

Supplementary Material

Shock-induced microtextures in lunar apatite and merrillite

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Table A1. Overview of electron backscatter diffraction (EBSD) instrument and analytical conditions.

Instrumentation	
Host Institute	Portsmouth University
SEM Model	Zeiss EVO MA 10 (LaB ₆ electron source)
EBSD System	Oxford Instrument Nordlys-Nano EBSD detector
EBSD Software	Oxford Instruments AZTEC
SEM settings	
Carbon coat (<5nm)	No
Acc. Voltage (kV)	20
Working distance (mm)	14 to 20
Probe current (nA)	1
Tilt (°)	70
EBSD data collection and processing	
EBSP* collection time per frame (ms)	< 120
Background (frames)	64
EBSP noise reduction (frames)	5
EBSP noise reduction (binning)	2x2
EBSP noise reduction (gain)	High
Hough resolution	70-75
Band detection min/max	10 to 12
Step size (nm)	100 to 200
Noise reduction	wildspike and zero solution

*Electron Backscatter Diffraction Pattern

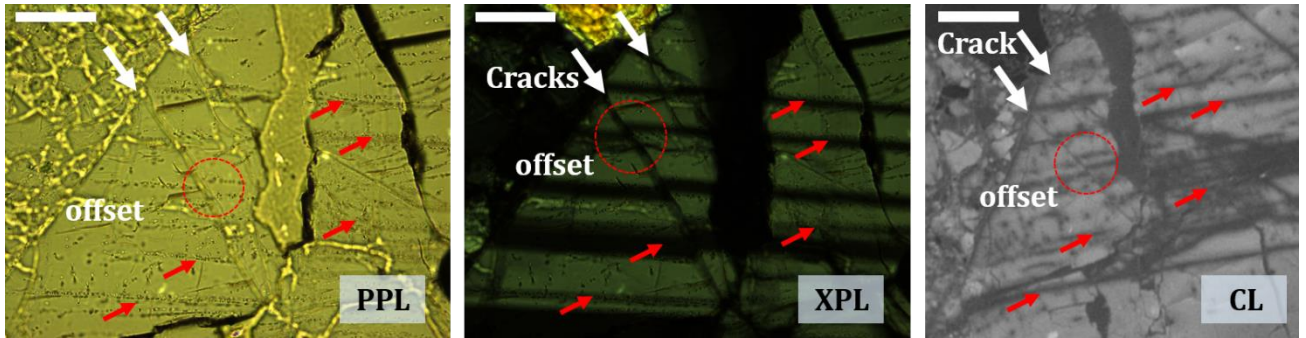
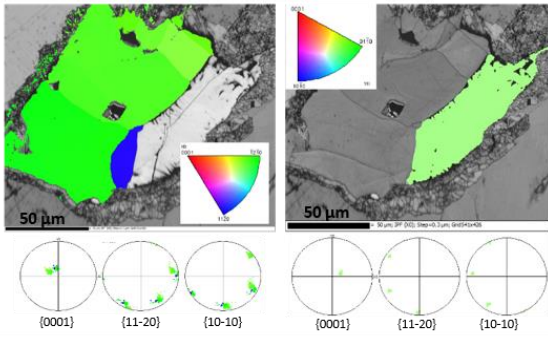
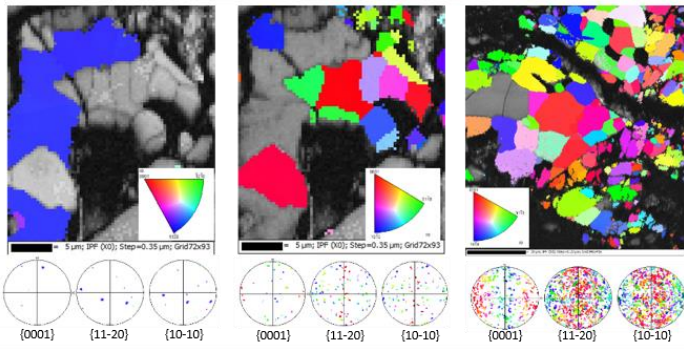


