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AN EARLY 3D-MAP OF A TERRITORY? THE BRONZE AGE CARVED SLAB FROM SAINT-BÉLEC, LEUHAN (BRITTANY, FRANCE)

Summary. While early maps are known from all over the world, the key questions always involve: what exactly do they show? And what spatial extent do they cover? In this context, we recently used 3D-modelling to re-examine a carved stone slab datable to the Early Bronze Age (c.2150–1600 BC) that was found at Saint-Bélec in Brittany. We show that the surface of the slab had been shaped in three dimensions to represent the relief of the surrounding landscape in which it was found, while several engraved motifs on it evoke contemporary structures known archaeologically. We argue that the Saint-Bélec slab represents an area of c.545 km² corresponding to the extent of a prehistoric political entity. The carving and subsequent burying of the slab can be linked to the postulated rise and fall of hierarchical societies and raises many wider questions about socio-economic structures in temperate Europe at that time.

INTRODUCTION

‘Describing this curious monument with its cup-marks, circles and various engraved figures, in which some see a shapeless human representation and that of a beast, is difficult. ... Let us not be misled by fantasy, leaving it to a Champollion, who may one day find himself to read it to us’ (Chatellier 1901a, 199).

More than a century ago, du Chatellier synthesized in these few words key issues about the engravings on the Saint-Bélec slab, which he had just unearthed in an Early Bronze Age barrow. Although it is the most intricately carved representation brought to light in a Bronze Age grave in Brittany (Pailler and Nicolas 2016), it has more or less fallen into oblivion; only a photograph of the slab by Paul du Chatellier was used in a later publication (Bénard 1929). Much later, Briard mentioned it once in a paper on cup-marked stones and suggested, through comparison with Alpine rock art (e.g. Valcamonica, Vallée des Merveilles), that it might be seen as a topographical figuration, which appeared to show a complex figuration of field-systems associated with cup-marks (Briard *et al.* 1994, 57 and 60). The rediscovery of the Saint-Bélec slab in 2014 gave

us the opportunity to study this rock art in depth. 3D-scanning has enabled us to record the whole slab and the engravings in detail to study the techniques used, the motifs and their relative chronology. Subsequently, we tried to understand what these engravings represented, following Briard's intuition: is it really a map? And if so, what does it represent?

THE SAINT-BÉLEC BARROW

The Saint-Bélec slab was recovered in June 1900 by du Chatellier (1900; 1901a; 1901b) during the excavation of a round barrow at Saint-Bélec in Leuhan parish, Finistère. The mound, which still survives, is located on the western edge of a hill, overlooking the Odet river valley (Fig. 1a–b). According to du Chatellier (1901a), the barrow measured 40 m in diameter and 2 m high, making it one of the larger barrows of the region. However, aerial photographs show a circular soil mark about 30 m in diameter, suggesting that its size might have been exaggerated or enlarged by ploughing (Fig. 1c).

When discovered, the slab formed the western end of one of the largest stone-cists in the region. It was orientated east-west and measured 3.86 m long, 2.1 m wide, and was 1.86 m high.

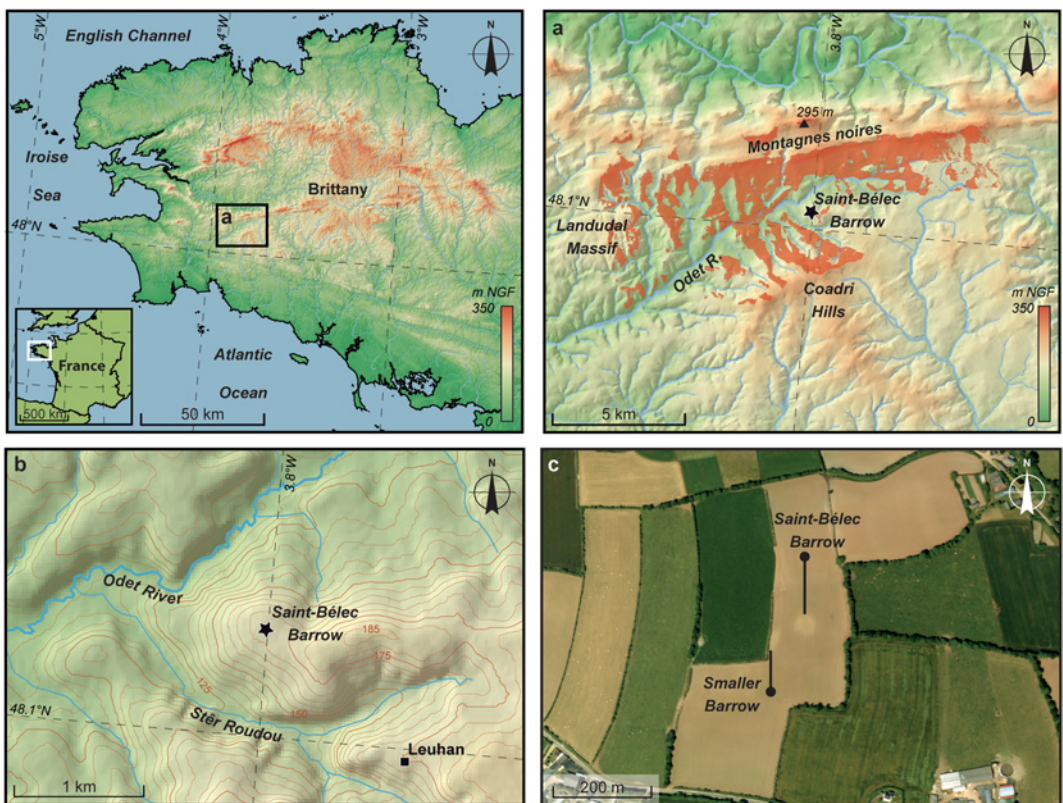


FIGURE 1

(a) Viewshed analysis, (b) location map and (c) aerial photograph of the Saint-Bélec Barrow (Institut Géographique National).

It was covered by a large capstone, $3.9 \times 2.7 \times 0.4$ m (Fig. 2a). The opposite eastern end consisted of a large quartz block, while the side walls were slightly inclined inwards and made from quartzite stones. Traces of wooden structures (floor, timbers) were found suggesting a complicated

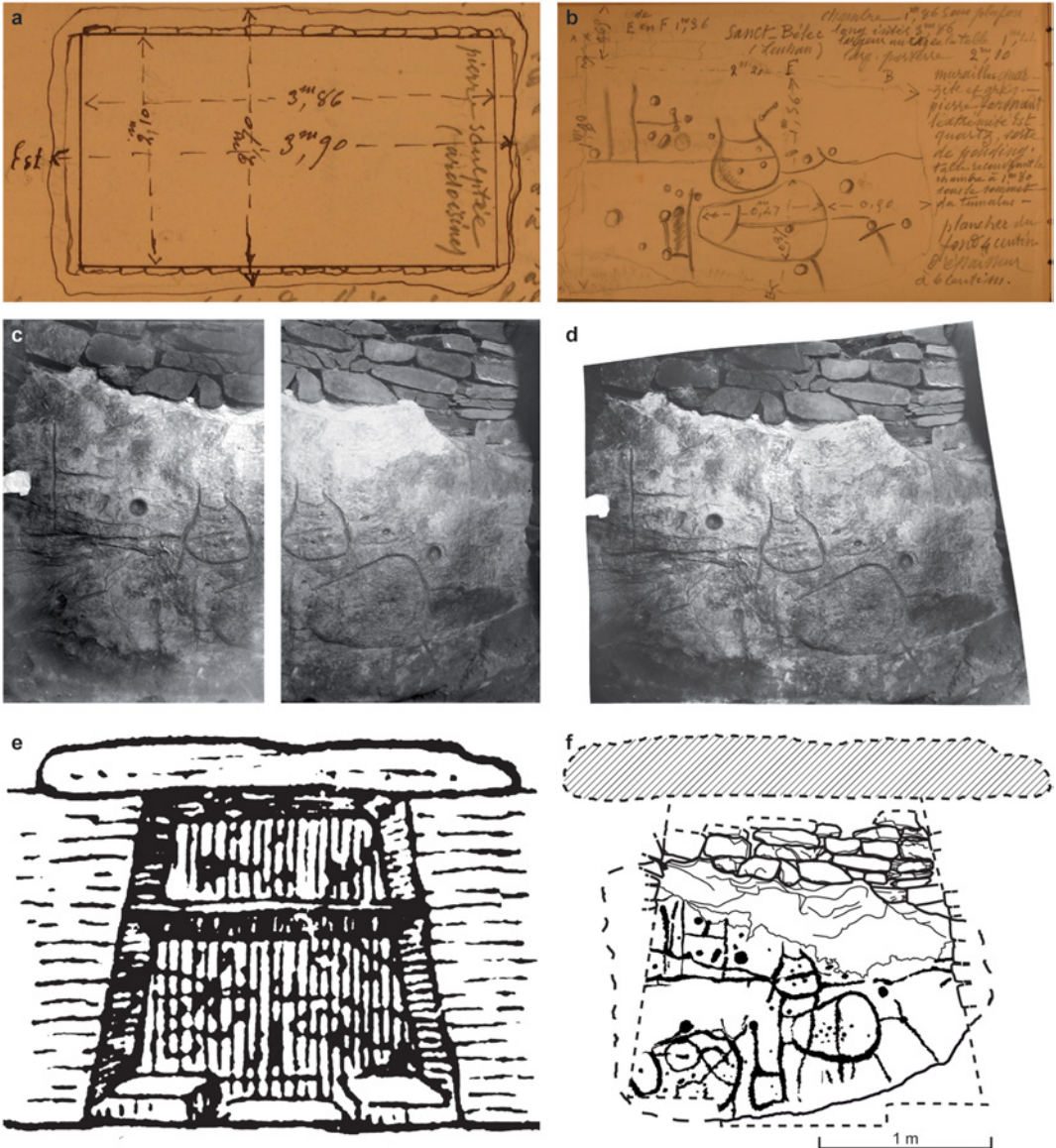


FIGURE 2

(a–b) Fieldwork sketches and (c–d) photographs of the Saint-Bélec excavation by Chatellier in 1900, and (e–f) reconstruction of the carved slab in the grave (e–f). (a–c: Archives Départementales du Finistère; d and f: assembly of fieldwork photographs and CAD C. Nicolas; e: after Chatellier 1901a).

multi-material construction. Drawings and photographs made in the course of the excavation show that the engravings on the slab faced inwards (Fig. 2b–c). However, at the time of the excavation, the slab was found to be partly broken, presumably in antiquity, with the upper part missing. It was surmounted by several layers of rubble stone (Fig. 2d–f). Within the grave was a broken ceramic vessel. Although now lost, it was accurately described by du Chatellier: ‘*this ceramic, made of coarse fired clay, without the help of potter’s wheel, had an handle and was decorated with deep lines forming saw teeth, a pottery very characteristic of the Bronze age*’ (Chatellier 1901b, 6). Such handled pottery is well known in graves in Brittany with examples dated by associated radiocarbon determinations to the Early Bronze Age; domestic contexts point towards the period 1900–1640 cal BC (Briard 1984; Escats 2011; 2013; Blanchet 2016; Pailler and Nicolas 2019). The stone-cist architecture and its large size conforms well with this chronology (Briard 1984).

THE SAINT-BÉLEC SLAB

After the excavation, the slab was moved in August 1900 to Kernuz Castle (Pont-L’Abbé, Finistère), du Chatellier’s home and private museum, whose collection was acquired in 1924 by the *Musée des Antiquités Nationales* held in the Saint-Germain-en-Laye castle (no. 90960; Giot 1997). However, the slab was not registered at that time and we had no assurance that it had followed the rest of the collection. Upon investigation, it turned out that the Saint-Bélec slab had been stored until the 1990s in a niche in the moat of Saint-Germain-en-Laye. It was then moved to one of the cellars of the castle, where we retrieved it.

At Kernuz, the slab was restored, six fragments being cemented in place by filling in some missing parts (Fig. 3a). Two are from the left-central part and probably result from the deterioration of the stone’s surface, the larger one being found within the cist (Chatellier 1900). A further four fragments, corresponding to the missing upper part, were picked up from contexts now unknown (presumably from the grave or the barrow mound), but three of them are now lost again. According to du Chatellier (1901b), the slab weighs between 1.5 and 2 tons and it required no less than fifteen people using rollers and a ramp to move it.

The slab is a grey-blue coloured rock, c.2.2 m long by 1.53 m wide and 16 cm thick. Under polarized light, the groundmass of the rock is dominated by oval-shaped quartz porphyroclasts (< 1 mm), of possibly volcanic origin, aligned parallel to pervasive schistosity (flattening) surfaces outlined by tiny muscovite porphyroblasts (white micas; Fig. 4). These petrographic and structural attributes typically characterize a low-grade metamorphic rock showing close affinities with the Brioverian (pre-Paleozoic) sericite-schists of the Douarnenez Phyllade series that extensively occur south of the highly strained Paleozoic series of Montagnes Noires shear zone (Darboux and Le Gall 1988). From these correlations between the regional geology and the Saint-Bélec slab, it is thus assumed that the latter has a local origin and was not transported any great distance to its final resting place.

METHODOLOGY

The study was conducted using whole slab observations, general and detailed photographs with oblique lighting (Cassen and Robin 2010), and several 3D survey methods (photogrammetry, general and high definition 3D-scanning) to record the surface topography of the slab at different scales and to analyse the morphology, technology, and chronology of the engravings

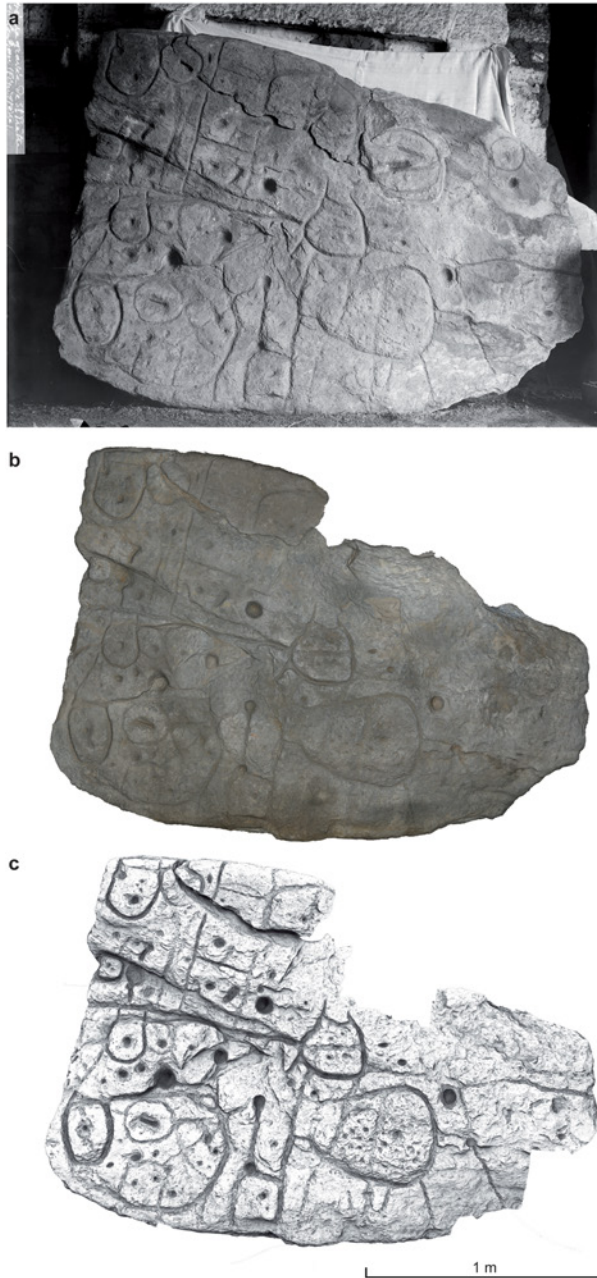


FIGURE 3

(a) The restored Saint-Bélec slab in 1900 by Chatellier (*Archives Départementales du Finistère*); (b) general 3D-model produced using ARTEC EVA (L. Aubry); (c) high definition 3D-model produced using ATOS Compact Scan and processed with Ambient Occlusion (V. Lacombe).

