

Authenticity Examination of Two Iron Age Ostraca from the Moussaieff Collection*

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INTRODUCTION

Two ostraca belonging to a private collector and bearing palaeo-Hebrew inscriptions, have been published in recent years and discussed by several scholars, suggesting that they are authentic and should be incorporated in the assemblage of Hebrew inscriptions of the Iron Age II. After the first publications (Bordreuil, Israel and Pardee 1996; 1998; Shanks 1997; 2003), some scholars challenged their authenticity on the basis of several epigraphic, palaeographic and syntax oddities (Eph'al and Naveh 1998; Rollston 2003: 145–147). The first ostrakon (henceforth: ostrakon 1) deals with an order by King Ashiyahu (presumably King Josiah) to give a man named Zecharyahu three silver shekels for the House of YHWH (fig. 1). The second (henceforth: ostrakon 2) contains a plea of a widow to some official to maintain her ownership over her late husband's property (fig. 2).

The present study focuses on the question of authenticity of these two ostraca after examining them by means of micromorphology, petrography and oxygen ($\delta^{18}\text{O}$) and carbon ($\delta^{13}\text{C}$) isotopic compositions of the secondary materials (patina) on their surface. The term 'patina' refers to the natural coating that is created over the surface due to the absorption or loss of various elements (Dorn 1998). It is commonly thought that the process of patination is slow; thus, genuine patina may be used as an indication for the antiquity of an object. A large body of literature has accumulated over the past four decades concerning the processing, weathering

* The ostraca were reportedly purchased by the antiquities collector Mr. S. Moussaieff, who loaned them for inspection to the Israel Antiquities Authority (IAA) and the Israeli police as part of a legal investigation of alleged forgeries. This study was carried out under special commission by Mr. S. Dorfman, Director of the IAA, with the kind help of Mr. A. Ganor, Head of the Antiquities Theft Inspection Unit of the IAA, and Major Jonathan Pagis of the Fraud Unit of the Israel Police. The examinations were conducted in the Laboratory for Comparative Microarchaeology of the Institute of Archaeology, Tel Aviv University, and the Stable Isotope Laboratories of the Geological Survey of Israel. We thank all the above, as well as Dr. A. Bein, Director of the Geological Survey of Israel, for their collaboration. We also thank Prof. A. Matthews for his critical comments of the manuscript. All authors contributed equally to this work.

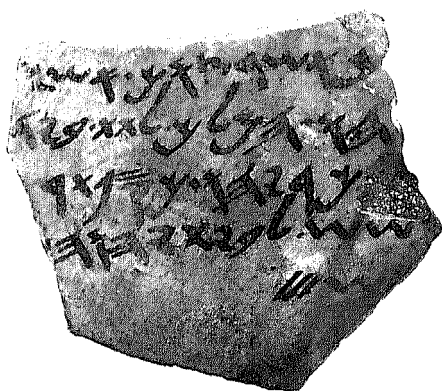


Fig. 1. Ostrakon 1

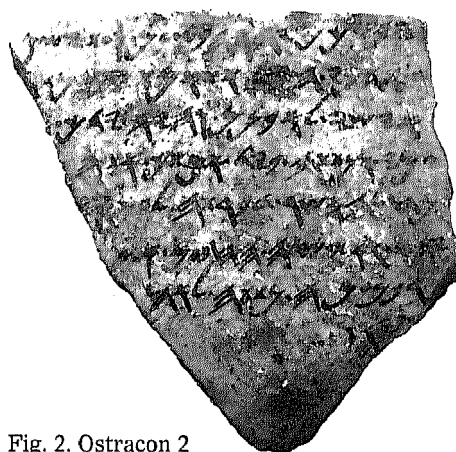


Fig. 2. Ostrakon 2

and dating possibilities of patina. From this data, it is evident that patination by itself is a somewhat unreliable indicator of antiquity, since patina-like coating can be created in the laboratory by various methods. While one can readily accept that genuine patina formed over an inscription is younger than the script, there are several difficulties in evaluating its age. Climatic factors, among them the presence of fluids and the pH, have considerable influence and can accelerate, delay, or completely inhibit patina formation. Moreover, the application of various dating techniques to the patina is dependent upon many factors (Bednarik 1996). Therefore, the presence or absence of patina over an artefact cannot be used *a priori* as an indicator for its authenticity.

