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Lead isotopes in silver reveal earliest Phoenician quest for metals in the west Mediterranean

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When and why did the Phoenicians initiate long-term connections between the Levant and western Europe? This is one of the most hotly debated questions in ancient Mediterranean history and cultural research. In this study, we use silver to answer this question, presenting the largest dataset of chemical and isotopic analyses of silver items from silver hoards found in Phoenician homeland sites. Intertwining lead isotope analysis of silver items with precise archaeological context and chronology, we provide analytical evidence for the onset of Phoenician westward expansion. We suggest that the quest for silver instigated a long, exploratory phase, first in Anatolia (Asia Minor) and Sardinia, and subsequently in the Iberian Peninsula. This phase preceded the establishment of sustainable, flourishing Phoenician colonies in the West by over a century. In so doing, our results buttress the "precolonization" theory, accord it a firm chronological framework, and demonstrate that the quest for silver (and probably other metals) was an incentive for Phoenician westward expansion. Furthermore, our results show that the Phoenicians introduced innovative silver production methods to historic Europe.

silver | lead isotope analysis | Phoenicians | Sardinia | Iberia

The Phoenicians,* a Levantine people that did not survive the vicissitudes of history, are known for spreading to Europe long-lasting innovations, including the alphabet, murex-based purple dye, and masterful craftsmanship (3) (Fig. 1). However, above all, the Phoenicians are renowned for their seafaring prowess and far-flung trade (4, 6). It is generally accepted that the quest for metals, especially silver, was a crucial instigator of Phoenician "expansion" to the West (e.g., refs. 3, 4, and 7). This, however, was certainly not the sole stimulus and perhaps not the first (for agricultural land and produce, see, for example, refs. 1, 3, 8, and 9; for a dismissal of metals as a motivator, see ref. 10).

The Phoenician westward expansion in the first millennium BCE, reaching as far as the Atlantic, is one of the most intriguing phenomena in the history of the ancient Mediterranean. Negotiations between Phoenicians and European and African societies left an indelible impact on a plethora of sociocultural developments, including the emergence of new identities across the Mediterranean (1, 11). However, when, where, and why did these encounters begin? Currently, the late-ninth century BCE sees the earliest unequivocal evidence for the buds of Phoenician diasporas in North Africa, Sardinia, and Iberia, which became firmly established only a century later. This is based on the style of ceramics discovered, epigraphic data, and radiometric dating (e.g., refs. 6 and 12–16). [For suggestions that the site of Huelva in the Bay of Cadiz was founded earlier (late 10th to mid-9th centuries), see ref. 17. These dates are much contested and do not apply to any other Phoenician site in Iberia (16).] Several scholars, however, have envisioned an earlier, "precolonization" phase, starting as early as the 11th century BCE (for a review, see *SI Appendix*). This "reconnaissance" phase, by its transient nature, was not expected to leave explicit archaeological evidence, and its chronology and dynamics remain unknown (9, 16, 18), to the point that its historicity has been denied altogether (19). Possible memories of precolonization might be found in the Hebrew Bible, which narrates joint maritime ventures of kings Hiram of Tyre and Solomon of Israel, bringing gold, silver, and other exotica in the 10th century BCE according to biblical chronology (1 Kings, 10:22). These narratives also mention the name *Tarshish*, which is frequently identified with Tartessos in southwest Spain, one of the richest European metal-bearing regions (e.g., refs. 6, 9, 20, and 21) (Fig. 1), from which copious quantities of silver were shipped by the Phoenicians according to Greek and Latin sources (references in ref. 3). However, the above notwithstanding, no concrete data thus far support the precolonization hypothesis (3, 16, 22), and no mining or silver production site in the West associated with the Phoenicians has been dated conclusively earlier than the late-eighth century BCE (3). Since silver does not occur naturally in Phoenicia, we turned to the silver imported to this region to contextualize these initial contacts.

In antiquity, silver (Ag), which appears rarely in a native form, was generally produced from silver-rich galena (PbS) and cerussite ($PbCO_3$) lead ores (23). The production was two-stepped: smelting, involving the reduction of the ore into metallic Pb–Ag alloy; and cupellation, namely, the oxidation of the alloy in a cupel to extract Ag (and gold) and separate it from other metals (see

Significance

We offer here an answer to one of the most intriguing questions in ancient Mediterranean history: the timing/contexts and incentives of early Phoenician expansion to Mediterranean and Atlantic regions in Africa and Europe ~3,000 years ago. This was enabled by a rare opportunity to analyze a very large sample set of ancient silver items from Phoenicia. An interdisciplinary collaboration combining scientific methods with precise archaeological data revealed the Phoenicians' silver sources. We propose that Phoenicians brought silver to the Levant from southwest Sardinia ~200 years before they de facto settled there, and later, gradually, also from Iberia. We show that the quest for sliver was a major trigger for a long "precolonization" phase, during the 10th to 9th centuries BCE.

