Submarine Neolithic Stone Rows near Carnac (Morbihan), France: preliminary results from acoustic and underwater survey

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Carnac is internationally recognized as the best example of Neolithic rows of standing stones in western France. To better understand the significance of such alignments, an inventory of similar sites in the Carnac area was undertaken in 2003. Specifically, the alignment of 'Le Moulin', a site to the south of Carnac, which consists of five parallel lines of stelae inside the town of Saint-Pierre-Quiberon, was investigated. The extension of these stelae lines has been recognized to the east along the coast on an intertidal platform named Kerbougnec. The investigation aimed to assess whether this symbolic architecture continued offshore, which would give to this site a size comparable to that of Carnac. To answer to this question, several side-scan surveys have been conducted on the submerged part of the Kerbougnec platform, and these were validated by divers' observations on the identified acoustic anomalies. The concentration of acoustic anomalies forms a consistent extension of the architectural structure identified on land, and the orientation of the combined structure (on land and under the sea) is identical to the topological patterns recorded at Carnac.

Keywords: Neolithic, stelae, acoustic survey, underwater archaeology, western France

Introduction

The archaeology of the Neolithic rows of standing stones (straight or curvilinear, uninterrupted, or discontinuous) is a distinct feature of western France where such architecture is numerous and dense (Bailloud *et al*. 1995). Because of the lack of an appropriate conceptual framework, the interpretation of these sites is difficult, through both the lack of associated evidence and contextual information, and by confusion with persistence of ideas, opinions, and clichés developed from the beginning of the nineteenth century. Carnac epitomizes the problem. In this specific coastal zone of Brittany (Fig. 9.1), one of the unresolved problems remains the extent of this archaeological site, which spreads over several kilometres. It is not known where exactly it begins or ends (Boujot and Pinet 2007).

The main objective of the current research is to create an inventory of sites similar to Carnac, which might help in the general interpretation of standing stone alignments. The discovery of a significant site submerged in the Bay of Quiberon, near Carnac, also provided an opportunity to test the hypothesis formulated by Boujot *et al*. (1995) and Cassen (2009a). In this chapter we present the preliminary results of two side-scan sonar surveys validated by diver surveys, and will focus on the methods used to record the monoliths under the sea.

Figure 9.1: Top: The study area in Brittany. Bottom: location of Carnac north of the Bay of Quiberon (coloured composition of a Landsat ETM image dated 16.04.2003; topography by IGN–Institut Géographique National, using BD ALTI digital elevation model)

The question

Since the beginning of the nineteenth century, Carnac has generally been interpreted as a 'temple' (Cambry 1805; Mohen 2000), a rather vague term that is too poorly defined to apply accurately to such a cryptic architectural structure. In the second half of the twentieth century research on astronomic alignments and pseudo-scientific metrology was conducted on a restored (up to 80%) monument to determine if Carnac functioned as a lunar–solar observatory, earlier proposed by Gaillard (1897) and Devoir (1917), and to establish the existence of a prehistoric megalithic 'yard' (Thom 1955; Thom and Thom 1978). The result was to make obsolete any conclusion founded on such measurements, essentially based on alignments between imprecise points, and thus likely to fit to any geometric situation.

We suggest that the 'verticalization' of a monolithic object (a stele in this case) at the beginning of the Neolithic period may be regarded as a symbolic threshold between two dimensions, two spaces, two worlds, as a doorway-stele or a doorstep-stele. Furthermore, according to the definition of the anthropological concept of limit, the repetition of these stelae in a given space gives the impression of raising a barrier to prevent any intrusions, physical or virtual. We further propose the hypothesis that these stone rows acted as a 'cognitive barrier' (Cassen 2009a). They should be considered as a mineral fence that could stop, impede, or filter movement or passage. In this way, it is fundamental to define the topographical position and location of those rows (Cassen 2009b). We have been researching other sites, similar to Carnac, to develop a model that could help answer these questions.

At Saint-Pierre-Quiberon the alignment of Le Moulin (several parallel lines of stelae – Fig. 9.2), was restored in the nineteenth century, and constitutes a small, preserved archaeological site inside a modern housing development. The opportunity to follow the extension of these lines of stelae on the intertidal platform called Kerbougnec (or Kerbourgnec, but originally *Kerbonnec* in Breton) was a success, and groups of stelae were first mapped on the tidal flat by Cassen and Vaquero Lastre in 2003. Naturally, the question was raised, does this symbolic architecture continue under the modern sea level, which would confer to this site a size and importance similar to that of Carnac?

