Table of Contents


```
clear;
home;
close all;
```

The h5 file location

```
file1_folder='C:\Users\benja\OneDrive\Documents\GitHub\MTEX_Workshop
\Data'; %location where the data is stored
file1_name='Mg_Pecs1 Specimen 1 Site 1 Map Data 1'; %should be a h5oina file,
 do not add in the .h5oina file extension

% file1_folder='/MATLAB Drive/MTEX_Workshop/Data/';
% file1_name='Mg_Pecs1 Specimen 1 Site 1 Map Data 1'; %should be a h5oina
 file, do not add in the .h5oina file extension

file_dset='1'; %data set number of interest in the h5 file

mb_length = 500; %micro bar length for plots - if you want to override, you
 can comment this out/clear this variable and the override will not happen
```

Load MTEX

```
%location of MTEX 5.10.2
```

```
%if MTEX loaded this doesn't matter
%if MTEX is not loaded, then this will be used to start MTEX up
mtex_location='C:\Users\benja\OneDrive\Documents\MATLAB\mtex-5.10.2';
% mtex_location='/MATLAB Drive/mtex-5.10.2';

%start mtex if needed
try EBSD;
catch
    run(fullfile(mtex_location,"startup.m"));
end

%create a results folder
file1_name_us=file1_name;
file1_name_us(strfind(file1_name_us,' '))='_';

resultsdir=fullfile(cd,'results',file1_name_us);
if isdir(resultsdir) == 0; mkdir(resultsdir); end
```

Read the h5oina data into Matlab

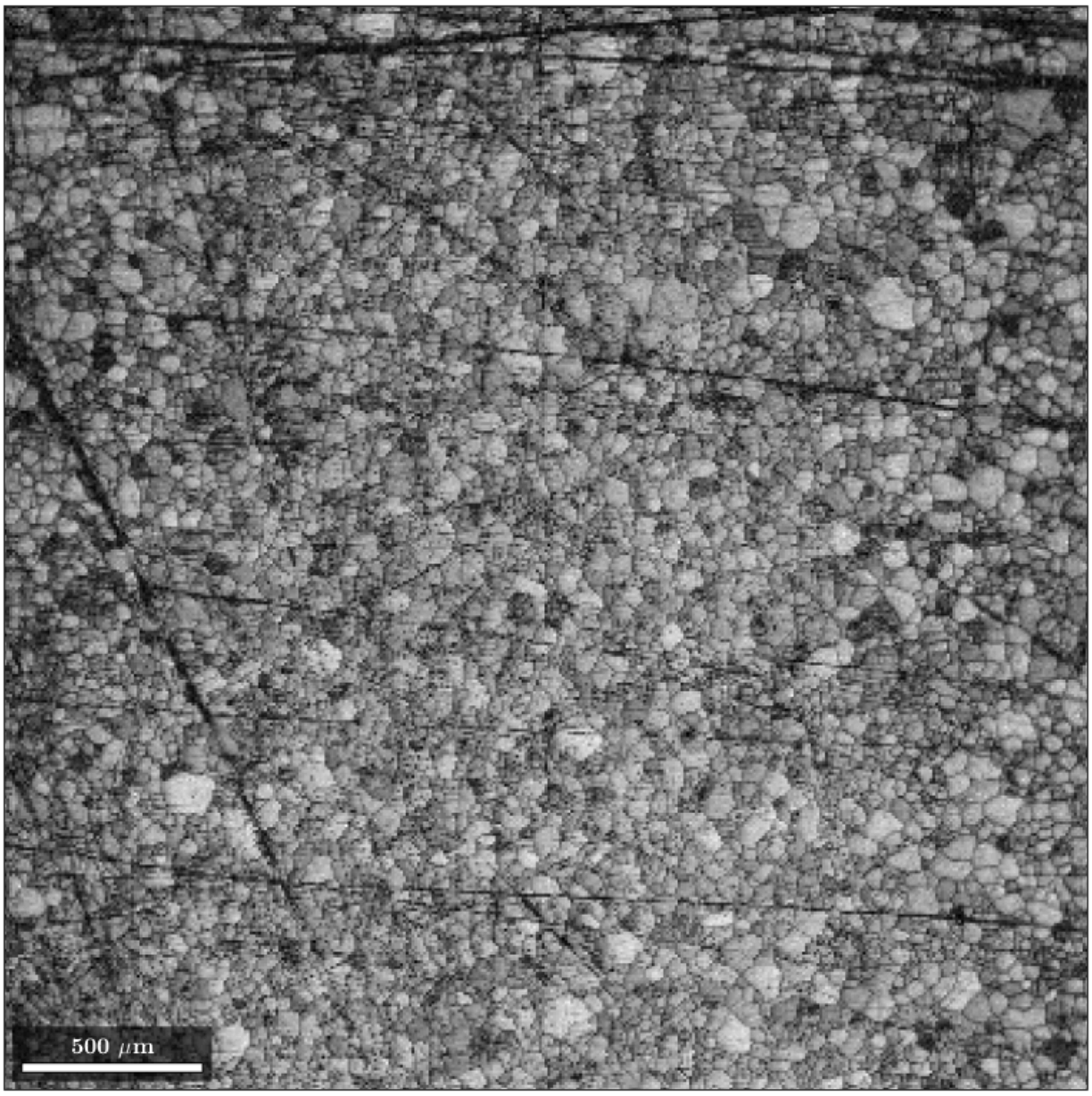
```
%Make this a full file name
file1_full=fullfile(file1_folder,[file1_name '.h5oina']);

%read the H5OINA EBSD Data - this will return two structures, with the data
%contained per layer/slice in the file, and also a contents file if you
%need to load anything else
[ebsd_data,header_data,h5oina_contents]=H5OINA_Read(file1_full);

%convert into a MTEX container
[ebsd] = H5OINA_Convert(ebsd_data,header_data,file_dset);
```

Set the plotting preferences - this has to be validated for your instrument

```
%this is set up for the pFIB and Oxford Insturments systems at UBC
setMTEXpref('xAxisDirection','east');          %aztec
setMTEXpref('zAxisDirection','outofPlane');    %aztec

%font size and overwrite the scale bar if you want
setMTEXpref('FontSize',12)
```

Now do some plots

```
%band contrast
figure;
plot(ebsd,ebsd.prop.Band_Contrast); colormap('gray');

if exist('mb_length','var'); mp = MTEX_mb_fix(mb_length); end %change the
 micronbar length to make it prettier/easier to read
```



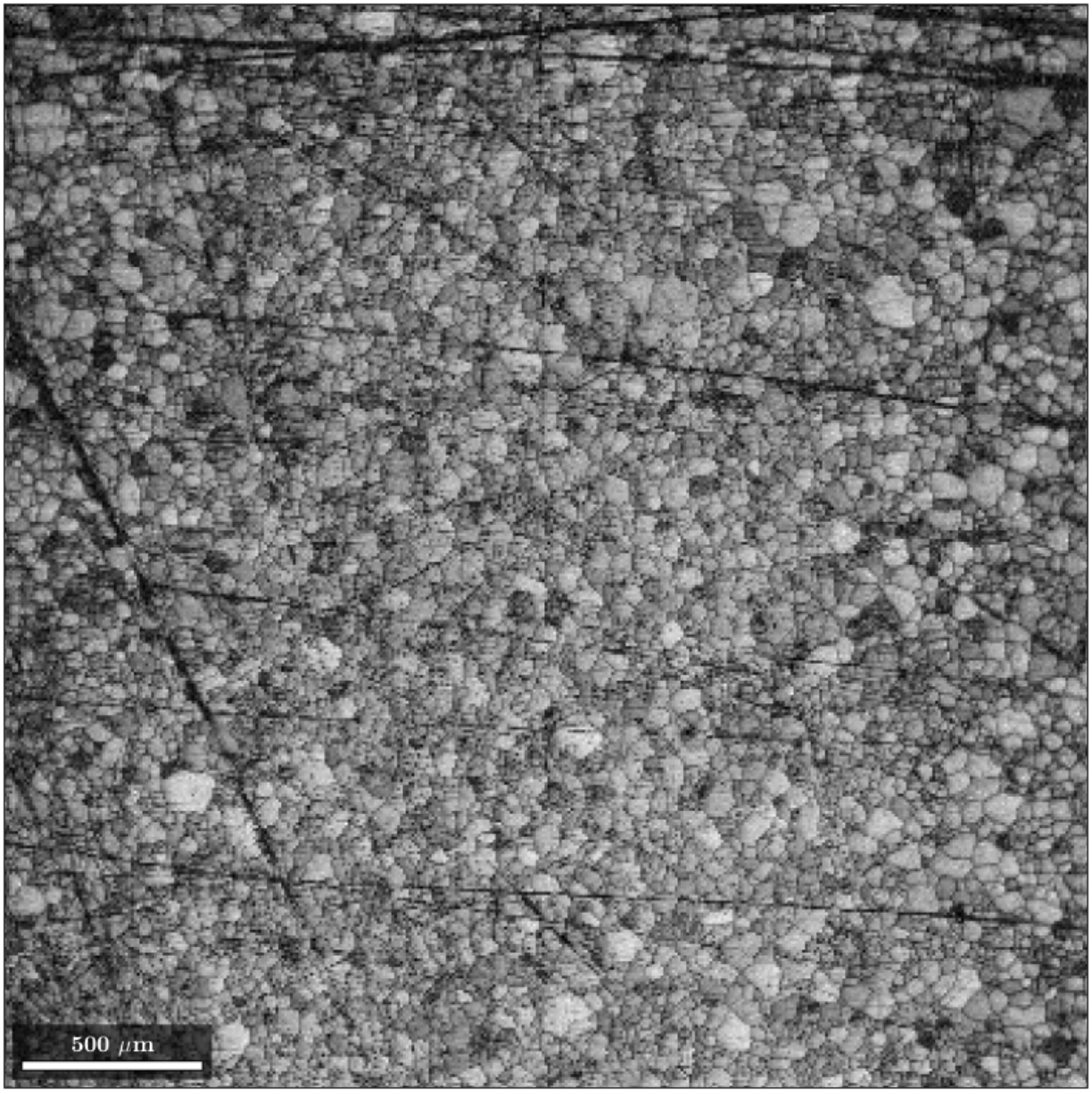
Extract the phase to plot

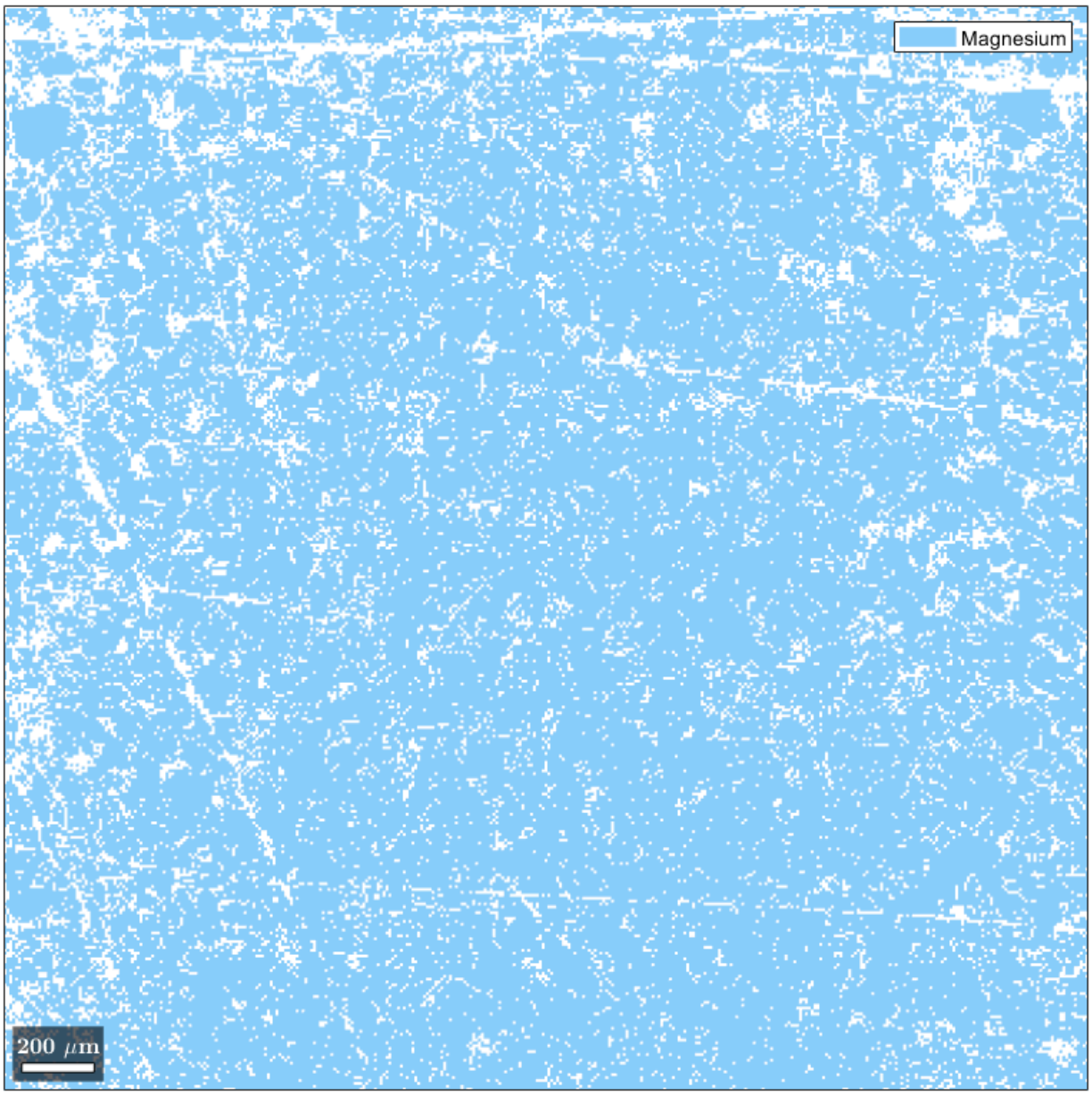
```
%select the mineral name
mineral_name=ebsd.CS.mineral;
% mineral_name='Magnesium';
```

