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# TWO BIRDS WITH ONE STONE: THE AERODYNAMIC VOICING CONSTRAINT AND THE LANGUAGES OF BORNEO[1]

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**Abstract**

A hallmark of any good scientific theory is its ability to derive two or more superficially unconnected phenomena from a single unifying principle. A classic example is Newton's gravitation theory, in which Kepler's laws of motion for the planets orbiting the sun and Galileo's laws of motion for objects falling on the earth, both of which had previously been recognized as valid but unconnected statements about physical processes, were shown to reflect the same fundamental force (gravity). This paper draws attention to the identity of a basic phonological process that has taken divergent paths in the history of particular languages or language groups. In particular, it is argued that the historical development of true voiced aspirates [bp$^h$], [dt$^h$], [gk$^h$] in the Kelabit-Lun Dayeh languages of Borneo, and the replacement of word-final voiced stops by the homorganic nasals in a number of languages in Borneo are outcomes of the same phonetic limitation, namely the aerodynamic voicing constraint (AVC).

**Keywords:** languages of Borneo, sound change, phonetic principles, phonological typology
**ISO 639-3 codes:** kzi

## 1 Introduction

It probably is safe to say that virtually all adult speakers of English are familiar with the expression 'to kill two birds with one stone.' But what, exactly, does this saying mean? To most people I suspect it means to find some way to solve two problems, or to address two tasks through a single effort, as by dropping off a letter in a mailbox while on one's way to the supermarket.

In science killing two birds with one stone can be used to describe a single hypothesis that explains two (or more) superficially unrelated observations about the real world. The classic example in physics is perhaps the unification of Kepler's laws of motion for the orbits of the planets around the sun, and Galileo's laws of motion for bodies falling on the earth. Although it is perhaps an apocryphal tale, Galileo Galilei, one of the pivotal figures in the history of science reportedly experimented with dropping objects of various weights from the leaning tower of Pisa, and from his observations determined the first laws of motion for bodies falling on the Earth. At about the same time the German astronomer Johannes Kepler formulated his three laws of planetary motion, which described the orbits of the planets about the sun. Kepler's first two laws were published in 1609 and his third in 1619, while Galileo's laws were not made public until 1638, when he was 74 years old. For nearly half a century both sets of laws were considered valid scientific generalizations, but what is of interest in the present context is that they were generally seen as independent truths having no relationship to one another.

Then, in 1687 Isaac Newton published his own three laws of motion, and in so doing he showed that the formulations of Kepler and Galileo were special cases of a more general theoretical construct that he called

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[1] Apart from those cases that are explicitly credited to others, data on the languages of Borneo is from fieldnotes I collected in northern Sarawak during the period April to November, 1971. Reconstructions are those commonly used in the Austronesian field (Blust and Trussel, ongoing). I wish to thank two anonymous reviewers for comments that led to improvements in an earlier version of the manuscript. Any remaining shortcomings are mine alone.

'gravity'. Stated somewhat differently, Newton's advance on the work of his predecessors showed that both sets of superficially unrelated laws were the expected consequences of a single explanatory principle. In short, Newton's gravitation theory killed two birds with one stone, and in so doing it moved science, and physics in particular, a giant step forward.

Some readers might be asking 'What does this have to do with linguistics?' My answer is that it has everything to do with linguistics, since if linguistics is a science, as some of us believe to be true, it should be concerned with generalizations which show that language phenomena that initially may appear unconnected are in fact the expected outcome of a single underlying principle.

## 2 The Kelabit voiced aspirates

Borneo has long been a linguistic backwater, with over 100 languages and few descriptions of any length, depth or accuracy. This situation has now begun to change, in large part because of the work of two of my former students, Jason Lobel, who has worked with the languages of Sabah, and Alex Smith, who has worked with a wide sample of the languages of Sarawak and Kalimantan. The linguistic observations that concern me in this paper are two different types of sound change that are largely, but not completely, confined to the languages of Borneo. Most of the data is from my own fieldnotes on languages of northern Sarawak, collected in 1971, but one key witness is from the work of Jason Lobel in Sabah, and in addition to these Bornean cases I will also cite data from published accounts of the Batak languages of northern Sumatra. But let me begin with Borneo, an island that is particularly close to my heart. This is where we will meet the two metaphorical birds that I will shortly be taking aim at.

In my first publication when I was a beginning graduate student in 1969 I drew attention to a typological oddity in the Bario dialect of the Kelabit language of northern Sarawak. Most Austronesian languages in insular Southeast Asia have two series of stop phonemes, plain voiced and plain voiceless unaspirated stops. Kelabit has these as well, but in addition it has a third series that is commonly written by native speakers and others as *bp*, *dt* and *gk*. For reasons that I will explain shortly I prefer to write these stops as $b^h$, $d^h$, $g^h$, that is as bilabial, alveolar and velar voiced aspirates. This is shown in Figure 1.

***Figure 1****: The stop system of Bario Kelabit*

| | | | | |
|---|---|---|---|---|
| plain voiceless | p | t | k | ʔ |
| plain voiced | b | d | g | |
| voiced aspirates | $b^h$ | $d^h$ | $g^h$ | |

Phonetically, the stops in this third series begin voiced and end voiceless, with aspiration of the voiceless closure for some speakers, and affrication of varying degrees for the coronal member. This is illustrated in Figure 2, which also provides evidence that the plain voiced stops and voiced aspirates are phonemically distinct.

***Figure 2****: The phonetics and phonemics of the Kelabit voiced aspirates*

| | | |
|---|---|---|
| b : $b^h$ | d: $d^h$ | g : $g^h$ |
| abuh 'ashes'<br>[ʔábuh] | idan 'when?'<br>[ʔídan] | ugam 'mat'<br>[ʔúgam] |
| təb$^h$uh 'sugarcane'<br>[tə́bp$^h$uh] | id$^h$uŋ 'nose'<br>[ʔídt$^h$ʊŋ] ~<br>[ʔídʧ$^h$ʊŋ] | ug$^h$aʔ 'stop spinning, as a top'<br>[ʔúgk$^h$aʔ] |

To many listeners the medial segments in words like 'sugarcane', 'nose' or 'stop spinning' sound like consonant clusters, with a voiced stop followed immediately by its voiceless counterpart. This is indeed the way that native speakers tend to write them, as I have already stated. However, there are several problems with viewing these stops as consonant clusters, which I will discuss shortly.

