On technical analysis of characters of the oldest Delhi Iron Pillar inscription

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A detailed technical analysis of the characters of the oldest Delhi Iron Pillar inscription has been conducted. It reveals that the characters were put on the surface by die-striking operation using dies of different characteristic shapes. The dies were struck more than once to provide each imprint on the surface. Both the die and material surfaces were in cold condition during the operation. Evidences have been provided to conclude that the inscription was die-struck on the pillar when it was in the vertical erect condition.

Keywords: Characters, Delhi Iron Pillar, inscription, technical analysis.

THE construction of the Delhi Iron Pillar (Figure 1), now located at the Quwwat-ul-Islam mosque in New Delhi, is a marvellous engineering achievement considering that it was manufactured by forge-welding, 1600 years ago during the Gupta period[1–3]. There are many inscriptions inscribed on the Iron Pillar[2,4,5]. The oldest and largest among these inscriptions is a six-line, three-stanza inscription in Sanskrit (Gupta-Brahmi), which states that the pillar was erected to serve as a standard of Lord Vishnu at a place called Vishnupadagiri. The complete translation of the inscription with critical comments is available elsewhere[1]. The inscription also elaborates the military exploits of a monarch, who is simply referred to as Chandra in the inscription. On palaeographic grounds (i.e. based on the nature of the characters of Gupta-Brahmi), the inscription can be dated to early fifth century AD[6]. Chandra has been identified unambiguously with Chandragupta II Vikramaditya (AD 375–414) based on a detailed analysis of the archer-type gold coins of the imperial Guptas (AD 320–600)[1,7]. The original location of the pillar, Vishnupadagiri (meaning 'Hill with footprint of Vishnu'), has been identified as modern Udayagiri, in the close vicinity of Besnagar, Vidisha and Sanchi, based on literary, archaeological, numismatic and geographic evidences[7]. Moreover, the Vishnupadagiri (i.e. Udayagiri) site was of astronomical importance as it is located on the Tropic of Cancer[8]. Recent research has shown that the Iron Pillar was located at an astronomically significant position at Vishnupadagiri, such that the early morning shadow of the Iron Pillar fell on the foot of Anantasayana Vishnu in cave 13, only in the time period of the year around summer solstice[9]. Therefore, the Delhi Iron Pillar also highlighted the astronomical knowledge that existed during the Gupta period, apart from providing solid proof of the metallurgical brilliance of this Golden Age of India.

In this article, an important problem in Indian history will be revisited using scientific analysis, namely when the inscription was actually imprinted on the pillar. Based on historical and numismatic data, we know that the inscription was not a posthumous one[1]. We will take recourse to technical analysis of the characters of the Iron Pillar inscription to provide additional inputs to understand this issue. The secondary aim of the analysis would be to reveal the method by which the inscription was imprinted on the pillar surface and the engineering design of the characters.

Figure 1. The Delhi Iron Pillar located at the Quwwat-ul-Islam mosque in the Qutub Complex at New Delhi. This photograph was taken on a rainy day in August 2006.

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The inscription

The six-line, three-stanza Sanskrit inscription in verse form, covers an area about 2′9″ broad and 10″ high at a level of about 7′ from the stone platform (Figure 2). It is interesting to note that the verse form in Indian inscriptions started only with Samudragupta and came into vogue after Chandragupta II Vikramaditya. Therefore, this is one of the oldest inscriptions in verse form in the Indian history. Fleet[10] mentions the characters being 5/16″ to 1/2″ in dimension. The characters in the first line are more closely spaced compared to the characters in the other five lines; therefore, the first line is shorter than the rest. The characters are distinct showing minimal corrosion damage, but for slight rounding of the sharp edges. Interestingly, the characters of the inscriptions are straighter rather than rounded, which Fleet[10] attributed to the difficulty of inscribing on the hard surface of the iron shaft. However, there is a different way of looking at this aspect and this will be expounded later in this article.

That the pillar was fabricated and erected at Vishnupadagiri during the reign of Chandragupta Vikramaditya II, is now certain. The image of the top pedestal of the decorative bell capital atop the Delhi Iron Pillar appears in one of the bas releifs of cave 6 at Udayagiri[11]. This provides firm evidence that the pillar was present at Vishnupadagiri (i.e. modern Udayagiri) in AD 402, based[12] on the dated Sanakanika inscription in cave 6. However, it is not clear whether the inscription was put up before or after the erection of the pillar. This important question will be addressed based on technical analysis.

The inscription is totally six lines long. As mentioned above, the first line is shorter than the other five lines that come below (Figure 2). The total number of characters in the first line is 37, while in all the other five lines, the total number of characters in each line are 38 (see Figure 3 for complete reading of the inscription). This reveals the symmetry of the composition in that it was composed keeping in mind the uniformity in the number of characters in most of the lines.

