

Supplementary Materials

Table S1. Calculated X-ray powder diffraction data for louisfuchsite ($I_{\text{rel}} > 1$).

| <i>h</i> | <i>k</i> | <i>l</i> | <i>d</i> [Å] | <i>I</i> _{rel} | | | | | |
|-----------|-----------|----------|--------------|-------------------------|----------|-----------|----------|--------------|-----------|
| 0 | 0 | 1 | 8.074 | 14 | -3 | 1 | 1 | 3.263 | 7 |
| 0 | 1 | 0 | 8.069 | 13 | 1 | 0 | 2 | 3.208 | 5 |
| 1 | 0 | 0 | 8.046 | 10 | 2 | -2 | 2 | 3.196 | 10 |
| 0 | -1 | 1 | 7.430 | 3 | -2 | -1 | 1 | 3.193 | 10 |
| -1 | 0 | 1 | 6.967 | 1 | 0 | 1 | 2 | 3.133 | 43 |
| 1 | -1 | 1 | 6.392 | 5 | 0 | 2 | 1 | 3.132 | 43 |
| 2 | -1 | 0 | 5.090 | 1 | 3 | -2 | 1 | 3.078 | 1 |
| 1 | -2 | 1 | 5.084 | 1 | -1 | -2 | 2 | 3.070 | 3 |
| -1 | -1 | 1 | 4.842 | 11 | 2 | -3 | 2 | 3.002 | 2 |
| 0 | 1 | 1 | 4.807 | 20 | -2 | -1 | 2 | 2.999 | 1 |
| 2 | -2 | 0 | 4.656 | 1 | 3 | -3 | 1 | 2.989 | 6 |
| -2 | 1 | 1 | 4.654 | 2 | 1 | 2 | 0 | 2.943 | 7 |
| 0 | -2 | 1 | 4.402 | 1 | 2 | -1 | 2 | 2.942 | 31 |
| -1 | 0 | 2 | 4.209 | 1 | 0 | -1 | 3 | 2.940 | 47 |
| 2 | -2 | 1 | 4.200 | 4 | 2 | 1 | 0 | 2.940 | 30 |
| -2 | 0 | 1 | 4.197 | 7 | 0 | -3 | 1 | 2.938 | 56 |
| 0 | 0 | 2 | 4.037 | 2 | -2 | 2 | 2 | 2.922 | 23 |
| 0 | 2 | 0 | 4.034 | 1 | -2 | 3 | 1 | 2.922 | 21 |
| 2 | -1 | 1 | 4.025 | 2 | -1 | -1 | 3 | 2.889 | 1 |
| 2 | 0 | 0 | 4.023 | 2 | 0 | -2 | 3 | 2.840 | 4 |
| 1 | -2 | 2 | 3.787 | 7 | 0 | -3 | 2 | 2.839 | 3 |
| 0 | -2 | 2 | 3.715 | 10 | -3 | 3 | 1 | 2.813 | 20 |
| 2 | -3 | 0 | 3.443 | 36 | -1 | 2 | 2 | 2.777 | 18 |
| -2 | 1 | 2 | 3.442 | 33 | 3 | -1 | 1 | 2.775 | 34 |
| 3 | -2 | 0 | 3.433 | 6 | -3 | 2 | 2 | 2.717 | 14 |
| 1 | 1 | 1 | 3.367 | 3 | 0 | 0 | 3 | 2.691 | 6 |
| | | | | | 0 | 3 | 0 | 2.690 | 6 |
| | | | | | 2 | -4 | 1 | 2.685 | 56 |

| | | | | | | | | | | |
|-----------|-----------|----------|--------------|------------|--|-----------|-----------|----------|--------------|-----------|
| -2 | 0 | 3 | 2.685 | 65 | | -3 | -1 | 1 | 2.329 | 4 |
| -1 | 3 | 1 | 2.684 | 15 | | 4 | -4 | 0 | 2.328 | 5 |
| 3 | 0 | 0 | 2.682 | 18 | | -4 | 2 | 2 | 2.327 | 1 |
| -3 | 0 | 2 | 2.679 | 4 | | 4 | -2 | 1 | 2.323 | 7 |
| 1 | -1 | 3 | 2.650 | 8 | | 4 | -1 | 0 | 2.322 | 7 |
| 1 | -3 | 3 | 2.571 | 4 | | -4 | 1 | 2 | 2.291 | 1 |
| -2 | 1 | 3 | 2.554 | 16 | | 0 | 1 | 3 | 2.287 | 1 |
| 2 | -4 | 0 | 2.554 | 14 | | -2 | 2 | 3 | 2.244 | 2 |
| 3 | -4 | 0 | 2.552 | 11 | | -2 | 4 | 1 | 2.244 | 3 |
| 4 | -2 | 0 | 2.545 | 100 | | 2 | -1 | 3 | 2.236 | 1 |
| 2 | -4 | 2 | 2.542 | 79 | | 2 | 2 | 0 | 2.234 | 2 |
| -2 | -1 | 3 | 2.541 | 72 | | 2 | -4 | 3 | 2.228 | 4 |
| -1 | 1 | 3 | 2.525 | 11 | | -2 | -2 | 3 | 2.226 | 4 |
| 3 | -2 | 2 | 2.524 | 9 | | -1 | -3 | 3 | 2.205 | 2 |
| 1 | 1 | 2 | 2.524 | 1 | | 0 | -2 | 4 | 2.202 | 4 |
| 0 | -3 | 3 | 2.477 | 9 | | 0 | -4 | 2 | 2.201 | 5 |
| 2 | 0 | 2 | 2.470 | 20 | | -4 | 4 | 1 | 2.185 | 1 |
| 2 | 1 | 1 | 2.469 | 18 | | -4 | 3 | 2 | 2.185 | 1 |
| 1 | 2 | 1 | 2.453 | 1 | | 0 | -1 | 4 | 2.180 | 7 |
| -4 | 3 | 1 | 2.451 | 2 | | 0 | -4 | 1 | 2.178 | 6 |
| 2 | -2 | 3 | 2.427 | 28 | | 3 | -5 | 1 | 2.147 | 7 |
| -2 | -2 | 1 | 2.424 | 31 | | -1 | -2 | 4 | 2.135 | 1 |
| 2 | -3 | 3 | 2.423 | 2 | | -1 | 0 | 4 | 2.131 | 5 |
| -2 | -2 | 2 | 2.421 | 3 | | 3 | -3 | 3 | 2.131 | 2 |
| -4 | 1 | 1 | 2.407 | 1 | | -3 | -1 | 3 | 2.128 | 1 |
| 0 | 2 | 2 | 2.403 | 4 | | 4 | -3 | 2 | 2.125 | 4 |
| 3 | -4 | 2 | 2.388 | 2 | | -4 | 0 | 1 | 2.123 | 3 |
| -1 | -3 | 1 | 2.364 | 4 | | 1 | -2 | 4 | 2.113 | 1 |
| -3 | 1 | 3 | 2.352 | 9 | | -2 | 0 | 4 | 2.105 | 83 |
| 1 | -4 | 0 | 2.331 | 6 | | 2 | -5 | 1 | 2.104 | 83 |

| | | | | |
|----------|-----------|----------|--------------|-----------|
| 4 | -4 | 2 | 2.100 | 11 |
| -4 | 0 | 2 | 2.099 | 8 |
| 4 | -1 | 1 | 2.090 | 88 |
| 3 | -4 | 3 | 2.075 | 1 |
| 0 | -3 | 4 | 2.073 | 4 |
| 0 | -4 | 3 | 2.073 | 4 |
| -5 | 3 | 1 | 2.052 | 2 |
| 4 | -5 | 1 | 2.046 | 3 |
| -5 | 2 | 1 | 2.022 | 1 |
| 0 | 0 | 4 | 2.018 | 2 |
| 0 | 4 | 0 | 2.017 | 2 |
| 4 | -2 | 2 | 2.012 | 4 |
| 4 | 0 | 0 | 2.011 | 2 |
| 1 | 2 | 2 | 2.010 | 1 |
| -2 | 1 | 4 | 1.988 | 18 |
| 2 | -5 | 0 | 1.988 | 16 |

Figure SF1. (a,c) Backscattered electron (BSE) and (b) secondary electron (SE) images of O-isotope SIMS spots 1–3 in louisfuchsite (lft) grain 1 in the CTA CAI #1 from NWA 4964 (CK3.8).

