# Tone Change in Lalo

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**Abstract**: Eastern (E) and Northwestern (NW) Lalo are dialect clusters of endangered Lalo varieties spoken in western Yunnan, China, and belonging to the Ngwi (Loloish) branch of Tibeto-Burman. This paper, the first linguistic treatment of tone in E and NW Lalo, describes the diachronic tonal developments that distinguish E and NW Lalo from other Lalo varieties. Based on audio recordings of cognates in one E variety and four NW varieties, I present acoustic and diachronic analyses of the varieties' tonal systems. I compare their tonal systems with Proto-Ngwi, Proto-Lalo and Central Lalo to posit their development path from Proto-Lalo. Tone change in Lalo varieties shows interaction not only between prevocalic consonants' laryngeal features and pitch contour, but also between phonation types and pitch height. The interactions between laryngeal features and pitch add to the understanding of how laryngeal features condition secondary tone change.

**Keywords**: tone change, Lalo, Lolo-Burmese, Ngwi, harsh phonation

## 1. Introduction

Even as the sense of urgency grows over endangered language documentation, many Ngwi (Loloish) languages in southwestern China are dying before we are aware of them (Bradley 2007). This paper presents new data on Eastern (E) and Northwestern

(NW) Lalo, two clusters of previously undescribed, endangered Lalo varieties spoken in western Yunnan. Lalo is a Central Ngwi language of the Burmic (Lolo-Burmese) branch of Tibeto-Burman (Bradley 2002). Earlier research on Lalo has focused exclusively on one variety spoken in southern Dali prefecture (Chen et al. 1985, Huang & Dai 1992, Björverud 1998). Lalo has been presented as having only two dialects (Chen et al. 1985). But recent fieldwork, including the collection of wordlists and texts in 18 Lalo villages, reveals that the communities who affiliate under the Lalo autonym show a striking, albeit fragile, linguistic diversity. This paper, the first linguistic analysis of E and NW Lalo tonal systems, accounts for the diachronic tonal developments that distinguish these two clusters from other Lalo languages.

While classic models of tonogenesis (Haudricourt 1954, Matisoff 1973) and Thurgood's (2002) revision are well-attested and phonetically plausible (Hombert et al. 1979), secondary tone change is less well understood. I use Ohala's (1993, 2003) phonetically grounded framework of diachronic change. The basic framework focuses on the central role of the listener's misperception of subphonemic synchronic variation as phonemic (a mini-sound change), which may spread through the community, leading to a macro-sound change (Ohala 2003). I draw from Kingston (2005), Edmondson & Esling (2006), Pittayaporn (2007) and Yip (2001) to explain the phonetic motivations of the observed tone changes.

After briefly reviewing the phonetic bases for tonogenetic mechanisms, I summarize how the Proto-Lalo tonal system developed from its ancestor, Proto-Ngwi (Bradley 1977). I then describe the methodology used for the acoustic and diachronic analyses of Lalo tonal systems. I describe how tone in E and NW Lalo languages has developed diachronically from Proto-Lalo and present the synchronic tonal inventories of several Central, E and NW Lalo varieties. Tone change in E Lalo shows a variation on the classic voiced-low principle: voiced prevocalic consonants lower the pitch onset of Tone *1 (a high, level pitch), creating a rising contour tone. Tone changes in NW Lalo illustrate several effects of prevocalic segments and phonation's laryngeal features on tone change: *preglottalized initials block the spread of the rising pitch in Tone *1, and harsh phonation conditions the raising of pitch heights in Tones *Low-stopped (low, harsh) and *High-stopped (mid, harsh).

## 2. The phonetic bases for tonogenesis and tone change

Haurdicourt's (1954) influential model of tonogenesis in Vietnamese and Matisoff's (1973) explanation of the model in a Tibeto-Burman context established principles that are borne out in languages all over the world. In Haudricourt's (1954) analysis of Vietnamese (also relevant to Old Chinese (Baxter 1992)), two mechanisms happened sequentially: 1) laryngeals in the coda (-ʔ and -h) condition pitch contours, which then become contrastive rising and falling tones when the laryngeals are lost; 2) prevocalic segments condition pitch height, which result in contrastive high and low registers when the contrast between voiced and voiceless prevocalic consonants is lost.

Prevocalic segments may also trigger the initial stage in tonogenesis; this process is widely documented (Hombert 1978). With the advent of increasingly sophisticated phonetic experiments, the phonetic plausibility of the voiced-low, voiceless-high principle has been affirmed (Hombert et al. 1979, Abramson 2004). Honda's (2004) summary of the physiological factors involved identifies two basic mechanisms: relaxed cricothyroid muscles and lowered larynx. The cricothyroid muscles, which control both voicing and pitch, are relaxed for voiced consonants and engaged for voiceless. The relaxation of the cricothyroid then enables a lower pitch at the beginning of the vowel sound (Löfqvist et al. 1989). With voiced obstruents, voicing has already begun during closure. One way to maintain the drop in pressure across the larynx that is necessary for maintaining voicing is to lower the larynx (Honda 2004). Lowering the larynx rotates the cricothyroid joint but does not translate it forward, so the result is relaxation of the cricothyroid muscles. Lowering the larynx also increases the size of the supralaryngeal cavity, with a correlate of lowered pitch. During the voicing of obstruents, pitch may be lowered as an automatic response to ensure voicing is maintained. The differences in pitch after voiced and voiceless obstruents are still significant even after 100 milliseconds, well into the pronunciation of the vowel, though not through the whole duration of the syllable (Hombert et al. 1979). In Tang's (2008) survey of tone languages, the pattern of voiced-low, voiceless-high holds in the majority of cases.

Thurgood (2002) introduces an important refinement to the model, moving away from the classic model's consonantal basis and towards a laryngeally based model.

Thurgood (2002:334) holds that it is not segments themselves that condition tone, but rather that "laryngeal gestures associated with voice qualities are the primary mechanism for pitch assignment." In Thurgood's view, segments condition the phonation type of the vowel, which then conditions pitch; segments do not directly affect pitch. Voiced obstruents result in breathy phonation, which in turn results in low pitch. Final stops may co-occur with glottal closure, leading to a constricted larynx, which can then result in either a falling or rising pitch contour depending on the degree and timing of glottal constriction. Thurgood therefore suggests that the role of segments in tonogenesis is mediated through the phonation types they engender.

Thurgood improves the classic model by explicitly placing the locus of tonogenesis in the larynx. Since pitch is controlled in the larynx, a segment's laryngeal features must be called on to explain perturbation in a rhyme's F0. This is exactly what experimental phonetics has proven: length and tension of the vocal folds combine with height of the larynx to manipulate pitch. However, tonogenesis does not necessarily have to pass through an intermediate phase in which phonation types (whether subphonemic or contrastive) affect pitch. In cases of ongoing tonogenesis, such as Korean (Silva 2006), Kammu (Svantesson & House 2006) and Kurtöp (Hyslop 2009), there is no evidence to suggest that vowel phonation as opposed to segment voicing plays a role. The above reports, based on rigorous acoustic analysis and perceptual experiments, identify an ongoing change in which the voicing of the prevocalic segments themselves has influenced pitch, not phonation of the vowel. Thurgood's insight of laryngeal gestures' influence on pitch holds, but those laryngeal gestures may belong solely to the prevocalic segment or occur across the whole syllable.