The possible reason for the first line being shorter than the others has been proposed to be due to the learning experience of the die-strikers while die-striking the first line[3]. They must have realized the difficulty in die-striking the relatively large characters of the inscription close to each other on the hard surface of the pillar. Therefore, the die-strikers must have decided to spread out the characters from the second line onwards. This conclusion is based on the first line being shorter than the other lines, while the actual size of the characters in the first line is the same as those in the other lines (Figure 3). Only the space between the characters was more spread out while inscribing the other five lines. The total number of characters in the first line is only one less than the number of characters in each of the other five lines.

It is possible to imagine that the actual verse would have been selected based on an open competition and the best must have been selected for inscribing on the pillar. It is well-known from historical records that poetry competi-

Figure 2. Oldest Sanskrit inscription on the Iron Pillar in Gupta-Brahmi script.

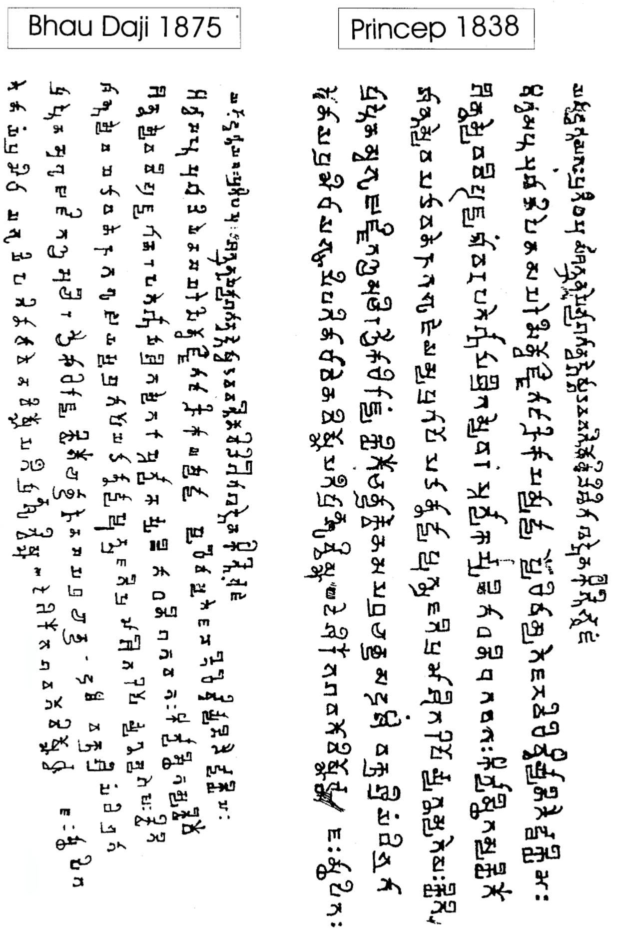

Figure 3. Reading of the inscription according to Princep[24] and Bhau Daji[25].

tions were frequently held in ancient India and the winner was awarded pride of place and felicitated. That this is probable in the case of the Iron Pillar inscription is revealed by the excellent composition and poetry inherent in the inscription. In fact, such is the beauty of the verse that this is prescribed as compulsory reading material in undergraduate courses on Sanskrit and History in several universities in India.

There are two possibilities for the time period when the inscription must have been put up on the pillar: just after the pillar was fabricated or when it was already erect. The pillar surface in the region where the inscription has been provided is smooth (Figure 2), thereby implying that the final surface finishing metallurgical operations on the pillar must have been completed when the inscription was die-struck. The manufacturing methodology of the pillar has been analysed in great detail elsewhere[13]. The pillar was manufactured by forge-welding together individual iron lumps. It has been shown that the pillar was fabricated in the horizontal position, and lumps of iron (that were the basic building blocks of the pillar) were added to the pillar in a sideways fashion[13].

Let us consider the first possibility of the inscription being imprinted immediately after the pillar was originally manufactured, but before its final erection. In view of the manufacturing methodology[13] outlined earlier, the inscription would have been easily die-struck on the surface with the pillar in the horizontal position.

The second possibility is after its initial erection. It does not have to necessarily mean after the demise of Chandra, but possibly at a later time than the original erection of the pillar. In such a case, the inscription must have been die-struck with the pillar in the vertical position, because the pillar was already erect. There is a remote possibility that the pillar may have been taken down and after die-striking the inscription, re-erected. We must understand that the pillar, considering the time it was originally fabricated (late fourth century–early fifth century AD[1]), was not a secular object but one closely associated with strong religious belief (i.e. the pillar was erected as a Standard of Vishnu–Vishnuordhvajah). It would have involved immense engineering skill to set upright the pillar on a proper foundation in its original erection site at modern Udayagiri[7]. Given the association of the pillar with religious belief, it is difficult to imagine that it would have been brought down and again re-erected.

