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Advanced imaging techniques applied to the Knossos statuette inscription

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Abstract

The inscription of the statuette from Knossos, Heraklion Archaeological Museum Λ 95, has proven over the years to be exceedingly difficult for the correct identification of its hieroglyphic signs. The signs vary widely in their quality of engraving, with some being so small and shallow that they cannot be recognized at all by traditional techniques, and the stone's surface shows evidence of 'staining' after many centuries of burial in the temperate soil. Furthermore, it appears that some signs were never actually completely engraved, with what appears to be remnants of the original marking paint, now bridging areas of disjoint engravings. Optical Profilometry equipment was employed to unambiguously resolve the engraved parts of the inscription, while Multi-Spectral Imaging was used to identify the areas of remnant marking paint.

Keywords Optical profilometry, Surface characterization, Multi-spectral imaging, Ancient pigment

Introduction

The Gneiss[1] statuette fragment, dedicated to an Egyptian official named User, was found by Evans at the palace of Knossos, Crete in 1900 [1]. Stylistically, it can be dated to the first half of the Egyptian 12'th Dynasty, i.e. approx. 1985–1880 BC [2, 3], and is now Λ 95 in the Heraklion Archaeological Museum, Greece.

It has been 'controversial' since the time of its discovery [4], with early hopes that it would provide assistance to the stratigraphic dating at Knossos eventually proving fruitless. Even the basic question of how it made its way from Egypt to Knossos is still not firmly established. One school of thought is that User was a traveller, in Knossos on diplomatic or commercial business, with the statuette possibly being set up in a local temple, to ensure User's spiritual survival in case of his demise, so far from his home in Egypt.[2] Another widely held belief is that the statuette was of intrinsic value to the chief administrator at Knossos, being available after having been robbed from a tomb in Egypt, many years after User's time, and eventually disposed of in Late Minoan times.[3]

An earlier study [5] dealt with the engraved signs on the Rear and Right side, which were characterized by an Optical Profilometry system. Used on-site at the Heraklion Archaeological Museum, the system provided ample accuracy to read the hieroglyphic signs involved.

The Left side inscription is the main focus of this study. It is concerned solely with User's mother, and has also had its engraved areas characterized by Optical Profilometry. In addition to its engraved features however, there is strong evidence of remnant areas of the ancient painting material, albeit now badly deteriorated and 'black', used to delineate the signs prior to engraving. It appears that the engraving step was not always fully completed, with some traces of this original paint substance now bridging areas of disjoint engravings. A Multi-Spectral Imaging camera was employed to differentiate these black paint remnants from the regions of the statuette's inherent

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[1] Often incorrectly referred to as 'diorite' in the past.
[2] This was the firm view of Pendlebury, Ward, Evans and others.
[3] As per the conclusions of Gill and Padgham [20].

Fig. 1 Overall view of the statuette's Left side. ©Heraklion Archaeological Museum

stone which also appear black. See Figure 1 for an overall view of the statuette's Left side.

Methods

The Optical Profilometry system employed was provided by the former Fries Research and Technology GmbH (MicroSpy® Mobile), on-site at the Heraklion Museum, May 2015, and used a 'chromatic white light (CWL)' technique [6].

The 'Chromatic White Light' method involves scanning a non-contact optical sensor over a surface, by means of a laterally-translated x–y stage, and progressively building up a computer model of the 3D features of the surface. It can achieve fine depth resolution in the z-axis (eg. 6 nm) by means of its strongly wavelength-dependent focal length sensor, which uses the normally-detrimental effects of chromatic aberration to great advantage.

The same basic technique (but using 'laser scanners') was used in recent years on a vastly larger scale by Factum Arte [7] to scan entire tomb wall inscriptions in Egypt,[4] albeit with a much coarser z-axis resolution of 100 μm or more. In a related field, high accuracy non-contact 3D measurements have been used for fine art paintings, such as by Van Gogh, to verify authenticity and determine artistic style, by the analysis of individual brushstrokes [8].