Sophisticated laryngoscopic photography by Edmondson & Esling (2006) has enabled new insight into the production of harsh phonation and its effect on pitch. Harsh phonation, found in Proto-Lalo's *L and *H tones (see Section 3 below), is produced by the engagement of the vocal folds, ventricular folds and the laryngeal sphincter (Edmondson & Esling 2006). The laryngeal sphincter is the thyroarytenoid muscle complex contracting to pull the arytenoids and aryepiglottic folds forward towards the epiglottis. The ventricular folds, located on either side of the vocal folds, move medially towards the vocal folds, coming up over them and dampening their oscillation, resulting in increased tension. The increased tension in the vocal folds increases pitch, resulting in harsh phonation having a high pitch correlate. Harsh phonation's higher pitch correlate forms the phonetic motivation for NW Lalo's changes in *L and *H tones, as discussed in Section 6.2 below.

## 3. Proto-Ngwi and Proto-Lalo tones

Lalo varieties are classified in descending order as Tibeto-Burman, Burmic (Lolo-Burmese), Ngwi (Loloish), Central Ngwi (Bradley 2002). Burmic, one of the more well-defined subgroups within Tibeto-Burman, includes two branches, Burmish, including Burmese, and Ngwi (Loloish) (Bradley 2002). Matisoff's (1969, 1972) and Bradley's (1979) reconstructions of Proto-Ngwi, based on hundreds of cognate sets from over a dozen languages, are generally acknowledged as reliable, thirty and forty years after their respective publications.

Bradley (1979, 2002) subgroups Ngwi languages into four branches: Northern, including Nosu and Nasu; Southern, including Hani and Akha; Southeastern, including Phula; and Central, including Lisu, Lahu, Lolo, and Lalo. Criteria for subgrouping include phonological innovations in initials, rhymes, and especially tones. Central Ngwi languages also have lexical innovations for 'dog' and 'fire' (Bradley 2004).

Ngwi languages are firmly within the Chinese cultural sphere of influence (a.k.a. the Sinosphere), and as such share certain areal features with Chinese languages, being tonal, monosyllabic, analytic type languages (Matisoff 2003). Ngwi languages such as Lahu and Lalo are characterized by Matisoff (1989) as "omnisyllabic" languages, in which each syllable is assigned a lexical tone, and tonal systems encompass a range of features including pitch height and contour, phonation, duration and intensity.

The Proto-Ngwi tonal system (Bradley 1977) had a three-way pitch height contrast in syllables ending in vowels or nasals: Tones *1, *2, and *3. Based on tonal reflexes in several Ngwi languages, Bradley (1977) posits the following pitch values for these proto-tones: *1 was high, *2 was low, and *3 was mid. Identical pitch values for these tone categories are still seen today in Hani and Central Lalo, both of which have kept the Proto-Ngwi tonal categories relatively intact. For other languages such as Lisu, Lahu and Sani, evidence for the phonetic values of the Proto-Ngwi categories is not as clear, as numerous conditioned splits and tonal innovation chains have drastically rearranged the systems. However, the modern tonal reflexes of all Ngwi languages can still be reasonably traced back to Bradley's hypothesized phonetic values of the Proto-Ngwi tone categories.

In syllables ending in final stops *-p, *-t, and *-k, Proto-Ngwi underwent a distinctive innovation wherein the voicing of the initial caused a split into two distinct tone categories, *Low-stopped and *High-stopped (Matisoff 1972). The basic rule for the split follows the voiced-low principle described above. In Proto-Ngwi, a voiced *initial or a voiced *prefix (such as the *C- prefix, a cover term for *b-, *d-, *g-, *r-, *l-) conditioned a lower pitch, and voiceless *initials (and the *s- prefix before nasal initials) conditioned a higher pitch. When changes in the initials (e.g., loss of the *C-prefix) destroyed the conditioning environment, the different pitches became phonemically contrastive. In most Ngwi languages, syllable-final *stops then merged to a glottal stop and finally to laryngealized vocal register on the vowel. Proto-Ngwi *High-stopped reflexes are usually a mid pitch with harsh phonation across Central and Southern Ngwi languages. Proto-Ngwi *Low-stopped reflexes are usually a low pitch with harsh phonation in Central Ngwi languages, unless prefixed with the *glottal stop or the *C- prefix, which triggered a tonal split in some Central Ngwi languages. In some Northern Ngwi languages (e.g. Nosu), *Low-stopped became high, an independent development from NW Lalo's similar change.

The following is a summary of Proto-Lalo phonology, from (Yang in prep). My reconstruction of Proto-Lalo is based on Bradley's (1979) Proto-Ngwi (PN), Matisoff's (1972, 2003) Proto-Lolo-Burmese (PLB), and historical-comparative analysis of 1,000-item wordlists from 18 Lalo varieties, recorded in 2008. The Proto-Lalo syllable template was *(C)VT, in which one of 43 optional *initials was followed by one of 9 obligatory *rhymes and one of 5 tones. Only one rhyme, *-aŋ, is nasal-final, and all others are open vowels.

Table 1 below gives the Proto-Lalo initials inventory. Proto-Ngwi *ʔ-prefixed stops became Proto-Lalo voiceless unaspirated stops, *plain stops became aspirated, and *voiced stops remained voiced. Proto-Ngwi *ʔ-prefixed sonorants developed into Proto-Lalo's contrastive series of *preglottalized sonorants (*ʔl, *ʔm, *ʔmj, *ʔn, *ʔɲ, *ʔŋ), and Proto-Ngwi *ʔ-w became the preglottalized fricative *ʔv. Proto-Lalo's *preglottalized sonorants and fricative are a crucial conditioning environment for E and NW Lalo's Tone *1 splits, discussed in Section 6.1.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| *p | *pj | *t | *ts | *tʃ | *k | *kj | |
| *p$^h$ | *p$^h$j | *t$^h$ | *ts$^h$ | *tʃ$^h$ | *k$^h$ | *k$^h$j | |
| *b | *bj | *d | *dz | *dʒ | *g | *gj | |
| *f | | | *s | *ʃ | *x | | *h |
| *v | | *l | *z | *ʒ | *ɣ | | |
| *ʔv | | *ʔl | | | | | |
| *ʔm | *ʔmj | *ʔn | | *ʔɲ | *ʔŋ | | |
| *m | *mj | *n | | *ɲ | *ŋ | | |

**Table 1. Proto-Lalo initials**

Table 2 gives the Proto-Lalo rhyme inventory. All open vowels were found in both modal and harsh phonation. Harsh phonation is marked with an underscore under the vowel, e.g., *e̠ versus *e.

| | | | | |
|---|---|---|---|---|
| *i | *y | *ɨ | *u | |
| *e | | | *o | |
| *ɛ | | | *a | *aŋ |

**Table 2. Proto-Lalo rhymes**

Table 3 below shows the development of tones from Proto-Ngwi to Proto-Lalo. The Proto-Lalo tonal system distinguished three pitch heights (high, mid, low) and two types of phonation, harsh and non-harsh. Proto-Lalo, like Proto-Ngwi, had a three-way pitch height contrast in syllables ending in vowels or nasals: *1, high; *2, low; and *3, mid. Proto-Ngwi syllable-final stops decayed to harsh phonation on the vowel by the Proto-Lalo stage. Thus, Proto-Ngwi *Low-stopped and *High-stopped categories in Proto-Lalo become *L, probably low pitch with harsh phonation, and *H, probably mid pitch with harsh phonation.