Before addressing these problems, however, I should take a moment to say that I encountered these sounds immediately upon eliciting Kelabit data, as it is my habit to begin work on a new language by asking how to count, and the number 'one' in Bario Kelabit is *əd$^h$əh*. I also discovered soon thereafter that Peter Ladefoged had published a slender but important book, *Preliminaries to linguistic phonetics* in 1971, and in it he took pains to show that the so-called ‘voiced aspirates’ of languages like Hindi are not aspirated, but are what he called ‘murmured stops’ --- that is, voiced stops followed by breathy voice, and hence segments that are voiced throughout. Despite this dismissal, or perhaps because of it, he then went on to provide a very clear definition of how a true voiced aspirate would be produced. According to him (1971:9) it would be:

> “..... a sound in which the vocal cords were vibrating during the articulation and then came apart into the voiceless position during the release of the stricture. *Such a sound has not yet been observed in any language*.” (italics mine).

As should be clear, what Ladefoged described as a sound that “has not yet been observed in any language” is essentially what I had described for Kelabit two years earlier --- that is, a unit phoneme that begins voiced and ends voiceless, with the voiceless setting of the vocal cords sometimes carrying into the onset of the following vowel. There is no need to go into details about this controversy here, but while I was still a student I sent Ladefoged tapes of these sounds. He never replied, and when I encountered him a few years later he expressed the view that they must be consonant clusters, an opinion that for some reason he and his former student Ian Maddieson maintained through his last major publication, which states (1996:80) that “Clusters involving obstruents with mixed voicing in the same syllable are very rare in the world’s languages, but they occur in !Xū languages and in Kelabit (Blust 1974, 1993)”.

Despite the perfect match of the Kelabit voiced aspirates with Ladefoged’s own definition of what a voiced aspirate would be, then, Ladefoged and Maddieson (1996) continued to insist that these segments are consonant clusters. The Khoisan language !Xu may well have “obstruents of mixed voicing in the same syllable” to quote Ladefoged and Maddieson, but a consideration of basic structural features of the language shows that this is decidedly not the case for Kelabit.

First, consonant clusters do not occur within a morpheme in Kelabit, although derived clusters may occur across a morpheme boundary through a process of medial schwa syncope (deletion of schwa in the environment VC__CV) that is widespread in the Austronesian family, as shown in Table 1.

***Table 1****: Conditions for derived consonant clusters in Kelabit*

| | | |
|---|---|---|
| [mp] | | |
| /piŋur/ | [píŋʊr] | ‘echo’ |
| /tə-piŋur/ | [təpíŋʊr] | ‘echoing back and forth’ |
| /t<in>ə-piŋur/ | [sɪmpíŋʊr] | ‘was used to create echos’ |
| [mb] | | |
| /bakaŋ/ | [bákaŋ] | ‘space between spread legs’ |
| /tə-bakaŋ/ | [təbákaŋ] | ‘spread apart, of the legs’ |
| t<in>ə-bakaŋ/ | [sɪmbákaŋ] | ‘was spread apart, of the legs’ |
| [nt] | | |
| /taʔut/ | [táʔʊt] | ‘fear’ |
| /pə-taʔut/ | [pətáʔʊt] | ‘to frighten’ |
| /p<in>ə-taʔut/ | [pɪntáʔʊt] | ‘was frightened by someone’ |
| [nd] | | |
| /kədaluh/ | [kədáluh] | ‘quarrel’ |
| /k<in>ədaluh/ | [kɪndáluh | ‘was made the object of someone’s anger’ |
| [ŋk] | | |
| /pəkupat/ | [pəkúpat] | ‘turned contrariwise (as head at foot of bed)’ |
| /p<in>əkupat/ | [pɪŋkúpat] | ‘was turned contrariwise’ |
| [ŋg] | | |
| /pəgamuŋ/ | [pəgámʊŋ] | ‘tangled (as thread, hair, etc.) |
| /p<in>əgamuŋ/ | [pɪŋgámʊŋ] | ‘was tangled by someone’ |
| [nl] | | |
| /lakut/ | [lákʊt] | ‘bending, as tips of bamboos’ |
| /bəlakut/ | [bəlákʊt] | ‘to bend over, incline’ |
| /b<in>əlakut/ | [bɪnlákʊt | ‘was bent or pulled over by someone’ |
| [nr] | | |
| /riər/ | [ríjər] | ‘rolling, of a log’ |
| /bə-riər/ | [bəríjər] | ‘to roll a log’ |
| /b<in>ə-riər/ | [bɪndríjər] | ‘was rolled by someone (of a log)’ |

As can be seen from these examples, clusters of both homorganically prenasalized stops and of /n/ plus a liquid are possible across a morpheme boundary. However, nothing like this is ever found within a morpheme. If the stops that I have written as *b*, *d*, *g* with a raised *h* were consonant clusters they would be the only underlying consonant clusters in the language.

Second, the voiceless stops of Kelabit are unaspirated, and it would be unprecedented for them to acquire aspiration only when following a voiced stop. With the alveolar member of this series the aspiration is strong enough for some speakers to produce moderate affrication, as in [ʔídʧ$^{h}$ʊŋ] ‘nose’. This phonetic feature is carried further in the closely related Lun Dayeh, so that /d$^{h}$/ is normally pronounced as a cluster of [d] plus a voiceless palatal affricate, and since neither Kelabit nor LD has a voiceless palatal affricate the alveolar voiced aspirate cannot be a consonant cluster in either language.

Third, as seen in the phonetic transcriptions in Figure 2 and Table 1, high vowels are lowered or laxed in syllables that are closed by any consonant other than glottal stop or /h/. Since high vowels do not lower before a voiced aspirate, as in the words for ‘nose’, or ‘stop spinning, of a top’ what immediately follows cannot be a consonant cluster, at least not a consonant cluster in which the first member is a syllable coda.

Fourth, the voiced aspirates alternate with their plain voiced counterparts under suffixation, in two distinct ways. In the first type of alternation an underlying voiced aspirate surfaces as a plain voiced stop in suffixed forms. In the second type an underlying word-final plain voiced stop following a schwa surfaces as a voiced aspirate. These are shown as Parts 1 and 2 respectively in Table 2.