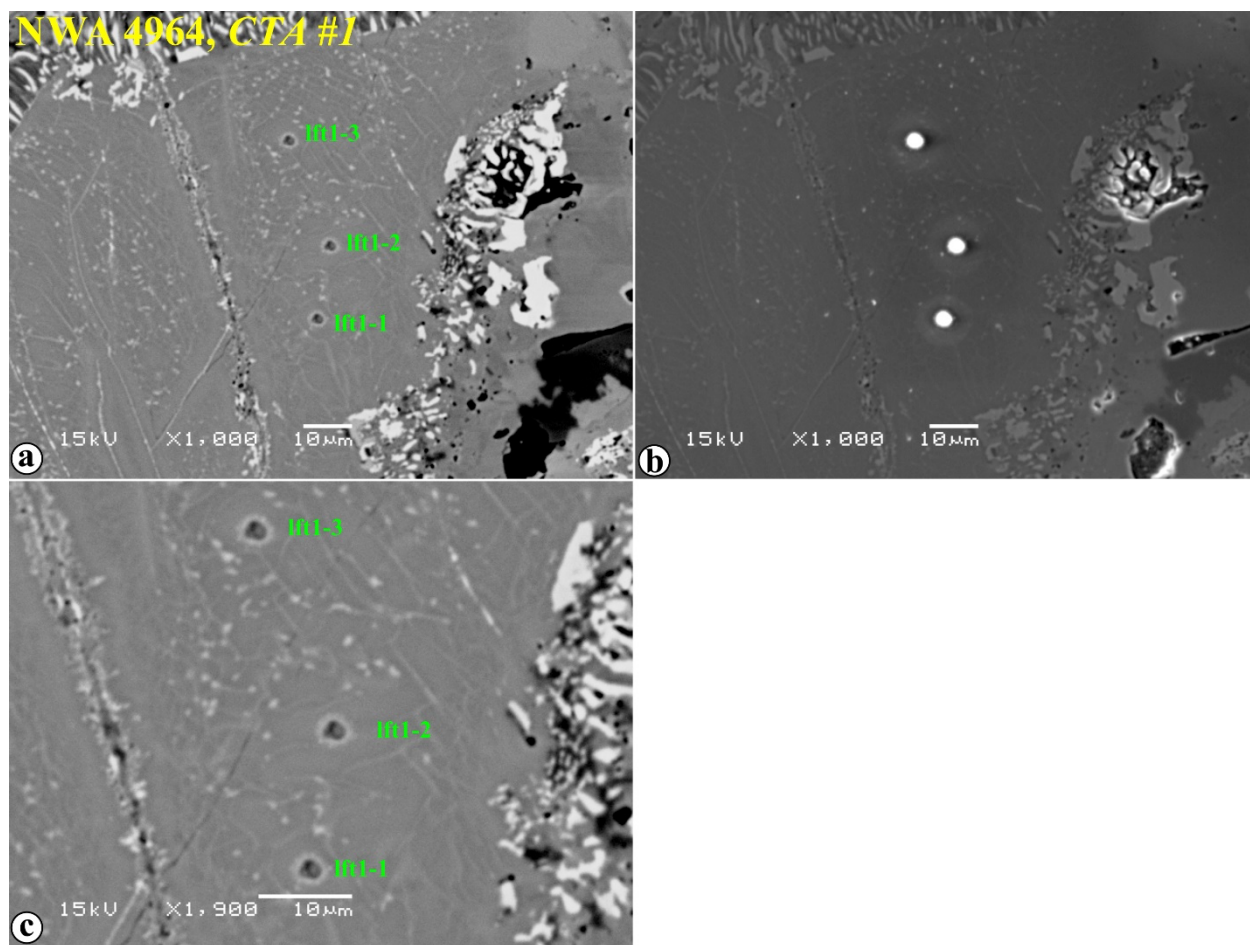


Figure SF2. (a,c,e) BSE and (b,d,f) SE images of O-isotope SIMS spots 1–4 in louisfuchsite (lft) grain 2, spots 3–4 in secondary olivine (ol), spots 19–20 in secondary grossular (grl), and spots 6–11 in secondary Al-diopside (px) in the CTA CAI #1 from NWA 4964 (CK3.8).

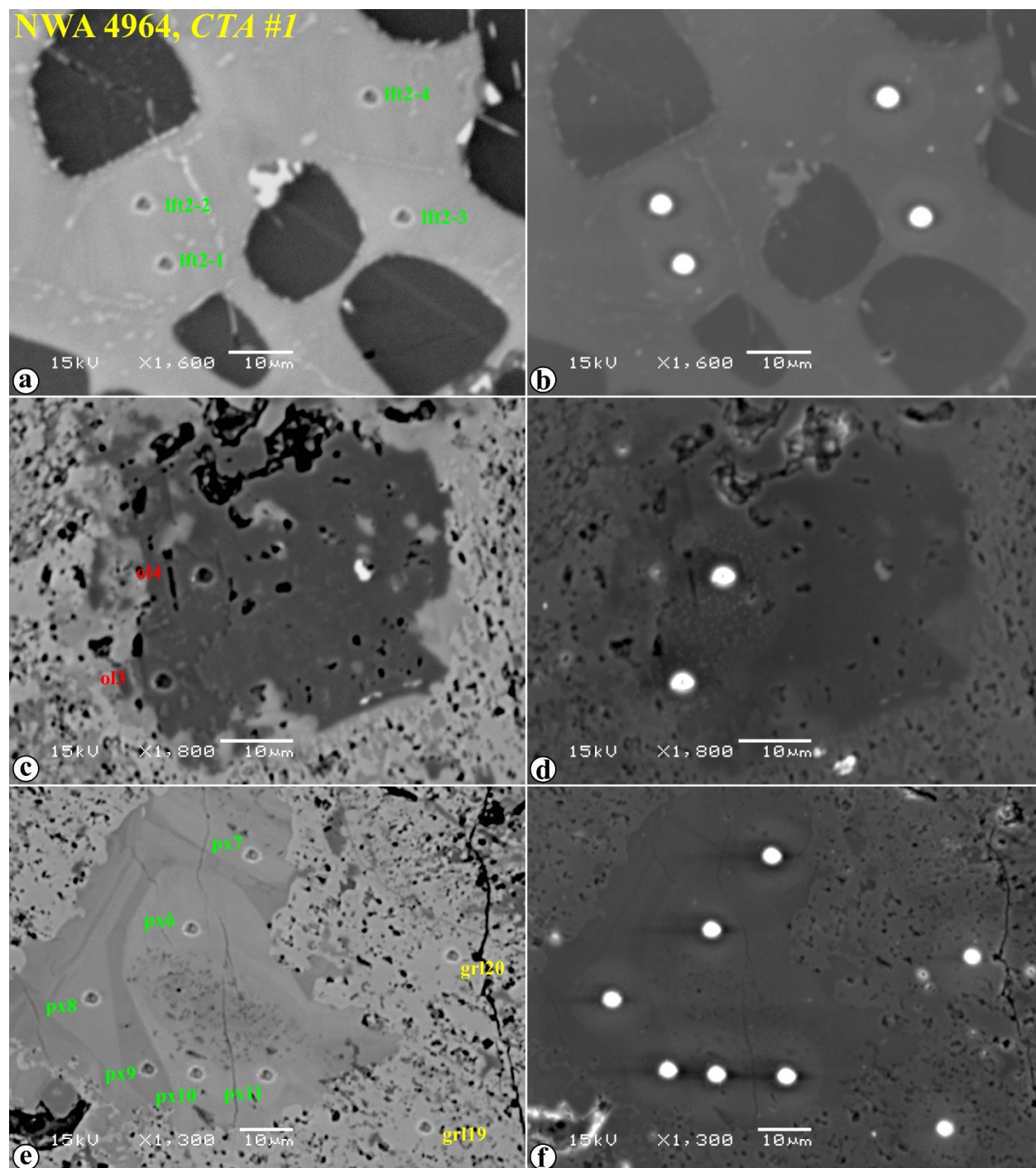


Figure SF3. (a,c,e) BSE and (b,d,f) SE images of O-isotope SIMS spots 4–8 in hibonite (hib), spots 1–3 in melilite (mel), and spots 1–5 in secondary Al-diopside (px) in the CTA CAI #1 from NWA 4964 (CK3.8).

