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# 1 **Metal provenance of Iron Age *Hacksilber* hoards in the southern** 2 **Levant**

3  
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## 12 **Abstract**

13 *Hacksilber* facilitated trade and transactions from the beginning of the second millennium  
14 BCE until the late fourth century BCE in the southern Levant. Here we demonstrate the use of  
15 new, data-driven statistical approaches to interpret high-precision Pb isotope analysis of silver  
16 found in archaeological contexts for provenance determination. We sampled 46 pieces of  
17 *Hacksilber* from five hoards (Megiddo Area H, Eshtemoa, Tel Dor, 'En Gedi, and Tel Migne-  
18 Ekron) and combined our data with recent literature data for the same hoards plus five more  
19 (Beth Shean, Ashkelon, Tell Keisan, Tel 'Akko, and 'En Hofez) thus covering silver from the  
20 Late Bronze Age III (c.1200 BCE) to the end of the Iron Age IIC (586 BCE).

21  
22 Samples were taken by applying a new minimally destructive sampling technique. Lead was  
23 extracted using anion-exchange chromatography and Pb isotopic compositions were measured  
24 by MC-ICP-MS. Data were treated using a new clustering method to identify statistically  
25 distinct groups of data, and a convex hull was applied to identify and constrain ore sources  
26 consistent with the isotopic signature of each group. Samples were grouped by minimizing  
27 variance *within* isotopic clusters and maximizing variance *between* isotopic clusters.

28  
29 We found that exchanges between the Levant and the Aegean world continued at least  
30 intermittently from the Late Bronze Age through to the Iron Age III, demonstrated by the  
31 prevalence of Lavrion (Attica), Macedonia, Thrace (northern Greece), Southern Gaul  
32 (southern France), and Sardinia as long-lived major silver sources. Occasional exchanges with  
33 other west Mediterranean localities found in the isotopic record demonstrate that even though  
34 the Aegean world dominated silver supply during the Iron Age, exchanges between the  
35 eastern and the western Mediterranean did not altogether cease. The mixture of silver sources

36 within hoards and relatively low purity of silver intentionally mixed with copper and arsenic  
37 suggest long-term hoarding and irregular, limited supply during the Iron Age I.

38

## 39 **1. Introduction**

40 *Hacksilber* is irregularly cut silver bullion made from broken pieces of silver ingots, jewelry,  
41 and other pieces of scrap silver. It served as a store of wealth and means of payment in the  
42 Ancient Near East for thousands of years. Used in local and international transactions, the  
43 value of *Hacksilber* was determined by weighing it on scales against standardized weights  
44 presumably allowing for the purity of silver. Evidence exists of cupellation being used for  
45 silver extraction since the fourth millennium BCE at sites in Greater Mesopotamia (Helwing,  
46 2014), and *Hacksilber* itself has been discovered in archaeological excavations in the region  
47 (for Middle Bronze Age II *Hacksilber* hoards see Kletter, 2003:148; Thompson, 2009 for  
48 Early Iron Age I hoards). In the southern Levant, *Hacksilber* facilitated trade and transactions  
49 from the beginning of the second millennium BCE (Kletter, 2003:148) until the late fourth  
50 century BCE (Farhi, 2014), with mixed hoards composed mainly of uncut coins supplemented  
51 by *Hacksilber* in equal or greater quantities (Gitler, 2006). A hoard allegedly found in the  
52 vicinity of Samaria illustrates that the practice of using cut coins alongside *Hacksilber*  
53 continued into the second half of the fourth century BCE (Gitler, 2006).

54 *Hacksilber* hoards have been found in excavations throughout the southern Levant in:

- 55 • Ceramic containers – e.g. ‘En Gedi (Kletter and De Groot, 2007), Eshtemoa  
56 (Kletter and Brand, 1998), ‘En Hōfez (Thompson and Skaggs, 2013), Tel  
57 ‘Akko (Thompson and Skaggs, 2013), and Tel Miqne-Ekron (Golani and Sass,  
58 1998).
- 59 • Bundles wrapped in linen bags and kept in ceramic containers – e.g. Megiddo  
60 Area H (Arie et al., 2019), Tell Keisan (Thompson and Skaggs, 2013), and Tel  
61 Dor (Shalev et al., 2014).
- 62 • Bundles wrapped in linen bags – e.g. Tel Beth-Shean (Thompson, 2009),  
63 Ashkelon (Thompson, 2020), and Tel Miqne-Ekron (Golani and Sass, 1998).
- 64 • Assemblages where no remains of the container or the textile bag have been  
65 found – e.g. Tel Miqne-Ekron (Golani and Sass, 1998) and Beth Shean  
66 (Thompson, 2009).

67 Recent research into *Hacksilber* has mostly concentrated on two questions. First, the extent to  
68 which *Hacksilber* filled the functions of money prior to the invention of coinage (Stos-Gale,  
69 2001; Thompson, 2003; Eshel et al., 2018). Second, identifying its silver sources with a focus  
70 on determining when and to what extent the Phoenicians were engaged in long-distance silver  
71 trade prior to their colonisation of the western Mediterranean (Thompson, 2003; Thompson  
72 and Skaggs, 2013; Murillo -Barroso et al., 2016; Eshel et al., 2019; Wood et al., 2019; Gitler  
73 and Tal, 2020; Eshel et al., 2021).

74

75 Arguably, the Hebrew phrase *bz' ksp*, meaning “intentionally cut pieces of silver”, was the  
76 biblical term for money itself (cf. Judges 5:19). The bundling of *Hacksilber* evoking the  
77 biblical expression “pouch of silver” (*zrwr ksp*, Genesis 42:35) has led to the contention that it  
78 functioned as money (Thompson (2003) or at least as pre-coinage (Gitin and Golani, 2001;  
79 Silver, 2006; Kroll, 2008; Gestoso-Singer, 2013, 2015; Heymans, 2018a). Eshel et al. (2018;  
80 2019) addressed this by investigating the context, chronology, weight, and typology of the  
81 *Hacksilber*, and comparing this information with a subset of major and minor elemental  
82 compositions. They found that neither the weight nor the fineness, that is the quality and the  
83 quantity of *Hacksilber*, are sufficiently consistent to support the theory that *Hacksilber* was a  
84 precursor to coinage. Rather, it would appear that the Phoenician perspective on silver before  
85 the 5<sup>th</sup> century BCE was to treat it as a commodity, not a currency (Gitler and Tal, 2006; Elayi  
86 and Elayi, 2009; Van Alfen, 2002; Albarède et al., 2020). This is an important finding which  
87 matches Davis’ (2012) conclusions about contemporary Archaic Athenian Greek use of  
88 *Hacksilber* and goes to the question of whether there was an adequate and reliable supply of  
89 silver to make true monetary use viable. If there was, then the expectation would be mostly  
90 homogeneous hoards especially within the bundles, a question tested in this research.

91 Albarède et al (2021) further investigate the apparent resistance to the adoption of money in  
92 the Western Mediterranean, tracing silver refining techniques in the region using lead and  
93 silver isotope analysis.

