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Medieval shipbuilding in Catalonia, Spain (13th–15th centuries): one principle, different processes

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Late medieval shipbuilding in Catalonia followed the Mediterranean trend in adopting a frame-first shipbuilding principle with planking placed edge-to-edge. The predetermination of frame shapes using moulds had modified the construction process, as seen in the 11th-century Serçe Limanı vessel with the use of a series of moulds, and 13th-century Culip VI, with the use of a master mould, rising square and rule. Between the 13th and 15th centuries all known Mediterranean shipwrecks were built using the master-mould method, but other factors caused variation in the construction process—not the principle—as exemplified by the 14th-century Les Sorres X built with two overlain keel timbers.

Key words: shipbuilding, construction process, Middle Ages, Mediterranean, Catalonia.

Barcelona, capital city of Catalonia and political and financial centre of the Crown of Aragón, was the region's only urban centre capable of sustaining maritime mercantile activity in the 12th century. Also, the city promoted territorial and maritime expansion that allowed it to become the third most powerful naval force in the Mediterranean, after Genoa and Venice, by the end of the 13th century. Increased middle- and long-distance trade stimulated shipbuilding in the second half of the 12th century. As Ferrer notes (2012: 29–30) the fleet was sufficiently large by the early 13th century to embark on an expedition to conquer Majorca in 1229 with a primarily Catalan fleet, rather than calling on those of Pisa or Genoa as had been the case for the first expedition to Majorca in 1113–1114 and the conquest of Tortosa in 1148. The conquest and the creation of the kingdoms of València and Majorca in the 13th century—from the kingdom of Sicily at the end of the same century, the Island of Sardinia in the middle of the 14th century, and finally from the kingdom of Naples in the 15th century—not only contributed to extending the territory of the Crown, but also reinforced its role as a naval power consolidating its presence in the central and western areas of the Mediterranean (Fig. 1). The term 'Catalan' in this period thus encompasses both Majorcans and Valencians.

The conquest of Majorca made the adjacent seas safer. The island served as a base for the merchant fleet, being close to North Africa and on the route to Sicily and the Levant. It was at the crossroads of maritime routes from Barcelona, Genoa and Marseilles to North Africa, Muslim Spain and Seville. Goods from many different places were gathered there. Genoans used Majorca not only as a stopover but also as a cargo port, where they collected merchandise to be transported to the Atlantic, also (Abulafia, 1994: 150–215; Ferrer, 2012: 30). Sicily, conquered by Peter III of Aragon in the context of the Sicilian Vespers (1282), played a similar strategic role as a stopping point and trading centre (Ferrer, 2012: 35).

The East, or the Mediterranean Levant, included three areas: the Byzantine Empire or Romania, the crusade states of Palestine and Syria, and the Islamic state of Egypt. It is known that in 1187 there were Catalan merchants in the city of Tyre. The Marquis of Montferrat granted them an exemption from all import and export taxes in Tyre, and in the entire Kingdom of Jerusalem. He recognized the autonomous administration of the city under the authority of a viscount and seven consuls with their own jurisdiction, a *fonduq* (a building complex which included a hostel, consulate, warehouse, baths and a chapel) an oven and a manor house. In the 13th century there was a colony of Catalan merchants in Acre (Akko), some of whom acquired influential posts, such as Ramon Marquet who was in charge of collecting harbour taxes until the Muslims conquered the city in 1291.

After the loss of the Crusader states, Catalan merchants remained in the Levant. In the 14th century they were present in Alexandria and Beirut. As Ferrer (2012: 42) states:

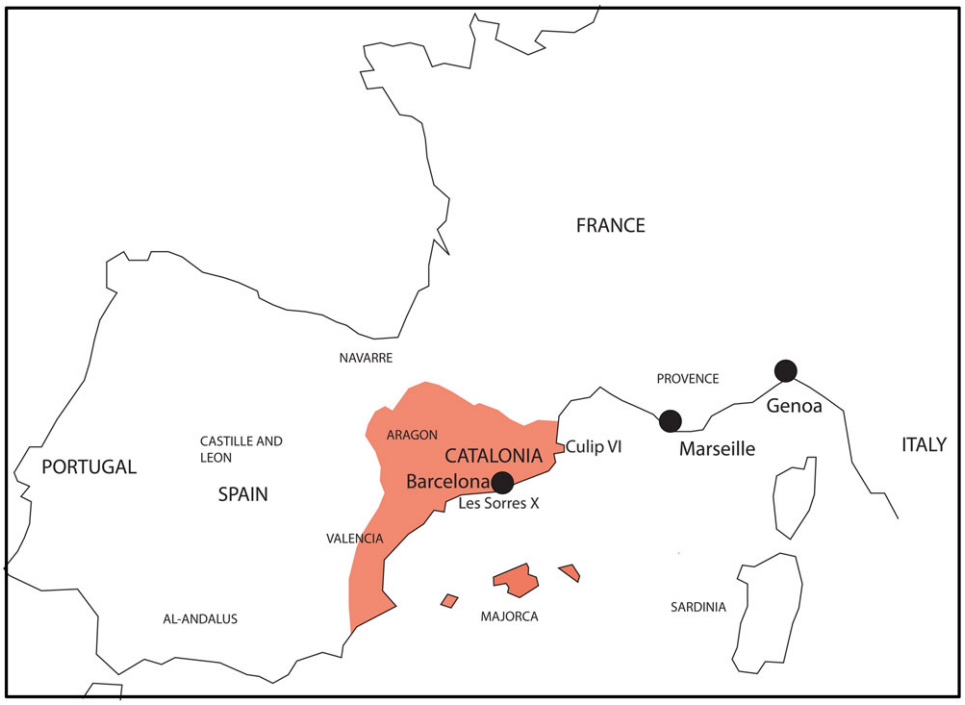

Figure 1. Location of the wrecks of Culip VI and Les Sorres X (Catalonia) and the Crown of Aragón, 14th–15th centuries. (Marcel Pujol i Hamelink/www.d-maps.com: Western Mediterranean)

> 'The Catalans were quite close to matching the Venetians and Genovese, the two leading commercial powers, although they had no base in the Orient as their counterparts did, with the exception of the duchies of Athens and Neopatria created by the Gran Companyia Catalana (1311–1388) (…). While 278 Venetian and 262 Genovese ships visited Beirut between 1394 and 1408, 224 Catalan ships travelled there, making Catalonia third in the ranking.'

In the 15th century, the island of Rhodes became the essential stopover for Catalans in the Levant, the main hub for the ships that went to Alexandria, Beirut and Constantinople.

In the late 13th century, the expansion of Castile in Andalusia allowed the control of the Strait of Gibraltar. In consequence, it opened new sailing routes to England and Flanders. Catalonia, Majorca and València became the centre of this new trading line. Catalans travelled to Portugal and Galicia as a destination, but also as a stopover on the way to Southampton and Bruges. The first documented Mediterranean ships in London, in 1281, were Guillem Bona's from Majorca and several other Genoese ships (Lopez, 1951). Other Majorcans, Catalans, Genoese and Venetians followed to the main ports of England and Flanders. During the 15th century, Middleburgh and Antwerp were also Flemish destinations.

