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A cargo of lead ingots from a shipwreck off Ashkelon, Israel 11th–13th centuries AD

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Shipwreck cargo of lead ingots, some marked, discovered off Tel Ashkelon, weighed about four tonnes. C14 analysis of charred wood from an ingot dated it to the 11th–13th centuries AD, Crusader times. Lead isotopic ratios provenanced the ingots to Mont-Lozère, France. Various aspects of the lead trade are discussed, including: lead sources, extraction, casting, lead in the international maritime trade, weight units in medieval trade, prices, transportation, sale and storage, lead cargo and ballast, reconstruction of the wrecking event, salvage after the vessel was wrecked, Ashkelon as a trading coastal town in the 11th–13th centuries AD, and the possible destination of the cargo.

Key words: Metal trade, underwater archaeology, salvage, Crusader Period, Cairo Geniza.

Over the past 30 years, remains of shipwrecks and cargoes have been discovered, scattered over a large area on the seabed off Tel Ashkelon (150 × 1500m). These remains may be dated to various periods: Persian, Hellenistic, Roman, Byzantine, early Islamic, Crusader and Ottoman (Galili and Sharvit, 1996, 2000; Galili *et al.*, 2000, 2001). The subject of this article is 57 lead ingots, discovered on the seabed west of Tel Ashkelon in February 1997 (Fig. 1). Lead cargoes that reached the coast of Israel have been discovered in shipwrecks dated from the Bronze Age through to the Roman and Byzantine periods. They include pipes and sheets dismantled to be reused, as well as ingots (Rosen and Galili, 2007; Raban and Galili, 1985; Galili *et al.*, 1993). Ingots marked with incisions were found in underwater sites of various eras, with the present find clarifying the picture for the Early Muslim and Crusader Periods.

†Prof. David Jacoby (1928–2018) passed away during the preparation of this article for publication. He was a leading expert in intercultural relations in the Eastern Mediterranean during the 11th–15th centuries CE. His studies covered the geo-political, socio-economic and religio-artistic history of the Levant, which in this era interacted with the Muslim world, the Byzantine empire, the Crusader states, and the Italian maritime powers, mainly Venice, as well as with the Jewish communities there.

Site and excavation

The underwater surveys and archaeological activities associated with the study of the ingots were carried out 1997–2000 by the Israel Antiquities Authority. The site where the lead ingots were discovered (N 31° 39′ 56.05″; E 34 ° 32′ 37.81″) is located at a distance of 100–150m west of Tel Ashkelon, at a depth of 3–4m, on a rocky seabed. The shore here is straight and sandy, without a proper sheltered anchorage. The ingots lay over a long, narrow strip extending north-south (*c.* 7 × 20m) (Fig. 2), while most of them were concentrated in a smaller area (4 × 10m). The finds were recorded under water by divers using measuring tapes, an underwater camera, and a water-resistant drawing board. About half of the ingots were retrieved by floating them using air bags.

The finds

The 57 lead ingots are the major items found from the shipwreck. In addition, three elongated iron artefacts

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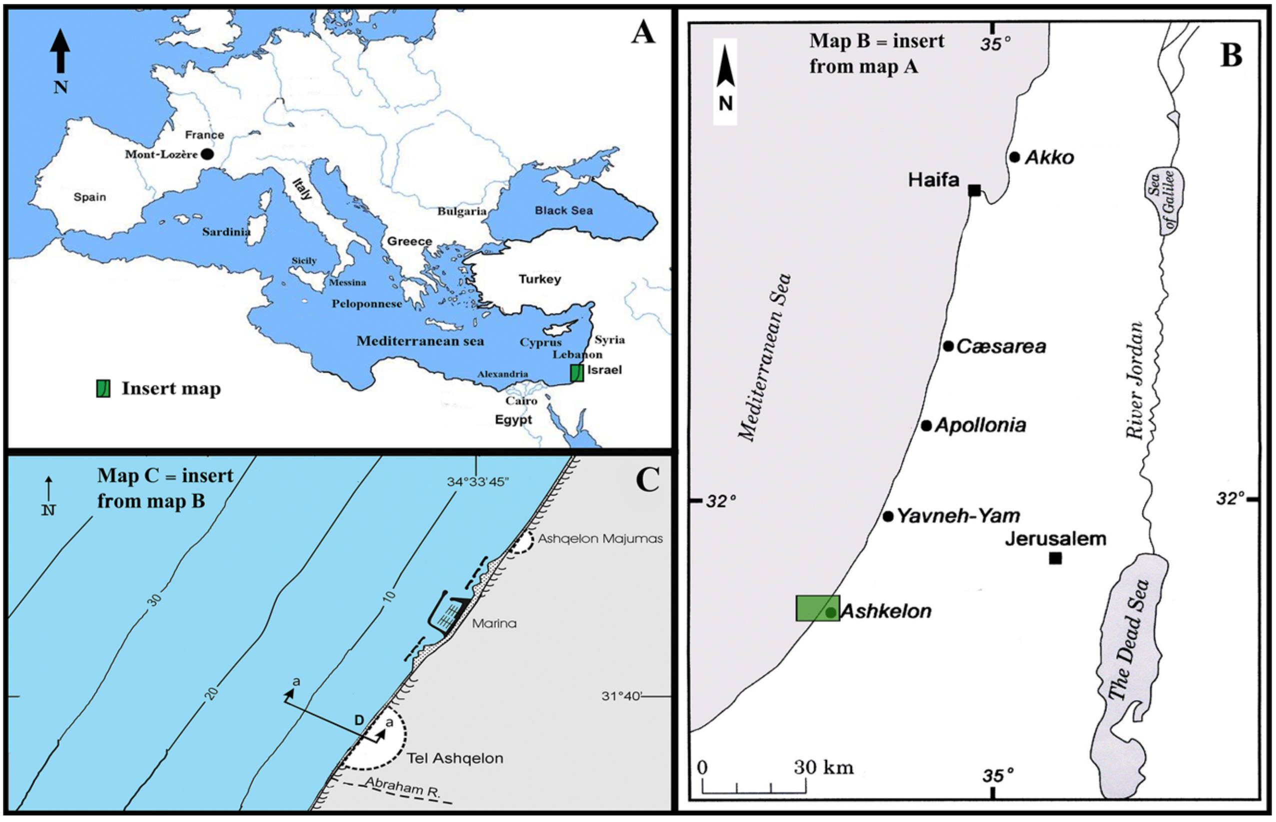

Figure 1. Location map. A: the Mediterranean; B: Israeli coast; C: Tel Ashkelon and the location of the lead-ingot shipwreck marked D.