For a Central Ngwi language, Proto-Lalo is conservative in its tonal development. Central Ngwi languages such as Lisu, Lahu, Lipo and Lolo, all show conditioned splits in Tone *2, in which the *ʔ- and *s- prefixes conditioned a higher pitch. Also, most Central Ngwi languages show an additional conditioned split in *Low-stopped, conditioned by the *ʔ- and *C- prefix. Proto-Lalo shows no evidence of a conditioned split in *L; there is only evidence of a micro-split in Proto-Lalo Tone *2.

Tone *2 syllables preceded by the *ʔ- prefix with *obstruent initials and open back vowel -a, as in *ʔ-ba² ‘male suffix,’ ‘frog,’ *ʔ-da² ‘put down,’ and *ʔ-dza² ‘feed,’ moved to the *L tone category.

| Proto-Ngwi (Bradley 1977) | Proto-Lalo |
|---|---|
| *1: High | *1: High |
| *2: Low | *2: a) Low |
| | b) > *L / ʔ-stop + a_ |
| *3: Mid | *3: Mid |
| *L: Low, stop-final | *L: Low, harsh |
| *H: Mid, stop-final | *H: Mid, harsh |

**Table 3. Proto-Ngwi and Proto-Lalo tones**

Based on innovations in Proto-Lalo initials, rhymes, and tones, most Lalo varieties can be grouped into three dialect clusters: Central (C), Eastern (E) and Northwestern (NW). The innovations given as evidence for subgrouping Lalo varieties are discussed in (Yang 2009).

## 4. Methodology

The comparative method and acoustic analysis of synchronic tonal systems are the two main methodologies used in this research. Fieldwork was conducted during 2008 as part of a research project on geographical dialect variation in Lalo. At each of the 18 Lalo villages visited, native speakers were recorded on site uttering lexical items along with carrier phrases, using a 1,000 item wordlist designed for historical-comparative purposes, adapted from (Pelkey 2008). An Edirol R-09 digital recorder was used to record in uncompressed .wav format. Two native speakers from each Lalo village served as speakers, one giving the citation form and the other giving the utterance medial form. The utterance medial form was embedded in one of several carrier phrases chosen for semantic plausibility and designed so that the elicited item was usually preceded by a word with mid level tone. Both citation and utterance medial forms were repeated three times.

After transcribing the recordings into a spreadsheet, I used the comparative method to reconstruct the Proto-Lalo phonological system summarized in Section 3. That hypothetical system was then used as a basis to posit probable changes that result in the variety of tonal systems seen in Lalo varieties today.

Acoustic analysis of synchronic tonal systems provides acoustic evidence for the phonological analysis and reveals possible phonetic motivations for tone change. The acoustic analysis presented here is based on the utterance medial form. The age and gender of the speakers who provided the utterance medial form is summarized in Table 4:

| Lalo dialect cluster | Village | Age | Gender | Speaker reference |
|---|---|---|---|---|
| Central | Qingyun | 20's | Female | QY1 |
| Eastern | Diaocao | 60's | Male | DC1 |
| NW | Yilu | 30's | Male | YL1 |
| NW | Dutian | 20's | Male | DT1 |
| NW | Shuizhuping | 40's | Female | SZP1 |
| NW | Shanglizhuo | 40's | Female | SLZ1 |

**Table 4. Information on speakers for acoustic analysis**

Monosyllabic, utterance medial target words were used, with nasal or liquid initials to avoid onset-related effects. For each tone, approximately 30 tokens were used (on average 10 lexical items, with three repetitions), for an average of 150 tokens per variety. Fundamental frequency (F0) measured in Hertz (Hz) was extracted using Praat language software (Boersma & Weenick 2009) with the _TimeNormalize-F0.praat script developed by Xu (2009). Xu's script measured F0 at 10 equally spaced locations throughout the vowels' duration, from 10% of the vowel onset to the vowel offset. For each tone category, Hertz values were averaged for all tokens at each normalized time point. Hertz values were then transformed to semitones. The musical semitone scale, a psycho-acoustic scale, is a logarithmic transformation of the Hertz scale, and has been shown to better model speakers' intuitions about pitch difference than the raw acoustic Hz scale (Nolan 2003). The Hertz-to-semitone conversion used here is taken from the Praat 5.1.07 manual: semitones = $[12 \times \ln(H/100)]/\ln 2$, where H is the frequency in Hertz. The mean of Tone 3, the mid-level tone, was defined as the zero level pitch value and thus served as the benchmark for normalized pitch for each speaker, as in Stanford (2008). Thus, the tonal inventories in 5.2 are presented in semitones and normalized for duration and mean Tone 3 F0. Tone 3 is marked with a dotted line, and the number of tokens used (N) is given for each tone category.

## 5. Results

### *5.1. Diachronic tonal development*

Table 5 below summarizes the development of Proto-Lalo tones in the Central Lalo, Eastern (E) Lalo and NW Lalo dialect clusters. Phonetic values are given using Chao's (1930) tone letters, in which 5 represents the highest pitch and 1 the lowest. Central Lalo has basically retained the Proto-Lalo tone system. Tone *1 has remained intact as the highest pitch in the system, but voicing of the initial has synchronically conditioned two Tone 1 allotones. In syllables with voiceless and preglottalized initials, Tone 1 is a high, level [55] pitch, but in syllables with voiced initials, the pitch onset is lowered, and Tone 1 is realized as a high rising [45] pitch. The acoustic analysis in Figure 1 illustrates the two allotones.

In E Lalo, Tone *1 underwent a phonemic split in which syllables with *voiceless initials and *preglottalized sonorants remained high, but syllables with *voiced initials split to low rising. This conditioning exactly parallels the subphonemic variation seen in C Lalo. In E Lalo, the Tone *1 split became phonemically contrastive when *preglottalized initials merged with their plain counterparts. E Lalo also shows loss of harsh phonation, a merger of Tone *3 and *H to mid level [33] pitch, and a phonetic change in *L to mid-falling [31] pitch.

In NW Lalo, a tonal chain of innovation occurred. Like E Lalo, Tone *1 underwent a split conditioned by voicing of the initial, but with a slightly different conditioning environment than E Lalo. Only syllables with *preglottalized initials remained high, and syllables with all other initials, including voiceless initials, split to low rising. NW Lalo also lost harsh phonation, which led to changes in *L and *H. *L changed from low with harsh phonation to high with modal phonation. *H changed from mid with harsh phonation to mid-high with modal phonation, and merged with Tone *1's syllables with *preglottalized initials. Although the ordering of the tonal chain is uncertain, a likely ordering is: 1) Tone *1 split to low rising while Tone *1's *preglottalized initials merged with *H, and then 2) *L was dragged up to the highest pitch slot in the system.

| Proto-Lalo | Central Lalo | Eastern Lalo | NW Lalo |
|---|---|---|---|
| *1: High | Allotones:<br>a) High, modal [55]/elsewhere_<br>b) High rising, modal [45]/[+voi]_ | Phonemic tone split:<br>a) High, modal [55]/*elsewhere_<br>b) Low rising [24]/*[+voi]_ | Phonemic tone split:<br>a) Mid-high, modal [44]/*ʔ_<br>b) Low rising [24]/elsewhere_ |
| *2: Low | Low, breathy [21] | Low, modal [21] | Low, modal [21] |
| *3: Mid | Mid, modal [33] | Mid, modal [33] | Mid, modal [33] |
| *H: Mid, harsh | Mid, harsh [33] | | Mid-high, modal [44] |
| *L: Low, harsh | Low, harsh [21] | Mid falling, modal [31] | High, modal [55] |

