# Chemical and Lead Isotope Composition of Metal Scrap from Giv'ati Parking Lot, Jerusalem

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Selected metal artifacts and slag from the small-scale Umayyad-period metallurgical workshop uncovered in Giv'ati Parking Lot (see Tchekhanovets, this volume: Figs. 8, 16, 17) were subjected to chemical and Lead Isotope Analysis (LIA), a method commonly used for provenancing metal objects (see Pernicka 2014, for discussion of the method). The artefacts include small fragments from cross-adorned chains (G-2 and G-4), calyx-shaped hooked hangers (G-3, G-5, G-6, G-7), crucible slag (G-1 and G-9) and lead fragments (G-8 and G-10; Table 1). According to Tchekhanovets (this volume) these belonged to swinging censers used for incense burning or lighting *polycandela*. It was hypothesized that the items were scavenged from an abandoned Byzantine church and intended for recycling.

**Table 1. List of Metallurgical Finds from the Excavation[i]**

| No. | Locus | Basket | Object | Material | Context | Sample No. |
|---|---|---|---|---|---|---|
| 1 | 920 | 10371 | Crucible fragment | Slag | Ash accumulation | |
| 2 | 920 | 10262 | Crucible fragment | Slag | Ash accumulation | G-9 |
| 3 | 910 | 10121 | Crucible fragment | Slag | Clay accumulation | G-1 |
| 4 | 920 | 10372 | Slag | Bronze | Ash accumulation | |
| 5 | 924 | 10420 | Slag | Lead | Collapsed debris | |
| 6 | 924 | 10423/1 | Unidentified fragment | Lead | Floor makeup | G-8<br>G-10 |
| 7 | 920 | 10376 | Calyx-shaped hooked hangers | Copper-based | Ash accumulation | G-7 |
| 8 | 920 | 10373 | Calyx-shaped hooked hangers | Copper-based | Ash accumulation | G-3 |
| 9 | 920 | 10375/1 | Calyx-shaped hooked hangers | Copper-based | Ash accumulation | G-5<br>G-6 |
| 10 | 920 | 10379 | Calyx-shaped hooked hangers | Copper-based | Ash accumulation | |
| 11 | 921 | 10247 | Cross | Copper-based | Ash accumulation | G-2 |
| 12 | 921 | 10248 | Cross | Copper-based | Ash accumulation | G-4 |
| 13 | 921 | 10249 | Cross | Copper-based | Ash accumulation | |
| 14 | 921 | 10251 | Small scrap | Copper-based with lead | Ash accumulation | |

[i] Items subjected to chemical and isotopic analyses are indicated by sample numbers.

**Table 2. Chemical Composition (wt%) of Copper-Based Objects**

| Sample No. | Iron (Fe) | Cobalt (Co) | Nickel (Ni) | Copper (Cu) | Zinc (Zn) | Arsenic (As) | Silver (Ag) | Tin (Sn) | Antimony (Sb) | Lead (Pb) | Bismuth (Bi) | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| G-2 | 0.007 | 0.004 | 0.07 | 65.9 | 0.0 | 0.00 | 0.001 | 0.053 | 0.001 | 18.3 | 0.001 | 84 |
| G-3 | 0.035 | 0.002 | 0.04 | 73.9 | 0.0 | 0.00 | 0.003 | 0.015 | 0.000 | 12.9 | 0.001 | 87 |
| G-4 | 0.088 | 0.008 | 0.08 | 85.0 | 1.1 | 0.00 | 0.002 | 0.007 | 0.000 | 13.0 | 0.001 | 99 |
| G-5 | 0.015 | 0.007 | 0.10 | 84.6 | 0.1 | 0.00 | 0.002 | 0.005 | 0.000 | 20.4 | 0.000 | 105 |
| G-6 | 0.019 | 0.006 | 0.02 | 77.6 | 0.0 | 0.01 | 0.001 | 0.000 | 0.000 | 0.04 | 0.000 | 78 |
| G-7 | 0.188 | 0.006 | 0.08 | 72.9 | 0.1 | 0.00 | 0.003 | 0.061 | 0.000 | 21.1 | 0.002 | 94 |

Samples were removed by drilling and dissolved using aqua regia. Following dilution, concentrations were determined using a quadrupole Inductively Coupled Plasma–Mass Spectrometer (ICP-MS, Agilent 7500cx). The ICP-MS was calibrated with a series of multi-element standard solutions (Merck; ME VI) and a blank. Drift was corrected by internal standards (750 µg/L Sc, 100 µg/L Re and 50 µg/L Rh). Standard reference samples (US Geological Survey standard reference samples T-201 and T-209) were examined after calibration for accuracy assessment. Precision and accuracy were up to 5%.