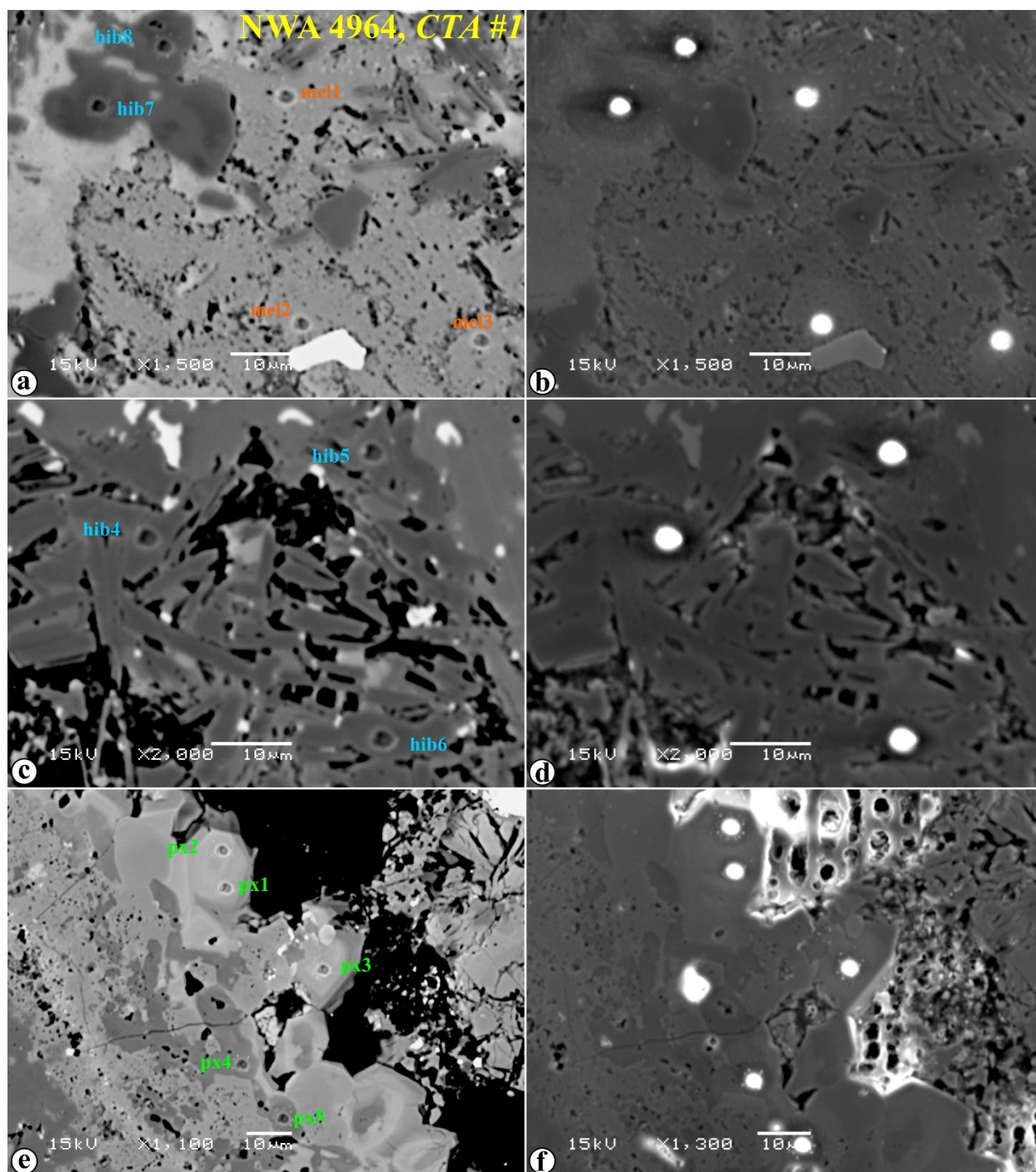


Figure SF4. (a,c,e) BSE and (b,d,f) SE images of O-isotope SIMS spots 1–6, 10–18 in secondary grossular (grl) and spots 28–31 in secondary Al-diopside (px) in the CTA CAI #1 from NWA 4964 (CK3.8).

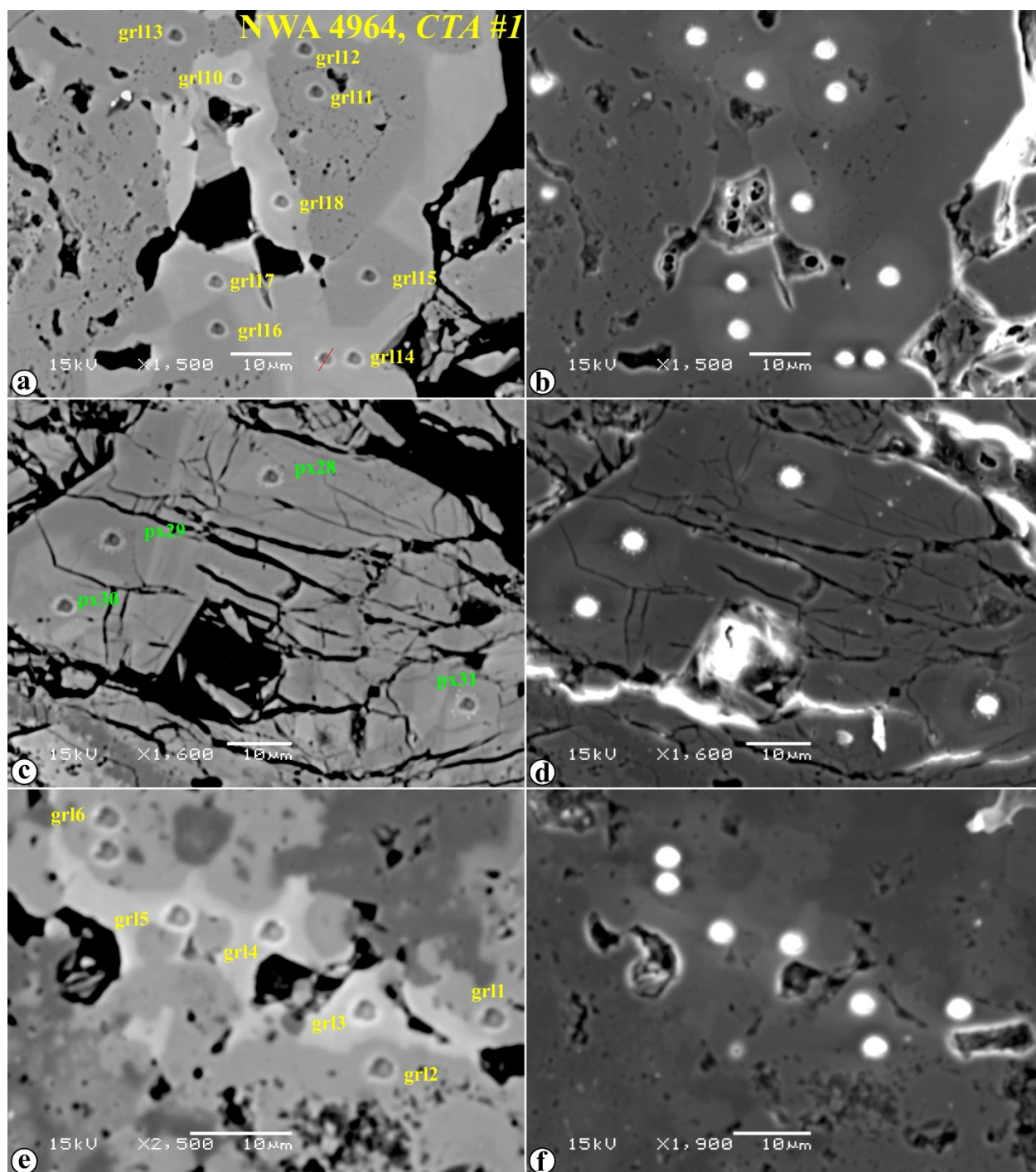


Figure SF5. (a,c,e) BSE and (b,d,f) SE images of O-isotope SIMS spots 7–9 in secondary grossular (grl) and spots 20–27 in secondary Al-diopside (px) in the CTA CAI #1 from NWA 4964 (CK3.8).

