

*The Clay Pot That Sings: The Ocarina of Time**

Ray and Lee Dessy
Virginia Tech
Blacksburg, VA
dessyre@vt.edu

What sounds like a recorder, looks like an egg, a goose or flying saucer, is made of raku-fired clay or wood, makes music like some cicadas or crickets, and is at the heart of Nintendo's most famous computer game? It's the ocarina. This article examines its history, fabrication, playing characteristics, and use in recorder consorts. We'll see how ocarinas differ from recorders, and explore their new shapes.

AN EARLY HITCHHIKERS GUIDE

Ocarina-type musical instruments probably date back to 10,000 years BCE. Spherical Chinese *Xun* instruments appeared as early as 7,000 years ago, and examples of ancient Egyptian globular flutes exist. Small whistle-based terra-cotta figures of birds and other animals were known in India 6,000 years ago. The earliest pre-Columbian clay instruments are found on the coast of present-day Ecuador, and date from 2,000 BCE. Aztec and Mayan zoomorphic hollow flute figures of armadillos, birds, and reptiles are known.

Typically single chambered, these latter instruments were often tuned to a non-Western scale, and were used in solo and ensemble playing for both ritual and pleasure. Some only played a few notes, but one ocarina archeological marvel, that X-rays show has three chambers, could play an impressive 17 notes.

* Originally published in *American Recorder*, March 2001;
<http://ourworld.compuserve.com/homepages/recorder/>

“People often think of these objects as playthings” says Sue De-Vale (UCLA). “That’s wrong”.¹ Sometimes “they’ve been written off as another small artifact” says Norman Hammond (Rutgers). Discoveries at Pacbitun (Belize), Guatemala, Honduras, Columbia, and Peru include double, triple, and even quadruple instruments, which can produce more than one note at a time. The ease with which clay could be rolled, pinched, pierced and cut allowed these cultures to advance musically at a time when Europe was playing with simple flutes.

Samuel Marti, a Mexican anthropologist, writes “There can be no doubt that pre-Columbian music reached a level of development comparable, perhaps superior, to the contemporary cultures of Europe”.¹ One early Mayan ocarina, dating from 500-600 BCE, is advanced enough to play the first five notes of a diatonic scale. Studies on Colombian instruments show that many had similar tuning systems, allowing them to play in harmony. Dale Olsen (FSU) says “The care that went into making these instruments suggests that they were more than diversions or toys.”¹

BEST OF TIMES, WORST OF TIMES

Ocarinas were brought to Europe after the Spanish conquest when Cortes sent a group of Aztec dancers and musicians to the court of Emperor Charles V. In 1527 they performed at Valladolid. The *alto-plano* bird dancers moved in synchronicity with the fippled pottery ocarinas.

One story has a Roman baker using his oven to make low-fire copies as toys and novelty items. The ovoid body and short stubby fipple neck led to the word “ocarina”, meaning “little goose” in the Emilian Italian dialect.

The ocarina was slowly “modernized”, and in the mid-1800’s Italian craftsmen produced instruments that played a complete scale. This was an era when the

¹ *New York Times*: Science Section March 29, 1988, p C-1
<http://www.statnekov.com/peruwhistles/nytimes.html>

demand for inexpensive musical instruments increased dramatically. It was the time for ocarinas and harmonicas. People were happy and prosperous. In the 1860's the economic growth rate in the North "German" area was 8-10% annually, thanks to free trade (*Zollverein*), new rail systems, the industrial revolution, and Bismark's luck. {The stock_fever.com bubble (*Grundungsfieber*) didn't break till 1873.} The Kingdom of Italy was formed in 1861. In the 1860's Giuseppe Donati set up his first workshop in Budrio, then Bologna, and finally Milan. In 1870 two ex-apprentices, Ercole and Alberto Mezzetti, set up shop in Paris and London, respectively. In 1878 Cesare Vicinelli began making ocarinas near Budrio, and in 1920 he left his workshop to his assistant Guido Chiesa. Arrigo Mignani finally bought the workshop, and its tools, in 1964. *Ocarina di Budrio* are now prominent at their Website.²

World-War I/II servicemen kept up morale with molded plaster and Bakelite ocarinas, respectively, because of their size and ease of instruction. All of these had the traditional goose or sweet-potato shape. The 1930's heard a new Broadway sound in *Girl Crazy* and *Anything Goes* from the "Sweet Potato Tooters", and in the 1950's ocarinas escaped in *Stalag 17*.