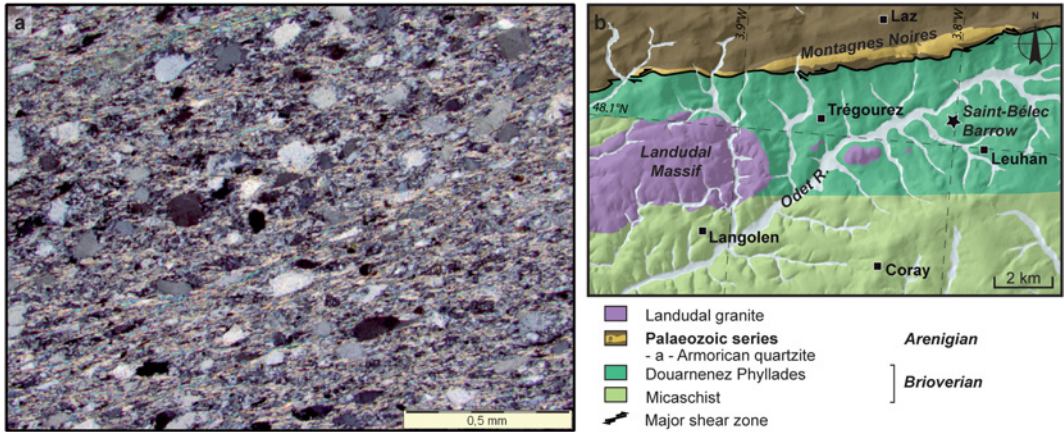


FIGURE 4

(a) Thin section of the fine-grained schist forming the Saint-Bélec slab (oriented orthogonally to the schistosity planar fabrics, crossed-nicol light-source; photograph B. Le Gall); (b) detail of the Gourin geological map (1:50 000) showing the location of the Saint-Bélec slab findspot in the Douarnenez Phyllades series that constitute the material of the carved slab (after Le Gall and Garreau 1988)

(see Supporting Information S11; Fig. S1–S2 and Fig. 3b–c). The generation of a 3D Digital Elevation Map (DEM) from high definition 3D-scanning was the basis for subsequent interpretation and analysis (cf. Cassen *et al.* 2014). Five software visualization techniques based on DEM manipulation methods were used, employing RVT Software to ensure the detection of all the engravings on the slab (Slope gradient image, Multi-Hillshading, Principal Components Analysis Hillshading, Anisotropic Sky-View Factor, and Simple Local Relief Model; Fig. S3). These relative relief processing procedures highlight the various features of the engravings (outlines, morphology, technological traces and overlapping; Fig. 5).

To facilitate the analysis of the engravings, their outlines were traced using vector drawing software (Adobe Illustrator). Due to the cleaved structure of the rock, directional flaking related to the engravings tended to create multiple outlines, especially in cases where they are shallow or intertwined. In such cases, we have retained the steepest delineations, created by repeated pecking or incising. This drawing process was controlled: cross-checking the results being conducted against the various relative relief depictions, as well as going back and forth to detailed photographs with oblique lighting, relief profiles generated from the DEM and direct observations. The early twentieth-century photographs have been manipulated as much as possible in order to fit with the elaborated DEM and to complete the now lost fragments.

DESCRIPTION OF THE ENGRAVINGS

All the engravings are relatively fresh, dark grey in colour, and are associated with sharp and plain flaking of the schistoid fabric. In contrast the original surface is light grey and variously rough or smooth as a result of localized natural weathering (Fig. 5a–b). Together, these features

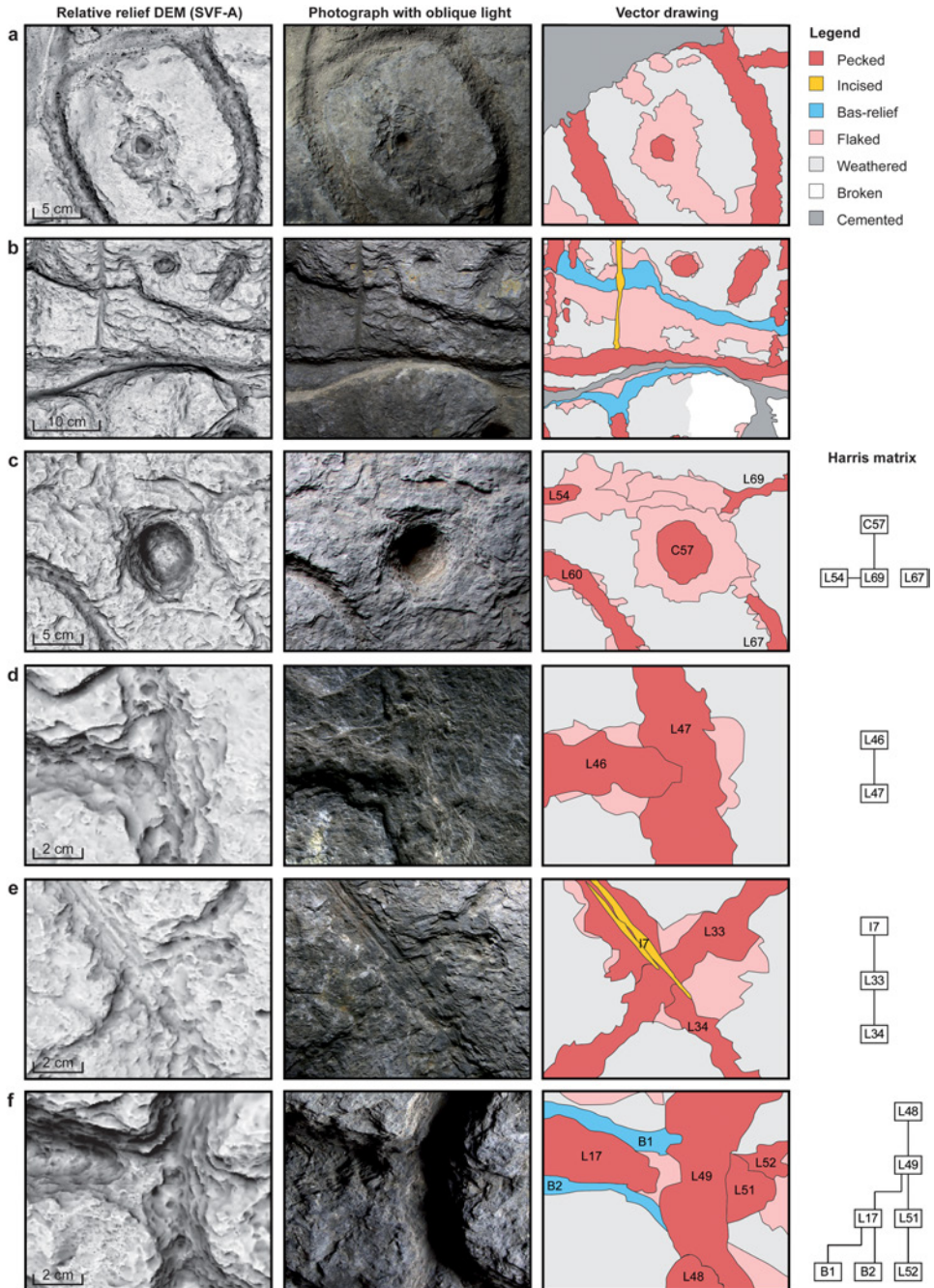


FIGURE 5

(a–b) Examples of surface conditions and (c–f) chronological relationships between engravings of the Saint-Bélec slab highlighted by relative relief processing (Anisotropic Sky-View Factor) of the Digital Elevation Model (DEM, V. Lacombe and P. Stéphan; Photographs and CAD, C. Nicolas).

AN EARLY 3D-MAP OF A TERRITORY?

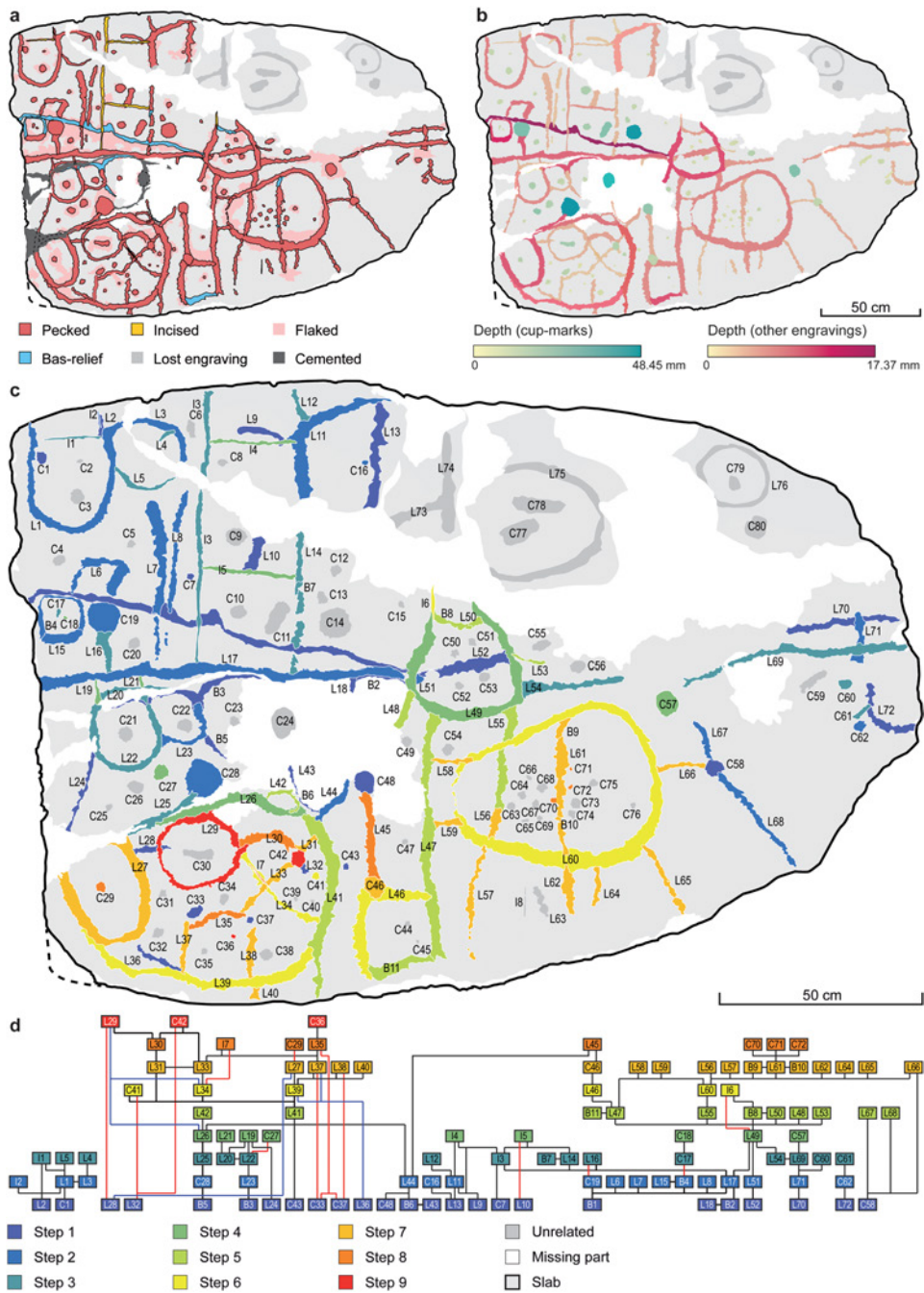


FIGURE 6

(a) Technology, (b) depth, (c) relative chronology and (d) Harris matrix of the engravings of the Saint-Bélec slab (C. Nicolas).

suggest that the carved slab was not exposed to the open air for long. The motifs cut into the surface are relatively uniform and show the repetition of simple geometric shapes: round and oval cup-marks; straight or curved lines; and squares, circles, ovals or other curved forms (Fig. 6). Some associations between certain motifs appear to form recurrent patterns, for example one or more cup-marks included in a closed shape, and cup-marks at line ends or intersections.

Various techniques had been used by the makers of the slab as to how they carved the stone to different depths (Fig. 6a–b): pecked lines (1.5–14.7 mm deep); pecked cup-marks (C) (1.4–48.5 mm); pecked bas-reliefs (3.6–25.3 mm); and incised lines (0.6–6.6 mm). To facilitate the description of the engravings they have been numbered according to their manufacturing technique. As such, 76 pecked lines (L), 80 pecked cup-marks (C), 11 pecked bas-reliefs (B) and 8 incised lines (I) have been identified. Almost all the engravings and bas-reliefs are associated with more or less extensive, directional flaking, which results from the rock splitting while being pecked or incised. Additional flaking seems to have been carried out by pecking at the rock surfaces as is indicated by the resultant impact points, while some other flaking unrelated to the engraving process probably results from rock desquamation (Fig. 6a).

As most patterns are interrelated (114 out of 175), a key issue was to establish their detailed chronology. Some overlaps were obvious, while others required in-depth cross-checking. From this point of view, the schistoid fabric of the rock was advantageous, as it tends to create relatively abrupt terminations and directional flaking. We recorded all direct cross-cutting of any engraved elements (Fig. 5d–f) and the relationships between engravings, when not joined, as indicated by the flaking related to their creation (Fig. 5c). A nine-step sequence in preparing the slab has been recognized, taking into account such overlaps of engravings and related flaking (Fig. 6c). All the relationships between engravings have been summarized in the form of a Harris matrix (Cassen *et al.* 2014; Fig. 6d).

On the left-central part of the slab, a triangular hollow has been carved from the centre to the left end. Its upper and lower edges have been shaped by deep pecking. The upper edge (B1) is peculiarly steep and deep (8.4–25.3 mm). The lower edge (B2/B3) is less perceptible as it has been largely split and then cemented. In between, the surface could be either weathered or freshly flaked by pecking or later engravings (Fig. 5b and 6a). At the left end of the triangular hollow, a squared-shaped bas-relief (B4/L15) has been preserved by the upper edge. The pecked lines and most of cup-marks constitute the main steps of the engraving process. They have been pecked at different stages without any specific order. Nevertheless, some round, large and deep cup-marks located in the middle part appear as quite early features (Fig. 6c).

The main changes are argued to be connected to the two oval-shaped pecked lines. The first one (L39) was filled successively by linear, oval, square or circular signs and cup-marks. The second one (L60) was divided into three parts by two vertical lines and then filled by very small and shallow cup-marks. At some point, its left end seems to have been changed: flakes erased the previous line and in its place were made two short horizontal pecked lines (L58, L59) connecting the oval shape (L60) to a vertical line (L47). Lastly, incised lines were used for adding a cross-linked pattern (I3–I5), closing an open oval shape (I1) or emphasizing some small sections of previous pecked lines (I2, I6, I7).

While there are relatively few blank areas on the decorated surface, there is very little overlap within the motifs, except at their ends where most join other motifs. Therefore, it appears that the successive phases in creating the panel did not significantly change the overall composition but rather added to it in a planned and structured way.

The most spectacular characteristic of the Saint-Bélec slab is its map-like pattern of repeated motifs, joined by a network of lines. The engravings appear rather homogeneous in technique and style, though a few patterns have been modified or added. Indeed, Delano Smith stated three conditions for recognizing prehistoric maps: ‘*that the artist’s intent was indeed to portray the relationship of objects in space; that all the constituent images are contemporaneous in execution; and that they are cartographically appropriate*’ (Delano Smith 1987, 61). The last requirement implies that the signs maintain some degree of correspondence between the motif and the object it is intended to represent or, at least, that there is a frequency of motifs comparable to those to be found on a modern map (Delano Smith 1987).

Among prehistoric maps, Delano Smith (1987) distinguishes the ‘plan topographic maps’, depicted as a bird’s eye view, and the ‘picture maps’, combining elements of the landscape (mountains, rivers, dwellings, *etc.*) in plan, elevation or profile, but also incorporating anthropomorphic or zoomorphic signs. Picture maps appear more like scenarios, in which the landscape is secondary to the event being depicted (Delano Smith 1987, 62). They appear to be the oldest topographical representations. Thus, in Upper Palaeolithic portable art, some engravings are interpreted more or less convincingly as representations of campsites, or even elements of the landscape including rivers and mountains (e.g. García-Diez and Vaquero 2015). But, it is the plan topographic maps that share the most common features with the Saint-Bélec slab.

One early example of map is the well-known wall painting at Çatalhöyük, central Anatolia, Tukey (Fig. 7a). It was found in a building from the level VII of this Neolithic village, dated between 6790 and 6430-cal BC (Mellaart 1964; Schmitt *et al.* 2014). The lower register includes square-shaped patterns, interpreted as plan of a village similar to Çatalhöyük, while the upper register depicts a double-peaked motif that might have figured a volcanic eruption. Indeed 130 km away, the twin peaks of the Hasan Dağı volcano is known to have erupted broadly within this time period (6960±640 BC; Schmitt *et al.* 2014). According to Delano Smith (1987), this depiction should be considered as a picture map, as it mixes both plan topographic representation and a profile of the landscape.

