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# EXPERIMENTAL EVIDENCE FOR A LEFT-TO-RIGHT READING DIRECTION OF THE PHAISTOS DISK

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## ABSTRACT

This paper provides conclusive experimental evidence that the Phaistos Disk was printed in a left-to-right or center-to-periphery direction. The paper gives a thorough analysis of six different aspects of the Phaistos Disk: (1) over stamped signs, (2) crowded signs, (3) bent dividing lines, (4) direction of strokes, (5) direction of faces, and (6) sequence matches among the Phaistos Disk, Arkalochori Axe, and Cretan Hieroglyphic inscriptions. The techniques used in the analysis are observations and two novel experiments.

The first experiment uses clay and different stamps. This experiment demonstrates that if stamp A is pushed deep into the clay and afterwards stamp B is pushed shallower into the clay, then it creates the false impression of stamp A over stamping stamp B.

The second experiment asked subjects to copy a sequence of signs that had strokes below them like the downward strokes below some of the Phaistos Disk signs. The given sequence of signs contained both downward and upward strokes. The subjects, who were all used to reading and writing in a left-to-right direction, tended to change the upward strokes to downward strokes. Hence downward strokes seem associated with left-to-right writing, while upward strokes are associated with right-to-left writing. This experiment demonstrates that the Phaistos Disk scribe also wrote left-to-right because the Phaistos Disk contains only downward strokes.

The paper also reviews the history of the controversy about the reading direction of the Phaistos Disk. With the conclusive proof that the Phaistos Disk needs to be read left-to-right, that is, from the center to the periphery, all previous attempts to read the inscription from the periphery to the center can be discarded.

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**KEYWORDS:** Cretan Hieroglyphs, epigraphy, left-to-right, Linear A, Minoan, palaeography, Phaistos Disk.

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## 1. INTRODUCTION

The Phaistos Disk (also spelled Phaistos Disc) is an artifact found in the Minoan palace of Phaistos in 1908 by the Italian archaeologist L. Pernier. The Phaistos Disk contains an inscription on both of its sides that are called sides A and B. The inscription runs along a spiral on both sides. A remarkable feature of the inscription is that each different sign was printed by a separate die or seal. After 114 years since its discovery, not only is it generally considered undeciphered despite numerous proposed translations, but also its nature of being an ideographic and syllabic writing and its reading direction remain controversial.

Section 7 of this paper argues that the Phaistos Disk is a syllabic writing by showing that several sign sequences of the Phaistos Disk have parallels on either the Archalochori Axe or Cretan Hieroglyphic inscriptions, which are generally assumed to be syllabic writings.

In 1909, Evans assumed a printing direction from the center to the periphery, that is, from left-to-right.

His initial numbering of the blocks or sections are shown in Fig. 1, which is taken from *Scripta Minoa* (Evans, 1909). A left-to-right reading direction is also assumed by Aartun (1992), Ephron (1962), Georgiev (1976), Martin (2000), Matossian (2013), Ohlenroth (1996), and Revesz (2016). Some of these works, including Revesz (2016), assumed a left-to-right direction but did not give any argument for it except that the apparent translations obtained are meaningful. On the other hand, many other authors argued for a printing and reading direction from the periphery-to-center, that is, from right-to-left, including Achterberg et al. (2004), Davis (2018), Duhoux (2000), Fauconnau (1999), Fisher (1997), Hempl (1911), Schwartz (1959), and Stawell (1911). These authors also obtained apparent translations that are meaningful. Hence the meaningfulness of the translations cannot be considered sufficient in identifying the correct reading direction of the Phaistos Disk. Some of the other arguments of these authors are discussed in Section 8.

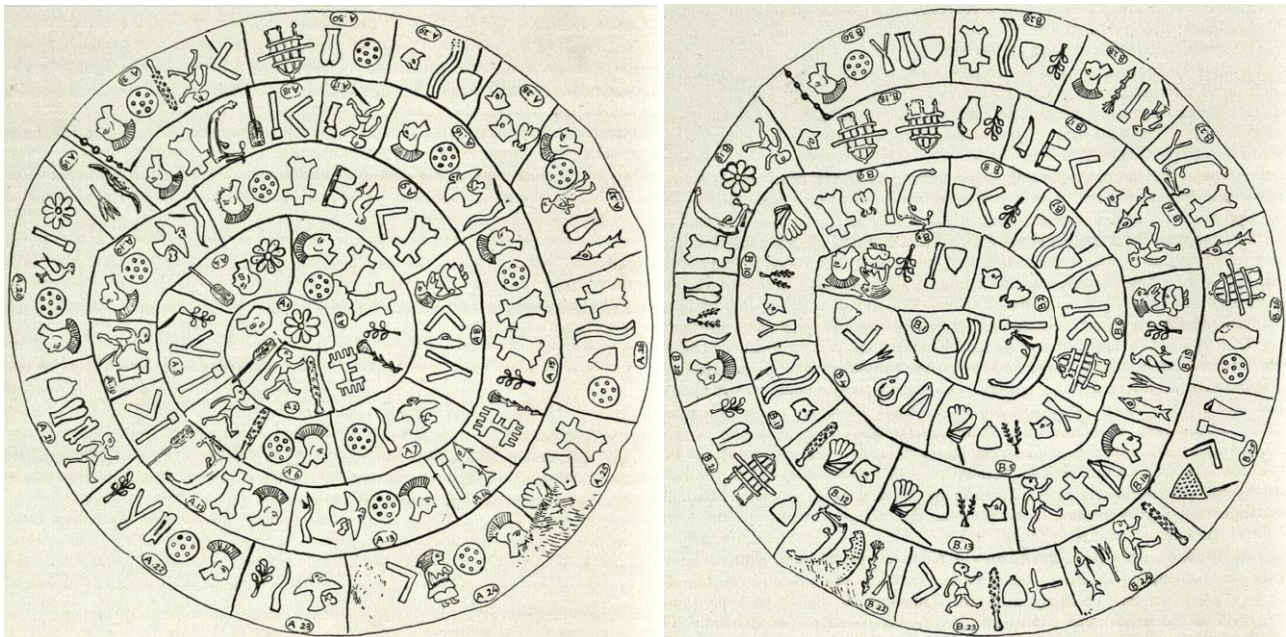


Figure 1. Phaistos Disk drawing and numbering of side A (left) and side B (right) by (Evans, 1909).

The aim of this paper is to prove that the Phaistos Disk must be read left-to-right. Such a proof is motivated by two major reasons. First, all would-be-decipherers would stop wasting their time by trying to read the inscription in the wrong direction. Second, a fresh look may be given to some proposed translations hitherto overlooked from prejudice by those who assumed an opposite reading direction.

The proof relies on new, detailed observations of the Phaistos Disk and two novel experiments. The first experiment uses clay and different stamps. This experiment demonstrates that if stamp A is pushed deep into the clay and afterwards stamp B is pushed

shallower into the clay, then it creates the false impression of stamp A overstepping stamp B. The second experiment asked subjects to copy a sequence of signs that had strokes below them like the downward strokes below some of the Phaistos Disk signs. The given sequence of signs contained both downward and upward strokes. The subjects, who were all used to reading and writing in a left-to-right direction, tended to change the upward strokes to downward strokes. Hence downward strokes seem associated with left-to-right writing, while upward strokes are associated with right-to-left writing. This experiment demonstrates that the Phaistos Disk scribe also wrote

left-to-right because the Phaistos Disk contains only downward strokes.

