

Masaryk University

The development of the IEclusters *obstruent + t/s(d^h)*

[habilitation thesis]

Brno 2020

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Hereby I state myself the sole author of the presented thesis, I used only the quoted literature as listed below.

1 On IE obstruents, examined clusters and used methods

1.0 Introduction remarks

The purpose of the present study is to describe the development of a particular set of consonantal clusters in the Indo-European languages and, in hindsight, to shed some light both on its earlier phase (shared in various degrees by the various sub-branches of the IE language family) and on the main tendencies present in the development of given Indo-European branches.

The set of consonantal clusters we will study are two-consonantal clusters (with a few exceptions, mentioned as such in the following text, used from necessity given by the lack of more suitable data) formed either by an Indo-European obstruent (in the context of the present study, an obstruent will be any IE plosive and a sibilant) in the left position and by either by **t-* or **s-* or **d^h-* in the right position (the terms ‘right’ and ‘left’ are arbitrarily used to mark the mutual relative position within the speech act).

The method used is the principally traditional structural analysis of clusters of our interest, primarily those synchronically productive, secondarily those etymological (i.e., synchronically unanalysable and with structure revealed only through the etymological analysis). The analysis is based on the assumption that the phonemic alternation (indifferent if synchronic or diachronic) could reveal, in its nature, functions and relations otherwise invisible to the pure phonemic analysis in the way of simple registration of elements and their description; this is the reason why we use the term ‘structural analysis’ since we are focused on mutual relations between segments as much as on the segments themselves.

On the following lines of this chapter in we will bring forth the reconstructed set of IE obstruents, the classification of given consonantal classes and a few methodological remarks.

1.1 Indo-European obstruents

The set of the Indo-European obstruents consists of a single voiceless sibilant **s* (split in languages affected by the Pedersen’s Law/the *ruki-rule* into two sibilants – in such languages, we will deal with both sibilants independently) and a numerous set of plosives, their number differing according to the used models.

The main differences between given models of the plosive sets used could be classified according to the number of modal classes used and on local series; the main points of divergence

we will sum up on following lines to express reasons for the list of plosive phonemes we will be using below.

1.1.1 Indo-European plosives I: the modal classes

The classification of IE obstruents according to their modality is a matter of debate both of their number and phonemic nature. The models used could be classified thus:

- i. the **quaternary model**, containing the voiceless-nonaspirated, voiced-nonaspirated, voiceless aspirated and voiced aspirated classes, is, in fact, a projection of the Vedic system backwards in time, was first proposed by Curtius (1853), and became the standard model for another century, being used by influential grammarians, especially by Brugmann. Hirt (1927: 218–219, 224, 240–241; Hirt 1939: 161) followed the quaternary model, though considering the secondary origin of the voiceless aspirates (as proposed by ternary models). From later supporters we have to mention Hiersche (1964) and especially Szemerényi (1967: 84, 88–89; Szemerényi 1996: 54); Rasmussen (1987: 81–109 = 1998: 216–243), Elbourne (1998: 1–30; 2000: 2–28).
- ii. the **ternary model** has numerous variants, all having in common a denial of the Indo-European origin of the voiceless-nonaspirates (since de Saussure 1892: 118), for its classical form see especially Pedersen (1926: 48); Kuryłowicz (1927: 202–204; Kuryłowicz 1973: 68–69); Lehmann (1952: 99). From its variants, we could mention the one assuming that the voiced-aspirates were originally the voiced spirants (cf. Brücke 1856: 59–60; Walde 1897: 466; Prokosch 1918–1919; Prokosch 1939: 39–41; Hammerich 1967: 839–849). More popular are various glottal models, denying the traditional values of three modal classes in various degrees, cf. Pedersen 1951: 10–16; Andreev 1957: 7–8; Griffen 1989. Often variant are purely glottalic models such as those by Martinet (1953: 67–68); Gamkrelidze/Ivanov (1972: 15–18); Hopper (1973: 141–166); Kortlandt (1978b: 107–108; Kortlandt 1985); Huld (1984: 140); Collinge (1985: 259–269); Salmons (1993); Fallon (2002: 284–288, 317–318). An interesting variant replaces the voiced non-aspirated with an implosive, cf. Haider (1985); Kümmel (2012: 303–306); Brett Miller (2012: 95, 236–266).

Note: The **binary** model, using the simple opposition of the voice was introduced by Schleicher (1861¹: 136–137; 1866²: 162–163) as the first stage in the common development of the IE languages; even Schleicher assumes the later existence of the ternary model. Erhart (1956; Erhart 1982: 39) later brings a similar model of the two-stages development with a later split of the voiced class on two modal classes.

Within the frame of this study, we will use the traditional variant of the ternary model, since it satisfyingly fits our purposes, especially since we will deal with plosives in the neutralization positions, where the distinction between the modal classes is subjected to various alternations. As we will see below, the contrast between the voiceless and voiced non-aspirates is always neutralized (as often are the voiced aspirates), and the distinction between both non-aspirated plosives on one side and the voiced aspirate on the other side is relevant only in some contexts of our interest for the Indo-Iranian languages (the contexts of Bartholomae's law).

The phonetic properties of the reconstructed IE phonemes are always only better or worse approximatively due to their necessarily abstract nature, this being the result of the reconstruction, not of direct observation. As we saw above, the conventional modal classes are variously interpreted. The terms *voiceless non-aspirates*, *voiced non-aspirates* and *voiced aspirates* will be used on following lines, with approximate values given by the names (except with the third modal class where the phonetic nature as *voiced aspirate* could be successfully doubted, cf. Kümmel 2015: 293; we would prefer the values of *voiced spirants*, as mentioned above, but we will use both the traditional values and frame)¹. However, Jakobson (1958: 22–23) and Hopper (1973: 141) are wrong when arguing that two voiced plosives in a single triadic system are impossible (cf. Kümmel 2012: 294–295), as demonstrate the typological parallel of Madurese or Kelabit (Blust 2009: 174–175, 182; added could be probably even Bintulu).

Note: The existence of the IE voiceless-aspirates we cannot be merely rejected, but we can surely assume that if such modal class did exist, it was not proportional to other classes (cf. Šefčík 2012; Šefčík 2016), as it is in Indic (the Indic state is a secondary leveling of the system, as we will demonstrate below). It should be noted that OIA, where the voiceless aspirates are a singular class (unlike in other languages – Greek voiceless aspirates usually reflect the IE voiced-aspirates), they never enter the context we will examine below, hence clearly demonstrating their unusual position in the whole phonemic system.

1.1.2 Indo-European plosives II: the local series

The reconstruction of the dental and labial series is not in doubt (though the status of the IE phoneme **b* is often questioned, the reconstructed existence rest of labials is accepted). However, the number and phonetic realization of a reconstructed velar series is a matter of debate.

To sum up, there are the following approaches to the ‘guttural question’:

- i. the **monic model** reconstructs only three series: labial, dental and (plain) velar series. This type of model was first used by Schleicher (1861¹: 136–1379; Schleicher 1866²: 162–165), who presupposed that other velar series (the terminology used today was not used in his days) developed due to the set of processes he even tried to list. Schleicher’s model in the original form was abandoned in favour of either dyadic or triadic models; however, even later the monic model was considered as a working model for an earlier stage of development of guttural series, i.e. used as a predecessor of later models with more series, cf. Pedersen (1897: 192; Pedersen 1900: 292–300; Pedersen 1908: 354; 1 Pedersen 951: 3); Ribezzo (1903; Ribezzo 1922–1923; Ribezzo 1929); Hirt (1927: 234–236; Hirt 1939: 162); Sturtevant (1930); Specht (1944: 316–317); Safarewicz (1945: 37); Vaillant (1950: 25); Otrębski (1963: 11–15). To the possibilities of the palatalization and labialization of velars see Solta (1965), who adds typological parallels. The monic model is, as an earlier stage of the development of IE guttural system, presupposed later by Markey (1980) and Szemerényi

¹ Peeters (1971) prefers to reconstruct non-phonemic voice (development later in context with the later creation of voiceless aspirates). Peeters assumes the non-occlusive character of IE **Dʰ*, though he does not directly state the spirant value.

- (1996: 149), first via the split of plain velars and labiovelars, followed (in *satəm*-languages) by the phonemization of palatovelars and the subsequent delabialization of labiovelars².
- ii. the **dyadic centum-model** presupposes that system of guttural series we meet in *centum*-languages, is already traceable back to Indo-European and consequently, the *satəm*-language model is considered a later innovation. According to this model, the three guttural series model is a pure phantom given by a generalization and merging of two models in a single one, without any real existence. The first proponent of the dyadic *centum* model was Meillet (1893), later Hirt (1899; also Hirt 1927: 226f; 1939); Vaillant (1950: 25), Lehmann (1952: 8; Lehmann 1993: 100–102); Sihler (1995: 151–165). Generally, the *satəm*ization is considered a process similar in its nature to later palatalizations of velars (in Indo-Iranian, Slavic, Romance etc.), though the specification of its conditions is quite vague. This *satəm*ization lead to the split of original plain velar series into two, the palatovelars later (af)fricativized. Numerous authors pointed out that *satəm*-languages form a single innovation area (i.e. area of *satəm*ization)³, cf. József Schmidt (1912: 45); Sköld (1931, 56–79); Pisani (1961); Porzig (1954: 76); W. P. Schmid (1966: 11); Shields (1981: 210–211); Sihler (1995: 153); Schmitt-Brand (1998, 88–90). Burrows (1955: 72–73) considers *satəm*ization in the *satəm*-languages as the first stage of a general process of palatalization (‘first palatalization’), followed by a ‘second palatalization’ of velars (< original IE **K* and **K*^u), occurring independently in the *satəm* Balto-Slavic and Armenian (Burrows 1955: 76–77), similarly Sihler (1995: 154–155); Sims-Williams N. (2017: 268–270). To generalize the thesis: the original state of IE was with plain velars and labiovelar, and some of the plain velars became secondarily palatalized (except in some positions like before *r*, *a* or after *u*, *ū* etc.) in the future *satəm*-languages. With a new marker in work, the original labiovelars lost their labiality and merged with original IE plain velar.
- iii. the **dyadic satəm-model** mirrors the dyadic *centum*-model in presupposing that the three-valued model is a purely reconstructional phantom. The difference in the idea that the *satəm*-model (i.e. the model with distinguished palatovelars and plain velars) was the original model of IE since in this model, the labiovelar series is a secondary series, arising due to some process of labialization of plain velars (‘centumization’), resulting in the secondary split of plain velar series into two. It is worthy of mention that this model was originally accepted by Brugmann in the first edition of his *Grundriss* (Brugmann 1886), though it was later abandoned and replaced by the triadic model. However, similar ideas were later stated by authors like Joh. Schmidt (KZ 25, 1881: 134); Ribezzo (1903; 1922–23; 1929); József Schmidt (1912: 54) and Reichelt (1922: 40–81). Later the main proponent of this model was Kuryłowicz, who voiced his opinion repeatedly (Kuryłowicz 1956: 356–375; Kuryłowicz 1964: 12). The mechanism of centumization was described by Szemerényi as the result of simplification of **Ku* clusters (where *K* is any plain velar) (Szemerényi 1964: 401; Szemerényi 1996: 145–146); in this he follows Vaillant (1950: 171–173).
- iv. the **dyadic equipollent model** assumes that there were two marked series (i.e. the labiovelar and the palatovelar series) and that the plain velar series, which are reconstructed for IE in an only very limited number (note that absolutely higher number of plain series in attested IE languages is given by the merging of one of marked guttural series with plain velar series, not inherited from IE), were not present in reconstructed Indo-European. As a proponent of this model, we can list Meillet (1893; Meillet 1934: 91–95), since in his model, plain velar is just an allophone of palatovelar and hence the phoneme is palatovelar in opposition to

² That the palatovelars must be arisen before the merging of plain velars and labiovelars is clear from the fact that there are no palatovelars arisen from original labiovelars since both sets of gutturals are clearly and strictly distinguished.

