



Report of Digital Microscopic Examination

PROJECT:

The Kensington Rune Stone
3D Microscopic Examination

Reported To:

Runestone Museum
325 Broadway
Alexandria, Minnesota 55325

Date: February 23, 2011

Attn: Carol Meyer

Introduction

This report presents the results of a microscopic examination performed on the Kensington Rune Stone using the latest digital microscopic technology that allows for topographical profiling of three-dimensional surfaces. This technology was developed by Keyence Corporation who also provided two technicians, Michael Vincent, and Julia Des Chenes, to operate the equipment during the examination.

The five-hour long examination was performed at the Runestone Museum under the direction of geologist Scott F. Wolter, P.G., on February 16, 2011. The examination was witnessed by the following individuals: Runestone Museum Director, Julie Blank, and Board Members, Laura McCoy, Carrie LiBaire, Jeanne Stamness, Carol Meyer, and Darwin Ohman.

The scope of this report is to present the results of the following specific items related to the examination performed on the artifact:

1. Provide background information regarding the recent visit of a Swedish runologist who made statements about the inscription that prompted this examination.
2. Provide suitable background information on the history of the geological investigations in the last decade to put the current examination in context.
3. Performing a microscopic examination of specific areas of the inscription including the dotted R rune on line six in the word "waR" to determine if the

shallow punch in the upper loop was man-made or is a natural feature in the rock.

Background Information

On September 30, 2010, Professor Henrik Williams of Uppsala University in Uppsala, Sweden, visited the Runestone Museum, in Alexandria, Minnesota, to examine the Kensington Rune Stone inscription. Upon completion of his hour-and-a-half long examination, with three Museum Board members present, Jim Adam, Laura McCoy, and Carol Meyer, Professor Williams made the following pronouncement: *"If the dot is man-made, the KRS is a genuine medieval artifact."*¹

Realizing that to properly document the physical attributes of the "dot" required the expertise of an experienced geologist, the Runestone Museum contacted forensic professional geologist, Scott Wolter. In addition to having extensive experience studying hundreds of man-made inscriptions carved into rock, Wolter has over a decade of direct experience with all geological aspects of the Kensington Rune Stone. Wolter also brought experience derived from his own experimental stone carving of runic inscriptions.



Figure 1: This four foot tall rune stone was carved by Scott F. Wolter in 2005.

¹ Runestone Museum Memo dated October 1, 2010.

The Runestone Museum made a conscious effort to obtain the critical data required to support Professor Williams' positive opinion of the authenticity of the artifact. The data and conclusions presented in this report support the authenticity of the artifact per Professor William's pronouncement.

Previous Kensington Rune Stone Research

Wolter has performed multiple geological examinations on the Kensington Rune Stone beginning when he was first contacted by the Runestone Museum in July of 2000. On October 9, 2003, a comprehensive report was issued that included the tombstone study. The report concluded the relative-age of the weathering of the inscription at greater than 200 years, from the date of its discovery in 1898.²

Later that same month, Wolter and the Rune Stone traveled to Stockholm, Sweden, where Swedish geologist, Runo Lofvendahl, examined the artifact and reviewed the geological report and found the data therein, and responses to his questions, agreeable.

Scott,

Generally I agree with your manuscript and your answers to questions. As you may notice weathering is a quite virgin field, especially concerning field studies. We know quite little about the timing of weathering of surfaces and weathering rates in nature, but quite a lot of weathering in the lab. Below I will just consider a few questions a little.

1/ The dressing of one of the sides as well as tools and technique to make the runes are an important issue. We will probably discuss this matter with a stone mason who know a lot of traditional techniques etc. The concoidal fractures also puzzles me a bit.

2/ The "tree-root-traces" is certainly something for a specialist on trees.

3/ Pyrite weathering: We have been occupied with this mineral quite a lot. The major question however was if the sulfur in sulfate minerals in some building stone containing pyrite, in particular Gotland sandstone, has been added from the stone itself (the pyrite) or from the atmosphere. Thus, we have analysed isotopes of sulfur in gypsum and jarosites (iron-sulfate-minerals). The results indicates that stones in urban areas are polluted with foreign sulfur, while that in rural areas mainly originates from the bedrock itself (oxidation of pyrite).

Your problem is another – can the oxidation of pyrite be monitored to arrive at weathering/dissolution rates of pyrite? Weathering of rock surfaces have interested us the last decade. We have used different methods to study these, but none is very dependable or exact. Guess the only way is to expose fresh surfaces to different surroundings, and follow the oxidation of pyrite – or to find surfaces, which have been exposed for known periods. The latter would be best of course, but how to find such surfaces? Your tombstone examinations might be a possible way, especially if you compare what happens above, at and below ground.