This maritime trade and military expansion are reflected in medieval documents, especially those of the late medieval period, and particularly in relation to our topic of interest: the construction principle and shipbuilding processes employed in the shipyards and arsenals on the Catalan coast, and, by extension, all those in existence along the coasts of the Crown. The fleet was made up of fishing boats, the crews of which doubled as sailors on merchant and military ships; coastal vessels that ensured the transport and redistribution of goods between Catalonia, València and Majorca; long-distance ships sailing to Italy, the Levant and Flanders; and military galleys. One should also bear in mind the expeditions made to discover new lands, markets and raw materials, such as the Catalan and Majorcan voyages to the Canary Islands in the 14th century (Sevillano, 1972: 27–56), or to Senegal, formerly named the 'River of Gold'. This latter was led by Jaume Ferrer and his *uixer* (a type of galley that could carry horses) in 1346. The historical importance of this expedition appears in the *Catalan Atlas*, produced by Abraham Cresques in 1375, considered the master of world mapping (Bibliothèque Nationale de France, http://gallica.bnf.fr/ark:/12148/btv1b55002481n/f9.image).

There are three sources of information about how medieval vessels were built along the coasts within the Crown of Aragón. First, we have the main source of information for all things medieval, the documentary archives. Second, there are images of vessels created as symbolic, narrative and decorative elements in altarpieces originally placed in churches, cathedrals and monasteries. Third, there are the archaeological remains of sunken boats and ships, often termed wrecks.

It is important for this period to refer to all three of these sources of information, given that each complements the other. This is clearly demonstrated by comparing iconographic and the archaeological evidence: the part of the hull shown in the images usually corresponds to the freeboard and the rigging, while the archaeological remains usually belong to the bottom of the hull or the part below the waterline. If the iconography provides images and archaeology provides material remains, the records give us the words to describe them: the names of the parts of the ship, of the parts of the ship structure, as well as other elements including the rigging. Through archaeology, we can also verify if the measurements, and the type and origin of the wood listed in the written records are those indicated by the material remains.

Historical sources

Written records

Of all the existing documentation relating to naval matters—inventories, sales and purchases, cargoes, and so on—there are two types that allow us to comprehend the principle and the process of shipbuilding: construction contracts and construction ledgers.

Shipbuilding contracts are found in notarial records, collections of which in Catalonia are kept in the following archives: the notarial districts of the province of Barcelona and the Crown of Aragón Archive (ACA); the Historic Archive of Protocols for Barcelona (AHPB); the Historic Archive of Girona (AHG); and the Historic Archive of Tarragona (AHT). Ledgers recording the building of ships, galleys, large naval and merchant vessels built for the King, the Generalitat or even for the city of Barcelona, are preserved in the ACA, in the Master Book section for Royal documents, in the Generalitat section for the institution of the same name. The Historic Archive for the city of Barcelona (AHCB) houses the documents concerning the city of Barcelona.

In the first of these types of documents, the building contracts, we find the name of the contractor or shipowner (Cat. *senyor de la nau*), who, if he was part of a company, was usually the largest shareholder and, at the same time, able to act as shipmaster. Also noted is the person under contract, the shipwright or 'master of the adze' (Cat. *mestre d'aixa*). The agreement between both parties informs us of the type of vessel, the general dimensions and the total price. In addition, on many occasions the building cost would be paid in several instalments as building progressed, coinciding with different stages of the building process—framing, planking, caulking and launching.

In the ledgers, the second type of document, are found sums relating to various costs such as workers' wages (shipwrights, caulkers, sawyers, and so on), the purchase of building and caulking material (wood, nails, bolts, pitch, oakum, and so on) as well as daily or advance purchases of food and drink. These costs also give us an insight into the celebrations held at the beginning or end of important phases of the building process. For example, the unusual purchase of white wine, veal and beef might serve to celebrate completing the planking of the hull, given that normally lamb and pork were eaten and red wine drunk. This celebration was known as the *festa del romball*. The *romball* is not in itself a plank, but is the final piece of wood used to complete the planking process. Another type of expense was the purchase of golden goblets by the shipowner. In this case the goblets are associated with celebrating the completion, naming and launching of the ship. They were given by the shipowner, or his representative, to the master shipwright and the master caulker, and they, in return, handed over their tools, the carpenter's adze and the caulker's hammer. In addition, the episcopal licence to name the ship had to be paid for, as well as all costs of a liturgical and celebratory nature incurred on this day, such as musicians, priests, crockery, food and drink.

Thus, the historical documents give us information about a series of construction stages beginning with: 1) *seure*, placing the keel on the slipway; 2) *enramar*, placing the frames; 3) *cenyir*, positioning all the interior and exterior longitudinal elements: keelson, stringers, side keels, wales, clamps and waterways; 4) *cloure* or *fer blanc*, planking the hull; 5) *calafatar* or *fer negre*, caulking; 6) *beneïr i varar*, naming and launching; and 7) *arborar*, masting (Pujol, 2012: 151). These stages clearly demonstrate that the frame-first construction principle was used, where the shape of the hull was determined by the longitudinal section, consisting of the stem, keel and sternpost, and the transverse section, shaped by the master frame. It was completed by the other frames and longitudinal strengthening elements of the structure, with the frames being covered with the planks at a later stage.

In essence, the framing was defined and built during the *seure*, *enramar* and *cenyir* stages, while the planking was fixed during the *cloure* stage. One of the most important characteristics of this construction principle was the caulking of the planking of the hull in order to seal it, which also indicates that the planking was placed edge-to-edge.

Iconography

The iconography that is most realistic and rich in detail is found in altarpieces. These, painted or carved, are works of exceptional quality and are very common, with more than 70 known to have been created in Catalonia from the 13th to the 15th century.

If we look carefully at the representations of the large trading vessels (*naus* and *coques* or ships and cogs[1]), we can see in the works from the 13th and beginning of the 14th centuries that they have two masts with lateen sails and side rudders (Pujol, 2012: 19–28). During the 14th century, the arrival of Atlantic naval technology brought about changes in the methods of propelling and steering such ships: two masts gave way to one, the use of the lateen sail was superseded by the square sail, and side rudders were replaced by stern rudders. From

the 15th century, we see the appearance of vessels with mixed rigging with two masts: the main mast towards the bow carried a square sail, while the second mast towards the stern had a lateen sail. As the century advanced, three-masted vessels began to appear, fore and main masts carrying square sails and a mizzen mast with a lateen sail (Pujol, 2012: 19–28).

This progression is noted, principally, for large trading ships. These appear in numerous altarpieces dedicated to saints who, at some point in their lives, had undertaken a voyage or had performed a maritime-related miracle: St Nicholas, St Ursula, St Magdalene, St Martin of Tours or Jonah, to name just a few. The bourgeoisie, guilds and various institutions that financed the creation of the altarpieces wished to represent their means of creating wealth in business and maritime activities through the depiction of ships. While the altarpieces allow us to perceive the technological advances in the systems of propulsion and steering, we are unable to discern the construction principle used, even when we can see that the planking was positioned edge-to-edge.