Lead (Pb) was separated from the copper-based samples using ion exchange columns (Dowex 1X8-100-200 mesh Ion Exchange Resin; for details of the procedure, see Erel et al. 2006) and its isotopic ratios were measured using a multi-collector ICP-MS (Neptune plus MC-ICP-MS). The MC-ICP-MS was calibrated by running NIST standard (SRM981) before, during and after the analysis of the samples. The SRM981 yielded a 6/4 = 17.178±0.57, 7/4 = 15.460±0.04, 8/4 = 36.882±0.49. Thallium was added to all samples and standards, and the 203Tl/205Tl ratio was used for correcting mass bias.

The results (Table 2) show that the small crosses and the calyx-shaped items are very similar in chemical composition, containing alloyed copper, i.e., leaded bronze, with 13–21 wt% Pb in almost all cases. One exception, Sample G-6, contained only a trace of Pb (0.04 wt%). Other chemical elements, including tin, mostly occurred in trace amounts, except in one of the crosses (Sample G-4) that had 1.1 wt% of zinc. The relatively low sum of elements indicated that tin was not dissolved and is therefore underestimated in the samples. This was confirmed by surface analysis of the artefacts using XRF.

Results of the lead isotope analysis (Table 3) show a similar isotopic composition for the majority of the samples ($^{206}Pb/^{204}Pb$ = 18.568–18.576; $^{207}Pb/^{204}Pb$ = 15.644–15.653; $^{208}Pb/^{204}Pb$ = 38.505–38.537). Sample G-6 produced a different isotopic signature, with values well below these ranges, perhaps due to a measurement error resulting from its very low Pb content.

Assuming that the fragments of copper-based objects belonged to more than one liturgical vessel, their homogeneous lead isotopic composition indicates that these were part of objects which were mass-produced during the Byzantine period, using lead from a single source, possibly commissioned by a single church. The lead fragments, also with similar isotopic composition, appear to have belonged to the same collection, although it is unclear

**Table 3. Lead Isotope Ratios of Metallurgical**

| Sample No. | 206Pb/204Pb | 207Pb/204Pb | 208Pb/204Pb |
|---|---|---|---|
| G-2 | 18.573 | 15.648 | 38.535 |
| G-3 | 18.575 | 15.653 | 38.536 |
| G-4 | 18.574 | 15.647 | 38.517 |
| G-5 | 18.572 | 15.653 | 38.537 |
| G-6 | 18.221 | 15.631 | 38.144 |
| G-7 | 18.568 | 15.647 | 38.511 |
| G-8 | 18.576 | 15.647 | 38.505 |
| G-9 | 18.573 | 15.644 | 38.531 |

to which specific type of artefact they belonged. The slag within the crucible, again, with the same Pb isotopic composition, suggests that similar artefacts were already remelted in this Umayyad-period workshop. The activity in the workshop may be thus reconstructed as remelting of older Byzantine-period cultic paraphernalia to form new objects.

Due to the deliberate addition of Pb to the alloys, the isotopic composition of the samples reflects the source of the added lead rather than that of the copper. In addition, the Byzantine date of the artefacts, based on their typology, naturally reflects sources of lead used during the Byzantine rather than the Early Islamic period. Lead ores with the closest isotopic values to those recorded here are known from north Yorkshire, Britain (Rohl 1996) and the Cevennes Mountain Range of southern France (Orgeval et al. 2000). An alternative possibility, that the lead isotopic values reflect a mixture of sources (i.e., Iberia and Anatolia), cannot be ruled out due to their considerable homogeneity. However, this is less likely, as lead from these distant sources would have to have been mixed locally prior to their use to create such values.

## References

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