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# Yak Domestication: A Review of Linguistic, Archaeological, and Genetic Evidence

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**Abstract** Yak, a species of bovid uniquely adapted to high-altitude environments, plays a critical role in the life of the inhabitants of the Tibetan Plateau and neighboring areas. There is currently no consensus on when these animals may have been domesticated. In this paper, we review the archaeological, genetic, and linguistic evidence relevant to this question, and suggest that the domestication took place following hybridization with taurine cattle from the end of the fourth millennium BCE. This study also shows that the original domesticators of yaks included not only the ancestors of the Tibetans, but also Rgyalrongic speaking people from Eastern Tibet.

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## Introduction

Yaks (*Bos grunniens*) provide important resources for millions of Tibetans, not just in the form of meat, but also in the form of secondary products such as milk products, hide, and fur that can be spun into black tents that retain moisture when it rains and prevents the tent from leaking. Yak dung provides a vital fuel source (Rhode et al. 2007); it also serves as construction material in walls, enclosures, storage houses for frozen meat, dog houses, tethers to which dogs and yaks can be attached, and even for manufacturing toys. Yaks are frequently crossbred with domestic cattle, producing a F1 hybrid dzo, which are valued for their increased milk production, and ability to adapt to the lower altitudinal range for yaks (between 2500–3500 masl). Rhode et al. (2007) have argued that meeting fuel needs may have led to the integration of the yak into early foragers survival mechanisms on the Plateau and eventually its domestication.

Yaks have a set of traits that have allowed them to adapt to the high-altitude environment of the Plateau: a thick coat that keeps them warm in freezing

winters, increased heart and lung size, and increased foraging ability through an adapted tongue that allows them to easily eat the low-lying forage grasses that characterize areas of the Plateau. They likely diverged from wild cattle 4.9 million years ago and adapted to the Plateau over the course of its uplift (Qiu et al. 2012). Recent genetic comparisons of the yak to cattle have found that yaks possess unique adaptations to the low oxygen conditions of the Plateau: they identified an expansion of protein domains associated with hypoxic stress and nutrition metabolism, both traits that were likely important over the course of its evolution on the Plateau (Qiu et al. 2012).

To date, there is only disparate archaeological evidence of when humans first began to manage and eventually domesticate this animal. Below, we review the archaeological, genetic, and linguistic evidence for yak domestication. Linguistic evidence reveals that languages which have the most elaborate terminology for yak are Tibetic and Rgyalrongic, suggesting that its domestication may have taken place somewhere among the speakers of the ancestors of these languages. The speakers of proto-Tibetic and proto-

Rgyalrongic appear to have independently cross-bred yaks with cattle, and the breeding of F1 hybrids predates the proto-Rgyalrongic split (3221 [2169–4319] BP, according to Sagart et al. 2019), which implies that the inhabitants of the eastern Plateau had begun to experiment with cattle/yak hybridization.

### Geographic Background

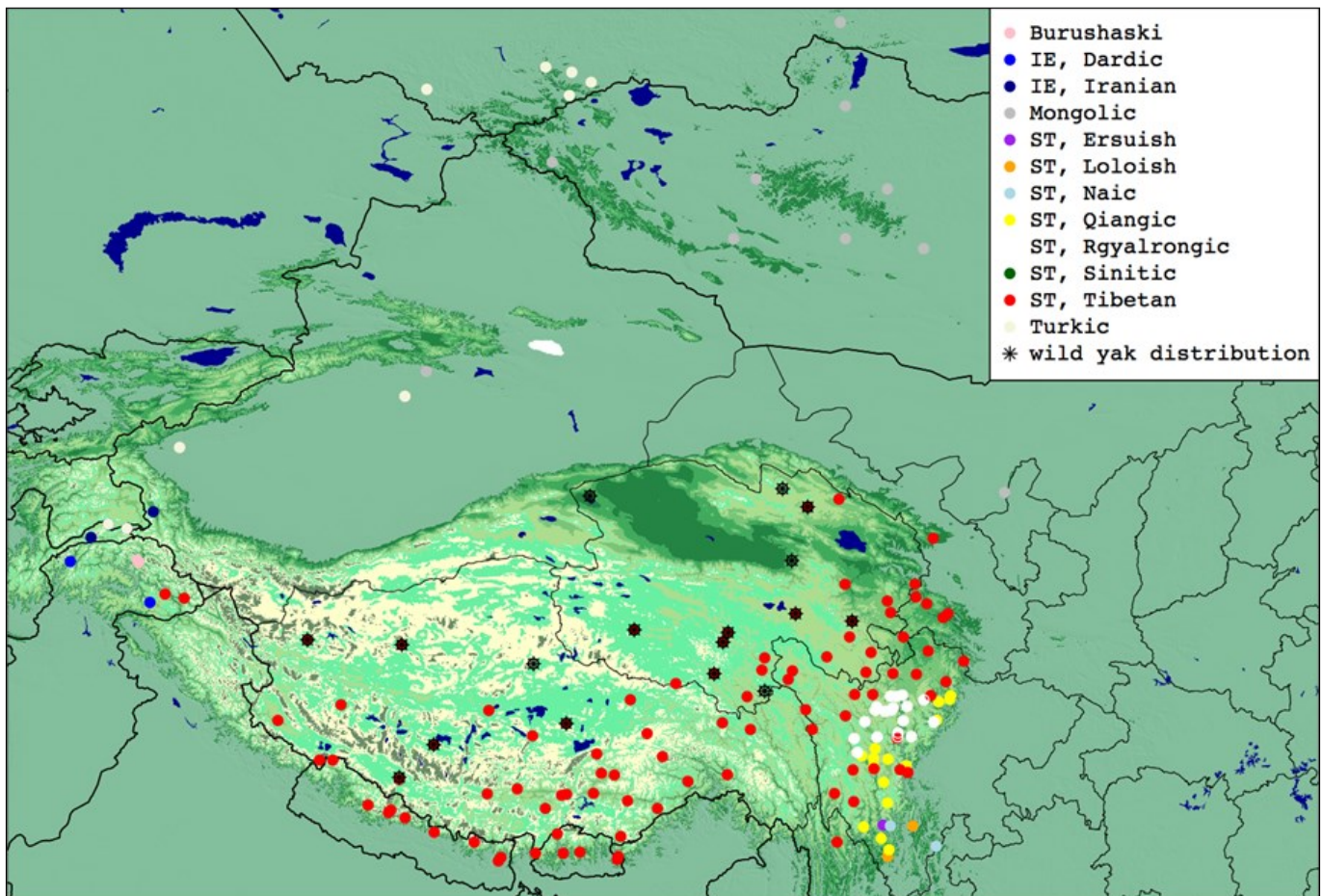
The domestic yak is present over a large area, spread over ten countries (Afghanistan, Bhutan, China, India, Kyrgyzstan, Mongolia, Nepal, Pakistan, Russia, and Tajikistan; Joshi et al. 2020) comprising a southern and a northern zone, linked in the west by the Pamir mountains, as shown in Figure 1<sup>1</sup>.