***Table 2**: Alternation of voiced aspirates and plain voiced stops*

| | | |
|---|---|---|
| Part 1 | | |
| /b$^h$/ ~ /b/ | | |
| /təb$^h$əŋ/ | [tə́bp$^h$əŋ] | ‘felling of large trees’ |
| /təb$^h$əŋ-ən/ | [təbə́ŋ:ən] | ‘fell it!’ (imper.) |
| /əb$^h$o/ | [ʔə́bp$^h$o:] | ‘act of soothing someone’s emotions’ |
| /əb$^h$o-ən/ | [bówən] | ‘soothe him/her’ (imper.) |
| /d$^h$/ ~ /d/ | | |
| /kəd$^h$a/ | [kə́dt$^h$a:] | ‘ability to withstand pain’ |
| /kəd$^h$a-an/ | [kədáan] | ‘suffering’ |
| /g$^h$/ ~ /g/ | | |
| /gəg$^h$əŋ/ | [gə́gk$^h$əŋ] | ‘numb with cold’ |
| /ŋ-gəg$^h$əŋ/ | [ŋə́gk$^h$əŋ] | ‘to make chilly’ |
| /gəg$^h$əŋ-ən/ | [gəgə́ŋ:ən | ‘make it cold!’ (imper.) |
| Part 2 | | |
| /b/ ~ [bp$^h$] | | |
| /kəkəb/ | [kə́k:əb] | ‘lid, cover’ |
| /kəkəb-ən/ | [kəkə́bp$^h$ən] | ‘cover it!’ (imper.) |
| /d/ ~ [dt$^h$] | | |
| /bəb$^h$əd/ | [bə́b$^h$əd] | ‘a bundle, as of firewood’ |
| /bəb$^h$əd-ən/ | [bəbə́dt$^h$ən] | ‘to be tied by winding around’ |
| /g/ ~ [gk$^h$] | | |
| /ələg/ | [ʔə́l:əg] | ‘cessation; divorce’ |
| /əm-ələg/ | [mə́l:əg] | ‘to cease; to divorce’ |
| /ələg-ən/ | [lə́gk$^h$ən] | ‘to cease (in questions of reason)’ |

It is important to take note of the context in which underlying voiced aspirates become the corresponding plain voiced stops and vice-versa. The important points to note are as follows. First, stress is penultimate on all lexical bases, and shifts one syllable to the right when a base is suffixed, so as to remain penultimate in the word. Second, a stressed schwa causes most immediately following consonants to geminate automatically (/r/, which varies freely between a tap and a trill, may be an exception).

The alternations in Part 1 are thus triggered by the loss of stress on a schwa that has moved from the penult to the antepenult as a result of suffixation, as in [tə́bp$^h$əŋ] and its suffixed form [təbə́ŋ:ən]. Note that if another consonant now follows a stressed schwa it geminates phonetically, as the velar nasal in [təbə́ŋ:ən].

The alternations in Part 2 on the other hand, are triggered by the shift of stress from an underlying penultimate vowel of any quality to an underlying schwa preceding a final voiced stop that is now placed in penultimate position as a result of suffixation. The result is that a voiced aspirate appears on the surface exactly where we would expect a surface geminate for any other consonant. Using only internal reconstruction, then, we are led to conclude that at least many of the Kelabit voiced aspirates probably arose from earlier plain voiced stops that were geminated after a stressed schwa.

This works for the majority of cases, although not all since, as already seen, the voiced aspirates also occur after /i/ and /u/ (but never after the low vowel /a/). In some cases, the appearance of voiced aspirates after vowels other than schwa can be explained as the product of earlier heterorganic consonant clusters that produced geminates when medial clusters were otherwise eliminated without a trace, as in the historically reduplicated monosyllables seen in Table 3.

***Table 3**: Historical treatment of medial consonant clusters involving stops:*

| Earlier | Bario Kelabit | |
|---|---|---|
| voiced stops | | |
| *bakbak | bəb$^h$ak | 'to peel off (bark), torn (shirt)' |
| *bəjbəj | bəb$^h$əd | 'to tie by wrapping around' |
| *bunbun | bub$^h$un | 'a heap, pile' |
| *butbut | bub$^h$ut | 'to pluck feathers' |
| *dakdak | dəd$^h$ak | 'to slam down with force' |
| *dəmdəm | dəd$^h$əm | 'dark, darkness' |
| voiceless stops | | |
| *kəbkəb | kəkəb | 'lid, cover' |
| *kəŋkəŋ | kəkəŋ | 'to shrink, as clothing' |
| *pagpag | pəpag | 'to slap hard' |
| *pədpəd | pəpəd | 'to come to an end' |
| *puqpuq | pupuʔ | 'to hit, strike' |
| *tuktuk | tutuk | 'to knock, pound, beat' |

While most of the voiced aspirated that appear in this environment follow a schwa in any case, those in *bub$^h$un* and *bub$^h$ut* do not, suggesting that the Kelabit voiced aspirates reflect earlier geminates from two distinct sources, namely from voiced stops after a stressed schwa, and from medial consonant clusters in historically reduplicated monosyllables that underwent total assimilation.

A small number of other forms contain a voiced aspirate following a high vowel in a non-reduplicated base, and for these there is as yet no explanation. In addition, a plain voiced stop was recorded in two forms following a penultimate, hence stressed, schwa (in both cases a /b/). These presumably are loans, although a source is still unknown. For a full discussion of the distributional properties of these consonants, cf. Blust (2006:324-330).

While the preceding conclusion follows from structural considerations internal to Kelabit phonology, it is also supported by comparative evidence, since wherever etymologies are available they show that the voiced aspirates of Kelabit have developed from single plain voiced stops, as seen in Table 4, Part A., and that when they have changed they have become unit phonemes, as in Part B.

***Table 4****: Comparative evidence for a unitary source of the Kelabit voiced aspirates*

| Part A<br>Selected cognates of Kelabit forms that contain a voiced aspirate: | | Part B<br>Lenitions in other Kelabit dialects | | | |
|---|---|---|---|---|---|
| PAN *tebuS ‘sugarcane’ | | *$b^h$ | *$d^h$ | *$g^h$ | dialect |
| <u>Taiwan</u> | | | | | |
| Kavalan | təbus | p | s | k | (Pa’ Dalih) |
| Paiwan | tjəvus | f | s | k | (Long Napir) |
| <u>Philippines</u> | | p | c | k? | (Long Terawan Tring) |
| Tagalog | tubó | p | t | k? | (Pa’ Mada) |
| Yakan | təbbu | | | | |
| <u>Borneo</u> | | | | | |
| Kelabit | tə$b^h$uh | | | | |
| Bintulu | təɓəw | | | | |
| <u>Malay peninsula</u> | | | | | |
| Malay | təbu | | | | |
| <u>Micronesia</u> | | | | | |
| Chamorro | tupu | | | | |
| <u>Eastern Indonesia</u> | | | | | |
| Tetun | tohu | | | | |
| Windesi | tobu | | | | |
| <u>Pacific</u> | | | | | |
| Wuvulu | tofu | | | | |
| Fijian | tovu | | | | |

Setting these details aside as peripheral to the main discussion, the central question to ask is why earlier voiced geminates would have evolved into true voiced aspirates—that is, single, phonetically long stops that begin voiced and end voiceless. This is where the stone in our story comes in, but before throwing it we need to chase down another bird.

