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An acoustic investigation**

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# **Non-modal phonation in Quiavini Zapotec: An acoustic investigation<sup>\*</sup>**

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## **1. Introduction**

Quiavini Zapotec has a cross-linguistically uncommon four-way phonation contrast between modal /a/, breathy /a̤/, creaky /a̰/ and interrupted /aʔ/ vowels (Munro and Lopez, 1999; Gordon and Ladefoged, 2001; Ladefoged 2003). Of particular interest is the distinction between creaky and interrupted voice, a phonetic distinction that is rarely used contrastively (Ladefoged and Maddieson, 1996). Here, I provide new phonetic and phonological evidence that supports these contrasts, and propose a novel analysis of the tone-phonation interaction in this language. Departing from Munro and Lopez (1999), Chávez-Peón (2010) demonstrated that tone is used contrastively in Quiavini Zapotec, showing that modal vowels —the default phonation type— may be associated with all four tones in this language (high, low, rising and falling). Within non-modal vowels, I propose in this study that breathy vowels are restricted to syllables with low and falling tones, whereas creaky and interrupted vowels appear with high, low and falling tones. That creaky and interrupted vowels can bear the same tones means that the distinction between them cannot be derived phonologically from tonal differences. The goal of this study is to present descriptive generalizations governing tone and non-modal phonation in Quiavini Zapotec.

Here, I present a separate section to each non-modal phonation type in Quiavini Zapotec: breathy, creaky and interrupted vowels. Each section provides a detailed acoustic description of these vowels based on the tones they interact with, along with minimal pairs. Issues in these analyses include the interaction between phonology and phonetics: how contrastive tone and phonation are manifested phonetically. This study finishes with a typological discussion of these findings.

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## 2. Breathy vowels

### 2.1. Introduction

This section presents a phonetic and phonological description of breathy vowels in Quiaviní Zapotec, with the aim of providing a descriptive generalization of this voice in the language. Breathy voice is a phonation in which the vocal cords vibrate, as they do in normal (modal) voicing, but are held further apart, so that a larger volume of air escapes between them (see Laver 1980, Ladefoged 1971, Gordon and Ladefoged, 2002 among others). A slightly less open stage of the vocal folds is attained with slack voice, where the vocal folds vibrate more loosely than in modal voice, also with a slightly higher rate of airflow than in modal voice (Ladefoged and Maddieson, 1996: 48). Breathy and slack voices may freely vary with each other allophonically. I show that breathy vowels in Quiaviní Zapotec may be associated with low and falling tones, as presented in Table 1.

Table 1. Breathy vowels and tone interaction

	High	Low	Falling	Rising
Breathy	X	√	√	X

The following examples illustrate the contrast between breathy-L (low tone) and breathy-F (falling tone).

(1) Breathy -L

/ bɛ̃ /ɿ → [ bɛ̃: ~ βɛ̃: ] ‘mold (growth)’

(2) Breathy-F

/ beṽ / ʋ → [ béṽ ~ βéṽ ] ‘turtle’

As the narrow phonetic transcription shows, the realization of these items normally includes a modal vowel portion followed by breathiness. As explained below, length patterns are the same for breathy-L and breathy-F lexical items. I now turn to the description of each of the breathy vowels.

### 2.2. Breathy-Low tone

An interaction between low tone and breathiness is extremely common cross-linguistically (see Gordon and Ladefoged 2002 and references therein), and is found in Quiaviní Zapotec. Examples below include fortis and lenis coda consonants. Arellanes and Chávez-Peón (2009) demonstrated that vowel length in Valley zapotec is determined by the coda type; phonetically, fortis consonants are preceded by short vowels, whereas vowels are long before lenis consonants or in open syllables.

(3) Breathy-L examples: fortis coda consonant

- a. / tʌp / ɹ → [ tʌp: ] ‘four’
- b. / gjet / ɹ → [ gjet: ] ‘squash’
- c. / nʌʃ / ɹ → [ nʌʃ: ] ‘chocolate’
- d. / nʌs / ɹ → [ nʌs: ] ‘the day before yesterday’

(4) Breathy-L examples: lenis coda consonant or open syllable

- a. / geɪz / ɹ → [ geɪz ] ‘town’
- b. / nʌ / ɹ → [ nʌ: ] ‘now’<sup>1</sup>
- c. / jʊ / ɹ → [ jʊ: ] ‘soil’

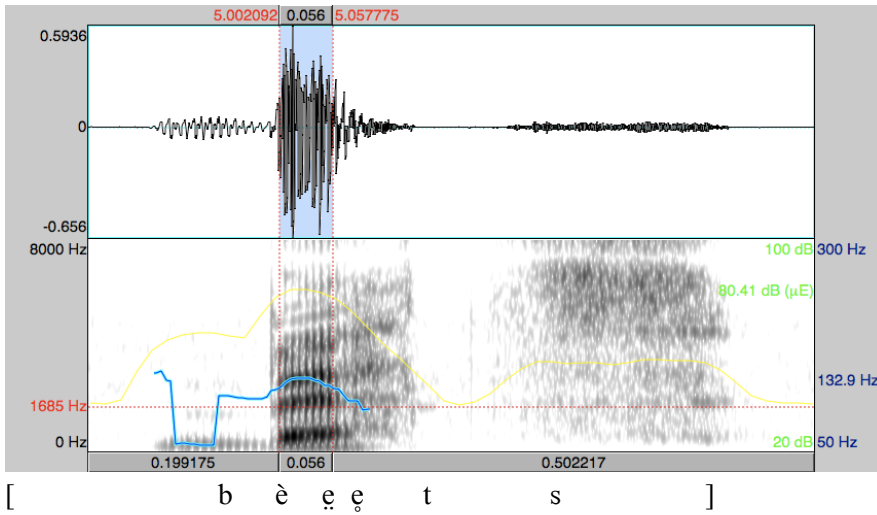


Figure 1. Waveform and spectrogram of / brɛtɪs / ɹ → [ brɛtɪs: ~ βɛ̃tɪs:] ‘(man’s) brother’ by male speaker TiuN.

<sup>1</sup> Also / nʌ / ɹ ‘hard’ (*nahah* ‘hard’ vs. *nah* ‘now’ in Munro & Lopez, 1999).

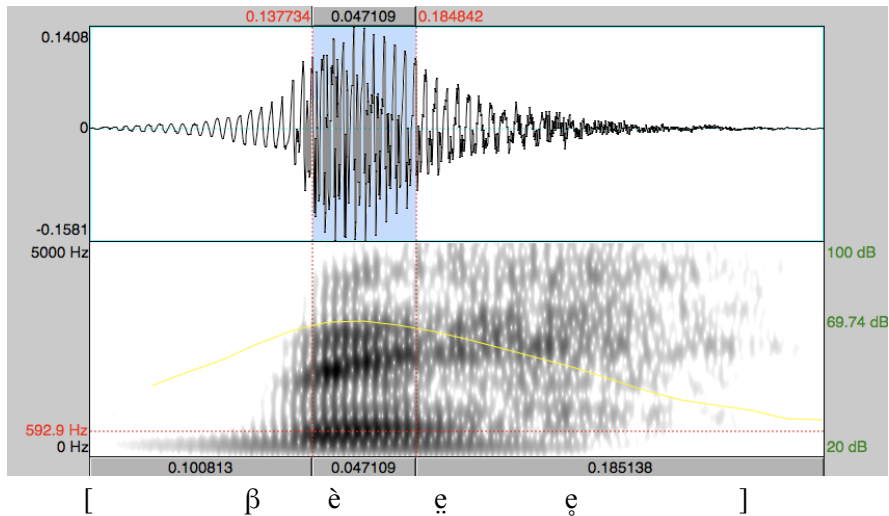


Figure 2. Waveform and spectrogram of /βɛ̃ / ɰ → [βɛ̃: ~ βɛ̃ɛ̃:] ‘mold (growth)’ by female speaker LiaL.

