Salt Damage Related to Material Properties of Ceramics

Brunella Santarelli, Dr. Nancy Odegaard
Department of Preservation, Arizona State Museum
University of Arizona, Tucson, AZ

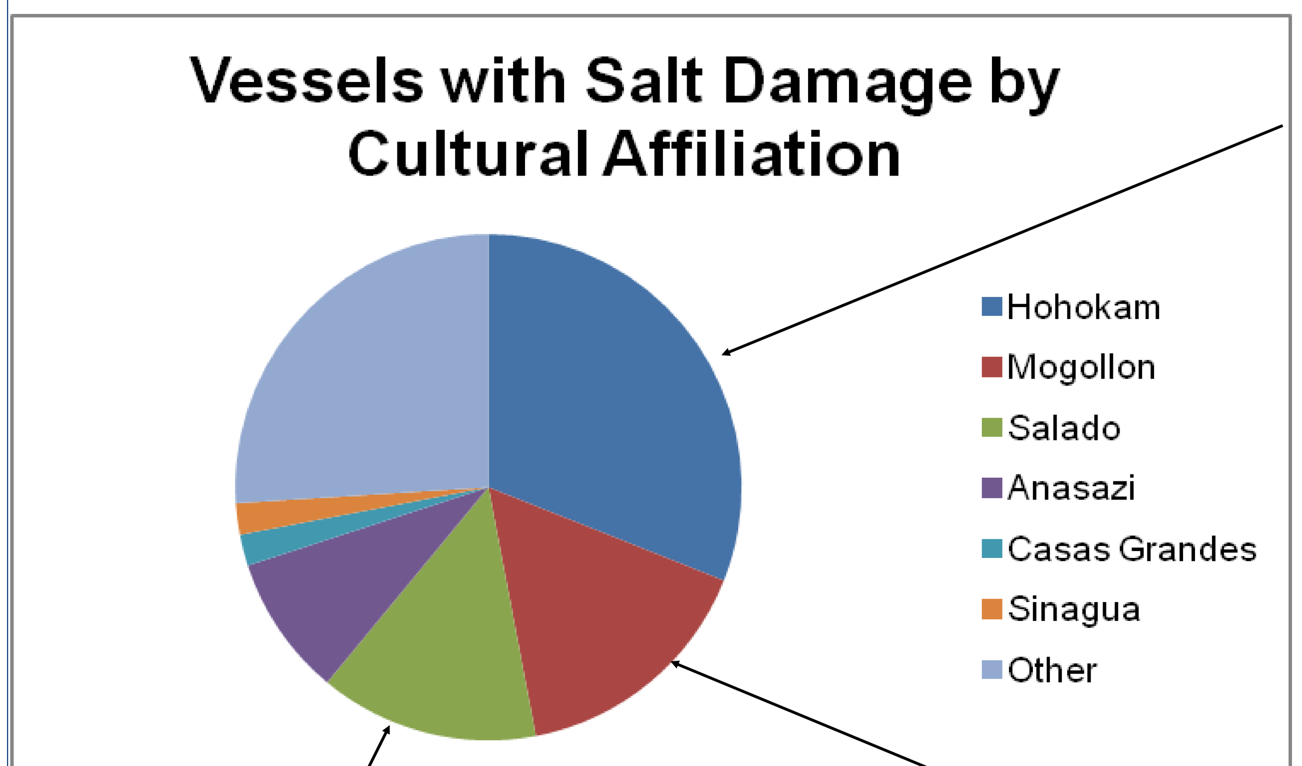
Arizona State Museum
THE UNIVERSITY OF ARIZONA

Introduction

A pressing concern in the conservation of archaeological ceramics is the damage caused by soluble salts. When salts crystallize in the pores of a ceramic their expansion affects the internal structure of the matrix and causes powdering and spalling of the surface, thus weakening the ceramic body. Salt damage is increased if the ceramic is not treated and stored appropriately after excavation. Salt damage to ceramics is of particular concern to conservators working with ceramics from the Southwestern United States. The Pottery Project at the Arizona State Museum was initiated as an effort to survey, treat and provide adequate storage conditions for the whole vessel collection at ASM, which at over 20,000 vessels is the largest collection of Southwestern ceramics in the world. With support from the Institute for Museum and Library Services, the Conservation Laboratory of ASM has worked for the past two years to treat the 700 ceramics that were designated during the initial survey as being high conservation priority. The Pottery Project also includes a research initiative, to better understand how the ceramics degrade over time and what conservators can do to ensure the preservation of the collection. The survey of the collection identified salt damage as an immediate concern to the preservation of the collection. Certain patterns of damage were observed during this survey, and this research is concerned in identifying the factors that affect these patterns, and how they relate to the preservation state of a collection.