The southern zone corresponds to the entire Tibetan Plateau from Qinghai and Sichuan in the East up to Baltistan in the West, including the southern slope of the Himalayas in India, Nepal, and Bhutan. This area reflects the maximal extent of the Tibetosphere, mainly inhabited by speakers of Tibetic

languages (i.e., in direct descent from the language of the Tibetan empire, 618–842 CE; Tournadre and Suzuki 2021), but also speakers of Burushaski (a language isolate), Indo-Iranian (Indo-European), Turkic, Mongolic, and Sino-Tibetan languages that are culturally and linguistically influenced by Tibetan.

The non-Tibetic Sino-Tibetan languages of this zone mainly comprise either groups that are closely related to Tibetic, such as Tamangic, East Bodish (Hyslop 2013) and Bragsum (Tournadre and Suzuki 2021), languages of the Na-Qiangic branch, in particular Naic (Jacques and Michaud 2011), Ersuic (Yu 2012), Rgyalrongic (Sun 2000), as well as Muya, Zhaba and Queyu, and several isolated branches of the family including Tshangla (Bhutan), Kho-Bwa (Arunachal Pradesh, India) and Guiqiong (Sichuan, China).

The northern zone spreads from the Pamir mountains up to the Hangai mountains in Mongolia, north of the Taklamakan desert (Qi et al. 2008:429),



**Figure 1** Geographic distribution of wild and domesticated yak.



and is inhabited by speakers of Mongolic and some Turkic languages (Tyva, Altai).

Wild yaks (*Bos mutus*) are only restricted to a much smaller range, in several discontinuous refuge zones: the Chantang, Hoh Xil, Sanjiangyuan and Altun shan National Nature reserves, the Qilian mountains and an area in Ngari district in Tibetan autonomous region.

### Genetics and Archaeology

Yaks belong to the Bovini tribe, a group of bovids, which have played an important role in human life: a source of milk, meat, hide for leather but also as draft animals where their muscle power was used for moving produce and ploughing fields. Several genera are important in understanding the history of domestication in Asia: the genus *Bos* which includes taurine cattle (*Bos taurus taurus*), Zebu (*Bos taurus indicus*), Yak (*Bos grunniens*), and domestic gaur (*Bos frontalis*). The genus *Bubalus*, which includes water buffalo (*Bubalus arnee*), were also important domesticates in Asia.

#### Cattle

Archaeological evidence suggests that taurine cattle were introduced to China from west Asia between 4500–2000 BP (Brunson et al. 2020; Cai et al. 2014; Flad et al. 2007; Lu et al. 2017). Ancient DNA analysis on mtDNA from 53 cattle remains between 4500–2300 years ago from across Northern China showed predominantly taurine cattle, an exotic introduction from the Near East (Cai et al. 2014), introduced at the same time as other Near Eastern species like wheat and barley.