The above examples illustrate the modal-breathy-voiceless phonetic sequence as a common realization of breathy vowels. This is especially clear in the long vowel of /βɛ̃ / ɰ ‘mold (growth)’, where the high amplitude and the periodicity of the waveform decreases as the vowels progresses and fades away. Pitch values during the modal portion are equivalent to those of modal-L items for these speakers. Cross-linguistically, non-modal vowels are commonly accompanied by modal phonation, especially at the beginning of the vowel. This is the case in both tonal and non-tonal languages (Gordon and Ladefoged 2002); however, for tonal languages this laryngeal timing is particularly important as it is during modal phonation that tone is realized, because tone is realized during modal phonation (see Silverman, 1997). As implied by examples in (3) and (4), when underlyingly breathy vowels encode breathiness and tone, modal voice is used to implement phonetically the realization of tone (see also breathy vowels with falling tone below).

In order to confirm the contrastive character of breathy vowels in Quiavini Zapotec, the following minimal (contrast) sets consist of triplets made of modal-H, modal-L and breathy-L items.

- (5) a. / ʒi / ɰ → [ ʒí: ] ‘tomorrow’  
 b. / ʒi / ɰ → [ ʒì: ] ‘quite’  
 c. / ʒi. / ɰ → [ ʒĩ: ] ‘day’
- (6) a. / gjiɑ / ɰ → [ gjíɑ ] ‘will go home’  
 b. / gjiɑ / ɰ → [ gjìɑ ] ‘agave root’  
 c. / gjiɑ / ɰ → [ gjĩɑ ] ‘rock’

(7) a. /nɜ́ɪbj/ ɿ → [ nɜ́ɪ:bʲ ] ‘scared’

b. ---

c. /nɜ́ ɪbj/ ɿ → [ nɜ́ ɪbʲ ] ‘knee’

(8) a. ---

b. / na / ɿ → [ nà: ] ‘is (copula)’

c. / nà / ɿ → [ nâ: ] ‘now, hard’

### 2.3. Breathy-Falling tone

The following examples illustrate breathy vowels with falling tone.

(9) Breathy-F: fortis coda consonant

a. / nɟɛs / ʋ → [ nɟɛ̃s: ] ‘water’<sup>2</sup>

b. / bájɟ / ʋ → [ báá!ɟ ] ‘fire’

(10) Breathy-F: lenis coda consonant

a. / nǎɟ / ʋ → [ nǎǎ:ɟ ]<sup>3</sup> ‘wet’

b. / gǎ!gǐɟ / ʋ → [ gǎ!gǐ!ɟ ] ‘sickness’

c. / búɟ / ʋ → [ bú!ɟ ] ‘chicken’

d. / kǔb / ʋ → [ kǔ!b ] ‘tejate (traditional beverage)’

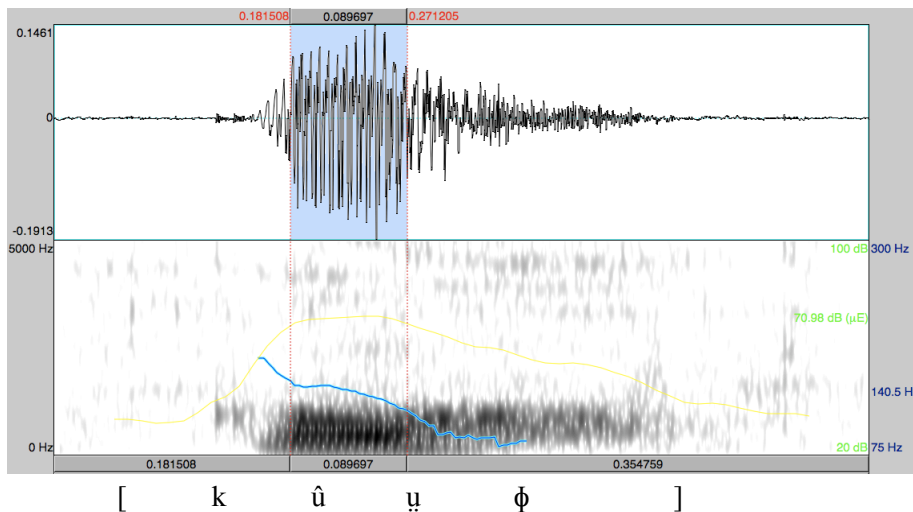


Figure 3. Waveform and spectrogram of / kǔb / ʋ ‘tejate’ by male speaker TiuR.

<sup>2</sup> One variant of this item contains a diphthong: / nɟɛs / ʋ → [ nɟɛ̃s ] ‘water’.

<sup>3</sup> Recall from Chapter 2 that lenis obstruents typically devoice word finally.

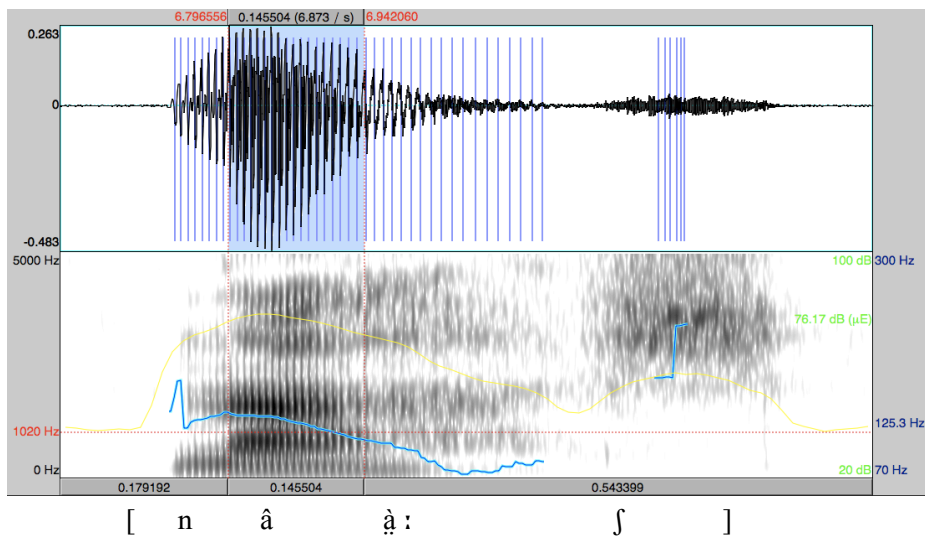


Figure 4. Waveform and spectrogram of / nəʒj / \ ‘wet’ by male speaker TiuL (Munro et al., 2008; Sound file: L3-3B)

As with breathy-L (low tone) examples, the modal-breathy voice quality sequence is also noticeable in breathy-F (falling tone) examples. During the modal portion of the vowel in Figures 3 and 4 we observe a quick rise (during the vowel in / kʊb / \ and during the nasal in / nəʒj / \) and a slow fall, becoming breathy towards the end. The preliminary rise can be analyzed as a phonetic preparation to reach a high pitch level so that the falling tone can be adequately perceived. In Figure 4, for instance, pitch reaches 130 Hz (equivalent to modal-H for this speaker) and falls below 100 Hz during the breathy portion.

The minimal pair in (11) contrasts modal-F vs. breathy-F, whereas (12) illustrates the distinction between breathy-L vs. breathy-F.

Modal-F vs. Breath-F:

- (11) a. / beu / \ → [ béù ] ‘moon’  
 b. / beʊ / \ → [ béù ] ‘turtle’

Breathy-L vs. Breath-F:

- (12) a. / nʌʃ / \ → [ nà:ʃ ] ‘chocolate’  
 b. / nəʒj / \ → [ ná:ʒʲ ] ‘wet’

### 3. Creaky vowels

#### 3.1. Introduction

Creaky voice, also called laryngealized voice or vocal fry,<sup>4</sup> is produced with the vocal folds vibrating anteriorly, but with the arytenoid cartilages pressed together; this induces a considerably lower rate of airflow than in modal voice (see e.g. Laver, 1980; Ladefoged, 1971; Gordon and Ladefoged, 2001).

In Quiavini Zapotec creaky vowels may be associated with both high and low level tones, as well as the falling contour tone. This is shown in the following table and illustrated with examples (13-15).

Table 2. Creaky vowels and tone interaction

	High	Low	Falling	Rising
Creaky	√	√	√	X

(13) Creaky H

/ bɛl̥ / ɿ → [ bɛ̃l̥ : ]<sup>5</sup> ‘(woman’s) sister’

(14) Creaky L

/ bɛl̥ / ˩ → [ bɛ̃ɛ̃l̥ : ] ‘snake’

(15) Creaky F

/ bɛl̥ / ˨˨ → [ bɛ̃ɛ̃ : l̥ ] ‘meat’

The purpose of this section is to describe in detail the phonetic and phonological properties of creaky vowels, providing a full account of the expression of creaky voice in Quiavini Zapotec.