It could be argued that the die-striking operation was a prolonged one that necessitated the taking down of the already erect pillar and later re-erecting it after the inscription was imprinted. We shall soon deduce the characters were created by die-striking operation and that many die-strikes of different shapes were necessary to build the characters of the inscription. There are a total of 227 characters in the inscription. Considering that four dies were used on the average for each character, a total of $227 \times 4 = 908$ die shapes may have been used. Considering again that each die shape was die-struck three times, a lower estimate of the total number of die-strikes would be 2724, which can be approximated to 3000 strikes. Considering the time taken for each die-strike to be about 5 s, the minimum total time taken for die-striking all the characters of the inscription would be approximately 15,000 s or slightly above 4 h. Of course, the planning of placing the characters and the die to use for achieving each character could have taken more time and this could have been independently performed. It is clear that the time taken for die-striking the inscription was not a prolonged operation. Therefore, there was no need for the erect pillar to be taken down and re-erected after die-striking the inscription.

The major question that needs to be addressed is, therefore, whether the inscription was put up on the pillar before or after its erection. In order to answer this question, it is important to find out whether the characters were put on the surface with the pillar in the horizontal or vertical direction.

Die-striking

The first important aspect of the characters of the Iron Pillar inscription that needs to be explained is how they were put up on the pillar. Not much attention has been paid to this aspect as most of the commentators of the inscription, excepting Balasubramaniam[3], and Prasad and Ray[14], have simply stated that it has been inscribed, thereby implying that the characters were created by gouging-out material from the surface. In the strict engineering sense, inscribing implies an operation of taking out metal from the surface and thereby creating a depression, which delineates the character of the inscription. This type of gouging-out operation is termed as inscribing. The other method by which precise depressions can be created on a malleable surface is by die-striking. This operation is made possible by the fact that metals are ductile (i.e. deformable) and therefore the impression of the die will be imprinted on the die-struck surface.

In the die-striking operation, the die with the required impression to be imprinted, is placed on the surface, and an impact force is applied to the die (possibly placed in a suitable die-holder), such that the impression of the die is reproduced on the surface.

Three characters of the inscription (namely characters 18, 19 and 20 of line 5) are seen in Figure 4. It can be noted that the lines that delineate the characters are sharp and that the depression apparently appears even. It is clear that the characters have been put on the pillar by die-striking operation and not inscribing (i.e. by gouging the metal out from the surface). The sharp features of the characters firmly attest to the use of dies for the inscription.

There is supporting evidence for the characters being die-struck. In case the character had been inscribed, it would have smooth corners and ends. Some later-period inscriptions on the Iron Pillar that have been imprinted on the surface by inscribing are shown in Figure 5. Notice the smooth nature of the inscriptions, which is the characteristic of the inscribing process. Moreover, material removal would be even throughout the character had the oldest Sanskrit inscription been inscribed. This is not the case because there are several instances (i.e. several characters) where gaps can be observed in the grooves that make up the character. In these locations, material has not been removed. One good example is shown in Figure 6, in which the fourteenth and fifteenth characters of line 2 are seen. In the case of the character on the right, the top stroke (that defines the 'maatra' or vowel mark) is not continuous with the character. There is a region, just below the maatra stroke, where the material has not been removed because the die that was used to strike the stroke did not go over this location.

Two other supporting facts further provide strong clues to the possibility that the characters must not have been inscribed but die-struck: appearance of multiple die-strikes in some of the characters and evidence for several dies of different shapes having been used for each character. These issues will be discussed later.

Figure 4. That the characters were created by die-striking is revealed by the sharp nature of the edges and corners of the characters. Characters 18, 19 and 20 of line 5 are shown.

Figure 5. Example of inscribed inscriptions on the Delhi Iron Pillar. Notice the smooth nature of the inscribed inscriptions compared with the die-struck inscription (Photograph courtesy: K. K. Prasad).

Hot versus cold die-striking

The die-striking operation conducted on the Iron Pillar surface will now be discussed. It is known that the Iron Pillar is a hard material and this is reflected in the high hardness of the material. The hardness of Delhi Pillar iron has been measured using a sample cut from the pillar surface[15]. The hardness is sufficiently high. The compressive stresses that were introduced on the surface during the manufacturing (i.e. forge-welding and hammering of the surface) resulted in higher hardness[16]. Given the hard condition of the Iron Pillar, Prasad and Ray[14] proposed that it would have been much easier to process the surface in hot condition rather than cold condition. However, the surface, although sufficiently hard, is also ductile and therefore toughness is high. Sledge-hammer and cannon-shot marks on the surface provide proof of the ductile nature of the material. Therefore, the material possesses sufficient ductility even in the cold condition, that allows for the die-struck inscriptions to appear sharp.