³ Less probably is the idea supported by Georgiev (1937: 124; 1966: 46) and Abaev (1965: 140f.), who suppose the independent process of *satəm*ization in given IE languages.

labiovelar. Steensland (1973, cf. especially 96–127) presupposes two series, marked in a purely algebraic way as *KA* and *KB*, the first of them developing in palatovelar series in the *satəm*-languages and plain velars in the *centum*-languages, the second of them developing into labiovelar series in the *centum*-languages and plain velars in the *satəm*-languages; plain velars are then a result of neutralization of one of his series. A very similar model was developed by Kortlandt (1978a; Kortlandt 1994a: 2–3) and Woodhouse (1998; 2000), who advances the opposition between prevelars and backvelars. Even Beekes (2011: 124–126), who otherwise reconstructed three guttural series, seems to tend to accept the opinion that plain velars were just positional allophones either of palatovelars or labiovelars (cf. Cavoto 2001: 51).

- v. the **triadic model** assumes the original existence of all three velar series and was first introduced by Bezenberger (Bezenberger 1890), named by von Bradke (1890) and accepted by Brugmann (1897) (both by the second edition of his great comparative grammar and also by his concise grammar). Since that time, this model has been used by many authors; for example by Szemerényi (1990: 71). This model became a widely accepted standard, having the advantage of covering all possible guttural series. However, it could still contain a reconstructional error since the possibility of reconstructing three guttural series does not necessarily mean that the system with three series ever existed at the same time (cf. Sihler 1995: 154). This traditional model is accepted by Allen (1978); Tischler (1990: 93–94); Kapović (2017: 14–15, 21–28). The fact that attested Indo-European languages have only two guttural series⁴, led Burrows (1955: 75–76), Kuryłowicz (1956: 356; Kuryłowicz 1973: 64); Meillet (1893: 278); Lehmann (1952: 100), Bernabé Pajares (1971: 84) and others to state that the triadic model is therefore impossible, but since there are external parallels in the Northern Caucasian and other languages, it is hardly possible to say that the system of three guttural series is impossible from the typological point of view, and we will demonstrate that some version of it even exists in Indo-European language. A slightly modified statement is that by Cavoto (2001: 51), who namely considers three phonetically distinct guttural series, but only two phonemic series for IE (cf. Beekes 2011: 126, too). A very similar statement was already earlier made by Safarewicz (1945: 37). Speaking about the triadic system, we have to mention the variants given by Huld (1986; 1997) and by Kümmel (2007: 310–327), working with the triad with traditional labiovelars, but where traditional palatalovelars are plain velars (hence there is no depalatalization in the *centum*-languages, but there is a palatalization in the *satəm*-languages), and traditional plain velars are uvulars (de-uvularized in both branches) (cf. also Huld 1986: 144–147; Huld 1997; Woodhouse 1998). Lipp (2009a, especially: 5–19) postulates two stages system, similar to that by Szemerényi (1996: 60–61), with an original distinction between plain- and labiovelars, but with a later split of palatovelars from the plain velars in languages which later became the *satəm*-languages; the *satəm*ization as a first step in the general development of palatalization (cf. two stages of palatalization in Burrows 1955: 72–73).

The aforementioned lack of the whole triadic system in attested IE languages led numerous authors to raise grave objections against the triadic system (cf. Meillet 1893: 278; Lehmann 1952: 100; Burrows 1955: 75; Kuryłowicz 1956: 356; Kuryłowicz 1973: 64 as examples). However the traces of a triadic system were stated to be found in Albanian, since Pre-Albanian labiovelars **k^h* and **g^h* (< IE **g^h*, **g^h*) were later palatalized to Albanian *s*, *z* before the palatal

⁴ The question of preserving at least of traces of three guttural series in IE we will deal with below.

vowel but merged with plain velars in other positions and hence giving, as plain velars, *k and *g (< IE *g, *g^h); cf. Alb. *sjell* ‘to bring’ < IE *√k^uelH₁- but Alb. *pjek* ‘to bake’ < IE *√pek^u-; Alb. *zorrë* ‘gut’ < IE *√g^{hu}ērn- but Alb. *djeg* ‘to burn’ < IE *√d^heg^{uh}-. Moreover, since Albanian is a *satəm*-language (IE palatovelar *k developed into Alb. *th*, the IE palatovelars *g, g^h merged into Albanian *dh*), Albanian preserved traces of the original triadic system. The first proponent of this theory was already Pedersen (1900a), similarly Jokl (1937), Huld (1984: 144; Huld 1997); Rusakov (2017: 569–571); for the opposing points of view cf. Ölberg (1976), Kortlandt (1980a), Orël (2000: 66–74).

A similar development was stated for Armenian, in which, again, the IE voiceless labiovelar⁵ was in some cases palatalized before the merging of labiovelars and plain velars (cf. Stempel 1994; Kortlandt 1980; Kümmel 2007: 311; Olsen 2017: 426–428; for data see at least Schmitt 2007: 62–65): IE *√k^{ér}di- > Arm. *sirt* ‘heart’; IE *√k^{ér}-ō > Arm. *kerem* ‘I scratch’; IE *√k^uet(y)ores > Arm. *čork* ‘four’. A contrary view that the distinction between original labiovelars and plain velars is secondary and accidental is held by Kortlandt (1975), Beekes (2003: 176–179) and Martirosyan (2010: 711), who consider the palatalization as regular for both original labiovelars and plain velars, the regularity of this process later being disrupted by the excessive analogy.

Note: A model of three velars series was proposed for Luvo-Lycian by Melchert (1987: 182–204; Melchert 1994: 251–256)⁶ but was later distinctly decreased by Melchert himself (Melchert 2012: 206–218), not being unconditioned, but having conditioned palatalization of original palatovelars (but not plain velars) before front vowels, *i* and *y* (the phenomenon seems to be proved for voiceless palatovelars, but not fully affirmed for voiced palatovelars); cf. Cuneiform Luv. *ziyari*, Lyc. *sijēni* ‘lies’ < IE *√k^{ēsā}īe- vs Cuneiform Luv. *kišā(i)*- ‘to comb’ < IE *√k^{ēs}- vs Cuneiform Luv. *kui*-, Lyc. *ti* ‘who’ < IE *√k^ui-. In contrast, the traces of three guttural series in Phrygian are assumed by Woodhouse (2005) as the result of the further development of the original IE dyadic two-valued model, based originally on front velar and back velar (in this respect he is following Steensland 1973: 96–107; Kortlandt 1978a: 237; see above).

Other traces of the original existence of the labiovelars in the future *satəm*-languages are considered to be found in original reduced grades such as OIA *guru*- ‘heavy’ and *gūrta*- ‘welcome’, similarly in OCS *gъnati* (cf. *ženq* ‘propel, drive, chase’) from IE *√g^{uh}en- (cf. Burrows 1957; Pisani 1961; Mayrhofer 1986: 104–105).

The striking phenomenon of the *satəm*-languages, especially present in Balto-Slavic, but traceable in Indo-Iranian, too, is the existence of parallel roots with plain velar or original

⁵ Surprisingly, this change did not affect IE *g^u.

⁶ Melchert (1987: 204) mentions an independent statement made by Warren Cowgill in his unpublished manuscript from the early seventies, though based on less evidence (which was probably the reason why the paper was never published). For another independent statement on the preservation of the IE triadic system in Luwian, see Morpurgo Davies/Hawkins (1988: 169–182).

palatovelar, not caused by any noticeable first-hand alternation-trigger, cf. OIA \sqrt{klam} - ‘be tired’ vs \sqrt{slam} - ‘be tired’; OIA \sqrt{ruc} - ‘shine’ vs $\sqrt{ru\acute{s}ant}$ - ‘be bright’; OIA \sqrt{sruc} - ‘hear’, OCS *slyšati* ‘hear’ vs Lith. *klausyti* ‘hear’; Lith. *pekus* ‘domestic animal’ vs OIA *paśu-* ‘cattle’; OIA *śvaśura-* ‘father-in-law’ vs OCS *svekrъ* ‘father-in-law’; OIA *aśman-* ‘stone’, Lith. *aśmuō*, Latv. *asmens* ‘sharpness’ vs Lith. *akmuō*, Latv. *akmens*, OCS *kamy* ‘stone’ etc. (cf. Hirt 1927: 238–241; Vaillant 1950: 171–173; Burrows 1955: 75–76; Steensland 1972: 102–104; Čekman 1974; Allen 1978: 103; Shields 1981: 210–211; Mayrhofer 1986: 105–106; Szemerényi 1996: 146; Lipp 2009a: 5–98; Kapović 2017: 26–27; Young 2017: 497).

To the phonemic status of given velars: the labiovelars were determined as such⁷ at least since Zupitza (1896: 1–2). Sköld doubted the monophonemic value of labiovelars (Sköld 1924: 128; similarly Whatmough 1937: 52–56) and preferred the double articulated labial-velar plosives (i.e. as Ewe \overline{kp} , \overline{gb}), Salmons and Smith (2005) returned to the monophonemic status of (voiced) labiovelars, independently confirming it. Palatovelars are not attested as such in a single *satəm*-language (here we usually meet sibilants or affricates); their phonetic value is then a reconstruction⁸.

We will use the two-stages triadic model based on Lipp (2009a: 5–19), assuming the older distinction between the plain velar (unmarked) and the labiovelar (marked series). This model was replaced in the area of the later *satəm*-languages by the classical triadic model (this explains why there are traces of the old labiovelar vs plain velar distinction in the *satəm*-languages, but not the traces of the palatovelars in the *centum*-languages). However, it is highly probable that the ‘palatovelars’ were affricates at the same time, not true palatovelar plosives.⁹ With such massive remodelling, the primordial distinction between old labiovelars and plain velars was neutralized in all positions, resulting in a merging of both guttural series (similar processes are known from the *centum*-languages, e.g. *k*-Celtic, Tocharian, later Germanic languages).

⁷ Similar sounds are present in North-Caucasian, the Suto-Chuana subgroup of Bantu languages and Salish languages.

⁸ Again, palatovelars as such are attested in Ubykh and other North-Caucasian languages.

⁹ However, the classical triadic system has typological parallels in some non-Indo-European languages, especially in North-Caucasian; we should mention especially recently extinct Ubykh or in Abaza and Abkhaz. Edel’man (1973: 540–546) demonstrated that the guttural system based on three series (plain, palatalized, labialized) is attested in Yazghulami, an East Iranian dialect in the North Pamir, and it should be noted that this system is not a directly inheritance from IE, but secondarily created. It is worthy of mention that Yazghulani has not only three guttural series, but a plain uvular and labialized uvular series, too. Ossetian has a pair of guttural and uvular series in opposition plain vs labialized, too, again independently developed, not inherited from IE. That the triadic system of related series could exist, is demonstrated in OIA in Šefčík 2012.

