

Supplemental Figures A

Outcrop and Grain Images

American Mineralogist
Henze et al.



Figure A1. Notch Peak, one of the most dramatic peaks in Utah. The high cliffs are Cambrian sedimentary rocks. The pinkish lower cliffs are the Notch Peak pluton.



Figure A2. Around the margins of the Notch Peak pluton sills of granite, aplite, and pegmatite have intruded into and altered the Cambrian sedimentary rocks.

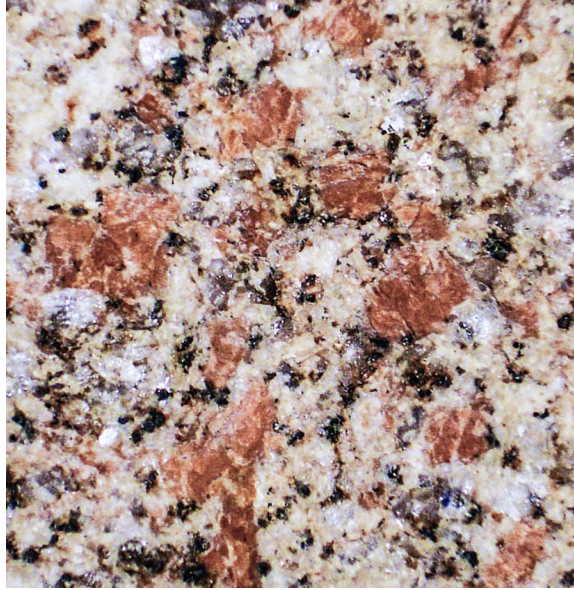


Figure A3. Notch Peak granite with quartz (white), plagioclase (light gray), K-feldspar (red), and biotite (black) as the main mineral components.



Figure A4. Little Cottonwood Canyon looking out over south Salt Lake Valley. Note the glaciated shape of the canyon and the outcrops of the Little Cottonwood granodiorite on the sides of the canyon.



Figure A5. Little Cottonwood granodiorite with several mafic enclaves.

Notch Peak grain images

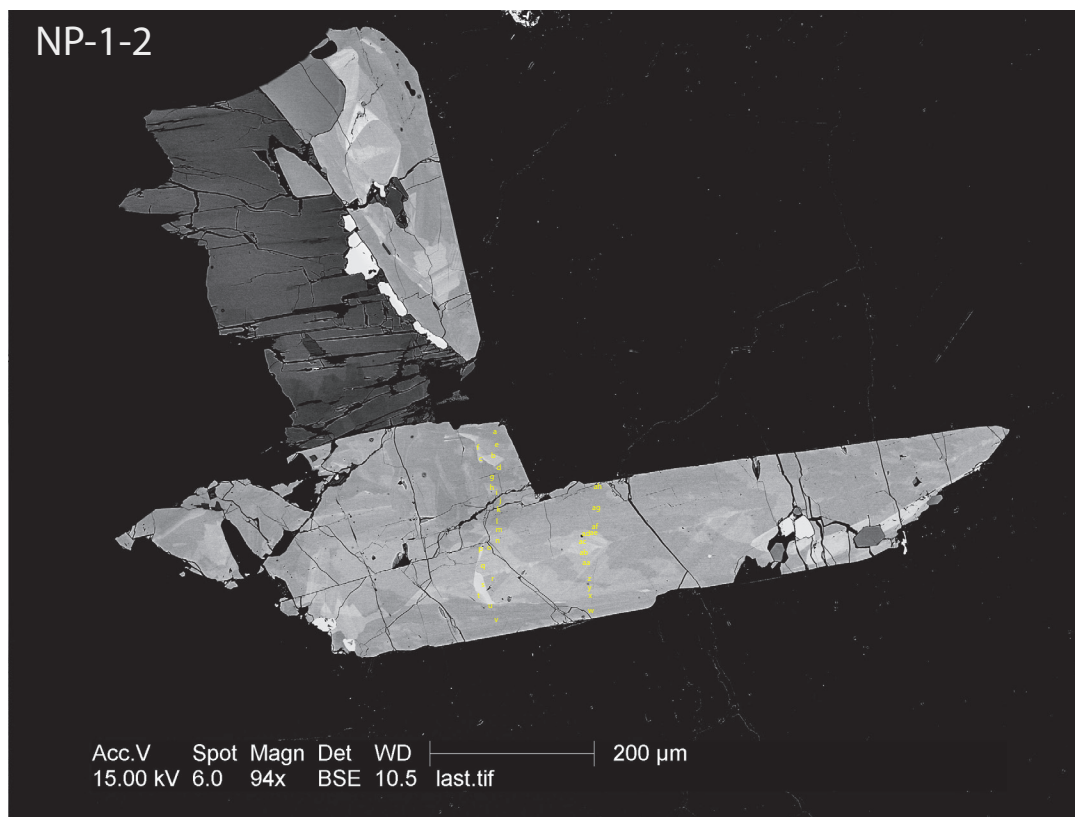
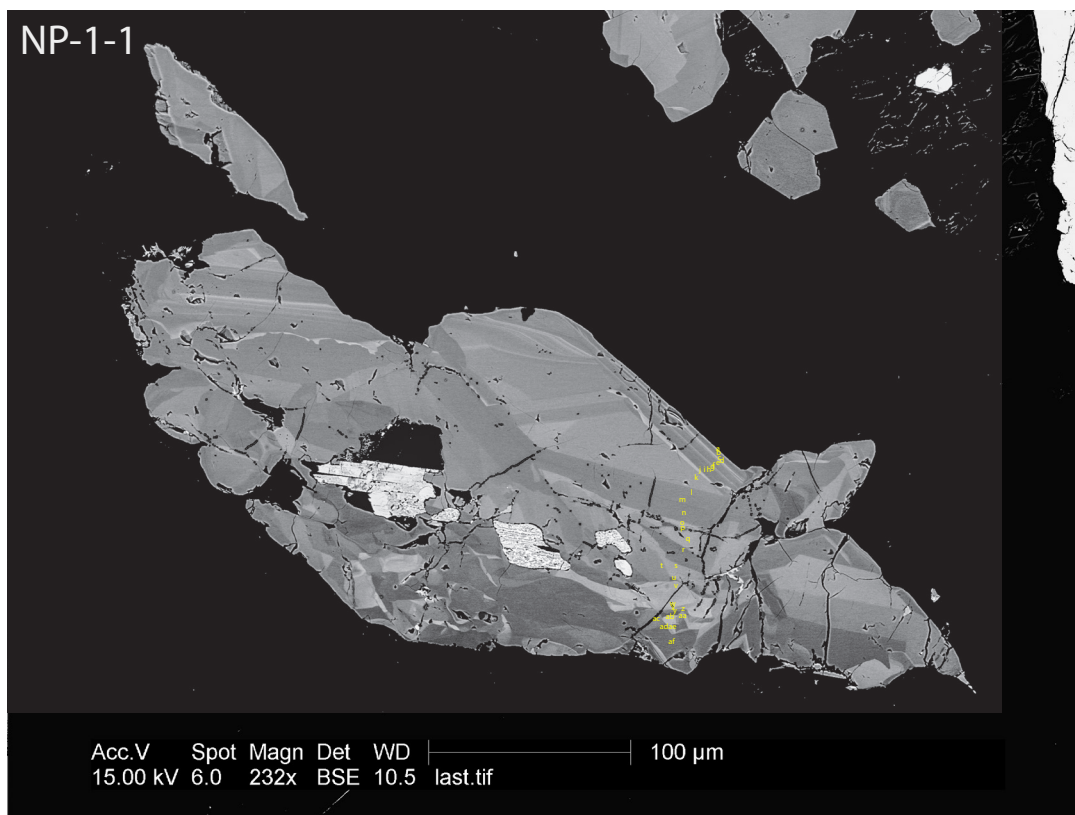


Figure A6. Notch Peak grains NP-1-1 and NP-1-2 with electron microprobe spots (yellow letters).

Notch Peak grain images

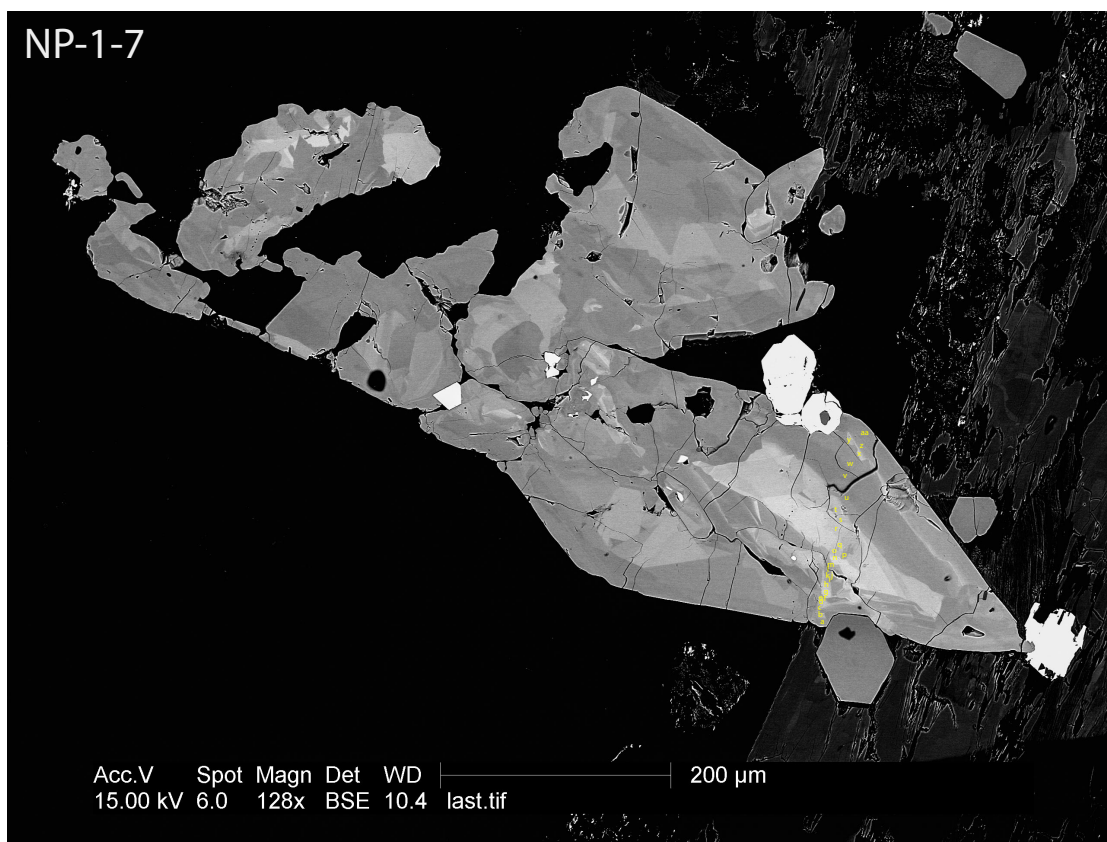
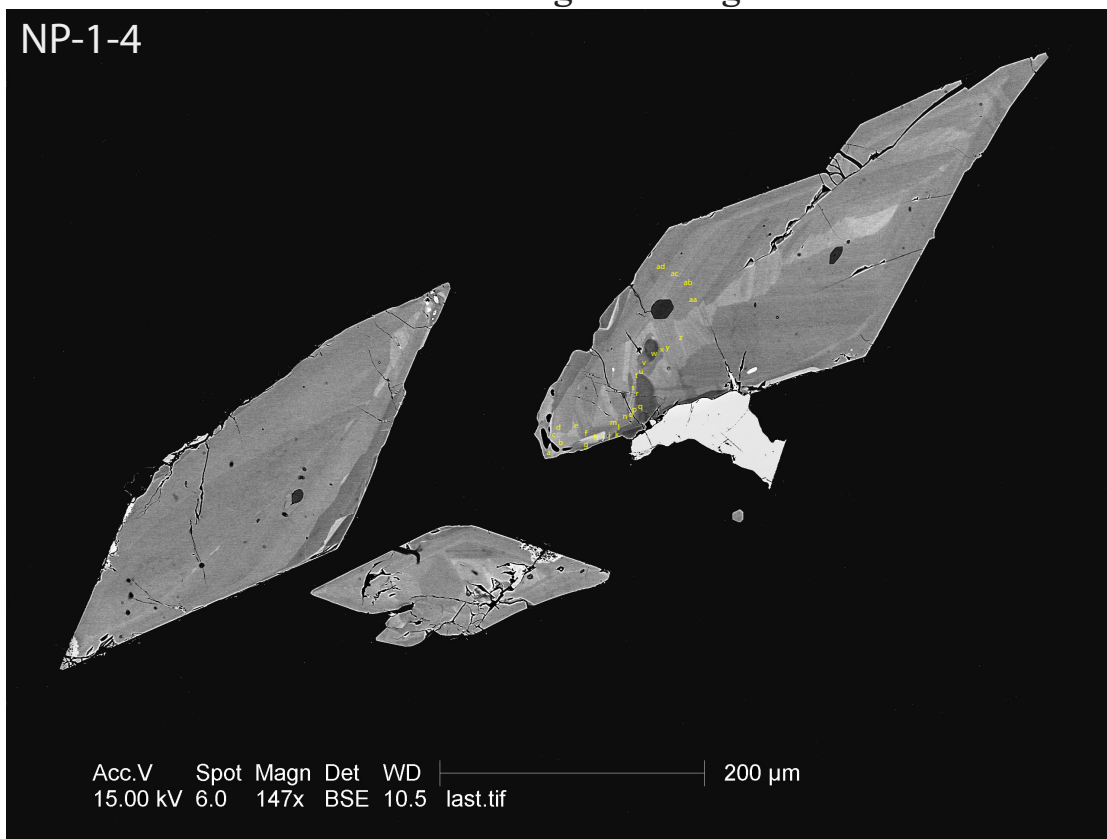


Figure A7. Notch Peak grains NP-1-4 and NP-1-7 with electron microprobe spots (yellow letters).

Notch Peak grain images

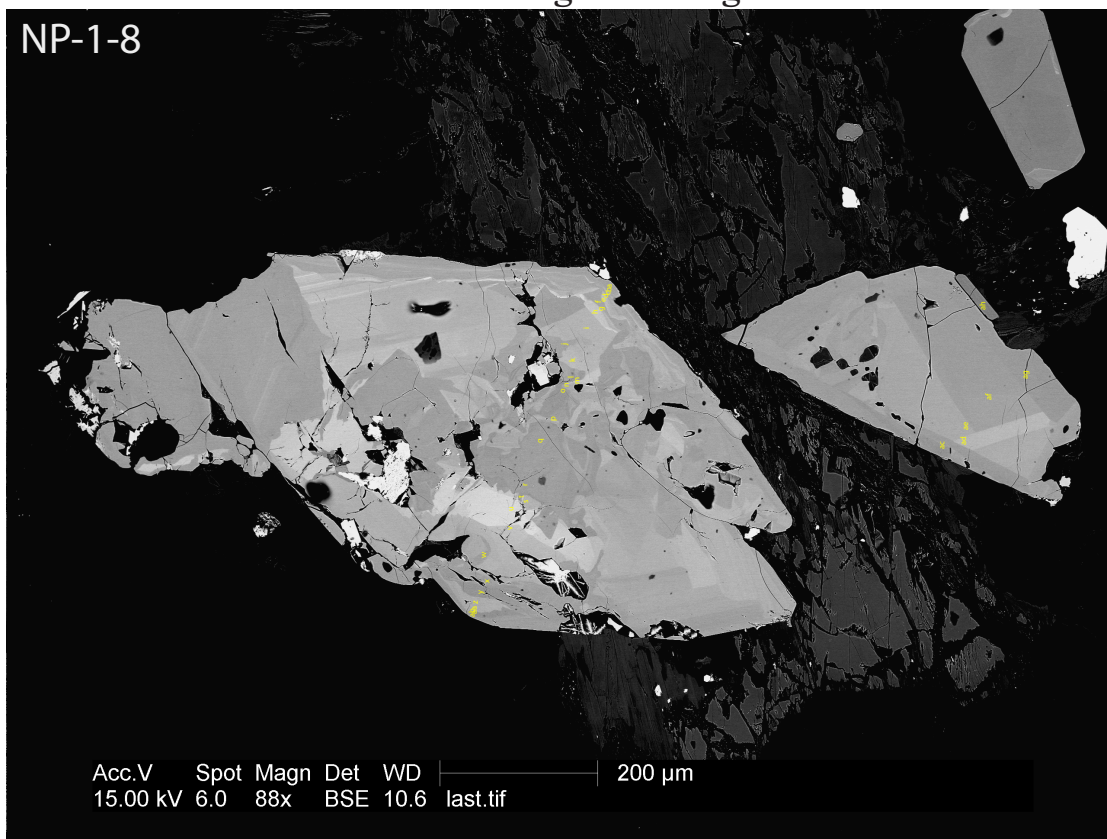


Figure A8. Notch Peak grain NP-1-8 with electron microprobe spots (yellow letters).

Notch Peak grain images

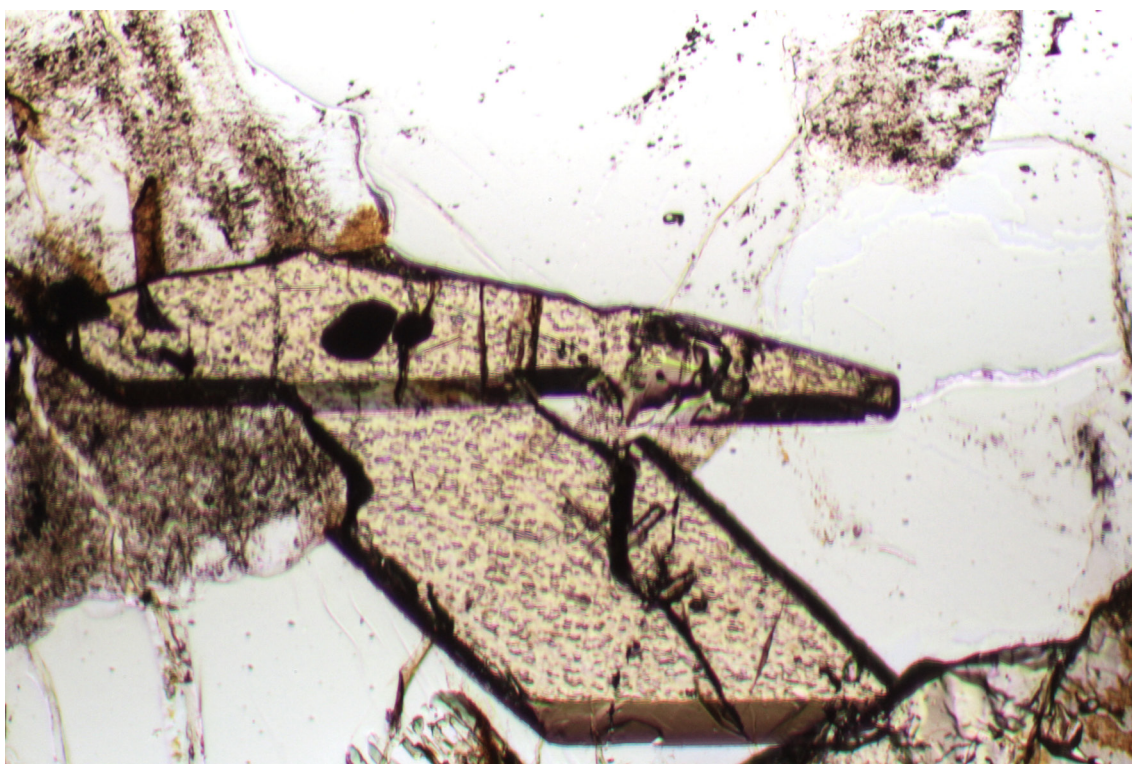
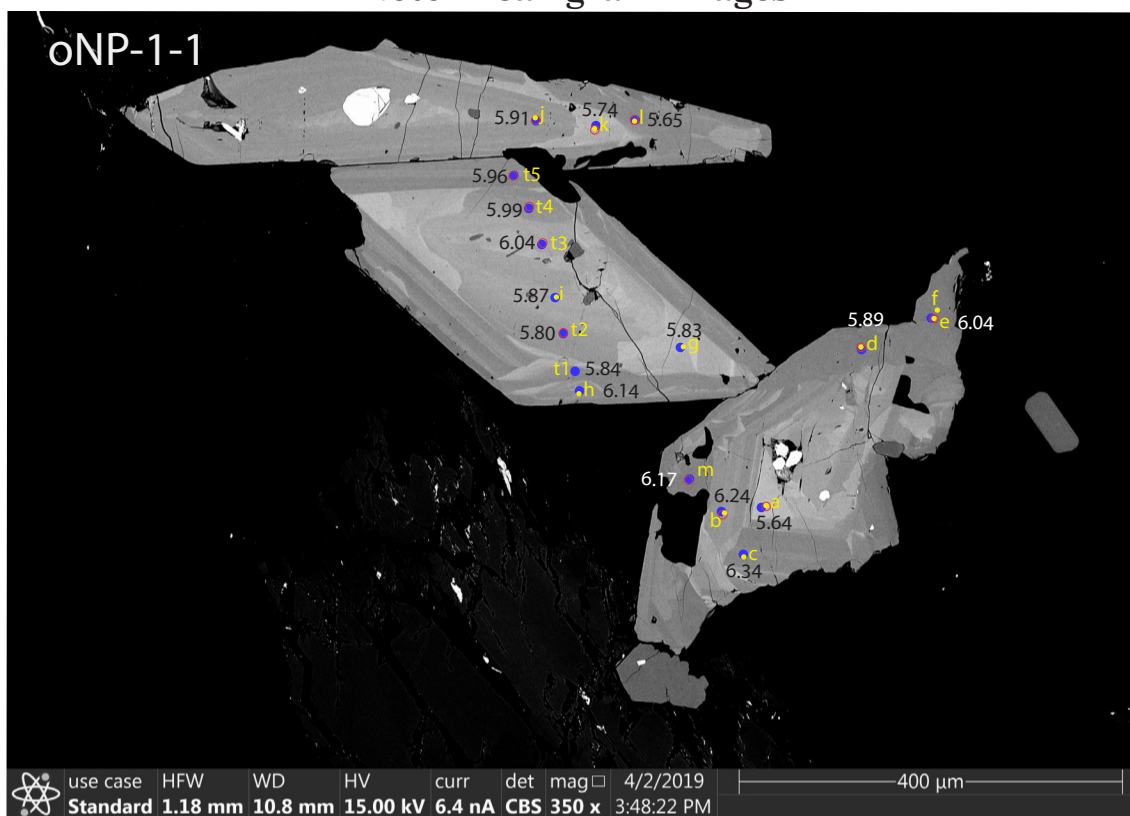


Figure A9. Top: Notch Peak grains oNP-1-1 with electron microprobe spots (yellow), LA-ICP-MS spots (red), oxygen isotope spots (blue). Numbers are $\delta^{18}\text{O}$ ‰ values. Bottom: Petrographic view of the two upper grains in the BSE photo above.

Notch Peak grain images

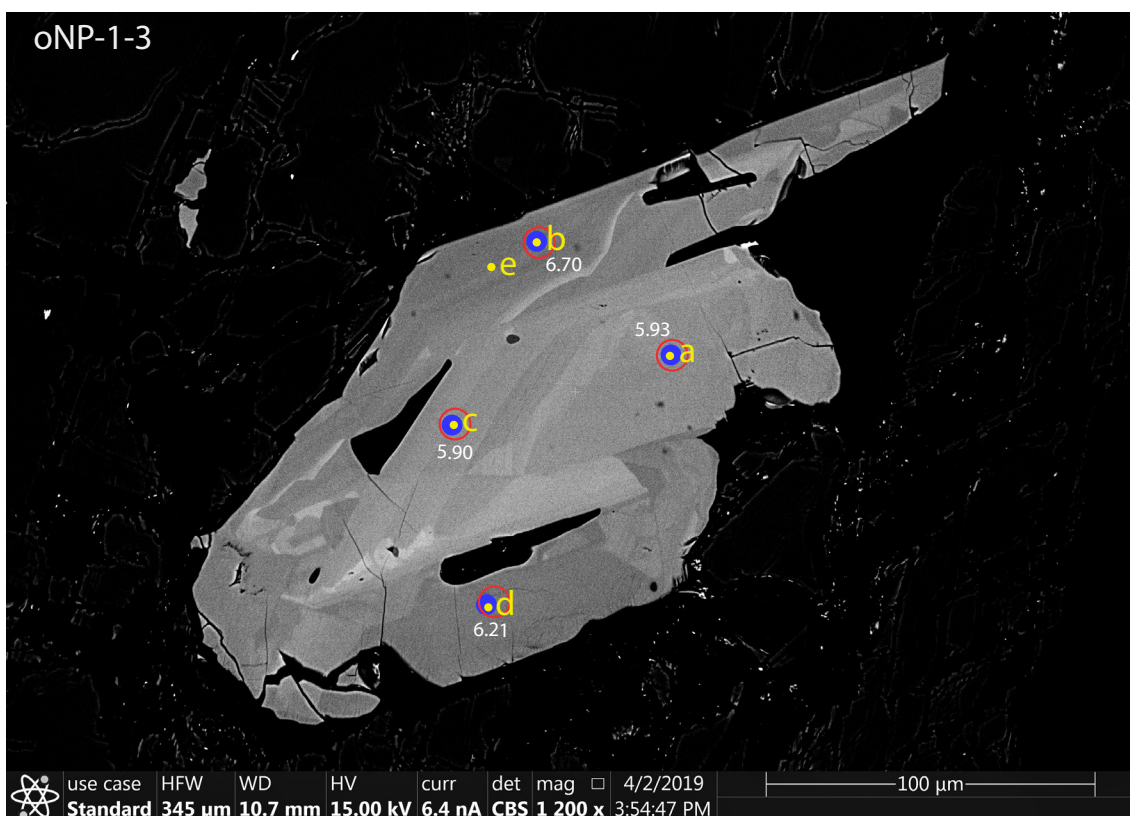
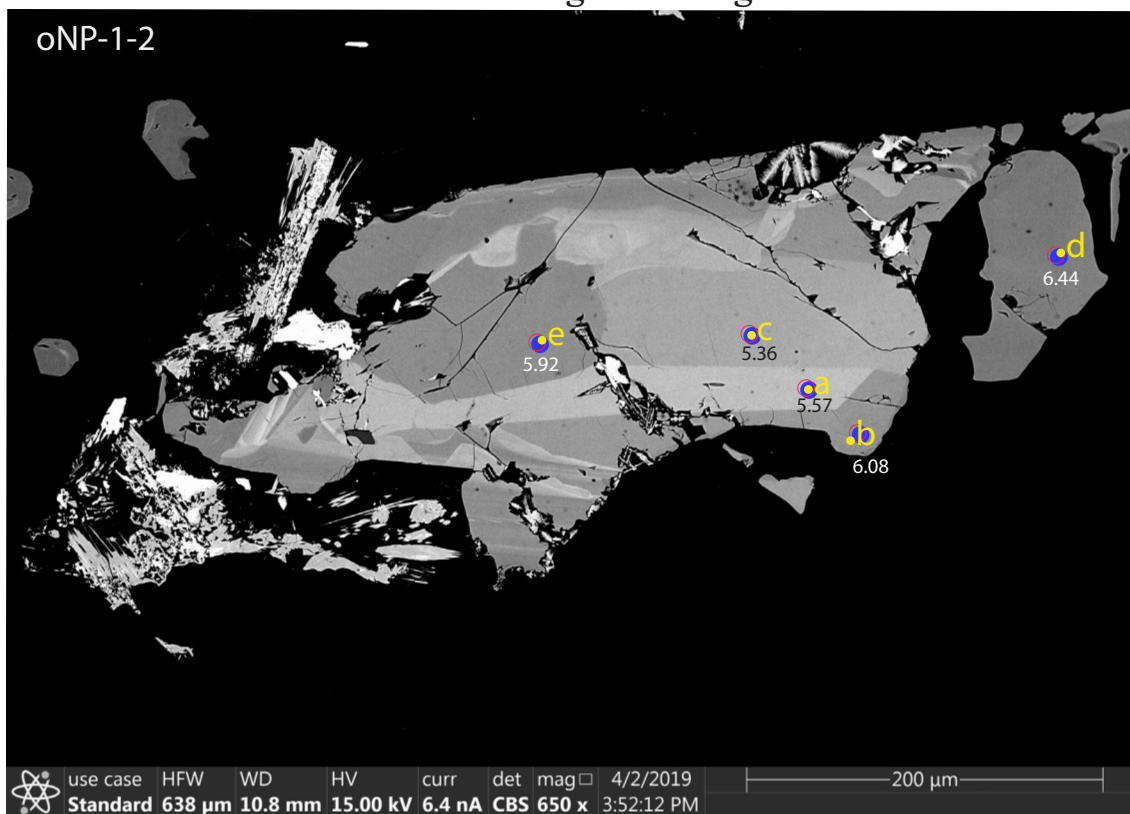


Figure A10. Notch Peak grains oNP-1-2 and oNP-1-3 with electron microprobe spots (yellow), LA-ICP-MS spots (red), oxygen isotope spots (blue). Numbers are $\delta^{18}\text{O}$ ‰ values.

Notch Peak grain images

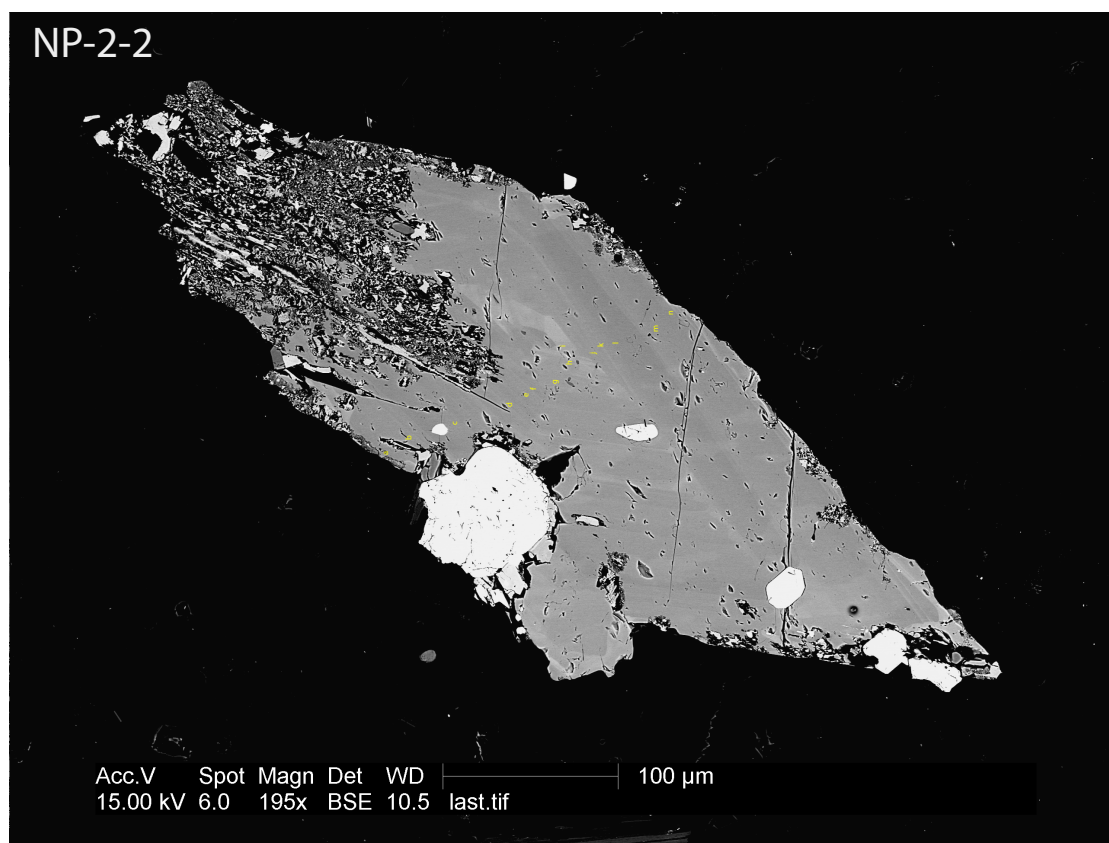
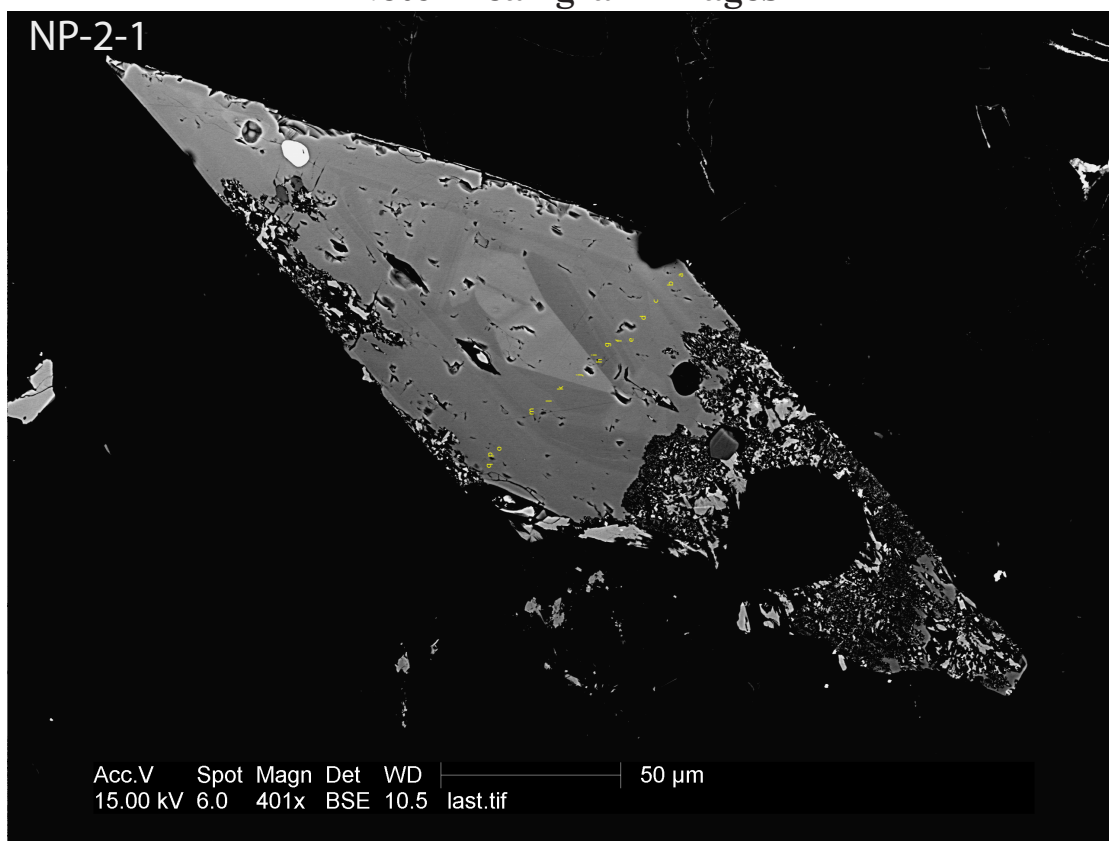


Figure A11. Notch Peak grains NP-2-1 and NP-2-2 with electron microprobe spots (yellow letters).

Notch Peak grain images

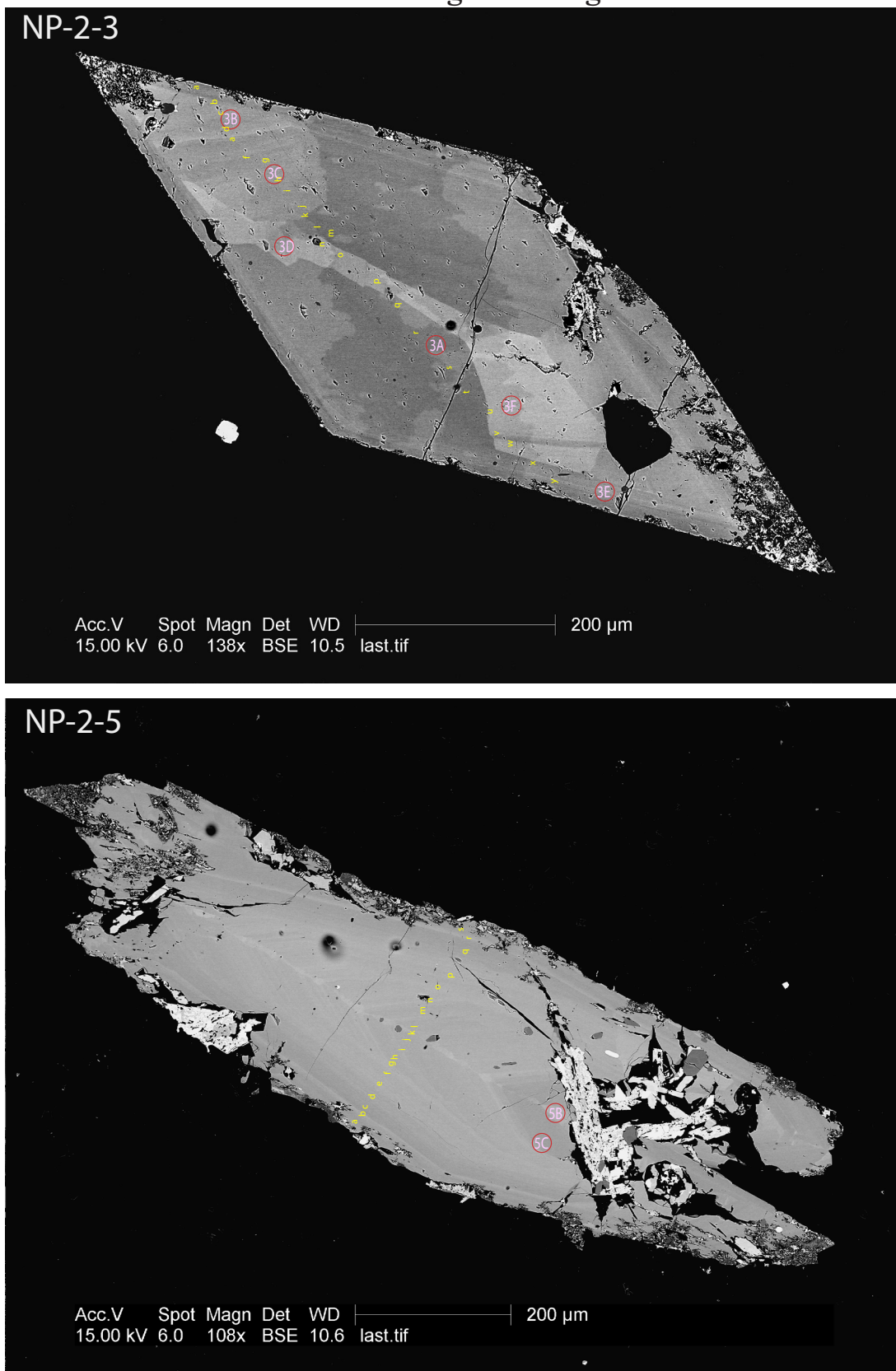


Figure A12. Notch Peak grains NP-2-3 and NP-2-5 with electron microprobe spots (yellow letters) and LA-ICPMS spots (red with pink letters).

Notch Peak grain images

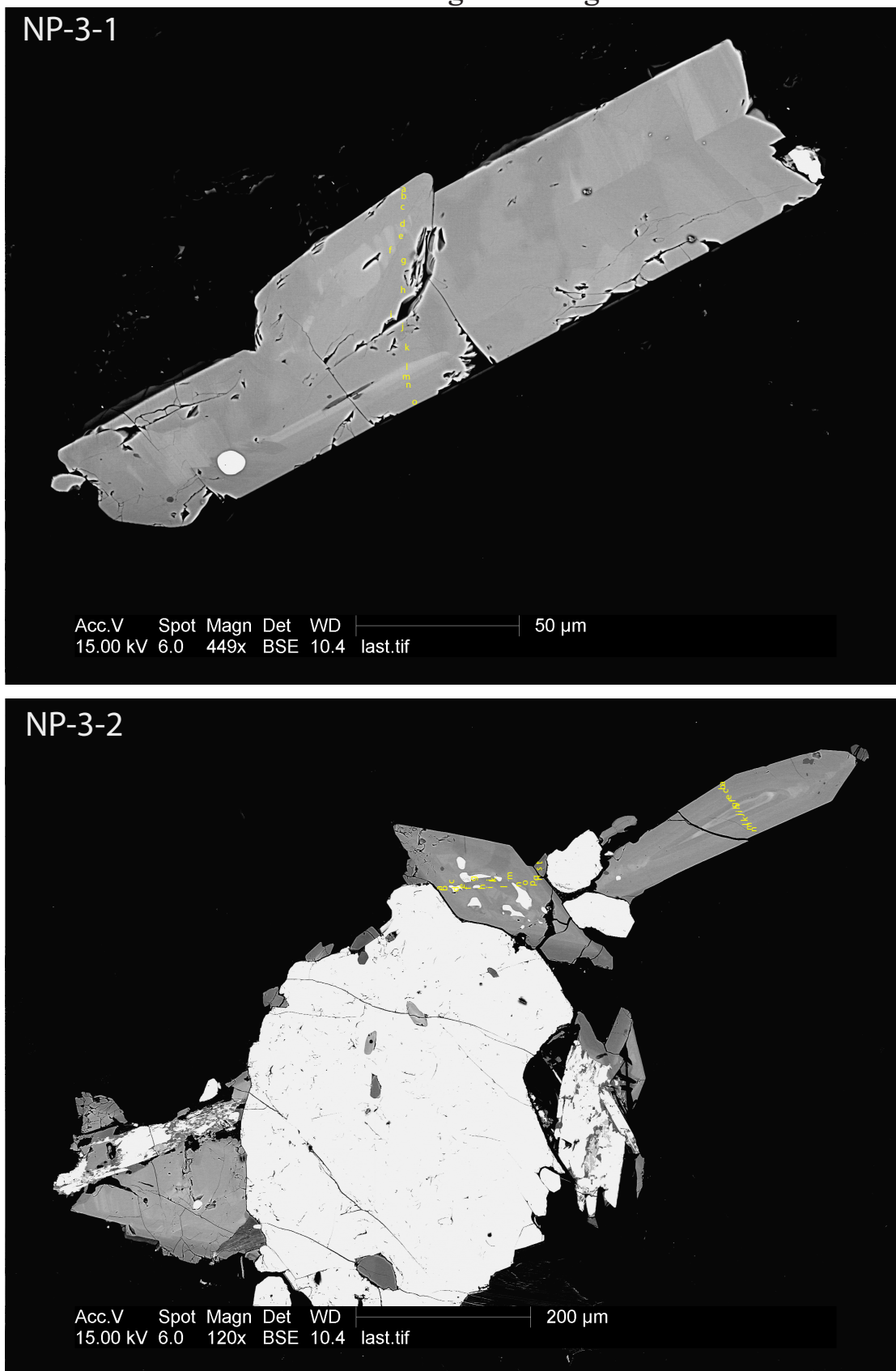


Figure A13. Notch Peak grains NP-3-1 and NP-3-2 with electron microprobe spots (yellow letters).

