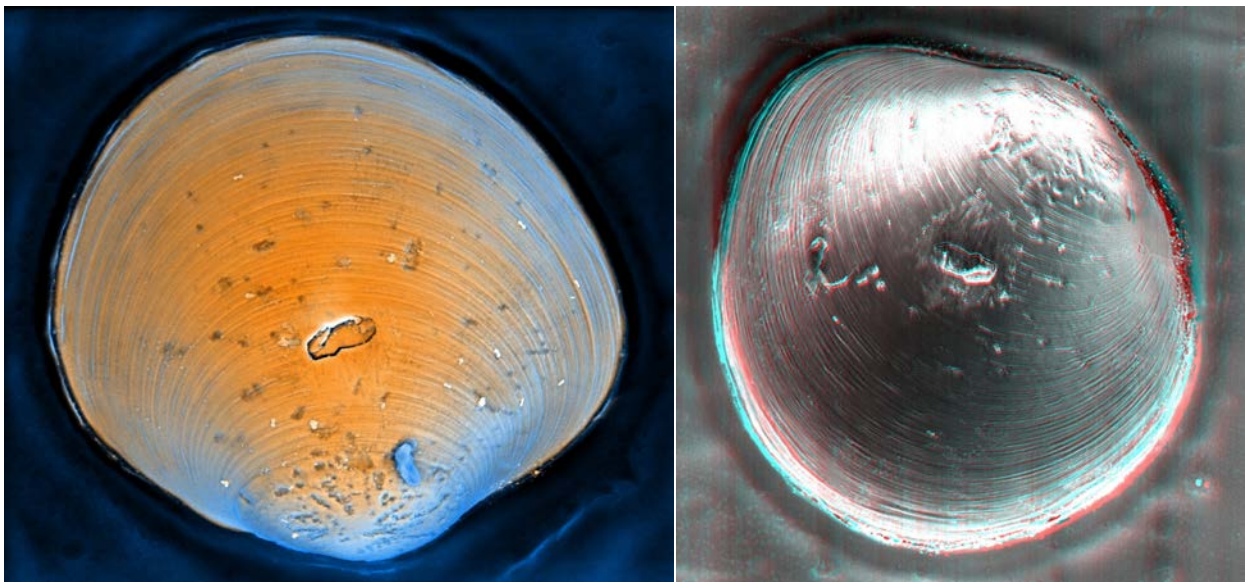
RECLAMATION

Managing Water in the West

Scanning Electron Microscope (SEM) Imaging and Anaglyphs of Invasive Mussel Veligers

Research and Development Office
Science and Technology Program
Final Report ST-2015-7361



Audrey Rager

U.S. Department of the Interior
Bureau of Reclamation
Research and Development Office

December 2015

Mission Statements

The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

REPORT DOCUMENTATION PAGE		Form Approved OMB No. 0704-0188
T1. REPORT DATE Dec 31, 2015	**T2. REPORT TYPE** Research	**T3. DATES COVERED**
T4. TITLE AND SUBTITLE Scanning Electron Microscope (SEM) Imaging and Anaglyphs of Invasive Mussel Veligers		**5a. CONTRACT NUMBER** 15XR0680A1-RY1541ZQ201517361
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER 1541 (S&T)
6. AUTHOR(S) Audrey Rager, 303-445-2377, arager@usbr.gov		**5d. PROJECT NUMBER** 7361
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER 86-68530
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Audrey Rager, U.S. Bureau of Reclamation, Denver, CO		**8. PERFORMING ORGANIZATION REPORT NUMBER** MERL-2015-108
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Research and Development Office U.S. Department of the Interior, Bureau of Reclamation, PO Box 25007, Denver CO 80225-0007		**10. SPONSOR/MONITOR'S ACRONYM(S)** **R&D: Research and Development Office** **BOR/USBR: Bureau of Reclamation** **DOI: Department of the Interior**
		11. SPONSOR/MONITOR'S REPORT NUMBER(S) ST-2015-7361

12. DISTRIBUTION / AVAILABILITY STATEMENT
Final report can be downloaded from Reclamation's website: https://www.usbr.gov/research/

13. SUPPLEMENTARY NOTES

14. ABSTRACT *(Maximum 200 words)*

Zebra and quagga mussels are prolific breeders, clogging water intake structures that impact water treatment facilities and power-producing infrastructure. Because adult populations are difficult to discover by normal field sampling procedures, the Reclamation Detection Laboratory for Invasive and Native Species has discovered that identifying the mussels in their veliger stages gives water managers an earlier warning about a possible infestation than waiting for adult populations. The purpose of this scoping study was to determine whether 3D images and anaglyphs created from stereo-pairs of SEM images could aid Detection Laboratory biologists in identifying and studying morphological differences and changes in invasive mussels. This report includes the SEM images of invasive mussel veligers as well as anaglyphs created from selected stereo-pairs of these images.

15. SUBJECT TERMS
Invasive mussels, quagga mussels, zebra mussels, SEM, scanning electron microscopy, 3D model, anaglyph

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON** Audrey Rager
a. REPORT U	**b. ABSTRACT** U	**c. THIS PAGE** U	**U**	54	**19b. TELEPHONE NUMBER** 303-445-2125

S Standard Form 298 (Rev. 8/98)
P Prescribed by ANSI Std. 239-18

PEER REVIEW DOCUMENTATION

Project and Document Information

Project Name 3D Models of Invasive Mussel Veligers WOID Z7361

Document Scanning Electron Microscope (SEM) Imaging and Anaglyphs of Invasive Mussel Veligers

Document Author(s) Audrey Rager Document date 12/31/2015

Peer Reviewer Denise Hosler

Review Certification

Peer Reviewer: I have reviewed the assigned items/sections(s) noted for the above document and believe them to be in accordance with the project requirements, standards of the profession, and Reclamation policy.

Reviewer Denise M. Hosler (Signature) Date reviewed 12/31/2015

Executive Summary

Introduction

The original goal of this project was to determine whether Alicona MeX software could be used to create 3D models and anaglyphs from stereo-pairs of Scanning Electron Microscope (SEM) images of invasive mussel veligers. However delays in receipt of funding and purchase of software necessary to complete the work prevented completion of the project as proposed.

Purpose

Zebra and quagga mussels are prolific breeders, clogging water intake structures that impact water treatment facilities and power-producing infrastructure. Because adult populations are difficult to discover by normal field sampling procedures, the Reclamation Detection Laboratory for Invasive and Native Species has discovered that identifying the mussels in their veliger stages gives water managers an earlier warning about a possible infestation than waiting for adult populations.

Veligers, the larval form of mussels and other bivalves, are microscopic (between 97 and 492 microns). The purpose of this scoping study was to determine whether 3D images and anaglyphs created from stereo-pairs of SEM images could aid Detection Laboratory biologists in identifying and studying morphological differences and changes in invasive mussels.

Increasing our knowledge of these species may (1) help Reclamation in early detection, (2) add to our understanding of the conditions under which these species thrive, and (3) help determine how invasive species spread by defining morphological differences in populations.

Results

Between August, 2014 and September, 2015, Detection Laboratory biologists collected ten samples of possible invasive mussels from nine water bodies. These samples were submitted to the PI for SEM imaging during FY2015.

Because of delays in receiving funding and the Alicona MeX software, 3D models were not created. However, anaglyphs were created using stereo-pair SEM images of some samples.

SEM images of the samples may be found in Appendix A. Appendix B includes the anaglyphs created for some of the samples using Alicona MeX software (Alicona, 2013). Anaglyphs can be viewed with 3D glasses with a red filter in the left lens and a blue filter in the right lens.

Table 1 summarizes the invasive mussel sample ID numbers, sample locations and where the images can be found in the appendices.

Table 1. Summary of Invasive Mussel Veliger Samples and their associated SEM images and Anaglyphs.

Sample ID	State	Water Body	Date Collected	SEM Images (Appendix A)	Anaglyphs (Appendix B)
E0767	SD	Angostura Reservoir	08/05/2014	Figure A-1 Figure A-2 Figure A-3 Figure A-4 Figure A-5 Figure A-6 Figure A-7 Figure A-8 Figure A-9	-----
E0934	KS	Glen Elder Reservoir	09/11/2014	Figure A-10 Figure A-11	-----
E0940	OK	Lake Thunderbird (Norman Dam)	09/04/2014	Figure A-12	Figure B-1 Figure B-2 Figure B-3
E1212	CA	Santa Margarita River	10/26/2014	Figure A-13 Figure A-14 Figure A-15	-----
E1264	UT	Deer Creek Reservoir	10/30/2014	Figure A-16	Figure B-4
E1366	AZ	Apache Lake (Horse Mesa Dam)	12/19/2014	Figure A-17	Figure B-5
F0321	SD	Belle Fourche (Orman) Reservoir	06/01/2015	Figure A-18 Figure A-19 Figure A-20 Figure A-21	-----
F0573	AZ	Roosevelt Lake	07/21/2015	Figure A-22	Figure B-6
F0843	AZ	Apache Lake (Horse Mesa Dam)	08/19/2015	Figure A-23	Figure B-7
F0889	CO-NM	Navajo Reservoir	09/02/2015	Figure A-24 Figure A-25 Figure A-26 Figure A-27 Figure A-28 Figure A-29 Figure A-30 Figure A-31	Figure B-8 Figure B-9

References

Alicona, 2013, Alicona MeX User Manual: Turn Your SEM Into A 3D Measurement Device, MeX 6.1-EN-08.06.2013, 208 pp.

Appendix A

Scanning Electron Microscope Images of Mussel Veligers
FY 2015

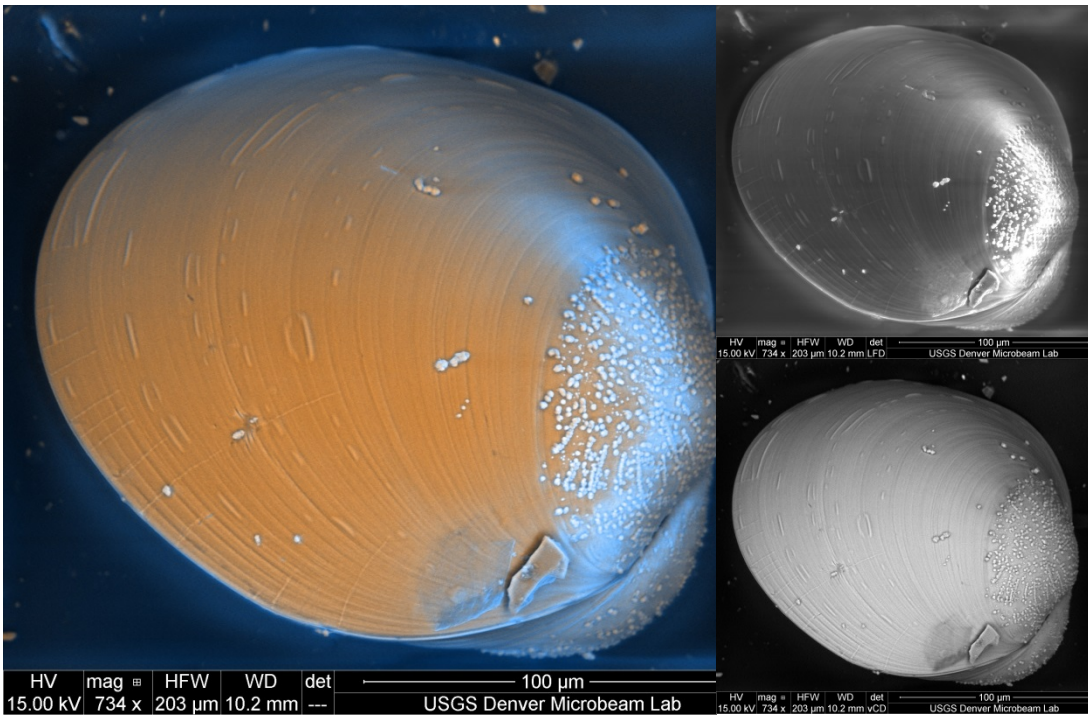


Figure A-1. Secondary Electron Image (SEI; upper right), Backscatter Electron Image (BSC; lower right), and false color composite image (left) of the SEI and BSC images.

ID	State	Water Body	Date Collected	Date Imaged
E0767	SD	Angostura Res	08/05/2014	11/14/2014

Scanning Electron Microscope (SEM) Imaging and Anaglyphs of Invasive Mussel Veligers

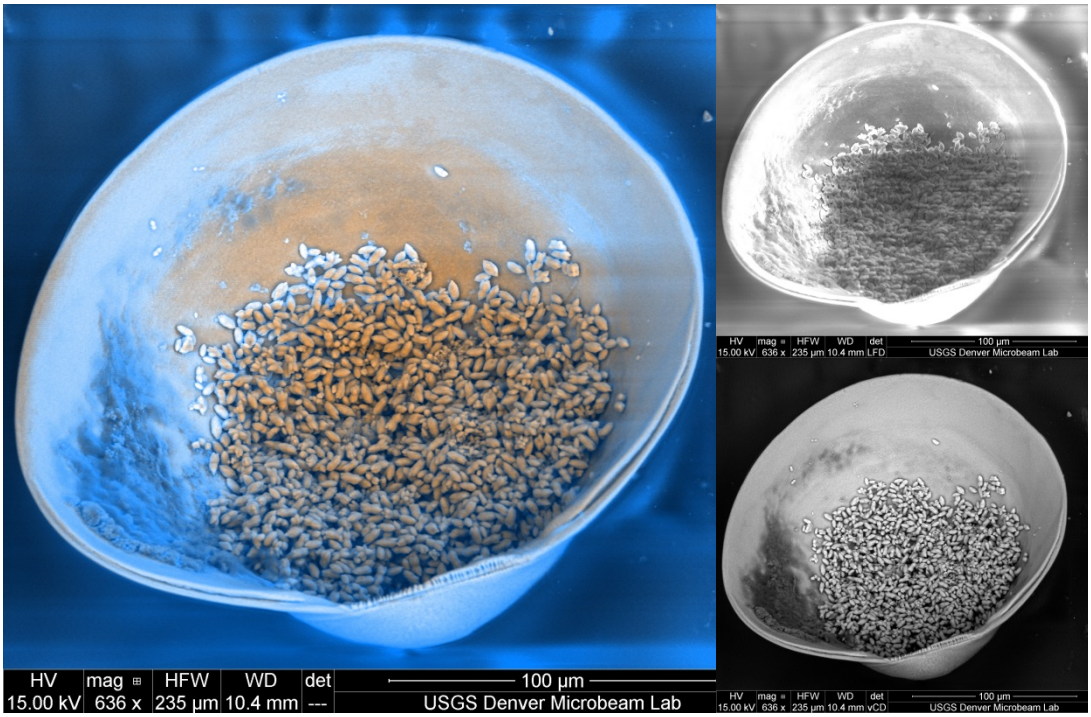


Figure A-2. SEI (upper right), BSC (lower right), and false color composite image (left) of the SEI and BSC images.

ID	State	Water Body	Date Collected	Date Imaged
E0767	SD	Angostura Res	08/05/2014	11/14/2014

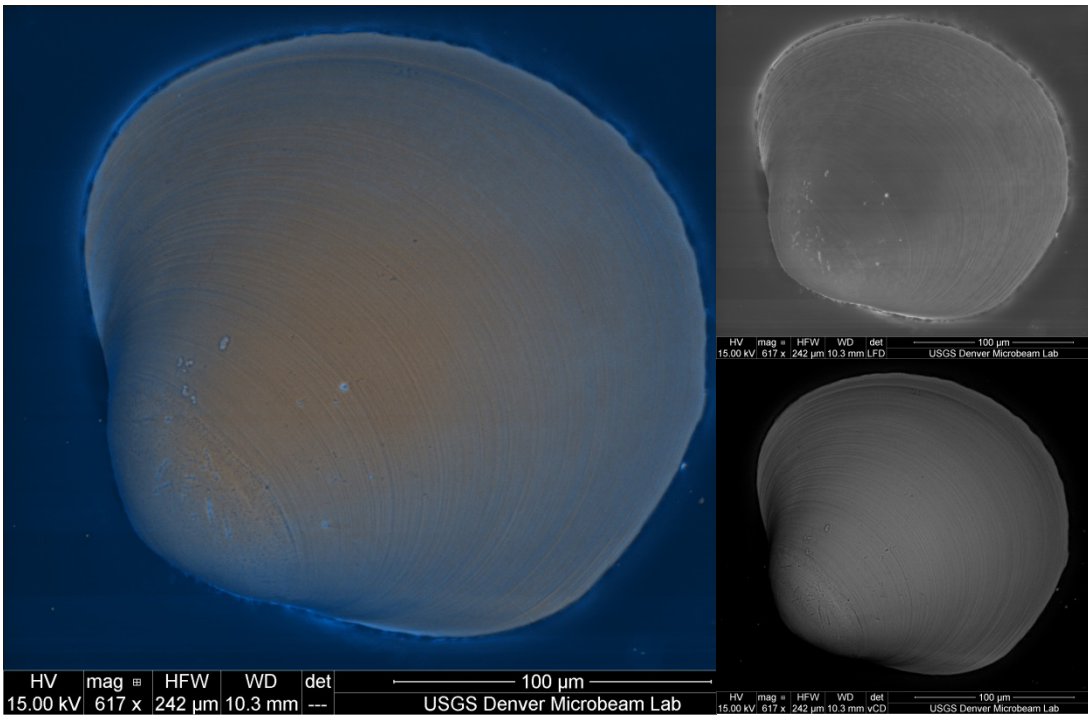


Figure A-3. SEI (upper right), BSC (lower right), and false color composite image (left) of the SEI and BSC images.

