The background of the slide is a dense field of small, irregular mineral grains in various shades of brown, tan, and yellow. Overlaid on this background are several large, solid-colored shapes: a bright yellow shape in the upper right, a light orange shape in the lower left, and a dark brown shape in the lower right. The text is centered in the white space between these shapes.

Mineralogical Analysis of Fossilized Edmontosaurus Skin

NDSU Petrology 2024
Eugene Barnes



Acknowledgments

North Dakota Geologic Survey

Dr. Saini-Eidukat

Background

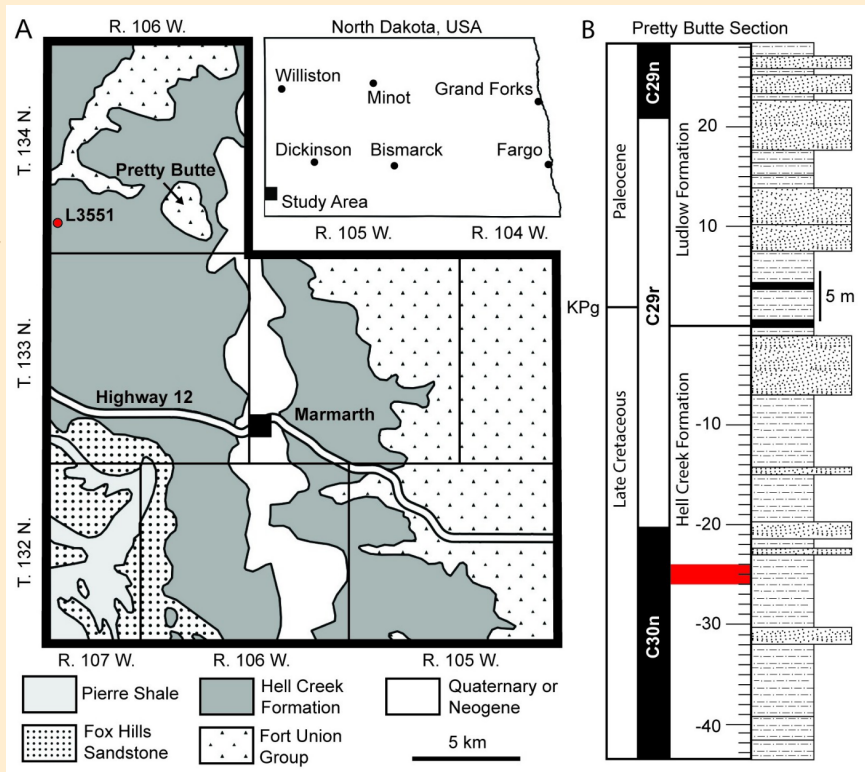
Dakota the Dinomummy



Natee Puttapipat

Dakota the Dino Mummy

- Dakota is an Edmontosaurus
- Dakota was found by Tyler Lyson in Slope County, ND near Marmarth in 1999
- Found in the Late Cretaceous Hell Creek Formation
- The formation is fluvial to deltaic (Vajda et al., 2013)
- The host rock for Dakota is a fine grained sandstone
- Donated to the NDGS in 2008



(A) Geographic location, (B) Stratigraphic position
Source: Drumheller, et al., 2022

The slide features a light beige background with decorative fossil fragments in the corners. The fragments are irregularly shaped and colored in shades of brown, tan, and yellow, resembling fossilized plant or animal remains. The main title is centered at the top in a large, bold, brown font.

Dakota the Dino Mummy: Previous Research

- Handheld XRF was done on Dakota by the NDGS, revealed increasing Fe, Mn, P, S, and Ni, and decreasing light elements moving towards the preserved soft tissues (Boyd et al., 2023)
- Dr. Saini-Eidukat and Cristian Pereira did optical petrography, XRD, and SEMEDS work on 4 other thin sections from the sediments surrounding Dakota to identify the composition (Saini-Eidukat & Pereira, 2023)

The background of the slide features a dense field of small, irregular mineral grains in shades of brown, tan, and purple. Overlaid on this are several large, semi-transparent shapes in bright yellow and orange, which appear to be stylized or abstract representations of mineral forms or perhaps light patterns.

Research

Transmitted and Reflected Light
Microscopy, SEMEDS

Methods: Microscopy

1. Thin sections were set in a UV reactive epoxy (blue) and polished
2. The thin sections were examined using a transmitted light microscope
3. Photos were taken with transmitted light of the entire thin section and areas identified as skin
4. The thin sections were examined using a reflected light microscope to show more detail in the opaque areas
5. Photos were taken with reflected light of the areas identified as skin to better identify the opaque minerals

Methods: SEM and EDS

1. Thin sections were exceptionally polished
2. Thin sections were adhered to circular mounts
3. Thin sections were coated with gold 99% in a sputter coater (Fig. 1)
4. Thin sections were loaded into the JSMT200 (Fig. 2)
5. Thin sections were examined using back scatter electrons for SEM (Scanning Electron Microscope) images
6. EDS (Energy Dispersive Spectroscopy) was used to analyze the elemental composition of skin, cement, and matrix
7. Results were summarized using the atom % for each point or box count and compared to known mineral formulas
8. Results were summarized with carbon removed from the total