Notch Peak grain images

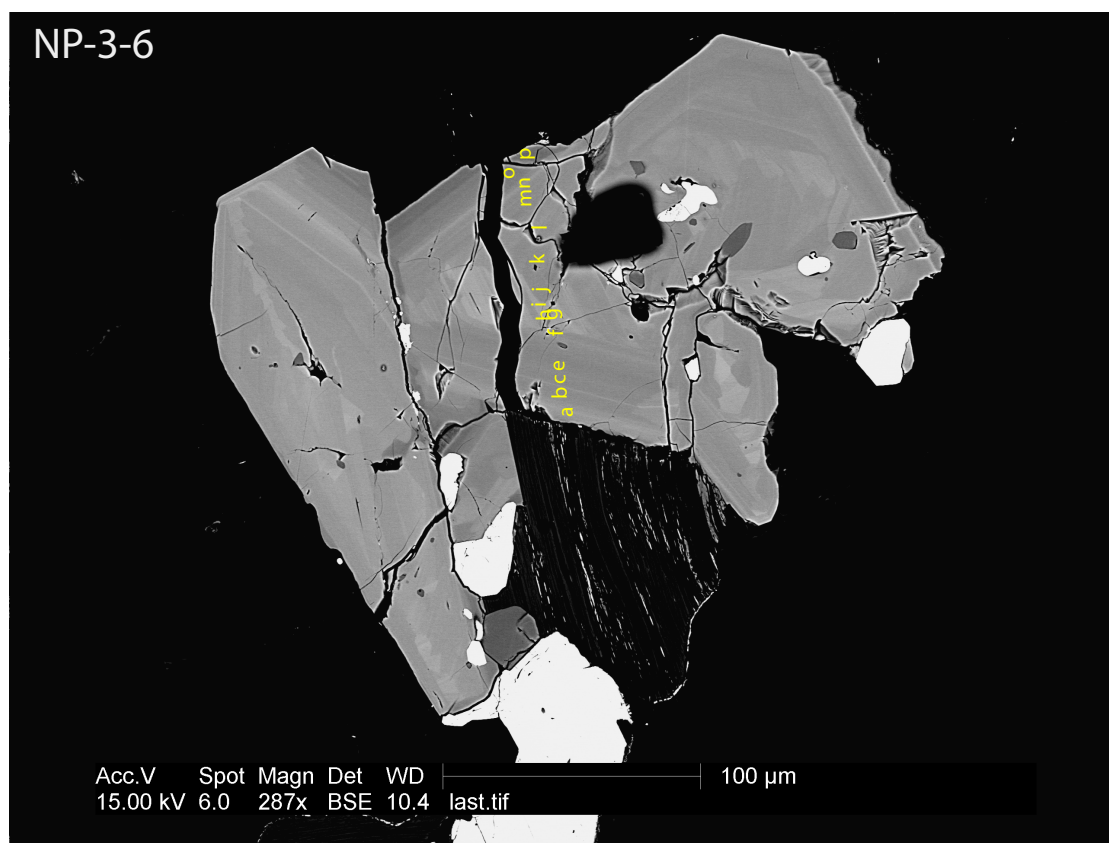
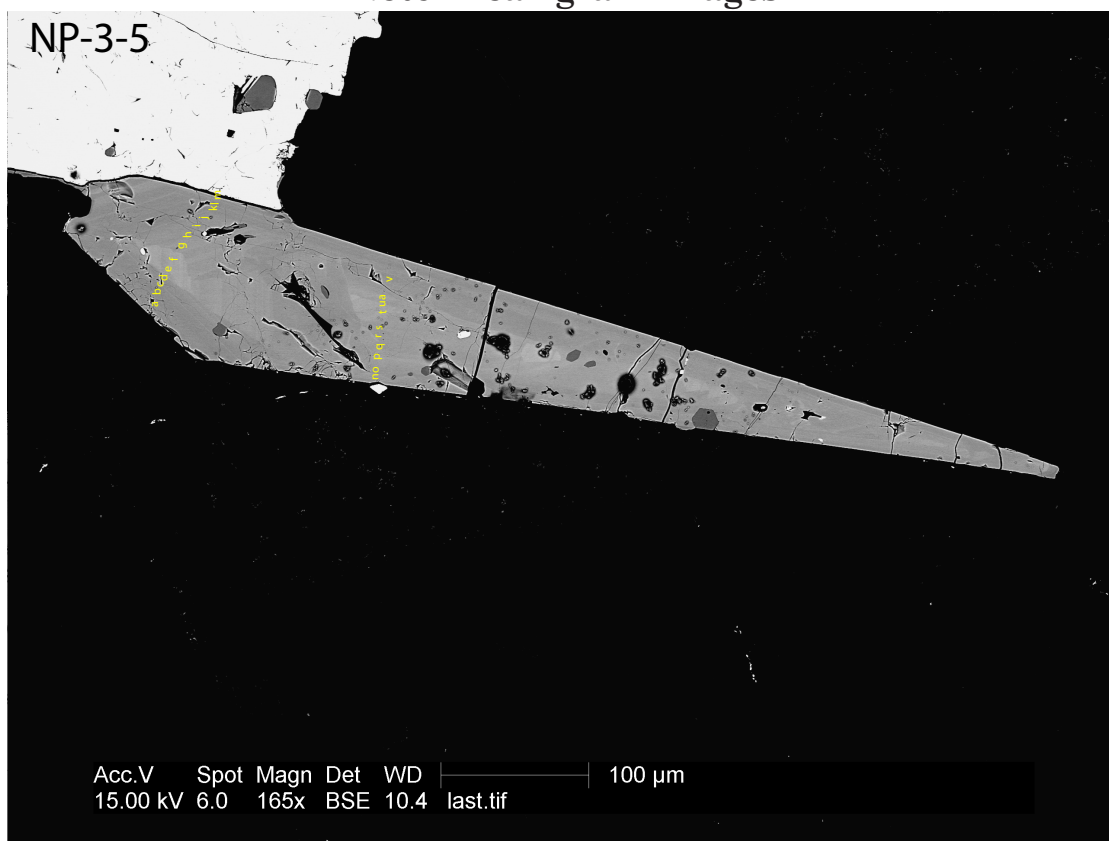


Figure A14. Notch Peak grains NP-3-5 and NP-3-6 with electron microprobe spots (yellow letters).

Notch Peak grain images

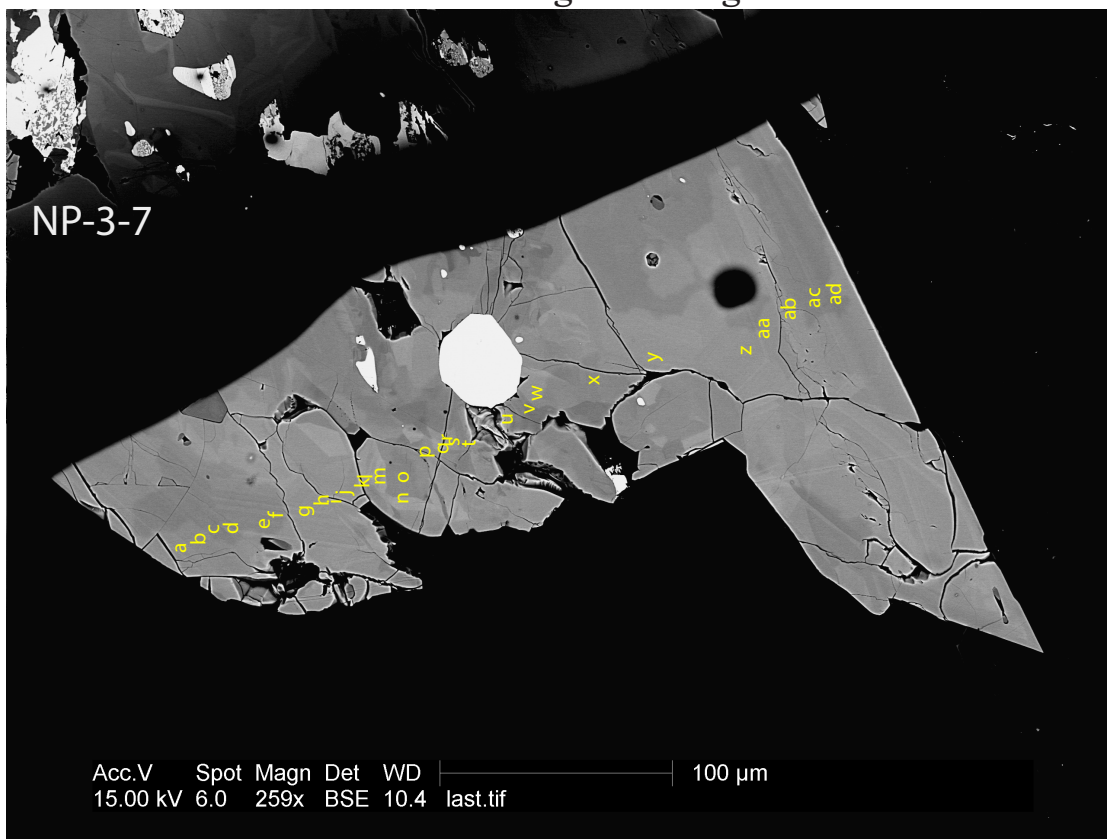


Figure A15. Notch Peak grain NP-3-7 with electron microprobe spots (yellow letters).

Notch Peak grain images

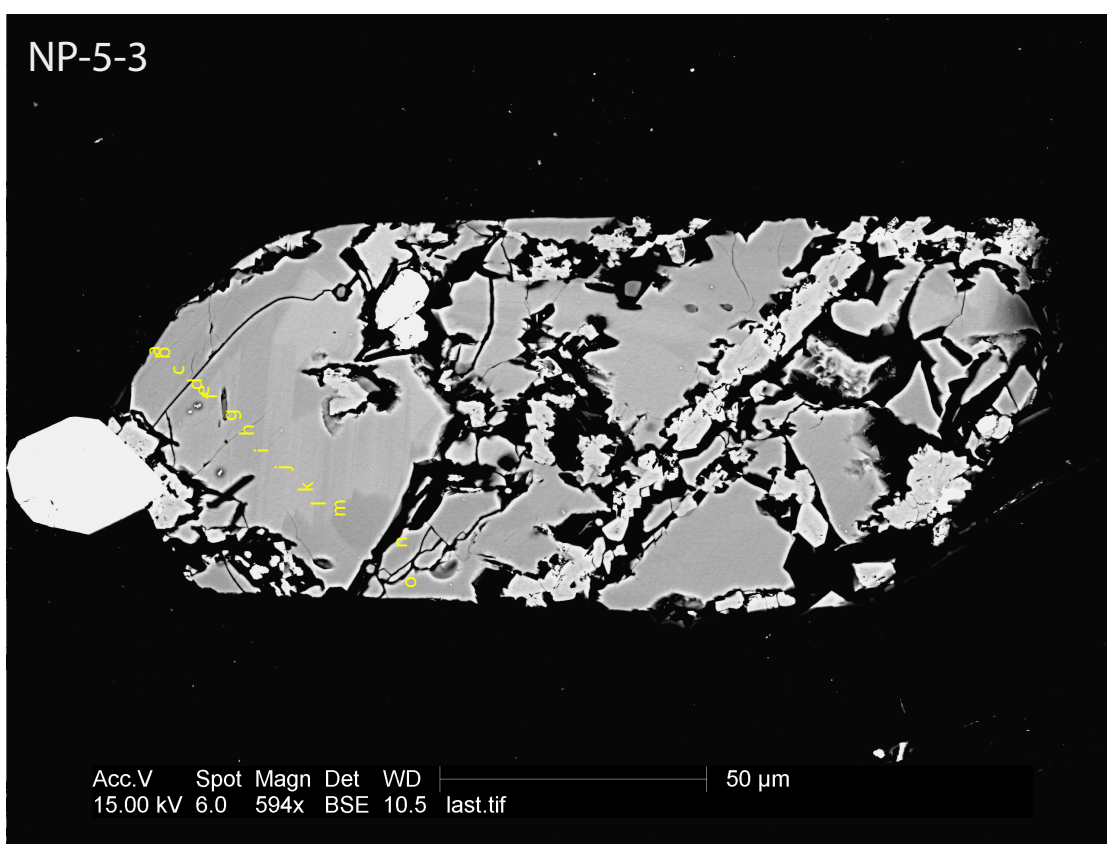
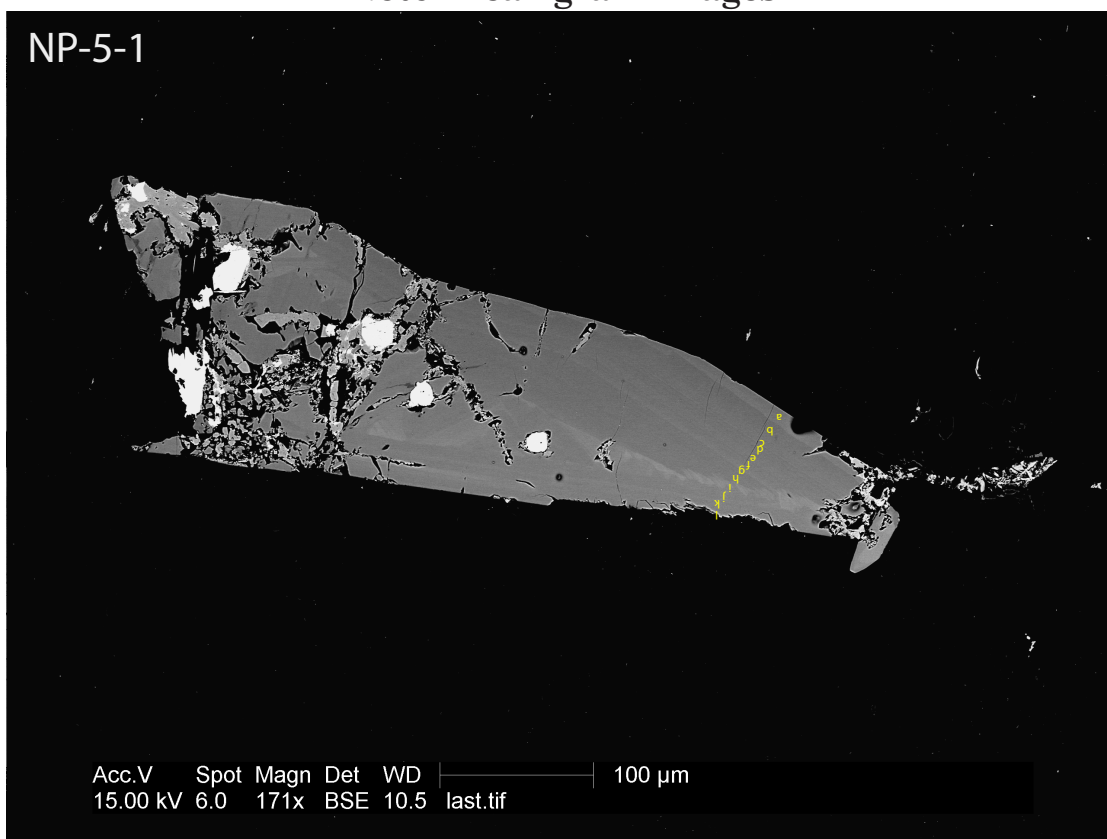


Figure A16. Notch Peak grains NP-5-1 and NP-5-3 with electron microprobe spots (yellow letters).

Notch Peak grain images

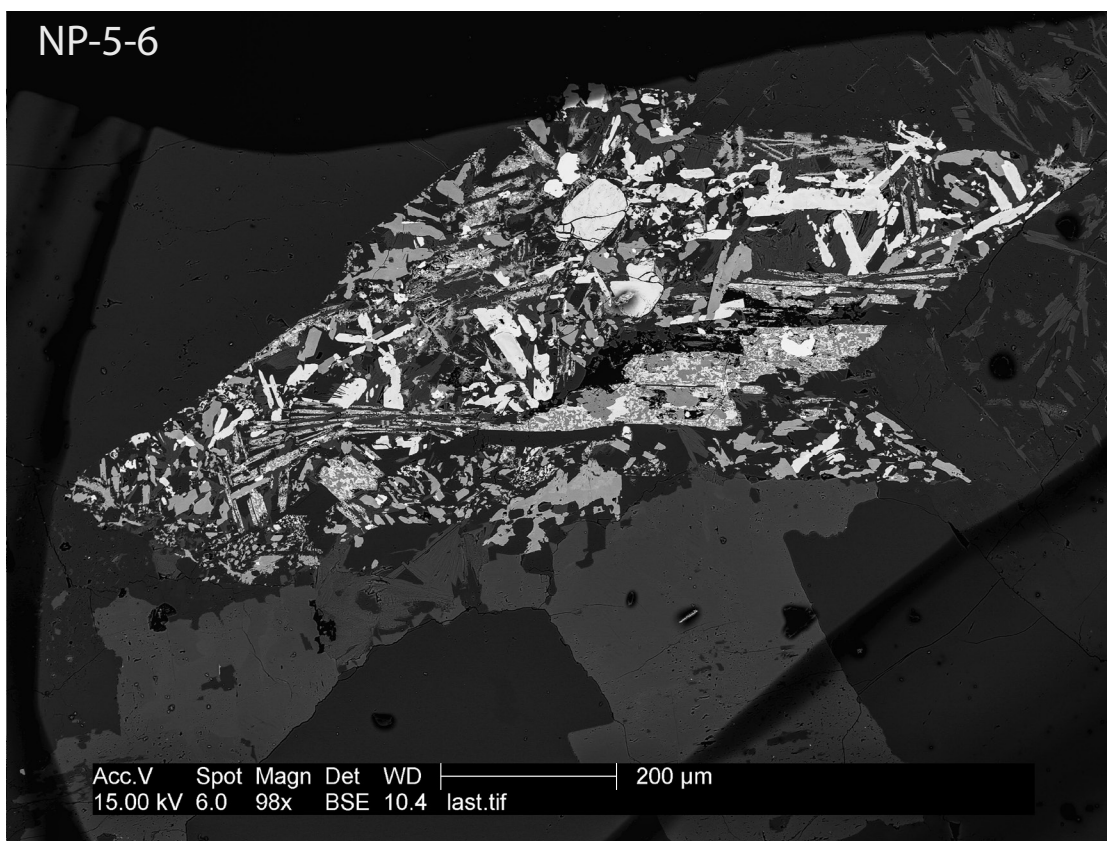
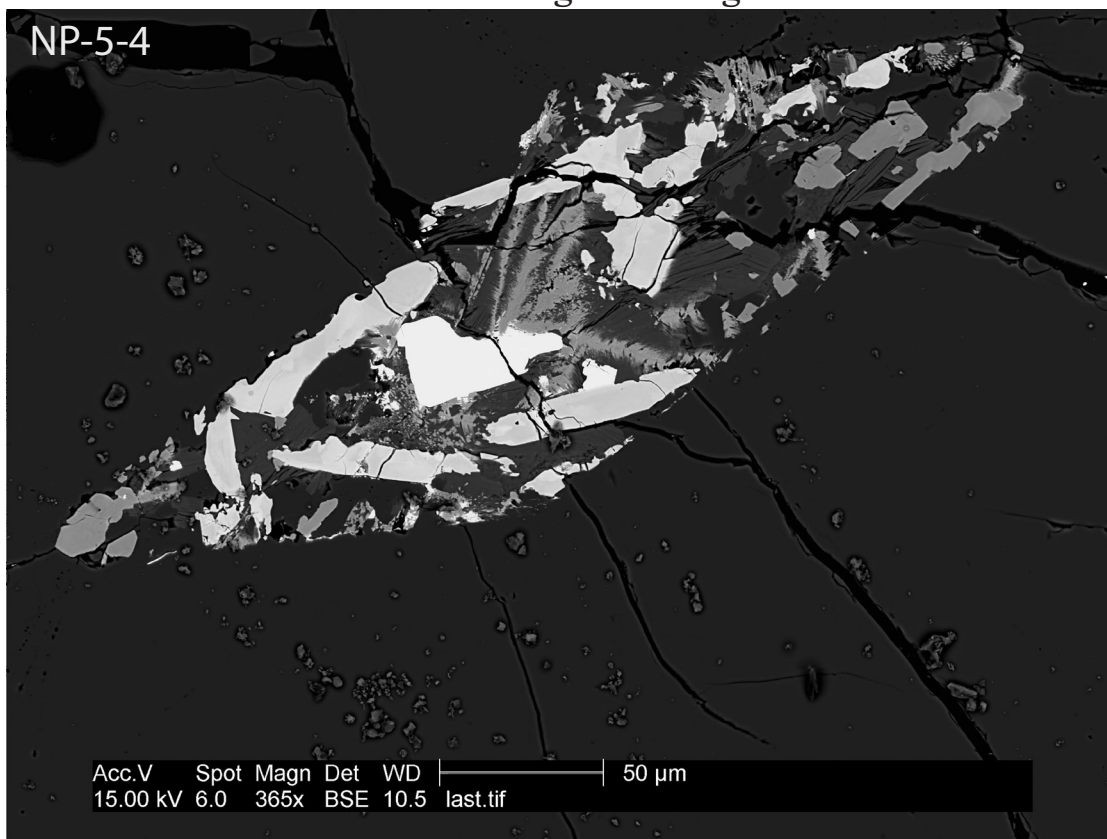


Figure A17. Notch Peak grains NP-5-4 and NP-5-6 showing complete replacement of titanite by secondary minerals.

Notch Peak grain images

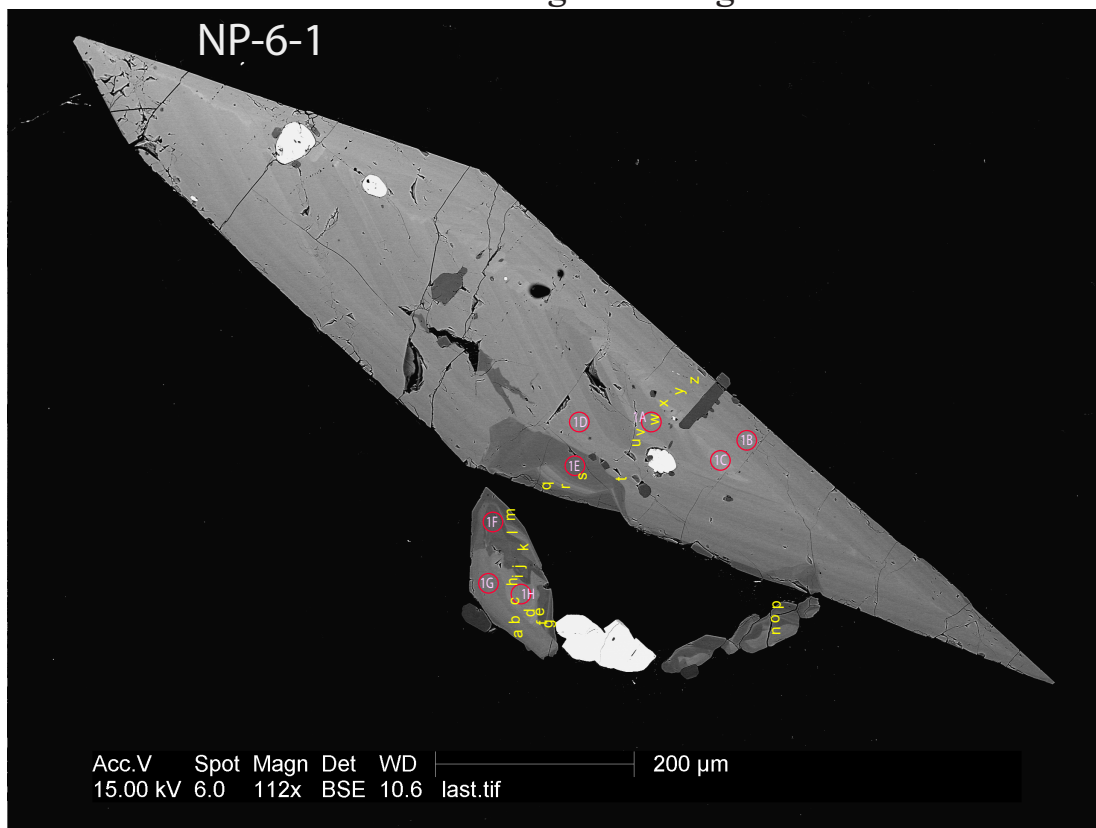


Figure A18. Top: Notch Peak grains in NP-6-1 with electron microprobe spots (yellow letters) and LA-ICP-MS spots (red with pink letters). Bottom: Petrographic view of the grains in the BSE photo above. Bubbles in epoxy seem to accumulate under titanite grains preferentially in thin sections.

Notch Peak grain images

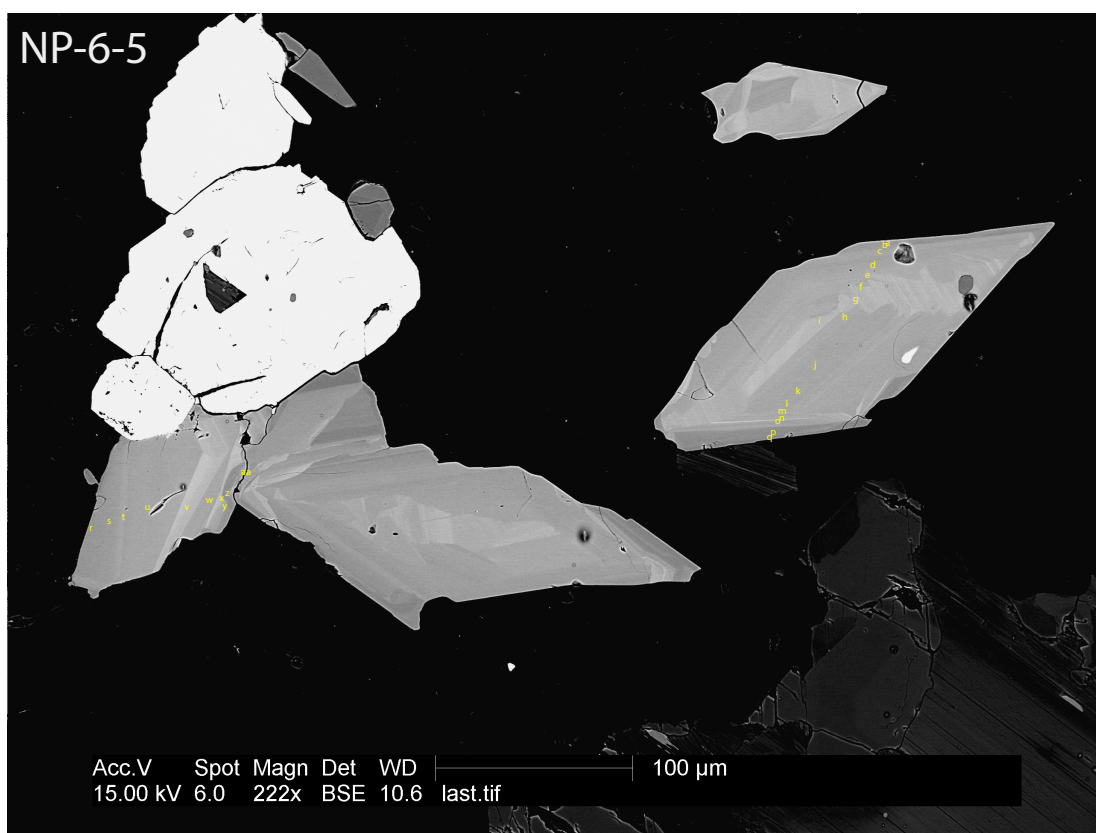
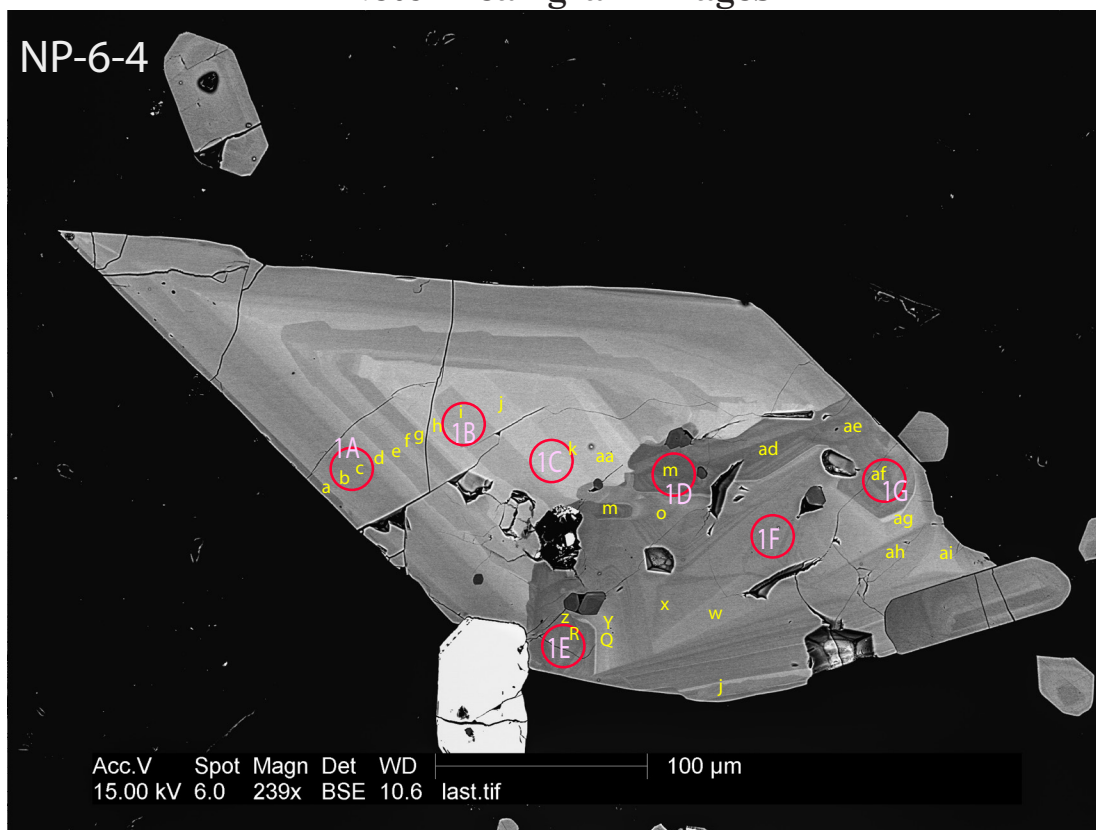


Figure A19. Notch Peak grains in NP-6-4 and NP-6-5 with electron microprobe spots (yellow letters) and LA-ICPMS spots (red with pink letters).

Notch Peak grain images

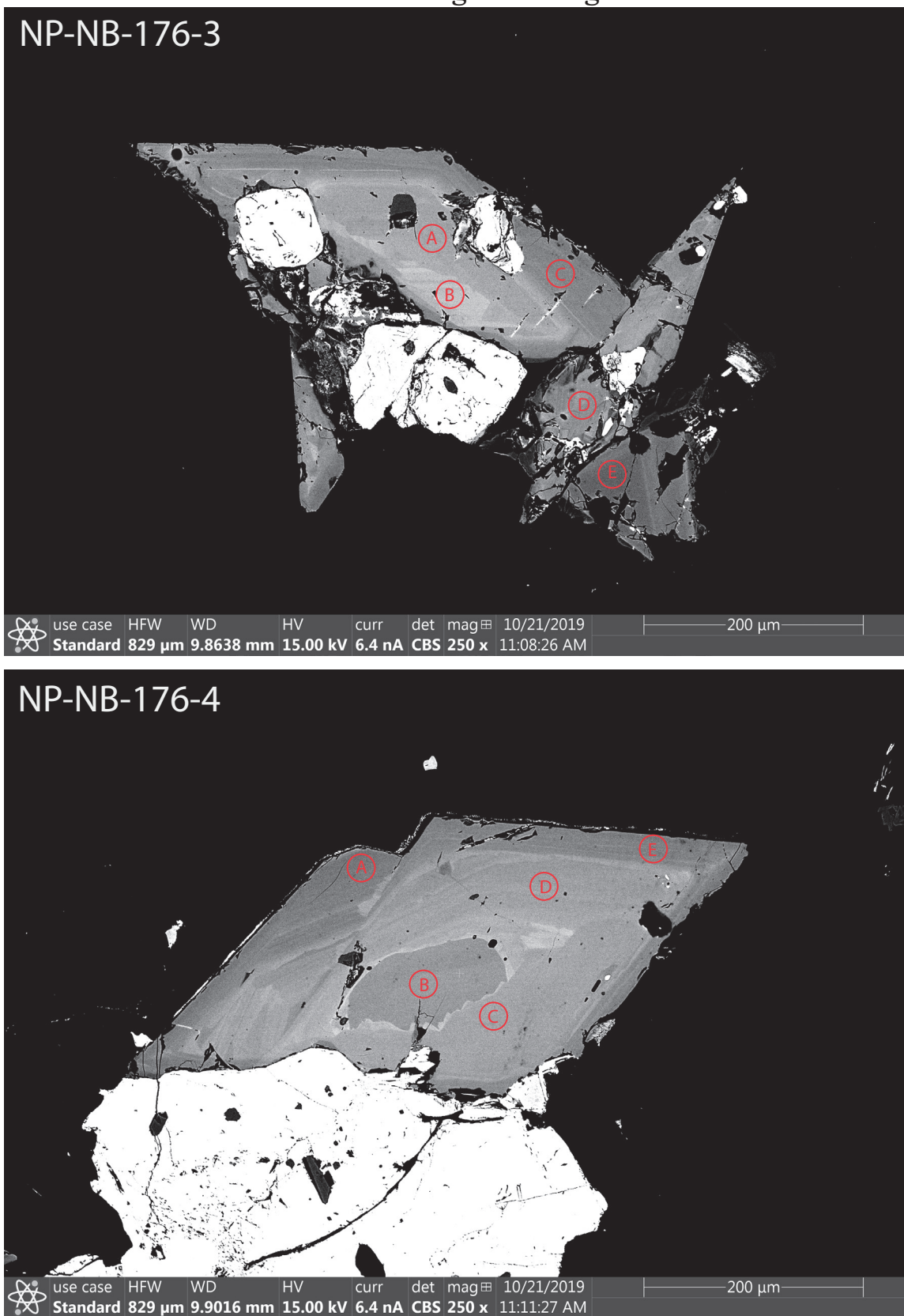


Figure A20. Notch Peak grains in NP-NB-176-3 and NP-NB-176-4 with LA-ICP-MS points (red).

Notch Peak aplite grain images

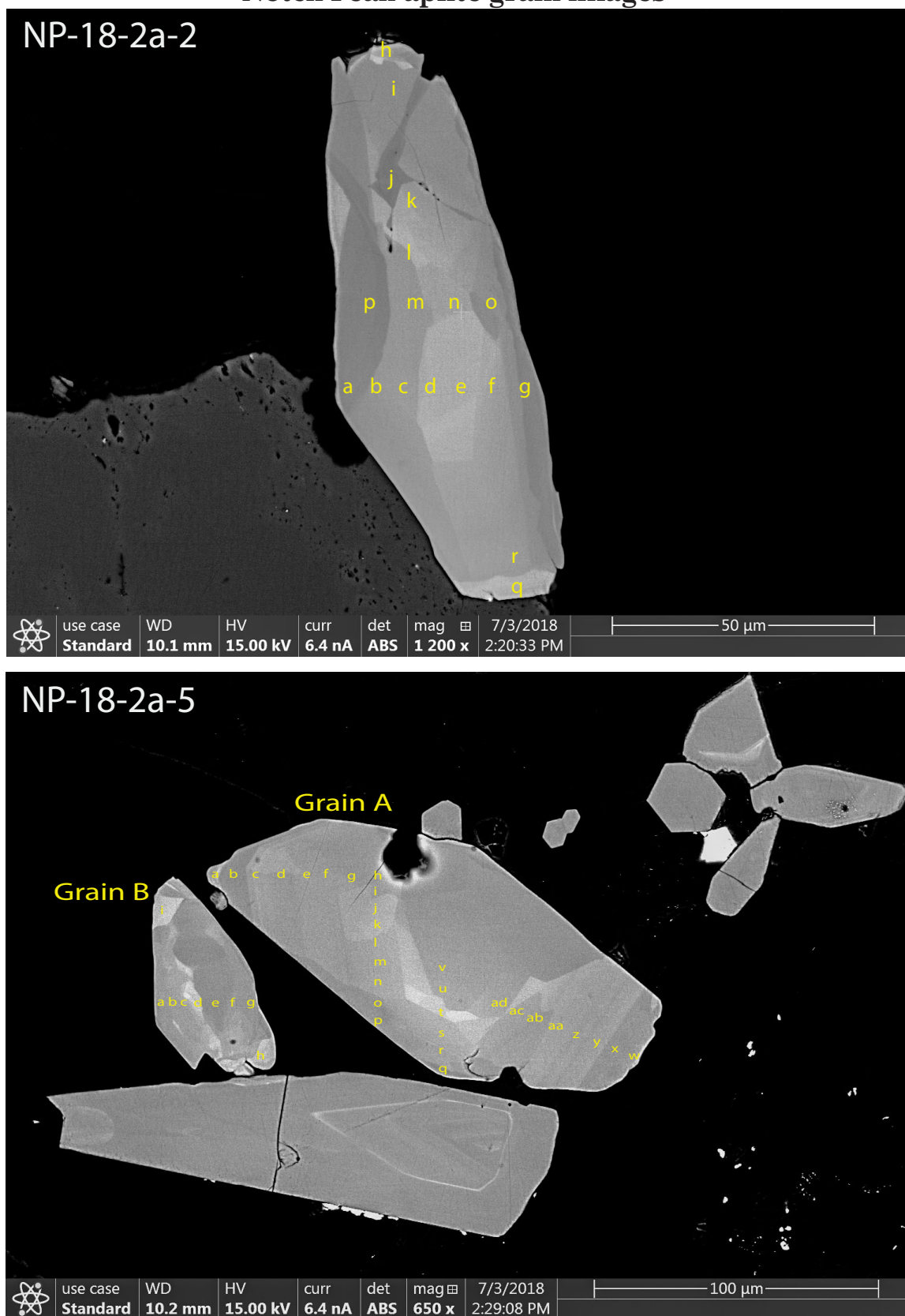


Figure A21. Notch Peak aplite grains in NP-18-2a-2 and NP-18-2a-5 with electron microprobe spots (yellow letters).

Notch Peak aplite grain images

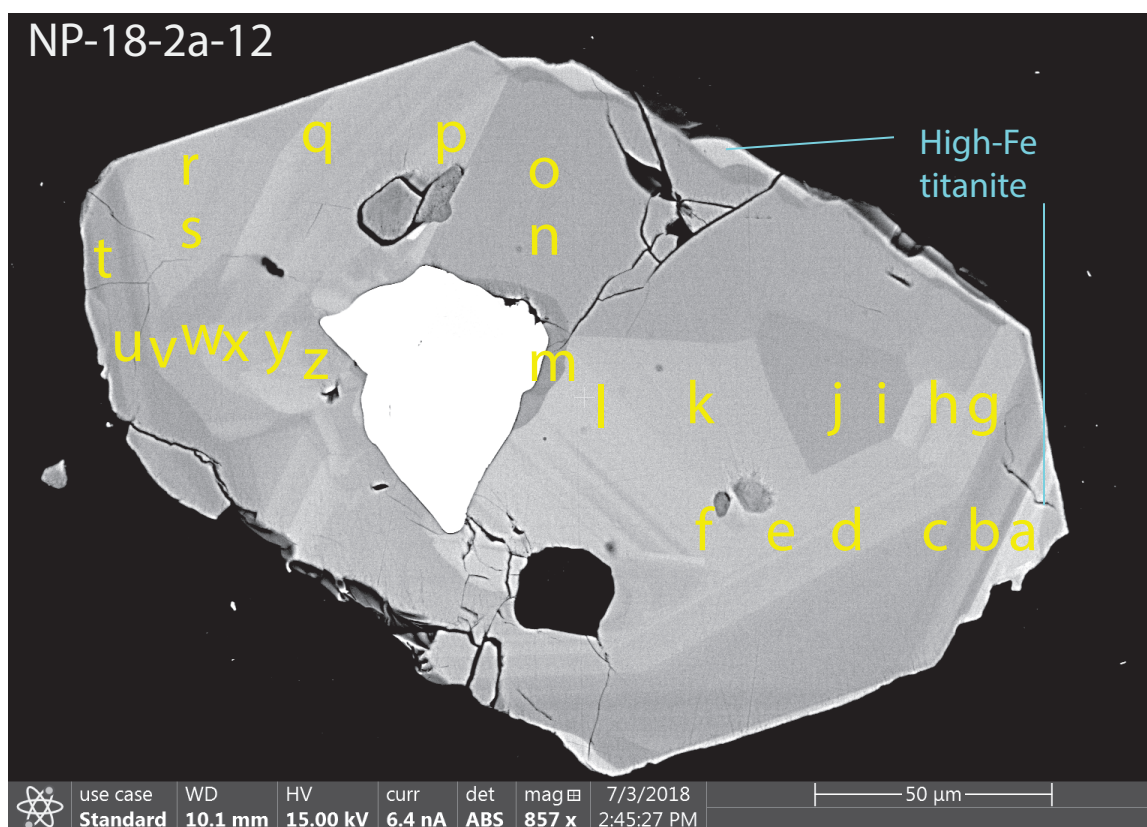
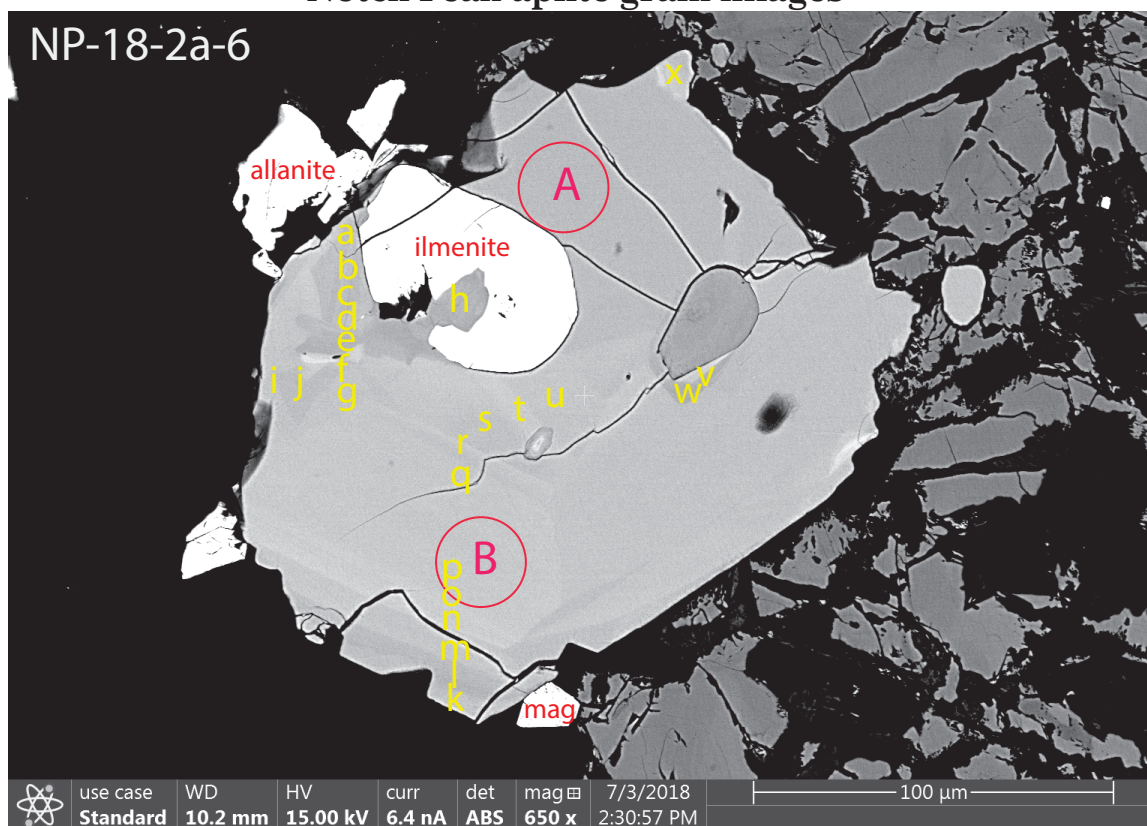


Figure A22. Notch Peak aplite grains in NP-18-2a-6 and NP-18-2a-12 with electron microprobe spots (yellow letters) and LA-ICP-MS points (red).