## 3 Final devoicing and its kin

Linguists have long known that voiced stops make conflicting articulatory demands, requiring airflow to produce voice, but obstruction of airflow to produce a stop, placing certain limitations on their distributional privileges. I like to call this ‘the voiced coda quandary’, or VCQ. So, what does this have to do with the languages of Borneo?

PAN had four voiced stops, conventionally written *b, *d, *j and *g, where *j apparently was a palatalized voiced velar stop [$g^j$]. Although *j could not occur as a syllable onset, all four of these stops occurred as syllable codas. In many languages these voiced stops remain in coda position, but in others they have been altered. Where they have been replaced it is usually by final devoicing, a sound change or synchronic phonological process known to have very high cross-linguistic frequency. However, this is not always the case. Adelaar’s (1981) reconstruction of Proto-Batak, the immediate ancestor of the Batak languages of northern Sumatra, for example, shows that Karo Batak replaced earlier voiced stop codas with the corresponding nasals, as seen in Table 5 (PB = Proto-Batak, KB = Karo Batak, TB = Toba Batak, SI = Simalungan Batak; N = nasalization, D = devoicing, NC = no change).

***Table 5**: Voiced stop coda asalization in Karo Batak of northern Sumatra*

| | | | |
|---|---|---|---|
| PB | *abab 'ashes' | *alud 'to massage' | *dələg 'mountain' |
| KB | abam (N) | alun (N) | dələŋ (N) |
| TB | abap (D) | alut (D) | dolok (D) |
| SI | abab (NC) | alud (NC) | dolog (NC) |
| | | | |
| PB | *saŋkəb 'lid of pot' | *kaləd 'swollen' | *lanəg 'housefly' |
| KB | saŋkəm (N) | kalən (N) | lanəŋ (N) |
| TB | saŋkop (D) | halot (D) | lanok (D) |
| SI | saŋkəb (NC) | ----- | lanog (NC) |
| | | | |
| PB | *tərəb 'mob' | *baləg 'border' | *pusəg 'navel' |
| KB | tərəm (N) | baləŋ (N) | pusuŋ (N) |
| TB | torop (D) | balok (D) | pusok (D) |
| SI | ----- | alog (NC) | pusog (NC) |

Because it will help to shed light on the complementarity of voiced coda nasalization (VCN) and final devoicing, the internal relationships of the Batak languages, as determined by Adelaar (1981) are shown in Figure 3.

***Figure 3**: A Batak family tree*

| Northern Batak (NB) | Southern Batak (SB) |
|---|---|
| 1. Alas | 4. Toba |
| 2. Karo | 5. Angkola-Mandailing |
| 3. Dairi-Pakpak | 6. Simalungun (SI) |

Proto-Batak codas included voiceless stops, voiced stops and nasals. SB apart from Simalungun merged voiced stop codas with voiceless stops, and NB merged them with nasals, strongly suggesting that these were alternative strategies for solving one and the same problem.

Although Karo Batak provides the only known evidence of this type of sound change in the whole of Sumatra, a similar nasalization of voiced stop codas arose through historical changes that apparently were independent in at least three separate areas of Borneo. In the first of these, which affected Kalabakan Murut of eastern Sabah as recorded by Jason Lobel, the change produced both phonological restructuring (where a base could not be suffixed), as shown Table 6, Part 1, and voiced stop/nasal alternations before a suffix, as seen in Table 6, Part 2 (PM = Proto-Murutic).

***Table 6****: Voiced coda nasalization in Kalabakan Murut of southeast Sabah*

Part 1

| PM | KM | |
|---|---|---|
| *kusob | kusom | 'betel nut' |
| *liab | ŋa-liam | 'to winnow' |
| *uab | aŋ-uam | 'to yawn. |
| *atud | atun | 'knee' |
| *laid | leen | 'old (objects)' |
| *pusod | puson | 'navel' |
| *tukad | tukan | 'ladder' |
| *apug | apuŋ | 'lime (for betel chew)' |
| *iwog | iwoŋ | 'saliva' |
| *liog | lioŋ | 'neck' |

Part 2

PM *sərəb 'burn'
KM no-nolom 'burned' (actor voice past)
KM solob-oʔ 'to burn (object voice imperative)

PM *takub 'catch'
KM a-nakum (actor voice, non-past)
KM takub-on (object voice, non-past)

PM *bilad 'unroll mat'
KM a-milan (actor voice, non-past)
KM bilar-on (object voice, non-past)

PM *takod 'climb tree'
KM a-nakon (actor voice, non-past)
KM tokor-on (object voice, non-past)

PM *ipag 'call'
KM aŋ-ipaŋ 'to call' (actor voice non-past)
KM ipah-in 'is being called' (locative voice.non-past)

PM *sikag 'push'
KM a-nikaŋ 'to push' (actor voice non-past)
KM sikah-i 'push it!' (locative voice imperative)

Note that in the object voice a historical voiced labial stop is retained in the synchronic phonology, since under suffixation it is a syllable onset, but in the actor voice, which is formed by prefixation together with homorganic nasal substitution it is nasalized because it remained a coda. As a result of other sound changes the original coronal and velar voiced stop codas underwent lenition to *-r-* and *-h-* respectively in the object voice, where they were intervocalic, but underwent voiced coda nasalization in the actor voice, where they remained in final position.

The second Bornean example is from Berawan, a language that is both genetically and geographically distant from Kalabakan Murut. Berawan is a relatively small language with dialects spoken in four longhouses on the Tutoh and Tinjar branches of the Baram river in northern Sarawak. It belongs to the Berawan-Lower Baram branch of the North Sarawak subgroup of Austronesian languages, which has the structure seen in Figure 4.

