Tone-driven epenthesis in Wamey

This paper argues that tone-driven epenthesis is possible in tonal languages, contrary to claims in the literature that it is unattested/impossible. In Wamey, an epenthetic [ə] is inserted to host a high tone in two contexts. The first is to host a tone which would otherwise be left floating due to a restriction on rising tones in closed syllables, i.e. /cv̀cⒽ/ maps to [cv̀cə́] due to a ban *[cv̌c]. The second is to host a tone which is introduced by word-level morphology but is restricted from associating across a stem boundary, i.e. an input /(cv̀cv̀)cⒽ/ maps to [(cv̀cv̀)cə́] not *[(cv̀cv́)c]. These patterns cannot be attributed to syllable phonotactics, which freely allow all consonants in coda position. We assemble the evidence for tone-driven epenthesis, focusing on the distribution of final [ə] in lexical stem structure and [ə]-alternating suffixes which pattern as underlyingly consonant-final. A simple OT analysis derives [ə]-epenthesis, utilising common constraints (e.g. *FLOAT, *RISE, OCP(H), DEP(μ), *etc.*) together with constraints against associating tone across certain prosodic boundaries. In total, Wamey provides evidence for parallelism between tonal and intonational languages given that intonation-driven epenthesis is well-established in the literature. This parallelism is predicted under a model where both types of prosodic systems make use of the same phonological substance and autosegmental architecture, and have the same functional pressures to cultivate segmental environments best suited for realizing pitch targets.

1 Introducing the issue: The interaction of tone and epenthesis

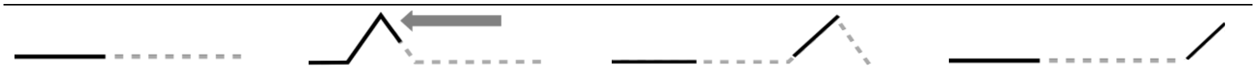
Pitch is present in the linguistic signal of all languages. Roughly speaking, pitch can be exploited as lexical and grammatical tone in ‘tonal languages’, and as pitch accents and boundary tones in ‘intonational languages’. For both tonal and intonational languages, the basic units of pitch contrast are referred to as TONES. Such tones may be pre-associated to a specific tone-bearing unit (TBU) such as a mora, or enter the derivation unassociated to any TBU in which case they are referred to as FLOATING TONES.

As a null hypothesis, we expect that floating tones in tonal languages and intonational languages should not be ontologically distinct, i.e. comparable representations and behaviour should be able to be identified in both. We refer to this premise as TONE-INTONATION PARALLELISM. To exemplify, consider first a tonal language Kalabari (Ijoid: Nigeria), which has a basic distinction between H and L plus downstep (i.e. ꜜH). To express the imperative, a floating tone sequence H L is appended to the right edge of the verb and co-occurs with its lexical tone (Harry 2004). For example, a low tone root like /sɔ̀/ ‘cook’ has the imperative form [sɔ̀̂] ‘cook!’ with a LHL pattern, where the floating tones dock to the lone TBU.

We can compare this to (American) English, an intonational language. Jeong & Condoravdi (2018) highlight the use of the so-called ‘calling contour’ (Pike 1945) in certain imperatives, e.g. used in the mnemonic imperative *Don’t forget to feed the cats!* Phonologically, this is analysed as a complex H*ꜜH-L% intonation configuration, in essence a H* pitch accent on the (final) stressed syllable *cats* followed by a downstepped ꜜH. In both Kalabari and English, the tonal inventory can be deconstructed into basic tonemes (H, L, ꜜH), and floating tones are unassociated in the input, target specific positions, co-occur with no segmental exponents, and systematically express complex meaning as part of the grammar (here, flavours of imperative).

What happens when there is no appropriate TBU in the targeted location for a floating tone to dock to, or docking to this TBU would create a banned structure? One strategy in a number of intonational systems is to induce epenthesis of a TBU to host the floating tones, typically some default vowel (e.g. /ə/). Consider the case of intonation in Tashlhiyt (Berber: Morocco), a book-length treatment of which is provided by Roettger (2017). A floating H is found in several intonational contexts, where it serves in part to indicate yes-no and echo questions, as well as contrastive statements (see also Grice *et al*. 2015 for details). One area of focus involves cases where intonational floating tones – what Roettger refers to as the ‘tune’ – target a word which does not have an appropriate TBU to host the tone – referred to as the 'text'. Such a mismatch is found in words composed entirely of voiceless consonants, e.g. /tfsχt/ 'you cancelled'.

Roettger identifies three general strategies for tune-text alignment in such cases, shown in Table 1. The solid black line indicates pitch over voiced segments, and the dashed grey line over voiceless segments. In the first strategy, the tune is simply deleted and no pitch rise is seen. In the second, tone is anticipated on some TBU before the targeted portion, e.g. a vowel of a preceding word. The third option involves the insertion of a default vowel /ə/, to which the tune associates. This may be at some point within the voiceless sequence (a), or at the end of the sequence (b).



. . . t f s χ t #	. . . t f s χ t #	. . . t f s ə χ t #	. . . t f s χ t ə #
No surfacing tone	Anticipated tone	Tone on schwa (a)	Tone on schwa (b)

Table 1: Strategies for realizing intonation on voiceless sequence in Tashlhiyt (Roettger 2017: 98)

In his discussion, Roettger (2017: 126) interprets schwa insertion as serving as "a landing site for a communicatively relevant tone". Although this is not a categorical pattern (epenthesis sometimes occurs even without a tune), two observations are important. First, insertion is more often observed in sentence modalities with "complex tonal movements", thus showing a correlation between tone and epenthesis. Second, vowel insertion is observed significantly more in phrase-final position than phrase-medially, the former more often being the target of the intonational tune. Taken together, the presence of /ə/ can be understood (in part) as driven by the needs of intonational floating tones.

We refer to patterns like these as TONE-DRIVEN EPENTHESIS. Tashlhiyt is but one of the languages for which the intonational literature identifies tone-driven epenthesis. Roettger & Grice (2019) summarise a number of studies which show vowel insertion correlating solely or primarily with intonational properties of the clause, including Galician (Martínez-Gil 1997), Bari Italian (Grice *et al.* 2018), and Tunisian Arabic (Hellmuth 2021).

Having established this, we are now in a position to ask: is tone-driven epenthesis possible in *tonal* languages, where pitch is used for lexical/grammatical functions? There is no *a priori* reason to exclude this possibility based on production, perception, or from the architecture of the phonology module. To date this question remains unanswered, absent from all major surveys of tonal languages (Pike 1948, Fromkin 1978, Yip 2002, Hyman 2011a, Wee 2019, *inter alia*).[1] In fact, Wee (2019: 208) broadly summarises that while it is common for segments to affect tone, "[t]here is … little evidence of reciprocation and very little evidence of tone affecting segments", which would include vowel epenthesis.[2]

Equally, the epenthesis literature in general does not address tone-driven epenthesis (Broselow 1982, Ito 1989, Piggott 1995, Blumenfeld 2006, de Lacy 2006, 2007, Hall 2006, 2011, Baković 2007, Moore-Cantwell 2016, *inter alia*). Epenthesis is frequently cited as having three main patterns, as laid out in Broselow (1982). One is SYLLABICALLY-TRIGGERED EPENTHESIS, where a vowel is inserted for syllable well-formedness, e.g. as a response to a ban on word-final codas (…C# → …Cə#). A second is SEGMENTALLY-TRIGGERED EPENTHESIS, responding to a ban against

[1] Direct discussion of tone and epenthesis in tonal studies is chiefly limited to the tonal valuation of epenthetic vowels after they are inserted (e.g. whether by tone spreading or default tone – Hyman & Schuh 1974: 90, McDonough 1996: 249, Yip 2002: 204, Akanlig-Pare & Kenstowicz 2002: 60ff., Frajzyngier 2003), and more generally the derivational order of epenthesis and tone association (e.g. before or after epenthetic vowel insertion in Japanese – Kubozono 2001). None of this literature discusses epenthesis conditioned by tone.

[2] As an anonymous reviewer points out, however, one well-known type of segment-tone interaction is low tone inducing consonant voicing, e.g. Poser (1981), Hansson (2004), Pearce (2013), Sossoukpe (2017), *inter alia*.

certain configurations of segments (e.g. adjacent sibilants in English *brush*[ə]*s* – Moore-Cantwell 2016: 239). The third is MINIMALITY-TRIGGERED EPENTHESIS, e.g. a response to a ban against monosyllabic words (#CV# → #ə.CV#). These three functions are corroborated in de Lacy (2006: 287ff.), whose survey of 105 cases of vowel epenthesis shows that all are triggered in order to "satisfy a general phonological requirement such as minimal word restrictions, metrical conditions, and segmental phonotactic restrictions".

Of the few epenthesis studies which address the possibility of tone-driven epenthesis in tonal languages, it is assumed to either be impossible or unattested. Brief mention is found in Blumenfeld (2006), who pursues a maximally restrictive theory of epenthesis (p. 153ff.).[3] Blumenfeld hypothesises a number of impossible interactions involving epenthesis, one being that "tone conditions cannot affect string structure", and therefore tone "cannot force epenthesis/syncope" (Blumenfeld 2006: 41). Blumenfeld concludes explicitly that epenthesis is "used exclusively as a response to pressures of syllable structure, sonority sequencing, syllable contact, and word minimality, but cannot be used to avoid violations of other metrical constraints" (p. 5). He characterises this generalisation as "equivalent to saying that in all cases where epenthesis applies, the winner of the alternative grammar without epenthesis contains either a marked consonant cluster, or is a subminimal word" (p. 158).

Gleim (2019) recently summarises this literature and concludes that tone-driven epenthesis in tonal languages is unattested (we return to Gleim and his analysis of Arapaho in section 5). He leaves open the question of "how to restrict the grammar in such a way that it excludes tone-triggered epenthesis" (p. 24), which of course presupposes that such epenthesis is impossible.

In the sections which follow, we illustrate that Wamey shows exactly such a pattern and thus fills an empirical gap in the literature. In section 2, we lay out the relevant background on Wamey and its phonology. In section 3, we present our evidence for tone-driven epenthesis, drawing on root and stem structure as well as a class of [ə]-alternating suffixes. Here, we also show the preferability of a [ə]-epenthesis analysis to an alternative analysis involving [ə]-deletion. In section 4, we provide an OT analysis where we derive the epenthesis patterns, and situate Wamey within a larger theoretical context. In section 5, we discuss similar phenomena, other (potential) cases of tone-driven epenthesis in tonal languages, and speculate as to why it is so rare. Section 6 provides a conclusion.

2 The Wamey language

Wamey [wæ̀-mèỹ; ISO 639-3: `cou`] belongs to the Tenda subgroup within Niger-Congo.[4] It is spoken on both sides of the border between Senegal (Salémata Department) and Guinea (Koundara prefecture) by at least 18,000 speakers (Jenkins & Amdahl 2007). The core of Wamey is described in detail in Santos' (1996) comprehensive grammar (including a 4000-entry lexicon), where all data in this paper are taken from. Hereafter, we refer to this grammar as [S96]. We present the relevant preliminaries on Wamey phonology before moving to the issue of tone-driven epenthesis.

2.1 Basic segmental phonology

Wamey has a rich set of segmental contrasts, shown in Table 2.

[3] Blumenfeld himself builds on de Lacy (2003), an unpublished handout.

[4] Wamey and the Tenda group are traditionally classified as 'Atlantic', a group within Niger-Congo which is an areal cluster than a true genetic unit (Merrill 2018, Güldemann 2018: 180). Additional names for the language include *Mey, Wèy, W̃eỹ, Konyagi, Koñagi*, and *Coniagui*.

Consonants:	LAB	COR	PAL	VEL	LAB-VEL	Vowels:
STOP	p b	t d	c j	k g	kw gw	i e a o u ə æ
PRE-NASALISED	mp mb	nt nd	nc nj	nk	nkw	
NASAL	m	n	ñ	ŋ	ŋw	
GLOTTALISED	ɓ	ɗ	ƴ			
FRICATIVE	f v	s		x	xw	
APPROXIMANT	w	l	y			
NASAL APPROX.	w̃	l̰	ỹ			
TRILL		r	ry			

Table 2: Segmental contrasts in Wamey[5]

Digraphs and trigraphs represent single segments (consonant clusters are highly restricted, which we turn to shortly). Wamey exhibits an extensive mutation system targeting root-initial consonants (Merrill 2018: 302ff). The details of the mutation system are irrelevant to the current discussion, but its effects are seen in several of the examples that we cite.

Of the seven contrastive vowels, Santos identifies /ə, æ/ as 'weak' for a number of reasons, such as their inability to be stressed (i.e. bear word-level 'accent') and positional restrictions (/ə/ is not allowed in word-initial position, and /æ/ not in final position) [S96:40-41,53,56]. However, all vowels including /ə, æ/ can appear as the sole root vowel (e.g. /lə̀n/ 'snake', /sǽt/ 'blood'). Wamey has no underlying long vowels, and surface long vowels are restricted to contexts in which one vowel assimilates to another vowel in the same word across a morpheme boundary [S96:44].

Wamey prohibits both consonant clusters and vowel clusters within a morpheme. All consonants may appear in coda position at all prosodic levels (p-word, p-phrase, utterance), though type and token frequencies vary considerably [S96:47]. If a consonant cluster would arise across a morpheme boundary, Wamey shows three responses depending on the environment. One response simply allows the marked consonant cluster. This happens in compounding, full reduplication, and at clitic boundaries generally, in (1)-(3). The relevant portion is in bold. Bear in mind that complex consonants like <nkw> are single segments, i.e. /ᵑkʷ/.

(1) Consonant clusters in compounds
æ̀-nkə́**l̰-f**ǽc 'first crow of the rooster'
PFX-point-be.daylight [S96:594 – *premier chant du coq* ('*le point du jour*')]

(2) Consonant clusters in reduplication
a. væ̀-njæ̀**g-ƴ**æ̀g 'jaw joints' [S96:656 – *articulation des mâchoires*]
b. ɗə̀**nkw-ry**ə̀nkw 'first' [S96:338 – *premier*]

(3) Consonant clusters at clitic boundaries (generally)
a. úrú**s=l̰**æ̀ 'at *Ourous* (city)'
Ourous=LOC [S96:252 – …*à Ourous*]
b. dǽrə́**l=x**ǔ 'next to you'
near=2S.CL [S96:266 – *à côté de toi*]

The other two responses repair consonant clusters, either by deleting the second consonant C_2 or inserting [ə] between the consonants, which is the general epenthetic vowel. The more common

[5] A tilde above or below an approximant indicates contrastive nasalisation, and 'w' after a velar consonant indicates labialisation. Consonants are equivalent to their IPA values except: j=[ɟ], ñ=[ɲ], nc=[ɲc], nj=[ɲɟ], nk=[ŋk], nkw=[ŋkʷ], ƴ=[ʄ], y=[j], ỹ=[j̃], l̰=[l̃], and ry=[rʲ]. Note also that /r/ is a voiced trill, but patterns with the voiceless fricatives phonologically in the mutation system. Similarly, /s/ is phonetically coronal [s] but patterns as palatal phonologically.

phenomenon is consonant deletion, illustrated in Table 3. It is always the consonant of the second morpheme which deletes.