In the creation of patina, two factors play a crucial role. The first is the composition of the substrate over which the patina is processed, its capillary and absorbed water content. The second is the nature of the environment, namely, the sediment, pH, temperature and humidity that surround it, as well as the physical conditions (such as erosion and exfoliation). Obviously, an artefact subjected to a subterranean environment would develop different patina types from one subjected to an atmospheric environment. Since the composition of patina is the result of reaction between the base material and the surroundings, it is expected to reflect in its composition the characteristics of the depositional environment. While on exposed items the patina composition is usually the outcome of the autochthonous minerals, a buried artefact is coated by patina that results more from the mineralogy of the surrounding environment.

As for the ostraca, based on their epistolary style and textual content, it is evident that they were supposed to be written (and perhaps also found) in Judaea. The lithology of the Judaeian Hills and their foothills includes a set of Cenomanian-Turonian and Senonian limestone, chalk and dolomite series, typically capped by Terra Rossa or brown rendzina soils. In the Shephelah, mainly Eocene chalk series are exposed, capped by brown and pale rendzina soils (Arkin, Brown and Starinsky

1965; Buchbinder 1969). This would result in significant enrichment of calcite (CaCO_3) in the patina, as compared with the original sherd.

Taking all the above into consideration, the ostraca and the patina types over them were subjected to a set of micromorphologic, petrographic and geochemical examinations in order to examine their authenticity as a factor for assessing the antiquity of the inscription. Special attention has been paid to micromorphologic features, namely, the integrity of the inscribed surface as observed under the microscope, in comparison with the same features in legally excavated and well recorded ostraca from Arad, the City of David, Lachish, Tel Beer Sheva, Horvat 'Uza, and Tell el-Far'ah (S).¹

METHODS

The following procedure has been applied in order to examine the authenticity of the ostraca.

1. Tiny samples of the sherds were removed from the obverse of the ostraca for standard petrographic examination. This analysis was not intended for the examination of the authenticity of the ostraca *per se*, but in order to examine whether the petrography of the sherds was in agreement with the recorded composition of Iron Age pottery from Judaea. For comparison, we used our collection and database of archaeological vessels from Israel and adjacent areas, kept in the Institute of Archaeology of the Tel Aviv University.
2. Surface investigation of the ostraca was made under a stereomicroscope at magnifications up to $\times 60$ and under an incident light microscope at magnifications of $\times 40$ – $\times 400$, using brightfield and darkfield illuminations.
3. Two sample sets of patina were taken from the ostraca, using a scalpel and a set of dental tools. One set was used to prepare petrographic thin sections and the other set was used for the stable isotope analysis. The thin sections were examined under a polarising microscope at the same magnifications.
4. The oxygen ($\delta^{18}\text{O}$) and carbon ($\delta^{13}\text{C}$) isotopic composition of the carbonate component within the patina was analysed, using a VG Isocarb system attached to a SIRA-II mass spectrometer. All the $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ values were calibrated against the international standard NBS-19, and are reported in permil, relative to the PDB standard (Craig 1957).² Patina samples were collected for stable

1 We thank Ms. H. Katz, Head of the National Treasuries in the IAA, and Prof. Itzhak Beit-Aryeh and Ms. Lily Avitz-Singer from the Institute of Archaeology, Tel Aviv University, for supplying us with the ostraca for inspection.