The rest of this paper is organized as follows. Section 2 considers the issue of over stamping of one sign by another sign. Section 3 considers the crowdedness of signs in certain blocks of the Phaistos Disk. Section 4 discusses bent dividing lines as another evidence of left-to-right printing. Section 5 discusses the directions of stokes, which are frequent diacritical marks on the Phaistos Disk. Section 6 discusses the direction of faces of humans and animals represented by the stamps. Section 7 shows that the left-to-right reading of the Phaistos Disk is consistent with the known readings of Cretan Hieroglyphic inscriptions by finding sign sequence matches. Section 8 discusses related work. Finally, Section 9 gives some concluding remarks and directions for future work.

## 2. OVERSTAMPED SIGNS

Numerous authors noticed several locations in the inscription where some sign seems to overstamp an adjacent sign. For example, on a photo of the Phaistos Disk the ship sign seems to overstamp the animal hide sign in block A12 as shown on the left side of Fig. 2. (In this paper we use the names of the Phaistos Disk signs given by Godart (1995).) Naturally, it is easy to think in this case that the animal hide sign was printed first, and then the ship sign over stamped it. Since the ship sign is to the left of the animal hide sign, if the ship sign over stamped the animal hide sign, then the printing direction must have been from right-to-left. A similar case of overstating occurs in block A15 as shown on the right side of Fig. 2.

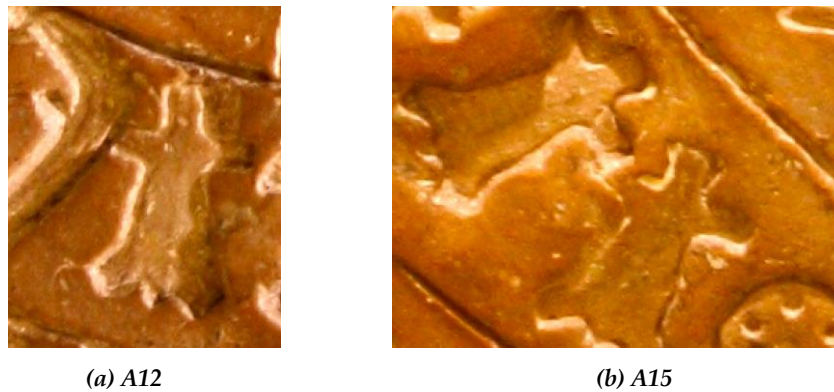


Figure 2. Two examples when the sign on the left over stamps the sign on the right. The example on the left is from block A12 and the example from the right is from block A15.

### 2.1. An experiment with over stamping

We made an experiment to test whether the above assumption of right-to-left printing is true. We took two metal objects, an owl with a rectangle base and a chess set king with a circular base as shown in Fig. 3 (a). Then we used the owl to stamp soft clay as shown

in Fig. 3 (b). At this point, we had only a mostly rectangular impression. Next, we used the king to stamp the clay as shown in Fig. 3 (c). The result is shown in Fig. 3 (d). Note that the result shows an apparent over stamp of the king by the owl because the leftmost piece of the circle is missing, whereas the entire rectangular base of the owl is visible.

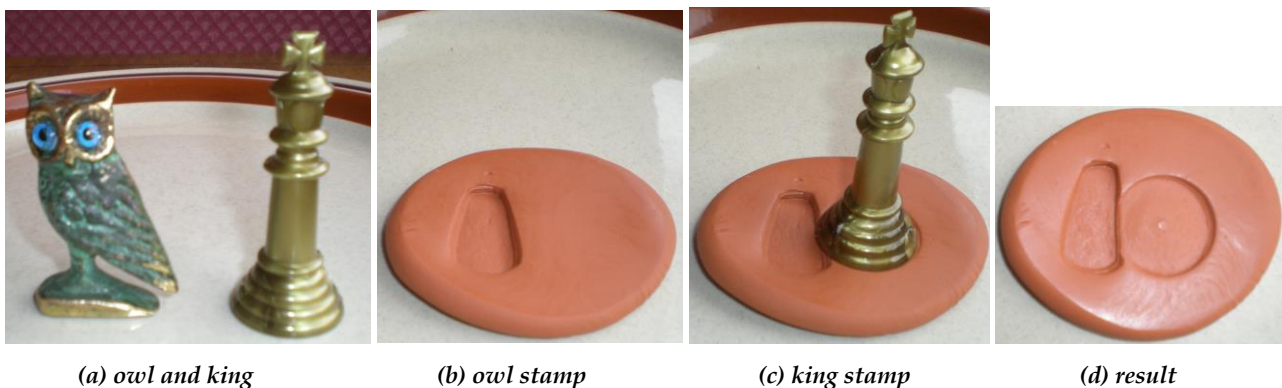


Figure 3. Experiment with an owl stamp and a king stamp to generate an apparent overstamp.

This experiment shows that apparent over stampings may not be actual over stampings. The reason is that in this experiment the owl stamp was pushed

slightly deeper into the clay than the king stamp. The experiment shows that in cases of overlaps the 3-di-

mensional environment of the clay preserves the contour of the stamp that is pressed deeper and destroys the contour of the stamp that is pressed shallower. Hence no conclusion of directionality can be made simply by checking which sign's contour is better preserved. Careful checking of the presumed overstampings in Fig. 2 reveals that in both cases the stamp on the left was pressed deeper into the clay than the stamp on the right side. That is exactly the situation in our experiment with the owl and the king. Hence all previous arguments of right-to-left directionality of printing based on observations of overstampings can be discarded as specious arguments.

### 3. CROWDED SIGNS

The Phaistos Disk contains several blocks where the signs are crowded. For example, crowded signs



Figure 4. Crowded signs in Phaistos Disk block A3 (a) and blocks A27 and A28 (b).

Therefore, the need to save space is consistent throughout block A3. However, some authors claim that the scribe wanted to save space because he/she was afraid to run out of space while approaching the center of the disk. That is a specious argument because in case of a periphery-to-center printing, once the center of side A was filled, the text could have continued from the periphery of side B. Instead, it appears that the scribe was trying to save space throughout the printing of the text. In block A28 the two cat head signs are also printed slightly above each other. Note that block A28 is on the periphery and close to the end of the printing of side A if it was printed from center-to-periphery. Hence one may as well argue that the scribe was worried of running out of space as he/she approached the end of side A and that's why he/she wrote the two cat heads on top of each other. However, as we said, there is no reason to assume that the scribe panicked because he/she could have continued writing on side B.

The crowdedness of signs in block A27 is likely due to insertion of some extra signs. The scribe likely noticed the omission of a shield and a plume head sign after reaching the red cat head sign. A careful consideration of blocks A27 and A28 reveals that a dividing

line and two stamp signs were removed from them. The contours of these are shown by a dashed blue line in Fig. 5. Our explanation of the events that led to the present state of blocks A27 and A28 is the following. The scribe simply forgot to print the shield and the plume-head signs and closed block A27 by a dividing line too early. Then the scribe continued left-to-right until the cat head sign shown in red. At that point the scribe noticed the omission error. In making a correction, he/she could have deleted all the inscription shown in blue and red. However, the scribe used a trick to minimize the number of corrected signs. The scribe deleted only those parts that are shown in blue. Then he/she could insert the shield, the plume-head and the fly signs and add a dividing line between the plume-head and the fly signs. In this way, the cat head sign shown in red was saved and did not need to be deleted. However, to avoid deleting the red cat head, three signs needed to be inserted into the deleted space of two signs. This caused the crowdedness that we see in A27. Hence, like in block A3, the scribe used the space saving trick of writing the plume-head sign below the shield sign.