**Table 5. Tonal development in Central, Eastern and NW Lalo**

Examples of Tones *1 and *H in C, E, and NW Lalo are given in Table 6 below to illustrate NW's Tone *1 split and merger with *H. Locations are abbreviated by the first letter of each syllable in the village name, and dialect affiliation (C, E, or NW) is given. NW's low-rising tonal reflex is seen in both voiced and voiceless initials, and Tone *1 with *preglottalized initials merges with *H to mid-high. Yilu (YL), a marginal NW variety, shares the same conditioning as E Lalo's Tone *1 split, rather than the typical NW tone split. However, Yilu shares other innovations in tone and initials that qualify it as a NW variety.

| Gloss | Proto-Lalo | QY-C | DC-E | YL-NW | SLZ-NW | DT-NW | SZP-NW |
|---|---|---|---|---|---|---|---|
| light (adj.) | *laŋ$^{1}$ | lu$^{45}$ | la$^{24}$ | lu$^{24}$ | lu$^{24}$ | la$^{24}$ | lu$^{24}$ |
| sick | *na$^{1}$ | na$^{45}$ | nɔ$^{24}$ | nɐ$^{24}$ | na$^{24}$ | no$^{24}$ | na$^{24}$ |
| iron | *xy$^{1}$ | ɕy$^{55}$ | xə$^{55}$ | ɕy$^{44}$ | xue$^{24}$ | xy$^{24}$ | xu$^{24}$ |
| star | *kɛ$^{1}$ | kɨ$^{55}$ | kɛ$^{55}$ | kɨ$^{44}$ | kɛ$^{24}$ | kɛ$^{24}$ | kɛ$^{24}$ |
| tongue | *ʔla$^{1}$ | ʔla$^{55}$ | lɔ$^{55}$ | lɐ$^{44}$ | la$^{44}$ | lo$^{44}$ | la$^{44}$ |
| listen | *ʔna$^{1}$ | ʔna$^{55}$ | nɔ$^{55}$ | nɐ$^{44}$ | na$^{44}$ | no$^{55}$ | na$^{44}$ |
| bean | *nu̠$^{H}$ | nə̠$^{33}$ | lu$^{33}$ | no$^{44}$ | nu$^{44}$ | nu$^{44}$ | nu$^{44}$ |
| stone | *lu̠$^{H}$ | lə̠$^{33}$ | nu$^{33}$ | lo$^{44}$ | lu$^{44}$ | lu$^{44}$ | lu$^{44}$ |

**Table 6. Examples of Tones *1 and *H in C, E, and NW Lalo**

Table 7 gives examples of *L in C, E, and NW Lalo. NW Lalo varieties all show a high pitch reflex for *L, although the phonetic values for *L vary by variety: high-falling in Yilu, high-rising in Dutian, and high rising-falling in SLZ and SZP. This regional variation in the phonetic value of *L is further discussed in Section 6.2.

| Gloss | Proto-Lalo | QY-C | DC-E | YL-NW | DT-NW | SLZ-NW | SZP-NW |
|---|---|---|---|---|---|---|---|
| hand | *le̠$^{L}$ | lɛ̠$^{21}$ | le$^{31}$ | lɛ$^{53}$ | le$^{45}$ | le$^{453}$ | le$^{453}$ |
| brains | *ʔnu̠$^{L}$ | ʔnə̠$^{21}$ | nu$^{31}$ | no$^{53}$ | nu$^{45}$ | nu$^{453}$ | nu$^{453}$ |
| to descend | *ze̠$^{L}$ | zɛ̠$^{21}$ | ze$^{31}$ | zɛ$^{53}$ | ze$^{45}$ | ze$^{453}$ | ze$^{453}$ |
| to swell | *p$^{h}$y̠$^{L}$ | p$^{h}$y̠$^{21}$ | p$^{h}$ə$^{31}$ | p$^{h}$y$^{53}$ | p$^{h}$y$^{45}$ | p$^{h}$i$^{453}$ | p$^{h}$y$^{453}$ |

**Table 7. Examples of *L in C, E, and NW Lalo**

### *5.2. Synchronic tonal systems*

The figures below show the tonal inventories of Qingyun (Central), Diaocao (Eastern), Yilu (NW), Shuizhuping (NW) and Dutian (NW), based on the acoustic analysis described in Section 4. Tone 3 is marked with a dotted line.

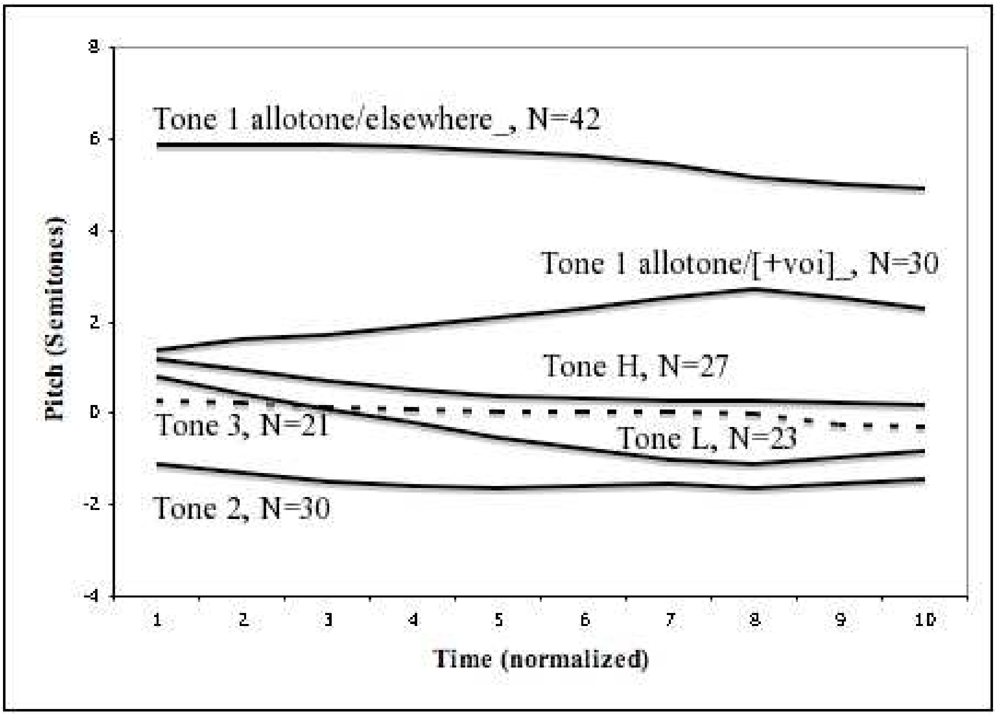


**Figure 1. Qingyun (C) tonal inventory (speaker QY1). Normalized for mean Tone 3 pitch; Tone 3 (N = 21) marked with dotted line. N = 173**

Central Lalo has basically retained the Proto-Lalo tonal system, with three pitch heights (high, mid, low) and two phonation types (harsh vs. non-harsh). In Qingyun (Central)'s tonal system, seen in Figure 1, the pitch onsets of harsh *L and *H are higher than their modal pitch counterparts of *2 and *3. The pitch in *L starts around mid range, then rapidly falls to near the bottom of speaker QY1's range. Likewise, *H starts off higher than mid before gradually falling to near mid by the end of the syllable. The higher onsets of *L and *H are caused by harsh phonation, which has an automatic high pitch correlate (as described in Section 2). Harsh phonation's influence on tone change in NW Lalo is further discussed in Section 6.2.