The Multi-Spectral Imaging camera used for this study was from SPECTRICON I.K.E. (MUSES9-HS), Crete, on-site at the Museum, May 2022, providing images from an InGaAs sensor at ambient temperature.

[4] Including KV62, Tutankhamun.

Multi-Spectral and Hyperspectral imaging involve recording multiple reflectance images of an object, each over a narrow wavelength range, made possible by technology such as an inbuilt monochromator. The aim is to build up a computer model, the so-called 'spectral cube', with the many 2-D images of the object each recorded at a different wavelength. In this way a 'spectrum per pixel' can be achieved, so that features at any 2-D position each have their own spectrum of reflectance versus wavelength, from which chemical or other physical properties may be inferred.

Hyperspectral systems may record several hundred 2-D images of an object at perhaps 5 nm intervals, while Multi-Spectral equipment may take only 8 or so images at 100 nm intervals. The use of Multi-Spectral and Hyperspectral imaging in various branches of archaeological science is today well established, with a number of firms providing equipment to, for example, differentiate multiple pigments on Old Master paintings [9–15], sometimes in conjunction with other techniques [16, 17], to discern normally hidden details on ancient codices [18] and to quantify the deterioration of masonry on Medieval buildings [19].

Results

General

Although the results largely agree with the published sign layout [20], some signs are shown to be significantly different, or not even acknowledged in the published information. Figure 2 shows an Optical Profilometry scan of the region of interest. The inset at lower left shows the part scanned compared to the traditionally accepted sign layout. Note that, for this figure and some other views, the vertical (depth) scale is increased to show more detail.

Painting material remnants

The statuette is composed of Anorthosite Gneiss [21, 22], consisting of white/pale grey Plagioclase Feldspar, along with random 'black' streaks and bands, as shown in Fig.1. The black areas are normally considered to be Hornblende Amphibole. The *lower* curve in Fig. 3 is a reflectance spectrum of an area of the black material, well away from any engraved hieroglyphic signs. This spectrum clearly shows a reflectance minimum (absorption peak) around 1080 nm, as per the arrow, and generally displays a monotonic rise in reflection for increasing wavelength.

There are however numerous other areas of the statuette that seem to also be coloured 'black', in visible light, and yet have substantially different Infrared reflectance spectra. These anomalous areas have a spectrum with a minimum at approximately 1250 nm, as per the *upper* curves of Fig. 3. Not only that, but these anomalous black areas are often of unnatural shape or position, as shown