2 There are two internationally accepted reference standards used to report variations in oxygen isotope ratios: PDB (Pee Dee Belemnite) and SMOW (Standard Mean Ocean Water). The PDB standard is used to report carbonate oxygen isotope ratios, and the SMOW standard is used to report variations in water oxygen isotope ratios.

isotope analysis from the inscribed surfaces of the ostraca. A control group of samples was taken from the sherds in order to check their original carbonates that could occur within the clay paste or the inclusions (temper). Caution was taken to avoid contamination of the patina samples by the underlying sherd. The results of the patina samples were compared with the $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ values from well-dated secondary calcite (speleothems) deposited inside caves in the Jerusalem area during the last 3,500 years (Kaufman *et al.* 1998; Bar-Matthews, Ayalon and Kaufman 1998; Frumkin, Ford and Schwarcz 1999), and of patinas from Early Roman Period ossuaries excavated in the Jerusalem area (Ayalon, Bar-Matthews and Goren 2004). In addition, the patina of a collection of legally excavated ostraca was analysed by the same method for comparison.³

RESULTS

A. Petrography of the Sherds

The petrographic examination of ostracon 1 revealed the following composition (fig. 3): The matrix is reddish-tan in PPL, silty (~20%), non-carbonatic, ferruginous, exhibiting isotropism (namely, absence of birefringence resulting in partial vitrification due to high firing temperature). The silt includes predominantly quartz with accessory hornblende, zircon and feldspars. The inclusions are made of well-sorted sand of quartz, some chert and remains of limestone that was decomposed by the high firing temperature (estimated at 900°C).

The petrography of ostracon 2 is as follows (fig. 4): the matrix is carbonatic, foraminiferous (rich in microfossils), slightly silty (~2%) and partially isotropic in

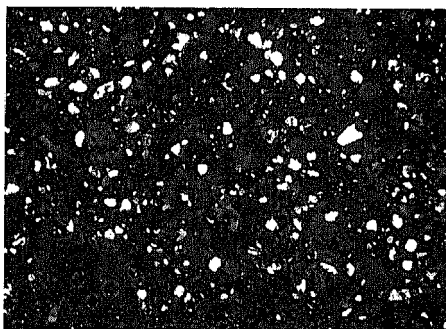


Fig. 3. Ostracon 1 under petrographic microscope, crossed polarisers (see text for details)

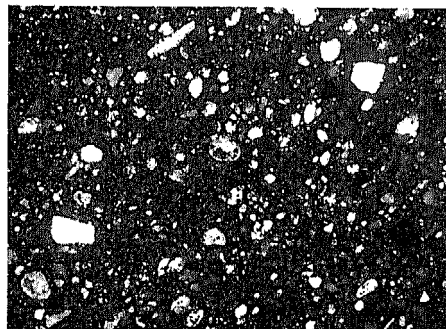


Fig. 4. Ostracon 2 under petrographic microscope, crossed polarisers (see text for details)

³ The following ostraca were used for comparison: Lachish (IAA no. 39.799), Tell el-Far'ah (S) (no. 395 F-C), Arad (no. 67-1894), the City of David (no. 96-3280), Tel Beer Sheva (nos. 2462/1 and 2177/1) and four additional ostraca from Horvat 'Uza.

places. The firing temperature is estimated at ~700°C. The inclusions contain rounded sand-sized grains of quartz, chert, chalk and Nari.

The matrix of ostracon 1 is readily identified as Terra Rossa soil mixed with fine sand. This soil unit occurs in the hilly areas of Israel, where a semi-arid Mediterranean climate prevails. The parent material is hard limestone, dolomitic limestone, or dolomite. Terra Rossa soil is rich in silt-size quartz grains and very fine sand of 30µm–100µm (Wieder and Gvirtzman 1999). Terra Rossa soil is widely exposed over the mountainous regions within the Mediterranean climatic zones of the southern Levant, including the central highlands, Mt. Carmel and the Galilee. They also appear in the Shephelah, in wadi channels draining these regions. The use of Terra Rossa as clay for ceramic vessels is known from assemblages belonging to the central hill country or the Upper Shephelah. In the City of David, most of the numerous clay figurines were made locally of this soil (Goren, Kamaishi and Kletter 1996). More relevant is the case of the *lmlk* stamped jars. A selection of 180 items of this jar type was examined by NAA (Mommensen, Perlman and Yellin 1984). The results suggested that the jars were produced at a single site, perhaps located in the Upper Shephelah. In a more recent study, samples of these jars were examined petrographically and proved to be made of Terra Rossa soil and quartz, chalk, and chert temper (similarly to ostracon 1).⁴ Based on these data, it is logical to assume that ostracon 1 was written on a body sherd of an Iron Age jar from Judaea.