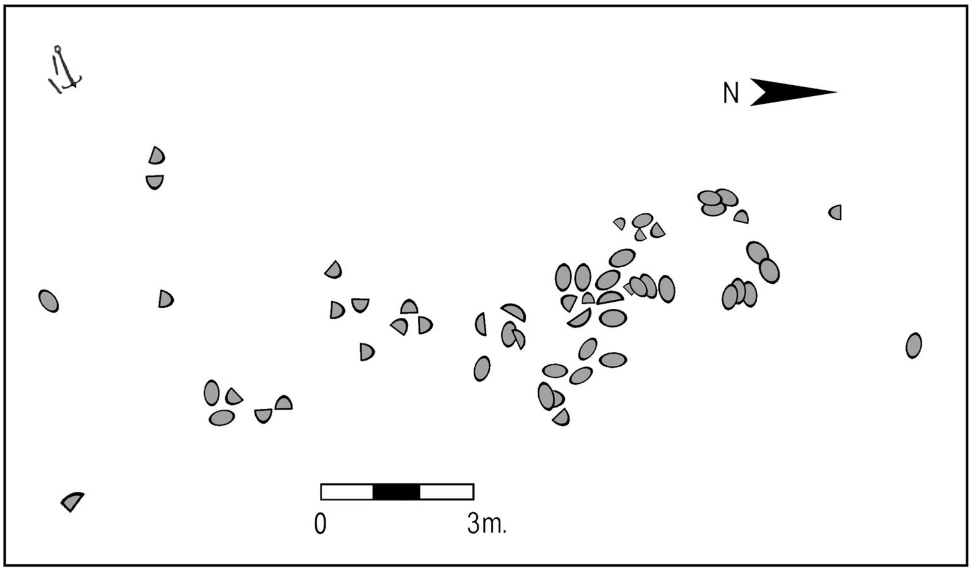

Figure 2. The site plan (for location see Fig. 1C: D) (E. Galili).

were discovered near the ingot concentration. They were *c.*0.50m long and unidentifiable. Also, a two-armed iron anchor, *c.*1.2m long, of a type generally dated to the Byzantine period was discovered there, as well as an unattached, broken, iron anchor stock (Fig. 2).

The lead ingots

Of the 57 ingots identified on the seabed, 30 were recovered, measured, studied, and characterized. The remaining ingots were left at sea to provide an underwater display. Twenty-eight ingots were whole, having a roundish/elliptical shape and a plano-convex profile (as originally cast). Twenty-nine were cut, probably by a heated iron blade or a broad chisel. Of the 30 retrieved ingots, eight were whole, weighing between 66.5 and 98kg (Table 1), with an average weight of 80kg. The other 22 cut ingots weighed between 23 and 109kg (average weight 63.1kg) (Figs 3–4). Two of the trimmed ingots are very heavy: 105 and 109kg. Their original weight was estimated to have been around 120 and 140kg respectively. The overall weight of the retrieved ingots was 2029.5kg. Assuming the retrieved ingots are a representative sample, the weight of the 27 ingots left on the seabed is estimated at 1900kg. The total cargo of lead ingots carried by the ship was therefore around four tonnes.

Incisions/engravings on the ingots

Ten of the recovered ingots bear incised marks on their flat upper face. These incisions were executed post solidification, by cold chiselling. The incisions are of recurrent shapes of several types: 1) fishbone (a straight line with 1–5 shorter lines perpendicular to it); 2) a rectangle missing one edge; 3) single lines; 4) crossing lines (Fig. 4). These incisions resemble Crusader mason marks (Clermont-Ganneau, 1899: 1–40) and may symbolize quality, ownership, workshop, or destination. Notably, fishbone incisions were found only on cut ingots, so it is probable that this sign contains information regarding the history of the ingot, such as parts trimmed, or treatment given to the metal. It is unlikely that the trimming was done in the casting facility. Probably the ingots were cut at the market on demand.

Hanging slot

In the flat upper side of most ingots there are two parallel, deep and narrow slots (Fig. 4). They seem to have had a role in pulling the ingot out of the mould, or for carrying it with lifting thongs, as well as hanging it from a steelyard for weighing. The slots were cold chiselled post casting, after the lead had solidified.

Dating the ingots

Embedded in one of the ingots (No. 3) was a charred piece of wood, trapped there in the process of casting and solidification (Fig. 5). A C14 test indicated a calibrated date of AD 1004–1226, and the uncalibrated date was AD 940 ± 125 (Weizmann Institute C14 lab, RT-2889-Ashkelon Lead, Segal and Carmi correspondence of 11/2/1998). It is reasonably assumed that the wood was trapped in the ingot during casting, near the lead quarry site. Such ingots are commercial items, probably intended for sale as soon as possible. Thus, the lead ingots, including the one containing the trapped wood, were unlikely to be stored in the mine for long. Therefore, it is plausible that the ship sank shortly after the ingots were cast, prior to the final destruction of Ashkelon by the Egyptian Ayyubid Muslims in 1247. If the ingots were intended to be delivered to Ashkelon, this was most probably associated with the intensive rebuilding of the Crusader Period.

Provenancing the ingots

Trying to verify the source of the lead ingots from Ashkelon, a preliminary examination of the lead isotopes of five samples of five ingots (Nos 11, 14, 16, 17, 19) was performed (Yigal Erel, pers. comm. 31 October 2017). The chemical composition of some ingots was also examined, using the X-Ray Fluorescence (XRF) method. A detailed Report by Yoram Nir-El appears in the supplementary material with this article. In the XRF test, a 3mm-thick sample was extracted from ingot No. 14 (the ingots are numbered according to Galili and Rosen, 2011). For calibration, standard samples of lead and tin, of chemical purities of 99.95% and 99.3%, respectively, were used.

Results suggest that the lead in ingot No. 14 is of high chemical purity (99.5 ± 0.4%) and is not alloyed with other metals of alloy concentrations. Tin concentration in the ingot was measured to be 0.08 ± 0.07%. The spectrum of the sample does not show characteristic peaks of silver (Ag), indium (In) and antimony (Sb). The concentration limit of detection (LOD) for these elements was calculated to be 0.05%.

Lead isotope analysis by the Multiple-Collector Inductively Coupled Plasma Mass Spectrometry (MC-ICP-MS) method was carried out on the five samples taken from the ingots. Results derived from the MC-ICP-MS analyses are the three isotope ratios 208Pb/206Pb, 207Pb/206Pb, 206Pb/204Pb, of the four stable isotopes of lead. The isotopic ratios of lead in the ingots were used for provenancing the ores. The measured isotopic ratios of the Ashkelon samples were compared to the OXALID dataset, compiling 2267 ores belonging to seven countries: Greece, Italy, Spain, Turkey, British Isles, Bulgaria and Cyprus (Stos-Gale and Gale, 2009). Although OXALID yielded potential candidates for lead provenancing, such as ores in Sardinia (Italy), Cumbria (England), the Peloponnese (Greece), and Lesovo (Bulgaria), it was concluded that the Ashkelon lead did not come from any of the seven countries of the OXALID compilation. This is because the present results of OXALID are inconclusive and are not substantiated by other independent data, such as geochronological measurements.

