Characterisation of Roman copper alloy artefacts and soil from Rakafot 54 (Beer Sheva, Israel)

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Rakafot 54

Rakafot 54 is a Roman archaeological site near Beer Sheva, Israel, which was probably established during the first century CE and demolished during the Bar Kochba revolt against Rome (132-135/6 CE). The site is placed near the border between Judea and Nabataea, close to a Roman road, and includes a watchtower, hearths, garbage pits, and an underground system. Numerous metallic objects were found during the excavations, including copper alloy coins minted across the empire throughout the first and second century CE.

Goals

Identification of main alloy components of the copper alloy artefacts

Mineralogical assessment of soil directly related to the artefacts

Characterisation of corrosion compounds found on the artefacts

Methodology

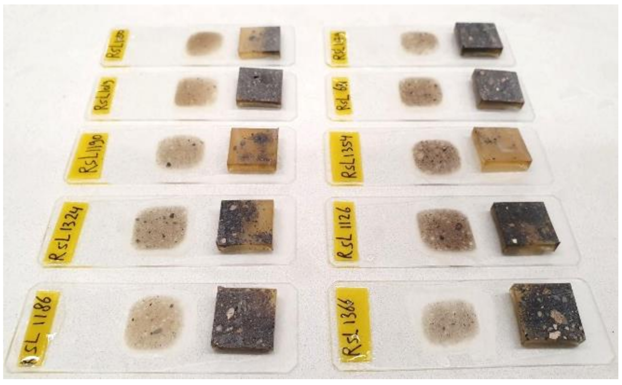
Portable XRF

Petrography

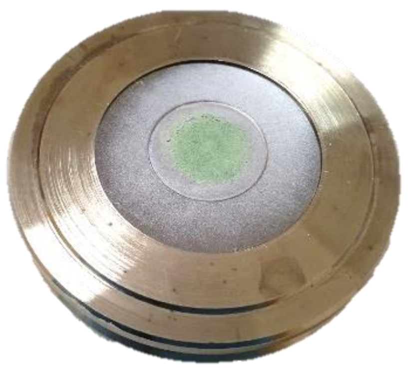
X-ray Diffraction

Samples

Heterogeneous artefact surface



Soil thin sections



Homogenised corrosion

Discussion

Comparisons were made to validate the results of the individual techniques. The atacamite in the diffractograms can be correlated with the Cl in the pXRF results, although it is unclear whether this is related to the hydroxy-chloride phases of the corrosion, or to Cl-based minerals in the soil. The paratacamite could be confirmed with small amounts of Zn in the alloy. A correlation could be observed between S and Pb in the pXRF data, and lead sulphate in the diffractograms. The presence of Sn is clear in the elemental analysis, but no Sn-based corrosion products were recognised in the diffractograms; these can be difficult to identify with XRD. The Si in the pXRF data could be related to the quartz observed in the diffractograms and the thin sections. The K and Si combination could be explained as K-based feldspars with the diffractograms, Si and Al could be identified together as feldspars and clay minerals. The micromorphological study of the soil corresponds with the results from the pXRF and XRD analyses, identifying it as loess, with micro-environments resulting from anthropogenic activities and post-depositional processes.

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Results

X-ray Fluorescence

Main alloy components (wt%)

Sample	Cu	Pb	Sn	Zn	Ag
B6058a	46.8	5.1	2.7	0.04	< 0.03
B6058b	45.1	5.7	1.0	< 0.03	< 0.03
B6081a	44.6	13.0	3.4	< 0.05	< 0.04
B6081b	47.5	5.6	0.45	< 0.03	< 0.03
B6101a	42.1	6.8	1.5	< 0.04	< 0.03
B6101b	36.0	14.4	4.4	< 0.04	< 0.04
B8103a	43.0	1.1	0.04	< 0.04	< 0.02
B8103b	36.0	3.4	2.1	0.02	< 0.02
B8764a	43.9	3.2	0.34	0.03	< 0.02
B8764b	46.5	3.0	2.6	0.05	< 0.03
B9803a	44.0	5.1	1.3	< 0.03	< 0.02
B9803b	32.1	14	5.0	< 0.04	< 0.04