The petrographic properties of the matrix of ostracon 2 represent pale rendzina soil. The inclusions contain chalk, chert and Nari from the mother-rock of the rendzina soil and some wind-blown quartz sand. Brown rendzinas occur together with pale rendzinas in the semi-arid Mediterranean climate. The distribution of the two soils is related to catenary differentiation (Dan *et al.* 1972). The brown rendzina derives from the Nari upper crust, where dissolution and recrystallisation processes destroy the foraminifers, while pale rendzina is made of the lower Nari where approximately 30% foraminifer biorelicts occur. The appearance of the foraminifers is one of the important components in the description and classification of these soils and of the pottery that is made from them.

The combination of rendzinal matrix with chalk, chert, Nari and quartz inclusions is known from several sites in the Shephelah. It appears in Late Bronze to Iron Age pottery from Lachish (Goren and Halperin 2004), Tel Ḥarasim and Tel Maresha. Therefore, the sherd could have originated in the Shephelah, and it accords with Iron Age pottery technology.

B. Surface Examination under an Incident-Light Microscope

Micromorphologic examination of the ostraca under the stereomicroscope and the

⁴ The study, carried out by Y. Goren and S. Bunimovitz (Tel Aviv University), is as yet unpublished.

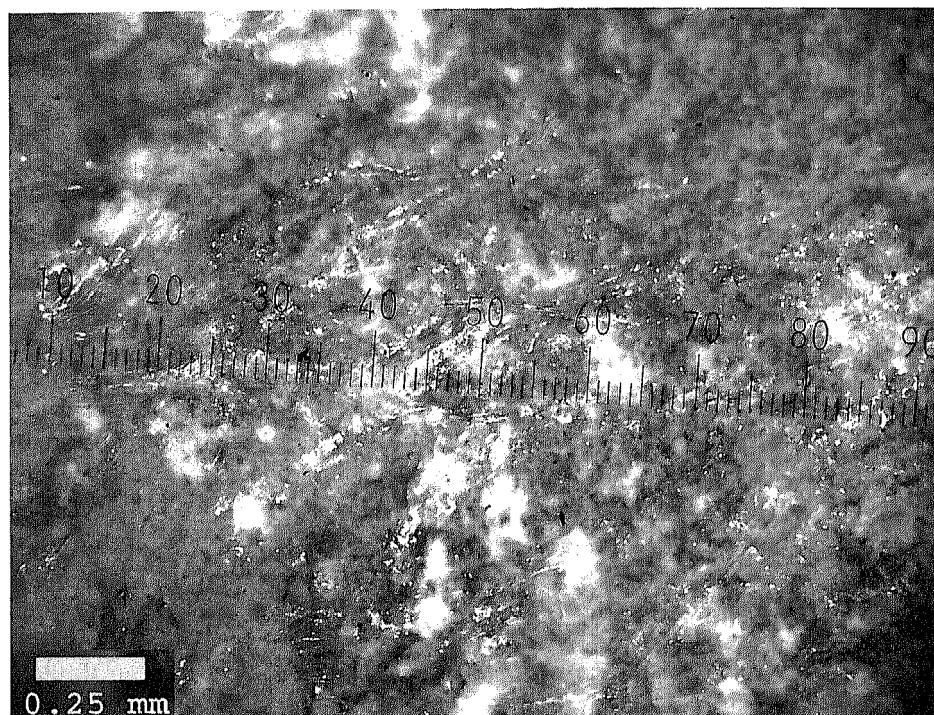


Fig. 5. Ostrakon 1 as viewed under incident-light microscope (brightfield). Dark areas represent part of letter, written with black ink. Fresh scratches made by sharp metallic tool are seen, covered by patina-like material (the bright 'cloudy' areas)

incident-light microscope revealed that they share the same properties. A thin layer of translucent material has been observed, coating the surface of the sherd over the inscription (fig. 5). This material is soft when scratched by a sharp tool and melts easily when exposed to the flame of a mini gas burner spreading the smell of paraffin. When examined in thin section under the petrographic microscope, it is seen as translucent greenish matter with no crystalline properties, isotropic under crossed polarisers. Hence it was identified as wax (paraffin).