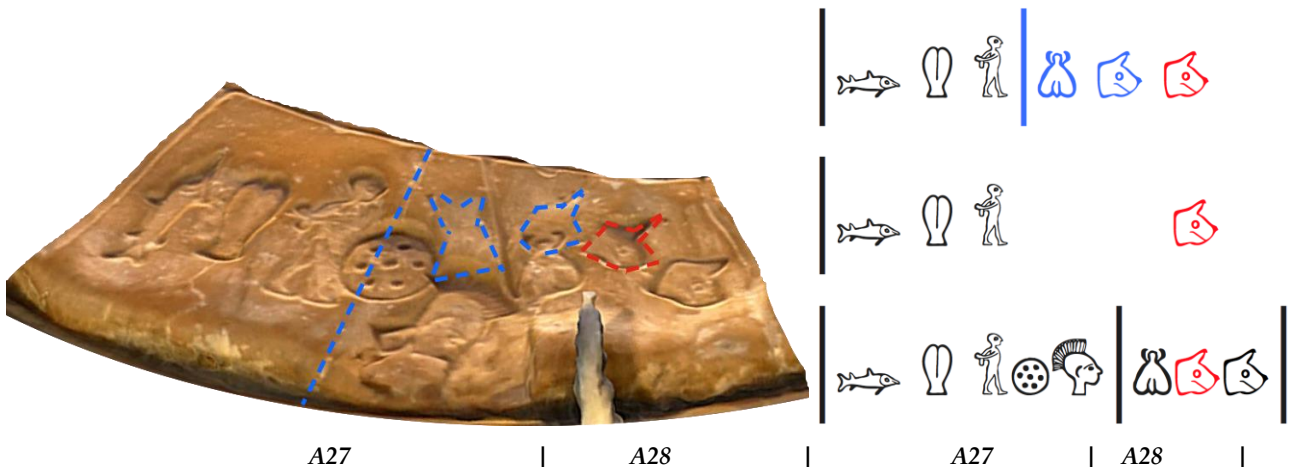


Figure 5. Extra lines that were apparently deleted are highlighted in blue (left). The likely sequence of events that lead to crowding in blocks A27 and A28 (right).

Note that our sequence of events assumes a left-to-right printing of the text. There were no good explanations given by those authors who assumed a right-to-left printing. In fact, in case of a right-to-left printing the scribe could have noticed the missing signs after printing the captive, the ox-back or the fish sign. However, in any of those cases it would have been more natural to delete those signs and avoid the crowdedness in block A27.

#### 4. BENT DIVIDING LINES

In almost all cases, the scribe used perfectly straight dividing lines. That makes the few exceptions where the dividing lines are slightly bent particularly noteworthy. Fig. 6 shows the five cases of bent dividing lines that can be found on the Phaistos Disk.

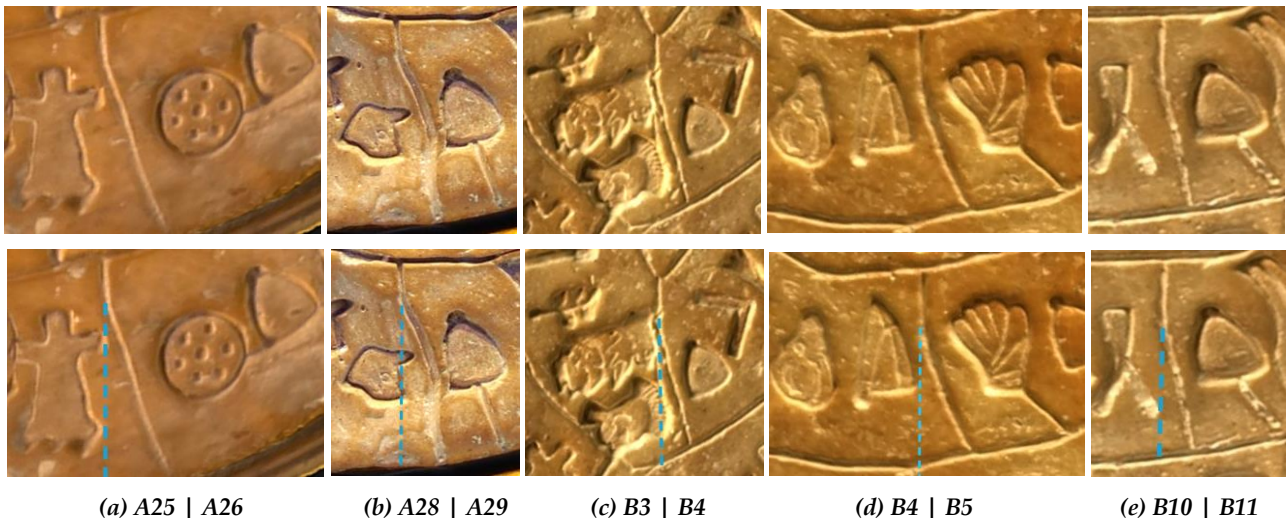


Figure 6. Examples of bent dividing lines (a)-(e) with the actual bent dividing line (top row) and with a hypothetical blue dividing line (bottom row).

In each of these five cases the line starts from the top and goes straight down a little and then suddenly bends rightward. Why do all the dividing lines that are not straight bend rightward? The reason seems to be that if they were continued straight, then they would cross the stamped signs on the left as shown in Fig. 6. Clearly, the scribe, who apparently had a strong preference for straight dividing lines, was worried about crossing some already stamped sign. Therefore, the signs on the left had to exist before the scribe drew the dividing lines shown in Fig. 6. That is a

strong indication that the scribe was stamping the signs from left-to-right. Once a block was finished, then the scribe added a dividing line to close the blocks. However, the scribe apparently drew the spirals before stamping, as we see for example in block B3, where the plume-head sign slightly overstamp the spiral line. To our knowledge previous authors did not notice or comment on these bent dividing lines, although the bending is a key evidence for a left-to-right direction of stamping.

## 5. DIRECTION OF STROKES

The scribe added a small stroke by hand to several Phaistos Disk signs. The first row of Fig. 7 shows five examples of strokes from blocks A5, A10, A16, A17 and A31 of the Phaistos Disk. In addition, block B5 in Fig. 6 (d) and block B11 in Fig. 6 (e) also contain strokes.

We searched for similar diacritical marks in other scripts. We found similarities with the Brahmic script *virama*, the Greek *iota subscript*, and the Native American *ogonek* diacritical marks, which are shown in the third row of Fig. 7. All the strokes on the Phaistos Disk and the diacritical marks in the other scripts run downward from left-to-right because the left end is higher than the right end.



Figure 7. Examples of strokes on side A of the Phaistos Disk (a)-(e), and in the Brahmic (f), Greek (g), and Native American (h) scripts.

These diacritical marks are used for different purposes in the three other scripts. Hence, they are likely unrelated to each other and can be considered separate inventions. However, these three scripts all have in common that the diacritical mark is running slightly downward from left-to-right. In addition, all three of these scripts are written from left-to-right. We could not find any example of a script that is written left-to-right and uses a stroke like a diacritical mark that runs the opposite direction below the letters, i.e., its left end is lower than its right end. Hence it seems natural in a left-to-right writing to use a diacritical mark below the signs in a way that the diacritical mark's left end is higher than its right end.