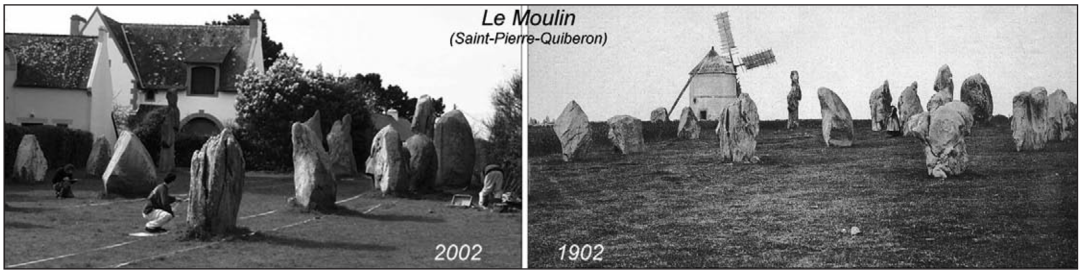


Figure 9.2: Two pictures of the high part of Le Moulin Neolithic stone rows (Photos: Z. Le Rouzic 1908, S. Cassen 2002)

The exploration of the Kerbougnec site (Quiberon Bay)

Graphically recorded and georeferenced in 2002 by DGPS (Differential Global Positioning System: Cassen and Vaquero Lastres 2003), the monoliths discovered on the rocky platform of Kerbougnec appear to be organized in parallel rows in the sectors that are most protected from swell and wave action (in comparison to the high-energy environment of the 'Côte sauvage' on the west part of the peninsula).

At the eastern base of the biggest block of a broken granite slab (Grande Stèle no. 1), a buried axe-head of Alpine jadeitite was discovered in 2003 (Fig. 9.3; petrographic determination by M. Errera, of the Agence Nationale de Recherche sponsored 'Programme Jade', directed by Pierre Pétrequin). This axe-head is a curiosity because of the distant provenance of the rock (Monte Viso, Italy). It is, however, not exceptional as four similar specimens – apparently non-functional axes – have been discovered at the site of the Petit Rohu, *c.* 100 m further to the south. These polished blades seem to have been symbolically powerful objects rather than everyday tools. The presence of these emblematic objects in Kerbougnec confirmed the importance of this underwater site and encouraged us to extend our exploration toward the open sea.

Side-scan sonar surveys

The difficulty of prospecting in a marine environment with our usual archaeological methods encouraged us to collaborate with geographers and geologists. The terrestrial part of the archaeological and geomorphological survey was made on the rocky intertidal platform during

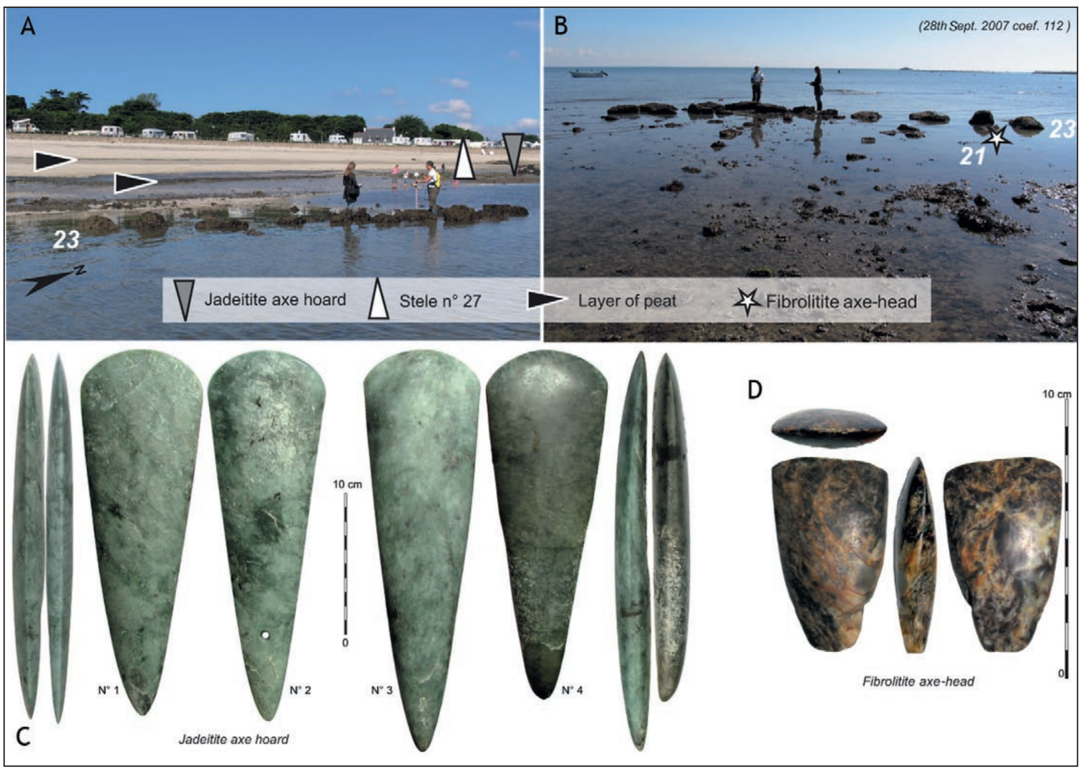


Figure 9.3: A–B Row of stelae discovered at low tide on the intertidal platform of Le Rohu, between Quiberon and Saint-Pierre-Quiberon. C–D Polished axe-heads found near the stelae at the positions marked '23' and '21' (After Cassen et al. *2010)*

very low tides by traditional terrestrial and shallow water survey methods. For the marine part (2–10 m water depth), a geophysical survey of the possible submerged architecture was performed using side-scan sonar and diver observations.