In another provenance analysis, the lead isotopic ratios of Ashkelon were compared to 35 galena (lead sulphide, PbS) samples found around the Mont-Lozère Massif in the Cévennes, France (Baron *et al.*, 2006). The Cévennes region, located some 90km from the Mediterranean coast, was the largest medieval site of lead-silver metallurgical activity in France in the Middle Ages. It can be easily seen in plots of lead isotopic ratios (for example Fig. 6), that the Ashkelon values are located within the distribution of the Cévennes galena ores, which form a distinct compositional group. Some Cévennes ores are very close to the Ashkelon ingots, and therefore can be identified as potential candidates for best matches. The nearest ores were determined by the 'minimum distance

Table 1. *Properties of the lead ingots*

Cat. no	Ref. no	Part of whole %	Slots	Weight (kg)	Length (m)	Width (m)	Thickness (m)	Marks (See Fig. 4)	Remarks
1	30/97 29/1	100	2	66.5	0.57	0.42	0.07	Yes	—
2	30/97 29/2	70	2	59.5	0.43	0.36	0.07	Yes	—
3	30/97 29/3	60	2	58.5	0.41	0.28	0.11	Yes	Wooden remains
4	30/97 29/4	70	2	60	0.44	0.37	0.07	Yes	—
5	30/97 29/5	60	2	65	0.47	0.29	0.10	Yes	—
6	30/97 29/6	70	2	48	0.48	0.35	0.06	Yes	—
7	30/97 29/7	60	2	62.5	0.52	0.31	0.10	Yes	—
8	30/97 29/8	100	2	98	0.52	0.44	0.07	---	—
9	30/97 29/9	100	?	83	0.54	0.39	0.07	?	Concreted
10	30/97 29/10	60	2	44	0.335	0.29	0.07	?	Concreted
11	30/97 29/11	70	1	67	0.53	0.37	0.07	Yes	—
12	30/97 29/12	40	2	58.5	0.43	0.285	0.07	---	—
13	30/97 29/13	100	1	77	0.56	0.39	0.08	?	Concreted
14	30/97 29/14	25	2	25	0.31	0.21	0.085	Yes	—
15	30/97 29/15	100	?	75	0.55	0.42	0.07	?	Concreted
16	30/97 29/16	70	?	84.5	0.71	0.31	0.07	?	—
17	30/97 29/17	100	?	72	0.585	0.39	0.07	?	Concreted
18	30/97 29/18	70	2	76.5	0.525	0.37	0.07	---	—
19	30/97 29/19	60	?	83	0.425	0.29	0.095	?	Concreted
20	30/97 29/20	85	?	105	0.52	0.35	0.09	?	Concreted
21	30/97 29/21	70	4?	90.5	0.51	0.36	0.08	---	—
22	30/97 29/22	55	?	109	0.57	0.45	0.08	?	Concreted
23	30/97 29/23	90	3?	83	0.51	0.41	0.06	---	Concreted
24	30/97 29/24	100	?	90.5	0.582	0.43	0.08	?	Concreted
25	30/97 29/25	50	?	41	0.39	0.29	0.08	?	Concreted
26	30/97 29/26	20	?	23	0.28	0.26	0.09	?	Concreted
27	30/97 22/1	60	2	67	0.485	0.31	0.085	---	—
28	30/97 21/2	100	2	78	0.54	0.45	0.06	---	—
29	30/97 21/3	55	2	51	0.36	0.29	0.065	---	—
30	30/97 22/2	60	2	28	0.375	0.215	0.095	Yes	Concreted

procedure' and found to be at the neighbouring sectors of Montmirat and Les Bondons, which are only 3km apart. These findings indicate that the Ashkelon ingots have probably a common source location in the Cévennes region of southern France.

The lead metallurgical activity in the Cévennes has been dated by the C14 method on five charcoal samples (Baron *et al.*, 2006). The samples were beech wood that was used as combustion fuel for ore smelting and yielded the dates of AD 985–1280 (calibrated).

Figure 3. The retrieved lead ingots (E. Galili).

These medieval ages agree very well with the date of AD 1004–1226 (calibrated) for the Ashkelon ingots, measured by C14 in a charred wood specimen trapped in ingot No. 3. Hence, the corresponding two lead-related activities of extraction in the Cévennes and transportation in Ashkelon, are contemporaneous. It is concluded that the lead of the Ashkelon ingots did not come from Roman mines, nor from any of the seven countries in the OXALID database. The present provenance analysis based on French data, shows that the Ashkelon ingots were manufactured by smelting lead ores from the Mont-Lozère Massif in the Cévennes Mountains, France. This provenance conclusion is spatiotemporal; it is based on the very similar lead isotopes compositions in galena ores (Cévennes) and in artefacts (Ashkelon)—that is spatial agreement—and on matching medieval dates for the metallurgical activities—that is the events occurred at the same date.

Discussion

At the time of the shipwreck, the site and the city of Ashkelon were for most of the time under the Fatimid and Ayyubid dynasties, which ruled Egypt at the time.