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*"Phoenicians" is a Greek term, which first appeared in the eighth century BCE. The Phoenicians were never united politically, and their definition as an ethnos is continuously being questioned (1, 2). Generally, however, they are linked with the relatively autonomous late-second and first millennium BCE city-states in Lebanon, mainly Tyre, Sidon, Byblos, and Aradus, which shared political–economic traits and material culture (3). During the early Iron Age (11th to 9th centuries BCE), territories south of Lebanon, on the northern coast of present-day Israel, were also included in the Phoenician sphere (e.g., refs. 4, 5, and 16).

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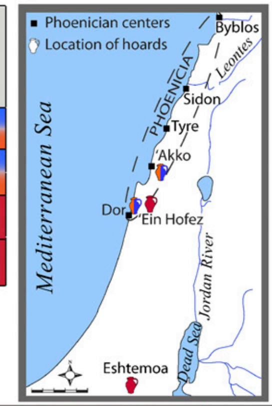
A

Hoard	Southern Levantine terminology	Approximate date BCE	Provenance
Dor	Early Iron Age IIA	2nd half of the 10th century BCE	Anatolia & Sardinia
ʻAkko	Iron Age IIA	10th-9th centuries BCE	Anatolia & Sardinia
ʻEin Hofez	Late Iron Age IIA	9th century BCE	Iberia
Eshtemoa	Iron Age IIB	8th century BCE	Iberia

B



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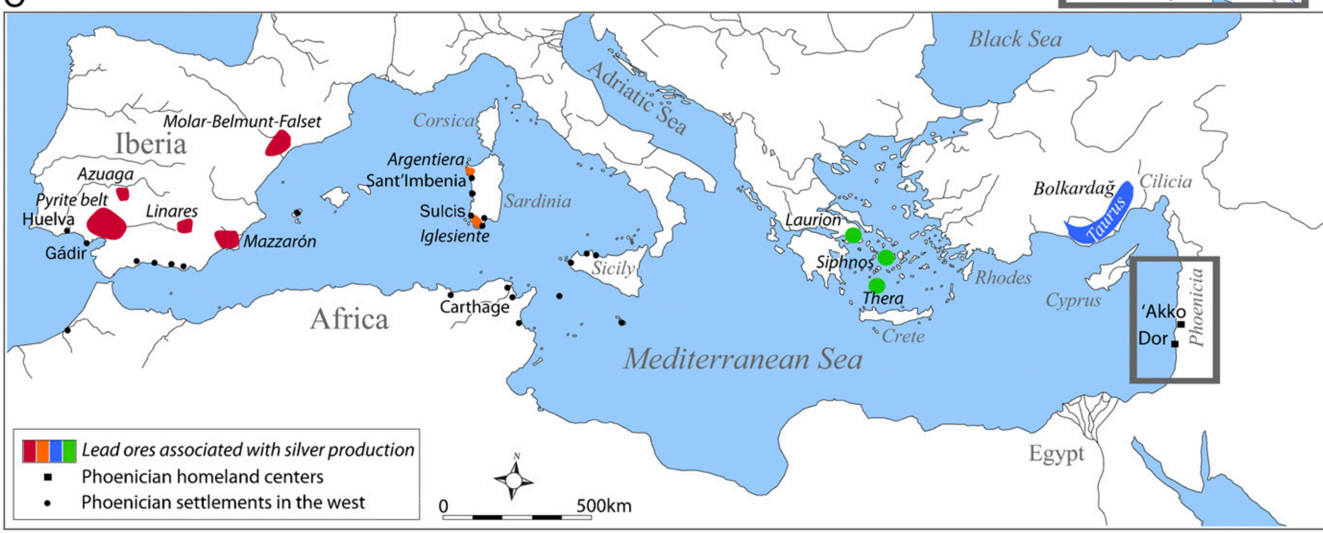

Fig. 1. (*A*) Relative and absolute chronology of the main hoards mentioned in the paper and provenance of the silver in them. (*B*) Location of hoards mentioned in this study. (*C*) The Mediterranean Sea, lead ores, Phoenician sites (after ref. 55), and other locations referenced in the text. Red, Iberia; orange, Sardinia; green, The Aegean; blue, Anatolia. Maps courtesy of Svetlana Matskevich (illustrator).