Survey and Sampling

1) Survey of ASM's Southwest Pottery whole vessel collection: The data collected from the Pottery Project survey was catalogued in a Microsoft Access database, recording relevant condition information including the presence of salt related damage. The data in this database was analyzed to develop an overview of salt damage in the collection; a total of 698 vessels exhibited active soluble salts, while almost 4,000 vessels had evidence of salt damage. The records of the 698 vessels were reviewed to determine the cultural distribution of these vessels.



Courtesy of Arizona State Museum, University of Arizona

2) Sample selection: The analysis of the data collected during the survey showed a certain pattern in the presence and appearance of salt damage. A set of Southwestern ceramics representative of the ones with the highest levels of salt damage in the collection of the Arizona State Museum was selected for a study of their material properties and how they relate to degrees of observable damage. Four samples were selected: 2 Hohokam types (Gila plain and Santa Cruz red-on-buff), 1 Salado type (Gila polychrome) and 1 Mogollon type (Reserve indented corrugated).

Gila plain sherd

Santa Cruz red-on-buff sherd

Gila polychrome sherd

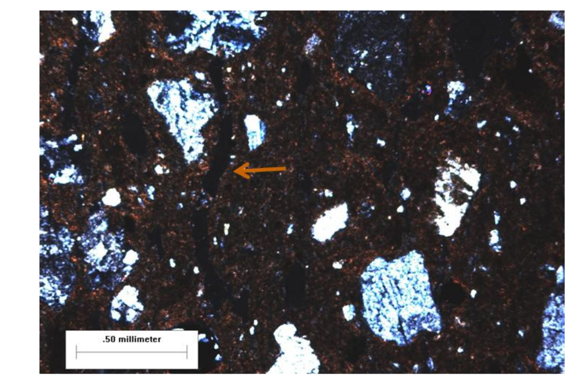
Reserve indented corrugated sherd

Material Characterization: Physical Properties and Technological Considerations

A material characterization was carried out to study the physical properties of the ceramics: porosity, pore-size distribution and permeability. Porosity and pore-size distribution were measured using optical petrography methods. The permeability was measured with a water absorption experiment, following ASTM Standard 1585.

Table 1 : Physical properties of experimental samples

Sample	%Porosity	Pore Diameter (mm)	Permeability (mm/s$^{1/2}$)
Gila plain	3.7	60-80	0.0527
Santa Cruz red-on-buff	4.4	60-80	0.0725
Gila polychrome	7.0	80-100	0.0596
Reserve indented corrugated	7.8	140-160	0.0790



Micrograph of Gila Polychrome sherd, taken under cross polarized light at 5X

The construction method and surface treatment of a ceramic can affect their physical properties, so it is necessary to that these technological factors be described.

Table 2: Construction technology and surface treatment of experimental samples

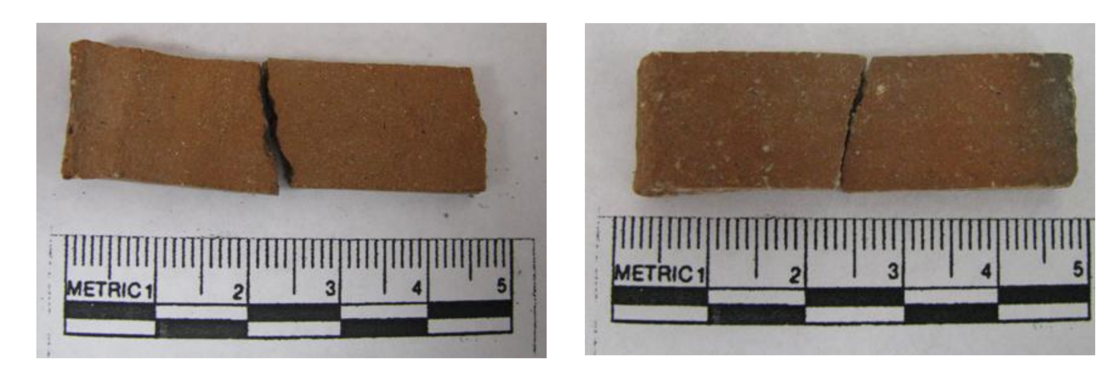
Sample	Construction Technology	Surface Treatment
Gila plain	Coiling, paddle and anvil	Smooth surface, no decoration
Santa Cruz red-on-buff	Coiling, paddle and anvil	Thin layer of buff clay slip with red paint
Gila polychrome	Coiling, smoothing	White slip with black carbon paint on interior, brown/red slip on exterior
Reserve indented corrugated	Coiling	Corrugated exterior, scraped interior

Accelerated Aging Experiments and Results

Salts were introduced into the ceramic samples and they were run through an accelerated aging experiment to model the effect of extreme environmental fluctuations. The accelerated aging was done by fluctuating the relative humidity of the environment, by cycling the samples between a wet chamber (~95% RH) and a dry chamber (~10% RH). Two different salts ($NaNO_3$ and NaCl) were introduced into the ceramic samples; the cation was kept constant to investigate the effect of the anion. Damage to the ceramic samples was assessed quantitatively by percent weight loss and percent increase in porosity.

