How Do Dongba Glyphs Transcribe IPA? Analysis of a Note by a Ruke Dongba Priest Learning IPA

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Abstract: Dongba script is one of the very few pictographic writing systems still in use in the world, known as a “living fossil” among the writing systems [1] (p. 31). This script evolved over time and is still evolving. There are some epistemological disagreements about the Unicode process of Dongba script, i.e., its definition as a writing system or a pre-mature writing system (cf. Unicode Consortium Documentation on Scriptsource).

Traditionally, Dongba script is used by Dongba (to-imboi/) priests. Dongbaism is an indigenous religion of the Moso People, living on the border between Yunnan and Sichuan Provinces in Southwest China. “Moso” is the historical name used to refer to this ethnic group, which can be dated back to the Jin Dynasty (317–420 AD) and was used until the 1950s. Some common transliterations of this designation in Chinese literature include: 摩沙, 摩些, 麽些, and 摩梭.

During the nationwide census of ethnic groups, the western branch of Moso was assigned a new designation, “Naxi” (/naçi-i/), based on the related endonym, in 1954 [2] (p. 3). The eastern branch of Moso People living in Sichuan Province, on the other hand, was recognized as Mongolian (Menggu Zu 蒙古族). The meaning of the syllable “mo” remains unclear. One of the interpretations is “yak” [3]. Another interpretation collected during the author’s fieldwork interview is “heaven”. The syllable “so” is generally interpreted as the word for “people, ethnic group”.

The endonyms of the Moso People generally consist of the syllable “na” (/na/), which is homophonic to the word for “black” and “noble”, and the word for “people” (e.g., /çi-i/, /hei-i/, /zu-i/). Therefore, in some contemporary research, the Moso People are addressed as “Naish People”. Nevertheless, the old term “Moso” is still kept as the official endonym of some minor branches living in Yunnan Province.

In the early Dongba scriptures, one or two glyphs may represent the plot of an oral traditional story. Grammatological/grapholinguistic elements (the glyphs) and grammatical
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features (the underlying language) are considered as syncretistic paintings, and Zhou [4] (p. 59) defines the Dongba script as a set of “symbols for chapters”. Scholars noticed that Dongba scriptures record keywords of verses of traditional stories, possibly configured as narrative poems [5] (p. 6). These symbols, sometimes composed in a rebus fashion, function as prompts for the chanting [6]. In recent Dongba scriptures, the density of written text has considerably increased. Some examples of varieties in the written forms of the same verses can be found in [7] (p. 85).

Dongba script has also been used to transcribe vernacular documents, such as property deeds (the most ancient can be dated back to the Qing Dynasty, according to the chronology reconstructable through the texts), letters, banners, speeches, and panels, which can be found everywhere in the town of Lijiang. In this context, Dongba glyphs represent a one-to-one relation between the syllable and the glyph [6] (p. 54).

Some of the Dongba scriptures should be read according to a Tibetan interpretation, i.e., in a foreign language. In order to ‘adapt’ to the phonemic system of Tibetan, some glyphs have been specifically created and are referred to as “Guzong Syllabaries” (古宗音字 Guzong Yinzi) [10] (p. 128–130). In the ‘diploma’ of Dongba Yang Zhashi, bestowed by a senior Dongba master in Baidi (the sacred place and cradle of Dongba culture), Tibetan spells written through Dongba glyphs appear, which grant spiritual power to the Dongba priest. Naxi manuscripts that record Bon sutras (cf. [11]) represent another instance of this process, in which Dongba glyphs transcribe the Tibetan language.

It is possible to conclude that Dongba script represents an early writing system in a transitional stage between religious and secular usage. Dongba script can be used in a syllabic mode, while homophonic variants, as well as words with slight differences in rhymes and tones, could be chosen on a random basis to represent the syllables. Therefore, Dongba script functions as a logographic writing system.

Besides Dongba script, the Naxi People have another traditional Sinographic/Sinoxenic writing system, the Geba script [12,13]. Geba script is a set of syllabaries, which are prototypes of pictographs [2]. Fang [14] documented 688 Geba syllabaries, while Li et al. [10] documented 2379 Geba syllabaries. Both statistics are inclusive of variants. The character repertoire of the E-Dongba keyboard contains 661 Geba syllabaries.