Recent genetic work supports the two introductions of taurine cattle into East Asia that took place (Chen et al. 2018). Zooarchaeological evidence contains evidence for taurine cattle by roughly 5500 cal. BP in Gansu/Qinghai province, although more secure evidence dates to roughly 1000 years later (4500 cal. BP). Lu et al. (2017) point out, however, that the proportions of *Bos taurus* in earlier assemblages are very low and they do not appear to have formed an important component of the diet. On the Tibetan Plateau and its margins, bones of Bovids (*Bos* sp.) which may be *Bos taurus*, have been unearthed at Tawendaliha (3350–2750 cal. BP) and Talitaliha (3350–2750 cal. BP), Xiariyamakebu (3300 cal. BP; Dong et al. 2016), Ashaonao (2800–200 cal. BP; Kaoguxi et al. 2017).

*Bos javanicus* (banteng) and *Bos frontalis* (gayal) introgressed with both Zebu and taurine cattle in East Asia, providing cattle with adaptive traits to high temperatures. Likewise, yak was introgressed with taurine cattle on Tibet's margins, conferring adaptive traits to altitude (Chen et al. 2018).

#### Archaeological Evidence for Yak Domestication

Unfortunately, there is currently very little concrete evidence for yak domestication in the archaeological record. Physical evidence of yak skeletal remains has been found at Nuomohong sites on the northeastern Plateau, including Xiariyamakebu and Tawendaliha (3300–2700 BP), however, only their presence is noted, and it is unclear if they show signs of domestication (or what these signs of domestication might look like in yaks). At Talitaliha (3000–2700 BP), a clay sculpture of a yak demonstrates the importance this animal may have held for the inhabitants of the site (Qinghai Sheng Wenwu Guanli Huiyuanhui and Zhongguo Shehui Kexue Yuan Kaogu Yanjiusuo Qinghai Dui 1963). At Qugong, a yak skull was also unearthed in an ashpit that dates to roughly 3650 BP (Zhongguo Shehui Kexue Yuan Kaogu Yanjiusuo 1999). The authors argued that because of the relatively small size of the horns of the animal, it was likely domesticated (or hybridized with cattle). Yak skulls are also present in Samdzong 5 dating to 450 CE (Aldenderfer and Eng 2016).

Using pollen and charcoal analysis, some scholars have argued that humans may have modified yak's grazing lands via burning and encouraged the growth of grass and forbs on which these animals rely as early as 8000 BP (Huang et al. 2020; Mische et al. 2009, 2014). This agrees with other sources on anthropogenic modification of the landscape as taking place by c. 5900 BP (Meyer et al. 2009; Schlütz and Lehmkuhl 2009).

#### Genetic Evidence for Yak Domestication

Genetic data has not been helpful in resolving this debate: some genetic papers predict a very early domestication (c. 10,000 BP; Guo et al. 2006), while other MtDNA data suggest that it took place twice roughly 5000 years ago (see discussion in Rhode et al. 2007; Bailey et al. 2002). Qiu et al. (2015) use molecular clocks to date yak domestication to roughly 7300 BP and document a large increase in yak populations corresponding to 3600 BP or the known spread of pastoral economies into the region.

While there is no evidence for pastoralism as early as 7300 BP, it is possible that the encouragement of the growth of plant species on which yaks rely by foragers may have led to the population expansion and divergence in yak populations.

Following yak's domestication on the Tibetan Plateau, genetic evidence appears to support that it was then moved to Mongolia however it is unclear from the current data when this took place (Qi et al. 2010).

*Bos taurus* has been interbred with a number of other different species across Asia. A number of genetic studies have documented the introgression of taurine cattle genomes into yak populations and of yak genomes into taurine cattle on the Tibetan Plateau and in Mongolia (Chen et al. 2018; Medugorac et al. 2017; Qi et al. 2010). Medugorac et al. (2017) see an increase in the amount of introgression between yak and cattle populations taking place 1500 years ago with particular peaks around the Medieval Climate Anomaly (897–1121 CE) and the Dzungar-Qing Wars (1687–1758 CE).

Future genetic analysis on archaeological specimens may help us resolve the timing of the domestication of the yak.

### Linguistic Evidence

Linguistics provide important evidence for the domestication of plants and animals. The study of systematic correspondences between related languages to reconstruct the vocabulary of their common ancestor (a field called *Linguistic Paleontology*) allows to constrain the range of hypotheses regarding the origin and way of life of the speakers of that proto-language (Hock 1991:573–578). It can be further applied to investigate the date of and place of domestication of plant and animal species (Brown et al. 2013).

This field of research uses the regular sound correspondences between cognate words in attested languages to reconstruct the proto-language (the *comparative method*). This procedure can distinguish genuinely related words from chance resemblance, and cognates inherited from the proto-language from loanwords.

Language phylogenies obtained by Bayesian phylogenetic methods (Sagart et al. 2019; Zhang et al. 2019; Zhang et al. 2020)<sup>2</sup> on the basis of cognates in the basic vocabulary provide dates for proto-languages which can be compared with archaeological evidence. We use the dates in Sagart et al. (2019),

which is the only one of the three studies that took borrowing from Tibetan and Chinese into account.

### *Yak Terminologies*

Yak-related terminology varies considerably in size and complexity. Languages spoken outside of the natural habitat of domestic and wild yaks (see Supplementary Materials 2) usually lack specific terms for this animal, and with a few exceptions detailed below, employ borrowings from Tibetan (like English *yak*).