The sharp nature of the die-strikes (Figure 4) leads one to conclude that the surface possessed sufficient ductility. This also indicates that the force required to die-strike the dies was not difficult to achieve, and that the contours of the die shapes were transferred to the surface without much effort.

Figure 6. Gap observed in the grooves of characters (arrowed) supporting the viewpoint that dies were used to strike the characters. Characters 14 and 15 of line 2 are shown.

It would have been difficult to maintain the surface in a relatively hot condition during the die-striking operation because of the practical difficulties in holding the die assembly on the hot surface while imparting the impact force.

There is another argument for the surface having been in the cold rather than hot condition during the die-striking operation. In the case of Gupta coin minting technology, the material (i.e. blank) used for die-striking coins was in the cold condition[17].

As regards the condition of the surface of the metal on which the dies were struck, we can arrive at some conclusions based on the nature of fracture observed around some of the characters. In Figure 7, we notice that the material at the bottom of one of the characters (namely the middle character on the bottom line, which is character number 34 on line 5) has chipped out more than the material at the top. Such fracture of material would result if the surface of the material was in the cold rather than hot condition.

Not all the characters show this kind of cracking in the bottom region. Generally, fracture of material is noticed below the lower portion of the characters rather than in the top region. This is an important observation which also provides a clue to the possible direction of the pillar when the cold dies were struck on the surface. This issue will be taken up later.

Multiple die-strikes

As the surface of the Iron Pillar was in the cold condition, the surface must have been relatively hard to die-strike. Given this scenario, it would have taken more than one strike of the die to impart its impression on the surface. This implies that more than one blow must have been provided to the die assembly to enable the impression of the die to be imprinted on the pillar. Drawing a parallel with Gupta coin minting technology, we know that the gold coin blanks were struck three times to produce the impression[17].

Let us understand this based on technical analysis. In some characters, multiple die marks can be noted in the same location. One such example (twenty-fifth character of line 5) is shown in Figure 8. We can notice that there are three continuously displaced marks on the surface in the location indicated by an arrow. The cause for multiple die marks at the location is also known. The die that was placed on the surface for creating the impression, has been misplaced in the process of die-striking, thereby leading to slight shift in the die. Therefore, multiple marks appear. A river-line kind of pattern emerges because of the small relative shifts of the die during the die-striking operation. Evidences for multiple die-strikes are also available in several other characters. The presence of multiple die marks is again an indication that the characters of the inscription were imprinted on the surface by die-striking and not by inscribing.

Shape of dies

The Gupta-Brahmi script consists of basic characters and then additional markings to indicate the maatra of the character. Given the relatively simple and small number of basic characters in the Gupta-Brahmi script, it is interesting to research on the possible die shapes used in the creation of the full inscription. It is certain that dies possessing the shape of the entire character were not used. This is based on close observation of the characters that make up the inscription.

It is clear that each character was created using dies of different shapes. Detailed study of all characters of the inscription indicated that each character was not die-struck using a single die but a combination of dies of dif-

Figure 7. Material chipped at the bottom more than at the top of the middle character (number 34 on line 5) on the bottom line. This supports the view that the surface of the pillar was in cold condition rather than hot during the die-striking operation.

Figure 8. Multiple die-strikes seen at one location (arrowed) indicating that the die was struck more than once to provide the imprint on the surface. The second character is the twenty-fifth of line 5.

ferent shapes. Let us take the example of the characters shown in Figure 9. These characters are the fifth through eighth on the third line. The straight line features have been die-struck using a rectangular die. Interestingly, we may note the gap created between the horizontal and vertical strokes in the middle of the second character (from the left) in Figure 9. This location has been arrowed in Figure 9. This also proves that the characters were die-struck and not inscribed.

Then there were other dies used specifically for providing the maatra of the inscription (for example, see the arrowed vowel mark in Figure 6). This constitutes another type of die used for die-striking the characters.

In such a manner, all the characters of the Iron Pillar inscription were analysed and it was concluded that relatively few distinct die shapes were used to inscribe the entire inscription. A rigorous analysis of die shapes requires an involved discussion and this is not attempted here. Some of the die shapes that have been identified based on a detailed analysis of the characters of the inscription are shown in Figure 10. It is clear that the designers of the dies were master craftsmen who had planned the entire operation well before the actual die-striking process.