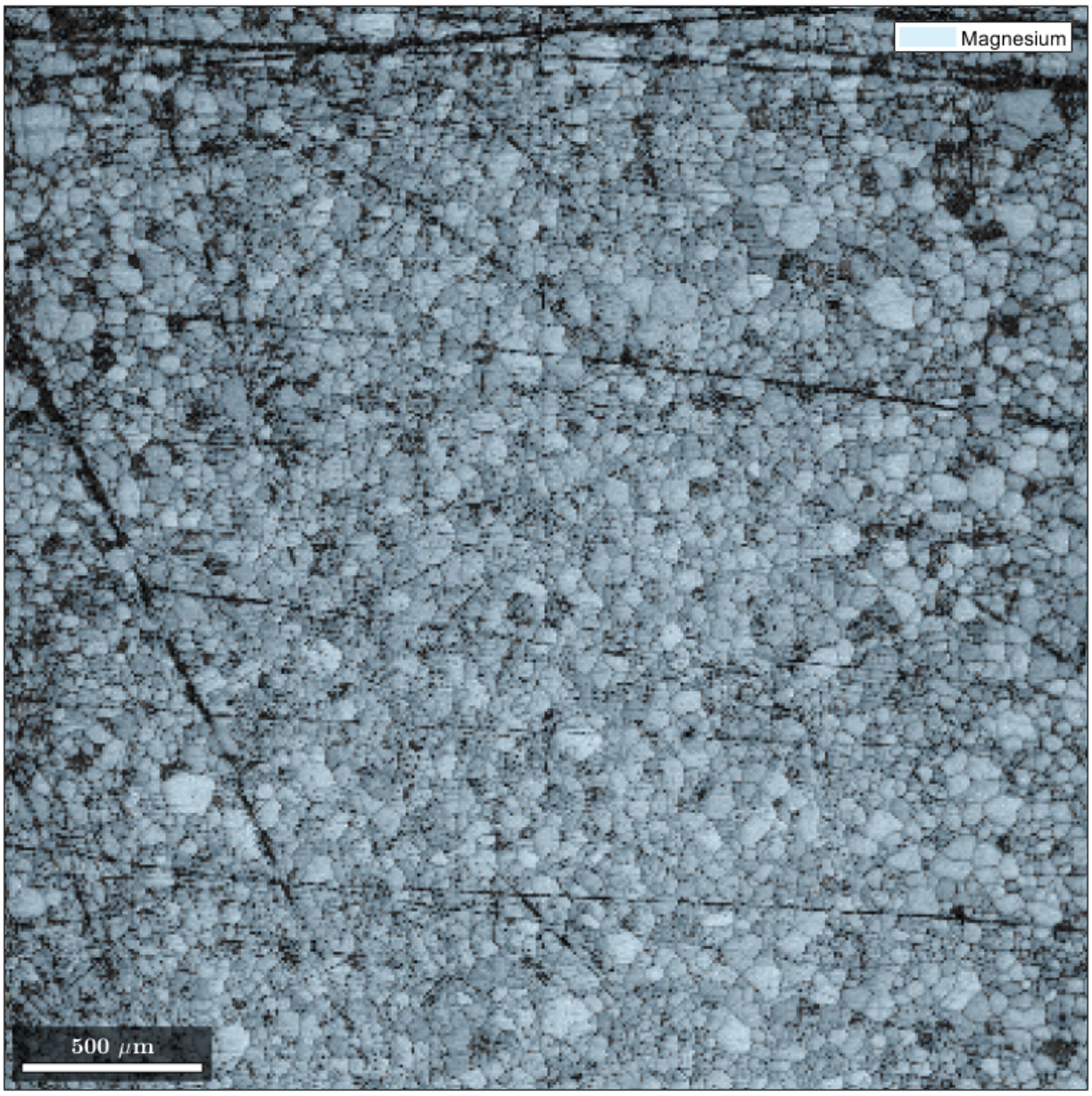
Plot the map of phases/indexed data

```
figure;
plot(ebsd');

%overlay with Band Contrast
```

```
figure;
plot(ebsd,ebsd.prop.Band_Contrast); colormap('gray');
hold on;
plot(ebsd,'FaceAlpha','0.3');
hold on;
if exist('mb_length','var'); mp = MTEX_mb_fix(mb_length); end %change the
 micronbar length to make it prettier/easier to read
```




Magnesium
200 μm

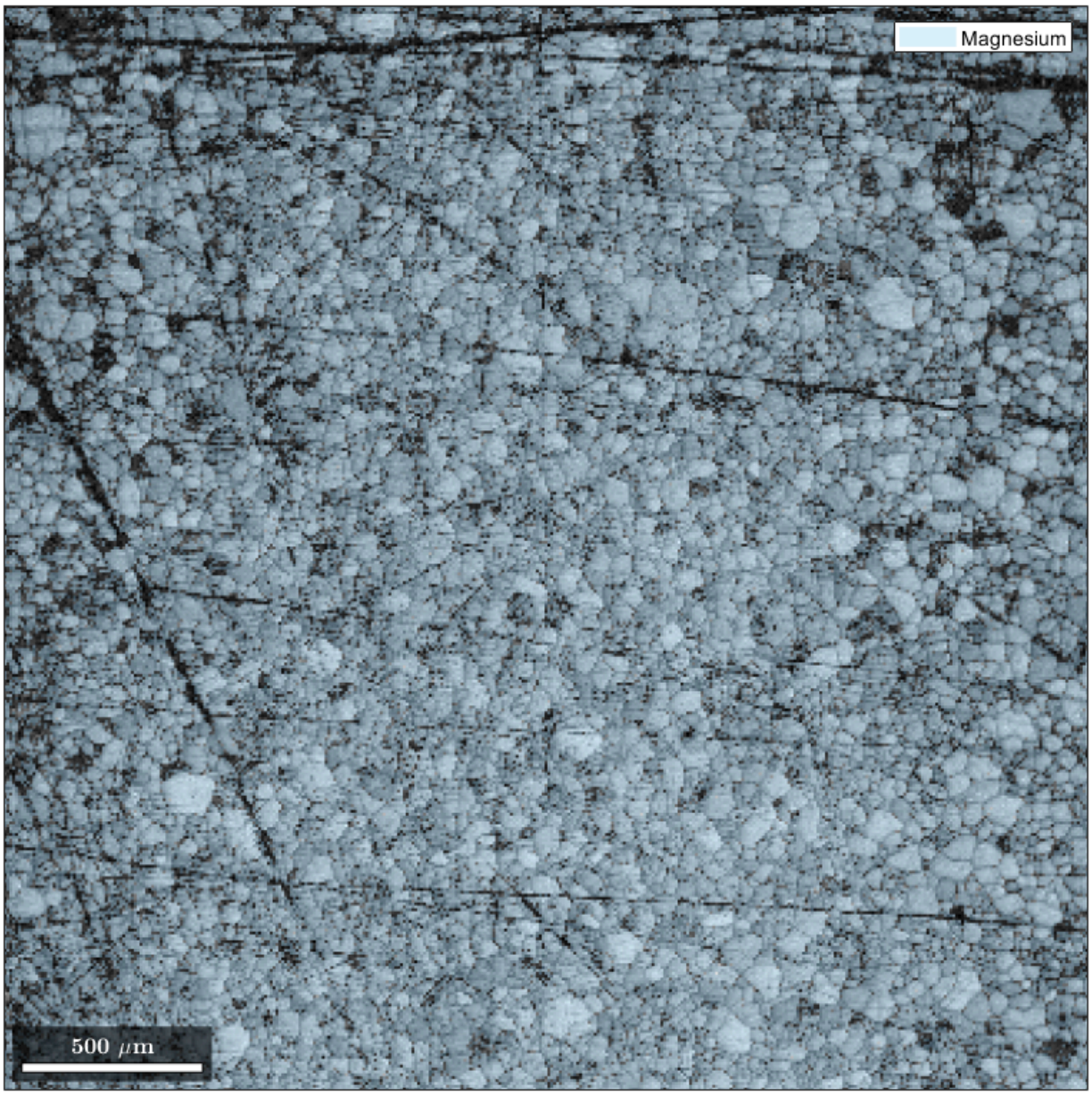


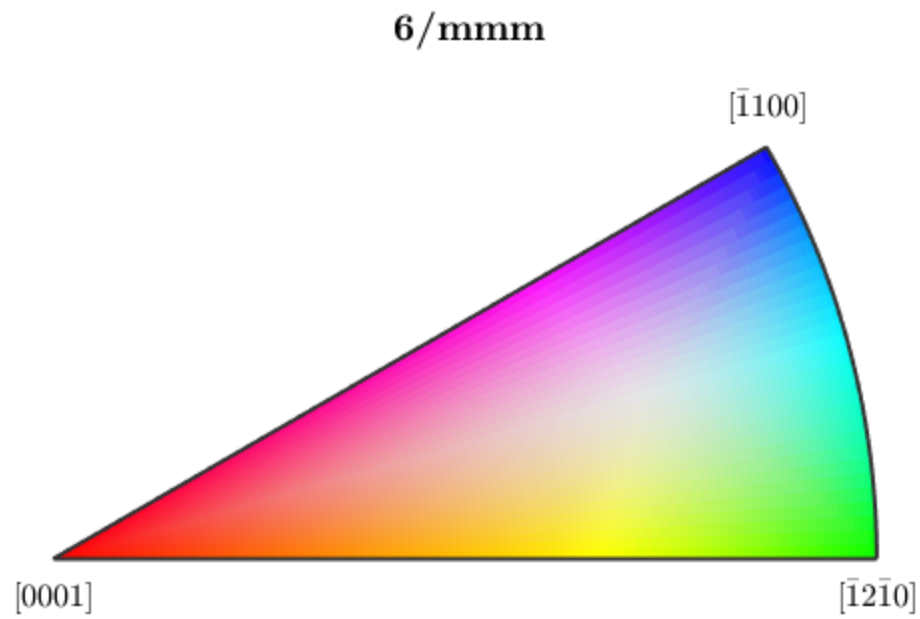
IPF-x, y and z

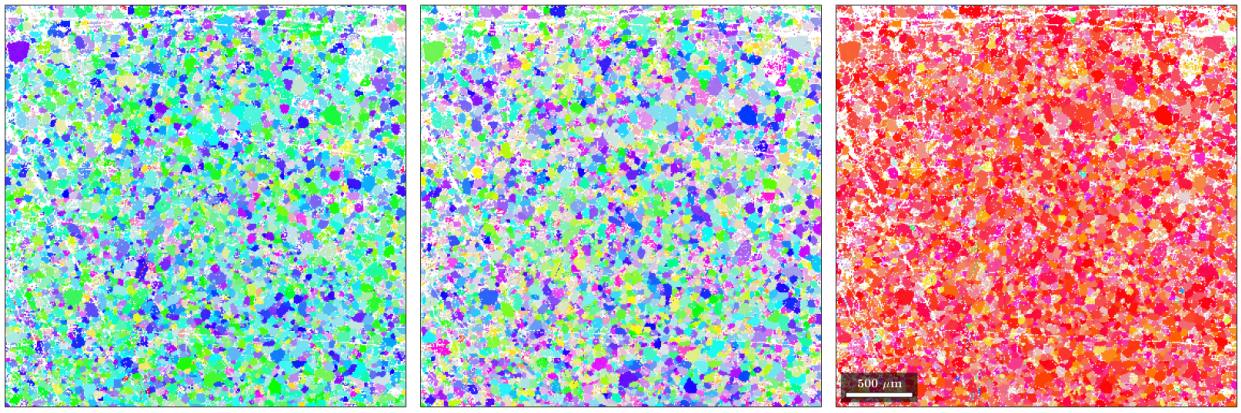
compute the colors

```
ipfKey = ipfHSVKey(ebsd(mineral_name));

%plot the key
f1=figure;
plot(ipfKey)

% now generate the IPF colour maps
ipfKey.inversePoleFigureDirection = vector3d.X;
colors_X = ipfKey.orientation2color(ebsd(mineral_name).orientations);
```

```
ipfKey.inversePoleFigureDirection = vector3d.Y;
colors_Y = ipfKey.orientation2color(ebsd(mineral_name).orientations);
ipfKey.inversePoleFigureDirection = vector3d.Z;
colors_Z = ipfKey.orientation2color(ebsd(mineral_name).orientations);

%now plot the three IPF coloured maps
f2=figure;
plot(ebsd(mineral_name),colors_X,'micronbar','off');
nextAxis
plot(ebsd(mineral_name),colors_Y,'micronbar','off');
nextAxis
plot(ebsd(mineral_name),colors_Z,'micronbar','on');

if exist('mb_length','var'); mp = MTEX_mb_fix(mb_length); end %change the
 micronbar length to make it prettier/easier to read

%save the figures;
drawnow(); %updates the graphics engine to make sure it saves things properly
print(f1,fullfile(resultsdir,'Map_IPFkey.png'),'-dpng','-r600');
print(f2,fullfile(resultsdir,'Map_IPF.png'),'-dpng','-r600');
```