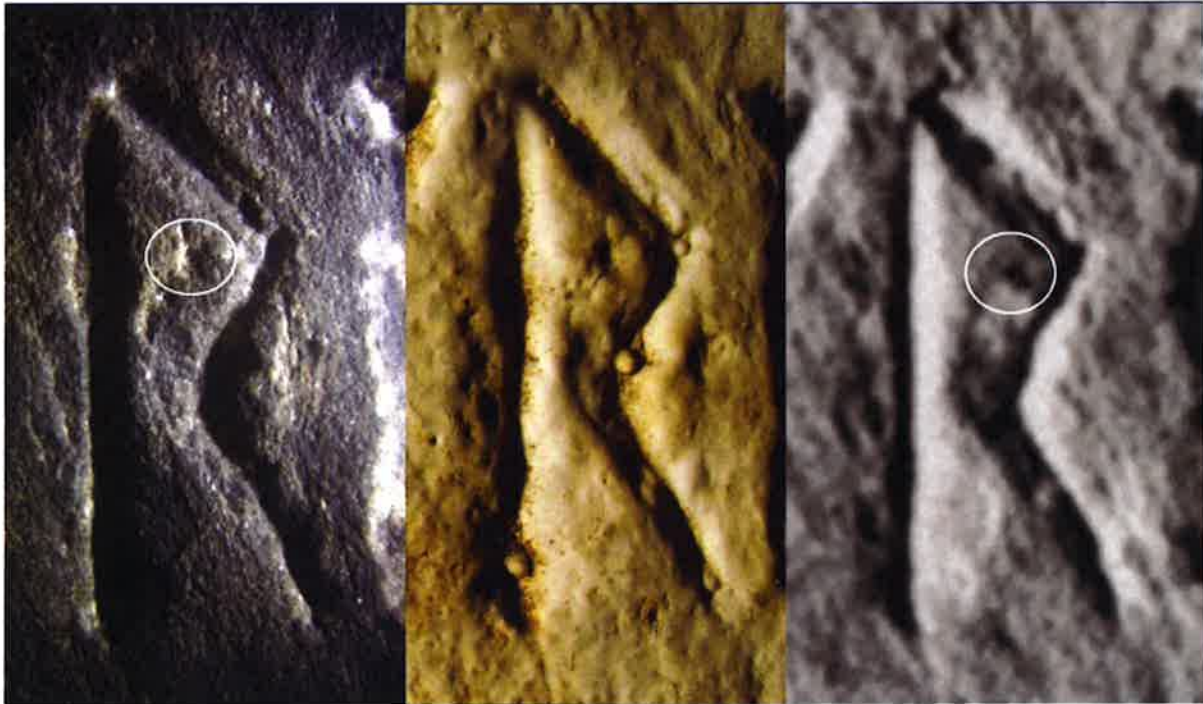
4/ Concerning your offer to study thin sections of the core. I must discuss this with Dr. Morth. In principle we can only study KRS in spare time. I think it is better to look at the stone before deciding to do any further examinations.

Runo

Figure 2: This memo was written by Swedish Geologist, Runo Lofvendahl, after reviewing and generally agreeing with the report on the geological investigation of the Kensington Rune Stone dated October 9, 2003.

² Wolter, Page 55, 2003.

On January 19, 2004, Wolter and Richard Nielsen (an engineer and amateur runologist) discovered a shallow punch mark in the upper loop of the first “R”-rune on line six on a full-sized cast of the Kensington Rune Stone. This discovery of the dotted R rune on the Kensington Rune Stone was vitally important since this extremely rare rune was unknown until Scandinavian scholars discovered it in 1935. Its presence on the Rune Stone in 1898 proved, all by itself, the medieval origin of the inscription.³



Figures 3, 4 & 5: Three images of the Dotted R on line six clearly show the presence of the dot in the upper loop. These images represent a photograph taken by Wolter in 2002 (left), the Rodney Beecher Harvey cast made in 1937 (middle), and a reserve image from photograph taken by John Steward, in March of 1899 (right).

Subsequent examination of the photo-library of the inscription made by Wolter in 2002, confirmed the presence of three dotted R's on the Kensington Rune Stone on lines, one, five and six (see figure 6). The first example indicated the carver had difficulty with the hard and brittle greywacke for nearly the entire plateau of rock in the upper loop spalled off from excessive force making the punch. The carver made the punch between the legs of the dotted “R”-rune on line five. After apparently learning from his error on line one, the carver used less force and made a shallower pit, or “dot”, in the dotted R on line six (see figures 7, 8 & 9).⁴

³ Wolter/Nielsen, Pages 49-58, 2006.

