1. Background

In the original version of the proposal to encode Znamenny musical symbols (L2/19-053, Andreev and Simmons), the various combining marks used as part of the notation system were proposed with non-zero CCC values corresponding to their placement on and around base characters. This was later revised to make all such marks non-reorderable instead.

I propose reconsidering that decision.

2. Rationale

Canonical reordering is an important and powerful tool to allow Unicode-compliant applications to recognise and treat visually and semantically identical, but codepoint-wise different strings as being equivalent. As such, many scripts make generous use of this feature, with two main exceptions: Brahmic-type scripts, where all combining marks save for nuktas and viramas must be input in a strictly phonetic/linguistic order, and Sutton SignWriting, whose complex interplay of components and modifiers would have made designing a sensible encoding model built around non-zero CCCs next to impossible.

Making an entire writing system non-reorderable has its advantages; processing text becomes easier because all characters can always be assumed to be in canonical order even before it has been normalised. The downside is, however, that the normalisation algorithm can no longer fold “equivalent” sequences of combining characters into a common, canonical form, because such canonical form does not exist.

As a result, the UTC must decide in these cases which of these “equivalent” forms is the actual, canonical representation for any given sequence of characters – something the normalisation algorithm would have taken care of automatically otherwise – and implementations must be taught to reject all other “improper” representations, as having two non-equivalent forms of the same underlying message would be a catastrophe for security and searching purposes.

This manifests the most prominently in fonts for Indic scripts, where an incorrect order of combining marks causes ligatures to break and dotted circles to be displayed, signalling to the user that they have entered the text in the wrong order. The user simply has to learn what the one correct order expected by the Unicode Standard is, which isn’t always obvious. This is different from, say, applying diacritical marks to Latin letters, where non-interacting diacritics can be input in any order without causing the string to become semantically malformed.

In Znamenny notation, combining marks are used on base neumes to represent properties like pitch, note length or other musical qualities. These properties form an unordered set and it would be...
nonsensical to ascribe any kind of “priority” to each possible modifier – it cannot be said that, for example, the pitch of a note applies “before” or “after” its duration.

From an encoding perspective, this aspect of Znamenny notation is therefore comparable to the various stems, flags, dots, and diacritics of articulation in the Musical Symbols block. Consider this complex note:

![Figure 1](image1)

In Unicode, this is represented as the following sequence:

- U+1D158 MUSICAL SYMBOL NOTEHEAD BLACK
- U+1D167 MUSICAL SYMBOL COMBINING TREMOLO-1 (CCC = Overlay)
- U+1D165 MUSICAL SYMBOL COMBINING STEM (CCC = Attached_Above_Right)
- U+1D17B MUSICAL SYMBOL COMBINING ACCENT (CCC = Below)
- U+1D16D MUSICAL SYMBOL COMBINING AUGMENTATION DOT (CCC = Right)

Because the four combining marks do not interact typographically with each other, they were rightfully assigned distinct CCC values. They can therefore be input in any order and normalisation will take care of the rest. The user does not need to remember that the tremolo must be entered before the stem – which is very unintuitive given the note’s glyphic representation – or that the accent must necessarily precede the augmentation dot to form a valid sequence. Instead, all possible arrangements of these four marks are equally valid and fully equivalent under Unicode normalisation.

Let’s compare this to a Znamenny example from page 28 of the original proposal:

![Figure 2](image2)

The proposed Unicode representation of this note is:

- U+1CF51 ZNAMENNY NEUME KRYUK TIKHY
- U+1CF31 ZNAMENNY COMBINING TONAL RANGE MARK SVETLO
All of these characters have a CCC value of 0 and so cannot be reordered in any way, even though once again none of the combining marks typographically interact. In other words, the above sequence is the only valid representation of that particular symbol. Arranging the combining marks in a different order, for example svetlo + lomka + povyshe, would theoretically produce exactly the same glyph and the resulting neume would have exactly the same meaning, but that sequence must never be used because none of these permutations are canonically equivalent.

Fonts and rendering engines would need to deliberately break the glyphs for these incorrect sequences (by inserting dotted circles or through similar measures) to let the user know that the text they have typed is malformed and does not mean anything as far as the Unicode Standard is concerned, which they had no way of predicting. In contrast to the encoding model used for Western musical notation, the user would therefore need to remember the exact prescribed order of combining marks every time they want to typeset Znamenny notation, which strikes me as a vastly inferior solution.