Figure 9. Gap created between die-strikes (arrowed) indicating that dies of different shapes were used for each character. These characters are (from left) fifth through eighth of line three.

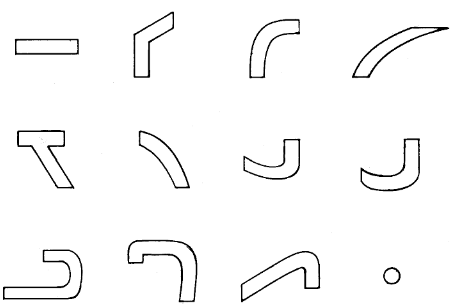

Figure 10. Some die shapes used to die-strike the characters of the inscription.

What is really fascinating is the ingenuity of the Gupta artists in devising a small number of die shapes in order to create all the characters in the inscription, using a combination of these dies. This must be appreciated as it also shows the ingenious engineering planning of the Gupta metallurgists. Another remarkable fact is revealed by analysis of relative dimensions of the characters (to be discussed in detail below), which is related to the relative dimensions of possible die shapes. There was clearly a drive towards standardization.

Finally, we note that the shapes that make up the characters were arrived at by intelligent use of the dies. An example will illustrate this point. Two typical shapes that frequently appear are half and full triangle (Figure 11). Considering these shapes (indicated as (i) and (ii) in Figure 12 *a*), they would have been achieved using die shapes as shown in Figure 12 *b*.

It is appropriate at this juncture to note the relatively small size of the die shapes used to create the characters. This must have been indirectly beneficial in allowing the erect pillar to withstand the die-strikes without endangering its stability. Assuming the hammer used to create the die-strike to be about 20 kg in weight, the impact force created by a moderate hammer strike can be appreciable and localized. We note that the impact force is applied to the pillar surface through a small area of the die surface. Therefore, the pressure exerted locally in the region just beneath the die was significant to deform the cold material underneath (which possessed sufficient ductility). Due to this local nature of the impact force, the stability of the upright structure must not have been affected during the die-striking operation.

Die material

Let us digress briefly to address the material that must have been used for making the dies. If the die had to impact hard into the surface of the Iron Pillar, then it must be strong and not deform itself. It is therefore reasonable to state that the material of the die must have been hard and strong. It is clear that a material harder than that of the Iron Pillar must have been used for the dies. It is reasonable to propose that the dies were made of high carbon steel, because the exceptional strength (and toughness) of high carbon steels was known to Indians from the historical period[18].

This is attested by the widespread use and application of a class of high carbon steels known as wootz steel[19,20]. While it is normally difficult to work with such high carbon steels (of the order of 1.0–1.5 wt% carbon), the ancient Indian blacksmiths had mastered the thermomechanical working of such wootz steel in specific range of temperature (700–800°C), such that the microstructure of the high carbon steels was engineered to produce a tough material[21,22]. Therefore, it is reasonable to propose that the

Figure 11. Typical half and full triangle shapes noted in several characters of the inscription. ***a***, Characters 2, 3, and 4 of line 3. ***b***, Characters 31, 32 and 33 of line 1.

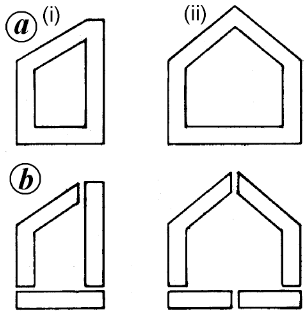

Figure 12. Intelligent method by which the half and full triangle shapes were constructed. Shapes (***a***) and die shapes (***b***) used to create them.

dies must have been fabricated out of high carbon steels. Another fact that is readily obvious is that the dies must have been in the cold condition rather than hot condition during the die-striking operation, so that they retained their high hardness.

Position of pillar during die-striking

Let us imagine the typical characteristics of characters that will result if the inscription was die-struck, with the pillar in the horizontal position. In such a case, it would be easy to place the inscription on the pillar because of proper balance available during the die-striking operation. It is known that massive stone pillars, which were used in the construction of large structures, were traditionally fabricated in India by placing them in the horizontal position and later on, being erected vertically. It would have been therefore much easier to die-strike the inscription on the surface with the pillar in the horizontal position. Therefore, if the inscription was imprinted on the pillar just before it was first erected, then the nature of characters will provide indications for such a methodology. What would be the unique features of the characters if they were put on the pillar placed in the horizontal direction? One typical feature would be that the depression of the die-strike would be even and therefore, the depth of the die-struck impression would be uniform throughout the length and breadth of the character.

