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Lifting and transport by sea of great stone columns: evidence of traditional methods used in 18th and 19th century building programs as a clue to reconstructing Roman marble transport processes

Alzamiento y transporte marítimo de grandes columnas líticas: evidencia de métodos tradicionales usados en programas constructivos de los siglos XVIII y XIX, como indicio para la reconstrucción de los procesos romanos de transporte

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ABSTRACT
Aim of this paper is to investigate the traditional technologies of lifting and sea transport of large stone blocks (time spent for sea transport, ways of charging and stewing large stone pieces, number of people engaged) with evidence from 18th and 19th century Italy, as a key to understand ancient Roman practices. I shall use data from reconstruction of the 5th century Christian basilica of St. Paul at Rome, burnt in 1823, where new granite shafts, mainly from Italian quarries, replaced the Roman ones. Other documentary sources help to understand some details related to heavy transport, otherwise unknown for Roman period. It should be obviously dangerous to induce directly that the same technologies used for lifting and transport of columns in 18th or 19th century were in use also in Roman Imperial age, but the study of such processes can help us to put in the right view our reconstruction of ancient reality.

Keywords: marble; transport; contract; Italy; ship; technology.

RESUMEN
El objetivo de este trabajo es la investigación de las tecnologías tradicionales de alzamiento y transporte marítimo de grandes bloques líticos (tiempo pasado en el viaje, maneras de cargar y estibar piezas grandes de mármol, número de personas empleadas) a través de la evidencia extraída da la Italia de los siglos XVIII y XIX, como indicio para comprender las prácticas romanas antiguas. Voy a utilizar algunos dados extraídos de la reconstrucción de la basílica paleocristiana de San Pablo Extramuros de Roma, quemada en el 1823, en que nuevos fustes de granito, sobre todo de canteras italianas, remplazaron los fustes de edad Romana. Otras fuentes pueden ayudar a comprender detalles relacionados con el transporte pesado, que no se podrían conocer de otra manera para la edad Romana. Sería arriesgado deducir directamente que las mismas tecnologías utilizadas en los siglos XVIII y XIX estuvieran en uso en la edad Romana Imperial; pero, el estudio de tales procesos puede ayudar a poner en la luz adecuada nuestras reconstrucciones de la realidad antigua.

Palabras clave: mármol; canteras; contrato; Italia; barco; tecnología.

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INTRODUCTION

A major question for scholars of Roman imperial architecture is how so many large marble shafts or blocks, mostly from quarries very far from the building site, reached their destination. Many scholars formulated hypotheses about type and size of ships involved, techniques of lifting and stowage, as well as the organization of such transport, in first place extracting data from ancient sources, not always so clear on this subject. The research on size of largest commercial ships in Roman age can count on ancient sources and shipwrecks (Pomey and Tchernia 1981), and it is possible to tell something about the types of contract involved (Fiori 2010 and Fant 2012). Byzantine sources, in particular, give a lot of information (Castagnino Berlinghieri and Paribeni 2011: 64-66), showing the use of both relatively small boats in Palestine, and of larger ships, previously charged of Egyptian corn, for transport of marble. The few ancient marble shipwrecks explored until now are another traditional field of research for this purpose, but their poor state of conservation often prevents from drawing a neat image of the original ships. One should consider the limits involved in the study of Roman marble wrecks to reconstruct the evidence of Roman marble traffic (Russell 2011: 139-145; Russell 2013b). Certainly, the very well investigated wreck at Kızılburun (reconstruction of hull: Littlefield 2012), transporting eight large Proconnesian marble drums and a Doric capital, pertaining to the temple of Apollo at Claros (Carlson and Aylward 2010), provides now a good example of reconstruction of a marble transport ship in the late Hellenistic period. It seems not very different from common commercial ships of medium size of the same period (cargo at Kızılburun roughly 70 tonnes, ship length 20 m).