Magnesium
500 μm

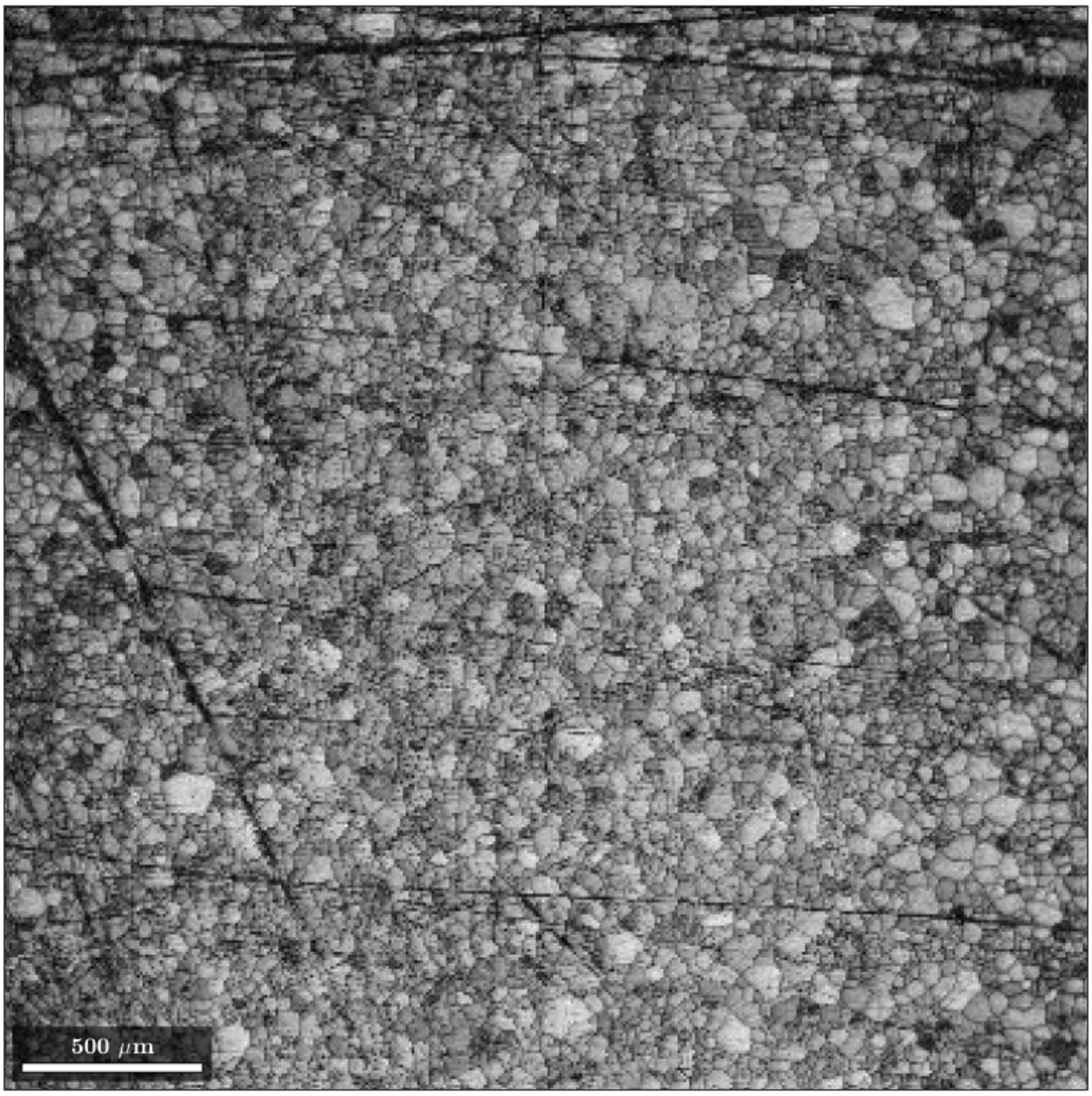


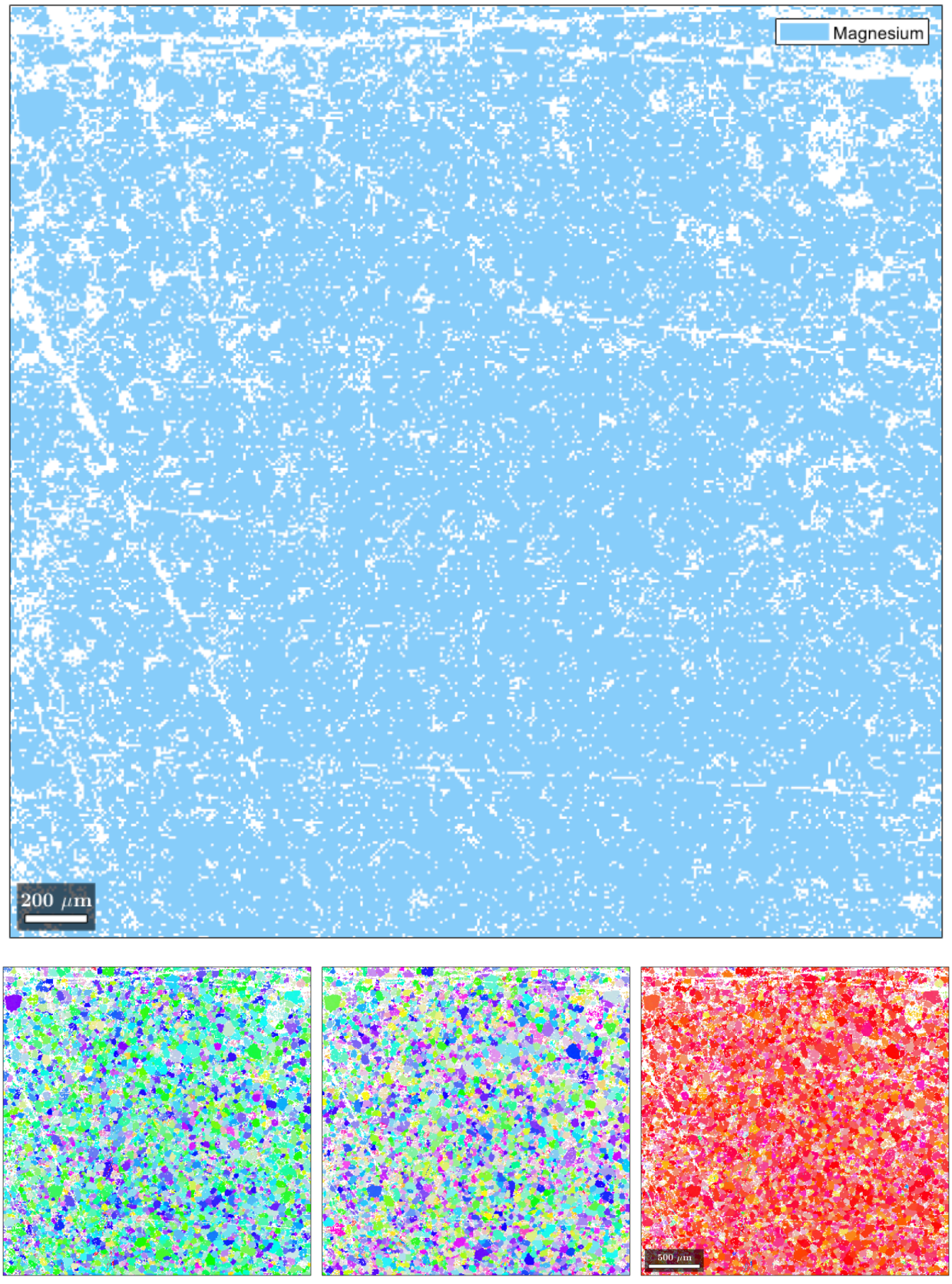


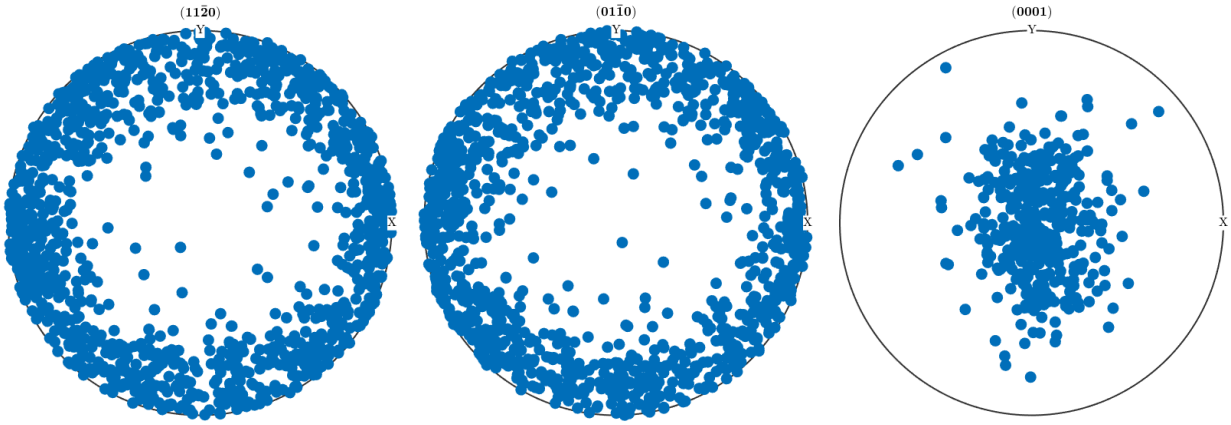
Plot the PF - scatter

```
%plot planes as spots, and use a subset
figure
plotPDF(ebsd(mineral_name).orientations,[Miller(1,1,0,ebsd(mineral_name).CS)
 Miller(0,1,0,ebsd(mineral_name).CS) Miller(0,0,1,ebsd(mineral_name).CS)])
%you can plot all - but this takes a while..
%plotPDF(ebsd(mineral_name).orientations,[Miller(1,1,0,ebsd(mineral_name).CS)
 Miller(0,1,0,ebsd(mineral_name).CS)
 Miller(0,0,1,ebsd(mineral_name).CS)],'Points','all')
```

I'm plotting 416 random orientations out of 114928 given orientations
You can specify the the number points by the option "points".
The option "all" ensures that all data are plotted


500 μm

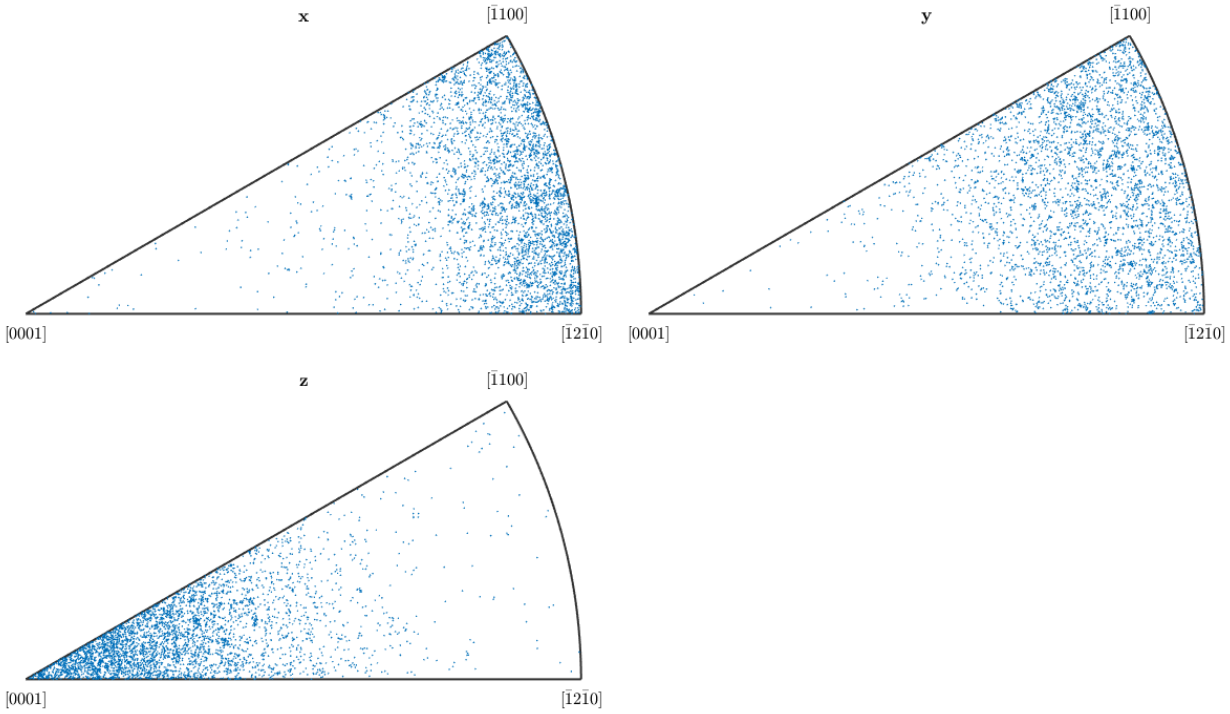

Magnesium
200 μm
500 μm



Plot the IPF - scatter

```
figure
plotIPDF(ebsd(mineral_name).orientations,[xvector yvector zvector])
```

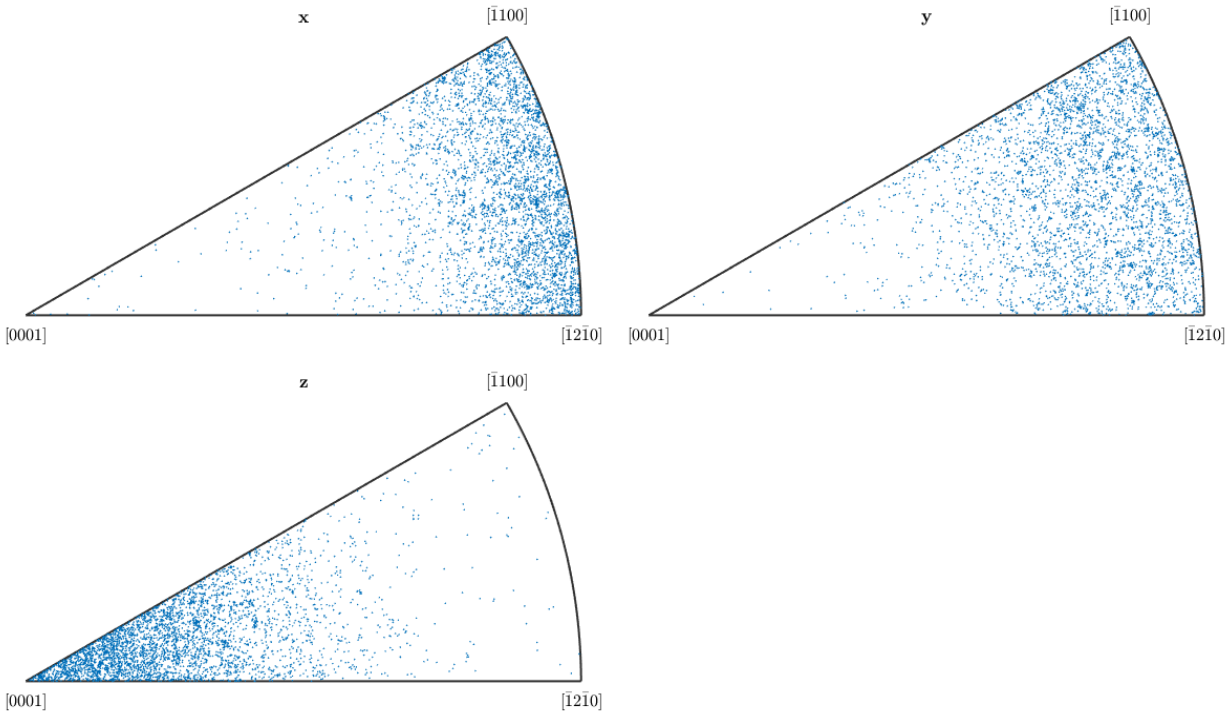
I'm plotting 4166 random orientations out of 114928 given orientations

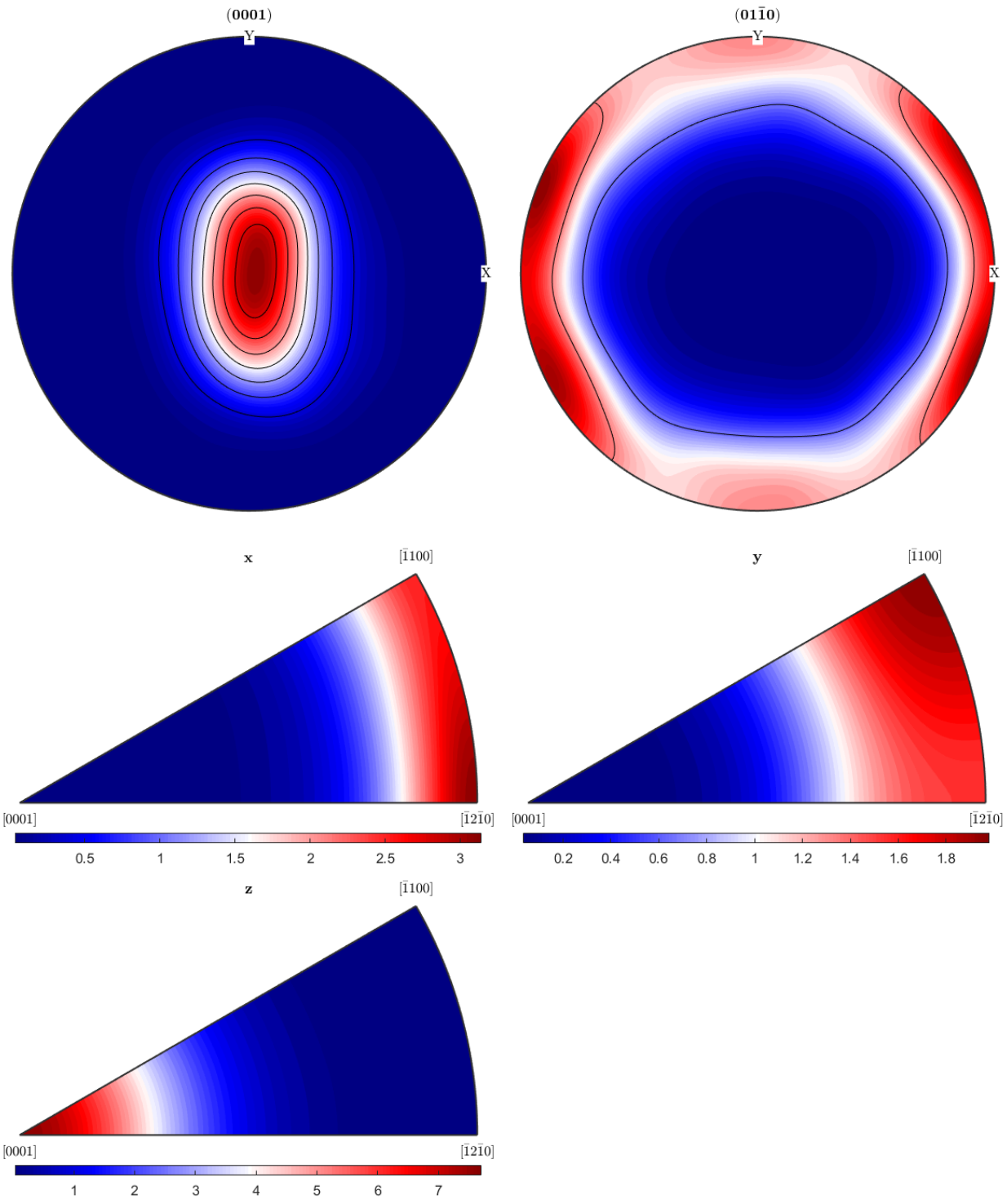


Construct the ODF

```
%suggested reading:
%https://mtex-toolbox.github.io/ODFTutorial.html
%https://mtex-toolbox.github.io/PoleFigure2ODF.html
```

```
% compute the ODF
odf = calcDensity(ebsd(mineral_name).orientations);
% You could also change/fix the half width - compare this different ODF
% odf = calcDensity(ebsd(mineral_name).orientations,'halfwidth',2*degree);

figure;
% plot the pole figure representation of the ODF
plotPDF(odf,[Miller(0,0,1,ebsd(mineral_name).CS)
 Miller(0,1,0,ebsd(mineral_name).CS)]);

mtexColorbar('location','southoutside')
mtexColorMap blue2red

%add contours
levels=[-7:7];
hold on;
plotPDF(odf,[Miller(0,0,1,ebsd(mineral_name).CS)
 Miller(0,1,0,ebsd(mineral_name).CS)],'contour',levels,'linecolor','k');
mtexColorbar('location','southoutside')


%you can also plot this ODF in the IPF
figure;
% plot the inverse pole figure representation of the ODF
plotIPDF(odf,[xvector yvector zvector])
mtexColorbar('location','southoutside')
mtexColorMap blue2red
```