It is probable that several different processes of development existed during the 14th and 15th centuries. The iconography that has been preserved mainly depicts large trading vessels of the period and a smaller number of fishing boats, the latter relating to trips made by Jesus and the apostle-fishermen Peter and Andrew on the Sea of Galilee. Other types of sailing vessels, such as galleys or the wide variety of small- and medium-sized trading vessels, are under-represented; in fact they are all but absent from the iconography.

These development stages can be followed in the written documents also, where we see the introduction of the stern rudder in the galleys, coexisting with the double side rudder. With regard to the rigging, the lateen sail remains in use, even when the large trading galleys, and especially those sailing to Flanders, used *treus* or square sails as a second set of sails. As for the medium-sized vessels, the archives provide us with evidence of a large variety of types and development processes. We see types peculiar to the Mediterranean, as well as the introduction of the stern rudder during the second half of the 14th century, used alongside the two rudder system, as seen in the galleys. In this case, one or the other was used depending on sea conditions or the type of manoeuvre being performed, with some vessels even using a double side rudder. In relation to the rigging, the square sail appears less in evidence. In the Mediterranean ship types, the lateen sail continues to be used, while vessels arriving from the Atlantic and sailing into the Mediterranean have square sails.

Apart from the images showing large trading ships there are other works that allow us see the interior of the hulls. These are smaller vessels without decks, such as fishing boats, or the support vessels of ships and galleys. In some cases frames divided into floor-timbers and futtocks, scarfed laterally, and placed at regular intervals are visible, with the planking joined edge-to-edge and nailed to the frames.

Probably the best example that gives us an accurate picture of what a ship or cog was like at the beginning of the 15th century, and specifically which construction principle was used, is the Mataró model, preserved at the Maritime Museum in Rotterdam (Westerdahl, 2013: 338, fig. 1). This is a model of a merchant ship, almost certainly built by a shipwright, as if building a real ship. Here we can clearly appreciate how the planks are placed edge-to-edge, how they are attached using iron nails that follow the vertical lines of the arms of the frames, as well as the regular intervals at which said frames are positioned. Through the hatchways we can see how the interior was formed by the keelson and other longitudinal pieces, and each of the frames. Unfortunately, the large quantity of pitch present makes a detailed study of the hull interior impossible (Winter, 1986: 7–46; Meer, 2004: 573–9).

Archaeological sources

Archaeology is the discipline that gives us the greatest insight into the construction principle used, and more especially the actual process of shipbuilding. From the 11th century, with the analysis of the Serçe Limanı (Turkey) wreck, we can confirm that the only construction principle used in the Mediterranean was that of frame-first with the planking placed edge-to-edge (Pomey *et al.,* 2012: 278–9). These two characteristics give us an indication of the skill and importance of both the shipwright and the caulker. The first determines the shape of the main pieces of the framework (stem, sternpost and frames) or the skeleton of the hull, and the second is an indispensable specialist in making the planking watertight, given that the planks are positioned edge-to-edge. The method used to determine the shape of the main pieces of the hull has been investigated by consulting different Venetian manuals or instructions on shipbuilding from the 15th and 16th centuries, particularly those described in the work of Mauro Bondioli (1996: 139–56; 2003: 10–13; 2007b: 92–8).

The relevant wrecks are limited to Culip IV in Catalonia, dated to the end of the 13th century and studied by Eric Rieth (1998: 137–90; 2005: 9–16), and the review and study of the wrecks found in a Venetian context, such as the Contarina I (Bonino, 1978: 9–28), the galley of San Marco in Boccalama and the light galley from Lazise dated from the 14th to the 16th centuries, both studied by the aforementioned Bondioli (2007a: 82–4; Beltrame and Bondioli, 2006: 89–94). From these, we are quite knowledgeable about how shipwrights created and used the Mediterranean whole-moulding method to shape the master floor-timber (and master frame), and used scale reduction diagrams, or gauges, to determine how to adapt the frames between the master frame and the quarters, through narrowing and rising. The shipwright would decide how to apply

these two reductions to the frames between the master frame and the bow and stern quarters, adapting his use of the whole-moulding method, the rising square and rule, and outlining the shape of the frame required using a type of ink called 'red ochre'.

How the shape of the frames was determined tells us which construction principle was used and gives us information about part of the construction process, but does not describe the entire process. Neither can we tell if once the frames were made in the shipyard they were positioned all at the same time on the keel, or if they were positioned in groups, or alternately—even if logic suggests that the master frame and the quarters would be the first to be positioned on the keel.

By studying the ship timbers in detail we gain a better understanding of the building process, the particularities of the structural pieces, the relationship between them, the joints and fasteners, and, with luck, find clues relating to the use of elements peculiar to the construction process that are not found in the finished hull. We must remember that a whole series of wooden pieces do not appear in the hull but were used during the construction phase and then removed. These include wedges for the blocks, shores and props that supported the hull, scaffolding and ladders, winches to manoeuvre large heavy pieces, the bilgeways and slipway rollers that facilitated launching and, above all, the wooden ribbands that were nailed longitudinally on the exterior of the hull to test that the frames were shaped correctly. The ribbands are pieces that were only used during the construction process, but their use can be identified by the holes made by the nails that temporarily fixed them to the frames.

Culip VI

Culip VI is the wreck of a ship that sailed from the North African coast or the coast of Andalusia to Roussillon or Languedoc, via Majorca. It was laden with ceramics from Andalusia (tablewares and medium and large receptacles), dried fruits and nuts, and a set of crockery for the crew that had been made in Catalonia and the Languedoc. These artefacts provide a date of around the end of the 13th century. According to the preserved remains of the hull, the ship was medium-sized, some 18–20 m in length, the presence of stanchions fitted into the keelson indicated that it had a deck, and the two mast-steps were each mounted with lateen-sail masts; a ship type known as a *lleny gros cobert* (Pujol, 1998: 210) (Table 1, Fig. 2).

This shipwreck marks a milestone in naval construction history. While the Serçe Limanı shipwreck from the 11th century is the earliest archaeological example for which a frame-first construction principle has been demonstrated, Culip VI, dating to the late 13th century, is the first for which the process of determining the shape of the frames by using a master mould and ribbands has been verified.