In case the characters were die-struck with the pillar in the vertical position, and if the die-striking operation was extremely good (i.e. the die was struck in exactly the perpendicular direction), then the depth of the characters of the inscription would be even. In case the die-striking operation was slightly imperfect, the depth of the impression would be different across the length and breadth of the character. In case the die was slanting slightly down or up, which can be anticipated when the die has to be held on the vertical surface before the impact force was applied, then the depth of the die-strike impression would not be constant across the length and breadth of the character, but would vary. The variation would be such that the depth at the top of the character would be more if the die were slanting upwards or the depth at the top of the character would be less if the die were slanting downwards. In this regard, 'slanting upwards' implies that the axis of the die assembly is not perpendicular to the surface, but makes an acute angle in the anticlockwise direction with respect to the perpendicular to the surface.

Depth of characters

In order to glean further insights on this problem in a scientific manner, casts (made of plaster of Paris) of four characters of the inscription were made for studying their dimensions in greater detail. It was not possible to pour liquid plaster of Paris directly on the inscription (due to the vertical position of the pillar) to obtain the casts. Therefore, the casts were obtained in an indirect manner. First, plasticene clay was placed on the selected characters. When removed, the clay carried the impression of the character.

The Gupta-Brahmi character 'ja' resembling a capital E was chosen from three different locations on the in-

Figure 13. Character 7 of line 5 (third from left (***a***)) and 13 of line 3 (middle character (***b***)).

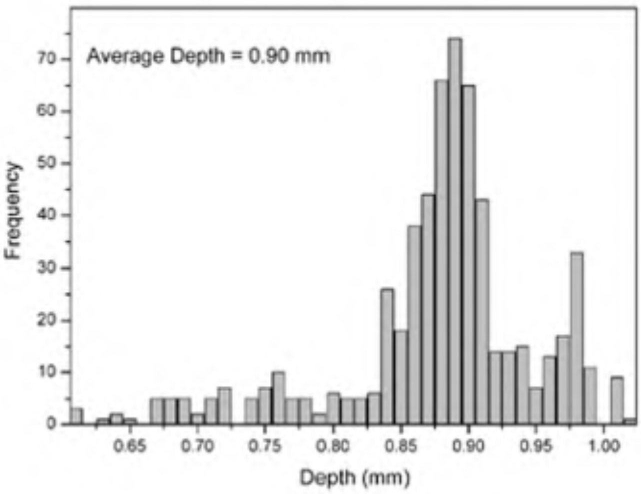

Figure 14. Histogram showing all the measured depths from the plaster of Paris casts of four characters.

scription. These locations are characters 15 of line 2 (Figure 6), 7 of line 3 (Figure 9) and 7 of line 5 (Figure 13 *a*). The fourth character chosen was 13th of line 3 (Figure 13 *b*), since it showed relatively straight line features.

Liquid plaster of Paris was poured around the clay casts immediately after they were removed from the surface of the pillar. The plaster of Paris was allowed to set and in this manner images of the characters were obtained on the casts. The casts were later analysed in the laboratory to determine the dimensions of various strokes as well as depth as a function of position. A digital vernier calipers (Mitutoyo, Japan) was used to measure the dimensions.

Figure 14 is a histogram showing the measured depths from all the plaster casts. An almost uniform depth was maintained in the die-strikes. The average value of the depth based on the analysed data is 0.90 mm.

Let us analyse the depth results of the samples. In case of samples seen in Figures 9 and 13 *a*, no particular trend could be discerned. The character in Figure 6 visually reveals deeper die-strike at the top than the bottom. Depth analysis shows that, at vertical strokes, the depth at the top was more than that in the bottom regions. Similarly, when one considers the horizontal strokes seen in the character, the depth along the top edge of the stroke was more than that along the bottom edge. In case of the character seen in Figure 13 *b*, the depth was slightly more at the top region of the character than the bottom region. The analysis therefore reveals that several characters are more deeply struck in the top region than in the bottom region. This conclusion is also evident based on visual observation of several characters of the inscription.

As a word of caution, it is important to note here that the above conclusions were drawn based on detailed analysis of only four characters. As there are 227 characters in the inscription, similar analysis of all other characters, if possible in the future, would provide a better understanding.

The possible reason for the characters being more deeply struck in the top than in the bottom region could arise due to the positioning of the die with respect to the surface. Had it been positioned with the pillar in the horizontal position, we must have expected more uniform depth for all the inscriptions. Since this is not the case, this probably indicates that the pillar was in the vertical position when the dies were struck on the surface.

Dimensions of characters

A careful analysis of the measured dimensions of the characters revealed valuable insights regarding the engineering design of the characters. The dimensions were measured in units of millimetres. This was converted to the ancient Indian unit of length, the ‘angulam’. The angulam measured 0.75 of the modern inch omitting microscopic measurements[23]. This was divided into 8 ‘yavas’. On the higher side, 12 angulams equalled 1 ‘vitasti’ and 2 vitastis equaled 1 ‘hasta’ or ‘aratni’. Further, 4 hastas resulted in 1 ‘danda’[23].