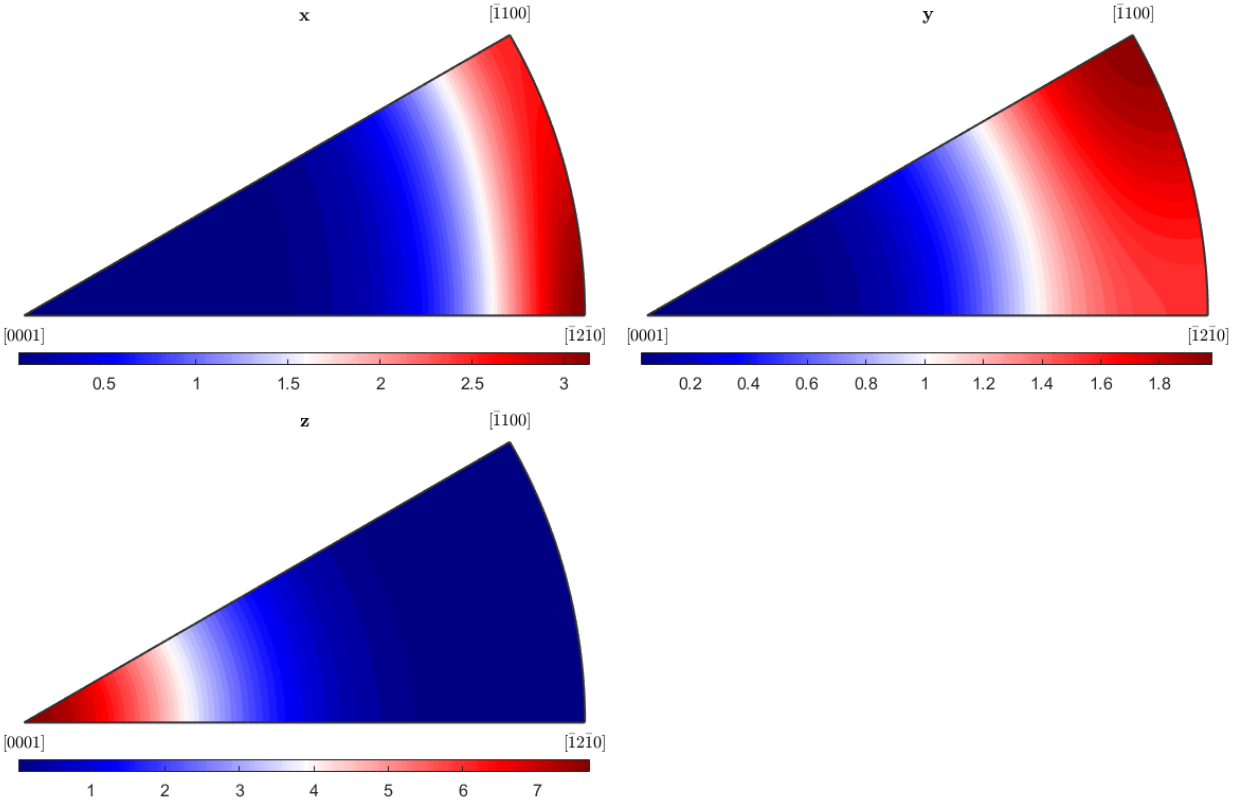


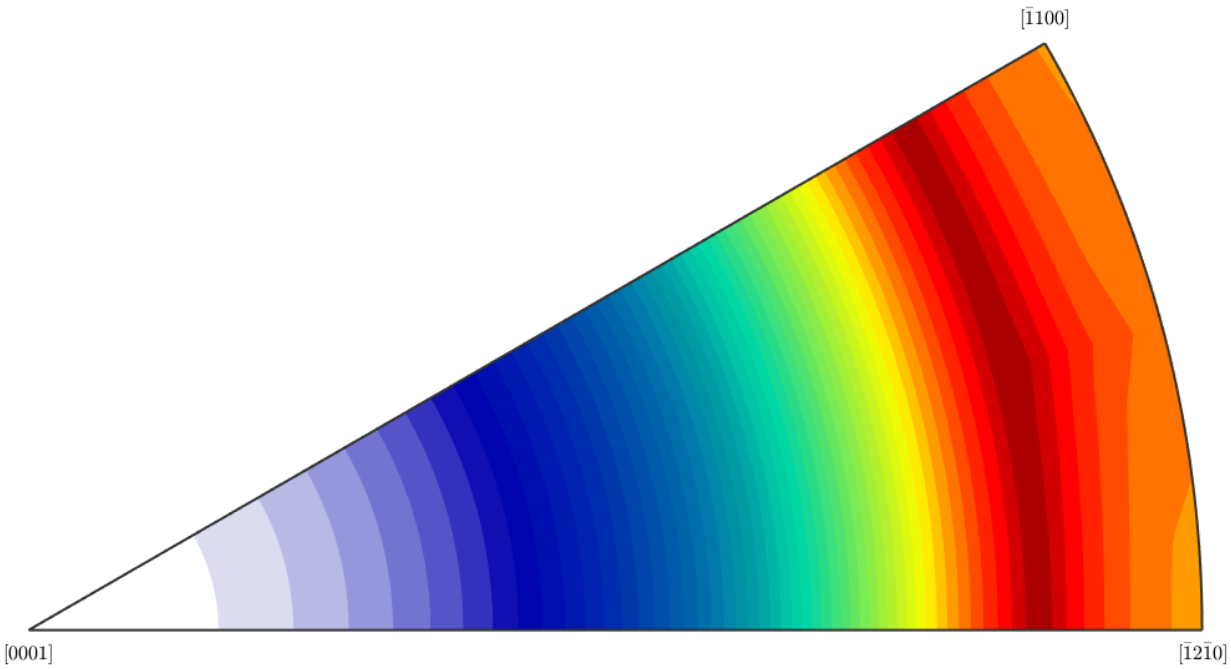


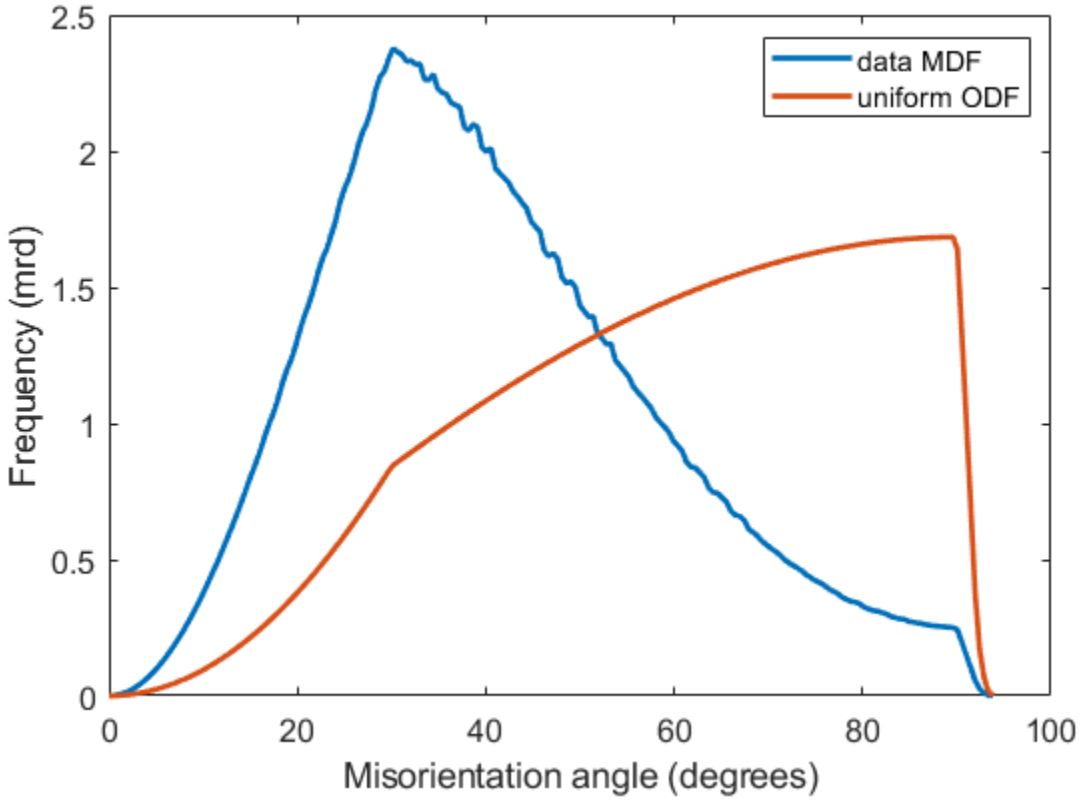
Plot the uncorrelated misorientation distribution

```
%see https://mtex-toolbox.github.io/MisorientationDistributionFunction.html
```

```
mdf = calcMDF(odf);

%plot the axis
figure;
plotAxisDistribution(mdf)

%plot the angle
figure;
plotAngleDistribution(mdf)
hold all
plotAngleDistribution(ebsd(mineral_name).CS,ebsd(mineral_name).CS)
hold off
legend('data MDF','uniform ODF')
```