In Tone *1, the voicing of the initial has synchronically conditioned two allotones, shown separately in Figure 1. The synchronic variation is completely predictable and not contrastive, because Central Lalo has retained Proto-Lalo's *preglottalized initials, rather than merging them with *plain *v and plain *sonorants as other Lalo varieties have. In syllables with voiceless initials and preglottalized initials, the Tone 1 allotone (marked Tone 1 allotone/elsewhere_) is a high, level pitch, found at the top of speaker QY1's range. The Tone 1 allotone in syllables with voiced initials (marked Tone 1 allotone/[+voi]_) shows a considerably lower pitch onset with a gradual rise in pitch through the midpoint and slight fall at the end of the syllable.

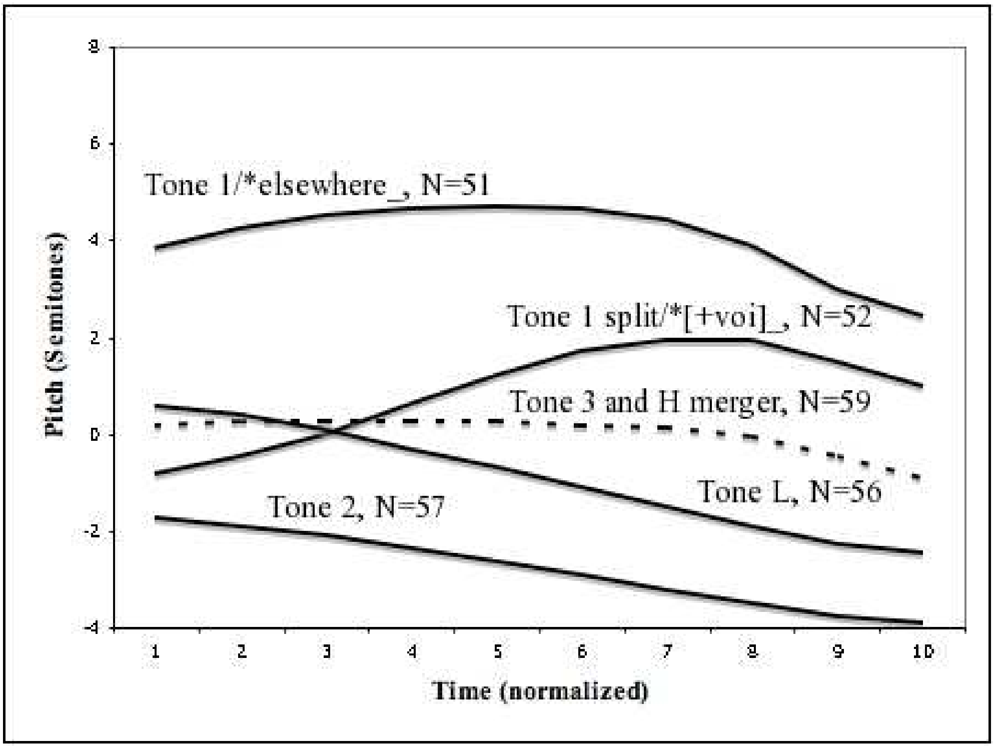


**Figure 2. Diaocao (E) tonal inventory (speaker DC1). Normalized for mean Tone 3 pitch; Tone 3 marked with dotted line. N = 275**

In Figure 2 above, which shows Diaocao (Eastern)'s tonal system, the Tone *1 reflex with *voiceless and *preglottalized initials (marked Tone 1/*elsewhere_) is found at the highest pitch level for speaker DC1. The Tone *1 reflex for syllables with *voiced initials (marked Tone 1 split/*[+voi]_) has a pitch onset that begins lower than the mid pitch but steadily rises past the midpoint of the syllable before a slight drop off at the end. In Eastern Lalo, the depression of the pitch onset is greater than in Central Lalo; the pitch begins in the lower register and rises into the higher register. Because E Lalo has lost *preglottalization (e.g., *ʔm, *ʔl, *ʔv > m, l, v), Tone *1's high pitch reflex is now seen on syllables with voiced sonorants and the voiced fricative /v/. The Tone *1 split to low rising is also seen on syllables with voiced sonorants and fricative (from Proto-Lalo *plain sonorants and *v). Thus, the high level and low rising pitch reflexes of Tone *1 are now phonemically contrastive. The loss of *preglottalized fricative and sonorants in E Lalo triggered the change from subphonemic variation to a phonemic tone split.

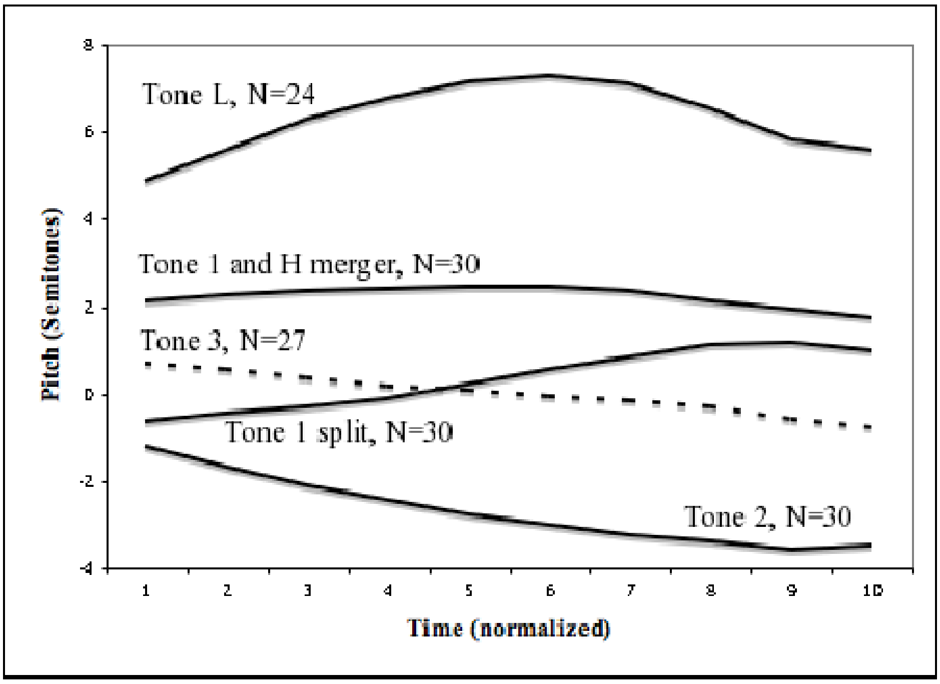


**Figure 3. Shuizhuping (NW) tonal inventory (speaker SZP1). Normalized for mean Tone 3 pitch; Tone 3 marked with dotted line. N = 141**

In Shuizhuping (NW) Lalo, seen in Figure 3 above, *L is now the highest pitch in the tone system, with a rise to the midpoint of the syllable followed by a fall. All *H syllables and Tone *1 syllables with *preglottalized initials have merged to a mid-high reflex, a level pitch located roughly equidistantly between the pitch onset of *L and the mid level pitch of *3. Tone *1 with initials other than *preglottalized initials are reflected by the low rising pitch (marked Tone 1 split), beginning in the lower register and rising to above mid by the end of the syllable.

