Explaining Disyllabic Tone Sandhi in Linchuan[1]

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Abstract:

This article provides a fine-grained description of the phonology of the Linchuan (<Gan Chinese) language/dialect, especially regarding tone and tone sandhi, and seeks a typological analysis of tone inventory and tone sandhi in the framework of constraint-based phonology (Prince & Smolensky 2002). By means of this tone sandhi analysis, this article discusses three topics: (1) The interaction between the diachrony and synchrony of tonal systems, (2) The constraint of slope correspondence MATCH-SLOPE, and (3) The interaction between tone inventory and tone sandhi. The presentation of these topics sets up the stage for future research on the phonological typology and the modeling of tone and tone sandhi.

1. Introduction

Tone sandhi is a kind of tonal alternation which occurs when tones are combined. For example, there are four basic tones in Mandarin Chinese[2]:

(1) Mandarin tones (Chen 2000)

T1 *ma* [55] 'mother' 媽
T2 *ma* [35] 'hemp' 麻
T3 *ma* [214] 'horse' 馬
T4 *ma* [51] 'to scold' 罵

(2) Mandarin tone sandhi (adapted from Zhang & Lai 2010)

214→35 /__214
xɑu^{213} tɕjəu^{213}→ xɑu^{35} tɕjəu^{213} 'good wine' 好酒

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[2] All tones are marked with Chao tone numbers (Chao 1948, Li 2009, Zhang & Lai 2010); '5' marks the highest pitch, '1' marks the lowest pitch. Also "Contour tones are marked with two juxtaposed numbers" (see Zhang & Lai 2010).

In (2), Tone 3 [214] becomes Tone 2 [35] before Tone 3 [214], which is called "Tone 3 sandhi". In a rule-based framework, the study of tone sandhi has been done by generalizing tone rules, such as assimilation: ∅→ [-upper]/___[-upper]. However, this approach is inadequate to explain both the presence and absence of tone sandhi in Chinese contour tone. Previous feature theory of tone, which is the base of rule-based analysis, has fallen out of usage as previous literature (Bao 1999, Chen 2000) shows that the structure of tones in Chinese varieties is different from African and Amerindian languages, which makes universal tonal features unavailable in analyzing Chinese tones. For example, the feature bundle of tone 15 contains conflicting features [-upper] for the number 1 and [+upper] for the number 5.

In the framework of constraint-based phonology, applying Optimality Theory (OT; Prince & Smolensky 2002), I intend to uncover what shapes tone sandhi in Linchuan, offering an analysis of 41 and 5q ("q" marks tones in checked syllables) sandhi. Other tonal changes, such as the slight raising of 23 or downstep of 31, are not treated but only notated as ↓. Instead of separating tone inventory and tone sandhi, I combine the analysis of both of them, through which candidates that are not included in the language are eliminated by the undominated constraints of tone inventory (except the default tone 33).

This article is rooted in Phonetically Based Phonology (Hayes et al. 2004), especially Dispersion Theory (Flemming 2006). Specifically, Dispersion Theory states that "Distinctiveness constraints are required to account for the preference for more distinct contrasts that can be observed in the typology of segment inventories" (Flemming 2004, 2006). Parallel to the research on segment inventory, I argue that tone inventory is also shaped by the markedness which penalizes perceptually indistinct contrasts that can be observed in the typology of tone inventories. This argument forms the base of the analysis of tone inventory and tone sandhi. In this article, the analysis of tone inventories is based on a sampling of forty-three Chinese languages, mainly Gan and Xiang languages because they are geographically close to Linchuan, but exhibit varied tonal systems.

After building up the constraints of tone inventory, the foundation of my analysis, I discuss the constraints of tone sandhi. I propose a novel way to compute the violation of MATCH-SLOPE which is rooted in Hypothesized Maximum Tonal Contrast adapted from Hsieh's "hypothetical slope categories" (Hsieh 2007). I expect this inquiry will set up the stage for the computational modeling of tone and tone sandhi in the framework of constraint-based phonology.

The organization of this article is as follows: In §2, I begin by providing a fine-grained description of Linchuan's phonological system, historical tonal merger, and disyllabic tone sandhi. §3 introduces the methods of analyzing the typology of tone inventories and the constraint of slope correspondence MATCH-SLOPE. By applying the methods introduced in §3, §4 gives a typology of tone inventories. §5 analyzes the disyllabic tone sandhi.

2. Linchuan and Linchuan phonology

Linchuan is located in Jiangxi province, China. Linchuan is seen as a dialect of Gan Chinese language and belongs to Fu-Guang language group (Luo 1958). Linchuan's tone sandhi has never been studied or documented before. The earliest research of tone pattern in Linchuan is *Linchuanyinxi* [Linchuan Phonology] 臨川音系 (Luo 1958), which was written in the 1940s. In this work, Luo analyzed seven tones in Linchuan:

Luo	T1: 32	T2: 25	T3: 45	T4: 51	T5: 23	T6: 32q	T7: 5q

Luo observed the natural phonetic changes; for example, 32 is higher after 32, and 45 becomes 434 after 45, which is a possible tone sandhi. Linchuan tone sandhi has never been researched and cannot be found even in Chen's *Tone Sandhi* (Chen 2000), which is widely considered to be the most comprehensive handbook on tone sandhi of Chinese dialects available.

The following paragraphs describe Linchuan's phoneme inventory and tone inventory. The term 'rhyme' is occasionally used to refer to the nucleus and coda of the syllabic structure. This section presents the phoneme and tone inventory of Linchuan based on my fieldwork in Spring 2017 and the *Linchuanyinxi* (Luo 1958).

2.1. Phoneme inventory: the following charts exhibit 19 consonants, 9 vowels, 16 diphthongs and triphthongs, and six possible codas in Linchuan. In diphthongs and triphthongs, the /ɛ//e/ in [ɛu], [em], [en], [uen], is close to long vowels /ɛː//eː/ in terms of perception.

Consonant inventory—19 consonants in Linchuan

	Bilabial	Alveolar	Palatal-alveolar		Velar	Glottal
Stop	p	t	ts	tɕ	k	ʔ
Aspirated Stop	pʰ	tʰ			kʰ	
Sibilant Affricates			tsʰ	tɕʰ		
Fricative	f		s	ɕ		h
Nasal	m	n	ȵ		ŋ	

Vowel Inventory—9 vowels in Linchuan

i (ɿ) y		u
e		o
ɛ	ɘ ə	
a		

Diphthongs and Triphthongs

	uo		yo
	ua	ia	
		ie	
oi	uoi		
ai	uai		
əi	ui		
au		eau	
ɛu		iu	
op			

Possible Codas

	Stop	Nasal
Bilabial	-p	-m
Alveolar	-t	-n
Velar		-ŋ
Glottal	-ʔ	

2.2. Tone Inventory

The chart below shows the seven lexical tones in Linchuan.