Evidence suggests that between the 11th and 13th centuries, the techniques that regulated the construction process may have been simplified. We do not have much information on this subject however, particularly considering the extent of the coastal area where ships and boats were built using moulds and ribbands (Rieth, 1996: 149–65). Recent evidence from Bahia, Brazil, suggests a wide variety of 'whole moulding' solutions or 'recipes' could be used to achieve any hull shape (Castro and Gomes-Dias, 2015: 421). It seems that, at least in some regions, shipwrights consolidated the information required to determine the shapes of the frames in a single template. By doing this they eliminated the use of several different templates and the wales and ribbands became less important in determining the shapes of the frames. The Mediterranean whole-moulding method consists of using a template to determine the shape of the master frame, or rather half the master floor-timber, the mirror image of which shapes the entire floor and, in some cases, is also used for the two main futtocks. In addition, the narrowing of the frames, as they get further from the master frame and closer to the bow and stern ends, is obtained by using different gauges, as reflected in several Venetian documents of the 15th century, but which were already commonly used in the 12th and 13th centuries (Rieth, 2008, 2009). The use of the Mediterranean whole-moulding method, the rising gauge and a rule allowed shipwrights to shape almost all the frames of the hull. These, consisting of floor-timbers and futtocks, were laid out on the ground with the three instruments being used to mark the shape required. In the Culip VI shipwreck, three lines were marked, the first corresponding to the axis of symmetry, or the part of the floor-timber that would be seated on the keel, and the other two at either extremity of the floor-timber, marking the position of the bilge or the start of the bilge. The shape of the piece was painted with red ochre while the three lines were marked with an awl. The large number of frames meant that the order in which they were to be positioned on the keel, and their location, had to be monitored, and they were often numbered. Logically, the master frame was numbered I and then sequentially towards the bow and stern, II, III, IIII, V, VI and so on. Once the floor-timbers were shaped, the entire framing might not be assembled immediately and it could be several days before all the frames were positioned on the keel. Therefore, rather than paint, an awl was used to mark the position of the frames on the keel, the ends of the floor-timbers, and the number indicating the position assigned to each frame.

The floor-timbers and futtocks were scarfed laterally and fixed using two long nails from floor-timber to futtock and from futtock to floor-timber, thus creating the frame. Once all the frames were made, they were positioned on the keel, stem and sternpost.

From this point in the construction, a whole series of pieces were placed that, over time, are seen to have increasing importance. These longitudinal timbers,

Table 1. *Dimensions of Contarina I, Culip VI (revised by Lluís Rovira, pers. comm., 2004), and Les Sorres Mediterranean shipwrecks dated from the 13th to the end of the 14th century*

Shipwrecks	Total length (m)	Keel length (m)	Beam (m)	Floor width (m)	Depth (m)	Capacity (tons)
Les Sorres X	9.5–10	6.20	1.9	1.2	0.9	5.4
Culip VI	18.80	13.50	4.8	1.9	2.2	55
Contarina	21	16.5	5.2	2.1	2.46	75

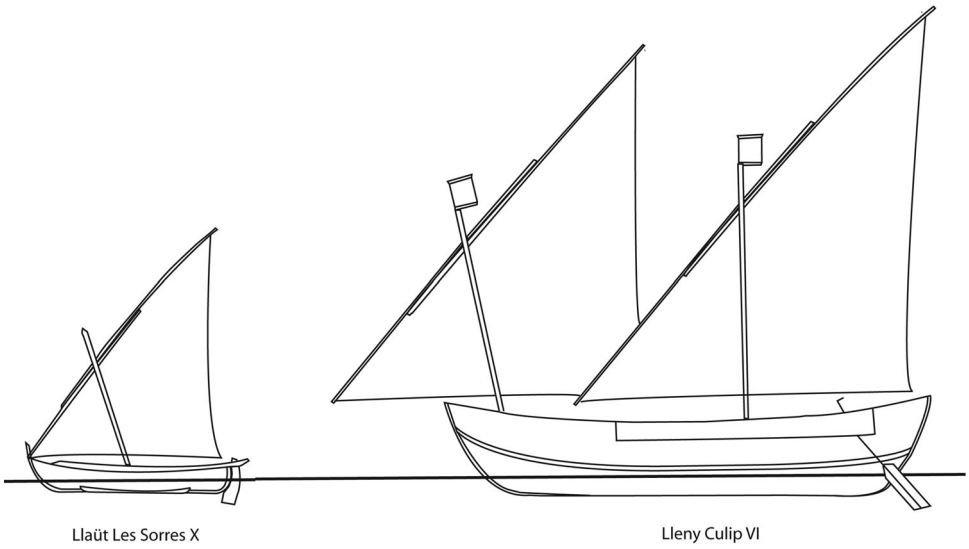

Figure 2. Les Sorres X boat and Culip VI medium-sized cargo ship. (Marcel Pujol i Hamelink)

both interior and exterior, served to make the structure more cohesive, and, at the same time, reduce the thickness of the frames making the hull lighter. Firstly, the keelson would be fitted on to the floor-timbers and fixed to the keel using iron bolts. As a rule, the bolts were inserted through the spaces to avoid damaging the floor timbers, which were not thick enough to have large holes drilled through them. In Culip VI, the bilge strakes were positioned on both sides, from the outboard, and notched and fitted to the frames. Moreover, the bilge planks were made of a different type of wood from the ordinary planking. Their main function was to maintain the frames in position, ensure that they had the required separation, or space, and, in a sense, they also acted as ribbands, ensuring a fair turn of the bilge run. In addition, one or two stringers were positioned on both sides, and these were also notched and fitted to the frames, running over the area where floor-timbers and first futtocks overlap. One of the two stringers was fixed to the bilge planks using treenails or iron bolts, again inserted in the spaces between the floor-timbers. The importance of wales to the cohesion of the structure seen in earlier vessels is transferred to a variety of longitudinal elements, such as the bilge strakes, and the interior elements such as the stringers, clamps and waterways. This is clearly indicated in the Culip VI shipwreck and, in the Venetian context, in the Contarina I wreck and the galley found at San Marco in Boccalama, both from the 14th century, as well as in the naval plans from the Arsenal in Venice from the 15th century (Beltrame and Bondioli, 2006: 89–94). For each outboard longitudinal piece there was a corresponding inboard piece to which it was fixed using bolts. The keel was fixed to the keelson, the bilge strake to the stringer, and the wale to the clamp. These pieces allowed a greater cohesion within the entire structure and reduced the thickness of all the hull timbers, thus obtaining a stronger and lighter boat.

Les Sorres X

Les Sorres X was a coastal trader, some 9–10 m in length, which sank in a salt marsh of the River Llobregat delta, south of Barcelona (Fig. 3, Table 2). It was carrying ceramic jars containing preserved fish, which dated the wreck to the end of the 14th century (Fig. 4).

The hull had a mast-step, formed from a single timber, placed on top of the keelson, at a fixed distance fore of the master floor-timber, which, and in conjunction with its date, tells us that it had only one mast with a lateen sail (Fig. 5). In addition, sections of the stern rudder were found (Fig. 6). The boat has a round stern, typical of Mediterranean boats, to which the rudder was fixed using two pintles: one short, positioned for the upper part of the rudder