94

95 Eshel et al. (2021) raise the point of whether systematic debasement by copper and arsenic  
96 during the period 1200-950 BCE in the southern Levant was intentional or just common  
97 economic practice in a region that could only acquire silver from abroad. They argue that the  
98 use of arsenic (up to 4.6 wt.% in Megiddo Area H) to maintain a silvery shine indicated  
99 deliberate debasement. However, there is no evidence to support Eshel et al.’s statement that  
100 “the local administrations initiated sophisticated devaluation methods to compensate for the

101 lack of silver”, and full-scale tampering with all silver circulating in the southern Levant in its  
102 various forms is unlikely. An equally reasonable assumption is that relatively low-quality  
103 silver alloys were broadly accepted during the Late Bronze to Iron Age transition period.  
104 Understanding silver sources and thus trade routes in use at the time will help in better  
105 understanding this phenomenon.

106

107 The focus of the present research is on Iron Age *Hacksilber* hoards in the southern Levant  
108 when the geopolitical circumstances were different from the preceding Late Bronze Age.  
109 Material found in controlled archaeologically excavated hoards and single finds provides the  
110 best evidence because it has secure contexts. Research questions for this study to be addressed  
111 by Pb isotopic analysis are:

- 112 1. How many silver sources were there, and which ones can be identified?
- 113 2. Do the silver sources change with time?
- 114 3. To what extent is the silver in each hoard internally homogenous?

115 The hoards described in this work have been dated based on their archaeological context, and  
116 a generally agreed ceramic pottery typology (Mazar, 2011). For a description of the  
117 methodology behind the dating of each hoard see Eshel et al. (2018; 2021). For details of the  
118 archaeological context and relative dating for individual sites see Rowe (1940) (Beth Shean),  
119 Arie et al. (2019) (Megiddo Area H), Balmuth (2001 p.15) (Ashkelon), Nodet (1980 pp. 323-  
120 326) (Tell Keisan), Stern (1998) and Shalev et al. (2014) (Tel Dor), Thompson and Skaggs  
121 (2013) (Tel ‘Akko), Alexandre (1997 p. 53) (‘En Ḥofez), Kletter and Brand (1998)  
122 (Eshtemoa), Golani and Sass (1998) and Gitin and Golani (2001) (Tel Miqne-Ekron), and  
123 Kletter and De Groot (2007) (‘En Gedi). For a broader understanding of the hoards in relation  
124 to each other see Thompson (2003) and Eshel et al. (2018). The Bronze Age and Iron Age are  
125 convenient constructs understood to start and end at different times in different places. In the  
126 southern Levant, the Bronze Age is considered to end around 1200 BCE with the cultural  
127 collapse of the dominant states, and the Iron Age ends in 586 BCE marked by the Babylonian  
128 conquest and destruction of the temple in Jerusalem. Within these two periods are separations  
129 into shorter time phases (e.g. Iron Age I, Iron Age II), which can be further divided (e.g. Iron  
130 Age IIA, Iron Age IIB, Iron Age IIC). The dates associated with each division remain  
131 intensely debated (e.g. Gilboa et al., 2008; Finkelstein and Piasezky, 2011; Mazar, 2011),  
132 with ranges for the transition between each period being accepted within ‘low’ and ‘high’  
133 chronologies. The time periods are being tightened as further data are gathered in

134 archaeological excavations, especially by radiometric dating (Webster, 2015), but the exact  
135 dating does not affect the arguments presented in this paper.

136 Lead isotope analysis of *Hacksilber* hoards has been conducted before, most notably through  
137 the ‘*Hacksilber* Project’ undertaken by Balmuth and Thompson with Stos-Gale (Stos-Gale,  
138 2001; Stos-Gale and Gale, 2012). These data were produced by thermal-ionization mass  
139 spectrometry (TIMS), which does not control analytical mass bias as efficiently as multiple-  
140 collector inductively-coupled plasma mass spectrometry (MC-ICP-MS). The ‘*Hacksilber*  
141 Project’ publication included a chapter on lead isotope analysis of excavated *Hacksilber* at Tel  
142 Miqne-Ekron, Shechem, and Selinus (Stos-Gale, 2001). When interpreting results from lead  
143 isotope analysis in these *Hacksilber* hoards, Stos-Gale observed that they are consistent with  
144 lead isotope ratios of ores from the Aegean, Spain, and Iran. A further observation made by  
145 Stos-Gale was that the data did not support a hypothesis of widespread mixing, positing that  
146 melting and re-casting was done on individual objects on a small scale. Stos-Gale pointed out  
147 that a silver object of unknown provenance can only be assigned an ore source if data from  
148 that ore source exist and called for further lead isotope analyses of *Hacksilber*.

149  
150 Stos-Gale’s conclusions were re-examined by Thompson and Skaggs (2013) for hoards from  
151 Tel ‘Akko, Tel Dor, ‘En Hōfez, and Tell Keisan against geological data from the Forum of the  
152 European Geological Surveys (FOREGS) Geochemical Baseline Mapping program.

153 Thompson and Skaggs concluded that at least one sample from each of the *Hacksilber* hoards  
154 under consideration could have lead isotope ratios consistent with those of silver-bearing ores  
155 from Sardinia and southern France and inconsistent with Aegean and Anatolian sources.

156 Apparent in this paper and elaborated on in Thompson’s unpublished “A Brief History of  
157 *Hacksilber* Project Research” (2017), is the criticism of previous assumptions that *Hacksilber*  
158 was unlikely to originate in the western Mediterranean. Further, with regards to the problem  
159 of mixing, Thompson (2017) asserted that even before 800 BCE silver sources were multiple  
160 and bullion travelled long distances.

161  
162 Eshel et al. (2019) analysed numerous pieces of *Hacksilber* from the same hoards analysed by  
163 Stos-Gale (2001) for lead isotope composition, comparing their results to lead isotope  
164 compositions of silver-bearing ores available in the Oxford Archaeological Lead Isotope  
165 Database (OXALID). The study focused on the hoards from Tel Dor, Tel ‘Akko, ‘En Hōfez,  
166 and Eshtemoa. The authors were critical of Thompson and Skaggs (2013) for assuming that

167 *Hacksilber* hoards were not mixed. They suggested that *Hacksilber* from Tel Dor and Tel  
168 'Akko originated from both Anatolia and Sardinia, while *Hacksilber* from 'En Hōfez and  
169 Eshtemoa originated from Iberia (Spain). Based on the chronology of these hoards, they  
170 proposed that the Phoenicians brought knowledge of silver refining acquired in Anatolia to  
171 tribes in Iberia in the mid-10<sup>th</sup> century BCE, 150 to 200 years prior to Phoenician settlement  
172 in Iberia. However, while the data may be consistent with the conclusions, they do not  
173 necessarily go so far as to support them.