Figure A1. Plane polarized, crossed-polarized and CL image of a twinned plagioclase in 76335,60 containing inclusions. Scale bar is 50 μm . White arrows indicate mechanical cracks that offsets the twins, but do not activate CL. Red circle highlights an offset that is easily recognizable in all three images. Red arrows indicate inclusions, aligned alongside the twinning plane. In general, CL signal is suppressed in areas with large number of inclusions.

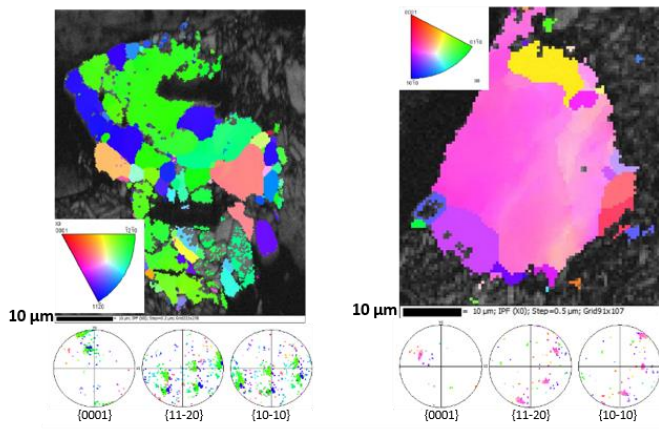
S1 Sample 76535,51



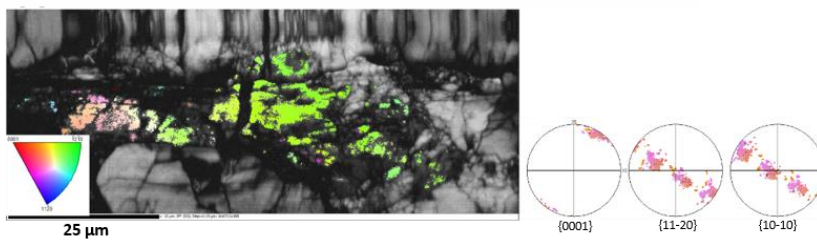
S2 Sample 76335,60



S3-S4 Sample 72255,100



S5 Sample 78236,22



S5 Sample 78236,22

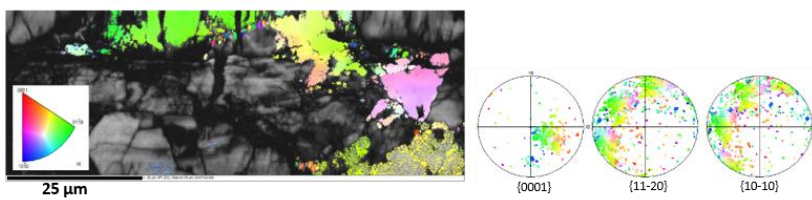


Figure A2. Inverse Pole Figures (IPF) and corresponding pole figures of all apatites and merrillites from S1 to S5, presented in the main text (Figures 3 and 4).

