Twin/host classification as seen from a geologist’s perspective

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Presented at the MTEX 2021 workshop in the «online» location of Chemnitz

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Department of Geoscience and Petroleum

Norwegian University of Science and Technology

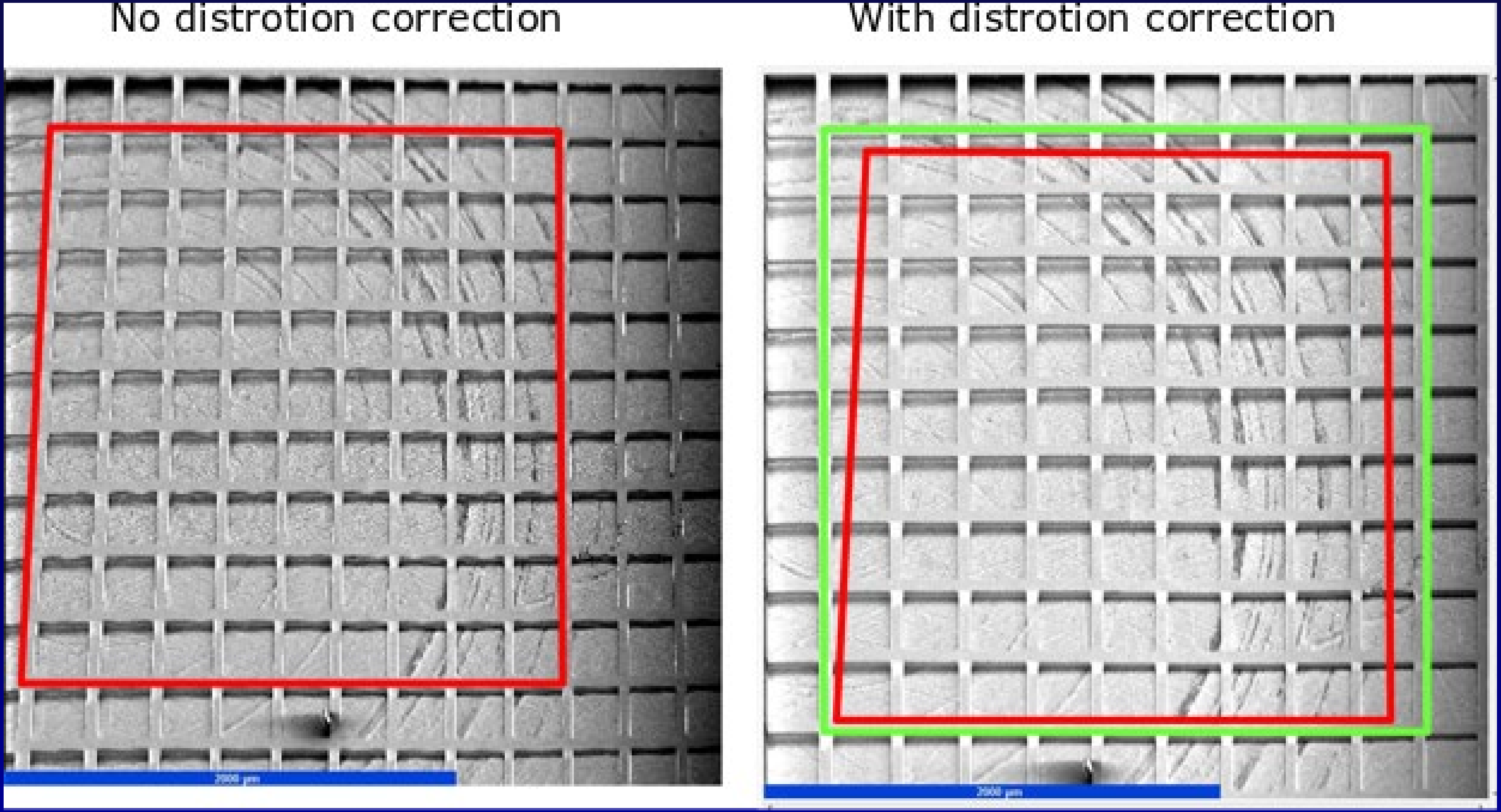
Trapezoidal scan correction

Step 1: Use a regular grid, where a square is a square

Should be aligned with stage movement first!

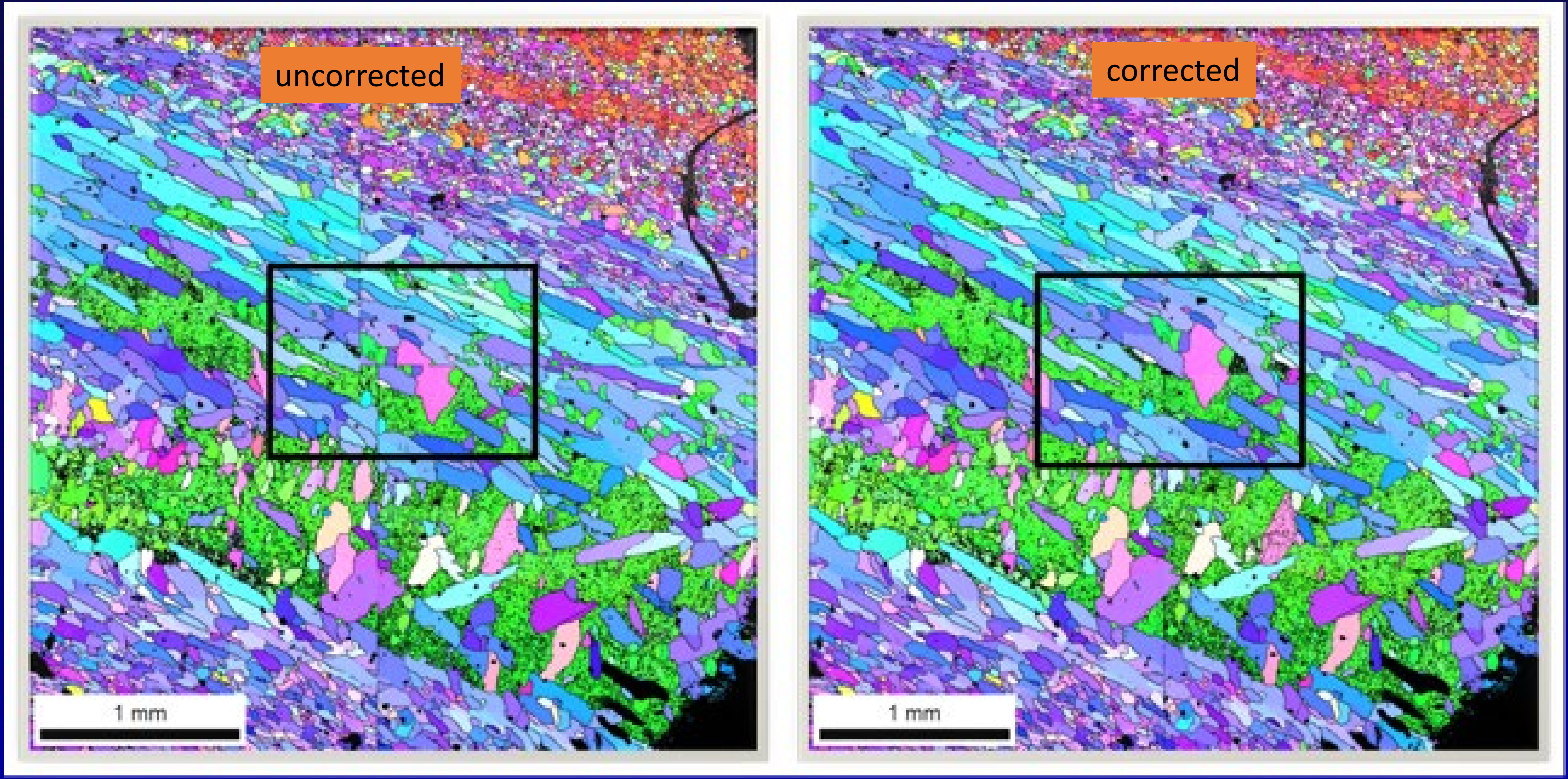
Collect SEM image at the desired: magnification, working distance and acceleration voltage

Dynamic focus is essential to adjust correct!

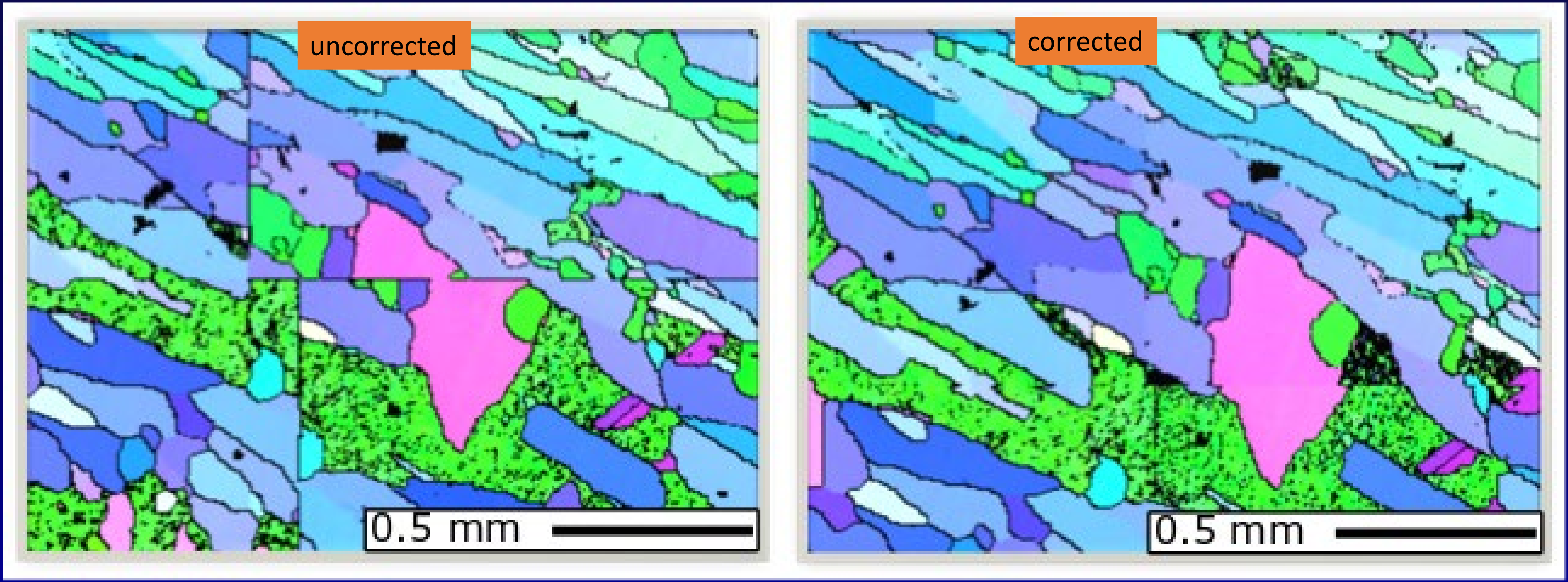


https://iopscience.iop.org/article/10.1088/1757-899X/891/1/012021/meta

Trapezoidal scan correction



Trapezoidal scan correction



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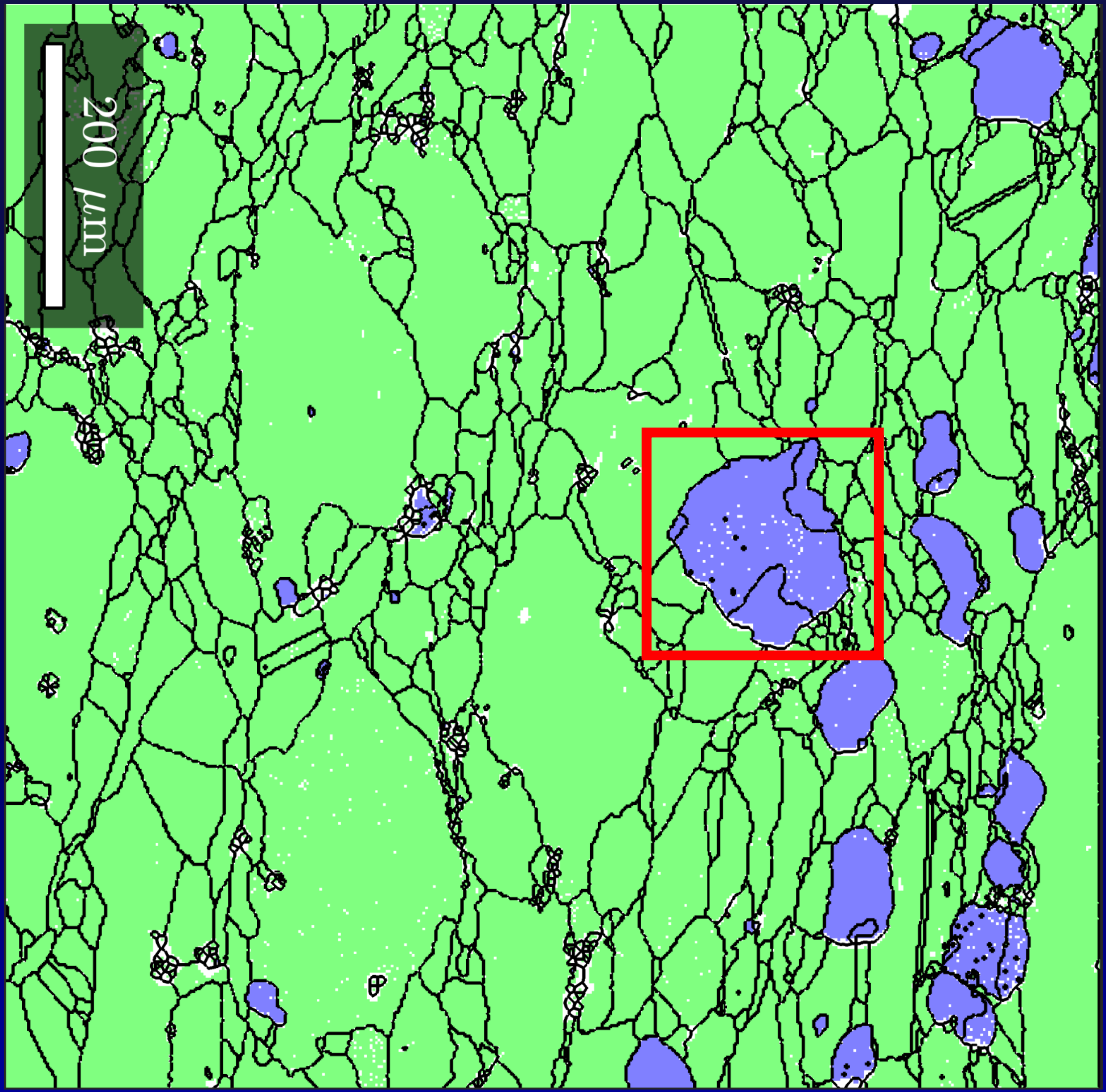

