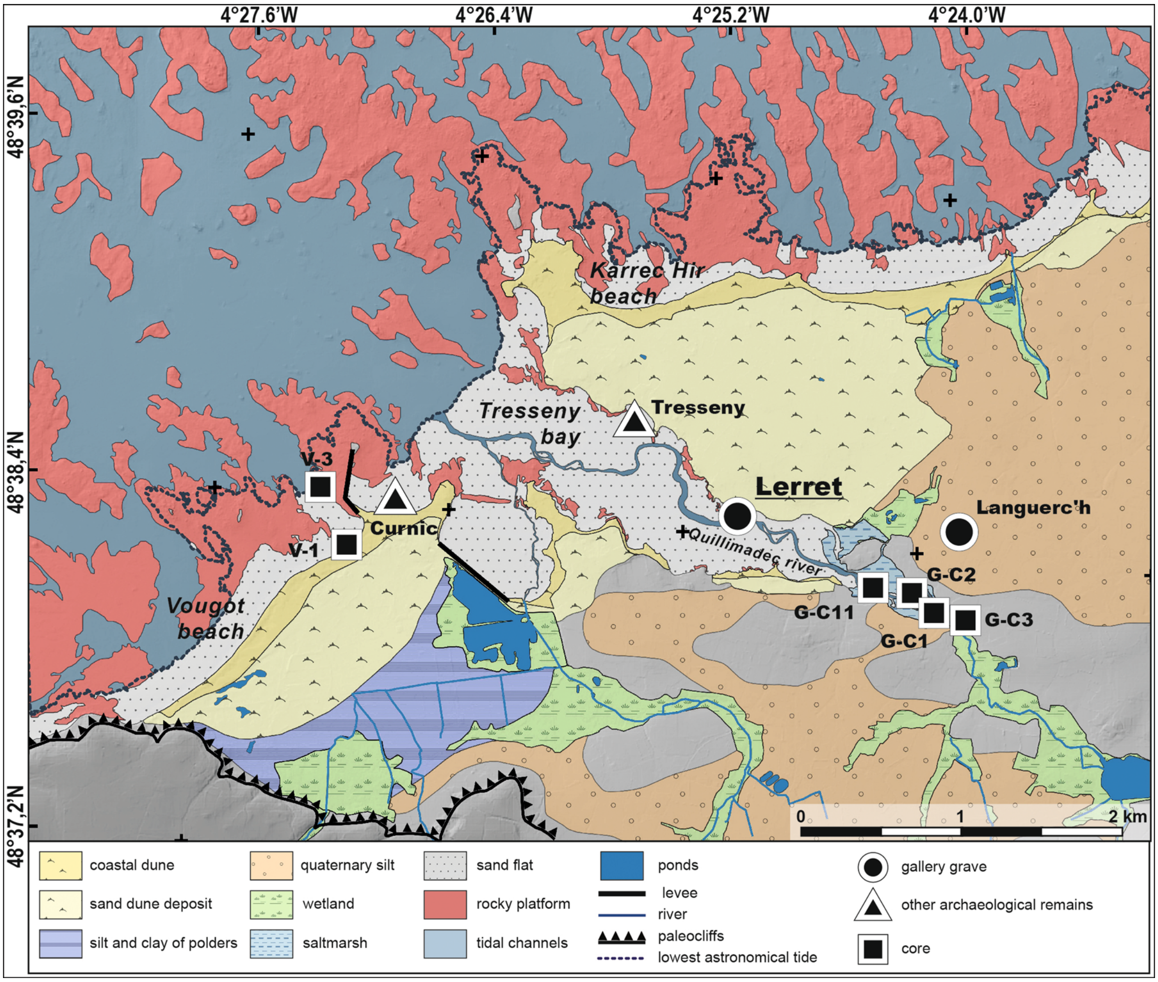

FIGURE 5 Geomorphological map of the Tresseny Bay area showing the location of archaeological sites (including the Lerret gallery grave) and the cores. Modified from Hallégouët (1978) and Suanez and Cariolet (2010). [Color figure can be viewed at wileyonlinelibrary.com]

currently exposed (Goslin, 2014). *P. australis* remains and the absence of foraminifera suggests a marsh or brackish swamp environment (Goslin, 2014; Stéphan et al., 2015).

The base of the V-1 succession is also formed by a 60-cm-thick peat deposit overlying a pre-Holocene surface (Pleistocene loess) at −1.25 m altitude and dated to 2841–2467 cal. B.C. (Goslin et al., 2013). The absence of foraminifera and the remains of *P. australis* indicate a former marsh or brackish swamp environment. This basal unit is overlain by a 1.6-m-thick layer of white sand (between −0.55 and 0.75 m asl) and becomes gradually more organic at the top. The 0.1 m upper section corresponds to the peat deposit exposed at the surface (Goslin, 2014; Goslin et al., 2013).

At Curnic (Figure 5), to the west of Vougot beach, a paleosoil formed on the Pleistocene silt (loess) and containing numerous archaeological remains (ceramic pieces, knapped and polished stone tools and a series of fireplaces) was discovered in the intertidal zone (Briard et al., 1960; Giot, 1966; Giot et al., 1965). Analysis of the archaeological remains and radiocarbon dating indicate a Middle to Late Neolithic settlement (ca. 4800–3200 cal. B.C.). All the remains were subsequently overlaid by a 12-cm-thick peat deposit containing remains of *P. australis* (Giot et al., 1965) (Figure 7). Palynological analysis of the peat indicates a marsh environment with occasional freshwater ponds (Van Zeist, 1963).

At Tresseny (Figure 5), to the north of the Lerret gallery grave, an archaeological settlement with similar characteristics as the Curnic site was documented in the intertidal area (Hallegouet et al., 1971). The ceramic pieces and the knapped and polished stone tools are contained in a paleosoil developed on Pleistocene silt (loess) and overlaid by a 0.1-m-thick peat deposit (Figure 7). No radiocarbon dates have been obtained, but the analysis of the archaeological remains indicates a Middle to Final Neolithic settlement (ca. 4600–2150 cal. B.C.) (Hallegouet et al., 1971).

4.2 | The Kernic gallery grave

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

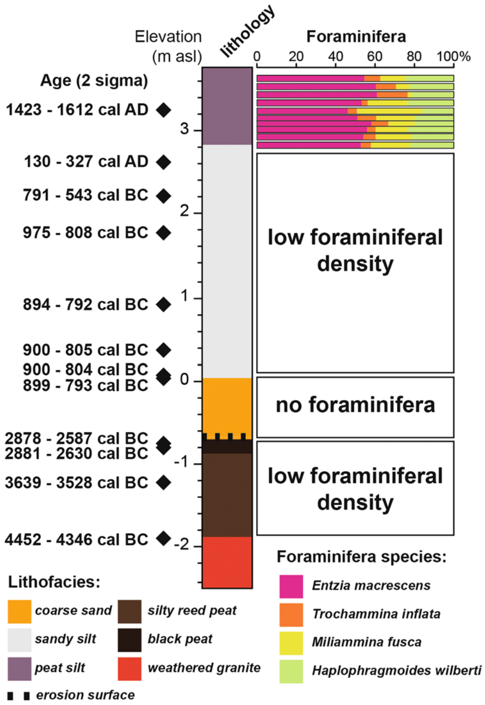

FIGURE 6 Major sedimentological and paleontological attributes of the sedimentary succession cored at site G-C2 in Tresseny Bay. Modified from Goslin et al. (2015) and Stéphan et al. (2015). [Color figure can be viewed at wileyonlinelibrary.com]

4.2.1 | Architectural and archaeological data

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

The Kernic gallery grave was most likely initially enclosed in an unpreserved barrow. The only preserved remains are parts of (i) the internal wall, still present in the cella area, and (ii) a peristalith composed of slabs along most of the length of the monument, except for the northern part. The initial dimensions of the barrow are estimated at 15–16 × 6 m.

The archaeological artefacts collected during previous investigations are ceramic pieces, knapped and polished stone tools and ornamental elements (Lecerf, 1985). Radiocarbon dating is not available for the Kernic gallery grave, but its archaeological style, as well as its composite archaeological remnants, all indicate an age of