The opposite seems unnatural and not used in any left-to-right script. Presumably, in a right-to-left writing the opposite would be the case. That is, in a right-to-left writing it would be natural to draw a stroke-like diacritical mark below the signs in a way that the diacritical mark's left-end is lower than its right end, and it would be unnatural to do the opposite. This seems to be a reasonable assumption, although at this time we could not find any examples of

the use of stroke-like diacritical marks below the signs in any right-to-left writings. In fact, if it were written right-to-left, then the Phaistos Disk's strokes would be the only example of using stroke-like diacritical marks below the signs. However, if the Phaistos Disk were written left-to-right, then it would fit in with the other three scripts.

Some diacritical marks in other scripts are little quarter circles at the bottom of signs and turn left. However, these do not have a resemblance to a stroke, which is a straight line segment.

### 5.1. An experiment with strokes

In this experiment, nine graduate students in the author's Computational Linguistics 990 class at the University of Nebraska-Lincoln were asked to copy within one minute the list of signs shown in Fig. 8. The normal writing direction for each of the subjects was left-to-right. None of these subjects were used to the signs with the diacritical marks shown in Fig. 8.



Figure 8. The list of signs that the subjects were asked to copy.

Table 1 shows the copying errors made by the subjects on two letters which had diacritical marks like an *ogonek*. The sign — indicates that the subject did not get far enough to attempt to copy the letter. In the last row of Table 1, the percentage error is calculated as follows:

$$\text{Error \%} = \text{Erroneous Attempts} / \text{Total Attempts}$$

We did not include the other signs because there were no significant copying errors for them. For example, those who got as far as the Brahmi letter that is the second from the right, copied it correctly including the virama. Even its mirror image, which was the sixth letter from the left, was also copied correctly by all but two students, who interpreted the backward-looking virama as a comma between the fifth and the sixth letters.

Table 1. Copying errors made by the subjects.

Subject ID	Ç	ö
1		
2		
3		—
4		
5	—	—
6	—	—
7		—
8		
9		
Error %	28.6	60

As Table 1 shows, for the two signs we studied the copying errors were 28.6 and 60 percent, respectively. The errors consisted in interpreting the leftward curling ogonek as a straight rightward stroke, just as on the Phaistos Disk. We counted subject 7's copy of the first letter as this type of error because it starts out as a straight rightward stroke although a small leftward segment is also added at the end. Subject 7 likely recognized his/her copying error and tried to adjust it, but it is still not a leftward curl as in the original.

Clearly, the subjects' normal left-to-right direction of writing together with the strict time limit contributed to these errors. Hence it appears that for a left-to-right writing direction the most natural diacritical mark below a sign is a straight stroke whose left end

is higher than the right end. Presumably, for writers who are used to a right-to-left direction, the situation would be reversed. For them the natural diacritical mark would be strokes whose left end is lower than the right hand. This experiment also supports the left-to-right direction of printing the signs and writing by hand the strokes on the Phaistos Disk because the left ends are always higher than the right ends on the strokes on the Phaistos Disk, which is shown to be natural for a left-to-right direction.

## 6. DIRECTION OF FACES

Several authors argue that the reading direction should be right-to-left because the printed signs of humans and animals face to the right, and in Egyptian

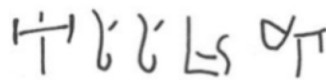
Hieroglyphic texts, the reading direction is towards the faces of humans and animals. The Egyptian style is just a convention that was apparently not followed on Crete.

Consider the Linear A inscriptions shown in Fig. 9. Both examples are taken from Godart and Olivier's *Recueil des inscriptions en Linéaire A* (commonly abbreviated as GORILA) where a left-to-right reading is

assumed. In the Linear A inscription in Fig. 9 (a), the fifth sign from the left is the head of a human or a bird. The head seems to look right, while the reading direction is left-to-right. Therefore, the reading direction is toward the back of the head of humans and animals. Similarly, in the Linear A inscription in Fig. 9 (b), the fourth sign from the left is a duck that faces to the right, while again the reading direction is left-to-right.



(a) A crystal bowl Linear A inscription, identified as IO Za 6 in (GORILA, vol. 5, p. 26).



(b) Another Linear A inscription, identified as IO Zb 10 in (GORILA, vol. 5, p. 34).

Figure 9. Two examples of Linear A inscriptions with left-to-right reading into the back of human and animal heads.

For Cretan Hieroglyphic inscriptions, the convention is to mark the beginning of the text with a cross mark (Olivier and Godart, 1996). This convention allows both a left-to-right reading direction as shown in Fig. 10 (a)-(c) and a right-to-left reading direction as

shown in Fig. 10 (d)-(g). In Fig. 10 (a)-(c), all the animal heads face right, while in Fig. 10 (d)-(g), all the animal heads face left. Hence in the Cretan Hieroglyphic inscriptions the direction of reading matches the direction of where the animals look.

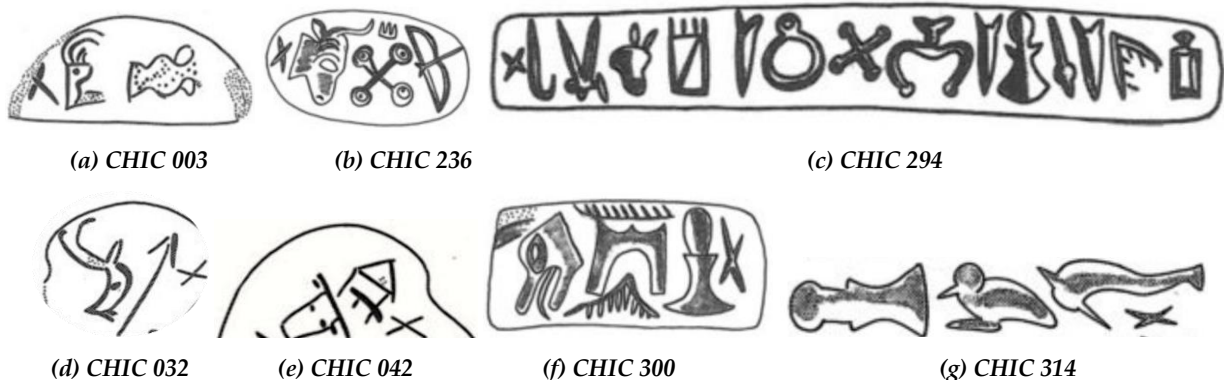


Figure 10. Examples of Cretan Hieroglyphic inscriptions from (CHIC) with left-to-right reading direction (a)-(c) and right-to-left reading direction (d)-(g).

### 6.1. Consistency of the Phaistos Disk, Cretan Hieroglyphic and Linear A reading directions

Both the Cretan Hieroglyphic and the Linear A inscriptions follow the convention of reading in the direction where the animals and the humans are looking. As shown in Fig. 1, the animal and human heads look to the right on the Phaistos Disk. Hence, if the Phaistos Disk follows the same convention as the Cretan Hieroglyphic and the Linear A inscriptions, then we would need to read the Phaistos Disk from the center to the periphery.