However, for simplicity, we will use the traditional marking for the palatovelars, as we do for other reconstructed Indo-European phonemes.

1.1.3 Indo-European obstruents: the list

Considering the issues as mentioned above, the set of Indo-European obstruents we work with is then the seemingly conventional set (including the *ruki*-sibilant *š), we can put as follows:

	plosives			sibilant
labiovelars:	k ^ʷ	g ^ʷ	g ^{ʷh}	
plain velars:	k	g	g ^h	
palatovelars:	k̑	g̑	g̑ ^h	(š)
dentals:	t	d	d ^h	s
labials:	p	b	b ^h	

This model does not probably reflect any actual state in the development of the Common Indo-European but serves as a panchronic working model (as we have already mentioned above, the guttural triad was limited to future *satəm*-languages and palatovelars were probably not phonetic palatovelar plosives, and we have to repeat that the modal values are probably simplified, etc.). For panchronic reasons, the *ruki*-palatal š is included in the list, though never reconstructable outside the *satəm*-area and even so it's existence is questionable for Pre-Albanian and Pre-Armenian).

1.2 Segments and contexts

The focus of our study is clusters of IE obstruents in three different contexts.

The obstruent segments (i.e., the left part) of clusters could be split into the following blocks:

- i. the **central** block¹⁰ containing IE dentals (phonetically could also be realized as alveovelars in some of the languages) and palatovelars (in the *satəm*-languages only);
- ii. the **peripheral** block¹¹ containing IE labials, plain velars and labiovelar series (in the *centum*-languages only);
- iii. the **sibilant** block¹² containing the old IE sibilant *s, the most *satəm*-languages have a secondary sibilant *š, arising due to Pedersen's Law/the *ruki*-law.

Similarly, the context (i.e., the right part) of clusters could be classified as:

- i. the context of *t-, causing the devoicing and deaspiration of the left obstruent in all Indo-European languages; the exception is languages with Bartholomae's Law;

¹⁰ In terms of Jakobson / Halle (1956: 31), we can term it an *acute* block.

¹¹ Using the terminology of Jakobson/Halle again, the block could be termed a *grave* block.

¹² This block is defined, as we see, not by its localization, but its sonority.

- ii. the context of **d^h-*; causing the voicing and deaspiration of the left obstruent in languages where the voicing is preserved (here especially in Indo-European);
- iii. the context of **s-*;¹³ also causing the devoicing and deaspiration of the left obstruent; again; these clusters could be affected by Bartholomae's Law, the feature well preserved in Iranian only.

1.3 On trajectories of the development in general

The development from the Indo-European stage to a given language stage is the transformation between two (or more) states-of-arts; each state is a set of elements.

Within this analysis, we generally distinguish at least three stages of the development from the input Indo-European into a given output language:

- i. the (Late) *Indo-European stage*, the initial state, arrived at by reconstruction;
- ii. the *intermediate stage*, the transitional stage (or, more appropriately, a set of sub-stages) between Indo-European and an output language;
- iii. the *given language stage*, the actually attested language¹⁴.

The *Indo-European-stage* and the *given-language-stage* are hence both *termini* of the whole complex of the development processes, and both serve either as an *input* or respectively *output* of the complex transformation of the reconstructed Indo-European phonemic system into a given phonemic system. This transformation, concerning the processes involved, could be described more appropriately as a set of minor transformations, not as a single giant transformation of its own.

Note that the input (i.e., the *Indo-European-stage*) is a result of *reconstruction*, but the output is actual language matter, recorded as a hard fact. Both are fixed sets objects, though results of a different approach (output is simply observed, the input is reconstructed).

The *intermediate-stage* (or stages) is, on the contrary, a set of *trajectories* between the input and the output and hence a matter of more or less analytic nature.

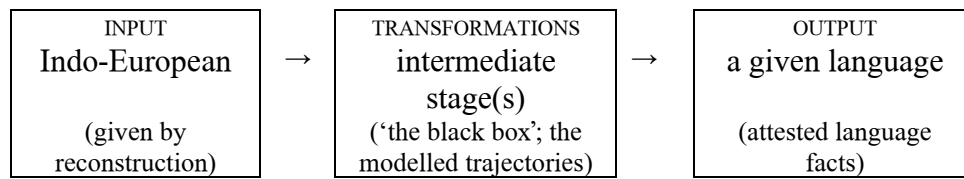
It is a paradox that often the reconstructed stage (the input) can be quite securely reconstructed without a more profound analysis, e.g. the merging of both voiced modal classes of plosives in Iranian, Balto-Slavic, etc., since it can be based on a simple observation.

The *intermediate stage* is based both on a comparative reconstruction and an internal reconstruction and in this very aspect the *intermediate-stage* is a kind of *black box* since we do

¹³ In some context realized as **š-*; the distribution, in this case, is affected by the left phoneme in the cluster, i.e., by the Pedersen's Law/*ruki*-rule; securely attested in Indo-Iranian and Balto-Slavic);

¹⁴ At this moment, we leave aside the often insecure knowledge of the phonetic realization (cf. the phonetic nature of the 'tau gallicum', the value of Hittite plosives, etc.).

not see immediately what is inside, but we project the possible trajectories in it and choose that which fits most the known data both of the input and the output.



When speaking about the trajectory from the input to the output, there are often multiple ways of plotting the trajectory, i.e., there could be competing scenarios, though leading from the same input towards the same outcome, as we will see on the examples of the development of various clusters below (a typical case is the development of the peripheral clusters + *t/s*- in Pre-Slavic).

Note: On the following lines, the terms ‘major’ and ‘minor’ developments will be sometimes used. A minor development is a development which in its results differs from the expected *lautgesetzlich* development according to a given known sound law but falls with a possible range of outputs, though the precise reasons for this special development are not clear (otherwise they would fit within a defined sound law).

1.4 On language material and its analysis

The focus of the present analysis is on clusters of Indo-European obstruents (in a sense described above) + **t/s*- clusters. The reason we have picked these clusters is obvious and apparent: formations of these two types are very numerous and well-attested, and the observation of their function could be applied, in the basic features, to all other clusters formed by voiceless obstruents.

The clusters of the same obstruents with **d^h*- were used only with languages with extensive and productive use of this kind of formation, namely in Indo-Iranian (here especially since the comparison of the *d^h*-context clusters are important due to Bartholomae’s Law and subsequently for the *t*-context clusters), Baltic (more to illustrate the situation outside of Indo-Iranian) and Greek (besides the purely illustrative use, it was important to demonstrate the **d^h*-context clusters after the phonemic revaluating of voice and subsequent remodelling of whole **d^h*-context clusters in Greek). Again, the function of the **d^h*-context clusters can be applied and generalized to other IE voiced aspirated contexts, namely to IE **b^h*-context.

The reader will notice that a natural complement to the present study could be the ‘thorn’-question, which was deliberately and willingly omitted, since the sheer number of examples would increase the number of pages required – the author of the present lines could only recommend comprehensive study by Lipp (2009b – covering 350 print pages!).

The work on this analysis was made possible due to preceding important works, quoted in the lines below. Especially worthy of mention are authors of LIV (the second edition of it was used), the more so since our focus was mainly on the productive verbal formations, NIL (used when verbal data were not sufficient) and of various quoted etymological dictionaries of given languages (often of the Leiden origin) but also with the use of the classical works like Pokorny (IEW). Of valuable help were lists of OIA verbal forms by Whitney (1885) and MacDonell (1916), the list of the Avestan verbal forms by Kellens (1984) and the list of Tocharian verbal forms by Malzahn (2010). From monographs at least few of many should be noted in alphabetic order: Görtzen (1998), Hill (2003), Kümmel (2007) and two-part monumental volume by Lipp (2009a; 2009b). To the quoted literature, we should attribute all the positive sides of the present works; all mistakes are fully the author's alone.

The analysis is segmented in accordance with given branches of the IE languages, represented either by a single language (Old Church Slavonic for the whole Slavic family, Gothic for the whole Germanic) or more languages (OIA, Avestan, Persian and Nūrīstānī represent the Indo-Iranian branch; Italic languages are represented by both by Latin and Sabellian languages) if the data they bring are substantially and significantly different (the aforementioned Italic languages differ in their development of the peripheral series, Indo-Iranian languages substantially differ in the development of all local series). The ordering of the given branches is not accidental – first, we will follow the *satəm*-languages, followed by the *centum*-languages and finally by two peripheral (technically *centum*) languages with a remarkable difference in the development of the clusters of *dental* plosive + **t/s* (Hittite for Anatolian languages, and Tocharian). Each chapter on a given branch/language is then written as an independent study, both for convenience of the reader and for the simplicity of the present treatise as a whole.

Chapters 2–12 hidden

13 The development of the two-obstruent clusters in the Indo-European languages: the summary and conclusions

The processes affecting the development of clusters of *obstruent + t/d^h/s* in various Indo-European sub-branches could be classified as:

- i. the *shared*-processes, i.e. the processes in similar contexts, of the same origin (e.g., the Common Indo-European first phase of the development of the *dental + t/d^h/s* clusters; another example is the earliest phase of the development of the *palatovelar + t/d^h/s* clusters in the *satəm*-languages; the third example is the old neutralization of labiovelars in the context of *+ t/d^h/s*, securely attested at least in some of the *centum*-languages);
- ii. the *drift*-processes, i.e. parallel processes in similar contexts, independently caused (e.g., the spirantization of the peripheral series in Iranian, Celtic, Sabellian, Slavic);
- iii. the *zero*-processes; i.e. the retention of the original state (e.g., the preservation of the peripheral series in Latin, Greek, Vedic, Baltic). *Zero*-processes seems to be trivial, but we have to remember that the preservation of a state is as important as a change of it, especially in comparison. The *zero*-processes has to be distinguished from *re-archaization* processes (as is the restitution of a plosive in clusters of *dental + t/s/d^h-* in Indic).

In the following lines, we will list the known outcomes of the IE clusters in given daughter languages and branches and then sketch up possible trajectories. The boldly marked outcomes are attested; the lightly marked outcomes are constructs. Analogous forms are listed, but not included in the trajectories graphs.

13.1 The development of the central series

There are two developments of the central series: the shared development of the dental series, present in some form in all Indo-European languages, with the seemingly (and false) exception of Indo-Aryan; and the shared development, limited to the *satəm*-languages, of the palatovelar series.

A similarity in the development of both series is striking since both series, however, with original plosive inputs, usually have sibilant outcomes (Hittite and Tocharian being remarkable exceptions with affricate outcomes of the IE cluster **Tt*, Nūristānī and Armenian with a zero outcome for the same cluster, Albanian with a zero outcome both for the IE **Tt*, but also for IE **Kt*).

For the development of both central series we can draw two possible trajectories through the ‘black box’, which could be summed under terms of the *affricativization* trajectory and the *spirantization trajectory*.

13.1.1 The development of central series I: the dental series

The singular development of the IE cluster **Tt*, common to all sub-branches of Indo-European languages, is the development of the dental series.

Note: Surprisingly, Kümmel (2007: 349–350) gives a shortlist of shared IE consonantal developments without at least the first phase of the development of the dental series, but deals with the whole process with as a series of later developments in each of the IE sub-branches (Kümmel 2007: 350–411).