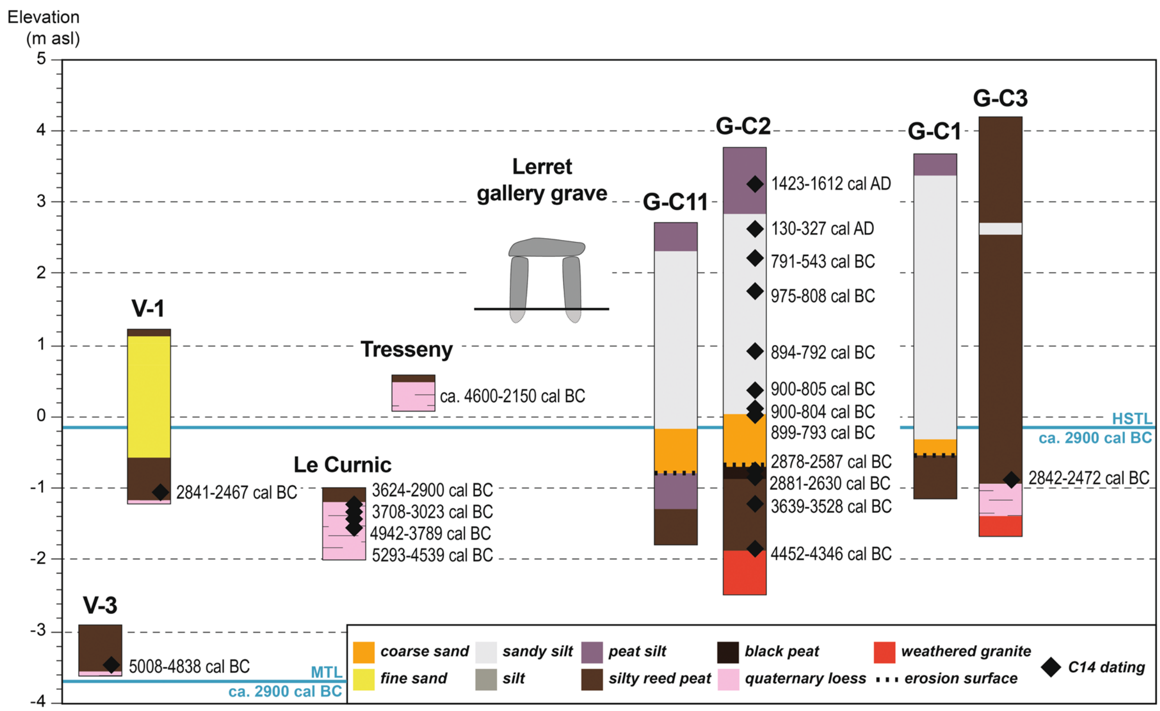

FIGURE 7 Lithology, dating and elevation of all records in the Tresseny Bay area (according to data from Giot et al., 1965; Goslin et al., 2013, 2015; Hallegouet et al., 1971; Stéphan et al., 2015; Van Zeist, 1963). HSTL, high spring tide level; MTL, mean tide level. [Color figure can be viewed at wileyonlinelibrary.com]

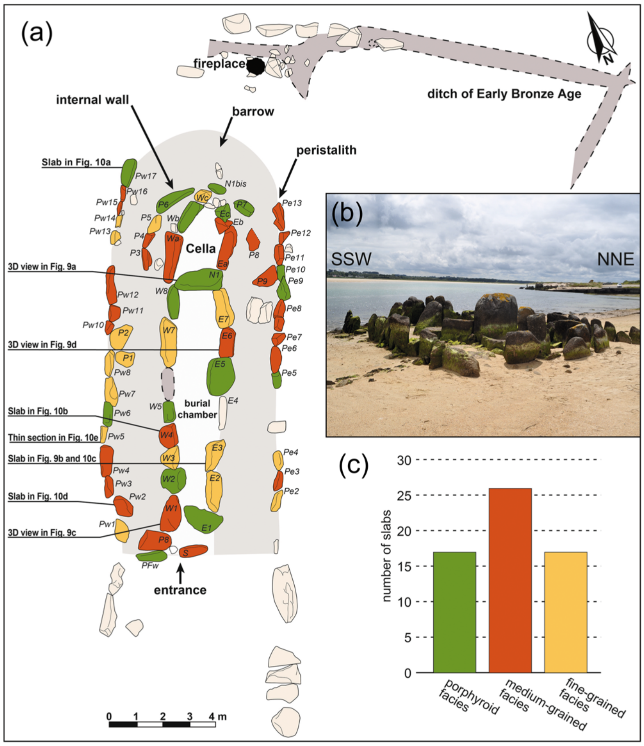

FIGURE 8 Main structural features of the Kernic gallery grave. (a) Plan view of the megalith (obtained from the photogrammetric three-dimensional [3D] model and completed by information collected during excavation stages) showing the spatial distribution of the various granitic rock types as defined in (c). Some of the numbered slabs are cited in the text. (b) View (looking to the SW) at low tide. (c) Graph showing the population of slabs of each granitic facies. [Color figure can be viewed at wileyonlinelibrary.com]

Late/Final Neolithic. Its reuse as a funeral monument by Bell Beaker populations has been previously assessed (Nicolas et al., 2013), while Bronze Age ditches, bounded by standing stones, present in the vicinity of the Kernic site, were tentatively regarded as parts of a field system (Blanchet et al., 2019; Lecerf, 1985) (Figure 8a).

4.2.2 | 3D-morphostructural analysis and weight determination of slabs

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

Discriminating initial *weathered* and *fresh* faces and identifying natural microforms or human reshaping are made difficult because most of the block facets are relatively eroded under atmospheric agents and sea action, and also because those partly immersed are commonly covered by seaweed and lichen. Most of the studied slabs (39) display *weathered* and *fresh* faces (e.g., Figure 9a,b). Eight slabs show two opposite *fresh* faces, whereas two opposite exposed surfaces are observed on four slabs. Eleven slabs display one or more surfaces of undetermined origin. The internal wall of the burial chamber and the cella is formed by the most planar surfaces (*fresh* faces). This pattern is not systematically observed in the peristalith, since eight slabs (out of 30) show a reverse orientation. The erosional forms (according to Sellier, 2013) have been discovered on only 18 slabs (Supporting Information 2). They chiefly consist of upper grooves, the pre- or post-megalith origin of which is not firmly established.

Very few slabs show tool marks synchronous to the building of the megalith. A few removal marks are present on slabs from the grave gallery (e.g., Figure 9b,c), probably to better join the slabs. No evidence for hammering or polishing has so far been observed. By contrast, the reuse of slabs in post-megalith times has been argued by Lecerf (1985) in the grave gallery by the two missing orthostats (nos. W6 and E4 in Figure 8a) currently deduced from their dug pits. Evidence for recent reuse is also found in the removed uppermost parts of orthostats in the cella (nos. Wa, Wb, Wc and Ea in Figure 8a) and the burial chamber (nos. W7, W8, E6 and E7 in Figure 8a). This results in their reduced height by between 0.30 and 0.98 m. However, traces of slicing by metallic edges are not present, contrary to reshaped megaliths observed in other sites. These sliced upper parts usually form a horizontal surface, further intersected by a smaller and inclined surface (Figure 9d). The techniques used for these removals remain unknown. The presence of capstones over the burial chamber is also questionable but is confidently inferred here via comparisons with other megalithic monuments in Britanny (L'Helgouach, 1965). A number of slabs are also currently missing on the eastern and western parts of the peristalith, while they have been totally removed from the northern part (Figure 8a).

The weight of 61 of the 62 slabs of the Kernic gallery grave has been estimated and averages 0.63 T (Supporting Information 2), but it changes significantly in relation to a slab's position in the monument. The average weight of the interior parts of the monument (burial chamber + cella + front) is 1.04 T and that of the peristalith and the internal walls is 0.32 T. The heaviest element is the backstone (no. N1 in Figure 8a), which weighs 4 T. The total weight of the slabs is estimated at 38.49 T. The weights of porphyroid facies and medium-grained facies slabs are nearly equal and are 14.74 and 13.34 T, respectively. The total weight of the fine-grained facies slabs is slightly lower, at only 10.41 T.

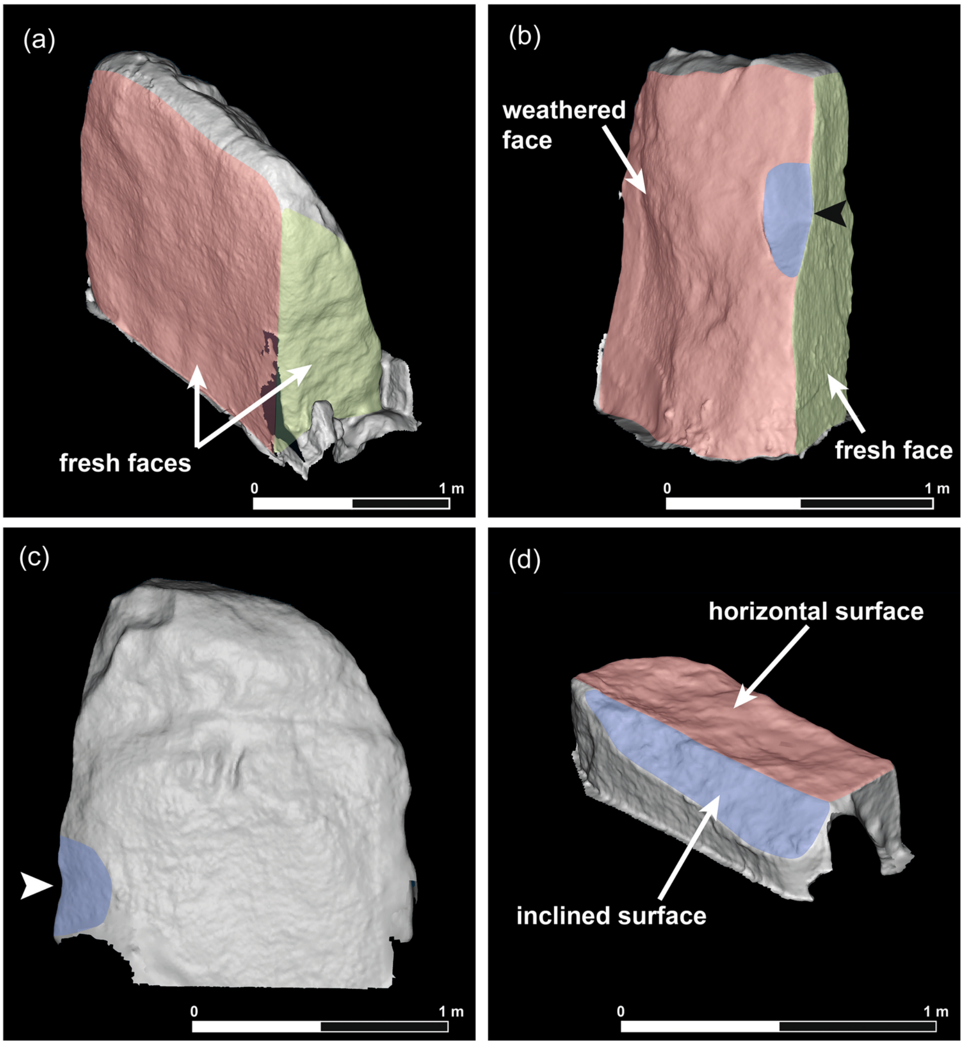

FIGURE 9 Morphological features of the slabs forming the Kernic gallery grave, based on terrestrial laser scanner three-dimensional (3D) surveys. (a) Fresh and weathered faces were identified on slab no. N1. (b) Fresh and weathered faces, as well as marks of removed material attributed to the Neolithic period on slab no. E3. (c) Marks of removed material attributed to the Neolithic period on slab no. W1. (d) Marks of removed material, expressed by two surfaces in horizontal and inclined attitudes, and attributed to modern or contemporary human acts on slab no. E6. Location of slabs in Figure 8a. [Color figure can be viewed at wileyonlinelibrary.com]

