

## *Pueblo Bonito Flute Replicas*

by Jonathan Walpole

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## Pueblo Bonito Flute Replicas

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This document describes the construction of several working replicas of flutes found at Pueblo Bonito, Chaco Canyon, New Mexico. The original flutes, estimated to be between 1000 and 1300 years old, and of Anasazi (Ancestral Puebloan) origin, are shown in Figure 1. The replicas described here are of H-4559 and H-4560, both of which are complete flutes. These flutes are the uppermost flutes in Figure 1.



*Figure 1: Pueblo Bonito Flutes (image from Flutopedia)*

The tone hole positions for the replicas were calculated by enlarging the photograph shown in Figure 1, taking measurements from the enlarged photograph, and then scaling those measurements to the overall length of the flutes reported in George Pepper's original account [1]. The tone holes were sized based on the measurements reported in [1]. The replicas were made from PVC and CPVC tubing, with bore diameter similar to the measurements given in [1]. Heat was used to stretch the PVC pipe in order to taper the bore at the foot of each flute. The length and width of the taper was based approximately on the measurements reported in [1].

The precise details of the bore profile were not available. In

the absence of this important information, the replicas used a straight cylindrical bore. It is likely that the original bores were slightly conical, flaring toward the foot.

The measurements for each flute, original and replica, are given below. The holes are numbered from the foot up, and their position is measured relative to the blowing edge, in mm and as a percentage of the overall sounding length (SL).

H-4559 Original dimensions from scaled photograph:

H4	111 mm	21.5%
H3	159 mm	30.8%
H2	210 mm	40.7%
H1	256 mm	49.7%
SL	515 mm	100.0%

H-4559 Replica dimensions measured directly:

H4	111 mm	21.5%
H3	159 mm	30.8%
H2	210 mm	40.7%
H1	257 mm	49.8%
SL	516 mm	100.0%

Bore: 15 mm at head  
20 mm at base  
30 mm of flare  
Hole size: 4-5 mm  
Material: 1/2" PVC pipe

H-4560 Original dimensions from scaled photograph:

H4	126 mm	18.2%
H3	191 mm	27.5%
H2	265 mm	38.1%
H1	332 mm	47.8%
SL	695 mm	100.0%

H-4560 Replica dimensions measured directly:

H4	126 mm	18.2%
H3	191 mm	27.6%
H2	265 mm	38.3%
H1	332 mm	48.0%
SL	692 mm	100.0%

Bore: 17 mm at head  
21 mm at base  
35 mm of flare  
Hole size: 5-6 mm  
Material: 3/4" CTS CPVC pipe

The goal of making these replicas was to obtain a general idea of the sound of the original flutes. Given the lack of precise information about the bore profiles of the originals it is unreasonable to expect to reproduce the precise scale of the originals, because any discrepancies between the bore profiles of the originals and the replicas will influence the precise notes and fingerings. However, in most respects the replicas are quite close to the dimensions of the originals (within a few mm). Attempts to compensate for changes in bore and embouchure style did result in changes to the performance of the replicas, but such changes were relatively small.



*Figure 2: Replicas of H-4559, H-4560, and a "Desert" flute from Coyote Oldman*





*Figure 3: Tone hole placement for replicas of H-4559 and H-4560 compared to a modern "Desert" flute from Coyote Oldman*

The dimensions and scales of these replicas contrast sharply with those of other modern Anasazi flutes. For a visual comparison see Figures 2-5, which show the replicas of H-4559 and H-4560 alongside a modern "Desert" flute from Coyote Oldman.

The visual information alone suggests that the Pueblo Bonito flutes are high-pitched flutes. First, their high aspect ratio bore should optimize the performance of higher harmonics over lower harmonics. Second, the bell shape at the foot will amplify higher harmonics. Third, the placement of all tone holes in the upper half of the flute suggest that all notes will be at least an octave higher than the flute's bell note. These are some of the characteristics expected of the performance of the replicas.

## Scales and Fingering Charts for the Replicas

Each replica was played in front of an electronic tuner calibrated to A = 440 HZ. A variety of fingering and cross-fingering options were explored for each replica. The notes produced are presented below. The scale descriptions are consistent with the notes played and the general performance of the flute, but are essentially speculative.

### Notes Produced By Replica of H-4559

The tone holes are numbered from the foot up.

\* represents a closed hole, - represents an open hole.