This development has the following outcomes:

- i. IE *Tt** > *t^st^(s)*, attested in Anatolian and Tocharian;
- ii. IE *Tt** > *tt*, attested in Old Indo-Aryan (and probably attested in Nūristānī);
- iii. IE *Tt** > *st*, attested in Iranian, Greek, Balto-Slavic;
- iv. IE *Tt** > *ss*, attested in Italic, Celtic¹⁵ and Germanic;
- v. IE *Tt** > *ut*, attested in Armenian;
- vi. IE *Tt** > *c*, attested Albanian;

The Albanian outcome could not be the result either of an older *st*-outcome (Balto-Slavic/Iranian/Greek style) since IE **st* is realized as Albanian *št* nor could it be a result of the Italic/Celtic/Germanic **ss*-outcome, since the outcome of the IE **ss* in Albanian is *oš* (as it is of the IE **Ts*). The most probable predecessor of IE **Tt* in the earlier stages of the Albanian development was probably an affricate (Anatolian/Tocharian style) or a fricative (assumed as on older stage for all developments outside the Anatolian/Tocharian model).

The Armenian outcome could not be attributed directly to one of the four types mentioned above either, since the stage **st* is impossible, since the IE **st* cluster is fully preserved and if this cluster merged with that of IE **Tt*, the outcome would be the very same. Moreover, the **ss* outcome for **Tt* is also impossible since IE **ss* is realized as Arm. *Os*.

The development of the cluster of dental plosive + *s* in various IE branches can be listed as:

- i. IE **Ts* > *ts*, attested Old Indo-Iranian, Hittite and Tocharian;
- ii. IE **Ts* > *Os*, attested in Avestan, Baltic, Slavic, Greek and Albanian;¹⁶
- iii. IE **Ts* > *ss*, attested in Italic, Celtic (the Gaulish *đđ* being its variant) and Germanic;
- iv. IE **Ts* > *t^s*, attested in Nūristānī;
- v. IE **Ts* > *c*´, attested in Armenian;

The Hittite and Tocharian developments are securely archaic, preserving the older state. The Indo-Aryan development can not be detached from the Iranian – we have all the reasons to assume that both branches had a shared development, from which we have to model both

¹⁵ The Gallic outcome *đđ* (of the insecure phonetic value) alternates with *ss* and is considered both a variant and a predecessor of the *ss* outcome.

¹⁶ In Albanian, the outcome is *oš*, due to later palatalization of the sibilant.

trajectories; therefore the preservation of the older state (as in Hittite and Tocharian) is then impossible for Indo-Aryan. We assume the spirantization of *T* before *s* not only for Indo-Iranian but for all IE languages (outside Hittite and Tocharian); the Indic outcome is the later re-archaization, while the Iranian state is a progressive outcome, resulting from the merging of the dental spirant with a sibilant. All other languages with *Os* outcomes followed the same trajectory.

The development of the clusters of *dental plosive + d^h* can be securely reconstructed in a few languages, and we have to highlight that the outcome is **always** given by the voicedness of these right contexts, even in Greek, where the IE **d^h* was devoiced, and subsequently, the clusters were analogically remodelled. The outcomes in Indo-Iranian, Greek and Baltic are:

- i. IE **Td^h* > *dd^h*, attested in Old Indo-Aryan as the *major* outcome;
- ii. IE **Td^h* > *zd*, attested in Iranian and Baltic as a regular outcome, in OIA in the form of *Od^h* as the *minor* outcome;
- iii. IE **Td^h* > *st^h*, attested in Greek;

The traditional **affricativization trajectory**, first formulated by Kräuter (1977: 88)¹⁷, evaluated by Verner (1878: 341–342) and popularized by Brugmann (1880 and *passim*) is usually assumed for the whole development, which can be modelled for first four outcomes as follows: with a sibilantization of the left plosive (= the loss of the plosive segment of the affricate), with a loss of the sibilant segment (= re-archaization) or with a further affrication of the whole cluster and its simplification of sibilants:

$$\begin{array}{l} Tt > tt > \mathbf{t^st} > \mathbf{st} \\ > \mathbf{tt} \\ > \mathbf{t^st^s} > \mathbf{ss} \end{array}$$

Note: Both the Armenian and Albanian outcomes could hardly be put within the affricativization trajectory, hence we do not dare to propose any trajectories of their developments.

The great advantage of the affricativization trajectory is the attested preservation of affricates in Hittite and Tocharian (exceptions in Tocharian could be explained as a further development along the very same trajectory). What is problematic is application for the development of Armenian, which could not be attached to the affricate stage, to a sibilant or to the double sibilant stage. Similarly we might be tempted to attach the Albanian outcome to the double-sibilant outcome, but the Albanian outcome of *Tt* is different from that of *Ts* and *ss*, hence impossible. That the Indo-Aryan outcome is re-archaized is supported by the fact that the IE cluster **ss* is realized in OIA usually as *ts*, which demonstrated that outcomes of IE **Tt* and **ss*

¹⁷ Also Verner (1878: 341–342).

were merged in some point of development. Italo-Celtic-Germanic development is the result of a similar trajectory.

Note: A specific development of the final $-d^h$, affected by Bartholomae's Law, is known from Indo-Iranian. The trajectory would be modelled, according to the affricativization strategy, as:

$$d^ht > d^zd^h > \mathbf{dd}^h \\ > \mathbf{zd}^{(h)}$$

The affricativization trajectory for the development of IE clusters of $*Ts$ was reconstructed fully only by Lipp (Lipp 2009a: 169) for the Indo-Iranian languages. It is remarkable that both languages with affricate outcomes of the $*Tt$ cluster (Hittite and Tocharian) do not show any trace of the more complex developments attested in languages **without** the attested affricativization of $*Tt$ clusters. The Hittite/Tocharian development could be either an archaic feature or a simplification of the affricate back to ts by the loss of one of the sibilants. We can also consider Indic, Nūristānī and Armenian outcomes as archaic (or re-archaized) (here with later aspiration).

$$Ts > \mathbf{ts} \\ > t^s > \mathbf{ss} > \mathbf{0s} \\ > \mathbf{ts} (?)$$

The affricativization trajectory assumes affricativization, followed in OIA by re-plosivation, and by a sibilantization in other languages (and the same process is the minor process in OIA, the loss of a voiced sibilant allophone is known from proper sibilants in the same context, cf. below). The Greek trajectory is affected by analogy remodelling, hence omitted:

$$Td^h > d^zd^h > \mathbf{dd}^h \\ > \mathbf{zd}^{(h)} > \mathbf{0d}^h$$

The **spirantization trajectory** was independently brought forward for Italic by de Saussure (1877), independently by Cocchia (1883: 16–58)¹⁸ and Bartholomae (1887: 83; Bartholomae 1895: 16), followed by Leumann (1942: 13) and Morgenstierne (1942: 80; for Iranian only). Applying this trajectory to the development of the IE cluster of *plosive + t*, the trajectories for the *st*-group (Iranian, Greek, Balto-Slavic), Indic and the *ss*-group (Celts-Italic-Germanic) could be modelled as:

¹⁸ And we have to remark that his idea was dismissed by Brugmann (1885: 183).

$$\begin{aligned} Td^h &> \delta d^h > \mathbf{dd}^h \\ &> zd^{(h)} > \mathbf{0d}^h \end{aligned}$$

Note: Principally the same development is valid for the development of IE clusters of $*d^h d^h$ into Indo-Iranian.

To sum up: there are two languages with affricate outcomes both for the $*Tt$ and $*Ts$ clusters, namely Hittite and Tocharian, both being peripheral languages, and there is no other possible trajectory for both languages than the affricativization trajectory. On the other hand, for all other languages the spirantization trajectory is more probable, since especially the development of the $*Ts > (s)s$ excludes the possibility of affricativization (the intermediate $*t^s s$ could be easily simplified on t^s but we have full sibilant outcomes). Affricativization development is wholly impossible for Indic: if we accepted affricativization development both for the dental and the palatovelar series, it would be impossible for the assumed ($*Tt >$) $t^s t$ ($>$ Indic tt) to lose the plosive segment and the parallel and contemporary (since both processes are operating after the split of the Indo-Iranian languages) ($*\acute{K}t >$) $t^{\acute{s}} t$ ($>$ Indic $\acute{s}t$) would lose the fricative segment of the affricate – this paradox is not present within the spirantization trajectory.

The spirantization trajectory also makes it easier to explain Italic-Celtic-Germanic ss -outcome; the merging of the IE $*Ts$ and $*ss$ in a single θs output also explains why the Indic outcome of the $*ss$ is surprisingly ts (and of $*\acute{s}s$ is $k\acute{s}$), which is otherwise a solitary and isolated process.

However, the distinction between the affricativization and the spirantization trajectory is not as wide as it could see: both fell within the same frame of fricativization, and while the affricativization presumes the insertion of the fricative segment into a given cluster, the spirantization presumes the fricativization of the already existing segment. Both peripheral languages (Tocharian and Hittite) used the affricativization variant of the fricativization trajectory, but all other languages used the spirantization variant of the same trajectory.

13.1.2 The development of the central series II: the palatovelar series

The development of the IE clusters of $*\acute{K}t$ into given *satəm*-languages usually has an outcome in the form of a sibilant (either palatal or non-palatal) + t . The single exception is Albanian, where the outcome is $0t$:

- i. IE $\acute{K}t^*$ $>$ $\acute{s}t$, attested in Iranian, Lithuanian;
- ii. IE $\acute{K}t^*$ $>$ $\acute{s}t$, attested in Indo-Aryan and Nūristānī; the geographical variant of the preceding development;
- iii. IE $\acute{K}t^*$ $>$ st , attested in Slavic and Armenian;
- iv. IE $\acute{K}t^*$ $>$ $0t$, attested in Albanian;
- (v. IE $\acute{K}t^*$ $>$ kt , attested in the *centum*-languages).

The development of the cluster of *palatovelar* + *s* in various IE branches can be listed as:

- i. IE **ǵs* > *kʰs*, attested Old Indo-Iranian;
- ii. IE **ǵs* > *oš*, attested in Avestan, Lithuanian and Albanian;¹⁹
- iii. IE **ǵs* > *os*, attested in Slavic;
- iv. IE **ǵs* > *tʰ*, attested in Nūristānī; the outcome *č*, attested in Armenian, is a variant;
- v. IE **Ks* > *oš*, attested in the *centum*-languages)

The **affricativization strategy** assumes the affricativization of the original palatovelar in the *satəm*-languages, and its later sibilantization (in Indo-Iranian, Armenian and Balto-Slavic).²⁰

$$\begin{aligned} \acute{K}t > t^{\acute{s}}t > \acute{s}t > st \\ > \acute{s}t \end{aligned}$$

Note: Bartholomae's cluster of **ǵ^ht*, according to the affricativization trajectory, can be modelled as follows both for Indic (*ǰd^h*) and Iranian (*žd*):

$$\begin{aligned} g^ht > jd^h > žd^h > z^d^h > \acute{jd}^h \\ > \acute{žd} \end{aligned}$$

The development for the cluster of **ǵs* in the *satəm*-languages within the affricativization trajectory can be modelled as follows (with affricativization, sibilantization, simplification for Iranian, Lithuanian and Albanian with depalatalization for Slavic; with de-affricativization and location shift for Indic; with the later aspiration of the affricate in Armenian; a simplified affricate is attested in Nūristānī):

$$\begin{aligned} \acute{K}s > t^{\acute{s}}s > \acute{s}\acute{s} > \mathbf{0}\acute{s} > \mathbf{0}s \\ > t\acute{s} > \mathbf{k}\acute{s} \\ > \mathbf{ts} > \mathbf{c}^{(i)} \end{aligned}$$

Note: Bartholomae's cluster of **ǵ^hs*, the affricate model is (the Indic outcome is due to the analogy):

$$\begin{aligned} g^hs > j\acute{z}^h > d\acute{z}^h > d\acute{z} & (\rightarrow \mathbf{k}\acute{s}) \\ > \acute{z}\acute{z}^h > \acute{z}\acute{z} > \mathbf{0}\acute{z} \end{aligned}$$

Within the **spirantization strategy**, we assume that the clusters were spirantized, either as a palatal spirant or as a velar one (either directly from the 'neutralization' form *kt* or due to the depalatalization of **çt*). The palatal spirant was later sibilantized (eventually depalatalized later), the velar spirant was debuccalized as simple *ht* or even fully elided (we model this development for Albanian, since in Albanian even IE **Kt* realizes as *Ot*).