The side-scan sonar is an acoustic geophysical instrument that, typically, is towed in the water behind the survey vessel. The method is based on recording echoes of an acoustic wave issued artificially and reflected by the different interfaces (Hobbs *et al.* 1994), the seafloor, and the boundaries between sedimentary layers. The results of a side-scan sonar survey are a map or image of the seafloor acoustic properties that can be interpreted for different objects on the seafloor or different seafloor types. The signal frequency and speed of the boat determine the image resolution: the higher the frequency, the higher the resolution, and the slower the boat speed the higher the resolution. From the side-scan image features such as dunes, sand waves, ripples, and rocky outcrops are readily identified (Augris *et al.* 1996). With the sonar towed *c.* 5–10 m above the seafloor an image (a band) 50–100 m wide on each side of the sonar can typically be recorded. The acquisition of several juxtaposed bands allows the realization of a 'sonar mosaic', which constitutes a very precise picture (with a resolution of *c.* 20 cm) of the seafloor. The resulting acoustic map can be geographically referenced (Bonnot-Courtois *et al.* 2005; Ehrhold *et al.* 2007, 2008; Fournier *et al.* 2009) to allow interpretation of different acoustic facies. Isis Sonar software and a Trimble Pathfinder Pro XRS GPS positioning system were used for data acquisition. To build mosaics we employed Isis Sonar and Deph Map software. Two sonars have been tested on the site:

- an Edgetech 272 TD was used with a frequency of 100 kHz. It is characterized by a maximum signal penetration of 1 cm into the sediment and a horizontal resolution of 30 cm. This sonar was used for initial reconnaissance to provide wide coverage in profiles up to 200 m wide;
- a dual-channel SH1 (devised by Sture Hultqvist) was used with a frequency of 500 kHz allowing a horizontal resolution of about 10 cm. This system is commonly used in the exploration of wrecks (Cazenave de la Roche 2009) and allowed us to acquire two smaller 'mosaics' with profiles 25 m wide on each side.

In processing the data, the first step was to recognize the different types of acoustic anomalies that could indicate the presence of monoliths beneath shallow coastal waters. Potentially there is a risk of misinterpretation between monoliths and objects such as concrete blocks that served as moorings for yachts and are now covered by oysters and seaweed (cf. Atallah *et al.* 2005). The second step was to confirm the archaeological or autochthonous nature of these anomalies by diving.

Results from the acoustic surveys

The methodology proposed for the study, and in particular the ability to recognize the stelae as significant archaeological features was tested on the site of 'Le Petit Rohu', situated in the south of Kerbougnec (Fig. 9.3). This site revealed an extraordinary find in 2007: four polished axes made in Alpine jadeitite recovered within a submerged alignment of 26 monoliths, at 3.5 m below MSL (Cassen *et al.* 2008). Figure 9.4 shows the position of the sonar track acquired on this structure. The survey yielded sonar records of variable quality, as shown in Figure 9.5 for record Mos028bis. For each discrete anomaly identified from the sonar record, a corresponding anomaly was mapped by the archaeologists with DGPS (Cassen *et al.* 2008). The DGPS records were obtained during periods of very low tide (for a complete plan of the architecture, see Cassen *et al.* 2010). The sonar image (Fig. 9.5) clearly shows the group of fallen stelae (dimensions around 1 m), in spite of their relative burial in the sandy gravel seafloor.

At the site of Kerbougnec (further north), several of the sonar records acquired in 2009 also reveal a continuation of the monoliths recorded in 2002 onto the tidal flat (Fig. 9.6). In this area, the bathymetry already gives an idea of the ancient topography of the site before its invasion by the sea – a gently elevated platform. One can easily distinguish the details of the rocky platform under the sea on the photograph, as the site is characterized by an unusually high transparency of the water.

A number of profiles were acquired with the SH1 sonar between the buoy of L'Ours de Kerbougnec ('The Bear', which in this case refers to a reef or shallow waters area, and the rocky intertidal platform exposed at low tide. Figure 9.7 shows the acoustic anomalies (marked by arrows) on a homogeneous sedimentary floor and the rocky platform (top, left) on which it is difficult to distinguish naturally deposited granite blocks from prehistoric monoliths placed on this