The first step in a more recent "ocarina of time" revolution occurred in the 1960's when folk-music and folk-instruments began to come out of the woods. The reshaping of the ocarina began with John Taylor of London, who made the first modern four-hole ocarinas in 1963. Imagine four different sized holes as binary bits. How many combinations are there?- 16. And here, we must pause to outline the difference between recorders and ocarinas.

OCARINAS FROM VENUS; RECORDERS FROM MARS

Recorders (*flûte à neuf trous*, with nine holes) play a fifteenth or more. They rely on the ability of opened holes to shorten the effective length of the bore, and

² <http://www.ocarina.it/>

support four registers as the wavelength of the standing acoustic wave is shortened, and the acoustic frequency correspondingly increased (wavelength = speed-of-sound/frequency).³ The complex airflow moving from the windway over the labium develops a resonance condition with the standing wave in the bore, stabilizing the struck note. Resonance describes things like pushing a swing to greater excursions by timing the push with the swing's motion.

Ocarinas are Helmholtz resonators. **(Figure 1)** Named after Hermann von Helmholtz (1821-1894), a German physiologist and philosopher, they were originally a collection of hollow spherical containers that had a small open neck at one end, and a smaller ear canal tube at the other. They were used to analyze complex musical tones. When the partial of a tone had the correct frequency, it would resonantly couple with the air in the sphere, and an amplified signal of only that sound would be heard by the listener. Until electronic instruments became available, it was the only way musical tones could be analyzed.

What does this have to do with ocarinas? An ocarina is a hollow vessel with a fipple assembly built into an extended section, or directly into the wall. This fipple is just like that in a recorder. The window plane is tangential to the body. As in a recorder, the ocarina's fipple assembly causes an in/out air motion that synergistically interacts with the Helmholtz resonator and creates a stable, loud sound for a desired note.⁴

Let's play with just one note-hole open. The mass of air in the vessel acts like a spring **(Figure 2)**. When you blow into the fipple assembly it creates an alternating pressure change uniform throughout the vessel's volume. This affects the plug of air in the note-hole, moving it in and out, just like the piston of a car engine. The mass of this air-piston is proportional to the (hole-area) * (hole-depth). As the piston air-plug pushes in, the air-spring in the vessel pushes it outward. As the air-piston pulls out, the air-spring pulls it back in. The open

³ "Principles of Recorder Design Explained, **AR, June 1992**, pp. 7-14

⁴ cf.: "What New Experiments ... Are Telling Us About Real Recorders", *AR*, 40: March 1999, p8.

note-hole in a thin vessel wall acts as if it had a flange, $_ | _ |$, on the inside and outside of the vessel, each with a height equal to the hole radius, making the hole-depth about twice the radius, or equal to the hole diameter. The physics of this Helmholtz Resonator is simple, and theory tells us that the oscillation frequency (sound frequency) is roughly proportional to the square-root of the (hole-diameter/vessel-volume).⁵ And, they're easy to make (**Fig 3**).