#### 3.2. Creaky-High tone

The first cases I analyze are creaky vowels with high tone. This interaction is uncommon, as creaky voice is cross-linguistically associated with lowering of the fundamental frequency. As we will see below, the actual realization of creaky vowels with high tone is a weak laryngealization, in the form of tense (stiff) voice, which is presented in Ladefoged and Maddieson (1996, p. 48) as an intermediate step between modal and creaky voice, where the vocal folds vibrate more stiffly and with a slightly lower rate of airflow than in modal voice.<sup>6</sup> Tense voice, in contrast to prototypical creaky voice, is compatible with the manipulation of pitch.

As mentioned above, fortis coda consonants are preceded by short vowels, and lenis consonants by long vowels. Both types of syllables are found with creaky vowels as well.

<sup>4</sup> The term *laryngealized* voice is used here as a cover term to refer to both creaky and interrupted vowels.

<sup>5</sup> As illustrated here, creaky-H vowels are produced with tense voice, [ ẽ ] (symbol from Ladefoged and Maddieson, 1996, p. 100).

<sup>6</sup> This voice is not to be confused with harsh voice, sometimes also called “pressed” voice, which is produced with a different mechanism, with the upper larynx becoming highly constricted with the ventricular folds (see Edmonson and Esling 2006 for more details).



(16) Creaky-H examples: fortis coda consonant

- a. / bɛl̥ / ɿ → [ bɛl̥ : ] ‘(woman’s) sister’
- b. / rɣil̥:j / ɿ → [ rɣil̥:j ] ‘looks for’
- c. / zil̥:j / ɿ → [ zil̥:j ] ‘a lot of’

(17) Creaky-H examples: lenis coda consonant

- a. / bɛl / ɿ → [ bɛ̃ɛ̃:l̥ ] ‘naked’
- b. / rɣibj / ɿ → [ rɣĩĩ:ϕ̃ʲ ] ‘washes’

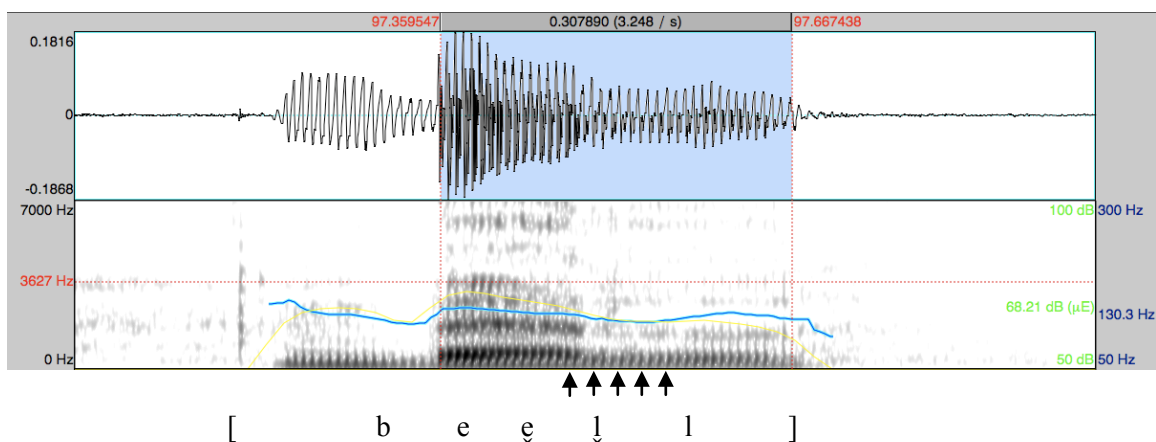


Figure 5. VCfortis example: Waveform and spectrogram of / bɛl̥ / ɿ ‘(woman’s) sister’, by male speaker TiuL (arrows indicate the tense voice portion).

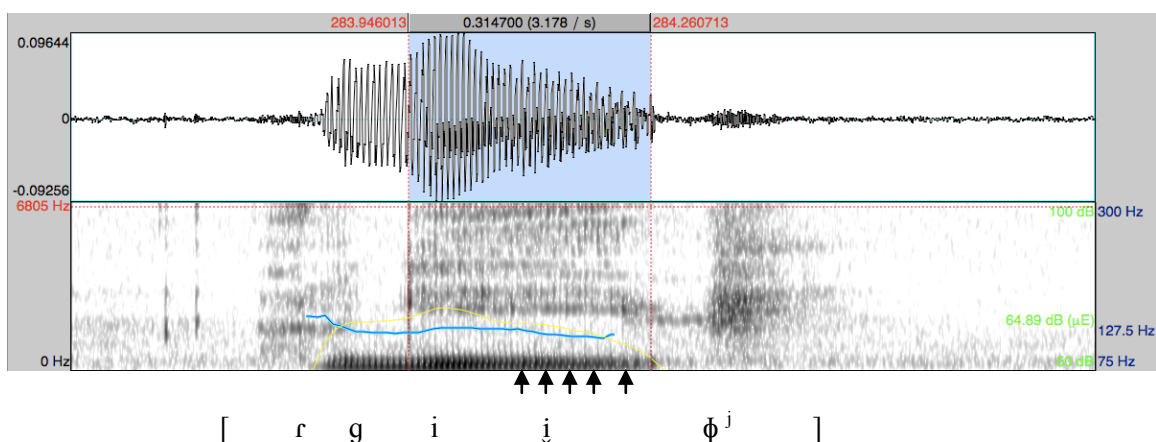


Figure 6. VClenis example: Waveform and spectrogram of / rɣibj / ɿ ‘washes’, by male speaker TiuL (arrows indicate the tense voice portion).

In terms of phonation, we observe in Figures 5 and 6 that the first part (or beginning) of the vowel is modal, whereas the second portion of it shows tense voice, mainly characterized here by the lower amplitude envelope.<sup>7</sup> In the case of / bɛl' / ɿ '(woman's) sister', the stiff or tense voice is observed at the end of the vowel and beginning of the fortis liquid. In addition, / rɔibj/ ɿ 'washes' (Figure 6) shows aperiodicity of the signal (i.e. some creakiness) at the end of the vowel.

Due to the possible co-articulation of tense voice and high tone, there might be instances without modal voice in the realization of short vowels. The degree of laryngealized voice varies by speaker.

With respect to tone, we observe a relatively flat pitch all the way through the vowel (and the fortis /l'/ in Figure 5), in both the modal and tense portions. It never drops so much that it can no longer be tracked automatically by pitch extraction, which commonly happens with true creaky vowels that have low and falling tones (see below).

### 3.3. Creaky-Low tone

As mentioned above, creaky voice is commonly associated with lowering of the fundamental frequency; thus, we would expect to find creaky-L items in Quiavini Zapotec. Consider the following examples.