ID	State	Water Body	Date Collected	Date Imaged
E0767	SD	Angostura Res	08/05/2014	11/14/2014

Scanning Electron Microscope (SEM) Imaging and Anaglyphs of Invasive Mussel Veligers

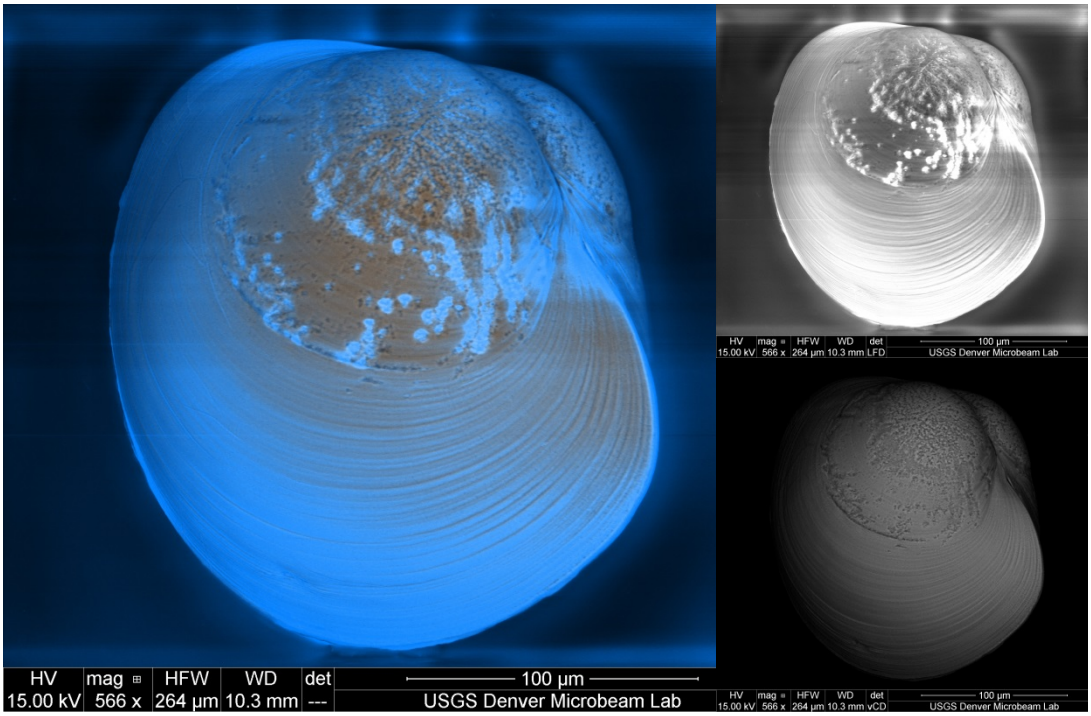


Figure A-4. SEI (upper right), BSC (lower right), and false color composite image (left) of the SEI and BSC images.

ID	State	Water Body	Date Collected	Date Imaged
E0767	SD	Angostura Res	08/05/2014	11/14/2014

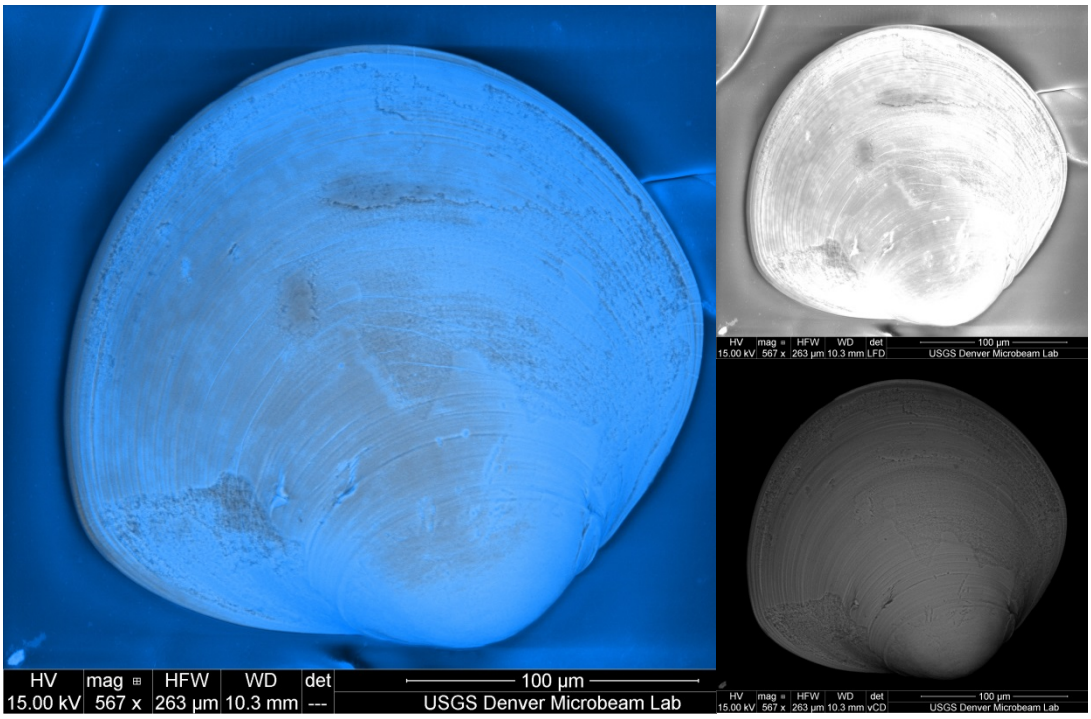


Figure A-5. SEI (upper right), BSC (lower right), and false color composite image (left) of the SEI and BSC images.

ID	State	Water Body	Date Collected	Date Imaged
E0767	SD	Angostura Res	08/05/2014	11/14/2014

Scanning Electron Microscope (SEM) Imaging and Anaglyphs of Invasive Mussel Veligers

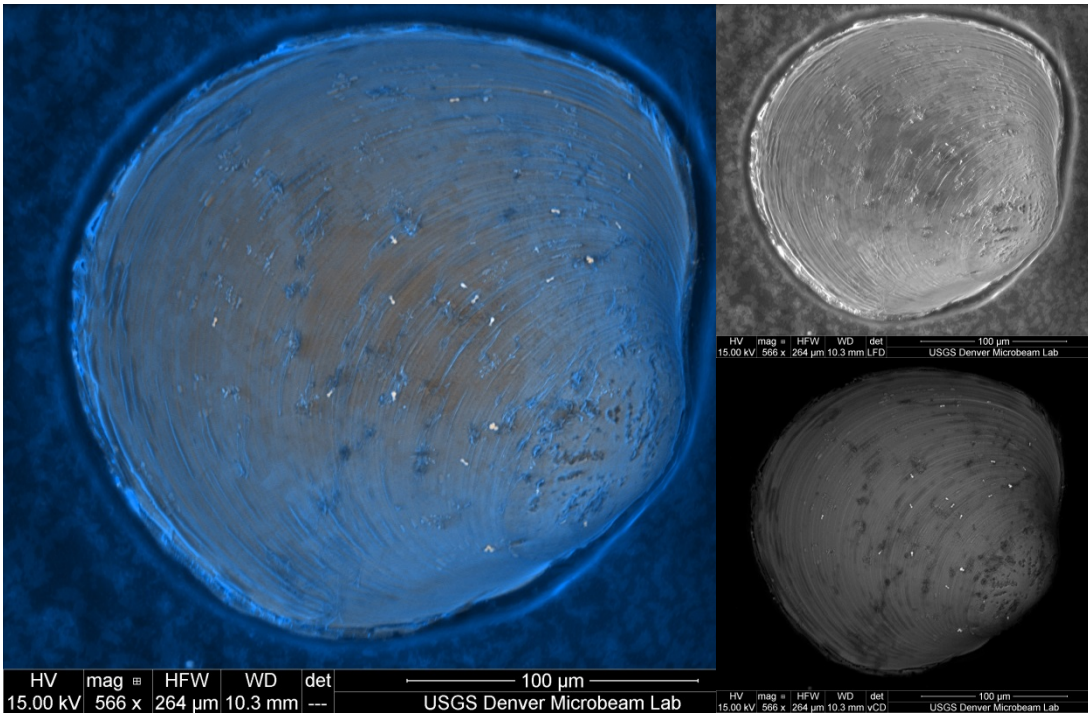


Figure A-6. SEI (upper right), BSC (lower right), and false color composite image (left) of the SEI and BSC images.

ID	State	Water Body	Date Collected	Date Imaged
E0767	SD	Angostura Res	08/05/2014	11/14/2014

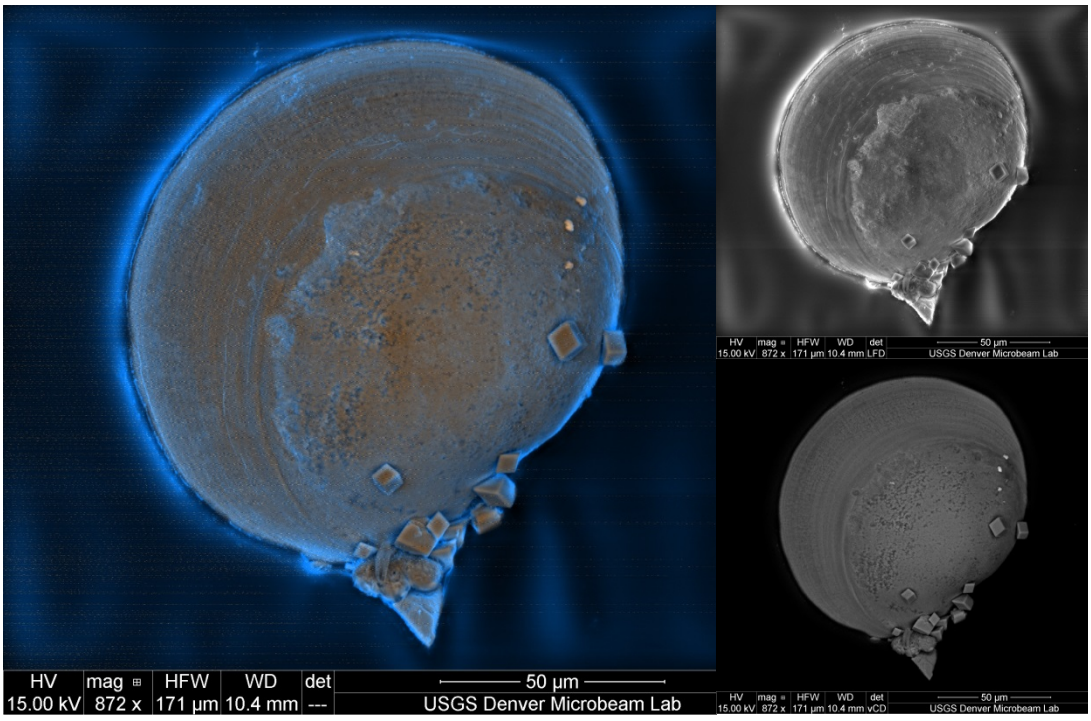


Figure A-7. SEI (upper right), BSC (lower right), and false color composite image (left) of the SEI and BSC images.

ID	State	Water Body	Date Collected	Date Imaged
E0767	SD	Angostura Res	08/05/2014	11/14/2014

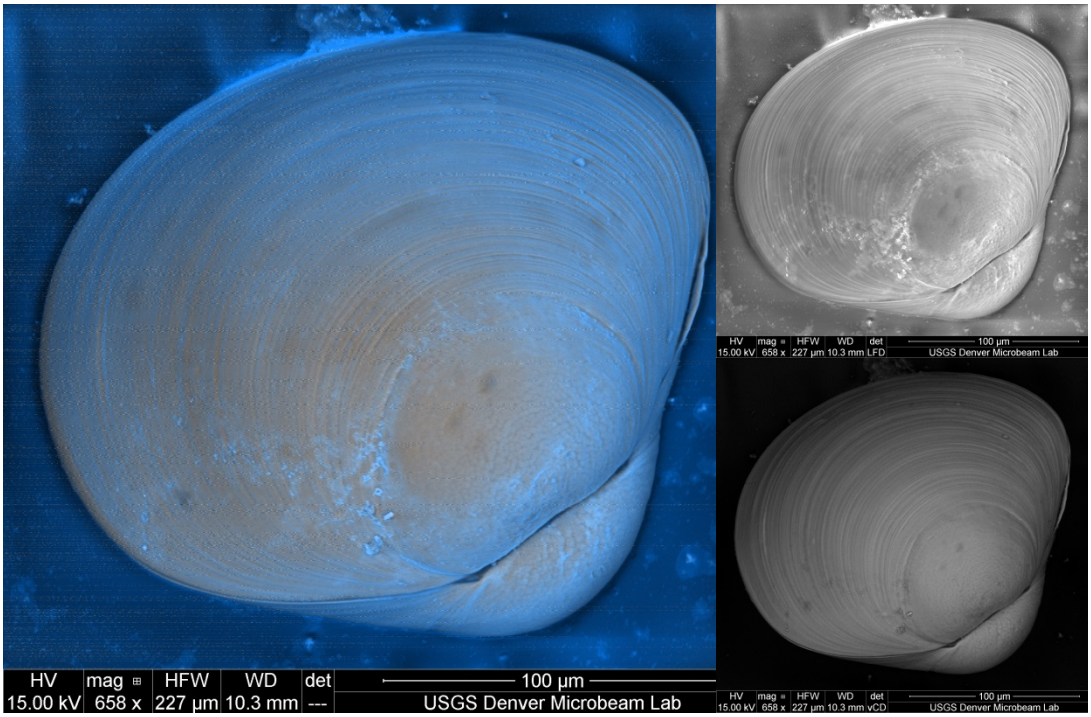


Figure A-8. SEI (upper right), BSC (lower right), and false color composite image (left) of the SEI and BSC images.

ID	State	Water Body	Date Collected	Date Imaged
E0767	SD	Angostura Res	08/05/2014	11/14/2014

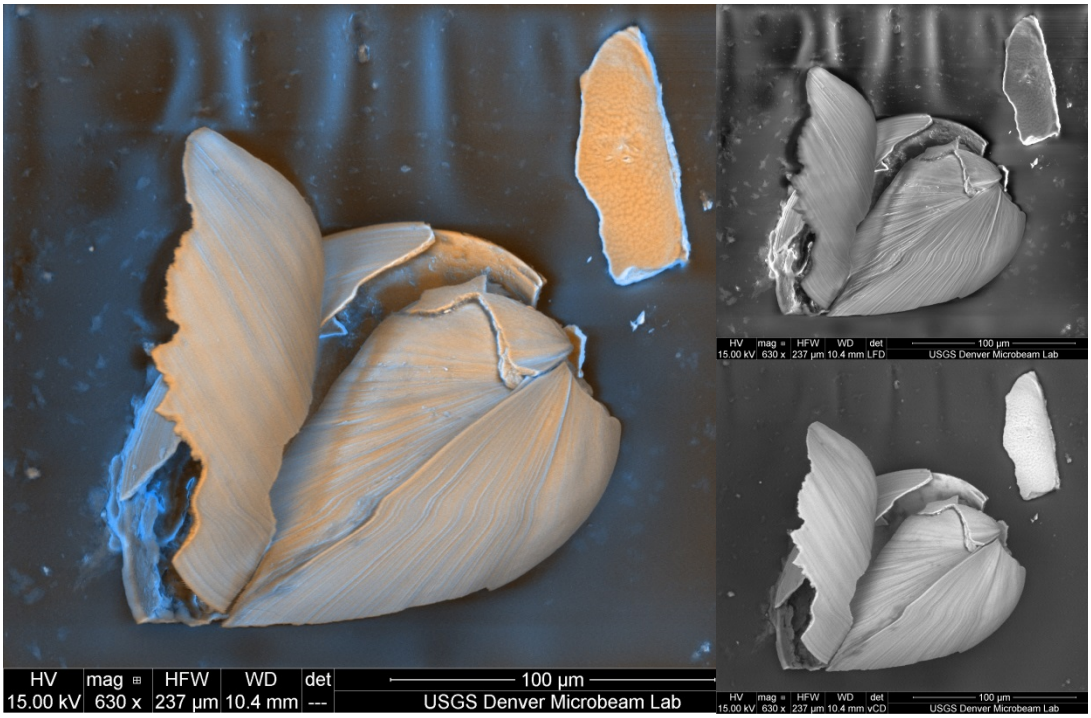


Figure A-9. SEI (upper right), BSC (lower right), and false color composite image (left) of the SEI and BSC images.