	Morpheme	Consonant cluster		C_2 deletion	
a.	/-ryǽry/	/i-mə́t-**ryǽry**/	→	[ì-mə́t-**ǽry**]	
	ASSOCIATIVE	PFX-make.war-**ASSOC**		'to fight'	[S96:57 – *combattre*]
	/-nə́nd/	/i-gwə́t-**nə́nd**/	→	[ì-gwə́t-**ə́nd**]	
	FACTITIVE	PFX-empty-**FACT**		'make empty'	[S96:305 – *faire vider*]
	/-xə́t/	/i-pàƴ-**xə́t**/	→	[ì-pàƴ-**ə́t**]	
	INVERSIVE	PFX-pay.dowry-**INVER**		'take back (a dowry)'	[S96:296 – *reprendre* (*la dot*)]
b.	/-xâw̃/	/njə̀ɗǎ-l̰-**xâw̃**/	→	[njə̀ɗǎ-l̰-**à**]	
	3S.OBJECT	give-3S-**3S.O**		'(that) he gives him'	[S96:59 – *qu'il lui donne*]
c.	/=ŋǎ/	æ-tə́x=**ŋǎ**	→	[æ̀-tə́x=**ǎ** ~ æ̀-tə́x=**ŋǎ**]	
	DEF.CL3	CL3-tree=**DEF.CL3**		'the tree'	[S96:211 – *l'arbre*]

Table 3: Cluster repair – Delete C_2

Nearly all (consonant-initial) derivational morphology (row a.) and inflectional morphology (b.) show this type of repair. Both sets exhibit representative samples. For instance, the inflectional suffix /-xâw̃/ 3S.OBJECT in (b.) is part of a series of /x/-initial suffixes all of which show /x/-deletion when adjacent to a consonant. Further, definite clitics which begin with /ŋ w̃ ỹ/ (row c.) optionally delete this consonant when consonant-adjacent, a pattern which holds for demonstratives as well. We return to these inflectional suffixes and clitics in section 3, where we use them to diagnose the underlying representation of preceding morphemes.

The other cluster repair is much more limited, and involves [ə]-insertion, shown in Table 4.

	Morpheme	Consonant cluster		[ə]-insertion	
a.	/-lél̰/	/mə̀ɗ-**lél̰**/	→	[mə̀ɗ**ə̀lél̰**]	
	DURATIVE	get.dark-**DUR**		'to pass (of a day)'	[S96:58 – *passer* (*pour le jour*)]
	/-t/	/i-ƴǽk-**t**/	→	[ìƴǽk**ə́t**]	
	INTENSIVE	PFX-be.hot-**INT**		'to accelerate'	[S96:296 – *accélérer*]
b.	/-k/	/cǽs-**k**/	→	[cǽs**ə́k**]	
	3S.MINIMAL	suffer-**3S.MIN**		'he suffers'	[S96:43 – *il souffre*]
	/-ɗ/~/-nd/	/péñ-**ɗ**-ê/	→	[péñ**ə́ɗ**è]	
	IMPERFECTIVE	push-**IPFV**-PASS		'he is pushed'	[S96:248 – *il est poussé*]

Table 4: Cluster repair – Insert [ə]

These include both derivational (a.) and inflectional suffixes (b.). One thing which sets these affixes apart is that three of the four consist only of a single consonant. It therefore seems to be the case that deletion is blocked if not enough phonological substance of the morpheme would remain. The exception is /-lél̰/ DURATIVE. Diachronically, this likely consists of a frozen, non-productive suffix /-l/ plus /-él̰/ CAUSATIVE FACTITIVE, leading to a bigram /-l-él̰/ whose first morpheme still retains its monoconsonantal behaviour (cf. Wolof *-taan* with the same meaning, also ultimately from two suffixes in combination). As it stands, however, we must classify /-lél̰/ as an exception.

What is important to take away from this discussion is that this syllabically-driven vowel-epenthesis is independent from tone-driven ə-epenthesis we discuss in section 3.[6]

2.2 Basic tonal phonology

Wamey has a basic distinction between H and L tone, with contours HL and LH permitted but subject to various restrictions. A minimal pair for a monosyllabic base is shown in (4).

(4) Basic tonal contrasts on CVC roots [S96:50]

a.	L	-cæ̀w̃	‘hiding’	[*fait de cacher*]
b.	H	-cǽw̃	‘urinating’	[*fait d’uriner*]
c.	HL	-cæ̂w̃	‘domestic animal’	[*animal domestique*]
d.	*LH			

A falling HL contour is generally restricted to CVC words (or larger). The only cases of HL on a CV word are reduced forms of interrogatives, [mô] ‘who’ (< /mógà/) and [nê] ‘where’ (< /négà/). A rising LH contour is not found on the surface in either CV or CVC words (a point we return to).

In multi-syllabic words, contours are found predominantly in word-final position, as in (5). Here we see a contrast between LH and HL contours.

(5) Final contours [S96:50]

a.	L.HL	kòmbô	‘sorghum’	[*sorgho*]
b.	H.HL	ì-támpûl	‘navel’	[*nombril*]
c.	H.LH	æ̀-ŋómpě	‘falcon’	[*faucon*]
d.	*L.LH			

The LH contour must be preceded by a H tone; [L.LH] is unattested. The most common realisation of LH is as a surface mid tone (c. above would be [æ̀ŋómpē]). For completeness, other tone rules of Wamey are provided in (6).

(6) Other tone rules in Wamey

a.	Decontouring (only applies to inflection):	τ̀τ̌ → τ̀τ́ , τ́τ̂ → τ́τ̀ , τ̀τ̌τ̀ → τ̀τ̀τ̀ , τ̀τ̌τ́ → τ̀τ́τ́
b.	Three-tone simplification on a single TBU:	τ̌̂ → τ̀ , τ̂̌ → τ́
c.	Rightward spreading to toneless TBUs:	τ́τ → τ́τ́
d.	Default low insertion:	τ → τ̀

Finally, a crucial part of our analysis involves positing floating tones which are part of the lexical representation of certain morphemes. For example, the marker of *mode énonciatif* – a multi-functional morph marking certain classes of non-negative clauses – is realised variably as a prefix /ǽ-/ or as a floating tonal morph Ⓗ (hereafter, a tone within a circle indicates a floating tone). An example is shown in (7) where we gloss it as INFL.

[6] Santos additionally identifies two other suffixes as triggering [ə]-insertion, /-má/ ‘always’ and /-nká/ ‘(not) early’.

(i)	/-ɣ́ív-**má**/	→	[-ɣ́ív**ə́má**]	‘be always (doing) well’	[S96:58 – *être toujours bien*]
cf.	/-mé-**má**/	→	[-mé**má**]	‘be always (doing) bad’	[S96:295 – *vivre dans de mauvaises conditions*]
(ii)	/-tòk-**nká**/	→	[-tòk**ə̀nká**]	‘(not) eat early’	[S96:58 – (*ne pas*) *manger tôt*]
cf.	/-nə́gá-**nká**/	→	[-nə́gá**nká**]	‘(not) wake up early’	[S96:622 – (*ne pas*) *se réveiller tôt*]

However, both of these suffixes are marginal and appear with only a couple roots. We therefore take these to be frozen morphology, with no synchronic epenthesis operation for these forms.

(7) Floating tone in Wamey

a.	ǽ-tòk-ə́nì	və-sæ̀n=v-ǎ	→	[<u>ǽtòk</u>ə́nì və̀sæ̀nvá]	
	INFL-eat-3P	CL2-man=CL2-DEF		‘The men ate’	~
b.	Ⓗ-tòk-ə́nì	və-sæ̀n=v-ǎ	→	[<u>tókə̌</u>nì və̀sæ̀nvá]	
	INFL-eat-3P	CL2-man=CL2-DEF		‘The men ate’	[S96:217 – *ils ont mangé, les hommes*]

In the second example, the floating tone docks to the initial TBU. This pushes the lexical L tone onto the following vowel, resulting in a rising tone [tókə̌nì] (a rare case where a contour is not domain-final).

3 Tone-driven [ə]-epenthesis

This section lays out the evidence for tone-driven epenthesis, from two areas of Wamey grammar. The first involves the complementary distribution of word-final [ə] with Ø which is straightforwardly accounted for if [ə]-final roots are actually consonant-final underlyingly. The other involves alternations between [ə] and Ø in what we term [ə]-alternating suffixes.

Before we begin, we emphasise that several of the analytic generalisations should be attributed to Santos’ (1996) grammar itself. In discussing the behaviour of /ə/, she states overtly its role in providing ‘support’ for tone: “the vowel /ə/ supports a high tone after a low tone, or a low-high tone after a high tone”, in which case “it is always realised even when it is in final word position” (p. 43) even though forms with final /ə/ constitute “a base with a final consonant at the structural level” (p. 189, fn3).[7] Her grammar has unfortunately gone unnoticed in the phonology literature, and we are happy to bring it to the fore. Where she provides analytic generalisations overtly, we state as much, but in most places we go beyond her original study in scope and theoretical modelling, and in other places we make reanalyses.

3.1 Evidence from root and stem structure

The first piece of evidence for tone-driven epenthesis in Wamey involves the phonological patterns of roots/stems. Recall that CVC roots surface as H, L, or HL, but not LH, from (4). CVC patterns are actually in complementary distribution with CVCə roots with a final schwa, e.g. [ì-nkæ̀w̃ə́] ‘dance’ (n.), [æ̀-mbə̀ỹə́] ‘leper’, [à-l̪ə̀nkwə́] ‘imbecile’, [ì-còkə́] ‘to weld’, [ì-mènə́] ‘to fish’, [dòlə́] ‘today’, [tàmpə́] ‘enslaved’, among many others. All other tone patterns are unattested on CVCə roots. This complementarity is shown in Table 5. Note that the dash indicates that these normally appear with noun class prefixes.

Tone	CVCə		CVC	
L	*cv̀cə̀		-cæ̀w̃	‘hiding’
H	*cv́cə́		-cǽw̃	‘urinating’
HL	*cv́cə̀		-cæ̂w̃	‘domestic animal’
LH	-nkæ̀w̃ə́	‘dance’ (n.)	*-cv̌c	

Table 5: Complementary distribution of CVCə and CVC roots

This complementarity is categorical across Santos’ lexicon. We digitised this lexicon and coded all lexical roots and stems for segmental structure, syllabic structure, and tone patterns (*n*=3518). We counted as lexical roots monomorphemic nouns, verbs, adjectives, adverbs, ideophones, temporals/locatives, and numerals. If they were provided by Santos, we included

[7] The original: “*la voyelle* /ə/ *supporte un ton haut derrière un ton bas ou un ton bas haut derrière un ton haut. Dans ce cas, elle est toujours réalisée, même lorsqu’elle est en position finale de mot*” and “*rappelons qu’une base à finale* /ə/ *au niveau phonologique est une base à consonne finale au niveau structurel*” (see also pp. 55, 71, 75-76).

proper nouns such as names of villages and certain Wamey names. We also included a large number of multi-morphemic lexical stems which contain derivational morphology, a point we return to below. Both these and plain lexical roots constitute morphological stems, hereafter simply referred to as stems. We set aside any noun class prefixes (including the infinitive prefix /i-/), which are always outside the stem. In our database, we excluded grammatical morphemes such as conjunctions, connectives, demonstratives, interrogatives, pronouns, prepositions, quantifiers, and relative markers. We also excluded complex constructions like set phrases/idioms, reduplicated words, and compounds. A copy of this database is found in the supplemental materials. Note that adjectives marked with the adjectival suffix are within their own section of the database.

Let us first examine monosyllabic CV and CVC stems compared to bisyllabic CVCə stems which end in [ə]. As above, Table 6 shows that while LH sequences are banned in CV and CVC stems, they represent the primary pattern found in CVCə stems.

CV (*n*=107)			CVC (*n*=1352)			CVCə (*n*=179)					
H	cv́	56	H	cv́c	576	H	cv́cə́	0	H.HL	cv́cə̂	0
L	cv̀	50	L	cv̀c	741	L	cv̀cə̀	0	L.HL	cv̀cə̂	0
HL	cv̂	1	HL	cv̂c	35	H.L	cv́cə̀	0	H.LH	cv́cə̌	2
LH	cv̌	0	LH	cv̌c	0	L.H	cv̀cə́	177	L.LH	cv̀cə̌	0

Table 6: Comparison of 1σ and 1σ+ə stems[8]

Parallel patterns are found for longer lexical stems. Just as CVC and CVCə stems are in complementary distribution, so are CVCVC and CVCVCə. Table 7 shows the number of these longer stems with each tone pattern. As in Table 6, patterns with final L.H appear only on ə-final stems, and ə-final stems never host any other tone pattern.

CVCVC (*n*=717)			CVCVCə (*n*=61)			CVCVCə (with final contour)		
H.H	cv́cv́c	239	H.H.H	cv́cv́cə́	0	L.H.HL	cv̀cv́cə̂	0
L.L	cv̀cv̀c	104	L.L.L	cv̀cv̀cə̀	0	H.L.HL	cv́cv̀cə̂	0
H.L	cv́cv̀c	19	H.L.L	cv́cv̀cə̀	0	L.H.LH	cv̀cv́cə̌	0
L.H	cv̀cv́c	245	L.H.H	cv̀cv́cə́	0	H.L.LH	cv́cv̀cə̌	0
H.HL	cv́cv̂c	26	H.H.L	cv́cv́cə̀	0	H.H.HL	cv́cv́cə̂	0
L.HL	cv̀cv̂c	82	L.H.L	cv̀cv́cə̀	0	L.L.HL	cv̀cv̀cə̂	0
H.LH	cv́cv̌c	2	H.L.H	cv́cv̀cə́	19	H.H.LH	cv́cv́cə̌	0
L.LH	cv̀cv̌c	0	L.L.H	cv̀cv̀cə́	42	L.L.LH	cv̀cv̀cə̌	0

Table 7: Comparison of (C-final) 2σ and 2σ+ə stems[9]

This complementarity also holds for the small number of 3σ(+ə) stems in our database (*n*=12), i.e. CVCVCVC versus CVCVCVCə stems. All such CVCVCVCə stems end as expected with a low tone on the penult and a high tone on the final [ə], e.g. the [L.L.L.H] stem [-nkə̀rə̀ŷàlə́] 'sand', the [L.H.L.H] stem [-gèkə́lèrə́] 'snuffbox', and the [H.H.L.H] stem [-ŷǽlǽnkònə́] '*Cram-Cram* grain'.

In these [ə]-final stems, the [ə] cannot be attributed to any syllabically- or segmentally-triggered epenthesis. As stated above, all consonants are permitted in coda position. For all stems with a final schwa, there are equivalent words which end in the consonant before that schwa. This

[8] The two [H.LH] stems are [ñóñə̌] 'nothing' and [tə́kə̌] 'already' [S96:625, 648 – *rien, déjà*]. These are at least historically derived from simpler roots, namely /-nín/~/-ñə́/~/-ỹín/~/-ỹə́/ 'thing', and /-tə̀k/ 'arrive'.

[9] The two exceptional CVCVC forms with a [H.LH] pattern are [æ̀-ntə́pǒt] 'tadpole' and [ì-léjǐk] 'larceny' (cf. [ì-dé] 'to steal') [S96:583]. These end in a final LH rising tone, where our analysis predicts that it should end in high-toned [ə]. We suspect that their exceptionality is due to their diachronic origins. A small number of transparently derived words also show a final rising tone, e.g. [pə̀mpə́lǽ̌x] 'mean' (ADJ) [S96:638 – *méchant*] (< [ì-pə̀mpə̂l] 'wickedness').

is shown in Table 8 with plain stops (palatal /c/ in row a.), pre-nasal stops (/nd/ in b.), implosives (/ɓ/ in c.), fricatives (/s/ in d.), and sonorants (/l/ in e.). All rows show that if the syllable ends in a low, high, or falling tone, no [ə] is inserted.