⁴ Wolter, Pages 31-33, 2009.

The Dotted R on line six was first discovered and published by Wolter and Nielsen in 2005. The importance of this rare runic feature prompted a personal visit to the Runestone Museum by Swedish runologist, Professor Henrik Williams. William's likely would have made a positive statement about the authenticity of the Kensington inscription had a geologist been present to examine the punch mark to attest to its man-made origin.

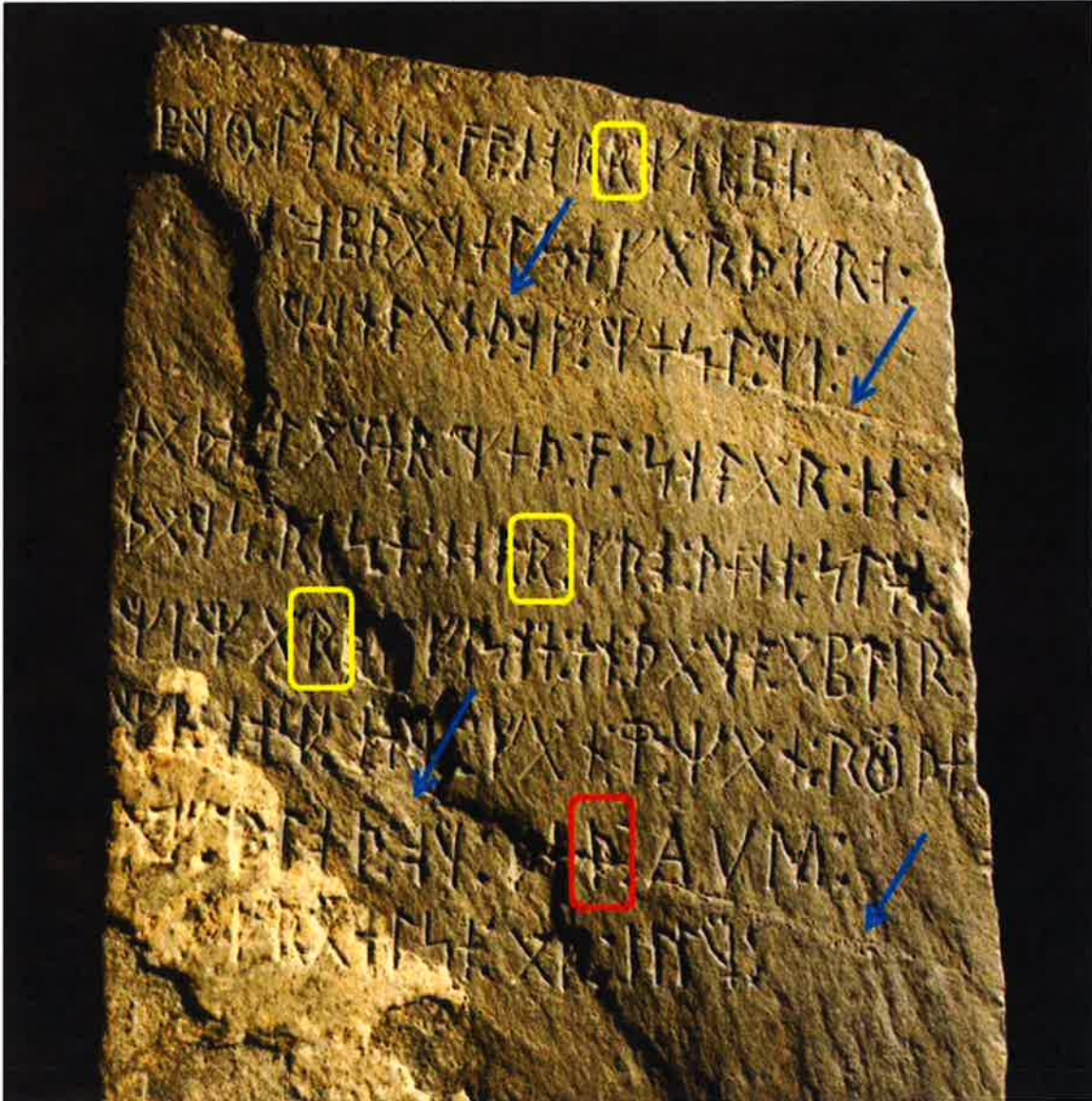


Figure 6: The three dotted R's are circled in yellow and appear on lines number 1, 5 and 6, of the Kensington Rune Stone inscription. The newly discovered dotted "thorn" rune is found on line 8 and is circled in red. The blue arrows highlight two, roughly parallel, joint fractures within the rock that pass through several runes including the dotted "thorn". Closer views of the dotted R's can be seen in figures 7, 8 & 9, and the dotted "thorn" in figure 13.