On page 15, the proposal states that neumes are “commonly” written in a certain order: Base neume, then tonal range markers, then other black modification marks, then cinnabar pitch marks, and finally other red modification marks. This is visualised with the following diagram:
This proposed ordering is quite complex and groups marks in wildly different positions together. While the idea of ordering marks within a grapheme cluster primarily by function rather than by position is not per se bad, it is fundamentally at odds with how Unicode deals with combining characters in most other contexts through the use of canonical reordering.

Glyphic appearance is the important factor – the goal is after all to prevent visual confusables. This is why most CCC values correspond directly to where the mark is placed in relation to the base character; only the order of marks that interact typographically with each other can affect the appearance of the whole grapheme.

In my view, the order in which an actual scribe would write neumes with pen and paper is only of secondary relevance to the notation system’s digital representation, as this is also never a concern elsewhere. A character like U+1E68 $LATIN CAPITAL LETTER S WITH DOT BELOW AND DOT ABOVE may have its upper dot written before the lower one or the other way around varying from person to person and from situation to situation, but Unicode does not prescribe either order as the correct one and normalisation will treat both variants as fully equivalent to the precomposed letter. And again, the canonical representation of the Western musical note shown above has the tremolo mark encoded before the stem on which it rests, which no actual person would ever think to do on paper.

If Znamenny marks had non-zero CCC values, individual users could still input them in the order put forth by the proposal (or in any other order they see fit), but it would not be a requirement to memorise and enforce this exact sequence to produce a well-formed neume. The order of marks would then only matter when multiple signs in the same typographic position are applied to a base neume. In this case, the interacting marks would simply be stacked outwards from the base character or – for pitch marks – stacked diagonally from left to right as suggested by the authors on page 16.

3. Proposed Values

Looking through the large list of examples starting on page 28, I have found several sequences whose proposed order of codepoints I cannot explain based on the other information in the document, such as #82 and #85:

![Image of neumes and codepoints]

Figure 4

Here, both neumes use the same four combining marks, with only the order of U+1CF30 and U+1CF33 changing between them. However, there is no visual difference in the resulting glyph as
far as the combining marks are concerned, so the changed order seems to have been completely meaningless.

Because these two marks never interact with each other, their relative order should not matter, but that requires them to have distinct CCC values.

Examining all the example sequences, I have come to the conclusion that it is indeed possible to assign each combining character a non-zero CCC. In fact, most of them can be directly derived from the stand-alone sample glyphs provided in the proposal by simply observing where the mark is drawn in relation to the dotted circle placeholder.

- Black pitch marks are all Above.
- Black modification marks occupy a variety of classes depending on their position.
- Left-attaching pitch marks are all Above_Left.
- Red modification marks likewise occupy a variety of classes.
- Right-attaching pitch marks are all Right.

This approach will occasionally result in sequences where marks are rendered in places that are non-obvious from the alias assigned to their respective CCC. Notable examples are U+1CF24 ZNAMENNY COMBINING MARK BORZAYA and U+1CF25 ZNAMENNY COMBINING MARK UDARKA, which have a proposed CCC of Below, but are sometimes drawn to the left of the base neume. Another edge case is U+1CF29 ZNAMENNY COMBINING MARK KACHKA, which can appear both above and to the left of its base.

However, CCC aliases are merely abstractions and need not correspond directly to actual positions. There are other cases where the placements of combining marks is non-obvious, such as the aforementioned tremolo mark which appears above and to the right of the note head to match the stem despite being classified as an Overlay. Some Latin letters will also occasionally produce such apparent irregularities.

What is important is that my proposed ordering possesses the following properties:

- There is never a case where two characters with distinct CCCs interact typographically, meaning that their relative order to one another never has an effect on the appearance of the whole neume.
- There is never a case where two characters with identical CCCs can be input in a different order to one another without inducing some change in the final glyph. Of course, such rearrangements may not always have any defined meaning or ever occur in real writing.
- When two characters with identical CCCs appear on the same base neume, their relative placement is always predictable. If they are red pitch marks, they are stacked diagonally from left to right. Otherwise – with some exceptions that are particular to certain marks – they stack growing outwards from the base.

Whenever a black mark and a red mark occur in the same typographic position, the red mark is written after the black mark (i.e. further away from the base), both in the character stream and on actual paper.