	[…cv̀cə́]	cf.	[…cv̀c]	[…cv́c]	[…cv̂c]
a.	[ì-kòcə́]		[ì-kæ̀c]	[ì-ŋàbə́c]	[kùmpôc]
	‘to finish an animal’		‘skin’	‘to take a big share’	‘pumpkin and peanut dish’
b.	[ì-kòndə́]		[æ̀-ncæ̀nd]	[ì-ñæ̀ŋə́nd]	[ì-tônd]
	‘to stack up’		‘shell’	‘to teach’	‘type of arrow for birds’
c.	[æ̀-kə̀ɓə́]		[ì-còɓ]	[ì-gwæ̀lǽɓ]	[æ̀-kæ̂ɓ]
	‘type of owl’ (*Otus leucotis*)		‘to stick on’	‘to talk a lot’	‘rubber vine’
d.	[ì-cùsə́]		[ì-ɗæ̀s]	[ì-kə̀rós]	[ù-xùwâs]
	‘to take out (with utensil)’		‘to laugh’	‘to scrape’	‘sock’
e.	[à-væ̀lə́]		[ì-ɓòl]	[ì-tàmból]	[ì-kàyə̂l]
	‘shoemaker’		‘to refuse’	‘to climb to the top’	‘to be back to back’

Table 8: Lack of final [ə] epenthesis in other tone contexts

A straightforward interpretation of this complementarity is that CVC and CVCə structures derive from a common underlying structure conditioned by tone. Logically, the common structure could be underlying /CVC/ in which case [CVCə] is derived via epenthesis, or /CVCə/ with [CVC] derived via deletion. There is no contrast in the language between /CVC/ and /CVCə/ stems, which compounds the difficulty in choosing between the two analyses (on this fundamental difficulty as it pertains to consonant epenthesis, see Morley 2015).

The simpler of the two involves positing less underlying structure, which is the epenthesis account advocated in this paper. The four basic tone patterns – H, L, H L, and L H – as they appear on CVC stems is illustrated in Table 9. Inputs with H, L, or H L sequences associate straightforwardly to the vowel. However, due to constraints on rising tones, a L H sequence cannot associate both tones to the TBU. In order to preserve all tones in the input, an epenthetic schwa is inserted to host what would otherwise be a floating H.

a.	H		H	b.	L		L	c.	H L		H L	d.	L H		L H
		→	|			→	|			→	\/			→	| |
	cvc		cv́c		cvc		cv̀c		cvc		cv̂c		cvc		**<u>cv̀cə́</u>**

Table 9: Interpretation as /CVC/ – [ə]-insertion to host the H tone

In what follows, we analyse the underlying structure of such words to be /cv̀cⒽ/ with a pre-linked low tone and an underlying floating high tone (circled hereafter), rather than as underlying /cv̌c/ with both tones pre-linked. Regardless of analysis, as stated there is no contrast between these two representations in CVC stems.

We can refer to the alternative as tone-driven /ə/-retention, shown in Table 10. Here, underlying /ə/ is deleted in word-final position unless it would result in a floating tone or a rising tone. Under this alternative (which we reject), there is no epenthesis and therefore Wamey does not constitute a true counter-example to the previous aforementioned claims in the literature.

a.	H		H	b.	L		L	c.	H L		H L	d.	L H		L H
	/\	→	|		/\	→	|		| |	→	\/		| |	→	| |
	cv́cə́		cv́c		cv̀cə̀		cv̀c		cv́cə̀		cv̂c		cv̀cə́		**<u>cv̀cə́</u>**

Table 10: Alternative (*rejected*) – Tone-driven /ə/-retention

We must therefore adjudicate between two competing sets of underlying representations:

(8) Competing sets of URs

a. URs under tone-driven [ə]-epenthesis: /cv́c/ /cv̀c/ /cv̂c/ /cv̀cⒽ/

b. URs under tone-driven /ə/-retention: /cv́cə́/ /cv̀cə̀/ /cv́cə̀/ /cv̀cə́/

Before beginning to compare these two, we stress an important commonality: the occurrence of final [ə] on the surface is entirely determined by tonal factors, and insensitive to segmental ones.[10]

One piece of evidence in favour of epenthesis comes from the general shape of monomorphemic roots in the lexicon. In the alternative /ə/-retention analysis, there are no C-final roots. We might therefore expect /CVCV/ roots in general to be common, with a full range of final vowels and tonal patterns. However, this is not the case in Wamey. Of the unambiguously vowel-final /CVCV/ stems in the lexicon (*n*=621; cf. 1352 CVC stems), the vast majority end in /a/ (478/621, or 77%). Most of these are decomposable into a CVC root plus a derivational -V suffix, and are transparently related to a CVC base; some others contain frozen morphology. The anticausative/middle suffix /-á/ is particularly common, and like its equivalent in other Atlantic languages is often used to form denominal verbs.

(9) CVCV stem as /CVC/ root plus suffixal /-V/

a.	-á MIDDLE	-kùɓ-á	'hunchbacked, crooked'	(< -kùɓ 'bend')
b.	-á DEVERBAL	ì-fə́nk-á	'leash-tying post'	(< -pǽnk 'leash animal to post')
c.	-á 'do alone'	-tòk-á	'eat alone'	(< -tòk 'eat')
d.	-ì (frozen suffix)	-ɓǽl-ì	'mobilise'	(< -ɓǽl 'frighten, be afraid')

Further, those CVCV structures which cannot be morphologically segmented are overwhelmingly loanwords, mostly from Malinke. Many of these loanwords are additionally marked in that they lack an overt noun class prefix.

(10) Examples of borrowed roots in Wamey ending in vowels

a.	Malinke:	ɗòkû 'work', kíryì 'gun, rifle', gàrâ 'indigo'
b.	Pajade:	ɓésù 'mead,' làwó 'friend,' kǽntíká 'scarf'
c.	Arabic:	ɓùñâ 'reward', ɗṹníỹá 'material world,' sédé 'witness (n)'
d.	French, Portuguese:	dámìyè 'checkerboard,' kójírá 'spoon,' kæ̀lérà 'cooking pot'
e.	*Wanderwörter*:	kùrû 'cola nut', kèmé 'hundred', kóryí 'money'

Another point concerns CV roots, which are very rare (*n*=108). This is summarised in Table 11. Unlike the CVCV roots, these are mostly native roots in which it is likely that an earlier root-final consonant was deleted. A striking gap can be seen here. While generally vowels are evenly distributed, there is a near complete lack of CV roots which end in [ə].[11] We can compare this to the distribution of vowels in CVC roots where [ə] is the predominant vowel.

[10] While tone-driven epenthesis has been claimed to be unattested/impossible in tonal languages, there are numerous cases identified of tone-driven vowel retention. We discuss this in section 5.1 below.

[11] Final /æ/ is rare too, but this is independently ruled out by a dispreference for word-final /æ/ regardless of tonal factors [S96:40-41].

CV	*n*=	Example		(Cf. CVC roots	*n*=)
/i/	19	ì-ɓí	'to resume, recover'		84
/e/	19	ì-vé	'dog'		109
/æ/	3	ì-ñǽ	'to be very'		375
/a/	20	ì-ɓá	'to be small'		129
/u/	25	ì-mbú	'hippopotamus'		125
/o/	21	ì-kó	'knee'		104
/ə/	1	à-jə́	'(grand)son of' [(*petit*) *fils de*]		426

Table 11: CV roots by final vowel – Lack of final /ə/

The only exception is the bound root /-jə́/ '(grand)son of' which can never appear on its own, shown in (11). It might even be analysed as a prefix, rather than a root.

(11) à-**jə́** ỹìnə́ 'son of Hyena' [S96:253 – *fils de Hyène*]

Under the alternative /ə/-retention analysis, final /ə/ is deleted unless it is retained to host tone. Using the data in (11), for instance, final underlyingly /ə/ would not be deleted because it would result in a banned floating high tone. Under the alternative, it is therefore unexplained why there is not a comparable number of /Cə/ roots, where the final /ə/ should always surface transparently to host a tone.

In contrast, under tone-driven [ə]-epenthesis these facts are straightforwardly unified via a constraint banning word-final [ə] at the prosodic stem-level. This prosodic constituent would equally apply to CV and CVCV stems and apply regardless of tonal pattern.[12] Under this analysis, surface [ə] in [CVCə] patterns only emerge at a later stage where the (prosodic) word is evaluated. Underlyingly, roots in Wamey are canonically CVC and deviations from this template come about through synchronic/diachronic morphological processes. The canonical root shape in this Atlantic linguistic area is in fact CVC, as found for example in Wolof, Fula, and most notably the two remaining Tenda languages Bassari and Bedik related to Wamey. These languages have CVC roots wherever Wamey has [CVCə].

To summarise: in surface CVCV roots, the final vowel is overwhelmingly [ə], which appears only in the appropriate tonal context. This fact is easily explained if the [ə] is inserted to allow for the realisation of the underlying tones. If on the other hand the [ə] is present underlyingly, there is no explanation for why other vowels are not also attested in this position proportionate to their occurrence in other positions. The ə-epenthesis analysis simply treats underlying CVCV roots as uncommon and non-canonical, which aligns with the historical and areal facts. The /ə/-retention analysis must treat CVCV roots as the norm, but does not provide any independent reason why /ə/ is overwhelmingly preferred as the underlying root-final vowel. In fact, the evidence from CV roots shows that underlying /ə/ is specifically banned in this position unless it serves a tonal purpose.

3.2 Evidence from C deletion in enclitic determiners

If at the stem-level, [cv̀cə́] forms are actually /cv̀cⒽ/ as we advocate, then they should also pattern as consonant-final in morphophonological processes. This is indeed the case. Consider the following data involving definite marker enclitics which appear after all other elements in the noun phrase. The definite marker has the form /=(C)ǎ/ with an underlying rising tone. The identity of the consonant is dictated by noun class agreement, demonstrated in (12).

[12] For discussion on how to model this restriction especially in light of Richness of the Base, see section 4.

(12) Definite marker noun class agreement [S96:209]

a.	vì-líyá=**vǎ**	b.	fæ̀-rə̀mp=**fá**	c.	gà-tə́x=**gǎ**
	CL8-tool=**DEF.CL8**		CL15-tortoise=**DEF.CL15**		CL20-tree=**DEF.CL20**
	'the tools'		'the tortoise'		'the big tree' (augmentative)

For most noun class contexts, the consonant of the definite marker is fixed and obligatory. However, if the noun class prefix begins with /w, y, ỹ/, a vowel, or is null, then the corresponding definite marker has two variants which occur in free variation: =Că and =ă. The form of the =Că variant is [=ŋă~ỹă~w̃ă], depending on the noun class. This free variation is demonstrated in (13) below.

(13) Definite markers: =Că and =ă variants [S96:211]

a.	wæ̀-sæ̀l=**w̃á** ~ wæ̀-sæ̀l=**á**	b.	æ̀-tə́x=**ŋǎ** ~ æ̀-tə́x=**ǎ**	c.	Ø-ràsə́l̠=**ỹǎ** ~ Ø-ràsə́l̠=**ǎ**
	CL11-guinea.fowl=**DEF.CL11**		CL3-tree=**DEF.CL3**		CL7B-axe=**DEF.CL7B**
	'the guinea fowls'		'the tree'		'the axe'

This variation is possible only after a consonant. If the stem ends in a vowel, only the =Că form is found. This is shown in Table 12 with vowel-final CV stems (row a.) and CVCV stems (b.). Importantly, Santos is explicit that the same variation found in CVC stems is found for those CVC stems analysed with a floating Ⓗ – e.g. /-mbə̀lⒽ/ [mbə̀lə́] 'milk' – despite the fact that the latter surface with a final schwa in context (c.-d.) [S96:209]. The importance of such data is clear: these stems pattern as consonant-final, suggesting that surface forms with final [ə] are derived.

	Final σ	Stem	=Că form	=ă form	Translation	
a.	CV	/i-ɓú/	ì-ɓú=ŋǎ	*	'the baobab fruit'	[*le pain de singe*]
b.	CVCV	/i-líyá/	ì-líyá=ỹǎ	*	'the tool'	[*l'outil*]
c.	CVC	/æ-tə́x/	æ̀-tə́x=ŋǎ	æ̀-tə́x=ǎ	'the tree'	[*l'arbre*]
d.	CVC+Ⓗ	/wæ-mbə̀lⒽ/	wæ̀-mbə̀lə́=ŋǎ	wæ̀-mbə̀lá=ǎ	'the milk'	[*le lait*]

Table 12: Variants of definite clitics in different contexts [S96:211]

Table 13 below shows the interaction of the three phonological processes present here: consonant-deletion in the clitic, [ə]-epenthesis, and assimilation of this vowel. The optional consonant deletion applies first in these simplified derivations, which accounts for why inputs like /mbə̀lⒽ/ condition deletion as well.

Input	wæ- mbə̀lⒽ =ŋǎ	æ- tə́x =ŋǎ	i- líyá =ỹǎ
1 Consonant deletion:	wæ-mbə̀lⒽ=**ǎ**	æ-tə́x=**ǎ**	-
2 [ə]-epenthesis:	wæ-mbə̀l**ə́**=ǎ	-	-
3 Assimilation:	wæ-mbə̀l**á**=ǎ	-	-
Surface	[wæ̀-mbə̀lá=ǎ]	[æ̀-tə́x=ǎ]	[ì-líyá=ỹǎ]

Table 13: Derivation with definite enclitics

In this table, notice that an epenthetic vowel is still inserted after consonant deletion, to host the otherwise floating tone. This then assimilates to the following vowel. This is one of the few places in the language where a surface long vowel is seen. We return to this fact in section 4.3.

Consider now the competing analysis involving /ə/-deletion, shown in Table 14. Here, we must adopt a far less phonologically natural operation, whereby certain intervocalic consonants delete, but only if the first vowel is /ə/. Further, as discussed in section 2 there are several independently-motivated operations which repair CC clusters that arise from morphological concatenation. One of these is the deletion of the second consonant, which the derivation in Table 13 can be interpreted as also exemplifying. In contrast, the derivation in Table 14 must propose a novel and idiosyncratic deletion process triggered only by a preceding /ə/.

Input	wæ- mbə̀lə́ =ŋă	æ- tə́xə́ =ŋă	i- líyá =ỹă
1 Consonant deletion:	wæ-mbə̀lə́=**ă**	æ-tə́xə́=**ă**	-
2 /ə/-deletion:	-	æ-**tə́x**=ă	-
3 Assimilation:	wæ-mbə̀l**á**=ă	-	-
Surface	[wæ̀-mbə̀lá=ă]	[æ̀-tə́x=ă]	[ì-líyá=ỹă]

Table 14: Alternative derivation with definite enclitics (*rejected*)

In total, [cv̀cə́] stems pattern as consonant-final and not as vowel-final. This supports an underlying (segmental) representation as /CVC/, which entails that surface [ə] is inserted rather than deleted.

3.3 Evidence from [ə]-alternating suffixes

Further evidence for the epenthesis analysis comes from bound morphology, specifically from what we call [ə]-ALTERNATING SUFFIXES which display an alternation between [C]-final and [Cə]-final variants. The relevant suffixes are summarised in Table 15. For each pair, the variants are predictable based on the phonological context, and therefore should not be considered suppletive allomorphs.