SEA TRANSPORTS DURING ROMAN TIMES AND IN THE 18TH AND 19TH CENTURY

Dimensions and weight of wrecked marble cargoes carried by Roman ships are a more reliable source. On this basis, Ben Russell stated that nearly 50% of cargoes weigh less than 50 tonnes (in many cases much less). Small ships were mainly used for this purpose, then, even if there is also evidence of wrecked ships carrying 90 tonnes or more, concentrated in the centre of Mediterranean. These data suggest that major ships travelled on long-range traffic, while the small ones, mostly wrecked near to the land, sailed along coastline (Russell 2011: 146). However, many aspects of this traffic remain obscure: the role of ship owner and of transport contractor, the system of stowing, ship dimensions and traffic organization, still show many dark points. For example, was the transport commissioned ("direct") or with the purpose of selling the cargo at destination ("indirect")? Studies on some cargoes with this purpose concluded that in the majority of cases the commerce was direct (Russell 2011: 148-150).

It is perhaps possible to enlarge our vision of this problem, by investigating the traffic of marble and stone in a recent past, when traditional methods of lifting and sea transport were still in use, before invention of new transport technologies in the late 19th century. The conditions of marble trade in modern age, indeed, are similar to those in Roman period, because we can detect the same need for transport of heavy charges from quarries to farther building yards, using ships by sea and barges by rivers and lakes. Besides, the study is easier, in a way, because there are more sources at our disposal, while for matters of technique and port organizations posed by marble trade in Roman period we have just a few sources (Gianfrotta 2008: 80-83). Of course, the organization of marble commerce in the last three centuries was not as centralized as the Roman Imperial one, but it was mainly left to the market. Single state authorities exercised some control, however, in order to keep clear the port embankment from marble blocks, for example, or to collect taxes from this commerce (Santamaria 2004: 38).

The evidence raised from many documents dated to 18th-19th century, relating to marble sea trade, could be used to investigate traditional technologies of heavy lifting and sea transport, estimating the time involved, the ways of charging and stewing large stone columns, the number of people engaged. It could be an instrument to understand some processes used in Roman Imperial period for lifting and transport of large columns by sea. For example, the packing material used in Carrara marble ship in nineteenth century, to secure the marble cargoes, was also a saleable product: this circumstance has been used to infer that Roman Imperial marble transport ships could have used the same device, too (Russell 2011: 147). The study of some typical examples could then be useful for this aim.

The reconstruction of *S. Paolo fuori le mura* in Rome and its marble import

The first example I have chosen is the rebuilding of the fifth century Christian basilica of *San Paolo fuori le mura* in Rome, with its huge Roman marble columns reused in the naves. After a disastrous burning that almost destroyed it, in 1823, the new basilica, consecrated by pope Pius IX in 1854, respected the forms of fifth century as close as possible, using new shafts of granite and white marble capitals. A contemporary report on its costs was edited just before the beginning of work (Della Somaglia and Uggeri 1831-33), while the projects presented for the rebuilding raised questions about how close to the original should have been the new church (Docci 2006: 145-169).

The project chosen for the reconstructed basilica used many qualities of marble (Del Signore 1988: 85-97). The new architectural elements mainly came from Italian quarries (bases and capitals in white marble from Carrara), except ten columns of Egyptian alabaster ("cotognino", quarries at Beni Suef), 7 meter tall. The Viceroy of Egypt Mohammed Ali had gifted to the Pope 4 shafts and 9 large blocks in alabaster "cotognino" (Ravioli 1870: 199), worked to get six columns on the inner façade wall (fig. 1), and four columns on the new ciborium, dismantled in 1912 (Del Signore 1988: 90). Commander A. Cialdi, of Pontifical Navy, had already led the expedition to fetch two obelisks 10 meter tall from Baveno quarries to Rome in 1839, that he embarked at Venice, choosing a ship of only 70 tonnes ("pielego") because strong enough, with a flat keel, having also a low draught useful for the sailing of the Tiber (Gasparoni 1842: 16). To carry out the expedition in Egypt, he wanted a small fleet composed of three sail ships - two tartans of 70 tonnes each and a "mistico" of 57 tonnes (Ravioli 1870: 2). Ox-driven carts carried the blocks to a river port on the Nile, with a journey by land of three months, travelling only by night, along 47 miles (Ravioli 1870: 132). Then some barges brought them along the River Nile, to the sea port of Rosetta, on the Nile Delta, where the ships embarked the cargo, of Roman pounds 459,046, or Kg 155,662, roughly 57 m^3, distributed on the three ships according their size (Ravioli 1870: 198). Roman pound was equal to Kg 0,3391 (Guidi 1855: 22).