references in *SI Appendix*). The earliest examples of cupellation are from the fourth millennium, in Anatolia, Syria, and Iran (references in ref. 24). In the Aegean, cupellation was practiced no later than the second millennium BCE (25, 26). Indeed, Anatolia and the Aegean are known to be the main Mediterranean producers of silver in the second millennium BCE (23, 25). Phoenician exploitation of silver-rich ores is currently associated by scholars with Sardinia and southern Iberia (13). In Iberia, silver production is considered a Phoenician innovation (27, 28), while for Sardinia there is no clear evidence to suggest otherwise (29–31). The significant occurrence of silver-rich ores in these regions is particularly noteworthy in view of the scarcity of ancient silver artifacts there (28, 29). In contrast, numerous Iron Age (11th to 6th centuries BCE) silver objects and hoards are known from the southern Levant, including abundant finds that specifically date to the postulated precolonization epoch (refs. 32 and 33).

Today, lead isotope (LI) analysis is the main method used to associate between silver items and their original ore source (for the method, including references, see *SI Appendix*). Silver hoards, comprising mostly cut ingots and broken jewelry (which served as a form of currency), provide a large and extendable dataset (32). To date, only four Iron Age silver hoards are known from Phoenicia, all originating in southern Phoenicia (northern modern Israel). The earliest Phoenician hoard, from Tell Keisan, dating to the 11th century BCE (for chronology and chronological terminology, see Fig. 1 and *SI Appendix*), was excluded from this study since, like other Iron Age I hoards in the southern Levant, the addition of copper to its silver items likely influenced Pb isotopic ratios (32). The remaining three hoards, from Dor, ʻAkko, and ʻEin Hofez, date to the Iron Age IIA (10th to 9th centuries BCE) (see Fig. 2) and are currently the only hoards known from this specific subperiod in the Levant (32).[†] They predate or are contemporary with the earliest known Phoenician settlements in the West (*Discussion*) and are the subject of this paper.

Results

Dor (Second Half of the 10th Century BCE). The first, striking observation regarding the Pb isotopic ratios of silver items from this hoard (Fig. 3 *A* and *B*) is that 10 out of 49 items (groups 2 and 3) have Pb isotopic compositions that plot outside the isotopic field of the Aegean–Anatolian ores. This is the earliest known Levantine hoard displaying such isotopic values. Furthermore,

[†]Dor and ʻAkko were major Phoenician cities between the 12th and the mid-9th centuries BCE. Both had active anchorages on the Mediterranean shore and were extremely prosperous and cosmopolitan. Dor also had tight commercial connections with Egypt, a fact that distinguished it from the Northern Phoenician city-states (e.g., Tyre). While ʻAkko was politically and culturally affiliated with Phoenicia throughout the Iron Age, excavations at Dor have revealed that, around the mid-9th century BCE, the Phoenician town was transformed into an administrative center, probably under the control of the Israelite Kingdom (34, 35). ʻEin Hofez is a large Iron Age village, located in the Carmel Mountains, the agricultural hinterland of Southern Phoenicia. It was short lived (10th to 9th centuries BCE) and was gradually abandoned during the 9th century BCE (36). For more on the context of the hoards, see *Materials and Methods*.

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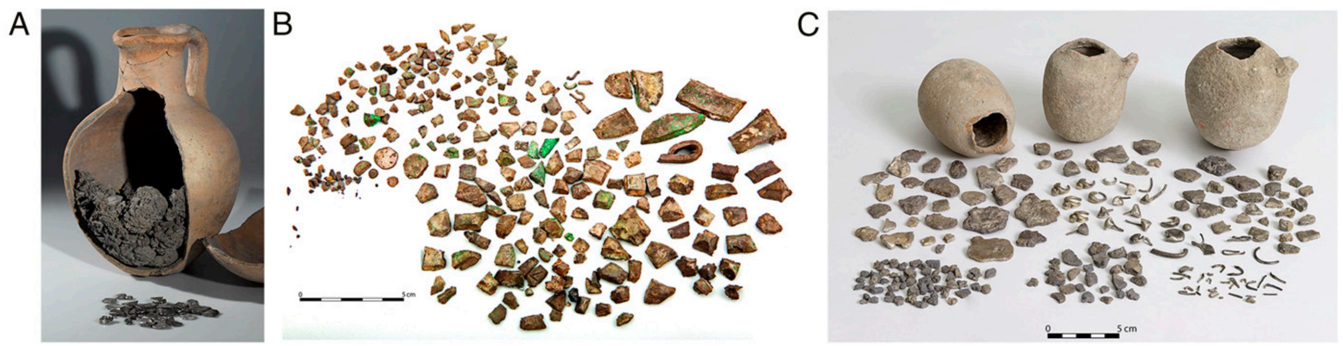