	[C]-final ~	[Cə]-final	Gloss		Santos gloss
a.	[-k]	[-kə́]	3S.MINIMAL	(3S.MIN)	*indice personnel minimal (ps. min.)*
	[-n]	[-nə́]	2P.IMPERATIVE	(2P.IMP)	*impératif (deuxième personne du pluriel)*
b.	[-ǽx]	[-æ̀xə́]	ADJECTIVAL1	(ADJ1)	*adjectif*
	[-ák]	[-àkə́]	ADJECTIVAL2	(ADJ2)	*adjectif*
	[-ǽk]	[-æ̀kə́]	ANTERIOR	(ANTER)	*modalité verbale d'antériorité*
	[-(ry)ǽry]	[-(ry)æ̀ryə́]	ASSOCIATIVE	(ASSOC)	*associatif*
	[-(x)ǽl̰]	[-(x)æ̀l̰ə́]	LOCATIVE	(LOC)	*locatif*

Table 15: Summary of [ə]-alternating suffixes

The suffixes in (a.) alternate between shapes [C] and [Cə́], the latter of which bears a high tone. The first, [-k]~[-kə́], is roughly equivalent to third singular subject marking in perfective aspect, which we gloss as 3S.MINIMAL following Santos' terminology (*indice personnel minimal*). The second, [-n]~[-nə́], marks imperatives with plural addressees. The data in (14) are representative examples which illustrate the conditioning factor: the [C] form appears if the preceding vowel is high-toned, while the [Cə́] variant appears if the preceding vowel is low-toned (the preceding syllable is underlined, and the [ə]-alternating suffix is in bold).

(14) 3S.MINIMAL [-k]~[-kə́]
 a. After H ì-cǽs 'to suffer' > cǽsə́-**k** 'he suffers' [S96:43 – *il souffre*]
 b. After L ì-tòk 'to eat' > tókə̀-**kə́** 'he ate' [S96:43 – *il a mangé*]

(15) 2P.IMP [-n]~[-nə́]
 a. After H yɜ̃ɗ-ə́ry-æ̀kə́-**n** 'give!' [S96:554 – *donnez donc*!]
 b. After L tòk-ə́ryì-**nə́** 'eat!' [S96:220 – *mangez!*]

The second group of affixes (b. in Table 15) is identical in its distribution. All of these additionally consist of a low vowel [æ] or [a], and some have an initial consonant (subject to deletion). The first two are adjectival suffixes [-ǽx]~[-æ̀xə́] (ADJ1) and [-ák]~[-àkə́] (ADJ2). ADJ1 and ADJ2 are in complementary distribution, with ADJ2 appearing after [a]-final stems. Representative examples of these variant pairs are provided in (16)-(18). As with the first group of suffixes, the [v́c] variant occurs if the stem ends in a high tone, while the [v̀cə́] one appears if the stem ends in a low tone.

(16) ADJ1 [-ǽx]~[-æ̀xə́]
 a. ì-ƴǽk 'be hot' → wə̀-nkà wæ̀-ƴǽk-**ǽx** 'hot water' [S96:183 – *de l'eau chaude*]
 b. ì-gùk 'be sliced' → wæ̀-wə́d wæ̀-wùk-**æ̀xə́** 'sliced mangoes' [S96:107 – *des mangues talées*]

(17) ADJ2 [-ák]~[-àkə́] (ADJ2 is used after [a])
 a. ì-dáñá 'to sit down' → dáñá-**ák** 'seated' [S96:200 – *assis*]
 b. ì-ɓávà 'to (still) be green' (of fruit) → ɓávà-**àkə́** 'still green' [S96:115 – *encore vert*]

(18) ASSOC [-(ry)ǽry]~[-(ry)æ̀ryə́]
 a. ì-cónk 'to discuss' → ì-cónk-**ǽry** 'to argue with (s/o)' [S96:306 – *se disputer avec* (*qqn*)]
 b. ì-næ̀ỹ 'to be big' → ì-næ̀ỹ-**æ̀ryə́** 'to be big like (s/o)' [S96:306 – *être grand comme*]

The patterns of both sets of suffixes corroborate the static distribution with lexical stems detailed in section 3.1. If a word-final [ə] is present, it is always high-toned and appears after a low. There are no instances of final word shapes *[cv̀cə̀], *[cv́cə́], and *[cv́cə̀] involving these suffixes.

Parallel to the argument involving definite enclitics above, we can probe the underlying representation of [ə]-alternating suffixes based on how they condition the affixes which follow them. As expected under our analysis, these suffixes pattern as underlyingly consonant-final. The relevant data involve the interaction with another class of suffixes, in which an initial /x/ is deleted. We call these /x/-ALTERNATING SUFFIXES. An example is /-xâw̃/, which indexes third singular objects (3S.O). If it appears after a consonant then the initial /x/ deletes, shown in (a.) in (19). In contrast, if it appears after a vowel then the /x/ surfaces, in (b.).

(19) /x/-alternating suffixes
 a. ƴə̂ɗ-əl-ún-**xâw̃**-lá → [ƴə̂ɗ-əl-ún-**à**-lá]
 give-NEG-2P-**3S.O**-NEG 'you didn't give it to him' [S96:261 – *vous ne le lui avez pas donné*]
 b. Ⓗ-péñ-əɓú-**xâw̃** → [péñ-əɓú-**xà**]
 INFL-push-1S-**3S.O** 'I pushed him' [S96:57 – *je l'ai poussé*]

Table 16 lists two classes of /x/-alternating suffixes, consisting of a full set of object-indexing suffixes (a.), as well as the past tense suffix /-xôw̃/ (b.). Note that all of these suffixes have final consonants (n or w̃) which only surface before a vowel; this alternation is irrelevant to the current discussion.

	UR	Tone	Gloss	After V	After C	Cf. Santos gloss
a.	/-xów̃/	H	1S.O	[-xo(w̃)]	[-o(w̃)]	1°ps.sg.o
	/-xîn/	HL	2S.O	[-xi(n)]	[-i(n)]	2°ps.sg.o
	/-xâw̃/	HL	3S.O	[-xa(w̃)]	[-a(w̃)]	3°ps.sg.o
	/-xə́fùn/	H.L	1P.O	[-xəfu(n)]	[-əfu(n)]	1°ps.pl.o
	/-xûn/	HL	2P.O	[-xu(n)]	[-u(n)]	2°ps.pl.o
	/-xə́l̰ìw̃/	H.L	3P.O	[-xəl̰i(w̃)]	[-əl̰i(w̃)]	3°ps.pl.o
b.	/-xôw̃/	HL	PAST	[-xo(w̃)]	[-o(w̃)]	passé

Table 16: /x/-alternating suffixes

Let us now look at the interaction of [ə]-alternating suffixes with /x/-alternating suffixes. For consistency, we only use the suffix [-k]~[-kə́] 3S.MINIMAL in these data, which we take to be representative of the [ə]-alternating class. Table 17 shows verb forms with /-k/ followed by each /x/-alternating suffix. In all cases /-k/ conditions the deletion of /x/, suggesting that /-k/ is underlyingly consonant-final.

	Underlying	Surface		[S96:253,235]
a.	/ Ⓗ-ɣ͡ə̂ɗ-k̲-**xów̃** /	[njə́ɗ͡ə̀-k̲-**ó**]	'he gave me'	[*il m'a donné*]
	/ Ⓗ-ɣ͡ə̂ɗ-k̲-**xîn** /	[njə́ɗ͡ə̀-k̲-**î**]	'he gave you'	[*il t'a donné*]
	/ Ⓗ-ɣ͡ə̂ɗ-k̲-**xâw̃** /	[njə́ɗ͡ə̀-k̲-**â**]	'he gave him/her'	[*il lui a donné*]
	/ Ⓗ-ɣ͡ə̂ɗ-k̲-**xə́fùn** /	[njə́ɗ͡ə̀-k̲-**ə́fù**]	'he gave us'	[*il nous a donné*]
	/ Ⓗ-ɣ͡ə̂ɗ-k̲-**xûn** /	[njə́ɗ͡ə̀-k̲-**û**]	'he gave you (all)'	[*il vous a donné*]
	/ Ⓗ-ɣ͡ə̂ɗ-k̲-**xə́l̰ìw̃** /	[njə́ɗ͡ə̀-k̲-**ə́l̰ì**]	'he gave them'	[*il leur/les a donné*]
b.	/ Ⓗ-ɣ͡ə̂ɗ-k̲-**xôw̃** /	[njə́ɗ͡ə̀-k̲-**ô**]	'he had given'	[*il avait donné*]

Table 17: [ə]-alternating suffixes pattern as consonant-final

We can contrast [ə]-alternating suffixes such as /-k/ 3S.MIN with other suffixes of the same relative morphological class and position. For example, /-ərú/ indexes second person singular subjects and also directly precedes the relevant /x/-alternating suffixes. In contrast to third person /-k/, second person /-ərú/ underlyingly ends in a vowel and therefore it conditions the /x/-initial variant without deletion. This is shown in (20) where the /-ərú/ is underlined and the /x/-alternating suffix is in bold.

(20) No deletion of /x/ after a vowel

a. ɗ͡ə̀k-ɗ͡ə́ ɓáwò ǽ-pə̀ɣ͡ə̆-ərú̲-**xów̃** [ɗ͡ə̀kə̀ɗ͡ə́ ɓáwò ǽpə̀ɣ͡ə̆-rú̲-**xó**]
dare-IPFV.1S.NEG because INFL-warn-2S-**1S.O** 'I won't dare since you warned me'
[S96:399 – *je n'oserai pas puisque tu m'as prévenu*]

b. gé Ⓗ-tùmp-ərú̲-**xâw̃** [gé túmp-ə̌rú̲-**xà**, …]
if INFL-twist-2S-**3S.O** 'if you twisted it, …' [S96:241 – *si tu l'as tordu, …*]

Given these distributions, we posit the underlying representations in Table 18 for the [ə]-alternating suffixes. All bear an underlying floating Ⓗ tone, even those which contain a TBU (e.g. /-æxⒽ/ in b.).[13]

[13] Evidence that these suffixes do not have a pre-linked tone comes from comparison to other suffixes. While suffixes like /-æxⒽ/ alternate between high and low on their vowel (i.e. [-ǽx] vs. [-æ̀xə́]), suffixes with pre-linked tone surface with this tone in all tonal contexts, e.g. /-(x)ə́t/ INVERSIVE, /-ə̀x/ DISTANCIATIVE, and /-ə̂l/ RECIPROCAL. See [S96:314] for a summary of underlying tone values on (derivational) suffixes.

a.	/-kⒽ/	3S.MIN	b.	/-æxⒽ/	ADJ1	/-ækⒽ/	ANTER	/-xæl̰Ⓗ/	LOC
	/-nⒽ/	2P.IMP		/-akⒽ/	ADJ2	/-ryæryⒽ/	ASSOC		

Table 18: Underlying representations of C-final suffixes with floating Ⓗ

An alternative underlying representations would posit a final /ə/ to which the high tone is pre-linked, parallel to the alternative representations for stem structure in the previous section. Alternative URs would be as in (21).

(21) Alternative URs (*rejected*)
 a. /-kə́/ 3S.MIN b. /-æxə́/ ADJ1 *etc*.

Under this alternative, we must account for the fact they condition /x/-deletion with /x/-alternating suffixes. An anonymous reviewer suggests that underlying morpheme-final /ə/ would not pattern with other vowels due to /ə/'s status as being 'weak' and more easily deleted when in marked positions. This alternative would be as in (22), where both /ə/ and /x/ are deleted.

(22) Alternative underlying representation (*rejected*)
 /Ⓗ-y͡ə̂ɗ-**kə́-xôw̃**/ [njə́ɗ͡ə̀-**k-ô**]
 INFL-give-**3S.MIN-PAST** 'he had given'

Under the alternative, it is predicted that [x] should delete whenever it is adjacent to [ə]. However, there are several places where this is not the case. One such environment involves a small set of suffixes expressing imperfective aspect, one [-ɗ]~[-ɗ͡ə] glossed as IPFV1 and another [-nd]~[-ndə́] glossed as IPFV2.[14] They constitute a type of [ə]-alternating suffix, where the [-C] variant is used following a high-toned stem (the a. examples in (23)-(24)), while the [-Cə́] variant is used with a low-toned stem (the b. examples).

(23) IPFV1 [-ɗ]~[-ɗ͡ə]
 a. [y͡ə̂t-ə̀lá bí mô kǽrǽsə́-**ɗ**] 'I don't know who will be dug up'
  know-1S.NEG who dig.up-**IPFV1** [S96:240 – *je ne sais pas qui sera creusé*]
 b. [nkwə̀r nkè-**ɗ͡ə́**] 'it will be enough'
  be.sufficient be-**IPFV1** [S96:238 – *ce sera suffisant*]

(24) IPFV2 [-nd]~[-ndə́]
 a. [njə́ɗ-æ̀kə́-**nd**] 'he would give'
  give-ANTER-**IPFV2** [S96:235 – *il donnerait*]
 b. [y͡ə̂ɗ-ə́ryì-**ndə́**] 'give again!'
  give-IMP-**IPFV2** [S96:235 – *donne encore*!]

However, their behaviour diverges from other [ə]-alternating suffixes in that they do *not* condition the deletion of /x/. Examples are in (25)-(26), where these imperfective suffixes are compared to /k/ 3S.MIN. For clarity, the /x/-alternating suffix is in bold.

[14] They are transparently related to one another via consonant mutation. According to Santos, in short the /-ɗ͡ə/ variant is used in *l'énociatif non antérieur* while /-ndə́/ is used elsewhere [S96:113-114, 198ff., 221ff., 238ff., 383-384].

(25) Contrast in the realisation of /-xôw̃/ PAST

a.	[njə́ɗə̀-ɗə́-**xò**]	‘he gave’ ~ ‘he was giving’	*[…ɗ-ô]
	INFL\give-IPFV1-**PAST**	[S96:235 – *il donnait*]	
b.	[njə́ɗ-æ̀kə́-ndə́-**xò**]	‘he would have given’	*[…nd-ò]
	INFL\give-ANTER-IPFV2-**PAST**	[S96:234 – *il aurait donné*]	
c.	Cf. [njə́ɗə̀-k-**ô**]	‘he had given’	*[…kə́-xò]
	INFL\give-3S.MIN-**PAST**	[S96:235 – *il avait donné*]	

(26) Contrast in the realisation of /-xâw̃/ 3S.OBJECT

a.	[môl yó-ɗə́-**xà** l̰ə́m]	‘who will take her over there?’	*[…ɗ-à]
	who carry-IPFV1-**3S.O** over.there	[S96:513 – *qui la transportera là-bas?*]	
b.	[nùỹá-ákə́-ndə́-**xà**]	‘he could receive it’	*[…nd-à]
	receive-ANTER-IPFV2-**3S.O**	[S96:363 – *il pourrait la recevoir*]	
c.	Cf. [njə́ɗə̀-k-**â**]	‘he gave him/her’	*[…kə́-xà]
	INFL\give-3S.MIN-**3S.O**	[S96:253 – *il lui a donné*]	

In preserving /x/, the imperfective suffixes pattern with the vowel-final suffixes, as in (20).

There are two ways to interpret the special behaviour of imperfective suffixes. The first is to assume that these suffixes are underlyingly /ɗ/ and /nd/, and trigger a segmentally-driven [ə]-epenthesis rule to break up consonant clusters. Here, their representations would be identical with other [ə]-alternating suffixes (e.g. /-k/ 3S.MIN). Recall from section 2.1 that segmentally-driven [ə]-epenthesis is sensitive to the morphological identify and thus the special behaviour of the imperfective suffixes would simply be another case of such morphological sensitivity.

Alternatively, we could attribute their behaviour to a difference in underlying structure. Here, the imperfective suffixes would underlyingly end in /ə/ and therefore not condition [x]-deletion because they end in a vowel underlyingly. This analysis is sketched in (27).

(27) Possibly distinct representations of [ə]-alternating suffixes

a.	Imperfective:	/-ndə́/	→	[-nd]~[-ndə́]
b.	Other [ə]-alternators:	/-kⒽ/	→	[-k]~[-kə́]

What is common to these two analyses of imperfective suffixes is that they unequivocally tolerate patterns where [ə] does *not* condition deletion of a following /x/. This therefore undermines the position that /x/ deletes because it is adjacent to a weak vowel [ə], rather than our more phonologically natural interpretation that /x/ deletes when it is adjacent to a consonant.

