

# Oneota Food Storage Technology- Experiment in Pit Storage of Maize

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Little is known about the food storage technology of the late prehistoric Oneota societies (AD 1000 to AD 1650 ) of the Upper Midwest. Aspects of Oneota storage pit forms, as found on archaeological sites in the Upper Mississippi Valley, indicate that they may have been similar to those used by some Plains agricultural peoples in early historic times, such as the Hidatsa of the Upper Missouri River Valley.

This project, conducted during the winters of 1996-97 and 1997-98, tested four experimental maize (corn) storage pits, constructed according to ethnographically reported methods. Results indicate that this method of storage works very well, during a typical midwestern winter, and also during a winter that was unusually warm. Upon opening these storage pits most of the corn was found to be in good condition, with little evidence of mold, and with no signs of insect or rodent infestation. Germination tests indicated that up to 99% of the seed in some samples remained viable.

Study of experimental storage pits will help to interpret the significance of pit features found in archaeological sites, such as the seasonality and length of occupation at a site, and the relationship between numbers of pits and population size.

## INTRODUCTION

Storage of food surplus is a type of subsistence strategy allowing people to reduce the risk of food shortages by smoothing out fluctuations in both the availability of wild food resources and variations in yield of agricultural crops. Other motivations for storage include saving seed for future crops and the use of food surplus for trade (Gallagher and Arzigian 1994). Subterranean pit storage is one of the methods for which we find archaeological evidence, and is a method still in use in the recent past and among some traditional peoples (Reynolds 1974, Wilson 1987 [1917]).

Stored food is subject to loss from a variety of agencies. Predation by humans, other mammals, or insects is a danger, as is spoilage or reduction in nutritional value of the food through bacterial or fungal action. Stored seed for future crops must retain its viability. Successful storage of food, therefore, requires certain conditions to be met. Insects must be prevented from infesting the food, or killed or kept from developing if they are already present. The stored food must be protected against access by other animals (hidden or guarded from humans). The action of fungi must be prevented or kept to a minimum. These last conditions are best met by keeping stored food dry and cool (Bassett 1993). Storage in subterranean pits is known ethnographically to provide all these conditions.

Sites recorded or excavated in Africa (Bassett 1993), Europe and Great Britain (Nash,

n.d.), as well as the Americas have demonstrated prehistoric use of underground pit storage. Archaeological evidence of such storage pits is frequently found in the Midwest, as well as in other parts of the world. In this region of North America, such storage was used by the Oneota in precontact times (Overstreet 1976, Straffin 1971, many others), and also historically by people such as the Hidatsa (Wilson 1987 [1917]) and Ioway (Blaine 1979).

In Britain, research done on barley in the rocky chalk soils (Reynolds 1974) has shown that anaerobic conditions are produced in a sealed storage pit. Seeds, being living organisms, continue to have a respiration cycle-similar to, although slower than, that of a growing plant. The British studies (Reynolds 1974) indicate that a specific chain of events occurs in a sealed storage pit that causes the grain to remain edible and viable as seed for long periods. According to these studies, moisture from the soil can cause the outermost layer of grains in the pit to sprout. This activity uses up the available oxygen in the sealed pit, and raises the percentage of carbon dioxide to a level that causes the remaining seeds to become dormant. They continue in this dormant state as long as the pit remains sealed. The lack of oxygen also tends to kill any insects present in the grain, and to prevent further infestation. Modern sealed grain silos operate on similar principles.

This research has also shown that if grain in a storage pit becomes wet from ground moisture, the seed loses its viability, but may retain its edible qualities under some conditions. Grain in storage pits which were flooded by groundwater after heavy rains remained edible if quickly dried on recovery, as long as the grain remained submerged until the pit was opened. Grain that had been wet for a short time only before the groundwater receded from the pits quickly spoiled.

No experimental work has been reported on food storage methods in the cold, damp Upper Mississippi Valley winter climate. Some work has been done in the Southwestern United States with pit storage of corn in very dry climates (Bassett 1996).

## **PIT STORAGE IN THE PAST: MIDWEST AND PLAINS**

From archaeological and ethnographic evidence, the most commonly stored food in the American Midwest was maize, along with dried squash, sunflower seeds, and beans. Food must be dry to store well; the lower the moisture content, the less likely the food is to be infested by molds. Ethnographic accounts (Wilson 1987 [1917]) indicate that food was sometimes dried artificially, usually in the sun. Temperature is another factor affecting the successful storage of food: lower temperatures inhibit or prevent the development of molds and of any insects or insect larvae, features that are presumed to be present at the time of storage.