In order to appreciate the symmetry of the dimension of the four characters analysed, the measured dimensions

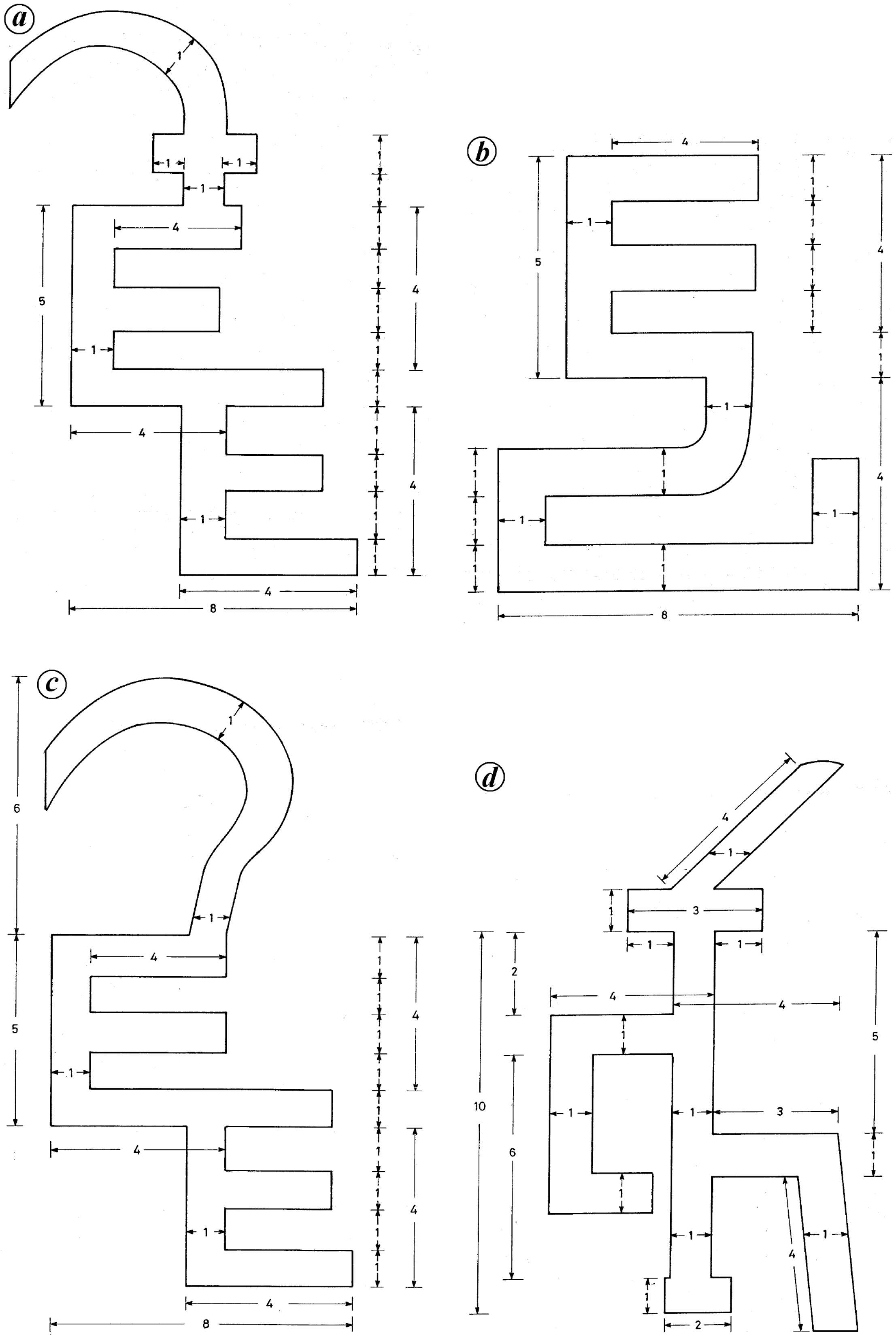

Figure 15. Measured dimension of the characters in terms of the ancient Indian unit of length yava, which is one-eighth of an angulam (19.05 mm). The ancient Indian angulam measured three-fourths of the modern inch. ***a***, Character 15 of line 2; ***b***, Character 7 of line 3; ***c***, Character 7 of line 5, and ***d***, Character 13 of line 3.

in millimetres have been converted to units of yavas, which is one-eighth of the angulam. Since one modern inch corresponds to 25.4 mm, the ancient Indian angulam is 19.05 mm. As one yava is one-eighth of the angulam, each yava is equal to 2.38 mm. The yava was used as the basis for indicating the measured dimensions of the strokes of the four characters, which have been provided in Figure 15. In some cases, the measured dimension was slightly less or more than the precise number of yavas. These minor variations were ignored because the purpose of the dimensional analysis was to reveal the symmetry of the engineering design of the characters.