One possible objection is that the other well-known Minoan spiral inscription, the Mavrospilio gold ring, which is identified as KN Zf 13 in (GORILA, vol. 4, p. 153), is said to be read from the periphery to the center. The reasoning is that if the Mavrospilio inscription is read from the periphery to the center, then the Phaistos Disk also must be read from the periphery to the center. However, Fig. 11 shows that this reasoning is not a serious objection. Fig. 11 reveals that the signs of the Mavrospilio gold ring point away from the center, while the signs of the Phaistos Disk point toward the center. Hence if we want to read the Phaistos Disk from left to right, then we must read from the center



to the periphery, and if we want to read the Mavrospilio inscription from left to right, then we must read from the periphery to the center. Therefore, the two spiral inscriptions share the important feature of left-to-right reading direction, which was clearly an

established convention for Linear A inscriptions. They just do not share the center-to-periphery reading direction, but that is unimportant because there is no evidence for a center-to-periphery reading direction convention in Minoan times.

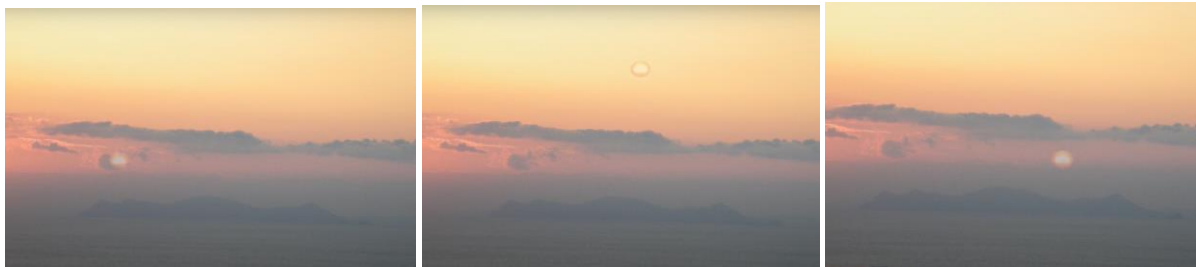


Figure 11. The signs of the Phaistos Disk point toward the center (left, red arrows), while the signs of the Mavrospilio gold ring point toward the periphery (right, green arrows).

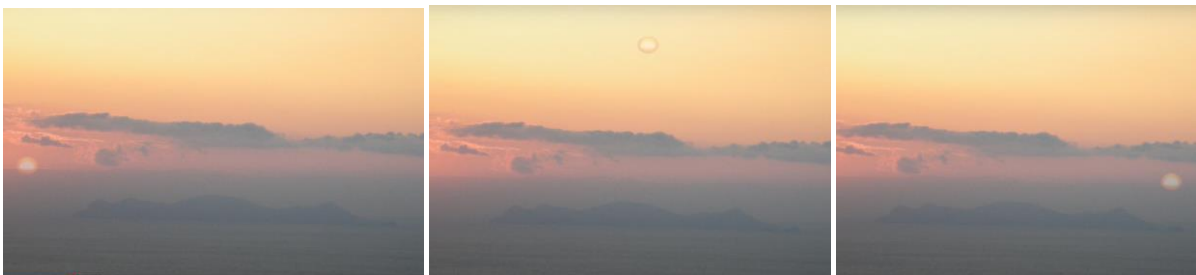
## 6.2. Deeper significance of spiral inscriptions and their reading directions

Section 6.1 pointed out that the left-to-right reading direction can be kept for a spiral inscription while leaving free the choice of center-to-periphery or periphery-to-center reading. It is likely that scribes

choose carefully between the two choices, albeit our guesses regarding their choices will necessarily remain speculative until more Minoan spiral inscriptions are found. Nevertheless, let us mention some possibilities.



(a) During a winter day the Sun appears to make a smaller half-circle in the sky.



(b) During a summer day the Sun appears to make a wider half-circle in the sky.

Figure 12. From the winter solstice (a) to the summer solstice (b), the Sun appears to make increasingly larger half-circles in the sky. In the imagination of ancient people, the Sun continued to complete the circle in the underworld each night. Furthermore, this imagination likely led to the view of the Sun's movement as an expanding spiral movement between the winter and the summer solstices. This illustration is based on the author's video:

[https://youtu.be/7RunFz\\_clqY?t=417](https://youtu.be/7RunFz_clqY?t=417)

A periphery-to-center reading seems to imply some convergence. If the Mavrospilio gold ring is a wedding ring, then the scribe may have chosen a periphery-to-center reading to imply the unification of the husband and the wife. In fact, Revesz (2017) gave a translation of the Mavrospilio inscription as a love message that is suitable for a couple.

In contrast, a center-to-periphery reading seems to imply some divergence or growth. Ancient people believed that the Sun made a circle each day, half of it was visible during the day, and the other half was invisible because it occurred below the horizon as illustrated in Fig. 12. Moreover, the Sun appeared to make

the smallest circle at the time of winter solstice, and then it appeared to make increasingly bigger circles until the summer solstice.

It seems likely that the imagination of ancient people also extended this concept to a growing spiral movement of Sun from the winter to the summer solstice, and a decreasing spiral movement from the summer to the winter solstice. Fig. 13 shows a stone carving from Knowth, Ireland that may reflect his belief. The carving consists of a pair of expanding and shrinking spirals, hence likely the Sun's movement during an entire year.



Figure 13. Double spiral carved into a stone at the Neolithic passage grave at Knowth, Ireland.

Photo (detail): Kafka Liz CC by 3.0

[https://commons.wikimedia.org/wiki/File:NG\\_Kerbstone\\_with\\_spirals\\_and\\_lozenges.jpg](https://commons.wikimedia.org/wiki/File:NG_Kerbstone_with_spirals_and_lozenges.jpg)

## 7. SEQUENCE MATCHES AMONG THE PHAISTOS DISK, ARKALOCHORI AXE, AND CRETAN HIEROGLYPHIC INSCRIPTIONS

In this section, we search for matching sign sequences between the Phaistos Disk blocks and either the Arkalochori Axe inscription, which is shown in Fig. 14, or the Cretan Hieroglyphic inscriptions. This task requires first the matching of individual signs, then identifying the proper reading direction of each inscription, and finally searching for matching sequences.

As can be seen in Fig. 14 (a), the Arkalochori Axe signs stand upright. It would be uncertain whether we need to read the inscription bottom-to-top or top-to-bottom without some marker. Luckily, the scribe added dot marks to the top of each row as shown in Fig. 14 (d). These dots indicate the end of each row of the Arkalochori Axe inscription. Hence the rows need to be read bottom-to-top. The scribe also marked the beginning of the inscription at the

bottom of the third row from the left by an X shown in a yellow box in Fig. 14 (e). Fig. 14 (b) is a detail of the bottom two signs of the first column from the left, while Fig. 14 (c) is a detail of the bottom three signs of the second column.

Several authors tried to match the Phaistos Disk signs with the signs of the Arkalochori Axe inscription, which is shown in Fig. 14, and the Cretan Hieroglyphs. Our proposed matches are shown in Table 2 based on Revesz (2016c, 2017b). The Phaistos Disk signs are numbered as in Evans (1909), and the Cretan Hieroglyphs are numbered as in Olivier and Godart (1996), *Corpus Hieroglyphicarum Inscriptionum Cretae* (CHIC). The matches in Table 2 are only current guesses based on the visual similarity between pairs of signs. The visual similarity is hard to measure for hieroglyphs, and we must rely on our eyes as many earlier researchers did who proposed similar sign comparison tables. A mathematical similarity measure for comparing linear signs, which are composed mostly of line segments such as Linear A, Linear B and the Carian alphabet is proposed by Revesz (2017).