In Europe, the most acknowledged plan topographic depictions are those found in the Alpine rock art, especially in Valcamonica, Italy, and the Vallée des Merveilles, France (Arcà 2016; Huet 2017). The earliest (style II), dated to the fourth millennium BC, show geometric, mainly quadrangular-shaped patterns that are sometimes dotted or cross-linked, and frequently set close to one another. They are considered to represent pastoral systems or cultivated fields, an interpretation supported by their association with ploughing scenes. Later panels (style IV) show more complex representations with dotted squares linked by a network of straight or more sinuous lines: these might represent more scattered settlements and, presumably, more extensive territories (Arcà 2016). In particular the Bedolina Map (Capo di Ponte, Lombardy) consists of *c.*40 squared motifs and some circular or oval shapes, mostly joined by straight, sinuous or zigzag lines, forming a 4.3×2.4 m panel on an outcrop overlooking the middle valley of the Valcamonica (Turconi 1997; Fig. 7b). E. Casti (2018) observed that the outcrop relief has been respected by the engravings: where the surface is plane, lines tend to be straight, while on sloping areas, lines are rather sinuous or zigzag, as paths that wind through mountainous terrain. This suggests that the Bedolina map is not only a planimetric representation but also a 3D-map and the outcrop might have been especially selected for its morphological features in order to represent the desired relief of the surrounding landscape. The latter is supposed to correspond broadly to a mountainous environment or, more

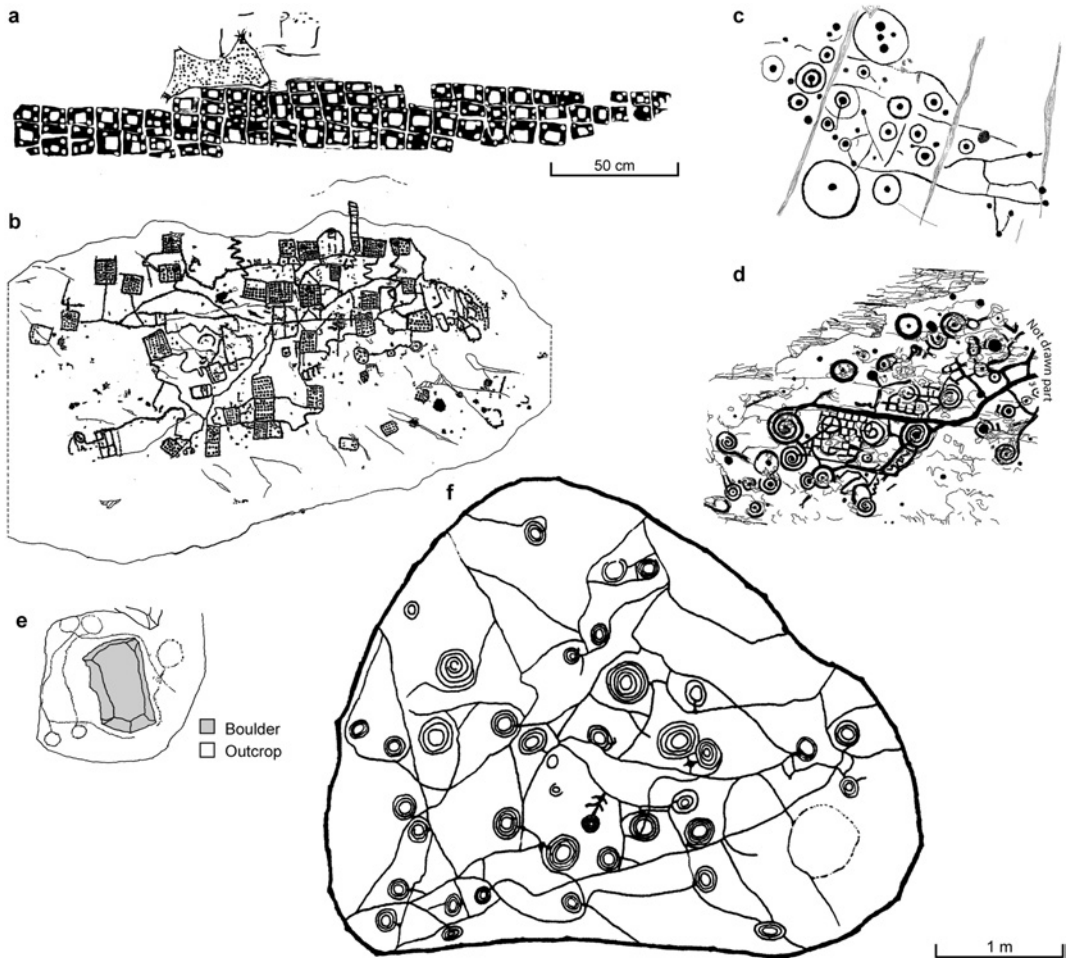


FIGURE 7

Examples of early cartographic representations: (a) Çatalhöyük, Konya, Turkey (after Mellaart 1964); (b) Bedolina 1, Capo di Ponte, Lombardy, Italy (after Turconi 1997); (c) Staigue Bridge, Kilcrohane, co. Kerry, Ireland (after Finlay and Harris 2018); (d) Fornos dos Mouros, Sever do Vouga, Aveiro, Portugal (after Alves 2003); (e) Harmonie, KwaZulu-Natal, South Africa (after Maggs 1998); (f) Lydenburg area, Mpumalanga, South Africa (after Maggs 1998).

specifically, to a local territory, the scale of which remains to be defined (Casti 2018). Although these Bedolina-like maps have long been considered to be Bronze Age in date, recent chronologies for the engravings put them rather later, well into the Iron Age between the seventh and the fourth centuries BC (Arcà 2016). Comparisons with enclosures and field systems in Celtic Europe confirm both the revised dating and the interpretation of the motifs as being related to an agrarian landscape (Brocard 2005).

Westwards, Atlantic rock art may similarly show topographic features, being broadly dated to the fifth to the first millennia BC (Bradley 1997; Bueno Ramírez *et al.* 2007; Cassen 2009).

Crossed-linked patterns are well known in megalithic and open-air art from Iberia to the Anglo-Celtic Isles (e.g. Shee Twohig 1981; Bradley 1997; Hidalgo Cuñarro *et al.* 2005; Cassen *et al.* 2018; Finlay and Harris 2018; Fig. 7c–d). They are repeatedly interpreted as field systems or, at least, as divided and defined areas of land (Cassen and Grimaud 2020). There are also numerous cup-and-ring motifs with one or more concentric rings that are organized in various ways, some of them being joined by a network of lines and/or associated with crossed-linked patterns (Fig. 7d). As early as the mid-nineteenth century, Graves (1873) as well as Greenwell (in Delano Smith 1987) regarded such representations as distribution maps of the ‘forts’ of the area (Fig. 7c). Ever since, various topographic interpretations of the cup-and-rings have been purposed, such as house or grave plans (Bradley 1997). At Fornos dos Mouros on Mount Arestal (Aveiro, Portugal), Alves (2003 and 2012) observed that the carved outcrop, which overlooks the area up to the Atlantic Ocean, seems to reflect the local relief. As with Mount Arestal, the outcrop is a mass of granite emerging from the schist bedrock and has a similar profile. The rock surface itself seems to have been remodelled, removing the outer crust, before being carved. Engravings were organized in three phases in a rather planned way, with the addition of new motifs that respected the previous executed ones (crossed-linked patterns, then circular motifs, and finally a network of lines; Fig. 7d).

Across the world, rock art shows some similarities with prehistoric topographic maps in Europe. In South Africa, Maggs (1995 and 1998) recorded several rock panels depicting simple or concentric rings or more complex circular motifs that might be linked by networks of lines (Fig. 7e–f). This art is thought to be related to agro-pastoralists, who reached the region in the first millennium BC. The engravings frequently exploit the relief of the outcrops, especially in the KwaZulu-Natal region, with zigzagging lines on slopes, similarly to the Bedolina Map, or with motifs set around a boulder (Fig. 7e). Local people consider that these engravings depict the settlements of their ancestors, an interpretation which is supported by close similarities with archaeological structures (Maggs 1995). In the United States, several depictions of sinuous or meandering lines, associated or not with geometric or zoomorphic patterns, are thought to represent river systems (Lewis 1998; Dockal and Smith 2005). The most convincing example is undoubtedly the Shoshoni stone (Idaho) which is interpreted as the representation of the middle and upper valley of the Snake river and the surrounding landscape stretching for over 600 km (Lewis 1998). Further parallels might eventually be found in the Aboriginal art of the Panaramitee tradition in Australia. This rock art style was produced from the Upper Palaeolithic to the twentieth century (Bednarik 2010) and includes repeated geometric motifs, straight or sinuous lines, as well as animal and human footprints (Franklin 2007). Aboriginal people who still practice similar art recognize in this rock art cosmogonic representations of the ‘Dreamtime’, figuring the journeys of the ancestors and the landscape they created; as such, they should be regarded as mapping and explaining the landscape (Flood 2004).

The cartographic interpretation of these prehistoric depictions is far from consensual, especially the Çatalhöyük wall painting, which has been criticized by Meece (2006). She considered that it was very unlikely that such a small-scale society without writing was able to produce bird’s eye view map, as ‘*the process of actually making a map, including reducing a space, constructing analogies between two-dimensional and three-dimensional space, and representing distant features is a significant development of abstract thinking and symbolic representation*’ (Meece 2006, 9). According to her, ‘proper’ topographic maps in plan view do not appear before the third millennium BC in Mesopotamia with the city-states, where several building, town and cadastral plans are known (Millard 1987).

However, this evolutionist view is contradicted by literature produced by early explorers and through ethnographic research. Early accounts of the North Amerindians testify that they used portable two-dimensional maps made of birch bark, skin or hard animal materials, depicting roads, river systems, landing places and mountains (Lewis 1998). In Africa, ground maps besought by explorers attest that indigenous peoples were able to draw precise maps covering more than 200 km through the thick tropical forest, while the Tuareg could map the main towns across the Sahara (Bassett 1998). In the 1960s and later in the 1990s, Bernus (1988 and 1995) asked several Tuareg from Niger and Mali to draw mental maps of their regions (Fig. 8a–b). The maps thus produced were more or less accurate, depending on social class, but all of them depicted the fossil river network and water sources over a distance of several tens of kilometres. Similarly in the 1990s, Wassmann (1993) conducted a mapping experiment among the Yupno in eastern Papua New Guinea. They had been reached by missionaries in 1928, leading to the merging of formerly scattered hamlets into villages for the sake of evangelisation. Although they were not accustomed to making maps, 28 people were asked to draw on the ground the territory where they lived. The elders, who never left the valley, in particular drew the world as enclosed by an oval of steep-sided mountains, in the middle a river and possibly its tributaries made of lines, and, on both sides, repeated patterns of ovals, punctual signs or lines representing palisaded villages (Fig. 8c).

These examples from around the world show, *contra* Meece's views, that 'small-scale societies', although they are no longer cut off from the Western world, have no difficulties in representing their environment in two dimensions and mapping it over distances that go beyond the needs of everyday life – from a range of ten kilometres to the extreme case of the Tuareg who are able to map a large part of the Sahara. Among prehistoric and ethnographic maps, some common features can be highlighted: maps are frequently river-centred, depicted by a series of lines, while both manmade and natural landscapes are figured by repeated geometric patterns

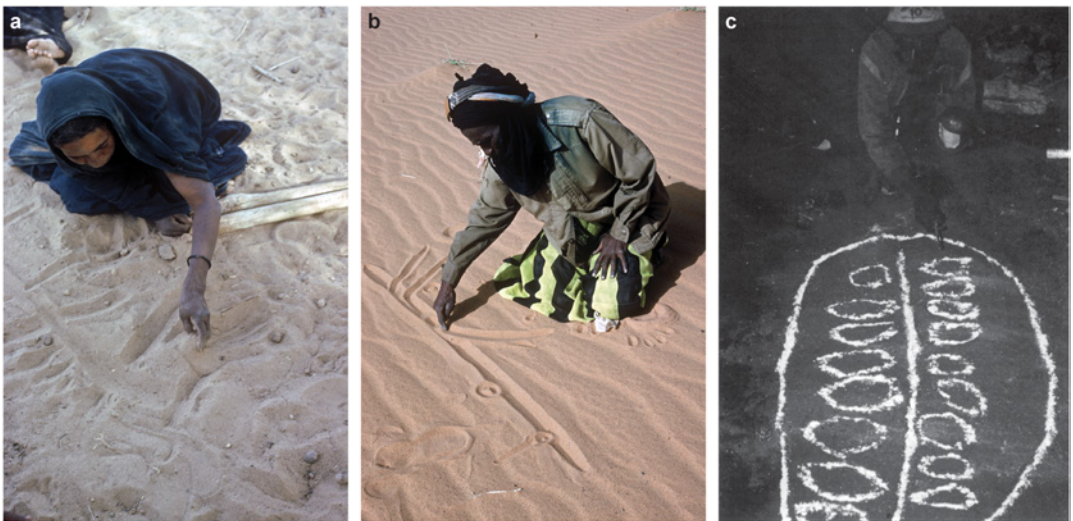


FIGURE 8

Examples of solicited ground maps in the 1990s among (a–b) the Touaregs in Mali (©IRD – Edmond Bernus, <http://www.indigo.ird.fra>) and (c) the Yupno in Papua New Guinea (after Wassmann, 1993).

(circles, squares, dots). Another feature of several prehistoric maps is that engravers use, even modify, the three-dimensional morphology of the rock ‘canvas’ to depict the topography of the surrounding landscape. All these characteristics appear on the Saint-Bélec slab.

AN EARLY BRONZE AGE 3D-MAP

The Saint-Bélec barrow overlooks the upper valley of the Odet river which is oriented approximately 70°N (Fig. 1a and 9b). This relatively steep-sided valley opens to the west at a fairly

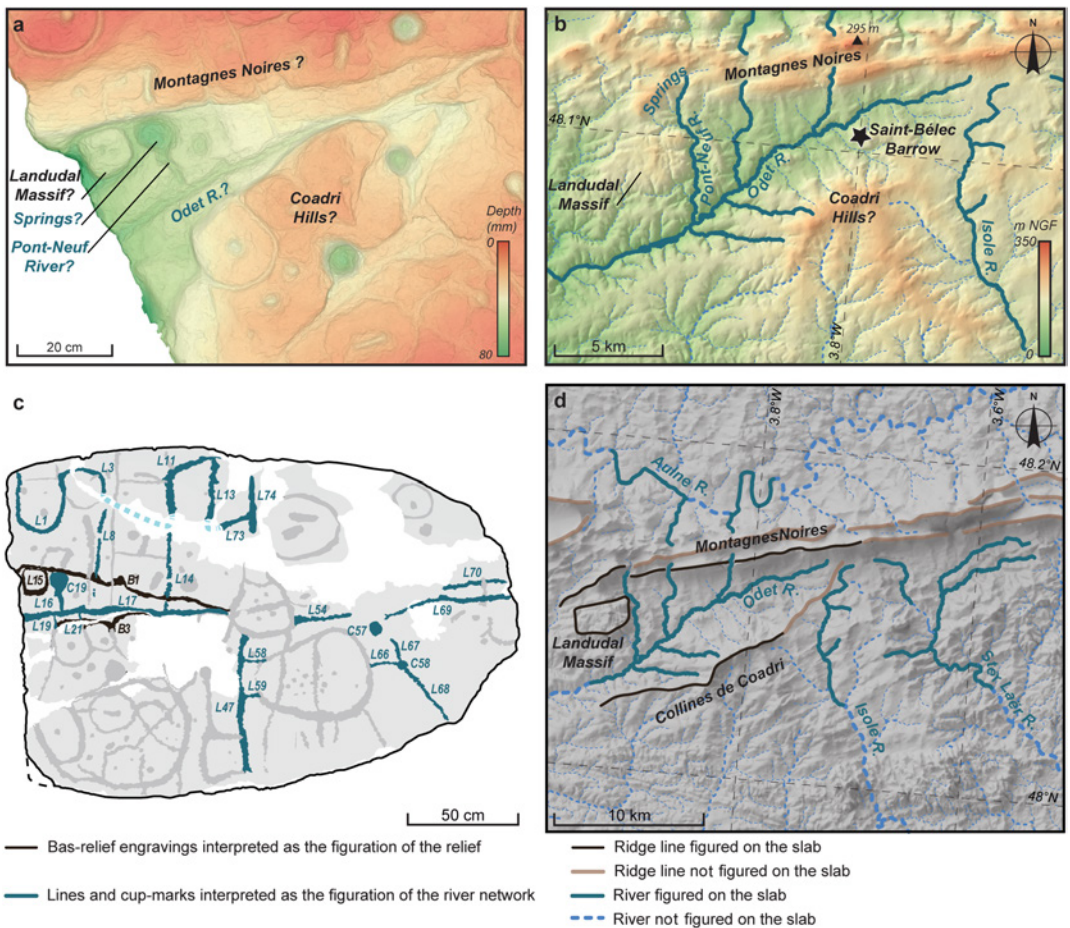


FIGURE 9

Comparison between the engravings of the Saint-Bélec slab and the topography of the *Montagnes noires* area: (a) zoomed DEM view of the carved triangular hollow on the left-central part of the Saint-Bélec slab to be compared with (b) the topography around the Saint-Bélec Barrow; (c) interpretation of some engravings as the figuration of the relief and the river network to be compared with (d) the relief and river shapes of the *Montagnes noires* area (background maps Institut Géographique National; a, V. Lacombe and P. Stéphan; c, CAD, C. Nicolas; d, map P. Stéphan).

acute angle (21°N); it abuts northwards and southwards against the linear and N80°-oriented relief of the *Montagnes Noires* and the Coadri Hills respectively. The Landudal granitic massif, a square tabular relief, slightly tilted towards the *Montagnes noires*, encloses the landscape to the west. The valley's shape nearly corresponds to the carved triangular hollow (B1–B3), which has roughly the same angle, the square bas-relief (B4/L15), and the horizontal central line (L17) that seemingly represents the course of the river (Fig. 9a). In addition, a large cup-mark (C19) and the related line (L16) joined to the horizontal central axis (L17) might represent the springs and the course of a tributary (Pont-Neuf river) of the Odet river. Further lines might represent the surrounding rivers: the Aulne river and its meanders (L1/L3, L11/L13 and L73/L74), the Isole river (L47) and the Stér Laër river (L67–L70) and some of their respective tributaries; further, some cup-marks (C57 and C58) might correspond to confluences (Fig. 9c–d).