4.2.3 | Petrographic and structural analyses of the megalithic slabs

The 61 slabs involved in the Kernic megalith are all composed of a leucogranitic material dominated by quartz and K-feldspar porphyroblasts. However, the size and relative abundance of these constitutive minerals and those of white (muscovite) versus black (biotite) micas allow us to discriminate three distinct petrographic facies with porphyroblasts >2–3 cm in porphyroid facies, averaging 1 cm in medium-grained facies and <1 cm in fine-grained facies (Figure 10a–d). The microscopic inspection of a fine-grained granitic slab (Pw5 in Figure 10e) confirms the modest size of the porphyroblasts and shows the relative abundance of biotites and plagioclases.

The spatial distribution and relative proportion of each type of granitic material in the Kernic megalith are depicted in Figure 8a,c. The medium-grained granitic slabs are more numerous (27, i.e., 44%) and preferentially form the peristalith. The porphyroid and fine-grained slabs are equally present (17, i.e., 28%); the former ones appear to be the main component of the burial chamber.

Strong correlations between the three granitic facies identified both in the megalithic slabs and in the various types of granites in the surrounding Plouescat intrusion allow us to regard the latter as the potential source of the Kernic megalith slabs. Consequently, specific extraction sites can then be identified using complementary structural criteria.

The facet pattern of the Kernic slabs shows no evidence of human reshaping, except for the very recent (post-megalith) reworking of a few of them. They are thus assumed to correspond to natural planar fabrics that were exploited by Neolithic people for the easier splitting of the granitic geological substrate (e.g., Figure 9a,b). Evidence for internal pervasive ductile strains has not

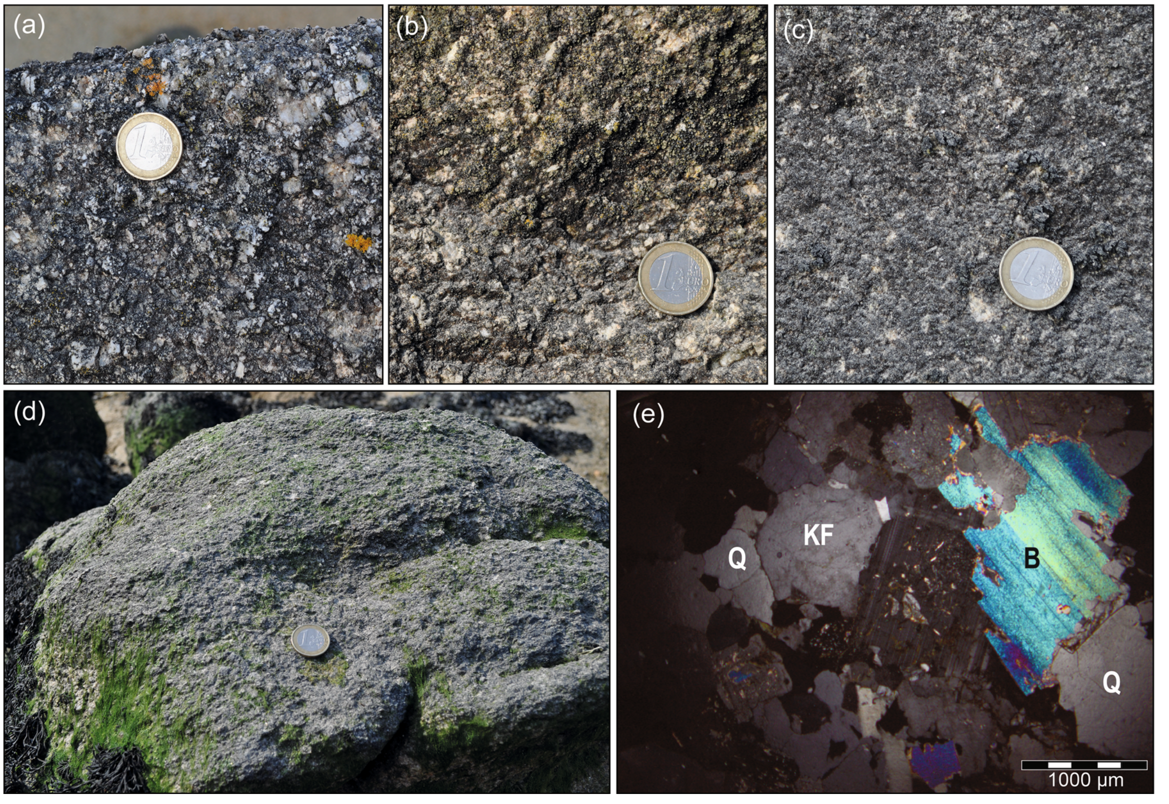

FIGURE 10 Petrography of the granitic material involved in the Kernic slabs. (a–d). Macroscopic views of the porphyric slab no. Pw17 (a), the medium-graded slab no. W4 (b), the fine-grained slab no. E3 (c) and the medium-grained slab no. Pw2 (d). (e). Thin section of slab no. Pw5. Crossed nicols, ×25. Same abbreviations as in Figure 3d,e. Location of slabs in Figure 8a. [Color figure can be viewed at wileyonlinelibrary.com]

been observed in the granitic slab material. The planar fabric outlined by aligned K-feldspar porphyroblasts on the upper surface of slab no. Pw2 (Figure 10d) has a magmatic origin and results from the magma flowing during the intrusion of the pluton. Consequently, nearly all the facet patterns in the Kernic megalith correspond to brittle fractures (joints), as those typically form during the cooling stage of any magmatic intrusions. A similar 3D-orthogonal joint network should be necessarily displayed by the three petrographic facies of the Plouescat granitic geological substrate to be regarded as potential extraction sites.

4.2.4 | Potential extraction sites

The Kernic site occurs at the western extremity of the ca. 30 × 15 km Plouescat granitic pluton on the northern flank of an EW-oriented coastal embayment occupied by recent sediments (Figure 11a). The metamorphic host rocks of the granite are only exposed as a small patch of orthogneiss (Plounevez-Lochrist formation) at the southern end of Porz Meur beach (Figure 11a) (Chauris et al., 1998). The Plouescat leucocratic granite comprises three distinct map-scale petrographic facies that differ in the dimensions of their common constitutive minerals, that is, quartz, K-feldspar, white (muscovite) and black (biotite) micas (Figure 11a–c,e). (I) In a central position, the Brignogan facies sensu stricto is a porphyroid granite with porphyroblasts usually greater than centimetres (Figure 11c). It is surrounded by two narrow belts of (ii) medium-grained granite (Cleder facies) (Figure 11b) and (iii) a third fine-grained facies (Mogueriec) with <2 cm porphyroblasts is extensively exposed further south (Figure 11e). The only tectonic deformations recorded by the Plouescat intrusion are variously oriented fracture networks, without any evidence of ductile strain. The Kernic site occurs on the southernmost edge of the Brignogan porphyroid granite (Figure 11a). The closest potential extraction site forms a shallow platform in the intertidal zone at the western extremity of the Porz Meur beach (outcrop no. 5 in Figure 11a). There, the Brignogan granite is dissected by three regular and orthogonal joint networks (Figure 11c): (i) the most prominent joint pattern is oriented N135° E, in a nearly vertical attitude, and with a regular spacing of 0.4–0.7 m. These surfaces are disrupted by (ii) a steeply dipping joint network, oriented N60° E, that results in slab lengths in the range 0.2–2 m. (iii) A third and less regular fracture population, perpendicular to the two former ones, determines slab heights of ca. 1 m (Figure 11c). The 3D morphology of the resulting fractured blocks is quite similar to those of the porphyroid megalithic slabs, hence allowing us to identify a first potential extraction site at ca. 600 m NW of the Kernic site (Figure 11a). Extraction sites for the medium-grained megalithic slabs are documented in the Cleder-type granite exposed at the northeastern end of Porz Meur beach (outcrop no. 6 in Figure 11a). There, the morphology of the shallow granitic platform is shaped by a joint network dipping