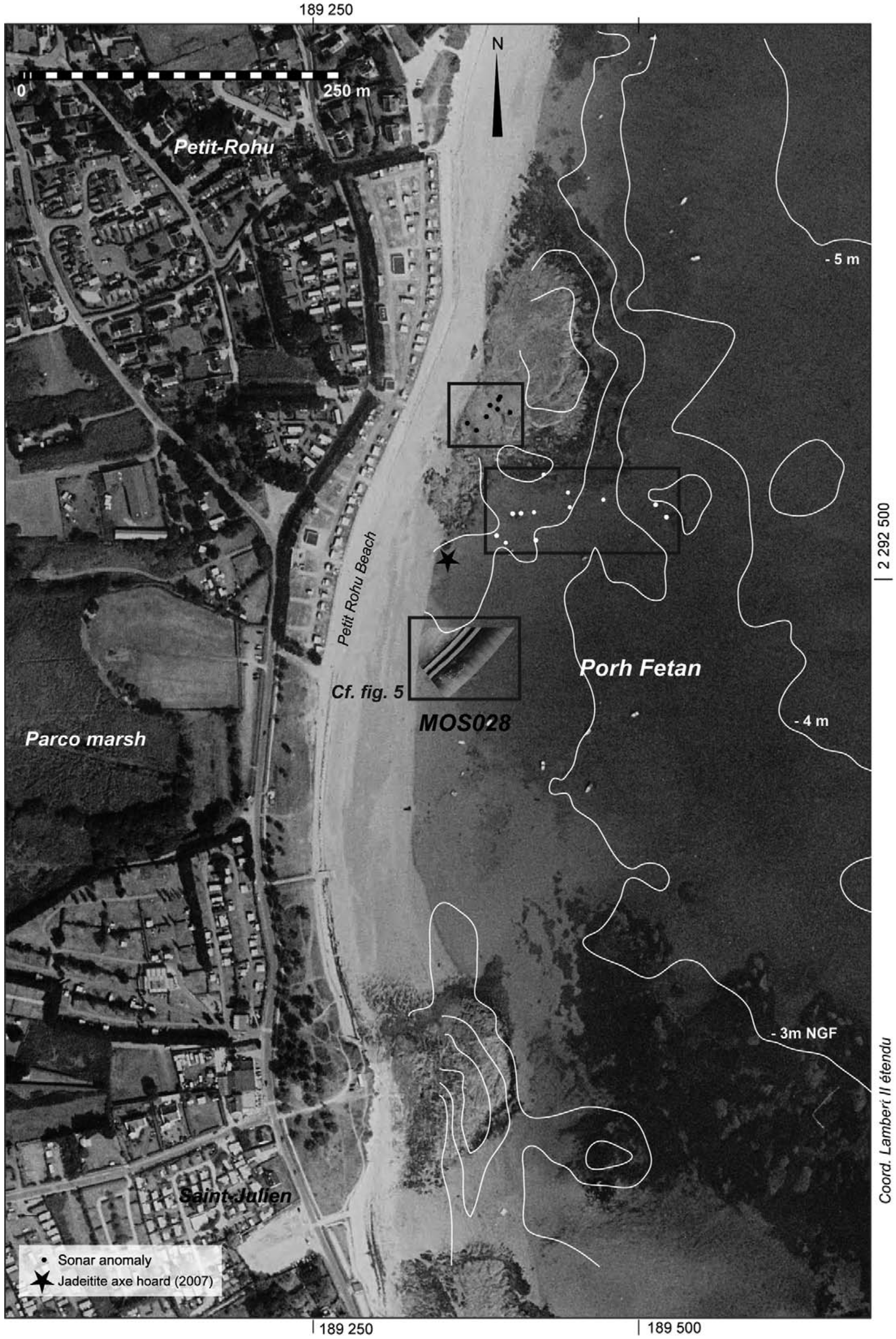


Figure 9.4: Petit Rohu. Location of the sonogram Mos028 above the Neolithic stone row, the positions of the monoliths detected by side-scan sonar, and the position of the polished axe deposit (Photo: IGN 2000)