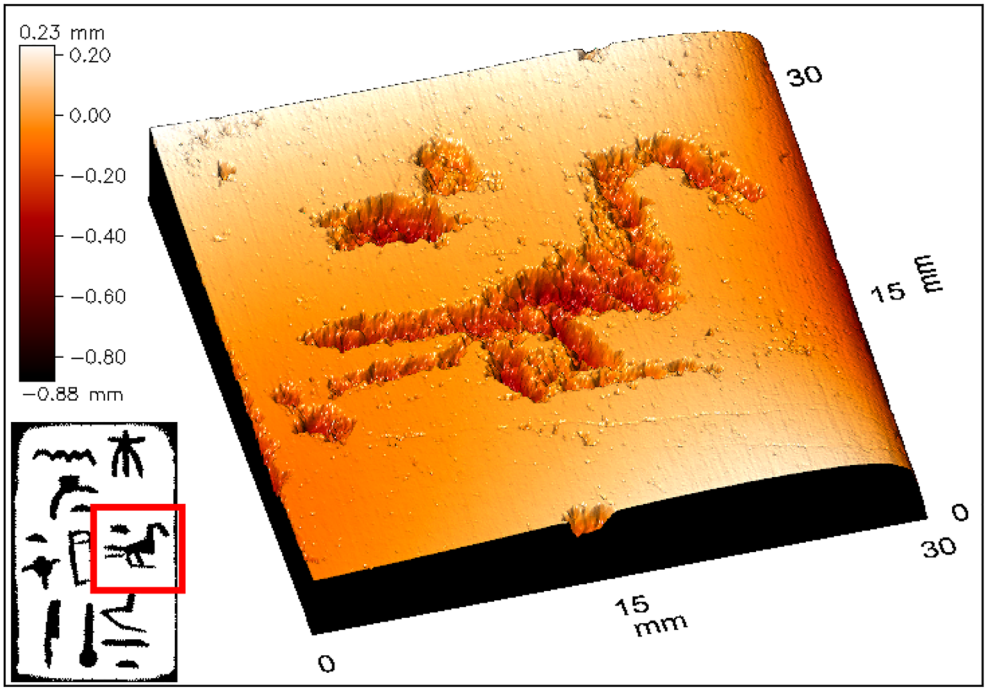

Fig. 2 Profile scan of the area under consideration. ©Heraklion Archaeological Museum

in Fig. 4, where they display unusually straight or parallel edges.

It is proposed then that such anomalous areas are remnants of the original painting material, used to mark out the positions of the hieroglyphic signs before engraving. Most of these remnants have probably already disappeared, by chemical reaction after thousands of years beneath the moist Cretan soil. Those still present have presumably lost their initial highly contrasting colour, now generally showing a black appearance, possibly due to the decomposition of their original organic binder.

Area above bird sign's tail

Figure 5 shows a Profilometry scan of the area above the Bird sign's tail. The Figure unambiguously shows a deep engraving to the bottom left, with clear striations which are, without doubt, tool marks. Figure 5 also shows, however, a *second*, smaller feature to the upper right (at the arrows' intersection), so far acknowledged only in some published sketches [23, 24].

This second feature is shallower than the larger one to its bottom left, and is tenuously joined to it by a very thin 'web' of stone. The fact that the two areas are separated by such a thin 'web' strongly suggests that both features

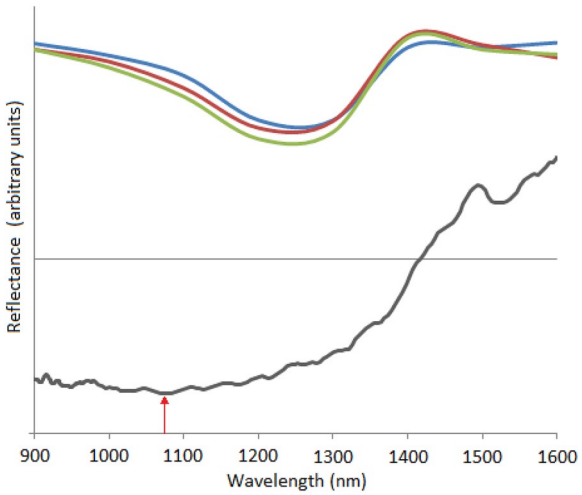

Fig. 3 Reflectance spectrum of black stone (lower curve), and anomalous 'black' material (upper curves) ©Heraklion Archaeological Museum

are manmade, since later, random damage could not be expected to sustain such a delicate structure.

When a 'threshold' of approx. 180 μm below the surface level is imposed across the entire region, the total