The bigger the vessel (the spring), the lower the frequency of the sound. The bigger the hole-area (the piston), the higher the frequency. The tone is quite pure, since harmonics and overtones are discouraged. The fascinating part is that for a given volume, the frequency is nearly ***independent of the shape*** of the vessel. The frequency is nearly ***proportional to the square-root of the hole-diameter***. The "hole/piston-mass of air" need not involve just one open hole, but can be made up of numerous "note" holes. Several holes open at the same time simply add together.⁶ (**Figures 4, 5**) (* **see sidebar below**)

THE GOOD AND THE BAD

Theoretically, a clever pottery maker could pierce the walls of a hollow, fipple equipped vessel with four different sized holes and make an instrument that produces sixteen different rather pure tones that are chromatically related. The holes can be almost anywhere that makes playing easy.⁷ (**Figures 4, 5**) Their total open area is the important factor. John Taylor did just this, and created a road that many have followed. Unfortunately physics is always exact but often unkind. A little geometry and algebra suggests that some of the finger combinations are going to sound a bit "off" and a chromatic eighth is a reasonable goal. If you add another hole, the good combinations will allow a ninth. Some think that a sixth hole makes accepted fingering patterns sound better. Other makers suggest shading the window will let you add one note at

⁵ cf.: http://www.phy.duke.edu/~dtl/36h4_sho.html

⁶ The authors appreciate the experiments, comments and collegiality of John Coltman

⁷ <http://www.clayz.com>

the bottom. One maker adds a small hole near the fipple entrance, and your lip is used to open/close it, perhaps adding versatility.

The beauty of the ocarina is that the sound frequency is not determined by the length of a bore, as in a recorder. Recorder basses are big, since the scaling is linear! If you want to halve the frequency, you must double the length. In ocarinas, the frequency is determined by the ratio of dimensions in the square-root term, so that bass instruments don't need to be quite as big, in comparison.

What becomes important at the two extreme limits are: (1) is the instrument too small to accommodate big fingers, and will it output enough sound?, *versus* (2) is it too big for convenience, and will your finger pads cover the biggest holes? In between is a vast world for creativity. I have a five-hole clay ocarina in ~C5 that is 2 1/2 inches in diameter, about 1 1/2 inches thick, shaped like a flying saucer. The windway entrance is on the rim, the window and blade are on the bottom with the fifth hole, and it has four unequal diameter note-holes on the top. It can be worn with a thong around the neck as a pendant. (**see Ocarina photos**)

The "Italian Connection" of the ocarina made it natural to feature ocarinas in Ennio Morricone's film *The Good, The Bad, and the Ugly*, (original Italian title: *Il Buono, Il Brutto, Il Cattivo*). Public popularity grew. In Japan, Sohjiro's ocarina concerts and recordings generated a cult status, as we'll see when we look at the "Nintendo Connection".

TEN YEARS THAT SHOOK THE WORLD

When folk music was rediscovered in the '60s an ocarina rebirth took place. Recently, artisans have produced a phantasmagoria of shapes, kiln colors, plus single, double and triple ocarinas. Some of these are delights, while others may represent only "The Ugly" toys. We'll look at some of the best. Many Web sites offer sound bytes, so you can hear the bird sing.

Darryn Songbird⁸ makes a soprano alto, tenor, baritone, bass set in raku -fired unglazed clay. Clayz⁷ and Clay-Wood-Winds⁹ offer a glazed sopranino, soprano, alto, and tenor series. Often the naming of the instruments is inconsistent with recorder practice, so it is best to ask. Clay has a tendency to shrink in the firing process, so it is also common to find instruments that are in tune with themselves, and fully chromatic, but which are not tuned to a common scale. Alone, in the woods, on the street, or in your home, that doesn't matter. If you play with other instruments, it will, so it is best to request a concert pitch. Egg, arrowhead, ellipsoid and flying saucers shapes are available from a group associated with John Taylor.¹⁰ The Budrio² site displays the world of the "classical ocarina" from 6 hole- 10 hole, covering 4 octaves in a presentation set of 5 instruments, or individual units. **(see Ocarina photos)**

Hind¹¹ offers American Walnut ocarinas with 4, 6 or 8 holes, soprano, alto, tenor and bass, and double ocarinas pitched a fifth apart. *Avante garde* ceramic artisans such as Susan Rawcliffe and Anita Feng craft an eclectic, exotic collection.^{12,13} Ocarinas come with 4 to 10 holes, diatonic or chromatic, covering from an octave to an eleventh+. The shapes challenge anyone's imagination. **(see Ocarina photos)**

More complicated instruments are available. Some have more than one chamber in the instrument. Play a duet with yourself. Tune the two chambers a little apart, and get a harmony similar to dual reeded harmonicas. Janie Rezner¹⁴ makes a triple ocarina whose two front chambers play a full scale, while the back chamber plays a two note drone. The chambers come together at the top into a single divided mouthpiece, so the two front chambers can be played with/without the drone background.