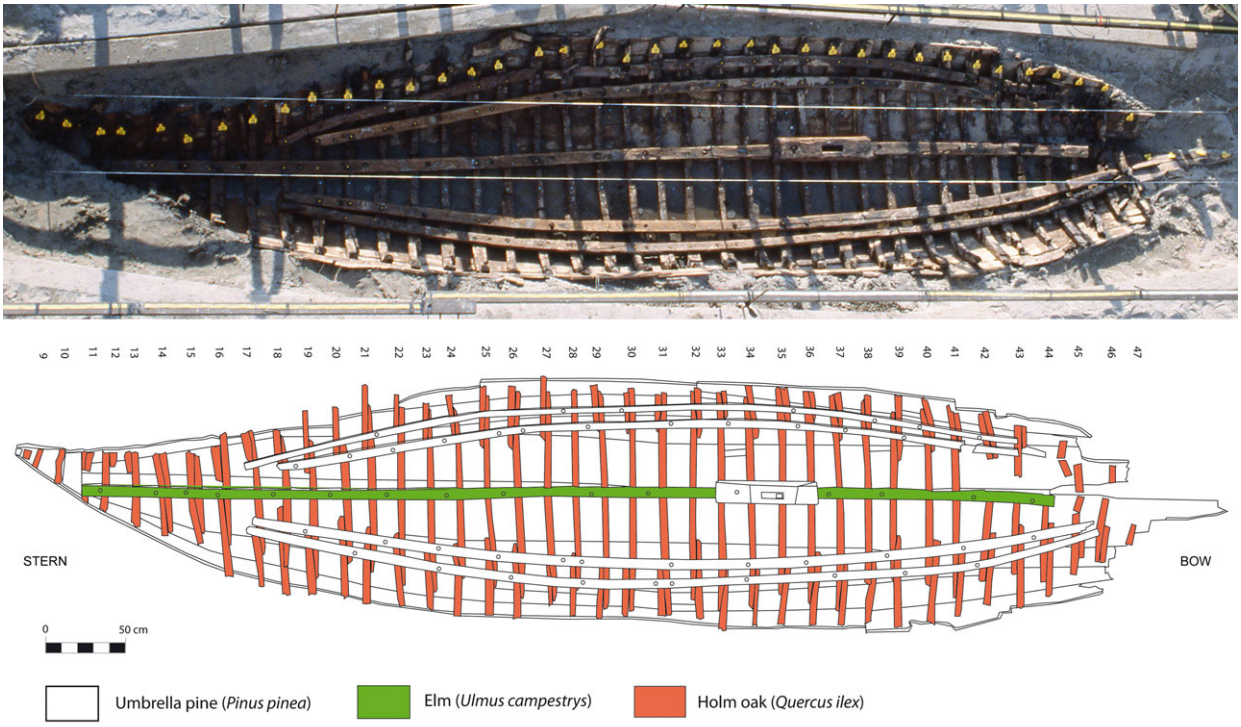

Figure 3. *a)* Plan view of Les Sorres X wreck (Xavier Nieto Prieto); *b)* plan of the hull and different types of wood. (Marcel Pujol i Hamelink)

Table 2. *Dimensions of specific Les Sorres X timbers*

	Length (m)	Width (mm)	Depth (mm)
'Keel plank'	6.50	100	20
Keel	6.20	70	60
Stem	0.30	70–80	130
Sternpost	0.93	70–80	110–130
Keelson 1	1.90	60	90–120
Keelson 2	4.50	60	90–120
Stringer larboard upper.	5.10	50	80–110
Stringer larboard lower.	4.90	50	80–110
Stringer starboard upper	5.50	50	80–110
Stringer starboard lower	5.40	50	80–110
Mast-step	0.70	120	110–120
Side keel larboard	5.00	70–80	80–90
Side keel starboard	4.85	70–80	80–90

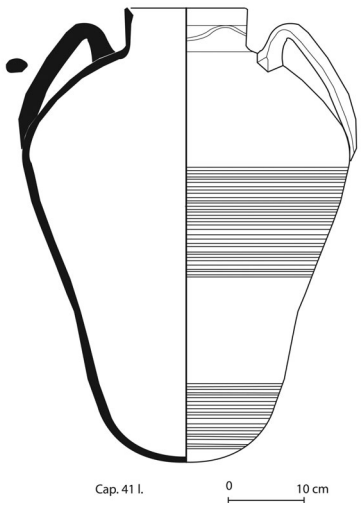

Figure 4. Jar containing salted fish. (Albert Martín i Menéndez)

and the other long, positioned for the lower part of the rudder. The long pintle was found in its original position, still nailed to the sternpost. The date indicated by the cargo of ceramics makes this wreck the oldest-known Mediterranean-type vessel with a stern rudder. This archaeological exception is probably the result of the absence of recorded wrecks from the period, as documentary archives tell us that the stern rudder was already widely used in the second half of the 14th century (Pujol, 1992: 29–48).

The body of the hull was quite well preserved, with a total of 40 frames, with half of those in the stern being preserved intact.[2] We can identify the double master frame (Q31 and Q32) by a change in the side of the floor-timber to which the futtocks were joined. From the master frame to the stern there were 23 frames, while in the bow half there were 15 frames to the base of the

Figure 5. Mast-step of Les Sorres X. (Albert Martín i Menéndez)

stem (Q47), the remainder being lost as the bow of the boat had not survived (Fig. 3). There were marks traced by the shipwright on the floor-timbers that indicate that the Mediterranean whole-moulding method was used to determine the shape of the frames. The marks were of two types corresponding to the centre and the turn of the bilge, exactly like those seen on Culip VI. In Les Sorres X, however, no numerical marks were found on any of the floor-timbers.

If these details inform us about the method of propulsion (the mast-step), steering (the stern rudder) and the methods of design and manufacture of the frames (the marks), there are also a series of details that can be considered atypical. The keel—or rather the collection of timbers that form the keel—provides a unique example with regard to its construction.

In almost all boats and ships, the spine of the hull is the keel. The keel carried out a series of functions, the first and most important being its role as the centre piece of the construction; the second being that it held the garboard strake; the third that it linked frames and keelson, which was essential to the structure; the fourth that it served to resist or receive the impacts of the hull against the bottom; and finally, it prevented lateral drifting caused by currents or the force of the wind. The keel of this shipwreck is composite. It is a rare and totally atypical piece. It was composed of two pieces, the first we have termed the 'keel plank' and the second the 'keel', with both of these in conjunction fulfilling the roles of the keel.

The 'keel plank' is of the same thickness as the planking strakes (20 mm), and is laid flush with these (Fig. 7). It is the main timber of the construction on to which the frames are positioned and fixed in place using iron nails, as well as holding the garboard strakes. The lower part, or 'keel', protrudes from the hull and complies with all the other functions assigned to a keel: it is the essential linking piece joining the 'keel plank' and keelson using treenails, it receives the impacts of the hull against the bottom or scraping when launched or beached, as well as preventing lateral drifting (Fig. 8).

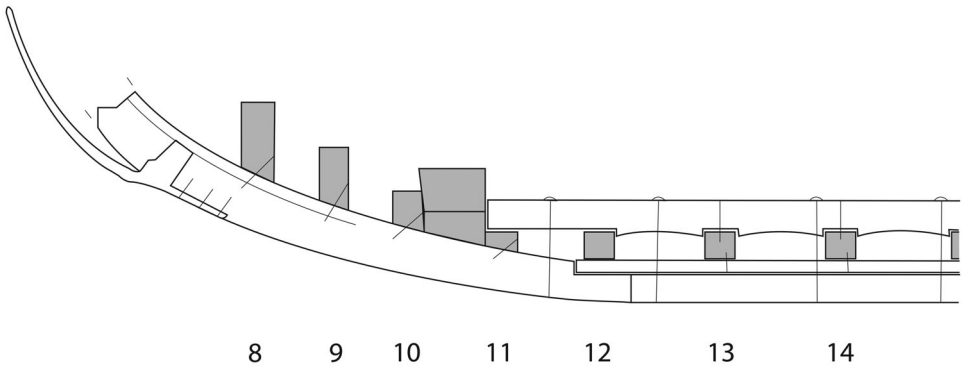

Figure 6. Longitudinal section of the stern: detail of the pintle of the stern rudder. (Marcel Pujol i Hamelink)