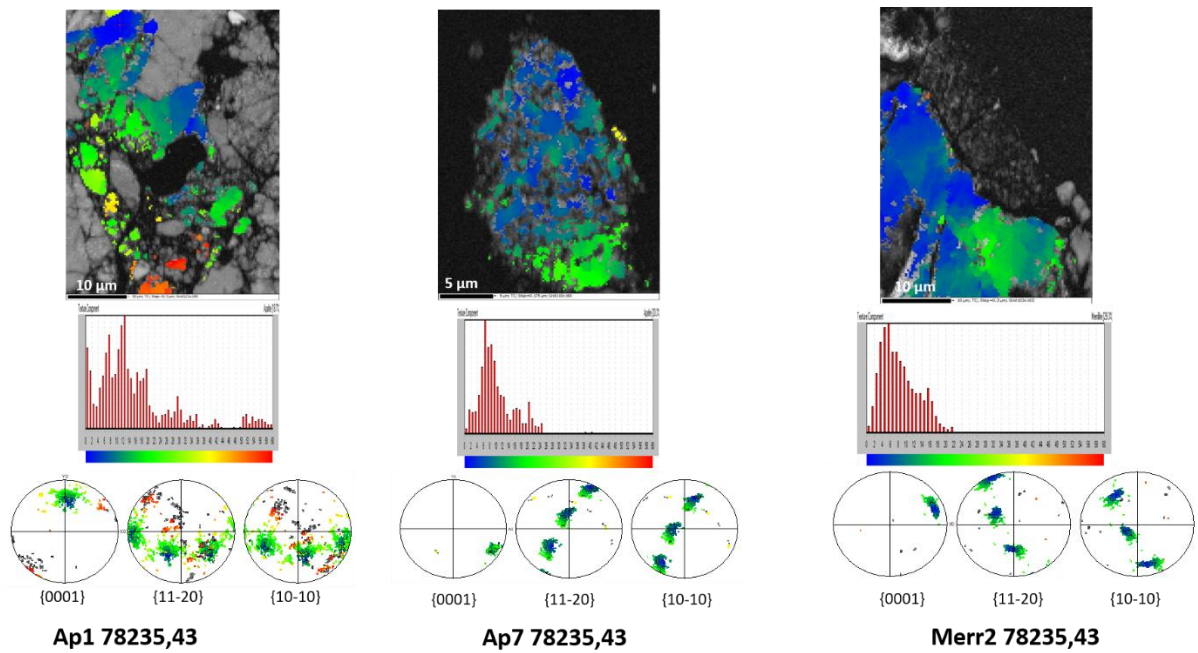


Figure A3. Other examples of highly (S5) shocked apatite (Ap1 and Ap7) and merrillite (Merr2) from sample 78235,43. Severity of CPD as evident from the TC maps is similar to that presented in the main text, $\sim 25^\circ$ grain misorientation for apatite and $\sim 30^\circ$ for merrillite.