Tone 1: 31 (ML)	Tone 2: 24 (LH)	Tone 3: 35 (MH)	Tone 4: 41(HL)	Tone 5: 23 (LM)	Tone 6: 3q (M)	Tone 7: 5q (H)

(6) Linchuan tones

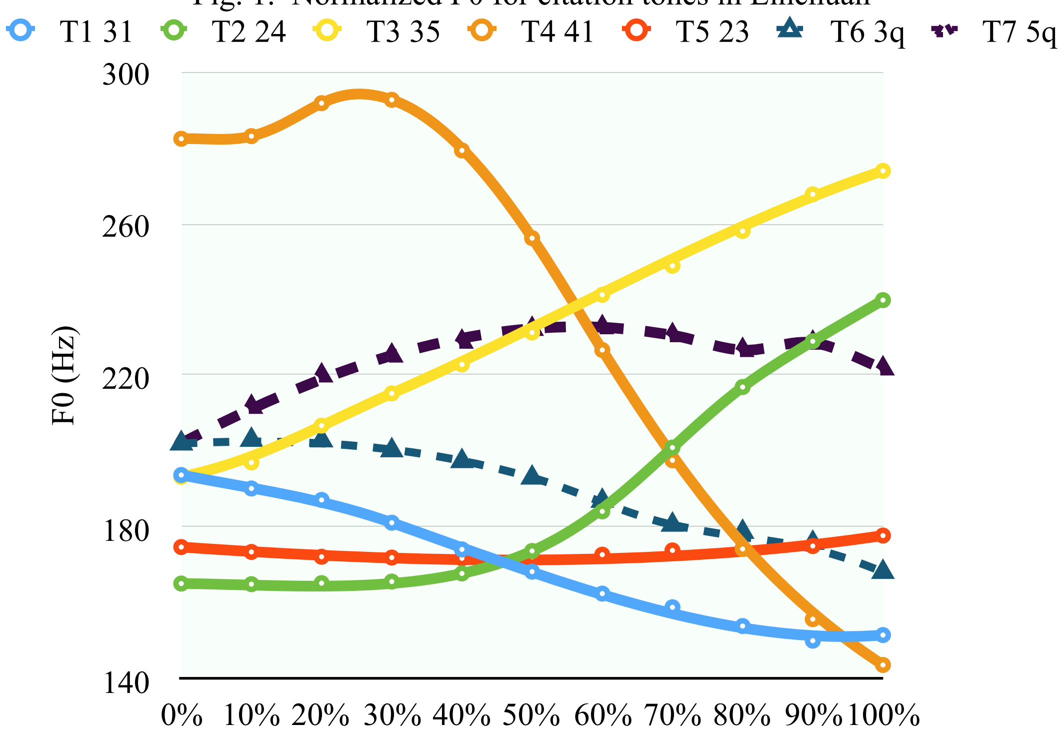
T1 *fu* [31] ‘husband’ 夫
T2 *fu* [24] ‘fox’ 狐
T3 *fu* [35] ‘tiger’ 虎
T4 *fu* [41] ‘rich’ 富
T5 *fu* [23] ‘father’ 父
T6 *fuʔ* [3q] ‘happiness’ 福
T7 *fuʔ* [5q] ‘abdomen’ 腹
(Default tone 33)

Note:

1. 33 is analyzed as the default tone in this article because it does exist in tone sandhi.

2. The beginning point of the contour tone 24 (LH) is slightly lower than the lowest point of 23 (LM).
3. 31 (ML) was mistaken as 22 or 33 in previous literature (see Chen 1991, Liu 1999), due to the lack of apparent fall in pitch. However, in the perceptions of native speakers, 31 is seen as a falling tone, and my analysis reflects this data. The tone has been reanalyzed as 31 (ML). Evidence for this reanalysis is substantiated by the diagram of F0 of lexical tones of Linchuan (see Fig. 1).
4. I analyzed that 41 (HL) is close to 42. In comparison to 24, the pitch target of the contour tone 41 is even lower than 2.
5. Pitch traces of the seven melodies are given in Figure 1 which is based on the recordings in my fieldwork in Spring 2017. All recordings were made using the built-in microphone of the SoundRecorder of Praat (Boersma & Weenink 2013) at a sampling rate of 48 kHz. Speaker read single syllable in the vocabulary list from Luo (1958) twice. Each lexical tones have ten lexemes on average. Recordings were saved as .WAV files and analyzed using Praat. The duration of F0 was normalized as 0% to 100%, while T4, T6, and T7 do have a shorter duration than the other tones.

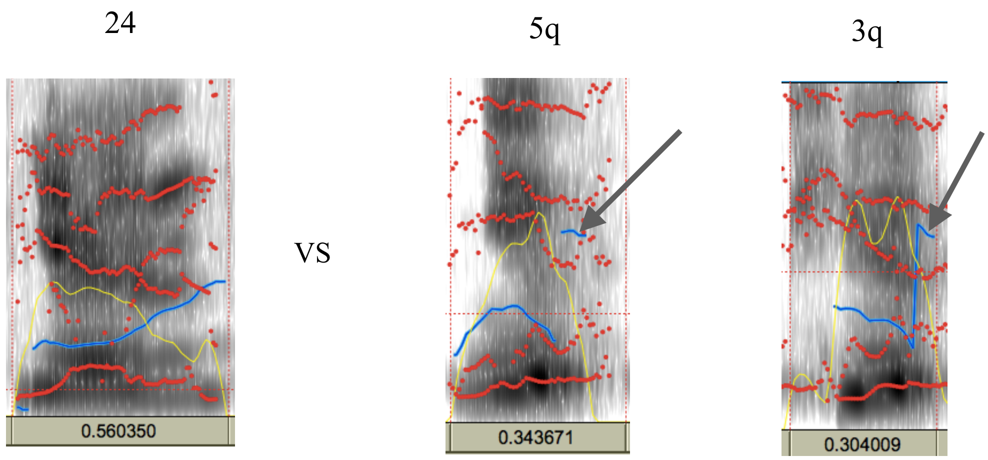
Fig. 1. Normalized F0 for citation tones in Linchuan



6. 3q (M) and 5q (H) are checked tones. They have a special phonation type, which causes abnormal pitch excursion of the word segments, especially when the rhyme is /iɛp/, or /ap/. This phonation type needs further research. Figure 2 exhibits the comparison between 24 and

checked tones 5q and 3q—extracted from Praat Software (Boersma and Weenink 2006). The arrows show the phonation types.