174

175 Wood et al. (2019) used lead isotope analysis to further investigate whether *Hacksilber* silver  
176 sources were mixed. They re-examined the lead isotope ratios in *Hacksilber* produced by  
177 Stos-Gale (2001) against compositional data. Wood et al. (2019) proposed a comparison of  
178 the crustal age of the metal calculated from the lead isotope ratios against the compositional  
179 ratio of gold to silver. Where the gold to silver ratio did not match the crustal age, Wood et al.  
180 (2019) proposed that mixing of silver from different sources is evident. In this way, mixing  
181 lines were identified, and the authors proposed considerable mixing between several potential  
182 ore sources. The authors used the chronology of the hoards, identified via their archaeological  
183 contexts, to suggest where and when mixing of silver may have taken place. The study  
184 focused on the use of mixing lines to identify mixing events, with only some of the end-  
185 member clusters identified in terms of geological sources. Crucially, the authors noted that  
186 further work is needed to contextualize their findings, acknowledging that apart from the  
187 archaeological chronology, there is little evidence to support where or when potential mixing  
188 took place. The authors applied their proposed methodology in Wood et al. (2020) by  
189 reanalysing legacy lead isotope data from Stos-Gale (2001) in order to determine the source(s)  
190 of the Tel Dor *Hacksilber* hoard. The authors concluded that the Phoenicians learned silver  
191 refining in Cyprus, rather than Anatolia as Eshel et al. (2019) had suggested, and introduced  
192 the methodology to Iberia. The authors further suggested that silver objects which were  
193 previously identified as having originated from Thera, Kythnos, or Cyprus (Wood et al.,  
194 2019) are in fact silver mined at Kalavassos in Cyprus, or lead used for cupellation of silver  
195 from a different, so-far unidentified source. These conclusions are unsupported. The  
196 geochemistry of ores on the islands of Kythnos and Thera is inconsistent with significant  
197 silver production. As to the silver extraction from the ores in Kalavassos, one of the copper  
198 mines of Cyprus, this speculation is also unfounded. Even though intrusions of porphyries are  
199 ubiquitous from the Aegean to modern Afghanistan and contain substantial traces of silver  
200 (Zürcher et al., 2019), the historical context shows that silver from these ores could never

201 compete with peri-Aegean mines. A simple interpretation is technological: Cu and Ag form a  
202 eutectic barrier at 28% Cu (Baker , 1992) making silver purification by cupellation of Cu-rich  
203 alloys a major hurdle. This problem does not exist with Ag-Pb alloys. In a more geological  
204 context, finding Ag and Pb ores in Cyprus, a textbook example of an ophiolite, would be very  
205 unexpected.

206

207 Eshel et al. (2019; 2021) conducted further research on *Hacksilber* using lead isotope  
208 analysis, with the premise that interpretations based on lead isotopes can be further refined  
209 using elemental compositions. The elements they considered diagnostic are Cu (<5.5%), Pb,  
210 Au, and Bi, which may be indicative of silver that has been cupelled, and Co, Ni, Zn, and Sn,  
211 the absence of which likewise is indicative of silver that has been cupelled but the presence of  
212 which is consistent with the addition of smelted copper. A caveat, however, is that some  
213 elements (Zn, Bi, As) (Honig , 1969) are more volatile than silver and, according to Henry's  
214 Law, should be at least partially lost during the metallurgical process. Arsenic and antimony  
215 were also considered carefully, as they may have been added intentionally to the alloy, and  
216 not introduced via the addition of copper. All compositional data were collected using  
217 quadrupole ICP-MS. Rather than using compositional information for provenance  
218 determination, this information was directed towards identifying mixing and alloying. When  
219 various mixes or alloys were identified, the results were placed within their specific  
220 archaeological context (particularly hoard location and approximate date of deposition) to  
221 draw conclusions about the broader political situation at the time. Their key claim was that  
222 high copper contents in *Hacksilber* date from around the Bronze Age collapse (c.1200 BCE)  
223 correlated with a purported end to ready access to Aegean silver in the Levant due to break  
224 down of trade connections. They proposed that a perceived influx of silver from Anatolia and  
225 the West Mediterranean (based on lead isotope results in Eshel et al., 2019) is reflected in  
226 considerably lower copper contents in *Hacksilber* deposited after approximately 950 BCE.

227

228 As discussed in the literature, a geological perspective is crucial to understanding lead isotope  
229 analysis of archaeological objects (Albarède et al., 2012; Blichert-Toft et al., 2016; Albarède  
230 et al., 2020). The advantage of using the geological perspective approach, which involves  
231 calculating Pb model ages and time-integrated parent-daughter (U/Pb) and parent-parent  
232 (Th/U) ratios from measured Pb isotope data, is that it is data driven and is performed  
233 independently of any archaeological or numismatic conclusions drawn about the samples. The  
234 former set of evidence thereby complements the latter two in an objective manner. As a

235 caveat, mixing trends are linear only if the  $x$  and  $y$  axis denominators are identical, as in Pb-Pb  
236 isotopic plots. Lead model ages are, to a first approximation, proportional to  $^{207}\text{Pb}/^{206}\text{Pb}$   
237 (Albarède et al., 2021) and mixing lines using Pb model ages vs elemental ratios such as  
238 Au/Ag (e.g. Figs. 4 and 6 in Wood et al., 2019) are strongly curved as a function of the Pb  
239 contents of the coins. Mixing patterns, therefore, should be interpreted with the utmost  
240 caution.

241  
242 Prior attempts of provenance calculations have relied on one-to-one comparisons between  
243 individual ores and *Hacksilber* fragments (Thompson and Skaggs, 2013; Delile et al., 2014;  
244 Westner et al., 2020). Our approach is different. We provide 46 new high-precision Pb isotope  
245 compositions of *Hacksilber* fragments from seven southern Levantine hoards and combine  
246 them with Eshel et al.'s (2019; 2021) data. Eshel et al.'s data were all obtained by MC-ICP-  
247 MS, as were the new data of this study, hence justifying the merging of the two data sets. We  
248 further apply a new, more encompassing approach to statistically interpret the data, based on  
249 'convex hulls' of the 3-dimensional Pb isotope data of each hoard (i.e., the smallest convex  
250 volume that contains the data). By using a data-driven approach to the statistical interpretation  
251 of lead isotope data, combined with lead isotope data for likely ore sources, we identify which  
252 ore sources could have contributed to the *Hacksilber* hoards and determine the homogeneity  
253 of silver sources for each hoard. By then combining these data with the archaeological  
254 chronology of the hoards in question, we identify changes in silver sources over time.

## 255 **2. Materials**

256 Thirty-four *Hacksilber* hoards dating to the Iron Age (c.1200-600 BCE) from 15 different  
257 sites in Israel and under the control of the Palestinian Authority were identified by Thompson  
258 as part of her '*Hacksilber* Project' (2017). The 13 sites listed in Table 1 were selected for the  
259 present research project to provide representative samples from the end of the Late Bronze  
260 Age through the Iron Age, from different find-spots in the southern Levant, which can best  
261 answer the research questions identified in this paper. There is a strong focus on the rich  
262 material from the seventh century sites of Tel Mique-Ekron, with its multiple hoards, and 'En  
263 Gedi, as this was the century when coined money was invented and monetary use of  
264 *Hacksilber* might be expected.