⁸ <http://www.songbirdocarina.com>

⁹ <http://www.clay-wood-winds.com>

¹⁰ <http://www.ocarina.demon.co.uk>

¹¹ <http://germanmarketplace.com/hind.htm>

¹² <http://artawakening.com/soundworks/>

¹³ <http://www.scn.org/~bg599/ocarinas.html>

DIY: DO IT YOURSELF

Making ceramic ocarinas is an art. There are two basic approaches. One uses a mold like a tennis ball to form the two halves of the shell from moist clay.¹⁵

(Figure 3) The two halves are joined by slip clay, and pinched together. The windway and vent are put in place using wooden tools, and then the holes created with plunge sticks. The slightly dried instruments are tuned, and then fired. Post-firing tuning is necessary because of shrinkage. The other technique uses a solid body of clay, in the approximate final shape.¹⁶ It is cut apart by a string-cutter, and the interiors scooped out. The parts are reassembled, and then treated as described above. Some artisans use polychrome luster, white crackle glazes, seaweed, or other interesting things for decorative purposes during firing. In the best playing instruments the windway is tapered, the exit and the blade are positioned similar to that of a recorder, and the window has an aspect ratio a little squarer than the recorder.

CRICKETS, CICADAS, AND NINTENDO

With any musical instrument that has mass appeal, is easy to learn, and is not in the modern orchestral ensemble, there is always the caustic comment “It isn’t a serious instrument”. For such ocarina critics there is always Harrison, (Canticle 3 for ocarina, guitar and percussion); Budaschkin, (Domra Concerto for accordion, ocarina, and mandolin); Ichiyanagi (Concerto for 4 recorders, 2 ocarinas); or even Janacek and Respighi. If you like the sound, who cares what others say?

But the ocarina has at least one trump card recorders can't claim.

Nintendo’s best selling video game, *Legend of Zelda*TM: Ocarina of Time, has generated money for Nintendo (>250 million copies), as well as recognition for artisans like Anita Feng. Perhaps ocarinas have another card. Biological studies on the sound producing and sound detecting organs in certain cicadas and crickets involve Helmholtz Resonators. In some Australian species the male

¹⁴ *Ceramics Monthly*, May 1999, p64

¹⁵ <http://www.geocities.com/RainForest/Canopy/2525/whistles/whistle.html>
Clay Whistles...the Voice of Clay, Moniot, J., Whistle Press, 1990

¹⁶ <http://village.infoweb.ne.jp/~flute/egeioseisaku.htm>

abdomen forms such a structure, using a large air sac as the cavity vessel, and the tympana as the neck of the resonator. In some antipodal crickets a similar mechanism is involved. Within the same species, the maximum sensitivity of the female's ear, also a Helmholtz Resonator tuned device, coincides with the male's call carrier frequency.¹⁷ If it didn't, there'd be no little cicadas or crickets.

MAKING RECORDERS SWEETER

We urge you to experiment. The musical instruments are not expensive and well-tuned ocarinas can be purchased from ~\$25-\$75. They combine well with recorders, since the purity of their own sound complements the reediness of many recorders. For old movie buffs, watch Frank Capra's *Meet John Doe*.