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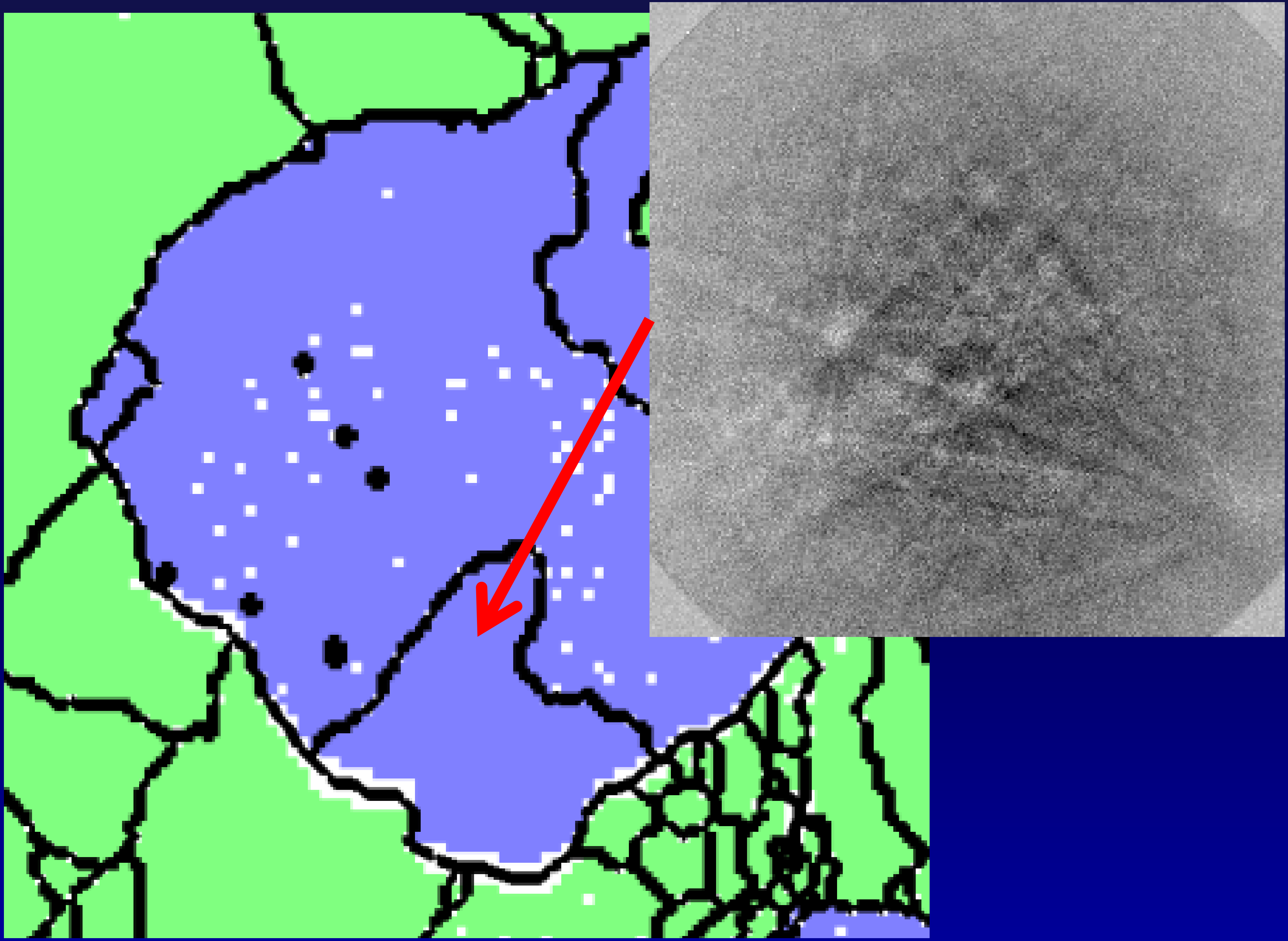

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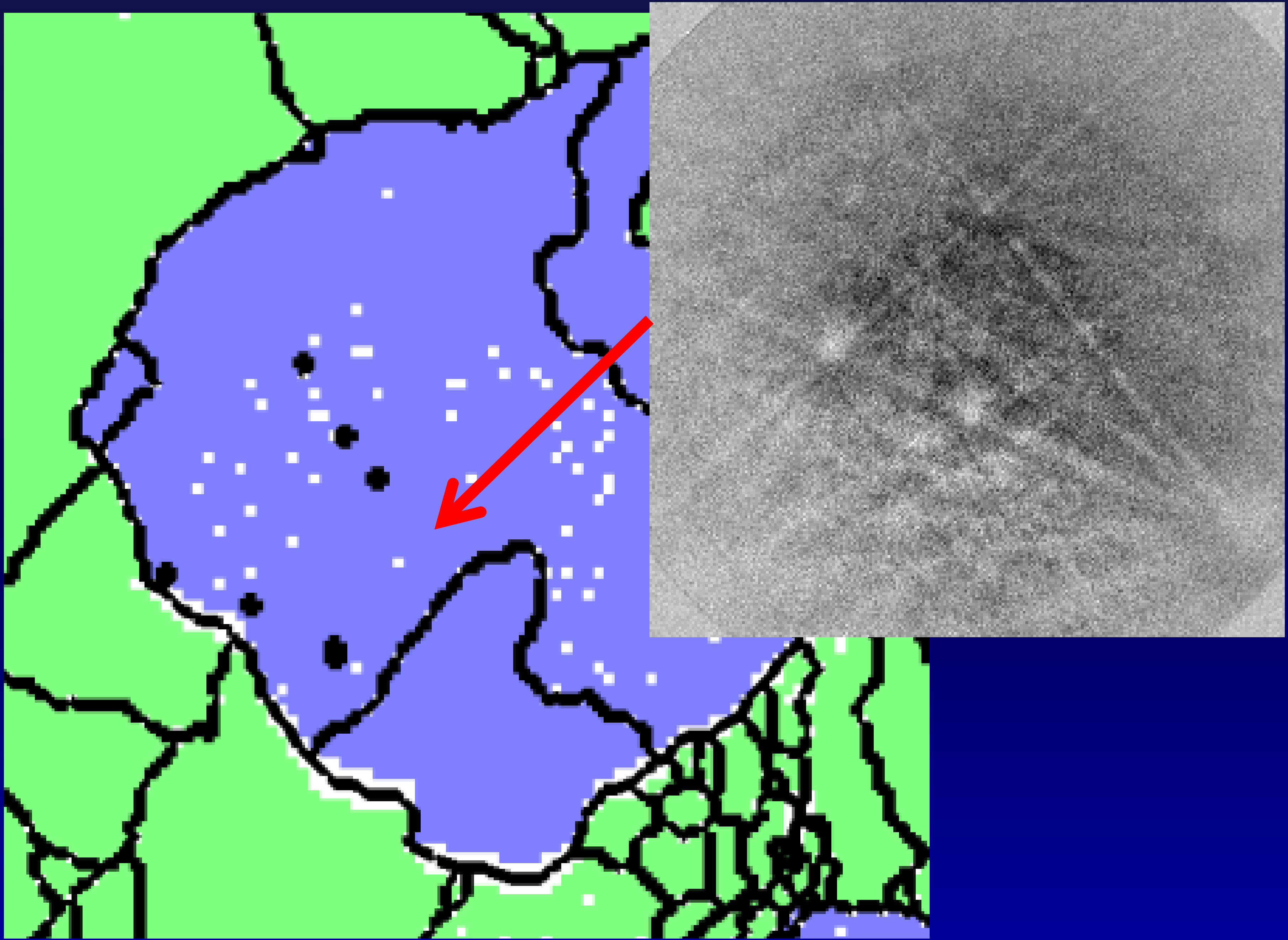

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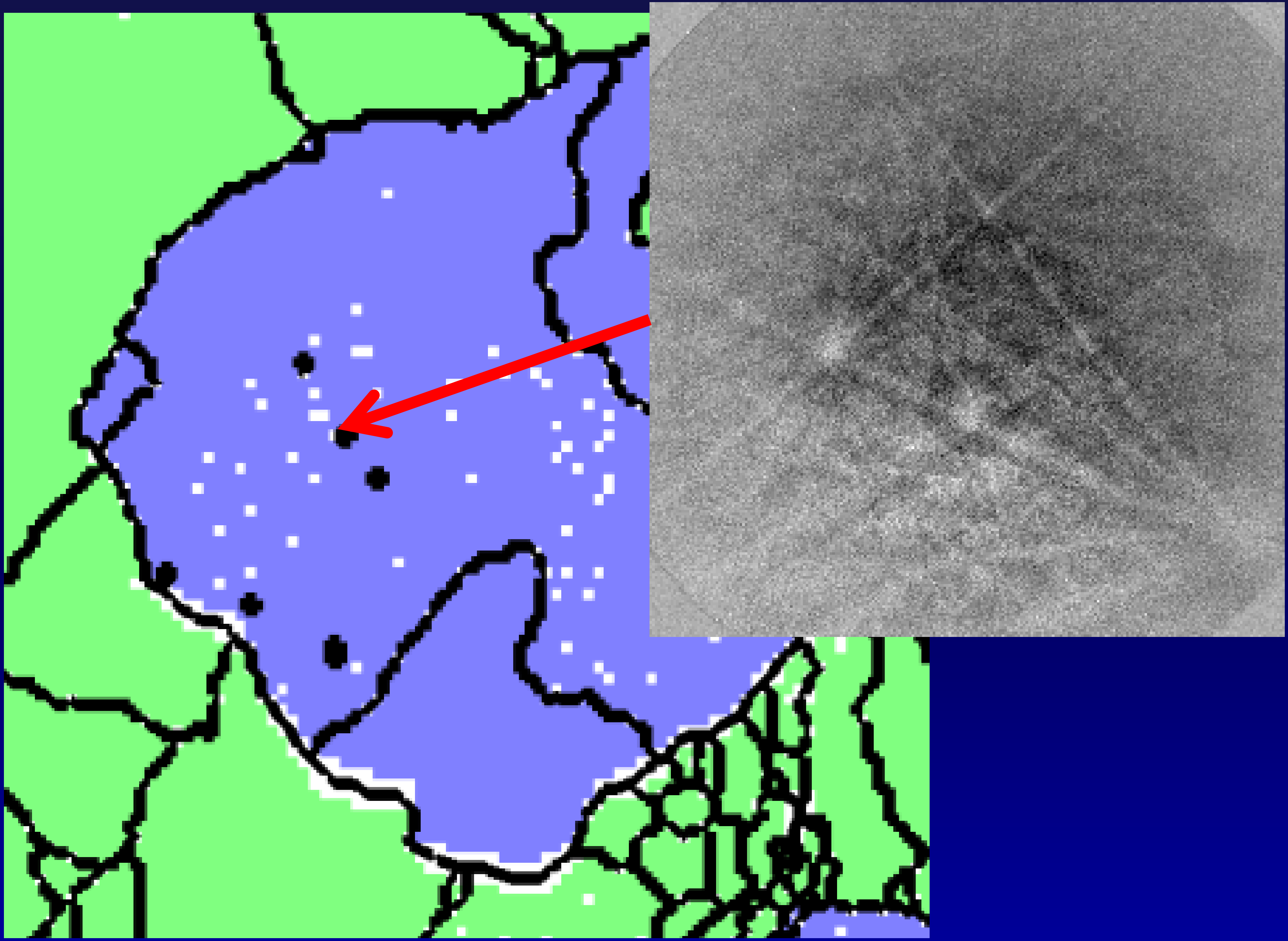


https://iopscience.iop.org/article/10.1088/1757-899X/891/1/012021/meta

Data presented are from:

Syn-orogenic exhumation of high-P units by upward extrusion in an accretionary wedge: Insights from the Eastern Elba nappe stack (Northern Apennines, Italy)

1 Eric Ryan (Department of Geosciences and Petroleum, Norwegian University of Science and Technology - NTNU)

2 Samuele Papeschi (University of Pisa)

3 Giulio Viola (Dipartimento di Scienze Biologiche, Geologiche ed Ambientali, Università degli Studi di Bologna) (corr-auth)