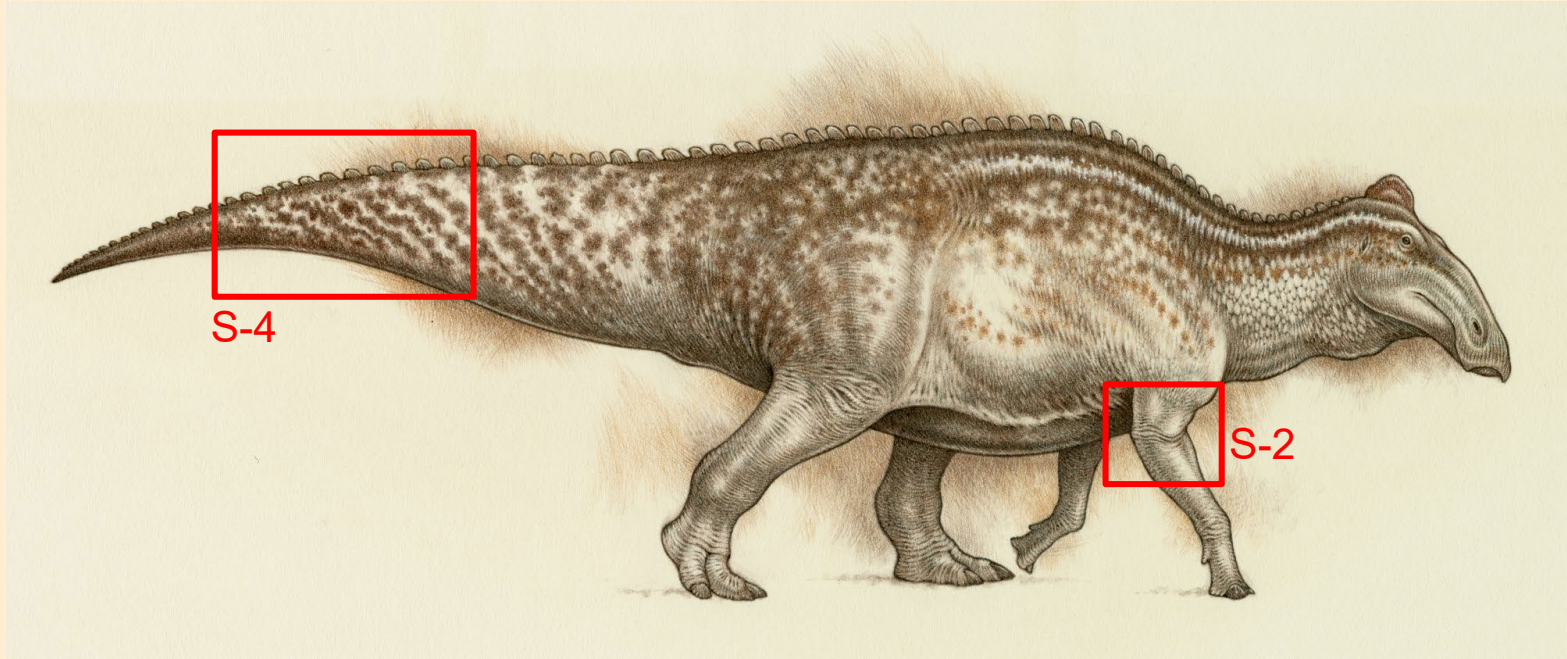


Fig. 1



Fig.2

Dakota the Dino Mummy: Sample Locations



S-4

S-2

Natee Puttapipat

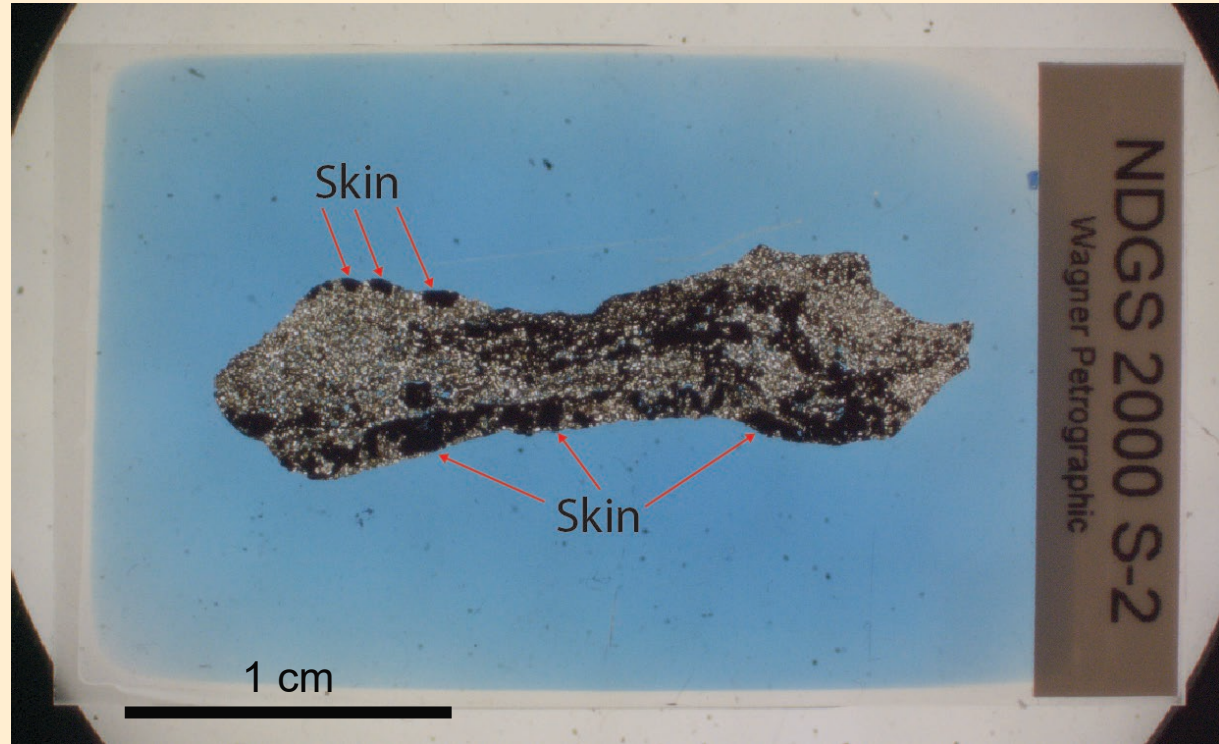
NDGS2000-S-2

- Skin from the elbow region
- Best preserved region on Dakota
- The skin has been folded/collapsed (visible in thin section)



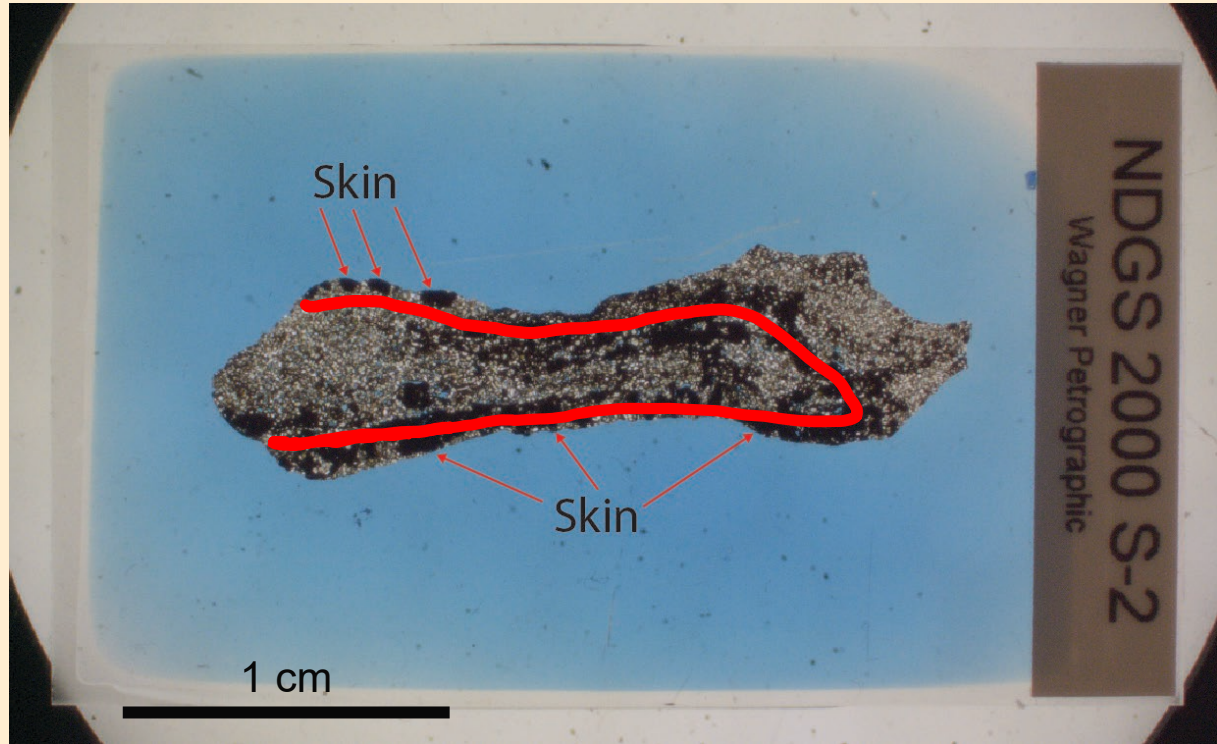
NDGS2000-S-2

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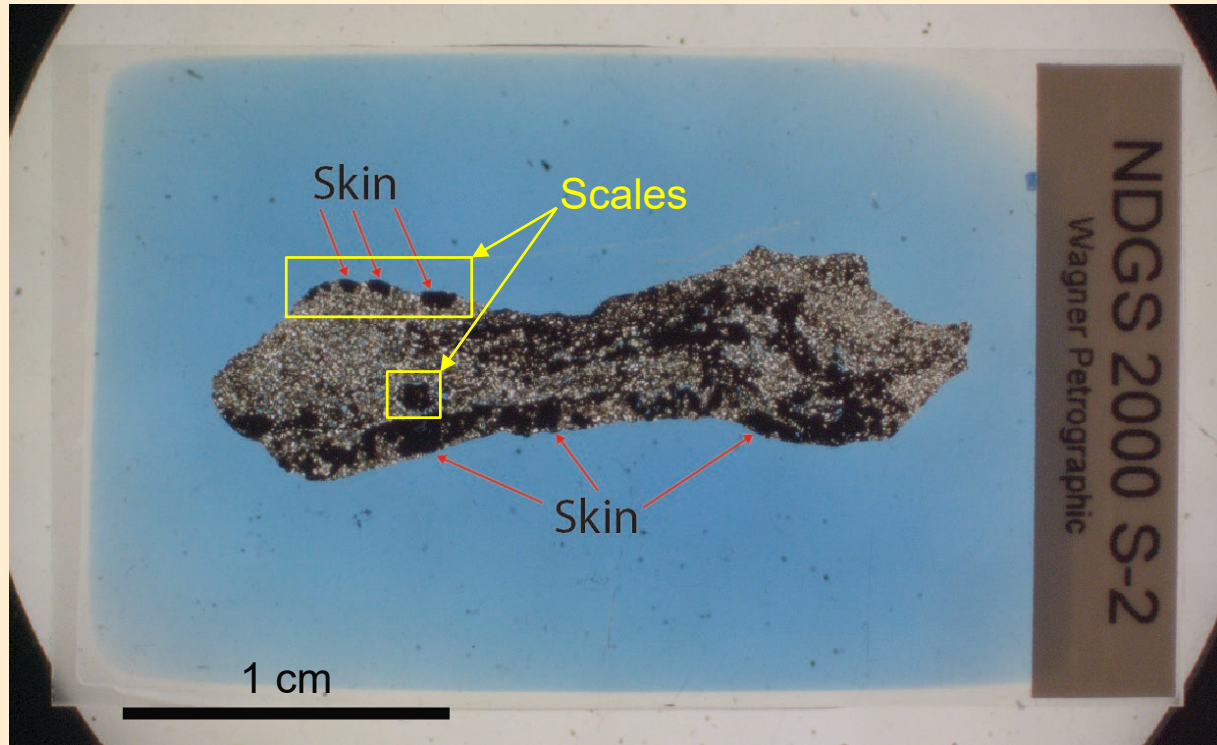
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NDGS2000-S-2

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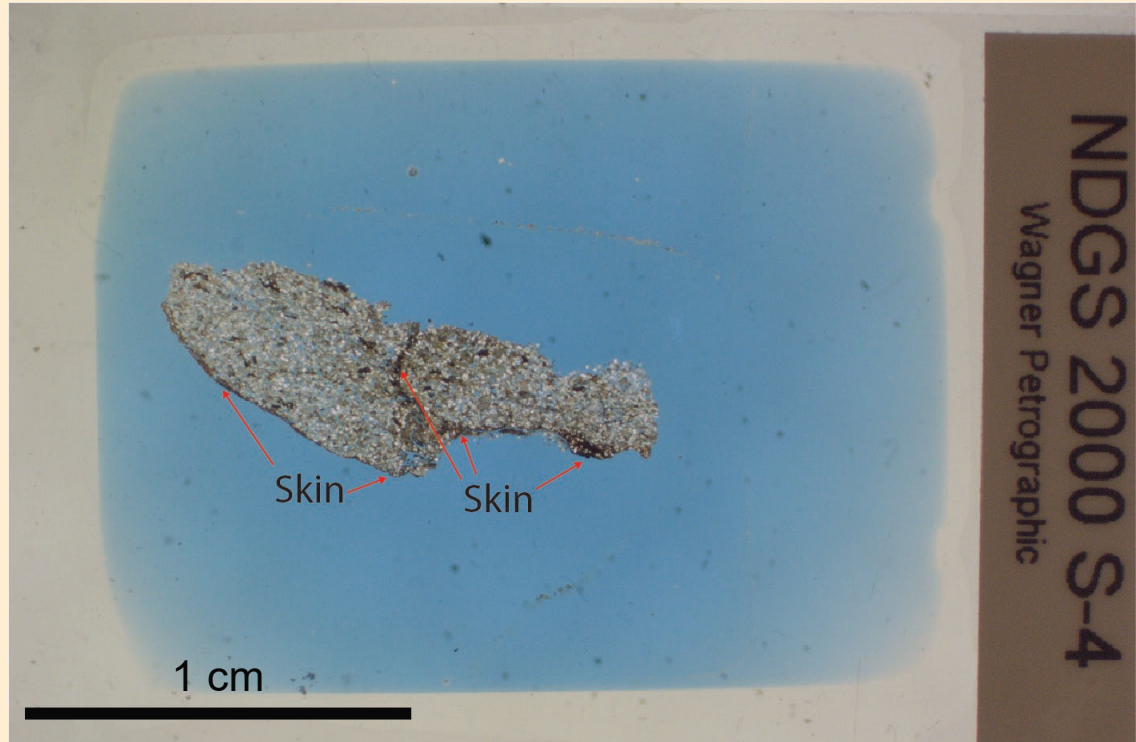
NDGS2000-S-4