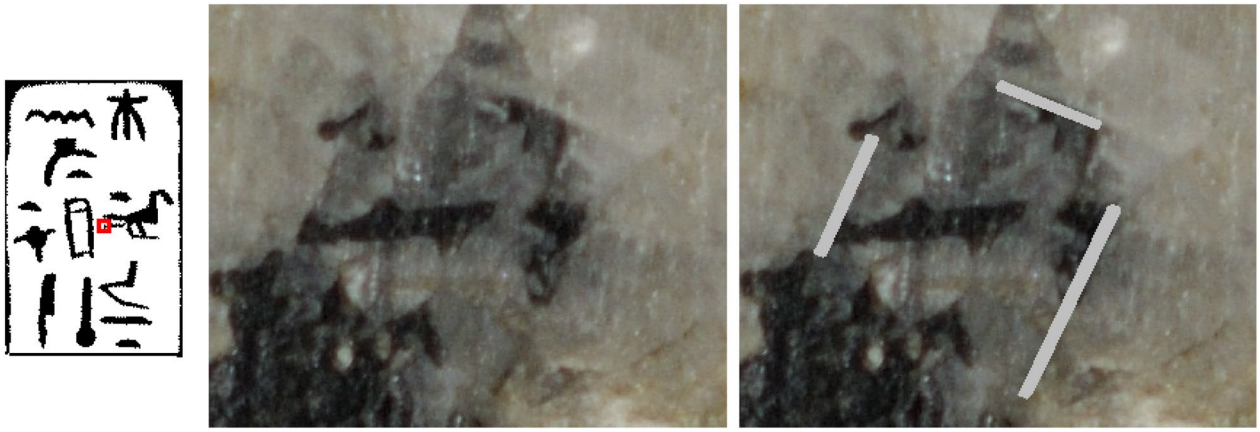

Fig. 4 Feature with unnaturally straight and parallel lines, on left. On right, highlighted view. ©Heraklion Archaeological Museum

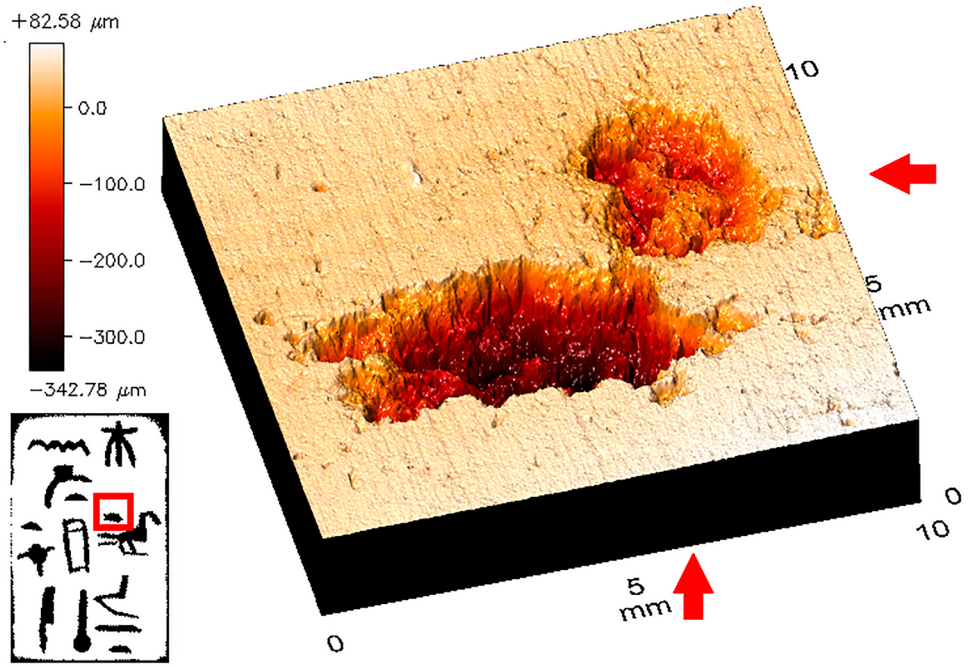

Fig. 5 Profile scan of the area above the bird sign's tail. ©Heraklion Archaeological Museum

engraved area is shown in Yellow in Fig. 6, superimposed onto a basic photograph[5] of the statuette.

Many apparently 'black' regions of this part of the statuette have a reflectance minimum around 1250 nm, which indicates anomalous material—more specifically painting material remnants. These are depicted in Grey in Fig. 7, which offers the most likely reconstruction for the original hieroglyphic sign. Areas considered to have once been applied with paint, but which is now totally lost, are depicted in Beige.

With front and back paws, and a tail, this sign is proposed to be the Recumbent Lion,[6] E23 in Gardiners Sign List [25]. Also, the end of the Lion's tail might reasonably be considered to possess a 'tuft' feature, unique to the Lion. Note that this sign is now larger and higher than

[5] Taken with a Nikon D300s digital SLR camera by the author, Feb. 2013.