Notch Peak aplite grain images

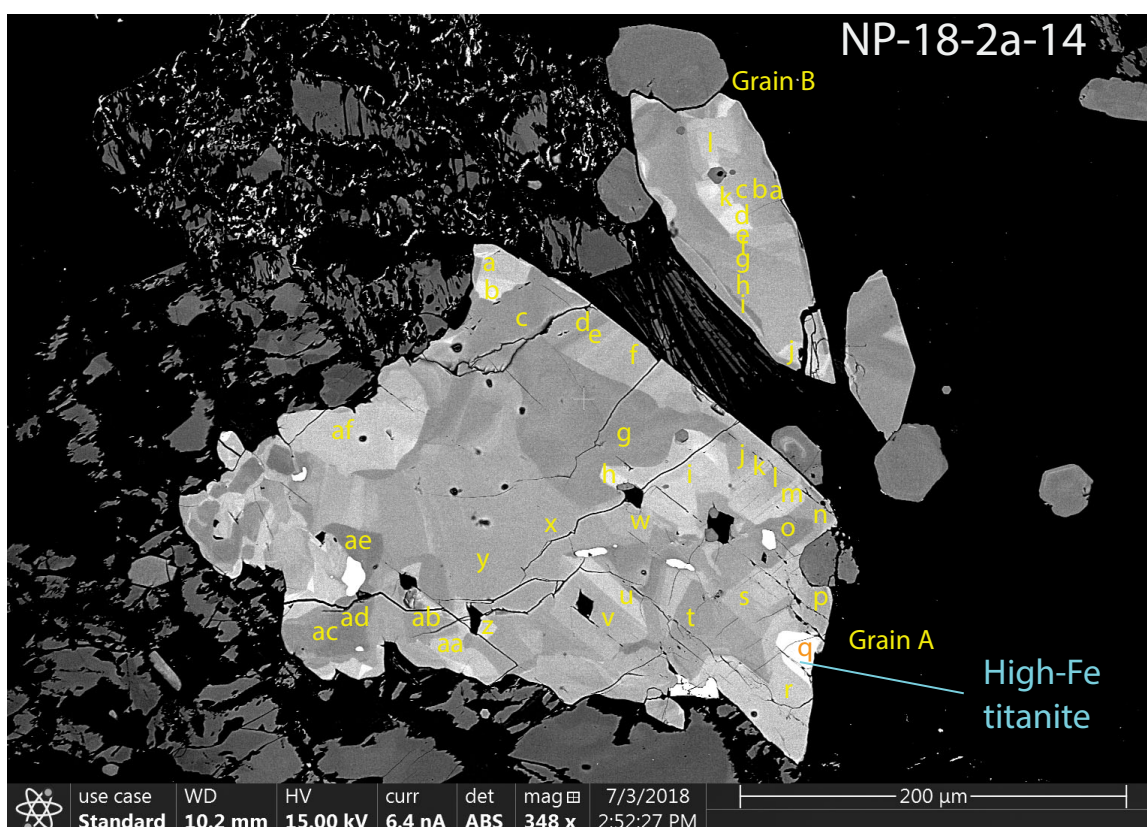
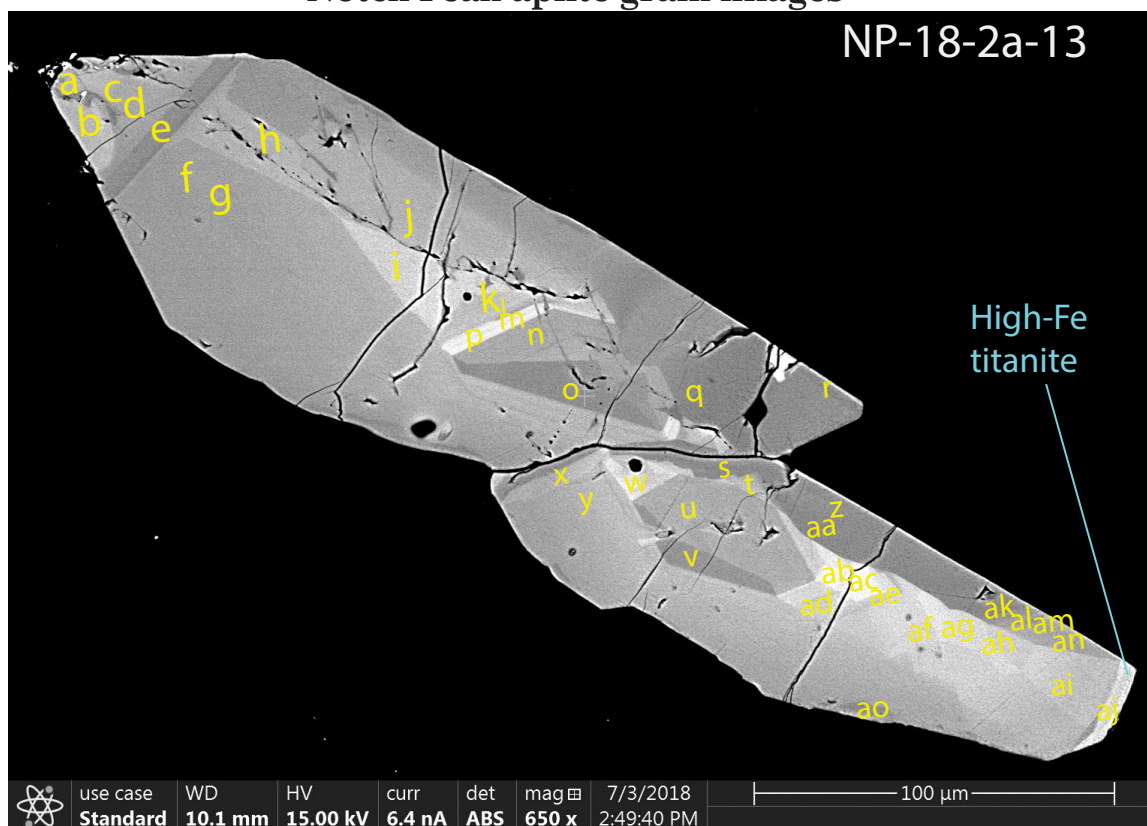


Figure A23. Notch Peak aplite grains in NP-18-2a-13 and NP-18-2a-14 with electron microprobe spots (yellow letters).

Notch Peak aplite grain images

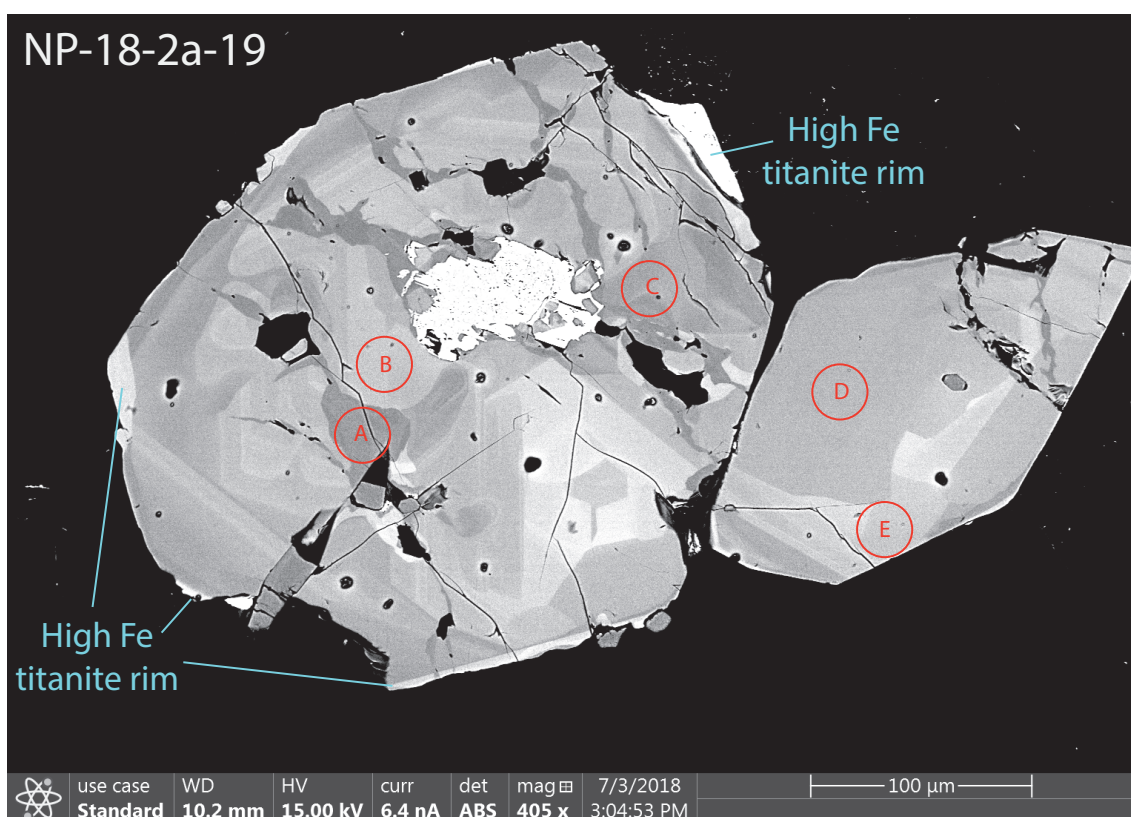
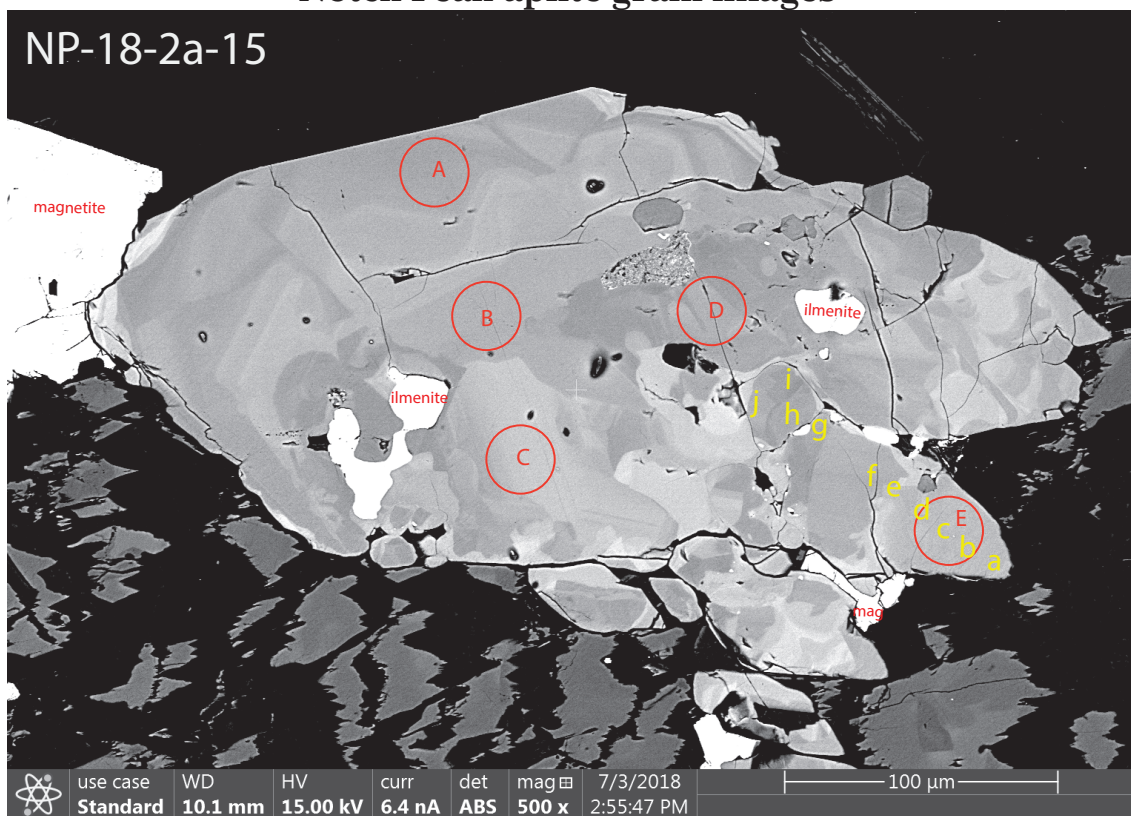


Figure A24. Notch Peak aplite grains in NP-18-2a-15 and NP-18-2a-19 with electron microprobe spots (yellow letters) and LA-ICP-MS points (red).

Notch Peak aplite grain images

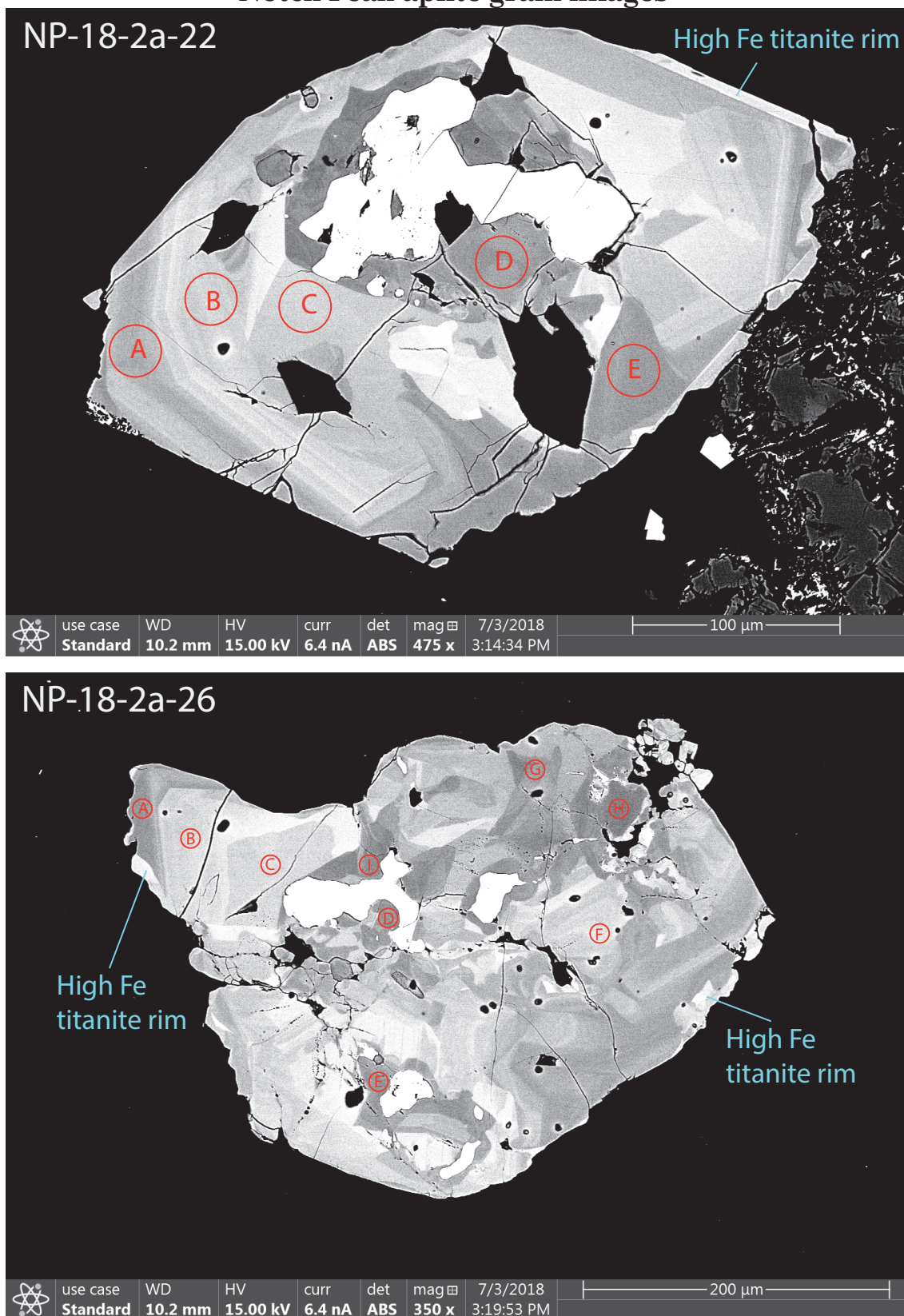


Figure A25. Notch Peak aplite grains in NP-18-2a-22 and NP-18-2a-26 with LA-ICP-MS points (red).

Notch Peak aplite grain images

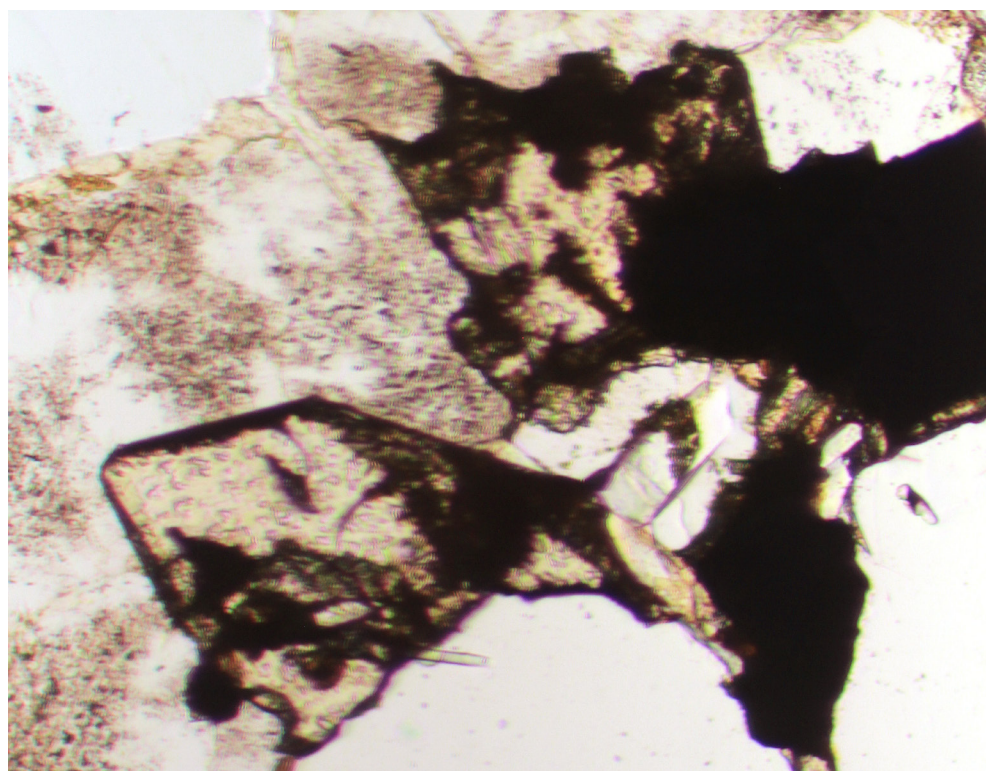
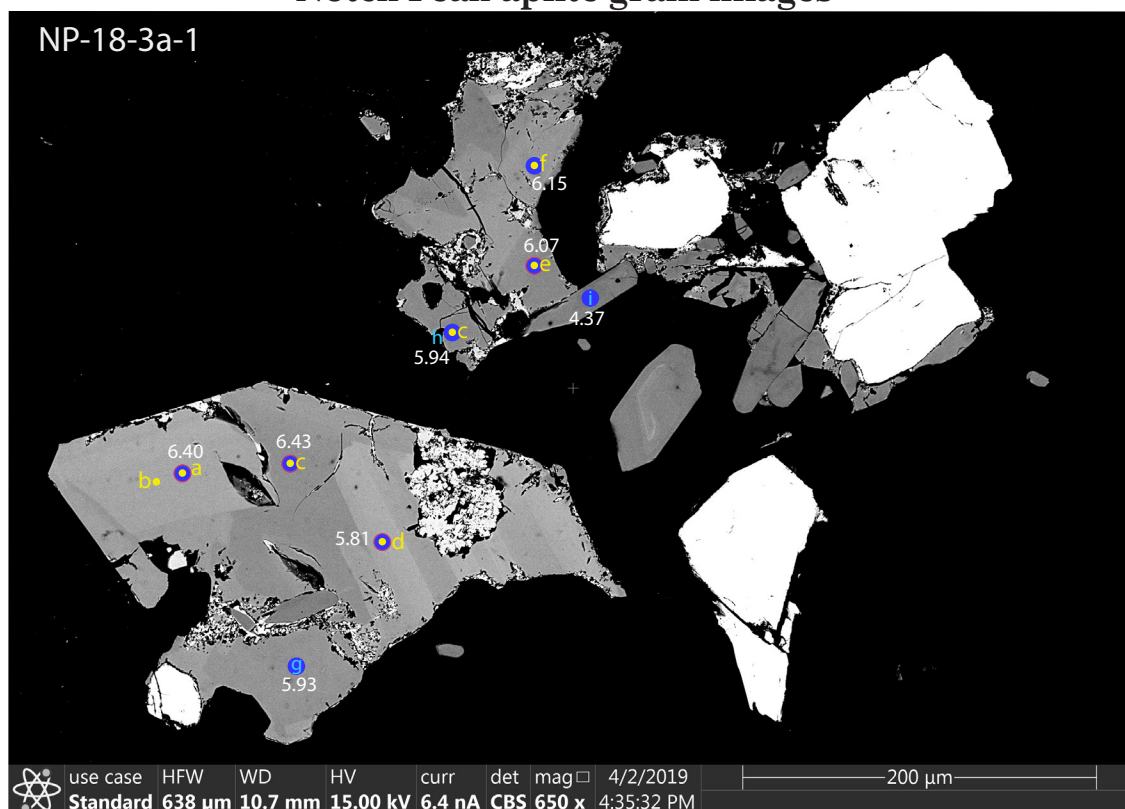


Figure A26. Notch Peak aplite grains in NP-18-3a-1. Top: BSE photo with electron microprobe points (yellow), LA-ICP-MS points (red), and oxygen isotope points (blue). Bottom: Petrographic photo of same grains. Numbers are $\delta^{18}\text{O}$ ‰ values.

Little Cottonwood stock grain images — Cherry Creek locality (CC)

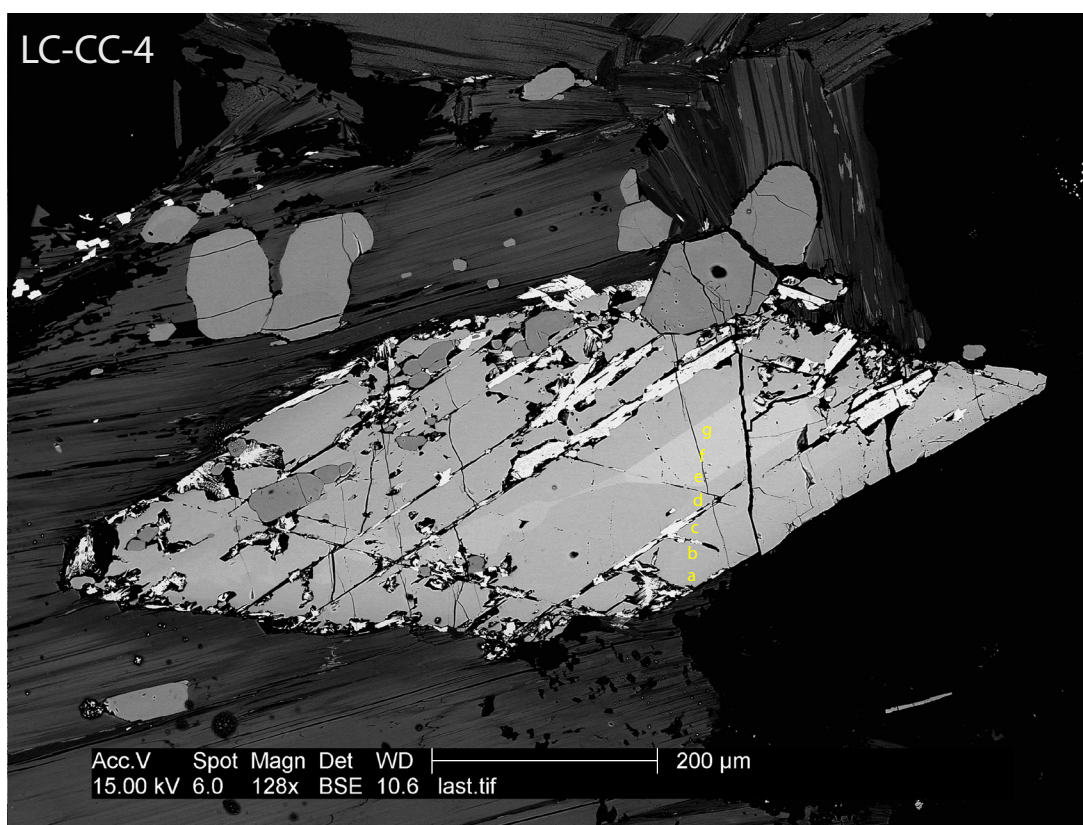
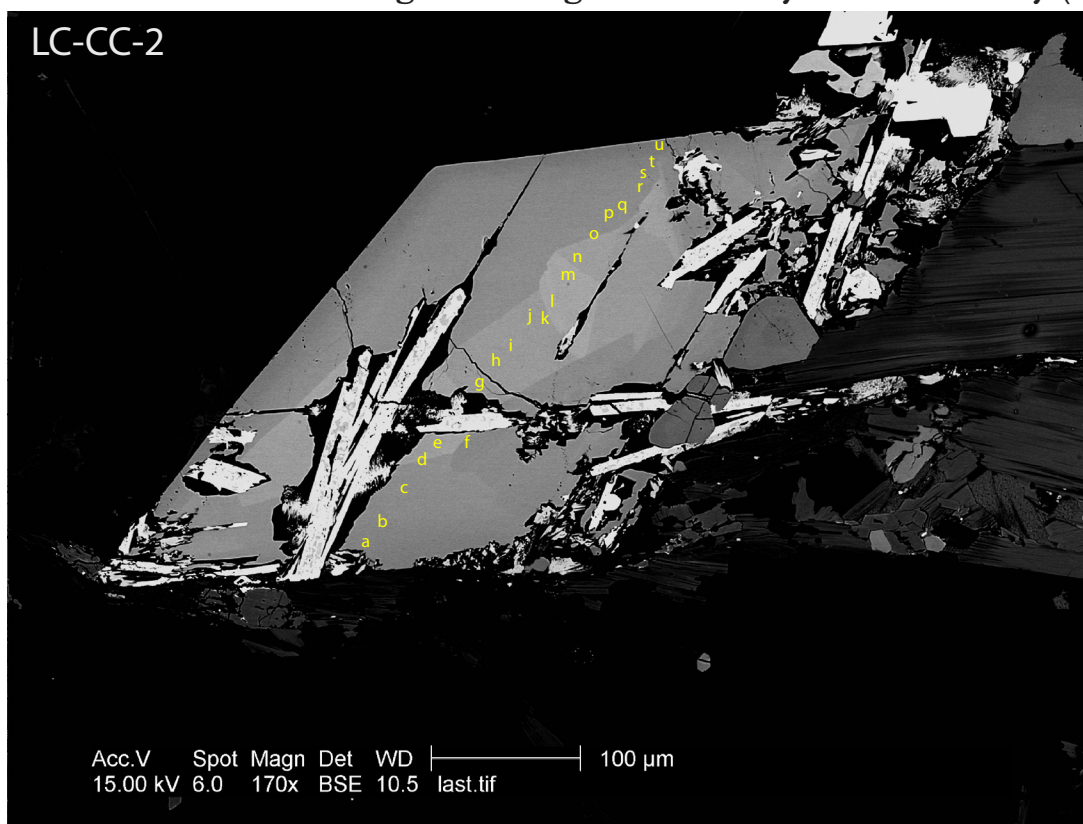


Figure A27. Little Cottonwood stock titanite grains in LC-CC-2 and LC-CC-4 with electron microprobe spots (yellow).

Little Cottonwood stock grain images — Cherry Creek locality (CC)

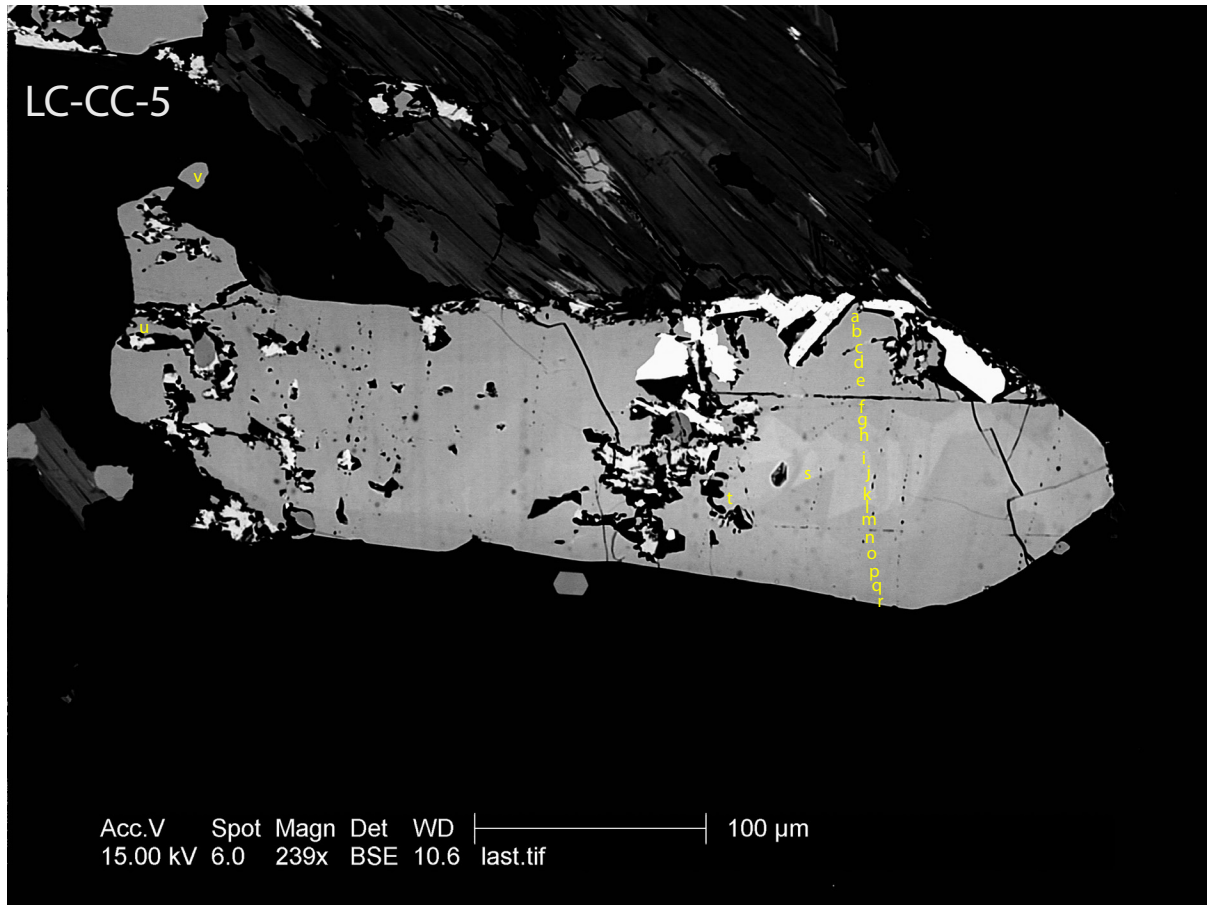


Figure A28. Little Cottonwood stock titanite grain in LC-CC-5 with electron microprobe spots (yellow).

Little Cottonwood stock grain images — Hogum Fork Turnout (HFT)

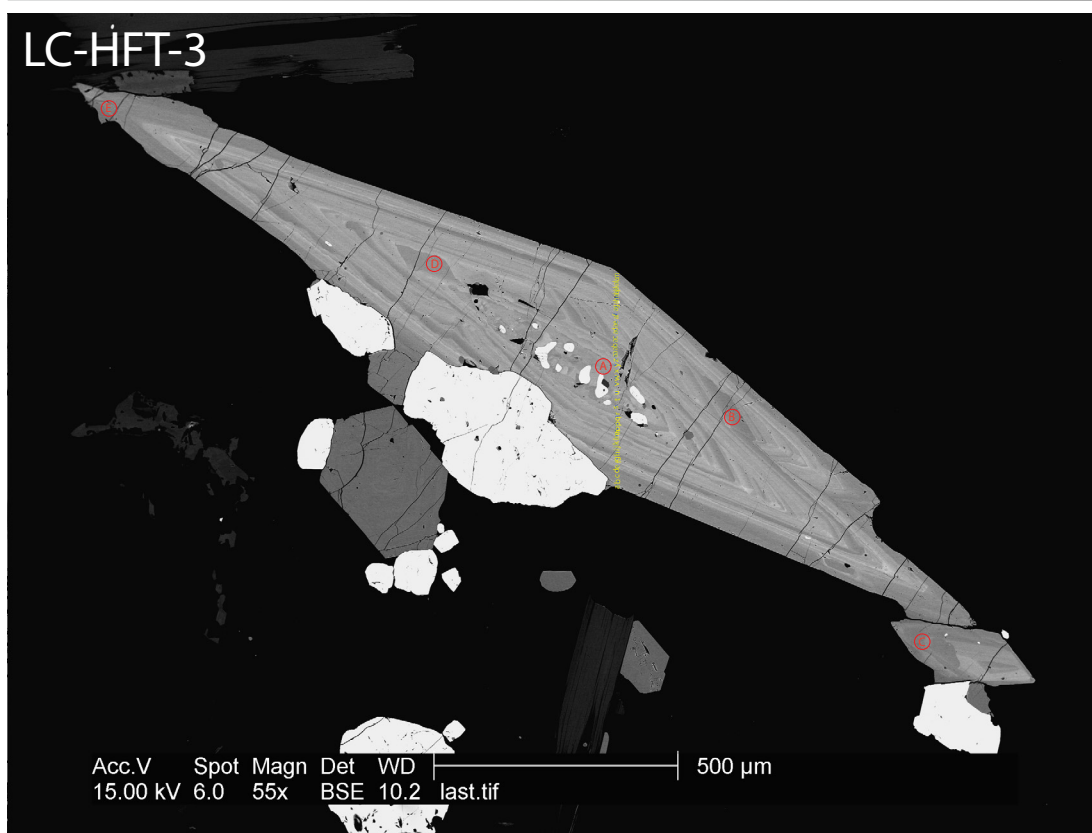
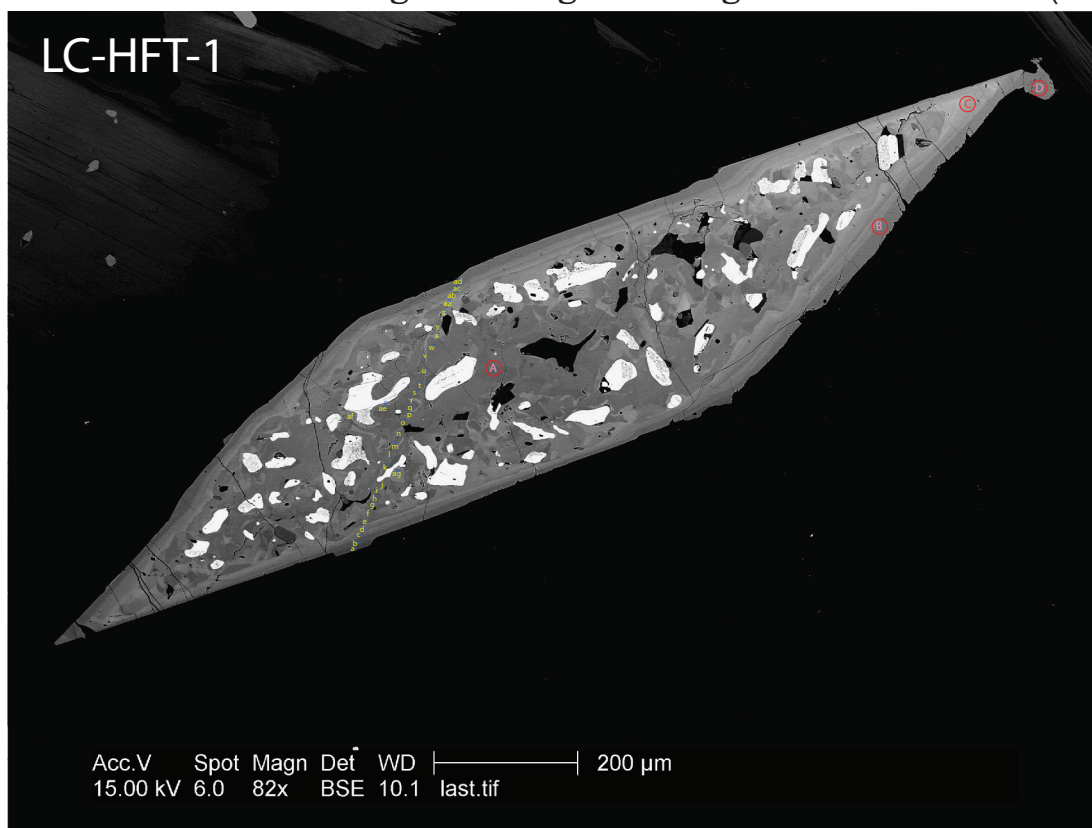


Figure A29. Little Cottonwood stock titanite grains in LC-HFT-1 and LC-HFT-2 with electron microprobe spots (yellow) and LA-ICP-MS spots (red).

Little Cottonwood stock grain images — Hogum Fork Turnout (HFT)

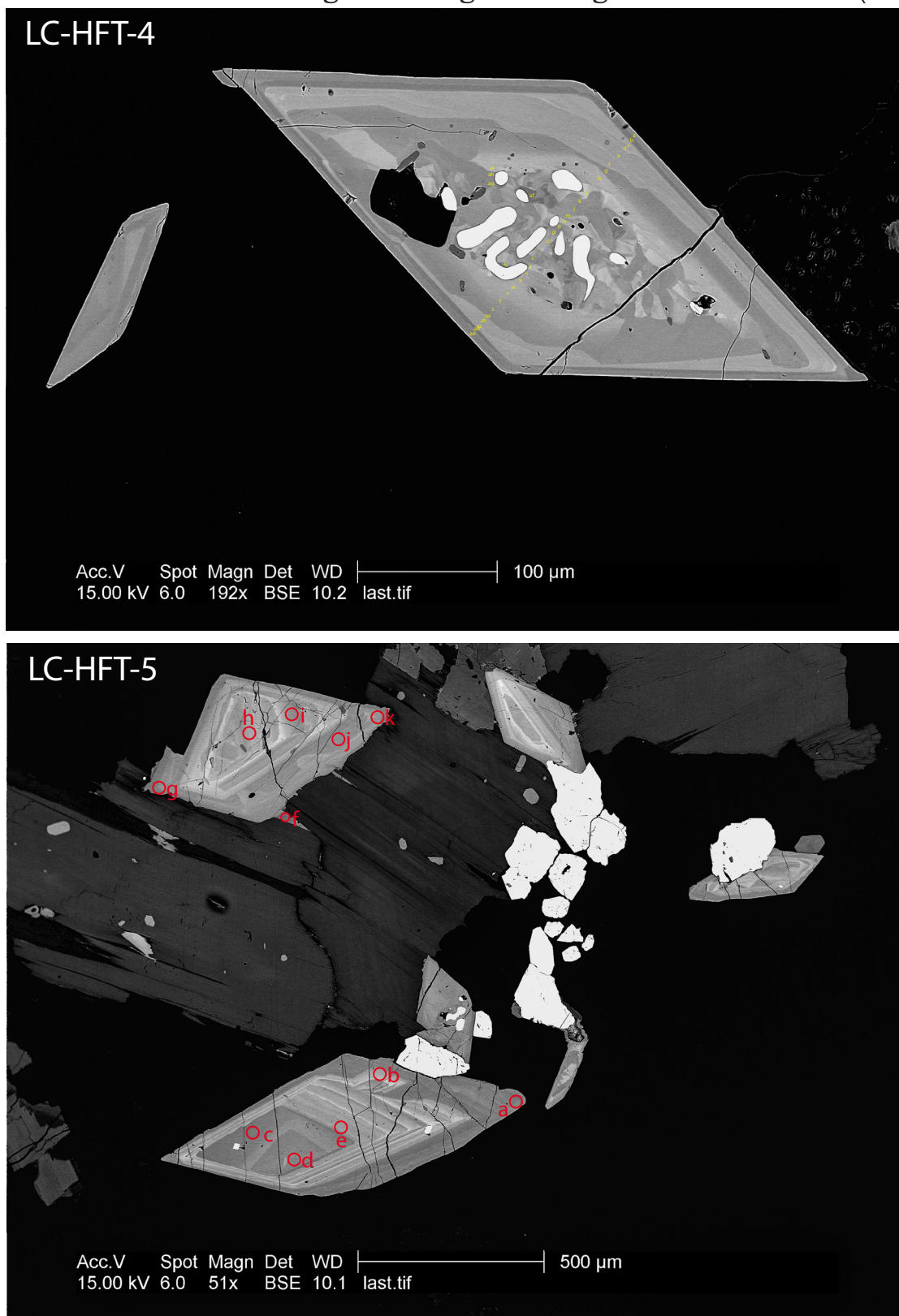


Figure A30. Little Cottonwood stock titanite grains in LC-HFT-4 and LC-HFT-5 with electron microprobe spots (yellow) and LA-ICP-MS spots (red).

Little Cottonwood stock grain images — Hogum Fork Turnout (HFT)

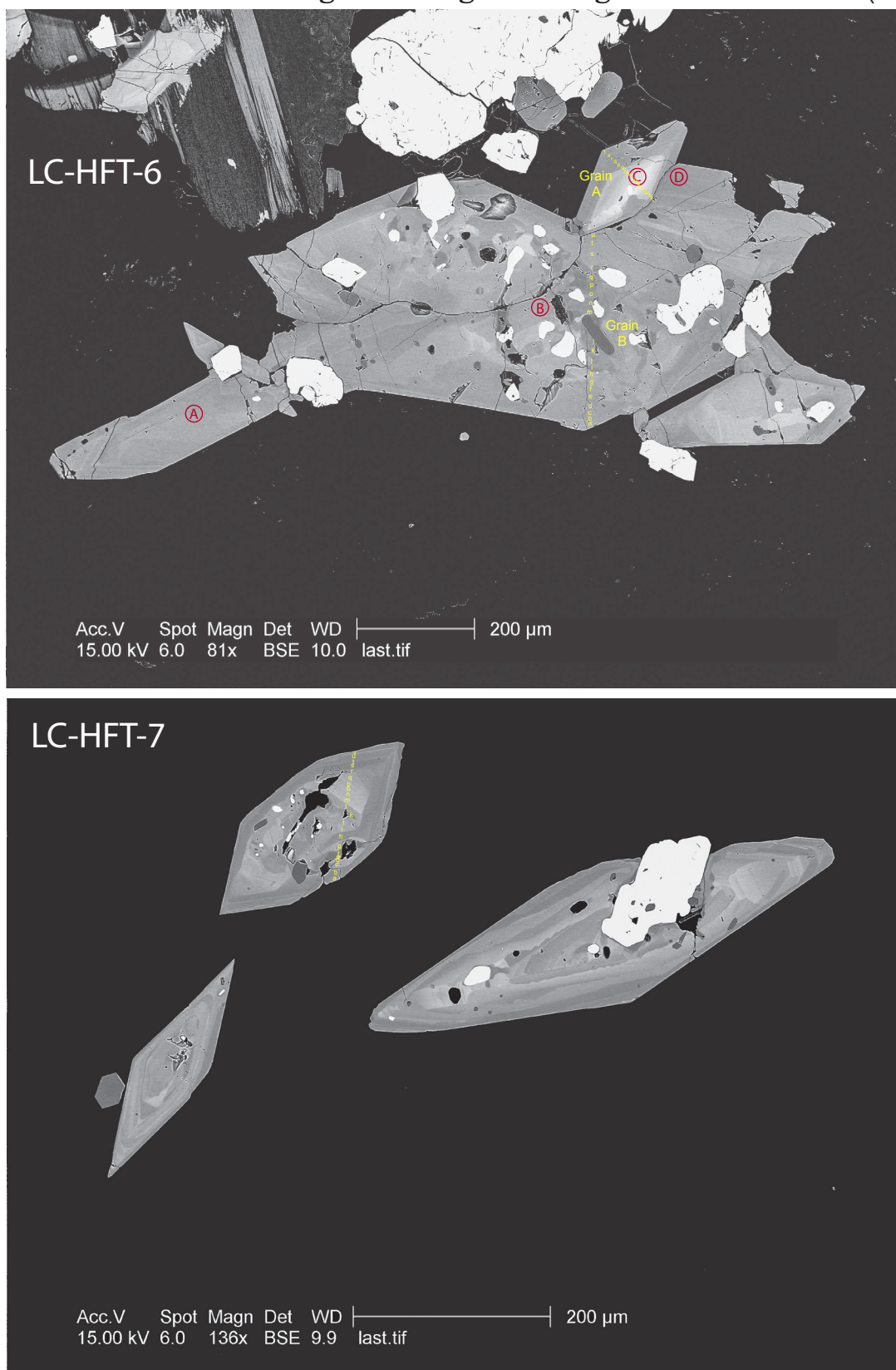


Figure A31. Little Cottonwood stock titanite grains in LC-HFT-6 and LC-HFT-7 with electron microprobe spots (yellow) and LA-ICP-MS spots (red).