The architects of the new Basilica had to buy most of the shafts of columns for the naves at quarries, however. The two columns of the Basilica triumph arch ("Arco di Galla Placidia": Uggeri 1827), 11.50 m high, monolithic too, lower diameter of 1.36 m, are in red granite from Baveno; the shafts of nave columns are in black-and-white granite from Montorfano, four rows of 20 monolithic shafts, 9 m high, with lower diameter of 1.11 m, dividing the basilica interior in five naves (fig. 2). Before this choice, the building commission of the new Basilica of San Paolo considered many kinds of stone (granites of Elba, Giglio, Corsica; breccia of Broccatello) for this purpose. Preference was given to the granite "del Sempione", from quarries on the Lago Maggiore, mainly for its solidity and light colour, similar to the ancient columns (Della Somaglia and Uggeri 1831-33: 6-11). The quarries at Baveno and Montorfano are on the same branch of the Lago Maggiore (Bombicci 1873: 501): they were used also for the 64 ionic columns in the outer atrium, laid out in 1869 by V. Vespignani, but erected only between 1890 and 1928 (Del Signore 1988: 87).

A long journey by land and water brought the granite shafts from Lago Maggiore to Rome. They embarked on barges near the quarries, on the river Toce, reaching then the river Ticino via Lago Maggiore, and following the canal "Naviglio Grande" arrived to Milan (in 15th century this canal reached the construction yard of the Duomo: Bruschetti 1842: 10-11). Once there, the shafts were roughly finished ("*fusate*"), and then sent by barges through the Pavia canal to the river Po, then to the Adriatic Sea, at the port of Venice, where they were loaded in lugger ships, "trabaccoli" (Silvestro 1996; Codemo 2008; Galloni 1988).

Their travel around Italy went on along the Adriatic coast to the strait of Messina, then up to the Tiber, and from there to the Basilica of San Paolo via a canal dug for the purpose: a journey of km 2,220, lasting an average of four months. The "pielego" *SS. Francesco e Paolo* (tonnage 82) carried the two shafts for the Triumphal Arch (45 tonnes each, m^3 16.7), under command of Giuseppe Paci, in two journeys. The first one left from Venice in July, arriving to Rome in October 1827, but could offload only in January 1828, because the docks had to be prepared for the operations. The second one, quarried in January 1828, set off in April and arrived to Rome in July 1828. The cost for the two great columns of the Galla Placidia Arch was of 8,500 silver Scudi each, comprising material, rough working and transport to the building yard (Silvestro 1996: 26). The dimensions of the ship used to transport these major columns allowed the loading of just one shaft per trip, while the smaller Montorfano shafts (weight roughly 23.5 tonnes)

Fig. 1. Rome. San Paolo fuori le mura. Columns on the inside façade wall in "cotognino" alabaster from Egypt. Author.

travelled in two per single ship. Another source gives the cost of each column of 9 meters of the interior, material and transport, of 4,000 silver Scudi (Campori 1865: 16).