Fig. 2. Comparison between 24 and checked tones 5q and 3q—extracted from Praat Software (Boersma and Weenink 2006)



2.3. Tone sandhi in Linchuan and its problem: In Table 1a, the shaded cells show the tone sandhi of 41 and 5q. The leftmost column of this table represents the first tone in a disyllabic tonal

Table 1a: Linchuan disyllabic tonal combinations 5q sandhi)

	Tone 1: 31	Tone 2: 24	Tone 3: 35	Tone 4: 41	Tone 5: 23	Tone 6: 3q	Tone 7: 5q
Tone 1: 31	31-31↓	31-24	31-35	31-33/31-41	31-23	31-3q	31-3q
Tone 2: 24	24-31	24-24	24-35	24-33/24-41	24-23	24-3q	24-3q
Tone 3: 35	35-31	35-24	35-35	35-33/35-41	35-23	35-3q	35-3q
Tone 4: 41	33-31/41-31	33-24/41-24	33-35/41-35	33-33/33-41/41-33/41-41↓	33-23/41-23	33-33/41-3q	33-3q/41-3q
Tone 5: 23	23-31	23-24	23-35	33-33/33-41	33-23	33-3q	33-3q
Tone 6: 3q	3q-31	3q-24	3q-35	3q-33/3q-41	3q-23	3q-3q	3q-3q
Tone 7: 5q	3q-31	3q-24	3q-35	3q-33/3q-41	3q-23	3q-3q	3q-3q

combination, and the top column represents the second one. One should read down the left column then across to the right.

2.3.1. Historical merger of tonal types

41 maps to two different surface forms in tonal combinations, 33 and 41. I analyze that they have different underlying forms which are labeled 41a and 41b. Though 41a and 41b share the same surface form in the tone inventory, 41a always maps to 33, but 41b keeps 41. For example:

(1) a. 41a+5q→33-33 e.g. t^{h}an^{33} p^{h}oʔ^{33} 'indifferent' 淡薄
b. 41b+5q→41-33 e.g. han^{41} ts^{h}uʔ^{33} 'Han nationality' 漢族

(2) a. 41a+41a→33-33 e.g. t^{h}oŋ^{33} tioŋ^{33} 'weight' 重量
b. 41b+41a→41-33 e.g. ti^{41} n̥ian^{33} 'will' 志愿

(3) a. 41a+23→33-33 e.g. t^{h}oŋ^{33} hai^{33} 'important' 重大
b. 41b+23→41-33 e.g. p^{h}au^{41} t^{h}an^{33} 'bomb' 炮彈

Historical phonology provides an explanation for this conflict. In (1a), (2a), and (3a), the initial of the first syllable was a voiced obstruent in Middle Chinese (MC) (Baxter 1992, Li 2009); in (1b), (2b), and (3b), the initial of the first syllable was voiceless in MC. For example, in (1a) [t^{h}an^{33} p^{h}oʔ^{33}] 'indifferent' 淡薄, /th/ is from a voiced obstruent **d* in MC, but in (1b) [han^{41} ts^{h}uʔ^{33}] 'Han nationality' 漢族, /h/ in [han^{41}] is from the voiceless velar fricative **x* in MC. Figure.3 indicates the diachronic correspondence between tonal categories in Linchuan and MC is analyzed:

- MC's I: If the initial of a syllable was voiceless (VL) and its tone was I in MC, this tone is Tone 1: 31 in Linchuan; if the syllable onset was a voiced obstruent (VO) or a voiced resonants (VR), the corresponding tone in Linchuan is Tone 2: 24.
- MC's II: If the syllable onset was voiceless or a voiced resonant, the corresponding tone in Linchuan is Tone 3: 35; if the syllable was a voiced obstruent, the corresponding tone in Linchuan is Tone 4: 41.
- MC's III: If the syllable onset was voiceless, the corresponding tone in Linchuan is Tone 4: 41; if the syllable initial was a voiced obstruent or a voiced resonant, the corresponding tone in Linchuan is Tone 5: 23.
- MC's IV: If the syllable onset was voiceless or a voiced resonant, the corresponding tone in Linchuan is Tone 6: 3q; if the syllable onset is a voiced obstruent, the corresponding tone in Linchuan is Tone 7: 5q.
- Tone 41 has different historical origins. 41a diverged from II in MC, while 41b is from III (MC), which corresponds to their different performances in the sandhi forms.

Fig. 3. The Changes of Tones from MC to Linchuan

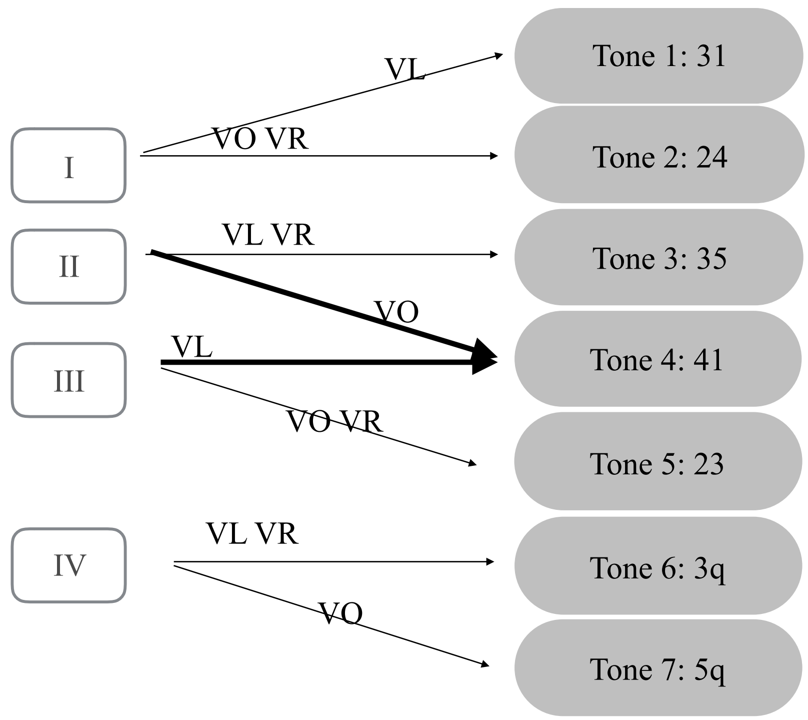


Table 1b: Revised Linchuan disyllabic tonal combinations

	Tone 1: 31	Tone 2: 24	Tone 3: 35	Tone 4: 41a	Tone 4: 41b	Tone 5: 23	Tone 6: 3q	Tone 7: 5q
Tone 1: 31	31-31↓	31-24	31-35	31-33	31-41	31-23	31-3q	31-3q
Tone 2: 24	24-31	24-24	24-35	24-33	24-41	24-23	24-3q	24-3q
Tone 3: 35	35-31	35-24	35-35	35-33	35-41	35-23	35-3q	35-3q
Tone 4: 41a	33-31	33-24	33-35	33-33	33-41	33-23	33-33	33-3q
Tone 4: 41b	41-31	41-24	41-35	41-33	41-41↓	41-23	41-3q	41-3q
Tone 5: 23	23-31	23-24	23-35	33-33	33-41	33-23	33-3q	33-3q
Tone 6: 3q	3q-31	3q-24	3q-35	3q-33	3q-41	3q-23	3q-3q	3q-3q
Tone 7: 5q	3q-31	3q-24	3q-35	3q-33	3q-41	3q-23	3q-3q	3q-3q

In the following passages, I divide 41 into two categories: 41a and 41b. They exhibit different sandhi forms. The tone sandhi of checked tone 5q overlaps with 41 sandhi. For example, when 41a is adjacent to 5q, 41a maps to 33, as 5q maps to 3q. Table 1b reflects this change.