Fig. 2. The silver hoards analyzed in this study; the ceramic vessels are the original containers. (*A*) Dor silver hoard image courtesy of the Collection of Israel Antiquities Authority © The Israel Museum by Ardon Bar-Hama (photographer), the Tel Dor Expedition, and ref. 32; (*B*) ʿAkko silver hoard image courtesy of Michael Eisenberg (photographer) and ref. 32; (*C*) ʿEin Hofez silver hoard image courtesy of the Collection of Israel Antiquities Authority by Warhaftig Venezian (photographer).

using a geological age model, it becomes evident that the Dor silver is a mixture of two major endmembers (for an explanation of the term, see *SI Appendix*), which are indicated by clusters on the graph. Group 1, on the right-hand side of the graph (11/49 items), is consistent with two overlapping Pb ores: Taurus 1A in the Bolkardağ valley (Taurus Mountains), Anatolia, and Cape Athinios on the Island of Thera (Cyclades, The Aegean) (37, 38). Anatolia is the more probable source historically (37) and isotopically, since Thera actually appears to the left of group 1 samples (*SI Appendix*, Fig. S2). The second end member, group 2, is a tight cluster (4/49 silver items), consistent with ores from Iglesiente, southwest Sardinia, particularly the San Giovanni and Monteponi deposits [Oxford Archaeological Lead Isotope Database (OXALID)]. Most of the remaining (32/49) items reflect a mixing of the two end members, and possibly additional sources (groups 3 and 4). In six of them (group 3), a Sardinian isotopic contribution is very likely (Fig. 3 *A* and *B*). Hence, groups 2 and 3 provide the earliest evidence for western-Mediterranean silver in the Levant.

ʿAkko (10th to 9th Centuries BCE). The Pb isotopic ratios here resemble those of Dor, with two end members: group 1, 6/22 silver items, consistent with the Bolkardağ valley (in the Taurus mountains) in Anatolia; and group 2, 5/22, with Sardinian ores (Iglesiente region). The remainder are mixed (groups 3 and 4); group 3 ($n = 2$) has clear Sardinian isotopic contributions (Fig. 3 *A* and *B*). The ʿAkko hoard, although dated with lesser resolution than the others, demonstrates that the occurrence of Sardinian and Anatolian silver in early Iron Age Phoenicia was not episodic.

ʿEin Hofez (Ninth Century BCE). Only two items in this hoard (Fig. 3 *C* and *D*, group 1, 2/29 items) are consistent with the Taurus 1A isotopic field. The other samples plot outside the isotopic field of the Aegean–Anatolian ores and are inconsistent with that of the Iglesiente ores. Group 2 (6/29 items) forms the other end member, and its isotopic values are consistent with Pb ores of Linares in Iberia. The isotopic compositions of the remaining items (group 3; 21/29 items) plot between several Iberian Pb ores (in its south and west). Thus, the ʿEin Hofez silver records the earliest phase of Phoenician presence there (see below). In another eighth-century BCE large hoard in Israel, from Eshtemoa in the Judean Hills (ancient Judah; ref. 39), the silver items analyzed ($n = 15$) have similar isotopic ratios as in the ʿEin Hofez hoard (Fig. 1, LI ratios are available on the OXALID database). This suggests that silver from Iberia continued to dominate the Levantine market for more than a century.

Discussion

The three hoards presented here are the earliest, and in fact the only silver hoards known so far from Phoenicia, after more than a century of archaeological excavations in this region (excluding the Cu–Ag alloy hoard from Tell Keisan, as previously explained). Therefore, they are to-date the best and widest source of knowledge for early Phoenician silver trade. Our results show that each hoard represents a mixture between two or more ore sources, and that each silver ore source is represented in more than one hoard. The chronological trajectory and periodical changes in silver sources, as outlined above, are reinforced by the fact that later, seventh-century BCE hoards in the Levant sampled thus far, mirror yet another change, since they contain mostly silver from Lavrion in mainland Greece (ref. 40; OXALID). This, and considering that silver losses in antiquity were high (41), strongly suggest that the items we analyzed are representative of the silver circulating in the market at the time. Nevertheless, our results are still restricted by the limitations of LI analysis, some of which we attempted to overcome using a large dataset and by incorporating geological considerations into the interpretation, as described in *SI Appendix*. The possibility, for example, that unknown overlapping ore sources will be revealed in the future and may alter our conclusions, cannot be dismissed. Still, since Phoenician expansion was designated to specific, known locations, this is not very probable. Based on the above, we are able to identify the sources of silver shipped to the Levant in the early Iron Age with high probability: Anatolia and Sardinia as early as the mid-10th century BCE and Iberia from the 9th century BCE. Our results indicate the existence of Phoenician precolonial and early colonial interactions in these regions, which we contextualize below.