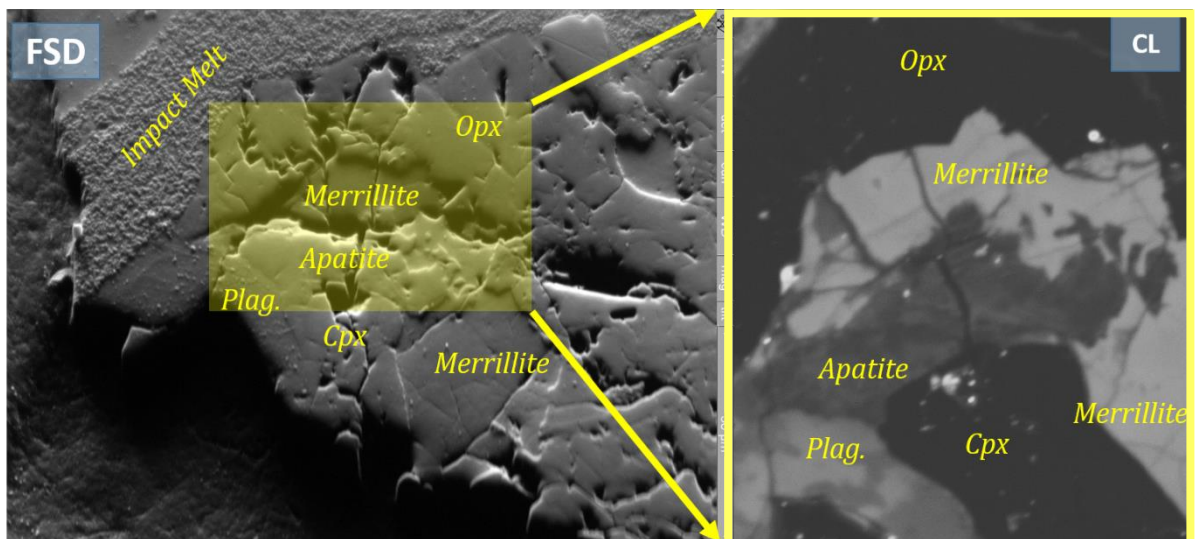


Figure A4. Forward scatter diffraction (FSD) image of the area including S5 deformed apatite and merrillite (76236,22), presented in the main text (Fig. 4). FSD image enhances surface features, displaying low relief of the two phosphates in contrast to the silicate minerals, and shows particularly well developed rough surface of the melted plagioclase glass. CL image highlight the difference between the apatite and the merrillite grain. Apatite CL response indicates internal complexity of the crystal lattice.