Most of the languages of the southern zone belong to the Sino-Tibetan family, and the relevant terms are indicated in Table 1<sup>3</sup>. The phylogenetic relationship between these subgroups is shown in Figure 2, representing the nodes with posterior probability >90% in Sagart et al. (2019). The group 'Para-Rgyalrongic' in Table 1 is paraphyletic.

Tibetan also has special names for F2 hybrids, only involving female hybrid yaks, since the males are sterile: མགལ་ **mgal** and རྩོལ་ **rtol**, which refer to the offspring of female hybrids with male yaks and bulls, respectively. In addition to Tibetan, Rgyalrongic languages also have a distinct term for F2 hybrids: **kətó** in Situ and **rts<sup>h</sup>æqætú** in Khroskyabs, whose last syllable could be reconstructed to proto-Rgyalrongic.

Some languages have only one word for both males and females, and do not distinguish between yaks and hybrid yaks, whereas other languages have four different terms, in all cases different from those that designate taurine cattle.

Among the languages that have distinct terms for male and female animals, some express it by using feminine or masculine suffixes (for instance, the suffix **-mo** in མཚོ་མོ་ **mdzo.mo** 'female yak-cattle hybrid'), while other languages have suppletive forms, i.e., use different roots to designate female and male animals. Amdo Tibetan is reported to have more than 24 terms for yaks depending on sex and age (Tournadre and Suzuki 2021:11.7.1), but these terms are transparently analyzable and therefore recent.

The Tibetan terms have been borrowed by neighboring Sino-Tibetan speakers who lack native terms for yaks, F1 and F2 hybrids. This is the case of Guiqiong in Eastern Tibet, of Kurtoep and other East Bodish languages in Bhutan (Gwendolyn Hyslop, p.c.), of Bokar among Tani languages (the other Tani languages lack terms for yaks altogether, Mark Post,



**Table 1** Terms for domestic yaks in selected Sino-Tibetan languages of the Southern zone.

Subgroup	Language	Yak		Yak-Cattle hybrid	
		Male	Female	Male	Female
Tibetic	Old Tibetan	གཤམ་ gjaḡ	འབྲི <sup>n</sup> bri	མཚོ mdzo	མཚོ་མོ mdzo.mo
	Lhasa Tibetan	jâ	tʂi	tsò	tsòmo
	Amdo Tibetan	hjaḡ	ndzə	ndzo	ndzomo
Tamangic	Thakali	<sup>545</sup> ja	<sup>545</sup> pri		
Rgyalrong	Japhug	qambrw	qra	jla	fstoɤ
	Zbu	qe <sup>n</sup> brúʔ	q <sup>h</sup> ríʔ	ljéʔ	fts <sup>h</sup> óɤʔ
	Tshobdun	qe <sup>n</sup> brúʔ	qrê	jlê	ftsô
	Situ	kəmbrû	karâ	təjliê	mbəçák
	Khroskyabs	ɤbrô	q <sup>h</sup> rí	çê	vzəy
	Stau	ɤja <sup>#</sup>	qrə	xə	zə
	Para-Rgyalrongic	Smarskad	mdzɔ̃	râ	zɔ̃
	Ndrapa	ptʂi <sup>55</sup>	zi <sup>55</sup>	a <sup>33</sup> ʂko <sup>55</sup>	zo <sup>55</sup>
	Rma	zɔ̃	ɤu miɛ	khʂɛ	khʂɛ miɛ
	Muya	ndzɔ̃ <sup>53</sup>	rə <sup>33</sup> ma <sup>53</sup>	ziyə	zi <sup>53</sup> zə <sup>33</sup> ma <sup>53</sup>
	Pumi	ɔ̃wé	ɔ̃wemí		tçú
Naic	Namuyi	bu <sup>53</sup>	bu <sup>55</sup> mi <sup>53</sup>	zɤ <sup>55</sup> yə <sup>31</sup>	zɤ <sup>55</sup> yə <sup>31</sup> mi <sup>53</sup>
	Naxi			bəɭ	
Ersuic	Ersu			bɤɭ	
	Lizu			<sup>f</sup> ɔ̃jæ	
Kiranti	Limbu			phuŋbit	
Mishmic	Idu			sā pūú	
Kho-Bwa	Puroik			çi <sup>33</sup> -be <sup>1</sup> 55#	
Hruso-Miji	Hruso			fu bzə	
Chinese	Old Chinese	犛 mæw < *mr <sup>h</sup> u			
	Mandarin	牦牛 máoniú		犏牛 piān niú	

<sup>#</sup>Terms borrowed from Tibetan.

p.c.), and Kho-Bwa languages including Puroik and Duhumbi (Bodt 2020:296).

A specific term for wild yak is found in Tibetic languages (Old Tibetan འབྲི་ *bron*), which has been borrowed into neighboring languages, including Japhug *ɤmbrɔŋ* and Pumi *ɔ̃*.