Anatolia. The Taurus Mountains in south Anatolia boast some of the richest argentiferous Pb ore deposits in the Near East. In the third to second millennia BCE, silver from this region reached Mesopotamia (42). Surprisingly, and despite the region's relative proximity to the Levant, it was only rarely considered a Phoenician target of exploitation, and even then, not before ∼800 BCE (refs. 5 and 43; but see ref. 3). Our analysis highlights the Phoenician interest in north Syria and Cilicia, en route to the Taurus Mountains (Fig. 1), showing that the Taurus was a major early supplier of silver to Phoenicia (10th to 9th centuries BCE). This predates any other ceramic or epigraphic findings linking Phoenicia with this region.

Sardinia. It is unclear when, and by whom, were the island's Pb ores first exploited for silver (29, 44). Rare third-millennium Ag artifacts found locally are considered a product of simple smelting (45, 46). Subsequently, in the second and early first millennia BCE, silver artifacts are practically absent from Sardinia (44). The Dor and ʿAkko hoards currently contain the only Iron Age silver known anywhere, which is isotopically consistent with Sardinian Pb ores, suggesting that silver was produced in southwest Sardinia, by cupellation, as early as the second half of the 10th century

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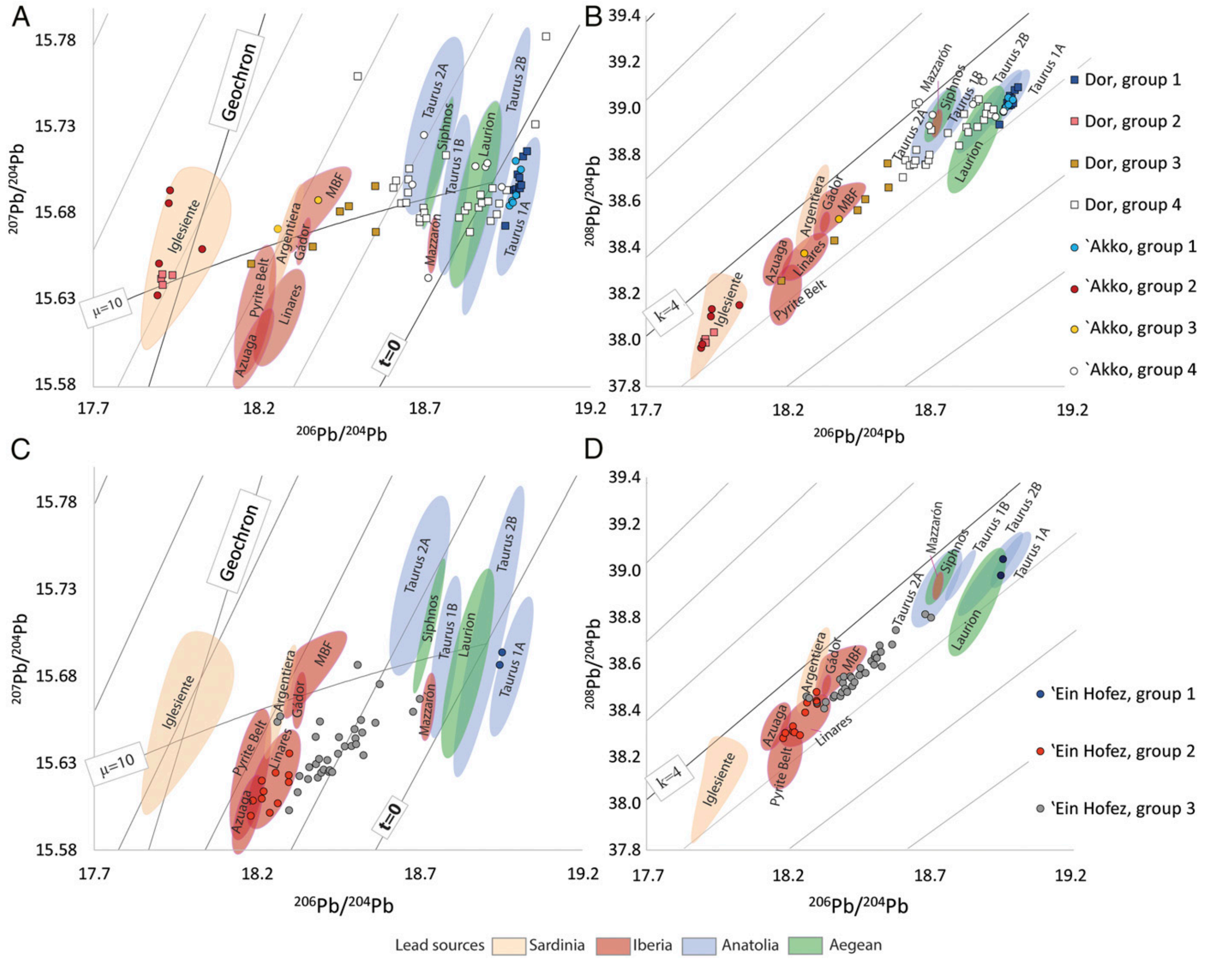