Figure 4 and Figure 5 below show the tonal inventories of NW varieties Yilu and Dutian, respectively. These inventories match Shuizhuping except for the phonetic value of *L. In Yilu (Figure 4), *L is reflected as a high pitch with a slight fall, and in Dutian (Figure 5) as a high-rising pitch. A possible phonetically based explanation for this dialect variation is discussed in Section 6.2. Yilu's tonal system also differs from prototypical NW Lalo in that its Tone *1 split follows the conditioning of Eastern Lalo, with * + voi conditioning the low rising pitch.

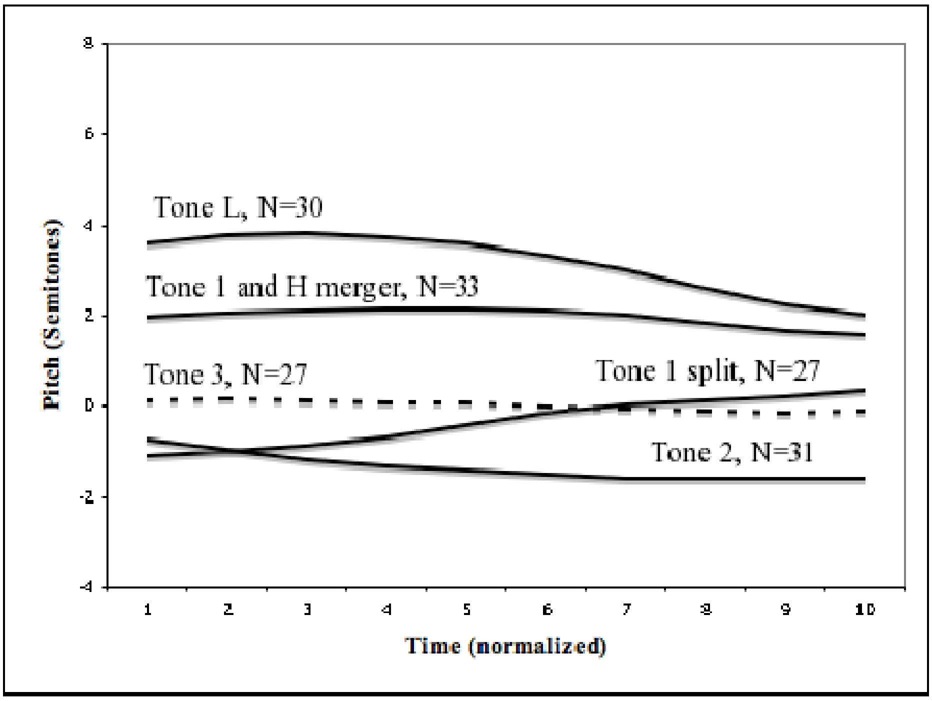


Figure 4. Yilu (NW) tonal inventory (speaker YL1). Normalized for mean Tone 3 pitch; Tone 3 marked with dotted line. N = 148

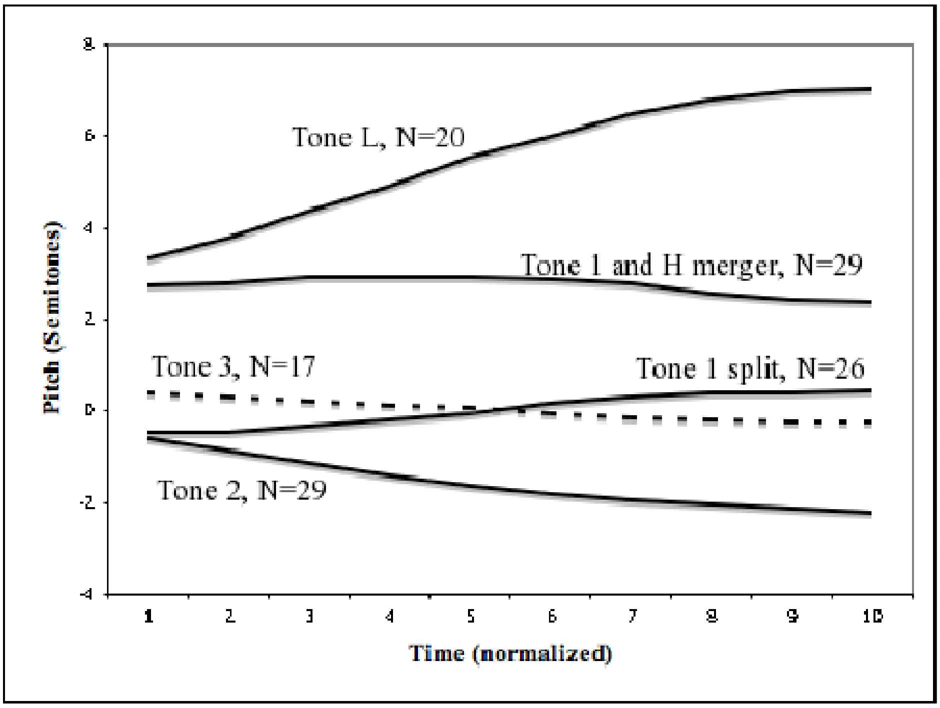


Figure 5. Dutian (NW) tonal inventory (speaker DT1). Normalized for mean Tone 3 pitch; Tone 3 marked with dotted line. N = 121

## 6. Discussion and conclusion

Table 8 summarizes the Proto-Lalo, Eastern and Northwestern Lalo tonal systems using tone features. Lalo varieties' phonological features of Tone and Register are useful for linking the phonology to the phonetic interactions of laryngeal features and pitch, as discussed in 6.1 and 6.2 below. Yip (1980) first suggested using two features to define tone: Register (+/-Upper, or High/Low) and Tone (+/-high, or high/low). Register (here as High (H) and Low (L)) divides the tonal space into two equal halves, and Tone splits each register in two, with the possibility of combinations of high and low to create contour (here, as h, l, hl, lh). Mid is unmarked, without specification of Register or Tone. Proto-Lalo had a mixed system of phonation and pitch, in which the harsh phonation of *L and *H kept them distinct from their modal counterparts *2 and *3. The feature [+harsh] distinguishes *L and *H from *2 and *3; thus, only a Register feature is specified for *L and *H, not a Tone feature.

<table>
<tr><th>Proto-Lalo</th><th>Proto-Lalo features</th><th>E Lalo</th><th>E features</th><th>NW Lalo</th><th>NW features</th></tr>
<tr><td>*1/*voiced_</td><td rowspan="3">H, h</td><td>Low rising</td><td>L, lh</td><td rowspan="2">Low rising</td><td rowspan="2">L, lh</td></tr>
<tr><td>*1/*voiceless_</td><td rowspan="2">High</td><td rowspan="2">H, h</td></tr>
<tr><td>*1/*ʔ_</td><td rowspan="2">Mid high</td><td rowspan="2">H, l</td></tr>
<tr><td>*H</td><td>H, harsh</td><td rowspan="2">Mid</td><td rowspan="2">--</td></tr>
<tr><td>*3</td><td>--</td><td>Mid</td><td>--</td></tr>
<tr><td>*L</td><td>L, harsh</td><td>Mid falling</td><td>L, hl</td><td>High</td><td>H, h</td></tr>
<tr><td>*2</td><td>L, l</td><td>Low</td><td>L, l</td><td>Low</td><td>L, l</td></tr>
</table>

**Table 8. Proto-Lalo, E and NW Lalo tone features**

Using this feature system, it is possible to summarize the changes in Eastern Lalo as follows:

*1 (H, h) /*[+voi]_ > low rising /L, lh/

*H (H, harsh) > mid, merging with *3

*L (L, harsh) > mid falling /L, hl/

The Tone *1 split to low rising changes Register from High to Low, and Tone adds a low to create a rising contour. Harsh phonation is lost in both *H and *L; while *H merges with *3 to mid, *L remains in the Low register but Tone adds a high to create a falling contour.

