Chemical and Isotopic Study of Lead-Based Objects from a Late Roman Tomb on Ṣallaḥ ed-Din Street, Jerusalem

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During the excavations of an ancient burial site on Ṣallaḥ ed-Din Street, Jerusalem, several lead-based artifacts were discovered together in T2200, dated to the Late Roman period (see Avni and Adawi, this volume). No similar objects of this type are known from this period (see Winter, this volume). Chemical and isotopic analyses were carried out on tiny pieces that had crumbled off the better-preserved artifacts or accompanied them. The aim of this study was to elucidate the chemical composition of the objects and to determine their provenance.

The chemical composition of six samples was defined under a Scanning Electron Microscope equipped with an Energy Dispersive Spectrometer (SEM-EDS). The provenance study was carried out using lead-isotope ratio measurements. From four of the samples, 10 mg of pure drillings were dissolved in 10% nitric acid. This solution, diluted by double-distilled water, was analyzed for lead isotope composition with a Multiple Collector Inductively Coupled Plasma Mass Spectrometer (MC-ICP-MS, NU Plasma).

Results

The chemical composition of the objects, each determined from an average of five local analyses (Table 1), reveals that Sample No. 5 was made of pure lead, whereas the other samples contained tin in various concentrations (2.5–77%). Sample No. 3, which contained 77% tin, is actually tin-based with a lead addition. Contrary to the other samples, Sample No. 6 contained 1% copper as well as lead and tin. As will be shown below, this object differs from the other objects also in its lead isotope ratios.

The results of the lead-isotope ratio measurements are shown in Table 2. In Fig. 1:a, the ratios of the objects from Ṣallaḥ ed-Din Street are plotted together with lead isotope ratios of lead ores from other Mediterranean countries: Turkey (Gale 1980; Pernicka et al. 1984; Pernicka and Wagner 1985; Seeliger et al. 1985; Vavelidis et al. 1985; Wagner et al. 1985; Dayton and Dayton 1986; Wagner et al. 1986a; Yener et al. 1991; Hirao, Enomoto and Tachikawa 1995; Sayre et al. 2001), Cyprus (Spooner and Gale 1982; Hamelin et al. 1988; Gale et al. 1997), Greece (Barnes et al. 1974; Chamberlain and Gale 1980; Gale 1980; Gale and Stos-Gale 1981; Gale, Stos-Gale and Davis 1984; Vavelidis et al. 1985; Wagner et al. 1986b; Chalkias et al. 1988; Stos-Gale, Gale and Annetts 1996), Spain (Graeser and Friedrich 1970; Dayton and Dayton 1986; Tornos and Arias 1993; Velasco et al. 1993, 1996; Arribas and Tosdal 1994; Stos-Gale et al. 1995; Tornos et al. 1996; Canals and Cardellach 1997; Lescuyer et al. 1998; Marcoux 1998; Pomiés

Table 1. SEM-EDS Analyses of the Objects from T2200 (B11038), in Wt. %

Sample No.	Pb	Sn	Cu
1	97.5	2.5	n.d.
2	52.3	47.7	n.d.
3	23.0	77.0	n.d.
4	82.6	17.4	n.d.
5	100.0	n.d.	n.d.
6	91.0	8.0	1.0

n.d. = not detected

Table 2. Lead-Isotope Ratios of the Objects from T2200 (B11038)

Sample No.	$^{204/206}$Pb	2σ	$^{208/206}$Pb	2σ	$^{207/206}$Pb	2σ
1	0.053957	0.000010	2.08309	0.00005	0.84415	0.00003
2	0.053952	0.000004	2.08331	0.00006	0.84418	0.00002
5	0.053947	0.000002	2.08319	0.00002	0.84388	0.00001
6	0.053606	0.000006	2.07533	0.00007	0.83926	0.00002

et al. 1998; Trincherini et al. 2001; Santos Zalduegui et al. 2004; Tornos and Chiaradia 2004), Italy (Stos-Gale et al. 1995; Dayton and Dayton 1986) and France (Brevart, Dupré and Allegre 1982; Le Guen, Orgeval and Lancelot 1991; Sinclair, Macquar and Rouvier 1993; Orgeval et al. 2000; Baron et al. 2006; 2009), as well as Britain (Rohl 1996).

Ratios of ores from Laurion (Barnes et al. 1974; Chalkias et al. 1988; Stos-Gale et al. 1995), Sardinia (Swainbank et al. 1982; Boni and Koeppel 1985; Dayton and Dayton 1986; Ludwig et al. 1989; Stos-Gale et al. 1995; Valera, Valera and Rivoldini 2005), Tuscany (Stos-Gale et al. 1995), Germany (Large, Schaeffer and Höhndorf 1983; Bielicki and Tischendorf 1990; Schneider 1998; Krahn and Baumann 1996; Durali-Muller 2005; Durali-Muller et al. 2007; Bode 2008; Bode, Hauptmann and Mezger 2009) and Egypt (Stos-Gale and Gale 1981; Hassan and Hassan 1981) were out of range and do not match the lead objects from Jerusalem; therefore, they are not shown in Fig. 1.