Fig. 3. (*A*) $^{207}Pb/^{204}Pb$ vs. $^{206}Pb/^{204}Pb$ of the Dor and 'Akko hoards. (*B*) $^{208}Pb/^{204}Pb$ vs. $^{206}Pb/^{204}Pb$ of the Dor and 'Akko hoards (*SI Appendix*, Table S1, and OXALID). (*C*) $^{207}Pb/^{204}Pb$ vs. $^{206}Pb/^{204}Pb$ of the 'Ein Hofez hoard. (*D*) $^{208}Pb/^{204}Pb$ vs. $^{206}Pb/^{204}Pb$ of the 'Ein Hofez hoard. The results are plotted against a geological age model, which correlates between ores and their U-Th-Pb model age (*SI Appendix*, Fig. S1). Shades represent the isotopic fields of major silver ore sources in the Near East and around the Mediterranean potentially exploited for silver in the Iron Age (Pb values from OXALID). Colors of artifacts relate to the matching lead ores, by geographic regions: light blue, four separate isotopic fields of the Taurus mountains, Anatolia (1A, 1B, 2A, 2B); green, Lavrion and Siphnos in the Aegean, which partially overlap compositionally with Taurus ores (23, 25); peach, Sardinia—Iglesiente and Argentiera (29); red, Pb ores in Iberia. These include the Pyrite Belt, Linares, Molar–Belmunt–Falset (MBF), Azuaga, Sierra de Gádor, Almeria, and Cartagena/Mazarrón (28).

BCE. This specific region was indeed a focus of Phoenician settlement, but not before the eighth century BCE (refs. 47 and 48, Fig. 1). Earlier Phoenician finds and impact (late ninth/early eighth centuries BCE) are attested some 300 km northwest, at Sant'Imbenia (ref. 49, Fig. 1), 15 km south of the Argentiera silver-rich lead deposit, characterized by isotopic values that differ from those of the Iglesiente ores (28). Our finds therefore show that silver from Iglesiente was produced by cupellation and shipped eastward already in the mid-10th century BCE, 150–200 y before Phoenician settlement in this region is attested. [Although Pb was produced in Sardinia prior to the 10th century BCE, this does not imply that silver was produced as well (cf. refs. 29 and 50).] At present, we cannot rule out the possibility that cupellation was practiced in Sardinia before Phoenician contact and that silver was distributed eastward by others, perhaps indigenous Nuraghic societies. We claim, however, that the fact that the Sardinian silver was found in Phoenicia, bolsters the likelier scenario in which Phoenicians were the first to mobilize Sardinian silver to the Levant. They probably also introduced cupellation to Sardinia.

Iberia. Based on finds in silver production sites, it has been concluded that from ∼800 BCE silver was extracted from the abundant Pb-deficient argentiferous jarositic ores in the Iberian Pyritic Belt by Phoenicians, via the deliberate addition of Pb from other Iberian sources (refs. 27 and 51–53; for the process, see references in *SI Appendix*). Isotopic ratios of Iberian silver thus point mainly to the source of the added lead. This has been determined through the analysis of Iron Age silver from Iberia, attesting to an extensive production system that mobilized the needed lead mainly through maritime and riverine routes (54) (Fig. 1).