Little Cottonwood stock grain images — Hogum Fork Turnout (HFT)

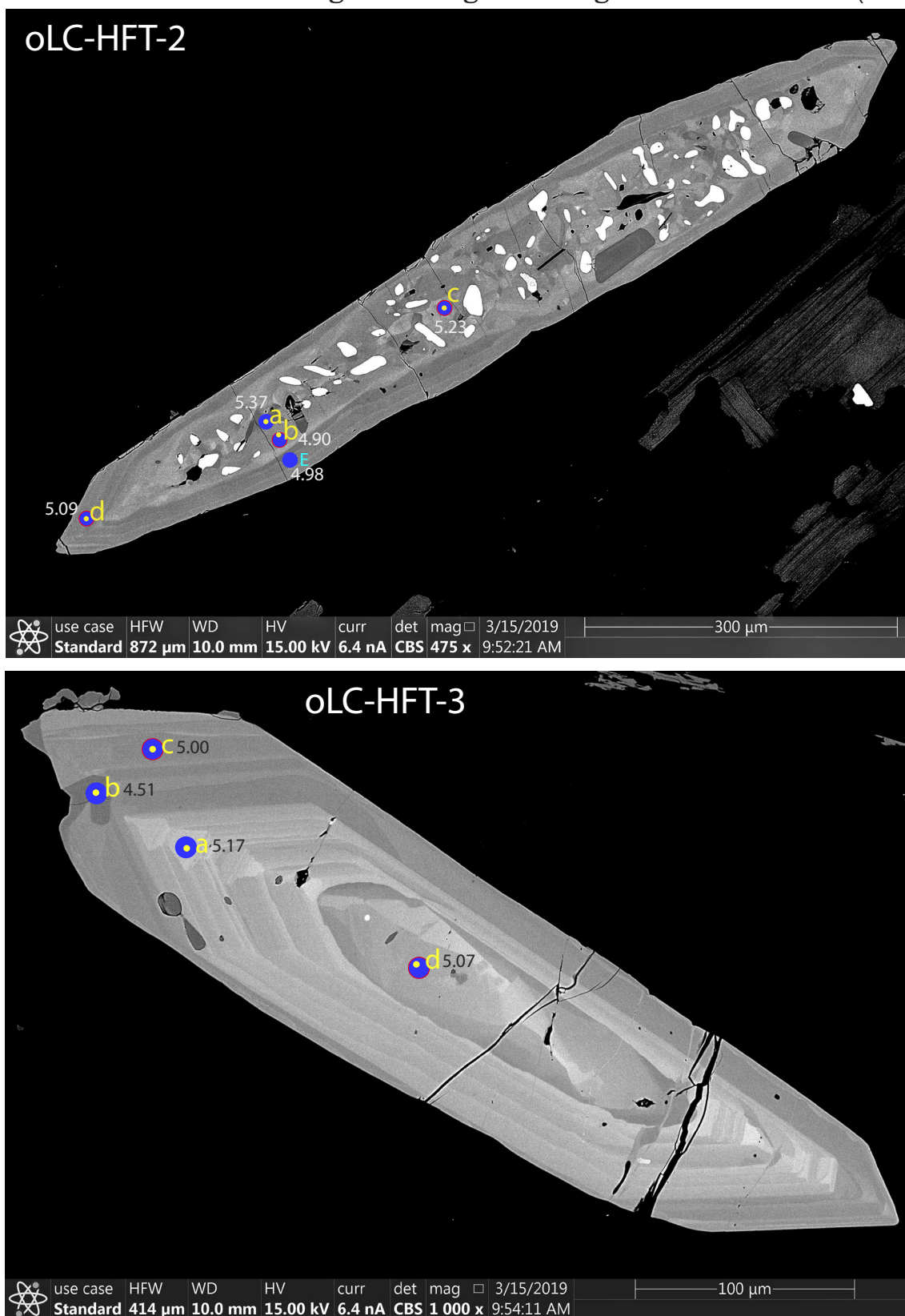


Figure A32. Little Cottonwood stock titanite grains in oLC-HFT-2 and oLC-HFT-3 with electron microprobe spots (yellow), LA-ICP-MS spots (red), and oxygen isotope spots (blue). Numbers are $\delta^{18}\text{O}$ ‰ values.

Little Cottonwood stock grain images — Hogum Fork Turnout (HFT)

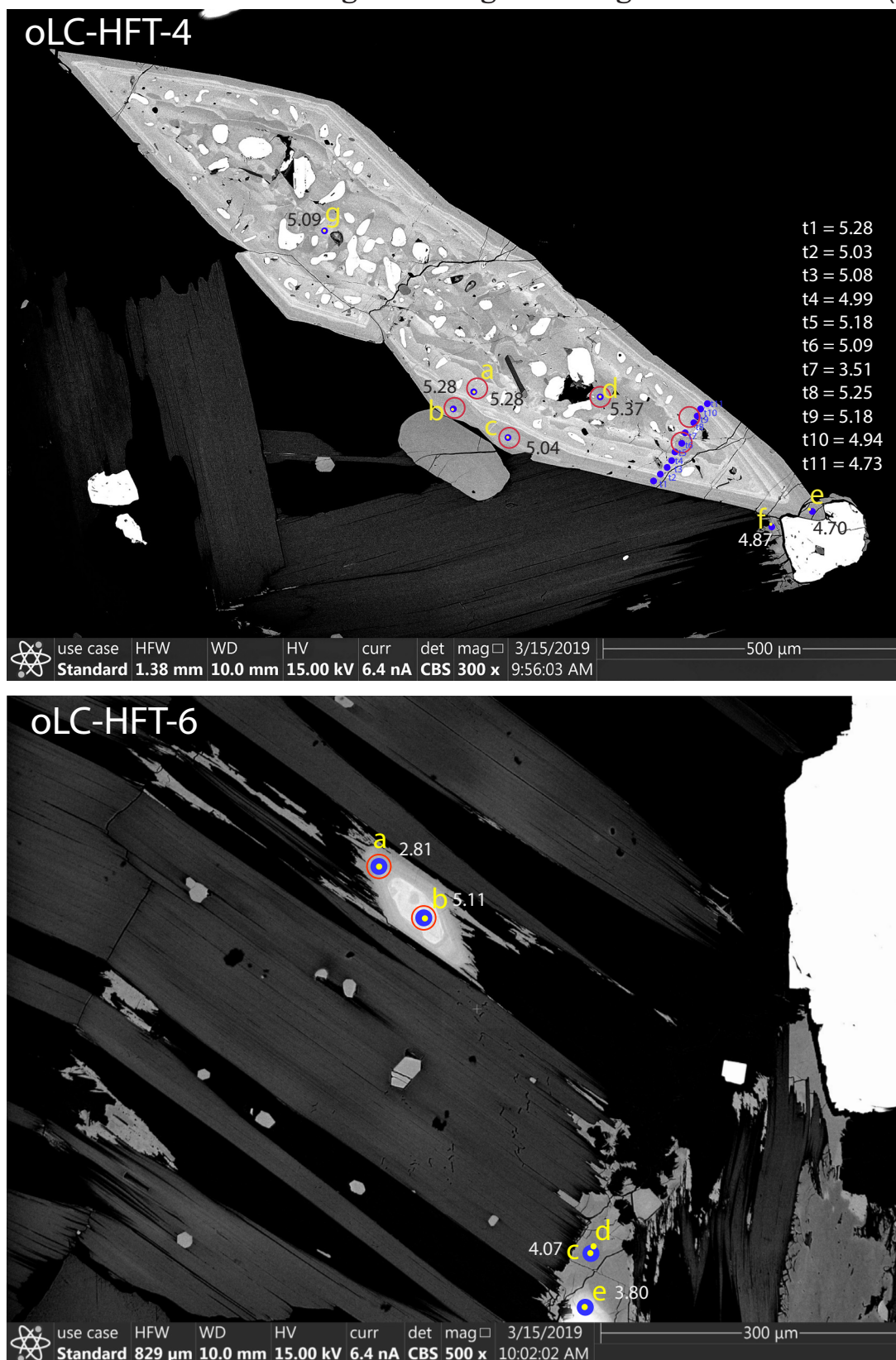


Figure A33. Little Cottonwood stock titanite grains in oLC-HFT-4 and oLC-HFT-6 with electron microprobe spots (yellow), LA-ICP-MS spots (red), and oxygen isotope spots (blue). Numbers are $\delta^{18}\text{O}$ ‰ values.

Little Cottonwood stock grain images — Hogum Fork Turnout (HFT)

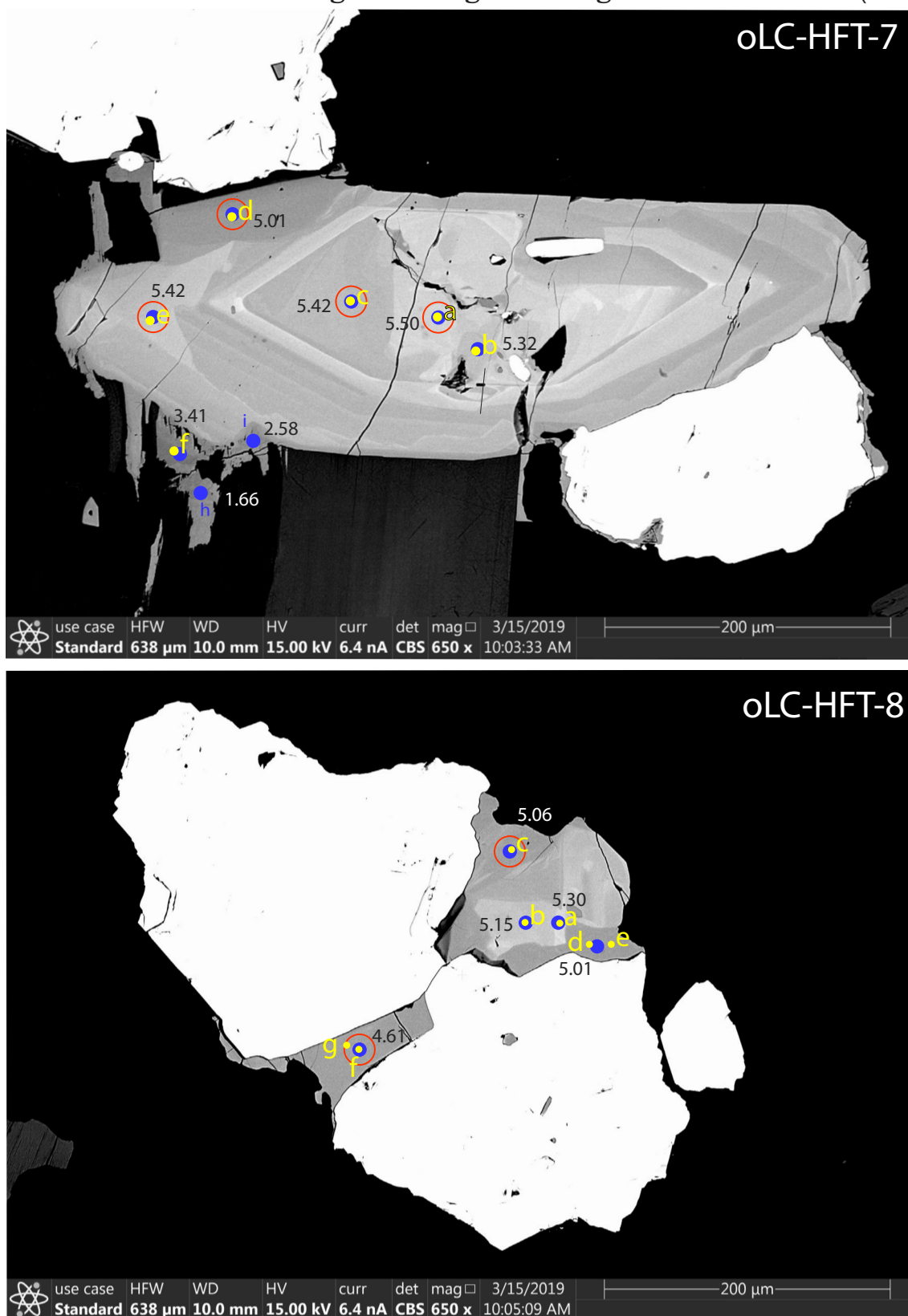


Figure A34. Little Cottonwood stock titanite grains in oLC-HFT-7 and oLC-HFT-8 with electron microprobe spots (yellow), LA-ICP-MS spots (red), and oxygen isotope spots (blue). Numbers are $\delta^{18}\text{O}$ ‰ values.

Little Cottonwood stock grain images — Snowbird locality (SB)

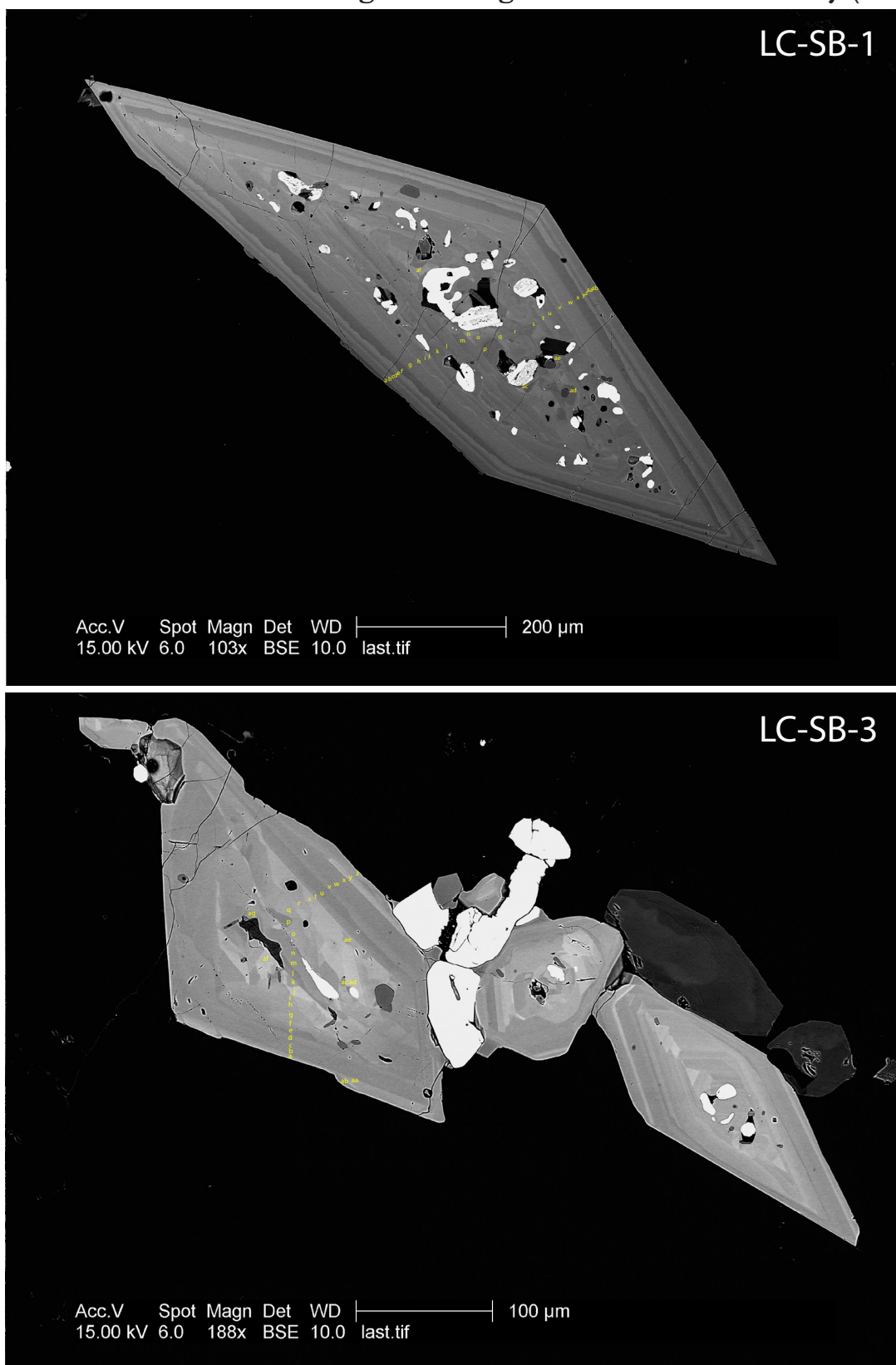


Figure A35. Little Cottonwood stock titanite grains in LC-SB-1 and LC-SB-3 with electron microprobe spots (yellow).

Little Cottonwood stock grain images — Snowbird locality (SB)

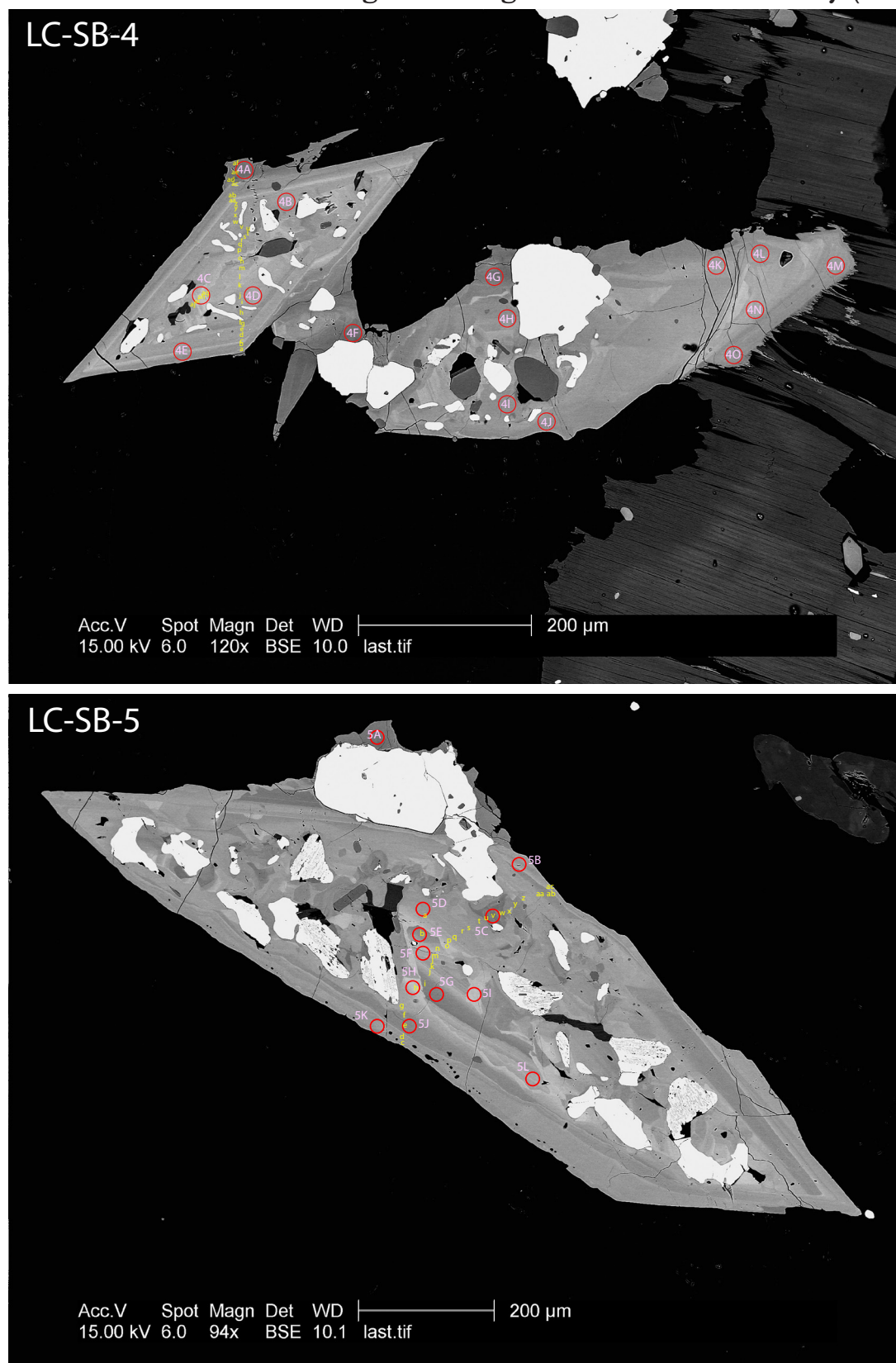


Figure A36. Little Cottonwood stock titanite grains in LC-SB-4 and LC-SB-5 with electron microprobe spots (yellow) and LA-ICP-MS spots (red).

Little Cottonwood stock grain images — Snowbird locality (SB)

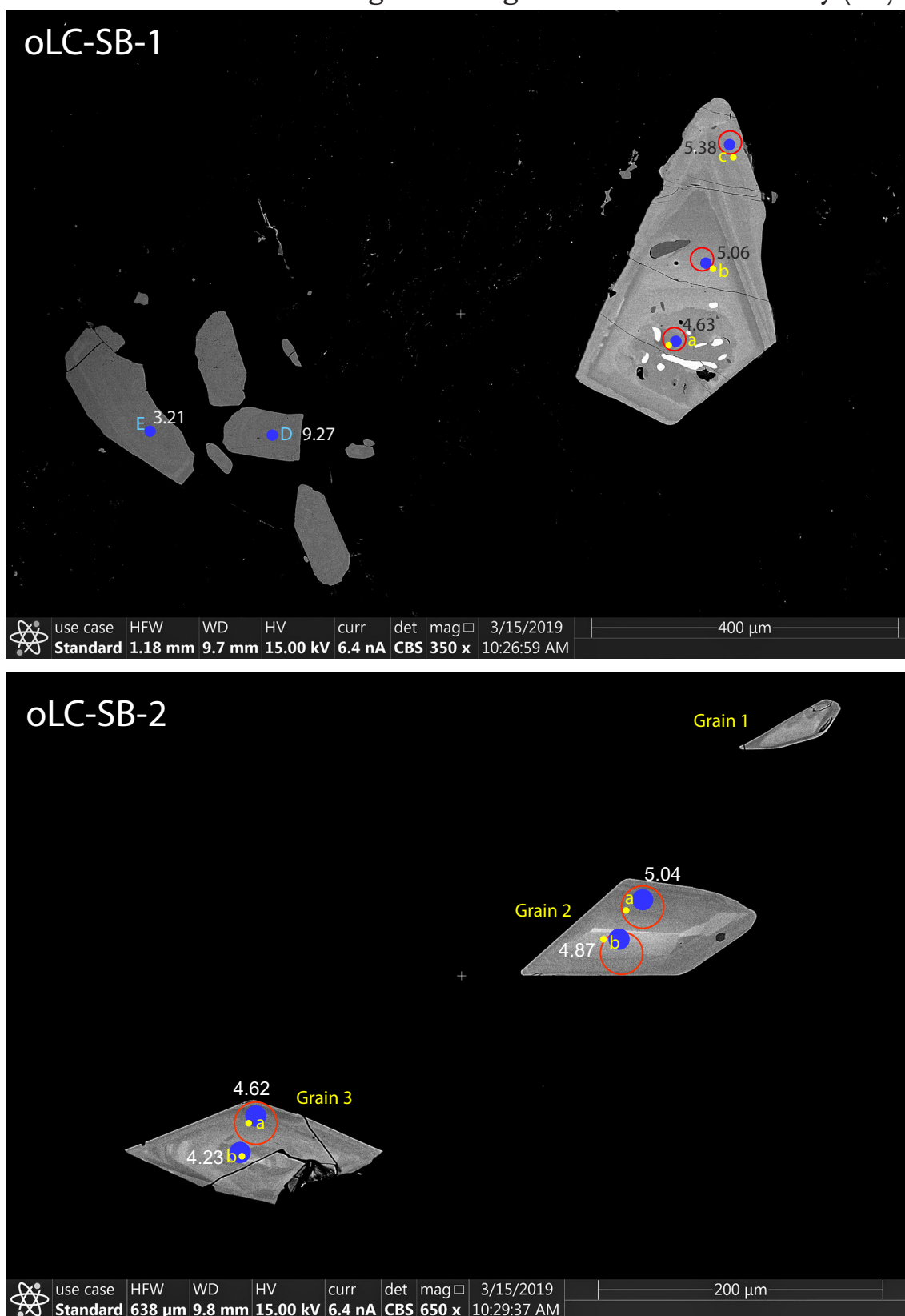


Figure A37. Little Cottonwood stock titanite grains in oLC-SB-1 and oLC-SB-2 with electron microprobe spots (yellow), LA-ICP-MS spots (red), and oxygen isotope spots (blue). Numbers are $\delta^{18}\text{O}$ ‰ values.

Little Cottonwood stock grain images — Snowbird locality (SB)

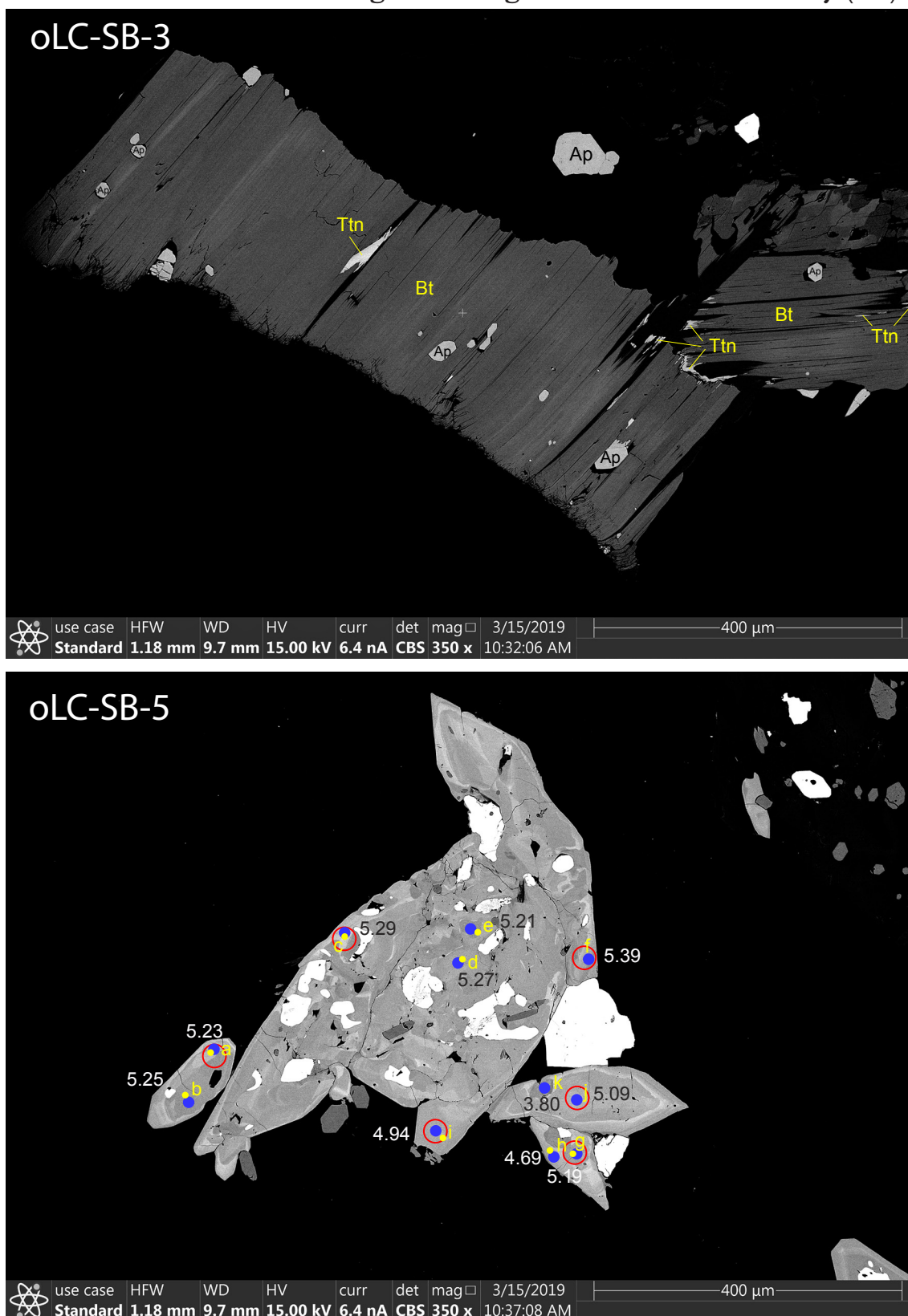


Figure A38. Little Cottonwood stock titanite grains in oLC-SB-3 and oLC-SB-5 with electron microprobe spots (yellow), LA-ICP-MS spots (red), and oxygen isotope spots (blue). In top photo, titanite (Ttn), apatite (Ap), biotite (Bt). Numbers are $\delta^{18}\text{O}$ ‰ values.

Little Cottonwood stock grain images — Snowbird locality (SB)

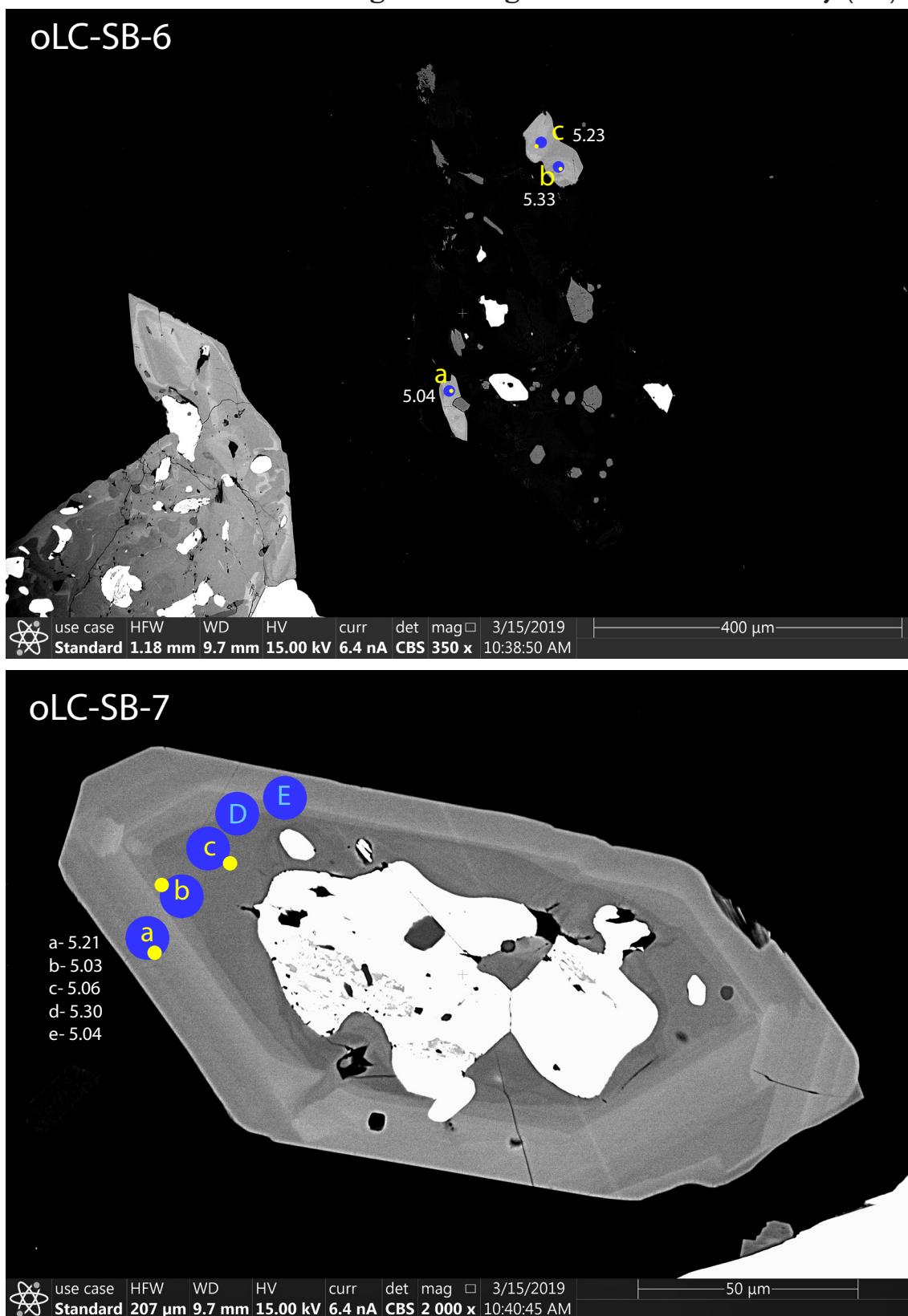


Figure A39. Little Cottonwood stock titanite grains in oLC-SB-6 and oLC-SB-7 with electron microprobe spots (yellow) and oxygen isotope spots (blue). Numbers are $\delta^{18}\text{O}$ ‰ values.

Little Cottonwood stock grain images — Silver Lake locality (SL)

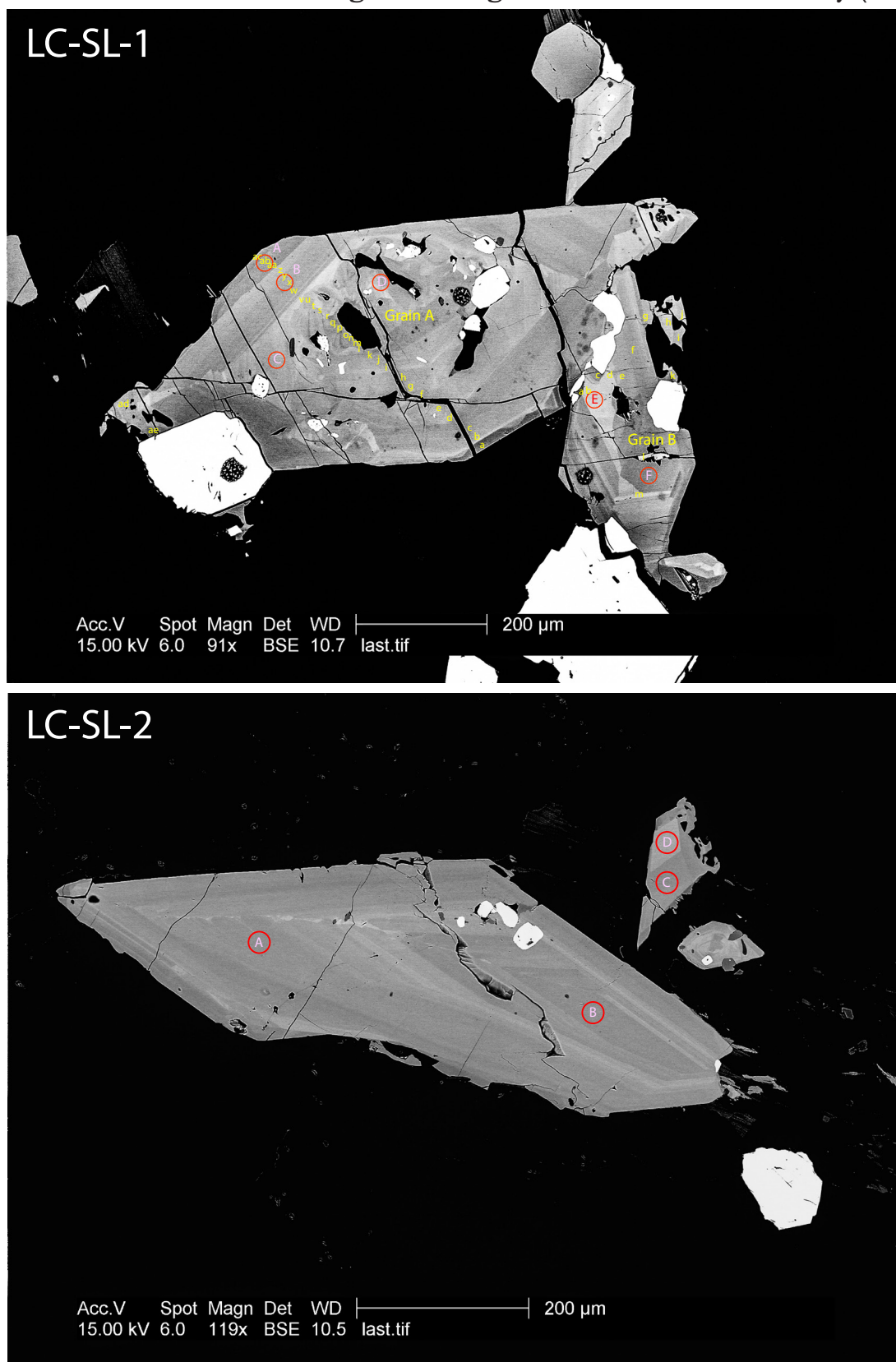


Figure A40. Little Cottonwood stock titanite grains in LC-SL-1 and LC-SL-2 with electron microprobe spots (yellow) and LA-ICP-MS spots (red).

Little Cottonwood stock grain images — Silver Lake locality (SL)

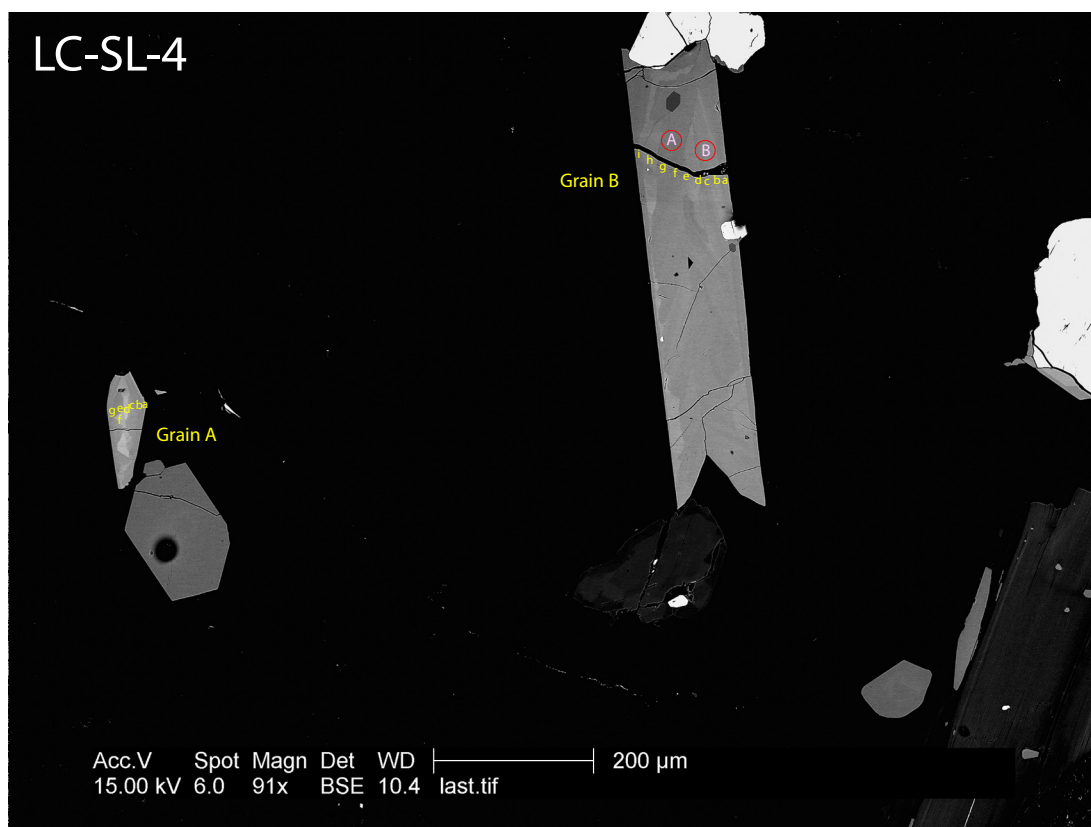
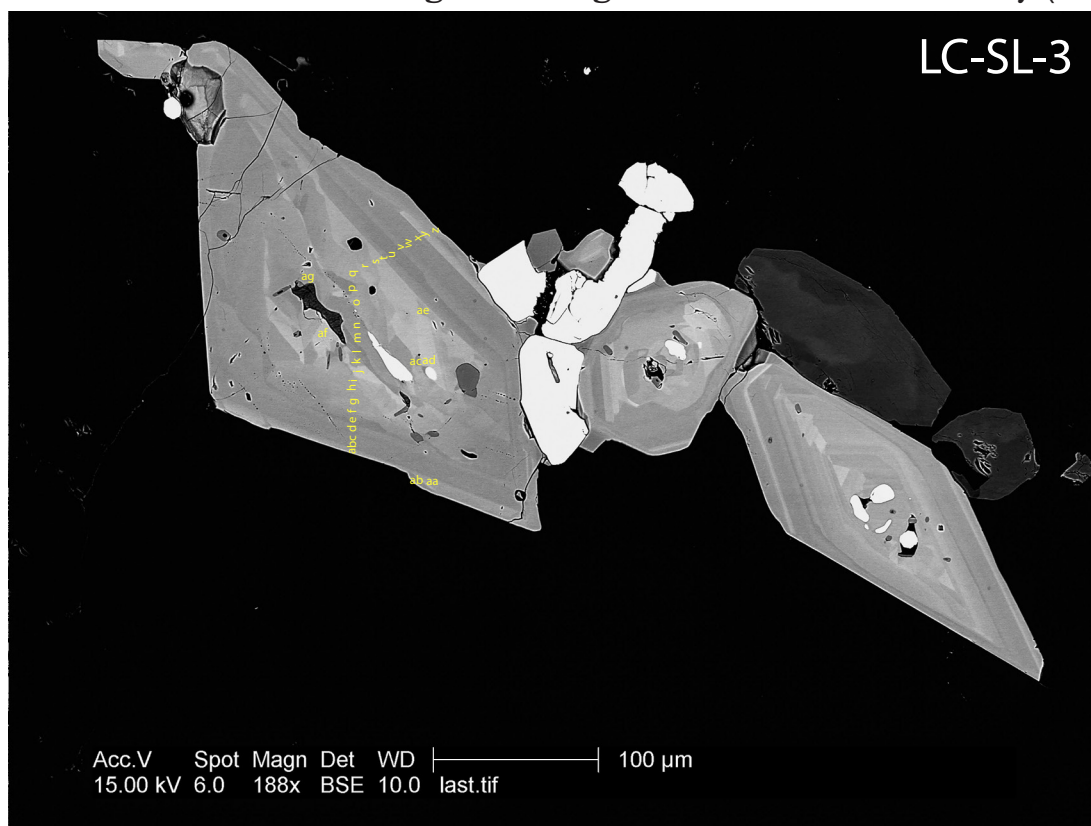


Figure A41. Little Cottonwood stock titanite grains in LC-SL-3 and LC-SL-4 with electron microprobe spots (yellow) and LA-ICP-MS spots (red).