ID	State	Water Body	Date Collected	Date Imaged
E0767	SD	Angostura Res	08/05/2014	11/14/2014

Scanning Electron Microscope (SEM) Imaging and Anaglyphs of Invasive Mussel Veligers

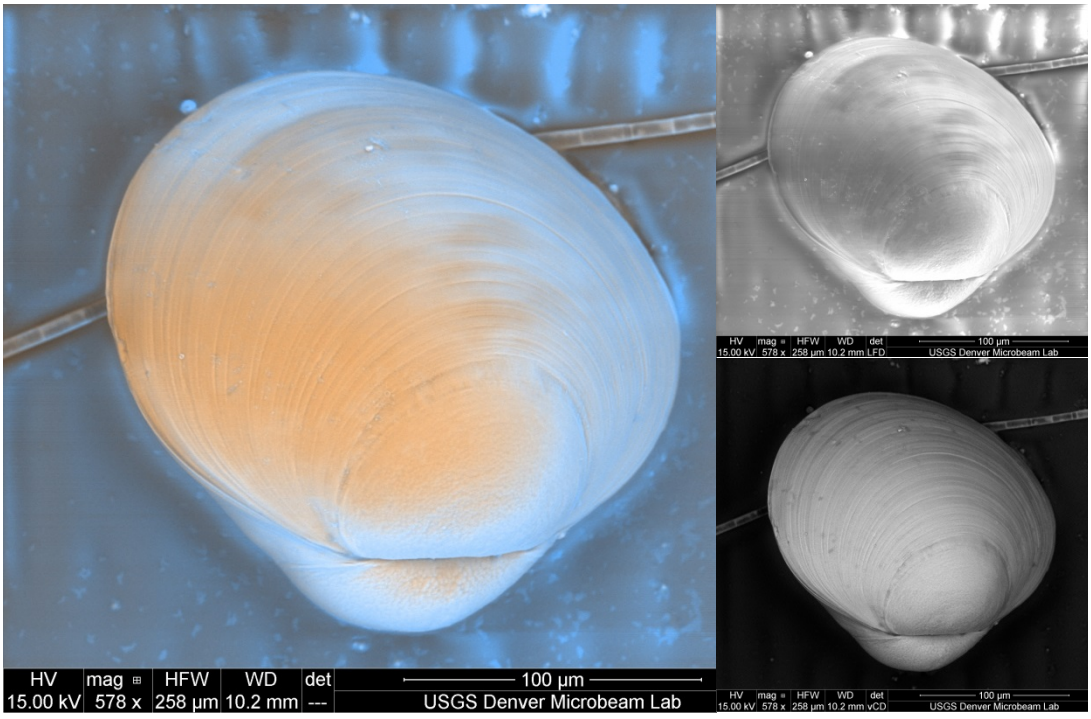


Figure A-10. SEI (upper right), BSC (lower right), and false color composite image (left) of the SEI and BSC images.

ID	State	Water Body	Date Collected	Date Imaged
E0934	KS	Glen Elder Res.	09/11/2014	11/14/2014

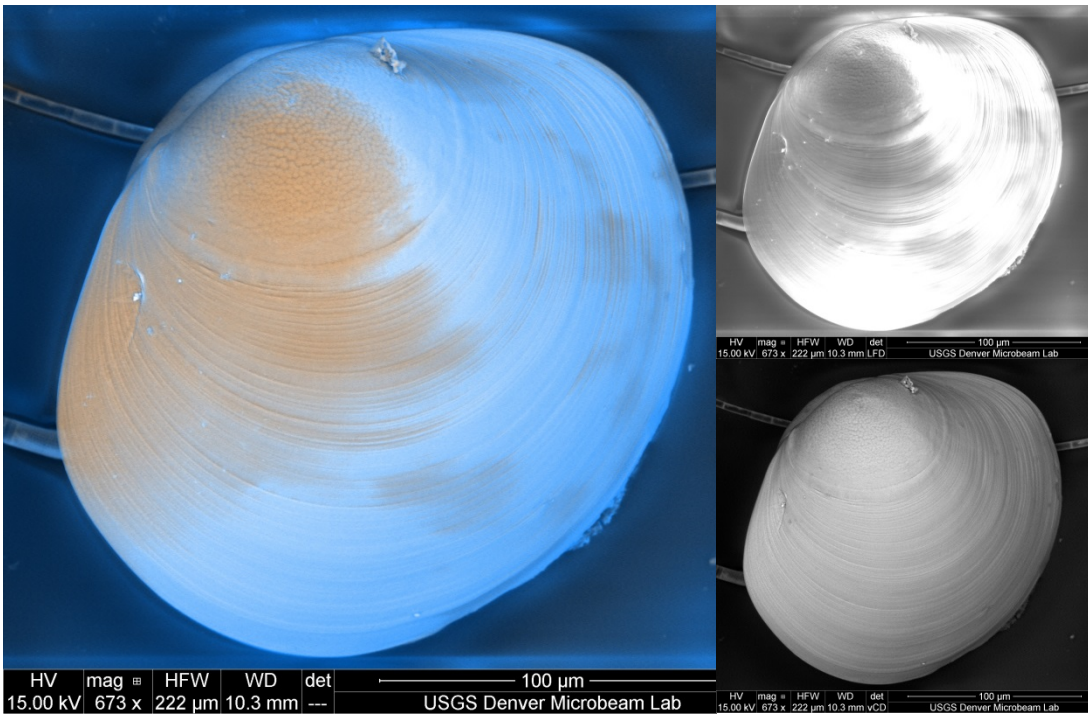


Figure A-11. SEI (upper right), BSC (lower right), and false color composite image (left) of the SEI and BSC images.

ID	State	Water Body	Date Collected	Date Imaged
E0934	KS	Glen Elder Res.	09/11/2014	11/14/2014

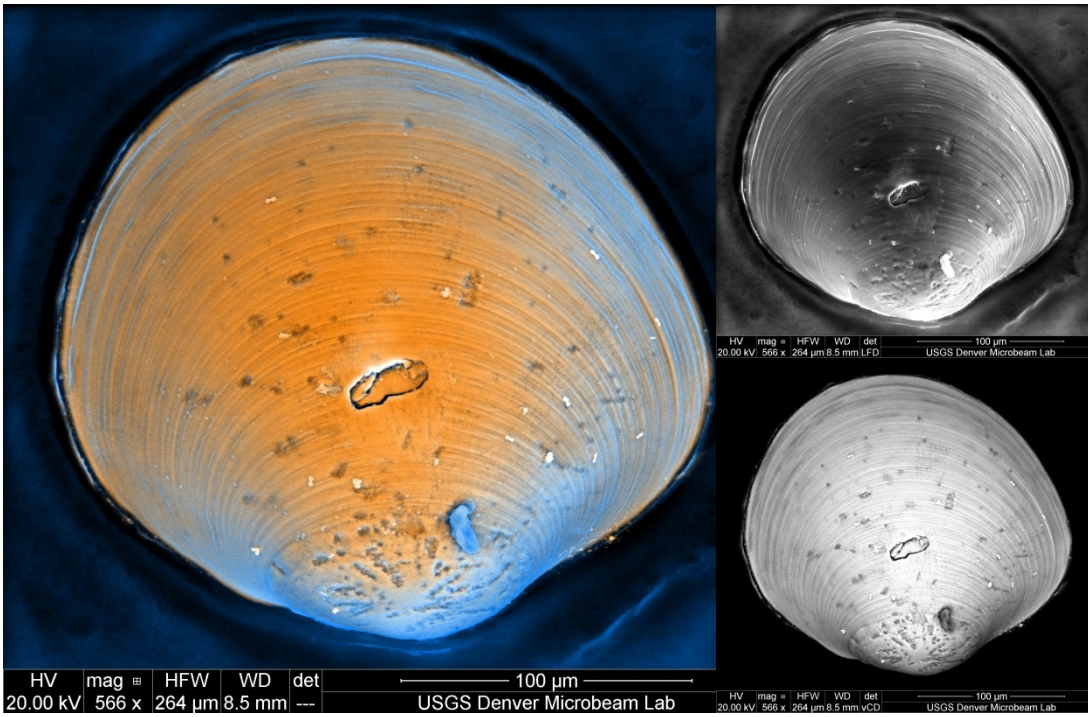


Figure A-12. SEI (upper right), BSC (lower right), and false color composite image (left) of the SEI and BSC images.

ID	State	Water Body	Date Collected	Date Imaged
E0940	OK	Lake Thunderbird (Norman Dam)	09/04/2015	02/03/2015 09/09/2015

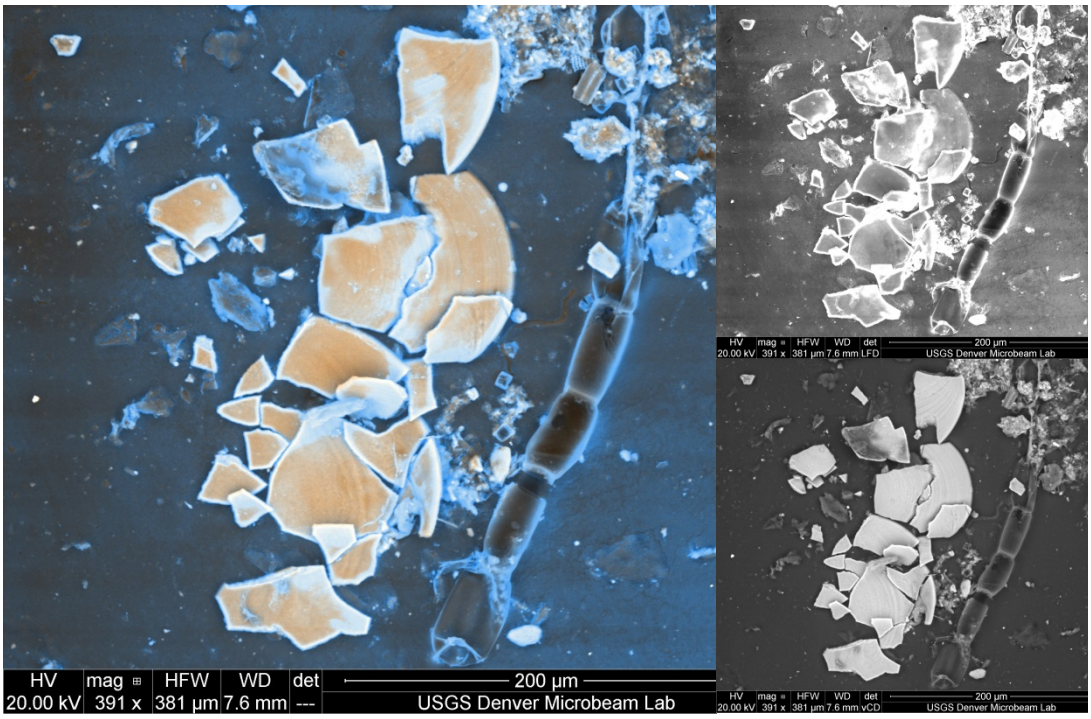


Figure A-13. SEI (upper right), BSC (lower right), and false color composite image (left) of the SEI and BSC images.

ID	State	Water Body	Date Collected	Date Imaged
E1212	CA	Santa Margarita River	10/26/2014	02/03/2015

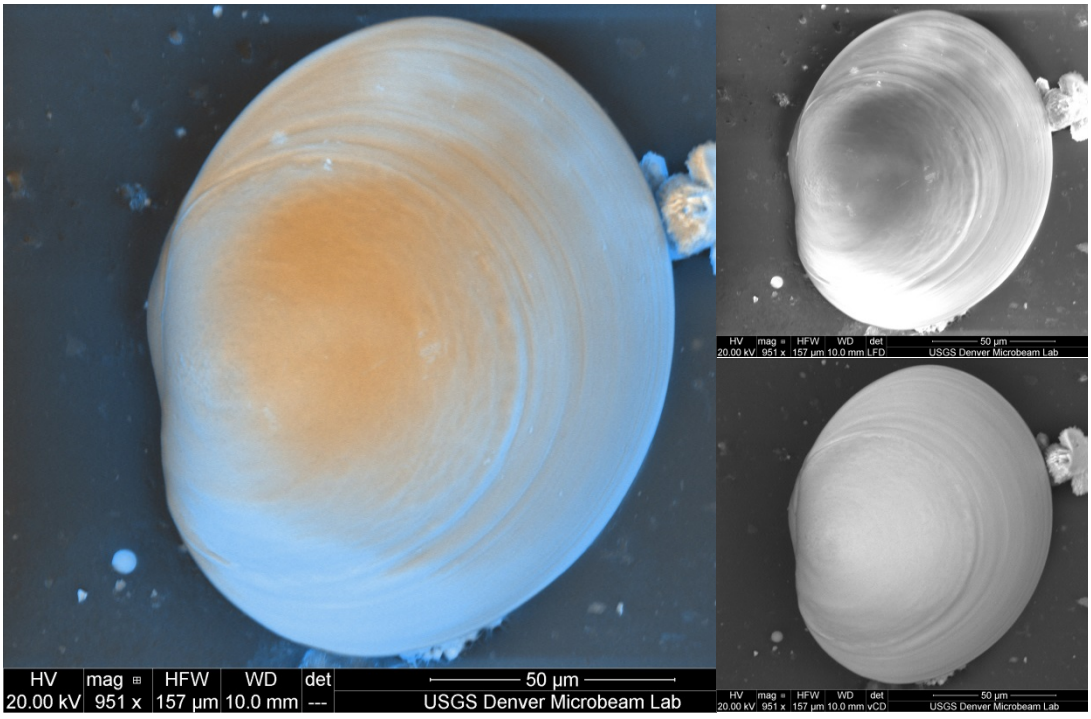


Figure A-14. SEI (upper right), BSC (lower right), and false color composite image (left) of the SEI and BSC images.

ID	State	Water Body	Date Collected	Date Imaged
E1212	CA	Santa Margarita River	10/26/2014	02/03/2015

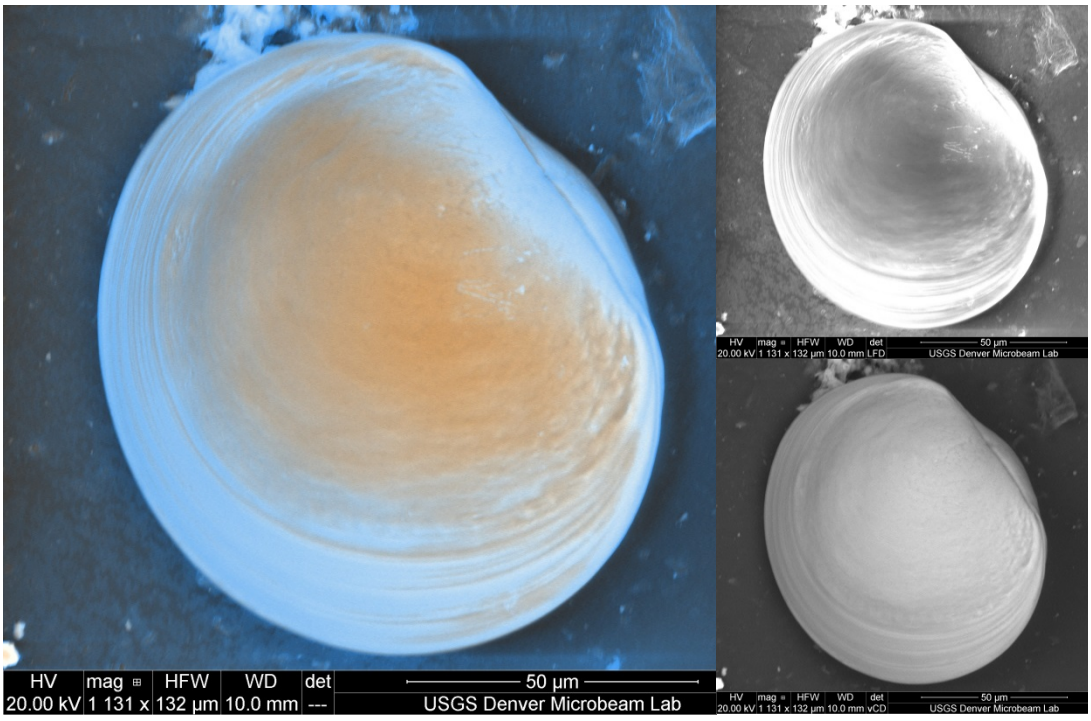


Figure A-15. SEI (upper right), BSC (lower right), and false color composite image (left) of the SEI and BSC images.