Storage pits found at Oneota sites include basin, bell, or cylindrical shapes, and include well described examples found at the Sand Lake (47Lc44) and Herbert (47Lc43) sites (Boszhardt 1985), and at the Trane (47Lc447) site (Boszhardt 1992a). They tend to average about 1 meter in width by about 1 to 1 1/2 meters in depth, although larger examples are sometimes found. Lining materials, if any, are not generally preserved, however strips of bark (Boszhardt 1992a) or other materials which may have been used as pit lining are sometimes present. One pit at the Sand Lake Site may have evidence of a clay cap (Boszhardt 1985).

According to Buffalo Bird Woman, the informant in Gilbert L. Wilson's (1987

[1917]) ethnography, the Hidatsa of the Upper Missouri used bell-shaped pits for storage of maize, dried squash, sunflower seeds, and beans. These storage pits varied in size from "eye-level of a person standing in the pit" (about 4 1/2-5 feet deep?) to very large pits which required a ladder to get into and out of (only relative dimensions are given). The width of their pits at ground level was about 2-2 1/2 feet, widening downwards. The pits were floored with dry willow twigs, lined and covered with dry bundled grass, with an inner floor and cover over the top of hide. Short sections of log were laid across the top covering (to support the weight of horses and people walking over the pit), and the pit was topped with a thick layer of earth and ashes. The Hidatsa were concerned with hiding their food supplies from raiding Sioux, so they were not marked on the surface in any way. (Wilson 1987 [1917])

Wilson's study is one of the most detailed accounts available describing the way in which one historic Plains group prepared food for storage and constructed underground storage pits. Prehistoric peoples did not necessarily use the same methods, but the pit features from archaeological sites often appear to be similar in shape to those in Wilson's and other ethnographic accounts. This method is therefore being used as a starting point in investigating Oneota food storage.

## RESEARCH OBJECTIVES

The questions being investigated include: how must storage pits be constructed in order to best maintain low temperature and humidity in stored food, deter infestation by insects and predation by other animals, and maintain the food in edible condition (free of excessive mold infestation) and viable as seed?

## METHODS

This experiment was conducted in two phases; Phase One (pits #1 and #2) over the winter of 1996-97, and Phase Two (pits #3 and #4) over the winter of 1997-98. The pits were situated on the edge of a terrace on a known Oneota site (the Swennes site, 47Lc333) in La Crosse Co., Wisconsin. The site was chosen for its proximity to known areas of Oneota pit construction, and for its position at the top of a slope, to provide good soil drainage.

## CONSTRUCTION OF EXPERIMENTAL STORAGE PITS

Pits #1, #2, and #3 were floored with 5-10cm. of dry twigs, and lined with 15-20cm of dried, bundled marsh grass (*Phalaris arundinacea*). Pit #4 was unlined; having only a 10cm. twig floor. A piece of cowhide (bison or deer being unavailable) was used as an inner lining for the floor of each pit. Dried corn on the ear was placed in a single layer on the floor liner of each pit, and stacked in a single circular row around the pit wall to a depth of about 45cm below ground surface. The cylindrical space left in the center of each pit was filled with dried shelled corn level with the top of the corn ears. The corn in all pits was covered with 15-20cm of dried grass and another piece of hide. The pits then had sections of 5-7cm. diameter branches placed across the contents, and then both pits were filled to slightly above ground level (to allow for settling) with packed earth.

The corn used was feed corn which had been grown without the use of pesticide sprays and dried standing, without the use of artificial heat.

Phase One pits contained one year old, 1995 corn (pit #1), and corn grown in 1996,

the year of the pit construction (pit #2). The corn used in Phase Two (pits #3 and #4) was grown in 1997, the year the Phase Two pits were constructed.