The recorder player will have little trouble adapting to the pendant five hole ocarina, and the tonguing techniques used are identical. (For those interested, a following sidebar, called *Inside Spirit Vessels*, discusses the acoustics of Ocarinas and Spirit Vessels a bit more in depth). Although the resonance condition for a given ocarina note is a bit broader than a good recorder, and overblow or underblow will shift the frequency more than might be expected, the instrument returns in multiple kindness. It does not "break" with over or under pressure and uses almost a constant breath pressure from one end of the scale to the other. Air movement in and out of the tone holes seems a bit more sensitive to the proximity of lazy fingers. It is therefore easier to do slides, and you can use the fifth hole to do a glissando fifth! It is a wonderful instrument for the Blues and jazz. And if improvisation is new to you, the ocarina provides a wonderful companion that won't compromise your finger's muscle memory for stricter, more rigid music. Perhaps these lines sum up the ocarina:

"Come, visitant, attach to my reed your nest of clay,
And let my ear your music catch."¹⁸

¹⁷ J. Experimental Biology, 173: 123-163 (1992), Intl. J. Insect Morphology 22: 185-205 (1993)

¹⁸ Charlotte Smith (1749-1806) *Beachy Head with other poems* (1807)

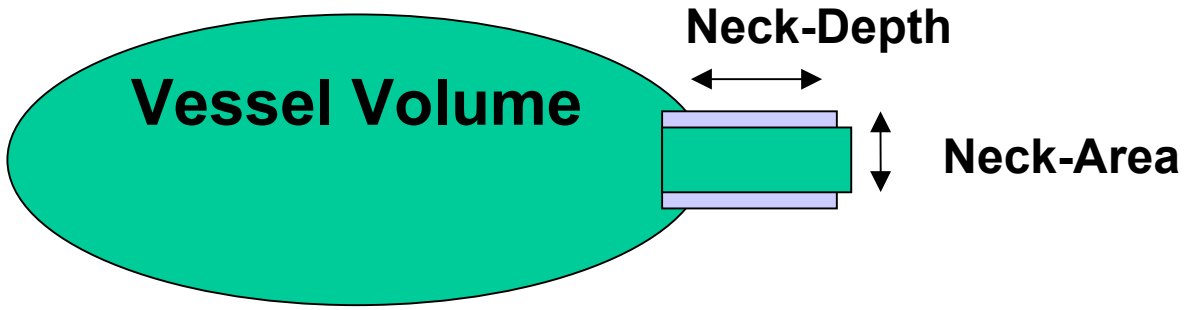
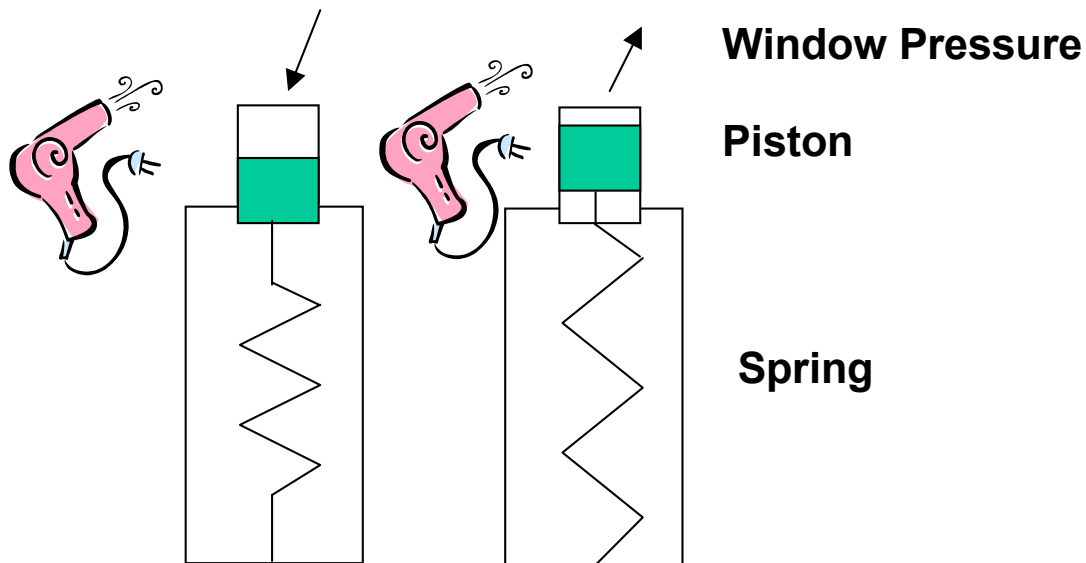