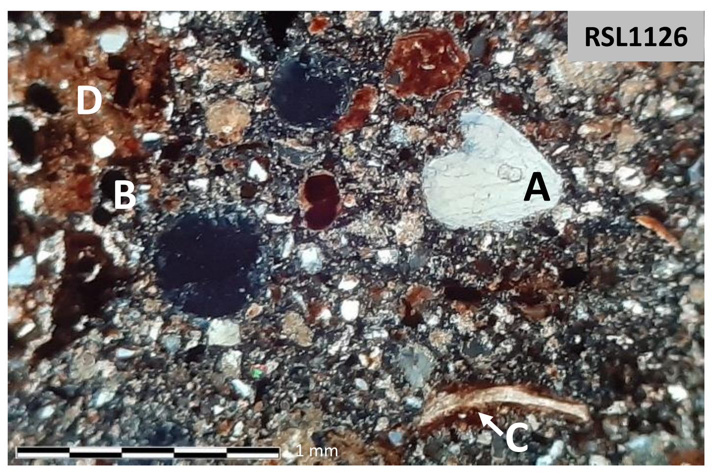
Soil composition (wt%)

Sample	Al	Ca	Cl	K	S	Si
B6058a	2.1	8.7	4.61	0.25	1.12	9.1
B6058b	2.3	4.9	5.09	0.38	1.52	13.1
B6081a	1.4	5.4	5.77	0.11	3.81	4.7
B6081b	0.9	2.9	9.9	0.15	2.18	3.2
B6101a	2.1	6.0	5.46	0.35	2.20	9.1
B6101b	1.0	10.1	3.22	0.20	3.44	9.1
B8103a	1.9	7.4	3.67	0.31	0.55	11.9
B8103b	1.6	8.4	1.27	0.34	1.42	13.4
B8764a	1.9	4.9	8.0	0.32	1.66	7.4
B8764b	1.7	10.6	6.27	0.26	1.33	6.0
B9803a	2.7	10.7	4.33	0.39	1.13	11.5
B9803b	3.2	13.9	2.34	0.70	1.35	12.5

The preliminary pXRF screening indicates that most artefacts are made of copper-lead-tin alloys, with relatively high amounts of lead. The results are largely dependent on the corrosion layers and sediments on the surface. Inconsistencies between obverse (a) and reverse (b) sides possibly due this presence and the positioning of the artefact. Soil components such as calcium, chlorine, silicon, aluminium, potassium, and sulphur can be observed as well.

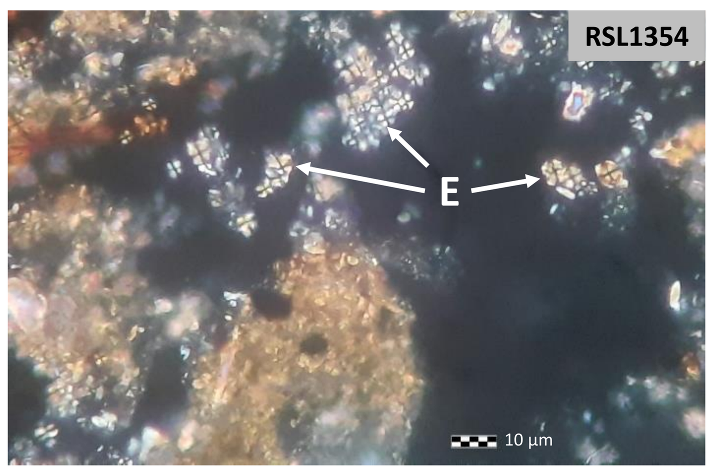
Micromorphology

1



Silty and calcareous matrix with rounded quartz sandy grain (A), charred ash material (B), shell fragment (C), and burnt soil with ferric corrosion products (D).