Little Cottonwood stock grain images — Silver Lake locality (SL)

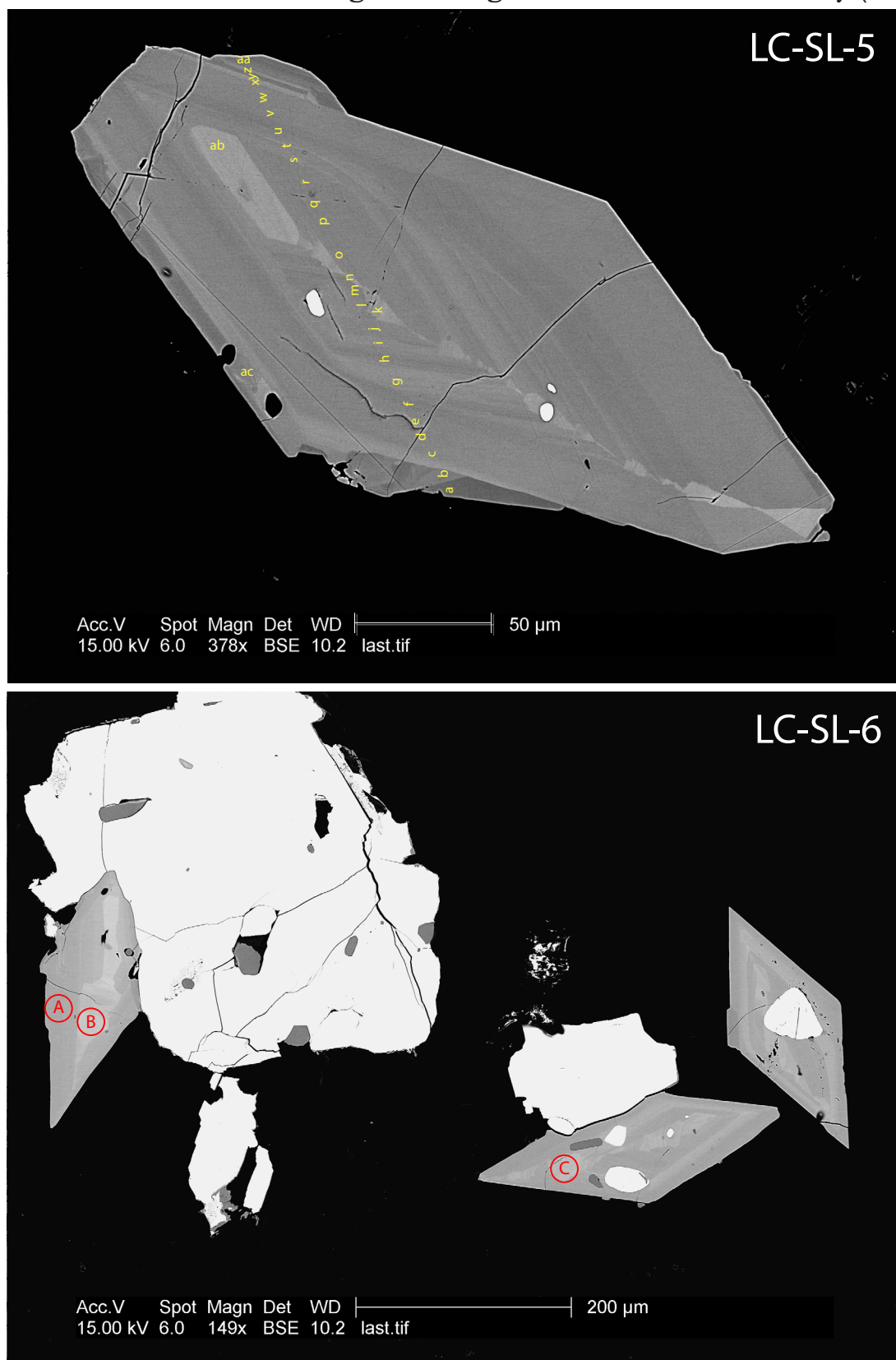


Figure A42. Little Cottonwood stock titanite grains in LC-SL-5 and LC-SL-6 with electron microprobe spots (yellow) and LA-ICP-MS spots (red).

Little Cottonwood stock grain images — Temple Quarry locality (TQ)

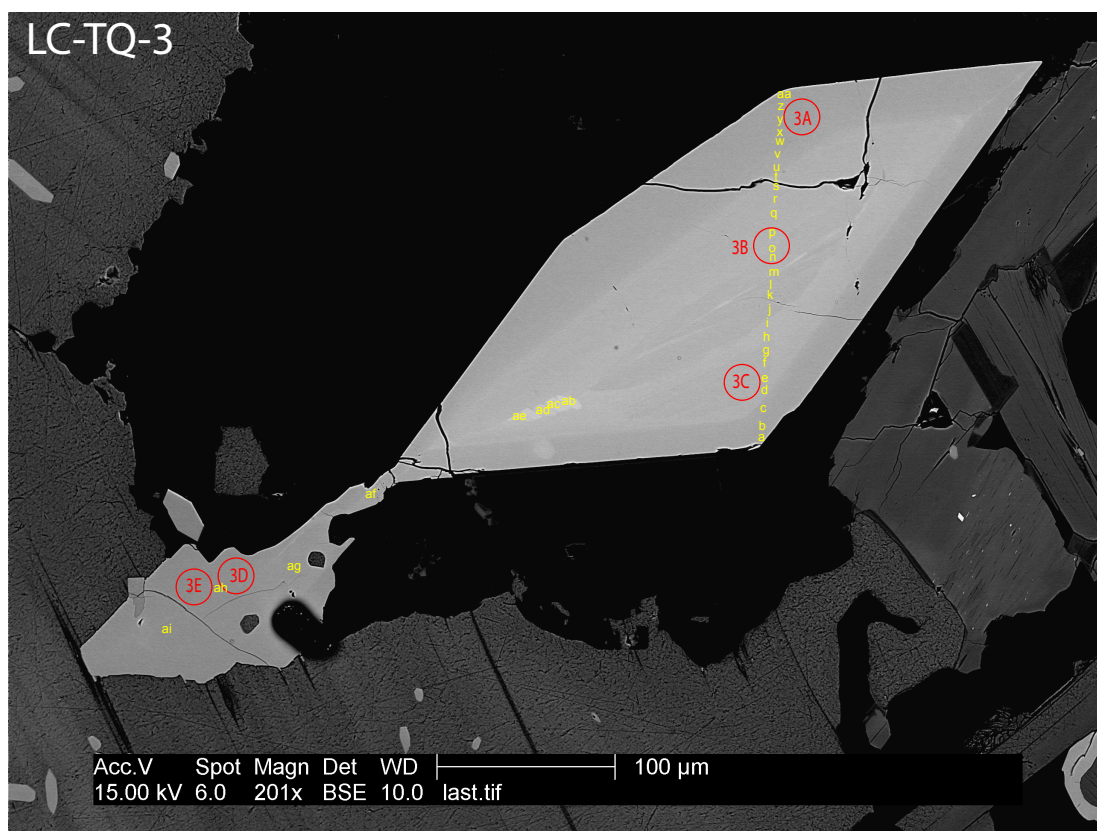
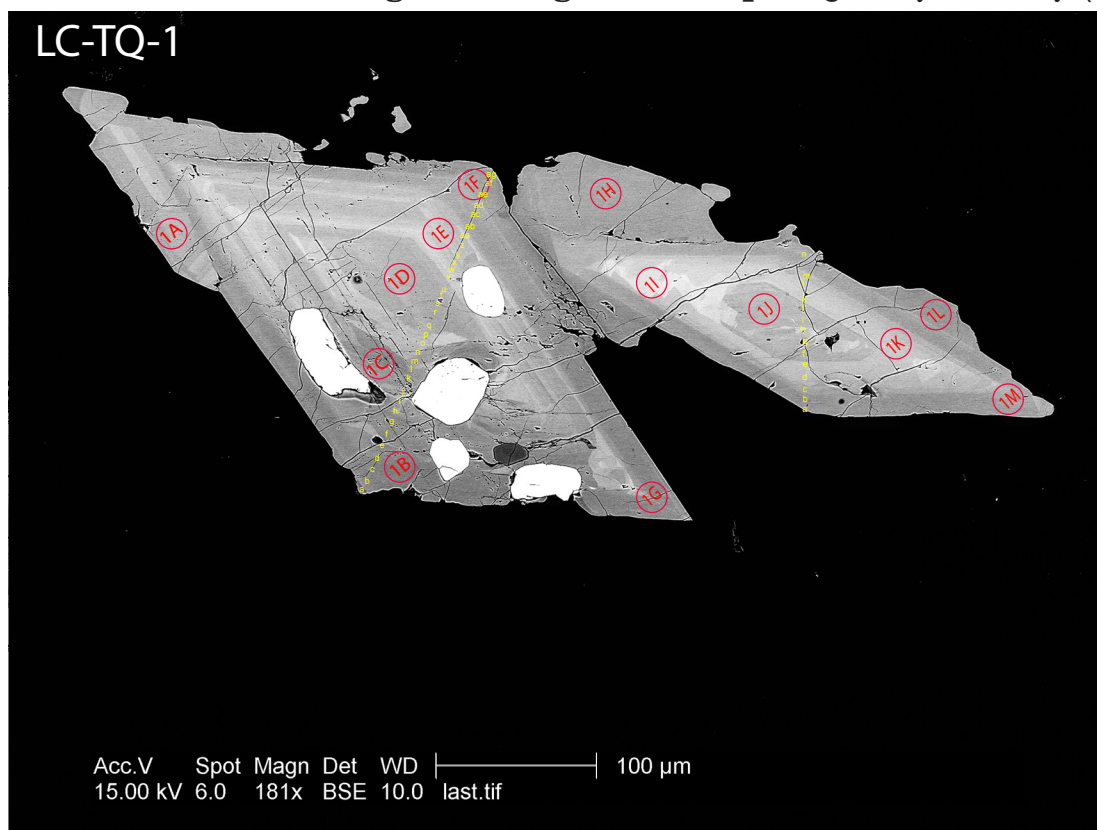


Figure A43. Little Cottonwood stock titanite grains in LC-TQ-1 and LC-TQ-3 with electron microprobe spots (yellow) and LA-ICP-MS spots (red).

Little Cottonwood stock grain images — Temple Quarry locality (TQ)

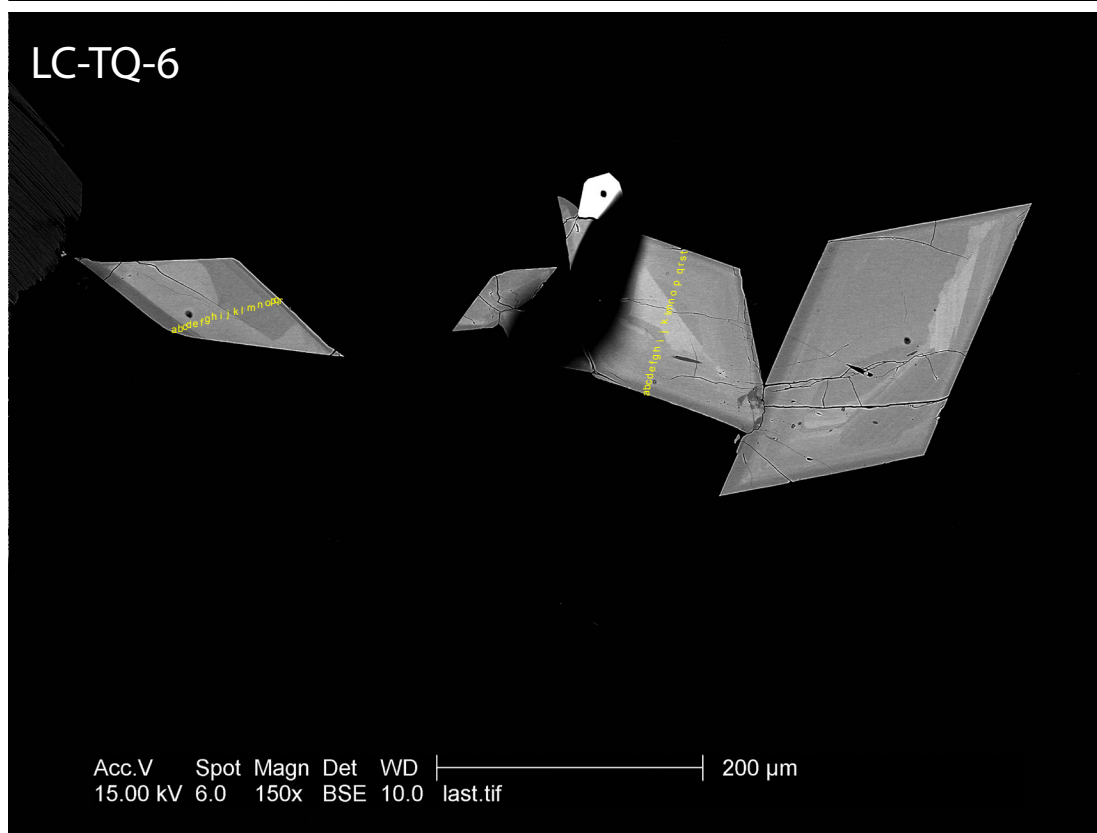
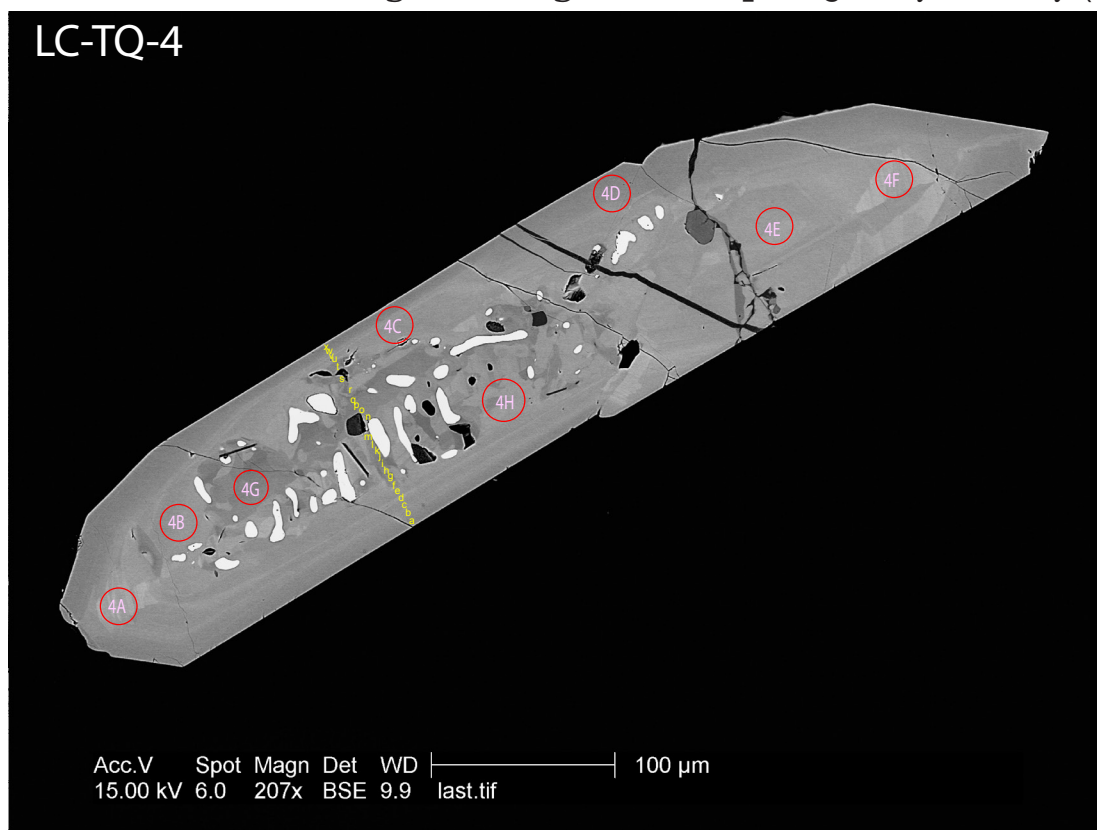


Figure A44. Little Cottonwood stock titanite grains in LC-TQ-4 and LC-TQ-6 with electron microprobe spots (yellow) and LA-ICP-MS spots (red).

Little Cottonwood stock grain images — LC-23 locality

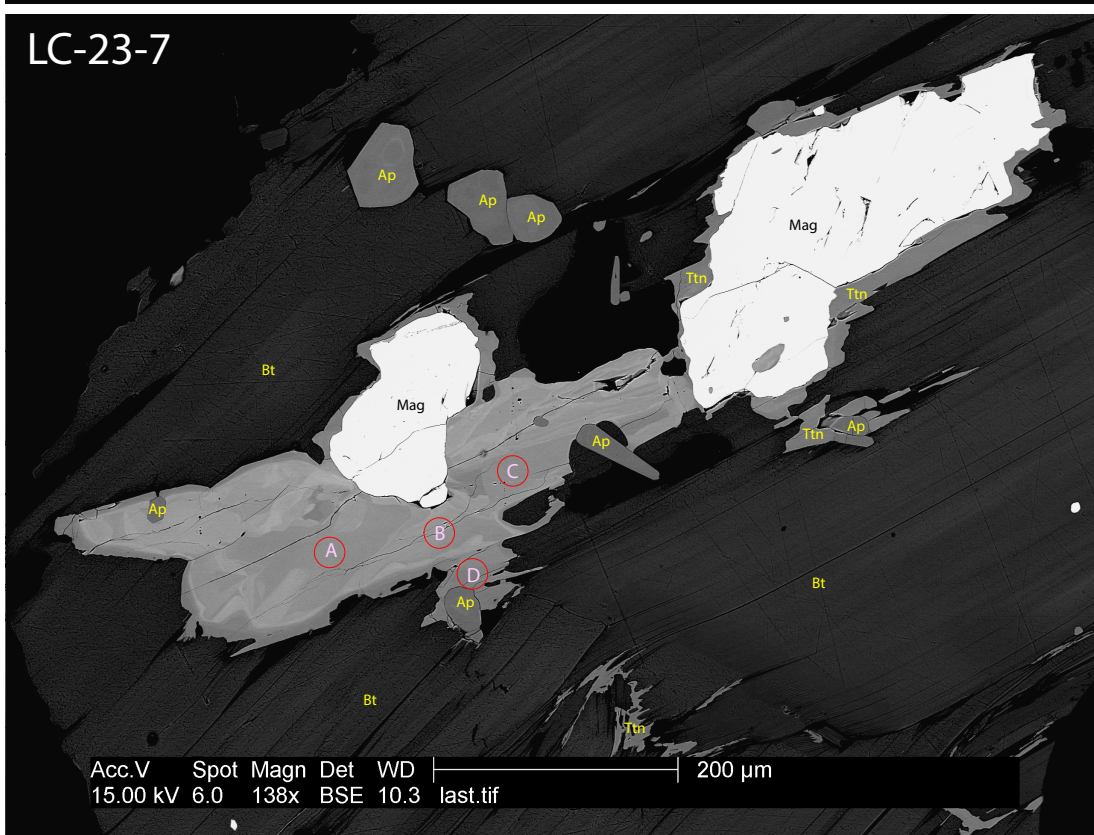
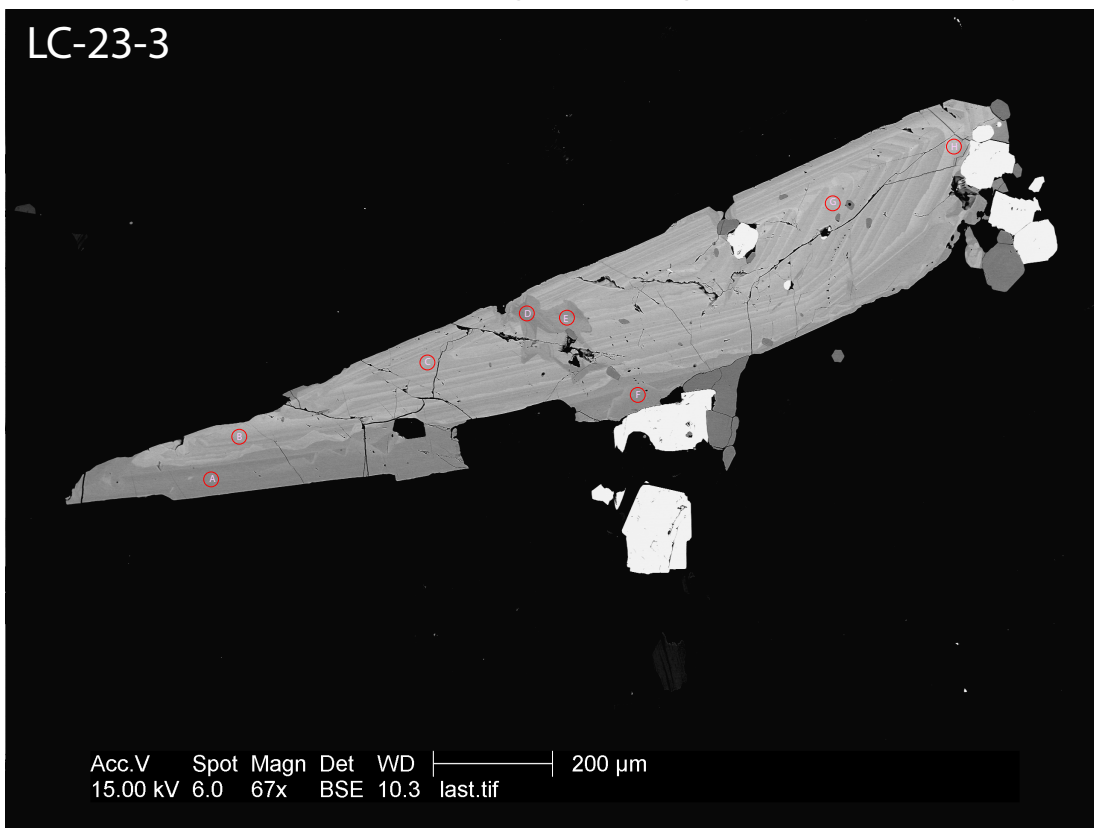


Figure A45. Little Cottonwood stock titanite grains in LC-23-3 and LC-23-7 with LA-ICP-MS spots (red). In lower photo, titanite (Ttn), biotite (Bt), apatite (Ap), and magnetite (Mag).

Little Cottonwood stock grain images — LC-23 locality

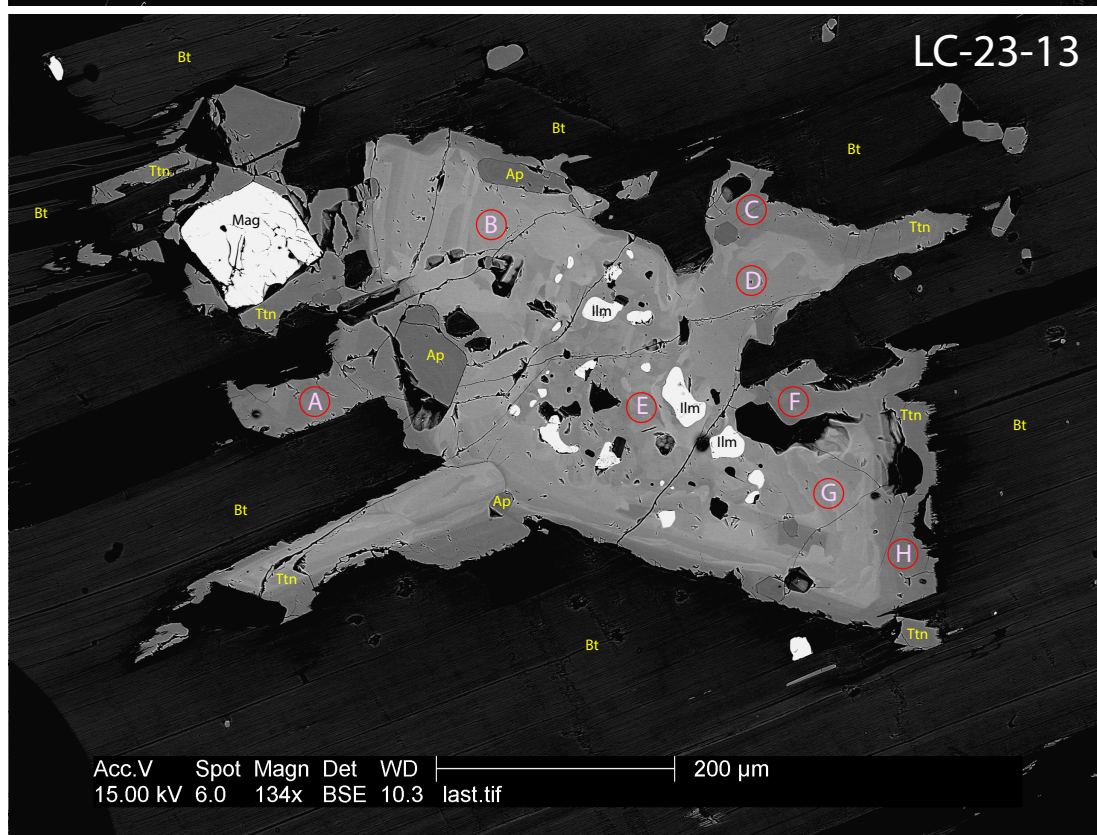
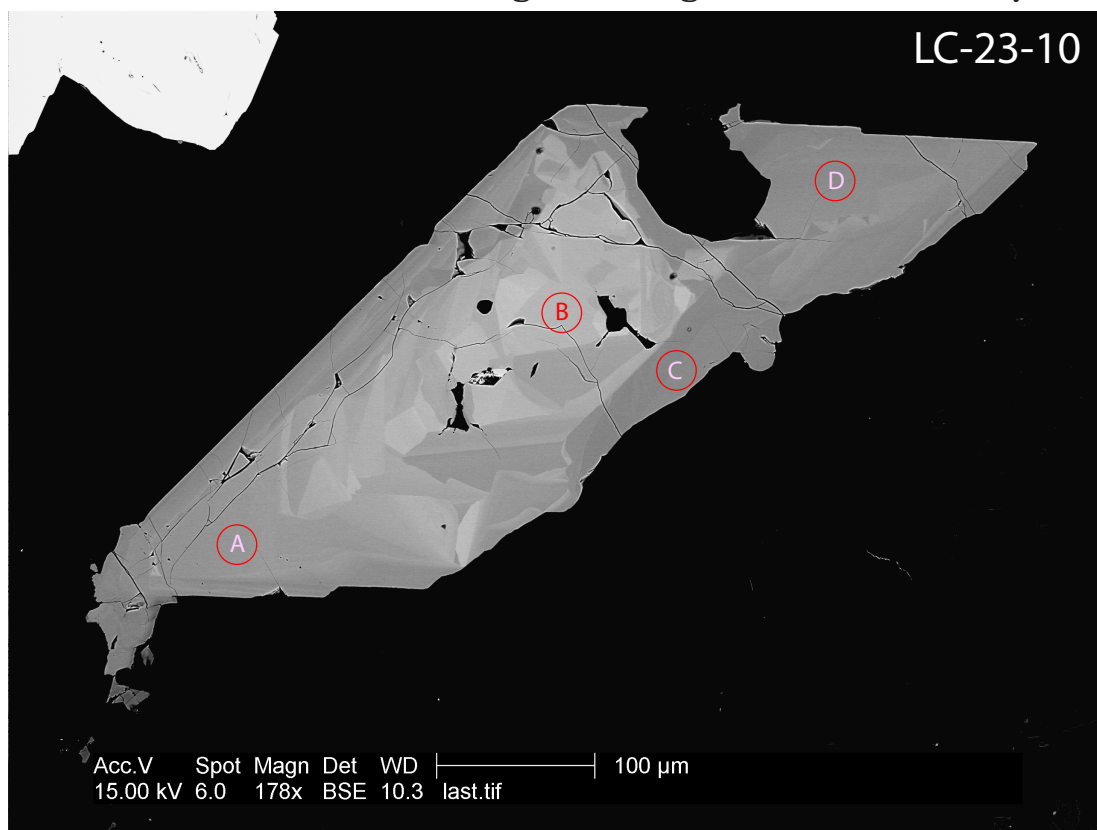


Figure A46. Little Cottonwood stock titanite grains in LC-23-10 and LC-23-13 with LA-ICP-MS spots (red). In lower photo, biotite (Bt) surrounds the titanite (Ttn) mass. Also present are apatite (Ap), ilmenite (Ilm), and magnetite (Mag).

Little Cottonwood stock grain images — LC-36 locality

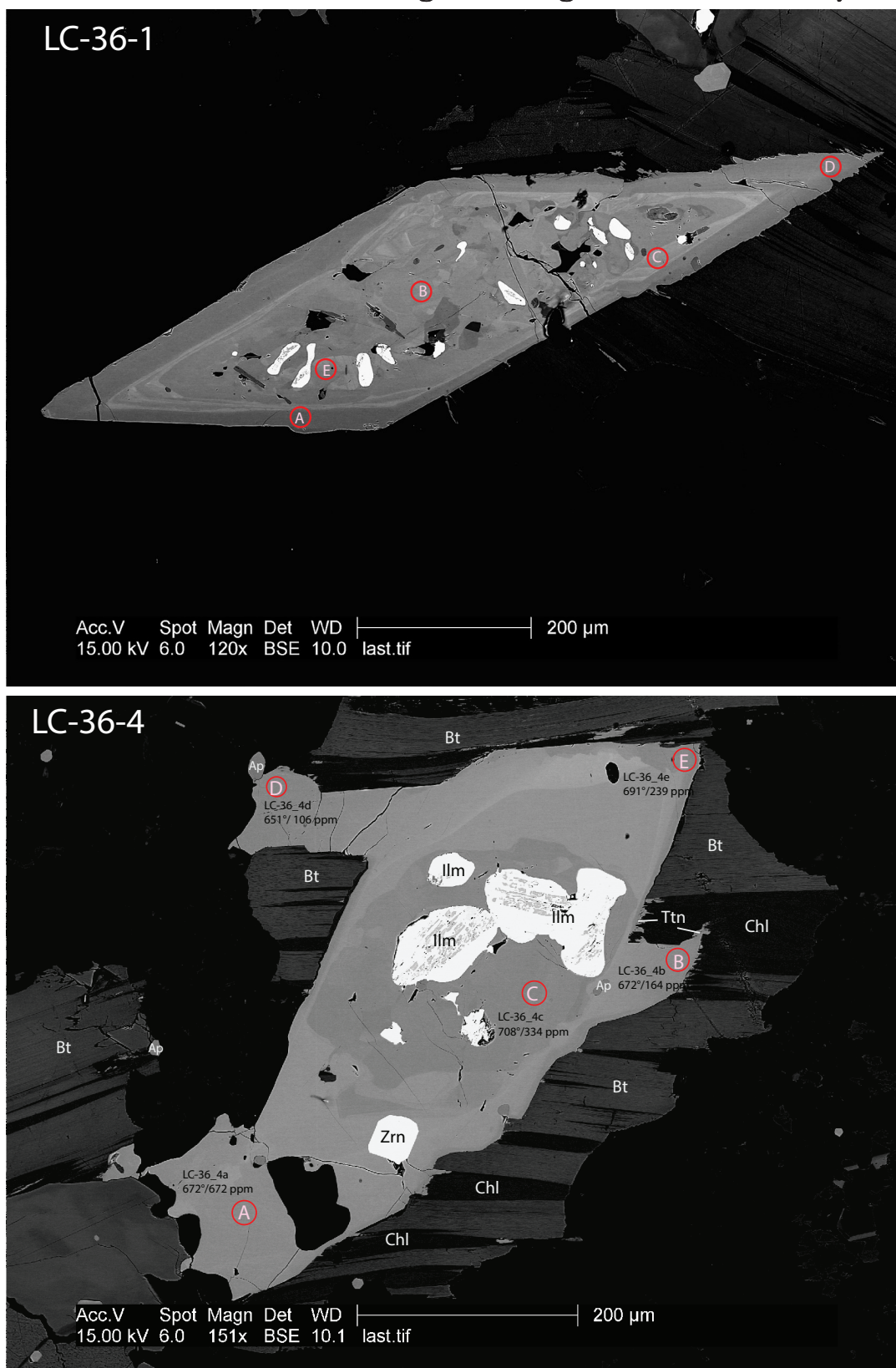


Figure A47. Little Cottonwood stock titanite grains in LC-36-1 and LC-36-4 with LA-ICP-MS spots (red). In lower photo, biotite (Bt) altering to chlorite (Chl) surrounds the titanite (Ttn) grain. Also present are apatite (Ap), ilmenite (Ilm), and zircon (Zrn). Note how the tiny titanite fingers usually grow out into the chloritized part of the biotite. Numbers are Zr in titanite temperatures ($^{\circ}\text{C}$) and concentrations (ppm).

Little Cottonwood stock grain images — LC-36 locality

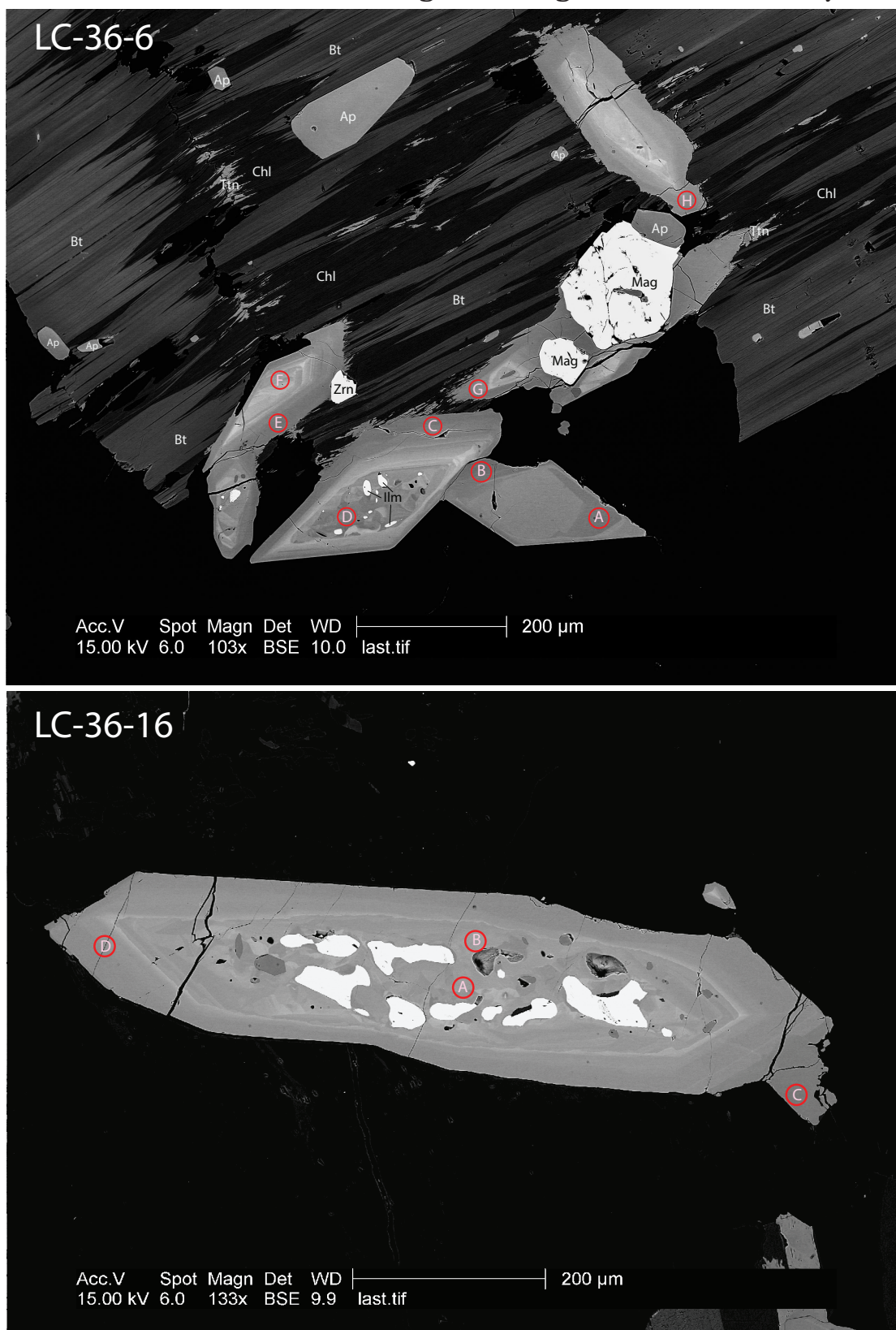
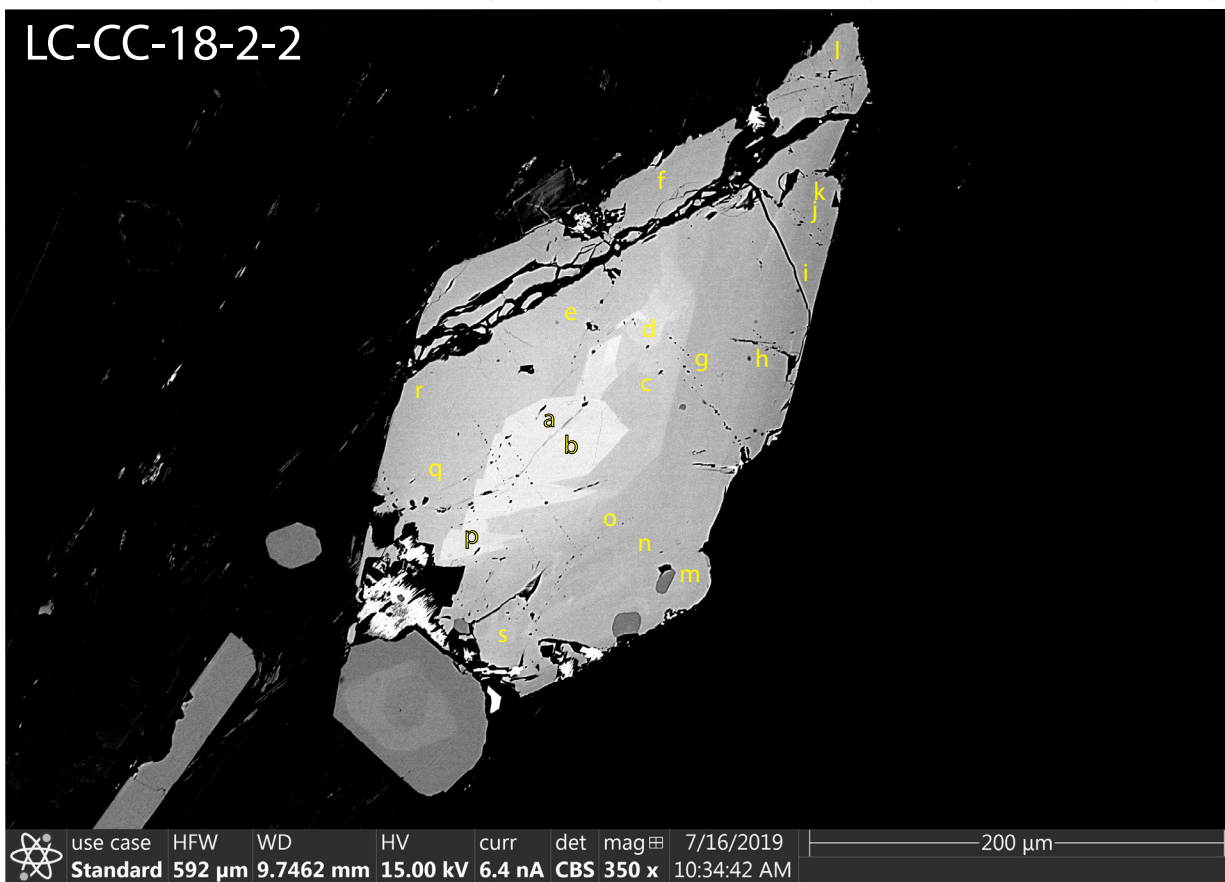


Figure A48. Little Cottonwood stock titanite grains in LC-36-6 and LC-36-16 with LA-ICP-MS spots (red). In upper photo, biotite (Bt) altering to chlorite (Chl) surrounds most of the titanite (Ttn) grains. Also present are apatite (Ap), ilmenite (Ilm), magnetite (Mag) and zircon (Zrn). Titanite slivers grow out into the chloritized part of the biotite.

Little Cottonwood enclave grain images — Cherry Creek locality (CC)

LC-CC-18-2-2



LC-CC-18-2-3

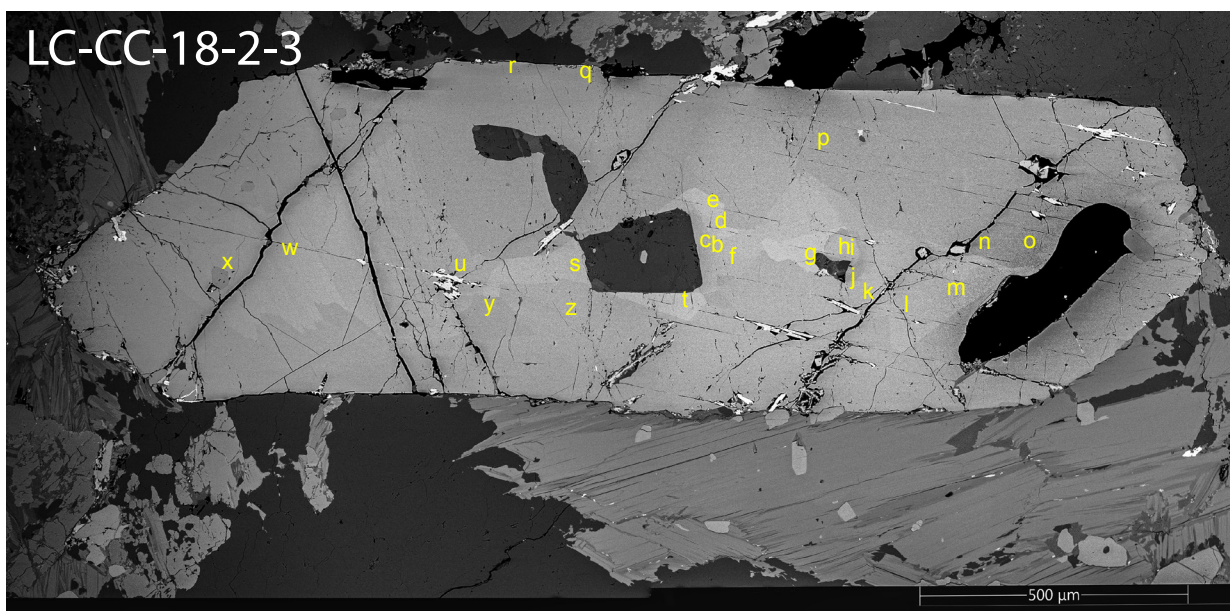


Figure A49. Little Cottonwood enclave titanite grains in LC-CC-18-2-2 and LC-CC-18-2-3 with electron microprobe spots (letters).