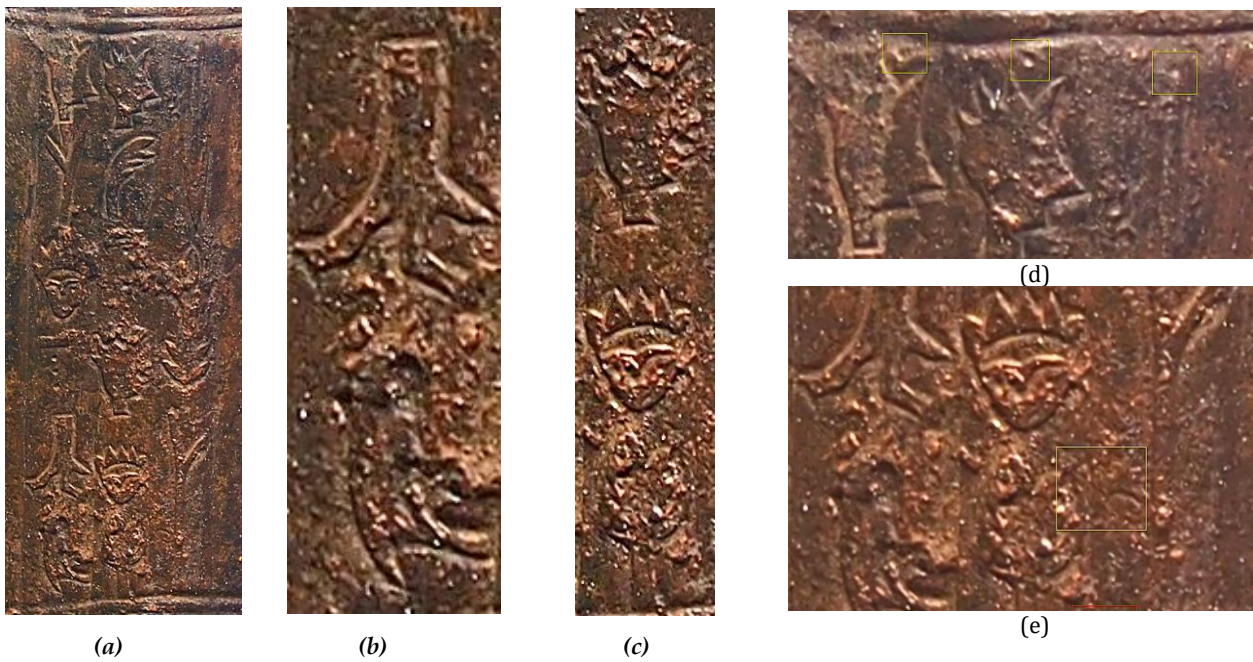


Figure 14. The Arkalochori Axe inscription (a), bottom two signs in the first column from the left (b), bottom three signs of the second column (c), top of the inscription with yellow boxes for the dot marks indicating the ends of columns (d), and bottom of the inscription with yellow box for the X mark indicating the beginning of the entire inscription (e).  
 Photo: Wikipedia CC by 1.0, [https://commons.wikimedia.org/wiki/File:Arkalochori\\_Axe\\_1c.jpg](https://commons.wikimedia.org/wiki/File:Arkalochori_Axe_1c.jpg)

Table 2. Phaistos Disk, Cretan Hieroglyph, and Arkalochori Axe sign correspondences based on Revesz (2016c, 2017b).

Phaistos Disk	Cretan Hieroglyph	Arkalochori Axe	Phaistos Disk	Cretan Hieroglyph	Arkalochori Axe	Phaistos Disk	Cretan Hieroglyphs	Arkalochori Axe
1			16			31		
2			17			32		
3			18			33		
4			19			34		
5			20			35		
6			21			36		
7			22			37		
8			23			38		
9			24			39		
10			25			40		
11			26			41		
12			27			42		
13			28			43		
14			29			44		
15			30			45		

For each Phaistos Disk block, we searched for Arkalochori Axe and Cretan Hieroglyphic inscription sign sequences that matched at least two adjacent signs within the block according to Table 2. The search was facilitated by the AIDA (Ancient Inscription and Data Analytics) system, which is under development at the University of Nebraska-Lincoln (Revesz et al., 2019).

Table 3 lists thirteen matches between the Phaistos Disk blocks and either the Arkalochori Axe or the Cretan Hieroglyphic inscriptions. The Cretan Hieroglyphic inscriptions are numbered by the CHIC inscription id numbers given in the third column of Table 3. If the match occurs with a column of the Arkalochori Axe inscription, then we indicate that by Arka1, Arka2, and Arka3 for the first, second and third columns from the left, respectively.

**Table 3. Sequence matches (highlighted in brown) between the Phaistos Disk blocks, and either the Arkalochori Axe or Cretan Hieroglyphic inscriptions. These matches are revised and extended from (Revesz, 2016c, 2017b).**

Phaistos Disk Block #	Phaistos Disk sign sequence	CHIC # or Arkalochori column #	CHIC's reading direction	Cretan Hieroglyphic Inscription (CHIC photo)	Inscription written left-to-right
A1		298d	right-to-left (wrong)		
A5		182	clockwise		
A6		113a	right-to-left		
A9		089b	right-to-left		
A12		053a	right-to-left		
A23		320	left-to-right		
B2		127	right-to-left		
B2		303a	left-to-right		
B3		Arka2	bottom-to-top	Figure 14 (c)	
B4		113b1	right-to-left		
B17		125	left-to-right		
B26		65a	left-to-right		
B27		Arka1	bottom-to-top	Figure 14 (b)	

In Table 3, the matching Phaistos Disk signs and Cretan Hieroglyphs are shown in brown. The matching sign sequences seem to be either root words as in blocks A1, A23, B2 and B4 or suffixes as in blocks A6, A12 and B17. In block A9 the matching signs also seem to be root words given in the Cretan Hieroglyphic inscription, where a dot indicates that there is some sign which is difficult to read. Probably the first three signs in block A9 contain some prefix or other grammatical elements. The matching sequences as well as the fact that they tend to be simultaneously either at the beginning or at the end on both the Phaistos Disk and Cretan Hieroglyphic inscription blocks, form another strong indication that the correct reading direction of the Phaistos Disk is left-to-right. The reading direction of the Cretan Hieroglyphic inscriptions is clear because the beginning is indicated by an X sign or there are other indications supporting CHIC's reading direction. The only place where we disagree with CHIC's reading direction is for CHIC #298d shown in the first row. Here CHIC assumes a

right-to-left reading direction, but there is no X on either the right or the left side. On the other hand, there is an X on the right side of 298a, 298b and 298c. Apparently, the Minoan scribe assumed a left-to-right default reading and indicated a right-to-left reading by an X sign on the right side. It also can be noted that there are numerous instances of the pair of signs  $\delta$   $\uparrow$  and they are routinely read left-to-right. These also support a left-to-right reading of CHIC #298d and the block A1 of the Phaistos Disk.

## 8. RELATED WORK

Many researchers proposed various contradictory translations of the Phaistos Disk using either a left-to-right or a right-to-left reading direction without any justification for their choices. Table 4 is a summary of the reading directions used in earlier translations, if a translation was given, or the main arguments for the proposed reading direction if no translation was given.