3. Methodologies

Given the tonal systems and tone sandhi in Linchuan, I argue that the constraints of tone inventory partially account for tone sandhi. In terms of tone sandhi, I propose the constraint MATCH-SLOPE to illustrate tonal correspondence.

3.1. The typology of tonal inventories in Chinese varieties

Based on the data of 19 Gan Chinese dialects (Coblin 2015; see Appendix), 12 Central Xiang languages (Coblin 2011), and 12 Chinese languages mentioned in Bao (1999), I reveal that all tone can contrast with less than seventeen tones instead of with all logical possible tones from the maximum set of tones{11, 12, 13, 14, 15, 21, 22, 23, 24, 25……54, 55}, named $\mathscr{T}$.

Table 2 exhibits the typology of tone inventories in Chinese varieties, which shows the absence of 12, 14, 25, 43, 52, 54 in all Chinese varieties. The leftmost column of Table 2 represents all possible lexical tones in Chinese languages, including 19 tones in $\mathscr{T}$, but no 12, 14, 25, 43, 52, 54. Regardless of the accuracy of notation, the typology of tone inventories reveals that 12, 14, 25, 43, 52, 54 are infrequent and marked in Chinese varieties.

Table 2: The typology of tone inventories in Chinese varieties

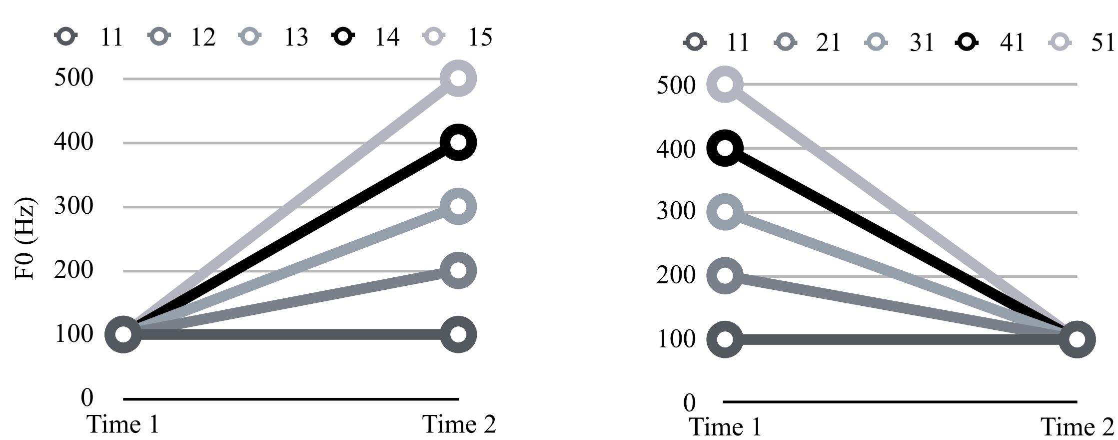
	11	12	13	14	15	21	22	23	24	25	31	32	33	34	35	41	42	43	44	45	51	52	53	54	55
11			√						√		√		√		√		√		√				√		√
12																									
13	√					√	√		√		√	√	√		√	√	√		√	√			√		√
14																									
15					√								√		√										
21			√						√				√	√	√	√	√			√	√				
22			√						√		√		√		√				√				√		√
23									√		√				√	√									
24	√		√			√	√	√			√		√		√	√	√			√					√
25																									
31	√		√				√	√	√				√	√	√	√							√		√
32			√												√	√									

	11	12	13	14	15	21	22	23	24	25	31	32	33	34	35	41	42	43	44	45	51	52	53	54	55
33			√			√	√		√					√	√	√	√			√	√				
34						√					√		√				√						√		
35	√		√		√	√	√		√		√	√	√			√	√		√	√			√		√
41			√					√	√		√	√	√		√										
42			√			√			√				√	√	√	√				√	√				
44	√		√				√								√										
45			√			√			√				√	√	√	√	√				√				
51						√							√	√						√					
52																									
53			√				√				√			√	√										√
54																									
55	√		√				√		√		√		√		√								√		

The top column in this table shows the 𝒯. Checkmark (√) indicates the tonal contrasts between the lexical tones in the typology. For example, tone 11 in the leftmost column can only contrast with seven tones, including 13, 24, 31, 33, 35, 44, and 55. Moreover, the table reveals some implicational universals; for instance, if a language has tone 11, it cannot have tone 22, because 11 only co-occurs with 13, 24, 31, 33, 35, 44, and 55, such as in Songjiang, a dialect of Wu spoken in southwest Shanghai.

3.2. MATCH-SLOPE: Adapted from Hsieh's "hypothetical slope categories" (Hsieh 2007), a "Hypothesized Maximum Tonal Contrast" is proposed, which presumes a tonal language logically has less than nine tonal contrast (Fig. 4). 15 and 51 represent the steepest slope, 14 and

Fig. 4. Hypothesized Maximum Tonal Contrast



41 the second steepest slope, 13 and 41 the slope with average steepness, 12 and 21 the fourth steepest, and 11 is level tone. Adapted from Steriade (2006) and Hsieh (2007, 2008), MATCH-SLOPE is posited.

(1) MATCH-SLOPE:

Match the slope of input and output.

The computation of MATCH-SLOPE follows the Hypothesized Maximum Tonal Contrast which suggests that there are nine possible tonal shapes in a tonal language. For the convenience of computation, I postulate that the unit of time as $1 = 2 - 1$. In addition, the slope of two-place tone is equal to the height of second place minus the height of the first place ($Slope = T2 - T1$). For example, the slope of the tone 15 is $4 = 5 - 1$, and the slope of the tone 55 is $0 = 5 - 5$. The slope of raising tones are all positive number, while falling tones are negative. *I analyze* the violation of MATCH-SLOPE is equal to the absolute value of the slope of input minus the slope of candidate:

$$VIOLATION_{MATCH-SLOPE} = |(Slope\ of\ Input - Slope\ of\ Candidate)|$$

As indicated in Table (3a), when the input *x* belongs to {41, 52}, if the input *x* is equal to 41, then the violation is $0 = |(1-4)-(1-4)| = |(2-5)-(1-5)|$. Each slope of an input and candidates has corresponding number of violations. In Table (3b), with the input 33 which belongs to {11, 22, 33, 44, 55}, if the candidate *y* belongs to {11, 22, 33, 44, 55}, the violation of MATCH-SLOPE is $0 = |(1-1)-(1-1)|$; when $y \in$ {12, 23, 34, 45} or $y \in$ {21, 32, 43, 54}, the violation of MATCH-SLOPE is $1 = |(1-1)-(1-2)|$.