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Figure 7, 8 & 9: The carver had difficulty carving the three Dotted R's that appear on lines one (left), five (middle), and six (right) of the inscription. The carver used too much force making the punch in the middle of the upper loop of the character causing it to spall. The carver then placed the punch between the legs of the second Dotted R. Deciding to make the punch in the upper loop again, the carver used less force creating a shallow punch mark.

Test Results

A summary of the microscopic examination of the dotted characters is as follows:

The Dotted R

High resolution three-dimensional images clearly show the equal-dimensional shape and conically symmetrical, neatly centered pit in the middle of the plateau of rock in the upper loop of the character.

The pit is significantly shallower than other punch marks is logically explained by the difficulties the carver experienced with the first dotted R on line one. By making the punch mark with less force it made the pit less notable.

Naturally occurring pits are present on the surface of the stone. However, they are not conical or symmetrical and typically irregular in shape. The glacial surfaces of the stone do contain extensive very small scale pitting (50 microns across or less) due to weathering of fine-grained feldspars mineral grains, or plucking out of quartz sand grains from the surface of the meta-greywacke (See figure 10).

Further, the reported correct linguistic association of dotted R within the Old Swedish word "waR," supports the intentional man-made origin of the pit.



Figure 10: This reflected light image of the area in the upper loop of the first "R"-rune on line six, shows the uniform shape and depth (approximately 400 microns in diameter) of the pit, or "dot", in the upper plateau of rock. Very small-scale pitting (50 microns in diameter or less) can be seen on the glacial surfaces due to weathering of fine-grained feldspar mineral grains, or plucking out of quartz sand grains from the surface of the meta-greywacke. (Magnification 30X)