To assess the degree of similarity between these engravings and the river network and the relief, several network and shape analyses have been carried out (see Supporting Information SI2). The results show a quite good statistical correspondence (up to 80%; Fig. S4), equivalent to those obtained for mind maps among the Tuareg and the Yupno (Fig S5 and Fig S6). Such striking correlations give the opportunity to at least approximately georeference the slab and define the scale of the space represented: an area *c.*30 km long and 21 km wide (Fig. S7 and Fig. 10c).

The main matter surrounding the dating of the Saint-Bélec slab is its re-use. Stylistically, the motifs are quite different from those found in the regional traditions of 'megalithic' art (Pailler and Nicolas 2016) and therefore rule out the re-use of a Neolithic carved slab. This is also supported by the freshness of the engravings which implies a relatively short time-span between their creation and the subsequent burial of the slab.

Several motifs on the Saint-Bélec slab can be echoed in archaeological structures dated to the Early Bronze Age. The cup-marks of various sizes (1–10 mm in diameter) find correspondence with the distribution of Early Bronze Age barrows that are known to range in size from 5 to 60 m in diameter (Briard 1984; Fig. 10a–b). A significant number of them are located along the so-called 'Roman roads', some of which can be dated back to the Bronze Age (Leroux 2015). In the Saint-Bélec area, the Tronoën–Trégueux road (Éveillard 2016) is bordered by several barrows and might correlate with some pecked lines (L48, L52, L53? and L26?). Other alignments of round barrows in the area, perhaps secondary routes, could correspond to some pecked lines on the slab (e.g. L11/L14, L31/L33/L44).

Above all, the shape of the central pattern (L49) resembles a large curvilinear Early Bronze Age settlement enclosure excavated at Lannion (Brittany). Covering 3.7 ha, the boundary earthwork included a substantial ditch up to 3 m wide and 1.7 m deep. The enclosure opens out to the south-west towards a small barrow cemetery set in line with a 'Roman' road (Escats 2011; 14; Fig. 11a–b). Interestingly, the La Motta barrow situated in front of the entrance at a distance of 1 km contained a richly furnished grave typical of elite burials at the time (Butler and Waterbolk 1974). The enclosure was built *c.*1900 cal BC, contemporaneously with the related elite barrow (Escats 2011; Nicolas 2016). This settlement neatly matches the central motif on the Saint-Bélec slab, which lies amid a dense network of lines (roads?), and is surrounded by a series of cup-marks (barrows?). Squared and cross-linked motifs might represent field systems, some of which date back to *c.*2000 cal BC in north-west France (Marcigny 2012; Blanchet *et al.* 2019). Archaeologically they consist of relatively deep straight or sinuous ditches, orthogonally organized, and sometimes quite extensive (Fig. 11c–d).

To sum up, the carved surface of the Saint-Bélec slab is interpreted as representing the local topography while the superimposed motifs appear to show the recorded distribution of Early Bronze

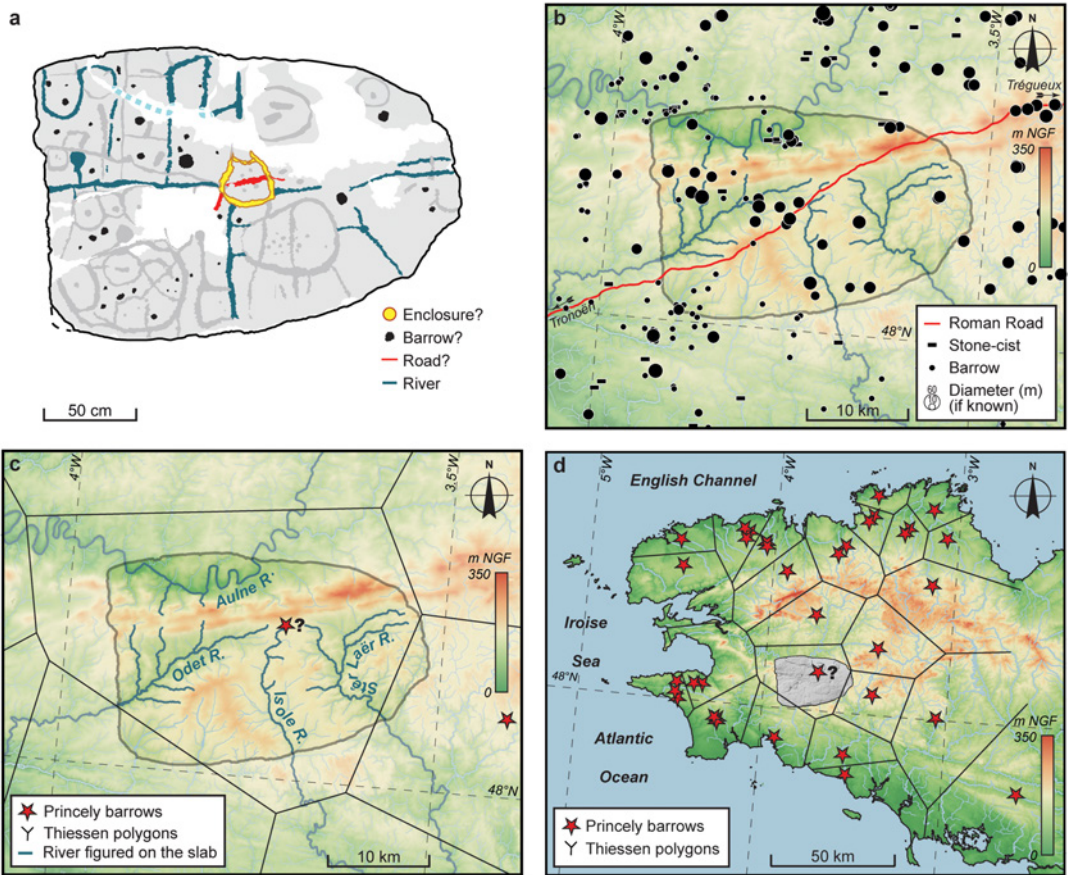


FIGURE 10

The Saint-Bélec slab as the map of an Early Bronze Age territory in Brittany: (a) interpretation of some engravings as the depiction of the river network and human landscape (enclosures, barrows) to be compared with (b) early Bronze Age structures known in the *Montagnes noires* area; (c) comparison between the georeferenced extent of the Saint-Bélec slab and the corresponding theoretical territory, drawn from a postulated princely centre in the middle of the springs of the Odet River, Isole River and Stër Laër River; (d) map of the princely barrows and their corresponding theoretical territories in Brittany (background maps Institut Géographique National; a, CAD C. Nicolas; b: barrows according to Fily 2008 with updates, 'Roman road', DRAC/SRA Bretagne; c–d, maps C. Nicolas).

Age settlements, barrows, field systems, and tracks. Some elements are more difficult to interpret, but might represent further components of the local landscape, for example springs, tributaries or folds in the landscape, or additional anthropogenic structures. Taken as a whole the carvings seem to show two scales of representation: one which is fairly realistic figuring the general topography; the other one, slightly magnified, shows pieces of the anthropogenic landscape. This is a trait of map-making also seen on large-scale medieval maps (Harvey 1987), and means that physical distances between the places depicted have been shortened because of the exaggerated scale of the symbols.

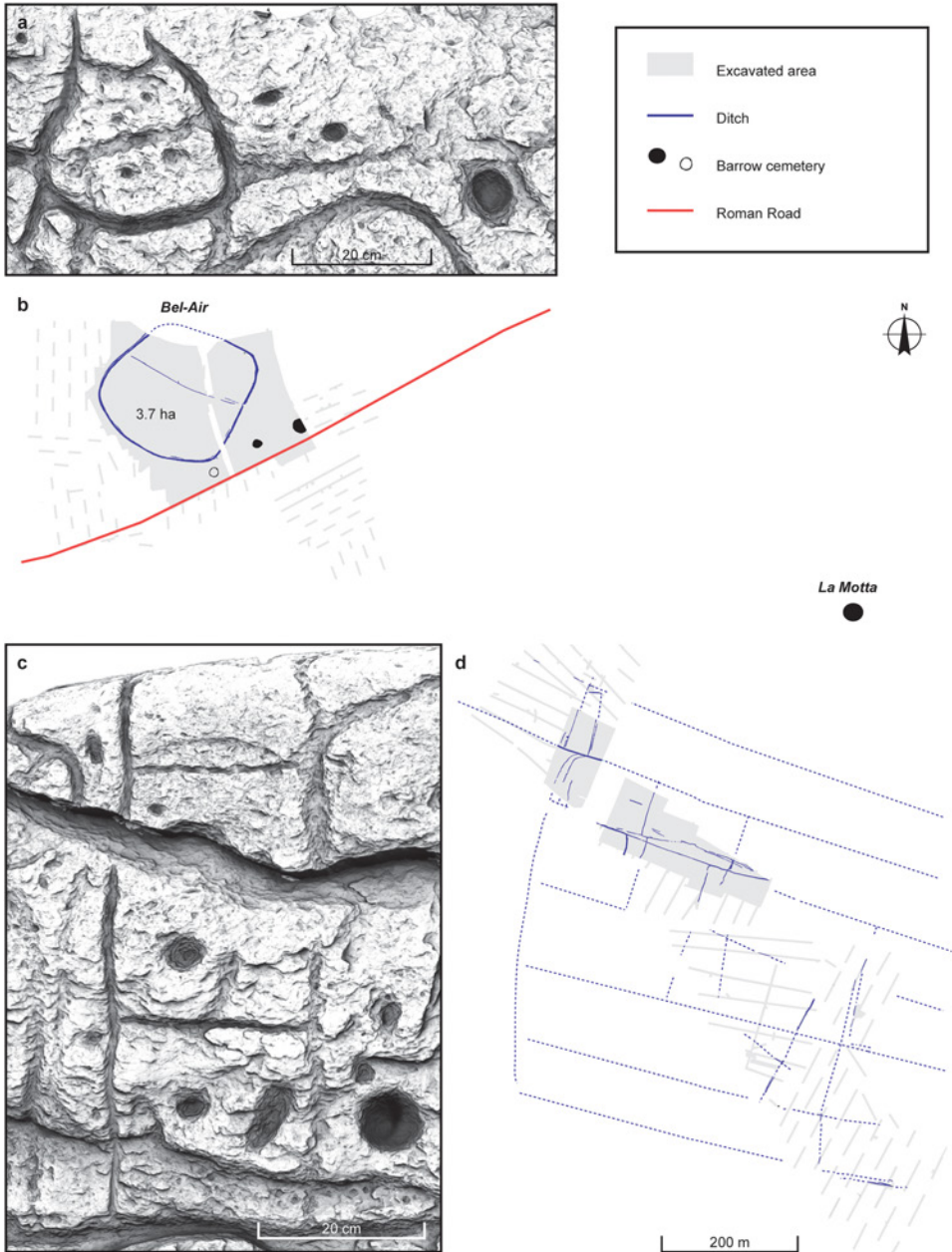


FIGURE 11

Comparison between some carved patterns of the Saint-Bélec slab with Early Bronze Age enclosure (above) and field-system (below) in north-west France: (a) central pattern and adjacent pecked lines and cup-marks of the Saint-Bélec slab (V. Lacombe); (b) Bel-Air enclosure, Lannion, Côtes-d'Armor (after Escats 2013); (c) cross-linked pattern of the Saint-Bélec slab (V. Lacombe); (d) Cairon field system, Calvados, excavations C.-C. Besnard-Vauterin and D. Giazzon, Inrap (after Marcigny 2019).

A MAP OF A POLITICAL ENTITY?

The fact that the Saint-Bélec slab was engraved on its whole surface while modifying it to reflect the local topography suggests that the carver(s) intended to represent a well-defined portion of land. Yet, the Early Bronze Age in Brittany is well known for its large number of barrows and stone-cists (over 3000), and its elite burials showing a strong social and spatial hierarchy (Nicolas 2016; see Supporting Information SI3). These elite burials are regularly distributed in western Brittany, and are assumed to reflect the centres of established territories (*c.*160–1600 km²) that can be modelled using Thiessen Polygons (Brun 1998; Nicolas 2016; Fig. S8). Such assumptions find additional support from the association between the well-furnished La Motta barrow and the Lannion enclosure that could have acted as a central place. The location of the elite barrows along roads or overlooking estuaries suggests that controlling long-distance movements and the flow of trade and exchange was important (Needham 2009).

Unfortunately, few archaeological excavations have so far been carried out in the Saint-Bélec countryside. Nevertheless, the interpretation of the central motif (L49) as a central place associated with a high-status burial under a large round barrow is supported by analogy with the recorded evidence at Lannion. Thus, taking the centre of the territory figured on the Saint-Bélec slab and drawing a Thiessen polygon around it produces an interesting result (Fig. 10d). The outlines of both the territory depicted on the slab and the theoretical territory predicted by the Thiessen polygon match roughly at several hundred square kilometres in size (respectively 843 and 545 km²). As a result, we can reasonably infer that the map on the Saint-Bélec slab refers to an established territory or polity of some kind.

DISCUSSION

The Saint-Bélec slab is not particularly unusual among prehistoric maps. What is so is the opportunity it affords to provide an idea of the scale of such representations. While early depictions of the topography and the social uses of the landscape have been recognized in Alpine rock art, further map-like engravings, particularly in Atlantic Europe, would undoubtedly deserve a closer examination of their relationship with their rock surface and their surrounding environment. In north-west Europe, the Saint-Bélec slab appears to be contemporary with the Nebra skydisc found in central Germany (Meller 2010), although its chronology has been controversially challenged (Gebhard and Krause 2020; Pernicka *et al.* 2020). Buried about 1600 BC and attributed to the Únětice culture, the bronze disc (*c.*30 cm in diameter) appears to show a map of the heavens with celestial bodies picked out in gold. The disc and its wider context suggest a hierarchical social organization and an economy based on land and the control of trade, much like that in Brittany (Bartelheim 2009; Meller 2019). In both regions, Early Bronze Age social organizations collapsed or drastically changed around 1600 BC (Risch and Meller 2015). At almost the same time, at either end of western Europe, two communities symbolically buried images of the natural world (land and sky). Both suggest the end of attempts by elite groups to harness power through controlling elements of the natural world in which they lived.