The letters under the paraffin were written with a dark pigment. The examination of small samples of the pigment under the incident-light and petrographic microscopes suggests the use of carbonised matter with no added colorants (e.g., iron or manganese minerals), and it may be assumed that carbon ink was used here. However, this issue was not investigated in depth since carbon inks, similar to the types that were used in antiquity, are still commercially sold.

Under incident-light microscopy, the letters of the two ostraca reveal fresh treatment signs by a sharp metallic tool (figs. 5, 6), appearing underneath the paraffin coating and the patina layer.



Fig. 6. Ostrakon 2 as viewed under incident-light microscope (brightfield), presenting same features as ostrakon 1 (fig. 5)

C. Petrographic Examination of the Patina

White calcitic patina overlies the inscriptions and the paraffin layers in the two ostraca (figs. 5, 6). When examined in thin section under the petrographic microscope, the patina is seen to contain three components. It is dominated by an accumulation of micron-sized, fibrous crystals of calcite, typical of burnt lime (Gourdin and Kingery 1975; Goren and Goldberg 1991; Goren and Segal 1995). This material is locally stained by some reddish clay (fig. 7) and mixed with abundant phytoliths and some carbonised organic matter, representing ash from vegetal material. These characteristics are typical of the patina of the two ostraca.

The examination of the legally excavated ostraca from Lachish, Tel Beer Sheva, Arad, the City of David, Ḥorvat 'Uza and Tell el-Far'ah (S) discloses entirely different traits. In all cases, the pigment forming the letters is seen under the incident-light microscope as dispersed matter appearing mainly in the sherd's cavities, lacking any fresh scratches by a sharp tool and coated directly by calcitic patina with no paraffin inlay. When examined in thin sections under the petrographic microscope, the patina samples exhibit microcrystalline accumulation of euhedral calcite crystals, dissimilar to the fibrous texture of the