¹⁹ The Albanian outcome should be listed with Slavic, since old sibilants merged into *š* in Albanian.

²⁰ The Albanian development (based on Schumacher 2013: 243) assumes deaffricativization (technically gemination) and simplification of the cluster (*ǵt* > *tʰt* > *tt* > *Ot*). This development definitely must have been later than the development of the IE cluster **Tt*, since it had not merged with it.

$\acute{K}t > \text{çt} > \text{št} > \text{st}$
 (> kt) > xt > ht > **0t**

Note: As with all series, there is a specific development of $-g^h+t$ in Indo-Iranian, affected by Bartholomae's Law. We model the following spirantization trajectory, assuming the spirantization of the palatovelar:

$g^ht > j\delta > \text{ž}\delta > \text{zd}^h > \text{0d}^h$
 $> \text{žd}$

Within the **spirantization** strategy, for the development of the cluster of a palatovelar plosive + *s*-, we assume first the neutralization of a palatalization (and palatalization of a sibilant due to the *ruki*-rule), followed in many languages by spirantization, sibilantization and simplification:

$\acute{K}s > \text{kš} > \text{kş}$
 $> \text{çš} > \text{šš} > \text{0š}$
 $> \text{ʁš} > \text{ts} > \text{0s}$

Note: We can model the 'Bartholomaen' development of the cluster of $*g^hs$ according to the spirantization trajectory as (valid for Iranian; Indic development was replaced by the analogy):

$g^hs > jz > \text{jž} > \text{žž} > \text{0ž}$

The development of the clusters of *palatovelar plosive* + d^h can be securely reconstructed in a few *satəm*-languages (technically: Indo-Iranian and Baltic), and the outcomes are always voiced. The outcomes in Indo-Iranian and Baltic are:

- i. IE $*\acute{K}d^h > \text{d}d^h$, attested in Old Indo-Aryan;
- ii. IE $*\acute{K}d^h > \text{žd}$, attested in Iranian and Baltic;

The proposed trajectory assumes the spirantization of the palatovelar and later sibilantization of the spirant, this sibilant is lost in Indic:

$\acute{K}d^h > \text{jd}^h > \text{žd}^h > \text{0d}^h$
 $> \text{žd}^h > \text{žd}^{21}$

Note: Essentially the same development is valid for the development of IE clusters of $*g^hd^h$ into Indo-Iranian, since they share the same outcome.

13.2 The development of the peripheral series

The set of the input peripheral series differ according to the *centum/satəm* languages dichotomy, the first having labiovelars preserved (at least on a re-constructible level) beside plain velars

²¹ The outcome is *zd* after depalatalization in Prussian and Latvian.

and labials, the second having the old IE labiovelars merged fully with the plain velars (however, such merging is known from the *centum*-languages as well).

Note: The logical consequence of this feature is clear: the positive marker we can use to distinguish the *centum/satəm* languages is not the presence of the labiovelars series, but the presence of the palatovelar series. In other words: the *centum*-languages are all languages without the presence of the original palatovelar series, so the *centum*-languages are hence ‘negatively’ defined and the *satəm*-languages are defined ‘positively’.

Regarding the data of the attested Indo-European languages, we can state that there are two strategies in general: the **conservative strategy** (with the ‘zero’ trajectory) and the **progressive strategy** (with the spirantization/lenition trajectory). We can express the distribution of both strategies in the following table:

CONSERVATIVE STRATEGY	PROGRESSIVE STRATEGY
Old Indo-Aryan	Old Iranian
Baltic	Slavic
	Armenian
Greek	Albanian
Latin	(Middle Greek)
	Sabellian
	Celtic
	Germanic
Hittite	
Tocharian	

A remarkable feature is that the split between both strategies could run through a given sub-branch, as we can see in the examples of the Indo-Iranian, Balto-Slavic or Italic language families.

Note: As we can see in the example of Middle Greek, spirantization could affect archaic clusters later. Similarly process we can see in the development of French from (Vulgar) Latin.

Note: Beside spirantization, there is another progressive strategy, far less attested: gemination. The process of gemination of the consonantal clusters is known from Middle Indo-Aryan and Italian. It is also usually attributed to the Pre-Slavic development.

13.2.1 The development of the peripheral series I: the plain velar series

A development of the plain velar series can be listed as:

- i. IE $*Kt > kt$, attested in Old Indo-Aryan, Baltic, Greek, Latin, Hittite and Tocharian;
- ii. IE $*Kt > xt$, attested in Iranian, Gallic, Irish;
- iii. IE $*Kt > ht$, attested in Sabellic and Gothic;
- iv. IE $*Kt > jt$, attested in Brythonic;
- v. IE $*Kt > Ot$, attested Nūristānī, Armenian, Albanian and as a minor outcome in Slavic;
- vi. IE $*Kt > št$, attested in OCS as the major outcome.

The first group is within the *zero*-process, the old plain velars are preserved as plain velar stops.

The outcomes from ii. to v. are products of various lenitions, which we can order according to decreasing consonantal strength, \dot{i} being the palatal counterpart of h :

$$\mathbf{Kt} > \mathbf{kt} > \mathbf{xt} > \mathbf{ht} > \mathbf{0t} \\ > \mathbf{\dot{i}t}$$

The $\dot{s}t$ - outcome of OCS (c/\acute{c} -outcome in other Slavic languages) is an original prepalatal variant, extended, due to analogy, to all productive clusters.

Note: The Armenian outcome displays aspiration of the t -context, known from the development of the all peripheral series (but not the central series!) in Armenian, cf. the development of labials in Armenian below.

The older form was highly probably a spirant: the trajectory is: $\mathbf{Kt} > \mathbf{xt} > \mathbf{x\theta} > \mathbf{h\theta} > \mathbf{0t}$.

Note: We model the ‘Bartholomaen’ development of the cluster of $-g^h+s$ as:

$$g^ht > \gamma\delta > gd^{(h)22}$$

The development of the cluster of *plain velar* + s in various IE branches can be listed as:

- i. IE $*Ks > ks$, attested in Hittite, Tocharian, Greek, Latin and in Baltic²³;
- ii. IE $*Ks > k\dot{s}$, attested Old Indo-Aryan;
- iii. IE $*Ks > x\dot{s}$, attested in Avestan;
- iv. IE $*Ks > xs$, attested in Gaulish;
- v. IE $*Ks > hs$, attested in Gothic;
- vi. IE $*Ks > 0x$, attested in Brythonic and Slavic (beside its palatalized variant $0\dot{s}$);
- vii. IE $*Ks > 0\dot{s}$, attested in Armenian, Albanian and Slavic (beside its non-palatalized variant $0x$);
- viii. IE $*Ks > ss$, attested in Goidelic, with $0s$ attested in Sabellian;

The ks -outcome is the conservative one, with OIA $k\dot{s}$ as its *ruki*-variant attested in OIA. The progressive outcomes follow the spirantization/lenition trajectory:

$$\mathbf{Ks} > \mathbf{ks} > \mathbf{xs} > \mathbf{hs} \\ > \mathbf{xx} > \mathbf{0x} \\ > \mathbf{ss} > \mathbf{0s} \\ > \mathbf{k\dot{s}}^{24} > \mathbf{x\dot{s}} > \mathbf{\dot{s}\dot{s}} > \mathbf{0\dot{s}}$$

Note: Similarly, we model the ‘Bartholomaen’ development of the cluster of $-g^h+s$ as follows (the outcome is attested in Iranian, Indic has the analogous levelling again):

$$g^hs > \gamma z > g\check{z}^{25}$$

²² This reconstruction is also valid for the development of $*K^u t$ clusters, since there is no distinction between plain velars and labiovelars in Indo-Iranian.

²³ The Baltic outcome is surprising, since it is the position where the *ruki*-rule is supposed to be operating.

²⁴ Also represents OIA $k\dot{s}$ here.

²⁵ Similarly to the development of the cluster of $*K^u t$, this reconstruction is also valid for the development of $*K^u s$ clusters, since there is no distinction between plain velars and labiovelars in Indo-Iranian.

The development of the *plain velar plosive* + d^h clusters can be reconstructed securely in Indo-Iranian, Baltic and Greek, and the outcomes are always voiced. The outcomes in Indo-Iranian, Greek and Baltic are:

- i. IE $*Kd^h > gd^h$, attested in Old Indo-Aryan;
- ii. IE $*Kd^h > gd$, attested in Iranian and Baltic;
- iii. IE $*Kd^h > k^h t^h$, attested in Greek;

The trajectory is simple for OIA and Baltic, but in Iranian we meet a typical spirantization and Greek has an analogy-based outcome, omitted below:

$$Kd^h > \mathbf{gd^h} > \gamma d^h > \gamma \delta / \mathbf{gd}$$

Note: The clusters of $*g^h d^h$ are similarly developed.

13.2.2 The development of the peripheral series II: the labiovelar series

The development of the cluster of *labiovelar* + t in various IE branches can be listed as:

- i. IE $*K^u t > k^u t$, attested in Hittite and Mycenaean;
- ii. IE $*K^u t > kt$, attested in Latin, Tocharian, partially in Greek;
- iii. IE $*K^u t > pt$, attested in partially in Greek;
- iv. IE $*K^u t > xt$, attested in Goidelic (and probably in Gaulish);
- v. IE $*K^u t > ht$, attested in Sabellic and Gothic;
- vi. IE $*K^u t > \dot{i}t$, attested in Brythonic;

The first group could be suspected to represent the *zero*-process, but it is more probable that this development is the result of a secondary analogous levelling, the older state being preserved in the second outcome, with the neutralization of the related series on the plain velars.

Note: The outcome in the conservative *satəm*-languages (OIA, Baltic) is also kt , the outcomes in the progressive *satəm*-languages follows the development of the kt -clusters (see above). We dare to propose that it is was the neutralization of labiality in the $t/s/d^h$ -contexts (and in some other context too, especially before labial vowels, the process well known from Italic) which caused the final loss of labiality of the old labiovelars in later *satəm*-languages (the process with its parallel in Tocharian).

The third version of the development is limited to Greek and it is a secondary outcome of the development of labiovelars in Greek; here a labial is a direct heir of Mycenaean k^u .