Although ‘syllabograms’ and ‘logograms’ are terms used to label the smallest units of a writing system (cf. [15], p. 57; [16], p. 35; [17], p. 75), Dongba script is generally referred to as a pictographic writing system (Xiangxing Wenzi 象形文字), especially because of the form of its characters. According to Zhou [18], the majority of the script, 47% of Dongba glyphs, are pictograms. However, the script is also defined as a logographic writing system. In other words, the two terms, pictographic and/or logographic, reflect different aspects in the framework of describing the writing system.

Dongba glyphs can be categorized into three types: basic pictographs (‘Danzi 单字’), complex pictographs—fusion units (‘Hewen 合文’), and complex pictographs—composed units (‘Zizu 字组’; cf. [8,19]). The basic pictographs may be graphemes of complex pictographs, along with some indicative signs.

This paper documents and analyses a study note written by the priest Ruke Dongba during field work (Figure 1). In that note, the Dongba priest correlated the phonemes from the Ruke Naxi dialect to IPA with Dongba pictographs.

Dongba script, as mentioned, is a pictographic writing system and can represent conceptual contents. Over time, it has developed the function to transcribe every syllable of the language. The Naxi language is a monosyllabic language with the syllabic structure C(G)V(T). Its features in IPA provide a foundation for the transcription of contemporary Tibetan.
Figure 1. The note written by Ruke Dongba Yang Zhashi, pictures taken by Zhao Liming in 2011 [20] (p. 76). The left image (a) is the first page of the note, listing the initials. The right image (b) is the second page, listing other initials and rhymes.

2. The Phonemic System of Ruke Naxi

The Ruke People are represented by around 7000 individuals who live in Labo Township, Ninglang County, Shangrila Township, Sanba County, Luoji County, Yunnan Province, and Yiji Township, E’ya Township, Muli County.

Naish languages have two major dialects: the western branch, Naxi (ISO 639-3: nxq, around 35,000 speakers), and the eastern branch, Na (ISO 639-3: nru, around 50,000 speakers). The Ruke People speak a hybrid dialect of the Naish languages (a subgroup of Tibeto-Burman), with phonemic features of both main dialects. Ruke Dongba culture is a branch of Dongbaism, with distinctive characteristics from Naxi Dongba and Na Daba. For instance, Ruke Dongba people worship a god of war, instead of a god of heaven [2] (p. 55). Ruke Dongba uses some Dongba glyphs which are different from the ones in the mainstream Dongba script and which are recorded as a separate chapter in Li et al. [10]. Their linguistic variety is still only partially documented [21].

The hometown of the priest Dongba Yang Zhashi, Yomi Natural Village (Jiaze Village, Labo Township, Ninglang County, Yunnan Province), is one of the traditional Ruke hamlets. Ruke Dongba culture is preserved in an ecological context, in the Yomi Village, where around 400 inhabitants live, spread across 72 families. Besides two families of Han People, the others are all Ruke People (registered as Moso People, 摩梭人). The different ethnic groups can communicate with each other in Southwestern Mandarin. The village name is transliterated as “Yaomi” in Li et al. [10] (p. 125).

The endonym of the Moso People in Yomi Village is “Ruke” (/ʁuə’tɕhə/). It has been transcribed as “zher-khin” [22], “Ruoka” [23] (p. 32), “Ruanke” (/ʁuə’tɕhə/; [24,25]), and “Ruka” (/ʁuə’tɕhə/, /ʁuə’tɕhə/, /ʁuə’tɕhə/) [26]. The transliteration “Ruke”, in the present study, is based on the accent of Ruke Naxi in Yomi Village and has obtained the approval of the native speakers. Another endonym of Ruke is “Naru” (/na_u/). The first syllable “na” is a common component in the endonyms of Moso People. The second syllable “ru” means “warm”. The literal meaning of “Naru” is “Na People living in the lower and warmer land”. It is translated as “Jiangbian Ren 江边人 (“people living at the riverside”) in local Mandarin.

The main speakers of Yomi Ruke documented in the study are Dongba Yang Zhashi and Dongba Shi Maning. Yang Zhashi, born in 1952, speaks fluent Ruke Naxi. Shi Maning, born in 1974, speaks Ruke Naxi as his mother tongue. Both Dongba priests can communicate
in Mandarin. Table 1 illustrates the phonemic system of Ruke Naxi based on vocabulary recordings. There are 45 initials (inclusive of 2 glides), 23 rhymes, and 4 tonemes. Among the monophthongs, the letter “r” following the vowel indicates the retroflexive feature of the rhyme. The phonemes in brackets are conditional variants, which are not counted as independent phonemes.