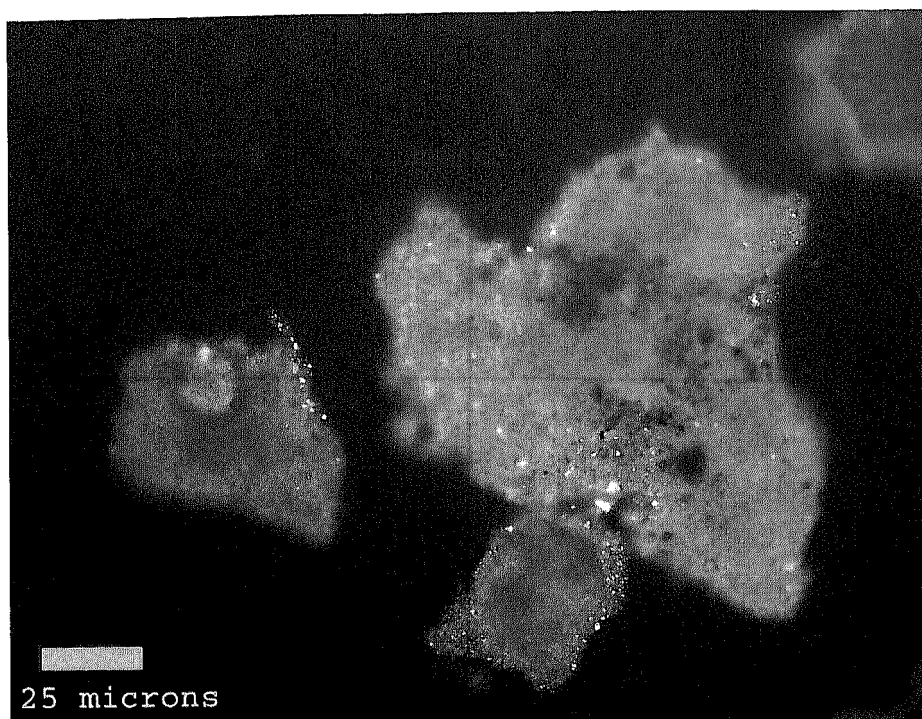


Fig. 7. Patina-like matter from ostrakon 2 as seen under petrographic microscope (crossed polarisers), exhibiting fibrous, micron-sized carbonate crystals typical of burnt lime, together with some clay (darker spots) and few opaques (probably iron minerals, appearing as dark dots)

patina-like material coating the ostraca. Hence, the two ostraca in question are markedly different in these properties from the control group of the authentic items.

D. Oxygen and Carbon Isotopic Examination

The study focused on oxygen ($\delta^{18}\text{O}$) and carbon ($\delta^{13}\text{C}$) isotope composition in the calcite samples taken from the objects' surface. Isotope composition of oxygen is a function of precipitation temperature and isotope composition of water from which the patina precipitated. The carbon isotopic composition is a function of the soil CO_2 and the $\delta^{13}\text{C}$ value of the country rock. The study method is based on background data from our previous studies of secondary calcite (formed in similar conditions to those from which patina is formed) in the Judaeen Hills, Samaria, Galilee and the northern Negev. The data show that the $\delta^{18}\text{O}$ value in carbonate patina formed on the surface or in shallow burials in these areas in the last three thousand years is in the range of -6.5 to -3.5‰ (PDB) (table 1 and fig. 8). These $\delta^{18}\text{O}$ values are in agreement with the expected range of naturally formed secondary

carbonates in the climatic conditions that prevailed in Judaea during the last 3,000 years ($\delta^{18}\text{O}$ water -6‰ to -4‰ [SMOW])⁵ and mean annual temperatures of 18–19°C (Bar-Matthews *et al.* 1996; Bar-Matthews, Ayalon and Kaufman 1997).

The premise of our work is that a significantly different patina composition from this range would indicate artificial production of patina. This theory was tested by examining the subject artefacts as well as the above-mentioned ostraca from legal excavations. Surface patina was sampled from all the items in order to test whether the patina samples contain calcite from the sherd itself (which also contains carbonate); it was tested as well for its isotope composition.

The $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ values in patina from the ostraca found at legal archaeological excavations lie within the range of -6.8 to -3.1‰ and the range of -13.4 to -4.9‰ respectively. These values are within the expected oxygen and carbon isotope composition of patina that was precipitated naturally. $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ values of the calcite in the sherd samples vary between -6.0 and -1.5‰ and between -10.0 and -6.1‰ respectively (fig. 8). In the sherd we also find 'modified' calcite, the isotope composition of which changed as a result of the firing process at high temperatures