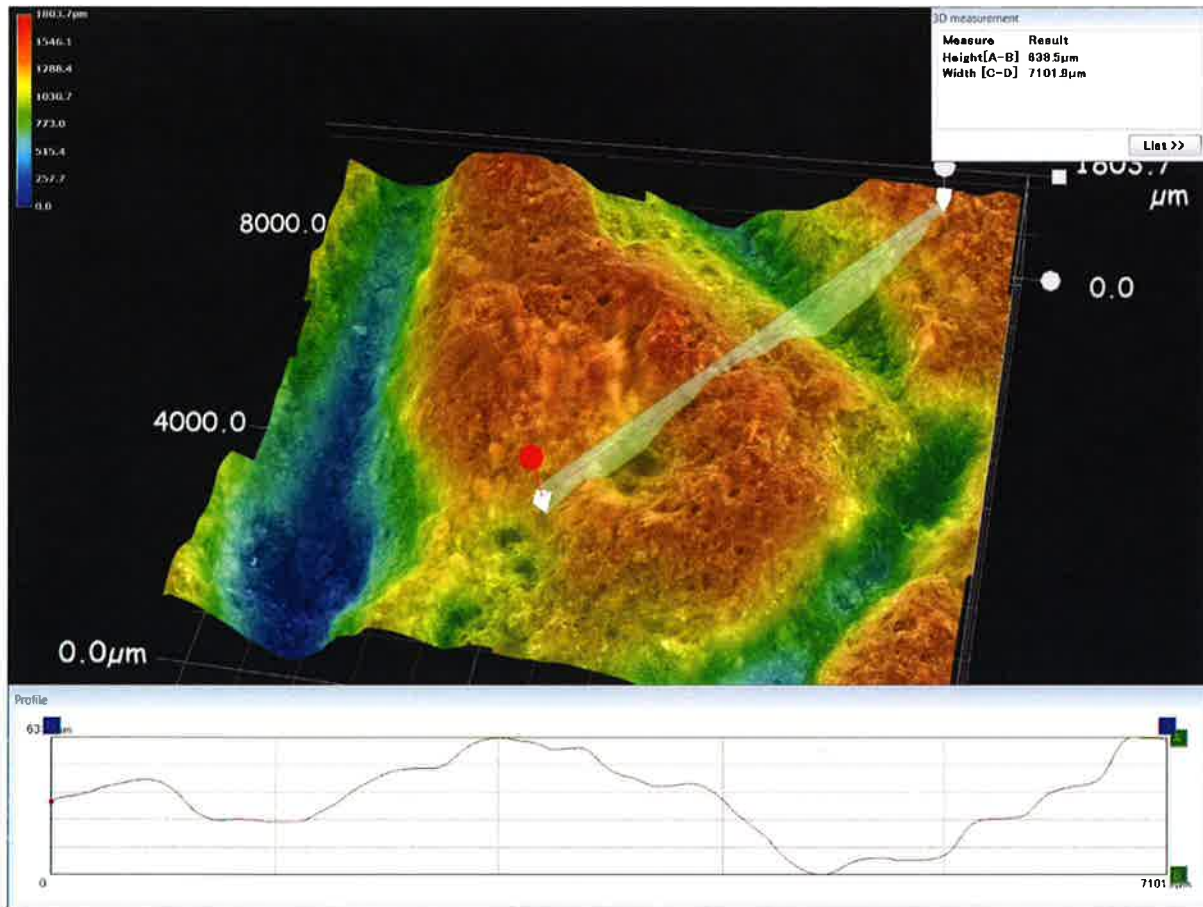


Figure 11: When a digital cross-sectional profile is created and reviewed the maximum depth of the man-made pit, or “dot”, in the upper plateau of rock of the “R”-rune in line six is 383 microns. The maximum depth of the carved groove in upper