### **Dimensions**

Pit #1- 80 cm wide (top) 100cm wide (bottom) x 120cm deep

Pit #2- 92cm wide x 115cm deep

Pit #3- 90cm wide (top) 100cm wide (bottom) x120cm deep

Pit #4- 90cm wide x 110cm deep

## **DATA COLLECTION**

During filling, a remote-reading thermometer probe was placed in the center of each pit. Phase Two pits (#3 and #4) were also fitted with a 1" PVC pipe, which had a plastic cage attached to its lower end and an airtight cap at the upper end. This pipe was placed with the cage at the center of the pit, and the capped end extending about 4" above the soil surface. This pipe allowed access to the center of the pit for gas sampling and measurement of humidity. The aboveground ends of the sampling tubes and instrument leads were covered with an upturned 5-gallon plastic bucket, to protect the instruments from accidental damage or water entry.

The internal temperature and external air temperature were monitored at one-week intervals in all pits. In the Phase Two pits (#3 and #4), internal humidity and percentages of carbon dioxide and oxygen were also measured at one-week intervals. The pits remained sealed until spring, when they were opened at different times and the contents tested for signs of mold or insect infestation, disturbance by animals, and seed viability. Moisture content analysis was performed on samples of the corn taken before storage, as well as samples taken when the pits were opened.

## **INSTRUMENTS**

Phase one temperature monitoring was done using Fisher Scientific 15-077-8C Monitoring Thermometers, one instrument for each pit. Phase two used a single Fisher Scientific 15-077-17A Sentry Thermometer, with one detachable sensor lead in each pit. Humidity was measured using a Fisher Scientific 11-661-18 Memory Hygrometer with Probe. Carbon dioxide and oxygen levels were sampled with a Bacharach, Inc. Fyrite™ Gas Analyzer, with CO<sub>2</sub> and O<sub>2</sub> indicators.

## **RESULTS**

### **Phase One-**

#### **Pit #1-**

Filled and sealed November 1, 1996; containing 550 whole ears and 38 liters of shelled corn.

Temperature Data- After initial cooling, the temperature in the pit remained just under 40 degrees F for most of the test period, while the air temperature varied between a low of 13.5 degrees F in January and a high of 73.2 degrees F in April. (see Graph #1)

Opened May 11, 1997. The soil covering the pit was damp, but not saturated. The hide and grass capping the pit were wet, as was the grass lining down to 70cm below ground surface. Below 70cm, the lining was dry, except for a narrow strip on the downslope side. Water had run down through the lining at this point, pooling at the bottom of the pit, in and under the layer of twigs forming the floor. The corn in the pit had settled,

compressing the twig floor and allowing the bottom layer of corn to become wet along one side. Thirty-two ears at the bottom of the pit showed some mold (6% of the total). The remaining 94% of the corn ears, and all of the shelled corn, were dry and free of visible mold.

#### **Pit #2-**

Filled and sealed November 8, 1996; containing 300 whole ears and 33 liters of shelled corn.

Temperature data- After initial cooling, the temperature in the pit remained close to 40 degrees F for the first 16 weeks of the test period, though varying somewhat more than those from pit #1. After the 16th week, the temperature readings began to vary wildly with changes in the air temperature, and were not consistent with the readings from pit #1, or with air temperature measurements taken with another thermometer of the same type. The pit #2 thermometer was determined to be defective, but replacing it was not possible without opening the pit (see graph #2).

Opened April 27, 1997. The hide and grass capping the pit, and the lining of the pit sides, were only slightly damp. The settling of the corn had compressed the twig floor, allowing the grass and the corn in the bottom of the pit to come into contact with the soil and to become damp. Eighty ears of corn in the bottom layers (27% of the total) and the lower 1/3 of the shelled corn were molded. Ears which were still covered by their husks showed very little or no mold, even when damp.

#### **Phase Two-**

**Pits #3 and #4**, were constructed in the same manner as the Phase One pits, but with a thicker layer of twigs at the bottom to prevent the corn from coming into contact with the bottom of the pit, in spite of compression due to settling. More attention was paid to the grass lining in pit #3; making sure that it was tightly bundled and even in thickness throughout the pit. Pit #4 was unlined, but floored with twigs and capped with grass in the same manner. Care was taken to ensure a tight seal around the sampling tubes.

A thermometer with detachable sensor leads was used in pits #3 and #4, to avoid weather damage to the instrument- the probable cause of the failure of the pit #2 thermometer.

#### **Pit #3-**

Filled and sealed November 8, 1997; containing 330 whole ears and 38 liters of shelled corn.