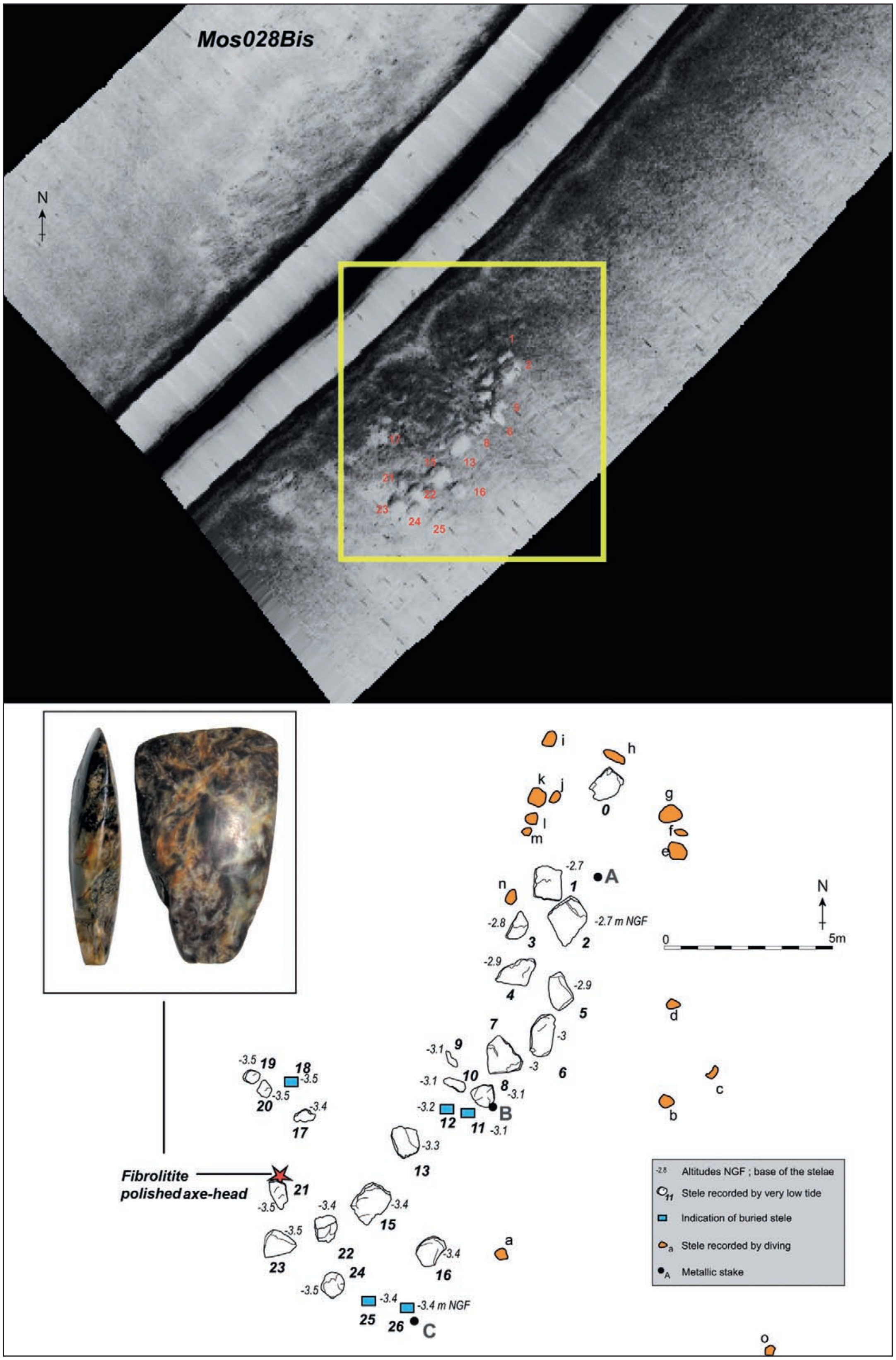


Figure 9.5: Petit Rohu. Comparison of the archaeological plan of the Neolithic stone row (After Cassen et al. *2010) and the side-scan sonar image of the structure (freq. 500 kHz)*

Figure 9.6: Kerbougnec. Side-scan sonogram mosaic between the rocky intertidal platform and the Ours shoal (Photo: IGN 2000)

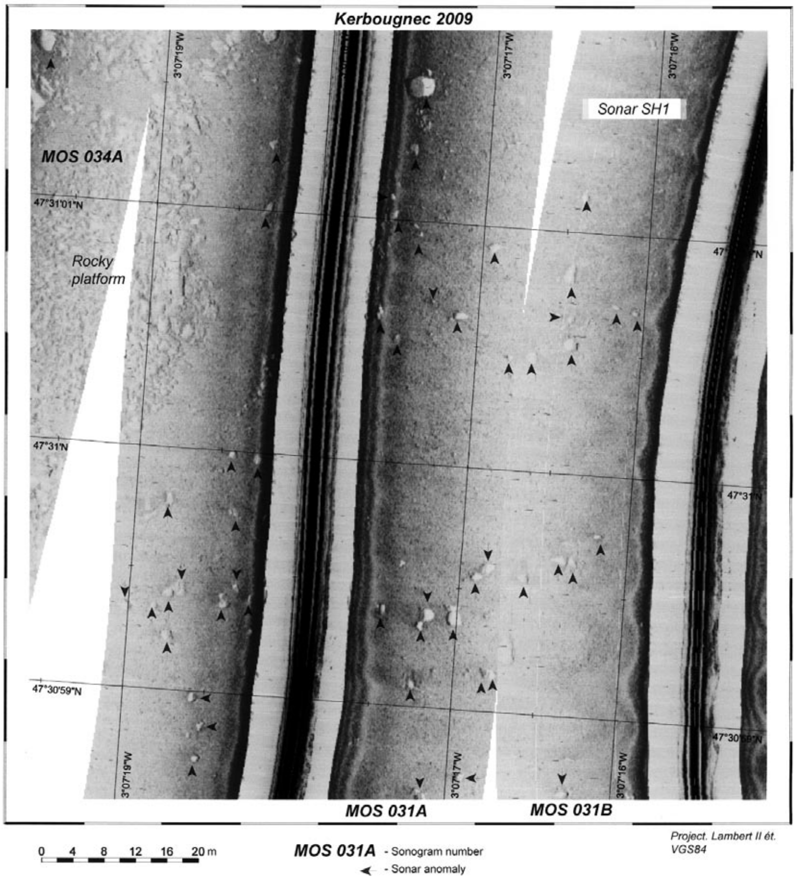


Figure 9.7: Kerbougnec. Zoom on sonograms Mos034A, Mos031A and Mos031B. Localization of the anomalies

substrate. Figure 9.8 synthesizes the anomalies extracted from six sonar records. There is an absence of features to both the north and south (for 100 m) from the area linking the beach with the reef of Kerbougnec.