The innovative processes involved in silver production and trade in Iberia are attributed to the Phoenicians (27, 28). They required complex organization and know-how for mining the two ore types (galena and jarosite), smelting and mobilizing Pb, extracting silver via cupellation, and finally transporting the silver to the east (55). The Pb isotopic ratios of the 'Ein Hofez silver significantly reflect a

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mixture of several Iberian Pb sources, with Linares being an important contributor (Fig. 3). The results provide an additional explanation for the density of early-eighth century BCE Phoenician posts along the rivers and shores of southern Iberia (e.g., ref. 55, Fig. 1); these served as transport stations for the mobilization of lead. The results also provide testimony for the hitherto-missing link: the dissemination of silver as a commodity. The 'Ein Hofez hoard demonstrates that at least part of the Iberian silver reached the Levant, and that this occurred as early as the ninth century BCE. Thus, we show that Iberian silver was possibly the prime, and likely the earliest, reason for Phoenician endeavors in the peninsula, preceding, or contemporaneous with, the earliest stages of settlement there (e.g., refs. 14–16). From this point onward, the Phoenician market was dominated by Iberian silver for more than a century.

Conclusions

The LI ratios of silver items in three hoards from southern Phoenicia provide evidence of Phoenician precolonization and early colonization and enable us to outline a geographic-temporal trajectory for the Phoenicians' far-flung quest for silver. The large number of sampled items—a rare opportunity when dealing with ancient precious metal objects—allows a meaningful quantitative study. While in the second millennium BCE, silver reached the Levant from Anatolia/the Aegean, the situation changed gradually but dramatically in the first millennium, a process that we can now follow with high chronological and geographical resolution. The earliest silver from the West, specifically from Sardinia's Iglesiente region, reached Phoenicia already during the second half of the 10th century BCE, well before permanent Phoenician settlements were established on the island or elsewhere in the West. However, silver during this time still reached Phoenicia primarily from southeast Anatolia, continuing Bronze Age patterns. Our results call for a reconsideration of the extent to which Phoenicians were involved in Anatolian silver production and commerce and suggest that the Phoenicians acquired their metallurgical know-how in Anatolia. Based on the existing data, in the course of the ninth century BCE, Sardinian silver disappeared from the Phoenician hoards, and silver from Anatolia became scarce as well. From this point onward, the Phoenician market was dominated by Iberian silver. Our study shows that silver production there was at least as early as the first permanent Phoenician settlement on the peninsula. It certainly predates most of the Phoenician activity in southwest Iberia and demonstrates that silver exploitation in Iberia was a major goal from the outset. The rather abrupt shift in ore sources, which drove the Phoenicians to search for silver ever farther, may be explained by changes in political structures in the Near East, which rendered Anatolia inaccessible (3, 43), combined with the outstanding efficiency of the Iberian exploitation systems.

So, when and why did the Phoenicians first traverse the vast expanses of sea between the shores of the Levant and the far West? We answer: at least as early as the mid-10th century BCE, much earlier than any other current attestation, inter alia searching for silver. The Phoenician expansion phenomenon should be revisited in light of these data.

Materials and Methods

The hoard from Dor is very large (~8.5 kg; Fig. 2*A*) and dates to the second half of the 10th century BCE (the Ir 1|2 transition in Phoenicia, Early Iron IIA in the terminology used generally in the Levant). The 'Akko hoard is small (200 g; Fig. 2*B*), and its stratigraphic position is only generally known; it could date anywhere in the 10th to 9th centuries BCE. The 'Ein Hofez hoard (1.2 kg; Fig. 2*C*) dates to the ninth century BCE (Ir 2a in Phoenicia, Late Iron Age IIA in the Levant). Seventy-five cut-ingot items from the hoards were subjected to LI and chemical analyses: 34 from Dor, 29 from 'Ein Hofez, and 12 from 'Akko (*SI Appendix*, Table S1). This, as mentioned, is the largest dataset obtained from Phoenician hoards, a crucial factor in our ability to present reliable results (*SI Appendix*). Our results are presented alongside LI ratios available in the OXALID database (oxalid.arch.ox.ac.uk/Silver/Silver.html), including previously analyzed samples from the same hoards: from Dor ($n = 15$), 'Ein Hofez ($n = 15$), and 'Akko ($n = 10$), and from additional Levantine hoards. Some of these results remain unpublished, while others were published with an interpretation which we do not accept,[‡] strengthening the need for a larger dataset and a better understanding of the relevant archaeology and geology. For further details regarding the contexts and dating of the hoards, their current locations, and permissions to sample, see Fig. 1, ref. 32, and *SI Appendix*.