Holes			
4	3	2	1
* - * -	root + octave + major third		G#6
* * - -	root + octave		E6
* * * *	root + major seventh		Eb6
- * * -	root + minor sixth		C6
- * * *	root + fifth		B5
- - * -	root + fourth		A5
- * - -	root + major third		G#5
* - - -	root + major second		F#5
* * - -	root		E5
* * * *	root - minor second		Eb5
* * * -	root - minor second		Eb5 (Bb4 faint)
* * * *	root - (octave + minor second)		Eb4

The intervals, in semitones, between the scale notes for H-4559, assuming E as the root are: 2 2 1 2 1 3 1

These intervals represent a harmonic major scale. The replica is also able to play the notes Bb4, C5, and Bb5, but these notes are faint and transient, coming from a harmonic that is difficult to sound.

An additional replica of H-4559 was made with enlarged tone holes, at the same locations. This large hole replica gave easier access to these harmonics and had a remarkable degree of instability between the different harmonics on several notes. A link to a recording of this modified replica, in addition to recordings of the more visually accurate replicas, is provided below.



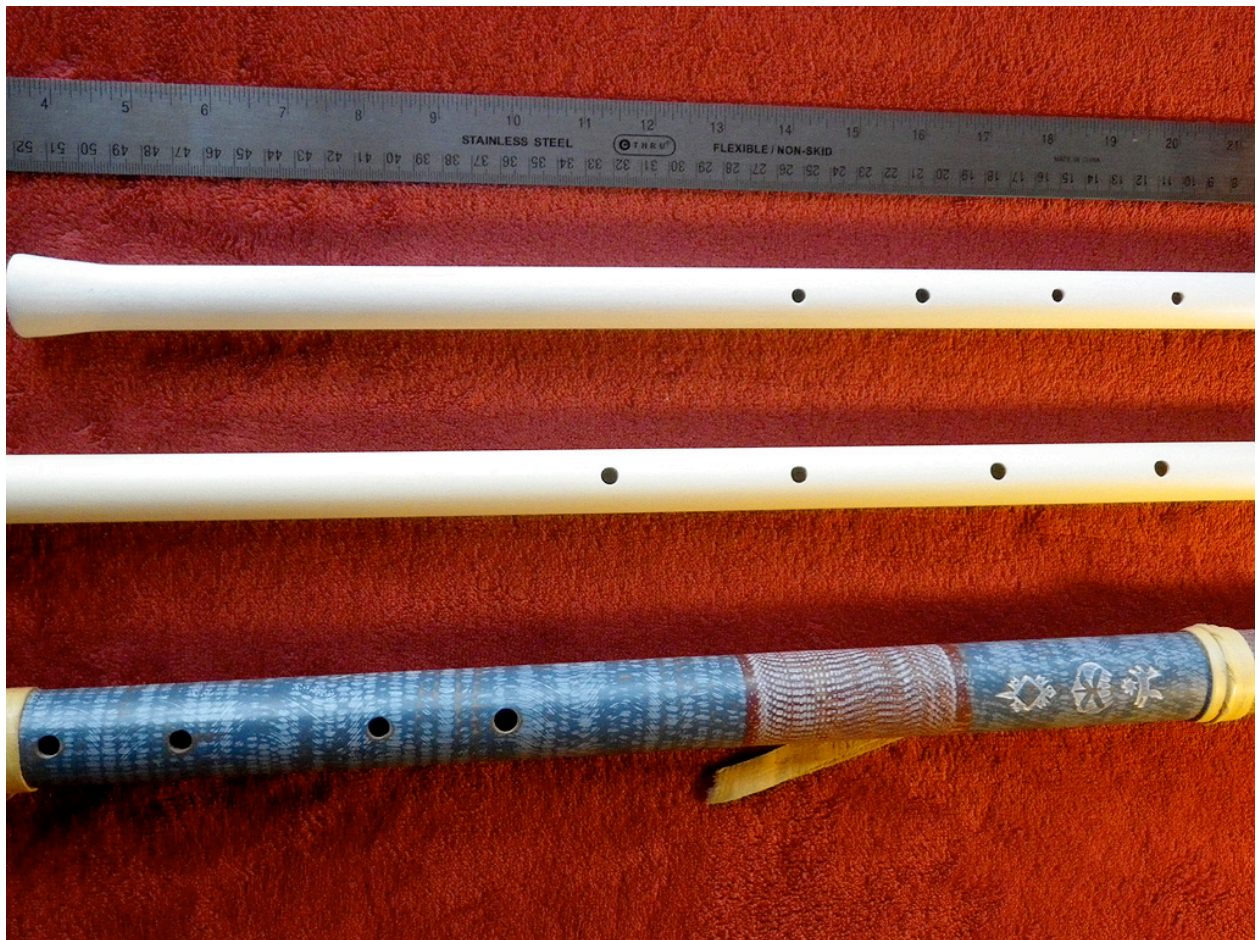
## Sound Samples for H-4559

A recording of the H-4559 replica is posted here:

<http://web.cecs.pdx.edu/~walpole/music/SmallMojaveWet.mp3>

A recording of a modified version of H-4559 with larger tone holes, allowing use of the faint harmonics discussed in the scale and fingering notes above is posted here:

<http://web.cecs.pdx.edu/~walpole/music/SmallMojaveLargeHoles.mp3>



*Figure 4: Tone hole placement for replicas of H-4559 and H-4560 compared to a modern "Desert" flute from Coyote Oldman*

## Notes Produced by Replica of H-4560

Holes

4 3 2 1

* - * *	F6	root + octave + perfect fifth
* - - *	Eb6	root + octave + perfect fourth
* * * *	D6	root + octave + major third
- * - -	B5	root + octave + minor second (Alt. * * - *)
- * * *	Bb5	root + octave (Alt. - * * -, * * * *)
- - * -	G#	root + minor seventh (Alt. - * * -)
- * * *	G5	root + major sixth
* * * *	F5	root + perfect fifth (Alt. * - * *)
* - - -	Eb5	root + perfect fourth
* - * -	D5	root + major third
* * - -	B4	root + minor second
* * * -	Bb4	root
* * * *	Bb3	root - octave

The intervals, in semitones, between the scale notes of H-4560, assuming Bb as the root, are: 1 3 1 2 2 1 2

Hence, the scale played by the replica of H-4560 is an inverse harmonic minor scale. Interestingly, the harmonic major and inverse harmonic minor scales share the same sequence of intervals, but each starts at a different point in the sequence. It seems unlikely that this similarity between H-4559 and H-4560 is purely coincidental.

**Sound Sample:** A recording of the H-4560 replica is posted here:

<http://web.cecs.pdx.edu/~walpole/music/BigMojaveWet.mp3>

## Replicas for Use With Oblique-Style Embouchure

The replicas discussed above used a slightly notched blowing edge and were tested using a vertical blowing style similar to that used when playing a shakuhachi. Evidence of a notched blowing edge was not visible in the photographs of the original flutes. Therefore, additional replicas of H-4559 and H-4560 were constructed with plain blowing edges and were tested using an oblique embouchure (as would be used to play an Arab or Turkish ney, or a kaval). These replicas used slightly narrower bore tubing. Specifically, the H-4559 replica used  $\frac{1}{2}$  inch schedule 80 PVC pipe, and the H-4560 replica used  $\frac{1}{2}$  inch schedule 40 PVC pipe. The use of an oblique embouchure lowers the pitch of both flutes, but has more effect on H-4559, lowering it by a semi-



tone.

### Notes produced by replica of H-4559 with oblique embouchure

Holes				
4	3	2	1	
*	*	-	-	root + octave Eb6
*	*	*	*	root + major seventh D6
-	*	*	-	root + minor sixth B5
-	*	*	*	root + fifth Bb5
-	-	*	-	root + fourth G#5
-	*	-	-	root + major third G5
*	-	-	-	root + major second F5
*	*	-	-	root Eb5
*	*	*	*	root Eb5

The intervals, in semitones, between the scale notes for H-4559, assuming Eb as the root are: 2 2 1 2 1 3 1. Hence the harmonic major scale remains unchanged.

The notes produced by the replica of H-4560 using an oblique embouchure were the same as the previous replica of H-4560.

Note that the scale of H-4559 is now pitched a perfect fourth higher than the scale of H-4560.

### Concluding Remarks

Working replicas of Pueblo Bonito flutes H-4559 and H4560 were produced. Both flutes were high pitched, seemingly optimized to play in the second and third octave, rather than the first. Despite having only four tone holes each they both played seven note scales. The scales while different shared the same underlying intervals between notes. H-4559 played a harmonic major scale. H-4560 played an inverse harmonic minor scale. When blow obliquely the roots of the two scales were separated by a perfect fourth.

The performance of the replicas was sensitive to small changes in bore profile, tone hole size and placement. However, among a dozen or so replicas that varied different parameters the following basic performance characteristics remained constant: all flutes were optimized for second octave performance and were capable of many small steps between notes in the second octave, generally sufficient to produce a scale similar to those described in this document.