The following values are proposed. Cinnabar marks are listed in red for convenience.
Overlay (1)

- U+1CF23 ☚ ZNAMENNY COMBINING MARK TIKHAYA

Attached_Right (210)

Note that U+1CF40 Kryzh does not fully attach to all base neumes; one such exception is U+1CF56 Stopitsa. Several instances of Kryzh on the same neume also don’t attach to each other, but likewise leave a small gap between individual glyphs.

It would be possible to merge these two characters into the Right class with other black modifying marks. This wouldn’t affect encoded character order in practice, but it would allow the representation of additional sequences that are meaningless and never appear in actual use.

- U+1CF3E ☚ ZNAMENNY COMBINING ATTACHING VERTICAL OMET
- U+1CF40 ☚ ZNAMENNY COMBINING MARK KRYZH

Below_Left (218)

While U+1CF27 Lomka is drawn above and to the right of the dotted circle in the code chart, in all the examples provided it occurs below and to the left. Aleksandr Andreev explained to me that its placement varies from source to source and that the original proposal followed a particular tradition where Lomka is always drawn below-left. When it appears on the right side instead, there are no other marks with which it can meaningfully interact there.

U+1CF41 Lower Tonal Range Indicator may be drawn centred below the base. Under very rare circumstances, it can occur on the same neume as U+1CF36 Podchashie (CCC=Below). However, these two characters never interact typographically.

- U+1CF27 ☚ ZNAMENNY COMBINING MARK LOMKA
- U+1CF28 ☚ ZNAMENNY COMBINING MARK KUPNAYA
- U+1CF41 ☚ ZNAMENNY COMBINING LOWER TONAL RANGE INDICATOR

Below (220)

By default, U+1CF24 Borzaya and U+1CF25 Udarka are drawn below the base neume. However, if the base neume is shaped in such a way as to prevent placement below, or if U+1CF36 Podchashie is also present, Borzaya and Udarka get pushed to the left side of the neume instead.

Podchashie is a black mark and thus always written before the red marks Borzaya and Udarka, which would need to be reflected in the character stream. While the reverse order is not canonically equivalent, it never occurs in practice and has no defined glyphic appearance.

Borzaya and Udarka shifting position is unproblematic as there are no marks on the left side of the neume with which they exhibit interactions.
• U+1CF24 ZNAMENNY COMBINING MARK BORZAYA
• U+1CF25 ZNAMENNY COMBINING MARK UDARKA
• U+1CF36 ZNAMENNY COMBINING MARK PODCHASHIE
• U+1CF37 ZNAMENNY COMBINING MARK PODCHASHIE WITH VERTICAL STROKE

Below_Right (222)
While U+1CF2A Zevok is drawn above and to the right of the dotted circle in the code chart, in actual use it always appears below and to the right of the base neume. Andreev has confirmed to me that below-right is the standard usage and that the code chart glyph will probably be adjusted.

• U+1CF2A ZNAMENNY COMBINING MARK ZEVOK

Right (226)
This class includes all right-attaching pitch marks (U+1CF0C–U+1CF17), as well as one red modifying mark (U+1CF26). The remaining characters are black modifying marks.

U+1CF3C Tochka, U+1CF3D Dvoetochie, and U+1CF3F Curved Omet behave more or less identically to the black modifying marks in the Attached_Right class, but do not graphically attach to their base in the literal sense, so that CCC value seemed inappropriate.

In the presence of U+1CF3B Sorochya Nozhka, the right-attaching pitch marks are sometimes drawn above the base neume. In these cases, they are differentiated from the left-attaching pitch marks by being drawn further to the right. This doesn’t always happen, but Sorochya Nozhka being a black mark, it is always encoded before the red pitch marks either way. The position of Sorochya Nozhka itself varies from neume to neume, but it does not interact with any other characters.

U+1CF26 Podvertka exhibits variable placement, appearing to the right, below-right or directly below the base. Right was chosen as its CCC because it only interacts with other characters of that particular class.