- Skin from the tail region
- Preserves “nested” feature scales
- Analogous to scales on modern crocodiles and iguanas
- Preservation is less detailed than on S2



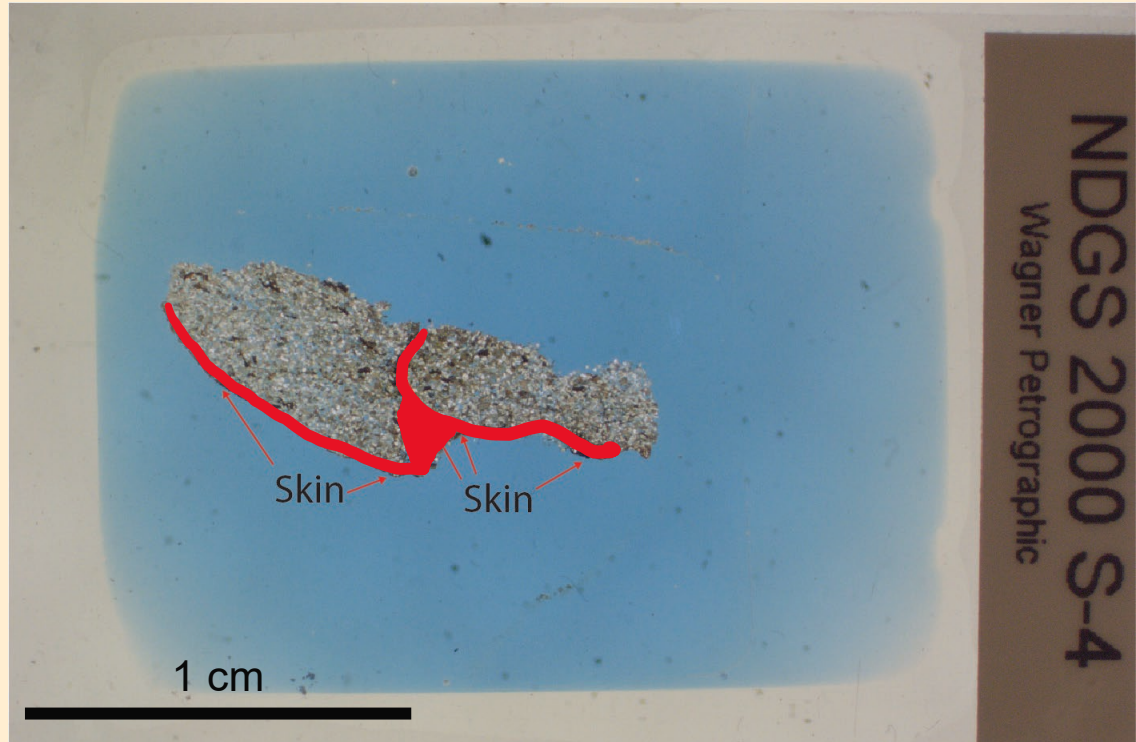
NDGS2000-S-4

- Skin from the tail region
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NDGS2000-S-4

- Skin from the tail region
- Preserves “nested” feature scales
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Minerals Identified

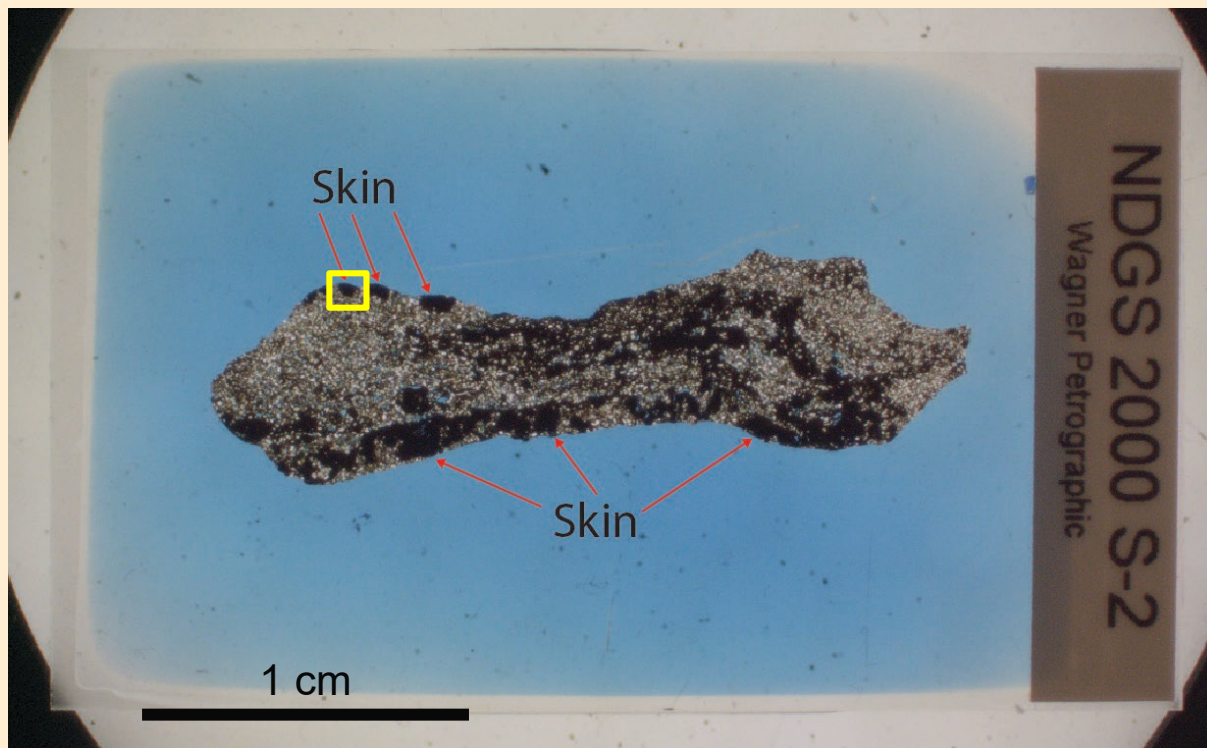
Name	Ideal Formula
Quartz	SiO_2
Siderite	FeCO_3
Calcite	CaCO_3
Monazite-Ce	CePO_4
Goethite	FeO(OH)

Epoxy

- EDS was run on the epoxy to confirm the contents picked up by the SEM
- Contains Cl which could account for the anomaly in a few samples
- High C, could account for high C in most samples

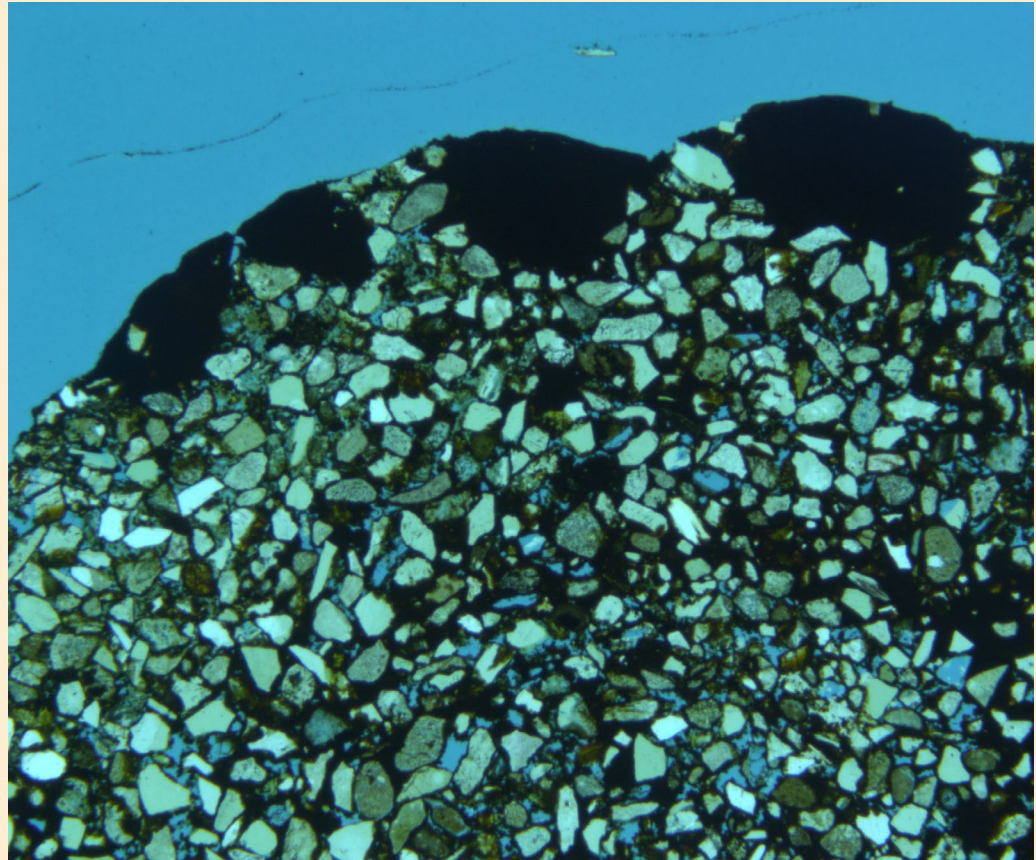
Sample NDGS-2000-S-2	
SEM Area ITSEM-1416	
Atom %	
Identifier	Spc_029
C	72.84
O	26.38
P	0.01
Cl	0.71
Fe	0.05
Total	100.00
Description:	Epoxy
Type:	Point
Identification:	Epoxy
Notes:	