The last three outcomes are all results of the spirantization (attested directly in Goidelic) or of a further lenition (attested in Sabellic, Gothic and Brythonic), all within the progressive strategy, following the development of plain velars, as described above²⁶:

$$K^u t > \mathbf{kt} > \mathbf{xt} > \mathbf{ht} \\ > \dot{i}t$$

²⁶ A remarkable difference is the non-existence of the elided form $0t$, since it is attested for velars only in the *satəm*-languages.

The development of the cluster labiovelar + *s* in various IE branches could be listed as:

- i. IE $*K^u s > k^u s$, attested in Hittite and Mycenaean;
- ii. IE $*K^u s > ks$, attested in Latin, Tocharian, partially in Greek;
- iii. IE $*K^u s > ps$, attested in partially in Greek;
- iv. IE $*K^u s > hs$, attested in Gothic;
- v. IE $*K^u s > ss$, attested in Goidelic and *Os* attested in Sabellic;
- vi. IE $*K^u s > Ox$, attested in Brythonic;

The $k^u s$ -outcome is in our opinion a result of analogical levelling (as $k^u t$ is), while the *ps*-outcome is a result of the specific Greek development of the levelled clusters of $k^u s$, hence the conservative outcome follows the spirantization/lenition trajectory:

$$\begin{aligned} K^u s &> \mathbf{ks} > \mathbf{xs} > \mathbf{hs} \\ &> \mathbf{xx} > \mathbf{0x} \\ &> \mathbf{ss} > \mathbf{0s} \end{aligned}$$

Note: The *satəm*-languages follow the same trajectory as the *Ks* clusters (see above), with the exception of Baltic languages.

Note: Since there are no wide and secure examples of the development of the IE clusters of $*K^u + d^h$ in the *centum*-languages (Greek clearly restoring both the labialization of the labiovelar and remodelling the cluster due to the loss of voicedness of the d^h), we willingly omit to reconstruct the trajectory.

Note: The development of the clusters of $*K^u d^h$ and $*g^u d^h$ is essentially the same as the developments of the clusters of $*K d^h$ and $*g^h d^h$, respectively (cf. above).

13.2.3 The development of the peripheral series III: the labial series

The development of the cluster of *labial* + *t* can be summed up as:

- i. IE $*Pt > pt$, attested in Old Indo-Aryan, Avestan, Baltic, Greek, Latin, Hittite and Tocharian;
- ii. IE $*Pt > ft$, attested in Oscan, Gothic, reconstructed for Old Persian;
- iii. IE $*Pt > \dot{i}t$, attested in Brythonic;
- iv. IE $*Pt > Ot$, attested in Nūristānī, Slavic (as a major outcome), Armenian, Albanian;
- v. IE $*Pt > st$, attested as a minor outcome in Slavic;

The first outcome is a conservative one, other clusters falling within the spirantization/lenition trajectory, the oldest stage of which is roughly represented in the second outcome (for the first stage $*\varphi t$ seems to be a more probable variant). Brythonic attests the further weakened approximant, the outcome *Ot* the final, elided form. The minor outcome *st* known from Slavic is a result of a parallel process: sibilantization instead of lenition.

$$\begin{aligned} Pt &> \mathbf{pt} > \varphi t > \mathbf{ft} \\ &> \mathbf{ht} > \mathbf{0t} \\ &> \mathbf{\dot{i}t} \\ &> \mathbf{st} \end{aligned}$$

Note: The Armenian outcome displays the aspiration of the *t*-context, known from the development of all the peripheral series (but not the central series!) in Armenian. The older form was highly probably a spirant; the trajectory is: *Pt* > *φt* > *φθ* > *hθ* > *θt*.

Note: We model the ‘Bartholomaen’ development of the cluster of *-b^h+t* again with a spirantization in the first phase:

$$\mathbf{b^h s} > \beta\delta > \mathbf{bd^{(h)}}$$

The development of the cluster of *labial plosive + s* in various IE branches can be listed as:

- i. IE **Ps* > *ps*, attested in OIA, Lithuanian, Greek, Latin, Hittite and Tocharian;
- ii. IE **Ps* > *fs*, attested in Avestan (beside *fš*)²⁷ and Gothic;
- iii. IE **Ps* > *Os*, attested in Slavic, Armenian, Albanian²⁸ and Sabellic;
- iv. IE **Ps* > *xs*, attested in Gaulish;
- v. IE **Ps* > *ss*, attested in Goidelic;
- vi. IE **Ps* > *θx*, attested in Brythonic;

$$\begin{aligned} \mathbf{Ps} > \mathbf{ps} > \varphi\mathbf{s} > \mathbf{fs} > \mathbf{0s} \\ > \mathbf{xs} > \mathbf{0x} \\ > \mathbf{ss} > \mathbf{0s} \end{aligned}$$

Note: Similarly, we can model the ‘Bartholomaen’ development of the cluster of *-b^h+s* with an early spirantization as follows (again, Indic development is based on the analogy):

$$\mathbf{b^h s} > \beta z > \mathbf{bz}$$

The development of the clusters of *labial plosive + d^h* can be reconstructed again securely in Indo-Iranian, Baltic and Greek, and the outcomes are always voiced. The outcomes in Indo-Iranian, Greek and Baltic are:

- i. IE **Pd^h* > *bd^h*, attested in Old Indo-Aryan;
- ii. IE **Pd^h* > *bd*, attested in Iranian (the two-spirant cluster *βδ* being its variant) and Baltic;
- iii. IE **Pd^h* > *p^ht^h*, attested in Greek;

The trajectory is simple for OIA and Baltic; in Iranian we meet a typical spirantization; Greek has an analogy-based outcome, omitted below:

$$\mathbf{Pd^h} > \mathbf{bd^h} > \beta\mathbf{d^h} > \mathbf{bd}$$

Note: Clusters of **b^hd^h* are similarly developed.

²⁷ This outcome is an extension of the *ruki*-rule in Iranian (actually attested in Avestan only, not in Old Persian).

²⁸ The variant Albanian outcome *f* is a result of a metathesis of IE **ps* on **sp*. The trajectory is: *ps* > *sp* > *hf* > *of*, see above. The Albanian outcome of a cluster without this metathesis is *θš*, i.e., with a typical Albanian palatalization of a sibilant.

13.3 The development of the sibilant clusters

The set of phonemes of the reconstructed IE obstruent system has a single sibilant phoneme **s* (with a positional allophone **z* before voiced plosives). The *satəm*-languages had another phoneme **š*, resulting from the split of the old single sibilant due to Pedersen's law (the *ruki*-rule), securely attested for four of the six *satəm*-branches, but insecure for Albanian and Armenian.

The development of the sibilant clusters are remarkably stable, the Celtic development being an exception.

The developments of the IE cluster of **st* could be summed as:

- i. IE **st* > *st*, attested in all branches except Celtic and Albanian;
- ii. IE **st* > *št*, attested in Albanian;
- iii. IE **st* > *ss*, attested in Celtic languages (in Gaulish beside the variant *ðð* of the insecure phonemic value);

The conservative *st*-outcome is a regular one, the Albanian *št*-outcome is a later result of the independent Albanian development.

The Celtic development, tied with the development of the IE clusters **Tt*, **Ts* (see above), can be explained only within this wider frame. If the Gaulish *ðð* had a value of an affricate, the trajectory would be, if we accept the proposal of Lewis/Pedersen (1937: 20): *st* > *ts* > *ss*, or, as we dare to propose: *st* > *st^s* > *t^st^s* > *ss*.

$st > \mathbf{st} > s\mathfrak{d} > \mathfrak{d}\mathfrak{d} > ss$

The developments of the *satəm*-cluster of **št* can be summed up as:

- i. IE **št* > *št*, attested in Iranian and Lithuanian;²⁹
- ii. IE **st* > *št*, attested in OIA and Nūristānī;

Note: The OIA–Nūristānī outcome is just an area variation of the preceding regular outcome, as it is in the case of IE clusters of **Ķt* > OIA *št*.

The development of the clusters of *sibilant* + *s* usually leads towards the degeminated form of a single sibilant or to the preservation of the geminate. The bisibilant cluster could be considered not as a preserved one, but as an analogical restoration, since we have all the reason to consider the simplification **ss* > *0s* as already being Indo-European at least in the 2nd sg. pr. of the root **√H₁es-* 'be' (cf. OIA *asi*, L. *es*, OCS *jesi*, Lith *esi*). A remarkable development is attested in OIA, where the verbal forms have the outcome *ts*. This form can be traced back to the older

²⁹ The Albanian outcome can not be distinguished from the outcome of the IE cluster **st*, since the old IE sibilant was regularly palatalized in Albanian.

spirant stage, resulting from the levelling of this cluster with a cluster of \mathfrak{S} , which we reconstruct as a stage of the development of the IE cluster Tt , later re-buccalized in OIA.

$ss > \mathbf{ss} > \mathbf{0s}$
 $> \mathfrak{S} > \mathbf{ts}$

The development of the clusters formed by a *ruki-sibilant* + s in the *satəm*-languages³⁰ usually also leads towards the degeminated form of a single sibilant or to the preservation of the geminate. Again, OIA is an exception, where the right sibilant is replaced by a plosive, this time velar (and the sibilant is cerebral). Even in this case we assume the shift of the original sibilant towards a spirant and later re-buccalization of the spirant (and an area cerebralization of a right sibilant):

$\check{s}s > \check{\mathbf{s}}\check{\mathbf{s}} > \mathbf{0}\check{\mathbf{s}}$
 $> x\check{\mathbf{s}} > \mathbf{k}\check{\mathbf{s}}$

The development of the clusters of *sibilant* + d^h is simple outside Indic (where any voiced sibilant of any origin is regularly lost), with the voicing of a sibilant. The Greek development is remodelled due to devoicing of the original IE context $*d^h$. For the IE $*s$ the development can be modelled as:

- i. IE $*sd^h > 0d^h$, attested in Old Indo-Aryan;
- ii. IE $*sd^h > zd$, attested in Iranian and Baltic;
- iii. IE $*sd^h > st^h$, attested in Greek;

And similarly, for the *ruki-sibilant* $*\check{z}$ the outcomes are in the *satəm*-languages, with a loss of a sibilant in OIA, preserved as voiced in Iranian and Baltic:

- i. IE $*\check{s}d^h > 0d^h$, attested in Old Indo-Aryan;
- ii. IE $*\check{s}d^h > \check{z}d$, attested in Iranian and Baltic;

The trajectories for both sibilants we can model as:

$sd^h > \mathbf{zd}^{(h)} > z\check{\mathfrak{d}} > \check{\mathfrak{d}}\check{\mathfrak{d}} > \mathbf{0d}^h$
 $\check{s}d^h > \check{\mathbf{z}}\mathbf{d}^{(h)} > \check{z}\check{\mathfrak{d}} > \check{\mathfrak{d}}\check{\mathfrak{d}} > \mathbf{0d}^h$

³⁰ Again, the Albanian and Armenian data do not distinguish this outcome from that of $*ss$, since the validity of Pedersen's Law in these languages is questionable.