*Table 4. Proposed reading directions of the Phaistos Disk and the language when a translation was given.*

Author (year)	Reading Direction	Language	Argument beyond translation
Aartun (1992)	left-to-right	Semitic	
Achterberg et al. (2004)	right-to-left	Luwian	
Davis (2018)	right-to-left	not Greek	The Phaistos Disk and Linear A homomorphs are homophones.
Duhoux (2000)	right-to-left	not Greek	"Several peculiarities indicate that the disc was stamped from the exterior to the interior, with the exceptions of a few corrections."
Eisenberg (2008)	none	none	The Phaistos Disk is claimed to be a forgery.
Ephron (1962)	left-to-right	Greek	There are overstamps, and imprints only touch each other, except in block A27, which supports a left-to-right reading.
Evans (1909)	left-to-right		It is easier to resize the disk as needed if printing starts from the center.
Faucounau (1999)	right-to-left	Greek	The spiral lines are traced from the outside to the center.
Fisher (1997)	right-to-left	Greek	There are instances of overstamping.
Georgiev (1976)	left-to-right	Hittite	
Hempl (1911)	right-to-left	Greek	Virama indicates a silent letter "a" in Ca syllables at the ends of words in the Cypriot syllabary, while vowels are unique signs at the beginnings.
Martin (2000)	left-to-right	Greek	
Ohlenroth (1996)	left-to-right	Greek	
Revesz (2016)	left-to-right	Proto-Ugric	
Schwartz (1959)	right-to-left	Greek	There are overstamping instances in blocks A15, A18 and A27.
Stawell (1911)	right-to-left	Greek	It is easier to read cramped signs of A3 after equivalent uncramped A15.

The list in Table 4 is necessary selective, incomplete, restricted to published scientific works and does not include manuscripts, Internet blogs and self-published books. We also exclude publications that claim that the Phaistos Disk is a calendar or an ideographic text, for example Matossian (2013), because the sign sequence matches in Table 3 indicate that the Phaistos Disk is like the non-calendrical, syllabic Cretan Hieroglyphic inscriptions. The works in Table 4 are serious non-ideographic attempts either for a decipherment or some analysis of the Phaistos Disk. Since the translation works are clearly contradictory, at most one of them can be correct. Nevertheless, it seems proper to discuss all these publications as related works.

Davis (2018) presents an interesting experiment comparing pairs of Phaistos Disk signs read right-to-left to pairs of Linear A signs read left-to-right and to pairs of Linear B signs read left-to-right. In the experiment, the number of matches between the Phaistos Disk and Linear A pairs was much higher than random, while the number of matches between the Phaistos Disk and Linear B pairs was what can be expected to occur randomly between unrelated languages. According to Davis, the experiment shows both the correctness of the right-to-left reading direction and that the language of the Phaistos Disk and Linear A are the same.

There are several problems with the experiment of Davis (2018). First, he does not consider allographs,

which are difficult but possible to detect in undeciphered scripts (Daggumati and Revesz, 2021). Since Linear A has about twice the number of signs than the Phaistos Disk, it is conceivable that each Phaistos Disk sign has two Linear A allograph signs on average. Hence if Linear A signs a1 and a2 are allographs of Phaistos Disk sign p1, and Linear A signs b1 and b2 are allographs of Phaistos Disk sign p2, then the four pairs a1-b1, a1-b2, a2-b1, and a2-b2 are allographs of p1-p2, but without a consideration of allographs only one of these four Linear A pairs will be matched with the Phaistos Disk pair.

The second problem is that Davis does not explain how he matched the Phaistos Disk and Linear A signs. A well-designed experiment requires an objective, algorithmic matching of the signs between different scripts as was already done between the Phaistos Disk and Linear A signs by Revesz (2016c). Relying only on one's own eyes while doing such an experiment can introduce subtle bias errors. Table 5 shows that Davis' matchings are often different from those in Revesz (2016c). The differences may be instances of allographs. For example, Phaistos Disk sign #45, could be associated with a water wheel, which could explain the sign shown in the lower right corner of Table 5. Davis's matching choice for the ship sign is a safe bet. However, it is a rather rare Linear A sign whereas Phaistos Disk sign #25 is a frequent sign. Hence the choice given in Revesz (2016c) could be a better match for Phaistos Disk sign #25.

Table 5. Differences between Davis (2018) and Revesz (2016c) in matching Phaistos Disk and Linear A signs.

Phaistos Disk ID	7	8	12	16	19	22	23	25	29	31	34	35	36	39	43	45
Phaistos Disk sign																
Davis (2018)																
Revesz (2016c)																

Duhoux (2000) makes a statement that probably refers to some apparent overstacking (see Section 2) but also points out that there is an inconsistency because the overstacking implies a left-to-right direction for the corrections in block A27. Duhoux does not explain this inconsistency. Duhoux (2000) also summarizes an earlier study (Duhoux, 1983) that compares the prefix-to-suffix ratios of the Phaistos Disk, Linear A inscriptions, and Linear B inscriptions. According to his calculations, the ratios are 15:8 for the Phaistos Disk, 17:12 for Linear A, and only 1-2:4-9 for Linear B. Since Linear B is written in Greek, his conclusion is that the language of the Phaistos Disk cannot be Greek. However, we believe that he assumes a

wrong reading direction, hence the Phaistos Disk ratio should be 8:15, which is the reverse of his stated ratio. Even such a ratio is highly hypothetical because blocks could be sentences instead of individual words.

Eisenberg (2008) claims that the Phaistos Disk was forged by the Italian archaeologist Luigi Pernier, who led the excavations at Phaistos, out of jealousy for Evans' successes at Knossos. Eisenberg (2008) lists numerous parallels between Phaistos Disk signs and other Bronze Age archaeological artifacts. These parallels help place the Phaistos Disk firmer into a Bronze Age context rather than cast dispersions on Pernier's reputation. Baldacci (2017) describes that the Phaistos Disk sign #21, which archaeologists call the comb

sign, also occurs with slight variations on the imprint of seal CMS II.5, No. 246 and on a bowl F 4718. These objects were found during excavations at Phaistos in the 1960s, that is, long after the Phaistos Disk was discovered in 1908 (Pernier, 1909). Baldacci points out that the complexity of the signs shows that they were different reproductions of the same original sign rather than that they arrived at their shapes by independent processes. We add that most Cretan Hieroglyphic inscriptions were also excavated after 1908. Hence a forger could not have known about the Cretan Hieroglyph sign sequences shown in Table 4 and imitate those sign sequences on the Phaistos Disk. Moreover, the Arkalochori Axe also contains a version of Phaistos Disk sign #2, called the plumed head sign. A forger would not have known about the plumed head sign because the Arkalochori Axe was discovered only in 1934 (Marinatos, 1962).

Ephron (1962) supports a left-to-right reading of the Phaistos Disk by claiming that there are over-stamps because the imprints of the signs only touch each other except in block A27, where the clear over-stamps imply a left-to-right printing direction. Ephron's view cannot be accepted because the enlarged photos in Fig. 2 clearly show that the signs are somehow overstamped instead of only touching each other as Ephron claims.

Evans (1909) considered the printing direction to be left-to-right because in that way it is easier to extend the size of the disk in case the scribe runs out of space. The two sides of the Phaistos Disk seem to use the available space well to discuss two apparently separated topics because the sign frequencies are very different on the two sides. Evans' intuition that such a good use of space is nearly impossible when one starts from scratch to compose a writing seems correct. However, the good use of space can be also explained if the scribe copied the writing from a template.

Faucounau (1999, 2001) observes that the scribe traces the spiral lines from the periphery to the center. He argues that this means that the printing also proceeded from the periphery to the center, that is right-to-left. However, it is perfectly possible to draw the spiral from the periphery to the center and then print from the center to the periphery in a left-to-right direction. The reason why a scribe would draw the spiral line from the periphery to the center is that it makes easier to ensure that there are parallel lines in the outmost layers, which leads to a better use of the available space.

