Costs and Benefits of Fremont Food Storage: Granary Construction Experiments in Range Creek Canyon

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1-Introduction

Food storage is an important adaptive strategy among many organisms faced with seasons of resource scarcity, including humans. Over 100 Fremont granaries and storage cists have been recorded in Range Creek Canyon (Figure 1). A permanent field station in the canyon provides a unique opportunity to study the relationship between time spent in granary construction and how well they protect the stored food from non-human competitors such as rodents, insects, and fungi.

Over the last three years, students in the University of Utah Archaeological Field School have constructed small scale replicas of prehistoric granaries recorded in the canyon. Construction techniques and raw materials were manipulated to provide variation in the cost of granary construction. These costs were measured as amount of time it took to acquire the raw materials as well as to construct the granary. Relative benefits were measured as the length of time that elapsed before non-human competitors breached the granary and pilfered the stored maize.

Our 2018 experiment focuses on the time of year granaries are filled. The results of this research are presented and avenues for future work outlined. Since the broad environmental setting of the canyon has remained relatively unchanged, these results have direct implications for modeling the costs and benefits of Fremont storage in Range Creek Canyon (RCC). More importantly, they illuminate the broad categories of costs and benefits associated with food storage in general.

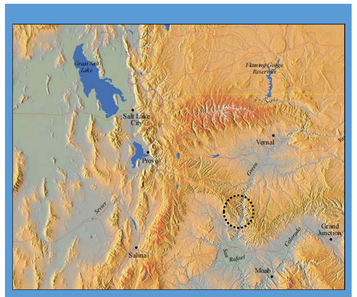


Figure 1. Map of central Utah showing the location of Range Creek Canyon.

2-Range Creek Archaeology

~500 sites recorded since 2002 showing intense Fremont occupation AD 900-1200.

Evidence for reliance on maize farming includes:

- maize starch on ground stone tools
- numerous maize cobs associated with storage features
- evidence for maize farm fields from sediment cores (isotopic chemistry, charcoal record, and maize pollen)

There are 112 storage sites recorded in RCC. Storage structures are not unique to RCC, or the Fremont, but RCC is significant for the density of storage facilities and their variability in size, construction techniques, and visibility.

Granaries are often situated on strikingly difficult to access ledges and on cliff faces well above the ground surface. The cost of constructing and using these granaries is very large, but we assume the benefits of preserving food for future use outweighs those costs, relative to the available alternatives options.

Size Summary

Large (n=48), Med (n=26), and Small (n=33)

Largest-Interior 158 x 130 cm Exterior 190 x 147 x 100 cm

Smallest-Interior 53 x 35 x 30 cm Exterior 72 x 45 cm

Wood Framing

Platform (n=8), interior base, roof/collar, or all three.

Number of walls and use of natural walls

Multi chamber/bins (n=14) Incorporate natural walls (n=52)

Figure 2. Summary of characteristics of construction used in cost investment analysis of RCC granaries including size, wood elements and number of walls.

3-Context: Investment in Construction of RCC Granaries

A series of actualistic experiments were conducted to investigate the tradeoff between effort spent in construction of granaries and their ability to protect stored maize. The emphasis is on construction type and material used, no effort was made to locate the experimental granaries in the same difficult to access settings as the prehistoric ones. Variability in prehistoric granaries in RCC served as the template, with descriptive summary of investment in construction emphasizing the following:

- Size. Larger granaries are more costly to construct because they require more raw material and labor investment relative to smaller granaries. Not all recorded granaries have complete size measurements because they are partially collapsed or impossible to access. Size for these granaries was estimated based on complete and measured examples (Figure 2) .
- Wood used in construction (complex framing, platform, interior/exterior base, roof, etc.). Granaries constructed with wood elements are considered to be more costly than those without (Figure 2).
- Use of natural features. Granaries that were constructed using natural features (ledges, small fissures, or cliff walls for one or more of their major boundaries (sides, floor, or roof) are considered less expensive than those that do not (Figure 2).
- Mud to stone ratio. All the prehistoric granaries in RCC use mud in their construction, but the proportion of mud to stone varies dramatically. Water is typically only available from seeps, springs, and Range Creek, all located on the canyon floor often well away from the locations of granaries. We assume that mud is more expensive than stone because of the transport costs. Stone is ubiquitous in RCC, water is not. We expected a higher proportion of stone to be used because it is more readily available on the landscape and more resistant to pest infiltration. This is not what we found.

The proportion of mud to stone was visually assessed for 73 structures (Figures 3 and 4). The majority of granaries examined were constructed of ≥50%. The spike at 30% mud includes all stone-lined, semi-subterranean cists. We realized our assumption that stone would be a less costly and therefore a preferred building material needed to be evaluated further. Our analysis of investment in construction combining all these characteristics is summarized in Figure 5.