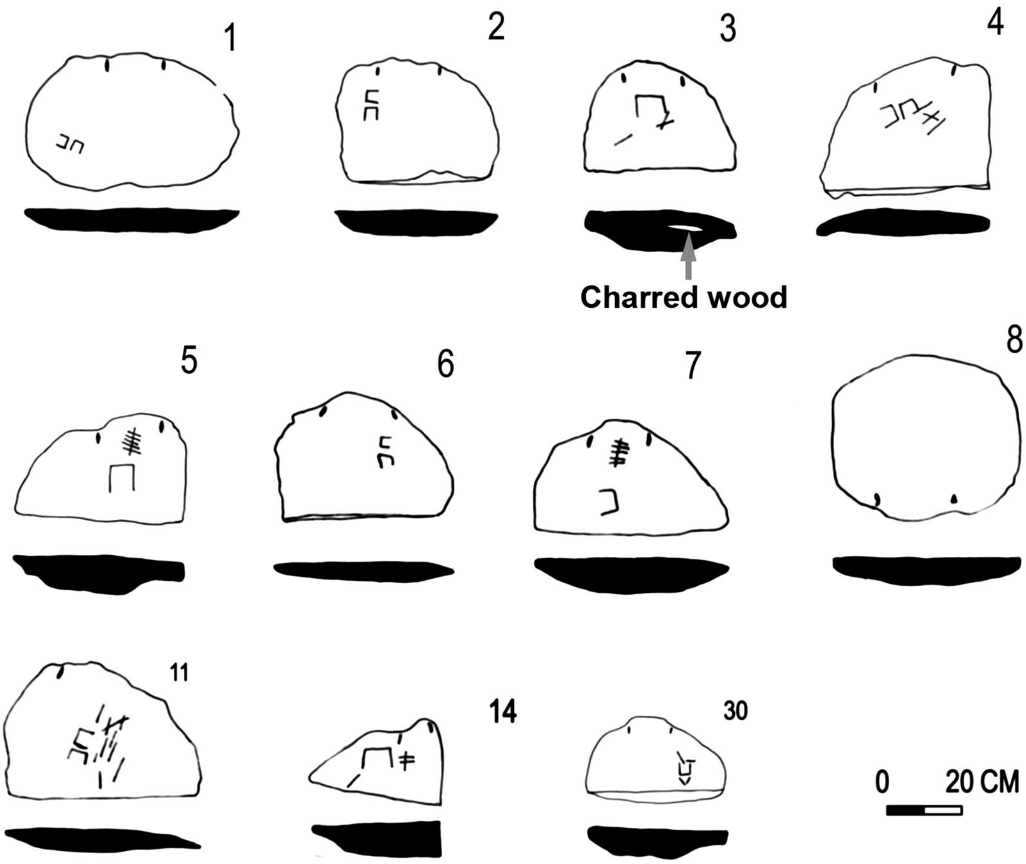

Figure 4. Selected lead ingots bearing inscriptions (Israel Antiquities Authority).

Figure 5. Charred wood embedded in ingot No. 3 (Israel Antiquities Authority).

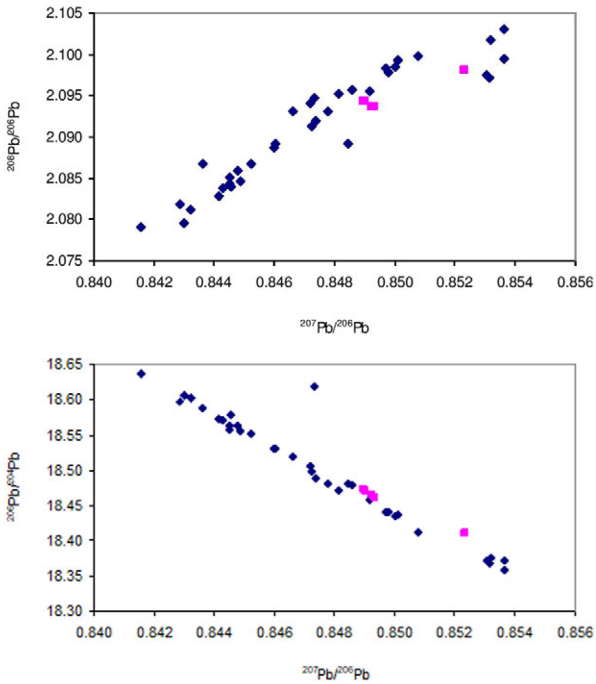

Figure 6. Lead isotopes in M-L galena ores samples found around the Mont-Lozère Massif, Cévennes, southern France (Baron *et al.*, 2006) (35 dark-blue diamonds) and in Ashkelon ingots (5 violet squares) (Y. Nir-El) (for further details on the lead isotopes see Nir-El attached supplementary material).

For short periods the Crusaders ruled the city between AD 1153–1187 and AD 1229–1247. Written sources of this period discussed below indicate a lively trade in metals, including lead, in the eastern Mediterranean. The ingot cargo of this period from the waters of Ashkelon is a rare find, offering a unique glimpse at the character of the lead trade in the region. The site could represent a stage on the maritime metal trade route, connecting the metal sources, in this case lead, in Europe to consumers in the Islamic and Crusader East. Hitherto such information was mostly conjectured from written sources.

Lead casting and shipwreck date

According to the C14 test, ingot No. 3, which contains a piece of wood, was cast in the second half of the 10th century at the earliest, a date probably relevant to the rest of the ingots, or most of them. The existence of wood in an ingot of this size points to a product that has not passed through many phases of melting and purification since its initial casting. During the 11–12th centuries, most lead casting in Europe was done using natural air flow, without a blower (Blanchard, 1981: 72–84). In such basic, open smelting-casting, a hollow depression was dug in the ground, branches and logs were laid over it, and the lead bearing ore was put on top, intertwined with wood, to ensure maximum exposure and air flow. The pure lead, protected from oxygen by the burning charcoal, flowed into the dug depression. This method was still prevalent in the 16th century (Hoover and Hoover, 1950: 390–394). Logs and branches used for such process would not have been stored for a long time. When pieces of such materials are trapped in the solidifying lead right after casting it is reasonable to assume that only a short time had passed between cutting the wood and casting the metal. Therefore, the C14 dating of the wood is likely to be close to the time of casting the ingots. As these ingots required an investment both in casting and in trading, a fast return on this investment would usually have been sought. The Geniza documents even tell of selling lead on credit in order to speed up the return on the investment (Gil, 1997: vol. 3: 417, 546). The procedures in the Crusader East would probably have been quite similar. It may be assumed that the vessel wrecked in the years following 1004 and before the destruction of Ashkelon by the Mamluks in 1270.

Lead in marine trade and written sources

Lead in the Cairo Geniza

A comprehensive written source on international maritime trade in the Levant, in the period in which the vessel was wrecked, are the hundreds of commercial documents recovered from the Cairo Geniza. These were written in Judeo-Arabic by Jewish merchants and were preserved in the Cairo Geniza. Most of the lead trade documents cover the time span of the 11th to 13th centuries. The dates deduced for the lead ingots found at Ashkelon (that is from the early 11th to the early 13th centuries AD) correspond with that time span. From the 846 letters published, 47 mention lead as included in shipments at the time. Complementing the archaeological finds with the reflections of daily transactions found in the documents of the Cairo Geniza sheds light on trade in lead in the 11th–13th centuries.

The most commonplace fact emerging from the letters is that lead was usually combined with additional cargoes. Alongside the units of lead, which could range from 3 to 69 pieces, there were other metals, such as iron, copper, tin and mercury (Gil, 1997, vol. 2: 726; vol. 3: 340–341, 671–672; vol. 4: 687). Beside the metals, in the same shipment, there were goods as varied as luxury textiles, wax, oil, spices such as turmeric, hides, silk, pearls of various sizes, and even galls. In one case, some silk, separated by sheets of paper, was loaded with the lead cargo (Gil, 1997, vol. 3: 162). In another case, a small additional parcel of material termed 'Ammonia' was added to the main load of lead (Gil, 1997, vol. 3: 253). Thus, it is highly possible that the shipwreck studied here carried an additional cargo that did not survive beside the lead.