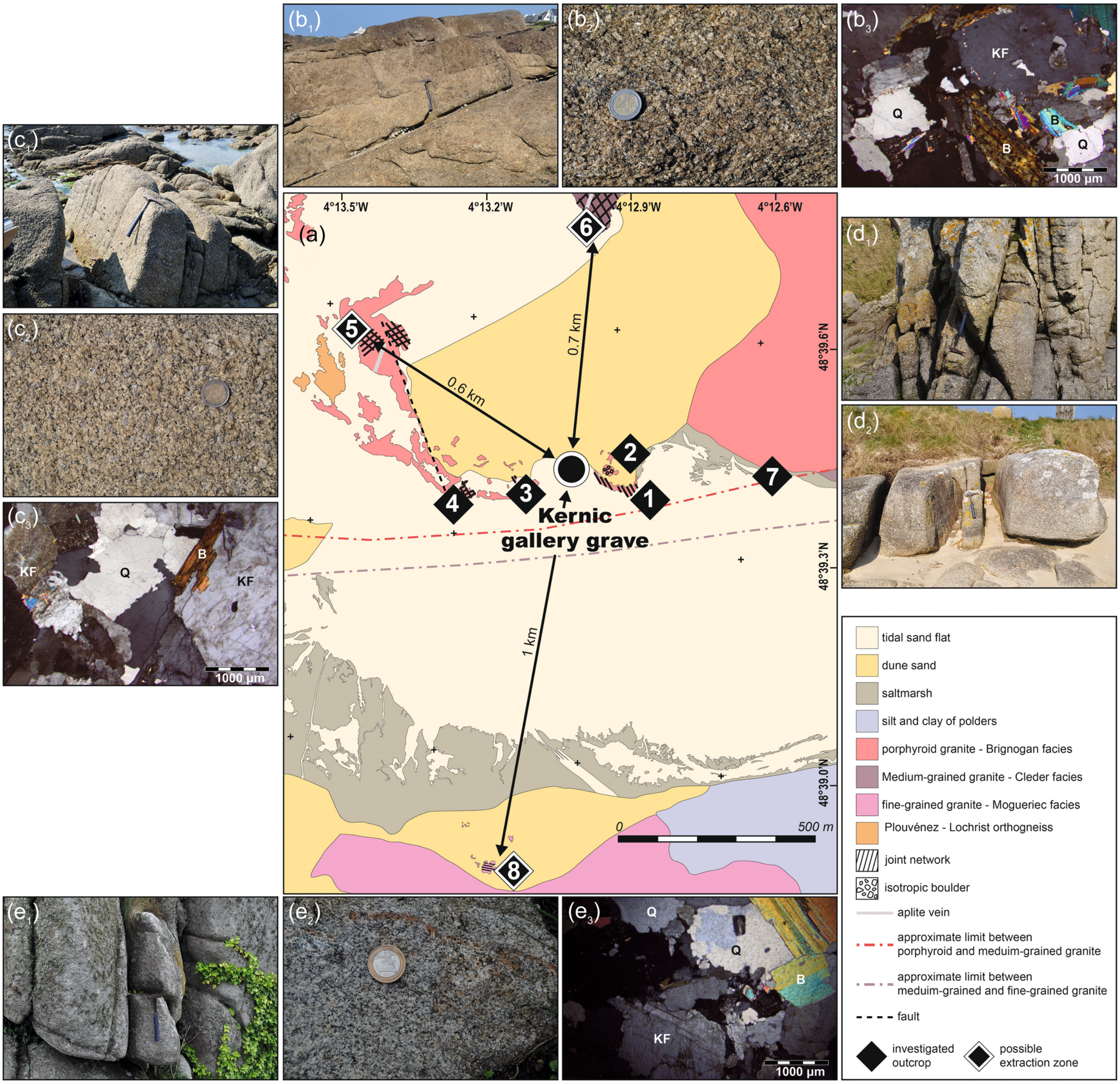

FIGURE 11 Potential source-stone material of the Kernic gallery grave. (a) Detailed geological map of the Kernic area with the location of all investigated outcrops. Arrows indicate the distance between the megalith and possible extraction zones. (b) Petrography and structure of the Cleder medium-grained granite at the potential extraction site no. 6. (b_1) Three-dimensional (3D)-shaped blocks in a shallowly dipping attitude position. (b_2) Macroscopic view. (b_3) Microscopic view. Crossed nicols, ×25. Same abbreviations as in Figure 3d,e. (c) Petrography and structure of the Brignogan porphyric granite at the potential extraction site no. 5. (c_1) 3D-shaped blocks in a vertical attitude displaying dimensions that fit with those of the megalith slabs. (c_2) Macroscopic view. (c_3) Microscopic view. Crossed nicols, ×25. Same abbreviations as in Figure 3d,e. (d) Petrography and structure of the Brignogan porphyric granite. (d_1) Vertical fracture pattern at site no. 1. (d_2) 3D-shaped blocks in a vertical position at site no. 3. (e) Petrography and structure of the Moguериec fine-grained granite. (e_1) 3D-shaped block displaying dimensions that fit with those of the megalith slabs. (e_2) Macroscopic view. (e_3) Microscopic view. Crossed nicols, ×25. Same abbreviations as in Figure 3d,e. [Color figure can be viewed at wileyonlinelibrary.com]

shallowly at 20° to the west, with an average spacing of 0.6 m (Figure 11b). A second joint population, oriented N150° E in a vertical position, determines, in addition to a more irregular third one, 3D blocks displaying dimensions slightly greater than, but still comparable with, those of the petrologically similar slabs in the megalith. It is thus argued that the NE granitic shore of the Porz Meur beach represents a second extraction site ca. 700 m away from the Kernic megalith (Figure 11a).

The potential source of the fine-grained megalithic material was investigated by studying the closest Moguériec-type granite exposed south of the Kerallée River (outcrop no. 8 in Figure 11a). Under the microscope, the exposed leucogranitic rock shows a mineral assemblage composed of quartz–K-feldspar–biotite porphyroblasts, <1 cm, and subsidiary plagioclases (Figure 11e), that is, similar to the petrology of the slab sample PW5. Most of the granitic outcrops are dissected by two orthogonal joint networks, a vertical one (oriented N100° E) and a second one in a horizontal position. The resulting 3D-fractured blocks (Figure 11e) correlate with many of the megalith slabs, hence suggesting the location of a third source at ca. 1 km south of the Kernic megalith (Figure 11a).

4.2.5 | Paleoenvironmental setting

Four vibracores were collected in the inner part of the Kerallé River (ANE-C1, ANE-C2, ANE-C3 and ANE-C4 in Figure 12).

In core ANE-C1, sampled in the most seaward part of the Kerallé River valley (Figure 12), the base of the Holocene deposits was not reached (Figure 13). The lowermost part of the sedimentary sequence is composed of a 5.4-m-thick silty sand unit containing estuarine carbonate foraminifera assemblages typical of the intertidal zone (dominated by species *Elphidium* sp. and *M. fusca*) (Figure 13) (e.g., Delaine et al., 2015; Stéphan et al., 2015). This deposit, dated between 4653–4452 and 1609–1437 cal. B.C., is thus confidently interpreted as an intertidal sand flat. This unit is overlain by a 0.2-m-thick sandy silt deposit. The foraminiferous assemblage dominated by *E. macrescens* and *T. inflata* indicates the salt-marsh environment (e.g., Delaine et al., 2015; Stéphan et al., 2015). The upper part of the core ANE-C1 contains 2.2-m-thick alternating deposits of organic-rich silt and silty peat dated between 1609–1437 cal. B.C. and 434–601 cal. A.D. The absence of foraminifera indicates a freshwater marsh environment (Figure 13).

Core ANE-C3 was collected from the inner part of the Kerallé River valley (Figure 12). The lower part of the sequence consists of a peat silt unit 0.7 m thick (Figure 13) covering a weathered granite at −6.39 m asl. The absence of foraminifera suggests a freshwater marsh environment. This unit is overlain by a 0.78-m-thick sandy silt layer and becomes more organic at the top. The foraminiferal