One outstanding question about the Saint-Bélec slab is why it was made. It is conceivable that there was a mythological, cosmogonic or religious discourse attached to it, but such dimensions have been irretrievably lost. One possibility, following Arcà (2004) and Casti (2018) in relation to Alpine rock art, is that such a territorial depiction was a material and symbolic act enforcing ownership. Set alongside the contemporary development of field systems

in Brittany, the making of the slab perhaps suggests the appearance of a new form of land tenure (Brun and Marcigny 2012), while the distribution of elite graves is closely linked to soil fertility (Nicolas 2016). Against this background we can hypothesize that the Saint-Bélec slab was used as either a medium asserting authority over the territory or as a tool for managing the territory and controlling land, like a cadastre. Something similar was happening in the Near East during the third and second millennia BC where early cadastral plans on clay tablets seemingly gave the land owners' names (Millard 1987). Despite the different postulated socio-economic contexts — emergent states in the Near East (Scott 2017) as against chiefdom-based systems in temperate Europe (Brun 1998; Earle 2002) — similar concerns clearly came to the fore. This all leads to the obvious conclusion that closer attention needs to be paid to the meaning and reading of rock-art panels elsewhere in north-west Europe and the relationship they bear to social organization.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table S1. List of the photogrammetric dataset of the Leuhan Slab.

SI1– METHODS

SI2– NETWORK AND SHAPE ANALYSES AND GEOREFERENCING OF THE SLAB

SI3–THE EARLY BRONZE AGE IN ARMORICA

FIGURE S1. Photogrammetry and general scanning of the Saint-Bélec slab. (a) Photogrammetric 3D-models of the front face (left) and the rear face while lifting (right). (b) General 3D-model acquired by ARTEC EVA device. (c–d) Details of the general 3D-model (L. Aubry).

FIGURE S2. 3D-scanning of the Saint-Bélec slab with ATOS Compact Scan. (a) 3D-scanning of an area of c. 30×30 cm in process. (b–d) The 3D-model and zoomed views of the same area, showing the planar schistosity fabric (a, P. Stéphan; b–d V. Lacombe).

FIGURE S3. Various visualizations of the Saint-Bélec slab obtained by relative relief processing of the Digital Elevation Model. (a) Slope gradient image. (b) Multi-hillshading (MHS). (c) PCA Hillshading (PCA-HS). (d) Anisotropic Sky-View Factor (SVF-A). (e) Simple Local Relief Model (SLRM) with 20 mm radius superimposed with Slope gradient image (P. Stéphan).

FIGURE S4. Network and shape analyses comparing the relief and the river network depicted on the Saint-Bélec slab to those of the *montagnes Noires* area. (a) Jaccard distance, (b) Mantel test, (c) Pompeiu-Hausdorff distance, (d) Wilcoxon test (Slab DEM: V. Lacombe and P. Stéphan; background maps: IGN; CAD: J. Pierson).

FIGURE S5. From solicited mind map to network analysis: a Tuareg case. (a) Reproduction of a map drawn by Kili ag Najim, Illabakan chief's son, Niger, 1960s. (b) map of the corresponding river network. (c) network analysis (Jaccard distance) comparing the river network of the ethnographic solicited map to the local topography (a, after Bernus 1974; b, CAD C. Nicolas after OpenStreetMap and Bernus 1974; c, CAD J. Pierson).

FIGURE S6. From solicited mind map to network analysis: a Papuan case. (a) Reproduction of a map drawn by an elder Yupno, Papua New Guinea, 1990s. (b) map of the corresponding relief and river network. (c) network analysis (Jaccard distance) comparing the relief

and river network of the ethnographic solicited map to the local topography (a–b, after Wassmann 1993; c, CAD J. Pierson).

FIGURE S7. Control points and georeferencing of the Saint-Bélec slab (DEM: V. Lacombe and P. Stéphan; background map, *Institut Géographique National*).

FIGURE S8. Early Bronze Age chief's graves and theoretical territories in northwestern France and Channel Islands (background map, *Institut Géographique National*).

FIGURE S9. The grave goods of the La Motta Barrow (Lannion, Brittany), including bronze daggers and axes, a large whetstone or touchstone, a gold-sheet bracer and finely shaped 'Armorican' flint arrowheads. This is a good example of a richly furnished elite burial in northwestern France. *Musée d'Archéologie Nationale, Saint-Germain-en-Laye*. © C. Nicolas.

AN EARLY 3D-MAP OF A TERRITORY? THE BRONZE AGE CARVED SLAB FROM SAINT-BÉLEC, LEUHAN (BRITTANY, FRANCE)

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SI1– METHODS

The study of the slab was conducted using several 3D survey methods to record the surface topography of the slab at different scales and to analyse the morphology, technology, and chronology of the engravings.

Photography

Following the methodology developed by Cassen and Robin (2010) to study megalithic art, many photographs were taken from fixed stations with several oblique lights in order to highlight the outlines of the engravings and superimpose their drawing. The storage conditions (dark cellar with low ceiling, lying slab), quite similar to those of caves or megalithic graves, hindered good quality vertical shots of the whole object. We therefore favoured close-up shots, divided into eight distinct zones, using a Canon EF-S camera (18-55 mm f/3.5-5.6 IS) mounted on a tripod. Up to 98 shots were taken for each of the eight zones. As most patterns are deeply interrelated, the optical distortions between these sets of photographs proved too important to assemble the eight zones and draw the outlines of the engravings. However, all these photographic documents have proved essential for analysing the state of the surfaces or the details of the engravings.

Photogrammetry

Photogrammetry was used for the whole slab and was quick to implement, something which was especially helpful when working on the back face of the slab as for this the whole piece had to be lifted.

In order to create a 3D-model by photogrammetry it is necessary to photograph the object of study from different perspectives with large overlapping areas between shots. The photogrammetry software used the similarities between the images to reconstruct the three-dimensional geometry of the object. For the Saint-Bélec slab, accessibility to the slab was the main difficulty. It was necessary to make the engraved face accessible to photogrammetry shots.

As the slab weighs approximately two tonnes the first mosaic of images was made on the rear face when it was lifted. Coverage of the engraved face was carried out when the slab was placed horizontally on pallets.

The photographic mosaic was made with two digital cameras (Canon EOS 70D at 20 Mpixels and a Nikon P520 at 18 Mpixels for vertical shots). The light was best controlled by diffused white light illumination via four light boxes. Finally, on a more experimental basis, three series of photographs were taken using three orientations of oblique lighting in order to exaggerate the relief of the engravings and to verify the impact of light oriented towards photogrammetric analysis (Fig. S1).

Photogrammetry consists in developing a 3D-model from photographic pictures. Thus, the model obtained reflects the geometry of the photographed object and not its dimensions. In order to overcome this problem, photogrammetric targets have been placed near the slab and allow the sizing of the generated models as well as measurements during the operation. During this phase, different data sets with 40–220 photographs each were acquired (Table S1).

Dataset	Camera	Number of photographs	Slab position	Face	Lighting
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D2V	Canon EOS 70D	146	Vertical	Rear	Diffuse
D2R	Canon EOS 70D	220	Horizontal	Front	Diffuse
D2R	Coolpix p520	40	Horizontal	Front	Diffuse
D2R_ER1	Canon EOS 70D	67	Horizontal	Front	Oblique
D2R_ER2	Canon EOS 70D	84	Horizontal	Front	Oblique
D2R_ER3	Canon EOS 70D	141	Horizontal	Front	Oblique

Table S1. List of the photogrammetric dataset of the Saint-Bélec slab.

The data were processed using Photoscan Pro software (Agisoft) at the UMR 8215 (Nanterre, France) photogrammetric computing stations into as many models as data sets. The models have a dimensioning accuracy ranging from 30mm (for the less precise) down to a few mm (for the more precise). The model of the carved front face was obtained with the dataset acquired with Canon EOS 70D under diffuse lightning conditions. The photogrammetric model was calculated from the 220 photos of the dataset and is composed of almost 6 million faces for 3 million vertexes.

General 3D-scanning

To complement the photogrammetry, the research laboratory Trajectoires (CNRS, UMR 8215) used a 3D-scan device EVA from ARTEC, owned by the Labex Dynamite. This portable scanner has structured light projection to predefine patterns on the object with a white flash light. With two cameras, the device measures the deformation of light produced by the shape of the object and models it. In contrast to the photogrammetry process, this device sizes the object of study directly, so a topographical protocol is not necessary to avoid errors. Furthermore, this device has its own source light so there is no need of external light to obtain the texture of the object.

In the 3D data recording of the Saint-Bélec slab, the operator manually passes the device across the surface at a distance of about 0.5m. The device acquires data at 16 frames per second and the operator verifies on the control screen the scanned zone to minimize the blind areas. Regarding the dimensions of the slab and the movement constraints, ten datasets were acquired to achieve a global registration without blank areas.

Post-processing consists mainly in erasing outlier points and noise from the datasets and combining all of them by semi-automatic shape recognition process to produce the final model. In this case the model produced has a resolution of 0.5mm with given precision of 0.1 mm (about 4pts/mm²).

High definition 3D-scanning

A second and much finer 3D-scanning process was carried out by one of the author (V.L., DIGISCAN3D) using 3D Metrologic Industrial measuring equipment such as GOM ATOS Compact Scan 5M (shape recording) to provide the best results currently available on the 3D measurement and control market (Fig. S2).

Based on stereographic images and phase-shift analysis, this device allows the accurate full-field, high-density, recording and measurement of all the points that make up the surface of a given structure. The ATOS Compact Scan scanner allows all the surfaces of an intricate 3D-structure to be measured in the field without any contact. By simply changing the measurement

volume, the sensor can measure surface differences up to 0.05mm. Depending on the chosen measurement volume, this sensor allows the acquisition of clouds of dense points (5pts/mm²) to very dense points (3400pts/mm²). This level of detail allows most planar structures (including schistosity fabrics) to be recorded, while morphological features as well as the chronology of the engravings are also accurately depicted (Fig. S2b–d).

In order to ensure the quality of the measurements, a calibration of the instruments was carried out at each step of the process, determining the intrinsic and extrinsic geometric characteristics of the devices and ensuring that deviations are known, constrained and minimal. Calibration of measuring systems, which is monitored in real time, allows accurate, precise and exhaustive measurements. The quality of the data is known during the acquisition operations, as well as the overall measurement uncertainty.

In the course of 3D-scanning, the device was calibrated in *c.*0.3×0.3m measuring volume, which allows a 75pts/mm² density (up to 8 million points have been recorded). The system was then faced to the surface to measure and was moved as many times as necessary to scan the whole slab (Fig. S2a). Each acquisition required to have a sufficient overlap surface with the previous position. So, it can be realigned within the global 3D bundle thanks to the homologous surfaces recognition algorithm of the system measurement, while the software, GOM ATOS Professional, instantly generates a 3D preview mesh.

Unfortunately, some parts of the slab could not be integrated into the 3D-model as they were too flat (weathered or broken surfaces) and didn't provide sufficient information, like engravings or bumps, for analysing overlaps and recognising homologous surfaces. Thus, all the engravings have been 3D-scanned but some peripheral areas (upper break, right bottom corner) were not. A larger measuring volume would have provided more space for recognising homologous surfaces and scanning the whole slab. However, the 3D-model would have lost in resolution and point density and, therefore, hindered the study of engravings.

Digital Elevation Map and visualization techniques

Point cloud produced from high definition 3D-scanning (in *.xyz format) totalize a number of 35.106 points corresponding to a mean spatial density of 13.9pts/mm² homogeneously distributed over the slab. In order to optimize the processing time, the data volume and the use of visualization tools, the point cloud was integrated into a single spatial model by rasterizing the (x, y, z) data. Surfer 9.0 software was used to import and process the (x, y, z) data. The generation of a 3D Digital Elevation Map (DEM) was the basis for subsequent interpretation and analysis. The kriging interpolation method was used to generate a regular 0.5×0.5mm grid. The grid resolution was adapted to the density of the point cloud to avoid aggregation (or upscaling) and/or disaggregation (downscaling) of the micro-topographical information (Hengl 2006). The pixel size is considered as suitable enough to capture the micromorphological details by the output DEM.

Five visualization techniques based on DEM manipulation methods were used from RVT Software (Kokalj *et al.* 2011; Zakšek *et al.* 2011) to ensure the detection of the overall engravings on the slab:

1. Slope gradient image was calculated from the DEM and represents the maximum rate of change between each cell and its neighbours (Kokalj *et al.* 2011; Zakšek *et al.* 2011). Cell values are expressed in percentage of slope (from 0 to 1). The representation of the relief is

given by applying an inverted greyscale scheme (steep slopes are darker). Additional information is generally needed to distinguish between convex (e.g. bumps) and concave (e.g. engravings) features. Consequently, slope gradient was combined with the other images by applying a transparency degree (Fig. S3a).

2. Multi-hillshading (MHS) image was based on a relief shading method emphasizing features that are obliquely illuminated in several directions. The multi-hillshading method was preferred to the single hillshading method which tends to hide features that are illuminated along the perpendicular axis. The MHS image used in this study combines a set of 16 images produced from 16 different directions of the illumination source (from 0° to 360°). The sun elevation angle used is 35° (Fig. S3b).

3. Principal Components Analysis Hillshading (PCA-HS) image statistically summarizes the information of 16 relief images, shaded with evenly distributed illumination sources which are correlated between them using a PCA. The sun elevation angle used is 35°. A false colour composite image in RGB is produced from the first three components of the PCA analysis (first component in the red band-R, second component in the green band-G, third component in the blue band-B). This shading method simplifies the interpretation of multiple shading data (Devereux *et al.* 2008; Fig. S3c).

4. Anisotropic Sky-View Factor (SVF-A) image corresponds to a supplementary analytical hillshading method used to address the shortcomings of relief shading (directional illumination source) by diffuse illumination relief shading models (Zakšek *et al.* 2011). Sky-View Factor is a measure for the portion of the sky visible from a certain point. The portion of the visible sky limited by the relief horizon corresponds to the relief illumination (e.g. a bump is more illuminated than the bottom of a steep engraving). Anisotropic Sky-View Factor assumes that the sky is brighter in some directions than in others. Three parameters need to be set (Kokalj *et al.* 2011; Zakšek *et al.* 2011): the azimuth of the highest weight, the exponent defining the gradient from maximal to minimal weight (level of anisotropy), and the minimal possible weight. The weights are based on the cosine function of half angle (Zakšek *et al.* 2011). The SVF-A image produced in this study used a low anisotropy level with a minimal weight of 0.4 and an exponent of 4. For each cell of the raster image, the Anisotropic Sky-View Factor was calculated using a search radius of 10 pixels and a number of search directions of 16. The main direction of anisotropy was 315°N. Cell values of the SVF-A image ranges from 0 to 1. Values close to 1 mean that almost the entire hemisphere is visible, which is the case in exposed features (planes and peaks), while values close to 0 present lower parts of deep engravings from where almost no sky is visible (Fig. S3d).

5. Simple Local Relief Model (SLRM) images (also called ‘deviation map’; Cassen *et al.* 2014) were produced by a trend removal procedure that separates local small-scale topographic features from large-scale forms. The procedure first calculates a trend DEM (also called ‘smoothed elevation model’) by resampling to a lower resolution and then subtracts it from the original DEM, producing a local relief model (LRM). The process of DEM generalization used by the RVT Software is based on a low pass convolution filter calculating the mean (z) value within a pre-defined radius (Kokalj *et al.* 2011; Zakšek *et al.* 2011). Authors recommend adapting the calculation radius according to the size of the small-scale features to be detected (Hesse 2010). In this study, we tested 6 different calculation radius (5, 10, 15, 17.5, 20, 22.5mm) because of the various sizes of engravings and bumps on the slab. Finally, we used the SLRM image produced with a radius value of 20mm because it proposes the best fitting with the microtopographical features of the slab (Fig. S3e).

Drawings of the engravings

To facilitate the analysis of the engravings, their outlines were traced using vector drawing software (Adobe Illustrator). Thanks to the DEM and relative relief processing, we have obtained different depictions of the 3D acquisition (MHS, PCA-HS, SVF-A, SLRM) to highlight the various features of the engravings (outlines, morphology, technological traces and overlapping). Due to the cleaved structure of the rock, directional flaking related to the engravings tend to create multiple outlines, especially in cases where they are shallow or intertwined. In such cases, we have retained the steepest delineations, created by a repeated gesture of pecking or incising. This drawing process was controlled cross-checking the various relative relief depictions, as well as going back and forth to the detailed photographs with oblique lighting, relief profiles generated from the DEM and direct observations. The early 20th century photographs have been distorted as much as possible in order to fit with the elaborated DEM and to complete the lost fragments.

SI2– NETWORK AND SHAPE ANALYSES AND GEOREFERENCING OF THE SLAB

In order to test the degree of similarity between the engravings of the Saint-Bélec slab and the corresponding landscape elements (relief and river network), shape and network analyses were performed using QGIS software and the Python language (network module).