Temperature Data- After initial cooling, the temperature in the pit again remained just below 40 degrees F for most of the test period, while the air temperature varied between a low of 20 degrees F in January and a high of 64 degrees F in April (see Temperature Graph #3).

Humidity-Fell over the first eight weeks (with a temporary rise in week 6) from an initial reading of 96% to 74%, where it remained until the last week of the test period (see pit #3 humidity graph).

Gasses-The oxygen reading in the pit one week after sealing was at 20%. This decreased slowly through the 11th week, and more quickly thereafter, to a final reading of 9.5%. The carbon dioxide level was at 0% after one week. This increased gradually until week 11, then more rapidly to a final level of 6%. (see pit #3 gas graph)

Opened April 4, 1998. The soil was thoroughly saturated, and the hide covering was wet. The grass layer over the corn was damp adjacent to the hide covering, but almost totally dry nearest the corn. The lining was also almost totally dry, having only a slightly "clammy" feel. Ten ears of corn (3% of the total ) showed a small amount of mold, most on the ends of the cobs- only a few of the grains were affected. The remaining 320 ears (97%) and all of the shelled corn were entirely free of visible mold. The thicker layer of twigs forming the pit floor had resisted compression by the settling corn enough to keep both the corn and the underlying grass from coming into contact with the soil.

#### **Pit #4-**

Filled and sealed November 8, 1997; containing 280 whole ears and 33 liters of shelled corn.

Temperature Data- As before, after initial cooling the temperature in the pit remained just below 40 degrees F for most of the test period, while the air temperature varied between a low of 20 degrees F in January and a high of 66 degrees F in April (see Temperature Graph #4).

Humidity-Readings fell throughout the test period (with a temporary rise during weeks 6 and 8, following snowfalls and thaws ) from an initial reading of 98% to 72% (see pit #4 humidity graph).

Gasses-The oxygen reading in the pit one week after sealing was at 20%. This decreased slowly through the 8th week, and more rapidly thereafter, to a final reading of 3.5%. The carbon dioxide level was at 0% after one week. This increased gradually until week 8, then more quickly to a final high of 18% (see pit #3 gas graph).

Opened April 18, 1998. The soil was damp but not saturated. The hide covering over the pit was wet and showed a small amount of mold. The grass covering the top of the pit was slightly damp near the top, and dry nearest the corn. A strong odor as of fermentation issued from the interior of the pit when it was opened.

All the ears of corn in direct contact with the walls of the pit (about 50% of the total) had a thick covering of mold- they were attached to the soil and to each other with mold. Some of the shelled corn which had come into contact with the pit wall during filling was also heavily molded. The ears not in direct contact with the walls of the pit had very little or no visible mold, and the shelled corn in the center of the pit was also free of visible mold.

After sampling, the corn from #3 and #4 was returned to the pits, along with the lining material, hide, and branches, and re-buried. If possible, the pits will be re-opened after several years, and the progress of decay and compression documented.

No sign of infestation by insects was found in any of the four pits, and no indication of disturbance by rodents or other mammals was seen.

## **GERMINATION TESTS**

For each sample (one of shelled corn and one of ear corn from each pit), 100 grains were picked at random (excluding grains with visible damage or mold) and soaked in water for 24 hours. After soaking, they were put into sprouting jars and rinsed daily for one week.

Sampling procedure:

Shelled: The shelled corn was stirred thoroughly and a handful taken, from which

100 grains were counted out.

Ears: five ears with no visible mold were chosen at random for each sample, shelled, kernels mixed thoroughly, and 100 grains selected as above.

After one week:

Pit #1, 1995 corn	ear; 0 of 100 sprouted	shelled; 5 of 100 sprouted
Pit #2, 1996 corn	ear; 77 of 100 sprouted	shelled; 73 of 100 sprouted
Pit #3, 1997 corn	ear; 99 of 100 sprouted	shelled; 9 of 100 sprouted
Pit #4, 1997 corn	ear; 94 of 100 sprouted	shelled; 10 of 100 sprouted

## MOISTURE CONTENT

Samples of corn were taken from each pit for moisture determination, one sample before closing and one after opening. Moisture content was determined by weighing the samples, drying in a laboratory oven for one week at 70 degrees C, and then re-weighing.