NW Lalo changes are summarized as:

*1 (H, h) /elsewhere_ > low rising /L, lh/

*1 (H, h) /*ʔ_ > mid-high /H, l/, merging with *H

*H (H, harsh) > mid-high /H, l/

*L (L, harsh) > high /H, h/

The changes can be understood as *1 in almost all environments changing Register from High to Low and Tone taking on a lh contour. As in E Lalo, harsh phonation is lost in *H and *L. *L loses harsh phonation, changes Register from Low to High and adds a Tone specification of h, and so is now the highest pitch in the system. *H merges with *1 after *preglottalized initials, whose Register has remained High but Tone has changed from high to low, possibly pushed down by the movement of *L to the highest slot. The merger of *1 and *H must have happened after *1's split to low rising, however, because no *H reflex with voiced initials are low rising. If the merger happened first, it would be expected that *H syllables with voiced initials would have taken part in the split to low rising.

### *6.1. Tone *1 split*

E and NW Lalo's Tone *1 splits are variations on the voiced-low principle so prevalent in tonogenesis. Classic models of tonogenesis (Haudricourt 1954, Matisoff 1973) predict that voiced prevocalic consonants will condition low pitch, and voiceless will condition high pitch. Laryngeal features of prevocalic segments interact with pitch in predictable ways: the lowered larynx and relaxed cricothyroid muscles of voiced obstruents depress F0 (fundamental frequency), while the engaged cricothyroid muscles of voiceless obstruents raise F0 (Löfqvist et al. 1989, Honda 2004).

Differences in pitch after voiced and voiceless obstruents are still significant after 100 milliseconds, well into the pronunciation of the vowel, though not through the whole duration of the syllable (Hombert et al. 1979). Prevocalic segments thus have a microprosodic effect on the pitch, affecting pitch at the vowel onset but not over the entire syllable. In Thurgood's (2002) model, original tonogenesis leads to a two-way contrast of High and Low, without contrastive contour. One of the puzzles of original tonogenesis that Thurgood attempts to explain is, given that prevocalic segments only have a local effect on pitch, how then do level pitches of High and Low come about, in which the pitch height is evenly distributed across the syllable? He argues that it is prevocalic segments' effect on voice quality that result in pitches distributed over the entire syllable, not the segments' local effect on pitch. Phonation is a property which holds over the entire syllable, not just the pitch onset or offset. Thurgood therefore adds an intermediate stage in which the breathy phonation conditioned by voiced initials leads to low pitch, which may contrast with creaky or modal voice syllables with high pitch.

In E Lalo's tone change, in contrast with original tonogenesis, prevocalic segments' microprosodic effects directly influence the development of contour tones. As seen in Eastern Lalo's Tone *1 split, voiced prevocalic consonants depressed only the pitch onset, not the pitch over the entire syllable. The result is a new rising contour tone. According to Pittayaporn's (2007) tone change model, a prevocalic segment's local effects are more likely to affect only the pitch onset, not the pitch over the entire syllable. In Thai, aspirated obstruents conditioned a low rising tone; this, like the Eastern Lalo Tone *1 split, is a case where prevocalic segments only affected the tonal onset, not the entire syllable.

Insight into the probable path of tonal change may be gained by comparing Central Lalo's tonal system, which is the most conservative, to the more innovative Eastern tonal system. The subphonemic variation seen in Central Lalo today, as shown in Figure 1, was probably found in Proto-Eastern Lalo. Because the original pitch target of Tone *1 was /H, h/, voiced segments' lowering of the pitch onset caused the pitch to take on a rising contour, creating a rising allotone. In E Lalo, the rising allotone became contrastive after the loss of *preglottalization, and the difference between the new rising tone and all other tones became enhanced. The new rising tone was perceived as a contour tone, contrastive not only in pitch height, but also in pitch contour. Pittayaporn (2007) predicts that, in order to maintain perceptual maximization, F0 excursion (i.e. the difference between maximum and minimum F0) increases to maintain the contrast. E Lalo's tone change fits this prediction: the pitch onset has fallen from the High register to the Low register, and the F0 excursion is greater in E Lalo than in C Lalo's rising allotone.

E Lalo has shifted from the Proto-Lalo system of level pitches and harsh versus non-harsh phonation to a system containing both level and contour pitches, all in modal phonation. Phonologically, the low rising tone (/L, lh/) contrasts with Tone *2's low tone (/L, l/), and Tone *L's mid-falling /L, hl/. Although low rising shares the lower register with the low tone and mid-falling tone, all are phonemically contrastive. Low rising is not simply filling in the low register slot in the system. The salient cue that distinguishes the new tone is its rising contour. This is in contrast to Central Lalo, in which the tones can be phonologically represented as level tones.

In NW Lalo's Tone *1 split, preglottalization blocked the spread of low rising; syllables with *preglottalized initials maintained the original high, level pitch, while all other syllables took a low rising pitch. Syllables with *preglottalized initials began with glottal closure. To produce a glottal stop, vocal folds adduct through movement of the arytenoid cartilages and through increased tension in the cricothyroid muscles, the same muscles that control pitch. The increased tension in the vocal folds increases both voice onset time and pitch, thereby decreasing the likelihood of a lowered pitch onset. As discussed in 6.2, glottal constriction is also the underlying phonetic motivation for the raising of pitch seen in *L and *H tone changes.

### *6.2. Changes in *L and *H*

NW Lalo tone changes in *L and *H show the influence of harsh phonation on pitch. Glottal constriction in the form of harsh phonation conditioned the raising of pitch height, just as *preglottalization blocked the spread of a low rising tone. As seen in Figures 3-5 above, NW Lalo's *L has become the highest tone in the system, while *H has merged with *1 as mid-high. As described in Section 3, Proto-Ngwi's syllable final *stops merged to a post-vocalic glottal stop, which by the Proto-Lalo stage had conditioned harsh phonation on the vowel. Harsh phonation then conditioned raising of the pitch height, resulting in *L (L, harsh) > /H, h/ and *H (H, harsh) merging with the remnants of Tone *1 to mid-high (/H, l/).

Kingston (2005) explicitly connects the phonetics of phonation types to tonogenesis as he explains why syllable final glottal closure led directly to high tone in some

Athabaskan varieties and low tone in others. He posits that the postvocalic glottal stop conditioned tense (harsh) phonation in some varieties, leading to high tone, and creaky phonation in others, resulting in low tone. His key insight identifies the related but somewhat independent mechanisms involved in producing tense (harsh) voice and creaky voice. As shown by Edmondson & Esling (2006), harsh voice involves incursion of the ventricular folds up over the vocal folds, increasing their tension and thereby raising the pitch. With creaky voice, the vocal folds are still loose enough for slow and undulating vibrations, resulting in lower pitch.