• U+1CF0C ZNAMENNY COMBINING MARK GORAZDO NIZKO S KRYZHED ON RIGHT
• U+1CF0D ZNAMENNY COMBINING MARK NIZKO S KRYZHED ON RIGHT
• U+1CF0E ZNAMENNY COMBINING MARK TSATA ON RIGHT
• U+1CF0F ZNAMENNY COMBINING MARK GORAZDO NIZKO ON RIGHT
• U+1CF10 ZNAMENNY COMBINING MARK NIZKO ON RIGHT
• U+1CF11 ZNAMENNY COMBINING MARK SREDNE ON RIGHT
• U+1CF12 ZNAMENNY COMBINING MARK MALO POVYSHE ON RIGHT

7/15
• U+1CF13  ZNAMENNY COMBINING MARK POVYSHIE ON RIGHT
• U+1CF14  ZNAMENNY COMBINING MARK VYSOKO ON RIGHT
• U+1CF15  ZNAMENNY COMBINING MARK MALO POVYSHIE S KHOKHLOM ON RIGHT
• U+1CF16  ZNAMENNY COMBINING MARK POVYSHIE S KHOKHLOM ON RIGHT
• U+1CF17  ZNAMENNY COMBINING MARK VYSOKO S KHOKHLOM ON RIGHT
• U+1CF26  ZNAMENNY COMBINING MARK PODVERTKA
• U+1CF3B  ZNAMENNY COMBINING MARK SOROCHYA NOZHKA
• U+1CF3C  ZNAMENNY COMBINING MARK TOCHKA
• U+1CF3D  ZNAMENNY COMBINING MARK DVOETOCHIE
• U+1CF3F  ZNAMENNY COMBINING MARK CURVED OMET

Above_Left (228)
• U+1CF00  ZNAMENNY COMBINING MARK GORAZDO NIZKO S KRYZHREM ON LEFT
• U+1CF01  ZNAMENNY COMBINING MARK NIZKO S KRYZHREM ON LEFT
• U+1CF02  ZNAMENNY COMBINING MARK TSATA ON LEFT
• U+1CF03  ZNAMENNY COMBINING MARK GORAZDO NIZKO ON LEFT
• U+1CF04  ZNAMENNY COMBINING MARK NIZKO ON LEFT
• U+1CF05  ZNAMENNY COMBINING MARK SREDNE ON LEFT
• U+1CF06  ZNAMENNY COMBINING MARK MALO POVYSHIE ON LEFT
• U+1CF07  ZNAMENNY COMBINING MARK POVYSHIE ON LEFT
• U+1CF08  ZNAMENNY COMBINING MARK VYSOKO ON LEFT
• U+1CF09  ZNAMENNY COMBINING MARK MALO POVYSHIE S KHOKHLOM ON LEFT
• U+1CF0A  ZNAMENNY COMBINING MARK POVYSHIE S KHOKHLOM ON LEFT
• U+1CF0B  ZNAMENNY COMBINING MARK VYSOKO S KHOKHLOM ON LEFT
• U+1CF18  ZNAMENNY COMBINING MARK TSATA S KRYZHEM
• U+1CF19  ZNAMENNY COMBINING MARK MALO POVYSHE S KRYZHEM
• U+1CF1A  ZNAMENNY COMBINING MARK STRANNO MALO POVYSHE
• U+1CF1B  ZNAMENNY COMBINING MARK POVYSHE S KRYZHEM
• U+1CF1C  ZNAMENNY COMBINING MARK POVYSHE STRANNO
• U+1CF1D  ZNAMENNY COMBINING MARK VYSOKO S KRYZHEM
• U+1CF1E  ZNAMENNY COMBINING MARK MALO POVYSHE STRANNO
• U+1CF1F  ZNAMENNY COMBINING MARK GORAZDO VYSOKO
• U+1CF20  ZNAMENNY COMBINING MARK ZELO
• U+1CF21  ZNAMENNY COMBINING MARK ON
• U+1CF22  ZNAMENNY COMBINING MARK RAVNO
• U+1CF2D  ZNAMENNY COMBINING MARK KRYZH
• U+1CF34  ZNAMENNY COMBINING MARK DEMESTVENNY ZADERZHKA

Above (230)

U+1CF29 Kachka sometimes exhibits variable placement, similar to U+1CF27 Lomka. In some examples it is drawn to the left of the neume, but there exist no other marks with which it ever interacts while in that position.