[6] It must be admitted that this Lion is rather 'short' in bodily proportions, but such a form is attested with the figurines Louvre E 7168 and MMA 26.7.1341.

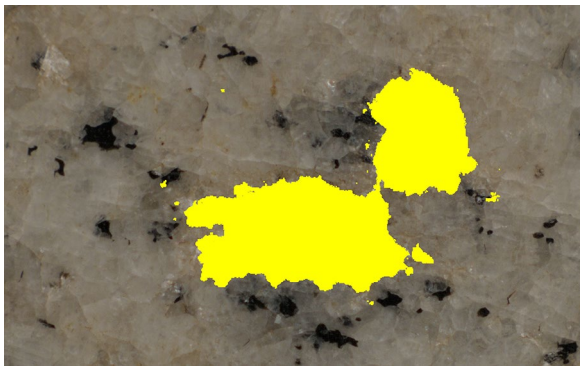

Fig. 6 Engraved areas in Yellow, superimposed onto basic photograph. ©Heraklion Archaeological Museum

Fig. 7 Proposed reconstruction of sign. Yellow: engraved areas; Grey: surviving paint material; Beige: areas postulated as previously painted. ©Heraklion Archaeological Museum

previously acknowledged, extending over the top of the Bird sign, so that the hieroglyphic reading order should be reconsidered.

Area below bird sign's tail

Figure 8 shows a Profilometry scan of the area to the lower-left of the bird sign, and features two long, roughly horizontal engraved 'lines'. The lower one is traditionally considered to be part of the bird's tail, although its connection to the bird is tenuous at best, with its depth and width decreasing sharply as it approaches the bird sign.

More significantly, there is also a substantial, but isolated, diagonal feature to the extreme left of Fig. 8 (at the arrows' intersection). Although it has never been acknowledged, it is just discernable even in published photographs [26, 27]. At this feature's centre, the topography is relatively shallow and horizontal, and shows clear striations, which appear to also extend down its steep sides. With such a detailed form, and being well spaced with respect to other nearby signs, it seems almost certain that this diagonal feature is a deliberate engraving, with its striations being tool marks. It has not been acknowledged so far, presumably because it is disjoint from the other engraved areas of the inscription.

When a 'threshold' of approximately 150 μm below the surface level is imposed across the selected region, the engraved area is shown in Yellow in Fig. 9, superimposed onto a basic photographic image.

Many of the 'black' areas of Fig. 9 display a reflectance minimum of approximately 1250 nm, suggesting anomalous material, i.e. painting material remnants, and these are depicted in Grey in Fig. 10. Furthermore, some of these Grey/paint remnant areas are seen to actually *join* the acknowledged, lower horizontal engraved 'line', to the seemingly disjoint, diagonal engraved feature.

It seems most likely that this sign is the Harpoon, Gardiner's T21, albeit the simplified, Hieratic form, as found for example on Berlin stela 7765 [28]. It is also *reversed,* but this was not unusual for statue inscriptions after the very end of the Old Kingdom [29].

Finally, in the lower-right part of Fig. 10, there are separate paint remnant areas which are proposed as tracing the outlines of two Bread Loaf signs, Gardiner's X1, which was not unusual for many inscriptions involving the Harpoon sign.

The bird sign

Although traditional identifications have taken the bird sign to be Gardiner's G38/39, a Pintail Duck or Goose, Fig. 2 shows its beak to be large, in fact disproportionably so, and very much turned down, not horizontal or nearly so, as with a typical Pintail Duck sign. Figure 2 also reveals that the bird's beak comes precariously close to the edge of the statuette, less than 3 mm, amongst the closest of any sign of this inscription.

Furthermore, Fig. 11, a Profilometry scan showing subtle depth variations, suggests a different 'style' of engraving for the high, vertical neck, compared to the bird's actual body: the neck is engraved in a vertical direction, but the body is done in a complex, diagonal fashion, with broad cuts at some 50° to the horizontal. Also, the body area is slightly 'disjoint' from the base of the neck, at an unusually shallow region (indicated by the arrow). The question arises as to why the entire front of the bird sign, from the lower body through to the vertical neck, was not done in the same direction, and seamlessly.