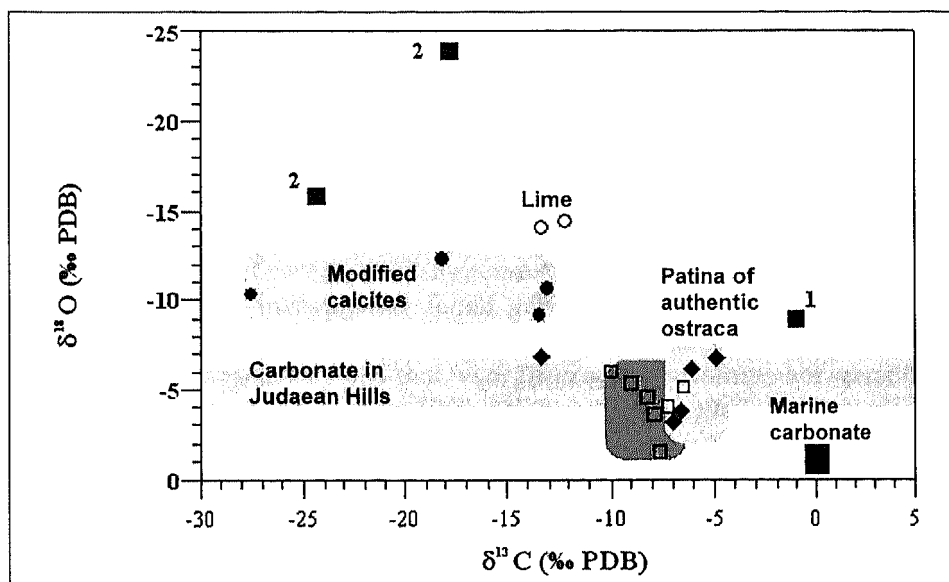


Fig. 8. Oxygen and isotopic composition of patina from ostraca 1 and 2 (solid squares) and patina of ostraca (solid rhomboheders) from collections found in methodical and documented archaeological excavations (Tell el-Far'ah [S], Tel Lachish, Tel Arad, Tel Beer Sheva and City of David). Also shown: isotopic compositions of calcite present in sherd (open squares) and 'modified' calcite (solid circles) from the studied ostraca. $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ values of lime (open circles), marine carbonate and carbonates from the Judaeen Hills are shown for reference

⁵ See above, n. 2.

(above 750°C, similar to lime production), leading to partial breakdown of the calcite present in the sherd. This calcite is characterised by significantly low $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ values (-12.4 to -9.1‰ and -27.6 to -5.7‰ respectively; table 1 and fig. 8).

Table 1. Oxygen and carbon isotopic composition of patina, sherd and 'modified calcite' sampled from the studied ostraca

Sample no.	Description	Oxygen $\delta^{18}\text{O}$	Carbon $\delta^{13}\text{C}$
Patina			
No. 1	Ostrakon 1	-8.95	-0.98
No. 2	Ostrakon 2	-15.82	-24.34
No. 2	Ostrakon 2	-23.89	-17.78
No. 3	Tel Lachish	-3.78	-6.62
No. 3	Tel Lachish	-3.11	-7.06
No. 4	Tell el-Far'ah (S)	-6.74	-4.87
No. 5	Tel Arad	-6.08	-6.07
No. 6	City of David	-6.84	-13.42
No. 7	Tel Beer Sheva (no. 2462/1)	-6.42	-8.37
Sherd			
No. 1	Ostrakon 1	-1.47	-7.68
No. 2	Ostrakon 2	-4.55	-8.25
No. 3	Tel Lachish	-3.57	-7.98
No. 4	Tell el-Far'ah (S)	-6.04	-9.97
No. 4	Tell el-Far'ah (S)	-4.07	-7.34
No. 6	City of David	-5.38	-9.05
No. 7	Tel Beer Sheva (no. 2462/1)	-3.85	-9.12
No. 7	Tel Beer Sheva (no. 2177/1)	-3.75	-6.14
'Modified' calcite			
No. 3	Tel Lachish	-10.63	-27.63
No. 4	Tell el-Far'ah (S)	-12.38	-18.24
No. 4	Tell el-Far'ah (S)	-9.20	-13.45
No. 5	Tel Arad	-10.63	-27.63
No. 7	Tel Beer Sheva (no. 2177/1)	-9.08	-5.72
Commercial lime samples		-14.13	-13.33
"		-14.46	-12.24

The relatively low $\delta^{13}\text{C}$ values may indicate alteration of the sherd's calcite. This calcite should be carefully treated during patina sampling in order to prevent contamination of the sample by calcite of particularly low composition.

To substantiate our finds, samples of industrial lime were tested for comparison. Both oxygen ($\delta^{18}\text{O} = -14.5$ and -14.1‰) and carbon ($\delta^{13}\text{C} = -13.3$ and -12.2‰) show characteristically low values.