Moisture contents ( % by weight) were as follows:

Pit #1	pre-storage	13.9% (1 year old corn)	
	post-storage ears	16.4%	shelled 15%
Pit #2	pre-storage	18.5%	
	post-storage ears	22.7%	shelled 20.6%
Pit #3	pre-storage ears	23.2%	shelled 11.8%
	post-storage ears	20.1%	shelled 19.4%
Pit #4	pre-storage ears	23.2%	shelled 11.8%
	post-storage ears	21.3%	shelled 22.1%

## MOLDS

Two types of mold were identified on the affected corn:

Pit #4(unlined pit)- a *Fusarium* species, which may produce dangerous mycotoxins.

All pits- a *Penicillium* species, most of which are harmless, although a few produce mycotoxins (which, however, tend to be less severe than those produced by the *Fusarium* species) (Tom Volk, personal communication 1998).

## DISCUSSION

The "traditional" method of storage pit construction employed in this experiment was found to be a useful one for the Upper Midwest. The losses of stored corn over the winter were very low, in spite of the researcher's inexperience with pit construction. Lined pits produced the best results: in the best case (pit #3), greater than 97% of the corn was in excellent condition, although even the unlined pit kept over half of the corn in edible condition. Some degree of mold may not have prevented stored corn from being eaten, particularly in the event of extreme food shortage. While some molds produce dangerous toxins, others are harmless, and some may be beneficial. Historically, some cultures have intentionally inoculated grains and similar starchy seeds with molds, to produce foods

such as the Asian tempeh, which consists of soybeans and other grains bound together with a *Rhizopus* mold. Such foods can be an important source of vitamin B12 in the human diet. One might speculate on the origins of such foods-were they discovered when someone ate molded grain out of necessity, and found it good? This researcher was not brave enough, or foolish enough, to sample the spoiled corn from these pits.

Corn stored in this way does not seem to act in a manner entirely consistent with the abovementioned British studies. While oxygen levels in the pits decreased and carbon dioxide levels increased during the time the grain was stored, none of the grain, even in the unlined pit, showed signs of sprouting. The change in concentrations of these gasses seems to be consistent with the slow respiration of dormant seeds. The increase seen in the rate of change near the end of the storage period may indicate the seeds beginning to come out of their dormant state, and may also indicate gas production caused by mold growth (Jerry Davis, personal communication 1998).

Temperatures in the pits remained quite stable in both phases of the experiment, not much affected by outside conditions. The winter of 1996-97 was fairly typical of weather in this region, while the winter of 1997-98 was much warmer than usual. The pit contents maintained an average temperature (after initial cooling) at or just below 40 degrees F throughout both winters, not rising until the outside temperatures reached the 60's. The pit temperatures did not fall below this range, even when the air temperature was in the 20's and below. There were no extended periods of sub-zero weather during the course of the experiment; so it is not known what effect prolonged extreme cold would have on the temperature profiles of this type of storage pit.

Seed viability remained very high with this method of storage, but only in corn that was stored the year it was grown. The year-old corn used in pit #1, while it kept very well, had an extremely low germination rate. This unexpected result may be due to the lower moisture content of the year-old seeds; further experiments might be done to test this. Modern feed corn seed can normally be expected to remain viable for up to five years under ideal storage conditions (Joseph Lauer, personal communication 1989).

Wilson's ethnography reports that the Hidatsa seed corn might remain usable for up to three years, although decreasing in viability after the second year (Wilson 1987 [1917]).

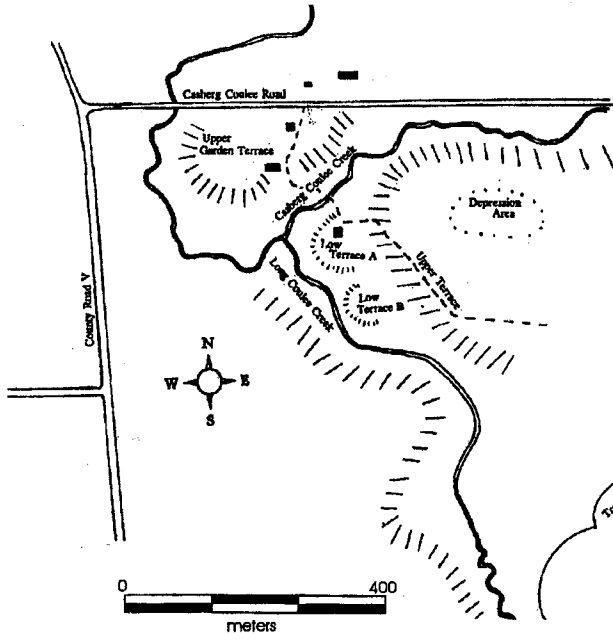
None of the numerous varieties of seed-eating rodents present in the Midwest discovered the pits, possibly because the pits were filled late in the fall (early November), when such creatures may have already established their winter quarters and food supply.