Marks on the lead ingots

The incisions found on the Ashkelon ingots may be understood by an expression used in the Geniza documents to define copper ingots that were, at times, shipped together with the lead. In one shipment, there is reference (Gil, 1997, vol. 2: 606) to *nahhas mad'rub*, which Gil renders as 'stamped copper'. Goitein translates this expression as 'hammered copper' (Goitein, 1973: 86). Presumably this is a technical term referring to chisel marks on the copper ingots. This term may also refer to the incisions found on the Ashkelon lead ingots. It may also indicate a technical treatment associated with the process of purification of the metal, after the initial stage. The stamped signs may be associated with the properties of the ingots, the owners, or the workshop that produced the ingots.

Weight units

In the medieval period, each city and economic entity had its own system of weights and measures for each commodity, and the values changed with time. Deciding the exact value of the *qintar* used for lead in the various locations in the East in the 11th–13th centuries is beyond our scope here, so we follow Ashtor (Ashtor, 1982: 448–471) in this matter. The units of lead are called *qit'a*, translated by Gil (from Judeo-Arabic to Hebrew) as a unit, a piece, or a parcel (Gil, 1997, vol. 2: 612). In one letter, there is reference to 'tongues of lead', a form used commonly for tin (Gil, 1997, vol. 3: 161, 625). As to the weight of the lead ingots, the Geniza documents usually give a lump sum, which does not help to define the weight of a single piece. For example, 19 pieces weighing 69 *qintar*, which 'should be sorted out' or 'marked' (Gil, 1997, vol. 2: 612), 20 pieces weighing 24 *qintar* (Gil, 1997, vol. 3: 691). Most probably the *qintar* mentioned is the Egyptian *qintar garwi*, used for heavy goods (weighing around 90kg). It is approximately equivalent to two *qintar furfuri* (used for light goods such as pepper, 44kg) and to the *milliaro/migliao grosso* in the Italian system (Ashtor, 1982: 473). Gil (1997, vol. 1: 564) wrote that the weight of a lead unit was 160kg based on a letter mentioning 19 units of a total weight of 69 *qintar* (equal to 3036kg) (Gil, 1997, vol. 2: 612). This probably refers to *qintar furfuri* (3036/69 = 44) and to a unit of *c.*160kg. He took this further by deducing that the weight of each of the 31 units of lead mentioned in another letter was 160kg (Gil, 1997, vol. 3: 859). However, the archaeological evidence from Ashkelon shows clearly that the lead units (ingots) were not uniform in size and weight. It is corroborated by another letter (Gil, 1997, vol. 3: 69), which mentions 20 units of a total weight of 24 *qintar*, that is 2.2 *qintar furfuri* (96.8kg), compared to the 3.7 above (162.8kg). Not only is the unit weight in *qintar* variable (3.7 versus 2.2), so also is the value of the *qintar*. In the documents there is also a frequent reference to a wrapping called *rizm* or *rizma* (Gil, 1997, vol. 3: 625).

Lead trade in Italian sources

The rich Italian sources—notarial acts, merchant manuals, and marine legislation—are mostly later in date and reflect a different commercial system (Ashtor, 1982). In the Italian commercial manuals, additional packing units are cited, such as the *himl* or *'Idl* = *sporta* = *c.*200–270kg (three heavy *qintars garwi*) or the *qafas* = *collo* = *pondo* = 180kg (two heavy *qintars*). There seems to be a connection between the weight of the ingots and the size of the standard package.

Price of lead according to the Geniza

The Geniza letters mention prices and describe the process of selling the lead. The aforementioned 20 units, weighing 24 *qintars garwi*, cost 203 quarter dinars. Sicilian quarter dinars were the most popular currency with the Geniza merchants (Gil, 1997, vol. 1: 566), who probably imported the lead from Sicily. This price (see below) included transportation and bribes, that is about two dinars per *qintar garwi* (Gil, 1997, vol. 3: 69). That was a low price, as in another letter it is reported that the price of lead rose from three to four dinars (Gil, 1997, vol. 3: 592). Elsewhere, a merchant advised his agent/partner not to sell below five dinars, and try to get five and a half dinars (Gil, 1997, vol. 3: 552). Another letter corroborates the five dinars per *qintar* selling price but also cites a buying price of 60 dinars for 20 *qintars garwi* (Gil, 1997, vol. 3: 671). A strange piece of information regarding prices comes from a letter citing a low winter price of two dinars per *qintar garwi*, while after the ships came in, it rose to 14 quarter dinars, that is 3 1/2 dinars per *qintar garwi* (Gil, 1997, vol. 4: 454). This price rise could have been caused by the ships arriving without lead. A more reasonable situation is described elsewhere, with a rise in price after the ships had left (Gil, 1997, vol. 2: 743), or in a letter advising to send the lead in the first ship sailing out, to get the best price (Gil 1997, vol. 3: 611–612). In conclusion, the price of lead fluctuated between two and five dinars per *qintar* of *c.*90kg, which could help in estimating the value of the lead cargo. The approximately four tonnes of lead that lay on the seabed were equivalent to *c.*44 *qintars garwi*, which would worth between 88 and 220 dinars before sale, or an average of about 150 dinars, as a cautious estimate.

Transportation, sale, and storage

The transportation price varied but seems to have been around one-and-a-quarter dinar per load (Gil, 1997, vol. 3: 552). A merchant writes of his great disappointment when the shippers demanded another three and a half dinars for transportation, otherwise they would retain the four biggest pieces of lead transported (Gil, 1997, vol. 3: 27). After paying all the customs dues and other duties, including bribes when necessary, merchants obtained clearance from the Customs Office (Dar al Manac in Alexandria) and could sell or export their goods (Gil, 1997, vol. 3: 625). Again, there were expenses involved, such as intermediaries and discounts. Sometimes selling was not an easy task, and the merchants were compelled to hire a storage space or magazine (Gil, 1997, vol. 3: 12, 625, 982). This storage could be official (Gil, 1997, vol. 3: 982), such as a caravanserai, or private, in one case a doctor's place—although he might have been the buyer (Gil, 1997, vol. 3: 417). In case of unfavourable circumstances for the sale—such as 'lead is not being sold in Fustat' (Gil, 1997, vol. 3: 737, 809)—there are frequent orders to try to sell the goods on credit for two months, 'but it should be to an honest man or a Jew' (Gil, 1997, vol. 3: 28, 417, 546), or get an advance payment (Gil, 1997, vol. 4: 590). Sometimes the ship would change course unexpectedly, as in a case of a ship bound for Alexandria, which sailed instead to Syria (Gil, 1997, vol. 3: 828). This could explain the existence of a ship sailing to Alexandria, found wrecked on the coast of Ashkelon. Regarding transportation, it should be noted that although most ship types mentioned in the documents are regular merchantmen (*markab*, *karib*), two letters specify that the lead was loaded on *'ushari* (Gil, 1997, vol. 3: 501, 518). This was originally a river boat, a type of hybrid ship carrying both sails and oars and serving on special missions in the navy. These ships are estimated to have been of 20–25 tonnes capacity but may have been much larger (Arenson, 2007: 198; Gil, 2007: 153–154). Obviously, it was extremely important to properly mark the ownership of the goods. We hear of some 25 pieces of lead inscribed 'Yakub & Nissim' (Gil, 1997, vol. 3: 982), but also of a case when lead was left in the magazine because the owner could not be identified (Gil, 1997, vol. 3: 12). Gil describes several ways of marking the cargo, usually on the packing material, in writing, in drawing (sometimes in colour), and in various other markings (2007: 179).