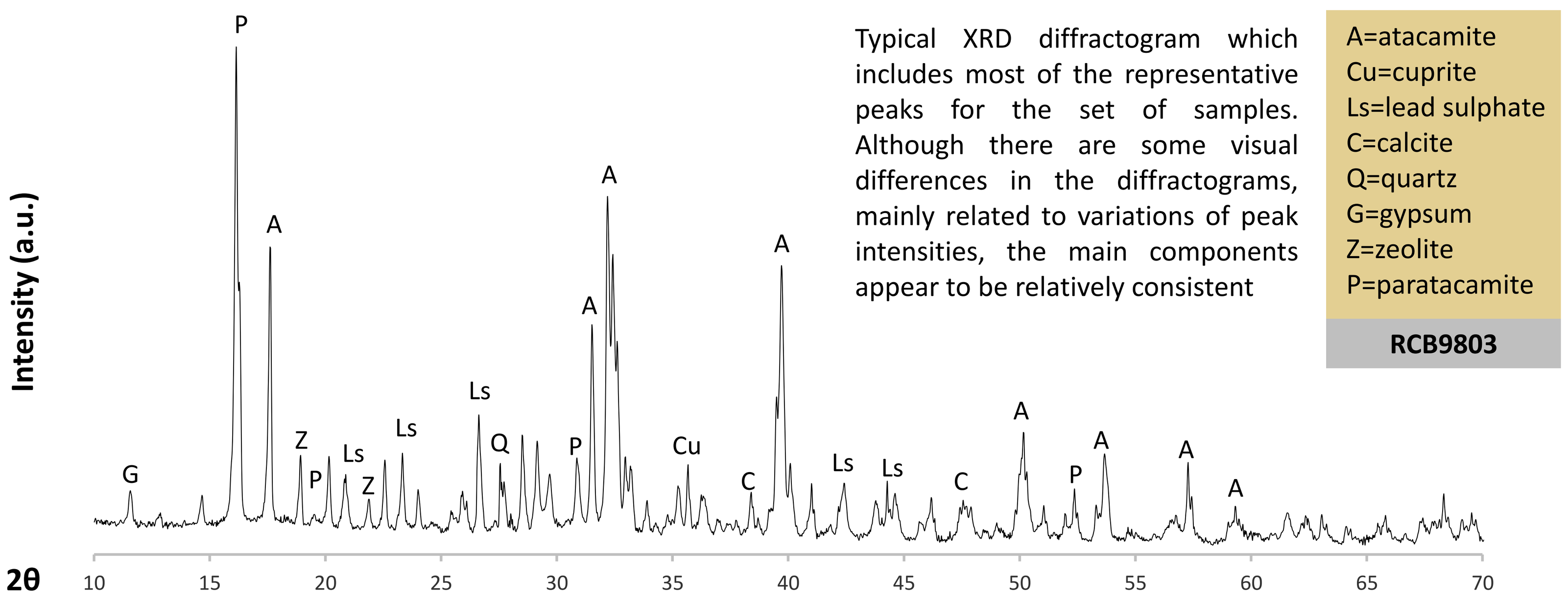
2



Herbivore dung spherulites (E) in ash layer from a hearth.

The silt is well-sorted and contains mainly quartz and other minerals, including hornblende, zircon, mica minerals, feldspars, tourmaline, augite, and more rarely garnet, epidote and rutile. Ore minerals are abundant. The sand fraction includes dense, well-sorted, rounded sand-sized quartz grains, and limestone.

X-ray Diffraction



The primary compound in all samples was identified as atacamite ($Cu_2(OH)_3Cl$), common for copper alloy archaeological objects extracted from salty soils. Clinoatacamite has been detected in two samples, while its presence is unclear in the others. Paratacamite ($Cu_3(Cu,Zn)(OH)_6Cl_2$) and lead sulphate were found in most samples, and cuprite in all except RCB6081 (probably due to inconsistencies in sampling depth). The soil on the surface of the artefacts contains quartz, K- and Na-based feldspars, and clay minerals. Gypsum and its polymorphs were determined in RCB6058, RCB6101, and RCB9803, possibly in other samples.

Conclusions

The main alloy components were identified as copper, lead, and tin. The soil mainly consists of quartz, calcite, feldspars, clay minerals, and gypsum. There is an overwhelming presence of copper hydroxy-chlorides such as atacamite, clinoatacamite, and paratacamite, related to the Cl in the soil, while lead sulphates were also identified. Although there are local differences in the soil components of the various samples, they do not appear to have a clear effect on the corrosion. Future research will focus more strongly on the relationship between alloy components and microstructure, soil conditions, and corrosion products.

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