ID	State	Water Body	Date Collected	Date Imaged
E1212	CA	Santa Margarita River	10/26/2014	02/03/2015

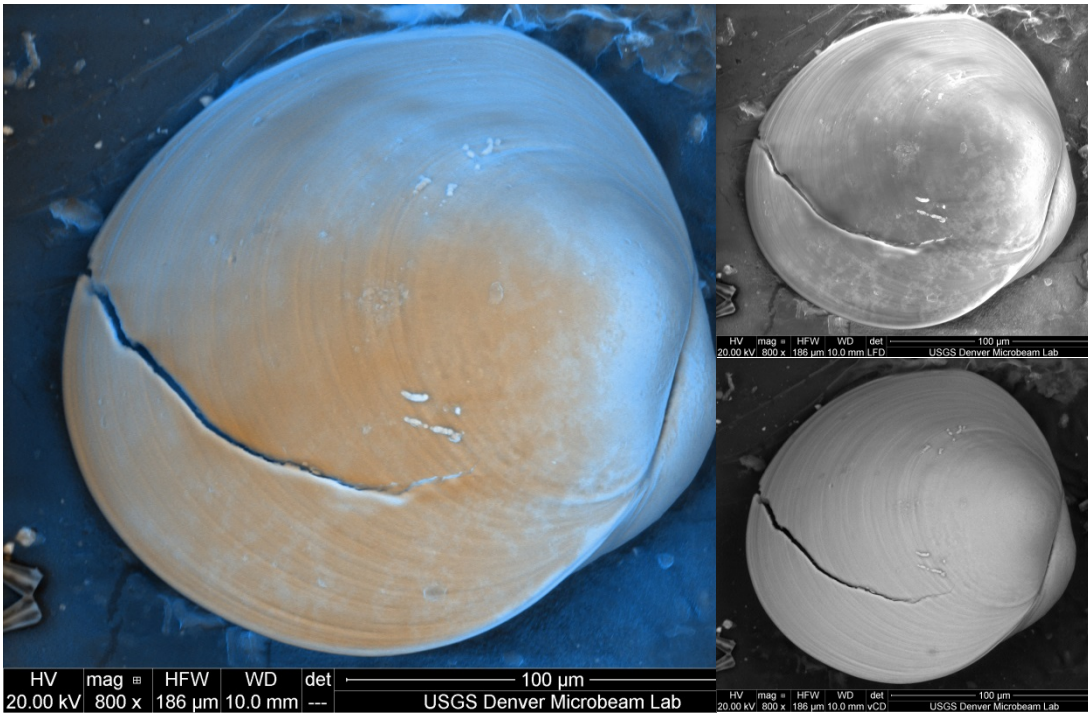


Figure A-16. SEI (upper right), BSC (lower right), and false color composite image (left) of the SEI and BSC images.

ID	State	Water Body	Date Collected	Date Imaged
E1264	UT	Deer Creek Res.	10/30/2014	02/03/2015

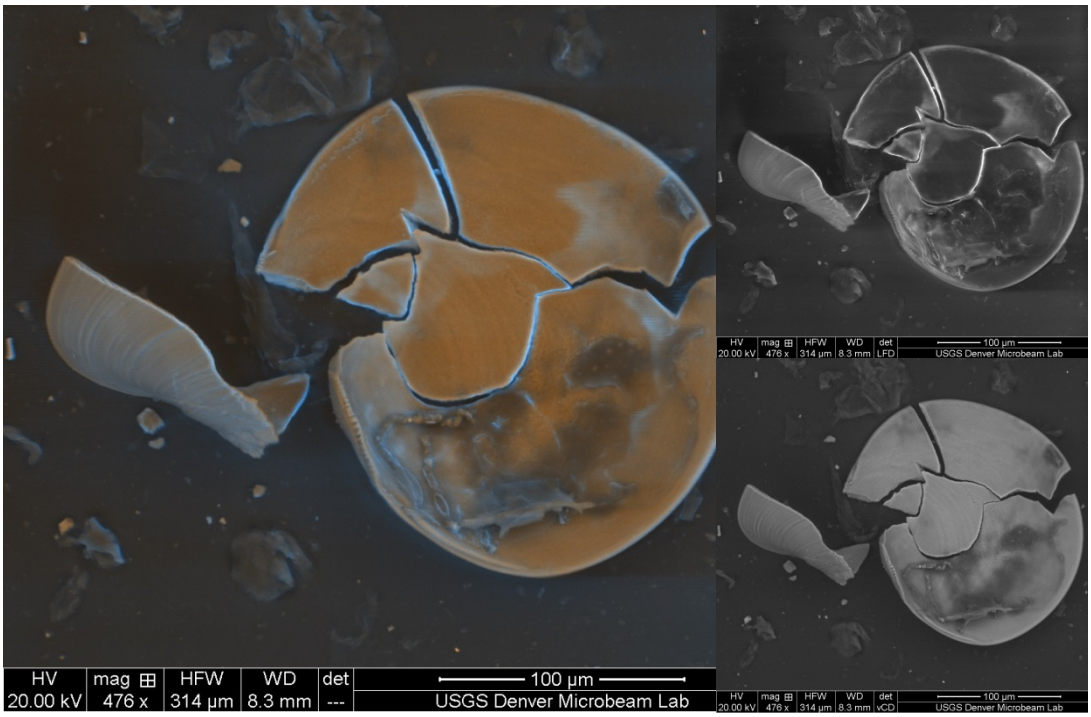


Figure A-17. SEI (upper right), BSC (lower right), and false color composite image (left) of the SEI and BSC images.

ID	State	Water Body	Date Collected	Date Imaged
E1366	AZ	Apache Lake (Horse Mesa Dam)	12/19/2014	09/09/2015

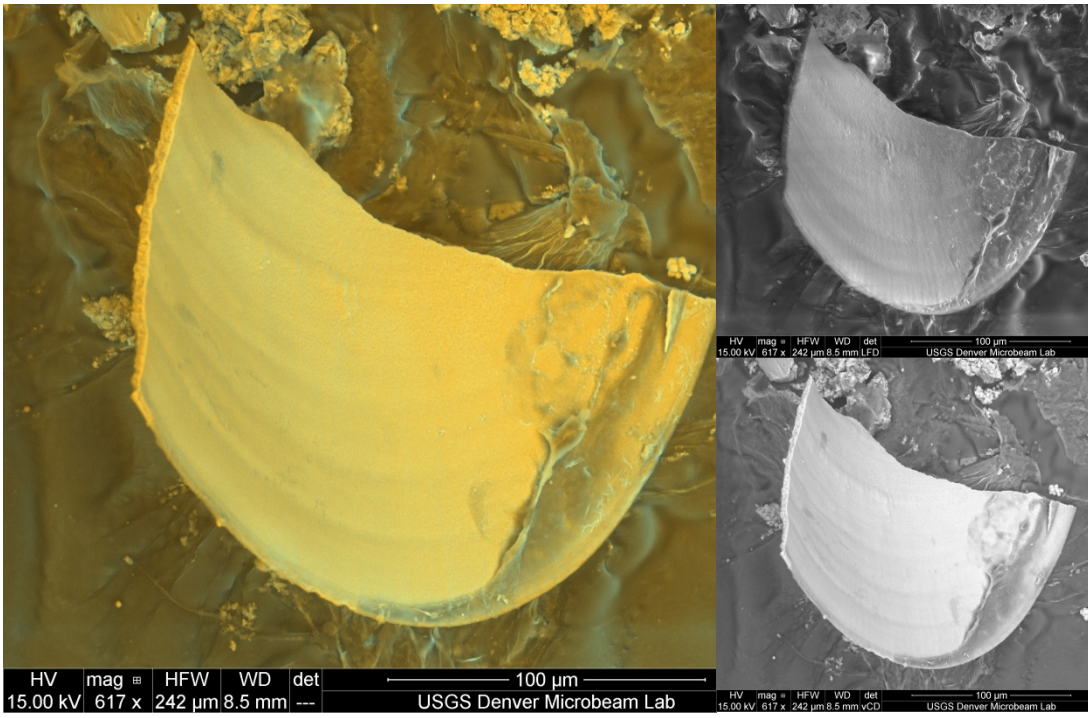


Figure A-18. SEI (upper right), BSC (lower right), and false color composite image (left) of the SEI and BSC images.

ID	State	Water Body	Date Collected	Date Imaged
F0321	SD	Belle Fourche (Orman) Res.	06/01/2015	07/09/2015

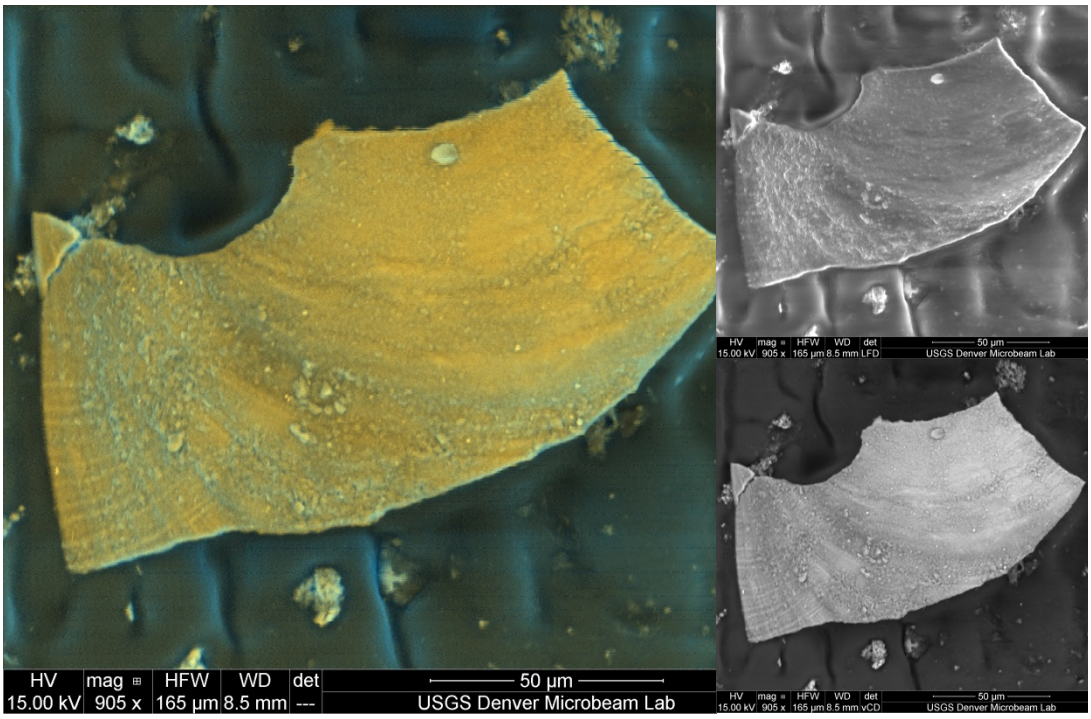


Figure A-19. SEI (upper right), BSC (lower right), and false color composite image (left) of the SEI and BSC images.

ID	State	Water Body	Date Collected	Date Imaged
F0321	SD	Belle Fourche (Orman) Res.	06/01/2015	07/09/2015

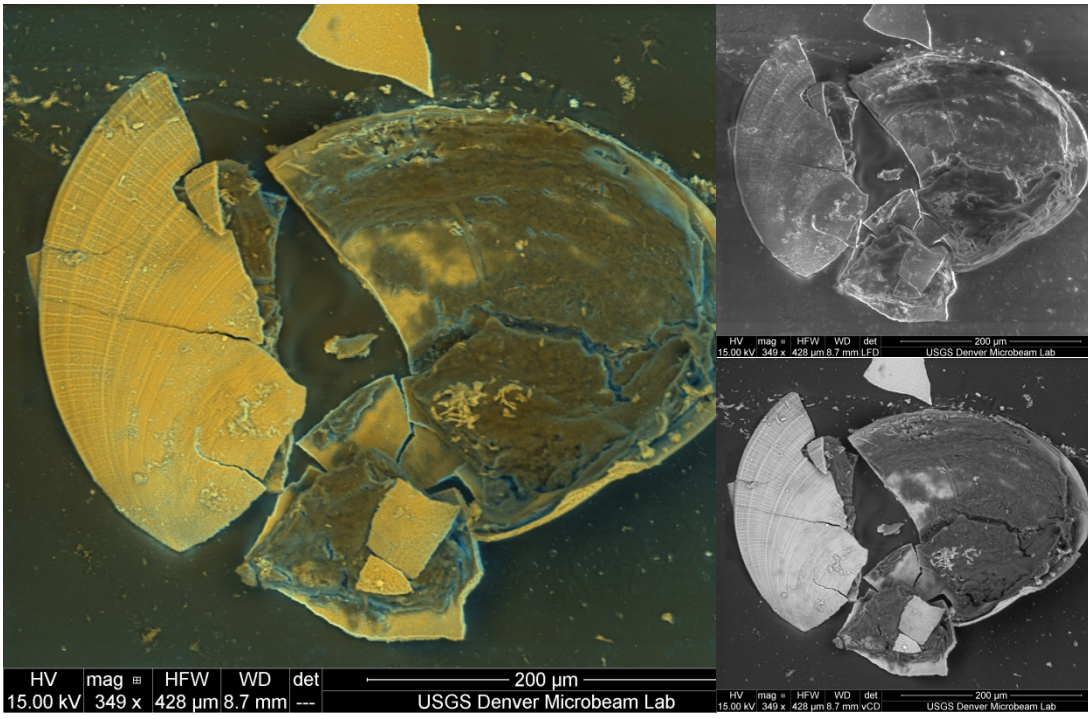


Figure A-20. SEI (upper right), BSC (lower right), and false color composite image (left) of the SEI and BSC images.

ID	State	Water Body	Date Collected	Date Imaged
F0321	SD	Belle Fourche (Orman) Res.	06/01/2015	07/09/2015

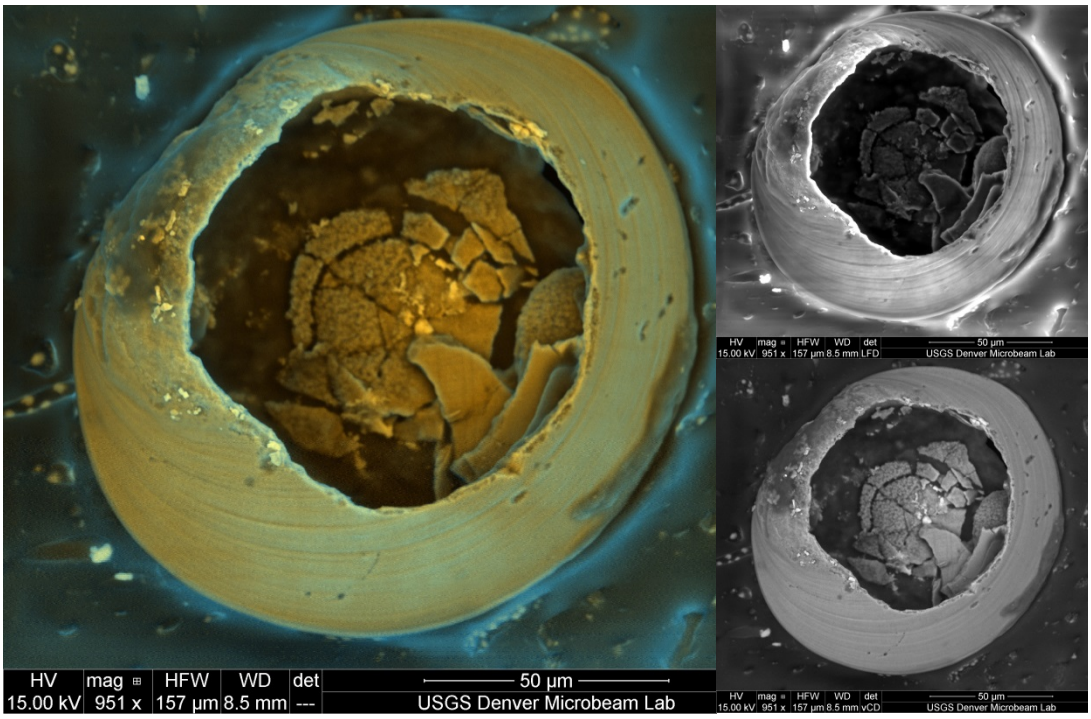


Figure A-21. SEI (upper right), BSC (lower right), and false color composite image (left) of the SEI and BSC images.