The transport of the obelisks of Villa Torlonia in Rome

We have a good description of loading operations for the two obelisks in granite of Baveno, 10 m high each, leaving from the port of Venice to Villa Torlonia at Rome (fig. 3). In August 28, 1839, five winches, pulled by 25 rows of people, that is 250 workers, assembled around an arsenal with wooden roof, where the barge carrying the obelisk was driven. Winches pulled up the obelisks from the barge, with pulleys hanged to derricks ("*bighe*") composed by two large wooden beams and fixed to the roof of the arsenal. Then, they inserted the obelisks into the ship's stow with its top on, one after the other, in less than three hours, after the ballast had been loaded (fig. 4). The day after, the load was backed up, the ship provided with masts, and the journey began (Gasparoni 1842: 19-20, tav. IV). We can add that when the ship arrived at San Paolo in Rome through the Tiber, pulled by oxen, the problem arose of reaching Villa Torlonia, on Via Nomentana, 5 miles afar. Of course, it would have been possible to offload there the obelisks, using a wooden derrick ("castello") prepared to offloading

Fig. 2. Rome. San Paolo fuori le mura. Columns of the nave in Montorfano granite and triumphal arch with Baveno granite. Author.

San Paolo columns, and then transporting them by land, but with danger of breakings, and almost 50 days of time needed (Gasparoni 1842: 27). Commander Cialdi decided then to send the whole ship along the Tiber and the River Aniene until the Nomentano Bridge, pulled by oxen or by men, carrying then it by land until the Villa Torlonia, mile 1 afar, pulled by winches (Gasparoni 1842: 29-40). Commander Cialdi will assemble similar derricks for the loading of the alabaster blocks at Rosetta, some year later (Ravioli 1870: 183). This kind of simple derrick, "biga", was in use in port practice almost since the beginning of 19th Century (Cavalieri di San Bertolo 1833: 160-161). Zabaglia (1743: tavv. 46-48) shows other derricks and lifting towers for San Pietro in Vaticano, even higher and complicated, not used in ports but in building practice. Large port cranes powered by thread-wheels were in use since late Middle Age in North Sea harbours, lifting loads until 14 tonnes (De Decker 2010), but not in the Mediterranean, as far as I could see.

Columns of the Catania Cathedral

Another good example for quarrying and transport of stone monolithic columns comes from the contracts for the stones in the prospect of Catania cathedral (fig. 5), rebuilt in 1756 by architect G.B. Vaccarini (Magnano di San Lio 2008). The first order of the façade reused ancient grey granite columns from the collapsed interior, but for the second order new shafts were bought and transported from quarries in northern Sicily (Billemi, near Palermo),

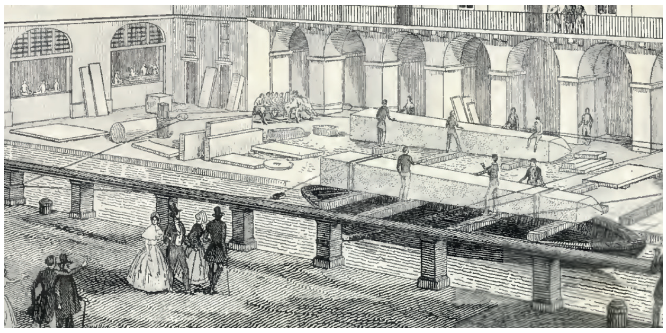

Fig. 3. Milan. The Torlonia obelisks, in Baveno granite, being worked before embarkation. From Gasparoni F. 1842: *Sugli obelischi Torlonia nella villa Nomentana,* Roma, tav. III.

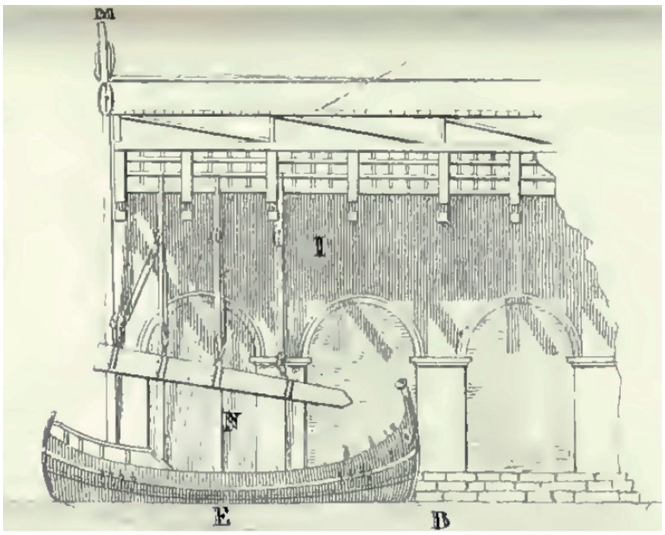

Fig. 4. Venice. One of the Torlonia obelisk being embarked on the pielego "Il Fortunato". From Gasparoni F. 1842: *Sugli obelischi Torlonia nella villa Nomentana,* Roma, tav. IV.