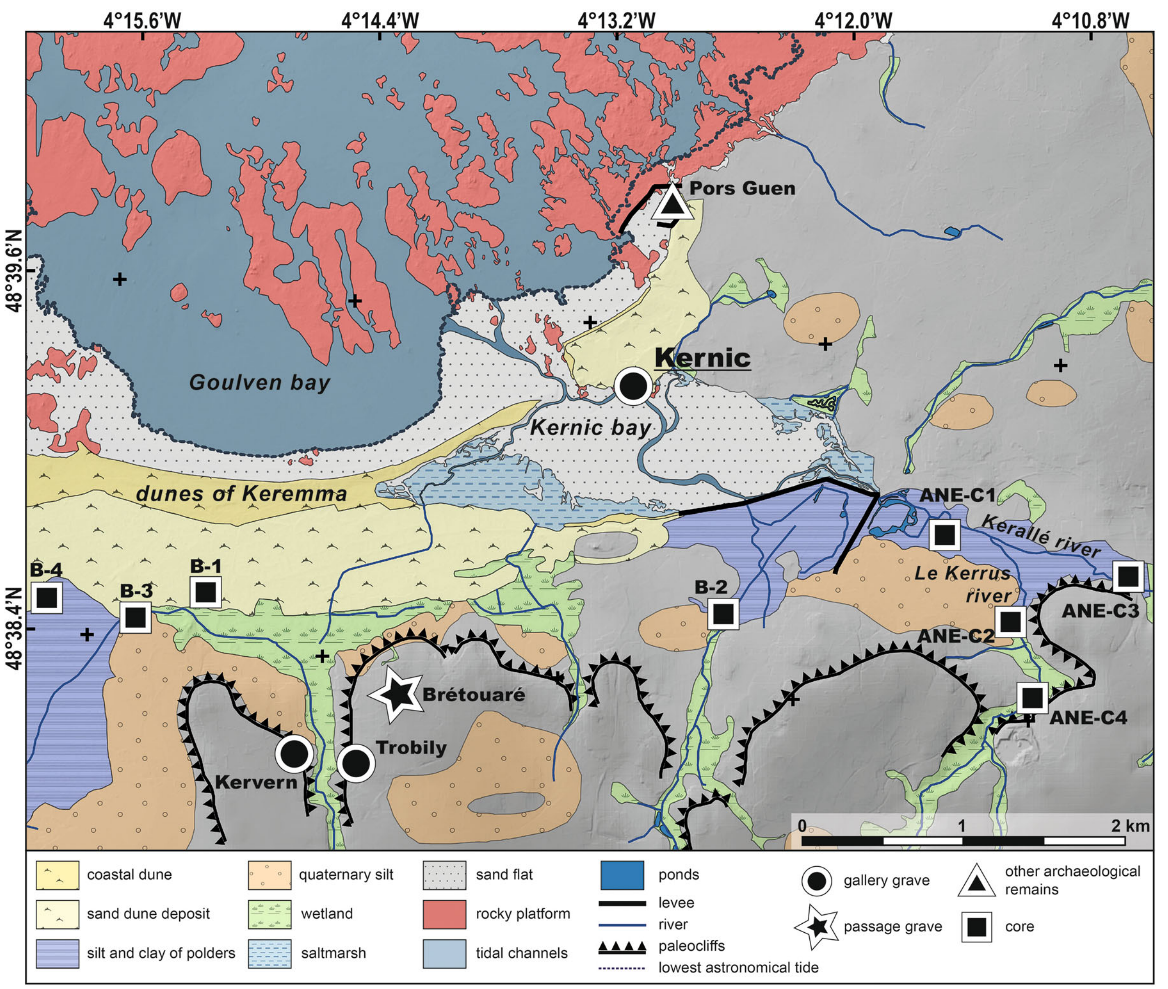

FIGURE 12 Geomorphological map of the Kernic Bay area showing the location of archaeological sites (including the Kernic gallery grave) and cores. Modified from Hallégouët and Moign (1976) and Stéphan et al. (2018). [Color figure can be viewed at wileyonlinelibrary.com]

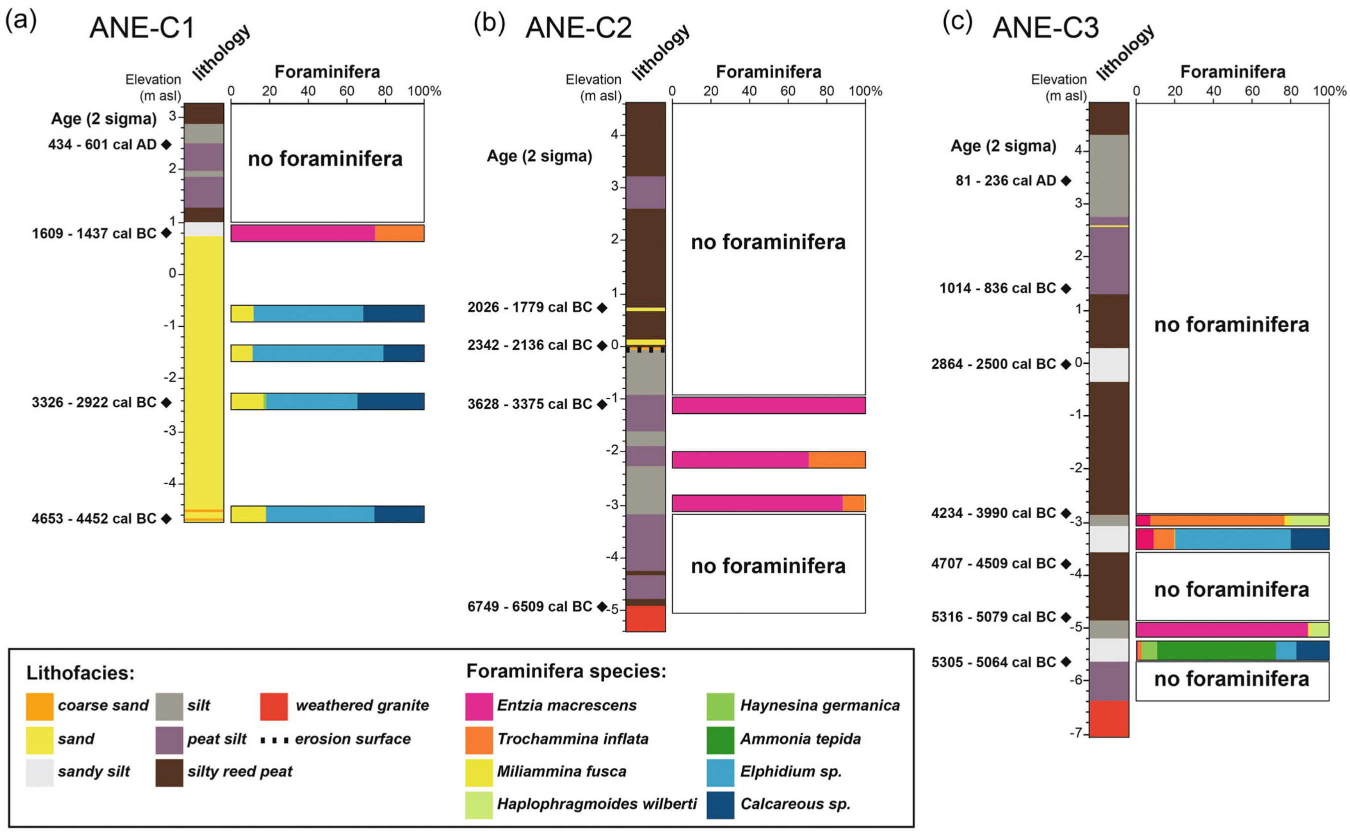

FIGURE 13 Major sedimentological, paleontological and radiometric data of the sedimentary succession cored at sites ANE-C1 (a), ANE-C2 (b) and ANE-C3 (c) in Kernic Bay. [Color figure can be viewed at wileyonlinelibrary.com]

assemblages indicate a gradual change from a tidal flat (dominated by *Ammonia tepida*) to a salt-marsh environment (dominated by *E. macrescens)* (e.g., Delaine et al., 2015; Stéphan et al., 2015). This deposit was dated from 5305–5064 to 5310–5079 cal. B.C. Between −4.87 and −5.58 m asl, a peat layer devoid of foraminifera indicates the development of freshwater wetlands. This peat is in turn overlain by a new deposit of sandy silt 0.71 m thick, evolving into organic silts. The foraminiferal assemblages suggest a progressive transition from a tidal flat to a salt-marsh environment between 4707–4509 and 4234–3990 cal. B.C. The upper part of core ANE-C3 contains 7.8-m-thick alternating deposits of organic-rich mud and muddy peat. The absence of foraminifera indicates a freshwater marsh environment (Figure 13).

Cores ANE-C2 and ANE-C4 were collected in the Le Kerrus river valley, a tributary of the Kerallé River (Figure 12). At core ANE-C2, the Holocene deposits overlay a weathered granite surface at −4.9 m asl (Figure 13). The lower part of the sequence is constituted by a 1.73-m-thick peaty silt, the base of which dates to 5008-4838 cal. B.C. The absence of foraminifera suggests a freshwater marsh environment. This basal unit is overlaid by a 2.21-m-thick layer of silt and peat silt containing estuarine foraminifera assemblages typical of the upper part of salt marsh (dominated by species *E. macrescens* and *T. inflata*) (e.g., Armynot du Châtelet et al., 2018; Horton et al., 1999; Stéphan et al., 2015). At −0.74 m asl, this deposit evolved into a 0.83-m-thick silt unit dated between 3628–3375 and 2343–2136 cal. B.C. The characteristics of the sediments and the absence of foraminifera suggest the formation of a floodplain. Its eroded surface is overlain by a sandy layer dated around 2342–2136 cal. B.C. and interpreted as channel-fill deposits. The upper part of the sequence is composed of a peat and peat silt units. The nature of the deposit and the absence of foraminifera indicate a freshwater marsh environment in perennially saturated flood basins.

Core ANE-C4 is comprised of 4.35-m-thick Holocene sediments resting on top of a granite surface at 1.85 m asl (Figure 14). The lower part of the sequence is composed of a 3-m-thick peat silt unit. Its base dates to 1218–1016 cal. B.C. The upper part of the sequence is composed of a peat unit. The absence of foraminifera and the nature of the deposits indicate continental environments without marine influences.

West of Kernic Bay, four geotechnical surveys (B1, B2, B3 and B4 in Figures 12 and 14) were conducted in the back of the Kerrema dune complex (https://infoterre.brgm.fr/). At B4, the 1-m-thick Holocene deposits overlie a granite surface at 5.1 m asl. Its position and nature are indicative of terrestrial sediments (Figure 14). At B1 and B3, fine sand deposits overlay the pre-Holocene altered granite at −6.5 and 0.6 m asl, respectively (Figure 14). They are attributed to either a sand flat or an aeolian environment. At B2, a 7-m-thick peat deposit overlying a granite surface at −1.9 m asl (Figure 14) may represent a marine or a freshwater marsh environment.