3.4 Deriving the final [ə] in suffixes

To conclude this section, we briefly outline how the [C]-final and [Cə]-final variants are derived, shown with a series of input-output mappings. For reasons of space, we only show derivations with /-kⒽ/ 3S.MIN. Our discussion here is fully formalised in section 4 within an OT framework.

Table 19 shows /-kⒽ/ with CVC and CVCV stems of four lexical tone patterns (H, LH, L, HL). As established, the variant [-k] appears after a stem H tone, and [-kə́] after L.

Shape	Tone	Stem		/-kⒽ/ 3S.MIN		
CVC	H	lə́c	‘fart’	[lə́cə́-**k**]	‘farted’	[S96:368]
	LH	yòmpⒽ	‘not tense’	[yòmpə́-**k**]	‘well-stretched’	[S96:435]
	L	ròk	‘eat’	[ròkə̀-**kə́**]	‘eats’	[S96:217]
	HL	nkôx	‘stay away’	[nkóxə̀-**kə́**]	‘stayed away’	[S96:298]
CVCV	H	yáry-í	‘baptise-PASS’	[yáryí-**k**]	‘be baptised’	[S96:385]
	LH	ròk-í	‘eat-PASS’	[ròkí-**k**]	‘has been eaten’	[S96:228]
	L	nùfì	‘go look for’	[nùfì-**kə́**]	‘went to get’	[S96:350]
	HL	kécè	‘enclose’	[kécè-**kə́**]	‘made (fence)’	[S96:388]

Table 19: Distribution of /-kⒽ/ variants: [-k] after H, [-kə] after L[15]

Let us first provide derivations of simple low-toned and high-toned stems. In (28) with a low-toned stem, a syllabically-triggered epenthetic schwa is inserted between the consonant-final root and the consonant-initial suffix. Here and throughout, epenthetic material is in grey. As stated previously, Wamey generally disallows consonant clusters. With such low-toned stems, the low spreads from the root to the syllabically-triggered epenthetic [ə]. This happens even though a floating high tone is available which could value this epenthetic vowel (LH sequences are perfectly acceptable, e.g. [yòmpə́-k] in Table 19 above).

```
(28)     L             Ⓗ             L        Ⓗ
         |                  →       /    \     |
     r   ò   k  +  k            r  ò  k  ə̀  k  ə́

(29)        L           Ⓗ              L        Ⓗ
          /    \            →        /    \      |
     n   ù   f   ì  +  k          n  ù  f  ì  k  ə́
```

In both these examples, a word-final [ə] is inserted which the floating Ⓗ docks to. A constraint against creating rising tones forbids docking the Ⓗ leftward (i.e. *[ròkə̌k] and *[nùfǐk]), and a constraint against tone deletion forbids simply deleting Ⓗ (i.e. *[ròkə̀k] and *[nùfìk]).

Next consider the high-toned stems in (30)-(31). As above, a syllabically-triggered epenthetic [ə] is inserted between consonants (in grey). The first high tone (H_1) spreads rightward to the epenthetic vowel.

```
(30)    H1            Ⓗ2             H1
        |                   →       /   \
     l  ə́   c  +  k              l  ə́  c  ə́  k

(31)       H1            Ⓗ2              H1
          /    \              →         /    \
     y   á   ry   i  +  k           y  á  ry  i  k
```

The surface forms here are [lə́cə́k] and [yáryík], rather than *[lə́cə́kə́] and *[yáryíkə́]. This indicates that the second high tone (the floating tone Ⓗ2) does not trigger epenthesis in this context. To account for this, we assume a simple rule of high tone deletion: when a string of high tones H_1 H_2

[15] Note that some of the stems here show effects of consonant mutation, and their initial consonant may not be the same as its citation form (i.e. the forms in Santos’ lexicon where they bear a “grade II” consonant).

appears domain-finally, the second is deleted (a type of OCP dissimilation rule). Inserting [ə] here would not circumvent any OCP violation.

Further, derivations for HL stems are in (32)-(33). These are derived in the same way as the L stems: spreading of the root tone, followed by epenthesis to host the floating Ⓗ tone due to a restriction on rising tones.

```
(32)  |     H L           Ⓗ  |     |     H    L    Ⓗ  |
      |      \/              |  →  |     |    |    |  |
      | nk   ô   x  +  k     |     | nk  ó  x ə̀  k  ə́  |

(33)  |   H    L          Ⓗ  |     |   H    L    Ⓗ  |
      |   |    |             |  →  |   |    |    |  |
      | k é  c è  +  k       |     | k é  c è  k  ə́  |
```

Likewise, derivations for LH stems are in (34)-(35), in which the two adjacent high tones constitute an OCP violation and the second is deleted. Note for (34) that the surface form is [yòmpə́k] rather than conceivable alternate forms like *[yòmpə̀kə́].

```
(34)  |   L      Ⓗ1        Ⓗ2 |     |   L     Ⓗ1      |
      |   |                   |  →  |   |     |       |
      | y ò  mp        +  k   |     | y ò  mp ə́    k  |

(35)  |  L     H1        Ⓗ2 |     |  L     H1     |
      |  |     |            |  →  |  |     |      |
      | r ò  k í   +  k     |     | r ò  k í   k  |
```

4 OT analysis

In this section, we develop an analysis in Optimality Theory (OT) to derive the insertion of epenthetic [ə] based on the interaction of segmental and tonal constraints. The OT analysis aims to show that a small set of familiar constraints can generate the attested Wamey patterns, showing that all the ingredients needed to generate tone-driven epenthesis are already present in the theory. We begin with deriving the patterns with simple stems, before moving on to derivations in three more complex contexts: data with nominal enclitics, with [ə]-alternating suffixes, and with [x]-alternating suffixes. Note that the complete set of constraints plus their crucial orderings are found in the supplemental materials.

4.1 Stems

The most basic pattern involves the isolation form of a stem which sponsors a floating Ⓗ, in (36). Here, the input is given as a pre-linked low tone plus a floating high which triggers schwa-epenthesis in the surface form. We adopt a two-step derivation involving stem-level followed by word-level phonology.

(36) /y͡òmpⒽ/ $\xrightarrow[\text{(stem-level)}]{}$ y͡òmpⒽ $\xrightarrow[\text{(word-level)}]{}$ [y͡òmpə́] ‘slack’ [S96:659 – *ne pas être bien tendu*]

While this is in the spirit of derivational OT models (e.g. Stratal OT – Kiparsky 2015, *inter alia*), we are not explicitly arguing for one model over another *per se* in this paper.[16]

First, a key component is that forms like /ɣ͡ɔmpⒽ/ do not undergo tone-driven epenthesis in the stem-level phonology, but only at word-level phonology. The simple constraint set in Table 20 can derive the correct input-output mappings at these two stages. These involve a faithfulness constraint MAXTONE and three markedness constraints NORISE, NOFLOAT, and NOEDGESCHWA.

Name	Definition	Abbreviation
NORISE	A closed syllable cannot bear a LH tone sequence	*R
NOFLOAT	All tones must be associated to a TBU	*Ⓣ
MAXTONE	Do not delete tones	MAX(T)
NOEDGESCHWA	ə does not appear at the edge of a prosodic constituent	$*ə|_{\Phi}$

Table 20: Constraint set (continued below)

The constraint NOEDGESCHWA is abbreviated as $*ə|_{\Phi}$, which is meant to restrict [ə] from appearing at either the right or left edge of any prosodic constituent (whether prosodic stem, prosodic word, prosodic phrase, *etc*.). The subscript Φ denotes a prosodic constituent in general. This is motivated by the fact that [ə] in word-initial position is banned regardless of tonal environment (section 2.1).

Tableau 1 shows stem-level phonology using these constraints, where *Ⓣ is crucially ranked below the others. In this tableau, the morpheme is placed within a prosodic stem, denoted with a subscript Σ (for a cross-linguistic overview of the prosodic stem, see Inkelas 2014, Downing & Kadenge 2020, *inter alia*). Note that epenthetic material is in grey, as throughout.

[16] Moreover, our analysis is part of the growing literature examining phonological reflexes of word-internal hierarchical relations/syntax (Marvin 2002, Guekguezian 2017, Newell *et al*. 2017, *inter alia*), though we take no explicit stance on the details of these works.

<table>
<tr><th colspan="2">L H
|
(y͡ ò mp)Σ</th><th>*ə|Φ</th><th>*R</th><th>MAX(T)</th><th>*Ⓣ</th></tr>
<tr><td>☞ a.</td><td>L H
|
(y͡ ò mp)Σ</td><td></td><td></td><td></td><td>*</td></tr>
<tr><td>b.</td><td>L
|
(y͡ ò mp)Σ</td><td></td><td></td><td>*!</td><td></td></tr>
<tr><td>c.</td><td>H
|
(y͡ ó mp)Σ</td><td></td><td></td><td>*!</td><td></td></tr>
<tr><td>d.</td><td>L H
| /
(y͡ ǒ mp)Σ</td><td></td><td>*!</td><td></td><td></td></tr>
<tr><td>e.</td><td>L H
| |
(y͡ ò mp ə́)Σ</td><td>*!</td><td></td><td></td><td></td></tr>
<tr><td>f.</td><td>L
/ \
(y͡ ò mp ə̀)Σ</td><td>*!</td><td></td><td>*</td><td></td></tr>
</table>

Tableau 1: Stem-level phonology – /y͡òmpⒽ/ → y͡òmpⒽ

Candidates e. and f. violate the first constraint by placing [ə] at a prosodic constituent edge, d. has a rising tone on a closed syllable, and candidates b. and c. delete a tone. Fully faithful candidate a. is optimal, even though it still retains the floating tone.

It is at word-level phonology that [ə] is epenthesised, shown in Tableau 2. Crucially, here the constraints *ə|Φ and *Ⓣ are re-ranked.

<table>
<tr><td colspan="2">L H
|
((y͡ ò mp)Σ)ω</td><td>*Ⓣ</td><td>*R</td><td>MAX(T)</td><td>*ə|Φ</td></tr>
<tr><td>☞ a.</td><td>L H
| |
((y͡ ò mp ə́)Σ)ω</td><td></td><td></td><td></td><td>*</td></tr>
<tr><td>b.</td><td>L
/ \
((y͡ ò mp ə̀)Σ)ω</td><td></td><td></td><td>*!</td><td>*</td></tr>
<tr><td>c.</td><td>L
|
((y͡ ò mp)Σ)ω</td><td></td><td></td><td>*!</td><td></td></tr>
<tr><td>d.</td><td>H
|
((y͡ ó mp)Σ)ω</td><td></td><td></td><td>*!</td><td></td></tr>
<tr><td>e.</td><td>L H
| /
((y͡ ǒ mp)Σ)ω</td><td></td><td>*!</td><td></td><td></td></tr>
<tr><td>f.</td><td>L H
|
((y͡ ò mp)Σ)ω</td><td>*!</td><td></td><td></td><td></td></tr>
</table>

Tableau 2: Word-level – y͡òmpⒽ → [y͡òmpə́]

Candidates b.-e. all violate constraints which are still highly ranked, namely *R and MAX(T). Further, because *Ⓣ is re-ranked candidate f. is sub-optimal and candidate a. is optimal despite its insertion of [ə]. This tableau illustrates the ease with which tone-driven epenthesis can be modelled in OT.

In addition to inputs like /y͡òmpⒽ/, we must also entertain underlyingly /ə/-final inputs, for example a hypothetical (abstract) input /cv́cə́/. This is due to the standard principle in OT of Richness of the Base (Prince & Smolensky 2004 [1993]), which states that we cannot prohibit any input shapes. This is where our demarcation into stem-level vs. word-level phonology is crucial. Tableau 3 shows that inputs like /cv́cə́/ are mapped to cv́c outputs at stem-level phonology, where the final /ə/ has been deleted. This tableau involves three additional constraints, in Table 21.

Name	Definition	Abbreviation
DEPCONSONANT	Do not insert a consonant	DEP(C)
*SPREAD(FEATURE)	Do not spread a segmental feature to another segment	*SPR(F)
MAX(V)	Do not delete a vowel	MAX(V)

Table 21: Continued constraint set (for stem-level phonology)

<table>
<tr><th colspan="2">H
/\
(c v́ c ə́)Σ</th><th>*ə|Φ</th><th>*R</th><th>MAX(T)</th><th>DEP(C)</th><th>*SPR(F)</th><th>MAX(V)</th><th>*Ⓣ</th></tr>
<tr><td>☞ a.</td><td>H
|
(c v́ c)Σ</td><td></td><td></td><td></td><td></td><td></td><td>*</td><td></td></tr>
<tr><td>b.</td><td>H
/\
(c v́$_i$ c v́$_i$)Σ</td><td></td><td></td><td></td><td></td><td>*!</td><td></td><td></td></tr>
<tr><td>c.</td><td>H
/\
(c v́ c ə́ c)Σ</td><td></td><td></td><td></td><td>*!</td><td></td><td></td><td></td></tr>
<tr><td>d.</td><td>H
/\
(c v́ c ə́)Σ</td><td>*!</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Tableau 3: Stem-level – /cv́cə́/ → cv́c

The fully faithful candidate d. violates high-ranked *ə|$_\Phi$, while candidates b. and c. both violate newly introduced constraints against consonant deletion and feature spreading. Candidate a. is optimal even though it violates MAX(V). None of the candidates violate tonal constraints *R, MAX(T), or *Ⓣ, which play no role in this tableau.

A two-step grammar accounts for the shape of stems and their mapping to words when no word-level suffixes are additionally added. The fact that stem-level phonology eliminates any stem-final /ə/ accounts for the /Cə/ gap in CV roots, as shown in Section 3.1. Recall that the only exception was a root /jə́/ '(grand)son of'. However, its exceptional status can be straightforwardly derived from the fact that it is a bound root which never appears on its own, unlike other nouns. If we treat this as a type of lexical affix, we can assume that it does not go through stem-level phonology and thus it is predicated that its final /ə/ is not ruled out.

4.2 [ə]-alternating suffixes

Next, let us examine more complex data involving [ə]-alternating suffixes. We will illustrate this with the subject agreement suffix /-kⒽ/ 3S.MIN, which alternates between forms [-k] and [-kə́] depending on its tonal environment. We must derive the three (word-level) input-output mappings in (37) (repeated from Table 19).

(37) Word-level input-output mappings with [ə]-alternating suffixes

a.	L-toned stem:	ròk + **kⒽ**	→	[ròkə̀-**kə́**]	(*ròkə́k, ròkə́kə́)
b.	H-toned stem:	lə́c + **kⒽ**	→	[lə́cə́-**k**]	(*lə́cə́kə́)
c.	LⒽ-toned stem:	yòmpⒽ + **kⒽ**	→	[yòmpə́-**k**]	(*yòmpə̀kə́)

We must add four new constraints to the word-level phonological grammar, in Table 22.

Name	Definition	Abbreviation
*ConsonantCluster	Consonants are not adjacent in a prosodic word (ϖ)	*CC
Align(●,Φ)	Align (colourless) epenthetic material to a prosodic constituent edge (Φ)	Al(●,Φ)
*Cross-stem-R(T-μ)	Do not associate a tone (T) to a mora (μ) across a right edge stem boundary, i.e. $)_\Sigma$	* μ-$)_\Sigma$-T
OCP(H)	H tones are not adjacent on the tone tier within a prosodic word (ϖ)	OCP(H)

Table 22: Continued constraint set for word-level phonology (continued below)

*CC and OCP(H) are standard markedness constraints. Align(●,Φ) is an alignment constraint which requires that any epenthetic material (e.g. an epenthetic [ə]) be aligned to some prosodic constituent edge. This will help dictate the optimal position of epenthetic [ə]'s below. Further, *Cross-stem-R(T-μ) states that a tone must not associate to a TBU (the mora, μ) across the right edge of a prosodic stem boundary. This will dictate in part the optimal host for floating tones.[17]

Tableau 4 shows how adding the first three of these constraints derives the correct mapping with a low-toned stem (i.e. ròk + kⒽ → [ròkə̀-kə́]).