4 Giovanni Musumeci (Dipartimento di Scienze della Terra, Università di Pisa)

5 Francesco Mazzarini (Istituto Nazionale di Geofisica e Vulcanologia - Pisa)

6 Espen Torgersen (Geological Survey of Norway)

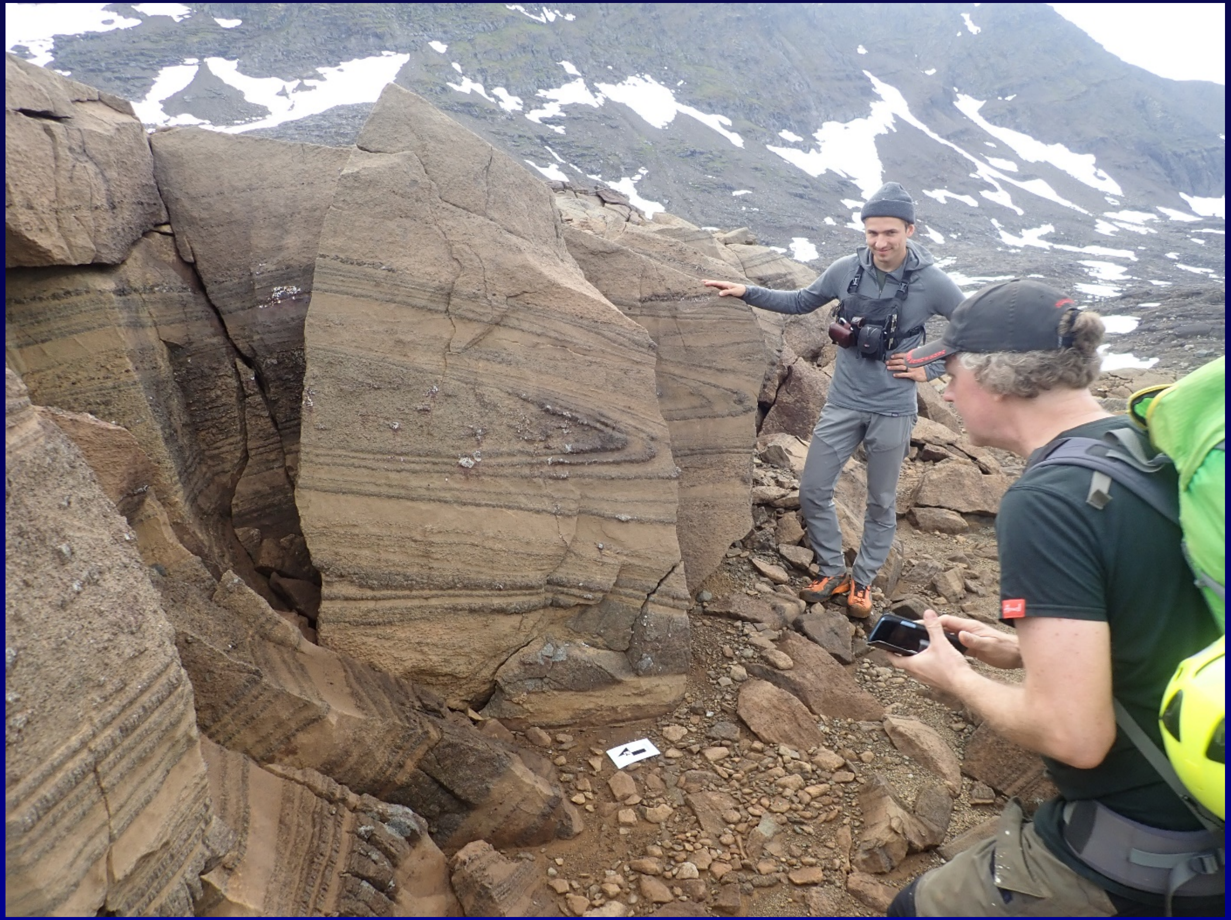
7 Bjørn Eske Sørensen (Department of Geoscience and Petroleum, Norwegian University of Technology and Science)

8 Morgan Ganerød (Geological Survey of Norway)

Host/twin determination

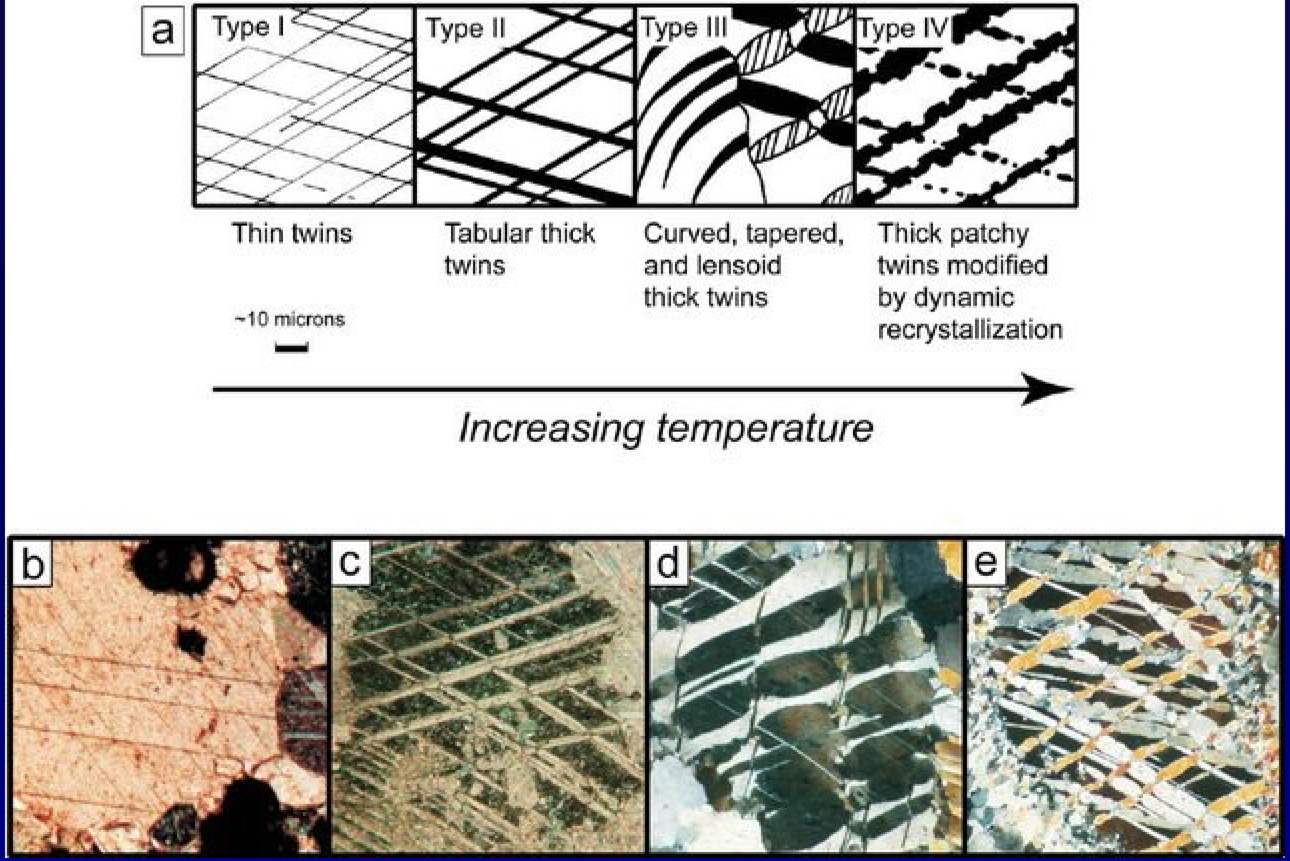
- Why?

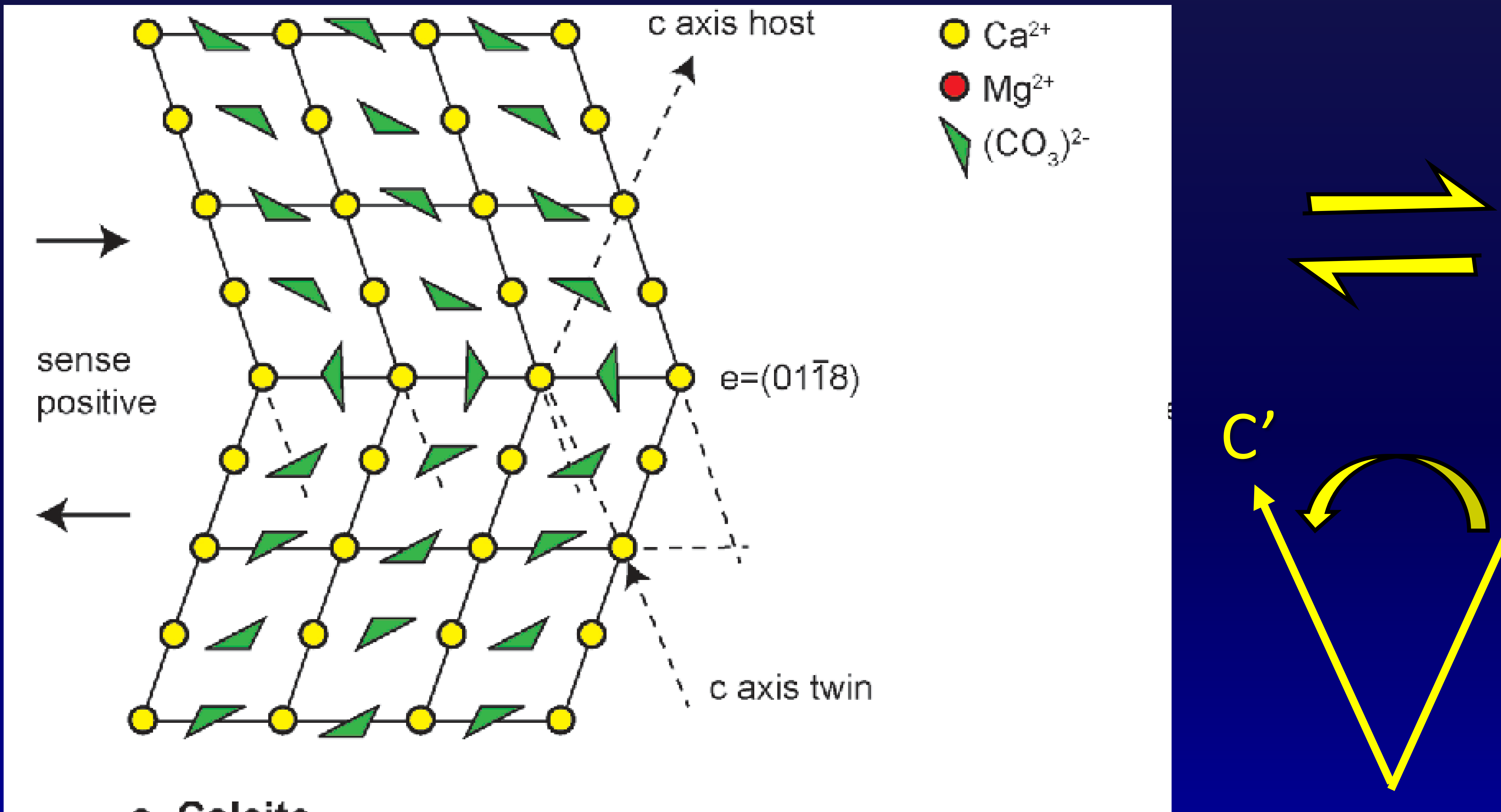
The large scale reference frame



Example Calcite

- E-twins easily form when calcite is subject to external stress, even at room temperature

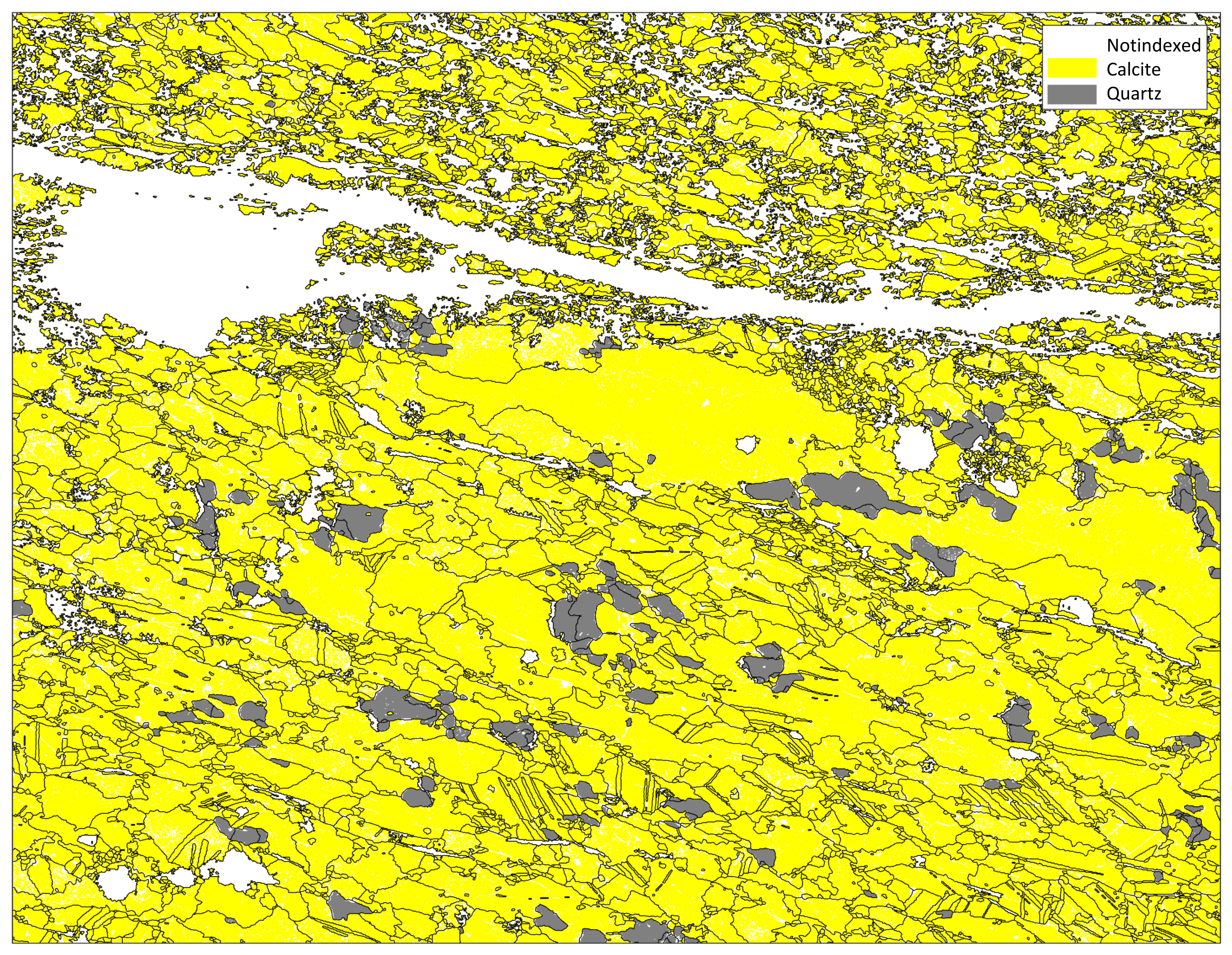

a
Type I
Type II
Type III
Type IV
Thin twins
Tabular thick twins
Curved, tapered, and lensoid thick twins
Thick patchy twins modified by dynamic recrystallization
~10 microns
Increasing temperature
b
c
d
e