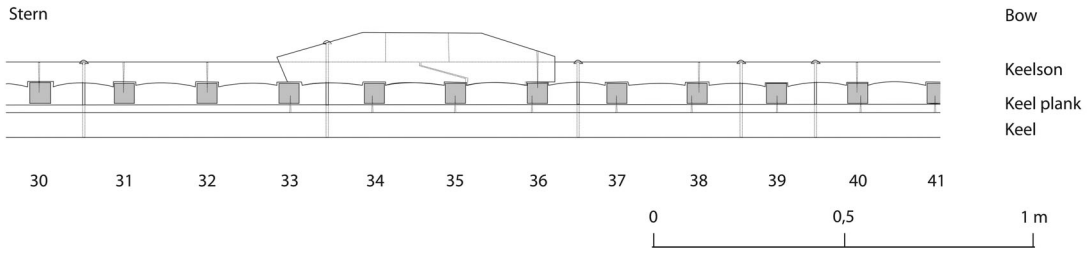

Figure 7. Longitudinal section and detail of the scarf of the keelson under the mast-step. (Marcel Pujol i Hamelink)

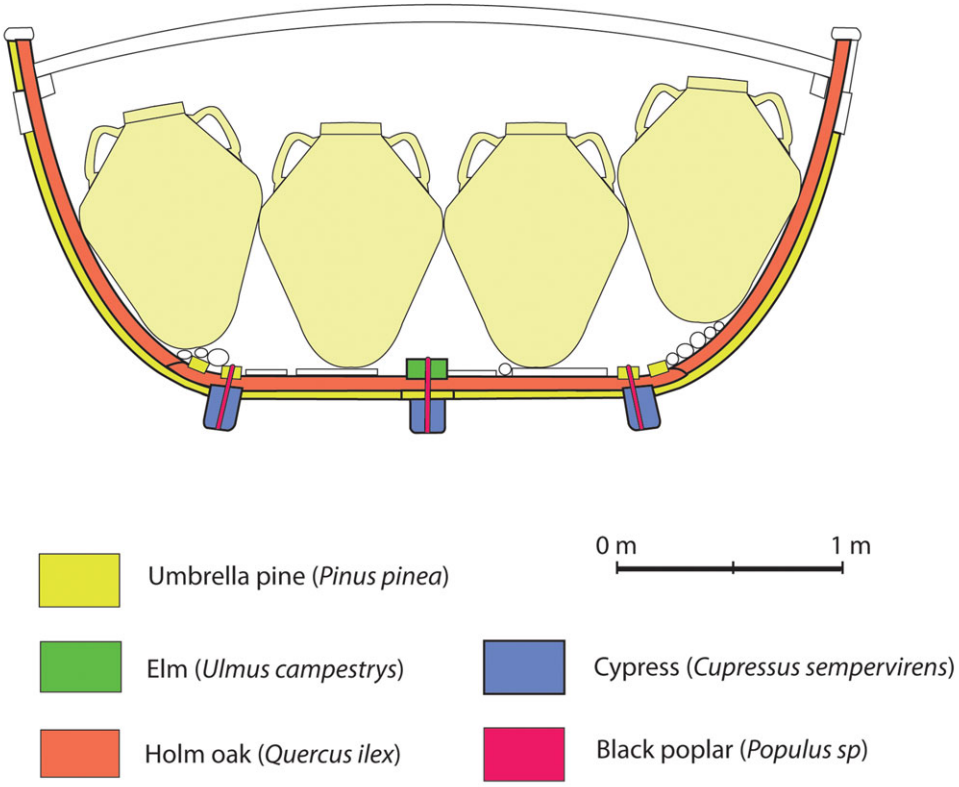

Figure 8. Transversal section and different types of wood. (Marcel Pujol i Hamelink)

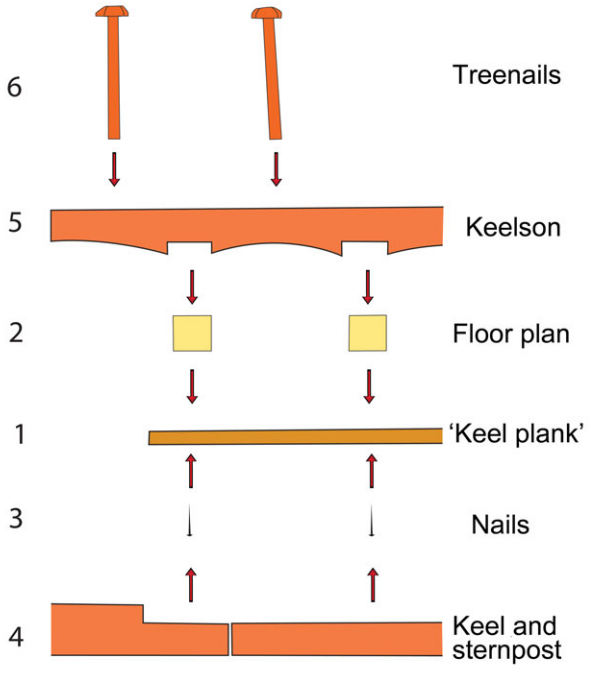

Figure 9. Longitudinal section of the stern and process of its construction: 1–3: 'keel plank' nailed to the frames. 4–6: keelson, 'keel' and sternpost joined with treenails. (Marcel Pujol i Hamelink)

The 'keel plank' (6.50 m) is 150 mm longer than the keel at the fore and aft ends of the vessel (6.20 m), and overlaps the stem and sternposts. The keel simply abuts the stem and sternposts, but the presence of the 'keel plank' transforms these joints into horizontal flat scarfs (Fig. 9).

Another unusual feature of this shipwreck is that the bilge strakes are true side keels. While the shipwright used a two-piece system for the keel, it was not, however, used for the side keels (Figs 8, 10, 11). These were positioned on each side of the keel and their purpose was to prevent lateral drift when the boat listed, to reduce rolling, and to maintain the boat upright when it was drawn up on the beach. The side keels were constructed in one piece and were placed directly against the floor-timbers, without intervening planking, and were fastened to the stringers with treenails.