[17] The *Cross-stem-R(T-μ) constraint brings up a well-known precedence problem in autosegmental phonology (Archangeli & Pulleyblank 1994, Jurgec 2011: 31, *inter alia*): by itself, a floating tone is not technically before or after a counterpart segment since they are on separate autosegmental tiers. In our analysis, therefore, it is crucial that there be prosodic constituency on both the tonal and the segmental tier, i.e. in Tableau 4 both tiers show prosodic stem (Σ) and prosodic word (ϖ) constituency. It is in connecting these two tiers that constituency violations may emerge, e.g. an association line crossing certain stem boundaries incurs violations of *Cross-stem-R(T-μ). That prosodic constituency be subject to violable constraints rather than fixed universals is in line with modern work on the prosodic hierarchy (e.g. Match Theory – Selkirk 2011).

Further, an anonymous reviewer presents a morphological alternative whereby an output incurs violations if phonological structure from distinct morphemes is associated, e.g. structure of the suffix is associated to the root. Under this conceptualization, what is banned is association between morphemes rather than association across prosodic constituents. We reject this alternative because (i) in Tableau 4 the floating tone is associated to an epenthetic vowel which by definition has no morphological affiliation, and (ii) in later tableaux (e.g. Tableau 10) we see that structure from one morpheme *is* able to associate to another morpheme.

<table>
<tr><th></th><th>((L)$_\Sigma$ H)$_\varpi$
|
μ
|
((r ò k)$_\Sigma$ k)$_\varpi$</th><th>*CC</th><th>*Ⓣ</th><th>AL(●,Φ)</th><th>*μ-)$_\Sigma$-T</th><th>MAX(T)</th><th>*ə|$_\Phi$</th></tr>
<tr><td>☞ a.</td><td>((L)$_\Sigma$ H)$_\varpi$
| \ |
μ μ μ
| | |
((r ò k ə̀)$_\Sigma$ k ə́)$_\varpi$</td><td></td><td></td><td></td><td></td><td></td><td>**</td></tr>
<tr><td>b.</td><td>((L)$_\Sigma$)$_\varpi$
| \
μ μ
| |
((r ò k ə̀)$_\Sigma$ k)$_\varpi$</td><td></td><td></td><td></td><td></td><td>*!</td><td>*</td></tr>
<tr><td>c.</td><td>((L)$_\Sigma$ H)$_\varpi$
| /
μ μ
| |
((r ò k ə́)$_\Sigma$ k)$_\varpi$</td><td></td><td></td><td></td><td>*!</td><td></td><td>*</td></tr>
<tr><td>d.</td><td>((L)$_\Sigma$ H)$_\varpi$
| / \
μ μ μ
| | |
((r ò k ə́)$_\Sigma$ k ə́)$_\varpi$</td><td></td><td></td><td></td><td>*!</td><td></td><td>**</td></tr>
<tr><td>e.</td><td>((L)$_\Sigma$ H)$_\varpi$
| |
μ μ
| |
((r ò k)$_\Sigma$ ə́ k)$_\varpi$</td><td></td><td></td><td>*!</td><td></td><td></td><td></td></tr>
<tr><td>f.</td><td>((L)$_\Sigma$ H)$_\varpi$
| \
μ μ
| |
((r ò k ə̀)$_\Sigma$ k)$_\varpi$</td><td></td><td>*!</td><td></td><td></td><td></td><td>*</td></tr>
<tr><td>g.</td><td>((L)$_\Sigma$ H)$_\varpi$
| |
μ μ
| |
((r ò k)$_\Sigma$ k ə́)$_\varpi$</td><td>*!</td><td></td><td></td><td></td><td></td><td>*</td></tr>
</table>

Tableau 4: Word-level phonology – ròk-kⒽ → [ròkə̀kə́]

Candidate g. is ruled out by *CC because its consonant cluster is not repaired in the output, while in candidate f. is ruled out because the floating tone sponsored by /-k/ remains floating. Candidates c.-e. are ruled out by the more complex constraints. In candidate e., [ə] is inserted to break up the cluster, but it is placed outside the prosodic stem rather that inside it. It therefore does not align to the edge of any prosodic constituent it is contained within, and is sub-optimal. Further, in candidates c. and d. the floating tone associates to [ə] within a prosodic stem. By crossing a right edge prosodic stem boundary, this violates *μ-)$_{\Sigma}$-T. Finally, candidate b. deletes the floating high, in violation of MAX(T), leaving candidate a. [ròk-ə̀-kə́] as optimal even though it has inserted two epenthetic vowels at constituent edges (violating *ə|$_{\Phi}$).[18]

In short, Tableau 4 shows that if a floating tone cannot dock 'backwards' into the stem, then an epenthetic vowel is inserted to host it. This shows that there are two contexts where tone-driven epenthesis arises: to avoid a rising tone on a closed syllable, and to avoid docking a word-level floating tone to an inner constituent, the prosodic stem.

Further, Tableau 5 and Tableau 6 show the input-output mappings with a high-toned stem (lɔ́c) and a stem with a floating tone (yòmpⒽ), respectively. Both of these stems end in a high tone, and as such we now see the role of OCP(H) in the grammar.

[18] Note that there must be some undominated constraint prohibiting deleting /-k/ and other monoconsonantal suffixes (as well as the exceptional affix /-lél̰/ – section 2.1), which we assume but do not show within this or other tableaux.

	Input / Candidate	OCP(H)	AL(●,Φ)	*μ-$)_\Sigma$-T	MAX(T)	*ə|$_\Phi$
	((H_1 $)_\Sigma$ H_2 $)_\omega$ μ ((l ə́ c $)_\Sigma$ k $)_\omega$					
☞ a.	((H_1 $)_\Sigma$ $)_\omega$ μ μ ((l ə́ c ə́ $)_\Sigma$ k $)_\omega$				*	*
b.	((H_1 $)_\Sigma$ $)_\omega$ μ μ μ ((l ə́ c ə́ $)_\Sigma$ k ə́ $)_\omega$				*	**!
c.	(($)_\Sigma$ H_2 $)_\omega$ μ μ ((l ə́ c ə́ $)_\Sigma$ k $)_\omega$			*!*	*	*
d.	((H_1 $)_\Sigma$ $)_\omega$ μ μ ((l ə́ c $)_\Sigma$ ə́ k $)_\omega$		*!		*	
e.	((H_1 $)_\Sigma$ H_2 $)_\omega$ μ μ μ ((l ə́ c ə́ $)_\Sigma$ k ə́ $)_\omega$	*!				**
f.	((H_1 $)_\Sigma$ H_2 $)_\omega$ μ μ ((l ə́ c ə́ $)_\Sigma$ k $)_\omega$	*!		*		*
g.	((H_1 $)_\Sigma$ H_2 $)_\omega$ μ μ μ ((l ə́ c ə́ $)_\Sigma$ k ə́ $)_\omega$	*!		*		**

Tableau 5: Word-level – lə́c-kⒽ → [lə́cə́k]

	Input	OCP(H)	AL(●,Φ)	*μ-)Σ-T	MAX(T)	*ə|Φ
	((L H₁)Σ H₂)ω | μ | ((y ò mp)Σ k)ω					
☞ a.	((L H₁)Σ)ω | | μ μ | | ((y ò mpə́)Σ k)ω				*	*
b.	((L H₁)Σ)ω | | \\ μ μ μ | | | ((y ò mpə́)Σ k ə́)ω				*	**!
c.	((L)Σ H₂)ω | \\ | μ μ μ | | | ((y ò mpə̀)Σ k ə́)ω				*	**!
d.	((L)Σ H₂)ω | / μ μ | | ((y ò mpə́)Σ k)ω			*!	*	*
e.	((L)Σ H₂)ω | | μ μ | | ((y ò mp)Σ ə́ k)ω		*!		*	
f.	((L H₁)Σ H₂)ω | | | μ μ μ | | | ((y ò mpə́)Σ k ə́)ω	*!				**

Tableau 6: Word-level – yòmpⒽ + kⒽ → [yòmpə́k]

Considering these tableaux together, in the input of both two high tones are adjacent. High-ranked OCP(H) rules out all candidates which does not delete one of these two tones.[19] Next, AL(●,Φ) eliminates those candidates which insert an epenthetic [ə] outside the prosodic stem, and *μ-)Σ-T eliminates those whereby a word-level floating tone docks inward into the prosodic stem. The

[19] OCP(H) as it is formulated here is actually too powerful if we consider other Wamey data which show that pre-linked high tones frequently become adjacent under morphological concatenation. One straightforward response would be to counterweight OCP(H) with a faithfulness constraint to underlying pre-linked high tone, which would not apply to floating tones. For space reasons, we do not settle this matter in this paper.

remaining candidates all violate the lower-ranked MAX(T) by deleting one of the input tones. The optimal candidates in each are those which violate $*ə|_{\Phi}$ the least, essentially the candidates which have the fewest epenthetic [ə]'s. The floating tone is deleted here due to the general phonological grammar, and thus there is no longer any reason to insert an epenthetic [ə] to host it.[20]

4.3 Definite enclitics

Next, consider data involving the definite enclitic from section 3.2. The input-output mappings are repeated in (38) with a definite enclitic /=ŋǎ/. Recall that output forms in this context have two forms, one with the initial consonant of the enclitic, and one where it has been deleted.

(38) Definite enclitics (repeated from above)

a. /æ-tə́x=**ŋǎ**/ → [æ̀-tə́x=**ŋǎ**] ~ [æ̀-tə́x=**ǎ**] 'the tree'

b. /wæ-mbə̀lⒽ=**ŋǎ**/ → [wæ̀-mbə̀lə́=**ŋǎ**] ~ [wæ̀-mbə̀l**á**=**ǎ**] 'the milk'

The data in (b.) show that in both contexts, the floating tone of the stem triggers an epenthetic host. As we showed in that section, this variation is not found in underlyingly vowel-final roots (e.g. /i-ɓú=**ŋǎ**/ → [ì-ɓú=**ŋǎ**] 'the baobab fruit').

To account for this variation, we posit that definite enclitics have two prosodic parses: one where they form their own phonological word (ϖ) and one where they form a recursive word with the stem (Bennett 2018, Ito & Mester 2021, *inter alia*). This is exemplified in (39).

(39) Two prosodic parses with definite enclitics

a. Separate words: $(\text{æ̀-tə́x})_{\varpi}$ $(\textbf{ŋǎ})_{\varpi}$

b. Recursive word: $(\,(\text{æ̀-tə́x})_{\varpi}\ \textbf{ǎ})_{\varpi}$

That consonant clusters are allowed in (a.) but not (b.) is in line with other facts about when clusters are permitted, e.g. compounds, reduplication, and with other clitics (see Section 2.1).

To see how this works, consider Tableau 7 and Tableau 8 with the data from (39). We add a constraint MAX(C) prohibiting deleting consonants to the grammar. Note for simplicity we do not include the noun prefix in these tableaux.

[20] Note that [ə]-alternating affixes like /-æxⒽ/ ADJ1 still need to be explained, i.e. data like /cæ̀pⒽ-æxⒽ/ → [cæ̀p-**ǽx**] 'split' versus /tès-æxⒽ/ → [tès-**æ̀xə́**] 'sick'. In the latter example, we cannot appeal to constraints on crossing stem boundaries to account for why the floating tone does not dock to /æx/. A straightforward analysis would involve van Oostendorp's (2007) constraint ALTERNATION ("if an association line links two elements of colour α, the line should also have colour α"), used to ban association of floating material to the morph which sponsors it.

	Input	*CC	*ə|Φ	MAX(C)
	(H)ω (L H)ω | \/ μ μ | | (t ə́ x)ω (ŋ ǎ)ω			
☞ a.	(H)ω (L H)ω | \/ μ μ | | (t ə́ x)ω (ŋ ǎ)ω			
b.	(H)ω (L H)ω | \/ μ μ | | (t ə́ x)ω (ǎ)ω			*!
c.	(H)ω (L H)ω | \ \/ μ μ μ | | | (t ə́ x ə́)ω (ŋ ǎ)ω		*!	
d.	(H)ω (L H)ω | \ \/ μ μ μ | | | (t ə́ x ə́)ω (ǎ)ω		*!	*

Tableau 7: Word-level – tə́x=ŋǎ → [tə́x=ŋǎ]

	Input	*CC	*ə|$_{\Phi}$	MAX(C)
	((H)$_{\varpi}$ L H)$_{\varpi}$ | V μ μ | | ((t ə́ x)$_{\varpi}$ ŋ ǎ)$_{\varpi}$			
a.	((H)$_{\varpi}$ L H)$_{\varpi}$ | V μ μ | | ((t ə́ x)$_{\varpi}$ ŋ ǎ)$_{\varpi}$	*!		
☞ b.	((H)$_{\varpi}$ L H)$_{\varpi}$ | V μ μ | | ((t ə́ x)$_{\varpi}$ ǎ)$_{\varpi}$			*
c.	((H)$_{\varpi}$ L H)$_{\varpi}$ | \ V μ μ μ | | | ((t ə́ x ə́)$_{\varpi}$ ŋ ǎ)$_{\varpi}$		*!	
d.	((H)$_{\varpi}$ L H)$_{\varpi}$ | \ V μ μ μ | | | ((t ə́ x ə́)$_{\varpi}$ ǎ)$_{\varpi}$		*!	*

Tableau 8: Word-level – tə́x=ŋǎ → [tə́x=ǎ]

In these tableaux, all consonant clusters which appear within a prosodic word violate *CC. In the first tableau the two morphemes form separate words and therefore none of the candidates violate *CC, even when the two consonants are adjacent. In contrast, in the second tableau candidate a. violates this and is eliminated. Next, candidates which epenthesise [ə] to break up this cluster violate the high-ranked constraint *ə|$_{\Phi}$ against [ə] at a prosodic boundary. The remaining candidate is optimal, which in the first tableau shows no violations and in the second violates MAX(C).

Let us now move to the more complicated data with floating tones. Tableau 9 shows such data, with the variant involving separate words. We add three more constraints to the word-level grammar, defined in Table 23.

Name	Definition	Abbreviation
*CROSS-WORD-L(T-μ)	Do not associate a tone (T) to a mora (μ) across a left-edge word boundary, i.e. ($_{\varpi}$	*T-($_{\varpi}$-μ
*CROSS-WORD-L(μ-V)	Do not associate a mora (μ) to a vowel (V) across a left-edge word boundary, i.e. ($_{\varpi}$	*μ-($_{\varpi}$-V
DEP(μ)	Do not insert a mora (μ)	DEP(μ)

Table 23: Continued constraint set for word-level phonology (continued below)

The first two constraints have a structure parallel to *CROSS-STEM-R(T-μ) above, but reference distinct phonological units and constituent edges.