Ostrakon 2 has a thick patina layer, which allows taking a reliable sample, uncontaminated by the sherd. The oxygen (and carbon) isotopic composition of the patina samples from the inscribed surface of ostrakon 2 reveals extremely low oxygen and carbon isotope values. $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ values of patina from these ostraca range between -23.9 and -15.8‰ and between -24.3 and -14.9‰ respectively (fig. 8), and were significantly different from the expected calcite values in the geographical areas mentioned above (fig. 8). These values are also significantly lower than those of the patina of the letters in the James ossuary (Ayalon, Bar-Matthews and Goren 2004) and of the patina on the Jehoash tablet (Goren *et al.* 2004). The $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ values of the patina from ostrakon 1 are -8.5 and -0.98‰ respectively. This value is found in the isotope value range measured in the patina of the letters on the James ossuary and the Jehoash tablet. It should be noted that this object has a relatively thin patina layer in comparison with the other ostraca tested, and it is possible that the isotopic composition measured in this sample represents a mixture of the isotopes of the patina with the sherd.

The very low $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ values found in the 'modified' calcite in the sherd, in the comparative commercial burnt lime sample and in the patina which covers ostrakon 1 and 2 are the result of isotopic fractionation due to kinetic effects which accompany the firing process, which increase with increasing temperature during the firing. Previous investigators found good correlation between the firing temperature in preparing pottery vessels and the $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ values in calcite in clays that contain carbonate and that were fired at temperatures between 500°C and 700°C (Baertchi 1952; Bottinga 1968; Shieh and Taylor 1969; Nissenbaum and Killebrew 1995). They found that original carbonate was either completely decomposed or that it exchanged with environmental CO_2 to demolish the original isotopic signature. Very low $\delta^{13}\text{C}$ values (-21‰ to -26‰) and $\delta^{18}\text{O}$ values (-17.8‰ to -22‰) were reported for quicklime prepared from chalk heated to 900°C and cooled in room temperature (Ambers 1987).

The oxygen and carbon isotope composition of the patina of ostrakon 2 is clearly different from the range of values expected for carbonate patina formed today and from that formed in the Judaeen Hills, northern Negev, Samaria and Galilee in the last three thousand years. Assuming customary burial conditions and given the very negative values for oxygen and carbon isotope composition in the patina of this object, this patina could not have formed naturally under typical climatic conditions and water composition in the above-mentioned geographical zones within the last three thousand years.

The very negative oxygen and carbon isotope values clearly indicate that the isotopic composition can be used as criteria to demonstrate that the patina that covers ostrakon 2 is in fact an artificially-made lime, which was poured onto the surface of the object.

Oxygen isotope composition in the patina of ostrakon 1 is also different from the expected range for naturally-formed carbonate patina, indicating that the patina is not natural. As noted, this item exhibits a relatively thin patina layer when compared to the other nine ostraca, and it is possible that its isotope composition represents a mixture of patina with sherd. Therefore, based on its oxygen isotope composition alone, it is impossible to determine whether or not the patina of this object developed naturally.

CONCLUSIONS

The micromorphologic, petrographic and isotopic examination of the two ostraca indicate without a doubt that these are modern forgeries. The results of the analyses presented here enable the reconstruction of the sequence of actions taken by the forger(s). First, a body sherd from an Iron Age large vessel was selected. The surface of the sherd was cleaned from its original patina to enable writing on it. The inscribing was carried out in carbon ink, presumably using a calligraphy pen. After drying, the letters were 'aged' by scratching them with a scalpel or a razor blade, in order to give them a weathered appearance. In order to enable the 'patination' process and to prevent dissolution of the letters by water, the entire inscribed surface was coated by a thin film of paraffin, over which the simulated patina was applied. The latter was made by mixing commercial burnt lime with some plant ash and clay, most likely in order to give it the greyish hue that is typical of genuine calcareous patina. Since the two ostraca share precisely the same forging technique, it may be suggested that they could both have been prepared in the same workshop, although this hypothesis cannot be proved conclusively. It should be noted that this forgery technique is not very sophisticated and that expert laboratories can readily notice the presence of the irrelevant materials (paraffin and lime).

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