NDGS2000-S-2



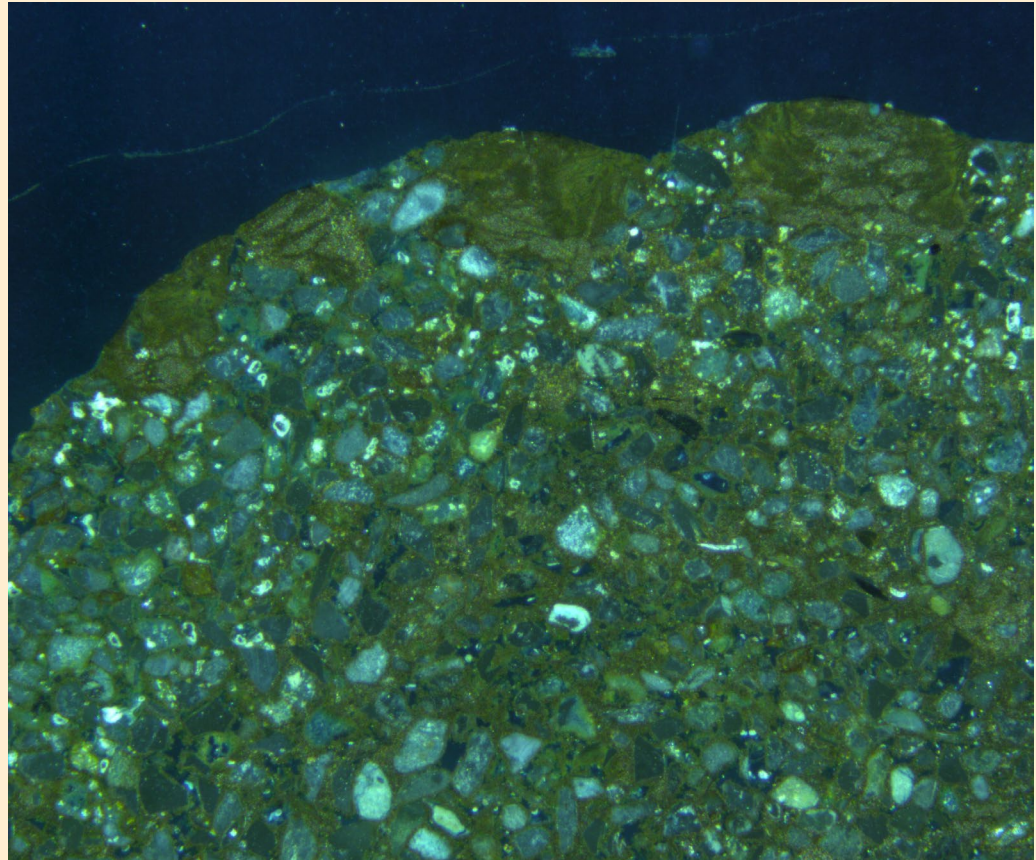
NDGS2000-S-2: 1413 Transmitted Light

- Transmitted light images showed that the scales as opaque
- Sandstone matrix



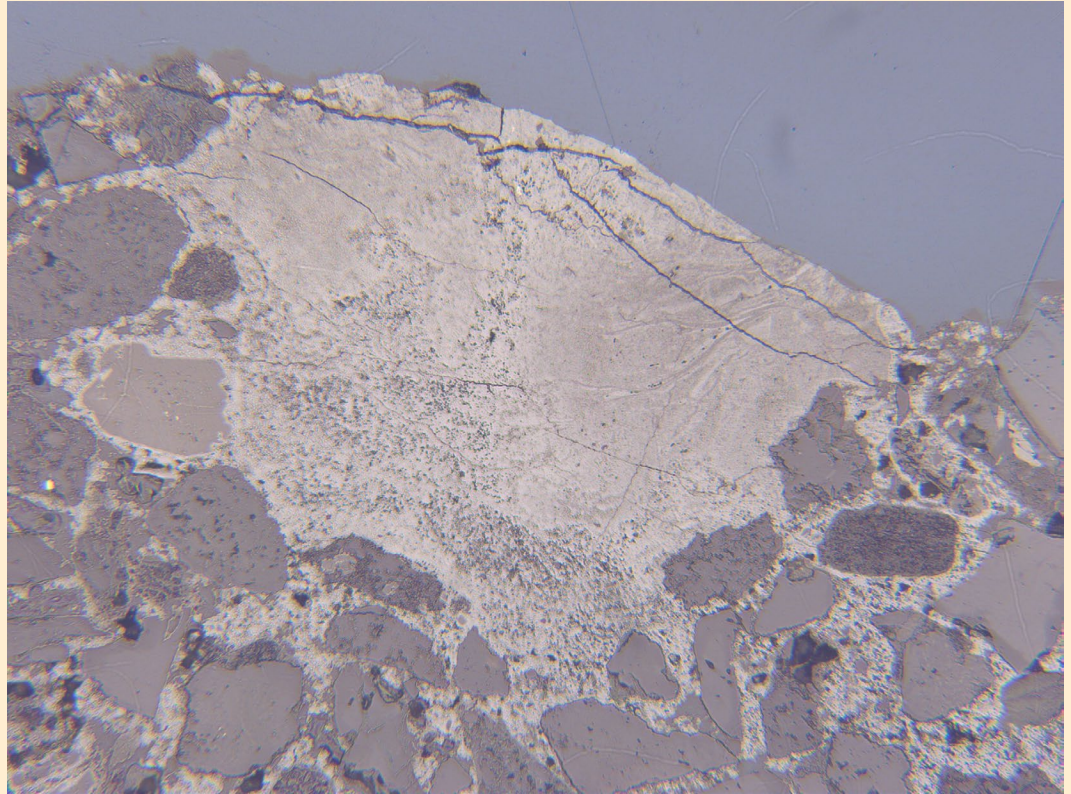
NDGS2000-S-2: 1413 Transmitted Light

- Reflected light images (on the same scope as transmitted light) showed that the scales as having internal structure
- More cement visible in the matrix



NDGS2000-S-2: 1413 Reflected Light

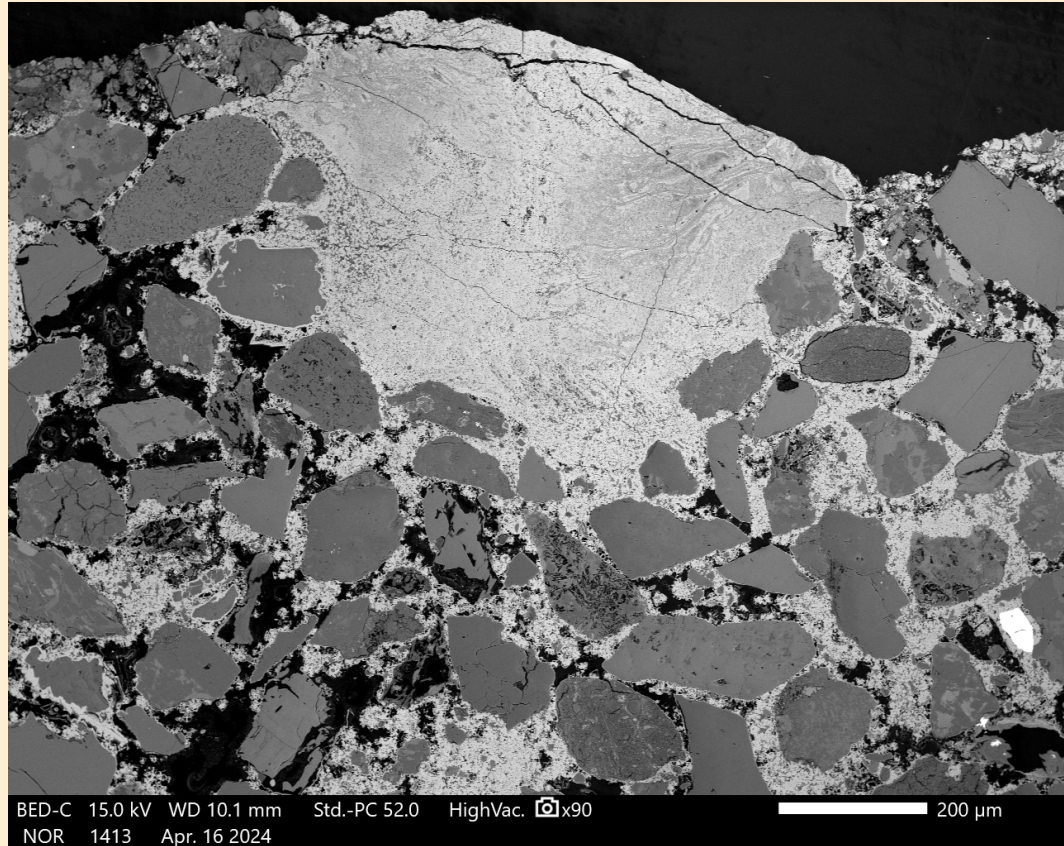
- Reflected light image third scale from the left on the top of S-2
- The linear quality around the edges may represent high quality preservation of connecting tissue
- Stronger tissue attachments expected on the edges of the scales, less underneath