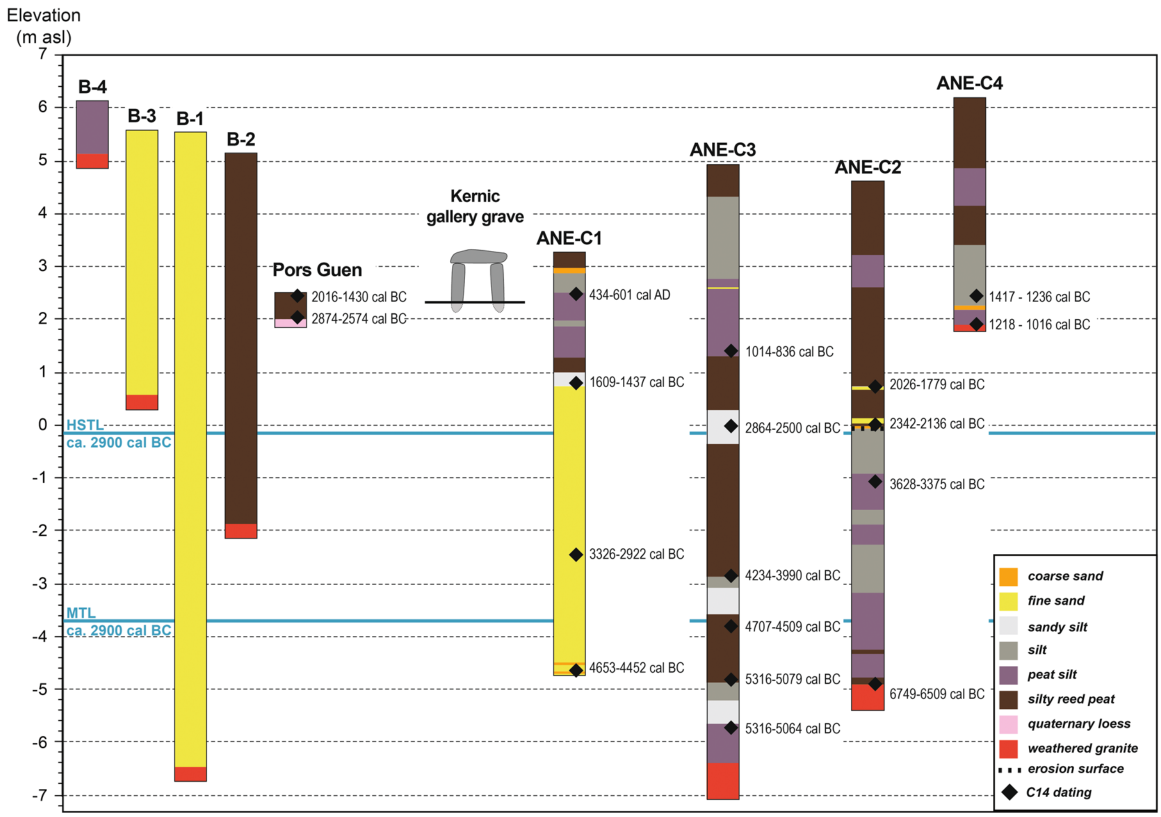

FIGURE 14 Lithology, ages and elevation data of all records in the Kernic Bay area (Briard et al., 1970; Morzadec-Kerfourn, 1974 and from BRGM (Bureau de Recherches Géologiques et Minières), https://infoterre.brgm.fr/). Same abbreviations as in Figure 7. [Color figure can be viewed at wileyonlinelibrary.com]

North of the Kernic gallery grave, a 0.6-m-thick zone of peat deposits exposed in the intertidal zone overlies Pleistocene loess at about 2.4 m asl (Briard et al., 1970; Morzadec-Kerfourn, 1974) (Figures 12 and 14). Its base is a charcoal level that dates to 2874–2574 cal. B.C. Palynological analyses indicate a freshwater marsh environment (Morzadec-Kerfourn, 1974). The top of the unit, dating to 2016–1430 cal. B.C., contains sparse dinoflagellate cysts that reflect periodic seawater intrusions into the marsh at that time (Morzadec-Kerfourn, 1974).

4.3 | Intervisibility analyses

The results of the intervisibility analysis of 12 monuments (including the Brétouaré passage grave and 11 gallery graves) are synthesised in Figure 15. Of the 133 evaluated connections, 32 are positive. All monuments are visually linked; eight have more than one connection. The two monuments under study are in very different places in this theoretical network. The Lerret gallery grave has only one visual connection with the Languerc'h monument (locality Kerlouan). It is characterised by low values of the centrality index (*degree* = 0.18, *closeness* = 0.32, *betweenness* = 0) and a low connection success index (10%). By contrast, the Kernic gallery grave is connected to three other sites, including the Brétouaré passage grave. The used indexes show higher values as compared to the Lerret monument (*degree* = 0.55, *closeness* = 0.41, *betweenness* = 0.02, *connection successes* = 27%) (Supporting Information 3).

The analysis reveals the central place of the Brétouaré passage grave (Plounévez-Lochrist) in this theoretical network. It is connected to the largest number of sites ($n = 6$) and has the highest index values (Figure 15). A Spearman's rank test shows a significant positive correlation between the architectural complexity of gallery graves and their visual connection to the Brétouaré passage grave ($\rho = 0.025$, $r = 0.469$).

5 | DISCUSSION AND INTERPRETATIONS

5.1 | Two strategies for the exploitation of stone material

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

Petrographic and structural analyses of the Lerret monument slabs show strong correlations with granitic outcrops close to the site. Three potential extraction sites (outcrop nos. 1, 2 and 7 in Figure 4)

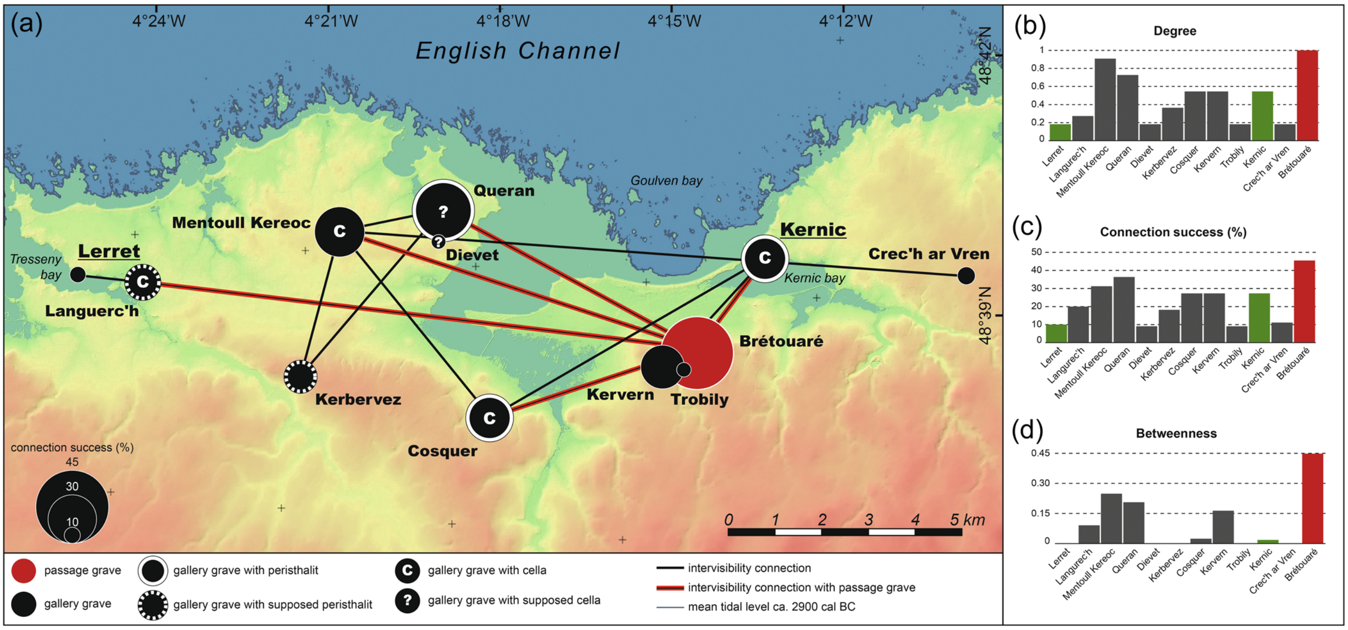

FIGURE 15 Intervisibility of the funerary megaliths in the study area with their centrality index and the connection success index. (a) Map of intervisibility connections identified between the megalithic sites; (b) degree index for all investigated monuments; (c) connection success index for all investigated monuments; and (d) betweenness index for all investigated monuments. [Color figure can be viewed at wileyonlinelibrary.com]

have been identified. They all supply similar stone material and are located at a short distance from the monument (50 m for outcrop nos. 1 and 2, 200 m for outcrop 7). Each of them provided a sufficient quantity of slabs for the complete construction of the sites. The morphological analysis of the slabs reveals a dominance of *fresh* faces, suggesting the exploitation of a single rock outcrop (Mens, 2008). Thus, the parties that constructed the Lerret monument appeared to have utilised a single, local rock outcrop. This strategy potentially reduced the energy required for construction by limiting the transport distance of the megalithic slabs. The availability of building materials may also have determined (at least in part) the choice of the erection site of the monument.

The petro-structural analysis of the Kernic monument slabs shows a very different pattern of rock exploitation. Our study confirms the local origin of granitic material in agreement with Chauris (2021), but it also suggests the existence of three extraction sites in three facies of the Brignogan–Plouescat granitic complex. The three identified outcrops could have supplied all of the slabs for the construction of the Kernic monument, and none of them are located in the immediate proximity of the monument. This result seems to be confirmed by the morphological analysis of the slabs, since many present weathered faces indicate primary exploitation of the rocky outcrops (Mens, 2008) and a multisource supply. The distance between the megalithic monument and the potential extraction sites (up to 1 km) also indicates that the availability of construction material did not determine the choice of monument location. However, the location of potential sites should be considered with caution. Indeed, it is possible that several outcrops exposed during the construction period are no longer visible, either due to quarrying or due to recent covering by dune deposits after the Neolithic period (see Section 5.5). Thus, the distance between the supply sources and the Kernic monument may have been shorter than estimated by this study. However, it is clearly established that the three facies were not collected from a single site. The intentional diversification of the supply sources, which implies the displacement of blocks over several hundred metres, appears very likely and required increased effort for their transport.