• U+1CF29  ZNAMENNY COMBINING MARK KACHKA
• U+1CF2B  ZNAMENNY COMBINING MARK SKOBA
• U+1CF2C  ZNAMENNY COMBINING MARK RAZSEKA
• U+1CF30  ZNAMENNY COMBINING TONAL RANGE MARK MRACHNO
• U+1CF31  ZNAMENNY COMBINING TONAL RANGE MARK SVETLO
• U+1CF32  ZNAMENNY COMBINING TONAL RANGE MARK TRESVETLO
• U+1CF38  ZNAMENNY COMBINING MARK CHASHKA
• U+1CF39 ZNAMENNY COMBINING MARK CHASHKA POLNAYA

• U+1CF3A ZNAMENNY COMBINING MARK OBLACHKO

Above_Right (232)

• U+1CF33 ZNAMENNY COMBINING MARK ZADERZHKA
• U+1CF35 ZNAMENNY COMBINING MARK OTSECHKA

1CF00;ZNAMENNY COMBINING MARK GORAZDO NIZKO S KRYZH ON LEFT;Mn;228;NSM;;;;N;;;;;
1CF01;ZNAMENNY COMBINING MARK NIZKO S KRYZH ON LEFT;Mn;228;NSM;;;;N;;;;;
1CF02;ZNAMENNY COMBINING MARK TSATA ON LEFT;Mn;228;NSM;;;;N;;;;;
1CF03;ZNAMENNY COMBINING MARK GORAZDO NIZKO ON LEFT;Mn;228;NSM;;;;N;;;;;
1CF04;ZNAMENNY COMBINING MARK NIZKO ON LEFT;Mn;228;NSM;;;;N;;;;;
1CF05;ZNAMENNY COMBINING MARK SREDNE ON LEFT;Mn;228;NSM;;;;N;;;;;
1CF06;ZNAMENNY COMBINING MARK MALO POVYSHE ON LEFT;Mn;228;NSM;;;;N;;;;;
1CF07;ZNAMENNY COMBINING MARK POVSHE ON LEFT;Mn;228;NSM;;;;N;;;;;
1CF08;ZNAMENNY COMBINING MARK VYSOKO ON LEFT;Mn;228;NSM;;;;N;;;;;
1CF09;ZNAMENNY COMBINING MARK MALO POVYSHE S KHOKHLOM ON LEFT;Mn;228;NSM;;;;N;;;;;
1CF0A;ZNAMENNY COMBINING MARK VYSOKO S KHOKHLOM ON LEFT;Mn;228;NSM;;;;N;;;;;
1CF0B;ZNAMENNY COMBINING MARK GORAZDO NIZKO S KRYZH ON RIGHT;Mn;226;NSM;;;;N;;;;;
1CF0C;ZNAMENNY COMBINING MARK NIZKO S KRYZH ON RIGHT;Mn;226;NSM;;;;N;;;;;
1CF0F;ZNAMENNY COMBINING MARK TSATA ON RIGHT;Mn;226;NSM;;;;N;;;;;
1CF10;ZNAMENNY COMBINING MARK GORAZDO NIZKO ON RIGHT;Mn;226;NSM;;;;N;;;;;
1CF11;ZNAMENNY COMBINING MARK SREDNE ON RIGHT;Mn;226;NSM;;;;N;;;;;
1CF12;ZNAMENNY COMBINING MARK MALO POVYSHE ON RIGHT;Mn;226;NSM;;;;N;;;;;
1CF13;ZNAMENNY COMBINING MARK POVSHE ON RIGHT;Mn;226;NSM;;;;N;;;;;
1CF14;ZNAMENNY COMBINING MARK VYSOKO ON RIGHT;Mn;226;NSM;;;;N;;;;;
1CF15;ZNAMENNY COMBINING MARK MALO POVYSHE S KHOKHLOM ON RIGHT;Mn;226;NSM;;;;N;;;;;
1CF16;ZNAMENNY COMBINING MARK VYSOKO S KHOKHLOM ON RIGHT;Mn;226;NSM;;;;N;;;;;
1CF17;ZNAMENNY COMBINING MARK SREDNE S KHOKHLOM ON RIGHT;Mn;226;NSM;;;;N;;;;;
1CF18;ZNAMENNY COMBINING MARK MALO POVYSHE S KHOKHLOM ON RIGHT;Mn;226;NSM;;;;N;;;;;
1CF19;ZNAMENNY COMBINING MARK SREDNE ON RIGHT;Mn;226;NSM;;;;N;;;;;
1CF1A;ZNAMENNY COMBINING MARK STRANNO MALO POVYSHE;Mn;228;NSM;;;;N;;;;;
1CF1B;ZNAMENNY COMBINING MARK POVSHE S KHOKHLOM;Mn;228;NSM;;;;N;;;;;
1CF1C;ZNAMENNY COMBINING MARK STRANNO POVSHE;Mn;228;NSM;;;;N;;;;;
1CF1D;ZNAMENNY COMBINING MARK SREDNE POVSHE;Mn;228;NSM;;;;N;;;;;
1CF1E;ZNAMENNY COMBINING MARK TIKHAYA;Mn;218;NSM;;;;N;;;;;
1CF1F;ZNAMENNY COMBINING MARK KUPNAYA;Mn;218;NSM;;;;N;;;;;
1CF20;ZNAMENNY COMBINING MARK GORAZDO VYSOKO;Mn;228;NSM;;;;N;;;;;
1CF21;ZNAMENNY COMBINING MARK ZELO;Mn;228;NSM;;;;N;;;;;
1CF22;ZNAMENNY COMBINING MARK RAVNO;Mn;228;NSM;;;;N;;;;;
1CF23;ZNAMENNY COMBINING MARK TIKHAYA;Mn;218;NSM;;;;N;;;;;
1CF24;ZNAMENNY COMBINING MARK BORZAYA;Mn;220;NSM;;;;N;;;;;
1CF25;ZNAMENNY COMBINING MARK UDARKA;Mn;220;NSM;;;;N;;;;;
1CF26;ZNAMENNY COMBINING MARK PODVERTKA;Mn;226;NSM;;;;N;;;;;
1CF27;ZNAMENNY COMBINING MARK LOMKA;Mn;218;NSM;;;;N;;;;;
1CF28;ZNAMENNY COMBINING MARK KACHKA;Mn;230;NSM;;;;N;;;;;
1CF29;ZNAMENNY COMBINING MARK KRYZH;Mn;230;NSM;;;;N;;;;;
1CF2A;ZNAMENNY COMBINING MARK ZELO;Mn;228;NSM;;;;N;;;;;
1CF2B;ZNAMENNY COMBINING MARK RAZSEKA;Mn;230;NSM;;;;N;;;;;
1CF2C;ZNAMENNY COMBINING MARK KRYZH;Mn;230;NSM;;;;N;;;;;
1CF2D;ZNAMENNY COMBINING MARK KRYZH;Mn;230;NSM;;;;N;;;;;
1CF2E;ZNAMENNY COMBINING MARK MRACHNO;Mn;230;NSM;;;;N;;;;;
4. Changes