If the 'keel plank' is the base unit of the construction, to which the frames were attached, the first to be positioned were the two master frames. Q31 and Q32 were fixed using an iron nail driven from the floor-timber to the 'keel plank', along with a third frame, Q30, of the same shape (Fig. 12). By contrast, all the fore and aft frames, from Q33 to Q43 (fore) and Q29 to Q13 (aft) (Fig 13), were fixed in position using an iron nail inserted vertically from the 'keel plank' to the floor-timbers. The two remaining frames, Q44 and

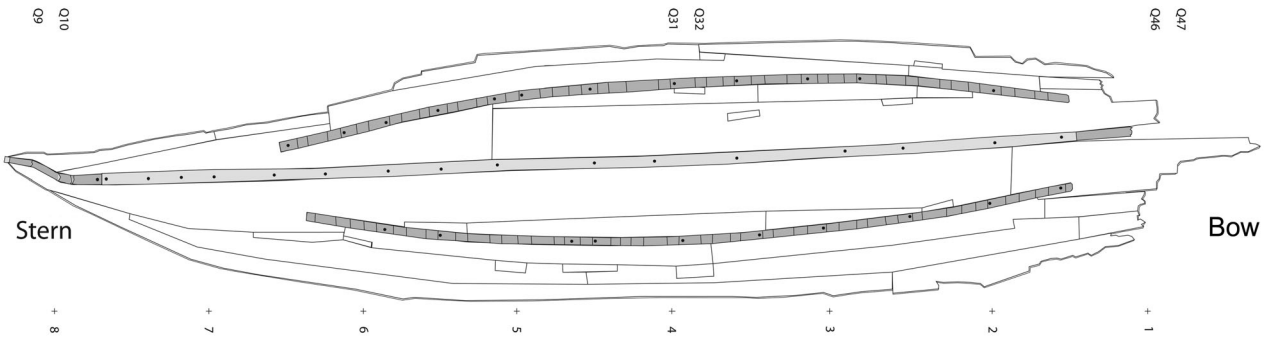

Figure 10. Plan of the planking, 'keel plank', stem, sternpost and the side keels. (Marcel Pujol i Hamelink)

Figure 11. View the hull without frames, with the stern at the background, the 'keel plank' in the centre and side keels on each side. (Albert Martín i Menéndez)

Q12, at either end of the 'keel plank', bow and stern respectively, were not physically attached to the 'keel plank'. These two frames might be tail frames, the last fore and aft pre-designed frames of this vessel. The frames positioned over the sternpost were fixed in position using one or two iron nails, driven diagonally from the interior of the boat to the sternpost.

Hypothetical construction process

Our first hypothesis about the construction process is that the 'keel plank', or centre piece, remained in contact with the blocks until the keel, stem and sternpost were put into position. It was the first structure laid, placed directly on the blocks. Immediately afterwards frames Q32, Q31 and Q30 were positioned on the 'keel plank' and attached using one iron nail each. It is thought that the tail frames were put in at the same time as the master frame, at the end of the keel, which, in this case, would correspond to those found at either end of the 'keel plank', frames Q44 and Q12. Yet, given that there were no nails used to fasten these, the tail frames must be those immediately before them (Q43 and Q13). Once the master frames and the tail frames were positioned, the other frames between Q43–Q33 and Q29–Q13 were put in place. Since almost all the frames were nailed to the 'keel plank' from below, this would mean that the entire structure would have had to be moved or raised first, given the presence of the blocks. Once all the frames were mounted and fastened on to the 'keel plank', the shipwright had to lift the structure to allow the keel to be placed underneath and the stem and sternpost positioned. This may explain why frames Q44 and Q12 were not nailed, as they could not be placed until after the stem and sternpost were in position. Inexplicably, they were not then nailed to the posts, but rather they were supported by the keelson.

Once the stem and the sternpost were in position, floor-timbers Q11–Q8 were nailed to the sternpost using two iron nails, driven diagonally from the frame towards the sternpost. It is also certain that the position of the floor-timbers was also ensured by placing ribbands on both sides of the hull, and at different levels.

All the frames were also kept in place by the keelson, which, being notched, held them securely. The keelson was nailed to the frames and, moreover, to reinforce the structure, all the treenails were inserted from the keelson, through the spaces between floor-timbers, the 'keel plank' and into the 'keel'.

There were four stringers, two on each side, one upper and one lower. One supposition is that the upper

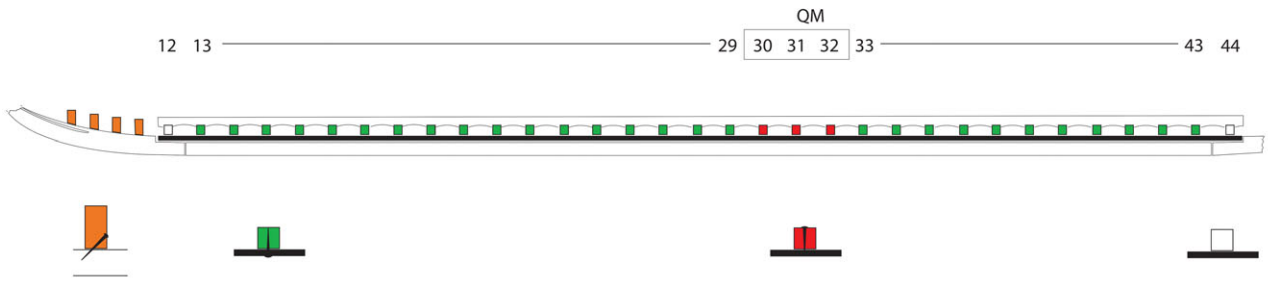

Figure 12. Longitudinal section with the different kind of joints between frames and the 'keel plank'. (Marcel Pujol i Hamelink)

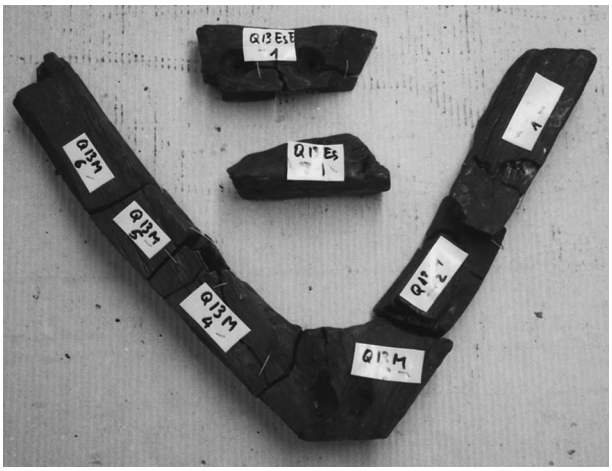

Figure 13. Tail frame Q13. (Xavier Nieto Prieto)

stringer for each side (Figs 3, 14) was put in position and fixed to an upper ribband using treenails. This was a provisional solution given that immediately afterwards the two slightly thicker and more robust lower stringers were put in place, as well as the side keels. These—side keels and lower stringers—were fastened together using treenails, which were also inserted in the spaces between floor-timbers. It is also assumed, though we have no archaeological evidence to support this claim, that the wales and clamps were also put into position, and that these were probably fastened together using the same method.

Once the process of planking the hull was started, the upper stringer treenails were cut, the ribbands were removed, and all the strakes placed between the 'keel plank' and the side keels, and then from the side keels to the wales. In fact the part of the construction process that gives rise to most doubt is the presence of severed treenails in the two upper stringers. These fasteners served to join, even if only provisionally, a 'bilge' plank or a ribband or even, earlier in the process, to support the side keels. This is our hypothesis of the construction process of the coaster Les Sorres X. Although it is obviously a boat built using the frame-first principle with carvel planking, its particularities suggest the process could be subject to different interpretations and variations leading to differences in the way each vessel was constructed. While the frame-first construction principle was ubiquitous in the Mediterranean medieval period, the construction process used here differed as a result of local customs, the size and tonnage of the vessel, the weight of the structure, and the availability of raw materials, among other possible reasons.