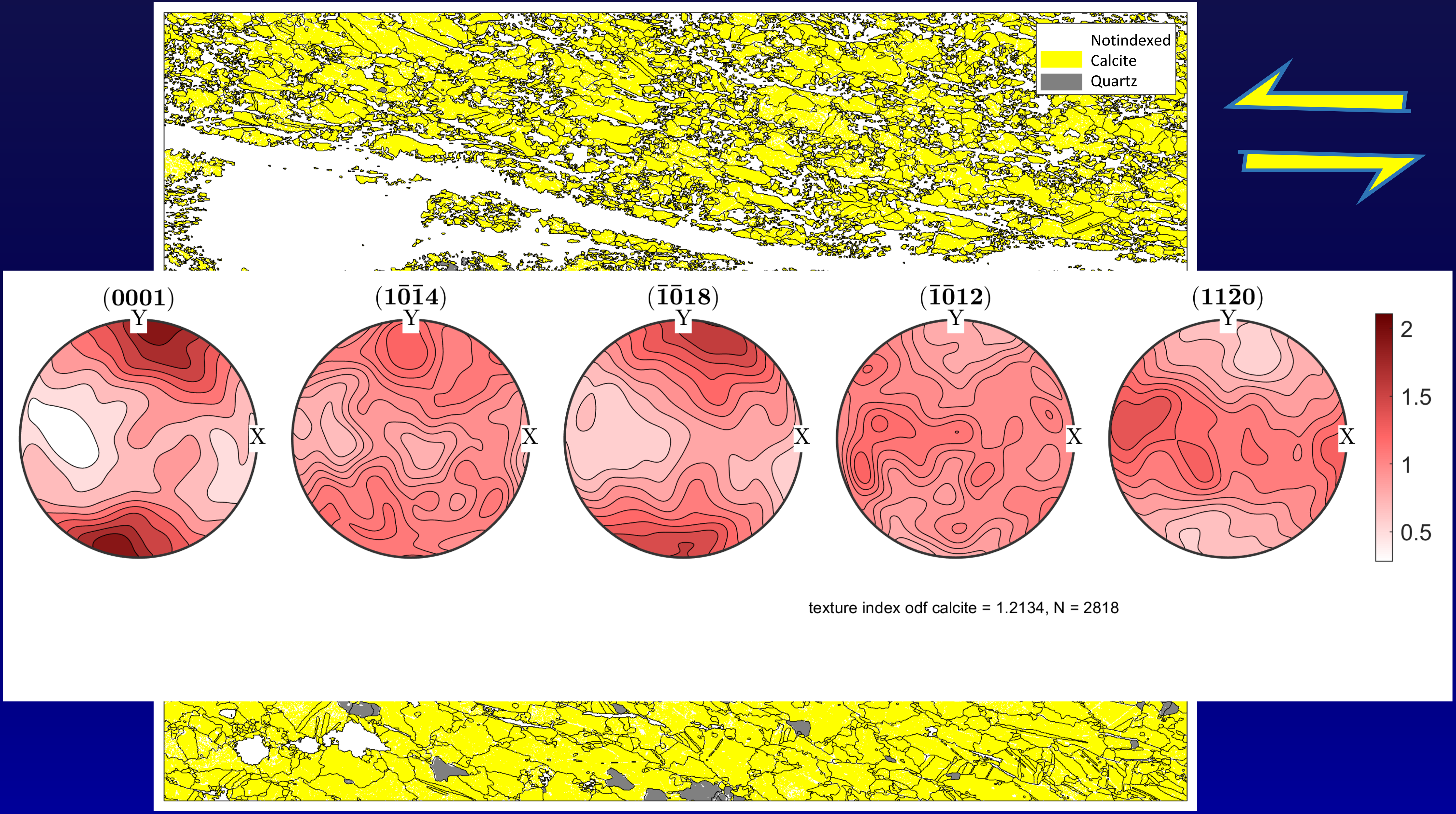


•DOI:10.5474/geologija.2018.005

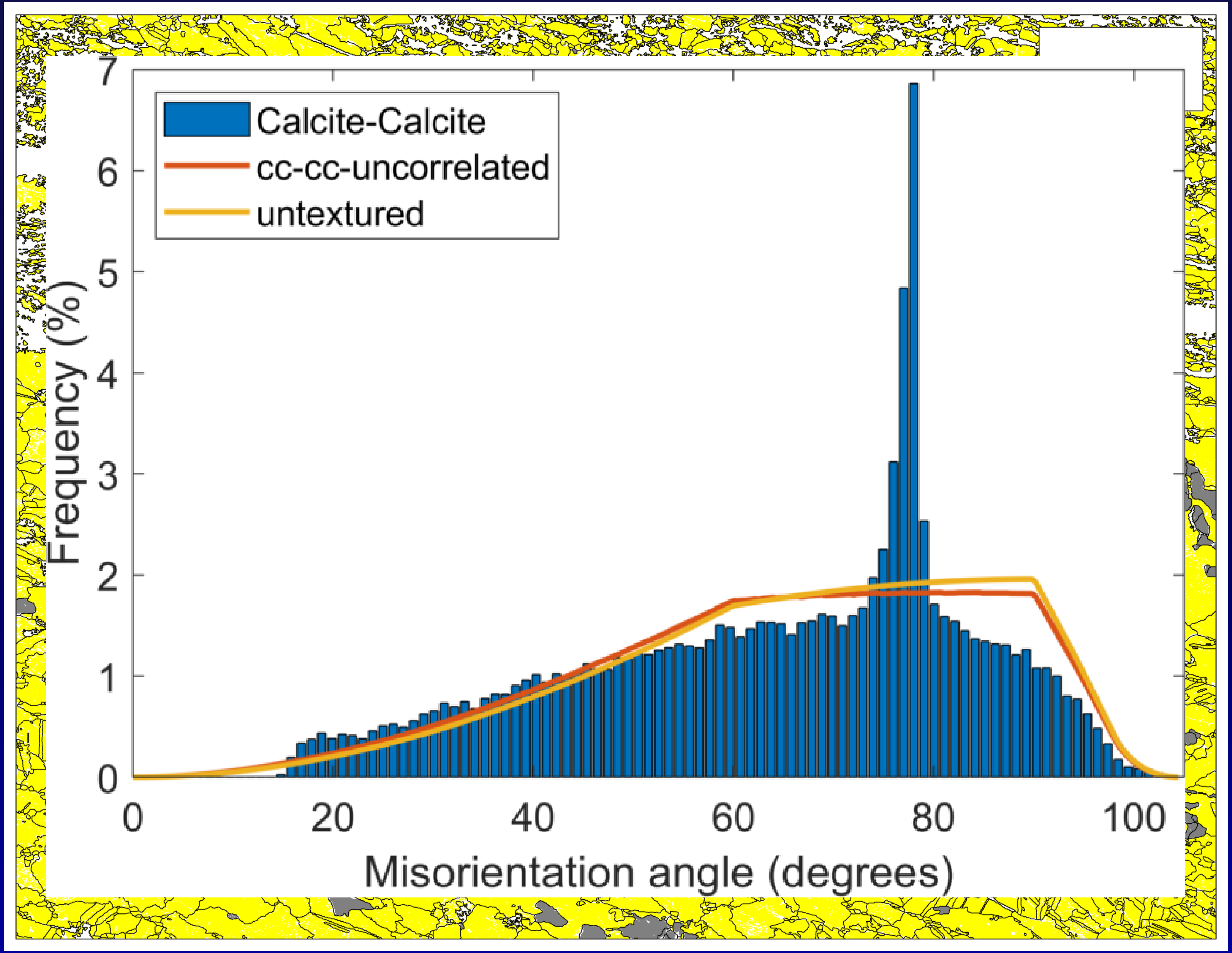
Host/twin determination

- Why?
  - Geologist commonly do not know the stress sytem, so we cannot use assumption that we know the stress system an then predict which are twins
  - Rather we want the twins to tell us about the stress system in order to understand deformation history
    - Depends on twin/host determination!