Since the yak is known through products from its fur and horns, terms for yak also exist in Sino-Tibetan languages spoken outside of the natural range of the animal. In Yunnan and Burma, languages with native terms for yaks include Jinghpo (*wāhpò* ‘yak’), Rawang (*shívpè*) and some Lolo-Burmese languages such as Lahu (*nu<sup>53</sup>mv<sup>33</sup>* ‘yak’, *nu<sup>53</sup>tə<sup>53</sup>* ‘yak hybrid’), Zaiwa (*mau<sup>55</sup>phjap<sup>51</sup>no<sup>21</sup>* ‘yak’, *no<sup>21</sup>phu<sup>51</sup>* ‘yak hybrid’), all involving the native words for ‘cow’ (for instance, the syllable *nu<sup>53</sup>* in Lahu).

The yak-related vocabulary is less rich in non-Sino-Tibetan languages, as shown in Table 2<sup>4</sup>. Only some Mongolic languages, notably Khalkha, have

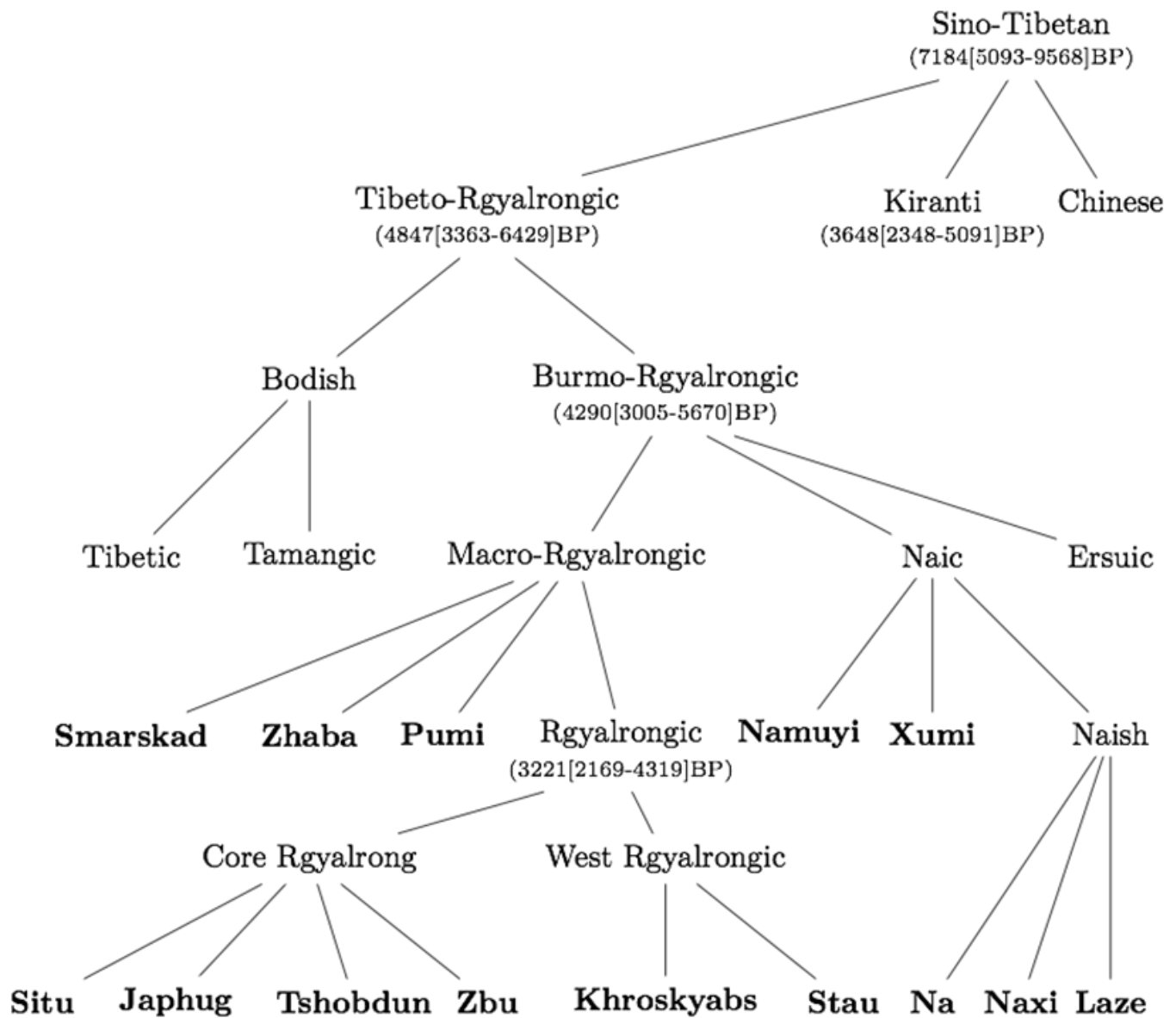
native terms for yak hybrids; the other languages, including Burushaski and Southern Mongolic languages, have borrowed the term from Tibetic (Nugteren 2011:532).

In addition, Mongghul has innovated a term for ‘wild yak’ *se:nag* from an etymon designating bovids or ovids in other Mongolic languages (Nugteren 2011:486).

*Attested Semantic Innovations*

Among the language groups discussed in the previous section, only Tibetic, Chinese, Turkic, Mongolic, and Indic have ancient written records. Comparison of the meanings of these words in ancient texts with recent languages offers insight into possible semantic changes. Two cases are detailed below.