Appendix I: The comparative table of IE clusters *plosive* + *t/s-* in the given Indo-European languages³¹

i. the clusters *dental plosive* + *t/s-*:

IE	OIA	Av.	N.	Lith.	OCS	Arm.	Alb.	Gr.	L.	Os.	Gal.	Ir.	W.	Goth.	Hitt.	TB
Tt	tt	st	0t	st	st	ʉt	0s	st	ss	ss	đđ	ss	ss	ss	tʰt	tʰtʰ
Ts	ts	0s	ć	0s	0s	cʰ	0š	0s	ss	ss	đđ	ss	ss	ss	ts	ts
tV	tV	tV	tV	tV	tV	tV	tV	tV	tV	tV	ss tV	tV	tV	ɸV	tV	tV

ii. the clusters *palatovelar plosive* + *t/s-*:

IE	OIA	Av.	N.	Lith.	OCS	Arm.	Alb.	Gr.	L.	Os.	Gal.	Ir.	W.	Goth.	Hitt.	TB
ǵt	ʃt	št	ʃt	št	st	st	0t	kt	kt	ht	xt	xt	jt	ht	kt	kt
ǵs	kʃ	0š	c	0š	0s	cʰ	0š	ks	ks	0s	xs	ss	0x	hs	ks	ks
ǵV	šV	šV	cV	šV	sV	sV	ɸV	kV	kV	kV	kV	kV	kV	hV	kV	kV

iii. the clusters *velar plosive* + *t/s-*:

IE	OIA	Av.	N.	Lith.	OCS	Arm.	Alb.	Gr.	L.	Os.	Gal.	Ir.	W.	Goth.	Hitt.	TB
Kt	kt	xt	0t	kt	št	0tʰ	0t	kt	kt	ht	xt	xt	jt	ht	kt	kt
Ks	kʃ	xš	?	ks	0x	0š	0š	ks	ks	0s	xs	ss	0x	hs	ks	ks
kV	kV cV	kV cV	kV cV	kV cV	kV čV	kV	kV	kV	kV	kV	kV	kV	kV	hV	kV	kV

iv. the clusters *labiovelar plosive* + *t/s-*:

IE	OIA	Av.	N.	Lith.	OCS	Arm.	Alb.	Gr.	L.	Os.	Gal.	Ir.	W.	Goth.	Hitt.	TB
Kʰt	kt	xt	kt	kt	št	0tʰ	0t	pt ³²	kt	ht	(xt)	xt	jt	ht	kʰt	kt

³¹ The examples are limited on the non-Bartholomaeian clusters. The *dʰ*-clusters are fully omitted since not securely attested in many daughter languages. The cluster *obstruent* + *vowel* is added to demonstrate the unmarked form of the given obstruent (secondarily palatalized velars from Indo-Iranian and Slavic are omitted, as similar secondary forms).

³² *kʰt*, *kʰs* in Mycenaean.

K^us	kʂ	xš	?	ks	0t 0x	0š	0š	kt ps	ks	0s	(xs)	ss	0x	hs	k ^u s	ks
k^uV	kV cV	kV cV	kV cV	kV	0š kV čV	kV	kV	ks pV	k ^u V	pV	pV	kV	pV	h ^u V	k ^u V	kV

v. the clusters *labial plosive* + *t/s-*:

IE	OIA	Av.	N.	Lith.	OCS	Arm.	Alb.	Gr.	L.	Os.	Gal.	Ir.	W.	Goth.	Hitt.	TB
Pt	pt	pt	0t	pt	0t	0t'	0t	pt	pt	ft ³³	xt	xt	jt	ft	pt	pt
Ps	ps	fs fš		ps	0s	0s	0š (0f) ³⁴	ps	ps	0s	xs	ss	0x	fs	ps	ps
pV	pV	pV	pV	pV	pV	hV	pV	pV	pV	pV	0V	0V	0V	fV	pV	pV

vi. the clusters *sibilant* + *t/s-*:

IE	OIA	Av.	N.	Lith.	OCS	Arm.	Alb.	Gr.	L.	Os.	Gal.	Ir.	W.	Goth.	Hitt.	TB
st	st	st	st	st	st	st	št	st	st	st	đđ	ss	ss	st	st	st
ss	ts	0s		0s	0s	0s	0š	0s	0s	0s	0s	0s	0s	(ss)	ss	ss
sV	sV	hV	sV	sV	sV	hV	gjV šV	hV	0s	0s	0s	0s	0s	sV	sV	sV
(št)	ʂt	št	ʂt	št	st	st	št	st	st	st	đđ	ss	ss	st	st	st
(šs)	kʂ	0š		0š	0š	0s	0š	0s	0s	0s	0s	0s	0s	(ss)	ss	st
(šV)	ʂV	šV	ʂV	šV	šV	hV	šV	hV	sV	sV	sV	sV	sV	sV	sV	sV

³³ Umbr. *ht*

³⁴ Due to metathesis of **ps* on **sp*, later fricativized, debuccalized and elided.

Appendix II: The pan-chronic overviews of the given developments

i. The pan-chronic overview of the Indic development:

Kt > kt			
Ḷt > çt > št > ṣṭ	(SPT)	vel	Ḷt > t^{št} > št > ṣṭ (AFT)
Tt > Ṯt > tt	(SPT)	vel	Tt > tst > tt (AFT)
Pt > pt			

g^{ht} > γδ > gd^h			
ḡ^{ht} > jδ > žδ > zḍ^h > ḷḍ^h	(SPT)	vel	ḡ^{ht} > d^žd^h > žd^h > zḍ^h > ḷḍ^h (AFT)
d^{ht} > δδ > dd^h	(SPT)	vel	d^{ht} > d^zd^h > dd^h (AFT)
b^{ht} > βδ > bd^h			

st > **st**
št > **št** > **ṣṭ**

Kd^h > γδ > gd^h			
Ḷd^h > jδ > jj > ḍḍ^h	(SPT)	vel	Ḷd^h > d^žd^h > žd^h > ḍḍ^h (AFT)
Td^h > δδ > dd^h/0d^h	(SPT)	vel	Td^h > d^zd^(h) > dd^h/0d^h (AFT)
Pd^h > βδ > bd^h (?)			

g^{hd^h} > γδ > gd^h (?)			
ḡ^{hd^h} > jδ > žd^h > ḷḍ^h > 0ḍ^h	(SPT)	vel	ḡ^{hd^h} > d^žd^h > žd^h > ḷḍ^h > 0ḍ^h (AFT)
d^{hd^h} > δδ > ḷḍ^h	(SPT)	vel	d^{hd^h} > d^zd^h > ḷḍ^h (AFT)
b^{hd^h} > βδ > bd^h (?)			

sd^h > **zδ** > **hδ** > **ḷḍ^h**
šd^h > **žδ** > **jδ** > **ḍḍ^h**

Ks > kš > kṣ			
Ḷs > çš > xš/Ṯš > kṣ	(SPT)	vel	Ḷs > t^{šš} > kš/tṣ > kṣ (AFT)
Ts > Ṯs > ts	(SPT)	vel	Ts > t^{ss} > ts (AFT)
Ps > ps			

g^{hs} > γž → kš > kṣ			
ḡ^{hs} > jž → kš > kṣ	(SPT)	vel	ḡ^{hs} > d^{žž} → kš > kṣ (AFT)
d^{hs} > δz → ts	(SPT)	vel	d^{hs} > d^zz → ts (AFT)
b^{hs} > βz → ps			

ss > **Ṯs** > **ts**
šs > **çš** > **kṣ**

ii. Pan-chronic overview of the Iranian³⁵ development:

Kt > kt > xt			
Ḷt > çt > št	(SPT)	vel	Ḷt > t^{št} > št (AFT)
Tt > Ṯt > st	(SPT)	vel	Tt > tst > st (AFT)
Pt > pt > ḡt ⇒ pt/*ft (?)			

³⁵ There is no difference in the general features of the development between Avestan and Old Persian.

g^{ht} > γδ > gd				
ǵ^{ht} > jδ > ǰd	(SPT)	vel	ǵ^{ht} > d ^ž d ^(h) > ǰd	(AFT)
d^{ht} > δδ > zd	(SPT)	vel	d^{ht} > d ^z d ^(h) > zd	(AFT)
b^{ht} > βδ > bd				

st > **st**

št > **št**

Kd^h > γδ > gd				
ǰd^h > jδ > ǰd	(SPT)	vel	ǰd^h > d ^ž d ^(h) > ǰd	(AFT)
Td^h > δδ > zd	(SPT)	vel	Td^h > d ^z d ^(h) > zd	(AFT)
Pd^h > βδ > bd				

g^{hd} > γδ > gd (?)				
ǵ^{hd} > jδ > ǰd	(SPT)	vel	ǵ^{ht} > d ^ž d ^(h) > ǰd (?)	(AFT)
d^{hd} > δδ > zd	(SPT)	vel	d^{ht} > d ^z d ^(h) > zd	(AFT)
b^{hd} > βδ > bd (?)				

sd^h > **zd**

šd^h > **ǰd**

Ks > kš > xš				
ǰs > čš > šš > 0š	(SPT)	vel	ǰs > t ^š š > šš > 0š	(AFT)
Ts > θs > ss > 0s	(SPT)	vel	Ts > t ^s s > ss > 0s	(AFT)
Ps > ps > φs > fs/fš				

g^{hs} > γž				
ǵ^{hs} > jž > žž > 0ž	(SPT)	vel	ǵ^{hs} > d ^ž ž > žž > 0ž	(AFT)
d^{hs} > δz > zz > 0z	(SPT)	vel	d^{hs} > d ^z z > zz > 0z	(AFT)
b^{hs} > βz > βž				

ss > **0s**

šs > **šš** > **0š**

iii. Pan-chronic overview of the Nūristānī development:

Kt > kt > tt > 0t				
ǰt > čt > št	(SPT)	vel	ǰt > t ^š t > št	(AFT)
Tt > θt > tt > 0t	(SPT)	vel	Tt > t ^t t > tt > 0t	(AFT)
Pt > pt > tt > 0t				

st > **st** > **st/št**

št > **št** > **ʃt** (/ > tt > **0t** ?)

šd^h > **ǰd^(h)** > **ǰd** (/ > dđ > **0đ** ?)

ǰs > čš > θš > ts	(SPT)	vel	ǰs > t ^š š > tš > ts	(AFT)
Ts > θs > θs > tš (?)	(SPT)	vel	Ts > t ^s s > tš (?)	(AFT)

iv. Pan-chronic overview of the Baltic³⁶ development:

K^(w)t > kt				
Ķt > çt > št	(SPT)	vel	Ķt > > t^{št} > št	(AFT)
Tt > ʒt > st	(SPT)	vel	Tt > tst > st	(AFT)
Pt > pt				

K^(w)s > ks				
Ķs > çš > šš > 0š	(SPT)	vel	Ķs > t^{šš} > šš > 0š	(AFT)
Ts > ʒs > ss > 0s	(SPT)	vel	Ts > t^{ss} > ss > ts	(AFT)
Ps > ps				

st > st
št > št

ss > 0s
šs > 0š

v.: Pan-chronic overview of the Old Church Slavonic development:³⁷

K^(w)tⁱ > xtⁱ > çt > št	(SPT)	vel	K^(w)tⁱ > ttⁱ > št	(GET)
K^(w)t > xt > ht > 0t	(SPT)	vel	K^(w)t > tt > 0t	(GET)
Ķt > çt > ʒt > st	(SPT)	vel	Ķt > t^{št} > št > st	(AFT)
Tt > ʒt > st	(SPT)	vel	Tt > tst > st	(AFT)
Pt > φt > ht > 0t	(SPT)	vel	Pt > tt > 0t	(GET)
Pt > φt > st	(SPT)	vel	Pt > ? > st	(GET)

K^(w)s > xx/šš > 0x/0š	(SPT)	vel	K^(w)s > kš > šš > 0x/0š	(GET)
Ķs > çs > ʒs > ss > 0s	(SPT)	vel	Ķs > t^{šs} > šs > ss > 0s	(AFT)
Ts > ʒs > ss > 0s	(SPT)	vel	Ts > t^{ss} > ss > 0s	(AFT)
Ps > φs > ss > 0s	(SPT)	vel	Ps > ss > 0s	(GET)

st > st
št > st

ss > 0s
šs > > šš > 0š

vi. Pan-chronic overview of the Armenian development:

K^(w)t > xʒ > hʒ > 0t^ç
Ķt > çt > št > st
Tt > ʒt > ht > ʉt
Pt > φʒ > hʒ > 0t^ç

K^(w)s > xš > šš > 0š^ç³⁸
Ķs > çs > ʒs > c^ç
Ts > ʒs (?) > c^ç
Ps > φs > hs > 0s^ç³⁹

³⁶ Here demonstrated on the Lithuanian data.