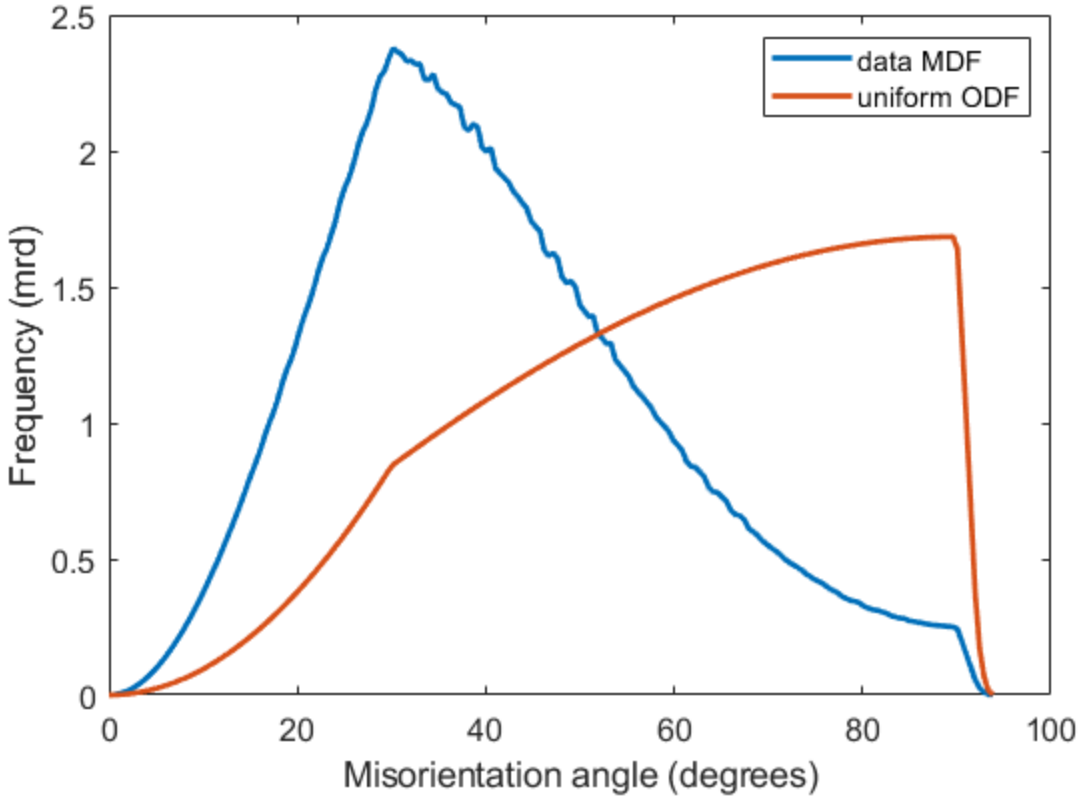


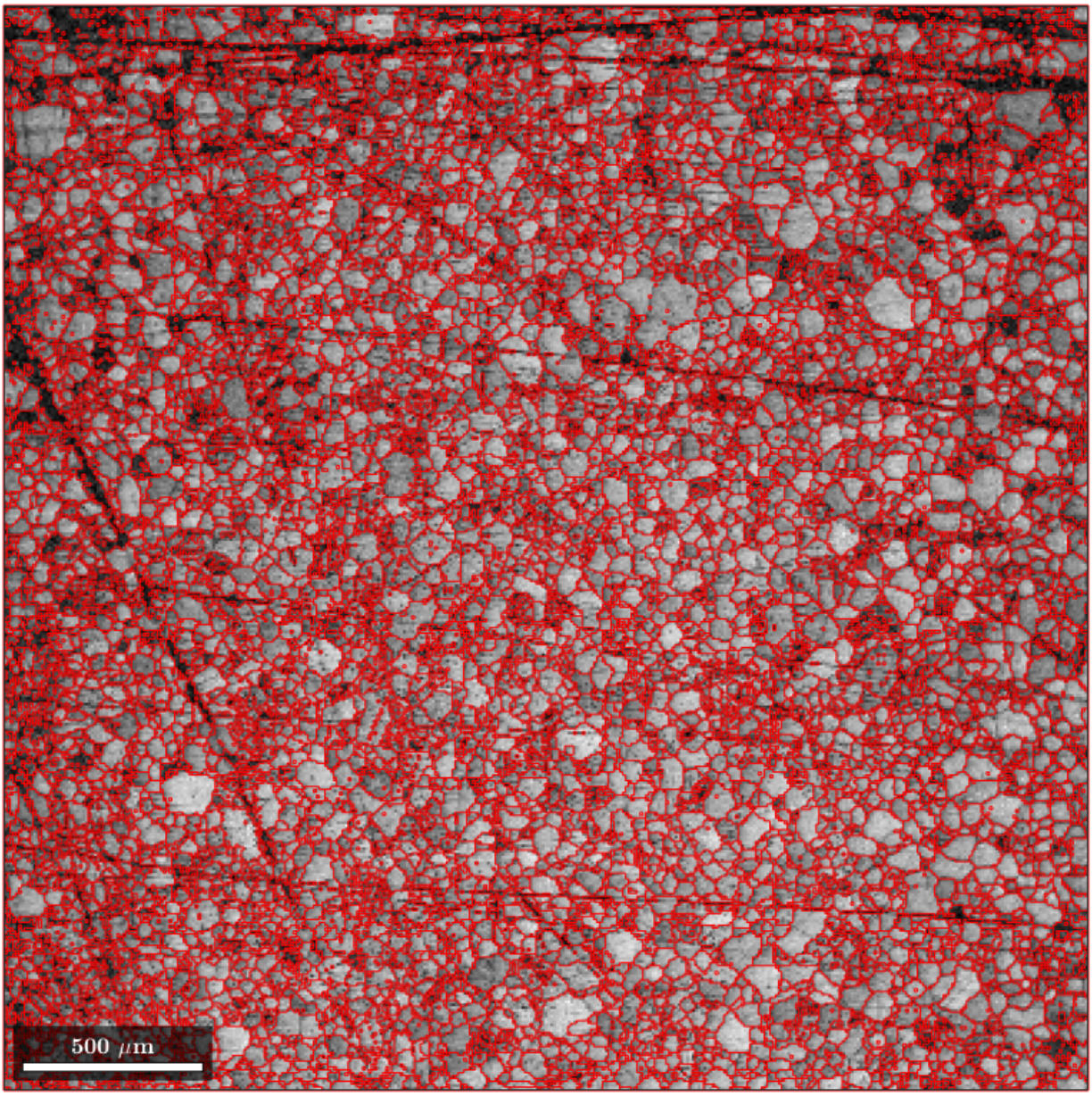


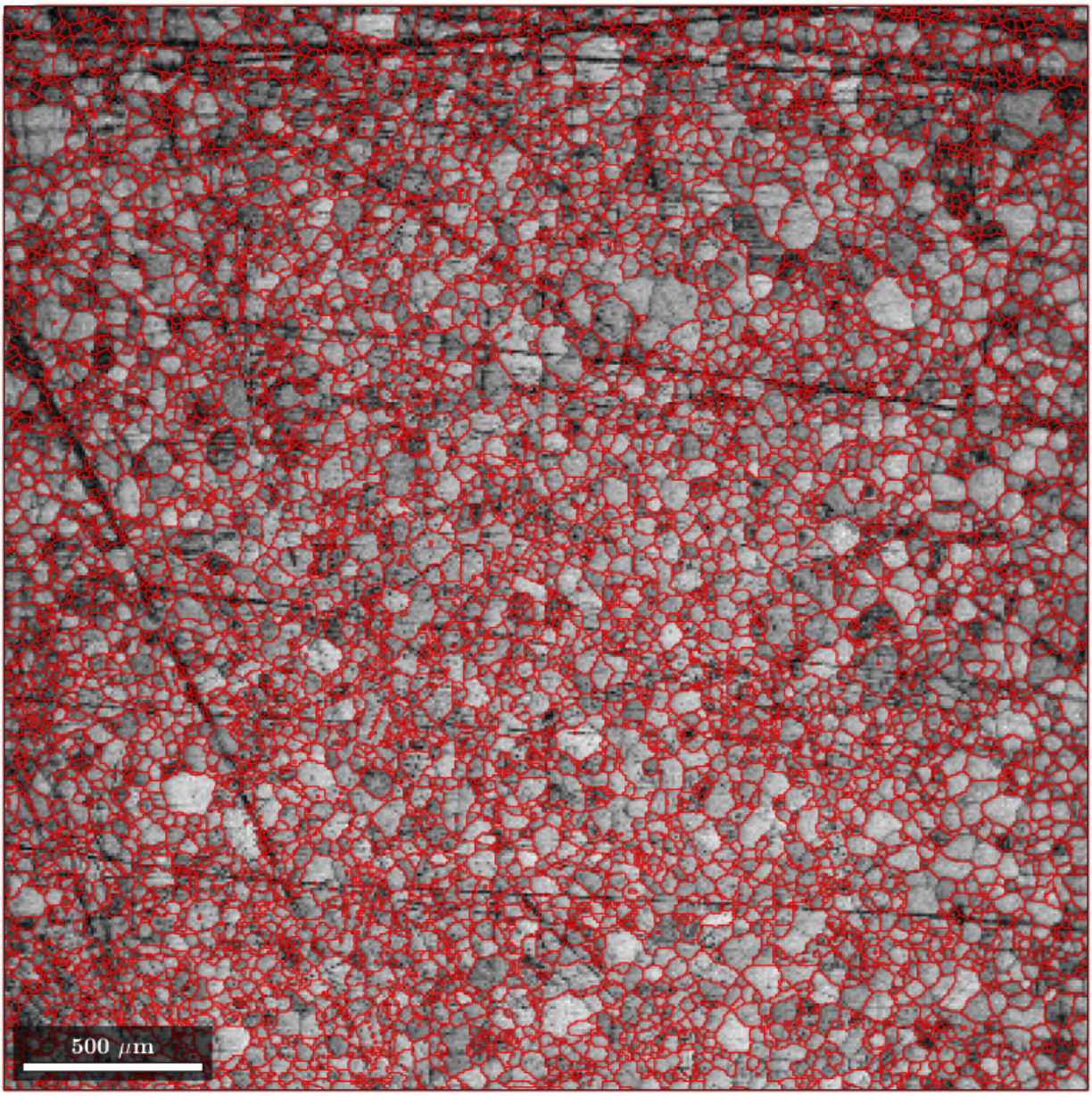
Calculate grains and grain boundaries

```
%see https://mtex-toolbox.github.io/GrainReconstruction.html
```

```
[grains,ebsd.grainId] = calcGrains(ebsd,'angle',10*degree);
%care with this threshold value - you can look at the angle distribution for
 some guidance

%Now plot the grian boundary map on the band contrast map
figure;
plot(ebsd,ebsd.prop.Band_Contrast); colormap('gray');
if exist('mb_length','var'); mp = MTEX_mb_fix(mb_length); end %change the
 micronbar length to make it prettier/easier to read
hold on
plot(grains.boundary,'linewidth',0.5,'lineColor','r')
hold off

%contrast this with the grain boundaries for indexed only points
% (look at the scratches)
grains_indexed = calcGrains(ebsd('indexed'));
% If the edge grains are being annoying - don't use the convex hull
% grains_indexed = calcGrains(ebsd('indexed'),'boundary','tight');

figure;
plot(ebsd,ebsd.prop.Band_Contrast); colormap('gray');
if exist('mb_length','var'); mp = MTEX_mb_fix(mb_length); end %change the
 micronbar length to make it prettier/easier to read
hold on
plot(grains_indexed.boundary,'linewidth',0.5,'lineColor','r')
hold off

%subset to only have the interior grains
grains_indexed_int=grains_indexed(~grains_indexed.isBoundary);
% hold on
% plot(grains_indexed_int.boundary,'linewidth',0.5,'lineColor','g')
% hold off
```


data MDF
uniform ODF
Frequency (mrd)
Misorientation angle (degrees)
0
0.5
1
1.5
2
2.5
0
20
40
60
80
100

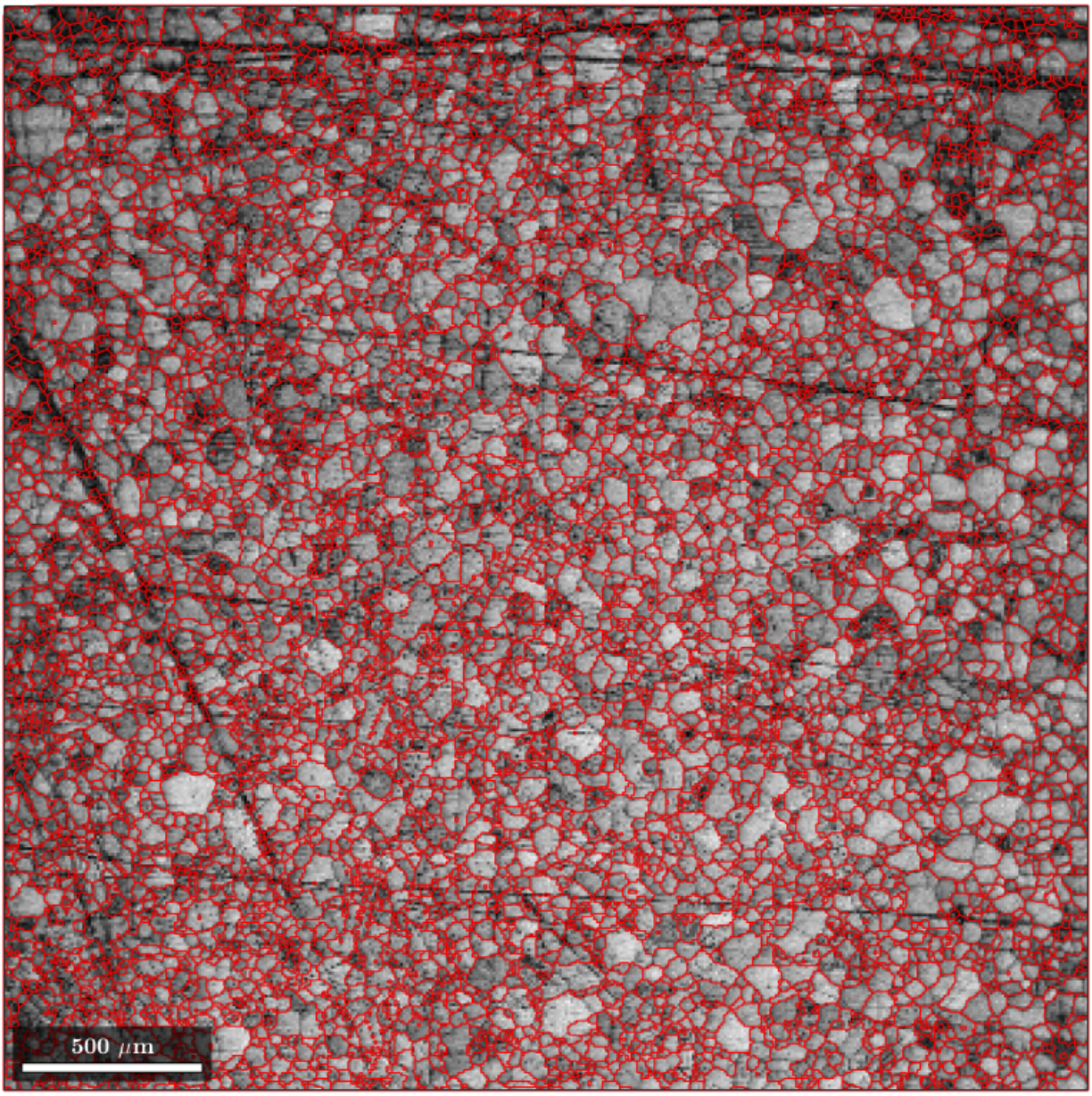

500 μm

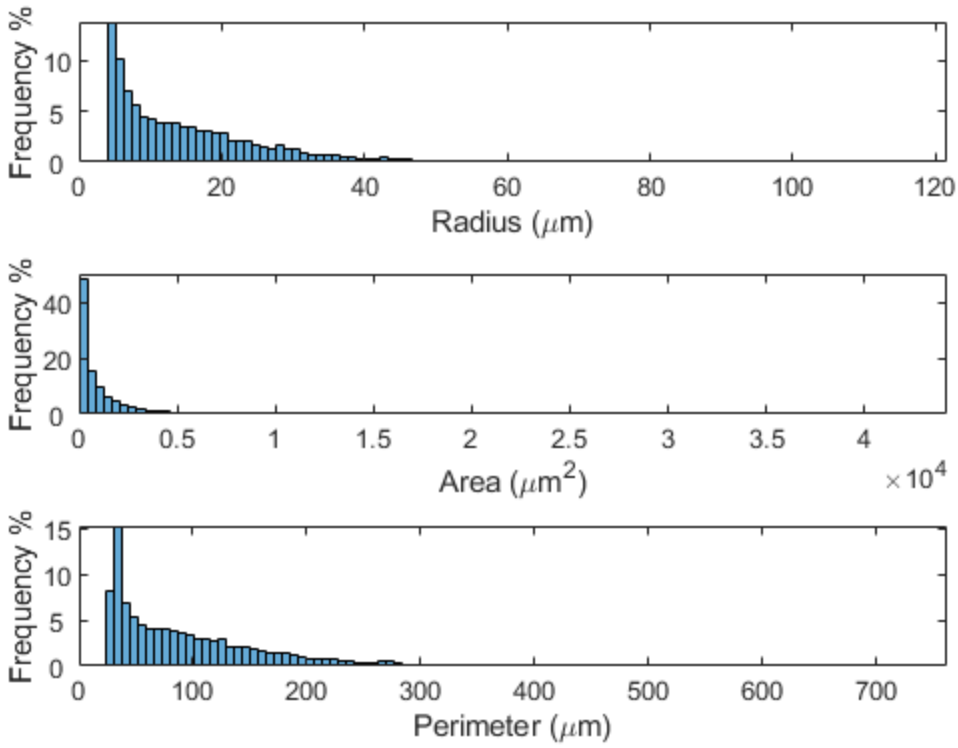


Plot the grain size distributions

```
%extract some different distributions
grain_radius=grains_indexed_int.equivalentRadius;
grain_area=grains_indexed_int.area;
grain_perimeter=grains_indexed_int.equivalentPerimeter;
% for a full list of shapes - https://mtex-toolbox.github.io/
ShapeParameters.html

histogram_bins=100;

figure;
subplot(3,1,1);
```

