UNIVERSITY OF MINNESOTA

Duluth Campus

Department of Geological Sciences

College of Science and Engineering

229 Heller Hall
1114 Kirby Drive
Duluth, Minnesota 55812-3036

218-726-7238
Fax: 218-726-8275
E-mail: geol@d.umn.edu

29 April 2002

Hi Scott:

I read the report with great interest. And if you recall, I always read with a red pencil in hand, so don't let the red suggestions/corrections bother you. Most of my remarks are ON the manuscript itself.

I liked the report, and I especially liked the excellent photographs! You have done a lot of work!

Suggest you present the entire decoded message on page 2. (Does Nielsen's work change anything relative to the original wording.)

"Retooling" was cited early in the manuscript without mentioning when and why and by whom it was retooled--i.e., "cleaned"? I would give the retooling more emphasis--it has removed the original weathered material, making it more difficult to study the alteration. Also, emphasize how the retooling has produced white areas, as in Photos 17 & 18 that so nicely show it.

I think you must stay objective as to the "final word", as the final word won't be in until your additional recommendations are performed. And it is likely that even then, it may not be a "final word". Sometimes conclusive and definite answers are just not obtainable. Such is science. However, you can certainly give your tentative speculative answers, clearly labeled as such. I think that you are making too strong a statement in conclusion 5 on page 8. I know you want it to be so, and I would like it to be so, too, BUT . . . . . We just DO NOT KNOW at this time, and must remain totally objective, even if it "hurts". There is no need to rush to a final conclusion, that you could regret later if newer information shows you to be wrong.

I am, of course, still interested. One place I may be of some help is on the source of the stone--which graywackes , and what age?

Keep it up! Cheers!

Dick O.

Dick

AMERICAN
PETROGRAPHIC
SERVICES, INC.

PROJECT:

KENSINGTON RUNESTONE

INVESTIGATION

REPORTED TO:

KENSINGTON RUNESTONE
FOUNDATION
206 BROADWAY
ALEXANDRIA, MINN. 56308

ATTN: LuAnn Patton

APS JOB NO: 10-01120

DATE: January 4, 2001

Introduction

This report presents the results of laboratory work we performed on one stone slab artifact referred to as the "Kensington Runestone" or KRS. Our work was requested and authorized by Ms. LuAnn Patton of the Kensington Runestone Foundation on July 3, 2000. The scope of our work was limited to the following:

1. Performing petrographic observations to document physical aspects of the man-made carvings on the stone as well as on the stone itself.

2. Obtaining one rock core and one chip sample from the KRS.

3. Performing thin section analysis and scanning electron microscopy on the rock core and the chip sample.

4. Providing opinions, based on the geological aspects of the stone, regarding the relative age of the man-made features observed on the KRS.

5. Providing an opinion regarding the authenticity of the KRS and suggest recommendations for additional testing.

Background Information

The KRS was first unearthed by a Swedish farmer named Olof Ohman, who was grubbing trees on his land near Kensington, Minnesota on November 8, 1898. It was well documented by interviews with several witnesses, including Mr. Ohmans' 10 year-old son, that the stone was entangled in the roots of a tree when it was pulled out of the ground. The original position of the main inscription or face side of the stone when it was found, was downward.

The KRS is a tabular shaped stone weighing roughly 200 pounds, that was probably left as a memorial, and is dated 1362 A.D. Shortly after its discovery, the KRS was studied by many language experts from both the United States and Scandinavia. The stone contained a carved message that was written using Old Swedish language forms called runes. The message carved into the stone tells of the massacre of 10 people in an exploration party from Scandinavia. Many of the characters were unfamiliar to the language experts which led to their conclusion that it must be a forgery. The only expert to look at the KRS in a scientific way was N. H. Winchell in 1909-10. Mr. Winchell was a well respected geologist/archeologist who first described the geology of the stone. After his physical examination of the stone and investigation of the geological conditions and physical changes of the region where the KRS was found, he reached an opinion. He concluded that "The said stone is not a modern forgery and must be accepted as a genuine record of an exploration in Minnesota at the date stated in the inscription". His conclusion, as well as the conclusion of the Minnesota Historical Society, which was based largely on Professor Winchell's work, was that the Kensington Runestone was authentic. Extensive background information about the KRS can be obtained in the Minnesota Historical Society preliminary report published in 1915 (MHS Collections, Volume 15, 1915).

Much speculation about the authenticity of the KRS, pro and con, has been written and debated in the past 102 years. However, little scientific information has been published. Recent language studies of the KRS by Dr. Richard Nielsen, strongly supports it's authenticity. The KRS was brought to the American Petrographic Services Inc. (APS) laboratory in October of 2000 for the examination and testing.

Sample Identification

Sample Type	Original Sample Dimensions
KRS Stone Slab	Approx. 31" x 16" x 5 ½" thick
Rock Core (RC) *	1 $^{1}/_{4}$" diameter by 2" long
Rock Chip	Approx. ½" x $^{1}/_{4}$" x $^{1}/_{8}$" thick

* - The rock core was cut into five (5) separate samples including two (2) thin sections. One thin section was orientated parallel to, and the other perpendicular to, the glacial top surface of the core. The perpendicular thin section included a vertical profile of a white leached area observed on the glacial back and side surface (See photo # 3).

Test Results

Petrographic Observations

Description Of KRS Surfaces (Sides) - The stone is flat and elongate in shape with three distinct types of sides:

1. The face side exhibits weathering similar to the glacial sides, but has no obvious glacial striations. The face side contains the beginning of the man-made, carved inscription (See photo #1).

2. The entire split side was clearly man-made, or dressed, at the same time as the original carving of the message. The last part of the message is on this side. This surface exhibits weathering that appears much younger than the glacial and face sides (See photo # 2).

3. The glacial sides exhibit striations and weathering of at least 10,000 years, or weathering that commenced after glacial transport and deposition. These areas are referred to as the following (See photos # 3, 4, 5 & 6):

   a. Glacial back side
   b. Glacial side
   c. Glacial top end
   d. Glacial bottom end

General Geology - The KRS is a light to medium gray colored, meta-graywacke of probable Archean age (approximately 2.7 billion years). Archean age graywackes from Canadian Shield bedrock sources are commonly found in glacial deposits throughout much of Minnesota. The top face side of the stone contains a triangle-shaped, exposed hydrothermal calcite vein filling. The calcite vein is approximately 3 to 5 mm in thickness and exhibits a strong preferred orientation (sub-parallel to the long axis of the stone) of the medium to coarse sized (2-3 mm) calcite and chlorite minerals (See photos # 9, 35 & 36). The KRS also exhibits well developed joint fracture planes in at least three directions. These inherent fracture planes directly influenced the tabular shape of the stone.

Glacial Geology - The KRS is a portion of a previously larger glacial erratic. The glacial back side exhibits several, large and relatively deep striations running sub-parallel to the long axis of the stone. This length and depth of the striations suggest that they were produced at the base of a glacier moving over the stone while it was still a part of the bedrock (See photos #11 & 12). Additionally, many smaller (up to 3" in length) and shallower groups of striations were also observed on the glacial back side, that were orientated in various directions. This suggests the striations developed during transport within the ice. The face side exhibits weathering consistent with the glacial sides but does not have striations (See photo #10). This suggests the slab may have broken off from a larger erratic near the end of it's glacial transport, possibly from frost shattering.

Coatings - Roughly 10 to 15% of the glacial bottom end surface is covered with intermittent yellowish-white, secondary calcite coatings deposited after glacial deposition and before the man-made carvings (See photos # 6, 7 & 8).

Contemporaneous Weathering Surfaces- The KRS exhibits four distinct man-made fracture surface types that were made at the time the stone was originally carved.

1. The entire split side exhibits a surface that is devoid of evidence indicating glacial abrasion. This side is a darker bluish-gray color than the adjacent glacial surfaces. The edge of the split side which meets the glacial back side, has 6 to 7 pseudo-conchoidal fractures (approximately 2-4 cm) which appear related to purposeful impact. The previously larger, flat, original stone appears to have been reduced in size to it's present shape, prior to the original carving (See photo # 2).

2. During the original chiseling of the rune forms, low angle fractures or "flaking" occurred that are present immediately adjacent to many of the characters. These flaked areas are similar in color and texture to the previous described fracture surfaces associated with the original carvings (See photos #13 & 14). Subsequent retooling into the deepest part of the original grooves did not affect the flaked surfaces. The weathering on the flaked areas, where present, has remained intact.

3. In the upper left corner on the face side of the stone is a small ledge (approx. 1 cm) that was fractured off leaving a vertical fracture face with the same dark, blue-gray color and appearance as the entire split side. This surface, called the "Oh Shoot" area, is located where the second line of the message likely would begin. The second line of the message appears to have been restarted immediately to the right of this vertical fracture face (See photo #15).

4. Several rune forms on the glacial top end of the split side do not appear to have been retooled at all. The texture and appearance of these grooved surfaces match the entire weathered split side making the characters in this area harder to see (See photo #16).

Weathering Environment - Since the KRS was found shallowly buried in the ground, it is assumed the stone and it's inscription were exposed to a below grade weathering environment within 24" of the surface. Since it is unknown how long the KRS was buried, it is assumed that natural processes alone would have begun to bury the stone within a short period of time after it was set (probably upright) in the ground. The soil horizon in this zone would have experienced periodic fluctuations in moisture content due to precipitation. Additionally, the stone has been exposed to annual frost penetration but relatively few freezing and thawing cycles. The stone shows no apparent evidence of surface spalling or delaminations associated with freeze-thaw deterioration.

Apparent Root Leaching - Two, approximately 1 cm wide, roughly parallel, light tan colored, slightly undulating linear discoloration run across the glacial back and side surfaces of the stone. They look quite similar to tree roots. If this discoloration is associated with tree roots, a chemical leaching reaction appears to have occurred between the roots and mafic (magnesium and iron-rich) minerals in the stone, producing the discoloration. These suspected root leaching lineations are consistent with the stone reportedly being found with the inscription face side down, wrapped in the roots of a tree (See photo #3).

"H" Control - An "H" control letter (approx. 3 cm) was observed near the glacial bottom end of the split side (See photo # 2). The "H" does not appear to have undergone any observable weathering. It was reportedly chiseled into the stone in 1908, by one-time owner Mr. Hjalmar Holand.

Retooling - All of the original rune form grooves on the face side and 75% of the rune forms on the split side have been scratched on or completely retooled. The retooling on the face side appears to have been done with greater force than the split side. This retooling has removed alteration products from within the grooves and crushed the surface minerals. This has produced a white color that looks "fresh" at first glance. The date when the retooling occurred is unclear. However, close inspection of photographs taken of the KRS in March of 1899, appear to show retooling present at that time. The suggests the retooling occurred shortly after discovery, perhaps within days (See photos # 13 & 14). Retooling and scratching on the rune forms may have occurred multiple times over the years.

Gypsum Deposits - Initial observations revealed intermittent areas of very small (approx. 1 mm) white deposits on several surfaces including original rune form grooves on the split side. Powder mounts reviewed under polarized light at magnification up to 400X, indicated the material was comprised of gypsum. A number of plaster casts of the stone have been produced in the past (reportedly the 1930's). The gypsum deposits observed are believed to be remnants of the plaster.

Iron Oxide Deposits - Significant iron-oxide deposits were observed on several original groove surfaces and flaked areas adjacent to retooled grooves. The iron deposits are the by-product of the decomposition of pyrite from within the stone (See photos # 19, 20, 21, 22, 23 & 24). These deposits give the appearance of great age and may well have developed decades or centuries ago. However, because pyrite can oxidize very quickly, these deposits could also have developed a year or two after exposure.

Winchell Sampling Area - In the lower right area of the face side of the KRS is a number of obvious chisel marks. The timing of when these impacts occurred is unclear. However, professor Winchell states in 1909 *, that "I took a small flake from its lower end...". We assume that this flake was where a thin section was eventually made that he reviewed. This area appears to be the likely source of his sample (See photo # 9).

* - Minnesota Historical Society Collections Report on the Kensington Runestone, December 13, 1909.

Thin Section Analysis

Thin section analysis of a core sample reveals the KRS is a fine-grained, meta-sedimentary rock with a strong preferred orientation of very fine-grained mica minerals, that is consistent with a relatively low grade of metamorphism (greenschist facies). This well developed lineation represents either relict bedding planes, a metamorphic foliation or both (See photos # 25 & 26). The mineralogy consists of the following (See attached data sheet):

Mineral	Estimated Percentage
1. Quartz (See photo # 27)	30
2. Sericite (See photo # 27)	25
2. Chlorite (See photo # 30)	15-17
3. Orthoclase (See page # 29)	10
4. Pyrite (See page # 24)	5-7
5. Muscovite	5
5. Plagioclase (See page # 28)	3-5
7. Biotite	3
8. Poly-crystalline Quartz or Quartzite	1-2
9. Calcite	<1
Total	100

Scanning Electron Microscopy (SEM)

White Discoloration (Apparent Root Leaching) - SEM images were generated on the polished vertical profile of the top ½" portion of the core sample with the undulating, white discoloration. Images generated of the polished surface exhibit greater undercutting of the fine-grained mica matrix in the white areas suggesting the integrity of the minerals had been degraded by chemical reactions. This apparent root leaching was observed to a maximum depth of 1.5 mm (See photo # 38).

what do you mean?

Weathering Surfaces - SEM images were also generated from three different surfaces of the stone to compare weathering characteristics of the fine-grained mica matrix. The three surfaces examined included the following:

1. The freshly fractured surface on the bottom of the core where it was broken off (See photos #31, 33, 39, 41 & 49).

2. The glacial back surface of the core that has experienced at least 10,000 years of weathering (See photos # 32 & 40).

3. The chip sample obtained from the split side of the stone that was first exposed at the time of the original carving and may represent as long as 500 years of weathering in the ground (See photos # 42 & 54).

The freshly fractured surface exhibited well-developed quartz, feldspar and mica crystals with clearly defined mineral boundaries. The glacial back side exhibited a muddy-looking surface with protrusions of harder, blocky-shaped minerals (quartz and feldspars). The platy mica minerals (muscovite, biotite and chlorite) were completely decomposed to clay minerals. Lastly, the weathered surface of the split side chip sample looked very similar to the weathered glacial back surface. A few areas were observed on the chip sample with clusters of mica that were severely deteriorated. This suggests a slightly lesser degree of overall weathering on the split side than the glacial back surface.

Conclusions

Based on our observations, test results and past experience, our conclusions are as follows:

1. The KRS is a light to medium-gray colored, meta-graywacke of Archean age (approximately 2.7 billion years old). The stone appears to be a portion of a previously larger sized glacial erratic that has clearly been shaped, or "dressed" to it's present shape. Additionally, there are hundreds of man-made tool marks that were purposefully carved into two sides of the stone. The tools marks are reportedly old Scandinavian rune forms that present a message and is dated 1362 (See photos # 1 & 2).

2. We observed four, separate, original man-made fracture surface types that were made at roughly the same time. These surfaces clearly exhibit weathering of a shorter length of time than the surfaces of the stone that have been impacted by glacial action (>10,000 years). Additionally, we observed evidence of more recent carving, or retooling, in roughly 95% of the carved rune-forms. The retooled areas appear white in color and do not exhibit evidence of weathering. The four original surfaces are described as follows:

   a. The entire split side of the KRS that was made or "dressed" at the time of the original carving (See photo # 2).

   b. Areas of flaking produced during the original carving that are immediately adjacent to the deepest retooled grooves (See photos #13 & 14).

   c. The vertical fracture face, called the "Oh Shoot" area, where part of the stone chipped off along a cleavage plane during the original carving (See photo #15).

d. Several rune forms on the glacial top end area of the split side of the KRS, that do not appear to have been retooled (See photo #16).

3. SEM analysis of surfaces on the core and chip samples indicate that the four, original man-made surfaces have experienced extensive mica degradation from prolonged weathering, presumably while in the ground (See photos # 39, 40, 41 & 42).

4. The glacial back side of the KRS exhibits two white, roughly parallel, undulating discolorations that branch out at two locations, suggesting an organic-based origin. We suspect these lineations were produced by chemical leaching of iron and magnesium from minerals in the stone, due to prolonged contact with tree roots in the ground (See photos # 3, 37, 38, 43, 47, 48, 49 & 50).

5. It is clear that the four man-made fracture surface types on the KRS, exhibit weathering (primarily mica degradation) consistent with being buried in the ground for at least decades and probably centuries. This being the case, the logical conclusion is that the KRS is an authentic artifact, presumably made at the time it is dated (1362 A.D.). (See photo #17).

Recommendations

Additional work that should be performed to better understand both the time-line for weathering and the various aspects of the inscription are as follows:

1. Tombstone Studies - To quantify the rate of mica decomposition, a testing program using gravestone chip samples should be performed. Chip samples should be taken from gravestones comprised of rock containing fine-grained mica minerals, from both above and below grade. Gravestones of incremental age (Example: 5, 10, 25, 50, 100, years etc.) should be sampled for analysis using the SEM. A time-line for mica degradation could then be generated for comparison with the man-made surfaces on the KRS. Additional testing to quantify the degradation rate of constituent minerals, such as water loss, specific elemental loss, conversion to clay minerals, etc., would help in better defining the time-line of weathering of the man-made surfaces.

2. Identify Graywacke Bedrock Source - Locating the bedrock source of the KRS would be comprised of two parts. First, a map and literature search should be performed to locate likely source areas. Secondly, perform field work to identify the bedrock source and obtain samples for testing.

3. Accelerated Weathering Testing - The samples obtained from the bedrock source would undergo accelerated weathering testing under similar below-grade conditions.. The use of an autoclave and an accelerated freeze-thaw chamber would be appropriate to simulate the weathering the KRS was exposed to. Chip and polished section samples should then be reviewed and photographed using reflected light microscopy and SEM.

4. Comparative Time-Line Projections - The accelerated weathering data should then be analyzed to project mica degradation and weathering time-lines. This information could then be compared with the time-line data generated from the tombstone studies. These results would give the best information possible to date the weathering on the man-made surfaces of the KRS.

5. Microscopic Documentation of the Inscription - A thorough microscopic digital photo library of the entire inscription should be produced. The catalog of photos should include each word and every individual rune form, number and word separator under various magnifications. Careful observations should be made during photography to document any important aspects of the stone itself as well as the inscription (See photo #18 as an example).

6. Depth of Root Leaching - A qualified plant specialist should be consulted to investigate the chemical processes and timing involved to develop the apparent root bleaching observed on the glacial back side of the KRS.

Test Procedures

Laboratory testing was performed on September 11, 2000 and subsequent dates. Our procedures were as follows:

Petrographic Observations

Petrographic observations were performed in accordance with APS Standard Operating Procedure 00 LAB 004b, "Petrographic Examination of Aggregates for Concrete", ASTM:C295. Observations were made using a Olympus SZH binocular stereo-microscope with magnification up to 250x. Photo micrographs were taken using digital equipment.

Thin Section Analysis

Thin section analysis was performed in accordance with APS Standard Operating Procedure 00 LAB 004b, Petrographic Examination of Aggregates for Concrete, ASTM:C295. Thin sections were reviewed under an Olympus BH-2 polarizing microscope with magnification up to 1000x. The samples are first highly polished, then epoxied to a glass slide. The excess sample is cut from the glass and the slide is polished until the rock reaches 25 microns or less in thickness. The top ½" of the core sample was cut off with thin sections made from both the horizontal and perpendicular orientations to the "glacial" back surface. Powder mounts were also generated from coatings obtained from the KRS.

Scanning Electron Microscopy

SEM observations, images and elemental maps were generated at magnification up to 5000x using environmental scanning electron microscope equipment at the Iowa State University-Materials Research Laboratory.

Rock Coring and Chip Sampling

On October 3, 2000, one 1 1/4" diameter rock core sample was removed from the "glacial" back side of the KRS. The core location was selected in an area that included an obvious fracture plane as well as the root bleaching discoloration. The sample was removed using a water-cooled, diamond studded coring bit. The hole was not patched after coring (See photos # 43, 44, 45, 46 & 47). The chip sample was obtained on October 21, 2000, by using a two-pound hammer and steel chisel (See photos # 51, 52, 53 & 54).

Remarks

The samples obtained from the KRS will be retained for future study unless otherwise authorized, in writing, by the Kensington Runestone Foundation.

Report Prepared By:

_____

Scott F. Wolter P.G.
Geologist/Petrographer
Minnesota License #30024

00 LAB 004

PETROGRAPHIC EXAMINATION OF AGGREGATES FOR CONCRETE, ASTM:C295

APS JOB NO: 10-01120 DATE: 7-23-01

SAMPLE NO: Thin Section #1 PETROGRAPHER: M. Haskin/Scott Wolter

HAND SPECIMEN DESCRIPTION:

A light to medium gray colored quartz wacke or graywacke. Grains primarily quartz and K-feldspar with minor amounts of plagioclase and polycrystalline quartz. Generally grains are about 300 μm (although some grains are quartz up to 0.75 mm). Opaques are pyrite and comprise about 7% of the rock. About half of the observed section is comprised of secondary alteration minerals that makes the original mineralogy indiscernible. Authigenic minerals are primarily chlorite and sericite with minor amounts of fine grained biotite, muscovite and calcite. According to the abundance of clay/mica minerals and slight foliation, subparallel to a fracture system, sample may be slightly metamorphosed (lower green schist facies). The largest (up to 0.75 mm) minerals are sedimentary clasts and comprise approximately 50% of the sample. The remaining 50% is very fine-grained and comprised of sericite, chlorite, biotite, and muscovite. A predominance of sub-parallel orientation of elongate quartz and feldspar grains may indicate relict bedding planes.