Notindexed
Calcite
Quartz

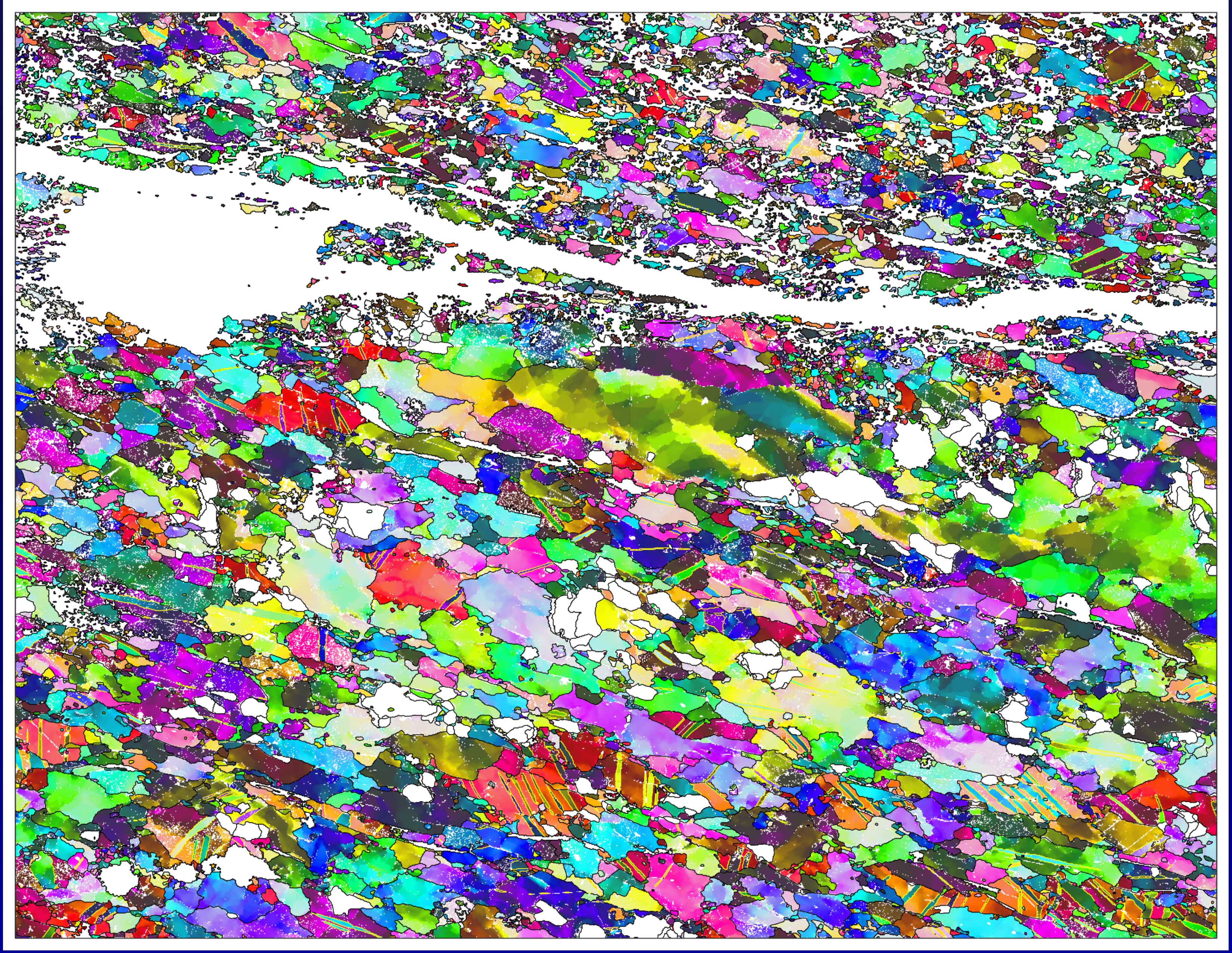


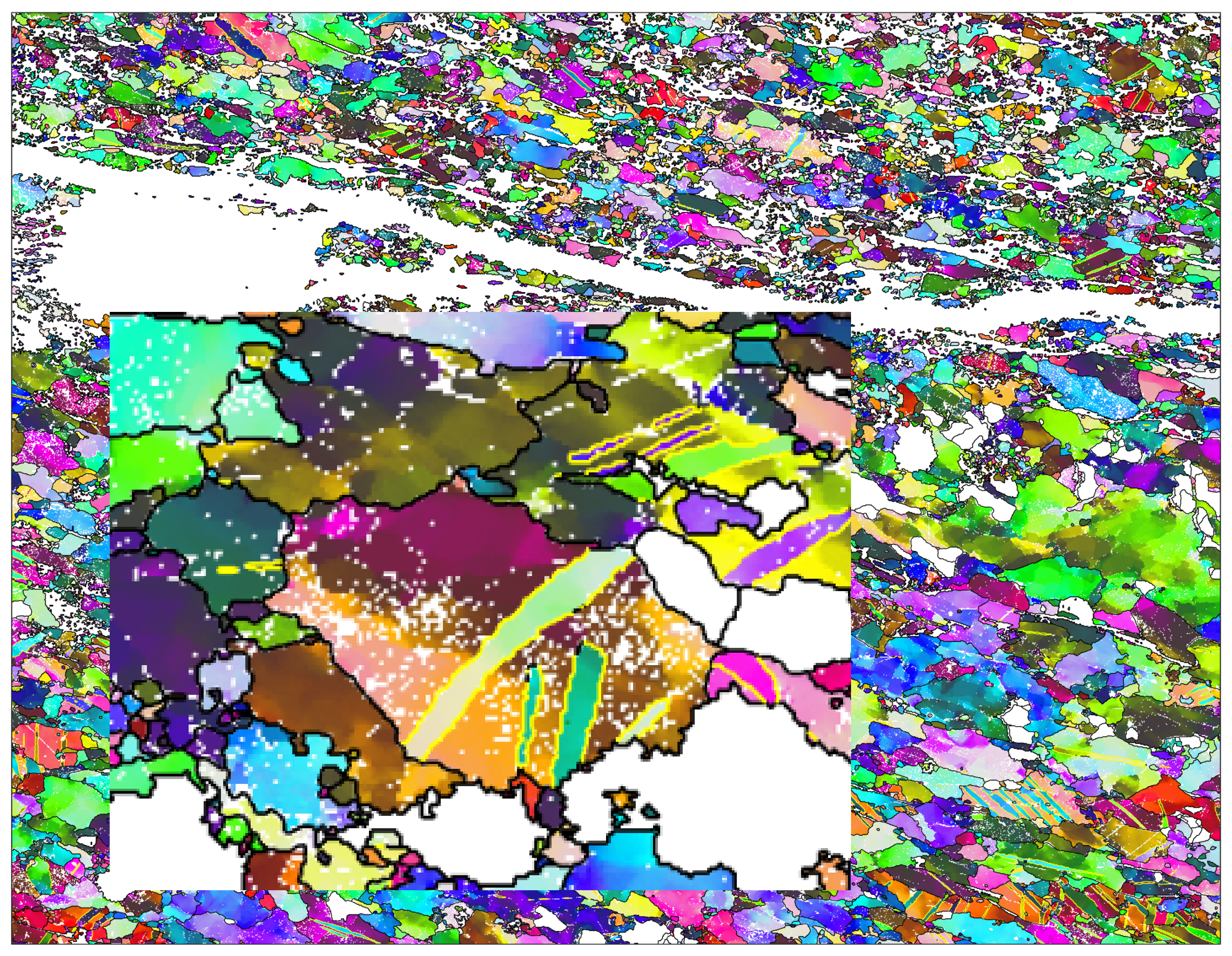
texture index odf calcite = 1.2134, N = 2818

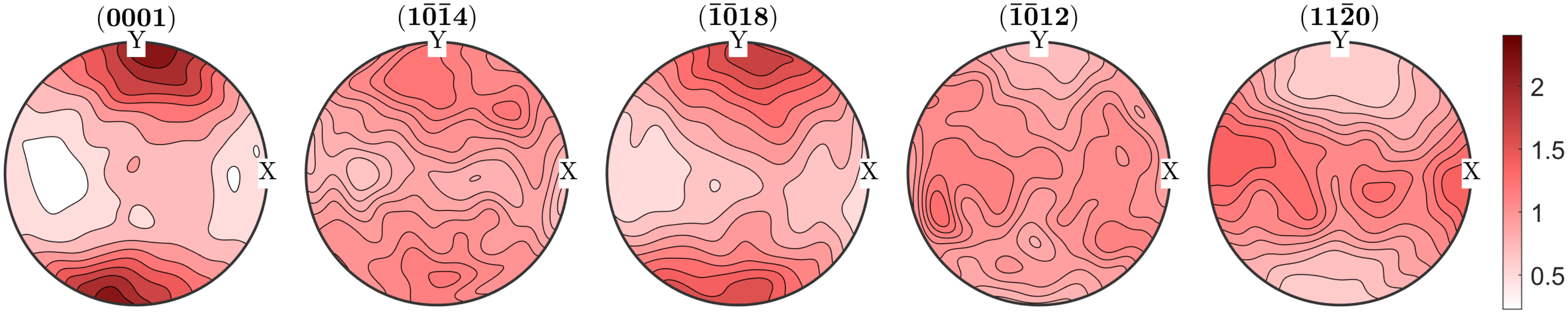

Calcite-Calcite
cc-cc-uncorrelated
untextured
Frequency (%)
0
1
2
3
4
5
6
7
0
20
40
60
80
100
Misorientation angle (degrees)

We need to identify the twins

```
%% twinning analysis
% definition of eTwin with full symmetry
eTwinCalcite = -rotation('axis',Miller(-1,0,1,8,cs_cc),'angle',180*degree)
% find the symmetrically equivalents
eTwinCalcite_symmetrised = symmetrise(eTwinCalcite,cs_cc)
% take only the proper rotations
eTwinCalcite_symmetrised_proper =
eTwinCalcite_symmetrised(~isImproper(eTwinCalcite_symmetrised))
%and chose the min angle
ind =
eTwinCalcite_symmetrised_proper.angle==min(eTwinCalcite_symmetrised_proper.angle)
eTwin = eTwinCalcite_symmetrised_proper(ind)
%% check which grain_boundaries that are e-twins
isTwinning = angle(gB_cc.misorientation,eTwin(1)) <
8*degree|angle(gB_cc.misorientation,eTwin(2)) < 8*degree;
etwinBoundary = gB_cc(isTwinning);
```

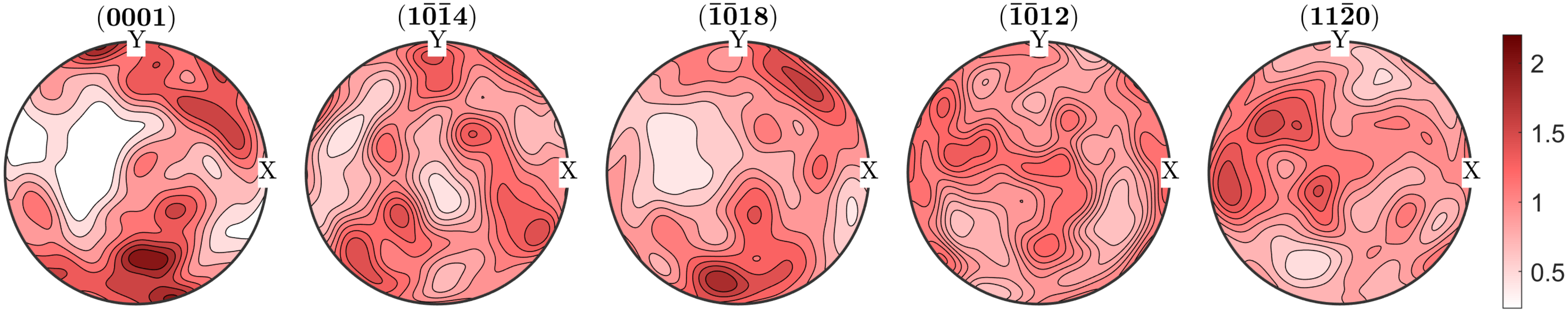






Unwinned grains

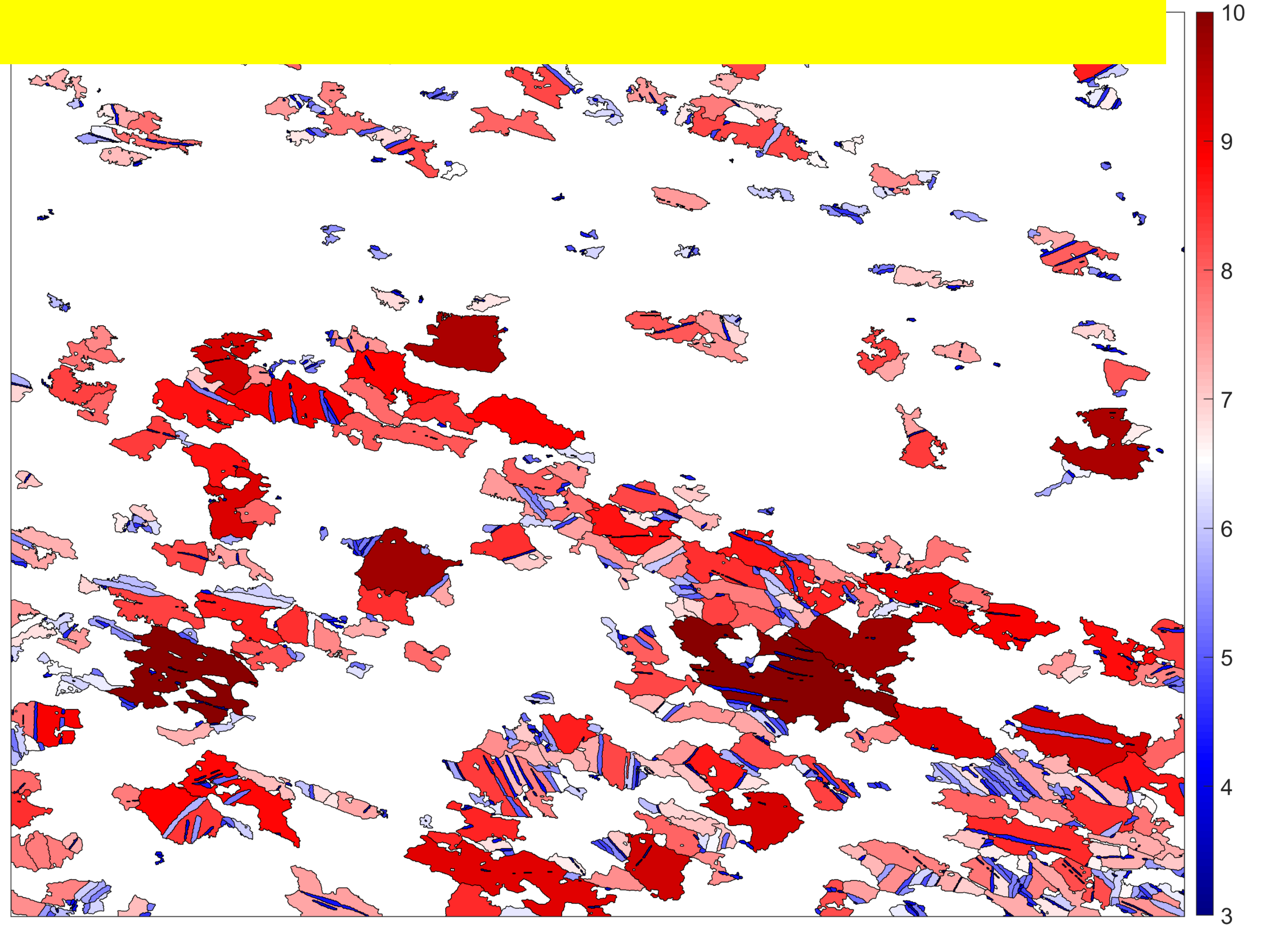
textureindex odf untwinned calcite = 1.2729, N = 2158