Little Cottonwood enclave grain images — Cherry Creek locality (CC)

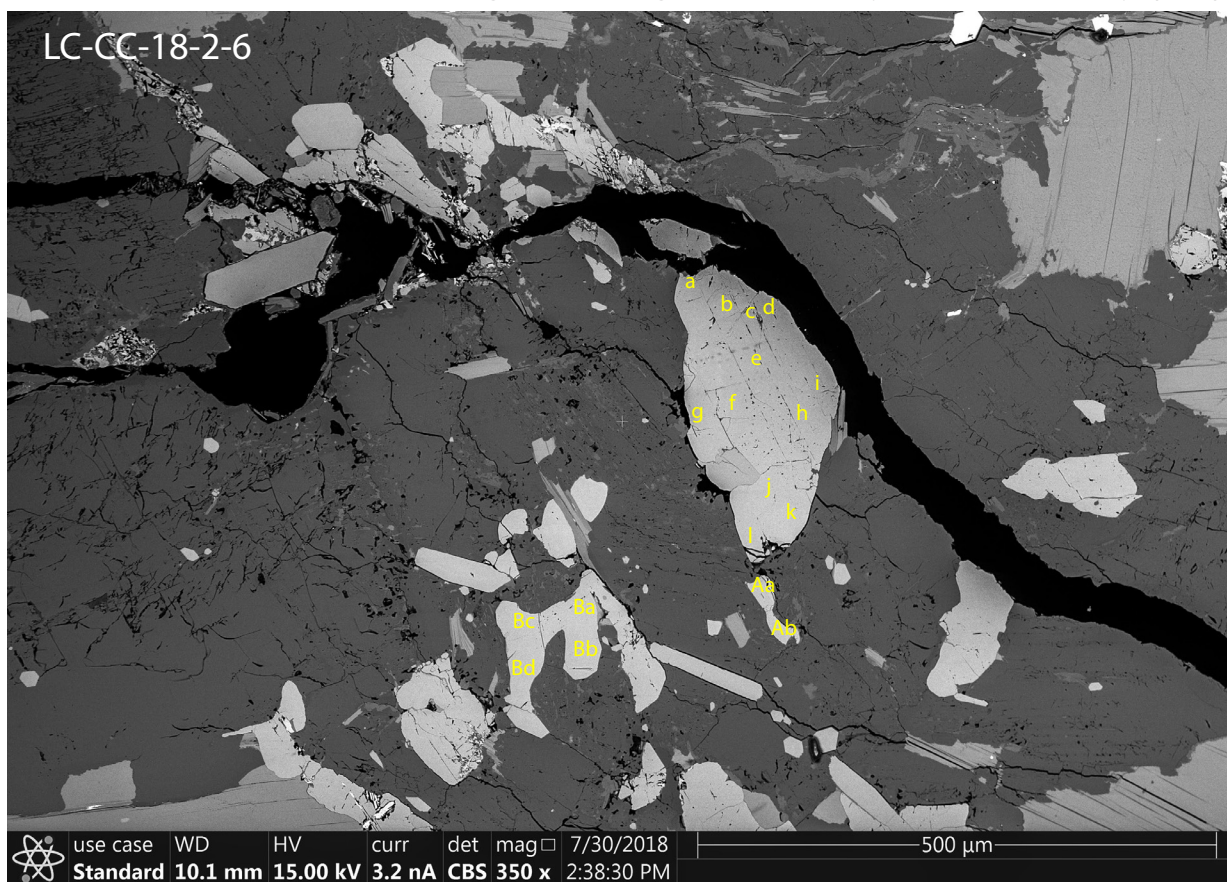
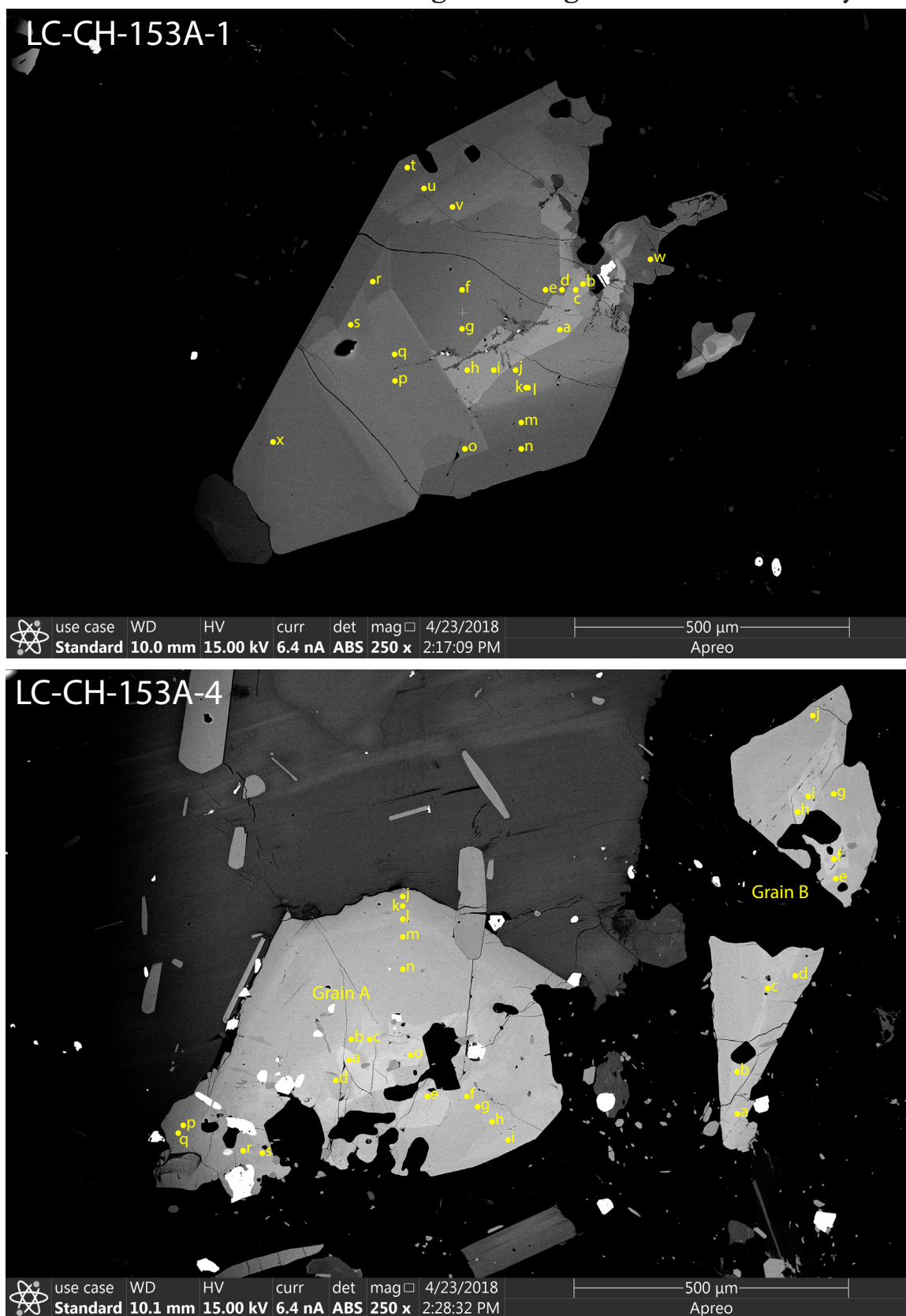


Figure A50. Little Cottonwood enclave titanite grains in LC-CC-18-2-6 with electron microprobe spots (letters).

Little Cottonwood enclave grain images — LC-CH locality



Little Cottonwood enclave grain images — LC-CH locality

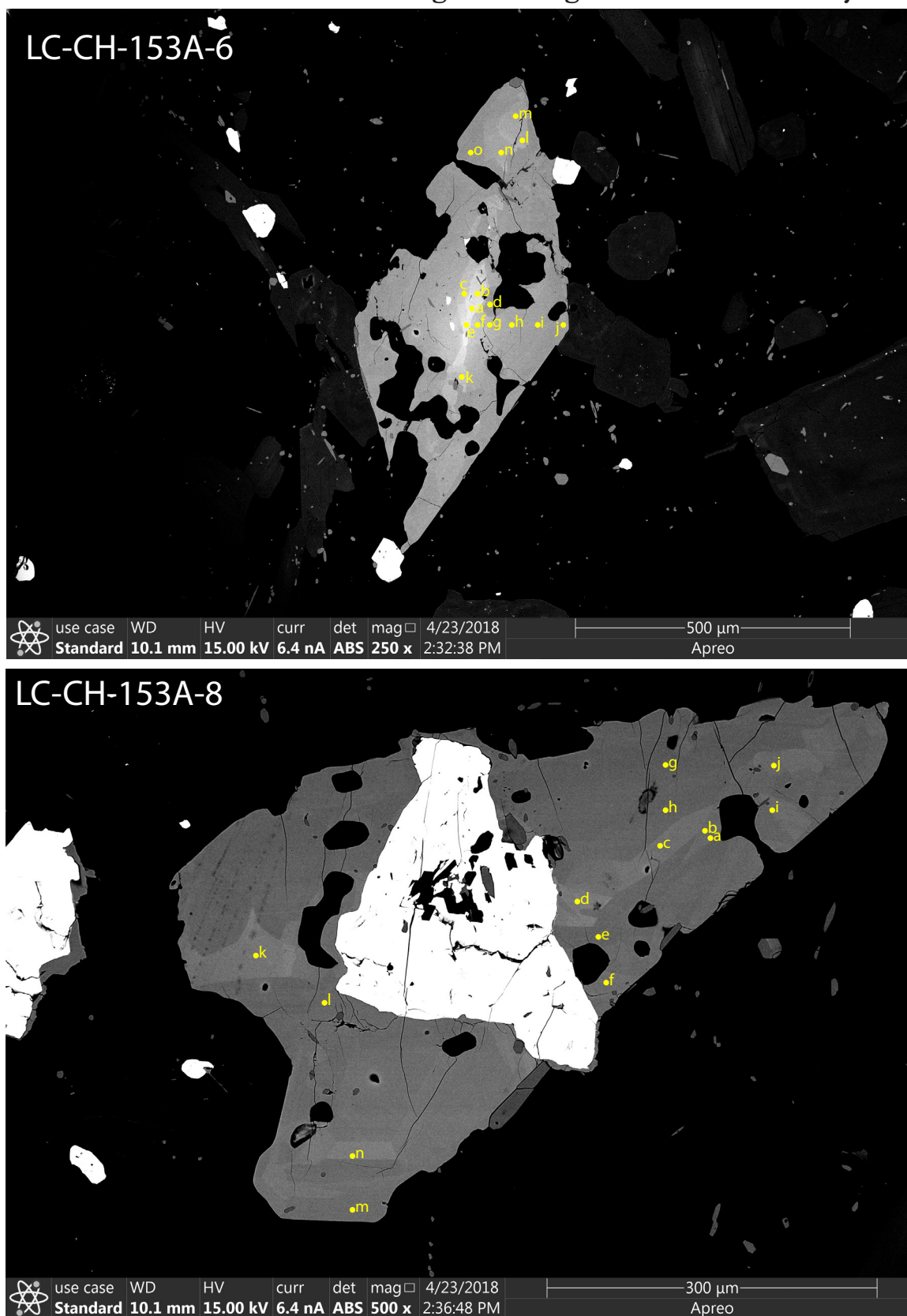


Figure A52. Little Cottonwood enclave titanite grains in LC-CH-153A-6 and LC-CH-153A-8 with electron microprobe spots (yellow).

Little Cottonwood enclave grain images — LC-CH locality

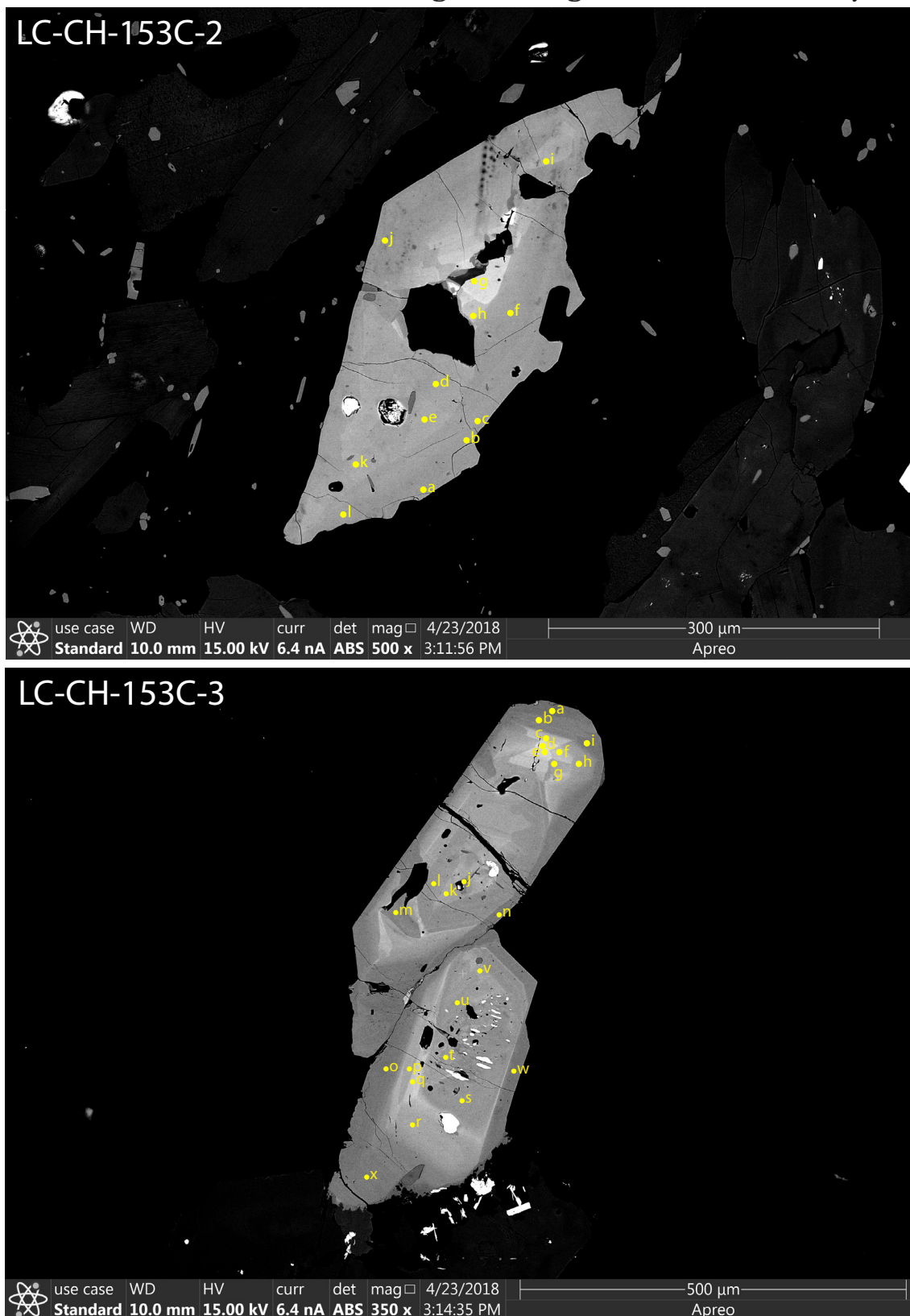


Figure A53. Little Cottonwood enclave titanite grains in LC-CH-153C-2 and LC-CH-153C-3 with electron microprobe spots (yellow).

Little Cottonwood enclave grain images — LC-CH locality

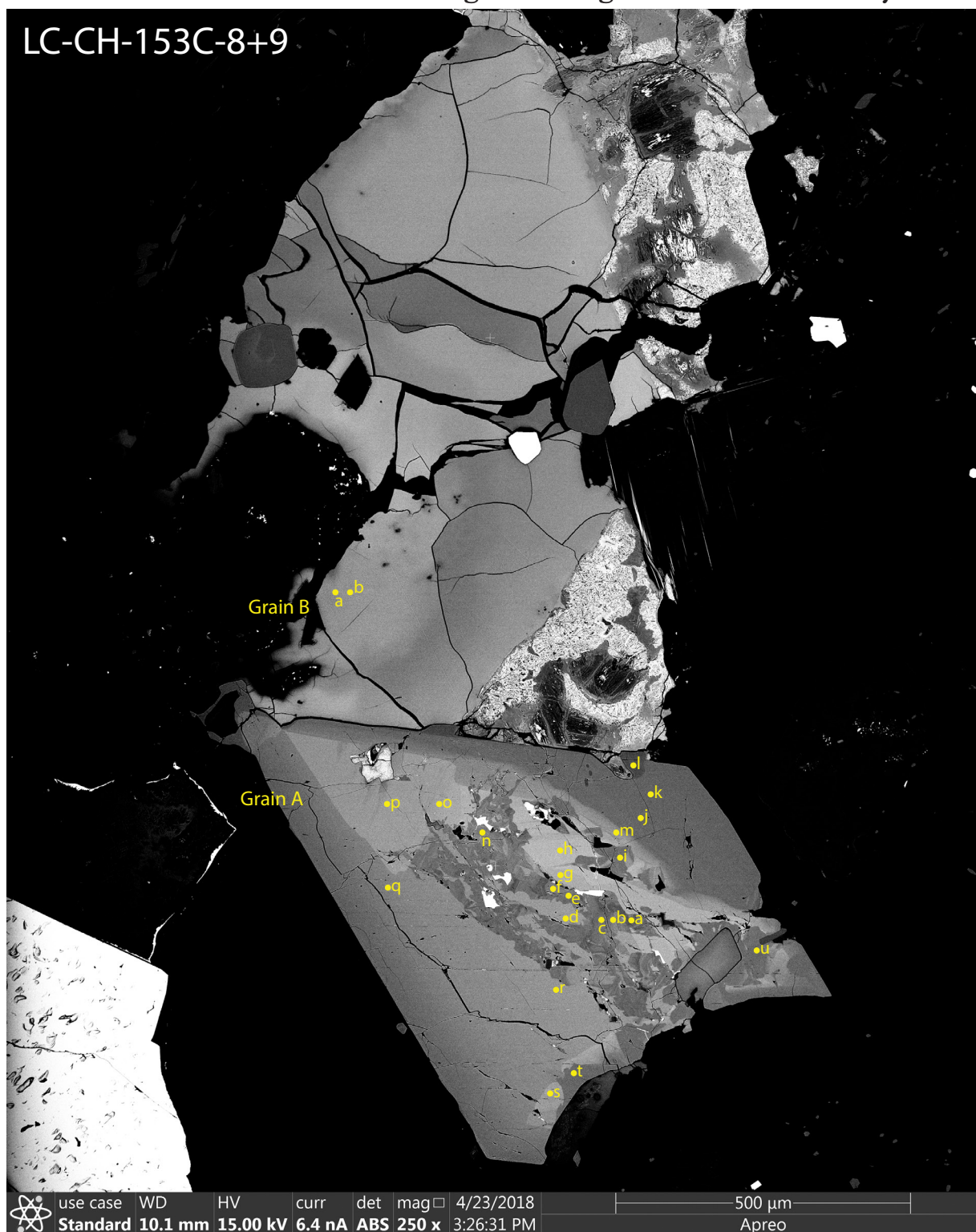


Figure A54. Little Cottonwood enclave titanite grains in LC-CH-153C-8+9 with electron microprobe spots (yellow).

Little Cottonwood enclave grain images — LC-CH locality

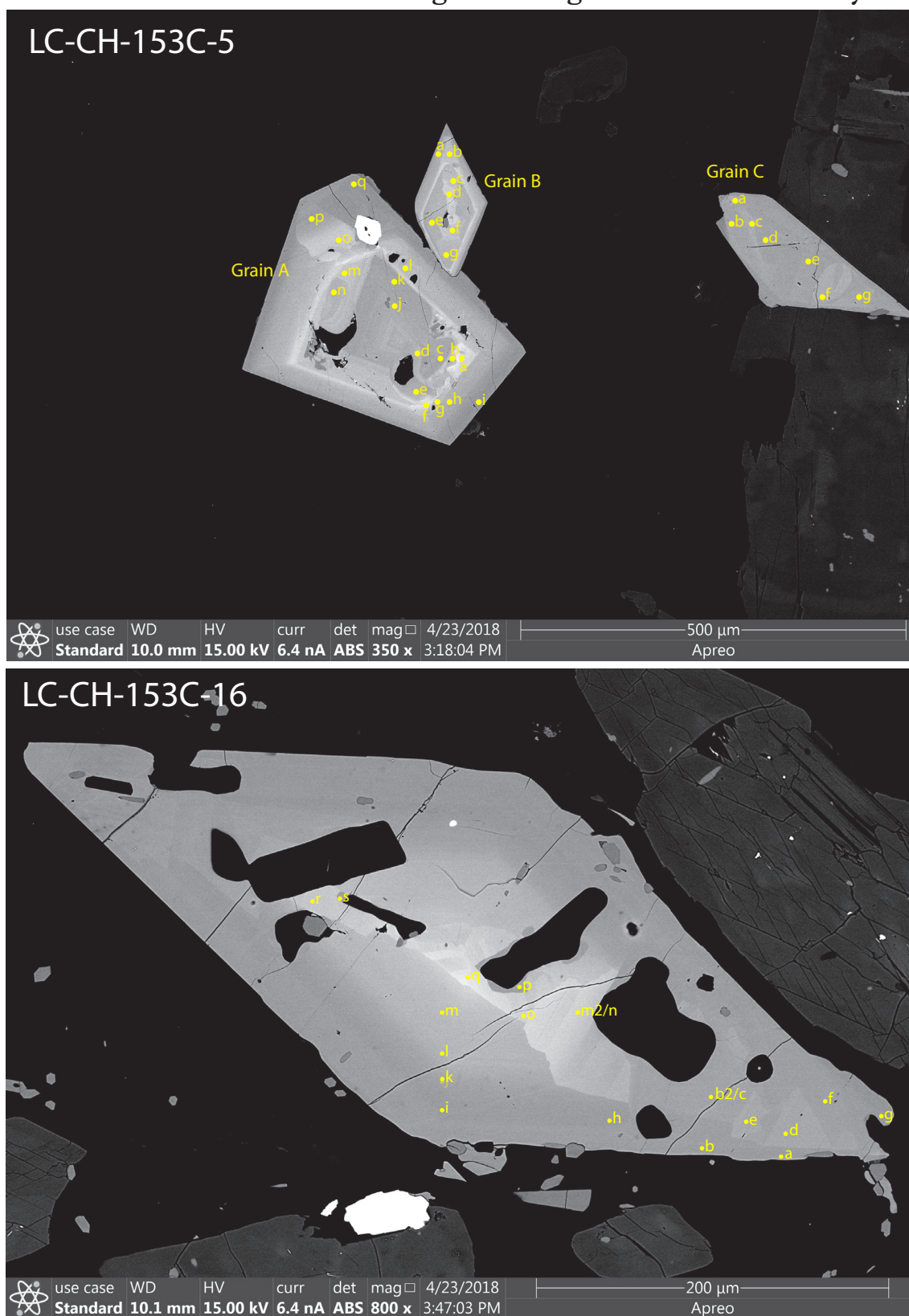


Figure A55. Little Cottonwood enclave titanite grains in LC-CH-153C-5 and LC-CH-153C-16 with electron microprobe spots (yellow).

Little Cottonwood enclave grain images — LC-CH locality

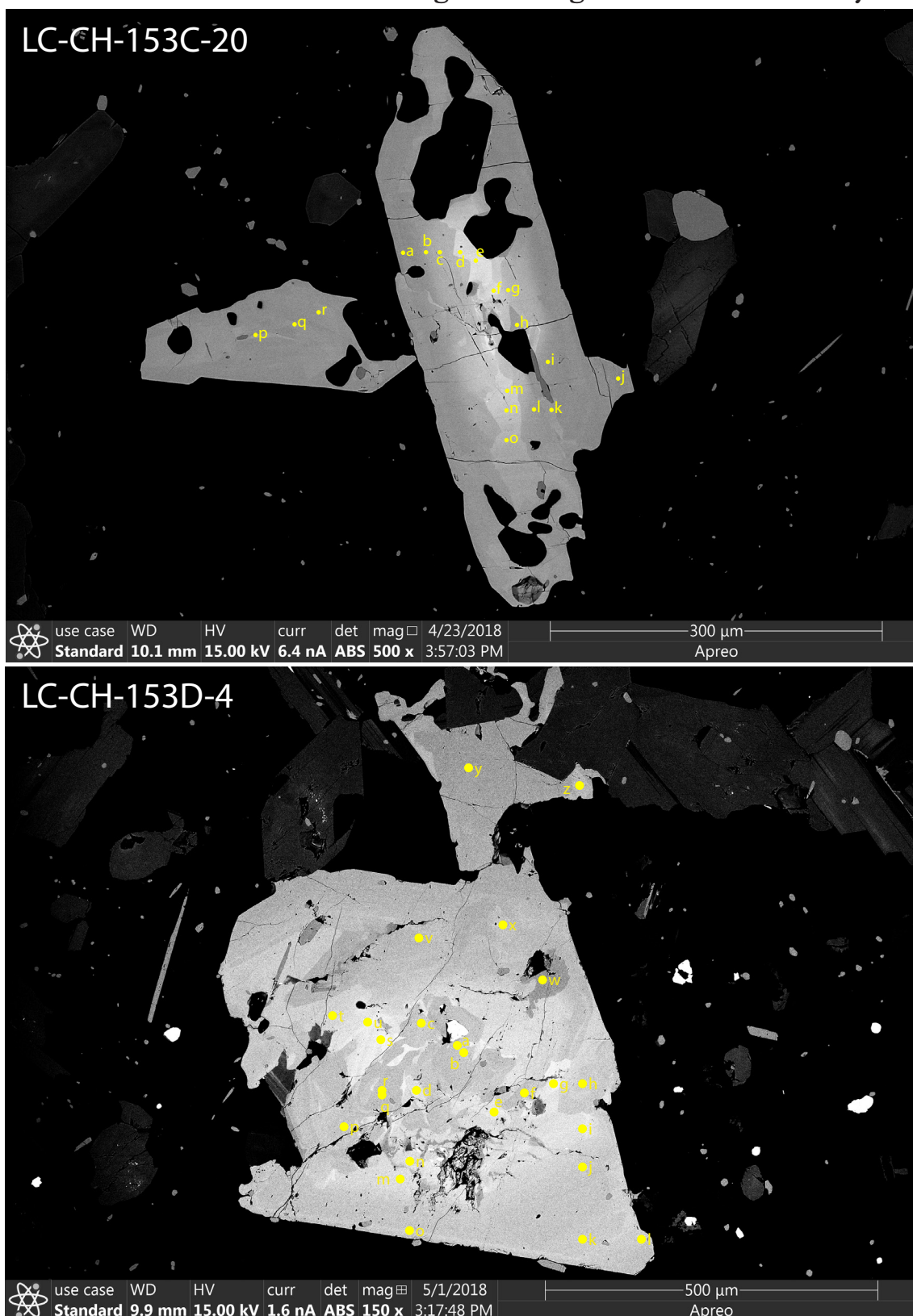


Figure A56. Little Cottonwood enclave titanite grains in LC-CH-153C-20 and LC-CH-153D-4 with electron microprobe spots (yellow).

Little Cottonwood enclave grain images — LC-CH locality

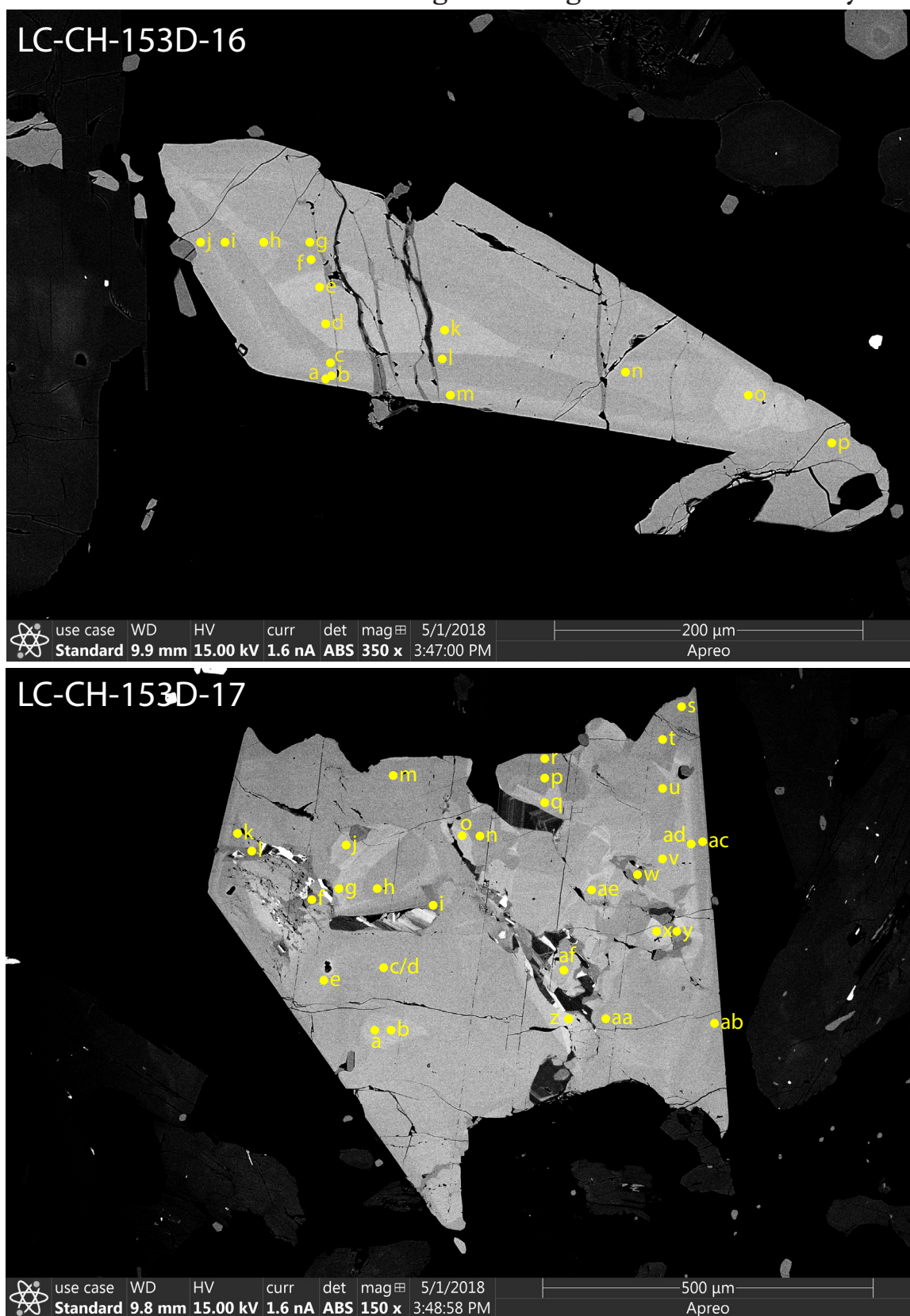


Figure A57. Little Cottonwood enclave titanite grains in LC-CH-153D-16 and LC-CH-153D-17 with electron microprobe spots (yellow).

Little Cottonwood enclave grain images — LC-CH locality

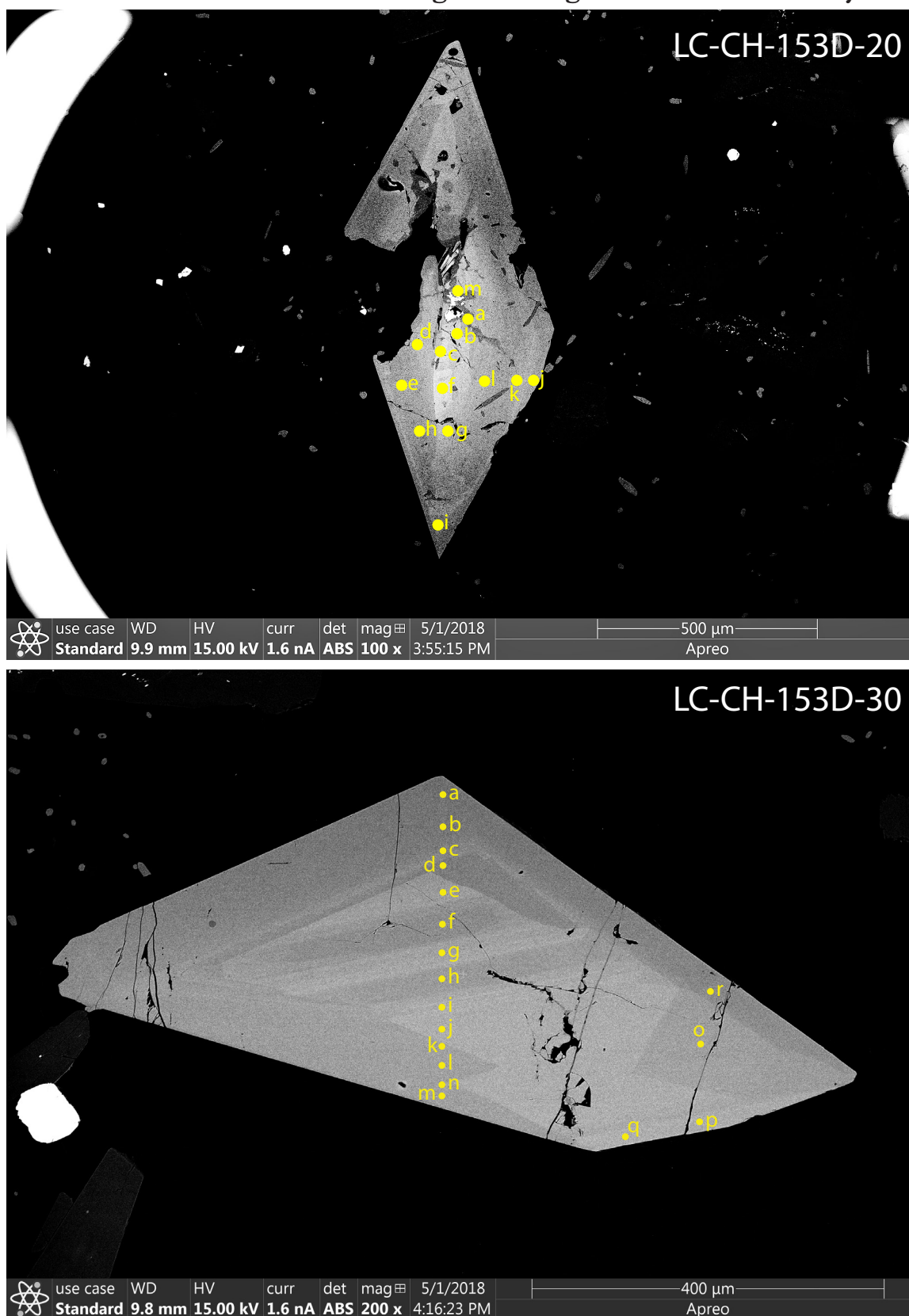


Figure A58. Little Cottonwood enclave titanite grains in LC-CH-153D-20 and LC-CH-153D-30 with electron microprobe spots (yellow).

Little Cottonwood enclave grain images — Corner Canyon locality

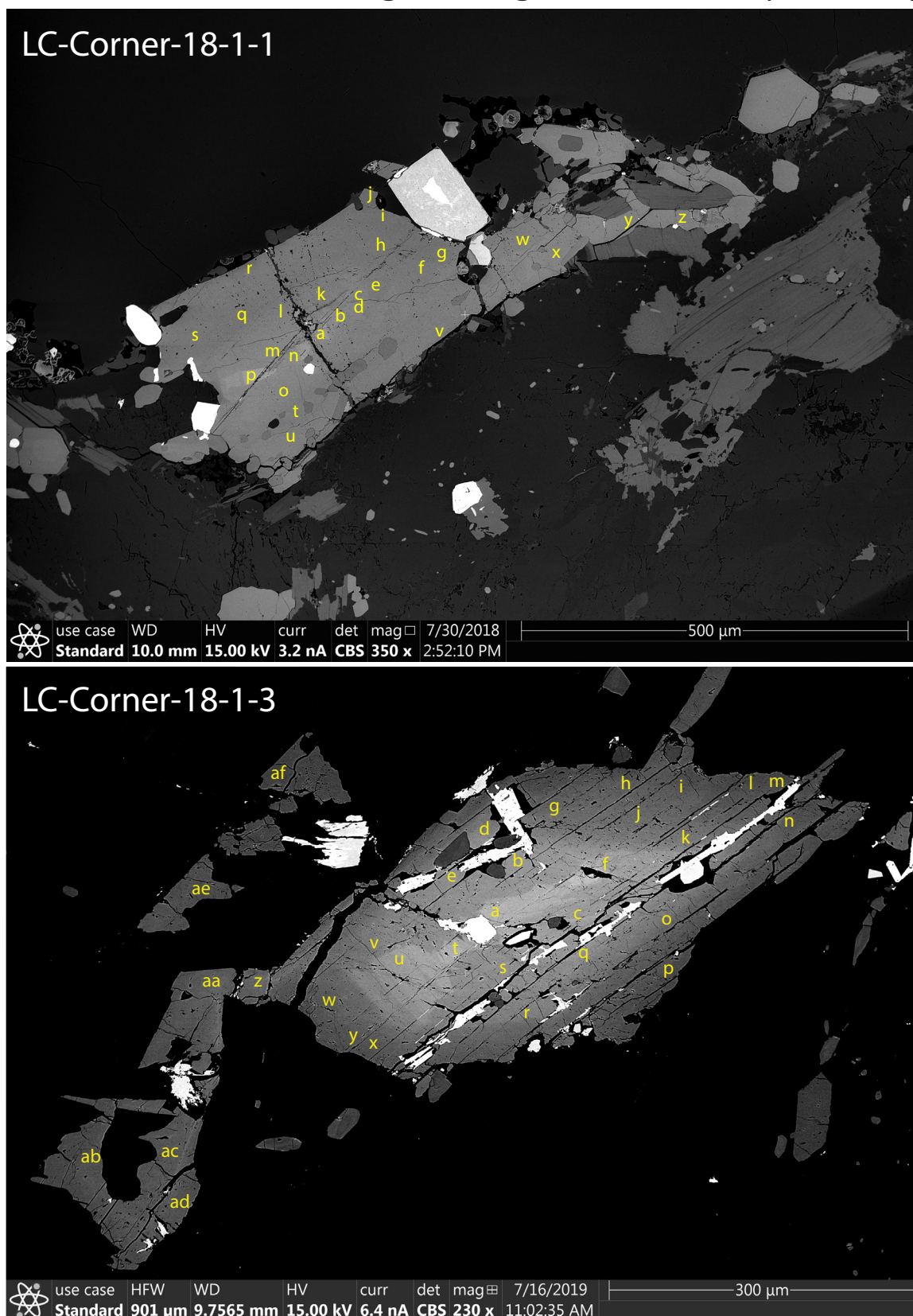


Figure A59. Little Cottonwood enclave titanite grains in LC-Corner-18-1-1 and LC-Corner-18-1-3 with electron microprobe spots (yellow).

Little Cottonwood enclave grain images — Corner Canyon locality

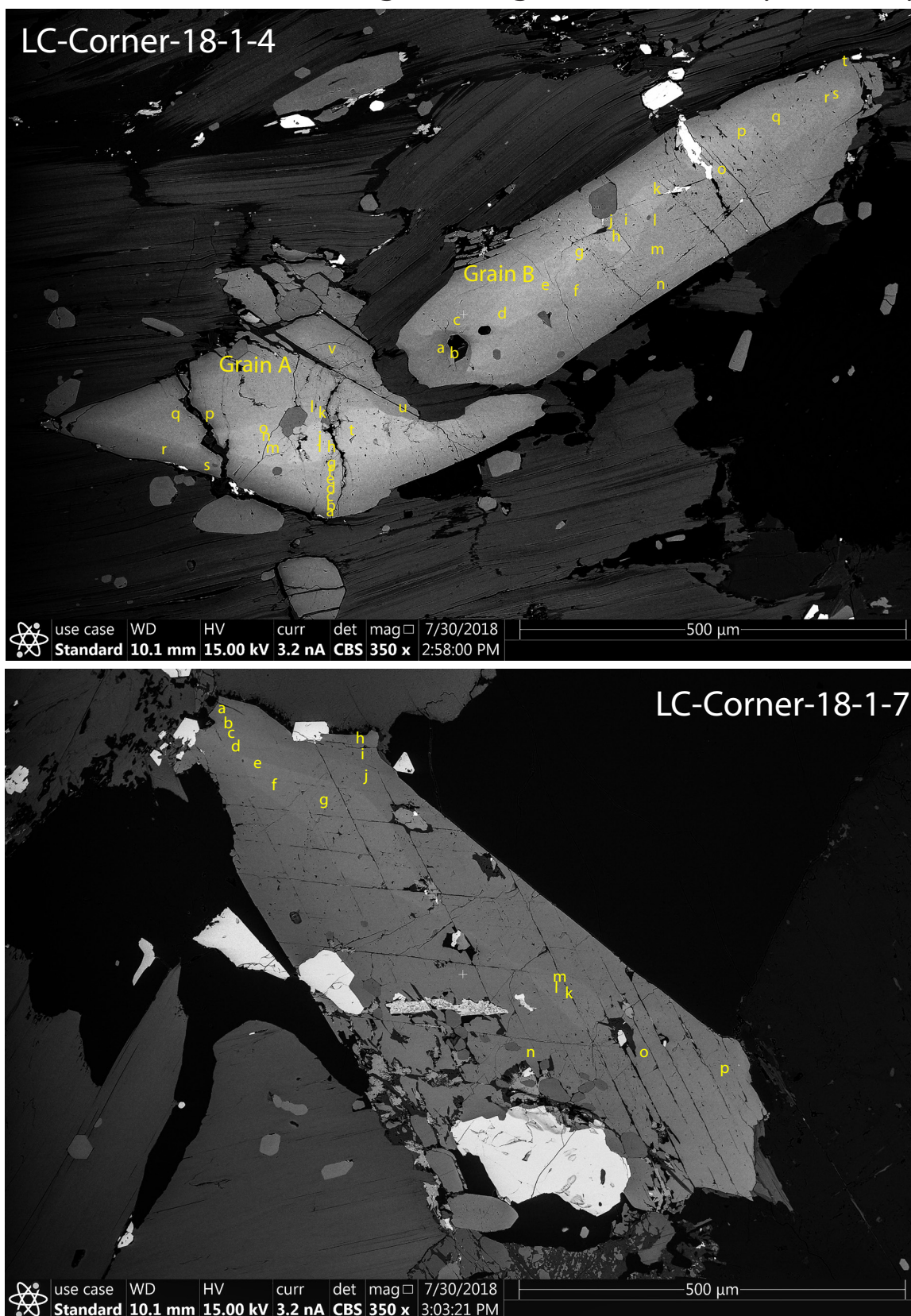


Figure A60. Little Cottonwood enclave titanite grains in LC-Corner-18-1-4 and LC-Corner-18-1-7 with electron microprobe spots (yellow).

Little Cottonwood enclave grain images — Corner Canyon locality

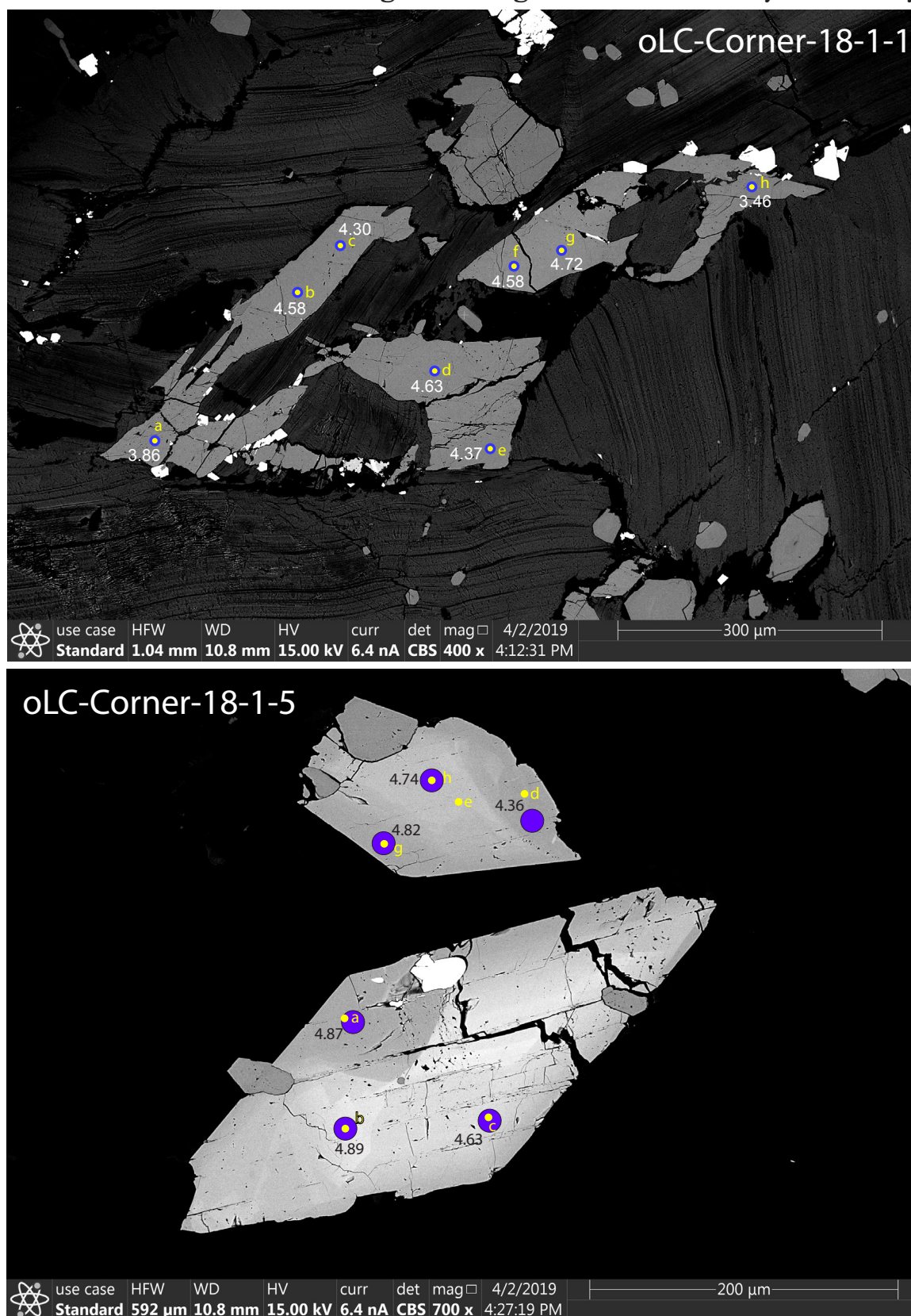


Figure A61. Little Cottonwood enclave titanite grains in oLC-Corner-18-1-1 and oLC-Corner-18-1-5 with electron microprobe spots (yellow) and oxygen isotope spots (blue). Numbers are $\delta^{18}\text{O}$ ‰ values.