MINERALOGY — **OPTICAL PROPERTIES**

MINERALS	VOL	COLOR	BIREFRINGENCE	RELIEF	HABIT, OTHER
Quartz	~30%	-	1st order gray-yellow	Low	Up to 0.75 mm sub-angular-angular with slight undulose extinction
Sericite	25%	-			<100 μm
Chlorite	15-17%	Green			Up to 200 μm fibrous masses-acicular texture disseminated throughout, but concentrated in veins with opaques
K-Feldspar (Orthoclase)	~10%	-	1st order gray-yellow		100-300 μm sub-angular sericite coated, irregular edges minor lath shaped crystals
Opaques (pyrite)	5-7%	Black	-	-	Equant, stubby, 30-300 μm
Plagioclase	3-5%	-	1st order gray-yellow		Equant to lath shaped up to 300 μm polysynthetic twinning visible, slightly sericite altered, angular to sub-angular
Polygonal Quartz	1-2%	-		Low	Up to 300 μm sub-angular, sub-rounded
Muscovite	5%	-			100 μm in length
Biotite	3%	Brown			10-50 μm very fine fibrous
Calcite	<1% trace	-	3rd order pink, 4th order green	Medium	100 μm irregular shaped isolated

Kensington Runestone Investigation List Of Photographs

A. Overall Photos of the KRS

1. Face Side with the First Part of the Inscription
2. Split Side with the Second Part of the Inscription
3. Glacial Back Side with the Apparent Root Bleaching
4. Glacial Side
5. Glacial Top End
6. Glacial Bottom End
7. Calcite Coatings on Glacial Bottom End Back Side
8. Calcite Coatings on Glacial Bottom Side
9. Hydrothermal Calcite Vein Filling
10. Fracture Planes on Face Side with Low Angle Light
11. Striations on Glacial Back Side with Low Angle Light
12. Striations at Lower Angle View

B. Reflected Light Photos (up to 20x)

13. Flaked Area Adjacent to Retooled Runeform
14. Flaked Area(s) Adjacent to Retooled Runeform
15. "Oh Shoot" Area
16. Inscription Area on the Split Side with Little or No Retooling
17. Date of the Inscription
18. "R" Rune Carved Over Punch Chisel Marks (Word Separator)
19. Iron Oxide Deposits in Original Carved Area of Runeform
20. Iron Oxide Deposits in Original Carved Area of Runeform
21. Retooling Through Well Developed Iron Oxide Deposits
22. Closer View of Photo # 21

C. Reflected and Transmitted Light Microscopic Photos (40x to 100x)

23. Weathered Out Pyrite Crystals
24. Iron-oxide Deposit from Weathered Pyrite Crystal (ppl)
25. Weathered Fracture (ppl)
26. Weathered Fracture (cpl)
27. Quartz Sand Grain (cpl)
28. Plagioclase Sand Grain (cpl)
29. Weathered Orthoclase Sand Grain (cpl)
30. Chlorite Mica (ppl)
31. Freshly Fractured Bottom Surface of Core
32. Highly Weathered Glacial Top Surface of Core
33. Freshly Fractured Bottom Surface of Core
34. Significantly Weathered Split Side Surface

35. Vein Calcite Scrapping (cpl)
36. Vein Calcite Scrapping (ppl)

(cpl) - cross polarized light
(ppl) - plane polarized light

D. Scanning Electron Microscopic Photos (100x to 500x)

37. Root Leaching Profile (Reflected Light)
38. Undercutting of Degraded Minerals in Root Leached Area
39. Freshly Fractured Bottom Surface of Core
40. Highly Weathered Glacial Top Surface of Core
41. Freshly Fractured Bottom Surface of Core
42. Significantly Weathered Split Side Surface

E. Coring Photos

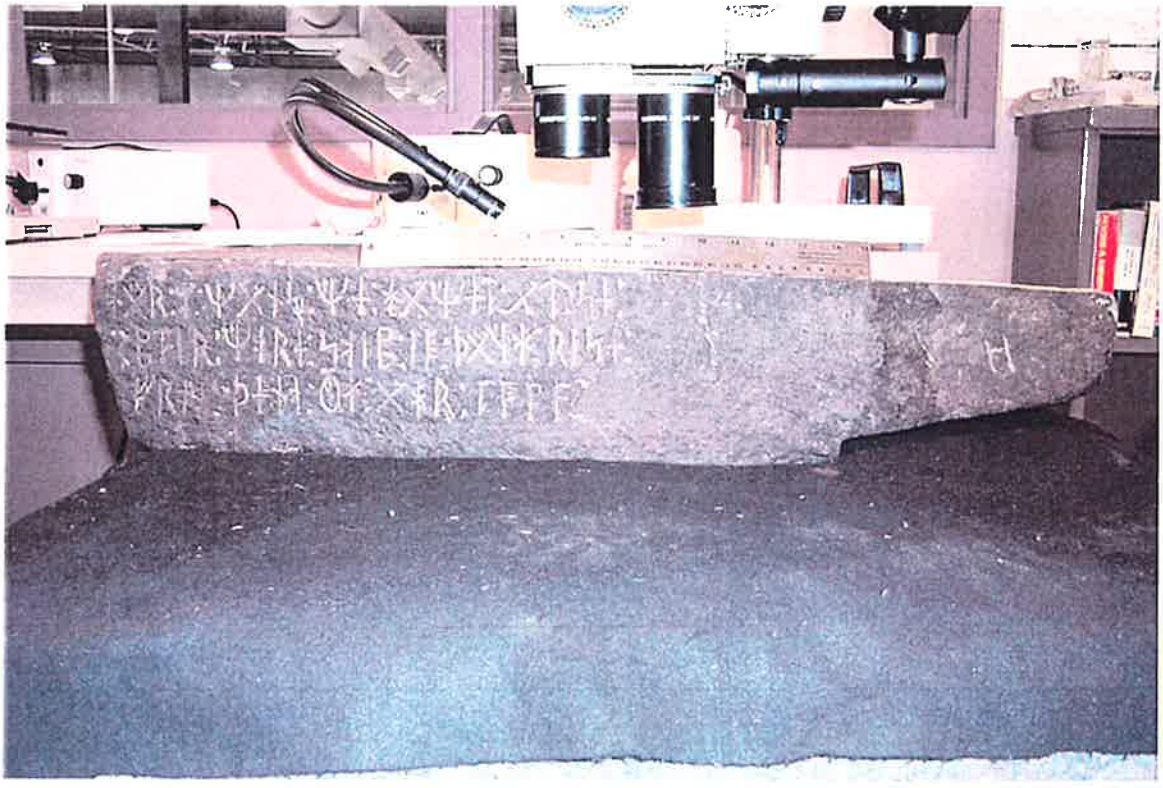
43. Area On Glacial Back Side where Core was Taken
44. Positioning of Core Barrel
45. Vacuuming
46. Breaking off Core
47. Core Removal
48. Top of Core
49. Bottom of Core
50. Side of Core

F. Obtaining Chip Sample Photos

51. Chip Sample Location
52. Pail to Capture Chip Sample
53. Location After Sampling
54. Captured Chip Sample

APS# 10-01120 DATE: July 17, 2001
PROJECT: Kensington Runestone Investigation

SAMPLE ID: KRS
PHOTO # 1
MAGNIFICATION: None
SAMPLE DESCRIPTION: Overal view of the face side of the stone.



SAMPLE ID: KRS
PHOTO # 2
MAGNIFICATION: None
SAMPLE DESCRIPTION: Overall view of the split side of the stone.

APS# 10-01120 DATE: July 17, 2001
PROJECT: Kensington Runestone Investigation

SAMPLE ID: KRS
PHOTO # 3
MAGNIFICATION: None

SAMPLE DESCRIPTION: Overall view of the glacial face side of the stone. Notice the white, sub-parallel undulating lineations that each branch off. At first glance, they appear to be bleached areas from prolonged root contact.

SAMPLE ID: KRS
PHOTO # 4
MAGNIFICATION: None

SAMPLE DESCRIPTION: Overall view of the glacial side of the stone.

APS# 10-01120 DATE: July 17, 2001
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SAMPLE ID: KRS
PHOTO # 5
MAGNIFICATION: None

SAMPLE DESCRIPTION: Overall view of the glacial top end of the stone.

SAMPLE ID: KRS
PHOTO # 6
MAGNIFICATION: None

SAMPLE DESCRIPTION: Overall view of the glacial bottom end with white secondary calcite deposits intermittently scattered on the surface.

APS# 10-01120 DATE: July 17, 2001
PROJECT: Kensington Runestone Investigation

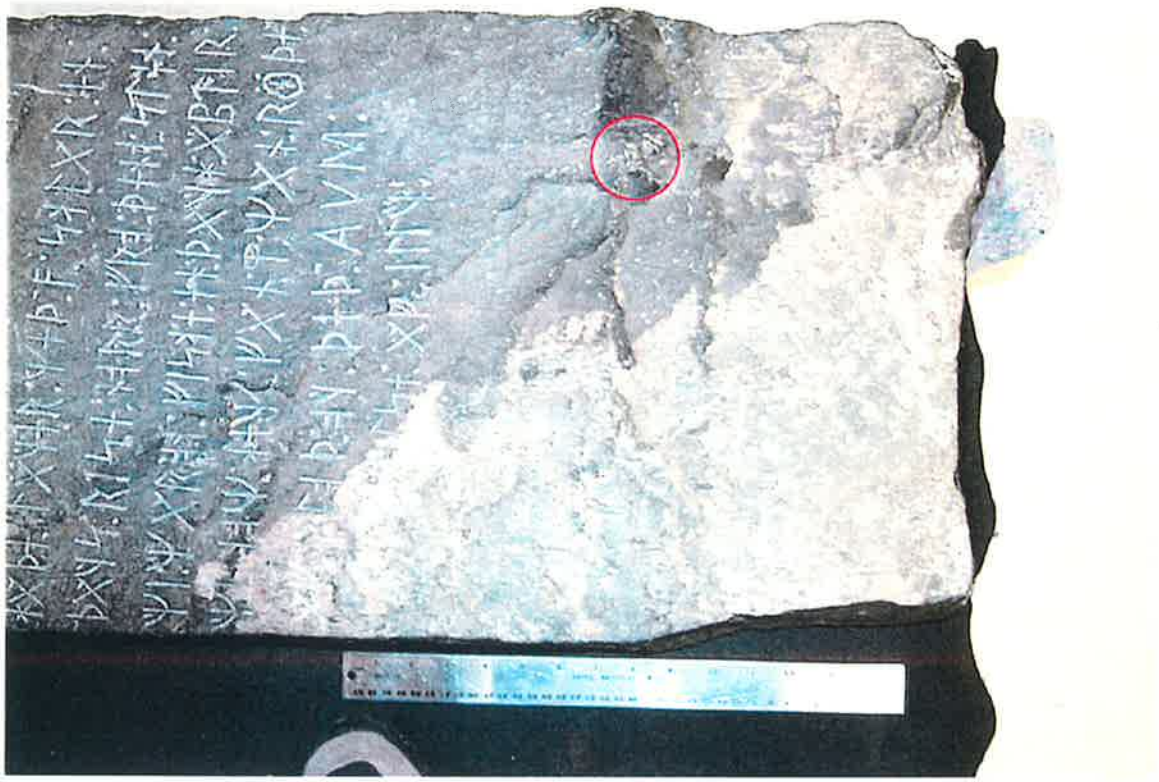
SAMPLE ID: KRS
PHOTO # 7
MAGNIFICATION: None

SAMPLE DESCRIPTION: Yellowish-white calcite coatings developed on the glacial bottom end after glacial deposition prior to the original dressing and carving of the stone.

SAMPLE ID: KRS
PHOTO # 8
MAGNIFICATION: None

SAMPLE DESCRIPTION: Relatively thick calcite coatings on the glacial bottom end side of the stone.

APS# 10-01120 DATE: July 17, 2001
PROJECT: Kensington Runestone Investigation



SAMPLE ID: KRS
PHOTO # 9
MAGNIFICATION: None

SAMPLE DESCRIPTION: White, triangular shaped hydrothermal calcite vein filling on the glacial face side. Elongate chlorite crystals are alinged roughly parallel to the long axis of the stone. Circled area is the likely source of N. H Winchell thin section sample.

SAMPLE ID: KRS
PHOTO # 10
MAGNIFICATION: None

SAMPLE DESCRIPTION: Low angle light highlights three distinct, parallel fracture planes that run at roughly a 15-degree angle to the bottom end of the KRS. The entire face of the stone has a lack of glacial striations. Two, clear cleavage/fracture planes comprise this side of the stone.

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SAMPLE ID: KRS Glacial Back Side
PHOTO # 11
MAGNIFICATION: None

SAMPLE DESCRIPTION: Low angle light highlights sub-parallel alinged, relatively deep (up to 3mm) glacial striations. Circular hole is where core sample was taken.

SAMPLE ID: KRS Glacial Back Side
PHOTO # 12
MAGNIFICATION: None

SAMPLE DESCRIPTION: Glacial striations at a lower angle view.

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SAMPLE ID: KRS W-8, R-42
PHOTO # 13
MAGNIFICATION: 3.75x

SAMPLE DESCRIPTION: Dark gray flaked areas adjacent to white, retooled areas represent surfaces that were made at the time of the original carving of the runeforms.

SAMPLE ID: KRS W-7, R-35
PHOTO # 14
MAGNIFICATION: 3.75x

SAMPLE DESCRIPTION: Dark gray flaked areas exhibit similar color, texture and weathering as other surfaces made at the time of the original carvings. Retooled did not affect these areas.

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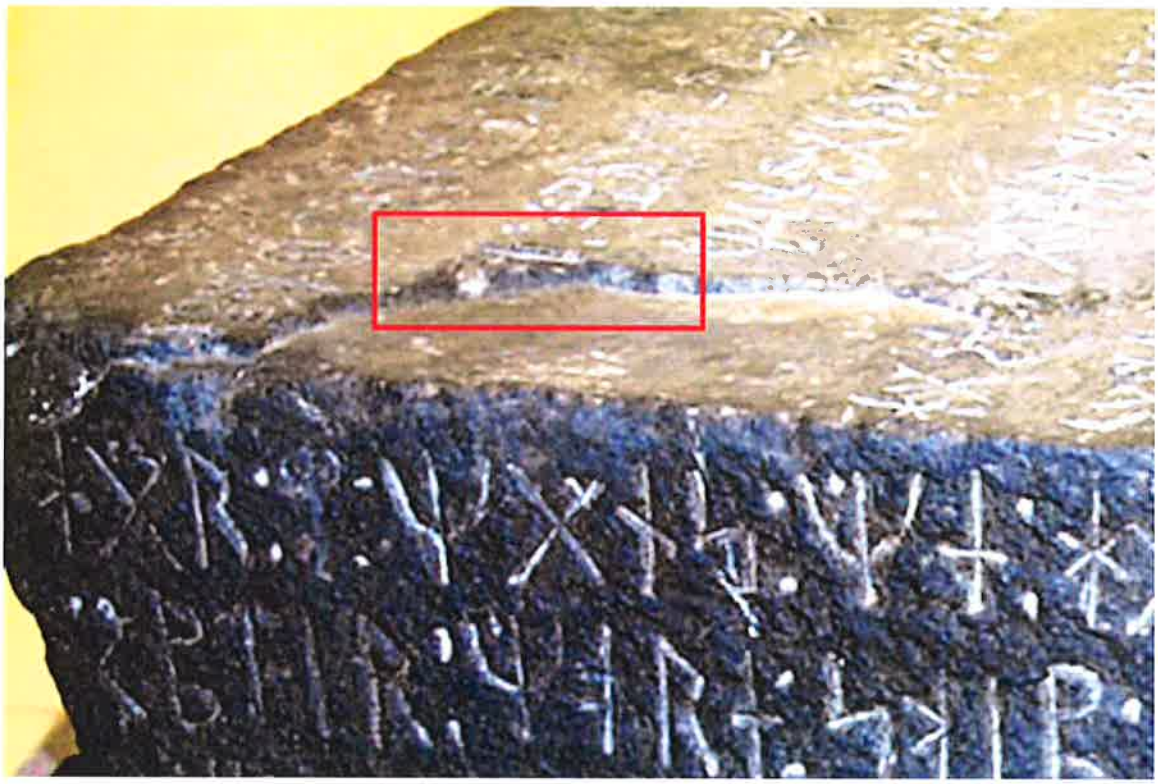

SAMPLE ID: KRS "Oh Shoot" Area
PHOTO # 15
MAGNIFICATION: None

SAMPLE DESCRIPTION: Vertical fracture face where part of the stone chipped off along a cleavage plane on the glacial face side during the original carving of the stone.

SAMPLE ID: KRS Original Carving Area
PHOTO # 16
MAGNIFICATION: None

SAMPLE DESCRIPTION: Area on the split side that appears to have been very lightly retooled or not at all. is outlined in blue, the letters have been retooled.

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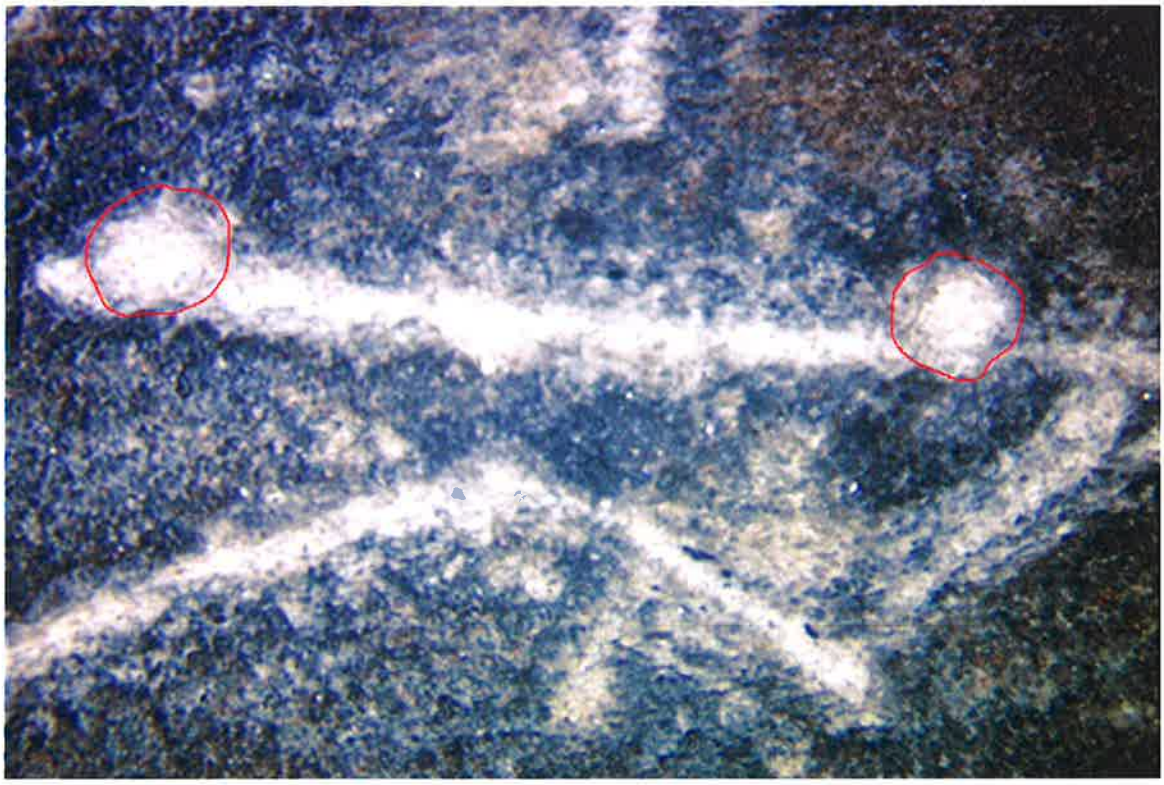
SAMPLE ID: KRS Split Side
PHOTO # 17
MAGNIFICATION: None

SAMPLE DESCRIPTION: Date at the end of the inscription (1362).



SAMPLE ID: KRS W-13, R-60
PHOTO # 18
MAGNIFICATION: 7.5x

SAMPLE DESCRIPTION: Two, round, punch chisel marks (circled in red), probably used as a word separator is over-written by the runic letter "R."

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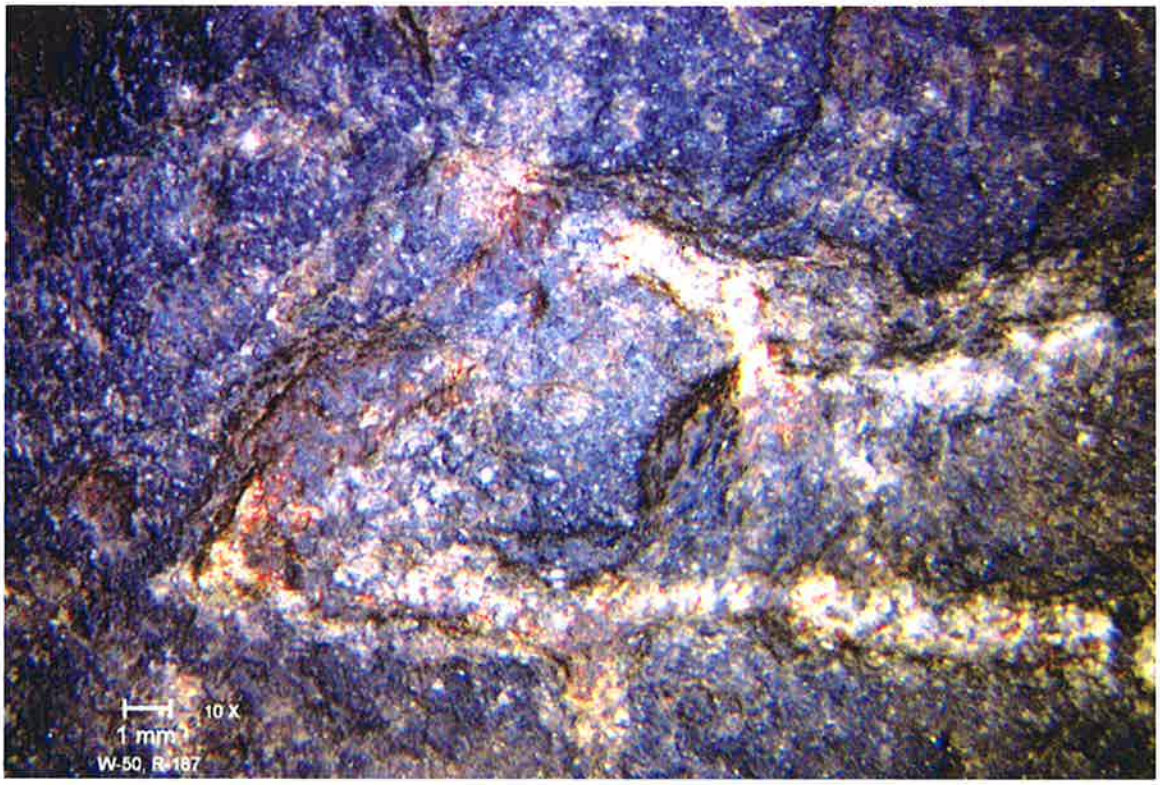
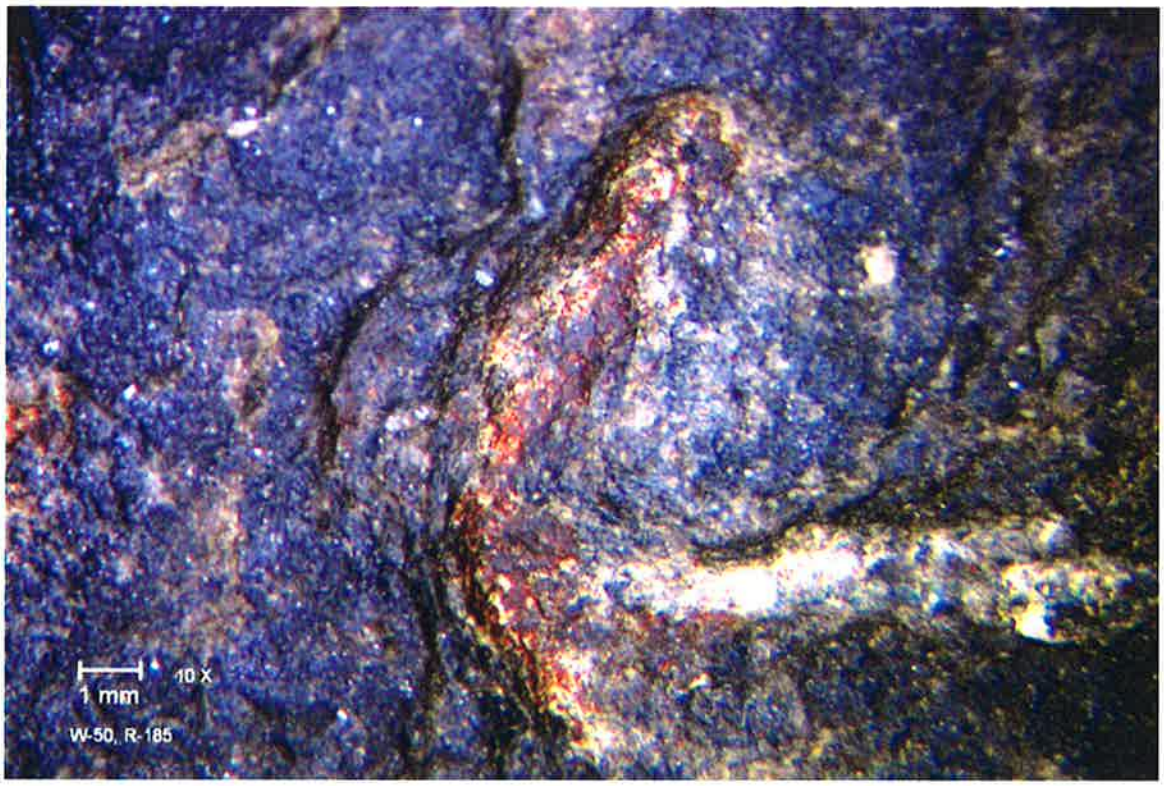


SAMPLE ID: KRS W-50, R-187
PHOTO # 19
MAGNIFICATION: 10x

SAMPLE DESCRIPTION: Iron oxide deposits in the original carved area of runeform in the upper left. Light colored areas in runeform are retooled areas.