Figure 1. Helmholtz Resonator

$$f = (\text{sound_speed} / 2\pi) \sqrt{(\text{neck_area}) / (\text{neck_depth} * \text{vessel_volume})}$$

Figure 2. Why ocarinas work



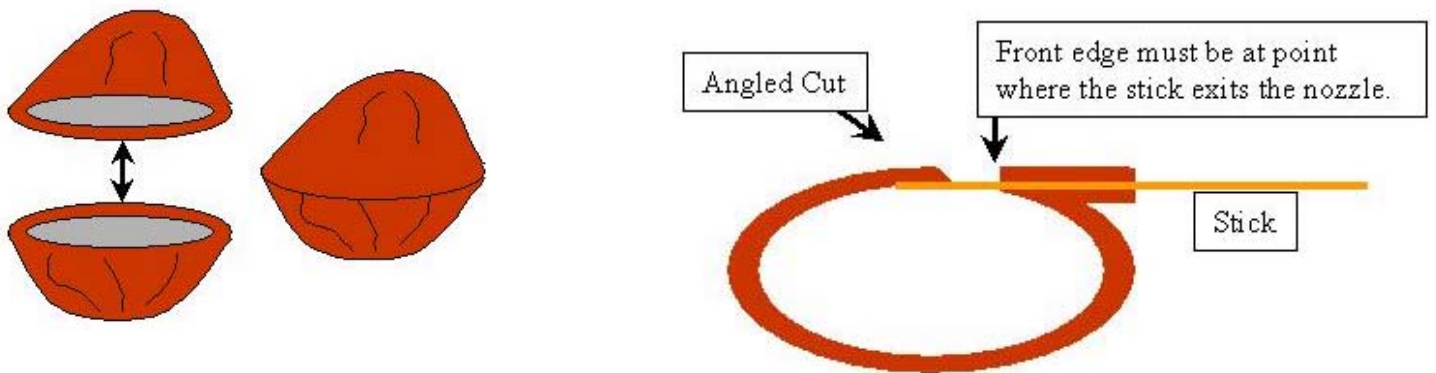
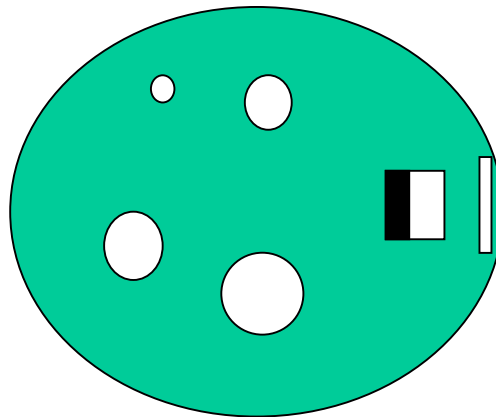
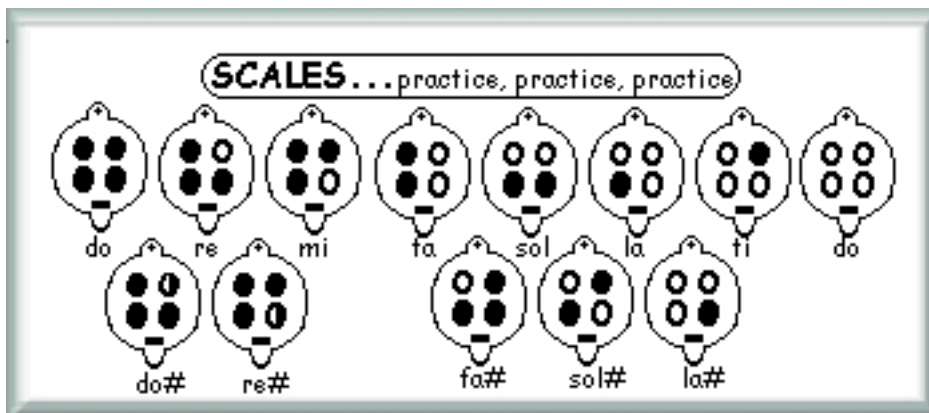