Table 1. Phonemic system of Ruke.

| Plosives | Bilabial | Labio-Dental | Alveolar | Retroflexive | Alveo-Palatal | Velar | Uvular | Glottal |
|----------|----------|--------------|----------|--------------|--------------|-------|--------|--------|
| t | p | tʰ | t | tʰ | k | kʰ | [q] | [qʰ] |
| d | mb | nd | d | nd | g | ŋ | [ŋ] | [ŋ] |
| f | s | f | ʃ | c | h | z | z | ʃ |

Approximants: w

Laterals: l, ɻ

Affricates: tʃ, tʃʰ, tʂ, tʂʰ, tɕ, tɕʰ, dʐ, dnd, dʐ, dŋ, dz, ndz

Rhymes:
- 11 monophthongs: /i/, /e/, /æ/, /ɒ/, /u/, /ʊ/, /o/, /ʌ/, /o/, /ɑ/, /ɜ/.
- 6 nasalized rhymes: /i/, /ɜ̃/, /u/, /ʊ̃/, /o/, /ɔ̃/.
- 6 rhymes with glides: /we/, /wæ/, /wɜ/, /wɔ/, /wʌ/, /wɔ̃/.

Tonal letters:
- Low-falling: 0
- Mid: 0
- High: 0
- Low-rising: 0

Tonal values: 31/11, 53/33, 55, 24

3. Transcription and Analysis

As shown in Tables 2 and 3, the words represented by Dongba glyphs are transcribed and translated in order to compare their initials and rhymes with the listed phonemes.

Table 2. Initials recorded by Ruke Dongba glyphs.

| Initial | Glyph | IPA | Gloss | Initial | glyph | IPA | Gloss | Initial | Glyph | IPA | Gloss |
|---------|-------|-----|-------|---------|--------|-----|-------|---------|-------|-----|-------|
| p       | poʡ| pʰ| to lift up | t | j | ndi | pair (cl.) | tʰ | tʰ | flag |
| b       | boʡ| pʰu| to run | tʰ | tʰ | q | nasal to hide |
| mb      | mbeʡ| to snow | nd | d | ʂur | seven | q | qul | big |
| m       | muʡ| to water | n | ɲ | Indica rice | n | ni | fish |
| f       | fuʡ| cooked crops | l | leʡ | tea |
| k       | kurʡ| gut | q | quʡ | good; tired |
Table 2. Cont.

| Initial | Glyph | IPA   | Gloss            | Initial | Glyph | IPA   | Gloss            | Initial | Glyph | IPA   | Gloss            |
|---------|-------|-------|------------------|---------|-------|-------|------------------|---------|-------|-------|------------------|
| kʰ     |       | kʰ[i] | dog              | qʰ     |       | qʰ[aː] | bitter           |         |       |       |                  |
| g       |       | g[aː] | small table;     | g       |       | g[aː] | crane            |         |       |       |                  |
| ñ       |       | ñ[aː] | I                | ñg      |       | ñg     | to win           |         |       |       |                  |
| x       |       | xiː   | tooth            | x       |       | xæ.l  | god              |         |       |       |                  |
| Y       |       | ngg   | to pick up       | s       |       | hæ.l  | bone joint       | tsurː |       | tsurː | wooden drill     |
| tc      |       | tcː   | cloud            | ts      |       | tsurː | to hide          | ts     |       | tsurː | wooden drill     |
| tcʰ    |       | tcʰː  | cold             | tsʰ     |       | tsʰː | goat             | tsʰ    |       | tsʰː | lung            |
| dz      |       | dzː   | water            | dz      |       | dzː    | ethnic group     | dz     |       | dzː    | numerous         |
| c       |       | ciː   | yellow           | s       |       | surː  | branch           | s      |       | surː  | seven           |
| z       |       | ziː   | snake            | z       |       | zurː  | grass            | z      |       | zurː  | enemy           |
| h       |       | hː    | people           | hː      |       | hwæ.l | stream (cl.)     |         |       | hwæ.l |                |
| w       |       | wː    | good             | y       |       | zœ.l  | ancestor         |         |       | zœ.l  |                |