SAMPLE ID: KRS W-50, R-185
PHOTO # 20
MAGNIFICATION: 10x

SAMPLE DESCRIPTION: Well developed iron oxide deposits in bottom of original carved runeform surface.

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SAMPLE ID: KRS W-45, R-162
PHOTO # 21
MAGNIFICATION: 10x

SAMPLE DESCRIPTION: White area that clearly cuts through adjacent, well developed iron oxide deposits indicating retooling occurred after original carving and weathering of the runeform.

SAMPLE ID: KRS W-45, R-162
PHOTO # 22
MAGNIFICATION: 20x

SAMPLE DESCRIPTION: Closer view of above photo.

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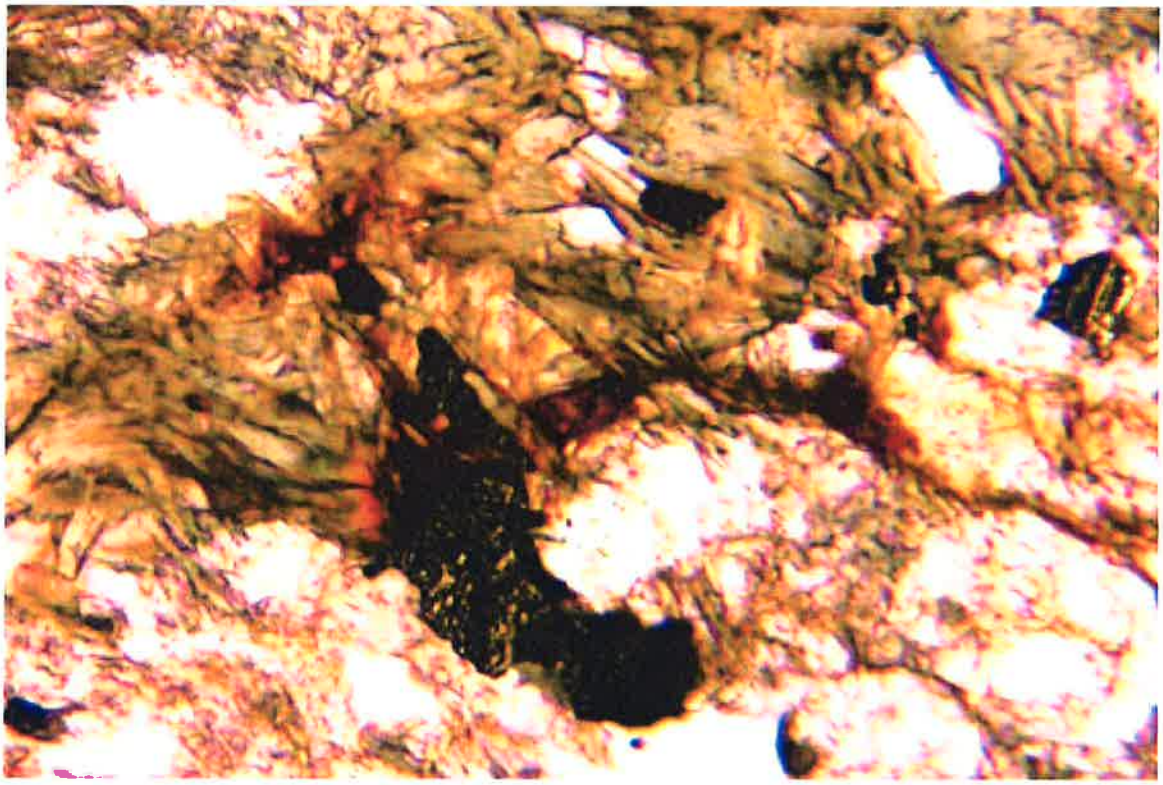
SAMPLE ID: KRS Glacial Surface
PHOTO # 23
MAGNIFICATION: 56x

SAMPLE DESCRIPTION: Two weathered out pyrite crystals with iron-oxide deposits, or oxidation halos (red arrows) under reflected light.



SAMPLE ID: Core Thin Section at 1/2" Depth
PHOTO # 24
MAGNIFICATION: 100x

SAMPLE DESCRIPTION: Reddish-brown colored iron-oxide deposits developing from brassy-gold colored pyrite crystals along a weathering fracture under plane polarized light.

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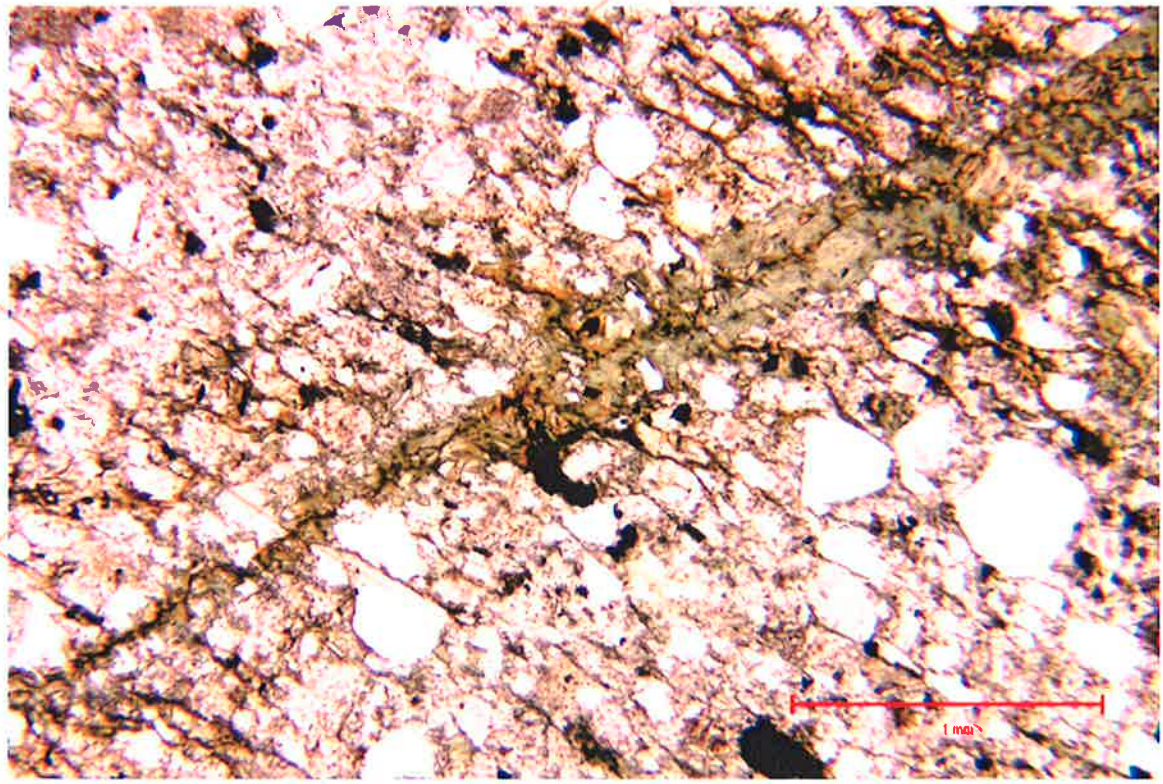
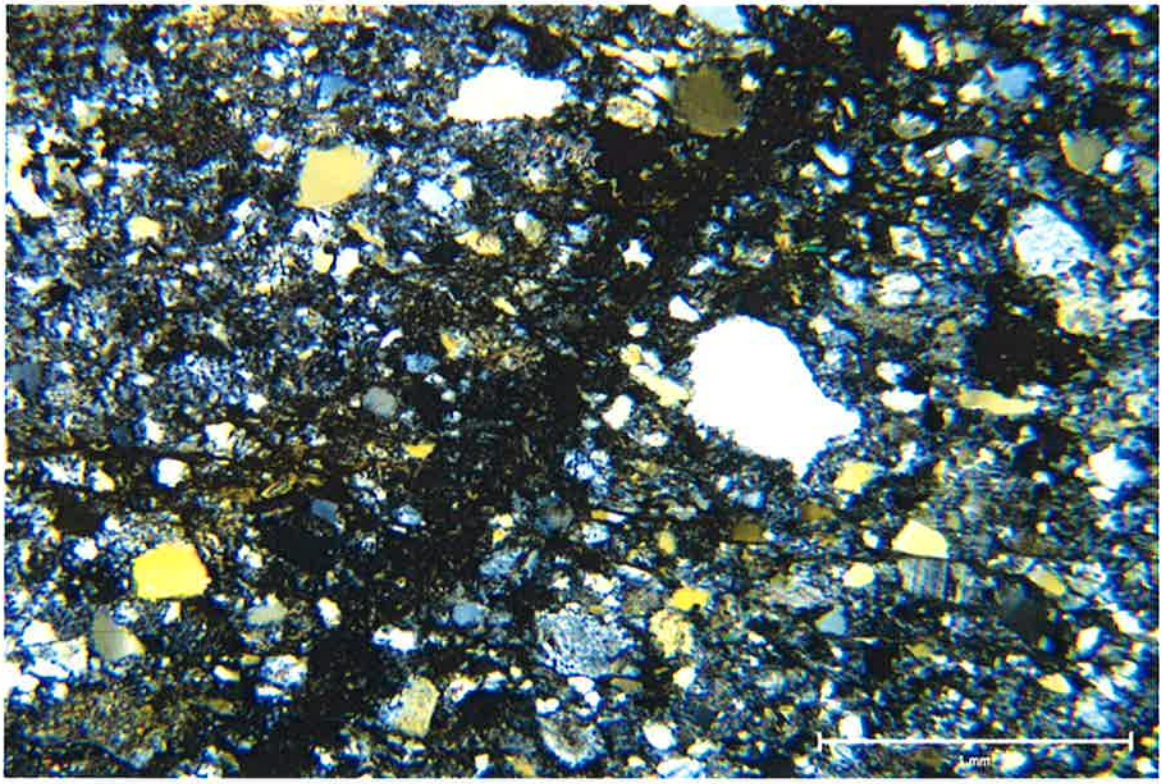


SAMPLE ID: Core Thin Section at 1/2" Depth
PHOTO # 25
MAGNIFICATION: 40x

SAMPLE DESCRIPTION: A weathered fracture plane cutting across relect bedding or a foliation at roughly a 50 degree angle under plane polarized light. Notice the mostly sub-angular to angular sand grains.



SAMPLE ID: Core Thin Section at 1/2" Depth
PHOTO # 26
MAGNIFICATION: 40x

SAMPLE DESCRIPTION: Same area as above photo under cross polarized light. Notice elongate sand grains aligned roughly parallel to the relict bedding or foliation.

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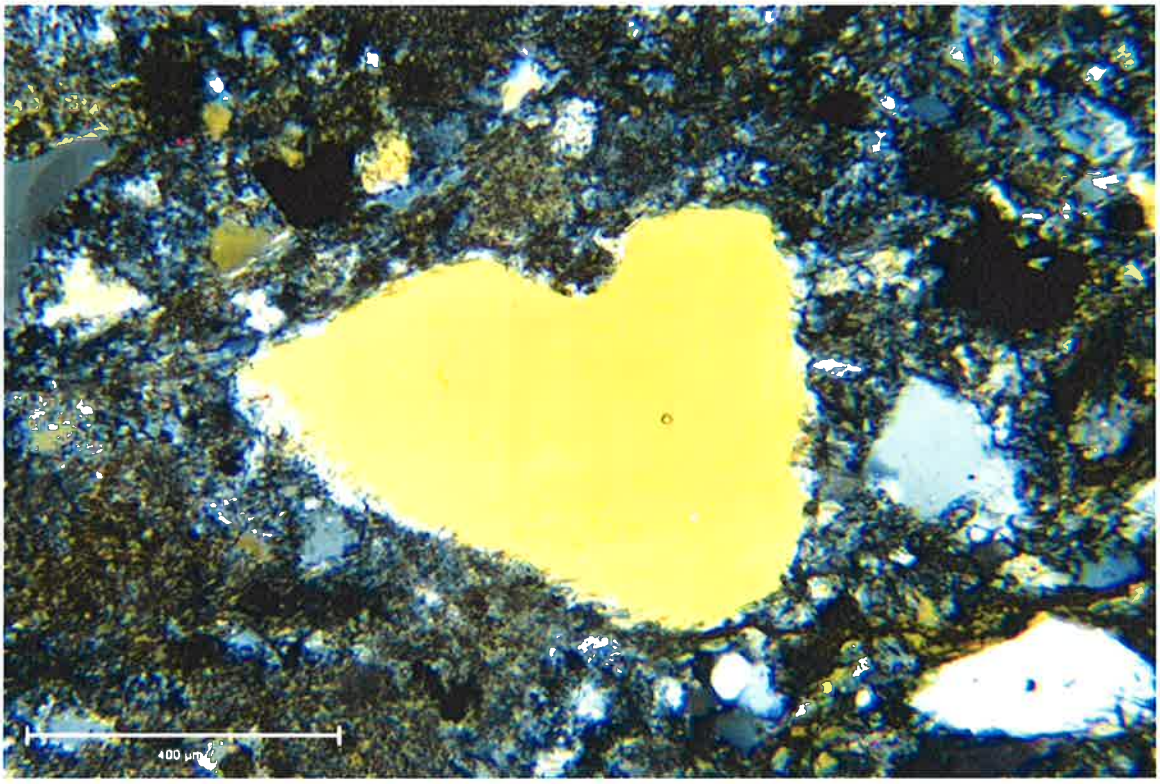
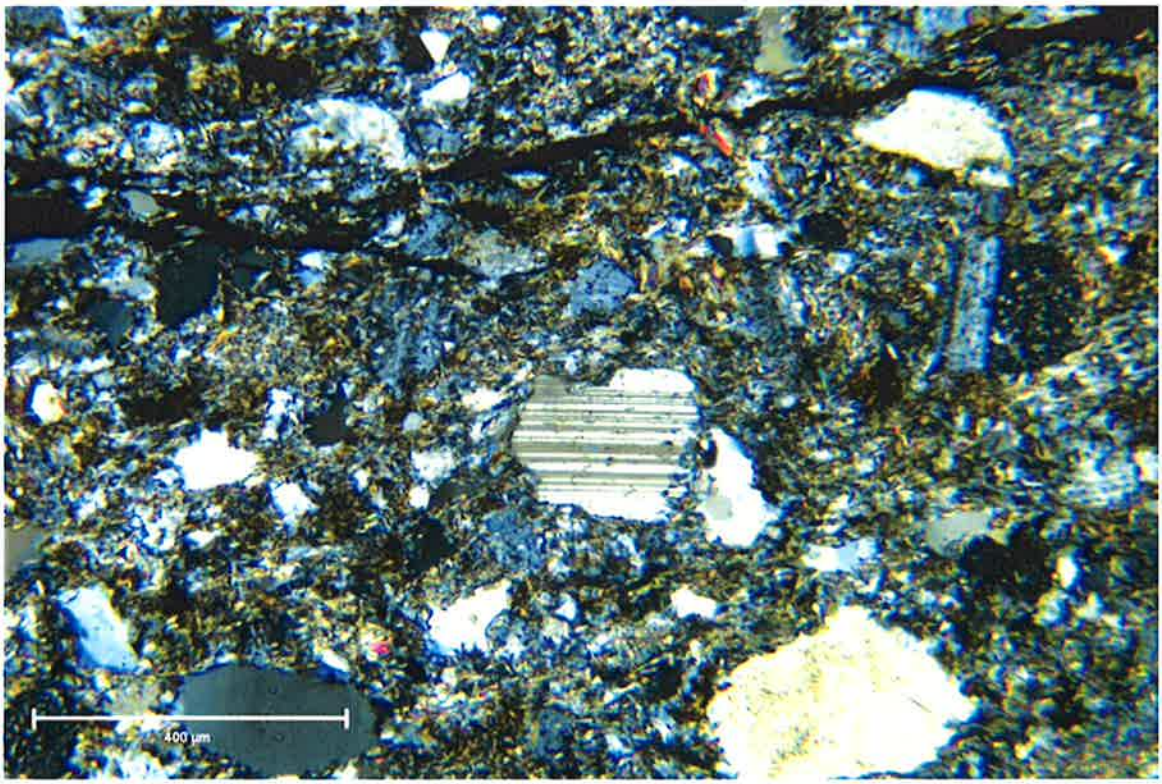


SAMPLE ID: Core Section at 1/2" Depth
PHOTO # 27
MAGNIFICATION: 100x

SAMPLE DESCRIPTION: Sub-rounded quartz sand particle surrounded by fine-grained sericite and other micas under cross polarized light.



SAMPLE ID: Core Section at 1/2" Depth
PHOTO # 28
MAGNIFICATION: 100x

SAMPLE DESCRIPTION: Sub-angular plagioclase feldspar sand particle with diagnostic albite twinning under cross polarized light.

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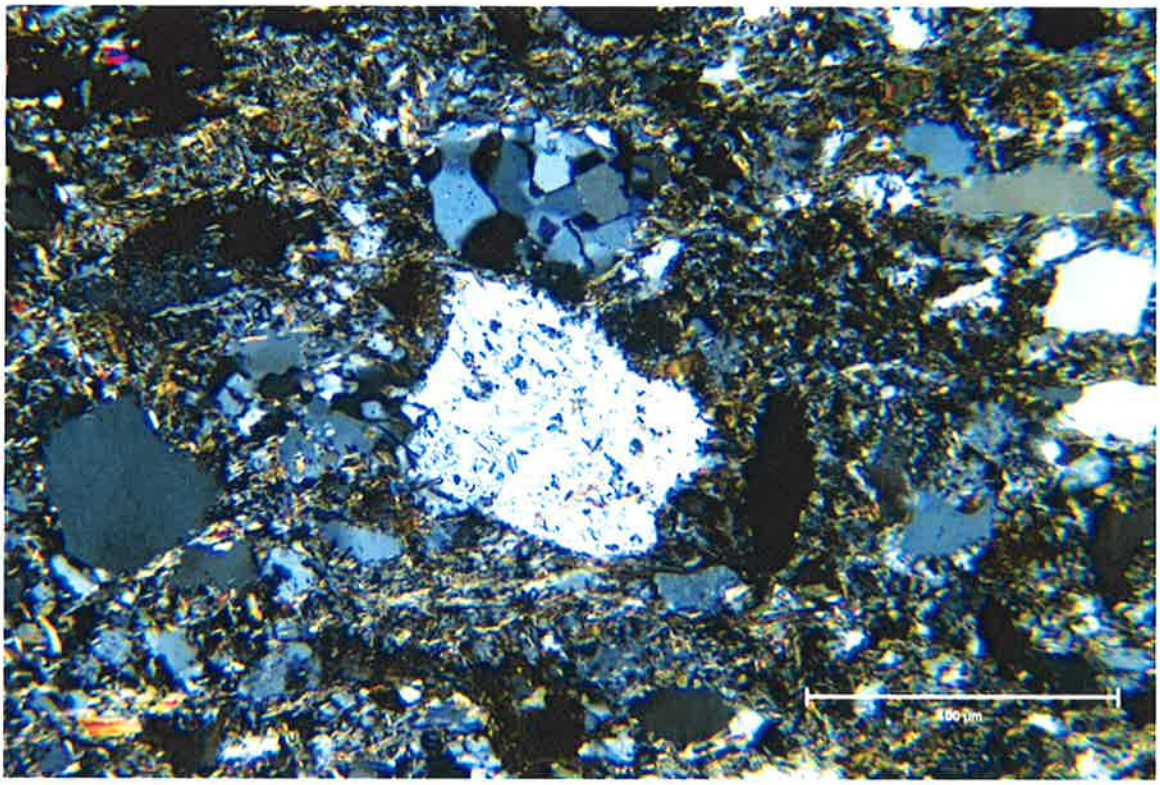
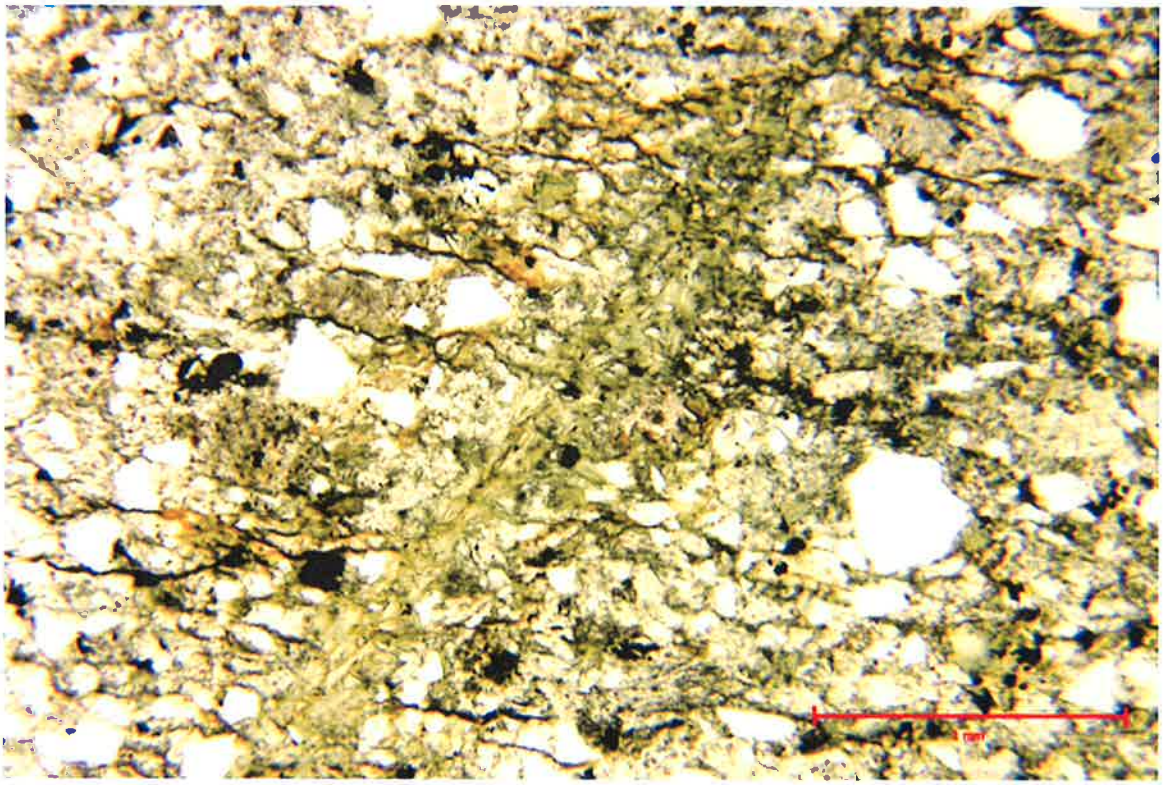


SAMPLE ID: Core Section at 1/2" Depth
PHOTO # 29
MAGNIFICATION: 100x

SAMPLE DESCRIPTION: Moderately weathered sub-angular orthoclase sand grain under cross polarized light.



SAMPLE ID: Core Section at 1/2" Depth
PHOTO # 30
MAGNIFICATION: 40x

SAMPLE DESCRIPTION: Light green colored chlorite mica within a weathered fracture under plane polarized light.