This apparent difference in technique of engraving, combined with the beak coming unusually close to the edge of the statuette, suggests that this sign has been *reworked* following the initial engraving process. The high, vertical neck seems to have been added to an earlier version—the shallow, almost haphazard near-vertical lines to the left of the 'join' were probably an attempt to blend the two areas together.

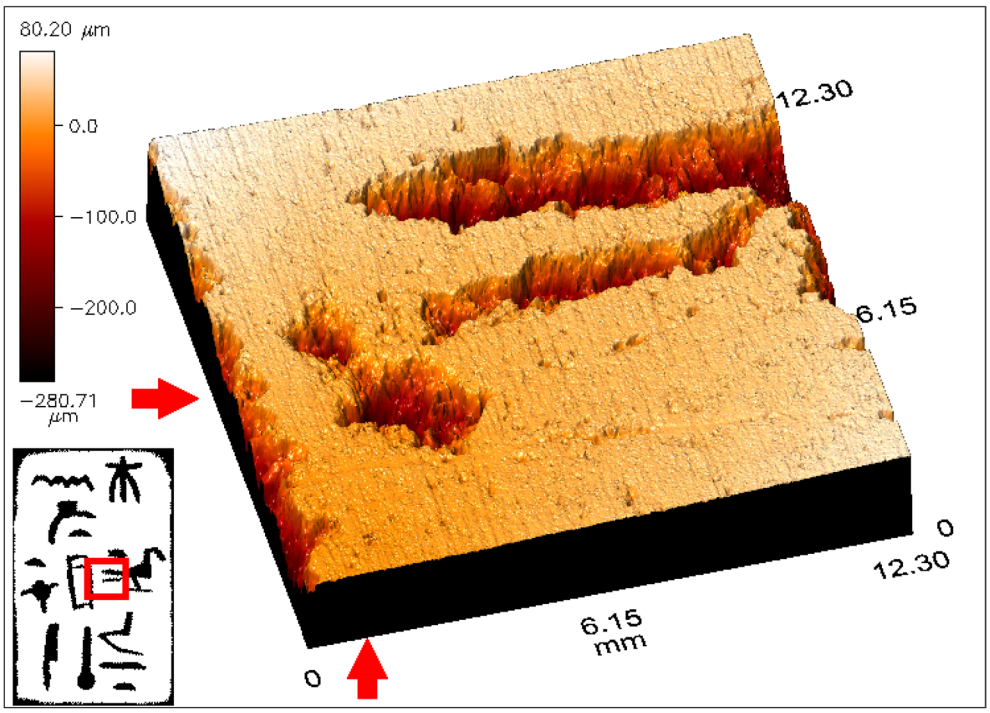

Fig. 8 Area below bird sign's tail. ©Heraklion Archaeological Museum

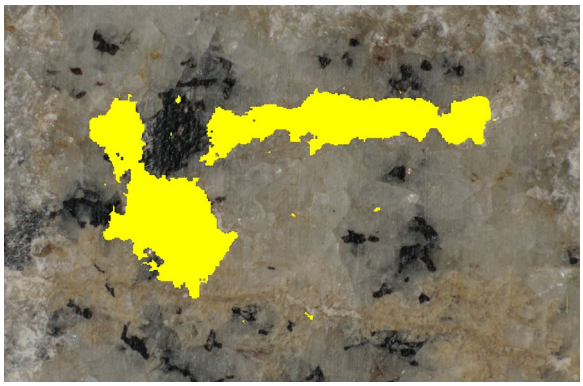

Fig. 9 Engraved areas in Yellow, superimposed onto basic photograph. ©Heraklion Archaeological Museum