ID	State	Water Body	Date Collected	Date Imaged
F0321	SD	Belle Fourche (Orman) Res.	06/01/2015	07/09/2015

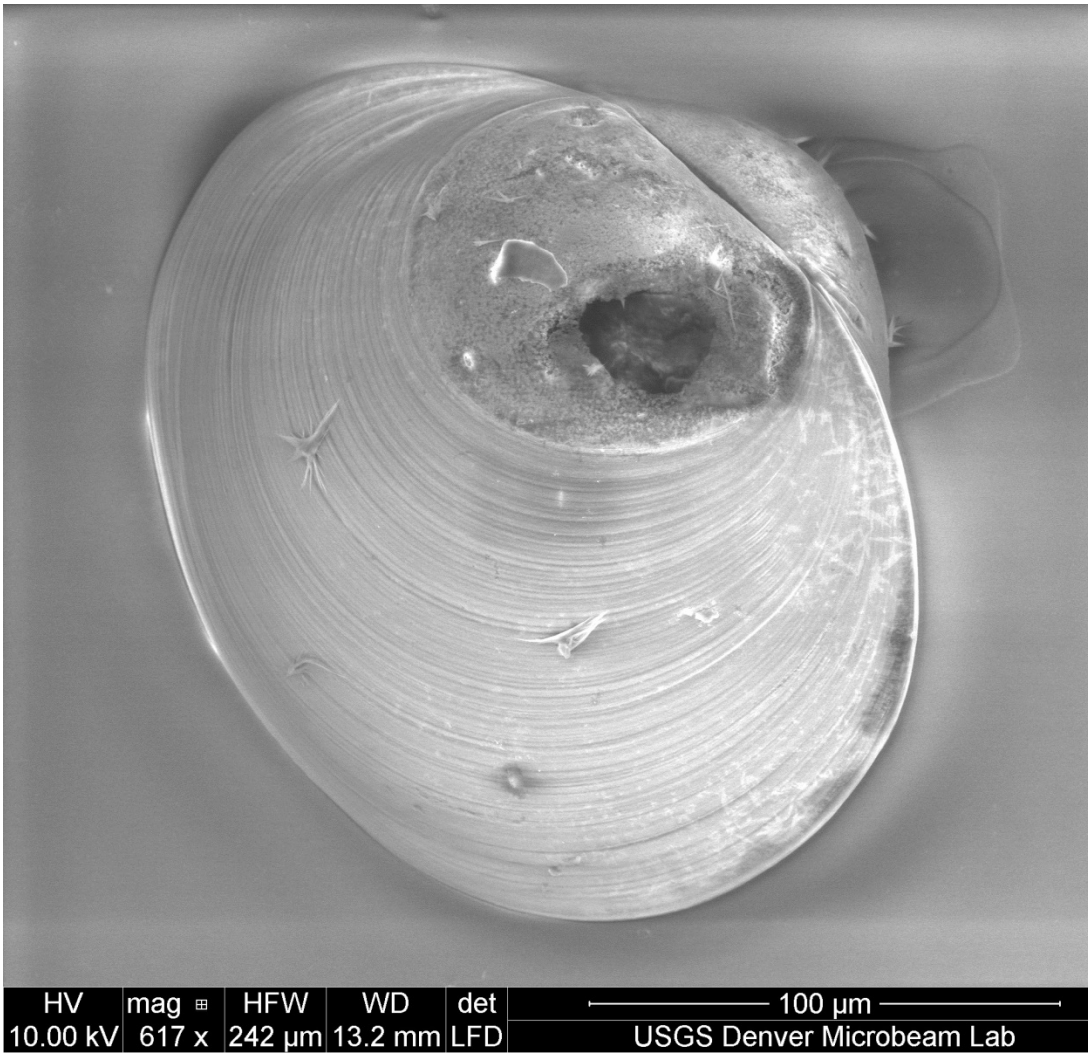


Figure A-22. SEI image

ID	State	Water Body	Date Collected	Date Imaged
F0573	AZ	Roosevelt Lake	07/21/2015	09/09/2015

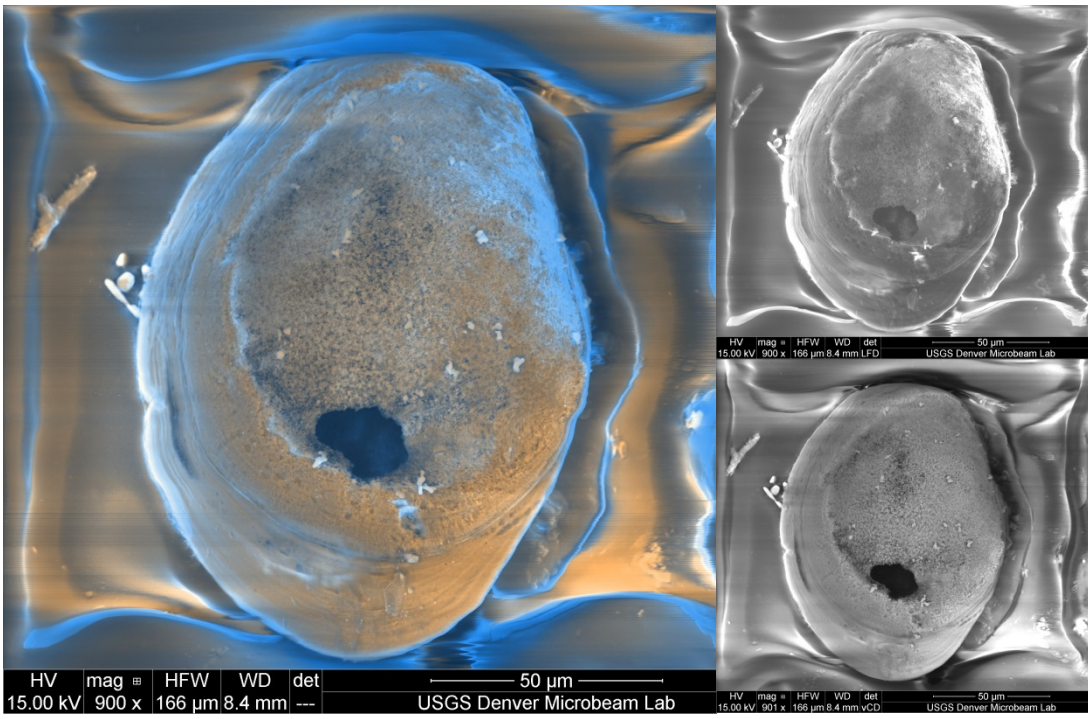


Figure A-23. SEI (upper right), BSC (lower right), and false color composite image (left) of the SEI and BSC images.

ID	State	Water Body	Date Collected	Date Imaged
F0843	AZ	Apache Lake (Horse Mesa Dam)	08/19/2015	10/09/2015

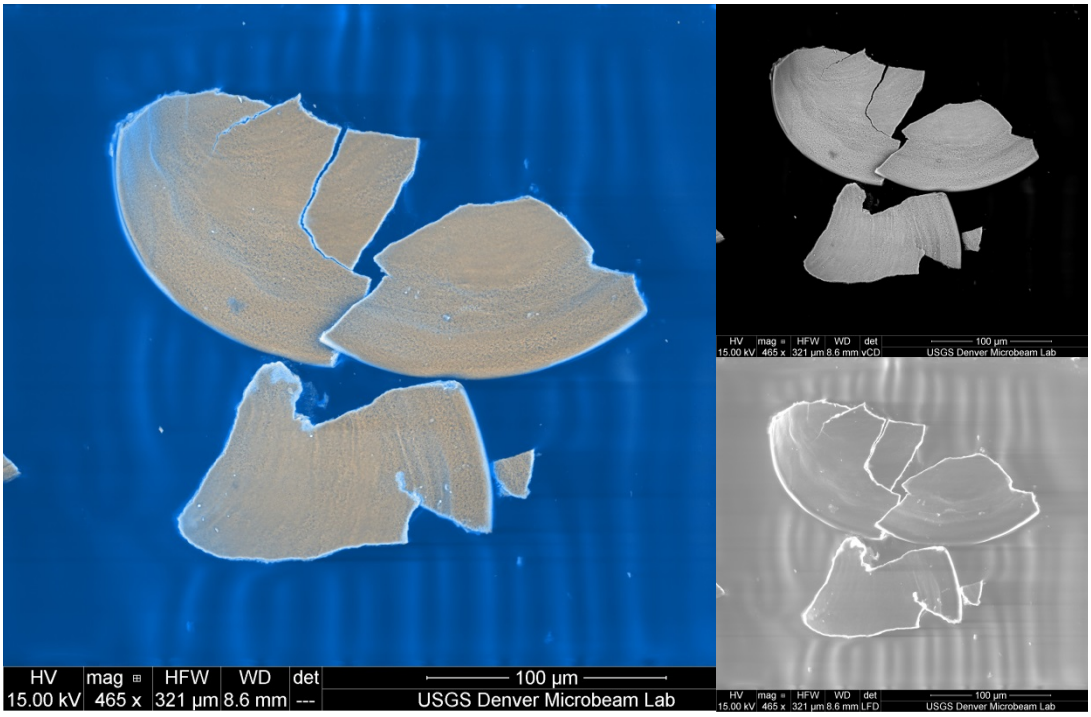


Figure A-24. SEI (upper right), BSC (lower right), and false color composite image (left) of the SEI and BSC images.

ID	State	Water Body	Date Collected	Date Imaged
F0889	CO-NM	Navajo Res.	09/02/2015	10/09/2015

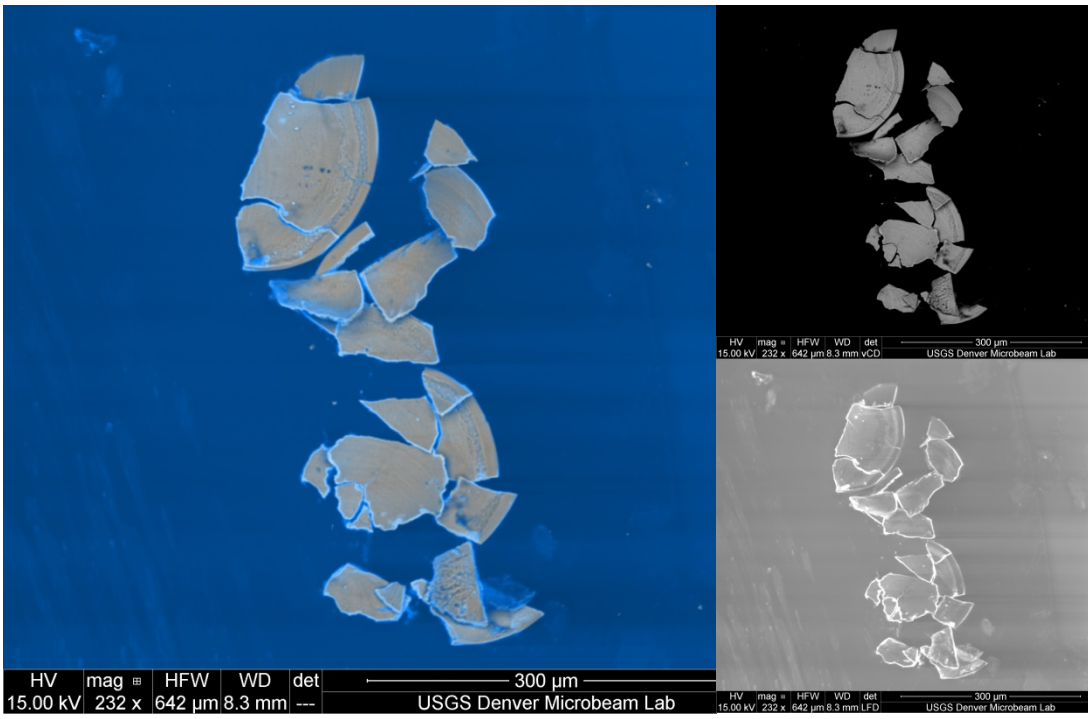


Figure A-25. SEI (upper right), BSC (lower right), and false color composite image (left) of the SEI and BSC images.

ID	State	Water Body	Date Collected	Date Imaged
F0889	CO-NM	Navajo Res.	09/02/2015	10/09/2015

Scanning Electron Microscope (SEM) Imaging and Anaglyphs of Invasive Mussel Veligers

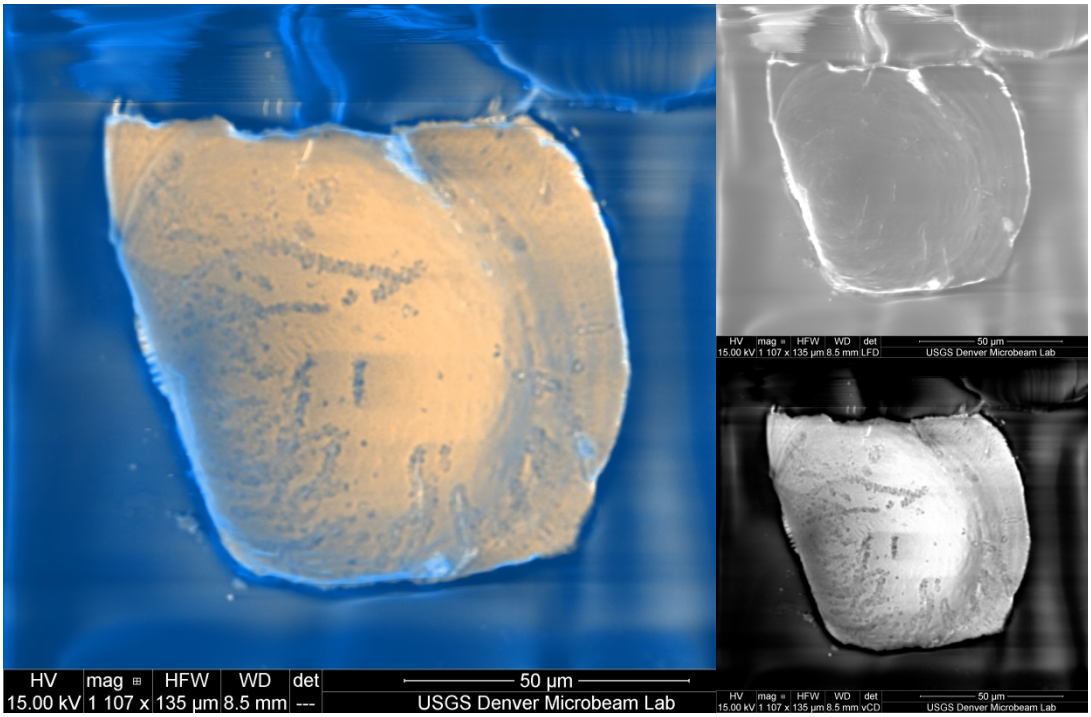


Figure A-26. SEI (upper right), BSC (lower right), and false color composite image (left) of the SEI and BSC images.