The network analysis first required the creation of two graphs representing the engravings of the slab and the corresponding landscape elements, respectively. These graphs are composed of nodes connected by edges whose length was measured. Two metrics were then computed in order to evaluate the degree of concordance between the graphs, by comparing the edges by Jaccard's distance (Jaccard 1901) and by a comparison of the distance matrices of the two networks via Mantel's test (Mantel 1967).

The Jaccard distance provides a percentage of similarity between the two graphs. This distance does not take into account the distance between the nodes but only the connection (or not) of these nodes to each other: it simply compares the edges, each edge being of the form (x, y) where x and y are the identifiers of the two nodes of the edge. In our case, we obtain a Jaccard distance of 0.8, which means that our two graphs are 80% similar (Fig. S4a). This result is based on the assumption that the three meandering signs (L1/L3, L11/L13 and L73/L74) were indeed connected. If this assumption is removed from the analysis (excluding nodes 25 and 26), Jaccard's distance is found to be slightly lower (0.7).

The Mantel test (Mantel 1967) is a statistical test commonly used to compare two by two matrices of distances whose units are not necessarily identical. It is often used in population genetics studies to compare genetic and geographic distances. However, this test is calculated from a graph whose nodes must be connected to each other. Therefore, the test is limited to the subgraph of the upper left quarter of the slab, for which we obtain a correlation coefficient of 0.81, i.e. a strong correlation between the two subgraphs. The associated p-value is 0.001, indicating that the relationship is not random (Fig. S4b). The Mantel test excluding nodes 25 and 26 was not conducted because it only allows the comparison of distance matrices of the same dimensions, thus networks with the same number of nodes.

The shape analysis was conducted using two methods to obtain comparative metrics. First, the Pompeiu-Hausdorff distance (Rockafellar and Wets 2004, 117), which corresponds to the maximum distance between two superimposed line forms, was calculated to compare the triangular line formed by the bas-relief B1 and the staked line L17 with the ridge line of the *Montagnes noires* and the course of the Odet River. These two landscape elements represent a linear distance of more than 42 km. After an affine transformation of this line on the slab to best match the corresponding line on the map, the Hausdorff distance was estimated to be only 713 m in this area (Fig. S4c). Comparison of the B4/L15 pattern with the Landudal massif (10.2 km perimeter) yielded a higher Hausdorff distance (843 m).

The second shape analysis employed was based on a method of standardizing the lines to avoid scale, rotation and translation effects. Then, the Wilcoxon statistical test was performed on the standardized lines to estimate their degree of similarity using the Line Similarity experimental extension of the QGIS software. This non-parametric test allows for the comparison of datasets, based on the comparison of ranks. Because this test works only on unbranched lines, we chose to compare the lines formed by the Odet Valley and the contours of the Landudal massif to the corresponding engravings. The results give p-values close to 1, which means that the hypothesis of similarity cannot be rejected (Fig. S4d).

Finally, a network analysis was also performed on two mind maps drawn by the Tuareg (Fig. S5a–b) and the Yupno (Fig. S6a–b) in order to compare the results obtained on the Saint-Bélec slab with those of other proven cartographic representations. A pairwise comparison of nodes by Jaccard distance yields a similarity of 0.75 for the Yupno map and 0.625 for the Tuareg map (Fig. S5c and Fig. S6c). These values are equivalent and even lower than those we obtained for the engravings analyzed on the Saint-Bélec slab and support our hypothesis that the latter is a cartographic representation of a river network.

Based on these statistical results, a georeferencing of the Saint-Bélec slab was carried out from ArcGIS software using about twenty control points. These points correspond to the sources of the rivers, the hydrographic confluences and, in the case of the Aulne River, the main inflections of the meanders (Fig. S7). Georeferencing is a procedure classically used in geomatics to align and geometrically rectify raster data (maps and aerial photographs) that present limited deformations. Here, the engravings may represent objects distributed in space, but their layout and overall distribution do not respect current cartographic conventions (respect of scales, distances and orientation, *etc.*). Some of the landscape elements represented were oversized, while their respective positions are not proportional to the distance separating them from each other on the ground. Therefore, we only used a georeferencing approach to roughly define the boundaries of the represented space. A linear transformation was employed to perform the displacement, scaling and rotation of the slab. The residual error measured at each of the control points is particularly large, up to 4.7 km. The sum of the root mean square errors of all residuals is 2.9 km. The georeferencing procedure indicates that the area presented by the slab is about 30 km long and 21 km wide, oriented along an ENE-WSW axis corresponding to the course of the Odet River.

SI3- THE EARLY BRONZE AGE IN ARMORICA

The Early Bronze Age in northwestern France was recognized initially through the excavation of burial mounds. Indeed, these barrows, several thousand of which are known in Brittany and to a lesser extent in Normandy, were for the most part well preserved in the 19th century (Fig. S8). Like many regions in Europe, these monuments, which are easily identifiable in the landscape, were the subject of numerous excavations, often connected with the rise of learned societies and their desire for fieldwork in the second half of the 19th century.

History of the research

With the exception of ancient casual finds, the first real excavation took place in 1843 when Arthur Boutarel explored the Lothéa Barrow in Quimperlé (Finistère), a large mound perfectly preserved in the Carnoët forest. The exceptional results from this excavation in the form of a richly furnished grave including arsenical copper daggers and gold and silver ornaments encouraged others to tackle similar sites (Nicolas *et al.* 2013).

It is undeniable that Paul du Chatellier, from the 1870s onwards, worked hardest on this vast endeavour effort, leading or funding the exploration of several hundred barrows and cists. Nevertheless, this research has been carefully documented and regularly published in accordance with the standards of the time, notably in his book *Les Époques préhistoriques et gauloises dans le Finistère* (Chatellier 1907). Thus, by the turn of the 20th century, the main characteristics of funerary practices of the Early Bronze Age were perfectly known. The abundance of grave goods (metal, ceramics, stone) made it possible to identify specific cultures, and elites in western Brittany, who were distinguished by the quality and quantity of crafted goods (bronze weapons, goldwork, flint arrowheads, leather objects; Chatellier 1907; Aveneau de la Grancière 1899; Martin 1900).

Between the two World Wars, the scale of excavation declined sharply except in the Morbihan with the work of Zacharie Le Rouzic (1934). At that time, Stuart Piggott brought this Armorican Tumulus Culture closer to that of Wessex in southern England on the basis of objects that were found in elite graves on both sides of the Channel (Piggott 1938). It is also worth noting the 1939 excavation of A.E. van Giffen at La Motta (Lannion, Côtes-d'Armor) using trenches and stratigraphic surveys that served as models for the ensuing decades (Butler & Waterbolk 1974).

At the end of the Second World War, typological analysis drew upon the large funerary assemblage to define and illustrate many types of objects (Briard & Giot 1956). A typology of grave goods was also established, distinguishing between the richly equipped, supposedly earlier, graves with arrowheads and the presumed later tombs characterized by their pottery (Giot & Cogné 1951). At the same time, the development of industrial-scale agriculture in Brittany with the regrouping of fields and arrival of tractors proved tragic for Bronze Age monuments. The mechanization of ploughing and the levelling of the field banks led to the flattening of many burial mounds and the removal of many capstones from stone-cists. This destruction triggered numerous rescue excavations by the *Laboratoire d'Anthropologie* of the University of Rennes, main directed by Jacques Briard (1984). These excavations, often carried out using trenches, made it possible to record the graves and to document the structure and form of barrow construction.

By the turn of the 21st century, excavations at Early Bronze Age sites were very rare, in part due to the death of Jacques Briard (1933-2002). However, the rise of development-led

archaeology has since led to a new approach to excavations. Thanks to extensive open-area stripping, discoveries of settlements and fieldsystems have multiplied, and new classes of monuments such as pit graves have been recognised. Research excavations have also contributed to the renewal of knowledge (Pailler & Nicolas 2019). Regions that were little known in earlier centuries because of the ancient levelling of barrows, such as Lower Normandy, have upon detailed investigation proved to be very dense in remains of the Early Bronze Age (Marcigny 2016). In parallel, several collective research programmes and academic works have made it possible to synthesize the results of these new excavations (Pailler & Nicolas 2019; Blanchet *et al.* 2019). It is within the framework of the collective research programme '*Éléments pour une nouvelle approche de l'âge du Bronze en Bretagne*' (dir. S. Blanchet) that the Saint-Bélec slab was rediscovered. Incidentally, typochronology and the increased availability of radiocarbon dates on short-lived samples have made it possible to revise and refine the relevant chronological framework (Needham 2000; Marcigny 2016; Nicolas 2016; Pailler & Nicolas 2019). In consequence, these advances have made it possible to propose an analysis of the social and territorial structures of Early Bronze Age communities in northwestern France that is now underway (Brun 1998; Needham 2000; Marcigny 2016; Nicolas 2016).

Graves

A recent inventory compiled by two of the authors (C.N., Y.P.) and Muriel Fily (*Centre départemental d'Archéologie du Finistère*) based on previous work and aerial photographs has doubled the number of known graves in Finistère. And it is anticipated that western Brittany has at least 3 000 recorded graves.

These graves are of various sizes, from simple pit to large stone-cists measuring more than 4m in length and 2m in height. The combination of wooden, dry-stone walling and slab architecture shows a great diversity, likely reflecting chronological and territorial disparities. The graves can be grouped into small cemeteries of about ten stone-cists or pits. Nevertheless, most burial sites include one or more burial mounds covering a central grave and one or more satellite graves. The barrows variously comprise a stone cairn, and several levels of piled-up earth. They generally measure 10 to 30m in diameter but the most monumental ones reach 60m in diameter and 5 to 6m in height (Briard 1984). These imposing structures, which sometimes cover perfectly enclosed cists, include a wide range of grave goods. The presence of copper oxides from the corrosion of bronze weapons have often favoured the conservation of organic remains, such as floors, coffins, leaf beds, or boxes containing funerary deposits. These stone cists and barrows are found in western Brittany, northern Cotentin and the Channel Islands (Patton 1995; Delrieu 2012; Fig. S8). In eastern Brittany and in the Caen plain, the graves are generally in pits and can be surrounded by a circular ditch that once circumscribed mounds (Le Maire 2014; Marcigny 2016). Moreover, not all individuals were buried within a pit or a stone-cist because human remains might be found in domestic middens (Pailler & Nicolas 2019).

Funeral practices in the Early Bronze Age favour individual burial, although multiple burials are known along with rare cremations (Briard 1984; Blanchet *et al.* 2019). Skeletons are mostly found in a crouched position (left-sided or right-sided) but sometimes laying on the back. They are mainly deposited along an E-W or NW/SE axis, with the head to the east or west (Tonnerre 2015). In the previous period (Bell Beaker culture), this dichotomy in body orientation corresponds to a gendered division between males and females (Turek & Černý 2001; Salanova 2011). However, with the acidic soils of Armorica, large numbers of well-preserved skeletons are still lacking to affirm that this Early Bronze Age dichotomy results from a gender division.

The majority of graves do not deliver any grave goods that have survived. In Brittany, the most common grave goods consist of pottery. These ceramics, often handled vessels, sometimes with incised decoration, characterize the ‘Armorican’ products of the Early Bronze Age, and have been found both in funeral and domestic contexts. These rather diverse ceramics undoubtedly express territorial identities in their form and decoration (Stévenin & Nicolas 2019; Blanchet *et al.* 2019).

Rather distinctive are the so-called ‘Armorican’ copper-alloy daggers, triangular or with curved edges, decorated with grooved lines to the edges and riveted (Briard 1984). These can be of varying sizes from about ten centimetres to half a metre in length. In some contexts, the good preservation of organic remains in contact with the blade shows that the hilt was made of wood and that the sheaths were made of a triple thickness of skin (inside), bark (middle) and decorated leather (outside). The assembly of the parts of the sheaths is done by means of edge-to-edge sewing with intricate stitches less than one millimetre wide, indicating a high level of skill. A luxurious version of these daggers exists with the addition of tiny gold nails (1–3 mm in length) on the wooden handle. Other items include ‘Armorican’ low-flanged axeheads, and gold or silver (ornaments and cups; Needham *et al.* 2006; Nicolas 2016).

A few graves yield dozens of flint arrowheads. These finely-shaped arrowheads are specific to northwestern France. Knapped from imported flint (Tours area), they have been produced by craftsmen. Although they show signs of hafting, they show no signs of use and seem to have been reserved for display before being placed in wooden boxes in the graves. Some larger stone tools are also occasionally present, including querns or whetstones (Nicolas 2016).

The vast majority of ornaments appear to be imported, mainly from the Great Britain, whether produced there or transited there. These include British faience beads, Baltic amber, Whitby jet from northern England or Iberian spiral chains in gold or silver (Gardin 1996; Sheridan & Shortland 2004; Nicolas *et al.* 2013; Nicolas 2016). An Armorican speciality is the production of bracer ornaments in precious metal (gold) or exotic stone (amber, jet), reminiscent in miniature form of the Bell Beaker models (Nicolas 2019).

Finally, rare remains attest to the presence of shells or fabrics in the graves, but their poor state of preservation prevents any detailed reconstruction (Briard 1984).

Settlements

For a while, settlements were only known through archaeological remains found within the barrow mounds, the result of stripping land near the settlements to build the mounds (Briard 1984). It is only recently, thanks to development-led excavations and extensive topsoil stripping that the first settlement structures have been recognized.

The few houses recognized are oval or rectangular in plan and measure 7–21m in length and 3–6m in width (Nicolas 2011; Roy 2014; Pailler 2019; Pailler & Nicolas 2019). They were built of timber posts or, in island contexts, in dry-stone walling as in Molène, Finistère (Pailler & Nicolas 2019). In two sites, there is a partial superposition of two houses, which indicates a certain durability of the settlements (Pailler & Nicolas 2019; Roy 2014). However, these houses generally appear isolated. Occupation layers and floors of these houses are very rarely preserved, limiting functional interpretation; Molène where the site was quickly buried under the dune is an exception (Pailler & Nicolas 2019).

In addition to these open settlements, there are curvilinear enclosures in both Brittany and Normandy. They range from 1 500m², as in Colombelles, Calvados, to nearly four hectares in Lannion, Côtes-d'Armor (Escats 2013; Nicolas 2021; Fig. 11b). The enclosure ditches can be quite massive, reaching 4.5m wide and 2m deep. Unfortunately, the levelling of these structures does not allow the recognition of buildings inside or an understanding of how these enclosures work. Only waste materials incorporated into ditch fills allow the function of these sites to be considered. The remains, particularly ceramics and lithic tools (querns in particular), testifies at least to a domestic function.

Economy

Like most pre-industrial societies, the economy of Early Bronze Age Armorican communities is mainly based on the exploitation of agro-pastoral resources. Concerning agriculture, four cereals were cultivated (hulled barley/*Hordeum vulgare*, naked barley/*Hordeum vulgare* var. *nudum*, emmer/*Triticum dicoccum*, and common wheat/*Triticum aestivum*) as well as two legumes (broad bean/*Vicia faba* var. *minuta*, and pea/*Pisum sativum*). Stock rearing is based on the domestic triad (beef/*Bos taurus*, sheep-goat/*Ovis aries*-*Capra hircus*, and pork/*Sus scrofa domestica*), although in varying proportions. The diet was supplemented by the collection of fruits (hazelnut/*Corylus avellana*, hawthorn/*Crataegus monogyna*, and dogwood/*Cornus sanguinea*) and, to a small extent, hunting (deer/*Cervus elaphus*, hare/*Lepus*, wild boar/*Sus scrofa*, and birds). Along the coastlands, there was intensive exploitation of the foreshore for shellfish collection or fish-capture using stone or wooden fish weirs (Billard & Bernard 2016; Marcigny 2016; Pailler & Nicolas 2019).

Although this subsistence economy does not seem to differ in appearance from that of the preceding Neolithic period, profound changes can be observed with the development of fieldsystems from the early 2nd millennium BC onwards (Marcigny 2016; Blanchet *et al.* 2019). These ditch-defined systems appear as islands with the unenclosed landscape and that can extend over several tens of hectares (Fig. 11d). On coastlands, these field boundaries can be reinforced with megalithic slabs, joined or associated with dry-stone walling (Lecerf 1985; Pailler & Nicolas 2019). Domestic and funeral structures can also be integrated into these fieldsystems, similar to what is known in England (Fleming 2008). However, most of the time, the enclosures seem to be outside the fieldsystems. Although these ditch/bank systems may have had practical advantages (drainage, wind and pest protection), their creation probably reflects a new land tenure system (Marcigny 2016).