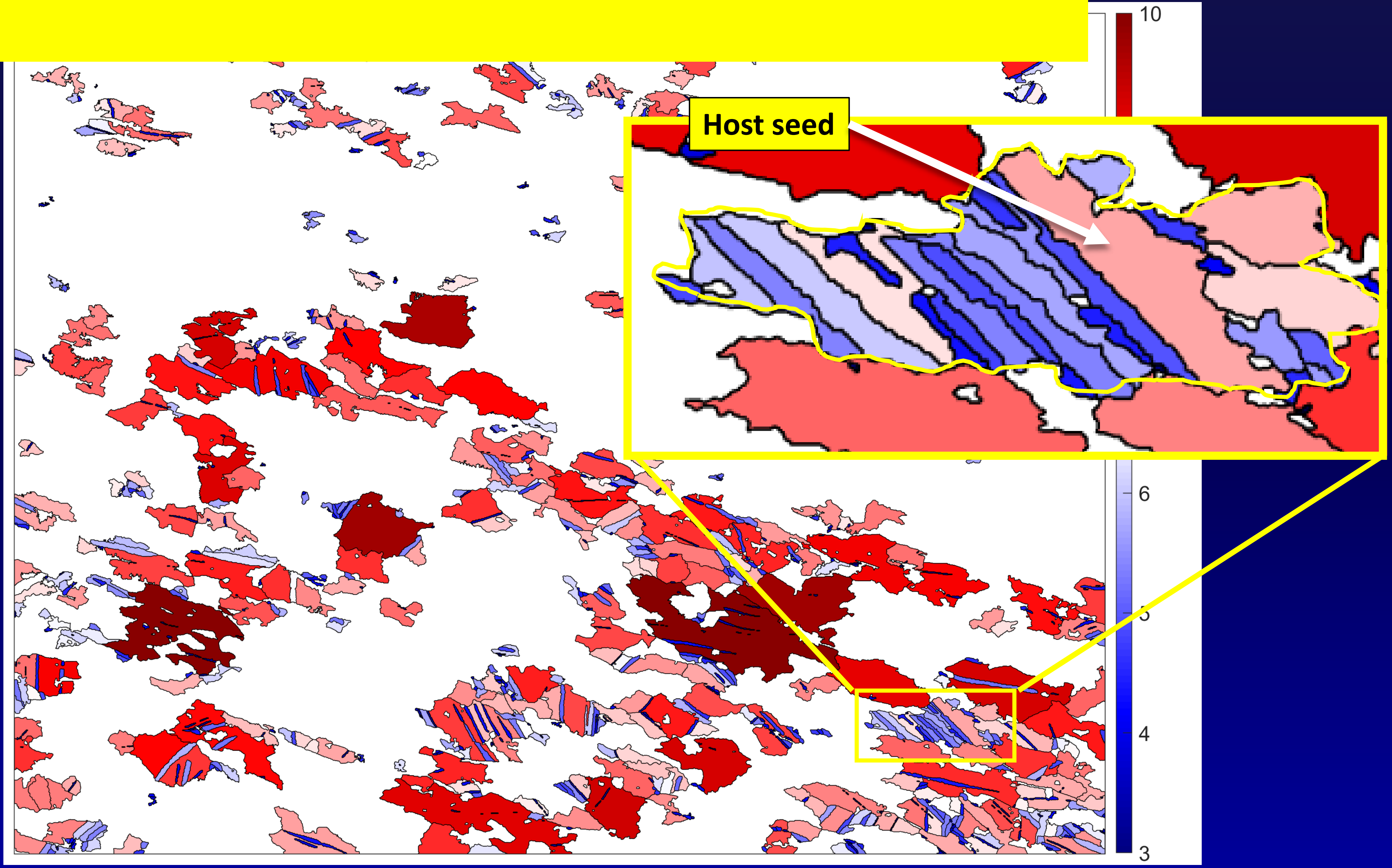
Twinned grains

textureindex odf twinned calcite = 1.4354, N = 1173

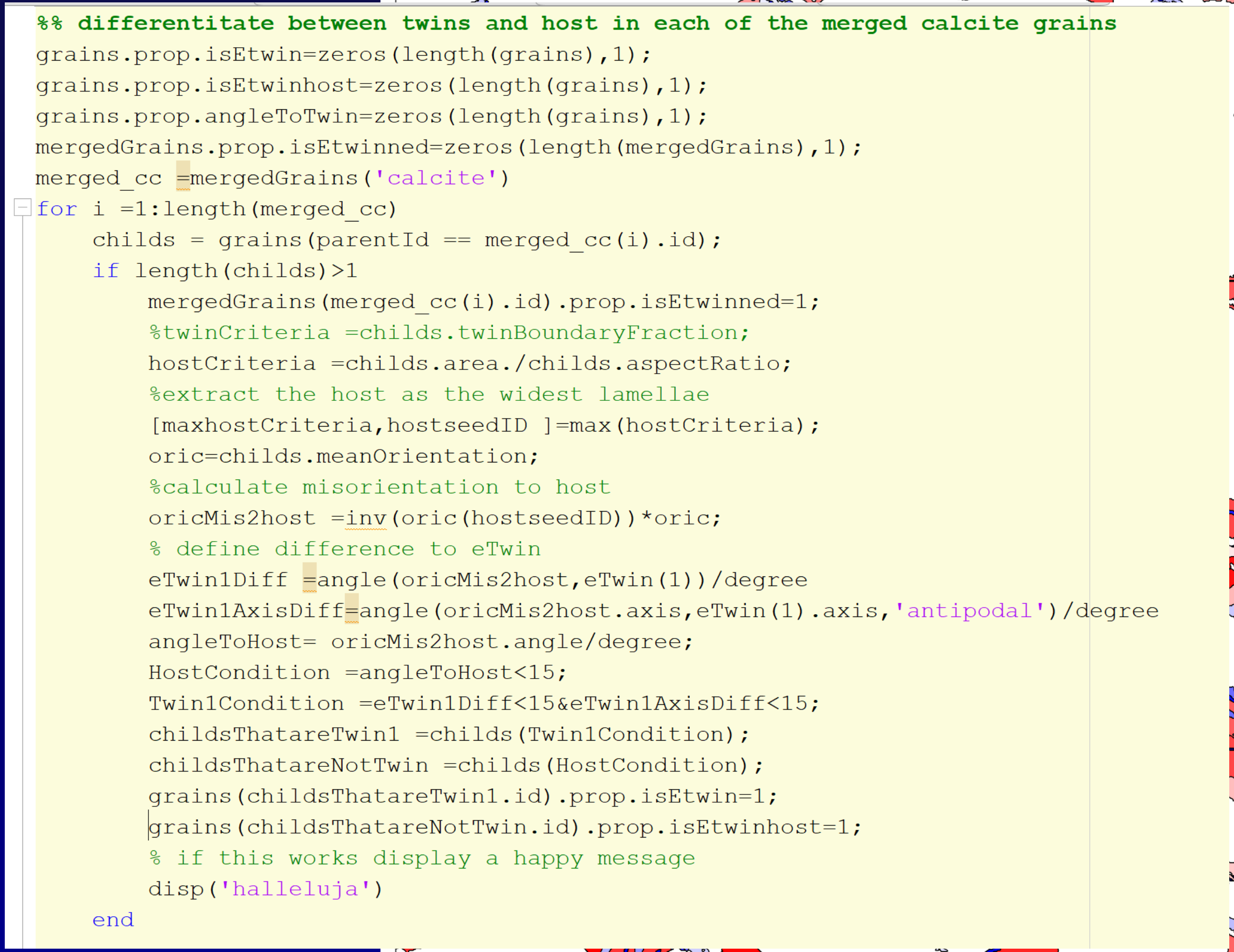
```
grain_width =(twinned_calcite.area)./(twinned_calcite.aspectRatio);
```



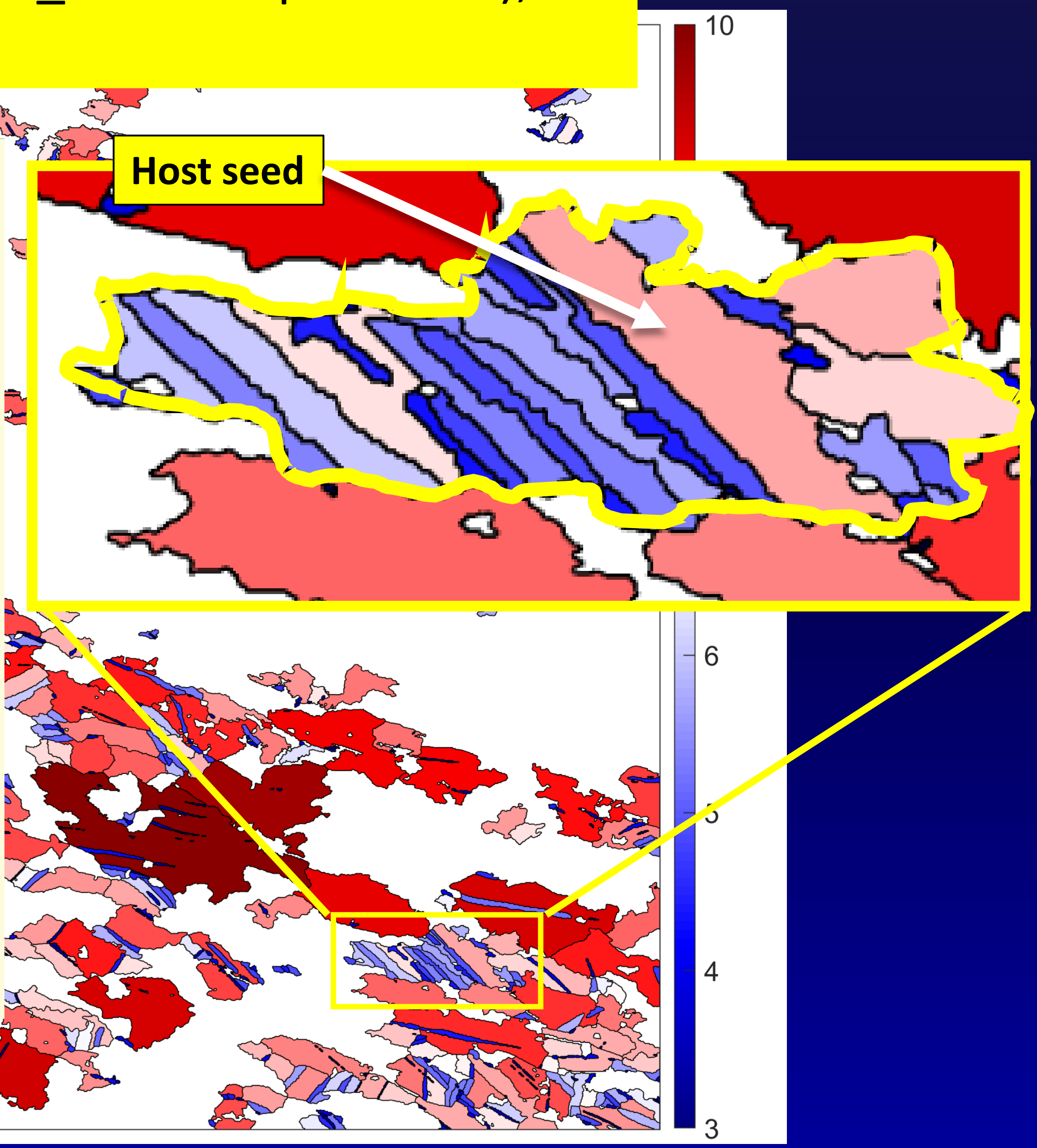
```
grain_width =(twinned_calcite.area)./(twinned_calcite.aspectRatio);
```



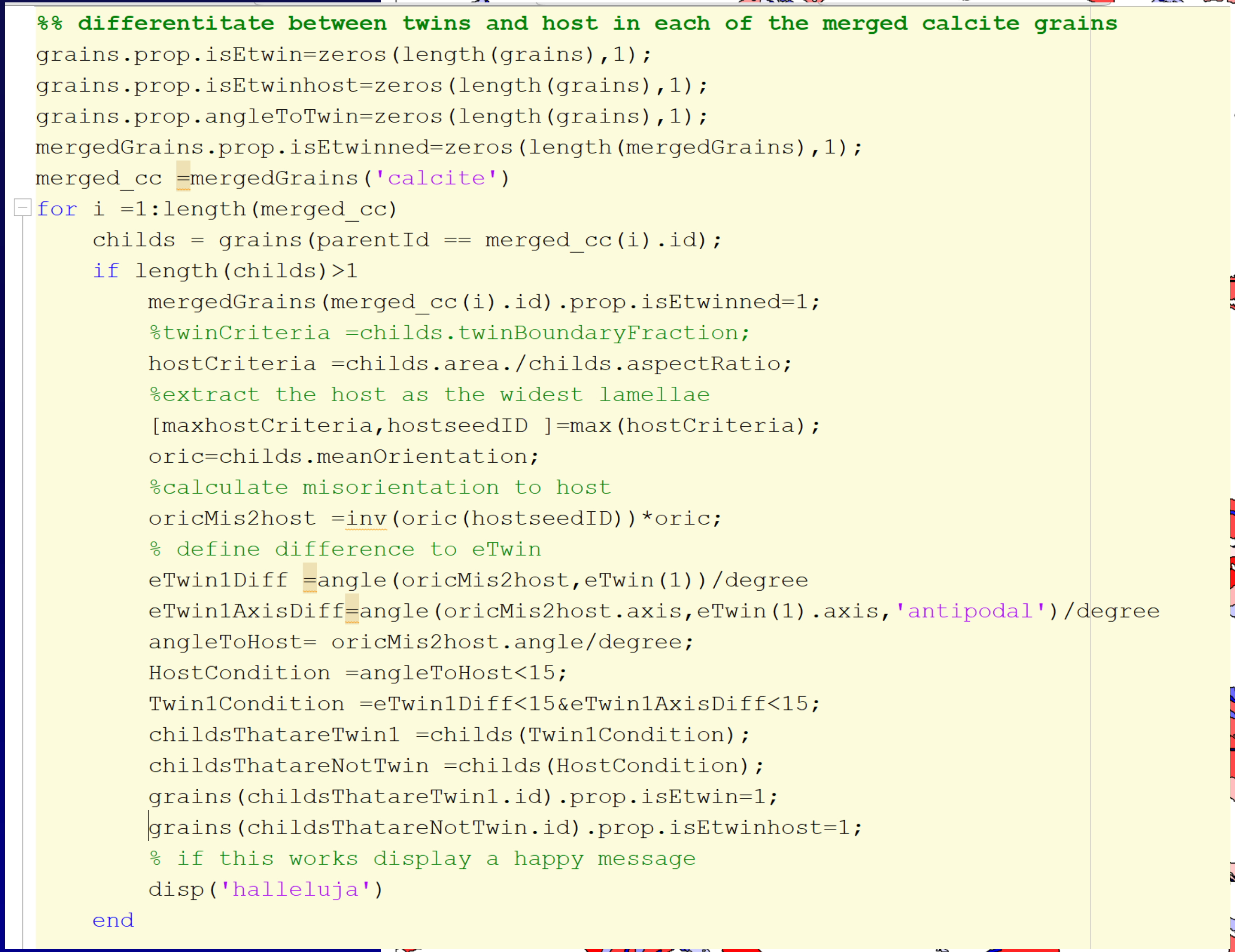
grain_width =(twinned_calcite.area)./(twinned_calcite.aspectRatio);