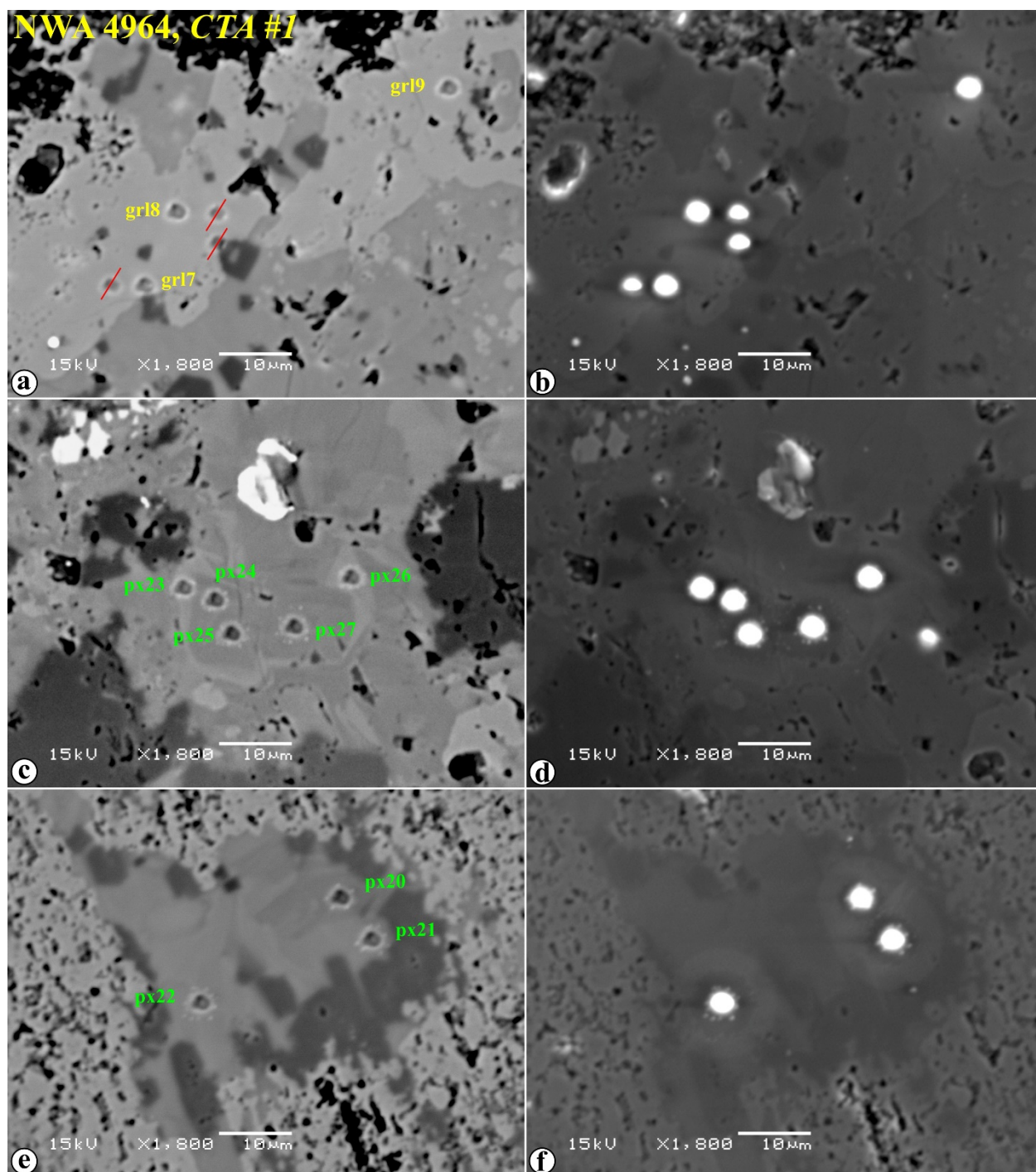


Figure SF6. (a,c,e) BSE and (b,d,f) SE images of O-isotope SIMS spots 12–19 in secondary Al-diopside (px) in the CTA CAI #1 from NWA 4964 (CK3.8).

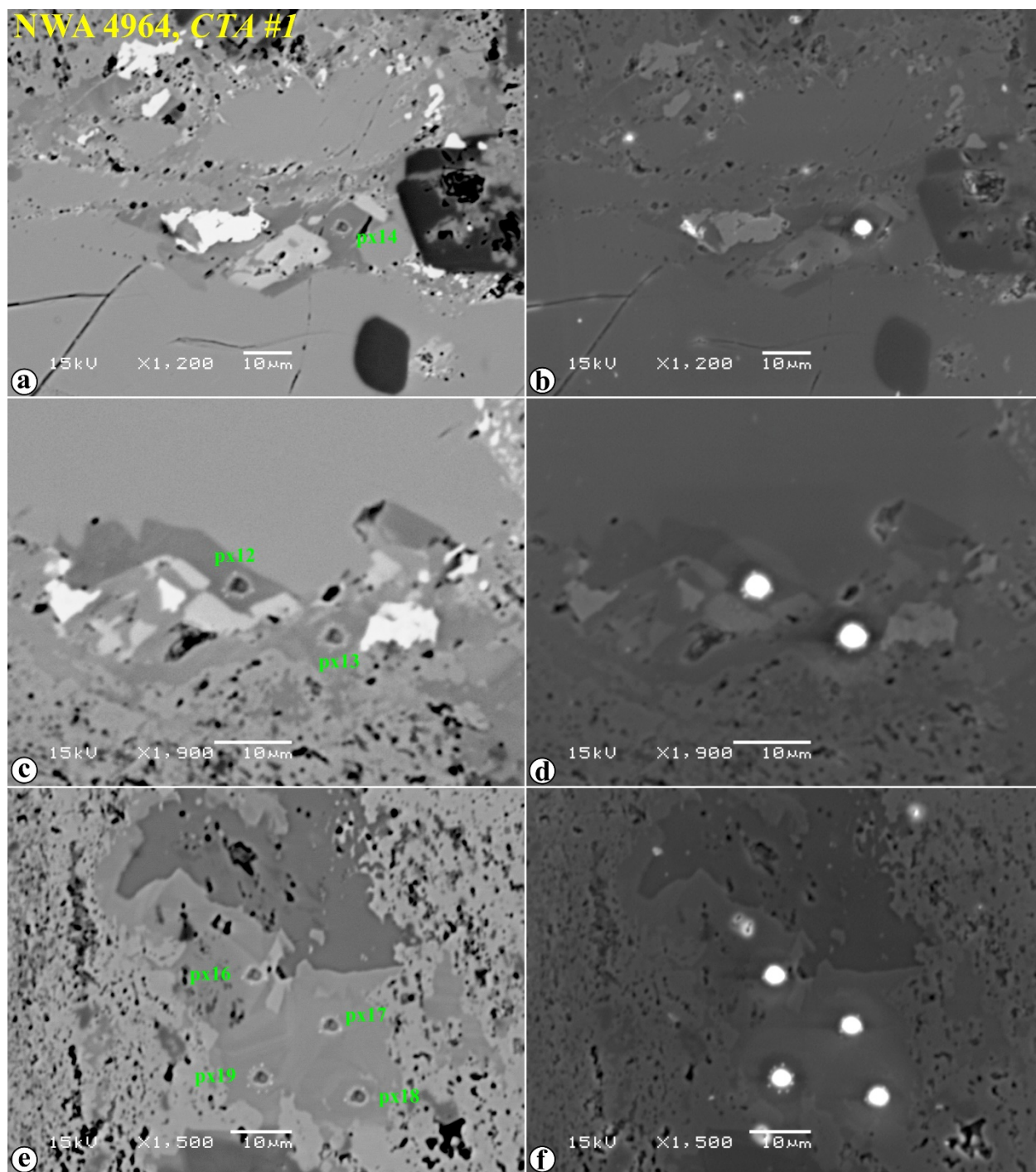


Figure SF7. (a,c) BSE and (c) SE (b) images of O-isotope SIMS spot 1-1 in grossmanite inclusion in a spinel (sp) grain enclosed by louisfuchsite (lft) in the CTA CAI #1 from NWA 4964 (CK3.8).