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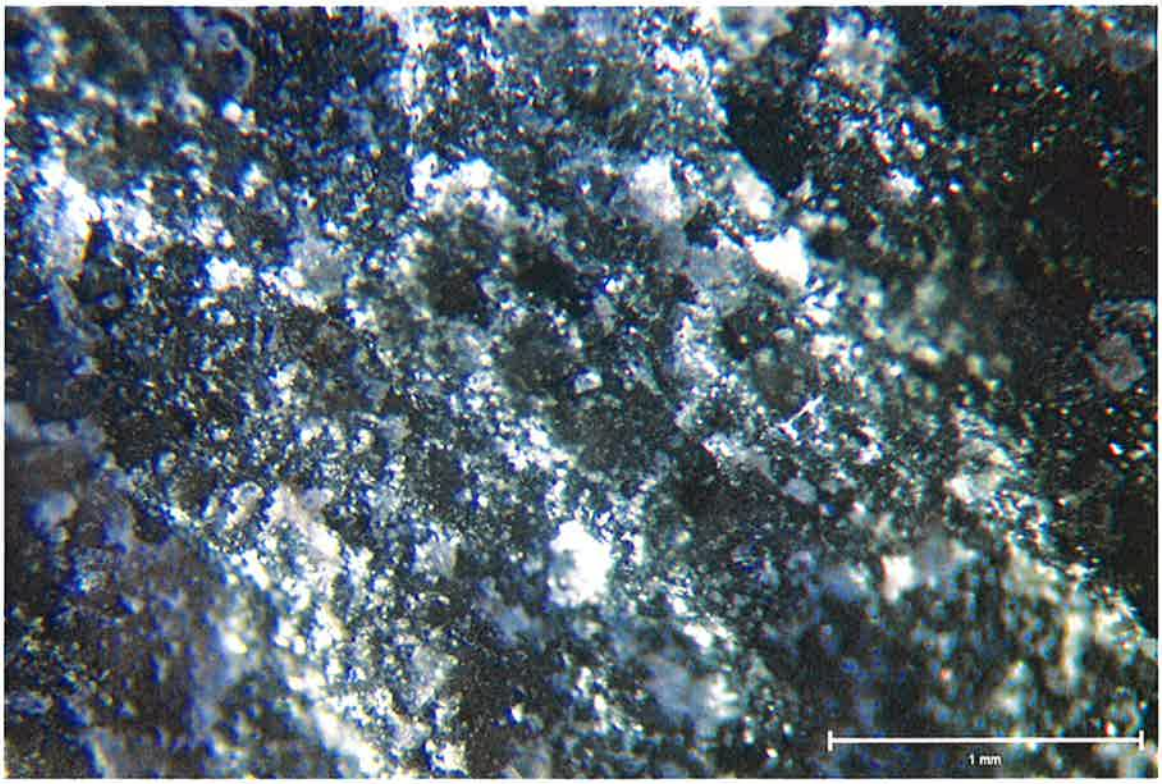
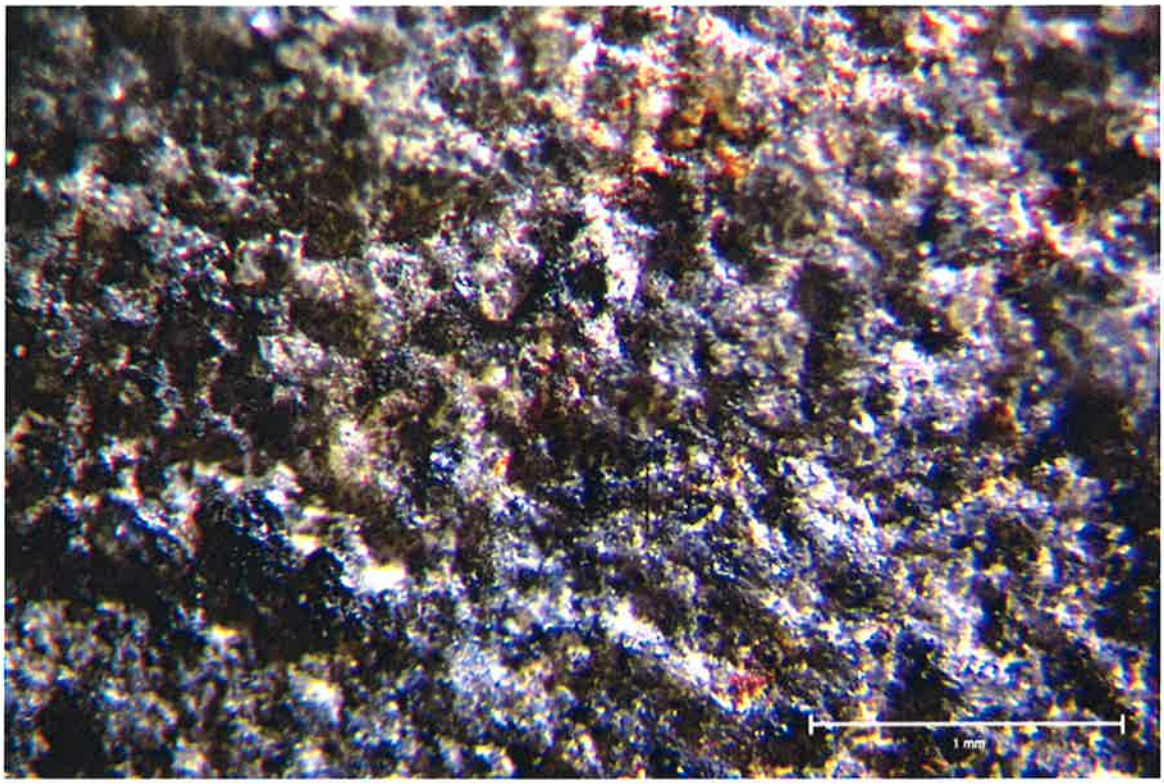


SAMPLE ID: Core Sample
PHOTO # 31
MAGNIFICATION: 50x

SAMPLE DESCRIPTION: Freshly fracured bottom surface of the core sample under reflected light.



SAMPLE ID: Core Sample
PHOTO # 32
MAGNIFICATION: 50x

SAMPLE DESCRIPTION: Highly weathered glacial top surface of the core sample under reflected light. Notice the irregular pitted surface developed over a period of at least 10,000 to 12,000 years.

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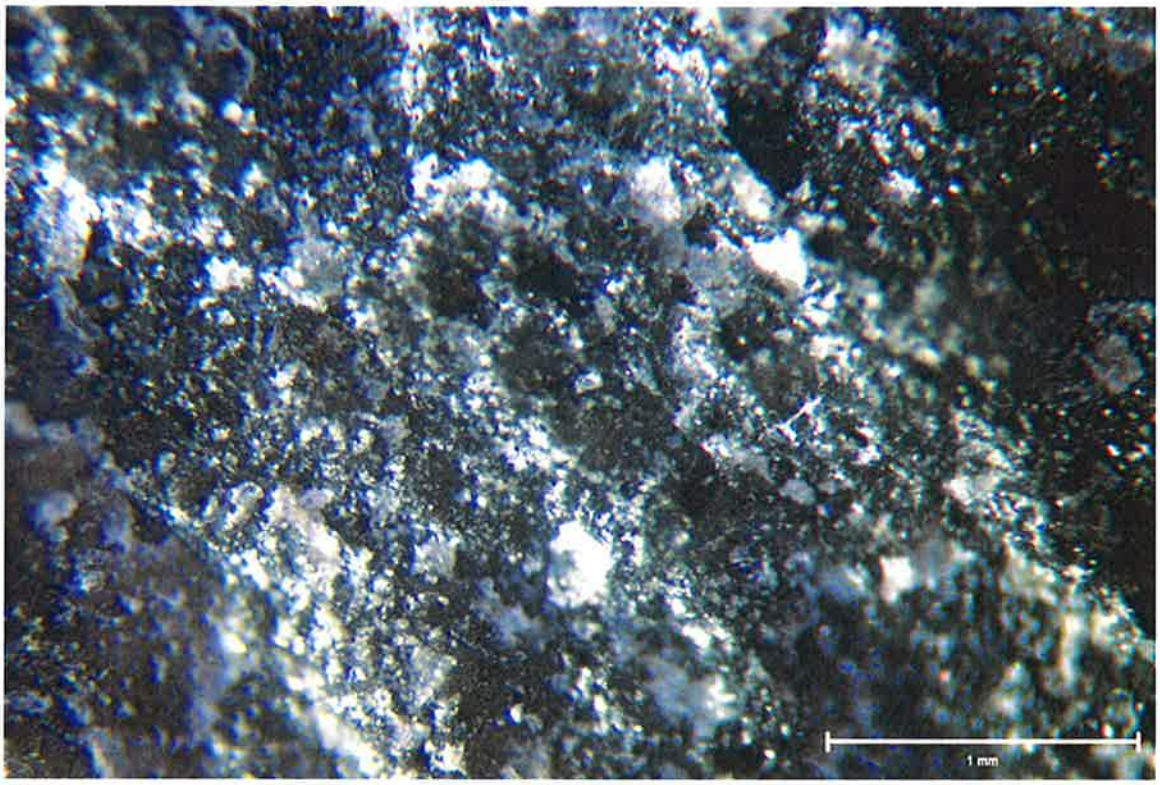
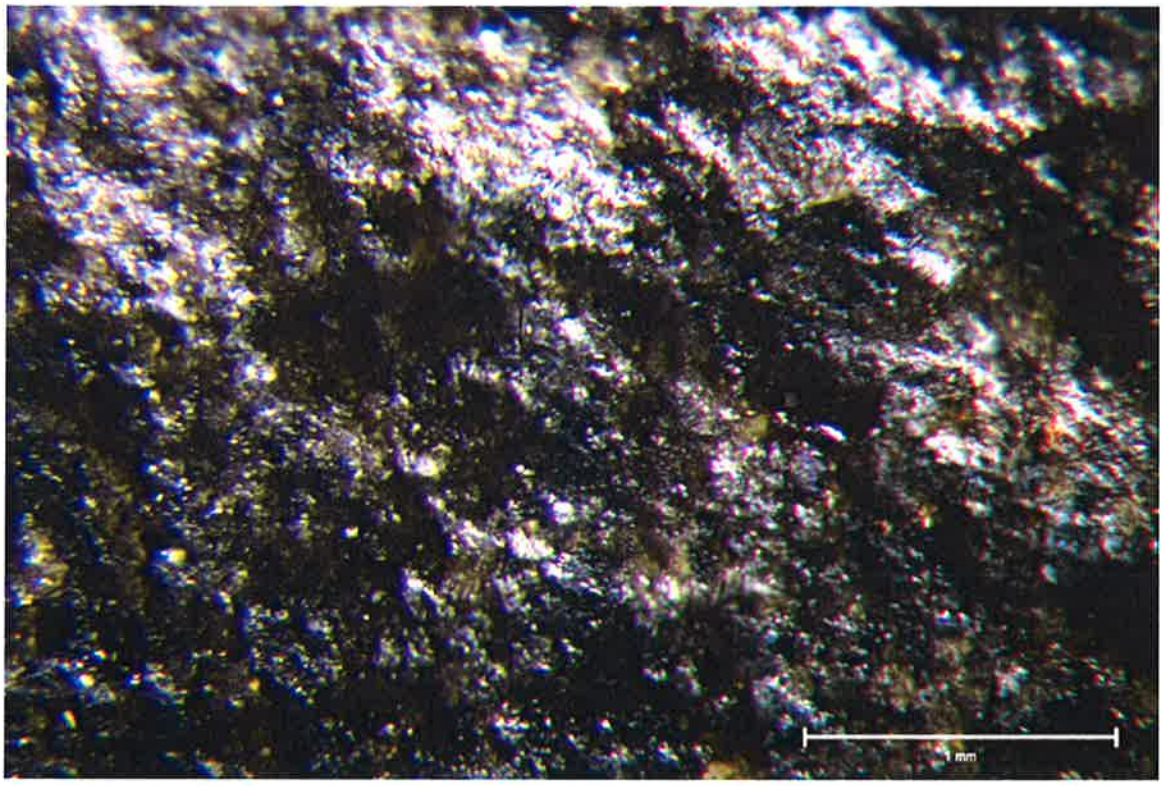


SAMPLE ID: Core Sample
PHOTO # 33
MAGNIFICATION: 50x

SAMPLE DESCRIPTION: Freshly fractured bottom surface of the core sample under reflected light.



SAMPLE ID: KRS Split Side
PHOTO # 34
MAGNIFICATION: 50x

SAMPLE DESCRIPTION: Significantly weathered surface of the split side of the KRS which was made at the time of the original carving.

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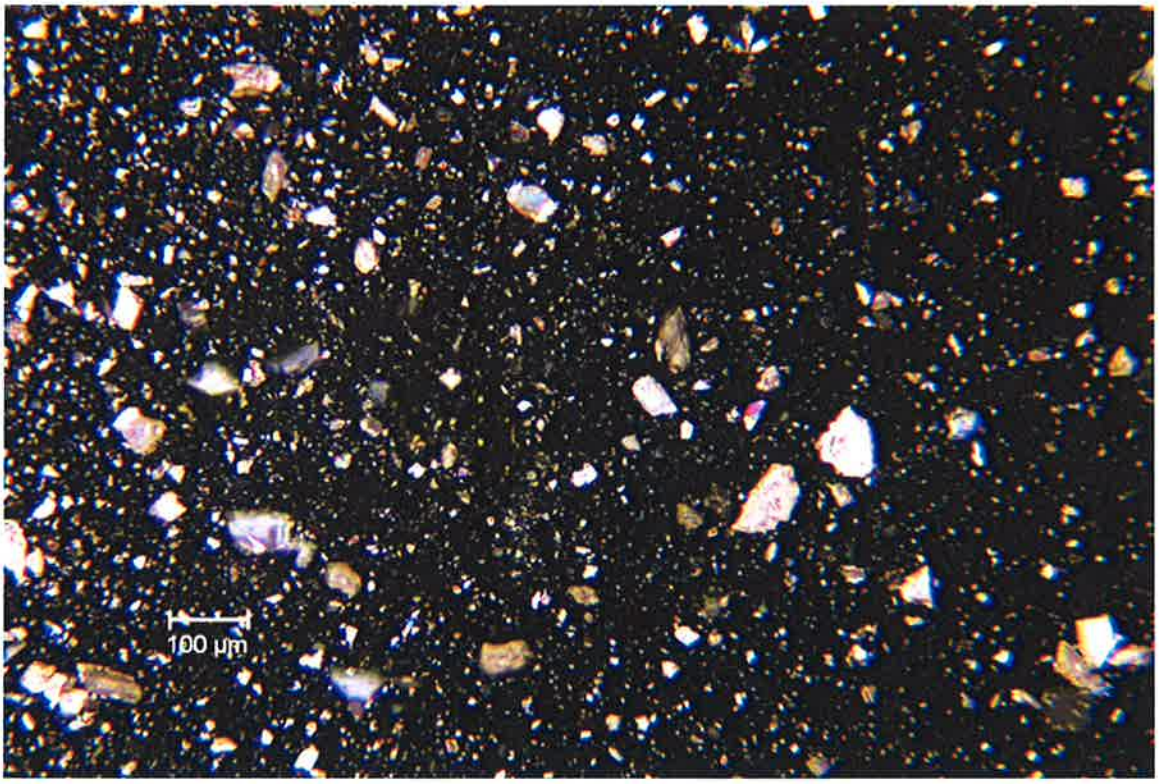
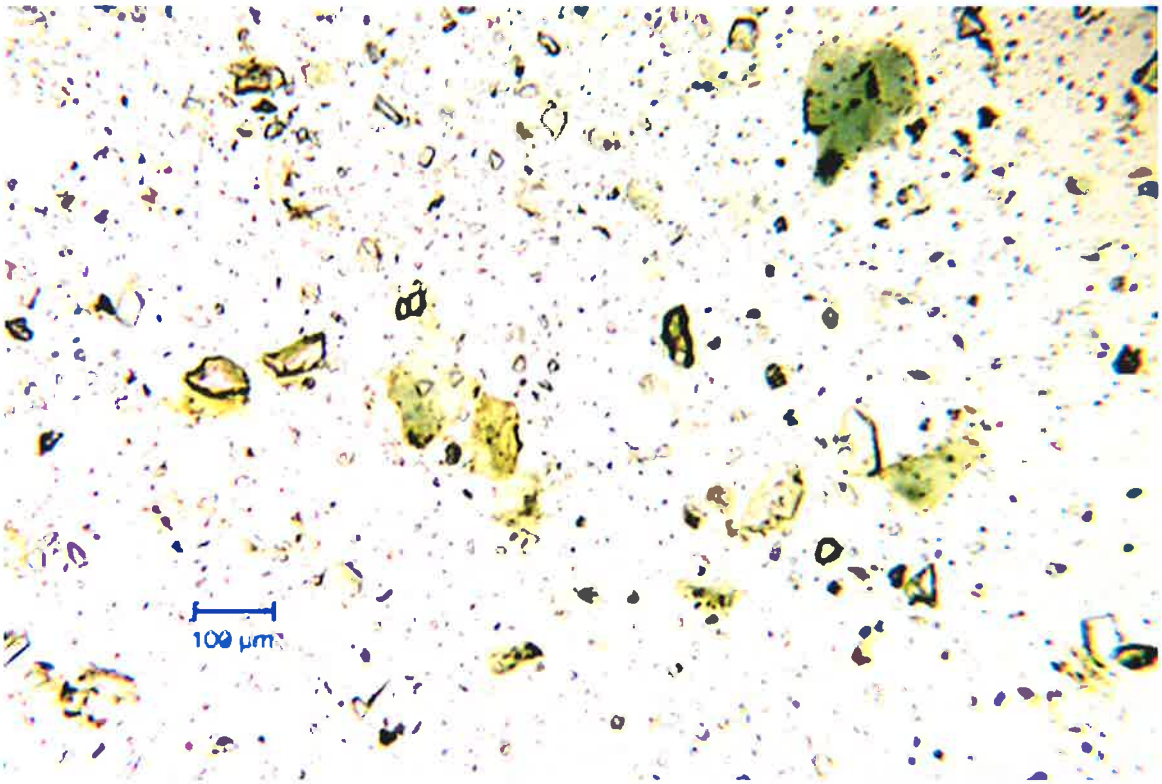


SAMPLE ID: Vein Calcite Off "Face" Side
PHOTO # 35
MAGNIFICATION: 100X

SAMPLE DESCRIPTION: Coarsely crystalline calcite particles from a scraping which is consistent with hydrothermally deposited calcite under cross polarized light.



SAMPLE ID: Vein Calcite Off "Face" Side
PHOTO # 36
MAGNIFICATION: 100X

SAMPLE DESCRIPTION: Same photo as above under plane polarized light.

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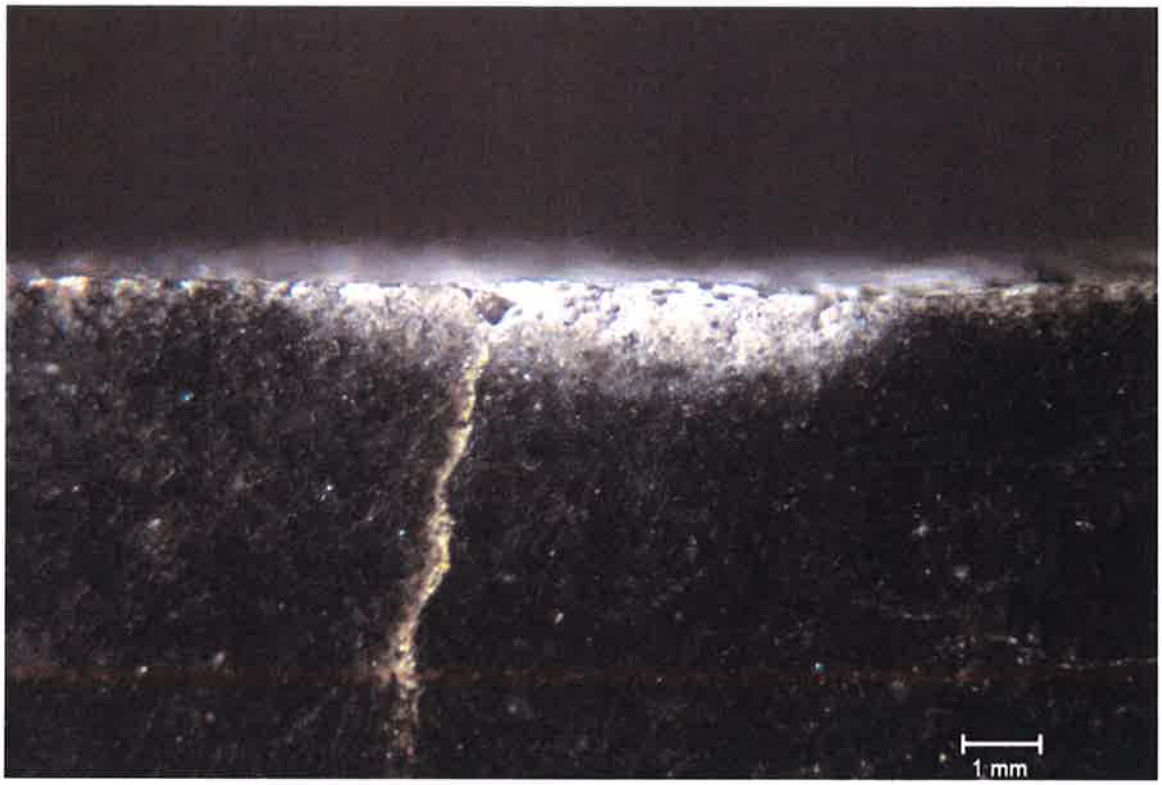
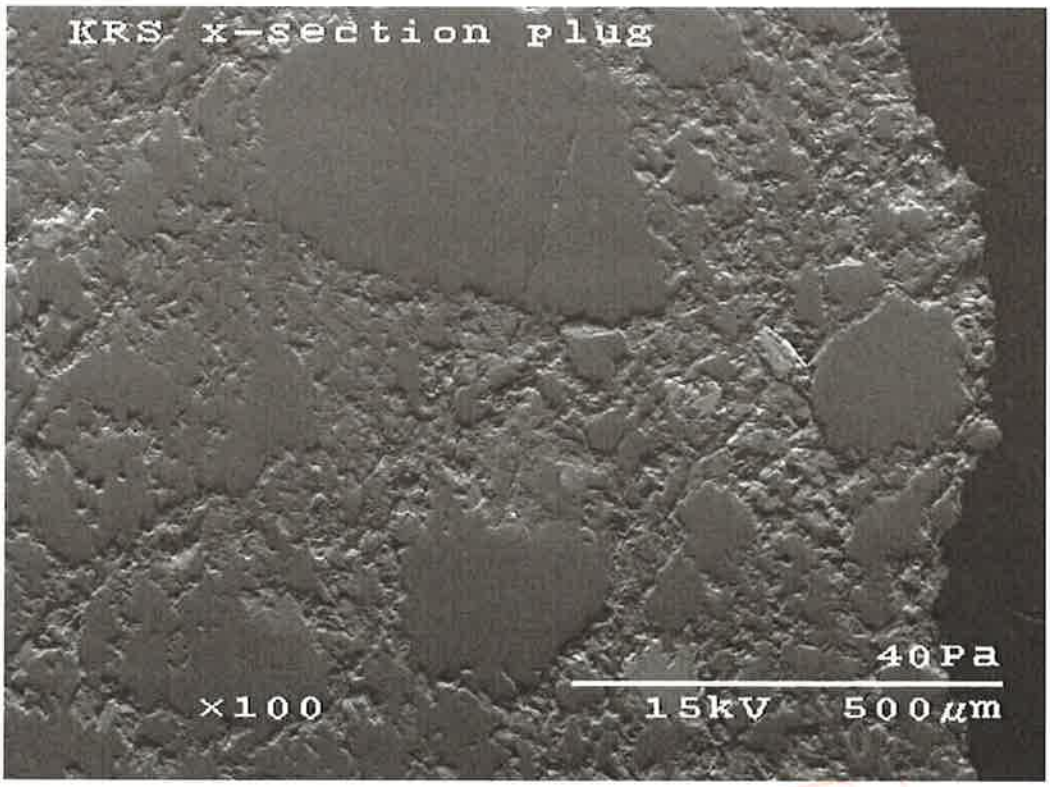


SAMPLE ID: KRS Core Puck Cross-Section under Relfected Light
PHOTO # 37
MAGNIFICATION: 10x

SAMPLE DESCRIPTION: White, apparent root leaching zone to a maximum depth of 1.5mm.