Nor did larger animals find the pits - tracks in the soil and snow around and over the pits showed the occasional passage of deer and raccoons, but there were no indications of disturbance. Cattle and horses were also present in the area during the course of the experiment - this method of pit construction, with its supporting layer of large branches covering the contents, was adequate to support the weight of these animals without damage or disturbance to the pits.

Surprisingly, there were no problems with insect infestation. No insects, living or dead, adult or larval, were found, even in the unlined pit with its higher proportion of spoiled grain. Examination of the corn for insect eggs was not performed.

If an examination of the re-buried contents of pits #3 and #4 can be performed at some later date, it will be instructive to see whether infestation has taken place.





Map of Swennes Site (47Lc333) with Location of Experimental Storage Pits

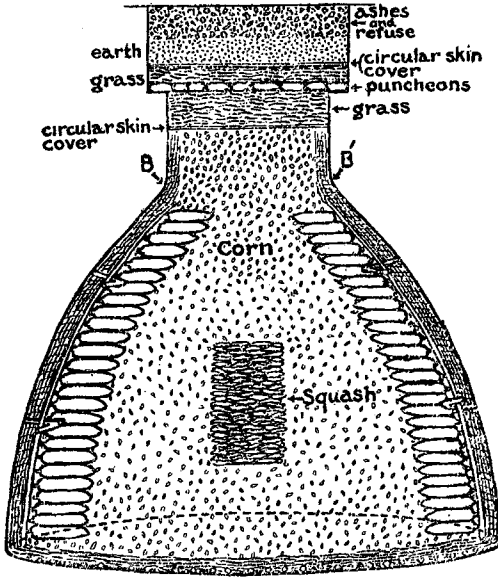
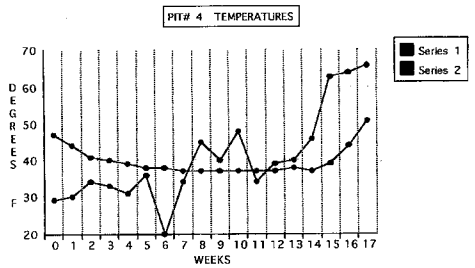
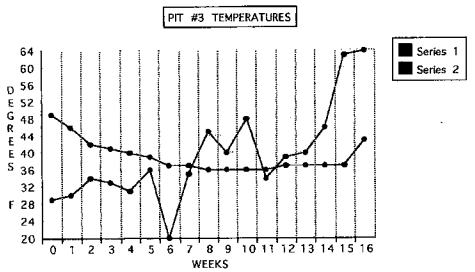
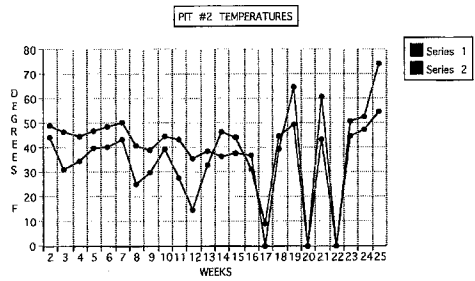
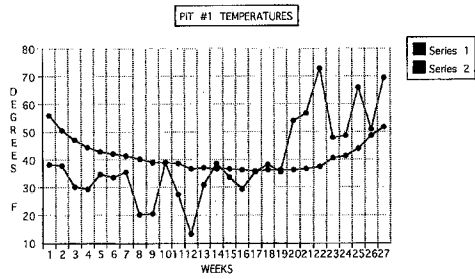
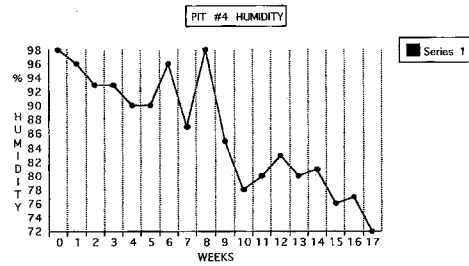
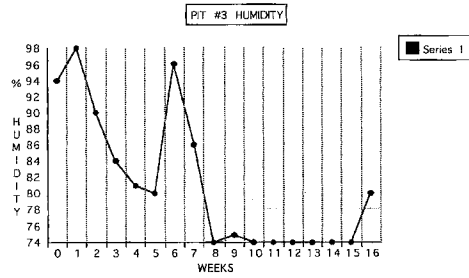
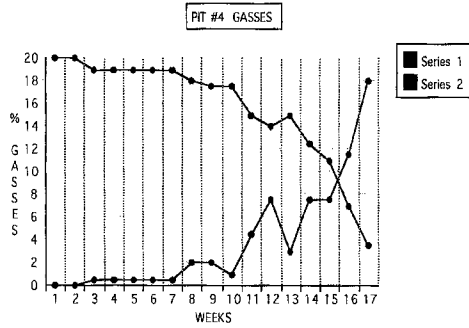
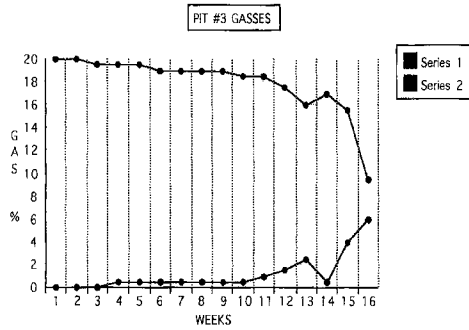