FOV: 1.15 mm

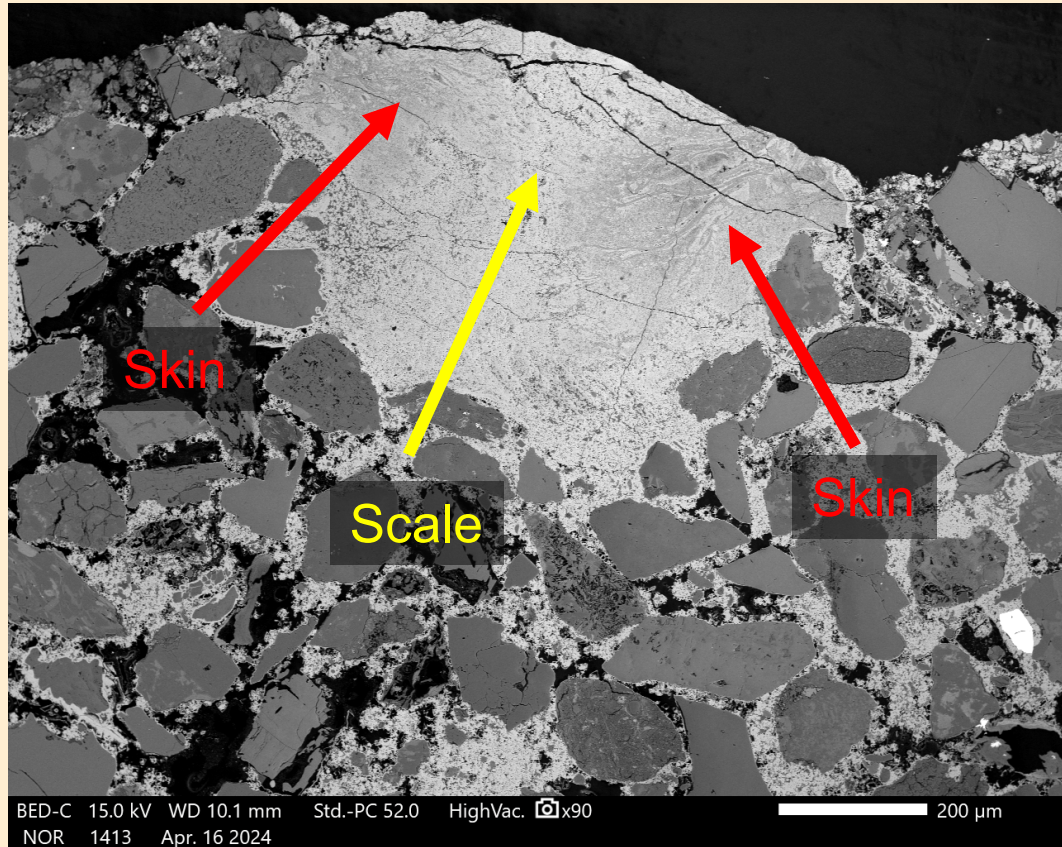
NDGS2000-S-2: 1413

- SEM image of the rightmost scale on the top of S-2
- The linear quality around the edges may represent high quality preservation of connecting tissue
- Stronger tissue attachments expected on the edges of the scales, less underneath



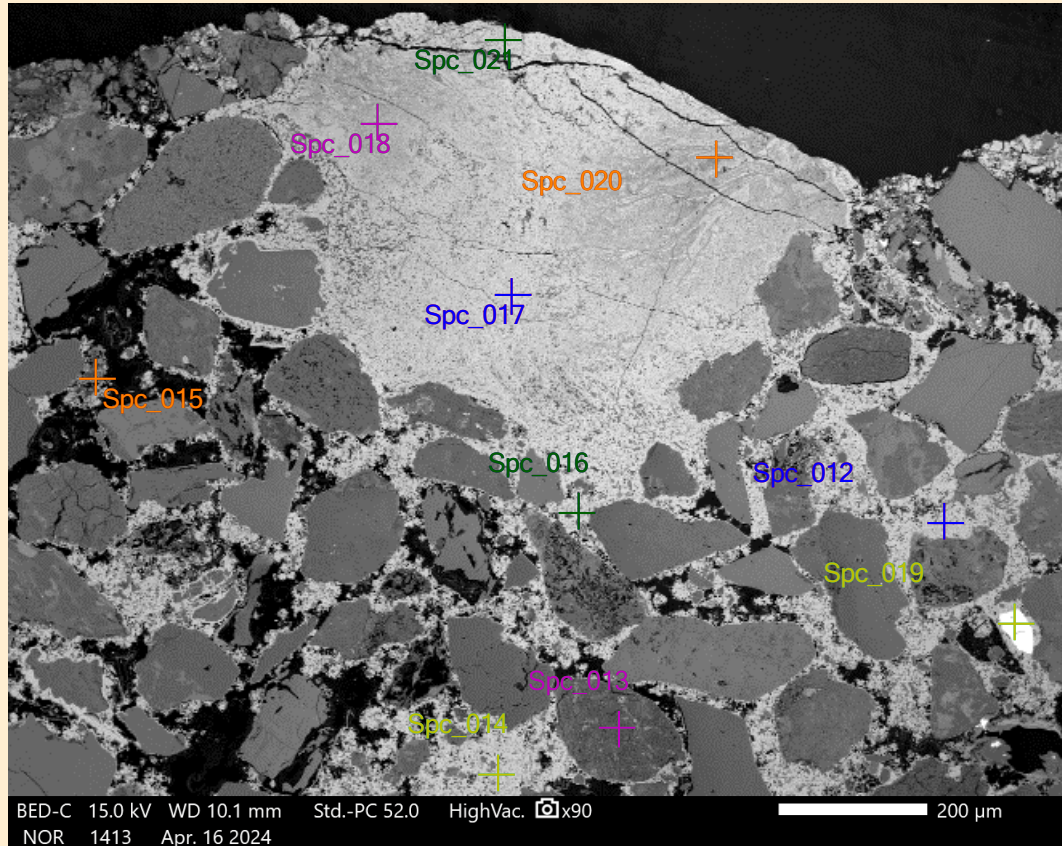
NDGS2000-S-2: 1413 SEM & EDS

- SEM image of the rightmost scale on the top of S-2
- The linear quality around the edges may represent high quality preservation of connecting tissue
- Stronger tissue attachments expected on the edges of the scales, less underneath