ID	State	Water Body	Date Collected	Date Imaged
F0889	CO-NM	Navajo Res.	09/02/2015	10/09/2015

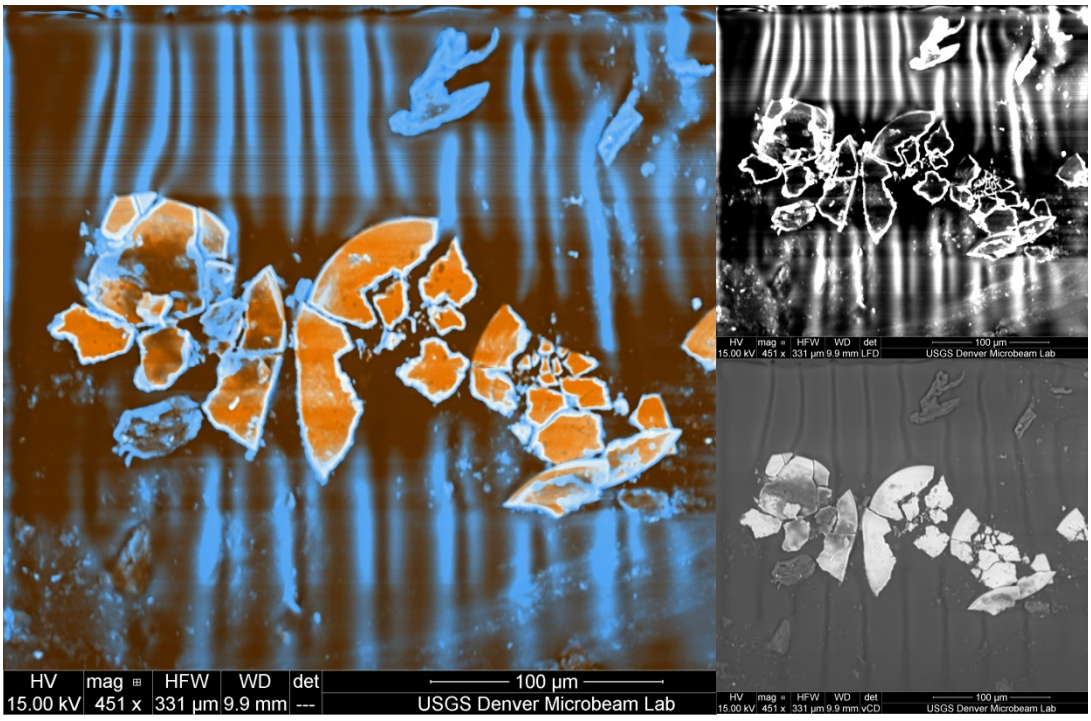


Figure A-27. SEI (upper right), BSC (lower right), and false color composite image (left) of the SEI and BSC images.

ID	State	Water Body	Date Collected	Date Imaged
F0889	CO-NM	Navajo Res.	09/02/2015	10/09/2015

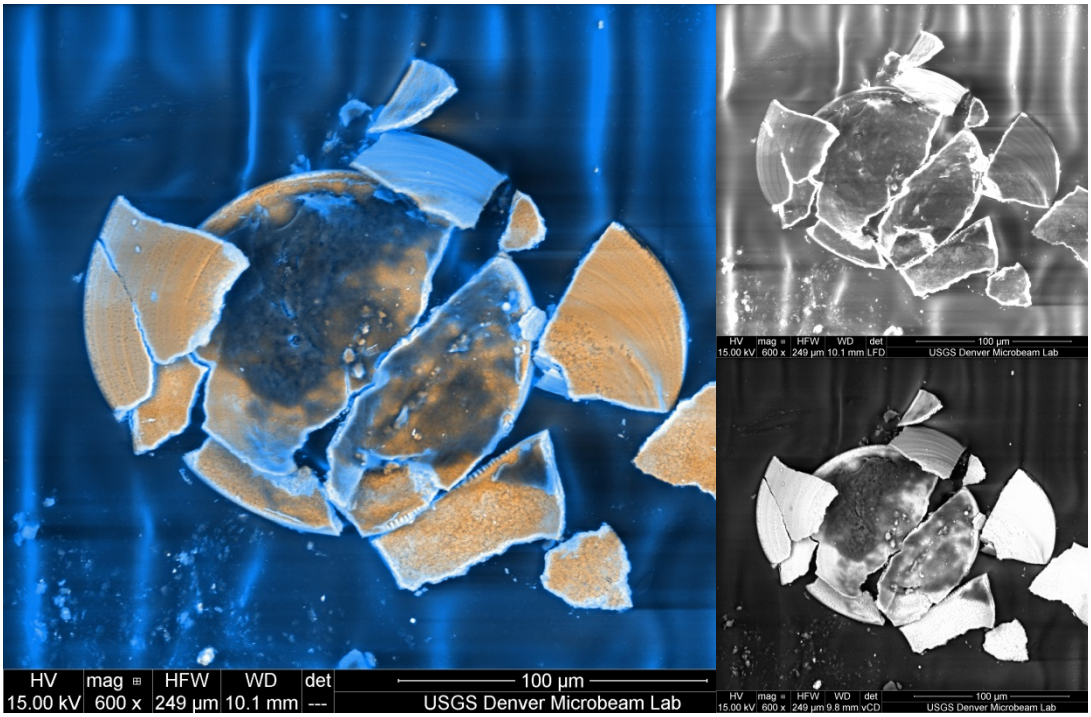


Figure A-28. SEI (upper right), BSC (lower right), and false color composite image (left) of the SEI and BSC images.

ID	State	Water Body	Date Collected	Date Imaged
F0889	CO-NM	Navajo Res.	09/02/2015	10/09/2015

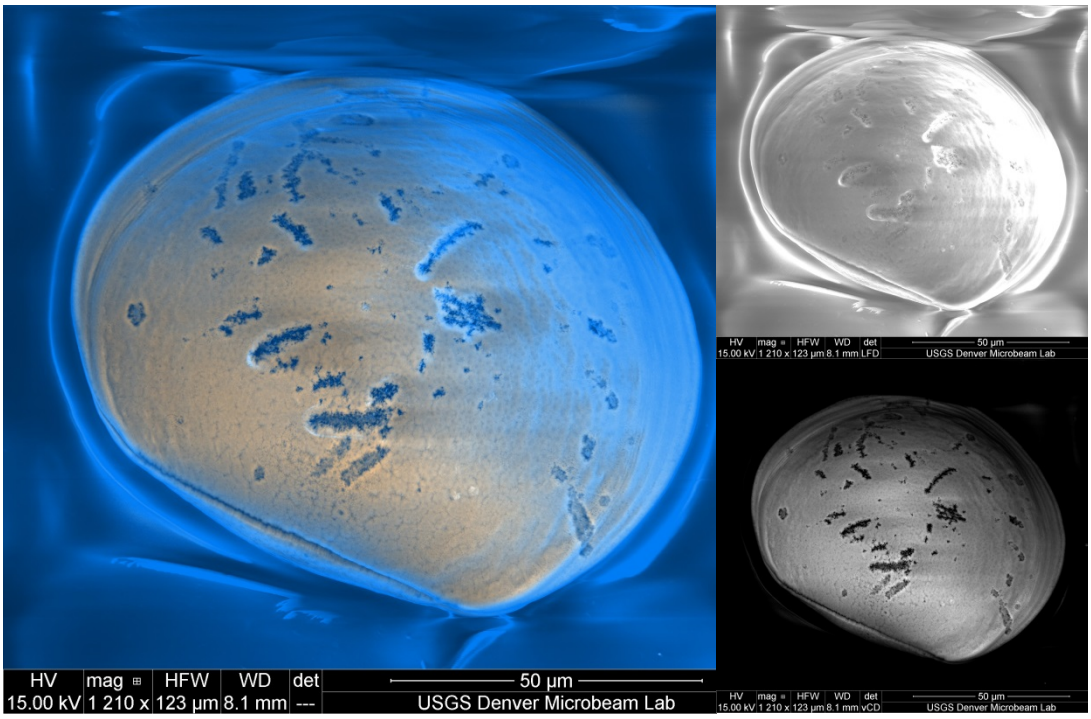


Figure A-29. SEI (upper right), BSC (lower right), and false color composite image (left) of the SEI and BSC images.

ID	State	Water Body	Date Collected	Date Imaged
F0889	CO-NM	Navajo Res.	09/02/2015	10/09/2015

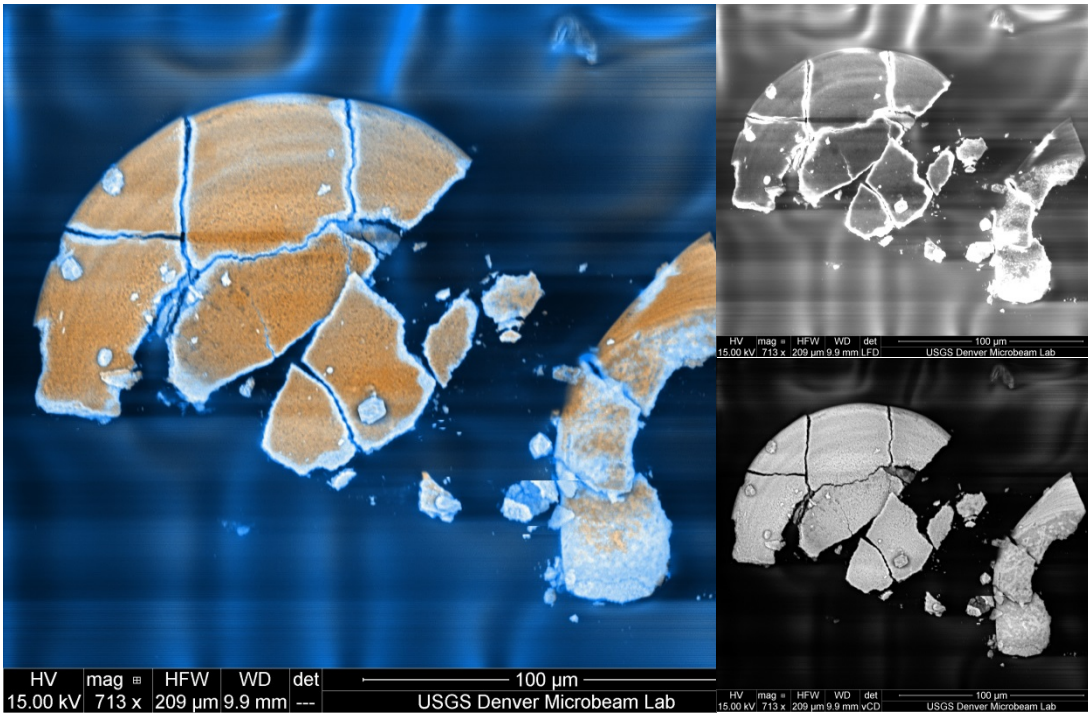


Figure A-30. SEI (upper right), BSC (lower right), and false color composite image (left) of the SEI and BSC images.

ID	State	Water Body	Date Collected	Date Imaged
F0889	CO-NM	Navajo Res.	09/02/2015	10/09/2015

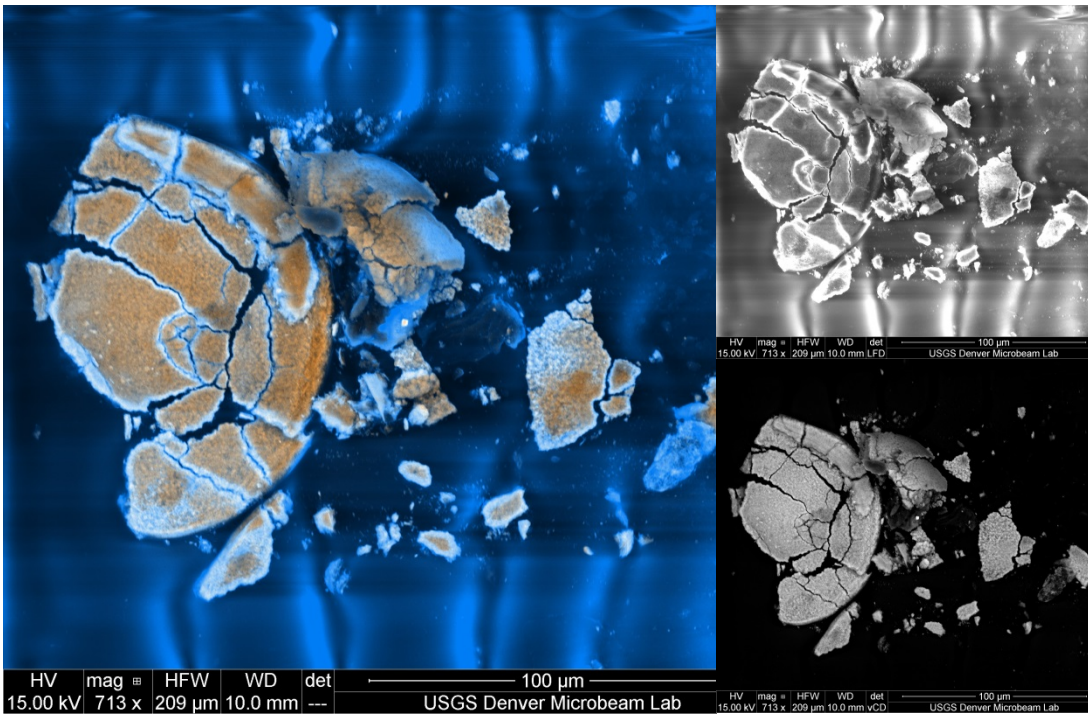


Figure A-31. SEI (upper right), BSC (lower right), and false color composite image (left) of the SEI and BSC images.

ID	State	Water Body	Date Collected	Date Imaged
F0889	CO-NM	Navajo Res.	09/02/2015	10/09/2015

Scanning Electron Microscope (SEM) Imaging and Anaglyphs of Invasive Mussel Veligers

This page intentionally left blank

Appendix B

Anaglyphs Created from
Scanning Electron Microscope Images
Of Mussel Veligers - FY 2015

Anaglyphs can be viewed with 3D glasses with a red filter in the left lens and a blue filter in the right lens.

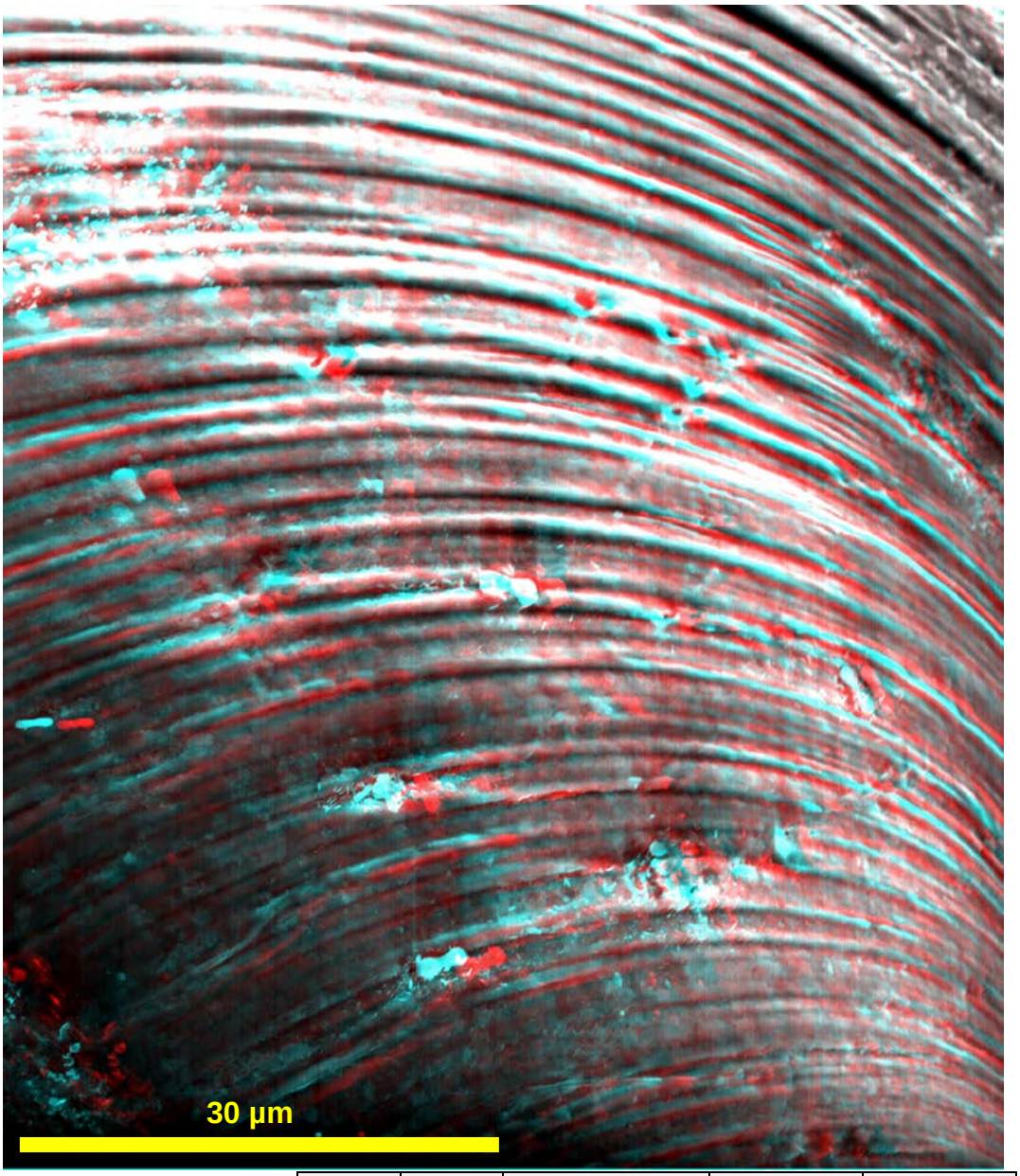


Figure B-1. Anaglyph created from stereo pair of SEM/BSC images

ID	State	Water Body	Date Collected	Date Imaged
E0940	OK	Lake Thunderbird (Norman Dam)	09/04/2015	09/09/2015