For the Early Bronze Age, various manufactured products are known, both household and specialized. Although craft productions were known in previous periods, such as the Late Neolithic Grand-Pressigny flint daggers (Pelegrin 2002), a greater specialization of manufacturing activities can be observed at the beginning of the Bronze Age.

The most emblematic production is that of copper-alloy objects, mainly weapons (daggers, axes) and to a lesser extent ornaments. The metal objects found in the graves of northwestern France (c.250 daggers and 50 axes; Briard 1984) constitute one of the largest corpuses of Early Bronze Age material in western Europe. Despite this abundance, no early copper mining is known so far, although Armorican rocks do contain some copper ores; too weak or formerly exhausted, they have not been the subject of modern exploitation (Guénin 1911; Kerforne 1918), although the latter have often helped to identify prehistoric mines (O'Brien 2014). In parallel, some deposits of copper ingots imported from Ireland are known for the period

(Gandois *et al.* 2019). If the existence of these imports is secure, could they have been enough to support the development of a flourishing bronze production in Armorica? On the other hand, the region has abundant tin resources a material essential for the production of bronze (Guigues 1970; Chauris 1989). Cassiterite is found in magmatic rocks (granites), in related veins, and especially in alluvial deposits where it is found in the form of small prismatic crystals or rounded grains, which can be sorted and accumulated by rivers. The extraction of these alluvial deposits proves to be easier than mining but is also a vanishing tradition. Nevertheless, work carried out by the *Bureau des Recherches Géologiques et Minières* on a stanniferous flat in northwestern Brittany has led to the discovery of several traces of ancient exploitation, one of which is radiocarbon dated to the Middle/Late Bronze Age (Giot & Lulzac 1998). The care given to dagger production, particularly the gold nail decorations, attests to an undeniable mastery of metallurgy by craftsmen. Productions seem to take place on a small scale in dedicated places outside the settlements, as suggested by the recent discovery of a bronze workshop in Kersulec, Plonéour-Lanvern, Finistère (Pailler 2016). Armorican dagger production is found all-over northwestern France but seems to have been exported or imitated far beyond in France, in England and western Germany (Needham 2000; Nicolas 2016). Although these bronze products characterized the period, they were confined during the Early Bronze Age to social display items (weapons, ornaments). They were certainly recycled and systematically recast but marginal in everyday life, which still seemed largely dominated by stone tools (Nicolas *et al.* 2015a).

Beside bronze items, there is a wide range of socially valued objects in flint (arrowheads), leather (sheaths), precious materials (gold, silver) or exotic materials (amber, jet, faience). The production of these luxury goods requires the existence of specialized craftsmen. Nevertheless, their rarity and limited distribution shows that these prestigious objects were intended for a few, probably the same people that controlled production (Nicolas 2016; Nicolas *et al.* 2015b).

Finally, there is a whole range of products that are not especially specialized. Ceramics show a wide range of qualities, from coarse and irregular pottery to thin-walled and carefully decorated pots (Stévenin & Nicolas 2019). There are few evidences of textile production (Pénisson 2019). The flint tools were still widely used on coastlands where the raw material is abundant and show poorly standardized manufacturing (Rousseau 2015). Nevertheless, this lithic industry, sometimes discovered in the form of waste heaps, could be involved in specific activities (Rousseau *et al.* 2014). The same is true for macrolithic tools, many of which show a greater functional specialization, especially for metalworking (Nicolas *et al.* 2015a).

The various evidences of specialization that can be perceived through craft production, and new land tenure, or the exploitation of certain coastal resources could testify to a search for a surplus in order to supply exchange networks. Prestigious objects have undeniably circulated long distances on both sides of the Channel and, to a lesser extent, around the Bay of Biscay (Needham 2009; Nicolas 2016). Nevertheless, one may wonder about the significance of these flows of precious goods, which probably correspond to non-market reciprocal exchanges, in order to form alliances between elites (Godelier 1999). Thus, following the example of the *Kula* exchange in Melanesia (Malinowski 1922), it is likely that these circulating prestigious items are the visible part of exchanges of other, more common, products. Thus, since copper and tin, essential for casting bronze, are unequally distributed in Europe, it is reasonable to believe that this trade may have encouraged the development of wider trade networks. Other products may have been traded, like textiles, as suggested by recent isotopic analyses of Bronze Age wool in Denmark (Frei *et al.* 2015).

Social and Territorial organisation

Grave goods and funerary architectures show highly hierarchical societies during the Early Bronze Age in Armorica. At least three or four social classes can be recognized: the largest number of people were buried, whether under a barrow or not, without preserved grave goods or with one ceramic vessel ('commoners'); a few people were buried along with a bronze dagger, a distinctive object at this time of early metallurgy, and frequently buried under large barrows ('nobles'); a limited number of individuals (about 40 graves all-over Armorica) were over-equipped with specific grave goods (gold ornamented bronze daggers, bronze axes, flint arrowheads, precious or exotic finery) and are usually found under the largest barrows suggesting they were the ruling elite (Nicolas 2016; Fig. S9). Such items of power, exclusively intended for the chiefs, could be considered as 'sacred objects', as defined by M. Godelier(1999), which are for the elite real means of reproducing life and interceding with the gods. Finally, we cannot rule out the possibility of needy people or slaves at the very bottom of the social scale to whom formal burial was refused. The settlement patterns seem to be congruent with this social hierarchy, with buildings that could house a family unit and related to cemeteries of flat graves, like at Ergué-Gabéric (Pailler 2019), stone-cists or small barrows like at Molène (Pailler & Nicolas 2019) and enclosures linked to elite burials like at Lannion and Colombelles (Escats 2013; Nicolas 2021; Fig. 11b).

This strong hierarchy is well supported by the spatial distribution of the grave goods. While pottery is found regularly, daggers are unevenly distributed with higher concentration around elite barrows. Furthermore, some daggers found within child burials might suggest a hereditary status (Briard 1984). This pattern suggests control by the elite of the metal producers. Except British faience beads, all precious or exotic goods are found in elite burials suggesting the existence of objects of power intended for the chiefs and a control by the latter over these specialized crafts and exchange networks (Nicolas 2016). Furthermore, these elite barrows are frequently located at key places, along such so-called 'Roman' roads that could be dated back to the Early Bronze Age, or above upper estuaries at the point where tidal movement ends, suggesting a control of trade flows (Nicolas *et al.* 2013).

The link between barrows and 'Roman' roads is well supported by recent excavations at Piré-sur-Seiche (Ille-et-Vilaine), where an Early Bronze Age grave has been found close to a road whose foundation dates back to the same period (Leroux 2015). Thus, Early Bronze Age graves seem to be located in relation to a road network, perhaps already existing but which is accompanied by the creation of new pathways. Controlling the road network through settlements located on crossroads or 'hubs', between terrestrial and maritime routes, seem to play a key role in the organization of Early Bronze Age territories.

Elite barrows are regularly distributed in western Brittany, as well as in Lower Normandy. They can be found alone or in small clusters which are separated by a few or several tens of kilometres (Fig. S8). The association of large enclosures with elite barrows, like at Lannion (Fig. 11b), makes likely that such structures acted as the central places within territories. These theoretical territories can be drawn from Thiessen Polygons (Fig. S8) and show quite coherent patterns congruent with geographical (rivers, mountains) and historical boundaries (Brun 1998; Nicolas 2016). Such territories measure between 160 and 1 600km² in size. Furthermore, elite burials are found more frequently on the most fertile land, in particular the northern coastlands of Brittany, so they were perhaps primarily related to the control of agricultural products (Nicolas 2016). And this makes sense with the development of the fieldsystems, which could be interpreted as a new way for controlling land ownership.

To sum up, Early Bronze Age societies in Armorica attest a stratified organization likely to be hereditary. They are settled in defined political entities and ruled by a distinctive elite. The power of these elites seems to be based on the control of land, agricultural and craft productions and long-distance exchange networks. Such societies are conventionally classified as 'chiefdoms', as defined by E.R. Sevice (1962) and later by A.W. Johnson and T.K. Earle (1987), although their socio-economic organization may share some common features with the first agrarian States; in particular while considering the possibility of land ownership by the elites, as may be suggested by the development of the fields and the Saint-Bélec slab. Indeed, such land ownership would lay the foundations of the state according to A. Testart (2005). Such questions deserve close attention, bringing together archaeological facts and ethnographic data (Jeunesse 2019).

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SUPPLEMENTARY FIGURES



FIGURE S1

Photogrammetry and general scanning of the Saint-Bélec slab. (a) Photogrammetric 3D-models of the front face (left) and the rear face while lifting (right). (b) General 3D-model acquired by ARTEC EVA device. (c-d) Details of the general 3D-model (L. Aubry).

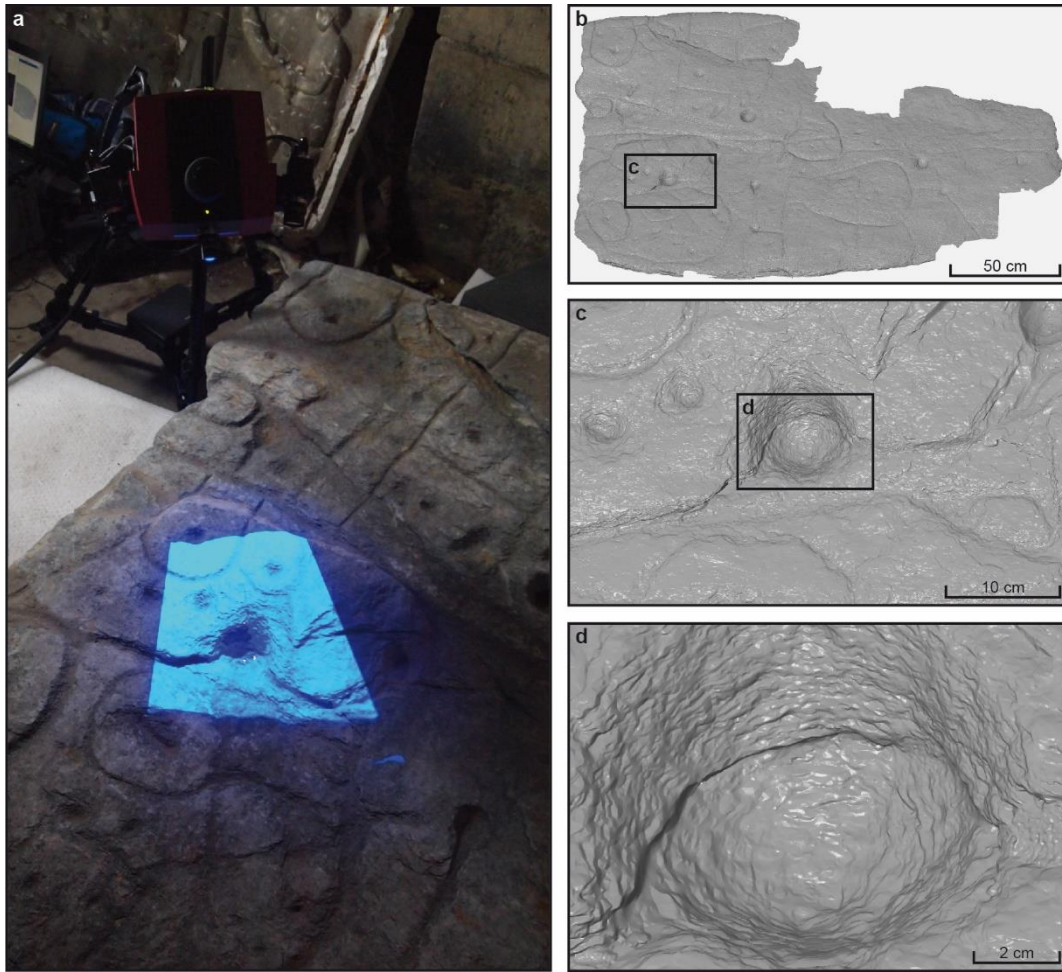


FIGURE S2

3D-scanning of the Saint-Bélec slab with ATOS Compact Scan. (a) 3D-scanning of an area of *c.* 30×30 cm in process. (b–d) The 3D-model and zoomed views of the same area, showing the planar schistosity fabric (a, P. Stéphan; b–d V. Lacombe).

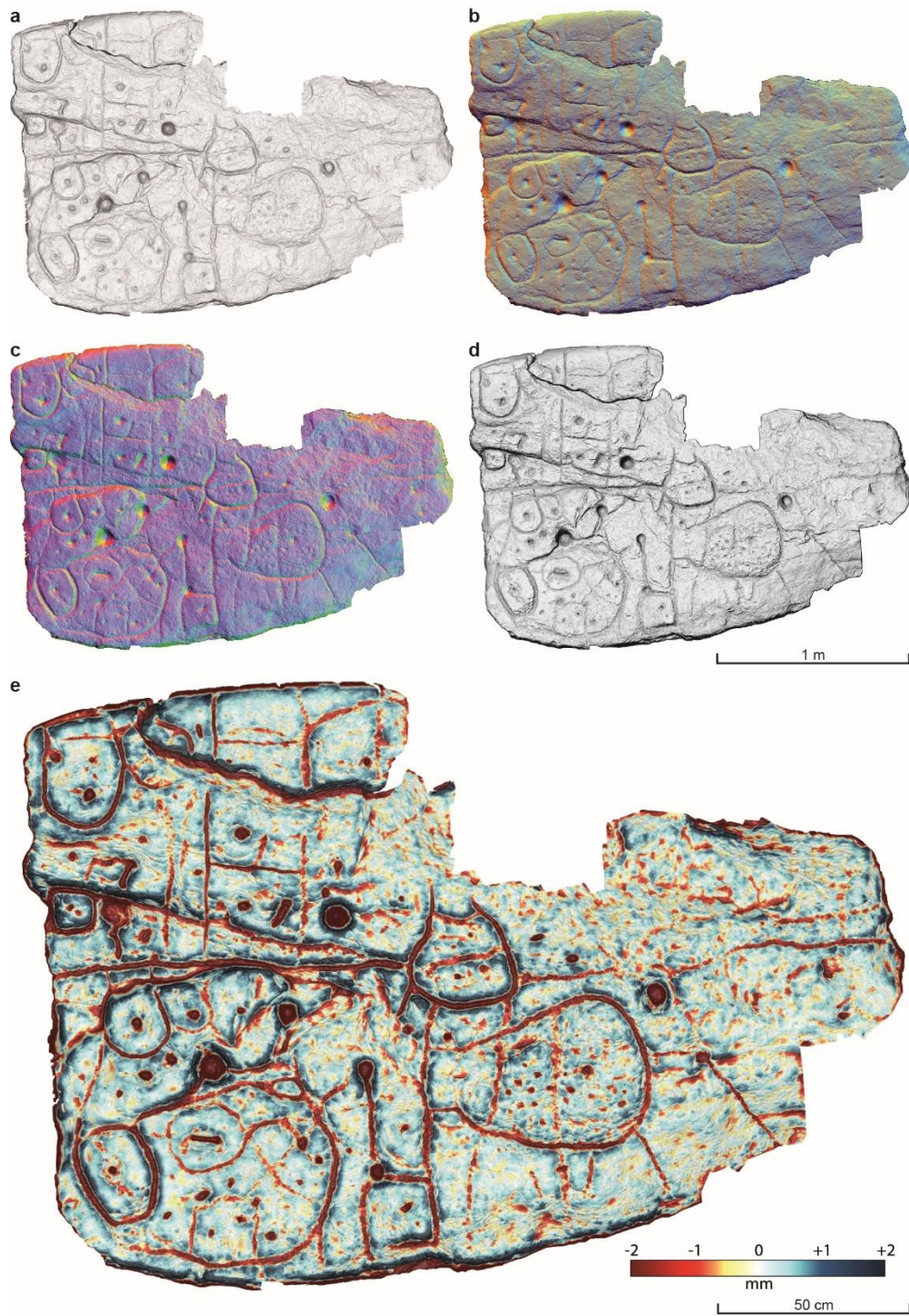


FIGURE S3

Various visualizations of the Saint-Bélec slab obtained by relative relief processing of the Digital Elevation Model. (a) Slope gradient image. (b) Multi-hillshading (MHS). (c), PCA Hillshading (PCA-HS). (d) Anisotropic Sky-View Factor (SVF-A). (e) 5. Simple Local Relief Model (SLRM) with 20 mm radius superimposed with Slope gradient image (P. Stéphan).