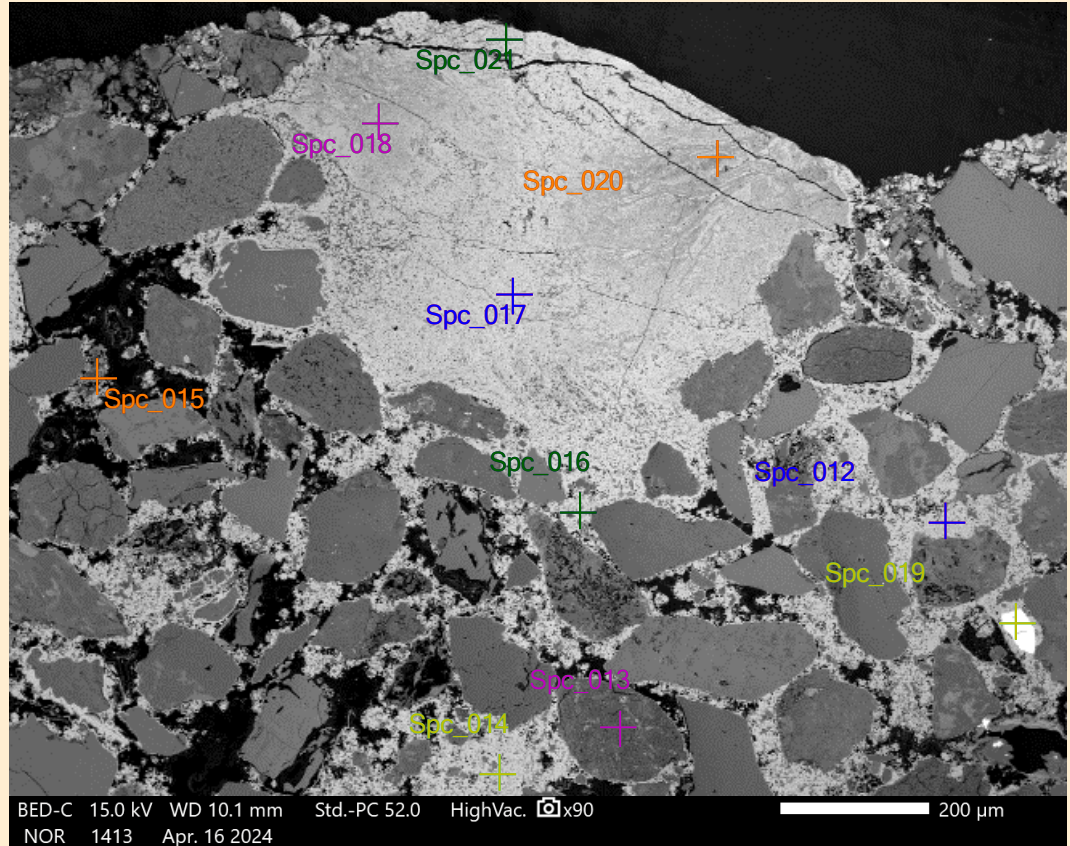
NDGS2000-S-2: 1413 SEM & EDS

- 10 points were chosen for EDS analysis
- Mix of skin, cement, and matrix

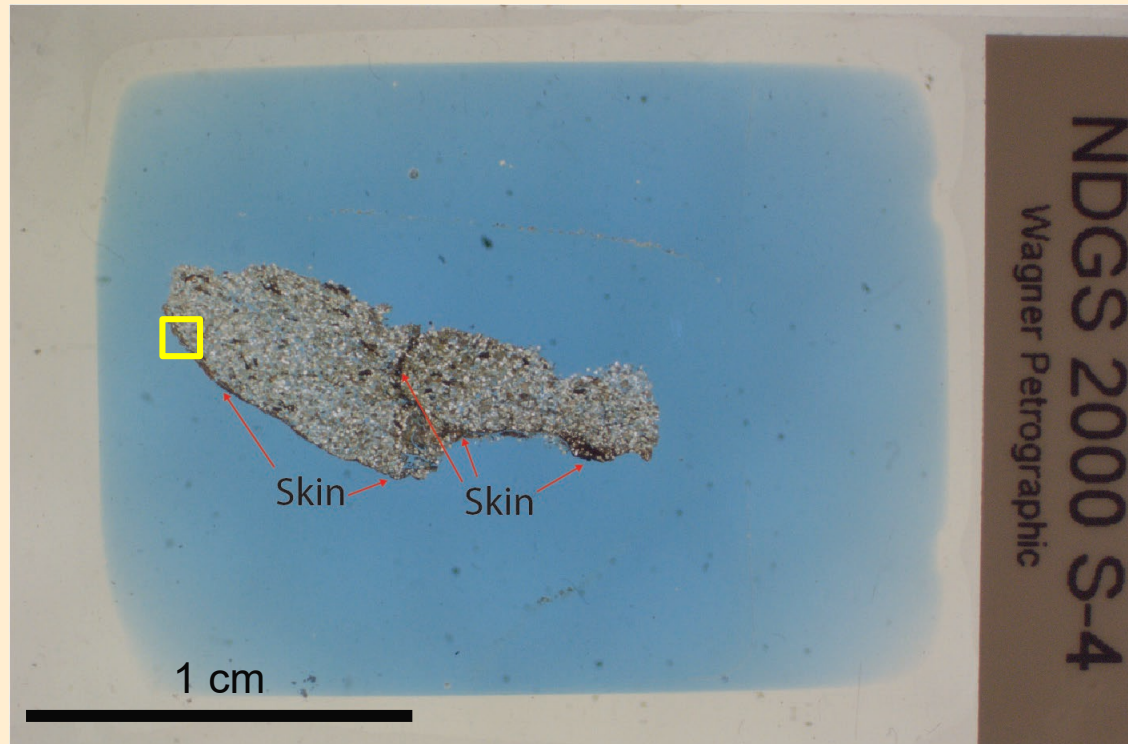


NDGS2000-S-2: 1413 SEM & EDS

- The skin is composed of an iron oxide, probably goethite
- The cement is also mainly goethite
- The matrix grains are of mixed composition
- The bright grain is composed of phosphate and rare earth elements (REE's), identified as Monazite-Ce

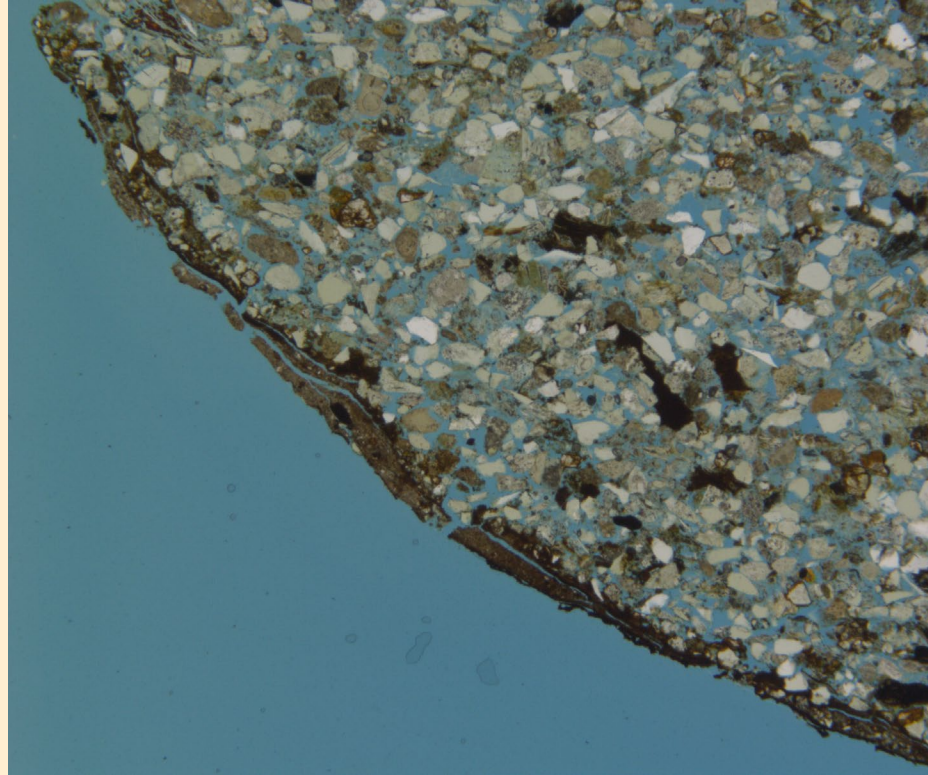


NDGS2000-S-4



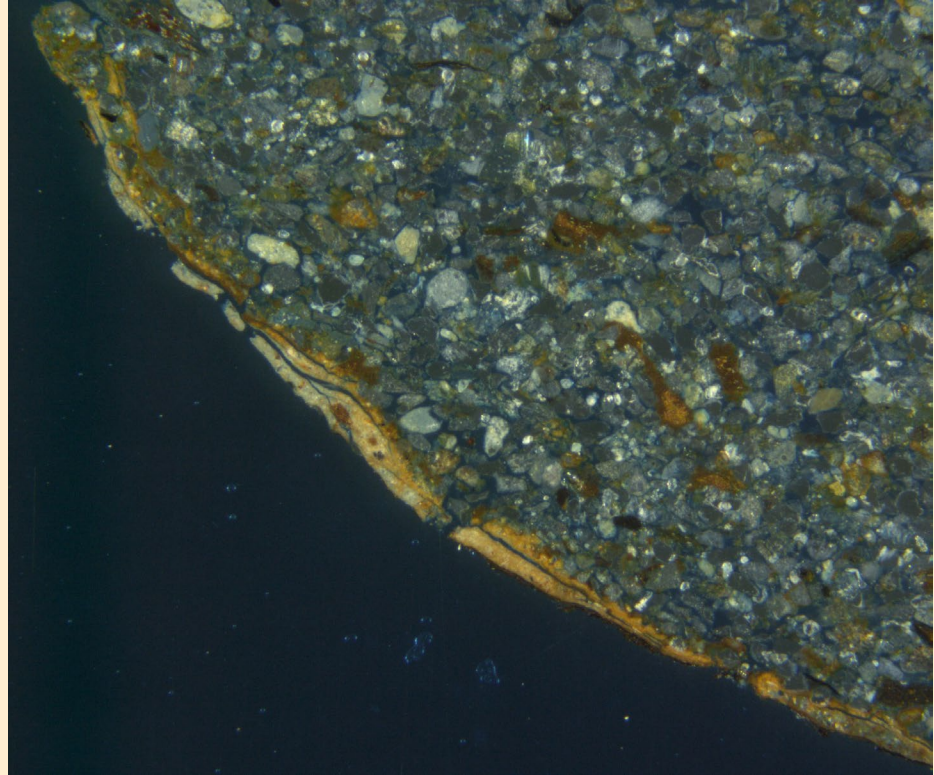
NDGS2000-S-4: 1418 Transmitted Light

- Best preserved skin on S4
- Less internal structure than on S-2
- Distinct layer visible, crack that runs through the skin across most of the sample
- Less cement than S2



NDGS2000-S-4: 1418 Transmitted Light

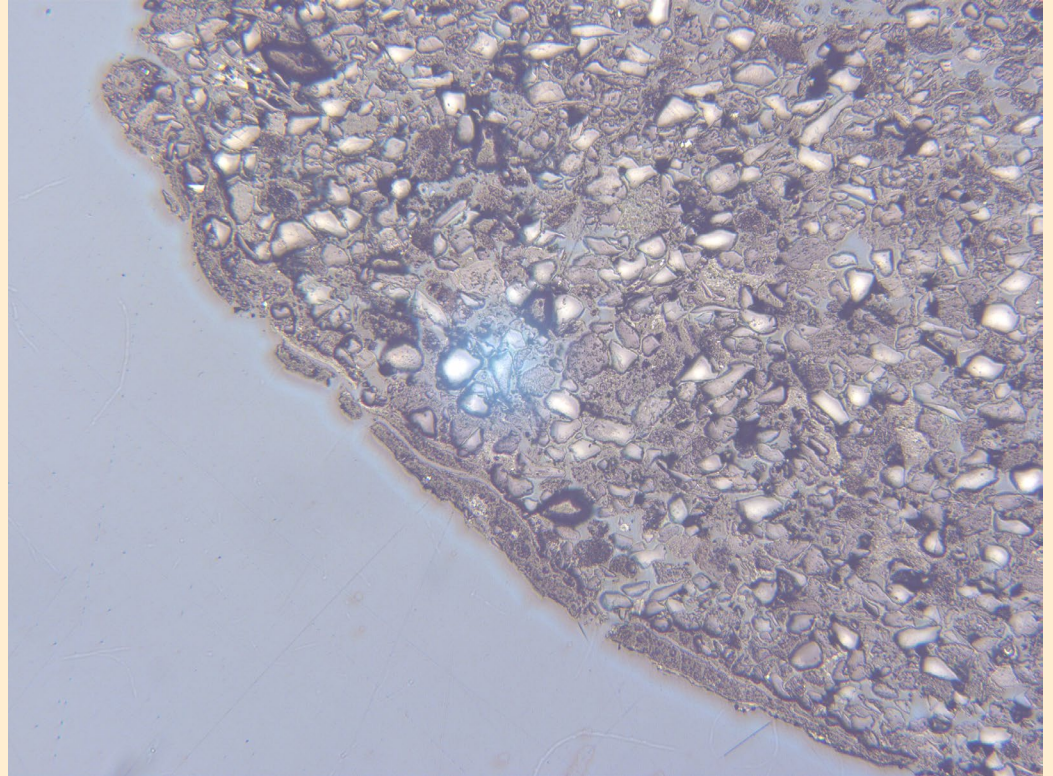
- Best preserved skin on S4
- Less internal structure than on S-2
- Distinct layer visible, crack that runs through the skin across most of the sample
- Less cement than S2