***Figure 4:*** *Structure of the Berawan-Lower Baram subgroup*

1. BERAWAN (Long Terawan, Batu Belah, Long Teru, Long Jegan)
2. LOWER BARAM (Tutong, Kiput, Lemeting, Belait, Narum, Lelak, Dali', Miri)

The language/dialect distinction within Berawan remains unsettled: Long Terawan probably is a distinct language, but it is unclear whether the other three communities represent a single language or more than one (despite high cognate percentages in basic vocabulary they are all phonologically highly innovative, and this has produced sharp phonetic divergence over what may have been relatively short separation times). In any case, all Berawan communities show nasalization of earlier voiced stop codas, as seen in Table 7 (PBLB = Proto-Berawan-Lower Baram; data for Long Teru and reflexes of *-g in all languages are too limited to permit inclusion).

***Table** 7: Reflexes of voiced stop codas in Berawan-Lower Baram languages*

| | | |
|---|---|---|
| PBLB | *sab 'smoke' | *quləd 'maggot' |
| Long Terawan | cam (N) | ulən (N) |
| Batu Belah | cam (N) | ulan (N) |
| Long Jegan | cam (N) | olən (N) |
| Kiput | saap 'fire' (D) | ulət (D) |
| Narum | saap (D) | ulat (D) |
| Miri | sap (D) | ulat (D) |
| | | |
| PBLB | *likud 'back' | *tumid 'heel' |
| Long Terawan | likon (N) | tumin (N) |
| Batu Belah | likoŋ (N) | tumeŋ (N) |
| Long Jegan | lækauñ$^w$ (N) | toməɲ (N) |
| Kiput | cut (D) | tumet (D) |
| Narum | ihaut (D) | tumait (D) |
| Miri | lihud (NC) | tumait (D) |

It is noteworthy that, like Northern Batak versus Southern Batak in Sumatra, Proto-Berawan nasalized voiced stop codas, while Proto-Lower Baram, the immediate ancestor of its sister group, devoiced them, reflecting a parallel pattern in which final devoicing and voiced stop nasalization appear to be alternative strategies chosen by closely related languages to solve the same problem.

The third Bornean example is from Kayan-Murik. Kayan is spoken throughout central Borneo in both Central Kalimantan (Indonesian Borneo) and in Sarawak (Malaysian Borneo), while Murik is a distinct, but closely related language in Sarawak. Although they are spoken in Borneo, these languages are geographically separated from Kalabakan Murut, and are genetically and typologically quite different from it, since Kalabakan Murut has preserved much of the Philippine-type morphosyntax that it inherited from PAN and PMP, while Kayan and Murik show highly restructured systems of verbal morphology with fewer suffixing possibilities. Kayan and Murik are also very distinct from the Berawan languages of northern Sarawak, and had little known contact with them before the modern era, as the Kayan were greatly feared as aggressive headhunters.

Data from three Kayan dialects (Uma Juman, Uma Bawang and Long Atip), and one Murik dialect (Long Semiang) are considered here in relation to Proto-Kayan-Murik (PKM). In both Kayan and Murik reflexes of *-g are rare, but reflexes of *b and *d show a clear avoidance of voiced stop codas, as shown in Table 8 (PKM = Proto-Kayan-Murik, UJ = Uma Juman dialect of Kayan, UB = Uma Bawang dialect of Kayan, LgA = Long Atip dialect of Kayan, L = lenition, N = nasalization, D = devoicing):

***Table 8**: Reflexes of voiced stop codas in Kayan dialects and Murik*

| **PKM** | ***kələb 'tortoise'** | ***tandab 'dive'** | ***huab 'yawn'** |
|---|---|---|---|
| UJ | kələv (L) | tadav (L) | uhav (L) |
| UB | kələm (N) | ----- | m-uham (N) |
| LgA | kələm (N) | nadam (N) | huam (N) |
| Murik | kələp (D) | ----- | t-uap (D) |
| **PKM** | ***anud 'adrift'** | ***atəd 'convey'** | ***uləd 'maggot'** |
| UJ | anur (L) | atər (L) | ulər (L) |
| UB | anun (N) | ----- | ulən (N) |
| LgA | anun (N) | atən (N) | ulən (N) |
| Murik | anun (N) | atən (N) | ulən (N) |

What is especially noteworthy about the historical treatment of final voiced stops in Kayan-Murik is that these have been altered through three different avoidance strategies: conversion to a fricative or rhotic in Uma Juman, to a nasal in Uma Bawang and Long Atip, and to a voiceless stop (with bilabials) or a nasal (with alveolars) in Murik. Given this diversity, and the limited comparative work done so far on Kayanic languages (Blust 1974b, 1977, 2002, Smith 2017), at least minimal documentation should be given for these developments. In part because this material is based on fieldnotes there are some gaps in attestation. Note, however, that the material in Rousseau (1974) and Southwell (1980) agrees with the Uma Bawang and Long Atip dialects in showing nasalization of final voiced stops, while that in Barth (1910) agrees with Uma Juman in showing *-b > *v* and *-d > *r*:

The treatment of voiced stop codas in Kayan-Murik is complex, and points to parallel historical developments within Kayan itself, and between Kayan and Murik, hence potentially to as many as three independent developments within this group of closely-related languages.

Murik data is limited, but is consistent with a hypothesis that *-b devoiced, and *-d nasalized, a development that appears to be unique, but which again drives home the point that final devoicing and voiced coda nasalization are alternative strategies for resolving the same conflict in insular Southeast Asia. In the Batak languages these strategies are distributed across different languages --- VCN in Northern Batak and final devoicing in Southern Batak apart from Simalungun ---, but in Murik they appear to be distributed across different places of articulation in the same language, in effect using a split strategy to achieve the same effect. Moreover, where Murik has devoiced *-b Uma Bawang and Long Atip have nasalized it, again pointing to complementary strategies in closely-related languages for solving the same problem.