Table 3. Rhymes recorded by Ruke Dongba Glyphs.

| Rhyme | Glyph | IPA   | Gloss          | Rhyme | Glyph | IPA   | Gloss          |
|-------|-------|-------|----------------|-------|-------|-------|----------------|
| i     |       | ziː   | Buffalo        | u     |       | zː  | hunger         |
| y(y)  |       | zoː   | Sheep          | ø     |       | uː  | Chinese character “吾” (Wu)” (W) |
| e     |       | eː    | Chinese character “吹” (He)” (Hey)” | vø    |       | oː  | name of a god |
| ø     |       | tʰuː | to grow sores  | o     |       | burː | intestine      |
| æ     |       | æː   | Copper         | a     |       | aː  | “ah”            |
| æ     |       | æːː | Rooster        | a     |       | wæː | jewel           |
| λ(ø)  |       | muː  | Chinese character “吹” (to blow)” | wː  |       | –   | –              |

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There are 48 initials recorded in Table 2. The missing phonemes, if compared to Table 1, include: /ndz/, /ndz/, /ndz/. The sample words with these initials, with the corresponding non-pre-nasalized initials, include: /ndzo/‘turnip’, /ldzoz/‘right’; /ndzoz/‘bridge’, /dzoz/‘wine jar’; /ndzW-/‘dew’, /dzW-/‘crime’. Among the dialectal varieties of Naish languages, Dayan Naxi uses the pre-nasal initials, but not the voiced initials of the corresponding articulations (cf. [14]). In Na, the pattern is the opposite, while, in some Naxi varieties, both sets exist (cf. [10,27,28]), as well as in Ruke. Take the bilabial set, for instance, where the words with initials /mb/ and /m/ followed by rhyme /o/ include: /mbo-/‘ridge’, /mo-/‘mosquito’. In this note, the pre-nasal initials are often missing, which may indicate the apparently nonexistent distinction between these two sets of initials among native speakers. The subtle contrast between the pre-nasal initials and the voiced initials of the same articulations can also be interpreted as a manifest of sound change.

The conditional variants of phonemes are highlighted in green in Table 2, including: uvular consonants and alveolo-palatal nasals. The sample words with uvular initials displayed in Table 2 depict the complementary contribution of uvular and velar initials in Ruke Naxi: the velar plosives [k], [kʰ], [q], and [ŋq] can combine with rhymes /i/, /u/, /u/, and /æ/, while the uvular initials [q], [qʰ], and [ŋq] can combine with rhymes /æ/, /a/, /ɑ/ and /o/; and [c] can combine with /o/, /ɑ/, /ɑ/, and /o/. In the syllables with glides, velar initials can be followed by /wɑ/, while the uvular initials can be followed by /wæ/ and /wə/. The samples words include ‘gut’ ([kwa-]), ‘good’, and ‘tired’ ([qa-w]), which are written in the Dongba glyphs, and resemble the Tibetan letter “’”.

The initial /ŋ/ is not among the phonemes in Table 2. However, sample words with the variant of /ŋ/ are attested: [ŋga-] ‘to win’, after the uvular initial [ɡ] and [ŋga-] ‘to pick up with tongs’, after the velar initial /ɡ/. The Dongba glyph is also used to represent the word ‘wither’, in Dongba scriptures, which is read as /ŋɡu/. Another sample word with the same vowel is /qul/ ‘correct’.

Sound changes developed over generations and attested in Naxi and Na are also reflected in this note. One of these changes is represented by the weakening/dropping of the uvular fricative /u/. In the Dongba note, the sample word for the glide /w/ is ‘good’ (/mun-), and for /u/ is ‘bone joint’ (/mar-). Such misconnections between initials and the words are ‘visual’ evidence of the barely used phoneme /u/. The phonemic load of the velar fricative [ɣ] is also so light that, for the minimal pair of ‘bone joint’, the Dongba priest provided the word with a pre-nasal uvular plosive ‘to pick up (with tongs)’ ([ŋga-]). In fact, /u/ combines with very limited rhymes. Some sample words include /wɑ/ ‘skin’, /wɑ/ ‘head’, and ‘narrow’ (MAR-). In Fang [14], it combines with /u/ and /a/. According to Fu [28], /ɣ/ remains a velar fricative in front of /u/ and /a/, and becomes /l/ in front of other vowels (/a/, /a/, /o/, /a/, /l/). This velar/uvular fricative is omitted in the phonemic system presented in Li et al. [10] and Pinson [29]. The words mentioned here, e.g., ‘skin’, are transcribed as syllables without initials.