265

**Table 1 – Hoards selected for analysis (for the description and dating of these hoards see Heymans , 2018b, pp. 256-269)**

<b>Hoard</b>	<b>Period</b>	<b>Approximate date (BCE)</b>	<b>Contents</b>	<b>Sampled for new lead isotope analysis</b>	<b>Previous lead isotope analysis available in the literature</b>
Beth Shean 10704 (L.88866)	Late Bronze Age III	1200-1150	Cut ingots, wires, broken jewellery stored in a bundle	0	13 (Eshel <i>et al.</i> 2021)
Megiddo Area H	Iron Age I	1070	3 linen-wrapped bundles of <i>Hacksilber</i> - cut ingots, jewellery	5	13 (Eshel <i>et al.</i> 2021)
Beth Shean 1095	Iron Age I	1150-950	Ingots, wires and jewellery stored in a bundle	0	5 (Eshel <i>et al.</i> 2021)
Megiddo 2012	Iron Age I	1050-950	Cut ingots, sheet fragments, and jewelry stored in three bundles	0	11 (Eshel <i>et al.</i> 2021)
Ashkelon	Iron Age I	1050-950	2 linen-wrapped bundles of <i>Hacksilber</i>	0	12 (Eshel <i>et al.</i> 2021)
Tell Keisan	Iron Age I	1050-950	Silver fragments including sheet silver + jewellery stored in a single jar	0	20 (Eshel <i>et al.</i> 2021)
Tel Dor	Iron Age IIA	2nd half of 10 <sup>th</sup> century	17 linen-wrapped bundles of <i>Hacksilber</i> stored in a single jar + ingots	14	34 (Eshel <i>et al.</i> 2019)
Tel `Akko	Iron Age IIA	10 <sup>th</sup> -9 <sup>th</sup> centuries	Cut ingots, tokens, wires, sheets stored in a juglet	0	12 (Eshel <i>et al.</i> 2019)
Beth Shean 1029a and b	Iron Age IIA	950-800	Jewellery and ingots store in a ceramic vessel	0	15 (Eshel <i>et al.</i> 2021)
‘En Hofez	Iron Age IIA	9 <sup>th</sup> century	<i>Hacksilber</i> , ingots + some jewellery stored in 3 jugs	0	29 (Eshel <i>et al.</i> 2019)
1029a and ba and b					
Eshtemoa	Iron Age IIB	8 <sup>th</sup> century	<i>Hacksilber</i> , ingots + jewellery stored in five jugs	5	0
Tel Miqne-Ekron	Iron Age IIC	Late 7th-early 6th century	<i>Hacksilber</i> , ingots, jewellery + a foundation deposit. Hoards 1, 3 and 5 were stored in a jug, Hoard 2 shows traces of textile impressions, Hoard 4 was found as an assemblage and Hoard 6 was covered by an overturned bowl.	16	0
‘En Gedi	Iron Age IIC	Late 7th-early 6th century	62 pieces of silver, mostly ingots stored in a cooking pot	5	0
<b>Total</b>				<b>45</b>	<b>164*</b>

270  
271 Pre-MC-ICP-MS legacy data is dominated by more ‘noise’, and therefore less precision, than  
272 data from the MC-ICP-MS era. Precision and accuracy of early (pre-2000) TIMS and modern  
273 MC-ICP-MS Pb isotopic data may differ by up to two orders of magnitude. Furthermore, the  
274 archaeological literature tends to reference the data relative to  $^{204}\text{Pb}$  (e.g. Eshel et al., 2018;  
275 2019; 2021), which is the least abundant isotope rather than, for example,  $^{206}\text{Pb}$  or  $^{208}\text{Pb}$   
276 (Albarède et al., 2012; 2020). When lead isotope data are examined using  $^{204}\text{Pb}$  as the  
277 denominator on both the x and y axes, ‘noise’ is greater and, hence, precision is poorer.  
278 Interpreting geological provenance from data represented in this way, therefore, is not ideal.  
279 In order to avoid merging data of heterogeneous quality in the same database,  $^{204}\text{Pb}$ -  
280 referenced legacy data as well as Pb isotope data measured by TIMS, mostly from the  
281 OXALID database (which includes *Hacksilber* data published in Stos-Gale, 2001), have not  
282 been included in this study. This choice does not imply that the inclusion of these data would  
283 have modified the conclusions reached here but was made to limit the present assessment to  
284 high-precision data only. The merging of our data with those of Eshel et al. (2019; 2021) is  
285 justified by their similar level of precision acquired via solution purification chemistry and  
286 MC-ICP-MS measurement.

### 287 **3. Methods**

#### 288 *3.1. Artefact sampling*

289 All samples were etched on their edges using a novel technique (Milot et al., 2021) which  
290 removes only a few micrograms of material, less than one-millionth the total weight of the  
291 object (or less depending on the size of the object in question). To briefly summarize the  
292 technique, the artefact is rolled for about 90 seconds onto a strip of chromatographic paper  
293 impregnated with a solution of  $\text{H}_2\text{O}_2$ ,  $\text{NH}_4\text{OH}$ , and  $\text{H}_2\text{O}$  in the proportions of 1:1:1 using a  
294 custom-made set of felt-covered pliers (Milot et al., 2021). In cases where the shape of the  
295 object does not permit rolling, such as is often the case with unevenly shaped *Hacksilber*, a  
296 cotton bud is used instead of the pliers and chromatographic paper. The strips and cotton buds  
297 were air-dried under an IR lamp and placed into clean 10 mL centrifuge tubes, which were  
298 closed tightly with screw lids and wrapped in multiple layers of film for transportation back to  
299 the Lyon clean laboratory for Pb separation and isotopic analysis (as artefacts were usually  
300 sampled on-site in a distant museum). There, 10 mL double-distilled 1M HBr, for which Pb  
301 has strong affinity, were added to the tubes, thereby submerging the strips (or cotton buds)  
302 which were subsequently left to leach at ambient temperature for 24 hours. The HBr

303 containing the Pb leached from the strips (or cotton buds) was then transferred to a clean  
304 Savillex (PFA) beaker and evaporated to dryness on a hotplate at approximately 130°C.  
305 Meanwhile, the HBr-leached strips (or cotton buds) were submerged in 10 mL distilled 0.5M  
306 HNO<sub>3</sub> and left to leach further at ambient temperature for another 24 hours. The HNO<sub>3</sub> was  
307 transferred to the same beakers containing the now dried-down HBr solutions and evaporated  
308 to dryness under the same conditions.

### 309 *3.2 Lead purification*

310 Lead was eluted from the samples following a one-step anion-exchange (AG1-X8, 100-200  
311 mesh) column chromatography protocol. The dry residues from the leaching procedure were  
312 dissolved in 1 mL double-distilled 1M HBr, and alternately heated at 110°C on a hotplate and  
313 placed in an ultrasonic bath to ensure total dissolution. The cooled-down samples were loaded  
314 onto the anion-exchange columns, the sample matrix eluted with 1M double-distilled HBr,  
315 and Pb subsequently collected with 6M distilled HCl. The Pb fractions were evaporated to  
316 dryness at approximately 110°C, redissolved with a few drops of concentrated distilled HNO<sub>3</sub>  
317 to remove any traces of HBr and organic material, dried down again and finally dissolved in 1  
318 mL distilled 0.05M HNO<sub>3</sub> with 5 ppb Tl prior to Pb isotope analysis.