right is 638 microns. The shallow depth of the “dot” is consistent with being made with less force when carved than the deeper surrounding grooves that were made to create the character. (Magnification 30X)

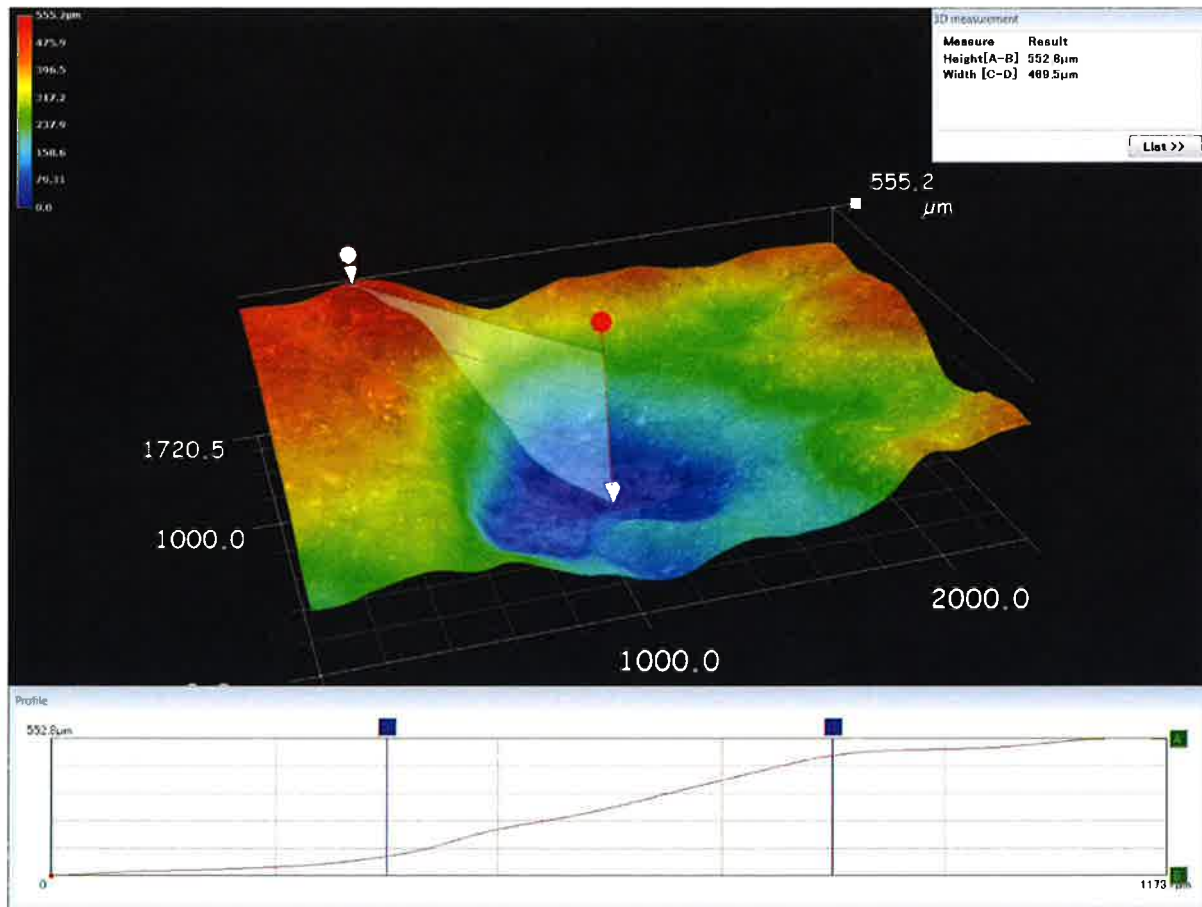
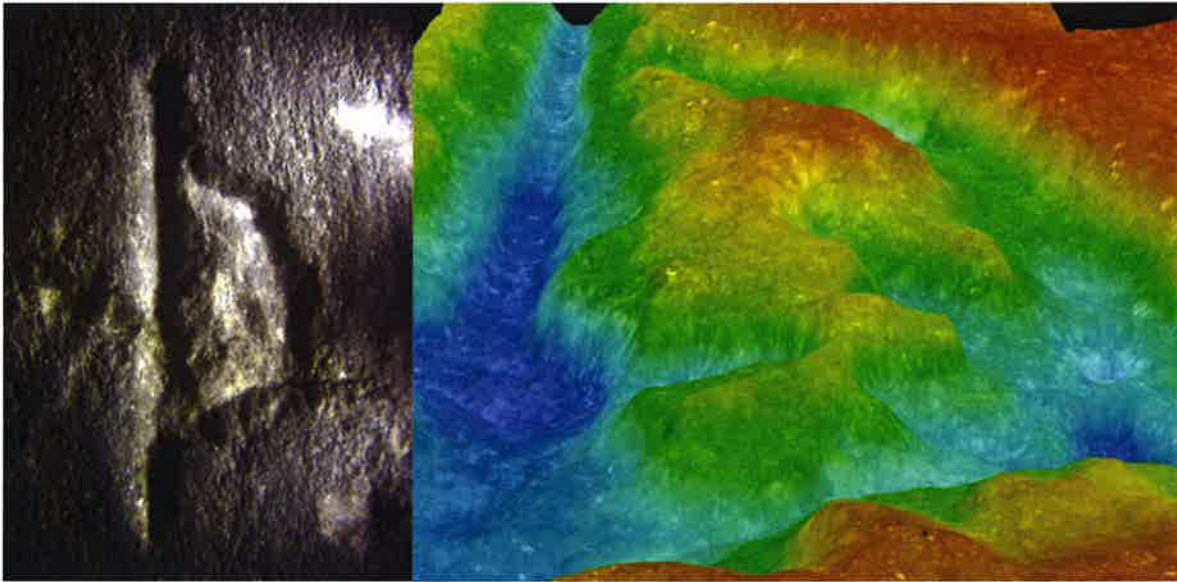