First, the terms for male and female hybrid yaks (*མཚོ་མོ* *mdzo* and *མཚོ་མོ་མོ* *mdzo.mo* in Old Tibetan) have become *ndzò* ‘bull’ and *ndzō*: ‘cow’ in Cone (by



**Figure 2** Simplified topology of the Sino-Tibetan phylogenetic tree (terminal nodes in bold). Tree topology and ages inferred are based on the relaxed-clock covarion model, data cited from Sagart et al. (2019).

contrast, the terms for ‘yak’ have remained stable).

Second, in the Mongolic languages of Gansu and Qinghai (Shironglic), the inherited ‘hybrid yak’ etymon *qayinuɣ* has shifted to ‘yak’ as in Mongghul *ɣe:nag* (Nugteren 2011:532), ousting the etymon *sarluy* ‘yak’. The semantic slot ‘hybrid yak’ was filled by a loanword from Tibetan མཚོ *mdzo* (for instance Mongghul *musu*), which may have already been borrowed in the common ancestor of Shironglic languages (Nugteren 2011:400).

These two examples show that semantic shifts between ‘yak’ and ‘yak hybrid’ are bidirectional.

#### *Etymology and Phylogeny*

In the data presented in 4.1, some languages (for instance, Burushaski, Uighur, Wakhi or Rawang) have isolated terms for ‘yak’. Two sets of terms with suppletive gender distinction are reconstructible for Tibetic and Rgyalrongic languages.

In Tibetic, the terms གཤམ་ *gɣag* ‘male yak’, འབྲི *‘bri* ‘female yak’, མཚོ *mdzo* ‘male hybrid yak’ and འབྲོང་ *‘bron*

**Table 2** Terms for domestic yaks in the non-Sino-Tibetan languages.

Family	Language	Male Yak	Female yak	Yak hybrid
Indo-European	Sanskrit	camara-	camarī-	
	Nepali	caumrī		
	Wakhi	dzuuḡ		
Buruskaski	Hunza	bépaḡ		zó <sup>#</sup>
	Yasin	bépa	sum bépa	
Turkic	Old Uighur	qotoz		
	Tuva	sarlık		hainak sarlık
Mongolic	Cl. Mongolian	sarluy		qayinuy
	Khalkha	сарлаг		хайнаг
	Mongghul	xe:naḡ		musu <sup>#</sup>
	Yugur	xainaḡ		omsə <sup>#</sup>
	Bonan	warḡan	ndzə <sup>#</sup>	emsə <sup>#</sup>

<sup>#</sup>Terms borrowed from Tibetan.

‘wild yak’ are attested in documents from the Tibetan empire (Laws of hunting, PT 1071, 8<sup>th</sup> century CE), and have remained stable in most Tibetic languages (except isolated cases like Cone, see section 4.2). These etyma are not based on the words for taurine cattle (མཁའ་ *glan* ‘bull’, འ་ *ba* ‘cow’), and have been largely borrowed, either partially or as a full set, into neighboring languages (Mongolic, Buruskaski, Guizhong, Kho-Bwa). Genuine cognates of the Tibetan etyma for domestic yak are only found in Tamangic (<sup>\*</sup>Bhja: ‘male yak’, <sup>\*</sup>Bprit ‘female yak’; Mazaudon 1994), the closest relatives of Tibetic (Figure 2). The term རྩོད་ *broṅ* ‘wild yak’, on the other hand, has many extra-Tibetic cognates, discussed below.

The Tibetic-Tamangic etymon for ‘female yak’ itself is the probable source of the Sanskrit word *camarī* ‘female yak’ and its reflexes in modern Indic languages (such as Nepali *caumrī* ‘yak’), through a series of complex sound changes (Jacques 2016). This etymon has been also borrowed into Kho-Bwa languages as a general term for the animal, early enough to display the same sound correspondences as the noun ‘name’ (illustrated in Lieberherr and Bodt 2017).

Unlike Tibetic languages, whose common ancestor is attested as a written language, proto-Rgyalrongic is not an attested language, and can only be reconstructed by using the comparative method. The only ancient Rgyalrongic language, Tangut, only has one term for ‘yak’<sup>25</sup>, possibly a consequence of the migration of its speakers from North-West Sichuan into Ningxia and Shaanxi (Lai et al. 2020).

All Rgyalrongic languages other than Tangut have suppletive terms (Table 3), and present the phonetic correspondences expected from cognates: at least ‘male yak’, ‘female yak’ and ‘female yak-cattle hybrid’ are reconstructible to proto-Rgyalrongic.

Other domesticated mammals whose names are reconstructible to proto-Rgyalrongic include taurine cattle (two terms, see Table 3), sheep, goat, and pigs (Sagart et al. 2019). In addition, the reconstructibility of the verb ‘to herd’ (Japhug *lyḡ*, Situ *lék*, Khroskyabs *lôḡ*) confirms that the common ancestors of Rgyalrong-speaking peoples were familiar with cattle herding.