Given these striking differences of detail, this set of data suggests at least two historically independent innovations that were motivated by the need to resolve the VCQ, one in Kayan, and another in Murik. If we felt constrained to consider only final devoicing and voiced stop nasalization as alternative strategies available to speakers we would perhaps stop here, but the data from the Uma Juman dialect of Kayan suggest that the replacement of voiced stop codas by corresponding continuants may be a third avoidance strategy. While the lenition of voiced stops to fricatives or rhotics is common in intervocalic position across the world's languages, it is far less common word-finally, particularly for a bilabial stop. Kayan dialects show lenition of *b and *d in both intervocalic and final positions, and while the former is best treated as a garden variety assimilation of stops to the continuant features of adjacent vowels, the latter cannot be explained in the same way. Although it is somewhat concealed, then, by mimicking the change in intervocalic position, the lenition of *b and *d word-finally in Kayan may reveal another path for escaping the VCQ.

## 4 Data and theory

We have now seen the two birds that are the topic of this paper, namely the appearance of a typologically rare series of phonemic voiced aspirates in Kelabit-Lun Dayeh dialects, and the occurrence of a cross-linguistically rare alternative, or set of alternatives, to final devoicing in Karo Batak of northern Sumatra, and various languages of Borneo. What do these sound changes or synchronic phonological processes, have in common? At first, one might be inclined to say 'Nothing', but that would be the wrong answer. John Ohala (1997:92) describes the relationship between voicing and stops as follows:

"In order for voicing to occur there are two basic requirements: first the vocal cords must have the appropriate degree of tension and the appropriate degree of adduction and second, there must be air flowing through the vocal cords. During stops, even if the vocal cords are properly configured, the maintenance faces an inherent obstacle. The air flowing through the vocal cords accumulates in the oral cavity and as a consequence the oral air pressure P *oral,* eventually approaches or reaches the same level as the subglottal pressure P *sub-glot.* When the airflow falls below a certain level (estimated at 1 to 2 cm H2O), voicing will cease (Catford 1977:29)."

Ohala (1983, 1997) calls this relationship 'the aerodynamic voicing constraint', and although he may have been the first to name it, he points out that its function in language has been recognized at least since the University of Paris doctoral dissertation of the French phonetician Paul Passy in 1890. Where voiced stops can be released into a sonorant the conflict is reduced, but where they are codas or geminates it has triggered adjustments in many of the world's languages. The best known of these adjustments undoubtedly is final devoicing. In final devoicing the conflict inherent in voiced stops is resolved by relinquishing voicing but maintaining the stop. However, a moment's reflection will show that in principle it should be possible to resolve this conflict in other ways, as by relinquishing the stop but maintaining voicing and so converting voiced stop codas to the corresponding nasals or fricatives. Other speaker strategies are also possible, as releasing the closure before a voiced stop coda loses its voicing, or lengthening vowels in syllables closed by a voiced stop, but these will not be pursued further here.

In 2008, following a privately circulated paper written in 2001 that had already begun to have an influence in its unofficial form, Donca Steriade published an article in which she claimed that of all possible solutions to the VCQ the only solution chosen in natural languages is final devoicing, a claim that has been repeatedly cited with approval in the phonological literature until quite recently, as seen in the following.

> "The range of segmental repairs predicted by the theory is far greater than the attested repairs: *only devoicing is attested as a response to *[+voice]/Coda.*" (Blumenfeld 2006:21)

> "All repairs can be used in other circumstances (at least nasalization, lenition, deletion and epenthesis are well-attested processes in natural language phonology), *but they are never employed to repair *[+voice]/__] word*." (Hermans and van Ostendorp 2007:3)

> "Many languages disfavor coda voiced stops, but the number of ways in which languages resolve coda voiced stops is limited: i.e. *languages alter voiced stops by devoicing but not by any other phonological means*." (Kawahara and Garvey 2010:1)

> Merrill notes an apparent (but ultimately spurious) violation of the P-map in the Senegalese language Noon, in which nasal codas alternate with voiced stop onsets, commenting "However, *the only otherwise attested repair to this marked structure is devoicing*." (Merrill 2015:1)

Taking this as fact, Steriade then argued that the putatively exclusive role of final devoicing in solving the VCQ is due to a principle she called 'the P-map'. According to Steriade the P-map, which was intended as an adjunct to Optimality Theory, favors the minimization of perceptual differences. In the case of final devoicing this means that a voicing difference in stops is perceptually less salient than a manner difference in consonants made at the same point of articulation. In other words, a change such as *b* to *p* in coda position is less disruptive to the listener's perception of the speech signal than a change from *b* to *m*, or other possible solutions to the VCQ. There is some experimental work that has supported this claim (particularly that of Kawahara and Garvey 2010), so my point here is not to disagree with the P-map as such, but rather to disagree with the widely accepted claim that final devoicing is the only solution to the VCQ ever chosen in natural languages, since that has already been shown to be false.

This brings us back to our two birds and the search for a stone that could kill them both. As John Ohala has stressed repeatedly, the aerodynamic voicing constraint (AVC) presents difficulties for voiced stops under certain conditions, since these segments embody an inherent conflict of articulatory requirements that is less serious in some environments and more serious in others. It has been known for nearly a century that voiceless stops occur much more commonly than voiced stops as geminates, but for many years this observation had no explanation. However, as Ohala (1997:1) makes clear, the AVC tells us why. Some languages do manage to maintain voiced geminates, which, to quote Ohala, "can have well over 100 msec of voicing", but to do so requires active expansion of the oral area to permit continuing airflow, and this is achieved "by lowering the larynx, lowering the tongue, elevating the already closed soft palate a bit more, and expanding the pharyngeal walls."

If voiced stops require airflow and obstruction of airflow at the same time, it is clear that this conflict will be ameliorated if the stop is shorter, and exacerbated if it is longer. In most languages geminates have approximately twice the duration of their singleton counterparts, making geminated voiced stops an especially unstable configuration. Many languages solve this problem by reducing the duration of the geminate, converting it to a singleton stop. Proto-North Sarawak, the immediate ancestor of the Kelabit-Lun Dayeh dialects which still have true voiced aspirates, and of other languages which show the past presence of these segments in their distinctive reflexes (Blust 1969:88, 2006:321), solved the problem in another way, namely by terminal devoicing of earlier voiced stop geminates. As seen already, allophonic gemination is part of the synchronic phonology of Bario Kelabit. The voiced aspirates are longer than the corresponding plain voiced stops, and so are similar to other consonants in geminating environments, the only difference being that they show terminal devoicing. In other words, rather than sacrifice duration to maintain full voicing of the stop, PNS sacrificed full voicing of the stop to maintain duration.