Table 3a: The Computation of MATCH-SLOPE when input x ∈ {41, 52}

Input	Slope of Input	Candidate	Slope of Candidates	Violation
$x \in$ {41, 52}	3	$y \in$ {51}	4	1
$x \in$ {41, 52}	3	$y \in$ {41, 52}	3	0
$x \in$ {41, 52}	3	$y \in$ {31, 42, 53}	2	1
$x \in$ {41, 52}	3	$y \in$ {21, 32, 43, 54}	1	2
$x \in$ {41, 52}	3	$y \in$ {11, 22, 33, 44, 55}	0	3
$x \in$ {41, 52}	3	$y \in$ {12, 23, 34, 45}	1	4
$x \in$ {41, 52}	3	$y \in$ {13, 24, 35}	2	5
$x \in$ {41, 52}	3	$y \in$ {14, 25}	3	6
$x \in$ {41, 52}	3	$y \in$ {15}	4	7

Table 3b: The Computation of MATCH-SLOPE when input x ∈ {11, 22, 33, 44, 55}

Input	Slope of Input	Candidates	Slope of Candidate	Violation
$x \in \{11, 22, 33, 44, 55\}$	0	$y \in \{51\}$	4	4
$x \in \{11, 22, 33, 44, 55\}$	0	$y \in \{41, 52\}$	3	3
$x \in \{11, 22, 33, 44, 55\}$	0	$y \in \{31, 42, 53\}$	2	2
$x \in \{11, 22, 33, 44, 55\}$	0	$y \in \{21, 32, 43, 54\}$	1	1
$x \in \{11, 22, 33, 44, 55\}$	0	$y \in \{11, 22, 33, 44, 55\}$	0	0
$x \in \{11, 22, 33, 44, 55\}$	0	$y \in \{12, 23, 34, 45\}$	1	1
$x \in \{11, 22, 33, 44, 55\}$	0	$y \in \{13, 24, 35\}$	2	2
$x \in \{11, 22, 33, 44, 55\}$	0	$y \in \{14, 25\}$	3	3
$x \in \{11, 22, 33, 44, 55\}$	0	$y \in \{15\}$	4	4

Table 4: The computation of MATCH-SLOPE (Linchuan)—I(nput), C(andidate) and V(iolation)

I	**C**	**V**	**I**	**C**	**V**	**I**	**C**	**V**	**I**	**C**	**V**	**I**	**C**	**V**	**I**	**C**	**V**	**I**	**C**	**V**
41	31	1	31	31	0	24	31	4	35	31	4	23	31	3	3q	31	1	5q	31	1
	24	5		24	4		24	0		24	0		24	1		24	3		24	3
	35	5		35	4		35	0		35	0		35	1		35	3		35	3
	41	0		41	1		41	5		41	5		41	4		41	3		41	3
	23	4		23	3		23	1		23	1		23	0		23	2		23	2
	3q	2		3q	1		3q	3		3q	3		3q	2		3q	0		3q	0
	5q	2		5q	1		5q	3		5q	3		5q	2		5q	0		5q	0
	33	3		33	2		33	2		33	2		33	1		33	1		33	1

Table 4 exhibits how to apply this computation in Linchuan tones; for instance, when the input is 41, the candidate 31 has one violation of MATCH-SLOPE. In the top row of Table 4, I represent input, C represents candidate, and V represents violation.

MATCH-SLOPE illustrates the importance of slope-matching in tone sandhi. When the input is 24, MATCH-SLOPE predicts 35 is more optimal than 33 because 35 matches the slope of 24, while 33 has two violations of MATCH-SLOPE, differentiating with traditional correspondence constraints for tone such as IDEN-IO (Tone) which are rooted in "correspondence theory" (McCarthy & Prince 1995) which was originally applied to deal with reduplication. In previous literature, Zhang (2001) proposes PRESERVE (tone), Hsieh (2007) suggests *The Index of Slope Difference* (ISD) and MATCH-SLOPE$_{ISD}$. Both of these constraints share the same principle with MATCH-SLOPE in this article. Hsieh (2008) argues the MATCH-SLOPE$_{ISD}$ is a markedness constraints family; for example, he proposes the constraint MATCH-SLOPE$_{ISD>0}$: the ISD value should be positive, which indicates that there is 'no smooth-to-steep slope matching' (Hsieh 2008), which could be interpreted as the high value of violation of MATCH-SLOPE in this article.

One puzzle is how to compute MATCH-SLOPE in checked tones. Phonetically, checked tones 5q and 3q are all falling tones, and they share a similar tonal slope (cf. Fig.2. Two clips extracted from Praat). 5q and 3q are analyzed to be shorter 54 and 32. 54 and 32 share the same slope, which means 5q and 3q also have the same slope. When the slope of checked tone is compared with normal contour tones, its slope is closed to 54 or 32.

4. The analysis of tone inventory

This section analyzes three pairs of tonal contrast in Linchuan: 23 and 24, 24 and 35 and 31 and 41, and introduces the constraints of Linchuan's tone inventory, with reference to Dispersion Theory (Flemming 2006).

4.1. The constraints of Linchuan tone inventory are analyzed. The method is, given the maximum tone pool $\mathscr{T}$ of all logical possible tones, tones that are not in Linchuan tone inventory are ruled out step by step, and a phonetically based analysis is pursued to posit the markedness constraints of Linchuan tone inventory.

Step 1: Given the maximum tone pool $\mathscr{T}$ of tone.

		T2				
		1	**2**	**3**	**4**	**5**
	1	11	12	13	14	15
	2	21	22	23	24	25
T1	**3**	31	32	33	34	35
	4	41	42	43	44	45
	5	51	52	53	54	55

Step 2: Rule out typologically marked tones.

Five tones are typologically unfavored in Chinese varieties, namely, 12, 14, 25, 52, and 54, according to Coblin (2011, 2015), Bao (1999), and Chen (2000).

Markedness constraint *{12, 14, 25, 52, 54} is posited to rule out these tones. This constraint must be undominated. In the table Step 2, tone 12, 14, 25, 52, and 54 are in the bordered cells, and they are eliminated in Step 3.