Outside of Rgyalrongic, the etymon for ‘female yak’ is attested with certainty only in Ersuic <sup>\*</sup>rA ‘yak’ (Yu, 2012, 73, 84).

By contrast, the etymon for ‘male yak’ (Zbu *qe<sup>n</sup>brú?*, Khroskyabs *ḡbrô*) has cognates outside of this subgroup. It seems to correspond to the word for ‘male yak’ in some Para-Rgyalrongic languages (notably Muya *ndzō*<sup>53</sup>), though this is difficult to prove in the absence of in-depth study of the historical phonology of these languages. It is also cognate to the unique etymon for ‘yak’ in Naish (Naxi *bəɿ*, Na *bɿɿ*, Laze *bɿɿ*, Proto-Naish <sup>\*</sup>bru; Jacques and Michaud 2011), to Xumi (formerly known as Shixing) <sup>HL</sup>bō (Chirkova 2009:17), Ersuic <sup>\*</sup>bu ‘male yak’ (Yu 2012:100), and to Tibetan རྩོད་ *broṅ* ‘wild yak’.

In addition, Burmese *pron* ‘gaur’ (*Bos gaurus*) is a likely cognate of this etymon. Given the fact that this etymon means ‘yak’ in both Tibetic and Rgyalrongic on the one hand, and that Rgyalrongic and Burmese



**Table 3** Cognate sets in Rgyalrongic languages.

	Cattle		Yak		Yak-Cattle hybrid	
	Male	Female	Male	Female	Male	Female
Japhug	mbala	nwɿa	qambruw	qra	jlɑ	ftsoɤ
Zbu	<sup>h</sup> boléʔ	ŋwéʔ	qe <sup>h</sup> brúʔ	q <sup>h</sup> ríʔ	ljéʔ	fts <sup>h</sup> óɤʔ
Tshobdun	<sup>h</sup> boléʔ	ŋê	qe <sup>h</sup> brúʔ	qrê	jlê	ftsɔ
Situ	baliê	nəŋjiê	kəmbɾu	karâ	təjliê	
Khroskyabs	bələ	ŋî	ɤbrô	q <sup>h</sup> ríʔ		vzəy
Stau				qrə		zə

are closer to each other than either it to Tibetan on the other hand (since they belong to the Burmo-Rgyalrongic branch, a clade supported by all phylogenetic studies, Zhang et al. 2019; Sagart et al. 2019; Zhang et al. 2020), Burmese has undergone a semantic shift from ‘yak’ to ‘gaur’ than the other way round, and the meaning ‘yak’ can be reconstructed back to the common ancestor of Tibetic and Rgyalrongic.

The Old Chinese term *mæw* 犛 (first attested in the text *Guoyu*, dating from the Warring states period, 475–221 BCE) is reconstructed as \*mr<sup>h</sup>u (in Baxter and Sagart’s 2014 system). This reconstructed form is compatible with the Rgyalrongic-Tibetic etymon, and could reflect a borrowing from a Rgyalrongic language after the loss of final \*-ŋ.

Two conclusions relevant to the question of yak domestication can be drawn from the evidence presented above.

First, one term for ‘yak’ is reconstructible to proto-Tibeto-Rgyalrongic (4847[3363–6429] BP; Sagart et al. 2019)<sup>6</sup>, without distinction between wild and domesticated animals, and between yaks and yak-cattle hybrids. This fact indicates familiarity with the animal but does not necessarily imply domestication.

Second, at least three etyma for male and female yak and F1 hybrids distinct from those of cattle, are reconstructible in proto-Rgyalrongic (3221 [2169–4319] BP; Sagart et al. 2019)<sup>7</sup>. Since all Rgyalrongic languages (except Tangu, whose migration is documented in historical records) are spoken in the Rngaba and Dkarmdzes districts of western Sichuan (see the map in Figure 1), the reconstructibility of these etyma entails that cross-breeding between taurine cattle and yak was already well-established in this part of the Eastern Tibetan Plateau before the

split of the Rgyalrongic subgroup three millennia ago.

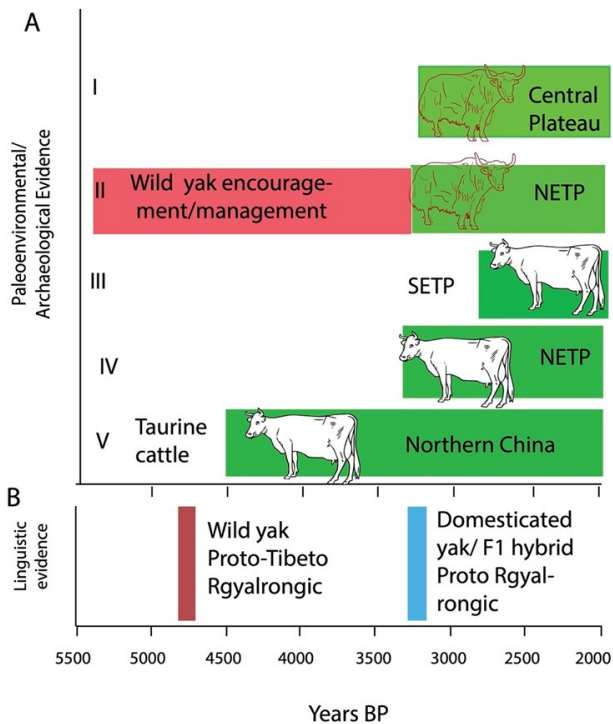
### Discussion

Our linguistic reconstruction indicates that domestication of yaks took place sometime after the split of Tibeto-Rgyalrongic (4847[3363–6429] BP), but before that of Rgyalrongic (3221 [2169–4319] BP), and that the domestication process possibly took place independently in two places, among the ancestors of Rgyalrongic and Tibetic, respectively.