That is one bird down. Now, how about the other? As also noted earlier, final devoicing is one of the commonest types of sound change, a conditioned change that has left a synchronic residue in many languages, including paradigm cases such as German. Why is this such a common type of change? By now the reason should be obvious: the voicing of stops in coda position is no less difficult than the maintenance of voicing throughout a geminated voiced stop. Again, the AVC tells us that something must be done to repair the situation, and the most common way to do this is to sacrifice voicing while maintaining the stop, changing voiced stops to voiceless stops. However, at least some of the cases I have cited in this paper have chosen a different solution, namely to sacrifice the stop while maintaining voicing, thereby changing final *-b/d/g to -m/n/ŋ. Despite their superficial differences, then, it is clear that the typologically rare voiced aspirates of Kelabit-Lun Dayeh dialects and the almost equally rare nasalization of voiced stop codas in various languages of western Indonesia are consequences of the same underlying principle, the AVC. We have found our stone, and it has served us well in showing that surface differences may conceal an underlying unity, a unity that is the goal of all scientific endeavors, whether in linguistics or other branches of knowledge.

## 5 Why Austronesian?

One major problem remains**.** Since no plausible counterexample to the P-map has previously been proposed, a question that is sure to arise is why there are as many as four (and perhaps more) historically independent examples of VCN in Austronesian (AN) languages: why AN, and more precisely, why AN languages that are found in a fairly confined geographical area in the western part of insular Southeast Asia?

The first answer likely to be suggested by outsiders is that voiced stops in AN languages have some phonetic property that predisposes them to nasalization when they appear as codas. This is the proposal of Blevins (2007:110), who assumes on the basis of what she calls ‘typology’ that a voiced stop coda could not “turn into a nasal.” Instead, *-b/d/g must have been phonetically prenasalized, as with the Senegalese language Noon reported by Merrill (2015), where earlier clusters *mb, *nd, *ŋg split into obstruent onsets and nasal codas which appear to violate the P-map, but actually do not.

Let me be absolutely clear about this: no Austronesian comparativist has ever described voiced stop codas as anything but canonical voiced stops (Brandstetter 1916:223-351, Dempwolff 1934-1938, Dyen 1953, Mills 1975, Nothofer 1975, Dahl 1976, Tsuchida 1976, Zorc 1977, Sneddon 1978, 1984, Ross 1992, Li 2004, Wolff 2010, Blust 2013, Lobel 2013, 2016, Smith 2017, Blust and Trussel ongoing), and no description of any AN language of insular Southeast Asia recognizes prenasalized codas of any kind In summary, the peculiar limitation to date of legitimate cases of VCN to AN languages cannot be explained on phonetic grounds.

There probably is more than one reason that all known violations of the P-map are found in a single language family, but one prominent and probably underappreciated reason is the rarity of proto-languages reconstructed with voiced stop codas. Of 49 language families for which I have obtained reliable information, as few as four, and no more than seven, or only 8% to 14% allow plain voiced stop codas. The relevant proto-languages are shown in Table 9, and the full set of proto-languages from which these are drawn is given in Appendix 1.

***Table 9**: Proto-languages reportedly reconstructed with voiced stop codas*

| No. | Proto-language | -C? | -vd. stop? |
|---|---|---|---|
| 01. | Proto-Austronesian | yes | yes |
| 02. | Proto-Indo-European | yes | yes? |
| 03. | Proto-Mayan | yes | yes? |
| 04. | Proto-Munda | yes | yes? |
| 05. | Proto-Nilotic | yes | yes |
| 06. | Proto-Semitic | yes | yes |
| 07. | Proto-Turkic | yes | yes |

In each of the three cases with a question mark there was stated disagreement among specialists about whether the proto-language in question had plain voiced stops in coda position or not. Of 49 language families for which information could be obtained, then, only Proto-Austronesian, Proto-Nilotic, Proto-Semitic and Proto-Turkic appear to have universally-accepted voiced stop codas.

Put simply, what this means is that unless voiced stop codas develop later, most language families lack the preconditions for testing how common it is to find alternatives to final devoicing. It is not uncommon for linguists to think that language families like Indo-European, which have been explored through the comparative method for over two centuries, have no more secrets to yield, but many of the modern languages remain poorly described (in the Indo-European case this is especially true of the Indo-Iranian group), and the dialect picture naturally offers even wider prospects for discovering sound changes that were previously unnoticed.

A second reason why the only known cases of VCN recorded to date are confined to AN is the sheer size of the family, comprising over 18% of the world's languages (Simons and Fettig 2018). When dialects are included the number of testable data points becomes truly staggering. Given this enormous database the likelihood of rare sound changes in at least a few of them is considerably higher than for small collections of related languages.

The number of AN languages may well play a part in their providing the only known cases of VCN as an alternative to final devoicing, but this does not account for the geographical skewing of this phenomenon. About 460 of the 1,200+ AN languages belong to the Oceanic subgroup, and about 90% of these have lost final consonants, while most of those that retain them have added echo vowels. A similar situation holds for most of the roughly 100 languages on the island of Sulawesi in Indonesia (Sneddon 1993), and for many of the 150-200 languages of eastern Indonesia. Together this goes some way toward explaining the geographical skewing of Austronesian languages that show VCN, although it still leaves the Formosan and Philippine languages with no known cases of VCN (and few of final devoicing).

A third reason for the genetic exclusiveness of VCN so far is that, apart from Indo-European, probably no language family is better studied from a comparative standpoint than Austronesian. Scholarship of real scientific value began as early as the 1860s with the work of H.N. van der Tuuk (Blust 2013:512ff), and reached a level of considerable sophistication with the work of Otto Dempwolff in the 1920s and 30s. At present, so far as we have been able to determine through active contact with compilers of comparative dictionaries in other language families, Blust and Trussel (ongoing) is the largest and most detailed comparative dictionary for any language family, including Indo-European.

To conclude by appealing once again to the avian metaphor with which I began, the AVC has allowed me not only to kill two birds with one stone, but each of these 'birds' has turned out to be a *rara avis*, to use an apt Latin expression. Both the presence of true voiced aspirates in a language and the replacement of voiced stop codas by corresponding nasals follow straightforwardly from a widely accepted phonetic principle, yet there has been a remarkable resistance among both phoneticians and phonologists to accepting the reality of these phenomena, no doubt because of their rarity. Why haven't more of the world's languages solved the problem of voiced stop geminates by terminal devoicing rather than reduction in length? Why haven't more of the world's languages nasalized voiced stop codas as a solution to the VCQ? I think the answer to each of these questions must be that linguists simply haven't looked hard enough yet at what is left of the world's rapidly diminishing linguistic resources to find other examples that may well be there waiting to be discovered. But until then these well-established empirical expressions of a well-established phonetic principle must stand alone, and at least for the time being it is literally 'Austronesian against the world'.