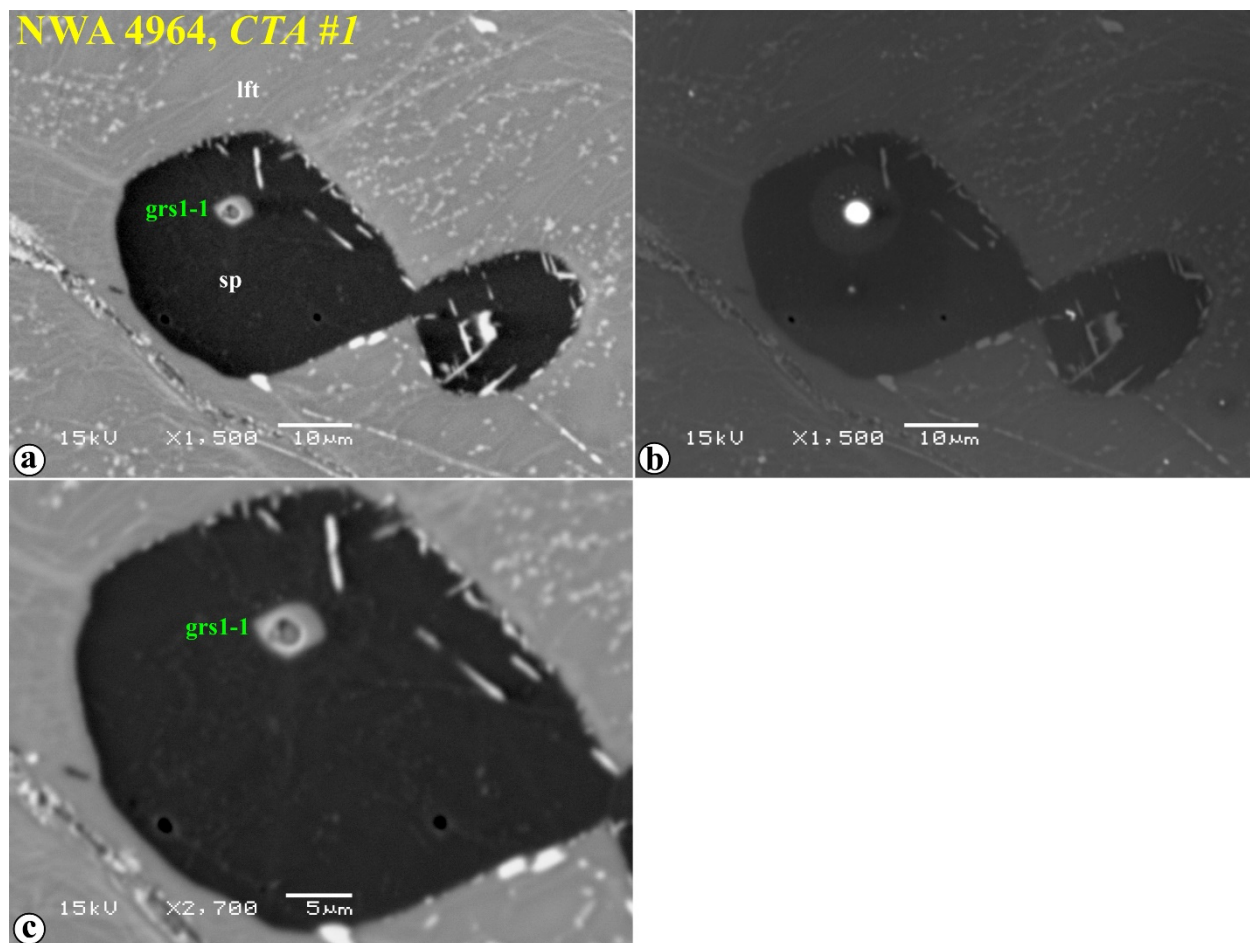


Figure SF8. (a,c) BSE and (b,d) SE images of O-isotope SIMS spot 1 in AlTi-diopside (fas) inclusion in perovskite and spot 15 in secondary Al-diopside (px) in the CTA CAI #1 from NWA 4964 (CK3.8).

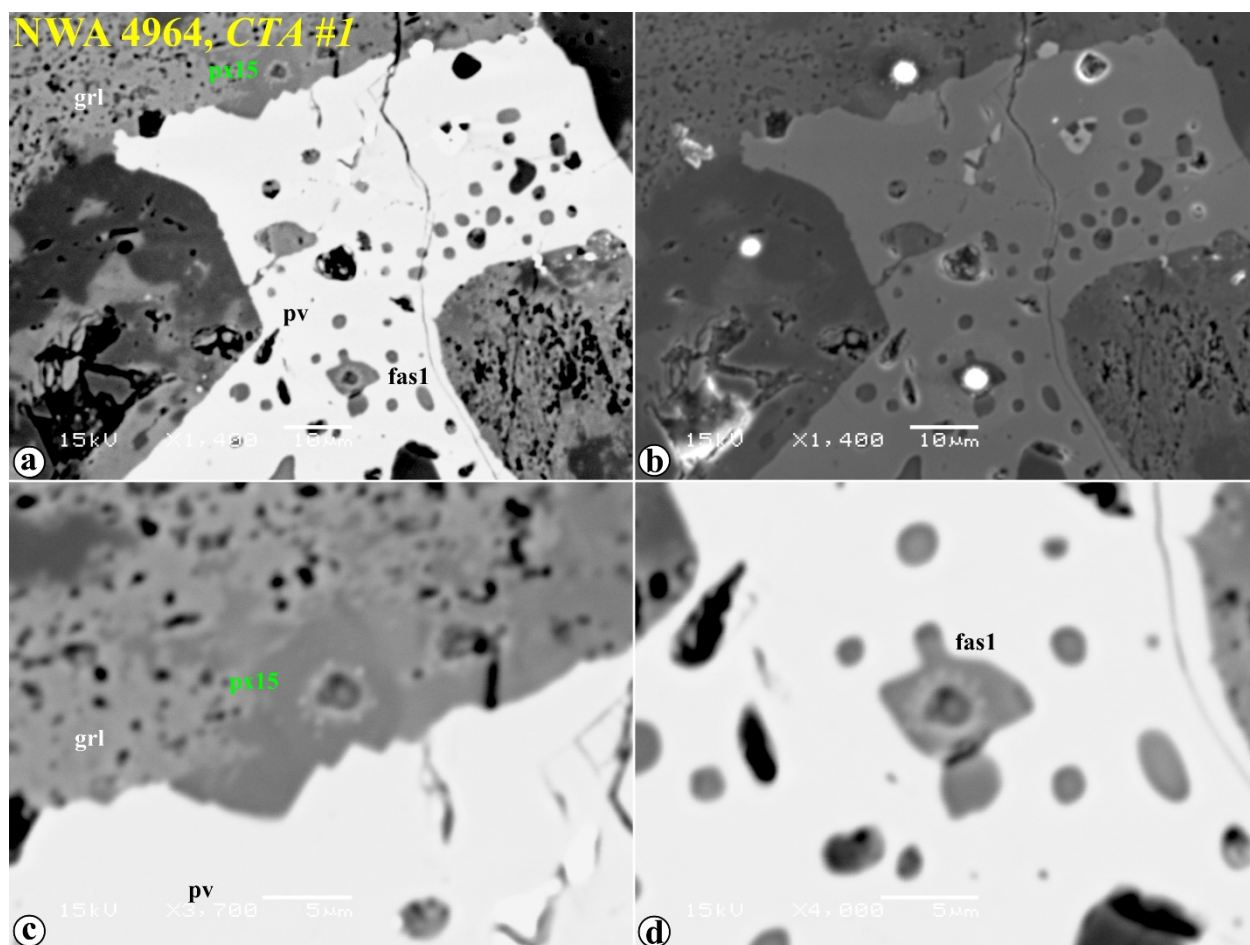


Figure SF9. (a,c,e) BSE and (b,d,f) SE images of O-isotope SIMS spots 1–3 in hibonite (hib) and spots 1–2 in secondary olivine (ol) in the CTA CAI #1 from NWA 4964 (CK3.8).

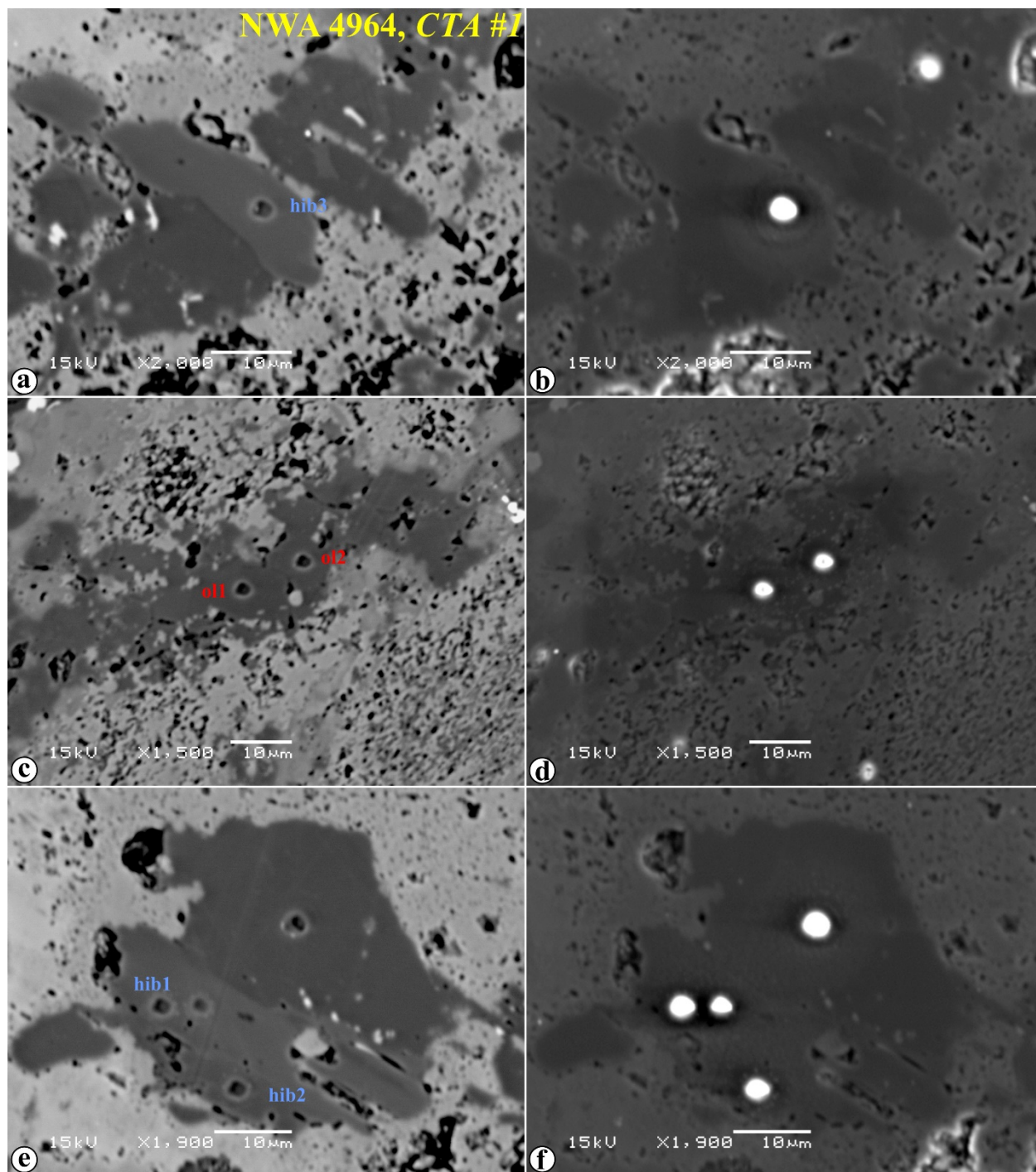


Figure SF10. (a,c,d) BSE and (b,e) SE images of O-isotope SIMS spots 1–4 in perovskite (pv) in the CTA CAI #1 from NWA 4964 (CK3.8).