In agreement with the particular architecture of the two monuments, the differences in the choice of stone extraction strategies between the two gallery graves may reflect the different status of the two communities at their origin. Indeed, the tomb in the Kernic gallery has a much more monumental appearance than the Lerret monument, due to external structures (such as the peristalith and the monumental façade) and the larger weight and dimensions of the orthostats. As a result, its construction required about three times as many megalithic blocks. The total weight of the lithic material transported is also twice as great. The builders of the Kernic megalith were able to mobilise more resources, suggesting greater political and economic power.

5.2 | A functional and symbolic interpretation of the construction material diversification

Regarding the selection of stones in the construction of the passage grave, it is important to understand whether the decision to use certain stone types was based on functional considerations or aesthetic or symbolic values. The selection of stone material may have been a function of either the slab size or the mechanical constraints of the final construction. This interpretation has been applied to various monuments, such as the passage grave of Puigseslloses, Barcelona, Spain (Vicens et al., 2010), the monument of La Varde in Guernsey, Channel Islands, the United Kingdom (Bukach, 2003) and the megalithic complex of Bougon, Deux-Sèvres, France (Mohen & Scarre, 1993; Scarre, 2004). Concerning the two Neolithic monuments under study, this interpretation may only be applied to the Kernic grave. Indeed, the granitic rocks used in the Kernic gallery grave appear to have very similar mechanical characteristics. The position of the various granitic facies in the monument is not correlated with block size or location, so the mechanical properties of the rocks clearly did not determine the choice of the constructors of the monument.

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

Lastly, the diversification of construction material may also result from practical constraints linked to work organisation. It is possible that each outcrop was successively quarried after leaving the previous one. This abandonment of supply sources may be due to the depletion of natural outcrops and changes in the initial construction project (e.g., abandonment and then resumption of the construction). However, this hypothesis is contradicted by our data, which instead argue that each identified outcrop could satisfy the entire block supply needed for the construction. Similarly, the Kernic monument shows a coherent and uniform architectural plan and appears to be the result of a single architectural project. The 'random' arrangement of the petrographic facies also suggests that the three supply sources were used simultaneously. Thus, the use of different stone materials seems deliberate and was probably determined at the beginning of the construction project.

The symbolic and aesthetic qualities of the rocks have also often been considered in the megalithic monuments in France (e.g., Gouézin, 2017, 2022; Mens et al., 2021). Some monuments, such as the Dissignac tumulus (Saint-Nazaire, Loire-Atlantique) and the Dolmen de la Croix (Pornic, Loire-Atlantique), are composed of very contrasting rock types and colours (Mens et al., 2021). The disposition of the various stones is very ordered, and a number of characteristics, such as the preferential placement of light-coloured stones at the entrance, typify many monuments. Therefore, the physical characteristics of rocks likely contribute to a particular symbolism. However, this hypothesis was ruled out by Scarre (2004), who noted that the diversity of rocks used in the monuments might merely reflect the diversity of the surrounding geological context. It is perhaps the symbolic value of the natural outcrops that is incorporated into a monument beyond these physical characteristics (Scarre, 2004). This is supported by the integration of a few worked blocks in a number of megalithic monuments. The aim to include natural rocks in monuments appears especially relevant to the Late and Final Neolithic periods, as a number of them were directly derived from natural rock outcrops (Gouézin, 2015, 2017, 2022).

The three granitic facies used for the Kernic gallery grave do not display particularly contrasting visual characteristics, while the arrangement of stones is very irregular. It is thus suggested that the symbolic value of rocks, as much as the element of the surrounding landscape, was significant for the people constructing the Kernic gallery grave, a symbolic value whose nature remains to be specified.

The identity value of specific rock types has been argued by Bukach (2003) about the Guernsey and Jersey Islands passage graves. According to this author, stones from prominent geological complexes could be imbued with the landscape's sacred and mythical nature. They can provide symbols of identity and place within and between communities. Such an association between places and different human groups unified during the construction of a collective funeral monument seems to apply to the Kernic gallery grave. The quantity of each facies block, and their irregular arrangement seem to confirm this hypothesis. It was previously highlighted that the extraction of slabs from the three distinct outcrops was probably carried out simultaneously. This suggests the existence of three distinct human groups involved in the extraction and transport of stones. The number and total weight of blocks on each facies are nearly equal. It is, therefore, possible that each of these groups contributed a similar effort to the construction of the Kernic gallery grave. The construction and use of collective burials, such as gallery graves, are generally attributed to societies based either on lineage (Gallay, 2011) or clan systems (Testart, 2005, 2012). In this regard, the question arises if the Kernic monument was built as a collective burial of clans (or lineages) forming part of a single community.

5.3 | The spatial distribution of gallery graves in the study area

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

In contrast to the Middle Neolithic monuments, the collective burials never occur in great concentrations (L'Helgouach, 1956). Exceptionally, the monuments are grouped in twos or threes, such as at Laniscat, (Nothern Brittany, Le Roux, 1975, 1977). More generally, there is no more than one gallery grave in a current locality (L'Helgouach, 1956). In a given territory, a collective tomb (or, more rarely, a small grouping) seems to correspond to a single community (of the village type). Furthermore, access to the tomb may be restricted either to the community as a whole or only to members of one or several clans (or lineages) (Chambon, 2003; Marçais, 2016; Masset, 1997; Salanova et al., 2017). The existence of clustered monuments in relatively limited spatial areas can be understood in two different ways. First, there may exist a chronological gap between each monument in the same group. The erection of a new monument could be justified if the older one is considered insufficient or inadequate for the needs of a community, which increased with time. Second, within each community, the coexistence of several clans (or lineages) of similar importance and perhaps in competition may occur. In this case, each of them may have its own burial monument located on the community's territory. The two hypotheses can also be combined with the emergence of important new clans (or lineages) over time, possibly causing a territorial division in some cases.

The spatial distribution of gallery graves in our study area seems to support such a general pattern. If we consider monuments less than 1 km distant as groupings, the distribution of collective burials is very uniform. For the majority, the closest monuments are located at a distance between 3.9 and 4.3 km. However, exceptions exist, as exemplified by the Lerret monument, which is located only 1.3 km from the Languerc'h gallery grave. Determining whether the two monuments represent two distinct communities or two clans (or lineages) forming part of the same community is a difficult task. However, in both cases, the constructors of the Lerret gallery grave might have occupied a smaller territory than the communities who built other burial monuments in the study area, such as the Kernic gallery grave.

5.4 | Intervisibility analysis and territory patterning

The intervisibility analysis carried out in this study reveals a relatively dense visual connection network, furthermore, strongly structured around the Brétouaré passage grave (Figure 15). It also emphasises the importance of the Kernic monument in this theoretical network with respect to the Lerret gallery grave that appears as a more subsidiary feature.

5.4.1 | Limitations of the method

Three main limitations of this analysis can be highlighted. (i) First, the visual barriers represented by the vegetation are complex to consider. However, palynological research indicates that the coastal areas of Brittany were cleared during the Middle Neolithic (e.g., Marguerie, 1992; Morzadec-Kerfourn, 1974). In particular, fire clearing has been documented in the study area as early as ca. 2900–2600 cal. B.C. (Morzadec-Kerfourn, 1974). It is, therefore, possible that during the Neolithic, the densely populated coastal areas were an open landscape without dense forest vegetation. Cummings and Whittle (2004) also highlighted the high variability of vegetation cover, partly due to seasonal variations. The available data for the studied area do not provide sufficient information for developing a good vegetation cover model. Due to the spatial and temporal complexities of vegetation patterns through time, and the scarcity of data for the study area, analyses conducted on topographic models without vegetation cover seem most appropriate (Čučković, 2014b). (ii) Additional visual barriers may result from paleogeographical changes that have occurred since the Neolithic period. Indeed, the sea-level variations and morphological and climatic factors have led to major changes in the coastal zone (see Section 5.5). In our study, only sea-level rise was considered and simulated at the mean tidal level around 2900 cal. B.C. Despite the extensive available paleographical data for the studied area (see Section 5.5), they did not allow us to construct an accurate DTM that would have illustrated possible environmental changes (filling of coastal valleys, formation of dune complexes). From this point of view, the results presented in this paper are preliminary and will need to be developed in the future. (iii) Third, the intervisibility analysis is based on an incomplete archaeological data set. Some monuments no longer exist, their architecture and location are only recorded in ancient documents. In addition, only the Kernic gallery grave has benefited from previous archaeological investigations in the studied area. The monuments' architecture is mainly known from descriptions and analysis of the exposed structures.

For these reasons, and considering the character of the investigated sites, the intervisibility connections identified here should be interpreted with caution. The resulting network is considered as a synthetic picture of possible connections (perhaps even symbolic) rather than an established communication network.

5.4.2 | Intervisibility links with the passage grave: A prestige element for the gallery graves?

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

Second, our analysis highlights (i) the central position of the Brétouaré passage grave in this theoretical network and (ii) the most complex architecture of the visually linked gallery graves. In a society where reference to ancestors (real or mythical) must have been very strong, the visual link to an older monument was likely an important parameter when selecting the erection sites of new monuments (e.g., Wheatley, 1995). The co-visibility with a passage grave may thus have increased the significance of the gallery grave.