Ratios for Sample No. 6 are located in the lower range in Fig. 1, while those for the other objects are in the high range (marked by a circle). Therefore, these two groups may have had different ore sources. In Fig. 1:a, the $^{208/206}$Pb ratio of Sample No. 6 matches the northern Turkish ores, whereas in Fig. 1:b, the $^{204/206}$ Pb ratio for this sample is most consistent with those of Greek ores, but is also close to those of northern Turkey. Northern Turkey can thus be considered the most probable source.

For the second group, comprising Samples 1, 2 and 5, $^{208/206}$ Pb ratios match the ores from Spain, France and Britain (Fig. 1:a), while the $^{204/206}$ Pb ratios (Fig. 1:b) match ores from Turkey (one point for Turkish ore completely overlaps with Samples 1 and 2) and Britain. It seems that, the source of the ore for this group could have been the West Cumbrian and Durham mining districts located in central Britain (Rohl 1996). As there was very little trade between Britain and the Levant in the Late Roman period, no typological parallels for the lead-based objects from Jerusalem are known.

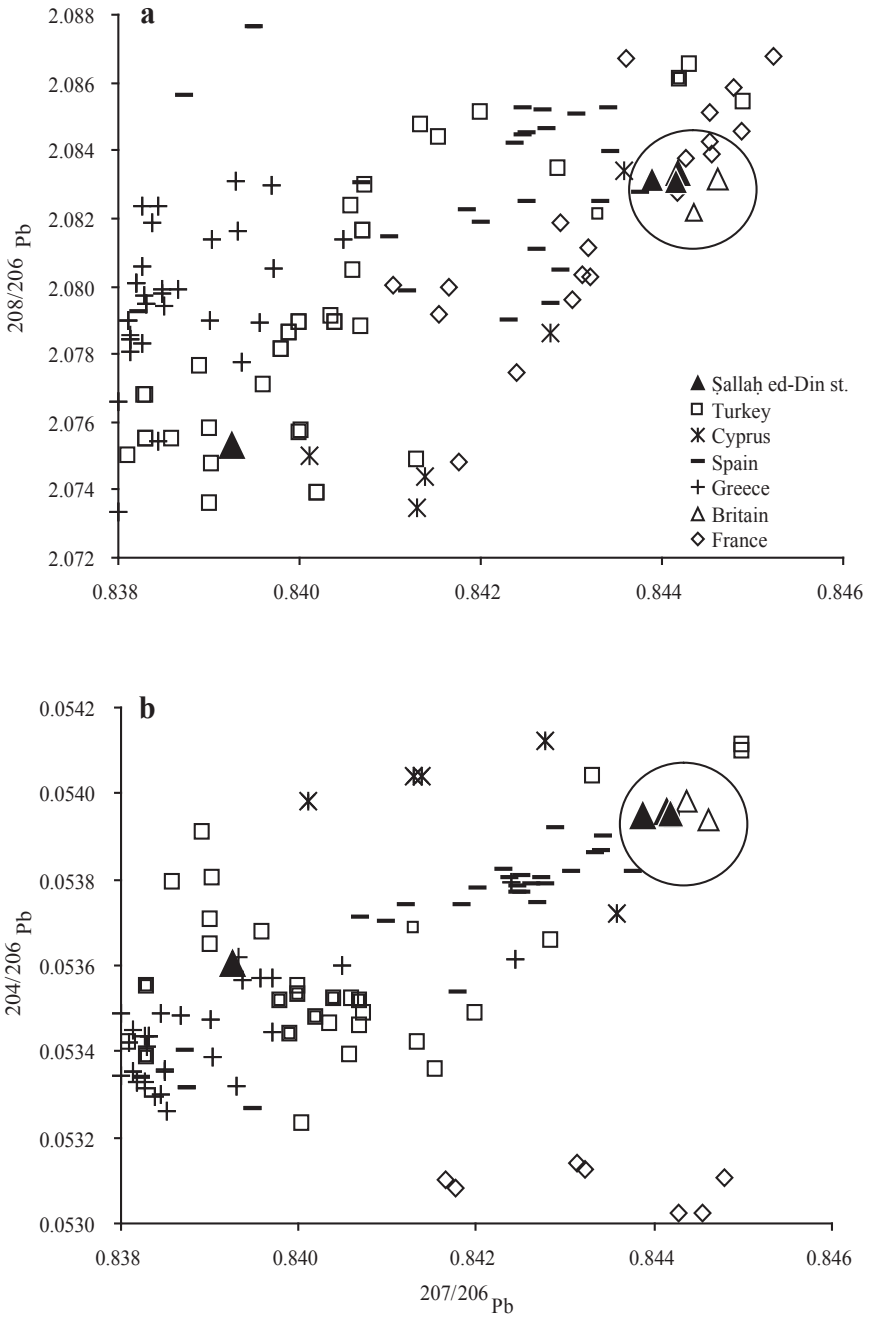

Fig. 1. Lead isotope ratios of the lead-based objects from Ṣallaḥ ed-Din St. compared with those of lead ores from the Mediterranean region and Britain. The circles indicate the matching of lead isotope ratios of Sample Nos. 1, 2 and 5 from Ṣallaḥ ed-Din St. with those of ores from central Britain. Errors (2σ) of our measurements are within the symbols.

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