## Appendix 1: Proto-Languages and Final Voiced Obstruents[2]

| No. | Proto-language | -C? | -vd. stop? |
|---|---|---|---|
| 01. | Proto-Austronesian | yes | yes |
| 02. | Proto-Indo-European | yes | yes? |
| 03. | Proto-Mayan | yes | yes? |
| 04. | Proto-Munda | yes | yes? |
| 05. | Proto-Nilotic | yes | yes |
| 06. | Proto-Semitic | yes | yes |
| 07. | Proto-Turkic | yes | yes |
| 08. | Proto-Ainu | yes | no |
| 09. | Proto-Algonquian | no | no |
| 10. | Proto-Asmat-Kamoro | yes | no |
| 11. | Proto-Athabaskan | yes | no |
| 12. | Proto-Araucanian | yes | no |
| 13. | Proto-Arawakan | no | no |
| 14. | Proto-Awyu-Dumut | yes | no |
| 15. | Proto-Bantu | no | no |
| 16. | Proto-Caddoan | yes | no |
| 17. | Proto-Carib | no | no |
| 18. | Proto-Chadic | yes | no |
| 19. | Proto-Chibchan | no | no |
| 20. | Proto-Chukchi-Kamchatkan | yes | no |
| 21. | Proto-Chumash | yes | no |
| 22. | Proto-Dravidian | yes | no |
| 23. | Proto-Engan | no | no |
| 24. | Proto-Eskimo(-Aleut) | yes | no |
| 25. | Proto-Hmong-Mien | yes | no |
| 26. | Proto-Iroquoian | yes | no |
| 27. | Proto-Japonic | yes[3] | no |
| 28. | Proto-Keresan | yes | no |
| 29. | Proto-Khoe-Kwadi | no | no |
| 30. | Proto-Koreanic | yes | no |
| 31. | Proto- Kx'a (Ju + =Amkoe) | no | no |
| 32. | Proto-Mongolian | yes | no |
| 33. | Proto-Mon-Khmer | yes | no |
| 34. | Proto-Muskogean | yes | no |
| 35. | Proto-Otomanguean | no | no |
| 36. | Proto-Pama-Nyungan | yes | no |
| 37. | Proto-Quechuan | yes | no |
| 38. | Proto-Salishan | yes | no |
| 39. | Proto-Siouan | no | no |
| 40. | Proto-Tai-Kadai | yes | no |
| 41. | Proto-Tibeto-Burman | yes | no |
| 42. | Proto-Tucanoan | yes[4] | no |
| 43. | Proto-Tungusic | yes | no |
| 44. | Proto-Tupian | yes | no |
| 45. | Proto- Tuu (!Ui + Taa) | no | no |
| 46. | Proto-Uralic | yes | no |
| 47. | Proto-Uto-Aztecan | yes | no |
| 48. | Proto-West Caucasian | no | no |
| 49. | Proto-Yuman | yes | no |

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[2] - C = word-final consonant, -vd. stop = word-final voiced stop.

[3] Only *-N, *-m and *-y.

[4] Only –h and -ʔ.

**Note**: Information regarding final consonants in proto-languages is from the following sources (personal communications indicated by m/d/y): Proto-Indo-European (Brent Vine 6/11/13), Proto-Mayan (Kaufman 2003), Proto-Munda (Patricia Donegan 5/30/13, Gregory Anderson 5/31/13), Proto-Nilotic (Gerrit Dimmendaal 6/11/13), Proto-Semitic (Weninger 2011), Proto-Turkic (Stefan Georg 6/4/13), Proto-Ainu (Alexander Vovin 5/31/13), Proto-Algonquian (Ives Goddard 5/30/13), Proto-Araucanian (Willem Adelaar 6/1/13), Proto-Arawakan (Noble 1965), Proto-Asmat-Kamoro (Voorhoeve 2005), Proto-Athabaskan (James Crippen 5/24/13), Proto-Awyu-Dumut (Voorhoeve 2005), Proto-Bantu (Larry Hyman 5/30/13), Proto-Caddoan (David Rood 5/29/13), Proto-Cariban (Spike Gildea 5/31/13), Proto-Chadic (Paul Newman 5/28/13), Proto-Chibchan (Wheeler 1972), Proto-Chukchi-Kamchatkan (Alexander Vovin 5/31/13), Proto-Chumash (Klar 1977), Proto-Dravidian (Burrow and Emeneau 1984), Proto-Engan (Franklin 1975), Proto-Eskimo (Michael Krauss 6/10/13),Proto-Hmong Mien (James Matisoff 5/23/13, Martha Ratliff 5/29/13), Proto-Iroquoian (Marianne Mithun 5/28/13), Proto-Japonic (Alexander Vovin 5/31/13), Proto-Keresan (Miller and Davis (1963), Proto-Khoe-Kwadi (Bonny Sands 6/2/13), Proto-Koreanic (Alexander Vovin 5/31/13), Proto-Kx'a (Bonny Sands 6/2/13), Proto-Mongolian (Alexander Vovin 5/31/13), Proto-Mon-Khmer (James Matisoff 5/23/13), Proto-Muskogean (Emanuel Drechsel 5/28/13, Pamela Munro 6/2/13), Proto-Otomanguean (Rensch 1977), Proto-Pama Nyungan (Nick Evans 6/9/13), Proto-Quechuan (Willem Adelaar 6/1/13), Proto-Salishan (Gregory Anderson 5/31/13), Proto-Siouan (Robert Rankin 5/30/13), Proto-Tai-Kadai (James Matisoff 5/23/13), Proto-Tibeto-Burman (James Matisoff 5/23/13), Proto-Tucanoan (Thiago Chacon 5/30/13), Proto-Tungusic (Alexander Vovin 5/31/13), Proto-Tupian (Carolina Aragon 5/28/13), Proto-Tuu (Bonny Sands 6/2/13), Proto-Uralic (John Kupchik 5/28/13), Proto-Uto-Aztecan (Jane Hill 6/2/13), Proto-West Caucasian (Johanna Nichols 6/17/13), Proto-Yuman (Mauricio Mixco 5/29/13)

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