### 319 *3.3 Lead isotope analysis*

320 Lead isotope analysis was done using a Nu Plasma 500 HR MC-ICP-MS at the Ecole  
321 Normale Supérieure de Lyon. Blichert-Toft et al. (2003) and White et al. (2000) describe the  
322 analytical method of Pb isotope analysis by MC-ICP-MS in detail. Instrumental mass bias was  
323 corrected with added Tl using the reference values for Tl and Pb of Eisele et al. (2003).  
324 Sample-standard bracketing relative to the NIST 981 Pb standard, which was run  
325 systematically every two samples throughout each analytical session, further ensured the  
326 accuracy of the measured Pb isotope compositions of the unknowns. The repeated  
327 measurements of NIST 981 yielded an external reproducibility of 30-100 ppm (0.003-0.01%)  
328 for <sup>204</sup>Pb-normalized ratios and of 6 ppm (0.0006%) for <sup>207</sup>Pb/<sup>206</sup>Pb and <sup>208</sup>Pb/<sup>206</sup>Pb.  
329 Estimation of internal analytical uncertainties was based on the measurement of 60 isotope  
330 ratios with 10 seconds integration time for each sample and standard expressed as twice the  
331 standard deviation (2SD). The Pb isotope data of the 46 Hacksilber samples analyzed in this  
332 study are listed in Supplementary Table S1.

### 333 *3.4. Parameter calculation and statistical analysis*

334 Traditionally in archaeometric research, lead isotopes are used for provenance determination  
335 based on the interpretation of plots of the raw isotopic data. In this study, we additionally take

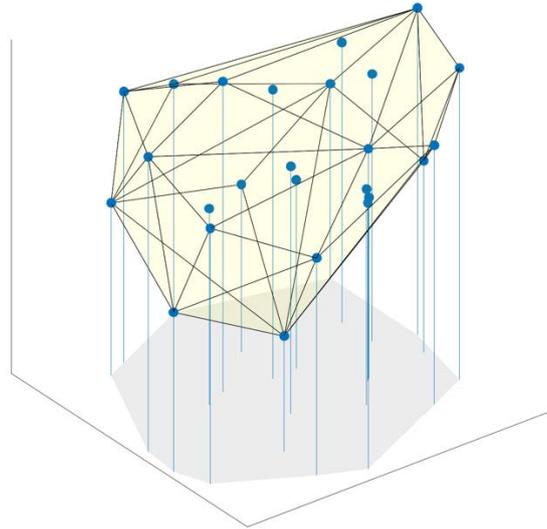
336 the geologically-informed approach proposed by Albarède et al. (2012) and further developed  
337 in Albarède et al. (2020) to explore Pb model ages  $T_{\text{mod}}$  and the  $^{238}\text{U}/^{204}\text{Pb}$  ( $\mu$ ) and  $^{232}\text{Th}/^{238}\text{U}$   
338 ( $\kappa$ ) parameters of each sample.

### 339 3.5. Provenance assessment

340 In previous studies (e.g. Delile et al., 2014; Westner et al., 2020), the ‘consistencies’  
341 (Thompson and Skaggs, 2013) are established by testing the error-weighted or unweighted  
342 distance between a particular ore and a particular archaeological sample in one of the 3-  
343 dimensional spaces of Pb isotopes (with isotopic ratios preferentially normalized to  $^{206}\text{Pb}$  to  
344 avoid the strong correlations arising from  $^{204}\text{Pb}$ -normalized ratios; see Albarède et al., 2020).  
345 The pair-wise approach ignores the fact that ore data tend to form regionally coherent  
346 populations, which the geologically-informed parameters (model age  $T_{\text{mod}}$ ,  $\mu$ , and  $\kappa$ ) clearly  
347 confirm (Blichert-Toft et al., 2016; Milot et al., in press). These groups must, in one way or  
348 another, manifest themselves in the *Hacksilber* Pb isotope record. Here we adopted the  
349 alternative strategy of detecting the ores that are consistent with the range of Pb isotopic ratios  
350 defined by the samples. This led us to introduce the concept of the ‘sample convex hull’,  
351 which is the smallest volume in the 3-dimensional space of isotopic ratios which contains all  
352 the sample values. As a preliminary step, we used the standard clustering technique applied to  
353 Iberian galenas by Albarède et al. (2020) with the expectation that distinct isotopic groups  
354 would be found. The next step consisted in separating the data within each hoard into distinct  
355 groups, typically one to three as a function of the number of samples. At that point, a convex  
356 volume circumscribing the points of the group, known as a convex hull and meshed with  
357 tetrahedra, is calculated by Delaunay triangulation (e.g. Aurenhammer et al., 2013) (Fig. 1).  
358 Convexity is required to ensure that points do not lie in gulfs or embayments. Finally, an  
359 algorithm was run for each datum of the ore database to determine if the corresponding point  
360 lay inside or outside the volume. Minor improvements were added: the hoard data were scaled  
361 to unit variance and zero mean, and some slack around the volume was allowed for. The  
362 successful data finally were plotted on a map of the circum-Mediterranean regions. The  
363 necessary algorithms were all implemented with the MATLAB software.

364  
365 The convexity of the hull guarantees that if extreme points lie in the hull, so will all the points  
366 that are lying on the mixing lines between the extremes. The problem is that if a single sample  
367 with a completely different isotopic composition (i.e., an outlier) is included in the sample set,  
368 the hull will include the empty volume between the outlier and the rest of the data. We found  
369 that a preliminary identification of distinct groups, as explained above, avoids including data-

370 intermediate free volumes in the search. As will be shown below, all the hoards include one or  
371 two groups. It must be remembered that the extreme points are still included and should show  
372 up in the search.



373  
374 Figure 1. Sketch of a convex hull (in yellow) built by Delaunay triangulation. The original  
375 data (blue circles) were generated as a set of 25 random points in 3-dimensional space. In  
376 practice, the convex hull is the 3D convex volume that contains all the isotopic coordinates of  
377 the samples in each hoard. The Delaunay triangles have been made transparent to show the  
378 points inside the hull.

#### 379 **4. Results**

380 We first explored the space of the  $^{209}\text{Pb}$  isotope data (including those produced by Eshel et  
381 al. (2019; 2021) and the  $^{46}\text{Pb}$  isotope data produced in the present work), from the 13  
382 different *Hacksilber* hoards listed in Table 1. We proceeded hoard by hoard by:

- 383 (1) identifying significantly different isotopic groups in each hoard,
- 384 (2) constructing the corresponding convex hulls for each of them by Delaunay triangulation,
- 385 (3) searching the ore database for the points lying within each hull, and
- 386 (4) identifying the location of potential sources.

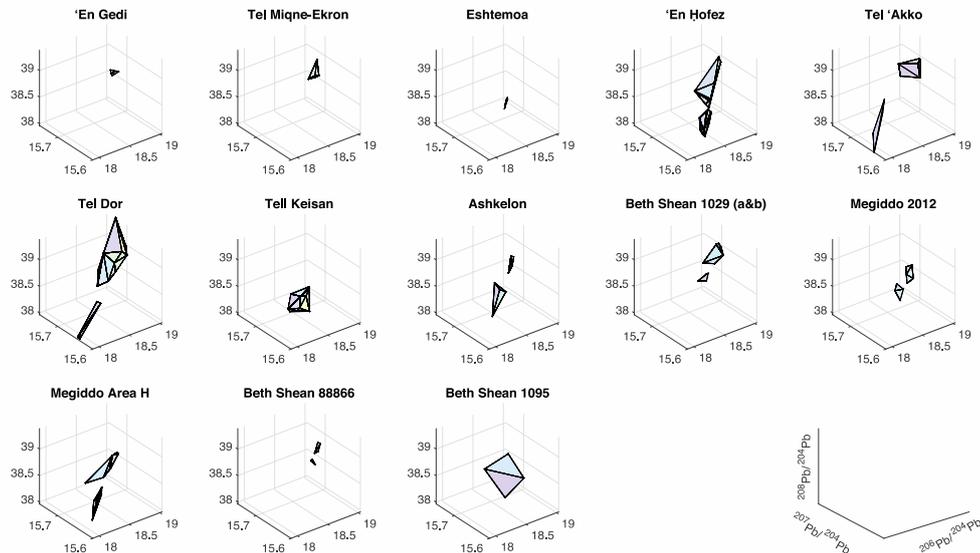
387

##### 388 *4.1. Constructing the convex hulls*

389 Convex hulls were obtained for each hoard by Delaunay triangulation. By maximizing the  
390 smallest angle of all the triangles, Delaunay triangulation makes fewer elongated triangles. In  
391 order to avoid enclosing large unpopulated ('empty') volumes, a rough cluster analysis was