(18) Creaky-L examples: fortis coda consonant

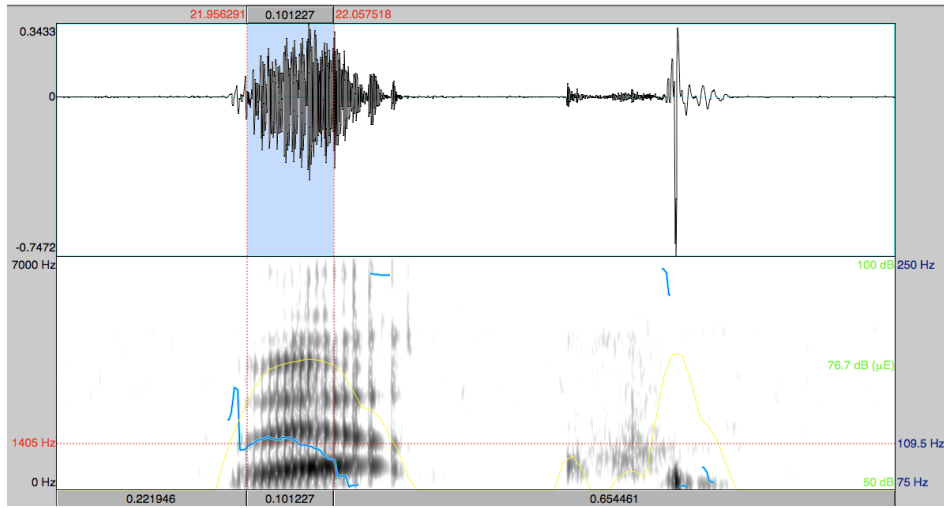
- a) / bɛl' / ɿ → [ bɛ̃ɛ̃l' ] 'snake'
- b) / bɛkw / ɿ → [ bɛ̃k'w ] 'dog'

(19) Creaky-L examples: lenis coda consonant or open syllable

- a) / rɔilj / ɿ → [ rɔ̃ĩ:l' ] 'waters'
- b) / sɪlj / ɿ → [ sɪ̃ĩ:l' ] 'breakfast'
- c) / rɔidj / ɿ → [ rɔ̃ĩ:d' ] 'sticks on'
- d) / bdɔ / ɿ → [ bd̃ɔ̃: ] 'baby'
- e) / rkaz / ɿ → [ rk̃ã:z ] 'wants'
- d) / jdɔ / ɿ → [ jd̃ɔ̃: ] 'church'

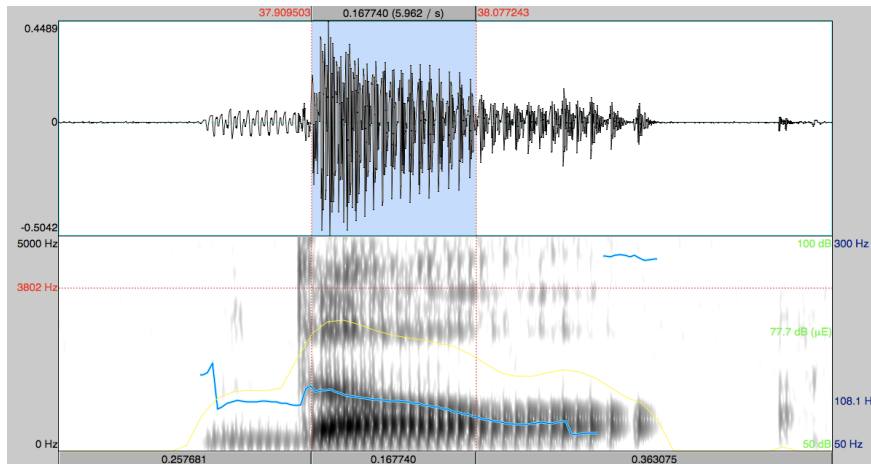
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<sup>7</sup> As noticed in Chapter 4, this striking change in the amplitude envelope is not observed in modal vowels with low, rising or falling tones, previously analyzed as items with weak laryngealization (Munro & Lopez, 1999).



[ b ɛ̃ k̃ w̃ ]

Figure 7. Waveform and spectrogram of / bɛ̃k̃w̃ / ʅ ‘dog’, by male speaker TiuL (Munro et al., 2008, sound file L3-3C).



[ b d ò ]

Figure 8. Waveform and spectrogram of / bdò / ʅ ‘baby’, by male speaker TiuL (Munro et al., 2008, sound file L3-3C).

Figures 7 and 8 exemplify the fact that Creaky-L items normally start with modal phonation, to continue into a creaky voice portion. Due to the degree of variation, it is possible to find some tokens with short vowels with creaky voice only; since creaky

voice inherently has low pitch, tone and non-modal voice may phonetically co-occur for these items.

A crucial point here in determining the tone of these items is that pitch values during the first portion of the vowel are similar to modal-L values. Concomitantly, the amplitude envelope goes along with pitch: it is sustained (higher) during the less laryngealized vowel portion, and then it drops as the vowels show more laryngeal constriction.

Figure 7 illustrates a rhyme formed by a short vowel with fortis coda consonant. The highlighted part corresponds to the less laryngealized portion of the vowel (close to modal). The pitch averages 110 Hz (range 100-114 Hz). Although the pitch is not quite flat, the numbers are in the range of modal-L tokens of this speaker (whose pitch also tends to drop towards the end).

Figure 8 illustrates a long vowel in an open syllable. The mean pitch of the first portion (highlighted) is 107 Hz (range 115-98 Hz). Phonetically, these long vowel tokens may seem to have falling pitch. However, two points suggest that these tokens are creaky-L. First, creaky-F items normally have a phonetic rise in pitch at the beginning of the vowel, but no rise is found in creaky-L items. Second, and more important, the values of the first portion of creaky-L items are lower than those found in the first portion of creaky-F vowels, and within the modal-L range.

### 3.4. Creaky-Falling tone

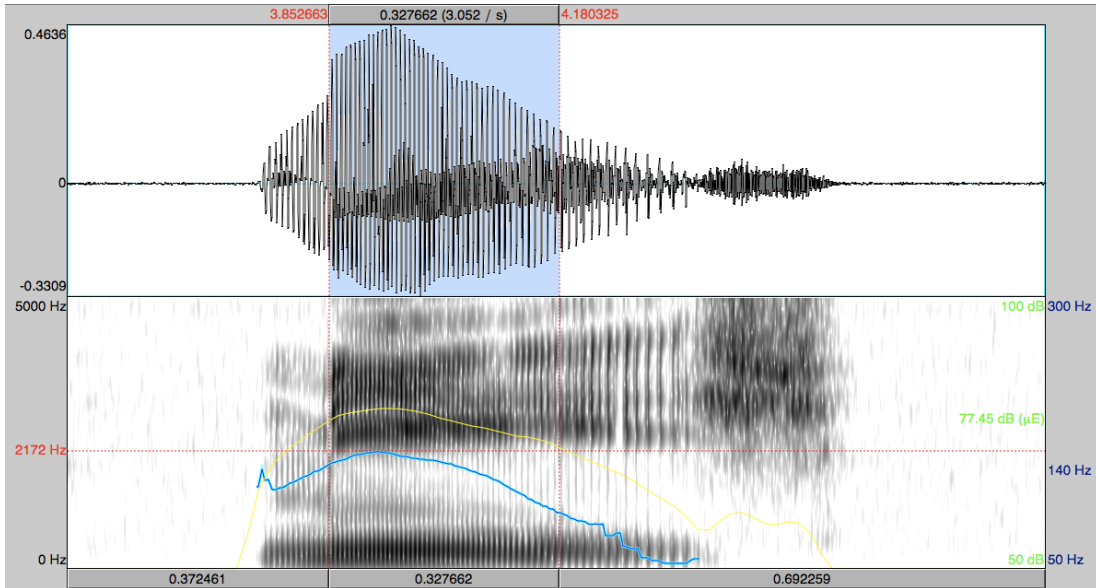
Creaky vowels also occur with falling tone, as illustrated below.

(20) Creaky-F examples: fortis coda consonant

- a) / n-gąts / ʌ → [ n̩gá̃̀ą̀ts: ] ‘yellow’  
 b) / n-gąsjąts / ʌ → [ n̩gąsjá̃̀ą̀ts: ] ‘really black’

(21) Creaky-F examples: lenis coda consonant or open syllable

- a) / mĩɜ / ʌ → [ m̩ĩ̃̀:ɜ ] ‘Mixe’  
 b) / ją / ʌ → [ j̩á̃̀: ] ‘up’  
 c) / ndą / ʌ → [ nd̩á̃̀: ] ‘hot’  
 d) / ɜjɜ / ʌ → [ ɜ̩ĩ̃̀:ɜ ] ‘pineapple’  
 e) / beu / ʌ → [ be̩ũ̀ ] ‘coyote’



[ m i: ɨ ʒ ]

Figure 9. Waveform and spectrogram of / miɜ /  $\backslash$ 'Mixe', by male speaker TiuL (Munro et al., 2008, sound file L3-3D).