Fisher (1997) briefly mentions the issue of reading direction on page 50, where he refers to over-stamping and a presumed consensus of reading from right-to-left.

Hempl (1911) considers the strokes below some of the signs to be viramas that indicate a silent /a/ vowel when written under syllabic signs that normally have the phonetic value Ca, where C is some consonant. Hence, according to Hempl, the stroke is used to indicate word final consonants. Since the strokes always occur under the leftmost sign within each block, the text must be read right-to-left. Hempl also remarked that some signs, such as the plumed head sign, only occur on the right side of blocks. He interprets these as word initial vowels in a right-to-left reading. Hempl's arguments are not convincing. One can easily reverse Hempl's arguments saying that the strokes indicate silent consonants, and the signs that occur only on the right side indicate word final consonants in a left-to-right reading. Hempl's idea is implausible because viramas are not used in any other Aegean script or the related Cypriot syllabary. In addition, the blocks may not be words but sentences. Then in a left-to-right reading, the strokes may indicate the beginning of questions like the upside-down question mark (¿) in Spanish.

Martin (2000) only gives a left-to-right Greek translation for side A of the Phaistos Disk. The other side is said to be a uniquely Minoan language, that is, the Phaistos Disk is considered a bilingual document.

Schwartz (1959) argues for a right-to-left reading direction based on the over-stamping instances in blocks A15, A18 and A27. Section 2 already showed that this argument does not hold because the apparent over-stamping could be the result of the stamp on the left being pushed deeper into the clay than the stamp on the right.

Stawell (1911) argues that when there are repetitions like in blocks A3 and A15, then the block closer to the center (A3) tends to be cramped, while the one closer to the periphery (A15) tends to avoid cramping. Hence it is easier to repeat texts from the periphery to the center, that is from right-to-left. This argument is defeated by the observation that the cramping occurs on the right side of block A3. Section 2 already mentioned that the right-side cramping could result from a left-to-right printing direction as the scribe was running out of space.

In general, the advocates for a left-to-right reading did not list arguments for the reading direction probably because a left-to-right reading is common in all Greek inscriptions, including Linear A and Linear B. On the other hand, those advocating a right-to-left reading offered several divergent arguments. However, each of those arguments can be countered, as we have done in this paper. In conclusion, while a left-to-right reading seems a naïve approach, it is the logical conclusion. The right-to-left reading may seem a more sophisticated approach, but the arguments for it are specious.

Table 4 shows that Greek is a frequently considered language by would-be translators. Greek looks like a natural choice because the Phaistos Disk was found in Greece. However, according to Marija Gimbutas' Kurgan hypothesis of Indo-European origins, the earliest Greek-language speakers arrived at Greece only in the Bronze Age, while she viewed the Minoan civilization as a late survivor of the Neolithic Old European culture, which flourished in Southeastern Europe (Gimbutas, 1989). Recent archaeogenetic and art motif studies (Revesz, 2019, 2019b, 2021) support a Danube Basin origin of the Minoans. In addition, the Minoan scripts, which appear suddenly in a developed form on Crete, also seem to derive from the Old European or Danubian script (see Fig. 15, based on Gimbutas, 1991).

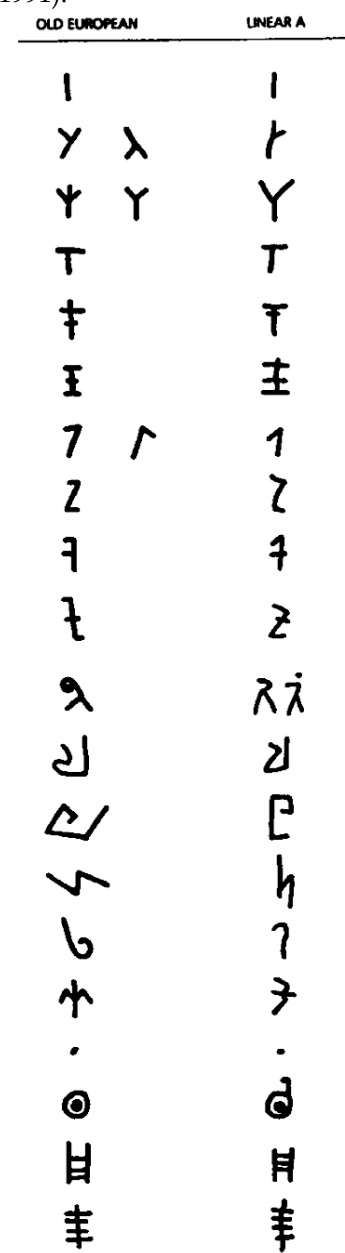


Figure 15. A comparison of Old European and Linear A signs by Gimbutas (1991).

The language of the Old European culture is unknown currently because the Old European inscriptions are undeciphered. However, there are some conjectures. Revesz (2021b) conjectures that it may belong to the Finno-Ugric language family and within that to a West-Ugric branch, which includes Minoan as well as Hattic and Hungarian (Revesz, 2017). Recently, Rouard (2022) conjectures that an archaic Euro-Asiatic language, which may be a common ancestor of the Altaic, Burushaki, Dravidian, Elamite, Ibero-Caucasian and Indo-European languages, expanded with pastoralism and agriculture from Central Asia and northern India to the Caucasus, Anatolia, the Balkans, and Western Europe by the Neolithic. Hence the Old European culture may be descendant from this archaic Euro-Asiatic language. The conjecture of Rouard (2022) seems to be an extended version of the Anatolian hypothesis of Indo-European origin (Renfrew, 1990), while the conjecture of Revesz (2017) fits better with the Kurgan hypothesis of Indo-European origin (Gimbutas, 1989).

According to Baldacci (2017) seal CMS II.5, No. 246 has a MM IIB, and bowl F 4718 has an early MM IIIA date. These dates suggest that the Phaistos Disk was also made between MM IIB and MM IIIA. That information is valuable because the original report about the discovery of the Phaistos Disk (Pernier, 1909) left a wider range of possible dates. This narrower date range also fits well with the recent analysis of Minoan archaeogenetic data that supports a migration from the Danube Basin to Crete during that period (Revesz, 2021).

**9. CONCLUSIONS AND FUTURE WORK**

This paper gave a comprehensive proof that the reading direction of the Phaistos Disk is left-to-right. A left-to-right reading also means a center-to-periphery reading when the signs point toward the center like on the Phaistos Disk as shown in Fig. 11. The left-to-right reading direction of the Phaistos Disk was proven using a multifaceted approach that included close observations of the following features of the Phaistos Disk: overstamped signs, crowded signs, dividing lines, direction of strokes, and direction of faces, and matching sign sequences with sign sequences on the Arkalochori Axe and several Cretan Hieroglyphic inscriptions.

In addition, the paper described two novel experiments. The first experiment, which is presented in Section 2.1, shows that the perception of overstamping depends on the two stamps' impressions' relative depth rather than their order. The second experiment, which is presented in Section 5.1, shows that when people write left-to-right, then they tend to use downward strokes like the downward strokes on the Phaistos Disk.



Given the main result of this paper, the proposed translations of the Phaistos Disk that read it from left-to-right need to be reconsidered, including the author's earlier proposal (Revesz 2016). In a future paper, we plan to give a textual analysis and comparison of those Phaistos Disk translation proposals that read it from left-to-right.

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