In conclusion

The use of the frame-first construction principle and carvel planking in Catalan shipbuilding during the late medieval period is confirmed by different sources of information. The documentary records tell us about the phases in the construction process and the use of carvel planking. The first is implicit in the construction principle (*seure, enramar, cinglar* or *cenyir* and *cloure*). The second is made evident by the important role given to the caulking: the master caulker was paid the same as the master shipwright, even if the latter was the overall construction manager. Moreover, the *romball* festival was held to celebrate the fitting of the last piece which filled a gap in the planking. In fact, this is absent in earlier boats built using a shell-first construction principle, in which the strakes are positioned in rows; as they are self-supporting there is no possibility of leaving spaces in the planking.

The skeleton of frames formed by the floor-timbers and futtocks, assembled laterally and nailed together, is visible in the iconography that allows us to view the interior of vessels, such as images of fishing boats or the Mataró model. In addition, on the exterior they show nails fixing the planks in a series of vertical lines that follow each frame.

The archaeological records allow us to better understand how the construction principle was used and show how shipwrights of the 13th century were already using scale diagrams, or gauges, and the Mediterranean whole-moulding method to determine the shape of the frames. Even though the construction principle is confirmed by all the sources of information as the only one in use in Catalan shipyards and

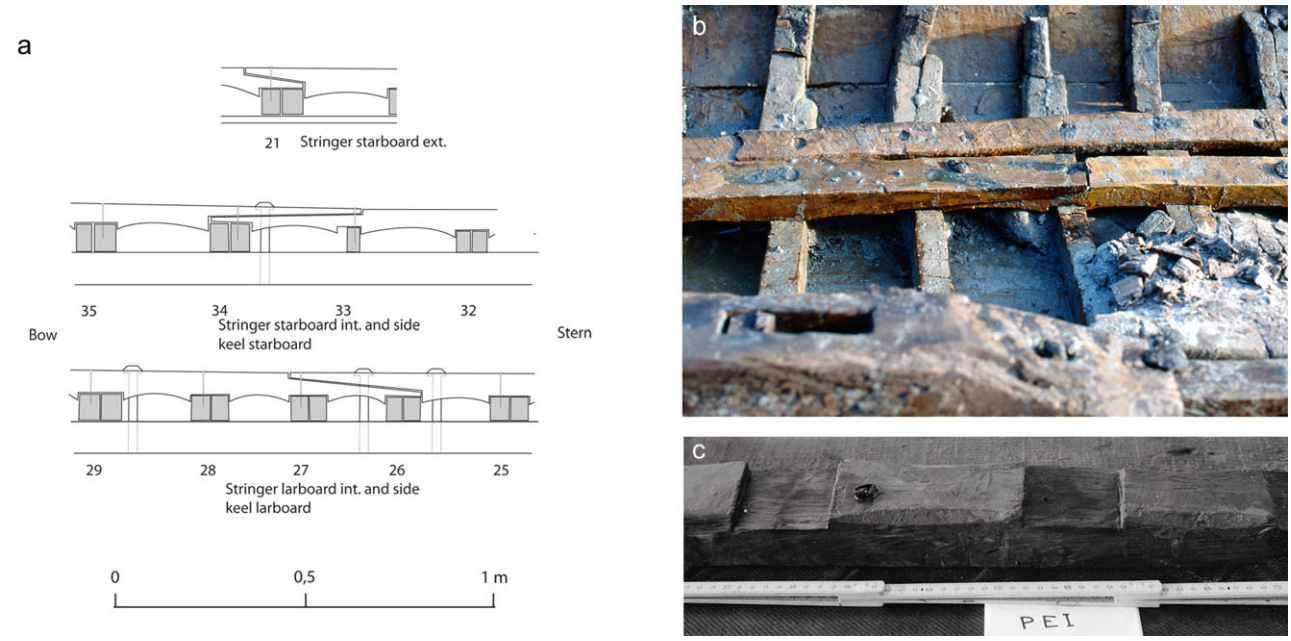

Figure 14. *a)* Detail of the scarfs of three stringers (Marcel Pujol i Hamelink); *b)* detail of the mast-step and the scarf of the internal starboard stringer on frames Q33–Q34 (Xavier Nieto Prieto); *c)* detail of the notches worked under the stringer starboard interior. (Xavier Nieto Prieto)

dockyards, it does not appear that the construction process was always the same. The Culip VI wreck follows the norm; the construction process does not differ from that recorded in other parts of the Mediterranean, as demonstrated by the wrecks in the Venetian area. By contrast, Les Sorres X, dated to the end of the 14th century, has an atypical keel, formed by two pieces, which predetermines the construction process, altering that which should have been the standard prescribed sequence. Furthermore, this wreck confirms the use of the Mediterranean whole-moulding method to determine the shape of the frames, underlines the important role given to the longitudinal elements that results in a hull that is both light and strong, shows the use of two methods of fastening (treenails and iron nails), and is also exceptional because of the presence of its side keels and stern rudder.

As a result of the lack of construction notebooks or manuals in the Western Mediterranean, historians need to turn to archaeological evidence. As yet, the only known shipwrecks that give us information about the use of the master frame and ribbands method in this period in the Mediterranean are Culip VI and Les Sorres X, both found on the Catalan coast. They also inform us about other aspects of Catalan shipbuilding, such as the quality of the shipwrights' work, in particular the way they shaped the longitudinal pieces: keelson, stringers, and side keels. They not only enrich our knowledge of medieval Mediterranean shipwrecks generally, but are particularly important because they are evidence of the shipbuilding revolution that occurred in the 14th century. Culip VI was dated to the end of the 13th century, just before the technological changes of the introduction of the stern rudder and square sail that took place between 1320 and1330, as documented in the iconography and in the records. On the other hand, Les Sorres X, dated at the end of the 14th century, used a stern rudder, as shown by the pintle still fixed to the sternpost.

The 13th century can be considered a time of contact and technical exchange in the naval traditions of the Western Mediterranean—Genoa, Marseilles and Barcelona—and the Eastern Mediterranean—Venice and the Byzantine Empire—of which Contarina I and Culip VI provide good examples. The 14th century, in contrast, is a period of contact and technical exchange between the Mediterranean and the Atlantic naval traditions. A good example of this is provided by Les Sorres X.

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Notes

1. In the Mediterranean, the term *coca*, *cocca* or *cocha* (cog) is used throughout the 14th century as a simile of *nau*, the big trading ship. It was equipped with one single mast, rigging a square sail, and a stern-rudder, independent of its Mediterranean or Atlantic origin (Ciciliot, 1998: 192–3; Bellabarba, 1999: 85–86; Pujol, 2012: 181–2).
2. Analysis of wood species was carried out by Fréderic Guibal: Mediterranean cypress (*Cupressus sempervirens L.*): keel, stempost, sternpost, side keels; umbrella pine (*Pinus pinea L.*): keel plank, planking, stringers, mast step; elm (*Ulmus campestrys L.*): keelson, holm oak (*Quercus ilex L.*): floor timbers and futtocks; poplar (*Populus sp.*): treenails.

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