Figure 12: This three-dimensional image with rainbow colors that correspond to depth includes a cross-sectional profile extending to the maximum depth (555 microns) of the conical shaped pit, or “dot”, in the first “R”-rune on line six. (Magnification 150X)

The Dotted “Thorn” Rune

During the examination, an unexpected feature was found inside the loop of the second “thorn” rune in the word “death”, on line eight of the inscription.

Three-dimensional topographic images clearly show a circular pit connected to a channel running in a southeast direction ending in a deeper hole within the previously carved curved groove of the character (see figures 14, 15 & 16). This feature was previously overlooked due largely to several irregular shaped pits created by raveling along a joint fracture running diagonally across the entire stone and through this particular character (see blue arrows in figure 6).



Figures 13 & 14: The second “thorn” rune in the word “death”, on line eight, has a man-made mark in the middle of the plateau of rock within the loop (left). (5X) The image on the right is rainbow-colored based on elevation, and shows a three-dimensional, low-angled view of the physical topography of the carved rune. A channel starts in center plateau and runs downward to the lower right terminating in the dark blue area. (Magnification 25X)

It is now up to the runologist and linguists to determine the meaning and relevance of this new man-made addition to the inscription.

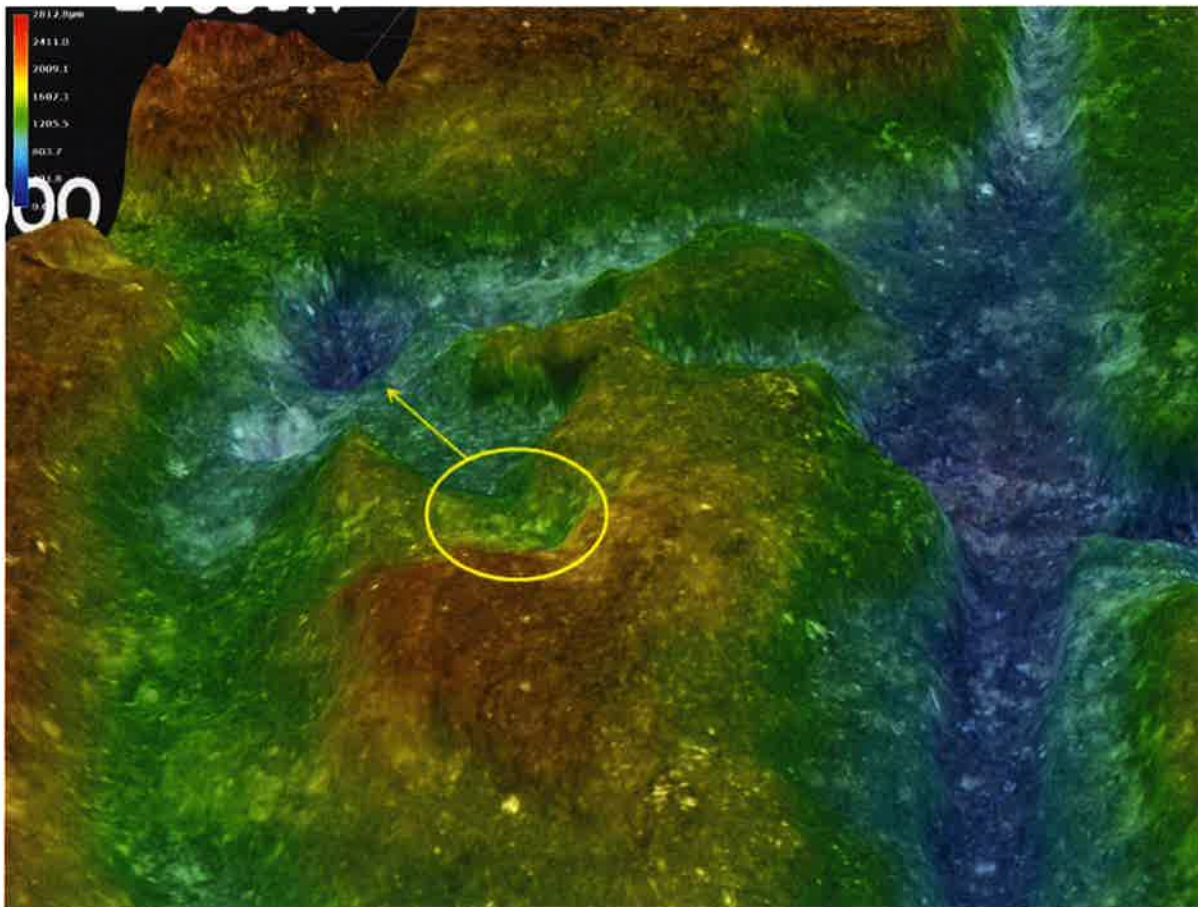


Figure 15: This three-dimensional view from the upper end of the character shows the initial depression where the chisel started (yellow oval). The yellow arrow marks the channel the pointed chisel cut until it stopped in the pit (blue) it created within the previously carved curved groove. (Magnification 25X)