SAMPLE ID: KRS Core Puck Cross-Section Under SEM
PHOTO # 38
MAGNIFICATION: 100x

SAMPLE DESCRIPTION: Under-cutting of degraded matrix minerals (micas) in zone of apparent root leaching to a maximum of 1.5mm depth. Top of core at right.

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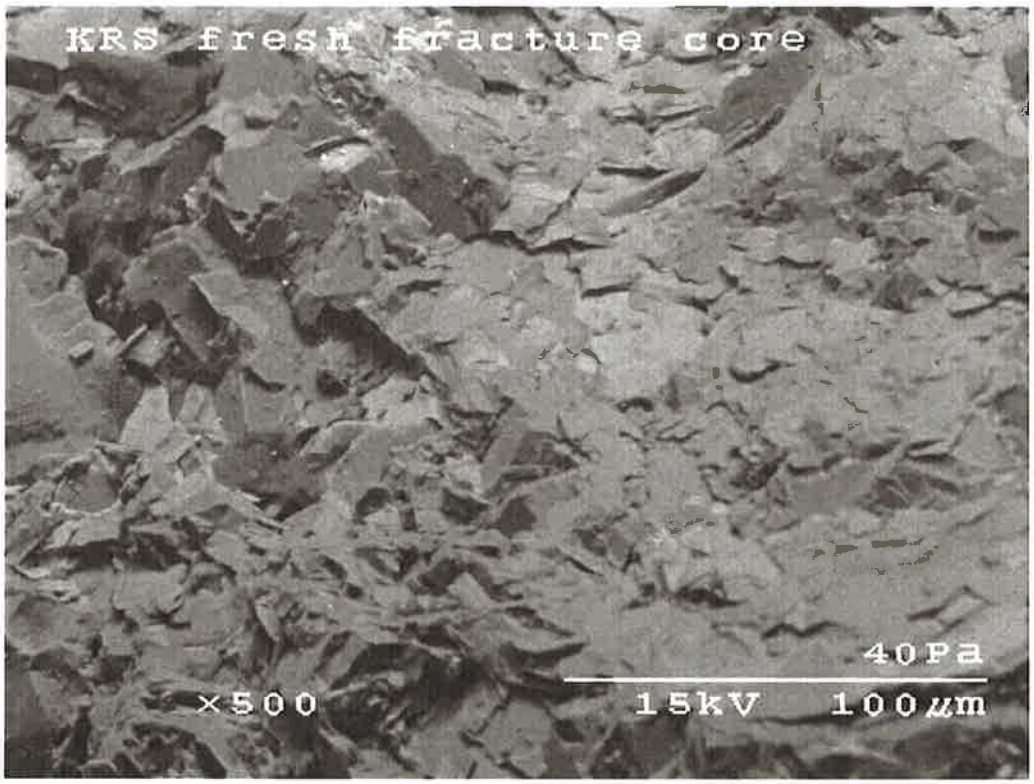
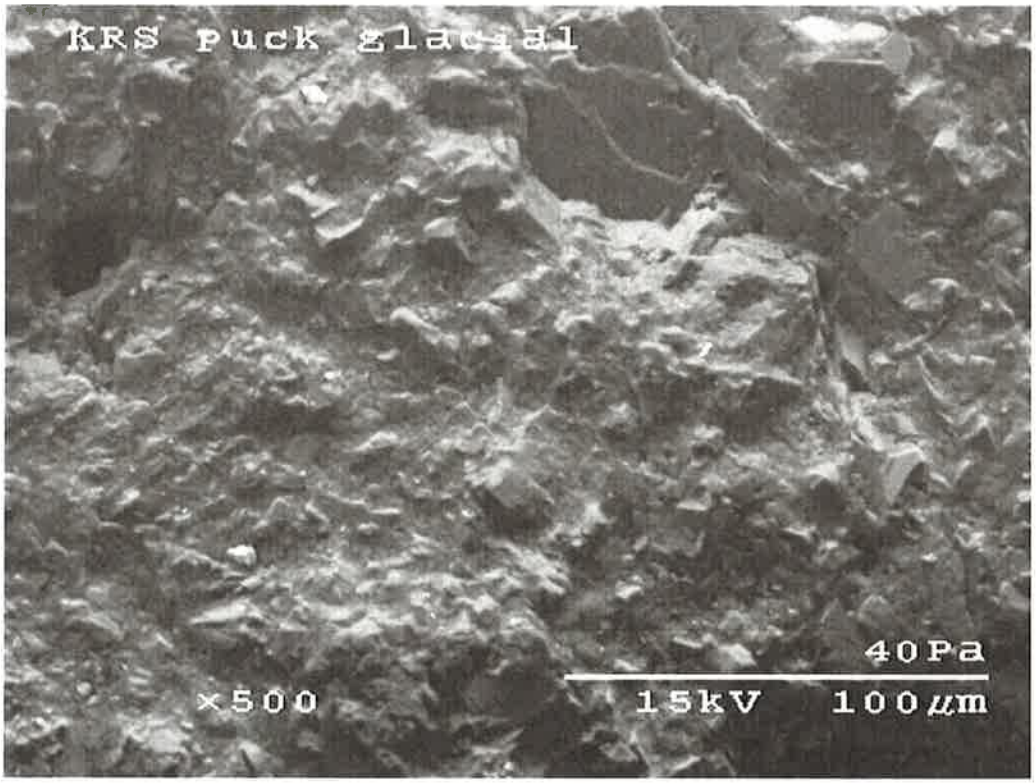


SAMPLE ID: Core Bottom Surface Under SEM
PHOTO # 39
MAGNIFICATION: 500x

SAMPLE DESCRIPTION: Sharp, well-defined mineral grains (mostly micas including biotie, muscovite and chlorite) along a freshly fractured surface.



SAMPLE ID: Core Top Surface Under SEM
PHOTO # 40
MAGNIFICATION: 500x

SAMPLE DESCRIPTION: Highly weathered "glacial" surface with a lack of mica minerals that have decomposed to clay minerals. Protruding minerals are angular quartz and feldspars grains.

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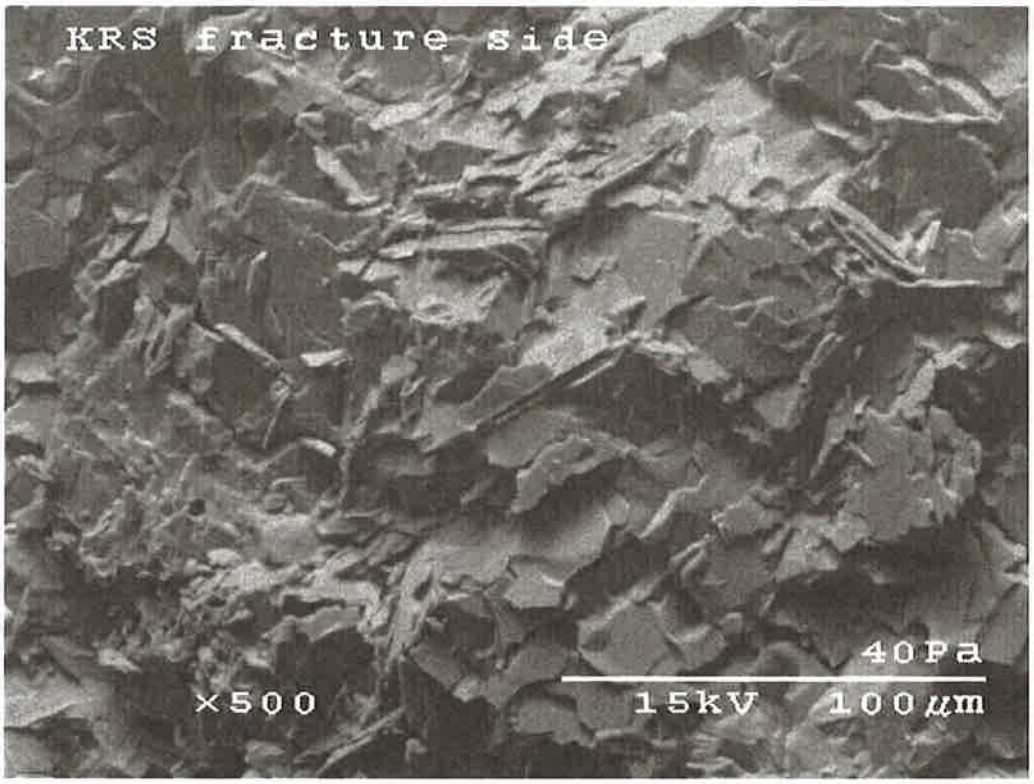
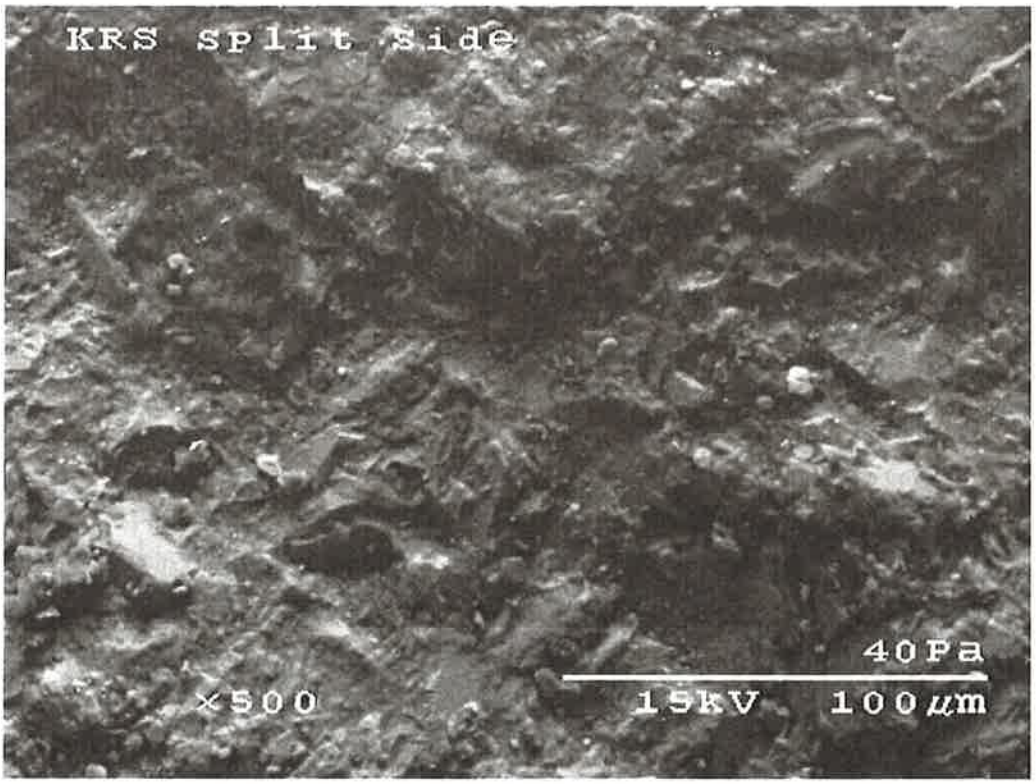


SAMPLE ID: Core Bottom Surface Under SEM
PHOTO# 41
MAGNIFICATION: 500x

SAMPLE DESCRIPTION: Sharp, well-defined mineral grains (mostly micas including biotite, muscovite and chlorite) along a freshly fractured surface.



SAMPLE ID: Split Side Chip Sample Under SEM
PHOTO # 42
MAGNIFICATION: 500x

SAMPLE DESCRIPTION: Highly weathered that appears nearly identical to the "glacial" surface with decomposed micas and protruding quartz and feldspar grains. Relatively slow weathering micas are virtually gone.

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SAMPLE ID: KRS Coring on October 3, 2000
PHOTO # 43
MAGNIFICATION: None

SAMPLE DESCRIPTION: Area where core was taken that included branching lineation and apparent bedding or fracture plane.

SAMPLE ID: KRS Coring on October 3, 2000
PHOTO # 44
MAGNIFICATION: None

SAMPLE DESCRIPTION: Positioning of core barrel.

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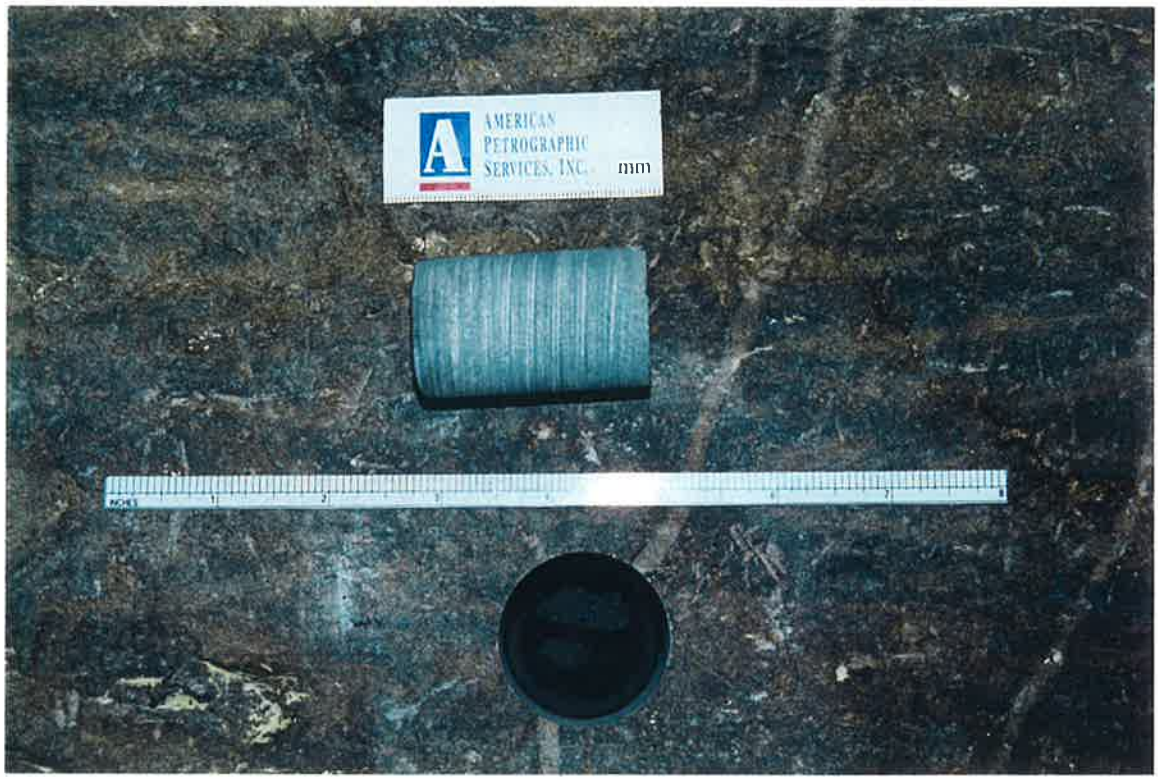
SAMPLE ID: KRS Coring on October 3, 2000
PHOTO # 49
MAGNIFICATION: None

SAMPLE DESCRIPTION: Top view of fractured end of core sample.



SAMPLE ID: KRS Coring on October 3, 2000
PHOTO # 50
MAGNIFICATION: None

SAMPLE DESCRIPTION: Side view of core sample. Lines are due to the rotating drill bit.

AMERICAN PETROGRAPHIC SERVICES, INC.

JCG comments

PROJECT:

KENSINGTON RUNESTONE

INVESTIGATION

REPORTED TO:

KENSINGTON RUNESTONE FOUNDATION
206 BROADWAY
ALEXANDRIA, MINN. 56308

ATTN: LuAnn Patton

APS JOB NO: 10-01120

DATE: January 4, 2001

Introduction

This report presents the results of laboratory work we performed on one stone slab artifact referred to as the "Kensington Runestone" or KRS. Our work was requested and authorized by Ms. LuAnn Patton of the Kensington Runestone Foundation on July 3, 2000. The scope of our work was limited to the following:

1. Performing petrographic observations to document physical aspects of the man-made carvings on the stone as well as on the stone itself.

2. Obtaining one rock core and one chip sample from the KRS.

3. Performing thin section analysis and scanning electron microscopy on the rock core and the chip sample.

4. Providing opinions, based on the geological aspects of the stone, regarding the relative age of the man-made features observed on the KRS.

5. Providing an opinion regarding the authenticity of the KRS and suggest recommendations for additional testing.

Background Information

The KRS was first unearthed by a Swedish farmer named Olof Ohman, who was grubbing trees on his land near Kensington, Minnesota on November 8, 1898. It was well documented by interviews with several witnesses, including Mr. Ohman's 10 year-old son, that the stone was entangled in the roots of a tree when it was pulled out of the ground. The original position of the main inscription or face side of the stone when it was found, was downward.

published in later?

The KRS is a tabular shaped stone weighing roughly 200 pounds, that was probably left as a memorial, and is dated 1362 A.D. Shortly after its discovery, the KRS was studied by many language experts from both the United States and Scandinavia. The stone contained a carved message that was written using Old Swedish language forms called runes. The message carved into the stone tells of the massacre of 10 people in an exploration party from Scandinavia. Many of the characters were unfamiliar to the language experts which led to their conclusion that it must be a forgery. The only expert to look at the KRS in a scientific way was N. H. Winchell in 1909-10. Mr. Winchell was a well respected geologist/archeologist who first described the geology of the stone. After his physical examination of the stone and investigation of the geological conditions and physical changes of the region where the KRS was found, he reached an opinion. He concluded that "The said stone is not a modern forgery and must be accepted as a genuine record of an exploration in Minnesota at the date stated in the inscription". His conclusion, as well as the conclusion of the Minnesota Historical Society, which was based largely on Professor Winchell's work, was that the Kensington Runestone was authentic. Extensive background information about the KRS can be obtained in the Minnesota Historical Society preliminary report published in 1915 (MHS Collections, Volume 15, 1915).

Much speculation about the authenticity of the KRS, pro and con, has been written and debated in the past 102 years. However, little scientific information has been published. Recent language studies of the KRS by Dr. Richard Nielsen, strongly supports it's authenticity. The KRS was brought to the American Petrographic Services Inc. (APS) laboratory in October of 2000 for the examination and testing.

Sample Identification

Sample Type	Original Sample Dimensions
KRS Stone Slab	Approx. 31" x 16" x 5 ½" thick
Rock Core (RC) *	1 $^{1}/_{4}$" diameter by 2" long
Rock Chip	Approx. ½" x $^{1}/_{4}$" x $^{1}/_{8}$" thick

* - The rock core was cut into five (5) separate samples including two (2) thin sections. One thin section was orientated parallel to, and the other perpendicular to, the glacial top surface of the core. The perpendicular thin section included a vertical profile of a white leached area observed on the glacial back and side surface (See photo # 3).

Test Results

Petrographic Observations

Description Of KRS Surfaces (Sides) - The stone is flat and elongate in shape with three distinct types of sides:

1. The face side exhibits weathering similar to the glacial sides, but has no obvious glacial striations. The face side contains the beginning of the man-made, carved inscription (See photo #1).

2. The entire split side was clearly man-made, or dressed, at the same time as the original carving of the message. The last part of the message is on this side. This surface exhibits weathering that appears much younger than the glacial and face sides (See photo # 2).

3. The glacial sides exhibit striations and weathering of at least 10,000 years, or weathering that commenced after glacial transport and deposition. These areas are referred to as the following (See photos # 3, 4, 5 & 6):

   a. Glacial back side
   b. Glacial side
   c. Glacial top end
   d. Glacial bottom end

General Geology - The KRS is a light to medium gray colored, meta-graywacke of probable Archean age (approximately 2.7 billion years). Archean age graywackes from Canadian Shield bedrock sources are commonly found in glacial deposits throughout much of Minnesota. The top face side of the stone contains a triangle-shaped, exposed hydrothermal calcite vein filling. The calcite vein is approximately 3 to 5 mm in thickness and exhibits a strong preferred orientation (sub-parallel to the long axis of the stone) of the medium to coarse sized (2-3 mm) calcite and chlorite minerals (See photos # 9, 35 & 36). The KRS also exhibits well developed joint fracture planes in at least three directions. These inherent fracture planes directly influenced the tabular shape of the stone.

Glacial Geology - The KRS is a portion of a previously larger glacial erratic. The glacial back side exhibits several, large and relatively deep striations running sub-parallel to the long axis of the stone. This length and depth of the striations suggest that they were produced at the base of a glacier moving over the stone while it was still a part of the bedrock (See photos #11 & 12). Additionally, many smaller (up to 3" in length) and shallower groups of striations were also observed on the glacial back side, that were orientated in various directions. This suggests the striations developed during transport within the ice. The face side exhibits weathering consistent with the glacial sides but does not have striations (See photo #10). This suggests the slab may have broken off from a larger erratic near the end of it's glacial transport, possibly from frost shattering.

Coatings - Roughly 10 to 15% of the glacial bottom end surface is covered with intermittent yellowish-white, secondary calcite coatings deposited after glacial deposition and before the man-made carvings (See photos # 6, 7 & 8).

Contemporaneous Weathering Surfaces- The KRS exhibits four distinct man-made fracture surface types that were made at the time the stone was originally carved.

1. The entire split side exhibits a surface that is devoid of evidence indicating glacial abrasion. This side is a darker bluish-gray color than the adjacent glacial surfaces. The edge of the split side which meets the glacial back side, has 6 to 7 pseudo-conchoidal fractures (approximately 2-4 cm) which appear related to purposeful impact. The previously larger, flat, original stone appears to have been reduced in size to it's present shape, prior to the original carving (See photo # 2).

2. During the original chiseling of the rune forms, low angle fractures or "flaking" occurred that are present immediately adjacent to many of the characters. These flaked areas are similar in color and texture to the previous described fracture surfaces associated with the original carvings (See photos #13 & 14). Subsequent retooling into the deepest part of the original grooves did not affect the flaked surfaces. The weathering on the flaked areas, where present, has remained intact.

3. In the upper left corner on the face side of the stone is a small ledge (approx. 1 cm) that was fractured off leaving a vertical fracture face with the same dark, blue-gray color and appearance as the entire split side. This surface, called the "Oh Shoot" area, is located where the second line of the message likely would begin. The second line of the message appears to have been restarted immediately to the right of this vertical fracture face (See photo #15).

4. Several rune forms on the glacial top end of the split side do not appear to have been retooled at all. The texture and appearance of these grooved surfaces match the entire weathered split side making the characters in this area harder to see (See photo #16).