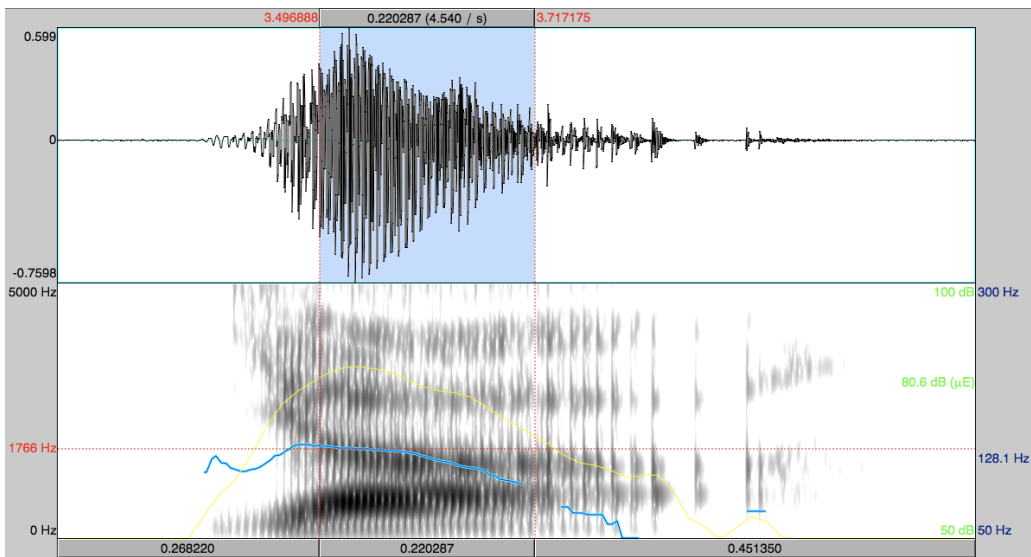


Figure 10. Waveform and spectrogram of / ja /  $\backslash$ 'up', by male speaker TiuL (Munro et al., 2008, sound file L3-3D).<sup>8</sup>

<sup>8</sup> Minimum pitch: 105 Hz; Maximum pitch: 142 Hz.

In terms of phonation, the first part of the vowel in creaky-F tokens is always modal, whereas the second (or last) part is creaky. Both Figures 9 and 10 clearly illustrate this voice sequence.

With respect to tone, often there is a small rise at the beginning of the vowel, so that the pitch might be sufficiently high to attain a significant falling contour.<sup>9</sup> This initial rise is clear at the beginning of the vowel in Figure 9, which reaches a maximum pitch of 157 Hz (even higher than the high tone pitch average of this speaker). The pitch falls to 101 Hz during the modal portion, continuing to fall even lower during the final creaky vowel portion.

These high pitch values at the beginning are similar to those found in modal-H values and this is the crucial difference to distinguish creaky vowels with falling tone versus low tone. Let us consider in parallel an example of each.

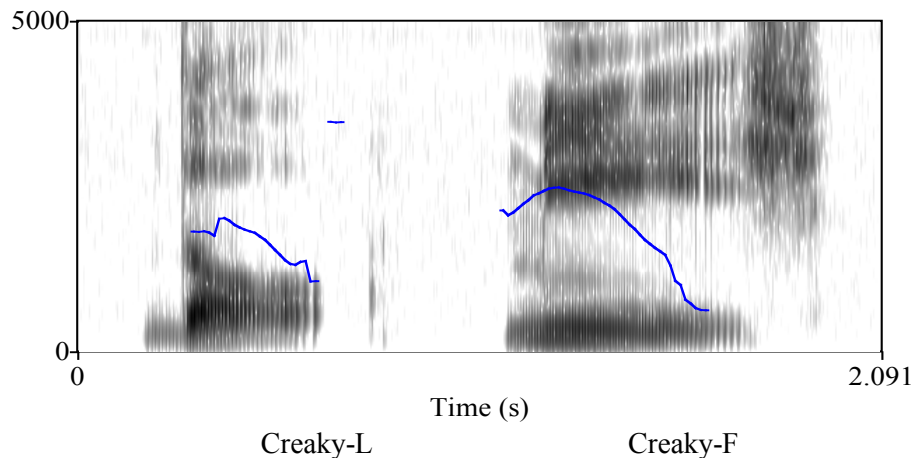


Figure 11. Spectrograms and pitch of / bdɔ̥ / ɹ 'baby' and / mɪ̥ʒ / ʌ 'Mixe', by male speaker TiuL.

There are important differences between creaky-L and creaky-F items, illustrated by Figure 11. For the former items there is never a clear pitch rise at the beginning, pitch is relatively flat during the less laryngealized portion, where I claim the phonological tone is expressed; then the pitch drops as the vowel gets creakier, to the point that it becomes difficult (or impossible) to track. On the other hand, creaky-F tokens normally show a rise at the beginning of the vowel and always have higher pitch values during the first modal vowel portion, showing a different pitch contour than that of creaky-L tokens.

<sup>9</sup> In Figures 8, we also observe a small rise at the beginning the creaky-L vowel (/ bdɔ̥ / ɹ 'baby'), but this seems to be related with the voicing of the consonant (Hombert et al., 1979). In contrast, the rise is clearer with /m/ in Figure 9 for / mɪ̥ʒ / ʌ 'mixe', and cross-linguistically nasals don't lower F0.

Strictly speaking both types of creaky vowels phonetically have a falling pitch (creaky-F shows a high-falling contour, whereas creaky-L a low-falling one); however, in the case of creaky-L tokens most of the fall occurs during the laryngealized portion, where the phonological tone is no longer expressed. In contrast, the examples of creaky-F tokens show that the fall is noticeable during the modal portion.

Perceptually, this seems like a case where the listener may be abstracting away from effects that are predictable, as in the case of abstracting away from the effects of co-articulation. Perceivers know that creaky voice causes pitch lowering, so the lowering due strictly to such phonation does not cause the tone to be perceived as falling.

The phonetic pitch fall characteristic of creaky vowels with low tone has also been described for other languages. According to Picanço (2005), Mundurukú (a Tupí language spoken in the Amazonian basin of Brazil) has both contrastive tones and phonation types: modal voice allows high vs. low tone, whereas creaky vowels only allow low tone. Comparing modal vs. creaky vowels with low tone, the latter is characterized by “lowered fundamental frequency, glottal pulses with longer duration, and variation between adjacent glottal pulses”; on top of that, pitch may lower as the vowel gets creakier, in other words, “Creaky voice is [...] manifested as a gradual fall in pitch.” (Picanço, 2005, p. 38).

## 4. Interrupted vowels

### 4.1. Introduction

In terms of the aperture between the arytenoid cartilages, the two extreme glottal states are a voiceless sound, with the arytenoids furthest apart, and a glottal closure, with the arytenoids closest together. This glottal closure is part of the fourth phonation type found in Quiavini Zapotec, that is *interrupted vowels* (or glottalized voice); the goal of this section is to present the phonetic and phonological characteristics of these vowels and the tones they may be associated with.

In Quiavini Zapotec, the term *interrupted vowels* refers to the strongest degree of laryngeal constriction in vowels in this language, phonologically transcribed as /a<sup>ʔ</sup>/. The superscript glottal stop indicates that the glottal closure is part of the vowel, i.e. it is a vocalic feature and not an independent segment (see Arellanes, 2009 and Chávez-Péon, 2010, Chapter 6 and for detailed discussion on regard the phonological status of the glottal stop).

Interrupted vowels are phonetically pronounced either as checked [a<sup>ʔ</sup>] (a modal vowel followed by a glottal closure) or as rearticulated [a<sup>ʔ</sup>a] (a sequence of modal vowel-glottal stop-modal vowel). Both realizations have a similar overall duration, but the glottal closure in the former is normally longer, and thus, it is not transcribed with a superscript. The glottal stop in interrupted vowels (either as checked or rearticulated) can range from a full closure to extremely low amplitude glottalized vowel. Which output is produced depends on the tone the vowels occur with. High-tone items are manifested with checked vowels, whereas low and falling tones are produced with rearticulated vowels. These different productions (checked vs. rearticulated) are grouped together

because they use the same laryngeal mechanism: extreme glottalization (either glottal closure or very pronounced creakiness). This phonation is not found with a rising tone (Table 3).