392 run for each hoard defining a maximum of three groups (in practice one or two) in the  
393 conventional space of  $^{204}\text{Pb}$ -normalized ratios. Choosing a different normalization isotope  
394 does not affect the definition of the clusters. Figure 2 shows how different the hulls are from  
395 hoard to hoard.

396



397

398

399 Figure 2. Scaled convex hulls obtained by Delaunay triangulation in the space of  $^{204}\text{Pb}$ -  
400 normalized ratios. The data were first standardized to zero mean and unit variance and cluster  
401 analysis allowing for up to three separate groups to help define tighter hulls.

402

403 A remarkable property of the technique is that, since the hull is convex, all the data  
404 corresponding to intermediate mixtures of different isotopic components plot within the hull  
405 defined by the data corresponding to the extreme mixtures. Let us assume a series of samples  
406 resulting from mixing components A and B, and label  $x_1$ ,  $x_2$ ,  $x_3$  three of these mixtures with  
407 proportions of component B increasing in that order. If samples  $x_1$  and  $x_3$  plot in the convex  
408 hull, so will sample  $x_2$ . A potential risk is that a mixture of components A and B may end up  
409 fortuitously producing a mix similar to an unrelated component C, thereby leading to an  
410 erroneous provenance assignment. Our experience with the available data is that if the risk of  
411 such a fortuitous coincidence in two-dimensional plots exists, it essentially disappears in  
412 three-dimensional space, or at the very least, concerns only isolated hits. We found that 'hot  
413 spots' with multiple hits are robust against such a fortuitous coincidence and that the  
414 robustness may be conveniently illustrated by frequency peaks of model ages.

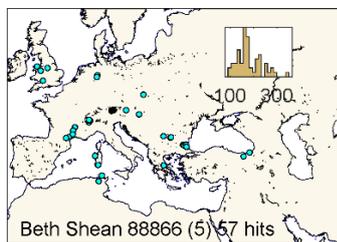
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416

417 *4.2. Permissible silver sources*

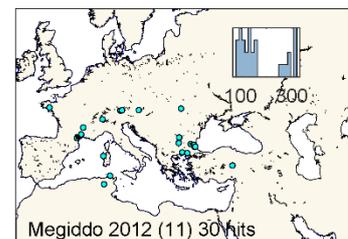
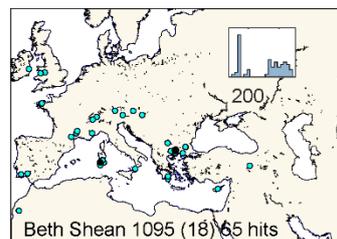
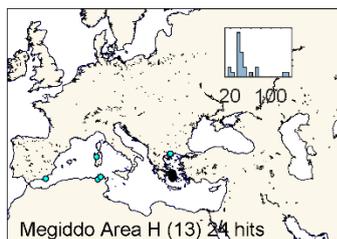
418 Once the hulls were defined, each sample from our ore database, which includes about 7000  
419 samples of galena (Milot et al., in press), was tested for being inside or outside the hulls  
420 defined for each hoard. Although this database borrowed many references from the OXALID  
421 database, only Pb sulphides were retained and artefacts such as slags were carefully  
422 eliminated. A tolerance of 2% was allowed for on the standardized data, which is equivalent  
423 to considering the hull boundary as fuzzy. In-hull ores with isotope compositions falling in the  
424 hull of each hoard are considered ‘hits.’ The results are displayed for each hoard in Fig. 3.  
425 Each hit should not be considered as decisive, but only as a permissible source. Given the  
426 large number of ore samples in the database, a handful of geographically consistent hits may  
427 not be significant (e.g. Eshtemoa). Hits in unexpected localities, such as the modern United  
428 Kingdom or modern Tunisia may be disregarded on two different grounds: a very small  
429 number of hits or lack of archaeological evidence for mining. In contrast, ores that are no-hit  
430 can be excluded with a high degree of confidence.

431

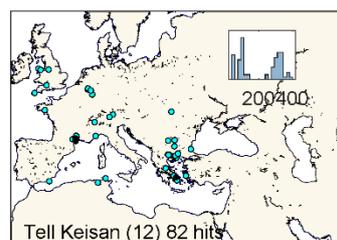
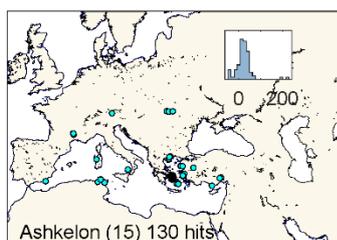


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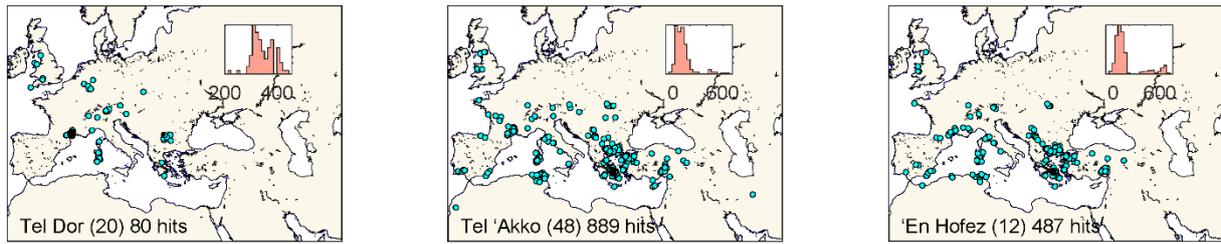
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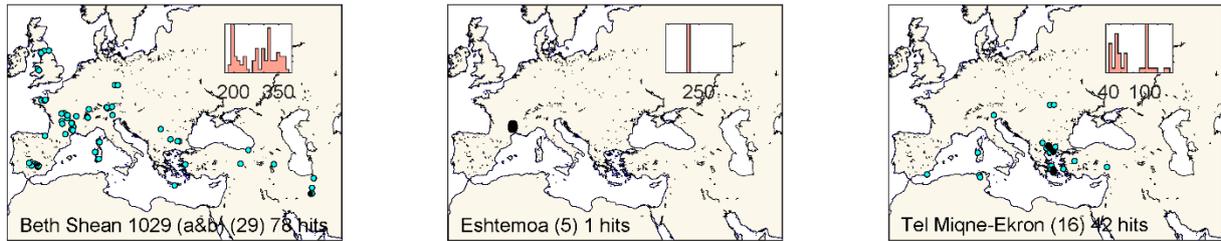
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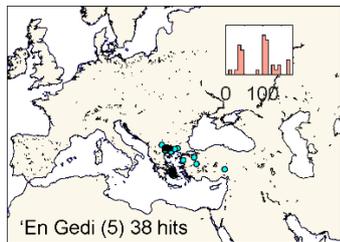
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437