As discussed in Section 6.1, comparison of C Lalo's tonal acoustic analysis to NW Lalo varieties' tonal systems yields insight into the probable phonetic basis of the NW Lalo tone changes. In the acoustic analysis of C Lalo (Figure 1), the pitch heights of both *L and *H are higher than their modal phonation counterparts in *2 and *3. The pitch in *L starts slightly above mid level, then rapidly falls to the lower register, but remains at all times slightly higher than modal voiced *2. Likewise, *H starts at mid-high before gradually falling to just above the mid pitch level of *3. The higher pitch heights of *L and *H are caused by the articulation of harsh phonation, which has an automatic high pitch correlate. As the Central Lalo tone system has basically retained the Proto-Lalo tonal system, I suggest that these subphonemic higher pitches existed in Proto-Lalo as well. In NW Lalo, as harsh phonation was lost, the subphonemic higher pitches became contrastive, resulting in *L's leap to the higher register and *H's merger with the remaining high pitch syllables of Tone *1.

All NW Lalo varieties show *L as the highest pitch in the tonal inventory, but the contour shape varies across NW Lalo varieties. *L is realized as a high falling pitch, a high rising-falling pitch, or a high rising pitch in the different NW varieties. Figure 6 shows the synchronic reflexes for *L in three Northwestern Lalo varieties: Yilu, Shuizhuping, and Dutian. Shanglizhuo, a fourth NW variety, shows essentially the same rising-falling contour as Shuizhuping and so is not included. To compare across speakers, pitch in semitones is normalized according to the maximum and minimum F0 (F0max and F0min), instead of being normalized to the Tone 3 mean, using the following formula: F0normalized = 100*(St-F0min)/(F0max-F0min), where St refers to the actual value of the pitch in semitones.

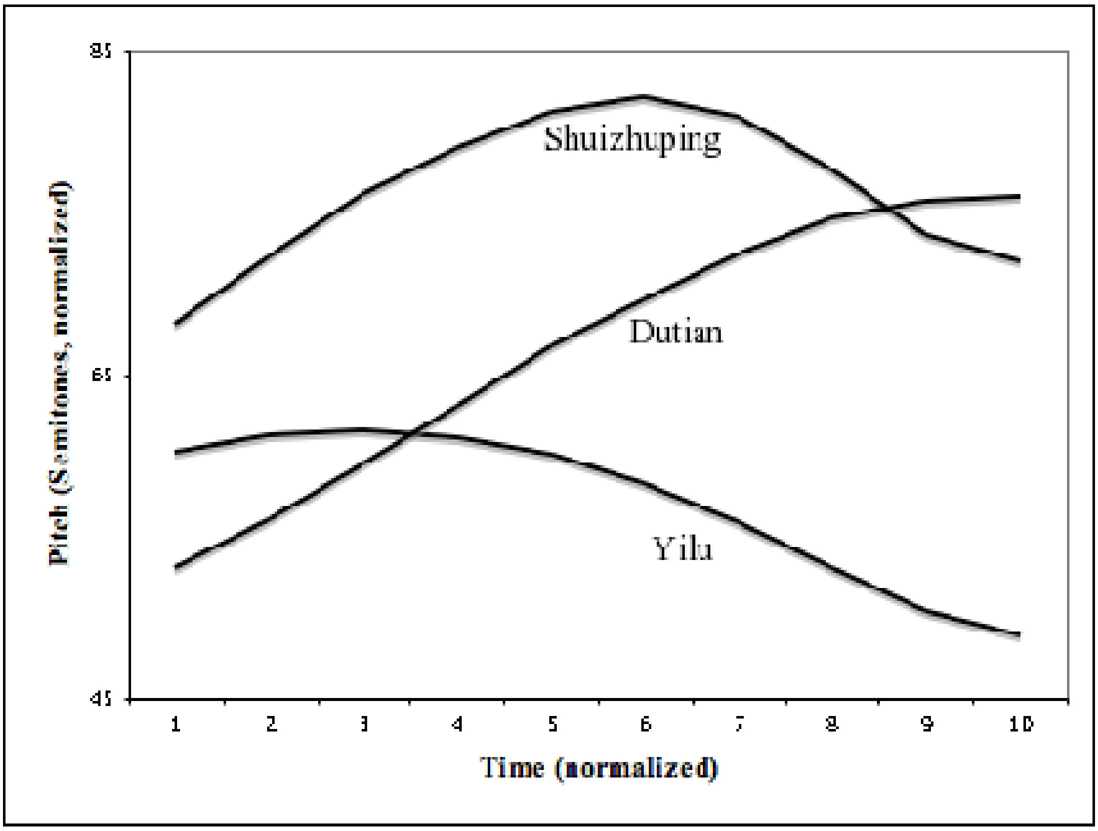


**Figure 6. Variation in *L in NW Lalo varieties. Pitch (in semitones) normalized across speakers according to maximum and minimum F0**

All NW Lalo varieties are closely related, and all share the change in which *L > high. In reconstructing Proto-NW Lalo, I therefore only reconstruct *L's Tone feature as high, without specifying a contour. The varying contour shapes may have arisen from the physiological factors involved in producing a high pitch target. Xu & Wang (2001) find that physiologically, rises in pitch take a longer amount of time than a fall. The time lag for rising pitch sometimes results in peak delay, in which a rising pitch's peak actually occurs on the following syllable. Building on these findings, Pittayaporn (2007), in his tone change model, states that pitch peaks are more likely to slide to the right than to the left. A high falling tone is more likely to become a convex contour than the other way around. A convex contour could then in turn become a rising contour. Peak sliding leads to a possible phonetic explanation for the dialectal variation in *L's contour shapes. *L > high across all NW Lalo varieties, and the pitch peak has remained at the pitch onset in Yilu. In Shuizhuping and Shanglizhuo, the pitch peak has slid to the middle of the tone span, resulting in a convex pitch contour. In Dutian, the peak has slid all the way to the right, resulting in a high rising pitch contour. Although the geographic variation in pitch contour does not prove peak sliding has occurred, the mechanism of peak sliding is a reasonable phonetic explanation for the variation seen in closely related varieties.

New data from E and NW Lalo varieties show interesting interactions between laryngeal gestures and pitch, leading to several tone changes. E Lalo's Tone *1 split shows voiced prevocalic segments' microprosodic lowering of the pitch onset result in the introduction of a rising contour tone into a system that previously only had level pitches of high, mid, and low. NW Lalo's Tone *1 split shows *preglottalization as a key conditioning factor in maintaining Tone *1's original high level pitch, while all other Tone *1 syllables become low rising. The correlation between glottal constriction and pitch height is seen again in NW Lalo's changes in *L and *H, in which harsh phonation conditions raising of the pitch: *L flips to high, *H is raised to mid-high, and harsh phonation is lost, leaving only contrastive pitch. Finally, peak sliding (from Pittayaporn (2007)) is offered as a phonetically based, diachronic explanation for the synchronic, dialectal variation in the realization of *L's contour shape in NW varieties.

## 7. Acknowledgments

I wish to thank the Lalo language consultants in Dutian, Yilu, Shuizhuping and Shanglizhuo villages for their patience and helpfulness in recording the data. Also, many thanks are due to David Bradley and to two anonymous reviewers for their useful comments on earlier versions of this paper.

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