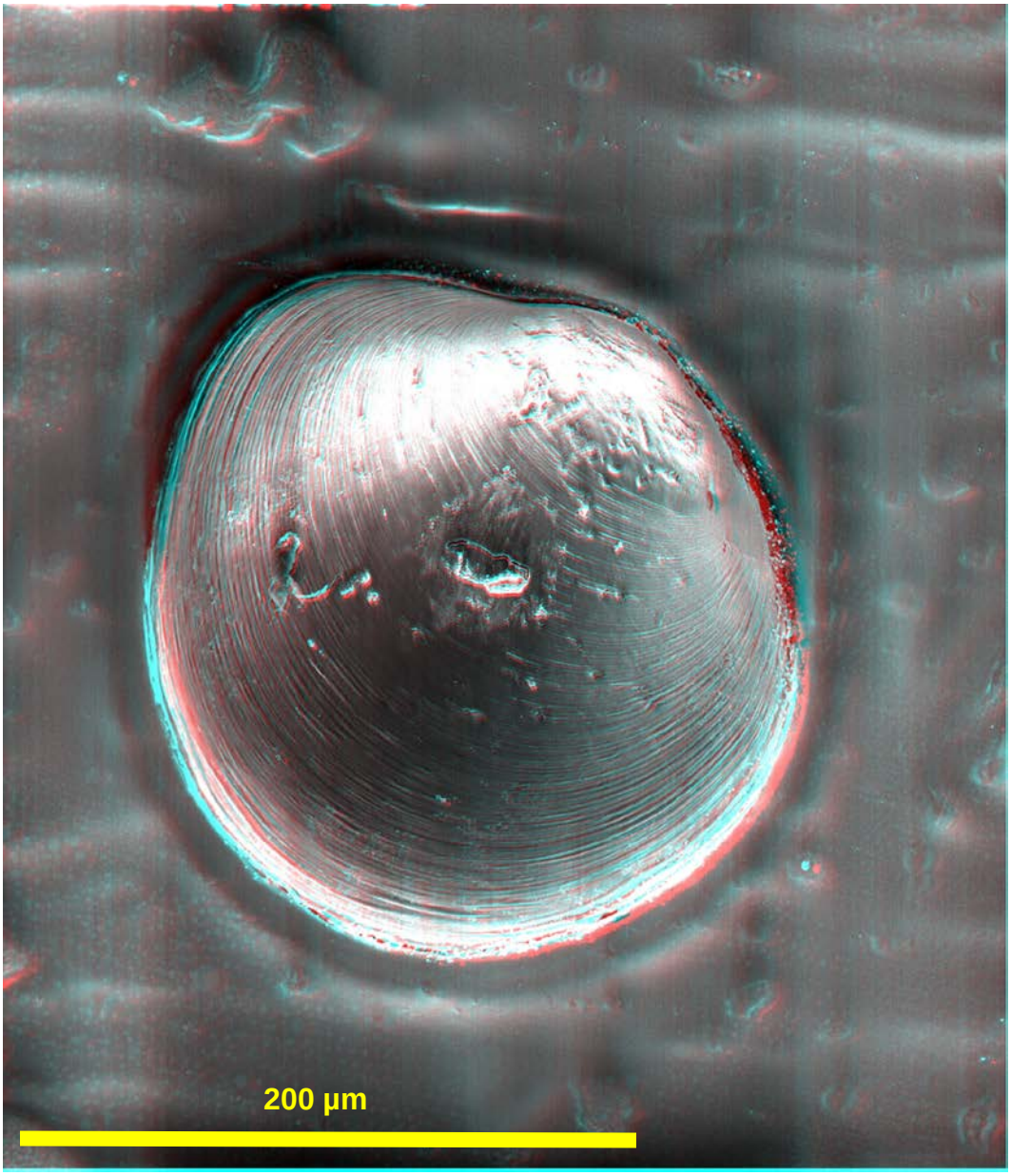


Figure B-2. Anaglyph created from stereo pair of SEM/BSC images

ID	State	Water Body	Date Collected	Date Imaged
E0940	OK	Lake Thunderbird (Norman Dam)	09/04/2015	09/09/2015

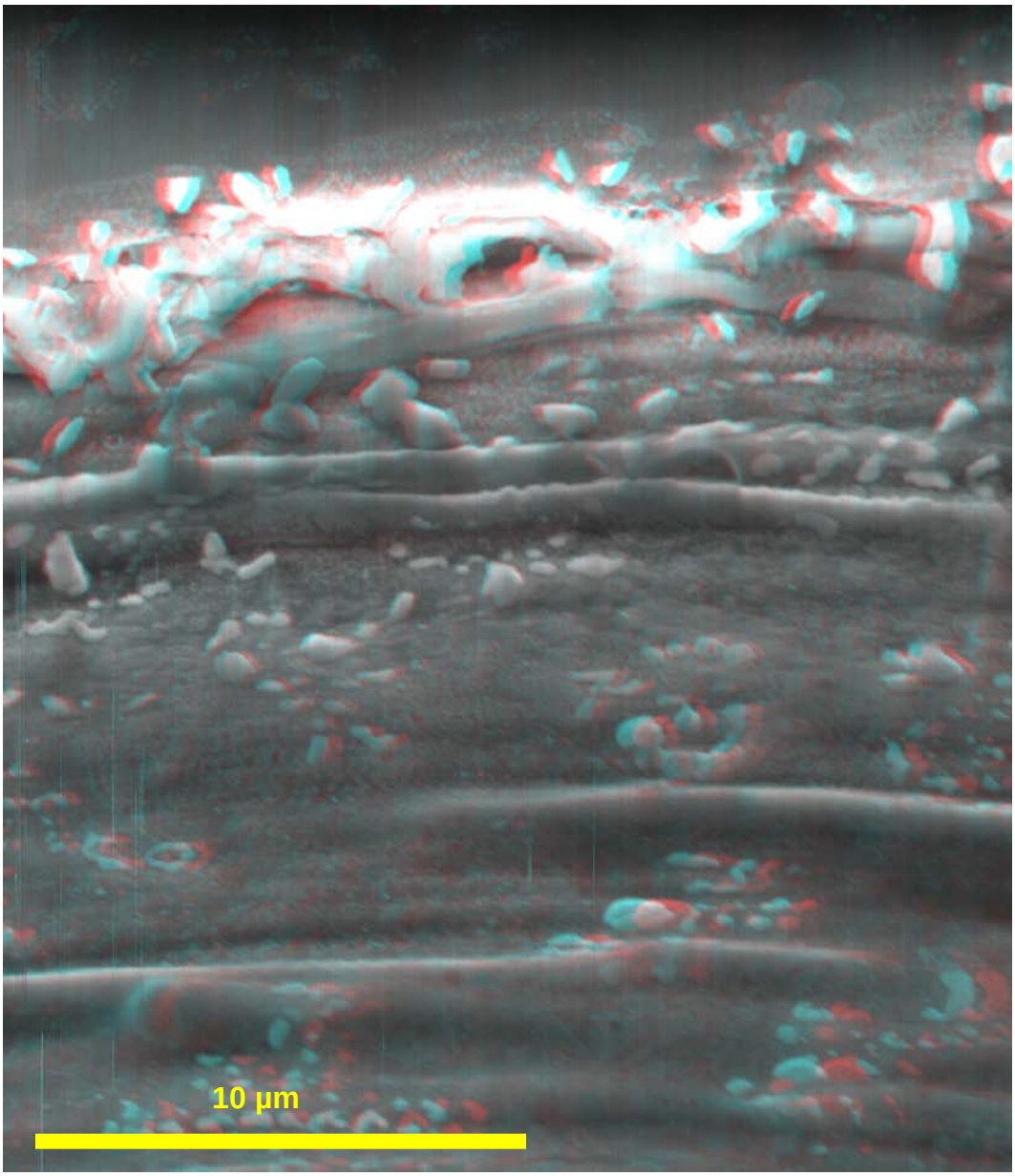


Figure B-3. Anaglyph created from stereo pair of SEM/BSC images

ID	State	Water Body	Date Collected	Date Imaged
E0940	OK	Lake Thunderbird (Norman Dam)	09/04/2015	09/09/2015

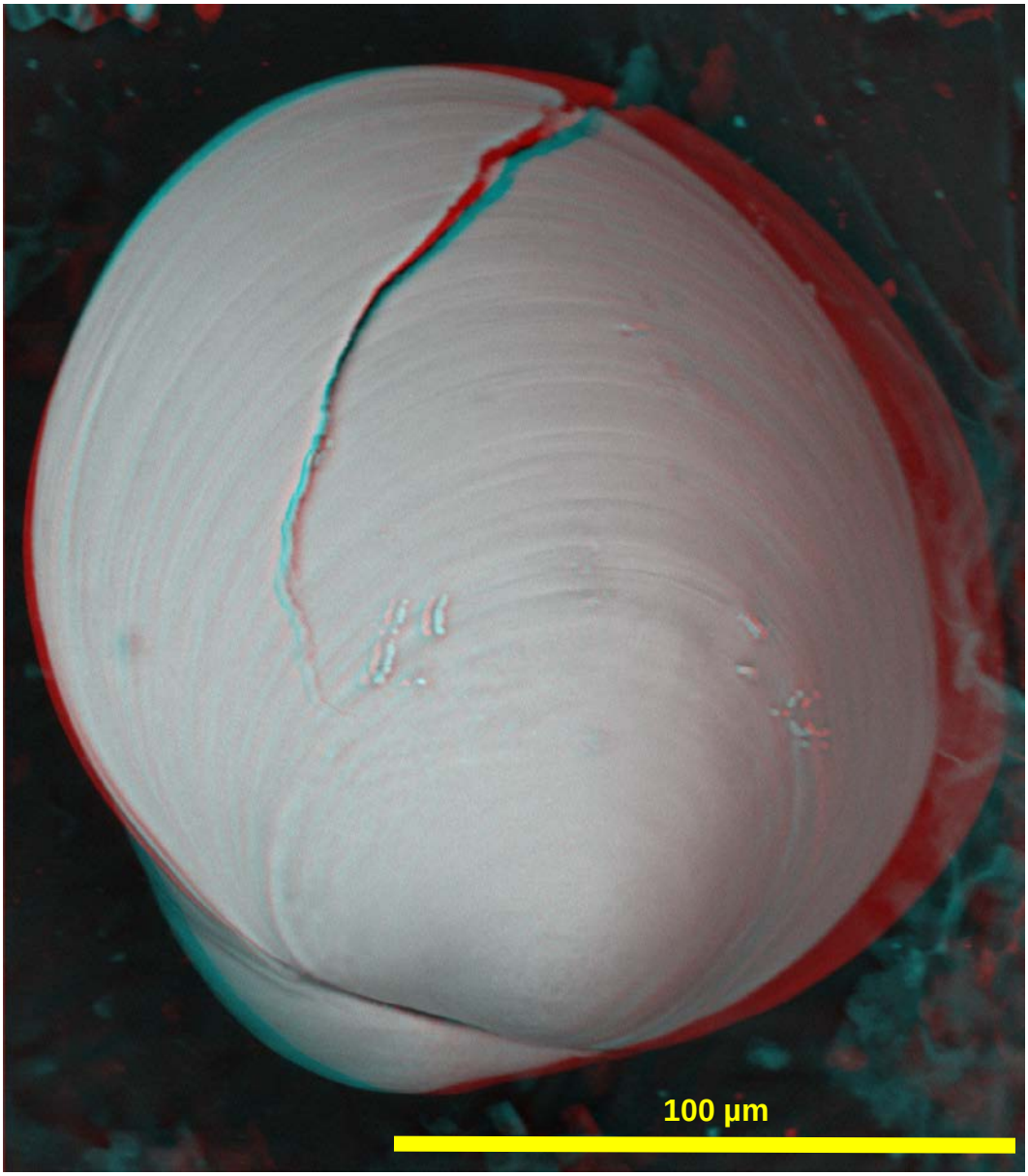


Figure B-4. Anaglyph created from stereo pair of SEM/BSC images

ID	State	Water Body	Date Collected	Date Imaged
E1264	UT	Deer Creek Res.	10/30/2015	02/03/2015

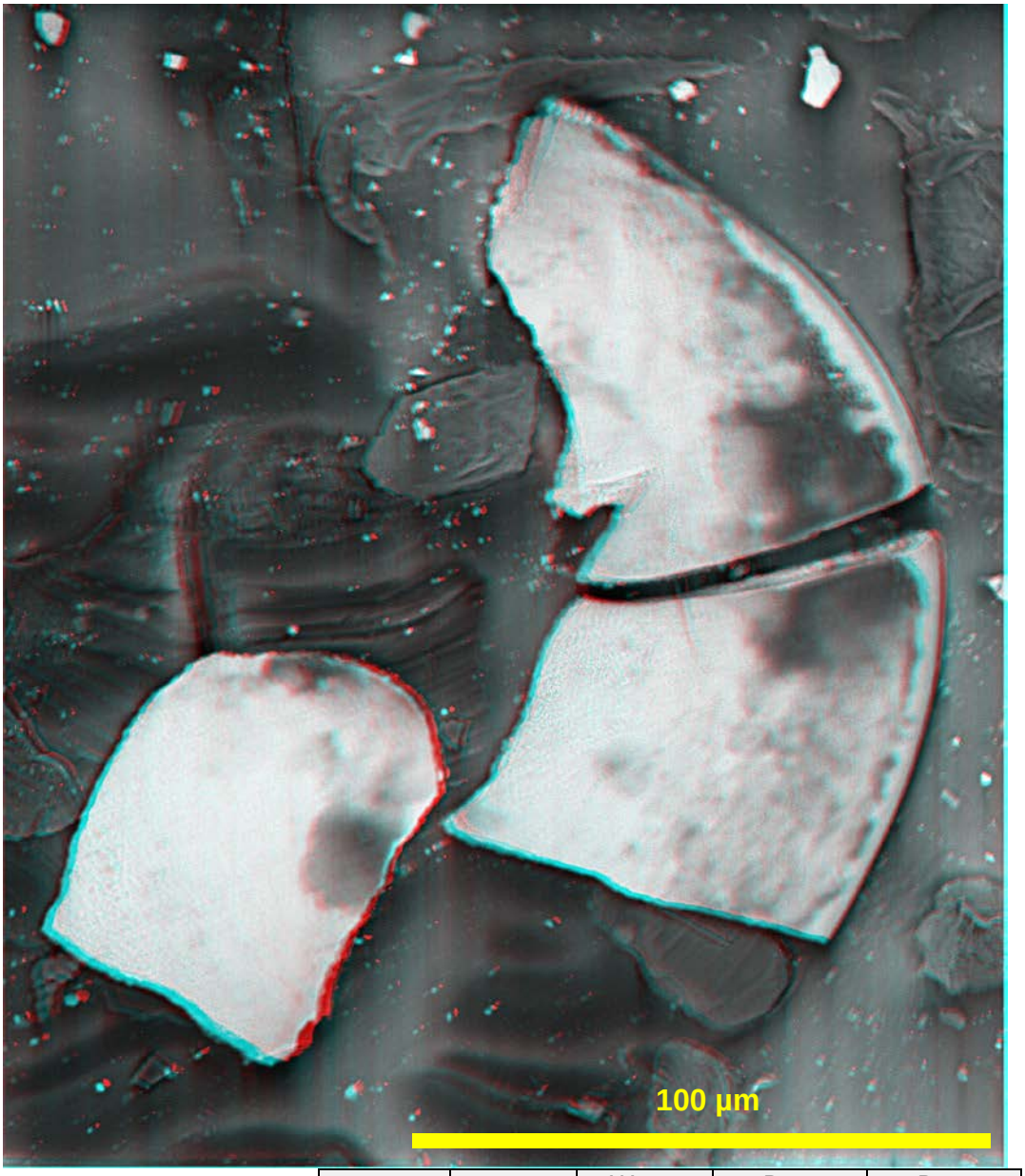


Figure B-5. Anaglyph created from stereo pair of SEM/BSC images

ID	State	Water Body	Date Collected	Date Imaged
E1366	AZ	Apache Lake (Horse Mesa Dam)	12/19/2014	09/09/2015