of a stone quality similar in colour to the grey granite used in the order below (Sutera 2009).

Archive documents help to reconstruct the steps for purchasing and transport, each with separate procedures,

Fig. 5. Catania. Façade of the Cathedral with "pietra di Billiemi" columns and stones on the second order. Author.

consisting of a preliminary contract with general terms (with number and size of pieces to buy or to transport), an auction for the lower offer, and a final report, to verify that the measures of pieces transported were as long as those stipulated. In 1756 Filippo Salamone, commander of "sciabecco" (chebec) "il SS.mo Crocifisso, S. Rosalia e S. Francesco di Paola", tonnage of 1800 "salme" (*portavit salmas milleoctocentum mensurae generalis*: Magnano di San Lio 2008: I, 121), agreed to carry 8 columns, each 18 "palmi" high = m 4.64 (1 Sicilian "Palmo" = cm 25.80: Amante 1844: 45), and 231 blocks, all in "pietra di Billemi". We can reconstruct that 1 "salma di misura generale" = hectolitres 2.75 (Guidi 1855: 218) = 0.275 m^3, then 1800 salme = 495 m^3 = 412 tonnes of tonnage at a rate of 42 cubic feet per tonne, which was deemed adequate for this period (Ivan 1819: 405).

The total volume of the blocks was of 3,941 "palmi cubi" (Magnano di San Lio 2008: I, 123) = 68 m^3, increased by the roughly 10 m^3 of the columns. At a weight of 2.7 tonnes per m^3, commander Salamone would have received 78 x 27 = 2,106 quintali x 3 = 6,318 tarì = 210 onze and 6 tarì. The stone price, agreed after another contract and paid after due measuring at Palermo port, was of 183 onze, composed by 143 onze for "fattura di pierrera", at quarry, and 40 onze for "lavorature", workmanship. From the published document, it seems that it was needed another unforeseen expense of 390 onze to transfer the stones by land from the place of offloading to the embankment, according to orders of the Road Authority (Magnano di San Lio 2008: I, doc. 09/11, 122-123). "Onza" was a golden coin of weight 4.39 gr divided in 30 silver "tarì", 20 copper "grana" each (Guidi 1855: 158 n. 25).

The journey from the port of Palermo to the port of Catania should have been paid at a price of 3 *tarì* (silver coins) per 100 kg ("quintale"): but the payment would have been done only after measuring the stone at the port of destination, in "palmi cubbi", that would have then been translated in weight units. Expenses for ropes, winches, boat transformations, were all at contractor's charge, as like as the operations needed to embark the stone. The owner would have carry all the blocks to the ship at his expenses (Magnano di San Lio 2008: I, 120-121).