Figure 3. How Ocarinas are made, and Figures 4, 5. How Ocarinas make their various notes.



$$f = (c / 2\pi) \sqrt{((D1 + D2 + D3...) / V)}$$

$$Dn = \text{diameter_hole}\#n$$





OCARINA PHOTOS





* **SIDEBAR: INSIDE SPIRIT VESSELS, HOW THEY PLAY, HOW WE THINK:**

A classical Helmholtz Resonator might have a high resonance "quality" factor (Q) of 50 or more, depending upon the frequency. Q describes how narrow (Hi Q) or broad (Lo Q) a range of frequencies can easily excite resonance. Typical modern flutes have a Q of 35-40. You have to "hit" them just right. John Coltman, the flute expert, has taken a plastic toilet float ball (volume = 500 ml, or ~ 1 pint) and cut a 26 mm hole in it (~ 1 inch). For this Helmholtz Resonator the resonant frequency was 363 Hertz ($F\#(4)$ - $G(4)$), and the Q was 45. Very unusual interior shapes will add wall area, and reduce Q . Coltman has taken a somewhat irregularly shaped ocarina-like vessel flute in his collection, made by Martin Breton of Quebec, with ~2.5" x 2.5" x 2" inside dimensions. The blowing aperture is rectangular, 8 mm wide, 5 mm in the jet direction. With one finger hole opened the resonant frequency is 479 Hz (~ $B(4)$) with a $Q = 16$. Lower Q values would correlate with the ability of the ocarina to strike a note with ease, and shift frequencies with changes in breath pressure levels, yet not "break". "Bending" a note is simple. But, getting out of tune is also made easier.

The fact that the summed hole-size determines ocarina pitch explains why one can do glissandos over a wide range. Recorders often tend to "break" if the shading, sliding or rolling coverage is not smooth, and some holes are quite sensitive. In ocarinas, as the number of open holes changes, or as their size is changed, the frequency goes up or down easily. They are very tolerant of various shading, sliding, rolling and trilling techniques at any hole. Wipes and multi-finger warbles are simple, and chiffs are very rare. The effective flange height at each hole seems high, and offers performance opportunities. At higher frequencies the acoustic pressure in the vessel may not be constant throughout, especially in elongated shapes. Inharmonicities will result. You can't fight physics and the scale ends. The recorder goes on playing. The two are not competitors, but synergistic.

The basic dissonance between theory, artisan and player is summed up in an IRC exchange between David Peterson and Barry Jennings (John Taylor's associate). (<http://www.ocarina.demon.co.uk/FAQacad.html>)

Peterson: I am a mathematician. I have a partially verified formula (for the four hole ocarina) - the primary vagaries are the fipple impedance and equivalent depth of holes. Do you or John Taylor have any comment?

Jennings: (I am an instrument maker) Your terms ... are quite different- though we may refer to the same specifics. For instance you say "mass" whereas we think "volume". Can you (relate) the (volume) of an ocarina to pitch?

MANY SING, BUT NO ONE LISTENS

=====

Photo, drawing credits:

Dwight Bartholomew	(DIY ocarina sketch)
Sandi and Richard Schmidt	(fingering chart, clayz.com)
Robin Hodgkinson (photo by Coulter)	(instrument UL)
Charlie Hind	(instrument UR)
Darryn Songbird	(instrument LL)
Anita Feng	(instrument LR)
Kenji Ogawa	(classic ocarinas)