In this perspective, and with regard to the existing monument groups described in Section 5.3, a hierarchy is suspected between the gallery graves under study. Three types of sites are distinguished: (i) The most important and architecturally complex monuments have a direct link to the Brétouaré passage grave and show more visibility links with other monuments (e.g., Kernic, Mentoull Kereoc, Cosquer; Figure 15). Some of them occupy a central place in a group as described in Section 5.3 (e.g., Queran, Languerc'h; Figure 15). (ii) The gallery graves forming part of a group, and considered as subsidiary features, are architecturally less complex and present links only with the central tomb of the group (e.g., Dievet, Lerret; Figure 15). (iii) Lastly, discrete monuments without any visible link to the Brétouaré passage grave also present less complex architecture (e.g., Kerbervez, Crec'h ar Vren; Figure 15). According to this interpretation, the Lerret and Kernic monuments are assumed to occupy a distinct position within this theoretical network.

5.5 | Paleoenvironmental reconstructions and their implications

5.5.1 | Paleogeography of the Tresseny Bay (Lerret gallery grave)

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

As similarly reported for coastal areas in Brittany (e.g., Goslin et al., 2013, 2015; Morzadec-Kerfourn, 1974; Stéphan et al., 2015), the first *Phragmites*-dominated swamps formed around 4900 cal. B.C. in the lower part of the Tresseny Bay (core V-3; Figures 5 and 7) and then at around 4400 cal. B.C. in its inland section (core G-C2 Figures 5 and 6). The development of the oldest basal peat occurred under the combined influence of the slowing down of the Holocene sea-level rise (García-Artola et al., 2018; Goslin et al., 2013, 2015) and the stabilisation of the first coastal barriers (Gorczyńska et al., 2023; Morzadec-Kerfourn, 1974; Stéphan et al., 2015).

Around 2700 cal. B.C., the sedimentary records show an expansion of wetlands throughout the bay. In the lower part of the bay, *Phragmites*-dominated swamps and freshwater ponds developed (core V-1 and Curnic site; Figures 5 and 7). In the inner part of the valley, the peat deposit records a decreasing marine influence (core G-C2; Figures 5 and 6). Stéphan et al. (2015) also demonstrated the extent of salt marshes in other Brittany coastal systems during this period. This expansion probably resulted from the development of gravelly or sandy coastal barriers that provided sheltered conditions for high-marsh development (Stéphan et al., 2015). Unfortunately, determining the exact position of such a system in Tresseny Bay from current data is difficult. However, the formation of freshwater marshes on Curnic Beach (Van Zeist, 1963) and the development of peat deposits at the Tresseny site (Hallegouet et al., 1971) both indicate that the bay was protected from marine influence during Final Neolithic times and that a coastal barrier system may have developed in its lower part. With respect to this pattern, the Lerret gallery grave, which is currently located in the upper part of the bay, was constructed in a protected environment close to a high salt-marsh or freshwater swamps.

5.5.2 | Paleogeography of the Kernic Bay (Kernic gallery grave)

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

The presence of foraminifera in the organic deposits at the base of the sedimentary sequences in core ANE-C3 attests to marine influences in the lower Kerrallé valley as early as 5400–5200 cal. B.C. As mentioned by many authors (Goslin et al., 2015; Morzadec-Kerfourn, 1969; Stéphan et al., 2015), the deposition of peat material at the base of coastal sedimentary sequences in Northwestern Brittany at the beginning of the Neolithic period is associated with the formation of extensive *Phragmites* marshes around the present-day shoreline position (see Section 5.4.1).

From ca. 4500 cal. B.C., the lower Kerralé River valley was transformed into an estuarine mouth composed of (i) an intertidal sand flat (ANE-C1 coring point), (ii) a salt marsh (ANE-C2 coring point) and (iii) a freshwater marsh environment (ANE-C3 coring point). This spatial distribution of depositional environments persisted until ca. 2200 to 1500 cal. B.C. Located closer to the sea, the Kernic archaeological remains were built along this estuarine mouth. Although no coring investigation was carried out at the front of the archaeological site, the Kernic gallery grave is assumed to have topographically dominated a coastal landscape dominated by intertidal sand flats.

The development of large transgressive dune complexes in Brittany, such as the Keremma complex (Figure 12), took place in post-Neolithic times (Gorczyńska et al., 2023). Archaeological remains of the Iron Age and/or Medieval periods discovered in paleosols at the base of aeolian deposits confirm that the principal phase of dune formation post-dated the construction of the Kernic monument (Giot & Marguerie, 1994). It is likely that small coastal sand barriers formed in the Neolithic period, establishing an evolutive basis for the present dune complex. However, their development in this period seems insufficient to have later resulted in the formation of wetlands in the southwestern part of the estuary. Indeed, the geotechnical surveys (core B-3 and B-1 in Figures 12 and 14) conducted in this area reveal dominantly sandy sequences, probably deposited in a sand-flat environment. According to these data, Kernic Bay was significantly more open to the sea at the moment of the monument's construction than at present.

5.5.3 | The role of valleys and estuaries in Late/Final Neolithic landscape patterns

Our paleogeographic analysis reveals that the two monuments under study were built and used in quite different paleoenvironments. The Lerret gallery grave was erected close to a marshland zone (brackish or freshwater), while the Kernic monument was constructed along an estuary, open to the sea. This suggests a distinct role for the two coastal systems in the Late/Final Neolithic cultural landscape. From its location at the periphery of the group of monuments, Tresseny Bay may represent a territorial limit to all communities established in this area.

In contrast, Kernic Bay, and to a larger extent Goulven Bay, appear to occupy a central position in this territory. The gallery graves' orientation suggests this maritime area's importance for all the communities. Indeed, the Kernic monument and those of Mentoull Kereoc and Cosquer present facades facing the bay. The Brétouaré passage grave is a major landmark in this coastal landscape. In the case of Kernic Bay (and more generally, Goulven Bay), the maritime space was probably integrated into the communities' territory, possessing significance in its organisation. Anthropological studies have highlighted that, in some geographical and cultural contexts, maritime spaces (and also lakes or rivers) can be the subject of physical and mental territorialisation by communities (e.g., Bataille Benguigui, 1992; Calandra, 2018; Cormier-Salem & Mbaye, 2018). From this perspective, the fact that the rocks of the Kernic monument originated from the two shores of the estuary could be very symbolic, since it implies the transport of blocks over a maritime zone. The monument could thus be a visible and lasting demonstration of navigation techniques. But it may also indicate a symbolic integration of this maritime territory into the Kernic monument and, thus, perhaps into the territorial system of the community(ies) that constructed it.

6 | CONCLUSIONS

The Kernic and Lerret gallery graves under study were previously regarded as identical monuments, constructed in similar environments. Our multidisciplinary study instead reveals important differences between the two monuments in terms of architecture, source-stone material and geographical position. The Lerret monument was erected close to the stone extraction sites in a marsh environment. The spatial analysis also indicates its subsidiary and peripheral place in a group of megalithic monuments located in the study area. In contrast, the Kernic gallery grave shows a deliberate diversification of rocky material with three potential supply sources, the furthest of which is situated approximately 1 km away from the monument. The Kernic monument was built on the margin of an estuary widely exposed to the sea, and its construction required the transport of megalithic blocks through this maritime zone. This tomb also seems to occupy a more central position in a group of clustered monuments.

We also propose a social interpretation. In the case of the Kernic monument, we suggest that the building stones display a particular symbolism, referring to their specific places in the landscape and/or to human groups involved in its construction. It also appears that some maritime areas, such as Kernic Bay, had an important role in the patterning of landscapes during the Late/Final Neolithic. Regarding their architecture and geographical position, we also suppose that the visual connection with the other megalithic sites, particularly with the only passage grave, was an important factor in the choice of the gallery graves' location in this zone.

The new approach applied here to megalithic monuments is based on (i) a comparative petro-structural analysis of the building slabs and the surrounding geological substrate, (ii) a morphological analysis of each block, (iii) a fine reconstruction of the paleoenvironment and (iv) intervisibility analyses carried out on a coherent set of sites. The identification of potential extraction sources indicates that some megalithic sites (Kernic) show a deliberate diversification of local source-stone material. It is also shown that 3D monument models are an interesting support for this type of study, particularly in the case of sites with limited access. The paleogeographic approach conducted at the scale of each coastal system adjacent to the sites shows that major paleoenvironmental changes occurred in the two coastal areas, underlining the various responses of coastal systems to Holocene sea-level rise and climatic variations. Thus, the locally collected data are a pre-requisite for conducting accurate paleogeographical reconstructions of individual archaeological sites. The intervisibility analysis carried out on all the Neolithic funerary megalithic monuments present in the study area shows a dense network of visual connections, therefore regarded as a strong element in the patterning of Neolithic coastal territories.

Our study illustrates the significant potential of a multidisciplinary approach for studying megalithic monuments, and the overlapping scales of the applied analyses allow the formation of several new hypotheses about the Neolithic societies' social and territorial organisation. Finally, it demonstrates that despite their extreme degradation, the Kernic and Lerret monuments can provide useful insights regarding Late/Final Neolithic societies and their relationships with the natural environment.

AUTHOR CONTRIBUTIONS

Aneta Gorczyńska: Conceptualisation; investigation; funding acquisition; methodology; visualisation; validation; data curation; formal analysis; project administration; writing—original draft; writing—review and editing. **Bernard Le Gall**: Conceptualisation; investigation; methodology; funding acquisition; data curation; supervision; validation; writing—original draft; writing—review and editing. **Pierre Stéphan**: Conceptualisation; investigation; funding acquisition; methodology; supervision; validation; writing—review and editing. **Yvan Pailler**: Conceptualisation; investigation; methodology; supervision; validation; funding acquisition; writing—review and editing.

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