(4) *{12, 14, 25, 52, 54}: No tone 12, 14, 25, 52, and 54. Mark one violation for every tone in this set.

Step 3: Language specific markedness constraints of Linchuan

(5) KEEP (31): Keep tonal contrast between 31 and the other tones. Assign one violation for inventory without 31.

(6) KEEP (41): Keep tonal contrast between 41 and the other tones. Assign one violation for inventory without 41.

Step 2

11	12	13	14	15
21	22	23	24	25
31	32	33	34	35
41	42	43	44	45
51	52	53	54	55

Step 3

11		13		15
21	22	23	24	
31	32	33	34	35
41	42	43	44	45
51		53		55

Step 4: Rule out implicationally unfavored tones of tone 31.

Step 5: Rule out implicationally unfavored tones of tone 41.

Correlated with tone 31 and 41, there are two implicational universals (c.f. §3):

a. If the language has 31, it won't have 15, 21, 23, 32, 42, 43, 44, 45, and 51; vice versa;

b. If the language has 41, it won't have 11, 22, 34, 53, and 55, vice versa;

Two markedness constraints are proposed:

(7) *(31— 15, 21, 23, 32, 42, 43, 44, 45, 51): If the language has 31, it won't have 15, 21, 23, 32, 42, 43, 44, 45, and 51, vice versa;

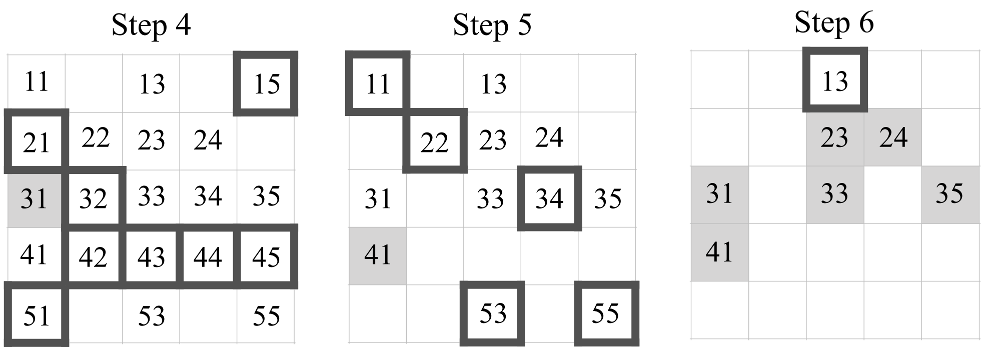
(8) *(41— 11, 22, 34, 53, 55): If the language has 41, it won't have 11, 22, 34, 53, and 55, vice versa.

Step 6: Find the tone inventory, compare with Linchuan's tone inventory

In contrast to Linchuan, the tone inventory obtained has one extra tone 13.

(9) *13: No low raising tone 13.

There is no tonal contrast between 13 and the other tones in Linchuan, that's why it is banned in tone inventory. However, tone 13 is attested in some Chinese varieties. For instance, in Jiangxi province, Fengxin, Gaoan, Chalin, Lianhua, Nancheng, Lichuan have 13; in Central Xiang, Xiangxiang, Shuangfeng, Loudi (Laojie), Loudi (Jiaolongcun), Lianyuan, Anhua, Xinhua, Xupu, Chenxi have 13, and Luxi has a 113. Tone 13 also exists in the other languages, such as Weining



Miao, a Hmong–Mien language spoken in Miao Autonomous County, and Xiamen (Amoy dialect), a dialect of Hokkien spoken in Xiaomen, Fujian province. Because *13 is not universal in all languages, this constraint must be low ranked in *13-favored* languages.

4.2. Markedness constraints rule out all unattested tones in Linchuan. On the other hand, Dispersion Theory (Flemming 2006) suggests the constraint MAXIMIZECONTRAST (Flemming 2006), which is entertained to maximize tonal contrast in tone inventory[3].

(8) MAXIMIZECONTRAST (adapted from Flemming 2006): Maximize tonal contrast of tone inventory. Assign one violation mark if any tone in the inventory {11, 12, 13, 14, 15, 21, 22, 23, 24, 25…54, 55} is deleted.

MAXIMIZECONTRAST keeps the contrast between 23, 24, 35, 31, and 41. The optimal candidate is inventory {23, 24, 35, 31, 41} while smaller inventory {23} has twenty-four violations of MAXIMIZECONTRAST. The ranking of the constraints in this section is:

(9) Ranking for the constraints of tone inventory: *{12, 14, 25, 52, 54} >>{KEEP(31), KEEP(41)}>>*(31— 15, 21, 23, 32, 42, 43, 44, 45, 51)>>*(41— 11, 22, 34, 53, 55) >> *13>> MAXIMIZECONTRAST

{11, 12, 13, 14, 15, 21, 22, 23, 24, 25…54, 55}	*{12, 14, 25, 52, 54}	KEEP(31)	*(31— 15, 21, 23, 32, 42, 43, 44, 45, 51)	KEEP(41)	*(41— 11, 22, 34, 53, 55)	*13	MAX-CONTRAST
{11, 12, 13, 14, 15, 21, 22, 23, 24, 25…54, 55}	5!		9		5	1	
{11, 13, 15, 21, 22, 23, 24, 31, 32, 33, 34, 35, 41, 42, 43, 44, 45, 51, 53, 55}			9!		5!	1	

[3] I would like to give Adam Albright (MIT) credit for this idea.

{11, 13, 15, 21, 22, 23, 24, 32, 33, 34, 35, 41, 42, 43, 44, 45, 51, 53, 55}		1!				1	
{11, 13, 15, 21, 22, 23, 24, 31, 32, 33, 34, 35, 42, 43, 44, 45, 51, 53, 55}				1!		1	
{13, 23, 24, 31, 33, 35, 41}						1!	
☞{23, 24, 31, 33, 35, 41}							19
{23}							24!
{24}							24!

The approach works even if introducing KEEP (23) and KEEP (35). However, Tone 35 has contrast with almost all the other tones in $\mathscr{T}$, which suggests the markedness KEEP (35) are not a language-specific constraint for Linchuan, and cannot rule out enough nonexistent tones in $\mathscr{T}$. On the other hand, Tone 23 only exists in Linchuan, which makes 23 unusual in typology. This is the reason why I introduce KEEP (31) and KEEP (41), but not the other language-specific constraints beforehand.

The research on the acquisition of these tones could provide the evidence for the approach. For example, if children learn tones 31 and 41 earlier than the other tones in Linchuan, it would support my analysis.

In the interest of space, a "compact" constraint INVENTORY which represents all constraints on tone inventory is proposed as follows:

(11) INVENTORY: Assign one violation to the output if a tone is neither the default tone 33 nor from tone inventory.