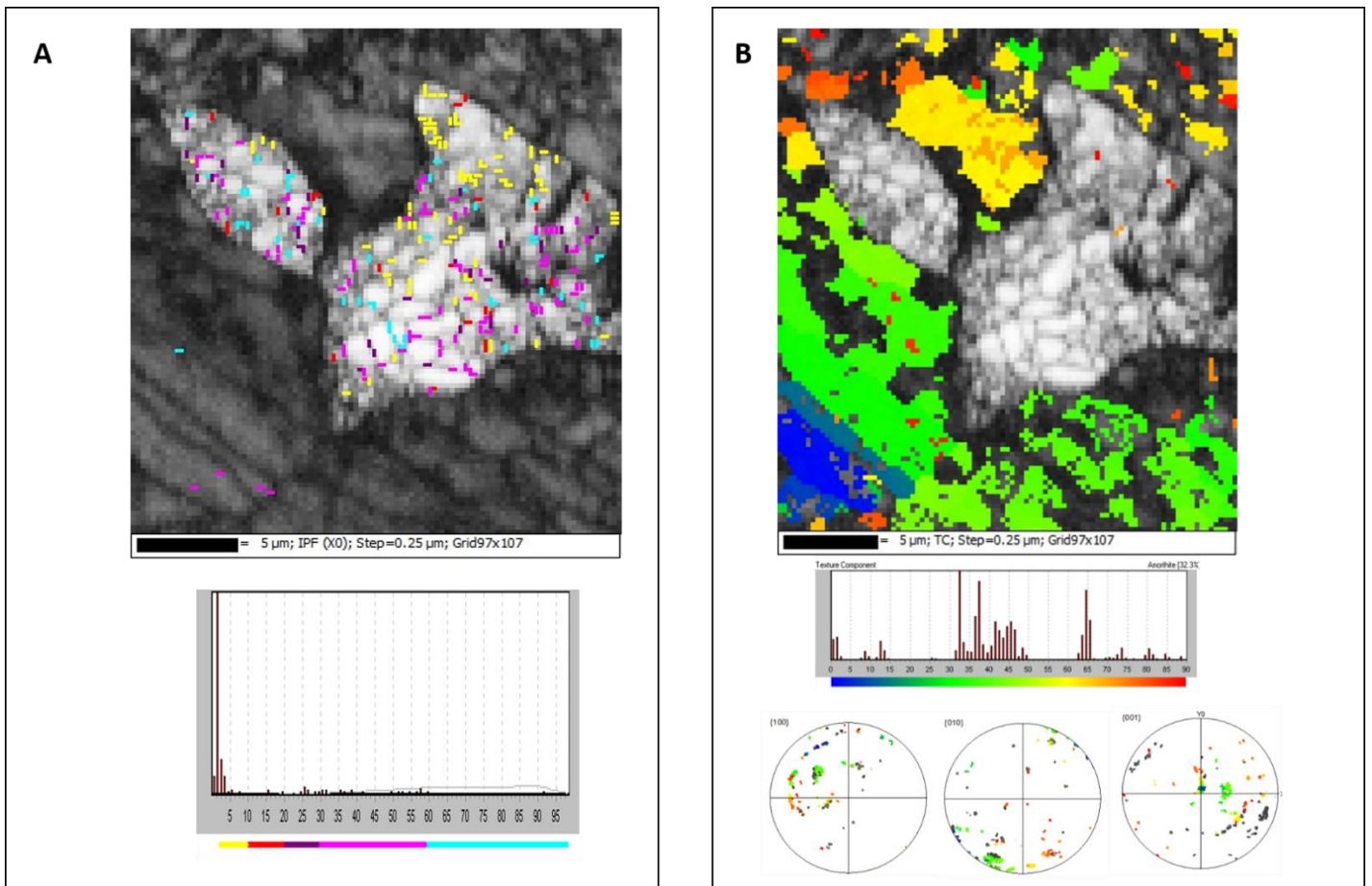


Figure A5. **A)** Grain boundaries in the recrystallized merrillite. Although the low-angle grain boundaries ($<10^\circ$) are frequent, a high number of high-angle grain boundaries is present in the grain. **B)** Recrystallization of plagioclase melted glass and maskelynite in the sample 78236,22 surrounding recrystallized merrillite grain. Both melted and solid plagioclase are well-diffracting at EBSD scale and are readily indexed with the triclinic unit cell of anorthite. The recrystallization seems to follow an ordered, albeit highly-deformed, crystallographic orientation.

Table A2. Peak fitting parameters including standard deviation of the characteristic peaks in Raman spectra of plagioclase, apatite and merrillite representative of different shock stages. These spectra are shown in Figure 2, in the main text and are labelled here, in addition to individual mineral and its shock stage, by the file name provided as Supplementary Material.