The combined approach undertaken at this site reveals the performance of each side-scan sonar system. The highest frequency was very helpful for discerning blocks of 1–2 m length, and sometimes down to 0.5 m, upstanding by 0.5–1 m on the textured sandy floor and by only 0.2 m on a relatively homogeneous bottom. However, when flora and fauna cover the blocks on the rocky platform, the detection of acoustic anomalies is more challenging. Among all the sonar records, ten sites were chosen because of their quality in terms of resolution, repetition, and concordance of anomalies. From these, a preliminary (but not exhaustive) list of anomalies was selected for diving targets.

Results from the diving surveys

Surveys by divers were conducted in order to identify the nature of the acoustic anomalies. In this way it was shown that the majority of the anomalies correspond to granite monoliths. Their location on a sandy gravel seafloor was the first indication of their allochthonous origin. The divers conducted excavations around the base of each of the stones, to check that they were not connected with the subjacent substrate. Subsequent removal of seaweed, shells, etc., from a dozen of the blocks allowed us to observe the diversity of the monoliths' surfaces. On some of them, sharp edges have been noticed (Fig. 9.9D). Others have blunted edges belonging to ancient surfaces of the outcrop. If some marks indicate the original extraction face from the substrate

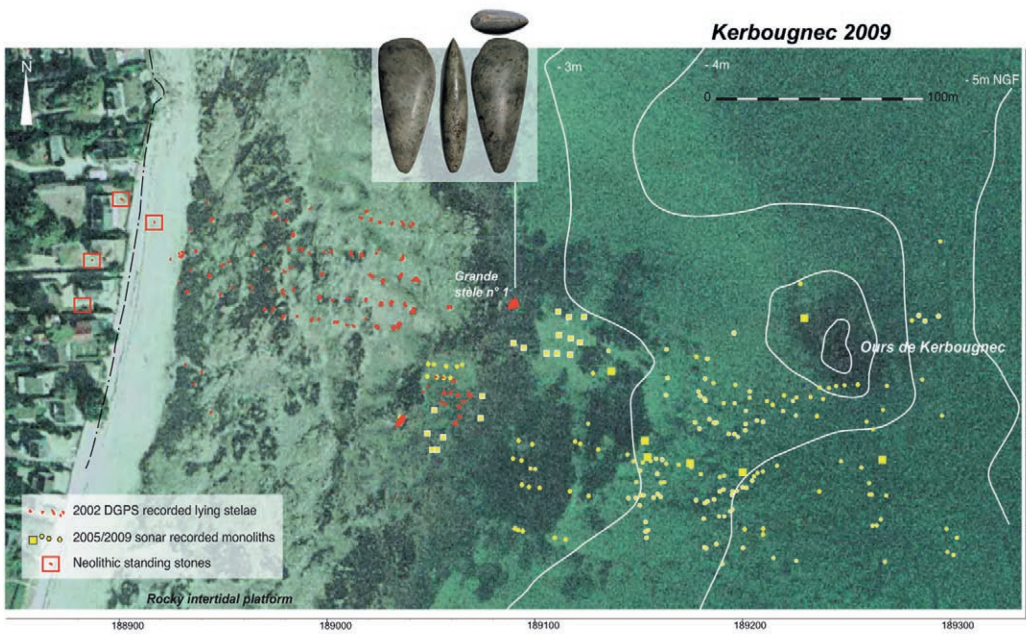
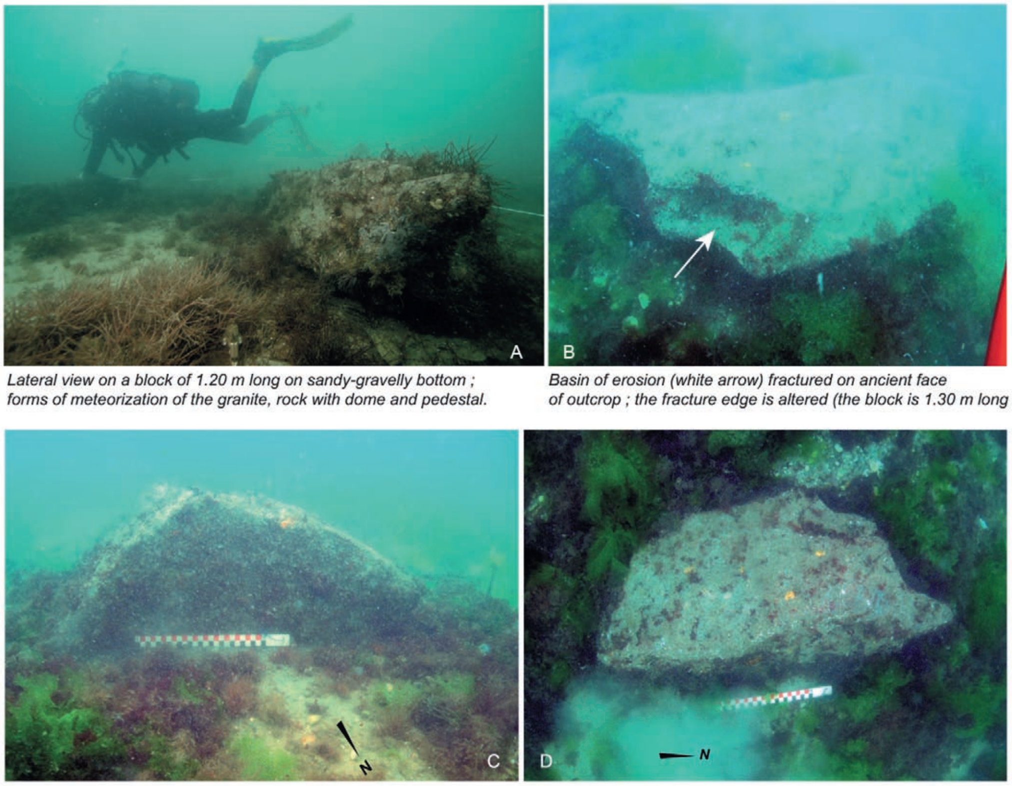