<table>
<tr><th></th><th>(L H)ω (L H)ω
| ∨
μ μ
| |
(mb ə̀ l)ω (ŋ ǎ)ω</th><th>*CC</th><th>*R</th><th>*Ⓣ</th><th>*T-(ω-μ</th><th>*μ-(ω-V</th><th>MAX(T)</th><th>*ə|Φ</th><th>MAX(C)</th><th>DEP(μ)</th></tr>
<tr><td>☞ a.</td><td>(L H)ω (L H)ω
| | ∨
μ μ μ
| | |
(mb ə̀ l ə́)ω (ŋ ǎ)ω</td><td></td><td></td><td></td><td></td><td></td><td></td><td>*</td><td></td><td>*</td></tr>
<tr><td>b.</td><td>(L H)ω (L H)ω
| | ∨
μ μ μ
| | |
(mb ə̀ l ə́)ω (ǎ)ω</td><td></td><td></td><td></td><td></td><td></td><td></td><td>*</td><td>*!</td><td>*</td></tr>
<tr><td>c.</td><td>(L)ω (L H)ω
| ∨
μ μ
| |
(mb ə̀ l)ω (ŋ ǎ)ω</td><td></td><td></td><td></td><td></td><td></td><td>*!</td><td></td><td></td><td></td></tr>
<tr><td>d.</td><td>(L H)ω (L H)ω
| | ∨
μ μ μ
| |
(mb ə̀ l)ω (ŋ ã)ω</td><td></td><td></td><td></td><td></td><td>*!</td><td></td><td></td><td></td><td>*</td></tr>
<tr><td>e.</td><td>(L H)ω (L H)ω
| ∨
μ μ
| |
(mb ə̀ l)ω (ŋ ã)ω</td><td></td><td></td><td></td><td>*!</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>f.</td><td>(L H)ω (L H)ω
| ∨
μ μ
| |
(mb ə̀ l)ω (ŋ ǎ)ω</td><td></td><td></td><td>*!</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>g.</td><td>(L H)ω (L H)ω
| / ∨
μ μ
| |
(mb ǎ l)ω (ŋ ǎ)ω</td><td></td><td>*!</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Tableau 9: Word-level – mbə̀lⒽ=ŋǎ → [mbə̀lə́=ŋǎ]

Examining this tableau, the highly-ranked constraints MAX(T), *Ⓣ, and *R eliminate candidates c., f., and g. respectively. Further, candidates d.-e. violate the newly introduced constraints*T-($_{\omega}$-μ and *μ-($_{\omega}$-V. Candidate d. shows a mora associating to a vowel over a left-edge word boundary, and similarly e. shows a tone associating to a mora over this boundary. The remaining candidates in a.-b. each violate *ə|$_{\Phi}$ by epenthesising a vowel to host the tone, and the more faithful a. wins.

Next, consider the variant in Tableau 10 which shows word recursion. Here, due to this recursion we require sensitivity both to the left edges of prosodic words (above) as well as to the right edges. We therefore add the constraints in Table 24 to the grammar.

Name	Definition	Abbreviation
*CROSS-WORD-R(T-μ)	Do not associate a tone (T) to a mora (μ) across a right-edge word boundary, i.e.)$_{\omega}$	*T-)$_{\omega}$-μ
*CROSS-WORD-R(μ-V)	Do not associate a mora (μ) to a vowel (V) across a right-edge word boundary, i.e.)$_{\omega}$	*μ-)$_{\omega}$-V

Table 24: Continued constraint set for word-level phonology (final additions)

	((L H)$_\omega$ L H)$_\omega$ ((mb ə̀ l)$_\omega$ ŋ ǎ)$_\omega$	*CC	*R	*Ⓣ	*T-)$_\omega$-μ	*T-($_\omega$-μ	*μ-($_\omega$-V	MAX(T)	*ə|$_\Phi$	MAX(C)	DEP(μ)	*μ-)$_\omega$-V
☞ a.	((L H)$_\omega$ L H)$_\omega$ ((mb ə̀ l)$_\omega$ ã̌)$_\omega$									*	*	*
b.	((L H)$_\omega$ L H)$_\omega$ ((mb ə̀ l ə́)$_\omega$ ŋ ǎ)$_\omega$								*!		*	
c.	((L H)$_\omega$ L H)$_\omega$ ((mb ə̀ l)$_\omega$ ã̌)$_\omega$				*!					*		
d.	((L H)$_\omega$ L H)$_\omega$ ((mb ə̀ l)$_\omega$ ŋ ã̌)$_\omega$	*!									*	*
e.	((L H)$_\omega$ L H)$_\omega$ ((mb ə̀ l)$_\omega$ ŋ ã̌)$_\omega$	*!			*							

Tableau 10: Word-level – mbə̀lⒽ=ŋǎ → [mbə̀lá=ǎ]

Here, because the morphemes are grouped into a single word they are subject to *CC, which eliminates candidates d.-e. Next, candidate c. violates *T-)$_\omega$-μ by associating a tone across the right edge of a word boundary. None of the candidates, however, violate similar constraints involving the left edge *T-($_\omega$-μ or *μ-($_\omega$-V due to the recursive word structure. Of the remaining two candidates, candidate b. violates *ə|$_\Phi$ and is therefore eliminated. The winning candidate violates DEP(μ) by epenthesising a mora to host the floating tone, as well as low-ranked *μ-)$_\omega$-V by associating this mora across a right-edge word boundary.

Taking this all together, the optimal output is one where the floating tone triggers mora epenthesis but not vowel epenthesis; the epenthesised mora is able to parasitically associate to another vowel. This results in one of the few long vowels found in Wamey, an output [mbə̀láǎ]. We return to tone-driven μ-epenthesis in our discussion in section 5.1.

4.4 /x/-alternating suffixes

The final forms to derive using our phonological grammar is the interaction of [ə]-alternating suffixes with the /x/-alternating suffixes introduced in Section 3.3. We illustrate their interaction using the data point in (40) (repeated from Table 17), showing the deletion of /x/.

(40) / Ⓗ-ɣ͡ə̂ɗ-kⒽ-xîn / → [njə́ɗ͡ə̀-k-î] (cf. long *[njə́ɗ͡ə̀-kí-ì])
INFL-give-3S.MIN-2S.O 'he gave you'

Notice in this example that the floating Ⓗ does not condition mora-insertion (the final vowel remains short). We can compare this to a minimal pair in (41) with the demonstrative enclitic /=ŋî/ 'this'. This too bears a lexical HL tone, and like with the definite enclitics it may optionally undergo /ŋ/-deletion when adjacent to a consonant. With this clitic, however, the final vowel surfaces as long […l**íì**] (cf. short […k**î**] immediately above).

(41) wæ-mbə̀lⒽ=ŋî → [wæ̀-mbə̀lə́=ŋì] ~ [wæ̀-mbə̀lí=ì] (cf. short *[wæ̀-mbə̀l=î])
CL12B-milk-DEM.CL12B 'this milk'

How we account for this contrast is shown in Tableau 11, showing the input-output mapping of the form in (40). No new constraints need to be added.[21]

[21] As before, for simplicity and reasons of space we do not include the inflectional prefix in this tableau (the floating Ⓗ tone prefix), nor do we account for the deletion of the coda /n/ of the final suffix. In the tableau, we also provide the verb in its unmutated form /ɣəɗ/ rather than its actual surface form [njəɗ].

	Candidate	OCP(H)	AL(●,Φ)	*μ-)$_\Sigma$-T	*T-)$_\omega$-μ	MAX(T)	*ə|$_\Phi$	MAX(C)	DEP(μ)
	((L)$_\Sigma$ H$_1$ H$_2$ L)$_\omega$ μ μ ((yˤ ə̀ ɗ)$_\Sigma$ k x î n)$_\omega$								
☞ a.	((L)$_\Sigma$ H$_1$ L)$_\omega$ μ μ μ ((yˤ ə̀ ɗ ə̀)$_\Sigma$ k î)$_\omega$					*	*	*	*
b.	((L)$_\Sigma$ H$_1$ L)$_\omega$ μ μ μ μ ((yˤ ə̀ ɗ ə̀)$_\Sigma$ k î)$_\omega$					*	*	*	**!
c.	((L)$_\Sigma$ H$_1$ L)$_\omega$ μ μ μ ((yˤ ə̀ ɗ ə́)$_\Sigma$ k ì)$_\omega$			*!		*	*	*	*
d.	((L)$_\Sigma$ H$_1$ L)$_\omega$ μ μ μ ((yˤ ə̀ ɗ)$_\Sigma$ ə́ k ì)$_\omega$		*!			*		*	*
e.	((L)$_\Sigma$ H$_1$ L)$_\omega$ μ μ μ μ ((yˤ ə̀ ɗ ə̀)$_\Sigma$ k ə́ x ì)$_\omega$		*!			*	*		**
f.	((L)$_\Sigma$ H$_1$ L)$_\omega$ μ μ μ μ ((yˤ ə̀ ɗ ə̀)$_\Sigma$ k ə̀ x î)$_\omega$		*!			*	*		**
g.	((L)$_\Sigma$ H$_1$ H$_2$ L)$_\omega$ μ μ μ μ ((yˤ ə̀ ɗ ə̀)$_\Sigma$ k ə́ x î)$_\omega$	*!	*				*		**

Tableau 11: Word-level – yˤə̀ɗ-kⒽ-xîn → yˤə̀ɗə̀-k-î

First, candidate g. is eliminated because it fails to delete one of the two high tones, in violation of OCP(H). Next, candidates d.-f. each violate AL(●,Φ) by epenthesising [ə] between the two consonants rather than at a prosodic constituent edge. The remaining candidates all equally violate MAX(T) and *ə|$_\Phi$. Candidate c. violates *μ-)$_\Sigma$-T by associating the floating tone over a stem boundary, leaving candidates a. and b. The winner is a. which epenthesises less structure compared to b. which epenthesises an additional mora. Notice that because all of the morphemes are within a single non-recursive word, candidate a. does not violates *T-$)_{\omega}$-μ (prohibiting associating a tone over a word boundary). This accounts for the fact that the floating tone does not require a mora to host it here, while it does require a mora with an enclitic in a recursive word (cf. Tableau 10).

5 Discussion

As we introduced, TONE-INTONATION PARALLELISM is the premise that tones (and in particular floating tones) in tonal languages and intonational languages should not be ontologically distinct, i.e. they should have comparable representations and behaviour. We explored this premise looking at tone-driven vowel-epenthesis, which is well-attested in intonational systems but has been claimed to be impossible/unattested in tonal languages where tone is used for lexical, derivational, and inflectional purposes. We presented Wamey as the best case to date for tone-driven epenthesis in a tonal language, filling an important empirical gap and supporting tone-intonation parallelism. In this section, we situate the Wamey data by (i) discussing phenomena similar to tone-driven epenthesis, (ii) call attention to a small number of other cases where tone-driven epenthesis has been postulated (or, at the very least, considered), and (iii) speculate as to why tone-driven epenthesis is so rare.

5.1 Similar phenomena

Tone-driven vowel-epenthesis is one of several phenomena which demonstrate linguistic systems cultivating segmental environments "better suited for realizing meaningful f_0 movements" (Roettger & Grice 2019: 279). One such phenomenon has been already introduced, namely TONE-DRIVEN VOWEL-RETENTION, which was entertained as a possible alternative to epenthesis in Wamey in section 3. Under this type, vowels which are otherwise expected to delete and/or reduce are retained in full if they bear tone. Roettger & Grice (2019) identify several such cases in intonational systems, e.g. Standard European Portuguese, Bulgarian, Greek, Ath-Sidhar Rifian Berber, Moroccan Colloquial Arabic, Bonaara Oromo, and Tunica, and highlight parallel patterns in lexical accent/tone systems, e.g. Cheyenne, Acoma, Konso, Shanghainese, and Japanese. To these we can add tone-driven vowel-retention in tonal languages Baraïn (Lovestrand 2012), Sumi Naga (Teo 2009), and Arapaho (Cowell & Moss 2008, Gleim 2019). For example, in Arapaho an epenthetic vowel surfaces to break up certain consonant clusters only if it additionally hosts a high tone, e.g. the floating high in (42).

(42) Arapaho tone-driven vowel-retention

a. /tʃew-Ⓗsee/ → [tʃeb-**í**-see] 'to walk along'
b. /tʃew-kóóhu/ → [tʃeb-kóóhu] 'run along'

Gleim (2019) presents a lengthy presentation of the Arapaho facts as tone-driven vowel-retention rather than tone-driven epenthesis, crucially showing that consonant mutation (e.g. w→b above) provides evidence for A→B→A Duke-of-York derivations (i.e. C-C→C-**i**-C→C-C).

Further, in contrast to the rarity of tone-driven insertion of a vowel, there are in fact several languages where a mora is inserted to realise tone, which then associates to some already present segmental root node. We saw this already in Wamey in one environment, namely across an internal word boundary with definite enclitics (sections 3.2 and 4.3). Two other examples come from tonal languages Kuria (Marlo *et al*. 2015: 256ff.) and Gokana (Hyman 1985: 24, 2011b: 74), amongst other examples in African languages.

5.2 Other cases of tone-driven vowel-epenthesis in tonal languages

Outside of Wamey, we are aware of only a handful of tonal languages where tone-driven vowel-epenthesis has been posited, or at least entertained. These are Kejom (a.k.a. Babanki – Akumbu *et al*. 2020), Kifuliiru (van Otterloo 2011: 71-73), Hdi (Frajzyngier & Shay 2002), and Ghomala' (a.k.a. Bandjoun/Banjun – Nissim 1981, Eichholzer 2010). Of these, the first two are morphologically quite restricted rather than phonologically general, and the case of Hdi has been dismissed as a case of epenthesis already (Gleim 2019: 4).

The most convincing case of these by far is Ghomala'. There are five main tone patterns on monosyllabic roots, shown in Table 25. The pattern denoted as L^{o} is a low pitch which does not fall to the bottom of a speakers pitch range (i.e. level low), while L is a low pitch which *does* fall to the bottom (i.e. falling low).

H	/láp/	[láp]	˥	'be bland'	[*être fade*]
L^{o}	/bàp^{o}/	[bàp^{o}]	˧	'animal'	[*bête, animal*]
L	/làp/	[làp]	˩	'mock'	[*se moquer*]
HL	/lâp/	[lâp]	˥˩	'elegance'	[*élégance, fierté*]
LH	/lǎp/	[lǎp ~ làpə́]	˩˥ ~ ˧ ˥	'pool of water'	[*mare d'eau*]

Table 25: Ghomala' tone contrasts (Eichholzer 2010: 31)

In general, if a root ends in an obstruent (possible codas: /p k ʔ/), then that obstruent faithfully surfaces in final position. However, with LH roots and *only* LH roots, this may variably be realised either as a rising tone, or L on the first syllable and H on an epenthetic [ə]. This is very similar to Wamey in that (i) it involves the general unmarked vowel [ə], (ii) it is a solution to avoid a rising tone on a closed syllable (a common restriction – Zhang 2013), and (iii) CVCV roots are otherwise not allowed. It is clear that in both languages the epenthetic [ə] cannot be attributed solely to a syllabically-driven restriction on codas. Nissim (1981) in fact is explicit, stating that words with rising tone ending in obstruents are realised with an epenthetic final vowel (p. 63, footnote 12). Active alternations exist as well, which show that if the rising tone is eliminated (e.g. by regular tone rules), no epenthetic vowel can surface. We refer the reader to Nissim (1981) for details.

5.3 Rarity

In total, if the patterns of Wamey (and Ghomala') constitute genuine cases of tone-driven epenthesis in tonal languages, then such systems cannot be banned by some universal component of phonological architecture. At the same time, it is indisputable that tone-driven epenthesis is very rare. If we cannot point to a universal restriction on such systems, we are forced to find additional avenues to explain its particular rarity. We conclude this section by speculating why this rarity exists, focusing on two features of floating tone in tonal languages which make it different from its use in intonational systems: co-exponence with segmental material and positional (un)restrictedness.