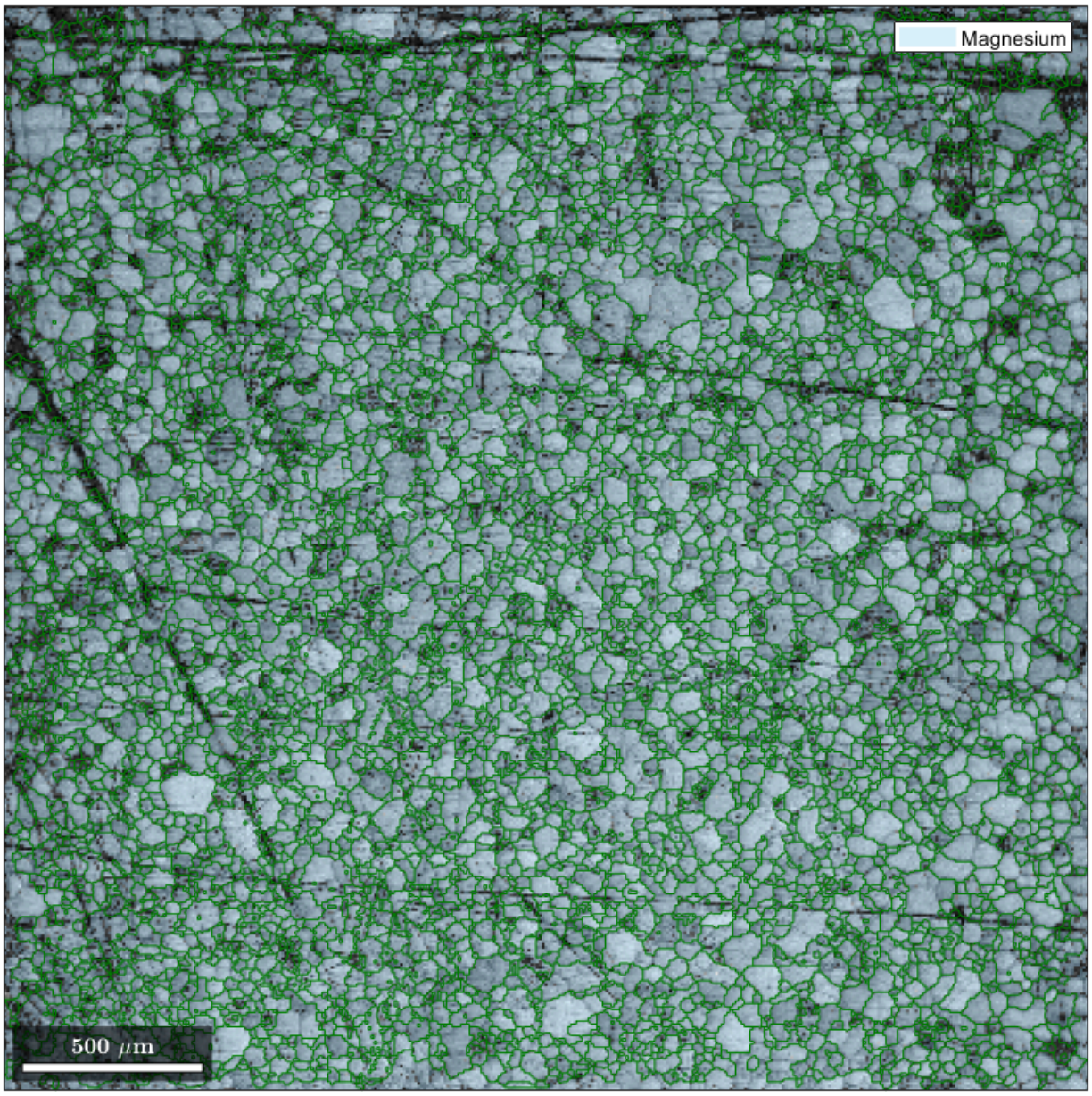
```
histogram(grain_radius,histogram_bins,'Normalization','probability');
%meddle with the displays
ytix = get(gca, 'YTick');
set(gca, 'YTick',ytix, 'YTickLabel',ytix*100);
ylabel('Frequency %'); xlabel('Radius (\mum)')
xlims=xlim; xlim([0 xlims(2)]);

subplot(3,1,2);
histogram(grain_area,histogram_bins,'Normalization','probability');
%meddle with the displays
ytix = get(gca, 'YTick');
set(gca, 'YTick',ytix, 'YTickLabel',ytix*100);
ylabel('Frequency %'); xlabel('Area (\mum^2)')
xlims=xlim; xlim([0 xlims(2)]);

subplot(3,1,3);
histogram(grain_perimeter,histogram_bins,'Normalization','probability');
%meddle with the displays
ytix = get(gca, 'YTick');
set(gca, 'YTick',ytix, 'YTickLabel',ytix*100);
ylabel('Frequency %'); xlabel('Perimeter (\mum)')
xlims=xlim; xlim([0 xlims(2)]);

%are any of these Normally distributed ? If so, have a think about what you
%call an average 'grain size'
```


500 μm



Filter the grain size data

```
%mostly to demo that this can be done

min_grain_radius=10;
grains_reduced=grains_indexed_int(grains_indexed_int.equivalentRadius>min_grain_radius);

figure;
plot(ebsd,ebsd.prop.Band_Contrast); colormap('gray');
hold on;
plot(ebsd,'FaceAlpha','0.3');
hold on;
if exist('mb_length','var'); mp = MTEX_mb_fix(mb_length); end %change the
 micronbar length to make it prettier/easier to read

hold on
plot(grains_reduced.boundary,'linewidth',0.5,'lineColor','g')
hold off
```

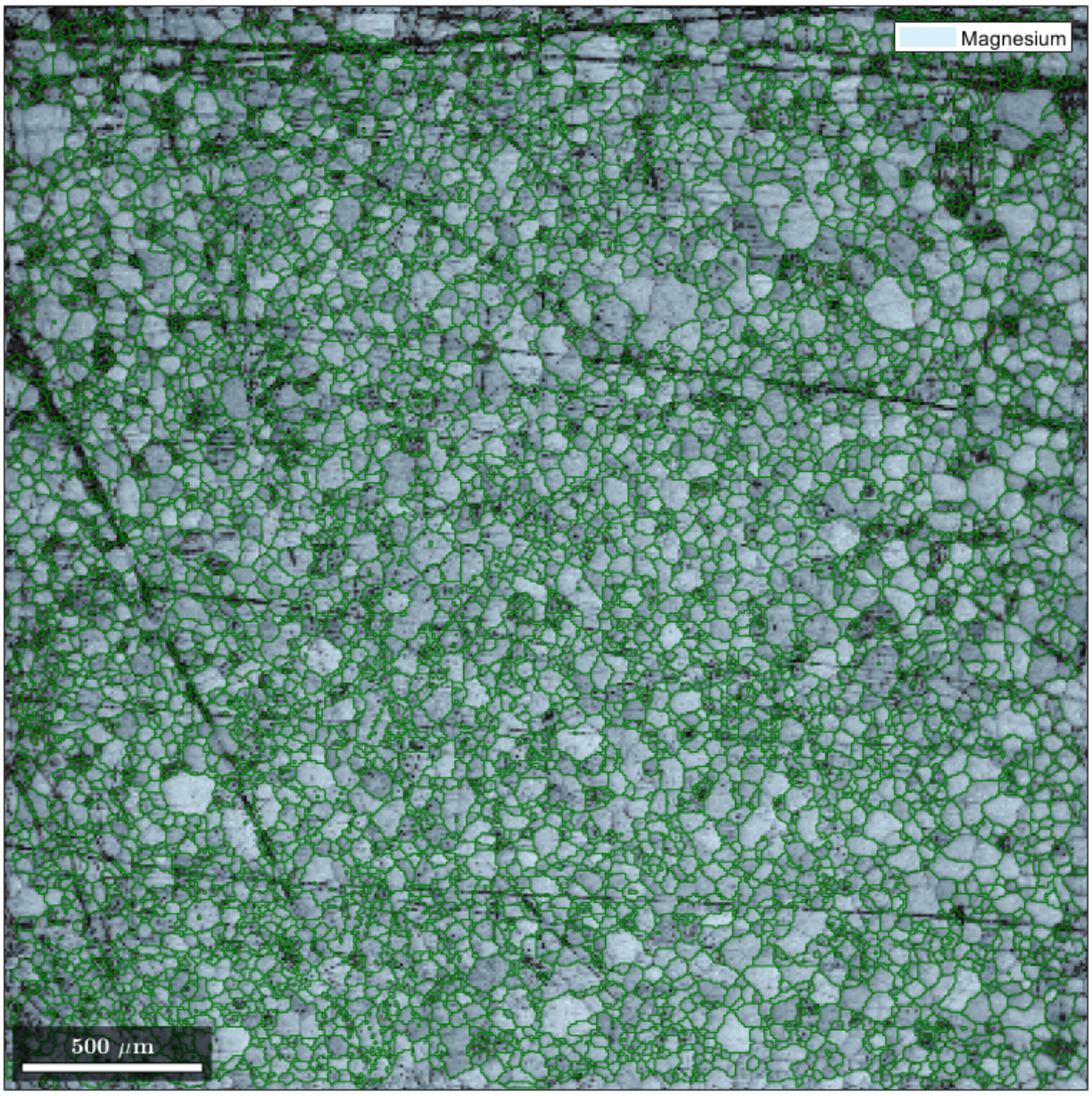


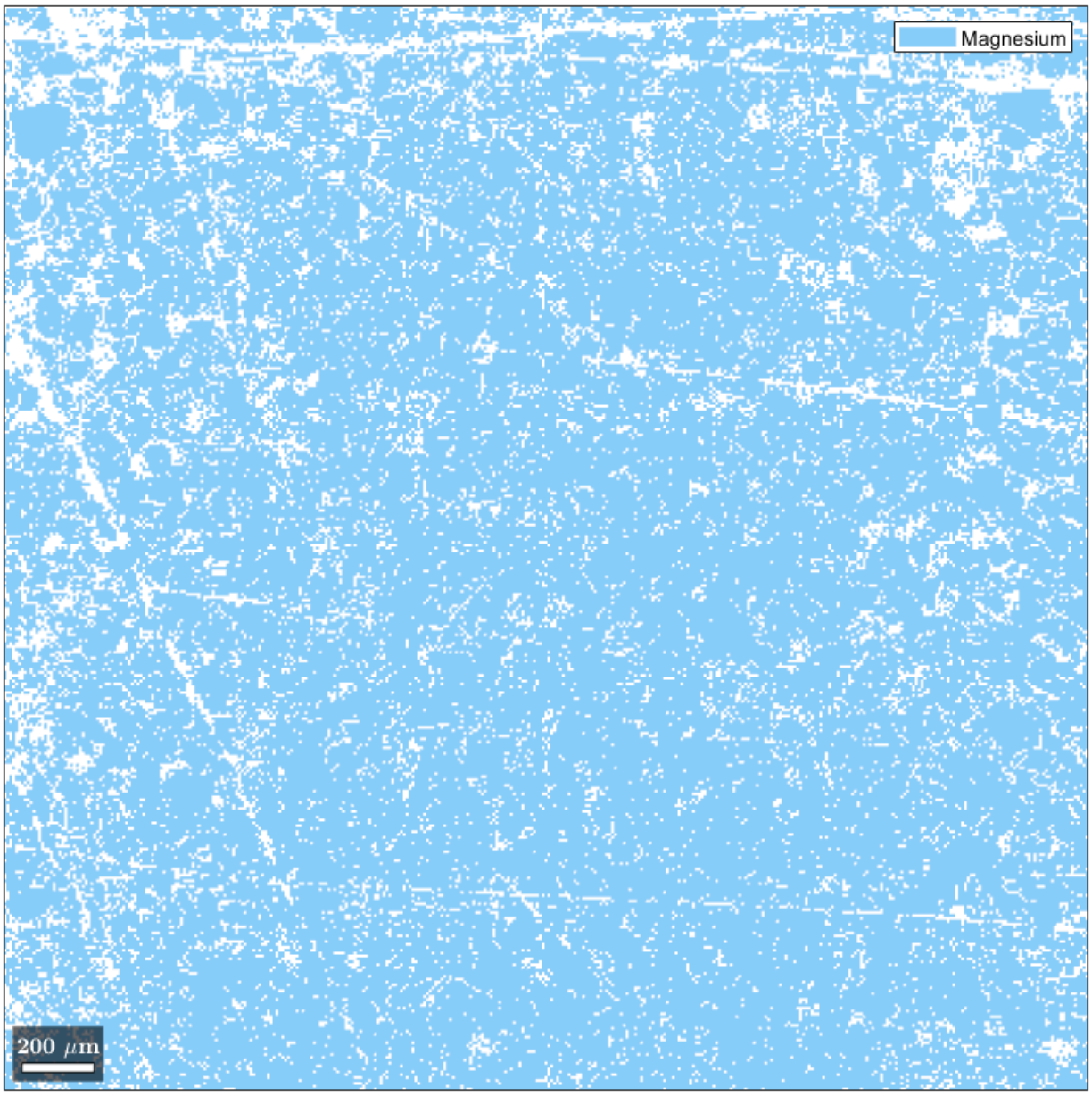
Demonstrate that we can extract a point from this map

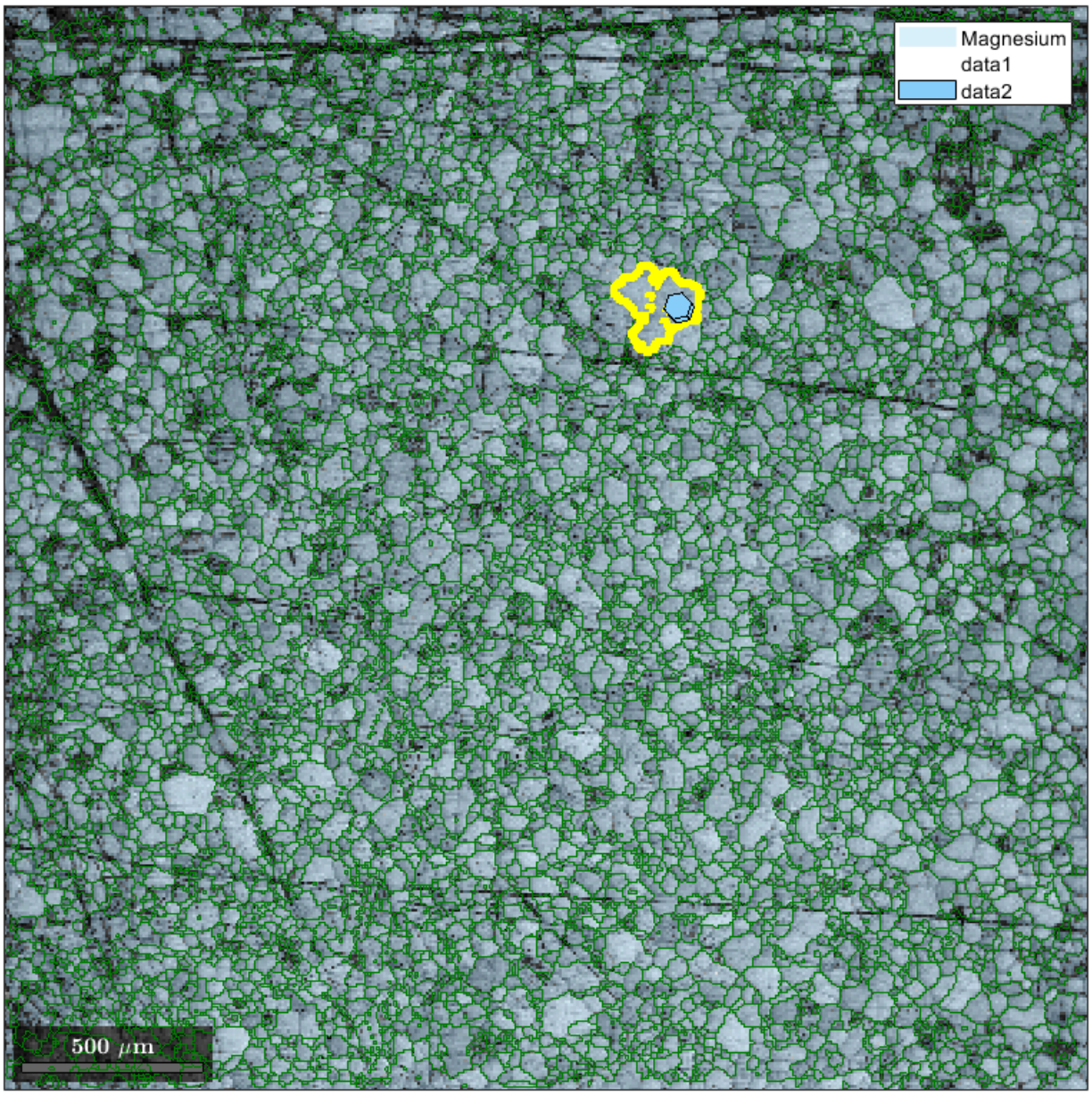
```
%plot the phase data + grain boundaries + bc
figure;
plot(ebsd');

%overlay with Band Contrast
figure;
plot(ebsd,ebsd.prop.Band_Contrast); colormap('gray');
hold on;
plot(ebsd,'FaceAlpha','0.3');
```

```
hold on;
if exist('mb_length','var'); mp = MTEX_mb_fix(mb_length); end %change the
 micronbar length to make it prettier/easier to read

hold on
plot(grains_indexed_int.boundary,'linewidth',0.5,'lineColor','g')
hold off

%take a mouse input
disp('Click a grain to select it')
[x_g,y_g]=ginput(1);

%find the nearest point in the data to this point
p_map=(ebsd.prop.x-x_g).^2+(ebsd.prop.y-y_g).^2;
[mv,pattern_number]=min(p_map);
ebsd_point=ebsd(pattern_number);

hold on;
% % scatter(x_g,y_g,'r');
%mark this point
scatter(ebsd_point.x,ebsd_point.y,'w');

%plot the grain for this
hold on
plot(grains(ebsd_point.x,ebsd_point.y).boundary,'linewidth',4,'linecolor','y')
hold off

%plot the crystal shape for this point
hold on
scaling = 100; % scale the crystal shape to have a nice size
%here we use a hexagon, but you could use a cube for cubic
%crystalShape.cube
cS = crystalShape.hex(ebsd(mineral_name).CS);
plot(ebsd(pattern_number).prop.x,ebsd(pattern_number).prop.y,50,
 ebsd(pattern_number).orientations * cS * scaling)
hold off
```