The Capo Bianco shipwreck near Crotone

The examples I have shown are certainly of "direct" commerce, in response to a specific order sent to quarries. A document of "indirect" commerce, purchase of marble in the quarries to be sold retail, is, for example, the marble wreck at Capo Bianco near Crotone, with small or medium-sized marble shafts or plaques. These shafts had different dimensions and shapes, coming mainly from Liguria, France and Tuscany, with a reconstructed volume of almost m^3 12,39 – a rather small ship (Beltrame and Medaglia 2012: 377; Beltrame, Lazzarini and Medaglia 2012). This wreck helps to reconstruct a commercial marble web handled by Genoa, involving the Carrara marble too, almost throughout the whole of the 18th Century (Beltrame and Medaglia 2012: 379). The stonecutters in Genoa worked marbles arriving by sea, especially from Carrara, since the 15th century (Santamaria 2004: 30). Many documents show that sculptors and stonecutters' workshops at Genoa purchased raw marble from Carrara and other sites, arrived with small Genoese ships, which transported sometimes already finished sculptures, too, in wooden chests (Santamaria 2004: 33-34). Of course, in other cases the commanders could give freight their ships to transport marble going to a specific customer, mainly in Liguria (Santamaria 2004: 35). At the port of Genoa, stone workshops paid a rent to have at disposal some embankments close to the place of their work (Santamaria 2004: 37). As like in other sea towns with marble commerce, Genoa port authorities had to face the problem of marble chippings that, after partial working of raw blocks arrived by ship, were dropped at sea: a very hard problem, in course of time (Santamaria 2004: 38). It reminds the well-known similar situations of Roman Imperial times at Ephesus and elsewhere (Gianfrotta 2008: 77-80).There is also evidence that in 17th Century existed an "indirect" commerce of Carrara marble, sold by some merchants at the ports in just roughly squared blocks, that could then be finished by customers (Federici 2013: 85-86). It seems that this kind of commerce could fit not so much to architectural large elements, but to statuary marble, above all – something similar to Parian *lychnites* in Roman imperial age (Pensabene 2013: 278-281). Veneer plaques and small ornamental objects could fill spaces in a useful manner. In that case, the ship owner and the marble seller could have a high profit, if they sold the marble at a good price, so they loaded ships at their maximum (Federici 2013: 86-87). From the price of marble, the ship owner deducted anyway the cost of transport, usually 5 ducats per *carrata* (800 Kg), while the price at the quarry was of 6 scudi per *carrata*. A typical marble transport ship could carry at maximum 70 *carrate* = 56 tonnes = 20.7 m^3 (Federici 2013: 86-87).

Ships and sea transport during the 18th-19th century

It seems that boats involved in heavy marble transport during 18th and 19th century were not of large dimensions: like the tartan (fig. 6), a one-mast lateen-rigged ship, or two-mast ships like the lugger (Italian "trabaccolo" and "martinaca"), both of 70-80 tonnes. In 1839 Commander Cialdi took the deck away from his "pielego" (a small tartan, tonnage of 70 tonnes), *Il Fortunato*, preparing in the stow a slipway ("invasatura") to receive the two obelisks which he had to carry to Rome. Long wooden beams leaning on the ship's ribs offered to the obelisks a flat base (Gasparoni 1842: 18), showing that ships could be adapted to the purpose of marble carrying. In that case, a ship with flat bottom was preferred, because it had to go up the Tiber; but maybe also because it offered a better load resistance. We remind here that the late Hellenistic marble transport ship wrecked at Kızılburun had a rather flat bottom too (Littlefield 2012). We have also evidence of a ship built with the purpose of marble transport, at expense both of a ship owner and of a stonecutter's workshop, but the main difference with "normal" ships seems the existence of machines to raise heavy marble blocks into the stow. It was a medium-sized ship, of 28.5 tonnes (Santamaria 2004: 36). The lack of "*naves lapidariae*", built on the purpose (Russell 2012: 537), seems to match the most recent picture of sea marble transport during the Roman Empire, contemplating a more frequent use of "normal" merchantmen. Gianfrotta (2008: 86-87) underlines the advantage of using "normal" ships to transport marble, in order to charge return loads.

Medium sized ships, modified for stone transport, carried few large and heavy shafts or blocks. Smaller blocks or shafts were stowed into larger ships, like the chebec (fig. 7), with three masts and lateen-rigged sails. It seems that this was the case for the Catania chebec, while for heavier shafts, like those from Sempione quarries, the shipping was made in couple or single. We can resume as follows the relationships between tonnage and cargo in the above studied examples.