Figure 9.8: Kerbougnec. Synthesis between Neolithic monoliths recorded by DGPS on the rocky intertidal platform (left) and the anomalies recorded by side-scan sonar (right). Inset: the jadeite polished axe discovered at the base of Grande Stèle no. 1 (After Cassen et al. *2010)*



Lateral view on a block of 1.20 m long on sandy-gravelly bottom ; forms of meteorization of the granite, rock with dome and pedestal.

Basin of erosion (white arrow) fractured on ancient face of outcrop ; the fracture edge is altered (the block is 1.30 m long

Monolith K11, north section, on sandy-gravelly bottom ; sharp edges testifying an extraction.

Monolith K10 on sandy-gravelly bottom ; north extremity truncated (probable base of the stele) ; the edge of the fracture is still sharp.

Figure 9.9: Kerbougnec. Variations in the surface condition of the monoliths recorded, and forms of weathering of the granite (Photos: T. Abiven and A. Lorin)

(the usual forms of weathering of the granite), the sharp, angular section of the monolith sometimes indicates a secondary position on the floor (Fig. 9.9C); in other words, extraction and displacement. The questions surrounding these features remained focused on the anthropogenic nature of the observed phenomena. Therefore, our main effort is concerned with surfaces that are consistent with typical forms of weathering of granite described by geomorphologists (Fig. 9.9B – face of extraction uppermost, sharp edges; Fig. 9.9A – rock with an older weathering pattern known as 'dome' and 'pedestal'), and comparable to the Neolithic standing stones of Carnac used as a reference (Sellier 1995, 1997). After validation by divers, several arguments can be made to assert the anthropogenic character of these features:

1. In spite of the obvious disorganization of the original architectonic structure owing to the force of the ocean, a regular pattern can be drawn in the plan at Kerbougnec, which shows straight and curvilinear alignments of granite stones.
2. The observation of the slab surfaces allows us to conclude that the majority of the stelae were extracted from a substrate different from the surface on which they presently stand. These blocks are also marked with forms of weathering of the granite attesting to the fracture of some of them and confirming an extraction from an outcrop before the sea invaded the area. These fractures, testifying to the movements of the blocks, could be explained by erosion and disruption caused by the ocean (Fichaut and Suanez 2006). However, such an explanation would be very difficult to defend as the blocks are situated in a protected area inside Quiberon Bay (Stephan 2009). Moreover, the concentration of anomalies forms a consistent extension of the already confirmed architectural structure, and does not continue to the north or the south, supporting the interpretation.
3. Regarding the formation of the features we note an observable change of direction in Kerbougnec (Fig. 9.10): two main lines, comprising around 30 monoliths, appear to bend toward the southern base of the natural outcrop known as L'Ours, following the curves of the underwater relief (3 m and 4 m below MSL). This change of axis is comparable to a similar phenomenon noticed on the submarine Neolithic stone row at Kerdual (La Trinité-sur-