The following changes have been made to this encoding model from the previous iteration:

- The numerical value associated with CCC Attached_Right was corrected from 208 to 210 in accordance with section 5.7.4 of UAX #44.

- The CCC of U+1CF3F Curved Omet was changed from Attached_Right to Right. This has no bearing on character order in practice, but better describes the character’s glyphic behaviour.

- The CCC of U+1CF2A Zevok was changed from Above_Right to Below_Right. The original value was a mistake, as Zevok never interacts with other characters in the Above_Right class.

- The CCC of U+1CF24 Borzaya and U+1CF25 Udarka was changed from Left to Below. These two characters can appear in either position depending on the shape of the base neume, but also based on whether a U+1CF36 Podchashie is present or not. Since this technically means that Borzaya and Udarka interact typographically with Podchashie, they were merged into the same CCC.

- The CCC of U+1CF2D Kryzh was changed from Left to Above_Left because the character has interactions with the left-aligned pitch marks. This value is preferred by Aleksandr Andreev. As a consequence of this change, there will no longer be any Znamenny characters belonging to class Left.

- The CCC of U+1CF26 Podvertka was changed from Below_Right to Right. While its placement can be highly variable, it reacts directly to the presence of other marks in the Right class. However, there is no case where Podvertka can meaningfully change places with another Right character, so in actual use it will always be encoded before any other red Right marks.

- The CCC of U+1CF3B Sorochya Nozhka was changed from Above_Right to Right because its presence can cause other Right characters – namely the right-attached pitch marks – to shift to a different position in some cases.

5. Case Studies

The following are several examples demonstrating some of the more complex interactions between Znamenny combining marks. In every case, the fixed order of marks put forth by the original proposal is canonically equivalent to a well-formed (i.e. meaningful and graphically well-defined) sequence if the proposed CCC values are used.
Canonical order:

- U+1CF92  Strela Prostaya (0: Not_Reordered)
- U+1CF24  Borzaya (220: Below)
- U+1CF26  Podvertka (226: Right)
- U+1CF07  Povyshe on Left (228: Above_Left)
- U+1CF31  Tonal Range Mark Svetlo (230: Above)

By default, Borzaya rests directly below the base neume.