## References

- [1] Pepper, George H., 1909. The Exploration of a Burial-Room in Pueblo Bonito, New Mexico. In *Putnam Anniversary Volume: Anthropological Essays Presented to Frederic Ward Putnam in Honor of His Seventieth Birthday, April 16, 1909, by His Friends and Associates*, 196-252. New York: G. E. Stechert & Co. Transcript available online at: <http://gamblershouse.wordpress.com/2009/09/19/room-33/>

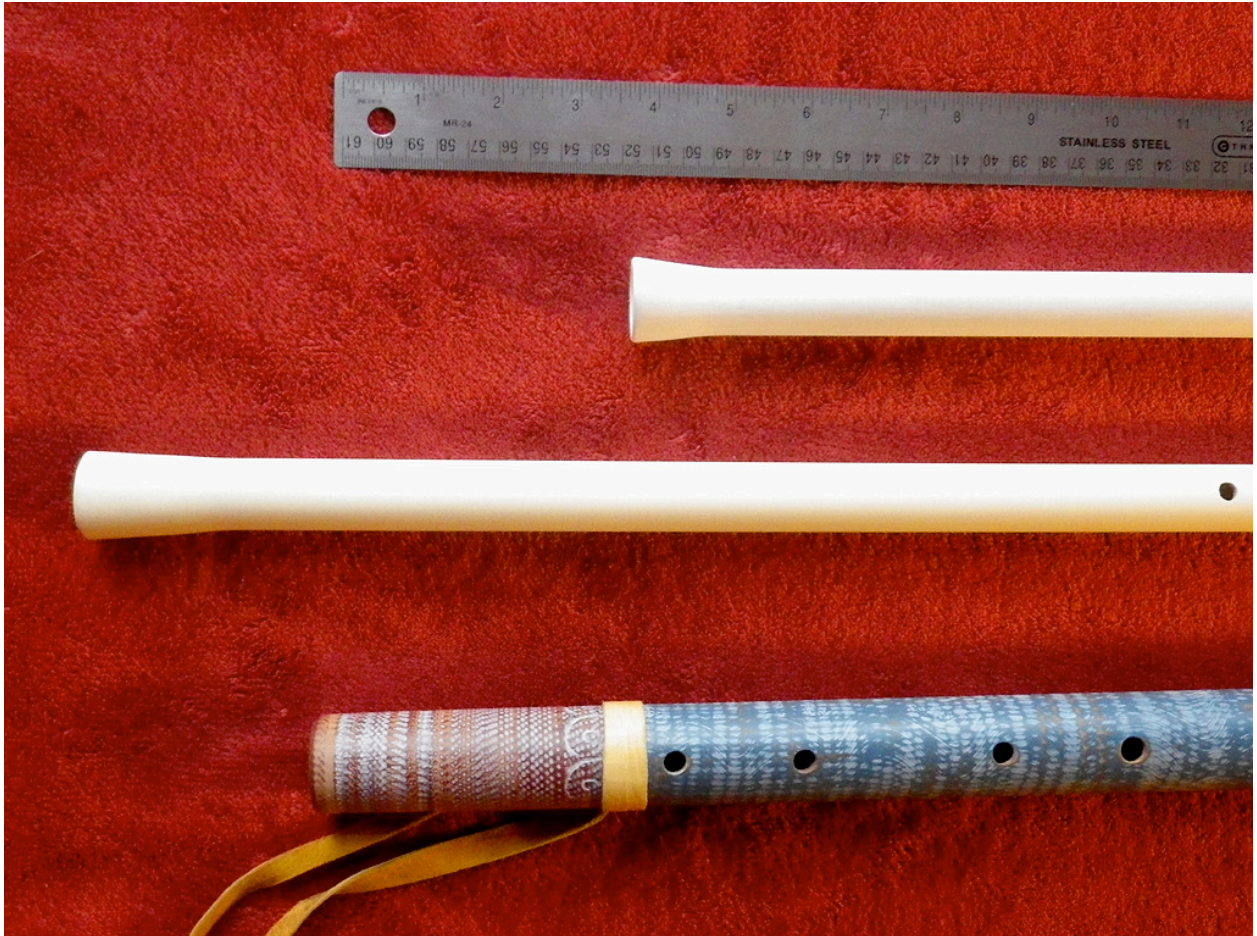


Figure 5: Foot of H-4559, H-4560 and modern "Desert" flute from Coyote Oldman