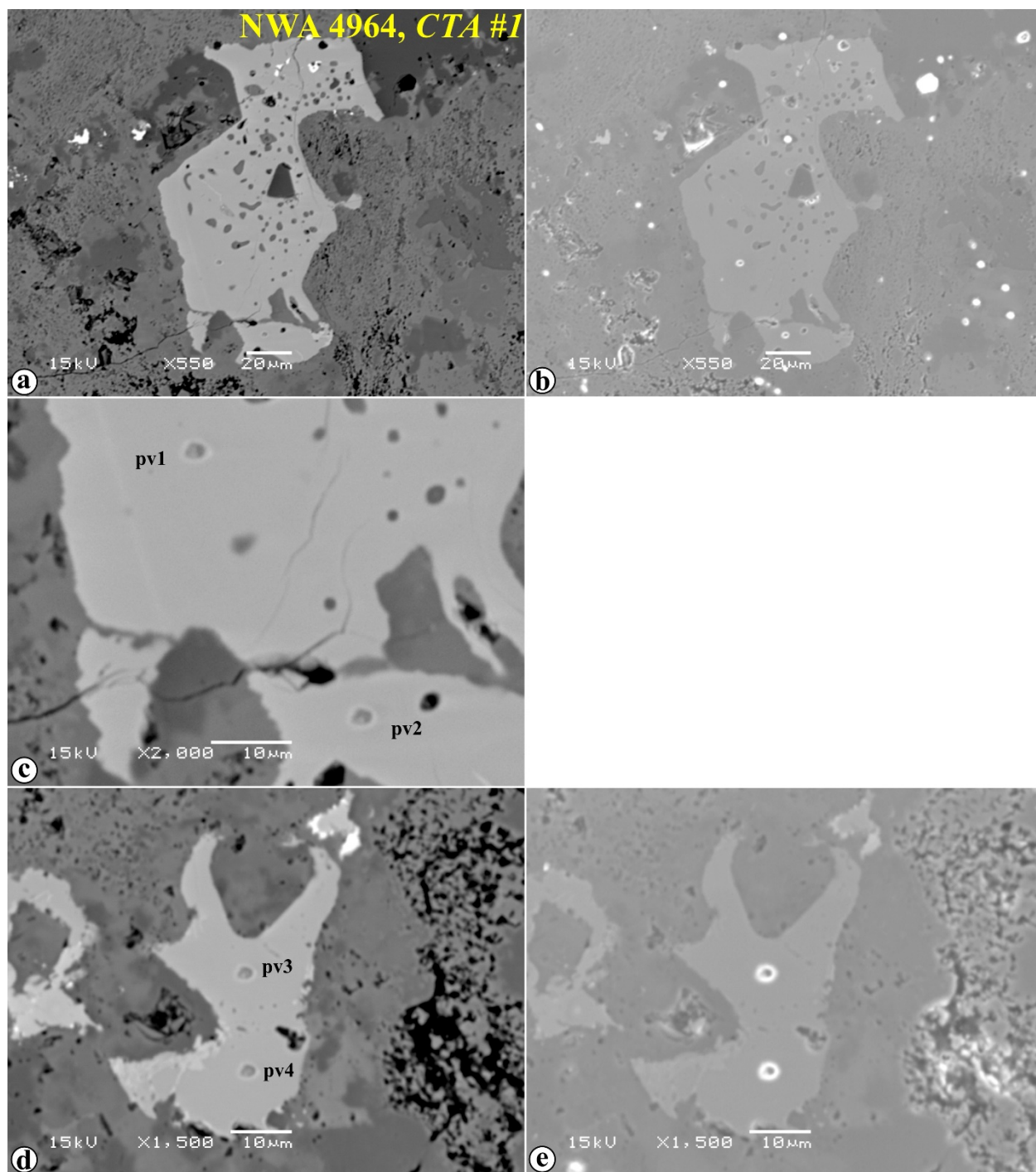


Figure SF11. (a,c,d) BSE and (b,e) SE images of O-isotope SIMS spots 1–7, 14–18 in grossmanite (grs), spots 1–3 and 6–8 in spinel (sp), and spots 1–8–1–10 in secondary Al-diopside (px) in the CTA CAI #1 from NWA 4964 (CK3.8).

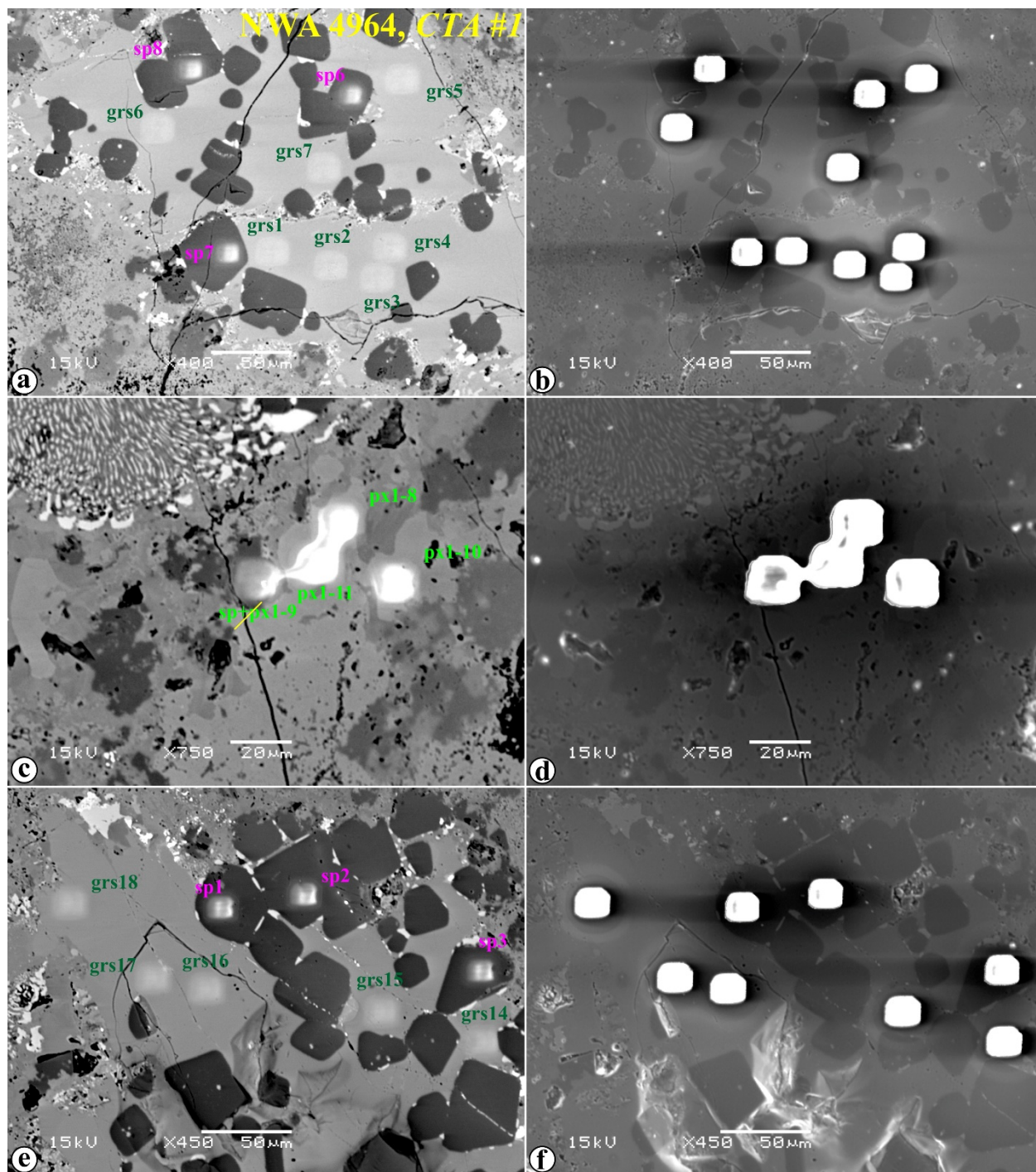


Figure SF12. (a,c,d) BSE and (b,e) SE images of O-isotope SIMS spots 12 and 13 in louisfuchsite (lft) grain 1 and spots 4, 5, 9 in spinel (sp) in the CTA CAI #1 from NWA 4964 (CK3.8).