Table 3. Interrupted (Checked/rearticulated) vowels and tone interaction

	High	Low	Falling	Rising
Interrupted	√	√	√	X

(22) Interrupted-H (checked)

/ rga<sup>2</sup> / ɿ → [ rgáʔ<sup>a</sup> ]<sup>10</sup> ‘gets green again’

(23) Interrupted-L (rearticulated)

/ rga<sup>2</sup> / ɿ → [ rgáʔ<sup>a</sup> ] ‘gets caught’

(24) Interrupted-F (rearticulated)

/ rga<sup>2</sup> / ʋ → [ rgáʔ<sup>a</sup> ] ‘pours’

I now turn to the description of each of the tonal types of interrupted vowels. The acoustic examples used for the following sections correspond to the productions of one male speaker, TiuC (42 years old).

#### 4.2. Interrupted-High tone

The first type of interrupted vowel I will describe is interrupted-H, which is realized as checked. Additional examples are provided in (25).

(25) Interrupted-H examples

a. / rga<sup>2</sup> / ɿ → [ rgáʔ<sup>a</sup> ] ‘gets green again’

c. / ba<sup>2</sup> / ɿ → [ báʔ<sup>a</sup> ] ‘earlier today’

b. / ʒi<sup>2</sup> / ɿ → [ ʒíʔ<sup>i</sup> ] ‘cold’

d. / rʒi<sup>2</sup> / ɿ → [ rʒíʔ<sup>i</sup> ] ‘spills’

e. / = a<sup>2</sup> / ɿ → [ aʔ ] ‘1s clitic’

Interrupted vowels with high tone are produced as checked vowels: a modal vowel portion followed by a glottal closure. This interrupted portion is commonly released into a voiceless short vowel that resembles what has been analyzed in other languages as an echo vowel (e.g. Hindi, Chumash (Cram, Linn and Nowak, 1996)), which will be discussed in more detail below. Consider the waveform and spectrogram of following acoustic examples of interrupted vowels with high tone.

<sup>10</sup> Interrupted vowels with high tone normally have an echo vowel after the glottal stop. This is discussed in detail in subsequent sections.



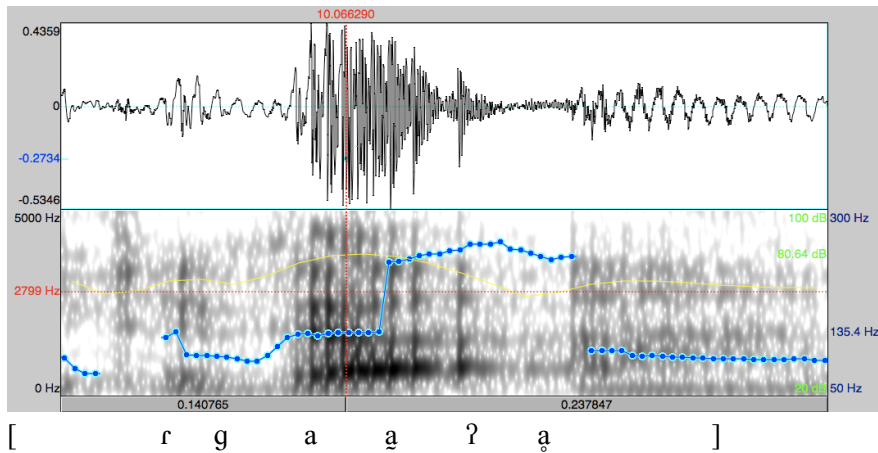


Figure 12. Waveform and spectrogram of /rgaʔ/ → [rgáʔ<sup>a</sup>] ‘gets green again’ by male speaker TiuC.

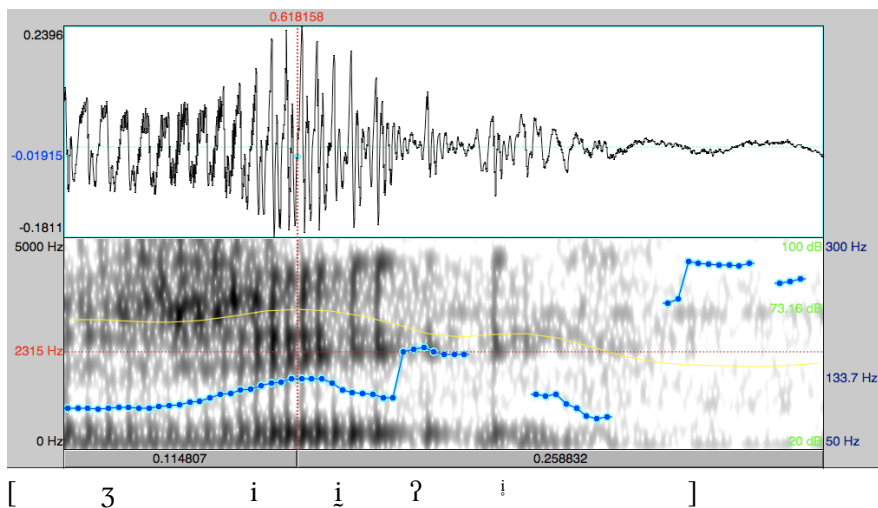


Figure 13. Waveform and spectrogram of /ʒiʔ/ → [ʒíʔ<sup>i</sup>] ‘cold’ by male speaker TiuC.

Both examples show high pitch values for the first vowel portion, averaging 131 Hz for the first example and 129 Hz for the second. Modal-H tokens for this speaker are normally produced above 120 Hz; hence, these tokens are well within the range of high tone pitch values. The duration of the portion with modal voicing (first portion) may be difficult to measure as the interrupted boundary is not always clear. For the first example, [rgáʔ<sup>a</sup>] ‘gets green again’, the first 70 ms can certainly count as the first vowel portion. The next 15 ms show clear glottalization before the actual glottal closure. By the same token, it is difficult to determine the exact duration of the laryngealized portion of the vowel. Is it exclusively the glottal stop? Shall we include the previous glottalization in the vowel? This is a difference of 16 ms (50 vs. 66 ms) for the same item. Because the

period in question is basically a transitional one, I will consider anticipatory creaky voice as part of the interrupted portion of the interrupted vowel for two reasons: 1) it no longer conveys to the tonal information of the vowel, that is, the pitch is normally not recoverable; and (2) for some tokens —particularly in interrupted-L and F— there may be no actual glottal stop, but a short very-low-amplitude period of strong glottalization (i.e. creaky voice). I analyze the first example as an initial modal vowel portion of 70 ms followed by 66 ms of glottalization, and the second example as an initial vowel portion of 68 ms plus 70 ms of glottalization.

With respect to the release of the glottal closure, the term “echo vowel” has been applied for a vowel-glottal stop sequence at the end of the phrase; the echo vowel is the same as the vowel before the glottal stop, but it is whispered and faint (e.g. [ aʔ̥ ] for /aʔ/ ‘arrow’ in Chumash (Cram, Linn and Nowak 1999)). I adopt this term for the glottal release in the case of interrupted vowels with high tone. This echo vowel does not seem to be relevant to tone, as its pitch is inconsistent (commonly voiceless) and the formants are very weak. Nonetheless, interrupted vowels in roots (prominent positions) are claimed to be bimoraic (Chávez-Peón, 2010), thus, the release of the glottal portion is necessary to identify the long duration of the whole vowel.

Considering all interrupted vowels, the acoustic analysis of interrupted-H tokens shows that the release of the glottal closure is weaker compared to the second vowel portion (after the glottalization) of rearticulated vowels with low and falling tone. The latter has more regular pulses and modal-like voice quality, higher intensity values, and clearer formants than those of interrupted-H items (see next sections).

Diphthongs may be used as another piece of evidence determining the phonological status of the echo vowel. In Quiavini Zapotec, glottalization appears in between the two vowel qualities for diphthongs in interrupted vowels. Accordingly, if interrupted-H items are realized as checked vowels, we do not expect to find diphthongs. This prediction is correct: for interrupted vowels with high tone, we find only homorganic examples (same vowel quality).<sup>11</sup> On the other hand, both interrupted vowels with low and falling tones have lexical items with diphthongs.