Weathering Environment - Since the KRS was found shallowly buried in the ground, it is assumed the stone and it's inscription were exposed to a below grade weathering environment within 24" of the surface. Since it is unknown how long the KRS was buried, it is assumed that natural processes alone would have begun to bury the stone within a short period of time after it was set (probably upright) in the ground. The soil horizon in this zone would have experienced periodic fluctuations in moisture content due to precipitation. Additionally, the stone has been exposed to annual frost penetration but relatively few freezing and thawing cycles. The stone shows no apparent evidence of surface spalling or delaminations associated with freeze-thaw deterioration.

Apparent Root Leaching - Two, approximately 1 cm wide, roughly parallel, light tan colored, slightly undulating linear discoloration run across the glacial back and side surfaces of the stone. They look quite similar to tree roots. If this discoloration is associated with tree roots, a chemical leaching reaction appears to have occurred between the roots and mafic (magnesium and iron-rich) minerals in the stone, producing the discoloration. These suspected root leaching lineations are consistent with the stone reportedly being found with the inscription face side down, wrapped in the roots of a tree (See photo #3).

"H" Control - An "H" control letter (approx. 3 cm) was observed near the glacial bottom end of the split side (See photo # 2). The "H" does not appear to have undergone any observable weathering. It was reportedly chiseled into the stone in 1908, by one-time owner Mr. Hjalmar Holand.

Retooling - All of the original rune form grooves on the face side and 75% of the rune forms on the split side have been scratched on or completely retooled. The retooling on the face side appears to have been done with greater force than the split side. This retooling has removed alteration products from within the grooves and crushed the surface minerals. This has produced a white color that looks "fresh" at first glance. The date when the retooling occurred is unclear. However, close inspection of photographs taken of the KRS in March of 1899, appear to show retooling present at that time. The suggests the retooling occurred shortly after discovery, perhaps within days (See photos # 13 & 14). Retooling and scratching on the rune forms may have occurred multiple times over the years.

Gypsum Deposits - Initial observations revealed intermittent areas of very small (approx. 1 mm) white deposits on several surfaces including original rune form grooves on the split side. Powder mounts reviewed under polarized light at magnification up to 400X, indicated the material was comprised of gypsum. A number of plaster casts of the stone have been produced in the past (reportedly the 1930's). The gypsum deposits observed are believed to be remnants of the plaster.

Iron Oxide Deposits - Significant iron-oxide deposits were observed on several original groove surfaces and flaked areas adjacent to retooled grooves. The iron deposits are the by-product of the decomposition of pyrite from within the stone (See photos # 19, 20, 21, 22, 23 & 24). These deposits give the appearance of great age and may well have developed decades or centuries ago. However, because pyrite can oxidize very quickly, these deposits could also have developed a year or two after exposure.

Winchell Sampling Area - In the lower right area of the face side of the KRS is a number of obvious chisel marks. The timing of when these impacts occurred is unclear. However, professor Winchell states in 1909 *, that "I took a small flake from its lower end...". We assume that this flake was where a thin section was eventually made that he reviewed. This area appears to be the likely source of his sample (See photo # 9).

* - Minnesota Historical Society Collections Report on the Kensington Runestone, December 13, 1909.

Thin Section Analysis

Thin section analysis of a core sample reveals the KRS is a fine-grained, meta-sedimentary rock with a strong preferred orientation of very fine-grained mica minerals, that is consistent with a relatively low grade of metamorphism (greenschist facies). This well developed lineation represents either relict bedding planes, a metamorphic foliation or both (See photos # 25 & 26). The mineralogy consists of the following (See attached data sheet):

Mineral	Estimated Percentage
1. Quartz (See photo # 27)	30
2. Sericite (See photo # 27)	25
2. Chlorite (See photo # 30)	15-17
3. Orthoclase (See page # 29)	10
4. Pyrite (See page # 24)	5-7
5. Muscovite	5
5. Plagioclase (See page # 28)	3-5
7. Biotite	3
8. Poly-crystalline Quartz or Quartzite	1-2
9. Calcite	<1
Total	100

Scanning Electron Microscopy (SEM)

White Discoloration (Apparent Root Leaching) - SEM images were generated on the polished vertical profile of the top ½" portion of the core sample with the undulating, white discoloration. Images generated of the polished surface exhibit greater undercutting of the fine-grained mica matrix in the white areas suggesting the integrity of the minerals had been degraded by chemical reactions. This apparent root leaching was observed to a maximum depth of 1.5 mm (See photo # 38).

Weathering Surfaces - SEM images were also generated from three different surfaces of the stone to compare weathering characteristics of the fine-grained mica matrix. The three surfaces examined included the following:

1. The freshly fractured surface on the bottom of the core where it was broken off (See photos #31, 33, 39, 41 & 49).

2. The glacial back surface of the core that has experienced at least 10,000 years of weathering (See photos # 32 & 40).

3. The chip sample obtained from the split side of the stone that was first exposed at the time of the original carving and may represent as long as 500 years of weathering in the ground (See photos # 42 & 54).

The freshly fractured surface exhibited well-developed quartz, feldspar and mica crystals with clearly defined mineral boundaries. The glacial back side exhibited a muddy-looking surface with protrusions of harder, blocky-shaped minerals (quartz and feldspars). The platy mica minerals (muscovite, biotite and chlorite) were completely decomposed to clay minerals. Lastly, the weathered surface of the split side chip sample looked very similar to the weathered glacial back surface. A few areas were observed on the chip sample with clusters of mica that were severely

deteriorated. This suggests a slightly lesser degree of overall weathering on the split side than the glacial back surface.

Conclusions

Based on our observations, test results and past experience, our conclusions are as follows:

1. The KRS is a light to medium-gray colored, meta-graywacke of Archean age (approximately 2.7 billion years old). The stone appears to be a portion of a previously larger sized glacial erratic that has clearly been shaped, or "dressed" to it's present shape. Additionally, there are hundreds of man-made tool marks that were purposefully carved into two sides of the stone. The tools marks are reportedly old Scandinavian rune forms that present a message and is dated 1362 (See photos # 1 & 2).

2. We observed four, separate, original man-made fracture surface types that were made at roughly the same time. These surfaces clearly exhibit weathering of a shorter length of time than the surfaces of the stone that have been impacted by glacial action (>10,000 years). Additionally, we observed evidence of more recent carving, or retooling, in roughly 95% of the carved rune-forms. The retooled areas appear white in color and do not exhibit evidence of weathering. The four original surfaces are described as follows:

a. The entire split side of the KRS that was made or "dressed" at the time of the original carving (See photo # 2).

b. Areas of flaking produced during the original carving that are immediately adjacent to the deepest retooled grooves (See photos #13 & 14).

c. The vertical fracture face, called the "Oh Shoot" area, where part of the stone chipped off along a cleavage plane during the original carving (See photo #15).

d. Several rune forms on the glacial top end area of the split side of the KRS, that do not appear to have been retooled (See photo #16).

3. SEM analysis of surfaces on the core and chip samples indicate that the four, original man-made surfaces have experienced extensive mica degradation from prolonged weathering, presumably while in the ground (See photos # 39, 40, 41 & 42).

4. The glacial back side of the KRS exhibits two white, roughly parallel, undulating discolorations that branch out at two locations, suggesting an organic-based origin. We suspect these lineations were produced by chemical leaching of iron and magnesium from minerals in the stone, due to prolonged contact with tree roots in the ground (See photos # 3, 37, 38, 43, 47, 48, 49 & 50).

5. It is clear that the four man-made fracture surface types on the KRS, exhibit weathering (primarily mica degradation) consistent with being buried in the ground for at least decades and probably centuries. This being the case, the logical conclusion is that the KRS is an authentic artifact, presumably made at the time it is dated (1362 A.D.). (See photo #17).

Recommendations

Additional work that should be performed to better understand both the time-line for weathering and the various aspects of the inscription are as follows:

1. Tombstone Studies - To quantify the rate of mica decomposition, a testing program using gravestone chip samples should be performed. Chip samples should be taken from gravestones comprised of rock containing fine-grained mica minerals, from both above and below grade. Gravestones of incremental age (Example: 5, 10, 25, 50, 100, years etc.) should be sampled for analysis using the SEM. A time-line for mica degradation could then be generated for comparison with the man-made surfaces on the KRS. Additional testing to quantify the degradation rate of constituent minerals, such as water loss, specific elemental loss, conversion to clay minerals, etc., would help in better defining the time-line of weathering of the man-made surfaces.

2. Identify Graywacke Bedrock Source - Locating the bedrock source of the KRS would be comprised of two parts. First, a map and literature search should be performed to locate likely source areas. Secondly, perform field work to identify the bedrock source and obtain samples for testing.

3. Accelerated Weathering Testing - The samples obtained from the bedrock source would undergo accelerated weathering testing under similar below-grade conditions.. The use of an autoclave and an accelerated freeze-thaw chamber would be appropriate to simulate the weathering the KRS was exposed to. Chip and polished section samples should then be reviewed and photographed using reflected light microscopy and SEM.

4. Comparative Time-Line Projections - The accelerated weathering data should then be analyzed to project mica degradation and weathering time-lines. This information could then be compared with the time-line data generated from the tombstone studies. These results would give the best information possible to date the weathering on the man-made surfaces of the KRS.

5. Microscopic Documentation of the Inscription - A thorough microscopic digital photo library of the entire inscription should be produced. The catalog of photos should include each word and every individual rune form, number and word separator under various magnifications. Careful observations should be made during photography to document any important aspects of the stone itself as well as the inscription (See photo #18 as an example).

6. Depth of Root Leaching - A qualified plant specialist should be consulted to investigate the chemical processes and timing involved to develop the apparent root bleaching observed on the glacial back side of the KRS.

Test Procedures

Laboratory testing was performed on September 11, 2000 and subsequent dates. Our procedures were as follows:

Petrographic Observations

Petrographic observations were performed in accordance with APS Standard Operating Procedure 00 LAB 004b, "Petrographic Examination of Aggregates for Concrete", ASTM:C295. Observations were made using a Olympus SZH binocular stereo-microscope with magnification up to 250x. Photo micrographs were taken using digital equipment.

Thin Section Analysis

Thin section analysis was performed in accordance with APS Standard Operating Procedure 00 LAB 004b, Petrographic Examination of Aggregates for Concrete, ASTM:C295. Thin sections were reviewed under an Olympus BH-2 polarizing microscope with magnification up to 1000x. The samples are first highly polished, then epoxied to a glass slide. The excess sample is cut from the glass and the slide is polished until the rock reaches 25 microns or less in thickness. The top ½" of the core sample was cut off with thin sections made from both the horizontal and perpendicular orientations to the "glacial" back surface. Powder mounts were also generated from coatings obtained from the KRS.

APS# 10-01120 DATE: July 17, 2001
PROJECT: Kensington Runestone Investigation

SAMPLE ID: KRS
PHOTO # 9
MAGNIFICATION: None

SAMPLE DESCRIPTION: White, triangular shaped hydrothermal calcite vein filling on the glacial face side. Elongate chlorite crystals are aligned roughly parallel to the long axis of the stone. Circled area is the likely source of N. H Winchell thin section sample.

SAMPLE ID: KRS
PHOTO # 10
MAGNIFICATION: None

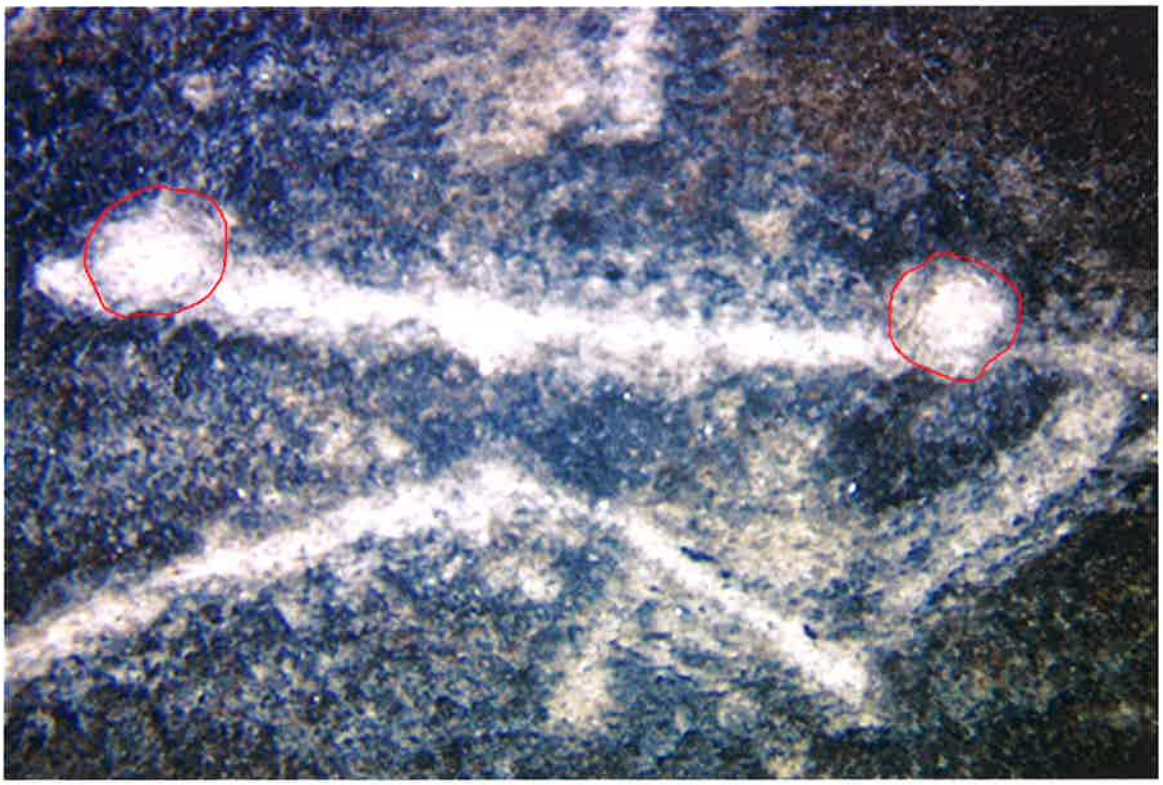
SAMPLE DESCRIPTION: Low angle light highlights three distinct, parallel fracture planes that run at roughly a 15-degree angle to the bottom end of the KRS. The entire face of the stone has a lack of glacial striations. Two, clear cleavage/fracture planes comprise this side of the stone.

Not necessarily! Looks like a nice set of striations running in this low-angle lighting

APS# 10-01120 DATE: August 24, 2001
PROJECT: Kensington Runestone Investigation

SAMPLE ID: KRS Split Side
PHOTO # 17
MAGNIFICATION: None

SAMPLE DESCRIPTION: Date at the end of the inscription (1362).



SAMPLE ID: KRS W-13, R-60
PHOTO # 18
MAGNIFICATION: 7.5x

SAMPLE DESCRIPTION: Two, round, punch chisel marks (circled in red), probably used as a word separator is over-written by the runic letter "R."

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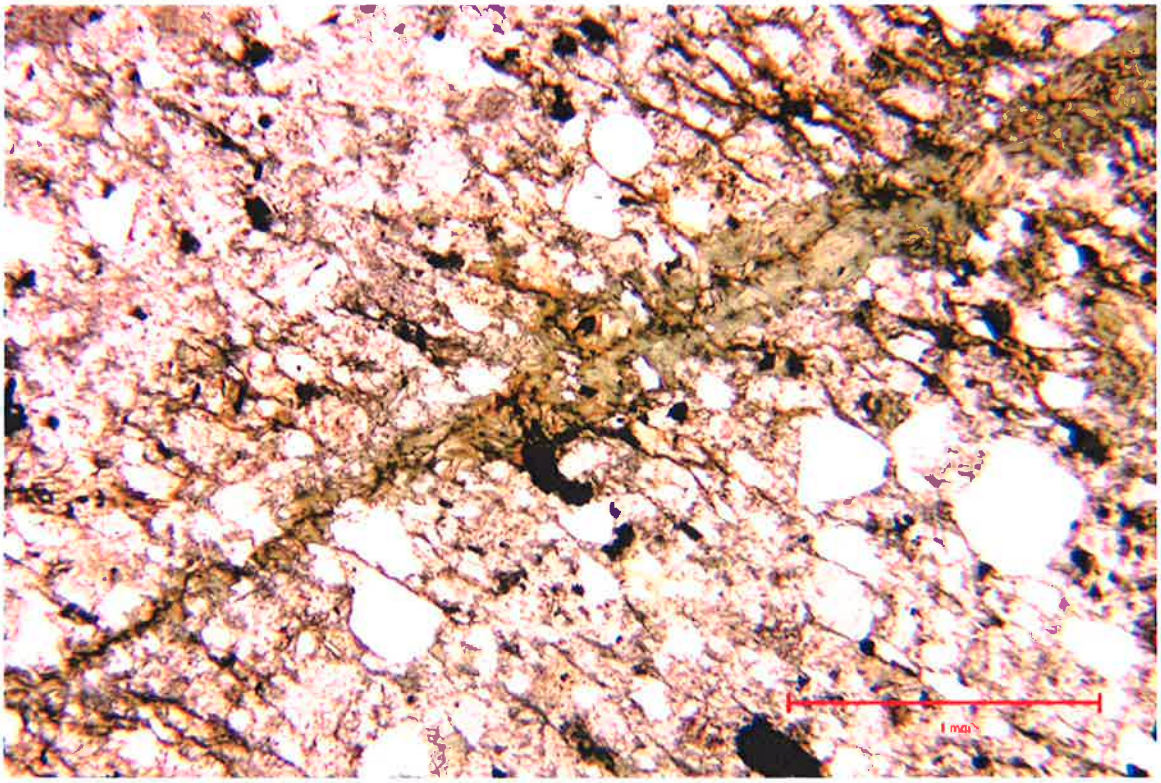
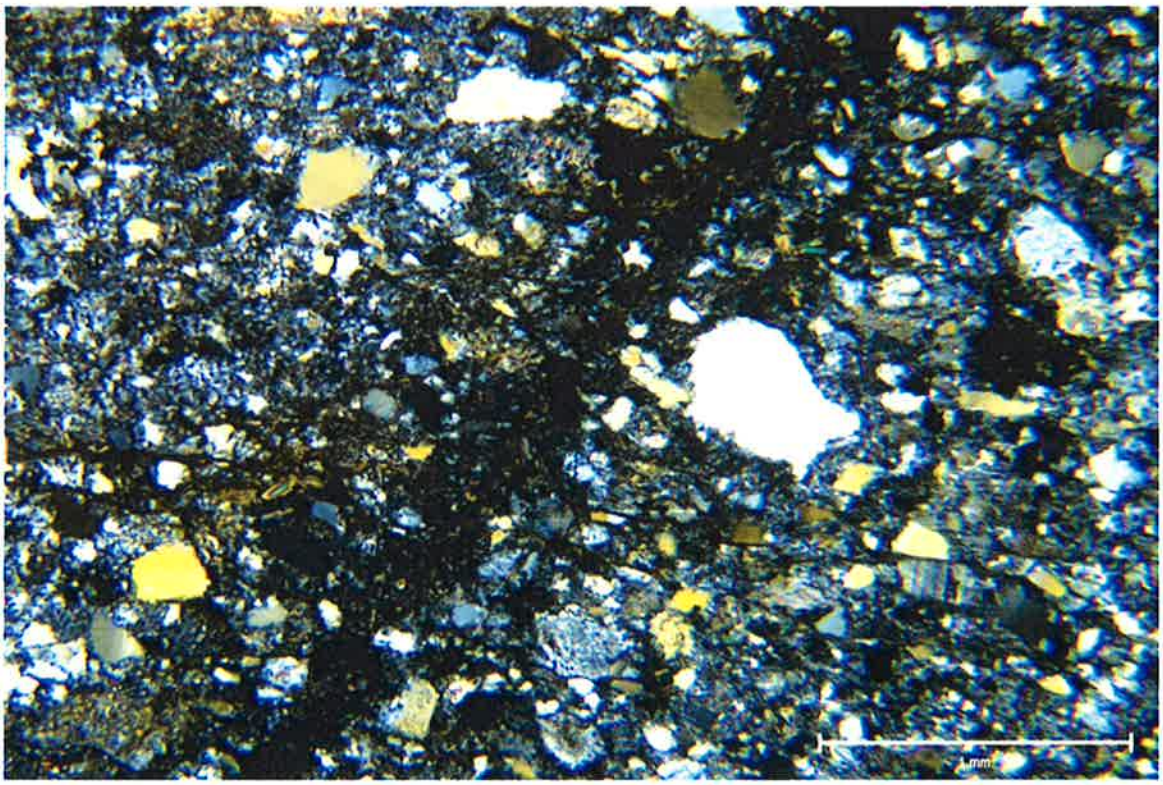


SAMPLE ID: Core Thin Section at 1/2" Depth
PHOTO # 25
MAGNIFICATION: 40x

SAMPLE DESCRIPTION: A weathered fracture plane cutting across relect bedding or a foliation at roughly a 50 degree angle under plane polarized light. Notice the mostly sub-angular to angular sand grains.



SAMPLE ID: Core Thin Section at 1/2" Depth
PHOTO # 26
MAGNIFICATION: 40x

SAMPLE DESCRIPTION: Same area as above photo under cross polarized light. Notice elongate sand grains aligned roughly parallel to the relict bedding or foliation.