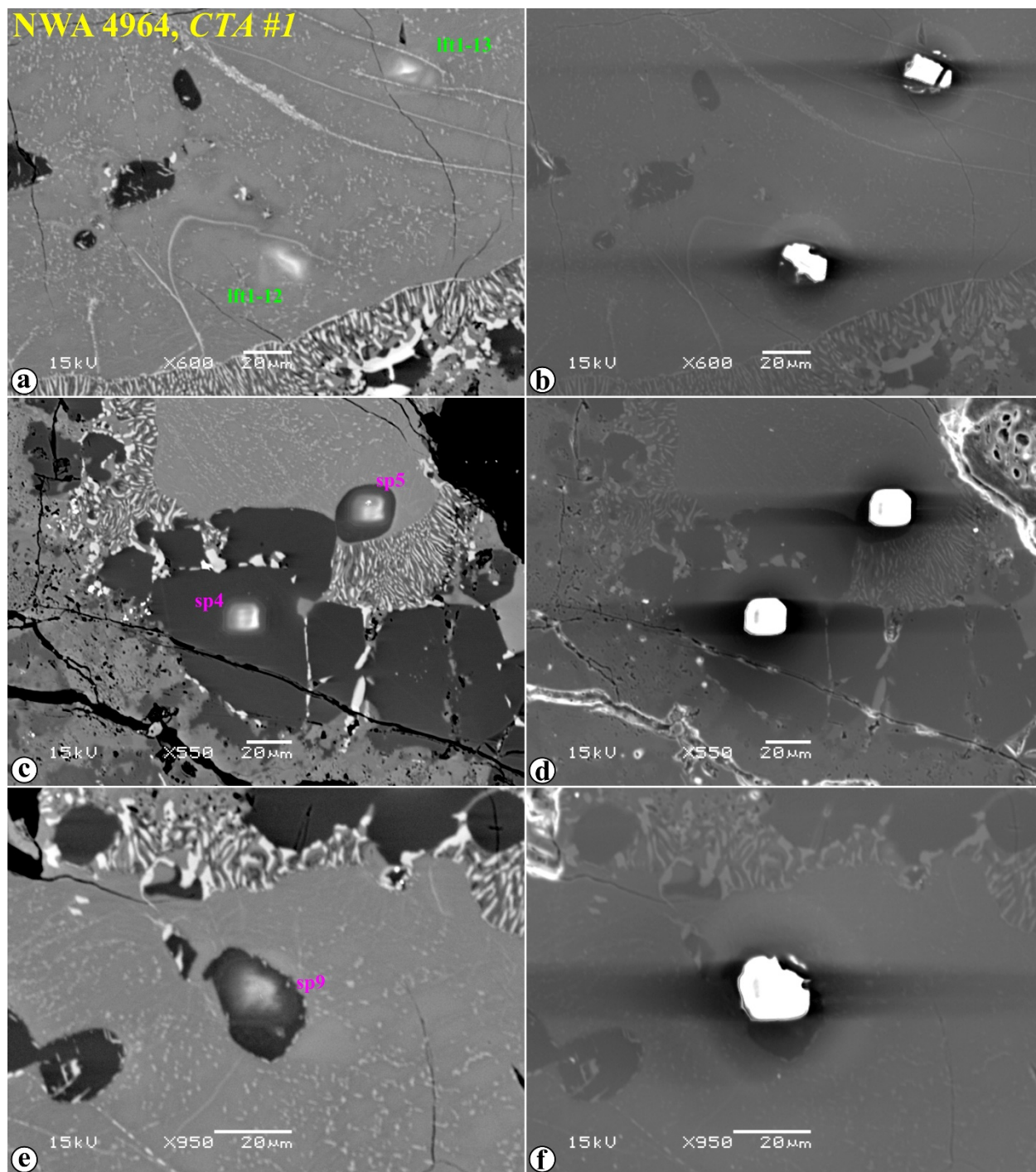


Figure SF13. (a) BSE and (b) SE images of O-isotope SIMS spots 1-1 and 1-2 in secondary olivine (ol) and spots 1 in secondary plagioclase (an) in the CTA CAI #1 from NWA 4964 (CK3.8).

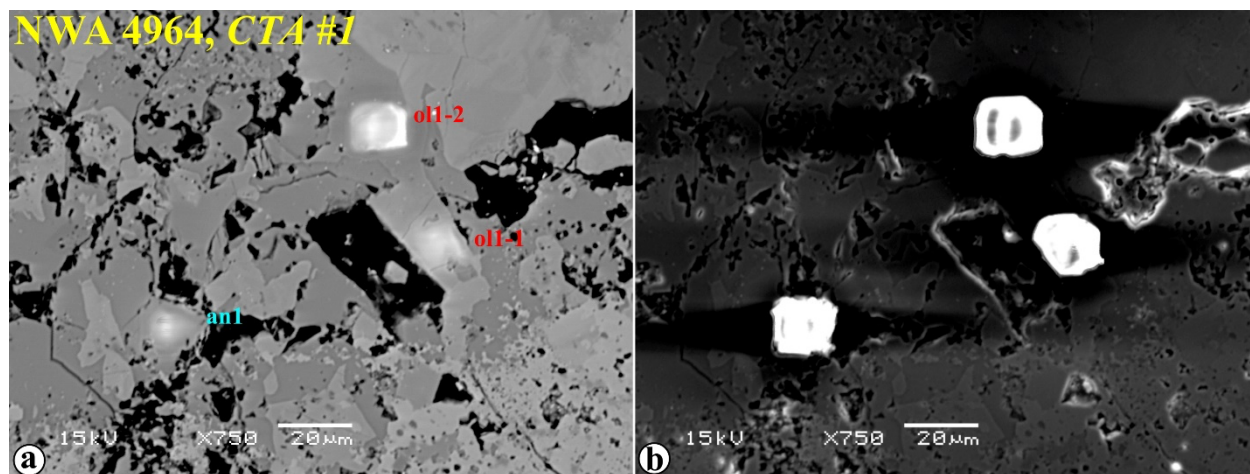


Figure SF14. BSE images of Al-Mg isotope SIMS spots 1–7 in grossmanite (grs) and spots 1–4 in spinel (sp) in the CTA CAI #1 from NWA 4964 (CK3.8).