Marble cargo usually will not fill completely the stowage capacity of a ship, expressed in tonnes of tonnage (a capacity measure expressing how many tonnes of a merchandise occupying 42 cubic feet can be charged into a ship). 1 tonne of tonnage in that period was 42 cubic feet, an average between the specific weights of any merchandise (Gille 1957: 92 and Ivan 1819: 405), because marble has a much higher specific weight respect to the average of other kinds of merchandise, for which tonnage is calculated. The capacity (in cubic meters) of stone loading (average specific weight 2.7 t per m^3) can be found multiplying the tonnage (as weight measure) per 13, that is the number of cubic feet per marble tonne:

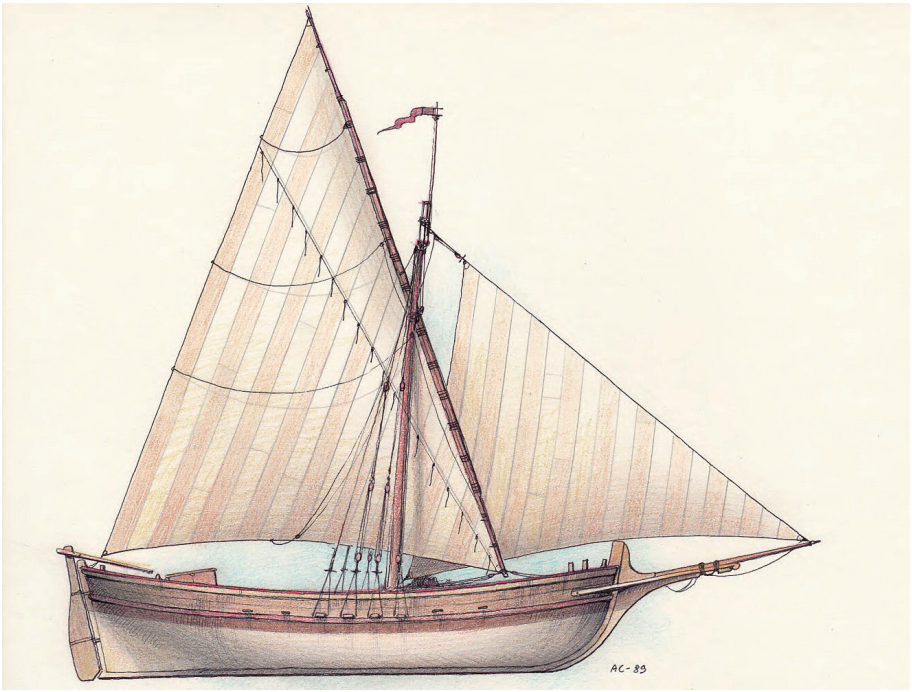

Fig. 6. A tartan or "pielego", one-masted sailing ship. From http://www.cherini.eu/etnografia/NBM/slides/Tartana.html

Fig. 7. A sciabecco (chebec), three-masted sailing ship. From http://www.cherini.eu/etnografia/NBM/slides/Sciabecco%20veneziano.html

this will be the maximum amount of volume which will be filled by marble cargo without danger for the ship (Ivan 1819: 411). But it is in cubic feet: to translate it in cubic meters we have to divide it for 35, that is the number of cubic feet in one cubic meter.

For example, if a ship had a tonnage of 100 tonnes, it will be able to load 4200 cubic feet = 120 cubic meters of normal merchandise, but only 1300 (100 x 13) cubic feet = 37,14 cubic meters of stone, or other heavy loads (Fig. 8).

In the case of the ships transporting alabaster columns from Egypt to Rome in 1840, we know only the total cargo volume (57 m^3), and the tonnage of the three ships (2 tartans of 70 tonnes, 1 mistico of 57 tonnes), but we do not know how the cargo was divided within them. I have tried to divide it in proportion to the major capacity of the two tartans and lesser capacity of the "mistico", or 2:2:1. Our source, then, says that the amount of the blocks they charged at Rosetta was higher than it was told before the journey (Ravioli 1870: 198),