When handling this cargo, the heavy ingots were treated as one piece, while the trimmed ones, as found in Ashkelon, were packed in parcels weighing hundreds of kg, which could not have been carried by one person. The transportation of lead ingots and parcels of ingots from the casting site to the shore, loading them on board, arranging them in the hull, then unloading, especially in a small vessel anchored in the open sea, were complicated tasks requiring mechanical tools and special know-how.

Gil (2007: 170) evaluates the rate of marine catastrophes as 5%, calculating that out of *c.*270 ships mentioned, 11 were reported wrecked. We counted *c.*30 shipwrecks reported in the documents, that is closer to 10%. In any case, the loss of about four tonnes of lead in one shipment, worth (on average) *c.*150 dinars, must have been a major blow to all concerned, even disregarding the other merchandise on board. Although we hear of larger or comparable shipments of lead (Gil, 1997, vol.2: 612; vol. 3: 69, 859), this was a big order and a major economic loss. To this should be added the value of an additional cargo and the ship itself.

Mediterranean lead sources and its uses

Lead has been used in the East since the Bronze Age, during times of peace and war, for various purposes: making tools, in structures, for piping and roofing, for coffins, containers, fishing gear, ornaments and sculpture, and also as slingshot (Rosen and Galili, 2007). During the Roman and Byzantine periods, lead was used also in shipbuilding (Kahanov, 1993; Rosen and Galili, 2007). During the Middle Ages, lead and its compounds were used in the building industry (Viollet-le-Duc, 1865: 209–220), in metal vessels (Al Sa'ad, 2000: 385–397; Craddock, 1979: 68–79), and in cosmetics and medications (Lev and Amar, 2006: 428–444). In the Islamic East (Fustat, Egypt) in the 11th–13th centuries it served in the glaze of ceramics and in glass vessels (Charlestone, 1960; Wolf *et al.*, 2003: 405–420). There are no significant lead mines in the land of Israel, nor in Egypt. In Anatolia and regions to the west, such as Greece, Italy, Sardinia, and Spain and France there were lead mines in this period (Baron *et al.*, 2006: 241–252), and in England. Therefore, lead was imported into the region by ship and information regarding shipping routes to the Levant during the period in question is found in the Geniza documents. According to Gil (1997, vol. 1: 563):

> 'The very fact that lead was mentioned in a letter lacking the details of the sender and the place of issue may indicate that the letter was sent from Sicily'.

Lead was not mined in Sicily during that period, but it reached the island from Spain, Sardinia, France, and the Balkans. The assumption that lead was imported to Egypt from Spain or Sardinia (via Sicily?) is supported by establishing the provenance of lead used in glazed ceramics made in Egypt at this period (Wolf *et al.*, 2003: 405–420). Sicily must have served as a hub of the lead trade, as well as other metals (copper, tin, mercury, and iron), that appear together in the Geniza documents. These documents show that most maritime trade from the West reached Egypt, mainly Alexandria, via intermediary stops along the way (Gil, 1997: vol. 4: 627–631). However, some voyages were made directly from Sicily to the ports of the Levant (Abulafia, 1980). Lead destined for the Crusader East would also reach it directly from the Christian lands in the West, therefore it is possible for the ingot-carrying ship discussed here to have reached Ashkelon directly from Sicily and the West. The route between Sicily and the Crusader Kingdom of Jerusalem was quite busy during the 12th–13th centuries (Pryor, 1992: 649–657). After the Crusader conquest of the Holy Land, the lead trade may have developed new patterns, going directly from the Crusaders' places of origin to their new kingdom in the east. For example, in the 12th century, Genoa exported lead directly to Syria (Byrne, 1920: 191–219). In another example, in 1234 merchants from Marseille sent a ship laden with salted pork, textiles, and lead to Acre or 'any other port in Syria' (Abulafia, 1997: 19–39). The ship arrived at the end of September in Messina, where the lead was sold.

Lead as cargo and ballast

Overloading or a badly arranged cargo in any ship could endanger the safety of the ship, its crew, passengers, and cargo. That is especially true for a wooden sailing ship because of the distribution of mass and operating forces (relative to a raft, oared ship, or modern mechanized iron ships). Such problems in loading or in the arrangement of the lead cargo could have contributed to the wrecking of the lead-carrying ship at Ashkelon. Lead was the heaviest cargo in relation to volume among metals traded in those days, except for gold and mercury, which were traded in much smaller quantities. Lead weighs 11.3 tonnes/m^3, while flax weighs 0.4 tonnes/m^3. The Geniza documents of the time reflect awareness of safe loading, distinguishing the different kinds of goods to be loaded: 'every merchandise you wish to transport will be accepted, whether light or heavy… and will be stowed in the best of places' (Gil, 1997, vol. 2: 453). Detailed loading instructions first appeared in 13th-century Venice, and allotted an important role to lead (Lane, 1966: 238–239, 261). These instructions aimed to dictate loading methods essential for securing a safe sailing. Before the establishment of these regulations, the loading capacity of ships was treated only generally (Khalilieh, 2005: 243–263). To provide merchants and seamen with the necessary practical information, goods were listed in groups referring to weight without reference to volume (Dotson, 1982: 52–62). Goods were purchased by weight and taxed by weight, so the merchants knew their weight and could supply this information to the seamen loading the cargoes. The amount of goods to be loaded from each group was decided according to equations reflecting weight and practical experience concerning cargoes, their character, and their behaviour at sea. Goods were divided into several groups, where a certain number of *qintars* of lead would equal a certain number of *qintars* of other goods. With the help of these freight equivalents, merchants and seamen could deal with mixed cargo. In order to stabilize a ship laden with light voluminous goods, such as flax or cotton, it is necessary to lower the ship's centre of gravity, especially for wooden ships with sails and high standing rig. Lead served a double role as a ballast and trading commodity. The carrying capacity of ships could be utilized by logical loading of mixed cargoes of heavy and light commodities, such as lead and cotton (Khalilieh, 2005: Goitein, 1973: 314). If a ship carrying ingots was loaded in the proper way, lead was probably placed at its bottom. After a vessel wrecked, as in our case, and the ship disintegrated, the heavy lead ingots would have stayed where they had sunk. Then, as is common in that coast, the ingots settled into the sand because of the sand movement during the storm that wrecked that ship. This brings us to the problem of the wrecking event and of the likely ensuing salvage attempts (Khalilieh, 2006: 205–223).