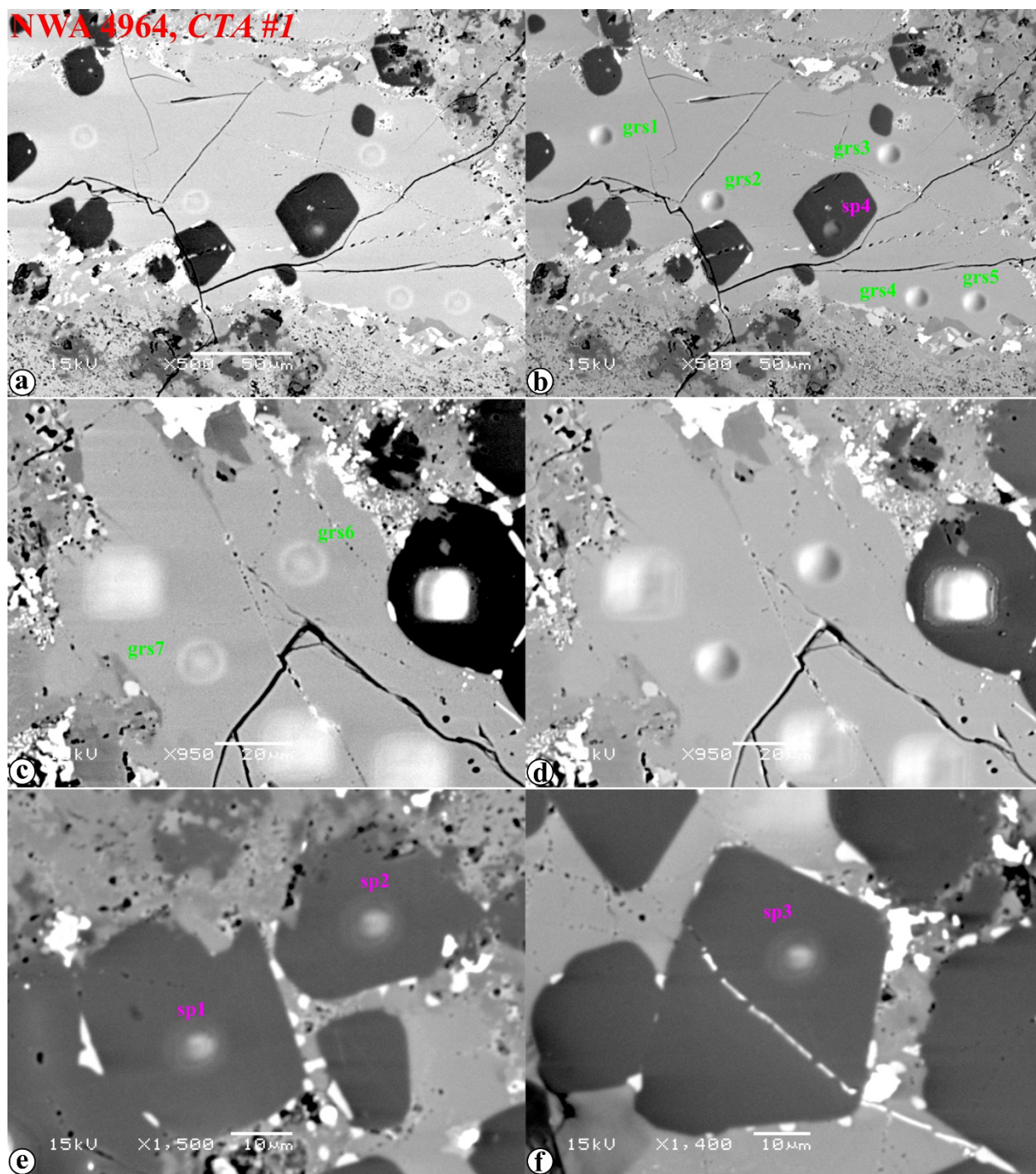


Figure SF15. BSE images of Al-Mg isotope SIMS spots 4–7 in spinel (sp) in the CTA CAI #1 from NWA 4964 (CK3.8).

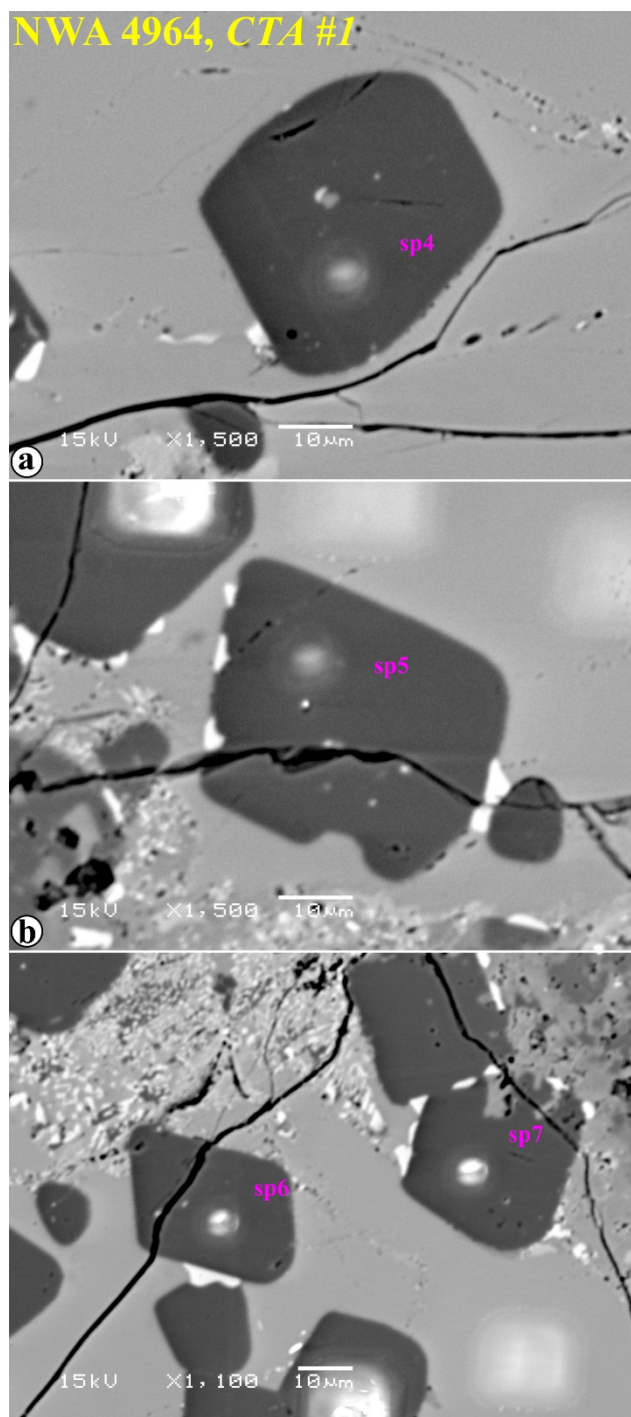


Figure SF16. BSE images of Al-Mg isotope SIMS spots 1–7 in hibonite (hib) and spots 1–2 in melilite (mel) in the CTA CAI #1 from NWA 4964 (CK3.8).

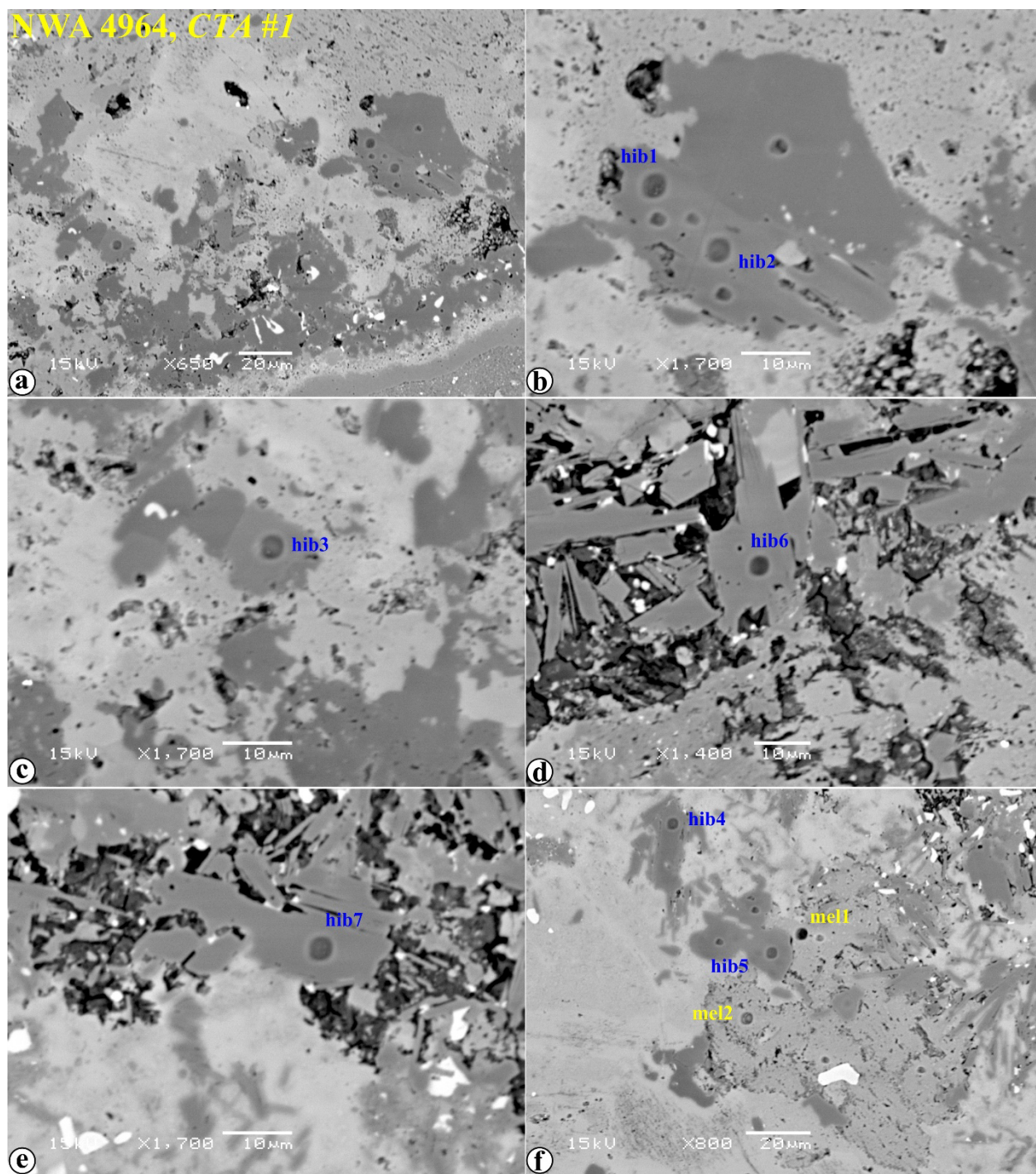


Figure SF16 (cont.).