Because Podchashie is present, Borzaya gets pushed to the left side of the neume. Podchashie is a black mark and therefore always encoded before the red mark Borzaya in the same typographic position. The inverse order never occurs in practice and is undefined.
 Canonical order:

- U+1CF0A mechik klyuchepovodny (0: Not_Reordered)
- U+1CF26 podvertka (226: Right)
- U+1CF11 sredne on right (226: Right)
- U+1CF08 vysoko on left (228: Above_Left)
- U+1CF29 kachka (230: Above)

While it isn’t obvious at first given their code chart glyphs, modifying mark podvertka and pitch mark sredne on right do indeed occupy the same typographic position. The presence of the former causes to latter to be drawn further away from the base neume. The inverse order never occurs in practice and is undefined.

Canonical order:

- U+1CF94 strela kryzhevaya (0: Not_Reordered)
- U+1CF24 borzaya (220: Below)
- U+1CF2A zevok (222: Below_Right)
- U+1CF3B sorochya nozhka (226: Right)
- U+1CF07 povyshe on left (228: Above_Left)
- U+1CF30 tonal range mark mrachno (230: Above)

The lower element of the base neume leaves no room for borzaya, which gets pushed to the left side even in the absence of podchashie. On this particular neume, sorochya nozhka visually appears above-right, but on other neumes it could also be centred above or directly right. Zevok is drawn below-right despite its misleading code chart glyph.
Canonical order:
- U+1CF5C Palka (0: Not_Reordered)
- U+1CF26 Podvertka (226: Right)
- U+1CF06 Malo Povyshe on Left (228: Above_Left)

On this particular neume, Podvertka is drawn below by default despite being classified as Right. However, when fellow Right mark Dvoetochie is also present, Podvertka interacts with it and shifts to a different position.

Note also the instance of Kachka appearing to the left of the base neume in this example. This is not caused by typographic interaction with Malo Povyshe on Left (Kachka never interacts with left-attached pitch marks), but rather a feature of the particular type of notation that these examples were derived from.

![Figure 9](image)

Canonical order:
- U+1CF5C Palka (0: Not_Reordered)
- U+1CF3D Dvoetochie (226: Right)
- U+1CF06 Malo Povyshe on Left (228: Above_Left)
- U+1CF29 Kachka (230: Above)

Malo Povyshe on Right shifts to an upper position due to the presence of Sorochya Nozhka, which would not have happened with other right-aligned marks such as U+1CF3F Curved Omet. Due to this, the left-attached pitch mark Nizko and the right-attached pitch mark Malo Povyshe now appear closer together. If both were left-attached instead, they would be stacked diagonally upwards.

![Figure 10](image)

Canonical order:
- U+1CF59 Perevodka Nepostoyannaya (0: Not_Reordered)
- U+1CF3B Sorochya Nozhka (226: Right)
- U+1CF12 Malo Povyshe on Right (226: Right)
- U+1CF04 Nizko on Left (228: Above_Left)

Malo Povyshe on Right shifts to an upper position due to the presence of Sorochya Nozhka, which would not have happened with other right-aligned marks such as U+1CF3F Curved Omet. Due to this, the left-attached pitch mark Nizko and the right-attached pitch mark Malo Povyshe now appear closer together. If both were left-attached instead, they would be stacked diagonally upwards.
Canonical order:

- U+1CF9B  
  \textit{Strela Dvoechelnaya} (0: Not_Reordered)

- U+1CF40  
  \textit{Kryzh} (210: Attached_Right)

- U+1CF3B  
  \textit{Sorochya Nozhka} (226: Right)

- U+1CF12  
  \textit{Malo Povyshe on Right} (226: Right)

- U+1CF06  
  \textit{Malo Povyshe on Left} (228: Above_Left)

- U+1CF22  
  \textit{Ravno} (228: Above_Left)

- U+1CF07  
  \textit{Povyshe on Left} (228: Above_Left)

In this example, \textit{Malo Povyshe on Right} does not get pushed to an upper position by \textit{Sorochya Nozhka}, instead remaining on the right. Without cases such as the previous one, it would not be obvious that these two marks can interact at all.

The three left-aligned pitch marks exhibit their default behaviour of stacking diagonally from left to right.