The timing of yak domestication according to linguistic reconstructions appears to correspond to a period of time that postdates the introduction of taurine cattle to the Northwestern China and the margins of the Tibetan Plateau, as shown in Figure 3. Given the fact that the name for F1 hybrids is reconstructible to proto-Rgyalrongic, it is possible that the introduction of taurine cattle and contact with people who herded cattle may have inspired proto-Rgyalrongic speaking peoples to begin to herd, pen and carry out the more intensive type of management of this animal that led to its domestication. Hybridization of taurine cattle with yaks may have further conferred traits that further facilitated human management such as higher quality milk production, lower aggressivity and increased tolerance to human presence.

This hybridization process may have resulted from human intervention but could also have taken place between wild yaks and feral cattle, the resulting offspring being more amenable to human management.

Linguistic evidence further suggests that two yak domestication events may have taken place, one on the western Tibetan Plateau, associated with the ancestors of Tibetan speakers, and one on the eastern Plateau, associated with proto-Rgyalrongic speakers.



**Figure 3** Comparison of linguistic and archaeological evidence for yak domestication. Panel A indicates the archaeological and paleoenvironmental evidence for yak domestication and management. In lines I-II, the area in red indicates the period during which wild yak population growth may have been encouraged through anthropogenic burning. Areas in green indicate potentially domesticated yak. In lines III-V, areas in green indicate the introduction of taurine cattle. Panel B shows the hypothesized date at which terms for wild and domesticated yak are present.

This is unsurprising as Kham and Amdo contain some of the richest biomes for wild forage used by yaks and wild animals would likely have concentrated in this area. The large numbers of lower altitude river valleys which cross-cut this area also likely brought yaks into contact with farmers who had begun to fodder taurine cattle and other domesticates like sheep.

As this paper details, we are only beginning to learn about how humans first began to manage and eventually domesticate yaks. Future archaeological and genetic research will be important in testing the time frame that the linguistic evidence we presented in this paper suggests for this animal's domestication. Future aDNA work could help resolve the timing of when hybridization between yak and taurine cattle

first took place and the location of where such hybrids were first developed. In order to carry out this work, we require more systematic sampling of animal bones to take place at excavations on the Plateau. Since the male yak-cattle hybrids are sterile (Niayale et al. 2021), and only the female can have offspring, we would expect absence from introgression in the Y-chromosome (Medugorac et al. 2017). For this reason, aDNA sampling would need to be based on large samples to identify female individuals on which sampling could be carried out. Future zooarchaeological work could also help identify how humans managed the yaks that they began to domesticate. Do kill off profiles show strategies aimed primarily at meat or milk extraction (Vigne and Helmer 2007)? We hope that future research in this area will help resolve some of these issues.

### Notes

<sup>1</sup>In addition, yaks have been more recently introduced in other areas, including Yakutia and Ossetia, which are not represented here. This map is based on different sources depending on the countries: for Mongolia, the official statistics on yak population ([http://www.1212.mn/tables.aspx?TBL\\_ID=DT\\_NSO\\_1001\\_052V2](http://www.1212.mn/tables.aspx?TBL_ID=DT_NSO_1001_052V2)) were consulted, for China we used an important number of sources to ascertain the existence of yaks in various districts, cited in the supplementary document, and was used for other countries.

<sup>2</sup>The applicability of phylogenetic methods in historical linguistics is still controversial. However, while these three articles were based on three independent datasets, their results present a high degree of congruence.

<sup>3</sup>For editorial reasons, the complete dataset and the references cannot be shown here and are included in a supplementary document.

<sup>4</sup>This table does not include all Indo-Aryan and Mongolic languages spoken in yak-herding areas. The relevant data on Mongolic languages can be found in (Nugteren 2011:400, 532).

<sup>5</sup>Tangut 1195 k<sup>h</sup>ie 'yak' is cognate with the word meaning 'female yak' in other languages.

<sup>6</sup>This date reflects the covarion relaxed clock analysis; Sagart et al. (2019) obtained 5816 [5007–6715] BP and 5684 [4916–6449] BP in the Dollo and Covarion strict clock analyses for this branch, respectively. Other phylogenetics studies (Zhang et al. 2019; 2020) find less support for a Tibeto-Rgyalrongic branch. The

common ancestor of Rgyalrongic and Tibetic is thus slightly more ancient in their results.

<sup>7</sup>With other methods the dates obtained were 4026 [3430–4640] BP for Covarion strict clock and 3540 [3540–4063] for Dollo.

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