#### 4.3. Interrupted-Low tone

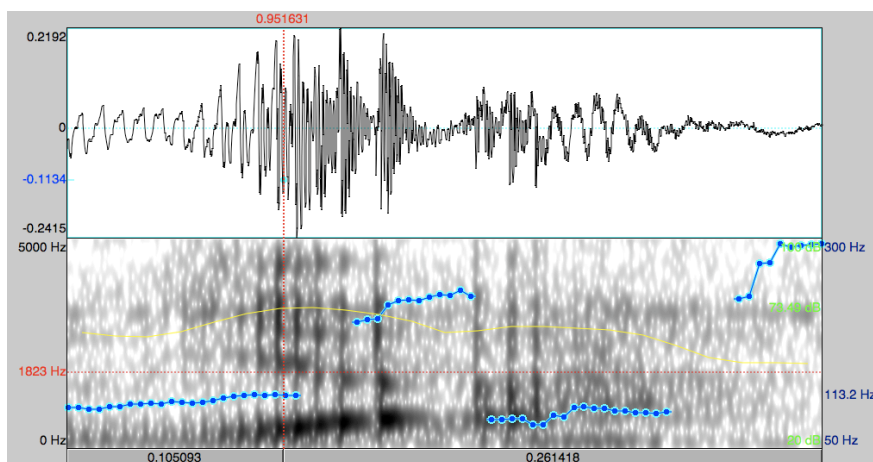
In this section I address the manifestation of low tone with interrupted vowels. Consider the examples in (26) and the acoustic figures that follow.

##### (26) Interrupted-L examples

- a. / rgaʔ / ʃ → [ rgàʔ̥ ] ‘gets caught’
- b. / rgjaʔ / ʃ → [ rgjàʔ̥ ] ‘dances’
- c. / btjaʔ / ʃ → [ btjàʔ̥ ] ‘epazote’
- d. / ndaʔ / ʃ → [ ndàʔ̥ ] ‘had broken’

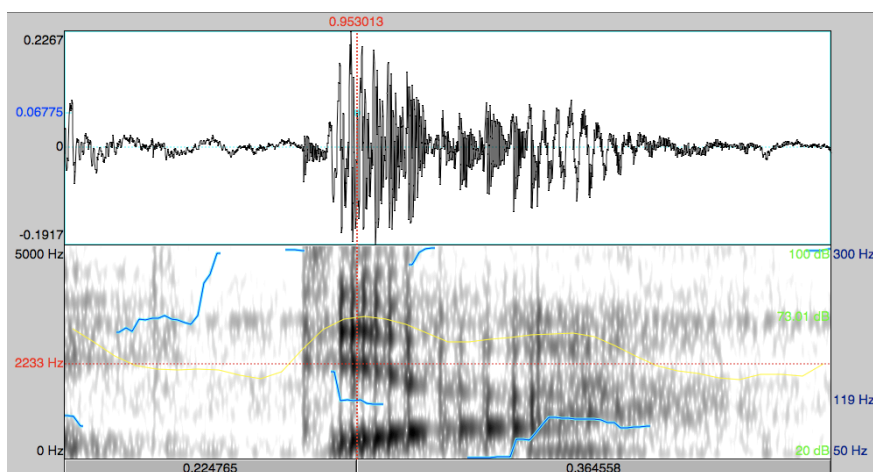
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<sup>11</sup> Interrupted vowels with high tone correspond to the dictionary pattern *aa'ah*. Within this pattern there is only one example of a diphthong *gii'ah* ‘will drink’. The pitch pattern of this item, nonetheless, corresponds to that of interrupted vowels with falling tone; thus, we may reclassify the item.



[ r y j à a ʔ à ]

Figure 14. Waveform and spectrogram of /rqja²/ → [rqjà²à] ‘dances’ by male speaker TiuC.



[ β t h j à a à ]

Figure 15. Waveform and spectrogram of /btja²/ → [btjà²à] ‘epazote’ by male speaker TiuC.

The pitch of the first portion of the vowel in the examples above is 103 Hz for [rqjà²à] ‘dances’ and 98 Hz for [btjà²à] ‘epazote’, clearly different from the interrupted-H items (above 125 Hz), and in the range of modal-L values (~100 Hz for TiuC). The second portions of the vowels show 90 Hz for the first example and 97 Hz for the second; again, low pitch values. As with interrupted high-tone vowels, it is difficult to define the interrupted period of interrupted-L vowels because the boundaries are not always clear. Both examples have an initial modal vowel portion of approximately 50 ms. The first

example then has a short period of creakiness followed by a short glottal stop, of another 50 ms; the second example does not show a proper sustained glottal closure at any point, but continuous strong creaky voice with a pronounced drop in the amplitude envelope, lasting 70 ms. Finally, we have between 60 to 70 ms for the second vowel portion. Total duration of these vowels is 180 ms and 222 ms, respectively. These numbers correspond to the duration of long vowels and, therefore, justify an analysis as bimoraic vowels.

Based on the analysis of several examples, (27) illustrates some of the phonetic variation of interrupted vowels with low tones.<sup>12</sup>

(27) / a<sup>?</sup> / ɟ → [ à<sup>?</sup>à ] ~ [ à<sup>?</sup>à ] ~ [ à<sup>?</sup>à ]

The glottal closure of the interrupted vowel with low tone (as well as with falling tone as we will see below) has some variation in its phonetic realization as it may be pronounced as a full glottal stop, as a short one, or as a period of strong glottalization. An obligatory modal vowel portion follows all these variants. One question about the analysis of interrupted-L vowels is the phonetic and phonological role of the second vowel portion, which, in contrast with interrupted-H vowels, does not seem to be an echo vowel (which is very short, and voiceless or breathy), but a fully voiced portion relevant for the phonological identification of interrupted (rearticulated)-L vowels.

The first argument for such consideration is the acoustic characteristics of the second vowel portion in interrupted-L vowels. Although it is never as consistent as the first portion, we normally find modal voice or modal-like voice; consequently, we find meaningful measures of pitch and intensity values. These pitch values are normally similar for the first and second vowel portions, giving the impression of a single vowel gesture interrupted in the middle by a laryngeal gesture.

Another important argument for the rearticulated realization of interrupted vowels with low tone is the existence of diphthongs with this vowel pattern. For interrupted vowels, the realization of diphthongs is a rearticulated vowel, having one vowel quality before and the other after the glottalization.<sup>13</sup> Consider the examples in (28).<sup>14</sup>

(28) Interrupted-L (diphthongs)

- |   |  |                       |
|---|--|-----------------------|
| a. / gi <sup>?</sup> a /                | ɟ → [ gi <sup>?</sup> à ]                | ‘market’              |
| b. / gagje <sup>?</sup> i /             | ɟ → [ gagjè <sup>?</sup> i ]             | ‘around’              |
| c. / rti <sup>?</sup> a /               | ɟ → [ rti <sup>?</sup> à ]               | ‘drinks’              |
| d. / z <sub>c</sub> gi <sup>?</sup> a / | ɟ → [ z <sub>c</sub> gi <sup>?</sup> à ] | ‘Teotitlán del Valle’ |

<sup>12</sup> The main difference between the realizations of full glottal stop versus a short one is not only duration, but also a more noticeable drop in the amplitude envelope for the former.

<sup>13</sup> As mentioned in the previous section, the two possibilities for a diphthong to be realized as an interrupted vowel with high tone are: (i) as a checked vowel where both vowel qualities are produced before the glottalization; or ii) as a rearticulated vowel (with one vowel quality before and the other after the glottalization). In both cases pitch should be high to be classified as interrupted-H tokens. However, all checked vowels (i) are monophthongal, whereas for all rearticulated vowels (ii) the second vowel portion has low pitch.

<sup>14</sup> See §1.4.4 (phonotactics) in Chapter 1 for the diphthongs possible in Quiavini Zapotec.

- e. /bar kigi²a/ ɿɿ → [ b̄ar kigi²à ] ‘first barrio’  
 f. / ndu²a / ɿ → [ ndù²à ] ‘Oaxaca’

Possibly, another reason for these vowels to be pronounced as rearticulated vowels is to simply cue the speakers to a different tone. Realizing both interrupted H and L as checked vowels could obscure the contrast, whereas having an additional timing cue might facilitate such discrimination.

#### 4.4. Interrupted-Falling tone

Finally, I conclude with the description of interrupted vowels with falling tone. Below, I list some examples of this type of vowel and describe the acoustic properties of some representative examples.