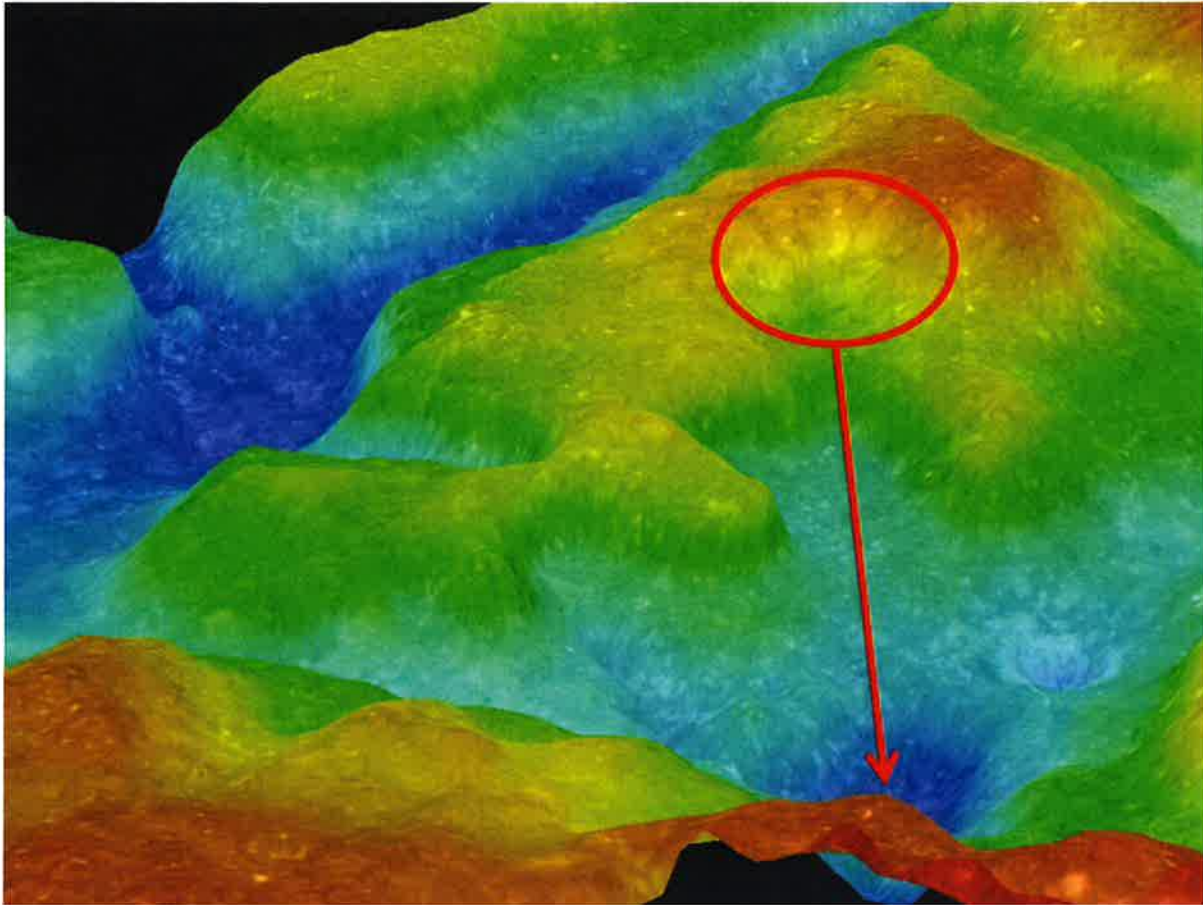


Figure 16: This head-on view shows where the carver's point-chisel struck the center of the plateau of rock and then cut a channel downward when the chisel slipped. The chisel stopped after running into the previously carved groove comprising the loop the character creating a deeper hole. (Magnification 25X)

Interpretations

Based on the data collected during the microscopic analysis that following interpretations are appropriate:

Dotted R

1. The highly uniform shape and central positioning of the shallow pit in the upper loop of the first "R" rune on line six is consistent with being intentionally man-made by a carver using a pointed "punch" chisel.
2. Earlier researchers were unaware of the existence of such a rune so even if the punch mark was noticed it wouldn't have been considered significant.

Dotted “Thorn”

1. After already having difficulties with Dotted R’s, it appears the carver tried to carefully make a small “dot” in the plateau of rock within the loop of this rune on the eighth line. Unexpectedly, the punch chisel slid off the plateau creating a linear groove until the tip created a hole, roughly 400 microns deeper than the previously carved groove that stopped it.
2. This unexpected discovery came as a welcome surprise since it appears to represent important and likely very rare, new linguistic evidence consistent with a medieval origin.

Conclusions

Based on our observations, test results, and past ten years of experience with this specific artifact our conclusions are as follows:

1. The conical-shaped circular pit in the upper loop of the first “R”-rune on line six of the inscription, is an intentional man-made mark. The relatively shallow pit was intentionally cut into the surface most likely using a sharp punch chisel at the time the inscription was carved.
2. The relatively shallow pit in the “R”-rune on line six was made using less force due to spalling in the plateau of rock in the upper loop of the “R”-rune on line one that occurred when the carver used greater force making the pit, or “dot”.
3. The circular pit in the middle of the loop of the “thorn” rune in line eight of the inscription, together with the groove sloping down and to the lower right that terminates in a deeper pit within the curving carved loop of the rune is man-made. This “Dotted Thorn” is a new discovery that represents an important, previously unknown detail that will likely shed new light on the inscription.
4. The microscopic examination confirms the presence of the dotted R rune on line six of the inscription. Therefore, since the dotted R was unknown to modern scholars until its discovery in 1935, its presence on the Kensington Rune Stone in 1898 confirms the medieval origin of the inscription and the authenticity of the artifact.

Recommendations

Based upon our microscopic observations and past history with the artifact the following recommendations are appropriate for follow-up work:

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1. Examine and digitally capture 3-D microscopic data of the entire inscription.
2. Generate 3-D imaging microscopic data of the three different weathering surfaces of the artifact: the glacial surfaces, the split side and original inscription, and the freshly fractured bottom surface of the core sample, and the retooled areas at the bottom of the characters.


Test Procedures

The five-hour long microscopic examination was performed inside the Discovery Room of the Runestone Museum on Wednesday, February 16, 2011. The characters and other geological features of the artifact were examined using the VHX-1000 Digital Microscope manufactured by Keyence Corporation of America. The optical microscope has High Dynamic Range Function that exponentially increases the levels of observable color gradation. The microscope creates calibrated 2D & 3D imaging with real-time vertical stitching and horizontal tiling at magnification up to 5000X.

Remarks

All data generated was given to the Runestone Museum immediately upon completion of the microscopic examination. Requests by researchers for access to the data should be made directly to the Runestone Museum.

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