4-Granary Construction Experiments 2006-2017

The first experiment in building a Fremont type granary in RCC was in 2006. A single granary was built in a shallow rock shelter (Figure 6). The granary is semi-circular measuring 68 X 117 X 113 cm. It incorporated the natural stone wall of the shelter and is constructed with an alternating mud brick and slab-stone wall, wood collar, and capstone. A second granary was constructed during the filming of Time Team America in 2008 (Figure 7). This granary was built against a large boulder exposed to the elements. It is similar in wall construction to the first granary but has two chambers and is considerably larger, measuring 56 X 183 X 83 cm. In both experiments, materials were gathered from within the canyon but not necessarily close to the construction sites. Modern equipment used included buckets, wheel barrel, vehicles for transportation, and water from a modern ditch. Some aspects of construction costs were recorded, such as amount of time and water required but total costs without the use of modern technology are not available. Both granaries were filled with dried seed corn (on the cob) in October and opened the following year when the field season began. Only the 2006 granary remained intact and protected corn from insects, pests, and water. The 2008 granary suffered rodent and water damage, and loss of all the stored maize, during the fall and winter months.

Figure 6. Photograph of the 2006 experimental granary.

Figure 7. Photograph of the 2008 experimental granary.

In 2016, the storage construction experiments continued with a more systematic approach to documenting costs for varying types of construction. Students in the archaeological field school were split into two groups to construct five types of small semi-subterranean cists (~35 x 35 cm; Figure 8). The cist types are based on the initial assumptions about the relative labor involved and the costs of different construction materials.

- Type 1-hole in the ground with a capstone
- Type 2-slab-lined and dry-laid with capstone
- Type 3-slab-lined, dry-laid, juniper-bark mat, and a capstone
- Type 4-slab-lined with mud mortar between slabs and a capstone
- Type 5-slab-lined, mortared, juniper-bark mat and capstone

Figure 8. Photographs showing examples of Type 2, Type 3, Type 4, and Type 5 cists (left to right) from 2016 experiment.

Our expectation was that Type 1 cists would require the least effort to construct and Type 5 the greatest, with the remaining types falling between these extremes. This ranking assumed that as additional types of raw material were added, there would be the additional cost of procuring, transporting and processing that material. Juniper bark was added to two of the types because juniper-bark mats have been observed in many RCC cists and interpreted as a rodent deterrent, natural desiccant, or both. Each group of students built two cists of each type only using tools available to the Fremont and construction materials had to be collected and transported on foot. Time investment includes: material collection, excavation, wall construction, problem solving and communication, filling, capping, and burying. Each cist was filled with 6 cups dry seed corn, end of July, and monitored for evidence of pest disturbance. All granaries were broken into by rodents within one month of completion. This pilot study was a great learning experience and foundation for designing future experiments, but yielded only preliminary data on costs and benefits of construction techniques (Figure 9, Boomgarden et al. 2017).

Based on lessons learned in 2016, in 2017 the following changes were made to the experimental design. First, only three types of granaries were constructed, all were completely above ground and distributed further apart compared to the previous year. All the granaries were either wet-laid or constructed entirely of mud, similar to Fremont granaries recorded in RCC. Students worked alone and built one example of each of the three granary types (Figure 10). Each granary wall was pierced by a small, closable access tube allowing active monitoring of the stored maize kernels. Last, we offered a substantial prize for the granary that protected stored maize the longest.

- Type 1 – Constructed entirely of mud bricks, wood collar and a capstone
- Type 2 – Mud mortared, upright slabs (ca. 10-20% mud), wood collar and capstone
- Type 3 – Wet-laid, horizontally-coursed, stone (ca. 50% mud), wood collar and capstone

Eight students built 24 granaries in 2017. Recording costs was much more successful than in previous experiments (Figure 11). Pests managed to access the stored maize in all 24 granaries within 26 days of completion, so the benefits of the different construction techniques is unclear.

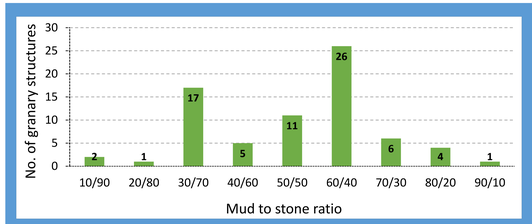


Figure 3. Chart showing the ratio of mud to stone used in the construction of 73 structures. The majority of the structures had equal or greater amount of mud in the construction except in those granaries with a stone-lined subterranean construction which account for the spike in the ratio of 30/70.

Figure 4. These photographs show some examples of the range of variability in mud to stone ratio with examples of more stone on the left to a more mud and mud bricks on the right and the variability in mixing roughly equal amounts of stone and mud in the middle.

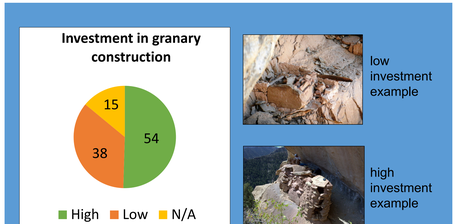


Figure 5. Chart summarizing level of investment in granary construction based on size, wood elements, number of walls and mud to stone ratio.