Diagram of Hidatsa Storage Pit from Buffalo Bird Woman's Garden by Gilbert L. Wilson





## REFERENCES

- Arzigian, Constance M. , Robert F. Boszhardt, James L. Theler, Rolland Rodell, and Michael J. Scott 1989 Human Adaptation in the Upper Mississippi Valley: A Study Of The Pammel Creek Oneota Site (47Lc61) La Crosse, Wisconsin *The Wisconsin Archeologist* vol. 70, nos. 1-2 March-June  
 Site report; including information on profiles, distribution, and contents of pit features. Floral remains, subsistence practices, seasonality.
- Arzigian, Constance M., Robert F. Boszhardt, Holly P. Halverson, and James L. Theler 1994 The Gunderson Site: An Oneota Village and Cemetary In La Crosse, Wisconsin *Journal of the Iowa Archaeological Society* vol. 41  
 Site report, including placement and contents of storage/refuse pit features. no profiles.
- Bassett, Everett Diet Breadth and the Limitations and Potential of Prehistoric Subterranean Storage 1996 University of Utah Unpublished Paper- presented at the Society for American Archaeology annual meeting, New Orleans  
 Experimental work-in-progress: different pit linings and shapes being tested, physical characteristics of pits, food loss, infestation, respiration replication of prehistoric technology.
- Blaine, Martha Royce 1979 The Ioway Indians University of Oklahoma Press Norman, OK  
 General history of the Ioway from contact to removal and assignment of allotments. Information on lifeways, including agriculture , other food-getting strategies and storage.
- Boszhardt, Robert F. 1985 Final Cultural Resources Investigations Along CTH "SN" in La Crosse County, Wisconsin with contributions by James Theler, Arthur Bettis, Dean Thompson, and Cynthia Stiles-Hanson. Reports of Investigations #33 Mississippi Valley Archaeology Center  
 Site reports for 47Lc43, 47Lc44, and 47Lc45; many pit features, information on size and shape of pits. Possible clay pit cap.
- Boszhardt, Robert F. 1992a Phase III Archaeological Mitigation at the Trane Site (47Lc447) La Crosse, Wisconsin Reports of Investigations #138 Mississippi Valley Archaeology Center  
 Information on size, shape, and placement of storage pits with respect to burials, pit contents including floral remains: bark and squash in one pit.
- Dickens, Roy S. Jr. and H. Trawick Ward, eds. Structure and Process in Southeastern Archaeology University of Alabama Press (no date)  
 Partial xerox of book, no date on title page. Different types of storage pits in the Southeastern U.S., their functions, seasonality, and use after emptying.
- Funk, Robert E. and Charles F. Hayes III, eds. 1977 Current Perspectives in Northeastern Archaeology- Essays in Honor of William A. Ritchie New York State Archaeological Association Rochester and Albany, New York  
 Pits in the Northeastern U.S., storage and other. Pit shapes, locations, and functions. Statistical analysis of pit similarities.