The sample word for /n/ is ‘Indica rice’ ([nou-]). The consonant [s] combines with high vowels and distributes complementarily with [n]. The initial /y/ listed in the note possibly corresponds to the glide /j/.

The voiceless fricatives [x], [x], and [h] are merged to the phoneme /h/ in the phonemic system. According to the samples in Table 2, these three variants represent different conditions of /h/: when followed by non-nasalized high vowels, the phonetic value of /h/ approximates [x]; when followed by /æ/, a monophthong with a nasalized feature, the phonetic value of /h/ approximates [x]; when followed by /wæ/, a rhyme with a glide and nasalized vowel, the aspiration of /h/ increases further, which makes it sound like [l], in Na, the eastern dialect of the Naish language.

The ‘mis-matched’ sample words and the initials are highlighted in orange. Several of them are attested among the alveolar initials. The sample word for /d/ is ‘seven’ ([sa-]), which is homophonic to copula “/le/”, in Mandarin, a synonym of to ‘correct’ (“/le/ dui”). The sample word for /nd/, ‘see’ ([弟弟]), is with an initial without pre-nasal consonant, while the sample word with a pre-nasal initial, ‘pair (cl.)’ ([ndi-]), is listed after the phoneme /tl/.
Additionally, no lexemes showing consonantal contrasts between alveolar and retroflexive initials in Table 2 can be interpreted as a marginalized position of retroflexive initials in the phonemic system.

From the perspective of the monophthongs, Table 3 lacks the rhyme /u/ if compared to Table 1. This phoneme exists in sample words such as 'light' (/l,u,Ç,t/). The syllables of the sample words for [e] and [æ] are the same. They are considered two rhymes due to the different tones. The phoneme /u/, in 'to grow sores’, ‘to blow’, and ‘I’, is divided into three rhymes, in the note. The words without initials or acoustically 'harmonic’ to the rhymes (e.g., /s/ followed by /ï/) are the sample words correlated to the IPA symbol more accurately. In other words, it is challenging for Dongba glyphs to identify the rhymes without ‘zero initial’ sample words.

4. Discussion

During the fieldwork, Dongba Shi Maning was also interested in IPA and wrote a chart of syllabary of Ruke Naxi through Dongba glyphs (Figure 2). There are 88 syllables, in that note, with distinctions between velar and uvular initials, alveolar and retroflexive initials, and without distinctions between alveolar nasal and alveolo-palatal nasal, without distinctions of tones among the syllables. The missing phonemes include the fricative /f/ and the glide /j/. Only one syllable with an alveolo-palatal initial is recorded: /dzl/. The syllables recorded twice include: /ndy/ ‘ground’ () and ‘to chase’ (Definitions/humans-164184-i003.pdf); /ne/ ‘Indica rice’ () and ‘a kind of bird’. In Ruke Naxi, the pronunciation of ‘ground’ is /dzÕ/; ‘to chase’ is /ndÕ/, and ‘Indica rice’ is /nv/. The initials of ‘ground’ and ‘to chase’, being considered identical, provide additional proof of the vague border between voiced and pre-nasal initials.

Figure 2. Ruke Naxi Syllabary by Dongba Shi Maning. The left image (a) is the first page of the note and the right image (b) is the second page.

In these two learning notes created by the Dongba priests, the glyphs chosen to represent the phonemes are mostly basic pictographs ('Danzi 单字'), along with a few complex pictographs—fusion units ('Hewen 合文'). There are corresponding glyphs selected by the two Dongba priests to represent the phonemes, such as: “flag”, “pair”, “Indica rice”, “tea leaf”, “big”, “tooth”, “good”, “pond”, “numerous”, ‘dog’, “crane”, “wooden drill”, and
“bone joint”. A possible rationale for the selection of these glyphs may be represented by the concision of each glyph and the frequency of usage. Some of these glyphs are highlighted as the head of sections or representative glyphs for sections in Dongba script and are the repeatedly used components in Dongba glyphs.