First, in tone languages, when floating tones realise a specific lexical, derivational, or inflectional category, they typically are accompanied by segmental co-exponents. This was the case in Wamey, where the relevant floating tones we examined appear with other segmental material, e.g. roots like /-mbə̀lⒽ/ 'milk' and affixes like /-æxⒽ/ ADJ1 or /-kⒽ/ 3S.MIN. Such segmental co-exponents provide additional cues (if not the primary cues) for the intended meaning target. If the floating tone was simply to delete in these cases without triggering epenthesis, little information would be lost. For example, of the 177 Wamey stems of the (surface) shape [cv̀cə́], only 35 of these form minimal pairs with a [cv̀c] stem with which they would merge if their floating high were deleted, e.g. /i-yʊ̂r/ [ì-yʊ̂r] 'drool' vs. /i-yʊ̂rⒽ/ [ì-yʊ̂rə́] 'a tuft of unshaven hair'. Of these 35, many would still remain distinct due to different noun class prefixes (e.g. /æ-mbə̀l/ [æ̀-

mbə̀l] ‘Guinea worm’ vs. /wæ-mbə̀lⒽ/ [wæ̀-mbə̀lə́] ‘milk’), and/or part of speech differences (e.g. /wæ-pèl̰/ [wæ̀-pèl̰] ‘sword peas’ vs. /i-pèl̰Ⓗ/ [ì-pèl̰ə́] ‘to keep food scraps’).

In contrast, floating tones in intonational systems typically do not occur with segmental co-exponents. The consequence is that the functional load of floating tone in tonal vs. intonational systems in expressing linguistic meaning is quite different. Losing the floating tone in intonational systems would be far more ‘costly’, and to avoid this epenthesis may be employed. Relatedly, due to the tendency for floating tone to co-occur with segmental material in tonal systems but not in intonational systems, tone-driven epenthetic material in a tonal system would be more likely to be reinterpreted as part of the underlying representation. In other words, a surface form [ə́] would be more likely to be reinterpreted as /ə́/ in a tone language than in an intonational language.

Second, while less common than in intonational systems, it is certainly the case that floating tone may appear as the sole exponent of some meaning targets in tone languages. For example, both Ghomala’ and Gokana (previously mentioned) have an associative construction [N_1 Ⓣ N_2] used for possession and compounds, where the sole marking of association is a floating tone Ⓣ which does not co-occur with any segmental morphology. Even in such cases, however, there is a key difference. In intonational systems, floating tones are often positionally quite restricted, e.g. to stressed syllables or to prosodic domain edges, especially the right edge of large prosodic constituents like the intonational phrase. This restricts the ‘window’ within which the floating tone can search to find a host. In contrast, floating tone association in tonal languages tends to be more flexible and need not specifically target a stressed syllable or domain edge.

For example, the other Mbam-Nkam languages of Cameroon all have [N_1 Ⓣ N_2] associative constructions cognate with those in Ghomala’. Hyman & Tadadjeu (1976) show that in these languages whether the floating tone in such constructions will be ‘grounded’ to the right or to the left will depend on a complex set of factors. These include attaching in the direction which (i) has the greatest tonal effect, (ii) creates the more natural tonal contour, and (iii) complies with syllable or other boundaries. What this shows is that there are more potential targets of the floating tone in tonal languages than there are in intonational systems, and as such epenthesis is less likely to be required in order to host the floating tone than it would be in an intonational context.

6 Conclusion

We have argued that theories of tone/epenthesis interaction must be amended to include tone-driven epenthesis. While it was previously claimed that tone-driven epenthesis is unattested/impossible (Blumenfeld 2006, Gleim 2019), we have argued that the Wamey language provides the best case to date which falsifies this position. We demonstrated that in Wamey an epenthetic [ə] is inserted to host a high tone in two contexts. The first was to host a tone which would otherwise be left floating due to a restriction on rising tones in closed syllables, i.e. /cv̀cⒽ/ maps to [cv̀c**ə́**] due to a ban *[cv̌c]. The second was to host a tone which was introduced by word-level morphology but restricted from associating across a stem boundary, i.e. /(cv̀cv̀)cⒽ/ maps to [(cv̀cv̀)c**ə́**]. These patterns cannot be attributed to syllable phonotactics, which freely allow all consonants in coda position. We presented the evidence for tone-driven epenthesis focusing on the distribution of final [ə] in lexical stem structure and [ə]-alternating suffixes which pattern as underlyingly consonant-final. We showed that a simple OT analysis derives [ə]-epenthesis, utilising common markedness constraints (e.g. *FLOAT, *RISE, OCP(H), DEP(μ), *etc.*) together with constraints against associating tone across certain prosodic boundaries. In total, Wamey provides evidence for parallelism between tonal and intonational languages, given that intonation-driven epenthesis is well-established in the literature. This parallelism is predicted under a model where both types of prosodic systems make use of the same phonological substance and autosegmental architecture, and have the same functional pressures to cultivate segmental environments best suited for realizing pitch targets.

7 References

Akanlig-Pare, George & Michael Kenstowicz. 2002. Tone in Buli. Studies in African Linguistics 31(1/2). 55–96.

Akumbu, Pius W., Larry M. Hyman, & Roland Kießling. 2020. The segmental and tonal structure of verb inflection in Babanki. Phonological Data and Analysis 2(2). 1–33.

Archangeli, Diana & Pulleyblank, Douglas. 1994. *Grounded Phonology*. Cambridge MA: MIT Press.

Baković, Eric. 2007. A revised typology of opaque generalisations. *Phonology*. 217-259.

Bennett, Ryan. 2018. Recursive prosodic words in Kaqchikel (Mayan). *Glossa* 3(1): 67. http://dx.doi.org/10.5334/gjgl.550

Blumenfeld, Lev A. 2006. Constraints on phonological interactions. Stanford University dissertation.

Broselow, Ellen. 1982. On predicting the interaction of stress and epenthesis. Glossa 16: 115–132.

Cowell, Andrew & Alonzo Moss, Sr. 2008. The Arapaho language. Boulder: Boulder: University Press of Colorado.

de Lacy, Paul. 2003. Fixed ranking and the 'Too Many Solutions' problem. Unpublished conference handout presented at the CASTL Kick-off conference, CASTL.

de Lacy, Paul. 2006. Markedness: Reduction and preservation in phonology Vol. 112. Cambridge University Press.

de Lacy, Paul. 2007. The interaction of tone, sonority, and prosodic structure." The Cambridge Handbook of Phonology 281-307.

Downing, Laura J. & Maxwell Kadenge. 2020. Re-placing PStem in the prosodic hierarchy. *The Linguistic Review*, 37(3): 433-461. https://doi.org/10.1515/tlr-2020-2050

Eichholzer, Erika. 2010. Dictionnaire Ghomálá'-Français. http://www.lielatatomdjap.org/images/pdf/DICTIONNAIRE_GHOMALA.pdf

Frajzyngier, Zygmunt. 2003. Tone and vowel deletion, insertion, and syllable structure. Stress and Tone. The African Experience: Frankfurt African Studies Bulletin 15.

Frajzyngier, Zygmunt & Erin Shay. 2002. *A grammar of Hdi*. Berlin, New York: Mouton de Gruyter. DOI: https://doi.org/10.1515/9783110885798

Fromkin, Victoria A. 1978. Tone: A linguistic survey. New York: Academic Press.

Gleim, Daniel. 2019. A feeding Duke-of-York interaction of tone and epenthesis in Arapaho. Glossa 4(1). 97.1–27.

Grice, Martine, Rachid Ridouane & Timo B. Roettger. 2015. Tonal association in Tashlhiyt Berber: Evidence from polar questions and contrastive statements. *Phonology* 32(2). 241–266.

Grice, Martine, Michelina Savino, & Timo B. Roettger. 2018. Word final schwa is driven by intonation—The case of Bari Italian. *The Journal of the Acoustical Society of America* 143(4). 2474–2486.

Grice, Martine, Michelina Savino, & Timo B. Roettger. 2019. Tune-text negotiation: the effect of intonation on vowel duration. In *Proceedings of the 19th International Congress of Phonetic Sciences, Melbourne, Australia*. 562–566.

Guekguezian, Peter Ara. 2017. Prosodic Recursion and Syntactic Cyclicity Inside the Word. Doctoral dissertation, University of Southern California.

Güldemann, Tom. 2018. Historical linguistics and genealogical language classification in Africa. In Tom Güldemann (ed.), *African Languages and Linguistics*, 58-444. Berlin: Mouton De Gruyter.

Hall, Nancy. 2006. Cross-linguistic patterns of vowel intrusion. *Phonology* 23(3): 387–429.

Hall, Nancy. 2011. Vowel epenthesis. In Marc van Oostendorp, Colin J. Ewen, Elizabeth V. Hume, & Keren Rice (Eds.), *The Blackwell Companion to Phonology*, 1576–1596. Oxford: Wiley-Blackwell.

Hansson, Gunnar O. 2004. Tone and voicing agreement in Yabem. In B. Schmeiser, V. Chand, A. Kelleher & A. Rodriguez (eds.), *WCCFL 23 Proceedings*, Somerville, MA, Cascadilla Press, p. 318−331.

Harry, Otelemate. 2004. *Aspects of the tonal system of Kalaḅarị-Ịjọ*. Stanford, Calif.: CSLI.

Hellmuth, Sam. 2021. Text-tune alignment in Tunisian Arabic Yes-No questions. In Marisa Cruz, Sónia Frota, & Pedro Oliveira (Eds.), *Prosodic Variation (with)in Languages: Intonation, Phrasing and Segments* (Studies in Phonetics and Phonology). Sheffield: Equinox.

Hyman, Larry M. 1985. *A theory of phonological weight*. Dordrecht: Foris.
Hyman, Larry M. 2011a. Tone: Is it different? In John Goldsmith; Jason Riggle & Alan C. Yu (eds.), *The Handbook of Phonological Theory*, 197–239. Chichester: Wiley-Blackwell.
Hyman, Larry M. 2011b. Does Gokana really have no syllables? Or: what's so great about being universal? *Phonology*, 28: 55–85.
Hyman, Larry M., & Russell G. Schuh. 1974. Universals of tone rules: Evidence from West Africa. *Linguistic Inquiry* 5(1). 81–115.
Hyman, Larry M., & Maurice Tadadjeu. 1976. Floating Tones in Mbam-Nkam. In *Studies in Bantu Tonology*. (Southern California Occasional Papers in Linguistics, 3) ed. Larry M. Hyman, pp. 59-111. Los Angeles: The Department of Linguistics, University of Southern California.
Inkelas, Sharon. 2014. *The interplay of morphology and phonology*. Oxford: Oxford University Press.
Ito, Junko. 1989. A prosodic theory of epenthesis. *Natural Language & Linguistic Theory* 7(2). 217–259.
Ito, Junko & Armin Mester. 2021. Recursive prosody and the prosodic form of compounds. *Languages* 6: 65. https://doi.org/10.3390/languages6020065
Jenkins, Susan Goddard & JoLynn Eller Amdahl. 2007. A Survey of the Tenda Languages in SE Senegal (SIL Electronic Survey Report 2007-011 No. SIL Electronic Survey Report 2007-011). SIL. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.512.1014&rep=rep1&type=pdf
Jeong, Sunwoo & Cleo Condoravdi. 2018. Imperatives and intonation: The case of the down-stepped level terminal contour. In *Proceedings of the 35th West Coast Conference on Formal Linguistics*, ed. Wm. G. Bennett et al., 214–223.
Jurgec, Peter. 2011. Feature Spreading 2.0 A Unified Theory of Assimilation. PhD thesis, University of Tromsø.
Kager, René. 1999. *Optimality theory*. Cambridge: CUP.
Kiparsky, Paul. 2015. Stratal OT: A synopsis and FAQs. In, *Capturing phonological shades within and across languages 2.* 1-45.
Kubozono, Haruo. 2001. Epenthetic vowels and accent in Japanese: Facts and paradoxes. Issues in Japanese Phonology and Morphology 113–142.
Lovestrand, Joseph. 2012. The linguistic structure of Baraïn (Chadic). Graduate Institute of Applied Linguistics MA thesis. https://www.diu.edu/documents/theses/Lovestrand_Joseph-thesis.pdf
Marlo, Michael R., Leonard Chacha Mwita & Mary Paster. 2015. Problems in Kuria H tone assignment. *Natural Language & Linguistic Theory* 33:1, 251–265.
Martínez-Gil, Fernando. 1997. Word-final epenthesis in Galician. In Fernando Martínez-Gil & Alfonso Morales-Front (Eds.), Issues in the Phonology and Morphology of the Major Iberian Languages, 270–340. Washington, DC: Georgetown University Press.
Marvin, Tatjana. 2002. Topics in stress and the syntax of words. Doctoral dissertation, MIT.
McDonough, Joyce. 1996. Epenthesis in Navajo. Athabaskan Language Studies: Essays in Honor of Robert W. Young 235–257.
Merrill, John T. M. 2018. The Historical Origin of Consonant Mutation in the Atlantic Languages. PhD dissertation. UC Berkeley.
Moore-Cantwell, Claire. 2016. Contexts for epenthesis in Harmonic Serialism. Harmonic Grammar and Harmonic Serialism. Equinox, London.
Morley, Rebecca L. 2015. Deletion or epenthesis? On the falsifiability of phonological universals. *Lingua* 154: 1-26.
Newell, Heather, Máire Noonan, Glyne Piggott, & Lisa Travis (eds.). 2017. *The Structure of Words at the Interfaces*. Oxford: OUP.
Nissim, Gabriel M. 1981. *Le Bamileke-Ghomálá' (parler de Bandjoun, Cameroun)*. Vol. 45. Paris: Centre National de la Recherche Sciéntifique.
Pearce, Mary. 2013. *The Interaction of Tone with Voicing and Foot Structure: Evidence from Kera Phonetics and Phonology*. Stanford: CSLI Publications.
Piggott, Glynn L. 1995. Epenthesis and Syllable Weight. *Natural Language & Linguistic Theory* 13: 283-326.

Pike, Kenneth L. 1945. *The intonation of American English*. Ann Arbor: University of Michigan Press.
Pike, Kenneth L. 1948. *Tone Languages*. Ann Arbor: University of Michigan Press.
Poser, William. 1981. On the directionality of the tone-voice correlation, *Linguistic Inquiry* 12, 3: 483−488.
Prince, Alan, & Paul Smolensky. 2004 [1993]. *Optimality theory: Constraint interaction in generative grammar*, Rutgers University, Center for Cognitive Science Technical Report 2.
Roettger, Timo B. 2017. *Tonal Placement in Tashlhiyt: How an Intonation System Accommodates to Adverse Phonological Environments*. Berlin: Language Science Press.
Roettger, Timo B. & Martine Grice. 2019. The tune drives the text: Competing information channels of speech shape phonological systems. *Language Dynamics and Change* 9(2): 265–298.
Santos, Rosine Sachine. 1996. Le mey: Langue ouest-atlantique de Guinée. Université de la Sorbonne nouvelle, doctoral dissertation.
Sossoukpe, Jacques. 2017. Effet voisant du ton bas flottant sur les obstruantes en akebou. In F. Ahoua & B. Elugbe (eds.), *Typologie et documentation des langues en Afrique de l'Ouest*, 139−146. Paris: Harmattan.
Teo, Amos Benjamin. 2009. "Sumi tone: A phonological and phonetic description of a Tibeto-Burman language of Nagaland". Unpublished MA thesis. University of Melbourne.
van Oostendorp, Marc. 2007. Derived environment effects and consistency of exponence. In: Blaho, S., Bye, P., Krämer, M. (Eds.), Freedom of Analysis? Mouton de Gruyter, Berlin, pp. 123—148.
van Otterloo, Karen. 2011. The Kifuliiru language, volume 1: Phonology, tone, and morphological derivation. Dallas: SIL International.
Wee, Lian-Hee. 2019. *Phonological Tone*. Cambridge: Cambridge University Press.
Yip, Moira. 2002. *Tone*. Cambridge: Cambridge University Press.
Zhang, Jie. 2013. *The Effects of Duration and Sonority on Countour Tone Distribution: A Typological Survey and Formal Analysis*. Routledge.