This constraint must be undominated in the analysis of tone sandhi to eliminate unattested tones.

5. Constraint-based analysis of tone sandhi

5.1. First of all, I analyze the 41 sandhi, with reference to the historical reconstruction of tonal types in section 2. I have argued that the different underlying forms 41a and 41b share the same surface form 41 because 41b derived from Tone II in MC, while 41a derived from Tone III in MC, as indicated in §2. Thus, 41a and 41b must be treated as different inputs in the analysis of 41 sandhi. The evidence supports the statement that the tone sandhi of 41a is lexically specific. A lexeme-specific markedness[4] constraint is proposed to eliminate the falling tones in the lexeme with tone 41a.

(1) *FALL/ττ-41a: No falling tone in lexemes which have 41a.

(2) **Ranking 1**: INVENTORY>>*FALL/ττ-41a>>MATCH-SLOPE

Tableau 1 shows the OT analysis of 41a + 41a goes to 33-33 by 'comparative tableaux' (Prince 2000; McCarthy 2001). In this tableau, INVENTORY is not relevant. The Richness of the Base (ROTB; see Kager 1999) suggests that the input is unconstraint, which makes all sandhi forms of the language included in the Tableau 1, as the constraints of inventory eliminate those unattested combinations in Linchuan. However, the following tableaux will exhibit fewer candidates to save space. In tableau 1, INVENTORY eliminates unattested tones and *FALL/ττ-41a eliminates all falling tones including 41 or 31, if lexeme belongs to 41a. All the other candidates, except 33-33, have more than 8 violations of MATCH-SLOPE.

Tableau 1

41a+41a	INVENTORY	*FALL/ττ-41a	MATCH-SLOPE
☞33-33			6
24-24			8 W
33-35			8 W
24-33			8 W
35-33			8 W
24-33			8 W
35-33			8 W
35-24			8 W
33-24			8 W
23-35			9 W
24-35			10 W
35-35			10 W
31-24		1 W	
41-41		2 W	

[4] Many methods from morphophonology are available for historical tonal merger; for example, Cophonology Theory (Orgun 1996; Inkelas et al. 1997; Anttila 2002) and Stratal Optimality Theory (Stratal OT; Kiparsky 2000, 2008; Bermúdez-Otero 2016). In the second one, people stipulate lexemes from 41a and lexemes from 41b as separate stratum and assigning constraints for different stratum. However, the discussion of this topic is not the task of this article.

41-31		1 W	1 L
31-31		1 W	2 L
41-33		1 W	3 L
33-41		1 W	3 L
33-31		1 W	4 L
31-33		1 W	4 L
23-31		1 W	5 L
41-24		1 W	5 L
41-35		1 W	5 L
24-41		1 W	5 L
35-41		1 W	5 L
24-31		1 W	6
35-31		1 W	6
31-35		1 W	6
31-41		2 W	1 L

Ranking 1 works well in all the nonchecked tonal combinations; for example, when the input is 41a + 31, Ranking 1 makes the correct prediction. The constraint INVENTORY eliminates all the tones that are neither the default tone nor citation forms of the language. *FALL/ττ-41a eliminates all the candidates that include 31 and/or 41 when lexemes are ‘41a’. 33-33 competes with 33-31 in the constraint MATCH-SLOPE. The winner in this tableau is 33-31 because 33-31 only has three violations of MATCH-SLOPE, while 33-33 has five.

Tableau 2

41a+31	INVENTORY	*FALL/ττ-41a	MATCH-SLOPE
☞33-31			3
33-33			5 W
41-41		1 W	1 L
41-33		1 W	2 L
33-41		1 W	4 W

With the nonchecked tones where tone sandhi does not occur, Ranking 1 correctly predicts the output forms. For example, when the input is 31 + 31, the candidate 31-31 does not violate any constraints, while the other candidates more or less violate INVENTORY or MATCH-SLOPE, as illustrated in Tableau 3.

Tableau 3

31+31	INVENTORY	*FALL/ττ-41a	MATCH-SLOPE
☞31-31			
41-41			2 W
41-33			3 W
33-41			3 W
33-33			4 W
11-55	2 W		4 W

5.2. However, Ranking 1 makes incorrect predictions when inputs include 5q. For example, when the input is 41a + 5q, Ranking 1 predicts the winner is 33-5q instead of 33-3q, as 5q and the input 3q share the same slope and have the same number of the violation of MATCH-SLOPE.

Tableau 4

41a+5q	INVENTORY	*FALL/ττ-41a	MATCH-SLOPE
☹ 33-3q			3
☹ 33-5q			3
33-41			6 W
41-41		1 W	3
41-33		1 W	1 L

Markedness constraint *5q/ττ is proposed to eliminate 5q in the sandhi forms. However, this constraint needs more typological evidence. A hypothesis is when there are more than one checked tones in Chinese languages, 5q, corresponding with voiced IV in MC, are marked.

(4) *5q/ττ: No high checked tone in the tonal combination.

(5) **Ranking 2:** INVENTORY>>{*FALL/ττ-41a, *5q/ττ}>>MATCH-SLOPE

As indicated in Tableau 5, 33-5q is eliminated by *5q/ττ, and the candidates 41-41 and 41-33 are eliminated by *FALL/ττ-41a. MATCH-SLOPE rules out 33-41 for it has more violations (6) than the optimal candidate 33-3q (3).

Tableau 5

41a+5q	INVENTORY	*FALL/ττ-41a	*5q/ττ	MATCH-SLOPE
☞33-3q				3
33-41				6 W
33-5q			1 W	3
41-41		1 W		3
41-33		1 W		1 L

Ranking 2 INVENTORY>>{*FALL/ττ-41a, *5q/ττ}>>MATCH-SLOPE works on **all** disyllabic tonal combinations in Linchuan. Other tableaux examining all the data in Table 7 are omitted to save space.

6. Discussion

The research of Linchuan disyllabic tone sandhi raises questions or topics for future research. First of all, The analysis of tone inventory and tone sandhi reveals the historical tonal merger of citation form 41 and illustrates a lexeme-specific markedness constraint *FALL/ττ-41a, which raises a hypothesis that a voiced initial in Middle Chinese triggers low tone (L) in sandhi form, while a voiceless initial triggers high tone (H), which causes the appearance of L tone in sandhi form and makes 41 map to 33, as indicated in the following process.