The Guzong syllabaries provide another perspective on foreign languages phoneticized through the Dongba script. They (‘Guzong Yinzi 古宗音字’) represent Tibetan syllables. They are also defined as ‘Qieyin Zi 切音字’, a term based on traditional Chinese Rime Dictionaries. According to He [30], there are three types of Guzong syllabaries, including: Qieyin 切音 (‘combination of the initial and the rhyme’), Liandu 连读 (‘combination of the syllables’), and Bianyin 变音 (‘similar pronunciation’). Among the 32 Guzong glyphs documented in Li et al. [10], 5 belong to the “Qieyin” category, among which No. 1683 is a Geba syllabary (the syllabic script of Naxi People), while No. 1685, No. 1689, No. 1693, and No. 1706 are not identical to the combination of their initials and rhymes. Nevertheless, the phonemes [a] and [æ], and [t] and [t], are occasionally free variants, and these four glyphs are classified as “Qieyin” type. These five glyphs are listed in Table 4, along with the syllables represented by their components. Apart from the Geba syllabary (No. 1683), it is possible to notice that the initials of the Guzong syllabary and the glyphs providing initials are identical, while the rhymes do not distinguish strictly between /a/ and /æ/, and the tones as well. These features are concordant to the analyses on the Dongba glyphs transcribing IPA symbols.

Table 4. The “Qieyin” pattern of Guzong Syllabaries in Li et al. [10] (Ludian Naxi).

| No. | Guzong Syllabary (Qieyin zi) | Glyph Providing Initial | Glyph Providing Rhyme |
|-----|-----------------------------|-------------------------|-----------------------|
| 1683 | gi,i | gu,i | dz,i |
| 1685 | ia,i | io,i | i,i |
| 1689 | [h]ur | [h]v | qur |
| 1693 | to,i | tv,i | qo,i |
| 1706 | ga,i | nv,i | η,i |

A more recent attempt to connect Dongba glyphs with IPA notation can be found in the table in the *Dongbawen Guifan Shiyong Shouce* (“Practical Manuscript of Normalized Dongba Script”, pp. 96–97) published in 2017 [31]. The table displays a complete syllabary of the Naxi language (Dayan dialect), corresponding to the Naxi Dongba glyphs. Nine monophthongs have their corresponding Dongba glyphs, which represent syllables without initials. The initials, along with the other ten rhymes listed in the row of the table, apparently do not have independent phonetic representations. Each combination of consonants and vowels is transcribed through a different Dongba glyph.

5. Conclusions

According to the analyses performed above, it is possible to notice that the Dongba glyphs can transcribe initials quite efficiently. For instance, the samples for velar and uvular initials neatly fit the complementary distribution pattern of these two sets of initials. To be more specific, ‘gut’ (/kẈ/|) is used as a representative word for /k/, and ‘the Tibetan alphabet བ (\%/q\%/|, homophonic to ‘good’ and ‘tired’, in Ruke) is used as a representative word for /q/. For another instance, four conditional varieties of /h/ are recorded in this note. Conversely, it is difficult, due to their intrinsic nature, for Dongba glyphs to differentiate rhymes and tones. This is plausibly due to the interferences from the initials. The rhymes without initials (or acoustically ‘harmonic’ with the initials) have been linked to the IPA vowel correctly, e.g., ‘buffalo’ (/zi,i/), ‘rooster’ (/æ,i/).
Some sound changes can be reconstructed, through this note: for example, the indication of the different load of phonemes in the Ruke phonemic system, such as the vague boundary between pre-nasalized initials and voiced initials, which implies a lighter load of pre-nasalized consonants. Another instance can be represented by the limited usage of /j/.

To sum up, the learning note by the Ruke Dongba priest depicts the phonemic system of Yomi Ruke in a ‘natural’ status before phonological analysis. The ‘mismatches’ between Dongba glyphs and IPA symbols, to some extent, indicate the sound changes in Ruke Naxi. It is a seemingly isolated, yet pioneering case, which shows a Dongba priest’s observations and reflection on his own language, with his script considered as a technical tool.

At a more general level, this study may also contribute to the current techniques of conversion between syllabic scripts and target languages. Due to the need to transcribe phonetically, the Geba syllabary, known as ‘the disciple of Dongba script’, was developed.

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