The enigma of the port of Ashkelon

Underwater archaeological finds and literary sources point to intensive maritime activity and international trade in ancient and medieval Ashkelon. However, all such sources suggest that the city has never had a sheltered, built harbour (Galili *et al.*, 2001). The 12th-century historian William of Tyre, who had visited the site, commented on the inadequate mooring conditions at Ashkelon:

> Ashkelon has no advantage by being situated on the sea shore, as it offers neither any mooring facilities nor a safe anchorage. It only has a sandy beach, with violent winds that cause especially high seas, so whoever arrives there is highly anxious, unless the sea is very calm. (Babcock (trans.), 1943: XVII, 22–25, 27–30)

Judging by the archaeological finds and the historical records, it seems that in Ashkelon ships anchored a few hundred metres offshore, where there were submerged kurkar ridges that could be used as anchor holds (Fig. 7). Cargoes and passengers were transported from the ships ashore and vice versa by lighters (Galili *et al.*, 2001). Thus, the ship that carried the ingots could have been sailing along the coast, or anchored offshore, before it wrecked. The problems of anchoring offshore had been solved hundreds of years previously. Remains of wooden piles, set in a line parallel to the coast, 150m offshore, were recently discovered. These were dated by C14 to the late Roman Period: AD 265 (10.3%); AD 275; AD 330 (57.9%); AD 385 (Calibrated range $\pm 1\sigma$) and AD 255 (25.3%); AD 300; AD 315 (70.1%); AD 395 (Calibrated range $\pm 2\sigma$) (E. Boaretto D-REAMS Radiocarbon Dating Laboratory Weizmann Institute of Science; Galili, 2017). The piles, probably used for mooring watercraft offshore, eventually decayed and, at

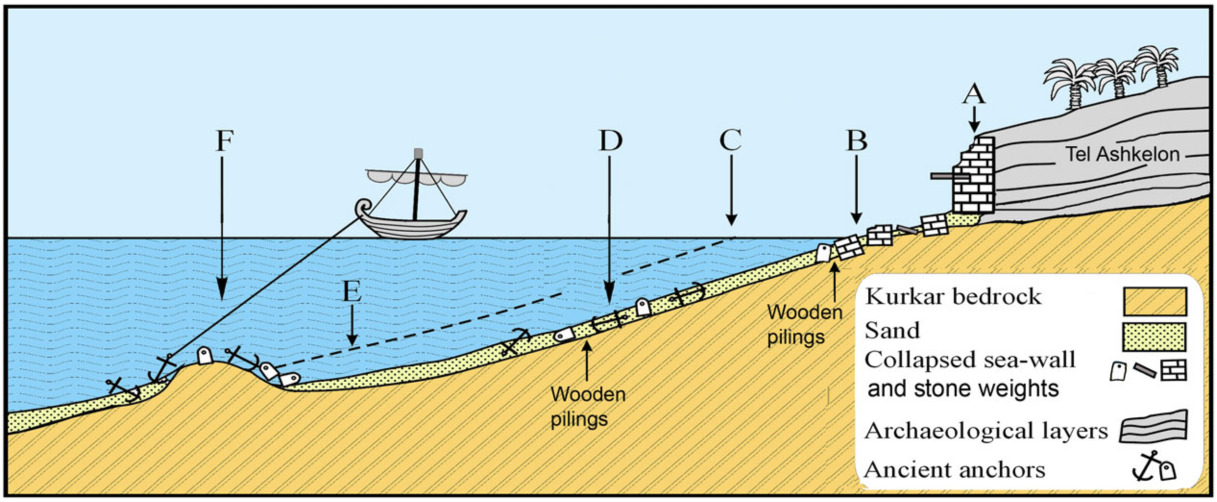

Figure 7. Schematic reconstruction of the cross-section of the Tel Ashkelon coast and the main archaeological features on the sea-floor (for location see Fig. 1C). A: ancient sea wall with granite columns in secondary use; B: remnants of the seawall and ancient settlement that collapsed into the sea, and stone weights (depth 0–1.5m); C: location of the ancient coastline; D: remains of wrecked watercraft (depth 2.5–4.5m); E: ancient level of sand; F: offshore anchor-hold on a submerged kurkar ridge (after Galili *et al.*, 2001).

the time the vessel wrecked, the coast was as described above (Galili *et al.,* forthcoming).

Reconstruction of the wreck event

On the basis of the dispersion of the ingots and their total weight, assuming all the lead cargo has remained on site since the vessel wrecked, it is proposed that they were carried in a medium-sized vessel (*c.*12–15m long, 10–12 tonnes capacity), as were common in the Levant at this period (Pryor, 1992: 27–29; Jacoby, 2017: 634–635). Local site formation studies (Galili *et al.*, 2002, 2009), the shallow water, and the find distribution pattern (an elliptical concentration parallel to the shore line), are typical of ships encountering a storm in the south-east Levant (Fig. 7). Lacking any protected anchorage, the ship probably lost control, drifted to the shore, grounded, and disintegrated in the breakers. Many of the cargoes discovered along the Israeli coasts and around Ashkelon have been discovered at a water depth of 2.5–4m. It seems that this ingot cargo reached the seabed under similar circumstances, although the possibility that the ship sank because of a hostile human act, such as a naval battle, cannot be ruled out.

The ingots sank in shallow waters, close to a large city, and in an area accessible to free divers: why were the ingots not salvaged? The reason lies in the physical traits of the wreck-site. An analysis of the site-formation and post depositional processes may explain this enigma. Until the 20th century the seabed adjacent to the shore of Ashkelon was covered by several metres of quartz sand. When the ship carrying the ingots was wrecked, the heavy cargo would have sunk rapidly into the sand because of the sand turbulence caused by the currents and waves during the storm. After the wreckage, the wooden parts of the ship would have drifted to shore, together with the lighter cargo items, while the lead ingots remained concealed at the wreck-site, covered by a thick layer of sand. Some ingots may have been salvaged, but if the storm lasted several days it would have been impossible to find the rest. The ingots were exposed recently because of important changes in the sand balance along the coasts of Israel due to human intervention. The High Aswan dam on the Nile and the extensive construction of sand-trapping structures on the coast and in the shallow sea, such as a marina and a port in Ashkelon, have caused a severe shortage of sand and the exposure of the ingots.