(1) The sound changes from Middle Chinese to Linchuan (// represents the underlying forms)

Input	/+voiced/	*MM	/-voiced/
[+voiced] triggers L tone	[+voiced, L]	*MM	[-voiced]
[-voiced] triggers H tone	——————	*MM-L	[-voiced, H]
MM-L→ML-L	——————	*ML-L	——————
ML-L→HL-L	——————	*HL-L	——————
[+voiced]→[-voiced]	[-voiced, L]	————	——————
Low tone disappears in surface forms	[-voiced, (L)]	HL	——————
Output	[-voiced, (L)]	HL(41)	[-voiced, H]

However, now that low floating tone does not exist in lexical tones, since there is no 33 in lexical tones, why does it appears in sandhi form? A tentative explanation is that speakers learn the tonal combination as one unit which always retains old forms, while tones in two-word units are more colloquial and reflect the citation forms of Linchuan. In the other words, 33 is close to the ancient form of the lexeme, and the tone sandhi reflect the historical sound.

(2) The appearance of L tone in sandhi forms (hypothesis)

Input	/-voiced, (L)/	HL(41)	/-voiced, H/
Low floating tone appears in sandhi forms	[-voiced, L]	L-HL	————
L-HL→L-ML	————	L-ML	————
L-ML→MM	————	MM	————
Output	[-voiced, L]	MM(33)	[-voiced, H]

This analysis might be improved if a "Wug test" to the 41 and 5q sandhi is pursued. The productivity of the 41 and 5q sandhi needs the evidence from the novel and ungrammatical words. Wug test also helps to examine the hypothesis that tone sandhi is the result of diachrony. If 41 and 5q sandhi also work on novel words, they might have a high productivity, which falsifies the statement that tone sandhi is only the memorization of old forms.

In addition, problems are raised in the typology of tone inventories. First of all, the linguistic data of the typology is not from one worker, and have no sound files to support these data. For example, the 11 of Coblin (2015) could be 22 of another fieldworker or researcher. Only if there are valid natural linguistics data to support, the foundation of this typology is not solid. One way in which the weak point might be improved is examining these data in the fieldwork or the recordings, instead of only notations from previous literature. Another place is the languages are mainly Gan and Xiang languages, and the number of the other Chinese varieties is comparatively few. Data-collection from the other languages, such as Cantonese and Wu would help to refine the typology in this article.

Last but not least, markedness constraint *FALL/ττ-41a hides a serious problem: why 41 cannot map to 31 but 33? *FALL/ττ-41a is stipulated to eliminate 31 in the output, while this constraint is both lexeme-specific and language-specific. This is a problem I am unable to resolve at present, while the research on the tone sandhi in the other languages might improve the analysis.

7. Conclusion

In this article, I have described the phoneme and tone inventory in Linchuan, and analyze the tone inventory based on the typology of Chinese varieties. Moreover, I proposed constraint MATCH-SLOPE which works not only in explaining why 41a and 5q will change, but also why the other tones will not change. Comparing with simply banned specific forms in the output, e.g. *31: No 31, which incorrectly ban all 31 in a language, or traditional constraints of correspondence, e.g. IDENT(tone), which is unable to explain disyllabic tone sandhi in Linchuan, MATCH-SLOPE provides an ideal way to explain tonal alternations in Chinese languages.

By researching slope correspondence (or contour correspondence, generally speaking), I seek a way to combine the slope correspondence in classic Optimality Theory with computational phonology in the framework of constraint-based phonology, a topic which is not discussed in this article.

The analysis of tone inventory and tone sandhi takes both a global and a narrow perspective at how to understand tone sandhi. In this way, the attempt to incorporate the constraint on tone inventory and tone sandhi provides a novel way for researching the tonal system of languages.

8. Appendix

Ia, Ib, IIa, IIb, IIIa, IIIb, IVa, and IVb are the traditional terms in Chinese historical phonology for tonal categories. IVa and IVb are checked tones and has been shaded, which is not taken into consideration in the typological inquiry because the transcription of checked tones cannot exhibit all phonetic information of them.

Tone inventories in Gan Chinese (adapted from Coblin 2015)								
Language	Ia	Ib	IIa	IIb	IIIa	IIIb	IVa	IVb
Tongshan 通山	213	21	42		45	33	55	
Wuning 武寧	34	21	51		45	33	5	2
Tongcheng 通城	212	22	31		24	33	55	
Xingzi 星子	33	24	31		55/214	11	35	
Yongxiu 永修	35	21	42		45	33	5	2
	24				445		45	
Duchang 都昌	33	35	351		15	313	5/1	3
Anyi 安義	22	31	214		55	223	5/54	3

Nanchang 南昌市	42	24	213		45	21	5	21
Fengxin 奉新	41	13	35		33	21	44	21
Gao' an 高安	24	13	31		55	22	4	1
Chalin 茶陵	35	13	53		55			
Pinxiang 萍鄉	13	44	35		11			
Anfu 安福	44	21ʔ12	53	31ʔ13	22			
Lianhua 蓮花	44	13	53		22	35		
Jian吉安	35		31		22			
Suichuan 遂川	53	22	31		213	34	5	
Linchuan 臨川	32	25	45		51	23	32	5
Nancheng 南城	32	35	41		3	13	5	
Lichuan 黎川	22	35	44		53	13	3	5

Tone inventories in Central Xiang (Coblin 2011)

Language	Ia	Ib	IIa	IIb	IIIa	IIIb	IVa	IVb
Xiangxiang 湘鄉	55	13	21		45	33		
		23			35			
Shuangfeng 雙峰	55	13	31		35	33		
Loudi(Laojie) 婁底老街	44	13	42		35	11		
Loudi(Jiaolongcun) 婁底蛟龍村	44	13	42		35	21		
Lianyuan 漣源	44	13	42		55	11	33	
Anhua 安化	33	13	31		45	21		
					24			
Xinhua 新化	33	13	21		45		24	
Xupu 溆浦	44	13	23		35	53		
Chenxi 辰溪	44	13	21		24	53		
Luxi 瀘溪	35	24	42		113	55		
Huitong(Lincheng) 會同林城	21	31	24		55	22		

Huitong(County) 會同縣	11	31	24		45	33		

Tone inventories in the other Chinese languages (adapted from Bao 1999)								
Language	Ia	Ib	IIa	IIb	IIIa	IIIb	IVa	IVb
Danyang Literary 丹陽文讀	33		55		24		4	
Danyang Colloquial 丹陽白讀	33	24	55	24	24	11	3	4
Changzhi 長治	21	24	535		44	53	4	54
Gao'an 高安	55	24	42		33	11	3	1
Weining Miao 威寧苗語	53	31	44	22	35	13	5	3
Wenzhou 溫州	44	31	45q	34q	42	22	323	212
Xiamen 廈門	23	213	55	13	53	31	5	212
Zhenjiang 鎮江	42	35	31		55		5	
Pingyao 平遙	13		53		35		23	54

Tone inventories in Bai, Songjiang, and Wuyi—from Bao 1999

Language							
Bai 白語	Lax	33	31	55	35		
	Tense	42	44	21	55		
Songjian 松江		55	33	11	53	31	13
Wuyi 武夷		55	35	53	31	33	

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