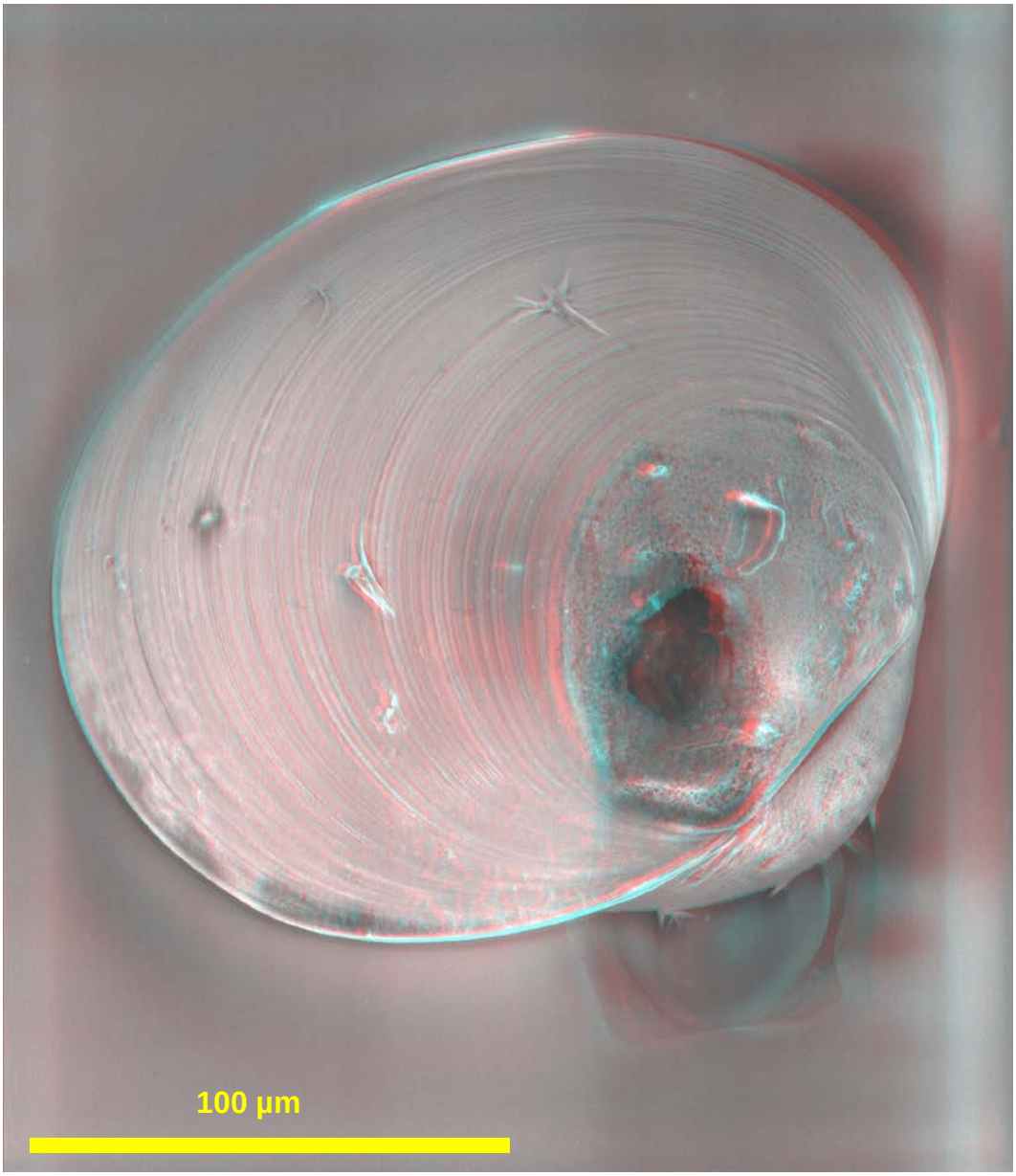


Figure B-6. Anaglyph created from stereo pair of SEM/BSC images

ID	State	Water Body	Date Collected	Date Imaged
F0573	AZ	Roosevelt Lake	07/21/2015	09/09/2015

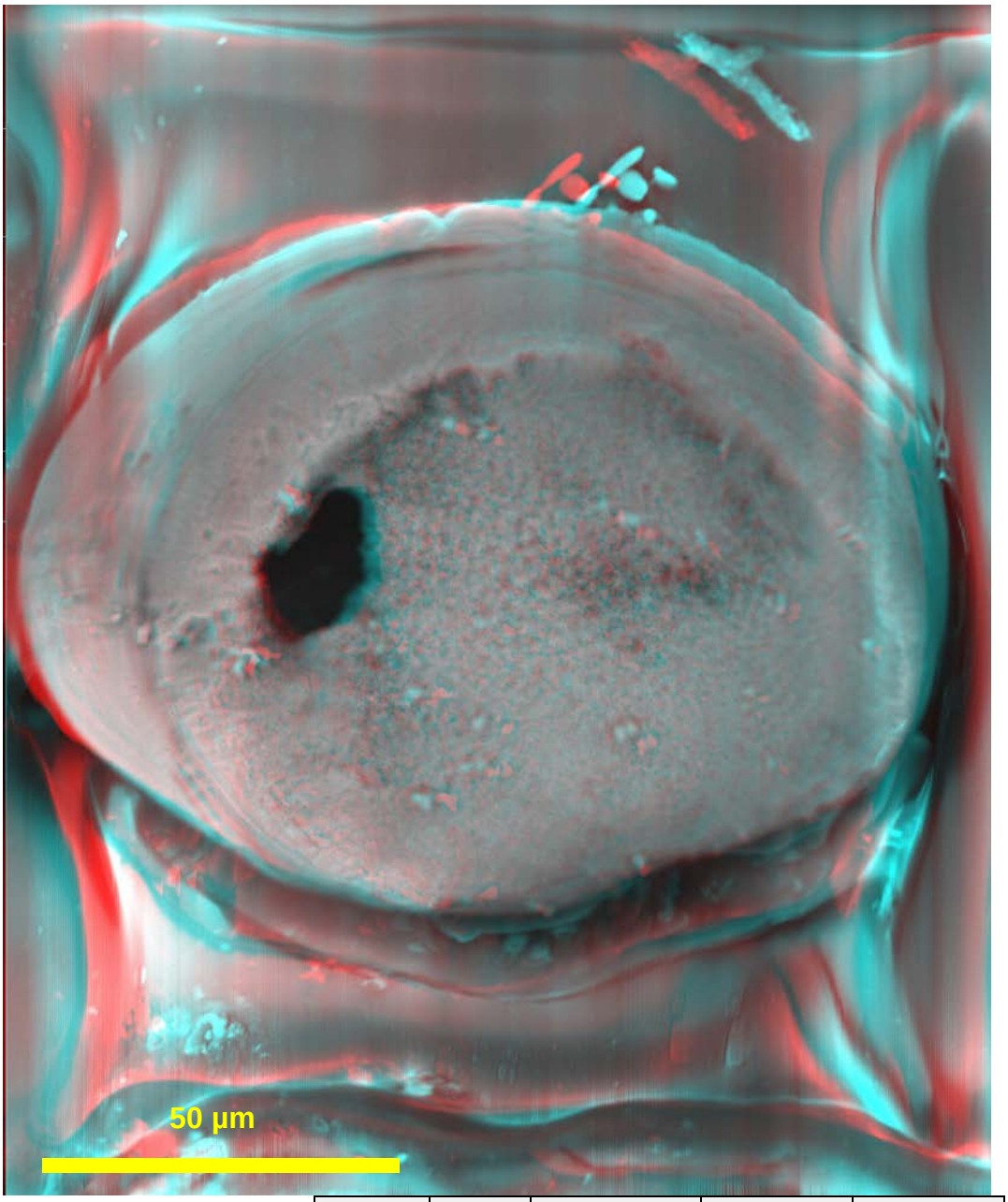


Figure B-7. Anaglyph created from stereo pair of SEM/BSC images

ID	State	Water Body	Date Collected	Date Imaged
F0843	AZ	Apache Lake (Horse Mesa Dam)	08/19/2015	10/09/2015

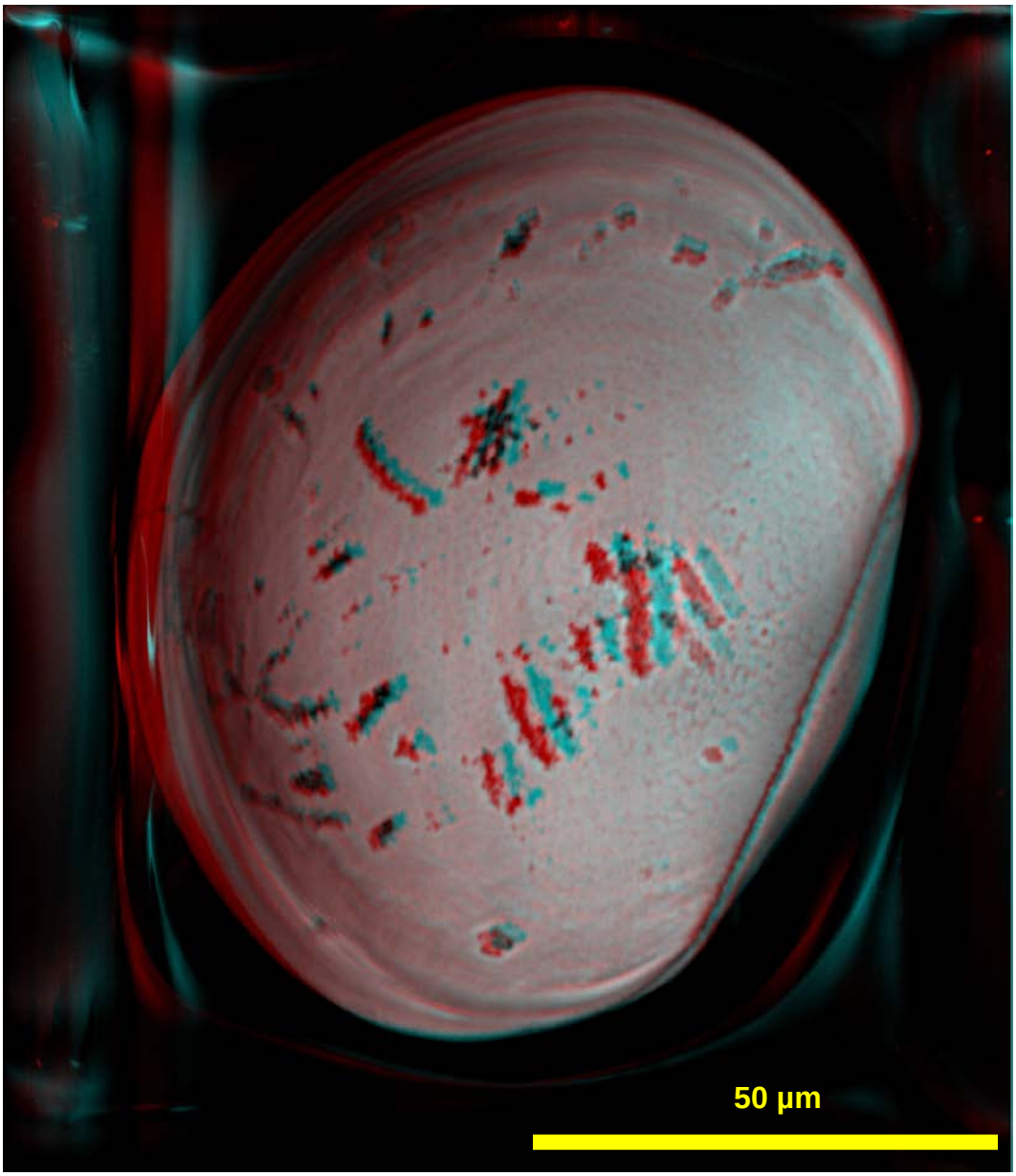


Figure B-8. Anaglyph created from stereo pair of SEM/BSC images

ID	State	Water Body	Date Collected	Date Imaged
F0889	CO-NM	Navajo Res.	09/02/2015	10/09/2015

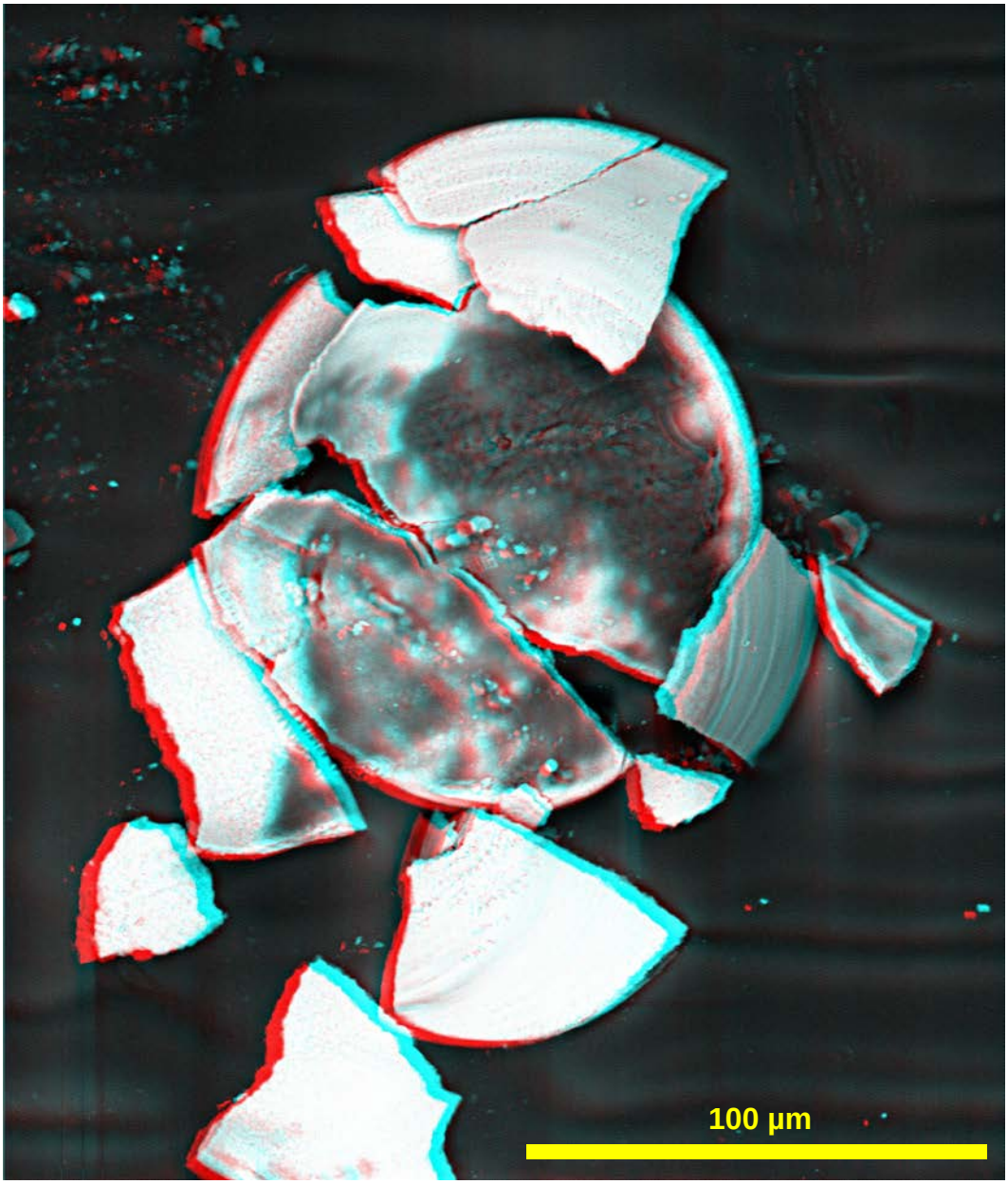


Figure B-9. Anaglyph created from stereo pair of SEM/BSC images

ID	State	Water Body	Date Collected	Date Imaged
F0889	CO-NM	Navajo Res.	09/02/2015	10/09/2015