438

439 Figure 3. Map hits for the different hoards (in cyan). Each hit represents an ore falling in the  
 440 sample convex hull of each hoard. The Pb isotope compositions of ~7000 ores were tested for  
 441 inclusion in the convex hull of each hoard. Top panel: Bronze Age (yellow). Middle five  
 442 panels: Iron Age I (blue). Bottom seven panels: Iron Age II (red). The black fields ('hot  
 443 spots') include areas making up more than 10% of the hits (an equivalent of bi-dimensional  
 444 histogram peaks). Upper right-hand corner insets are Pb model age histograms (Ma).

445

446 The most common hot spots are from Lavrion, Thrace, Macedonia, Sardinia, and the  
 447 Cévennes (Southern Gaul) (Table 2). Fewer hits are found for some hoards in northern  
 448 Sardinia, Illyria, the Betics, the Ossa-Morena Zone (southern Iberia), and Taurus. Only one hit  
 449 was found for Eshtemoa, which we considered insufficient for source assignment.

450

451 Table 2. Approximate dates of deposition of the *Hacksilber* hoards analysed for Pb isotopes,  
 452 number of hits, and probable origin of the metal.

Hoard	Period	Years (BCE)	Ref.	Hits	Probable silver source(s)
Beth Shean 88866	Late Bronze Age III	1200-1150	1	24	Unknown

Megiddo Area H	Iron Age I	1070	2	56	Lavrion
Beth Shean 1095	Iron Age I	1150-950	3	57	Thrace, Sardinia
	Iron Age I	1050-950	4	31	Cevennes
	Iron Age I	1050-950	6	78	Lavrion
Tell Keisan	Iron Age I	1050-950	7	86	Lavrion, Cevennes
Tel Dor	Iron Age IIA	2 <sup>nd</sup> half 10 <sup>th</sup> century	8	786	Cevennes
Tel 'Akko	Iron Age IIA	10 <sup>th</sup> to 9 <sup>th</sup> centuries	9	422	Lavrion
Beth Shean 1029a and b	Iron Age IIA	950-800	3	134	Sierra Morena, Eastern Persia
'En Hofez	Iron Age IIA	9 <sup>th</sup> century	9	78	Attica
Eshtemoa	Iron Age IIB	8 <sup>th</sup> century	10	1	Unknown
Tel Miqne-Ekron	Iron Age IIC	Late 7 <sup>th</sup> early 6 <sup>th</sup> century	11	35	Lavrion, Thrace
'En Gedi	Iron Age IIC	Late 7 <sup>th</sup> early 6 <sup>th</sup> century	12	33	Lavrion, Macedonia

453 References: 1 – Thompson, 2009; 2 – Arie, 2013; 3 – Rowe, 1940; 4 – Paice, 2004, Hall, 2016; 5 – Balmuth,  
454 2001; 6 – Nodet, 1980; 7 – Stern, 1998; 2001; 8 - Thompson and Skaggs, 2013; 9 – Alexandre, 1997; 2013; 10 –  
455 Yeivin, 1990; Kletter and Brand, 1998; 11 - Golani and Sass, 1998; Gitin and Golani, 2001; 12 - Kletter and De  
456 Groot, 2007.

457

## 458 5. Discussion

459 Eshel et al. (2021) argue that the Pb isotope data of the Levant can be accounted for by mixing  
460 different end-members and we have tested this model here. We normalized the data to <sup>206</sup>Pb  
461 (<sup>204</sup>Pb/<sup>206</sup>Pb, <sup>207</sup>Pb/<sup>206</sup>Pb, and <sup>208</sup>Pb/<sup>206</sup>Pb) to minimize error correlations and then ran a  
462 principal component analysis both globally and hoard by hoard. Table 3 shows that, with the  
463 exception of Tel Miqne-Ekron, the third principal component accounts for only a negligible  
464 fraction of the variance in each hoard. Two principal components (i.e., three end-members,  
465 but often only two) therefore adequately account for the observed isotopic variability, which  
466 in general is consistent with the number of modes in the histograms of Fig. 3, and agrees with  
467 Eshel et al.'s (2021) conclusions.

468

469 A concern raised by Eshel et al. (2021) is that Pb isotopes in *Hacksilber* may have been  
470 drastically altered by copper-based debasement. A puzzle in this context is the contrast  
471 between the well-defined mixing arrays observed by these authors for some hoards (Tell  
472 Keisan, Megiddo Area H) in Pb isotope diagrams and the lack of mixing hyperbolae observed

473 in the  $^{206}\text{Pb}/^{204}\text{Pb}$  vs Cu diagram (Eshel et al., 2021, Fig. 8). The key to solving this puzzle is  
 474 the limited solubility of Pb in Cu (a few hundred ppm, Vaajamo et al., 2013). In contrast, Pb  
 475 solubility in Ag is substantial (up to a few percent, Karakaya and Thompson, 1987). It  
 476 therefore takes up to several tens of percent of Cu addition to silver to alter the original Pb  
 477 isotope composition. This is the case for the Tell Keisan and Megiddo Area H hoards. The  
 478 mixing lines observed by Eshel et al. (2021) are therefore better interpreted as a mixture of  
 479 silver components than as an effect of debasement by copper addition. The range of  
 480  $^{206}\text{Pb}/^{204}\text{Pb}$  observed at nearly constant Cu concentration by Eshel et al. (2021, Fig. 8) for  
 481 Beth Shean 1029a and b and 1095 and for Ashkelon confirms the lack of correlation between  
 482 the two variables and cautions against overemphasizing the effect of debasement.

483  
 484 Table 3. Results of principal component analysis in the  $^{204}\text{Pb}/^{206}\text{Pb}$ - $^{207}\text{Pb}/^{206}\text{Pb}$ - $^{208}\text{Pb}/^{206}\text{Pb}$   
 485 space for each hoard. PC1, PC2, and PC3 represent the percentage of variance accounted for  
 486 by the corresponding component. One, two, and three significant percentages correspond to  
 487 the presence of 2, 3, and 4 end-members, respectively.

488

<b>Hoard</b>	<b>PC1</b>	<b>PC2</b>	<b>PC3</b>	<b>N° of end-members</b>
Beth Shean 88866	98.1	1.9	0.0	2-3
Megiddo Area H	99.8	0.1	0.1	2
Beth Shean 1095	77.8	21.4	0.8	3
Megiddo 2012	95.5	4.5	0.0	2-3
Ashkelon	99.3	0.7	0.0	2
Tell Keisan	96.0	4.0	0.1	2-3
Tel Dor	99.2	0.8	0.0	2
Tel 'Akko	98.8	1.2	0.0	2
'En Hofez	99.7	0.2	0.1	2
Beth Shean 1029a and b	99.4	0.5	0.1	2
Eshtemoa	97.9	2.1	0.0	2-3
Tel Miqne-Ekron	85.4	10.8	3.8	4
'En Gedi	98.5	1.5	0.0	2-3

489

490

491 We took advantage of Eshel et al.'s (2021) mixing model to calculate the hits for each of the  
 492 convex hulls displayed in Fig. 2, with the expectation that potential end-members would be  
 493 more frequent in the ore database if they could be safely considered as end-members.