Click a grain to select it


Magnesium
500 μm


Magnesium
200 μm

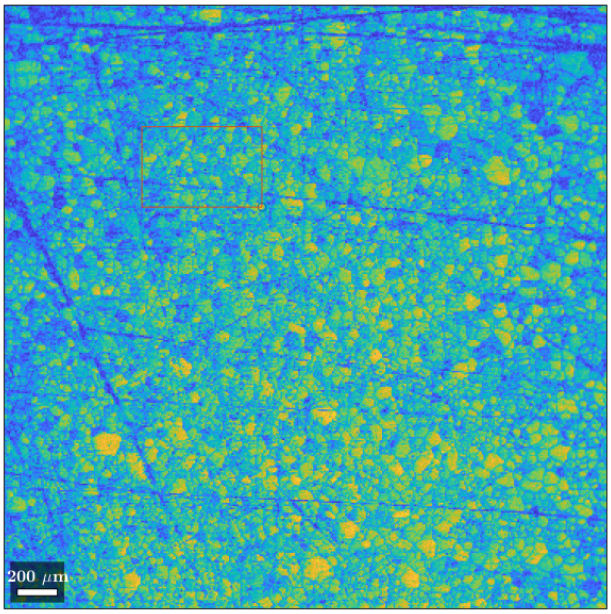


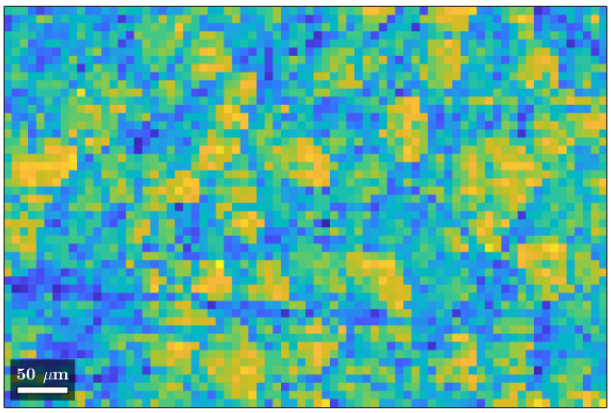
Extract a subset of the map

```
figure;
plot(ebsd,ebsd.prop.Band_Contrast)

%here we will use a mouse click pair to cut out the box - pick two opposite
%diagonals
disp('Click two diagonal points to select a box to subset the data')
[x_i,y_i]=ginput(2);

% x_i=[-918;-205];
% y_i=[572;1010];
```

```
hold on;
scatter(x_i,y_i);

x_i=sort(x_i); y_i=sort(y_i);
box_bounds=[x_i(1),x_i(2),x_i(2),x_i(1),x_i(1);y_i(1),y_i(1),y_i(2),y_i(2),y_i(1)];
plot(box_bounds(1,:),box_bounds(2,:));
points_box=inpolygon(ebsd,box_bounds');
ebsd_small=ebsd(points_box);

nextAxis;
plot(ebsd_small,ebsd_small.prop.Band_Contrast);
```

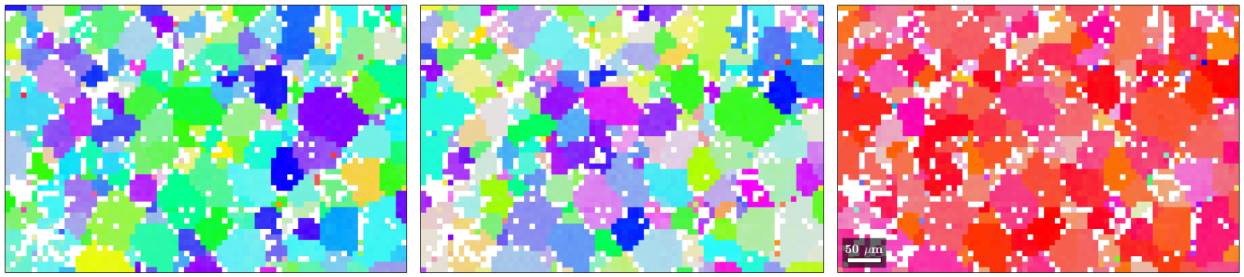
Click two diagonal points to select a box to subset the data





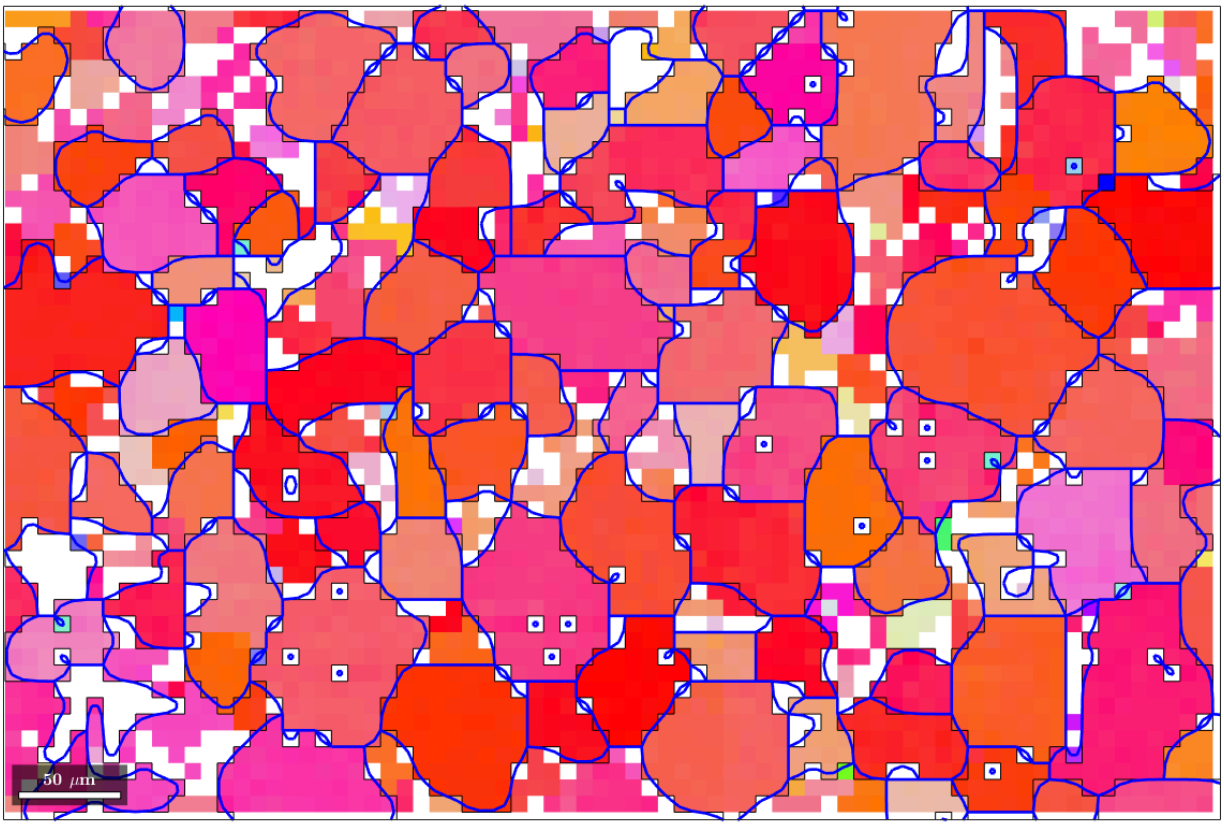
For this smaller region, plot all the IPFs

```
ipfKey2 = ipfHSVKey(ebsd_small(mineral_name));

ipfKey2.inversePoleFigureDirection = vector3d.X;
colors_X2 = ipfKey2.orientation2color(ebsd_small(mineral_name).orientations);
ipfKey2.inversePoleFigureDirection = vector3d.Y;
colors_Y2 = ipfKey2.orientation2color(ebsd_small(mineral_name).orientations);
ipfKey2.inversePoleFigureDirection = vector3d.Z;
colors_Z2 = ipfKey2.orientation2color(ebsd_small(mineral_name).orientations);

%now plot the three IPF coloured maps
figure;
plot(ebsd_small(mineral_name),colors_X2,'micronbar','off');
nextAxis
plot(ebsd_small(mineral_name),colors_Y2,'micronbar','off');
nextAxis
plot(ebsd_small(mineral_name),colors_Z2,'micronbar','on');
```



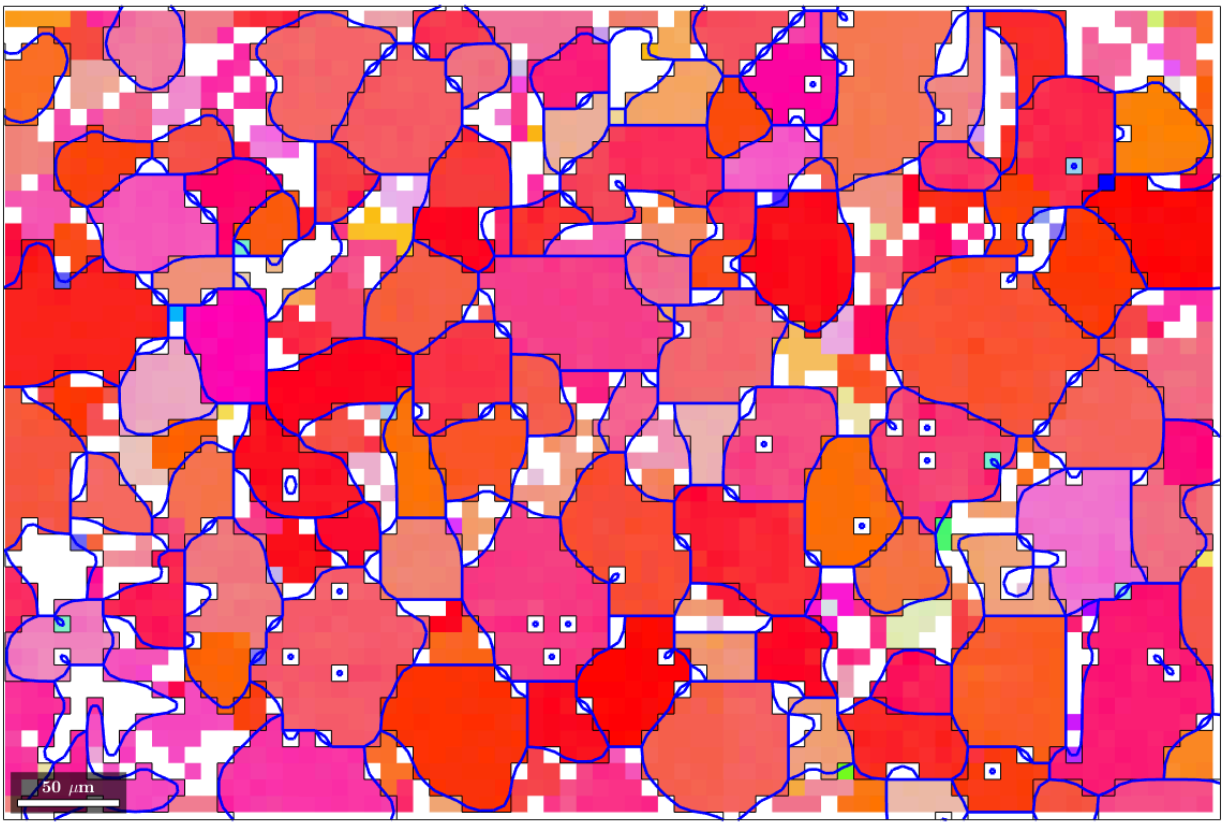
extract the grain data from the big map that fits within this smaller map

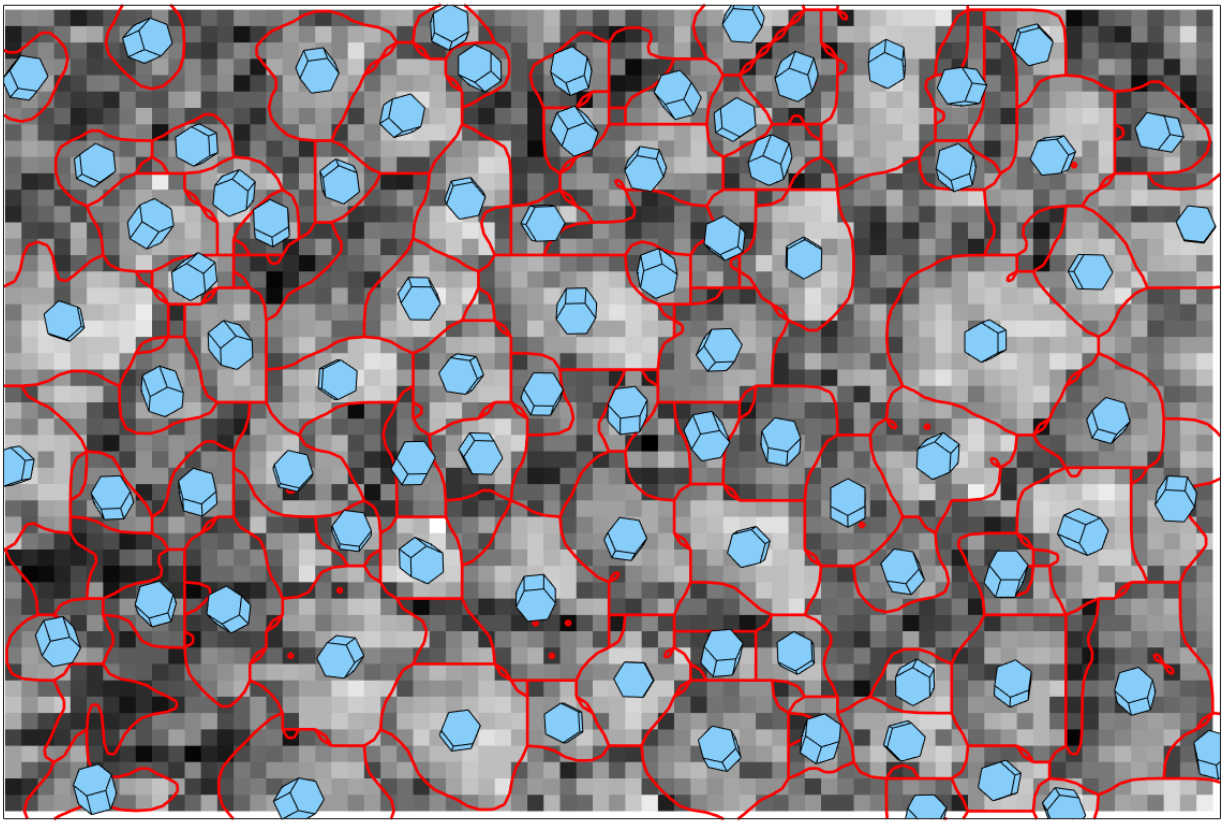
```
grains_small_ID=inpolygon(grains,box_bounds');
grains_small=grains(grains_small_ID);
grains_small=grains_small(grains_small.grainSize>10); %at least 10 pts per
 grain

figure;
plot(ebsd_small(mineral_name),colors_Z2,'micronbar','on');

hold on
plot(grains_small.boundary,'linewidth',0.5,'lineColor','k')
hold off

%smooth these boundaries - note smoothing changes the data and its statistics
% see -  https://mtex-toolbox.github.io/GrainSmoothing.html
% grains_smooth = smooth(grains_small); %single pass
grains_smooth = smooth(grains_small,5); %5 iterations
% see https://mtex-toolbox.github.io/GrainSmoothing.html

hold on
plot(grains_smooth.boundary,'linewidth',2,'lineColor','b')
hold off

%fix the bounding edges
xlim(x_i); ylim(y_i);
```