Little Cottonwood enclave grain images — Hogum Fork Turnout (HFT)

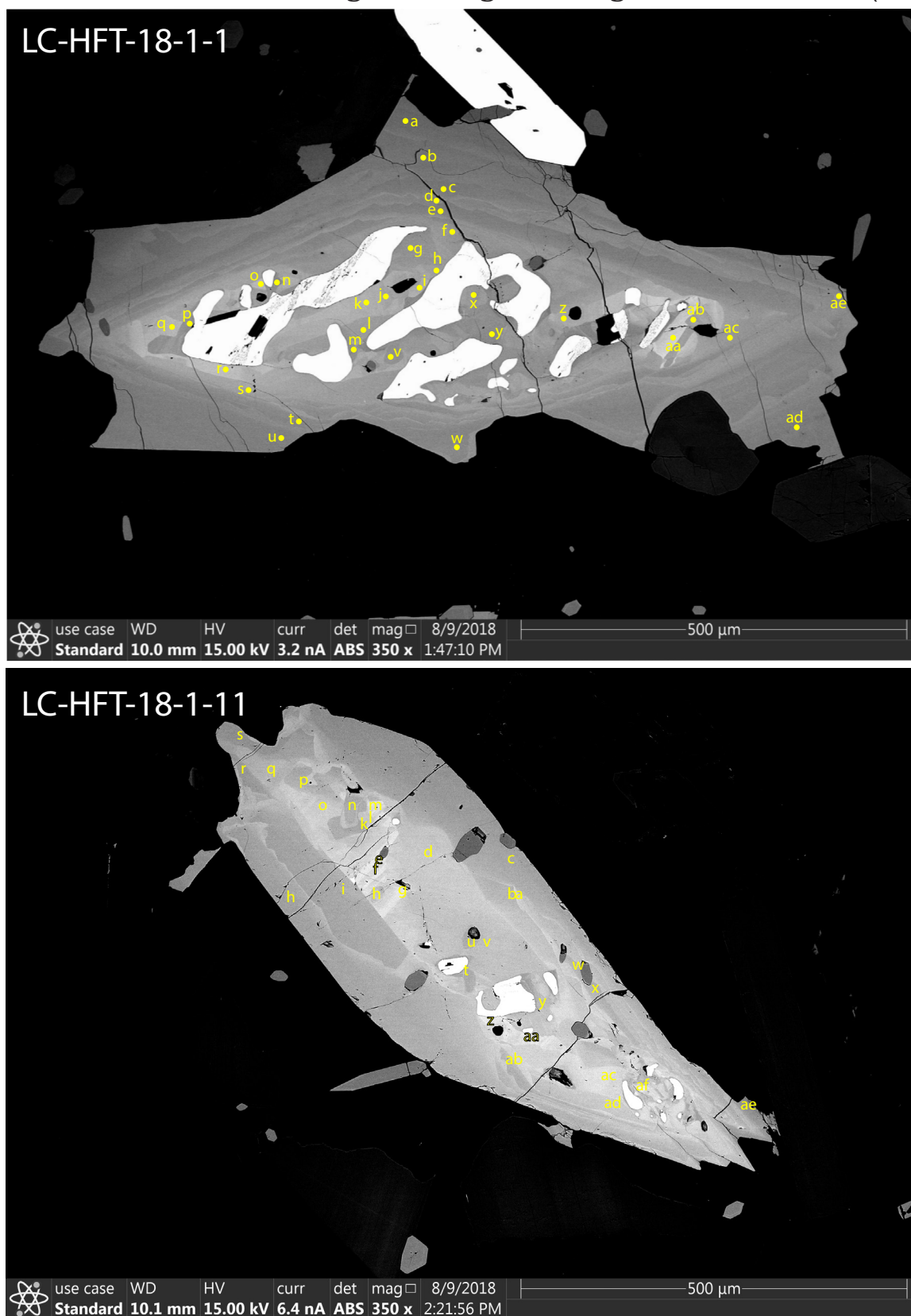


Figure A62. Little Cottonwood enclave titanite grains in LC-HFT-18-1-1 and LC-HFT-18-1-11 with electron microprobe spots (yellow).

Little Cottonwood enclave grain images — Hogum Fork Turnout (HFT)

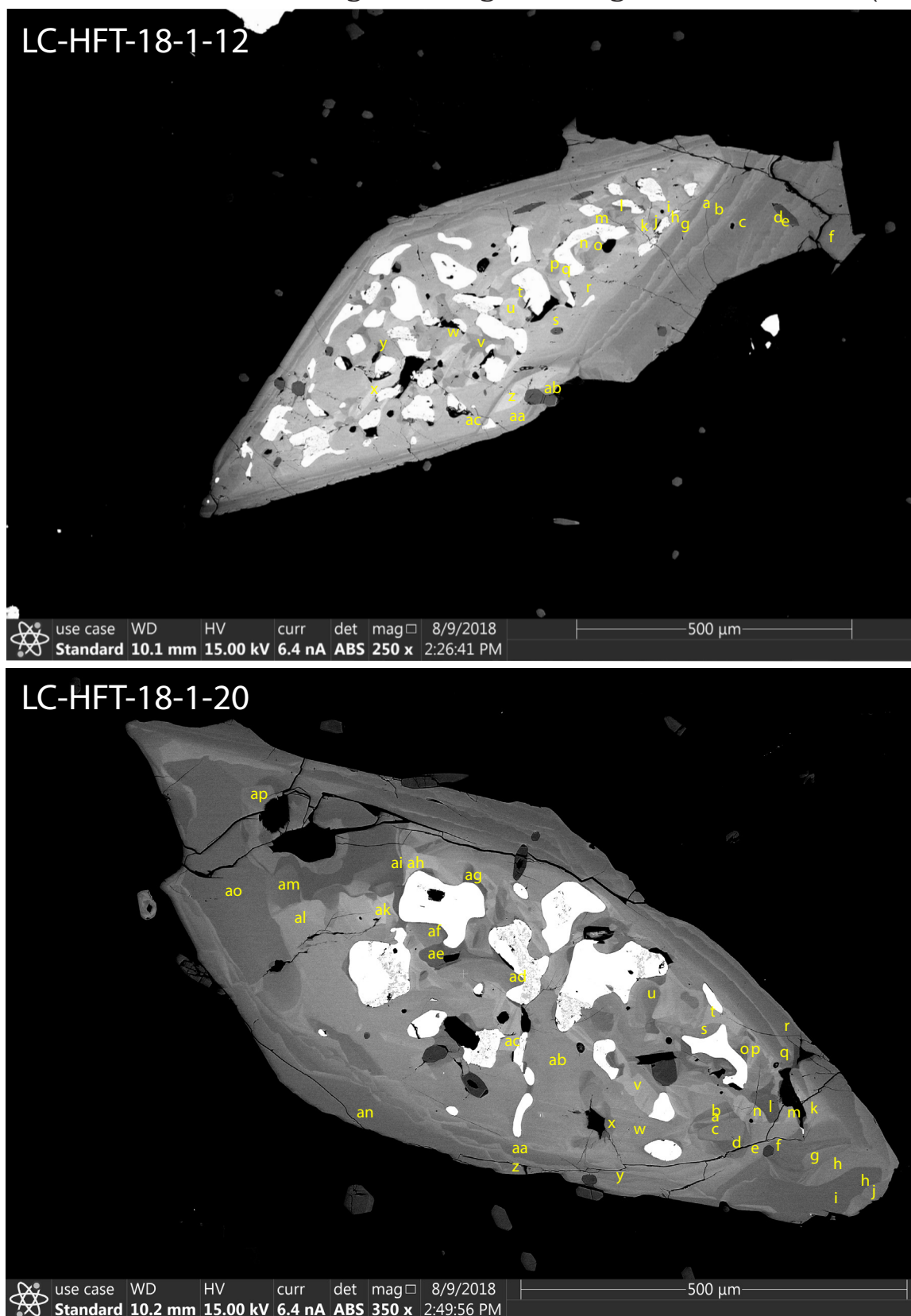


Figure A63. Little Cottonwood enclave titanite grains in LC-HFT-18-1-12 and LC-HFT-18-1-20 with electron microprobe spots (yellow).

Little Cottonwood enclave grain images — Hogum Fork Turnout (HFT)

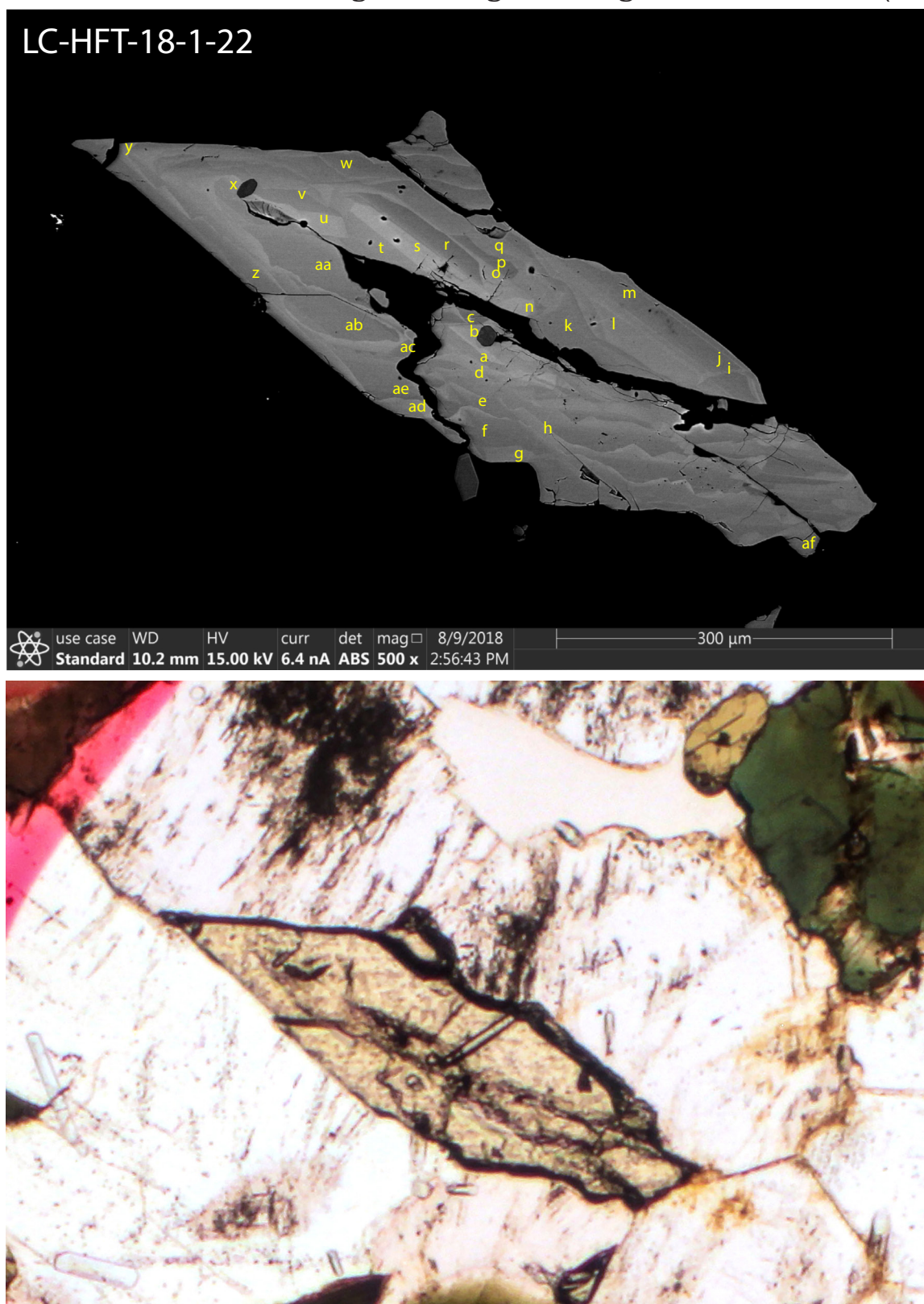


Figure A64. Top: Little Cottonwood enclave titanite grains in LC-HFT-18-1-22 with electron microprobe spots (yellow). Bottom: Petrographic photo of same grain in plane polarized light.

Little Cottonwood enclave grain images — Hogum Fork Turnout (HFT)

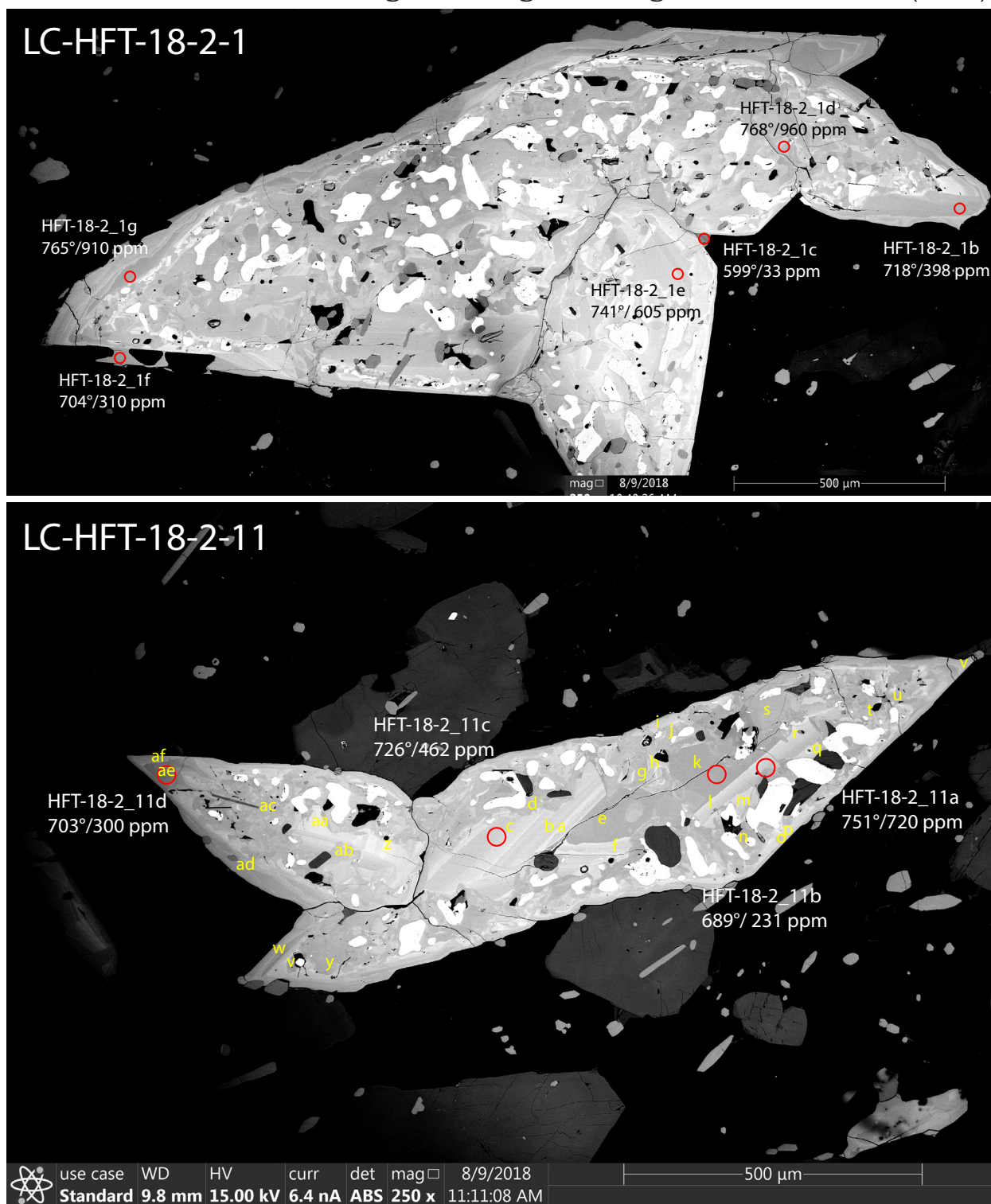


Figure A65. Little Cottonwood enclave titanite grains in LC-HFT-18-2-1 and LC-HFT-18-2-11 with electron microprobe spots (yellow) and LA=ICP-MS spots (red) with zirconium (ppm) and Zr in titanite temperatures.

Little Cottonwood enclave grain images — Hogum Fork Turnout (HFT)

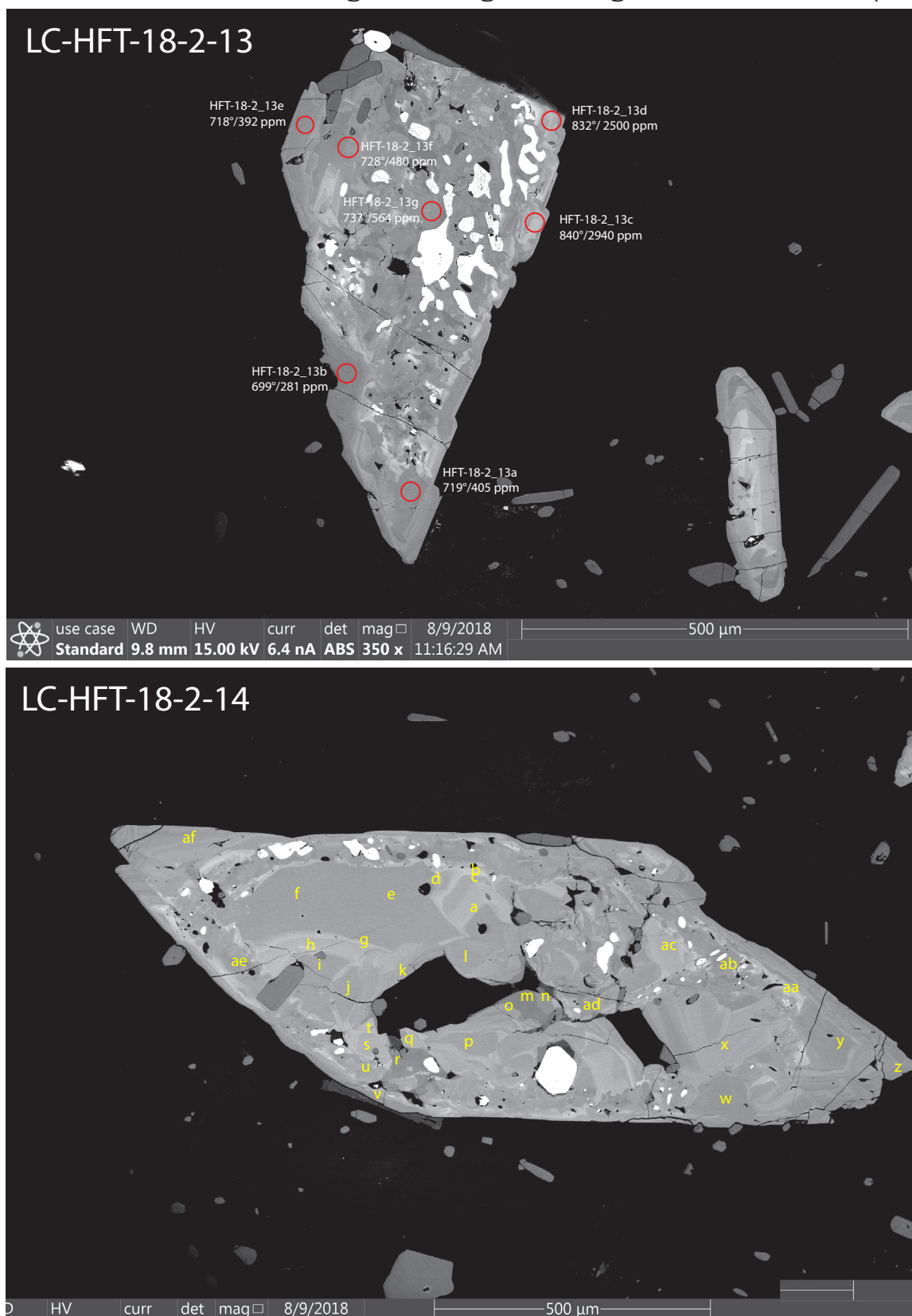


Figure A66. Little Cottonwood enclave titanite grains in LC-HFT-18-2-13 and LC-HFT-18-2-14 with electron microprobe spots (yellow) and LA=ICP-MS spots (red) with zirconium (ppm) and Zr in titanite temperatures.

Little Cottonwood enclave grain images — Hogum Fork Turnout (HFT)

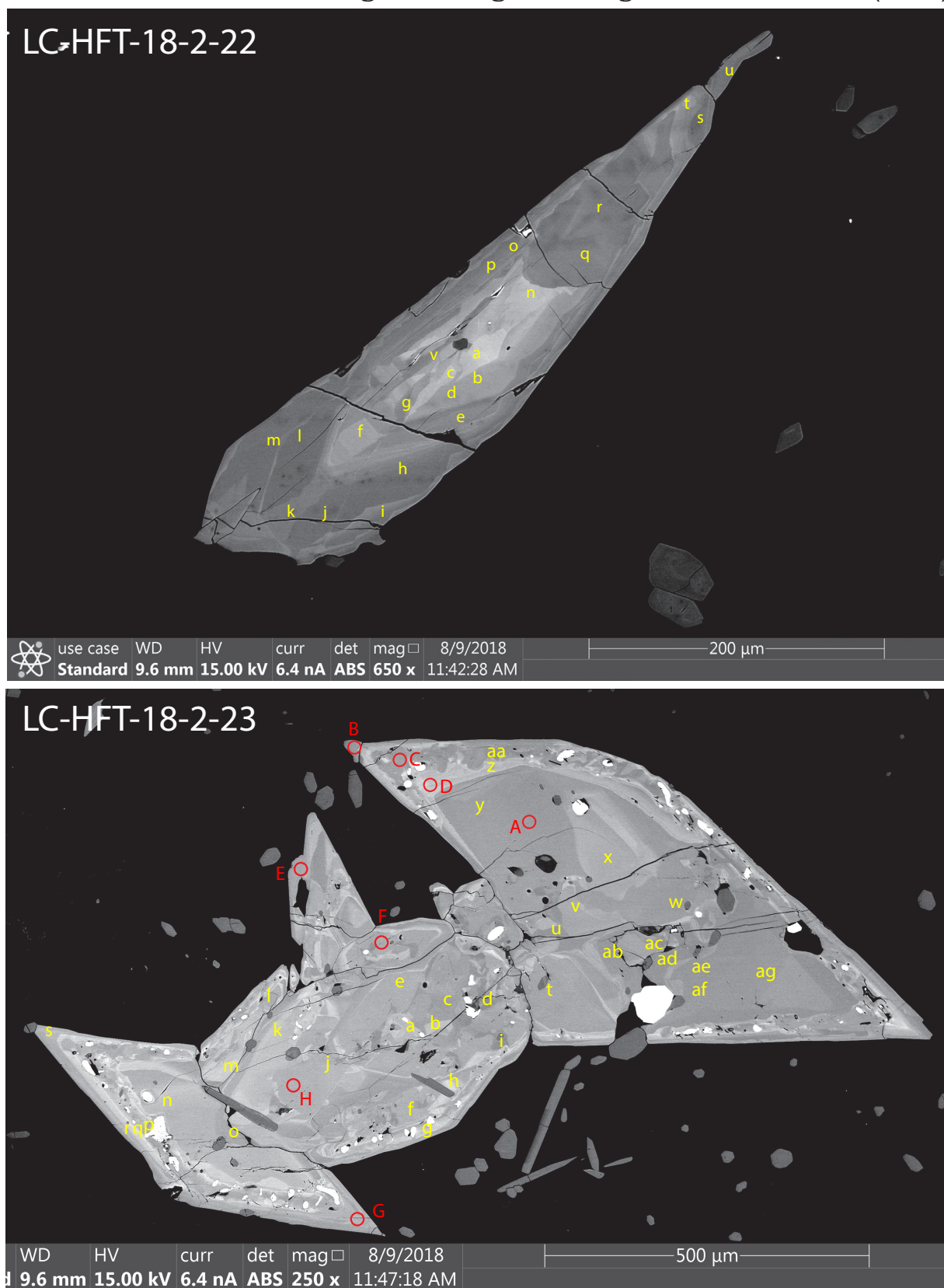


Figure A67. Little Cottonwood enclave titanite grains in LC-HFT-18-2-22 and LC-HFT-18-2-23 with electron microprobe spots (yellow) and LA=ICP-MS spots (red).

Little Cottonwood enclave grain images — Hogum Fork Turnout (HFT)

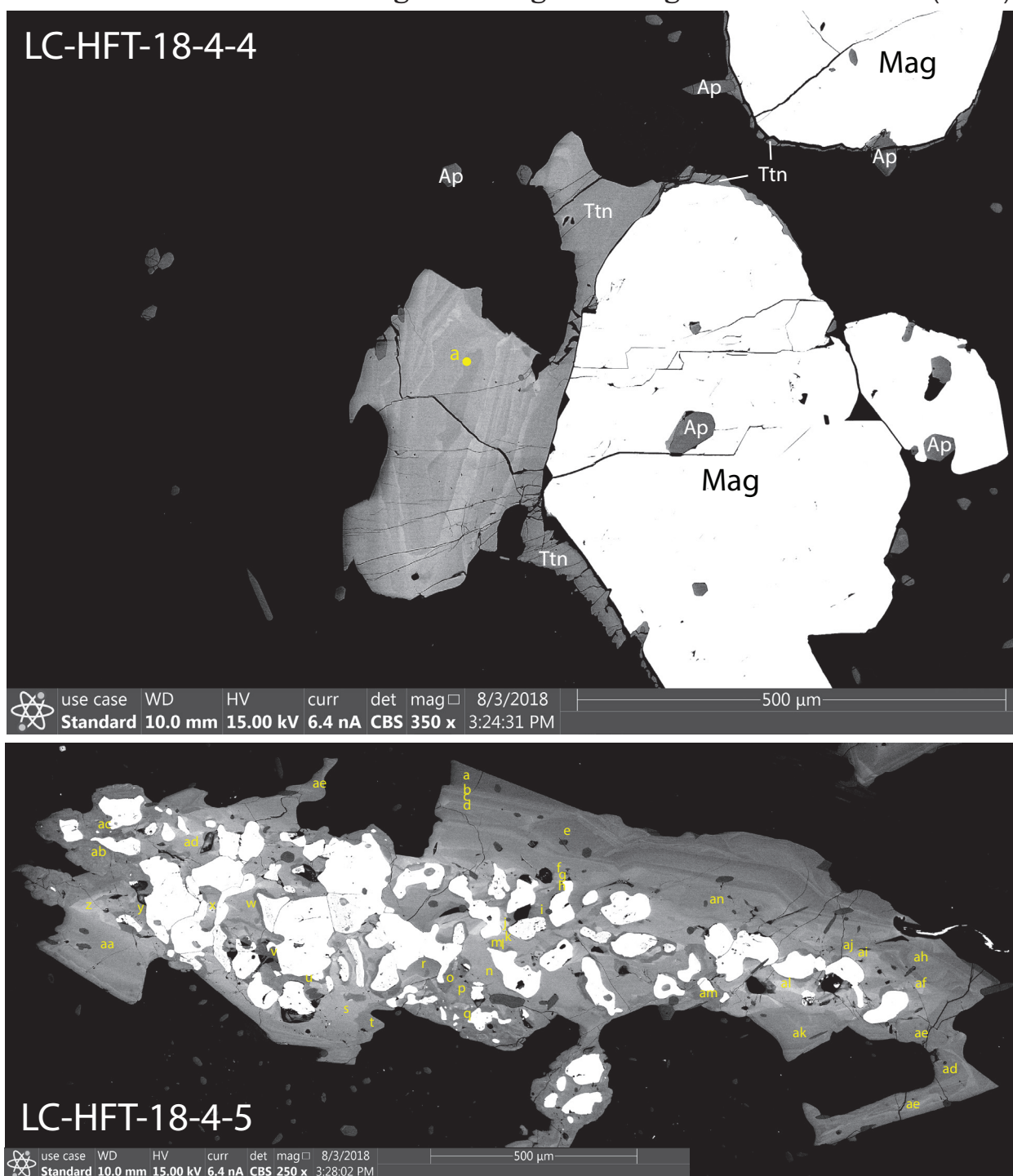


Figure A68. Little Cottonwood enclave titanite grains in LC-HFT-18-4-4 and LC-HFT-18-4-5 with electron microprobe spots (yellow). In the upper photo, grains of magnetite (Mag) are overgrown by titanite (Ttn).

Little Cottonwood enclave grain images — Hogum Fork Turnout (HFT)

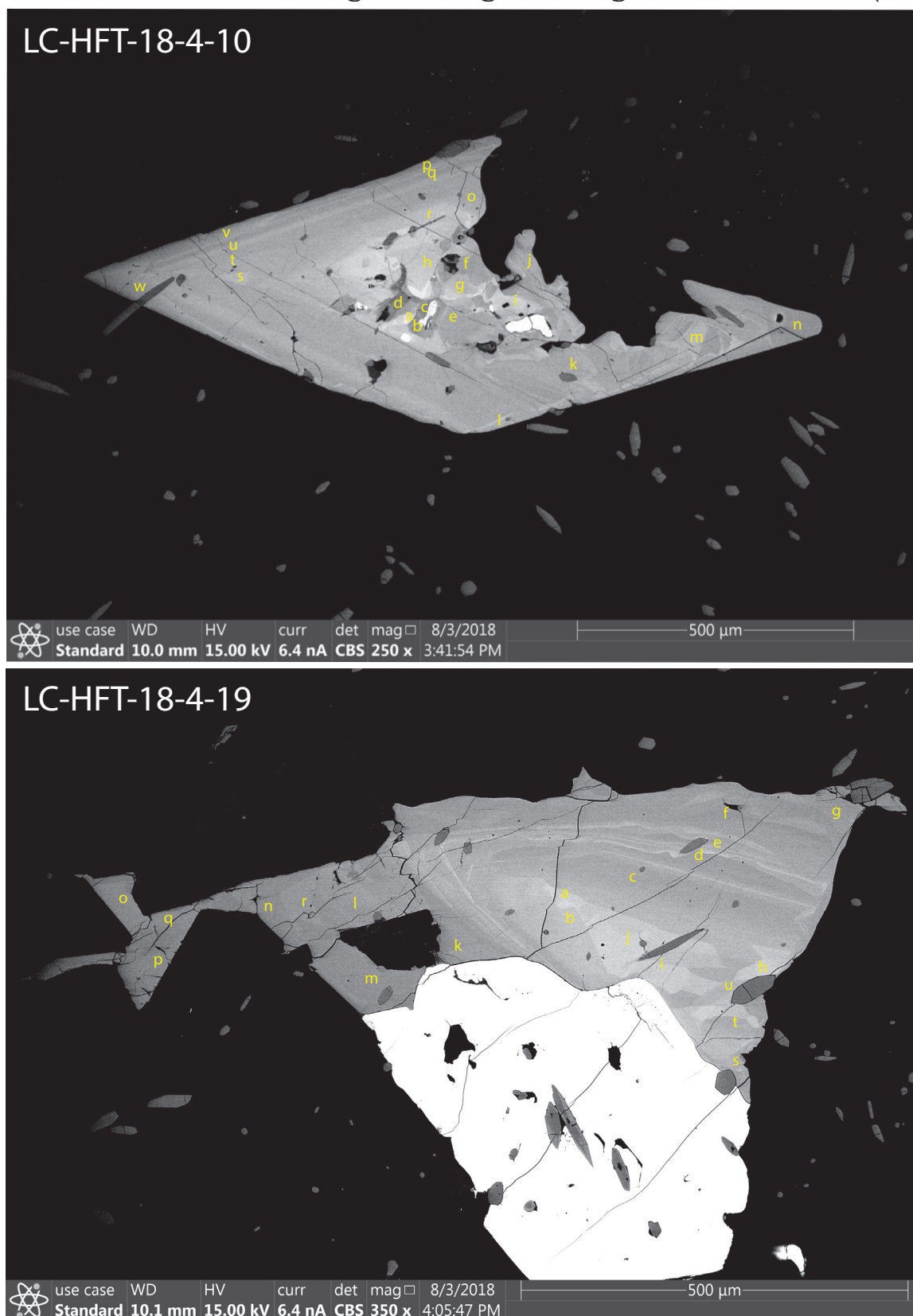


Figure A69. Little Cottonwood enclave titanite grains in LC-HFT-18-4-10 and LC-HFT-18-4-19 with electron microprobe spots (yellow). Most of the small gray minerals in the black background are apatite.

Little Cottonwood enclave grain images — Hogum Fork Turnout (HFT)

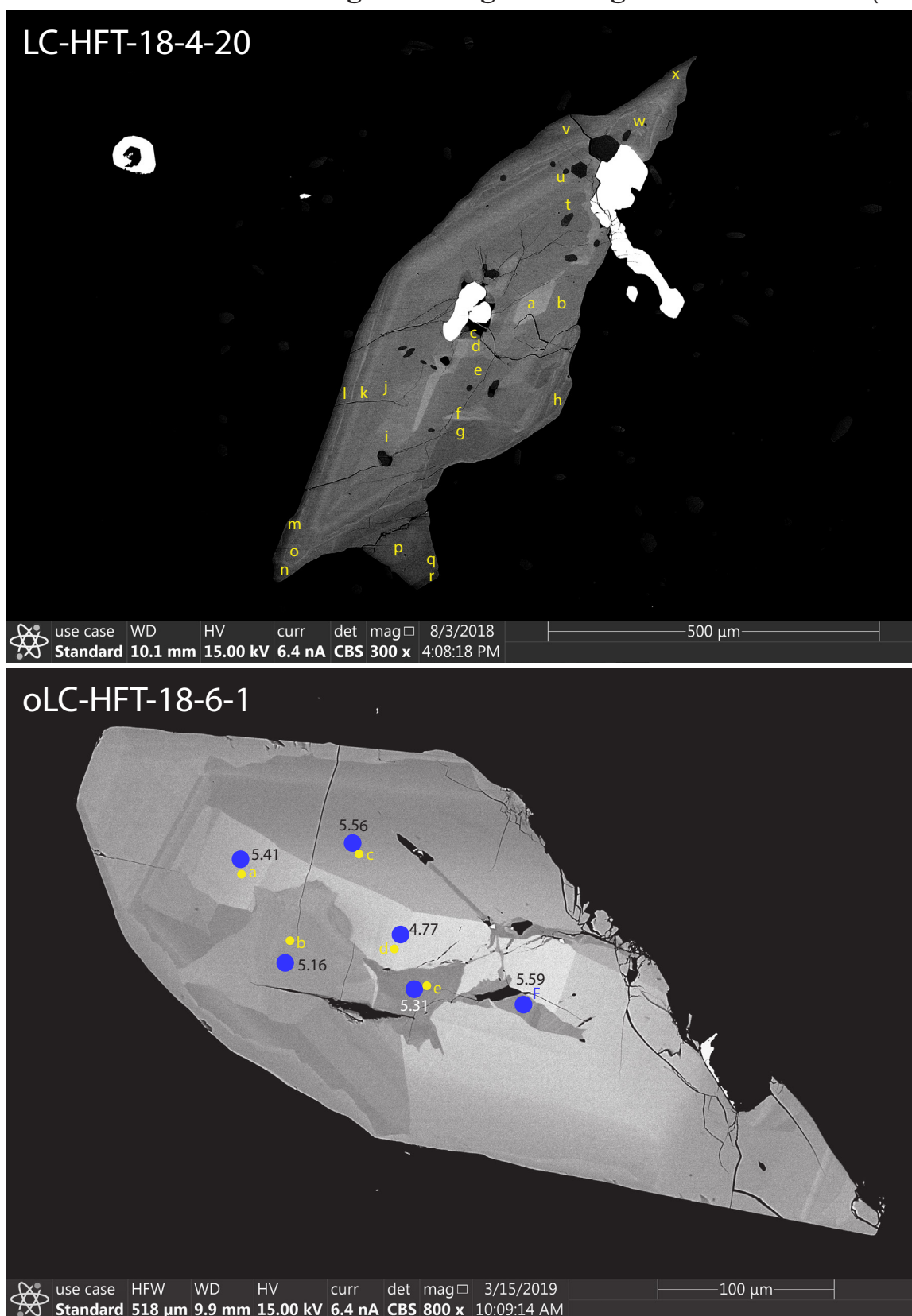


Figure A70. Little Cottonwood enclave titanite grains in LC-HFT-18-4-20 and oLC-HFT-18-6-1 with electron microprobe spots (yellow) and oxygen isotope spots (blue). Numbers are $\delta^{18}\text{O}$ ‰ values.

Little Cottonwood enclave grain images — Hogum Fork Turnout (HFT)

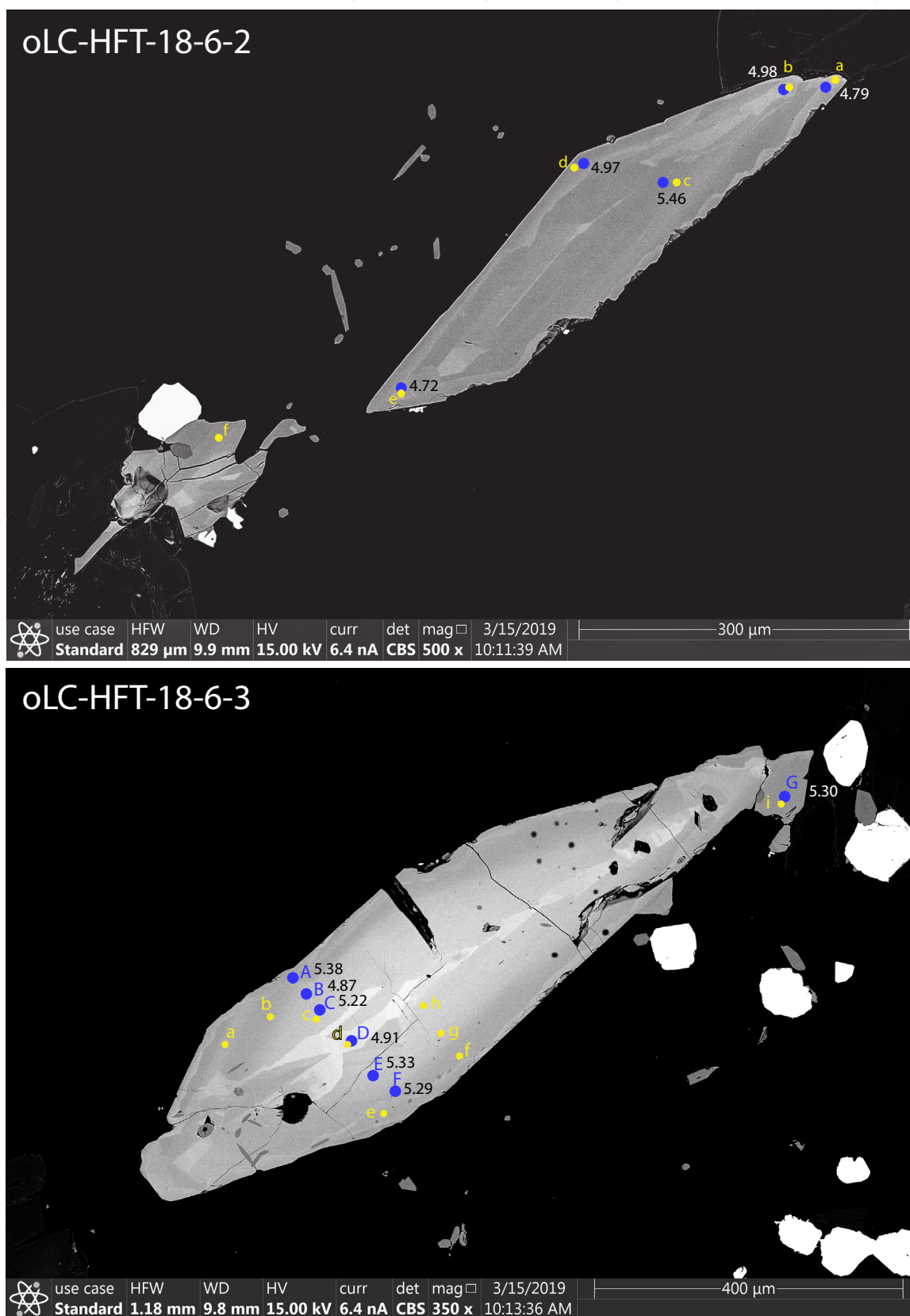


Figure A71. Little Cottonwood enclave titanite grains in oLC-HFT-18-6-2 and oLC-HFT-18-6-3 with electron microprobe spots (yellow) and oxygen isotope spots (blue). Numbers are $\delta^{18}\text{O}$ ‰ values.

Little Cottonwood enclave grain images — Hogum Fork Turnout (HFT)

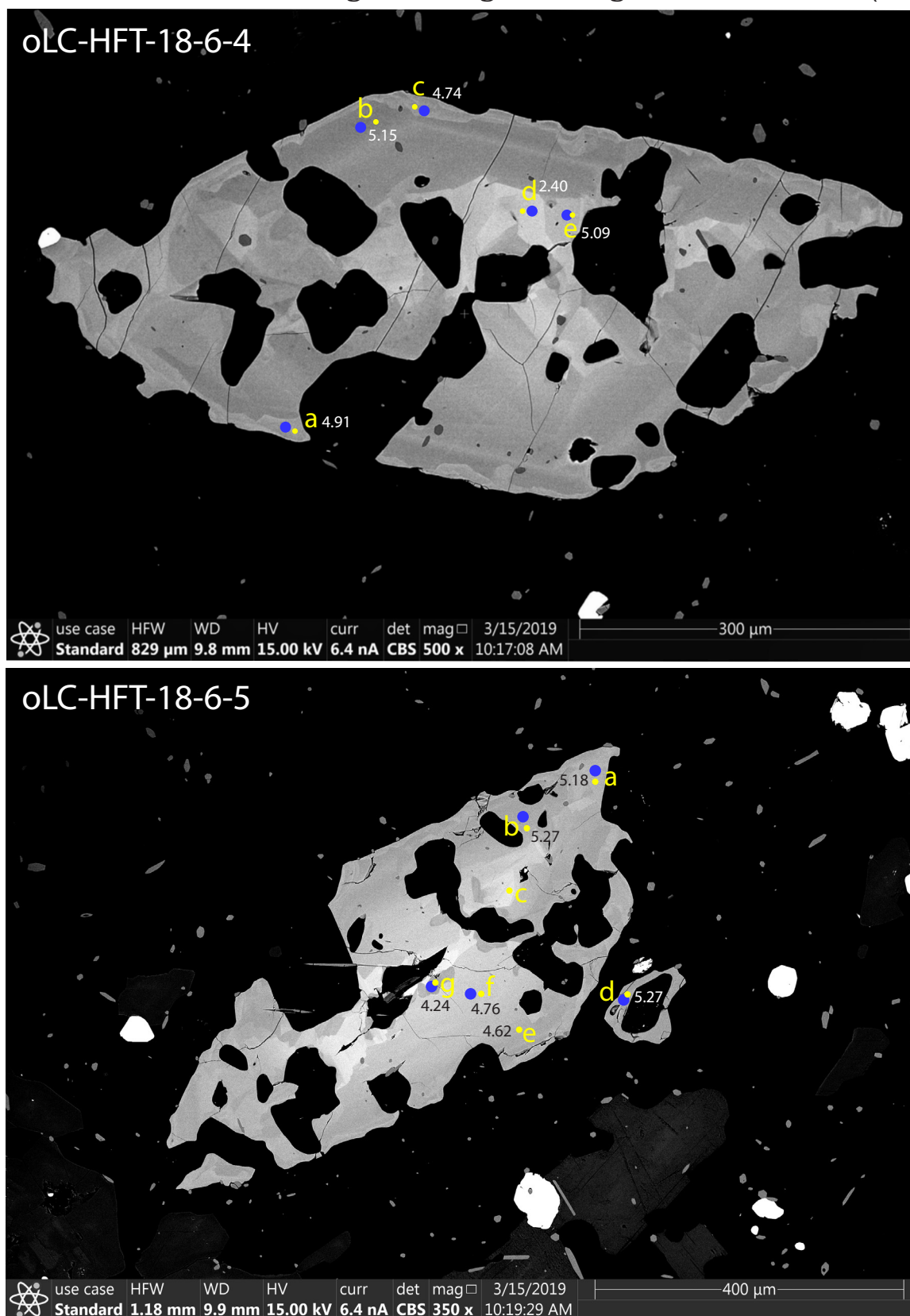


Figure A72. Little Cottonwood enclave titanite grains in oLC-HFT-18-6-4 and oLC-HFT-18-6-5 with electron microprobe spots (yellow) and oxygen isotope spots (blue). Most of the small gray minerals in the black background are apatite. Numbers are $\delta^{18}\text{O}$ ‰ values.