494 Evidence obtained from these convex hull analyses is extremely rich and found to support or  
495 falsify previous theories as follows:

496

- 497 • The prevalence of Lavrion, Macedonia, Thrace, Sardinia, and southern Gaul (the  
498 Cévennes) as silver sources is particularly strong. Communication between these areas and  
499 the Levant, whether peacefully by trade or by way of war, never really stopped during the  
500 Late Bronze Age through the Iron Age IIC, and/or *Hacksilber* was recycled from earlier  
501 times.
- 502 • The prevalence of hits from southern Gaul is particularly interesting, as these mines have  
503 been known to be active since Roman times (Baron *et al.* 2005; Elbaz-Poulichet *et al.*,  
504 2017). The present study, however, indicates mining activity in the area centuries prior. We  
505 posit that this activity would conform to a broader pattern of silver exploitation and sale by  
506 dominant local tribes across Thrace and Iberia.
- 507 • The case of Sardinia is only strong for Beth Shean 1095. Iron Age Nuragic settlements are  
508 known from Sardinia and Corsica (Balmuth, 1992), but evidence of contemporaneous  
509 mining is missing. Taurus provided a few hits (Tel 'Akko, 'En Hofez), but the small  
510 number of ore samples does not make this area an incontrovertible source of silver.  
511 Modern Iran and Cyprus, with few hits and inadequate geology, are unlikely to have been  
512 significant silver providers.
- 513 • Evidence of exploitation of silver ore sources in Iberia is surprisingly scant, with one  
514 exception being the Sierra Morena (Beth Shean 1029a and b). Hits in the Betics exist but  
515 are in general second to more productive areas in the Aegean domain. Possible hits near  
516 Huelva and in southern Portugal are uncommon, limited to Meggido Area H and Tel Dor.  
517 This area may be underrepresented because silver from southwest Iberia was mined from  
518 the mineral jarosite in the Lower Guadalquivir (Tartessos) to which extraneous Pb needed  
519 to be added for cupellation rather than from Pb-rich galena (Anguilano *et al.* 2010), which  
520 itself was obtained from the distant Betics and Ossa Morena Zone. This may be why the  
521 latter district is found only in the Tel 'Akko and 'En Hofez hoards.
- 522 • The assignment of silver to other localities is more speculative, either because the number  
523 of hits is too small or because little evidence is known from archaeological and textual  
524 contexts. This is the case of the Eifel, Germany, the Palaeozoic basement of the southern  
525 Massif Central of France (the Cévennes), the Alps, and the Carpathians. Hits in Crete,

526 Peloponnese, Tunisia, and even the British Isles may at this point be considered  
527 coincidental because they are unsupported by archaeological evidence.

528 One possible conclusion is that exchanges between the southern Levant and the Aegean world  
529 never entirely came to a full stop during the Late Bronze and Iron Ages. What supported these  
530 exchanges is not always clear; war, as attested to by the violent demise of large towns, and  
531 trade, the only possible way to attract silver to the Levant, a territory where silver mines are  
532 absent. In the context of the overall fineness of *Hacksilber* (Eshel et al., 2018; 2021),  
533 occasional silver famines may be the reason for unusually high Cu contents in Beth Shean  
534 88866 and Megiddo Area H (Eshel *et al.*, 2021) rather than deliberate debasement but other  
535 explanations are possible.

536  
537 Alternatively, the prevalence of mixing in some hoards, the low percentage of silver, and the  
538 relatively few hoards from over half a millennium suggest that bullion was hoarded over long  
539 periods of time. The scatter of isotopic values within some hoards can be taken as evidence of  
540 such long-term hoarding, while the scatter in the plot of  $^{206}\text{Pb}/^{204}\text{Pb}$  vs Cu in wt.% (Eshel et  
541 al., 2021, Fig. 8) shows the lack of coherent mixing hyperbolae for hoards such as Tell  
542 Keisan, Megiddo Area H, and Beth Shean 1095, and requires that the analysed samples were  
543 produced from silver with widely different Pb contents and not from a single source. This  
544 pattern may be usefully contrasted with early minting of silver coinage in the Late Archaic  
545 period which overwhelmingly came from single ore sources refined to a very high percentage  
546 of silver (Stos Gale and Davis, 2020; Birch et al., 2020). If mixing with recycling is the case,  
547 we would in theory expect to see a linear array which tends to be parallel to the Pb evolution  
548 curve (lines of constant  $\mu$  and  $\kappa$ ) (Albarède et al. 2020). Good examples of mixing are those of  
549 Megiddo Area H and the Tell Keisan hoards (Eshel et al., 2021). However, mixing is by  
550 definition between different end-members (A and B) which should manifest in ore 'hits' on the  
551 end-members A and B, but not on the mixtures between A and B which have no natural  
552 match. If the mixture is between different 'pure' issues (without remelting), it would show up,  
553 not as alignments, but as separate groups of points corresponding to each issue. Although the  
554 hoards seem to show both types of behavior, there are not enough samples at present to  
555 conclusively separate the groups. Hence, until enough data points have become available to  
556 conclusively demonstrate via statistical means long-term hoarding and mixing, trade  
557 continuity is not contradicted by the present data and overall remains a valid working  
558 hypothesis.

559

560 Exchanges between the eastern and western Mediterranean are more problematic. They may  
561 have been less active during the turmoil of the end of the Late Bronze Age but clearly were  
562 revived in the Early Iron Age I.

## 563 **6. Conclusions**

564 This study has demonstrated the applicability of a data-driven approach to lead isotope  
565 analysis. Principal component analysis of the most precise Pb isotope data (this work  
566 combined with Eshel et al., 2019; 2021) confirms that isotope compositions of each element  
567 in each hoard can be accounted for by a small number of end-members (2-3). The new  
568 ‘convex hull’ approach applied to the ore database of Pb isotopes identifies more previously  
569 unrecorded potential source end-members. The concepts of ‘hits’ and ‘hot spots’ turned out to  
570 be critical in assigning a provenance to individual isotopic data and data groups.

571

572 The prevalence of Aegean sources including Lavrion, Macedonia, Thrace, Sardinia,  
573 and southern Gaul as long-lived major sources of silver shows that exchanges between the  
574 southern Levant and the Aegean continued at least intermittently from the end of the Late  
575 Bronze Age through the Iron Age IIC. A caveat is that long-term hoarding suggested by  
576 isotopically heterogeneous hoards and use of low-purity silver may have blurred evidence of  
577 trade disruption. Southern Gaul is proposed as an Iron Age silver source. Occasional  
578 exchanges with Sardinia and southern Iberia in the Iron Age are confirmed. The Aegean  
579 world, including Thracio-Macedonian sources, dominated silver supply presumably because of  
580 its proximity, but exchanges between the eastern and western Mediterranean did not disappear  
581 from the isotopic record.

582

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