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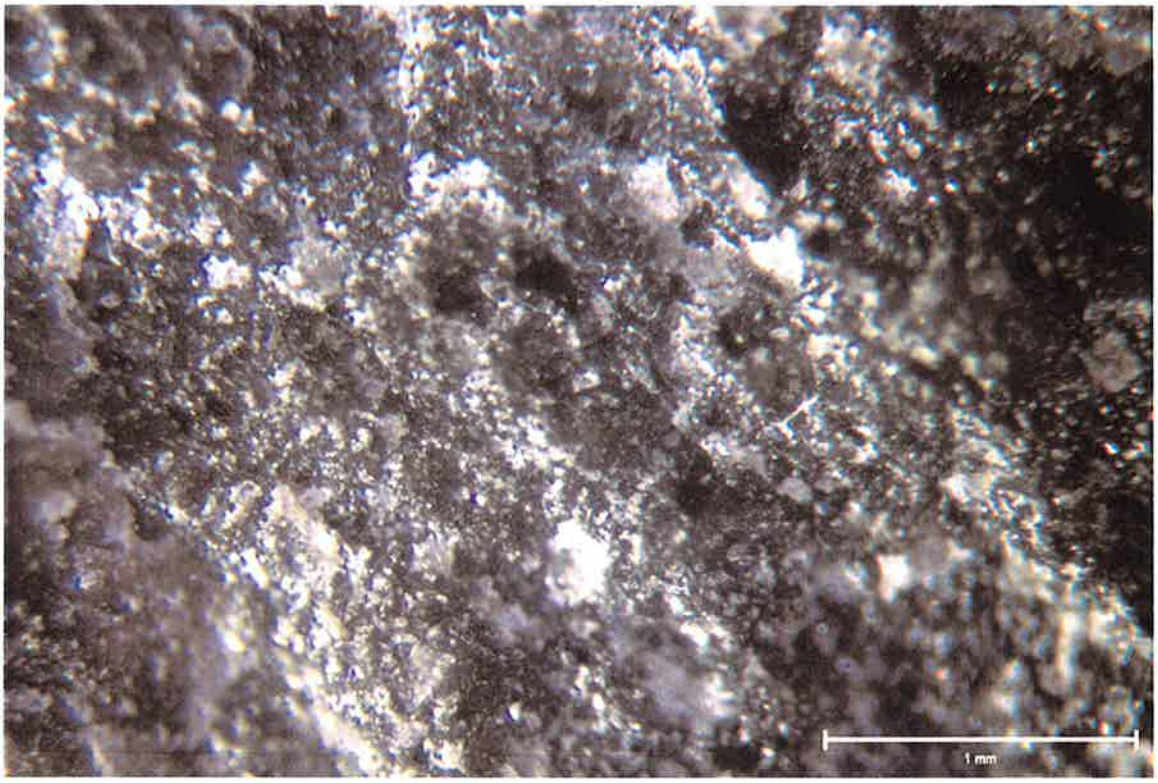
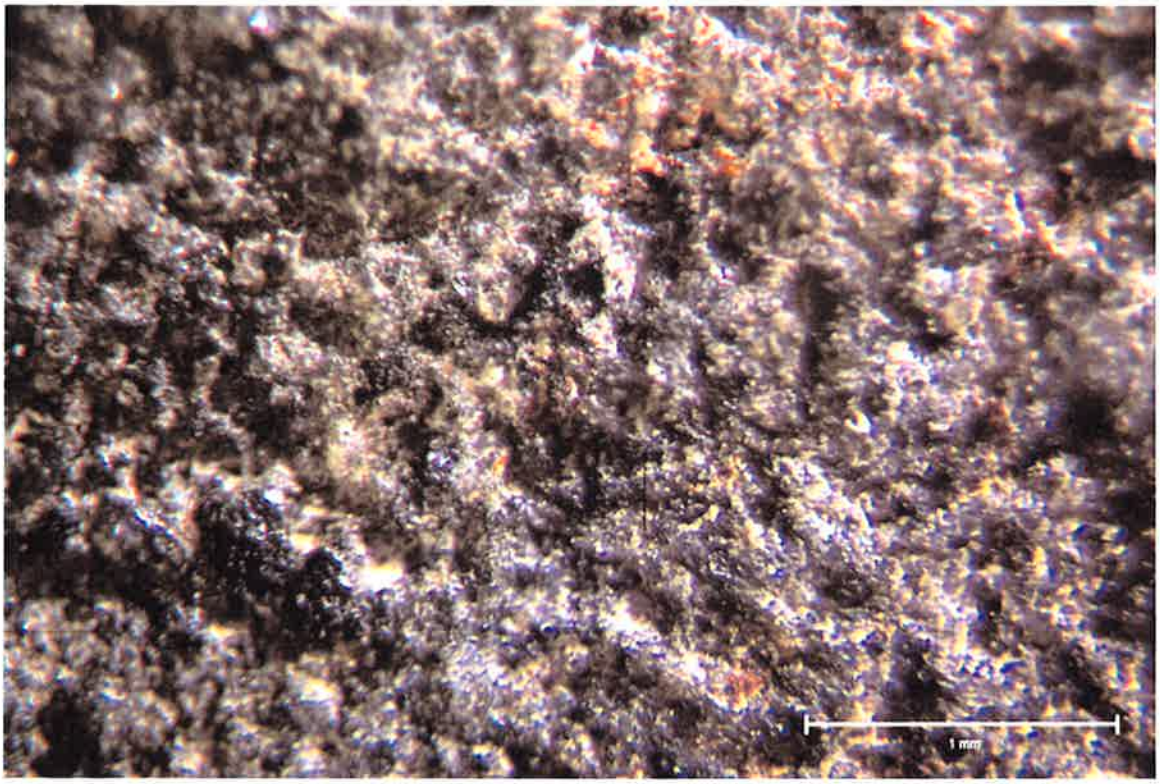


SAMPLE ID: Core Sample
PHOTO # 31
MAGNIFICATION: 50x

SAMPLE DESCRIPTION: Freshly fracured bottom surface of the core sample under reflected light.



SAMPLE ID: Core Sample
PHOTO # 32
MAGNIFICATION: 50x

SAMPLE DESCRIPTION: Highly weathered glacial top surface of the core sample under reflected light. Notice the irregular pitted surface which developed since it was originally deposited by a glacier.

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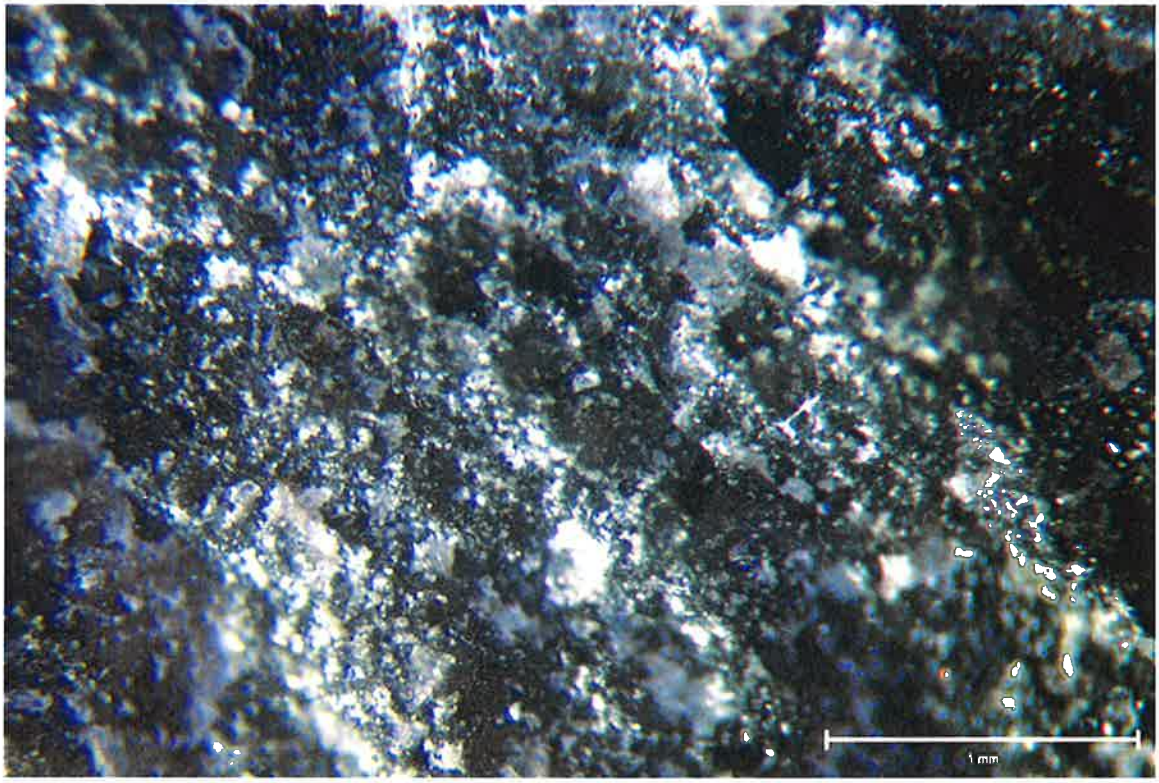
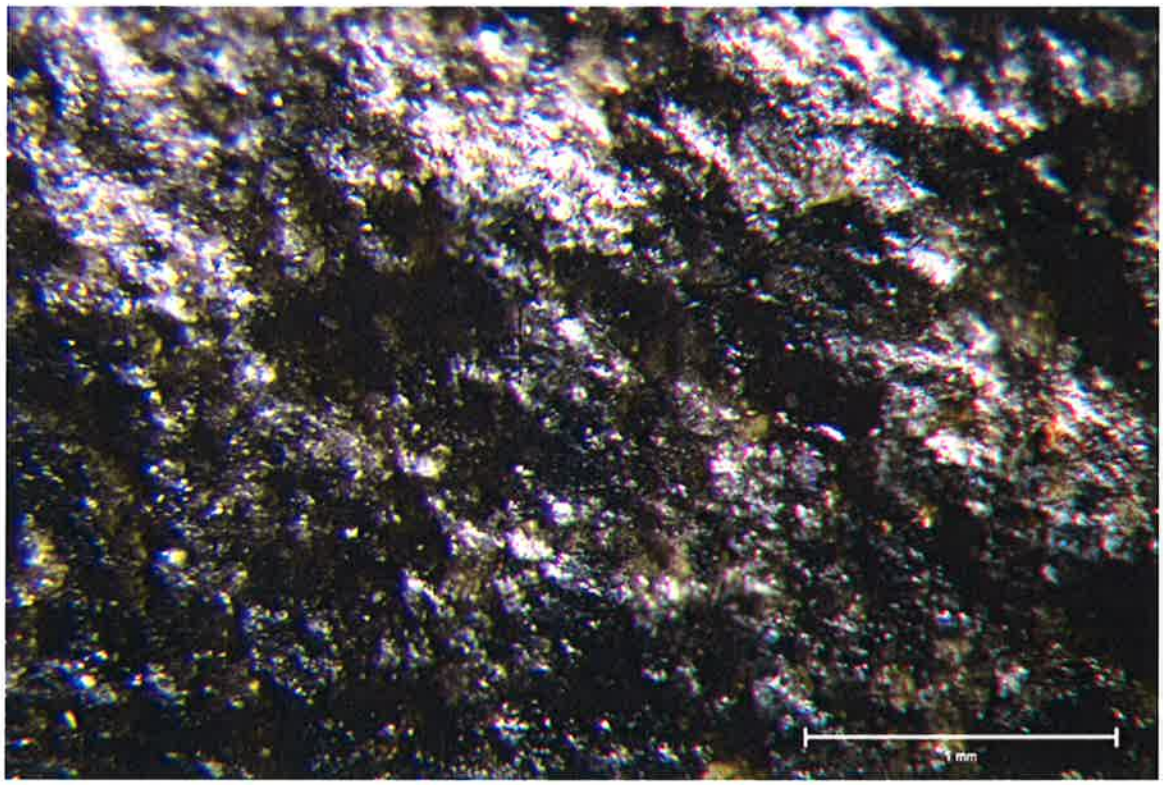


Same as 31

SAMPLE ID: Core Sample
PHOTO # 33
MAGNIFICATION: 50x

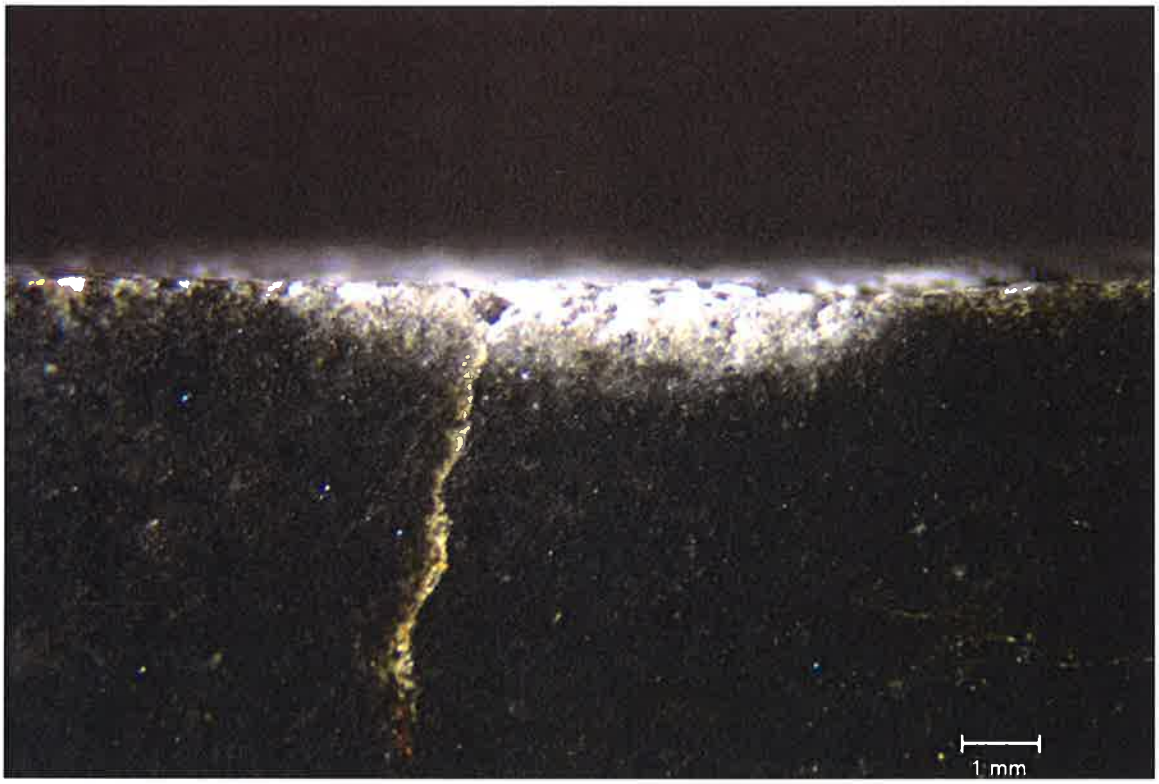
SAMPLE DESCRIPTION: Freshly fractured bottom surface of the core sample under reflected light.



SAMPLE ID: KRS Split Side
PHOTO # 34
MAGNIFICATION: 50x

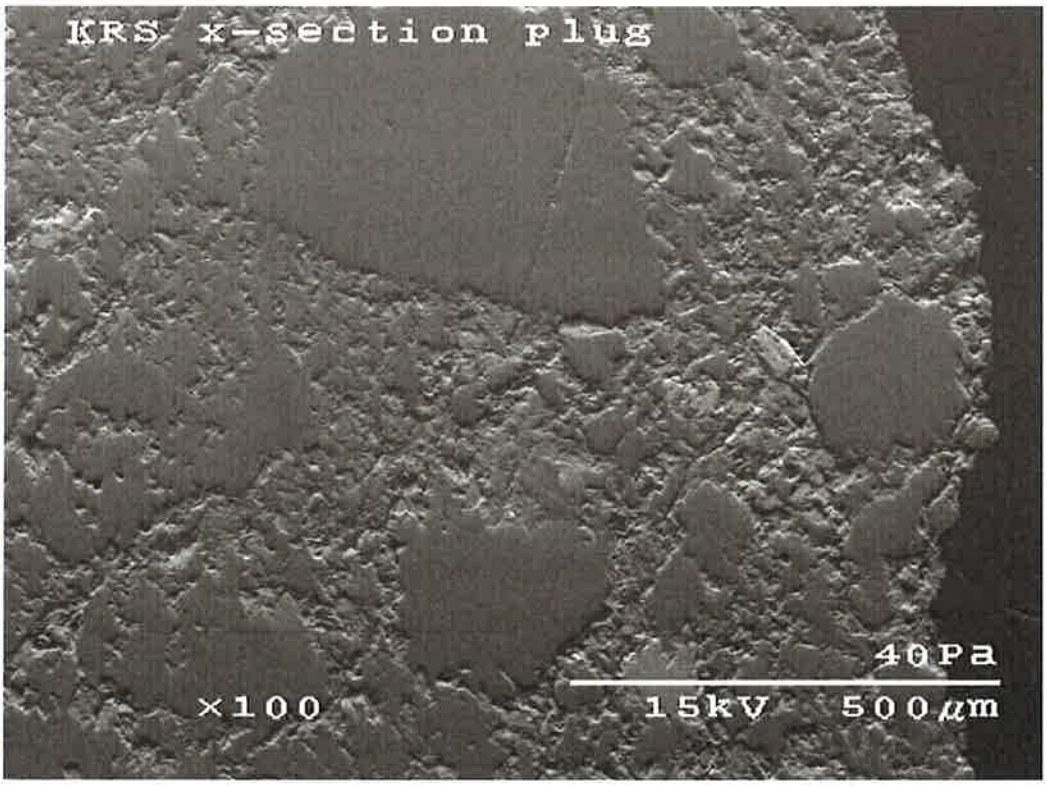
SAMPLE DESCRIPTION: Significantly weathered surface of the split side of the KRS which was made at the time of the original carving.

APS# 10-01120 DATE: August 24, 2001
PROJECT: Kensington Runestone Investigation



SAMPLE ID: KRS Core Puck Cross-Section under Relfected Light
PHOTO # 37
MAGNIFICATION: 10x

SAMPLE DESCRIPTION: White, apparent root leaching zone to a maximum depth of 1.5mm.



SAMPLE ID: KRS Core Puck Cross-Section Under SEM
PHOTO # 38
MAGNIFICATION: 100x

SAMPLE DESCRIPTION: Under-cutting of degraded matrix minerals (micas) in zone of apparent root leaching to a maximum of 1.5mm depth. Top of core at right.

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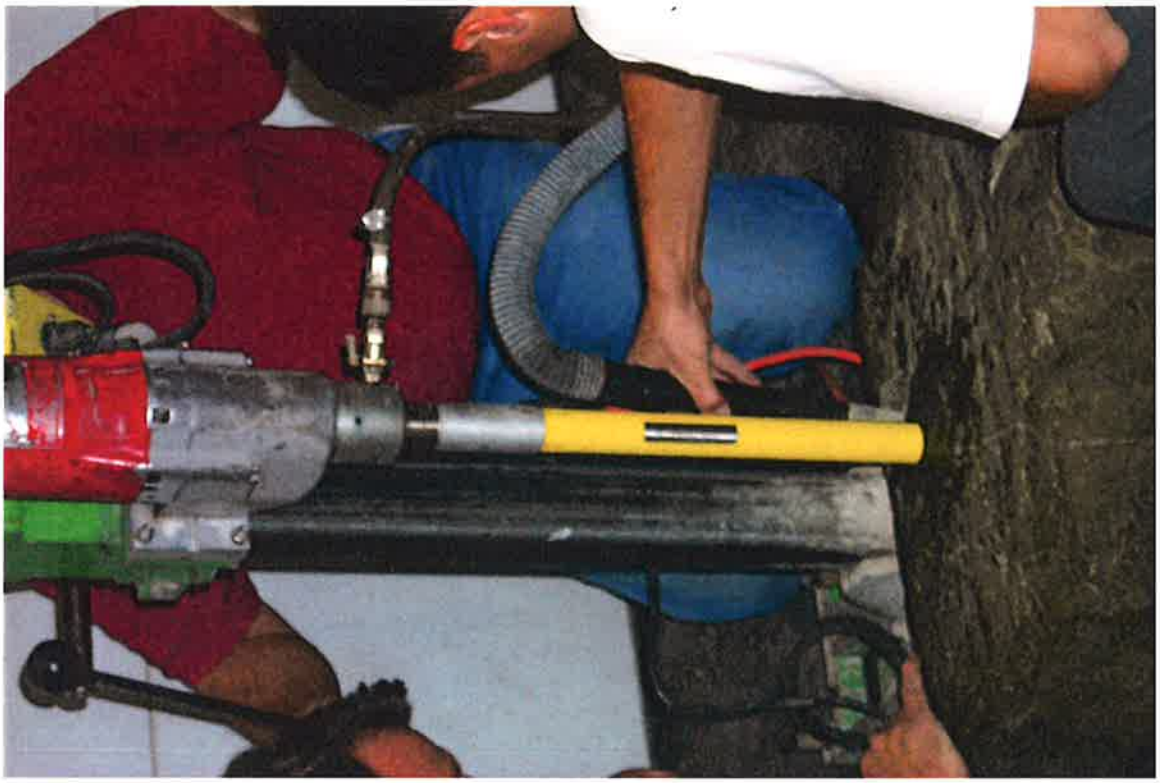


SAMPLE ID: KRS Coring on October 3, 2000 SAMPLE DESCRIPTION: Vacuuming of excess water during coring.
PHOTO # 45
MAGNIFICATION: None

SAMPLE ID: KRS Coring on October 3, 2000 SAMPLE DESCRIPTION: Breaking off core.
PHOTO # 46
MAGNIFICATION: None

APS# 10-01120 DATE: July 17, 2001
PROJECT: Kensington Runestone Investigation

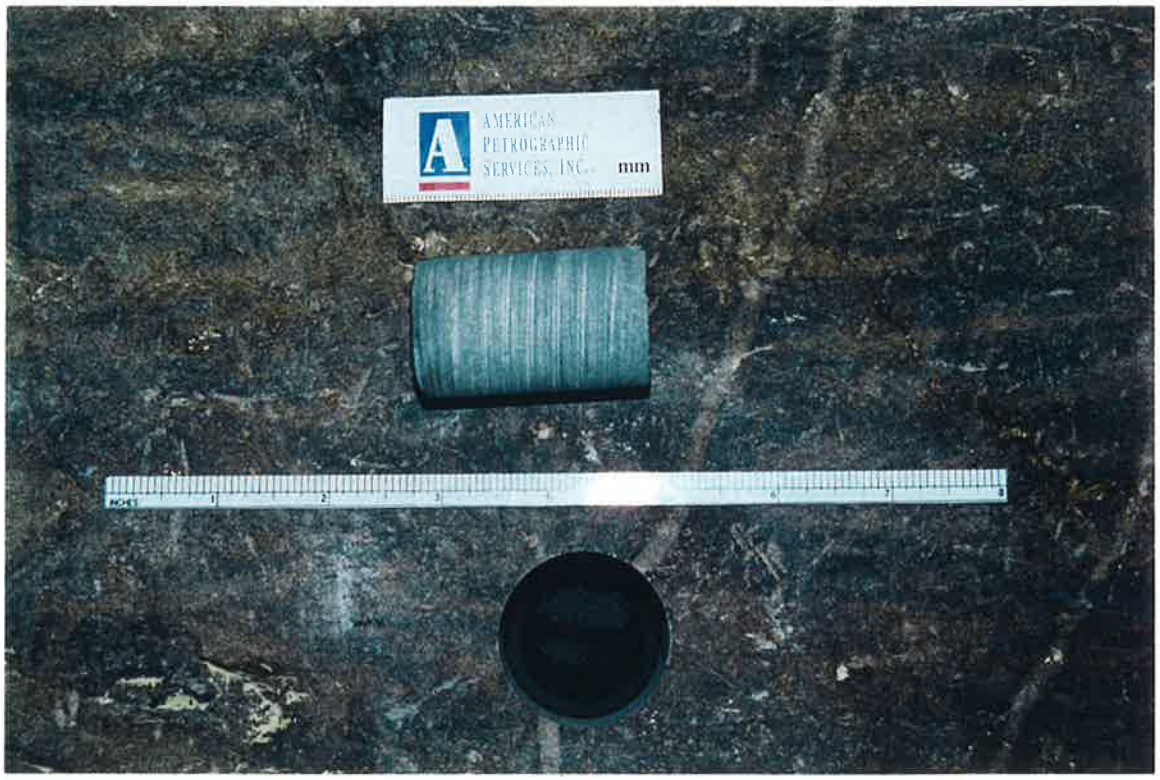
SAMPLE ID: KRS Coring on October 3, 2000 SAMPLE DESCRIPTION: Core sample after break-off and removal
PHOTO # 47
MAGNIFICATION: None

SAMPLE ID: KRS Coring on October 3, 2000 SAMPLE DESCRIPTION: Top surface of core.
PHOTO # 48
MAGNIFICATION: None

APS# 10-01120 DATE: July 17, 2001
PROJECT: Kensington Runestone Investigation

SAMPLE ID: KRS Coring on October 3, 2000
PHOTO # 49
MAGNIFICATION: None

SAMPLE DESCRIPTION: Top view of fractured end of core sample.



SAMPLE ID: KRS Coring on October 3, 2000
PHOTO # 50
MAGNIFICATION: None

SAMPLE DESCRIPTION: Side view of core sample.

Slight curve on core sample not an artifact of the coring / drilling process.

APS# 10-01120 DATE: July 17, 2001
PROJECT: Kensington Runestone Investigation

SAMPLE ID: KRS Split Side Chip Sampling on October 21, 2000.
PHOTO # 51
MAGNIFICATION: None

SAMPLE DESCRIPTION: Location of chip sample prior to obtaining it.

SAMPLE ID: KRS Split Side Chip Sampling on October 21, 2000
PHOTO # 52
MAGNIFICATION: None

SAMPLE DESCRIPTION: Pail used to capture chip.

APS# 10-01120 DATE: July 17, 2001
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SAMPLE ID: KRS Split Side Chip Sampling on October 21, 2000.
PHOTO # 53
MAGNIFICATION: None

SAMPLE DESCRIPTION: Location of chip sample after sampling.