FOV: ~4 mm

NDGS2000-S-4: 1418 Reflected Light

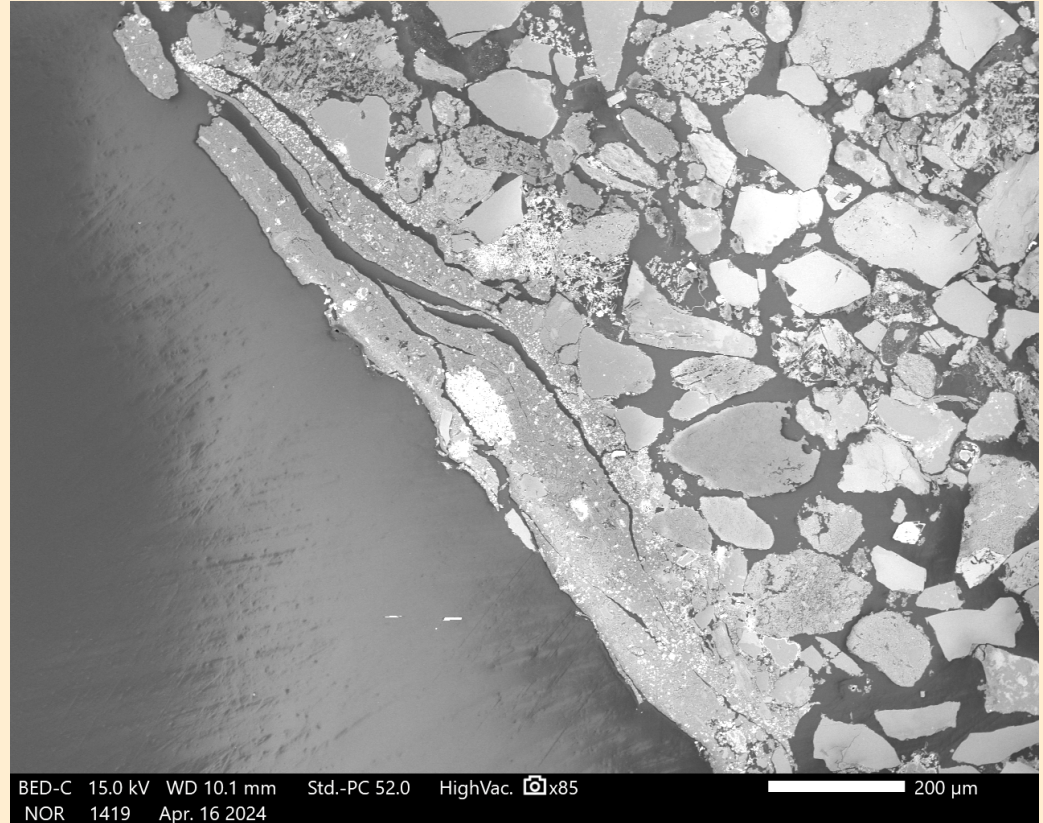
- Best preserved skin on S4
- Less internal structure than on S-2
- Distinct layer visible, crack that runs through the skin across most of the sample
- Less cement than S2



FOV: 4.5 mm

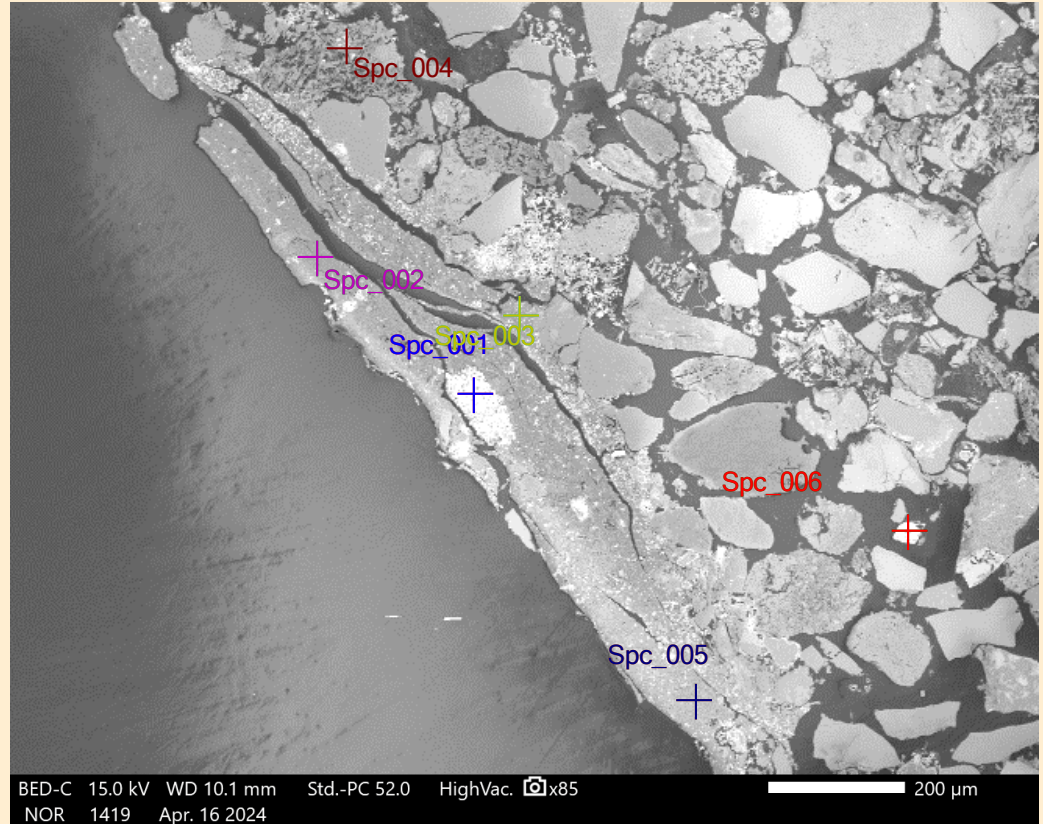
NDGS2000-S-4: 1418 SEM & EDS

- Bright grain visible in the skin
- Layer against the matrix has more impurities



NDGS2000-S-4: 1418 SEM & EDS

- 6 points were chosen for EDS analysis
- Mix of skin, cement, and matrix



NDGS2000-S-4: 1418 Initial Results

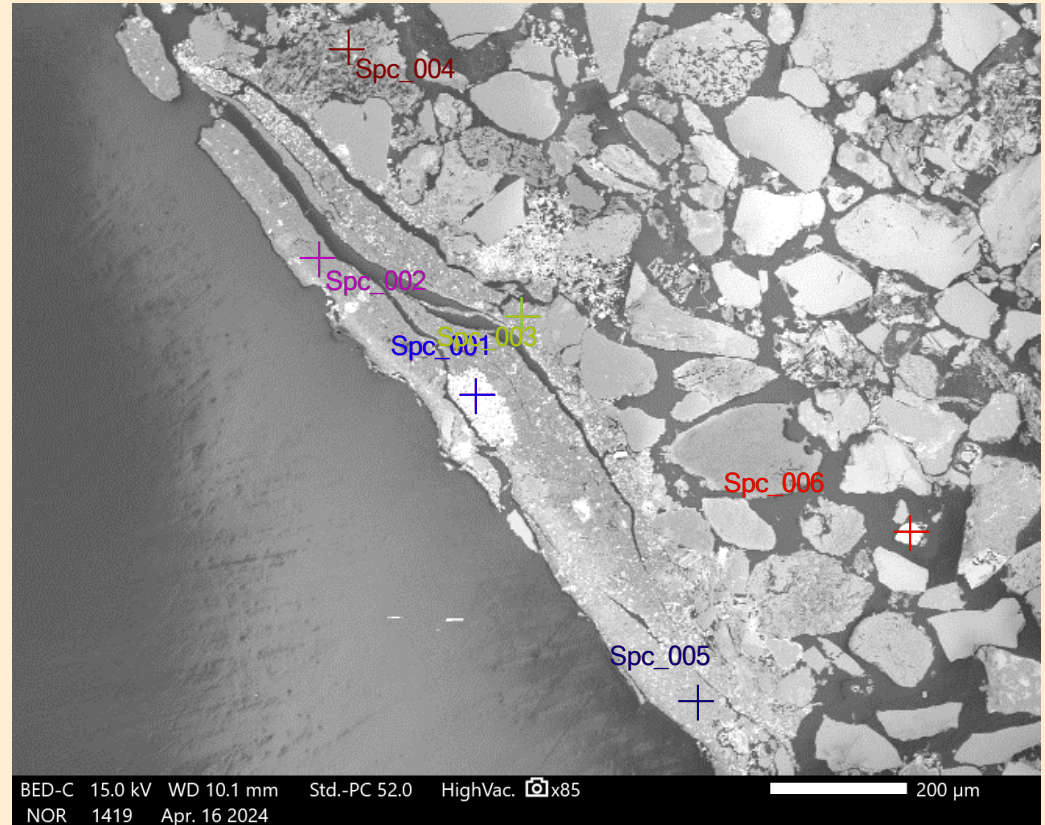
Sample NDGS-2000-S-4						
SEM Area ITSEM-1418		Location: Just under leftmost tip				
Atom %						
Identifier	Spc_001	Spc_002	Spc_003	Spc_004	Spc_005	Spc_006
C	9.89	17.26	19.6	50.85	18.62	9.09
N				2.83		
O	69.33	56.62	55.88	37.22	56.94	71.1
Na		0.85	0.59	0.41	0.74	0.75
Mg	1.56	1.19	0.99	0.25	0.88	0.36
Al	1.14	6.78	6.25	0.89	6.88	
Si	4.12	15.02	14.53	2.64	14.18	5.56
P						0.09
Cl				0.23		
K	0.32	0.39	0.19		0.67	
Ca	0.33			0.15		0.61
Ti		0.26		0.85		
Mn	0.48			0.09		
Fe	12.84	1.63	1.97	3.58	1.08	12.44
Total	100.00	100.00	100.00	100.00	100.00	100.00
Description:	Light grain in skin	Skin	Skin	Cement	Skin	Light grain (matrix)
Type	Point	Point	Point	Point	Point	Point
Identification:	Siderite	Unsure, Al Si CO3	Unsure, Al Si CO3	Unsure, very high C	Unsure, Al Si CO3	Siderite? High Si
Notes:						