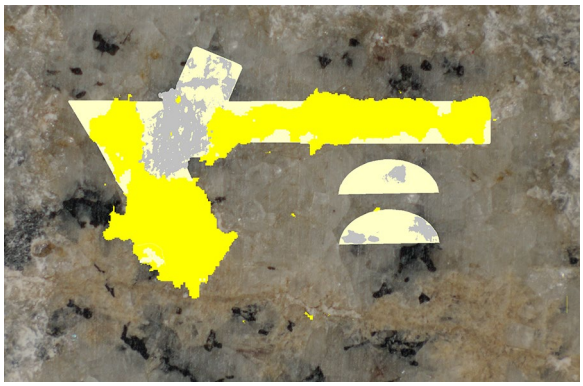

Fig. 10 Proposed reconstruction of signs. Yellow: engraved areas; Grey: surviving paint material; Beige: areas postulated as previously painted. ©Heraklion Archaeological Museum

Figure 12 shows the proposed reconstruction, in white outline on the original form, being most likely the Flamingo,[7] Gardiner's G27. It is true that the bird's neck is unusually 'pushed forward' toward the bottom, and not hanging symmetrically, but such a form is attested in Mariette's mastaba B4 [30].

Even if the present, i.e. reworked, form is considered alone, it shows a good resemblance to an actual Flamingo bird, but in the upright, 'alert posture' [31]. Valid hieroglyphic variants, quite different from Gardiner's G27, were occasionally employed for the Flamingo sign, and showed a similarly upright posture, with the bird's long neck substantially straight and vertical, and with the head well above the top of the body. See, for example, the late Sixth Dynasty funerary monument of Pepi

[7] See MMA photo T2513, and Chicago Oriental Institute photo 2920.