##### (29) Interrupted-F examples

- a. / rga² / ɿ → [ rgá²à ] ‘pours’  
 b. / ra²n / ɿ → [ rá²àn ] ‘plows’  
 c. / ʒi² / ɿ → [ ʒí²ì ] ‘nose’  
 d. / ʒi²nj / ɿ → [ ʒí²ìɲ ] ‘son’  
 e. / btja² / ɿ → [ btjá²à ] ‘scrapped’  
 f. / rti²a / ɿ → [ rtí²à ] ‘gathers’  
 g. / rze²inj / ɿ → [ rzé²ìɲ ] ‘get capricious’

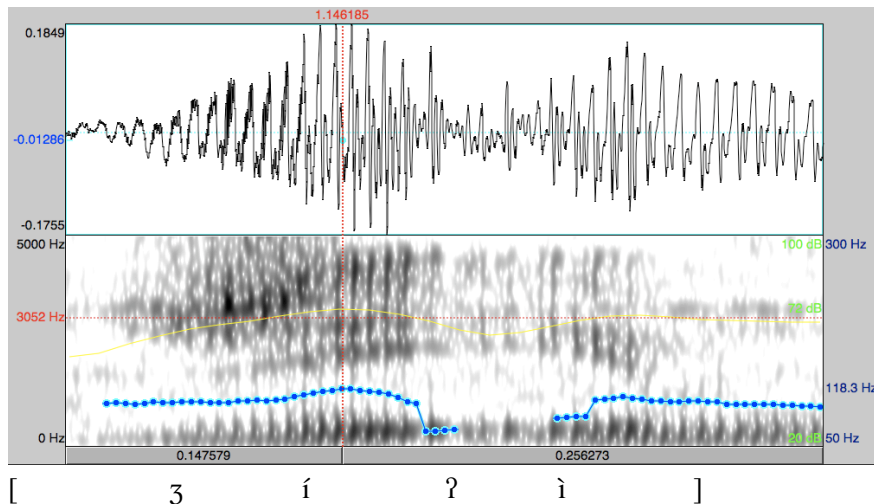


Figure 16. Waveform and spectrogram of / ʒi² / ɿ → [ ʒí²ì ] ‘nose’ by male speaker TiuC.

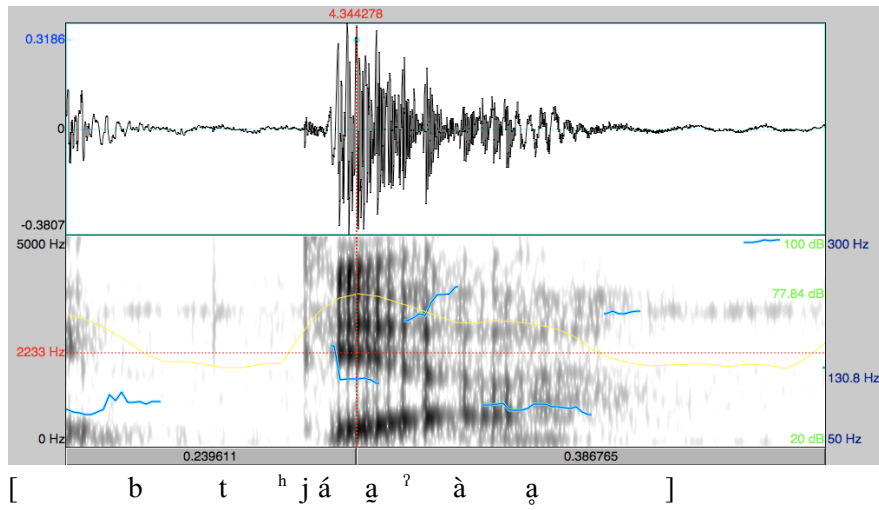


Figure 17. Waveform and spectrogram of / btjaʔ / ↷ [ btjáʔà ] ‘scrapped’ by male speaker TiuC.

Starting with the analysis of pitch, both vowels show falling contours for the vowel as a whole. Based on the first and second vowel portions, the word [ ʒíʔi ] ‘nose’ shows a contour of 118-104 Hz, and [ btjáʔà ] ‘scrapped’, 121-100 Hz. Both examples are comparable to modal-H beginning and modal-L end equivalences, or to modal-F contour values. As the examples illustrate, falling tone is divided into the first and second vowel portions of the rearticulated vowel, and phonetically it is realized as a relatively flat high tone, on the first vowel portion, and a relatively flat low on the second vowel portion; instead of what could have been a high-mid contour followed by mid-low contour. Similar phonetic realizations of falling tone in interrupted vowels have been found for Quiavini Zapotec children (J. Stemberger, personal communication, February 17, 2010).

Regarding duration, the first word starts with a modal vowel portion (68 ms), followed by a short creaky vowel and a glottal closure (less than 50 ms), and then a second modal vowel period (~ 65 ms). The syllable nucleus of the second word starts with a modal vowel portion (51 ms), followed by 68 ms of glottalization (a creaky portion with a short glottal stop, or simply as a period of creakiness), and a modal vowel portion (~ 61 ms) trailing off into voicelessness. The manifestation of these vowels is similar to that of interrupted-L vowels, showing variation for the interrupted portion in the middle. All these vowels have a larger amplitude drop than with simple creaky vowels. As a final point, these vowels can also be analyzed as phonologically long, at 199 and 195 ms, respectively.

## 5. Conclusions

In this study, I have presented new phonological and phonetic evidence in the distribution and contrastive use of non-modal phonation in Quiavini Zapotec. This includes modal, breathy, creaky and interrupted vowels, as originally described by Munro

and Lopez (1999), considered under a new analysis that addresses the use of contrastive tone within non-modal phonation.

Chávez-Peón (2010) showed that tone is contrastive in Quiaviní Zapotec (cf. Munro and Lopez, 1999), and that all four tones can occur with modal voice. The present description has shown that breathy vowels can appear with low and falling tones, and both creaky and interrupted vowels appear with high, low and falling tones. The 12 vowel patterns in Quiaviní Zapotec are summarized in Table 4.

Table 4. Tone and phonation distribution in Quiaviní Zapotec

	High	Low	Falling	Rising
Modal	√	√	√	√
Breathy	X	√	√	X
Creaky	√	√	√	X
Interrupted	√	√	√	X

The phonotactics of tone and phonation, shown in Table 4, illustrate the contrastive but restricted distribution of non-modal phonation. While modal voice may be associated with all four tones, non-modal phonation's main gap is the lack of rising tone. This proposal represents a considerable simplification of Munro and Lopez's (1999) analysis, since it reduces their proposal of 36 possible combinations to 12 contrasts (see Chávez-Peón, 2010, Chapters 6 and 8 for a full comparison).

An important aspect of non-modal phonation in Quiaviní Zapotec is the phonetic implementation of phonological contrasts. I have shown that non-modal voice does not last for the whole duration of the vowel, but is localized to a portion of it. In other words, a portion of the vowel is characterized by modal phonation. This modal portion takes place at the beginning of breathy, creaky and interrupted vowels, and it normally constitutes about the first half of the duration of the vowel. Breathy-L and creaky-L are the only instances where modal voice may not be present at all, as breathiness and creakiness are compatible with lowered pitch. This phonetic realization is schematized in Table 5.

Table 5. Tone and phonation distribution (phonetic implementation)

	High	Low	Falling	Rising
Modal	modal	modal	modal	modal
Breathy	X	(modal)-breathy	modal-breathy	X
Creaky	modal-tense	(modal)-creaky	modal-creaky	X
Interrupted	modal-glottal-(echo)	modal-glottal-modal	modal-glottal-modal	X

Previous studies have reported this modal voice component in the implementation of breathiness and creakiness, as in the case of Jalapa Mazatec, also an Otomanguan language (Silverman et al., 1995; Blankenship, 1997; see also Herrera, 2000; Arellanes 2009). Silverman (1997) suggests a link between the confinement of non-modal phonation to a portion of vowels and the contrastive use of tone in Jalapa Mazatec. He goes further and states that non-modal phonation affects fundamental frequency and

unfavorably influences the ability of vowels to maintain tonal contrasts. As such, tone and phonation contrasts are realized via sequential timing: tonal contrasts are cued during modal phonation, followed by breathiness or laryngealization.

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