Shock Stage	File name	Peak 1	Peak 2	Peak 3	Peak 4	Peak 5	
Plagioclase							
S1	76535_51_Plag2#1_200-2000_40sec_50%_632nm_no_cc_fit	Location = 282.89 +/- 0.42963 Height = 2366.7 +/- 132.45 Area = 57077 +/- 3334.2 FWHM = 15.353 +/- 1.2425	Location = 486.33 +/- 0.48414 Height = 1576.6 +/- 182.72 Area = 20039 +/- 3557.8 FWHM = 8.0915 +/- 1.6525	Location = 505.33 +/- 0.2299 Height = 5092.1 +/- 127.62 Area = 1.3181e+05 +/- 5168.1 FWHM = 16.479 +/- 0.78069	Location = 558.78 +/- 0.65566 Height = 1922.4 +/- 104.48 Area = 72360 +/- 4479.7 FWHM = 23.963 +/- 1.9957		
S2	76335_Area1_Plag1d_#1_200-1400_50%_632nm_no_cc_base_corr	Location = 281.66 +/- 0.96475 Height = 1261.2 +/- 109.78 Area = 43954 +/- 3956.9 FWHM = 22.187 +/- 2.7792	Location = 487.04 +/- 0.741 Height = 1086.6 +/- 171.12 Area = 15452 +/- 3459.4 FWHM = 9.0532 +/- 2.4289	Location = 505.78 +/- 0.27306 Height = 3792.7 +/- 138.27 Area = 82356 +/- 4233.1 FWHM = 13.824 +/- 0.8812	Location = 561.03 +/- 1.2186 Height = 657.14 +/- 159.95 Area = 10337 +/- 2590.5 FWHM = 10.015 +/- 3.5033		
S3-4	72255_100_PlagAp#1_50%_200-2000_632_no_cc_base_corr	Location = 284.55 +/- 0.73857 Height = 1154.4 +/- 128.87 Area = 22965 +/- 3757.3 FWHM = 12.664 +/- 2.4392	Location = 486.62 +/- 0.29309 Height = 2353.7 +/- 147.87 Area = 33277 +/- 2989.3 FWHM = 9.0009 +/- 0.9677	Location = 505.33 +/- 0.19465 Height = 5024.6 +/- 138.35 Area = 93447 +/- 5497.6 FWHM = 11.84 +/- 0.77868	Location = 560.11 +/- 0.80148 Height = 735.51 +/- 143.96 Area = 94681 +/- 1931.2 FWHM = 8.1952 +/- 2.2939		
RUFF	Anorthite X050020 West side, Great Sitkin Island, Aleutian Islands, Alaska Source: G.R. Rossman 1597 Owner: Caltech Description: NMNH 137041, Ca0.96	Location = 281.79 +/- 1.1966 Height = 166.99 +/- 24.064 Area = 4126.4 +/- 842.08 FWHM = 15.731 +/- 3.8744	Location = 486.03 +/- 0.50951 Height = 326.36 +/- 32.809 Area = 4920.8 +/- 800.65 FWHM = 9.599 +/- 1.7298	Location = 504.71 +/- 0.3728 Height = 770.29 +/- 37.06 Area = 16905 +/- 2166.9 FWHM = 13.971 +/- 1.5421	Location = 558.08 +/- 0.65294 Height = 232.46 +/- 29.678 Area = 3724.8 +/- 526.09 FWHM = 10.201 +/- 1.9459		
Apatite							
S1	76535_51_Ap2#1_200-1200_40sec_50%_632nm_no_cc_base_corr	Location = 431.08 +/- 1.2723 Height = 1036 +/- 269.21 Area = 15317 +/- 6951.1 FWHM = 9.4118 +/- 4.4699	Location = 445.29 +/- 1.0291 Height = 2175.4 +/- 267.33 Area = 45474 +/- 9316.8 FWHM = 13.308 +/- 3.1041	Location = 580.13 +/- 0.26851 Height = 3977.6 +/- 374.26 Area = 34467 +/- 4249.4 FWHM = 5.5165 +/- 0.85513	Location = 591.1 +/- 1.5577 Height = 789.21 +/- 398 Area = 7361.1 +/- 4582.3 FWHM = 5.9379 +/- 4.9446	Location = 962.72 +/- 0.039091 Height = 30711 +/- 306.31 Area = 3.7815e+05 +/- 3825.7 FWHM = 7.8388 +/- 0.11136	
S2	76335_Area1_Ap1_#1_200-2000_x50_50_632_no_cc_base_corr	Location = 430.0 +/- 0.61487 Height = 2693.3 +/- 377.74 Area = 42384 +/- 14706 FWHM = 10.365 +/- 2.918	Location = 447.12 +/- 4.47 Height = 1372.9 +/- 259.79 Area = 81544 +/- 21736 FWHM = 37.813 +/- 7.0378	Location = 584.26 +/- 3.5409 Height = 1611 +/- 379.51 Area = 81927 +/- 17877 FWHM = 32.375 +/- 5.6125	Location = 591.49 +/- 0.37326 Height = 3011.7 +/- 513.36 Area = 26335 +/- 10660 FWHM = 5.5667 +/- 1.8259	Location = 963.35 +/- 0.041897 Height = 29239 +/- 306.03 Area = 3.6771e+05 +/- 3910.7 FWHM = 8.0062 +/- 0.11945	