- Gallagher, J.P. , Constance M. Arzigian, Robert F. Boszhardt, Charles R. Moffat, and James L. Theler 1992 Phase III Excavations at the Tremaine Site (47Lc95) The Midvale Interceptor Project Report of Investigations#133 Mississippi Valley Archaeology Center, University of Wisconsin-La Crosse  
 Site report; includes size (expressed as 'small', 'medium', or 'large'), shape, and placement of pit features (no profiles included), as well as content analysis, including charred floral remains.
- Gallagher, J.P., and Constance M. Arzigian 1994 A New Perspective on Late Prehistoric Agricultural Intensification in the Upper Mississippi River Valley Agricultural Origins and Development in the Midcontinent William Green, ed. Report #19, Office of the State Archaeologist, University of Iowa, Iowa City, IA  
 Subsistence strategies, risks in agricultural production, reasons for generation of food surplus, food storage.
- Gibbon, Guy 1986 The Mississippian Tradition: Oneota Culture Introduction to Wisconsin Archaeology: Background for Cultural Resource Planning W. Green, J.B. Stoltman, and A. Kehoe, eds. Special Issue of *The Wisconsin Archeologist* vol. 67, nos. 3-4 Sept.-Dec.  
 General description of Oneota artifacts and cultural practices, including food storage.
- Harvey, Amy E. 1979 Oneota Culture in Northwestern Iowa Report #12, Office of the State Archaeologist University of Iowa Iowa City, IA  
 Comparison of several Oneota sites, including dimensions of storage pits for some sites.
- McKusik, Marshall 1973 The Grant Oneota Village Report #4 Office of the State Archaeologist The University of Iowa, Iowa City, IA  
 Site report, includes information on dimensions of storage pits.
- Nash, Michael John (no date) Crop Conservation and Storage in Cool Temperate Climates Pergamon Press  
 Partial xerox copy of book; no date on title page. In spite of the title, mostly references to Roman storage methods (in this section), pit storage in Ethiopia, pre-storage treatments to improve keeping qualities.
- O'Gorman, Jodie 1995 The Tremaine Site Complex: Oneota Occupation in the LaCrosse Locality. Wisconsin Volume 3: The Tremaine Site (47Lc95) State Historical Society of Wisconsin Madison, Wisconsin  
 Massive report; Extensive and detailed feature summary, with information on exact dimensions and profiles of features (976 of them!) as well as feature contents.
- Overstreet, David F. 1976 The Grand River, Lake Koshkonong, Green Bay, and Lake Winnebago Phases: Eight Hundred Years of Oneota Prehistory in Eastern Wisconsin Ph.D. Thesis University of Wisconsin- Milwaukee  
 Ties together several sites into a regional system. Discussions of sites include shape and distribution of pits found, function, and contents. Emphasis on cultural similarities between sites.

Reynolds, Peter J. 1974 Experimental Iron Age Storage Pits: An Interim Report

Proceedings of the Prehistoric Society v.40 December

Work done in Britain on stored barley in chalk and clay soils, pit shapes and sizes, different ways of preparing grain for storage (whole ear, threshed with hulls left on, hulled). Seed respiration, temperature profiles, pit linings.

Smyth, Michael P. (no date) Domestic Storage Behaviour in Mesoamerica: An Ethnoarchaeological Approach

Partial xerox copy of book, no title page. Different types of storage in Mesoamerica with respect to politics: domestic, regional, and central State storage, and the different types of storage facilities used for each. How and why surplus is generated at these different levels.

Straffin, Dean 1971 The Kingston Oneota Site Office of the State Archaeologist of Iowa University of Iowa Iowa City, IA

Site report; includes good drawings of storage pit profiles.

Wilson, Gilbert L. 1987 Buffalo Bird Woman's Garden: Agriculture of the Hidatsa Indians Minnesota Historical Society Press St. Paul, MN (Originally published as Agriculture of the Hidatsa Indians: An Indian Interpretation University of Minnesota, 1917)

Ethnographical account; description by the informant of Hidatsa agricultural practices, including preparation of food for storage and construction of storage pits.

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