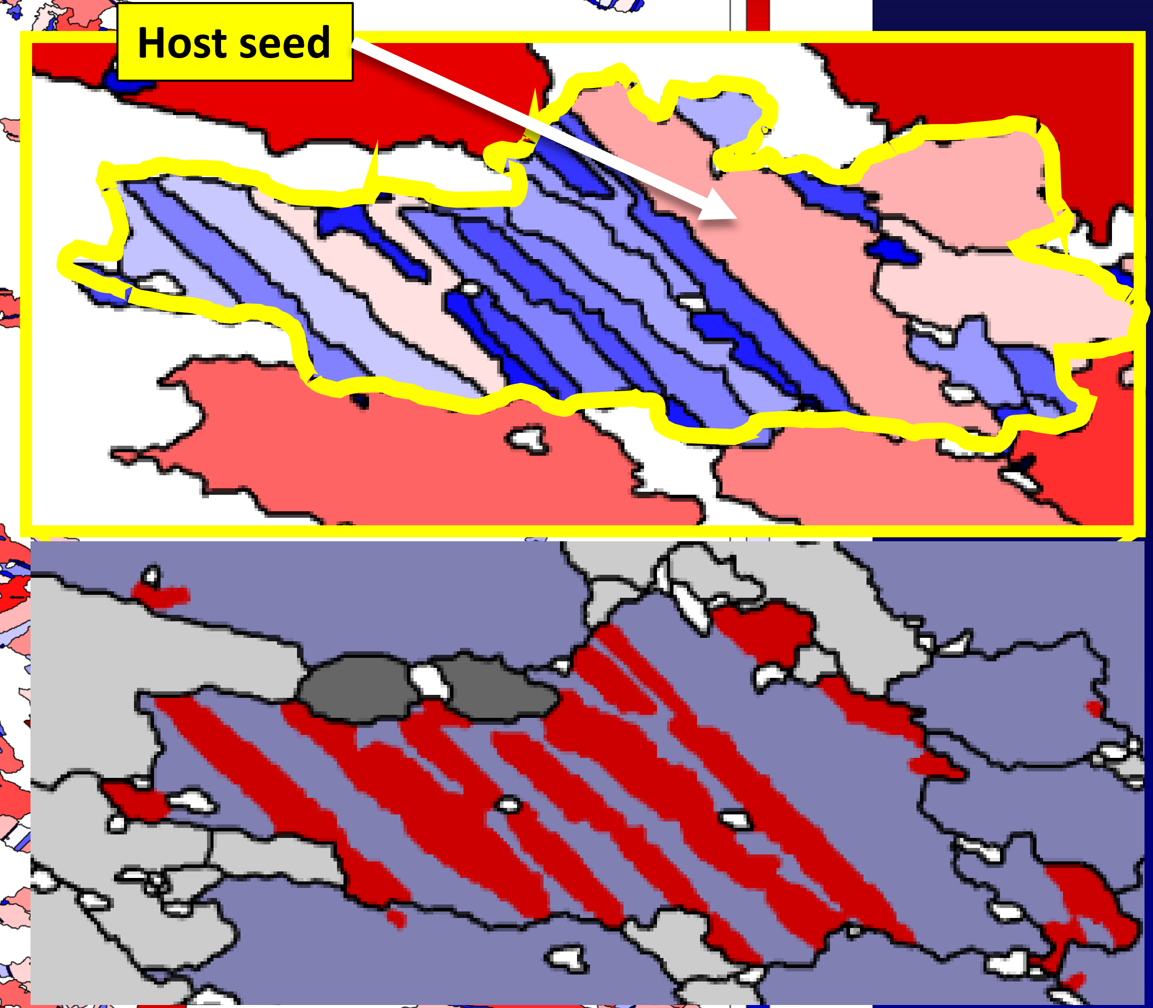
```
%% differentitate between twins and host in each of the merged calcite grains
grains.prop.isEtwin=zeros(length(grains),1);
grains.prop.isEtwinhost=zeros(length(grains),1);
grains.prop.angleToTwin=zeros(length(grains),1);
mergedGrains.prop.isEtwinned=zeros(length(mergedGrains),1);
merged_cc =mergedGrains('calcite')
for i =1:length(merged_cc)
    childs = grains(parentId == merged_cc(i).id);
    if length(childs)>1
        mergedGrains(merged_cc(i).id).prop.isEtwinned=1;
        %twinCriteria =childs.twinBoundaryFraction;
        hostCriteria =childs.area./childs.aspectRatio;
        %extract the host as the widest lamellae
        [maxhostCriteria,hostseedID ]=max(hostCriteria);
        oric=childs.meanOrientation;
        %calculate misorientation to host
        oricMis2host =inv(oric(hostseedID))*oric;
        % define difference to eTwin
        eTwin1Diff =angle(oricMis2host,eTwin(1))/degree
        eTwin1AxisDiff=angle(oricMis2host.axis,eTwin(1).axis,'antipodal')/degree
        angleToHost= oricMis2host.angle/degree;
        HostCondition =angleToHost<15;
        Twin1Condition =eTwin1Diff<15&eTwin1AxisDiff<15;
        childsThatareTwin1 =childs(Twin1Condition);
        childsThatareNotTwin =childs(HostCondition);
        grains(childsThatareTwin1.id).prop.isEtwin=1;
        grains(childsThatareNotTwin.id).prop.isEtwinhost=1;
        % if this works display a happy message
        disp('halleluja')
    end
```



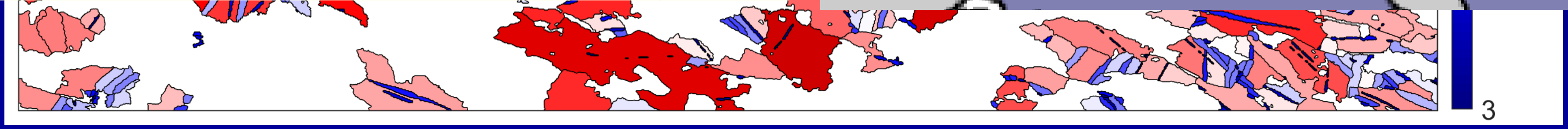
grain_width =(twinned_calcite.area)./(twinned_calcite.aspectRatio);

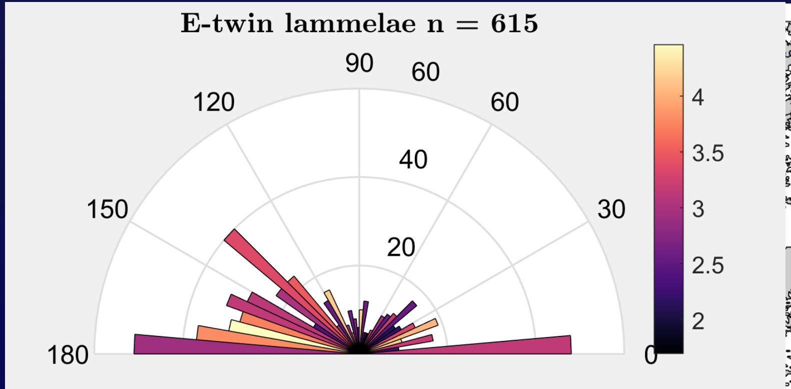


```
%% differentitate between twins and host in each of the merged calcite grains
grains.prop.isEtwin=zeros(length(grains),1);
grains.prop.isEtwinhost=zeros(length(grains),1);
grains.prop.angleToTwin=zeros(length(grains),1);
mergedGrains.prop.isEtwinned=zeros(length(mergedGrains),1);
merged_cc =mergedGrains('calcite')
for i =1:length(merged_cc)
    childs = grains(parentId == merged_cc(i).id);
    if length(childs)>1
        mergedGrains(merged_cc(i).id).prop.isEtwinned=1;
        %twinCriteria =childs.twinBoundaryFraction;
        hostCriteria =childs.area./childs.aspectRatio;
        %extract the host as the widest lamellae
        [maxhostCriteria,hostseedID ]=max(hostCriteria);
        oric=childs.meanOrientation;
        %calculate misorientation to host
        oricMis2host =inv(oric(hostseedID))*oric;
        % define difference to eTwin
        eTwin1Diff =angle(oricMis2host,eTwin(1))/degree
        eTwin1AxisDiff=angle(oricMis2host.axis,eTwin(1).axis,'antipodal')/degree
        angleToHost= oricMis2host.angle/degree;
        HostCondition =angleToHost<15;
        Twin1Condition =eTwin1Diff<15&eTwin1AxisDiff<15;
        childsThatareTwin1 =childs(Twin1Condition);
        childsThatareNotTwin =childs(HostCondition);
        grains(childsThatareTwin1.id).prop.isEtwin=1;
        grains(childsThatareNotTwin.id).prop.isEtwinhost=1;
        % if this works display a happy message
        disp('halleluja')
    end
```