YEAR / JOURNEY	SHIP	TONNAGE (t)	CARGO (t = m^3)	STONE CAPACITY (m^3)
1756 / Palermo-Catania Billemi stone	chebec "SS. Crocifisso"	412	210.6 = 78	153
1839 / Baveno-Rome 2 Baveno granite obelisks	pielego "Il Fortunato"	70	45.9 = 17	26
1840 / Egypt-Rome Beni Suef alabaster	tartan "San Pietro" and "San Paolo"	70	55.89 = 20.7	26
Id. Beni Suef alabaster	mistico "La Fedeltà"	57	41.85 = 15.5	21
1840 / Baveno-Rome 1 Baveno granite shaft	pielego "S. Francesco di Paola"	82	45.09 = 16.7	30
1840 / Montorfano-Rome 2 Montorfano granite shafts	pielego ?	82?	46 = 17	30

so the ships were presumably loaded at maximum of their capacity. On the contrary, the tonnage of the ships used to carry the shafts of Montorfano granite to Rome is unknown, but we suppose that it was close to that of the pielego used to transport the major Baveno shafts.

CONCLUSIONS

The results above show that the larger ship, the chebec, was loaded only at half of its capacity; but we cannot know if the commander loaded also other merchandise or ballast that could be useful to increase his gain. Other ships were loaded at 2/3 or ¾ of their capacity, but with few large blocks. A single cargo of 56 tonnes of Carrara marble was considered the maximum for a marble transport ship of 18th century, the tonnage of which unfortunately is not known (as we saw above). The evidence of marble shipwreck Punta Scifo A (Pensabene 1978 and Pensabene 2013: 164-175) shows that a ship 30-35 m long and almost 9 m wide transported almost 300 tonnes of marble (column shafts, pedestals, basins), filling its hold. In order to make a comparison, the amphora-carrying ship at the Madrague des Giens, with roughly similar dimensions, had a tonnage of 364-474 tonnes (Pomey and Tchernia 1981: 30-31). If we take an average value of 419 tonnes, we should have 419 x 13 : 35 = 155 m^3, while the 300 tonnes of marble weight occupied 111 m^3; so, there was a relationship of 3:2 between capacity and cargo, very close to the limit of 1:1, but also to the examples of modern age we have seen before.

Clayton Fant has convincingly stated that the contract used for transports of large blocks in Roman law was the *locatio navis per aversionem*, that is chartering the whole ship: in this way the heavy cargo could occupy a reduced part of the hold, paying as much as the ship were full. In case of cargo composed by different parts belonging to different owners, each of them could rent a single part of the ship: in this way, the ship commander could fill better his hold, and this case is well illustrated by the Punta Scifo A wreck (Fant 2012: 530-531. *Digestum* XIV.1.1.15).

The price asked by Commander Salamone in 1756 for sea transport was 3 tarì per 100 Kg of stone (I remind that 1 Sicilian silver tarì of 2.41 gr of weight was equivalent to 1/11 of 1 silver Scudo). It seems distant from the costs for Carrara marble transport in 16th Century, when we know that the costs to ship a *carrata* of marble (800 Kg) from Carrara arrived to 3 - 5 golden ducats (between golden onza and ducato weight there was a relation 5:4 = gr 4,39 : 3,44). An expedition to Venice costed almost the same as to Rome, so the cost was given mainly from the hardness of loading and unloading (Russell 2013a: 111-112; Klapisch-Zuber 1969: 209). At that time, Carrara lacked a port with embankment for marble; barges carried the blocks to the ships, or the ships themselves were hauled to the beach (Beltrame and Medaglia 2012: 378).

The study of some case of stone sea transport in modern age seems to have almost helped us to put in the right view our reconstruction of ancient reality. In the same way, reconstruction of ancient building processes can be helped by knowledge of traditional technologies. From this study we have seen how the transport of large shafts was faced in not different ways than in Roman age, and traditional mechanisms used for lifting and stowing stone can help to imagine similar devices used by Romans. It has been possible to calculate how much marble a ship could put in the hold without danger for sailing, making a comparison with Roman marble transport ships. New data could be raised deepening this field of research, helping archaeology to imagine in a more realistic way ancient marble transport.

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