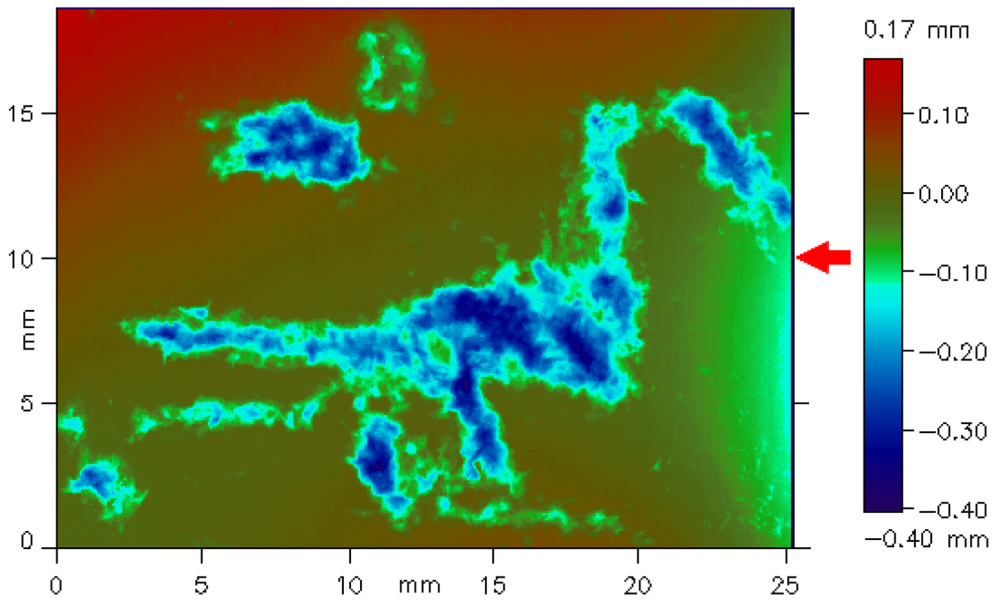

Fig. 11 Profile scan of the Bird sign. ©Heraklion Archaeological Museum

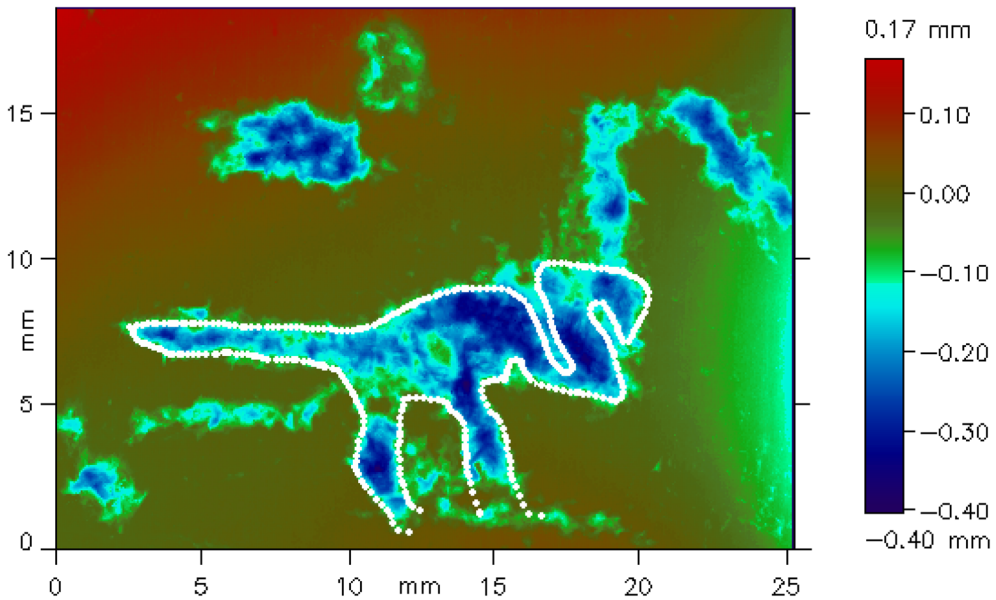

Fig. 12 Proposed reconstruction of the Bird sign. ©Heraklion Archaeological Museum

II [32], and the mid-Eighteenth Dynasty tomb TT85 of Amenemhab [33, 34].

Discussion—proposed new reading

See Fig. 13 for the statuette's revised Left side inscription.

It is now apparent that the Mother's name is given simply by the Recumbent Lion and Flamingo signs, i.e. ***Rw-dšr***. This name is not so far attested, although the female name using the Recumbent Lion sign alone, ***Rw***, is well known [35].

The Mother's name is followed by the Harpoon sign with two Bread Loaf signs, then by the divine name Hathor. A first attempt at a plausible translation might be 'Sole one of Hathor', but even 'Sole one of [deity]' finds no support whatsoever in published texts. If, however, the text has been *abbreviated*, by necessity of the small available area on the statuette, then

Fig. 13 Revised Left side inscription. ©Heraklion Archaeological Museum

a reasonable translation could be the very common pair of female titles 'Sole Royal Ornament; Priestess of Hathor', a suggestion regarded as plausible by Jones [36]. These two titles were frequently used together in Old Kingdom and early Middle Kingdom times [37].

The complete Left side inscription could now be translated as "Born of the Revered One (The Lady) ***Rw-dšr***, Sole [Royal Ornament; Priestess of] Hathor, True of Voice (Justified)".

Conclusion

The advanced imaging techniques employed here, Optical Profilometry and Multi-Spectral imaging, have proven to be necessary to correctly read the hieroglyphic signs of this inscription. Several signs are so small and shallow that traditional methods, such as normal photography, have been shown to be simply inadequate - some form of Profiling is required. Some other signs were finished only in paint, with little or no engraving, and after several thousand years buried in the moist soil at Knossos, one cannot expect the original colours to be preserved - some form of spectral analysis is necessary.

Equipped with these state of the art measurement techniques, all signs of the inscription were finally able to be correctly read, allowing a new translation to be achieved, changing the Mother's name and titles.

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Author contributions
All parts of the manuscript prepared by LG.

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Availability of data and materials
The datasets analyzed during the current study are available from the author on reasonable request.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Granted by the Director, Heraklion Archaeological Museum, Crete, Greece.

Competing interests
The authors declare no competing interests.

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