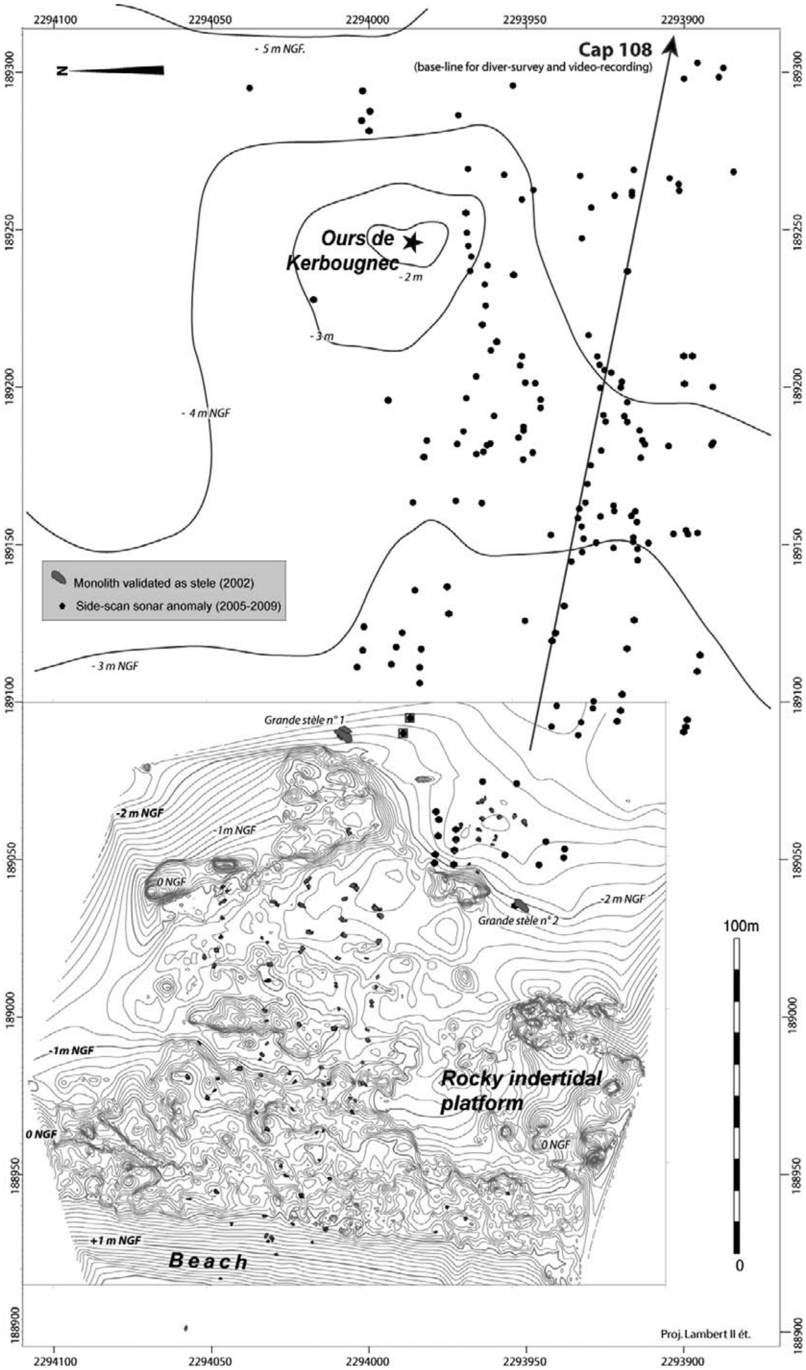


Figure 9.10: Kerbougnec. Lower part of Le Moulin/Kerbougnec stone rows; synthesis of the anomalies detected on the sandy-gravel seafloor (the intertidal platform after Cassen and Vaquero Lastres 2003)

Mer), which is also centred on a natural rock outcrop (Cassen and Vaquero Lastres 2003; Cassen 2009b).

4. Finally, the direction of the structure is identical to the pattern noticed in Carnac, from Menec to Le Petit Menec, through Kermario, Manio, and Kerlescan, not in terms of strict topographical rules, or astronomic situation, but topological pattern which prevents movement in a given space (see Cassen 2009a).

Conclusion

This chapter has focused on the use of side-scan sonar to identify prehistoric monoliths in a marine context, in water depths of 2–5 m below MSL. During the research programme (2005–2009), two different side-scan sonar systems were tested with distinct frequencies (100 and 500 kHz). The instruments proved to be complementary and both useful for this type of fieldwork. For the identification of discrete targets the highest frequency sonar (500 kHz) is best suited, whereas the lower frequency sonar is most useful for site contextualization. On both sites, exceptional archaeological objects (polished axe-heads made from Alpine jadeitite and Iberian fibrolitite) confirm the age of these architectural structures as *c.* 4500 cal BC. The resulting maps of the structures showed the direction of stelae alignment to be identical to the pattern observed at Carnac, from Menec to Le Petit Menec, through Kermario, Manio, and Kerlescan in terms of topological pattern, a feature that prevents movement in a given space. We therefore suggest that such Neolithic architectural features be described as a 'barrier of stelae'.

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