5- Granary Construction Experiment 2018

The 2018 experimental granary protocol differed from 2017 in one significant attribute: rather than filling and sealing the granaries shortly after completion in July, this task was delayed until October. Because of the success of the 2006 granary at protecting stored maize from predation, we wanted to investigate the possibility that leaving the granaries open longer might allow for more complete drying of the mud mortar, and whether the incentives for rodents and other competitors might decrease later in the season. It also more closely replicates the probable timing of Fremont use of granaries: maize would not have been harvested until fall and would have to be air-dried before storage. Another difference between 2017 and 2018 is that students were required to construct only one granary.

Each student was assigned one of the three types defined in 2017 (Figure 10). The students recorded all the costs associated with each of the construction activities and in the fall the granaries were filled and capped (Figure 12). The granaries will not be checked again until the spring of 2019 and evidence of weathering, pest damage, structural failure, and remaining stored maize will be recorded at that time. This will allow the variation in costs of construction to be assessed in terms of the benefits of storing food in these facilities. The results will inform the 2019 experiment.

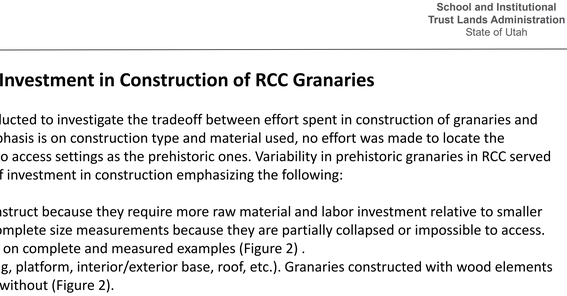
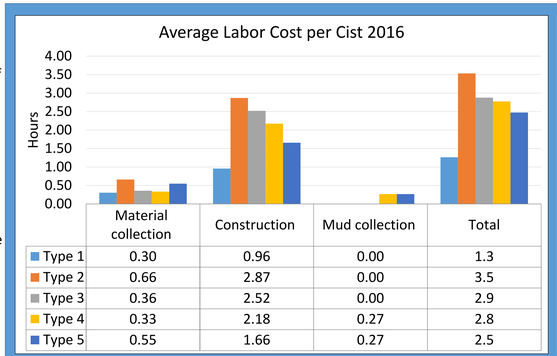
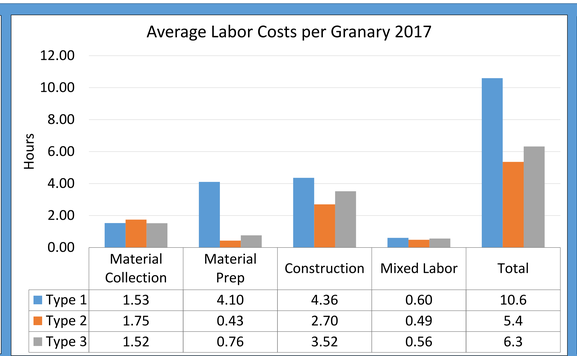


Figure 10. Examples of 2017-18 experimental granaries (below) and their RCC counterpart (above).



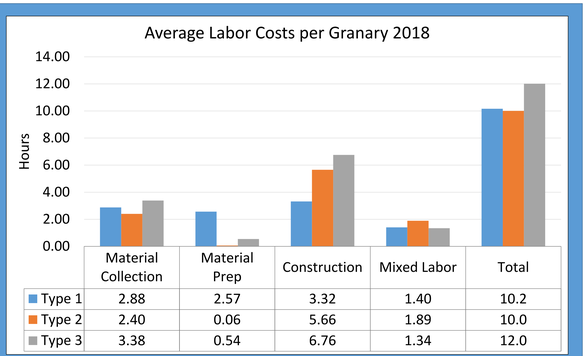
	Material collection	Construction	Mud collection	Total
Type 1	0.30	0.96	0.00	1.3
Type 2	0.66	2.87	0.00	3.5
Type 3	0.36	2.52	0.00	2.9
Type 4	0.33	2.18	0.27	2.8
Type 5	0.55	1.66	0.27	2.5

Figure 9. Graph summarizing the average labor costs per in person hours per cist in the 2015 experiment. These results are for 20 cists (2 of each type) built by five students.



	Material Collection	Material Prep	Construction	Mixed Labor	Total
Type 1	1.53	4.10	4.36	0.60	10.6
Type 2	1.75	0.43	2.70	0.49	5.4
Type 3	1.52	0.76	3.52	0.56	6.3

Figure 11. Graph summarizing the average labor costs per in person hours per granary in the 2017 experiment. These results are for 24 granaries (8 of each type) built by 8 students



	Material Collection	Material Prep	Construction	Mixed Labor	Total
Type 1	2.88	2.57	3.32	1.40	10.2
Type 2	2.40	0.06	5.66	1.89	10.0
Type 3	3.38	0.54	6.76	1.34	12.0

Figure 12. Graph summarizing the average labor costs per in person hours per granary in the 2018 experiment. These results are for 11 granaries (4 Type 1, 4 Type 2, and 3 Type 3) built by 8 students.