NDGS2000-S-4: 1418 Without Carbon

Sample NDGS-2000-S-4						
SEM Area ITSEM-1418		Location:		Just under leftmost tip		
Atom %						
Identifier	Spc_001	Spc_002	Spc_003	Spc_004	Spc_005	Spc_006
N	0.00	0.00	0.00	5.76	0.00	0.00
O	76.93	68.43	69.50	75.74	69.98	78.21
Na	0.00	1.03	0.73	0.83	0.91	0.82
Mg	1.73	1.44	1.23	0.51	1.08	0.40
Al	1.26	8.19	7.77	1.81	8.46	0.00
Si	4.57	18.15	18.07	5.37	17.43	6.12
P	0.00	0.00	0.00	0.00	0.00	0.10
Cl	0.00	0.00	0.00	0.47	0.00	0.00
K	0.36	0.47	0.24	0.00	0.82	0.00
Ca	0.37	0.00	0.00	0.31	0.00	0.67
Ti	0.00	0.31	0.00	1.73	0.00	0.00
Mn	0.53	0.00	0.00	0.18	0.00	0.00
Fe	14.25	1.97	2.45	7.29	1.33	13.68
Total	100.00	100.00	100.00	100.00	100.00	100.00
Description:	Light grain in skin	Skin	Skin	Cement	Skin	Light grain (matrix)
Type	Point	Point	Point	Point	Point	Point
Identification:	Goethite	Unsure, Al, Mg, Fe rich silicate?	Unsure, Al, Mg, Fe rich silicate?	Unsure	Unsure, Al, Mg, Fe rich silicate?	Goethite
Notes:						

NDGS2000-S-4: 1418 SEM & EDS

- Results are less cohesive
- Goethite detected in the skin and matrix
- Composition of the skin is uncertain, mostly SiO₂ with some Al, Mg, and Fe
- Could be the result of a microscopic mixture of minerals
- Need to run XRD



Future Work

- Opaque minerals reading as siderite will be reevaluated
- Siderite and other relevant minerals will be tested using the same SEM for reference
- SEM-EDS work will be continued on the thin sections to cover more area
- Spot XRD will be run on some of the opaque areas to help narrow down the mineral composition

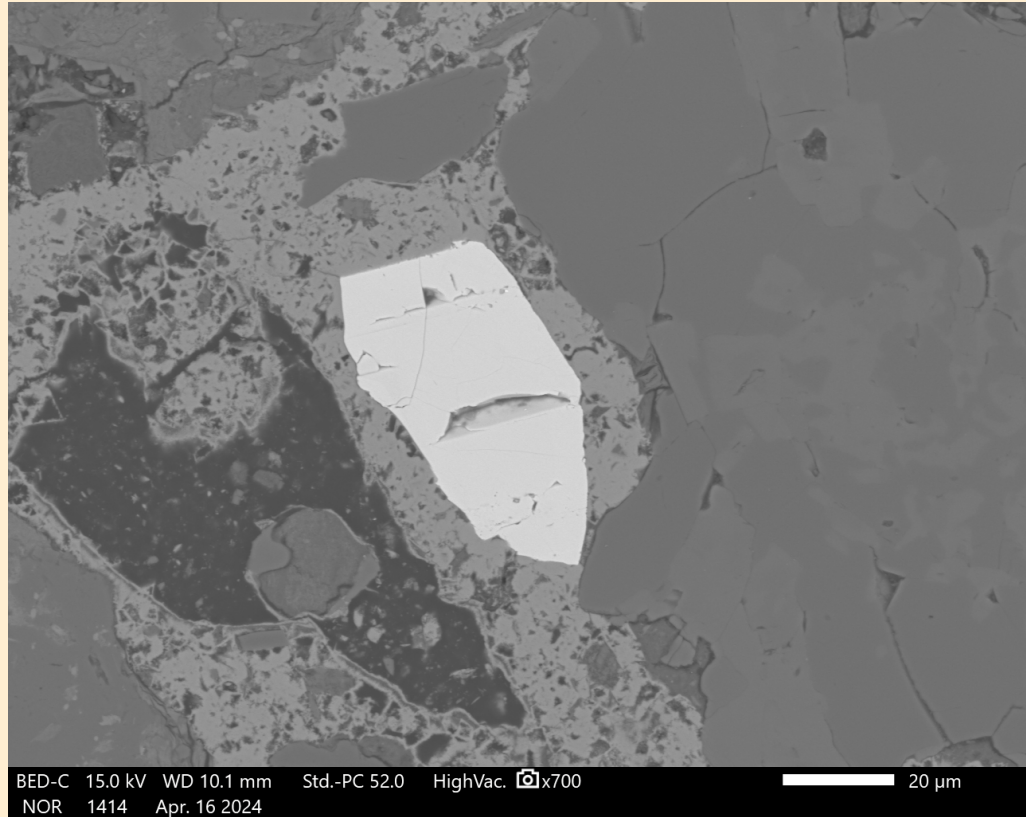


References

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5. Vajda, V., Lyson, T.R., Bercovici, A., Doman, J.H., and Pearson, D.A., 2013, A snapshot into the terrestrial ecosystem of an exceptionally well-preserved dinosaur (Hadrosauridae) from the Upper Cretaceous of North Dakota, USA: Cretaceous Research, v. 46, p. 114–122, doi: 10.1016/j.cretres.2013.08.010.

NDGS2000-S-2: 1414

- Close up of the Monazite grain
- Very bright
- A box was used to test the grain using EDS



NDGS2000-S-2: 1414 Initial Results

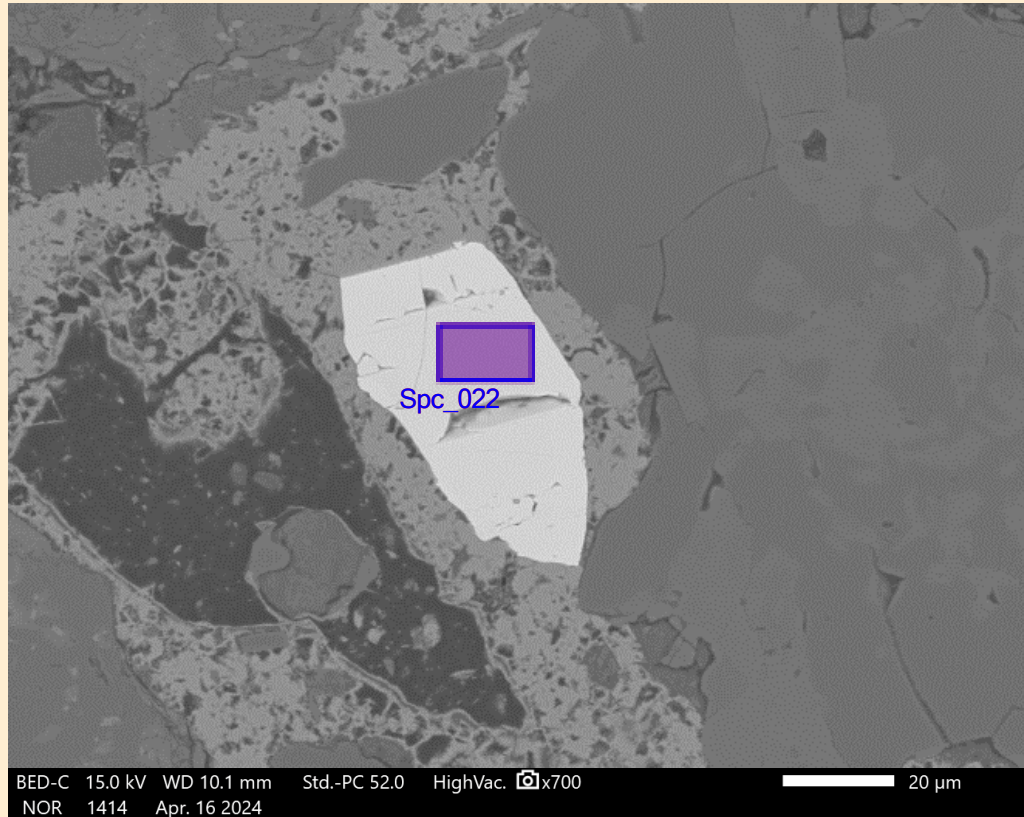
Sample NDGS-2000-S-2			
SEM Area ITSEM-1414	Location:	Third scale from the left	
Atom %			
Identifier	Spc_022		
C	9.12		
O	66.19		
P	13.66		
Ca	0.82		
La	3.1		
Ce	5.81		
Th	1.3		
Total	100.00		
Description:	Bright grain		
Type:	Point		
Identification:	Monazite group		
Notes:			

NDGS2000-S-2: 1414 Without Carbon

Sample NDGS-2000-S-2			
SEM Area			
ITSEM-1414	Location:	Third scale from the left	
Atom %			
Identifier	Spc_022		
O	72.83		
P	15.03		
Ca	0.90		
La	3.41		
Ce	6.39		
Th	1.43		
Total	100.00		
Description:	Bright grain		
Type:	Point		
Identification:	Monazite group		
Notes:			

NDGS2000-S-2: 1414

- Close up of the Monazite grain
- Monazite is a Ce phosphate
- Very bright
- A box was used to test the grain using EDS
- High REE's expected with the phosphate



Danke!

Habt ihr noch Fragen?

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