³⁷ The “strategy of simplification”, since trivial, is omitted in this overview.

³⁸ Alternatively with the same frame: **K^(w)s > xš > hš > 0š**.

³⁹ Alternatively within the same frame: **Ps > φs > ss > 0s**.

St > **st**

Ss > **0s**

vii. Pan-chronic overview of the Albanian development:

K^(u)t > **kt** > **xt** > **ht** > **0t**

Ķt > **çt** > **xt** > **ht** > **0t**

Tt > **ʒt** > **ʒʒ** > **c** > **0s** (SPT) vel **Tt** > **t^st** > **cc** > **0c** > **0s** (AFT)

Pt > **pt** > **φt** > **ht** > **0t**

K^(u)s > **ks** > **xs** > **hs** > **0s** > **0š⁴⁰**

Ķs > **çs** > **xs** > **hs** > **0š⁴¹**

Ts > **ʒs** > **ss** > **0s** > **0š** (SPT) vel **Ts** > **t^ss** > **ss** > **0s** > **0š** (AFT)

Ps > **ps** ⇒ **sp** > **hf** > **0f**

St > **st** > **št**

Ss > **ss** > **0s** > **0š**

viii. Pan-chronic overview of the Ancient Greek development:

K^(o)t > **kt**

K^ut > **pt**

Tt > **ʒt** > **ʒʒ** > **ss** (SPT) vel **Tt** > **t^st** > **tst** > **st** (AFT)

Pt > **pt**

Kd^h > **gd^h** ⇒ **Kt^h** > **k^ht^h**

K^ud^h > **g^ud^h** ⇒ **K^ut^h** > **p^ht^h**

Td^h > **δd^h** ⇒ **tt^h** > **ʒt^h** > **st^h** (SPT) vel **Td^h** > **d^zd^h** ⇒ **t^st^h** > **tst^h** > **st^h** (AFT)

Pd^h > **bd^h** ⇒ **pt^h** > **p^ht^h**

K^(o)s > **ks**

K^us > **ps**

Ts > **ʒs** > **ss** > **0s** (SPT) vel **Ts** > **t^ss** > **tss** > **ss** > **0s** (AFT)

Ps > **ps**

st > **st**

sd^h > **zd^h** ⇒ **st^h** > **st^h**

ss > **0s**

ix. Pan-chronic overview of the Mycenaean development:

K^(o)t > **kt**

K^ut > **k^ut**

Tt > **ʒt** > **ʒʒ** > **ss** (SPT) vel **Tt** > **t^st** > **tst** > **st** (AFT)

Pt > **pt**

⁴⁰ In the case of the validity of the *ruki*-rule for Proto-Albanian: **K^us** > **kš** > **hš** > **0š**.

⁴¹ If we assume that Albanian was affected by *ruki*-rule, the development will be: **Ķs** > **kš** > **xš** > **hš** > **0š**.

Kd^h > gd^h ⇒ Kt^h > k^ht^h
K^ud^h > g^ud^h ⇒ K^ut^h > k^ut^h
Td^h > > δd^h ⇒ tt^h > ʒt^h > st^h (SPT) vel **Td^h > d^zd^h ⇒ t^st^h > tst^h > st^h (AFT)
Pd^h > bd^h ⇒ pt^h > p^ht^h**

K⁽⁾s > ks
K^us > k^us
Ts > ʒs > ss > 0s (SPT) vel **Ts > t^ss > tss > ss > 0s (AFT)**
Ps > ps

st > st

sd^h > zd^h ⇒ st^h > st^h

ss > 0s

x. Pan-chronic overview of the Latin development:

K⁽⁾t > kt
K^ut > kt
Tt > ʒt > ʒʒ > (s)s (SPT) vel **Tt > t^st > tss > (s)s (AFT)**
Pt > pt

K⁽⁾s > ks
K^us > ks
Ts > ʒs > (s)s (SPT) vel **Ts > t^st > tss > (s)s (AFT)**
Ps > ps

st > st

ss > (s)s

xi. Pan-chronic overview of the Sabellic development:

K⁽⁾t > xt > ht (> 0t)
K^ut > kt > xt > ht
Tt > ʒt > ʒʒ > (s)s (SPT) vel **Tt > t^st > tss > (s)s (AFT)**
Pt > > ʔt > ft⁴²

K⁽⁾s > xs > hs > 0s
K^us > ks > xs > hs > (s)s
Ts > ʒs > (s)s (SPT) vel **Ts > t^st > tss > (s)s (AFT)**
Ps > > ʔs > hs > 0s

st > st

ss > (s)s

⁴² Umbrian: **Pt > ʔt > xt > ht**

xii.: Pan-chronic overview of the Brythonic development:

K⁽⁾t > xt (> ht) > ĵt				
K^ut > xt (> ht) > ĵt				
Tt > ʒt > ʒʒ > ss	(SPT)	vel	Tt > t ^s t > tsts > ss	(AFT)
Pt > ʔt > (ft > ht >) ĵt				
K⁽⁾s > xs > xx > 0x				
K^us > xs > xx > 0x				
Ts > ʒs > ss	(SPT)	vel	Ts > t ^s s > tsts > ss	(AFT)
Ps > ʔs > xx > 0x				
st > sʒ > ʒʒ > ss	(SPT)	vel	st > ts > ss	(AFT)

xiii. Pan-chronic overview of the Goidelic development:

K⁽⁾t > xt				
K^ut > xt				
Tt > ʒt > ʒʒ > ss	(SPT)	vel	Tt > t ^s t > tsts > ss	(AFT)
Pt > ʔt > (ft >) xt				
K⁽⁾s > xs > ss				
K^us > xs > ss				
Ts > ʒs > ss	(SPT)	vel	Ts > t ^s s > tsts > ss	(AFT)
Ps > ʔs > ss				
st > sʒ > ʒʒ > ss	(SPT)	vel	st > ts > ss	(AFT)

xiv. Pan-chronic overview of the Gallic development:

K⁽⁾t > xt				
(K^ut > xt)				
Tt > ʒt > ʒʒ > dd/ss	(SPT)	vel	Tt > t ^s t > tsts > dd/ss ⁴³	(AFT)
Pt > ʔt > (ft >) xt				
K⁽⁾s > xs				
(K^us > xs)				
Ts > ʒs > ʒʒ > dd/ss	(SPT)	vel	t ^s s > t ^s t > tsts > dd/ss	(AFT)
Ps > ʔs > xs				
st > ʒs > ʒʒ > dd/ss	(SPT)	vel	st > ts > dd/ss	(AFT)

xv.: Pan-chronic overview of the Gothic development:

K⁽⁾t > kt > xt > ht				
K^ut > kt > xt > ht				
Tt > ʒt > ʒʒ > ss	(SPT)	vel	Tt > t ^s t > tsts > ss	(AFT)
Pt > pt > ʔt > ft				
K⁽⁾s > ks > xs > hs				
K^us > ks > xs > hs				
Ts > ʒs > ss	(SPT)	vel	Ts > t ^s s > tss > ss	(AFT)

⁴³ Here *dd* marks two dental affricates, probably voiceless.

Ps > ps > φs > fs

st > st

ss > ss (?)

xvi. Pan-chronic overview of the Hittite development:

K⁽⁰⁾t > kt

K^ut > kt / ⇒ k^ut

Tt > t^st > tst

Pt > pt

K⁽⁰⁾s > ks

K^us > (ks ?) / ⇒ k^us

Ts > t^ss > ts

Ps > ps

st > st

ss > ss

xvii. Pan-chronic overview of the Tocharian development:

K⁽⁰⁾t > kt

K^ut > kt

Tt > t^st > tst/t^s

Pt > pt

K⁽⁰⁾s > ks

K^us > (ks ?)

Ts > t^ss > ts

Ps > ps

st > st

ss > ss

Abbreviations of languages

Aeol. – Aeolic	OCorn. – Old Cornish
Alb. – Albanian	OCS – Old Church Slavonic
Arc. – Arcadian	OE – Old English (Anglo-Saxon)
Arm. – Armenian	OGeg. – Old Gegh
Att. – Attic	OHG – Old High German
Av. – Avestan	OIA – Old Indo-Aryan
B. – Bulgarian	OIr. – Old Irish
Br. – Breton	OL. – Old Latin
Bryth. – Brythonic	OLith. – Old Lithuanian
Celt. – Celtic	ON – Old Norse
Corn. – Cornish	OP – Old Persian
CS – Common Slavic	OPol. – Old Polish
Cypr. – Cypriot	OS – Old Saxon
Cz. – Czech	Os. – Oscan
Dor. – Dorian	PAlb. – Proto-Albanian
Gal. – Gaulish	PAnat. – Proto-Anatolian
Germ. – Germanic	PArm. – Proto-Armenian
Goid. – Goidelic	PCelt. – Proto-Celtic
Goth. – Gothic	PGerm. – Proto-Germanic
Gr. – Greek	PGr. – Proto-Greek
Hitt. – Hittite	Phl. – Pahlavi
Hom. – Homeric	PItal. – Proto-Italic
IE – Indo-European	Pol. – Polish
Ir. – Irish	PPAlb. – Pre-Proto-Albanian
L. – Latin	Pruss. – (Old) Prussian
Latv. – Latvian	PSab. – Proto-Sabellian
Lith. – Lithuanian	Ru. – Russian
Luw. – Luwian	RuCS – Russian Church Slavonic
MBr. – Middle Breton	Sab. – Sabellian
MCorn. – Middle Cornish	SCr. – Serbo-Croatian
MĪr. – Middle Irish	Slk. – Slovakian
MHG – Middle High German	Sln. – Slovenian
MW. – Middle Welsh	Toch. – Tocharian
N. – Nūristānī	Uk. – Ukrainian
NP – New Persian	Um. – Umbrian
OAlb. – Old Albanian	W. – Welsh
OAv. – Old Avestan	YAv. – Young Avesta
OBr. – Old Breton	

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⁴⁴ Name is also transliterated as: Ĵahukyan, Djahukian. Since the quoted work is in Russian, we use the transliteration of the Russian variant of transliteration.

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