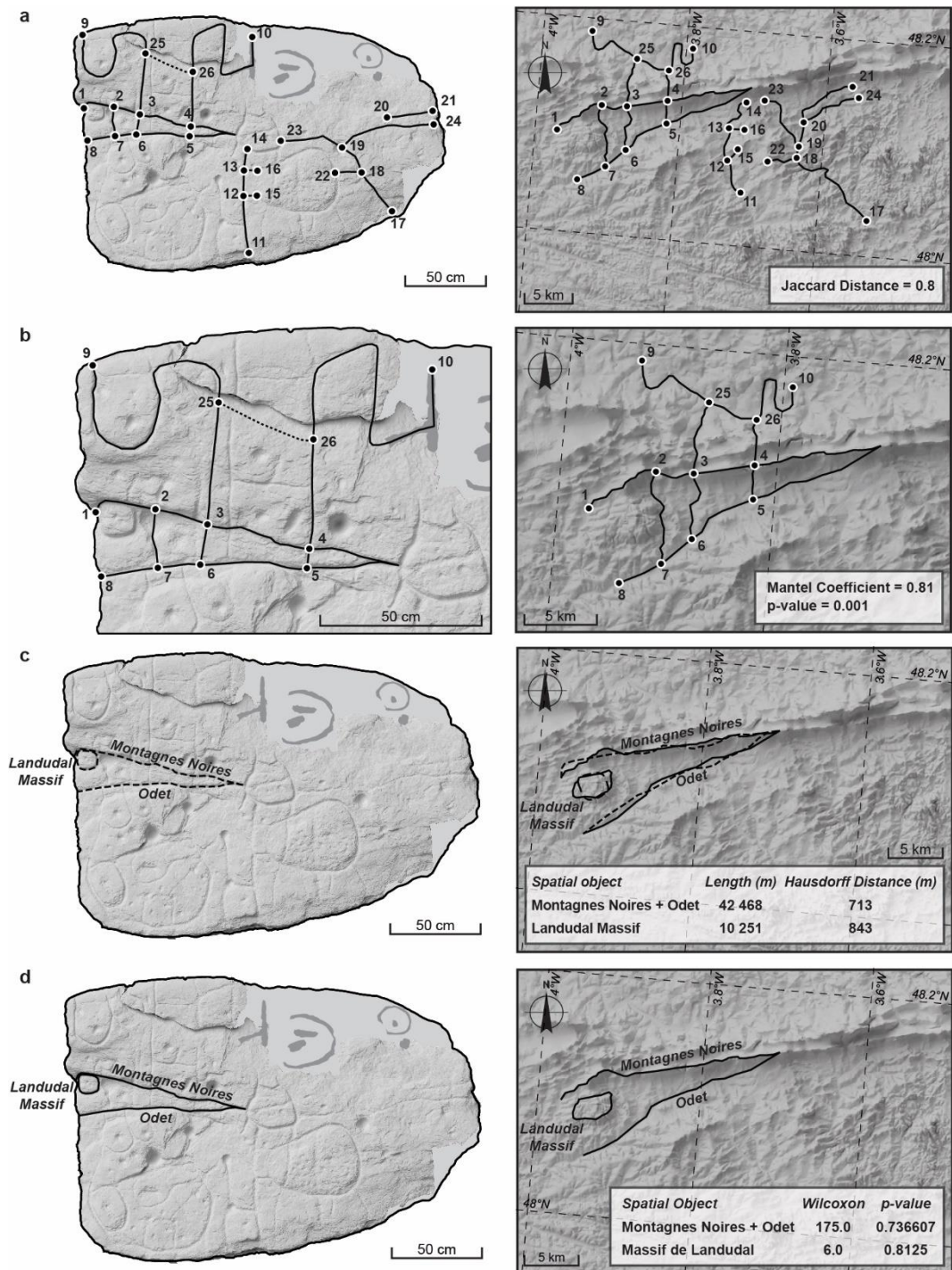


FIGURE S4

Network and shape analyses comparing the relief and the river network depicted on the Saint-Bélec to those of the *montagnes Noires* area. (a) Jaccard distance, (b) Mantel test, (c) Pompeiu-Hausdorff distance, (d) Wilcoxon test (Slab DEM: V. Lacombe and P. Stéphan; background maps: IGN; CAD: J. Pierson).

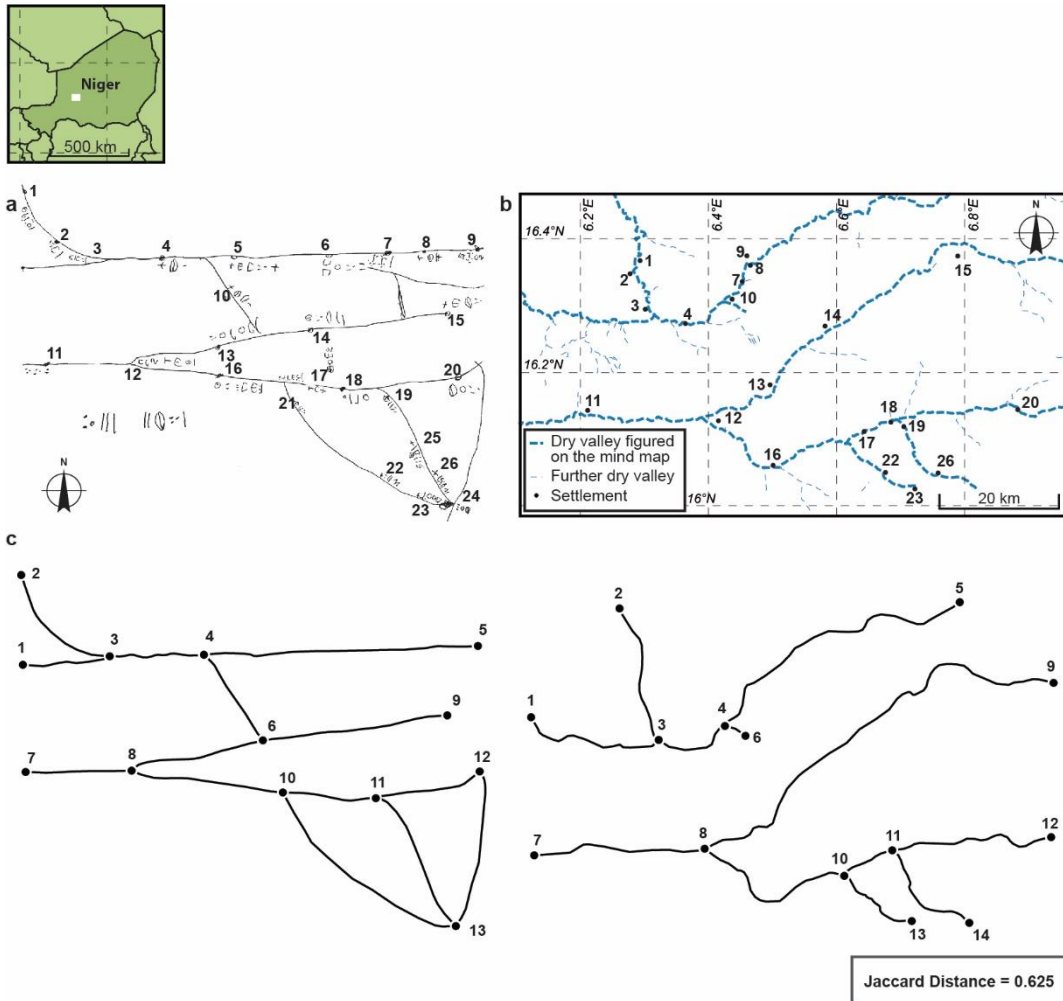


FIGURE S5

From solicited mind map to network analysis: a Tuareg case. (a) Reproduction of a map drawn by Kili ag Najim, Illabakan chief's son, Niger, 1960s, (b) map of the corresponding river network, (c) network analysis (Jaccard distance) comparing the river network of the ethnographic solicited map to the local topography (a, after Bernus 1974 ; b, CAD C. Nicolas after OpenStreetMap and Bernus 1974; c, CAD J. Pierson).

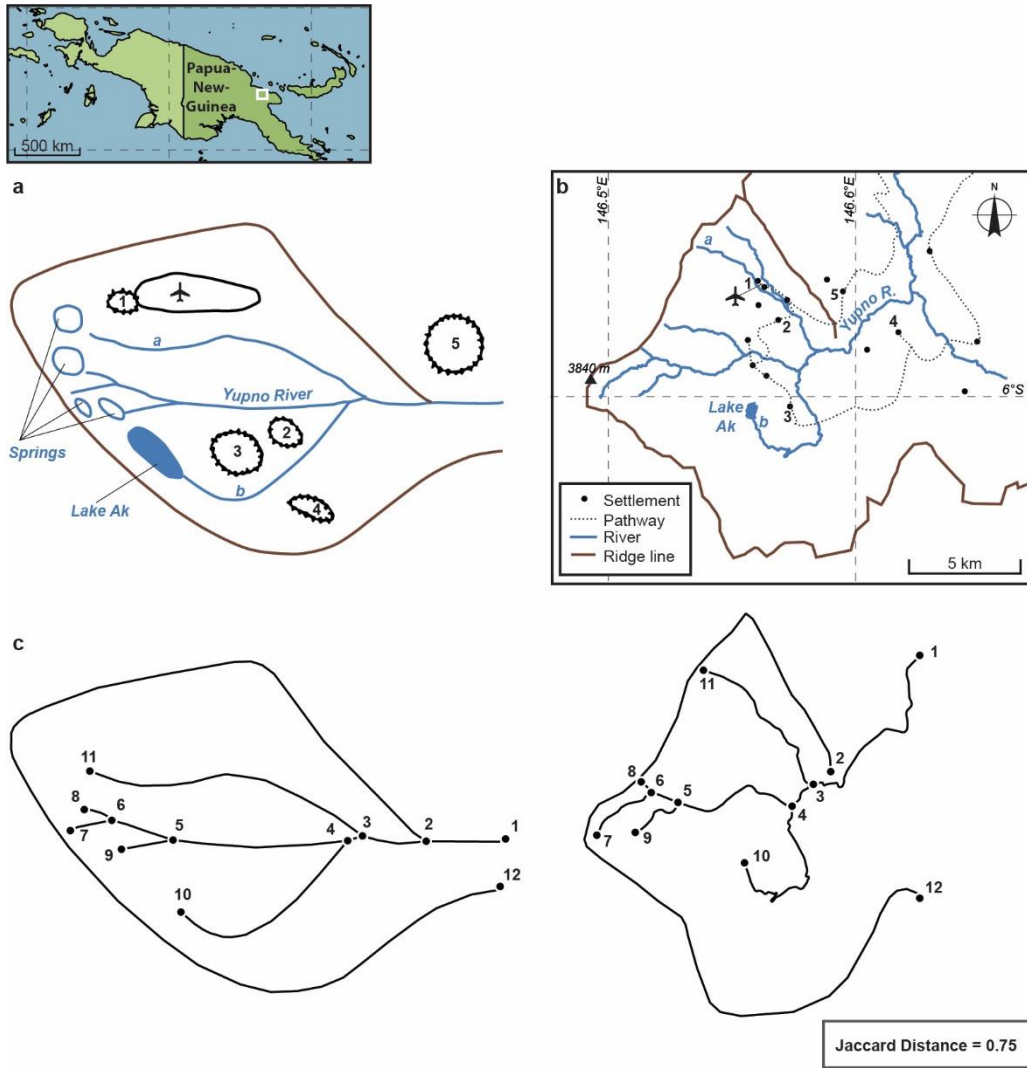


FIGURE S6

From solicited mind map to network analysis: a Papuan case. (a) Reproduction of a map drawn by an elder Yupno, Papua New Guinea, 1990s, (b) map of the corresponding relief and river network, (c) network analysis (Jaccard distance) comparing the relief and river network of the ethnographic solicited map to the local topography (a–b, after Wassmann 1993; c, CAD J. Pierson).

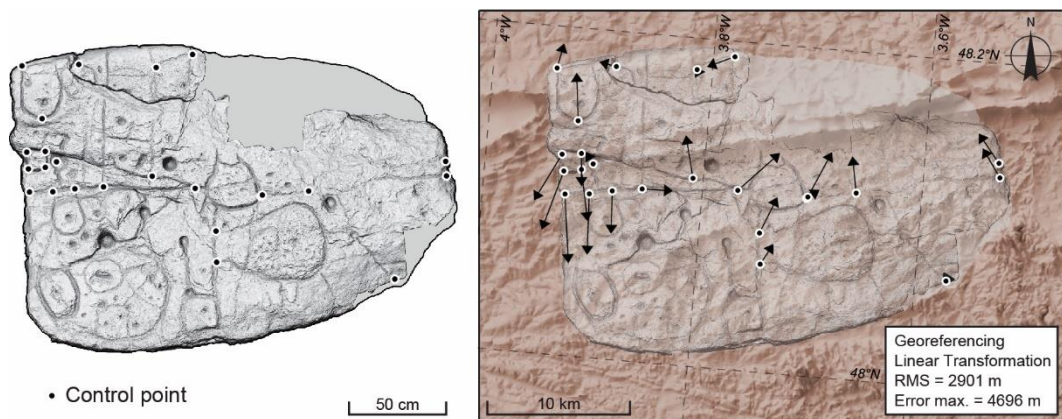


FIGURE S7

Control points and georeferencing of the Saint-Bélec slab (DEM: V. Lacombe and P. Stéphan; background map, *Institut Géographique National*).

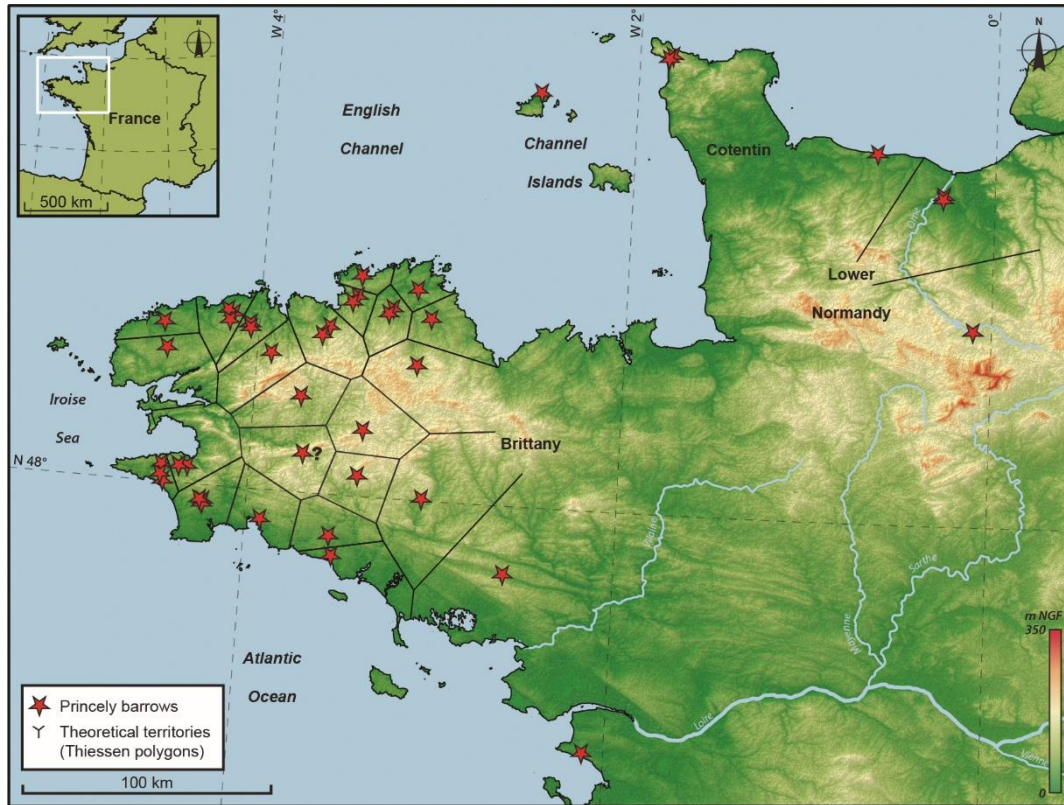


FIGURE S8

Early Bronze Age chief's graves and theoretical territories in northwestern France and Channel Islands (background map, *Institut Géographique National*).



FIGURE S9

The grave goods of the La Motta Barrow (Lannion, Brittany), including bronze daggers and axes, a large whetstone or touchstone, a gold-sheet bracer and finely shaped 'Armorican' flint arrowheads. This is a good example of a richly furnished elite burial in northwestern France. *Musée d'Archéologie Nationale, Saint-Germain-en-Laye.* © C. Nicolas.