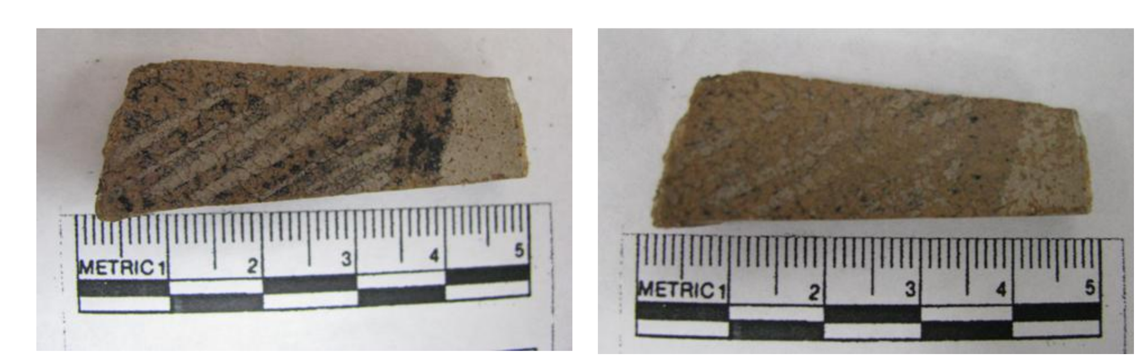
Table 3: Changes to physical properties after accelerated aging

Sample	Salt	% Increase in Porosity	% Mass Lost
Gila plain	$NaNO_3$	50	3
	NaCl	46	0.9
Santa Cruz red-on-buff	$NaNO_3$	43	4
	NaCl	32	0.7
Gila polychrome	$NaNO_3$	11	6
	NaCl	10	2
Reserve indented corrugated	$NaNO_3$	40	3
	NaCl	21	1.5



Gila plain sample after 1 month of accelerated aging (left) and after two months (right). The only noticeable difference is the presence of a white efflorescence on the surface after two months. No damage or crumbling of the surface visible.

The crystallization pressure of salts inside a pore is inversely related to the radius of the pore, so smaller pores can maintain higher crystallization pressures. The results above show that physical properties and salt identity alone do not explain the pattern of degradation observed. Therefore, it is necessary to look at another factor: the construction technology and surface treatment of the ceramic. Hohokam ceramics are constructed by coiling and the surface is paddled. Paddling compacts the surface and explains the low porosity of the Hohokam ceramics. The Hohokam ceramics showed significant changes to the microstructure during the experiment, but no damage to the surface, suggesting that the crystallization pressure maintained was not high enough to cause surface loss. The only evidence of salt damage to the Hohokam ceramics during the accelerated aging study was the appearance of a white efflorescence. The Salado ceramics exhibit a large mass loss, but a small increase in porosity; this is because the damage is concentrated to the surface, and is characterized by spalling and loss of slip and paint. It is likely that the salts crystallize at the surface below the slip, and the crystallization pressure causes the slip to spall. The Mogollon ceramic, which has a corrugated exterior had large increase in porosity and large mass loss. The damage is concentrated to the exterior; pores concentrate between coils, so salts will also concentrate there, therefore explaining why the damage is on the surface.



Gila polychrome sample after 1 month of accelerated aging (left) and after two months (right). The white slip and black carbon paint began spalling almost immediately; after two months all of the black carbon paint was lost, as well as a majority of the white slip.

Conclusions and Future Work

The results from this experiment showed that there are several factors that affect the degree of damage and the pattern of degradation. The **physical properties** (porosity and permeability) of a ceramic sample determine the degree of damage a ceramic will exhibit from salt action. The **construction technology and the surface treatment** of a ceramic will affect the pattern of salt damage observed. The **identity of the salt** is also an important factor, as the more hygroscopic salts caused the most damage. Other factors that need to be considered, but cannot easily be controlled in a laboratory experiment, are environment of deposition and time.

Acknowledgements

We thank the Institute for Museum and Library Services IMLS No. IC-04-10-0292-10 and the Raymond H. Thompson Fellowship Research Award for the support given to this work.