Sample preparation, chemical analysis, and LI analysis were performed in the clean laboratory of the Institute of Earth Sciences at the Hebrew University of Jerusalem. The items were drilled using a 1-mm drill. To avoid external contamination, surface drilling materials were discarded. The following 20–25 mg of silver were dissolved in HNO_3 and diluted with distilled water (10 mL). Residue was separated from the solution, dissolved in aqua regia (HNO_3:HCl = 1:3), and diluted with distilled water (up to 10 mL). Aliquots were taken from these solutions for major and trace element analyses (Ag, Au, Pb, Cu, Bi, As, Sb, Sn, and Zn) using inductively coupled plasma mass spectrometry (ICP-MS) (Agilent; 7500cx). Before the analysis, the ICP-MS was calibrated with a series of multielement standard solutions (Merck; ME VI). A solution of internal standards (750 μg/L Sc, 100 μg/L Re, and 50 μg/L Rh) was injected alongside the samples during the analytical session for drift correction. The contribution of metals by the reagents used in the procedures was determined by measuring procedural blanks. For precision and detection-limit estimation, the blank and four selected standards were reexamined every 30 samples and at the end of the analysis. In addition, for accuracy estimation, standard reference samples (US Geological Survey standard reference samples T-209 and T-201) were examined following calibration and at the end of the analysis. The precision and accuracy of the ICP-MS were ±5%. The concentrations of minor elements (Pb, Cu, Au, and Bi) were used to identify possible additions of these metals to the silver items, which may affect their LI values. The absence (or very low concentrations) of As, Sn, Sb, and Zn strengthen our assumption that silver was, in fact, produced by cupellation, as these elements are easily oxidized and removed in the cupellation process (see more in *SI Appendix*).

For LI analysis, aliquots containing 100 ng of Pb from all samples ($n = 75$) were processed through ion exchange columns (Dowex 1X8 resin) according to the protocols outlined in ref. 58. Isotopic measurements were conducted with a MC-ICP-MS (Thermo Neptune Plus). Blank levels were checked regularly and never exceeded 1% of the samples. Mass fractionation corrections for Pb isotopes were based on a ^{205}Tl/^{203}Tl isotopic ratio of 2.3875 after adding Tl solution (50 ppb) to all samples and standards. The corrections were closely monitored by frequent analysis of NIST SRM-981 standards, which were measured under identical running conditions as samples. Replicate measurements of National Institute of Standards and Technology (NIST) SRM-981 standards over the course of this study yielded mean values of $^{206}Pb/^{204}Pb = 16.928 \pm 0.002$, $^{207}Pb/^{204}Pb = 15.480 \pm 0.002$, and $^{208}Pb/^{204}Pb = 36.667 \pm 0.004$ (2σ, $n = 12$).

In *SI Appendix*, Figs. S1 and S2 and Table S1, readers are provided with a full explanation on the methodology of Pb isotopes for tracing ore sources; the limitations of this method; our suggestions to overcome some of these limitations, including a graphic and textual explanation of the geological model used in this paper; and the full results of the chemical and isotopic analyses (including uncertainties).

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[‡]In ref. 56, it was a priori assumed that "hacksilber" items in hoards were not mixed (for an explanation of the term, see *SI Appendix*), and therefore each individual item represents one ore source. Thus, only a fraction of the sampled items per hoard were included in the study, hampering the ability to reach concrete conclusions (only 2 samples from Dor, 3 from 'Akko, 5 from Tell Keisan, and 15 samples from 'Ein Hofez). The four hoards, spanning two to three centuries (11th to 9th BCE), were discussed as one group, despite the chronological differences between them, and the concomitant difference in historical context. In addition, chemical composition was not considered by the authors. Therefore, the practice of alloying silver with copper, common in the 11th century BCE south-Levantine hoards, and noticeable in the Tell Keisan hoard, passed unnoticed. As suggested in ref. 32, a probable ore source for the copper in these hoards (which consists up to 80% of the alloy in some items) is Timna in the Araba valley in southern Israel, which is Pb-rich. If so, this would have introduced another meaningful source of lead, blurring the original isotopic signal in the silver. Graphically, the results create a mixing line between silver and copper ore sources, rather than between several lead ores (results available at OXALID). Since the Cu ores of Timna have a wide Pb isotopic range (57), they overlap both with the Pb ores of Sardinia and of Iberia. Consequently, silver from Tell Keisan might have been mistakenly interpreted as "Western" (32). Additionally, the authors did not identify Iberian silver in the 'Ein Hofez hoard, possibly because they might not have been acquainted with the complex production process of silver in southwest Iberia (references available in *SI Appendix*). Moreover, plots of $^{207}Pb/^{204}Pb$, $^{206}Pb/^{204}Pb$, and $^{208}Pb/^{204}Pb$ that add valuable information were not used (*SI Appendix*). The authors did recognize that some west Mediterranean silver was present in the hoards but admitted that they could not differentiate between Sardinia and Iberia. They selected Sardinia as the single source of Western silver in all four hoards, based on historical/philological considerations. Finally, the paper ignored Anatolian silver and its significance.

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