S3-4	72255_100_Ap8#2_50%_200-2000_632_no_cc_base_corr	Location = 430.2 +/- 0.43988 Height = 1994.9 +/- 232.77 Area = 36329 +/- 10021 FWHM = 11.593 +/- 2.2418	Location = 444.72 +/- 2.8781 Height = 1185.3 +/- 168.97 Area = 64481 +/- 14438 FWHM = 34.631 +/- 4.8368	Location = 582.89 +/- 6.3041 Height = 1120.7 +/- 447.86 Area = 46472 +/- 17051 FWHM = 38.955 +/- 14.447	Location = 591.3 +/- 1.9196 Height = 1616 +/- 987.67 Area = 12009 +/- 9572.8 FWHM = 6.9811 +/- 5.1122	Location = 962.79 +/- 0.029277 Height = 20231 +/- 133.85 Area = 2.8126e+05 +/- 1896.2 FWHM = 8.8506 +/- 0.083588	
S5	78236_22_area1_ap1_#3					Location = 962.46 +/- 0.098018 Height = 6767.3 +/- 193.52 Area = 72947 +/- 2516.1 FWHM = 6.8623 +/- 0.30449	
S6	Area_2_Ap2_#1_10%_200-1400_632nm_no_cc_base_corr					Location = 963.05 +/- 0.1711 Height = 6237.3 +/- 315.26 Area = 66328 +/- 3434.6 FWHM = 6.7699 +/- 0.4898	
Merrillite							
S1	76535_51_Merr1#1_200-1200_40sec_50%_base_corr	Location = 408.47 +/- 1.36 Height = 1279.5 +/- 184.4 Area = 37933 +/- 5893 FWHM = 18.874 +/- 3.9787	Location = 953.32 +/- 0.85229 Height = 2390.3 +/- 213.39 Area = 60056 +/- 10282 FWHM = 15.995 +/- 2.6874	Location = 971.2 +/- 0.21266 Height = 9329.9 +/- 224.17 Area = 2.2049e+05 +/- 10141 FWHM = 15.045 +/- 0.67698			
S2	76335_Area1_Merr1_#1_200-2000_x50_50_632_no_cc_base_corr	Location = 408.26 +/- 0.3661 Height = 1564.2 +/- 40.262 Area = 51889 +/- 2165.5 FWHM = 31.163 +/- 1.148	Location = 951.69 +/- 0.6525 Height = 2598.6 +/- 119.41 Area = 92353 +/- 10514 FWHM = 22.625 +/- 2.1878	Location = 971.46 +/- 0.13844 Height = 9531.1 +/- 136.87 Area = 2.623e+05 +/- 8290.7 FWHM = 17.52 +/- 0.46853			
S3-4	72255_100_Merr9#1_50%_200-2000_632_no_cc	Location = 406.98 +/- 0.52528 Height = 1503.7 +/- 147.92 Area = 26048 +/- 4876.3 FWHM = 11.028 +/- 2.0678	Location = 953.8 +/- 0.61183 Height = 2365.8 +/- 121.17 Area = 71387 +/- 7478.3 FWHM = 19.21 +/- 1.7496	Location = 971.99 +/- 0.13219 Height = 9455.2 +/- 132.16 Area = 2.4756e+05 +/- 7099.7 FWHM = 16.668 +/- 0.40888			
S5	Area_2_Merr1_#2_10%_200-1400_632nm_no_cc_base_corr	Location = 408.44 +/- 0.64553 Height = 559.86 +/- 66.346 Area = 9524.4 +/- 1277.3 FWHM = 10.83 +/- 1.9559	Location = 956.03 +/- 0.47658 Height = 1361.7 +/- 61.967 Area = 35649 +/- 3299.9 FWHM = 16.666 +/- 1.3732	Location = 971.71 +/- 0.15281 Height = 3612.2 +/- 69.382 Area = 79581 +/- 3122.5 FWHM = 14.026 +/- 0.47727			
S6	Area_2_Merr2_#2_10%_200-1400_632nm_no_cc_base_corr	Location = 407.6 +/- 3.0637 Height = 731.2 +/- 347.44 Area = 14812 +/- 7247.5 FWHM = 12.896 +/- 8.7553	Location = 953.34 +/- 5.0294 Height = 712.35 +/- 375.95 Area = 18345 +/- 19572 FWHM = 16.395 +/- 15.629	Location = 971.8 +/- 1.3255 Height = 2940.7 +/- 335.4 Area = 87841 +/- 20203 FWHM = 19.016 +/- 3.9386			