Little Cottonwood enclave grain images — Hogum Fork Turnout (HFT)

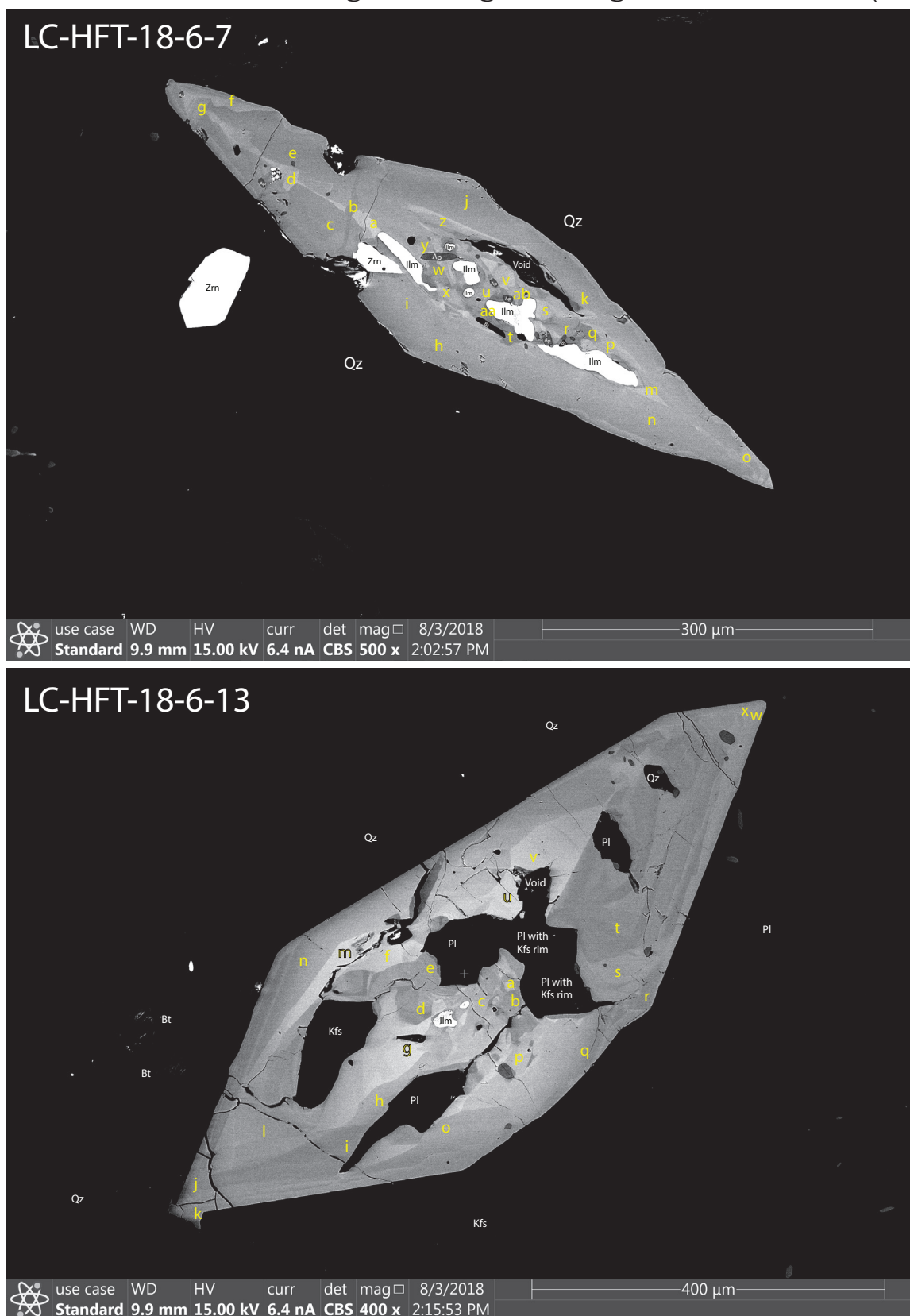


Figure A73. Little Cottonwood enclave titanite grains in LC-HFT-18-6-7 and LC-HFT-18-6-13 with electron microprobe spots (yellow). Note the enclosed feldspar and quartz in lower photo of poikilitic grain.

Little Cottonwood enclave grain images — Hogum Fork Turnout (HFT)

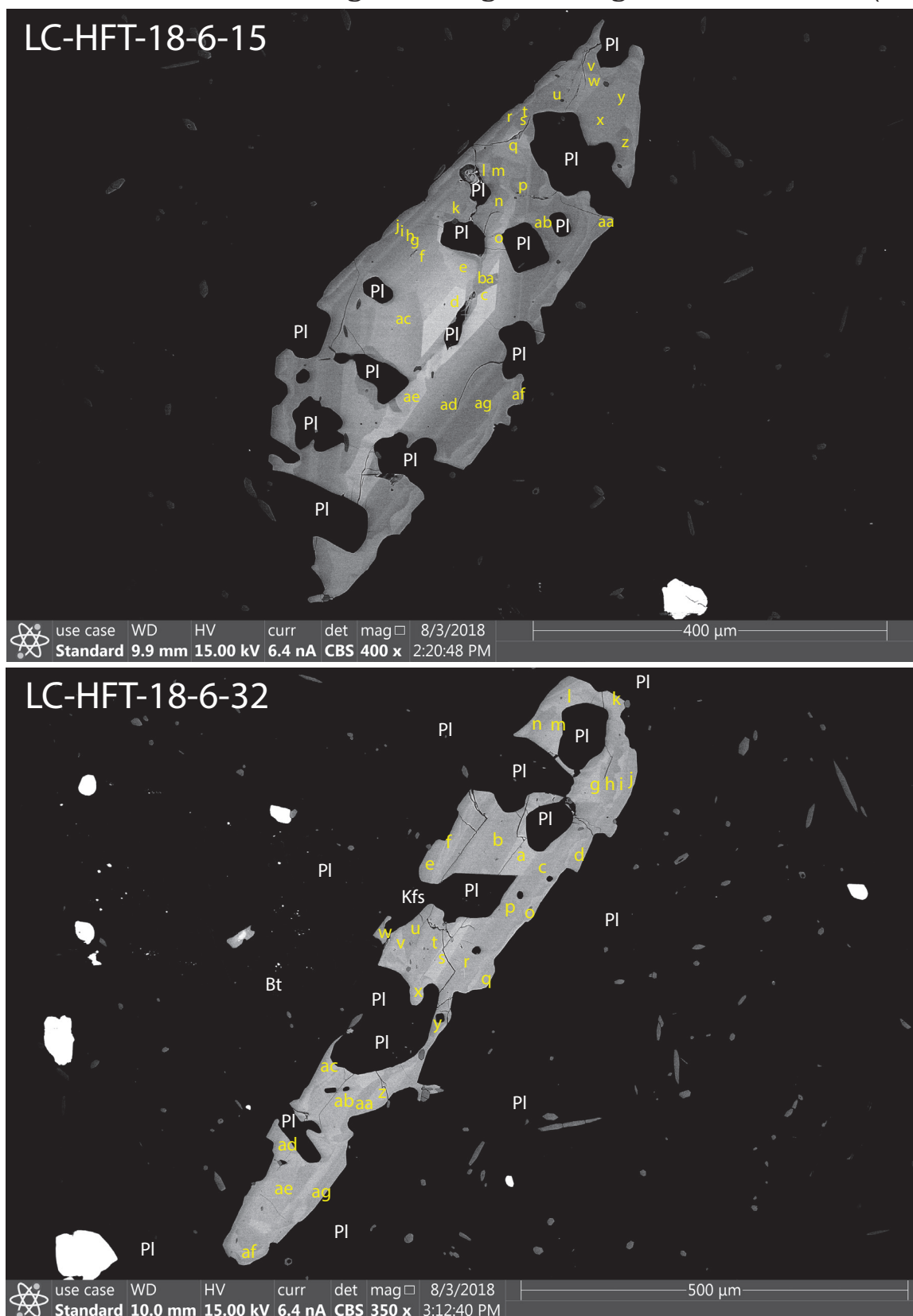
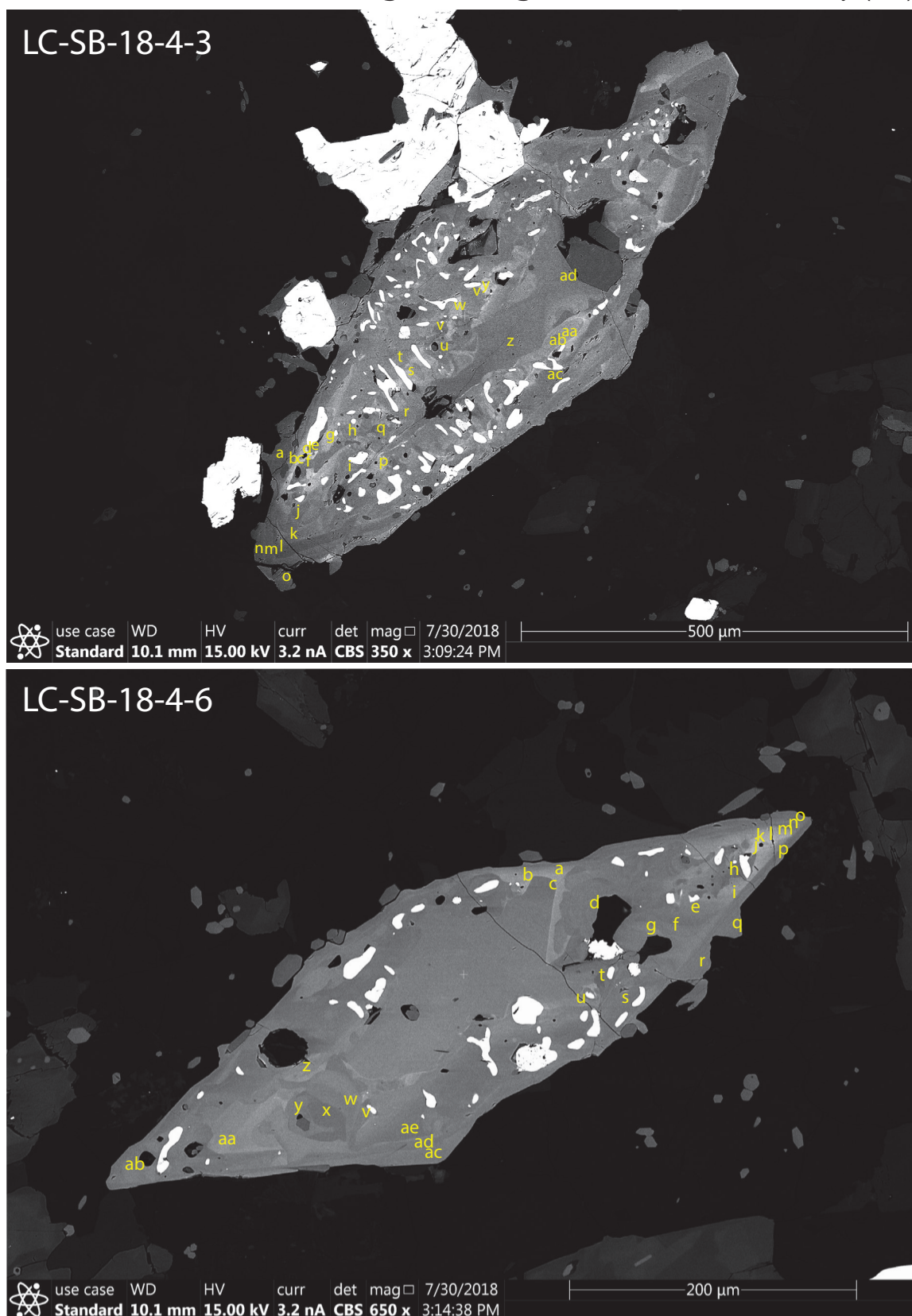


Figure A74. Little Cottonwood enclave titanite grains in LC-HFT-18-6-15 and LC-HFT-18-6-32 with electron microprobe spots (yellow). Most of the small gray minerals in the black background are apatite.

Little Cottonwood enclave grain images — Snow Bird locality (SB)



Little Cottonwood enclave grain images — Snow Bird locality (SB)

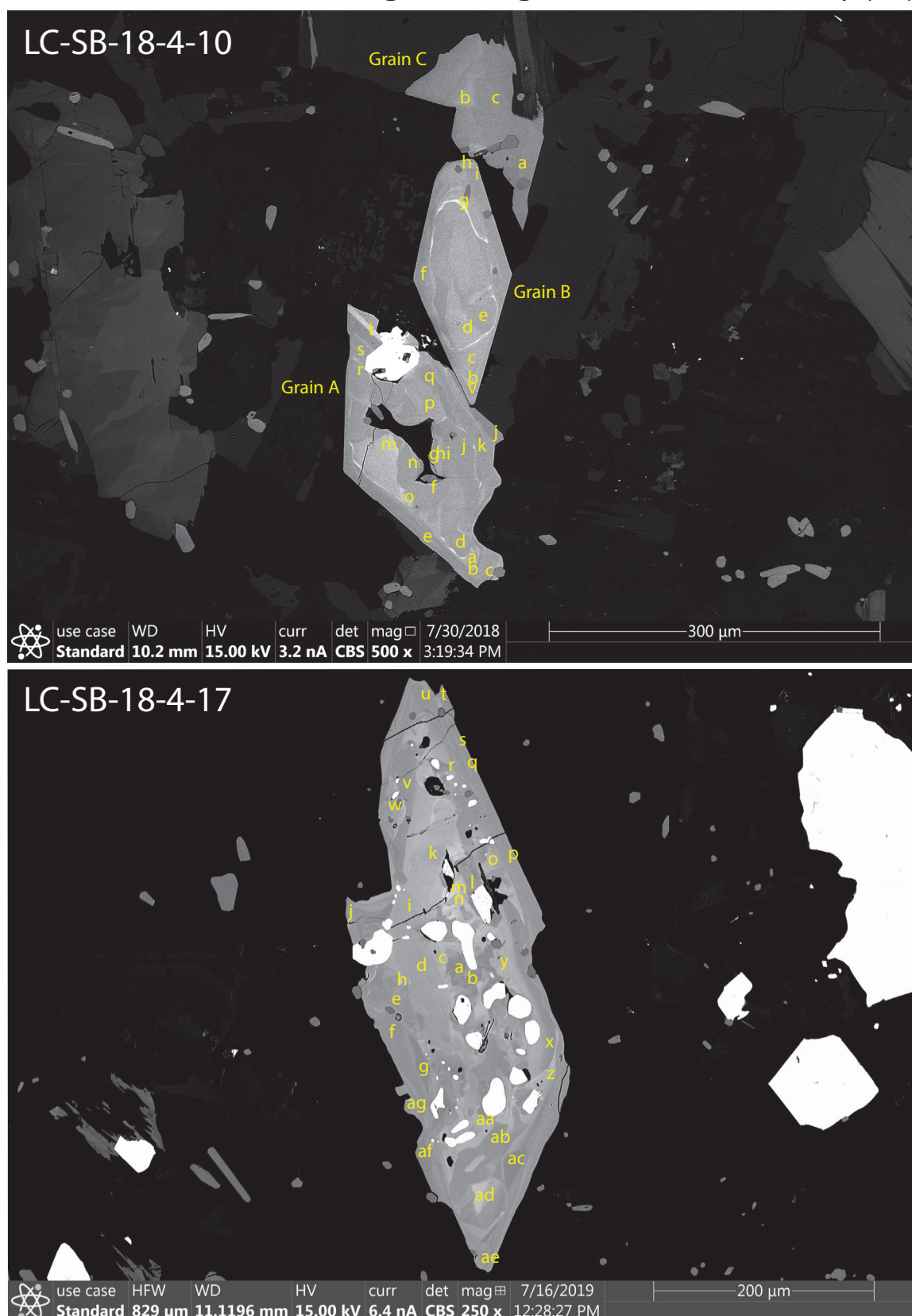


Figure A76. Little Cottonwood enclave titanite grains in LC-SB-18-4-10 and LC-SB-18-4-17 with electron microprobe spots (yellow).

Little Cottonwood enclave grain images — Snow Bird locality (SB)

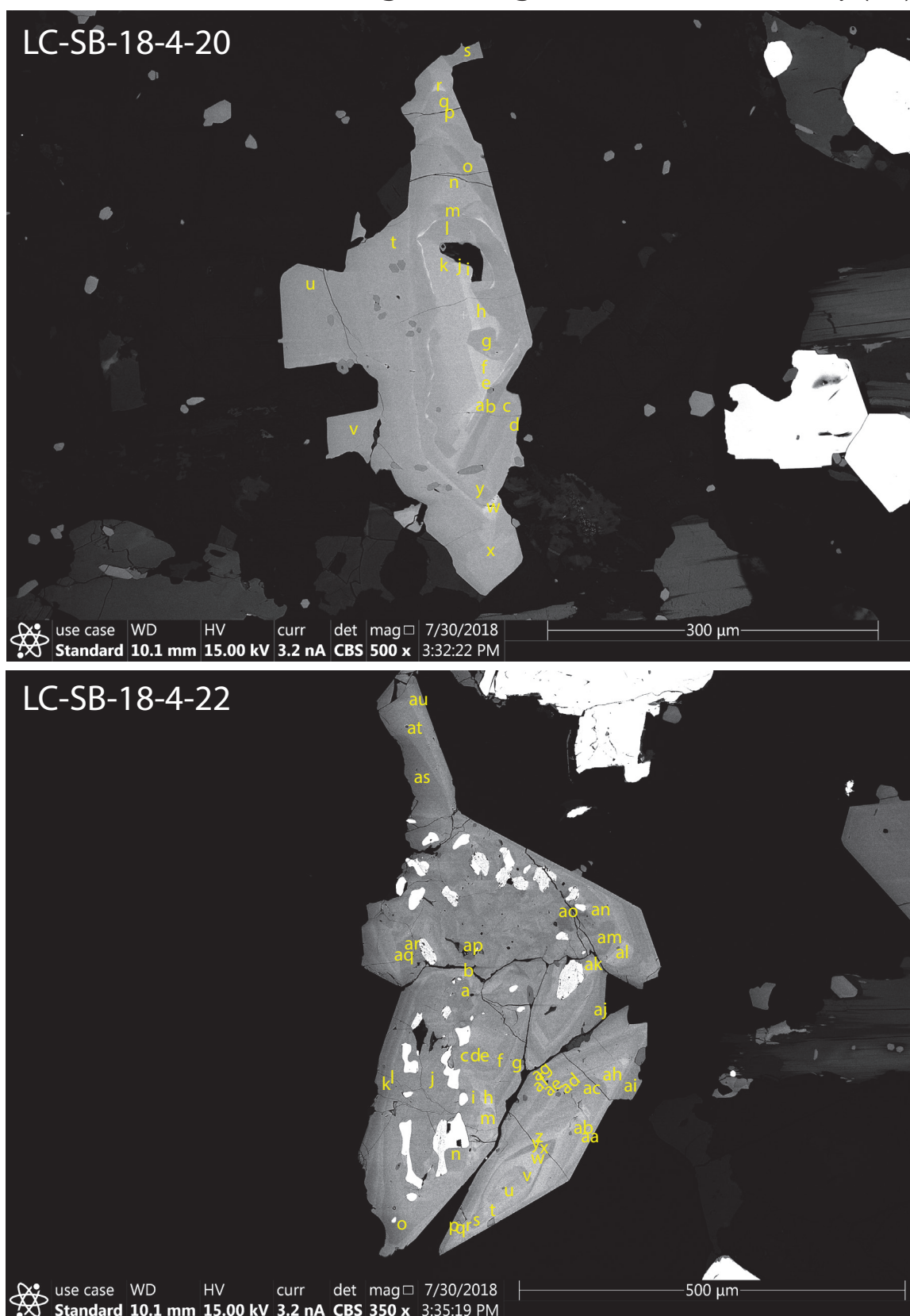


Figure A77. Little Cottonwood enclave titanite grains in LC-SB-18-4-20 and LC-SB-18-4-22 with electron microprobe spots (yellow).

Little Cottonwood enclave grain images — Snow Bird locality (SB)

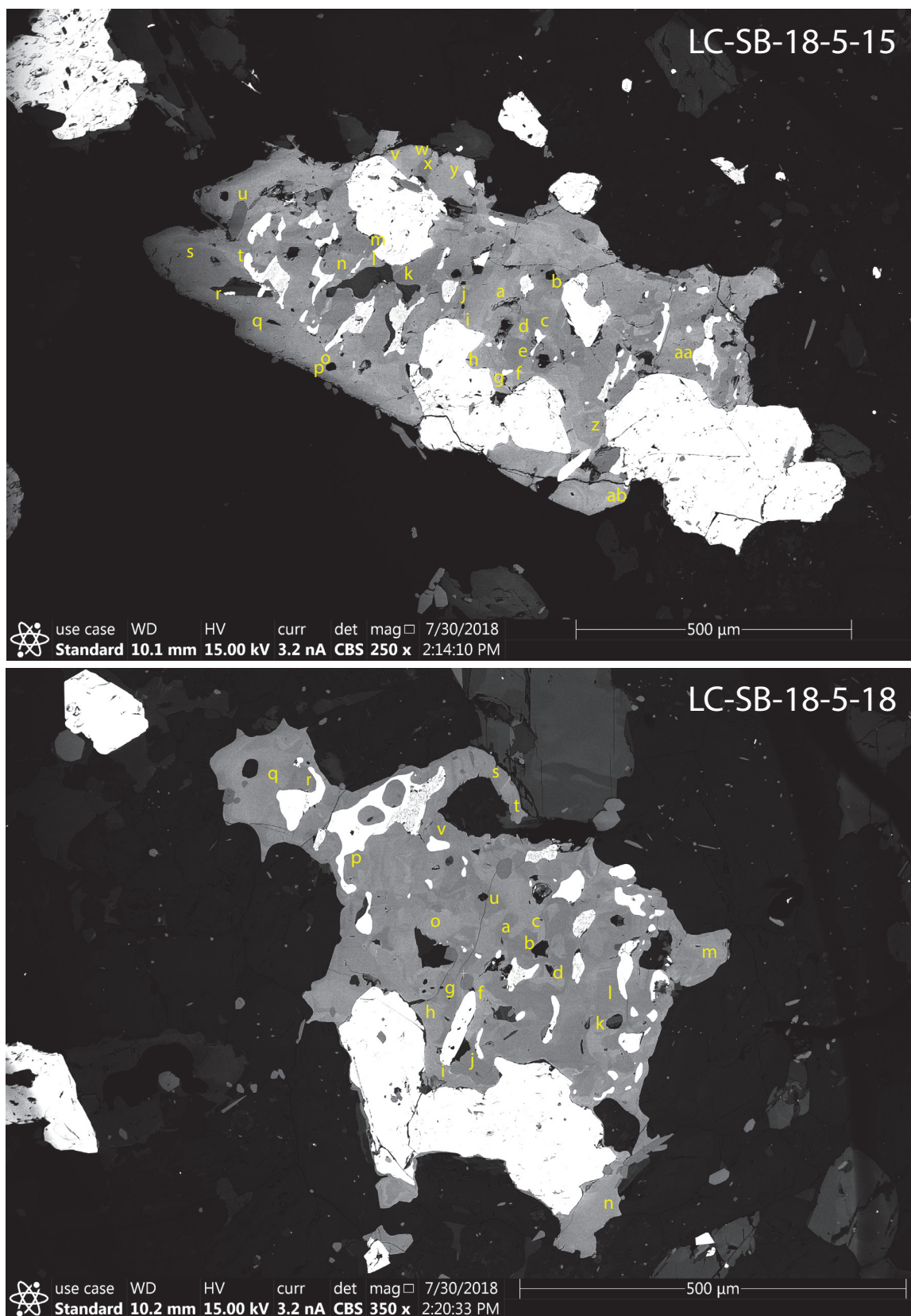


Figure A78. Little Cottonwood enclave titanite grains in LC-SB-18-5-15 and LC-SB-18-5-18 with electron microprobe spots (yellow).

Little Cottonwood enclave grain images — Snow Bird locality (SB)

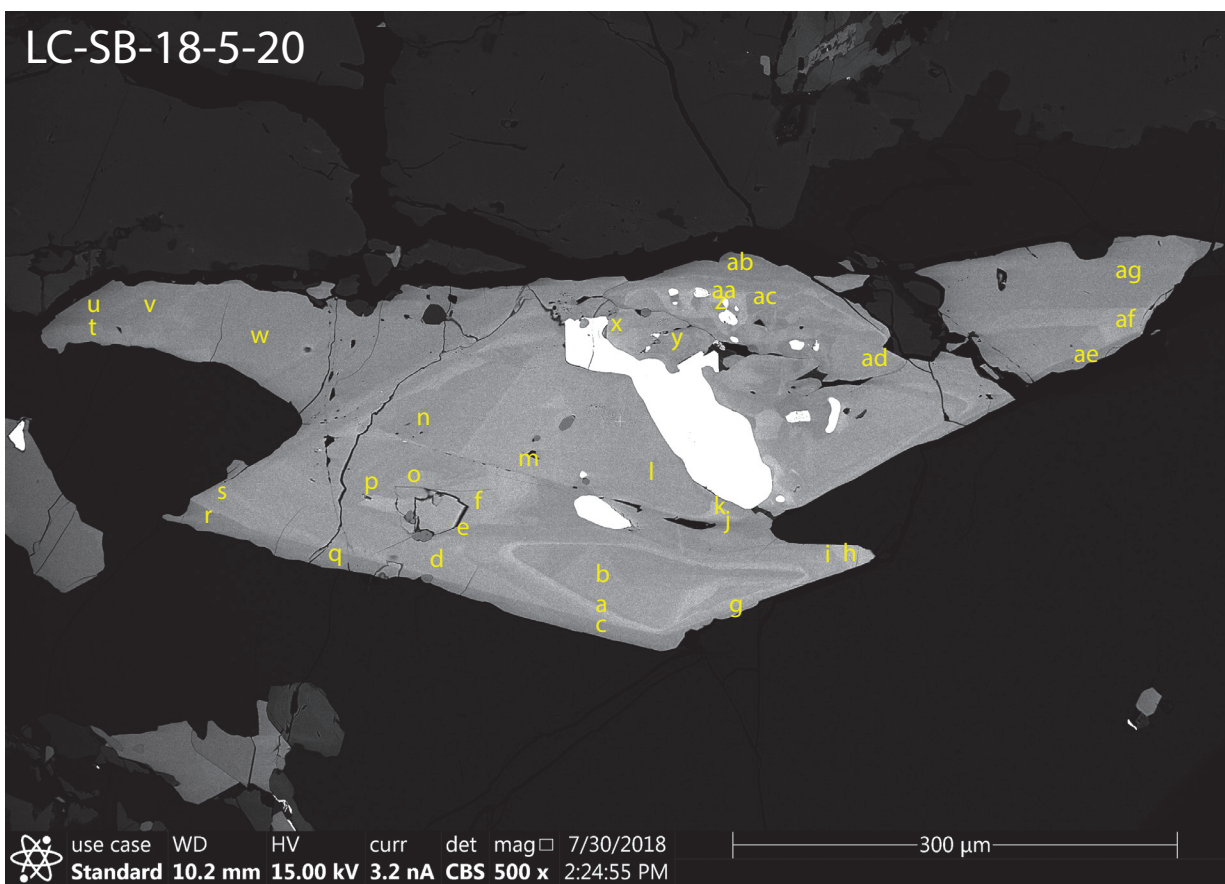


Figure A79. Little Cottonwood enclave titanite grains in LC-SB-18-5-20 with electron microprobe spots (yellow).

Little Cottonwood enclave grain images — Snow Bird locality (SB)

oLC-SB-18-5-1

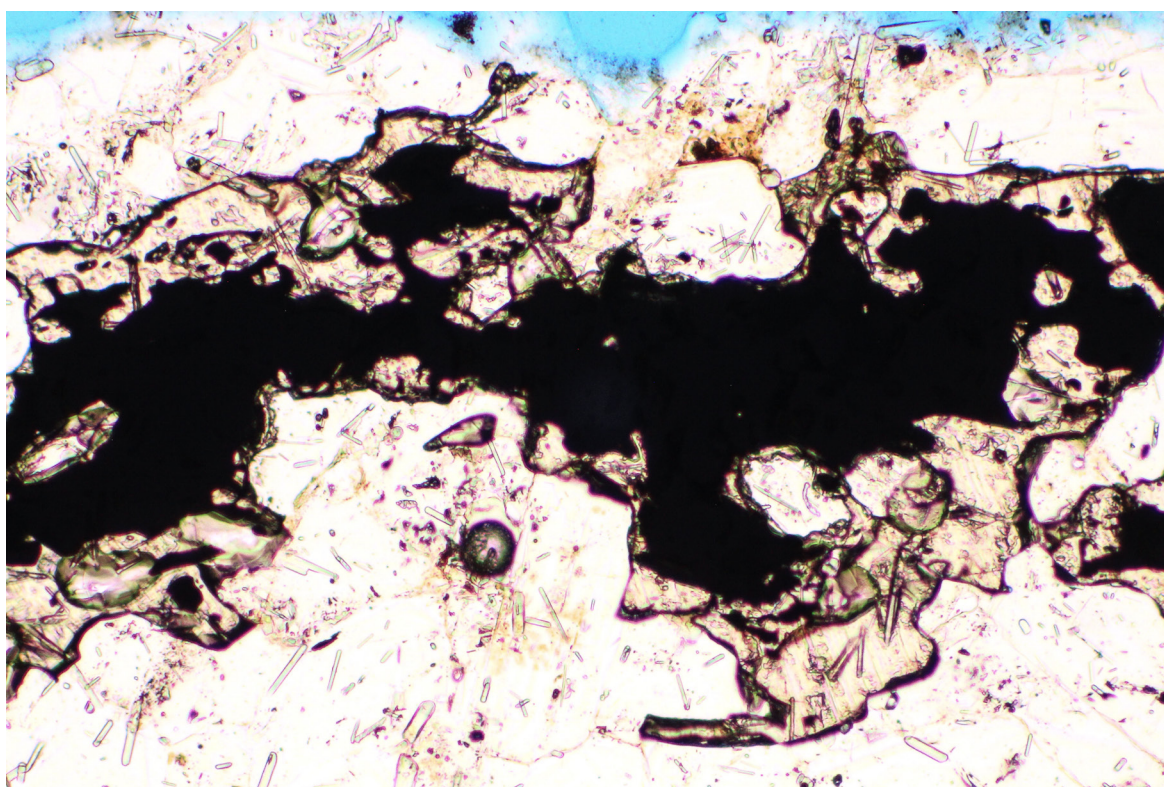
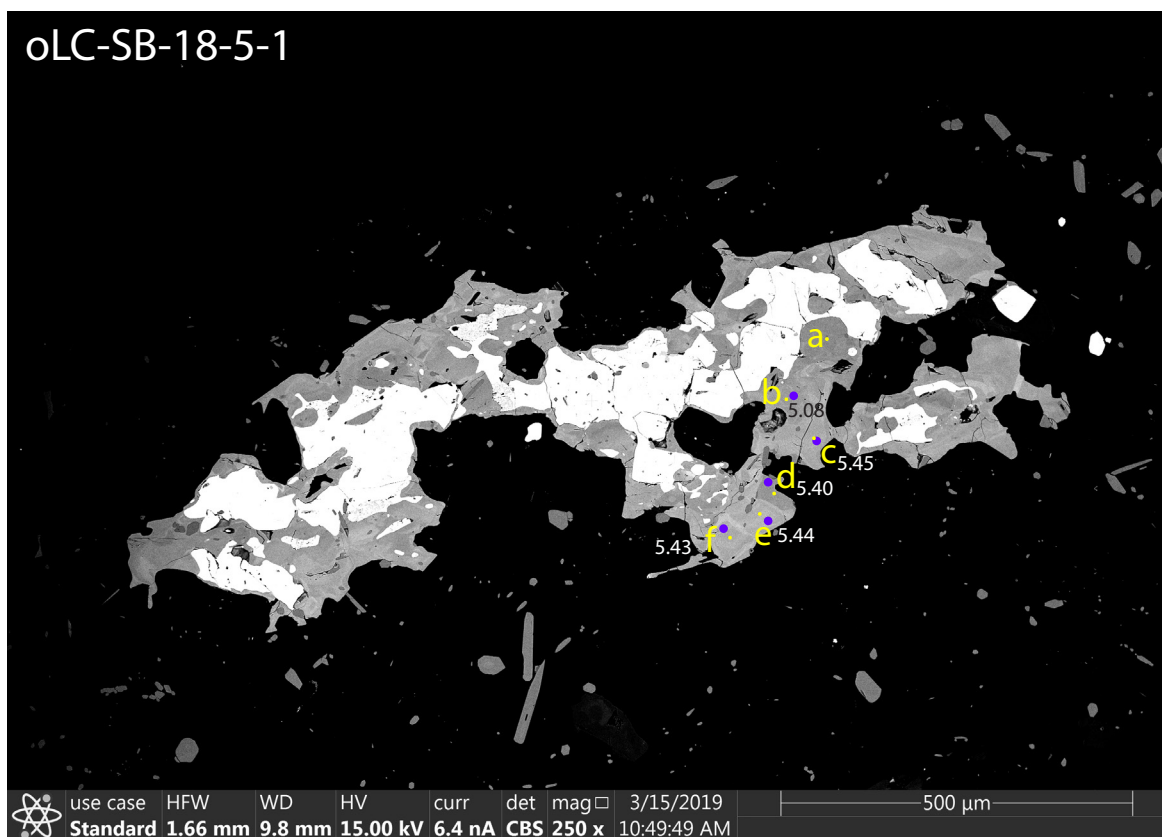


Figure A80. Little Cottonwood enclave titanite grains in oLC-SB-18-5-1 with electron microprobe spots (yellow) and oxygen isotope spots (blue). Plane polarized light photo of part of the image at top. Numbers are $\delta^{18}\text{O}$ ‰ values.

Little Cottonwood enclave grain images — Snow Bird locality (SB)

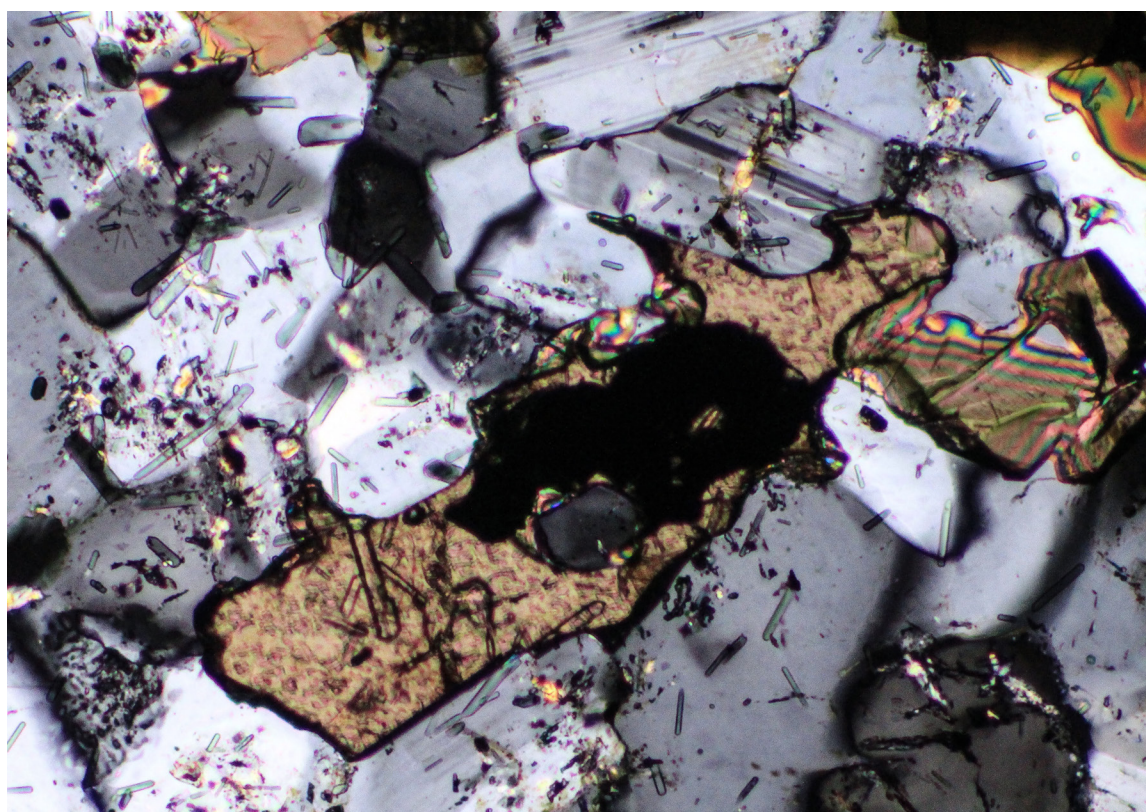
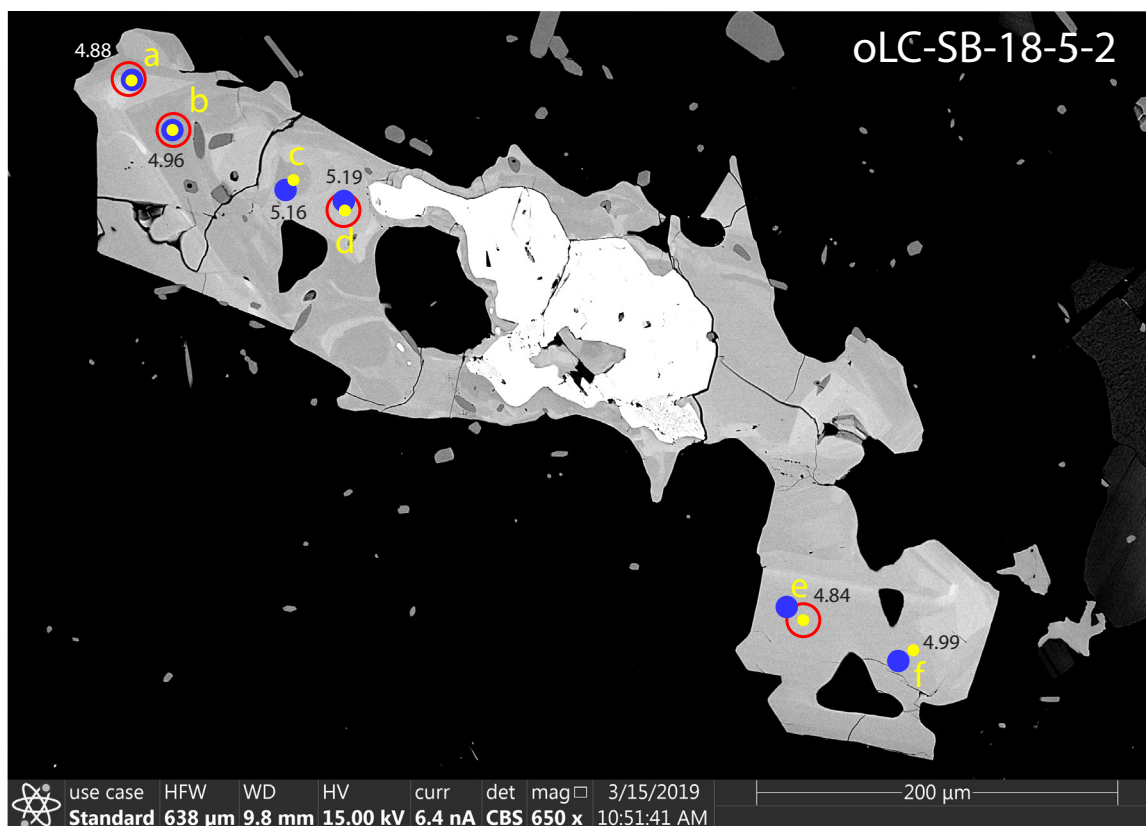


Figure A81. Little Cottonwood enclave titanite grains in oLC-SB-18-5-2 with electron microprobe spots (yellow) and oxygen isotope spots (blue). Cross polarized light photo of the image at top. Numbers are $\delta^{18}\text{O}$ ‰ values.

Little Cottonwood enclave grain images — Snow Bird locality (SB)

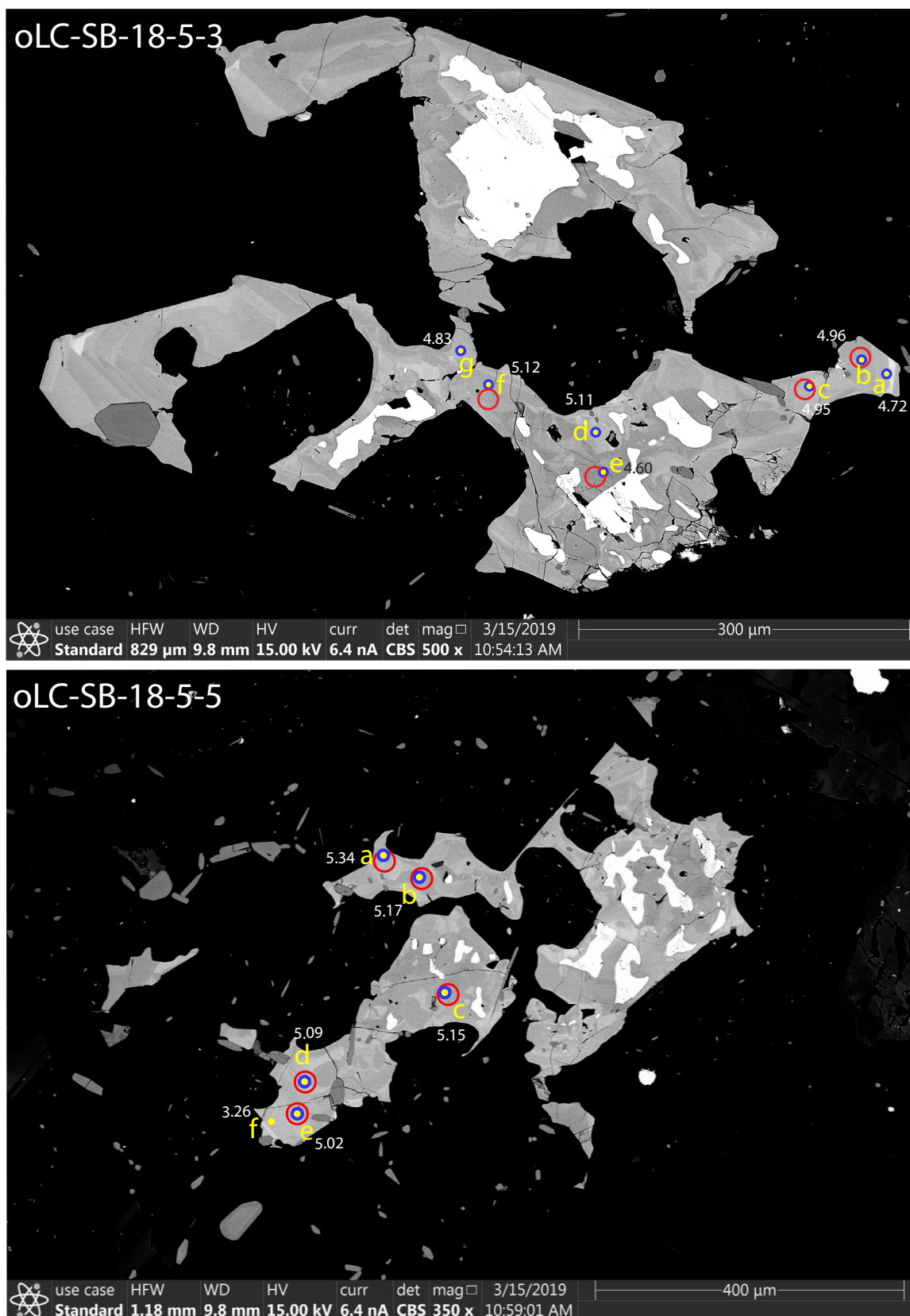


Figure A82. Little Cottonwood enclave titanite grains in oLC-SB-18-5-3 and oLC-SB-18-5-5 with electron microprobe spots (yellow) and oxygen isotope spots (blue). Numbers are $\delta^{18}\text{O}$ ‰ values.