Plot a subset map with the unit cells over the top

```
figure;
plot(ebsd_small,ebsd_small.prop.Band_Contrast,'micronbar','off'); %the scale
 bar is turned off because we are going to make it hard to see
colormap('gray');
hold on
plot(grains_smooth.boundary,'linewidth',2,'lineColor','r')

% plot the unit cells
%plot the crystal shape for this point
scaling = 25; % scale the crystal shape to have a nice size
%here we use a hexagon, but you could use a cube for cubic
%crystalShape.cube
cS = crystalShape.hex(grains_small(mineral_name).CS);
grain_centroids=grains_small.centroid;
plot(grain_centroids(:,1),grain_centroids(:,2),50,
 grains_small.meanOrientation * cS * scaling)

%fix the bounding edges
xlim(x_i); ylim(y_i);
```


50 μm



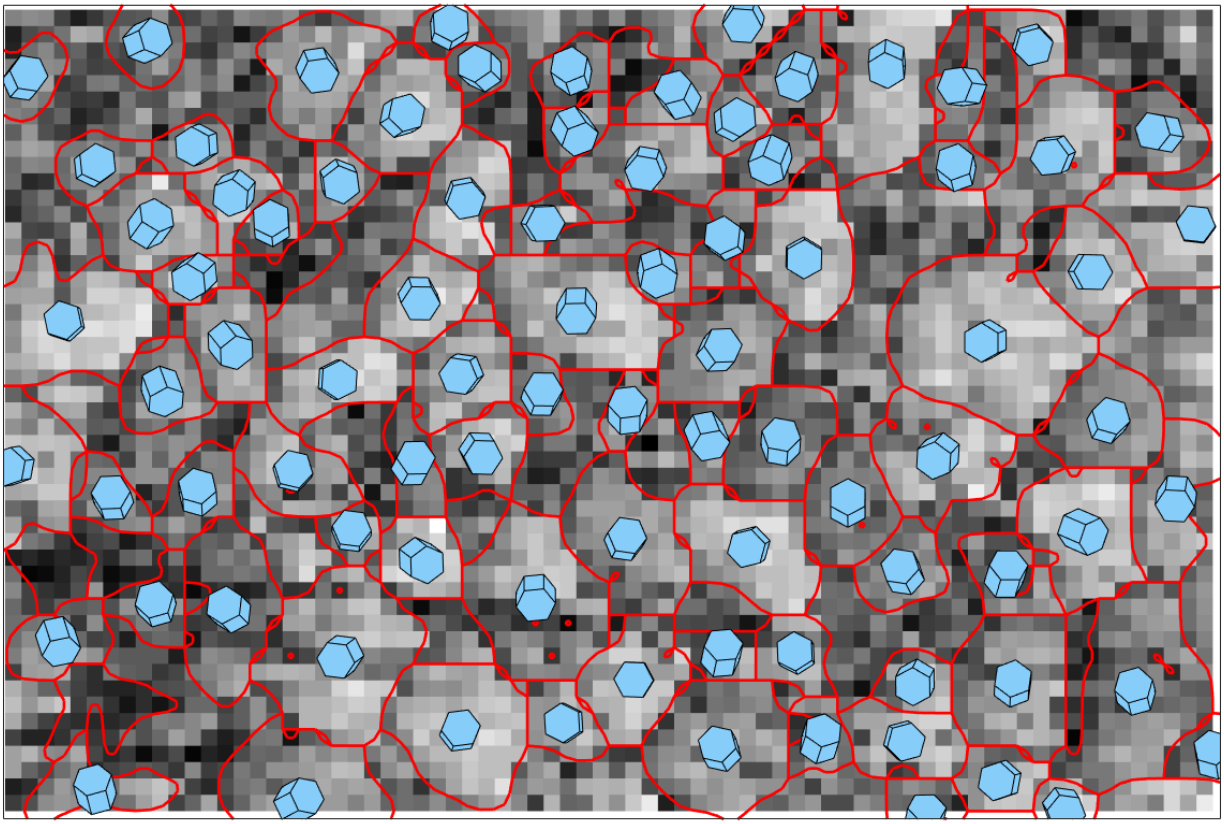
Select an individual grain for texture based segmentation

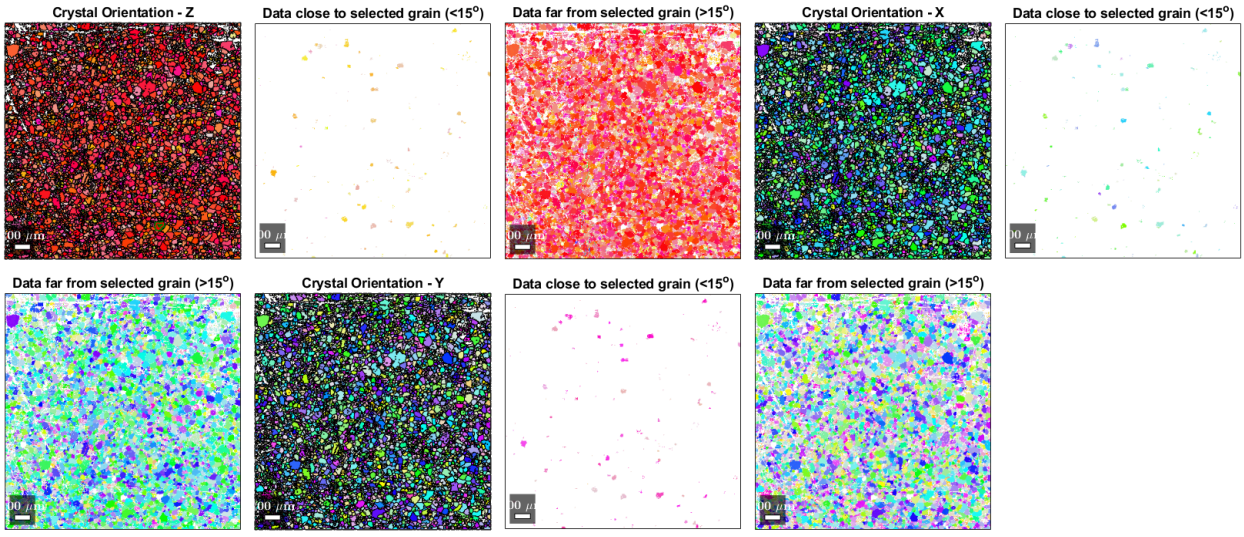
use grains(x,y) to select a grain from a map based on x and y coordinates grain_selected = grains(200,500);

```
%3 check you have the right grain by plotting, then calculate the mean
%orientation

%create a container for EBSD phase 1 (alpha - HCP)
ebsd_2=ebsd(mineral_name);

% figure('Position',PlotData.ssize);
figure;
subplot(1,3,1);
ipfKey.inversePoleFigureDirection = vector3d.Z;
plot(grains(mineral_name),ipfKey.orientation2color(grains(mineral_name).meanOrientation));
title('Crystal Orientation - Z')


% take a mouse input
disp('Select an individual grain as your seed grain orientation');
 [x,y]=ginput(1);

% % hard code the mouse input to run this - swap the commenting around
% % if you want a ginput
% % hard coded position, in um
% x=1379; y=1331;

%add the point to the figure as a black spot
hold on;
scatter(x,y,100,'k','filled');

% find the corresponding grain
grain_sel = grains(x,y);

plot(grain_sel.boundary,'linecolor','g','LineWidth',3,'parent',gca)
plot(grain_sel.boundary,'linecolor','r','LineWidth',1,'parent',gca)
hold off

orientation_threshold=15; %in degrees
% Segment EBSD Cubes based on grain orientation
%1 Define a fibre
% fibre_test = fibre(Miller(1,1,0,ebsd(phase1).CS),yvector);
%2 Extract Orientations using angle function to within 20 degrees of the fibre
 axis (generates a logical array)
test_orientations_2 =
 angle(ebsd_2.orientations,grain_sel.meanOrientation,'antipodal')<orientation_threshold*de
 20 degrees is arbitary
% test_orientations_2 =
 angle(ebsd_2.orientations,fibre_test,'antipodal')<20*degree;

%3 Segment original cube based on Phase (can only do this with one phase)
```

```
test_orientations_in = ebsd_2(test_orientations_2 == 1);
test_orientations_out = ebsd_2(test_orientations_2 == 0);

%5 Plot to check
nextAxis;
plot(test_orientations_in,
 ipfKey.orientation2color(test_orientations_in.orientations));
title(['Data close to selected grain (<'
 int2str(orientation_threshold) '^o)'])
nextAxis;
plot(test_orientations_out,
 ipfKey.orientation2color(test_orientations_out.orientations));
title(['Data far from selected grain (>'
 int2str(orientation_threshold) '^o)'])

ipfKey.inversePoleFigureDirection = vector3d.X;
nextAxis;
plot(grains(mineral_name),ipfKey.orientation2color(grains(mineral_name).meanOrientation));
title('Crystal Orientation - X')
nextAxis;
plot(test_orientations_in,
 ipfKey.orientation2color(test_orientations_in.orientations));
title(['Data close to selected grain (<'
 int2str(orientation_threshold) '^o)'])
nextAxis;
plot(test_orientations_out,
 ipfKey.orientation2color(test_orientations_out.orientations));
title(['Data far from selected grain (>'
 int2str(orientation_threshold) '^o)'])

ipfKey.inversePoleFigureDirection = vector3d.Y;
nextAxis;
plot(grains(mineral_name),ipfKey.orientation2color(grains(mineral_name).meanOrientation));
title('Crystal Orientation - Y')
nextAxis;
plot(test_orientations_in,
 ipfKey.orientation2color(test_orientations_in.orientations));
title(['Data close to selected grain (<'
 int2str(orientation_threshold) '^o)'])
nextAxis;
plot(test_orientations_out,
 ipfKey.orientation2color(test_orientations_out.orientations));
title(['Data far from selected grain (>'
 int2str(orientation_threshold) '^o)'])
```

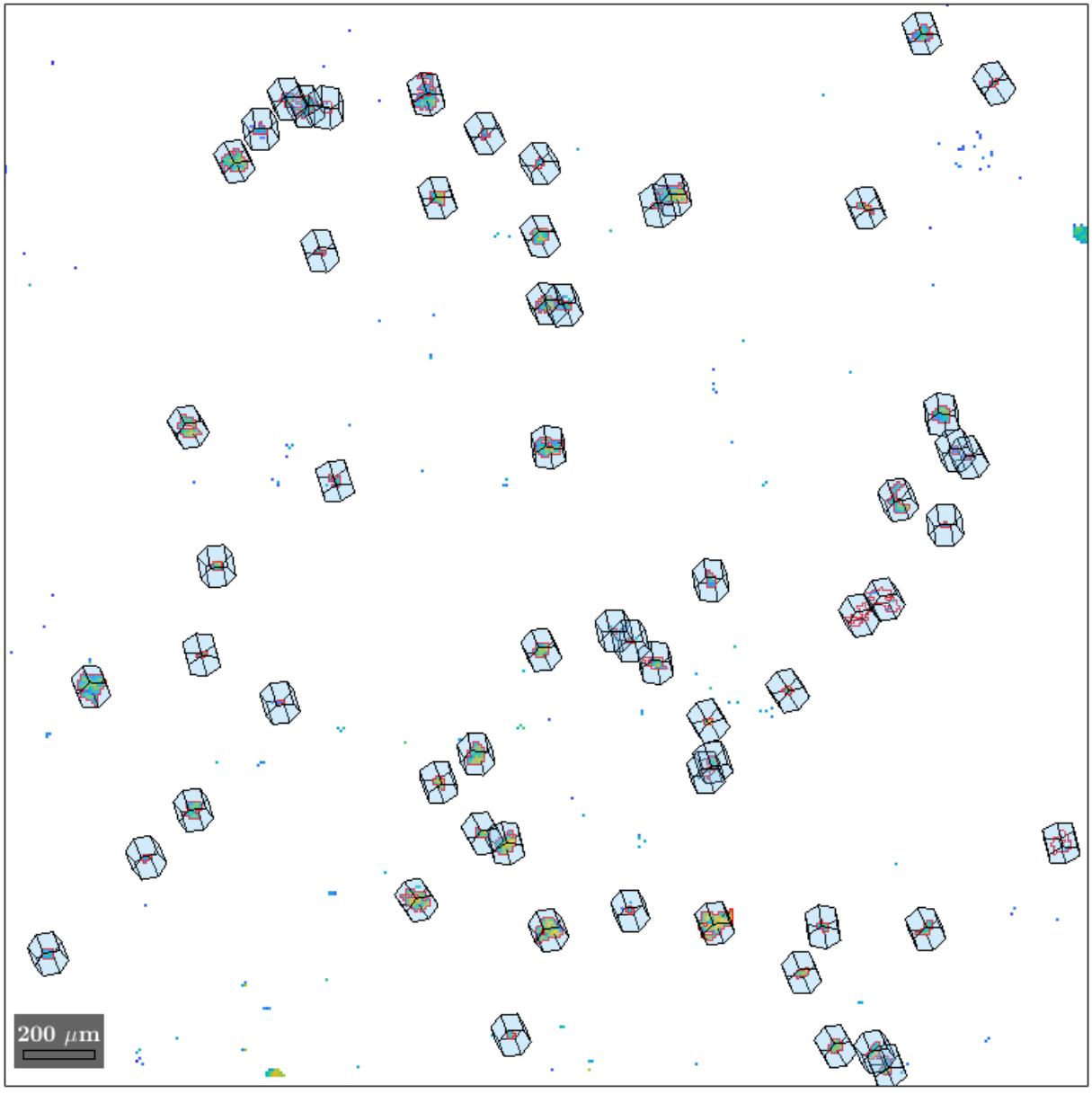
Select an individual grain as your seed grain orientation






```
grain_IDs_close=unique(test_orientations_in.grainId);
grains_close=grains(grain_IDs_close);
grains_close=grains_close(grains_close.grainSize>3);
grains_close=grains_close(~grains_close.isBoundary);

figure;
plot(test_orientations_in, test_orientations_in.prop.Band_Contrast);
% title(['Data far from selected grain (>' int2str(orientation_threshold)
 '^o)'])
```

```
hold on
plot(grains_close.boundary,'linewidth',1,'lineColor','r')

% plot the unit cells
%plot the crystal shape for this point
scaling = 125; % scale the crystal shape to have a nice size
%here we use a hexagon, but you could use a cube for cubic
%crystalShape.cube
cS = crystalShape.hex(grains_close(mineral_name).CS);
grain_centroids=grains_close.centroid;
plot(grain_centroids(:,1),grain_centroids(:,2),50,
 grains_close.meanOrientation * cS * scaling,'FaceAlpha',0.2); %make the
 hexagons also transparent so you can see the grains behind
```



copy this m file over, for archival purposes

```
mf_long=mfilename('fullpath');
[f1,f2,f3]=fileparts(mf_long);
mf_start=[mf_long '.m'];
mf_end=fullfile(resultsdir,[f2 '.m']);
try
copyfile(mf_start,mf_end)
catch
    warning('m file not saved, likely due to spaces in the file name');
end
```

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