The weight of the lead found on site is close to four tonnes. Lead was then, as now, a valuable commodity. Unlike many other commodities traded in maritime commerce, such as textiles, leather, food, and spices, lead is not damaged by exposure to sea water and so its value does not deteriorate. Even today, lead salvaged from the seafloor has a monetary value. The fact that the ingots have remained apparently *in situ*, despite being in reach of free divers, suggests they have remained covered by sand between the wrecking and their discovery in 1997.

On wrecks and salvage

The salvage of shipwrecks and their cargo, as well as the salvage of items lost at sea during loading and unloading or as jettison is a common practice in ports around the world (Khalilieh, 2006: 205–223). Divers can be found in every active port to bring up lost items and check the vessels in port. In Ashkelon, as elsewhere, members of the local maritime community such as fishermen, seamen, and longshoremen might be happy to join an occasional salvage dive. This was true also in ancient times: in Rome in the 1st century AD there was an association of divers, the *Urinatores*, who engaged in salvage activities (Oleson, 1976: 22–29). Roman law dealt with compensation for divers who retrieved goods from the seabed (Melikan, 1990: 164–166). The Rhodian Sea Law, dated to around 600–800 AD (Ashburner, 1909: 119), rates compensation for retrieved goods according to depth, and mentions depths much greater than that discussed here. The maritime laws of Trani, dated to the 11th century, also deal with salvage (Twiss, 1871), as well as the Laws of Oleron of the 13th century, probably the oldest maritime law of Atlantic Europe (Robinson, 1937: 229–268). Geniza documents of the period under discussion mention several cases of wrecked ships that had their cargoes salvaged by divers. In Egypt in 1050, divers salvaged sunken cargo (Gil, 1997, vol. 3: 614); in Bab el Mandeb in 1139, divers from Aden salvaged a cargo of iron from a sunken ship (Goitein, 1973: 189); while in Palermo in the first third of the 11th century, merchandise was thrown into the sea to be pulled out later (by divers?), probably to avoid customs (Gil, 1997: vol. 2: 557).

In Pisa, from the beginning of the 13th century, municipal laws gave the following compensation for salvage operations: general cargo—1/4 of its value; iron and lead—1/4; tin and steel—1/6; silver—1/20; gold and precious stones—1/30 (Melikan, 1990: 163–182). The laws of the Crusader Kingdom gave a third of the salvaged goods value to the honest salvage diver (Twiss, 1871: vol. 55, part 4: 517). According to these laws then, a team of divers engaged in salvaging the lead ingots from Ashkelon, would have been compensated with 30–50 dinars. The daily wage of a simple labourer in Egypt in the 11th–12th centuries was between 1.5–3 dirham, while a dinar equalled 36–40 dirham (Cohen, 2005: 407–421). A seaman in Ashkelon would probably live on less than this sum. A middle-class family in the Egyptian cities of the period would spend some two dinars a month for living expenses (Cohen, 2005: 407–421), so the compensation of the salvage team (or their employer, in case they were hired or simply slaves) would have amounted to the living expenses of a family for many months, even years.

Ashkelon as a coastal trading town

Historical sources dealing with the coasts of Israel during the Byzantine, Early Islamic Period, and Crusader Period present Ashkelon as a centre of maritime trade, second only to Acre (Gil, 1983, vol. 1: 159–165). Ashkelon served as an important commercial hub under the Fatimids till the middle of the 12th century. The naval bases of the Fatimids in the region were in Ashkelon, Acre, and Tyre (Rose, 1999: 561–578). Ashkelon remained in Islamic hands even after the conquest of Jerusalem in 1099 and the foundation of the Crusader Kingdom. In 1123 the city of Tyre was conquered with the help of the Venetians, and in their demands included a clause for extensive privileges in Ashkelon, similar to those granted them in Tyre (Prawer, 1963, vol. 1: 219, 223; Runciman, 1951, vol. 2: 166–168). Such a demand indicates the importance of Ashkelon in the maritime trade of the area. Ashkelon was fortified by the Fatimids before the Crusader conquest of 1153. There is limited quantitative information about the demography of the city at that time. In September 1116, about a hundred Jewish families lived there (Gil, 1983, vol.1: 159), among them some well-to-do merchants. It may be assumed that some thousands of households existed in the city. After the establishment of the Crusader Kingdom, Italian merchants continued their business in metal and timber with the Islamic countries, as testified by a letter from Saladin to the Caliph in Bagdad, 1174: 'There is not one of them who does not supply us with war materials' (Gibb, 1973: 50). The Crusaders conquered the city in 1153. Ashkelon played a major role in the Crusader Kingdom for short periods (Prawer, 1963, vol.1: 309–315; 1958; Pringle, 1984), serving as the foremost bastion against the Egyptian forces. Just before his great defeat at the Horns of Hittin in 1187, the Crusader king Guy de Lusignan ordered a citadel to be built in the city (Runciman, 1951–1954, vol. 2: 424). Since 1187 the city changed hands several times as a result of wars and treaties (Runciman, 1951–1954, vol. 2: 424). At the end of his Crusade, in 1191, King Richard the Lionheart ordered the rebuilding of the 'strongest castle on the shores of the Crusader Kingdom' (Runciman, 1951–1954, vol. 3: 62). The castle, which was later destroyed again by the Ayyubids, was rebuilt by Richard of Cornwall in 1241 (Prawer, 1963, vol. 2: 277–279). With the final Islamic conquest of the city in 1247, its maritime trade deteriorated (Runciman, 1951–1954, vol. 3: 229). The Mamluks instigated a policy of total destruction of the coastal cities, which was realized in Ashkelon in 1270.

Destination of the cargo

Did the lead-carrying ship discussed here have Ashkelon as its destination, or did it drift there during a storm and wreck on its way to the major port of Alexandria, not too far to the south-west? This question cannot, of course, be answered with certainty. On the one hand, Alexandria was indeed the major port of call in the south-eastern Mediterranean, with most trade routes connecting the western Mediterranean ports with the Levant leading to it. But there was at the same time a vast cabotage network, connecting Alexandria (and the West) with other minor ports along the eastern Mediterranean shore. Thus, Alexandria could have been the destination for the ship carrying the lead ingots discussed in this article; however, intensive building and military activity in Ashkelon during the 11th–13th centuries also increased the demand for lead to be used in roofing, gutters, and in architectural clamps (Viollet-le-Duc, 1865). Thus, it is also possible that the lead cargo was destined to Islamic or Crusader Ashkelon, or to another port in the Levant. In any case, it did not reach its destination, and served indirectly to increase our knowledge of maritime trade in lead in the Medieval Mediterranean.

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Supplementary Information

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

Supporting Information: 'Elemental and isotopic analyses of the Ashkelon lead ingots' by Yoram Nir-El