SAMPLE ID: KRS Split Side Chip Sampling on October 21, 2000
PHOTO # 54
MAGNIFICATION: None

SAMPLE DESCRIPTION: Captured chip sample.

Thin Section Analysis

graywacke

Thin section analysis of a core sample reveals the KRS is a fine-grained, meta-sedimentary rock with a strong preferred orientation of very fine-grained mica minerals, that is consistent with a relatively low grade of metamorphism (greenschist facies). This well developed lineation represents either relict bedding planes, a metamorphic foliation or both (See photos # 25 & 26). The mineralogy consists of the following (See attached data sheet):

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9. Calcite	<1
Total	100

Scanning Electron Microscopy (SEM)

White Discoloration (Apparent Root Leaching) - SEM images were generated on the polished vertical profile of the top ½" portion of the core sample with the undulating, white discoloration. Images generated of the polished surface exhibit greater undercutting of the fine-grained mica matrix in the white areas suggesting the integrity of the minerals had been degraded by chemical reactions. This apparent root leaching was observed to a maximum depth of 1.5 mm (See photo # 38).

Weathering Surfaces - SEM images were also generated from three different surfaces of the stone to compare weathering characteristics of the fine-grained mica matrix. The three surfaces examined included the following:

1. The freshly fractured surface on the bottom of the core where it was broken off (See photos #31, 33, 39, 41 & 49).

2. The glacial back surface of the core that has experienced at least 10,000 years of weathering (See photos # 32 & 40).

3. The chip sample obtained from the split side of the stone that was first exposed at the time of the original carving and may represent as long as 500 years of weathering in the ground (See photos # 42 & 54).

The freshly fractured surface exhibited well-developed quartz, feldspar and mica crystals with clearly defined mineral boundaries. The glacial back side exhibited a muddy-looking surface with protrusions of harder, blocky-shaped minerals (quartz and feldspars). The platy mica minerals (muscovite, biotite and chlorite) were completely decomposed to clay minerals. Lastly, the weathered surface of the split side chip sample looked very similar to the weathered glacial back surface. A few areas were observed on the chip sample with clusters of mica that were severely deteriorated. This suggests a slightly lesser degree of overall weathering on the split side than the glacial back surface.

Conclusions

Based on our observations, test results and past experience, our conclusions are as follows:

1. The KRS is a light to medium-gray colored, meta-graywacke of Archean age (approximately 2.7 billion years old). The stone appears to be a portion of a previously larger sized glacial erratic that has clearly been shaped, or "dressed" to it's present shape. Additionally, there are hundreds of man-made tool marks that were purposefully carved into two sides of the stone. The tools marks are reportedly old Scandinavian rune forms that present a message and is dated 1362 (See photos # 1 & 2).

2. We observed four, separate, original man-made fracture surface types that were made at roughly the same time. These surfaces clearly exhibit weathering of a shorter length of time than the surfaces of the stone that have been impacted by glacial action (>10,000 years). Additionally, we observed evidence of more recent carving, or retooling, in roughly 95% of the carved rune-forms. The retooled areas appear white in color and do not exhibit evidence of weathering. The four original surfaces are described as follows:

   a. The entire split side of the KRS that was made or "dressed" at the time of the original carving (See photo # 2).

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d. Several rune forms on the glacial top end area of the split side of the KRS, that do not appear to have been retooled (See photo #16).

3. SEM analysis of surfaces on the core and chip samples indicate that the four, original man-made surfaces have experienced extensive mica degradation from prolonged weathering, presumably while in the ground (See photos # 39, 40, 41 & 42).

4. The glacial back side of the KRS exhibits two white, roughly parallel, undulating discolorations that branch out at two locations, suggesting an organic-based origin. We suspect these lineations were produced by chemical leaching of iron and magnesium from minerals in the stone, due to prolonged contact with tree roots in the ground (See photos # 3, 37, 38, 43, 47, 48, 49 & 50).

5. It is clear that the four man-made fracture surface types on the KRS, exhibit weathering (primarily mica degradation) consistent with being buried in the ground for at least decades and probably centuries. This being the case, the logical conclusion is that the KRS is an authentic artifact, presumably made at the time it is dated (1362 A.D.). (See photo #17).

Possibly ?

↑ This conclusion is not supported by the preceding statement.

Recommendations

Additional work that should be performed to better understand both the time-line for weathering and the various aspects of the inscription are as follows:

1. Tombstone Studies - To quantify the rate of mica decomposition, a testing program using gravestone chip samples should be performed. Chip samples should be taken from gravestones comprised of rock containing fine-grained mica minerals, from both above and below grade. Gravestones of incremental age (Example: 5, 10, 25, 50, 100, years etc.) should be sampled for analysis using the SEM. A time-line for mica degradation could then be generated for comparison with the man-made surfaces on the KRS. Additional testing to quantify the degradation rate of constituent minerals, such as water loss, specific elemental loss, conversion to clay minerals, etc., would help in better defining the time-line of weathering of the man-made surfaces.

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3. Accelerated Weathering Testing - The samples obtained from the bedrock source would undergo accelerated weathering testing under similar below-grade conditions.. The use of an autoclave and an accelerated freeze-thaw chamber would be appropriate to simulate the weathering the KRS was exposed to. Chip and polished section samples should then be reviewed and photographed using reflected light microscopy and SEM.

This being the case, the logical conclusion is that weathering characteristics neither support nor deny that the KRS is an authentic artifact dated 1362 A.D.

4. Comparative Time-Line Projections - The accelerated weathering data should then be analyzed to project mica degradation and weathering time-lines. This information could then be compared with the time-line data generated from the tombstone studies. These results would give the best information possible to date the weathering on the man-made surfaces of the KRS.

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6. Depth of Root Leaching - A qualified plant specialist should be consulted to investigate the chemical processes and timing involved to develop the apparent root bleaching observed on the glacial back side of the KRS.

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Scanning Electron Microscopy

SEM observations, images and elemental maps were generated at magnification up to 5000x using environmental scanning electron microscope equipment at the Iowa State University-Materials Research Laboratory.

Rock Coring and Chip Sampling

On October 3, 2000, one 1 1/4" diameter rock core sample was removed from the "glacial" back side of the KRS. The core location was selected in an area that included an obvious fracture plane as well as the root bleaching discoloration. The sample was removed using a water-cooled, diamond studded coring bit. The hole was not patched after coring (See photos # 43, 44, 45, 46 & 47). The chip sample was obtained on October 21, 2000, by using a two-pound hammer and steel chisel (See photos # 51, 52, 53 & 54).

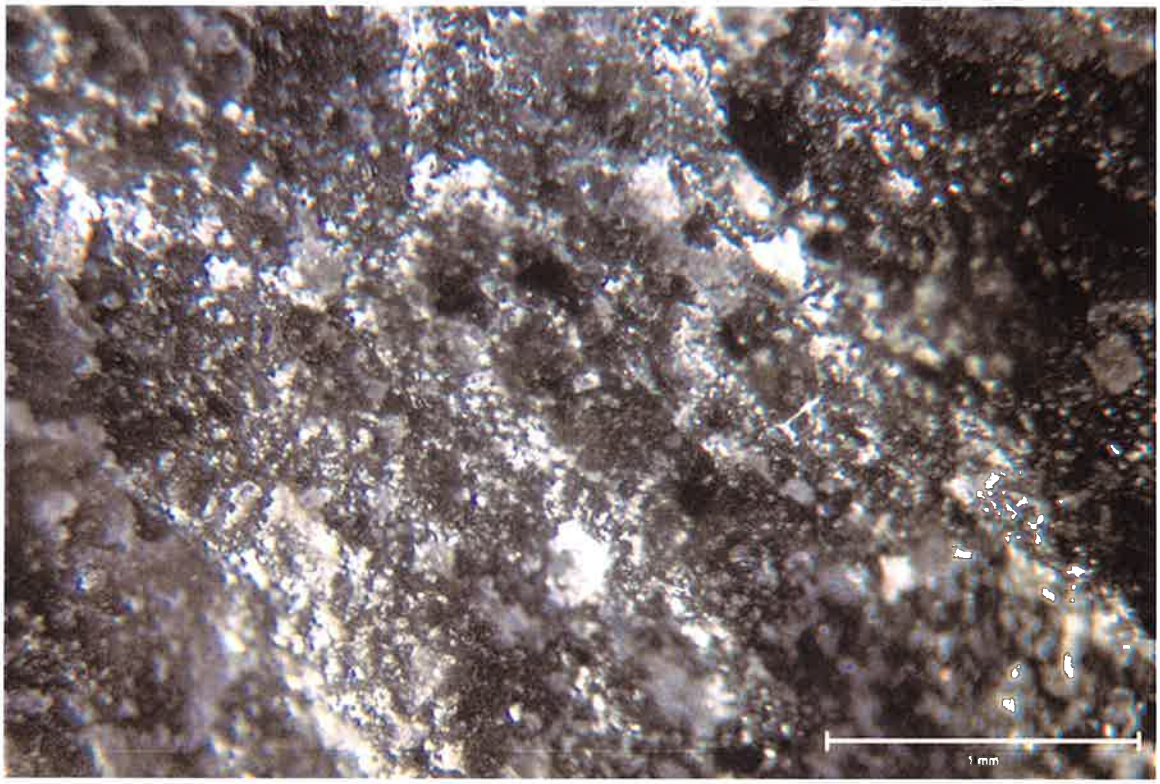
Remarks

The samples obtained from the KRS will be retained unless otherwise authorized, in writing, by the Kensington Runestone Foundation.

Report Prepared By:

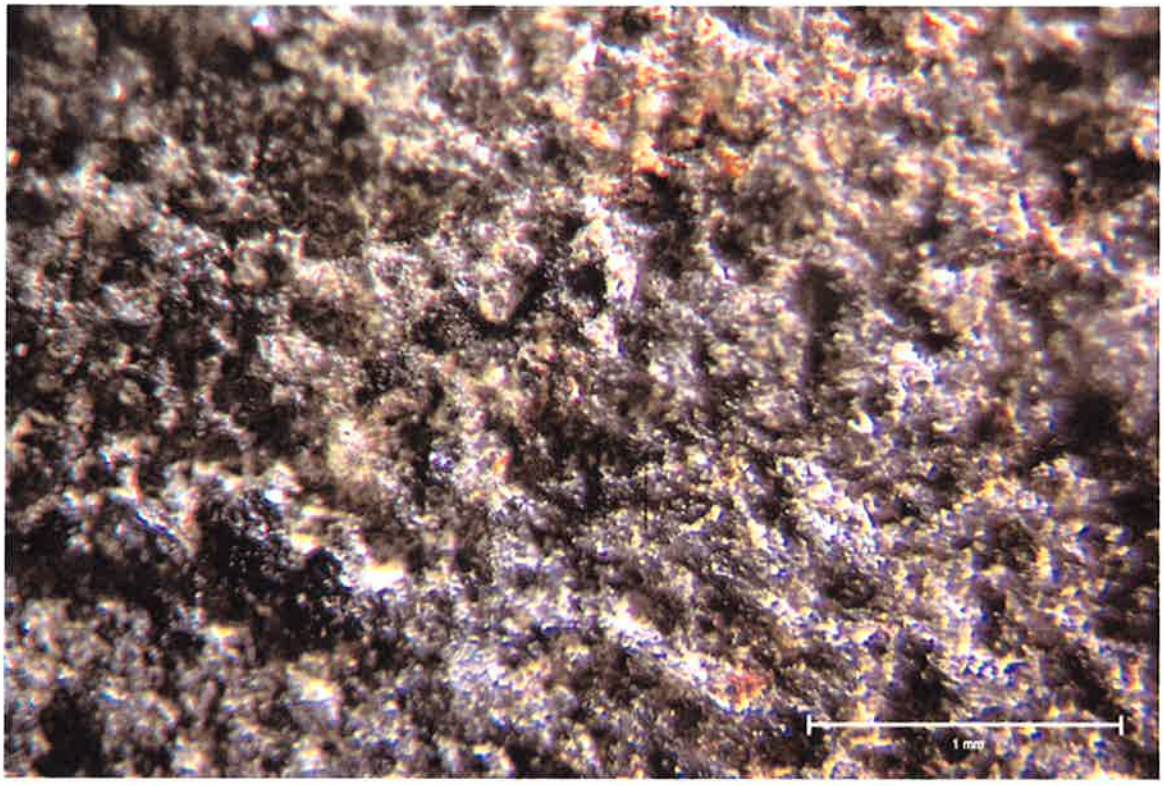
Scott F. Wolter P.G.
Geologist/Petrographer
Minnesota License #30024

APS# 10-01120 DATE: July 17, 2001
PROJECT: Kensington Runestone Investigation



SAMPLE ID: Core Sample
PHOTO # 31
MAGNIFICATION: 50x

SAMPLE DESCRIPTION: Freshly fracured bottom surface of the core sample under reflected light.



SAMPLE ID: Core Sample
PHOTO # 32
MAGNIFICATION: 50x

SAMPLE DESCRIPTION: Highly weathered glacial top surface of the core sample under reflected light. Notice the irregular pitted surface which developed since it was originally deposited by a glacier.

AMERICAN PETROGRAPHIC SERVICES, INC.

CLM

PROJECT:

KENSINGTON RUNESTONE

INVESTIGATION

REPORTED TO:

KENSINGTON RUNESTONE FOUNDATION
206 BROADWAY
ALEXANDRIA, MINN. 56308

ATTN: LuAnn Patton

APS JOB NO: 10-01120

DATE: January 4, 2001

Introduction

This report presents the results of laboratory work we performed on one stone slab artifact referred to as the "Kensington Runestone" or KRS. Our work was requested and authorized by Ms. LuAnn Patton of the Kensington Runestone Foundation on July 3, 2000. The scope of our work was limited to the following:

1. Performing petrographic observations to document physical aspects of the man-made carvings on the stone as well as on the stone itself.

2. Obtaining one rock core and one chip sample from the KRS.

3. Performing thin section analysis and scanning electron microscopy on the rock core and the chip sample.

4. Providing opinions, based on the geological aspects of the stone, regarding the relative age of the man-made features observed on the KRS.

5. Providing an opinion regarding the authenticity of the KRS and suggest recommendations for additional testing.

Background Information

The KRS was first unearthed by a Swedish farmer named Olof Ohman, who was grubbing trees on his land near Kensington, Minnesota on November 8, 1898. It was well documented by interviews with several witnesses, including Mr. Ohmans 10 year-old son, that the stone was entangled in the roots of a tree when it was pulled out of the ground. The original position of the main inscription or face side of the stone when it was found, was downward.

I Think you should be more objective here and not say anything about its age or purpose as a runestone. Instead, address its geological origin and eventual use: ... originated from glacial erosion of a bedrock source, transportation by glacier ice, and deposition as a glacial erratic. Subsequently, the stone was used by ~~human hands~~ as a tablet and incised by human hands.

The KRS is a tabular shaped stone weighing roughly 200 pounds, that was probably left as a memorial, and is dated 1362 A.D. Shortly after its discovery, the KRS was studied by many language experts from both the United States and Scandinavia. The stone contained a carved message that was written using Old Swedish language forms called runes. The message carved into the stone tells of the massacre of 10 people in an exploration party from Scandinavia. Many of the characters were unfamiliar to the language experts which led to their conclusion that it must be a forgery. The only expert to look at the KRS in a scientific way was N. H. Winchell in 1909-10. Mr. Winchell was a well respected geologist/archeologist who first described the geology of the stone. After his physical examination of the stone and investigation of the geological conditions and physical changes of the region where the KRS was found, he reached an opinion. He concluded that "The said stone is not a modern forgery and must be accepted as a genuine record of an exploration in Minnesota at the date stated in the inscription". His conclusion, as well as the conclusion of the Minnesota Historical Society, which was based largely on Professor Winchell's work, was that the Kensington Runestone was authentic. Extensive background information about the KRS can be obtained in the Minnesota Historical Society preliminary report published in 1915 (MHS Collections, Volume 15, 1915).

Much speculation about the authenticity of the KRS, pro and con, has been written and debated in the past 102 years. However, little scientific information has been published. Recent language studies of the KRS by Dr. Richard Nielsen, strongly supports it's authenticity. The KRS was brought to the American Petrographic Services Inc. (APS) laboratory in October of 2000 for the examination and testing.

Sample Identification

Sample Type	Original Sample Dimensions
KRS Stone Slab	Approx. 31" x 16" x 5 ½" thick
Rock Core (RC) *	1 $^1/_4$" diameter by 2" long
Rock Chip	Approx. ½" x $^1/_4$" x $^1/_8$" thick

* The rock core was cut into five (5) separate samples including two (2) thin sections. One thin section was orientated parallel to, and the other perpendicular to, the glacial top surface of the core. The perpendicular thin section included a vertical profile of a white leached area observed on the glacial back and side surface (See photo # 3).

Test Results

Petrographic Observations

Description Of KRS Surfaces (Sides) - The stone is flat and elongate in shape with three distinct types of sides:

1. The face side exhibits weathering similar to the glacial sides, but has no obvious glacial striations. The face side contains the beginning of the man-made, carved inscription (See photo #1).

2. The entire split side was clearly man-made, or dressed, at the same time as the original carving of the message. The last part of the message is on this side. This surface exhibits weathering that appears much younger than the glacial and face sides (See photo # 2).

3. The glacial sides exhibit striations and weathering of at least 10,000 years, or weathering that commenced after glacial transport and deposition. These areas are referred to as the following (See photos # 3, 4, 5 & 6):

   a. Glacial back side
   b. Glacial side
   c. Glacial top end
   d. Glacial bottom end

General Geology - The KRS is a light to medium gray colored, meta-graywacke of probable Archean age (approximately 2.7 billion years). Archean age graywackes from Canadian Shield bedrock sources are commonly found in glacial deposits throughout much of Minnesota. The top face side of the stone contains a triangle-shaped, exposed hydrothermal calcite vein filling. The calcite vein is approximately 3 to 5 mm in thickness and exhibits a strong preferred orientation (sub-parallel to the long axis of the stone) of the medium to coarse sized (2-3 mm) calcite and chlorite minerals (See photos # 9, 35 & 36). The KRS also exhibits well developed joint fracture planes in at least three directions. These inherent fracture planes directly influenced the tabular shape of the stone.

Glacial Geology - The KRS is a portion of a previously larger glacial erratic. The glacial back side exhibits several, large and relatively deep striations running sub-parallel to the long axis of the stone. This length and depth of the striations suggest that they were produced at the base of a glacier moving over the stone while it was still a part of the bedrock (See photos #11 & 12). Additionally, many smaller (up to 3" in length) and shallower groups of striations were also observed on the glacial back side, that were orientated in various directions. This suggests the striations developed during transport within the ice. The face side exhibits weathering consistent with the glacial sides but does not have striations (See photo #10). This suggests the slab may have broken off from a larger erratic near the end of it's glacial transport, possibly from frost shattering.

Coatings - Roughly 10 to 15% of the glacial bottom end surface is covered with intermittent yellowish-white, secondary calcite coatings deposited after glacial deposition and before the man-made carvings (See photos # 6, 7 & 8).

Contemporaneous Weathering Surfaces- The KRS exhibits four distinct man-made fracture surface types that were made at the time the stone was originally carved.

1. The entire split side exhibits a surface that is devoid of evidence indicating glacial abrasion. This side is a darker bluish-gray color than the adjacent glacial surfaces. The edge of the split side which meets the glacial back side, has 6 to 7 pseudo-conchoidal fractures (approximately 2-4 cm) which appear related to purposeful impact. The previously larger, flat, original stone appears to have been reduced in size to it's present shape, prior to the original carving (See photo # 2).

2. During the original chiseling of the rune forms, low angle fractures or "flaking" occurred that are present immediately adjacent to many of the characters. These flaked areas are similar in color and texture to the previous described fracture surfaces associated with the original carvings (See photos #13 & 14). Subsequent retooling into the deepest part of the original grooves did not affect the flaked surfaces. The weathering on the flaked areas, where present, has remained intact.

3. In the upper left corner on the face side of the stone is a small ledge (approx. 1 cm) that was fractured off leaving a vertical fracture face with the same dark, blue-gray color and appearance as the entire split side. This surface, called the "Oh Shoot" area, is located where the second line of the message likely would begin. The second line of the message appears to have been restarted immediately to the right of this vertical fracture face (See photo #15).

4. Several rune forms on the glacial top end of the split side do not appear to have been retooled at all. The texture and appearance of these grooved surfaces match the entire weathered split side making the characters in this area harder to see (See photo #16).

Weathering Environment - Since the KRS was found shallowly buried in the ground, it is assumed the stone and it's inscription were exposed to a below grade weathering environment within 24" of the surface. Since it is unknown how long the KRS was buried, it is assumed that natural processes alone would have begun to bury the stone within a short period of time after it was set (probably upright) in the ground. The soil horizon in this zone would have experienced periodic fluctuations in moisture content due to precipitation. Additionally, the stone has been exposed to annual frost penetration but relatively few freezing and thawing cycles. The stone shows no apparent evidence of surface spalling or delaminations associated with freeze-thaw deterioration.

Apparent Root Leaching - Two, approximately 1 cm wide, roughly parallel, light tan colored, slightly undulating linear discolorations run across the glacial back and side surfaces of the stone. They look quite similar to tree roots. If this discoloration is associated with tree roots, a chemical leaching reaction appears to have occurred between the roots and mafic (magnesium and iron-rich) minerals in the stone, producing the discoloration. These suspected root leaching lineations are consistent with the stone reportedly being found with the inscription face side down, wrapped in the roots of a tree (See photo #3).

"H" Control - An "H" control letter (approx. 3 cm) was observed near the glacial bottom end of the split side (See photo # 2). The "H" does not appear to have undergone any observable weathering. It was reportedly chiseled into the stone in 1908, by one-time owner Mr. Hjalmar Holand.

Retooling - All of the original rune form grooves on the face side and 75% of the rune forms on the split side have been scratched on or completely retooled. The retooling on the face side appears to have been done with greater force than the split side. This retooling has removed alteration products from within the grooves and crushed the surface minerals. This has produced a white color that looks "fresh" at first glance. The date when the retooling occurred is unclear. However, close inspection of photographs taken of the KRS in March of 1899, appear to show retooling present at that time. The suggests the retooling occurred shortly after discovery, perhaps within days (See photos # 13 & 14). Retooling and scratching on the rune forms may have occurred multiple times over the years.

Gypsum Deposits - Initial observations revealed intermittent areas of very small (approx. 1 mm) white deposits on several surfaces including original rune form grooves on the split side. Powder mounts reviewed under polarized light at magnification up to 400X, indicated the material was comprised of gypsum. A number of plaster casts of the stone have been produced in the past (reportedly the 1930's). The gypsum deposits observed are believed to be remnants of the plaster.

Iron Oxide Deposits - Significant iron-oxide deposits were observed on several original groove surfaces and flaked areas adjacent to retooled grooves. The iron deposits are the by-product of the decomposition of pyrite from within the stone (See photos # 19, 20, 21, 22, 23 & 24). These deposits give the appearance of great age and may well have developed decades or centuries ago. However, because pyrite can oxidize very quickly, these deposits could also have developed a year or two after exposure.

Winchell Sampling Area - In the lower right area of the face side of the KRS is a number of obvious chisel marks. The timing of when these impacts occurred is unclear. However, Professor Winchell states in 1909 *, that "I took a small flake from its lower end...". We assume that this flake was where a thin section was eventually made that he reviewed. This area appears to be the likely source of his sample (See photo # 9).

* - Minnesota Historical Society Collections Report on the Kensington Runestone, December 13, 1909.