Analysis of the dimensions of the characters proves that the ancient Indian unit of length, angulam was used in the creation of the characters. Further, the symmetry of construction of each of the characters can be appreciated by viewing the relative dimensions measured (Figure 15). For example, the bottom-most horizontal stroke of the character in Figure 15 *b* measures precisely to one angulam (the actual measured dimension being 19.08 mm and the angulam measures to 19.05 mm). Similarly, the bottom-most horizontal strokes in the characters of Figure 15 *a* and *c* have been extended slightly more to the right than the horizontal strokes above, in order to provide a complete unit of length (namely 8 yavas or 1 angulam) for the complete width of these characters.

Another interesting aspect is the distance between the characters. This was also measured from the die casts. Considering the topmost horizontal stroke of the characters, the measured distance between the character in Figure 15 *a* and the one on its left is 6.28 mm and the one on its right is 11.68 mm. Similarly, for the character in Figure 15 *b*, the measured dimensions are 8.78 and 8.78 mm respectively. In case of the character in Figure 15 *c*, they are 7.54 and 11.80 mm, while in case of the character in Figure 15 *d*, they are 11.04 and 8.40 mm. On adding these spaces on the left and right, they almost measure one angulam, but not precisely. However, this analysis reveals that the spacing between characters (when added on the left and right) was almost kept constant. This provides an insight into the engineering design of spacing of the characters.

Comprehensive picture

A comprehensive view of the die-striking process to create the characters of the inscription can now be presented. The pillar was erected in the royal presence of Chandragupta II Vikramaditya. After the erection of the pillar, there must have been an open competition to determine the best verse to imprint on it. Once the verse was selected, the process of imprinting the inscription on the pillar surface was undertaken. The pillar was in the vertical position when the dies, of different shapes, were struck on its surface to create the characters of the inscription. The characters of Gupta-Brahmi were obtained using dies of specific shapes. These dies had to be placed in suitable die-holders. The entire assembly must have been placed on the surface of the pillar and an impact force applied to the die assembly in order to impart the imprint of the die onto the surface. This kind of methodology (i.e. die-striking) was used, although in a different context, in the case of minting of Gupta gold coins[17]. In the case of the inscription on the pillar, that a similar methodology must have been used, attests to the mastery of the Gupta metallurgists in the processing and shaping of metals.

Conclusion

The nature of the characters of the oldest Delhi Iron Pillar inscription has been understood based on a detailed technical analysis. The inscription was produced by die-striking operation. Dies of different shapes were used and more than one die was used for each character of the inscription. The possible die shapes have been described. The dies were struck more than once to produce each impression. The surface of the pillar and the dies were in the cold condition during the die-striking operation. Finally, the pillar was in the erect vertical position when the characters of the inscription were die-struck on the surface. This implies that the inscription was put up on the pillar sometime after its original erection.

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MEETINGS/SYMPOSIA/SEMINARS

National Seminar on Magmatism, Tectonism and Mineralization (MTM-2007)

Date: 29–31 October 2007
Place: Nainital

Themes include: I. Mineralization in dynamic magmatic system: Mafic, ultramafic, alkaline and carbonatite magmatic systems; Lamproites and kimberlites; Felsic magmatic system and study of enclaves; Geological correlations and geochronological studies. II. Structure and tectonics in relation to mineralization: Structural and tectonic framework of ore deposits; Structural controls of mineralization; Tectonic evolution and metallogenesis. III. Metamorphism, anatexis and role of fluids in ore genesis. IV. Tectonomagmatism and mineralization in the Himalayan domains. V. Special Session on 'Earth surface environment and human health'.

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National Seminar on Quality Control & Standardization of Metal-based Siddha & Ayurveda Medicine

Date: 3 and 4 August 2007
Place: Thanjavur

Main focus: To sensitize and emphasize the need of QC and standardization and metal-based formulations using modern analytical tools; To identify the gap areas in the preparation and evaluation of metal-based formulations that could be bridged using modern analytical tools; To provide scientific document and evolve a blue print to several issues sought for globalizing metal-based Ayurveda and Siddha medicines.

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National Seminar on Nanotechnology and its Current Trends

Date: 26 July 2007
Place: Ahmedabad

The seminar has been organized to provide a forum for discussion on the present status and future perspectives in the emerging fields of nanotechnology.

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