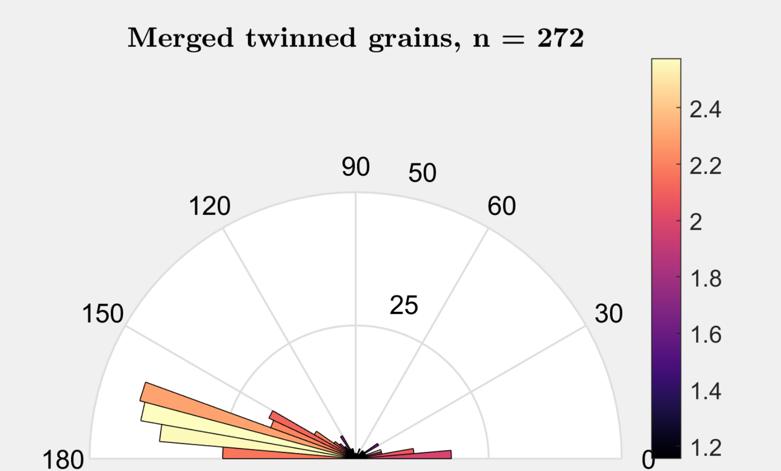


Host seed

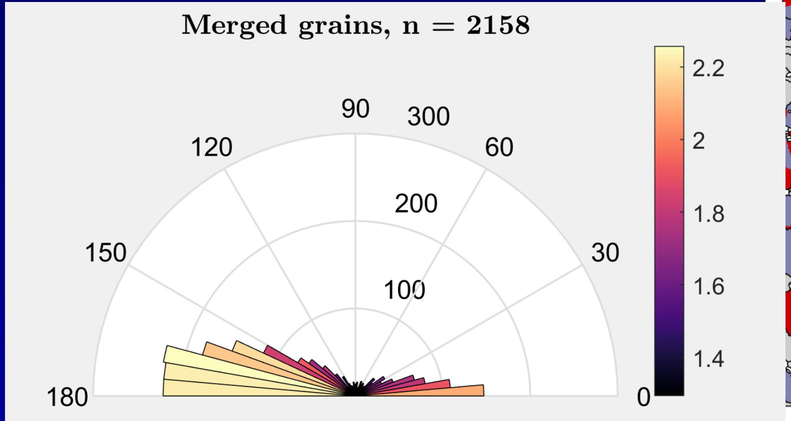




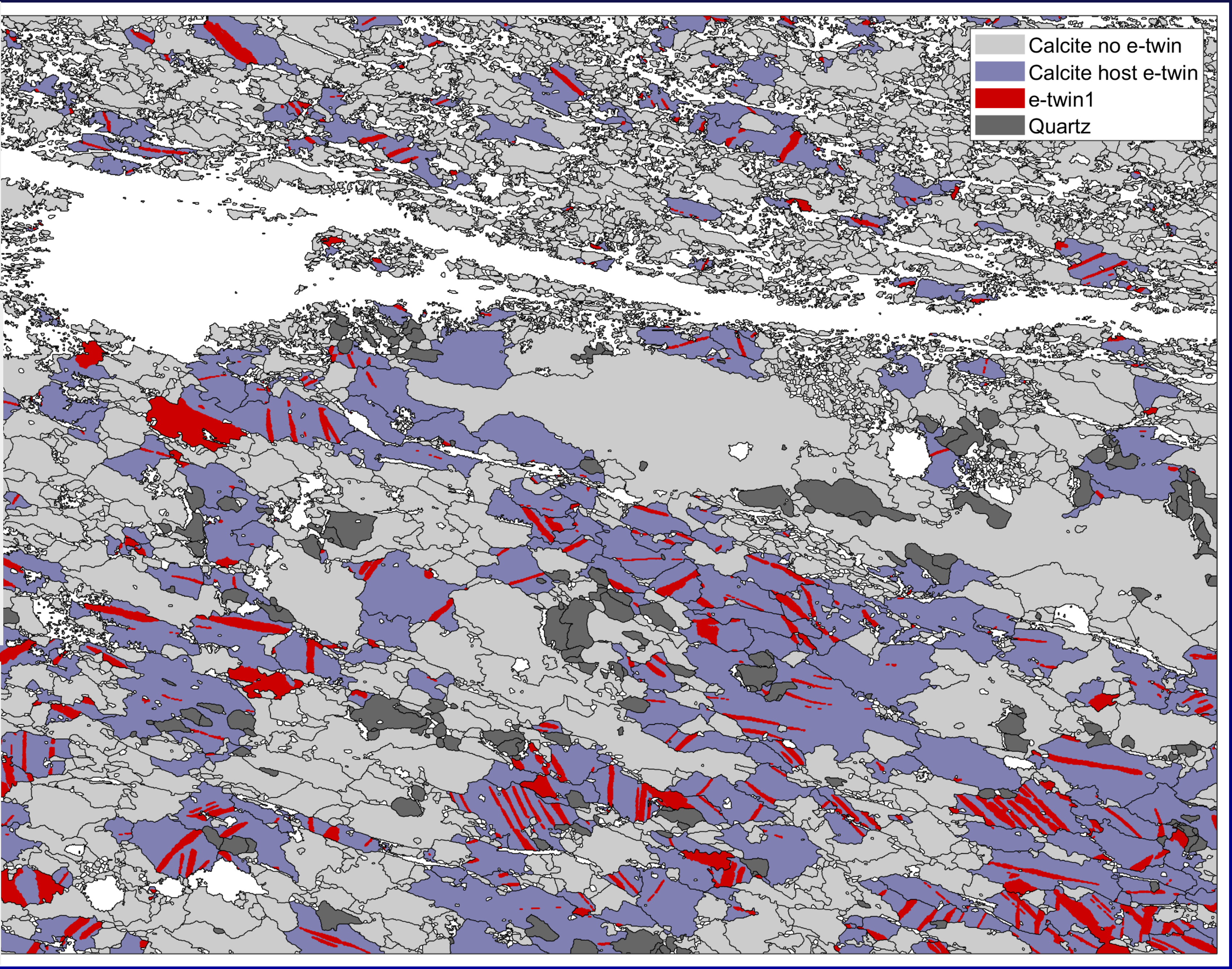
E-twin lammelae n = 615

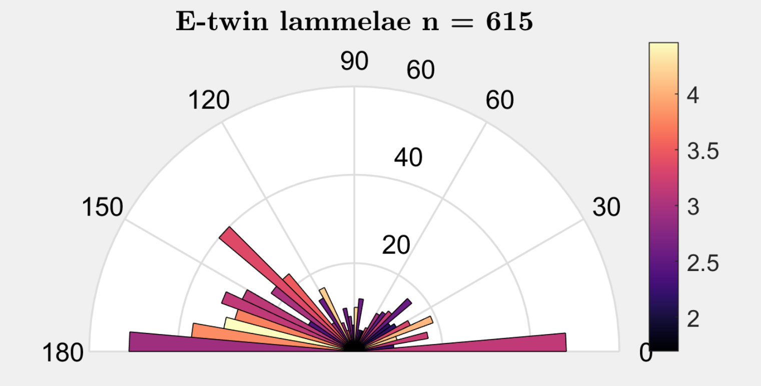


Merged twinned grains, n = 272

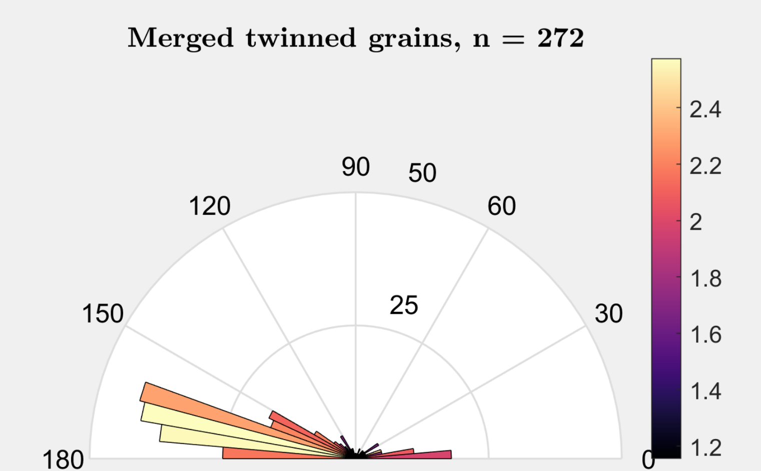


Merged grains, n = 2158

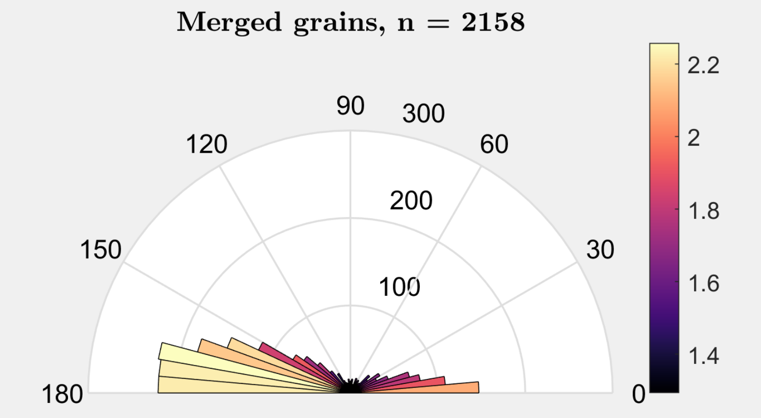




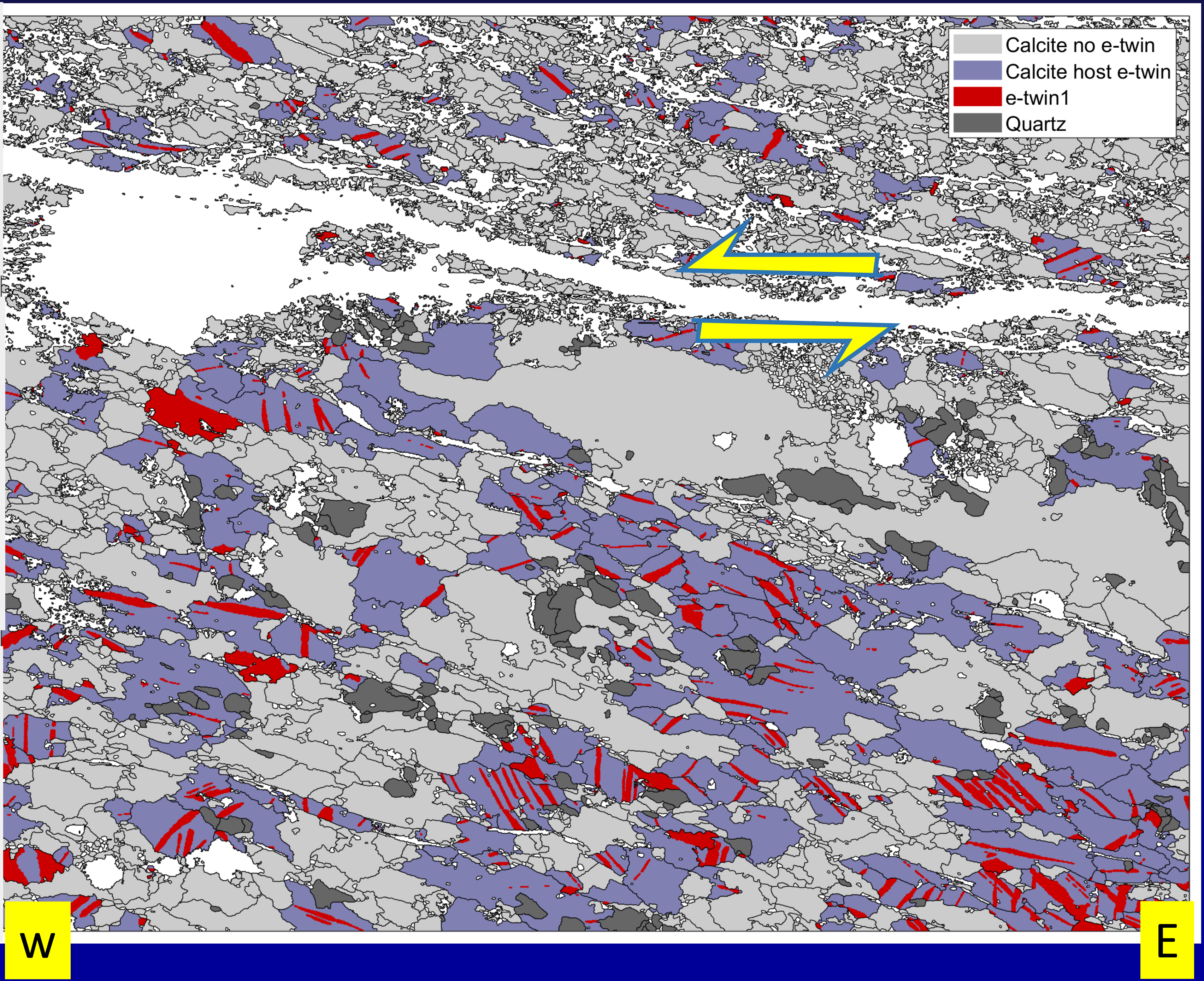
E-twin lammelae n = 615

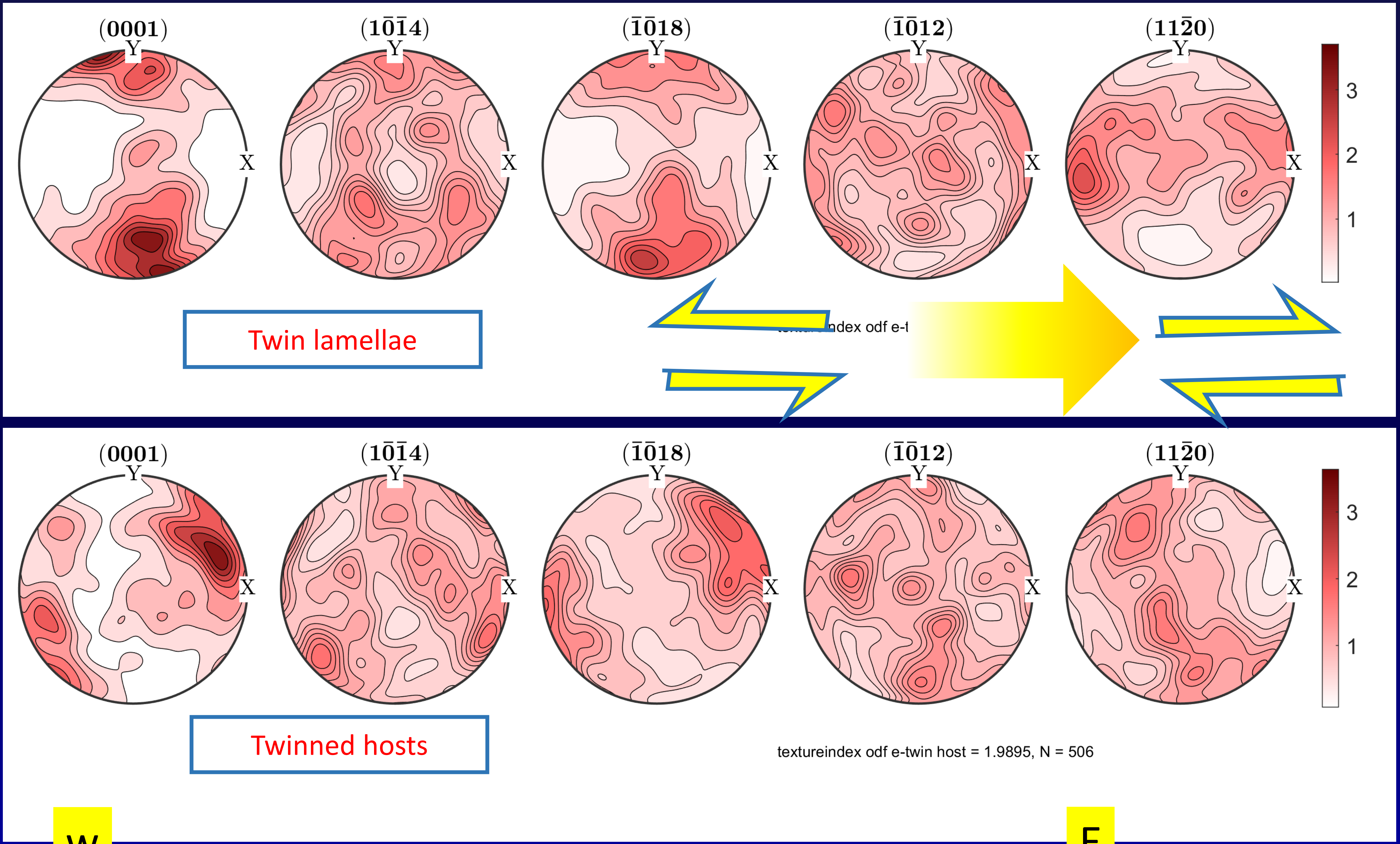


Merged twinned grains, n = 272



Merged grains, n = 2158





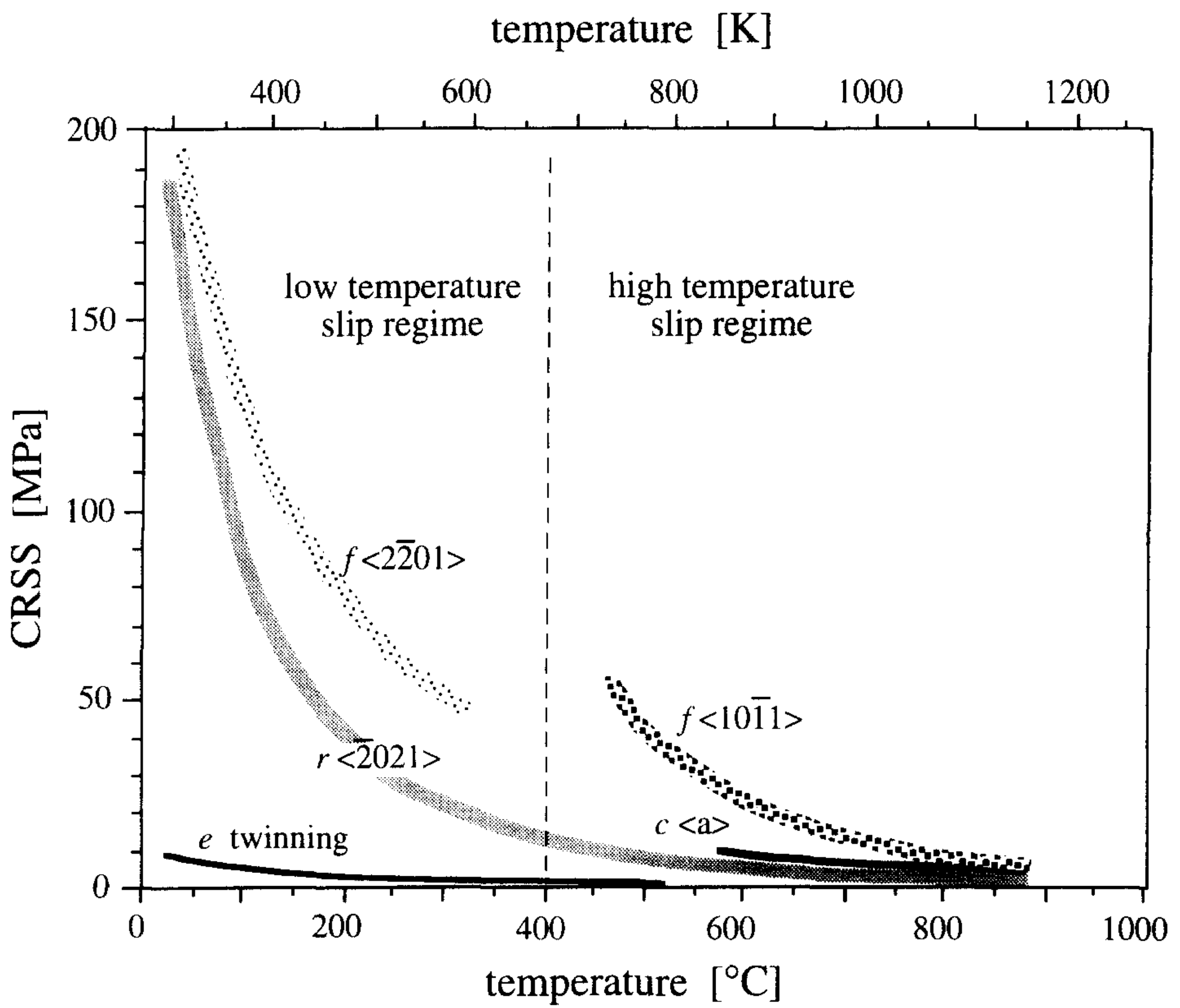
Twin lamellae

Twinned hosts

textureindex odf e-twin host = 1.9895, N = 506

W

E


temperature [K]
400
600
800
1000
1200
200
150
100
50
0
CRSS [MPa]
low temperature slip regime
high temperature slip regime
f <2$\bar{2}$01>
r <$\bar{2}$021>
f <10$\bar{1}$1>
c <a>
e twinning
0
200
400
600
800
1000
temperature [°C]

Thanks for the attention